EUMETSAT OPERATIONAL DUAL-METOP WIND PRODUCTS

Olivier Hautecoeur\textsuperscript{1,2}, Régis Borde\textsuperscript{2}, Marie Doutriaux-Boucher\textsuperscript{2}, Manuel Carranza\textsuperscript{3,2}

\textsuperscript{1} METIS S.A.S, France.
\textsuperscript{2} EUMETSAT, Germany
\textsuperscript{3} GMV Aerospace and Defence S.A., Spain

Abstract

EUMETSAT is currently deriving Atmospheric Motion Vectors (AMV) operationally from the satellite Metop over polar areas. The launch of Metop-B in 2012 enable to double the product frequency, extracting AMVs from both Metop-A and Metop-B satellite data. Moreover the tandem configuration with two satellites on the same orbital plane but with a phase difference provided an interesting opportunity to create global AMVs from Metop satellites with a significant overlap in imagery data.

Therefore the latest EUMETSAT AMV processors produce new dual Metop winds derived from a pair of Metop-A and Metop-B images. The temporal gap between the two images used for the tracking is about 50 minutes. The dual-Metop product has a global coverage, which allow a direct comparison with other AMVs derived from geostationary satellite.

The updates of the algorithm of winds extraction using Metop satellites will be presented together with the results of dual-Metop products validation. Inter-products consistency and statistics of Metop-A, Metop-B, and dual-Metop AMV products over Polar Regions are also discussed.

\textbf{Figure 1:} Example of dual Metop winds extracted over Europe the 25\textsuperscript{th} November 2013 at 09:58 UTC
INTRODUCTION

In 2012 EUMETSAT launched the Metop-B satellite, which took over primary operations in April 2013. The tandem configuration with the two Metop satellites in the same orbital plane provides an unique opportunity to create global AMVs from LEO satellites with a significant overlap in imagery data. The overlapping area seen consecutively by the two Metop satellites represents at the minimum half of the AVHRR swath width (~1000 km) at low latitude. This is an area large enough to extract wind information from consecutive AHVRR images. Figure 1 illustrates an example of dual Metop winds extracted over Europe area the 25th November 2013. Colour scale corresponds to the altitudes of the AMVs.

The AMV algorithm developed at EUMETSAT was adaptated to extract wind vectors from two consecutive images observed respectively by Metop A and Metop B satellites. Two complementary products are then extracted, one considering Metop A as the reference image and Metop B as the second image of the pair (noted dual-Metop A/B in the following), another one considering Metop B as the reference and Metop A as the second image of the pair (noted dual-Metop B/A). The temporal gap between the two consecutive images is equal to 46 min for the dual-Metop A/B product, and to 55 min for the dual-Metop B/A.

The dual-Metop winds algorithm is similar to the polar winds algorithm developed at EUMETSAT, which already used image pairs extracted from the same Metop satellite over polar areas. However, for dual Metop winds the consecutive AVHRR images are taken by the two different Metop satellites. The following common steps are performed to derive one single displacement vector: Target selection, Derivation of target displacement, Height assignment and Automatic quality control. The AMV extraction scheme uses the 91 levels forecast temperature profiles for height assignment.

The tracking of the targets is done using a classical cross correlation method. In order to replace the loss of the temporal consistency test between the two consecutive vectors obtained from image triplets, traditionally used when extracting winds from satellites, a second ‘reverse’ matching is made. In this, the initial target box used is the target box selected in the second image of the pair at the end of the first matching. The search box is then located at the initial position of the target box in the first image. The wind speed and direction extracted by this reverse tracking are compared to the first speed and direction estimated by the backward tracking using a vector consistency test [Holmlund 1998]. A poor quality index is set to the AMV when the two vectors are not in a good agreement, which means that the reverse tracking did not succeed in coming back to the initial position of the target box selected in the reference image.

The level of the tropopause is determined using the forecast fields, based on the World Meteorological Organization (WMO) definition of the tropopause. The altitudes of the AMVs are then set to an altitude comprised between the ground and the tropopause, avoiding the possibility to get wind vectors above the tropopause. The algorithm also checks if a temperature inversion layer exists in the corresponding forecast profiles interpolated at the AMV location. If a temperature inversion is found and if the retrieved temperature corresponds to that level, the altitude of the AMV is then set to the bottom of the inversion layer.

