ATOVS L2 Product Generation Specification

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Document Change Record

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
4, Rev 0.	April-May 2001	Not applicable	This is a draft issue. Version for EPS CGS PDR. All changes documented below are with respect to the previous issue of the document (Issue 3 Draft A). Whenever the word 'old' is used it refers to sections or requirements in the previous issue (Issue 3 Draft A)
			Page 1: Changed wording
			Page 6: Added reference documents: [RD-14], [RD-15], [RD-17] and [RD-18]
			Page 7: Added new text and reworded old text.
			Pages 8 and 9: Updated Table 1
			Pages 10 to 21: Updated Figure 1. Updated Figure 2 Updated Figure 3. New Figure 4 Updated Figure 5 (an update of old Figure 4) Updated Figure 6 (an update of old Figure 5) Updated Figure 7 (an update of old Figure 6) Updated Figure 8 (an update of old Figure 7) Updated Figure 9 (an update of old Figure 8) Deleted old Figure 9 Updated Figure 10. Updated Figure 11 New Figure 12 Updated Figure 13 (an updated of old Figure 12) Updated Figure 14 (an update of old Figure 13) Deleted old Figures 14, 15, 16 and 17. Updated Figure 15 (an update of old Figure 18) Updated Figure 16 (an update of old Figure 19) New Figure 17 New Figure 18 New Figure 19 New Figure 20 New Figure 21 (an update of old Figure 20) New Figure 22 New Figure 23 (state transitions) and clarified states vs modes in subsequent text.
			Page 26: Updated Section 2.3.1.4
			Page 34: Updated ATOVSL2-PPS-3.1.2-0100 Added new requirement ATOVSL2-PPS-3.1.2-0110
			Page 39: Updated ATOVSL2-PPS-3.1.4.3-0010. More functions have been added to this requirement which corresponds to the "AMSU-A Data Preparation Function" basic functionality.
			Page 40: Added two new requirements: ATOVSL2-PPS-3.1.4.3-0030 ATOVSL2-PPS-3.1.4.3-0040. Changed Section 3.1.4.3.2. Updated reqs. ATOVSL2-PPS-3.1.4.3.2-0010 to 0030 (Only the name of the function has changed from "AMSU-A Scattering Detection Function" to "AMSU-A Precipitation Signal Detection Function").
			Pages 41 and 42: Moved old section 3.1.4.3.4.3 to new section 3.1.4.3.4 Changed ATOVSL2-PPS-3.1.4.3.4-0020 to 0040 (Only the name of the function has changed). Deleted old section 3.1.4.3.4.4 and requirements ATOVSL2-PPS-3.1.4.3.2-0090 to 0120.

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
			Changed ATOVSL2-PPS-3.1.4.3.2-0140 Moved old section 3.1.4.3.4.1 to new section 3.1.4.3.2.3, together with unchanged reqs. ATOVSL2-PPS-3.1.4.3.4- 0020 to 0040.
			Page 42: Moved old section 3.1.4.3.4.2 to new section 3.1.4.3.2.4 together with unchanged reqs. ATOVSL2-PPS-3.1.4.3.4-0050 and 0070. Deleted ATOVSL2-PPS-3.1.4.3.4-0060. Added new section 3.4.3.2.5 with new requirement ATOVSL2-PPS-3.1.4.3.2-0180. Added new section 3.1.4.3.3.1 with new requirement ATOVSL2-3.1.4.3.3-0031 Deleted old requirement ATOVSL2-PPS-3.1.4.3.4-0010
			Page 43: Added new section 3.1.4.3.3 (Old section 3.1.4.3.3.2 was deleted). Added new requirement ATOVSL2-PPS-3.1.4.3.3-110. Deleted old requirements: ATOVSL2-PPS-3.1.4.3.3-0090 ATOVSL2-PPS-3.1.4.3.3-0100. Deleted old section 3.1.4.3.4 Section 3.1.4.3.4 was moved from page 41 in the old document. It corresponds to old section 3.1.4.3.2.2.
			Page 44: Changed requirement ATOVSL2-PPS-3.1.4.4-0010 Added new requirement ATOVSL2-PPS-3.1.4.4-0030
			Page 45: Added new requirements: ATOVSL2-PPS-3.1.4.4-0040, ATOVSL2-PPS-3.1.4.4-0050, ATOVSL2-PPS-3.1.4.4-0060. Deleted old section 3.1.4.3.3 Deleted requirements ATOVSL2-PPS-3.1.4.4.3--0010 to 0030.
			Page 46: Section 4.1.4.4.3 corresponds to old section 3.1.4.4.4 Section 3.1.4.4.4 corresponds to old section 3.1.4.4.5 Section 3.1.4.4.4.1 corresponds to old section 3.1.4.4.5.1 Section 3.1.4.4.4.2 corresponds to old section 3.1.4.4.5.2 Changed ATOVSL2-PPS-3.1.4.4.5-0070
			Page 47: Changed ATOVSL2-PPS-3.1.4.5-0010 Deleted old requirement ATOVSL2-PPS-3.1.4.5-0040
			Page 48: Deleted old section 3.1.4.5.2. IMPORTANT CHANGE: Deleted old requirements (They are now in [AD-21] AVHRR/3 Level 1 Product Generation Specification Document. This functionality is therefore not required in the ATOVS Level 2 processing chain anymore): ATOVSL2-PPS-3.1.4.5.2-0010 to 0240; ATOVSL2-PPS-3.1.4.5.3-0010 to 0050; ATOVSL2-PPS-3.1.4.5.4-0010 to 0060) Changed ATOVSL2-PPS-3.1.4.6-0010
			Added new requirements ATOVSL2-PPS-3.1.4.6-0050 to 0070
			Page 49: Deleled old section 3.1.4.6.2. Deleted old requirements: ATOVSL2-PPS-3.1.4.6.2-0010 to 0050.
			Page 50: Changed requirement ATOVSL2-PPS-3.1.4.7.1-0020
			Page 51: Changed requirement ATOVSL2-PPS-3.1.4.7.2-0020 Changed requirement ATOVSL2-PPS-3.1.4.7.3-0030
			Page 52: Deleted old sections 3.1.5.1 and 3.1.5.2

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
			IMPORTANT CHANGE: Deleted old requirements (The objectives of these requirements are been now covered by the new requirements added in page 54): ATOVSL2-PPS-3.1.5.1-0010 to 0060 ATOVSL2-PPS-3.1.5.2-0010 to 0030 ATOVSL2-PPS-3.1.5.2.1-0010 to 0050 ATOVSL2-PPS-3.1.5.2.2-0010 to 0060 ATOVSL2-PPS-3.1.5.2.3-0010 to 0030 ATOVSL2-PPS-3.1.5.2.4-0010 to 0030 ATOVSL2-PPS-3.1.5.2.5-0010 to 0020 ATOVSL2-PPS-3.1.5.3-0020 Updated ATOVSL2-PPS-3.1.5.3-0060
			Page 53: Deleted old sections 3.1.5.4, 3.1.5.5 and 3.1.5.6 IMPORTANT CHANGE: Deleted old requirements(The objectives of these requirements are been now covered by the new requirements added in page 54): ATOVSL2-PPS-3.1.5.4-0010 to 0060 ATOVSL2-PPS-3.1.5.5-0010 to 0030 ATOVSL2-PPS-3.1.5.5.1-0010 to 0040 ATOVSL2-PPS-3.1.5.5.2-0010 to 0050 ATOVSL2-PPS-3.1.5.6-0010 to 0030 ATOVSL2-PPS-3.1.5.6.1-0010 to 0270 Updated section 3.1.5.1.1 corresponding to the old section 3.1.5.6.2. Changed requirements: ATOVSL2-PPS-3.1.5.3-0070 ATOVSL2-PPS-3.1.5.6.2-0010 to 0040. Added new requirements: ATOVSL2-PPS-3.1.5.3-0080 ATOVSL2-PPS-3.1.5.3-0090 Deleted old section 3.1.5.6.2.1. Deleted old requirements: ATOVSL2-PPS-3.1.5.6.2-0050 to 0090 ATOVSL2-PPS-3.1.5.6.2-0110 Updated Section 3.1.5.1.1.1 which corresponds to old section 3.1.5.6.2.2.
			Page 54: IMPORTANT CHANGE: Added new requirements which covered the functionality before expressed by the requirements deleted from pages 52 and 53 (see above in this table for details on those): ATOVSL2-PPS-3.1.5.6.2-0150 to ATOVSL2-PPS-3.1.5.6.2-0200 Updated section 3.1.5.1.1.2 (corresponding to the old section 3.1.5.6.2.3).
			Page 58: Changed ATOVSL2-PPS-3.3-0030 and 0040.
			Page 59: Deleted old requirements: ATOVSL2-PPS-3.3-0050 to 0200.
			Page 63: Updated Section 4.1
			Page 64: Added new Table 7. Added new Sections: 4.1.1.1, 4.1.1.2, 4.1.1.3, 4.1.1.4, 4.1.1.5 and 4.1.1.6
			Page 65: Updated Sections 4.1.3, 4.1.4 and 4.2
			Page 66: Changed the numbering of Table 8 (This table corresponds to the old Table 7)
			Page 67: Changed the contents and numbering of Table 9 (This table corresponds to the old Table 8) Added new sections 4.2.3.1 and 4.2.3.3 Section 4.2.3.2 corresponds to the old section 4.2.3.1 Contents of section 4.2.3.4 (corresponding to the old section

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			4.2.3.2) have been updated.
			Page 68: Updated Table 10 (This table corresponds to the old table 9) Section 4.2.3.4.1 corresponds to the old section 4.2.3.2.1 Contents of section 4.2.3.4.2 (corresponding to the old section 4.2.3.2.4) have been updated.
			Pages 69 and 70: Section 4.2.3.4.2 has new text. It is a remake of the old section 4.2.3.2.4. Deleted old sections 4.2.3.2.2 (moved as new section 4.2.3.5) and 4.2.3.2.3. Added new sections 4.2.3.4.3 and 4.2.3.4.4 which are updated versions of the old sections 4.2.3.4.1 and 4.2.3.4.2 respectively. New equation added and Updated equation variables' names of old equations.
			Page 71: Added new sections 4.2.3.4.5. Section 4.2.3.5 corresponds to the old section 4.2.3.2.2 New text added to section 4.2.3.6 (section corresponding to the old section 4.2.3.3) Updated Table 11 (This table corresponds to the old table 10) Updated variables' names in Equation 8 (corresponds to the old Equation 3).
			Page 72: Added new section 4.2.3.6.1. Updated section 4.2.3.6.2 (this section corresponds to the old section 4.2.3.3.1) Added new section 4.2.3.6.3 Deleted old sections 4.2.3.3.2 and 4.2.3.4 Table 12 corresponds to the old table 11.
			Page 73: Section 4.2.3.6.4 corresponds to the old section 4.2.3.2.3 Old sections 4.2.3.4.1 and 4.2.3.4.2 are the new sections (contents are the same) 4.2.3.4.3 and 4.2.3.4.4 (see pages 71 and 72) Sections 4.2.3.7.1 and 4.2.3.7.2 correspond to old sections 4.2.3.5.1 and 4.2.3.5.2 respectively.
			Page 74: Updated section 4.2.4 Updated the contents of Table 14 (This table corresponds to the old table 14) Added new section 4.2.4.1 Updated section 4.2.4.2 (corresponding to old section 4.2.4.1)
			Page 75: Added new section 4.2.4.3 Updated sections 4.2.4.4 and 4.2.4.5 (corresponding to the old sections 4.2.4.2 and 4.2.4.4 respectively) Added new sections 4.2.4.6 and 4.2.4.7 Updated section 4.2.4.8 corresponding to the old section 4.2.4.5
			Page 76: Section 4.2.4.8.1 corresponds to the old section 4.2.4.5.1 Updated section 4.2.4.8.2 corresponding to the old section 4.2.4.5.2 Updated Table 16. Some entries deleted.
			Page 77: IMPORTANT CHANGE: Deleted old sections 4.2.5.2, 4.2.5.3 and 4.2.5.4 and all their subsections. (The contents of these sections are now in the AVHRR/3 Level 1 PGS document [AD-21].) Updated Table 17 (This table corresponds to the old table 22) Added new section 4.2.6.1

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			Page 78: Added new sections 4.2.6.2 and 4.2.6.3 Remake of the section 4.2.6.4 (corresponding to the old section 4.2.6.1). Updated equation variables' names.
			Page 79: Deleted old section 4.2.6.2. Table 18 corresponds to the old table 23. Added new equations.
			Page 80: Deleted Kringing method (a TBC) from the list of mapping methods. Updated sections 4.2.7.1 and 4.2.7.2.
			Page 81: Updated the contents of section 4.3 Updated Table 19 corresponding to old Table 24 (some entries deleted) IMPORTANT CHANGE: Deleted old sections 4.3.1 and 4.3.2 and all their subsections. The functionality described in these have been moved to section 4.3.2.1 (The section corresponding to the Default Retrieval Function. See details below in this table). Updated section 4.3.1 (corresponding to old section 4.3.3) IMPORTANT CHANGE: Deleted old sections 4.3.4 and 4.3.5. (The contents of these sections are now in the AVHRR/3 Level 1 PGS document [AD-21].)
			Page 82: Updated section 4.3.2 corresponding to the old section 4.3.6. Updated Table 20 (This table corresponds to the old table 27) IMPORTANT CHANGE: Deleted old section 4.3.6.1 and 4.3.6.2 and 4.3.6.2.1 (The contents of these sections are now part of section 4.3.2.1. For details see below in this table) Updated extensively section 4.3.2.1 (corresponds to the old section 4.3.6.2.2. This is the description of the "Default Retrieval Function" which now contains many of the functions that used to be described in the old sections 4.3.6.1 and 4.3.6.2. Added new Table 21. Added new section 4.3.2.1.1
			Page 83: Added new sections 4.3.2.1.2, 4.3.2.1.3 and 4.3.2.1.4 Added new Tables 22 and 23
			Page 84: IMPORTANT CHANGE: Section 4.3.2.1.4.1 is a remake of the old section 4.3.6.1.4 (This is the section describing the FRTM) Added new sections 4.3.2.1.4.2 and 4.3.2.1.4.3 Updated section 4.3.2.1.4.4 corresponding to the old section 4.3.6.1.1.2.1. Updated equation variables' names.
			Page 85: Updated section 4.3.2.1.4.5 corresponding to the old section 4.3.6.1.1.2.2 Updated equation variables' names
			Page 87: Table 24 corresponds to the old table 29 Added new section 4.3.2.1.4.6 Added new Table 25 Updated section 4.3.2.1.4.6.1 corresponding to the old section 4.3.5.1
			Page 88: Added new section 4.3.2.1.4.6.2 and 4.3.2.1.4.7 Updated section 4.3.2.1.4.7.1 corresponding to the old section 4.3.6.1 Updated equation variables' names

Issue / Revision	Date	DCN. No	Changed Pages / Paragraphs
			Pages 89 and 90: Table 26 corresponds to the old table 28 Section 4.3.2.1.4.7.2 corresponds to the old section 4.3.6.1.1. Updated section 4.3.2.1.4.7.3 corresponding to the old section 4.3.6.1.1.1. Updated section 4.3.2.1.4.7.4 corresponding to the old section 4.3.6.1.3 Updated section 4.3.2.1.4.7.5 corresponding to the old section 4.3.6.1.3.1 Updated equation variables' names
			Pages 91 and 92: Updated section 4.3.2.1.4.7.6 corresponding to the old section 4.3.6.1.3.2 Section 4.3.2.1.4.7.7 corresponds to the old section 4.3.6.1.5 IMPORTANT CHANGE: Updated extensively section 4.3.2.1.5 which contains the old sections 4.3.6.2 and 4.3.6.2.2 Updated equation variables' names
			Page 93: Updated Table 27 (This table corresponds to the old table 30) Updated equation variables' names.
			Page 94 and 95: Updated equation variables' names. Two equations have changed (Eqs. 32 and 34. They correspond to the old equations 82 and 84 respectively)
			Page 96: Updated equation variables' names. Added new section 4.3.2.1.6.
			Pages 97 to 103: Updated section 4.3.2.2 (corresponding to the old section 4.3.6.2.3). This is a complete remake, all sections new.
			Pages 107 to 110: Updated the table of variables with new variables' names that avoid confusions when reading the equations.
5 Rev. 0	12/2001–01 2002		
			Remove TBCs in 4.1 on page 65
			Exchange order of functions AMSU-A Antenna Correction and AMSU-A Brightness Temperature computation
			Page 66-67: Introduce inverse Planck function with bandwidth correction.
			Page 67-68: Exchange order of functions MHS Antenna Correction and MHS Brightness Temperature computation
			Page 68: Introduce MHS limb adjustment
			Page 68: Introduced formula for BT calculation for HIRS
			Page 73: Corrected equation 2 and text.
			Page 76: Explained Interpolation of Mean Brightnes Temperatures and Covariance Matrices.
			Page 79: Introduced bias correction algorithm for MHS.
			Page 83: Introduced HIRS/4 bias correction algorithm.
			Put Mapping function before HIRS/4 standalone cloud detection
			Page 87: Total ozone removed from output.
			Page 87: Reduced number of retrieval possible Retrieval algorithms for day 1.
			Annex A: Updated List of equation parameters
			Annex A: Updated FRTM specification to RTTOV-7
			Annex A: Provided Jacobians of the FRTM
5 Rev. 1	31/ 05/ 2002		All: Minor editorial modifications
			Chapter 1: Modified section 1.1, 1.3 Altered.

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			Added clarification to section 1.5.
			Chapter 2: removed diagrams and state transitions. 2.2.1 Removed table 2 2.3.1.3 changed phrasing. 2.3.1.3 removed reference to neural network. 2.3.2, 2.3.3 removed references to warm and cold starting. 2.3.4 modified Chapter 3: clarified wording; 3.1.1-0010 modified 3.1.2-0010, 3.1.2-0020 removed 3.1.2-0070-modified 3.1.3.2-0020 removed. 3.1.3.2-0050 removed. 3.1.3.3-0020 modifie 3.1.3.4-0010 removed point 1) 3.1.4.3.2-0150 modified 3.1.4.4.2-0020 modified 3.1.4.4.5-0080 modified 3.1.7 section removed. 3.2.2-0010 modified 3.2.3-10, 3.2.3-20 modified. 3.3-0020, 3.3-0030, 3.3-0040, 3.3-0050 removed 3.3-0230 removed 3.6 Section removed.
			Ch 4: Adapted AVHRR Scenes Analysis output to AVHRR Introduced MHS channels 3, 4 for retrieval Introduced GTS Product Content Introduced Comments Lydie Lavanant
5.2	14 March 2003	EUM.EPS. SYS.DCR.03.068	4.1.1.2 Eqs. 75, 76, 77 corrected, boundaries for brightness temperature added 4.1.1.5 Boundaries for brightness temperatures added 4.1.1.7 Boundaries for brightness temperatures added
			4.2.3.2 Box extension for AMSU-A surface type determination added 4.2.3.5.2 Values for the coefficients in Eq. 2 added 4.2.3.6 Eq. 8 corrected 4.2.3.6.4 removed and merged with 4.2.4.6 4.2.4.2 Box extension for MHS surface type determination added 4.2.4.8 Heading of Tab. 14 corrected
			4.2.7. Further specification of the default grid mapping procedures
			4.3.2.1.3. Precipitation flag added 4.3.2.1.3. Use of AVHRR land surface temperatures added
5.2	14 March 2003	EUM.EPS. SYS.DCR. 03.068	4.3.2.1.4.2 Eq. 17 corrected; Clarification of the use of different biases for Land/Sea/Coast
			4.3.2.1.4.3 Eq. 96 corrected
			4.3.2.1.4.6 Altitude dependence of microwave surface emissivity for land surfaces included
			4.3.2.1.4.6 Default values for the coefficients in Eq. 103 are added Eq. 103 is corrected Eqs. 116, 117 corrected
			4.3.2.1.4.7.2 Paramter description of Eq. 24 corrected
			4.3.2.1.4.8.1 Default number of minimum situations specified
			4.3.2.1.4.8.2 Values added, fixed threshold for added
			4.3.2.1.4.8.3 Eq. 153 corrected in Eq. 163 defined Eqs. 166, 167 corrected
			4.3.2.1.5 Eq. 32 modified Eqs. 38 and 40 clarified

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			4.3.2.1.5.4 Eqs. 173, 174 modified
5.3	26 March 2004	EUM.EPS. SYS.DCR.04.032	4.2.3.5.2 minor clarification of “zenith angle at t*he FOV on the Earth* surface”
			4.2.3.5.2 correction of the explanation of eq. 2
			4.2.3.5.2 clarification of satellite zenith and scan angles
			4.3.2.1.2.1 clarificaton of list of retrieval set-up parameters
			4.3.2.1.2.5 change from 2 to 3 emissivity classes
			4.3.2.1.4.2 correction of eq. 17 and its explanation
			4.3.2.1.4.5 1st paragraph “Over sea ... _IREMIS)” Dropped
			4.3.2.1.4.6 obvious correction from 5 to 59 in paragraph following eq. 23
			4.3.2.1.4.8.1 correction of “inversion” to “first guess selection” and other clarifications
			4.3.2.1.4.8.1 clarification of explanation of eq. 141
			4.3.2.1.4.8.2 clarification of the selective use of the nearest or the mean guess as the first guess to be used for the inversion + consistent use of the term “first guess” in the following sections
			4.3.2.1.4.8.3 removal of eq. 144 and 145 + provision of start condition of zi calculation
			4.3.2.1.4.8.3 correction of eq. 153 and its explanation
			4.3.2.1.4.8.3 clarification that g in eq. 157 andin eq. 163 is dependent on and z according toeq. 146
			4.3.2.1.4.8.3 correction of eq. 161 and eq. 162
			4.3.2.1.5 correction of typo: CTP >>> CTT
			4.3.2.1.5.1 clarification that different channel sets are tobe used for the different pairs of the surface type of theFOV and its cloudiness type
			Removed several TBCs, TBDs and TBW
			4.2.4.7 added: mapping = nearest neighbour
			4.2.6.1 removed threshold definition since already specified in 4.1.1.7
			4.2.7 added type of mapping of MHS onto HIRS grid
			4.3.2.1.4.2 corrected “scan angle” to “satellite zenithangle”
			4.3.2.1.4.4 corrected “dry adiabatic” to “mean temperature”
			4.3.2.1.4.5 removed “emissivity model is part of FRTM”
v6	6 Feb 2009	EPS_AB_DC R_EUM_27	4.3.2.2.5 & 4.3.2.2.6 corrected text and equations 59 &60 to specify ‘below’ 285 K instead of ‘above’.
v6A	31 May 2010	ODT_DCR_ 161	4.3.2.1.4.2 Added text on action if channel 7 or 8 missing. 4.3.2.2.1 Added missing page reference for AMSUAPGS.
v6B	31 May 2012	EUM/EPS/AR/61 05.6	In response to EUM/EPS/AR/6105.6. changes were made to text and graphics to reflect the fact that AVHRR L1B data is NOT used as input to the ATOVS L2 PPF. Figures 1 and 2, p. 10: removed input of AVHRR L1B data Figure 4, p. 22 removed input of AVHRR L1B data Figure 5 p. 12: removed input of AVHRR L1B data Page 22 removed reference to AVHRR L1B data on pages 22, 32, 48, 49 57, 61, and 77.
v6C			Original document in 10 separate Framemaker files converted to a single word document.
v7	16/12/2013		New document saved in DM tool. Reviewed/edited/checked versus original.

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1 INTRODUCTION

1.1 Purpose, Scope and Structure

Product Generation Function' (most of which is to be implemented as the ATOVS Level 2 Product Processing Software or ATOVSL2-PPS) which are not already covered in the Core Ground Segment Requirements Document (CGSRD) and the other applicable documents. This specification encompasses not only the required algorithm functions but also the identified supporting functions pertaining to the science aspects of the product generation function. The entire document is applicable to the implementation of the ATOVS Level 2 Product Processing Software (ATOVSL2-PPS). The CGSRD contains other requirements pertaining the ATOVSL2-PPS as well.

The document covers all the functions encompassed by the 'ATOVS Level 2 Product Generation Function', the interrelations between these functions and the relation to the other functions of the EPS Core Ground Segment (CGS).

1.2 Relation to EPS Core Ground Segment

This document addresses all the requirements pertaining to science aspects of the ATOVSL2-PPS of the EPS Core Ground Segment. The product generation function encompasses all the functions (algorithms & scientific functions, supporting function) required for the generation of the products, including some aspects of the instrument-specific usage of the Product Generation Environment (PGE) services.

The instrument product generation function being a constituent of the CGS, and unless otherwise specified, all the requirements of the Core Ground Segment Requirements Documents (CGSRD) also apply to this function.

1.3 Document Evolution

This document has evolved through the EPS project development lifecycle which had, among others, the following milestones:

- CGS Kick-off
- EPS Preliminary Design Review (PDR)
- EPS Critical Design Review (CDR).

The current version of the document is Issue v7.

1.4 Document Structure

Section	*Contents*
1	is this introduction
2	presents the overview of the instruments and the operational concept of the product generation function
3	contains the requirements of the ATOVS Level 2 Product Generation Function.
4	contains detailed descriptions of the scientific algorithms to be used by the ATOVS Level 2 Product Generation Function.
Appendix A	Equation Parameters List
Appendix B	User-Configurable Data List

1.5 Requirements Hierarchy and Precedence

The requirements presented herein are organised according to the hierarchical functional decomposition. The instrument product generation function is a constituent of the Core Ground Segment (CGS). Therefore, unless otherwise specified, all the requirements relevant to product generation in the Core Ground Segment Requirements Document (CGSRD) apply to this product generation function. In case of conflict between these Product Generation Function requirements and the ones in the Core Ground Segment Requirements Document (CGSRD) requirements, the latter shall take precedence. In case of conflict between the contents of Chapter 4 and any other portion of this document, the contents of Chapter 4 shall take precedence. Notwithstanding the designation of certain functions as critical or essential, all functionality required in this document is to be delivered by the PGF.

1.6 Identification of Requirements

DES	Design Constraints
FUNCT	Functional Requirements
INT	Interface Requirements
MMI	Man-Machine Interface Requirements
PERF	Performance (including Accuracy) Requirements
RES	Resource Usage Requirements
RAMS	Reliability, Availability, Maintainability and Safety Requirements
TEST	Testing Requirements

The numbering of the requirements follows the following convention:

ATOVSL2-PPS-NNNN TYPES

where TYPES indicate the relevant types of the requirement, according to the table above.

1.7 Acronyms and Abbreviations Used in this Document

Acronym	*Meaning*
AAPP	ATOVS and AVHRR Processing Package
AMSU	Advanced Microwave Sounding Unit
ATOVS	Advanced TIROS Operational Vertical Sounder
AVHRR	Advanced Very High Resolution Radiometer
CDA	Command and Data Acquisition
CGS	Core Ground Segment
CGSRD	Core Ground Segment Requirements Document
CTP	Cloud Top Pressure
CTT	Cloud Top Temperature
EPS	EUMETSAT Polar System
FOV	Field of View
FRTM	Fast Radiative Transfer Model
ICI	Imagery Coupled Inversion
GAC	Global Area Coverage
GTS	Global Telecommunication System (of the WMO)
G/S	Ground Segment
HIRS	High Resolution Infrared Radiation Sounder
IR	Infrared
LUT	Look-Up-Table
M&C	Monitor & Control
MCD	Mission Conventions Document
MHS	Microwave Humidity Sounder
MMI	Man Machine Interfaces
MSG	Meteosat Second Generation
NOAA	National Oceanographic and Atmospheric Administration
NRT	Near Real Time
PCD	Product Conventions Document
PGE	Product Generation Environment
PGF	Product Generation Function
PGS	Product Generation Specification
PPS	Product Processing Software
RMS	Root Mean Square
RTTOV	Radiative Trransfer Model for TOVS (TIROS Operation Vertical Sounder)
R/S	Radiosonde
SADT	Structured Analysis and Design Technique
S/C	Spacecraft

Acronym	*Meaning*
SI	Scattering Index
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
S/W	Software
TBC	To be Confirmed
TBD	To be Defined
TIROS	Television and Infrared Operational Satellite
TM	Telemetry and Monitoring
VIS	Visible
WMO	World Meteorological Organisation

1.8 System Definitions

Element	*Meaning*
ATOVS Instruments	The ATOVS Instruments are AVHRR/3, HIRS/4, AMSU-A and MHS.
ATOVS Level 2 Retrieved Geophysical Parameters	The list of parameters is composed of at least the following: Temperature Profiles; Humidity Profiles; total Ozone Column; Surface Temperature; Cloud Top Temperature; Cloud Top Pressure; Effective Cloud Amount; Surface Type.
Cold-start	A processing function is started using a pre-defined default configuration.
Critical Path	The path formed by a the application of a set of functions that need *all* to be performed in a specified way to get the desired output. Each of the functions is then critical to the production of the output.
Degraded Quality	accuracy of the PGF outputs during Degraded operational modes
Dynamic Data	Data that changes over time with a frequency above a certain threshold. In this case, the threshold is more than once per month on average.
Field of View (FOV)	The geometric projection of a single detector width onto the Earth's surface (usually expressed as an angle). The across- and along-scan movement creates a grid of FOVs called an image
Nominal mode	The function behaves as it has been specified by its requirements within its usage criteria, whether it is performing under normal or degraded circumstances.
Static Data	Data that does not change at all over time or changes over time with a frequency below a certain threshold, which in this case is less than once per month on average.

Element	*Meaning*
Target Quality	Accuracy of the PGF products during Normal NRT, Backlog and Reprocessing operational modes, when all the necessary Level 1b and auxiliary data with the required characteristics are available when certain atmospheric conditions are being measured.
User-configurable	A set-up parameter or a piece of software with set-up parameters held in a data file which can be edited via a suitable MMI without any code modifications.
Warm-start	A processing function is started using the latest-used or a different-than-the-default configuration.

1.9 Applicable Documents

Following documents are applicable to the ATOVS Level 2 Product Generation Specifications (numbering follows CGSRD numbering):

No.	*Document Title*	*EUMETSAT Reference*
AD 1	Core Ground Segment Requirements Document, Issue 4; 06/08/99	EPS.GGS.REQ.95327
AD 2	Product Processing to PGE Interface Requirement Document, Issue 3.01 Draft; 08/06/00	EPS.GGS.IRD.980255
AD 3	EPS Generic Product Specification Document, Issue 5.0; 01/06/01	EPS.GGS.SPE.96167
AD 4	AVHRR/3 Level 1 Product Format Specification Document, Issue 5.0; 01/06/01	EPS.MIS.SPE.97231
AD 5	AMSU-A Level 1 Product Format Specification Document, Issue 5.0; 01/06/01	EPS.MIS.SPE.97228
AD 6	MHS Level 1 Product Format Specification Document, Issue 5.0; 01/06/01	EPS.MIS.SPE.97229
AD 7	HIRS/4 Level 1 Product Format Specification Document, Issue 5.0; 01/06/01	EPS.MIS.SPE.97230
AD 8	AVHRR/3 Level 1 Product Generation Specification Document, Issue 4.0; 01/06/01	EUM.EPS.SYS.SPE.990004
AD 22	AMSU-A Level 1 Product Generation Specification Document, Issue 4.0; 01/06/01	EUM.EPS.SYS.SPE.990005
AD 9	MHS Level 1 Product Generation Specification Document, Issue 4.0; 01/06/01	EUM.EPS.SYS.SPE.990006
AD 10	HIRS/4 Level 1 Product Generation Specification Document, Issue 4.0; 01/06/01	EUM.EPS.SYS.SPE.990007
AD 11	ATOVS Level 2 Product Format Specification Document, Issue 5.0; 01/06/01	EPS.MIS.SPE.980759
AD 12	EPS Mission Conventions Document, Issue 1 Draft D; 29/07/99	EUM.EPS.SYS.SPE.990002
AD 98	EPS Product Conventions Document, Issue 2 Draft B; 23/07/99	EUM.EPS.SYS.TEN.990007

1.10 Reference Documents

No.	Document Title
RD 1	MSG Ground Segment: Meteorological Products Extraction Facility Algorithm Specification Document.
RD 2	K.D. Klaes, 1998: *ATOVS Data Processing in Europe*; Technical Proceedings of the Ninth International TOVS Study Conference; Vol. 9, 15-27. Igls, Austria, 20 – 26 February 1997, 267 – 274).
RD 3	M. Derrien, B. Farki, L. Harang, H. LeGléau, A. Noyalet, D. Pohic, A. Sairouni: *Automatic Cloud Detection Applied to NOAA-11/AVHRR Imagery*; Remote Sense. Environ. 1993, 46, 246 – 267.
RD 4	J. R. Eyre: *Inversion of cloudy satellite sounding radiances by nonlinear optimal estimation.* I: Theory and simulation for TOVS; Q. J. R. Meteorol. Soc. 1989, 115, pp. 1001 – 1026.
RD 5	J. R. Eyre: *Inversion of cloudy satellite sounding radiances by nonlinear optimal estimation. II*: *Application to TOVS data*; Q. J. R. Meteorol. Soc. 1989, 115, pp. 1027 – 1037
RD 6	Crosby, Ferraro and Wu: *Estimating the probability of rain in an SSM/I FOV using logistic regression* Journal of Applied Met. 1995, 34, 11.
RD 7	N. Grody: *Classification of snow cover and precipitation using the Special Sensor Microwave Imager*; Geophys. Res. 1996, 96.
RD 8	English, S.J., T.J. Hewison: *A fast generic millimetre-wave emissivity model; Microwave Remote Sensing of the Environment*, SPIE, 1998, Vol. 3502.
RD-9	Prigent, C., E. Mathews, R. Rossow*: Microwave land surface emissivities estimated from SSM/I observations*; J. Geophys. res. 1997, 102, 21867 – 21890.
RD-10	J. Clim: The Improved Initialisation Inversion Method: *A high-resolution physical method for temperature retrievals from satellites of the TIROS-N series*; Appl. Met. 1985, 24
RD-11	L. Lavanant, P. Brunel, G. Rochard and T. Labrot: NOAA-15 *Sounding profiles retrieved with the ICI scheme*; Proceedings International TOVS Study Conference, 1999, 321 – 328
RD-12	L. Lavanant, H. LeGléau, M. Derrien, S. Levasseur, G. Monnier, L. Ardouin, P. Brunel, B. Belleec: *AVHRR cloud mask for sounding applications*; Proceedings of the International TOVS Study Conference, 1999, 329 – 335
RD-13	M. D. Goalkeeper*: Generation of Retrieval products from AMSU-A*: Methodology and Validation; Proceedings of the International TOVS Study Conference, 1999, 219 – 229
RD-14	Grody, N.C: *Classification of snow cover and precipitation using the Special Sensor Microwave* Imager; J. Geophys. res., Vol. 96, pp. 7423 -7435
RD-15	http://tamalo.larc.nasa.gov:8080/surf-tituils/sARB-surf.html
RD-16	C. Prigent, W. B. Rossow, W. Matthews*: Microwave land surface emissivities estimated from SSM/I observations*; J. Geophysical Research., 1997, Vol 102, No. D18, 21867-21890
RD-17	K. Masuda, T. Takashima, Y. Takayama: *Emissivity of pure and sea waters for the model sea surface in the infrared window regions*; Remote Sensing Env., 1988, 24, 313-329
RD-18	Saunders Roger, Marco Matricardi and Pascal Brunel: *A fast radiative transfer model for assimilation of satellite radiance observations*-RTTOV-5; European Centre for Medium Range Weather Forecasts (ECMWF), Technical Memorandum No. 282, 29pp

2 SYSTEM AND OPERATIONS CONCEPT

2.1 ATOVS Instrument Description

The ATOVS (Advanced TIROS (Television and Infrared Operational Satellite) Operational Vertical Sounder) is a sounding instrument package, which was first flown on the NOAA-KLM Satellite series operated by NOAA. It is composed of the Advanced Microwave Sounding Units A and B (AMSU-A, AMSU-B) and is complemented by the High Resolution InfraRed Sounder (HIRS/3). For EPS and the Initial Joint Polar System and the Joint Polar System, the AMSU-B sounder will be replaced by the Microwave Humidity Sounder (MHS). The upgraded version HIRS/4 of the Infrared Sounder will be on the Metop Satellites and also the NOAA-N and N' satellites. Since the Advanced Very High Resolution Radiometer (AVHRR/3) will also support the ATOVS Product Generation, it is, in the context of this document, included into the term ATOVS. Thus, if not stated otherwise, the term ATOVS refers to the package of four instruments: AVHRR/3, AMSU-A, MHS and HIRS/4. The ATOVS instruments are described in the respective Level 1 Product Generation Specification Documents as listed in section 1.7. The channels of the ATOVS sounding instruments HIRS/4, AMSU-A and MHS are, for the purpose of the retrieval processing, numbered continuously as follows (this channel numbering applies if the instrument channels are not explicitly mentioned):

Half power points (µm)	*Channel Noise specifications*
HIRS/4 channels 1-20	ATOVS channels 1-20
AMSU-A channels 1-15	ATOVS channels 21-35
MHS channels 1-5	ATOVS channels 36-40

2.1.1 Spectral and Sampling Characteristics of the ATOVS instruments

The spectral and sampling (FOVs and FOVs grids) characteristics of the ATOVS instruments are described in the respective Level 1 Product Generation Specification Documents, applicable to this document: [**AD-21**], **[AD-22**], [**AD-23**] and [**AD-24**].

2.2 System Concept

The 'ATOVS Level 2 Product Generation Function' is divided in sub-functions to be performed on received input and auxiliary data so as to generate ATOVS Level 2 Retrieved Geophysical Parameters of a given quality in a given timeframe. Before presenting in detail the functional breakdown and the associated requirements of the ATOVS Level 2 Product Generation Function, it is useful to introduce the functional decomposition and the designated names for the function to be used in this document.

The diagrams are a functional decomposition of the 'ATOVS Level 2 Product Generation Function' (PGF). Thick borders denote that the function is critical. Solid arrows denote input and output dataflows and define interfaces. Dotted lines denote CGS commands or settings. A table indicating the naming convention for the sub-functions precedes the diagrams as an introduction. The diagrams and table are useful to rapidly locate a particular sub-function inside the processing and its relation to other sub-functions. All ATOVS Level 2 Product Generation Function sub-functions are designated as functions themselves.

ATOVS Level 2 Product Generation Functional Decomposition

- **Level 1b and Auxiliary Data Acceptance Function**
  - ATOVS-Instruments Level 1b Data Reception Function
    - Compute AMSU-A Brightness Temperatures Function
    - Perform AMSU-A Limb Correction Function
    - Perform AMSU-A Antenna Correction Function
    - Compute MHS Brightness Temperatures Function
    - Perform MHS Antenna Correction Function
    - Compute HIRS/4 Brightness Temperatures Function
  - AVHRR/3 Scenes Analysis Data Reception Function
  - Side Information Reception and Correlation Function
  - Appended Level 1b Information Preparation Function
- **Input Data Vector Preparation Function**
  - Input Satellite Data Vector Generation Function
  - Retrieval Grid Determination Function
  - AMSU-A Data Preparation Function
    - AMSU-A Bias Correction Function
    - AMSU-A Surface Type Land/Sea/Coast Determination Function
    - AMSU-A Limb Adjustment and Correction for Surface Emissivity Function
    - AMSU-A Precipitation Signal Detection Function
      - AMSU-A Bias Correction Function
      - AMSU-A Surface Type Land/Sea/Coast Determination Function
      - AMSU-A Limb Adjustment and Correction Surface Emissivity Function
      - AMSU-A Precipitation Signal Detection Function
        - *AMSU-A Sea FOV Selection Function*
        - *AMSU-A Scattering Index Calculation Function*
        - *Precipitation Test after Crosby et al. Function*
        - *Grody Light Rain Test Function*
        - *Set Flag Function*
      - Surface Analysis Function
        - *Interpolate Means and Covariances Scan Angle*
        - *Cost Function and Surface Type Determination Function*
        - *Check Surface Type Function*
      - Map MHS to AMSU-A one function
      - Contamination and Clear/Cloudy Flagging Function
  - MHS Data Preparation Function
    - MHS Bias Correction Function
    - MHS Surface Type Land/Sea/Coast Determination Function
    - MHS Limb Adjustment and Correction for Surface Emissivity Function
    - MHS Channel 1 (89 GHz) Medium Filtering Function
    - MHS to AMSU-A FOV Mapping Two Function

			MHS 89 GHz on AMSU-A to MHS Function	
			Map AMSU-A to MHS Function	
			MHS Scattering Detection Function	
		AVHRR/3 Data Preparation Function		
			AVHRR/3 Scenes Analysis Results Checking Function	
		HIRS/4 Data Preparation Function		
			HIRS/4 Bias Correction Function	
			HIRS/4 Land/Sea Mass Determination Function	
			HIRS/4 Limb Adjustment Function	
			HIRS/4-only Cloud Analysis Function	
				Long wave Window Channel Test Function
				Adjacent FOV Longwave Window Channel BT Test Function
				Check Day/night Function
				Multi- window Channel Difference Test Day Function
				Multi-window Channel Difference Test Night A
				Multi-window Channel Difference Test Night B
				Multi-window Channel Difference Test Night C
				Multi-window Channel Difference Test Night D
				Declare Pixel Clear Function
				Declare Pixel Cloudy Function
		Retrieval Grid Mapping Function		
			Input Data to Retrieval Grid Mapping Function	
			Appended Data to Retrieval Grid Mapping Function	
			Microwave Tests Recalculation Function	
	ATOVS Level 2 Retrieval Product Generation Function			
		Retrieval Method and FRTM Selection Function		
		Geophysical Parameter Retrieval Function		
			Default Retrieval Method Function	
				Accept Input Data for Retrieval Function
				Accept Support Data for Retrieval Function
				Loop Function
				Inversion Preparation Function
				Compute Geophysical Parameters Function
				TPW CLW by AMSU-A Function
			Alternative Retrieval Method Function	
Data Formatting Function				

Table 1: Functional Breakdown of the ATOVS Level 2 Product Generation Function

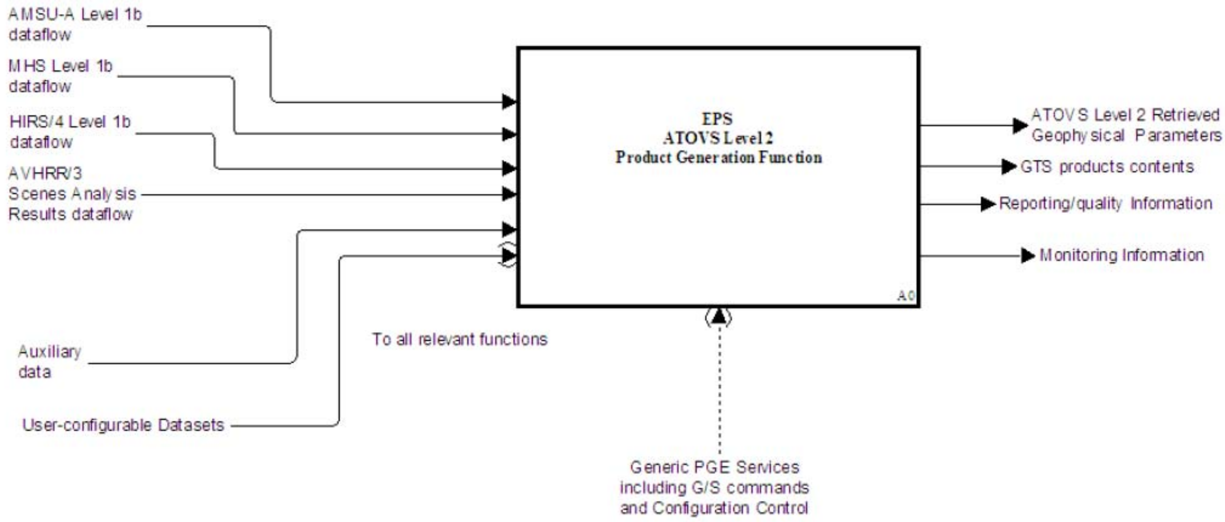

Figure 1: Context Diagram of the ATOVS Level 2 Product Generation Function

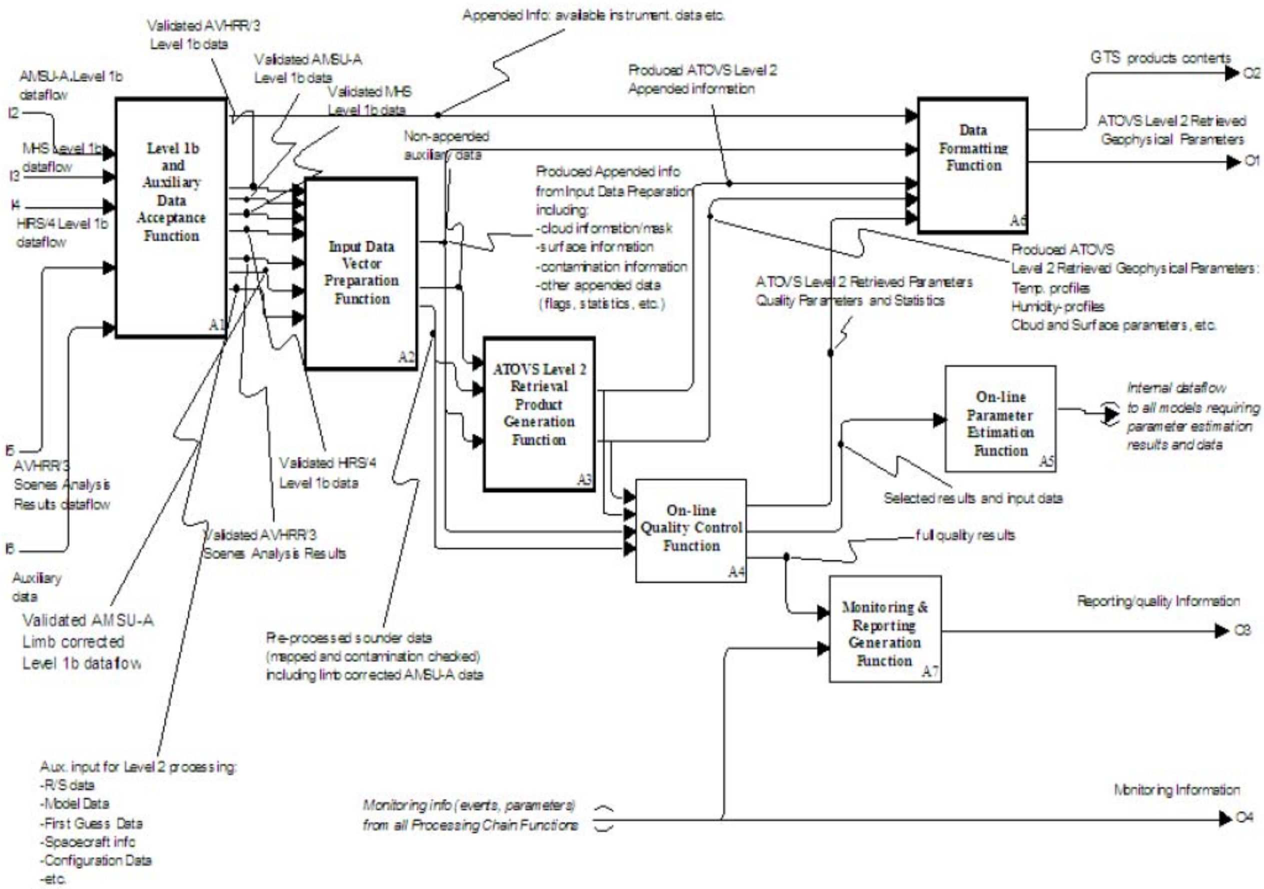

Figure 2: First-level Functional Diagram of the ATOVS Level 2 Product Generation Function

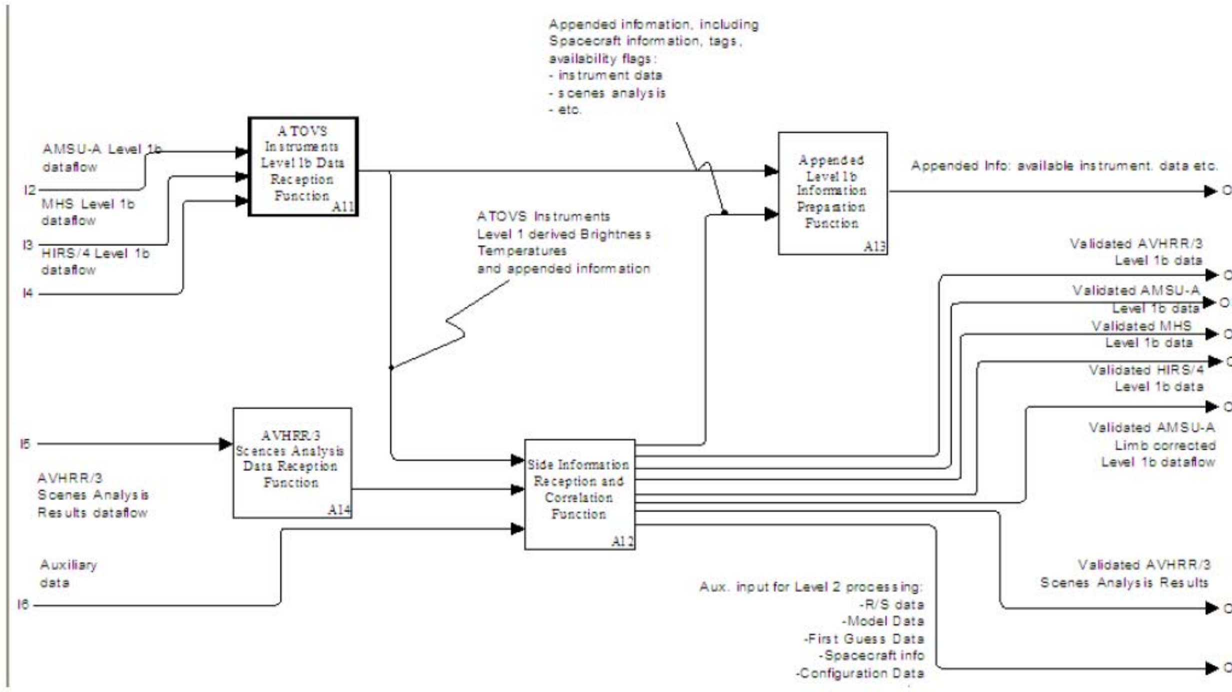

Figure 3: Second-level Functional Diagram of the 'Level 1b and Auxiliary Data Acceptance Function'

