AUTOMATIC QUALITY CONTROL WITH THE CIMSS RFF AND EUMETSAT QI SCHEMES

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ABSTRACT

At the 5th International Winds Workshop two different schemes, the Recursive Filter Function (RFF) developed at the Co-operative Institute for Meteorological Satellite Studies (CIMSS) and the Quality Indicator (QI) scheme developed at EUMETSAT, were compared and a combined scheme was presented. This paper will give a brief overview of the two methods and the proposed combined scheme. The paper will also give an overview of the status of the implementation of the two schemes at various centres producing operational wind products and the level of usage at different Numerical Weather Prediction Centres. The main objective of the paper is to instigate a discussion on the Automatic Quality Control procedures currently in use and to further endorse the utilisation of the RFF and QI schemes.

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. The Atmospheric Motion Vectors (AMVs) derived from sequences of image data from the geostationary meteorological satellites have already, since more than a decade, been an imperative part of the global observation system essential to medium range weather forecasting (e.g. Kelly, 1993). The use of the AMVs has also significantly contributed to improved forecasts in severe weather situations (e.g. Velden et. al. 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.

The main objective of Automatic Quality Control (AQC) is therefore to identify suspect vectors with errors related to tracking, height assignment and tracer representation. Furthermore, the AQC schemes should 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 users 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 or to modify observation operators. Finally the methods should be as forecast independent as possible as the use of the forecast data may lead to similar correlation errors as present in the model (e.g. Bormann, 2002). Strong dependence on forecast data may also make utilisation and interpretation of results more difficult (e.g. Mecikalski (2002).

The AQC schemes developed at EUMETSAT (EUropean organisation for the exploitation of METeorological SATellite data) and UW-CIMSS (University of Wisconsin - Co-operative Institute for Meteorological Satellite Studies) that are currently employed at their respective national AMV extraction centres were already been presented at the 4th International Winds Workshop (Holmlund and Velden, 1998). At the 5th International Winds Workshop further comparisons and validation results for the two different schemes, the Recursive Filter Function (RFF) developed at the CIMSS and the Quality Indicator (QI) scheme developed at EUMETSAT, were presented together with a model to combine the two methodologies (Holmlund et. al., 2000). This paper will give a brief overview of the two methods and the proposed combined scheme. The paper will also give an overview of the status of the implementation of the two schemes at various centres producing operational wind products and the level of usage at different Numerical Weather Prediction Centres. The main objective of the paper is to instigate a discussion on the Automatic Quality Control procedures currently in use and to further endorse the utilisation of the RFF and QI schemes.

2. The UW-CIMSS AQC Scheme

The Auto-Editor (AE) scheme is described in Hayden and Purser (1995). It was developed at UW-CIMSS and is currently used operationally by NOAA/NESDIS (National Oceanographic and Atmospheric Administration/National Environmental Satellite Data and Information Service) for processing high-density GOES winds. The scheme relies on a series of steps highlighted by two passes of a 3-dimensional recursive filter objective analysis of the wind field. The recursive filter determines the fit of each vector to the analysis. In addition, a variational penalty function is applied to each vector that seeks an optimal level for height assignment:

$$B_{m,k} = \left(\frac{V_m - V_{i,j,k}}{F_V}\right)^2 + \left(\frac{T_m - T_{i,j,k}}{F_T}\right)^2 + \left(\frac{P_m - P_{i,j,k}}{F_P}\right)^2 + \left(\frac{dd_m - dd_{i,j,k}}{F_{dd}}\right)^2 + \left(\frac{s_m - s_{i,j,k}}{F_s}\right)^2 \quad (1)$$

Subscript m refers to a single wind measurement; i and j are horizontal dimensions in the analysis and k is the vertical level. The denominators F_x (x=V, T, P, dd, s) are weights defining the relative importance of the different terms in the penalty function.

This step usually results in minor height assignment adjustments, and not major vertical displacements of vectors (e.g. Velden et al. 1998). The UW-CIMSS AQC scheme results in the attachment of a quality flag (recursive filter flag, RFF) between 0 and 100 to each vector based on the final fit. Only higher quality vectors with flags equal to or exceeding 50 are passed to the users (this threshold was determined empirically through a multitude of radiosonde collocation statistics).

