IMPROVED QUALITY ESTIMATES OF ATMOSPHERIC MOTION VECTORS UTILISING THE EUMETSAT QUALITY INDICATORS AND THE UW/CIMSS AUTO-EDITOR

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ABSTRACT

The development of reliable Automatic Quality Control (AQC) schemes has played a key role in the development of the new high density and high frequency Atmospheric Motion Vector (AMV) products at UW/CIMSS and EUMETSAT. Despite the fact that the AQC schemes in the two organisations differ significantly it has previously been shown that both schemes are capable of assigning reliability factors to every extracted vector. The two approaches both seem to have areas where they perform well, but simultaneously they also have some shortcomings. Therefore it has been a natural development to try to combine the two schemes in order to derive an even better approach for AQC.

The preliminary comparisons of the two schemes were already presented at the 4th International Winds WorkShop. Based on these results a combined AQC-scheme was developed and verified. This new approach was applied to high-density wind fields derived with both GOES and GMS imagery data during the North Pacific Experiment (NORPEX-98). In the combined approach the QI was used as a precursive filter to the AE and within the ECMWF assimilation scheme for data screening. The impact of the combined scheme was better than either scheme alone. This paper will present the new combined approach and the validation results from NORPEX-98.

1. Introduction

Since the launch of the first geostationary satellites the data has been used to improve the knowledge and description of atmospheric flow especially over the large ocean regions that are void of traditional land based observations. Today the Atmospheric Motion Vectors (AMVs) derived from sequences of image data from the geostationary meteorological satellites have established themselves as an imperative part of the global observation system essential to medium range weather forecasting (e.g. Kelly, 1993) and also for the prediction of severe weather (e.g. Velden 1998). The main problem of the AMV extraction schemes is that several of the extracted targets are not suitable to be used as passive tracers for atmospheric flow and that the matching techniques do not always find the correct target location in the subsequent images. Furthermore the height assignment invariable gives gross errors in the pressure estimates. Therefore it is imperative to employ quality control to remove poor vectors that do not represent the instantaneous atmospheric flow. The large amount of vectors that are currently derived is too demanding for manual editing. Therefore, emphasis has been placed on the research and development of robust Automated Quality Control (AQC) procedures that are capable of removing suspect vectors related to tracking, height assignment and tracer representation errors. Furthermore, these schemes are being designed to provide a quality estimate for each individual displacement vector, as well as provide information on how representative these vectors are to instantaneous motion at a single tropospheric level. These quality estimates can be employed by the user community to select the part of the vector field that best suites their application, as well as in data assimilation schemes for optimising the data selection procedures.

The AQC schemes developed at EUMETSAT and UW-CIMSS that are currently employed at their respective national AMV extraction centres have already been presented at the 4th International Winds Work Shop (Holmlund and Velden, 1996). The results from their inter-comparison study showed the strengths and weaknesses of the two respective approaches. Based on the previous work a new combined quality control approach that takes advantage of the strengths of each method was developed. This scheme is presented together with validation results based ECMWF (European Centre for Medium range Weather Forecasts) model forecast impact studies based on a common data set derived during the NORPEX (NORth Pacific Experiment) field campaign.

2. Comparison of the EUMETSAT and the UW-CIMSS AQC Schemes

The results from the initial comparison of the EUMETSAT AQC and the CIMSS RFF scheme were presented at the previous winds workshop (Holmlund and Velden, 1996). The main conclusions from the inter-comparison were the following:

Both schemes classify in general the AMVs in a similar fashion
The UW-CIMSS scheme is capable of deriving more coherent wind fields
The UW-CIMSS scheme can recover some height assignment failures by re-adjusting the derived heights
The EUMETSAT scheme is capable of retaining more winds in fast flow regimes
The EUMETSAT scheme lends itself more easily for implementation and interpretation
The best vectors are those accepted by both schemes whereas the winds rejected by both schemes simultaneously seem to have the lowest reliability as single point measurements. These findings are summarised in Table 1, showing the nrms (rms normalised with wind speed for four quality categories.

