OPERATIONAL WATER VAPOUR WIND VECTORS FROM METEOSAT IMAGERY DATA

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ABSTRACT

Vector fields derived from successive METEOSAT water vapour images have been produced semi operationally at ESOC (European Space Operations Centre) since summer 1992. After the initial validation period, modifications mainly related to the height assignment scheme and the quality control were introduced. After further validation the quality of the derived high level vector fields proved to be of an acceptable operational level. In the first part of this paper the water vapour vector field retrieval scheme will be presented. Main emphasis is on the changes which caused the final breakthrough.

The second part of this paper will present a real time water vapour vector field derivation technique, which at the present is used in a parallel mode at ESOC. This technique is based on parallel processing performed on a dedicated platform. Additionally to the real time performance the new system provides sophisticated quality control tools. The automatic quality control incorporates additionally to the traditional symmetry and local consistency checks also tests related to the spectral information. The final quality indicator for each vector is a linear combination of the individual tests. Each test is incorporated with a weight defining it's significance in the overall quality. The weights, as well as the parameters describing the individual tests, can be defined manually or automatically. The automatic optimisation scheme will vary the weights and parameters, until an optimum relationship between the overall quality indicator and the mean vector difference between the derived water vapour vector field and a background field is found.

1. Introduction

Motion vectors from successive satellite images have been derived operationally mainly from successive infrared images, specifically from images derived from measurements in the infrared window area (10.5 - 12.5 µm). These winds are used operationally in e.g. numerical weather prediction (NWP). The major shortcoming of the CMWs is their relationship to clouds, i.e. vectors can be derived only in cloudy areas. In order to retrieve winds also in cloud free areas efforts have been concentrating on successive water vapour images, derived in the 6.3 µm water vapour absorption band. Already early studies (e.g. Eigenwillig and Fischer, 1982, Kastner et al, 1980) showed that the wind vectors derived from sets of WV images can be used to interpret the medium and upper level tropospheric motion.

Based on these and other studies as well as the need to expand the CMW product, the European Space Operations Centre (ESOC), started to develop a scheme to retrieve vectors from successive images in the METEOSAT WV (5.7 - 7.1 µm) band. The first step was a study performed by the Laboratorie Meteorologie Dynamique (LMD) in France. The study concentrated on the feasibility to produce WV vectors with an automated system. Height assignment, image filtering and representative scale of the WV motion were the main problem areas investigated. The conclusions were (Laurent, 1991) that the best tracking performance is achieved with unfiltered images with a tracer scale of more than 30*30 pixels (the METEOSAT WV resolution at the subsatellite point is 5*5 km^2) and a height assignment based on a fraction of the coldest pixels.

As the existing CMW production chain was with minor modifications capable of producing WV vectors from tracers with the size of 32*32 pixels, the implementation of this scheme was straight forward. For details on the CMW extraction see Schmetz et al (1993). The basic WV vector derivation scheme is presented in figure 1.

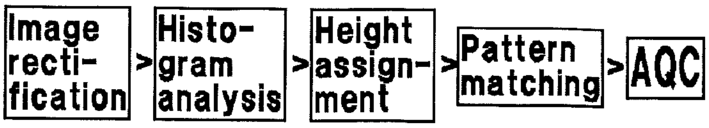

Figure 1. WVV extraction scheme at ESOC.

The MIEC extraction schemes use rectified Meteosat images. The images are segmented in 32*32 pixel subareas and then submitted to the wind module. The wind modules compute first an associated height for the investigated tracer and will then look for a best match of this tracer in the previous and the next image. This results in two vectors, which are then combined to produce a final displacement of the tracer over one hour. The main difference between the CMW and the WVV scheme is the absence of image filtering and manual quality control in the latter scheme.

The result achieved with this system proved, that the WV images were producing an extremely large number of high level winds, but comparisons against radiosonde measurements showed that not all of the winds were comparable to the point measurements given by the radiosondes. As the present NWP assimilation schemes are still treating CMWs and WVVs as 'pseudo' radiosonde data, it was clear that further refinement of the WVV derivation scheme was necessary before the product could be delivered freely to all users. This paper will present the main results from the development and improvements made at ESOC as well as present statistics from comparisons against collocated radiosondes.

