The Satellite Application Facility on Climate Monitoring (CM-SAF)

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1. Introduction

The amended EUMETSAT Convention, which came into force in November 2000, defines that a further objective of EUMETSAT is to contribute to the operational monitoring of the climate and the detection of global climatic change. To support this objective, within the EUMETSAT Satellite Application Facilities (SAF) Network, one SAF project is dedicated to Climate Monitoring (CM-SAF). The project team consists of six European National Meteorological Services (Belgium, Finland, Germany, Sweden, Switzerland, The Netherlands) led by the German DWD. This consortium started with the mandate to produce long term homogeneous climate records of derived geophysical variables at regional scale most importantly covering Europe, Africa and the Arctic. The products should support climate monitoring applications at European Weather Services and climate research. The project is currently in its so called Initial Operations Phase (2004-2007) in which the operational processing of the products and the delivery services have been established. First products are available to users at www.cmsaf.dwd.de. CM-SAF is producing cloud property products, top of atmosphere and surface radiation fluxes as well as temperature and water vapour products.

The potential contribution of the SAF network and especially the CM-SAF to the goals of GCOS and GEO was discussed at two joint EUMETSAT/GCOS/WMO meetings in Hamburg, 2004 and Nuremberg, 2005. The 2005 meeting reviewed results of pilot experiments that provided the basis for the planning of the Continued Development and Operations Phase (CDOP) for the years 2007-2012. Some of the findings and recommendations already led to changes of the CM-SAF IOP plan, e.g., CM-SAF water vapour products from polar orbiting satellites data will be produced globally in the near future. Recommendations targeting at SAF network products are reflected within the CDOP plans by the implementation of so called federate activities including several SAFs. The issue of homogenisation of satellite radiance records was also discussed at the workshop with the major recommendation that space operators are responsible for this and that CM-SAF should provide requirements for intercalibration. A first step towards an improved approach to obtain intercalibrated satellite data was made by forming a CM-SAF/EUMETSAT coordination group that held a first meeting in January 2006.

This paper describes the status of the CM-SAF products today and outlines the CM-SAF CDOP proposal and its possible connection to future global and regional reanalysis.

2. CM-SAF Products

CM-SAF products come in four major groups:

- **Cloud parameters**: Cloud fractional cover, cloud top pressure, height, and temperature, cloud type, cloud phase, cloud optical thickness and cloud water path;
- **Radiation budget at top of the atmosphere**: Incoming solar radiative flux, reflected solar radiative flux, emitted thermal radiative flux;
- **Radiation budget at the surface**: Surface: Incoming short wave radiation, outgoing long wave radiation, downward long wave radiation, broadband albedo;
- **Temperature and water vapour**: Total column precipitable water, vertically averaged temperature and relative humidity as well as vertically integrated precipitable water in five atmospheric layers (1000-850, 850-700, 700-500, 500-300, 300-200 hPa).

Top of the atmosphere radiation products are derived from the GERB (gerb.oma.be) instrument, surface radiation fluxes and cloud property products utilise the geostationary SEVIRI and the polar orbiting AVHRR instruments. The water vapour products are derived from a variety of instruments as passive microwave imagers for total column content over oceans, infrared and microwave sounding instruments as HIRS and AMSU, and the geostationary SEVIRI instrument.

Most of the products are available as daily and monthly averages with spatial resolutions of $(15\text{km})^2$, with the exception of the top of the atmosphere radiation at $(50\text{ km})^2$ and water vapour products from infrared and microwave sounders, which are at $(50\text{ km})^2$ and $(90\text{ km})^2$, respectively. Additionally for cloud and radiation products also the mean diurnal cycle is provided. The instantaneous retrieval products are also archived and available upon request.

During 2006 CM-SAF implements its so called system version 3. The focus here is on the extension of the service to the full Meteosat disc and the use of 15 minute temporal resolution for all products derived from geostationary orbit. In addition to that four significant changes following recommendations from the EUMETSAT/GCOS/WMO workshop and following some validation results have been realised:

- Global ice-free ocean total precipitable water derived from intercalibrated SSM/I radiances is added to the water vapour product group;
- Water vapour products derived from ATOVS are extended to global scale and are now based on level 1c data;
- A new optimum estimation retrieval for water vapour (total plus three layers integrated content) and surface temperature from SEVIRI measurements was developed at the University of Wisconsin and the Free University Berlin and implemented at DWD;
- The grid representation of water vapour products is constructed using an OI technique. Currently, the product contains only error information that reflects the unexplained variance of the product at a given spatiotemporal scale. However, the employed technique is also capable of including retrieval errors as delivered by new retrieval schemes and error covariance estimates.

Operational production with this version can be expected from spring 2007 on after the usual software and validation reviews. The SSM/I record is done in collaboration with the Max-Planck-Institute for Meteorology at Hamburg and will continue their series starting in 1987 (www.hoaps.org).

CDOP plan and its potential for future global reanalysis

The core activity of the CM-SAF during CDOP is the continuation and improvement of the IOP operational activities with the products integrated during the Initial Operations Phase. Development activities for the use of MetOp data (AVHRR, ATOVS, and IASI) into the operational processing and the extension of the region to the Arctic regime has been postponed to the CDOP due to the MetOp launch delay.

