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CURRENT STATUS OF EUMETSAT OPERATIONAL AMV PRODUCTS

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Abstract

Atmospheric Motion Vectors (AMVs) are an important product for NWP because they constitute the only observation of the upper troposphere dynamics that can feed the forecast models over the oceans and polar regions. AMVs are produced operationally at EUMETSAT from the Meteosat geostationary satellites as well as from the EUMETSAT Polar System Metop satellites. After a long stable period in the configuration of the EUMETSAT operational satellite fleet, several important changes are planned for the upcoming years, mainly due to the end of life of both Meteosat-7 and Metop-A satellites.

This paper gives an overview of these upcoming changes foreseen in the EUMETSAT satellite configuration, together with information on the recent operational development done on the EUMETSAT AMVs products. Indeed, recent research activities have led to important changes in the last MSG MPEF Release 2.2, like the use of the new Optimal Cloud Analysis (OCA) product to set the AMV altitude and the implementation of a new method to set the altitude of Clear Sky Water Vapour winds. On the Low Earth Orbit (LEO) satellite side, two new AMV products have been developed since the IWW12: a global AVHRR winds product derived from a pair of Metop-A and Metop-B images became operational in January 2015, and a triplet mode AVHRR wind product developed using three consecutive images taken by the two Metop satellites became operational in December 2015.

INTRODUCTION

EUMETSAT derives Atmospheric Motion Vectors (AMV) operationally from the Meteosat geostationary satellites as well as from the EUMETSAT Polar System Metop satellites. Several important changes in the EUMETSAT operational satellite configuration are planned for the upcoming years due to the end of life of both Meteosat-7 and Metop-A satellites. The decommissioning of Meteosat-7, presently located over the Indian Ocean, will be followed by orbit changes of all the other Meteosat satellites, with Meteosat-8 replacing Meteosat-7 for the Indian Ocean Data Coverage (IODC) service. The launch of Metop-C, planned for 2018, and the de-orbiting strategy of Metop-A will also impact the Low Earth Orbit satellite configuration. All these changes will of course impact the delivery of EUMETSAT meteorological products, having for example one Meteosat Second Generation satellite over the Indian Ocean for the first time. This should allow interesting comparisons of Meteosat-8 AMVs with those extracted from the FY 2/4 and Himawari satellites.

Recent research activities have led to important changes in the EUMETSAT operational AMV algorithms. The last Meteosat Second Generation (MSG) MPEF Release 2.2 includes the use of the new Optimal Cloud Analysis (OCA) product to set the AMV altitude, together with the implementation of a new method to set the altitude of Clear Sky Water Vapour winds. A new global AVHRR winds product derived from pairs of Metop-A and Metop-B images has been developed; it became operational in January 2015. The global coverage results in a homogeneous retrieval over the whole globe and helps to fill gaps between 50 to 70° latitude north and south, where few wind observations are available for assimilation. Finally, a new triplet mode AVHRR wind product has been developed using three consecutive images taken by the two Metop satellites. This new product is derived only over polar regions, and became operational in December 2015.

This paper gives an overview of the last developments in the current operational AMV products derived at EUMETSAT with a view to upcoming changes in the operational configuration of EUMETSAT satellites.

EUMETSAT SATELLITE CONFIGURATION

Geostationary satellites

Apart from the launch of MSG-4 on 15 July 2015 (renamed Meteosat-11 after commissioning, and now stored in orbit at 3.4 degrees west), no major change in the EUMETSAT operational geostationary satellite configuration has taken place since the IWW12 Winds Workshop. The primary service over the European region is still provided by the Meteosat-10 satellite. Meteosat-8 is still performing well and continues to provide the Rapid Scan Service (RSS) over Europe. The last satellite of the Meteosat First Generation (MFG) series, Meteosat-7, still ensures the nominal Indian Ocean Data Coverage (IODC) service from 57.5 degrees east.

However, several important changes are planned for the next two years in the EUMETSAT geostationary satellite configuration. Metosat-7 will be de-orbited in 2017 after nearly 20 years of operations (it was launched in 1997). It will be replaced for the IODC service by Meteosat-8, that will be relocated at 41.5 degrees east and should start operations by the end of 2016. In 2018 Meteosat-9 will drift to 3.5 degrees east, Meteosat-10 should replace Metosat-9 at 9.5 degrees east providing the RSS service, and Meteosat-11 will ensure the primary service at 0 degrees. EUMETSAT will then have 4 MSG satellites on operations.

