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On the use of observation error data in FGGE main level III b analysis

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1. Introduction

A key element in applying statistical, or so-called optimum, interpolation (OI) analysis schemes is the development and use of an algorithm for handling quantitative "observation error." Indeed, it is the magnitudes of "observation error" and "forecast error" which determine the degree to which the OI scheme accepts the observation. The tuning of the analysis scheme is largely, then, determined by these quantities (Bergman, 1978). In FGGE a variety of observing systems were deployed: some of these systems provided "error" or "uncertainty" information for each observation, while the conventional observing systems continued to provide data for which only system-wide information on "error" levels is available. I will henceforth term the former observation-specific error information, and the latter system-specific information.

The purpose of this note is to provide documentation for the FGGE observation error table. Included are brief explanations on how the various table entries were arrived at for conventional observing systems, and rather more detailed discussion of the entries for the special observing systems that produced data for the FGGE. The ECMWF FGGE Level III-b observation error table is attached as Appendix 1.

Table A

Directory FGGE Observation Errors

Observation-error Table line number		Variable, units	Documentation paragraph
1.	Sonde	wind component mps	3.3
2.	Sonde	geopotential m	3.1
3.	Sonde	thickness m	3.2
4:	TIROS-N	thickness (other) m	4.0
5.	"	" (mostly clear) m	"
6.	"	" (mostly cloudy) m	"
7.	"	" (microwave) m	"
8.	NOAA-A		"
9.	"	as	"
10.	"	above	"
11.	"		
12.	GOES 1	wind component mps	5.0
13.	GOES 2	" "	"
14.	GOES 3	" "	"
15.	LMD	" "	"
16.	DFVLR	" "	"
17.	METEOSAT	" "	"
18.	HIMAWAR 1	" "	"
19.	ASDAR/AIDS	" "	"
20.	AIREPS	"	"
21.	SONDE	dewpoint °C	3.4
22.	PAOBS Z	geopotential m	"
23.	PAOBS DZ	thickness m	"

Table A is intended as a directory, explaining the layout of the Observation Error Table and providing an index within this note for the documentation on each line. The OE Table is arranged by instrument type, so that the meteorological variable to which each line refers is somewhat implicit. At present the observation errors are specified at the 15 analysis levels used in FGGE Level II-b operations, although the generating program may be modified to produce an OE Table for any other selection of levels.

2. Preliminary Comments

In order to discuss the use of the quantitative uncertainty data in an optimum interpolation scheme, it is necessary to discuss briefly what the uncertainty data mean. The observation error tables presently used at ECMWF are scaled to accommodate both a "measurement" error and an error of "unrepresentativeness." That is, a measurement error is intended to indicate the uncertainty resulting from two or more hypothetical observing systems attempting to measure the same variable. The error of representation is intended to mean the difference between that variable given by a measure-error-free observing system and that which is desired by the analysis scheme. The latter, of course, is a function of the scale of the analysis and (possibly) the forecast model which the analysis will serve. It must, perforce, include any differences in the variable resulting from the fact that the various observing systems measure different space- and time-scale manifestations of the same meteorological variable.

The values in the present ECMWF Error Table have been developed by two different empirical means. One method, which estimates the observation error level of single-level wind vectors, uses statistics of co-located observations from different observing systems. The selection of the space-time window defining co-location provides an implicit definition of the error of representation. The other method has been used to help establish error levels of the rawinsonde observing system; the method, due to Hollett (1975) and Rutherford (1977), essentially partitions co-located forecast and rawin data into an "observation" and a "forecast" error. In both methods, the two types of error as I have defined them, error of measurement and error of representation, are lumped together and expressed in a statistical sense as a system-specific observational error.

In considering the FGGE Level III-b analysis procedure, we need to attempt to relate the system-specific and observation-specific errors in some consistent fashion. The following sections examine some aspects of the former and later sections will in some detail examine the latter.

3.1 Radiosonde Geopotential Height Observation Errors

The values used in the Observation Error Table are taken from Hollett (1975) for pressure levels up to 200 mb. Above that level the table error increases, as it should, in contradistinction to Hollett's values. In his study, a separation scheme was used to split forecast minus rawinsonde observation data into an observation and a prediction error. Limitations imposed by the particular forecast model used in generating Hollett's statistics--the model top was at 100 mb--undoubtedly are responsible for the decrease in observation error above 200 mb. Reference to the extensive analysis of radiosonde height and temperature errors in Finger et al. (1978) provides some basis for the extension into the stratosphere.

