Ronald Brown IMET Data Quality Control Report: February – May 2004

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1.0 Introduction

This report summarizes the quality of the surface meteorological data collected by the research vessel (R/V) *Ronald Brown* (identifier: WTEC) IMET system during the 5 cruises beginning 12 February 2004 and ending on 24 May 2004. The data were provided to the Florida State University – Research Vessel Surface Meteorology Data Center (RVSMDC) on compact disk by Jonathan Shannahoff. The ASCII files were converted to standard RVSMDC netCDF format. The data were preprocessed using an automated screening program, which automatically adds quality control flags to the data, highlighting potential problems. Next, the data are run through our statistical Spike and Stair-Step Indicator (SASSI), which adds flags for spikes and steps in the data. Finally, the Data Quality Evaluator (DQE) reviewed the data and current flags, whereby flags were added, removed or modified according to the judgment of the DQE and other RVSMDC personnel. Details of the quality control procedures can be found in Smith et al. (1996). The data quality control report summarizes the flags for the *Ronald Brown* IMET surface meteorological data, including those added by the preprocessor, SASSI, and the DQE.

2.0 Statistical Information

The *Ronald Brown* data were received as one minute averages. Observations for the following variables were provided:

Time	(time)
Latitude	(lat)
Longitude	(lon)
Platform Heading	(PL_HD)
Platform Course	(PL_CRS)
Platform Speed Over Ground	(PL_SPD)
IMET Platform-Relative Wind Direction (14.12m)	(PL_WDIR)
IMET Platform-Relative Wind Speed (14.12m)	(PL_WSPD)
Earth-Relative Wind Direction (14.12m)	(DIR)
Earth-Relative Wind Speed (14.12m)	(SPD)
IMET Platform-Relative Wind Direction 2 (25.5m)	(PL_WDIR2)
IMET Platform-Relative Wind Speed 2 (25.5m)	(PL_WSPD2)
Earth-Relative Wind Direction 2 (25.5m)	(DIR2)
Earth-Relative Wind Speed 2 (25.5m)	(SPD2)
Atmospheric Pressure (15.56m)	(P)
Air Temperature (12.98m)	(T)
Sea Temperature (5.6m)	(TS)
Relative Humidity (12.98m)	(RH)
Short-wave Atmospheric Radiation (10.01m)	(RAD)
Long-wave Atmospheric Radiation (10.01m)	(RAD2)
Precipitation	(PRECIP)

3.0 Results

A total of 2,069,613 values were evaluated with 182,135 flags added by the preprocessor, SASSI, and the DQE resulting in 8.80% of the values being flagged for the 4 months of cruises of the *Ronald Brown* from 2004. A breakdown of each of the cruises is provided in Table 1.

Table 1: Statistical 2004 Cruise Information

Cruise Identifier*	Cruise Dates	Number of Records	Number of Values	Number of Flags	Percent Flagged
04A	2/12 – 2/25	18,225	382,725	55,059	14.39
04B	3/1 – 3/15	19,724	414,204	55,247	13.34
04C	3/17 – 3/26	13,333	279,993	19,331	6.90
04D	3/29 – 4/13	21,207	445,347	20,582	4.62
04E	4/30 – 5/3	4,547	95,487	6,519	6.83
04F	5/9 – 5/24	21,517	451,857	25,397	5.62

