NOAA Technical Memorandum NESDIS 43

# A PRIMER FOR TUNING THE AUTOMATED QUALITY CONTROL SYSTEM AND FOR VERIFYING SATELLITE-MEASURED DRIFT WINDS

Washington, D.C.
July 1996

UNITED STATES DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Environmental Satellite, Data, and Information Service

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This primer describes how to tune the system used at NESDIS to quality control the drift winds obtained from animated satellite imagery. The system is formulated in McIDAS framework and is highly operator-interactive through the use of keywords. The keywords and their application are explained. The manuscript also explains a verification system (an expansion of the one used operationally at NESDIS) which can be used to evaluate the effectiveness of changes to the quality control parameters.

## I. INTRODUCTION

The processing of satellite-measured drift winds from the imagery obtained from geostationary satellites includes an automated procedure for quality control and editing of the data. This procedure has been documented in Hayden and Velden (1991), Hayden (1993), and Hayden and Purser(1995). The purpose of this document is to describe methods of "tuning" the editor which may be required to optimize performance for different types of winds or different geographical regimes. Evaluation of the effectiveness of "tuning" changes may be both qualitative and quantitative. For the latter it is most common to use comparison with other, collocated data. A second purpose of this primer is to explain the collocation-verification procedure used at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) where the drift wind Quality Control (QC) system was developed. It is however emphasized that qualitative evaluation is equally important. Procedures are executed within the University of Wisconsin McIDAS system which offers a highly interactive environment for development and evaluation.

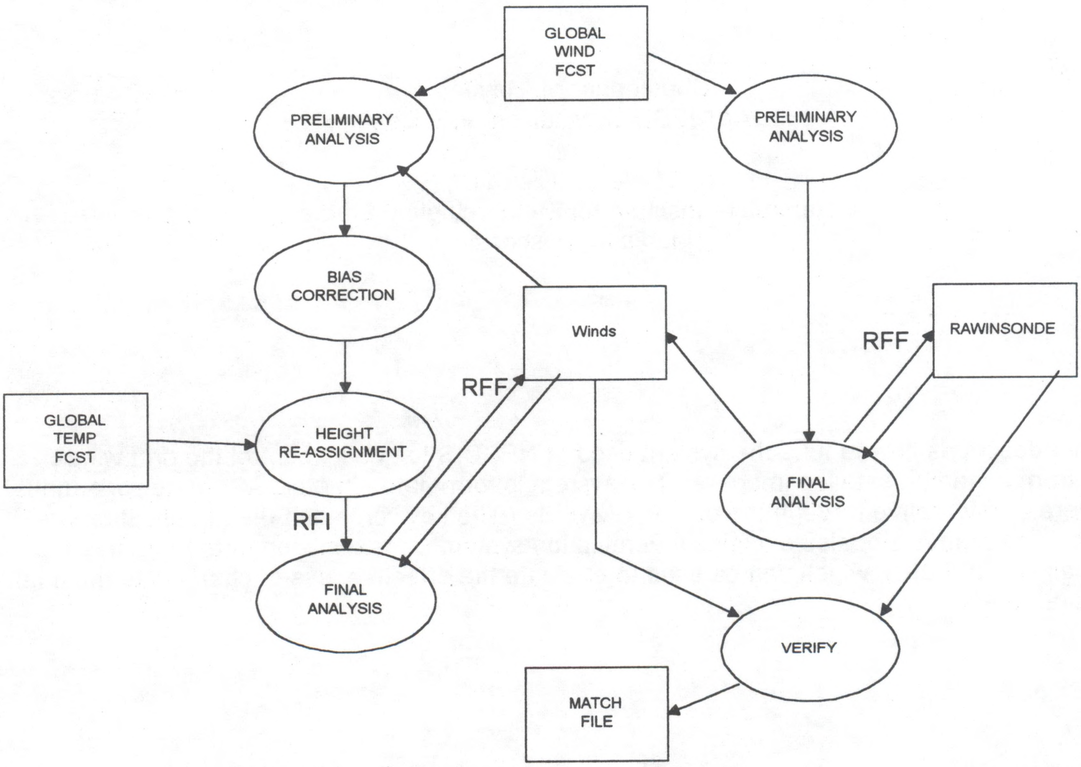



*Fig. 1. The drift wind editing and validation system.*

## II. QUALITY CONTROL

### *a. Framework*

Quality control of the drift winds is a two-step process which involves reassessing the pressure altitude assigned during the vector derivation and assigning a quality flag to each vector. As depicted on the left portion of Fig. 1., this involves a two stage, 3-dimensional objective analysis (Hayden and Purser, 1995) of the wind field using background information from a numerical forecast (In practice we use the same forecast used in deriving the vectors, though this is not necessary or even desirable.). The vertical dimension is in pressure at the default discretization shown in table 1. The first stage provides preliminary analyses using the satellite data at their initially assigned pressure height and pseudo data from the National Center for Environmental Prediction (NCEP) 12-hour aviation forecast (or the 6-hour forecast from the Global Data Assimilation System). Following a speed bias correction, the pressure altitudes of the drift winds are then adjusted by minimizing a simple variation penalty function (1) evaluated using the initial analyses and the NCEP temperature forecast.

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

$V = velocity,\ T = temperature,\ P = pressure,\ dd = direction,\ s = speed$

Subscript *m* refers to a measurement; *i* and *j* are horizontal dimensions in the analysis, and k is the vertical level. The *F* are established by keyword VAR which is explained below. A second analysis using the data at the reassigned pressure altitudes provides quality estimates for each vector based on the local quality of the analysis and the fit of the observation to that analysis. Thresholds are given for rejecting the data. Accepted data, with their quality estimate, are passed to the user.

| Level Number | Pressure (hPa) |
|---|---|
| 1 | 925 |
| 2 | 850 |
| 3 | 775 |
| 4 | 700 |
| 5 | 600 |
| 6 | 500 |
| 7 | 400 |
| 8 | 350 |
| 9 | 300 |
| 10 | 250 |
| 11 | 200 |
| 12 | 150 |
| 13 | 100 |

*Table 1. Default pressure levels for QC analyses, values in hPa.*

There is a wide variety of options available for regulating both the analysis (Hayden and Purser, 1995), the penalty function, and the final quality estimates. These have been empirically optimized, over several years of application, for the operational cloud drift product obtained from GOES. However, the optimal options are clearly situation dependent, and there is no reason to believe that what works best with GOES cloud-drift winds is optimal for water vapor winds, or winds generated at higher density, or winds generated with an improved background forecast etc. Ongoing research will be required to determine optimal tuning of this system in its various applications

Because the quality control system has been written in the McIDAS framework, the options for tuning its performance are accomplished by keyword entries in the initiation of the program. There are, regrettably, a large number of these, and many are interdependent. Considerable strategy within the algorithm has been directed to addressing the interdependence, and it is usually adequate to experiment with only a few in order to achieve a desired result.

In experimenting with the automated quality control system the user is strongly urged to use a simple macro which is designed to perform the quality control over a very limited region. This allows him to turn on various debugging (printing) options without being inundated by output. Often one may detect a vector which appears to be out-of-family while looking over an edited wind set. The procedure is then to use the latitude and longitude of the vector as input to the macro which contains the default options of the quality control system and defaults to the printout of the height reassignment (Table 2 in section II/b). One can vary the options of all the keywords described below with keywords used by the macro, and also the debugging options. An example is given in Appendix A.

### *b. Keywords*

The following list addresses the options normally used for tuning the QC.

**BFAC**

This keyword permits a bias correction to be applied to each vector. There are three entries. The first is a factor to be multiplied by the speed of the background field at observation location. The result is added to the speed of the vector. Operationally for GOES we have used .07, and this has clearly reduced the oft-quoted "slow bias" of the cloud drift winds. The second entry is a mean bias to be added to the speed of the vector. This has not proved to be effective and is not used operationally. The third entry allows for height reassignment before the first phase of the analysis is completed (to account for the new speed). This option has not proven useful.

**BUG**

This keyword permits display of debugging aids.:

- =1 lists values of parameters and the data (every 25th unless overridden by keyword OMOD)
- =3 lists values of pseudo obs from forecast (every 20th unless overridden by keyword GMOD)
- =5 lists reports rejected by height reassignment and reassignment increments in P, T and V (every 50th unless overridden by keyword ZMOD)
- =7 lists height reassignments at ZMOD frequency; statistics for each level where FIT<FITMAX.
- =8 lists some relatively esoteric statistical information for obs at OMOD frequency.

**FIT**

This keyword has 5 entries and assigns the *M* of (2) which are gross error limits placed on velocity, temperature, pressure , direction and speed before permitting a calculation of the penalty function (1):

$$
\begin{aligned}
&\left(V_m - V_{i,j,k}\right) < M_v F_v S && ; \quad M_v = 7. \\
&\left(T_m - T_{i,j,k}\right) < M_t F_t && ; \quad M_t = 2. \\
&\left(P_m - P_{i,j,k}\right) < M_p F_p && ; \quad M_p = 1.5 \\
&\left(dd_m - dd_{i,j,k}\right) < M_{dd} F_{dd} / S && ; \quad M_{dd} = 2. \\
&\left(s_m - s_{i,j,k}\right) < M_s F_s S && ; \quad M_s = 7. \\
&S = s / 30 && ; \quad 0.5 < S < 2.
\end{aligned}
\qquad (2)
$$

Note that the gross error limits associated with the wind vector are speed (*S*) dependent. With the default values assigned to $M_v F_v$, the velocity gross error check will vary between 7 and 28 ms$^{-1}$ depending on the speed of the vector. The value for velocity has the important additional function of defining the maximum permitted value of the penalty function according to:

$$B_{\max} = 0.75 S \left(M_v\right)^2 \qquad (3)$$

It is apparent from (2) that the keywords VAR (which adjusts *F* as discussed below) and FIT are closely related, and it will not always be obvious how mutually to adjust them. One can, for example, downweight the influence of the vector error in the penalty function (if for example, one has reason to believe that the background field is poor ) by increasing $F_v$. This will also increase the gross error tolerance according to (2) unless $M_v$ is adjusted to compensate. One can leave the role of the vector error unchanged in the penalty function and still adjust the gross error tolerance using $M_v$ only. But note that this will also affect the maximum value of the penalty function according to (3). To add to the complexity it should be further noted that this parameter will affect the pressure reassignment quality flag which is defined as:

$$RFI = 1. - B_m / B_{\max} \qquad (4)$$

Tuning is not simple or straightforward. It is a juggling act as demonstrated by the example give in section c.

**GINC**

This keyword controls the density of pseudo observations taken from the background field.. The default option is to pick up a pseudo observation at every fourth grid point along a row of the analysis. for every other row, staggered as shown below.

```
x   o   o   o   x   o   o   o   x   o

o   o   o   o   o   o   o   o   o   o

o   o   x   o   o   o   x   o   o   o

o   o   o   o   o   o   o   o   o   o

x   o   o   o   x   o   o   o   x   o

o   o   o   o   o   o   o   o   o   o

o   o   x   o   o   o   x   o   o   o
```

*Fig. 2: The selection of pseudo observations (x) from the grid points of the objective analysis. Example shown is for default option GINC=4.*

GINC =2 is the minimum permitted and the system exercises some control over what it will accept as a selection (based on INC). For GOES processing the default option has been used, but the higher density is recommended.