It should be noted that a realistic observation error table for radiosonde heights and temperatures should be dependent upon the particular sonde instrument used. For example, data from Finger et al. indicate uncertainties (differences) between 100 mb heights which may, depending upon the sondes compared, be biased by as much as 100 m with superimposed random standard errors of up to 70 m. Because the major source of measurement error in sonde-based geopotential measurements is solar heating of the thermometric element, each reported sonde-measured geopotential height should, in theory, be corrected by using information on the sonde used and the local time of the sounding. Possibly, an error table which is sonde dependent could be employed. In any case, the assimilation scheme would be forced to resort to a block and station number table in order to assess the appropriate course of action. While this is not an impossible procedure (such a scheme is used, e.g., at NMC), no steps toward implementing it have been taken.

Overall, considering Finger et al.'s study, the values in the FGGE Observation Error Table may be too small particularly in the stratosphere.

3.2 Radiosonde Thickness Observation Errors

The values of geopotential height differences between the tropospheric analysis levels shown in the Table have been calculated based upon an rms observation error in mean virtual temperature of 1°K. This value is in agreement with Hollett's derived values, which are essentially independent of pressure up to his 100 mb top level. The values in the stratosphere need to be increased from this value to accommodate the increase in radiosonde temperature errors there. The remarks in the previous section concerning sonde-dependent error also apply, of course, here.

3.3 Rawinsonde Wind Component Observation Error

The observation error for conventional wind soundings is a function of the measurement error, which is in turn dependent upon the method of tracking the ascending balloon; and of the error of representativeness, which is a function of the local synoptic situation. In theory, each wind vector could have an observation error assigned by using information on the type of sounding equipment used and the mean wind speed (for example) up to the appropriate level assigned to the vector.

Hollett's values, obtained by the "error-splitting" technique do not make physical sense entirely since they are only weakly dependent upon height (pressure). The values used in the FGGE Table have been estimated by co-location statistics, Section 5, and a modicum of physical sense on the magnitude of measurement error characteristic of radar and radio-direction-finding tracking techniques.

3.4 Radiosonde Dewpoint Observation Errors

The observation error for dew point is somewhat arbitrarily assigned values that were intended to represent an uncertainty in the basic observed variable of relative humidity of 10%.

4. Satellite Temperature (Thickness) Soundings

The literature on the errors of remotely-sensed temperature profiles is extensive. In summary, the error of the retrieved thicknesses is known to be comprised of a bias, or constant error, and a random error; and is also a function of the amount and type of cloud in the field of view of the satellite radiometer instrument. In the first instance, the assigned error in the OE Table attempts to account for both a bias and a random error by the use of a Table entry which approximates the sum of the two. In the second instance, the Table accommodates, for each of the two satellites, (TIROS and NOAA-A) a unique line for clear, cloudy, microwave and other categories.

The particular values in the Table are derived almost exclusively from Schlatter (1981). One comment is necessary, however. Since the thickness (layer-mean temperature) observation error covariance matrix is the quantity used by the OI analysis scheme, it is necessary to calculate the appropriate entries in the OE Table for <u>each</u> distribution of analysis levels. As the raw material for such calculations, the observation error program must use an estimate of the vertical thickness error for vanishingly small layers; in other words, the temperature error. Schlatter's estimates are for layers which are in fact courser than those used in the 15-level ECMWF analysis scheme. Therefore, some judicious extrapolation of his errors to a "continuous" curve was necessary. Also, since no microwave soundings were examined by Schlatter or used by the FGGE Level III-b production analysis scheme during the time when the OE Table was being constructed (October 1979 - October 1980), the Table entries for the microwave soundings are dummy values.

5. Single Level Wind Vectors (SATOB,AIREP,ASDAR)

5.1 Methodology

The estimates of single-level wind vector observation error were derived by the use of co-located observations. They are derived largely from information provided by NMC-NOAA (Morone, 1979; Tracton et al., 1979) and by Hubert (1979). However, since rawin data was included in the NMC co-location studies, a number of questions of mutual consistency arise.

Specifically, the Morone and Tracton et al. values were compiled by computing variances of the differences between co-located variables measured by the various observing systems and conventional rawinsondes. This material can be extended (and checked) by the examination of differences between all possible observing systems--essentially performing an analysis of variance.

