LONG-TERM STATISTICS OF MSG WINDS

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Abstract

Wind providers do not only generate wind products on a regular basis, but also monitor continuously the quality of their products. This presentation will show several aspects of the quality development of the AMVs from Meteosat 8 and Meteosat 9 since 2004.

The internal quality index (QI) applied at EUMETSAT is a weighted average of the temporal vector consistency and the spatial vector consistency. These consistency measures, together with the forecast consistency, show a clear improvement of the AMV quality over the last 8 years.

The quality improvement is not always gradual but tends to appear in jumps, related to algorithm changes on the AMV processing chains. Most of the quality jumps are easy to link to one or two modifications in the wind derivation, but sometimes this is not straightforward. That is a consequence of the algorithm modification strategy, in which several changes and anomaly fixes are bundled together into one major software upgrade.

Another way to study the long-term characteristics of the winds is to look at collocations with radiosonde observations and with NWP model profiles. This reveals a remarkable correlation between the bias results of both collocation types, at least for high level winds. But the fact that the biases, although clearly correlated, have different values, indicates that bias results should be interpreted with care. Moreover, it seems to prove the point that a zero bias is not just hard to achieve, but also not necessarily the right objective.

DESCRIPTION OF THE OPERATIONAL MSG AMV PRODUCTS

The Meteosat Second Generation (MSG) satellites normally scan the full Earth disc every 15 minutes. AMVs are generated on an hourly basis using all four images within a given hour, as follows:

- First, an AMV Intermediate Product is generated from the first pair of images, by tracking cloud or water vapour features located in the first image onto the second one.
- Then, a second and third AMV Intermediate Products are generated from the subsequent pairs of images (second and third, and third and fourth images, respectively), using the tracers found in the first AMV Intermediate Product.
- Finally, an AMV Final Product is computed, which is an average of all three AMV Intermediate Products.

Additionally, one AMV BUFR Product is generated and disseminated to the users every hour, containing information extracted mainly from the hourly-generated AMV Final Product. These BUFR files add up to a total of around 770,000 winds per day on average, out of about 1,100,000 winds that are generated (only good winds are encoded in the BUFR file).

In Rapid Scanning Service (RSS) mode, currently provided by Meteosat 8, images are taken every five minutes, thus allowing generating an AMV Final Product and an AMV BUFR Product every 20 minutes, instead of every hour.
AMV products are currently generated for the visible 0.8 µm, water vapour 6.2 µm, water vapour 7.3 µm, infrared 10.8 µm, and HRVIS (High Resolution Visible) channels.

Each individual wind is stored at the location given by the longitude and latitude of the centre of the cloud or water vapour tracer in the first image. The main parameters that are stored for each particular AMV are the following:

- speed and direction;
- height (pressure);
- quality indicators.

The main users of the MSG AMV products include ECMWF and national weather agencies like Met Office, Deutsche Wetter Dienst and Météo France.

**Quality parameters**

The most important consistency checks currently derived are the following:

- Forecast consistency, whereby each AMV is compared to the corresponding forecast wind. The exact formula is given by:

\[ f_{\text{cons}} = 1 - \left[ \tanh \left( \frac{|\vec{S} - \vec{F}|}{\max(0.4 \cdot |\vec{S} + \vec{F}|, 0.01) + 1} \right) \right]^2, \]

where \( \vec{S} \) represents a computed wind vector, and \( \vec{F} \) represents a forecast wind vector.

- Spatial vector consistency, whereby each AMV is compared to other AMVs in the close vicinity. The exact formula is given by:

\[ s_{\text{cons}} = 1 - \left[ \tanh \left( \frac{|\vec{S} - \overline{\vec{S}}_n|}{\max(0.2 \cdot |\vec{S} + \overline{\vec{S}}_n|, 0.01) + 1} \right) \right]^3, \]

where \( \vec{S} \) and \( \overline{\vec{S}}_n \) represent two neighbouring wind vectors.

- Temporal vector consistency, whereby each AMV is compared to the corresponding one in the previous AMV Intermediate Product. The exact formula is very similar to that of the spatial vector consistency, just substituting \( \overline{\vec{S}}_n \) by \( \overline{\vec{S}}_m \), which represents the corresponding wind vector in the previous AMV Intermediate Product.

