EPS Product Validation Report No. 6

Dissemination of Metop-A ATOVS Level 2 data via EUMETCast

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1 INTRODUCTION

1.1 Description of Change

The dissemination of Level 2 data from the ATOVS (Advanced TIROS Operational Sounder) instruments suite (High Resolution Infrared Radiation Sounder HIRS/4, Advanced Microwave Sounding Unit AMSU, Microwave Humidity Sounder MHS) onboard Metop-A comprises the Level 2 Product described in the document EPS.MIS.SPE.980759 Issue 6, Rev. 4 'ATOVS Level 2 Product Format Specification'
(see
http://www.eumetsat.int/Home/Main/Publications/Technical_and_Scientific_Documentation/Technical_Notes/SP_1126189367518?l=en) with some minor modifications discussed below. The released data will be BUFR encoded according to the specifications of the World Meteorological Organisation WMO.

1.2 Description of Validation Environment

The validation of the ATOVS Level 2 data has been performed by comparing the geophysically relevant products processed in the EPS Ground Segment 2 (GS-2) against the following data sets:

- ECMWF (European Centre for Medium Range Weather Forecast) Forecast and Reanalysis Data
- Radiosonde Data
- ATOVS Level 2 from Metop-A processed by NOAA (not in the draft of this document)
- IASI Level 2 data processed in EPS GS-1

In particular, the following parameters were validated on a pixel-by-pixel basis for individual pressure levels:

- Retrieved air temperatures for the first guess profile and the final profile.
- Retrieved water vapour (dew point temperatures) for the first guess profile and the final profile.

In addition, the following parameters were evaluated by visual inspection (results are not in the draft version of the document):

- Fractional cloud coverage
- Cloud liquid water content
- Surface pressure
- Precipitation flags

2 RETRIEVAL RESULTS

The ATOVS Level 2 data recorded between 00:21:18 UTC (orbit #7250) at 13. March 2007 and 00:00:17 UTC (orbit #7264) at 14. March 2008. In particular, the following 14 products were selected:

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ATOV_SND_02_M02_20080313002118Z_20080313020316Z_N_C_20080313020714Z
ATOV_SND_02_M02_20080313020316Z_20080313034814Z_N_C_20080313035044Z
ATOV_SND_02_M02_20080313034814Z_20080313053019Z_N_C_20080313053430Z
ATOV_SND_02_M02_20080313053019Z_20080313071217Z_N_C_20080313071543Z
ATOV_SND_02_M02_20080313071217Z_20080313085415Z_N_C_20080313085728Z
ATOV_SND_02_M02_20080313085415Z_20080313103315Z_N_C_20080313103911Z
ATOV_SND_02_M02_20080313103315Z_20080313121519Z_N_C_20080313121700Z
ATOV_SND_02_M02_20080313121519Z_20080313135419Z_N_C_20080313135923Z
ATOV_SND_02_M02_20080313135419Z_20080313153318Z_N_C_20080313153733Z
ATOV_SND_02_M02_20080313153318Z_20080313171516Z_N_C_20080313171706Z
ATOV_SND_02_M02_20080313171516Z_20080313185415Z_N_C_20080313185911Z
ATOV_SND_02_M02_20080313185415Z_20080313203614Z_N_C_20080313203931Z
ATOV_SND_02_M02_20080313203614Z_20080313221818Z_N_C_20080313222058Z
ATOV_SND_02_M02_20080313221818Z_20080314000017Z_N_C_20080314000428Z
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During the above mentioned time period, the Level 1 products of HIRS, AMSU, MHS, and AVHRR are nominal and actual forecast data have been received in time. Thus, all results of the validation of the ATOVS Level 2 products and all drawn conclusions are on the assumption of nominal instruments' behaviour and nominal performances of the four individual Level 1 Product Processing Facilities in GS-2. In particular, the selected retrieval grid to which all input and output data are mapped, is coincident with the geolocation of the HIRS pixels from the corresponding Level 1B product. The validation of products from non-nominal retrieval configurations (e.g. AMSU standalone retrieval) is not the scope of this document.

The use of 14 subsequent orbits for validation is necessary to ensure global coverage of the products and allows to detect possible differences in the performance of the retrieval under day time and night time conditions. In the following, the focus of the validation is on the quality of the vertical profiles for temperature and humidity. Provided that the quality of these products is sufficient, it is expected that several Level 2 pre-processing steps like the selection of the first guess profiles or the computation and mapping of brightness temperatures from individual instruments onto the HIRS grid work fine. Up to now, there is one known issue, which might have a negative impact on the retrieval quality: since the AVHRR scanning properties are non-nominal, the mapping of AVHRR information (surface temperatures, cloud top temperatures, fractional cloud cover) onto the HIRS pixel is still performed on the assumption of nominal attitude (no pitch, roll, or yaw corrections). Since the implementation of a pitch and roll offset correction in the AVHRR-to-HIRS mapping routine is necessary, this neglect might result in a degradation of the products especially at the scan edges, where the impact of mispointing is more pronounced than close to the nadir direction. In addition, heterogeneous atmospheric or surface conditions will produce a larger bias on the mapped AVHRR data than homogenous cloud coverage and smooth spatial changes in surface temperature.