*Assigned by RVSMDC to ease identification

3.1 Quality Control Information

The quality of the 2004 IMET data from the R/V *Ronald Brown* ranged between cruises from good, 1-5% flagged (04D), to poor , more than 10% flagged (04A, 04B). All other cruises were of fair quality. The quality of the data also varied for each variable between the different cruises. The data as a whole was of fair quality, 5 – 10% flagged, with 8.80% of the data having had flags added. When the cruises were considered as a whole, the navigation variables as well as the platform-relative wind speeds were of excellent quality with less than 1% of data having been flagged. The platform-relative wind directions were of good quality with only 1.69% of anemometer 1 data having flags added and 1.20% of the second anemometer's data having flags added. The calculated earth-relative wind directions for anemometer 2 were of fair quality with roughly 7% flagged for each parameter. The sea temperature, relative humidity, and the short and long-wave atmospheric radiation were of excellent quality with less than 1% of the data having flags added. The air temperature was of good quality with 1.32% of the data being flagged. The earth-relative winds from anemometer one at 14.12 m were of poor quality with 43.06% of the direction data flagged and 52.86% of the speed data having flags. The precipitation data had nearly half of the data receiving flags for being questionable, and this variable will be removed before the data is publicly released due to the suspect nature of the data. The atmospheric pressure had 20.89% of the data with flags added, although the majority were added to the 04A cruise for sensor malfunction. A discussion of the flagged and removed variables follows.

Note: SASSI only applied to scalar variables. These variables include the earth-relative wind speeds, sea temperature, air temperature, atmospheric pressure, and relative humidity.

Table 2: Number of Flags and Percentages Flagged for Each Variable

Variable	B	E	H	J	K	M	S	U	V	X	Y	Total Number of Flags	Percentage of Variable Flagged
TIME												0	0.00
LAT												0	0.00
LON												0	0.00
PL_HD												0	0.00
PL_CRS												0	0.00
PL_SPD							3					3	0.00*
PL_WDIR					1,290		379					1,669	1.69
PL_WSPD							92					92	0.09
DIR		33,832			8,354		253					42,439	43.06
SPD		42,215	2		9,086		114	569	49	43	17	52,095	52.86
PL_WDIR2					783		400					1,183	1.20
PL_WSPD2					97		76					173	0.18
DIR2		2,075			2,913		289					5,277	5.35
SPD2		335			6,358		185	323	16	14	5	7,236	7.34
P					2,208	18,383						20,591	20.89
T					1,302		3					1,305	1.32
TS					159		1	314	38	213	187	912	0.93
RH					86		2					88	0.09
RAD	4											4	0.00*
RAD2	14		2				39					55	0.06
PRECIP				47,573	1,440							49,013	49.73
Total Number of Flags	18	78,457	4	47,573	34,076	18,383	1,836	1,206	103	270	209	182,135	
Percentage of all Variables Flagged	0.00*	3.79	0.00*	2.30	1.65	0.89	0.09	0.06	0.00*	0.01	0.01		

*-Percentages < 0.01%

3.1.1 Deleted Data

The DQE determined that some of the 2004 *Ronald Brown* IMET data were unusable due to extensive missing, highly suspect, or erroneous data. As a result, these data were removed from the final quality controlled data set.

The atmospheric pressure data from the 04A cruise were removed due to a lack of data that prevented the data from being displayed in the visual editor, and therefore no visual quality control took place. The malfunction of the barometer was noted by the data provider resulting in the data having M-flags applied during conversion to netCDF format at the RVSMDC.

The DQE recommends that the precipitation data also be deleted due to consistently recording negative values of accumulated precipitation. There were also suspect events in which rapid, partial draining of the collection reservoir took place. For example, on 24 March, the initial amount of accumulated precipitation is negative, increases to near 35 mm in 1 minute and then drops to 10 mm in one minute, again demonstrating the suspect nature of the instrument for the period data were collected.

3.1.2 Missing Data

There was only one cruise to have an extended period of missing data, 04A. There were 31 minutes of missing data in all variables. The two identifiable periods of missing data during the 04A cruise were between 18:57 and 19:15 UTC and 22:23 and 22:31 UTC on 19 February. There were, however, random minutes in each cruise that the data were missing. These were only detected in daily statistics generated by the countflags routine, used to count the variables' flags and calculate statistics on the data. The cause of the missing data is unknown, but may be the result of instrument system maintenance or the rebooting of the data logger.