Table 1. nrms for AMVs vs. NCEP 12-hr forecast at different levels (High=H (above 400 hPa), Medium=M (400 – 700 hPa) and Low=L (below 700 hPa), for three channels (IR, WV and VIS) and for different combinations of RFF and QI. The number of collocations is in brackets for each case. Winds with a RFF > 50 are accepted by the CIMSS scheme, whereas winds with a QI > 0.60 are considered to be good by the EUMETSAT scheme.

	RFF > 50 QI > 0.60	RFF < 50 QI > 0.60	RFF > 50 QI < 0.60	RFF < 50 QI < 0.60
IR, H	0.39	0.47	0.70	0.78
WV, H	0.39	0.41	0.69	0.66
IR, M	0.26	0.56	0.57	1.12
WV, M	0.24	0.43	0.47	0.82
IR, L	0.35	1.48	0.51	1.45
VIS	0.32	0.37	0.72	0.93

3. Validation in the ECMWF Assimilation Scheme

Based on the previous experience with the two systems, several different combinations of the QI and the RFF schemes were explored. Three main experiments were undertaken using different QI values to select which vectors would be subjected to the RFF scheme. The selected minimum QI values were 0.3, 0.6 and 0.9. These thresholds were selected as 0.3 represents the operational cut-off, 0.6 provides a good coverage and reasonable quality and 0.9 as it only retains very good winds. Additionally to utilising the QI as a pre-filter it was also used to select the best vector for each assimilation box in the model as explained in section 4 a. The impact studies showed that the most promising approach was to use the QI with threshold 0.6 to pre-filter the raw wind field before submitting to the RFF scheme. The reason for the QI threshold of 0.3 not doing too well was that only a small number of very poor vectors were removed and these the RFF handles well. The QI threshold of 0.9 again did not keep enough vectors for the RFF to perform a coherent analysis of the data. Therefore the results for the QI threshold of 0.6 (RFFQI60) are discussed in more detail.

For our evaluation of this approach, all winds derived between 1 to 7 February 1998 during NORPEX were quality controlled by the RFF based approach only (RFF), and then also with the combined scheme using the QI information as a pre-filter to the RFF scheme. All data sets were disseminated to ECMWF. The AMVs are compared to the wind fields of the ECMWF 6-hour operational forecast with 31 model levels and T319 spectral resolution (Courtier et. al., 1998, Rabier et. al., 1998). For the statistical evaluation the background field was interpolated on a latitude longitude grid with 1.5° resolution. The model winds were then interpolated to the location and pressure of the satellite wind observations. For the evaluation, the wind vectors were sorted into quality classes based on their quality estimates. Each quality class was 0.02 wide (0.0 – 0.02, 0.02 – 0.04, 0.04 – 0.66, etc) and the mean wind speed (dashed line), rms departure (solid line) and bias (dotted line) as against the model winds was computed separately for each quality class.

