EUMETSAT Satellite Application Facility on Climate Monitoring

The EUMETSAT Network of Satellite Application Facilities

CM SAF Climate Monitoring

ATOVS tropospheric humidity and temperature data set

Algorithm Theoretical Basis Document

ATOVS edition 1

DOI: 10.5676/EUM_SAF_CM/WVT_ATOVS/V001

Vertically integrated water vapour	**CM-123**
Layered water vapour and temperature	**CM-132**
Specific humidity and temperature at pressure levels	**CM-138**

Reference Number:	SAF/CM/DWD/ATOVS
Issue/Revision Index:	1.1
Date:	13.03.2013

Document Signature Table

	Name	Function	Signature	Date
Author	Nathalie Courcoux Marc Schröder	CM SAF scientist		
Editor	Rainer Hollmann	Science Coordinator		
Approval	Rainer Hollmann	Science Coordinator		
Release	Martin Werscheck	Project Manager		

Distribution List

Internal Distribution	
Name	**No. Copies**
DWD Archive	1
CM SAF Team	1

External Distribution		
Company	**Name**	**No. Copies**
PUBLIC		1

Document Change Record

Issue/ Revision	Date	DCN No.	Changed Pages/Paragraphs
1.0	12/11/2010	SAF/CM/DWD/ATBD/ATOVS	First official version.
1.1	13/03/2013	SAF/CM/DWD/ATBD/ATOVS	Update following DRI7 reviewer comments; editorial changes

Applicable documents

Reference	Title	Code
AD 1	CM SAF Product Requirements Document	SAF/CM/DWD/PRD/2.0

Reference documents

Reference	Title	Code
RD 1	Product User Manual ATOVS data set edition 1	SAF/CM/DWD/PUM/ATOVS/1.1
RD 2	Product User Manual Water Vapour and Temperature from ATOVS	SAF/CM/DWD/PUM/WVT/1.0
RD 3	Validation Report ATOVS data set edition1	SAF/CM/DWD/VAL/ATOVS/1.1

Table of contents

List of Tables

List of Figures

1 The EUMETSAT SAF on Climate Monitoring (CM SAF)

The importance of climate monitoring with satellites was recognized in 2000 by EUMETSAT Member States when they amended the EUMETSAT Convention to affirm that the EUMETSAT mandate is also to “contribute to the operational monitoring of the climate and the detection of global climatic changes". Following this, EUMETSAT established within its Satellite Application Facility (SAF) network a dedicated centre, the SAF on Climate Monitoring (CM SAF, http://www.cmsaf.eu).
The consortium of CM SAF currently comprises the Deutscher Wetterdienst (DWD) as host institute, and the partners from the Royal Meteorological Institute of Belgium (RMIB), the Finnish Meteorological Institute (FMI), the Royal Meteorological Institute of the Netherlands (KNMI), the Swedish Meteorological and Hydrological Institute (SMHI), the Meteorological Service of Switzerland (MeteoSwiss), and the Meteorological Service of the United Kingdom (UK MetOffice). Since the beginning in 1999, the EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF) has developed and will continue to develop capabilities for a sustained generation and provision of Climate Data Records (CDR’s) derived from operational meteorological satellites.
In particular the generation of long-term data sets is pursued. The ultimate aim is to make the resulting data sets suitable for the analysis of climate variability and potentially the detection of climate trends. CM SAF works in close collaboration with the EUMETSAT Central Facility and liaises with other satellite operators to advance the availability, quality and usability of Fundamental Climate Data Records (FCDRs) as defined by the Global Climate Observing System (GCOS). As a major task the CM SAF utilizes FCDRs to produce records of Essential Climate Variables (ECVs) as defined by GCOS. Thematically, the focus of CM SAF is on ECVs associated with the global energy and water cycle.

Another essential task of CM SAF is to produce data sets that can serve applications related to the new Global Framework of Climate Services initiated by the WMO World Climate Conference-3 in 2009. CM SAF is supporting climate services at national meteorological and hydrological services (NMHSs) with long-term data records but also with data sets produced close to real time that can be used to prepare monthly/annual updates of the state of the climate. Both types of products together allow for a consistent description of mean values, anomalies, variability and potential trends for the chosen ECVs. CM SAF ECV data sets also serve the improvement of climate models both at global and regional scale.
As an essential partner in the related international frameworks, in particular WMO SCOPE-CM (Sustained COordinated Processing of Environmental satellite data for Climate Monitoring), the CM SAF - together with the EUMETSAT Central Facility, assumes the role as main implementer of EUMETSAT’s commitments in support to global climate monitoring. This is achieved through:

- Application of highest standards and guidelines as lined out by GCOS for the satellite data processing,
- Processing of satellite data within a true international collaboration benefiting from developments at international level and pollinating the partnership with own ideas and standards,
- Intensive validation and improvement of the CM SAF climate data records,
- Taking a major role in data set assessments performed by research organisations such as WCRP (World Climate Research Program). This role provides the CM SAF with deep contacts to research organizations that form a substantial user group for the CM SAF CDRs,

- Maintaining and providing an operational and sustained infrastructure that can serve the community within the transition of mature CDR products from the research community into operational environments.

