CURRENT STATUS OF THE EUMETSAT OPERATIONAL AND FUTURE AMV EXTRACTION FACILITIES

Kenneth Holmlund

EUMETSAT, Am Kavalleriesand 31, D-64295 Darmstadt, Germany

ABSTRACT

This paper will present the current status of the operational wind products derived with multi-spectral imagery data in the visible, infrared and water vapour bands. The operational wind products are generated currently with three satellites Meteosat-7 located at 0^o longitude, Meteosat-5 at 63 ^{o} East and Meteosat-6 at 10 ^{o} West. The wind fields derived with Meteosat-7 and Meteosat-5 are based on the nominal image interval of 30 min., providing full coverage over the full field of view. Meteosat-6, on the other hand, is currently providing wind fields based on 10 min. rapid scan imagery over the European and Northern Atlantic region.

A major event of the year 2002 at EUMETSAT is the launch of Meteosat Second Generation (MSG). After successful commissioning MSG will replace Meteosat-7 as the main satellite at 0^o longitude for the provision of imagery data and meteorological products derived with the Meteorological Products Extraction Facility (MPEF). Currently it is foreseen that MSG will start operations in the middle 2003.

The MSG MPEF will continue the derivation of Atmospheric Motion Vectors (AMVs) in the same spectral bands as Meteosat-7, however with two channels in the visible and two in the water vapour absorption region instead of the single channel imagery provided by the first generation Meteosat satellites. The sampling distance in these channels is 3-km compared to 5-km with Meteosat, hence providing the capability of a higher resolution product than with Meteosat. MSG is also imaging in the 3.8, 8.7 and 9.7 μm channels and has a high-resolution visible band with a sampling distance of 1-km. The potential of these channels for wind derivation will also be explored in the near future. This paper will detail the current implementation and status of the MSG MPEF AMV algorithms and the current plans for data dissemination.

1. Introduction

One of the key products derived from geostationary satellite imagery data is the Atmospheric Motion Vectors (AMVs). At EUMETSAT the AMVs are currently produced operationally with data from the Meteosat satellite series. Three satellites are now operated; Meteosat-7 located at 0^o longitude, Meteosat-5 at 63 ^{o} East and Meteosat-6 at 10 ^{o} West (Meteosat-6 will be moved to at 10^oE longitude at the start of MSG-1 commissioning). The wind fields derived with Meteosat-7 and Meteosat-5 are based on the nominal image interval of 30 min., providing full coverage over the full field of view. Meteosat-6, on the other hand, is currently providing wind fields based on 10 min. rapid scan imagery over the European and Northern Atlantic region (de Smet, 2002).

In 2002 EUMETSAT launched the first satellite of a new generation, MSG-1 (Meteosat Second Generation). After commissioning MSG-1 will replace Meteosat-7 as the operational satellite at 0^o longitude providing not only continuity for the products already derived with Meteosat data, but also several new and improved products. MSG will provide imagery data every 15-min. over the visible portion of the Earth with a sampling distance of 3 km enabling an improvement in the quality of the derived vectors. Furthermore MSG will observe the atmosphere in several spectral bands, amongst others two water vapour absorption channels at 6.3 and 7.2 μm and a CO_2 absorption channel. These channels will for the first time operationally enable the application of the IR/WV and IR/CO_2 ratioing methodologies simultaneously, thus providing more accurate estimates of the cloud heights. Further new channels like the 3.9 µm channel and High Resolution Visible channel at 1 km resolution are expected to improve especially the tracking of low-level clouds.

This paper will present the status of the current operational AMV products derived at EUMETSAT together with a view of future improvements expected especially with the introduction of MSG-1.

2. A COMPARISON OF THE MTP AND MSG AMV RETRIEVAL SCHEMES

The main components of the Meteosat and MSG AMV extraction scheme are the same. The most significant differences relate to the increased capabilities of MSG vis-à-vis Meteosat and to the departure form the Meteosat approach of deriving winds in fixed segments. The following section will give a brief description of the main differences in the main components of the AMV extraction scheme; Target extraction; Image enhancement; Tracking; Height Assignment; and Quality control.

