INTEGRATION OF THE EUMETSAT MULTI SENSOR PRECIPITATION ESTIMATE (MPE) IN AN OPERATIONAL REAL TIME PROCESSING ENVIRONMENT

T. Heinemann
EUMETSAT
Am Kavalleriesand 31, 64295 Darmstadt, Germany

ABSTRACT

EUMETSAT has implemented a near-real time precipitation retrieval scheme on the basis of a classical blending algorithm in its operational Meteosat ground segment. The EUMETSAT Multi-Sensor Precipitation Estimate product (MPE) is derived by merging data from Special Sensor Microwave / Imager (SSM/I) and the first generation Meteosat satellites. The applied algorithm is based on the Naval Research Laboratory (NRL) standard blending-algorithm and has been described in detail at the first IPWG meeting. Instantaneous rain rates are retrieved for the half hourly Meteosat-7 infrared images at original pixel resolution using information from co-located SSM/I data from the last 12 hours. An offline version of the algorithm was used for the validation of the algorithm against other rain rate retrieval methods. The comparison with the NRL blended algorithm showed very good agreement and demonstrated the functionality of the MPE algorithm. Since the two algorithms are based on the same principle the similarity of the results was expected. Comparisons with other data sets, like precipitation radar data showed clearly the deficiencies of the applied method in the case of warm, frontal precipitation.

EUMETSAT started to use the algorithm in the real-time processing environment of the Meteorological Product Extraction Facility (MPEF) in early June 2004. This step required the integration of the algorithm in the monitoring and control structures of an operational system with a 7/24 availability requirement. One major outstanding task is the necessary implementation of an automated quality control scheme. The global SSM/I data are pre-processed by the British Met Office and transferred via the German Weather Service (DWD) to EUMETSAT. The time delay between the measurements and the use at EUMETSAT is usually ~3h. In order to reduce the data transfer, only selected satellite paths are obtained. Rain rate products are generated for each available Meteosat image and the data are ready for distribution about 8 minutes after the end of the image acquisition.

The derived rain rates are displayed operationally in near-real time in the form of jpeg images and as a loop in a JAVA based viewer on the EUMETSAT Intranet and will be made available on the Internet approximately mid September. The rain-rate data will in the future also be made available via ftp encoded in the GRIB-2 and an operational dissemination via the EUMETCast system is foreseen during the first half of 2005.
1. INTRODUCTION

The processing of data from multiple sensors on different platforms in a real time or near-real time environment will play a more and more important role in the future. Especially the improved capabilities of geostationary satellites will move the focus towards combined multi-platform products. The precipitation retrieval is currently the most important application in this context because a geostationary microwave precipitation sensor will not be available for several years. The different needs for satellite based precipitation data in terms of accuracy, availability, timeliness and temporal and spatial resolution for different geographical regions and types of precipitation lead to the on-going development of numerous algorithms in the last decade. In the meantime some precipitation products are produced on a regular basis and can be derived via the Internet (e.g. NOAA/NESDIS, NASA and NRL).

EUMESAT is producing level 2 products for their geostationary satellites (Meteosat-5 to Meteosat-8) mainly for the assimilation in Numerical Weather Prediction (NWP) models and the direct use in weather prediction. Currently NWP models are not assimilating precipitation products from geostationary satellites. The models assimilate either rain-rates from microwave sensors on polar orbiting satellites or radiances from those sensors directly (e.g. Bauer et. al. 2002). The use of the much less accurate precipitation estimates from geostationary satellites shows not positive effect as modern assimilation schemes can compensate for the relatively low spatial and temporal resolution of the microwave measurements. On the other hand the direct use of precipitation estimates in weather forecasts requires a high temporal and spatial resolution as well as a high timeliness of data which can be provided only by geostationary satellites. In Europe the dense ground-based radar-network satisfies the needs of the weather prediction community, but in large parts of Africa and Asia the situation is quite different. Almost no ground-based radar stations exist and the connection to the Internet is very often slow or interrupted. In these areas the availability of satellite based precipitation data on an operational basis is for weather forecasting and especially for flood prognosis essential. EUMETSAT is co-operating with many African states in the frame of the PUMA project and provides satellite receiving stations and training on the application of satellite data to the National weather services of these countries.

In this context EUMETSAT decided to implement a retrieval algorithm for precipitation using the data of the first generation geostationary satellites. It also sponsors the development of advanced algorithms for the second generation geostationary satellites in the framework of its Satellite Application Facilities (SAF) (Thoss, 2005) and fellowships for young scientists hosted by the National Weather services of its member states.

