THE ATMOSPHERIC MOTION VECTOR RETRIEVAL SCHEME FOR METEOSAT SECOND GENERATION

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ABSTRACT

The advent of the Meteosat Second Generation (MSG) provides many new opportunities for improved derivation of Atmospheric Motion Vectors (AMVs) from geostationary satellite data. MSG will provide full field of view imagery data every 15 min. with a sampling distance of 3 km, already improving the capabilities to derive AMVs. Another main improvement is the large range of available channels that amongst others incorporate two water vapour absorption channels at 6.3 and 7.2 um and a CO2 absorption channel. These channels will enable the application of the IR/WV and IR/CO2 ratioing methodologies, providing a more accurate estimate of the cloud heights. Further new channels like the 3.9 um channel and High Resolution Visible channel at 1 km resolution are expected to improve especially the tracking of low level cloud structure during night and day.

This paper will present the MSG AMV retrieval scheme especially highlighting the changes with respect to the current Meteosat AMV scheme and the expected areas of improvements. Validation results of the new approach using current existing satellite data will also be provided.

1. Introduction

The current operational Meteosat satellites operated by EUMETSAT (EUropean organisation for the utilisation of METeorological SATellites) form an mandatory and integral part of the global meteorological satellite system. One of the most important products derived not only from Meteosat imagery data but from all geostationary satellites in general consists of, the Atmospheric Motion Vectors (AMVs). These vectors are extracted from sequences of well navigated and calibrated images. Typically the extraction frequency is between 1.5 to 6 hours and the horizontal density is of synoptic scale (100 km or worse). The AMVs are today an important part of the observation data fed to Numerical Weather Prediction (NWP) and are imperative over the vast data void ocean areas as shown already by Kelly (1993). Currently the scale and extraction frequency is sufficient for the NWP purposes, but in the future, global NWP as well as nowcasting will require data with a higher extraction frequency and higher density. Furthermore the height assignment that is currently one of the weakest parts of the AMVs should be improved. In order to meet these new and increased requirements new series of geostationary satellites are developed. At EUMETSAT the Meteosat-satellites will be complemented by Meteosat Second Generation in year 2001. This new satellite generation will provide enhanced capabilities to derive AMVs with a higher accuracy, extraction frequency and coverage. This paper will give a short overview of the new MSG satellite, introduce the current baseline MSG AMV extraction scheme and present validation and preparation activities.

2. The Meteosat Second Generation (MSG)

Meteosat Second Generation (MSG) is a spin-stabilised satellite in geosynchronous orbit. The spin rate is 100 rpm and with the new SEVIRI instrument the satellite will provide global imagery every 15 min. The sampling distance of SEVIRI is 3 km (1 km for High-resolution visible (HRVIS) data) and the radiometric resolution is 0.25 K. Figure 1 presents the EBBT as observed at the top of the atmosphere for Mid-latitude summer together with the infrared spectral band coverage of the MSG SEVIRI instrument. As a comparison the spectral coverage of the GMS-5 (Geostationary Meteorological Satellite, maintained by the Japan Meteorological Agency), GOES-8 (Geostationary Operational Environmental Satellite, maintained by National Oceanographic and Atmospheric Administration/National Environmental Satellite, Data and Information Service) sounder and GOES-8 imager are included.