3 VALIDATION

The first step of the validation was performed by comparing the output of the operational processor (PPF) against the prototype output. The main purpose of this step was to ensure functionality of the processor. However, to judge about the absolute quality of the retrieval, such a comparison is not reliable and is therefore not further discussed here. For final

validation, the use of other data sets like radiosonde ascents and ECMWF reanalysis data is necessary. In addition, coincident retrieval results from other sensors like IASI (Infrared Atmospheric Sounding Interferometer) onboard Metop-A, or from other operational ATOVS processors (i.e., from the Ground Segment of the National Oceanic and Atmospheric Administration NOAA) are quoted.

3.1 Validation of Temperature Profiles with ECMWF and Radiosonde Data

The retrieved temperature profiles represent the core ATOVS Level 2 product of the ATOVS Level 2. On 40 different pressure levels ranging from 1000hPa to 0.1hPa, atmospheric temperatures are derived from microwave (AMSU and MHS) and infrared (HIRS) Earth view radiances supplemented by products from imager data (AVHRR). The selection of radiance channels used for the retrieval depends primarily on the actual atmospheric situation (cloudy, partially cloudy, clear, precipitation), and the surface type (land, sea coast). In addition, the number of the chosen channels can be reduced, when moving from the first guess to the computation of the final profile.

The ECMWF reanalysis data cover the whole globe with a resolution of 1 deg in both, geographical latitude and geographical longitude. These data sets represent the atmospheric state at fixed day times of 0:00 UTC, 6:00 UTC, 12:00 UTC, and 18:00 UTC and are computed by assimilating past meteorological observations in numerical weather models in order to get a good estimate about the actual state of the atmosphere. Since also satellite data are assimilated especially over areas with a poor network of observations (open oceans, deserts, polar and mountain regions), there exists an ‘incest effect’ when comparing those data against actual satellite retrievals. To increase the confidence in those comparisons, independent observations from the global radiosonde network are used as an additional source. These pin-point measurements are irregularly scattered over the whole globe and cover mainly the land areas of North America, Asia, and Europe. They have the same common observation times as the reanalysis data, but not all stations perform measurements in six-hour intervals. Figure 1 shows the global distribution of the radiosonde ascents used in this analysis. The total number of available stations is 600.