The methodology is to compile a sample of co-located observations, subject to an arbitrary space-time "window," and aggragate mean squared differences (or, alternatively, the variances of the differences). If three different observing systems are to be examined, then the population statistics of the various variances of the differences should be consistent. That is, the variance of the differences; system A-system B, system A-system C, and system B-system C, should add appropriately. Furthermore, if we assume that the errors of observation for the systems are uncorrelated, then a three-way analysis of variance can assign consistent individual system errors to systems A, B and C.

Morone and Tracton et al. have contributed sample mean-square differences for satellite-derived cloud motion wind vectors (SATOBS) and rawinsondes, and aircraft winds and rawinsondes. Here I propose to close the loop by comparing cloud motion vector winds and aircraft winds; using, moreover, both ASDAR and AIDS-derived inertial navigation system aircraft winds and conventional AIREP winds. I will employ a more liberal space-time window and use a different data base. In particular, I will restrict the investigation to upper-level winds (<500 mb) only; not because of choice but because of the restrictions imposed by sample size. The space-time window is six hours, 3° of arc latitude, and 40 mb in pressure. The first and last are larger than that used by the above investigators, but are imposed here by the nature of the (single-level) observations, the uncertain height assignment of the SATOB winds, and the need to obtain a meaningful sample size quickly. I also assume, as did the above, that the wind errors are isotropic and that mean vector error be related to mean component error by the factor $\sqrt{2}$.

The following table sets out the results obtained by the above-named investigators. They estimate a standard vector wind error for the rawinsonde observations of 8.3 m/s.

Table 1
Single-level wind co-location statistics comparison with rawin winds, all units $(m/s)^2$

			Corrected for rawinsonde variance[1]	
	Low levels	Upper levels	Low	Upper
GOES-E	$(6.5)^2$	$(13.5)^2$	$(6.0)^2$	$(10.6)^2$
GOES-W	$(8.0)^2$	$(13.0)^2$	$(7.7)^2$	$(10.0)^2$
JMA	$(9.0)^2$	$(20.5)^2$	$(8.6)^2$	$(18.7)^2$
ESA	$(10.5)^2$	$(14.5)^2$	$(10.2)^2$	$(11.9)^2$
Aircraft	----	$(14.8)^2$	----	$(12.2)^2$

[1] Rawinsonde vector wind error variance taken to be $(2.6)^2$ and $(8.3)^2$ $(m/s)^2$, respectively. Table constructed from data in Morone 1979 and Tracton <u>et al.</u>, 1979.

A sample of cloud motion and aircraft-derived co-located winds was aggragated by using the Level II-b data set at ECMWF for the first two months of the FGGE year (Dec, Jan, 1979/80). Although the sample size is much smaller than that aggragated at NMC, the statistics presented here should be reasonably stable.

Table 2
Single-level wind co-location statistics, ECMWF sample

Part 1, SATOB vs. AIREP, AIDS, ASDAR combined

Data Source	Mean square diff. U	V	Mean diff. U	V	RMS vector Diff.	N cases
NESS,UWIS vs aircraft	115.4	76.0	-2.7	+0.9	13.8	183
ESA vs aircraft	124.9	76.0	-6.8	+2.3	14.2	50
JMA vs aircraft	278.5	119.3	-10.8	-0.4	19.9	24
Part 2, SATOB vs AIREP, AIDS						
NESS, UWIS vs AIREP	138.4	120.4	-0.8	+1.8	(16.1)	94
NESS, UWIS vs AIDS	92.5	77.0	-4.7	-0.1	13.0	85
Part 3, AIDS vs AIDS different aircraft						
AIDS vs AIDS	28.8	41.2	0.2	0.2	8.4	100

The results are shown in Table 2. Three sets are shown: CMVs from various data producers compared with lumped aircraft winds (AIREP, ASDAR, AIDS), USA SATOB winds compared with AIREP and AIDS aircraft winds separately, and co-located AIDS winds from different aircraft.

