CGMS-XXX EUM-WP-09
Prepared by EUMETSAT
Agenda Item: III.4
Discussed in Plenary

# OPERATIONAL AMV PRODUCTS DERIVED WITH METEOSAT-6 RAPID SCAN DATA


EUMETSAT started its Rapid Scanning Service on September 18th 2001, providing images from Meteosat-6 every ten minutes for a geographical area that covers a latitude range from approximately 10° N to 70° N. Since April 2002, EUMETSAT has generated wind products every 30 minutes, using non-overlapping triplets of rapid scan images.

This paper discusses EUMETSAT experiences with rapid scan winds and shows results from comparisons with operational, three-hourly winds derived from Meteosat-7 imagery. Although the comparison is based on a limited period of four months, it reveals some significant differences and agreements between both types of winds, which are summarised in the paper.

# OPERATIONAL AMV PRODUCTS DERIVED WITH METEOSAT-6 RAPID SCAN DATA

**Arthur de Smet**
EUMETSAT
Am Kavalleriesand 31, D-64295 Darmstadt, Germany

***ABSTRACT***

EUMETSAT started its Rapid Scanning Service on September 18th 2001, providing images from Meteosat-6 every ten minutes for a geographical area that covers a latitude range from approximately 10° N to 70° N. Since April 2002, EUMETSAT generates wind products every 30 minutes, using non-overlapping triplets of rapid scan images.

The wind derivation system that is used to generate these so-called rapid scan winds, does not differ from the operational system that is responsible for generating the Meteosat-7 winds, ignoring the latitudinal extension and arrival frequency of the underlying images.

This paper will discuss our experiences with rapid scan winds and will show results from comparisons with the operational, three-hourly winds derived from Meteosat-7 imagery. Although the comparison is based on a limited period of four months, it reveals some significant differences and agreements between both types of winds, which can be summarised as follows:

Rapid scanning produces significantly – i.e. 20 % to 30 %- more high-quality winds for the high-resolution visible channel.

Rapid scanning produces more high-quality winds for the infrared channel and low resolution visible channel.

With respect to the water-vapour channel, rapid scanning produces more high-quality winds derived from cloud tracers, but significantly less winds derived from clear-sky tracers.

Rapid scanning produces slightly – i.e. approximately 10 %- more high-quality winds for the high-resolution water vapour wind product.

The quality of the rapid scan winds shows less variation, with respect to time, than the quality of the operational winds.

The forecast consistency of the rapid scan winds is slightly higher than the forecast consistency of the operational winds. The only exception is the clear-sky water vapour winds, in which case rapid scanning has a small negative impact.

## 1 Introduction

EUMETSAT's Rapid Scanning Service started operation on September 18th 2001, providing images from Meteosat-6 every ten minutes for a geographical area that extends from Cape Verde and Yemen in the south up to Iceland in the north, roughly corresponding to a latitudinal range of 10° N to 70° N. Figure 1 shows an example IR channel image for the rapid scanning area.

Due to the characteristics of the satellites involved and their radiometers, the only difference between full-earth scanning and rapid scanning is the number of scan lines per image and, in direct relation to that, the number of images per hour. Meteosat-6 generates three rapid scan images per channel every 30 minutes, each having approximately 833 scan lines (1667 scan lines in the case of the visible channel images), whereas Meteosat-7 generates one image per channel every 30 minutes, having exactly 2500 scan lines (5000 scan lines in the case of the visible channel images). The pixel resolution and the number of pixels per scan line are identical for rapid scanning and full-earth scanning.