A catalogue of all available CM SAF products is accessible via the CM SAF webpage, www.cmsaf.eu. Here, detailed information about product ordering, add-on tools, sample programs and documentation is provided.

2 Introduction

This CM SAF Algorithm Theoretical Basis Document (ATBD) provides information on the algorithms used to generate the CM SAF ATOVS data set.

The CM SAF ATOVS data set provides global water vapour and temperature products. The products are available as daily and monthly means on a cylindrical equal area projection of 90km×90km. The temporal coverage of the data set ranges from the 1st of January 1999 to the 31st of December 2011. Figure 1 shows an example of a daily product.

The processing chain and algorithms used to generate the CM SAF ATOVS data set are based on the ones used for the processing of the CM SAF ATOVS operational products.

The products covered by this document are:

- HTW (CM-123): Vertically integrated water vapour (TPW) [kg/m^2]
- HLW (CM-132): Layered products in 5 layers:
    - layered vertically integrated water vapour [kg/m^2]
    - mean temperature [K]
- HSH (CM-137): products at 6 pressure levels:
    - specific humidity [g/kg]
    - temperature [K]

Relative humidity in 5 layers is provided as additional auxiliary data.
The definition of the pressure levels and layer boundaries is given in Table 1. TPW is integrated from the surface to 100 hPa. Any product is undefined if the corresponding layer or level is not filled with valid observations.

Table 1: Layer and level definitions for the ATOVS products.

HLW layer	1	2	3	4	5	-
Pressure [hPa]	300-200	500-300	700-500	850-700	Surface-850	-
HSH level	1	2	3	4	5	6
Pressure [hPa]	200	300	500	700	850	1000

The CM SAF ATOVS data set is derived from the ATOVS measurements. ATOVS flies since the 13th of May 1998 on NOAA and Metop polar orbiting satellites. So far six platforms carry the sounding instrument system composed for HIRS and AMSU, namely, NOAA-15, NOAA-16, NOAA-17, NOAA-18, NOAA-19, and Metop-A (ATOVS is also flying onboard the recently launched Metop-B). The AMSU instrument is composed of two separate radiometers, AMSU-A and AMSU-B (which is replaced by MHS on NOAA-18, NOAA-19 and Metop-A). AMSU-A and –B are cross track scanning total power radiometers. AMSU-A channels primarily provide temperature sounding of the atmosphere while AMUS-B channels mainly measure

water vapour and liquid precipitation over land and sea. The third ATOVS instrument, HIRS/3 (replaced by HIRS/4 on NOAA-18, and -19, and on Metop-A) is an infrared 20 channel cross track scanning sounder.
The number of available/operational satellites was varying with time, consequently different combinations of satellites were used depending on when the different satellites were available/operational. The Table 2 gives the details about when which satellite combination was used for the retrieval.

Table 2: The different satellite combinations used to generate the ATOVS products with the corresponding time period for which those combinations were used.

Time period	Satellite used
1999 01 01 – 2000 10 31	NOAA-15
2000 01 11 – 2001 01 31	NOAA-16
2001 02 01 – 2002 10 31	NOAA-15, NOAA-16
2002 11 01 – 2003 09 30	NOAA-15, NOAA-16, NOAA-17
2003 10 01 – 2005 08 31	NOAA-15, NOAA-16
2005 09 01 – 2007 05 31	NOAA-15, NOAA-16, NOAA-18
2007 06 01 – 2009 01 31	NOAA-15, NOAA-16, NOAA18, Metop-A
2009 02 01 – 2009 04 30	NOAA-15, NOAA16, Metop-A
2009 05 01 – 2009 06 30	NOAA-16, Metop-A
2009 07 01 – 2011 12 31	NOAA-16, Metop-A, NOAA-19

