Copernicus Climate Change Service

Product User Guide – Metop GRAS Level 1b Bending Angle FCDR Release 2

D 2.1

Issued by: EUMETSAT
Date: 19/07/2019
REF.: C3S_311b-WP2 Task 2.1
Service contract: 2016/C3S_311b _EUMETSAT

Contributors

EUMETSAT
Yago Andres
Rob Roebeling
Axel von Engeln
Christian Marquardt
Jörg Schulz

Contents:

List of Figures

List of Tables

1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this guide is to provide users with detailed information about Release 2 of the Fundamental Climate Data Record (FCDR) of Level 1b bending angles from the Global Navigation Satellite System (GNSS) Receiver for Atmospheric Sounding (GRAS) instrument on Metop-A and Metop-B, hereinafter referred to as Release 2 - GRAS Level 1b Bending Angle FCDR. This release was produced with the wave-optics-based retrieval implemented in Yaros 1.4 [RD 3], and comprises Level 1b data from Metop-A for the period 2006–2017 and from Metop-B for the period 2012-2017, and can be regarded as an FCDR, i.e., a long-term data record of calibrated and quality-controlled sensor data. This is designed to allow the generation of homogeneous products that are accurate and stable enough for climate monitoring and data assimilation for re-analysis of the recent climate.

The delivery of the Release 2 - GRAS Level 1b Bending Angle FCDR including documentation is part of the "Multiannual Agreement for the Provision of Climate Data for the Benefit of the Copernicus Climate Change Service (C3S)" (Milestone 7, Deliverable D.2.1, Work Package 2) [RD 6]. The FCDR described in this product user guide will be used for assimilation in ECMWF's Numerical Weather Prediction (NWP) model-based re-analysis. This FCDR provides a consistent record of bending-angle profile data from which, for example, stratospheric temperature and pressure, and tropospheric temperature, pressure and humidity profiles can be retrieved for climate monitoring and data assimilation.

This guide provides:
1. Specifications of the data record;
2. Scientific details on the generation and definition of the data record;
3. Characteristics and limitations of these products, aiming to assist the users in the decision of whether they can or should use the products of the data record for their applications;
4. Technical details on the format and the ordering of the data record, as well as information on the mechanisms to provide feedback.

1.2 Structure of this Document

This document has the following structure:

Section 1	Purpose and scope of this product user guide
Section 2	Background information on the product
Section 3	Definition of the product
Section 4	Generation of the product
Section 5	Product features
Section 6	Product ordering
Section 7	Product support and feedback
Section 8	Product referencing
Section 9	Acknowledgements
Section 10	References
Appendix	Metadata netCDF File

1.3 Acronyms and Abbreviations

The below table lists acronyms and abbreviations used in this document:

Acronym	Meaning
ATBD	Algorithm Theoretical Baseline Document
BUFR	Binary Universal Form for the Representation of meteorological data
C/A	Coarse/Acquisition
CDR	Climate Data Record
CDS	Climate Data Store
CF	Climate and Forecast
CODE	Center for Orbit Determination in Europe
DOI	Digital Object Identifier
ECMWF	European Centre for Medium-Range Weather Forecasts
EOP	Earth Orientation Parameters
EPS	EUMETSAT Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FCDR	Fundamental Climate Data Record
FDF	Flight Dynamics Facility
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRAS	Global navigation satellite system Receiver for Atmospheric Sounding
GSN	GRAS Support Network
ICRF	International Celestial Reference Frame
IGS	International GNSS Service
ITF	International Terrestrial Reference Frame
LEO	Low Earth Orbit
MDR	Measurement Data Records
MPHR	Main Product Header
NAS	Network Attached Storage
netCDF	Network Common Data Form
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NWP	Numerical Weather Prediction
POD	Precise Orbit Determination
PPF	Product Processing Facility
PRN	Pseudo Random Noise
RINEX	Receiver Independent Exchange

Acronym	Meaning
RO	Radio Occultation
ROM SAF	Radio Occultation Meteorology Satellite Application Facility
SNR	Signal to Noise Ratio
SOA	SOlar Activity
SLTA	Straight Line Tangent Altitude
UCAR	University Corporation for Atmospheric Research
UTC	Coordinated Universal Time
VR	Validation Report
WMO	World Meteorological Organisation
YAROS	Yet Another Radio Occultation Software

1.4 Definitions

The following definitions are used throughout the document.

Data levels:

- Level 0 - Reconstructed raw sounding data at full time resolution with all available supplemental instrument information used in subsequent processing included.
- Level 1a – individual occultations full information such as phases and amplitudes, Signal to Noise Ratios (SNRs), as well as all other information e.g. from the Precise Orbit Determination (POD), needed to process it further to Level 1b.
- Level 1b - Level 1a sounding data that have been processed to bending angles and impact parameters, tangent point location, and quality information.

Products types:

- Near Real Time (NRT) - refers to data delivered for Numerical Weather Prediction (NWP) applications and is generally provided within less than 2h 15min (for EUMETSAT GRAS L1B products). This data is available in NRT through EUMETCast, GTS, and from the archive (GRAS GDS Level 1B product).
- Fundamental Climate Data Record - is a well-characterised, long-term data record, usually involving a series of instruments, with potentially changing measurement approaches, but with overlaps and calibrations sufficient to allow the generation of products that are accurate[1] and stable, in both space and time, to support climate applications. FCDRs are typically calibrated radiances, backscatter of active instruments, or radio occultation bending angles. FCDRs also include the ancillary data used to calibrate them [RD 14].

[1] Note that this Product User Guide and the Validation Report generally discuss data quality in bias and standard deviation terms, which in metrology are called systematic and random uncertainty.

Statistics:

- Observations minus background departures - refers to departures that are derived using the *(O-B)/B* [%] quantity. *O* represents the observed profile, *B* the background profile (e.g. as taken from ECMWF ERA-Interim [RD 15]). This representation allows a better comparison for the exponentially varying bending angle profiles. *B* is sometimes not taken from the ECMWF ERA-Interim re-analysis, but from a match of another bending angle observation; then referring to $(O_1-O_2)/O_2$ where O_1 generally denotes the EUMETSAT data and O_2 the other bending angle observation. All profile data validation is based on "thinned" data, meaning that the high resolution profile data (which has > 1000 data points per profile) is thinned to a resolution varying with altitude (higher resolution near the surface of about 150m, to about 300m near 60km). This thinned profile data, comprising 247 data points, is also used in the Near-Real-Time product delivery to NWP users. The high resolution data is though also part of the GRAS Level 1b Bending Angle FCDR [RD 5].

Other:

- Straight Line Tangent Altitude (SLTA): the tangent altitude of the direct Low Earth Orbit (LEO) satellite and the GNSS satellite ray with respect to the Earth WGS84 Ellipsoid; it is generally > 0km, but in the lower troposphere can go to values <-200km due to the bending of the ray.
- Bending angle: the actual geometry of the limb sounding radio occultation measurement technique is shown in Figure 1. The figure shows the bending angle as the angle between the actual, measured, and the straight line propagation from the GNSS satellite to the LEO satellite. The SLTA altitude is also shown.

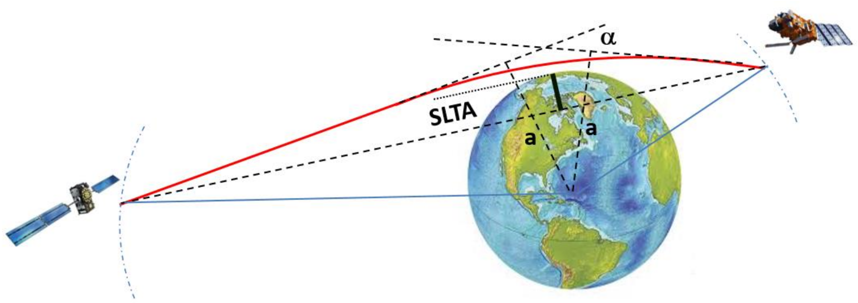


Figure 1 Radio occultation geometry, showing the bending angle α, the impact parameter a, and the straight line tangent altitude (SLTA). Note that α is generally below 1° and is measured in μrad, thus the figure is greatly exaggerated.

2 BACKGROUND

GRAS is an instrument flying on EUMETSAT's Metop satellites. It receives radio signals that are continuously broadcast by Global Positioning System (GPS) navigation satellites of the GNSS orbiting the Earth, and measures the time delay of the refracted GPS radio signals as the ray signal path skirts the Earth's atmosphere on its way from the transmitting GPS to the GRAS receiver on Metop. This time delay in the received signals can be processed to obtain vertical profiles of atmospheric parameters, such as temperature, pressure and water vapour in the stratosphere and troposphere. As such, GRAS is not a standalone, passive (e.g., microwave or infrared) instrument, but is critically dependent upon the availability of the constellation of GNSS satellites and the availability of high quality orbit information[2]. The GRAS requirements state that a minimum of 500 bending-angle profiles per day shall be provided - in practice, around 600 to 650 are achieved, since more GPS satellites are available (the initial estimate was based on the nominal 24 GPS satellite constellation).

The Release 2 - GRAS Level 1b Bending Angle FCDR is a EUMETSAT deliverable to the Copernicus for Climate Change (C3S), which aimed at the preparation of consistent input Copernicus Climate Change Service[3] (C3S), which is one of the six thematic information services provided by the Copernicus Earth Observation Programme of the European Union[4]. C3S is implemented by European Centre for Medium-Range Weather Forecasts[5] (ECMWF) on behalf of the European Commission. This delivery required the generation of consistent climate data records from satellite data and the application of the best available approaches for instrument calibration. Among others, EUMETSAT's contribution to the C3S was the generation of a homogeneous and consistent GRAS Level 1b Bending Angle FCDR of bending angles for the time-series of the Metop-A and Metop-B satellites.

The Release 2 - GRAS Level 1b Bending Angle FCDR has been produced employing EUMETSAT's Climate Data Record processing infrastructure. The available data record comprises reprocessed GRAS data from Metop-A during the period of 27 Oct 2006 – 31 December 2017 and Metop-B during the period 29 September 2012 – 31 December 2017, which matches with EUMETSAT's reprocessing commitments that are described in the Climate Services Development Plan [RD 2]. Please refer to the EUMETSAT website for access to GRAS NRT data.

3 PRODUCT DEFINITION

This chapter provides information on file sizes, file content, file formats, and file names for the Release 2 - GRAS Level 1b Bending Angle FCDR.

3.1 Physical Structure

The Release 2 - GRAS Level 1b Bending Angle FCDR covers the period from late 2006 till the end of 2017. It provides bending angle profile data, i.e., data of the angle between the actual, measured, and the straight line propagation from the GNSS satellite to the

[2] Provided by Center for Orbit Determination in Europe at the Astronomical Institute of the University of Bern (AIUB).
[3] https://www.copernicus.eu/en/services/climate-change Link valid 28/12/2018
[4] https://www.copernicus.eu/en Link valid 28/12/2018
[5] https://www.ecmwf.int/ Link valid 28/12/2018

LEO satellite (see Figure 1), for approximately 2.5 million occultations from GRAS on Metop-A and Metop-B. The data record is made available as:

i) individual occultation profiles in Network Common Data Form (NetCDF);

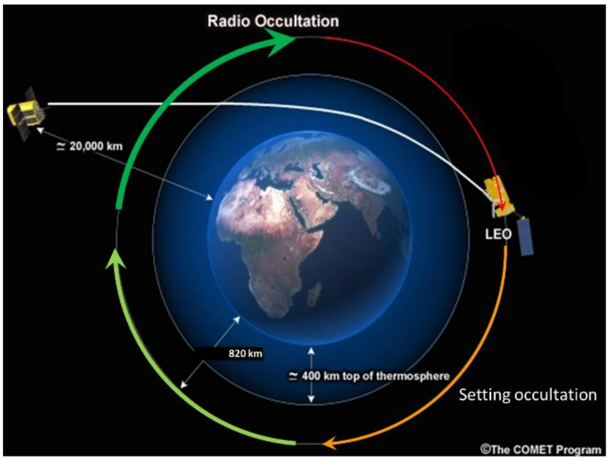
ii) multiple occultation profiles in EUMETSAT's native EPS format, and in the Binary Universal Form for the Representation of meteorological data (BUFR) format [RD 11]. The format of these data is identical to the data provided by the operational Near Real Time (NRT) stream of the GRAS instruments, except for meta-data describing the reprocessing itself [RD 5]. Typically, one multiple occultation product contains all occultations collected in one orbit.

The individual occultation files contain Radio Occultation measurements that are taken whenever one of the GNSS/GPS satellites, as seen from the observing spacecraft, sets or rises behind the Earth's horizon. Typically, a single occultation, covering the neutral atmosphere, lasts less than a few minutes. During a single occultation the line of sight between the two satellites moves from high altitudes into the troposphere (for setting occultations; vice versa for rising ones), scanning nearly vertically through the atmosphere (the reference location and the actual latitudes / longitudes of the profile are included in the data record). The location of the occultation (which is associated with the point where the straight line connecting the GNSS transmitter with the RO receiver touches the Earth's surface, i.e. SLTA equals 0) depends on the orbit geometry of the satellites being involved in the measurement. This location will typically be located about 3000 km away from the sub-satellite point of the RO receiver. Individual occultations, when being processed to Level 1b, therefore consist of vertical bending-angle profiles, which are more or less randomly distributed over the globe (see Figure 2). Note though that actual locations are driven by the satellites involved in the occultation, thus they "appear" random when looking at a plot with locations over the globe, but they are in fact predictable from the GPS and Metop orbits. Also, the Metop orbits lead to sampling around certain local solar times, thus in this domain, the data is not randomly distributed.

The multiple occultation files contain RO measurements that are collected during one download from the satellite to the ground receiving station at Svalbard, Norway. Since January 2011, a second ground station located in McMurdo, Antarctica, was started to be used to reduce the repatriation times of operational NRT Metop data (and it is operational since January 2014); level 0 data are in this case recombined in the operational ground processing at EUMETSAT. Each full-orbit level 0 file covers data collected during a period of ~101 minutes, with the data starting and ending at the edge of the Svalbard ground station coverage time. Please note that the start and end times of the Level 1b files do not exactly match the Level 0 files, rather they are composed of the time of the first and last occultation within the Level 1b file. Individual occultation products may also overlap, as more than a single occultation can take place simultaneously (with the instrument occultation channel availability, this leads to a maximum of 4; 2 rising and 2 setting; this is however rarely observed).

Table 1: List of satellite names, operational mission and the main years of operation.

Satellite	Mission	Main Operational Years
Metop-A	GRAS	2007-2017
Metop-B	GRAS	2012-2017



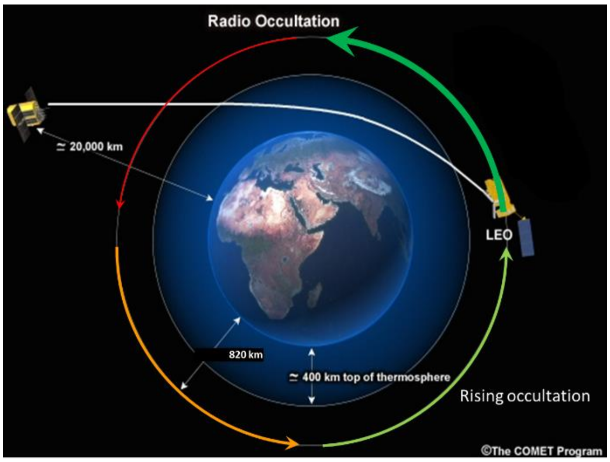


Figure 2: Example of GRAS radio occultation measurements for a setting and a rising orbit.

3.2 Product Contents

The Level 1b netCDF4 files contain information from a single occultation, which include the main variables used in the assimilation process, namely the bending angles (neutral, but also at L1, L2 GPS frequency) over impact parameter, along with information on the measurement time, geo-location of the tangent points, and some quality indicators. In addition, these files contain information on the GPS, Metop orbits and clocks, as well as amplitude and phase data at Level 1a. The bending angles are provided at high resolution as well as at a lower/thinned resolution. The vertical levels used for the thinned (and smoothed) bending angle profiles are the same for each occultation with respect to a geo-location based reference frame, and identical to the GRAS ones provided operationally for NWP models in BUFR format. The set of 247 standard vertical levels is used for assimilation purposes; other vertical resolutions can though be generated by the data user by applying suitable thinning and smoothing algorithms to the high resolution data if required. A full description of the metadata provided in the netCDF files is provided in [RD 5], and are also listed in APPENDIX 1.

The Level 1b BUFR files contain information from multiple occultations collected during one full orbit, and comprise the thinned bending angle profiles extracted from the full profiles available in the netCDF4 products. Due to the thinning the final file size or the BUFR files is an order of magnitude smaller than those of the netCDF4 files.

The Level 1b native EPS files contain information from multiple occultations collected during one full orbit, and comprise the full profiles available in the netCDF4 products. Nevertheless these files are just wrappers around the actual netCDF files. The individual netCDF files can be extracted from the EPS file with the help of the epsar tool. Epsar is a tar-like tool written in plain Perl allowing to list the contents of EPS files, and also to extract some or all netCDF files contained in the EPS file. The most recent version of the epsar software can be downloaded from https://github.com/leonid-butenko/epsar (assessed on 5 December 2018).

Measurment data sets

The files (netCDF and BUFR) comprise of the following measurement data sets that are provided for vertical levels, either at full resolution (can be thousands of data levels) or at thinned resolution (247 levels).

Table 2: Measurement data sets of the netCDF and BUFR files of the Release 2 - GRAS Level 1b Bending Angle FCDR. Note, the data sets marked with * are not available in the BUFR files.

Measurement data set	Long name
azimuth_tp	GNSS->LEO line of sight azimuth angles at tangent points (clockwise against True North)
bangle	Bending angle (ionospheric corrected)
bangle_ca	Bending angle (coarse acquisition (C/A) signal)
bangle_ca_p2_diff *	Bending angle difference, (L1 / C/A - L2 / P2, extrapolated)
bangle_p1*	Bending angle (P1 pseudorange frequency band L1)
bangle_p2	Bending angle (P2 pseudorange frequency band L2)
Impact	Impact parameter
impact_height*	Impact height (wrt WGS 84 ellipsoid)
lat_tp	Latitudes for tangent points
lon_tp	Longitudes for tangent points

Global attributes

The files (netCDF) comprise the following global attributes:

Table 3: Global attributes of the netCDF files of the Release 2 - GRAS Level 1b Bending Angle FCDR.

Name	Value
Conventions	"CF-1.7"
metadata_conventions	"Unidata Dataset Discovery v1.0"
title	"GRAS_1B_M02_20150612225357Z_20150612225545Z_R_O_20170215123716Z_G29_NN_0100.nc"
summary	"GRAS/Metop-A level 1a/b radio occultation data"
keywords	""
history	"original generated product"
institution	"EUMETSAT"
spacecraft	"M02"
instrument	"GRAS"
product_level	"1B"
type	"BND"
mission_type	"Global"
disposition_mode	"Operational"
sensing_start	"2015-06-12 22:53:57.799"
sensing_end	"2015-06-12 22:55:45.366"
environment	"Offline"
references	"www.eumetsat.int"
orbit_start	44869LL
orbit_end	44870LL

receive_start	"2015-06-12 22:45:51.000"
receive_end	"2015-06-13 02:11:10.000"
subsetting	"NONE"
receiving_ground_station	"SVL"

3.3 File Specifications

This section summarizes file format, file naming conventions and data record sizes of the Release 2 - GRAS Level 1b Bending Angle FCDR. Detailed information on the specification of metadata and variables in the netCDF, BUFR, and EPS files is given in [RD 5].

3.3.1 Individual occultation netCDF files

The netCDF data format is *self-describing*, *portable*, and *archivable*. Self-describing data contains a header which describes the layout of the rest of the file, in particular the data arrays, as well as arbitrary file metadata in the form of name/value attributes. Portable data can be accessed by computers with different ways of storing integers, characters, and floating-point numbers. Archivable means that all current and future versions of the software will support access to all earlier forms of netCDF data. The netCDF data format was developed, and is supported and maintained, by the Unidata program at the University Corporation for Atmospheric Research (UCAR). UCAR is also the chief source of netCDF software, standards development, updates etc. The format is an open standard. Most netCDF data sets developed at EUMETSAT use netCDF v.4. The Climate and Forecast (CF) conventions [RD 9] have been applied where applicable. The general structure of the netCDF4 files is shown in [RD 5], with a summary in APPENDIX 1.

The filenames of the netCDF4 data files identify the instrument, product level, spacecraft, start sensing time, end sensing time, product type, processing time, and orbit number. Sensing times are actually the start and end time of an occultation. The file naming conventions used for the netCDF4 files are shown in Table 4.

Table 4: File names identifying the Level 1b GRAS data set, corresponding to the netCDF format.

Naming convention Level 1b GRAS -netCDF
<instr>_1B_<sat>_<start_time>Z_<end_time>Z_<p>_<d>_<create_time>_<GXX>_<ff>_0200.nc
Example name Level 1b GRAS -netCDF
GRAS_1B_M02_20150612225357Z_20150612225545Z_R_O_20170215123716Z_G29_NN_0200.nc

where:

<inst>	4-character instrument ID (e.g., GRAS for the GRAS instrument)
<sat>	3-character satellite ID (e.g., M02 for Metop-A and M01 for Metop-B)
<start_time>	14-digit sensing start time (e.g., 20150612 22:53:57 UTC on 12 June. 2015)
<end_time>	14-digit timestamp characterising sensing end time

<p> 1-character processing mode for Nominal (N), Backlog (B), Reprocessing (R), or Validation (V). Please Note that 'R' is the processing mode for the complete dataset of this data release.

