THE APPLICATION AND IMPLICATIONS OF THE USE OF A UNIFIED BUFR TEMPLATE FOR THE EXCHANGE OF SATELLITE DERIVED WIND DATA

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ABSTRACT

At the meeting of the WMO CBS sub-group on data representation and codes in April this year, additional entries were agreed for addition to BUFR tables B and D, for the representation of satellite derived wind data. These entries should come into force on 4 November 1998. With the greater flexibility, which BUFR provides, it will be possible to exchange very detailed wind data and quality control information operationally via the GTS.

An illustration of the advantages of the "unified" BUFR wind template is provided by consideration of the possibilities for including quality control information. By using standard BUFR techniques it is possible to have different types of quality control data associated with each element of the wind observation. Each wind disseminated in the "unified" BUFR template by EUMETSAT has associated values of percentage confidence, type of quality control performed (manual, automatic, or a mixture), and a nominal percentage confidence threshold, beyond which the data can be considered "good". The quality control data must be supplied separately for each element of the observation, and this provides the opportunity for specific values to be given for the speed, direction and height assignment of a wind, for example. There still remains the issue of determining how to calculate these values, and some initial work on this subject will be included in the presentation.

1. SATOB to BUFR

BUFR encoding, because of its flexibility, allows for much more information to be included with each observation than was previously possible using SATOB. By including information about the quality control of the data, e. g. % confidence and the type of quality control performed (manual or automatic), a much greater quantity of data can be encoded, due to the inclusion of extra winds in addition to those accepted by manual quality control. The data, which are used for the SATOB products, can be identified within the BUFR data.

The differences between the SATOB CMW product and the new BUFR product are summarised in the following table.

BUFR wind data	**SATOB wind data**
Quality control information included	No quality control information included
All winds exceeding a nominal quality threshold encoded	Winds accepted by manual quality control encoded
All winds per segment included	One wind per segment included
Product every 90 minutes	4 manual quality controlled products per day

Two further aspects of the BUFR format, which make it appropriate, are its efficiency at compressing data, and its definition using tables. The compression is fully described within the WMO regulations and is particularly efficient for satellite products, where adjacent observations are similar to each other. Because BUFR is a table driven Data Representation Form (DRF), it can be updated and modified by changes to the tables themselves and without explicit software modifications. This flexibility means that updates to BUFR, like those to GRIB and CREX, are normally introduced via a fast-track scheme, and can therefore be in force within a number of months of their initial suggestion.

2. Unified Wind Template

In order to support the increased amount and types of data, a co-ordinated set of unified BUFR templates for the representation of geostationary satellite products has been developed. The process has involved the co-operation of EUMETSAT, NOAA/NESDIS, ECMWF and JMA in determining the required entries, and is being co-ordinated with the CBS Working Group on Data Management.

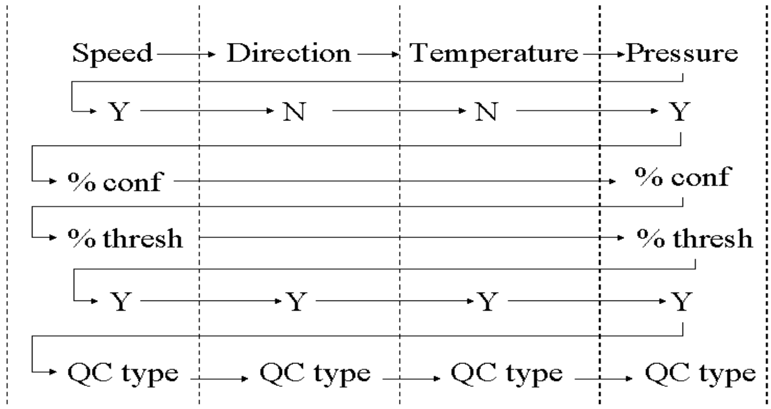
The wind template's contents were considered by the Sub Group on Data Representation and Codes, and have since been endorsed formally by WMO before coming into force in November 1998. The full template contains entries for all the fields required to encode wind data from either EUMETSAT or NOAA/NESDIS, but because of the compression method used by BUFR, the 'missing' fields which may be present for each observation do not lead to significantly larger bulletins. The template was also designed to be suitable for the Meteosat Second Generation (MSG) Atmospheric Motion Vector (AMV) product.

The following MPEF products are currently distributed regularly on the GTS in the new template: Expanded Low Resolution wind (ELW), Clear Sky Water Vapour Winds (WVW), and High Resolution Visible Winds (HRV). This will also be the *de jure* method for encoding any further wind products in the future, such as the High Resolution Water Vapour Winds (HWW) (Elliott, 1998), which will be available from the early part of 1999.