3. The EUMETSAT AQC Scheme

The EUMETSAT AQC scheme is described in Holmlund (1998). The baseline configuration is based on five different tests estimating the time consistency of the AMV vector as well as its direction and speed components. Additionally a local consistency check is performed against neighbouring vectors and against a background field. The AQC tests are normalised with a simple TANH-function that returns values between 0 and 1, where 0 indicates poor quality and 1 high quality. The tuning of the tests has been achieved by deriving statistics for the different tests against collocated rawinsondes as well as by qualitative validations performed by experienced shift meteorologists. The current tests have been tuned to perform in a binary-like mode, i.e. most tests return values preferably close to 0 or close to 1. The original configuration was selected in order for the new scheme to mimic the old threshold-based technique. The second important step in the EUMETSAT AQC is the combination of the normalised test values to provide a final quality estimate. As the distribution of the tests results do not generally follow statistically well behaved functions, the combination of the results to provide probabilities of vector quality is not possible. Instead a simpler approach, where the final quality indicator (QI) is a linear weighted average of the individual results, has been selected:

$$QI = \frac{1}{\sum w_i} \sum w_i \Phi_i \quad (2)$$

Additionally to the tests described above, the QI scheme also involves an inter-channel consistency check. This check compares low level IR (infrared) and VIS (visible) winds to collocated clear sky water vapour (CSWV) winds. Based on the notion that the IR and VIS low level winds should describe completely different motion than the CSWV winds, low-level winds that are similar to the CSWVs are removed. This test has proven to be important in removing vectors related to extremely thin cirrus that have remained unidentified in the image analysis and are therefore erroneously assigned to a low level.

4. Summary on Automatic Quality Control Procedures

Table 1 presents the NRMS as derived against the background field (model forecast) for winds at three levels and three channels and divided into four categories for one case during the NORPEX-98 (E.g. Langland et. al., 1999) experiment. The main conclusion from Table 1 seems to be that those vectors that both schemes find to be good are indeed of high quality (as compared to the background field) and when both schemes rate the quality as poor, the NRMS is higher. The interesting groups are where the two schemes disagree. The statistics tend to suggest that the QI scheme is capable of keeping more good winds than the AE scheme. However, the winds accepted by the AE and rejected by the QI scheme seem better than those rejected by both schemes. This generally indicates that both schemes tend to have some skill in identifying good winds. It should also be noted that for low level IR winds the AE seems to perform better than the QI scheme, which could be a result of the scheme being tuned mainly for Meteosat water vapour winds.

Table 1. NRMS for AMVs 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.

	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

To further improve the impact of the quality indicators it has been suggested to combine the two schemes. One possibility would be to use the RFF as separate function to assess height reliability in the QI approach or to use the QI as a separate term in the RF variational penalty function.

Summary on RFF and QI:

- Both schemes provide good estimates on the quality of individual vectors
- UW-CIMSS scheme provides more coherent fields
- The Eumetsat scheme retains more winds in fast flow regimes
- The best vectors are generally those given the highest quality by both schemes and:
- Result in the biggest NWP impact

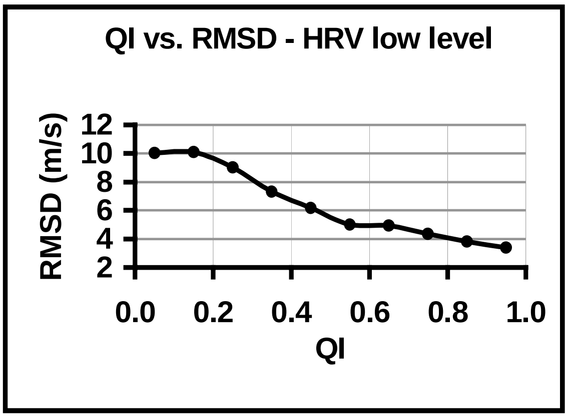
5. Current Implementations of Automatic Quality Control Schemes

Based on the results presented, the 5th International Winds Workshop (IWWS5, 2000) recommended all data producers to implement the RFF and QI schemes or equivalent schemes. As a result most operational agencies have implemented either the RFF scheme or the QI scheme and some even both. Table 2 presents the status of the current implementation of the two schemes at the various centres.

Table 2. The status of the implementation of the RFF and QI schemes at various operational and research centres producing AMVs. O = Operational indicates operational use, E = Under evaluation.

Centre	RFF	QI	Alternative methods
CIMSS	**O**	**O**	
NOAA/NESDIS	**O**	**O**	
USAF/USN	**O**	**O**	
EUMETSAT	**E**	**O**	
IMD	**E**	**-**	
JMA	**E**	**E**	**O**
BoM	**E**	**E**	**O**
NWC SAF	**-**	**O**	
CMA	**-**	**E**	**O**
LMD			**E**
CPTEC			**E**

Figures 1 demonstrates the relationship between the Quality Indicators (QI) derived with the Eumetsat scheme vs. RMS difference derived against collocated radiosondes. The results are based on implementations of the QI-scheme at JMA (Japan Meteorological Agency) (Kumabe et. al., 2002) and BoM (Bureau of Meteorology, Australia) (Le Marshall et. al., 2002). The left panel in Figure 1 shows the QI against the RMS vector difference against collocated radiosondes for High-Resolution Visible (HRV) winds. The right panel shows the relationship between QI and speed bias, Normalised RMS (NRMS) , Mean vector difference (MVD), mean wind speed (SPD) and RMS for medium level winds. Figure 2 shows the impact of the QI scheme integrated to the Nowcasting SAF (Satellite Application Facility) AMV at INM (Instituto Nacional de Meteorología). In the example presented the QI is used to identify poor vector colour-coded in white.