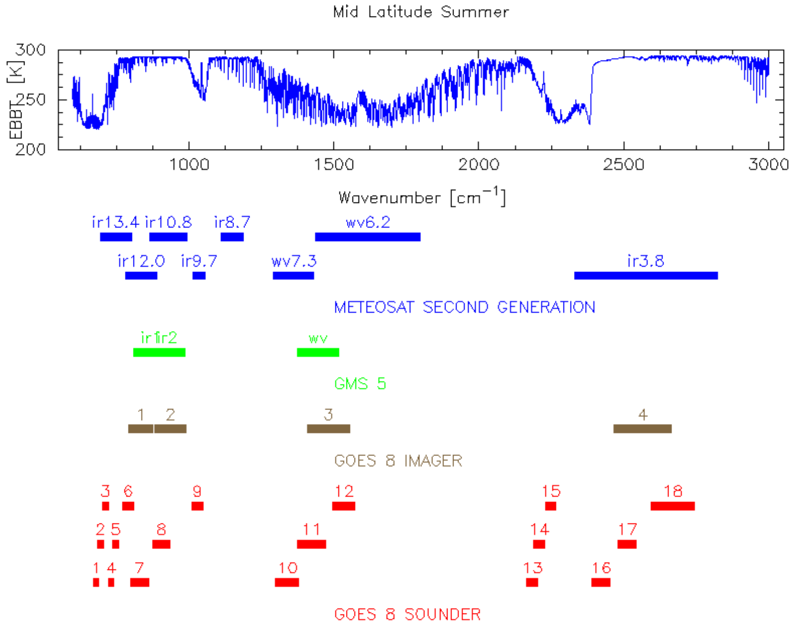

Figure 1. The EBBT as observed at the top of the atmosphere for Mid-latitude summer together with the infrared spectral band coverage of the MSG SEVIRI as well as the GMS-5, GOES-8 sounder and GOES-8 imager.

Table 1 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 are 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 quality has been performed.

Table 1. The AMV channels.

Baseline channels:		
Band	Central wavelength	Prime targets
IR	10.8 µm	Clouds
IR	6.2 µm	High level clouds/Moisture
IR	7.3 µm	High/Medium level clouds/Moisture
VIS	0.6 µm	Low level clouds over sea
VIS	0.8 µm	Low level cloud over land
Extended channels:		
IR	9.7 µm	Clouds and ozone features
IR	3.9 (8.7) µm	Low level clouds at night
HRVIS	0.8 µm	Low level clouds over sea

3. The Atmospheric Motion Vector (AMV) Extraction Scheme

The Atmospheric Motion Vector (AMV) extraction scheme will in general retrieve the AMVs in a similar fashion to the current operational extraction scheme at EUMETSAT (e.g. Schmetz et. al., 1993, Bühler and Holmlund, 1993). The main components are the following:

- Target extraction
- Image enhancement
- Tracking
- Height Assignment
- Quality control

In the following sections several examples are presented. These are based on a prototype AMV extraction scheme, currently employed at EUMETSAT for development and verification purposes. This system is able to digest various kinds of image data and for these examples simulated MSG data has been used. The simulated data is based on Meteosat-6 IR, WV and VIS data that has been re-sampled and calibrated to the MSG SEVIRI resolution.

3.1 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. In the new scheme the target size and extraction grid 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 local level and 2) Avoidance of extraction of targets in multi-layered cloud situations that have proven to be difficult to handle. These conclusions were already indicated by Holmlund (1995) and by the necessity to introduce complex image enhancement procedures (Hoffman, 1990). A variable target extraction scheme is already used operationally at NOAA/NESDIS and has proven to be reliable. The EUMETSAT target extraction scheme investigates the following features of each location:

- Minimum contrast
- Minimum acceptable local standard deviation
- Minimum 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 neighbouring targets. Currently the baseline overlap is limited to 30 %

Figure 2 shows the impact of the variable target extraction. In order to enhance 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.