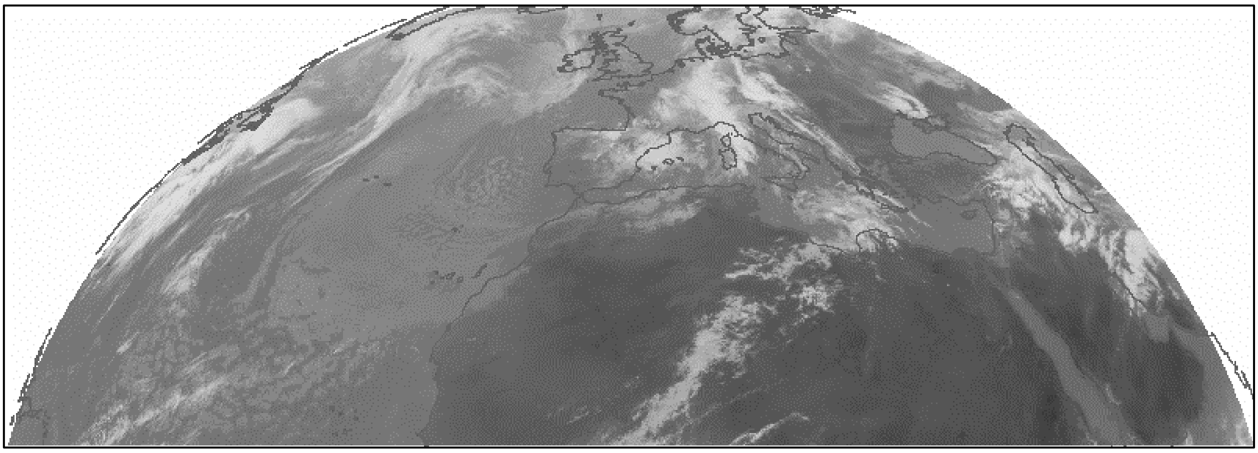

**Figure 1. Example rapid scan image: Infrared image of 3 May 2002, 0845 UTC.**

## 2 Operational wind derivation from METEOSAT 7 images

The Meteorological Product Extraction Facility at EUMETSAT currently generates the following operational wind products:

Cloud motion winds (CMW), derived from 5.0 km resolution imagery in all three Meteosat channels. These are distributed on the GTS in SATOB format at 00Z, 06Z, 12Z, and 18Z, and in standard BUFR format every 90 minutes.

High resolution visible winds (HRV), derived from full resolution, i.e. 2.5 km, visible images. These are distributed on the GTS in SATOB at 06Z, 12Z, and 18Z, and in standard BUFR format every 90 minutes between 06Z and 19.30Z.

Clear-sky water vapour winds (WVW), derived from water vapour channel images in cloud free areas. These are distributed on the GTS in standard BUFR format every 90 minutes.

High resolution water vapour winds (HWW), derived from water vapour channel images in cloudy areas, using a high resolution processing grid. These are distributed on the GTS in standard BUFR format every 90 minutes.

The wind derivation technique is fundamentally the same for all wind products. Each wind derivation cycle requires a triplet of consecutive images as basic input data. Prior to the actual wind processing, each image will be chopped into rectangular areas of 32 times 32 pixels, the so-called segments or target areas. The first step in the wind derivation is to identify patterns, or “tracers”, for each segment in the middle image. After localising the corresponding patterns in both the first and third images, two wind vectors can be derived from the tracer displacements. In the following step, these two wind vectors are combined into a single wind vector, and a height is assigned to it. At the core of the pattern localisation algorithm is a cross-correlation calculation. In order to find a pattern in the first or third image that corresponds to a given pattern in the middle image, one has to look for peaks in the correlation surface.

In the final step, the automatic quality control (AQC) calculates a number of consistency indicators for the extracted wind, and combines these as a weighted mean into an overall reliability indicator, the so-called Quality Indicator (QI). Each consistency indicator is a number between zero and one, where zero represents complete lack of consistency and one implies maximum consistency. The same principle applies to the Quality Indicator.

The following consistency indicators are based on the comparison of the two individual wind components within one derivation cycle:

Vector consistency,

Direction consistency,

Speed consistency.

Other consistency indicators, which we consider in this study, are:

Spatial consistency, which is a combination of a spatial wind consistency and a spatial height consistency. The former compares each wind vector to the wind vectors in adjacent segments, the latter compares the assigned height of each wind to the assigned heights in adjacent segments. If the difference in the assigned heights exceeds a predefined threshold value, the spatial wind consistency will be set to zero.

Forecast consistency, which compares each wind to the forecast wind interpolated to the same pressure level.

The final quality indicator (QI) is a weighted average of five consistency values, and is defined as follows:

$$QI = (w_d \bullet \text{direction consistency} + w_s \bullet \text{speed consistency} + w_v \bullet \text{vector consistency} + w_f \bullet \text{forecast consistency} + w_{sp} \bullet \text{spatial consistency}) / (w_d + w_s + w_v + w_f + w_{sp})$$

The weight factors are 2.0 for the spatial consistency ($w_{sp}$), 0.0 for the forecast consistency ($w_f$), and 1.0 for the other consistencies.

