EUMETSAT

# *Atmospheric Motion Vectors: Product Guide*


Doc.No. : EUM/TSS/MAN/14/786435
Issue : v1A
Date : 9 April 2015
WBS :



EUMETSAT
Eumetsat-Allee 1, D-64295 Darmstadt, Germany
Tel: +49 6151 807-7
Fax: +49 6151 807 555
http://www.eumetsat.int



© EUMETSAT
The copyright of this document is the property of EUMETSAT.

## *Document Change Record*

| *Issue / Revision* | *Date* | *DCN. No* | *Summary of Changes* |
|---|---|---|---|
| 1 | 17 Dec 2014 | | Document created |
| 1A | 9 April 2015 | | Review by subject matter expert. Changes to graphics. Product sorted by program (MTG-MSG). Legend for wind vector arrows added. |

## *Table of Contents*

1 PRODUCT DESCRIPTION ..... 3
1.1 Product history ..... 3
2 PRODUCT SPECIFICATIONS ..... 4
2.1 AMV in Meteosat First Generation (MFG) ..... 5
2.1.1 Expanded Low-resolution Winds (ELW) ..... 5
2.1.2 High Resolution Visible Winds (HRV) ..... 6
2.1.3 Clear Sky Water Vapour Winds (WVW) ..... 7
2.1.4 High Resolution Water Vapour Winds (HWW) ..... 8
2.1.5 Cloud Motion Winds (CMW) ..... 8
2.2 Quality Cut-off ..... 8
2.3 AMV in Meteosat Second Generation (MSG) ..... 9
3 BASIC STRUCTURE OF THE ALGORITHM ..... 12
3.1 Inputs: ..... 12
3.2 Image and Preprocessing Data (Dynamic Application Data) ..... 13
3.3 Static Application Data ..... 13
3.4 Processing Steps ..... 13
4 REFERENCES AND LINKS ..... 15
4.1 Reference Documents ..... 15
4.2 Online Resources and Assistance ..... 15

# 1 PRODUCT DESCRIPTION

Atmospheric Motion Vectors (AMV) at all heights below the tropopause are derived from a number of channels within the set of Meteosat image data. These AMVs are all combined into one encoded product. Vectors are derived by tracking the motion of clouds and other atmospheric constituents such as water vapour patterns. The initial resolution is a 24-pixel grid; but as the algorithm tries to adjust the position to the point of the maximum contrast, which are typically cloud edges, the end resolution can vary. The height assignment of the AMVs is now calculated using the Cross-Correlation Contribution (CCC) function to determine the pixels that contribute the most to the vectors. Nevertheless, each AMV is assigned to a height using techniques that vary depending on the channel and the feature to be tracked. An AMV product contains between 5,000 and 20,000 vectors, depending on UTC.

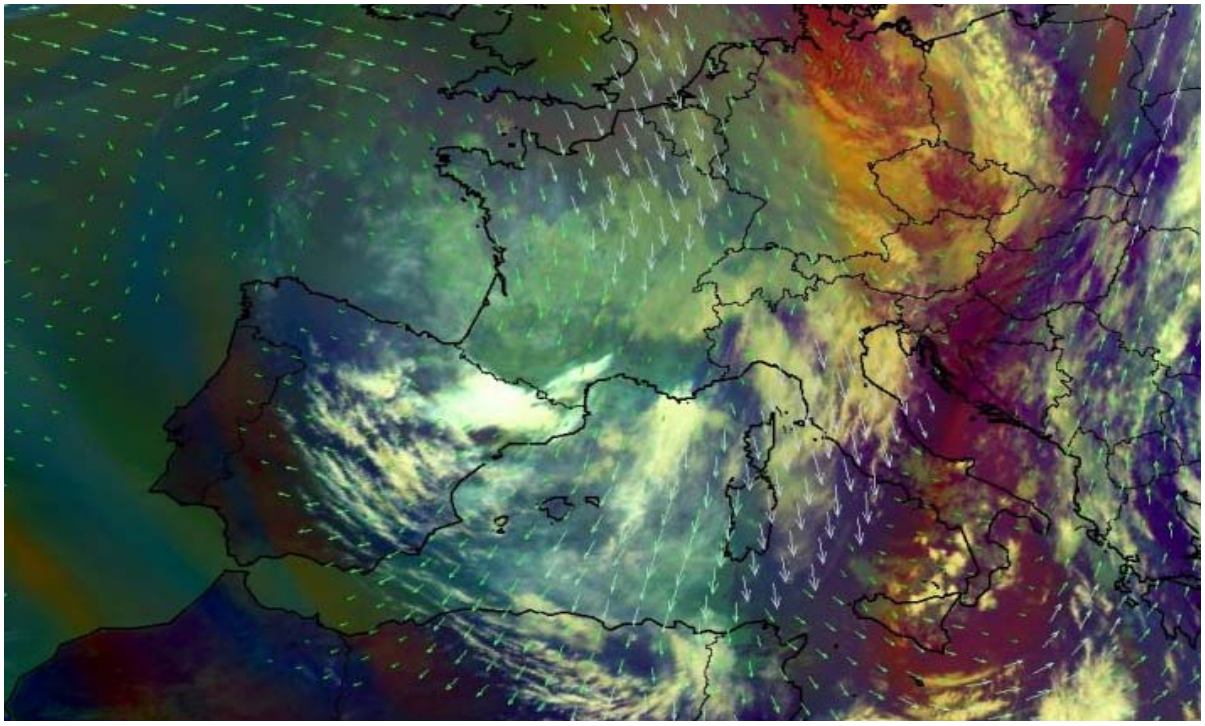


*Figure 1: Plot showing wind vector arrows taken from animation for 17 May 2007 (10:00 UTC).*