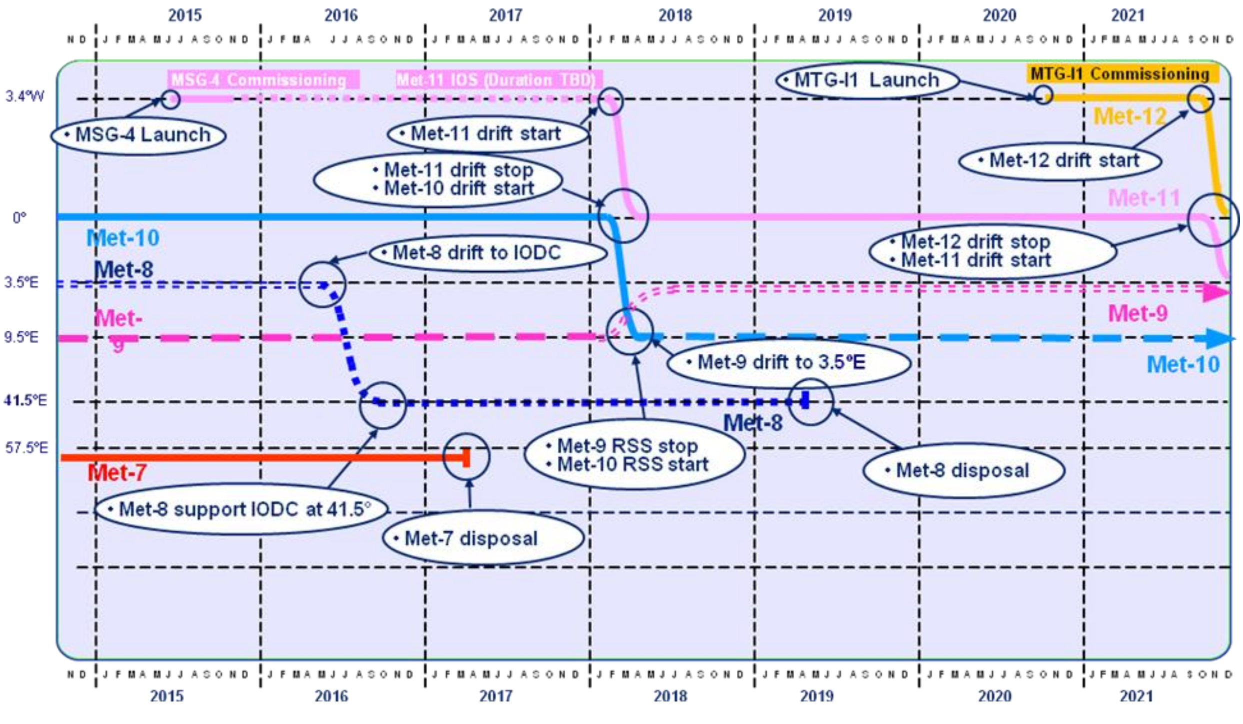

Figure 1: **The EUMETSAT geostationary satellite configuration for 2015–2021 (from the Spring 2016 STG-OWG).**

Later on, the Meteosat Third Generation (MTG) will start with the launch of the first imaging satellite MTG-I, scheduled for 2020. MTG is a dual-satellite system. The sounding satellite, MTG-S, will include an interferometer, the Infra-red Sounder (IRS), with hyper-spectral resolution in the thermal spectral domain, and the high resolution Ultraviolet Visible Near-infrared (UVN) spectrometer. Both instruments comprise the Sentinel-4 mission. The imaging satellite, MTG-I, will continue the imaging service currently provided by MSG by means of the Flexible Combined Imager (FCI); in addition, it will operate the Lightning Imager (LI), an imaging lightning detection instrument.

Prototyping activities of the MTG-FCI algorithms have already started at EUMETSAT, and the AMV prototype has been recently adapted to Himawari data (Carranza et al., 2016). Verification activities against the reference code developed by industry (L2PF) and the scientific validation activities will be pursued in the upcoming years.