3. Encoding Associated Values

The general mechanism by which associated values such as quality control data and statistical information can be attached to the data is illustrated in the following diagram. It uses the example of a simple observation consisting of only four elements: speed, direction, temperature and pressure.

Following after these data values, a ‘data present map’ is shown. This is used to say which of the original elements of the observation are referred to with the following information. In this case there is associated data following for only the speed and pressure. There then follows the data itself, in this case two percentage confidence values and two percentage confidence threshold



values. At any stage a new ‘data present map’ can be introduced, as is shown after the confidence threshold values. It is used in the example to indicate that there follows information about the type of quality control performed for all of the original elements, and is followed by this information. In this way it is possible for other users of the data to define there own quality control information and/or statistics, and append this quite simply to the end of the bulletin in a serial way.

4. Automatic Quality Control

For each of the wind products, the quality control mechanism consists of a set of normalised consistency tests. These checks can be divided into 3 distinct groups: the two component vectors which are combined to give each resultant vector are checked internally for their symmetric consistency, the vectors are checked for their spatial consistency with respect to any neighbouring vectors from the same height level (+- 50 hPa), and the forecast wind field data from the European Centre for Medium range Weather Forecasting (ECMWF) are used as an external validation. The results of these tests are linearly combined to give an overall extraction score.

Comparison with radiosonde observations has shown that the overall quality value assigned by the MPEF is a good statistical measure of the actual quality of the operationally derived winds, particularly those from the WV channel (Holmlund, 1996).

Analysis of the performance of the quality indicators for both the water vapour CMW winds and the 160km clear sky WV winds with respect to the ECMWF analysis data has also shown the reliability of the quality control mechanism. Although there may need to be some optimisation of the quality control parameters, it is clear that we can be reasonably confident that the individual tests themselves contain useful information.

5. Enhanced Quality Control

The overall quality control score / confidence is currently used repeatedly for each of the speed, direction, height and temperature of each wind. This is somewhat artificial, since the total score is comprised of information about each of these parts. We have developed a method for determining quasi-independent scores for the direction and speed of a wind, and have used the same simple method to show that a more reliable overall score can be calculated by modifying the weights given to the individual tests.

We seek to establish a reliable (i.e. consistent) and monotonic relationship between the quality / confidence assigned by the automatic quality control scheme, and the actual quality, as measured after the fact by comparison with co-located radiosonde data. With this in place, the user is then able to use the scores we assign to our winds as a measure of their real quality during assimilation. For the sake of simplified analysis of our results, we seek a linear relation ship between attributed and real quality in our calculations.

A first approach to determining independent quality measures for the separate components of the wind might be to use the result of the speed test for instance as a measure of the quality of the speed of the wind. Although this does give some information, a better speed confidence is given by taking a weighted mixture of all the tests, as we describe below.

6. Weight Optimisation

The mechanism for optimising the weights of the individual tests can be outlined as follows. First a set of co-located radiosonde data is selected to provide the ground truth for the comparison. Typically a months worth of data is sufficient. Then a measure of the actual quality of each wind with respect to the radiosonde measurement, ε, needs to be calculated. The exact method is not critical, as long as a result from 0 to 1 is calculated, 0 for bad winds and 1 for good ones. The following definitions of ε were used for this study:

For speed quality ε = MIN [1 - (speed difference / radiosonde speed)]
For direction quality ε = MIN [1 - (direction difference / 180.0)]
For overall quality ε = MIN [1 - (vector difference / radiosonde speed)]

For each wind vector, the results of the individual tests, t_i, are known. Then for a set of co-located data, a modified linear regression method is used to optimise the weights of the tests, w_i, over the condition for each wind,

$$\sum (w_i \times t_i) = \varepsilon$$

The linear regression is modified in that there is no constant allowed. This constant is removed in order to model the functionality of the operation quality control scheme as closely as possible.

In each of the analyses undertaken and additional, artificial test was also used as a control parameter. The test score was assigned a random number for each wind, and in every case the method assigned the result of this test the lowest weight in the overall score.

7. Results

One of the first results of our investigations was that the results generated by this scheme are not sensitive to number of co-locations used. When a data set of 12000 co-locations was split up into multiple smaller sets of different sizes, the values calculated for the various weights did not vary significantly from one sub set to another. It is clear that the more co-locations are used, the more statistically significant the result will be. However, it may be that as the prevailing meteorological situation varies throughout the year, the optimal weights for the tests may change. For this reason, probably not more than six weeks worth of data should be analysed at a time.