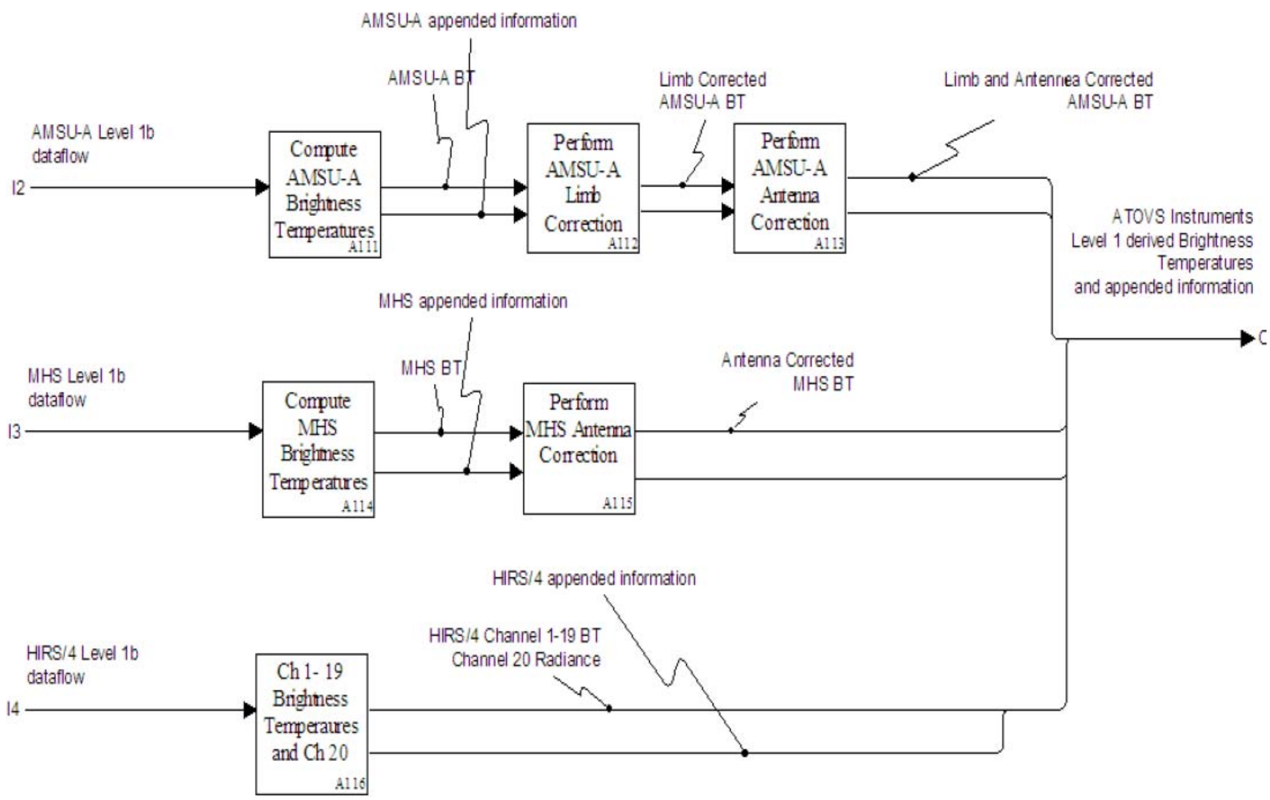

Figure 4: Third-level Functional Diagram of the ATOVS Level 1b Data Reception Function

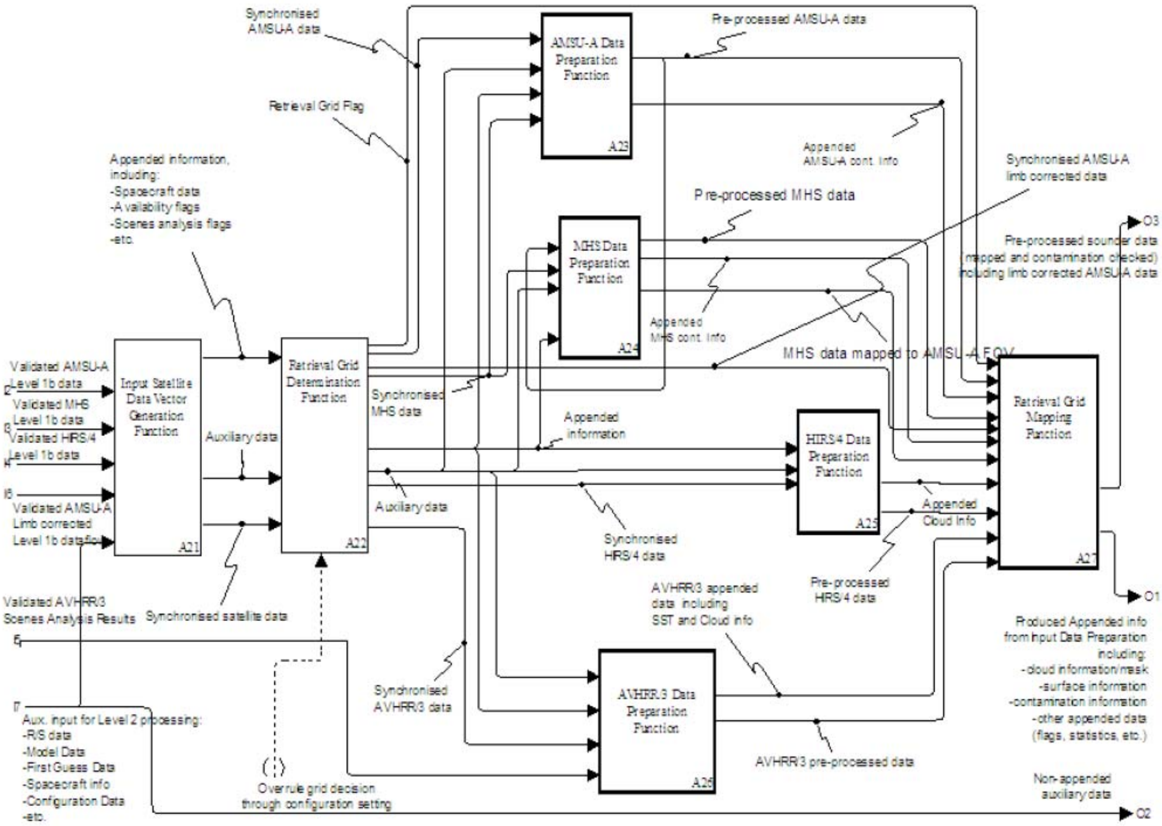

Figure 5: Second-level Functional Diagram of the Input Data Vector Preparation Function

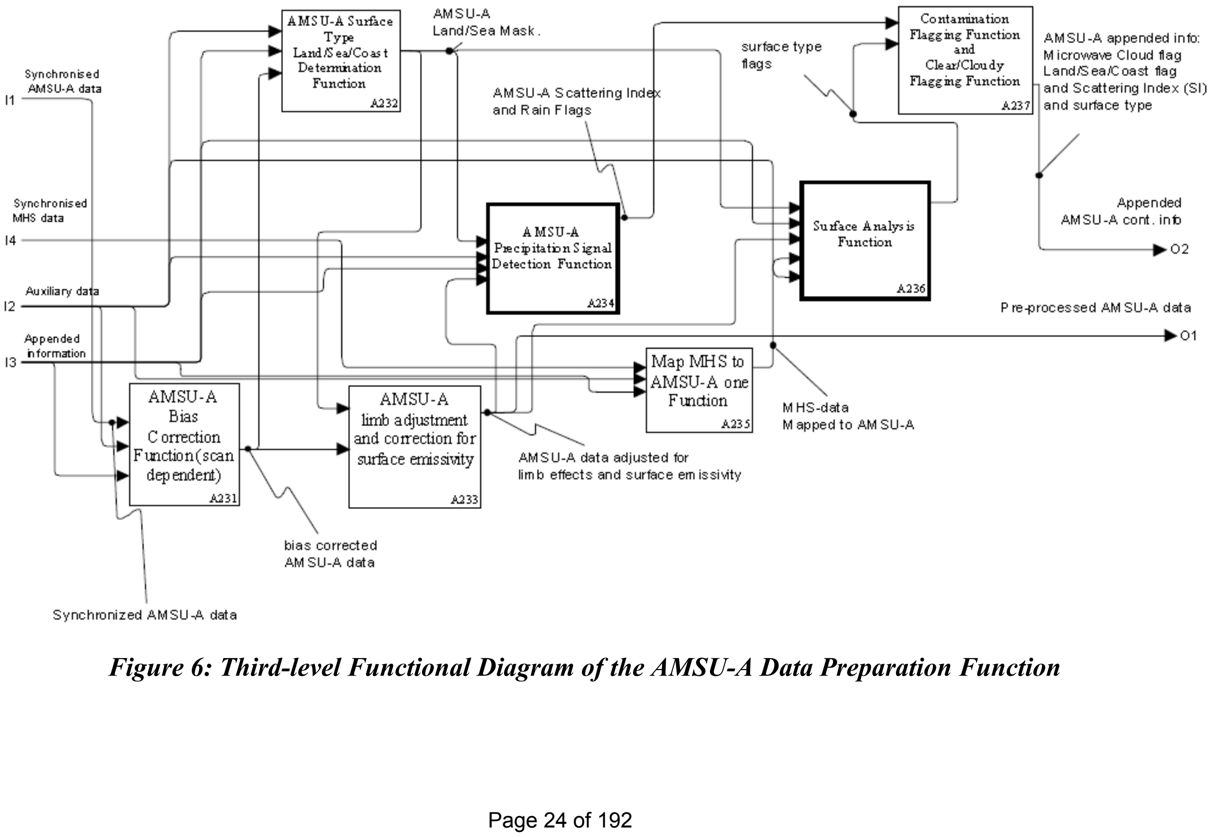

Figure 6: Third-level Functional Diagram of the AMSU-A Data Preparation Function

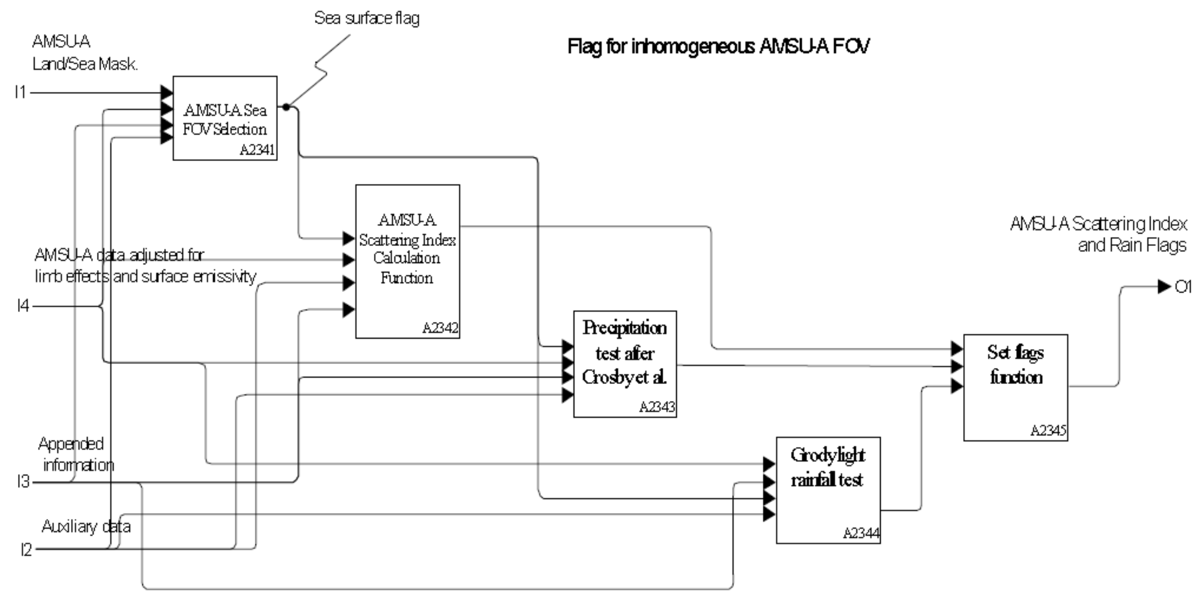

Figure 7: Fourth-level Functional Diagram of the AMSU-A Precipitation Signal Detection Function

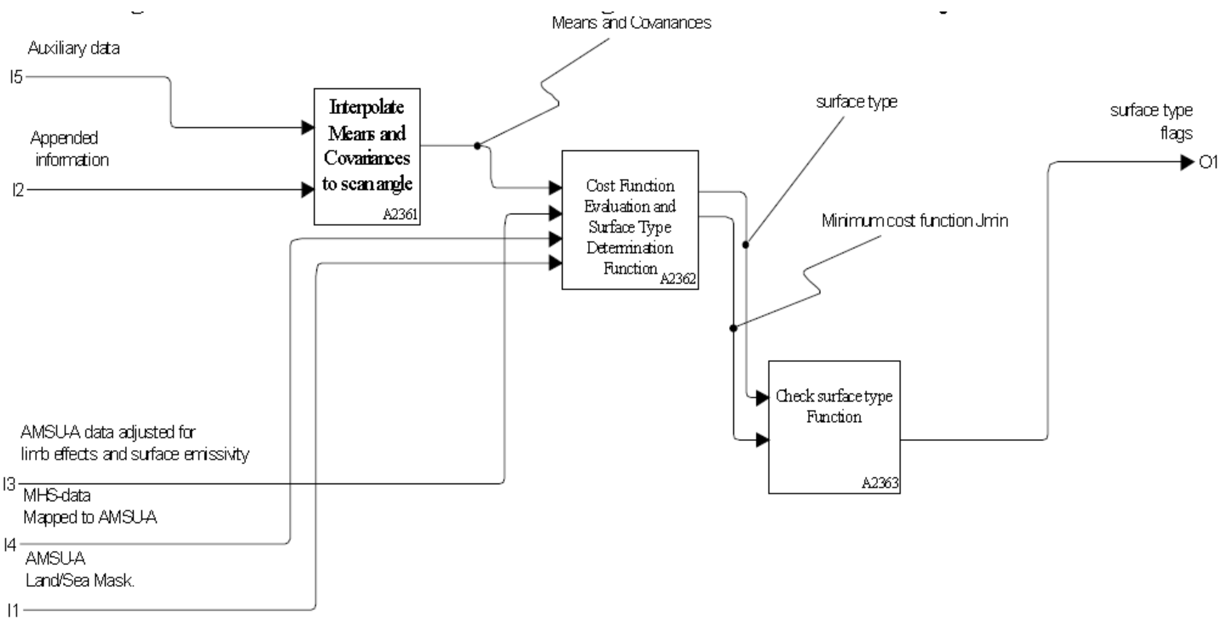

Figure 8: Fourth-level Functional Diagram of the Surface Analysis Function

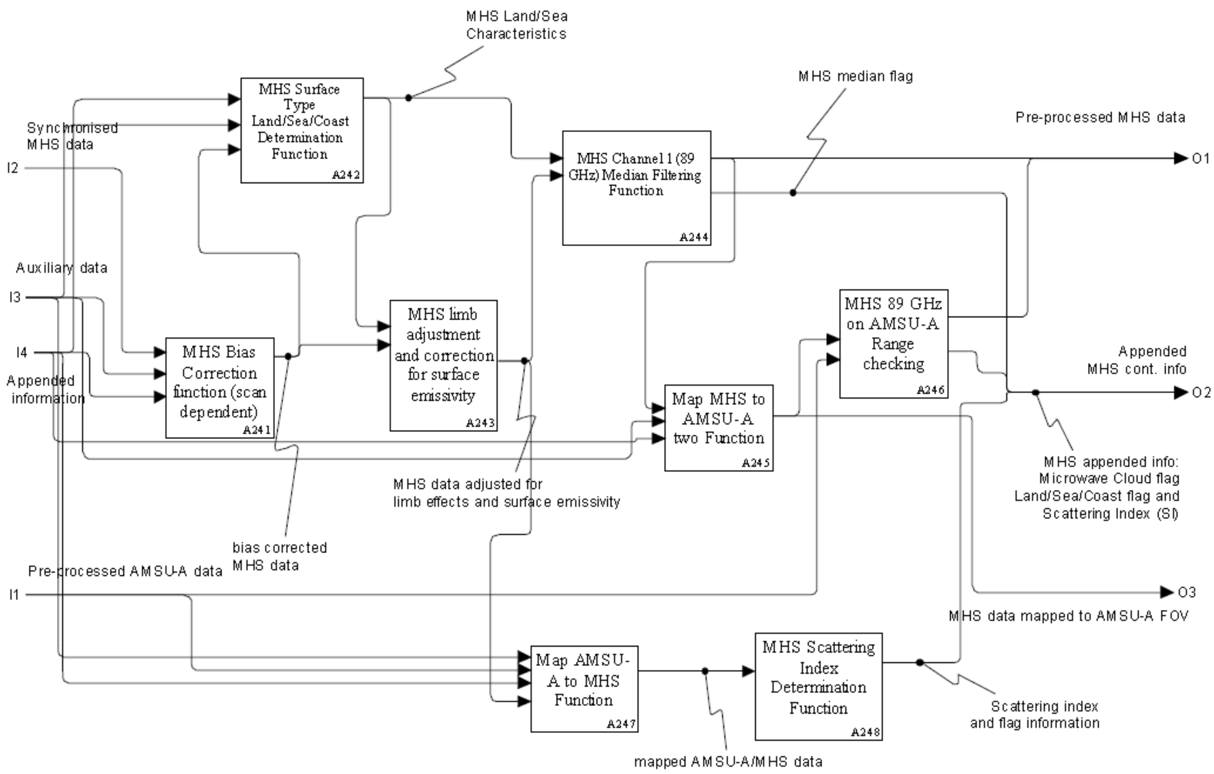

Figure 9: Third-level Functional Diagram of the MHS Data Preparation Function

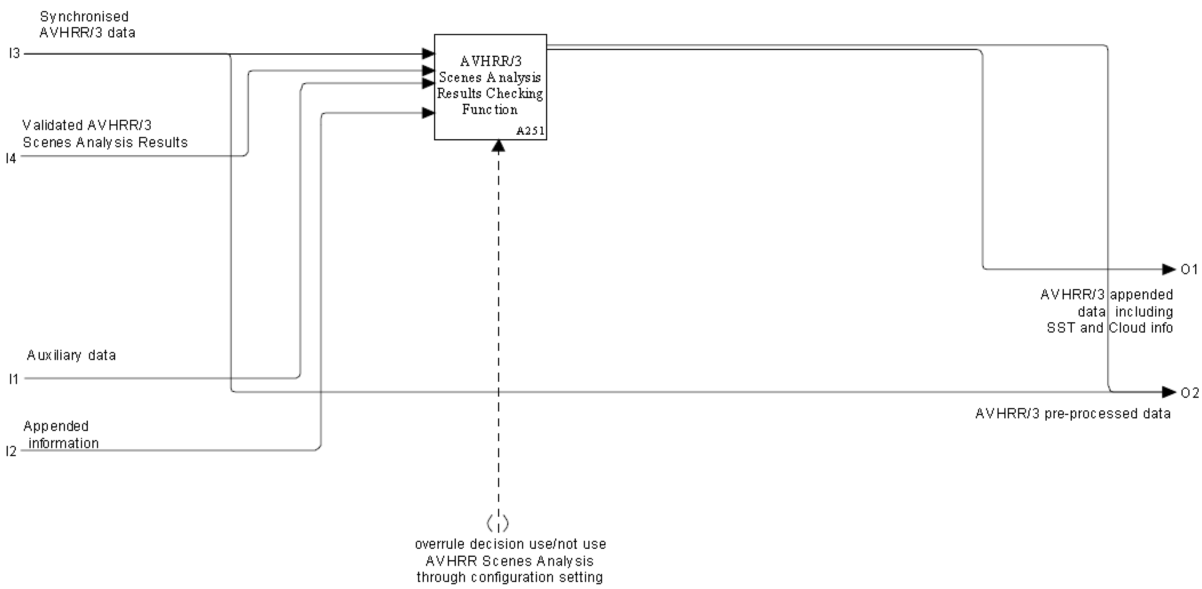

Figure 10: Third-level Functional Diagram of the AVHRR/3 Data Preparation Function

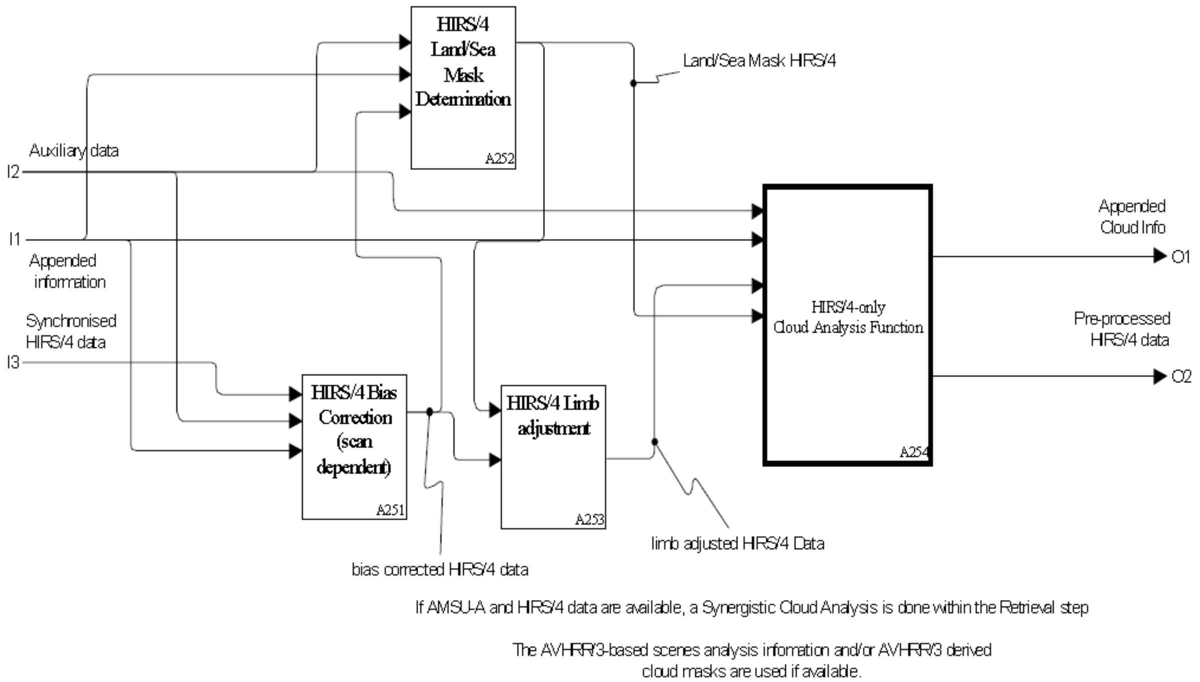

Figure 11: Third-level Functional Diagram of the HIRS/4 Data Preparation Function

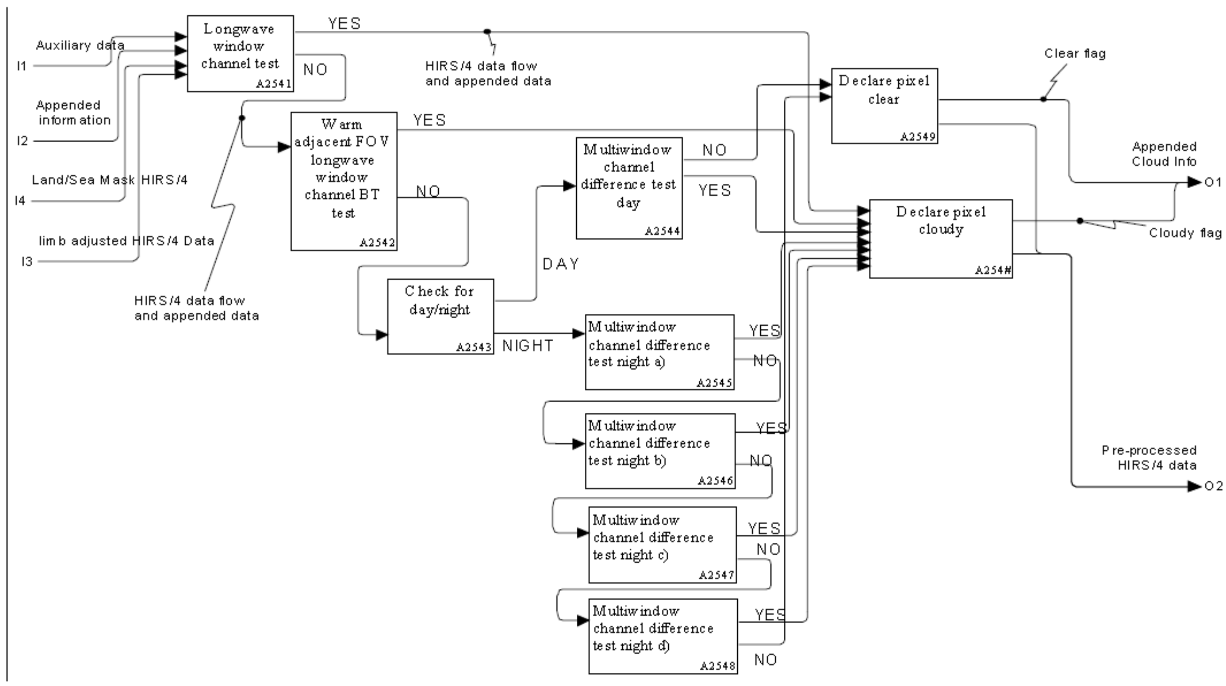

Figure 12: Third-level Functional Diagram of the 'HIRS/4-only Cloud Analysis Function'

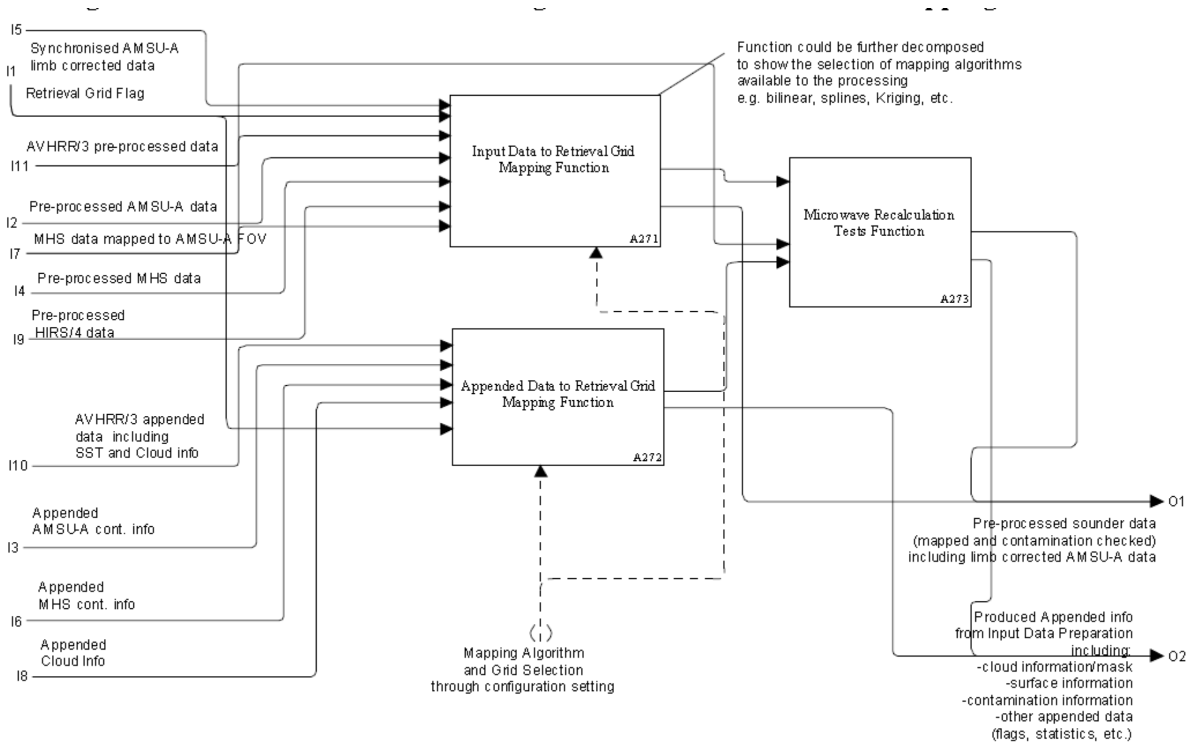

Figure 13: Third-level Functional Diagram of the 'Retrieval Grid Mapping Function'

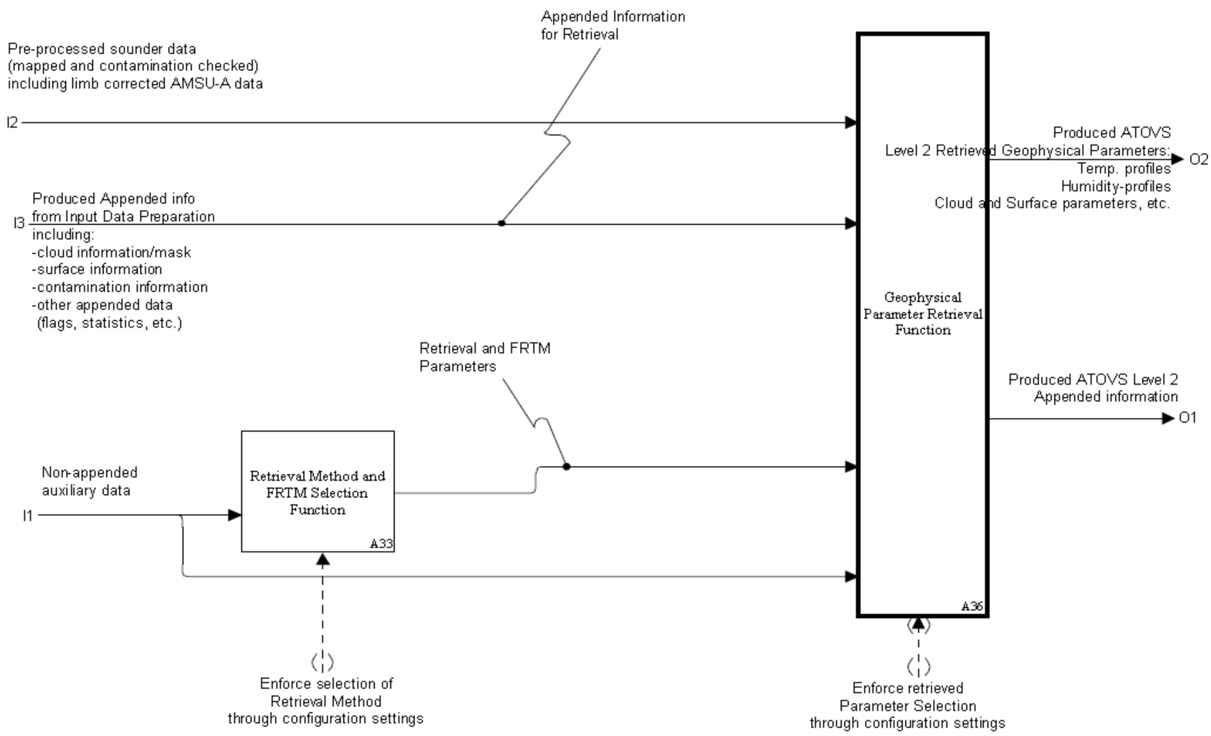

Figure 14: Second-level Functional Diagram of the 'ATOVS Level 2 Retrieval Product Generation Function'

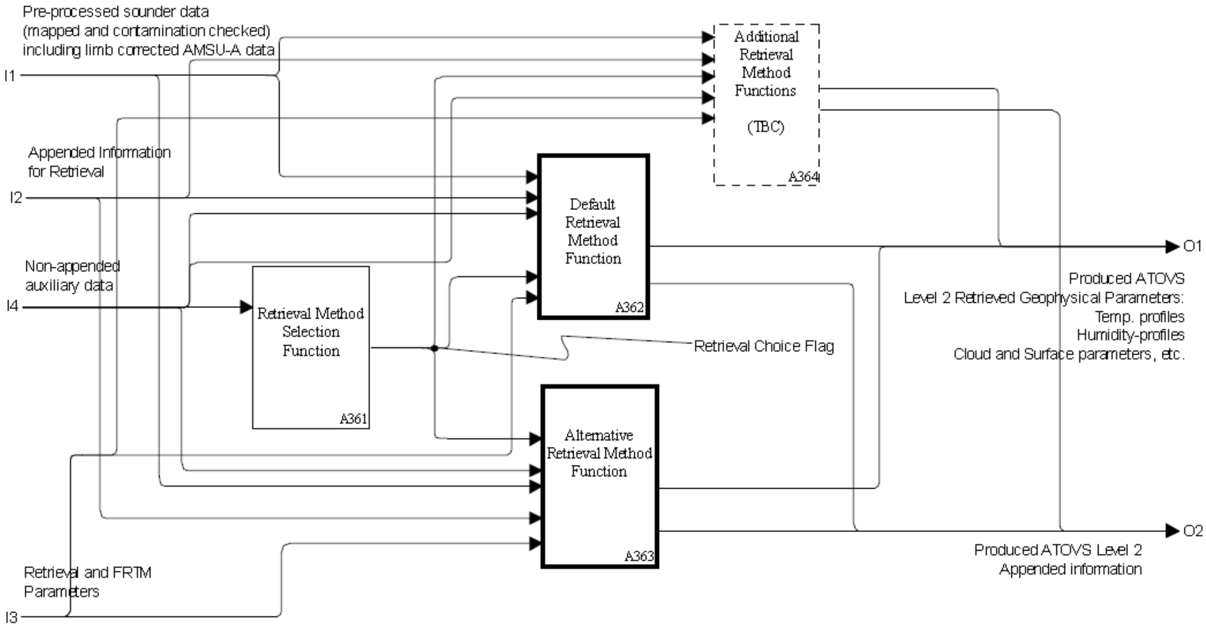

Figure 15: Fourth-level Functional Diagram of the 'Geophysical Parameter Retrieval Function

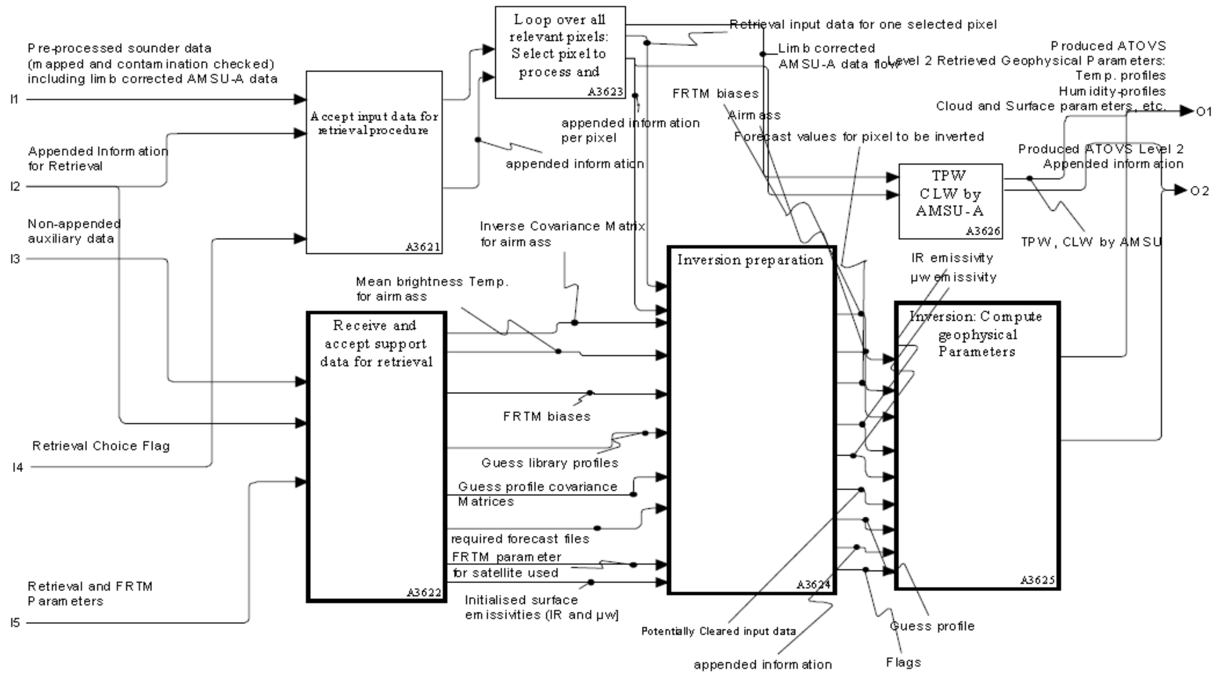

Figure 16: Context Diagram of the 'Default Retrieval Method Function'

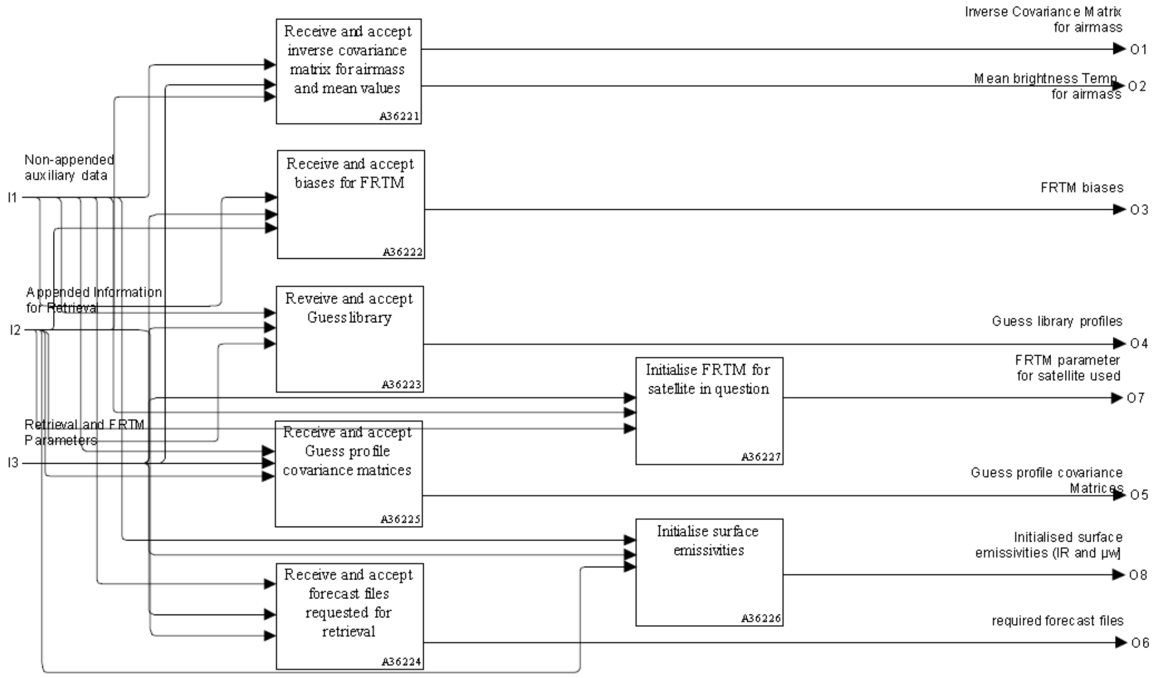

Figure 17: Context Diagram of the 'Accept Support Data for Retrieval Function

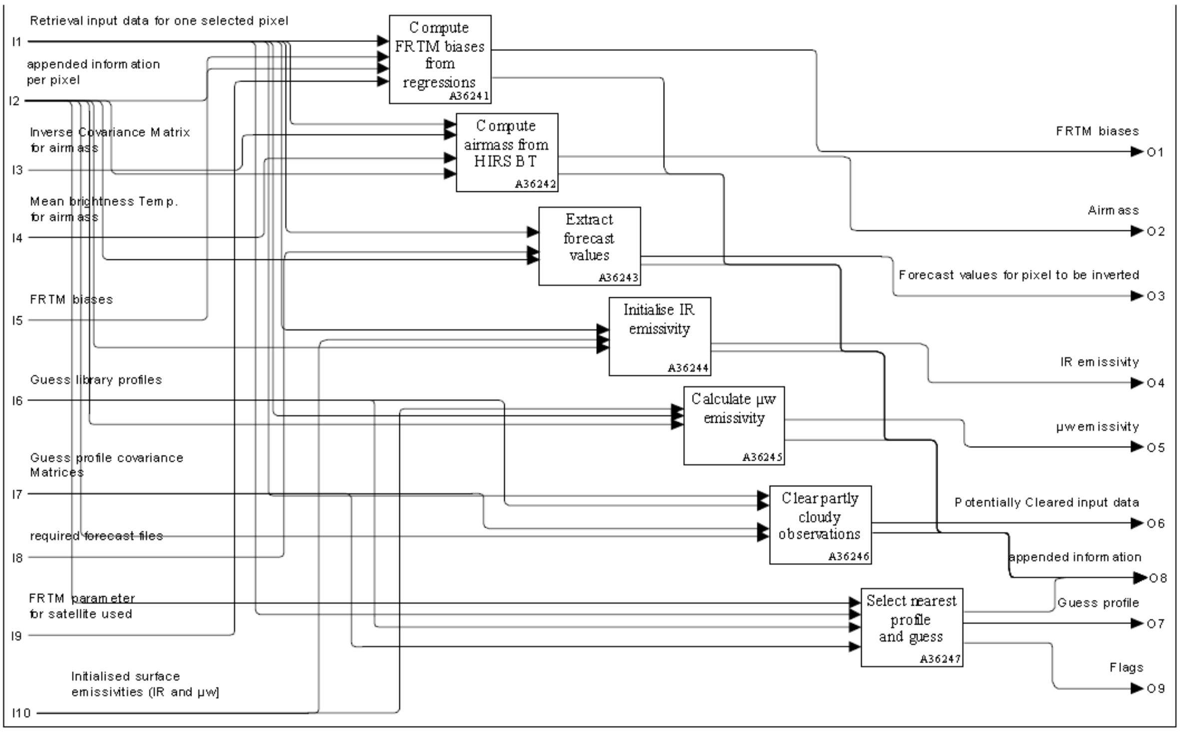

Figure 18: Context Diagram of the Inversion Preparation Function

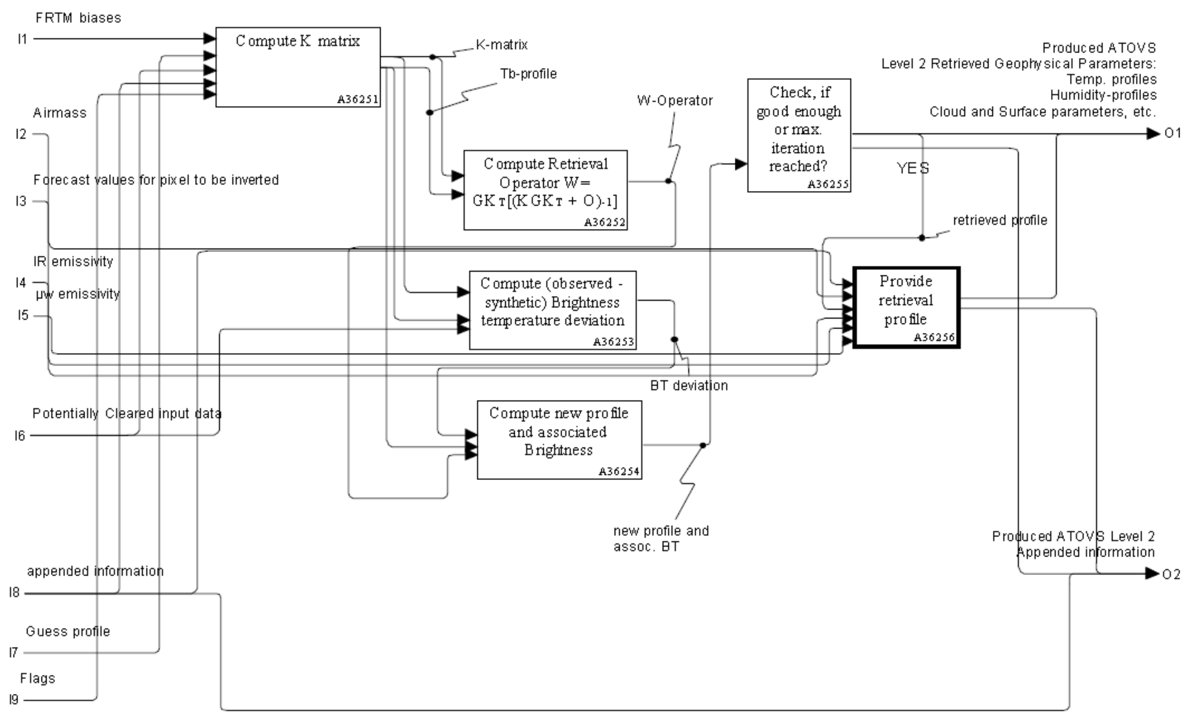

Figure 19: Context Diagram of the Compute Geophysical Parameters Function

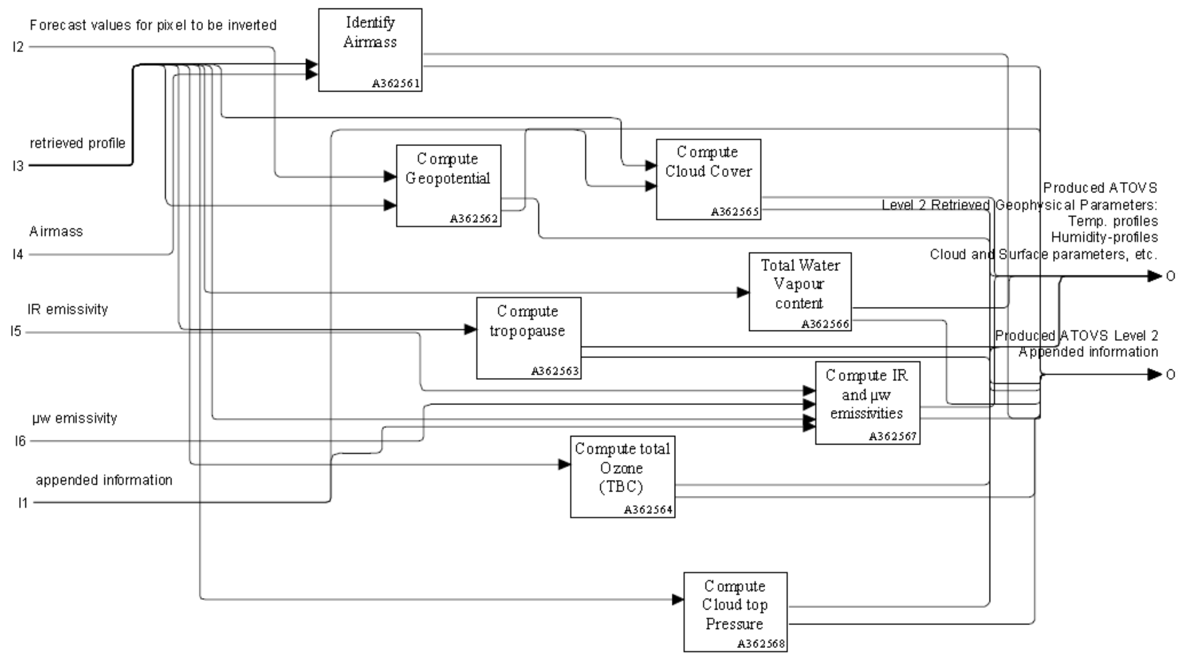

Figure 20: Context Diagram of the Provide Retrieval Profile Description Function

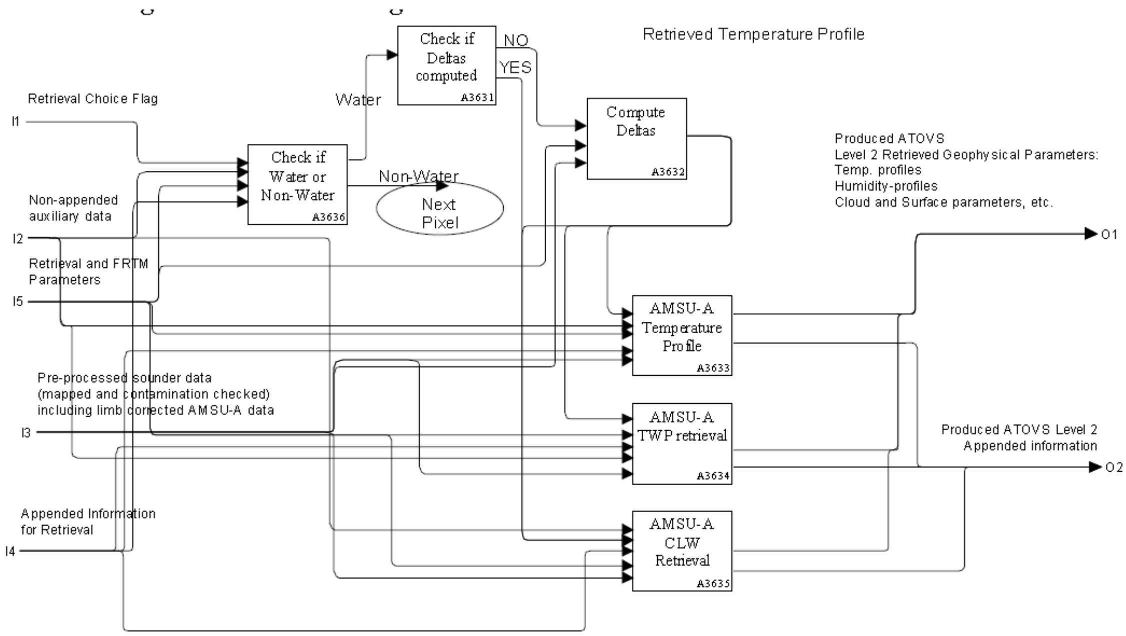

Figure 21: Context Diagram of the Alternative Retrieval Method Function

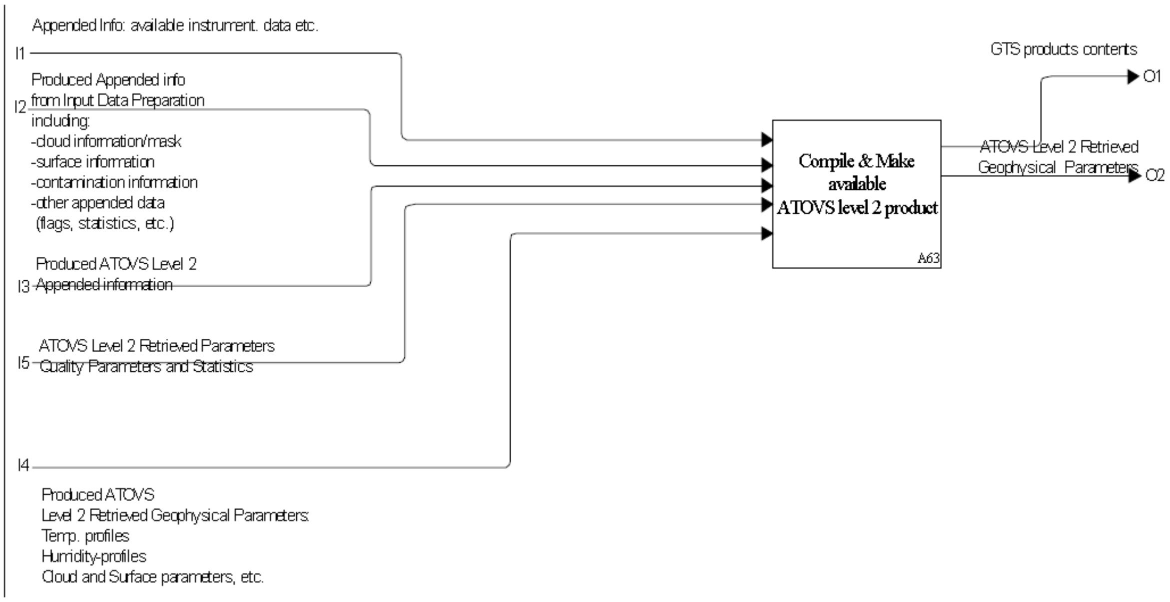

Figure 22: Context Diagram of the Data Formatting Function

2.2.1 System context

The ‘ATOVS Level2 Product Generation Function’ (PGF) interacts with the Core Ground Segment M&Cfunctionality by means of the Product Generation Environment (PGE) [AD-49] (EPS.GGS.REQ.95327,Issue 4; 06/08/99). Furthermore, the PGE provides the means by which the ‘ATOVS Level 2 ProductGeneration Function’ acquires satellite and instrument data downlinked via the CDA functionality. ThePGE also provides the means by which auxiliary data required by the processing is fed into the ‘ATOVS Level 2 Product Generation Function’.