The procedure for obtaining OE Table entries from the statistics available was as follows: using Part 3 of Table 2, the error or uncertainty variance assigned on AIDS vector wind is $(8.4)^2$ $(m/s)^2$, and from Table 1 the same quantity for an AIREP wind is $(12.2)^2$. Then, from Part 2, Table 2 the USA satellite SATOB producers (NESS, U. Wisconsin combined) the uncertainties follow from,

$(16.1)^2 - (12.2)^2 = (10.5)^2 (m/s)^2$ for SATOB from AIREP comparison and $(13.0)^2 - (8.4)^2 = (9.9)^2 (m/s)^2$ for SATOB from AIDS comparison.

Considering the very small sample sizes and, of course, the differing samples, the agreement here seems satisfactory. An assignment of a mean vector error of 10.1 m/s (component error 7.1 m/s) for the upper tropospheric cloud motion vectors from the USA producers is provisionally made. Part 1, Table 2 is then used to estimate the same quantities for the European Space Agency and Japan Meteorological Agency (Himawari) cloud motion vectors by using the ratios of the variances of rows 2 and 3, respectively, to row 1.

I did not have sufficiently large samples of co-located RAWIN-AIDS and RAWIN-SATOBs from ESA and JMA available, and therefore the complete analysis of variance loop could not be closed.

The statistics above may be checked against some material provided by Hubert (1979). His co-location studies show

Table 3
Single-level wind co-location comparisons from Hubert (1979)
all units m/s

	Surface – 700 mb	< 400 mb
RAWIN-SATOB (ESA)	$(6.8)^2$	$(13.1)^2$
RAWIN-SATOB (JMA)	$(6.0)^2$	$(15.8)^2$
RAWIN-SATOB (NESS)	$(6.5)^2$	$(12.1)^2$

If, again, $(8.3)^2 (m/s)^2$ is used as the RAWIN vector uncertainty then from Table 3, $(10.1)^2$ is obtained for the uncertainty of the ESA SATOBs in the upper troposphere and $(13.4)^2$ for the JMA SATOBs. These are both somewhat less than the values I estimate from the data in Table 2. But the value of $(12.1)^2$, row 3, is also less than the value obtained by Morone and Tracton et al., Table 1. I have chosen the OE Table entries, tentatively, to correspond more closely to my statistics than to Hubert's. If subsequent experience shows the SATOB values to be too large, adjustments can be made. At the lower tropospheric levels, I have depended entirely on Hubert's data.

A few other characteristics of the CMV and aircraft wind differences were investigated. It is conceivable that the wind uncertainty should be a function of the wind speed itself. This is so not only because a fixed space-time window would infer greater errors of representation with greater wind speeds (larger wind shears within the co-location window would be more likely), but because the instrumental error in, at least, the rawin system should increase with increasing wind speed. The component differences in the two samples, CMV minus aircraft winds, were correlated with the average speed of the wind. The correlation coefficients were 0.25 and 0.22 respectively, both of which are barely significant at the 5% level. However, significant or not the correlation is so small as to be of no practical significance--particularly in view of the increased programming necessary to employ normalized values of the wind components. Further, because of structure in the actual wind field over the space-time window dimensions we might expect a correlation between the observed component differences and the horizontal separation distance. However, these correlations were very small and not significant.

Two of the mean component differences (Table 2) were statistically significantly different from zero. Examination of the sample data set, particularly the SATOB-AIDS set, revealed a large bias in the pressure altitudes of the cloud motion and aircraft winds, in that the cloud winds were nearly always assigned lower pressures (higher altitudes) than the aircraft winds. Ideally, we would like the differences in the pressures assigned to averge zero to prevent a bias arising from any systematic shear in the wind. Such a bias could be real if the SATOB winds are assigned altitude which are systematically too high or low. That such might not be the case is suggested by the fact that the SATOB-AIREP sample bias (in pressure) was not nearly as great. In any case, the variances used in the analysis of variance were corrected for the mean component differences.

6. Consideration of Observation-Specific Error Information

Conventional windsoundings taken with ascending balloons have nearly a linear ascent rate in geometric height, generally in the range 250-300 m/min. Wind vector determination practice varies somewhat from country to country but generally 2 to 4 minute averages are used. Windfinding dropsondes on the other hand fall with a nearly linear descent rate in pressure. The following table summarizes some relevant information on the vertical averaging interval in meters.