<d> 1-character disposition mode for Testing (T), Operational (O), Commissioning (C)

<create_time> 14-digit timestamp characterising product creation time

<Gxx> 3-character satellite ID of occulting GNSS satellite (e.g., G23 for Pseudo Random Noise 23 of the GPS constellation)

<ff> 2-character flag field indicating nominal (N) or degraded (D) instrument and processing (e.g., ND for nominal instrument data, but degraded processing)

<0200> 4 digit code referring to release number 1 of the FCDR

The netCDF4 files have sizes varying between 1 and 10 Mb per file. The approximate size of the complete data record in netCDF4 format is about 22 TB. The data volumes per year per satellite are given in Table 5. The increasing data volume with years is not a result of more occultations, but actually the result of instrument updates that (1) collected more raw data; (2) made it possible to process more of the available instrument data to Level 1b.

Table 5: Size of the Level 1b GRAS data set (in TBs), corresponding to the netCDF format.

Satellite	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	***Total***
Metop-A	0.1	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.5	1.5	1.6	1.7	**14**
Metop-B							0.3	1.4	1.4	1.4	1.5	1.6	**7.6**

3.3.2 Multiple occultation BUFR files

The WMO Binary Universal Form for the Representation of meteorological data (BUFR) format, is a binary format designed to represent any meteorological dataset that employs a continuous binary stream. Please refer to the BUFR format description in [RD 11] for further information.

The filenames of the BUFR data identify the instrument, product level, spacecraft, start sensing time, end sensing time, product type, processing time, and orbit number. The file naming conventions used for the BUFR files are similar to those used for the netCDF files (see sub-section 3.3.1), and are shown in Table 6.

Table 6: File names identifying the Level 1b GRAS data set, corresponding to the BUFR format.

Naming convention Level 1b GRAS - BUFR <instr>_1B_<sat>_<start_time>Z_<end_time>Z_<p>_<d>_<create_time>Z_0200.bufr **Example name Level 1b GRAS – BUFR** *GRAS_xxx_1B_M02_20150612225207Z_20150613003506Z_R_O_20170215052803Z_0200.bufr*

The BUFR files contain the occultations collected during one orbit and have a size of about 0.5 MB per file. The approximate size of the complete data record in BUFR format is about 40 GB. The data volumes per year per satellite are given in Table 7.

Table 7: Size of the Level 1b GRAS data set (in GBs), corresponding to the BUFR format.

Satellite	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	***Total***
Metop-A	0.3	2.3	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.3	**26.8**
Metop-B							0.6	2.4	2.4	2.5	2.5	2.5	**12.9**

3.3.3 Multiple occultation EPS files

The organisation of radio occultation measurements in terms of individual occultations or granules is straightforward, but leads to a large number of data files. This has disadvantages when disseminating large amounts of data or archiving long-term data records. Therefore, EUMETSAT organises RO data in products covering a full orbit. Technically, the EPS native file format comprises individual granules (or occultations) that are “wrapped” into a single orbit file. At the conceptual level, the wrapping can be understood as using the EPS data format as a data container, similar to .tar or .zip data archives well known from Linux or Unix environments.

The native EPS Data Format consists of a fixed-length ASCII header, followed by one or more data records. Each such data record contains itself a header specifying the record’s type, length, and possibly some additional metadata. In particular, the EPS Data Format consists of the standard Main Product Header (MPHR) common to all EPS products, and one or more Measurement Data Records (MDRs). Each MDR, after its header is removed, is technically a netCDF occultation granule. The individual netCDF files can be extracted from the EPS files with the help of the epsar tool[6]. Detailed information on the EPS format can be found in [RD 10], although a description providing more details relevant for the reprocessed GRAS RO data is also part of [RD 5].

The filenames of the EPS data files identify the instrument, product level, spacecraft, start sensing time, end sensing time, product type, processing time, and orbit number. The file naming conventions used for native EPS files are the same as for all EPS level 1 data products, and are shown in Table 8.

Table 8: File names identifying the Level 1b GRAS data set, corresponding to the EPS format.

Naming convention Level 1b GRAS - EPS <inst>_xxx_1B_<sat>_<start_time>Z_<stop_time>Z_<p>_<d>_<create_time>Z_0200
Example name Level 1b GRAS - EPS *GRAS_xxx_1B_M02_20150612225207Z_20150613003506Z_R_O_20170215052803Z_0200*

The EPS files have a size varying between 200 and 400 Mb per file. The approximate size of the complete data record in EPS format is about 22 TB (as the netCDF record). The data volumes per year per satellite are given in Table 9.

[6] The most recent version of the epsar software can be downloaded from https://github.com/leonid-butenko/epsar (assessed on 5 December 2018).

Table 9: Size of the Level 1b GRAS data set (in TBs), corresponding to the EPS format.

Satellite	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	***2015***	***2016***	***2017***	***Total***
Metop-A	0.1	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.5	1.5	1.6	1.7	**14**
Metop-B							0.3	1.4	1.4	1.4	1.5	1.6	**7.6**

3.4 Supplementary files

The Release 2 - GRAS Level 1b Bending Angle FCDR is made available with two supplementary datasets, i.e., the RINEX dataset and the NAVBIT dataset.

The RINEX files contain pseudorange, carrier phase, and amplitude/SNR data of the zenith antenna, and are formatted in standard RINEX v2.10 observation format [RD 21]. One RINEX file is available per day, with a file size of approximately 65 MB per file. The approximate size of the complete RINEX data record is about 240 GB for Metop_A and 120 GB for Metop-B.

Table 10: File names identifying the RINEX files, corresponding to the RINEX v210 format.

Naming convention – GRAS RINEX files
<inst>_RNX_1A_<inst>_<start_time>Z_<stop_time>Z_create_time>_YARx_ *xxxxxxxxxx_0100*
Example name – GRAS RINEX files
GRAS_RNX_1A_M02_20150612225207Z_20150613003506Z_20170215052803Z_YARx_xxxxxxxxxx_0100

The NAVBIT files contain the navigation bit sequences which modulate each of the GPS signals and follow the format described in [RD 17]. One NAVBIT file is available per hour, and has a size of approximately 55 MB per file. The approximate size of the complete NAVBIT data record is about 220 GB.

Table 11: File names identifying the NAVBIT files.

Naming convention – NAVBIT files
xxxx_NAB_xx_xxx_<start_time>Z_<stop_time>Z_create_time>_PPFx_GIPPFB12xx_0100
Example name Level 1b – NAVBIT files
xxxx_NAB_xx_xxx_20150612225207Z_20150613003506Z_20170215052803Z_PPFx_G1PPFB12xx_0100

3.5 File Visualization

The netCDF files can be visualized with the commonly known netCDF viewers and netCDF image processing software. Among others the files can be viewed with HDFview (version 2.13 or later), Ncview (version 2.1.7 or later), Panoply (version 4.7.0 or later), and processed with IDL (version 8.0 or later) and netcdf4-python (version 1.2.4) on python (version 2.6 or later).

4 PRODUCT GENERATION

This chapter gives a high-level overview of how the data record was produced and describes the used input and auxiliary data, the processing software, and the setup of the reprocessing facility. The software used to perform the reprocessing is EUMETSAT's reference RO processor, also referred to as Yaros (Yet another radio occultation processor). We note that Yaros provides the reference implementation of all operational RO processing at EUMETSAT; for example, the operational GRAS processor is a re-implementation of Yaros, adapted to the operational needs in EUMETSAT's EPS ground segment. A schematic overview of the RO processing setup used for the reprocessing is shown in Figure 3; the individual input data and processing steps are described in more detail in the following sections.

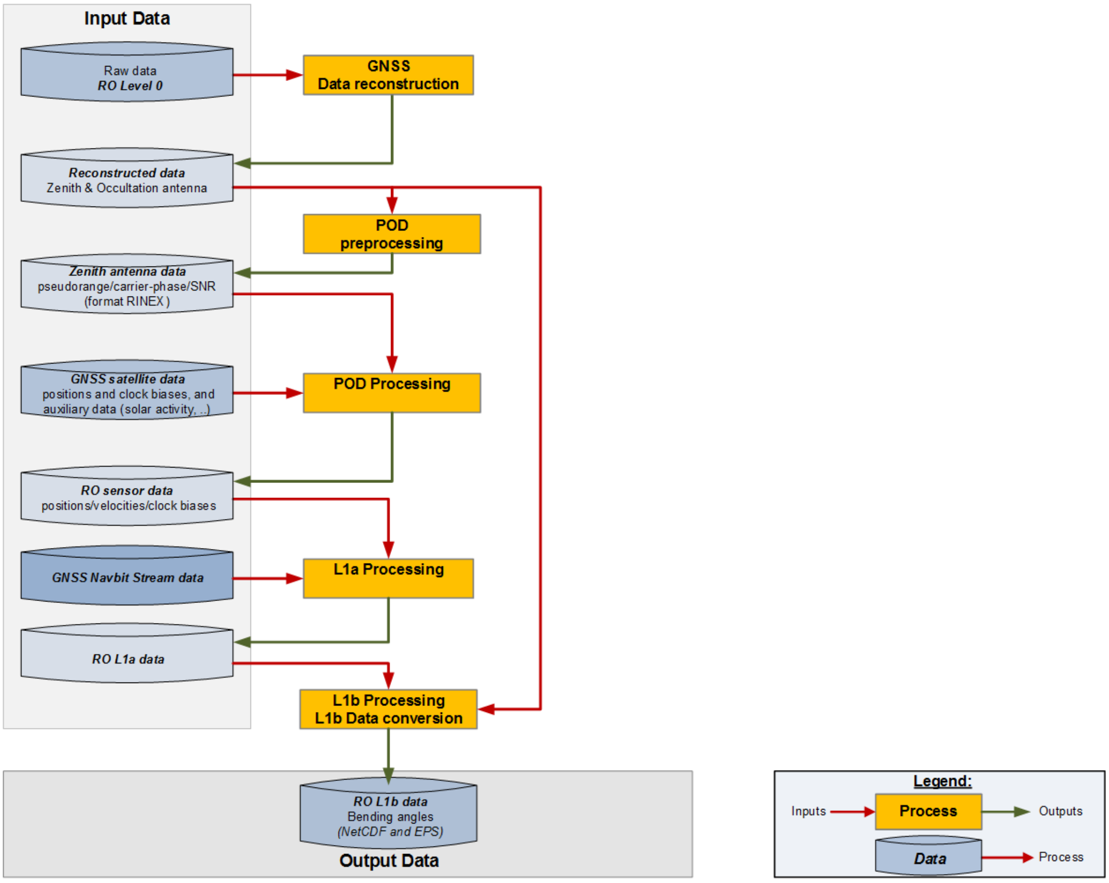


Figure 3: Schematic representation of inputs and outputs of the Yaros v1.4 reprocessing chain for the generation of Level 1b bending angles from GRAS Radio Occultation data.

4.1 Data Processing

A general introduction on the principles of RO sounding can be found in, e.g., [RD 12] and [RD 13]. The reprocessing of the GRAS RO data is based on a "wave optics" retrieval algorithm, and is fully consistent with the operational GRAS processing as introduced in November 2016. The reprocessed GRAS data thus extends the current (at the time of writing) operationally available data backwards in time towards shortly after the Metop-A launch in October 2006. The improvement of the processing between early operational

GRAS data and the reprocessed data set described in this document is shown in Figure 4 and Figure 5.

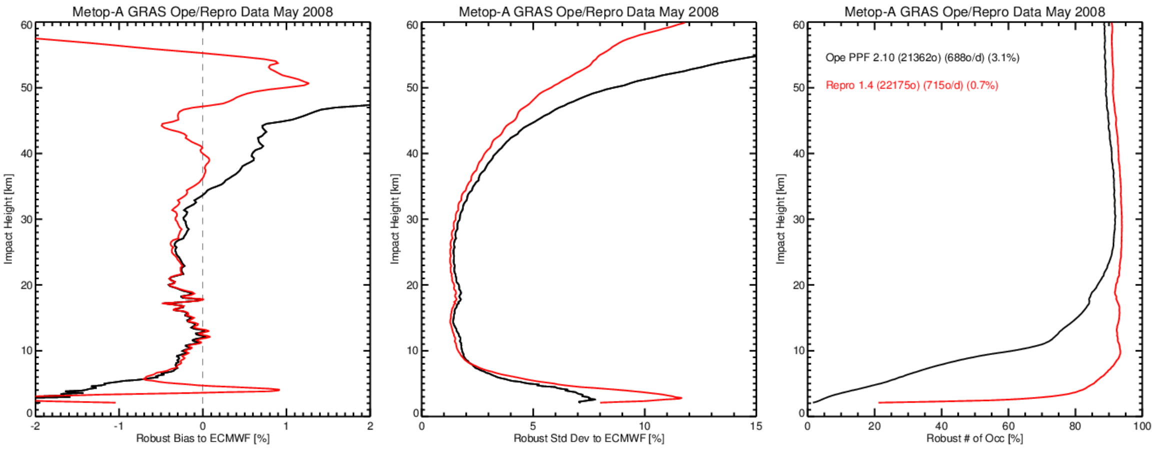


Figure 4: Example for May 2008 illustrating the improvements of operational NRT PPF 2.10 data versus Release 2 - GRAS Level 1b Bending Angle FCDR (v1.4) data. Shown is the global bending angle comparison to ECMWF ERA-Interim forward propagated data. Robust bias (left), standard deviation (centre), outlier distribution (right). In addition, the legend gives the total number of occultations, average occultations per day and the failure rate.

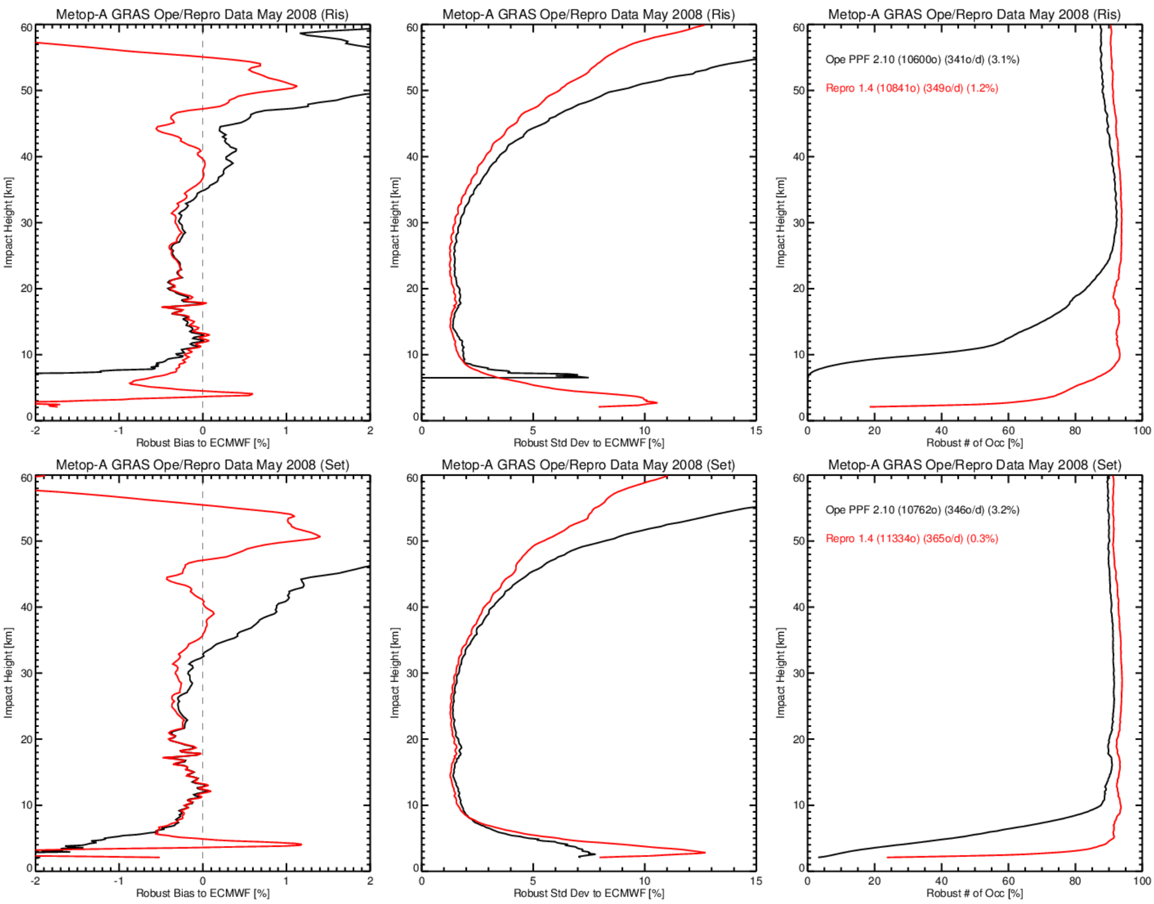


Figure 5: Same as Figure 4 but discriminated between rising occultations (top) and setting occultations (bottom).

Figure 4 and Figure 5 show the operational NRT GRAS data as provided by EUMETSAT in May 2008, around the time when GRAS data became operational for the first time. This was generated with the operational GRAS Product Processing Facility (PPF) at version 2.10. In addition, these figures show the reprocessed data set, Release 2 - GRAS Level 1b Bending Angle FCDR. Both data sets are compared to ECMWF ERA-Interim forward modelled bending angles. From the figures it can be seen that significant improvements are visible in the reprocessed data, e.g. caused by:

- the use of Wave Optics (at lower altitudes), where the raw sampling (open loop) data is actually included in the derivation of the bending angle (PPF 2.10 was not using raw sampling data);
- the use of a consistent smoothing / thinning of the data, bringing down the noise levels at higher altitudes;
- the use of a consistent POD processing and antenna position vectors, removing the bias between setting and rising, and reducing the bias at higher altitudes;
- higher number of total and daily occultations, as well as reduced number of failures, due to improved processing radio occultation algorithms, improved GPS orbits and clocks available in reprocessing, based on more GPS ground station data, improved algorithms, as compared to the ones available in Near Real Time when the operational products were generated.

Please note that the higher standard deviations at the lowest attitudes with the reprocessed data is not a data degradation, but is due to the use of the raw sampling and wave optics processing in this region. Thus, much more data is actually entering the statistics at these altitudes; this is also evident from the rightmost figures, in particular for rising occultations. PPF 2.10 was effectively ignoring highly variable data at the lowermost altitudes, in particular in rising occultations. Also note that the implemented smoothing of the data to a vertical grid relevant for NWP users/applications uses an agreed, adaptable filter width, which introduce some changing standard deviation behaviour around 55 km in the Release 2 - GRAS Level 1b Bending Angle FCDR.

4.2 Input Data

The Level 0 data from GRAS are used as the prime input data for the processing. These Level 0 data are downloaded from the satellite once per orbit over Svalbard and since January 2011 partially over McMurdo. The files are stored as orbit dumps, generally containing all the data starting from the last dumped data at the Svalbard ground station to all data collected up to the next dump, in the EUMETSAT Data Centre.

For this Release 2 - GRAS Level 1b Bending Angle FCDR data generation, Level 0 GRAS data was obtained from the EUMETSAT Data Centre for the reprocessing period.

4.2.1 Auxiliary Data

The auxiliary data consists of five elements: GPS navigation bits, GPS clock, GPS orbits, solar magnetic flux and Earth orientation, manoeuvre history. Each of these is described in the sections that follow.

4.2.1.1 GPS navigation bits

Navigation bit sequences are necessary to allow the correct reconstruction of the signal carrier phases when the receiver is in open-loop tracking mode. This auxiliary data files have been generated by EUMETSAT taking data from different sources and generating a merged dataset ([RD 16] provides more details on the process).The products contain the navigation bit sequences which modulate each of the GPS signals, and follow the format described in [RD 17].

4.2.1.2 GPS orbit/clock data

GPS orbits and clocks are not estimated in the framework of the re-processing. They were downloaded from the CODE Analysis Centre at the Astronomical Institute at the University of Bern (AIUB) which is a Global Analysis Center to the International GNSS Service (IGS). See [RD 18] for further details and DOI.

4.2.1.3 Solar flux and Earth Orientation Parameters

The Earth Orientation Parameters (EOP) file contains time series of coefficients necessary to allow the full transformation between the International Terrestrial Reference Frame (ITRF) and the International Celestial Reference Frame (ICRF). The file finals2000a.data is downloaded from the 'IERS Rapid Service Prediction Center for Earth Orientation Parameters' [RD 19]; its format is defined in [RD 20].

The file containing SOlar Activity (SOA) information, like the Solar Flux, is necessary for the POD function to correctly model forces impacting the satellite motion due to solar activity (in particular solar radiation drag). The file is provided by the EPS Flight Dynamics Facility (FDF) facility, which in turn uses space weather data made available by National Oceanic and Atmospheric Administration (NOAA).

4.2.1.4 Manoeuvre history

The LEO manoeuvre history is necessary to take into account all the manoeuvres applied to the Metop satellites. It is provided internally from the EPS FDF in ASCII format.

4.3 Reprocessing procedure

As shown in Figure 3, the processing of Level 0 raw radio occultation data to Level 1b vertical bending-angle profiles can be broken down into 5 major processing steps. This section summarizes the processing steps of the GRAS processor.