This paper describes the implementation of an improved algorithm for data from the IR channel of the first generation of Meteosat satellites (MTP), namely Meteosat-5 and Meteosat-7. As a single IR channel method would not be accurate enough the use of a blending algorithm was proposed. The selected approach is based on the work by Turk and Levizziani (Turk et. al., 1999). After the implementation of a prototype in a re-processing environment and the validation with historical data, the algorithm was also implemented in EUMETSATs operational real-time environment for the generation of meteorological products. A quality indicator was developed in order to identify the regions where the algorithm is reliable. The adaptation for the real-time processing required several changes in the algorithm set-up which are documented in this paper.

A detailed description of the algorithm itself has been given at different places already (Heinemann et. al., 2002, Heinemann and Kerényi, 2003). Therefore only an overview of the algorithm and a few validation results will be shown here. This paper will concentrate on the operational implementation and its implications for a future enhanced multi-sensor precipitation scheme involving Meteosat Second generation (MSG) data.
2. ALGORITHM OVERVIEW

The MPE algorithm uses the classical dynamic blending concept. Basis for the retrieval of the rain rate is the IR-image from the Meteosat satellite. The basic assumption of all IR-methods is that the surface rain rate is a function of the cloud top temperature. The form of this function depends on many factors such as the geographical location, the orography, the precipitation type and the synoptic situation. For convective precipitation in a specific weather situation and for a limited geographical region the assumption is valid that higher and therefore colder clouds are representing stronger convection and produce more rain than warmer clouds. In these areas only the form of the function and the threshold maximum cloud temperature for precipitation have to be determined. The MPE algorithm uses rain rates derived from passive microwave measurements by the Special Sensor Microwave / Imager (SSM/I) onboard of the US-DMSP satellites to calibrate this function dynamically. For this purpose SSM/I data from a specified period are co-located with the corresponding Meteosat images on SSM/I pixel basis. The co-located data pairs (SSM/I rain-rate and corresponding Meteosat IR brightness temperature) are collected in geographical grid boxes of 5°x5°. With a histogram matching technique a monotonic look-up table is derived for each grid box. The look-up tables are used to determine the rain rate from the brightness temperatures of the IR-image. The variable parameters of the algorithm are the start and end time of the accumulation period for the co-located data, the size of the geographical grid boxes, the bin size of the histogram matching and the method to calculate rain rates from the SSM/I data.

3. IMPLEMENTATION IN THE RE-PROCESSING ENVIRONMENT AND VALIDATION

The MPE algorithm was implemented first as a pre-operational prototype and tested for its technical performance. In order to validate the algorithm and to prepare for the implementation in an operational environment the next step was the implementation in the EUMETSAT Re-processing environment of Meteorological Products Extraction Facility (R-MPEF). This R-MPEF is a modified version of the real-time operational MPEF and was developed for the re-processing of historical satellite data with the most recent algorithms. It provides the same environment as the operational system and can run the same algorithms. Therefore it is a perfect test area for the operational implementation. In addition the R-MPEF environment can be used to produce products for validation purposes.

The instantaneous rain rates from the MPE algorithm were compared with ground based radar data, the direct SSM/I retrieval results and the NRL blending algorithm. The comparisons showed the expected results. A good agreement with the very similar NRL algorithm could be observed for the whole observation area. In weather situations with large-scale convective precipitation the results from MPE and SSM/I are similar. Problems occur in areas with strongly variable topography, for solid precipitation and over decaying cloud systems. Cold fronts can be described well, but the major precipitation may be miss-located. Precipitation from relatively low clouds at warm fronts cannot be described accurately enough. Very localised precipitation is smeared out to a larger area by the algorithm.

Fig. 1 shows an example of the validation efforts. It compares rain-rates from MPE, SSM/I and the Spanish radar network over the Iberian peninsula. The weather situation at the time of the comparison was dominated by frontal precipitation around Gibraltar. In general the rain pattern are well reproduced by the MPE algorithm.