Two quality indicators are then derived from the aforementioned consistency checks, one including the forecast consistency and another one excluding it.

**AMV data in the EUMETSAT database**

Given the limitations in storage capacity, not all data are currently stored in the EUMETSAT database. Data are stored both from the AMV Final Products and AMV BUFR Products. Mainly the number of winds and the quality indicators are stored. Besides, the data are stratified according to:

- Height level (low, medium, high).
- Region (global, Northern hemisphere, Southern hemisphere, tropics, etc.).

Unfortunately, little information is stored concerning the height assignment method employed. With the newly developed CCC method in place, this will not be a matter of concern anymore.

Apart from the mentioned data, results from radiosonde collocations are stored in the EUMETSAT database, thus allowing assessing the impact of every algorithm change in the long-term statistics.
AMV monitoring

Within MPEF, AMV monitoring is performed by comparing the data with radiosonde observations, aircraft observations, and forecast models. The collocations with radiosonde observations are in accordance with the following CGMS recommendations:

- maximum horizontal separation of 150 km;
- maximum vertical separation of 25 hPa;
- maximum time difference of 90 minutes;
- one collocation per AMV only.

Additional monitoring is carried out at the NWP (Numerical Weather Prediction) SAF, as well as both at ECMWF and the Met Office: by comparing data with forecast models, by means of the NWP monitoring pages, and by the collaboration of a “wind fellow” at ECMWF (currently Kirsti Salonen).

LONG-TERM STATISTICS

In the present paper, long-term statistics of the MSG AMV products are presented. Due to the large amount of data accumulated over the years, daily averages of the main parameters are presented: number of winds and quality indicators. Besides, statistics from collocations with radiosonde observations are also presented: number of collocations and speed bias.

Apart from that, statistics from verification against the Met Office forecast model are presented (speed bias).

The following time periods have been considered for the statistical analysis:

- Meteosat 9: from March 2006 to February 2012.

Number and quality of the MSG AMVs

Figure 1 shows the total number of winds per AMV Final Product for the infrared 10.8 µm channel. Figure 2 represents, correspondingly, the overall quality excluding forecast for the same channel. The thin vertical lines represent all major algorithm changes carried out within the MSG MPEF. The orange dotted vertical line represents the start of the operational phase of Meteosat 9.

![Figure 1: Number of winds per AMV Final Product, IR 10.8 µm channel.](image)

It is sometimes easy to relate a particular MPEF release or algorithm change to the corresponding
change in the AMV statistics (particularly, the number of winds and the quality). However, unfortunately this is not always the case.

Around January 2005, for instance, a series of changes in the height assignment and quality control processes led to a slight decrease in the total number of winds and a significant increase in the overall quality (roughly from 60% to 70%).

On the other hand, around April 2007 a series of changes in the height assignment process took place, together with an increase of the Earth disc coverage, leading to a significant increase in the total number of winds and a neutral impact on the overall quality.

Moreover, around January 2009 a series of minor changes were implemented in the AMV algorithm, leading to both a significant decrease in the number of winds and a significant increase in the overall quality (roughly from 70% to 85%).

Figure 3 represents the forecast consistency (upper left corner), temporal vector consistency (upper right corner), spatial vector consistency (lower left corner), and overall quality including forecast (lower right corner) for the infrared 10.8 µm channel.

The effect of the first and third aforementioned algorithm changes (namely, those on January 2005
and January 2009, respectively) can be noticed in all four graphs. On the contrary, the effect of the second algorithm change (that on April 2007) cannot be appreciated.

It can be appreciated that the overall quality including forecast is always smaller than the overall quality excluding forecast. This is due to the fact that the forecast consistency is in general rather low, usually between 50% and 60%. The temporal vector consistency and the spatial vector consistency usually range between 70% and 80%.

Figure 4 represents the total number of winds per AMV Final Product for the water vapour 6.2 µm channel. Around October 2009 an algorithm change was introduced in order to solve an anomaly, so that more winds could be computed over vast opaque cloud systems. The result, as expected, was a significant increase (around 10%) in the total number of winds. This change also resulted in a small drop in the average AMV pressure, and a neutral impact in the average AMV speed.