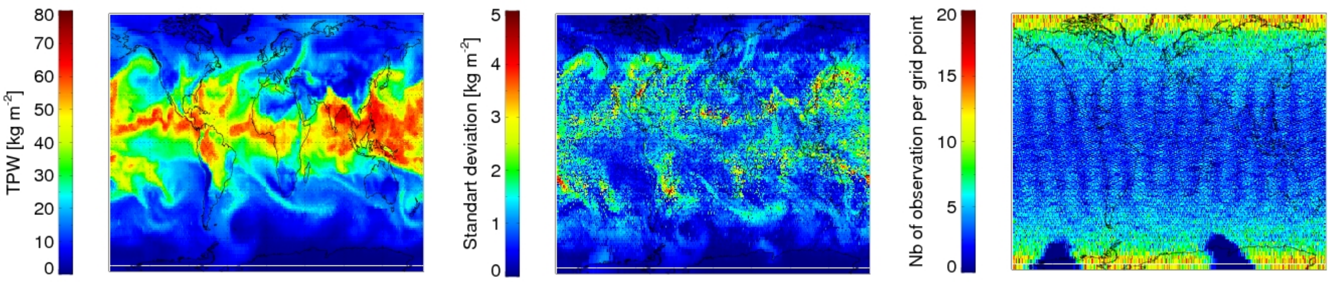

Figure 1: The left panel shows the global total precipitable water vapour (TPW) for the 20th of September 2007, the middle panel the corresponding extra-daily standard deviation and the right panel the corresponding number of observations per grid point.

The document will first give an overview of the processing algorithm, then the inputs and the different software used are described, finally the practical issues are considered and the limitations of the data set are discussed. Details about the products description and formats can be found in the Product User Manual **[RD 1]**, and the basic accuracy requirements are defined in the Product Requirements Document **[AD 1]**. A detailed validation of the products is shown in the Validation Report **[RD 3]**.

3 Algorithm overview

This chapter gives an overview of the ATOVS data set processing chain and Figure 2 graphically summarises the algorithm.

The core of the CM SAF ATOVS data set processing chain is the IAPP (International ATOVS Processing Package), a retrieval software which was developed by the University of Wisconsin in Madison, USA (Li et al., 2000). The IAPP needs ATOVS data and first guess data as input. Here, the ERA Interim reanalysis from the ECMWF (European Centre for Medium-range Weather Forecast) are used as first guess data.

Before being ingested by the IAPP both sets of data need to be pre-processed. The ATOVS l1c data are extracted from the ECMWF MARS (Meteorological Archival and Retrieval System), and the first step of the pre-processing consists of the correction of the NOAA-15 IDs. Then, the AMSU-B (and MHS) data are intercalibrated by applying SNO coefficients to the l1c brightness temperatures, and finally the AAPP (ATOVS and AVHRR Pre-processing Package) software is used to convert the l1c data to l1d. The AAPP software was developed by the NWP SAF and carries out the l1c to l1d conversion in three steps: first the BUFR files are decoded, then the scan lines are reordered, and finally the conversion is done.

The ERA Interim data are also extracted from the ECMWF MARS archive, but the only pre-processing step needed here are to compute from the available ERA interim forecast data additional parameters (relative humidity at 2m and surface height) required as input to the IAPP but not directly available from the ERA interim data, to arrange the data into the IAPP first guess input format and finally to write them in the required netcdf structure.

The IAPP is then fed with the ATOVS l1d data and the ERA Interim data (both arranged in 3-hourly time slot files). The water vapour and temperature profiles are retrieved on 42 pressure levels. A quality control is applied to the IAPP outputs and afterwards the profiles are sampled, integrated and averaged. Finally, a Kriging routine (Lindau and Schröder, 2010) is applied to obtain the daily and monthly means (together with the extra-daily standard deviation for the monthly means, the random error for the daily means, and the number of observations per grid point). A post-processing routine is applied to the data, mostly to rename the files according to the CM SAF filename convention.