Step 1 - Level 0 Reconstruction
This step involves the extraction of typical GNSS observables, i.e., carrier phase, pseudorange, signal amplitude and/or Signal-to-Noise Ratio (SNR) data, from the level 0 raw data of the RO receiver. For GRAS, the reconstruction of these GNSS observables requires significant processing from a very low, instrument level representation of the measurements. Step 1 results in reconstructed data from the zenith antenna (which is used for POD), and from the velocity and anti-velocity viewing occultation antennas.

Step 2 - Precise Orbit Determination pre-processing
The GRAS receiver is unique in that it does not provide common GPS observables such as pseudorange, carrier phase and amplitude (or Signal-to-Noise Ratios, SNRs) directly; they instead have to be reconstructed from the lower level 0 data contents. After the reconstruction of these observables for the zenith antenna data, pseudorange, carrier phase and SNR data are interpolated to a 1 Hz temporal resolution. They are then formatted into the Receiver Independent Exchange (RINEX) v2.10 standard GPS observation format. The RINEX format definition can be found in [RD 21].

Step 3 - Precise Orbit Determination
In this step, the precise orbit positions and velocities of the centre of mass of the Metop-A and Metop-B satellites carrying the GRAS receiver are determined from the RINEX files generated in step 2. In addition, the clock bias of the GRAS receiver with respect to the GPS system time is also estimated at each epoch. Precise positions and clock biases of the GNSS satellites are needed for performing this step. The latter are auxiliary data available from [RD 18]. In addition, the yaw-steering attitude of the Metop satellite is modelled. The POD processing is based on a commercial off-the-shelf (COTS) software package, which is fed by driver scripts and configuration templates from Yaros. For GRAS, EUMETSAT uses an adapted version of the NAPEOS suite as POD processor [RD 23]. Step 3 results in precise positions, velocities, and clock biases of the Metop-A and Metop-B satellites carrying the RO receiver.

Step 4 – L1a processing
This step processes the reconstructed GNSS data as measured by the occultation antenna, using information derived in the previous steps, i.e., the precise orbit and clock bias data from the GNSS and the LEO satellites and GNSS measurements from the occultation antennas. The processing of the reconstructed GNSS data aims at extracting all data relevant for individual occultation events. Precise orbit data from both the occulting GNSS satellite and the Metop satellite are used to apply geometric corrections, as are the centre of mass to Antenna reference point and antenna phase corrections. Finally, excess carrier phases are calculated. Clock errors of the receiver are compensated for by applying the GNSS and GRAS clock corrections computed in Step 3, a process known as zero-differencing [RD 24]. Finally, an initial georeferencing information (i.e., the location of the occultation as well as the centre and radius of curvature which will later be used in the level 1b processing) is calculated along with quality control and diagnostic data. Note that for GRAS, multiple measurement modes occur at the same time (e.g., single or dual frequency closed loop measurements at a sampling rate of 50 Hz, as well as single frequency open loop data measured at 1 kHz). This multi-mode multi-rate data set is converted into a single 50 Hz measurement time series for each GPS frequency. This data combination consists of merging of the closed and open loop data, rewriting the observations with respect to a common phase model. The modulation of the observed GNSS signals due to the navigation data transmitted by GPS satellites is also removed from the measurements using the GNSS Navigation Bits. Finally, the data is up-sampled and filtered. The processing applied to GRAS carrier phase is similar to procedures described in the literature (e.g., [RD 25]), but with the necessary adaptations to the GRAS data characteristic. Step 4 results in Level 1a georeferenced and differenced carrier phases, amplitude/SNR, and pseudoranges, as well as diagnostic data. This information is stored in a single file per occultation.

Step 5 – L1b processing
In Step 5, the final step, vertical bending-angle profiles are generated. These profiles are provided as a function of the impact parameter. Apart from "high resolution" profiles, a thinned variant providing data on a standard set of impact level heights is also generated for each occultation. The GRAS processing is based on the Full Spectrum Inversion (FSI) wave optics algorithm [RD 26], accompanied by a time-domain radio-holographic filtering [RD 27] applied of the signal preparation.

Bending-angle profiles derived independently from the two different carrier frequencies are down sampled, slightly (over a height interval of 200 m) smoothed, and eventually combined using a linear combination [RD 28] to form a neutral atmospheric bending-angle profile. As part of this process, missing data on GPS frequency L2 in the mid and lower troposphere is extrapolated from higher up using a model-based extrapolation method [RD 29, RD 30]; a second order correction of the usual linear combination of bending angles is also applied.

We note that EUMETSAT applies a wave optics retrieval over the entire vertical range of the profile; bending-angle profiles therefore do not exhibit changes in their error characteristics due to a transition between wave and geometrical optics processing. On the other hand, the high resolution bending angles resulting from the FSI still exhibits several 1000 data points, with some of them very closely spaced to each other. In order to reduce the number of data points to a manageable (and meaningful) level, the high resolution profiles are further interpolated to a set of 247 standard levels between the surface and 60 km (impact) altitude. As part of the interpolation, they are also smoothed with an altitude and latitude dependent local regression filter [RD 31; RD 32]. Based on input received from operational users at the time when the operational wave optics was introduced, the smoothing in this last filtering step is tuned towards providing error statistics similar to those obtained from the geometrical optics processing in earlier versions of EUMETSAT's operational processor in the stratosphere, but allows for higher resolutions in the troposphere.

Each occultation is processed independently and saved as a Level 1b netCDF file. In a final step, all occultations belonging to one orbit dump (approx. 100 minutes) are wrapped into an EPS format file. Therefore, Step 5 results in level 1b data stored in EPS files (one file per orbit), where each granule contains data from a single occultation. Apart from level 1b data, these products also include all level 1a and POD data as required to (re-) process the occultation in question.

5 PRODUCT FEATURES

This chapter gives a high-level overview of the scientific data available in the Release 2 - GRAS Level 1b Bending Angle FCDR files, as well as an example of their variation in time. In addition, a summary is provided of the technical and scientific assessments made to validate the released data.

5.1 Spatial and Temporal Characteristics

The data record is global, covers the latitude from 90° S to 90° N and is continuous over the data period. The Metop satellites have a polar, sun-synchronous orbit with 14.2 orbits per day. Depending on the availability of the GPS satellites more than 700 occultations per day can be retrieved prior to quality control. Figure 6 shows a typical GRAS bending-angle profile, both for the observation on the L1, L2 GPS frequencies (C/A and P2 respectively), as well as the neutral one and for comparison a climatological reference. Figure 7 shows the typical local solar time sampling of the GRAS instrument, which is driven by the sun-synchronous orbit of the Metop satellite. The actual local times are not only driven by the Metop orbit, but also by the GPS orbits. This, for example leads to no occultation measurements around 09:30 UTC and 21:30 UTC around 0° latitude since the GPS satellites are never visible right ahead or behind the Metop satellite (GPS inclination is 55°, thus observtions are always sidewards here).

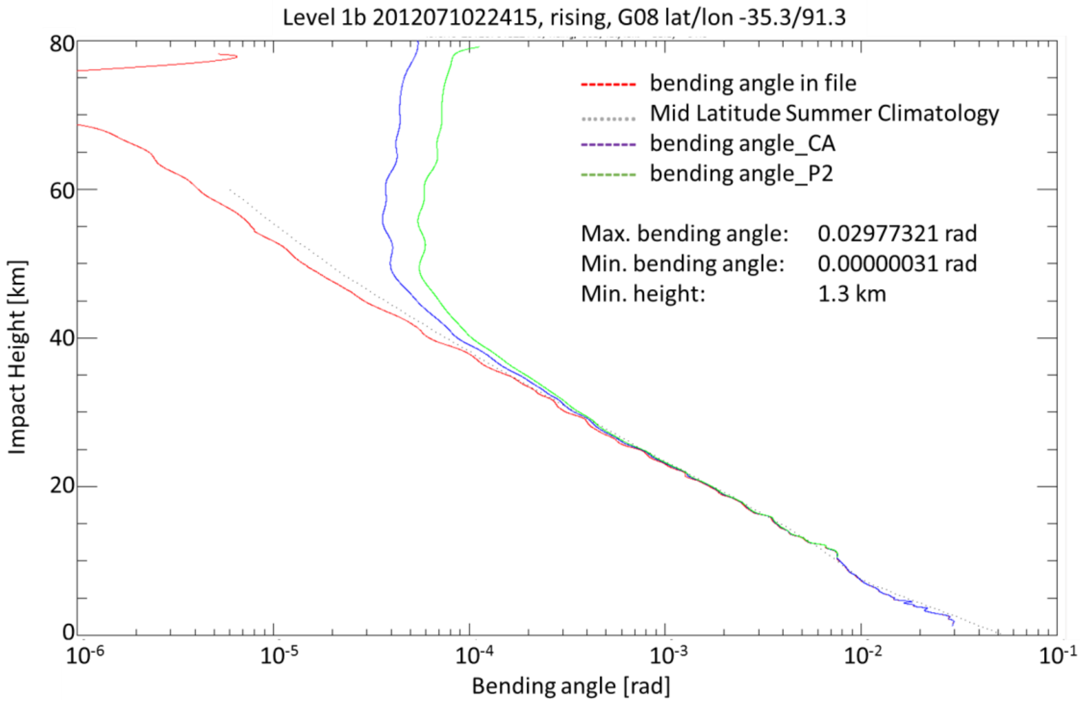


Figure 6: Example of Level 1b bending angle profile collected on 10 July 2012 over the Southern Pacific, the occultating GPS satellite was 08. The high resolution profile is shown, maximum and minimum observed bending angle, as well as the minimum height reached by the profile is also included.

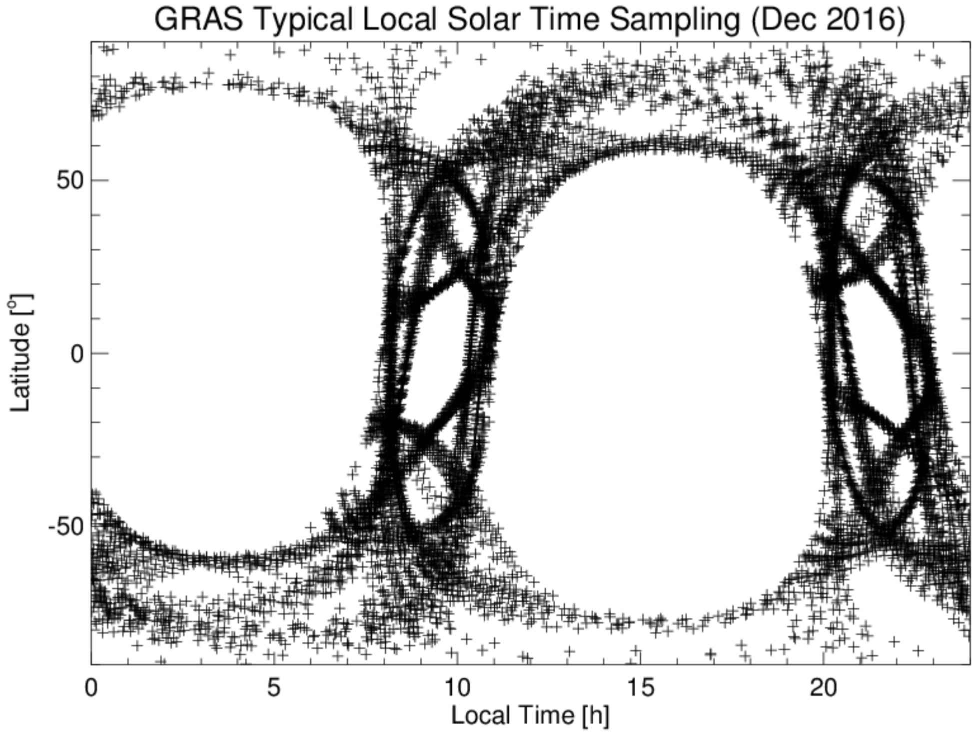


Figure 7: Typical local solar time of GRAS occultation sampling, here for 1 month (December 2016), each occultation is represented by a +.

5.2 Validation

This section summarizes the work done to validate the data record technically and scientifically, as well as the main feedback provided by beta-users of the data records. The full details of the validation work are described in the Validation Report (VR) [RD 1]. Please note there is no official reference document that provides requirements for the reprocessed Level 1b bending angle product, NRT requirements[7] though serve as a guideline [RD 33].

The technical condition of the Release 2 - GRAS Level 1b Bending Angle FCDR has been assessed with the following checks:

- Basic checks of the data record, ensuring all the products are present and readable and that the metadata available is complete and consistent with the re-processing system configuration;
- Basic monitoring of the geophysical information in the products to ensure that they are within the ranges expected;
- Analysis of non-nominal or degraded measurements and the effectiveness of internal product flags in identifying them;
- Monitoring of signal-to-noise levels and tracking states of the receiver in order to ensure that measurement data as provided by the instrument is fit-for-use; occultations not meeting this requirement are labelled as degraded.

[7] See e.g., Prospects of the EPS GRAS Mission For Operational Atmospheric Applications, J-P Luntama et al., Bulletin of the American Meteorological Society, December 2008, Vol. 89, No. 12.

The scientific quality of Release 2 - GRAS Level 1b Bending Angle FCDR has been assessed with the following analyses:

1. **Global analysis**: in this analysis data sets are compared with each other globally, using the ERA-Interim re-analysis as "reference"[8].
2. **Direct evaluation**: analysis of seasonal and annual trends in the time-series of Level 1b GRAS data. This analysis requires only Level 1b GRAS data. No additional information is taken, and thus avoids, e.g., the mixture of reanalysis and actual measurement errors;
3. **Match-up evaluation**: pairs Level 1b GRAS data processed by EUMETSAT with Level 1b GRAS data processed by another centre (direct match-ups), or with Level 1b data from another mission. For direct matching, it is assured that only the same occultations are compared. For match-ups with another mission, observations pairs within 3h and 300km are taken. The resulting statistics are thus a mixture of the measurement errors (if not using a direct match), co-location uncertainties (if not using a direct match), and differences in processing characteristics;
4. **Reanalysis evaluation**: departure analysis in which the observations are evaluated against an ERA-Interim background. ERA-Interim provides a consistent (in the sense that the assimilation setup was consistent throughout the period, impacts of changes in the observation system are though still present) data set over the full investigated record. The resulting statistics are a mixture of reanalysis errors and the actual measurement/processing errors.
5. **Product evaluation**: analysing annual trends in bending angles for different latitudes and altitudes, derived both from the here analysed Release 2 - GRAS Level 1b Bending Angle FCDR data, as well as the ECMWF ERA-Interim data.

Either all occultation data is shown, or the data is separated into setting and rising occultations, or into different latitude bands. These latitude bands are either considering 30° spacing, independent of whether they are on the Northern or Southern Hemisphere, or they separate that further by Hemisphere.

EUMETSAT provided test datasets of Metop-A and Metop-B bending angles to the ROM-SAF for beta-testing. The Metop-A test dataset were a beta version of the Release 2 - GRAS Level 1b Bending Angle FCDR. The ROM SAF statistically compared these bending angles against their ROM SAF CDR v1.0 bending-angle data [RD 22]. They found that the bending angles from EUMETSAT's test data and ROM SAF data are very similar above 10 km. Below 10 km, the two datasets show different biases. Compared to ERA-Interim reanalysis EUMETSAT's test data were up to 3% larger and ROM SAF bending-angle data up to 3% smaller. As written in the Limitations section (Section 5.3.1) below, a deeper analysis of the findings from the statistical comparison done by the ROM SAF will be included in Validation Report for Release 2 - GRAS Level 1b Bending Angle FCDR, which will include both Metop-A and Metop-B data.

[8] Note that even though a re-analysis is using the same assimilation software version for the complete data set, it is not a "reference" of the true atmospheric state, but serves here as a commonly used reference. See the Validation Report [RD 1] for more information.

5.3 Applicability

Radio occultation data are well known for being calibration free, weather independent, and SI traceable; most importantly, they do not require any kind of external calibration before being used in any application. Prime application areas are therefore data assimilation, Numerical Weather Prediction (NWP) as well as climate monitoring applications.

5.3.1 Limitations

Although the monitoring and validation described in [RD 1] has shown the reprocessed data is of consistently high quality over the entire campaign period, the following limitations are mentioned which will be addressed in future versions of the EUMETSAT RO processing:

- Due to the focus on operational NWP applications in the original development of the wave optics processing capability (and the initial version of the reprocessing primarily being understood as a backward extension of the operational GRAS data into the past), the smoothing of bending angles is mostly carried out as part of the thinning towards the standard set of 247 operational levels. Therefore, high resolution bending-angle profiles may exhibit noise related features to a larger degree than the thinned profiles.
- For about 15–17 % of the bending-angle profiles, non-physical oscillations are present above 45 km altitude. These oscillations are within the typical uncertainties of bending angles as, e.g., used in data assimilation, and are therefore not flagged as degraded. They also do not appear to pose a problem in variational retrievals and data assimilation. However, in direct retrievals towards refractivity and dry temperature via an Abel transform, they may lead to similar non-physical structures in higher level products.
- About 5-6% of the bending-angle profiles suffer from non-physical spikes at mid and lower tropospheric altitudes which are not flagged as degraded.

6 PRODUCT ACCESS

Access to the data record is granted to all users without charge. The data can be accessed in two manners:

1 The data are accessible via the Copernicus Climate Data Store (CDS) and are available from the Copernicus Climate Change Service (C3S) website: https://climate.copernicus.eu.

2 The data are accessible via the EUMETSAT Data Centre after accepting the EUMETSAT Data Policy [RD 8]. To access the data from EUMETSAT, you need to register with the EUMETSAT Data Centre. When registered, you can order the data through a written request send to EUMETSAT's helpdesk.

6.1 Register with the Data Centre

To register with the EUMETSAT Data Centre:

3 Register in the EUMETSAT EO-Portal (*https://eoportal.eumetsat.int/*) by clicking on the New User – Create New Account tab;

4 After finalization of the registration process, an e-mail is sent to the e-mail address entered in the registration. Click the confirmation link in the e-mail to activate your account;

5 Login and subscribe to the Data Centre Service by going to the Service Subscription Tab and selecting Data Centre Service. Follow instructions issued from the web page to add needed information.

6.2 Order Data

The data record described in this product user guide can also be ordered via the EUMETSAT User Service Helpdesk in Darmstadt, Germany. Please send a written request to this helpdesk, email *ops@eumetsat.int,* indicating the data record that you want to order including its Digital Object Identifier (DOI) number (10.15770/EUM_SEC_CLM_0029).

If you have more questions or support issues, please contact the User Service Helpdesk directly via e-mail: *ops@eumetsat.int*

7 PRODUCT SUPPORT AND FEEDBACK

For enquiries or feedback concerning the product described in this product user guide, the CDS offers Help & Support functionality. Alternatively, the user can contact the EUMETSAT User Service Helpdesk by email: *ops@eumetsat.int.*

8 PRODUCT REFERENCING

The product's filename provides a unique identifier for each product, which is also given in the *title* global attribute of the netCDF files. The data record described in this product user guide has a unique DOI, which is also given in the *doi* global attribute of each netCDF file. Please note that the DOI is not included in the BUFR native files.

9 ACKNOWLEDGEMENTS

Precise GPS ephemerides used for preparing this data record have been obtained from the Center for Orbit Determination in Europe at the Astronomical Institute of the University of Bern (AIUB). The support of this institution is gratefully acknowledged.