2.1 Target extraction

The main major change to the current operational AMV extraction scheme at EUMETSAT is the target extraction. Currently the AMVs are extracted on an equidistant grid (baseline 32*32 pixels) with a target size equivalent to the grid size (e.g. Schmetz et. al., 1993, Buhler and Holmlund, 199ü). In the new scheme the target size and extraction grids are controlled separately. Furthermore the exact location of the target is not fixed and centred at the grid location but optimised in a search area around the grid-location. The main two reasons for this approach are;

1) Better and more stable targets for tracking, e.g. the target area contains at least a certain minimum amount of the clouds at the highest level locally and
2) Avoidance of extraction of targets in multi-layered cloud situations that have proven to be difficult to handle

A variable target extraction scheme is already used operationally e.g. at NOAA/NESDIS and has proven to be reliable (e.g. Nieman et. al., 1997). The EUMETSAT target extraction scheme investigates the following features of each location:

- Contrast
- Local standard deviation
- Number of pixels with high local standard deviation
- Entropy
- Cloud configuration
- Land/Sea (water) distribution
- Overlap control

Suitable targets are typically targets that have the highest contrast and largest amount of standard deviation (highest entropy) within the optimisation area. Furthermore multilayered cloud situations should be avoided and a minimum amount of cloudy/clear sky pixels are required for respective target type. Coastal regions are avoided in the IR and VIS channel, as the coastal feature might have an impact on the tracking. Finally the overlap between targets is restricted in order to avoid vectors to be derived that contain a large amount of pixels from the same cloud (clear sky feature). This will minimise the impact of correlated errors by reducing the horizontal dependency between neighbouring targets. Currently the baseline overlap is limited to 30 %. It should be noted that for the Meteosat AMV extraction scheme, the only limitation to derive a wind in a segment is that a sufficient number of pixels are present of any cloud cluster.

Figure 1 shows the impact of the variable target extraction. In order to visualise the performance of the location optimisation a low-density grid was used. It can be seen in figure 1 that the target locations are preferably extracted along strong gradients in the coldest parts of the satellite imagery data.

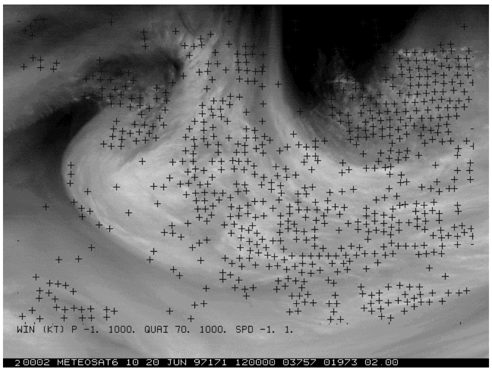

Figure 1. Low-density targets extracted with the MSG target extraction scheme with MSG like data simulated by data from Meteosat-6.

2.2 Image enhancement

The image enhancement is equivalent to the current methodologies applied at the Meteorological Product Extraction facility (MPEF) for the current Meteosat-satellites (Hoffman, 1990). The only important difference is the derivation of mean radiances of identified scenes used in the image enhancement. In the current operational scheme the mean radiances are based on a multi-dimensional histogram analysis. For MSG pixels in the target area will be clustered and averaged according to the results from a pixel based multi-channel analysis scheme (Lutz, 1999).

2.3 Tracking

The tracking of the targets is generally the task that uses the largest amount of computer resources in any AMV extraction scheme. Therefore several various alternatives have been explored in order to minimise the computational load. Generally the following methodologies have been employed;

1) Use of additional data for first guess estimates of the displacements
2) In cases where several consecutive vector fields are derived the search area is after the initial matching reduced for any subsequent derivation
3) Sequential derivation of matching surfaces with full surface calculated only at locations indicated by a low resolution matching surface

