INTRODUCTION OF THE RECURSIVE FILTER FUNCTION IN MSG MPEF ENVIRONMENT

Gregory Dew

EUMETSAT

Abstract

EUMETSAT currently uses its own Quality Index (QI) scheme applied to wind vectors derived from the Meteosat-8 (MSG-1) image data. This is a continuation of the scheme originally developed for the earlier generation of Meteosat satellites. Other AMV production centres use different quality indicators. One example is the so-called Recursive Filter Function (RFF), applied operationally by NOAA/NESDIS. As a response to a CGMS meeting action that all data producers should implement both the RFF and QI methods, EUMETSAT has begun to introduce the RFF scheme into the MSG MPEF Environment. This paper describes how this process was undertaken, the current status of the RFF implementation, preliminary indications of its impact, and the perceived way forward.

1. BACKGROUND

1.1 Quality Control Schemes

Quality Control schemes are routinely applied by all the current operational AMV extraction centres, as a means of filtering out bad winds or providing the user with an indication of the quality of a wind. Initially Manual Editing procedures were used at eg. EUMETSAT and NOAA/NESDIS. However, the increasing volume of winds, more channels and increased computing power led to the requirement for Automatic Editing procedures to be adopted.

The current operational AMV extraction centres all invoke Automatic Quality Control (AQC) schemes. Since 1996 NOAA/NESDIS have operated an AQC scheme called Recursive Filter Function (RFF). This results in the attachment of a quality flag (RFF) between 0 and 100 to each vector. This has for example been used to limit dissemination of winds to those with an RFF value above 50 (Holmlund, Velden et. al., 2002).

Since 1998 EUMETSAT have operated an alternative AQC scheme called Quality Indicator (QI). This scheme similarly attaches a quality flag (between 0 and 100) to each vector (Holmlund and Velden, 1998). Numerical Weather Prediction Centres such as the UK Meteorological Office and ECMWF (European Centre for Medium Range Weather Forecasting) use various thresholds for these QI values to limit assimilation in their models to only the best quality winds.

Alternative error characteristic schemes are also implemented at other operational and research centres, for example the Expected Error (EE) is now generated at the Australian Bureau of Meteorology (ABM) (Le Marshall et. al. 2004).

1.2 Overview Of Parallel AQC Schemes

The RFF was developed at UW–CIMSS (University of Wisconsin - Co-operative Institute for Meteorological Satellite Studies). It is an objective 3D recursive filter analysis of the derived AMVs, successively modifying a 3D background field defined at fixed grid locations, based on appropriately weighted contributions from the forecast field and the AMV observations. The fit of each AMV to the modified background field yields an adjusted AMV height. This is then used to further adjust the background field, to provide an RFF quality flag for each AMV based on the quality of the neighbouring analysis and the fit of the AMV to the background field.

The QI scheme was developed at EUMETSAT and derives a Quality Indicator for each AMV based on the temporal properties of the AMV, consistency with other AMVs in close proximity, and a forecast consistency check. The QI scheme employed operationally for Meteosat-8 provides separate QI values including and excluding forecast consistency checks.

The QI scheme gives a good estimate of the reliability of the tracking (derived displacements), but currently there is limited consistency checking for height assignment because there are problems identifying winds assigned to the wrong height.

The RFF scheme has the capability of re-adjusting the height of the AMV, but the forecast field influences the result, although its affect can be down weighted.

It was recognised at the 3rd International Winds Workshop in Ascona, Switzerland that it is important to develop consistent AQC methodologies that can be adaptable to all global extraction centres. A number of studies have been undertaken by EUMETSAT and NOAA/NESDIS to assess a combined approach to AQC using both RFF and QI, for example Holmlund and Velden (1998) and Holmlund, Velden et. al. (2002). The report from the Working Group on Verification at the 6th International Winds Workshop (Holmlund (2002)) stated in Recommendation IWW6_WGIII_4.3 that "Data Producers should implement both RFF and QI methods as minimum and distribute these flags to the users".

2. EUMETSAT RECURSIVE FILTER FUNCTION

2.1 Overview

Development of the EUMETSAT RFF scheme was started in 2005 and is applied to Meteosat Second Generation (MSG) (eg Meteosat-8, 9) winds. It is implemented hourly as a post-processing function applied to the MSG AMV Final Product winds for each channel, prior to BUFR encoding. UW-CIMSS provided supporting code and documentation, which was used as a starting point for the EUMETSAT RFF. Correspondence was maintained between EUMETSAT and UW-CIMSS during the course of the development. The first version of the RFF was completed in 2006.