## 1.1 Product history

| | | |
|---|---|---|
| Baseline: | 26 November 1996 | |
| Operational start | 1998 | |
| Revision | 4 December 2001 | Target extraction and height assignment added |
| Revision | 27 March 2007 | Updates include height assignment and target optimisation. |
| Revision | 2 December 2008 | Encoding filter added, two parameters for use in final vector derivation added. |
| Revision | 5 September 2012 | Introduction of the Algorithm update in the AMV height assignment using the Cross-Correlation Contribution (CCC) Method. |
| Revision | 16 April 2013 | Re-introduction of the inversion height assignment correction. |

# 2 PRODUCT SPECIFICATIONS

| *Category* | *Specification* |
|---|---|
| **Product users** | Weather forecasting, numerical weather prediction, climate research and monitoring. |
| **Input satellite data** | See Section 3.1. |
| **Product Distribution** | • GTS<br>• EUMETCast<br>• Direct<br>• EUMETSAT Data Centre |
| **Product Area** | • FES Area<br>• RSS Area |
| **Product Resolution** | Variable |
| **Product Distribution Frequency** | FES Area<br>• GTS: hourly for the 00:45, 01:45, 02:45, …23:45 UTC products<br>• EUMETCast: hourly for the 00:45, 01:45, 02:45, …23:45 UTC products<br>• EUMETSAT Data Centre: hourly for the 00:45, 01:45, 02:45, …23:45 UTC products<br>• Direct: hourly for the 00:45, 01:45, 02:45, …23:45 UTC products<br>RSS Area<br>• GTS: every 20 minutes for the 00:15, 00:35, 00:55, …23:55 UTC products<br>• EUMETCast: every 20 minutes for the 00:15, 00:35, 00:55, …23:55 UTC products<br>• EUMETSAT Data Centre: every 20 minutes for the 00:15, 00:35, 00:55, …23:55 UTC products<br>Direct<br>Every 20 minutes for the 00:15, 00:35, 00:55, …23:55 UTC products |
| **Product Names** | • EUMETCast FES Area:<br>L-000-MSG2__-MPEF_____-AMV_____-000001___-200611130045-__<br>• EUMETCast RSS Area:<br>L-000-MSG1__-MPEF_RSS____-AMV_____-000001___-200807230255-__<br>• Direct Dissemination:<br>L-101-MSG2__-MPEF_____-AMV_____-000001___-200611130045-__ |
| **Product Format** | BUFR format |
| **Product Size** | FES Area: about 3 MB (variable)<br>RSS Area: about 400 KB (variable) |
| **Known Operation Limitations** | Product accuracy and quality indicators are measured by derived rain rates. |

## 2.1 AMV in Meteosat First Generation (MFG)

In this section, we will dissect the AMV product to show its development and components as first realized in the Meteosat First Generation (MFG) mission. These components are illustrated:

- Expanded Low-resolution Winds (ELW)
- High Resolution Visible Winds (HRV)
- Clear Sky Water Vapour Winds (WVW)
- High Resolution Water Vapour Winds (HWW)
- Cloud Motion Winds (CMW)

### 2.1.1 Expanded Low-resolution Winds (ELW)

This product was introduced in 1996 as an alternative to the satellite cloud drift winds (SATOB) product, containing all winds from all three channels, using the low resolution 80 × 80 segment matrix. Since 2 December 2002, the ELW product has consisted of winds from the IR channel only. A selection of the Low-resolution VIS and WV AMVs are still available in the SATOB coded product, but users are encouraged to use the HRV and HWW models instead. Statistically, the quality of the HRV and HWW sub-products matches or exceeds that of the corresponding low resolution products, when verified against radiosonde observations. The ELW product is generated every 1.5 hours and distributed in BUFR code. A typical ELW product contains about 2000 IR winds, while the Rapid Scan ELW is generated every half hour and contains about 500 IR wind vectors.