There were also events in which an instrument failed to record any data. For example, anemometer one would frequently fail to record data for one reason or another. This resulted in the loss of platform-relative wind speed and direction data which is used, along with platform course, heading and speed, to calculate the earth-relative wind speed and direction. The calculated values of earth-relative winds were K-flagged in the absence of platform-relative winds since the DQE could not verify the true wind values. This occurred on March 3, 4, 5, 9, 10, and 26.

3.2.0 Variable Flagging

3.2.1 Stair Stepping

Stair stepping of the navigation variables is an inherent property of these variables due to the motion of the vessel. Stair stepping of the meteorological variables in response to a change in the vessel's motion, course, heading or speed, is often an indicator of questionable meteorological data values. Meteorological data in the absence of flow distortion, (See section 3.2.2), should not reflect the motion of the vessel. Therefore, such values received the cautionary K-flag. Some of the steps were caught by SASSI, the statistics based prescreener, and received the X-flag, usually in conjunction with the other flags used by the program. 1,685 U, X, and Y flags were added by SASSI. Nearly everyday in the data set had a questionable step in a variable's time series. There were events of stair stepping meteorological data in every cruise. This resulted in 33,987 K-flags, although not all of the K-flags were added for stair stepping. Note: some of the steps in the true winds may have been flagged with E-flags by the preprocessor for failing the true winds recalculation test. The meteorological variables that have steps in the data with the motion of the vessel are both sets of earth-relative winds, the air temperature, the relative humidity, the atmospheric pressure, and sea temperature.

There were 33 days in which the earth-relative wind direction from anemometer one were visually determined to step and had K-flags added. For example, on 12 May, during the 04F cruise, the earth-relative wind direction changed with all of the navigation variables.

The direction changed from 240º to 300º, out of the trend of the surrounding direction data. The winds then reverted back to the prior trend.

The earth-relative wind direction from anemometer two at 25.5 m had flags added for steps on 27 days. 12 May is also an example of stepping for the earth-relative wind direction at 25.5 m. In this case, the magnitude of the step is roughly 35º and is at the same time as the step from the earth-relative winds from anemometer one. Another example of true wind direction 2 stepping is 8 April. In this case the direction increases 100º with changes in the heading and course. It then returns to the previous trend.

The earth-relative wind speed from the first anemometer had steps during 26 days of this series of cruises. Many of the steps in the true wind speed occurred during periods of low platform speeds. An example of this situation took place on 11 April. 15 May had a step in the true wind speed at the beginning of the day. Speeds were generally low and highly variable until just before 5 UTC when the winds jump to 8 m/s. This was associated with a 40˚ shift in the heading. After the heading change the wind speeds were more consistent.

There were 29 days in which the earth-relative wind speed from the anemometer at 25.5 m had steps. 22 February was one example of the earth-relative wind speed from this anemometer having stepped. In this case, the speed changed with the platform speed. The magnitude of the step in the wind speed was near 8 m/s.

The air temperature had steps during 19 days from this period. Most of the steps in the air temperature were likely the result of ventilation issues (see section 3.2.4), steps with the platform-relative wind speed, or by exhaust contamination (see section 3.2.5). A step due to ventilation issues took place 10 April. In this example, the air temperature rose 1.5º C during the time that the platform-relative wind speed was less than 1 m/s. A pair of examples of the air temperature stepping due to ventilation and flow from the stern took place on 2 April and 15 May when the temperature rose ~1º C as the platform-relative wind speed was 1 - 2 m/s and the platform-relative wind direction was about 180º.

The relative humidity also stepped resulting from motion of the vessel. The stepping of the relative humidity took place during events in which the air temperature stepped. May 11 and 15 were the occurrences of the relative humidity stepping. On 11 May, there were several steps of about 0.5º C in the air temperature resulting in the relative humidity falling about 1.25%. The 15 May example took place during an event in which lack of ventilation caused the air temperature to rise 1º C and the relative humidity to fall 5%. The lack of ventilation was the result of the platform-relative wind speed decreasing 3 m/s to a value just over 2 m/s.