10 REFERENCES

RD 1.	Validation_Report - Release 1 - GRAS Level 1b Bending Angle FCDR	EUM/OPS/DOC/18/1008023
RD 2.	Climate Services Development Plan	EUM/STG/72/18/DOC/11
RD 3.	YAROS v1.4 Release Notes	EUM/TSS/TEN/16/829850
RD 4.	GRAS Product Guide	
RD 5.	Radio Occultation Level 1 Product Format Specification	EUM/TSS/SPE/16/817861
RD 6.	Multi-Annual Implementation Plan 2016- 2021. The Provision of Climate of Climate Data for the Benefit of the Copernicus Climate Change Service, C3S_311b D9.3, v1.0	
RD 7.	EUMETSAT Data Centre Archive Online Ordering Application User Manual	EUM/OPS/DOC/06/0873
RD 8.	EUMETSAT Data Policy	link to pdf file
RD 9.	Brian Eaton, Jonathan Gregory, Bob Drach, Karl Taylor, Steve Hankin, Jon Blower, John Caron, Rich Signell, Phil Bentley, Greg Rappa, Heinke Höck, Alison Pamment, Martin Juckes, Martin Raspaud, NetCDF Climate and Forecast (CF) Metadata Conventions (version 1.7), http://cfconventions.org/Data/cf-conventions/cf-conventions-1.7/cf-conventions.pdf , (accessed on 10 January 2019)	
RD 10.	Generic Product Format Specification, v8c, 9 June 2016	EPS.GGS.SPE.96167
RD 11.	WMO FM94 (BUFR) Specification for Radio Occultation Data, Version 2.4, 1 December 2016, SAF/ROM/METO/FMT/BUFR/001, available at http://www.romsaf.org/ romsaf_bufr.pdf, (accessed on 6 December 2018)	
RD 12.	Kursinski, E., G. Hajj, J. Schofield, R. Linfield, and K. Hardy (1997), Observing Earth's atmosphere with radio occultation measurements using GPS, J. Geophys. Res., 102(D25), 23,42923,465, http://dx.doi.org/10.1029/97JD01569	
RD 13.	Anthes, R.A. (2011) Exploring Earth\u2019s Atmosphere with Radio Occultation: Contributions to Weather, Climate and Space Weather. Atmospheric Measurement Techniques, 4, 1077-1103. http://dx.doi.org/10.5194/amt-4-1077-2011	
RD 14.	GCOS-154, 2011: Systematic Observation Requirements for Satellite-Based Products for Climate, 2011 Update, December 2011, 139 pp.	
RD 15.	Dee DP, Uppala SM, Simmons AJ, Berrisford P, Poli P, Kobayashi S, Andrae U, Balmaseda MA, Balsamo G, Bauer P, Bechtold P, Beljaars ACM, van de Berg L, Bidlot J, Bormann N, Delsol C, Dragani R, Fuentes M, Geer AJ, Haimberger L, Healy SB, Hersbach H, Holm EV, Isaksen L, K ´ allberg P, Kohler M, Matricardi M, McNally AP, Monge-Sanz BM, Morcrette J-J, Park B-K, Peubey C, de Rosnay P, Tavolato C, Thepaut J-N, Vitart F. 2011. The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q. J. R. Meteorol. Soc. 137: 553–597. doi:10.1002/qj.828	
RD 16.	A merged dataset of GPS Navigation Bit for the use in RO Data Processing	EUM/TSS/REP/14/759965
RD 17.	GRAS GSN / CGS Interface Control Document	EPS-ASP-ID-1086
RD 18.	Dach, Rolf; Schaer, Stefan; Arnold, Daniel; Prange, Lars; Sidorov, Dmitry; Stebler, Pascal; Villiger, Arturo; Jäggi, Adrian (2018). CODE final product series for the IGS. Published by Astronomical Institute, University of Bern. URL: http://www.aiub.unibe.ch/download/CODE; DOI: 10.7892/boris.75876.3.	
RD 19.	ftp://maia.usno.navy.mil/ser7/finals2000A.data (accessed on 29 November 2018)	
RD 20.	ftp://maia.usno.navy.mil/ser7/readme.finals2000A (accessed on 29 November 2018)	
RD 21.	ftp://igs.org/pub/data/format/rinex210.txt, (accessed on 29 November 2018)	
RD 22.	ROM SAF: Validation Report: Reprocessed Level 1B bending angle, Level 2A refractivity, Level 2A dry temperature CDR v1.0 products. SAF/ROM/DMI/REP/ATM/001, Version 1.1	
RD 23.	ESA: NAPEOS (NAvigation Package for Earth Orbiting Satellites), https://www.esa.int/Our_Activities/Operations/NAPEOS, cited 18. December 2018	

RD 24.	Beyerle, G. (2005). GPS radio occultation with GRACE: Atmospheric profiling utilizing the zero difference technique. Geophysical Research Letters, 32(13), 1–5. https://doi.org/10.1029/2005GL023109
RD 25.	Sokolovskiy, S., Rocken, C., Schreiner, W., Hunt, D., & Johnson, J. (2009). Postprocessing of L1 GPS radio occultation signals recorded in open-loop mode. Radio Science, 44(2), 1–13. https://doi.org/10.1029/2008RS003907
RD 26.	Jensen, A. S., Lohmann, M. S., Benzon, H.-H., & Nielsen, A. S. (2003). Full Spectrum Inversion of radio occultation signals. Radio Science, 38(3). https://doi.org/10.1029/2002RS002763
RD 27.	Gorbunov, M. E., Lauritsen, K. B., Rhodin, A., Tomassini, M., & Kornblueh, L. (2006). Radio holographic filtering, error estimation, and quality control of radio occultation data. Journal of Geophysical Research, 111(D10), 1–10. https://doi.org/10.1029/2005JD006427
RD 28.	Vorob'ev, V. V, & Krasil'nikova, T. G. (1994). Estimation of the accuracy of the atmospheric refractive index recovery from doppler shift measurements at frequencies used in the NAVSTAR system. USSR Phys. Atmos. Ocean, Engl. Transl., 29, 602–609.
RD 29.	Healy, S. B., & Culverwell, I. D. (2015). A modification to the standard ionospheric correction method used in GPS radio occultation. Atmos. Meas. Tech, 8, 3385–3393. https://doi.org/10.5194/amt-8-3385-2015
RD 30.	Danzer, J., Healy, S. B., & Culverwell, I. D. (2015). A simulation study with a new residual ionospheric error model for GPS radio occultation climatologies. Atmos. Meas. Tech, 8, 3395–3404. https://doi.org/10.5194/amt-8-3395-2015
RD 31.	Wand, M. P., & Jones, M. C. (1995). Kernel smoothing. Boca Raton: Chapman & Hall / CRC.
RD 32.	Loader, C. (1999). Local regression and likelihood. New York: Springer.
RD 33.	Prospects of the EPS GRAS Mission For Operational Atmospheric Applications, Juha-Pekka Luntama et al., Bulletin of the American Meteorological Society, December 2008, Vol. 89, No. 12