The first approach is often relying on NWP data and is therefore not recommended as flow with a large discrepancy to the NWP field might not be derived correctly. The second approach is better introduces however some limitations on the timely variation on the vectors and is implicitly invoking a quality control (by limiting the search area) that preferably is performed at a later stage. The third alternative is generally the most promising and for current satellite data and resolution it has been shown that the results are agreeing up to 97% of a full matching surface. The available processing capacity has in the past years increased tremendously and hence the requirement for a limited calculation of matching surfaces has decreased. Therefore the calculation of the full matching surface was regarded to be feasible for the MSG AMV scheme. The current operational approach for Meteosat still uses a two step approach where a reduced resolution correlation surface is first calculated and a refined location is extracted around the three most significant peaks in the reduced surface. Three basic matching methods have been implemented for MSG; Cross-correlation in the time domain; Cross-correlation in the Fourier domain; and Sum of Squared Distances. The detailed description of the implementation of these methods is given in Dew and Holmlund (2000). The targets are extracted from the first image in the sequence and are then followed in time throughout the other three images. For the Meteosat AMV scheme only three consecutive images are used. The tracking of the targets will also last longer, for 90 minutes, as the image frequency of Meteosat is lower than of MSG. The targets are in the Meteosat approach extracted from the central image and then the tracking is performed against the previous and next image.

2.4 Height assignment

The height assignment of AMVs is currently the most challenging task in the AMV extraction schemes. Broken clouds, multi-layered cloud targets, low level targets (requiring cloud base height assignment) and height assignment of clear sky targets, do all require their special attention. The biggest problems however are generally encountered with semi-transparent clouds.

With the advent of MSG it will for the first time be possible to operationally derive the correct height for semi-transparent clouds using two operationally established methodologies simultaneously; the semi-transparency correction utilising the WV and IR channel (e.g. Schmetz 1993) and the CO_2-ratioing method (Eyre and Menzel, 1989, Nieman et. al. 1997). Nieman et. al. (1993) showed that for high level clouds the mean pressure difference of the estimated cloud height is of the order of 20 hPa and the RMS difference is ca 80 hPa between the two methods whereas Schreiner and Menzel (2002) report higher RMS values up to 130 hPa with GOES-12. The implementation of these methods contains the following new features:

- channel dependant noise is included in the calculations
- refined selection of pixels or groups of pixels depending on the characteristics of the pixels and the neighbouring pixels
- various possibilities to extract background/surface information (real observations, history of previous observations, forecast, climatology)

Furthermore the utilisation of two water vapour channels provide the potential to derive semi-transparency corrected heights without using forecast data. This is illustrated in Figure 2, where two regression lines is derived in a similar fashion to the current operational IR/WV semi-transparency correction scheme and the corrected height is defined by the intersection of the two lines. As the 7.3 μm is looking deeper into the atmosphere some problems in this approach will occur due to surface contamination. This approach will be validated during the commissioning of MSG

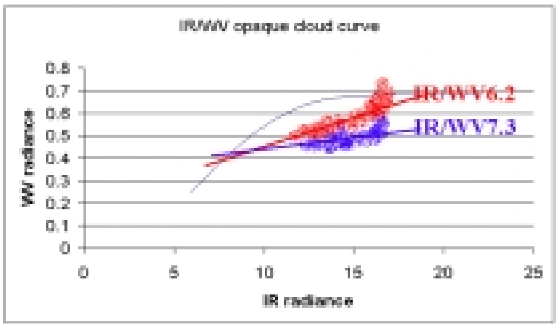

Figure 2. A forecast independent semi-transparency correction scheme using two water vapour channels and one infrared window channel.

2.5 Automatic quality control

The automatic quality control is based on the same principals currently used operationally (Holmlund, 1998). The scheme has been further improved with latest experiences with current operational AMVs and the new capabilities provided by MSG. The baseline Automatic Quality Control (AQC) tests are based on:

- local consistency (horizontal)
- speed consistency (in time)
- direction consistency (in time)
- vector consistency (in time)
- background consistency (currently against NWP)
- inter-channel consistency

The extraction cycle of the baseline AMV product consists for MSG of three vector fields. All vector fields contribute to the consistency calculations enabling a better estimation of the vector reliability.