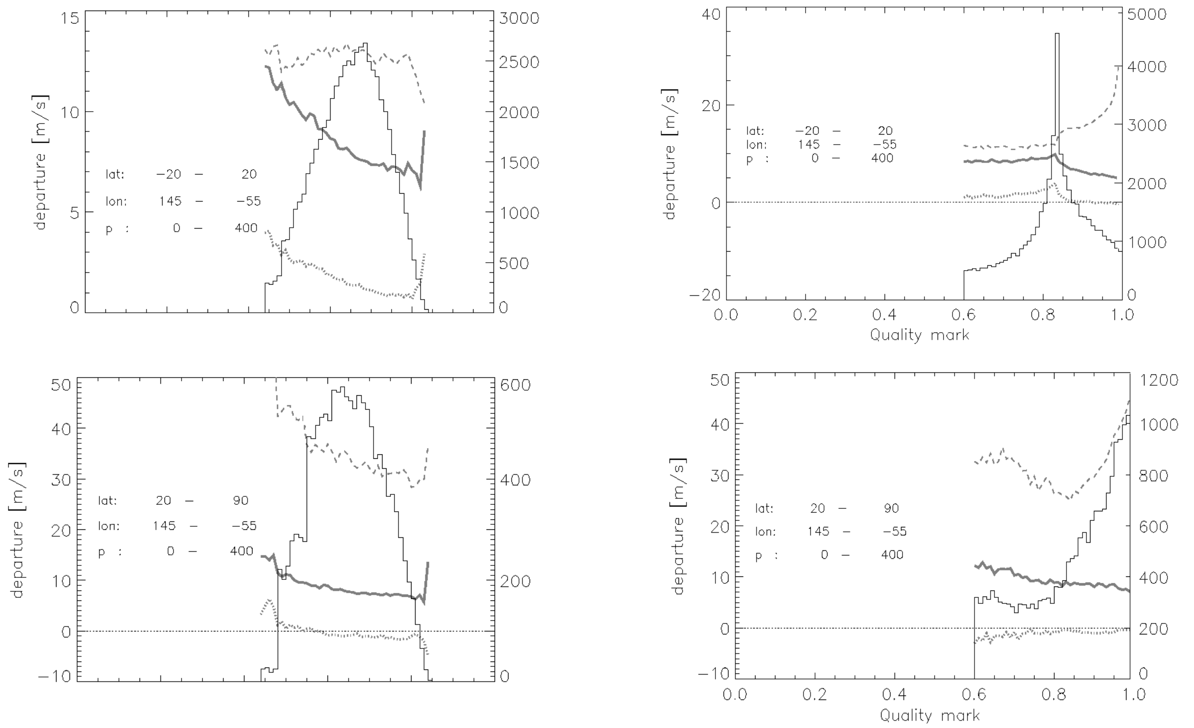

Figure 1. Comparison of background departures (The line for rms is solid, for speed bias dotted and for mean background speed dashed) of high level (p < 400 hPa) extratropical (bottom two figures) and tropical (top two figures) IR winds from the original NORPEX dataset (RFF only) to assigned RFF quality estimates. (The line for rms is solid, for speed bias dotted and for mean background speed dashed) of high level (p < 400 hPa) extratropical IR winds from the revised NORPEX dataset (RFFQI60) to assigned QI quality estimates.

Figure 1 presents these results for the IR high (above 400 hPa) and low (below 700 hPa) winds for the northern hemispheric extratropics (20° < latitude < 90°) and the tropics (0° < latitude <= 20°). The number of observations in each quality class is indicated by the histogram. Both quality indicators (RFF and QI) show decreasing rms departures and bias with increasing quality mark. The mean wind speed is almost constant for the RFF approach whereas it increases in the combined approach against the QI. The RFFQI60 winds reveal a pronounced step around QI=0.85 that is probably related to one of the EUMETSAT consistency tests indicating the need of further tuning for the tropical region. Below this threshold the rms departures are large and the mean wind speed low whereas above this threshold the bias and the rms departures decrease rapidly with an increase in the mean wind speed. This finding indicates the 0.6 threshold is not optimal for all channels, and the impact of this will be addressed in the next section.

4. Forecast Impact Studies with the ECMWF Model

4.1 Assimilation Strategy

For our study, the operational version of the ECMWF 4DVAR with an analysis resolution identical to the configuration under 5c is employed for data impact and sensitivity (Klinker et. al., 1999). The findings presented above are used to identify QI thresholds for selection of the winds to be considered for assimilation into the ECMWF analysis. The experiments using the original NORPEX high-density winds followed the operational usage of GOES-9 cloud-tracked winds, i.e. only winds with a quality estimate of RFF > 50 were considered. This follows the current practice of the ECMWF operational assimilation of GOES cloud drift winds from the IR and WV channels. Additionally, cloud drift winds from the VIS channel were introduced at low levels. Additionally to cloud drift winds, winds from cloud free regions are produced from the WV imagery data operationally. Also during NORPEX these so-called clear sky winds were produced and the medium and high level vectors were activated for the assimilation experiments.

The assimilation strategy for the revised data set using the QI as a pre-filter for the RFF scheme was based on the results described in section 4c). In the Northern Hemisphere extra-tropics all winds with a QI > 0.60 were considered. In the tropical belt a more restrictive use was introduced based on the findings in Figure 10, with a minimum QI value of 0.85 for high levels in the tropical belt. This is similar to the approach for the current operational usage of Meteosat winds, which is currently under investigation (Rohn et. al., 1998).