For a more detailed overview of the current status of the EUMETSAT wind products, refer to Rattenborg (2000).

## 3. Wind derivation based on rapid scan images from Meteosat 6

Since April 2002, EUMETSAT generates wind products for the rapid scan area every 30 minutes, derived from the rapid scan imagery from Meteosat 6. The actual wind product types are the same as the operational ones, as described in the previous section.

The wind derivation technique is identical to the one applied to the operational services. The only differences are the source of the images, their geographical coverage, and their temporal resolution.

Table 1 summarises these differences.

| Characteristic | Operational winds | Rapid-scan winds |
|---|---|---|
| Data source | Meteosat 7 | Meteosat 6 |
| Coverage | Global | Appr. 10 – 70 degrees North |
| Temporal resolution of imagery | 30 minutes | 10 minutes |
| CMW Product generation | Every 90 minutes | Every 30 minutes |
| WVW Product generation | Every 90 minutes | Every 30 minutes |
| HRV Product generation | Every 3 hours between 06Z and 18Z | Every 30 minutes between 06Z and 20Z |
| HWW Product generation | Every 90 minutes | Every 30 minutes |

**Table 1. Differences between operational full-earth wind processing and rapid scan wind processing.**

## 4. Comparison between rapid scan winds and Meteosat 7 winds

The most straightforward way to validate the rapid scan winds, and the one adopted for this presentation, is to make a direct comparison between the rapid scan winds and the operational winds. The comparison period runs from April 3$^{rd}$ to August 18$^{th}$, but contains several gaps. For

a sound statistical test one should consider a much longer period, preferably covering all seasons and a large number of different atmospheric circulation types.

But significant differences and agreements between both types of winds should also be evident in a limited sample of comparisons.

We have compared the following characteristics of the rapid scan and the operational winds:

- The total number of winds derived.

- The number of very good winds, i.e. those winds having a final quality (QI) of 0.90 or higher.
- The number of reasonable winds, i.e. those winds having a final quality (QI) of 0.70 or higher.
- The number of poor winds, i.e. those winds having a final quality (QI) below 0.30.
- The average consistency values for: vector, forecast, spatial, temporal, direction, and speed consistency.
- The average final quality, or QI.

For each comparison, we took the data from one operational wind product and compared these directly to the data from the rapid scan wind product that was closest in terms of attribution time. As a consequence, at least two thirds of all rapid scan wind products are not taken into account in the comparison. With respect to the HRV winds, we only considered the winds generated for 09, 12, 15, and 18 UTC.

Table 2 shows the total number of winds generated, along with the number of very good winds (QI = 0.9), reasonable winds (QI = 0.7), and poor winds (QI < 0.3).

| Wind product and source | Total number of winds | Number of winds, QI = 0.9 | Number of winds, QI = 0.7 | Number of winds, QI < 0.3 |
|---|---|---|---|---|
| CMW, rapid scan | 1243 ± 169 | 320 ± 82 | 700 ± 130 | 123 ± 25 |
| CMW, operational | 1224 ± 176 | 259 ± 79 | 631 ± 126 | 152 ± 44 |
| WVW, rapid scan | 586 ± 84 | 30 ± 14 | 114 ± 36 | 191 ± 44 |
| WVW, operational | 562 ± 98 | 48 ± 31 | 186 ± 71 | 96 ± 32 |
| HRV, rapid scan | 615 ± 252 | 507 ± 236 | 565 ± 249 | 5 ± 5 |
| HRV, operational | 600 ± 243 | 421 ± 225 | 498 ± 237 | 26 ± 17 |
| HWW, rapid scan | 1920 ± 244 | 360 ± 101 | 810 ± 110 | 525 ± 154 |
| HWW operational | 2026 ± 324 | 327 ± 96 | 743 ± 117 | 743 ± 232 |

**Table 2. Number of generated winds: rapid scan winds versus operational winds. The numbers shown represent average values and standard deviations.**

Although the total number of winds generated by the rapid scan wind derivation is roughly the same as the number for the operational one, there are some significant differences in the proportion of high and low quality winds. The rapid scan HRV winds perform clearly better than the operational ones, yielding roughly 20-30 % more very good (QI = 0.9) and reasonable winds (QI = 0.7), whereas the number of bad winds (QI < 0.3) has dropped. The CMW winds show a very similar picture, although the improvement is less significant. With respect to HWW, the most striking feature is the almost 30 % reduction in the number of bad winds; the number of good winds is up by approximately 10 %. The clear-sky water vapour winds (WVW) are the obvious losers in this comparison game: the number of good winds is 30 % lower in the case of rapid scanning, whereas the number of bad winds is even 90 % higher.