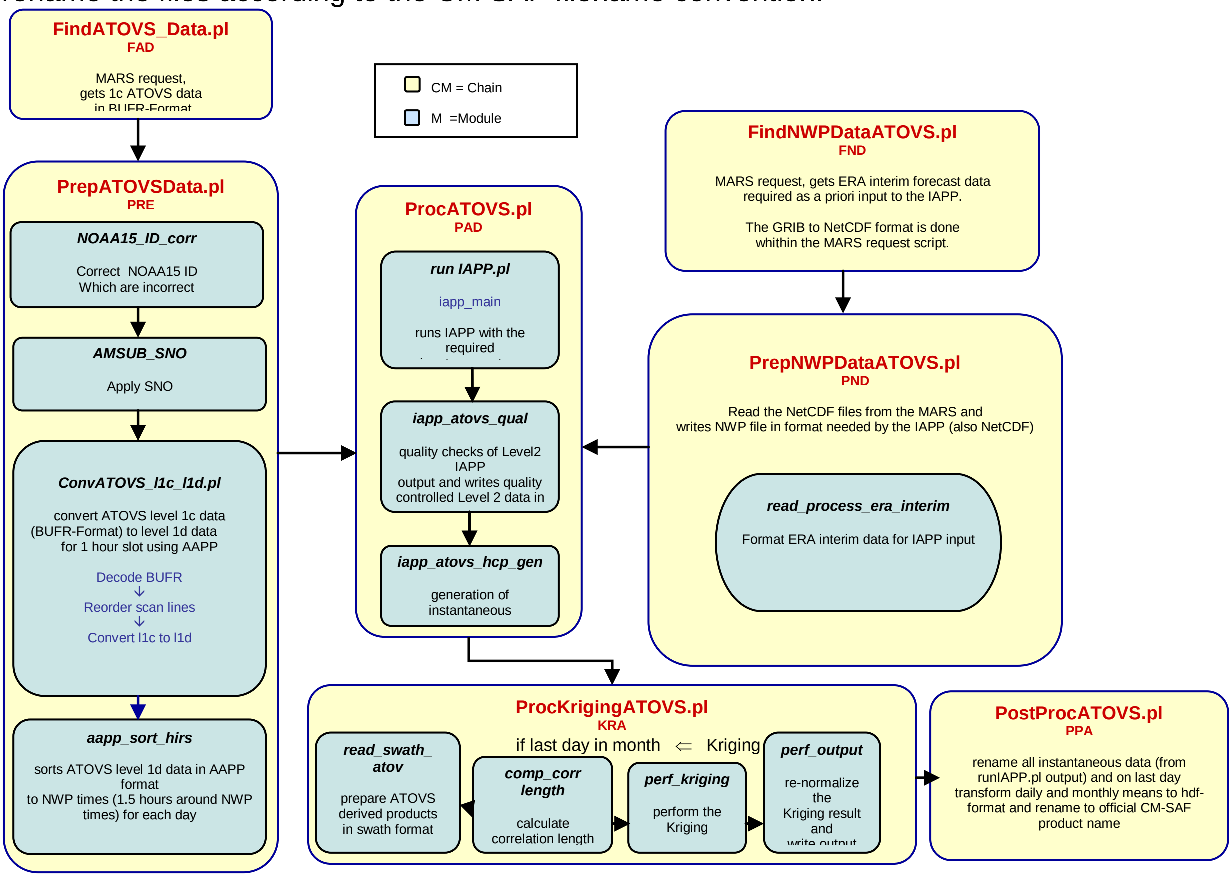

Figure 2: CM SAF ATOVS reprocessing chain flow chart.

4 Algorithm and input data description

The processing software package for CM SAF ATOVS data set is very similar to the CM SAF operational ATOVS products processing chain (see **[RD 2]**). Dedicated algorithms were developed for the generation of the CM SAF ATOVS data set but several external software were also used. This section described the input data to the processing, then it gives a theoretical description of the external software and finally the practical issues are described.

4.1 Input data

4.1.1 ATOVS data

For the generation of the CM SAF ATOVS data set, the ATOVS (AMSU-A, AMSU-B/MHS, and HIRS) l1c data stored in the ECMWF's MARS archive are used. Because of the design of the processing chain the satellite data are extracted hour per hour.

4.1.2 ERA Interim data

The ERA-Interim is the ECMWF global atmospheric reanalysis of the period 1979 to present. ERA-Interim products are retrieved from ECMWF's MARS (type=ai, class=ei, expver=1, the "class" keyword specifies the ECMWF classification given to the data (for example "e4" for ERA-40, "ei" for ERA Interim, "od" for Operations), the "type" keyword determines the type of the field to be retrieved from MARS, this keyword makes the selection between observations, images, or field and it also determines some of the valid remaining keywords of the request (examples of "type" are "an" for analysis, , "fc" for forecast, "ai" for analysis input, "ob" for observations), the "expver" keyword represents the version of the data, more information about the MARS keywords can be found in the MARS User guide (2009)). The ERA Interim products are described in the "ERA-Interim archive document (version 2)" available from the ECMWF's website. Dee et al. (2011) describes the forecast model, data assimilation method, and input datasets used to produce the ERA-Interim, and discusses the performance of the system. The forecast of the ERA Interim are available for 00:00 and 12:00, for the generation of the CM SAF ATOVS data set, the forecast time steps of +3,+6,+9,+12 hours are used for both forecast times. The ERA Interim pressure levels are used since they correspond to the IAPP pressure levels. The data are stored in GRIB format in the archive. However, it is possible to include the format conversion from GRIB to NetCDF in the database request, and this option was used.