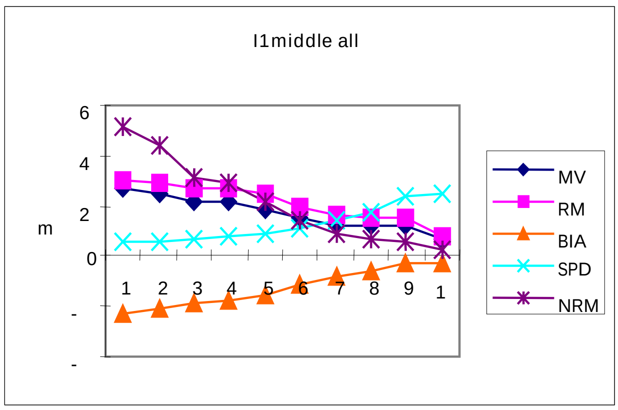


Figure 1.Left panel: QI vs. RMS vector difference for low level high resolution visible winds, derived at Bureau of Meteorology (Le Marshall et. al., 2002). Right panel: QI vs. RMS vector difference, mean vector difference bias, mean speed and Normalised RMS for medium level winds, derived at Japan Meteorological Agency (Kumabe et. al., 2002).

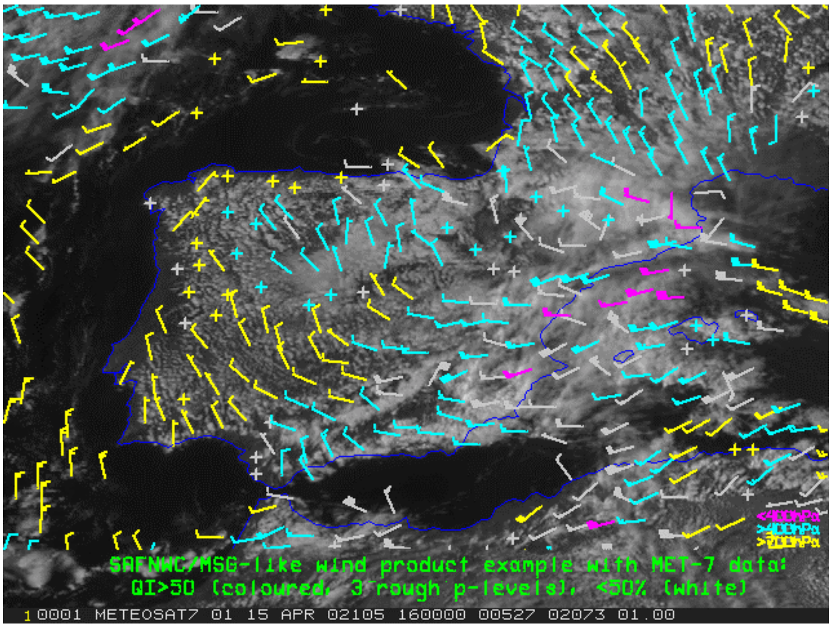


Figure 2. Impact of the Eumetsat based Automatic Quality Control scheme at NWC SAF At INM (Fernández Serdán, 2000). Coloured vectors are vectors with a QI value of 0.5 or above at different levels, white vectors have a QI < 0.5.

7. Utilisation of Quality Information at NWP Centres

The utilisation of the quality control information provided together with the winds data enables the users to select the subset of winds that best suite their application. The RFF and QI values are currently monitored and used in data selection processes during assimilation at various centres. At ECMWF the QIs are currently used in two different ways. Firstly, in every observation box the wind with the highest QI is selected for assimilation. Secondly, black-listing according to Table 3 is performed (Kelly and Rohn, 2000).