The Processing state of the ‘ATOVS Level 2 Product Generation Function’ is controlled by the Core Ground Segment M&C function. A processing state describes the state at which the ATOVS Level 2 PGFis and defines what types of commands can be accepted from the Core Ground Segment M&C function.Some commands the Core Ground Segment (CGS) functionality can send to the ‘ATOVS Level 2 ProductGeneration Function’ are specified in the Core Ground Segment Requirements Document [AD-49] These five functions are as follows: START, STOP, ABORT, PAUSE, RESUME.

2.2.2 Major Interfaces

2.2.2.1 Inputs

AMSU-A Level 1b dataflow
Corresponds to the AMSU-A level 1 processed dataflow received from theAMSU-A Level 1 Product Generation Function. This dataflow includes calibrated AMSU-A radiances,and Earth Location information on the original instrument grid.

MHS Level 1b dataflow
Corresponds to the MHS level 1 processed dataflow received from the MHSLevel 1 Product Generation Function. This dataflow includes calibrated MHS radiances, and Earth Location information on the original instrument grid.

HIRS/4 Level 1b dataflow
Corresponds to the AMSU-A level 1 processed dataflow received from the AMSU-A Level 1 Product Generation Function. This dataflow includes calibrated AMSU-A radiances, and Earth Location information on the original instrument grid.

AVHRR/3 Scenes Analysis dataflow
Corresponds to the results of the AVHRR/3 scenes analysis data flow received from the AVHRR/3 Level 1 Product Generation Function. This AVHRR/3 scenes analysis dataflow includes information on cloud coverage, scenes type, and Earth Location information on the original instrument grid, among others [AD-21].

Auxiliary data
Corresponds to all data that are required from the ground segment and that are not present in the Platform Telemetry and the Level 1b dataflows. These are typically all derived information (orbit,attitude, and required derived/extracted platform parameters) provided in a timely manner.

User-Configurable Data
Indicates to the *ATOVS Level 2 Product Generation Function* the version of the parameters and the datasets (static or dynamic) that are to be used for the processing. These datasets are indicated as the user-configurable parameters, coefficients, etc., throughout this document. A preliminary list can be found Appendix B: *User-Configurable And Auxiliary Data*. They define, together with the version of the installed processing software, the configuration of the processing that is used to derive the ATOVS Level 2 Retrieved Geophysical Parameters.

2.2.2.2 Outputs

ATOVS Level 2 Retrieved Geophysical Parameters
Corresponds to the ATOVS Level 2 retrieved parameters (Temperature and Humidity profiles, Cloud Top Temperature and Pressure, Effective Cloud Amount, Total Ozone Column, Cloud Cover, etc.) as defined in this document that will be used by a functionality in the Core Ground Segment to format the EPS ATOVS Level 2 Products as defined in the applicable document ATOVS Level 2 Product Format Specifications [AD-45] and the ATOVS Level 2 GTS Products.

Reporting/Quality Information
Corresponds to the compiled reporting information produced by the ATOVS Level 2 Product Generation Function (on the received data, on the instrument performance, on the quality of the processing and on the performance of the mission) that are transferred to the reporting function of the Core Ground Segment. It also includes all the quality information required by the offline Quality Control Function of the Core Ground Segment.

Monitoring Information
Contains all regular monitoring information of the ATOVS Level 2 Product Generation Function, providing the Core Ground Segment M&C function with the information on the status of the instrument, data, processing functions, processing platforms, links, etc. In addition, theinformation contains also all events and command acknowledgements raised by the ATOVS Level 2Product Generation Function.

2.2.2.3 Mechanisms and Controls

Generic PGE Services
The Product Generation Function makes use of the generic PGE services for(amongst others) the communication, the reporting the monitoring/logging [AD-49]

G/S Commands
This corresponds to the commanding generated by the ground segment of the product generation function . These commands influence only the way the processing is done and are not related to instrument or platform commands.

2.3 Operations Concept

While in the active state, the 'ATOVS Level 2 Product Generation Function' supports all the modes of operation identified in the CGSRD [AD-49]. Table 2 presents the behaviour of the ATOVS Level 2 Product Generation Function in the identified operational modes: Normal NRT, Backlog processing, and Reprocessing. Each of these operational modes is described in detail in the following subsections.

In cases where some degradation of the product quality may be expected due to a given circumstance, degraded product quality will be achieved under nominal product extraction (nominal meaning the function behaves as specified by its requirements within its usage criteria) while operating in any of the defined operational modes. The degraded scenarios identified so far are described in Section 2.3.4. The *target quality* and the *degraded quality* of a product are defined and specified in the Requirements Section (Section 3) of this document.

Operational Mode	*Behaviour of the ATOVS Level 2 PGF*
Normal NRT mode	Nominal product extraction (Target or degraded quality achieved)
Backlog processing	Nominal product extraction (Target or degraded quality achieved)
Reprocessing	Nominal product extraction but based on historical input data "re-injected" via the normal external interfaces. Possibility of modified algorithm version or same algorithm version.

Table 2: Operational modes of the ATOVS Level 2 Product Generation Function while in the Active processing state. (Nominal product extraction means the product processing is carried out and performs as specified by the requirements in this document.)

2.3.1 Normal Near-Real Time (NRT) Operations

Normal Near-Real Time Operations, or NRT processing, refers to the sequence of operations that need to be performed to generate and disseminate the ATOVS Level 2 Retrieved Geophysical Parameters satisfying performance and timeliness requirements. The ATOVS Level 2 NRT processing includes data acceptance, validation, parameters retrieval, reporting and preparation of data for formatting. As its core scientific functionality lies in the retrieval of the geophysical parameter profiles of temperature, water vapour and also surface and cloud parameters. The core functionality also includes the preparation of the individual instrument data received through the Level 1b dataflow and of the auxiliary data.

Since it is planned to use all ATOVS Level 1b instruments data for the ATOVS Level 2 product generation as the default case, the individual dataflows need to be synchronised before being processed so that co-registration of different dataflows is performed correctly. Further data preparation includes, in the case of the microwave instruments AMSU-A and MHS, the detection of contamination effects through ice cloud particles and precipitation and the detection of the surface type. In the case of the visible and infrared instruments, AVHRR/3 and HIRS/4, the data preparation includes the inclusion of cloud analysis, i.e. using the AVHRR/3 based scenes analysis results [RD-1], and further analysis of AVHRR and HIRS/4 data to specify a cloud mask. This goes along with the determination of the land/sea distribution, and the inclusion of the Earth's topography information.

According to the selected retrieval grid, which is done previously, all data and flags are mapped to the retrieval grid and the Retrieval Input Vector for the retrieval process is created. The retrieval step will perform a retrieval-method-dependent data preparation and corrections, the calculation of temperature and water vapour profiles, the calculation of surface parameters like surface temperature, surface emissivity and the calculation of cloud parameters. An overview over the mathematical formulation of the ATOVS Level2 retrieval problem, with associated error covariance calculations, and corrections, is provided in [RD-2] and [RD-3]. These documents give an insight into the complexity of the entire system.

The ATOVS Level 2 Product Generation Function is constituted by three main operations which are in the critical path of the processing of the ATOVS Level 2 Retrieved Geophysical Parameters and are sequentially performed as listed in Table3. Besides these critical path functions, there are also supporting functions which are not necessarily applied sequentially as listed in Table 3Table 3, but that are applied when required by the ATOVS Level 2 Product Generation Function, whether in parallel or sequentially.

ATOVS Level 2 PGF Critical Path Functions
1. Level 1B and Auxiliary Data Acceptance 2. Input Vector Data Preparation Function 3. ATOVS Level 2 Retrieval Product Generation
ATOVS Level 2 PGF Supporting Functions
a. M&C Services Usage b. On-line Quality Control c. On-line Parameter Estimation d. Report Generation e. Data Formatting

Table 3: ATOVS Level 2 Product Generation Function Critical Path and Supporting Functions

The following subsections outline the functionality of the ATOVS Level 2 Product Generation Function.

2.3.1.1 Level 1B and Auxiliary Data Acceptance Function

This functionality will receive all relevant data from the previous ATOVS-Instruments Level 1 processing steps, where instrument data were processed individually. The completeness and integrity of the ATOVS Instruments Level 1b products ([AD-37] to [AD-40]) will be checked and the data prepared for further processing. The intermediate AVHRR/3 Scenes Analysis Results data is in [AD-21].

The auxiliary data include static and dynamic data. The static data include topography data and also information on the instruments and scan characteristics data. The dynamic data include forecast model results and/or other meteorological data, which will be used in the data analysis as reference and also for validation purposes. These data will, using the relevant header information of the respective products, be extracted for the area on the Earth surface the ATOVS-Instruments data cover, and be appended to the 'ATOVS Level 2 Product Generation Function' internal dataflow. The validation function checks for the plausibility and completeness of the input data. Abnormal conditions will give rise to corresponding events and log/reports. Although the general communication-level checks may be performed using generic PGE services, the validation of the ATOVS-Instruments Level 1b dataflows is data- specific and instrument-specific.

The status of the ATOVS-Instruments Level 1b dataflows should be properly recorded and reported to the Core Ground Segment appropriate functions as part of normal operations.

The Level 1b and Auxiliary Data Acceptance Function consists of the following sub-functions:

- ATOVS Instruments Level 1b Data Reception Function,
- AVHRR/3 Scenes Analysis Data Reception Function
- Side Information Reception and Correlation Function
- Appended Level 1b Information Preparation Function.

For more details on these functions and their corresponding functional breakdowns and nature, see Section 2.3.1.2.

2.3.1.2 Input Data Vector Preparation Function

This functionality prepares the input data vector for the subsequent inversion process, which solves aFredholm integral equation of the first kind ([RD-4] and [RD-5]). Included in this preparation process is the determination of the retrieval grid from the available input satellite data, the contamination analysis of the input data – this includes contamination through precipitation and ice particles, as well as surface effects and characteristics. Within this function, the cloud mask is derived and also the land/sea distribution is determined, and a land/sea mask is provided. The function then performs the mapping of all input data to a common retrieval grid. This includes also the mapping of all the auxiliary and appended data, which will be required by the subsequent processing, the Level 2 retrieval. This function is composed of the following sub-functions:

- Input Satellite Data Vector Generation Function
- Retrieval Grid Determination Function
- AMSU-A Data Preparation Function
- MHS Data Preparation Function
- AVHRR/3 Data Preparation Function
- HIRS/4 Data Preparation Function
- Retrieval Grid Mapping Function

For more details on these functions and their corresponding functional breakdowns and nature see Section 4.1.1.

2.3.1.3 ATOVS Level 2 Retrieval Product Generation Function

This function performs one of the core processes of the ATOVS Level 2 Product Generation Function, the retrieval process. A retrieval method is chosen, either from the available input data and a default configuration, or by a command from outside. The first step is the examination of the input vector and the final decision, whether synergistic retrieval can be performed using all sounding instrument data. The second step is the examination of the complete retrieval input data for cloud coverage, the data are flagged as Clear, Partly-cloudy and Cloudy, as appropriate. A decision about cloud clearing is performed as the third step. This decision depends on whether the retrieval shall be performed in cloudy cases also from the cloud top upwards, and also whether Partly-cloudy input vector shall be used for retrieval and whether it shall be cloud cleared. The fourth step is the initialisation of the retrieval process and the choice of an initial guess profile, which can be taken from a specific library, weather forecasts or climatological data, depending on the selected retrieval procedure. The retrieval process, an iterative one which includes radiative transfer calculations, is then performed constituting the fifth and most complex step of the process.

The ATOVS Level 2 Product Generation Function will be capable, while in the active processing state, of continuously processing available input data sets so as to produce ATOVS Level 2 Retrieved Geophysical Parameters. This will be automated, with control via the Core Ground Segment.

The ATOVS Level 2 Retrieval Product Generation Function consists of the following sub-functions:

- Retrieval Input Selection Function
- Retrieval Method and FRTM Selection Function
- Retrieval Input Data Cloud Amount Examination Function
- Cloud Clearing Decision Function
- Cloud Clearing Function
- Geophysical Parameter Retrieval Function

For more details on these functions and their corresponding functional breakdowns and nature see Section 4.3.

2.3.1.4 ATOVS Level 2 PGF Configuration Settings and Options

Besides the commands the CGS can send to the ATOVS Level 2 Product Generation Function, and the CGS requirement that all the ATOVS Level 2 Product Generation Function information which can be expected to be modified shall be user-configurable, there are ATOVS Level 2-specific configuration settings that allow the user to tell the ATOVS Level 2 Product Generation Function what configurations options or parameters data to use at a given moment. The same configuration must be used while processing the data of a dump (that is, a one full-orbit data). Configuration changes should be uploaded between the end of dump and the start of the next dump data from the satellite. The following settings have been identified:

1. Select the retrieval grid to be used in the ATOVS Level 2 Retrieval Product Generation Function. See section 4.2.2 ;
2. Select the retrieval method to be used in the ATOVS Level 2 Retrieval Product Generation Function, See Section 4.3;
3. Select the cloud detection scheme that will be employed in the AVHRR/3 Data Preparation Function. See Section 4.2.5;
4. Select the retrieval mapping method to be used in the Input Data Preparation Function. See section 4.2.21.

2.3.1.5 Supporting Functions

The following is a list of all the supporting functions that are to be satisfied by the ATOVS Level 2 Product Generation Function. Their implementation may be instrument-specific or data-specific. This section describes only the purpose of each function. Requirements on their functionality are listed in Section 3 of this document.

M&C Services Usage
All functions of the ATOVS Level 2 Product Generation Function make use of the PGE to receive commands from the Core Ground Segment and to transfer log and monitoring information to the Core Ground Segment.

On-line Quality Control
This function will provide to the Core Ground Segment all required product quality statistics on the supported mission and status of the ATOVS Level 2 Product Generation Function.

Parameter Estimation
This function will re-estimate parameters of models used in processing in near-real time. These could correspond to time-varying parameters of the ATOVS Level 2 processor and/or the involved corrections, which are spacecraft and instrument specific, that are not covered by the nominal processing but need to be performed due to drifts in the instrument characteristics.

Report Generation
The ATOVS Level 2 Product Generation Function will generate messages that will be passed to the Core Ground Segment for the generation of reports on the ATOVS Level 2 product generation and thus the corresponding mission performance and status.

Data Formatting
The data formatting function compiles and prepares all the data produced, generated and used by the ATOVS Level 2 Product Generation Function that is required to generate, by a facility located in the Core Ground Segment, the EPS ATOVS Level 2 Products following the format specified in [AD-45] and the GTS ATOVS Level 2 Products.

2.3.1.5.1 On-line Quality Control

The ATOVS Level 2 specific contents of the On-line Quality Control section are in the preliminary stages of definition. On-line Quality Control is a function that should be implemented as part of the ATOVS Level 2 Product Generation Function. It should perform the following tasks, according to the Core Ground Segment Requirements Document (CGSRD) [AD-49]:

1. Monitoring of input data to establish data product availability, link quality, format compliance, timeliness, consistency and quality;
2. Monitoring of product processing to detect changes in the operations like degraded scenarios and processing events;
3. Monitoring of the generated ATOVS Level 2 Retrieved Geophysical Parameters to establish their quality, completeness and timeliness.

2.3.1.5.2 Reporting

Besides the set of processing events that need to be reported as specified in the Core Ground Segment Requirements Document. See [AD-49], At least, the following ATOVS Level 2 significant events and parameters need to be reported:

1. Appended information to the ATOVS Level 2 retrieved parameter cannot be produced in its entirety;
2. Appended information to the ATOVS Level 2 retrieved parameter is corrupted or invalid;
3. ATOVS Level 2 retrieved parameter could not be produced;
4. Absence of the required input data for ATOVS Level 2 product processing;
5. Any non-nominal processing behaviour has been detected.

Two different reporting modes have to be provided: the nominal one and the investigation mode, as specified in the Core Ground Segment Requirements Document (CGSRD) [AD-49]. Investigation modes will provide additional information, like intermediate results, in the case of a degraded scenario being reported.

2.3.2 Backlog Processing

Late arrival of some dataflows by more than a specified configurable time or a product generation failure of causes the ATOVS Level 2 Product Generation Function to go into Backlog operations or delayed processing in backlog processing mode. The purpose of backlog processing is to maintain the completeness of the archive. Target quality of the ATOVS Level 2 Retrieved Geophysical Parameters should be achieved.

2.3.3 Reprocessing

Reprocessing is the capability to process any archived data with a valid product processing software. In case the Product Generation Function operates in reprocessing mode, the information is received via the CGS function providing the reprocessing support. The data might also originate from one of the test tools if the Product Generation Function is being tested standalone. Target quality of the ATOVS Level 2 Retrieved Geophysical Parameters should be achieved.

2.3.4 Degraded Scenarios

Degraded scenarios are triggered when a particular situation inside or outside the ATOVS Level 2 Product Generation Function causes it to operate in such a way that the quality of the ATOVS Level 2 Retrieved Geophysical Parameters is either not affected by the situation (target quality is achieved) or it is affected in a controlled, measurable and predictable way (degraded quality characterizes the ATOVS Level 2 Retrieved Geophysical Parameters).

A degraded scenario can occur in any of the already-identified operational modes: Normal NRT, Backlog processing or Re-processing. The processing can act automatically to the presence of a detected degraded scenario depending of the configuration of the processing.

The requirements in Section 3 specify how a degraded scenario should be treated and whether it has to be dealt with the same in all operational modes or not.

The degraded scenarios that have been identified in Table 4 below.

Degraded Scenario	*Behaviour of the ATOVS Level 2 PGF*	*Impact on Product*
Manoeuvre	Normal processing if instruments are operating while the satellite is undergoing the manoeuvre. If the instruments are switched off, no processing can take place.	Depends on the availability of all dataflows (input and auxiliary dataflows). Target quality or degraded quality can be achieved.
Normal NRT mode: night/day side	This refers to AVHRR/3 data only: Channel 3a switched on through telecommand over the dayside, channel 3b over the night side; Channels 1,2, and 4, 5 are operated continuously. The Channels 1 and 2 will provide no information over the night side.	Target quality achieved
Missing Level 1 data	If the missing data is a subset smaller than a given configurable size, use a pre-defined missing data value with the corresponding flagging. Input data is not interpolated and ATOVS Level 2 Retrieved Geophysical Parameters are not derived (replaced by flagged information in the Level 2 product format). Examples of this scenario are: Continuous operation of AMSU-A and HIRS/4 and MHS, no or degraded AVHRR/3 in use; Continuous operation of AMSU-A and MHS, no or degraded HIRS/4, with or without AVHRR/3 in use; Continuous operation of AMSU-A, no or degraded HIRS/4, MHS and AVHRR/3 in use	Not derived in case of complete lack of level 1 data of all ATOVS instruments. Alternate degraded product in the case of lacking level 1 data of one or more instruments, but sufficient instrument level 1 data left to perform a retrieval.
Corrupted Level 1 data	Processing identifies and flags the corrupted data. Processing continues as specified, retrieved parameters are of degraded quality.	Degraded and flagged as such
Invalid , missing or late/delayed auxiliary information (Instrument Aux, platform TM, G/S aux data)	The processing continues in degraded mode using either interpolated, previous or default auxiliary information (this is case-by-case as per requirements). In case auxiliary data arrives later than a user-configurable delay, then this late arrival is considered like missing data followed by duplicate data. In this case, the operational practice would be to reprocess the data at a later stage to increase the quality of the archived retrieved parameters . An example of this scenario is: Continuous operation with missing or degraded AVHRR/3 Scenes Analysis dataflow	Degraded and flagged as such

Degraded Scenario	*Behaviour of the ATOVS Level 2 PGF*	*Impact on Product*
Duplicate data	Duplicate data is discarded. The most recent data will be kept. If the most recent data are corrupted and the old data are good, the old data should be kept.	Target quality achieved
Wrong satellite/ instrument	Data is discarded	Not derived
Missing Channels	Processing uses a reduced algorithm (to the extent specified in this document) and flags the results as degraded	Target or degraded quality achieved, outputs flagged as degraded
Invalid Calibration information	No calibration update – older calibration results should be applied	Target quality achieved if old calibration still within the specified accuracy

Table 4: Degraded Scenarios and their impact on the ATOVS Level 2 Product Generation Function

3 REQUIREMENTS

The requirements here specified must be entirely fulfilled by the ATOVS Level 2 Product Generation Function and derive directly from the basic requirements on the mission this product generation function supports as described in the corresponding applicable documents.

References to specific subsections in Section 4 are added to the requirements when necessary to facilitate understanding and maximize their clarity. References to specific auxiliary and/or configurable datasets are made using the names specified in Appendix B. These dataset names are intended as reference only and should not constraint the design of the ATOVS Level 2 PPS.

Although each requirement has its type(s) attached to its header (See Section 1.6), they have been conveniently divided in five major categories to improve the clarity of this section. The categories are as follows:

1. **Functional requirements**
Describe the required functionality of the 'ATOVS Level 2 Product Generation Function', including algorithms, user-configurable thresholds, criteria, etc. to be used and special procedures.

2. **Performance requirements**
Define the quality and resolution of the ATOVS Level 2 retrieved parameters for all the operational modes of the 'ATOVS Level 2 Product Generation Function'. In this sense, two terms are used to describe the quality of products throughout this document. Ssee also Section 1.8: • *Target quality*: accuracy of the ATOVS Level 2 Retrieved Geophysical Parameters during Normal NRT, Backlog and Reprocessing operational modes, when all the necessary Level 1b and auxiliary data with the required characteristics are available under certain atmospheric conditions being measured. • *Degraded quality*: accuracy of the ATOVS Level 2 Retrieved Geophysical Parameters during degraded scenarios. In some degraded scenarios, the degraded quality can be the same as the target quality.

3. **Interface requirements**
Describe the required interfaces related to auxiliary, input data and flag data to and from the 'ATOVS Level 2 Product Generation Function'. In particular, any requirements (accuracy, resolution, timeliness, etc.) on the auxiliary dataflows are specified here.

4. **Monitoring and Reporting requirements**
Describe functional requirements that apply to those functions that are to perform monitoring and on-line quality control of the ATOVS Level 2 Product Generation Function and reporting to the Core Ground Segment functionality.

5. **MMI Requirements**
Describe the required functionality of the man-machine Interface of the ATOVS Level 2 Product Generation Function.

The instrument-specific functionality of the ATOVS Level 2 Product Generation Function described by the requirements listed in the next subsections is in addition to the generic functionality ascribed to the product processing software identified in the Core Ground Segment Requirements Document (CGSRD).

3.1 Requirements

3.1.1 General ATOVS Level 2 PGF Requirements

ATOVSL2-PPS-3.1.1-0010	**FUNCT, INT, MMI**
The ATOVS Level 2 Product Generation Function shall provide all the functionality required and as specified in this document to support at least the following: 1. Reception and preparation of all the input and auxiliary data including all operations pertaining thereto specified in Section 4; 2. ATOVS Level 2 geophysical parameters retrieval including all operations pertaining thereto specified in Section 4; 3. Supporting functionality and including all operations pertaining to supporting functionality and all other functionality specified in Section 4. ***Note***: See also the ATOVS Level 2 PGF functional breakdown and the naming convention adopted in this document to denote these functions in Table 3.	

ATOVSL2-PPS-3.1.1-0020	**FUNCT, INT**
The ATOVS Level 2 Product Generation Function shall provide all the functionality required and as specified in this document to support the reception and preparation of all the input and auxiliary data in at least the following aspects: 1. Reception, acceptance and validation of the AMSU-A Level 1b dataflow; 2. Reception, acceptance and validation of the MHS level 1b dataflow; 3. Reception, acceptance and validation of the HIRS/4 Level 1b dataflow; 4. Reception, acceptance and validation of the AVHRR/3 Scenes Analysis Results dataflow; 5. Reception, acceptance and validation of all the auxiliary data required by the processing (instrument TM, G/S auxiliary data, other products, –also instrument-specific); 6. Preparation of Level 1b data for subsequent processing; 7. Configurable selection of functions parameters and elements via auxiliary data and settings;	

ATOVSL2-PPS-3.1.1-0030	**FUNCT, INT**
The ATOVS Level 2 Product Generation Function shall provide all the functionality required and as specified in this document to support the retrieval of ATOVS Level 2 geophysical parameters in at least the following aspects: 1. Generation of ATOVS Level 2 retrieved geophysical parameters and appended data; 2. Configurable selection of functions parameters and elements via auxiliary data and settings; 3. External control (optional) over ATOVS Level 2 product generation function element selection;	

ATOVSL2-PPS-3.1.1-0040	**FUNCT, INT, MMI**
The ATOVS Level 2 Product Generation Function shall provide all the supporting functionality required and as specified in this document, including at least the following: 1. On-line quality control of the products; 2. M&C interfacing functions using the generic Product Generation Environment services; 3. Preparation of the contents of the products for formatting (EPS products and GTS products); 4. Generation of monitoring information on the ATOVS Level 2 product generation and the ATOVS Level 2 Product Generation Function status using the Product Generation Environment services); 5. Visualisation of the processing event through a man-machine interface.	

ATOVSL2-PPS-3.1.1-0050	**FUNCT, PERF, INT**
The ATOVS Level 2 Product Generation Function shall support the production of ATOVS Level 2 products as specified in this document for input data that was acquired by the following platforms and instruments configurations: 1. MetOp-1 with ATOVS Instruments 2. MetOp-2 with ATOVS Instruments 3. MetOp-3 with ATOVS Instruments 4. NOAA-N with ATOVS Instruments 5. NOAA-N’ with ATOVS Instruments	

3.1.2 Supported Modes of Processing and Operational Scenarios Requirements

ATOVSL2-PPS-3.1.2-0030	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall support the production of ATOVS Level 2 products of target or degraded quality as specified in this document.	

ATOVSL2-PPS-3.1.2-0040	**FUNCT, INT**
The ATOVS Level 2 Product Generation Function shall accept and respond to commands sent from the Core Ground Segment functionality.	

ATOVSL2-PPS-3.1.2-0050	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall ingest and process all ATOVS Level 1b dataflows (AMSU-A, MHS, HIRS/4 and AVHRR/3) and auxiliary data to produce the corresponding ATOVS Level 2 retrieved geophysical parameters of target quality during Normal NRT processing, Backlog processing and Reprocessing operational modes as specified in this document.	

ATOVSL2-PPS-3.1.2-0060	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall use the same configuration settings for the processing of one orbit operation of all instruments (AMSU-A, MHS, HIRS/4 and AVHRR/3) and AVHRR/3 channel 3a in use or AVHRR/3 channel 3b in use.	

ATOVSL2-PPS-3.1.2-0070	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall process the ATOVS Level 1b dataflow and auxiliary data to produce ATOVS Level 2 retrieved geophysical parameters of degraded quality during Normal NRT processing, Backlog processing and Reprocessing operational modes while operating under a degraded scenario as specified in this document (see Table 4 for a description of some degraded scenarios).	

ATOVSL2-PPS-3.1.2-0080	**FUNCT**
The ATOVS Level 2 Product Generation Function shall support, during Normal NRT processing, Backlog processing and Reprocessing operational modes, and in addition to the processing of data from the continuous part of a dump, the processing at the beginning and the end of the dataset.	

ATOVSL2-PPS-3.1.2-0090	**FUNCT**
The ATOVS Level 2 Product Generation Functio' shall support, during Normal NRT processing, Backlog processing and Reprocessing operational modes, and in addition to the operation of data from the continuous part of a dump, the processing before and after dataflow gaps.	

ATOVSL2-PPS-3.1.2-0100	**FUNCT, INT**
As a minimum, the ATOVS Level 2 Product Generation Function shall provide while in the active processing state the following ATOVS Level 2-specific user-configurable settings: 1. Retrieval Grid Setting: Selects the retrieval grid to be used by the ATOVS Level 2 Retrieval Product Generation Function; 2. Retrieval Method Setting: Selects the retrieval method to be used by the ATOVS Level 2 Retrieval Product Generation Function; 3. MHS Mapping Decision Setting: Overrules the decision on the mapping of MHS data made by the MHS Data Mapping Decision Function;	

ATOVSL2-PPS-3.1.2-0110	**FUNCT, INT**
All the coefficients, settings, thresholds and parameters used by the ATOVS Level 2 Product Generation Function shall be user-configurable.	

3.1.3 Level 1b and Auxiliary Data Acceptance Function Requirements

ATOVSL2-PPS-3.1.3-0010	**FUNCT, INT**
The Level 1b and Auxiliary Data Acceptance Function shall provide all the functionality required and as specified in this document to support the following: 1. Acceptance and Validation of all the ATOVS Instruments Level 1b Data; 2. Acceptance and Validation of the AVHRR Scenes Analysis Results Data; 3. Acceptance and Validation of all the Auxiliary Data; 4. Preparation of the Level 1b Information Dataflow (Input Data Vector). ***Note***: For further details on these functions and the naming convention adopted in this document to denote them see Section 1.6 in this document.	

ATOVSL2-PPS-3.1.3-0020	**FUNCT**
The Level 1b and Auxiliary Data Acceptance Function shall operate as specified in Section 4.1.1 of this document.	

ATOVSL2-PPS-3.1.3-0030	**FUNCT**
The Level 1b and Auxiliary Data Acceptance Function shall be able to ingest data acquired from the MetOp spacecraft and from the NOAA spacecraft passed on by the Core Ground Segment through the Product Generation Environment (PGE).	

3.1.3.1 ATOVs Instruments Level 1b Reception Function Requirements

ATOVSL2-PPS-3.1.3.1-0010	**FUNCT**
The ATOVS Instruments Level 1b Reception Function shall operate as specified in Section 4.1.1 of this document.	

ATOVSL2-PPS-3.1.3.1-0020	
The ATOVS Instruments Level 1b Reception Function shall validate the Level 1b dataflow of each instrument by checking at minimum the following aspects: 1. Level 1b input data against the expected configuration; 2. Time coherency across all the ATOVS-Instrument Level 1b dataflows; 3. Correct sequence of the received ATOVS-Instrument Level 1b dataflows.	

ATOVSL2-PPS-3.1.3.1-0030	**FUNCT, INT**
The ATOVS Instruments Level 1b Reception Function shall validate the received ATOVS-Instruments Level 1b dataflows for the coarse radiometric aspects, detecting at least the following: 1. Data corruption resulting in contiguous unrealistic sequences or unrealistic values; 2. Data corruption resulting in an sudden change in the line histogram; 3. Abnormal gradients that are above a user-configurable threshold;	

ATOVSL2-PPS-3.1.3.1-0040	**FUNCT, PERF**
The ATOVS-Instruments Level 1b data detected as corrupted by the ATOVS Instruments Level 1b Reception Function shall be flagged as such.	

3.1.3.2 AVHRR/3 Scenes Analysis Data Reception Function Requirements

ATOVSL2-PPS-3.1.3.2-0010	**FUNCT**
The AVHRR/3 Scenes Analysis Data Reception Function shall operate as specified in Section 4.1.2 of this document.	

ATOVSL2-PPS-3.1.3.2-0030	**FUNCT**
The AVHRR/3 Scenes Analysis Data Reception Function shall check the AVHRR/3 Scenes Analysis Results data for consistency.	

ATOVSL2-PPS-3.1.3.2-0040	**FUNCT**
The AVHRR/3 Scenes Analysis Data Reception Function shall flag the AVHRR/3 Scenes Analysis Results data if it is inconsistent.	

ATOVSL2-PPS-3.1.3.2-0060	**FUNCT**
The AVHRR/3 Scenes Analysis Data Reception Function shall check the AVHRR/3 Scenes Analysis Results data for data out-of-bounds.	

ATOVSL2-PPS-3.1.3.2-0070	**FUNCT**
The AVHRR/3 Scenes Analysis Data Reception Function shall flag the AVHRR/3 Scenes Analysis Results data if it is out-of-bounds.	

3.1.3.3 Side Information Reception and Correlation Function Requirements

ATOVSL2-PPS-3.1.3.3-0010	**FUNCT**
The Side Information Reception and Correlation Function shall operate as specified in Section 4.1.3 of this document..	

ATOVSL2-PPS-3.1.3.3-0020	**FUNCT, INT**
The Side Information Reception and Correlation Function shall correlate the accepted ATOVS Instruments Level 1b dataflow with the accepted auxiliary data and extract the relevant information for the calibration and geolocation processing.	

ATOVSL2-PPS-3.1.3.3-0030	**FUNCT, INT**
The subset of data extracted by the Side Information Reception and Correlation Function for subsequent geolocation and calibration processing shall be user-configurable.	

3.1.3.4 Appended Level 1b Information Preparation Function Requirements

ATOVSL2-PPS-3.1.3.4-0010	FUNCT, INT
The Appended Level 1b Information Preparation Function shall support the following: 1. Appending of the required information to the ATOVS Level 1 internal dataflow of the ATOVS Level 2 Product Generation Function using the accepted ATOVS Instruments Level 1b input data and the accepted and correlated auxiliary data.	

ATOVSL2-PPS-3.1.3.4-0020	FUNCT
The Appended Level 1b Information Preparation Function shall operate as specified in Section 4.1.4 of this document.	

ATOVSL2-PPS-3.1.3.4-0030	FUNCT, INT
The Appended Level 1b Information Preparation Function shall compile and format the ATOVS Level 1b internal input dataflow in accordance with and using the validated ATOVS Level 1b input data.	

3.1.4 Input Data Vector Preparation Function Requirements

ATOVSL2-PPS-3.1.4-0010	FUNCT, PERF, INT
The 'Input Data Vector Preparation Function**'** shall perform at least the following operations: 1. Generate a vector of input level 1b satellite data, consisting of AMSU-A, MHS, HIRS-4 and AVHRR/3 data, if available; 2. Determine the retrieval grid, based on a nominal selection, from the available input data configuration; 3. Prepare the AMSU-A Data for subsequent product generation; 4. Prepare the MHS Data for subsequent product generation; 5. Prepare the HIRS/4 Data for subsequent product generation; 6. Prepare the AVHRR/3 Data for subsequent product generation; 7. Map input data, flags and auxiliary data of the function onto the retrieval grid; 8. Output the pre-processed (mapped and contamination checked) sounder data to the subsequent Level 2 Product Generation function; 9. Output the appended information from the Data Preparation steps to the subsequent Level 2 Product Generation function; 10. Output the non appended auxiliary data, such as associated model data, to the subsequent product generation function. ***Note:*** For more details regarding the functional breakdown and the naming convention adopted in this document to denote the functions of the Input Data Vector Preparation Function, see Section 4.2.	

ATOVSL2-PPS-3.1.4-0020	**FUNCT**
The Input Data Vector Preparation Function shall operate as specified in section 4.2 of this document.	

ATOVSL2-PPS-3.1.4-0030	**FUNCT, PERF, INT**
The Input Data Vector Preparation Function shall select the scientific algorithm for the ATOVS Level 2 retrieval processing according to the available instrument data and using user-configurable decision criteria.	

ATOVSL2-PPS-3.1.4-0040	**FUNCT, PERF, INT**
The Input Data Vector Preparation Function shall determine the ATOVS Level 2 Product Generation Retrieval Grid by comparing the available instruments ATOVS Level 1b data with a list of pre-defined and user-configurable data of required instrument ATOVS Level 1b data.	

ATOVSL2-PPS-3.1.4-0050	**FUNCT, INT**
The Input Data Vector Preparation Function shall provide the capability to optionally select through a user-configurable setting the retrieval algorithm used in the ATOVS Level 2 product generation.	

ATOVSL2-PPS-3.1.4-0060	**FUNCT, INT**
The Input Data Vector Preparation Function shall provide the capability to optionally select through a user-configurable setting the retrieval grid used in the ATOVS Level 2 product generation.	

ATOVSL2-PPS-3.1.4-0070	**FUNCT, INT, DES**
The Input Data Vector Preparation Function shall start from a user-configurable default configuration.	

ATOVSL2-PPS-3.1.4-0080	**FUNCT, PERF**
All the input data to the 'Input Data Vector Preparation Function' shall be validated with respect to the following: 1. the source of the data; 2. the data content and the completeness of the information before being used.	

ATOVSL2-PPS-3.1.4-0090	**FUNCT, INT**
The thresholds used by the Input Data Vector Preparation Function for validating the input dataflows shall be user-configurable.	

ATOVSL2-PPS-3.1.4-0100	**FUNCT, PERF**
The Input Data Vector Preparation Function shall at least verify the time consistency of the input dataflows.	

ATOVSL2-PPS-3.1.4-0110	**FUNCT, PERF**
The Input Data Vector Preparation Function shall verify the consistency of its output dataflow.	

ATOVSL2-PPS-3.1.4-0130	**FUNCT, PERF**
The Input Data Vector Preparation Function shall use the generic orbit and attitude services of the PGE to perform the geolocation processing if required.	

3.1.4.1 Input Satellite Data Vector Generation Function Requirements

ATOVSL2-PPS-3.1.4.1-0010	**FUNCT**
The Input Satellite Data Vector Generation Function shall operate as specified in Section 4.2.1 of this document.	

ATOVSL2-PPS-3.1.4.1-0020	**FUNCT**
The Input Satellite Data Vector Generation Function shall check the availability of the AVHRR/3, AMSU-A, MHS and HIRS/3 level 1b data and also the associated auxiliary data.	

ATOVSL2-PPS-3.1.4.1-0030	**FUNCT**
The Input Satellite Data Vector Generation Function shall create a data availability flag which reports the availability of the ATOVS Instruments Level 1b input data and the auxiliary data.	

ATOVSL2-PPS-3.1.4.1-0040	**FUNCT**
The Input Satellite Data Vector Generation Functio shall time synchronize all available ATOVS Instruments Level 1b input data.	

ATOVSL2-PPS-3.1.4.1-0050	**FUNCT**
The Input Satellite Data Vector Generation Function shall create the Input Data Vector using the synchronized ATOVS Instruments Level 1b input data for further product generation.	

ATOVSL2-PPS-3.1.4.1-0060	**FUNCT**
The Input Satellite Data Vector Generation Function shall generate auxiliary information that is synchronized to the Input Data Vector (see previous requirement) for each part of the Earth view data in the dump.	

ATOVSL2-PPS-3.1.4.1-0070	FUNCT
The Input Satellite Data Vector Generation Function shall pass the appended information: flags, Input Data Vector and synchronized auxiliary information to the subsequent product generation functions. See the diagrams in Section 2.2 of this document.	

3.1.4.2 Retrieval Grid Determination Function Requirements

ATOVSL2-PPS-3.1.4.2-0010	FUNCT, DES
The Retrieval Grid Determination Function shall operate as specified in Section 4.2.2 of this document.	

ATOVSL2-PPS-3.1.4.2-0020	FUNCT, INT, DES
The Retrieval Grid Determination Function shall determine the grid to be used by the ATOVS Level 2 Product Retrieval Generation Function according to the following criteria: 1. The available data do not allow the use of the default retrieval grid; 2. The use of the default grid is overruled by a user-configurable setting.	

ATOVSL2-PPS-3.1.4.2-0030	FUNCT
The default retrieval grid to be used by the Retrieval Grid Determination Function is the HIRS/4 FOV grid.	

ATOVSL2-PPS-3.1.4.2-0040	FUNCT, INT, DES
The default retrieval grid to be used by the Retrieval Grid Determination Function shall be user-configurable with the options being the AMSU-A FOV, the HIRS/4 FOV and the MHS FOV.	

3.1.4.3 AMSU-A Data Preparation Function Requirements

ATOVSL2-PPS-3.1.4.3-0010	FUNCT
The AMSU-A Data Preparation Function shall perform the following operations: 1. Bias correction of the AMSU-A data; 2. Determination of the AMSU-A data pixel surface type (Land, Sea or Coast); 3. Limb adjustment and correction for surface emissivity of the AMSU-A data; 4. Calculation of the Scattering index for the AMSU-A data 5. Test for precipitation conditions present in the AMSU-A data; 6. Test for cloudy conditions present in the AMSU-A data; 7. Analysis of the surface type of the AMSU-A data;	

8. Determine if the detected surface type will influence subsequent processing;
9. Flag the AMSU-A data for contamination and clear/cloudy conditions.

Note: For the details of these functions and the naming convention adopted in this document to denote them, see Section 4.2.3.

ATOVSL2-PPS-3.1.4.3-0020	**FUNCT**
The AMSU-A Data Preparation Function shall operate as specified in see Section 4.2.3 of this document.	

ATOVSL2-PPS-3.1.4.3-0030	**FUNCT**
The AMSU-A Bias Correction Function shall operate as specified in Section 4.2.3.1 of this document.	

ATOVSL2-PPS-3.1.4.3-0040	**FUNCT**
The AMSU-A Limb Adjustment and Correction for Surface Emissivity Function shall operate as specified Section 4.2.3.3 of this document.	

3.1.4.3.1 AMSU-A Surface Type Land/Sea/Coast Determination Function Requirements

ATOVSL2-PPS-3.1.4.3.1-0010	**FUNCT**
The AMSU-A Surface Type Land/Sea/Coast Determination Function shall operate as specified in Section 4.2.3.2 of this document.	

ATOVSL2-PPS-3.1.4.3.1-0020	**FUNCT, INT**
The AMSU-A Surface Type Land/Sea/Coast Determination Function shall use a topography dataset as input to determine the type of the AMSU-A FOV.	

ATOVSL2-PPS-3.1.4.3.1-0030	**FUNCT**
The AMSU-A Surface Type Land/Sea/Coast Determination Function shall flag the AMSU-A FOV as of type land, sea or coast (Land/Sea/Coast flag).	

3.1.4.3.2 AMSU-A Precipitation Signal Detection Function Requirements

ATOVSL2-PPS-3.1.4.3.2-0010	**FUNCT**
The AMSU-A Precipitation Signal Detection Function shall perform the following operations: 1. Selection of the Sea AMSU-A FOVs; 2. Calculate the AMSU-A Scattering Index; 3. Perform the precipitation tests; 4. Flag the AMSU-A data accordingly; ***Note:*** For details on these functions and the naming convention adopted in this document to denote them, see Section 4.2.3.5 of this document.	

ATOVSL2-PPS-3.1.4.3.2-0020	**FUNCT**
The AMSU-A Precipitation Signal Detection Function shall operate as specified in see Section 4.2.3.5 of this document.	

ATOVSL2-PPS-3.1.4.3.2-0030	**FUNCT**
The AMSU-A Precipitation Detection Function shall not calculate a scattering index over land and coastal surfaces.	

3.1.4.3.2.1 AMSU-A Sea FOV Selection Function Requirements

ATOVSL2-PPS-3.1.4.3.2-0040	**FUNCT**
The AMSU-A Sea FOV Selection Function shall operate as specified in Section 4.2.3.5.1 of this document.	

ATOVSL2-PPS-3.1.4.3.2-0050	**FUNCT**
The AMSU-A Sea FOV Selection Function shall select the sea surface AMSU-A FOV using the Land/Sea/Coast flag.	

ATOVSL2-PPS-3.1.4.3.2-0060	**FUNCT**
The output of the AMSU-A Sea FOV Selection Function, the selected AMSU-A Sea surface FOVs, shall be passed as input to the AMSU-A Scattering Index Calculation Function.	

3.1.4.3.2.2 AMSU-A Scattering Index Calculation Function Requirements

ATOVSL2-PPS-3.1.4.3.2-0130	**FUNCT**
The AMSU-A Scattering Index Calculation Function shall operate as specified in Section 4.2.3.5.2 of this document.	

ATOVSL2-PPS-3.1.4.3.2-0140	**FUNCT**
The AMSU-A Scattering Index Calculation Function shall determine the scattering index using Equation 3 in Section 4.2.3.5.2 of this document.	

ATOVSL2-PPS-3.1.4.3.2-0150	**FUNCT**
The AMSU-A Scattering Index Calculation Function shall flag those AMSU-A FOVs for which the scattering index is greater than a user-configurable threshold (default setting 10 K) or less than a user-configurable threshold (default setting –10 K).	

ATOVSL2-PPS-3.1.4.3.2-0160	**FUNCT**
The scattering index flag calculated by the AMSU-A Scattering Index Calculation Function shall by used by the subsequent processing.	

ATOVSL2-PPS-3.1.4.3.2-0170	**FUNCT, INT, DES**
The coefficients and thresholds used by the AMSU-A Scattering Index Calculation Function shall be user-configurable.	

3.1.4.3.2.3 Precipitation Test after Crosby et. al. Function Requirements

ATOVSL2-PPS-3.1.4.3.4-0020	**FUNCT**
The Precipitation Test after Crosby et. al. Function shall operate as specified in Section 4.2.3.5.3 of this document.	

ATOVSL2-PPS-3.1.4.3.4-0030	**FUNCT, INT, DES**
The Precipitation Test after Crosby et. al., Function shall set a rain flag on the AMSU-A FOV data if the probability of rain *P,* as calculated in Section 4.2.3.5.3 of this document, is greater than a user-configurable threshold with a default value of 0.05.	

ATOVSL2-PPS-3.1.4.3.4-0040	**FUNCT, INT, DES**
The coefficients and threshold used by the Precipitation Test after Crosby et. al. Function shall be user-configurable.	

3.1.4.3.2.4 Grody Light Rain Test Function Requirements

ATOVSL2-PPS-3.1.4.3.4-0050	**FUNCT**
The Grody Light Rain Test Function shall operate as specified in Section 4,2,3,5,4 of this document.	

ATOVSL2-PPS-3.1.4.3.4-0070	**FUNCT, INT, DES**
The coefficients used by the Grody Light Rain Test Function shall be user-configurable.	

3.1.4.3.2.5 Set Flag Function Requirements

ATOVSL2-PPS-3.1.4.3.2-0180	**FUNCT**
The Set Flag Function shall operate as specified in Section 4.2.3.5.5 of this document.	

3.1.4.3.3 Surface Analysis Function Requirements

ATOVSL2-PPS-3.1.4.3.3-0010	**FUNCT**
The Surface Analysis Function shall operate as specified in Section 4.2.3.6 of this document.	

ATOVSL2-PPS-3.1.4.3.3-0020	**FUNCT**
The Surface Analysis Function shall only use channels 1, 2 and 3 of AMSU-A for the processing.	

ATOVSL2-PPS-3.1.4.3.3-0030	**FUNCT, INT**
The Surface Analysis Function shall use pre-calculated (for different surface types and without cloud liquid water) mean brightness temperatures and brightness covariance matrices data for the 15 channels of AMSU-A to determine the surface type of the AMSU-A FOV Level 1b data.	

3.1.4.3.3.1 Interpolate Means and Covariances Scan Angle Function Requirements

ATOVSL2-PPS-3.1.4.3.3-0031	**FUNCT**
The Interpolate Means and Covariances Scan Angle Function shall operate as specified in Section 3.1.4.3.3.1 of this document.	

3.1.4.3.3.2 Cost Function and Surface Type Determination Function Requirements

ATOVSL2-PPS-3.1.4.3.3-0040	**FUNCT**
The Cost Function and Surface Type Determination Function shall operate as specified in Section 4.2.3.6.2 of this document.	

ATOVSL2-PPS-3.1.4.3.3-0050	**FUNCT**
The Cost Function and Surface Type Determination Function shall calculate the cost function according to Equation 8 in Section 4.2.3.6.2.	

ATOVSL2-PPS-3.1.4.3.3-0060	**FUNCT**
The Cost Function and Surface Type Determination Function shall evaluate the results of the cost function according to the settings in Table 11 to determine the surface type of the AMSU-A FOV.	