Finally, there were two instances in which the sea temperature stepped: both occurred 6 April. In this case, the vessel was in the Caribbean off the coast of Great Inagua. The magnitude of the step was an increase of about 0.7 - 1º C. What makes these changes suspect is the fact that the vessel was not moving when the steps occurred. Therefore, it is believed that the thermosalinograph may have been sampling water which had been warmed by the vessel.

3.2.2 Flow Distortion

Flow distortion was suspected to be a major problem for the 2004 cruises of the *Ronald Brown* detailed in this report. Flow distortion is the result of the wind flowing over and around the cargo on the deck and superstructure of the vessel relative to the location of the instrument sensors. Since the cargo varies from cruise to cruise, it is often very difficult to identify the source of the flow distortion problem. Some flow distortion is inevitable. With two sets of anemometers, occurrences of flow distortion can be identified by the differences in platform-relative wind speeds and directions between the two different anemometers and, also, the differences between the calculated true wind speeds and directions of the two anemometers. The *Ronald Brown* has multiple wind sensors enabling easier identification of flow distortion problems. Flow distortion often results in a high degree of uncertainty in the winds. Nearly every day had some degree of flow distortion taking place. Examples of flow distortion in the platform-relative wind speed took place on 11 and 12 May. In these examples, the wind speeds recorded by anemometer one at 14.12 m were 3 – 4 m/s less than those recorded by the anemometer at 25.5 m. Different velocities would be expected at different heights due to differing amounts of friction, although these are suspect. Also, on 12 May, there are large fluctuations in one anemometer's platform-relative wind directions that are not in the other (0 – 2 UTC, anemometer 2 noisy; and 18 – 22 UTC, anemometer one noisy). These fluctuations in the platform relative winds are apparent in the earth-relative winds since they are used in calculating the true winds. In this case, from 0 – 2 UTC, winds are from the port side of the vessel and the stern, 18 – 22 UTC the winds are from almost perpendicular to the starboard side of the vessel. This demonstrates that when the winds are from the left side of the vessel, the anemometer at 25.5 m is affected by flow distortion and when the winds are form the right side of the vessel the anemometer at 14.12 m is affected by the flow distortion. Improved documentation of sensor locations and their surrounding environment (i.e., digital photos of sensor sites) will improve our understanding of flow distortion affects on individual sensors.

3.2.3 Winds

The quality of the winds varied from cruise to cruise and from one anemometer to the other. The winds from anemometer one at 14.12 m were of poor quality for each of the cruises which is evident in the fact that when all cruises were combined, there was 43.06% of the earth-relative wind direction data and 52.86% of the earth-relative wind's speed data with flags added to for being suspect. The lowest percentage of data flagged for anemometer one's true winds occurred during the 04 cruise where 17.45% of the earth-relative wind direction data were flagged and 23.01% of the earth-relative wind speed data were flagged. Most of the flags added to data from anemometer one were added by the preprocessor as E-flags for failing the true winds recalculation test; 79.72%

of the earth-relative wind direction flags and 81.03% of the earth-relative wind speed were E-flagged. This implies that there may be different averaging techniques used between anemometers and also between the direction and speed values. The overall quality of the winds from anemometer two was much better when all of the data were treated as a whole, only 6.82% and 7.34% of the true wind direction and speed had flags added for suspect data, placing them into the 'fair' category. There were considerably fewer E-flags added to the data from anemometer two. This could be the result of the location of the anemometer being nearly twice as high as anemometer one, thus less influenced by flow distortion around the vessel structures or cargo. Most of the data from anemometer two was categorized as fair data with 5 – 10% of the data being flagged. However, the earth-relative wind direction from anemometer 2 was of poor quality during the 04C cruise as 12.36% of the data were flagged. The 04D cruise had 17.07% of the earth-relative wind speed from the anemometer at 25.5 m flagged, also of poor quality. The earth-relative winds from anemometer two during the 04E cruise had poor data with 15.94 and 22.43% of the earth-relative wind direction and speed data flagged respectively. The second anemometer's true wind direction from the 04B cruise had excellent data as only 0.91% of those data were flagged as suspect.