Figure 2 shows the number of very good and bad HRV winds as a function of time, both for the rapid scan and the operational case. The number and the quality of the rapid scan winds are consistently larger than those of the operational winds. Moreover, the QI values of the extracted winds show less variation in the rapid scan case. In general, one can conclude that the positive impact of rapid scanning is most dramatic when the number and quality of operational winds are below their average values.

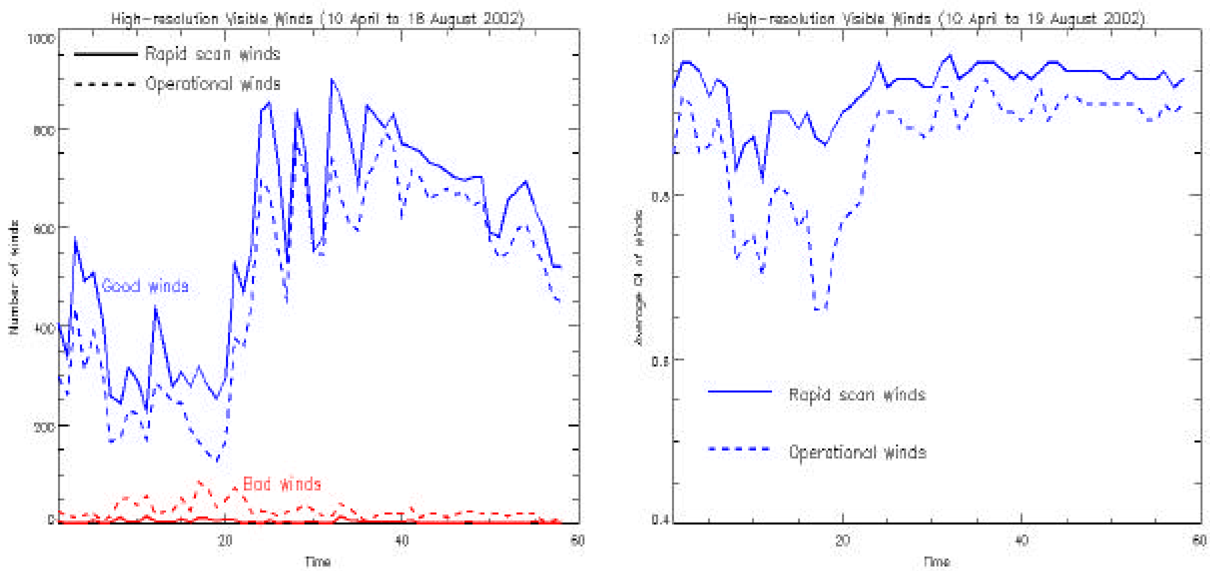


**Figure 2. Number and quality of derived high-resolution visible winds as a function of time. The left picture shows both the number of very good winds (QI ³ 0.9) and the number of poor winds (QI < 0.3). The right picture shows the average Quality Indicator (QI) of the extracted winds. The numbers on the horizontal axis represent the comparison index number.**

Table 3 shows the QI values for the winds, as well as the values for the individual consistency checks. These allow us to make some interesting observations. The first one is the bad performance of the clear-sky water vapour winds (WVW) in the rapid scan case. In terms of vector, direction and speed consistency these winds score much worse than the operational winds; the spatial and forecast consistencies do not differ much. The CMW winds show a slight improvement in all consistency values for rapid scanning, mainly for the vector and speed consistency. Not surprisingly, the impact of rapid scanning is largest for the high-resolution winds. All consistency values related to the rapid scan winds are clearly higher than those for the operational winds. HRV, in particular, shows large increases in each of its consistency values, except the forecast consistency, which performs only slightly better.