2.6 Final product

The AMV fields can be derived continuously, however the current baseline is that a final product should be extracted once every hour. The baseline product derivation is therefore set up to extract three intermediate AMV fields from four consecutive images during one hour. The targets are extracted from the first image in the sequence and are then followed in time throughout the other three images. The final vector components (speed, direction, height, temperature and quality) are based on a weighted mean of the intermediate vectors. The current baseline is however that the intermediate fields all have the same weight. For the Meteosat AMV scheme only three consecutive images are used. The tracking of the targets will also last longer, for 90 minutes, as the image frequency of Meteosat is lower than of MSG. The targets are in the Meteosat approach extracted from the central image and then the tracking is performed against the previous and next image.

3. The AMV products

3.1 The Current Meteosat AMV products

Table 1. The Meteosat AMV product suite.

Product type	Product Information	Quality Threshold	Type
CMW (Cloud Motion Winds)	Only winds above 995 hPa Only best wind in segment. WV winds only above 400 hPa Minimum speed 2.5 m/s	0.8	SATOB
ELW (Expanded Low-resolution Winds)	All three channels (VIS, IR and WV) at 160 km resolution at sub-satellite point (SSP)	0.3	BUFR
HRV (High Resolution Visible)	VIS winds at 80 km resolution at SSP	0.3	BUFR
WVW (Clear Sky Water Vapour Winds)	Only Clear Sky Targets	0.3	BUFR
HWW (High-resolution Water vapour Winds)	Only Cloudy Targets	0.3	BUFR

Table 1 presents the operational product suite derived with all three operational satellites. The dissemination frequency for BUFR encoded data is 90 min. for Meteosat-7 and Meteosat-5 and 30 min with the rapid scan data (10 min image interval) from Meteosat-6. The SATOB data is disseminated 4 times per day at the main synoptic hours. Table 1 also gives a short summary of the characteristics of the various products and the minimum quality for each vector as defined by the AMV Automatic Quality Control (Holmlund, 1998). The extraction times for the wind products will be adjusted and centralised around the main synoptic hours. This is now possible through the changes in the past years to the product extraction and quality control algorithms. Further details on the EUMETSAT AMV products can be found at the EUMETSAT WEB pages (www.eumetsat.de).

Since the 5th International Winds Workshop the following main changes have been introduced in the AMV processing and the calibration schemes at Eumetsat:

3/2000 High resolution Water Vapour Winds (80 km)
8/2000 New matching algorithm (SSD vs. CC)
Additional Height Assignment for Clear Sky WV
AMV location assign to gravity centre of cloud
6/2001 Forecast Independent QC in BUFR

Furthermore the calibration of the Meteosat infrared and water vapour image data is now based on the blackbody calibration of Meteosat-7 that became operational in May 2000. In May 2001 the calibration of Meteosat-5 was changed and the image data is now cross-calibrated via the Meteosat-7 imagery to the Meteosat-7 blackbody. Finally the cross-calibration for Meteosat-6 to Meteosat-7 blackbody was introduced in May 2002.

The quality of the AMVs has in general been stable in the past years. Figure 3 presents the Normalised RMS (NRMS) that is derived as the RMS difference to collocated radiosondes divided by the mean collocated radiosonde speed as a function of time. In general the NRMS is stable. However for Meteosat-5 a clear annual variation is detected that is currently being investigated, but assumed to be related to variation in meteorological conditions and the radiosondes used for the statistics.