A thorough inspection of the original WV scheme revealed several areas where improvements were expected to be achieved. The two main areas were height assignment and automatic quality control.

2. The height assignment

The original WVV height assignment method derived an equivalent black body temperature (EBBT) from the mean radiance of the 25% coldest WV pixels in the target area. As such a method is completely independent of the meteorological image content, it can be expected to be in some areas highly unreliable. Therefore the effort was made to develop a height assignment scheme which would use the information derived from the ESOC histogram analysis (Tomassini, 1981). As the CMWs derived at ESOC have proven to be of good quality, it was assumed that using the same height assignment as for the infrared tracking, could give a reasonable result in areas where high clouds were present. This method derives the semi transparency corrected cloud infrared EBBT (Schmetz et al, 1993), which is used for the height assignment. As a comparison, the cloud EBBT, as derived from the WV data was also computed. As these methods on the other hand are likely to fail in low cloud areas, alternative methods were required. These methods derived a mean water vapour radiance from pixels which were colder than a certain threshold. Three different thresholds which all were derived from the MIEC histogram analysis and all related to the coldest cloud in the segments were used. The first threshold was the mean WV radiance of the coldest cloud, the second was the warm boundary and the third the cold boundary of the cloud. These boundaries are defined by the MIEC histogram analysis and are roughly equivalent to a deviation of 0.7σ, assuming that the cloud radiances have a Gaussian distribution.

The four new methods were compared with the original fixed percentage WV EBBT method. Statistics were derived for a two week period in January 1992 against collocated radiosondes. The statistics are presented in three groups. The first group contains only vectors derived in areas where high clouds were present and the second is for areas where no high clouds were identified, but medium level clouds were found.

The statistics for clear sky areas are presented together with the statistics derived for areas with low level clouds, but no medium or high level clouds. This is justified as the low level contribution (below 700 hPa) in the water vapour signal is even in dry areas extremely small and the impact from a possible low level cloud is, except for some extreme cases, negligible.

Figure 2 presents the water vapour contribution function at the subsatellite point for a specific atmospheric standard profile (midlatitude summer). The dashed line represents the contribution function in clear areas. The solid line is the contribution function when a semitransparent cloud is inserted between 8 and 10 km, whereas the dotted lines represents the situation with opaque clouds between 8 - 9 km, 6 - 7 km and 4.5 - 5.5 km respectively.

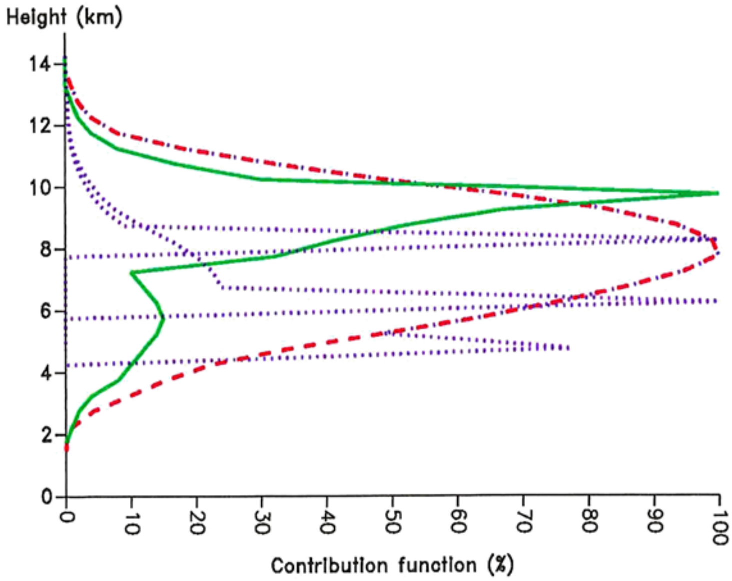

Figure 2. Water vapour contribution function for a standard atmospheric profile (Equatorial summer) for clear sky conditions (dashed line), with a semi transparent cloud (solid line) and several opaque clouds (dotted lines).