ATOVSL2-PPS-3.1.4.3.3-0070	**FUNCT**
The 'Cost Function and Surface Type Determination Function' shall reset the AMSU-A FOV to surface type equal to 9 (desert) if surface type is 1, 4 or 8 and AMSU-A FOV channel 1 > 275 K.	

ATOVSL2-PPS-3.1.4.3.3-0080	**FUNCT**
The Cost Function and Surface Type Determination Function shall set flags in the following cases as specified in Section 4.2.3.6.2 of this document. 1. The minimum cost function exceeds the cloud test threshold; 2. The estimated surface type is incompatible with the topography; 3. The surface type is not usable for the subsequent product generation.	

3.1.4.3.3.3 Check Surface Type Function

ATOVSL2-PPS-3.1.4.3.3-0110	**FUNCT**
The Check Surface Type Function shall operate as specified Section 3.1.4.3.3.3 in this document.	

3.1.4.3.4 MHS to AMSU-A FOV Mapping One Function Requirements

ATOVSL2-PPS-3.1.4.3.2-0070	**FUNCT**
The MHS to AMSU-A FOV Mapping One Function shall operate as specified in Section 4.2.3.4 in this document.	

ATOVSL2-PPS-3.1.4.3.2-0080	**FUNCT**
The MHS to AMSU-A FOV Mapping One Function shall map the higher-resolution MHS data to the AMSU-A FOV.	

3.1.4.3.5 Contamination Flagging Function Requirements

ATOVSL2-PPS-3.1.4.3.5-0010	**FUNCT**
The Contamination Flagging Function shall operate as specified in Section 4.2.3.7.1 of this document.	

ATOVSL2-PPS-3.1.4.3.5-0020	**FUNCT**
The Contamination Flagging Function shall flag an AMSU-A FOV as contaminated if it is flagged for precipitation (rain flag) and/or scattering (scattering index flag) by any of the tests specified in Section 4.2.3 of this document.	

ATOVSL2-PPS-3.1.4.3.5-0030	**FUNCT, INT, DES**
The decision criteria used by the Contamination Flagging Function shall be user-configurable.	

ATOVSL2-PPS-3.1.4.3.5-0040	**FUNCT**
The Contamination Flagging Function shall flag AMSU-A FOVs as contaminated in the following conditions as specified Section 4.2.3.7.1 of this document: 1. The surface types are incompatible; 2. The surface types that are not usable for the subsequent product generation functionality as determined from the Cost Function and Surface Type Determination Function (surface types 2, 3, 6, 7, and 9 in Table 11: Cost Function and Surface Type Determination Function Settings	

3.1.4.3.6 Clear/Cloudy Flagging Function Requirements

ATOVSL2-PPS-3.1.4.3.6-0010	**FUNCT**
The Clear/Cloudy Flagging Function shall operate as specified in Section 4.2.3.7.2 of this document.	

ATOVSL2-PPS-3.1.4.3.6-0020	**FUNCT**
The Clear/Cloudy Flagging Function shall flag an AMSU-A FOV as cloudy if this one is not declared contaminated, but cloud liquid water has been detected by the Precipitation Tests functionality.	

ATOVSL2-PPS-3.1.4.3.6-0030	**FUNCT**
The Clear/Cloudy Flagging Function shall flag an AMSU-A FOV as clear if it has not already been flagged as contaminated or as cloudy.	

3.1.4.4 MHS DATA PREPARATION FUNCTION REQUIREMENTS

ATOVSL2-PPS-3.1.4.4-0010	**FUNCT**
The MHS Data Preparation Function shall perform the following operations: 1. Bias correction of the MHS data; 2. Determination of the MHS Data Surface Type (Land, Sea or Coast); 3. Limb adjustment and correction for surface emissivity of the MHS data; 4. Median Filtering of the MHS Data Channel 1 (89 GHz); 5. Decision of the Mapping of the MHS Data onto the AMSU-A FOV grid; 6. Mapping of the MHS Data onto the AMSU-A FOV grid; 7. Re-calculation of the Scattering Index for the AMSU-A data using MHS data. ***Note:*** For details on these functions and on the naming convention adopted in this document to denote them, see Section 4.2.4 in this document.	

ATOVSL2-PPS-3.1.4.4-0020	**FUNCT**
The MHS Data Preparation Function shall operate as specified in Section 4.2.4 of this document.	

ATOVSL2-PPS-3.1.4.4-0030	**FUNCT**
The MHS Bias Correction Function shall operate as specified in Section 4.2.4.1 of this document.	

ATOVSL2-PPS-3.1.4.4-0040	**FUNCT**
The MHS Limb Adjustment and Correction for Surface Emissivity Function shall operate as specified in Section 4.2.4.3 of this document.	

ATOVSL2-PPS-3.1.4.4-0050	**FUNCT**
The MHS 89 GHz on AMSU-A to MHS Function shall operate as specified in Section 4.2.4.6 of this document.	

ATOVSL2-PPS-3.1.4.4-0060	**FUNCT**
The Map AMSU-A to MHS Function shall operate as specified Section 4.2.4.7 of this document.	

3.1.4.4.1 MHS Surface Type Land/Sea/Coast Determination Function Requirements

ATOVSL2-PPS-3.1.4.4.1-0010	**FUNCT**
The 'MHS Surface Type Land/Sea/Coast Determination Function' shall operate as specified in Section 4.2.4.2 of this document.	

ATOVSL2-PPS-3.1.4.4.1-0020	**FUNCT, INT**
The MHS Surface Type Land/Sea/Coast Determination Function shall use a topography dataset as input to determine the type of the MHS FOV.	

ATOVSL2-PPS-3.1.4.4.1-0030	**FUNCT**
The MHS Surface Type Land/Sea/Coast Determination Function shall flag the MHS FOV as of type land, sea or coast (Land/Sea/Coast flag).	

ATOVSL2-PPS-3.1.4.4.1-0040	**FUNCT, INT**
The MHS Surface Type Land/Sea/Coast Determination Function shall produce flagged data to be used in the construction of an input-data-based land/sea mask.	

3.1.4.4.2 MHS Channel 1 (89 GHz) Median Filtering Function Requirements

ATOVSL2-PPS-3.1.4.4.2-0010	**FUNCT**
The MHS Channel 1 (89 GHz) Median Filtering Function shall operate as specified Section 4.2.4.4 of this document.	

ATOVSL2-PPS-3.1.4.4.2-0020	**FUNCT**
The MHS Channel 1 (89 GHz) Median Filtering Function shall flag as contaminated the MHS FOV in the centre of a 3 × 3 FOVs box if the median value differs more than a threshold (default 10 K) from the brightness temperature of the central MHS channel 1 FOV.	

ATOVSL2-PPS-3.1.4.4.3-0030	**FUNCT, INT, DES**
The coefficients and thresholds used by the MHS Channel 1 (89 GHz) Median Filtering Function shall be user-configurable.	

3.1.4.4.3 MHS to AMSU-A FOV Mapping Two Function Requirements

ATOVSL2-PPS-3.1.4.4.4-0010	**FUNCT**
The MHS to AMSU-A FOV Mapping Two Function shall operate as specified in Section 4.2.4.5 of this document.	

ATOVSL2-PPS-3.1.4.4.4-0020	**FUNCT**
The MHS to AMSU-A FOV Mapping Two Function shall map shall map the higher-resolution MHS data to the AMSU-A FOV.	

3.1.4.4.4 MHS Scattering Detection Function Requirements

ATOVSL2-PPS-3.1.4.4.5-0010	FUNCT
The MHS Scattering Detection Function shall perform the following operations: 1. Selection of the Sea MHS FOVs; 2. Calculate the MHS Scattering Index. ***Note:*** For details on these functions and the naming convention adopted in this document to denote them, see Section 4.2.4.8 of this document.	

ATOVSL2-PPS-3.1.4.4.5-0020	FUNCT
The MHS Scattering Detection Function shall operate as specified in the Section 4.2.4.8 of this document.	

ATOVSL2-PPS-3.1.4.4.5-0030	FUNCT
The MHS Scattering Detection Function shall not be applied to the processing of the MHS data if the MHS Channel 1 (89 GHz) is not available.	

3.1.4.4.4.1 MHS Sea FOV Selection Function Requirements

ATOVSL2-PPS-3.1.4.4.5-0040	FUNCT
The MHS Sea FOV Selection Function shall operate as specified in Section 4.2.4.8.2 of this document.	

ATOVSL2-PPS-3.1.4.4.5-0050	FUNCT
The MHS Sea FOV Selection Function shall use the Land/Sea/Coast flag determined on the MHS data to select the Sea MHS FOV data.	

3.1.4.4.4.2 MHS Scattering Index Calculation Function Requirements

ATOVSL2-PPS-3.1.4.4.5-0060	FUNCT
The MHS Scattering Index Calculation Function shall operate as specified Section 4.2.4.8.2 of this document.	

ATOVSL2-PPS-3.1.4.4.5-0070	FUNCT
The MHS Scattering Index Calculation Function shall calculate the scattering index according to Equation 3 in Section 4.2.3.5.2 of this document by replacing the AMSU-A Channel 15 (89 GHz) observed brightness temperature by the MHS Channel 1 (89 GHz) observed brightness temperature if this one last is available.	

ATOVSL2-PPS-3.1.4.4.5-0080	FUNCT
The MHS Scattering Index Calculation Function shall flag an AMSU-A FOV as contaminated if the AMSU-A Channel 15 data and the MHS Channel 1 (89 GHz) data differ by a user-configurable amount.	

ATOVSL2-PPS-3.1.4.4.5-0090	FUNCT, INT, DES
The coefficients and thresholds used by the MHS Scattering Index Calculation Function shall be user-configurable.	

3.1.4.5 AVHRR/3 Data Preparation Function Requirements

ATOVSL2-PPS-3.1.4.5-0010	FUNCT
The AVHRR/3 Data Preparation Function shall perform the following operations: 1. Examine the AVHRR/3 Scenes Analysis Results; ***Note:*** For more details on these functions and the naming conventions adopted in this document to denote them, see Section 0 in this document.	

ATOVSL2-PPS-3.1.4.5-0020	FUNCT
The AVHRR/3 Data Preparation Function shall operate as specified in Section 0 in this document.	

ATOVSL2-PPS-3.1.4.5-0030	FUNCT, INT, PERF
The AVHRR/3 Data Preparation Function shall be able to process both GAC and full-resolution AVHRR/3 data.	

3.1.4.5.1 AVHRR/3 Scenes Analysis Results Checking Function Requirements

ATOVSL2-PPS-3.1.4.5.1-0010	FUNCT
The AVHRR/3 Scenes Analysis Results Checking Function shall operate as specified in Section 4.2.5.1 of this document.	

ATOVSL2-PPS-3.1.4.5.1-0020	FUNCT
The AVHRR/3 Scenes Analysis Results Checking Function shall verify that the AVHRR/3 Scenes Analysis Results, if available, contain the required and consistent cloud information and land/sea information.	

ATOVSL2-PPS-3.1.4.5.1-0030	FUNCT
The AVHRR/3 Scenes Analysis Results Checking Function shall decide based on the analysis of the AVHRR/3 Scenes Analysis Results whether to perform a separate cloud detection and not use the AVHRR/3 Scenes Analysis Results.	

ATOVSL2-PPS-3.1.4.5.1-0040	**FUNCT, INT, DES**
The decision criteria used by the AVHRR/3 Scenes Analysis Results Checking Function shall be user-configurable.	

ATOVSL2-PPS-3.1.4.5.1-0050	**FUNCT, INT, DES**
All the coefficients and thresholds used by the AVHRR/3 Scenes Analysis Results Checking Function shall be user-configurable.	

3.1.4.6 HIRS/4 DATA PREPARATION FUNCTION REQUIREMENTS

ATOVSL2-PPS-3.1.4.6-0010	**FUNCT**
The HIRS/4 Data Preparation Function shall perform the following operations: 1. Perform cloud detection based on HIRS/4 Level 1b data only; ***Note:*** For more details on these functions and the naming convention adopted in this document to denote them, see Section 4.2.6.	

ATOVSL2-PPS-3.1.4.6-0020	**FUNCT**
The HIRS/4 Data Preparation Function shall operate as specified Section 4.2.6 of this document.	

ATOVSL2-PPS-3.1.4.6-0030	**FUNCT, PERF**
The HIRS/4 Data Preparation Function shall determine cloud coverage based on the HIRS/4 Level 1b and AMSU-A Level 1b data if the AVHRR/3 Level 1b data or the AVHRR/3 Scenes Analysis Results are not available.	

ATOVSL2-PPS-3.1.4.6-0040	**FUNCT, PERF**
The HIRS/4 Data Preparation Function shall determine cloud coverage based on the HIRS/4 Level 1b only if the AMSU-A Level 1b data is not available or the AVHRR/3 Scenes Analysis Results are not available.	

ATOVSL2-PPS-3.1.4.6-0050	**FUNCT**
The HIRS/4 Bias Correction Function shall operate as specified Section 4.2.6.1 of this document.	

ATOVSL2-PPS-3.1.4.6-0060	**FUNCT**
The HIRS/4 Land/Sea Mass Determination Function shall operate as specified in Section 4.2.6.2 of this document.	

ATOVSL2-PPS-3.1.4.6-0070	**FUNCT**
The HIRS/4 Limb Adjustment Function shall operate as specified in Section 4.2.5.13 of this document.	

3.1.4.6.1 HIRS/4-only Cloud Analysis Function Requirements

ATOVSL2-PPS-3.1.4.6.1-0010	**FUNCT**
The HIRS/4-only Cloud Analysis Function shall operate as specified in Section 4.2.6.4 of this document.	

ATOVSL2-PPS-3.1.4.6.1-0020	**FUNCT, INT, DES**
All the coefficients and thresholds used by the HIRS/4-only Cloud Analysis Function shall be user-configurable.	

ATOVSL2-PPS-3.1.4.6.1-0030	**FUNCT**
The HIRS/4-only Cloud Analysis Function shall perform cloud detection cover when the AMSU-A Level 1b dataflow is not available and the AVHRR/3 Level 1b dataflow or the AVHRR/3 Scenes Analysis Results data are not available.	

ATOVSL2-PPS-3.1.4.6.1-0040	**FUNCT, PERF**
The HIRS/4-only Cloud Analysis Function shall calculate the following outputs for each HIRS/4 FOV: 1. The Cloud-top height; 2. The Cloud-top pressure; 3. The Effective cloud amount (Clear/Cloudy flag and fractional cloud cover); 4. The Surface Type (Land/Sea/Coast flag); 5. Ice and snow cover.	

3.1.4.7 Retrieval Grid Mapping Function Requirements

ATOVSL2-PPS-3.1.4.7-0010	**FUNCT**
The Retrieval Grid Mapping Function shall, depending on the selected retrieval grid, perform the calculation of a representative value for the data of every ATOVS-instrument pre-processed data at the location of the FOV of the selected instrument for the retrieval	

ATOVSL2-PPS-3.1.4.7-0020	**FUNCT**
The Retrieval Grid Mapping Function shall, depending on the selected retrieval grid, perform the mapping of the appended data of every ATOVS-instrument to the location of the FOV of the selected instrument for the retrieval	

ATOVSL2-PPS-3.1.4.7-0030	**FUNCT**
The Retrieval Grid Mapping Function shall be able to perform the calculation of a representative value for the data of any ATOVS-instrument pre-processed data at the location of the FOV of any other ATOVS instrument.	

ATOVSL2-PPS-3.1.4.7-0040	**FUNCT**
The Retrieval Grid Mapping Function shall be able to perform the mapping of the appended data of any ATOVS-instrument to the location of the FOV of any other ATOVS-instrument.	

ATOVSL2-PPS-3.1.4.7-0050	**FUNCT**
The Retrieval Grid Mapping Function shall perform the following operations: 1. Map the input data to the retrieval grid; 2. Map the appended data to the retrieval grid; 3. Perform the microwave tests. ***Note:*** For more details on these functions and the naming convention adopted in this document to denote them, see Section 4.2.7 in this document.	

ATOVSL2-PPS-3.1.4.7-0060	**FUNCT**
The Retrieval Grid Mapping Function shall operate as specified in Section 4.2.7 of this document.	

ATOVSL2-PPS-3.1.4.7-0070	**FUNCT, DES**
The Retrieval Grid Mapping Function shall be modular so that it can be used by other functionalities within the ATOVS Level 2 Product Generation Function.	

ATOVSL2-PPS-3.1.4.7-0080	**FUNCT, INT, DES**
All the coefficients used by the Retrieval Grid Mapping Function shall be user-configurable.	

3.1.4.7.1 Input Data to Retrieval Grid Mapping Function Requirements

ATOVSL2-PPS-3.1.4.7.1-0010	**FUNCT**
The Input Data to Retrieval Grid Mapping Function shall operate as specified in Section 4.2.7.1 of this document.	

ATOVSL2-PPS-3.1.4.7.1-0020	**FUNCT**
The Input Data to Retrieval Grid Mapping Function shall be able to use one of the following methods to perform the mapping: 1. Bilinear Transformation; 2. Nearest neighbour; 3. Spatial weighted average;	

ATOVSL2-PPS-3.1.4.7.1-0030	**FUNCT, INT, DES**
The mapping method used by the Input Data to Retrieval Grid Mapping Function shall be selected through a user-configurable setting.	

ATOVSL2-PPS-3.1.4.7.1-0040	**FUNCT**
The default mapping method used by the Input Data to Retrieval Grid Mapping Function shall be the Bilinear Transformation	

ATOVSL2-PPS-3.1.4.7.1-0050	**FUNCT**
The Input Data to Retrieval Grid Mapping Function shall recalculate the cost function and redetermine the surface type of the AMSU-A FOV Level 1b values that have been mapped to the default retrieval grid–as it was done for the unmapped AMSU-A Level 1b values as specified in Section 4.2.3.6.2 of this document.	

3.1.4.7.2 Appended Data to Retrieval Grid Mapping Function Requirements

ATOVSL2-PPS-3.1.4.7.2-0010	**FUNCT**
The Appended Data to Retrieval Grid Mapping Function shall operate as specified in Section 4.2.7.2 of this document.	

ATOVSL2-PPS-3.1.4.7.2-0020	**FUNCT**
The Appended Data to Retrieval Grid Mapping Function shall be able to use one of the following methods to perform the mapping: 1. Bilinear Transformation; 2. Nearest neighbour; 3. Spatial weighted average;	

ATOVSL2-PPS-3.1.4.7.2-0030	FUNCT, INT, DES
The mapping method used by the Appended Data to Retrieval Grid Mapping Function shall be selected through a user-configurable setting.	

ATOVSL2-PPS-3.1.4.7.2-0040	FUNCT
The default mapping method used by the Appended Data to Retrieval Grid Mapping Function shall be the Bilinear Transformation.	

ATOVSL2-PPS-3.1.4.7.2-0050	FUNCT, INT, PERF
The Appended Data to Retrieval Grid Mapping Function shall be able to produce the following intermediate ATOVS Level 2 Retrieved Geophysical Parameters given in the selected retrieval grid: 1. Sea Surface Temperature; 2. Cloud-Top Temperature; 3. Cloud cover; 4. Surface Type.	

3.1.4.7.3 Microwave Tests Recalculation Function Requirements

ATOVSL2-PPS-3.1.4.7.3-0010	FUNCT
The Microwave Tests Recalculation Function shall operate as specified in Section 4.2.6.5 of this document.	

ATOVSL2-PPS-3.1.4.7.3-0020	FUNCT
The Microwave Tests Recalculation Function shall calculate the Scattering Index for the pre-processed ATOVS-instruments Level 1b data mapped to the retrieval grid according to the equations in Section 4.2.3.5.2 of this document	

ATOVSL2-PPS-3.1.4.7.3-0030	FUNCT
The Microwave Tests Recalculation Function shall perform the precipitation tests on the pre-processed ATOVS-instruments Level 1b data mapped to the retrieval grid according to the tests specified in Section 4.2.3.5 of this document.	

3.1.5 ATOVS Level 2 Product Retrieval Generation Function Requirements

ATOVSL2-PPS-3.1.5-0010	FUNCT
The ATOVS Level 2 Product Retrieval Generation Function shall perform the following operations: 1. Select the input data to the retrieval process; 2. Examine the cloud amount of the input data selected for the retrieval; 3. Select the retrieval method and its associated Fast Radiative Transfer Model; 4. Decide if to perform and perform cloud clearing of the input data; 5. Retrieve the ATOVS Level 2 geophysical parameters. ***Note:*** For more details on these functions and the naming convention adopted in this document to denote them, see Section 4.3 in this document.	

ATOVSL2-PPS-3.1.5-0020	FUNCT, PERF, INT
The ATOVS Level 2 Product Retrieval Generation Function shall generate the ATOVS Level 2 products and appended information as described in Section 4.3 of this document.	

ATOVSL2-PPS-3.1.5-0030	FUNCT
The ATOVS Level 2 Product Retrieval Generation Function shall operate as specified in Section 4.3 of this document.	

ATOVSL2-PPS-3.1.5-0040	FUNCT, INT, DES
All parameters defining the windows or locations used for the extraction of retrieval statistics by the ATOVS Level 2 Product Retrieval Generation Function shall be user-configurable.	

3.1.5.1 Retrieval Method and FRTM Selection Function Requirements

ATOVSL2-PPS-3.1.5.3-0010	FUNCT
The Retrieval Method and FRTM Selection Function shall operate as specified in Section 4.3.1of this document.	

ATOVSL2-PPS-3.1.5.3-0030	FUNCT
The Retrieval Method and FRTM Selection Function shall initialize all the parameters necessary for the computations performed by the fast radiative transfer model selected within this functionality.	

ATOVSL2-PPS-3.1.5.3-0040	**FUNCT**
The Retrieval Method and FRTM Selection Function shall prepare all the auxiliary data necessary for the computations performed by the fast radiative transfer model selected.	

ATOVSL2-PPS-3.1.5.3-0050	**FUNCT, INT, DES**
The decision criteria used by the Retrieval Method and FRTM Selection Function shall be user-configurable.	

ATOVSL2-PPS-3.1.5.3-0060	**FUNCT, INT, DES**
It shall be possible to enforce a specific fast radiative transfer model selection to be made by the Retrieval Method and FRTM Selection Function via a user-configurable setting	

ATOVSL2-PPS-3.1.5.3-0070	**FUNCT**
A default retrieval method and a default fast radiative transfer model shall be made available to choose from to the Retrieval Method and FRTM Selection Function during Normal NRT operations.	

ATOVSL2-PPS-3.1.5.3-0080	**FUNCT**
The retrieval method and fast radiative model selected by the Retrieval Method and FRTM Selection Function shall be used for the processing of the entire dump of sensed data.	

ATOVSL2-PPS-3.1.5.3-0090	**FUNCT**
If the default retrieval method and any of the alternative methods can not be used as described in Section 4.3.1, then the retrieval shall not be performed and an error message shall be produced.	

3.1.5.1.1 Geophysical Parameter Retrieval Function Requirements

ATOVSL2-PPS-3.1.5.6.2-0010	**FUNCT**
The Geophysical Parameter Retrieval Function shall perform the following operations: 1. Select the retrieval method to use for the retrieval of the geophysical parameters; 2. Perform the retrieval of the ATOVS Level 2 Retrieved Geophysical Parameters. ***Note:*** For more details on these functions and the naming convention adopted in this document to denote them, see Section 4.3.12.	

ATOVSL2-PPS-3.1.5.6.2-0020	**FUNCT, PERF**
The Geophysical Parameter Retrieval Function shall perform the retrieval of at least the following ATOVS Level 2 Retrieved Geophysical Parameters: 1. Temperature Profiles; 2. Humidity Profiles; 3. Total Ozone Column ; 4. Surface Temperature; 5. Cloud Top Temperature; 6. Cloud Top Pressure; 7. Effective Cloud Amount.	

ATOVSL2-PPS-3.1.5.6.2-0030	**FUNCT**
The Geophysical Parameter Retrieval Function shall operate as specified in Section 4.3.2 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0040	**FUNCT, INT, DES**
All the coefficients, settings, parameters and thresholds used by the Geophysical Parameter Retrieval Function shall be user-configurable.	

3.1.5.1.1.1 Default Retrieval Method Function Requirements

ATOVSL2-PPS-3.1.5.6.2-0100	**FUNCT**
The Default Retrieval Method Function shall operate as specified in Section 4.3.2.1 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0120	**FUNCT, INT, DES**
The vertical grid used in the Default Retrieval Method Function shall be user-configurable.	

ATOVSL2-PPS-3.1.5.6.2-0130	**FUNCT, INT, DES**
The selection of sounder channels used for the retrieval by the Default Retrieval Method Function shall be user-configurable.	

ATOVSL2-PPS-3.1.5.6.2-0140	**FUNCT, INT, DES**
The coefficients and thresholds used in the Default Retrieval Method Function shall be user-configurable.	

ATOVSL2-PPS-3.1.5.6.2-0150	**FUNCT**
The Accept Input Data for Retrieval Procedure shall operate as specified in Section4.3.2.1.1 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0160	**FUNCT**
The Accept Support Data for Retrieval Function shall operate as specified in Section 4.3.2.1.2 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0170	**FUNCT**
The Loop Function shall operate as specified in Section 4.3.2.1.3 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0180	**FUNCT**
The Inversion Preparation Function shall operate as specified in Section 4.3.2.1.4 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0190	**FUNCT**
The Compute Geophysical Parameters Function shall operate as specified in Equation 159 in Section 4.3.2.1.4.8.3 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0200	**FUNCT**
The TPW and CLW by AMSU-A Function shall operate as specified in Section 4.3.2.1.5.7 of this document.	

3.1.5.1.1.2 Alternative Retrieval Method One-Function Requirements

ATOVSL2-PPS-3.1.5.6.2-0150	**FUNCT**
The Alternative Retrieval Method One Function shall operate as specified in Section 4.3.2.2 of this document.	

ATOVSL2-PPS-3.1.5.6.2-0160	**FUNCT, INT**
The Alternative Retrieval Method One Function shall use limb-adjusted-to-nadir-for-a-given-scan-angle AMSU-A brightness temperatures as input to retrieve temperature profiles , total precipitable water and cloud liquid water parameters.	

ATOVSL2-PPS-3.1.5.6.2-0170	**FUNCT, INT, DES**
The coefficients used by the Alternative Retrieval Method One Function to limb adjust to nadir the AMSU-A brightness temperatures shall be user-configurable.	

ATOVSL2-PPS-3.1.5.6.2-0180	**FUNCT**
The Alternative Retrieval Method One Function shall retrieve the temperature on the vertical grid of the default fast radiative transfer model provided by the Fast Radiative Transfer Model Function as a default	

ATOVSL2-PPS-3.1.5.6.2-0190	**FUNCT, INT, DES**
The vertical grid used in the Alternative Retrieval Method One Function shall be user-configurable.	

ATOVSL2-PPS-3.1.5.6.2-0200	**FUNCT, INT, DES**
The thresholds and coefficients used in the Alternative Retrieval Method One Function shall be user-configurable.	

ATOVSL2-PPS-3.1.5.6.2-0210	**FUNCT, INT**
The coefficients used for the regression by the Alternative Retrieval Method One Function shall be different for land and sea surfaces.	

ATOVSL2-PPS-3.1.5.6.2-0220	**FUNCT**
The combination of AMSU-A channels used for the regression by the Alternative Retrieval Method One Function shall be different for each level.	

ATOVSL2-PPS-3.1.5.6.2-0230	**FUNCT, PERF**
The Alternative Retrieval Method One Function shall retrieve Total Precipitable Water only over sea AMSU-A FOVs.	

ATOVSL2-PPS-3.1.5.6.2-0240	**FUNCT, PERF**
The Alternative Retrieval Method One Function shall retrieve Cloud Liquid Water only over sea AMSUA FOVs.	

3.1.6 Data Formatting Function Requirements

ATOVSL2-PPS-3.1.6-0010	**FUNCT**
The Data Formatting Function shall prepare the ATOVS Level 2 Retrieved Geophysical Parameters and appended data generated by the ATOVS Level 2 Product Generation Function needed for the generation of EPS ATOVS Level 2 Products specified in the ATOVS Level 2 Product Format Specification.	

ATOVSL2-PPS-3.1.6-0020	**FUNCT**
The Data Formatting Function shall prepare the ATOVS Level 2 Retrieved Geophysical Parameters and appended data generated by the ATOVS Level 2 Product Generation Function needed for the generation of GTS ATOVS Level 2 Products specified according to the World Meteorological Organization (WMO) Manual of Codes.	

ATOVSL2-PPS-3.1.6-0030	**FUNCT, INT, DES**
The Data Formatting Function shall be capable of selecting a user-configurable subset of the data generated by the ATOVS Level 2 Product Generation Function for forwarding to the Core Ground Segment GTS product formatting functionality by taking a user-configurable subset of the ATOVS Level 2 Retrieved Geophysical Parameters.	

ATOVSL2-PPS-3.1.6-0040	**FUNCT, INT, DES**
The Data Formatting Function shall be capable of selecting a user-configurable subset of the data generated by the ATOVS Level 2 Product Generation Function for forwarding to the Core Ground Segment GTS product formatting functionality by taking every *N*th-sample of the ATOVS Level 2 Retrieved Geophysical Parameters.	

ATOVSL2-PPS-3.1.6-0050	**FUNCT, INT, DES**
The Data Formatting Function shall be capable of selecting a user-configurable subset of the data generated at each processing function for forwarding to the Core Ground Segment GTS product formatting functionality by taking every N^{th} line of the ATOVS Level 2 Retrieved Geophysical Parameters.	

3.2 Performance Requirements

3.2.1 Target quality of the ATOVS Level 2 Retrieved Geophysical Parameters

No specifications.

3.2.2 Degraded quality of the ATOVS Level 2 Retrieved Geophysical Parameters

ATOVSL2-PPS-3.2.2-0010	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall achieve, whenever possible, a quality of the ATOVS Level 2 Retrieved Geophysical Parameters consistent with the operations specified in Section 4 of this book.	

3.2.3 Resolution of the ATOVS Level 2 Retrieved Geophysical Parameters

ATOVSL2-PPS-3.2.3-0010	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall produce temperature profiles at a user-configurable number. The levels will set as default in the levels specified in Section 4.	

ATOVSL2-PPS-3.2.3-0020	**FUNCT, PERF**
The ATOVS Level 2 Product Generation Function shall produce humidity profiles at a user-configurable number. The levels will set as default in the levels specified in Section 4.	

3.3 Interface Requirements

ATOVSL2-PPS-3.3-0010	**FUNCT, INT**
The Level 1b and Auxiliary Data Acceptance Function shall ingest the following input data coming either from the MetOp spacecraft or from the NOAA spacecraft: 1. AMSU-A Level 1b dataflow; 2. MHS Level 1b dataflow; 3. HIRS/4 Level 1b dataflow; 4. AVHRR/3 Scenes Analysis dataflow; 5. Auxiliary Data	

3.4 Monitoring and Reporting Requirements

ATOVSL2-PPS-3.4-0010	**FUNCT, INT, DES**
Each function of the ATOVS Level 2 Product Generation Function shall monitor its performance and raise events of user-configurable severity on the occurrence of at least one of the following : 1. Any abnormal input to the function being detected; 2. Any occurrence and transition to or from a degraded scenario of product generation; 3. Any non-nominal operation of the function being detected; 4. Any occurrence to have adversely affected the product quality being detected.	

ATOVSL2-PPS-3.4-0020	**FUNCT, INT, DES**
The ATOVS Level 2 Product Generation Function shall have the capability to select any of the following user-configurable parameters for forwarding to the Core Ground Segment M&C function for routine monitoring: 1. Any parameter contained in the ATOVS-Instruments Level 1b dataflows; 2. Any parameter derived from the contents of the ATOVS-Instruments Level 1b dataflows; 3. Any parameter in the auxiliary data; 4. Any parameter of the ATOVS Level 2 Product Generation Function itself.	

ATOVSL2-PPS-3.4-0030	FUNCT
The ATOVS-Instruments Level 1b data corruption flag set on by the ATOVS Instruments Level 1b Reception Function shall be used by the subsequent processing of the ATOVS Level 2 Product Generation Function to make decisions on the usage of the sounding data for the retrieval process as specified in this document.	

ATOVSL2-PPS-3.4-0040	FUNCT
The Side Information Reception and Correlation Function shall extract and generate information on the received data for the purpose of reporting. The information to be extracted and generated shall include: 1. Parameters describing the validity of the received data; 2. Timeliness information on the received data; 3. Completeness information on the received data.	

ATOVSL2-PPS-3.4-0050	FUNCT
The Input Data Vector Preparation Function shall produce reporting information on the corresponding Input Data Vector generation, including at least the following: 1. Information on occurrences of processing events; 2. Resulting Input Data Vector flags and parameters; 3. Information on completeness and timeliness of the produced data.	

ATOVSL2-PPS-3.4-0060	FUNCT, PERF, INT, DES
The Input Data Vector Preparation Function shall give rise to an event of user-configurable severity if any of the following conditions occurs: 1. Input Data corruption or inconsistency; 2. Successful completion of the Input Data Vector Preparation; 3. Successful completion of the Mapping for the corresponding dump; 4. Any failure of the above validation checks.	

ATOVSL2-PPS-3.4-0070	FUNCT, INT, DES
The First Guess Search Library Function shall raise events of user-configurable severity according to the following criteria: 1. If the flag, then the guess selection is OK. 2. If the flag, a warning is issued but the processing shall be continued. 3. If the flag, the situation is rejected and the next profile is processed.	

ATOVSL2-PPS-3.4-0080	**FUNCT, INT, DES**
The Default Retrieval Method Function shall reject the outputs of the retrieval generating an event of user-configurable severity if the internal variable '*dist'* is larger than a user-configurable threshold.	

ATOVSL2-PPS-3.4-0090	**FUNCT**
The On-line Quality Function shall collect all flags generated by other previous functional elements in the ATOVS Level 2 Product Generation Function.	

ATOVSL2-PPS-3.4-0100	**FUNCT**
The On-line Quality Function shall pass all generated flags to a Data Formatting Function for the inclusion in the ATOVS Level 2 appended output data produced by the ATOVS Level 2 Product Generation Function.	

ATOVSL2-PPS-3.4-0110	**FUNCT, PERF, INT, DES**
The On-line Parameter Estimation Function shall raise events of user-configurable severity whenever any of the following occurs: 1. The function fails to produce the estimated parameters (non-convergence); 2. The function lacks sufficient input data and measurements to achieved the nominal accuracy of the parameters derivation; 3. The produced parameters failed validation checks	

3.5 MMI Requirements

ATOVSL2-PPS-3.5-0010	**FUNCT, INT, MMI, DES**
The Level 1b and Auxiliary Data Acceptance Function shall support all required near-real-time MMI functionality, with the following ATOVS Level 2 data specific aspects: 1. Reduced resolution representation of the Level 1b dataflow of Level 1b AVHRR/3, AMSU-A, MHS and HIRS/4 data for all of the channels of the instrument; 2. A data set in the same reduced resolution of the Level 1b dataflow of Level 1b AVHRR/3, AMSU-A, MHS and HIRS/4 data for all of the channels of the instrument, with indication of missing and corrupted data; 3. A data set showing the identified ATOVS-Instruments Level 1b processing mode; 4. Data sets containing user-configurable subsets of the ATOVS-Instruments Level 1b appended data; 5. Data sets comprising multi-spectral images of up to three channels of ATOVS-Instruments Level 1b, along with geolocation information; 6. Data sets of AVHRR/3 scenes analysis results, along with geolocation information.	

4 SCIENTIFIC ALGORITHMS

4.1 Level 1b and Auxiliary Data Acceptance Function

In addition to the generic checks identified in the Core Ground Segment Requirements Document [AD-49], there is functionality that performs the instrument-specific acceptance and validation of the input data.

Its purpose is to accept the ATOVS Instruments Level 1b and the auxiliary data to determine its usability for further ATOVS Level 2 processing. In addition the AMSU-A radiances, MHS radiances, and the HIRS/4 radiances are converted into Brightness Temperatures, as those are needed for the subsequent processing. Antenna corrections are applied to the microwave radiances. Finally, the function correlates the level 1b data with the auxiliary data and extracts the relevant information for the calibration and geolocation processing;

Summarizing, this function is decomposed as specified in Table 5.

Level 1b and Auxiliary Data Acceptance Function Operations
1. ATOVS Instruments Level 1b Data Reception Function
2. AVHRR Scenes Analysis Data Reception Function
3. Side Information Reception and Correlation Function
4. Appended Level 1b Information Preparation Function

Table 5: Level 1b and Auxiliary Data Acceptance Function decomposition

Note that the function has to be able to cope with all the different MetOp and NOAA spacecraft, including the handling of the different data formats and data resolutions, in particular with the different AVHRR resolutions (GAC and full resolution).

Inputs
AMSU-A Level 1b dataflow; MHS Level 1b dataflow; HIRS/4 Level 1b dataflow; AVHRR/3 Scenes Analysis data; Auxiliary data.

Outputs
Appended Information; Validated AVHRR/3 Level 1b dataflow; Validated AMSU-A Level 1b dataflow; Validated MHS Level 1b dataflow; Validated HIRS/4 Level 1b dataflow; Validated AVHRR/3 Scenes Analysis Results; Auxiliary input for Level 2 processing (Model data, First- Guess data).

4.1.1 ATOVS Instruments Level 1b Data Reception Function

This function encompasses the check and validation of the ATOVS Instruments Level 1b data flows from the corresponding Level 1 Product Generation Functions. The generic checks identified in the CGSRD [AD-49] are followed by the verification against the expected Level 1 data / auxiliary data / S/C configuration. This is followed by coarse radiometric data check.

The function is decomposed into the following sub-functions:

Level 1b and Auxiliary Data Acceptance Function Operations
1. Compute AMSU-A Brightness Temperatures Function 2. Perform AMSU-A Limb Correction Function 3. Perform AMSU-A Antenna Correction Function 4. Compute MHS Brightness Temperatures Function 5. Perform MHS Antenna Correction Function 6. Compute HIRS/4 Brightness Temperatures Function

Table 6: ATOVS Instruments Level 1b Data Reception Function decomposition

4.1.1.1 Perform AMSU-A Antenna Correction

This function performs an antenna correction on the AMSU-A radiances. The level 1 b radiances are corrected for the efficiency, with which the instrument looks at the Earth, the spacecraft and space for each scan position. This is expressed by a set of three coefficients $A^{Earth}{}_{eff}$, $A^{Space}{}_{eff}$ and $A^{Platform}{}_{eff}$, which correct the level 1b radiance as follows:

$$R^{ant,cor}{}_{S} = \frac{R_S - A^{Space}{}_{eff} B^{Space}}{A^{Earth}{}_{eff} + A^{Platform}{}_{eff}}$$

Equation 74

B^{Space} is the radiance from cold space (cosmic background radiance at 2.73 K), precalculated for 2.73 K at each central wave number. It is assumed that the radiance from the platform is the same (reflected) radiance from the Earth. The adjustment provides the radiance we expect from the Earth alone. Coefficients are provided for each flight model for all channels and all scan positions as user configurable auxiliary data. A flag shall be set.

4.1.1.2 Compute AMSU-A Brightness Temperatures

This function computes Brightness Temperatures from the AMSU-A level 1b radiances. The Brightness Temperatures are checked against upper and lower boundary values. As default, the user configurable boundary values are 90 K as the minimum value for T_b and 340 K as the maximum value for T_b. A flag shall be set in case of out-of-boundary values. A general form used to calculate the brightness temperatures is this:

$$T_b = \frac{hc\nu}{k_B}\left[\ln\left(1 + \frac{2hc^2\nu^3}{R^{ant,cor}{}_{S}}\right)\right]^{-1}$$

Equation 75

where:

h	Planck's constant
k_B	Boltzmann's constant
c	the speed of light
ν	the channel frequency
$R^{ant,\ corr}{}_s$	Scene Radiance

This is often written in a simplified form, summarising the occurring constants in two other constants C_1 and C_2 which simplify the calculation:

$$T_b = C_2\nu\left[\ln\left(1+\frac{C_1\nu^3}{R^{ant,cor}}\right)\right]^{-1}$$

Equation 76

For broad-channel instruments, a bandwidth correction might be required, which is then taken into account by two additional band correction coefficients C_3 and C_4. They are user-configurable auxiliary data. Thus the bandwidth corrected inverse Planck function is as follows:

$$T_b = \frac{\left[C_2\nu\left[\ln\left(1+\frac{C_1\nu^3}{R_s^{ant,cor}}\right)\right]^{-1} - C_3\right]}{C_4}$$

Equation 77

Note: In the case of AMSU-A, the band correction coefficients are $C_3=0$ and $C_4=1$ respectively.

4.1.1.3 Perform AMSU-A Limb Correction

The calculated AMSU-A Brightness Temperatures are adjusted for limb effects. This function is identical to the one specified in the AMSU-A Standalone Retrieval. Presently there shall be no limb/emissivity adjustment done in the nominal processing. Presently, this is a empty function A flag shall be set.

4.1.1.4 Perform MHS Antenna Correction

This function performs an antenna correction on the MHS radiances. The algorithm is the same as for AMSU-A. The level 1 b radiances are corrected for the efficiency, with which the instrument looks at the Earth, the spacecraft and space for each scan position. This is expressed by a set of three coefficients $H^{Earth}{}_{eff}$, $H^{Space}{}_{eff}$ and $H^{Platform}{}_{eff}$, which correct the level 1b radiance as follows:

$$R^{ant,cor}{}_{S} = \frac{R_S - H^{Space}{}_{eff} B^{Space}}{H^{Earth}{}_{eff} + H^{Platform}{}_{eff}}$$

Equation 78

B^{Space} is the radiance from cold space (cosmic background radiance at 2.73 K), precalculated for 2.73 K at each central wave number. It is assumed that the radiance from the plaform is the same (reflected) radiance from the Earth. The adjustment provides the radiance we expect from the Earth alone. Coefficients are provided for each flight model for all channels and all scan positions as user configurable auxiliary data. A flag shall be set.

4.1.1.5 Compute MHS Brightness Temperatures

This function computes Brightness Temperatures from the MHS level 1b radiances. The Brightness Temperatures are checked against upper and lower boundary values. As default, the user configurable boundary values are 90° K as the minimum value for T_b and 340° K as the maximum value for T_b. A flag shall be set in case of out of boundary values. The algorithm is the same as for AMSU-A.

4.1.1.6 Perform MHS Limb Correction

The calculated MHS Brightness Temperatures are adjusted for limb effects. Presently there shall be no limb/emissivity adjustment done in the nominal processing. This is an empty function at present. A flag shall be set–no limb adjustment done.

4.1.1.7 Compute HIRS/4 Brightness Temperatures

This function computes Brightness Temperatures from HIRS/4 level 1b radiances of channels 1-19.

$$T_b = \frac{\left[C_2 \nu \left[\ln\left(1 + \frac{C_1 \nu^3}{R_S} \right) \right]^{-1} - C_3 \right]}{C_4}$$

Equation 78

For channel 20, the radiance shall be kept.

The Brightness Temperatures are checked against upper and lower boundary values. As default, the user-configurable boundary values are 150° K as the minimum value for T_b and 340° K as the maximum value for T_b. A flag shall be set in case of out of boundary values.

4.1.2 AVHRR/3 Scenes Analysis Data Reception Function

This function receives the AVHRR/3-based Scenes Analysis Data Flow (referred as AVHRR_L1_PGS_DAT_AVHSCE) detailed in [AD-21] and checks the received values for plausibility, according to their geographic location and the seasonal location. The data consist of the following information:

1. Time (per scan line)
2. Geodetic Geolocation (per pixel)
3. Cloud Flag (1 = cloudy, 0 = cloud free) (per pixel)
4. Cloud Top Temperature (in case of cloud flag = 1) (per pixel)
5. Surface Temperature (in case of cloud flag = 0–no cloud) (per pixel)
6. Surface elevation (per pixel)
7. Surface type (land, sea, or coast, per pixel)
8. Radiances (per pixel, per channel)
9. Satellite and Sun zenith and azimuth angles (per pixel).

The data are checked for out-of-bounds state and also for consistency.

4.1.3 Side Information Reception and Correlation Function

This function receives the auxiliary data (typically the auxiliary data, land/sea mask, forecast analyses and models and topography data), validates them and relates them to the ATOVS Instruments Level 1b data flows. The function also extracts the state of the Level 1b data.

4.1.3.1 Level 1b Information Preparation Function

This function constructs the ATOVS Level 1b internal dataflow of the ATOVS Level 2 Product Generation Function and appends the information with the accepted and correlated auxiliary data. The format of the ATOVS Level 1b internal dataflow is to be designed by the Contractor, but should be user-configurable to allow evolution.

4.2 Input Data Vector Preparation Function

This function performs the creation of the input data vector for the Retrieval Product generation, which is not only composed of data of the required ATOVS sounding and imaging instruments, but also of additional information such as the surface characteristics, contamination and cloud effects.

In the course of this data preparation, the input data at Level 1b shall be analysed for nominal configuration. Those data that are contaminated are not useful for the subsequent retrieval process and shall be flagged as contaminated (In particular microwave data contaminated through precipitation and large ice-particles). No correction of the data is foreseen in this step. At the end of this functionality, the input data shall be mapped to one common grid, which shall form the basis for the subsequent retrieval. This grid is nominal, or has been determined, in case of non nominal input data configuration, by the available data.

The algorithms of the data preparation mainly follow those which have been implemented in the ATOVS and AVHRR Processing Package (AAPP), which has been developed by a Group of European Institutions under the coordination of EUMETSAT See [RD-2].

The Input Data Vector Preparation Function selects the algorithm for ATOVS Level 2 processing according to the ATOVS Level 1b data that is available and certain decision criteria. It also determines the Level 2 Product generation grid by comparing the available Level 1b data to a pre-determined set of required Level 1b input data. It also provides the capability of selecting a different grid than the one selected as explained before. The function has a default configuration from which to start the processing of a dump of data from the satellite. It uses a set of threshold to validate the input data with respect to expected data contents.

All the information needed to perform the previously explained operations (the decision criteria, the predetermined set of Level 1b data expected, the options for retrieval grid and the default configuration of the function) constitutes the contents of an auxiliary dataset to the function referred to as ATOVS_L2_PGS_TYP_CONFIG. To validate the input data it uses the thresholds provided in ATOVS_L2_PGS_THR_L1VAL.

This function is decomposed in sub-functions as specified in Table 7.

Input Data Preparation Function operations
1. Input Satellite Data Vector Generation Function 2. Retrieval Grid Determination Function 3. AMSU-A Data Preparation Function 4. MHS Data Preparation Function 5. AVHRR/3 Data Preparation Function 6. HIRS/4 Data Preparation Function 7. Retrieval Grid Mapping Function

Table 7: Input Data Preparation Function decomposition

Inputs
Validated AVHRR/3 Brightness Temperatures and Reflectances dataflow; Validated AMSU-A Brightness Temperatures dataflow; Validated MHS Brightness Temperatures dataflow; Validated HIRS/4 Brightness Temperatures dataflow; Validated AVHRR/3-based Scenes Analysis Dataflow; Auxiliary data flow for ATOVS Level 2 processing .

Outputs
Produced Information from the data preparation including: cloud information mask, surface information and contamination information; additional auxiliary data; also pre-processed (mapped and contamination checked) sounder data.

4.2.1 Input Satellite Data Vector Generation Function

This function uses the validated brightness temperature data from the ATOVS instruments (from Metop or NOAA, as appropriate) and auxiliary input (like radiosonde data, model data) to establish the Input Data Vector.

The outputs of the function are synchronised satellite data and appended, associated information, including data availability information, which are needed for the subsequent data preparation.

4.2.2 Retrieval Grid Determination Function

According to the data availability flag, the grid on which the subsequent ATOVS Level 2 Product Generation shall be performed, is determined by this function. A default grid (HIRS/4 FOV) is assumed, and shall only be changed, if the available data do not allow the use of it, or the decision is overruled from the CGS by a user-configurable setting. No automatic change of the retrieval grid shall be performed.

The default grid (in this case HIRS/4 FOV) is user-configurable and it is specified in the dataset referred as ATOVS_L2_PGS_TYP_CONFIG. The other options for the retrieval grid are the AMSU-A FOV and the MHS FOV, besides the HIRS/4 FOV. The conditions under which a grid other than the default one is selected are the following:

1. No HIRS/4 data are available. The AMSU-A standalone retrieval may be performed. This setting will be configured off-line.
2. A sub-sampling of the HIRS/4 FOV will be used for retrievals (every second pixel, every second scan line). This setting will be done off-line.

4.2.3 AMSU-A Data Preparation Function

The function is decomposed in sub-functions as specified in Table 8.

AMSU-A Data Preparation Function Operations
1. AMSU-A Bias Correction Function (Scan dependent) 2. AMSU-A Surface Type Land/Sea/Coast Determination Function 3. AMSU-A Limb Adjustment and Correction for Surface Emissivity 4. Map MHS to AMSU-A one Function 5. AMSU-A Precipitation Signal Detection Function 6. Surface Analysis Function 7. Contamination and Clear/Cloudy Flagging Function

Table 8: AMSU-A Data Preparation Function decomposition

The AMSU-A Data Preparation Function shall check for cloudy and precipitation situations. In addition the function detects the surface type and defines if a detected surface type will influence the subsequent level 2 Product Generation function.

Inputs
Synchronized and validated AMSU-A Level 1b dataflow; Synchronized and validated MHS Level 1b dataflow; Auxiliary data (Topography dataset); appended information from the Retrieval Grid Determination Function and the Input Satellite Data Vector Generation Function.

Outputs
Appended AMSU-A information (Cloud flag, Land/Sea/Coast flag, Scattering Index, Rain flag), pre-processed AMSU-A dataflow.

4.2.3.1 AMSU-A Bias Correction Function

This function performs a bias correction of the AMSU-A Brightness Temperatures. The bias correction is scan angle dependent. In case no bias correction is required, the corrections have to be set to zero. A flag has to be set. The algorithm is the following:

$$T_b^{cor,\,bias}(j,k) \;=\; T_b(j,k) + \Delta T_{b,\,bias}(j,k) \qquad \textit{Equation 79}$$

where $T_b^{cor,bias}(j,k)$ is the bias corrected Brightness Temperature for a channel k and a FOV j, $T_b(j,k)$ is the Brightness Temperature for a channel k and FOV j, and $\Delta T_{b,bias}(j,k)$ is the bias correction to be applied. The bias correction is provided as user-configurable auxiliary data.