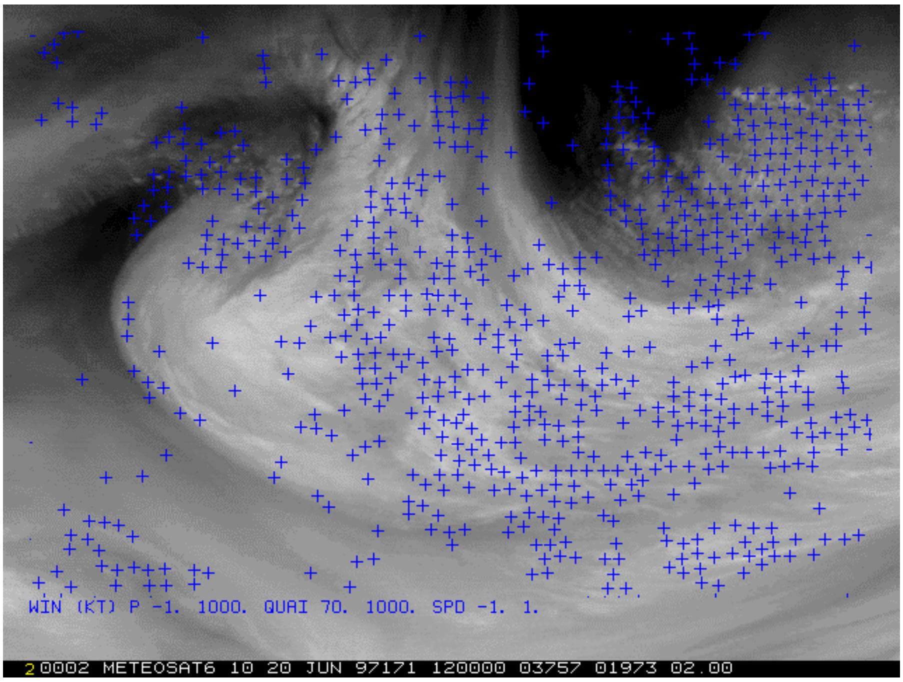

Figure 2. Low density targets extracted from MSG water vapour data simulated by WV data from Meteosat-6.

3.2 Image enhancement

The image enhancement is equivalent to the current methodologies applied at the Meteorological Product Extraction facility (MPEF) for the current Meteosat-satellites (Schmetz et. al., 1993). The only important difference is the derivation of cluster mean radiances, necessary for the image enhancement, that currently are directly retrieved from the targets analysis scheme. As the target location is only defined at the stage of AMV target-extraction a dynamical clustering has to be used. Currently it foreseen to use an approach similar to the one presented by Ebert et. al. (1993).

3.3 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 –are) 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. As the available processing capacity has in the past years increased tremendously the requirement for a limited calculation of matching surfaces has decreased and therefore the calculation of the full matching surface was regarded to be feasible. Three basic matching methods have been implemented 1) Cross-correlation in the time domain, 2) Cross-correlation in the Fourier domain and 3) Sum of Squared Distances. The detailed description of the implementation of these methods are given in Dew and Holmlund (2000). Figure 3 shows an example of water vapour vector fields derived with the current software version using simulated MSG image data.

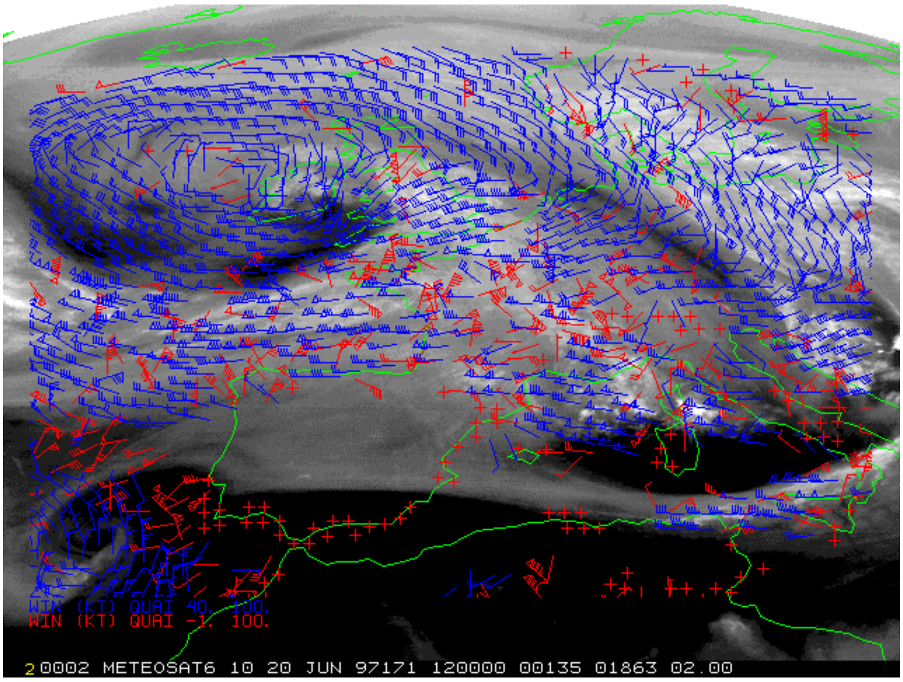

Figure 3. Water vapour vector field with water vapour imagery data from 20 June 1997.