The parameters from the ERA Interim forecast reanalysis used for the generation of the CM SAF ATOVS data set are the following:

- parameters on pressure levels:
  - temperature
  - relative humidity
- surface parameters
  - 2 m dew point
  - 2 m temperature
  - skin temperature
  - surface pressure
  - geopotential
  - sea ice cover
  - land sea mask
  - u and v winds at 10 m
  - total column water vapour

4.2 Theoretical description

4.2.1 IAPP

The IAPP retrieves among other atmospheric parameters, atmospheric temperature and moisture profiles in both, clear and cloudy atmospheres from the ATOVS measurements.
The IAPP algorithm can be decomposed into four steps:

- cloud detection and removal procedures,
- bias adjustment for ATOVS measurements,
- regression retrieval processes,
- nonlinear iterative physical retrieval.

The next sections these steps and are based on Li et al. (2000), who introduced the IAPP algorithm together with a validation study.

HIRS cloud detection algorithm

The HIRS instrument is an infrared instrument. Therefore, cloud detection and removal is needed to a retrieval under near all-sky conditions. In the IAPP, for each HIRS/3 FOV (Field Of View) a cloud detection algorithm is applied to obtain the clear/cloudy index. If any of the following tests performed by the cloud detection algorithm is fulfilled, the FOV is classified as cloudy:

- Longwave window channel (11.11 µm) brightness temperature (TB) is lower than 210 K.
- Significant discrepancy between the observed HIRS/3 and the AMSU-A predicted HIRS/3 brightness temperature for any of the cloud sensitive channels (4, 5, 6, 7, 13, 14, 15).
- Longwave window channel brightness temperature is 4 K cooler than the warmest of the 8 adjacent FOV.
- During daylight |TB(18)-TB(8)| > 10 K, or at night |TB(18)- TB(8)| > 2 K,
- |TB(8)-TB(18)| > 4 K, |TB(19)-TB(18) >2 K, and TB(18)-TB(19) > 4 K.

If there is one or more clear FOVs in the FOR (Field Of Regard, 3×3 adjacent HIRS/3 FOVs), the average of all the clear FOV radiances are used for this FOR and the AMSU-A and -B brightness temperatures are the average of all nine FOVs within this FOR. If it appears that there is no clear HIRS/3 FOV within the FOR after the cloud detection, then a cloud removal procedure is applied to obtain the HIRS/3 FOR clear radiance from the nine cloudy FOVs.

HIRS cloud removal procedure

The cloud removal procedure refers actually to the estimation of what the radiance of a cloudy FOV would be in the absence of clouds. The method used in the IAPP is known as the adjacent FOV approach. The HIRS observed radiance in a partially cloudy FOV consists of the radiance from the clear portion of the scene and the radiances from the portions covered by different types of clouds. For a given HIRS channel, the radiance for a partly cloudy FOV is given by:

$$R = (1 - \sum_{j=1}^{j} \alpha_j) R^{clr} + \sum_{j=1}^{j} \alpha_j R_j^{cld} ,$$

where α_j is the fraction of cloud type j, R^{clr} is the clear column radiance for this FOV, R^{cld}_j is the cloudy radiance of cloud type j, and j is number of cloud types. In the IAPP, it is assumed that up to two layers of clouds can exist. It is assumed that all the adjacent FOVs used in the cloud-removal procedure vary only in the cloud fractions for each type of clouds (that means that all the adjacent FOVs have the same R^{clr} and R^{cld}_j but a different α_j). The nine FOVs are sorted and grouped according to the amount of clouds. The HIRS channel 8 brightness temperatures of the nine adjacent FOVs are reordered from the warmest to the coolest and then the three FOVs with the warmest radiances, the three FOVs with the coldest radiances and the three remaining FOVs are averaged to reduce the noise. The cloud-removed equivalent clear column radiance for the FOR can be computed using the following equation:

$$\tilde{R}^{clr} = \overline{R}_1 + \eta_1(\overline{R}_1 - \overline{R}_2) + \eta_2(\overline{R}_1 - \overline{R}_3),$$

$\overline{R}_1$ (warmest), $\overline{R}_2$, and $\overline{R}_3$ (coldest) are the three averaged radiances as mentioned before. $\tilde{R}^{clr}$ is the HIRS cloud removed equivalent clear column radiance to be computed. The AMSU-A channels 6 to 14 are used to predict the HIRS channels 4, 5, 6, and 7 clear radiances that are used to solve η_1 and η_2.