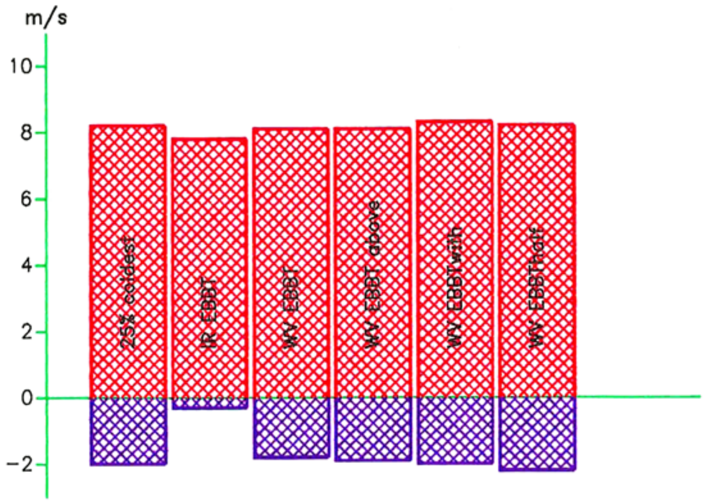

Figure 3. Statistics for different height assignment methods for areas where high clouds were present.The columns from left to right are: 1 =original WV EBBT of coldest pixels, 2 = IR cloud top, height, 3 = WV cloud top, 4 = WV EBBT of pixels colder than cloud, 5 = WV EBBT for pixels from cloud and colder than cloud, 6 = WV EBBT from pixels colder than cloud mean temperature and colder than cloud.

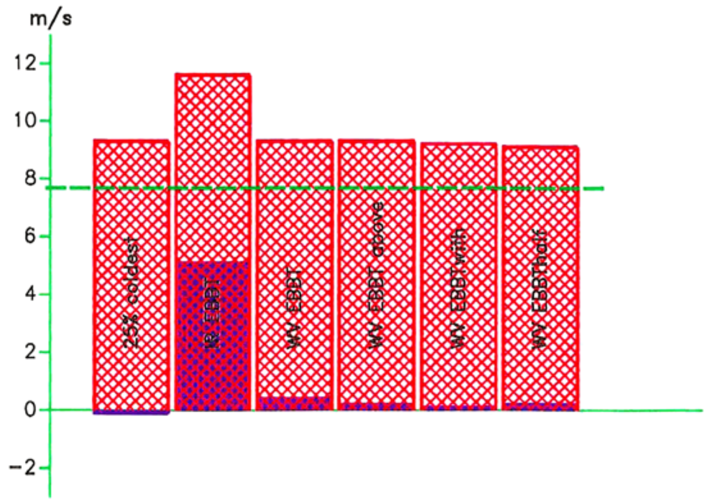

Figure 4. Statistics for different height assignment methods for areas where medium, but no high clouds, were present. Columns as in Figure 3.

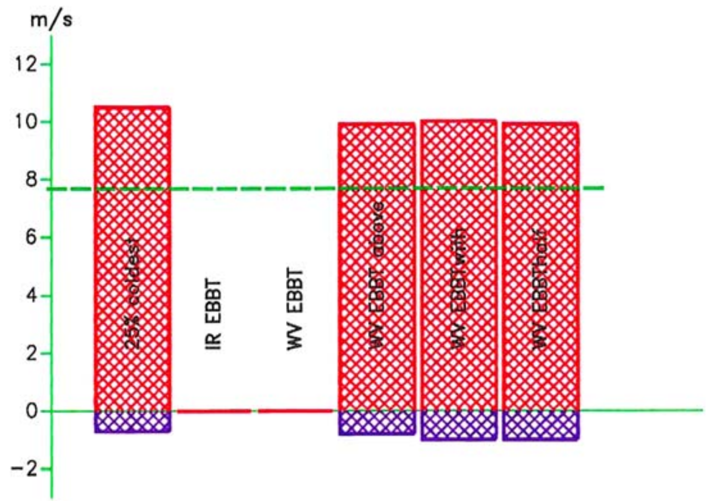

Figure 5. Statistics for different height assignment methods for areas where no high or medium clouds were present. Columns as in Figure 3.