Next to the continuation of IOP activities CDOP will focus more strongly on climate aspects. The following aspects are of primary importance in this context:

- Production of long time series with known error characteristic and temporal stability for CM-SAF core products. Examples for this activity are the production of a 30-year AVHRR based cloud property data set and a 30-year climatology of Meteosat Upper Tropospheric Humidity;
- Extension of the product palette to better facilitate climate understanding and monitoring, specifically by adding parameters for a more complete description of the energy and water cycle (inclusion of aerosol, precipitation and turbulent heat fluxes at least over oceans). CM-SAF will produce a global ocean turbulent heat flux data set based on passive microwave and infrared imager data;
- Improvement of error characterisation of the products by the introduction of error propagation from radiance to the product on a grid as well as an automation of quality control of radiances and derived geophysical products employing reference site measurements. The characterisation of errors in the CM-SAF products will further enhanced by additional validation activities exploiting for instance field experiment data obtained during the African Multidisciplinary Monsoon Analysis (AMMA) Experiment. Another element is the creation of temperature and water vapour data sets from instruments measuring in different wavelength. A SAF network activity will analyse instrument records coming from spectrometers measuring in the UV-VIS-NRT region (GOME), infrared and microwave sounders (HIRS, IASI, AMSU, MHS), and radio-occultation instruments like GRAS on MetOp. This multi-sensor system allows for the analysis of the systematic differences between the estimates which may be used to assess the quality of the instrument data assimilated into the atmospheric model used for reanalysis;
- Enhancement of support for the user community using the products for climate monitoring and climate research by the inclusion of dedicated training activities.

The above mentioned long series of cloud properties derived from AVHRR holds a great potential for the validation of reanalysis. Karlsson et al. (2003) presented a regional comparison of mean monthly total cloud amount (%) derived from NOAA AVHRR data, Rossby Centre climate simulation (RCA) and ERA-40 over Scandinavia for the time period 1991-2000. The results showed wintertime overestimation of cloud cover in models and a good agreement of ERA-40 data during the summer minimum cloudiness. The global AVHRR data set to be derived during the next five years will offer an independent observation dataset (not assimilated) with known quality characteristics. It provides an indirect evaluation of whether the reanalysed fields of humidity and temperature are consistent with observed cloud fields and may contributes to the validation of ECMWF cloud parameterization schemes and the achieved radiation budget components (the latter also being derived from AVHRR data using the cloud information).

The 30-year climatology of upper tropospheric humidity derived from a homogenised Meteosat record spanning over Meteosat First and Second Generation instruments will provide a very good data set to study the variability of water vapour at intra-seasonal scale. Brogniez et al. (2006) found from a series from Meteosat First generation for the period 1983-2005 an asymmetry between the two hemispheres along the annual cycle. Whereas the intra-seasonal variability is homogeneous in the Southern hemisphere the variability shows a distinct minimum in the Northern hemisphere during the summer. Thus, such a data set extended with data from the new SEVIRI instrument can be perfectly used to analyse the quality of this type of variability in the future global reanalysis.

The above mentioned inclusion of satellite-derived turbulent heat flux data over the oceans complements the radiative fluxes obtained from the AVHRR instrument. The turbulent heat fluxes can be derived by using methods as described by Schulz et al. (1997) for latent and Kubota and Shikauchi (1995) for sensible heat flux. From this, attempts can be made to produce net flux estimates over the ocean. As almost all components are derived without using any information from model reanalysis the data set bears the potential for validating the fluxes of the atmospheric reanalysis. The satellite products will be produced and assessed in the frame of the GEWEX SEAFLUX project (Curry at al., 2004) where several flux data set producers compare there flux estimates and also ocean modellers use them to drive ocean circulation models. Alongside with the turbulent heat fluxes also a microwave based precipitation product will be available that provides together with the latent heat flux an alternative estimate of E-P that also can be used to validate reanalysis data.

Top of the atmosphere radiation fluxes derived from GERB and SEVIRI have also the potential for being used for the evaluation of the radiative budget of climate models and reanalysis. As the temporal resolution of the geostationary satellite data (15 minutes) matches reasonable with the time step of current global models processes like convection and surface heating may be studied on a time step basis.

The SEVIRI based surface radiation fluxes, especially the direct solar irradiance is provided in much higher spatial resolution as the future global reanalysis will have. This kind of data set provides a climatology that finds customers in the solar energy sector. But it also has great potential to support efforts on regional reanalysis where it can either be used to perform statistical downscaling or be used to evaluate dynamical downscaling approaches. For the latter application also all other high spatial resolution SEVIRI derived products may serve well.

3. Summary

The Satellite Application Facility on Climate Monitoring has build a data processing system for water vapour – cloud – radiation products using several polar and geostationary instruments that allows for reprocessing of large data volumes. The so called system version 3 of GERB and SEVIRI products will be on full disc and for water vapour estimates a new 1D-Var retrieval scheme has been developed. Water vapour products from polar orbiting instruments are global and provide error information which will be further improved in the upcoming years.

During the CDOP product monitoring will be established ranging from radiance to gridded products employing reference site data as the observatory of DWD in Lindenberg. For MetOp satellite a federation activity of three SAFs (CM-, Ozone-, and GRAS-SAF) will provide radiosondes profiles matching overpasses of the satellite. A multi sensor approach for temperature and water vapour allows for the analysis of differences between observing systems; four independent systems ranging from ultraviolet/visible, infrared, microwave and radio-occultation measurements will be used.

The usefulness of current operational monitoring products depends largely on the stability of the calibration. Some are only usable for sub-seasonal analysis, e.g. some SEVIRI derived products, others like SSM/I derived integrated water vapour are already based on inter-calibrated radiances. However, the planned activities on long homogenous time series will provide a reasonable framework for the validation of future global reanalysis as described above. The addition of turbulent heat fluxes and precipitation over oceans in the frame of the GEWEX project SEAFLUX has potential for net energy flux estimates and provides an alternative E-P field.

High spatial resolution products derived from SEVIRI are useful for validation of future regional re-analysis and may have value for statistical downscaling and evaluation of dynamical downscaling approaches.

References

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