Bias adjustment

The bias adjustment for the IAPP is done using a collocated radiosonde dataset containing more than 1500 clear sky collocated samples collected from the 3rd of September 1998 to the 9th of March 1999 which meet the following specific requirements:

- The collocation is based on the IAPP retrieval FOR (3×3 FOVs) and the nearest collocated radiosonde observation in both space and time.
- The absolute distance between the position (latitude and longitude) of the radiosonde and the ATOVS retrieval FOR (represented by the central FOV) is less than 1.0°.
- The time difference between the radiosonde and the ATOVS measurements is less than 1.5 hour.
- The satellite zenith angle of the ATOVS measurement is less than 25°.
- The cloud detection described above is applied to each FOR, only the clear FORs are used.
- Only the FORs with a minimal topography variation are selected.

To carry out the comparison between the ATOVS data and the radiosonde data, the fast and accurate transmittance model (Pressure Layer Optical Depth (PLOD)) is used to solve the radiative transfer equation and then invert the radiosonde data. The systematic bias error between the calculated brightness temperatures from the radiosonde data and the directly observed ATOVS data can then be derived and adjusted in the retrieval. The bias correction can be carried our by either adjusting the ATOVS observations or the forward model calculation. In the IAPP, the ATOVS measurements are adjusted and then used in the retrieval algorithm. The adjusted brightness temperature is expressed as $T^*_B = aT_B + b$, where T^*_B is the adjusted ATOVS brightness temperature, and T_B the original observed brightness temperature for a given channel, a is the slope coefficient, and b the intercept coefficients which are derived from the comparison described above. These are listed in Li et al. (2000) for the HIRS and AMSU-A channels.

First guess and physical iterative retrieval algorithm

The IAPP retrieval involves two steps. First, initial temperature, water vapour, ozone profiles, and surface skin temperature are obtained by statistical regression between the ATOVS instruments and additional information (either climate mean, regression technique using NWP as done at CM SAF, or numerical forecast products). The second part of the retrieval is the computation of an iterative physical solution of the radiative transfer equation using the results of the first step of the retrieval as initial profile to get the final temperature profile, moisture profile and total atmospheric ozone. The equations used in the physical iterative retrieval algorithm are described in detail in Li et al. (2000).

4.2.2 AAPP

The AAPP (AVHRR and ATOVS Pre-processing Package) is a software developed by the NWP SAF to pre-process the AVHRR and ATOVS data and to convert the data between the different levels, the different levels of AAPP data are the following (Labrot et al, 2011):

- level 0: raw HRPT (High Resolution Picture Transmissions) data.
- level 1a: separated data for each instrument.
- level 1b: geo-referenced and calibrated data (reversible: calibration coefficients are separated from raw data).
- level 1c: geo-referenced and calibrated temperatures and albedo (non-reversible: calibration coefficients are applied to numerical data).
- level 1d: mapped and filtered data (cloud mask).

In the processing of the CM SAF ATOVS data, the AAPP is used to convert the l1c data (which are stored in the MARS archive at ECMWF) to l1d data (the input format required by the IAPP retrieval software). Furthermore, the bufr decoding tool to read the l1c data and the l1c reorder tool, that sorts the scan lines according to time are used. The latter is needed when the scan lines from two different orbits are mixed up or when the scan lines are not sorted by time. The AAPP is described in Labrot et al. (2011) and Labrot et al. (2012).

4.2.3 SNO

Simultaneous Nadir Overpasses (SNO) happen when two polar orbiting satellites fly over the same location simultaneously (or shortly one after the other), or when a polar orbiting satellite fly within the field of view of a geostationary satellite. In the case of polar orbiting satellites the SNO are most frequent in the polar regions.

Through the application of coefficients derived from classical SNO approach, AMSU-B instruments flying onboard different satellites can be intercalibrated. Such an analysis has been carried out by V. John (UKMO) and provides monthly mean brightness temperature differences for satellite pairs for the time period between 2001 and 2010. The satellites considered in this SNO data set are NOAA-15 to NOAA-18 and Metop-A (NOAA-19 is not considered). Since the NOAA-16 satellite was the only one being operational for the entire time period it was chosen as reference satellite.
John et al. (2012) developed a new method, so called “global SNOs”, to determine intersatellite biases. Their results suggest that the quality of the intercalibration using classical SNO approaches are hampered due to contributions from low brightness temperatures only. New intercalibration coefficients were not yet available at the time of processing

4.2.4 Kriging

A Kriging routine is applied to the swath based retrieval to obtain daily and monthly means. Kriging is an interpolation technique commonly used in geosciences. The principle is that an estimate or prediction for an unobserved location is performed by using the observations from locations in the vicinity. The optimal estimate at each grid point is found by a weighted average of the information from the surrounding points. The challenge is to determine the optimal weights for each of the used observations. These depend on two parameters: the distance-dependent spatial correlation function and the error of the used observation. The Kriging method used for the CM SAF ATOVS data set is described in details in Lindau and Schröder (2010). This Kriging routine also gives as outputs, besides the daily and monthly means, the extra-daily standard deviation for the monthly means, the random error for the daily means, and the number of observations per grid point.

