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REPORT ON THE USE OF RAPID SCANS FOR WIND DERIVATION

This paper provides a report on the activities undertaken at EUMETSAT to exploit the feasibility of using rapid scan images operationally for improved Atmospheric Motion Vector extraction. *(Action 27.20)*

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1 INTRODUCTION

This paper provides a report on the activities undertaken at EUMETSAT to exploit the feasibility of using rapid scan images operationally for improved Atmospheric Motion Vector (AMV) extraction.

The paper is divided in three parts. Part 1 summarises the experience using rapid scan images for AMV extraction. Part 2 summarises the result of studies conducted using Meteosat-6 Rapid Scan image data from 1999. Part 3 presents the Rapid Scanning Pre-operational Trial conducted by EUMETSAT in August-September 2000.

2 EXPERIENCE WITH WIND EXTRACTION FROM RAPID SCAN IMAGES

Work on rapid scans from geostationary satellites has been mainly conducted by researchers in the US and by the Japan Meteorological Agency (JMA). Europe did perform rapid scans with Meteosat-1 in support of ALPEX (Alpine Experiment) in 1979, however it seems that the value of those efforts was never realised.

Hamada (1983) was among the first to suggest intervals of 15 minutes to better cope with the short lifetime and rapid deformation of cloud targets. Shenk (1991) substantiated this suggestion and provided a graphical presentation of the percent of useful tracers as a function of time interval between GOES (VAS) images. He argued that the optimum time interval for the tracking of cumulus type clouds over land is between 10 minutes and less than one minute, whereas displacement of high level cirrus clouds is fairly well depicted by the standard imaging interval of 30 minutes.

Other studies corroborate the suggestion by Shenk (1991). Uchida et al. (1991) who studied low-level cloud motion winds around typhoons. They obtained winds of higher spatial density and closer to the typhoon centre when using 7.5 and 15 minutes as imaging intervals as opposed to 30-minute intervals. The 15-minute interval provides winds outside the 400 km radius from the typhoon centre whereas for the 30-minute interval the distance is 500 – 600 km. With 7.5 minute-intervals wind can be derived to a 200 km radius. The increase of low-level wind speed with proximity to the typhoon centre is also well depicted, as well as the increase from about 25 – 30 kts at 800 km distance to 55 kts at 200 km distance from the centre.

It is important to mention that the Japan Meteorological Agency (JMA) makes a special effort to operationally derive low-level winds in the vicinity of typhoons (e.g. Takata, 1993). The cloud motion winds are used in the numerical analysis over the typhoon area and for the prediction of gale-force area winds by the forecasting division of JMA.

In this context it interesting to note that the 3rd International Winds Workshop (Schmetz et al., 1997) recommended that research modes of using satellites should be considered for quasi-operational application. The JMA practice to use 15-minute imagery to derive winds near typhoons was mentioned as a good example how research modes could soon become operational practice.

Work in the US on rapid scans started already in the 1970s. Rodgers et al. (1979) showed that high spatial resolution and short imaging intervals increase the number of low-level winds around a hurricane. The hypothesis of the work of Rodgers et al. (1979) was that low-level clouds around tropical storms are too short-lived to be trackable with standard 30 (or 15) minute scan intervals. They derived cloud-tracked wind fields at high (200 hPa) and low altitudes (900 hPa) from rapid scans with SMS 2 at 7.5 minute intervals and with GOES-1 at 3 minute intervals, respectively, around tropical cyclones. The visible channel was used with spatial resolutions of 1, 2, 4 and 8 km. Those wind fields were compared with wind fields from 15 and 30 minute intervals: The result was that 10 (5) times as many clouds could be tracked with the rapid scans in comparison to the 30 (15) minute interval scans. They also demonstrate that the high temporal resolution necessitates a higher spatial resolution in order to get optimum results. A 2 km resolution was found adequate for low-level clouds over water. Generally, rapid scan full-resolution infrared and visible images minimised the ‘incorrect winds’ from tracking cloud elements which propagate by growing on one side and dissipating on the other side. Notable is also that the wind fields of Rodgers et al. (1979) had been validated with near simultaneous aircraft measurements.

A similar study by Johnson and Suchman (1980) deriving winds from SMS in 1978 with 30, 15, 6 and 3 minute intervals concludes that nearly 10 times as many low level cloud winds from 3 minute scans as compared to the 30 minute scans in cases of short lived clouds. They recommend scan interval of 6 – 10 minutes for the tracking of low-level clouds.