APPENDIX 1: Metadata netCDF File

List of variables names of the netCDF format.

```
// global attributes:
                :Conventions = "CF-1.7" ;
                :metadata_conventions = "Unidata Dataset Discovery v1.0" ;
                :summary = "GRAS/Metop-A level 1a/b radio occultation data" ;
                :keywords = "" ;
                :history = "original generated product" ;
                :institution = "EUMETSAT" ;
                :spacecraft = "M02" ;
                :instrument = "GRAS" ;
                :product_level = "1B" ;
                :type = "BND" ;
                :mission_type = "Global" ;
                :disposition_mode = "Operational" ;
                :sensing_start = "2015-06-12 22:53:57.799" ;
                :sensing_end = "2015-06-12 22:55:45.366" ;
                :environment = "Offline" ;
                :references = "www.eumetsat.int" ;
                :orbit_start = 44869LL ;
                :orbit_end = 44870LL ;
                :receive_start = "2015-06-12 22:45:51.000" ;
                :receive_end = "2015-06-13 02:11:10.000" ;
                :subsetting = "NONE" ;
                :receiving_ground_station = "SVL" ;
                :title                                                   =
"GRAS_1B_M02_20150612225357Z_20150612225545Z_R_O_20170215123716Z_G29_NN_0100.nc" ;
                :doi = "10.15770/EUM_SEC_CLM_0015" ;

group: status {

  group: satellite {
    variables:
        double epoch_time_utc ;
                epoch_time_utc:units = "seconds since 2000-01-01 00:00:00" ;
                epoch_time_utc:long_name = "Epoch time in UTC of the orbital elements
and the orbit state vector" ;
                epoch_time_utc:missing_value = NaN ;
        double semi_major_axis ;
                semi_major_axis:units = "m" ;
                semi_major_axis:long_name = "Semi major axis of the orbit at epoch
time" ;
                semi_major_axis:missing_value = NaN ;
        double eccentricity ;
                eccentricity:long_name = "Eccentricity of the orbit at epoch time" ;
                eccentricity:missing_value = NaN ;
        double inclination ;
                inclination:units = "degrees" ;
                inclination:long_name = "Inclination of the orbit at epoch time" ;
                inclination:missing_value = NaN ;
        double perigee_argument ;
                perigee_argument:units = "degrees" ;
                perigee_argument:long_name = "Argument of perigee of the orbit at
epoch time" ;
                perigee_argument:missing_value = NaN ;
        double right_ascension ;
                right_ascension:units = "degrees" ;
                right_ascension:long_name = "Right ascension of the orbit at epoch
time" ;
                right_ascension:missing_value = NaN ;
        double mean_anomaly ;
                mean_anomaly:units = "degrees" ;
```

```
                mean_anomaly:long_name = "Mean anomaly of the orbit at epoch time" ;
                mean_anomaly:missing_value = NaN ;
        double x_position ;
                x_position:units = "m" ;
                x_position:long_name = "X position of the orbit state vector in the orbit frame at ascending node [EARTH+FIXED]" ;
                x_position:missing_value = NaN ;
        double y_position ;
                y_position:units = "m" ;
                y_position:long_name = "Y position of the orbit state vector in the orbit frame at ascending node [EARTH+FIXED]" ;
                y_position:missing_value = NaN ;
        double z_position ;
                z_position:units = "m" ;
                z_position:long_name = "Z position of the orbit state vector in the orbit frame at ascending node [EARTH+FIXED]" ;
                z_position:missing_value = NaN ;
        double x_velocity ;
                x_velocity:units = "m/s" ;
                x_velocity:long_name = "X velocity of the orbit state vector in the orbit frame at ascending node [EARTH+FIXED]" ;
                x_velocity:missing_value = NaN ;
        double y_velocity ;
                y_velocity:units = "m/s" ;
                y_velocity:long_name = "Y velocity of the orbit state vector in the orbit frame at ascending node [EARTH+FIXED]" ;
                y_velocity:missing_value = NaN ;
        double z_velocity ;
                z_velocity:units = "m/s" ;
                z_velocity:long_name = "Z velocity of the orbit state vector in the orbit frame at ascending node [EARTH+FIXED]" ;
                z_velocity:missing_value = NaN ;
        double earth_sun_distance_ratio ;
                earth_sun_distance_ratio:long_name = "Ratio of current Earth-Sun distance to Mean Earth-Sun distance" ;
                earth_sun_distance_ratio:missing_value = NaN ;
        double location_tolerance_radial ;
                location_tolerance_radial:units = "m" ;
                location_tolerance_radial:long_name = "Nadir Earth location tolerance radial" ;
                location_tolerance_radial:missing_value = NaN ;
        double location_tolerance_crosstrack ;
                location_tolerance_crosstrack:units = "m" ;
                location_tolerance_crosstrack:long_name = "Nadir Earth location tolerance cross-track" ;
                location_tolerance_crosstrack:missing_value = NaN ;
        double location_tolerance_alongtrack ;
                location_tolerance_alongtrack:units = "m" ;
                location_tolerance_alongtrack:long_name = "Nadir Earth location tolerance along-track" ;
                location_tolerance_alongtrack:missing_value = NaN ;
        double yaw_error ;
                yaw_error:units = "degrees" ;
                yaw_error:long_name = "Yaw attitude bias" ;
                yaw_error:missing_value = NaN ;
        double roll_error ;
                roll_error:units = "degrees" ;
                roll_error:long_name = "Roll attitude bias" ;
                roll_error:missing_value = NaN ;
        double pitch_error ;
                pitch_error:units = "degrees" ;
                pitch_error:long_name = "Pitch attitude bias" ;
                pitch_error:missing_value = NaN ;
        double subsat_latitude_start ;
                subsat_latitude_start:units = "degrees_north" ;
```

```
                subsat_latitude_start:long_name = "Latitude of sub-satellite point
at start of the product" ;
                subsat_latitude_start:missing_value = NaN ;
        double subsat_longitude_start ;
                subsat_longitude_start:units = "degrees_east" ;
                subsat_longitude_start:long_name = "Longitude of sub-satellite point
at start of the product" ;
                subsat_longitude_start:missing_value = NaN ;
        double subsat_latitude_end ;
                subsat_latitude_end:units = "degrees_north" ;
                subsat_latitude_end:long_name = "Latitude of sub-satellite point at
end of the product" ;
                subsat_latitude_end:missing_value = NaN ;
        double subsat_longitude_end ;
                subsat_longitude_end:units = "degrees_east" ;
                subsat_longitude_end:long_name = "Longitude of sub-satellite point
at end of the product" ;
                subsat_longitude_end:missing_value = NaN ;
        double leap_second_utc ;
                leap_second_utc:units = "seconds since 2000-01-01 00:00:00" ;
                leap_second_utc:long_name = "UTC time of occurrence of a leap second
in this product (no leap second results in 0)" ;
                leap_second_utc:missing_value = NaN ;
        byte leap_second ;
                leap_second:units = "s" ;
                leap_second:long_name = "Value of leap second in product (1, 0, or -
1)" ;
                leap_second:missing_value = -128b ;
    } // group satellite

  group: processing {

    // group attributes:
                :generating_facility = "YAR" ;
                :processor_name = "YAROS" ;
                :processing_mode = "Reprocessing" ;
                :format_version = "11.0" ;
                :creation_time = "2017-02-15 12:37:16.662" ;
                :idb_info = "M02 A/S on v1.2" ;
                :processing_centre = "ERF2" ;
                :processor_version = "1.4" ;
                :source                                                         =
"GRAS_xxx_00_M02_20150612225402Z_20150613003558Z_N_O_20150613003050Z.nat" ;
                :baseline = "0100" ;
    } // group processing

  group: instrument {

    // group attributes:
                :instrument_mode = "Occultation" ;
                :onboard_sw_version = "1.11" ;
    } // group instrument
  } // group status

group: data {

  group: receiver {

    group: satellite {
      dimensions:
        xyz = 3 ;
      variables:
        double centre_of_mass(xyz) ;
                centre_of_mass:units = "m" ;
                centre_of_mass:long_name = "Centre of mass (in S/C coordinates)" ;
                centre_of_mass:missing_value = NaN ;
```

```
        double antenna_phase_centre(xyz) ;
                antenna_phase_centre:units = "m" ;
                antenna_phase_centre:long_name = "Antenna phase centre (in S/C
coordinates)" ;
                antenna_phase_centre:missing_value = NaN ;
        double antenna_orientation(xyz) ;
                antenna_orientation:units = "m" ;
                antenna_orientation:long_name = "Antenna orientation (unit vector
perpendicular to antenna plane in S/C coordinates)" ;
                antenna_orientation:missing_value = NaN ;

      // group attributes:
                :satellite = "Metop-A" ;
                :satellite_id_eum = "M02" ;
                :satellite_id_sp3 = "L14" ;
                :satellite_id_norad = "29499" ;
      } // group satellite

    group: orbit {

      group: centre_of_mass {
        dimensions:
                xyz = 3 ;
                t = 14 ;
        variables:
                int utc_absdate(t) ;
                        utc_absdate:units = "days since 2000-01-01 00:00" ;
                        utc_absdate:long_name = "Epochs (full days) in UTC" ;
                        utc_absdate:missing_value = -2147483648 ;
                double utc_abstime(t) ;
                        utc_abstime:units = "seconds since 00:00:00" ;
                        utc_abstime:long_name = "Epochs (seconds since last midnight)
in UTC" ;
                        utc_abstime:missing_value = NaN ;
                double position(t, xyz) ;
                        position:units = "m" ;
                        position:long_name = "Satellite position in J2000 reference
frame" ;
                        position:missing_value = NaN ;
                double velocity(t, xyz) ;
                        velocity:units = "m/s" ;
                        velocity:long_name = "Satellite velocity in J2000 reference
frame" ;
                        velocity:missing_value = NaN ;
                byte orbit_predicted(t) ;
                        orbit_predicted:long_name = "True if orbits are predicted
(instead of estimated)" ;
                        orbit_predicted:missing_value = -128b ;
                byte manoeuvre(t) ;
                        manoeuvre:long_name = "True if satellite undergoes a
manoeuvre" ;
                        manoeuvre:missing_value = -128b ;

        // group attributes:
                        :title = "Metop-A precise orbit (centre of mass) in J2000
reference frame" ;
                        :institution = " EUM" ;
                        :filename =
"L14_cod_j2000_20150611205944Z_20150613025944Z_20170203154957Z.sp3" ;
                        :coordinate_system = "J2000" ;
                        :orbit_type = "BHN" ;
                        :std_base_pv_sp3 = 0. ;
                        :std_base_clock_sp3 = 0. ;
                        :comments_1_sp3 = "   EUROPEAN SPACE OPERATIONS CENTRE -
DARMSTADT, GERMANY                      " ;
```

```
                        :comments_2_sp3 = "-----------------------------------------
-----------------                    " ;
                        :comments_3_sp3 = " SP3 FILE GENERATED BY NAPEOS BAHN TOOL
(DETERMINATION)                     " ;
                        :comments_4_sp3 = "PCV:IGS05_1552 OL/AL:FES2004  NONE     YN
ORB:CoN CLK:CoN                    " ;
                        :satellite_id_sp3 = "L14" ;
                        :accuracy_exponent_sp3 = 5 ;
        } // group centre_of_mass

      group: antenna_phase_centre {
        dimensions:
                xyz = 3 ;
                t = 14 ;
        variables:
                int utc_absdate(t) ;
                        utc_absdate:units = "days since 2000-01-01 00:00" ;
                        utc_absdate:long_name = "Epochs (full days) in UTC" ;
                        utc_absdate:missing_value = -2147483648 ;
                double utc_abstime(t) ;
                        utc_abstime:units = "seconds since 00:00:00" ;
                        utc_abstime:long_name = "Epochs (seconds since last midnight)
in UTC" ;
                        utc_abstime:missing_value = NaN ;
                double position(t, xyz) ;
                        position:units = "m" ;
                        position:long_name = "Satellite position in J2000 reference
frame" ;
                        position:missing_value = NaN ;
                double velocity(t, xyz) ;
                        velocity:units = "m/s" ;
                        velocity:long_name = "Satellite velocity in J2000 reference
frame" ;
                        velocity:missing_value = NaN ;
                byte orbit_predicted(t) ;
                        orbit_predicted:long_name = "True if orbits are predicted
(instead of estimated)" ;
                        orbit_predicted:missing_value = -128b ;
                byte manoeuvre(t) ;
                        manoeuvre:long_name = "True if satellite undergoes a
manoeuvre" ;
                        manoeuvre:missing_value = -128b ;

        // group attributes:
                        :title = "Metop-A precise orbit (GRAS rising antenna phase
centre) in J2000 reference frame" ;
                        :institution = " EUM" ;
                        :filename                                                 =
"L14_cod_j2000_20150611205944Z_20150613025944Z_20170203154957Z.sp3" ;
                        :coordinate_system = "J2000" ;
                        :orbit_type = "BHN" ;
                        :std_base_pv_sp3 = 0. ;
                        :std_base_clock_sp3 = 0. ;
                        :comments_1_sp3 = "   EUROPEAN SPACE OPERATIONS CENTRE -
DARMSTADT, GERMANY                      " ;
                        :comments_2_sp3 = "-----------------------------------------
-----------------                    " ;
                        :comments_3_sp3 = " SP3 FILE GENERATED BY NAPEOS BAHN TOOL
(DETERMINATION)                     " ;
                        :comments_4_sp3 = "PCV:IGS05_1552 OL/AL:FES2004  NONE     YN
ORB:CoN CLK:CoN                    " ;
                        :satellite_id_sp3 = "L14" ;
                        :accuracy_exponent_sp3 = 5 ;
        } // group antenna_phase_centre
      } // group orbit
```

```
    group: clock {
      dimensions:
        files = 1 ;
        t = 6 ;
      variables:
        string filelist(files) ;
                filelist:long_name = "List of files that were used to generate this
file" ;
                filelist:missing_value = "" ;
        int utc_absdate(t) ;
                utc_absdate:units = "days since 2000-01-01 00:00:00" ;
                utc_absdate:long_name = "Epochs (full days) in UTC" ;
                utc_absdate:missing_value = -2147483648 ;
        double utc_abstime(t) ;
                utc_abstime:units = "seconds since 00:00:00" ;
                utc_abstime:long_name = "Epochs (seconds since last midnight) in UTC"
;
                utc_abstime:missing_value = NaN ;
        double bias(t) ;
                bias:units = "s" ;
                bias:long_name = "Satellite/receiver/transmitter clock bias" ;
                bias:missing_value = NaN ;
        double rate(t) ;
                rate:units = "s/s" ;
                rate:long_name = "Satellite/receiver/transmitter clock drift" ;
                rate:missing_value = NaN ;
        char type(t) ;
                type:long_name  =  "Clock  error  type:  o(bserved),  p(ropagated),
e(stimated), i(nterpolated) or n(o obs)" ;
                type:missing_value = "" ;

      // group attributes:
                :title = "Metop-A/GRAS receiver precise clock error" ;
                :institution = "EUM" ;
                :periodic_relativistic_correction = "Yes" ;
                :transponder_id = "L14" ;
                :satellite_id = "M02" ;
      } // group clock
    } // group receiver

  group: transmitter {

    group: satellite {
      dimensions:
        xyz = 3 ;
      variables:
        double centre_of_mass(xyz) ;
                centre_of_mass:units = "m" ;
                centre_of_mass:long_name = "Centre of mass (in S/C coordinates)" ;
                centre_of_mass:missing_value = NaN ;
        double antenna_phase_centre(xyz) ;
                antenna_phase_centre:units = "m" ;
                antenna_phase_centre:long_name  =  "Antenna  phase  centre  (in  S/C
coordinates)" ;
                antenna_phase_centre:missing_value = NaN ;
        double antenna_orientation(xyz) ;
                antenna_orientation:units = "m" ;
                antenna_orientation:long_name  =  "Antenna  orientation  (unit  vector
perpendicular to antenna plane in S/C coordinates)" ;
                antenna_orientation:missing_value = NaN ;
        byte satellite_in_eclipse ;
                satellite_in_eclipse:long_name  =  "True  if  GNSS  satellite  is  in
eclipse during the occultation" ;
                satellite_in_eclipse:missing_value = -128b ;

      // group attributes:
```

```
                :satellite = "GPS-57" ;
                :satellite_block = "IIRM" ;
                :satellite_clock = "Rb" ;
                :satellite_prn = "G29" ;
                :satellite_id_sp3 = "G29" ;
                :satellite_id_norad = "32384" ;
      } // group satellite

    group: orbit {

      group: centre_of_mass {
        dimensions:
                xyz = 3 ;
                t = 10 ;
        variables:
                int utc_absdate(t) ;
                        utc_absdate:units = "days since 2000-01-01 00:00" ;
                        utc_absdate:long_name = "Epochs (full days) in UTC" ;
                        utc_absdate:missing_value = -2147483648 ;
                double utc_abstime(t) ;
                        utc_abstime:units = "seconds since 00:00:00" ;
                        utc_abstime:long_name = "Epochs (seconds since last midnight)
in UTC" ;
                        utc_abstime:missing_value = NaN ;
                double position(t, xyz) ;
                        position:units = "m" ;
                        position:long_name = "Satellite position in J2000 reference
frame" ;
                        position:missing_value = NaN ;
                byte orbit_predicted(t) ;
                        orbit_predicted:long_name = "True if orbits are predicted
(instead of estimated)" ;
                        orbit_predicted:missing_value = -128b ;
                byte manoeuvre(t) ;
                        manoeuvre:long_name = "True if satellite undergoes a
manoeuvre" ;
                        manoeuvre:missing_value = -128b ;

        // group attributes:
                        :title = "GPS transmitter precise orbit (centre of mass) in
J2000 reference frame" ;
                        :institution = "AIUB" ;
                        :filename                                                  =
"gps_cod_j2000_20150611205944Z_20150613024444Z_20170203154957Z.sp3" ;
                        :coordinate_system = "J2000" ;
                        :orbit_type = "FIT" ;
                        :std_base_pv_sp3 = 1.25 ;
                        :std_base_clock_sp3 = 1.025 ;
                        :comments_1_sp3 = "Center for Orbit Determination in Europe
(CODE)          " ;
                        :comments_2_sp3 = "Final GNSS orbits and GPS clocks for year-
day 15162      " ;
                        :comments_3_sp3 = "Note: Middle day of a 3-day arc
GPS/GLONASS solution     " ;
                        :comments_4_sp3 = "PCV:IGS08      OL/AL:FES2004  NONE     YN
ORB:CoN CLK:CoN" ;
                        :satellite_id_sp3 = "G29" ;
                        :accuracy_exponent_sp3 = 0 ;
        } // group centre_of_mass
      } // group orbit

    group: clock {
      dimensions:
        files = 1 ;
        t = 6 ;
      variables:
```

```
        string filelist(files) ;
                filelist:long_name = "List of files that were used to generate this
file" ;
                filelist:missing_value = "" ;
        int utc_absdate(t) ;
                utc_absdate:units = "days since 2000-01-01 00:00:00" ;
                utc_absdate:long_name = "Epochs (full days) in UTC" ;
                utc_absdate:missing_value = -2147483648 ;
        double utc_abstime(t) ;
                utc_abstime:units = "seconds since 00:00:00" ;
                utc_abstime:long_name = "Epochs (seconds since last midnight) in UTC"
;
                utc_abstime:missing_value = NaN ;
        double bias(t) ;
                bias:units = "s" ;
                bias:long_name = "Satellite/receiver/transmitter clock bias" ;
                bias:missing_value = NaN ;
        double rate(t) ;
                rate:units = "s/s" ;
                rate:long_name = "Satellite/receiver/transmitter clock drift" ;
                rate:missing_value = NaN ;
        char type(t) ;
                type:long_name  =  "Clock  error  type:  o(bserved),  p(ropagated),
e(stimated), i(nterpolated) or n(o obs)" ;
                type:missing_value = "" ;

      // group attributes:
                :title = "GPS transmitter precise clock error" ;
                :institution = "COD" ;
                :periodic_relativistic_correction = "Yes" ;
                :transponder_id = "G29" ;
                :satellite_id = "GPS-57" ;
      } // group clock
    } // group transmitter

  group: earth_orientation_parameters {
    dimensions:
        t = 7 ;
    variables:
        int utc_absdate(t) ;
                utc_absdate:units = "days since 2000-01-01 00:00" ;
                utc_absdate:long_name = "Epochs (full days) in UTC" ;
                utc_absdate:missing_value = -2147483648 ;
        double utc_abstime(t) ;
                utc_abstime:units = "seconds since 00:00:00" ;
                utc_abstime:long_name = "Epochs (seconds since last midnight) in UTC"
;
                utc_abstime:missing_value = NaN ;
        double xp(t) ;
                xp:units = "rad" ;
                xp:long_name = "x component of polar motion" ;
                xp:missing_value = NaN ;
        double yp(t) ;
                yp:units = "rad" ;
                yp:long_name = "y component of polar motion" ;
                yp:missing_value = NaN ;
        double ut1_utc(t) ;
                ut1_utc:units = "s" ;
                ut1_utc:long_name  =  "Difference  between  Universal  Time  (UT1)  and
Coordinated Universal Time (UTC)" ;
                ut1_utc:missing_value = NaN ;
        double dX(t) ;
                dX:units = "rad" ;
                dX:long_name  =  "dX  wrt  IAU2000A  Nutation,  Free  Core  Nutation  NOT
Removed" ;
                dX:missing_value = 0. ;
```

```
        double dY(t) ;
                dY:units = "rad" ;
                dY:long_name = "dY wrt IAU2000A Nutation, Free Core Nutation NOT
Removed" ;
                dY:missing_value = 0. ;
        byte flag_predicted(t) ;
                flag_predicted:long_name = "Estimated (0) or Predicted (1) flag for
polar motion values" ;
                flag_predicted:missing_value = -128b ;
        double LOD(t) ;
                LOD:units = "ms" ;
                LOD:long_name = "Length of Day (difference between the astronomically
determined duration of the day and 86400)" ;
                LOD:missing_value = NaN ;

    // group attributes:
                :title = "Earth orientation parameters" ;
                :model = "2000A" ;
                :filename                                                          =
"eop_ier_xxxxx_20150610000000Z_20150616000000Z_20170203155854Z.eop" ;
    } // group earth_orientation_parameters

  group: occultation {
    dimensions:
        xyz = 3 ;
    variables:
        int prn ;
                prn:long_name = "PRN number of the occulting GNSS satellite" ;
                prn:missing_value = -2147483648 ;
        int channel ;
                channel:long_name  =  "GRAS  channel  on  which  the  occultation  was
measured" ;
                channel:missing_value = -2147483648 ;
        int utc_georef_absdate ;
                utc_georef_absdate:units = "days since 2000-01-01 00:00:00.00" ;
                utc_georef_absdate:long_name = "Reference UTC time for georeferencing
(for SLTA = 0)" ;
                utc_georef_absdate:missing_value = -2147483648 ;
        double utc_georef_abstime ;
                utc_georef_abstime:units = "seconds since 00:00:00.00" ;
                utc_georef_abstime:long_name = "Reference UTC time for georeferencing
(for SLTA = 0)" ;
                utc_georef_abstime:missing_value = NaN ;
        int gps_georef_absdate ;
                gps_georef_absdate:units = "days since 2000-01-01 00:00:00.00" ;
                gps_georef_absdate:long_name = "Reference GPS time for georeferencing
(for SLTA = 0)" ;
                gps_georef_absdate:missing_value = -2147483648 ;
        double gps_georef_abstime ;
                gps_georef_abstime:units = "seconds since 00:00:00.00" ;
                gps_georef_abstime:long_name = "Reference GPS time for georeferencing
(for SLTA = 0)" ;
                gps_georef_abstime:missing_value = NaN ;
        double longitude ;
                longitude:units = "degrees_east" ;
                longitude:long_name = "Longitude of reference location (for SLTA =
0)" ;
                longitude:missing_value = NaN ;
        double latitude ;
                latitude:units = "degrees_north" ;
                latitude:long_name = "Latitude of reference location (for SLTA = 0)"
;
                latitude:missing_value = NaN ;
        double azimuth_north ;
                azimuth_north:units = "degrees" ;
```

```
                azimuth_north:long_name = "GNSS -> LEO line of sight azimuth angle
at reference location (for SLTA = 0, clockwise against