4.3 Practical considerations

This section describes the routines which were needed to solve practical issues.

4.3.1 Pre-processing of ATOVS data

In the MARS archive, the NOAA-15 data observed before the 1st of February 2006, have header that contained inconsistent WMO satID and satellite identifications. In order to allow a proper application of the AAPP software the WMO satID and the satellite identification were changed from 205 to 206 and from 14 to 15 for NOAA-15, respectively, when needed.

The ATOVS data are extracted from the archive hour per hour, and the ERA Interim data used as first guess data are available every three hours. The files containing the ATOVS data are formatted to match the first guess ERA Interim data files, so the ATOVS l1d data are sorted into three hour files as well (±1.5 hours around ERA Interim forecast time).

4.3.2 Pre-processing of ERA Interim data

The pre-processing of the ERA Interim data is twofold. First, it reads the ERA Interim data (in NetCDF format) extracted from the MARS archive, reorders the dimensions of the different parameters to fit the IAPP required input format and saved it into another NetCDF file. Secondly, the relative humidity at 2 m and the surface height, two parameters required as inputs to the IAPP but not directly available in the ERA Interim data are computed using the available ERA Interim data.

4.3.4 Quality control

The output of the IAPP are quality checked according to the following criteria:

- TPW between 0 kg/m^2 and 90 kg/m^2.
- Temperature between 180 K and 340 K.
- Specific humidity between 0 g/kg and 55 g/kg.
- Surface emissivity between 0 and 1.
- Surface pressure between 0 hPa and 1050 hPa.
- No superadiabaticity.
- Profiles of temperature and water vapour mixing ratio must reach 300 hPa.

The records failing at least one of the tests are set to a no_data value.

4.3.5 Product generation

The output of the IAPP software are profiles on 42 levels. These quality controlled retrieved profiles are read and the following CM SAF products are calculated:

- Total precipitable water
- Layered precipitable water for five layers
- Mean relative humidity for five layers (only as an additional auxiliary parameter)
- Mean temperature for five layers
- Temperature and mixing ratio at the six pressure levels are extracted.

5 Limitations

The CM SAF ATOVS data set offers a large range of products (total water vapour column, layered water vapour, layered temperature, water vapour and temperature at given levels) and was processed with a frozen processing system and up-to-date retrievals. However, the CM SAF ATOVS data set also presents few limitations which are described below.

The products are not independent from the ERA Interim model fields since those are used as first guess input to the retrieval. Considering the weighting functions of the ATOVS instruments, the results in the lower troposphere over land surface may be significantly influenced by the model fields. Another related limitation is that the ERA Interim model fields are not independent from ATOVS since the ATOVS data are assimilated in the reanalysis model.

As shown in Table 2, different satellites are used to generate the data set and the number of satellites which are used for the processing also varies from one to four. The satellites have different satellite local overpass times and some of them drifted with time - these two factors might affect the performance of the data. It is also evident that the data will exhibit a lower quality if only one satellite is used to generate the data set (limitation of the kriging routine which can be used only with at least 2 independent measurements (and consequently measurements from two different satellites).

The quality of the applied retrieval depends on the intercalibaration of the AMSU-A, AMSU-B/MHS and HIRS brightness temperatures. A missing or not optimal intercalibration might lead to artefact trends especially in the temperature products. Furthermore, the AMSU-B SNO intercalibration coefficient are used only for the time period 2001-2010 (John et. al. (2012)).

The AMSU-A and HIRS brightness temperatures are not intercalibrated. AMSU-B/MHS brightness temperatures are intercalibrated using the SNO method described in John et. al. (2012). It is shown in John et. al. (2012), that the measurements taken into account in the SNO occur only at the poles, so that only a small part of the dynamic range of the global measurements is represented in the SNO. Consequently, potential non-linear effects as a function of scene brightness temperature are not considered.

It has also been shown that there might be scan asymmetry in AMSU-B brightness temperatures (Buehler et. al., 2005).