The NORPEX high-density winds were assimilated during the two-week period from 25 January to 7 February 1998. Early experiments with the high density data showed some problems in assimilating large volumes and is likely to be related to horizontally correlated errors in the observation data and by out weighting other observations. Therefore the high-density wind data needed to be thinned prior to assimilation by selecting one vector per analysis grid point location. For each case the vector with the highest quality within a selection box was chosen for assimilation. This results in a minimum horizontal distance between assimilated observations of roughly 1.25°. In the vertical, only one satellite wind is allowed per nearest model pressure level (50, 70, 100, 150, 200, 250, 300, 400, 500, 700, 850, 925, 1000 hPa). In the situation of very dense coverage of observations, the QI flag is further employed in the RFFQI60 experiment as a criterion in order to assimilate only the one observation with the highest QI value.

4.2 Forecast Impact

Since the main objective of the NORPEX campaign was to test adaptive observing strategies in order to improve the forecast skill over the US (Langland et al. 1999), we follow the evaluation used in the investigation of the combined impact of both high-density winds and dropsondes on the NOGAPS (Navy Operational Global Atmospheric Prediction System) forecasts (Szunyogh et al. 1999 and Langland et al., 1999) at the Naval Research Laboratory. The rms errors of the 48-hour forecast for both the 1000 hPa and 500 hPa geopotential surfaces are summarised in Table 2. The verification is restricted to a western North American region (30° < latitude < 60°; -130° < longitude < -100°) in agreement with the studies by Szunyogh et al. (1999) and Langland et al. (1999).

Table 2. Influence of the experimental assimilation of high-density winds on ECMWF model 48-hr forecast errors of the 1000 hPa and 500 hPa geopotential surfaces. The relative forecast impact is given as rms error differences between forecasts starting from the analysis using the experimental satellite winds derived by UW-CIMSS for NORPEX, and the control analyses using only the operationally available GOES-9 and GMS winds over the Pacific. Results are shown for the RFF-only, QI-only and the combined RFF/QI60 experiments. The evaluation period is 25 January to 7 February 1998. Both the absolute forecast rms errors and the difference values are averaged over the region of interest (30°<latitude<60°; -130°<longitude<-100°). Negative difference values indicate forecast improvement over the control. The forecasts are verified against their own analyses.

Description	Pressure level	48h forecast mean difference (m)	48h forecast rms error (m)
RFF-only	1000 hPa	-0.56	17.91
	500 hPa	-1.82	23.23
QI-only	1000 hPa	1.24	19.71
	500 hPa	0.64	25.70
Combined (RFF/QI60)	1000 hPa	-1.29	17.19
	500 hPa	-2.65	22.40

Both data sets that used the RFF scheme (RFF only, RFF/QI60) lead to reduced forecast errors, whereas the QI-only scheme increased the errors. Note that the control system uses the operational GOES winds that have been subjected to the RFF scheme as well. Therefore it is encouraging to see that by utilising the combined approach further improvements are made. From the theoretical aspect of data assimilation any dependency of the observation data to a short-term numerical forecast is not desirable as it feeds the model. This is especially important in the context of the re-adjustment of speed and height as outlined in section 3. The current results demonstrate on the other hand the gain from the RFF scheme in the current assimilation of AMVs. The rms error of the 48-hour geopotential forecasts is further decreased by the combined scheme (RFF/QI60). This can be explained by that the QI-scheme is able to provide a more consistent data set for the RFF scheme, which is then able to perform a more consistent analysis of the data.

The restriction to a particularly limited verifying region and a single forecast time requires caution especially regarding the relatively short experimentation period of two weeks. We therefore include the geographical distribution of short term forecast error in Figure 2. Both panels show the differences in the averaged rms error (14 cases) of the geopotential forecast at 250 hPa between the system initialized with the RFF/QI60 data and the Control. The forecast field is verified against its own analyses. Negative values indicate reduced forecast errors and are marked in yellow shading. Positive values are marked green. The 48h forecast error differences (left panel) reveal an extended area of reduced errors over the north Pacific which is less pronounced in the forecast based on the RFF-only analysis (not shown). In the bottom panel the forecast impact has moved east showing propagation into the NORPEX target area (northern America).