Around April 2006 an anomaly was detected in the water vapour 6.2 µm channel statistics, due to which the number of winds computed by Meteosat 8 and Meteosat 9 were significantly different. The reason for this misbehaviour was the increased low frequency noise in two of the three 6.2 µm detectors on board Meteosat 9, which resulted in a noticeable striping of the image. Although the root cause for this problem has never been found, corrections were implemented in the Image Processing Facility (IMPF) around November 2006, which completely solved the issue.
Figure 5 and Figure 6 represent the overall quality excluding forecast for the water vapour 6.2 µm channel and the water vapour 7.3 µm channel, respectively. The aforementioned anomaly for the 6.2 µm channel can be clearly appreciated in Figure 5. Besides, Figure 5 shows a clear annual cycle, which is not evident in Figure 6.

A possible explanation of the annual cycle observed for the water vapour 6.2 µm channel is that in the tropical areas AMVs are mainly derived from convective cells that do not meet the assumption of passive cloud tracers, thus resulting in lower vector consistencies (both temporal and spatial). The proportion of tropical winds peaks around mid-summer, whilst it is lowest around mid-winter, hence providing the characteristic annual pattern.

Figure 7 shows the distribution of medium and high level winds in March 2010 (left hand graphs) and July 2010 (right hand graphs) for the WV 6.2 µm channel, as presented in the NWP SAF pages.
The upper graphs show the distribution of winds as a function of latitude and longitude. The lower graphs show the wind height as a function of latitude. The concentration of high level winds is clearly larger around mid-Summer in the tropical areas, whereas it decreases around mid-Winter.

**Collocations with radiosonde observations and the Met Office forecast model**

Figure 8 shows long-term MSG collocation statistics both with radiosonde observations (red curve) and the Met Office forecast model (blue curve) for the water vapour 6.2 µm channel high winds in the Northern Hemisphere. The speed biases are clearly correlated, something especially notable since the algorithm change that took place around October 2009 (which led to a higher amount of winds over large opaque cloud systems, with a slight increase in the average pressure, as stated above for Figure 4).

![Figure 8: Speed bias for collocations with radiosonde observations (red curve) and the Met Office forecast model (blue curve), WV 6.2 µm channel, high winds, Northern Hemisphere.](image)

This phenomenon can be seen for all high winds both in the water vapour and infrared channels, also in the Southern hemisphere, but not in the tropical areas.

Figure 9 represents the radiosonde wind speed as a function of the height (pressure) on 9 August 2011 at 0:00 UTC in Dakar (red curve), which is located at 15º North (extra-tropics), and Cape Town (blue curve), which is located at 36º South (tropics). It can be noted that the effect of the aforementioned AMV pressure drop on the speed bias depends mainly on the level and magnitude of the wind shear: it is small in the tropical areas, and potentially larger in the extra-tropics.

![Figure 9: Radiosonde wind speed as a function of the height (pressure) on 9 August 2011 at 0:00 UTC in Dakar (red curve) and Cape Town (blue curve).](image)
Figure 10 shows long-term MSG collocation statistics both with radiosonde observations (red curve) and the Met Office forecast model (blue curve) for the visible 0.8 µm channel low-level winds in the tropical areas. In this case, the speed biases are not as clearly correlated as for the water vapour 6.2 µm channel. A negative radiosonde bias is found for all low-level winds and most channels (visible, infrared, high resolution visible), mainly over the tropics, but also in the Southern hemisphere. The reason for this is not clear, but the majority of those AMV heights result from the Inversion Height Assignment method.

CONCLUSIONS

The main conclusion that can be extracted from the long-term statistics of MSG winds is that there is a gradual improvement in the overall quality of the various AMV products. This is a consequence of the gradual improvement of the different individual consistency checks (forecast consistency, spatial vector consistency, and temporal vector consistency).

Besides, by plotting long-term series of data, the impact of the various algorithm changes and MPEF releases can be visualized. As mentioned above, sometimes this is not easy, but in general there is a clear correlation between a given algorithm change and the corresponding impact in the statistics.

The information that is currently stored in the EUMETSAT database is very limited, mainly because there is hardly any information concerning the wind vector height assignment. This will be improved in the near future, with the inclusion of the relevant parameters.

REFERENCES