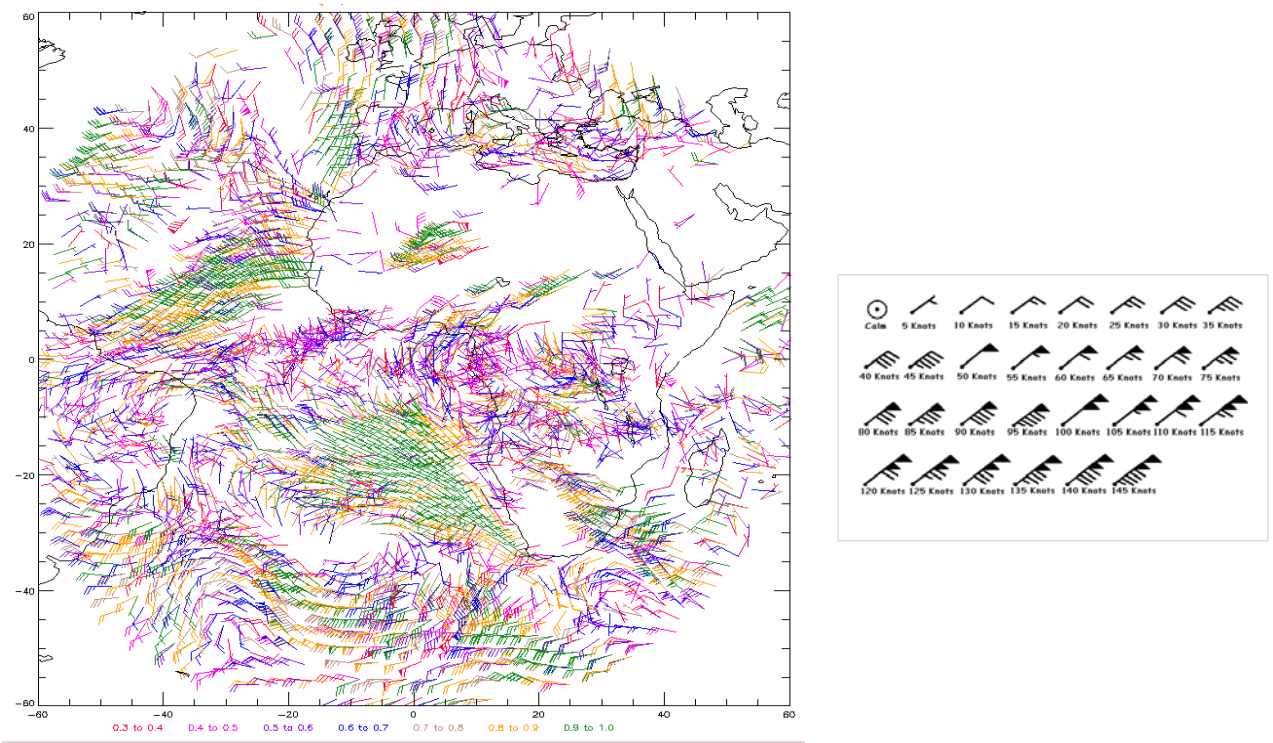



*Figure 2: Example of AMVs in a low-resolution wind plot using standard wind barbs. Wind bards equivalents table is shown at right.*

### 2.1.2 High Resolution Visible Winds (HRV)

The High Resolution Visible Winds sub-product is generated using essentially the same algorithm as the ELW product, but applied to the VIS images in full resolution using the high resolution segment matrix with a 16 × 16 pixels segment size. A typical product will contain up to 2000 winds and the product is generated every 1.5 hours during daytime and distributed in BUFR code. The Rapid Scan HRV contains about 1000 winds.

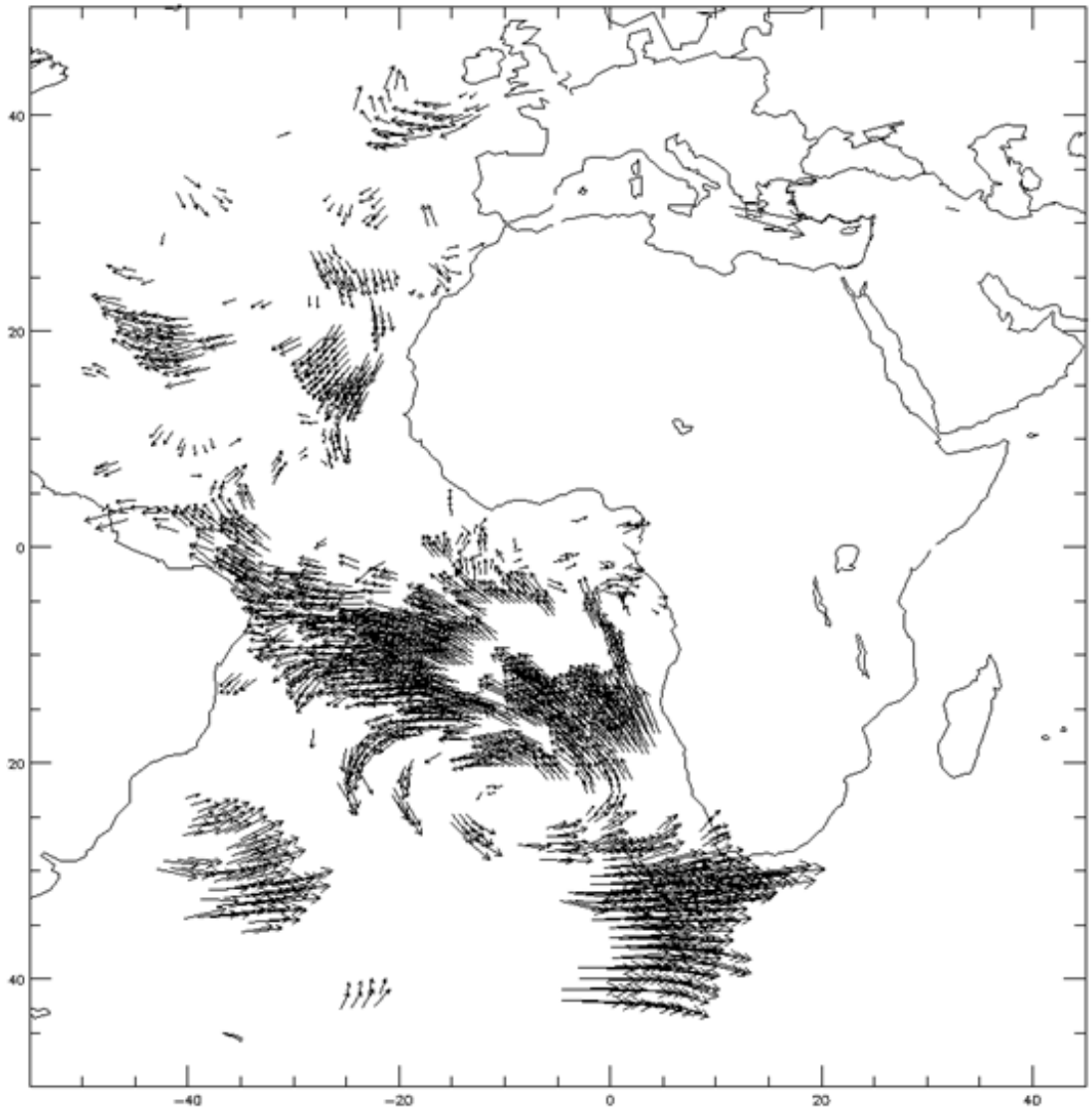



*Figure 3: Example of AMVs in a high-resolution visible winds plot 2 September 1996 1500 UTC.*

### 2.1.3 Clear Sky Water Vapour Winds (WVW)

The Clear Sky Water Vapour Winds product is generated using essentially the same algorithm as the other wind products, but uses tracking structures in the water vapour image from non-cloudy areas. Additional height assignment information is supplied – the 10%, 50% and 90% levels of the cumulative contribution function (based on ECMWF forecast data) – and the levels of the maximum gradient of the cumulative contribution function are inserted. These values allow characteristics of the layer being tracked to be determined. The values themselves are inserted in the slots designed for this purpose in the BUFR template. The product is generated every 1.5 hours and distributed in BUFR format.