**GOUT**

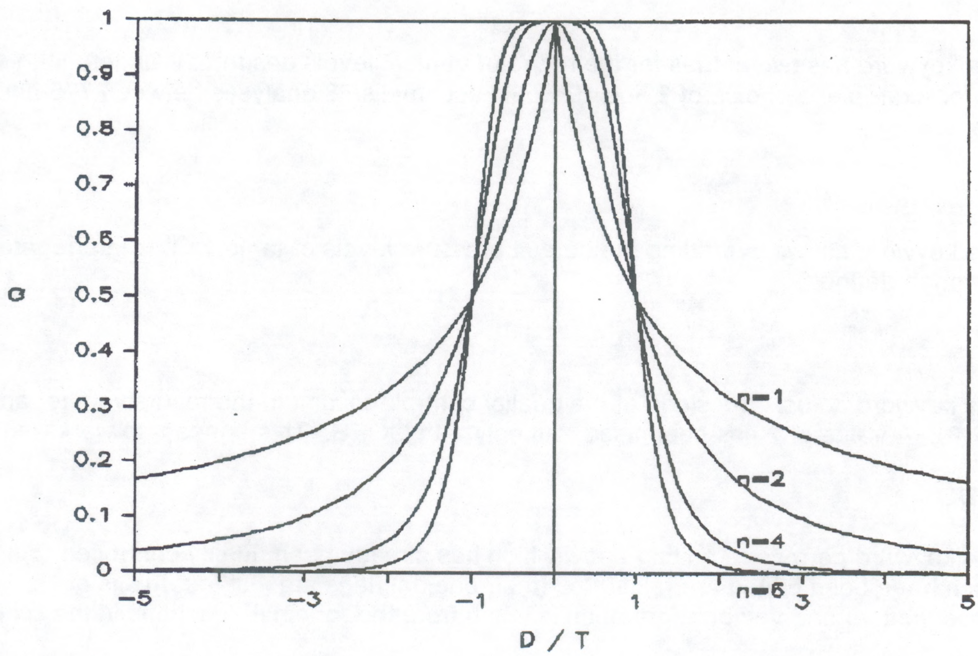
Non-zero causes grids to be written . A value of 1 outputs the final analyses, and other non-zero value outputs the background grids into the default grid file. These can be useful for evaluating data "impact".

**INC**

This keyword assigns the horizontal increment for the objective analysis. In the macro this defaults to 1 degree latitude/longitude. In GOES processing we have used 2 degrees. The keyword is entered as an integer, degrees*10. The analysis system has been designed to be relatively insensitive to the size of the grid increment, except for the feature that the density of pseudo reports, from the NCEP forecast background fields, is affected. A reduction of INC by a factor of 2, will increase the number of pseudo reports by 4. This will improve the representation of the background (i.e. you are more likely to hit the extremes), but not increase its influence relative to the drift winds. Internally, a factor controlling the weight of the pseudo observation is downweighted to offset the increased density. Currently the MD file containing pseudo obs from the NCEP aviation forecast is at a resolution of 2 degrees which suggests INC=1, GINC=2.

**NEWW**

This keyword allows the option of using the quality flag resulting from the height reassignment (RFI) as the initial quality flag in the second phase of the analysis. Since this flag is less than or equal to one, the final quality flag (RFF) will be lower and show more variance. However, the dependence on the forecast in determining RFF is increased, which is not necessarily desirable. Internally the threshold at which data are rejected is lowered by 0.1 when this keyword is invoked.



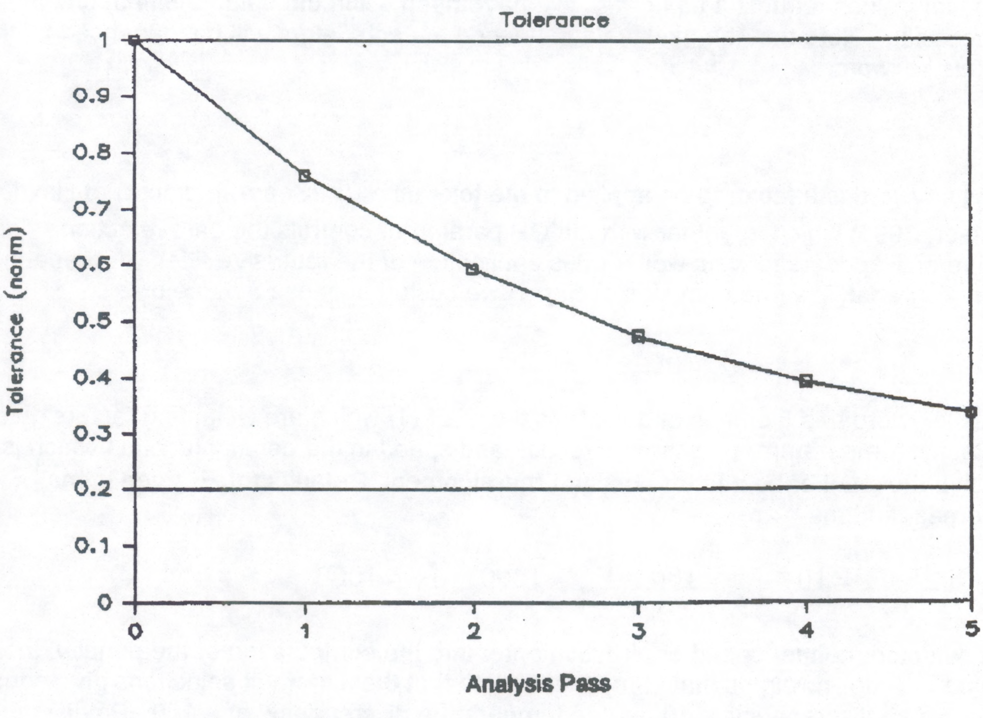




*Fig. 3. The quality control functions of the recursive filter. The quality fit parameter as a function of the exponential parameter QP (top). A schematic representation of change in the tolerance parameter with analysis pass. The tolerance is normalized to $T_0 = 1$. Asymptote is shown for $T_{infinity} = T_0/5$. Taken from Hayden and Purser (1995).*

**NZ**

This keyword has two entries for the range of vertical levels desired. Will default to 1 and 13, but for example, a choice of 3 and 10 would accomplish 8 analyses between 775 and 250 hPa.

**PL**

This keyword allows overriding the default pressure levels of table 1. It is interrogated for the NZ range defined.

**QP**

This keyword adjusts the slope of the quality control function in the recursive filter analysis (fig. 3). A value of 2 has been used routinely with GOES. This appears to work well.

**REDO**

This keyword permits re-editing a row which has already been quality controlled. All vectors which have been edited are reinstated (their original flags are lost, but this is of little consequence) and vector information is taken from the "original" locations in the schema.

**RF**

This keyword controls the fit of the analysis to the data. The analysis default value is 1. Smaller values request a tighter fit. We have been using the value 0.8 in operational processing. Note that the quality flag attached to each datum will be influenced by the choice of this keyword.

**TOL**

This keyword is a factor to be applied to the tolerance $T_0$ (See Appendix C of Hayden and Purser, 1995) which, together with the QP parameter controls the data rejection. The default value of 1 appears to work well for this application of the recursive filter. In preparing verifying analyses (the right side of Fig. 1) we customarily use a value of 2.

**VAR**

This keyword has 5 entries and controls the *F* of (1) which are weighting factors given to velocity, temperature, pressure , direction and speed in the penalty function which is used to assign the level of best fit for pressure reassignment. Defaults for *F,* given in $ms^{-1}$, °C, hPa, degrees, and $ms^{-1}$. are

$$F_v = 2 \quad F_t = 10 \quad F_p = 100 \quad F_{dd} = 1000 \quad F_s = 1000$$

As selected, neither speed or direction enter into the computation of the penalty. Increasing a value of F downweights that component Note that these default selections give equal "worth" to a 2 $ms^{-1}$ discrepancy, a 10 degree temperature discrepancy, or a 100 hPa discrepancy..

**WGS**

Within the analysis, the density of pseudo observations is controlled by keywords INC and GINC. In order that the pseudo observations not overwhelm the real observations, a weighting factor is applied to the reliability (nominally unity for both pseudo and real observations) of the pseudo observations based on the density:

$$(GINC * INC / 10)^2 / 32 \qquad (5)$$

For normal GOES processing where GINC=2 and INC=20 this gives a factor of 0.5. The WGS keyword can be used to override this factor.

**ZADJ**

This keyword allows the user to do the height reassignment based on an analysis of the background only or on an analysis which includes the vectors at their original pressure assignments. (ZADJ=1 or 2, respectively). The former option could be used if one had reason to suspect that the original height assignments were unusually bad, but generally it is not recommended.

**ZMET**

This keyword controls the vertical coupling of the analyses. A lower number means more vertical coupling (i.e. less independence for data at individual levels). An example follow where the 3- dimensional recursive filter was run with rawinsonde data (no guess) over the US. Two figures are given, one with ZMET=200 and one with ZMET=2000; all other parameters are the same. It is clear from Fig. 4 that the analysis draws more closely to the observed wind speed with the larger ZMET (less vertical coupling). A possible reason for increasing vertical coupling would be to give the single level drift winds more "buddy checking" in the vertical. The ZMET default value is 750.