Figures 3-5 clearly show that the best performance is achieved in areas where high clouds are present. Furthermore the lowest RMS and smallest bias values are achieved with the infrared EBBT height assignment. The RMS is roughly 1 m/s and 2 m/s higher for the second and third group respectively. It is also clear that the preferred height assignment method is related to the cloud configuration and hence to the water vapour distribution function. The applied methods are simple and straight forward, but do not take into account the variability of the water vapour above the cloud or the background. The height assignment, especially in areas where no high clouds are present, could therefore be improved, but this requires further investigations.

3. Automatic quality control

3.1 Original quality control

The second area where improvements were expected was the automatic quality control. The original quality control did only include a symmetry check, i.e. the vector difference between the two vectors derived from an image triplet was derived and if the vector difference was greater than a speed dependant threshold (Eq. 1), the corresponding wind was rejected.

Threshold = A*speed + B (1)

The vector difference is directly related to the vector quality. Figure 6 presents the speed bias and RMS for two scenarios. Figure 6a describes the impact of different values of A (B = 2.0 m/s) and 6b presents the effect of different values of B (A = 0.2).

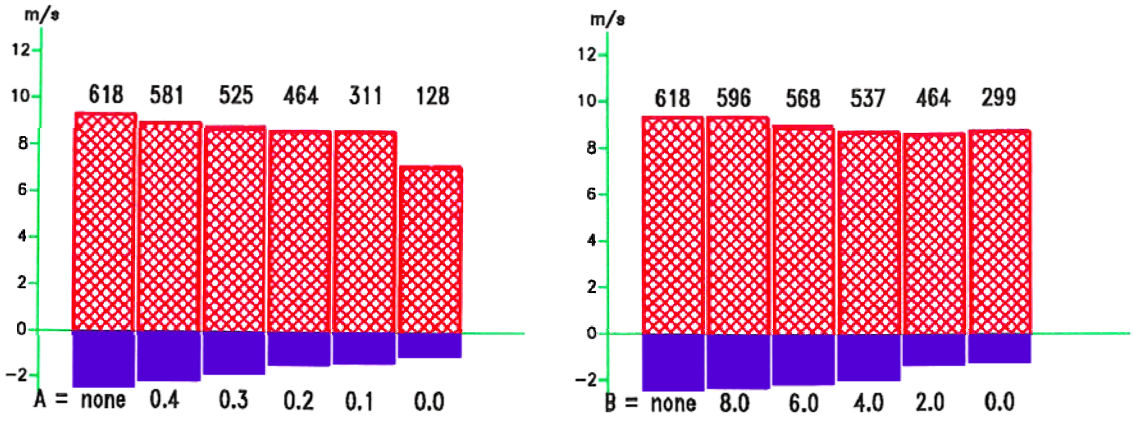

Figure 6. The impact of different symmetry check coefficients on the WV vector quality and total number of accepted vectors (indicated above the bars).

The present values for A and B (0.2 and 2.0 m/s) have been selected as a compromise between quality and number of accepted winds.

3.2 Local consistency check

The water vapour tracking provides a very good horizontal coverage. A typical vector field produced from a sequence of METEOSAT WV images is presented in figure 7.