As detailed above, the earth-relative winds from anemometer one were typically highly suspect which is evident in the high percentage of the data having been flagged. The true winds from the second anemometer were of much better quality, although there were still 5 – 10 % of the data flagged. The major problems with the winds were the stepping of the data with changes in the navigation data and flow distortion. There also could be some additional flow distortion that could be affecting the sensors resulting in more flags, but the DQE was not definitively able to identify these problems.

3.2.4 Ventilation

An insufficiently ventilated thermometer can experience steep rises in temperature in a relatively short period of time when the platform-relative wind speeds are light or when the flow over the instrument is blocked. Not all of the occasions of the ventilation problem are reflected in the relative humidity data since the relative humidity has its own independent sensor with a different time constant. The main pattern used to identify ventilation problems is a relative maximum in air temperature, or dew point temperature, or a relative humidity minimum during a relative minimum period in platform-relative wind speed. Note: the relative humidity could decrease if only the air temperature rose and only if it was derived from temperature sensor data. Ventilation problems are more pronounced when the atmospheric radiation is at or near the daily maximum. Ventilation issues, when identifiable, were K-flagged by the DQE or had U, X, and/or Y-flags added by SASSI to identify the steps. Not all of the values that were K-flagged in the air temperature and the relative humidity data were the result of ventilation issues. Another problem existed when the platform-relative winds were light and from the vicinity of 180º, or the stern of the vessel (see section 3.2.5).

With the exception of the 04B cruise, all other cruises had cases of ventilation and deck heating issues causing the temperature data that had been recorded to be suspect. The number of cases varied during the 04 cruises; A had 2, C had 1, D had the most with 9, E only had one, and there were 4 during the F cruise. The magnitude of the temperature changes were between 0.5º and 1º C. For example, on 15 May the temperature increased 1º C and the platform-relative wind speed decreased 4 m/s, from 6 m/s to 2 m/s.

Two of the steps in the temperature were also identifiable in the relative humidity data. These took place on 11 and 15 May. For the case of the 11^{th}, the steps in the temperature were near 0.5º C and resulted in 5 % decreases in relative humidity. For the 15^{th}, the steps were again 1º C and the relative humidity decreased 5% again.

3.2.5 Exhaust Contamination

The smoke stack of the *Ronald Brown* may occasionally contaminate the temperature data from the sensor located 12.98 m above the mean water line. The problem is the location of the sensor in relation to the exhaust stack of the vessel. The temperature, and possibly relative humidity data, increased during events in which the platform-relative winds are from the stern of the vessel, or 180º, resulting in suspect data. This most often occurs when the platform-speed over ground is low, and the vessel is nearly stationary. At these times, the exhaust is blown past the instruments, causing them to rise considerably and abruptly. The magnitude of the data steps varies between occurrences, although it is usually around 1º C during exhaust contamination events. Exhaust contamination events, when identified, received the K-flag on the suspect data.

An example of the exhaust contaminating the air temperature data took place on 2 April. In this case the air temperature increased roughly 1º C as the platform relative-wind speed was just around 1 m/s and the platform-relative wind direction was at about 150º. The vessel's speed over the ground during this period, from about 14:20 UTC until 15:30 UTC, was below 1 m/s the entire time. This allows for the platform-relative winds to go nearly slack and come from the stern of the vessel, if environmental conditions allow, blowing exhaust contaminated air past the temperature sensor, and thus increasing the temperature.

3.2.6 Navigation Data

The navigation variables experienced only one problem during the 04F cruise on 20 May when the platform-relative speed had 3 S flags added to the data as the vessel speed decreased 2 – 3 m/s, out of the trend of the other navigation variables.