The water vapour retrieval is not reliable in case of very elevated terrain (mostly in the Himalaya region), because in such regions the sounders “see” through the entire atmosphere down to the ground and the signal is contaminated with surface contributions.

6 References

Buehler, S. A., M. Kuvatov, and V. O. John (2005), Scan asymmetries in AMSU-B data, Geophysical Research Letters., vol. 32, L24810, doi:10.1029/2005GL024747.

Dee, D. P. *et al*, (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Quarterly Journal of the Royal Meteorological Society, 137:553-597.

ECMWF User Support, Operations Department (March 2009), MARS User Guide, ECMWF technical notes, available online at:
http://www.ecmwf.int/publications/manuals/mars/guide/index.html

John, V. O., G. Holl, S. A. Buehler, B. Candy, R. W. Saunders, and D. E. Parker (2012), Understanding inter-satellite biases of microwave humidity sounders using global simultaneous nadir overpasses, Journal of Geophysical Research, 117(D2), D02305, doi:10.1029/2011JD016349.

Labrot, T., L. Lavanant, K. Whyte, N. Atkinson, and P. Brunel (2011), AAPP documentation scientific description, NWP SAF documentation, Document NWPSAF-MF-UD-001 V7.0.

Labrot, T., N. Atkinson, and P. Roquet (2012), AAPP documentation software description, NWP SAF documentation, Document NWPSAF-MF-UD-002 V7.1.

Li, J., W. W. Wolf, W. P. Menzel, W. Zhang, H.-L. Huang, and T. H. Achtor (2000), Global sounding of the atmosphere from ATOVS Measurements: the algorithm and validation, Journal of applied meteorology, vol. 39, pp 1248-1268.

Lindau, R. and M. Schröder (2010), Algorithm Theoretical Basis Document Objective analysis (Kriging) for water vapour products (2010), CM SAF document, Ref: SAF/CM/DWD/ATBD/KRIGING/1.1.

Shi, L. and J. Bates (2011), Three decades of intersatellite calibrated High Resolution Infrared Radiation Sounder upper tropospheric water vapor, Journal of Geophysical Research Vol. 116, D04108, doi:10.1029/2010JD014847.

Zou, C.-Z. and W. Wang (2011), Inter-satellite calibration of AMUS-A observations for weather and climate applications, Journal of Geophysical Research, 116, D23, doi:10.1029/2011JD016205.

7 Glossary

AAPP	AVHRR and ATOVS Pre-processing Package
AD	Applicable Documents
AMSU	Advanced Microwave Sounding Unit
AMSU-A	Advanced Microwave Sounding Unit-A
AMSU-B	Advanced Microwave Sounding Unit-B
ATBD	Algorithm Theoretical Basis Document
ATOVS	Advanced TIROS-N Operational Vertical Sounder
AVHRR	Advanced Very High Resolution Radiometer
BUFR	Binary Universal Form for the Representation of meteorological data
CDR	Climate Data Record
CM SAF	Climate Monitoring Satellite Application Facility
DWD	Deutscher Wetterdienst
ECMWF	European Center for Medium-range Weather Forecast
ECV	Essential Climate Variable
ERA	ECMWF ReAnalysis
EUMETSAT	EUropean organisation for the exploitation of METeorological SATellites
FCDR	Fundamental Climate Data Record
FMI	Finnish Meteorological Institute
FOR	Field Of Regard
FOV	Field Of View
GCOS	Global Climate Observing System
GRIB	GRIdded Binary
HIRS	High-resolution InfraRed Sounder
HRPT	High Resolution Picture Transmissions
IAPP	International ATOVS Processing Package
KNMI	Koninklijk Nederlands Meteorologisch Instituut
MARS	Meteorological Archival and Retrieval System
Metop	METeorological Operational satellite
MHS	Microwave Humidity Sounder
NetCDF	Network Common Data Format
NMHS	National Meteorological and Hydrological Service
NOAA	National Oceanic and Atmospheric Agency
NWP	Numerical Weather Prediction
PLOD	Pressure Layer Optical Depth
RD	Reference Documents
RMIB	Royal Meteorological Institute of Belgium
SAF	Satellite Application Facility
SCOPE-CM	Sustained COordinated Processing of Environmental satellite data for Climate Monitoring
SMHI	Swedish Meteorological and Hydrological Institute
SNO	Simultaneous Nadir Overpass
TB	Brightness Temperature
TIROS	Television Infrared Observation Satellites
UKMO	UK MetOffice
TPW	Total Precipitable Water
WCRP	World Climate Research Program
WMO	World Meteorological Organisation