True North)" ;
                azimuth_north:missing_value = NaN ;
        double r_curve ;
                r_curve:units = "m" ;
                r_curve:long_name = "Radius of curvature (for SLTA = 0)" ;
                r_curve:missing_value = NaN ;
        double r_curve_centre(xyz) ;
                r_curve_centre:units = "m" ;
                r_curve_centre:long_name = "Centre of curvature position in Earth
centred inertial coordinates (J2000, for SLTA = 0)" ;
                r_curve_centre:missing_value = NaN ;
        double r_curve_centre_fixed(xyz) ;
                r_curve_centre_fixed:units = "m" ;
                r_curve_centre_fixed:long_name = "Centre of curvature position in
Earth fixed coordinates (for SLTA = 0)" ;
                r_curve_centre_fixed:missing_value = NaN ;
        double undulation ;
                undulation:units = "m" ;
                undulation:long_name = "EGM96 undulation at reference location" ;
                undulation:missing_value = NaN ;
        double longitude_rec ;
                longitude_rec:units = "degrees_east" ;
                longitude_rec:long_name = "Receiver longitude (for SLTA = 0)" ;
                longitude_rec:missing_value = NaN ;
        double latitude_rec ;
                latitude_rec:units = "degrees_north" ;
                latitude_rec:long_name = "Receiver latitude (for SLTA = 0)" ;
                latitude_rec:missing_value = NaN ;
        double altitude_rec ;
                altitude_rec:units = "m" ;
                altitude_rec:long_name = "Receiver altitude (for SLTA = 0, above
ellipsoid)" ;
                altitude_rec:missing_value = NaN ;
        double position_rec(xyz) ;
                position_rec:units = "m" ;
                position_rec:long_name = "Receiver antenna position in Earth centred
inertial coordinates (J2000, for SLTA = 0)" ;
                position_rec:missing_value = NaN ;
        double position_rec_fixed(xyz) ;
                position_rec_fixed:units = "m" ;
                position_rec_fixed:long_name = "Receiver antenna position in Earth
fixed coordinates (for SLTA = 0)" ;
                position_rec_fixed:missing_value = NaN ;
        double velocity_rec(xyz) ;
                velocity_rec:units = "m/s" ;
                velocity_rec:long_name = "Receiver antenna velocity in Earth centred
inertial coordinates (J2000, for SLTA = 0)" ;
                velocity_rec:missing_value = NaN ;
        double longitude_gns ;
                longitude_gns:units = "degrees_east" ;
                longitude_gns:long_name = "GNSS longitude (for SLTA = 0)" ;
                longitude_gns:missing_value = NaN ;
        double latitude_gns ;
                latitude_gns:units = "degrees_north" ;
                latitude_gns:long_name = "GNSS latitude (for SLTA = 0)" ;
                latitude_gns:missing_value = NaN ;
        double altitude_gns ;
                altitude_gns:units = "m" ;
                altitude_gns:long_name = "GNSS altitude (for SLTA = 0, above
ellipsoid)" ;
                altitude_gns:missing_value = NaN ;
        double position_gns(xyz) ;
                position_gns:units = "m" ;
```

```
                position_gns:long_name = "GNSS transmitter position in Earth centred
inertial coordinates (J2000, for SLTA = 0)" ;
                position_gns:missing_value = NaN ;
        double position_gns_fixed(xyz) ;
                position_gns_fixed:units = "m" ;
                position_gns_fixed:long_name = "GNSS transmitter position in Earth
fixed coordinates (for SLTA = 0)" ;
                position_gns_fixed:missing_value = NaN ;
        double velocity_gns(xyz) ;
                velocity_gns:units = "m/s" ;
                velocity_gns:long_name = "GNSS transmitter velocity in Earth centred
inertial coordinates (J2000, for SLTA = 0)" ;
                velocity_gns:missing_value = NaN ;
        double azimuth_antenna ;
                azimuth_antenna:units = "degrees" ;
                azimuth_antenna:long_name = "Antenna azimuth angle (for SLTA = 0)" ;
                azimuth_antenna:missing_value = NaN ;
        double zenith_antenna ;
                zenith_antenna:units = "degrees" ;
                zenith_antenna:long_name = "Antenna zenith angle (for SLTA = 0)" ;
                zenith_antenna:missing_value = NaN ;
        int n_analogue_gc ;
                n_analogue_gc:long_name = "Number of analogue gain changes during the
occultation" ;
                n_analogue_gc:missing_value = -2147483648 ;
        int n_digital_gc ;
                n_digital_gc:long_name = "Number of digital gain changes during the
occultation" ;
                n_digital_gc:missing_value = -2147483648 ;

    // group attributes:
                :occultation_type = "rising" ;
                :gnss_system = "GPS" ;
                :pod_method = "Batch (NAPEOS Bahn)" ;
                :phase_method = "zero differencing" ;
                :idb_info = "M02 A/S on v1.2" ;
                :title = "GRAS/Metop-A level 1a/b data (occultation information /
georeferencing)" ;
                :retrieval_method = "FSI" ;
    } // group occultation

  group: level_1a {
    variables:
        int utc_start_absdate ;
                utc_start_absdate:units = "days since 2000-01-01 00:00:00.00" ;
                utc_start_absdate:long_name = "Start (reference) UTC time for all
observation epochs / date" ;
                utc_start_absdate:missing_value = -2147483648 ;
        double utc_start_abstime ;
                utc_start_abstime:units = "seconds since 00:00:00.00" ;
                utc_start_abstime:long_name = "Start (reference) UTC time for all
observation epochs / time" ;
                utc_start_abstime:missing_value = NaN ;
        int gps_start_absdate ;
                gps_start_absdate:units = "days since 2000-01-01 00:00:00.00" ;
                gps_start_absdate:long_name = "Start (reference) GPS time for all
observation epochs / date" ;
                gps_start_absdate:missing_value = -2147483648 ;
        double gps_start_abstime ;
                gps_start_abstime:units = "seconds since 00:00:00.00" ;
                gps_start_abstime:long_name = "Start (reference) GPS time for all
observation epochs / time" ;
                gps_start_abstime:missing_value = NaN ;

    // group attributes:
                :title = "GRAS/Metop-A level 1a data" ;
```

```
    group: closed_loop {
      dimensions:
        t = 2151 ;
        xyz = 3 ;
      variables:
        double dtime(t) ;
                dtime:units = "seconds since 2015-06-12 22:53:57.83" ;
                dtime:long_name = "Measurement epoch" ;
                dtime:missing_value = NaN ;
        double slta(t) ;
                slta:units = "m" ;
                slta:long_name = "Straight line tangent altitude" ;
                slta:missing_value = NaN ;
        double samplerate ;
                samplerate:units = "Hz" ;
                samplerate:long_name = "Measurement sample rate" ;
                samplerate:missing_value = NaN ;
        int tracking_state(t) ;
                tracking_state:long_name = "Tracking states" ;
                tracking_state:missing_value = -2147483648 ;
        double phase_l1_nco(t) ;
                phase_l1_nco:units = "m" ;
                phase_l1_nco:long_name = "L1 carrier NCO phase" ;
                phase_l1_nco:missing_value = NaN ;
        double phase_l2_nco(t) ;
                phase_l2_nco:units = "m" ;
                phase_l2_nco:long_name = "L2 carrier NCO phase" ;
                phase_l2_nco:missing_value = NaN ;
        double phase_ca(t) ;
                phase_ca:units = "m" ;
                phase_ca:long_name = "C/A carrier phase including I/Q contributions"
;
                phase_ca:missing_value = NaN ;
        double phase_p1(t) ;
                phase_p1:units = "m" ;
                phase_p1:long_name = "P1 carrier phase including I/Q contributions"
;
                phase_p1:missing_value = NaN ;
        double phase_p2(t) ;
                phase_p2:units = "m" ;
                phase_p2:long_name = "P2 carrier phase including I/Q contributions"
;
                phase_p2:missing_value = NaN ;
        double exphase_l1_nco(t) ;
                exphase_l1_nco:units = "m" ;
                exphase_l1_nco:long_name = "L1 carrier NCO excess phase" ;
                exphase_l1_nco:missing_value = NaN ;
        double exphase_l2_nco(t) ;
                exphase_l2_nco:units = "m" ;
                exphase_l2_nco:long_name = "L2 carrier NCO excess phase" ;
                exphase_l2_nco:missing_value = NaN ;
        double exphase_ca(t) ;
                exphase_ca:units = "m" ;
                exphase_ca:long_name = "C/A carrier excess phase including I/Q
contributions" ;
                exphase_ca:missing_value = NaN ;
        double exphase_p1(t) ;
                exphase_p1:units = "m" ;
                exphase_p1:long_name = "P1 carrier excess phase including I/Q
contributions" ;
                exphase_p1:missing_value = NaN ;
        double exphase_p2(t) ;
                exphase_p2:units = "m" ;
                exphase_p2:long_name = "P2 carrier excess phase including I/Q
contributions" ;
```

```
                exphase_p2:missing_value = NaN ;
        double i_ca_uncorr(t) ;
                i_ca_uncorr:units = "V" ;
                i_ca_uncorr:long_name = "In-phase component I of C/A carrier phase
measurements, normalized to antenna port" ;
                i_ca_uncorr:missing_value = NaN ;
        double i_ca(t) ;
                i_ca:units = "V" ;
                i_ca:long_name = "In-phase component I of C/A carrier phase
measurements, navigation bits demodulated, normalized to ante
nna port" ;
                i_ca:missing_value = NaN ;
        double i_p1(t) ;
                i_p1:units = "V" ;
                i_p1:long_name = "In-phase component I of P1 carrier phase
measurements, normalized to antenna port" ;
                i_p1:missing_value = NaN ;
        double i_p2(t) ;
                i_p2:units = "V" ;
                i_p2:long_name = "In-phase component I of P2 carrier phase
measurements, normalized to antenna port" ;
                i_p2:missing_value = NaN ;
        double q_ca_uncorr(t) ;
                q_ca_uncorr:units = "V" ;
                q_ca_uncorr:long_name = "Quadrature component Q of C/A carrier phase
measurements, normalized to antenna port" ;
                q_ca_uncorr:missing_value = NaN ;
        double q_ca(t) ;
                q_ca:units = "V" ;
                q_ca:long_name = "Quadrature component Q of C/A carrier phase
measurements, navigation bits demodulated, normalized to an
tenna port" ;
                q_ca:missing_value = NaN ;
        double q_p1(t) ;
                q_p1:units = "V" ;
                q_p1:long_name = "Quadrature component Q of P1 carrier phase
measurements, normalized to antenna port" ;
                q_p1:missing_value = NaN ;
        double q_p2(t) ;
                q_p2:units = "V" ;
                q_p2:long_name = "Quadrature component Q of P2 carrier phase
measurements, normalized to antenna port" ;
                q_p2:missing_value = NaN ;
        double amplitude_ca(t) ;
                amplitude_ca:units = "V" ;
                amplitude_ca:long_name = "Amplitude of C/A carrier phase
measurements, normalized to antenna port" ;
                amplitude_ca:missing_value = NaN ;
        double amplitude_p1(t) ;
                amplitude_p1:units = "V" ;
                amplitude_p1:long_name = "Amplitude of P1 carrier phase measurements,
normalized to antenna port" ;
                amplitude_p1:missing_value = NaN ;
        double amplitude_p2(t) ;
                amplitude_p2:units = "V" ;
                amplitude_p2:long_name = "Amplitude of P2 carrier phase measurements,
normalized to antenna port" ;
                amplitude_p2:missing_value = NaN ;
        double snr_ca(t) ;
                snr_ca:units = "V/V" ;
                snr_ca:long_name = "Signal-to-Noise-Ratio of C/A carrier phase
measurements" ;
                snr_ca:missing_value = NaN ;
        double snr_p1(t) ;
                snr_p1:units = "V/V" ;
```

```
                snr_p1:long_name = "Signal-to-Noise-Ratio of P1 carrier phase
measurements" ;
                snr_p1:missing_value = NaN ;
        double snr_p2(t) ;
                snr_p2:units = "V/V" ;
                snr_p2:long_name = "Signal-to-Noise-Ratio of P2 carrier phase
measurements" ;
                snr_p2:missing_value = NaN ;
        double navbits_external(t) ;
                navbits_external:long_name = "External navigation data bits if
available" ;
                navbits_external:missing_value = NaN ;
        double navbits_internal(t) ;
                navbits_internal:long_name = "Internal navigation data bits" ;
                navbits_internal:missing_value = NaN ;
        double r_receiver(t, xyz) ;
                r_receiver:units = "m" ;
                r_receiver:long_name = "Receiver position in Earth centred inertial
coordinates (J2000)" ;
                r_receiver:missing_value = NaN ;
        double v_receiver(t, xyz) ;
                v_receiver:units = "m/s" ;
                v_receiver:long_name = "Receiver velocity in Earth centred inertial
coordinates (J2000)" ;
                v_receiver:missing_value = NaN ;
        double r_transmitter(t, xyz) ;
                r_transmitter:units = "m" ;
                r_transmitter:long_name = "Transmitter position (retarded) in Earth
centred inertial coordinates (J2000)" ;
                r_transmitter:missing_value = NaN ;
        double v_transmitter(t, xyz) ;
                v_transmitter:units = "m/s" ;
                v_transmitter:long_name = "Transmitter velocity (retarded) in Earth
centred inertial coordinates (J2000)" ;
                v_transmitter:missing_value = NaN ;
        double zenith_antenna(t) ;
                zenith_antenna:units = "degrees" ;
                zenith_antenna:long_name = "Straight line ray antenna zenith angle
(in S/C coordinates)" ;
                zenith_antenna:missing_value = NaN ;
        double azimuth_antenna(t) ;
                azimuth_antenna:units = "degrees" ;
                azimuth_antenna:long_name = "Straight line ray antenna azimuth angle
(in S/C coordinates)" ;
                azimuth_antenna:missing_value = NaN ;
        double snr_ca_mean ;
                snr_ca_mean:units = "V/V" ;
                snr_ca_mean:long_name = "Mean Signal-to-Noise-Ratio (amplitude) of
C/A carrier phase measurements (SLTA > 60 km)" ;
                snr_ca_mean:missing_value = NaN ;
        double snr_p1_mean ;
                snr_p1_mean:units = "V/V" ;
                snr_p1_mean:long_name = "Mean Signal-to-Noise-Ratio (amplitude) of
P1 carrier phase measurements (SLTA > 60 km)" ;
                snr_p1_mean:missing_value = NaN ;
        double snr_p2_mean ;
                snr_p2_mean:units = "V/V" ;
                snr_p2_mean:long_name = "Mean Signal-to-Noise-Ratio (amplitude) of
P2 carrier phase measurements (SLTA > 60 km)" ;
                snr_p2_mean:missing_value = NaN ;
        double cn0_ca_mean ;
                cn0_ca_mean:units = "dB Hz" ;
                cn0_ca_mean:long_name = "Mean Signal-to-Noise-Ratio (C/No) of C/A
carrier phase measurements (SLTA > 60 km)" ;
                cn0_ca_mean:missing_value = NaN ;
        double cn0_p1_mean ;
```

```
                cn0_p1_mean:units = "dB Hz" ;
                cn0_p1_mean:long_name = "Mean Signal-to-Noise-Ratio (C/No) of P1
carrier phase measurements (SLTA > 60 km)" ;
                cn0_p1_mean:missing_value = NaN ;
        double cn0_p2_mean ;
                cn0_p2_mean:units = "db Hz" ;
                cn0_p2_mean:long_name = "Mean Signal-to-Noise-Ratio (C/No) of P2
carrier phase measurements (SLTA > 60 km)" ;
                cn0_p2_mean:missing_value = NaN ;
        double signal_power_ca_mean ;
                signal_power_ca_mean:units = "db" ;
                signal_power_ca_mean:long_name = "Mean signal power for C/A carrier
phase measurements (SLTA > 60 km)" ;
                signal_power_ca_mean:missing_value = NaN ;
        double signal_power_p1_mean ;
                signal_power_p1_mean:units = "db" ;
                signal_power_p1_mean:long_name = "Mean signal power for P1 carrier
phase measurements (SLTA > 60 km)" ;
                signal_power_p1_mean:missing_value = NaN ;
        double signal_power_p2_mean ;
                signal_power_p2_mean:units = "db" ;
                signal_power_p2_mean:long_name = "Mean signal power for P2 carrier
phase measurements (SLTA > 60 km)" ;
                signal_power_p2_mean:missing_value = NaN ;
        double noise_power_l1_mean ;
                noise_power_l1_mean:units = "db/Hz" ;
                noise_power_l1_mean:long_name = "Mean noise power spectral density
for L1 carrier phase measurements" ;
                noise_power_l1_mean:missing_value = NaN ;
        double noise_power_l2_mean ;
                noise_power_l2_mean:units = "db/Hz" ;
                noise_power_l2_mean:long_name = "Mean noise power spectral density
for L2 carrier phase measurements" ;
                noise_power_l2_mean:missing_value = NaN ;
        double exphase_ca_noise ;
                exphase_ca_noise:units = "m" ;
                exphase_ca_noise:long_name = "Mean phase noise of C/A carrier excess
phase measurements (SLTA > 60 km)" ;
                exphase_ca_noise:missing_value = NaN ;
        double exphase_p1_noise ;
                exphase_p1_noise:units = "m" ;
                exphase_p1_noise:long_name = "Mean phase noise of P1 carrier excess
phase measurements (SLTA > 60 km)" ;
                exphase_p1_noise:missing_value = NaN ;
        double exphase_p2_noise ;
                exphase_p2_noise:units = "m" ;
                exphase_p2_noise:long_name = "Mean phase noise of P2 carrier excess
phase measurements (SLTA > 60 km)" ;
                exphase_p2_noise:missing_value = NaN ;
        double slta_ca_min_all ;
                slta_ca_min_all:units = "m" ;
                slta_ca_min_all:long_name = "Minimum overall SLTA of C/A carrier
phase data" ;
                slta_ca_min_all:missing_value = NaN ;
        double slta_ca_max_all ;
                slta_ca_max_all:units = "m" ;
                slta_ca_max_all:long_name = "Maximum overall SLTA of C/A carrier
phase data" ;
                slta_ca_max_all:missing_value = NaN ;
        double slta_p1_min_all ;
                slta_p1_min_all:units = "m" ;
                slta_p1_min_all:long_name = "Minimum overall SLTA of P1 carrier phase
data" ;
                slta_p1_min_all:missing_value = NaN ;
        double slta_p1_max_all ;
                slta_p1_max_all:units = "m" ;
```

```
                slta_p1_max_all:long_name = "Maximum overall SLTA of P1 carrier phase
data" ;
                slta_p1_max_all:missing_value = NaN ;
        double slta_p2_min_all ;
                slta_p2_min_all:units = "m" ;
                slta_p2_min_all:long_name = "Minimum overall SLTA of P2 carrier phase
data" ;
                slta_p2_min_all:missing_value = NaN ;
        double slta_p2_max_all ;
                slta_p2_max_all:units = "m" ;
                slta_p2_max_all:long_name = "Maximum overall SLTA of P2 carrier phase
data" ;
                slta_p2_max_all:missing_value = NaN ;
        double slta_ca_min_main ;
                slta_ca_min_main:units = "m" ;
                slta_ca_min_main:long_name = "Minimum SLTA of main (longest) C/A
carrier phase data segment" ;
                slta_ca_min_main:missing_value = NaN ;
        double slta_ca_max_main ;
                slta_ca_max_main:units = "m" ;
                slta_ca_max_main:long_name = "Maximum SLTA of main (longest) C/A
carrier phase data segment" ;
                slta_ca_max_main:missing_value = NaN ;
        double slta_p1_min_main ;
                slta_p1_min_main:units = "m" ;
                slta_p1_min_main:long_name = "Minimum SLTA of main (longest) P1
carrier phase data segment" ;
                slta_p1_min_main:missing_value = NaN ;
        double slta_p1_max_main ;
                slta_p1_max_main:units = "m" ;
                slta_p1_max_main:long_name = "Maximum SLTA of main (longest) P1
carrier phase data segment" ;
                slta_p1_max_main:missing_value = NaN ;
        double slta_p2_min_main ;
                slta_p2_min_main:units = "m" ;
                slta_p2_min_main:long_name = "Minimum SLTA of main (longest) P2
carrier phase data segment" ;
                slta_p2_min_main:missing_value = NaN ;
        double slta_p2_max_main ;
                slta_p2_max_main:units = "m" ;
                slta_p2_max_main:long_name = "Maximum SLTA of main (longest) P2
carrier phase data segment" ;
                slta_p2_max_main:missing_value = NaN ;
        double slta_ca_min_select ;
                slta_ca_min_select:units = "m" ;
                slta_ca_min_select:long_name = "Minimum SLTA of C/A carrier phase
data selected for processing" ;
                slta_ca_min_select:missing_value = NaN ;
        double slta_ca_max_select ;
                slta_ca_max_select:units = "m" ;
                slta_ca_max_select:long_name = "Maximum SLTA of C/A carrier phase
data selected for processing" ;
                slta_ca_max_select:missing_value = NaN ;
        double slta_p1_min_select ;
                slta_p1_min_select:units = "m" ;
                slta_p1_min_select:long_name = "Minimum SLTA of P1 carrier phase data
selected for processing" ;
                slta_p1_min_select:missing_value = NaN ;
        double slta_p1_max_select ;
                slta_p1_max_select:units = "m" ;
                slta_p1_max_select:long_name = "Maximum SLTA of P1 carrier phase data
selected for processing" ;
                slta_p1_max_select:missing_value = NaN ;
        double slta_p2_min_select ;
                slta_p2_min_select:units = "m" ;
```

```
                slta_p2_min_select:long_name = "Minimum SLTA of P2 carrier phase data
selected for processing" ;
                slta_p2_min_select:missing_value = NaN ;
        double slta_p2_max_select ;
                slta_p2_max_select:units = "m" ;
                slta_p2_max_select:long_name = "Maximum SLTA of P2 carrier phase data
selected for processing" ;
                slta_p2_max_select:missing_value = NaN ;

      // group attributes:
                :title = "GRAS/Metop-A level 1a data (closed loop measurements)" ;
      } // group closed_loop

    group: raw_sampling {
      dimensions:
        t = 43220 ;
        xyz = 3 ;
      variables:
        double dtime(t) ;
                dtime:units = "seconds since 2015-06-12 22:53:57.83" ;
                dtime:long_name = "Measurement epoch" ;
                dtime:missing_value = NaN ;
        double slta(t) ;
                slta:units = "m" ;
                slta:long_name = "Straight line tangent altitude" ;
                slta:missing_value = NaN ;
        double samplerate ;
                samplerate:units = "Hz" ;
                samplerate:long_name = "Measurement sample rate" ;
                samplerate:missing_value = NaN ;
        int tracking_state(t) ;
                tracking_state:long_name = "Tracking states" ;
                tracking_state:missing_value = -2147483648 ;
        double phase_l1_nco(t) ;
                phase_l1_nco:units = "m" ;
                phase_l1_nco:long_name = "L1 carrier NCO phase" ;
                phase_l1_nco:missing_value = NaN ;
        double phase_ca(t) ;
                phase_ca:units = "m" ;
                phase_ca:long_name = "C/A carrier phase including I/Q contributions"
;
                phase_ca:missing_value = NaN ;
        double exphase_l1_nco(t) ;
                exphase_l1_nco:units = "m" ;
                exphase_l1_nco:long_name = "L1 carrier NCO excess phase" ;
                exphase_l1_nco:missing_value = NaN ;
        double exphase_ca(t) ;
                exphase_ca:units = "m" ;
                exphase_ca:long_name  =  "C/A  carrier  excess  phase  including  I/Q
contributions" ;
                exphase_ca:missing_value = NaN ;
        double i_ca_uncorr(t) ;
                i_ca_uncorr:units = "V" ;
                i_ca_uncorr:long_name = "In-phase component I of C/A carrier phase
measurements, normalized to antenna port" ;
                i_ca_uncorr:missing_value = NaN ;
        double q_ca_uncorr(t) ;
                q_ca_uncorr:units = "V" ;
                q_ca_uncorr:long_name = "Quadrature component Q of C/A carrier phase
measurements, normalized to antenna port" ;
                q_ca_uncorr:missing_value = NaN ;
        double i_ca(t) ;
                i_ca:units = "V" ;
                i_ca:long_name  =  "In-phase  component  I  of  C/A  carrier  phase
measurements,    navigation    bits    demodulated,    normalized    to    ante
nna port" ;
```

```
                i_ca:missing_value = NaN ;
        double q_ca(t) ;
                q_ca:units = "V" ;
                q_ca:long_name = "Quadrature component Q of C/A carrier phase
measurements, navigation bits demodulated, normalized to an
tenna port" ;
                q_ca:missing_value = NaN ;
        double amplitude_ca(t) ;
                amplitude_ca:units = "V" ;
                amplitude_ca:long_name = "Amplitude of C/A carrier phase
measurements, normalized to antenna port" ;
                amplitude_ca:missing_value = NaN ;
        double snr_ca(t) ;
                snr_ca:units = "V/V" ;
                snr_ca:long_name = "Signal-to-Noise-Ratio of C/A carrier phase
measurements" ;
                snr_ca:missing_value = NaN ;
        double navbits_external(t) ;
                navbits_external:long_name = "External navigation data bits if
available" ;
                navbits_external:missing_value = NaN ;
        double navbits_internal(t) ;
                navbits_internal:long_name = "Internal navigation data bits" ;
                navbits_internal:missing_value = NaN ;
        double r_receiver(t, xyz) ;
                r_receiver:units = "m" ;
                r_receiver:long_name = "Receiver position in Earth centred inertial
coordinates (J2000)" ;
                r_receiver:missing_value = NaN ;
        double v_receiver(t, xyz) ;
                v_receiver:units = "m/s" ;
                v_receiver:long_name = "Receiver velocity in Earth centred inertial
coordinates (J2000)" ;
                v_receiver:missing_value = NaN ;
        double r_transmitter(t, xyz) ;
                r_transmitter:units = "m" ;