3.4 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; 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 bias of the estimated cloud height is of the order of 20 hPa and with a RMS pressure difference of ca 80 hPa between the two methods. With MSG it will be possible to simultaneously apply both methods. The implementation of these methods contains the following new features:

- channel dependant noise is included in the calculations
- refined selection of pixel 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)

Figure 4 presents an example of extracted IR vectors with their respective height over the South-Atlantic. The delineation between high (above 400 hPa) vectors (in red), medium (between 440 and 700 hPa) vectors (in blue) and low (below 700 hPa) level (in green) looks realistic and has been verified against operational heights derived from Meteosat-6 data. It should be noted that as these results are based on simulated MSG data based on the Meteosat-6 IR, WV and VIS data, no CO_2-channel is present and therefore only the semi-transparency correction method has been applied to the thin high level clouds.

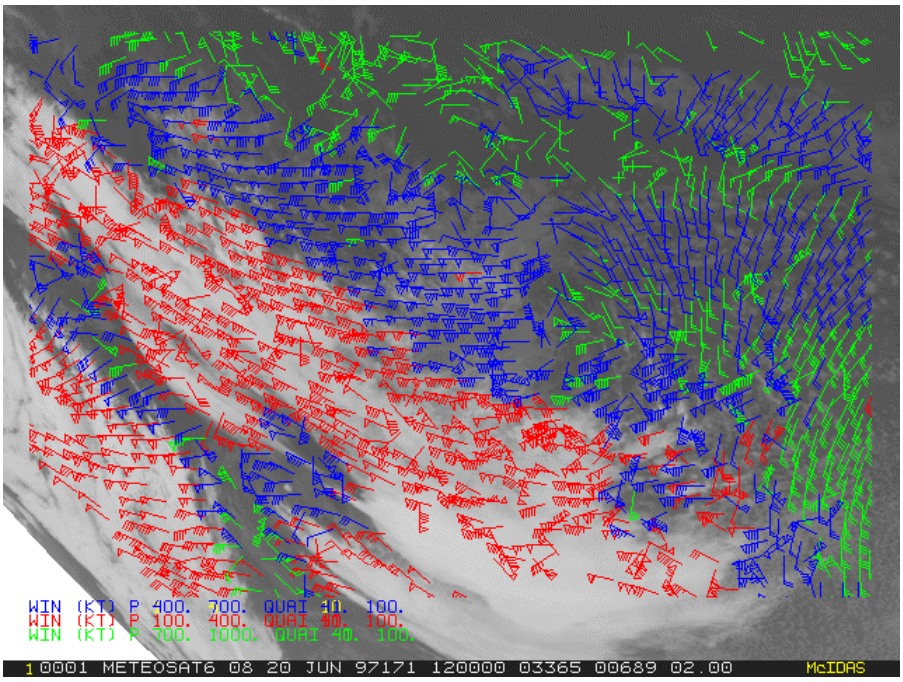

Figure 4. AMVs derived from simulated MSG images over the South-Atlantic. The image data has been simulated from Meteosat-6 data from 20 June 1997 1200 GMT. High (above 400 hPa) level vectors are coded in red, medium (between 400 and 700 hPa) level vectors are coded in blue and low level (below 700 hPa) vectors are coded in green.

3.5 Automatic quality control

The automatic quality control is based on the same principals used in MTP MPEF (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)

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.

3.6 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, quality) is based on a weighted mean of the intermediate vectors. The current baseline is however that all fields have the same weight.

4. Development approach

4.1 Pre-launch activities

The development of the MSG MPEF AMV scheme is based on previous experience with the Meteosat-satellites. It further incorporates the knowledge gained at the previous International Winds Workshops as well as information exchange during co-operation amongst the various AMV extraction centres. Finally results from various studies have been incorporated as well as in-house development activities. The development of the operational software has been given to industry and is based a formal Algorithm Specification Document and on in-house prototyping of all essential parts. The performance of the prototype code has been verified with comparisons against not only the operational extraction schemes but also with detailed case studies

4.2 Post-launch activities

The main goal for all 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. 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.

5. Conclusions

The Atmospheric Motion Vector (AMV) extraction scheme for Meteosat Second Generation (MSG) has been introduced. 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 are 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. 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). The launch of MSG is currently expected in mid 2001.

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