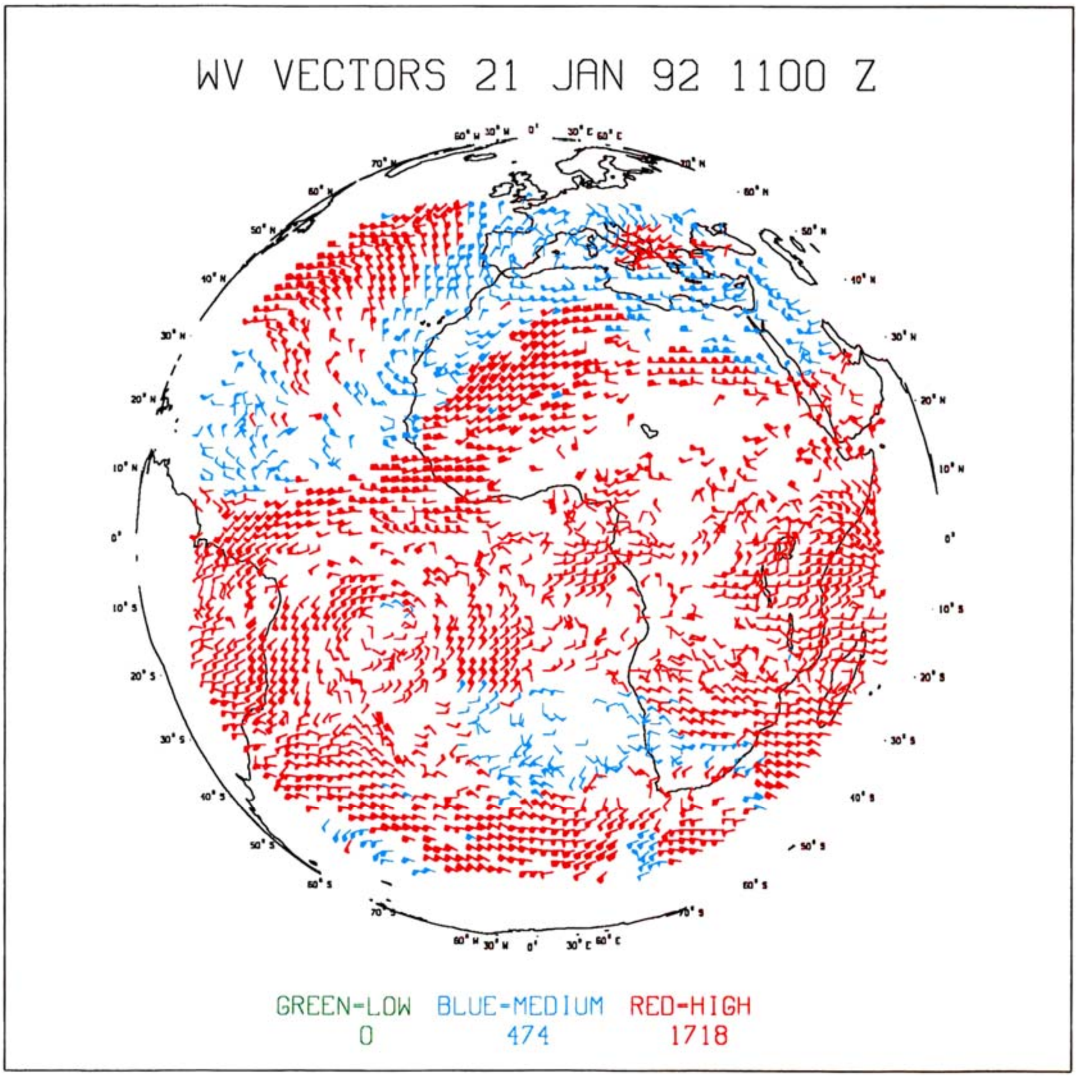

Figure 7. A typical vector field produced from a sequence of three METEOSAT WV images.

The vector field presented in Figure 7 is to a large extent smooth, but some outlayers can still be detected. These outlayers are to a large extent isolated and surrounded by vectors which show a reasonable agreement in direction, speed and height. It is therefore conceivable to remove these odd vectors with a local consistency check. The approach pursued at MIEC compares every wind to the maximum eight vectors derived in the surrounding segments. A vector is accepted if it finds a vector within a specified height range, which deviates less than a certain amount in speed and direction to the vector which is quality controlled. The impact of the quality control was investigated for several height ranges.