4.2.3.2 AMSU-A Surface Type Land/Sea/Coast Determination

From the topography dataset referred here as ATOVS_L2_PGS_DAT_SCFTOP and [AD-48] the surface type Land/Sea/Coast is determined for each AMSU-A (FOV). All grid points within a box centred on the AMSU-A instrument FOV at approximately the size of the FOV is examined. As default, the extension of the box is 100 km, but should be user configurable.

The AMSU-A FOV is classified land, if every grid point in the box is classified land, classified sea, if every grid point in the box is sea, and coast otherwise. If latitude or longitude are out of range, the surface type is set to a value for 'not determinable' (–9999).

The surface elevation is derived as the average of all surface elevations within the FOV. If the FOV is over sea, the surface elevation is determined zero. In case latitude or longitude are out of bounds the surface elevation is set to the value 'not determinable' (–9999).

4.2.3.3 AMSU-A Limb Adjustment And Correction For Surface Emissivity

This function corrects the AMSU-A Brightness Temperatures for limb effects and for surface emissivity effects. Presently this is an empty function. A flag has to be set.

4.2.3.4 MHS To AMSU-A Fov Mapping One Function

To make use of the higher spatial resolution of the MHS instrument the MHS level 1b data is mapped to AMSU-A FOVs. The mapped MHS data is then passed to the subsequent functionality.

4.2.3.5 AMSU-A Precipitation Signal Detection Function

The function is decomposed in sub-functions as specified in Table 9.

AMSU-A Precipitation Signal Detection Function Operations
1. AMSU-A Sea FOV Selection Function 2. AMSU-A Scattering Index Calculation Function 3. Precipitation test after Crosby et al. 4. Grody light rainfall test 5. Set flag Function

Table 9: AMSU-A Precipitation Signal Detection Function decomposition

Hydrometeors in the atmosphere typically have sizes of about 0.01 mm for liquid cloud droplets and .1 mm–1 mm for rain droplets. Size of ice crystals varies greatly; the crystals are generally bigger than cloud droplets. In large convective clouds, snowflakes and ice particles may reach 10 mm and more. When the wavelength of the observation instrument is large compared to the size of the particles under consideration, scattering is dominant. For most rain and ice cloud particles scattering starts to play a role at frequencies larger than 60 GHz (5 mm wavelength). Absorption remains important for wavelengths up to 20 mm (about 15 GHz in frequency). Consequently, rain and ice particles' signatures are provided through absorption in the AMSU-A channels 1 – 14 (23 – 57 GHz) and through scattering processes in AMSU-A channel 15 (89 GHz) and MHS channels 1 – 5 (89–190 GHz). If there are no scattering particles, the absorption by smaller particles will dominate the radiative processes at higher frequencies.

The features outlined above are taken into account in comparing a predicted channel 15 brightness temperature with the one observed at channel 15 (89 GHz). The predicted channel 15 brightness temperature is based on AMSU-A channels 1, 2, and 3. The assumption is that there are no scattering hydrometeors. The agreement between both temperatures will then be within 5 K. Once a larger number of scattering particles will be present, the brightness temperatures at higher frequencies will become cooler and a large difference between predicted and observed brightness temperature will occur. This difference is the scattering index.

The method described above is applied only over sea surfaces. Over land, the surfaces themselves can produce surface scattering, which may be confused with the scattering by rain and cloud ice particles. The scattering at water surfaces is bigger than at land surfaces. The emission of land surfaces is higher–there is no 'cold' background. Thus, at the moment, no scattering index is determined over land and coastal surfaces, that is to say the cold space reflection is much less over land than over oceans.

4.2.3.5.1 AMSU-A Sea FOV Selection Function

From the AMSU-A FOV surface type determination function results the Land/Coast/Sea flag is examined to select the Sea Surface FOVs. The Sea FOV selection is then passed to the function which calculates the scattering index.

4.2.3.5.2 AMSU-A Scattering Index Calculation Function

The Scattering index is calculated for sea FOVs only and is determined in the following way: An estimated AMSU-A brightness temperature at channel 15 (89 GHz) is calculated according to:

$$T_{b,A,est,15} = a_0(x) + a_1(x)T_{b,A,1} + a_2(x)T_{b,A,2} + a_3(x)T_{b,A,3}$$

Equation 1

from the brightness temperatures from AMSU-A channels 1, 2 and 3 ($T_{b,A,1}$, $T_{b,A,2}$ and $T_{b,A,3}$), where $T_{b,a,est,15}$ is the estimated channel 15 value and x = 1/(cosζ) - 1, ζ being the zenith angle at the FOV on the Earth surface. The coefficients $a_0(x)$, $a_1(x)$, $a_2(x)$ and $a_3(x)$ are third-order polynomial coefficients of the secant of the zenith angle.

These four zenith-angle-dependent coefficients are calculated from a third order polynomial x, one polynomial for each one of the four coefficients *ai(x), i* = 0,...3. The parameters of the polynomial are user-configurable auxiliary data in the auxiliary dataset referred as - ATOVS_L2_PGS_COF_AMSCI. The zenith-angle dependent coefficients $a_0(x)$, $a_1(x)$, $a_2(x)$ and $a_3(x)$ are then:

$$a_i(x) = b_{0,i} + b_{1,i} \times x + b_{2,i} \times x^2 + b_{3,i} \times x^3, i = 0, \ldots, 3$$

Equation 2

where x = 1/(cosζ) - 1. By default, the user configurable coefficients $b_{0,i}$, $b_{1,i}$, $b_{2,i}$ and $b_{3,i}$ have values of:

-179.588, -11.828385, -79.47264, and 7.7797457, respectively, for $i=0$
0.55091080, -0.79630378, 0.82639551, -0.25387738, respectively, for $i=1$
-0.24632506, 0.70550387, -0.78458517, 0.26119687, respectively, for $i=2$
1.61315530, -0.09248847, 0.41939181, -0.05278192, respectively, for $i=3$.

The satellite zenith angle ζ for each field of view at the Earth's surface is calculated as follows: Calculate the satellite scan angle for each scan position in one AMSU-A scanline. Convert the satellite scan angle into the satellite zenith angle ζ according to $\zeta = \mathrm{asin}(\sin(\eta) \times R)$, where $R = (r_{earth} + h_{sat})/r_{earth}$ involves the radius of the Earth and the satellite altitude. r_{earth} is the Earth's mean radius (r_{earth} = 6371.03 km) and h_{sat} is the satellite altitude.

The Scattering Index (I_{sc}) is then determined according to the following:

$$I_{sc} = T_{b,A,est,15} - T_{b,A,15}$$

Equation 3

where $T_{b,A,15}$ is the brightness temperature from AMSU-A channel 15.
Those FOVs where $I_{sc} > 10$ K , or $I_{sc} < -10$ K, are flagged by the functionality.
This function is also performed, after the mapping of AMSU-A brightness temperatures to HIRS/4 FOV, on the mapped AMSU-A brightness temperatures (see below).
The Scattering Index is passed to the subsequent ATOVS Level 2 Product Generation Functions.

4.2.3.5.3 Precipitation Test after Crosby et al.

The probability of rain within the AMSU-A FOV is calculated according to the method described by Crosby, Ferraro and Wu in [RD-6]. This test uses the relative scattering by hydrometeors at high frequency to flag rain or deep ice cloud. Insofar, this test may be redundant to the Scattering Index.

$$I_{prec} = \frac{1}{(1 + \exp(-f))}$$

Equation 4

the probability of rain I_{prec} in the FOV is computed where:

$$f = c_1 + c_2 \times T_{b,A,1} + c_3 \times T_{b,A,15}$$

Equation 5

where c_1, c_2 and c_3 are user-configurable coefficients. Their default values are as follows:

$c_1 = 10.5$

$c_2 = 0.184\ K^{-1}$

$c_3 = -0.221\ K^{-1}$

If the probability of rain I_{prec} is higher than a threshold value $P_{thres,rain}$, a rain flag is set. The default value of $P_{thres,rain}$ is $P_{thres,rain} = 0.05$. $T_{b,A,1}$ and $T_{b,A,15}$ are the channel 1 and channel 15 brightness temperatures respectively. The coefficients in Equation 5 and the threshold are user-configurable. These parameters are included in the configurable dataset ATOVS_L2_PGS_COF_AMSRAT.

4.2.3.5.4 Grody Light Rainfall Test Function

The Grody Light Rain Test is an adaptation of a Special Sensor Microwave/Imager (SSM/I) algorithm to the AMSU-A instrument [RD-14]. It shall be triggered by strong absorption and will thus flag deep liquid water cloud or an emission bright band.

An estimated AMSU-A channel 1 brightness temperature $T_{b,A,est,1}$ is computed according to this:

$$T_{b,A,est,1} = g_0 + g_1 \cdot T_{b,A,2}$$

Equation 6

where $T_{b,A,2}$ is the observed AMSU-A channel 2 brightness temperature. The coefficients g_0 and g_1 are user-configurable and are determined off-line. Their default values are as follows:

$g_0 = 38$ K
$g_1 = 0.880$
If

$$T_{b,A,1} < T_{b,A,est,1}$$

Equation 7

where $T_{b,A,1}$ is the observed AMSU-A channel 1 brightness temperature, then a rain flag is set. This functionality is also employed on AMSU-A mapped brightness temperatures on the HIRS/4 or MHS FOV. The coefficients and thresholds in Equation 6 are user-configurable. They are included in the configurable dataset ATOVS_L2_PGS_COF_AMSRAT.

4.2.3.5.5 Set Flags Function

This functionality collects the flags from the respective tests and provides a summary flag on the rain testing function.

4.2.3.6 Surface Analysis Function

The function is decomposed in sub-functions as specified in Table 10.

Surface Analysis Function operations
1. Interpolate Means and Covariances to scan angle 2. Cost Function and Surface Type Determination Function 3. Check Surface Type Function

Table 10: Surface Analysis Function decomposition

The surface is analysed from the AMSU-A brightness temperatures. A minimum variance scheme is employed for this purpose. In advance, off-line and before the processing takes place, mean brightness temperatures and brightness temperature covariance matrices have been calculated using a radiative transfer model for the 15 AMSU-A Channels and the five MHS channels (ATOVS_L2_PGS_DAT_AMTBM and ATOVS_L2_PGS_DAT_MHSTBM respectively).

These computations have been done for different surface types, without cloud liquid water. According to the microwave channels used (AMSU-A channels 1, 2 and 3 as default, but user-configurable) mean brightness temperatures $T_{b,A,m}$ and the covariance matrix $\boldsymbol{C}$ are determined: In the user-configurable data sets ATOVS_L2_PGS_DAT_AMTBM and ATOVS_L2_PGS_DAT_MHSTBM global mean AMSU-A and MHS brightness temperatures and covariance matrices are stored for each surface type. The brightness temperatures have been calculated with a radiative transfer model without cloud liquid water. For the microwave channels used (AMSU-A channels 1, 2 and 3 are default) the brightness temperatures and covariance matrices are extracted; the covariance matrix C is then inverted (see also Section 4.2.3.6.1). The vector of mean brightness temperatures and the inverse covariance matrix are then used to evaluate a cost function J_{stc} for each surface type:

$$J_{stc} = \left|(\boldsymbol{T}_{b,meas} - \boldsymbol{T}_{b,A,m})\boldsymbol{C}^{-1}(\boldsymbol{T}_{b,meas} - \boldsymbol{T}_{b,A,m})^{T}\right|$$

Equation 8

where $\boldsymbol{T}_{b,meas}$ are the observed brightness temperatures, denotes the inverse covariance matrix and the superscript **T** denotes the transpose of a vector or a matrix. The surface type is identified as the one minimising the cost function J_{stc}.

If the cost function exceeds a threshold value (normalised by number of channels squared), cloud liquid water may be present and a flag is set. Only channels 1, 2 and 3 of AMSU-A are used in the present setup. The channel numbers used in this algorithm shall be user-configurable.

This functionality shall also be employed on AMSU-A mapped brightness temperatures on the HIRS/4 or MHS FOV to determine again the surface type.

4.2.3.6.1 Interpolate Means and Covariances to Scan Angle Function

The Global Mean Brightness Temperatures $T_{b,A,m}$ and the Brightness Temperature covariance matrices $\boldsymbol{C}$ are stored for all AMSU-A and MHS channels and for a user-configurable number of secants of scan angle, the default number is five secants (1.00, 1.25, 1.50, 1.75, 2.00), which corresponds to scan angles of (0°, 36.86°, 48.19°, 55.15°, 60°) in the auxiliary dataset (ATOVS_L2_PGS_DAT_AMTBM and ATOVS_L2_PGS_DAT_MHSTBM respectively). Brightness Temperature vector and Covariance Matrices are then stored only for the user-configurable (reduced) set of channels used. The default is AMSU-A Channels 1, 2 and 3. The reduced Covariance Matrices are then inverted to obtain $\mathbf{C}^{-1}$. The Inverse Covariance Matrices and Brightness Temperature Means are furthermore interpolated to the scan angles *x* of the AMSU-A for each channel *j* and each surface type *l* according to the following:

$$T_{b,A,m}(x,l,j) = T_{b,A,m}(x,l,j) + \Delta\chi(T_{b,A,m}(k+1,l,j) - T_{b,A,m}(k,l,j))$$

Equation 80

where:

$$\Delta\chi = \frac{x - \chi_k}{\chi_{k+1} - \chi_k}$$

Equation 81

is the slope given by the neighboring secants, where the are taken from the secants, for which Mean Brightness Temperatures and Covariance Matrices are stored. The interpolation is done accordingly for the inverse covariance matrices.

4.2.3.6.2 Cost Function and Surface Type Determination Function

The cost function is computed according to **Eq. 8**. The surface type is identified as the one minimising the cost function, according to the settings in Table 11. The cost function is normalised according to the following:

$$J_{min} = \frac{J_{min}}{N_{srfchan}N_{srfchan}}$$

Equation 82

where J_{min} is the cost function minimising equation 8 and $N_{srfchan}$ is the number of Channels used in the procedure ($N_{srfchan}$ = 3 in the default case).

	Surface Type Determination Function Settings
1	New sea ice (new ice, no snow) = nilas and pancake ice
2	Dry land (dry with or without significant vegetation)
3	Dry snow (snow with water less than 2 %, over land)
4	Multi-year sea ice (old ice with snow (assumed dry) cover)
5	Sea (open water, no islands, ice-free, wind < 14 m/s)
6	Wet forest (established forest with wet canopy)
7	Wet land (non-forested land with a wet surface)
8	Wet snow (snow with water content > 2%)
9	Desert

Table 11: Cost Function and Surface Type Determination Function Settings

The 'Cost Function and Surface Type Determination Function' settings for Young and First Year Sea-ice are not available for day 1.

If surface type is 1, 4 or 8 and AMSU-A FOV channel 1 > 275 K, surface type is set to 9 (desert).

Flags are set in the following cases:

- the minimum cost function exceeds the cloud test threshold (default value is 5.5);
- the estimated surface type is incompatible with the topography (flag);
- the surface type is not usable for the subsequent product generation.

The cloud test threshold is user configurable and read from the Auxiliary Data set.

4.2.3.6.3 Check Surface Type Function

Some surface types are not usable for subsequent product generation. These surface types shall be user-configurable. The current default setting is that surface types

2 = Dry land

3 = Dry snow

6 = Wet forest

7 = Wet land

9 = Desert

cannot be handled in the subsequent processing (using surface channels). A check with the surface type (land, sea, coast) derived from the topography data shall be performed and a flag shall be set.

4.2.3.7 Contamination and Clear/Cloudy Flagging Function

The function is decomposed in sub-functions as specified in Table 12.

	Contamination and Clear/Cloudy Flagging Function operations
1	Contamination Flagging Function
2	Clear/Cloudy Flagging Function

Table 12: Contamination and Clear/Cloudy Flagging Function decomposition

4.2.3.7.1 Contamination Flagging Function

The subsequent product generation functionality needs information on the contamination estimation of each AMSU-A FOV. For this purpose the Contamination Flagging functionality classes an AMSU-A FOV as contaminated, if it is flagged for precipitation (rain flag) and/or scattering (scattering index flag) by any of the tests specified in the Section 4.2.3 of this document.

In addition,AMSU-A FOVs with incompatible surface types or surface types that are not usable for the subsequent product generation functionality, as determined from the Cost Function and Surface Type Determination Function, are classified as contaminated. The surface types which cannot be used are 2, 3, 6, 7, and 9. The inversion is done, but no surface channels can be used in these cases.

4.2.3.7.2 Clear/Cloudy Flagging Function

If an AMSU-A FOV is not declared contaminated, but if cloud liquid water has been detected (through the test indicated above–the cost function exceeds the cloud threshold), then it is classified ‘cloudy’. If an AMSU-A FOV is neither classified ‘contaminated’ nor ‘cloudy’, it is flagged as ‘clear’. This does not mean that no cloud is present, it means solely that no clouds have been detected in the microwave spectral region. There may well be clouds affecting the infrared and visible channels of the complementary instruments.

As a roughly guidance figure ‘clear’ means that the cloud liquid water path is less than 50 g/m^2 , ‘cloudy’ means that the cloud liquid water path is less than 500 g/m^2 . All higher values of liquid water path, whether combined with precipitation or not, ice cloud or mixed surface, shall be classified as contaminated. 500 g/m^2 will rarely be exceeded outside major tropical or mid-latitude storm systems, or in deep convection. A considerable percentage of the Earth’s extensive stratocumulus layers will contain liquid water paths less than 50 g/m^2.

4.2.4 MHS Data Preparation Function

The function is decomposed in sub-functions as specified in Table 13.

	MHS Data Preparation Function Operations
1	MHS Bias Correction Function (scan dependent)
2	MHS Surface Type Land/Sea/Coast Determination Function
3	MHS Limb Adjustment and correction for Surface Emissivity
4	MHS Channel 1 (89 GHz) Median Filtering Function
5	Map MHS to AMSU-A two Function
6	MHS 89 GHz on AMSU-A Range Checking Function
7	Map AMSU-A to MHS Function
8	MHS Scattering Detection Function

Table 13: MHS Data Preparation Function Composition

The MHS data preparation is limited to the examination of the MHS data for contamination and also the re-estimation of the scattering index.

Inputs
Synchronized and validated MHS-A Level 1b dataflow; Auxiliary data (Topography dataset); appended information from the Retrieval Grid Determination Function and the Input Satellite Data Vector Generation Function.

Outputs
Appended MHS information (Cloud flag, Land/Sea/Coast flag, Scattering Index, Rain flag, etc), pre-processed MHS dataflow, MHS Data mapped into the AMSU-A grid.

4.2.4.1 MHS Bias Correction Function

This function performs a bias correction of the MHS Brightness Temperatures. The bias correction is scan angle dependent. In case no bias correction is required, the corrections have to be set to zero. A flag has to be set. The algorithm is as follows:

$$T_b^{cor,\,bias}(j,k) = T_b(j,k) + \Delta T_{b,\,bias}(j,k)$$

Equation 83

where $T_b^{cor,bias}(j,k)$ is the bias-corrected Brightness Temperature for a channel k and a FOV j, $T_b(j,k)$ is the Brightness Temperature for a channel k and FOV j, and $\Delta T_{b,\,bias}(j.k)$ is the bias correction to be applied. The bias correction is provided as user-configurable auxiliary data.

4.2.4.2 MHS Surface Type Land/Sea/Coast Determination Function

From the topography dataset (ATOVS_L2_PGS_DAT_SFCTOP and also [AD-48]) the surface type Land/Sea/Coast flag is determined for each MHS Field of View (FOV). All grid points within a box centered on the MHS instrument FOV at approximately the size of the FOV is examined. The FOV is classified land, if every grid point in this box is classified land, classified sea if every grid point in this box is sea, and coast otherwise. As default, the user configurable box size is set to 15 km. If latitude or longitude is out of range, the surface type is set to a value for ‘not determinable’.

The surface elevation is derived as the average of all surface elevations within the FOV. If the FOV is over sea, the surface elevation is determined zero. In case latitude or longitude is out of bounds the surface elevation is set to the value ‘not determinable’.

4.2.4.3 MHS Limb Adjustment And Correction For Surface Emissivity

This function corrects the MHS Brightness Temperatures for limb effects and for surface emissivity effects. Presently, this is an empty function. A flag has to be set.

4.2.4.4 MHS Channel 1 (89 Ghz) Median Filtering Function

For each MHS FOV, the median value of the MHS channel 1 (89 GHz), the brightness temperature is found in the surrounding filter box of M × N FOVs. M and N are user-configurable parameters and should be odd numbers. The default values are M = 3 and N = 3. The maximum size M × N of the filter box should not exceed a value MN_{max}, which should be user-configurable. Its current default value is MN_{max} = 100. Only N_{max} fields of view per scan line should be allowed. The default value is N_{max} = 33. The size of the filter box needs to be reduced at the edges of a block of data, but should not go below 2 × 2 boxes in each corner.

The rationale to this functionality is that spikes in the MHS channel 1 (89 GHz) field may hint to contaminated data (due to scattering).

If the median value differs more than a threshold of $T_{b,med,thresh}$, which shall be user-configurable (the default is 10 K) from the brightness temperature of the central FOV, then the central FOV is flagged as contaminated. (Flag only needed.)

4.2.4.5 Map MHS to AMSU-A Fov Two Function

The MHS data is mapped to the AMSU-A FOV grid if the default case pertains. Note that only those MHS FOVs with the same surface type as the AMSU-A fov are mapped, unless the AMSU-A FOV is of mixed type. It this latter case all MHS FOVs are mapped.

The mapping acts on AMSU-A FOVs with primary calibration. If those are not available, the FOVs with secondary calibration are then used.

4.2.4.6 MHS 89 GHz on AMSU-A FOV Range Checking Function

To look for inhomogeneous 89 GHz values within the AMSU-A footprint, the MHS Channel 1 (89 GHz) values are examined in the AMSU-A FOVs. If there are inhomogeneities, these are due to contamination effects. A flag is set to these AMSU-A FOVs. The method employed is the following:

The range of the mapped MHS FOVs' Brightness Temperatures on the AMSU-A FOV is calculated. If this range exceeds a user configurable threshold $T_{thresh,AB,89}$, the AMSU-A FOV is flagged. The default value of $T_{thresh,AB,89}$ is $T_{thresh,AB,89}$ = 12 K.

4.2.4.7 Map AMSU-A To MHS FOV Function

AMSU-A Channel Brightness Temperatures are mapped onto the MHS FOV applying the nearest neighbour method. The number of channels to be mapped is user-configurable. The default channels used are AMSU-A channel 1, channel 2 and channel 3.

4.2.4.8 MHS Scattering Detection Function

This functionality is applied to mapped AMSU-A data, the AMSU-A channel 1, channel 2 and channel 3 data mapped on the MHS FOV. It performs the same scattering index calculation as the one for AMSU-A. The AMSU-A Channel 15 (89 GHz) data are replaced by MHS Channel 1 (89 GHz) data. In case the latter are not available, this functionality is not used.

An MHS FOV shall be flagged, if mapped AMSU-A Channel 15 (89 GHz) and MHS Channel 1 (89 GHz) differ by a value larger than a threshold $T_{thresh,AB,89}$. The default value of $T_{thresh,AB,89}$ is $T_{thresh,AB,89}$ = 12 K.

The function is decomposed in sub-functions as specified in Table 14.

	MHS Scattering Detection Function decomposition
1	MHS Sea FOV Selection Function
2	MHS Scattering Index Calculation Function

Table 14: MHS Scattering Detection Function decomposition

4.2.4.8.1 MHS Sea FOV Selection Function

From the MHS FOV Surface Type Determination Function results, the input-data-based land/sea mask (ATOVS_L2_PGS_DAT_LAMASK) where the Land/Coast/Sea flag is represented, the selection of the Sea Surface MHS FOVs is done. The Sea MHS FOV selection is then passed to the function which calculates the scattering index.

4.2.4.8.2 MHS Scattering Index Calculation Function

This functionality is applied to mapped AMSU-A data. AMSU-A Channel 1, 2, and 3 data are mapped onto the MHS FOVs. MHS channel 1 (89 GHz) data play the role of the AMSU-A Channel 15 data in the Scattering index calculation. Hence the scattering index is re-calculated using the method described in Section 4.2.3.5.2 for AMSU-A data, but replacing the AMSU-A Channel 15 (89 GHz) data ($T_{b,A,15}$) by the MHS channel 1 (89 GHz) data in Eq. 3 before performing the calculation. Everything else remains the same, in particular, the same value of $T_{b,A,est,15}$ is used.

An MHS FOV shall be flagged, if the scattering index is outside a specified range, expressed in a user-configurable threshold value (see above). The re-calculation of the scattering index must not be performed if the MHS Channel 1 data is not available. The coefficients and parameters used to calculate the Scattering Index by this functionality are user-configurable (ATOVS_L2_PGS_COF_MHSSCI).

4.2.5 AVHRR/3 Data Preparation Function

The function is decomposed into one sub-function as specified in Table 15.

	AVHRR/3 Data Preparation Function operations
1	AVHRR/3 Scenes Analysis Results Checking Function

Table 15: AVHRR/3 Data Preparation Function decomposition

Inputs
Synchronized, validated AVHRR/3 Scenes Analysis Results (see list of parameters below); Auxiliary data (Topography dataset, Sea Surface Temperature Climatological data, Albedo climatological Data, Air Temperature and Altitude Climatological Data, Available forecast Data, Configurable parameters like thresholds and coefficients to be used for cloud clearing.)

Outputs
AVHRR/3 Appended data (including Sea Surface Temperature and cloud information); AVHRR/3 Pre-processed data (Level 1 and Scenes Analysis); Land/Sea/Coast mask (using the corresponding flag); Clear/Cloudy mask (using the corresponding flag); AVHRR/3 Radiance Statistics appended to the selected retrieval grid.

Complementary AVHRR/3 data analysis to the Scenes Analysis is performed by this function to assure the maximum use of the AVHRR/3 data. This function works for GAC and for full resolution AVHRR/3 data. This functionality also produces AVHRR radiance statistics. If there is no Scenes Analysis available, but the AVHRR/3 data are available at sufficient quality for product generation, this function shall produce the cloud information required for the subsequent ATOVS Level 2 product generation.

4.2.5.1 AVHRR/3 Scenes Analysis Results Checking Function

The following operations are performed by this function:

- Input data to this functionality are the validated Scenes Analysis results and the synchronised AVHRR/3 Level 1b data.

These Scenes Analysis Results are checked for consistency and if they contain the required cloud information (Cloudy/Clear) and the associated Land/Sea information. This information is checked:

1. Geolocation
2. Cloud Flag (1 = cloudy, 0 = cloud free)
3. Surface Temperature (in case of cloud flag = 0, no cloud)
4. Cloud Top Temperature (in case of cloud flag = 1)
5. Surface elevation
6. Surface type)

The data are checked if they were out of bounds.

- A decision is made whether a separate cloud detection needs to be performed (the HIRS cloud detection standalone retrieval).
- It shall be possible to configure the decision criteria used by this function.

4.2.6 HIRS/4 Data Preparation Function

The function is decomposed in sub-functions as specified in Table 16.

	HIRS/4 Data Preparation Function Operations
1	HIRS/4 Bias Correction (Scan Dependent) Function
2	HIRS/4 Land/sea Mask Determination Function
3	HIRS/4 Limb Adjustment Function
4	HIRS/4-only Cloud Analysis Function
5	Microwave Tests Recalculation Function

Table 16: HIRS/4 Data Preparation Function decomposition

In the nominal case, the determination of cloud coverage is based on the AVHRR/3 Scenes Analysis supported by AMSU-A data. If the AVHRR/3 data are not available or the Scenes Analysis failed, the cloud detection is based on HIRS/4 level 1b data.

Similar to the AVHRR/3-based cloud detection the HIRS/4-based cloud detection makes use of a number of threshold tests. If AMSU-A data are available, these data is used to check the consistency of the cloud contamination.

Inputs
Synchronized HIRS/4 Level 1b dataflow; Validated AVHRR/3 Scenes Analysis Results; AVHRR/3 Appended Data (including Sea Surface Temperatures and Cloud information); Pre-processed AMSU-A dataflow; Appended AMSU-A dataflow; Auxiliary Data and Appended Data.

Outputs
Appended Cloud Information; Pre-processed HIRS/4 Level 1 dataflow.

4.2.6.1 HIRS/4 Bias Correction Function

The Bias corrections are added to the level 1b Brightness Temperatures before any other processing takes place. They are dependent on the channel and the scan angle. The data are provided through user configurable auxiliary data (ATOVS_L2_PGS_PAR_HIRSBC). The bias correction is only added where the data are valid. If no auxiliary data are available, the values of zero are used. The algorithm is as follows:

$$T_b^{cor,\,bias}(j,k) = T_b(j,k) + \Delta T_{b,\,bias}(j,k) \qquad \textbf{\textit{Equation 85}}$$

where $T_b^{cor,bias}(j,k)$ is the bias corrected Brightness Temperature for a channel k and an FOV j, $T_b(j,k)$ is the Brightness Temperature for a channel k and FOV j, and $\Delta T_{b.bias}(j,k)$ is the bias correction to be applied. The bias correction is provided as user configurable auxiliary data.

4.2.6.2 HIRS/4 Land/Sea Mask Determination

From the topography dataset (ATOVS_L2_PGS_DAT_SFCTOP and also [AD-48]) the surface type Land/Sea/Coast flag is determined for each HIRS/4 Field of View (FOV). All grid points within a box centered on the HIRS/4 instrument FOV at approximately the size of the FOV is examined. The FOV is classified land, if every grid point in this box is classified land, classified sea, if every grid point in this box is sea, and coast otherwise. Per default, the user configurable box size is 40 km. If latitude or longitude are out of range, the surface type is set to a value for ‘not determinable’.

4.2.6.3 HIRS/4 Limb Adjustment Function

This function performs a limb adjustment correction of the HIRS/4 Brightness Temperatures. The limb correction is scan angle dependent. In case no limb correction is required, the corrections have to be set to zero. A flag has to be set. Currently, an empty algorithm shall be implemented.

4.2.6.4 HIRS/4-only Cloud Analysis Function

Based on user configurable threshold values and coefficients (ATOVS_L2_PGS_COF_HIRCLD), the detection of clouds, is performed by this functionality for the case that AVHRR/3 processing (Scenes analysis, HIRS/4 Level 1 processing) has not provided cloud information to HIRS/4. The examined FOVs are flagged accordingly. In case there are only HIRS/4 sounding data available, there is the need to identify and eventually clear - if possible - clouds in the respective HIRS/4 Fields-of-view. The scheme applied is taken from [RD-14]. The test described there is modified in the sense that those involving AMSU-A brightness temperatures are not used. This leaves the testing sequence outlined below. There is also a distinction between the day and night situation. If any of the test outlined below is satisfied, then the field-of-view in question is declared cloudy.

Input to the tests are the HIRS/4 observations in terms of brightness temperatures. Output is a cloud mask on the HIRS/4 fields-of.-view. The HIRS/4 FOV is declared cloudy if any one of the tests specified below is satisfied. The following tests are specified:

1) Longwave window channel (HIRS/4 Channel 8 (11.11 μm)) brightness temperature threshold test:

$$T_{b,H,8} < 210K$$ ***Equation 9***

2) The warmest adjacent Fields-of-view longwave window channel (HIRS/4 Channel 8) brightness temperature test (spatial coherence).

$$T_{b,H,w,8} - T_{b,H,8} > 4K$$ ***Equation 10***

where $T_{b,H,w,8}$ is the warmest HIRS/4 channel 8 brightness temperature in any adjacent HIRS/4 field of view

3) Multi-window channels brightness temperature difference tests

During daylight conditions:
3a, day

$$|(T_{b,H,w,18} - T_{b,H,w,8})| > 10.0K$$ ***Equation 11***

During night conditions:
3a, night

$$T_{b,\,H,\,w,\,18} - T_{b,\,H,\,w,\,8} > 2.0K$$ *Equation 12*

During night conditions:
3b, night

$$T_{b,\,H,\,w,\,8} - T_{b,\,H,\,w,\,18} > 4.0K$$ *Equation 13*

During night conditions:
3c, night

$$T_{b,\,H,\,w,\,19} - T_{b,\,H,\,w,\,18} > 2.0K$$ *Equation 14*

During night conditions:
3d, night

$$T_{b,\,H,\,w,\,18} - T_{b,\,H,\,w,\,19} > 4.0K$$ *Equation 15*

If any of these tests is satisfied, the HIRS/3 field-of-view is declared cloudy, otherwise it is declared as clear.

4.2.6.5 Microwave Tests Recalculation Function

This functionality repeats the calculation of the microwave scattering index and the rain tests, as well as the surface analysis, for the mapped data on the retrieval grid. The details of the algorithms are specified in the previous sections.

4.2.7 Retrieval Grid Mapping Function

The function is decomposed in sub-functions as specified in Table 17.

	Retrieval Grid Mapping Function Operations
1	Input Data to Retrieval Grid Mapping Function
2	Appended Data to Retrieval Grid Mapping Function

Table 17: Retrieval Grid Mapping Function decomposition

Depending on the selected retrieval grid this functionality performs the calculation of a representative value for the data of one given ATOVS instrument at the location of the FOV of the selected instrument for the retrieval.

There shall be the capability of switching between mapping methods. The mapping shall be possible through the geographical location of individual pixels and their size and shape or through a look-up table (determined through a user configurable setting). Such a look-up table shall be calculated to address those mapping FOVs which are collocated with the retrieval grid FOV.

For both the Input Data to Retrieval Grid Mapping Function and the Appended Data to Retrieval Mapping Function, there shall be several mapping methods possible, any of which may be chosen for each instrument pair by a user-configurable switch from the Core Ground Segment functionality:

1. Bilinear interpolation (nominal and default)
2. Nearest neighbour
3. Spatial weighted average (the weighting function is Gaussian)

Bilinear interpolation shall be the default procedure for mapping AMSU-A to HIRS. For MHS to AMSUA and MHS to HIRS mapping, spatial weighted averaging is used, mapping of AMSU-A to MHS is done by the nearest neighbour method. The function shall allow the mapping of any appended ATOVS instrument data and flag data to any other ATOVS instrument grid.

Inputs
Retrieval Grid flag; Pre-processed AVHRR/3 dataflow; AMSU-A pre-processed dataflow; MHS Level 1b data mapped to the AMSU-A FOV grid; Pre-processed MHS dataflow; Pre-processed HIRS/4 dataflow; AVHRR/3 appended data (including Sea Surface Temperatures and Cloud information data); Appended AMSU-A data; Appended MHS data; Appended Cloud Data; Configuration settings and coefficients.

Outputs
Pre-processed, contamination checked and mapped to the retrieval grid sounder data; Produced Appended information (including Cloud information mask -Clear/Cloudy flags, Surface Information-Land/Sea/Coast flag, Contamination information - AMSU-A flags, etc.) from data preparation mapped to the retrieval grid; Intermediate products (Sea Surface Temperatures, Land/Sea Mask, Cloud cover mask).

4.2.7.1 Input Data to Retrieval Grid-Mapping Function

For all the instrument data to be mapped within this functionality, a representative value is calculated and provided on the target instrument grid. An example of a mapping algorithm is provided in [AD-24].

4.2.7.2 Appended Data to Retrieval Grid-Mapping Function

This functionality provides a representative value for all appended data to the input data on the selected retrieval grid. In particular, this function allows the creation of intermediate products (Sea Surface Temperatures *SST*, AVHRR/3 Cloud mask data) which are derived during the preparation of the Input Data Vector. This function includes the mapping of flag and mask data. An example of a mapping algorithm is provided in [AD-24].

4.3 ATOVS Level 2 Retrieval Product Generation Function

The function is decomposed in sub-functions as specified in Table 18.

	ATOVS Level 2 Retrieval Product Generation Function Operations
1	Retrieval Method and FRTM Selection Function
2	Geophysical Parameter Retrieval Function

Table 18: ATOVS Level 2 Retrieval Product Generation Function decomposition

The essential retrieval of geophysical parameters is done based on the provided input data and the selected retrieval method and thus grid. The results of this functionality is the ATOVS Level 2 output dataflow containing Temperature profiles, moisture profiles, cloud and surface parameters. Appended information is attached to the ATOVS Level 2 output dataflow.

Inputs
Pre-processed (mapped to retrieval grid and contamination checked) sounder data; produced Appended information from data preparation (including cloud information mask - Clear/Cloudy flag, Surface information - Land/Sea/Coast flag, Contamination information); Non-appended auxiliary data; Configuration settings, parameters, thresholds and coefficients.

Outputs
Produced ATOVS Level 2 Products (Temperature and Humidity Profiles, Total Ozone Column, Effective Cloud Amount, Top Cloud Temperature, etc); Produced ATOVS Level 2 Appended information.

4.3.1 Retrieval Method and FRTM Selection Function

Within this functionality all parameters and auxiliary information are initialised. There shall be only one retrieval method and an associated FRTM and First Guess Selection Method for the time being, although the possibility of choosing from several shall be left open.

A default fast radiative transfer model is selected during normal NRT operations (ATOVS_L2_PGS_TYP_CONFIG).

This functionality makes use of analyses of the available input data and the related flags and branches to the retrieval method to be used. A default has to be set. The retrieval method must be used for the entire dump.

There shall be the possibility to select between retrieval methods in a user-configurable manner (ATOVS_L2_PGS_TYP_RET).

The default retrieval method is derived from [RD-11].

In a case that does not allow to use the default retrieval method (the Retrieval Input Data Vector does not contain sufficient information) an alternative method shall be chosen among the following in this order of priority and availability at day one:

1. Regression algorithm, with AMSU-A standalone only

If these cases are not successful, no retrieval needs to be performed and an error message must be produced. The process must then conclude in an orderly manner (without abort).

4.3.2 Geophysical Parameter Retrieval Function

This is the essential function to produce the geophysical parameters to be retrieved from the ATOVS sounder data. The function is decomposed in sub-functions as specified in Table 19. These sub-functions are described in details in the following sections.

	Geophysical Parameter Retrieval Function Operations
1	Default Retrieval Method Function
2	Alternative Retrieval Method Function

Table 19: Geophysical Parameter Retrieval Function decomposition

Inputs
Retrieval Input Data Flow (AMSU-A, MHS and HIRS/4 Brightness Temperatures), mapped to the retrieval grid (HIRS/4 FOV as default), as produced by the previous functionality and auxiliary information for the retrieval; Retrieval Method and Fast Radiative Transfer Model parameters and configuration settings.

Outputs
ATOVS Level 2 Retrieved Parameters (Temperature and Humidity profiles, Total Ozone Column (as internal information, not part of the product), Cloud-Top Temperatures and Pressures,); and ATOVS Level 2 auxiliary information from the retrieval process.

4.3.2.1 Default Retrieval Method Function

This is the Retrieval Method nominally used, as indicated above. The function is decomposed in subfunctions as specified in Table 20. These sub-functions are described in details in the following sections.

	Default Retrieval Function Operations
1	Accept Input Data for Retrieval Procedure
2	Accept Setup and Support Data for Retrieval Function
3	Loop Function: over all relevant pixels. Select Pixels to process
4	Inversion Preparation Function
5	Inversion: Compute Geophysical Parameters Function
6	Complete Retrieval Results

Table 20: Default Retrieval Method Function decomposition

4.3.2.1.1 Accept Input Data for Retrieval Procedure

This function accepts all input data from the preparation functions, as specified above. Data accepted include the mapped sounder data, and also all auxiliary information required for the retrieval.

4.3.2.1.2 Accept Setup And Support Data For Retrieval Function

This functionality receives and accepts all setup and support data, required for the retrieval. These data include among others covariance matrices and mean values for airmass classes, biases for the fast radiative transfer model (FRTM) to be used, the Guess library, Guess covariance matrices, surface emissivities and forecast model profiles. The setup data include among others the list of sounding channels to be used (which may vary for different satellites), channel lists for the guess selection etc. The function is decomposed in sub-functions as specified in Table 21.

	Receive and accept support data for retrieval
1	Receive Setup data for the retrieval
2	Receive and Accept inverse covariance matrix and mean values for airmass
3	Receive and Accept biases for FRTM
4	Receive and Accept Guess Library
5	Receive and accept Guess profile covariance matrices
6	Receive and accept forecast files requested for retrieval
7	Initialise FRTM for satellite in question

Table 21: Receive and Accept Support Data for Retrieval Decomposition

4.3.2.1.2.1 Receive Setup data for the retrieval

This functionality receives all the setup data and parameters required to perform the retrieval function. These data and parameters are stored in an auxiliary data set and depend on the satellite and the instruments used for the retrieval. For each satellite the respective setup information needs to be available. With the satellite name known, the relevant information shall be selected and made available for the subsequent functions. Typically the following information needs to be provided:

Satellite name
Flag whether AVHRR information will be used/available
Number of channels with potential to be used in the retrieval
List of channels (following the notation given below:
1,...,20 HIRS/4 Channels 1-20
21,...,35 AMSU-A Channels 1-15
36,...,40 MHS Channels 1 - 5
41,...,46 AVHRR/3 Channels 1 - 5, including Channels 3a (43) and 3b (46))
Number of channels used in the FRTM (RTTOV)
List of channels used in FRTM (RTTOV)
Number of channels used in the air mass detection
List of channels used in the air mass detection
Number of Channels used for the dynamic Bias correction of the FRTM
List of channels used for the dynamic bias correction of the FRTM
Number of channels used in the guess library
List of channels used in the guess library

For each pair of surface type (land/sea/coast) and cloudy type (clear, partly cloudy, cloudy)
Surface type (land = 1, sea = 2, coast = 3),
Clear type (clear = clear AVHRR = 1, partly cloudy = cloudy AVHRR + clear AMSU-A = 2, cloudy = cloudy AMSU-A = 3),
Number of channels used for the first guess selection,
List of channels used for the first guess selection
For each pair of surface type (land/sea/coast) and cloudy type (clear, partly cloudy, cloudy)
Surface type (land = 1, sea = 2, coast = 3),
Clear type (clear = clear AVHRR = 1, partly cloudy = cloudy AVHRR+clear AMSU-A = 2, cloudy = cloudy AMSU-A = 3),
Number of channels used for the inversion,
List of channels used for the inversion.

This information will be provided in the user configurable auxiliary data set: ATOVS_L2_PGS_PAR_SETUP.

4.3.2.1.2.2 Receive and Accept Inverse Covariance Matrix and Mean Values for Airmass

This functionality receives the inverse covariance matrices, the mean brightness temperatures and standard deviations, required for the airmass selection. In the retrieval scheme there are five default airmass classes:

- Tropical
- Midlatitude 1
- Midlatitude 2
- Arctic 1
- Arctic 2

The retrieval itself is performed for ten secant (cosine of scan angle) classes (to the right and left of the subsatellite track–there are in total 19 secant areas). There are inverse covariance matrices, mean brightness temperatures and standard deviations for each airmass area ($N_{airmass}$ classes, default = 5, $N_{airmass}$ should be user-configurable) and each secant class (N_{secant} secant classes, default = 10, N_{secant} should be user-configurable). The matrices and mean brightness temperatures are provided for a ground pressure level of p_{sfc}=1000 hPa. The matrices have the dimensions ($N_{maxcanair} \times N_{maxcanair}$), where $N_{maxcanair}$ is the number of channels used for the airmass classification for the satellite in question; the value is taken from the setup auxiliary data set. Hence we have $N_{airmass} \times N_{secant}$ $N_{maxcanair} \times N_{maxcanair}$ -matrices and mean brightness temperature $N_{maxcanair}$ -vectors.

4.3.2.1.2.3 Receive and Accept biases for FRTM

This functionality provides the biases (mean errors – computed minus observed brightness temperatures (deltas)) and standard deviations of the errors of the fast radiative transfer model (FRTM). Furthermore, linear regression coefficients are provided required for a dynamic computation of biases (a_0, $a_k(i)$, *k denotes the channels used for the regression; the last k is used for the dependency in the secant (see below), i is the instrument data channel (46 used, including AVHRR*)). With the number of channels used for the delta correction N_{deltac} and the list of these channels (actually $N_{deltac} - 1$ coefficients (channels)), the last coefficient is used for the secant term. See below. The right set of coefficients can be used for the respective channel to be corrected.

4.3.2.1.2.4 Receive and Accept Guess Library

This functionality provides initial profiles, the upward and downward radiances at the surface for each scan angle class and the total transmittances surface to satellite from the initial guess library. The profiles have the same contents as the result profile and contain the following:

Identification of the Profile
surface variables:
surface temperature
land/sea/coast flag (1/2/3)
microwave surface emissivity for AMSU-A and MHS
variables describing the air just above the surface:
surface pressure (hPa)
surface temperature (K)
water vapour mixing ratio (kg/kg)
ozone mixing ratio (kg/kg)
wind speed at 10m (m/s)
variables describing the tropopause
tropopause pressure (hPa)
tropopause temperature (K)
water vapour mixing ratio at the tropopause (kg/kg)
ozone mixing ratio at the tropopause (kg/kg)
variables describing clouds (empty in the first guess library):
infrared cloud cover (0,...,1)
cloud top pressure (hPa)
cloud top temperature (K)
cloud base pressure (hPa)
cloud base temperature (K)
effective droplet radius (m)
cloud liquid water (mm)
total water vapour content (kg/m^2)
total ozone content (DU)
temperature profile (K)
water vapour mixing ratio profile (kg/kg)
ozone mixing ratio profile (kg/kg)
geopotential profile (gpm)

The profile variables shall be provided on the pressure levels on which the retrieval will be subsequently done.

4.3.2.1.2.5 Receive and Accept Guess Profile Covariance Matrices

This functionality reads the guess covariance matrices, the bias of guess deviation compared to real profiles and respective standard deviations. These items are provided for each emissivity and cloud class. There are per default three cloud classes, for which covariance matrices are provided (the number shall be user configurable):

- Clear AVHRR (more than 90 % clear AVHRR pixels in the HIRS/4 FOV) and AMSU-A clear
- Partly cloudy: AVHRR partly cloudy (90 % ≥ cloudy pixels ≥ 30%) and AMSU-A clear
- Cloudy: AMSU-A cloudy.

Matrices are provided for land,sea and coast, as the three emissivity classes used in the retrieval. Hence there shall be $N_{emi} \times N_{clear}$, $N_{maxbg} \times N_{maxbg}$ -matrices, with the same amount of N_{maxbg}- vectors of biases and standard deviations. N_{emi} is the number of emissivity classes (three per default), N_{clear} is the number of cloud classes (three per default, as indicated above).

4.3.2.1.2.6 Receive and accept forecast files requested for retrieval

This functionality provides data from numerical weather prediction files. It shall be used only if activated from user configurable control parameter. The files are provided in the GRIB format. From the forecast files, the following variables have to be provided:

- pressure at the sea surface level (hPa)
- Temperature at 1000 hPa (K)
- u-component of the wind at 10m (m/s)
- v-component of the wind at 10m (m/s)
- wind speed

If no AVHRR derived surface temperature is available, there are as well required

- Surface temperature (K)
- Surface type (Land/sea/coast)
- surface altitude (m).

A flag has to be set to indicate the processing conditions.

4.3.2.1.2.7 Initialise FRTM for Satellite in Question

This functionality initialises the fast radiative transfer model. Parameters to be set up include:

- Satellite ID
- Pressure level constants and limits
- Output array
- Upper level Humidity and Ozone constants
- Minimum stratospheric values
- Minimum Ozone mixing ratio
- Top level for Water vapour and water vapour transmittance calculation

In addition, this functionality transforms the water vapour specific humidity from the unit *kg/kg* to *g/kg*, and the ozone mixing ratio from *kg/kg* into *ppmv*.

$$q' = q \cdot 1000$$ **Equation 86**

where q is the specific humidity in *kg/kg* and q' is the specific humidity in *g/kg*.

$$q'_{O3} = q_{O3} R_{cnv}$$ **Equation 87**

where q'_{O3} is the Ozone mixing ratio in ppmv, q_{O3} is the Ozone mixing ratio in kg/kg, and R_{cnv} is the conversion factor (R_{cnv}=*6.03504 105*). All parameters are defined in a user-configurable auxiliary data set (ATOVS_L2_PGS_RTM_SETUP).

4.3.2.1.3 Loop Function

This function loops over all relevant pixels of the selected retrieval grid and selects the pixels to process. The retrieval shall be performed for each nth pixel and every mth line of mapped data (HIRS/4 is the default for mapping). The default values are n = 1 and m = 1. The subsequent functions of the retrieval shall be performed in looping over these pixels. If there is a "box" larger than 1 pixel defined, the clearest pixel from this box is selected for the retrieval. If there is no AVHRR cloud mask, the HIRS derived cloud amount shall be used to choose the pixel for the retrieval. If there is no cloud information there is no need to choose the clearest spot and the centre spot or spot nearest to the centre is chosen. A pixel is flagged bad and discarded, if the following criteria are not true:

$$T_{b,H,8} > 180K$$ **Equation 88**

$$0 \leq N_{clear} \leq 100$$ **Equation 89**

where $T_{b,H,8}$ is the HIRS Channel 8 Brightness Temperature and N_{clear} is the percentage of clear AVHRR pixels in a HIRS FOV.