                r_transmitter:long_name = "Transmitter position (retarded) in Earth
centred inertial coordinates (J2000)" ;
                r_transmitter:missing_value = NaN ;
        double v_transmitter(t, xyz) ;
                v_transmitter:units = "m/s" ;
                v_transmitter:long_name = "Transmitter velocity (retarded) in Earth
centred inertial coordinates (J2000)" ;
                v_transmitter:missing_value = NaN ;
        double zenith_antenna(t) ;
                zenith_antenna:units = "degrees" ;
                zenith_antenna:long_name = "Straight line ray antenna zenith angle
(in S/C coordinates)" ;
                zenith_antenna:missing_value = NaN ;
        double azimuth_antenna(t) ;
                azimuth_antenna:units = "degrees" ;
                azimuth_antenna:long_name = "Straight line ray antenna azimuth angle
(in S/C coordinates)" ;
                azimuth_antenna:missing_value = NaN ;
        double noise_power_l1_mean ;
                noise_power_l1_mean:units = "db/Hz" ;
                noise_power_l1_mean:long_name = "Mean noise power spectral density
for L1 phase measurements" ;
                noise_power_l1_mean:missing_value = NaN ;
        double slta_ca_min_all ;
                slta_ca_min_all:units = "m" ;
                slta_ca_min_all:long_name = "Minimum overall SLTA of C/A carrier
phase data" ;
                slta_ca_min_all:missing_value = NaN ;
        double slta_ca_max_all ;
                slta_ca_max_all:units = "m" ;
```

```
                slta_ca_max_all:long_name = "Maximum overall SLTA of C/A carrier phase data" ;
                slta_ca_max_all:missing_value = NaN ;
        double slta_ca_min_main ;
                slta_ca_min_main:units = "m" ;
                slta_ca_min_main:long_name = "Minimum SLTA of main (longest) C/A carrier phase data segment" ;
                slta_ca_min_main:missing_value = NaN ;
        double slta_ca_max_main ;
                slta_ca_max_main:units = "m" ;
                slta_ca_max_main:long_name = "Maximum SLTA of main (longest) C/A carrier phase data segment" ;
                slta_ca_max_main:missing_value = NaN ;
        double slta_ca_min_select ;
                slta_ca_min_select:units = "m" ;
                slta_ca_min_select:long_name = "Minimum SLTA of C/A carrier phase data selected for processing" ;
                slta_ca_min_select:missing_value = NaN ;
        double slta_ca_max_select ;
                slta_ca_max_select:units = "m" ;
                slta_ca_max_select:long_name = "Maximum SLTA of C/A carrier phase data selected for processing" ;
                slta_ca_max_select:missing_value = NaN ;
        double cl_rs_overlap_period ;
                cl_rs_overlap_period:units = "s" ;
                cl_rs_overlap_period:long_name = "Period with overlapping closed loop and raw sampling data" ;
                cl_rs_overlap_period:missing_value = NaN ;
        double cl_rs_phase_shift_mean ;
                cl_rs_phase_shift_mean:units = "rad" ;
                cl_rs_phase_shift_mean:long_name = "Closed loop vs. raw sampling phase shift mean" ;
                cl_rs_phase_shift_mean:missing_value = NaN ;
        double cl_rs_phase_shift_sdev ;
                cl_rs_phase_shift_sdev:units = "rad" ;
                cl_rs_phase_shift_sdev:long_name = "Closed loop vs. raw sampling phase shift standard deviation" ;
                cl_rs_phase_shift_sdev:missing_value = NaN ;
        double cl_rs_phase_shift_t ;
                cl_rs_phase_shift_t:long_name = "Closed loop vs. raw sampling phase shift t-test value" ;
                cl_rs_phase_shift_t:missing_value = NaN ;
        double cl_rs_phase_shift_prob ;
                cl_rs_phase_shift_prob:long_name = "Closed loop vs. raw sampling phase shift t-test probability" ;
                cl_rs_phase_shift_prob:missing_value = NaN ;
        double cl_rs_amplitude_ratio_mean ;
                cl_rs_amplitude_ratio_mean:long_name = "Closed loop vs. raw sampling amplitude ratio mean" ;
                cl_rs_amplitude_ratio_mean:missing_value = NaN ;
        double cl_rs_amplitude_ratio_sdev ;
                cl_rs_amplitude_ratio_sdev:long_name = "Closed loop vs. raw sampling amplitude ratio standard deviation" ;
                cl_rs_amplitude_ratio_sdev:missing_value = NaN ;
        double cl_rs_amplitude_ratio_t ;
                cl_rs_amplitude_ratio_t:long_name = "Closed loop vs. raw sampling amplitude ratio t-test value" ;
                cl_rs_amplitude_ratio_t:missing_value = NaN ;
        double cl_rs_amplitude_ratio_prob ;
                cl_rs_amplitude_ratio_prob:long_name = "Closed loop vs. raw sampling amplitude ratio t-test probability" ;
                cl_rs_amplitude_ratio_prob:missing_value = NaN ;

      // group attributes:
                :title = "GRAS/Metop-A level 1a data (raw sampling measurements)" ;
      } // group raw_sampling
```

```
    group: open_loop {
      dimensions:
        t = 2160 ;
        xyz = 3 ;
      variables:
        double dtime(t) ;
                dtime:units = "seconds since 2015-06-12 22:53:57.83" ;
                dtime:long_name = "Measurement epoch" ;
                dtime:missing_value = NaN ;
        double slta(t) ;
                slta:units = "m" ;
                slta:long_name = "Straight line tangent altitude" ;
                slta:missing_value = NaN ;
        double samplerate ;
                samplerate:units = "Hz" ;
                samplerate:long_name = "Measurement sample rate" ;
                samplerate:missing_value = NaN ;
        int tracking_state(t) ;
                tracking_state:long_name = "Tracking states" ;
                tracking_state:missing_value = -2147483648 ;
        double phase_l1_nco(t) ;
                phase_l1_nco:units = "m" ;
                phase_l1_nco:long_name = "L1 carrier NCO phase" ;
                phase_l1_nco:missing_value = NaN ;
        double phase_ca(t) ;
                phase_ca:units = "m" ;
                phase_ca:long_name = "C/A carrier phase including I/Q contributions"
;
                phase_ca:missing_value = NaN ;
        double exphase_l1_nco(t) ;
                exphase_l1_nco:units = "m" ;
                exphase_l1_nco:long_name = "L1 carrier NCO excess phase" ;
                exphase_l1_nco:missing_value = NaN ;
        double exphase_ca(t) ;
                exphase_ca:units = "m" ;
                exphase_ca:long_name = "C/A carrier excess phase including I/Q
contributions" ;
                exphase_ca:missing_value = NaN ;
        double i_ca_uncorr(t) ;
                i_ca_uncorr:units = "V" ;
                i_ca_uncorr:long_name = "In-phase component I of C/A carrier phase
measurements, normalized to antenna port" ;
                i_ca_uncorr:missing_value = NaN ;
        double q_ca_uncorr(t) ;
                q_ca_uncorr:units = "V" ;
                q_ca_uncorr:long_name = "Quadrature component Q of C/A carrier phase
measurements, normalized to antenna port" ;
                q_ca_uncorr:missing_value = NaN ;
        double i_ca(t) ;
                i_ca:units = "V" ;
                i_ca:long_name = "In-phase component I of C/A carrier phase
measurements, navigation bits demodulated, normalized to ante
nna port" ;
                i_ca:missing_value = NaN ;
        double q_ca(t) ;
                q_ca:units = "V" ;
                q_ca:long_name = "Quadrature component Q of C/A carrier phase
measurements, navigation bits demodulated, normalized to an
tenna port" ;
                q_ca:missing_value = NaN ;
        double amplitude_ca(t) ;
                amplitude_ca:units = "V" ;
                amplitude_ca:long_name = "Amplitude of C/A carrier phase
measurements, normalized to antenna port" ;
                amplitude_ca:missing_value = NaN ;
```

```
        double snr_ca(t) ;
                snr_ca:units = "V/V" ;
                snr_ca:long_name = "Signal-to-Noise-Ratio of C/A carrier phase
measurements" ;
                snr_ca:missing_value = NaN ;
        double navbits_external(t) ;
                navbits_external:long_name = "External navigation data bits if
available" ;
                navbits_external:missing_value = NaN ;
        double navbits_internal(t) ;
                navbits_internal:long_name = "Internal navigation data bits" ;
                navbits_internal:missing_value = NaN ;
        double r_receiver(t, xyz) ;
                r_receiver:units = "m" ;
                r_receiver:long_name = "Receiver position in Earth centred inertial
coordinates (J2000)" ;
                r_receiver:missing_value = NaN ;
        double v_receiver(t, xyz) ;
                v_receiver:units = "m/s" ;
                v_receiver:long_name = "Receiver velocity in Earth centred inertial
coordinates (J2000)" ;
                v_receiver:missing_value = NaN ;
        double r_transmitter(t, xyz) ;
                r_transmitter:units = "m" ;
                r_transmitter:long_name = "Transmitter position (retarded) in Earth
centred inertial coordinates (J2000)" ;
                r_transmitter:missing_value = NaN ;
        double v_transmitter(t, xyz) ;
                v_transmitter:units = "m/s" ;
                v_transmitter:long_name = "Transmitter velocity (retarded) in Earth
centred inertial coordinates (J2000)" ;
                v_transmitter:missing_value = NaN ;
        double zenith_antenna(t) ;
                zenith_antenna:units = "degrees" ;
                zenith_antenna:long_name = "Straight line ray antenna zenith angle
(in S/C coordinates)" ;
                zenith_antenna:missing_value = NaN ;
        double azimuth_antenna(t) ;
                azimuth_antenna:units = "degrees" ;
                azimuth_antenna:long_name = "Straight line ray antenna azimuth angle
(in S/C coordinates)" ;
                azimuth_antenna:missing_value = NaN ;
        double noise_power_l1_mean ;
                noise_power_l1_mean:units = "db/Hz" ;
                noise_power_l1_mean:long_name = "Mean noise power spectral density
for L1 phase measurements" ;
                noise_power_l1_mean:missing_value = NaN ;
        double slta_ca_min_all ;
                slta_ca_min_all:units = "m" ;
                slta_ca_min_all:long_name = "Minimum overall SLTA of C/A carrier
phase data" ;
                slta_ca_min_all:missing_value = NaN ;
        double slta_ca_max_all ;
                slta_ca_max_all:units = "m" ;
                slta_ca_max_all:long_name = "Maximum overall SLTA of C/A carrier
phase data" ;
                slta_ca_max_all:missing_value = NaN ;
        double slta_ca_min_main ;
                slta_ca_min_main:units = "m" ;
                slta_ca_min_main:long_name = "Minimum SLTA of main (longest) C/A
carrier phase data segment" ;
                slta_ca_min_main:missing_value = NaN ;
        double slta_ca_max_main ;
                slta_ca_max_main:units = "m" ;
                slta_ca_max_main:long_name = "Maximum SLTA of main (longest) C/A
carrier phase data segment" ;
```

```
                slta_ca_max_main:missing_value = NaN ;
        double slta_ca_min_select ;
                slta_ca_min_select:units = "m" ;
                slta_ca_min_select:long_name = "Minimum SLTA of C/A carrier phase
data selected for processing" ;
                slta_ca_min_select:missing_value = NaN ;
        double slta_ca_max_select ;
                slta_ca_max_select:units = "m" ;
                slta_ca_max_select:long_name = "Maximum SLTA of C/A carrier phase
data selected for processing" ;
                slta_ca_max_select:missing_value = NaN ;

      // group attributes:
                :title = "GRAS/Metop-A level 1a data (downsampled raw sampling / open
loop measurements)" ;
      } // group open_loop

    group: pseudo_range {
      dimensions:
        t = 51 ;
        xyz = 3 ;
      variables:
        double dtime(t) ;
                dtime:units = "seconds since 2015-06-12 22:53:57.83" ;
                dtime:long_name = "Measurement epoch" ;
                dtime:missing_value = NaN ;
        double slta(t) ;
                slta:units = "m" ;
                slta:long_name = "Straight line tangent altitude" ;
                slta:missing_value = NaN ;
        double samplerate ;
                samplerate:units = "Hz" ;
                samplerate:long_name = "Measurement sample rate" ;
                samplerate:missing_value = NaN ;
        int tracking_state(t) ;
                tracking_state:long_name = "Tracking states" ;
                tracking_state:missing_value = -2147483648 ;
        double pseudorange_ca(t) ;
                pseudorange_ca:units = "m" ;
                pseudorange_ca:long_name = "C/A pseudorange" ;
                pseudorange_ca:missing_value = NaN ;
        double pseudorange_p1(t) ;
                pseudorange_p1:units = "m" ;
                pseudorange_p1:long_name = "P1 pseudorange" ;
                pseudorange_p1:missing_value = NaN ;
        double pseudorange_p2(t) ;
                pseudorange_p2:units = "m" ;
                pseudorange_p2:long_name = "P2 pseudorange" ;
                pseudorange_p2:missing_value = NaN ;
        double expseudorange_ca(t) ;
                expseudorange_ca:units = "m" ;
                expseudorange_ca:long_name = "C/A excess (pseudo-) range" ;
                expseudorange_ca:missing_value = NaN ;
        double expseudorange_p1(t) ;
                expseudorange_p1:units = "m" ;
                expseudorange_p1:long_name = "P1 excess (pseudo-) range" ;
                expseudorange_p1:missing_value = NaN ;
        double expseudorange_p2(t) ;
                expseudorange_p2:units = "m" ;
                expseudorange_p2:long_name = "P2 excess (pseudo-) range" ;
                expseudorange_p2:missing_value = NaN ;
        double r_receiver(t, xyz) ;
                r_receiver:units = "m" ;
                r_receiver:long_name = "Receiver position in Earth centred inertial
coordinates (J2000)" ;
                r_receiver:missing_value = NaN ;
```

```
        double v_receiver(t, xyz) ;
                v_receiver:units = "m/s" ;
                v_receiver:long_name = "Receiver velocity in Earth centred inertial
coordinates (J2000)" ;
                v_receiver:missing_value = NaN ;
        double r_transmitter(t, xyz) ;
                r_transmitter:units = "m" ;
                r_transmitter:long_name = "Transmitter position (retarded) in Earth
centred inertial coordinates (J2000)" ;
                r_transmitter:missing_value = NaN ;
        double v_transmitter(t, xyz) ;
                v_transmitter:units = "m/s" ;
                v_transmitter:long_name = "Transmitter velocity (retarded) in Earth
centred inertial coordinates (J2000)" ;
                v_transmitter:missing_value = NaN ;
        double zenith_antenna(t) ;
                zenith_antenna:units = "degrees" ;
                zenith_antenna:long_name = "Straight line ray antenna zenith angle
(in S/C coordinates)" ;
                zenith_antenna:missing_value = NaN ;
        double azimuth_antenna(t) ;
                azimuth_antenna:units = "degrees" ;
                azimuth_antenna:long_name = "Straight line ray antenna azimuth angle
(in S/C coordinates)" ;
                azimuth_antenna:missing_value = NaN ;
        double pseudorange_ca_noise ;
                pseudorange_ca_noise:units = "m" ;
                pseudorange_ca_noise:long_name = "Mean C/A pseudorange noise (SLTA >
60 km)" ;
                pseudorange_ca_noise:missing_value = NaN ;
        double pseudorange_p1_noise ;
                pseudorange_p1_noise:units = "m" ;
                pseudorange_p1_noise:long_name = "Mean P1 pseudorange noise (SLTA >
60 km)" ;
                pseudorange_p1_noise:missing_value = NaN ;
        double pseudorange_p2_noise ;
                pseudorange_p2_noise:units = "m" ;
                pseudorange_p2_noise:long_name = "Mean P2 pseudorange noise (SLTA >
60 km)" ;
                pseudorange_p2_noise:missing_value = NaN ;
        double pseudorange_ca_offset ;
                pseudorange_ca_offset:units = "m" ;
                pseudorange_ca_offset:long_name = "Mean C/A pseudorange (vs. phase)
offset (SLTA > 60 km)" ;
                pseudorange_ca_offset:missing_value = NaN ;
        double pseudorange_p1_offset ;
                pseudorange_p1_offset:units = "m" ;
                pseudorange_p1_offset:long_name = "Mean P1 pseudorange (vs. phase)
offset (SLTA > 60 km)" ;
                pseudorange_p1_offset:missing_value = NaN ;
        double pseudorange_p2_offset ;
                pseudorange_p2_offset:units = "m" ;
                pseudorange_p2_offset:long_name = "Mean P2 pseudorange (vs. phase)
offset (SLTA > 60 km)" ;
                pseudorange_p2_offset:missing_value = NaN ;
        double slta_ca_min_all ;
                slta_ca_min_all:units = "m" ;
                slta_ca_min_all:long_name = "Minimum overall SLTA of C/A pseudorange
data" ;
                slta_ca_min_all:missing_value = NaN ;
        double slta_ca_max_all ;
                slta_ca_max_all:units = "m" ;
                slta_ca_max_all:long_name = "Maximum overall SLTA of C/A pseudorange
data" ;
                slta_ca_max_all:missing_value = NaN ;
        double slta_p1_min_all ;
```

```
                slta_p1_min_all:units = "m" ;
                slta_p1_min_all:long_name = "Minimum overall SLTA of P1 pseudorange
data" ;
                slta_p1_min_all:missing_value = NaN ;
        double slta_p1_max_all ;
                slta_p1_max_all:units = "m" ;
                slta_p1_max_all:long_name = "Maximum overall SLTA of P1 pseudorange
data" ;
                slta_p1_max_all:missing_value = NaN ;
        double slta_p2_min_all ;
                slta_p2_min_all:units = "m" ;
                slta_p2_min_all:long_name = "Minimum overall SLTA of P2 pseudorange
data" ;
                slta_p2_min_all:missing_value = NaN ;
        double slta_p2_max_all ;
                slta_p2_max_all:units = "m" ;
                slta_p2_max_all:long_name = "Maximum overall SLTA of P2 pseudorange
data" ;
                slta_p2_max_all:missing_value = NaN ;
        double slta_ca_min_main ;
                slta_ca_min_main:units = "m" ;
                slta_ca_min_main:long_name = "Minimum SLTA of main (longest) C/A
pseudorange data segment" ;
                slta_ca_min_main:missing_value = NaN ;
        double slta_ca_max_main ;
                slta_ca_max_main:units = "m" ;
                slta_ca_max_main:long_name = "Maximum SLTA of main (longest) C/A
pseudorange data segment" ;
                slta_ca_max_main:missing_value = NaN ;
        double slta_p1_min_main ;
                slta_p1_min_main:units = "m" ;
                slta_p1_min_main:long_name = "Minimum SLTA of main (longest) P1
pseudorange data segment" ;
                slta_p1_min_main:missing_value = NaN ;
        double slta_p1_max_main ;
                slta_p1_max_main:units = "m" ;
                slta_p1_max_main:long_name = "Maximum SLTA of main (longest) P1
pseudorange data segment" ;
                slta_p1_max_main:missing_value = NaN ;
        double slta_p2_min_main ;
                slta_p2_min_main:units = "m" ;
                slta_p2_min_main:long_name = "Minimum SLTA of main (longest) P2
pseudorange data segment" ;
                slta_p2_min_main:missing_value = NaN ;
        double slta_p2_max_main ;
                slta_p2_max_main:units = "m" ;
                slta_p2_max_main:long_name = "Maximum SLTA of main (longest) P2
pseudorange data segment" ;
                slta_p2_max_main:missing_value = NaN ;
        double slta_ca_min_select ;
                slta_ca_min_select:units = "m" ;
                slta_ca_min_select:long_name = "Minimum SLTA of C/A pseudorange data
selected for processing" ;
                slta_ca_min_select:missing_value = NaN ;
        double slta_ca_max_select ;
                slta_ca_max_select:units = "m" ;
                slta_ca_max_select:long_name = "Maximum SLTA of C/A pseudorange data
selected for processing" ;
                slta_ca_max_select:missing_value = NaN ;
        double slta_p1_min_select ;
                slta_p1_min_select:units = "m" ;
                slta_p1_min_select:long_name = "Minimum SLTA of P1 pseudorange data
selected for processing" ;
                slta_p1_min_select:missing_value = NaN ;
        double slta_p1_max_select ;
                slta_p1_max_select:units = "m" ;
```

```
                slta_p1_max_select:long_name = "Maximum SLTA of P1 pseudorange data
selected for processing" ;
                slta_p1_max_select:missing_value = NaN ;
        double slta_p2_min_select ;
                slta_p2_min_select:units = "m" ;
                slta_p2_min_select:long_name = "Minimum SLTA of P2 pseudorange data
selected for processing" ;
                slta_p2_min_select:missing_value = NaN ;
        double slta_p2_max_select ;
                slta_p2_max_select:units = "m" ;
                slta_p2_max_select:long_name = "Maximum SLTA of P2 pseudorange data
selected for processing" ;
                slta_p2_max_select:missing_value = NaN ;

      // group attributes:
                :title = "GRAS/Metop-A level 1a data (pseudo range measurements)" ;
      } // group pseudo_range
    } // group level_1a

  group: level_1b {
    variables:
        int utc_start_absdate ;
                utc_start_absdate:units = "days since 2000-01-01 00:00:00.00" ;
                utc_start_absdate:long_name = "Start (reference) UTC time for all
observation epochs / date" ;
                utc_start_absdate:missing_value = -2147483648 ;
        double utc_start_abstime ;
                utc_start_abstime:units = "seconds since 00:00:00.00" ;
                utc_start_abstime:long_name = "Start (reference) UTC time for all
observation epochs / time" ;
                utc_start_abstime:missing_value = NaN ;
        int gps_start_absdate ;
                gps_start_absdate:units = "days since 2000-01-01 00:00:00.00" ;
                gps_start_absdate:long_name = "Start (reference) GPS time for all
observation epochs / date" ;
                gps_start_absdate:missing_value = -2147483648 ;
        double gps_start_abstime ;
                gps_start_abstime:units = "seconds since 00:00:00.00" ;
                gps_start_abstime:long_name = "Start (reference) GPS time for all
observation epochs / time" ;
                gps_start_abstime:missing_value = NaN ;

    // group attributes:
                :title = "GRAS/Metop-A level 1b data" ;

    group: high_resolution {
      dimensions:
        z = 7210 ;
      variables:
        double impact(z) ;
                impact:units = "m" ;
                impact:long_name = "Impact parameter" ;
                impact:missing_value = NaN ;
        double impact_height(z) ;
                impact_height:units = "m" ;
                impact_height:long_name = "Impact height (wrt WGS 84 ellipsoid)" ;
                impact_height:missing_value = NaN ;
        double bangle(z) ;
                bangle:units = "rad" ;
                bangle:long_name = "Bending angle (ionospheric corrected)" ;
                bangle:missing_value = NaN ;
        double bangle_ca(z) ;
                bangle_ca:units = "rad" ;
                bangle_ca:long_name = "Bending angle (C/A)" ;
                bangle_ca:missing_value = NaN ;
        double bangle_p1(z) ;
```

```
                bangle_p1:units = "rad" ;
                bangle_p1:long_name = "Bending angle (P1)" ;
                bangle_p1:missing_value = NaN ;
        double bangle_p2(z) ;
                bangle_p2:units = "rad" ;
                bangle_p2:long_name = "Bending angle (P2)" ;
                bangle_p2:missing_value = NaN ;
        double bangle_ca_p2_diff(z) ;
                bangle_ca_p2_diff:units = "rad" ;
                bangle_ca_p2_diff:long_name = "Bending angle difference, (L1 / C/A -
L2 / P2, extrapolated)" ;
                bangle_ca_p2_diff:missing_value = NaN ;
        double lat_tp(z) ;
                lat_tp:units = "degrees_north" ;
                lat_tp:long_name = "Latitudes for tangent points" ;
                lat_tp:missing_value = NaN ;
        double lon_tp(z) ;
                lon_tp:units = "degrees_east" ;
                lon_tp:long_name = "Longitudes for tangent points" ;
                lon_tp:missing_value = NaN ;
        double azimuth_tp(z) ;
                azimuth_tp:units = "degrees" ;
                azimuth_tp:long_name = "GNSS->LEO line of sight azimuth angles at
tangent points (clockwise against True North)" ;
                azimuth_tp:missing_value = NaN ;
        double dtime_mean(z) ;
                dtime_mean:units = "seconds since 2015-06-12 22:55:45.34" ;
                dtime_mean:long_name = "Mean measurement epoch (used for
georeferencing only)" ;
                dtime_mean:missing_value = NaN ;
        double doppler_ca_max ;
                doppler_ca_max:units = "Hz" ;
                doppler_ca_max:long_name = "Maximum instantaneous Doppler (C/A)" ;
                doppler_ca_max:missing_value = NaN ;
        double doppler_p2_max ;
                doppler_p2_max:units = "Hz" ;
                doppler_p2_max:long_name = "Maximum instantaneous Doppler (P2)" ;
                doppler_p2_max:missing_value = NaN ;
        double doppler_rate_ca_max ;
                doppler_rate_ca_max:units = "Hz/s" ;
                doppler_rate_ca_max:long_name = "Maximum instantaneous Doppler rate
(C/A)" ;
                doppler_rate_ca_max:missing_value = NaN ;
        double doppler_rate_p2_max ;
                doppler_rate_p2_max:units = "Hz/s" ;
                doppler_rate_p2_max:long_name = "Maximum instantaneous Doppler rate
(P2)" ;
                doppler_rate_p2_max:missing_value = NaN ;
        double doppler_accel_ca_max ;
                doppler_accel_ca_max:units = "Hz/s^2" ;
                doppler_accel_ca_max:long_name = "Maximum instantaneous Doppler
acceleration (C/A)" ;
                doppler_accel_ca_max:missing_value = NaN ;
        double doppler_accel_p2_max ;
                doppler_accel_p2_max:units = "Hz/s^2" ;
                doppler_accel_p2_max:long_name = "Maximum instantaneous Doppler
acceleration (P2)" ;
                doppler_accel_p2_max:missing_value = NaN ;
        double exdoppler_ca_max ;
                exdoppler_ca_max:units = "Hz" ;
                exdoppler_ca_max:long_name = "Maximum instantaneous excess Doppler
(C/A)" ;
                exdoppler_ca_max:missing_value = NaN ;