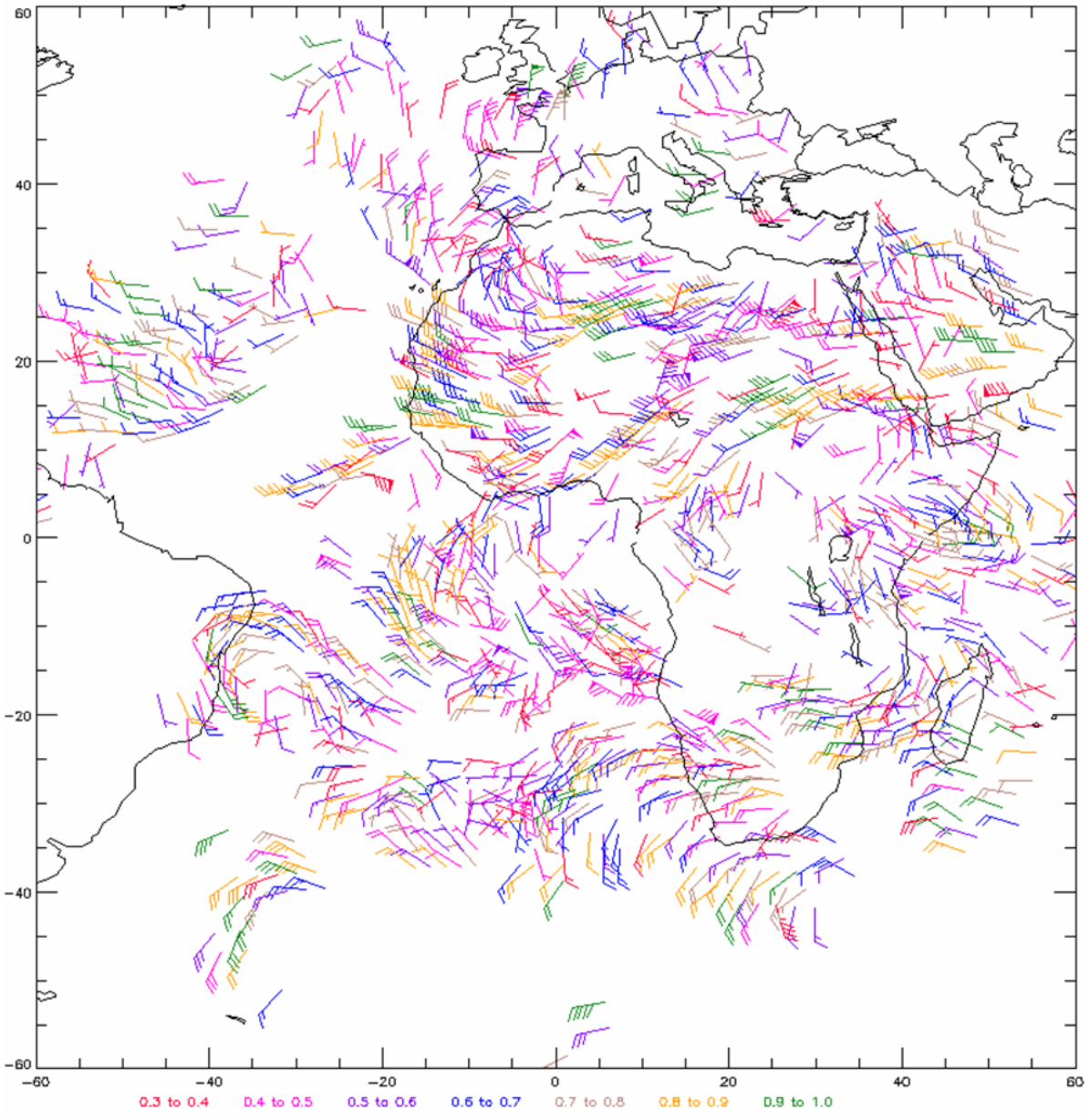



*Figure 4: Examples of AMVs for clear-sky water vapour winds. Standard wind bard symbols are used. See also the wind bard equivalents table in Figure 2.*

### 2.1.4 High Resolution Water Vapour Winds (HWW)

The High Resolution Water Vapour Winds product uses a slightly different algorithm (FFT surface correlation) than the water vapour part of the ELW product, and the water vapour images are divided into sub-areas of 16 × 16 pixels, the same resolution as the HRV product. Only segments where a cloud has been detected are processed. The HWW data is generated every 1.5 hours and distributed in BUFR.

### 2.1.5 Cloud Motion Winds (CMW)

This product is a high-quality subset of the ELW product. The winds are derived for all three spectral channels (VIS in half resolution) as for the ELW Product. However, the CMW product only includes the best wind for each segment determined from the QI value, and there are also other limitations specified in the dissemination limit table. A typical product will contain up to 750 winds per channel. The product is distributed for the synoptic hours of 00:00, 06:00, 12:00 and 18:00 UTC in SATOB code.

## 2.2 Quality Cut-off

The table below defines the quality cut-off for the different wind products. Only winds having a final AQC Quality Index (QI) above the defined limit are included. The QI used for all thresholds includes a consistency check against the forecast.