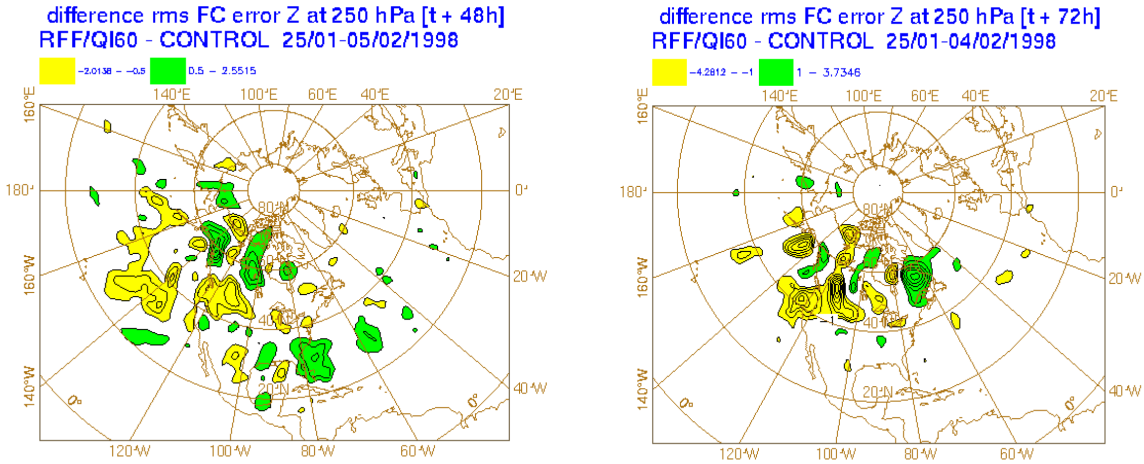

Figure 2. Differences of rms forecast error for the geopotential at 250 hPa between the RFF/QI60 experiment and the Control. Left: 48 hour forecast, Right: 72 hour forecast. Negative values indicate reduced forecast errors and are marked in yellow shading whereas positive values are marked green. All other areas do not show a significant change and are clear.

This development is supported by the verification of the forecast of vector wind at 850 hPa and 200 hPa within the Northern Hemisphere (Figure 3). All forecasts are verified against the Control analysis that explains the differences up to day one. The assimilation of the QI-only data results in increased rms errors in the medium range in agreement with the tendency indicated in Table 2. The combined quality control (RFF/QI60) shows a mainly neutral impact through day 2 and a small reduction of the medium range forecast errors beyond. These results support the positive impact of the presented combined quality control approach together with data screening decisions based on the quality estimates (RFFQI60).