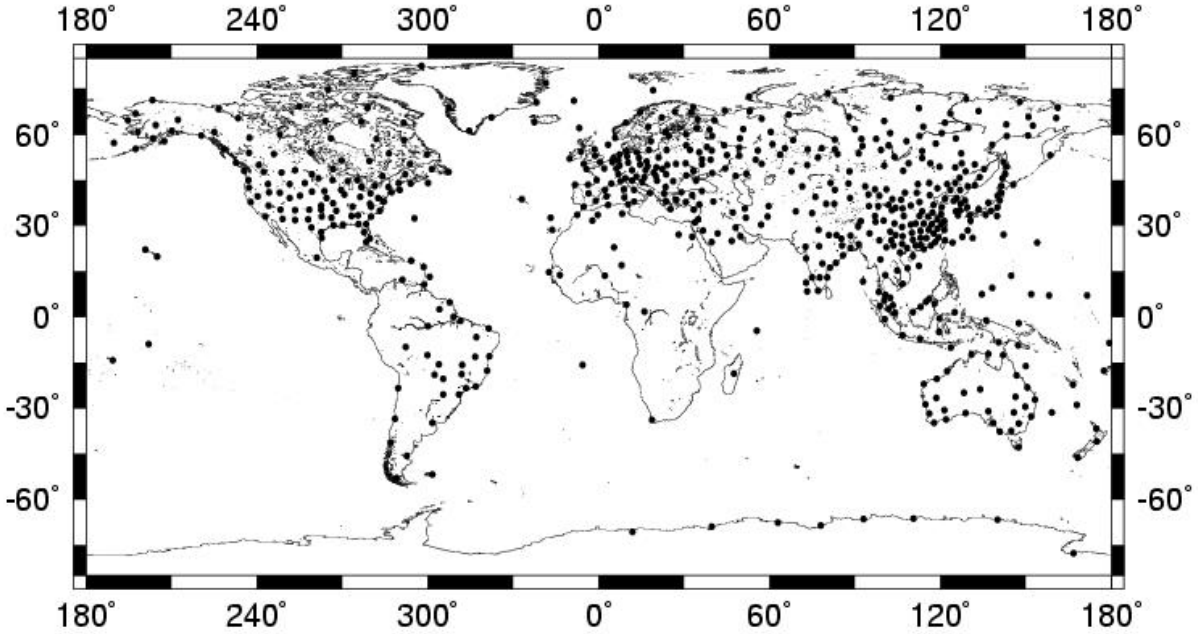
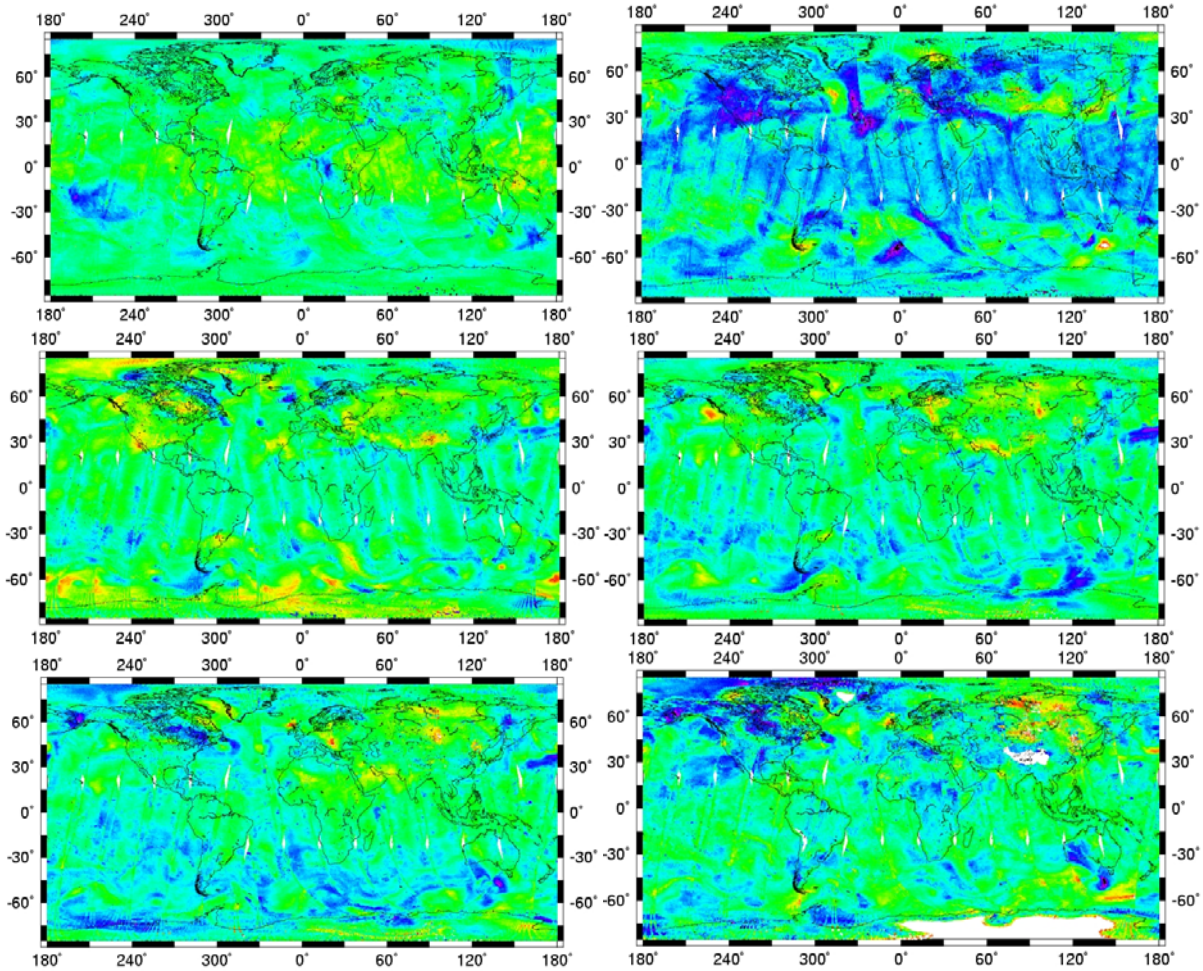


Figure 1: Geographical location of the 600 radiosonde ascents used for the validation



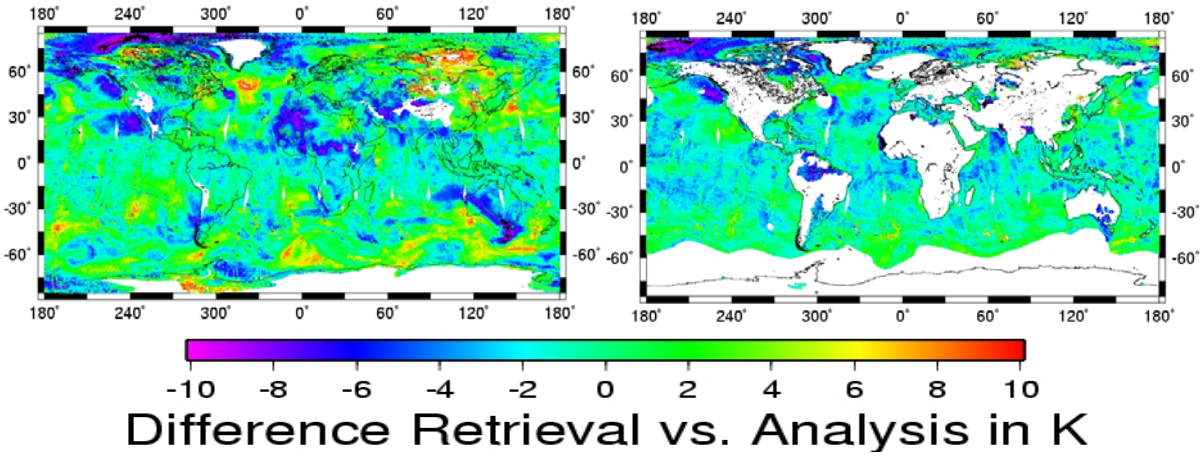


Figure 2: Global distribution of the temperature differences between the ATOVS Level 2 product and ECMWF reanalysis data. The pressure levels displayed here are (from upper left to lower right): 100hPa, 200hPa, 300hPa, 400hPa, 500hPa, 700hPa, 850hPa, 1000hPa.