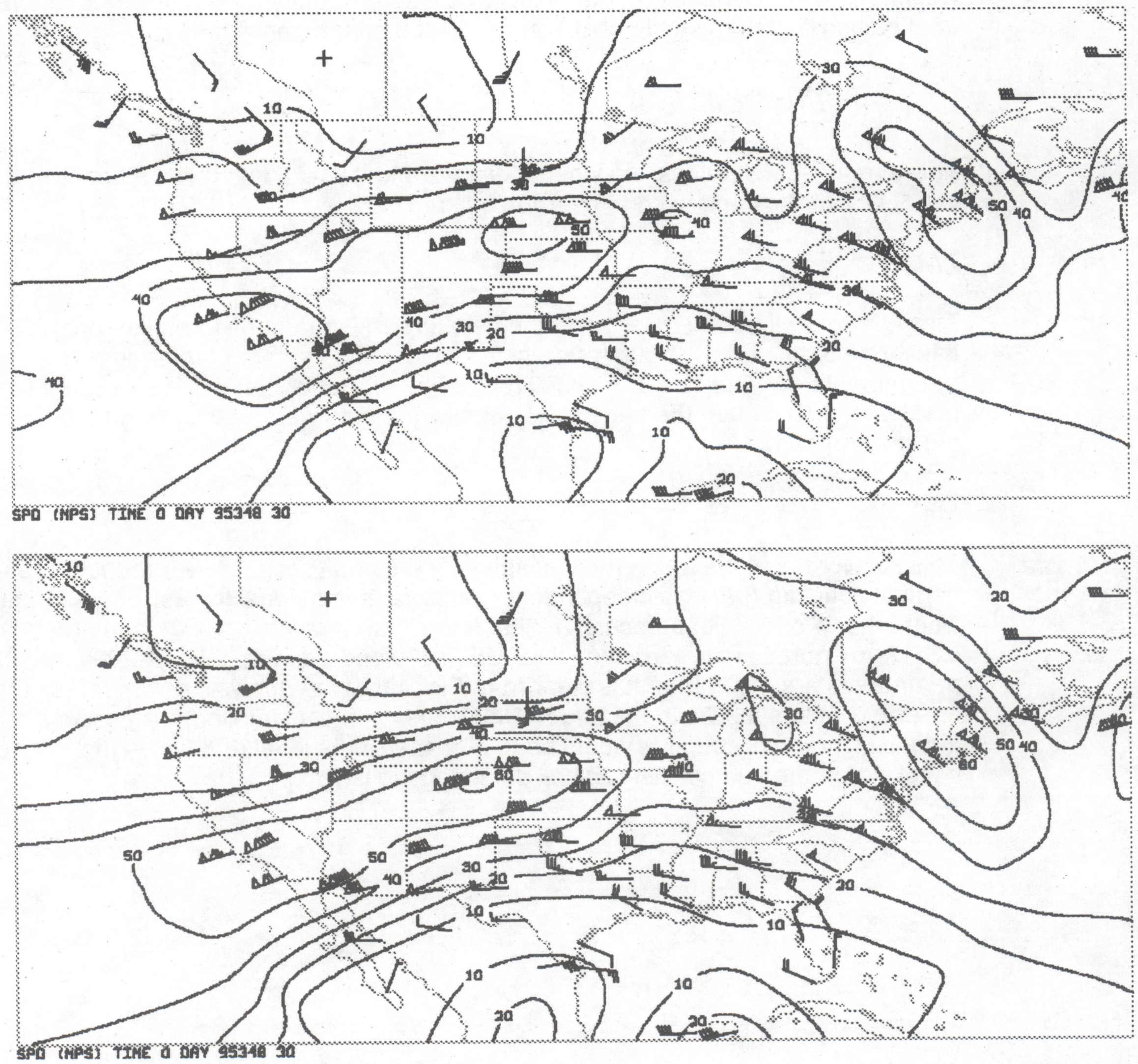



Fig. 4: Top: 300 hPa wind speed derived from wind analysis, ZMET=200; Bottom: Same but with ZMET=2000. Rawinsonde reports are plotted.

**ZNEW**

This keyword determines whether or not to reassign pressure altitudes. Zero indicates to perform analysis only and assign QC flags. A value of one uses the forecast only to reassign pressure; a value of 2 uses the preliminary analysis which is the operational practice.

Table 2 is an example of the effect of the ZMET parameter on the height reassignment. The vertical coupling affects the analysis of the wind components and therefore effects the fit of the wind vector at the various levels. FIT1 corresponds to ZMET=750 whereas FIT2 corresponds to the increased coupling of 200. It can be seen that reduced coupling (drawing more tightly to the observations) permits more variance in the "fit" as the pressure level is changed. This is directly related to the greater variance in the vector difference between observation and analysis (DVEC), or equivalently the differences in the speed (DSPD) or direction (DDIR). Curiously, however, in this example, the tighter fit caused a larger pressure reassignment. The original height assignment for this vector is 651 hPa. The optimum reassignment is 638 or 650 hPa for the loose and tight coupling respectively.

| | PRES | TEMP | TROP | DVEC | 2 | DDIR | 2 | DSPD | 2 | MEAS | FIT1 | 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 794. | 16.6 | .0 | 5.7 | 3.6 | 52.8 | 35.1 | 1.2 | .4 | 0 | 11.10 | 6.08 |
| 2 | 775. | 15.4 | .0 | 5.2 | 3.1 | 51.0 | 31.0 | .6 | .2 | 1 | 8.95 | 4.60 |
| 3 | 756. | 14.2 | .0 | 4.2 | 2.6 | 42.8 | 26.5 | .2 | .0 | 0 | 6.07 | 3.30 |
| 4 | 738. | 12.9 | .0 | 3.3 | 2.1 | 33.6 | 21.8 | -.1 | -.1 | 0 | 3.74 | 2.21 |
| 5 | 719. | 11.6 | .0 | 2.3 | 1.7 | 23.7 | 16.9 | -.2 | -.2 | 0 | 1.98 | 1.34 |
| 6 | 700. | 10.3 | .0 | 1.3 | 1.2 | 13.6 | 11.9 | -.2 | -.2 | 1 | .79 | .68 |
| 7 | 688. | 9.6 | .0 | 1.2 | 1.2 | 12.3 | 11.9 | -.2 | -.3 | 0 | .56 | .54 |
| 8 | 675. | 8.8 | .0 | 1.1 | 1.2 | 11.0 | 12.0 | -.3 | -.3 | 0 | .39 | .44 |
| 9 | 662. | 8.1 | .0 | 1.0 | 1.2 | 9.7 | 12.0 | -.3 | -.4 | 0 | .27 | .39 |
| 10 | 650. | 7.3 | .0 | .9 | 1.2 | 8.3 | 12.0 | -.4 | -.4 | 0 | .20 | .38 |
| 11 | 638. | 6.5 | .0 | .8 | 1.3 | 7.0 | 12.1 | -.4 | -.5 | 0 | .18 | .41 |
| 12 | 625. | 5.7 | .0 | .7 | 1.3 | 5.6 | 12.1 | -.5 | -.6 | 0 | .21 | .49 |
| 13 | 612. | 4.9 | .0 | .6 | 1.3 | 4.2 | 12.2 | -.5 | -.6 | 0 | .30 | .62 |
| 14 | 600. | 4.0 | .0 | .6 | 1.3 | 2.7 | 12.2 | -.5 | -.7 | 1 | .44 | .79 |
| 15 | 588. | 3.2 | .0 | 1.3 | 2.0 | 11.6 | 19.9 | -.7 | -.8 | 0 | 1.00 | 1.55 |
| 16 | 575. | 2.3 | .0 | 2.1 | 2.7 | 21.1 | 27.7 | -.9 | -.8 | 0 | 1.93 | 2.58 |
| 17 | 562. | 1.4 | .0 | 2.9 | 3.3 | 30.7 | 35.5 | -.8 | -.7 | 0 | 3.25 | 3.89 |
| 18 | 550. | .5 | .0 | 3.7 | 4.0 | 40.1 | 42.8 | -.7 | -.5 | 0 | 4.95 | 5.48 |
| 19 | 538. | -.4 | .0 | 4.5 | 4.7 | 48.6 | 49.6 | -.4 | -.3 | 0 | 7.04 | 7.35 |
| 20 | 525. | -1.4 | .0 | 5.4 | 5.4 | 56.1 | 55.8 | .0 | .0 | 0 | 9.51 | 9.50 |
| 21 | 512. | -2.4 | .0 | 6.2 | 6.0 | 62.6 | 61.2 | .5 | .4 | 0 | 12.38 | 11.93 |

*Table 2.. An example of the dependence of height reassignment on the ZMET parameter for one observation. Columns headed with "2" are the variable given to the left, but for an analysis with ZMET=200 rather than the default ZMET=750. Original height assignment = 651mb.*

### *c. An Example*

It was alluded to earlier that optimal choices for keyword parameters depend on the situation. In the past six months a great deal of effort has been put into increasing the density of satellite-measured vectors, especially in the vicinity of typhoons and hurricanes. Not surprisingly, the options exercised for routine GOES quality assurance have been found wanting in tropical storm environments. Research has suggested the changes to the standard options given as XP1 in Table 3 The effect of these XP1 changes is to increase the density of the pseudo observations; slightly to downgrade their quality (note from (5) that WGS=.13 when INC=10 and GINC=2); to slightly increase the fit to the observations, to strongly downweight the influence of the velocity discrepancy in the penalty function (and also increase the gross error check); and to strongly couple the analysis in the vertical.

| KEYWORD | NORMAL | XP1 | XP2 |
|---|---|---|---|
| INC | 20 | 10 | 10 |
| RF | 0.8 | 0.7 | 0.8 |
| VAR(1) | 2 | 5 | 5 |
| WGS | 0.1 | 0.5 | 0.5 |
| ZMET | 750 | 2000 | 750 |
| FIT(1) | 7 | 7 | 3 |
| NEWW | 0 | 0 | 1 |

*Table 3. An example of using keyword options to increase yield without accepting bad reports. Normal options are shown as NORMAL. Two experimental runs are also given as XP1 and XP2.*

The effect of these changes can be seen in comparing the first and second panels of Fig. 6. Many more vectors are retained in the experimental processing especially in the southwest quadrant of the typhoon. Qualitatively this is thought to be reasonable. Of course the relaxation of constraints is not entirely without price, and a 40 knot vector at 850 hPa ( the most southeastern vector in panel 2) was allowed to pass with a relatively high quality flag. Clearly this vector is incorrect. Using the WED macro (Appendix A) on this example, a number of keyword options was exercised to seek its deletion. The investigation suggested that the WGS of XP1 was too low and the ZMET too high.. Returning these to nominal values was not successful however, given the leniency of VAR(1). However, it was discovered that when FIT(1) was reduced to reduce the maximum permitted penalty function, and the NEWW option was exercised to include this effect in the final quality weight through (5), the vector was rejected. The full wind set was edited with the options of XP2 in table 3, and the result is shown in the third panel of Fig. 6. It can be seen that the desired coverage of the second panel is retained, but the offensive 850 hPa vector, and a couple of others, are removed.