Table 4

P level (mb)	T assumed, °C	ΔP of 100 mb(1)	2 min(2)	4 min(2)
1000	20	820 m	500 m	1000 m
200	-50	2700 m	500 m	1000 m

(1) Dropsonde, ACDWS, 4 min average, typical descent speed
(2) Upsonde, TWOS, variable, 250 m/min ascent rate

Near the sea surface, the Tropical Wind Observing Ships (TWOS) and Aircraft Dropwindsonde System (ACDWS) vertical averaging interval in meters (if TWOS uses 4 min or less) is roughly the same; but at aircraft flight level the ACDWS is averaging over 3 to 5 times the vertical distance of the conventional rawinsonde systems or TWOS.

It is thus apparent that the vertical averaging interval be accommodated in arriving at an observation error level for the OI analysis scheme. Because of the differing system and averaging characteristics of the TWOS-NAVAID and ACDWS and TCLBS, each must be considered separately.

6.1 TCLBS

Attached as Table 5 is the quality indicator table for the quality indicator IH and IV digits as set forth in the FGGE Data Management Plan. The IH digit contains coded information on the quantitative uncertainty in each wind vector: the value of vector error (in mps) may be generated in the computer from the IH digit by

ΔV = 0.5 * (IH) ** √3

The IV digit provides information on the averaging time used in calculating the wind vector. Since this information has been used by the data producer in arriving at a quantitative vector uncertainty (IH, above) no further use need to be made of this information.

Now, quantitatively, we need to examine the measurement error in the TCLBS wind determination. Experience with the doppler type location systems has demonstrated that the error of location of a drifting platform is a function of platform speed, but at the worst is in the order of 5 km, rms. If the wind vector is simply computed by differencing two locations each with a 5 km error over a 12 hour interval, the resulting rms vector error would be 0.16 m/s, a quite accurate wind indeed. Here, however, owing to the large averaging interval the resulting wind vector is not a representative one for a synoptic map. The wind vectors derived from the TCLBS are actually averages over one orbital period of the satellite or 100 min. Now, the rms vector error, using the same position errors, is 1.2 m/s: further (I would argue) the space-time scale represented by this 100 min average wind is quite nearly what is wanted for synoptic analyses. Note that winds measured by conventional rawin or radar systems have space-time scales of 10 s of meters and minutes (Table 4).

The TCLBS winds appearing the Level II-b data set have been interpolated in space-time to the standard observation times using an objective trajectory determination which uses all position <u>and</u> velocity information over a one-to-three day interval. The uncertainty of the interpolated vectors is thus not unequivocally determined. However, the trajectory calculated requires consistency in the positions and (integrated) velocities so that some measurement error is very likely reduced. On the whole I would argue that the measurement error in a Level II-b TCLBS wind vector is on the order of 1.2 - 1.5 m/s and that its representativeness compared with conventional rising-balloon-tracked winds is much superior. The values in the II-b data coded by the IH digit reflect this value except when all position and velocity data are not available to the trajectory scheme. Then, higher values are specified. Most of the time, however, the TCLBS vector error will be less than 3.3 m/s. Although some experimentation using the OI analysis scheme is clearly desirable, I would suggest the IH table values initially be used straightaway--it may be desirable later to increase them somewhat. For reference purposes, the present error table value for a conventionally observed wind vector at 150 mb is 8.3 m/s. Since the measurement error for conventionally determined winds is on the order of 2-5 m/s, the excess can be thought of as error of representation.

6.2 Aircraft dropwindsonde system

Attached as Table 6 are the IH and IV Tables appropriate to the ACDW system. The same arithmetic expression as in Table 5 may be used to convert IH and IV into uncertainties having physical dimensions. The winds derived from the ACDWS (and the TWOS, next section) are the result of an exceedingly complex system. I will attempt to simplify all the considerations so that the data user can appreciate what the quantified uncertainty means, although it may well be much more than he wants to know.

Wind vectors derived from an Omegasonde depend in a complex way on the accuracies with which the relative phase rates of the received omega navigational low frequency radio waves are measured. The received omega signals are noisy, the noise obscuring the true phase being a function of many physical and electronic parameters. Most, but not all, of the noise is of relative high frequency--relative, that is, to the time scales of the phase changes produced by the sonde moving through the omega phase network in response to the wind. The most basic part of the algorithm determining the winds is a signal processing involving a signal-to-noise reduction. The original signal-to-noise ratio and the particular geometry of the sonde and the omega stations determines the basic accuracy of the wind vectors. To determine the "signal" portion of the omega phase data both the ACDWS and TWOS assume that a smoothing or filtering of the received phase date (which is a function of time or, importantly, pressure altitude) will approximate the true signal. With this assumption, the calculated signal-to-noise ratios and the geometry may be used to assign a quantitative error to the derived winds. This value, scaled to meters per second, is coded by the IH digit attached to <u>each</u> vector; in general, it will vary in time or, equivalently, pressure. Since the smoothing or filtering must be done with time as the independent variable, the determination of the signal involves an averaging, in effect, in pressure. In the case of the ACDWS this averaging was constant and was equivalent to approximately 4 minutes or 100 mb of pressure. The IV digit codes the averaging depth in meters.