2.2 RFF Concepts

The basics of the RFF are described in Hayden and Purser (1995) with particular applications to NOAA/NESDIS winds in Hayden and Nieman (1996). A 3-dimensional background field is created and modified at regular latitude, longitude grid points and pressure levels in several analyses using the AMV wind (velocity component) data and (for the EUMETSAT RFF) the ECMWF forecast field. The background field is smoothed along 3 dimensions and each grid point/level has a degree of local influence on the smoothing, based on the quality of the analysis at each grid point. The quality of the analysis is essentially composed from a comparison of the AMVs with the background field and is dependent on pre-selected error tolerances. Where the quality analysis is low, for example where the AMV data and background field are significantly different, the local influence is small and information from other grid points is smoothed in. Where the quality analysis is high, smoothing from other grid points is small. Within each analysis, corrections to the background field are built up in several passes with increasingly rigorous quality control, beginning with coarse error tolerances and characteristic spatial scales, which are refined with successive passes. After a number of analyses (using the AMV and forecast field data), a best-fit of each AMV to the modified background field is carried out to provide an adjusted height. A further analysis of the background field is subsequently carried out using the adjusted AMV heights and a final quality indicator is assigned to the AMV based on the quality of the neighbouring analysis and the fit of the AMV to the data.

2.3 Implementation

Figure 1 provides a schematic of the implementation.

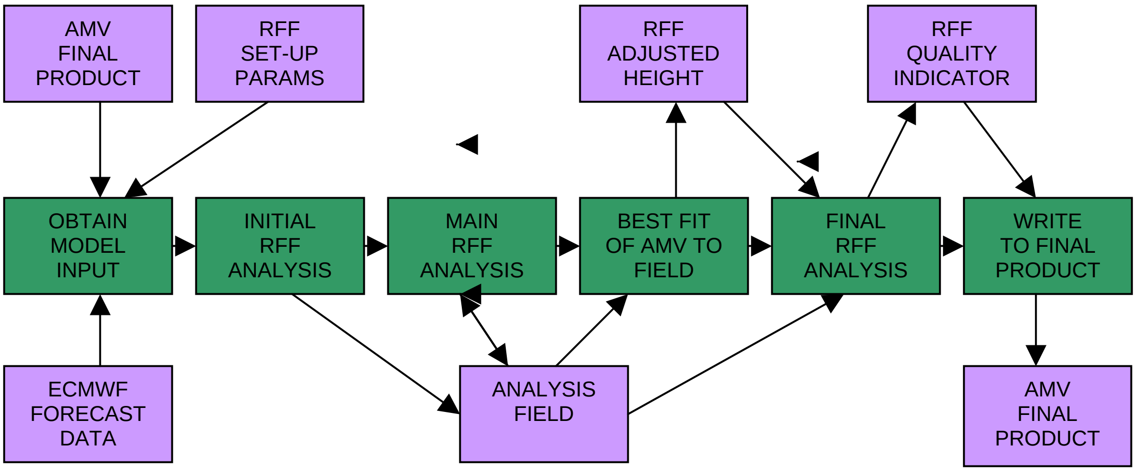

***Figure 1*: EUMETSAT RFF Implementation**

The **Initial Analysis** actually consists of two analyses using only the forecast data, the first with a single pass to effectively initialise the background (analysis) field. The second starts off with high error tolerances and large characteristic spatial scales (implying a large degree of smoothing) which reduce with subsequent passes depending on the local quality.

The **Main Analysis** is carried out using the AMV wind data and a significantly down-weighted forecast field, ie the theory being that the AMV wind data should dominant the analysis. The error tolerances are reduced over successive passes, but the initial values are significantly lower than for the Initial Analysis. The characteristic spatial scale follows the same pattern as for the previous analysis.

After the Main Analysis, the **Adjusted AMV Height** is calculated by minimising a variation penalty function in speed, direction, velocity, pressure, temperature between the AMV wind and the background (analysis) field.

The **Final Analysis** uses the AMV wind data with the adjusted AMV heights and the down-weighted forecast data. The characteristic spatial scale is lower than the Main Analysis.