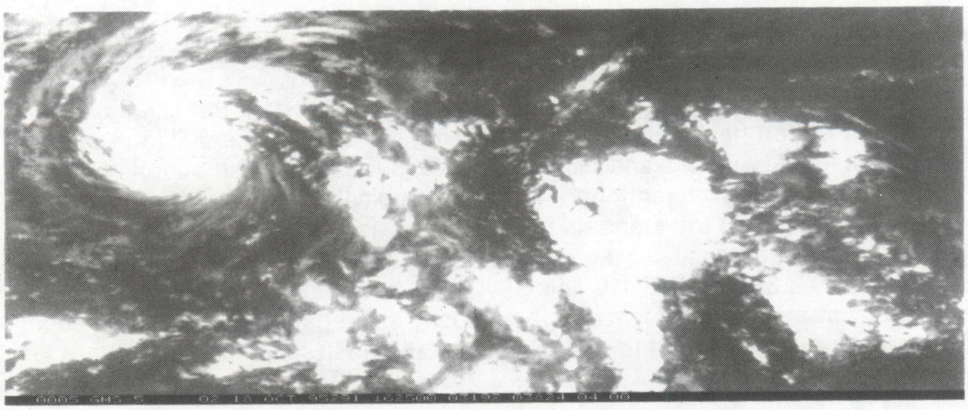


*Fig. 5 First image corresponding to the wind sets in figure 6.*

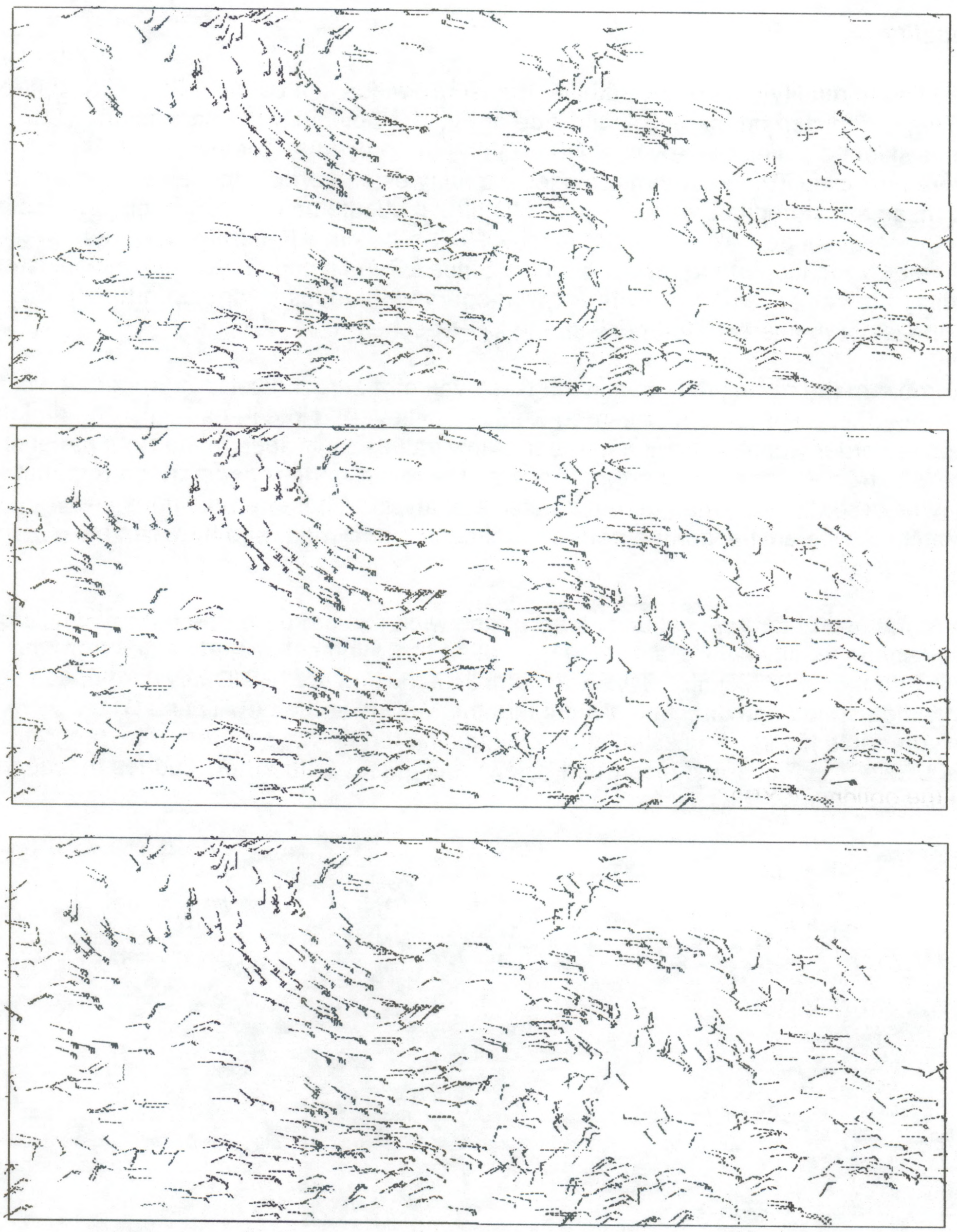


*Fig. 6: Edited winds for GMS-5. .Panel 1 was edited using the normal options described in table 3. Panel 2 was edited using the options labelled XP1 in table 3. Panel 3 (bottom) was edited using the options labelled XP2 in table 3.*

This example is given to show that the quality control system has enough flexibility to achieve a desired result. Obviously one cannot expend the level of effort given on this example in every instance, but as the satellite-measured wind systems evolve, case studies of this type can and must be made using the macro and keyword options as described here. Only in this way can a quasi optimal system be achieved.

### *d. Rawinsonde quality*

The same software used to quality control the satellite-measured winds can be used to quality control the rawinsondes. This is depicted on the right-hand side of Fig. 1. Obviously the section on reassigning altitude is skipped (using the keyword NEWZ) and the procedure reduces to a 3-dimensional objective analysis. The algorithm provides a quality estimate for each level reported by a rawinsonde, and these are stored in the rawinsonde MD file. It should be noted that this process is possible only when the rawinsondes are presented in the UPPR schema. Under this condition the RFF are written in the LEV location of the repeat groups. Since LEV is typed character routines such as MDL will not display the values (which are written as integers); a hideous kludge unfortunately required, because one is not at liberty to tamper with the UPPR schema.

Fig. 7 shows an example of the rawinsonde quality flags. (A value of zero indicates no reported wind at 300 hPa, and a value of 600 indicates no reported wind at any level.) Note in particular the region near the U.S.- Mexican border where there is a number of low values. It is seen in the right panel of the figure that there is extreme shear in this area. Probably the rawinsonde reports are correct, but the. scale which they represent is too small for the objective analysis. These rawinsondes are inappropriate for matching with anything but a perfectly collocated drift wind, and they can be screened using the QC flag.

Another procedure found useful for verification is to rerun the wind QC program (the left-hand side of Fig. 1) after the rawinsonde quality control step with the option of writing collocated values from the verification analyses into the CMV MD file. This is accomplished using the IGRID keyword option see Appendix B). Verification speed and direction are put into the MD file in the GRAD and STDV locations, another regrettable kludge necessitated by maintaining the GWIN schema. The program BESFIT (shown as VERIFY in Fig. 1 and discussed below) recognizes both of the kludges mentioned here.

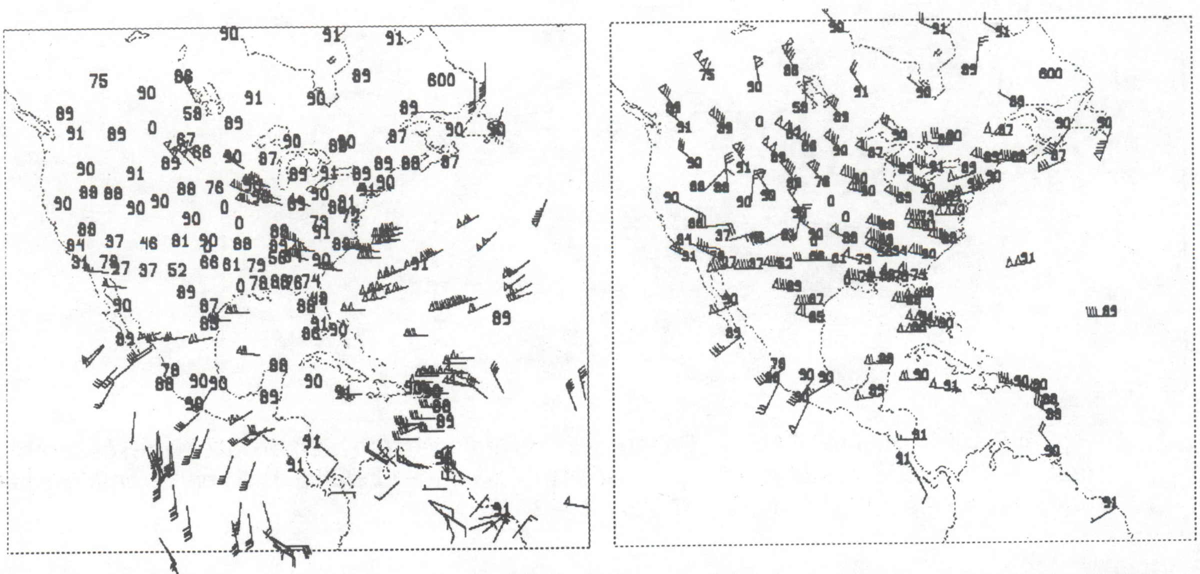


*Fig. 7. left: Water vapor drift winds (post editing) between 275 and 325 hPa for 14 February, 1996, 12 UT. Numbers plotted are 300 hPa quality flag for rawinsondes. Right: Rawinsonde 300 hPa winds.*

## III. VERIFICATION

### *a. Framework*

This section introduces the McIDAS program BESFIT. This program was initially designed to match satellite-measured drift winds against rawinsonde wind profiles in order to determine the level of best fit (LBF) for each match. The motivation was to provide a tool for relating measured radiance temperatures to atmospheric temperatures at the LBF in order to develop an algorithm for assigning pressure altitude based on radiance temperature (Stewart, Hayden and Smith, 1985). The LBF is determined using the first three terms of (1) with:

$$F_v = 2 \quad F_t = 10 \quad F_p = 100.$$

which are the same as the choices currently used for operational editing of the winds. The program was subsequently extended to serve as a vehicle for verification against rawinsondes; and a second pass was included with:

$$F_v = 200 \quad F_t = 200 \quad F_p = 20$$

This "verification" pass requires that the "match" depend almost exclusively on matching pressures.

In application, a single row of a satellite wind MD file (Schema GWIN) is considered. Each wind lat/lon is used to seek a collocation (def: 2 deg. latitude) against a dictionary of rawinsonde locations which is obtained from the contemporaneous rawinsonde MD file. After establishing a match, the rawinsonde (mandatory and significant level) data are decoded . The match is rejected if the rawinsonde does not reach a pressure lower than the satellite assigned level by an amount $F_p$.

The rawinsonde data from the surface to 100 hPa are interpolated to pressure levels which are no more than 20 hPa apart. Interpolation is linear in log p for temperature and linear in p for wind components. The satellite observation is compared with each level of the interpolated profile, and the level saved if very lenient gross error checks between satellite and rawinsonde values are met. The penalty function (1) is calculated for each level and the minimum chosen as the LBF. The objectively selected level may be further modified to an average with the adjacent levels above (below) the original choice if the averaged P, T ,V yield an improved minimum penalty. For the verification pass the averaging of levels above and below the drift wind's assigned pressure may also be averaged. A final check is made to insure adequate representation in the rawinsonde profile. It is required that an actual measured wind be given within 25 hPa of the selected level. If not, the match is rejected. The pressure tolerance can be adjusted using the keyword PRES and we generally override with a value of 50. The value is contained in the match file (see table 4), and samples can be filtered on this parameter.

| WORD | DESCRIPTION |
|---|---|
| 1 | Year-day-hour (YYdddHH) |
| 2 | Latitude of SAT wind |
| 3 | Longitude of SAT wind |
| 4 | Verification vector difference (SAT-RAOB) (ms-1) |
| 5 | Verification vector difference (GSS-RAOB) |
| 6 | Verification vector difference (SAT-GSS) |
| 7 | Verification vector difference (SAT-ANAL) |
| 8 | Verification vector difference (GSS-ANAL) |
| 9 | Speed Bias (SAT-RAOB) |
| 10 | Speed Bias (GSS-RAOB) |
| 11 | RAOB Temperature, K |
| 12 | SAT Temperature, K |
| 13 | RAOB Pressure, hPa |
| 14 | SAT Pressure, hPa |

| | |
|---|---|
| 15 | RAOB Speed (ms-1) |
| 16 | SAT Speed |
| 17 | Speed of the first guess |
| 18 | RAOB Vector Shear (per 100 hPa at PW) |
| 19 | RAOB Direction shear |
| 20 | RAOB Speed shear |
| 21 | Best fit vector difference (SAT-RAOB) |
| 22 | Best fit vector difference (GSS-RAOB) |
| 23 | Pressure for true best fit, LBF hPa |
| 24 | FIT for true best fit |
| 25 | FIT for verification |
| 26 | MOD value from GWIN |
| 27 | FLAG value from GWIN |
| 28 | Weight input from recursive filter (RFI) |
| 29 | Weight output from recursive filter (RFF) |
| 30 | Temperature at level of best fit |
| 31 | Speed Bias (SAT-ANAL) |
| 32 | Speed Bias (GSS-ANAL) |
| 33 | RFF for RAOB |
| 34 | Primary height assignment (PW) {Character} |
| 35 | TYPE (AIR,IR etc.) {Character} |
| 36 | Match Radius (degrees) |
| 37 | RAOB IDN |
| 38 | Wind Column number |
| 39 | Delta-Pressure sat pressure to nearest raob wind |
| 40 | HH |
| 41 | verif vector difference (SAT-RAOB) w/o bias corr |
| 42 | verif vector difference (SAT-GSS) w/o bias corr |
| 43 | U-bias (SAT-RAOB) w/o bias correction |
| 44 | V-bias (SAT-RAOB) w/o bias correction |
| 45 | Speed bias (SAT-RAOB) w/o bias correction |
| 46 | Original SAT pressure assignment, hPa |
| 47 | RAOB direction |
| 48 | SAT direction |
| 49 | dd bias (SAT-RAOB) degrees |
| 50 | dd bias (GSS-RAOB) degrees |

*Table 4. Contents of a "match " record in the match file. . Statistical programs (WSCATR, SCALST, CGMS) operate on the BESFIT output files and have options for sorting on the various parameters.*

### *b. Keywords*

**BUG**

The de-bugging keyword in this program permits:
=1 sat: col, p, t, u, v and raob id; dp, dt, dv and fit at LBF
=2 spd and dir of guess, drift vector and verification analysis
list first 15 entries of table 4.
=9 p, t, td, spd, and dir of rawinsonde by level; before and after expansion.