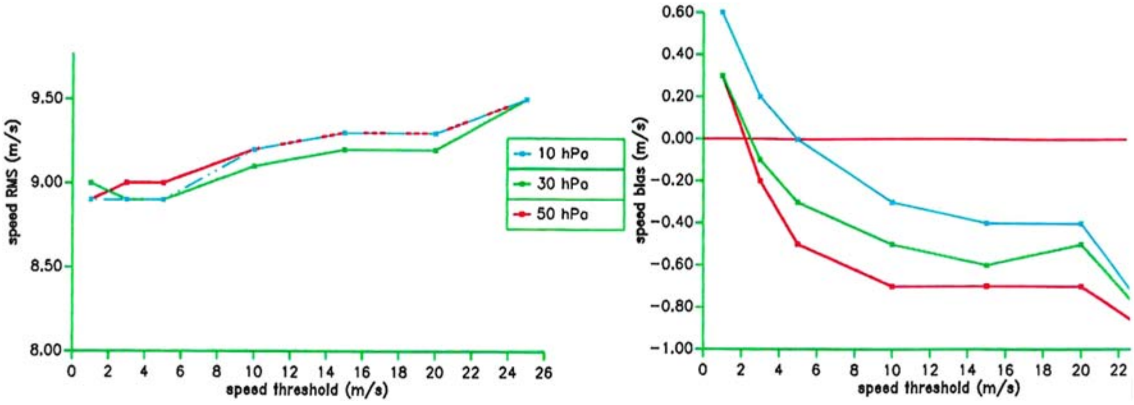

Figure 8. The impact of different speed thresholds for three different height ranges.

Figure 8 presents the results for three different height relaxation values, 50 hPa, 30 hPa and 10 hPa. It can be seen that for each range the speed bias and RMS is decreasing as the speed threshold is decreased. Extremely tight values, i.e. 10 hPa for height and 1 m/s for speed, provides good results but it also removes 95 % of all vectors which has passed the symmetry check. As a compromise between coverage and quality a final combination of 30 hPa and 3 m/s was selected. This removes roughly 2/3 of the vectors which has passed the symmetry check, but provides still a better coverage than the CMW high level field. After the local consistency check for speed the vector field still showed some directional outlayers. Vectors faster than 15 m/s are therefore removed if the direction difference to the best matching neighbour is more than 90 degrees.

3.3 Cloud configuration check

As the height assignment investigation indicated that the vectors derived in high cloud areas are of better quality than the vectors derived in the other areas a further quality measure was introduced. This cloud configuration check will remove all vectors which are derived in areas where no high clouds were present. Figure 9 presents the WV vector field from figure 7 after symmetry, local consistency and cloud configuration check.

4. Validation

The improved water vapour quality scheme was validated against collocated radiosondes. Figure 10 presents the statistics from comparisons against collocated radiosondes. The statistics is presented as weekly speed bias, speed RMS, vector difference and vector RMS. The speed bias is generally close to 0 m/s, whereas the speed RMS is on the average close to 8 m/s. These statistics also confirm the results derived during the two week test period in January 1992.