On completion of the analysis, the final RFF Quality Indicator is determined by a final pass of the quality analysis with stricter quality control.

2.4 Important Points

In the EUMETSAT implementation :

- The set-up parameters are based on comparisons with the NOAA/NESDIS code and adjusted to correspond with EUMETSAT model grid points and pressure levels
- Grid point spacing is 1 degree in latitude and longitude
- There are 24 model pressure levels between 100 and 1000 hPa
- All AMV winds are used in the analysis with equal weighting – no reliability weighting is applied
- The forecast data has a very low weighting in the Main and Final Analyses
- There are no weightings or adjustments for different latitudes and wind speeds

- No speed bias is applied to the AMV winds – in contrast to the NOAA/NESDIS RFF, however the EUMETSAT view is that the bias is a statistical rather a pure “Physics” process. Statistical biases against co-location radiosondes are not easy to accurately quantify, and statistical biases against model data are susceptible to model errors and choice of model

3. CASE STUDY

3.1 Overview

To provide a preliminary indication of the use of the RFF, a case study is presented for a single AMV Final Product. The details are :

- Meteosat-8
- IR 10.8 µm channel
- Time frame January 17th 2006 02000Z to 024500Z

The case will provide comparisons between the AMV Final Heights and the RFF Adjusted Heights, and the EUM QI and the RFF Quality Indicator.

3.2 AMV Final Heights and RFF Adjusted Heights

Figure 2 shows histogram comparisons of the AMV Final and RFF Adjusted heights. The heights are separated into 20 hPa wide bins.

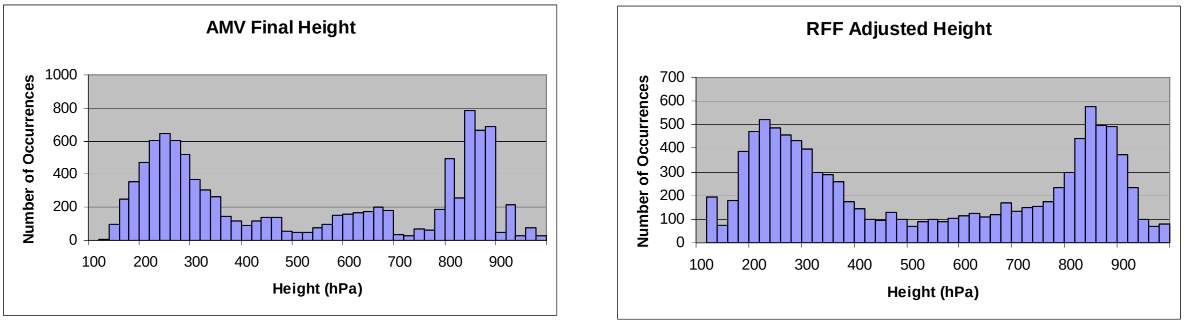

Figure 2: **Comparison between AMV Final and RFF Adjusted Heights**

The winds for this channel are mainly in the low and high level regions but the RFF has the effect of smoothing the histogram representation. A more detailed examination of the effect on individual winds is presented in Table 1. This presents statistics summarising the differences between the AMV Final Height and the RFF Adjusted height. The results are separated into 3 groups: all winds, those winds for which an EBBT (IR window) method was used for height assignment, and those winds for which a CO_2 absorption retrieval method was used for height assignment. (De Smet (2006) provides a more detailed description of the Height Assignment retrieval methods). The groups are further separated into Low, Medium, High Level clouds. The table illustrates the number of winds, and the mean and RMS differences.

	All	EBBT			CO2		
		Low	Med	High	Low	Med	High
Winds	10457	3717	1527	54	0	399	4760
Mean	8.9	-8.9	10.0	-7.9	-	40.0	20.1
RMS	83.1	71.4	102.0	60.9	-	88.7	84.7

***Table 1*: Height Difference (RFF Adjusted minus AMV Final) Statistics (hPa)**

The majority of high level winds are assigned a CO_2 method height while those at low level are assigned an EBBT height. Most of the low-level winds have a cloud base re-assignment which places them at a forecast determined level, which may explain why the RMS difference is lower for these cases. It is interesting to note that MSG MPEF co-location statistics for this winter period indicate a slow speed bias, ie the AMV Final Height is on average too high. This slow speed bias is worse at high levels. The RFF adjusted heights are on average lower for the high levels and so may be expected to improve the co-location statistics. However, the reverse may be true at low levels.