The BUFR-coded wind products also include a Recommended Quality Level expressed in terms of a minimum QI, indicating a certain quality higher than the dissemination limit, as shown in the table below. In addition, an AQC Acceptance Flag is included in the BUFR. This flag is set to accept or reject a QI that is above or below the Recommended Quality Level.

| ***Product*** | ***Distribution Limits (using QI with FC-consistency)*** | ***Distribution Limits (using QI with FC-consistency)*** | ***Recommended Quality Level without FC-consistency*** |
|---|---|---|---|
| **CMW** (SATOB) | AQC QI > 0.80, Speed > 2.5 m/s, Only IR and VIS winds above 995 hPa and WV winds above 400 hPa. Only one wind per segment (highest QI). | n/a | |
| **ELW** (BUFR) | AQC QI > 0.3 | AQC QI > 0.80 | All Recommended Quality Levels are 0.05 higher than for AQC with FC-consistency. |
| **HRV** (BUFR) | AQC QI > 0.3<br><br>See ***Note*** below. | AQC QI > 0.65<br><br>See ***Note*** below: | All Recommended Quality Levels are 0.05 higher than for AQC with FC-consistency. |
| **WVW** (BUFR) | AQC QI > 0.3 | AQC QI > 0.50 | All Recommended Quality Levels are 0.05 higher than for AQC with FC-consistency. |
| **HWW** (BUFR) | AQC QI > 0.3<br>Cloudy segments only | AQC QI > 0.80 | All Recommended Quality Levels are 0.05 higher than for AQC with FC-consistency. |

***Note:*** AQC scheme for HRV is slightly different from the other products.

*Table 1: Definitions for quality cut-off for different wind products.*

## 2.3 AMV in Meteosat Second Generation (MSG)

The product is based on the measurement of clouds or atmospheric element displacement between two or more consecutive images. The displacement is derived by means of matching a target area containing the tracer to the search area, and an interpolation in the matching surface.

The height at which the vector is measured is defined by the temperature of the tracer and converted to a pressure level via the forecast temperature-to-pressure profile of the atmosphere. Corrections for semi-transparent clouds, atmospheric absorption and cloud base for low-level clouds are also factored into the derivation.

The AMV baseline product will be derived continuously from five spectral SEVIRI channels. Illustrations for each of these five spectral channels follow:

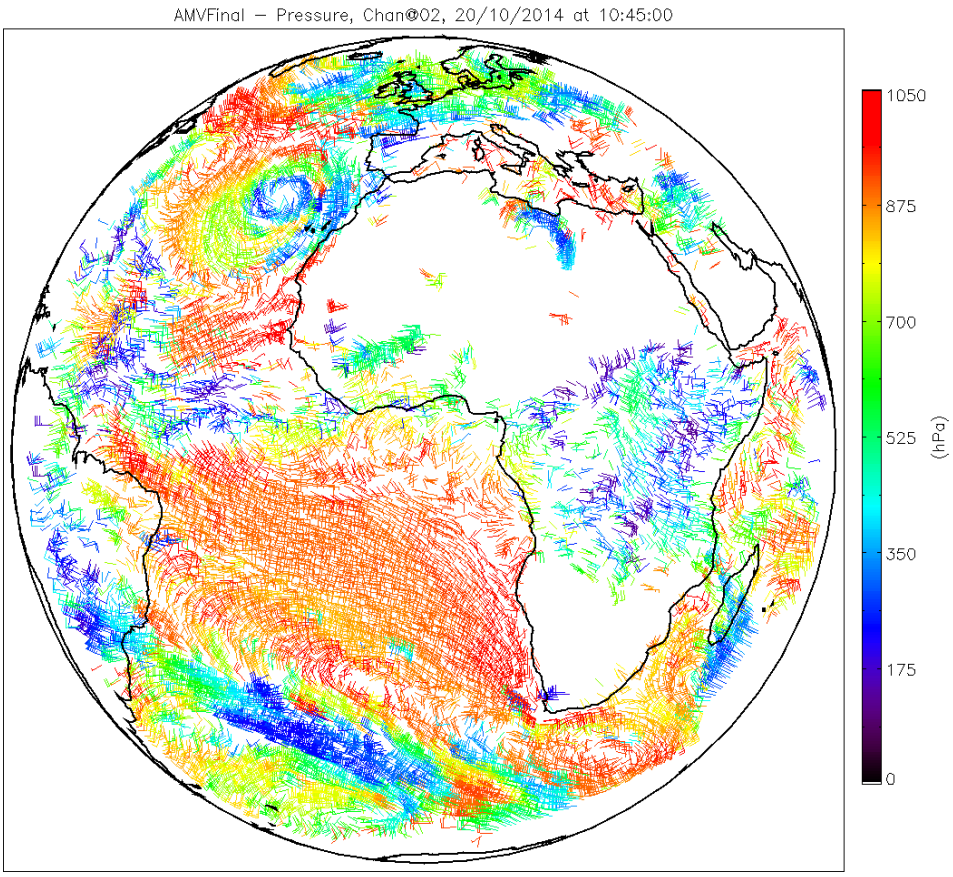



*Figure 5: AMV Final Product winds for Channel 2 on 20 October 2014 at 10:45:00 UTC. All winds have a Quality Index greater than/equal to 0*