Low Earth Orbit satellites

The EUMETSAT Low Earth Orbit (LEO) Metop satellite configuration has not changed since the launch of the Metop-B satellite on 17 September 2012. The last satellite of the series, Metop-C, is scheduled to be launched in 2018. Several scenarios have been discussed recently to manage the end of life of the Metop-A satellite, which was launched in 2006. Based on a fuel budget analysis and the still good performances of Metop-A, despite some instruments degradations, the Spring 2016 STG-OWG, has taken the decision for an additional Out Of Plane (OOP) manoeuvre in 2016. Therefore a single-burn OOP manoeuvre has been performed on 31 august 2016, which secures the dual Metop operations on the same ground track and phase for approximately five additional months, until June 2017. The possibility of an extended local-time (LTAN) drift using a drifting ground track/fixed phase is under analysis depending on the satellite health and the users' interest. Then a trident or tri-star configuration of three Metop satellites could provide operations until 2020-21 (EUM/STG-OPSWG/40/16/VWG/04).

The current EUMETSAT Polar System (EPS) Programme will end in the 2020 time frame, requiring a follow-on, the so-called EPS Second Generation (EPS-SG) Programme. AMVs over polar areas will then be extracted from the optical imager METImage of the first EPS-SG satellite (Spezzi et al., 2016). METimage is a cross-track-scanning imaging spectro-radiometer which measures reflected solar and emitted terrestrial radiation in the visible to infrared spectral domain between 0.445 and 13 µm with a moderate sampling resolution of 0.5 km. METImage shall simultaneously provide images in 20 spectral channels, allowing the extraction of AMVs in visible (0.8 mm), infra-red (10.7 mm) and water vapour (6.7 and 7.3 mm) channels. A launch is presently foreseen in the frame of 2020, and the algorithm prototyping activities for the METImage instrument will take place at EUMETSAT in the upcoming years.

RECENT CHANGES IN AMVs DERIVED AT EUMETSAT

From MSG satellites

The last version of the AMV algorithm included in Release 2.2 (April 2016) introduces: 1) the use of the Optimum Cloud Analysis (OCA) product to set the AMV altitude, 2) new Height Assignment (HA) methods for both Cloudy and Clear-Sky (CS) AMVs. The new altitudes (OCA and CS WV HA) have been put in the output files in addition to the current final altitude in order to give the users enough time to test them.

Use of OCA to set AMV HA

The most recent version of the OCA product is able to deal with two-cloud-layer situations (Watts et al., 2011), which is one of the most important tricky situations encountered in the AMV processing. The use of the OCA product to set the AMV altitude is then expected to improve the whole quality of the AMV product, especially in areas where multilayer clouds occur, or in very thin semi-transparent cloud situations. Carranza et al. (2014) showed that the OCA product could improve the AMV quality in the South Atlantic inversion area, where multilayer situations often occur, and in the jet over the Sahara desert, where the CTH of very thin clouds is very difficult to estimate. Preliminary monitoring of AMVs extracted using the OCA product at ECMWF shows promising results (Lean et al., 2016), especially at low levels below 700 hPa and in the tropics between 300 and 500 hPa. However, these results have still to be confirmed by an impact study started in September 2016.

Set AMV altitude in clear-sky areas

The current CS AMV altitude is obtained in the MPEF using Normalized Contribution Radiative Transfer Model (RTM) methods. These methods are not very accurate, and they have the big disadvantage of relying on the forecast model outputs through the RTM calculations. The change proposed in Release 2.2 uses the Cross Correlation Contribution (CCC) method to select the pixels used for the HA (Borde et al., 2014) together with their radiance in the corresponding water-vapour channel. Once the average weighted radiance is calculated, Equation 1, it is converted into EBBT and interpolated in the corresponding forecast profile.

$$< Rad >= \frac{\sum\limits_{\substack{cold\_branch \\ CC_{ij} > CCij\_thr}} CC_{ij} \cdot Rad^{wv}{}_{ij}}{\sum\limits_{\substack{cold\_branch \\ CC_{ij} > CCij\_thr}} CC_{ij}} \qquad (1)$$

Figure 2 shows the impact of the change on the CS AMV altitude for AMVs extracted on 11/06/2015 at 12:15 for the WV 6.2 channel (top) and the WV 7.3 channel (bottom). The current method is plotted on the left side, the new method on the right side. Using the new method the CS AMVs are obviously set at a higher altitude in the troposphere, which appears more realistic.