        double exdoppler_p2_max ;
                exdoppler_p2_max:units = "Hz" ;
```

```
                exdoppler_p2_max:long_name = "Maximum instantaneous excess Doppler
(P2)" ;
                exdoppler_p2_max:missing_value = NaN ;
        double exdoppler_rate_ca_max ;
                exdoppler_rate_ca_max:units = "Hz/s" ;
                exdoppler_rate_ca_max:long_name = "Maximum instantaneous excess
Doppler rate (C/A)" ;
                exdoppler_rate_ca_max:missing_value = NaN ;
        double exdoppler_rate_p2_max ;
                exdoppler_rate_p2_max:units = "Hz/s" ;
                exdoppler_rate_p2_max:long_name = "Maximum instantaneous excess
Doppler rate (P2)" ;
                exdoppler_rate_p2_max:missing_value = NaN ;
        double exdoppler_accel_ca_max ;
                exdoppler_accel_ca_max:units = "Hz/s^2" ;
                exdoppler_accel_ca_max:long_name = "Maximum instantaneous excess
Doppler acceleration (C/A)" ;
                exdoppler_accel_ca_max:missing_value = NaN ;
        double exdoppler_accel_p2_max ;
                exdoppler_accel_p2_max:units = "Hz/s^2" ;
                exdoppler_accel_p2_max:long_name = "Maximum instantaneous excess
Doppler acceleration (P2)" ;
                exdoppler_accel_p2_max:missing_value = NaN ;
        double bangle_upper_level_mean ;
                bangle_upper_level_mean:units = "rad" ;
                bangle_upper_level_mean:long_name = "Bending angle (ionospheric
corrected) - 60-80km mean" ;
                bangle_upper_level_mean:missing_value = NaN ;
        double bangle_upper_level_sdev ;
                bangle_upper_level_sdev:units = "rad" ;
                bangle_upper_level_sdev:long_name = "Bending angle (ionospheric
corrected) - 60-80km standard deviation" ;
                bangle_upper_level_sdev:missing_value = NaN ;
        double bangle_upper_level_mean_robust ;
                bangle_upper_level_mean_robust:units = "rad" ;
                bangle_upper_level_mean_robust:long_name = "Bending angle
(ionospheric corrected) - 60-80km robust mean" ;
                bangle_upper_level_mean_robust:missing_value = NaN ;
        double bangle_upper_level_sdev_robust ;
                bangle_upper_level_sdev_robust:units = "rad" ;
                bangle_upper_level_sdev_robust:long_name = "Bending angle
(ionospheric corrected) - 60-80km robust standard deviation" ;
                bangle_upper_level_sdev_robust:missing_value = NaN ;
        double bangle_resid_upper_level_mean ;
                bangle_resid_upper_level_mean:units = "rad" ;
                bangle_resid_upper_level_mean:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km mean" ;
                bangle_resid_upper_level_mean:missing_value = NaN ;
        double bangle_resid_upper_level_sdev ;
                bangle_resid_upper_level_sdev:units = "rad" ;
                bangle_resid_upper_level_sdev:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km standard deviation" ;
                bangle_resid_upper_level_sdev:missing_value = NaN ;
        double bangle_resid_upper_level_mean_robust ;
                bangle_resid_upper_level_mean_robust:units = "rad" ;
                bangle_resid_upper_level_mean_robust:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km robust mean" ;
                bangle_resid_upper_level_mean_robust:missing_value = NaN ;
        double bangle_resid_upper_level_sdev_robust ;
                bangle_resid_upper_level_sdev_robust:units = "rad" ;
                bangle_resid_upper_level_sdev_robust:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km robust standar
d deviation" ;
                bangle_resid_upper_level_sdev_robust:missing_value = NaN ;
        double impact_top ;
                impact_top:units = "m" ;
```

```
                impact_top:long_name = "Highest impact parameter (ionospheric
corrected)" ;
                impact_top:missing_value = NaN ;
        double impact_ca_top ;
                impact_ca_top:units = "m" ;
                impact_ca_top:long_name = "Highest impact parameter (L1 / C/A)" ;
                impact_ca_top:missing_value = NaN ;
        double impact_p1_top ;
                impact_p1_top:units = "m" ;
                impact_p1_top:long_name = "Highest impact parameter (L1 / P1)" ;
                impact_p1_top:missing_value = NaN ;
        double impact_p2_top ;
                impact_p2_top:units = "m" ;
                impact_p2_top:long_name = "Highest impact parameter (L2 / P2)" ;
                impact_p2_top:missing_value = NaN ;
        double impact_bot ;
                impact_bot:units = "m" ;
                impact_bot:long_name = "Lowest impact parameter (ionospheric
corrected)" ;
                impact_bot:missing_value = NaN ;
        double impact_ca_bot ;
                impact_ca_bot:units = "m" ;
                impact_ca_bot:long_name = "Lowest impact parameter (L1 / C/A)" ;
                impact_ca_bot:missing_value = NaN ;
        double impact_p1_bot ;
                impact_p1_bot:units = "m" ;
                impact_p1_bot:long_name = "Lowest impact parameter (L1 / P1)" ;
                impact_p1_bot:missing_value = NaN ;
        double impact_p2_bot ;
                impact_p2_bot:units = "m" ;
                impact_p2_bot:long_name = "Lowest impact parameter (L2 / P2)" ;
                impact_p2_bot:missing_value = NaN ;
        double ic_tec ;
                ic_tec:units = "m^-3" ;
                ic_tec:long_name = "Total electron content estimated in ionospheric
correction" ;
                ic_tec:missing_value = NaN ;
        double ic_bangle_diff_slope ;
                ic_bangle_diff_slope:long_name = "Bending angle L1-L2 difference fit
slope estimated in ionospheric correction" ;
                ic_bangle_diff_slope:missing_value = NaN ;
        double ic_bangle_diff_offset ;
                ic_bangle_diff_offset:long_name = "Bending angle L1-L2 difference fit
offset estimated in ionospheric correction" ;
                ic_bangle_diff_offset:missing_value = NaN ;
        double signal_cutoff_slta ;
                signal_cutoff_slta:units = "m" ;
                signal_cutoff_slta:long_name = "Deep occultation signal cut-off SLTA
(L1 / C/A)" ;
                signal_cutoff_slta:missing_value = NaN ;
        double impact_rate_mesosphere ;
                impact_rate_mesosphere:units = "m/s" ;
                impact_rate_mesosphere:long_name = "Mesospheric (> 50 km) neutral
impact parameter descent/ascent rate" ;
                impact_rate_mesosphere:missing_value = NaN ;
        double impact_rate_troposphere ;
                impact_rate_troposphere:units = "m/s" ;
                impact_rate_troposphere:long_name = "Tropospheric (< 5 km) neutral
impact parameter descent/ascent rate" ;
                impact_rate_troposphere:missing_value = NaN ;

      // group attributes:
                :title = "High resolution bending angle retrieval" ;
      } // group high_resolution

    group: thinned {
```

```
       dimensions:
         z = 247 ;
       variables:
         double impact(z) ;
                 impact:units = "m" ;
                 impact:long_name = "Impact parameter" ;
                 impact:missing_value = NaN ;
         double impact_height(z) ;
                 impact_height:units = "m" ;
                 impact_height:long_name = "Impact height (wrt WGS 84 ellipsoid)" ;
                 impact_height:missing_value = NaN ;
         double bangle(z) ;
                 bangle:units = "rad" ;
                 bangle:long_name = "Bending angle (ionospheric corrected)" ;
                 bangle:missing_value = NaN ;
         double bangle_ca(z) ;
                 bangle_ca:units = "rad" ;
                 bangle_ca:long_name = "Bending angle (C/A)" ;
                 bangle_ca:missing_value = NaN ;
         double bangle_p1(z) ;
                 bangle_p1:units = "rad" ;
                 bangle_p1:long_name = "Bending angle (P1)" ;
                 bangle_p1:missing_value = NaN ;
         double bangle_p2(z) ;
                 bangle_p2:units = "rad" ;
                 bangle_p2:long_name = "Bending angle (P2)" ;
                 bangle_p2:missing_value = NaN ;
         double bangle_ca_p2_diff(z) ;
                 bangle_ca_p2_diff:units = "rad" ;
                 bangle_ca_p2_diff:long_name = "Bending angle difference, (L1 / C/A -
L2 / P2, extrapolated)" ;
                 bangle_ca_p2_diff:missing_value = NaN ;
         double lat_tp(z) ;
                 lat_tp:units = "degrees_north" ;
                 lat_tp:long_name = "Latitudes for tangent points" ;
                 lat_tp:missing_value = NaN ;
         double lon_tp(z) ;
                 lon_tp:units = "degrees_east" ;
                 lon_tp:long_name = "Longitudes for tangent points" ;
                 lon_tp:missing_value = NaN ;
         double azimuth_tp(z) ;
                 azimuth_tp:units = "degrees" ;
                 azimuth_tp:long_name = "GNSS->LEO line of sight azimuth angles at
tangent points (clockwise against True North)" ;
                 azimuth_tp:missing_value = NaN ;
         double dtime_mean(z) ;
                 dtime_mean:units = "seconds since 2015-06-12 22:55:45.34" ;
                 dtime_mean:long_name = "Mean measurement epoch (used for
georeferencing only)" ;
                 dtime_mean:missing_value = NaN ;
         double doppler_ca_max ;
                 doppler_ca_max:units = "Hz" ;
                 doppler_ca_max:long_name = "Maximum instantaneous Doppler (C/A)" ;
                 doppler_ca_max:missing_value = NaN ;
         double doppler_p2_max ;
                 doppler_p2_max:units = "Hz" ;
                 doppler_p2_max:long_name = "Maximum instantaneous Doppler (P2)" ;
                 doppler_p2_max:missing_value = NaN ;
         double doppler_rate_ca_max ;
                 doppler_rate_ca_max:units = "Hz/s" ;
                 doppler_rate_ca_max:long_name = "Maximum instantaneous Doppler rate
(C/A)" ;
                 doppler_rate_ca_max:missing_value = NaN ;
         double doppler_rate_p2_max ;
                 doppler_rate_p2_max:units = "Hz/s" ;
```

```
                doppler_rate_p2_max:long_name = "Maximum instantaneous Doppler rate
(P2)" ;
                doppler_rate_p2_max:missing_value = NaN ;
        double doppler_accel_ca_max ;
                doppler_accel_ca_max:units = "Hz/s^2" ;
                doppler_accel_ca_max:long_name = "Maximum instantaneous Doppler
acceleration (C/A)" ;
                doppler_accel_ca_max:missing_value = NaN ;
        double doppler_accel_p2_max ;
                doppler_accel_p2_max:units = "Hz/s^2" ;
                doppler_accel_p2_max:long_name = "Maximum instantaneous Doppler
acceleration (P2)" ;
                doppler_accel_p2_max:missing_value = NaN ;
        double exdoppler_ca_max ;
                exdoppler_ca_max:units = "Hz" ;
                exdoppler_ca_max:long_name = "Maximum instantaneous excess Doppler
(C/A)" ;
                exdoppler_ca_max:missing_value = NaN ;
        double exdoppler_p2_max ;
                exdoppler_p2_max:units = "Hz" ;
                exdoppler_p2_max:long_name = "Maximum instantaneous excess Doppler
(P2)" ;
                exdoppler_p2_max:missing_value = NaN ;
        double exdoppler_rate_ca_max ;
                exdoppler_rate_ca_max:units = "Hz/s" ;
                exdoppler_rate_ca_max:long_name = "Maximum instantaneous excess
Doppler rate (C/A)" ;
                exdoppler_rate_ca_max:missing_value = NaN ;
        double exdoppler_rate_p2_max ;
                exdoppler_rate_p2_max:units = "Hz/s" ;
                exdoppler_rate_p2_max:long_name = "Maximum instantaneous excess
Doppler rate (P2)" ;
                exdoppler_rate_p2_max:missing_value = NaN ;
        double exdoppler_accel_ca_max ;
                exdoppler_accel_ca_max:units = "Hz/s^2" ;
                exdoppler_accel_ca_max:long_name = "Maximum instantaneous excess
Doppler acceleration (C/A)" ;
                exdoppler_accel_ca_max:missing_value = NaN ;
        double exdoppler_accel_p2_max ;
                exdoppler_accel_p2_max:units = "Hz/s^2" ;
                exdoppler_accel_p2_max:long_name = "Maximum instantaneous excess
Doppler acceleration (P2)" ;
                exdoppler_accel_p2_max:missing_value = NaN ;
        double bangle_upper_level_mean ;
                bangle_upper_level_mean:units = "rad" ;
                bangle_upper_level_mean:long_name = "Bending angle (ionospheric
corrected) - 60-80km mean" ;
                bangle_upper_level_mean:missing_value = NaN ;
        double bangle_upper_level_sdev ;
                bangle_upper_level_sdev:units = "rad" ;
                bangle_upper_level_sdev:long_name = "Bending angle (ionospheric
corrected) - 60-80km standard deviation" ;
                bangle_upper_level_sdev:missing_value = NaN ;
        double bangle_upper_level_mean_robust ;
                bangle_upper_level_mean_robust:units = "rad" ;
                bangle_upper_level_mean_robust:long_name = "Bending angle
(ionospheric corrected) - 60-80km robust mean" ;
                bangle_upper_level_mean_robust:missing_value = NaN ;
        double bangle_upper_level_sdev_robust ;
                bangle_upper_level_sdev_robust:units = "rad" ;
                bangle_upper_level_sdev_robust:long_name = "Bending angle
(ionospheric corrected) - 60-80km robust standard deviation" ;
                bangle_upper_level_sdev_robust:missing_value = NaN ;
        double bangle_resid_upper_level_mean ;
                bangle_resid_upper_level_mean:units = "rad" ;
```

```
                bangle_resid_upper_level_mean:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km mean" ;
                bangle_resid_upper_level_mean:missing_value = NaN ;
        double bangle_resid_upper_level_sdev ;
                bangle_resid_upper_level_sdev:units = "rad" ;
                bangle_resid_upper_level_sdev:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km standard deviation" ;
                bangle_resid_upper_level_sdev:missing_value = NaN ;
        double bangle_resid_upper_level_mean_robust ;
                bangle_resid_upper_level_mean_robust:units = "rad" ;
                bangle_resid_upper_level_mean_robust:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km robust mean" ;
                bangle_resid_upper_level_mean_robust:missing_value = NaN ;
        double bangle_resid_upper_level_sdev_robust ;
                bangle_resid_upper_level_sdev_robust:units = "rad" ;
                bangle_resid_upper_level_sdev_robust:long_name = "Bending angle
(ionospheric corrected) residual - 60-80km robust standar
d deviation" ;
                bangle_resid_upper_level_sdev_robust:missing_value = NaN ;
        double impact_top ;
                impact_top:units = "m" ;
                impact_top:long_name = "Highest impact parameter (ionospheric
corrected)" ;
                impact_top:missing_value = NaN ;
        double impact_ca_top ;
                impact_ca_top:units = "m" ;
                impact_ca_top:long_name = "Highest impact parameter (L1 / C/A)" ;
                impact_ca_top:missing_value = NaN ;
        double impact_p1_top ;
                impact_p1_top:units = "m" ;
                impact_p1_top:long_name = "Highest impact parameter (L1 / P1)" ;
                impact_p1_top:missing_value = NaN ;
        double impact_p2_top ;
                impact_p2_top:units = "m" ;
                impact_p2_top:long_name = "Highest impact parameter (L2 / P2)" ;
                impact_p2_top:missing_value = NaN ;
        double impact_bot ;
                impact_bot:units = "m" ;
                impact_bot:long_name = "Lowest impact parameter (ionospheric
corrected)" ;
                impact_bot:missing_value = NaN ;
        double impact_ca_bot ;
                impact_ca_bot:units = "m" ;
                impact_ca_bot:long_name = "Lowest impact parameter (L1 / C/A)" ;
                impact_ca_bot:missing_value = NaN ;
        double impact_p1_bot ;
                impact_p1_bot:units = "m" ;
                impact_p1_bot:long_name = "Lowest impact parameter (L1 / P1)" ;
                impact_p1_bot:missing_value = NaN ;
        double impact_p2_bot ;
                impact_p2_bot:units = "m" ;
                impact_p2_bot:long_name = "Lowest impact parameter (L2 / P2)" ;
                impact_p2_bot:missing_value = NaN ;
        double ic_tec ;
                ic_tec:units = "m^-3" ;
                ic_tec:long_name = "Total electron content estimated in ionospheric
correction" ;
                ic_tec:missing_value = NaN ;
        double ic_bangle_diff_slope ;
                ic_bangle_diff_slope:long_name = "Bending angle L1-L2 difference fit
slope estimated in ionospheric correction" ;
                ic_bangle_diff_slope:missing_value = NaN ;
        double ic_bangle_diff_offset ;
                ic_bangle_diff_offset:long_name = "Bending angle L1-L2 difference fit
offset estimated in ionospheric correction" ;
                ic_bangle_diff_offset:missing_value = NaN ;
```

```
        double signal_cutoff_slta ;
                signal_cutoff_slta:units = "m" ;
                signal_cutoff_slta:long_name = "Deep occultation signal cut-off SLTA
(L1 / C/A)" ;
                signal_cutoff_slta:missing_value = NaN ;
        double impact_rate_mesosphere ;
                impact_rate_mesosphere:units = "m/s" ;
                impact_rate_mesosphere:long_name = "Mesospheric (> 50 km) neutral
impact parameter descent/ascent rate" ;
                impact_rate_mesosphere:missing_value = NaN ;
        double impact_rate_troposphere ;
                impact_rate_troposphere:units = "m/s" ;
                impact_rate_troposphere:long_name = "Tropospheric (< 5 km) neutral
impact parameter descent/ascent rate" ;
                impact_rate_troposphere:missing_value = NaN ;

      // group attributes:
                :title = "Thinned bending angle retrieval" ;
                :thinner_method = "Local polynomial regression with z-dependent
(sine-squared) variable bandwidth on 247 standard impact
height levels" ;
      } // group thinned
    } // group level_1b
  } // group data

group: quality {
  variables:
        byte cl_data_available ;
                cl_data_available:long_name = "True if closed loop data is available"
;
                cl_data_available:missing_value = -128b ;
        byte rs_data_available ;
                rs_data_available:long_name = "True if raw sampling data is
available" ;
                rs_data_available:missing_value = -128b ;
        byte ol_data_available ;
                ol_data_available:long_name = "True if open loop data is available"
;
                ol_data_available:missing_value = -128b ;
        byte pr_data_available ;
                pr_data_available:long_name = "True if pseudorange data is available"
;
                pr_data_available:missing_value = -128b ;
        byte cl_rs_data_continuous ;
                cl_rs_data_continuous:long_name = "True if closed loop and raw
sampling data form continuous time series" ;
                cl_rs_data_continuous:missing_value = -128b ;
        byte cl_rs_consistency_ok ;
                cl_rs_consistency_ok:long_name = "True if closed loop and raw
sampling data are consistent in the overlap region" ;
                cl_rs_consistency_ok:missing_value = -128b ;
        byte cl_snr_ca_ok ;
                cl_snr_ca_ok:long_name = "True if upper level (SLTA > 60 km) mean
C/A carrier phase SNR > 200 V/V" ;
                cl_snr_ca_ok:missing_value = -128b ;
        byte cl_snr_p1_ok ;
                cl_snr_p1_ok:long_name = "True if upper level (SLTA > 60 km) mean P1
carrier phase SNR > 50 V/V" ;
                cl_snr_p1_ok:missing_value = -128b ;
        byte cl_snr_p2_ok ;
                cl_snr_p2_ok:long_name = "True if upper level (SLTA > 60 km) mean P2
carrier phase SNR > 50 V/V" ;
                cl_snr_p2_ok:missing_value = -128b ;
        byte rs_snr_ca_ok ;
                rs_snr_ca_ok:long_name = "True if raw sampling max C/A carrier phase
SNR > 200 V/V" ;
```

```
                rs_snr_ca_ok:missing_value = -128b ;
        byte ol_snr_ca_ok ;
                ol_snr_ca_ok:long_name = "True if open loop max C/A carrier phase
SNR > 200 V/V" ;
                ol_snr_ca_ok:missing_value = -128b ;
        byte cl_external_navbits_applied ;
                cl_external_navbits_applied:long_name = "True if external navigation
bit data available and used during closed loop proce
ssing" ;
                cl_external_navbits_applied:missing_value = -128b ;
        byte rs_external_navbits_applied ;
                rs_external_navbits_applied:long_name = "True if external navigation
bit data available and used during raw sampling proc
essing" ;
                rs_external_navbits_applied:missing_value = -128b ;
        byte ol_external_navbits_applied ;
                ol_external_navbits_applied:long_name = "True if external navigation
bit data available and used during open loop/downsam
pled raw sampling processing" ;
                ol_external_navbits_applied:missing_value = -128b ;
        byte analogue_gain_changes_ok ;
                analogue_gain_changes_ok:long_name = "True if occultation is not
affected by (analogue) gain changes." ;
                analogue_gain_changes_ok:missing_value = -128b ;
        byte gns_orbit_ok ;
                gns_orbit_ok:long_name = "True if GNSS orbit estimates are available"
;
                gns_orbit_ok:missing_value = -128b ;
        byte gns_clock_ok ;
                gns_clock_ok:long_name = "True if GNSS clock error estimates are
available" ;
                gns_clock_ok:missing_value = -128b ;
        byte rec_orbit_ok ;
                rec_orbit_ok:long_name = "True if receiver orbit estimates are
available" ;
                rec_orbit_ok:missing_value = -128b ;
        byte rec_clock_ok ;
                rec_clock_ok:long_name = "True if receiver clock error estimates are
available" ;
                rec_clock_ok:missing_value = -128b ;
        byte rec_clock_estimated ;
                rec_clock_estimated:long_name = "True if receiver clock error has
been estimated (False if interpolated due to missing ep
ochs from POD estimation)" ;
                rec_clock_estimated:missing_value = -128b ;
        byte fsi_done ;
                fsi_done:long_name = "True if full spectrum inversion retrieval has
been performed" ;
                fsi_done:missing_value = -128b ;
        byte go_done ;
                go_done:long_name = "True if geometrical optics retrieval has been
performed" ;
                go_done:missing_value = -128b ;
        byte thinned_done ;
                thinned_done:long_name = "True if thinned retrieval has been
performed" ;
                thinned_done:missing_value = -128b ;
        byte sl_done ;
                sl_done:long_name = "True if straight line retrieval has been
performed" ;
                sl_done:missing_value = -128b ;
        byte ol_data_used ;
                ol_data_used:long_name = "True if open loop data was used in
retrieval" ;
                ol_data_used:missing_value = -128b ;
        byte fsi_ok ;
```

```
                fsi_ok:long_name = "True if full spectrum inversion retrieval is ok"
;
                fsi_ok:missing_value = -128b ;
        byte go_ok ;
                go_ok:long_name = "True if geometrical optics retrieval is ok" ;
                go_ok:missing_value = -128b ;
        byte sl_ok ;
                sl_ok:long_name = "True if straight line retrieval is ok" ;
                sl_ok:missing_value = -128b ;
        byte overall_quality_ok ;
                overall_quality_ok:long_name = "True if retrieval is ok" ;
                overall_quality_ok:missing_value = -128b ;
        byte thinned_ok ;
                thinned_ok:long_name = "True if thinned retrieval is ok" ;
                thinned_ok:missing_value = -128b ;
        byte high_resolution_ok ;
                high_resolution_ok:long_name = "True if high resolution retrieval is
ok" ;
                high_resolution_ok:missing_value = -128b ;
        byte bangle_bias_ok ;
                bangle_bias_ok:long_name = "True if upper level (60 - 80 km) mean
bending angle is ok" ;
                bangle_bias_ok:missing_value = -128b ;
        byte bangle_sdev_ok ;
                bangle_sdev_ok:long_name = "True if upper level (60 - 80 km) bending
angle residual standard deviation is ok" ;
                bangle_sdev_ok:missing_value = -128b ;
        byte iono_corr_ok ;
                iono_corr_ok:long_name = "True if ionospheric correction is ok" ;
                iono_corr_ok:missing_value = -128b ;
        byte impact_top_ok ;
                impact_top_ok:long_name = "True if uppermost impact parameter height
is ok" ;
                impact_top_ok:missing_value = -128b ;
        byte impact_bot_ok ;
                impact_bot_ok:long_name = "True if lowermost impact parameter height
is ok" ;
                impact_bot_ok:missing_value = -128b ;
        byte impact_ca_top_ok ;
                impact_ca_top_ok:long_name = "True if uppermost C/A impact parameter
height is ok" ;
                impact_ca_top_ok:missing_value = -128b ;
        byte impact_ca_bot_ok ;
                impact_ca_bot_ok:long_name = "True if lowermost C/A impact parameter
height is ok" ;
                impact_ca_bot_ok:missing_value = -128b ;
        byte impact_p1_top_ok ;
                impact_p1_top_ok:long_name = "True if uppermost L1/P impact parameter
height is ok" ;
                impact_p1_top_ok:missing_value = -128b ;
        byte impact_p1_bot_ok ;
                impact_p1_bot_ok:long_name = "True if lowermost L1/P impact parameter
height is ok" ;
                impact_p1_bot_ok:missing_value = -128b ;
        byte impact_p2_top_ok ;
                impact_p2_top_ok:long_name = "True if uppermost L2/P impact parameter
height is ok" ;
                impact_p2_top_ok:missing_value = -128b ;
        byte impact_p2_bot_ok ;
                impact_p2_bot_ok:long_name = "True if lowermost L2/P impact parameter
height is ok" ;
                impact_p2_bot_ok:missing_value = -128b ;
        byte signal_cutoff_done ;
                signal_cutoff_done:long_name = "True if deep occultation signal cut-
off was done." ;
                signal_cutoff_done:missing_value = -128b ;
```

```
  // group attributes:
                :title = "GRAS/Metop-A level 1a/b quality" ;
  } // group quality
}
```

ECMWF Shinfield Park Reading RG2 9AX UK