From the ECMWF reanalysis data, the following 10 pressure levels have been selected for comparison: 1000hPa, 850hPa, 700hPa, 500hPa, 400hPa, 300hPa, 250hPa, 200hPa, 150hPa, and 100hPa. These pressure levels are also included in the 40 standard pressure levels of the ATOVS Level 2 retrieval. Therefore, a vertical interpolation of the retrieved temperature values is not necessary. To match the data sets horizontally, a bilinear interpolation is performed. In addition, a linear interpolation with respect to time has been applied to the reanalysis data in order to match with the sampling time of an individual scan line. The results of this comparison are plotted in Figure 2 for 8 different pressure levels. Negative differences indicate that the ATOVS Level 2 temperatures are lower than the coincident temperatures in the ECMWF reanalysis field. White areas in the images for the pressure levels closer to the surface mark those areas, where the surface pressure is lower than the actual pressure level. Those conditions occur over elevated terrain and over sea in the mid-latitude depression systems.

Closer to the surface, the influence of small scale perturbations due to inhomogeneities in the surface properties is evident through the patchy structure of the temperature differences. Since especially over polar areas, negative differences prevail, it is expected that the globally averaged bias for these pressure levels will be negative, too. From the pressure levels corresponding to higher altitudes, the differences at 200 hPa exhibit a broad area with negative values mainly over the tropics and the mid-latitudes, i.e. for low temperatures. One cause for these features is the lack of radiance information from the sounding instruments at this pressure level. In addition, these differences show a slight dependence on the pixel position, which will most probably result from an asymmetric bias in the AMSU measurements. It is expected that further refinements in antenna corrections for AMSU could diminish the observed scan-angle dependence of the temperature differences.

To make the discussed results and conclusions more reliable, the temperature profiles of radiosonde ascents from 600 stations (see Figure 1) are compared against both, the nearest ATOVS Level 2 retrieval, and the ECMWF reanalysis profile computed for this geolocation. The pressure levels, at which the atmospheric temperatures are recorded, are not fixed. Hence, the measured temperatures are linearly interpolated with respect to the geometrical

altitude computed by the hydrostatic equation. In addition, when comparing radiosonde data against ATOVS Level 2, the radiosonde data are linearly interpolated with respect to time to match with the local satellite overpass. Figure 3 shows the overall results for the bias (three curves on the left in Figure 3) and the root-mean-square error RMS (three curves on the right in Figure 3) when comparing each data set (retrieval, radiosondes, and reanalysis) against each other. The results 'Radiosondes vs. ECMWF' (grey curves) can be considered as a measure for the background noise in the differences between individual data sets: above 1000 hPa, the absolute of the bias remains below 0.5 K and the RMS is slightly larger than 1 K. These discrepancies may result from comparing a measurement at a distinct fixed location with a value interpolated to this location from the values at the surrounding grid-points. Especially over heterogeneous terrain (e.g. coastal areas), this method of data evaluation can introduce significant biases.
When comparing either radiosonde or reanalysis data against the ATOVS Level 2 products, the results are quite similar as can be seen from the similar shapes of the corresponding red and blue curves in Figure 3. The significant negative bias at the 200 hPa level is already reflected in Figure 2. In the troposphere, negative biases prevail, which indicates that overall, the retrieved temperatures are slightly cooler than the corresponding ones in the reference data sets.