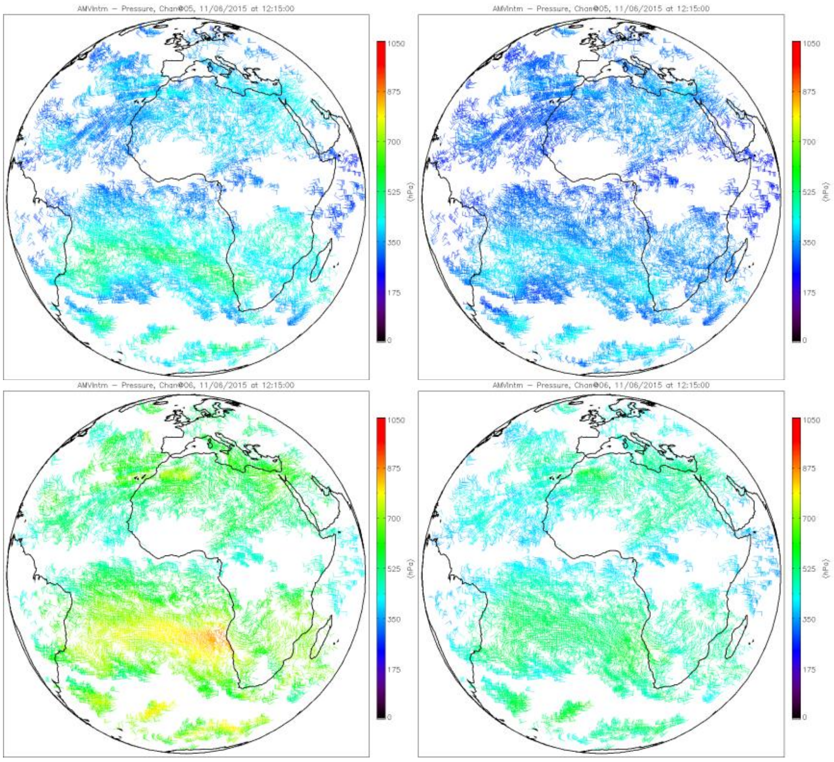

Figure 2: **CS AMV altitudes estimated using the current MPEF method (left) and the new one (right) on 11/06/2015 at 12:15, channels WV 6.2. (top) and WV 7.3 (bottom).**

The impact in the corresponding statistics is illustrated in Table 1 for the pressure and quality index (QI).

Channel	Number	Clear-sky		
		OLD	NEW	NEW – OLD
WV 6.2 µm	7,640	403 hPa	336 hPa	–67 hPa
WV 7.3 µm	7,730	618 hPa	482 hPa	–136 hPa

Channel	Number	Clear-sky		
		OLD	NEW	NEW – OLD
WV 6.2 µm	7,640	36.6	46.4	+9.8
WV 7.3 µm	7,730	30.1	51.5	+21.4

Table 1: **Performance statistics between ‚Old‘ and ‚New‘ schemes regarding the pressure (top) and QI (bottom).**

Re-set AMV altitude of cloudy WV AMVs found at low levels

When enough cloud pixels are found in the target box, the AMV is treated following the cloudy AMV process. So, sometimes it happens that AMVs are tracked at high levels using WV channels and the altitude is set at low levels using the CCC method and the CTH CLA product. After the introduction of CCC method to set the height, such AMVs were set to very poor QI to avoid their use by forecast centres.