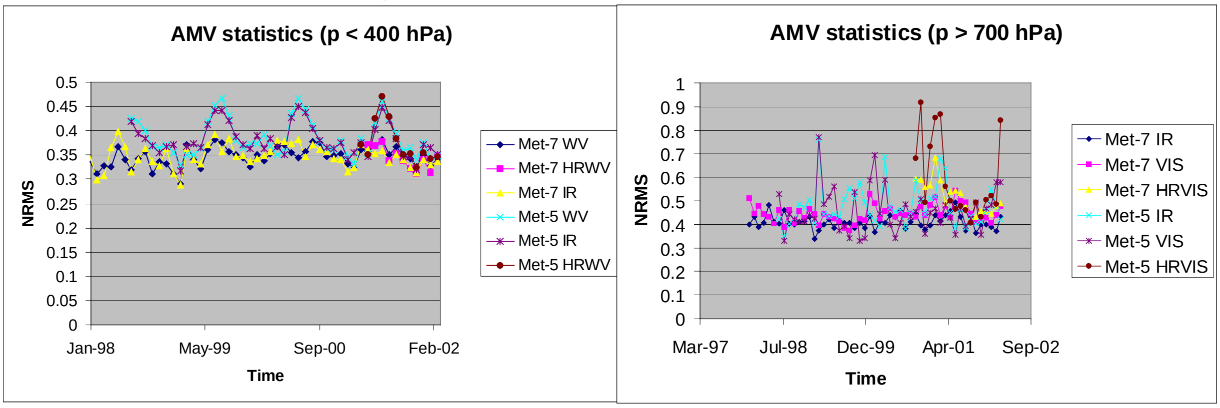

Figure 3. Normalised RMS difference between collocated radiosondes and high (p < 400 hPa) and low (p > 700 hPa) level AMVs for Meteosat-5 and –7. The normalisation is provided by the mean collocated radiosonde speed.

3.2 The MSG AMV products

Table 2 presents the current baseline channels for AMV extraction. The table also incorporates an extended set of channels that are highly likely to provide significant and improved data, but for which there is currently no experience. It is foreseen that the AMV-products derived from these channels are not declared operational at Day-1 (First day of operational dissemination), but at a later stage when a complete validation and assessment of the quality of the derived vectors has been performed. All products are distributed in BUFR format only.

Table 2. The AMV channels and target type. HLC, MLC and LLC refer to high, medium and low-level clouds, respectively.

	Baseline channels		Extended channels	
Band	Central wavelength	Prime targets	Central wavelength	Prime targets
IR	10.8 µm	Clouds	9.7 µm	Clouds/ozone
IR	6.2 µm	HLC/Moisture	3.9 (8.7) µm	LLC at night
IR	7.3 µm	HLC/MLC/Moisture		
VIS	0.6 µm	LLC over sea		
VIS	0.8 µm	LLC over land	HRVIS/broadband	LLC over sea

Table 3 presents a short summary of the differences between the Meteosat derived and MSG derived AMV products. MSG Day 1 is the initial configuration and MSG Day 1.5 is the goal for during early operations.

Table 3. A comparison between Meteosat and MSG AMVs.

	No. of channels	Average product density	Average number of vectors/product	Number of semi-transparency schemes
Meteosat	3	80/160 km	2000	1
MSG Day 1	5	80 km	18000	1
MSG Day 1.5	8	50 km	20000	4 (12)

4. Current Status of the Meteorological Product Extraction Facilities (MPEFs)

4.1 Meteosat MPEF

The current Meteosat Meteorological Product Extraction Facility (MPEF) is operational since November 1995, when the operations of the Meteosat satellites were transferred from the European Space Operations Centre (ESOC) to Eumetsat. The Meteosat MPEF has evolved significantly over the years and is now a fully mature system capable of supporting three operational satellites, with full redundancies and development chains. Additionally Eumetsat has a reprocessing MPEF that is currently used in support of the ECMWF Reprocessing Activities (ERA-40) and to derive several years of Meteosat Surface Albedo and Precipitation estimates. For ERA-40 the main derived products are the operational wind products (Gustafsson et. al., 2002) and clear sky radiance products.

4.2 MSG MPEF

The main goal for all current activities is to ensure that the derived software is capable to produce from the first day of operations products that are at least as good as the current operational products. As MSG incorporates a completely new instrument with new channels and performance the tuning of the configuration parameters will be an essential activity during satellite commissioning. Therefore it is foreseen that during commissioning of the satellite an early access to image data is granted to the MSG MPEF in order to tune all algorithms (not only the AMV-scheme). The use of real MSG data is also likely to identify possible problems in the software implementation and might also identify some shortcomings in the current baseline methodologies. The MSG MPEF is designed to be modular such that it will be possible to incorporate new software modules or to replace existing modules with improved modules if necessary. As the MSG MPEF has been developed through an industrial procurement and the specification have been written already in 1996 it is important to update the MSG MPEF such that it will represent the current state of the art in the field of AMV extraction. Most of these upgrades are already developed and tested and will be implemented during 2002. Furthermore it is foreseen to upgrade the MPEF hardware to enable proper debugging during commissioning, to incorporate some computer intensive improvements and to enable further evolution in product density, extraction frequency and number of image channels utilised.