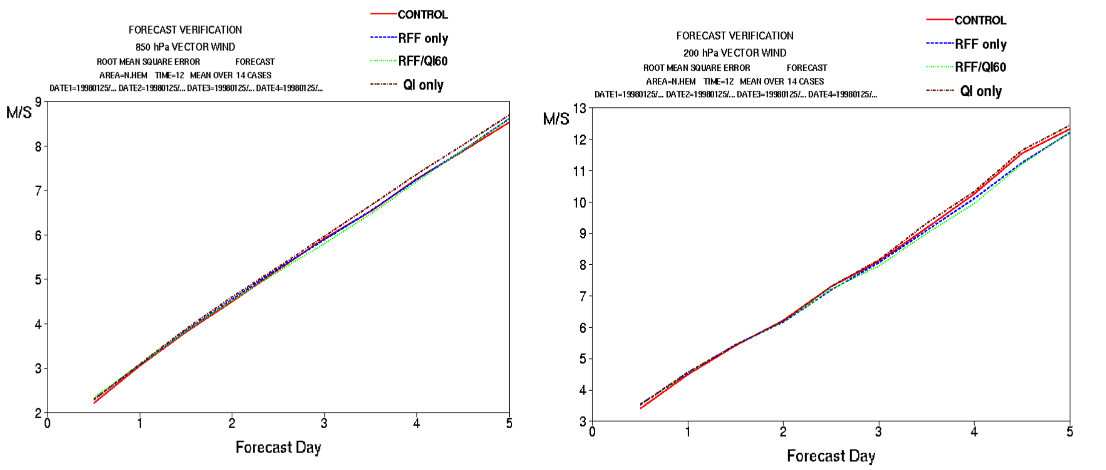

Figure 3. Verification of the rms forecast errors for vector wind at 850 hPa (left) and 200 hPa (right) in the Northern Hemisphere. All forecast are verified against the Control analysis.

5. Conclusions

The current operational automatic quality control schemes for satellite-derived atmospheric wind vector fields at high densities as applied at NOAA/NESDIS (UW-CIMSS scheme) and EUMETSAT have been briefly summarised. Even though the two schemes differ in their respective approaches, they generally classify the quality of vectors in a similar fashion. Both schemes have been shown to have advantages and disadvantages. The UW-CIMSS scheme is capable of providing more coherent wind fields and adjusts for some height assignment problems. The EUMETSAT scheme is capable of retaining more winds in the fast flow regimes and lends itself more easily for analysis and interpretation due to its straightforward formulation. It has been shown that the best vectors are generally those accepted by both schemes, whereas winds rejected by the two schemes simultaneously have a low reliability as single-level point measurements. In the case of disagreement between the two schemes, the EUMETSAT QI-scheme is capable of identifying and retaining more high-level water vapour and low-level visible winds, whereas the UW-CIMSS RFF based scheme retains a better low-level IR vector field.

Numerical model forecast impact experiments were performed on a two-week dataset during the NORPEX field program. The first two experiments used the original QC methods (RFF-only and QI-only), and the third assimilated a revised data set based on the application of the QI filter prior to the RFF based scheme and using the quality indicators to select the final winds for input. In general, results from the forecast impact studies show the assimilation of the high-density cloud and water vapour drift winds provided over the North Pacific region during NORPEX leads to a positive impact on the ECMWF model two-day forecast of the 1000 hPa geopotential height over a western North America region which was used as the primary verifying area for the NORPEX campaign. This result is consistent with the positive experience of using the NORPEX satellite-derived data set in other assimilation and forecast systems (Szunyogh et al., 1999; Langland et al. 1999).

The assessment of the geographical distribution of mean rms forecast errors differences appear to introduce an improvement by the revised QC strategy at day 2 which propagates into the NORPEX target area over the North West of the United States at day3. This tendency is supported by the verification of the rms forecast errors for vector wind at 850 hPa and 200 hPa in the Northern Hemisphere beyond day2. Note that in contrast to the comprehensive study by Langland et al. (1999) these results are based on the comparison to a Control system which uses the at that time operationally available GMS and GOES-9 satellite winds over the North Pacific.

Detailed analysis of the NORPEX cloud and water vapour drift wind sets by comparison with the ECMWF 6 hours forecasts revealed insight into the information content of the two different automatic quality control estimates, namely the recursive filter flag (RFF) and the quality indicator (QI). The QI+RFF value indicates the potential to mark the quality of single observations with respect to rms background departure and speed bias for data assimilation purposes. This study yields good evidence for the use of the combined QI and RFF values within the screening decisions of the ECMWF (and other) data assimilation system. The most promising approach was to use the QI with threshold 0.6 to pre-filter the raw wind field before submitting to the RFF scheme, and to subsequently use the QI, especially in high density areas, to select the best of the retained winds for data assimilation into a forecast model. A more complete analysis is given in Holmlund et. al. (2000).

Future work will concentrate on optimising the combined AQC approach described initially in this study. The effort on the data assimilation side should attempt to correct the representativeness error by modelling the vertical uncertainty of clouds and water vapour structures. Furthermore the discrepancy between the resolution of the extracted vector fields and the numerical analysis (Kelly et. al. 1996) should be reduced. In the area of AMV-extraction the efforts will be directed towards better target selection and height assignment methodologies including uncertainty estimates.

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