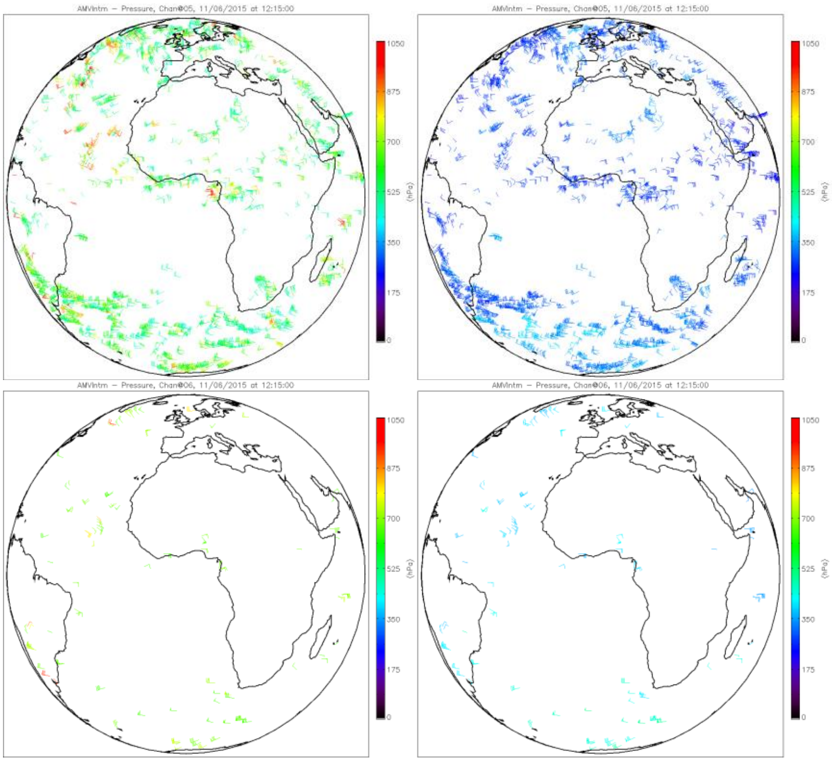

***Figure 3*: AMV altitudes estimated using the current MPEF method (left) and re-calculated using the new one (right) on 11/06/2015 at 12:15, channels WV 6.2. (top) and WV 7.3 (bottom).**

Channel	Number	Cloudy		
		OLD	NEW	NEW – OLD
WV 6.2 µm	921	600 hPa	301 hPa	–299 hPa
WV 7.3 µm	51	716 hPa	405 hPa	–311 hPa

Channel	Number	Cloudy		
		OLD	NEW	NEW – OLD
WV 6.2 µm	690	1.9	65.5	+63.6
WV 7.3 µm	30	4.0	69.7	+65.7

***Table 2:* Performance statistics between ‚Old‘ and ‚New‘ schemes regarding the pressure (top) and QI (bottom)**

The proposed change in the AMV process aims to consider now these AMVs as CS cases and calculate their altitudes accordingly. If a cloudy AMV is found at low levels using the WV channels, its altitude is re-calculated using CS HA methods (NTCC and the new method described above). The thresholds used to consider a too low AMV are 450 hPa for the WV 6.2 channel and 650 hPa for the WV 7.3 channel.

Figure 3 shows the impact of the change on AMVs extracted on 11/06/2015 at 12:15 for the WV 6.2 channel (top) and the WV 7.3 channel (bottom). The current method is plotted on the left side, the new method on the right side. As expected, the new AMV altitudes are found at a higher altitude in the troposphere. The corresponding pressure (top) and QI (bottom) statistics are shown in the Table 2.

From Metop AVHRR instruments

A new global AVHRR wind product derived from a pair of Metop-A and Metop-B images has been developed; it became operational in January 2015 (Borde et al., 2016). The global coverage results in a homogeneous retrieval over the whole globe and helps to fill gaps between 50 to 70° latitude north and south, where few wind observations are available for assimilation. Besides, a new triplet mode AVHRR wind product has been developed using three consecutives images taken by the two Metop satellites. This last product is derived only over polar regions, and became operational in December 2015. Hautecoeur and Borde, (2016) compared the performances of the three different AVHRR winds products (Single Metop polar winds, Global AVHRR wind product, and Triplet Mode AVHRR wind product) presently derived in the EPS ground segment at EUMETSAT, and they illustrated the role of the temporal gap between the two consecutive images on the AMV derivation and the impact of the use of a temporal consistency test in the calculation of the AMV quality index (QI).