In attempting to relate all these considerations to the problem of arriving at an observation-specific OI observation error we must then recognize the following facts. The IH figure includes information on the system error but it is a conservative value because of the fact that it ignores (because it cannot know) error in the winds caused by fluctuations in the omega phases which have the same or greater time scale as the variations in wind-incuded sonde movement. The IV figure is an estimate of the representativeness of the wind vector because it measures its vertical space scale. Two pieces of information are thus missing: a measure of the system error owing to omega phase variations on the order of four minutes and longer, and a measure of the horizontal unrepresentativenss of the omega wind vector. It is logical to assume that he latter is identical to that for conventional balloon wind soundings, the former, however, defies quantification except in a system sense. (If we test a stationary omega sonde by calculating its apparent movement using the received omega signals, we can estimate this component of uncertainty in a statistical sense.) Some work on this problem has been done (e.g., Olson _et al._, 1978) with the not surprising result that the bias is geographic dependent. It is also dependent on the state of the ionosphere (and therefore indirectly on the state of solar activity) since that state influences omega signal propagation.

6.3 TWOS-NAVAID

The considerations which apply for the TWOS-NAVAID (not the USSR TWOS radar-equipped ships) are basically the same as above. In the

TWOS-N data processing a variable time average was used; a basic 1.5 to 2 min (400-500 m) interval was used in the initial processing, but was increased up to a limit if necessary to reduce the rms error to order 1.5 mps. The result is that both omega-based wind systems produce winds employing a variable (in height) vertical averaging interval. It would seem reasonable then to make use of the information on the measurement and representation error that the IH and IV quality indicators represent--some combination of the two indicators seems appropriate.

7. Suggested Observation Error Formulae (ACDWS & TWOS)

There does not seem to be any objective method of scaling or aligning the system-specific and observation specific error except for the general principle that the average performance of the Special Observing Systems (omega windfinding) should equal that of the conventional systems. (There is no reason to believe that the former are any more accurate than the latter.) Therefore, to begin, I specify that the best omega-based winds should be no better than those coming from the conventional windfinding systems. As the IH and IV indicate an increasingly large measurement and representation error (if I may make this simplification) then the value of the observation-specific error should increase. The problem, however, is how large should that error be for the worst situation, viz., IH and IV = 9, Table 6.

Table 7 has been generated by a simple formula containing one adjustable constant, which specifies the amount of increase in observation error, for a given measurement error (IH), from the IV indicator. The values are to be added to the level-dependent values for conventional rawin winds in the present ECMWF Tables. The Table entries increase to values which are commensurate with tropical climatological wind component variability in the range IH $\geq$ 5 and IV $\geq$ 6. The values themselves, of course, are dependent upon the level.

Some experimentation with this scaling will certainly be necessary.

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Table 5
Tables for IH, IV for use with tropica constant level balloon data

IH

Code Figure	Wind Vector Uncertainty (m/s)
0	not specified
1	<0.5
2	0.6 - 1.6
3	1.7 - 3.3
4	3.4 - 5.5
5	5.6 - 8.1
6	8.2 - 11.1
7	11.2 - 14.5
8	14.6 - 18.3
9	18.4 - 22.4

IV

Code Figure	Averaging Time Used
0	Missing or not applicable
1	Standard doppler solution (100 minute average)
2	Interpolated from trajectory - 6 hours interpolation
3	Interpolated from trajectory - 12 hours interpolation
4	Interpolated from trajectory - 18 hours interpolation
5	Interpolated from trajectory - 24 hours interpolation
6	Interpolated from trajectory - >24 hours interpolation
7,8,9	Not used

Table 6
Tables for IH, IV for use with aircraft dropwindsonde and TWOS Navaid data