Recently Velden et al. (2000) have studied the optimal time lapse between images for different spectral channels on GOES-10 for the derivation of winds. Generally speaking the number of winds, and quality too, increases with decreasing time intervals and increasing resolution; they found:

i) The optimum time interval for VIS images with 1 km resolution is 5 minutes
ii) For IR window images with 4 km resolution it is 10 minutes
iii) For water vapour images with 8 km resolution it is 30 minutes.

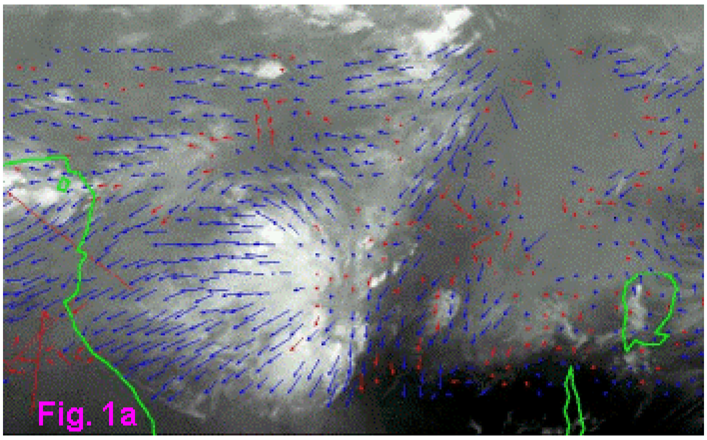
3 RAPID SCANS WITH METEOSAT-6 DURING 1999

In preparation for and during the Mesoscale Alpine Programme (MAP, Levizzani et al. 1999) several rapid scans have been taken with Meteosat-6. Here we report on two cases of rapid scan images from the water vapour channel (WV: 5.7 – 7.1 µm) consisting each of three images: i) a rapid scan of the tropical belt from about 6.7° S to 9.5° N with 7.5 minute intervals and ii) a rapid scan over the Alpine region from about 40.6° N to 53.5° N with 5 minute intervals. In both cases the rapid scan wind fields are compared with wind fields from standard intervals of 30 minutes. Winds have been derived using the Meteosat Second Generation (MSG) prototype algorithm described in more detail by Holmlund (2000). The vectors are derived with a cross-correlation technique using a 24x24 pixel template and searching in a area of 16x16 pixels. Overlap has been confined to 30% of the area in order to avoid tracking of the same feature. The wind fields are quality controlled following Holmlund (1998) and vectors with are quality indicator (QI) higher than 0.2 are retained.

An attempt is also made to derive wind divergence from the vector fields. Earlier work (e.g. Schmetz et al., 1995) has shown that it is difficult to infer divergence fields directly from the wind vectors since the differentiation amplified the noisy character of the wind field. Therefore a QI-weighted Barnes filter is run over the wind vectors before computing the divergence with finite differences over areas of 3x3 pixels as described in Holmlund (2000). The idea behind the derivation of divergence fields is to test whether this quantity can be derived in a sensible manner from rapid scans. If yes, the wind data could be used in the data assimilation for a numerical model in order to create upper level divergence fields and hence initiate model convection in the correct geographical location.

– Tropical Rapid Scan

Figure 1 a and 1 b show the wind fields derived for the tropical Africa from three images with 7.5 minute intervals and 30 minute intervals, respectively. While both images indicate that the outflow of this large convective system of several hundred kilometres diameter can be derived with both scan intervals, it is clearly discerned that the rapid scan provides a more consistent wind field.



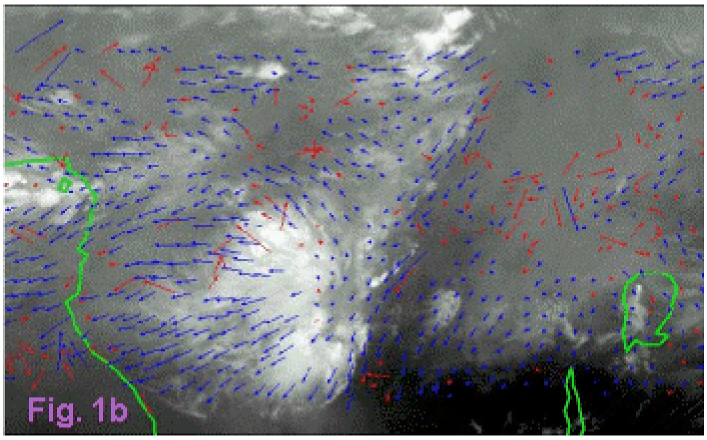


Figure 1: Wind fields derived from a triplet of WV images over tropical Africa (about 6.7° S to 9.5° N and 6.6° E to 36.1° E) from rapid scans with 7.5 minute intervals (Figure 1a) and nominal 30 minute scans (Figure 1b)