**EDIT**

This keyword sets the maximum value of the FLAG (failure flag) to be considered in the drift wind file. The default value is 3, which means no failures other than not agreeing with the forecast wind velocity. These are the data passed to the user. For research work EDIT can be increased to 5000 which is the largest value currently given (for failing the QC editor).

**ORIG**

This keyword allows the user to verify the original (unedited) wind vectors at their original pressures. Two verification runs with and without this keyword permit an evaluation of the effectiveness of the QC height reassignment.

**PRES**

This keyword sets the requirement for vertical “matching”. A measured rawinsonde wind must be within this pressure increment. Since the actual increment between drift wind pressure and nearest rawinsonde vector is an output parameter, the default of 25 hPa can be liberalized.

**SORT**

This keyword (common to many CIMSS statistical evaluation programs) permits sorting on the values of as many as five GWIN schema parameters (not repeat groups).

***c. An Example***

Table 5 gives an example of statistics which can be generated from the match file using the program CGMS. The top set corresponds to the statistics of all rawinsonde-matched, non-failing water vapor drift winds using the default collocation distance of 2 deg latitude. These are the statistics which have been routinely generated at NESDIS/CIMSS since November 1992. For this sample of 1059 matches the forecast vector error is 7.4 ms-1 and the drift wind error is 8.05 $ms^{-1}$. The errors are correlated at .73. Such numbers are fairly typical. Note that the results are categorized by the RFF flag at the bottom of the set. Again typically, as the quality indicator increases: the errors are generally lower, the drift wind error improves relative to the forecast error, and the error correlation increases. The second set of statistics exercises the rawinsonde quality control. Only those rawinsondes with a quality (RFF) of at least 80 are included. Overall, with the sample reduced to 858, the errors are reduced a bit more than 1 $ms^{-1}$. More importantly, however, for the high quality drift winds the apparent error is reduced more than 2 $ms^{-1}$ and the error correlation is reduced. The third set of statistics seeks to remove “apparent” error cause by inexact collocation. It is required that the difference between the match with the rawinsonde vs. the match with the exactly collocated verification analysis be no more 1 $ms^{-1}$ .. The sample is reduced to 436, and the overall errors are reduced another 1.5 $ms^{-1}$. In this case the drift vectors with RFF>70 are now shown to be more accurate than the forecast, and the error correlation is less than .5. It has been previously reported (Hayden, 1993) that an undesirably high correlation between forecast error and quality control drift wind error is inevitable with this type of drift wind processing. However, this example shows that most of the correlation is attributable to non-representativeness of the rawinsonde or large horizontal gradients in the wind. <u>The quality-controlled drift wind is not unduly biased to the forecast.</u>

| | NUM | AVER | SD | RMSE | XMEAN | YMEAN | XSTD | YSTD | XRMSE | YRMSE | CC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL | 1059 | -.60 | 3.17 | 3.23 | 6.14 | 6.74 | 4.11 | 4.41 | 7.39 | 8.05 | .73 |
| 20/60 | 877 | -.62 | 3.19 | 3.25 | 6.32 | 6.94 | 4.20 | 4.49 | 7.59 | 8.27 | .73 |
| HI | 691 | -.59 | 3.13 | 3.19 | 6.25 | 6.84 | 4.23 | 4.39 | 7.55 | 8.13 | .74 |
| MID | 186 | -.73 | 3.40 | 3.48 | 6.58 | 7.31 | 4.08 | 4.85 | 7.75 | 8.77 | .72 |
| -20/20 | 183 | -.53 | 3.06 | 3.11 | 5.28 | 5.82 | 3.57 | 3.85 | 6.38 | 6.97 | .66 |
| HI | 175 | -.49 | 3.10 | 3.14 | 5.37 | 5.86 | 3.63 | 3.92 | 6.48 | 7.05 | .66 |
| MID | 8 | -1.50 | 1.90 | 2.42 | 3.30 | 4.80 | .97 | 1.64 | 3.44 | 5.08 | .01 |
| SPD 0-10 | 87 | -.31 | 2.75 | 2.77 | 5.62 | 5.94 | 3.60 | 3.71 | 6.68 | 7.00 | .72 |
| SPD 10-20 | 176 | -.01 | 2.67 | 2.67 | 5.87 | 5.88 | 3.72 | 3.90 | 6.95 | 7.06 | .76 |
| SPD 20-30 | 349 | -.77 | 3.03 | 3.13 | 6.01 | 6.78 | 3.96 | 4.42 | 7.20 | 8.09 | .74 |
| SPD30-40 | 258 | -.63 | 3.27 | 3.33 | 6.14 | 6.77 | 4.24 | 4.64 | 7.46 | 8.21 | .73 |
| SPD40-50 | 150 | -.97 | 3.31 | 3.45 | 6.23 | 7.20 | 4.20 | 4.58 | 7.51 | 8.54 | .72 |
| SPD50-60 | 38 | -1.03 | 4.34 | 4.46 | 8.50 | 9.52 | 4.95 | 4.50 | 9.83 | 10.53 | .58 |
| RFF50-60 | 143 | -2.01 | 5.26 | 5.63 | 6.73 | 8.74 | 4.43 | 4.79 | 8.06 | 9.96 | .35 |
| RFF60-70 | 212 | -.59 | 3.67 | 3.71 | 6.11 | 6.70 | 3.91 | 4.15 | 7.25 | 7.88 | .59 |
| RFF70-80 | 349 | -.51 | 2.64 | 2.69 | 5.82 | 6.33 | 3.40 | 3.74 | 6.74 | 7.35 | .73 |
| RFF80-90 | 350 | -.10 | 1.77 | 1.78 | 6.26 | 6.37 | 4.69 | 4.80 | 7.83 | 7.97 | .93 |
| Rawinsonde quality checked | | | | | | | | | | | |
| TOTAL | 858 | -.67 | 3.11 | 3.18 | 5.31 | 5.99 | 3.11 | 3.60 | 6.16 | 6.99 | .58 |
| 20/60 | 692 | -.70 | 3.11 | 3.19 | 5.40 | 6.10 | 3.09 | 3.62 | 6.23 | 7.10 | .58 |
| HI | 544 | -.62 | 3.03 | 3.10 | 5.32 | 5.94 | 3.06 | 3.47 | 6.14 | 6.88 | .57 |
| MID | 148 | -1.00 | 3.35 | 3.50 | 5.72 | 6.72 | 3.20 | 4.05 | 6.56 | 7.85 | .59 |
| -20/20 | 166 | -.57 | 3.12 | 3.18 | 4.93 | 5.50 | 3.15 | 3.49 | 5.85 | 6.51 | .56 |
| HI | 158 | -.52 | 3.17 | 3.21 | 5.01 | 5.54 | 3.20 | 3.56 | 5.95 | 6.58 | .56 |
| MID | 8 | -1.50 | 1.90 | 2.42 | 3.30 | 4.80 | .97 | 1.64 | 3.44 | 5.08 | .01 |
| SPD 0-10 | 80 | -.35 | 2.85 | 2.87 | 5.27 | 5.63 | 2.96 | 3.10 | 6.05 | 6.42 | .56 |
| SPD 10-20 | 152 | -.07 | 2.74 | 2.74 | 5.25 | 5.32 | 3.19 | 3.46 | 6.15 | 6.35 | .66 |
| SPD 20-30 | 279 | -.95 | 3.00 | 3.14 | 5.20 | 6.15 | 3.15 | 3.73 | 6.09 | 7.19 | .63 |
| SPD 30-40 | 210 | -.72 | 3.40 | 3.48 | 5.39 | 6.10 | 3.15 | 3.79 | 6.24 | 7.18 | .53 |
| SPD 40-50 | 115 | -.58 | 3.05 | 3.10 | 5.30 | 5.88 | 2.83 | 3.12 | 6.01 | 6.66 | .48 |
| SPD 50-60 | 22 | -2.08 | 4.00 | 4.51 | 6.23 | 8.31 | 3.42 | 3.70 | 7.11 | 9.10 | .37 |
| RFF50-60 | 107 | -2.63 | 4.82 | 5.50 | 5.79 | 8.42 | 3.31 | 4.22 | 6.67 | 9.42 | .20 |
| RFF60-70 | 179 | -.58 | 3.58 | 3.62 | 5.55 | 6.13 | 3.43 | 3.80 | 6.52 | 7.21 | .51 |
| RFF70-80 | 294 | -.55 | 2.68 | 2.74 | 5.43 | 5.98 | 3.12 | 3.54 | 6.27 | 6.95 | .68 |
| RFF80-90 | 274 | -.07 | 1.87 | 1.87 | 4.84 | 4.82 | 2.73 | 2.70 | 5.56 | 5.61 | .76 |
| Colocation checked | | | | | | | | | | | |
| TOTAL | 436 | -.62 | 3.00 | 3.06 | 3.98 | 4.61 | 2.26 | 2.50 | 4.58 | 5.24 | .21 |
| 20/60 | 338 | -.61 | 2.96 | 3.02 | 3.98 | 4.58 | 2.21 | 2.41 | 4.55 | 5.18 | .18 |
| HI | 264 | -.45 | 2.90 | 2.93 | 3.98 | 4.43 | 2.27 | 2.33 | 4.59 | 5.00 | .21 |
| MID | 74 | -1.18 | 3.12 | 3.33 | 3.96 | 5.13 | 1.96 | 2.62 | 4.42 | 5.76 | .10 |
| -20/20 | 98 | -.68 | 3.15 | 3.22 | 4.00 | 4.68 | 2.47 | 2.81 | 4.70 | 5.46 | .29 |
| HI | 94 | -.65 | 3.18 | 3.25 | 4.06 | 4.70 | 2.50 | 2.84 | 4.76 | 5.49 | .30 |
| MID | 4 | -1.56 | 2.52 | 2.97 | 2.58 | 4.14 | .48 | 2.13 | 2.63 | 4.66 | -.80 |
| SPD 0-10 | 49 | -.56 | 2.98 | 3.04 | 4.27 | 4.83 | 2.46 | 2.79 | 4.93 | 5.58 | .36 |
| SPD 10-20 | 78 | .10 | 2.78 | 2.78 | 3.81 | 3.71 | 2.40 | 1.83 | 4.50 | 4.14 | .16 |
| SPD 20-30 | 134 | -.94 | 2.93 | 3.07 | 3.92 | 4.86 | 2.20 | 2.48 | 4.50 | 5.46 | .22 |
| SPD 30-40 | 109 | -.39 | 3.26 | 3.28 | 4.02 | 4.41 | 2.34 | 2.54 | 4.65 | 5.09 | .11 |
| SPD 40-50 | 60 | -1.11 | 2.72 | 2.94 | 3.82 | 4.93 | 1.65 | 2.30 | 4.16 | 5.44 | .08 |
| SPD 50-60 | 8 | -1.14 | 2.90 | 3.12 | 5.29 | 6.43 | 3.14 | 2.52 | 6.15 | 6.91 | .49 |
| RFF50-60 | 55 | -3.29 | 3.93 | 5.13 | 4.38 | 7.67 | 2.29 | 2.90 | 4.94 | 8.20 | -.15 |
| RFF60-70 | 102 | -.57 | 3.43 | 3.48 | 4.32 | 4.89 | 2.28 | 2.34 | 4.88 | 5.42 | -.11 |
| RFF70-80 | 150 | -.18 | 2.45 | 2.46 | 4.12 | 4.30 | 2.39 | 1.91 | 4.77 | 4.71 | .37 |
| RFF80-90 | 128 | .00 | 2.05 | 2.05 | 3.39 | 3.39 | 1.99 | 1.83 | 3.93 | 3.85 | .43 |