The table below shows the weights which were calculated for an optimal speed confidence, and optimal direction confidence, and an optimal over quality control score. The original, non optimised weights are also shown. For each case the standard deviation and correlation coefficient of the attributed quality against the 'actual' quality is shown. In order for a relationship between the two to be useful, the standard deviation should be as close to 0 as possible, and the correlation coefficient as close to 1 as possible.

It can be seen from the table that the optimised weights for each case perform better than the original weights. Of course, this is exactly what the method is supposed to provide, and so this result simply provides a confirmation of the implementation.

	Weight applied to test					Standard deviation	Correlation coefficient
	Speed	Direction	Forecast	Spatial	Vector		
Original Speed	1.000	0.000	0.000	0.000	0.000	0.364	0.168
Optimised Speed	0.345	0.485	0.347	0.135	-0.476	0.166	0.396
Original Direction	0.000	1.000	0.000	0.000	0.000	0.287	0.223
Optimised Direction	0.464	0.817	0.271	0.143	-0.734	0.189	0.350
Original AQC	0.1667	0.166	0.166	0.333	0.166	0.223	0.435
Optimised AQC	0.084	0.238	0.420	0.143	-0.128	0.156	0.546

In each of the cases where the weights have been optimised, there is a negative weight for the vector test. This seems counter intuitive, as it is known that the vector test does give a high score for 'good' winds and a low score for 'bad' winds. The difficulty arises because the vector test responds rather like a switch, giving very few score in the mid-range. A scatter plot of vector test score against one of the ε values described above, gives two fuzzy blobs of data, one in the 'good' corner with most of the data, and one in the 'bad' corner with fewer data points. Attempting to draw a best fit straight line through these points just fits a line through the bigger fuzzy blob in the 'good' corner, since that's where most of the points are. The fact that the data are constrained to be between 0 and forces edges on the distribution which in turn means that the best fit gradient will be negative (hence the negative weight). This is indicative of a feature of all of the tests, perhaps with the exception of the forecast test, which is that they have been parameterised and tuned to provide a scheme for filtering out bad data from a SATOB product. Our adoption of BUFR and the opportunity to distribute quality control information, which this provides, mean that the tests need to be reconfigured to provide a more graduated response. Once this has been performed the optimisation process will be of increased value in determining the weights of the tests.

In the optimised weights for the overall quality control, the forecast test weight is nearly three times the present value. This is in marked contrast to the ideal situation in which the quality control scheme is independent of the forecast wind field, thereby eliminating the possibility of complex feedback mechanisms forming through the data assimilation scheme at ECMWF.

		Standard deviation	Correlation coefficient
Original	With forecast	0.223	0.435
	Without forecast	0.246	0.358
Optimised	With forecast	0.177	0.536
	Without forecast	0.133	0.364

As another application of the general method described here, we investigated the performance of the quality control scheme without forecast data. The table above shows the standard deviations and correlation coefficients of four cases: with and without forecast data, both with and without optimisation of the weights of the remaining tests. It is clear that the inclusion of the forecast data provides a better result in both cases. The effect of introducing the optimisation in the absence of forecast data was essentially to decrease the standard deviation, without significantly improving the correlation coefficient. This means that although some compensation can be made for the removal of the forecast data, there is a limit as to how much can be done.

8. Conclusions

The use of BUFR allows far more information to be included with the wind data. We are able to derive and disseminate separate confidence measures for the speed and direction of each wind. These values can be determined statistically using co-located radiosonde data, and are found to give independent measures of the quality of the speed and direction of the wind. A separate method is required to define the confidence in the height assigned to the vectors.

The method described for calculating the quality control scores uses non-robust statistics, and does therefore not deal well with some data, e.g. bad radiosondes. Filtering the co-location data used in order to remove outliers is one way to make the statistics robust, but this complicates the analysis of the method. The results described above also indicate that the vector test, as currently defined, is not well suited to a linear combination method. Although in general this test is reliable, in that good winds get a good score, the response of the test needs to be re-parameterised in order to be really useful to the overall quality control.

The optimisation of the weights presented in this paper assumes that a perfect relationship between the attributed confidence score and the actual quality is linear. This need not necessarily be the case, since the relation need only be monotonic, and well defined. If this is the case then there exists a reliable mapping for the user between the calculated confidence score and the actual quality.

Finally, and most importantly, the user community must be prepared to receive and process these complex BUFR data. At present, only a limited number of centres are able to handle BUFR messages containing quality control information. The remaining users must be prepared where necessary in order for this type of data to be of any value to them.

Bibliographic References

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