3.2.7 B Flag

The B-flag is assigned to those values falling outside of a realistic, acceptable range by the preprocessor. On rare cases, the bounds flag highlights extreme, natural events. There were B-flags added to the short-wave (4) and long-wave (14) atmospheric radiation. All of these flags were added to negative values of the differing types of radiation.

3.2.8 E Flag

E-flags are added by the preprocessor to true winds for values that fail the true winds recalculation test. The values must have more than a 20º difference in the calculated and recorded true wind directions and the wind speed difference must be more than 2.5 m/s in order to have the E-flag applied. There were a total of 78,457 E-flags added to the two sets of anemometers. The true winds from the anemometer at 14.12 m had 33,832 E-flags added to the direction and 42,215 added to the speed. The anemometer at 25.5 m had only 2,075 E-flag applied to the direction data and 335 to the speed data. There may have been E-flags changed to another flag during the quality control process. There were some days in which all of the true wind data from the anemometer at 14.12 m were E-flagged. E-flags may also result from differing true wind calculation methods on the *Ronald Brown* and the RVSMDC. Insufficient metadata exists to confirm this possibility.

3.2.9 H Flags

The H-flag is used to identify discontinuities, large sudden shifts in the data time series, identified during visual inspection. These can occur for several reasons, such as electrical interference, although a return of the data to their original trend may not take place. There were a total of 4 discontinuity flags added among the cruises. The long-wave radiation had a discontinuity on 10 March as the values changed 15 W/m^2. This was not a large change but was unsupported by other data and the previous trend of the long-wave radiation data itself. The second case of a discontinuity took place on 22 May in the earth-relative wind speed data. Here the wind speed increased nearly 5 m/s for the anemometer at 14.12 m while the anemometer at 25.5 m actually decreases in magnitude for the time. This was also not supported in the other meteorological data provided.

3.2.10 J Flags

The J-flag is added to values that are clearly incorrect. There were J-flags added to the precipitation data (47,573). The precipitation data was clearly unreliable as values would decrease slowly and at times rapidly as if the collection bucket would drain automatically. More of the precipitation data would have been flagged but it was determined that all of the data would be removed before it was made public, thus eliminating the need for he flagging of the data. The RVSMDC is investigating more advanced QC methods for precipitation data.

3.2.11 M Flags

The M-flag is added to data recorded during an instrument malfunction or to a period of data collected between instrument malfunctions that may be suspect. M-flags were added to all of the atmospheric pressure data collected during the 04A cruise for a total of 18,383. The cause of the instrument malfunction is unknown. The DQE determined that the atmospheric pressure would be removed from the data for the cruise.

3.2.14 S Flag, Data Spikes

Isolated data spikes often occur with automated data and can be caused by various factors such as electrical interference. Acceleration spikes are also common when data is collected on moving vessels (Smith, 1999). These often appear as 'noisy' data. Spikes occurred in most of the variables in this data set. These points were assigned the S-flag when they were visually identified using VIDAT. There were also spikes flagged as V-flags added by the automated QC program SASSI. Spike flags were added to the platform speed over water, platform-relative wind direction from both anemometers, platform-relative wind speed from both anemometers, earth-relative wind directions from both anemometers, earth-relative wind speed from both anemometers, the air temperature, the sea temperature, the relative humidity, and the long-wave atmospheric radiation for a total of 1, 836 flags. There were more spike flags added to the platform-relative winds during the 04D – 04F cruise than other cruises. This may be related to a change in deck cargo between the 04C and 04D cruises, although this has not been confirmed.

The platform speed over water had 3 spike flags that were added 20 May during the 04F cruise for values out of the trend of the other data (see section 3.2.6).

The platform-relative wind direction from the anemometer at 14.12 m had 379 spike flags added for acceleration spikes. The 25.5 m anemometer had 400 spike flags added for acceleration spikes. 12 April is an example of a day with many S-flags added to both platform relative wind directions.