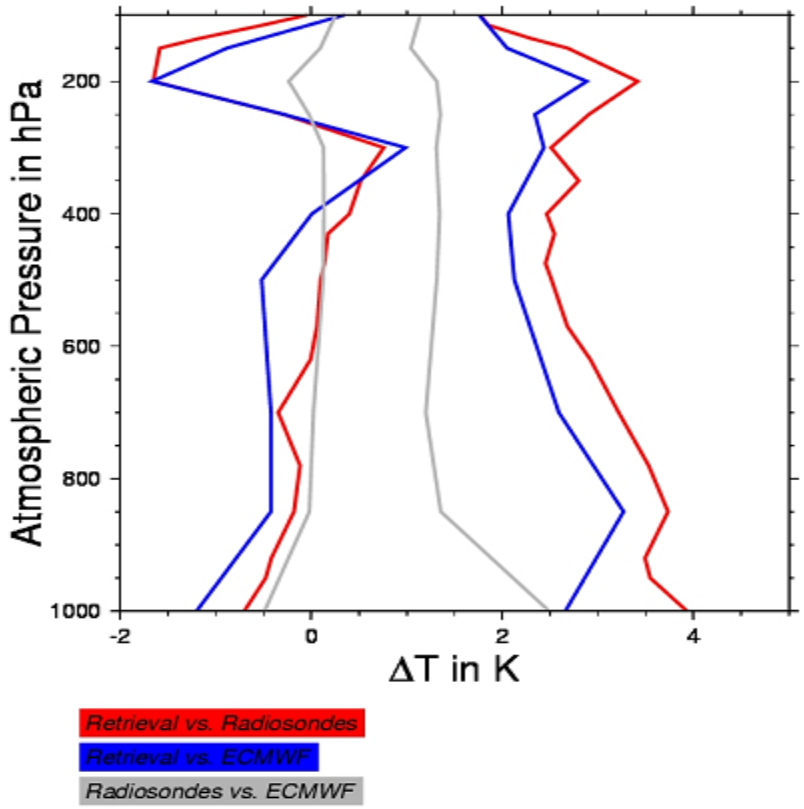


Figure 3: Vertical profiles of the biases (left curves) and the root-mean-squares (right curves) when comparing individual temperature data sets (coloured boxes). Data are from 13. March 2008

3.2 Comparison between IASI L2 and ATOVS L2 Temperature Profiles

Results for the ATOVS Level 2 temperature profiles are also validated against the coincident IASI Level 2 products. For this purpose, the comparison 'Retrieval vs. ECMWF' is repeated using the corresponding IASI Level 2 products and the results are shown in Figure 4: the curves 'ATOVS-2 Bias' and ' ATOVS-2 RMSE' correspond to the blue curves in Figure 3. They do not match exactly, since for this comparison, forecast data have been used instead of reanalysis data. The other two curves in Figure 4 show the corresponding results for IASI: in the lower atmospheric layers, the quality of both retrievals is quite similar, whereas for the upper troposphere, the IASI profiles are closer to the ECMWF data.

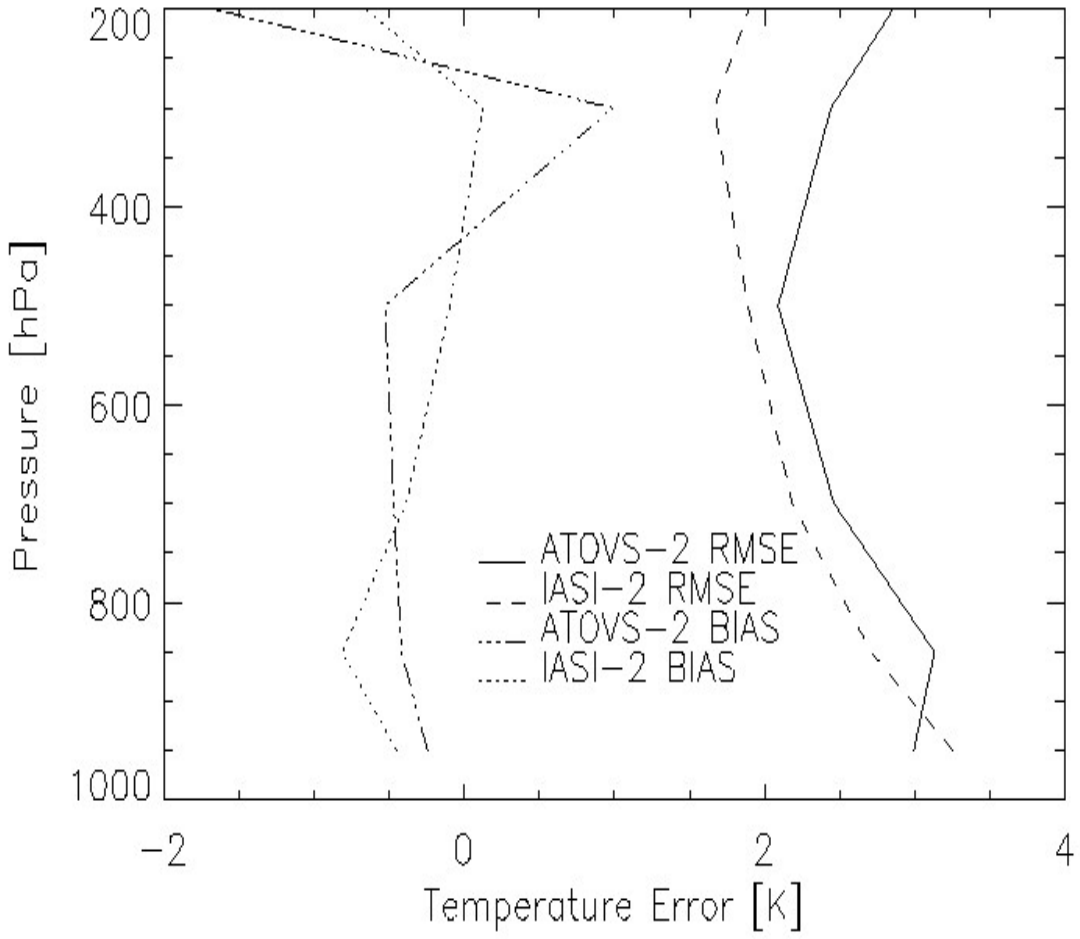


Figure 4: Vertical profiles of the biases (left curves) and the root-mean-squares (right curves) when comparing IASI L2 and ATOVS L2 temperature profiles against ECMWF data. Data are from 13. March

3.3 Validation of Water Vapour Profiles with ECMWF and Radiosonde Data

The analysis presented above has been repeated for the water vapour retrieval, which is another core product of the ATOVS Level 2 processing. Both, specific humidity and dewpoint temperature are used for comparison. Results representative for other atmospheric pressure levels are shown for 500 hPa, 700 hPa, 850 hPa and 100 hPa in Figure 5.