Table 3. Data selection according to quality estimate QI

Area	Channel	Low 700<p<=1000	Medium 400<p<=700	High p<=400
NH	IR	QI>0.85	QI>0.90	QI>0.60
lat>20°	VIS	QI>0.65		
	WVcloud		not used	QI>0.60
TR	IR	QI>0.85	QI>0.90	QI>0.85
-20°<lat<20°	VIS	QI>0.65		
	WVcloud		not used	QI>0.85
SH	IR	QI>0.85	QI>0.90	QI>0.60
lat<-20°	VIS	QI>0.65		
	WVcloud		not used	QI>0.60

The use of the QI at other centres has also increased since the last International Winds Workshop. Figure 3 presents the monitoring results currently derived at the CMC (Canadian Meteorological Centre) (Sarrazin and Brasnett, 2002)

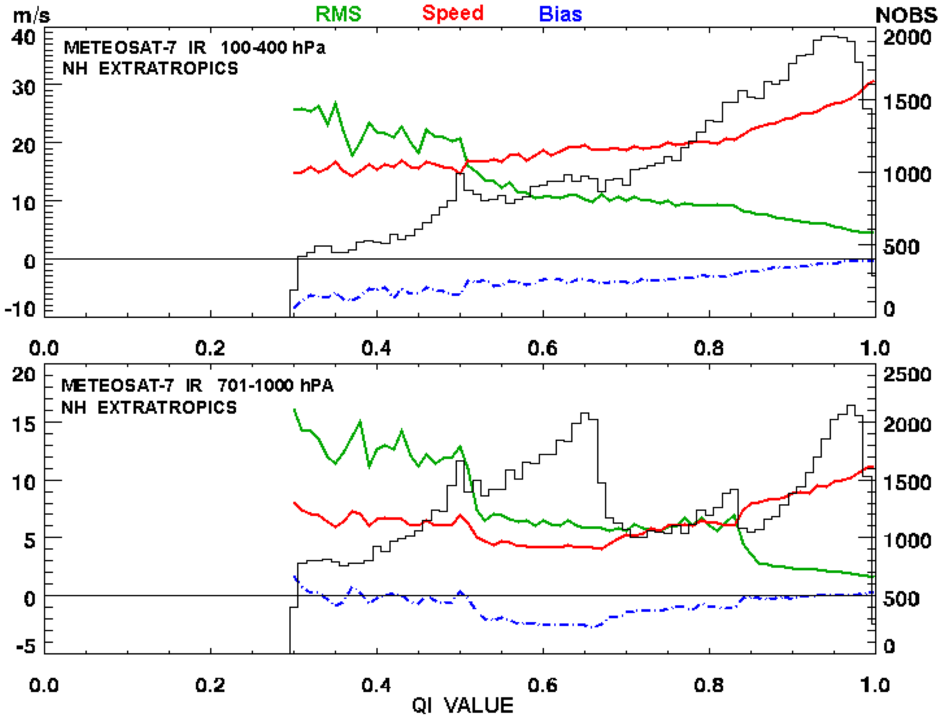


Figure 3.Monitoring results for the QI at the CMC, Canada (Sarrazin and Brasnett, 2002).

The first step towards the utilisation of the quality information provided by the operational AMV centres is to use the AMV data provided in BUFR format. The provision of quality information in the SATBOB format is not possible. Table 4 presents a summary of the use of AMV formats at various operational centres. This table is maintained by EUMETSAT.

(see http://www.eumetsat.de/en/dps/mpef/products/windsuse.html).

Table 4. Use of AMV data formats at various operational forecast centres.

Centre	CMW (SATOB)	CMW (SATOB)	CMW BUFR	CMW BUFR	HRV (Simplified BUFR)	HRV (Simplified BUFR)
	Monitored	Assimilated	Monitored	Assimilated	Monitored	Assimilated
BoM	X	X				
CMC	X	X				
DWD	X	X				
ECMWF			X	X	X	X
JMA	X	X			X	
Meteo France	X	X	X	X		
UKMO	X	X	X		X	X
NCEP	X	X				
FNMOC			X	X		
NCMRWF	X	X				
DAO						

8. Summary

The use of automatic quality control schemes based on the UW-CIMSS RFF and the EUMETSAT QI scheme has increased dramatically since the 5th International Winds Workshop. The methods that provide information on the quality of the derived AMVs are now generally used, or being evaluated at all major operational centres producing AMVs and are also incorporated in several research schemes. The increased provision of this data is also reflected in the utilisation of the data in NWP that also has increased in the past two years. The current schemes are however still not fully capable of providing all the information that is required by the end users. Further work should concentrate on full characterisation of the AMV errors and forecast independent schemes. Of particular importance are the issues related to height assignment, where forecast dependence enhances the strongly correlated horizontal errors of the AMVs. Therefore further work should also be concentrating on the development of improved height assignment schemes, including estimates of the height assignment errors, and layer thickness that also the cloud tracked AMVs represent. This work that can only be successfully completed in co-operation between data producers and users, will ensure that the derivation of AMVs, also in the future will be an important role in the global observing system.

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