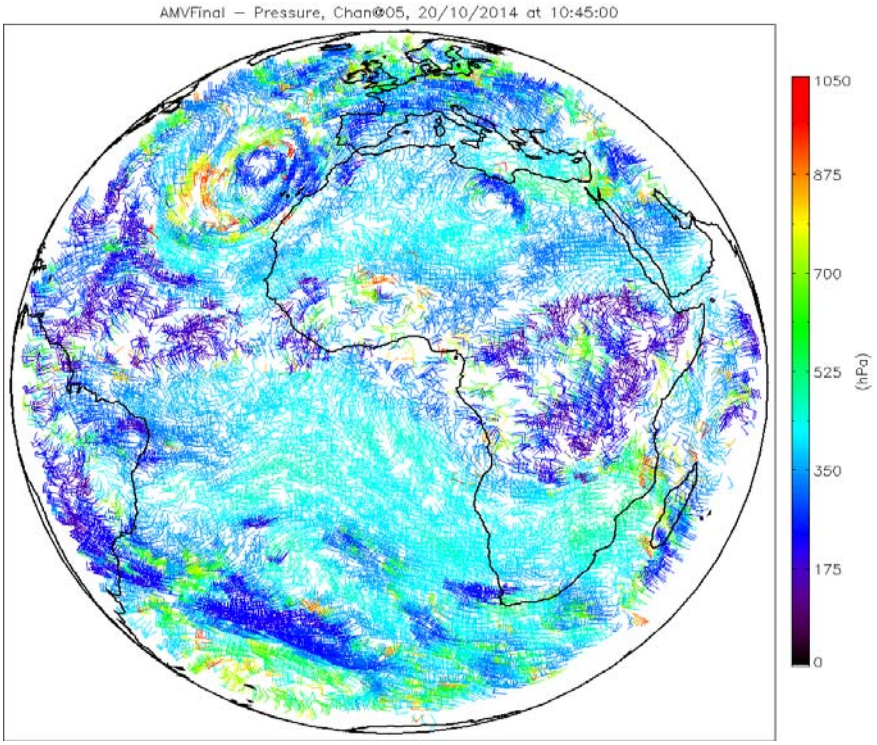



*Figure 6: AMV Final Product winds for Channel 5 on 20 October 2014 at 10:45:00 UTC. All winds have a Quality Index greater than/equal to 0.*

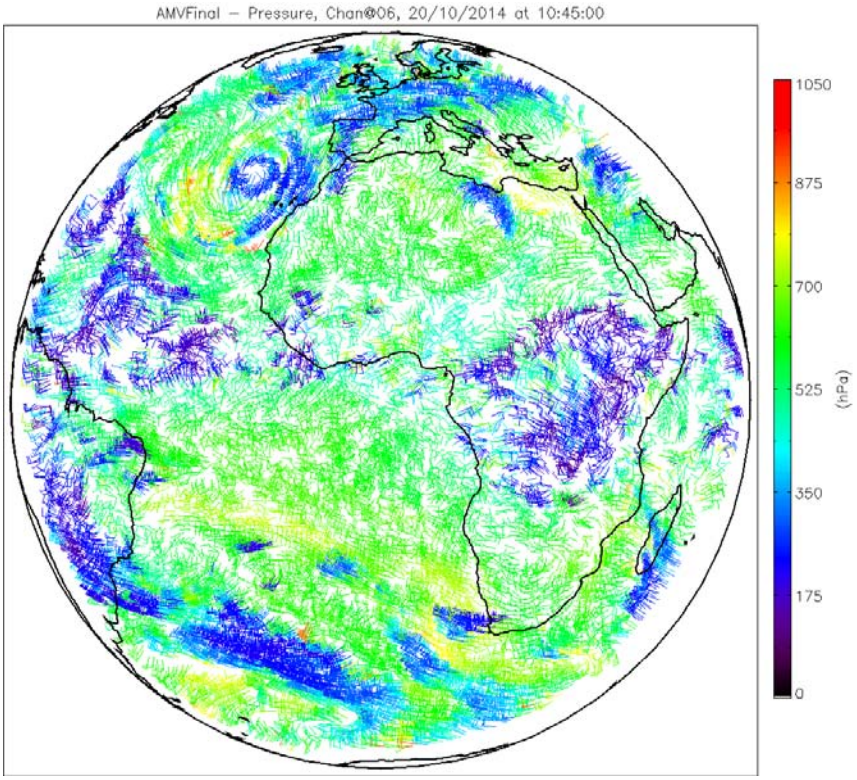



*Figure 7: AMV Final Product winds for Channel 6 on 20 October 2014 at 10:45:00 UTC. All winds have a Quality Index greater than/equal to 0.*

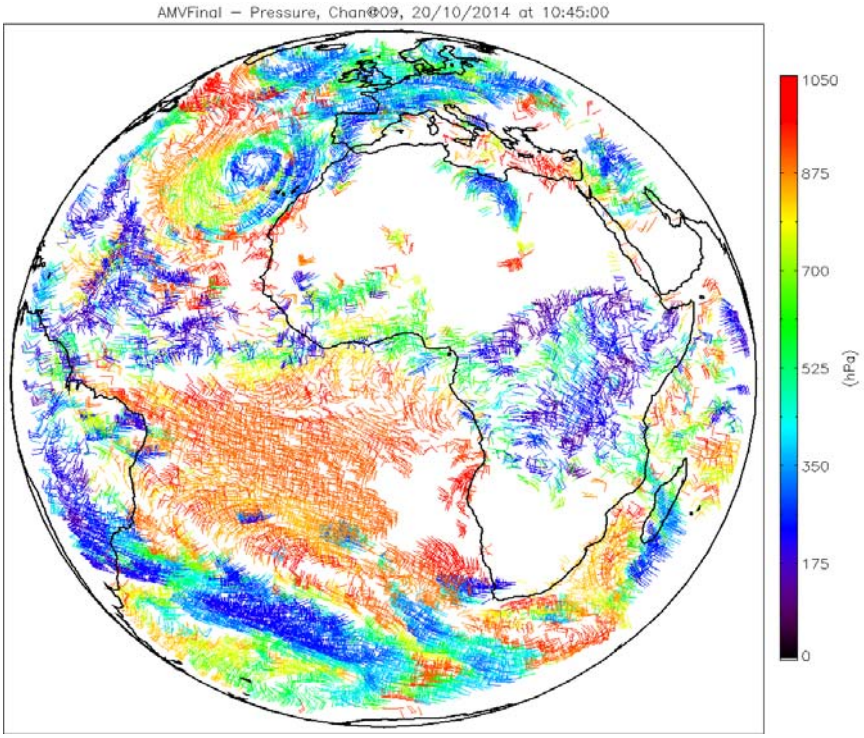



*Figure 8: AMV Final Product winds for Channel 9 on 20 October 2014 at 10:45:00 UTC. All winds have a Quality Index greater than/equal to 0.*