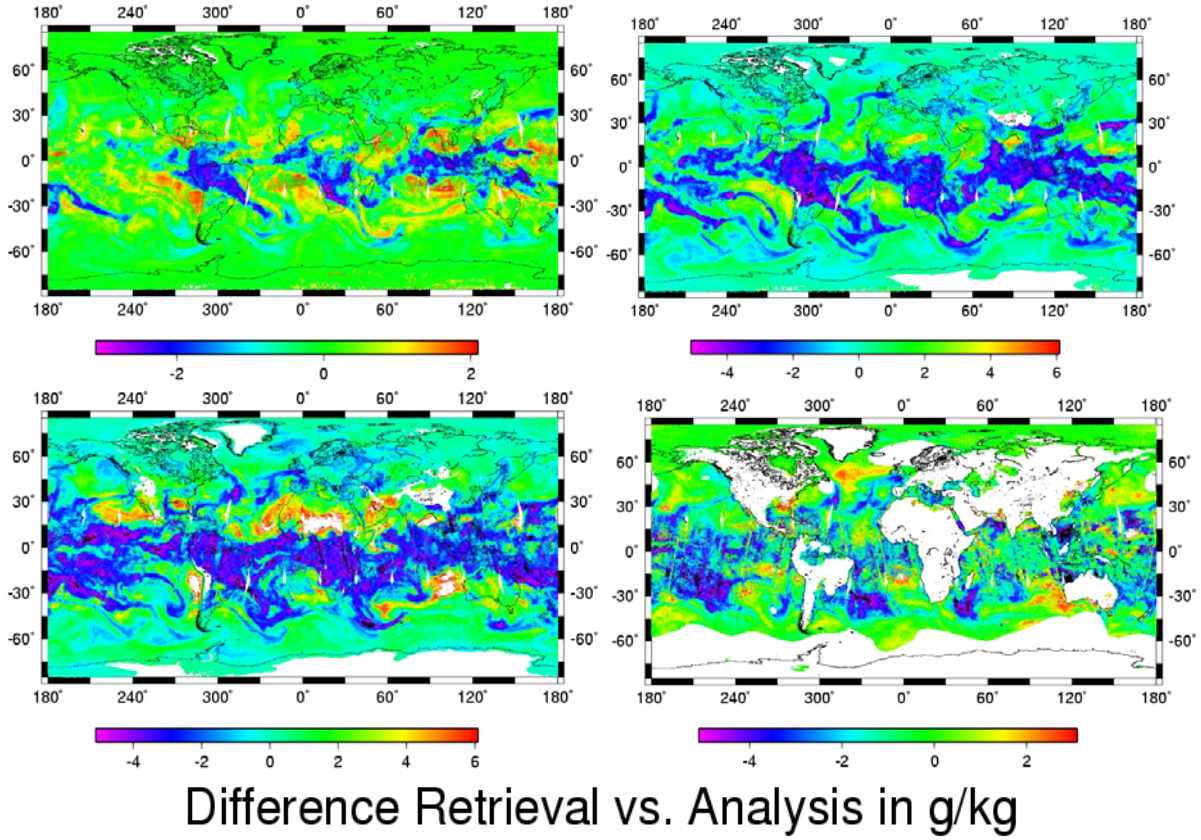


Figure 5: Global distribution of the specific humidity differences between the ATOVS Level 2 product and ECMWF reanalysis data. The pressure levels displayed here are (from upper left to lower right): 500hPa, 700hPa, 850hPa, 1000hPa

Largest absolute deviations are observed in areas with high values of specific humidity, i.e. in the tropics and the lower layers of the mid-latitude depression systems. Here, clouds have a significant impact on the quality of the water vapour retrieval. One remarkable feature is the strong positive bias at 850 hPa over the African deserts. It is assumed that this overestimation is caused by a poor representation of desert conditions in the first guess library of the retrieval scheme.
Like for the evaluation of the temperature retrieval, the different data sets for specific humidity have been validated against each other. Figure 6 displays the resulting statistics of the individual comparisons. The three curves on the left side show the values for the biases, and the three curves on the right side illustrate the RMS. All values are given in g/kg. The radiosonde data are nearly unbiased when compared to the collocated reanalysis values, wheras the corresponding RMS profile increases at lower altitudes. Since the main source for atmospheric water vapour is the Earth's surface with its variable evaporation rates, this shape of the curve is expected. However, since only six ECMWF pressure levels have been extracted, both curves appear very smooth.