Another way to analyse the respective heights is to make a forecast consistency comparison check. The forecast consistency check is one of the components of the EUMETSAT QI (Holmlund and Velden (1998)), and can provide a useful check of the reliability of the height assignment. Table 2 shows the mean forecast consistency of the winds.

Height	All	Low	Med	High
AMV Final	46.8	59.2	32.5	42.9
RFF Adjusted	56.6	66.8	43.9	53.9

***Table 2*: Mean Forecast Consistency**

The table clearly shows the RFF Adjusted height to have a better forecast consistency than the AMV Final Height. This is not too surprising as the adjusted background field, against which an RFF Adjusted height is calculated, is influenced by the forecast data. To further illustrate this, Figure 3 shows a wind vector field which displays the AMV Final Height and associated forecast consistency (in purple), as well as the corresponding data for the RFF Adjusted height (in black).

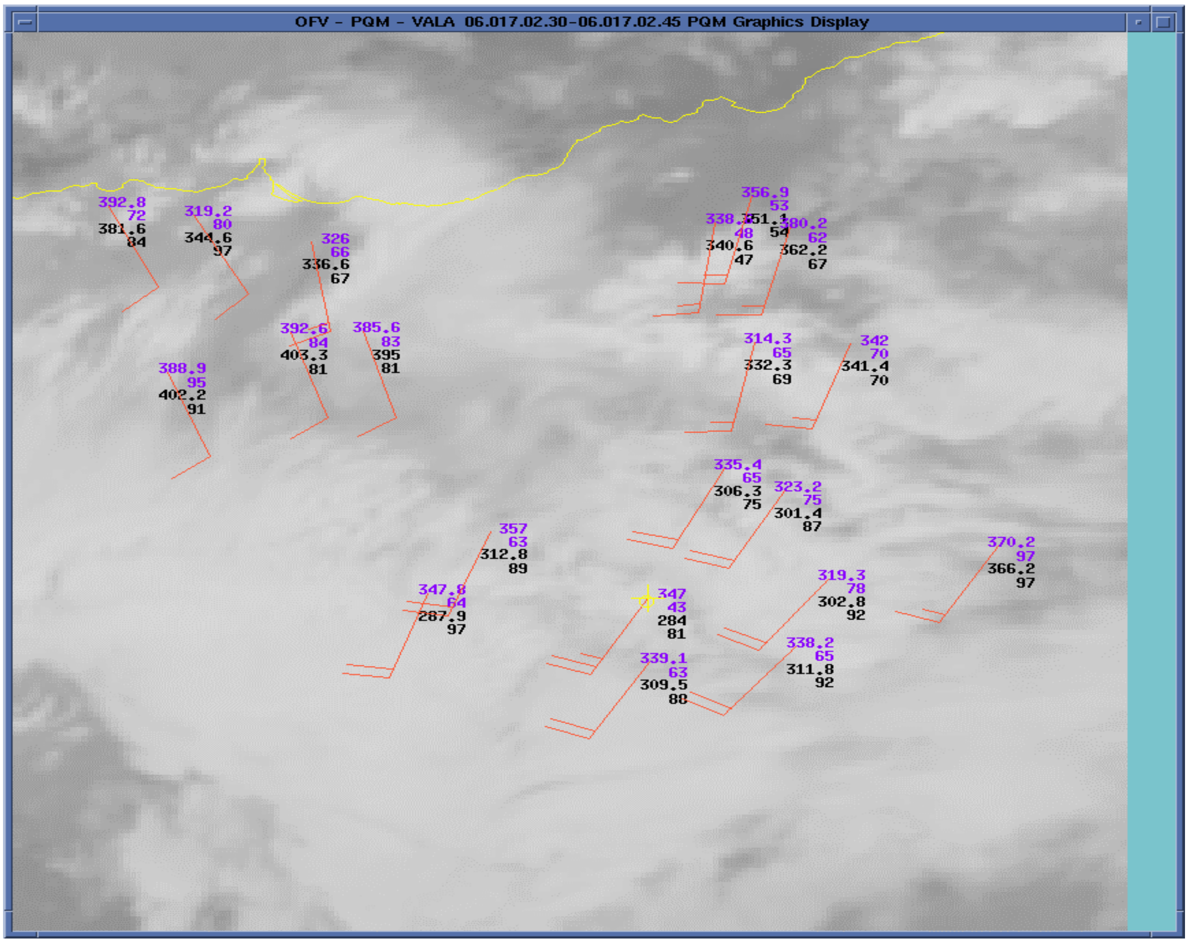

***Figure 3* : AMV Final Height and Forecast Consistency (purple); RFF Adjusted Height and Forecast Consistency (black)**