Within this functionality also the data for the processing of one pixel shall be assembled:

- Satellite name
- Orbit number
- Availability flag of AMSU-A
- Pixel time
- Pixel number
- Line number
- Latitude
- Longitude
- Solar zenith angle

- Solar azimuth angle
- Satellite zenith angle
- Satellite azimuth angle

- HIRS/4 Brightness Temperatures Channel 1-19
- HIRS/4 Radiance Channel 20
- AMSU-A Brightness Temperatures Channel 1-15
- MHS Brightness Temperatures Channel 1-5
- AVHRR Brightness temperatures Channel 3-5
- AVHRR Clear Brightness Temperatures Channel 3-5

- Preprocessor Flags (from data preparation steps)

- Surface altitude
- Sea/coast/land flag (2/3/1)
- Day/night flag (1/0)

twilight considered as day

- Clear Flag (0/1/2/3/4/-1)

0 calibration

1 clear AVHRR (percentage of clear pixels within retrieval grid box ≥ 90 %) + clear AMSU

2 cloudy AVHHR (percentage of clear pixels within retrieval grid box < 90 %) + clear AMSU

3 cloudy AVHHR + (cloudy AMSU or sea ice)

4 precipitation (according to the results of the AMSU-A precipitation tests)

–1 unprocessed FOV

- microwave preprocessing flags from data preparation
- cost function from surface type estimation in data preparation
- scattering index from data preparative
- precipitation probability from data preparation
- Surface type from AMSU-A (default set to 0 for day 1)
- Percent of clear AVHRR pixels
- Airmass type (initialisation value)
- Surface temperature
- Sea: from AVHRR processing (SST in clear case, forecast or climatology in case of missing forecast data)
- Land: from AVHRR processing in clear cases (from Forecast T_{2m} or climatology in case of missing forecast data)
- Cloud information (one cloud assumed for day 1):
- Cloud top temperature from AVHRR processing
- Cloud top pressure (computed from the cloud top temperature and a standard atmospheric temperature
- profile depending on the actual airmass class)
- Cloud amount from AVHRR processing

A check should be performed, whether all Brightness Temperatures required for the retrieval are not less than 0. If yes, the pixel shall not be processed.

4.3.2.1.4 Inversion Preparation Function

This functionality prepares all input data for a pixel selected for the subsequent inversion process. It is composed of the sub-functions summarised in Table 22.

	Inversion preparation Operations
1	Calculate Secant class
2	Compute FRTM Biases from Regressions
3	Compute Airmass
4	Extract forecast values
5	Calculate IR emissivity
6	Calculate microwave emissivity
7	Clear partly cloudy observations
8	Select nearest profile and guess

Table 22: Inversion Preparation Function Decomposition

4.3.2.1.4.1 Calculate Secant Class

The first step in the inversion preparation is the estimation of the secant class of the pixel from the satellite zenith angle. The secant of the current pixel to be processed is as follows:

$$\sec\zeta = \frac{1}{\cos\zeta}$$ ***Equation 90***

where ζ is the satellite zenith angle.

The secant classes of the retrieval model are predefined in a user configurable data set. As default values we have $N_\zeta = 10$ (user-configurable) secant values $\sec\zeta_{ts,i}$, which define the secant classes.

$$\sec\zeta_{ts,\,i} \in \{1.00,\ 1.01,\ 1.04,\ 1.10,\ 1.18,\ 1.28,\ 1.40,\ 1.50,\ 1.66,\ 1.90\}$$ ***Equation 91***

The secant classes of the retrieval model are predefined in a user configurable data set. As default values we have $N_\zeta = 10$ (user-configurable) secant values $\sec\zeta_{ts,i}$, which define the secant classes.

$$\zeta_{ts,\,i} \in \{0.0,\ 8.07,\ 15.94,\ 24.62,\ 32.06,\ 38.62,\ 44.42,\ 48.19,\ 52.96,\ 58.24\}$$ ***Equation 92***

The check is done as follows:

1. If $\sec\zeta < 1$, the first secant class is used. A flag should be set.
2. If $\sec\zeta > \zeta_{ts,N\zeta}$, the secant class number is set to N_ζ. A flag should be set.
3. Looping over all secant class values we determine whether this function holds true.

$$\sec\zeta_{ts,\,i} < \sec\zeta < \sec\zeta_{ts,\,i+1}$$ ***Equation 93***

Then, we define

$$\delta\sec\zeta_1 = \sec\zeta - \sec\zeta_{ts,\,i}$$ ***Equation 94***

and

$$\delta\sec\zeta_2 = \sec\zeta_{ts,\,i+1} - \sec\zeta$$ ***Equation 95***

If

$$\delta\sec\zeta_1 > \delta\sec\zeta_2$$ ***Equation 96***

then class *i+1* is used. Otherwise *i* is used.

4.3.2.1.4.2 Compute FRTM Biases from Regressions

The default Fast Radiative Transfer Model is specified in Annex 1. The specification of the model is expected to evolve, and due to its complexity, only one specification will be maintained. The specification is based on the Fast Radiative Transfer Model RTTOV7.

Prior to the retrieval process, the measured sounding observations $T'_{b,meas}$ have to be corrected by applying the bias correction for the Fast Radiative Transfer Model. This process results in synthetic brightness temperatures. The correction is defined in the following:

$$T_{b,\,meas}(i) = T'_{b,\,meas}(i) + \delta(i)$$ ***Equation 16***

where:

$T_{b,meas}$	is the bias corrected brightness temperature
i	is the channel number
$\delta(i)$	is the brightness temperature bias of a channel i of the fast radiative transfer model.

The biases are specified as a polynomial function of the observations and the satellite zenith angle as:

$$\delta(i) = a_0(i) + \sum_{j=k,l,m} [a_j(i)T'_{b,meas}(j)] + a_z(i)\sec\zeta$$

Equation 17

Coefficients are provided for each side of the scan wrt. nadir, hence a test has to be performed to determine which side of the spacecraft is considered. In addition, there exists three different sets of bias coefficients for three different surface types (Land/Sea/Coast). The summation comprises user-configurable HIRS/4 channels k, AMSU-A channels l, and MHS channels m (the HIRS/4 channels 1,2,3 (k = 1,...,3), AMSU-A channels 6,7,8 and 9 (l = 26,...,29), no MHS channel, are default), and the satellite zenith angle ζ.

The regression coefficients $a_j(i)$ and $a_z(i)$ used in these equations are user-configurable and must be computed off-line (ATOVS_L2_PGS_COF_DELTAC). There is one set for each satellite. The bias correction is performed over a user configurable number N_{bias} of sounding channels. The default value is 35.

If either AMSU-A channel 7 or channel 8 is not available due to technical problems with the satellite, and its application in the retrieval is switched off in the configuration; it shall be replaced for the bias correction by the values calculated from the neighbouring channels:

$$T_{b,meas}(7) = 0.4867 * T_{b,meas}(6) + 0.51101 * T_{b,meas}(8) - 1.2859$$

Or

$$T_{b,meas}(8) = 0.55225 * T_{b,meas}(7) + 0.44136 * T_{b,meas}(9) + 0.20479$$

If both channel 7 and channel 8 are missing or not suitable, no processing should take place.

4.3.2.1.4.3 Compute Airmass

This functionality calculates the airmass of the profile considered from $N_{ch,air}$ selected, user-configurable, available Brightness Temperatures. The algorithm used is as follows:

1. It is determined whether the pixel is over sea or over land or coast. Coast is treated as land in this case. Hence there are two surface types (Sea/Land).
2. For each airmass class n_{air} (n_{air} = 1,...,5 as default), and each secant class *i(i = 10 as default)* there is an inverse covariance matrix (see above).

The airmass class is estimated only with channels not seeing the surface. The channels used are user-configurable and have been read in before (see above). Looping over the airmass classes n_{air} the distance between the observed brightness temperatures and the average profile of each airmass is determined as follows:

$$d_{air}(n_{air}) = \left(\frac{1}{N_{ch,air}}(\boldsymbol{T}_{b,meas} - \overline{\boldsymbol{T}_{b,meas}})C^{-1}_{\boldsymbol{Tb},air}(\boldsymbol{T}_{b,meas} - \overline{\boldsymbol{T}_{b,meas}})^T\right)^{\frac{1}{2}}$$ ***Equation 96***

where $\boldsymbol{T}_{b,meas}$ is the measured bias corrected brightness temperature of the channels used for the airmass classification, $\overline{\boldsymbol{T}_{b,meas}}$ is the average Brightness temperature, and $C^{-1}_{Tb,air}$ is the inverse covariance matrix of the airmass classification. $N_{ch,air}$ is the user configurable number of channels used for the airmass classification. The minimum distance d_{min}.

$$d_{min} = min(d_{air}(n_{air}))$$ ***Equation 97***

determines the airmass class: n_{air} of the minimum distance.

4.3.2.1.4.4 Extract Forecast Values

This functionality extracts the required (if flag for forecast use is set) forecast profile and surface parametersfor the retrieval considered. The values of the forecast grid point nearest to the latitude/longitude of the pixelin question are extracted. The parameters to be extracted are as follows:

- surface pressure at sea level. It is initialised to $p_{sfc,fc} = 1013hPa$. From the surface pressure at sea level the surface pressure is computed according to the following:

$$p_{sfc} = p_{sfc,fc}\exp\left(-\frac{z}{H_{sc}}\right)$$ ***Equation 98***

where z is the altitude of the pixel and H_{sc} is the scale height of the atmosphere ($H_{sc}=8150\ m$)

- Temperature at 1000 hPa
- u-component of the wind
- v-component of the wind
- the wind speed is calculated from the components

$$|\vec{v}| = \sqrt{u^2 + v^2}$$ ***Equation 99***

- If there is no surface temperature (from AVHRR or climatology), and forecasts are used, the surface temperature is extracted as well. The surface temperature needs to be reduced to the altitude of the pixel according to the following:

$$T_{sfc,cor} = T_{sfc,fc} - \gamma_{dry} z$$

Equation 100

where z is the altitude of the pixel and γ is a mean temperature lapse rate
(default $\gamma = 0.65\ K/100m$).

4.3.2.1.4.5 Calculate IR Emissivity

Climatological values are used in case there are no forecast values available. See [RD-17].

Over land the surface emissivity is slightly variable. Under the grey body assumption, the following default values should be used, if there is any information about the surface type available:

- 0.980 for ice and snow
- 0.981 for green grass, forest and peat
- 0.960 for sandy loam and sand
- 0.898 for granite

If no information about the surface type is available, a surface emissivity of 0.98 should be used as default value [RD-15] over land. If the surface type is sea-ice, the infrared surface emissivity should be set to 0.99. Over sea, the SSIREM model is applied. This is a regression algorithm, where, in the normalised satellite zenith angle:

$$\zeta_0 = \frac{\zeta}{60}$$

Equation 101

the angles are provided in Degrees, and the regression is variable. The emissivity over sea is then computed according to the following:

$$\varepsilon_{IR,sea} = a_0 - a_1 \zeta_0^{\alpha} - a_2 \zeta_0^{\beta}$$

Equation 102

where a_0, a_1, a_2, α and β are user-configurable parameters, satellite and channel dependent, from an auxiliary data set (ATOVS_L2_PGS_PAR_IREMIS).

4.3.2.1.4.6 Calculate Microwave Emissivity

It is important to reflect correctly the surface emissivity with respect to microwave channels in the FRTM, if channels are used, which receive contributions from the surface. The microwave surface emissivities over land are initialised to 0.85 for altitudes less than 1 km and 0.95 for altitudes greater than 1 km. Sea ice detection is performed with the Brightness Temperatures of AMSU-A Channel 1 and Channel 3 according to the following:

$$\delta T_{seaice} = s_0 + s_1 T_{b,A,1} + (-s_2) T_{b,A,3}$$	***Equation 103***

The user-configurable default values are these:

- s_0: 2.85 *K*
- s_1: 0.02 K^{-1}
- s_2: 0.028 K^{-1}

If the latitude is higher than 60° N or 60° S and , then sea ice is assumed and the surface emissivity is set to 0.95.

Over land surface emissivities depend on the surface type, the surface state (they can vary considerably as after precipitation). No surface microwave channels are used for the retrieval.

Over sea the microwave emissivity is about 0.6. Equation 18 reflects the formula in the FASTEM model and should be the default for the microwave emissivity estimate with the default values 298.15 K and u = 7.4 m/s used when no other data are available.

Microwave emissivity is largely depending on the wind speed, the skin temperature, the foam, the scan angle and the channel polarisation. Observed values can range from 0.4–0.7.

Theory:

The FASTEM model of emissivity by English and Hewisson [RD-8] is used. A model emissivity must be calculated according to Equation 18:

$$\varepsilon(u, T_s) = [1 - R_s(T_s)B(u)] + \Delta\varepsilon(u)[1 - F(u)] + F(u)$$	***Equation 18***

where

u	is the wind speed,
T_s	is the surface temperature
$R_s(T_s)$	is Fresnel's specular reflection, computed at the surface temperature , T_s as a function of the sea refraction index and the scan angle.

The Fresnel reflectivities can be written as:

$$R_v(\nu, \theta) = \left\| \frac{-\varepsilon(\nu)\cos(\theta) + \sqrt{\varepsilon(\nu) - \sin(\theta)^2}}{\varepsilon(\nu)\cos(\theta) + \sqrt{\varepsilon(\nu) - \sin(\theta)^2}} \right\|^2$$	***Equation 19***

$$R_h(\nu,\theta) = \left| \frac{-\cos(\theta) + \sqrt{\varepsilon(\nu) - \sin(\theta)^2}}{\cos(\theta) + \sqrt{\varepsilon(\nu) - \sin(\theta)^2}} \right|^2$$

Equation 20

where

$\varepsilon(\nu)$	is the effective permittivity
ν	is the frequency of the observed radiance,
θ	is the incidence angle
B(u)	is the correction of the specular reflection to take into account capillary waves, of which the wavelengths can be compared to that of the sounding channel.

The correction for capillary waves (Bragg scattering correction) can be written as follows:

$$B(\nu,\theta,h) = \exp(-h\cos(\theta)^2)$$

Equation 21

where

	$h=(4\pi\ \nu\ \sigma/c)^2,\ = U^{\beta}/\nu^{4}$
β	is a constant (user-configurable).

$\Delta\varepsilon(u)$ is a correction to take into account the large scale sea roughness (in relation to the wavelength of the sounding channel), which causes a slope in the specular reflection. It is a polynomial, which depends on polarisation, frequency, wind speed and the scan angle.

The polynomial $\Delta\varepsilon(u)$ depends on polarisation, frequency, wind speed and scan angle and can be written as:

$$B(\nu,\theta,h) = \exp(-h\cos(\theta)^2)$$

Equation 22

where

e_i	are coefficients, which are a function of frequency and polarisation
F(u)	is the foam cover, as a function of wind speed. Foam is a blackbody in all frequencies and varies with wind speed.

The foam emissivity correction term can be written as follows:

$$F(u) = f_0 \times u^{f_1}$$ **Equation 23**

End of Theory

The FASTEM Model is based on 59 coefficients $e_{m,fastem}$, where $m = 1,...,59$ represents the coefficients in the above equations of the theoretical part and is stored in an auxiliary, user configurable data set (ATOVS_L2_PGS_DAT_MWEMIS).

In the FASTEM model the surface temperature is required in degrees Celsius:

$$t_{sfc} = T_{sfc} - 273.15$$ **Equation 104**

The first step is to compute two relaxation frequencies:

$$\tau_1 = e_{1,fastem} + e_{2,fastem} t_{sfc} + e_{3,fastem} t_{sfc}^2$$ **Equation 105**

$$\tau_2 = e_{4,fastem} + e_{5,fastem} t_{sfc} + e_{6,fastem} t_{sfc}^2 + e_{7,fastem} t_{sfc}^3$$ **Equation 106**

The static permittivity is calculated according to the following:

$$\varepsilon_{stat} = \Delta_1 + \Delta_2 + \Delta_{inf}$$ **Equation 107**

where:

$$\Delta_1 = e_{8,fastem} + e_{9,fastem} t_{sfc} + e_{10,fastem} t_{sfc}^2 + e_{11,fastem} t_{sfc}^3$$ **Equation 108**

$$\Delta_1 = e_{8,fastem} + e_{9,fastem} t_{sfc} + e_{10,fastem} t_{sfc}^2 + e_{11,fastem} t_{sfc}^3$$

Equation 109

and the infinite frequency permittivity:

$$\Delta_{inf} = e_{18,fastem} + e_{19,fastem} t_{sfc}$$

Equation 110

depends on the surface temperature. The double-Debye formula to calculate the complex permittivity μ is applied:

$$\nu_{en} = 2 \cdot e_{20,fastem} \nu_j 10^{-3}$$

Equation 111

where νj is the frequency in GHz.

The real and imaginary parts of the complex permittivity is then calculated as follows:

$$Re(\mu) = Re(\mu)_1 + Re(\mu)_2 + \Delta_{inf}$$

Equation 112

where

$$Re(\mu)_1 = \frac{\Delta_1}{1 + \nu_{en}^2 \cdot \tau_1^2}$$

Equation 113

and

$$Re(\mu)_2 = \frac{\Delta_2}{1 + \nu_{en}^2 \cdot \tau_2^2}$$

Equation 114

The imaginary part is calculated in a similar way and:

$$Im(\mu) = Im(\mu)_1 + Im(\mu)_2$$

Equation 115

where

$$Im(\mu)_1 = \Delta_1 \cdot \nu_{en} \cdot \frac{\tau_1}{1 + \nu_{en}^2 \cdot \tau_1^2}$$

Equation 116

and

$$Im(\mu)_2 = \Delta_2 \cdot \nu_{en} \cdot \frac{\tau_2}{1 + \nu_{en}^2 \cdot \tau_2^2}$$

Equation 117

The complex permittivity is then

$$\mu = Re(\mu) + iIm(\mu)$$

Equation 118

The complex Fresnel Reflection coefficients are depending on the zenith angle ζ and are polarisation dependent. The horizontally polarised component

$$R_H = \frac{\cos\zeta - \mu_1}{\cos\zeta + \mu_1}$$

Equation 119

and the vertically-polarised component

$$R_V = \frac{\mu_2 - \mu_1}{\mu_2 + \mu_1}$$

Equation 120

where

$$\mu_1 = \sqrt{\mu - (\sin\zeta)^2}$$

Equation 121

and

$$\mu_2 = \mu\cos\zeta$$

Equation 122

The vertical and horzintally-polarized components are then:

$$R'_V = Re(R_V)^2 + Im(R_V)^2$$

Equation 123

$$R'_H = Re(R_H)^2 + Im(R_H)^2$$

Equation 124

The small correction for capillary waves (Bragg scattering) is calculated according to this:

$$B(\nu_j, \zeta) = \exp\left(e_{21,fastem}|\vec{v}|\frac{(\cos\zeta)^2}{\nu_j^2}\right)$$

Equation 125

if the frequency in GHz ν_j is larger than 0.1 GHz. Otherwise the correction is this:

$$B(\nu_j, \zeta) = 1$$

Equation 126

The correction is applied to the horizontally and vertically-polarised Fresnel Reflection coefficients:

$$R_V = R'_V B(\nu_j, \zeta)$$ ***Equation 127***

$$R_H = R'_H B(\nu_j, \zeta)$$ ***Equation 128***

The large-scale correction is then computed with the polynomial approach outlined above. The polynomial coefficients are calculated according to the following:

$$z_{c,1} = e_{24,fastem} + e_{25,fastem}\nu_j + e_{25,fastem}\nu_j^2$$ ***Equation 129***

$$z_{c,2} = e_{27,fastem} + e_{28,fastem}\nu_j + e_{29,fastem}\nu_j^2$$ ***Equation 130***

... ***Equation 131***

$$z_{c,12} = e_{57,fastem} + e_{58,fastem}\nu_j + e_{59,fastem}\nu_j^2$$ ***Equation 132***

Then the corrections are calculated according to this equation:

$$\delta\varepsilon_1 = \frac{z_{c,1} + z_{c,2}\sec\zeta + z_{c,3}(\sec\zeta)^2 + z_{c,4}|\vec{v}| + z_{c,5}|\vec{v}|^2 + z_{c,6}|\vec{v}|\sec\zeta}{100.}$$ ***Equation 133***

and

$$\delta\varepsilon_2 = \frac{z_{c,7} + z_{c,8}\sec\zeta + z_{c,9}(\sec\zeta)^2 + z_{c,10}|\vec{v}| + z_{c,11}|\vec{v}|^2 + z_{c,12}|\vec{v}|\sec\zeta}{100.}$$ ***Equation 134***

which are used to obtain the corrected vertical and horizontal-polarised emissivities:

$$\varepsilon_V' = 1 - R_V + \delta\varepsilon_1$$

Equation 135

$$\varepsilon_H' = 1 - R_H + \delta\varepsilon_2$$

Equation 136

Finally, the foam correction is parameterised:

$$\delta\varepsilon_{foam} = e_{22,fastem}|\vec{v}|^{e_{23,fastem}}$$

Equation 137

which in turn is applied to the emissivities:

$$\varepsilon_V = \varepsilon_V' - \delta\varepsilon_{foam}\varepsilon_V' + \delta\varepsilon_{foam}$$

Equation 138

$$\varepsilon_H = \varepsilon_H' - \delta\varepsilon_{foam}\varepsilon_H' + \delta\varepsilon_{foam}$$

Equation 139

Finally, the emissivity is computed, taking into account the polarisation of the microwave channels through a coefficient m_{pol}, which is taken from a user configurable auxiliary data set, and where the coefficients are given for each instrument. *mpol* indicates the polarisation for a channel.

mpol	polarisation
0	0.5 (V+H)
1	90 - ζ
2	ζ
3	V
4	H

Table 23: Polarisation index in the FASTEM Model

Then, we have this for the emissivity:

$$\varepsilon = \varepsilon_V\{z_{1,V,mpol+1} + z_{2,V,mpol+1}(\sin\theta)^2 + z_{3,V,mpol+1}(\cos\theta)^2\} + \varepsilon_H\{z_{1,H,mpol+1} + z_{2,H,mpol+1}(\sin\theta)^2 + z_{3,H,mpol+1}(\cos\theta)^2\}$$

Equation 140

where the coefficients *zn,V,ipol* and *zn,H,ipol, n=1,...,3, ipol=mpol+1* are user-configurable and set before. θ is the nadir angle.

4.3.2.1.4.7 Clear Partly-Cloudy Observations

This function does not need to be implemented for day 1. A placeholder shall be implemented. The projected algorithm: The partly-cloudy pixels below a cloudiness threshold value are extracted and clear radiances are calculated. These cleared radiances are then included into the Retrieval Input Data Vector for the subsequent retrieval. The function is decomposed in sub-functions as specified in Table 24.

	Cloud Clearing Function Operations
1	Partly-cloudy FOV Extraction Function
2	Information from AMSU-A Generation and Regression Function

Table 24: Cloud Clearing Function decomposition

These sub-functions are described in details in the following sections.

Inputs
Input Data Vector containing Pre-processed (mapped to the selected retrieval grid and contamination checked) sounder data produced by the 'Retrieval Grid Mapping Function'; Retrieved Cloud Information; Retrieved Cloud Cover Information; Retrieved Cloud-Top Temperature, Retrieved Cloud-Top Pressure; Cloud cover mask; Produced Appended information from data preparation (including cloud information - Clear/Cloudy flag, contamination information, surface type - Land/Sea/Coast flag, etc); Cloud Clearing flag; Retrieval method and Fast Radiative Transfer Model configuration parameters and settings; Auxiliary data.

Outputs
ATOVS Level 2 Retrieval Input Data Vector (including clear radiances) containing the data for the retrieval and all the necessary Appended information for the retrieval.

4.3.2.1.4.7.1 Partly-cloudy FOV Extraction Function

All partly-cloudy pixels with cloud coverage below the threshold value for cloud clearing (ATOVS_L2_PGS_THR_CLDCLR) are extracted and put into the Retrieval Input Data Vector to the retrieval. In addition all information to create the clear radiances is added to the Retrieval Input Data Vector too.

4.3.2.1.4.7.2 Information from AMSU-A Generation and Regression Function

From the AMSU-A channels, which are not deemed to be contaminated, pseudo HIRS/4 channels are created. The method employed is a regression analysis. The results shall form the Retrieval Input Data Vector. The method implemented is the Ψ-method, first specified for TOVS in Chédin et al. 1985 [RD-10] In the user-configurable first guess library (ATOVS_L2_PGS_DAT_GUESS) a search for a realistic profile is performed using the HIRS/4 channels 2 and 3 and also the AMSU-A channels 5, 7 and 9. The tropospheric HIRS/4 channels 4, 5, and 15 are then cleared according to **Eq. 24**.

$$T_{b,H,cl}(i) = T_{b,meas}(i) + [T_{b,meas(AMSU5)} - T_{b,cal(AMSU5)}] \quad \textit{Equation 24}$$

where:

$T_{b,cal(amsu)}$	is the Brightness temperature of the calculated AMSU-A channel 5
$T_{b,meas}$	is the Brightness temperature of the actual HIRS/4 measurements
i	is the HIRS/4 channel number
$T_{b,meas(AMSU)}$	is the bias corrected AMSU-observation brightness temperature.

The coefficients and thresholds used by this functionality shall be user-configurable (ATOVS_L2_PGS_COF_HIRAMS).

4.3.2.1.4.8 Select Nearest Profile and Guess

According to the overlapping weighting functions of the retrieval channels, and their width, only a limitednumber of independent pieces of information is available to retrieve an atmospheric profile. Thus it is not possible to directly build a realistic profile from the satellite observations. In order to achieve this, an atmospheric profile, reflecting the real situation, has to be selected, close to the one to be retrieved. This is the ‘first guess’. It provides a forcing to the solution. The accuracy of the first guess determines the accuracy of the final solution. The inversion process shall correct the first guess profile and minimise the difference between the observed satellite measurements and the simulated measurements from the first guess profile. The first guess is selected from a user-configurable first-guess library (ATOVS_L2_PGS_DAT_GUESS) through a library search. This shall be the default first-guess estimation.

Some preparatory steps are required, before the selection of the first guess can take place. They are related to the estimation of surface parameters and the determination of the air mass type. The choice of initialisation for the retrieval shall be user-configurable (ATOVS_L2_PGS_TYP_INI, ATOVS_L2_PGS_TYP_CONFIG).

The function is decomposed in sub-functions as specified in Table 25. These sub-functions are described in details in the following sections.

	First Guess Retrieval Selection Function Operations
1	Compute Brightness Temperatures for Channels used in First Guess
2	Select nearest and guess profiles
3	Compute profile characteristics

Table 25: First Guess Retrieval Selection Function decomposition

4.3.2.1.4.8.1 Compute Brightness Temperatures for Channels used in First Guess

This functionality computes the Brightness Temperatures for Channels used in the first guess and computes the inverse covariance matrix of the first guess. Surface temperature and emissivities have a significant impact on the synthetic brightness temperatures of channels whose signals are influenced by the Earth's surface. As a start the guess library information needs to be adapted to the observation environment of the pixel in question, for example to the surface pressure p_{sfc}, the surface temperature T_s and surface emissivities ε as well as the scan angle ζ. Surface pressure is determined according to Equation 25:

$$p_s = p_{sea} \exp((-z)/(H_{sc}))$$

Equation 25

where p_s is the surface pressure, p_{sea} is the sea surface pressure, taken from a forecast field (ATOVS_L2_PGS_DAT_FCST), z is the altitude of the FOV, H_{sc} is the scale height (8150 m). If the FOV is 'clear', the skin surface temperature, originating from the AVHRR/3 split-window, is used as surface temperature. Otherwise the surface temperature shall be the climatological surface temperature over sea data or the forecast air temperature over land (ATOVS_L2_PGS_DAT_CLSISST or ATOVS_L2_PGS_DAT_FCST).

This surface temperature, which is estimated independently from the inversion step, is required to compute the synthetic brightness temperatures of the first guess library. (The guess library is for clear cases only).

Climatological values are used in case there are no forecast values available.

The brightness temperatures are computed for each profile of the guess library as well as the corresponding covariance matrix for the brightness temperatures T_{bcov}, and the correlation matrix $T_{b,cor}$ to reflect the inter-channel correlations. For each of the profiles and the N channels used for the first guess selection, the brightness temperature for the surface temperature and the infrared and microwave surface emissivities for the situation in question are calculated as in **Eq. 26**:

$$E(p, i) = \varepsilon_s \tau_s E(T_s) + E_{up} + E_{do}(1 - \varepsilon_s)\tau_s^2$$

Equation 26

where:

p	indicates the profile of the guess library
$i = 1, \cdots, N$	are the channels used for the first guess selection
ε_S	is the surface emissivity (calculated in real time)
$E(Ts)$	is the radiance for the surface temperature (calculated in real time)

The following listed values are logarithmically interpolated to the surface pressure ps from the values just above and below the surface pressure level, which are read from the initial guess library (see above):

also:

E_{up}	is the up-welling radiance
E_{do}	is the down-welling radiance
τ_s	is the total transmission at the surface between spacecraft and ground at slant path.

In the interpolations three cases have to be distinguished:

1. The surface pressure is a pressure of an inversion level
2. The surface pressure is between two inversion pressure levels
3. The surface pressure is higher than the surface inversion pressure level

The calculated brightness temperature is then given through the inverse Planck function ***B-1***:

$$T_{b,cal}(p, i) = B^{-1}(E(p, i))$$

Equation 27

The air temperature at 1000 hPa is extracted from the selected profile and added as an additional “channel” to the synthetic brightness temperatures. This is performed to support the capability to detect inversions near the surface.

The brightness temperatures covariance matrix and its inverse are calculated for all channels $N+1$, and also the vector of standard deviations:

$$T_{b,cov}(i,j) = \frac{1}{K}\sum_{k=1}^{K}(T_k(i)-\overline{T(i)})(T_k(j)-\overline{T(j)})$$

Equation 141

where K is the number of values taken into account out of the different airmass classifications available in the library, and $\overline{T(i)}$ the mean channel temperature computed from the profiles of the guess library with the required airmass type. As default, a minimum of 20 of these profiles should be extracted for the considered air mass class.

$$T_{b,cor}(i,j) = 100 \cdot \frac{T_{b,cov}(i,j)}{S_{Tb}(i)S_{Tb}(j)},\ i \neq j$$ **Equation 142**

where $S_{Tb}(i)$ is the standard deviation of the level i brightness temperatures and:

$$T_{b,cor}(i,j) = 100,\ i = j$$ **Equation 143**

The first-guess library profiles are classified through air mass classes. There shall be as a minimum five air mass classifications (tropical, mid latitude 1, mid latitude 2, polar 1 and polar 2).
A user-configurable factor $C_{cov}<1$, (default 0.8) is applied to the non-diagonal elements of $T_{b,cov}$ to adjust the weight of the profile values vs. the profile shape on the selection of the first guess profiles. This makes the inversion easier. The matrix $T_{b,cov}$ is then inverted to the inverse Covariance Matrix $T^{-1}_{b,cov}$ of the initial guess.

4.3.2.1.4.8.2 First Guess Library Search Function

The essential selection of the first guess profile is started with the computation of the mean squares distance $d_{rej}(p)$, weighted by the variability of each channel according to the covariance matrix $T_{b,cov}$, for each profile p as in **Eq. 28**:

$$d_{rej}(p) = [(T_{b,meas} - T_{b,cal}(p))^T T^{-1}_{bcov}(T_{b,meas} - T_{b,cal}(p))]^{1/2}$$ **Equation 28**

where:

$T_{b,meas}$	is the vector of brightness temperatures deduced from the measurements of $N+1$ channels
$T_{b,cal}(p)$	is the vector of computed brightness temperatures for profile p
$T^{-1}_{b,cov}$	is the inverse covariance matrix of brightness temperatures

The ^{T} and $^{-1}$ superscripts denote transpose of vector or matrix and the inverse matrix respectively.
Note: The covariance matrix is set for the airmass type in the actual situation. However, the distance $d_{rej}(p)$ is computed for all first-guess library profiles.

The first guess profile to be used in the retrieval process is either the nearest profile (see the bullet item above Equation 29) or the mean of up to the ten nearest profiles due to a user configurable parameter.

The algorithm for the calculation of the mean guess profile is as follows:

1. The closest profile according to the smallest distance is kept as the *nearest* profile
2. The selection under 1. is applied to additional profiles, increasing the search distance. A userconfigurable number of iterations, three as default (ATOVS_L2_PGS_DAT_FGCONF) are permitted by selecting all profiles with a distance shorter than . At least four profiles must be extracted. is user-configurable and taken from the first-guess configuration dataset (ATOVS_L2_PGS_DAT_FGCONF) (default value of : 1.25).
3. If more than 10 profiles are selected, the closest (default) must be retained.
4. The first-guess profile of temperature, moisture, ozone profile, surface air parameters is the mean of these parameters from the selected profiles. If observations are available, the skin surface parameters (surface temperature, surface pressure, surface emissivity, wind speed) are taken from these (see above). If not, climatological or forecast (land) values must be selected, with the wind speed chosen from a global wind climatology. If this is not available the wind speed must be set to 7.4 m/s, the global mean wind speed over sea. The associated calculated brightness temperatures are the means of the brightness temperatures for the selected profiles.

To prevent any false initialisation of the inversion, boundary checks are performed and error flags are set according to (the error flag is called *irejguess* in this document):

- The distance is not calculated with profiles, for which:

$$T_{b,\,meas(A6)} - T_{b,\,cal(A6)}(p) > C_1 \boldsymbol{S_{frtm}}(\text{AMSU-A ch6})$$

Equation 29

where:

Sfrtm	is the error standard deviation of the forward model
C_1	is user-configurable and taken from the user-configurable first guess dataset (ATOVS_L2_PGS_DAT_FGCONF) (default value of C_1: 4).

- If d_{rejmin} exceeds a reference distance d_{rejref} (ATOVS_L2_PGS_THR_FGR) then the error flag is set to $irejguess = 7$. The reference distance is computed according to:

$$d_{rejref} = C_2[\boldsymbol{S}^{\boldsymbol{T}}{}_{Tb}\boldsymbol{T}^{-1}{}_{b,\,cov}\boldsymbol{S}_{Tb}]^{1/2}$$

Equation 30

where:

S_{Tb}	is the vector of standard deviations for the brightness temperatures in the first guess library
C_2	is user-configurable taken from first-guess configuration dataset (ATOVS_L2_PGS_DAT_FGCONF) (default value of *C*2: 2.5).

- If there is no profile in the selection space, the error flag is set to *irejguess* = 6 (no first guess profile where ($T_{b,cal} - T_{b,meas}$)(microwave) < Threshold (so selected profile).
- If the number of channels for which the condition $T_{b,meas}(i) - T_{b,cal}(i) > C_1 S_{frtm}$ is fulfilled is larger than a threshold value N_b, both for the closest profile and for the guess profile, then the flag is set as *irejguess* = 4 ($X > N_b$ channes for closest profile), or *irejguess* = 5($X > N_b$ channels for guess profile). N_b is user-configurable and taken from the user configurable first guess configuration dataset(ATOVS_L2_PGS_DAT_FGCONF). It should also be possible to use a fixed threshold $T_{b,meas}(i) - T_{b,cal}(i)$ for the profile selection. The currently used value is 9 K, but should be user-configurable.
- If there is no surface temperature, the profile is rejected and *irejguess* = 9.

Summary of the error flag *irejguess*:

0	means	OK
4	means	X > N_b channels for closest profile
5	means	X > N_b channels for guess profile
6	means	no first guess profile with *TB* difference below threshold
7	means	d_{rej} > threshold
8	means	no selected profile
9	means	no surface temperature

Regarding the actions to take according to the error flag setting, the following applies:

If the flag *irejguess* = 0	the guess selection is OK
If the flag *irejguess* ≤ 5	a warning is issued but the processing shall be continued.
If the flag *irejguess* ≥ 0	the situation is rejected and the next profile is processed

4.3.2.1.4.8.3 Compute Profile Characteristics

As a last step in the first guess selection, characteristic values of the profile are computed:

- Geopotential height
- Airmass
- Tropopause height and temperature
- Total Ozone Content
- Total Water vapour content
- Cloud top pressure

Geopotential Height

The acceleration due to gravity $g(\varphi, z_i)$ is to be calculated for the Equations 157 and Equation 163 as a function of the geographic latitude $\varphi$and the height z_i of the level *i*. The acceleration due to gravity is given by:

$$g(\varphi, z) = g_0 - (3.085462 \cdot 10^{-4} + 2.27 \cdot 10^{-7} \cos 2\varphi) z + (7.254 \cdot 10^{-11} + 1.0 \cdot 10^{-18} \cos 2\varphi) z^2 - (1.517 \cdot 10^{-17} + 6 \cdot 10^{-20} \cos 2\varphi) z^3$$

Equation 146

where

$$g_0 = 9.806160(1 - 0.0026373 \cos 2\varphi + 0.0000059(\cos 2\varphi)^2)$$

Equation 147

The height levels z_i are calculated with the barometric equation starting with the altitude of the FOV. This equation needs to be applied layer wise as it represents an integration, where constant temperature and humidity is assumed. The height difference between two levels i and $i+1$ with known pressures p_i and p_{i+1}, is given by the following:

$$z_i - z_{i+1} = \frac{-R_L \overline{T_v}}{g(\varphi, z_i)} \ln\left(\frac{p_i}{p_{i+1}}\right)$$

Equation 148

If the heights z_i and $zi+1$ are known, the ratio between the two pressure levels is here:

$$\frac{p_i}{p_{i+1}} = \exp\left(\frac{-g(\varphi, z_i)(z_i - z_{i+1})}{R_L \overline{T_v}}\right)$$

Equation 149

where $R_L = 287.04\ J\ K^{-1}\ kg^{-1}$ is the gas constant for dry air.

$$\overline{T_v} = \frac{1}{2}(T_{v,i} + T_{v,i+1})$$

Equation 150

where the virtual temperature at a level i is given by

$$T_{v,i} = T_i(1 + 0.608 q_i)$$ ***Equation 151***

where q_i is the specific humidity at level *i.* The specific humidity is obtained from the mixing ratio m_i

$$q_i = \frac{m_i}{1 + m_i}$$ ***Equation 152***

Airmass estimation

This functionality computes the airmass class for the first guess profile. For the airmass classes (five as default, see above) available, the distance from the guess profile is computed according to the following:

$$d_{guess}(n_{air}) = \sqrt{\frac{1}{N_{lev}} \sum_{k=j}^{J} \left[\frac{(T_k - \overline{T_{n_{air},k}})}{T_{\sigma, n_{air},k}} \right]^2}$$ ***Equation 153***

where j is the level index for 100 hPa, J is the index for 400 hPa, N_{lev} is the number of levels used (user-configurable, the defaults are $j = 20$, $J = 28$ and $N_{lev} = 9$). $\boldsymbol{T_k}$ is the temperature on level k of the input profile, $\overline{T_{n_{air},k}}$ is a representative temperature on level k of a mean profile for the airmass n_{air}, and $T_{\sigma n_{air},k}$ is the standard deviation of this mean profile, both taken from a user-configurable data set, where these values are provided for all airmass classes.

The minimum distance is searched for, which then determines the airmass class:

$$d_{guess,\,min}(n_{air,\,guess}) = min(d_{guess}(n_{air}))$$ ***Equation 154***

Tropopause estimation

For the first guess profile, the tropopause pressure and temperature are estimated. The tropopause is determined through finding the minimum temperature between two levels $k_{start,airmass}$ and $k_{end,airmass}$, which are user-configurable parameters given for each airmass. The level $k_{tropo}$where this minimum occurs determines the tropopause pressure $p_{tropo} = p(k_{tropo})$, the tropopause temperature $T_{tropo}=T(k_{tropo})$ is the minimum found. The values for humidity and Ozone are set in the same manner.

Total Ozone Content

For the first guess profile, the total Ozone content is estimated. The mean layer volume mixing ratio of Ozone is computed as such:

$$\overline{m_{v,O3}} = \frac{1}{2}(m_{v,O3,k} + m_{v,O3,k-1})$$

Equation 155

The Ozone volume mixing ratios $m_{v,O3,k}$ of the individual layers k are calculated from the Ozone mass mixing ratio $q_{O3,k}$.

$$m_{v,O3,k} = q_{O3,k} \cdot \frac{m_{air}}{m_{O3}}$$

Equation 156

where m_{air} and m_{O3} are the mole masses of air and Ozone respectively. The number of Ozone molecules per square meter is then computed for the layer:

$$q_{NO3,k} = \frac{A_v}{g m_{air}} \overline{m_{v,O3}}(p_k - p_{k-1})$$

Equation 157

where the pressures p_k are given in Pa and g is the gravity acceleration according to Equation 146. This has to be transformed into Dobson Units according to the following:

$$q_{NO3,k,dob} = q_{NO3,k} \cdot \frac{T_0 \cdot p_0}{k_b}$$

Equation 158

where $T_0=273.15\ K$, $p_0=101325\ Pa$ are giving the normal surface conditions, and k_b is Boltzmann's constant.

The total Ozone content is then the sum over all N layers:

$$q_{O3,tot} = \sum_{k=1}^{N} q_{NO3,k,dob}$$

Equation 159

Total water vapour content

For the first guess profile the total water vapour content is computed in kg/m^2. This is equivalent to mm rain, divided by the factor 10 it would yield g/cm^2 or cm rain. The total water vapour content is calculated for layers centred on a level according to this:

$$\Delta p_i = \frac{1}{2} \cdot (p_{i+1} + p_i) - \frac{1}{2} \cdot (p_{i-1} + p_i)$$

Equation 160

At the top of the atmosphere we have:

$$\Delta p_1 = \frac{1}{2} \cdot (p_2 + p_1)$$

Equation 161

and on the ground:

$$\Delta p_N = \frac{1}{2} \cdot (p_N - p_{N-1})$$

Equation 162

The total water vapour content is then

$$q_{H2O,tot} = \sum_{k=1}^{N} \frac{m_k}{1+m_k} \cdot \frac{\Delta p_k}{g}$$

Equation 163

where m_k denotes the specific humidity in *kg/kg* and g is the gravity acceleration according to Equation 146.

Compute Cloud Parameters

If there is a cloud top temperature from AVHRR, cloud top pressure and total cloud cover is set into the first guess profile. The cloud top pressure is searched between surface pressure and 1000 hPa, in case $T_{cloud} > T_N$ (N the lowest level) and $T_{cloud} \le T_{sfc}$:

$$\ln(p_{cloud}) = \ln(p_N) + \frac{(T_{cloud} - T_N)\ln\frac{p_{sfc}}{p_N}}{(T_{sfc} - T_N)}$$

Equation 164

Otherwise, we have to search between the tropopause and 1000 hPa as long as:

$$(T_{cloud} - T_i)(T_{cloud} - T_{i-1}) > 0$$

Equation 165

If the level i found this way has a pressure greater than the tropopause pressure or 150 hPa and if:

$$(|T_{cloud} - T_i|) < 40K$$

Equation 166

we determine the cloud top pressure:

$$\ln(p_{cloud}) = \ln(p_{i-1}) + \frac{(T_{cloud} - T_{i-1})\ln\frac{p_i}{p_{i-1}}}{(T_i - T_{i-1})}$$

Equation 167

4.3.2.1.5 Inversion: Compute Geophysical Parameters Function

After the first guess atmospheric profile has been selected, the essential inversion process shall be performed. There is the possibility to select a retrieval method, in user-configurable manner. The following ATOVS Level 2 geophysical parameters are retrieved at least:

$$(\boldsymbol{T}, \boldsymbol{q}, O_{3,tot}, T_s, T_{cloudtop}, p_{cloudtop}, N\varepsilon)$$

where:

T	is the temperature profile
q	is the humidity profile
$O_{3,tot}$	is the total ozone column (shall be retrieved, but not provided in the product)

are results from the inversion step;

T_s	is the surface temperature
$T_{cloudtop}$	is the cloud top temperature *T(CTT)*
$P_{cloudtop}$	is the cloud top pressure *CTP*
$N\varepsilon$	is the effective cloud amount

are used in the FRTM and are coming from input data (cloud top temperature from AVHRR Scenes Analysis.)

Inputs
Retrieval Input Data Vector (including clear radiances); Appended information to the Retrieval Input Data Vector; First-Guess Atmospheric Profile; Selected Retrieval Method Flag; all the Auxiliary Data necessary to perform the retrieval.

Outputs
Produced ATOVS Level 2 Retrieved Geophysical Parameters; Produced ATOVS Level 2 Appended Information.

The Inversion Step is essentially finding the most probable atmospheric profiles of temperature and humidity. The function is decomposed of the parts indicated in Table 26:

	Inversion Function Operations
1	Initialise values and input
2	Compute **K** Matrix
3	Compute Retrieval Operator **W**
4	Compute (observed - synthetic) Brightness Temperature Deviation
5	Compute new profile and associated Brightness Temperatures
6	Check, if max. iteration reached and good enough
7	TPW and CLW by AMSU-A Function
8	Provide Retrieval Profile
9	Level 2 Retrieval Error Variances and Covariances

Table 26: Inversion Function Decomposition

Theoretical background

The first guess atmospheric profile must be available. In the inversion procedure, this first guess atmospheric profile $\boldsymbol{T_g}$ is perturbed, within limits such that the perturbed profile does not move too far away from it. The goal is to minimize the error between the measured profile $T_{b,meas}$ and the synthetic profile T_a. That means that the inversion of the clear situation means to find the most probable atmospheric profile T_a, taking into account the observations $T_{b,meas}$. That is equivalent to find the maximum value of the conditional probability of $\boldsymbol{T_a}$ for $T_{b,meas}$, according to:

$$P(\boldsymbol{T_a} | \boldsymbol{T}_{b,\,meas}) = \text{maximum}$$

Equation 31

According to Bayes theorem:

$$P(\boldsymbol{T_a} | \boldsymbol{T}_{b,\,meas}) = \frac{P(\boldsymbol{T}_{b,\,meas} | \boldsymbol{T_a}) P(\boldsymbol{T_a})}{P(\boldsymbol{T}_{b,\,meas})}$$

Equation 32

The measurements are considered as given, hence:

$$P(\boldsymbol{T}_{b,\,meas}) = 1$$

where

$P(T_{b,meas}\|\boldsymbol{T_a})$	is the probability of measuring $T_{b,\,meas}$ given the atmospheric state T_a
$P(\boldsymbol{T_a})$	is the probability to obtain the atmospheric state T_a before the inversion

Gaussian error distributions are assumed and probabilities are expressed in terms of the Gaussian law:

$$P(T_{b,meas} | T_a) = \exp\left(-\frac{1}{2}(T_{b,meas} - F_w(T_a))^T (O + F_{frtm})^{-1} (T_{b,meas} - F_w(T_a))\right)$$

Equation 33

$$P(\boldsymbol{T_a}) = \exp\left(-\frac{1}{2}(\boldsymbol{T_a} - \boldsymbol{T_{ag}})^T \boldsymbol{G}^{-1} (\boldsymbol{T_a} - \boldsymbol{T_{ag}})\right)$$

Equation 34

where

$\boldsymbol{O}$	is the error covariance matrix of satellite observations
$\boldsymbol{F_{frtm}}$	is the error covariance matrix of the Fast Radiative Transfer Model
$\boldsymbol{G}$	is the error covariance matrix of the guess
$\boldsymbol{T_{ag}}$	is the first guess
$\boldsymbol{F_w(T_a)}$	is the brightness temperatures calculated with the Fast Radiative Transfer Model from the atmospheric $\boldsymbol{T_a}$ profile.
^{T} and $^{-1}$	mean transpose and inverse matrix respectively

One can now define a penalty or "cost" function *J* which represents the deviation of a retrieved atmospheric profile $\boldsymbol{T_a}$ from the first guess $\boldsymbol{T_{ag}}$. Minimising the Cost function ***J:***

$$J(T_a) = (T_a - T_{ag})^T G^{-1}(T_a - T_{ag}) + (T_{b,meas} - F_w(T_a))^T (O + F_{frtm})^{-1}(T_{b,meas} - F_w(\underline{T_a}))$$

Equation 35

will yield the most probable solution. The most probable value for $\boldsymbol{T_a}$ can be obtained by directly minimising *J*:

$$\frac{\partial}{\partial T_a} J(T_a) = J'(T_a) = 0$$

Equation 36

assuming that there is only one minimum, or look for a profile $\boldsymbol{T_a}$ such that the gradient of $\boldsymbol{J(T_a)}$ in the direction of vanishes:

$$J'(T_a) = G^{-1}(T_a - T_{ag}) - K(T_a)^T (O + F_{frtm})^{-1}(T_{b,meas} - F_w(T_a)) = 0$$

Equation 37

where:

K(Ta) is the partial derivatives of $\boldsymbol{F_w(T_a)}$ with respect to elements of T_a. $\boldsymbol{K(T_a)}$ is sometimes thought of as the weighting function.
The superscripts ^{T} and $^{-1}$ denote the transpose and inverse of a vector (or a matrix) respectively

In the linear case, the matrix $\boldsymbol{K}$ is unrelated to the atmospheric profile $\boldsymbol{T_a}$, but constant, and:

$$F_w(T_a) = F_w(T_{ag}) + K \bullet (T_a - T_{ag})$$

Equation 38

Substituting this expression into the Equation 37 yields the result.

$$T_a = T_{ag} + GK^T[KGK^T + (O + F_{frtm})]^{-1}(T_{b,meas} - F_w(T_{ag})) \quad \text{Equation 39}$$

In clear cases, the linearity can be rather well confirmed. In slightly non-linear cases, (cleared observations), ***K*** varies slightly with and we have:

$$F_w(T_a) = F_w(T_{ag}) + K(T_{ag}) \bullet (T_a - T_{ag}) \quad \text{Equation 40}$$

The inverse operator (or retrieval operator) $GK^T[KGK^T + (O + F_{frtm})]^{-1}$ can be pre-computed off line and be introduced into a first-guess library for each one of the atmospheric profiles (ATOVS _L2_PGS_DAT_CLIM).

Non-linear case: The inversion of cloud contaminated observations and water vapour channels involves matrices ***K***, which can quickly vary with respect to certain components of $\boldsymbol{T_a}$. In addition cleared radiances often involve non-gaussian errors which are correlated between channels. Different types of parameters can be taken into account in the $\boldsymbol{T_a}$ profile vector

- Temperature
- Humidity
- Cloud amount
- Cloud top pressure
- Microwave emissivity.

The cost function $J(T_a)$ needs then to be minimised through an iterative process described in [RD-4]. This process suggests a method based on a Newtonian iteration, which involves the second derivative J'' of the cost function. For the $(n+1)^{th}$ iteration there is:

$$T_{a,n+1} = T_{a,n} - J''(T_{a,n})^{-1}J'(T_{a,n}) \quad \text{Equation 41}$$

where the derivative of with respect to is

$$J''(T_{a,n})^{-1} = G - GK_n^T[K_nGK_n^T + (O + F_{frtm})]^{-1}K_nG \quad \text{Equation 42}$$

Finally

$$T_{a,n+1} = T_{a,n} + (T_{ag} - T_{a,n}) + W_n[T_{b,meas} - F_W(T_{a,n}) - K_n(T_{ag} - T_{a,n})] \quad \text{Equation 43}$$

with

$$W_n = GK_n^T[K_nGK_n^T + (O + F_{frtm})]^{-1}$$

Equation 44

The iteration is considered convergent if ($T_{a,n+1} - T_{a,n}$) is below a user-configurable threshold (ATOVS_L2_PGS_THR_ITER) and if [$T_{b,meas} - F_w(T_{a,n})$] is of the order of the measurement error of all channels.
Note: The first iteration corresponds to the linear solution.