***Table 5: Verification statistics for February 1996, water vapor drift winds. AVER is the bias error, XRMSE is the forecast rms vector error, YRMSE is the drift wind rms vector error, and CC is the error correlation.***

It is apparent that as the match quality is improved (i.e. from the first to the third set of statistics), the errors of the high quality (large RFF) drift winds are reduced much more than those of lower quality. This is not the case with the forecast error which improves quite uniformly. We feel that this result is largely caused by the use of the forecast as a background in quality controlling the rawinsondes and generating the verification analyses. By requiring an RFF>80 we more or less define the background field as accurate. The drift winds have some independence. This same reasoning applies as to why it is so difficult to show that drift winds are as, or more accurate than the forecast.

One might ask, looking at the statistics for the collocation-checked sample, why we retain drift winds for RFF<60. Their error is 8.2 $ms^{-1}$ as compared to a forecast error of only 4.94 $ms^{-1}$. The reason is intuitive. We believe that such winds are useful where the forecasts are presumably not so good (i.e. not in the immediate vicinity of a rawinsonde). Qualitative inspection of wind fields in sparse data areas seems to confirm this belief. The user could certainly choose not to use winds of this quality in areas with good rawinsonde coverage.

***d. Impact***

It should by now be obvious that the most difficult part of optimizing the quality control procedure is in properly weighting the influence of the forecast. If large weight is given, one will inevitably edit good winds where the forecast is bad. Conversely, if small weight is given, one will retain poor winds where the forecast is good. The dilemma can be solved only by knowing where the forecast is good; which is impossible except in the broadest terms. The autoeditor does invoke a very crude latitudinal discrimination, but this could certainly be improved. A qualitative indication of whether or not the forecast has too much influence with the operational choice of quality control parameters is given in Fig. 7. This figure shows the change to the forecast wind speed at 300 hPa made by an analysis of the rawinsondes (left) and by an analysis of the GOES-8 water vapor drift winds. Drift winds within 25 hPa of 300 hPa are plotted. One sees that the drift winds have an impact comparable to that of the rawinsonde in some areas (in this case even in the middle of the U.S.). Changes of 10 or more knots are permitted. We conclude from this that we are not necessarily constraining the QC too closely to the forecast.

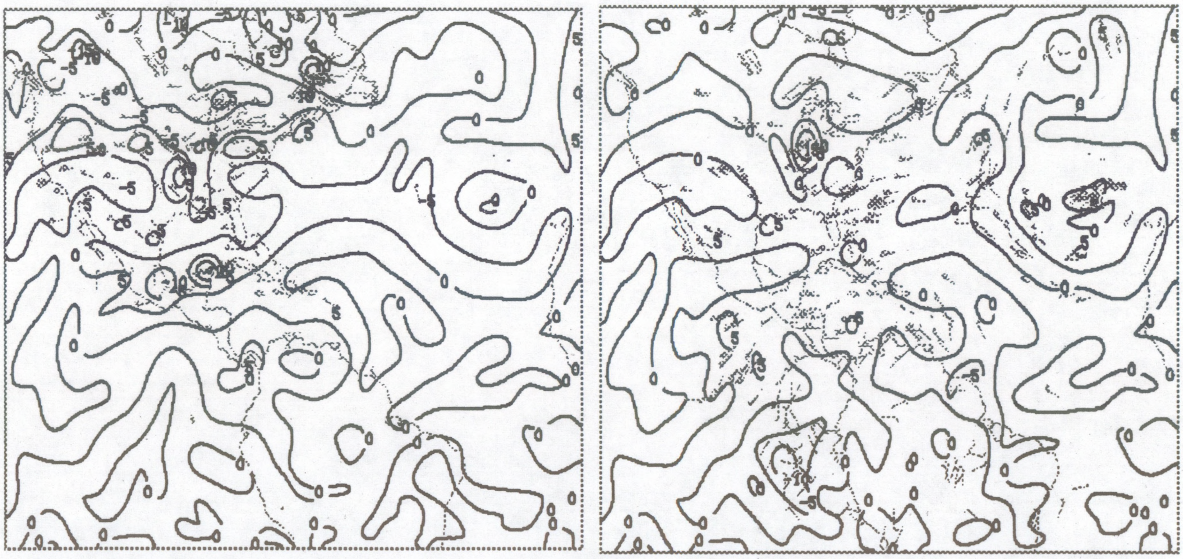


*Fig. 7. Changes to the 300 hPa wind speed effected by rawinsondes (top) and GOES-8 cloud drift winds (bottom). Situation is February 20, 1996 12UTC.*

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## APPENDIX A

The following WED macro is to be used for evaluating auto editing performance over limited geographical domain. It is assumed that a suitable TEXT file has been entered.

```
" ? MACRO TO INVESTIGATE BESFIT WEIGHTING OF WE
" ?  PROGRAM REQUIRES A CONTEXT FILE
" ?
" ? ENTER: WED   <KEYWORDS>
" ?
" ?    Keywords:
" ?      LAT= LATITUDE OF PARTICULAR REPORT TO EXAMINE
" ?      LON= LONGITUDE OF REPORT
REAL*8 DKWP
CHARACTER*12 CKWP
INC=  IKWP('INC',1,10)
NINC=IKWP('NINC',1,1)
DINC=FLOAT(INC)/10.+.5
KB= IKWP('BUG',1,7)
LATS=DKWP('LAT',1,0.d0)
LATN=LATS+DINC*NINC
LATS=LATS-DINC*NINC
LONE=DKWP('LON',1,0.d0)
LONW=LONE+DINC*NINC
LONE=LONE-DINC*NINC
VAR=DKWP('VAR',1,2.d0)
VAR2=DKWP('VAR',2,10.d0)
VAR3=DKWP('VAR',3,100.d0)
ZMET=DKWP('ZMET',1,750.d0)
G=DKWP('WGS',1,0.5d0)
IZ1=IKWP('ZADJ',1,2)
RF=DKWP('RF',1,.8d0)
TOL=IKWP('TOL',1,1)
QP=DKWP('QP',1,2.d0)
FF1=DKWP('FIT',1,7.d0)
FF2=DKWP('FIT',2,2.d0)
FF3=DKWP('FIT',3,1.5d0)
GG=IKWP('GINC',1,4)
CN=CKWP('WRITE',1,'NO')
IRD=IKWP('REDO',1,1)
.WE ZMOD= 1 WRITE= (CN) WGS= (G) BUG= (KB) VAR= (VAR) (VAR2) (VAR3) -
INC= (INC) ZADJ= (IZ1) ZMET= (ZMET) RF= (RF) TOL = (TOL) RMOD= 1 -
QP= (QP) FIT= (FF1) (FF2) (FF3) GINC= (GG) REDO = (IRD) -
LAT= (LATS) (LATN) LON= (LONW) (LONE)
```

The following is an example of using the macro. Suppose that BESFIT has been run on the quality controlled wind set and written the output file YY. One might choose to interrogate the match file using program FLMLIS; sorting such that drift wind error (location 4) be at least 10 ms-1 and the flag (position 27) less than or equal to 3. We wish to list latitude, longitude, drift wind error vs. rawin, forecast error vs. rawin, final pressure assignment, drift wind quality flag, rawin quality flag, and column number in the wind MD file.

FLMLIS 1 300 YY PAR,2 3 4 5 14 29 33 38 PSORT,4 10 100 27 0 3

yields the output:

```
SORTING WITH VARIABLE AND VALUES     4   10.00   100.00
SORTING WITH VARIABLE AND VALUES    27    0.00     3.00
   59  4411  10308  1465  1627  28700  7427  4600   24400
   60  4389  10133  1630  1532  28700  6881  4600   24500
   66  4436   9385  1849  1800  42500  7940  3700   25100
   73  4340   8155  1922  1182  30000  4790  9100   26000
   74  4482   7923  1663  1268  42500  6279  6100   26200
   75  4420   7690  1612   822  25000  5008  9000   26300
   76  4420   7684  1524   822  25000  5597  9000   26400
  123  3977   8728  1138   987  42500  7807  9200   39300
  128  3851   7938  1206  1032  30000  7637  9200   40000
  134  3913  11808  1325  1899  41200  4849  4100   44400
  140  3610   9077  1337   497  30000  6661  9200   46300
  141  3736   8820  1581   328  30000  4322  9000   46500
  142  3694   8771  1395   302  30000  4329  9000   46600
  145  3637   8229  1167  1552  33700  7110  9200   47100
  158  3601   9883  1024   371  33700  5144  9100   53200
  161  3559   9511  1305  1260  22500  7884  6100   53500
  164  3559   9228  1036   157  30000  4658  9200   53800
  165  3529   9036  1235   349  30000  4785  9200   53900
  174  3424   7716  1038  1528  33700  6146  4500   55200
  176  3397  11869  1846  1876  32500  8491  5900   59700
  192  3301   8902  1505   739  30000  4320  9000   62000
  196  3189   8500  1132   503  25000  6726  6500   62400
  203  3307  11770  1204  1473  31200  7368  5900   67800
  204  3339  11663  1088  1133  32500  8311  5900   67900
  207  3214  10607  1119   338  21200  4730  9200   68600
  225  2926  10934  1057  1056  20000  8596  9100   76600
  261  2561  11021  1098  1091  21200  8514  8800   93000
  262  2553  10937  1032  1036  21200  8220  8800   93100
  278  2489  11051  1009   919  21200  6928  8800  101300
  279  2461  10904  1077  1011  20000  6006  8800  101400
DONE FLMLIS
```

We note that match no. 165 has a rawin indicated error of 12 ms-1 whereas the forecast has an error of only 3 ms-1 (all values listed are x100). The vector quality is actually below the normal acceptable minimum of 50, but additional allowance is given for high speed vectors which are faster than the forecast. We might revisit this selection using the macro.