The platform-relative wind speed at 14.12 m had acceleration spikes totaling 92 flags. There were also 76 acceleration spikes added to the 25.5 m platform-relative wind speed. The platform-relative wind speeds had acceleration spikes on 11 May.

The earth-relative wind direction from the anemometer at 14.12 m had 253 S-flags which were typically added at times when there were acceleration spikes in that anemometer's platform-relative wind direction data. The same is true for the 25.5 m true wind direction data, as 289 S-flags were applied. The anemometer at 14.12 m had many acceleration spikes on 1 May. There were a few for the 25.5 m anemometer, but not nearly as many as the 14.12 m sensor.

The earth relative wind speeds also had acceleration spikes propagate into the calculated values from the platform-relative wind speeds. There were 114 acceleration spikes in the

14.12 anemometer speed data and 185 in the 25.5 m data. There were several spikes in the 14.12 m true-wind speed applied by the automated QC program SASSI. The earth relative wind speed from the anemometer at 25.5 had several acceleration spikes on 10 May.

The air temperature had 3 S-flags added throughout the data. There were 3 separate instances with spikes in the data: 23 and 25 February, and 3 March. On 23 February, the temperature dropped 0.4º C and rebounded in one minute, out of the trend of the data. The magnitude of the spikes on 25 February and 3 March were 0.5º C in one minute.

The sea temperature had one spike added 20 May for a spike of 0.5º C in just one minute, out of the trend of the other data off the New England coast.

The relative humidity also had 2 spikes in the data, both were during the 04A cruise on 19 February. The relative humidity spiked from 73% to 67% and returned to the previous trend in 3 minutes east of the Windward Islands.

There were 39 spike flags added to the long-wave radiation. There were several spikes in the data on 30 March as the long-wave radiation values dropped nearly 250 W/m^2 in one minute twice. Once for one minute and the other time for three minutes, both out of the trend of the other data.

3.3.0 Final Comments

3.3.1 Winds and Overall Quality

The majority of the flags added to the data recorded on the *Ronald Brown* were from the true winds having many E-flags added to the data for failing the true winds recalculation test and stair stepping of the meteorological data with the motion of the vessel. Many of the problems with the winds are related to the flow distortion historically recurring on the *Ronald Brown*. The high numbers of E and K flags demonstrate the problems with the winds, especially from the anemometer at 14.12 m, and the stepping of the meteorological data with the motion of the vessel. The data as a whole was of fair quality with 8.80% of the data having been flagged for being suspect. The navigation variables and platform-relative wind speeds were of excellent quality with less than 1% of the data having suspect flags applied. Other variables with excellent quality data were the sea temperature, relative humidity, and the short and long-wave radiation. The platform-relative wind directions were of good quality with just over 1% of the data flagged. The earth-relative winds from the anemometer at 14.12 m were of particularly poor quality with 43.06 % of the direction and 52.86 % of the speed data having been flagged. The anemometer at 25.5 m had considerably less flags applied, 5.35 % and 7.34 % for the direction and speed respectively.

3.3.2 Insufficient Data

In parts of each of the cruises, the DQE would like to note that some of the data may have been left unflagged, as in the 25.5 m true wind direction on 3 April, for example, due to insufficient meteorological backing because of the lack of data. In some cases there was not enough evidence to say whether or not certain questionable data should have been flagged.

References:

da Silva, A. M., C.C. Young and S. Levitus, 1994: *Atlas of Surface Marine Data 1994, Volume 1: Algorithms and Procedures.* NOAA Atlas Series.

Smith, S.R., C. Harvey, and D.M. Legler, 1996: *Handbook of Quality Control Procedures and Methods for Surface Meteorology Data.* WOCE Report No. 141/96, Report WOCEMET 96-1, Center for Ocean-Atmospheric Prediction Studies, Florida State University, Tallahassee, FL, 32306-2840.

Smith, S.R., M.A. Bourassa, and R.J. Sharpe, 1999: Establishing More Truth in True Winds. *J. Atmos. Oceanic Technol.,* **16**, 939 – 952.