In clear cases, the linear solution might be sufficient and one iteration will be sufficient to yield [$T_{b,meas} - F_W(T_{a,n})$] in the order of the measurement errors. However, in the general case, with water vapour channel used and in partly cloudy (cleared) cases the non linear approach will be needed.

The operator ***W*** is computed for each inversion to use the FRTM to calculate $F_W(T_{ag})$ and its **K**-matrix model to compute $K(T_{ag})$, partial derivatives of the fast forward model with respect to the profile.

The matrix ($O + F_{frtm}$)is replaced by the standard deviations of the fast-forward model errors [$T_{b,cal}(T_{meas}) - T_{b,meas}$]. This implies that the non-diagonal terms of the matrix are reset; it is very difficult to identify the source of the error, either from radiosondes measurements, from the co-location or from the extrapolation of the radiosonde measurements to the upper atmospheric levels of the Radiances Bias Correction Model.
The use of the Gaussian law for $P(T_a)$ uses the assumption, that the first guess profile is unbiased. This applies to models for which the first-guess atmospheric profile originates from a forecast. In cases where the first-guess atmospheric profile comes from a static dataset, the first-guess atmospheric profile is slightly biased and needs to be corrected before the inversion by the following:

$$T'_{ag} = \bar{T}_{ag} - \Delta T_{ag}$$

Equation 45

The error covariance matrices ***G*** (O + $\boldsymbol{F_{frtm}}$) and also $\Delta \boldsymbol{T}_{ag}$ need to be computed off-line for the three cloud conditions (clear/partly cloudy/cloudy) and for land and sea surfaces.

--This ends the background of this theory--

4.3.2.1.5.1 Initialise values and input

The channels used (of HIRS, AMSU-A and MHS) for the inversion process must be user-configurable. Specific for each satellite different channel sets may be used for each pair of surface type (land, sea, coast) of the FOV and its cloudiness type (clear, partly, cloudy, cloudy). The channels selected for the retrieval are user configurable (ATOVS_L2_PGS_SEL_CHAN).

The guess profile is initialised. There are as follows:

$$N_{profile} = N_{temp} + N_{hum} + N_{sfc}$$

Equation 168

variables in the atmospheric state vector, the guess atmospheric profile contains the same variables (see also above).

where:

$N_{profile}$	is the total number of elements in the state vector (57 is the default).
N_{temp}	is the number of temperature values (40 is the default),
N_{hum}	is the number of humidity values (the 15 lowest of the 40 before is the default*)*
N_{sfc}	is the number of surface values (the default is two, surface temperature and surface pressure are added to the profile).

The guess profile $\boldsymbol{T_{ag}}$ shall first be bias corrected with the mean deviation, read from a user-configurable auxiliary data set, resulting from off-line tuning:

$$\boldsymbol{T^{cor}}_{\boldsymbol{ag,k}} = \boldsymbol{T_{ag,k}} - \Delta \overline{\boldsymbol{T}_{ag,k}}(i_{emi}, i_{clear})$$

Equation 169

where $T^{cor}_{ag,k}$ is the corrected first guess profile, for each state vector component k, $k = 1,N_{profile}$, $T_{ag,k}$ is the initial guess profile, composed of the guess variables as derived in the previous section, and $\Delta\, \overline{T_{ag,k}}(i_{emi}, i_{clear})$ is the mean deviation from observed profiles. The correction shall be done for the cloud class of the situation (i_{clear}, see clear flag in Section 4.3.2.1.3) and for the respective (surface) emissivity class i_{emi} .(Land/Sea/Coast).

For the retrieval itself the non linear approach is specified. I_{ter} iterations (user-configurable) need to be performed, where $I_{ter} = 1$ means the linear case. The default value is $I_{ter} = 1$. The following steps are repeated for each iteration.

4.3.2.1.5.2 Compute K Matrix

First the secant of the satellite zenith angle ζ is computed from the satellite scan angle σ

$$\zeta = \operatorname{asin}\left(\frac{R+H}{R} \cdot \sin\sigma\right)$$

Equation 169.1

$$\sec\zeta = \frac{1}{\cos\zeta}$$	***Equation 170***

where:

R	radius of the Earth
H	height of the satellite above the Earth's surface.

The next processing step done is the computation of the K matrix and the associated Brightness Temperatures. This is done by passing the guessed profile $\boldsymbol{T_{a,n}}$ to the fast radiative transfer model and calculate the Jacobians and the associated Brightness Temperatures (see Annex 1). Note that for the first iteration (*n=1*) the linear equation is taken and the $\boldsymbol{K}$ matrix is computed for T_{ag}^{cor}.

This profile needs to be prepared for the fast radiative transfer model (FRTM). The FRTM is specified on N_{FRTM} levels (see Annex 1). The variables on the retrieval state vector levels need to be interpolated/ extrapolated onto the FRTM levels and vice-versa. Extrapolation is done linearly, interpolation is done linearly with the logarithm of the pressure levels for the temperature and ozone profiles and linearly in the logarithm of the humidity and the logarithm of the pressure levels for the humidity profile. In the FR M the mixing ratio needs to be transformed into specific humidity (see above, and Appendix 1).

In general, this step returns the $\boldsymbol{K_n}$-matrix and the associated Brightness Temperatures $\boldsymbol{F_W(T_{a,n})}$. For *n=1 (first iteration)* $\boldsymbol{K_1=K(T_{ag})}$ and $\boldsymbol{F_W(T_{a,1})=F_W(T_{ag})}$.

4.3.2.1.5.3 Compute the Retrieval Operator $\boldsymbol{W_n}$

The retrieval operator $\boldsymbol{W_n}$ is calculated in the next step of the iteration. To recall:

$$W_n = GK_n^T[K_nGK_n^T + S_{frtm}]^{-1}$$	***Equation 171***

Note that the Observation error covariance matrix ***O+F*** has been replaced by the Standard deviations for the direct model + observations (computed from collocation departures between observations and synthetic brightness temperatures with Radiosondes) errors $\boldsymbol{S_{frtm}}$. The transpose of the $\boldsymbol{K_n}$-matrix $\boldsymbol{K_n^T}$ is prepared. ***G*** is the error covariance matrix of the initial guess and was read in the beginning from the first guess library (see above). This matrix:

$$[K_nGK_n^T + S_{frtm}]$$	***Equation 172***

is computed first and inverted. Then the retrieval operator is completed.

4.3.2.1.5.4 Compute (observed - synthetic) Brightness Temperature Deviation

The next iteration step is the computation of the deviation of the observations from the synthetic brightness temperatures:

$$\Delta \boldsymbol{T}_{\boldsymbol{R},\,n} = \boldsymbol{T}_{\boldsymbol{b},\,\boldsymbol{meas}} - F_w(T_{a,\,n}) - \boldsymbol{K}_{\boldsymbol{n}}(\boldsymbol{T}_{\boldsymbol{ag}}^{cor} - \boldsymbol{T}_{\boldsymbol{a},\,\boldsymbol{n}})$$ ***Equation 173***

In the first iteration (*n = 1*) the guessed profile is the initial guess and the deviation reduces to this:

$$\Delta \boldsymbol{T}_{\boldsymbol{R},\,1} = \boldsymbol{T}_{\boldsymbol{b},\,\boldsymbol{meas}} - F_w(T_{a,\,1})$$ ***Equation 174***

4.3.2.1.5.5 Compute new profile and associated Brightness Temperatures:

A new guess profile $\mathbf{T}_{\mathbf{a,n+1}}$ is calculated according to the following:

$$\boldsymbol{T}_{\boldsymbol{a},\,\boldsymbol{n}+1} = \boldsymbol{T}_{\boldsymbol{a},\,\boldsymbol{n}} + (\boldsymbol{T}_{\boldsymbol{ag}} - \boldsymbol{T}_{\boldsymbol{a},\,\boldsymbol{n}}) + \boldsymbol{W}_{\boldsymbol{n}}\Delta \boldsymbol{T}_{\boldsymbol{R},\,\boldsymbol{n}}$$ ***Equation 175***

Note: For n=1 the linear solution results. The general case shall be implemented.

Associated Brightness Temperatures are computed according to the following:

$$\boldsymbol{T}_{\boldsymbol{b},\,\boldsymbol{equi}} = \boldsymbol{K}_{\boldsymbol{n}}\boldsymbol{W}_{\boldsymbol{n}}\Delta \boldsymbol{T}_{\boldsymbol{R},\,\boldsymbol{n}}$$ ***Equation 176***

4.3.2.1.5.6 Check, if good enough or maximum iteration reached

After this step, the iteration is redone, until $n = I_{ter}$.
A check is performed on convergence before: if

$T_{a,n+1} - \mathrm{T}_{\mathrm{a,n}} \leq threshold$

then the iteration is terminated.
Once the iteration loop has ended, the following quality check shall be peformed:
A reference distance is computed from the Standard deviation of the Fast Radiative Transfer Model Errors $\boldsymbol{S}_{frtm}$.

$$d_{st} = \frac{1}{N_{inv}} \cdot \sqrt{\sum_{i=1}^{N_{inv}} S^2_{frtm,\,i}}$$

Equation 177

where N_{inv} is the number of channels used in the inversion process.
A distance d_{rej} to check is then calculated:

$$d_{rej} = \frac{1}{N_{inv}} \cdot \sqrt{\sum_{i=1,\,N_{inv}} T^2_{b,\,equi}}$$

Equation 46

If d_{rej} is larger than a user-configurable threshold S (default value 5), then the inversion is rejected. This generates an event of user-configurable severity.

$$d_{rej} > S \cdot d_{st}$$

Equation 178

A flag must be set. The next pixel is then processed.

The retrieval shall be computed per default as follows:

- For temperature on the 40 atmospheric pressure levels (0.1 hPa–1000 hPa)
- For moisture on the 15 lower levels (50 hPa–1000 hPa)
- For air surface temperature
- For surface moisture
- For total ozone
- For total water vapour content
- Microwave emissivity values in clear conditions

The vertical grid and the number of levels on which the grid is defined shall be user-configurable (ATOVS_L2_PGS_DAT_VGRD).

4.3.2.1.5.7 TPW and CLW by AMSU-A Function

This function implements the functionality specified in Section 4.3.2.2.5 and Section 4.3.2.2.6 in this document. The values are computed on the HIRS pixels and shall be added to the retrieval results.

4.3.2.1.5.8 Provide Retrieval Profile

In this step the remaining characterisation variables for the retrieval profile are computed. These are as follows:

- Geopotential height
- Airmass
- Tropopause height and temperature
- Total Ozone Content
- Total Water vapour content
- Cloud top pressure
- Cloud cover from AVHRR.

Section 4.3.2.1.4.8.3 describes how to calculate these variables.

4.3.2.1.5.9 Level 2 Retrieval Error Variances and Covariances

The error characteristics of the retrieved profile are represented in the retrieval error covariance matrix ***S*** of the retrieval process. When the retrieval process came to a halt after the n^{th} iteration, we have the following:

$$\boldsymbol{S} = [\boldsymbol{G}^{-1} + \boldsymbol{K}_{\boldsymbol{n}}^{\boldsymbol{T}}(\boldsymbol{O} + \boldsymbol{F})^{-1}\boldsymbol{K}_{\boldsymbol{n}}]^{-1}$$

Equation 179

where:

G	error covariance matrix of the guess
O	error covariance matrix of the satellite observations
F	error covariance matrix of FRTM
K_n	K-matrix of the nth iteration of the retrieval process

To fully characterise the product, the retrieval error characteristics need to be included. This is done through the inverse retrieval error covariance matrix ***S′.***

$$S' = S^{-1}$$

Equation 179.1

Through a configuration parameter, it shall be possible to select different cases of error information provided with the profiles:

1. No errors are specified
2. Diagonal elements of the inverse error covariance matrix ***S′***
3. Diagonal elements of the inverse retrieval error covariance matrix ***S′*** and wavelet coefficients describing the correlation matrix (see next paragraph) as calculated from the inverse covariance matrix. The number of wavelet coefficients is determined by a threshold value determining the lower bound on coefficients to be included.

To reduce the size of the ATOVS L2 product, the inverse retrieval error covariance matrix shall be compressed. The compression of the inverse covariance matrix and subsequent unscaling cannot be done on this matrix as configured, because the variability of the elements in the state vector covers several orders of magnitude. Instead, the inverse covariance matrix $\boldsymbol{S'}$ is transformed into the correlation matrix $\boldsymbol{C}$ by the following:

$$C_{ij} = \frac{S'_{ij}}{\sqrt{S'_{ii}S'_{jj}}} \quad , \quad S'_{ij} \in S' \text{ , } i,j=1,\ldots,n$$

Equation 180

where

n = length of the state vector.

The correlation matrix can be compressed by means of a discrete wavelet transform, using the Daubechies' 4-coefficient wavelet filter. For doing so, the correlation matrix $\boldsymbol{C}$ with a dimension $n \times n$ must first be expanded to match the dimension of the smallest integer power of two with $m \times m = 2^p\, 2^p \geq n \times n$. The expansion is done by mirroring separately certain columns and rows of the matrix. The columns are expanded by this:

$$C_{i,j} = C_{i,\,2n-j+1} \text{ for } j=n+1,\ldots,m \text{ and } i=1,\ldots,n$$

Equation 181

and the four rows are expanded by:

$$C_{i,j} = C_{2n-i+1,j} \text{ for } i=n+1,\ldots,m \text{ and } j=1,\ldots,m$$

Equation 182

The wavelet decomposition of the expanded matrix is done vector-wise; first for all the rows of the expanded correlation matrix and then for the columns of the per rows wavelet transformed matrix.

The discrete wavelet transform maps a vector $\boldsymbol{V=(V_1,\ldots,V_m)}$ of a matrix of length m onto the vector $\boldsymbol{W=(W_1,\ldots,W_m)}$ according to the following formulas:

$$W_i = c_0V_{2i-1} + c_1V_{2i} + c_2V_{2i+1} + c_3V_{2i+2} \text{ for } i = 1, \ldots, \frac{m}{2} - 1$$

Equation 183

$$W_{m/2} = c_0V_{m-1} + c_1V_m + c_2V_1 + c_3V_2$$

Equation 184

$$W_{i+m/2} = c_3 V_{2i-1} - c_2 V_{2i} + c_1 V_{2i+1} - c_0 V_{2i+2} \quad \text{for} \quad i = 1, \ldots, \frac{m}{2} - 1$$ ***Equation 185***

$$W_m = c_3 V_{m-1} - c_2 V_m + c_1 V_1 - c_0 V_2$$ ***Equation 186***

The wavelet filter coefficients c_0, c_1, c_2 and c_3 are user-configurable with following default values:

$$c_0 = (1 + \sqrt{3})/(4\sqrt{2})$$ ***Equation 186.1***

$$c_1 = (3 + \sqrt{3})/(4\sqrt{2})$$ ***Equation 186.2***

$$c_2 = (3 - \sqrt{3})/(4\sqrt{2})$$ ***Equation 186.3***

$$c_3 = (1 - \sqrt{3})/(4\sqrt{2})$$ ***Equation 186.4***

Then m is set to:

$$m = m/2$$ ***Equation 186.5***

The above procedure (Equation 183–Equation 186.5) is reiterated on the $\boldsymbol{W}$-vector, renaming it $\boldsymbol{V}$, as long as $m \geq 4$ applies.

The above algorithm is applied to all 2^p row-vectors of the expanded correlation matrix resulting in a $2^p \times 2^p$ matrix where all rows are wavelet transformed.

The column vectors of the latter matrix are then wavelet transformed as well following the same algorithm. After the completion of the recursions the resulting $2^p \times 2^p$ matrix consists of wavelet coefficients (not to be mixed with the above wavelet filter coefficients). This matrix is compressed by extracting all wavelet coefficients, which are greater than a user-configurable threshold. The compressed retrieval error covariance matrix $\boldsymbol{S}$ is then represented in the product by the diagonal elements of the inverse retrieval error covariance matrix $\boldsymbol{S'}$, the wavelet coefficients after thresholding and their positions in the wavelet coefficients matrix.

4.3.2.2 Alternative Retrieval Method One Function

The alternative retrieval method one shall be used in case of non-suitability of the default retrieval method due to lack or corrupted input data. AMSU-A data must not be corrupted or lacking. The alternative retrieval method is based on AMSU-A data and applies the algorithm described in [RD-13]. The alternative Retrieval method performs functions listed in Table 27:

	Alternative Retrieval operations
1	Check if water or non-water pixel
2	Check if Deltas computed
3	Compute Deltas
4	AMSU-A Temperature Profile Retrieval
5	AMSU-A TPW Retrieval
6	AMSU-A CLW Retrieval

Table 27: Alternative Retrieval Function Decomposition

This section specifies a stand-alone temperature retrieval function based on AMSU-A only and performs the retrieval of temperature profiles, total precipitable water (TPW) and cloud liquid water (CLW). The temperature profile may be retrieved over ocean and land, the parameters TPW and CLW are derived over ocean only as a default. As an option, the derivation of these parameters over land shall be possible to be included.

The retrieval method chosen is a regression algorithm based on the work of Mitch Goldberg. See [RD-13]

The input to the retrieval algorithms are pre-processed AMSU-A brightness temperatures, which have to be adjusted for limb effects for a given scan-angle with user-configurable coef. (See above.)

The retrieval of temperature is done over water through a regression method. The regression coefficients were computed off-line from collocated radiosonde temperature profiles and limb-corrected AMSU-A brightness temperatures.

The retrieval of total precipitable water (TPW) and cloud liquid water (CLW) over water is done based on limb-adjusted AMSU-A brightness temperatures. Grody's algorithm is used [RD-14].

4.3.2.2.1 Data Preparation

This section specifies the preparation of the input data for the limb-adjustment step. Input to this function are the AMSU-A level 1b dataflow (antenna temperatures T_b^a), the topography file, the antenna-correction coefficients (if antenna correction is already done, there is no need), the limb-adjustment coefficients for sea and non-sea surfaces. Output from this step are antenna corrected, AMSU-A limb-adjusted brightness temperatures T_b^{lbcor} , on the same grid and Earth location as the level 1b information, and a land/sea mask for the AMSU-A grid. The land/sea information is either received together with the level 1b data (from the Earth parameter computation, see under section 5.2.2 of the AMSU-A PGS), or it is computed within this function.

If antenna corrections have been already performed to the AMSU-A Level 1b data, the following step is not performed. A configuration parameter i4_antenna_correction is set to 0. If this configuration parameter is not set to 0, the first step to prepare the data is performed. The user configurable antenna correction coefficients $f_0^{\,i,n}$, $f_1^{\,i,n}$ and $f_2^{\,i,n}$ i = 1,...,30, n=1,...,10 are read (AMSUA_L1_PGS_COF_ANTCOR in Annex B). The antenna correction coefficients are then prepared according to the following short algorithm, where all indexing shall be user-configurable:

$$f_k^{i,15}=f_k^{i,10},\ k=0,\ldots,2 \text{ and } i=1,30$$

Equation 188

$$f_k^{i,j}=f_k^{i,9},\ k=0,\ldots,2\ ;\ i=1,30 \text{ and } j=10,\ldots,14$$

Equation 189

$$f_k^{i,j}=f_k^{i,j}/100.,\ k=0,\ldots,2 \text{ and } i=1,30 \text{ and } j=1,\ldots,15$$

Equation 190

If the antenna correction configuration parameter is not set to 0 then for all 15 AMSU-A channels the antenna correction is performed according to the following parametric regression equation:

$$T_b^{a,cor,j,i} = \left(T_b^{a,j} - \eta(j)\times f_1^{i,j}\times 290. - f_2^{i,j}\times 2.73\right)/f_0^{i,j}$$

Equation 47

for all channels j = 1,.....,15 and all scan angle positions i = 1,....,30

η (j), j=1,...,15 is the AMSU-A channel number, is user configurable set of coefficients in AMSUA_L1_PGS_COF_ANTCOR in Annex B. The default settings are as follows:

η (1) = 0.01
η (2) = 0.08
η (3) = 0.03
η (4) = 0.04
η (5) = 0.04
η (6) = 0.03
η (7) = 0.03
η (8) = 0.04
η (9) = 0.04
η (10) = 0.04
η (11) = 0.04
η (12) = 0.04
η (13) = 0.04
η (14) = 0.04
η (15) = 0.11

4.3.2.2.2 Land/sea Mask Determination

The next step is to assure that for each AMSU-A pixel it is known whether it is over land or not over land. For this purpose, either the information from previous AMSU-A level 1 processing steps can be used (Earth parameter calculation) and a land/sea mask be extracted, or the land/sea mask is extracted now. The choice whether this is done at this stage shall be made by a configuration parameter. The default shall be that the distinction between land/sea had been determined already before. Coastal pixels are handled as land pixels.

If there is a need to determine the land/sea mask now, the terrain data (AMSUA_L1_PGS_DAT_SFCTOP) shall be read. For each geodetic location (latitude/longitude) of each AMSUA pixel it shall be determined, whether it is a land, sea or coast pixel. Thus a land/sea mask for the AMSUA FOVs is determined.

4.3.2.2.3 Limb-Adjustment function

The limb adjustment is the next step in the preparation of the AMSU-A data. Limb adjustment shall be different for AMSU-A pixels located over water and for pixels located not over water. The first step is to make the user configurable limb-correction coefficients available for sea and for nonsea locations (AMSUA_ L1_PGS_COF_LMBSEA, AMSU-A_L1_PGS_COF_LMBLND).

The limb-adjustment is then performed for the data located over water according to the following:

$$T_b^{lmbcor,j,i} = d_{m,s}^{j} + \sum_{k=1}^{ns(j)} \left(c_s^{j,i,n_{ss}(j,k)} \times T_b^{a,cor,n_{ss}(j,k)} - a_{m,s}^{j,i,n_{ss}(j,k)} \right)$$

Equation 48

The limb correction is done for all channels $j = 1,...,15$, and all pixel position (scan angles $i = 1,...,30$). *ns(j)* channels considered and the brightness temperature in channel $n_{ss}(j,k)$ are used together with the coefficient $c^{sj,i,n_{ss}(j,k)}$, as they are read from user-configurable data sets.

The coefficients $d_{m,s}^{j}$, $c_s^{j,i,n(j,k)}$, $a_{m,s}^{j,i,n(j,k)}$ and the sum parameter *ns(j)* are configurable limb-adjustment coefficients (AMSU-A_L1_PGS_COF_LMBSEA) for the adjustment over water.

For the data pixels not located over water the limb adjustment is performed with the user configurable nonsea set of coefficients $d_{m,l}^{j}$, $c_l^{j,i,n(j,k)}$, $a_{m,l}^{j,i,n(j,k)}$ and the sum parameter *nl(j)* are configurable limb-adjustment coefficients (AMSU-A_L1_PGS_COF_LMBLND).

$$T_b^{lmbcor,j,i} = d_{m,l}^{j} + \sum_{k=1}^{nl(j)} \left(c_s^{j,i,n_{ll}(j,k)} \times T_b^{a,cor,n_{ll}(j,k)} - a_{m,l}^{j,i,n_{ll}(j,k)} \right)$$

Equation 49

The limb correction is done for all channels j = 1,...,15, and all pixel position (scan angles i = 1,...,30). $nl(j)$ channels considered and the brightness temperature in channel $n_{ll}(j,k)$ are used together with the coefficient $c^{sj,i,n}{}_{ll}{}^{(j,k)}$, as they are read from user-configurable data sets.

At the end of this step, there shall be limb-adjusted brightness temperatures for all 15 AMSU-A channels and for all scan angles, in addition to the output of the AMSU-A level 1b processing.

4.3.2.2.4 Temperature Retrieval

The first step in the temperature retrieval is to establish the deltas–the difference between measured brightness temperatures and computed brightness temperatures to allow for a correction. First the deltas, which are user-configurable, are initialised (ATOVS_L2_PGS_COF_DELTA). The default values are as follows:

δ (1) = 0.
δ (2) = 0.
δ (3) = 0.
δ (4) = 0.
δ (5) = -0.04
δ (6) = -0.256
δ (7) = 0.119
δ (8) = 1.1
δ (9) = 0.3
δ (10) = 0.42
δ (11) = 0.88
δ (12) = 0.88
δ (13) = 0.88
δ (14) = 0.88
δ (15) = 0.

The δ (j), j = 1,...,15, are then modified according to the following formulas:

$$\delta(8) = d_{8,0} + d_{8,1} \times T_b^{lmbcor,8}$$ **_Equation 50_**

$$\delta(9) = d_{9,0} + d_{9,1} \times T_b^{lmbcor,9}$$ **_Equation 51_**

$$\delta(10) = d_{10,0} + d_{10,1} \times T_b^{lmbcor,9} + d_{10,2} \times T_b^{lmbcor,10} + d_{10,3} \times T_b^{lmbcor,11}$$ **_Equation 52_**

$$\delta(11) = d_{11,0} + d_{11,1} \times T_b^{lmbcor,10} + d_{11,2} \times T_b^{lmbcor,11} + d_{11,3} \times T_b^{lmbcor,12}$$ **Equation 53**

$$\delta(12) = d_{12,0} + d_{12,1} \times T_b^{lmbcor,11} + d_{12,2} \times T_b^{lmbcor,12} + d_{12,3} \times T_b^{lmbcor,13}$$ **Equation 54**

$$\delta(13) = d_{13,0} + d_{13,1} \times T_b^{lmbcor,12} + d_{13,2} \times T_b^{lmbcor,13} + d_{13,3} \times T_b^{lmbcor,14}$$ **Equation 55**

$$\delta(14) = \delta(13)$$ **Equation 56**

The coefficients $d_{j,k}$ are user configurable (ATOVS_L2_PGS_COF_DDELTA). Their default values are as follows:

$d_{8,0}$ = - 4.354
$d_{8,1}$ = 0.024
$d_{9,0}$ = - 0.341
$d_{9,1}$ = 0.003
$d_{10,0}$ = -0.742
$d_{10,1}$ = -0.254
$d_{10,2}$ = 0.377
$d_{10,3}$ = - 0.117
$d_{11,0}$ = - 2.647
$d_{11,1}$ = -0.196
$d_{11,2}$ = 0.330
$d_{11,3}$ = - 0.119
$d_{12,0}$ = - 2.976
$d_{12,1}$ = - 0.192
$d_{12,2}$ = 0.357
$d_{12,3}$ = - 0.148
$d_{13.0}$ = - 2.289
$d_{13,1}$ = - 0.273
$d_{13,2}$ = 0.528
$d_{13,3}$ = - 0.237

Subsequently, the essential temperature retrieval is performed. The retrieval is performed on a user - configurable number of pressure levels (40 is the default number of pressure levels) (ATOVS_L2_PGS_DAT_AMSPLV). The default pressure levels are p(l), l=1,...,40:

0.1,0.2,0.5,1.0,1.5,2.0,3.0,4.0,
5.0,7.0,10.0,15.0,20.0,25.0,30.0, 50.,60.,70.,85.,100.,115.,135.,150.,200.,250.,300.,350.,400.0,
430.,475.,500.,570.,620.,670.,700.,780.,850.,920.,950.,1000.,

all values are in hPa.

There must be the possibility to use a user-configurable number of sets of regression coefficients for a number of pressure layers. There are two sets of retrieval coefficients available as default: valid for pressure levels 1 to n_{up}, where n_{up} is the user-configurable pressure level as boundary of the firs coefficient set. The second set of retrieval coefficients is valid for pressure levels (n_{up} + 1) to $n_{p,max}$, where $n_{p,max}$ is userconfigurable. Default values are n_{up} = 8 and $n_{p,max}$ = 40.
The retrieved temperature is the derived from the limb corrected AMSU-A brightness temperatures for the levels from *p(1)* to *p(n_{up})*, presently .1 to 4 hPa:

$$T^{l}_{ret} = i(l) + \sum_{k=1}^{N(l))} C^{l,n(l,k)}_{reg} \times (T^{lmbcor,n(l,k)}_{b} - \delta(n(l,k))) \quad \textbf{\textit{Equation 57}}$$

where

l	is the level index
N(l)	is the number of coefficients used
i(l)	is the intercept used for the level l
$C_{reg}^{l,n(l,k)}$	the coefficient for level l and channel *n(l,k)*
δ *(l,k)*	is the respective delta used

For the levels (n_{up}+ 1) to 40, presently 5–1000 hPa, we have the following:

$$T^{l}_{ret} = i(l) + \sum_{k=1}^{N(l))} C^{l,n(l,k)}_{reg} \times T^{lmbcor,n(l,k)}_{b} \quad \textbf{\textit{Equation 58}}$$

where

l	is the level index
N(l)	is the number of coefficients used
i(l)	is the intercept used for the level l
$C_{reg}^{l,n(l,k)}$	the coefficient for level l and channel *n(l,k)*

4.3.2.2.5 Retrieval of total precipitable water (TPW)

Grody's algorithm [RD-14] is used for the retrieval of total precipitable water over water. If the brightness temperatures of AMSU-A channels 1 and 2 are below 285 K, then the retrieval is performed.

Hence we have:
If sea-surface and if $T_b^{lmbcor,1} < 285$ K and $T_b^{lmbcor,2} < 285$ K, then the parametric Equation 59:

$$q_{tot,p} = a_{0,p} + a_{1,p} \times \ln(T_{0,p} - T_b^{lmbcor,1}) + a_{2,p} \times \ln(T_{1,p} - T_b^{lmbcor,2}) + b_{0,p} + b_{1,p}$$

Equation 59

where the coefficients $a_{0,p}$, $a_{1,p}$, $a_{2,p}$, $b_{0,p}$ and $b_{1,p}$ are user-configurable, as are the temperatures $T_{0,p}$ and $T_{1,p}$. The default values are set to:

$a_{0,p} = 247.92$
$a_{1,p} = -116.270$
$a_{2,p} = 73.409$

$b_{0,p} = -69.235$
$b_{1,p} = 44.177$

$T_{0,p} = 285$
$T_{1,p}. = 285.$

In case that $q_{tot,p} < 0$, $q_{tot,p}$ is set to 0.001 mm. If $q_{tot,p} > 80$ mm, the value of $q_{tot,p}$ is set to 80 mm.

4.3.2.2.6 Retrieval of Cloud Liquid Water Content (CLW) Over Water

Cloud liquid water is retrieved with an algorithm by Grody, using the AMSU-A Channels 1 and 2:

If sea-surface and if $T_b^{lmbcor,1} < 285$ K and $T_b^{lmbcor,2} < 285$ K, then:

$$q_{cl} = a_{0,cl} + a_{1,cl} \times \ln(T_{0,cl} - T_b^{lmbcor,1}) + a_{2,cl} \times \ln(T_{1,cl} - T_b^{lmbcor,2}) + b_{0,cl} + b_{1,cl}$$

Equation 60

where the coefficients $a_{0,cl}$, $a_{1,cl}$, $a_{2,cl}$, $b_{0,cl}$ and $b_{1,cl}$ are user-configurable, as are the temperatures $T_{0,cl}$ and $T_{1,cl}$. The default values are set to the following:

$a_{0,cl} = 8.24$
$a_{1,cl} = 0.754$
$a_{2,cl} = -2.265$
$b_{0,cl} = -2.622$
$b_{1,cl} = 1.846$
$T_{0,cl} = 285$
$T_{1,cl} = 285.$

In the case where $q_{cl} < 0$, q_{cl} is set to 0.001 mm. If $q_{cl} > 4$ mm, the value of q_{cl} is set to 4 mm.

A bias correction must be applied <TBC> to the TPW and the correction equation is given through these equations:

$$q_{tot} = -k_0 + k_1 q_{tot}$$ ***Equation 61***

$$q_{cl} = m_0 + m_1 \ln(T_{0,cl} - T_{b,A,1}) - m_2 \ln(T_{0,cl} - T_{b,A,2})$$ ***Equation 62***

The coefficients and parameters in the above equations shall be user-configurable (ATOVS_L2_PGS_COF_REG). The default values are as follows:

$k_0 = 1.234$
$k_1 = 0.913$
$m_0 = 7.46$
$m_1 = 0.754$
$m_2 = 2.265$
$T_{0,cl} = 285$

4.3.2.3 Additional Retrieval Method(S) Functions

There shall be the possibility to introduce and select additional retrieval methods.

Specifications and associated Requirements on this activity are not provided for day 1. Potential additional retrieval methods will be specified in subsequent versions of this document.

4.4 On-line Quality Control Function

This function is mostly covered in the scientific section above. The functionality, which can be performed on-line, is restricted to the checking of variables on plausibility and the setting and summarising of flags set. The scientific quality assessment can only be done off- line.

The produced information shall be used to generate detailed quality statistics for analysis purposes. This information (subset) shall also be used for reporting on the mission performance/product accuracy.

4.5 Data Formatting Function

This function consists of as many sub-functions as there are streams of products leaving the ATOVS Level 2 Product Generation Function . Each of these functions performs the verification of the completeness of the product to be made available to other functions in the Core Ground Segment, pre-processes output data when needed for the preparation of certain products (like the GTS products) and generates detailed reporting information on the completeness of the products and the time at which they were sent. An ATOVS Level 2 output is considered sent if the required data has been made available to the receiving function of a function external to the ATOVS Level 2 Product Generation Function.

4.5.1 Level 2 Product

The data formatting function shall prepare the output data necessary for an external functionality to the ATOVS Level 2 Product Generation Function to prepare the EPS ATOVS Level 2 Products as defined in the ATOVS Level 2 Product Format Specification [AD-45].

4.5.2 GTS Product Contents

Finally, the data formatting function shall also prepare the output data necessary for the encoding of the products according to the WMO Manual of Codes (only for relevant ATOVS Level 2 products. See ATOVS_L2__PGS_COF_GTSRES). The encoding of the GTS products will be performed by another functionality in the Core Ground Segment.
The GTS product contents shall be user configurable and will be specified as follows:

4.5.2.1 Contents of The Level 2 GTS Product

Selected parts of the retrieval results shall be made available for the transmission over the Global telecommunication System (GTS). There shall be selected levels and parameters of the vertical profiles and the total column amounts (See AD 64 for details).

Every N^{th} profile of every M^{th} line of the ATOVS level 2 product shall be selectable. *N* and *M* shall be user-configurable.

Each of these GTS profiles shall contain the profile value of temperature and humidity of each *Kth* pressure level of the ATOVS level 2 product. The following user configurable information is required (default):

Latitude (real*4) # min -90.0 # max 90.0 # +/- 0.1 # degrees
Longitude (real*4) # min -180.0 # max 180.0 # +/- 0.1 # degrees
Number of vertical levels (integer*2) # min 0 # max 45 # +/-1 # numeric
Pressure of level 1 (real*4) # min 0.1 # max 1090.0 # +/- 0.1 # hPa
Temperature of level 1 (real*4) # min 100.0 # max 330.0 # +/- 0.1 # K
Water vapour mixing ratio of level 1 (real*4) min 0.000 max 0.8 # +/- 0.001 # kg/kg
...

and for every K_{th} pressure level

...
Pressure of level $1+N_{pres}*K$ (real*4) # min 0.1 # max 1090.0 # +/- 0.1 # hPa
Temperature of level $1+N_{pres}*K$ (real*4) # min 100.0 # max 330.0 # +/- 0.1 # K
Water vapour mixing ratio of level $1+N_{pres}*K$ (real*4) # min 0.000 # max 0.8 # +/- 0.001 # kg/kg
Surface Temperature (real*4) # min 0.000 # max 330.0 # +/- 0.1 # K
Surface mixing ratio(real*4) # min 0.000 # max 0.8 # +/- 0.001 # kg/kg
Surface pressure (real*4) # min 0.1 # max 1090.0 # +/- 0.1 # hPa

where N_{pres} is the number of pressure levels as indicated above.

If there is a need to convert the mixing ratios to relative humidities, this needs to be done beforehand according to the following:

$$U_k = 100 \cdot \frac{r_k}{r_{w,k}}$$ ***Equation 276***

where:

U_k	is the relative humidity at level k in percentage
r_k	is the mixing ratio at level k in *kg/kg*
$r_{w,k}$	is the saturation mixing ratio water/water at level k at pressure p_k and temperature T_k

$$r_{w,k} = \frac{R_L}{R_w} \frac{e'}{p_k - e'}$$ ***Equation 277***

where:

R_L	is the gas constant of dry air
R_w	is the gas constant of water vapour
p_k	is the pressure
e'	is the saturation water vapour pressure at temperature T_k and pressure p_k.

e' is calculated through the Goff-Gratch formula (for relative humidity e' is computed over liquid water, as per convention).

$$\log_{10}(e') = -7.90298(T_S/T - 1) + 5.02808 \log_{10}(T_S/T) - 1.3816\times10^{-7}(10^{11.344(1-T/T_S)} - 1) + 8.1328\times10^{-3}(10^{-3.49149(T_S/T-1)} - 1) + \log_{10}(e_{wS})$$ ***Equation 278***

where T_s is the steampoint temperature (373.15 K) and e_{ws} is the saturation pressure of pure liquid water at steampoint temperature (1 standard atmosphere = 1013.246 hPa).

4.6 Reporting Function

This function gathers all the reporting information (events, flags, etc.) produced by the different functions of the ATOVS Level 2 Product Generation Function and generates the input data for the full ATOVS Level 2 Product Generation Function for the Core Ground Segment reporting function. Both the reporting inputs and the full quality information are transferred to the Core Ground Segment for centralised mission reporting and off-line analysis.

APPENDIX A: LIST OF EQUATION PARAMETERS

Parameter	Meaning	Unit
-1	Inverse of a matrix or vector	
A^{Earth}_{eff}	Effective contribution of Earth in AMSU-A antenna correction	
$A^{Platform}_{eff}$	Effective contribution of the spacecraft in AMSU-A antenna correction	
A^{Space}_{eff}	Effective contribution of space in AMSU-A antenna correction	
a_0, a_1, a_2	Coefficients of SSIREM emissivity model	-,-,-,
a_0, a_1, a_2, a_3	Coefficients of estimated Brightness temperature regression polynomial, dep. on sec. of scan angle	K, -,-,-,
$a_k(i)$	Coefficients for brightness temperature bias correction, brightness temperature terms	
α	Exponent in the SSIREM IR emissivity model	
β	Exponent in the SSIREM IR emissivity model	
$a_\zeta (i)$	Coefficient for brightness temperature bias correction, secant term	
B^{Space}	Radiance from cold space at 2.73 °K	
$B(u)$	Correction term for Fresnel's specular reflection	
$b_{0,i}$,$b_{1,i}$,$b_{2,i}$,$b_{3,i}$	Polynomial coefficients to calculate the a_i, $i = 0,3$	
$B^{-1}(E,p,i)$	Inverse Planck function	
c_1, c_2, c_3	coefficients to estimate the form factor f in the precipitation test after Crosby	-,K^{-1}, K^{-1}
c_0, c_1, c_2, c_3	Daubechies' 4 coefficients wavelet filter coefficients	
C_1	= hc/k_b First constant in the calculation of the Brightness Temperature	m K
C_2	= $2hc^2$ Second constant in the calculation of the Brightness Temperature	W m^2
C_3	Third constant in the calculation of the Brightness Temperature, first band correction coefficient	K
C_4	Fourth constant in the calculation of the Brightness Temperature, second band correction coefficient	-
C_{ij}	Correlation Matrix of the Retrieval error covariance matrix	-
$\boldsymbol{C}$	Covariance matrix of AMSU-A and MHS brightness temperatures	
d_{st}	Reference distance to check retrieval quality	K
d_{rej}	Distance to check retrieval quality	K
$\delta (i)$	Brightness temperature bias for channel i	K
δT_{seaice}	Threshold for sea ice detection in microwave emissivity Model	K
$\Delta \varepsilon(u)$	Correction for large-scale sea roughness	

Parameter	Meaning	Unit
$\Delta\overline{T}_{\overline{ag,k}}(i_{emi}i_{clear}$	Mean deviation from observed profiles	K
Δ_1	Component of the static permittivity	
Δ_2	Component of the static permittivity	
Δ_{inf}	Permittivity at infinite frequency	
$\varepsilon_{IR,sea}$	Infrared surface emissivity over sea in the SSIREM model	
ε_V	Vertical-polarised microwave surface emissivity over sea in the FASTEM model	
ε_H	Horizontal polarised microwave surface emissivity over sea in the FASTEM model	
$d_{rej}(p)$	Threshold distance for inversion rejection for the profile p	
$d_{guess}(n_{air})$	distance from the guess profile for airmass class n_{air}	
e	water vapour partial pressure	hPa
e'	water vapour saturation partial pressure	hPa
$e_{m,fastem}$	Coefficients of the FASTEM microwave emissivity model, $m=1,...,59$	
$E(p,i)$	Radiance of profile p and channel i	$W/m^2/sr/\mu m^{-1}$
$E(T_s)$	Radiance for the surface temperature	$W/m^2/sr/\mu m^{-1}$
$\varepsilon(u,T_s)$	Microwave model emissivity	
E_{do}	Downelling radiance	$W/m^2/sr/\mu m^{-1}$
ε_s	Surface emissivity	
ε_{stat}	Static permittivity in the FATSEM microwave emissivity model	
E_{up}	Upwelling radiance	$W/m^2/sr/\mu m^{-1}$
f_o, f_1	Coefficients in the foam emissivity correction	-
f	Formfactor in precipitation index	-
$F(u)$	Foam cover correction	
$\mathbf{F}_{frtm}$	Error covariance matrix of the fast forward model	
$f_k^{i,j}$	Coefficients in antenna correction	
$\mathbf{F}_w\ (\mathbf{T}_a)$	Brightness temperature computed from the $\mathbf{T}_a$ profile	K
$\mathbf{G}$	Error covariance matrix of the guess	
g_o, g_1	Coefficients for regression in Grody's rain test	
$g(\phi,z)$	Acceleration of gravity, depending on latitude and height	m/s^2
γ dry	Dry adiabatic lapse rate	degree
η	Scan angle	
$\eta(i)$	Coefficients in antenna correction	-
$H^{Earth}{}_{eff}$	effective contribution of Earth in MHS antenna correction	-
$H^{Platform}{}_{eff}$	effective contribution of the spacecraft in MHS antenna correction	

Parameter	Meaning	Unit
H^{Space}_{eff}	effective contribution of space in MHS antenna correction	
h_{sat}	Satellite altitude	km
H_{sc}	Scale height of the atmosphere	m
h_{scale}	Scale height of the atmosphere	m
I_{prec}	Precipitation index	-
I_{ter}	Number of iterations in the retrieval process	-
I_{sc}	Scattering Index	K
J	Cost function for surface-type minimum variance retrieval	
$J(\boldsymbol{T}_a)$	Cost function for the retrieval	
$J'(\boldsymbol{T}_a)$	First Derivative of the Cost function	
$J''(\boldsymbol{T}_a)$	Second derivative of the Cost function	
J_{stc}	Cost function for surface type analysis	
$\boldsymbol{K}(\boldsymbol{T}_a)$	Partial derivatives of $\boldsymbol{F}_w(\boldsymbol{T}_a)$ with respect to elements of $\boldsymbol{T}_a$	
$\boldsymbol{K}_n(\boldsymbol{T}_a)$	Partial derivatives of $\boldsymbol{F}_w(\boldsymbol{T}_a)$ with respect to elements of $\boldsymbol{T}_a$ in iteration step n	
m_i	water vapour mixing ratio at level i	kg/kg
m_{air}	mole mass of air	
m_{O3}	mole mass of Ozone	
μ	Complex permittivity	
ν_j	Microwave frequency of channel j	GHz
ν_{en}	Double Debye frequency in FASTEM	GHz
$N_{airmass}$	Number of airmass classifications	
$N_{maxcanair}$	Number of channels used for the airmass classification	
N_{maxbg}	Number of vectors of biases of guess deviation and standard deviations	
N_{emi}	Number surface emissivity classes	
N_{clear}	number of cloud classes	
N_{clear}	Percentage of clear AVHRR pixels in HIRS FOV	
$N_{profile}$	Number of elements in the state vector	
N_{temp}	Number of temperature elements in the state vector	
N_{hum}	Number of humidity elements in the state vector	
N_{sfc}	Number of surface elements in the state vector	
$N\varepsilon$	Effective cloud amount	
$\boldsymbol{O}$	Error covariance matrix of satellite observations	
$O_{3,tot}$	Retrieved total column ozone	DU
$p_{cloud\ top}$	Cloud-top pressure	hPa

Parameter	Meaning	Unit
p_{cloud}	Cloud-top pressure	hPa
p_s	Surface pressure	hPa
p_{sfc}	Surface pressure	hPa
p_{sea}	Sea surface pressure	hPa
p_{tropo}	Tropopause pressure	hPa
$P_{thres,\ rain}$	Threshold for rain probability	gpm
Φ	Geopotential height	m^2/s^2
Φ_i	Geopotential height of the level *i*	kg/kg
$\boldsymbol{q}$	Vector of retrieved humidities	kg/kg
q	specific humidity	kg/kg
q'	specific humidity	g/kg
q_{O3}	Ozone mixing ratio	kg/kg
$q_{'O3}$	Ozone mixing ratio	ppmv
q_{cl}	Retrieved cloud liquid water	mm
θ	Nadir angle	degrees
$q_{tot,p}$	Retrieved total precipitable water	mm
$q_{NO3,k}$	Number of Ozone molecules in layer *k*	$Molecules/m^2$
$q_{NO3,k,dob}$	Ozone content in layer k	Dobson Units
$q_{O3,tot}$	total Ozone content	Dobson Units
$q_{H2O,tot}$	total water vapour content	kg/m^2
q_i	specific humidity at level *i*	kg/kg
R_{cnv}	Conversion factor for Ozone mixing Ratio from kg/kg to ppmv	
R	Ratio: (Earth radius + Sat. altitude)/(Earth radius)	
R_L	Gas constant of dry air	$J\ kg^{-1}\ K^{-1}$
r_k	water vapour mixing ratio at pressure level k	kg/kg
r'_k	water vapour saturation mixing ratio at pressure level k	kg/kg
r_{earth}	Earth mean radius	km
$R_s(T_s)$	Fresnel's specular reflection	
R_H	Fresnel's Reflection coefficient, horizontally-polarised component	
R_V	Fresnel's Reflection coefficient, vertically-polarised component	
R'_H	Fresnel's Reflection coefficient, horizontally-polarised component, real and imaginary part used	
R'_V	Fresnel's Reflection coefficient, vertically-polarised component, real and imaginary part used	

Parameter	Meaning	Unit
$\boldsymbol{S}_{frtm}$	Error standard deviation of the forward model	
s_0, s_1, s_2	Coefficients to calculate the threshold for sea ice in the microwave emissivity model	
$\boldsymbol{S}_{Tb}$	Brightness temperature standard deviation vector	
$\boldsymbol{S}$	Error covariance matrix of the retrieval	
T	Transpose of a matrix or vector	
$\boldsymbol{T}$	Vector of retrieved temperatures	K
$\boldsymbol{T}_a$	Synthetic atmospheric profile	K
$\boldsymbol{T}_{ag}$	Initial guess	K
$\boldsymbol{T}_{b,A}$	Vector of AMSU-A Brightness Temperatures	K
$T_{b,A,est,ii}$	Estimated Brightness Temperature of AMSU Channel ii	K
$T_{b,A,i}$	Brightness Temperature of AMSU Channel i	K
$\boldsymbol{T}_{b,A,m}$	Vector of mean brightness temperatures of AMSU-A and MHS in surface type estimation.	K
$T_{b,cal}$	Bias-corrected AMSU-A observations	K
$\boldsymbol{T}_{b,cov}$	Brightness temperature covariance matrix	
$\boldsymbol{T}_{b,cor}$	Brightness temperature correlation matrix	
$\boldsymbol{T}^{cor}{}_{ag,k}$	Bias-corrected guess profile	K
$T_{b,H,cl}$	Cleared HIRS/4 brightness temperature	K
$T_{b,H,i}$	Brightness temperature of HIRS/4 Channel i	K
$T_{b,H,w,i}$	Warmest adjacent FOV longwave windows brightness temperature of HIRS/4 channel i	K
$T_{b,med,thres}$	Threshold value used in the MHS Median Filter	K
$T_{b,meas}$	Measured brightness temperature	K
$\boldsymbol{T}_{b,meas}$	Vector of observations for $N+1$ channels	K
$\boldsymbol{T}_{b,equi}$	Associated brightness temperatures to the new guess profile	K
$\boldsymbol{T}_n$	Guess profile at iteration step n	K
$T_b^{cor,bias}(j,k)$	Bias-corrected brightness temperature for channel i from the Fast Radiative Transfer Model	K
$T_{b,meas}'(i)$	Bias-corrected brightness temperature for channel k and FOV j	K
$T_b^{a,cor,j,i}$	Antenna-corrected brightness temperature for channel j and pixel i	K
$T_b^{lmbcor,j,i}$	Limb-corrected brightness temperatures	K
$T_{cloud\ top}$	Retrieved cloud top temperature	K
$T^l{}_{ref}$	Retrieved temperature at level l	K
T_{tropo}	Tropopause temperature	K
T_v	Virtual Temperature	K

Parameter	Meaning	Unit
$T_{v,i}$	Virtual Temperature at level *i*	K
τ_s	Total transmission at the surface between satellite and ground	
T_s	Surface temperature	K
T_{sfc}	Surface temperature	K
t_{sfc}	Surface temperature	°C
T_s	Retrieved surface temperature	K
$T_{sfc,fc}$	Surface temperature from forecast	K
$\overline{T}_{\overline{nair,k}}$	Mean profile for the airmass n_{air}	K
$T_{\sigma,nair}$	Standard deviation of the mean profile for the airmass N_{air}	K
$T_{thres,\ AB,89}$	Threshold for MHS mapped to AMSU-A for optimum temperatures range	K
τ_1	First relaxation frequency in the FASTEM model	
τ_2	Second relaxation frequency in the FASTEM model	
u	Wind speed	m/s
u	Zonal wind speed	m/s
U_k	Relative humidity at pressure level k	%
v	Meridional wind speed	m/s
$\boldsymbol{v}$	Horizontal wind vector	m/s
$\boldsymbol{V}$	Vector of the extended Correlation matrix in the wavelet compression scheme	
$\boldsymbol{W}_n$	Retrieval operator	
W_n	Wavelet coefficients	
χ_k	Secant of secant class k	
Δ_χ	Slope given by neighboring secants to compute mean brightness temperaures	
z	Altitude	m
$z_{c,k}$	large scale correction coefficients in FASTEM, $k = 1,...,12$	
$z_{i,V,mpol}$	coefficients for nadir angle dependent contribution of vertical polarised microwave emissivity component to emissivity in the FASTEM model, i = 1,...,3	
$z_{i,H,mpol}$	coefficients for nadir angle dependent contribution of horizontal polarised microwave emissivity component to emissivity in the FASTEM model, i = 1,...,3	
ζ	Zenith angle at the surface	degree
ζ_0	Normalised zenith angle	
$\zeta_{ts,i}$	Zenith angle class *i* used for the retrieval	degree

APPENDIX B: USER-CONFIGURABLE AND AUXILIARY DATA

It is important to note here that the datasets contents and their identifiers are not meant to put constraints in the design of the ATOVS Level 2 Product Generation Function or on its implementation. They are to be treated in the same way that physical symbols or equation parameters are treated. The identifiers are used to keep the clarity and consistency across this document and with the AAPP prototype and to ease cross-referencing with other documentation.