| Wind product and source | QI | Spatial cons. | Vector cons. | Direction cons. | Speed cons. | Forecast cons. |
|---|---|---|---|---|---|---|
| CMW, rapid scan | 0.69 ± 0.03 | 0.63 ± 0.03 | 0.78 ± 0.03 | 0.88 ± 0.02 | 0.76 ± 0.03 | 0.50 ± 0.04 |
| CMW, operatnl. | 0.65 ± 0.04 | 0.61 ± 0.03 | 0.72 ± 0.05 | 0.86 ± 0.03 | 0.70 ± 0.05 | 0.48 ± 0.06 |
| WVW, rapid scan | 0.45 ± 0.04 | 0.56 ± 0.04 | 0.35 ± 0.06 | 0.57 ± 0.05 | 0.39 ± 0.05 | 0.28 ± 0.03 |

| | | | | | | |
|---|---|---|---|---|---|---|
| WVW, operatnl. | 0.54 ± 0.05 | 0.57 ± 0.07 | 0.54 ± 0.06 | 0.75 ± 0.05 | 0.54 ± 0.05 | 0.30 ± 0.05 |
| HRV, rapid scan | 0.92 ± 0.05 | 0.97 ± 0.04 | 0.87 ± 0.07 | 0.93 ± 0.05 | 0.87 ± 0.06 | 0.63 ± 0.18 |
| HRV, operatnl. | 0.85 ± 0.08 | 0.92 ± 0.06 | 0.76 ± 0.11 | 0.86 ± 0.08 | 0.78 ± 0.10 | 0.61 ± 0.16 |
| HWW, rapid scan | 0.56 ± 0.05 | 0.64 ± 0.05 | 0.50 ± 0.06 | 0.64 ± 0.06 | 0.50 ± 0.05 | 0.44 ± 0.07 |
| HWW operatnl. | 0.50 ± 0.07 | 0.55 ± 0.06 | 0.45 ± 0.07 | 0.58 ± 0.07 | 0.47 ± 0.06 | 0.40 ± 0.07 |

**Table 3. Quality and consistency indicators for rapid scan and operational winds. The numbers shown represent average values and standard deviations.**

These results are in reasonable agreement with those from previous studies on rapid scanning. In general, the number and quality of winds increases with increasing spatial resolution and decreasing temporal resolution. Velden, who studied the optimal temporal resolution for wind derivation from the GOES-10 image data, found the following optimum time intervals (Schmetz et al., 2000):

for 1 km resolution VIS images: 5 minutes.

for 4 km resolution IR images: 10 minutes.

for 8 km resolution WV images: 30 minutes.

Compared to these numbers, our rapid scan HWW winds perform surprisingly well. Tables 2 and 3 suggest these winds to perform better than the operational ones, which implies that for the HWW winds the optimum time interval is close to 10 minutes, not 30 minutes. However, one should realise that the HWW winds are derived from cloudy tracers only, not from clear-sky tracers. On the other hand, the poor performance of the rapid scan, clear-sky water vapour winds (WVW) is in much closer agreement with Velden's findings. This suggests that rapid scanning affects the derivation of water vapour winds in two different ways:

it leads to slightly more high-quality winds derived from cloudy tracers,

it leads to significantly less high-quality winds derived from clear-sky tracers.

Figure 3 shows the merits of rapid scanning in a more qualitative way, allowing for a less objective comparison. The left figure shows the operational infrared winds (i.e., CMW-IR) over the middle and south-eastern part of Europe, whereas the right figure shows the corresponding rapid scan winds.

A clear and convincing picture emerges from this comparison as well. The rapid scan winds reveal a wave-like structure over south-eastern Europe, which is much less pronounced in the operational case. Rapid scanning apparently results in an increase in the number of high-quality derived winds. One should be careful though with exaggerating the differences. The true picture is obscured by the presence of spurious winds, which are more numerous in the operational case (left picture). If we would remove all bad winds from both pictures, the differences would be less impressive.