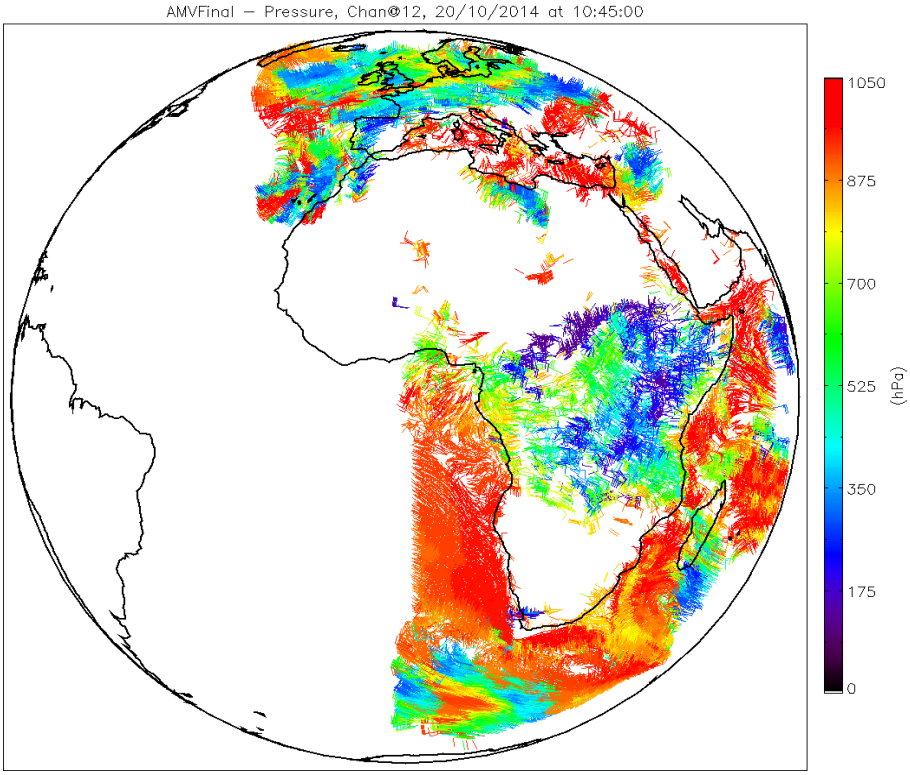



*Figure 9: AMV Final Product winds for Channel 12 on 20 October 2014 at 10:45:00 UTC. All winds have a Quality Index greater than/equal to 0.*

# 3 BASIC STRUCTURE OF THE ALGORITHM

For the Meteosat Second Generation (MSG) mission, the AMV product uses clear-sky radiances tables that relate the effect of opaque cloud at different heights to the radiances in the eight IR channels and to atmospheric correction tables provided by the Radiative Transfer Model. This information is provided to the AMV as equivalent black-body temperature. The RTM provides the clear-sky contribution functions for the selected IR channels. In the AMV retrieval, this RTM table is used as a continuous function interpolated in time and space to the gravity centre of the target. This implies that the table values are also be interpolated in height, as the table is provided only at discrete levels.

The results from the RTM and the Cloud Analysis are used to define the suitability of the channels to provide good displacement vectors at all locations, image enhancement and height assignment for each tracer. The AMV also uses the forecast temperature profiles for height assignment. Finally, the AMV requires an ensemble of AMV set-up parameters (static application data) to control the different processes.

## 3.1 Inputs:

The Atmospheric Motion Vector (AMV) generation uses the Level 1.5 image data from all spectral channels selected by the AMV channel selection table. Initially, the AMV is extracted from the following spectral channels:

- VIS 0.8 µm channel
- IR 10.8 µm channel
- WV 6.2 µm channel
- WV 7.3 µm channel
- HRVIS channel

Forecast data from the European Centre for Medium-Range Weather Forecasts (ECMWF) which are used in the following functionality:

- Estimating the Atmospheric Correction, i.e. estimating the impact of the atmosphere on radiation exiting from the surface
- Estimating the value for the semi-transparency correction
- Estimating the height of the individual AMVs
- Estimating the quality of the individual AMVs, which is an optional parameter in the encoded product

Results of the pixel-based cloud analysis (an internal product), giving the scenes type, cloud top height, cloud phase and cloud top radiance.

## 3.2 Image and Preprocessing Data (Dynamic Application Data)

The dynamic input is time-dependent and is different for each repeat cycle. The algorithm makes all data available for all the extractions performed, i.e. for every specified channel.

## 3.3 Static Application Data

The static application data input controls the complete AMV process. These data are changed infrequently during operations but are configurable.

The static application data used by the AMV algorithm consists of the following:

- Pixel-based map of surface-type
- Pixel-based map of distance to nearest coastline
- Pixel-based description of processing area
- Static parameters for different mathematical expressions and channel instrument characteristics
- Set-up parameters specific to the AMV processing algorithm

The static input is specified separately for every baseline channel used for the extraction of displacement vectors.

## 3.4 Processing Steps

The algorithm performs these processing steps to derive one single displacement vector for the intermediate channel.

1. Make a target selection
2. Prepare image data
3. Enhance the image
4. Derive target displacement
5. Perform height assignment

The final AMV product is generated at scheduled times and is based on intermediate AMV products, where the number of intermediate products used is specified by the set-up parameter *N_Gen.* Nominally, this is three.