In the ATOVS Level 2 retrieval, 15 atmospheric pressure levels are used to determine vertical profiles of water vapour. Therefore, when comparing the retrieval output against the radiosonde profiles, a higher vertical resolution is achieved. Since in the atmosphere, water vapour shows a higher horizontal variability than temperature, it is expected that due to local effects, radiosonde data might show these fluctuations when compared against retrievals, which are not able to resolve all details of the water vapour structures. The zig-zag shape of the red curves in Figure 6 confirm this. The blue curves ('Retrieval vs. ECMWF'), are - especially for the RMS-, a good estimate for low-pass filtered red curves. This fact demonstrates that the validation results are consisten when using either radiosonde data or reanalysis data as the reference for the retrieval validation.

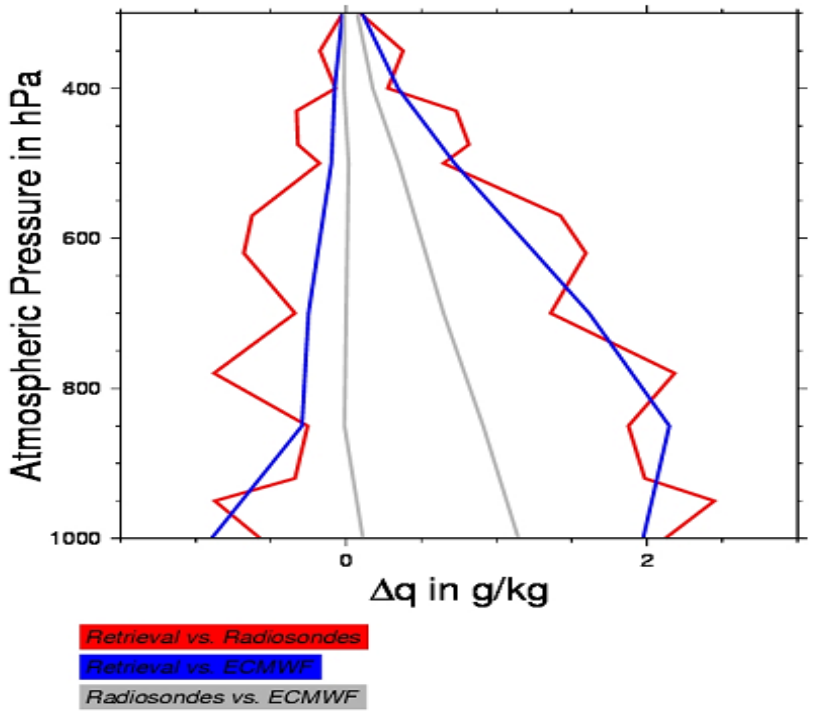


Figure 6: Vertical profiles of the biases (left curves) and the root-mean-squares (right curves) when comparing individual specific humidity data sets (coloured boxes). Data are from 13. March 2008

It is often convenient to compute also dewpoint differences when validating water vapour retrievals. This is especially useful for areas with low water vapour contents (polar and desert areas, subsidence regions of high pressure systems over land). Figure 7 shows the dewpoint differences between ATOVSL Level 2 products and collocated ECMWF forecast fields at 950 hPa, 850hPa, 700 hPa, and 500 hPa. This dewpoint temperature comparison exhibits the same areas with large differences than the specific humidity evaluation: especially the atmospheric conditions over African desert areas are only poorly retrieved, and also the water vapour amount in the source areas of the trade winds is significantly overestimated.