The HA is done using the CCC method (Borde and Oyama, 2008, Borde et al., 2014) which keeps a direct link between the tracking step and the calculation of the AMV altitude using the individual contribution to the cross correlation of each pixel in the target box (Büche et al., 2006). The CCC method uses normally the Cloud Top Height (CTH) calculated for each cloudy pixel, but such a product from AVHRR is currently not available for the winds processing. Therefore the AMV altitude is calculated as the average EBBT pressure of the pixels selected by the CCC method weighted by their individual contribution to the correlation. None of the semi-transparency correction methods usually applied in AMV algorithms, like water vapor intercept method (Schmetz et al., 1993) or CO2 slicing method (Menzel et al., 1993) can be used because there is no appropriate water vapor or CO2 channels on AVHRR instrument. The presence of IASI instrument on the same Metop satellite provides the possibility to use the IASI cloud top pressure product to set the dual Metop winds altitudes. However, the coarser sampling of the IASI footprints as compared to AVHRR does not cover the whole area seen by AVHRR.
instrument. This means that the feature tracked by the AMV algorithm does not always collocate with an IASI footprint, and this may be a source of error when using the IASI CTH product to setting the AMV altitude. In some cases the cloud layer seen by IASI footprint may be different to the one tracked using AVHRR images. Therefore a minimum distance threshold of 5km between the feature tracked and the IASI footprint is used to minimize the risk of error. The location of the feature tracked is determined by using the individual pixel contributions to correlation process of the CCC method. Furthermore it should be noted that the narrower swath width of IASI does not allow to apply an IASI height assignment over the full AVHRR domain.

PRELIMINARY RESULTS

Global coverage

Figure 2 shows the accumulated amount of AMVs and their average wind speed (Figure 3) for dual-Metop winds extracted on 25/04/2014. The quantities are averaged on a global equal-area grid with a bin size equal to 320x320 km$^2$. These plots illustrate the global coverage of the dual Metop wind products, allowing a homogeneous daily retrieval over the whole globe, including the Polar Regions. The AMV production is more important over polar areas because the Metop satellites fly over these areas every 100 minutes, and only twice per day over tropical areas.

![Figure 2: Accumulated amount of AMVs for dual-Metop winds extracted on 25 April 2014 (bin size: ~320x320 km$^2$).](image-url)
Figure 3: Averaged wind speed of dual-Metop winds on 25/04/2014 (bin size: ~320x320 km$^2$).

Statistics against Forecast fields

The table below presents the speed and direction global statistics of dual Metop winds (QI > 80) against forecast fields for December 2013. Statistics are split in four altitude levels as: all winds, high levels (above 400 hPa), mid levels (400-700 hPa) and low levels (below 700 hPa). Last columns show respectively the vector difference RMS, the mean forecast wind speed, and the NRMS estimated with and without the forecast consistency check. These statistics are preliminary results and based on the previous processor version (v2.3.2). Indeed, the global estimation hides important differences as function of the geographical areas like polar areas, tropics, mid-latitudes in northern and southern hemisphere, where very different types of clouds are considered.

<table>
<thead>
<tr>
<th>Dual Metop Winds against FC</th>
<th>Amount</th>
<th>Speed (m/s)</th>
<th>Direction (deg)</th>
<th>Vector difference RMS (m/s)</th>
<th>Mean fc wind speed (m/s)</th>
<th>NRMS</th>
<th>NRMS (without fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount</td>
<td>Bias</td>
<td>RMS</td>
<td>Bias</td>
<td>RMS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All levels</td>
<td>801 037</td>
<td>0.05</td>
<td>4.47</td>
<td>-11.11</td>
<td>40.20</td>
<td>5.90</td>
<td>16.54</td>
</tr>
<tr>
<td>High levels</td>
<td>301 688</td>
<td>-0.17</td>
<td>5.11</td>
<td>-5.68</td>
<td>22.31</td>
<td>7.09</td>
<td>27.04</td>
</tr>
<tr>
<td>Mid levels</td>
<td>408 439</td>
<td>0.45</td>
<td>4.95</td>
<td>-14.29</td>
<td>44.80</td>
<td>6.45</td>
<td>16.99</td>
</tr>
<tr>
<td>Low levels</td>
<td>90 910</td>
<td>0.03</td>
<td>2.93</td>
<td>-12.94</td>
<td>35.23</td>
<td>3.88</td>
<td>10.18</td>
</tr>
</tbody>
</table>

Comparison against Meteosat 10 AMVs

The global coverage of dual Metop winds allows a direct comparison with AMVs derived from geostationary satellites like Meteosat 10. Figure 4 shows scatter plots of respectively dual Metop winds speeds, directions and altitudes against collocated Meteosat 10 AMVs for the period November 2013 – January 2014. Collocations have been considered for QI > 80, horizontal distance smaller than 0.25 degree and a temporal gap smaller than 45 minutes. Results show a very good agreement between dual Metop winds and Meteosat 10 AMVs for speeds and directions. This means that the two
instruments detect the same motion at the same location and at the same time despite the difference of scaling extraction. Indeed MSG target box size is close to 80x80 km$^2$ when the AHVRR target box size is closer to 30x30 km$^2$. The scatter plot of the altitudes on Figure 4 show some differences especially at high levels where the dual Metop winds are found at lower altitude than corresponding MSG ones. The lack of water vapour channels on AVHRR instrument does not allow correcting the CTH retrieval for semi-transparent clouds. This is major difference between the two HA schemes that are used respectively for MSG and dual Metop AMV extraction algorithms.