In the nominal case, intermediate products are generated with time stamps of 15, 30 and 45 minutes into the synoptic hour. The final product is generated with a time stamp of 45 minutes into the synoptic hour. This means that, for example, for the 15-minute time stamp intermediate product, each target is selected from the image data (scan) starting at 0 minutes. The target displacement is extracted from the image data (scan) starting at 15 minutes into the synoptic hour. Then everything is shifted forward one repeat cycle for the next intermediate product. No intermediate products are generated at the 0-minute synoptic time. In effect, four images are used each hour to generate three intermediate products and a final product. The AMV processing flow is shown in Figure 10.

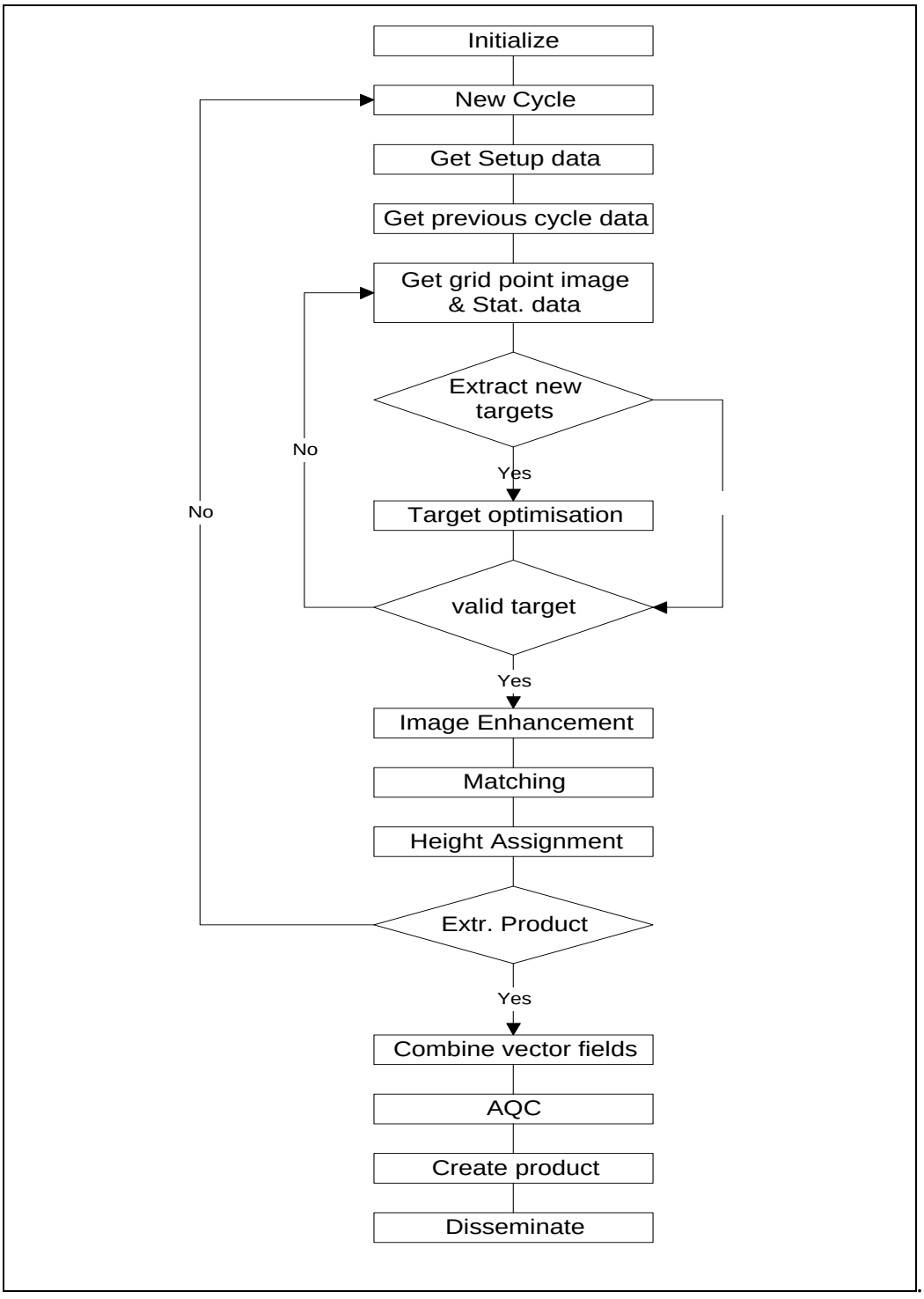



*Figure 10: AMV Algorithm processing*

# 4 REFERENCES AND LINKS

## 4.1 Reference Documents

| *Type* | *Document Name* | *Reference* |
|---|---|---|
| Validation | MSG-3 System Commissioning Product Validation Report | EUM/MSG/REP/12/0190 |
| Algorithm | MSG MPEF Algorithm Specification Document | EUM/MSG/SPE/022 |
| Science/Research | EUMETSAT has done research and exploration in this field for more than 10 years and sponsors a yearly workshop for presentation of the science and scholarship in the field. | Put *International Winds Workshop* into the EUMETSAT web page SEARCH field |

## 4.2 Online Resources and Assistance

All of the reference documents listed above are on the EUMETSAT Technical Documents page:

www.eumetsat.int > Satellites > Technical Documents
> Meteosat Services
> 0° Meteosat Meteorological Products

See the EUMETSAT Training page for topics related to AMV applications:

http://www.eumetsat.int > home > Data > Training

To register for data delivery from this product, go to the Data Registration page on the EUMETSAT web page:

www.eumetsat.int > Data > Data Delivery > Data Registration

Information about the service status of EUMETSAT satellites and the data they deliver is this EUMETSAT web page:

www.eumetsat.int > Data > Service Status

To get answers to any questions about data delivery, registration or documentation, contact the EUMETSAT User Service Help Desk:

Telephone: +49 6151 807 3660/3770
e-mail: ops@eumetsat.int