For each dataset, a description of its contents is included together with a list of related requirements that mention the dataset. The requirements lists are not complete at the moment. These lists will be completed by EPS Critical Design Review. The datasets are mentioned in Section 4. whenever they are needed by the processing.

Dataset Identifier	*Contents Of Datasets*
AVHRR_L1_PGS_DAT_AVHSCE	AVHRR/3-based Scenes Analysis Data [AD-37] (
ATOVS_L2_PGS_TYP_CONFIG	Configuration parameter to configure the retrieval type used and how to validate input dataflows.
ATOVS_L2_PGS_DAT_CLIALB	Climatological Albedo dataset.
ATOVS_L2_PGS_DAT_CLISST	Climatological Sea Surface Temperature SST dataset.
ATOVS_L2_PGS_COF_SSTSW	Coefficients for split window or triple window SST algorithm used by the 'Sea Surface Temperature Retrieval Function'.
ATOVS_L2_PGS_COF_REG	Regression Coefficients for AMSU-A alone Temperature Retrieval. Used by the Alternative Retrieval Method One Function.
ATOVS_L2_PGS_COF_LIMBD	Limb adjustment coefficients for AMSU-A. Used by the Alternative Retrieval Method One Function.
ATOVS_L2_PGS_DAT_FCST	Forecast dataset. Includes sea surface temperatures, two-meter-air temperatures, 1000 hPa air temperature and 1000 hPa height forecasts (12 h, 18 h, 36 h, 48 h) on orbits at 00, 06, 12, 18 UTC.
ATOVS_L2_PGS_DAT_MWEMIS	Microwave emissivity atlas
ATOVS_L2_PGS_DAT_IREMIS	Infrared emissivity atlas to be used in the calculation of the First Guess for the retrieval by the 'Initial Guess Retrieval Selection Function'.
ATOVS_L2_PGS_COF_HIRAMS	Coefficients and threshold values for the HIRS/ AMSU-A inter-channel regression tests of the cloud detection. Used by the Information from AMSU-A Generation and Regression Function.
ATOVS_L2_PGS_COF_HIRCLD	Coefficients and threshold values for the HIRS/4-only tests of the cloud detection. Used by the HIRS/4-only Cloud Analysis Function.
ATOVS_L2_PGS_COF_DELTAC	Bias correction coefficients for the FRTM bias correction used by the Radiances Bias Correction Function.

Dataset Identifier	*Contents Of Datasets*
ATOVS_L2_PGS_DAT_GUESS	First Guess library to be used by the First Guess Search Library Function.
ATOVS_L2_PGS_DAT_AVHSCE	AVHRR/3 Scenes Analysis Results data.
ATOVS_L2_PGS_DAT_FGCONF	Parameters for the First Guess selection method by the First Guess Search Library Function.
ATOVS_L2_PGS_DAT_CLIM	Climatological profiles and surface data used by the Climatological First Guess Composition Function.
ATOVS_L2_PGS_DAT_LAMASK	Geographical land-sea distribution and land type. This is an input-data-based dataset (Surface type and Land/ Sea/Coast flag). Not user-configurable.
ATOVS_L2_PGS_DAT_CLMASK	Cloudy/Clear mask. This is an input-data-based dataset (Clear/Cloudy flag). Not user-configurable.
ATOVS_L2_PGS_DAT_SFCTOP	Geographical land-surface topography distribution.
ATOVS_L2_PGS_DAT_VGRD	Pressure levels and number of levels defining the vertical grid to be used in the Fast Radiative Transfer Model that determines the resolution of the ATOVS Level 2 Retrieved Geophysical Parameters. Used by the ‘Default Retrieval Method Function’, the ‘Alternative Retrieval Method Function’ and the ‘Fast Radiative Transfel Model Function’.
ATOVS_L2_PGS_SEL_CHAN	Selection of channels to be used in the iterative retrieval. Used by the Default Retrieval Method Function.
ATOVS_L2_PGS_THR_ATOVS	Thresholds that will form the valid bounds of the ATOVS Level 2 retrieved geophysical parameters. Used by the On-line Quality Control Function and the ‘Data Formatting Function’.
ATOVS_L2_PGS_THR_AVCLD	Threshold on the weighted AVHRR/3-derived fractional cloud cover defining a HIRS/4 FOV as cloudy.
ATOVS_L2_PGS_THR_AVCLR	Threshold on the weighted AVHRR/3-derived fractional cloud cover defining a HIRS/4 FOV as clear.
ATOVS_L2_PGS_THR_AVFRAC	Minimum fraction of AVHRR/3 pixel that must lie within a HIRS/4 FOV in order to belong to it.
ATOVS_L2_PGS_THR_AVH	Thresholds that will form the valid bounds of the AVHRR/3 cloud mask and S/CTT
ATOVS_L2_PGS_THR_CLDCLR	Threshold values that will be used to determine whether cloud clearing will be carried out by the Cloud Clearing Decision Function.
ATOVS_L2_PGS_THR_FGR	Threshold values that will be used to determine whether the first-guess retrieval is within valid bounds
ATOVS_L2_PGS_THR_ATVCLD	Threshold giving the minimum fractional cloud cover that is declared cloudy in the combined ATOVSAVHRR/ 3 or HIRS/4 stand-alone cloud detection. Used by the HIRS/4-only Cloud Detection Function.

Dataset Identifier	*Contents Of Datasets*
ATOVS_L2_PGS_THR_ATVCLR	Threshold giving the maximum fractional cloud cover that is declared cloud free in the combined ATOVSAVHRR/ 3 or HIRS/4 stand-alone cloud detection. Used by the HIRS/4-only Cloud Detection Function.
ATOVS_L2_PGS_THR_ITER	Threshold determining the criteria for stopping the iterative retrieval. Used by the Default Retrieval Method Function.
ATOVS_L2_PGS_THR_L1VAL	Thresholds that that will form the valid bounds of the ATOVS level 1 radiances and brightness temperatures.
ATOVS_L2_PGS_TYP_INI	Type of initialisation for the retrieval
ATOVS_L2_PGS_TYP_RET	Decision criteria for the retrieval type to be used.
ATOVS_L2_PGS_COF_AMSCI	Coefficients for ‘AMSU-A Scattering Index Calculation Function’.
ATOVS_L2_PGS_COF_MHSSCI	Coefficients for MHS Scattering Index Calculation. Used by the MHS Scattering Index Calculation Function.
ATOVS_L2_PGS_DAT_AMTBM	AMSU-A mean brightness temperatures and brightness covariance matrices (calculated for the 15 channels using a fast radiative transfermodel off-line. Used in the Surface Analysis Function)
ATOVS_L2_PGS_DAT_MHSTBM	MHS mean brightness temperatures and brightness covariance matrices (calculated for the 5 channels using a fast radiative transfer model off-line. Used in the Surface Analysis Function)
ATOVS_L2_PGS_COF_AMSRAT	Coefficients for AMSU-A Rain Tests. Used in the Precipitation Tests Function.
ATOVS_L2_PGS_COF_GTSRES	Configuration file for sub-sampling and contents of the GTS product.used by the Data Formatting Function.
AVHRR_L1_PGS_DAT_FRTM	Power series expansion coefficients for the channel transmittance
AVHRR_L1_PGS_DAT_GAM	Expansion coefficients for the optical depth calculation in the radiative transfer model

APPENDIX C: FAST RADIATIVE TRANSFER MODEL

The specification of the Fast Radiative Transfer Model follows the one of the RTTOV7, which is described by Saunders (2002) (NWP-SAF Web-page). The upwelling spectral radiance $R_{\gamma,\zeta}$ at the top of the atmosphere is described by the following:

$$R_{\gamma,\zeta} = (1-N)\cdot R^{clr}_{\gamma,\zeta} + N\cdot R^{cld}_{\gamma,\zeta}$$

Equation 63

where:

$R^{clr}_{\gamma,\theta}$	upwelling spectral clear-column radiance
$R^{cld}_{\gamma,\theta}$	upwelling spectral overcast radiance
γ	wavenumber
N	fractional cloud cover
ζ	zenith angle

The upwelling spectral clear-column radiance $R_{\gamma,\theta}$ at the top of the atmosphere can be written as follows:

$$R^{clr}_{\gamma,\zeta} = \tau_{s\gamma,\zeta}\varepsilon_{\gamma,\zeta}B_{\gamma}(T)_s + \int_{\tau_{s\gamma,\zeta}}^{1} B_{\gamma}(T)d\tau_{\gamma,\zeta} + [1-\varepsilon_{\gamma,\zeta}]\tau^2_{s,\gamma,\zeta}\int_{\tau_{s\gamma,\zeta}}^{1} B_{\gamma}(T)/\tau^2_{\gamma,\zeta}d\tau_{\gamma,\zeta}$$

Equation 64

where:

$\tau_{\gamma,\zeta}$	atmospheric level to space spectral transmittance
$\tau_{s\gamma,\zeta}$	surface to space spectral transmittance
$\varepsilon_{\gamma},\zeta$	spectral surface emissivity
B_{γ}	spectral Planck's function
T	atmospheric temperature
T_s	surface temperature

where the Planck Function can be written as:

$$B_\gamma(T) = \frac{c_1 \nu^3}{\exp\left(\frac{c_2 \nu}{T} - 1\right)}$$

where $c_1=1.1910427\ 10^{-16}\ W\ m^2\ sr^{-1}$ and $c_2=1.4387752\ 10^{-2}\ mK$ are user-configurable constants.

The upwelling spectral radiance for the overcast sky assuming optically thick clouds is as follows:

$$R^{cld}_{\gamma,\zeta} = \tau^{cld}_{\gamma,\zeta} B_\gamma(T^{cld}) + \int_{\tau_{s\gamma,\zeta}}^{1} B_\gamma(T)\, d\tau_{\gamma,\zeta} \qquad \textbf{Equation 65}$$

where:

$t^{cld}_{\gamma,\zeta}$	is spectral cloud-top to space transmittance
T^{cld}	cloud-top temperature

The radiance is the upwelling spectral radiance convolved with the instrument response function $\Phi k(\gamma)$.

$$R_{k,\zeta} = \frac{\int_{-\infty}^{\infty} R_{\gamma,\zeta} \phi_k(\gamma)\, d\gamma}{\int_{-\infty}^{\infty} \phi_k(\gamma)\, d\gamma} \qquad \textbf{Equation 66}$$

Note: The three equations provided above are given to support user understanding of the concept.

The channel radiance can be calculated assuming that the spectrally averaged transmittance follows Lambert's extinction law. For the calculation of the spectrally averaged radiance in each channel the atmosphere is subdivided in L homogeneous layers, beginning with layer 1 at the top of the atmosphere to layer boundary L next to the surface. Ignoring the indication of the zenith angle one can write.

The upwelling spectral clear-column radiance Rγ,θ at the top of the atmosphere can be written as follows:

$$R_{\gamma}^{clr} = \tau_{s\gamma}\varepsilon_{\gamma}B_{\gamma}(T_s) + \sum_{j=1}^{L} R^{u}{}_{j,\gamma} + (1-\varepsilon_{\gamma})\left[\sum_{j=1}^{L} R^{u}{}_{j,\gamma}\left(\tau^{2}{}_{s\gamma}/(\tau_{j,\gamma}\tau_{j-1,\gamma})\right)\right] + R'_{\gamma}$$

Equation 67

where:

$\tau_{j,\gamma}$	is convolved transmittance from pressure level p_j to space
$T_{s,\gamma}$	is convolved transmittance from surface pressure level p_s to space
R'_{γ}	small atmospheric contribution from the surface to the first layer above the surface

where:

$$R'_{\gamma} = B_{\gamma}(T_{a1})(\tau_{L,\gamma} - \tau_{s,\gamma})$$

and

$$T_{a1} = \frac{1}{2}(T_s + T_L)$$

$$R^{u}{}_{j,\gamma} = [B_{\gamma}(T_j)](\tau_{j-1,\gamma} - \tau_{j,\gamma})$$

Equation 68

All variables with the index γ are spectral values integrated over the spectral channel response as indicated in Equation 64.

The upwelling radiance of the overcast cloudy atmosphere in channel γ is approximated by:

$$R^{cld}_{\gamma} = \tau_{\gamma}^{cld} B_{\gamma}(T^{cld}) + R''_{\gamma} + \sum_{j=1}^{L^{cld}} R^{u}_{j,\gamma}$$

Equation 69

where:

L^{cld}	isthe number of the layer above the cloud top
R’’γ	is additional radiance from the last full layer to the cloud top, obtained by interpolation of the radiance from the last level below the cloud top and the first level above the cloud top:

$$R''_{\gamma} = B_{\gamma}(T^{cl})(\tau_{L,\gamma} - \tau_{\gamma}^{cld})$$

Equation 191

where:

$$T^{cl} = \frac{1}{2}(T^{cld} + T_{L^{cld}})$$

Equation 192

The radiative transfer equation is solved on a vertical grid defined by the default reference pressure levels given in [RD-18] and listed in Table 29.

The level-to-space transmittance of an absorber, labelled n, is calculated from the convolved level to space optical depth $\delta_{j,k,n}$ in channel *k*:

$$\tau_{j,\gamma,n} = \exp(-\delta_{j,\gamma,n})$$

Equation 70

where the calculation of $\delta_{j,k,n}$ for a slant path from level *j* to space at a zenith angle θ involves functions of temperature, absorber amount, pressure and zenith angle:

$$\delta_{\gamma,j} = \delta_{\gamma,j-1} + \sum_{m=1}^{M} a_{\gamma,j,m}\Psi_{j,m}$$

Equation 71

where:

M	is the number of predictors, labelled m
$\Psi_{j,m}$	functions constituting the profile-dependent predictors,
$a_{k,j,m}$	expansion coefficients, depending on the channel , the atmospheric layer, and the predictor function.
$\zeta_{\gamma,0}$	equals 0

Following Lambert's law the total transmittance for the total number N of aborbers is written as:

$$\tau_{j,k} = \prod_{n=1}^{N} \tau_{j,k,n}$$

Equation 72

Predictor	***Mixed Gases***	***Water Vapour***	***Ozone***
$\Psi_{j,1}$	$sec(\zeta)$	$sec^2(\zeta)W_r^{\,2}(j)$	$sec(\zeta)O_r(j)$
$\Psi_{j,2}$	$sec^2(\zeta)$	$(sec(\zeta)W_w(j))^2$	$\sqrt{\sec(\zeta)O_r(j)}$
$\Psi_{j,3}$	$sec(\zeta)T_r(j)$	$(sec(\zeta)W_w(j))^4$	$sec(\zeta)O_r(j)\delta T(j)$
$\Psi_{j,4}$	$sec(\zeta)Tr^2(j)$	$sec(\zeta)Wr(j)\ \delta\ T(j)$	$(sec(\zeta)Or(j))2$
$\Psi_{j,5}$	$T_r(j)$	$\sqrt{\sec\zeta W_r(j)}$	$\sqrt{\sec(\zeta)O_r(j)}\,\delta T(j)$
$\Psi_{j,6}$	$T_r^{\,2}(j)$	$\sqrt[4]{\sec\zeta W_r(j)}$	$sec(\zeta)O_r^{\,2}(j)O_w(j)$
$\Psi_{j,7}$	$sec(\zeta)T_w(j)$	$sec(\zeta)W_r(j)$	$\frac{O_r(j)}{O_w(j)}\sqrt{\sec(\zeta)O_r(j)}$
$\Psi_{j,8}$	$sec(\zeta)T_w(j)/T_r(j)$	$(sec(\zeta)W_r(j))^3$	$sec(\zeta)O_r(j)O_w(j)$
$\Psi_{j,9}$	$\sqrt{\sec(\zeta)}$	$(sec(\zeta)W_r(j))^4$	$O_r(j)\sec(\zeta)\sqrt{O_w(j)\sec(\zeta)}$
$\Psi_{j,10}$	$\sqrt{\sec(\zeta)}\,\sqrt[4]{T_w(j)}$	$sec(\zeta)W_r(j)\ \delta\ T(j)\vert\ \delta\ T(j)\vert$	$sec(\zeta)O_w(j)$

Predictor	*Mixed Gases*	*Water Vapour*	*Ozone*
$\Psi_{j,11}$	*0*	$(\sqrt{\sec(\zeta)W_j(j)})\delta T(j))$	$(\sec(\zeta)O_w(j))^2$
$\Psi_{j,12}$	*0*	$\frac{(\sec(\zeta)W_r(j))^2}{W_w(j)}$	*0*
$\Psi_{j,13}$	*0*	$\frac{(\sqrt{\sec(\zeta)W_r(j)})W_r(j)}{W_w(j)}$	*0*
$\Psi j,14$	*0*	$\sec(\zeta)\cdot\frac{W_r^2(j)}{T_r(j)}$	*0*
$\Psi_{j,15}$	*0*	$\sec(\zeta)\cdot\frac{W_r^2(j)}{T_r^4(j)}$	*0*

Table 28: Predictors for mixed gases, water vapour and ozone.

The profile variables used are defined as follows:

$$T(1) = T^{profile}(1)$$

$$T(l) = \frac{1}{2}[T^{profile}(l-1) + T^{profile}(l)], \text{for } l \geq 2$$

Equation 195

$$W(1) = W^{profile}(1)$$

$$W(l) = \frac{1}{2}[W^{profile}(l-1) + W^{profile}(l)], \text{for } l \geq 2$$

Equation 196

$$O(1) = O^{profile}(1)$$

$$O(l) = \frac{1}{2}[O^{profile}(l-1) + O^{profile}(l)], \text{for } l \geq 2$$

Equation 197

$$P(l) = [Pres(l)]$$

Equation 198

$$T^*(1) = T^{reference}(1)$$
$$T^*(l) = \frac{1}{2}[T^{reference}(l-1) + T^{reference}(l)], \text{ for } l \geq 2$$

Equation 199

$$W^*(1) = W^{reference}(1)$$
$$W^*(l) = \frac{1}{2}[W^{reference}(l-1) + W^{reference}(l)], \text{ for } l \geq 2$$

Equation 200

$$O^*(1) = O^{reference}(1)$$
$$O^*(l) = \frac{1}{2}[O^{reference}(l-1) + O^{reference}(l)], \text{ for } l \geq 2$$

Equation 201

$$T_r(l) = \frac{T(l)}{T^*(l)}$$

Equation 202

$$O_r(l) = \frac{O(l)}{O^*(l)}$$

Equation 203

$$W_r(l) = \frac{W(l)}{W^*(l)}$$

Equation 204

$$\delta T(l) = T(l) - T^*(l)$$

Equation 205

$\bar{P}(1) = P(0)(P(1) - P(0))$

and

$\bar{P}(l) = P(l-1)(P(l-1) - P(l-2))$, for $l \geq 2$

where P(0) = 0.004985 hPa

$$T_w(l) = \sum_{i=2}^{l} \bar{P}(i) T_r(i-1)$$

Equation 206

$$W_w(l) = \frac{\sum_{i=1}^{l} \bar{P}(i) W(i)}{\sum_{i=1}^{l} \bar{P}(i) W^*(i)}$$

Equation 207

$$O_w(l) = \frac{\sum_{i=1}^{l} \bar{P}(i) O(i)}{\sum_{i=1}^{l} \bar{P}(i) O^*(i)}$$

Equation 208

where:

$T^{profile}(l)$	is temperature profile
$W^{profile}(l)$	is water vapour mixing ratio profile
$O^{profile}(l)$	is ozone mixing ratio profile
$T^{reference}(l)$	is corresponding temperature reference profile
$W^{reference}(l)$	is corresponding water vapour mixing ratio reference profile
$O^{reference}(l)$	is corresponding ozone mixing ratio reference profile
Pres(l)	is the value of the pressure at each layer boundary

For these variables, l refers to the l^{th} level, otherwise l is the l^{th} layer–the layer above the l^{th} level. Notice that:

$$T_w(1) = 0$$

Equation 210

j	p_j (Pa)	T_j^{ref} (K)	q_j^{ref} (ppm$_v$)	T_{Ol}^{ref} (K)	W_{Ol}^{ref} (ppm$_v$)	O_l^{ref} (ppm$_v$)
1	10	232.73560	5.62008	241.69600	5.62008	5.85000
2	29	247.98441	6.04690	256.76080	6.04690	6.03765
3	69	256.37299	5.95388	266.11090	5.95388	6.10709
4	142	254.91769	5.65560	263.09839	5.65560	6.14069
5	261	250.63200	5.24564	255.23019	5.24564	6.16667
6	441	242.91570	5.04672	244.63840	5.04672	6.18371
7	695	234.81230	4.74912	235.01649	4.74912	6.16342
8	1037	228.12920	4.52328	228.79649	4.52328	6.18313
9	1481	223.60210	4.29048	224.90050	4.29048	6.12541
10	2040	220.67709	4.21697	221.42419	4.21697	5.64727
11	2726	218.63890	4.24207	219.37669	4.24207	4.88745
12	3551	216.97780	4.18057	217.93150	4.18057	4.05588
13	4529	215.56230	4.00268	216.52980	4.00268	3.13329
14	5673	214.17599	3.86068	215.35519	3.86068	2.24745
15	6997	212.99350	3.65714	214.43350	3.65714	1.55810
16	8518	212.39110	3.43363	213.93800	3.43363	1.03926
17	10205	212.50810	3.57664	213.79111	3.57664	0.71842
18	12204	213.29730	6.89209	214.92430	6.50863	0.51004
19	14384	214.27960	11.92845	216.17690	10.74798	0.39213
20	16795	215.23340	19.74968	216.84129	18.10853	0.31788
21	19436	216.08591	31.17634	218.07600	27.61735	0.24911
22	22294	217.63040	47.35269	220.01019	41.94730	0.18302
23	25371	219.36549	70.29995	222.75391	61.91838	0.12726
24	28660	222.43520	101.04910	226.50169	85.31697	0.09432
25	32150	226.02679	151.17461	231.22990	144.46190	0.07452
26	35828	230.23210	230.19659	236.55690	252.89841	0.06492
27	39681	234.52570	334.61609	241.76810	422.00510	0.06077
28	43695	238.79111	478.42880	246.72301	654.98712	0.05793
29	47854	242.92999	664.99438	251.38110	949.25452	0.05533
30	52146	246.73830	896.79120	255.59019	1430.26501	0.05379

j	p_j (Pa)	T_j^{ref} (K)	q_j^{ref} (ppm_v)	T_{Ol}^{ref} (K)	W_{Ol}^{ref} (ppm_v)	O_l^{ref} (ppm_v)
31	56554	250.40460	1189.37695	259.53680	1924.21204	0.05109
32	61060	253.75180	1507.34302	263.14810	2592.13208	0.04898
33	65643	256.76779	1859.26501	266.46719	3027.12500	0.04696
34	70273	259.47131	2280.73096	269.49860	4154.72119	0.04570
35	74912	261.78741	2750.69189	272.26611	5588.23779	0.04295
36	79509	263.75479	3262.85010	274.85611	6866.95801	0.04004
37	83995	265.50671	3866.75806	277.17380	7878.44287	0.03718
38	88280	266.80969	4272.99121	279.26810	8984.39160	0.03426
39	92246	267.84000	4482.85400	281.14081	10166.28027	0.03146
40	95744	268.55490	4575.54883	282.75211	11667.99023	0.02892
41	98588	268.79541	4524.35791	283.99341	12805.48047	0.02679
42	100543	268.89209	4467.97412	284.84549	13587.11035	0.02533
43	101325	268.94189	4449.71387	285.18759	13901.19043	0.02474

Table 29: Reference profiles (user-configurable)

Note: The reference profile here is given as an example.

Derivatives of the Fast Radiative Transfer Model

There is a need to establish the Jacobians–the partial derivatives of the Brightness Temperatures– with respect to the elements of the state vector. (No indication of the zenith angle ζ is given to make the formula more readable.) A state vector element x_i leads to the following partial derivatives for the Fast Radiative Transfer Model:

$$\frac{\partial R_{\gamma,\theta}}{\partial x_i} = \frac{\partial R_\gamma}{\partial x_i} = \frac{\partial}{\partial x_i}[(1-N)R^{clr}{}_\gamma + NR^{cld}{}_\gamma] \qquad \textit{Equation 211}$$

where x_I is an element of the state vector and γ denotes the spectral index. The zenith angle index θ was omitted on right-hand sides of the equation.

Hence:

$$\frac{\partial R_\gamma}{\partial x_i} = \frac{\partial R_\gamma}{\partial N} + \frac{\partial R_\gamma}{\partial R^{clr}{}_\gamma}\frac{\partial R^{clr}{}_\gamma}{\partial x_i} + \frac{\partial R_\gamma}{\partial R^{cld}{}_\gamma}\frac{\partial R^{cld}{}_\gamma}{\partial x_i} \qquad \textit{Equation 212}$$

where

$$\frac{\partial R_\gamma}{\partial N} = -1R^{clr}{}_\gamma + R^{cld}{}_\gamma$$

Equation 213

$$\frac{\partial R_\gamma}{\partial R^{clr}{}_\gamma} = 1 - N$$

Equation 214

$$\frac{\partial R_{\gamma,\theta}}{\partial R^{cld}{}_\gamma} = N$$

Equation 215

$$\frac{\partial R^{clr}{}_\gamma}{\partial x_i} = \frac{\partial R^{clr}{}_\gamma}{\partial \tau_{S\gamma}}\frac{\partial \tau_{S\gamma}}{\partial x_i} + \frac{\partial R^{clr}{}_\gamma}{\partial B_\gamma}\frac{\partial B_\gamma}{\partial x_i} + \frac{\partial R^{clr}{}_\gamma}{\partial R^u{}_{j,\gamma}}\frac{\partial R^u{}_{j,\gamma}}{\partial x_i} + \frac{\partial R^{clr}{}_\gamma}{\partial R'{}_\gamma}\frac{\partial R'{}_\gamma}{\partial x_i} + \frac{\partial R^{clr}{}_\gamma}{\partial \tau_{j,\gamma}}\frac{\partial \tau_{j,\gamma}}{\partial x_i} + \frac{\partial R^{clr}{}_\gamma}{\partial \tau_{j-1,\gamma}}\frac{\partial \tau_{j-1,\gamma}}{\partial x_i}$$

Equation 216

where

$$\frac{\partial R^{clr}{}_\gamma}{\partial \tau_{S\gamma}} = \varepsilon_\gamma B_\gamma(T_S) + 2(1-\varepsilon_\gamma)\sum_{j=1}^{L} R^u{}_{j,\gamma}\left(\frac{\tau_{S\gamma}}{\tau_{j,\gamma}\tau_{j-1,\gamma}}\right)$$

Equation 217

$$\frac{\partial R^{clr}{}_\gamma}{\partial B_\gamma} = \tau_{S\gamma}\varepsilon_\gamma$$

Equation 218

$$\frac{\partial B_\gamma}{\partial x_i} \neq 0$$

Equation 219

only for T_s, hence with

$$B_\gamma(T_S) = \frac{c_1 \upsilon^3_\gamma}{(\exp((c_2\upsilon_\gamma)/T_s) - 1)}$$ **Equation 220**

we have:

$$\frac{\partial B_\gamma}{\partial T_S} = \frac{c_1 c_2 \upsilon_\gamma^4 \exp((c_2\upsilon_\gamma)/T_s)}{(\exp((c_2\upsilon_\gamma)/T_s) - 1)^2 T_S^2}$$ **Equation 221**

$$\frac{\partial R^{clr}{}_\gamma}{\partial R^u{}_{j,\gamma}} = 1 + (1 - \varepsilon_\gamma)\frac{\tau_{S\gamma}^2}{\tau_{j,\gamma}\tau_{j-1,\gamma}}$$ **Equation 222**

$$\frac{\partial R^{clr}{}_\gamma}{\partial \tau_{j,\gamma}} = (1 - \varepsilon_\gamma)(-1)R^u{}_{j,\gamma}\frac{\tau_{S\gamma}^2}{(\tau_{j,\gamma}\tau_{j-1,\gamma})^2}\tau_{j-1,\gamma}$$ **Equation 223**

$$\frac{\partial R^{clr}{}_\gamma}{\partial \tau_{j-1,\gamma}} = (1 - \varepsilon_\gamma)(-1)R^u{}_{j,\gamma}\frac{\tau_{S\gamma}^2}{(\tau_{j,\gamma}\tau_{j-1,\gamma})^2}\tau_{j,\gamma}$$ **Equation 224**

$$\frac{\partial R^{clr}{}_\gamma}{\partial R'_\gamma} = 1$$ **Equation 225**

$$\frac{\partial R^{cld}{}_\gamma}{\partial \tau_\gamma^{cld}} = B_\gamma(T^{cld})$$ **Equation 226**

$$\frac{\partial R^{cld}{}_{\gamma}}{\partial B_{\gamma}} = \tau_{\gamma}{}^{cld}$$ ***Equation 227***

$$\frac{\partial R^{clr}{}_{\gamma}}{\partial R''_{\gamma}} = 1$$ ***Equation 228***

$$\frac{\partial R^{cld}{}_{\gamma}}{\partial R^{u}{}_{j,\gamma}} = 1$$ ***Equation 229***

Assume:

$$T_{a1} = \frac{1}{2}(T_S + T_L)$$ ***Equation 230***

and

$$T_a^{cld} = \frac{1}{2}(T^{cld} + T_{LC})$$ ***Equation 231***

Then, we have

$$\frac{\partial R'_{\gamma}}{\partial x_i} = \frac{\partial R'_{\gamma}}{\partial B_{\gamma}}\frac{\partial B_{\gamma}}{\partial x_i} + \frac{\partial R'_{\gamma}}{\partial \tau_{L,\gamma}}\frac{\partial \tau_{L,\gamma}}{\partial x_i} + \frac{\partial R'_{\gamma}}{\partial \tau_{S,\gamma}}\frac{\partial \tau_{S,\gamma}}{\partial x_i}$$ ***Equation 232***

where

$$\frac{\partial R'_\gamma}{\partial B_\gamma} = \tau_{L,\gamma} - \tau_{S,\gamma}$$ ***Equation 233***

$$\frac{\partial R'_\gamma}{\partial \tau_{L,\gamma}} = B_\gamma(T_{a1})$$ ***Equation 234***

$$\frac{\partial R'_\gamma}{\partial \tau_{S,\gamma}} = -B_\gamma(T_{a1})$$ ***Equation 235***

$$\frac{\partial B_\gamma}{\partial x_i} = \frac{\partial B_\gamma}{\partial T_{a1}} \frac{\partial T_{a1}}{\partial x_i}$$ ***Equation 236***

$$\frac{\partial B_\gamma}{\partial T_{a1}} = \frac{c_1 c_2 \upsilon_\gamma^4 \exp((c_2 \upsilon_\gamma)/T_{a1})}{(\exp((c_2 \upsilon_\gamma)/T_{a1}) - 1)^2 T_{a1}^2}$$ ***Equation 237***

$$\frac{\partial T_{a1}}{\partial x_i} = \frac{1}{2}$$ ***Equation 238***

for $x_i = T_s$ or $x_i = T_L$. Otherwise, it is zero.

$$\frac{\partial \tau_{L,\gamma}}{\partial x_i} = \frac{\partial \tau_{L,\gamma}}{\partial \tau_{L,\gamma,n}} \frac{\partial \tau_{L,\gamma,n}}{\partial x_i}$$ ***Equation 239***

$$\frac{\partial \tau_{L,\gamma}}{\partial \tau_{L,\gamma,n}} = \prod_{m=1,\, n \neq m}^{N} \tau_{L,\gamma,m}$$

Equation 240

$$\frac{\partial \tau_{S,\gamma}}{\partial x_i} = \frac{\partial \tau_{S,\gamma}}{\partial \tau_{S,\gamma,n}} \frac{\partial \tau_{S,\gamma,n}}{\partial x_i}$$

Equation 241

$$\frac{\partial \tau_{S,\gamma}}{\partial \tau_{S,\gamma,n}} = \prod_{m=1,\, n \neq m}^{N} \tau_{S,\gamma,m}$$

Equation 242

$$\frac{\partial \tau_{j,\gamma}}{\partial x_i} = \frac{\partial \tau_{j,\gamma}}{\partial \tau_{j,\gamma,n}} \frac{\partial \tau_{j,\gamma,n}}{\partial x_i}$$

Equation 243

$$\frac{\partial \tau_{j,\gamma}}{\partial \tau_{j,\gamma,n}} = \prod_{m=1,\, n \neq m}^{N} \tau_{j,\gamma,m}$$

Equation 244

The derivative $\frac{\partial \tau_{j,\gamma}}{\partial x_i}$ is estimated in an analogue way by replacing j by j-1.

$$\frac{\partial \tau^{cld}{}_{\gamma}}{\partial x_i} = \frac{\partial \tau^{cld}{}_{\gamma}}{\partial \tau^{cld}{}_{\gamma,n}} \frac{\partial \tau^{cld}{}_{\gamma,n}}{\partial x_i}$$

Equation 245

$$\frac{\partial \tau^{cld}{}_{\gamma}}{\partial \tau^{cld}{}_{\gamma,n}} = \prod_{m=1,\, n \neq m}^{N} \tau^{cld}{}_{\gamma,m}$$

Equation 246

$$\frac{\partial R''_{\gamma}}{\partial x_i} = \frac{\partial R''_{\gamma}}{\partial B_{\gamma}} \frac{\partial B_{\gamma}}{\partial x_i} + \frac{\partial R''_{\gamma}}{\partial \tau_{L,\gamma}} \frac{\partial \tau_{L,\gamma}}{\partial x_i} + \frac{\partial R''_{\gamma}}{\partial \tau^{cld}{}_{\gamma}} \frac{\partial \tau^{cld}{}_{\gamma}}{\partial x_i}$$

Equation 247

$$\frac{\partial R''_{\gamma}}{\partial B_{\gamma}} = \tau_{L,\gamma} - \tau^{cld}{}_{\gamma}$$

Equation 248

$$\frac{\partial R''_{\gamma}}{\partial \tau_{L,\gamma}} = B_{\gamma}(T^{cld}{}_{a})$$

Equation 249

$$\frac{\partial R''_{\gamma}}{\partial \tau_{\gamma}^{cls}} = -B_{\gamma}(T_a^{cld})$$

Equation 250

$$\frac{\partial B_{\gamma}}{\partial x_i} = \frac{\partial B_{\gamma}}{\partial T^{cld}{}_{a}} \frac{\partial T^{cld}{}_{a}}{\partial x_i}$$

Equation 251

$$\frac{\partial T^{cld}{}_a}{\partial x_i} = \frac{1}{2}$$ ***Equation 252***

for $x_i = T_a^{cld}$ or $x_i = T_L$. Otherwise, it is zero.

$$\frac{\partial R^u{}_{j,\gamma}}{\partial x_i} = \frac{\partial R^u{}_{j,\gamma}}{\partial B_\gamma}\frac{\partial B_\gamma}{\partial x_i} + \frac{\partial R^u{}_{j,\gamma}}{\partial \tau_{j-1,\gamma}}\frac{\partial \tau_{j-1,\gamma}}{\partial x_i} + \frac{\partial R^u{}_{j,\gamma}}{\partial \tau_{j,\gamma}}\frac{\partial \tau_{j,\gamma}}{\partial x_i}$$ ***Equation 253***

where

$$\frac{\partial R^u{}_{j,\gamma}}{\partial B_\gamma} = (\tau_{j-1,\gamma} - \tau_{j,\gamma})$$ ***Equation 254***

$$\frac{\partial R^u{}_{j,\gamma}}{\partial \tau_{j-1,\gamma}} = B_\gamma(T_j)$$ ***Equation 255***

$$\frac{\partial R^u{}_{j,\gamma}}{\partial \tau_{j,\gamma}} = -B_\gamma(T_j)$$ ***Equation 256***

and

$$\frac{\partial B_\gamma}{\partial x_i} = \frac{\partial B_\gamma}{\partial T_k}\frac{\partial T_k}{\partial x_i}$$ ***Equation 257***

$$\frac{\partial B_\gamma}{\partial T_j} = \frac{c_1 c_2 \gamma_\gamma^4 \exp((c_2 \upsilon_\gamma)/T_j)}{(\exp((c_2 \upsilon_\gamma)/T_j) - 1)^2 T_j^2}$$ ***Equation 258***

$$\frac{\partial T_j}{\partial T_k} = \frac{1}{2}$$ ***Equation 259***

for $k = j, j+1$, zero else.

$$\frac{\partial \tau_{j,\gamma,n}}{\partial x_i} = \frac{\partial \tau_{j,\gamma,n}}{\partial \delta_{j,\gamma,n}} \frac{\partial \delta_{j,\gamma,n}}{\partial x_i}$$ ***Equation 260***

$$\frac{\partial \tau_{j,\gamma,n}}{\partial \delta_{j,\gamma,n}} = -\exp(-\delta_{j,\gamma,n})$$ ***Equation 261***

and in analogue way one obtains the derivatives for $\frac{\partial \tau_{S,\gamma,n}}{\partial x_i}$, $\frac{\partial \tau_{L,\gamma,n}}{\partial x_i}$ and $\frac{\partial \tau^{cld}_{\gamma,n}}{\partial x_i}$

Furthermore it is, under omission of the index for the absorber amount, *n*

$$\frac{\partial \delta_{j,\gamma}}{\partial x_i} = \frac{\partial \delta_{j-1,\gamma}}{\partial x_i} + \frac{\partial \delta_{j,\gamma}}{\partial \Psi_{j,m}} \frac{\partial \Psi_{j,m}}{\partial x_i}$$ ***Equation 262***

$\frac{\partial \delta_{j-1,\gamma}}{\partial x_i}$ is recursively calculated as $\frac{\partial \delta_{j,\gamma}}{\partial x_i}$, the index *j* replaced by *j-1*. $\delta_{0,\gamma}$ is set to zero:

$$\delta_{0,\gamma} = 0$$ ***Equation 263***

$$\frac{\partial \delta_{j,\gamma}}{\partial \Psi_{j,m}} = \sum_{m=1}^{M} \alpha_{\gamma,j,m}$$ ***Equation 264***

Partial derivatives used in Equation 262

	mixed gases
$\frac{\partial\Psi_{j,1}}{\partial x_i}$	0
$\frac{\partial\Psi_{j,2}}{\partial x_i}$	0
$\frac{\partial\Psi_{j,3}}{\partial x_i}$	$\sec\zeta\frac{\partial T_r(j)}{\partial x_i}$
$\frac{\partial\Psi_{j,4}}{\partial x_i}$	$2\sec\zeta T_r(j)\frac{\partial T_r(j)}{\partial x_i}$
$\frac{\partial\Psi_{j,5}}{\partial x_i}$	$\frac{\partial T_r(j)}{\partial x_i}$
$\frac{\partial\Psi_{j,6}}{\partial x_i}$	$2T_r(j)\frac{\partial T_r(j)}{\partial x_i}$
$\frac{\partial\Psi_{j,7}}{\partial x_i}$	$\sec\zeta\frac{\partial T_w(j)}{\partial x_i}$
$\frac{\partial\Psi_{j,8}}{\partial x_i}$	$\sec\zeta\left[\frac{\partial T_w(j)}{\partial x_i}\frac{1}{T_r(j)} - \frac{\partial T_r(j)}{\partial x_i}\cdot\frac{1}{T_r^2(j)}T_w(j)\right]$
$\frac{\partial\Psi_{j,9}}{\partial x_i}$	0
$\frac{\partial\Psi_{j,10}}{\partial x_i}$	$\sqrt{\sec(\zeta)}\cdot\frac{1}{4}\cdot\frac{1}{\sqrt[4]{T_w^3(j)}}\frac{\partial T_w(j)}{\partial x_i}$
$\frac{\partial\Psi_{j,11}}{\partial x_i}$	0

	mixed gases
$\frac{\partial \Psi_{j,12}}{\partial x_i}$	0
$\frac{\partial \Psi_{j,13}}{\partial x_i}$	0
$\frac{\partial \Psi_{j,14}}{\partial x_i}$	0
$\frac{\partial \Psi_{j,15}}{\partial x_i}$	0

	water vapour
$\frac{\partial \Psi_{j,1}}{\partial x_i}$	$2\sec(\zeta)W_r(j)\frac{\partial W_r(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,2}}{\partial x_i}$	$2\sec(\zeta)W_w(j)\sec(\zeta)\frac{\partial W_w(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,3}}{\partial x_i}$	$4(\sec(\zeta)W_w(j))^3\sec(\zeta)\frac{\partial W_w(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,4}}{\partial x_i}$	$\sec(\zeta)\left(W_r(j)\frac{\partial \delta T(j)}{\partial x_i}+\frac{\partial W_r(j)}{\partial x_i}\delta T(j)\right)$
$\frac{\partial \Psi_{j,5}}{\partial x_i}$	$\frac{1}{2}(\sec(\zeta)W_r(j))^{-\frac{1}{2}}\frac{\partial W_r(j)}{\partial x_i}$

	water vapour
$\frac{\partial \Psi_{j,6}}{\partial x_i}$	$\frac{1}{4}(\sec(\zeta)W_r(j))^{-\frac{3}{4}}\frac{\partial W_r(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,7}}{\partial x_i}$	$\sec\zeta\frac{\partial W_r(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,8}}{\partial x_i}$	$3(\sec(\zeta)W_r(j))^{2}\frac{\partial W_r(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,9}}{\partial x_i}$	$4(\sec(\zeta)W_r(j))^{3}\frac{\partial W_r(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,10}}{\partial x_i}$	$\sec(\zeta)\left\{\frac{\partial W_r(j)}{\partial x_i}\delta T(j)\lvert\delta T(j)\rvert + W_r(j)\left(\frac{\partial \delta T(j)}{\partial x_i}\lvert\delta T(j)\rvert + \delta T(j) sign(\delta T(j))\frac{\partial \delta T(j)}{\partial x_i}\right)\right\}$
$\frac{\partial \Psi_{j,11}}{\partial x_i}$	$\sec(\zeta)W_r(j))^{-\frac{1}{2}}\sec(\zeta)\frac{\partial W_r(j)}{\partial x_i}\delta T(j) + (\sec(\zeta)W_r(j))^{\frac{1}{2}}\frac{\partial \delta T(}{\partial x}$
$\frac{\partial \Psi_{j,12}}{\partial x_i}$	$:(\zeta)W_r(j))\frac{1}{W_w(j)}\frac{\partial W_r(j)}{\partial x_i} - (\sec(\zeta)W_r(j))^{2}\cdot\frac{1}{W_w^2(j)}\frac{\partial W}{}$

	water vapour
$\frac{\partial \Psi_{j,13}}{\partial x_i}$	$(\sec(\zeta) W_r(j))^{-\frac{1}{2}}$ $\frac{\partial W_r(j)}{\partial x_i}\frac{W_r(j)}{W_w(j)} + (\sec(\zeta) W_r(j))^{\frac{1}{2}}\left\{\frac{1}{W_w(j)}\frac{\partial W_r(j)}{\partial x_i} - \frac{1}{W_w^2(j)}\frac{\partial W_r(j)}{\partial x_i}\right\}$
$\frac{\partial \Psi_{j,14}}{\partial x_i}$	$\sec(\zeta)\left(\frac{2W_r(j)}{T_r(j)}\frac{\partial W_r(j)}{\partial x_i} - W_r(j)\frac{\partial T_r(j)}{\partial x_i}\right)$
$\frac{\partial \Psi_{j,15}}{\partial x_i}$	$\sec(\zeta)\left(\frac{2W_r(j)}{T_r^4(j)}\frac{\partial W_r(j)}{\partial x_i} - \frac{W_r^2(j)}{T_r^5(j)}\frac{\partial T_r(j)}{\partial x_i}\right)$

	Ozone
$\frac{\partial \Psi_{j,1}}{\partial x_i}$	$\sec(\zeta)\frac{\partial O_r(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,2}}{\partial x_i}$	$\frac{1}{2}(\sec(\zeta)O_r(j))^{-\frac{1}{2}}\frac{\partial O_r(j)}{\partial x_i}\sec(\zeta)$
$\frac{\partial \Psi_{j,3}}{\partial x_i}$	$\sec(\zeta)\left(\delta T(j)\frac{\partial O_r(j)}{\partial x_i} + \frac{\partial \delta T(j)}{\partial x_i}O_r(j)\right)$
$\frac{\partial \Psi_{j,4}}{\partial x_i}$	$2(\sec(\zeta)O_r(j))\frac{\partial O_r(j)}{\partial x_i}\sec(\zeta)$
$\frac{\partial \Psi_{j,5}}{\partial x_i}$	$\frac{1}{2}(\sec(\zeta)O_r(j))^{-\frac{1}{2}}\frac{\partial O_r(j)}{\partial x_i}\sec(\zeta)\delta T(j) + (\sec(\zeta)O_r(j))^{\frac{1}{2}}\frac{\partial \delta T(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,6}}{\partial x_i}$	$2(\sec(\zeta)O_r(j))\frac{\partial O_r(j)}{\partial x_i}O_w(j) + \sec(\zeta)O^2{}_r(j)\frac{\partial O_w(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,7}}{\partial x_i}$	$(\sec(\zeta)O_r(j))^{\frac{1}{2}}\left[\frac{\partial O_r(j)}{\partial x_i}\frac{1}{O_w(j)} - \frac{O_r(j)}{O^2{}_w(j)}\frac{\partial O_w(j)}{\partial x_i}\right] + \frac{O_r(j)}{O_w(j)}\frac{1}{2}(\sec(\zeta)O_r(j))^{-\frac{1}{2}}\frac{\partial O_r(j)}{\partial x_i}\sec(\zeta)$
$\frac{\partial \Psi_{j,8}}{\partial x_i}$	$\sec(\zeta)\frac{\partial O_r(j)}{\partial x_i}O_w(j) + \sec(\zeta)O_r(j)\frac{\partial O_w(j)}{\partial x_i}$

	Ozone
$\frac{\partial \Psi_{j,9}}{\partial x_i}$	$\sec(\zeta)\frac{\partial O_r(j)}{\partial x_i}(\sec(\zeta)O_w(j))^{\frac{1}{2}} + \frac{1}{2}\sec(\zeta)O_r(j)(\sec(\zeta)O_w(j))^{\frac{1}{2}}\sec(\zeta)\frac{\partial O_w(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,10}}{\partial x_i}$	$\sec(\zeta)\frac{\partial O_w(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,11}}{\partial x_i}$	$2\sec(\zeta)O_w(j)\sec(\zeta)\frac{\partial O_w(j)}{\partial x_i}$
$\frac{\partial \Psi_{j,12}}{\partial x_i}$	0
$\frac{\partial \Psi_{j,13}}{\partial x_i}$	0
$\frac{\partial \Psi_{j,14}}{\partial x_i}$	0
$\frac{\partial \Psi_{j,15}}{\partial x_i}$	0

Furthermore, we have:

$$\frac{\partial T_r(j)}{\partial x_i} = \frac{1}{T^*}\frac{\partial T(j)}{\partial x_i}$$ ***Equation 265***

where

$$\frac{\partial T(j)}{\partial x_i} = \frac{1}{2}$$ ***Equation 266***

for $x_i = T(j)$, $x_i = T(j + 1)$ and little else

It is as follows:

$$\frac{\partial T_w(j)}{\partial x_i} = \sum_{k=2}^{l} \frac{\partial T_r(k-1)}{\partial x_i} P(k)[P(k) - P(k-1)]$$ ***Equation 267***

$$\frac{\partial W_r(j)}{\partial x_i} = \frac{1}{W^*}\frac{\partial W(j)}{\partial x_i}$$ ***Equation 268***

where:

$$\frac{\partial W(j)}{\partial x_i} = \frac{1}{2}$$ ***Equation 269***

for $x_i = W(j)$, $x_i = \mathrm{W}(j + 1)$ and little else:

$$\frac{\partial W_w(j)}{\partial x_i} = \frac{\sum_{k=2}^{l} \frac{\partial W(k)}{\partial x_i} P(k)[P(k) - P(k-1)]}{\sum_{k=2}^{l} P(k)[P(k) - P(k-1)] W^*(k)}$$ ***Equation 270***

$$\frac{\partial \delta T(j)}{\partial x_i} = \frac{\partial \delta T(j)}{\partial T(j)} \frac{\partial T(j)}{\partial x_i}$$

Equation 271

where:

$$\frac{\partial \delta T(j)}{\partial T(j)} = 1$$

Equation 272

and zero else.

Finally:

$$\frac{\partial O_r(j)}{\partial x_i} = \frac{1}{O^*} \frac{\partial O(j)}{\partial x_i}$$

Equation 273

where

$$\frac{\partial O(j)}{\partial x_i} = \frac{1}{2}$$

Equation 274

for $x_i = O(j)$, $x_i = O(j+1)$ and zero else.

$$\frac{\partial O_w(j)}{\partial x_i} = \frac{\sum_{k=2}^{l} \frac{\partial O(k)}{\partial x_i} P(k)[P(k) - P(k-1)]}{\sum_{k=2}^{l} P(k)[P(k) - P(k-1)] O^*(k)}$$

Equation 275