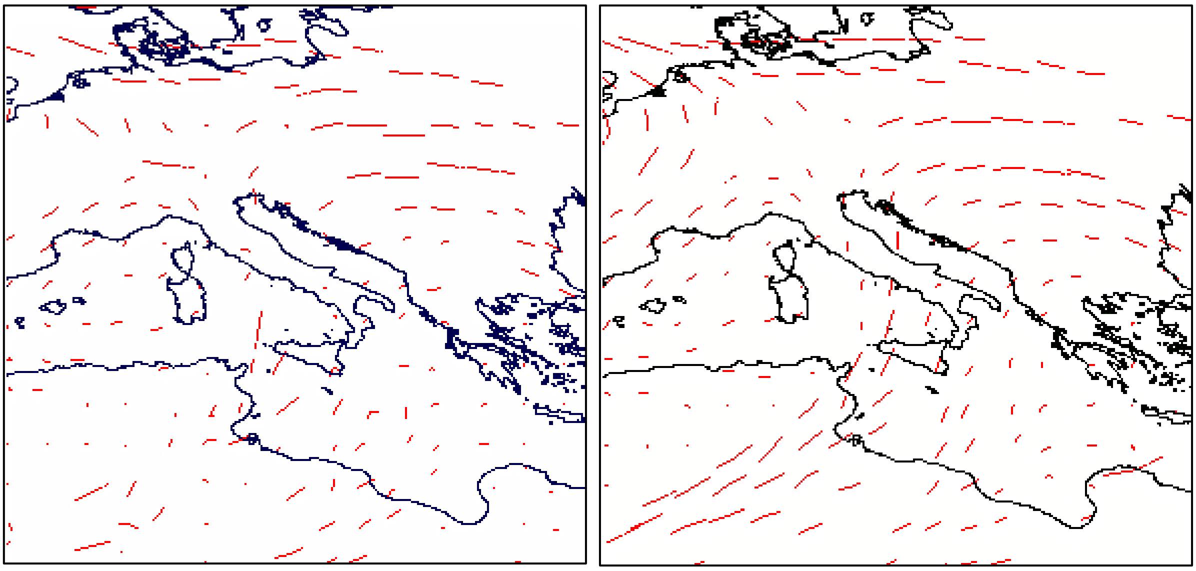

**Figure 3. Infrared winds (CMW-IR) derived from Meteosat imagery, March 6th 2002, 0500 UTC. The rapid scan winds (right figure) clearly have a more coherent structure than the operational winds (left figure).**

A potentially useful application of rapid scan winds is the derivation from them of the horizontal divergence. Schmetz et al. (2000) did an experiment for tropical Africa, deriving wind fields and the associated horizontal divergence from 7.5 minute interval rapid scan imagery. Using the relationship between horizontal wind divergence and the change of the vertical velocity with height, they estimated the mean vertical velocity in a large convective system. This resulted in realistic values of about 0.5 m/s at 300 hPa. The vertical velocity derived from the nominal 30 minute scans were smaller by about 15%.

This suggests that rapid scan winds can be useful in the data assimilation of mesoscale models, improving the strength and location of convection areas.

## 5. Summary

This paper contains an overview of the experiences with rapid scan winds at EUMETSAT, which are derived from the Meteosat 6 rapid scan imagery. It shows results from comparisons with the operational, three-hourly winds derived from Meteosat-7 imagery. The main conclusions are:

Rapid scanning produces significantly – i.e. 20 % to 30 %- more high-quality winds for the high-resolution visible channel.

Rapid scanning produces more high-quality winds for the infrared channel and low resolution visible channel.

With respect to the water-vapour channel, rapid scanning produces more high-quality winds derived from cloud tracers, but significantly less winds derived from clear-sky tracers.

Rapid scanning produces slightly – i.e. approximately 10 %- more high-quality winds for the high-resolution water vapour wind product.

The quality of the rapid scan winds shows less variation, with respect to time, than the quality of the operational winds.

The forecast consistency of the rapid scan winds is slightly higher than the forecast consistency of the operational winds. The only exception is the clear-sky water vapour winds, in which case rapid scanning has a small negative impact.

## REFERENCES

Rattenborg, M., 2000: Operational Meteosat wind products towards MSG, *Proceedings of the Fifth International Winds Workshop*, Lorne, Australia, 28 February – 3 March 2000. EUM P28, Published by EUMETSAT, D-64295 Darmstadt, 37-45.

Schmetz, J., K. Holmlund, H.P. Roesli, and V. Levizzani, 2000: On the Use of Rapid Scans, *Proceedings of the Fifth International Winds Workshop*, Lorne, Australia, 28 February – 3 March 2000. EUM P28, Published by EUMETSAT, D-64295 Darmstadt, 227-234.