3.2 EUM QI and RFF Quality Indicator

Figure 4 shows a graph which compares the quality indicators for EUM QI and RFF.

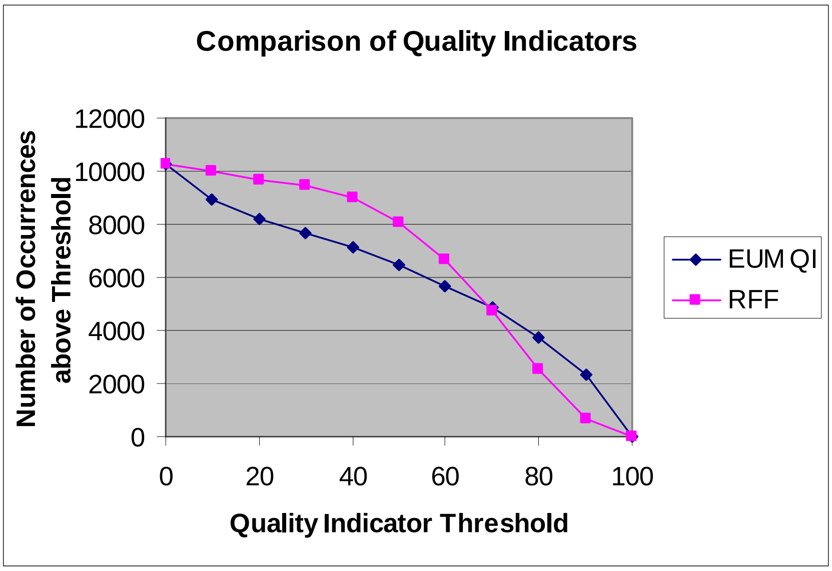

Figure 4 **: EUMETSAT QI and RFF Quality Indicator**

The equivalent RFF cut-off point for a EUM QI of 80 is about 75. Figures 5, 6 and 7 show the affect of filtering using the two quality schemes. Figure 5 illustrates a wind field with no filtering applied. In Figure 6 winds with EUM QI values below 80 are filtered out. This tends to remove the winds with a poor spatial and temporal consistency. In Figure 7 winds with an RFF value below 75 are filtered out. There is a similar trend observed.