Figure 4: Scatter plots of respectively dual Metop winds speeds, directions and altitudes against collocated Meteosat 10 AMVs for the period November 2013 – January 2014

Comparison of single Metop and dual Metop winds over polar areas

The current single Metop winds extracted over polar areas from the AVHRR instrument on Metop A or Metop B have a very long temporal gap of nearly 100 min between two consecutive images. This is clearly a weakness, which allows tracking only the most persistent clouds, and which makes the matching very difficult due to the cloud shape changes. The dual Metop winds extraction reduces the temporal gaps to 50 min and increase the overlapping area.

Filling the 50-70 deg latitude gap

Global coverage of dual Metop wind product obviously helps filling the gaps between 50 to 70° latitude north and south, where no wind observations are currently available for assimilation. Indeed the derivation of AMVs from geostationary satellites is done up to 55° latitude (45° S for GOES), and the assimilated MODIS polar winds extraction starts only above 70° latitude, leaving an area where no observations are extracted. This is very unfortunate because the polar jets associated to fast winds, are frequently located in these latitude bands. It is expected that the extraction and the assimilation of dual Metop AMVs in those regions will have a positive impact on the model forecast score.

Figure 5 shows the single (left) and dual (right) Metop wind speeds against corresponding forecast speeds for the period 22nd January to 5th February 2014. Only AMVs with QI > 80 have been considered. Dual Metop algorithm extracted more fast winds that have speed larger than 30 m/s, than single Metop algorithm. These fast speeds are mainly corresponding to target extracted in the polar jets, mainly located in this 50-70 deg latitude band. These winds are not detected by single Metop algorithm because the overlapping area is too small at these latitudes and it prevents the extraction of very fast winds.
This is well illustrated in Figure 6, which shows the amount of fast winds extracted over high latitude areas (latitude > 45°) on the 25th March 2014, Arctic is on the left side, Antarctic on the right side. Only winds having a QI larger than 60 and a wind speed greater than 30 m/s are plotted.

The fast speeds illustrated on Figure 7 describe very well the oscillation of the polar jets, especially over South Pole. The speeds extracted from dual Metop and single Metop algorithm are in good agreement, but the dual Metop algorithm extracts many more fast winds than single Metop algorithm, and at lower latitudes. Until now, the monitoring of the polar jets was not possible using the AMV derived from geostationary satellites, nor from MODIS, especially over Antarctic.

**AVHR_AMV_2D_20140325**

*platforms M01 and M02*

**Number of AMVs**

(speed > 30 m/s) and (QI > 60)

---

Figure 5: Single (left) and dual (right) Metop wind speeds against corresponding forecast speeds for the period 22nd January to 5th February 2014. Only AMVs with QI > 80 have been considered. The QI included FC check.

Figure 6: Dual Metop amount of winds over arctic (left) and Antarctic (right) extracted the 25th March 2014. Only AMVs with QI > 60 and speed > 30 m/s have been considered.
Figure 7: Single (top) and dual (bottom) Metop wind speeds over arctic (left) and Antarctic (right) extracted the 25th March 2014. Only AMVs with QI > 60 have been considered.

CONCLUSIONS AND OUTLOOK

This paper presents the new dual Metop AMV products developed at EUMETSAT. Preliminary results of the dual Metop AMV product are very encouraging and its assimilation in NWP models is expected to have positive impact. The global coverage allows getting homogeneous wind retrieval all around the world, including the polar regions. The temporal gap between the consecutive images used to derive AMVs over polar regions is divided by two when using the dual Metop configuration compared to single Metop extraction. This increase the amount of the wind vectors extracted over polar regions and allows to derive faster wind vectors.

Preliminary comparisons have been done against collocated Meteosat-10 AMVs and all the other satellite AMV products. An external validation study was compared the dual-Metop winds against several other winds observations, extracted especially from GOES, MTSAT, Meteosat, MODIS, and MISR. The study was realised by the TROPOS laboratory (Leipzig) and the results are presented in another paper.

The product is in pre-operational status and will be fully disseminated on September 2014.

REFERENCES

Borde, R., and R. Oyama, 2008: A direct link between feature tracking and height assignment of operational atmospheric motion vectors, proceeding from the 9th International Wind Workshop.