Currently the MSG MPEF is run in a semi-operational mode using simulated image data. It is foreseen that the MSG MPEF will be fed with real MSG data towards the end of 2002 and that dissemination trials will commence early 2003. A semi-operational service is expected to begin during the second quarter of 2003 and full operations towards the end of 2003.

5. CONCLUSIONS

The Atmospheric Motion Vector (AMV) extraction scheme for Meteosat Second Generation (MSG) has been compared to the Meteosat extraction scheme. The new scheme is based on well-established operational algorithms enhanced with new concepts utilising the foreseen new capabilities of the satellite. It is expected that the AMVs will be extracted in up to 7 image channels, with a target size of 80 km and an extraction grid of 50 km. The vectors will be disseminated hourly over the GTS in BUFR format. With the new capabilities of MSG it is expected that the quality of the AMV-products will improve, especially with respect to height assignment due to the new channels (especially the CO_2-channel). MSG was launched in August 2002 and is expected to be commissioned until mid-2003.

6. REFERENCES

Buhler Y. and K. Holmlund, 1993: The CMW Extraction Algorithm for MTP/MPEF. *Proc. Second Int. Winds Workshop*, Tokyo, Japan, 205-217.

De Smet, A., 2002: Operational AMV Products Derived with Meteosat-6 Rapid Scan Data. *Proc. Sixth Int. Winds Workshop*, Madison, Wisconsin, these proceedings.

Dew, G. and K. Holmlund, 2000: Investigations of Cross-Correlation and Euclidian Distance Target Matching Techniques In the MPEF Environment. *Proc. Fifth Int. Winds Workshop*, Lorne, Australia, EUMETSAT, 235 243.

Eyre J. and P. Menzel, 1989: Retrieval of Cloud Parameters from Satellite Sounder Data: A Simulation Study. *J. Appl. Meteor*., **28**, 267-275.

Gustafsson J., L. van de Berg, F. Roveda and Yildirim A., 2002: Reprocessing of Atmospheric Motion Vectors from Meteosat Image Data. *Proc. Sixth Int. Winds Workshop*, Madison, Wisconsin, these proceedings

Hoffman, J., 1990: The Use of Spatial Coherence Method for Cloud Motion Wind retrieval. *Proc. 8th Meteosat Scientific users Meeting*, Norröping, Sweden, EUMETSAT EUM P 05, 97-100.

Holmlund, K, 1998: The Utilization of Statistical Properties of Satellite-Derived Atmospheric Motion Vectors to Derive Quality Indicators. *Wea. Forecasting*, **13**, 1093-1104.

Lutz, H-J., 1999: Cloud Processing for Meteosat Second Generation. Tech. Mem. 4, Available from Eumetsat.

Nieman S. J., Schmetz J. and W. P. Menzel, 1993: A Comparison of Several Techniques to Assign Heights to Cloud Tracers. *J. Appl. Meteor*., **32**, 1559-1568.

Nieman, S.J., W. P. Menzel, C. M. Hayden, D. Gray, S. T. Wanzong, C. S. Velden, J. Daniels, 1997: Fully Automated Cloud-Drift Winds in NESDIS Operations, *Bull. Amer. Meteor. Soc.,* **78**, 1121-1133.

Schreiner A. J. and W. P. Menzel, 2002: Comparison of Cloud Motion Vector Height Assignment Techniques USING THE GOES-12 IMAGER, *Proc. Sixth Int. Winds Workshop,* Madison, Wisconsin, these proceedings.

Schmetz J., K. Holmlund, J. Hoffman, B. Strauss, B. Mason, V. Gärtner, A. Koch and L. van de Berg, 1993: Operational Cloud-Motion Winds from Meteosat Infrared Images. *J. Appl. Meteor*., **32**, 1206-1225.