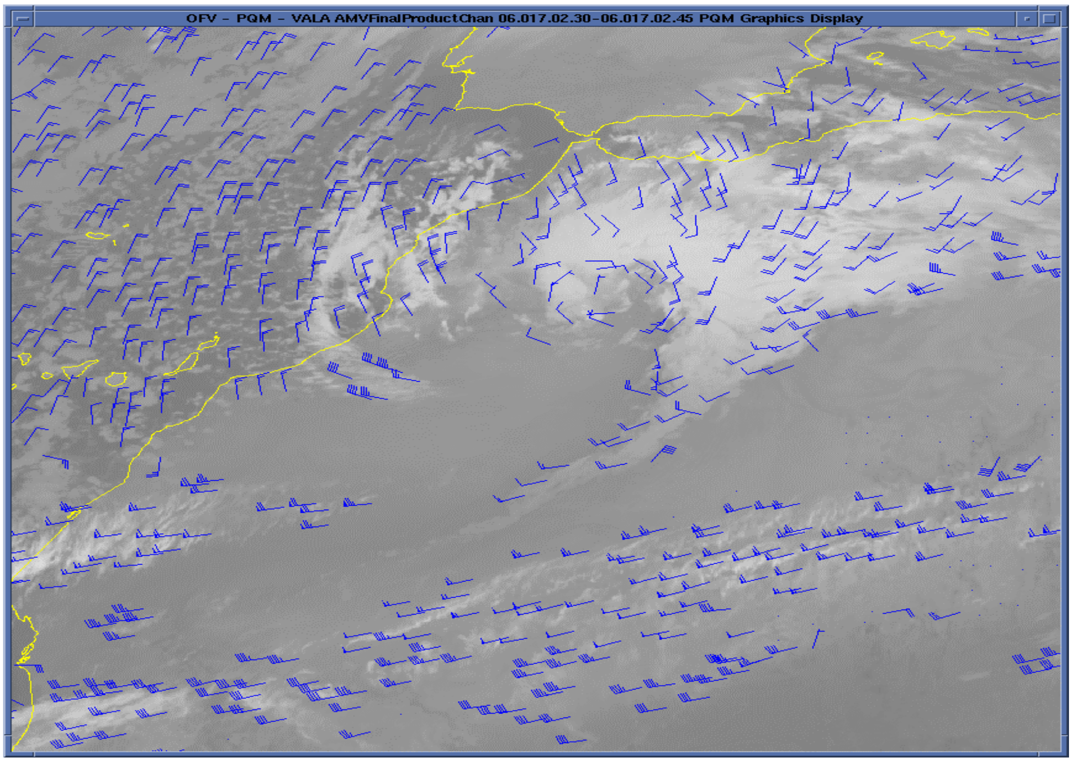

Figure 5 **: AMV Wind Field (all winds)**

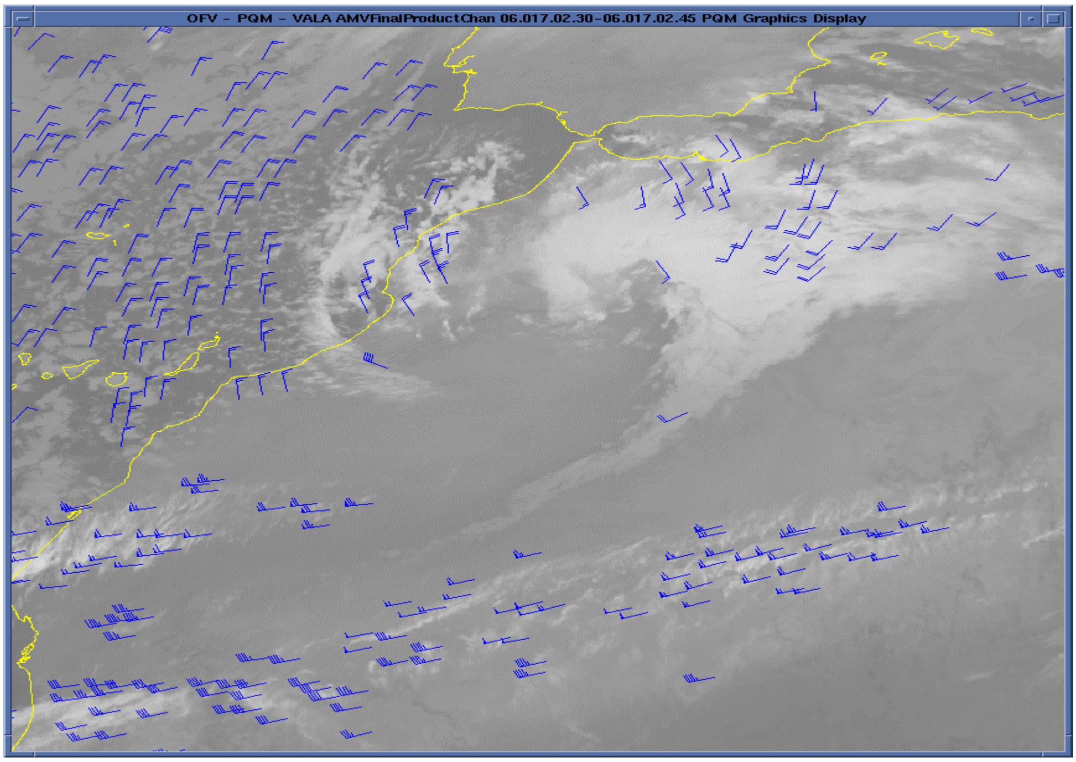

Figure 6 **: AMV Wind Field (EUM QI > 80)**

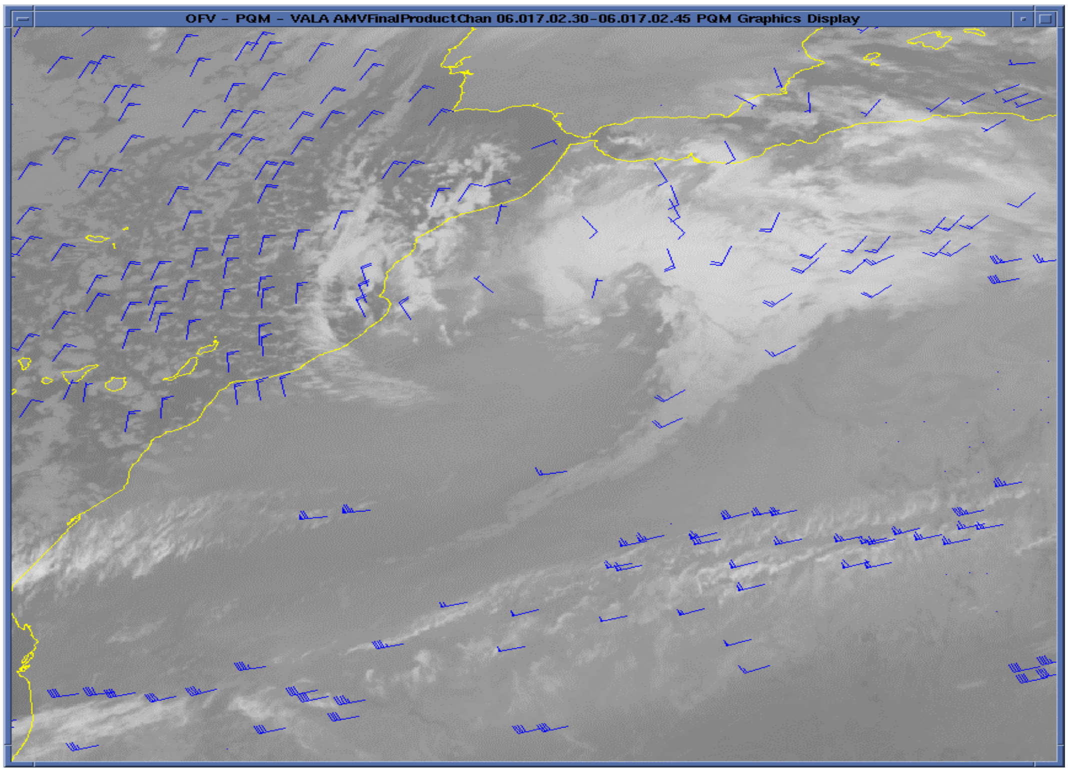

Figure 7 **: AMV Wind Field (RFF > 75)**

4. SHORT TERM OUTLOOK

The case study results in Section 3 are presented simply to demonstrate the use of the RFF as an alternative quality indicator to the EUM QI. The development is in the early stages. Further validation may necessarily involve further comparison against NWP forecast fields, further case studies and comparisons of radiosonde co-location statistics against the AMV Final Height and the RFF Adjusted Height.

In addition, further refinement of the RFF development and tuning of the set-up parameters will be carried out based on discussions with UW-CIMSS held at this conference in Beijing.

Following this, the RFF output will be included in the operational AMV BUFR product in the next major software release, scheduled for July 2006. There will be no impact on the disseminated winds. There are currently 9 occupied height assignment slots in the AMV BUFR product. The RFF Adjusted Height will be inserted in the 10^{th} slot. Currently the AMV BUFR product contains EUM QI values including and excluding forecast consistency. The RFF Quality Indicator will now be added.

5. LONG TERM OUTLOOK

The RFF Quality Indicator and Adjusted Height will be available for users as alternative quality indicators to the EUM QI. However, the use of the forecast data in the RFF is a factor of concern to some data users (eg ECMWF), although the forecast data contribution is down weighted.

Further development of the RFF by EUMETSAT, after the operational software release in July 2006, will be dependent to some extent on feedback from users. For example, the impacts of assimilating an RFF Adjusted height instead of the AMV Final Height, and/or using the RFF Quality Indicator instead of EUM QI. This may also involve the assessment of suitable RFF Quality Indicator thresholds for NWP model assimilation and radiosonde co-location statistics.

Inevitably, any changes will necessitate fine-tuning of the set-up parameters and co-operation between EUMETSAT and UW-CIMSSS.

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