A study is currently being conducted by LMD for EUMETSAT on advanced techniques for the extraction of low-level AMVs. In this framework rapid scan imagery taken with Meteosat-6 in 1999 has been used to analyse the effect of varying repeat cycle for the availability of low-level valid tracers, especially over land, and the quality of the extracted AMVs. An important result is presented in the following table (the row with applied solar correction should be ignored at this moment):

time interval	solar correction	average CMW velocity	bias	rms error	number of vectors
7.5 min	no	8.1	0.52	2.84	901
7.5 min	yes	8.0	0.71	2.88	868
15 min	yes	7.6	0.88	2.52	713
30 min	yes	9.8	0.83	3.00	160

Table 1: statistics on the comparison between CMWs (Cloud Motion Winds = Cloud Tracked AMVs) and ECMWF analysed winds at best fit level, for the eastern area (Central and East Africa, 28 July 1999, 12:00 UTC). Values of average CMW velocity, bias and rms. error are in m s^{-1}.

The table clearly shows that there is a huge increase in the number of valid tracers and a modest increase in the quality of the final wind product when decreasing the cycle time from 30 minutes to 15 and 7,5 minutes.

- **Rapid Scan for the Alpine Region**

Figure 2 shows the comparison of wind fields derived from rapid scans with 5 minute intervals and 30 minute intervals, respectively. Clearly the tracking based on rapid scans (2a) provides a much better depiction of the flow. However, as the image contains cloudy and clear sky features in close proximity, which are all tracked, the flow does not correspond to one well defined altitude level. This makes the derivation of divergence fields rather difficult, which is in contrast to the tropical convective system in Figure 1 where mainly cirrus outflow has been tracked.