The Single Metop polar winds and Global AVHRR wind product are now assimilated in NWP models (DWD, ECMWF and Met Office). It appears especially important for the future to sustain or increase the capability of AMV extraction in the 40-60 degrees latitude band between the GEO AMVs and the common polar winds. Unfortunately the drift of Metop-A in its orbit mentioned above may create a gap of observations before the launch and operational life of Metop-C, currently foreseen for the end of 2018.

Therefore it is presently planned to develop an AMV extraction algorithm from the Sentinel3/SLSTR instrument at EUMETSAT. Accounting its similarities with the AVHRR instrument (10.85 micron channel and 1 km pixel resolution), S3/SLSTR is indeed a good candidate to complement or eventually replace the global AVHRR AMV observations over polar areas and in the 40-60 degrees latitude band.

S3/SLSTR is a conical scanning imaging radiometer which employs the along-track scanning dual-view technique to provide a robust atmospheric correction over a dual-view swath. This configuration provides the following instrument swath coverage:

- ✓ oblique view swath: ~740 km;
- ✓ nadir view swath: ~1,400 km.
- ✓

The nadir swath is asymmetrical with respect to the ground track. The dual view of SLSTR provides theoretically also an interesting possibility to use a stereo method to set the altitude of the AMVs instead of the common Equivalent Blackbody Brightness Temperature (EBBT) method.

3D winds from Metop IASI

The AMVs commonly extracted from imagers provide cloud motions at a single level in the troposphere. They do not allow getting information on the whole wind profiles. Such profiles may theoretically be estimated from temperature and humidity fields retrieved from hyperspectral sounding, for which the height information is already available together with the retrievals. This is a very current topic in the USA, where CIMSS has recently developed 3D winds from the AIRS instrument (Santek et al., 2016), and where several projects have been proposed to extract 3D winds from micro infrared sounding satellite fleets (Maschhoff et al., 2016; Griffith and Glumb, 2016).

Studies on AMV extraction from humidity fields carried out by EUMETSAT in the past have illustrated the potential benefits of using optical flow methods on smooth water vapour fields, but they also pointed to important limitations of these methods. For example, the 2D framework of optical flow methods did not allow to correctly manage the frequent multilayer situations, or to properly consider the convection in cloudy areas. However, the 3D optical flow algorithm developed at INRIA/IRISA (Heas and Mémin, 2008), which is fed with several horizontal layers of atmospheric fields, should be more appropriate to extract dense wind fields for all the considered layers. This algorithm has been adapted at EUMETSAT to ingest IASI Level 2 temperature and humidity fields, and to extract dense wind fields from a pair of IASI data retrievals taken consecutively by the Metop-A and Metop-B satellites over high latitudes areas. Hautecoeur et al. (2016) presented the first preliminary results of this new development at the IWW13. A demonstrational product is going to be developed in the 2017 short-term perspective at EUMETSAT.

CONCLUSIONS

This paper gives a wide overview on the upcoming changes in the operational satellite configuration at EUMETSAT. These changes concern both geostationary satellites, with the decommissioning of Meteosat-7, and polar orbiting satellites, with the end of life of Metop-A. These initial changes are leading to orbit changes for other Meteosat satellites (Meteosat-8, Meteosat-9, Meteosat-10 and Meteosat-11) and will be followed by the commissioning of Metop-C.

This paper also summarizes the last recent changes implemented in AMV algorithms at EUMETSAT since IWW12 in 2014. Last MPEF Release 2.2 implemented in April 2016 includes several changes concerning the setting of the altitude in the AMV process. A more detailed description of the new method implemented to set the altitude of CS WV AMVs is given in this paper. Two new AMV products that extract AMVs from the AVHRR instrument have been developed and made operational since the IWW12. The Global AVHRR wind product has shown a positive impact on the forecast score in several NWP centres, especially due to its capability to fill the 40-60 degrees latitude band. The sustainability of this capability is now considered as a high priority in the EUMETSAT AMV strategy. Finally, the extraction of 3D winds from IASI L2 temperature and humidity fields has been investigated at EUMETSAT and preliminary results have been shown at the IWW13. Following the recently developed operational AIRS wind product at CIMSS (Santek et al., 2016), 3D winds retrieval sounds to be a very hot topic in the upcoming years.

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