The SSM/I data show an additional strong precipitation field directly over the Pyrenees that is a miss-interpretation of snow on the ground. A more detailed description of the validation can be found in (Heinemann and Kerényi, 2003).
4. IMPLEMENTATION IN THE REAL-TIME PROCESSING ENVIRONMENT

Operational data processing is defined by the high availability, timeliness and specified quality of their products. Especially processing in near-real time or real time on an operational basis requires a careful implementation of the algorithm in a dedicated environment. Data supply and product distribution have to be automated. The monitoring of the data flow to, within and from the processing algorithm should allow to determine the status of the data processing and to identify problems. Usually it is not possible to have algorithm specialists available around the clock. Therefore the information from the program should be divided in at least two information levels: high level notification and alarms for the controllers on duty in order to allow quick reactions to easy problems and low level information for the program and algorithm specialist who may have to fix more complex problems in the algorithm, the data supply or the data distribution.
The implementation of the MPE algorithm in the real-time operational MPEF environment had to fulfill these requirements especially because it was extremely important to avoid that the operational product generation of other operational EUMETSAT products was endangered. Most MPEF products are produced in real-time during the reception of the Meteosat images. After the end of each image there is a gap of about 5 minutes, which is necessary to bring the scanner on the satellite back to its start position. These gaps between the Meteosat images are used to produce the MPE product in near-real time. This reduces the competition between the MPE
algorithm and the other product algorithms for computer resources and reduces the probability of side effects.

The SSM/I data are received by the UK-Met.-Office and transferred to EUMETSAT via the German Weather Service (DWD). The time delay between the measurement and the reception of the data at EUMETSAT is between two and five hours with an average of about three hours. This time delay drives the setting of the parameters for the generation of the lookup-tables. The advantage of the dynamic adjustment of the lookup-tables by new SSM/I data is the possibility to react to changes in the synoptic weather situation. But for the near-real time processing the time delay of data from the polar orbiting satellites makes it impossible to use co-located data sets from the last three hours. Tests in the re-processing environment showed that an accumulation of at least 12-14 hours is necessary to reach a sufficient coverage of co-located data sets. Using only data sets from 3 to 15 hours before the processed Meteosat image would mean that the daily cycle of convective precipitation would be present in the data sets but the position in the cycle would not correspond to the image. Therefore we decided to choose an accumulation time of 24 hours for the near-real time processing.

The geographical grid for the lookup-table generation remains 5°x5° in latitude and longitude. This size has proofed to sufficient to describe the synoptic scale for precipitation (Heinemann, 2002). MPE products on Meteosat pixel resolution are produced on pixel resolution for each Meteosat image.

Figure 3: Rain rate for the Meteosat-5 field of view, Jan. 13th 2005, 13:30UTC
5. DATA DISTRIBUTION

After the product generation the rain rates are encoded in the GRIB-2 data format (WMO, 2004) which provides for the MPE product a lossless compression rate of 90%. In addition images in jpeg format with reduced resolution are produced from the data. At the moment the jpeg images of the MPE product from Meteosat-7 of the last 24 hours are displayed played on a web page which is accessible via the EUMETSAT web page and the Meteosat-5 based product is under implementation. In the near future the corresponding GRIB-2 data files will be provided for download as well. For the presentation of the jpeg images the EUMETSAT web-viewer was adapted to MPE data (Fig. 2). With this viewer it is possible to view single images as well as backward and forward loops. The final step is the near-real time dissemination of the MPE rain rate products via the EUMETCast service. EUMETCast is EUMETSATs satellite based data distribution system. It is based on the DVB from a commercial satellite and allows the reception of satellite images, meteorological products and related auxiliary data in Europe, Africa and the Near and Middle East. This is foreseen during the first half of 2005.

6. PLANNED FUTURE ACTIVITIES

Major issue of the MPE-implementation is the adaptation of the algorithm for Meteosat-5 data, which has been done for several test cases in the real-time MPEF already (see Fig. 3).

The Meteosat-5 and Meteosat-7 products will be monitored carefully and long term statistics will be produced. An archiving concept is under development. In addition it is crucial to add the product quality indicator from the prototype (Heinemann, 2002) to the MPEF implementation. Since the quality indicator is only defined on the 5°x5° lookup table grid the additional data amount for the each product file is relatively small.

The integration of newly operationally available microwave data from polar orbiting satellites such as TRIMM or SSM/I-S will be integrated as soon as data are available with the sufficient timeliness and suitable rain rate algorithms for the data are available.

The operation of the first generation Meteosat satellites is to be continued until the end of 2008. It is foreseen that the MPE products will be generated during this period for two satellite locations, namely for 0° (currently supported by Meteosat-7) and 63° (currently supported by Meteosat-5). EUMETSAT will continue to provide support for the development of precipitation algorithms for the next generation of geostationary and polar orbiting satellites.

7. REFERENCES