WED LAT,35 LON,90 WGS,.13

Note that the weight of the guess has been forced to be that of the full domain editing. The output (interspersed with comments in lower case) is:

```
HZ  925.  850.  775.  700.  600.  500.  400.  350.  300.  250.  200
GO!!!!!!!
  NROWS   NCOLS   INC
     4      4     10
GUESS INCREMENT IS  2
NO. OF REPORTS FROM GUESS IS  8
```

```
ADD MDF,ROW        9001          1
 MMAX IS  5000
SUBSCRIPTS FOR LAT,LON,CHAR          11          12          14
 FINAL GUESS WEIGHT IS          0.13
BEGIN INITIAL ANALYSIS
R0=  115.2 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 104.62 T0=99999.0 TL=99999.0
R0=  119.3 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 104.62 T0=99999.0 TL=99999.0
R0=  123.5 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 114.81 T0=99999.0 TL=99999.0
R0=  127.7 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 151.34 T0=99999.0 TL=99999.0
R0=  133.2 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 198.96 T0=99999.0 TL=99999.0
R0=  138.8 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 239.76 T0=99999.0 TL=99999.0
R0=  144.3 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 210.91 T0=99999.0 TL=99999.0
R0=  147.1 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 170.11 T0=99999.0 TL=99999.0
R0=  149.9 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 198.96 T0=99999.0 TL=99999.0
R0=  152.6 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 239.76 T0=99999.0 TL=99999.0
R0=  155.4 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 302.06 T0=99999.0 TL=99999.0
R0=  158.2 RL=  111.0 RF=    1.0 RS=    .00 ZMET= 302.06 T0=99999.0 TL=99999.0
 BEGIN ITERATION NO.  1
R0=  691.0 RL=   38.0 RF=     .7 RS=    .56 ZMET= 750.00 T0=99999.0 TL=99999.0
R0=  716.0 RL=   39.4 RF=     .7 RS=    .56 ZMET= 784.66 T0=99999.0 TL=99999.0
R0=  740.9 RL=   40.8 RF=     .7 RS=    .56 ZMET= 861.05 T0=99999.0 TL=99999.0
R0=  765.9 RL=   42.1 RF=     .7 RS=    .56 ZMET=1135.03 T0=99999.0 TL=99999.0
R0=  799.2 RL=   44.0 RF=     .7 RS=    .56 ZMET=1492.21 T0=99999.0 TL=99999.0
R0=  832.5 RL=   45.8 RF=     .7 RS=    .56 ZMET=1798.18 T0=99999.0 TL=99999.0
R0=  865.8 RL=   47.6 RF=     .7 RS=    .56 ZMET=1581.80 T0=99999.0 TL=99999.0
R0=  882.5 RL=   48.5 RF=     .7 RS=    .56 ZMET=1275.83 T0=99999.0 TL=99999.0
R0=  899.1 RL=   49.5 RF=     .7 RS=    .56 ZMET=1492.21 T0=99999.0 TL=99999.0
R0=  915.8 RL=   50.4 RF=     .7 RS=    .56 ZMET=1798.18 T0=99999.0 TL=99999.0
R0=  932.4 RL=   51.3 RF=     .7 RS=    .56 ZMET=2265.44 T0=99999.0 TL=99999.0
R0=  949.0 RL=   52.2 RF=     .7 RS=    .56 ZMET=2265.44 T0=99999.0 TL=99999.0
TOTAL NO. OF REPORTS IS  12
 TOTAL NO. OF DATA POINTS IS  96
 BEGIN ITERATION NO.  1
 BEGIN ITERATION NO.  2
 BEGIN ITERATION NO.  3
 BEGIN ITERATION NO.  4
 BEGIN ITERATION NO.  5
```

end of two step analysis using pseudo data (the forecast) only. List statistics of fit of drift winds to background.

```
 NO(DATA-STND)=     3  AVER.DIF=    4.26 RMSD=     6.69  RMSE=   10.39
   STND STD=     6.588   DATA STD=     4.589  CORR COEFF=     .3251
```

begin analysis using drift winds at original pressures.

```
R0=  691.0 RL=   38.0 RF=     .8RS=    .56 ZMET= 750.00 T0=     5.2 TL=    1.0
R0=  716.0 RL=   39.4 RF=     .8RS=    .56 ZMET= 784.66 T0=     5.6 TL=    1.1
R0=  740.9 RL=   40.8 RF=     .8RS=    .56 ZMET= 861.05 T0=     5.8 TL=    1.2
R0=  765.9 RL=   42.1 RF=     .8RS=    .56 ZMET=1135.03 T0=     6.0 TL=    1.2
R0=  799.2 RL=   44.0 RF=     .8RS=    .56 ZMET=1492.21 T0=     6.2 TL=    1.2
R0=  832.5 RL=   45.8 RF=     .8RS=    .56 ZMET=1798.18 T0=     6.5 TL=    1.3
R0=  865.8 RL=   47.6 RF=     .8RS=    .56 ZMET=1581.80 T0=     6.7 TL=    1.3
R0=  882.5 RL=   48.5 RF=     .8RS=    .56 ZMET=1275.83 T0=     6.9 TL=    1.4
R0=  899.1 RL=   49.5 RF=     .8RS=    .56 ZMET=1492.21 T0=     7.0 TL=    1.4
```

```
R0=  915.8 RL=   50.4 RF=    .8RS=   .56 ZMET=1798.18 T0=    7.1 TL=    1.4
R0=  932.4 RL=   51.3 RF=    .8RS=   .56 ZMET=2265.44 T0=    7.3 TL=    1.5
R0=  949.0 RL=   52.2 RF=    .8RS=   .56 ZMET=2265.44 T0=    7.4 TL=    1.5
 TOTAL NO. OF REPORTS IS  12
 BEGIN ITERATION NO.  1
 BEGIN ITERATION NO.  2
 BEGIN ITERATION NO.  3
 BEGIN ITERATION NO.  4
 BEGIN ITERATION NO.  5
```

Preliminary analysis complete, do height reassignment

```
NEW HEIGHT ASSIGNMENTS  NG,NB          9          12
```

The following is the vector of interest (no. 539)

```
COL,PSAT,USAT,VSAT,TSAT  539  286. 48.20-24.56-47.46
FIT MAX IS        66.27
    PRES  TEMP  TROP  DVEC  DDIR  DSPD  MEAS  FIT
  1  388. -28.9    .0  20.4    .3 -20.4    0 108.95
  2  375. -31.0    .0  18.8   1.5 -18.8    0  92.24
  3  362. -33.1    .0  17.3   3.1 -17.1    0  77.51
  4  350. -35.2    .0  15.9   4.5 -15.4    1  64.77
  5  338. -37.5    .0  13.7   4.6 -13.1    0  48.05
  6  325. -39.8    .0  11.6   4.8 -10.8    0  34.11
  7  312. -42.2    .0   9.5   4.9  -8.5    0  22.98
  8  300. -44.7    .0   7.6   5.0  -6.2    1  14.66
  9  288. -47.0 -47.0   8.2   5.4  -6.6    0  16.61
 10  275. -49.5 -49.5   8.7   5.7  -7.0    0  18.84
 11  262. -52.0 -52.0   9.2   6.1  -7.5    0  21.37
 12  250. -54.7 -54.7   9.7   6.5  -7.9    1  24.20
 13  238. -56.1 -56.1   9.5   4.6  -8.6    0  23.53
 14  225. -57.6 -57.6   9.6   2.6  -9.3    0  24.45
 15  212. -59.2 -59.2  10.0    .5 -10.0    0  26.95
 16  200. -60.8 -60.8  10.7   1.6 -10.6    1  31.06
 17  188. -60.8 -60.8  10.7   1.6 -10.6    0  31.29
```

The reassignment to 300 hPa has a fairly good fit though the vertical discrimination is not very good.

```
COL,PSAT,USAT,VSAT,TSAT  540  287. 41.26-26.80-47.56
FIT MAX IS        60.27
    PRES  TEMP  TROP  DVEC  DDIR  DSPD  MEAS  FIT
  1  400. -27.7    .0  17.1   6.5 -16.5    1  78.23
  2  388. -29.7    .0  15.2   4.6 -14.8    0  61.95
  3  375. -31.7    .0  13.3   3.0 -13.1    0  47.70
  4  362. -33.7    .0  11.5   1.5 -11.4    0  35.47
  5  350. -35.8    .0   9.7    .1  -9.7    1  25.28
  6  338. -38.1    .0   7.4    .0  -7.4    0  14.76
  7  325. -40.4    .0   5.1    .0  -5.1    0   7.05
  8  312. -42.7    .0   2.7    .1  -2.7    0   2.17
  9  300. -45.2    .0    .4    .1   -.4    1    .12
 10  288. -47.4 -47.4    .9    .5   -.8    0    .20
 11  275. -49.6 -49.6   1.4    .8  -1.2    0    .52
 12  262. -51.9 -51.9   1.8   1.1  -1.6    0   1.09
```

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | 250. | -54.4 | -54.4 | 2.3 | 1.5 | -1.9 | 1 | 1.94 |
| 14 | 238. | -55.7 | -55.7 | 3.1 | .7 | -3.1 | 0 | 3.33 |
| 15 | 225. | -57.2 | -57.2 | 4.8 | 3.0 | -4.1 | 0 | 7.00 |
| 16 | 212. | -58.7 | -58.7 | 6.7 | 5.4 | -5.0 | 0 | 12.96 |
| 17 | 200. | -60.3 | -60.3 | 8.7 | 7.9 | -5.9 | 1 | 21.21 |
| 18 | 188. | -60.3 | -60.3 | 8.7 | 7.9 | -5.9 | 0 | 21.44 |

COL,PSAT,USAT,VSAT,TSAT 620 337. 33.64-31.37-36.86
FIT MAX IS 56.35

| | PRES | TEMP | TROP | DVEC | DDIR | DSPD | MEAS | FIT |
|---|---|---|---|---|---|---|---|---|
| 1 | 425. | -22.6 | .0 | 20.5 | 15.3 | -18.2 | 0 | 108.05 |
| 2 | 412. | -24.4 | .0 | 19.4 | 13.8 | -17.3 | 0 | 96.12 |
| 3 | 400. | -26.2 | .0 | 18.3 | 12.4 | -16.4 | 1 | 84.91 |
| 4 | 388. | -28.1 | .0 | 16.7 | 11.2 | -15.0 | 0 | 70.90 |
| 5 | 375. | -30.2 | .0 | 15.2 | 10.1 | -13.6 | 0 | 58.21 |
| 6 | 362. | -32.3 | .0 | 13.6 | 9.1 | -12.1 | 0 | 46.84 |
| 7 | 350. | -34.5 | .0 | 12.1 | 8.2 | -10.7 | 1 | 36.81 |
| 8 | 338. | -36.7 | .0 | 10.7 | 8.8 | -8.6 | 0 | 28.87 |
| 9 | 325. | -39.1 | .0 | 9.6 | 9.4 | -6.6 | 0 | 23.16 |
| 10 | 312. | -41.5 | .0 | 8.8 | 9.9 | -4.6 | 0 | 19.67 |
| 11 | 300. | -44.0 | .0 | 8.4 | 10.3 | -2.6 | 1 | 18.43 |
| 12 | 288. | -46.4 | -46.4 | 8.5 | 10.3 | -2.9 | 0 | 19.12 |
| 13 | 275. | -49.0 | -49.0 | 8.5 | 10.2 | -3.2 | 0 | 20.02 |
| 14 | 262. | -51.6 | -51.6 | 8.6 | 10.2 | -3.5 | 0 | 21.15 |
| 15 | 250. | -54.3 | -54.3 | 8.7 | 10.2 | -3.7 | 1 | 22.53 |
| 16 | 238. | -56.0 | -56.0 | 10.5 | 12.7 | -3.9 | 0 | 32.00 |