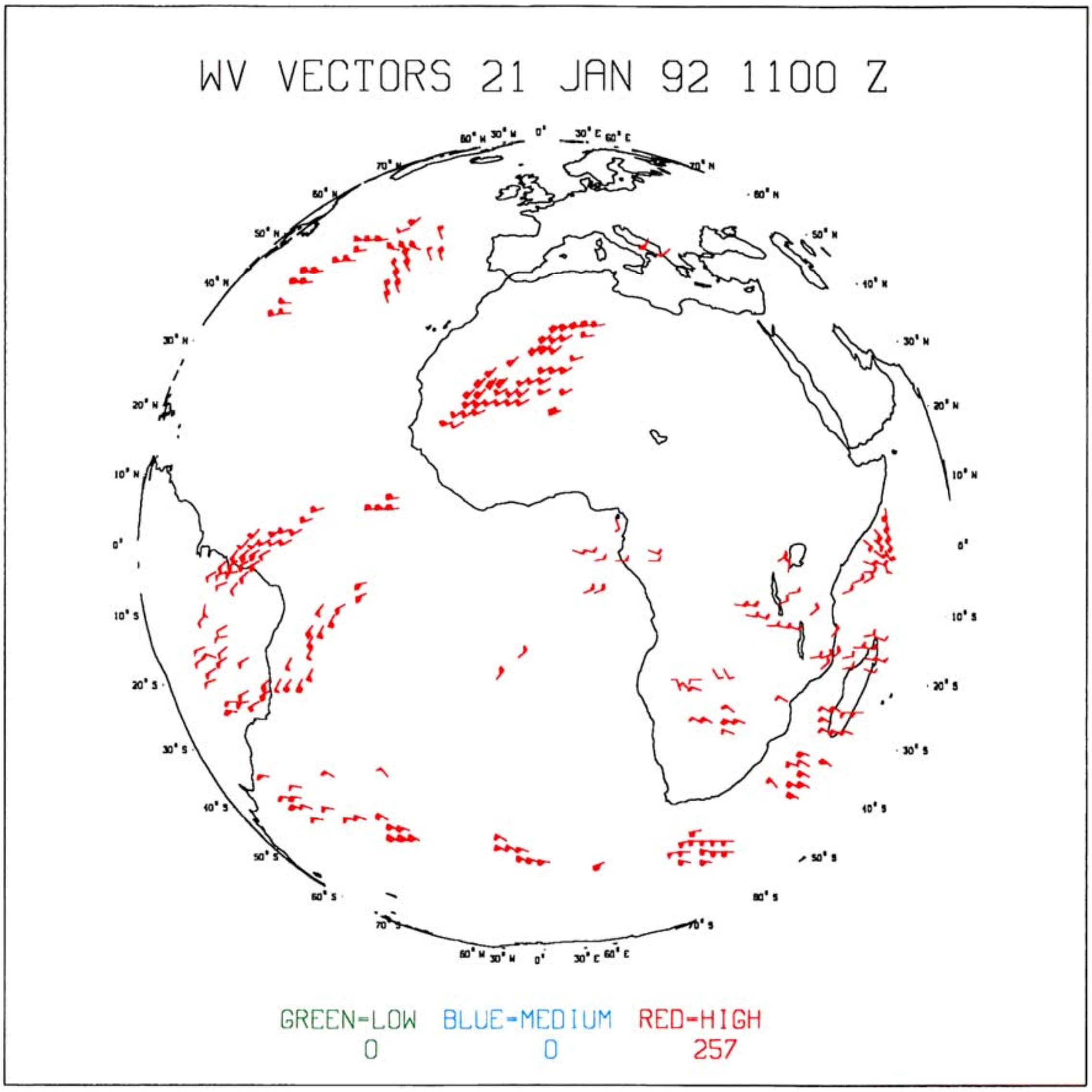

Figure 9. The vector field for the same situation as in figure 7, but after automatic quality control.

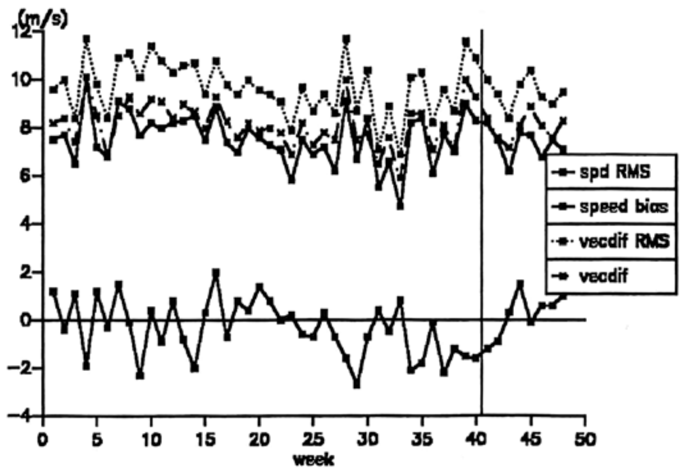

Figure 10. WV vector statistics against radiosondes for speed bias, speed RMS, vector difference and vector RMS for 31.12.1992 - 10.11.1993.