Quality indicator digit IH

IH	IV(m/s) Q=0.5	Z(gpm) 20	T(°C) 0.2	RH(%) 1
0	unknown or not applicable			
1	<0.5	<20	<0.2	<1.0
2	0.6-1.6	20-66	0.2-0.6	1.0-3.3
3	1.7-3.3	67-134	0.7-1.3	3.4-6.7
4	3.4-5.5	135-221	1.4-2.2	6.8-11.0
5	5.6-8.1	222-325	2.3-3.2	11.1-16.2
6	8.2-11.1	326-445	3.3-4.4	16.3-22.3
7	11.2-14.5	446-582	4.5-5.8	22.4-29.1
8	14.6-18.3	583-733	5.9-7.3	29.2-36.1
9	18.4-22.4	734-899	7.4-8.8	36.8-44.9

Quality indicator digit IV

IV	Vertical interval (m)
0	unknown or not applicable
1	<100
2	101-330
3	331-670
4	671-1100
5	1101-1620
6	1621-2227
7	2228-2909
8	2910-3666
9	3667-4495

Table 7

Wind component observation error, TCLBS and TWOS
m/s, to be added to present error table

IH	IV=1	2	3	4	5	6	7	8	9
1	0.0	0.0	0.0	0.0	2.6	5.2	7.8	10.4	13.0
2	0.0	0.0	0.0	0.0	2.6	5.2	7.8	10.4	13.0
3	.0	.0	.0	.0	2.6	5.2	7.8	10.4	13.0
4	1.6	1.6	1.6	1.6	4.2	6.8	9.4	12.0	14.6
5	3.4	3.4	3.4	3.4	6.0	8.6	11.2	13.8	16.4
6	5.5	5.5	5.5	5.5	8.1	10.7	13.3	15.9	18.5
7	8.0	8.0	8.0	8.0	10.6	13.2	15.8	18.4	21.0
8	10.6	10.6	10.6	10.6	13.2	15.8	18.4	21.0	23.6
9	13.6	13.6	13.6	13.6	16.2	18.8	21.4	24.0	26.6

APPENDIX 1
ECMWF FGGE Observational Error Table

Pressure(mb)	1000	850	700	500	400	300	250	200	150	100	70	50	30	20	10
VSONDE	1.8	1.8	2.9	3.9	4.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
ZSONDE	7.0	8.0	8.6	12.1	14.9	18.8	25.4	27.7	32.4	39.4	50.3	59.3	69.8	96.0	114.2
DZSONDE	0.0	5.4	6.3	12.9	9.8	13.5	9.6	13.1	17.7	24.9	24.0	26.6	47.9	45.1	91.4
TIR-N OTH	0.0	18.4	14.3	21.5	14.4	16.9	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	61.2
TIR-N CLR	0.0	9.5	10.4	16.5	11.8	15.2	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	81.2
TIR-N CLDY	0.0	9.5	10.4	16.56	11.8	15.2	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	81.2
TIR-N MICR	0.0	18.4	14.3	21.5	14.4	16.9	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	81.2
NOAA-A OTH	0.0	18.4	14.3	21.5	14.4	16.9	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	81.2
NOAA-A CLDY	0.0	9.5	10.4	16.5	11.8	16.0	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	81.2
NOAA-A MICR	0.0	18.4	14.3	21.5	14.4	16.9	10.1	13.1	19.4	30.9	30.3	31.5	52.4	45.1	81.2
NESS/UWIS	4.2	4.2	5.1	5.9	6.7	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
LMD	7.2	7.2	7.5	7.8	8.1	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
DFVLR	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0
METEOSAT	7.2	7.2	7.5	7.8	8.1	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
HIMAWARI	6.1	6.1	6.1	9.7	9.7	11.5	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
AIDS/ASDAR	1.8	1.8	2.9	3.9	4.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
AIREP	7.2	7.2	7.5	7.8	8.1	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
TDSONDE	3.0	3.0	6.0	6.0	6.0	6.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
PSEUDO Z	14.0	16.0	17.0	24.0	30.0	39.0	50.0	54.0	64.0	78.0	100.0	118.0	140.0	192.0	228.0
PSEUDO DZ	0.0	13.0	20.0	25.0	29.0	34.0	20.0	22.0	28.0	38.0	30.0	49.0	78.0	64.0	114.0