COL,PSAT,USAT,VSAT,TSAT 621 324. 39.87-32.28-39.86
FIT MAX IS 62.84

| | PRES | TEMP | TROP | DVEC | DDIR | DSPD | MEAS | FIT |
|---|---|---|---|---|---|---|---|---|
| 1 | 425. | -23.5 | .0 | 23.6 | 10.8 | -22.5 | 0 | 142.98 |
| 2 | 412. | -25.2 | .0 | 22.4 | 9.3 | -21.5 | 0 | 128.58 |
| 3 | 400. | -26.9 | .0 | 21.2 | 7.9 | -20.5 | 1 | 115.01 |
| 4 | 388. | -28.9 | .0 | 19.6 | 6.7 | -19.0 | 0 | 97.73 |
| 5 | 375. | -30.9 | .0 | 18.0 | 5.6 | -17.5 | 0 | 81.89 |
| 6 | 362. | -33.0 | .0 | 16.4 | 4.5 | -16.0 | 0 | 67.49 |
| 7 | 350. | -35.1 | .0 | 14.7 | 3.6 | -14.5 | 1 | 54.55 |
| 8 | 338. | -37.4 | .0 | 12.8 | 4.1 | -12.4 | 0 | 41.22 |
| 9 | 325. | -39.7 | .0 | 11.0 | 4.5 | -10.4 | 0 | 30.19 |
| 10 | 312. | -42.1 | .0 | 9.3 | 5.0 | -8.3 | 0 | 21.47 |
| 11 | 300. | -44.6 | .0 | 7.7 | 5.3 | -6.3 | 1 | 15.07 |
| 12 | 288. | -46.9 | -46.9 | 7.9 | 5.2 | -6.5 | 0 | 16.05 |
| 13 | 275. | -49.3 | -49.3 | 8.0 | 5.1 | -6.8 | 0 | 17.23 |
| 14 | 262. | -51.7 | -51.7 | 8.2 | 5.0 | -7.1 | 0 | 18.61 |
| 15 | 250. | -54.3 | -54.3 | 8.4 | 4.9 | -7.4 | 1 | 20.23 |
| 16 | 238. | -55.9 | -55.9 | 10.0 | 7.5 | -7.9 | 0 | 28.37 |
| 17 | 225. | -57.7 | -57.7 | 11.8 | 10.2 | -8.3 | 0 | 38.78 |
| 18 | 212. | -59.5 | -59.5 | 13.6 | 12.9 | -8.6 | 0 | 51.47 |

Begin the final analysis

R0= 230.3 RL= 12.7 RF= .8 RS= .56 ZMET= 250.00 T0= 5.2 TL= 1.0
R0= 238.6 RL= 13.1 RF= .8 RS= .56 ZMET= 261.55 T0= 5.6 TL= 1.1
R0= 247.0 RL= 13.6 RF= .8 RS= .56 ZMET= 287.02 T0= 5.8 TL= 1.2
R0= 255.3 RL= 14.0 RF= .8 RS= .56 ZMET= 378.34 T0= 6.0 TL= 1.2
R0= 266.4 RL= 14.7 RF= .8 RS= .56 ZMET= 497.40 T0= 6.2 TL= 1.2

```
R0= 277.5 RL=  15.3 RF=   .8 RS=  .56 ZMET= 599.39 T0=  6.5 TL=  1.3
R0= 288.6 RL=  15.9 RF=   .8 RS=  .56 ZMET= 527.27 T0=  6.7 TL=  1.3
R0= 294.1 RL=  16.2 RF=   .8 RS=  .56 ZMET= 425.28 T0=  6.9 TL=  1.4
R0= 299.7 RL=  16.5 RF=   .8 RS=  .56 ZMET= 497.40 T0=  7.0 TL=  1.4
R0= 305.2 RL=  16.8 RF=   .8 RS=  .56 ZMET= 599.39 T0=  7.1 TL=  1.4
R0= 310.8 RL=  17.1 RF=   .8 RS=  .56 ZMET= 755.15 T0=  7.3 TL=  1.5
R0= 316.4 RL=  17.4 RF=   .8 RS=  .56 ZMET= 755.15 T0=  7.4 TL=  1.5
 BEGIN ITERATION NO.  1
 BEGIN ITERATION NO.  2
 BEGIN ITERATION NO.  3
 BEGIN ITERATION NO.  4
 BEGIN ITERATION NO.  5
 BEGIN ITERATION NO.  6
THE AUTOEDITOR IS FINISHED
```

From the standpoint of the reassignment fit, there is nothing obviously wrong with this vector. The reason is that it is supported by neighbors. If the weight of the background is upgraded to .5 the vector is reassigned at 238 hPa and the fit is much poorer. Nevertheless the vector still passes, and has an error of 11 $ms^{-1}$.

## APPENDIX B

The following are a series of commands which can be used to quality control the rawinsondes and set up the more stringent verification shown in table 4.

The rawinsondes must be in the UPPR format. This can be generated from the normal McIDAS IRAB and ISIG files using the program RBTOUP. Assume that they exist in MD 10, row 1. It is convenient to have an empty grid file into which to write analyses. Assume this is grid file 1. The QC step is then:

WE INC,10 QP,2 RF,.8 GINC,2 WGS,.1 TOL,2. QFLAG,MOD OGRID,1 MDF,10 ROW,1

If it is not desired to put the averaged RFF into the MOD word, do not use the QFLAG entry. This procedure will write 24 grids of u and v components into gridfile 1. These are the verifying analysis.

The collocated verification from analyses is written into the GWIN file by rerunning the wind QC program

WE INC,10 QP,2 RF,.8 GINC,2 BFAC,.07 SLOW,3 FIT,X X 1 IGRF,1 OGRID,1

In this case we have chosen to write out the wind analyses as well so that it is possible to produce comparisons such as shown in Fig. 6. It is best to have the raw winds available, otherwise one can use the REDO keyword. Assuming that the QC'd winds are in MD 9001 ROW 1, the match file is created using:

BESFIT 9001 10 ROW,1 1 PRES,50. AUTO,1 INIT,99 EDIT,5000 FILE, Z00052

Statistics such as those shown in table 4 are obtained by:

CGMS Z00052 XVAL,5 YVAL,4
CGMS Z00052 XVAL,5 YVAL,4 PSORT,33 80 100
CGMS Z00052 XVAL,5 YVAL,4 PSORT,33 80 100 DIFF,4 7 1.

Continued From Inside Front Cover)

NESDIS 16 A Description of Prediction Errors Associated with the T bus-4 Navigation Message and a Corrective Procedure. Frederick W. Nagle, July 1986. (PB87-195913)
NESDIS 17 Publications and Final Reports on Contracts and Grants, 1986. Nancy Everson, April 1987. (PB87-220810/AS)
NESDIS 18 Tropical Cyclone Center Locations from Enhanced Infrared Satellite Imagery. J. Jixi, and V.F. Dvorak, May 1987. (PB87-213450/AS)
NESDIS 19 A Suggested Hurricane Operational Scenario for GOES I-M. W. Paul Menzel, Robert T. Merrill and William E. Shenk, December 1987. (PB-88-184817/AS)
NESDIS 20 Satellite Observed Mesoscale Convective System (MCS) Propagation Characteristics and a 3-12 Hour Heavy Precipitation Forecast Index. Jiang Shi and Roderick A. Scofield, December 1987. (PB88-241476)
NESDIS 21 The GVAR Users Compendium (Volume 1). Keith McKenzie and Raymond J. Komajda (MITRE), May 1988. (PB88-241476)
NESDIS 22 Publications and Final Reports on Contracts and Grants, 1987. Nancy Everson, April 1989. (PB88-240270)
NESDIS 23 A Decision Tree Approach to Clear Air Turbulence Analysis Using Satellite and Upper Air Data. Gary Ellrod, January 1989. (PB89-20775/AS)
NESDIS 24 Publications and Final Reports on Contracts and Grants, 1988. Nancy Everson, April 1989. (PB89-215545/AS)
NESDIS 25 Satellite-Derived Rainfall Estimates and Propagation Characteristics Associated with Mesoscale Convective Systems (MCSs). Xie Jying and Roderick A. Scofield, May 1989.
NESDIS 26 Removing Stripes in GOES Images by Matching Empirical Distribution Functions. M.P. Weinreb, R. Xie, J.H. Lienesch and D.S Crosby, May 1989. (PB89-21335/AS)
NESDIS 27 Geographic Display of Circulation Model Data. Kurt Hess, September 1989.
NESDIS 28 Operational Ozone Monitoring with the Global Ozone Monitoring Radiometer (GOMR). Walter G. Planet (Editor), August 1989. (PB90-114034/AS)
NESDIS 29 Preliminary Report on the Demonstration of the VAS CO2 Cloud Parameters (Cover, Height, and Amount) in Support of ASOs. W.P. Menzel and K.I. Strabala, November, 1989.
NESDIS 30 Instability Bursts Associated with Extra Tropical Cyclone Systems (ECSs) and a Forecast Index of 3-12 Hour Heavy Precipitation. Roderick A. Scofield, July 1990.
NESDIS 31 Evaluation of the GOES I-M Normalization Technique with the Visible Images of GOES-7. J.H. Lienesch, R. Xie and W.Y. Ramsey, April 1990.
NESDIS 32 Publications and Final Reports on Contracts and Grants, 1989. Nancy Everson, May 1990.
NESDIS 33 Publications and Final Reports on Contracts and Grants, 1990. Nancy Everson, May 1991.
NESDIS 34 Satellite Observation of Great Lakes Ice: Winter 1986-87. Sharolyn L. Young, July 1991.
NESDIS 35 Publications and Final Reports on Contracts and Grants, 1991. Nancy Everson, April 1992.
NESDIS 36 Publications and Final Reports on Contracts and Grants, 1992. Nancy Everson, April 1993.
NESDIS 37 Summary of Great Lakes Ice Conditions: Winter 1987-88, 1988-89, 1989-90. Sharolyn R. Young, May 1993.
NESDIS 38 NESDIS Guide to Satellite Products and Services Implementation. Barbara A. Banks and Frances C. Holt, April 1994.
NESDIS 39 NESDIS Publication Listing, 1993. Nancy Everson, May 1994.
NESDIS 40 The Geostationary Operational Environmental Satellite Data Collection System. Michael J. Nestlebush, June 1994.
NESDIS 41 NESDIS Publication Listing, 1994. Nancy Everson, September 1995.
NESDIS 42 NESDIS Publication Listing, 1995. Nancy Everson, July 1996.

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