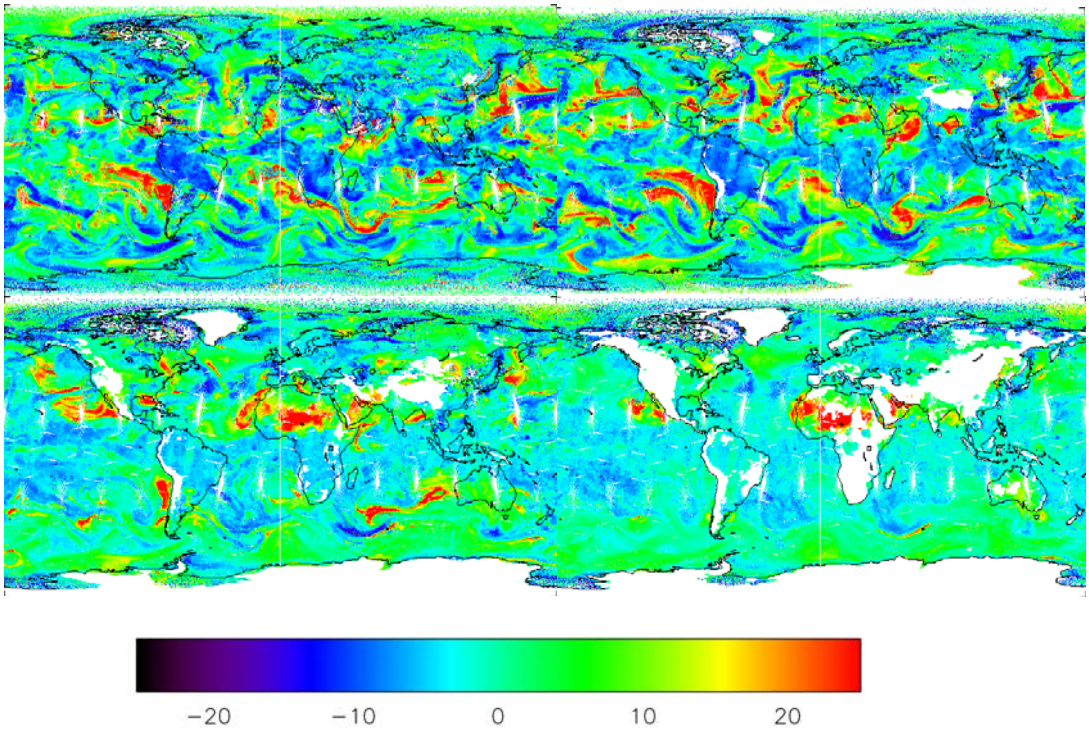


Figure 7: Global distribution of the dewpoint temperature differences (in K) between the ATOVS Level 2 product and ECMWF forecast data. The pressure levels displayed here are (from upper left to lower right): 500hPa, 700hPa, 850hPa, 950hPa

3.4 Comparison between IASI L2 and ATOVS L2 Humidity Profiles

Since the radiance signatures of water vapour are detected by only a small number of ATOVS sounders' channels, it is expected that the differences between IASI Level 2 products and ATOVS Level 2 products for water vapour should be larger than for the temperature profiles. Figure 8 confirms this suspect: whereas the biases for both retrievals are quite similar, the performance of the ATOVS water vapour retrieval is worse than that of the IASI retrieval. For most parts of the troposphere, the RMS for ATOVS level 2 products is about 2 K larger than for the collocated profiles retrieved from the IASI data. However, it is not expected that the ATOVS profiles can be improved due to e.g. tuning of the processor.

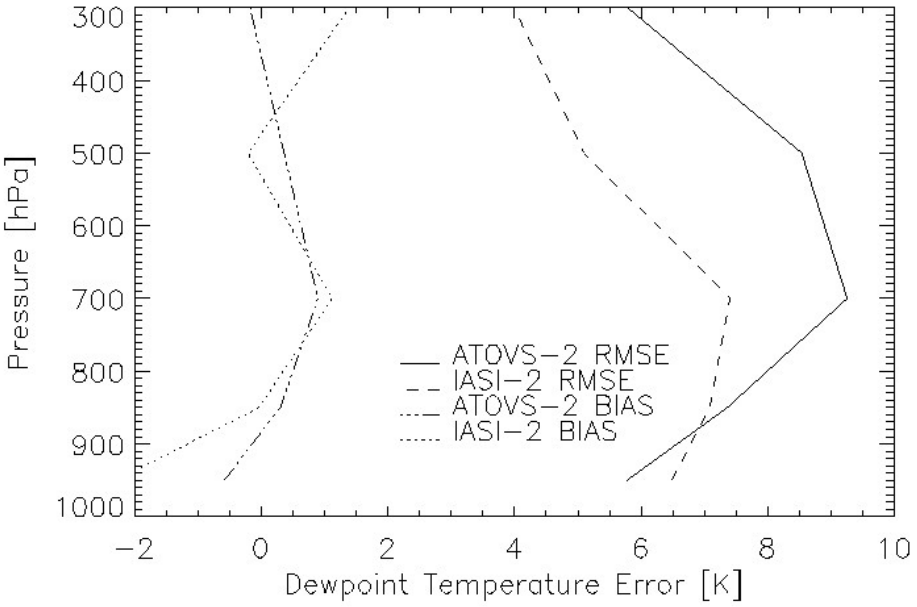


Figure 8: Vertical profiles of the biases (left curves) and the root-mean-squares (right curves) when comparing IASI L2 and ATOVS L2 dewpoint temperature profiles against ECMWF data. Data are from 13. March

4 EXTERNAL PARTNER VALIDATION

So far, no external validation of Level 2 products derived from the ATOVS instrumentation onboard Metop-A is known.

5 CONCLUSIONS

5.1 Product Validation Summary

The ATOVS Level 2 products investigated so far (mainly vertical profiles of temperature and water vapour) were globally validated against radiosonde data, ECMWF data, and coincident IASI Level 2 products by standard statistical methods for one full day (13 March 2008). Biases and root-mean square deviations are within the expected ranges and the results are consistent. Problem areas for the temperature retrievals are the polar areas, whereas the water vapour retrieval is of poor quality over desert areas.

The validation of these products has no impact on the currently existing software validation tools. It is not expected that the size of the ATOVS Level 2 product (approximately 24 MegaBytes per orbit) will lead to problems related to the EUMETCAST dissemination.

5.2 Actions for Product Rollout

The product rollout shall be announced at the EUMETSAT webpage as follows:

Actual Date
Dissemination of ATOVS Level 2 products.

EUMETCast dissemination of operational ATOVS Level 2 products started today. The data were already disseminated pre-operational and no change on the products have been performed since then.

5.2.1 User Notification

User notification required: Yes.

5.2.2 PGS Update

There is no update of the Product Generation Specification needed so far

5.2.3 ASD Update

None

5.2.4 WEB Update

None

6 RECOMMENDATION

None