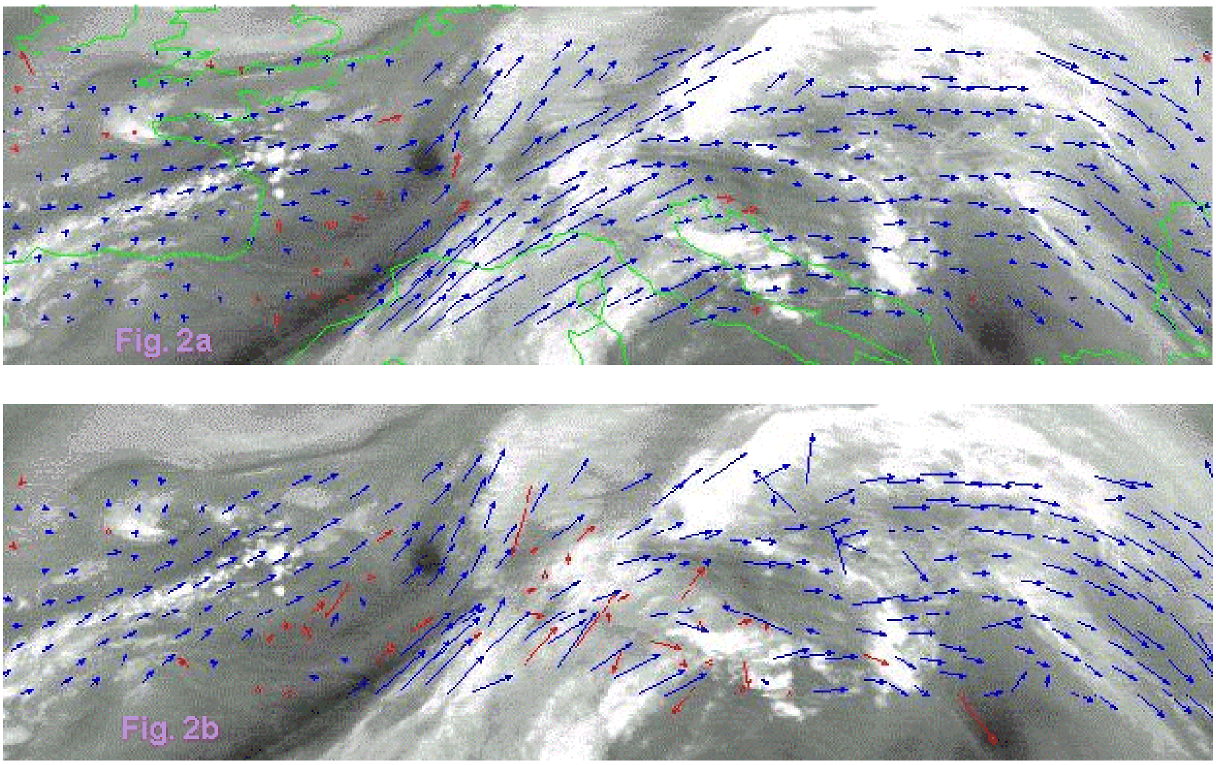


Figure 2: Wind fields derived from a triplet of WV images with rapid scans of 5 minute intervals (Figure 2a) and the nominal 30 minute scan (Figure 2b), respectively. The area covers the Alps and stretches from about 40.6° N to 53.5° N and 11.1° W to 28.5° E.

4 EUMETSAT RAPID SCANNING TRIAL

Based on the scientific experience it is clear, that rapid scan sequences of images with a scanning period of 10 minutes or less have great potential for improving the derivation of Atmospheric Motion Vectors. It is however also clear, that if this conclusion is to have a real impact on operational meteorology, it has to be exploited in an operational context. After the very successful support to the MAP experiment, it was therefore decided to analyse the potential for a continuation of the rapid scan imaging in an operational EUMETSAT service.

The main issue is to clearly identify the operational requirements for rapid scan imagery. Based on the scientific experience including the MAP experiment 3 application areas that could benefit from rapid scanning METEOSAT-6 imagery have been identified:

1 – Hurricane monitoring (Cap Verde cyclones);
2 – Improved wind product derivation in the tropics and at low levels;
3 – Severe weather monitoring in Europe

The target was then set to define a pre-operational trial using METEOSAT-6 that could cover as many as possible of the requirements for these three application areas. As the utility of rapid scans for wind extraction has been demonstrated in scientific studies using real rapid scan data,

the primary question was whether this requirement could be combined with requirements from severe weather monitoring and tropical cyclone monitoring

It was clear, that such a service would require redefinition of the scanning parameters from the MAP set-up, which covered a limited part of central Europe. It also became clear, that a combination of several scanned areas is not possible on Meteosat, as it is a spinning spacecraft. For a spinning spacecraft the scanning pattern is limited by the 2 possible motions of the scanning mirror, forward motion at 100 lines per minute and backward retrace motion at 10 times the forward speed. It is therefore not possible to set up a flexible scanning scheme with scanning of multiple areas at high time-resolution.

The conclusion was, that a scanning strategy had to be based on a fixed area, scanned with a fixed repeat cycle, interleaved with occasional (every few days) full-earth scans giving horizons required for navigation.

Based on the experience from MAP an extensive redesign of the procedure to command Meteosat-6 into rapid scanning mode has allowed the radiometer to be in ‘forward scan’ for a higher percentage of time during rapid scanning than was possible for MAP support. This allows a higher number of lines to be scanned at a similar repeat cycle repetition rate. The table below shows the number of IR scan lines that can be acquired with varying time frequency.

Scans per 30 minute slot	Repeat Cycle Duration	Lines per scan (30 sec standby)
2	15	1319
3	10	864
4	7.5	637
5	6	500
6	5	410

Table 2: IR scan lines that can be acquired with varying time frequency.

Based on all these elements, a target area of approximately 800 lines was selected, covering the tropics to southern Scandinavia, with a scan frequency of 10 minutes. The area is shown on the figure below.

Figure 3: selected target area of ca.800 lines for scan frequency of 10 minutes

In order to coordinate the trial with ongoing operational activities, the most optimal solution was to combine the rapid scans with the other activities involving Meteosat-6, i.e. to rapid scan for 48 hours per week for the month of August 2000.

At the time of writing, the rapid scan trial is being conducted and it is likely that it will be extended to the end of September 2000. EUMETSAT and the user community representatives will then evaluate the results of the trial. Based on the outcome of the analysis, a decision will be taken whether to establish an operational rapid scan service. If this is decided, the operational METEOSAT data processing system, including the wind derivation software, will be adapted to fully support the rapid scanning images.

5 CONCLUSION

The paper shows that wind fields derived from rapid scans over the tropical belt and over the Alpine region provide better and spatially more consistent wind fields, thus confirming results of earlier work. The paper also shows how EUMETSAT is working towards applying this scientific experience in an operational context with the pre-operational rapid scan trial.

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