Further assessments relating to comparisons against radiosondes and to CMWs can be found in Holmlund et al (1994). Quality assessments derived at ECMWF can be found in Strauss (1994).

5. Future outlook

The fully automated WV vector derivation and quality control scheme enables a frequent production of WV vector fields. This expansion has been realised in a test environment based on a fast transputer augmented workstation (TAW) (figure 11).

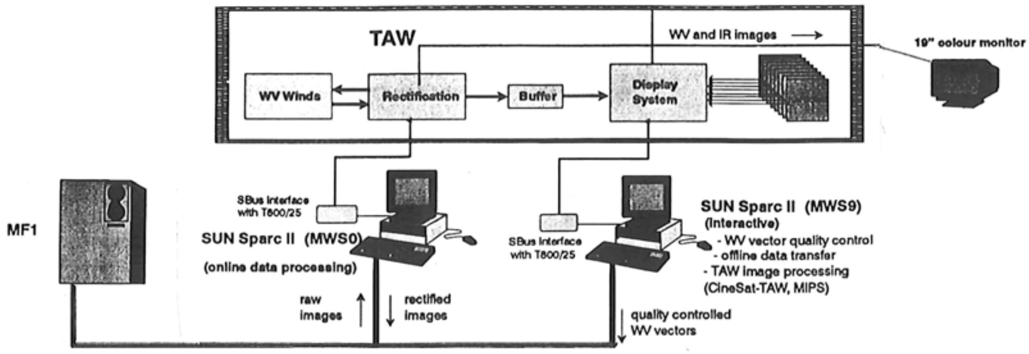

Figure 12. The Transputer Augmented workstation configuration.

This system which is available at MIEC is capable of deriving half hourly WV vectors in real time as well as quality control them and disseminate them to any user. Due to the experimental nature of the hardware and the software this system is not operational, but the capabilities will be studied in a WV wind campaign during 1994. The TAW incorporates all the presented automatic quality control methods and in addition several new tests. A summary of the tests is presented in table 1.

Table 1. Quality control tests implemented on the TAW.

Type of quality control		
Consistency **-direction** **-speed** **-height**	**Image content** **-clouds** **-dynamic range** **-temperature**	**Matching surface** **-shape of peak**

All tests are normalised to deliver a quality indicator between 0 and 1. It is foreseen that the final vector quality is a linear combination of all individual quality values. The importance of all tests will be evaluated during the wind campaign and the goal is to find an optimum combination of tests, delivering reliable information about the total quality of each wind. This would then enable the dissemination of all vectors with an associated quality indicator. The wind campaign is also intended for the study of the interaction of atmospheric humidity and atmospheric flow.

6. Conclusions

The present status of the WV vector retrieval scheme used at ESOC has been presented. The main emphasis has been on the investigations, which made significant improvement to the final product. The new height assignment scheme improved the speed RMS with 0.5 m/s, whereas the modifications to the automatic quality control scheme brought another 1.5 m/s improvement. At present only vectors derived in high cloud areas are disseminated, but the WV vector field is still producing a significantly larger amount of high level vectors than the operational CMW technique. As an example the total number of disseminated CMWs was in December 1993 25809, whereas the equivalent figure for WVWVs was 48540. The WV vector fields have been freely disseminated from ESOC from the beginning of November. At the same time the production frequency has been increased and the data is now disseminated four times a day, at the main synoptic hours.

The encouraging results from the WV scheme has led the MIEC into development of further water vapour applications. The relationship between monthly mean water vapour and UTH fields has been investigated (Schmetz, 1993). Also the capabilities of hourly real time WV vectors will be investigated in the near future as well as the interaction between atmospheric humidity and flow. These investigations will performed during a dedicated WV vector campaign in 1994.

7. References

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