Ron Brown IMET Data Quality Control Report: September – November 2003

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1.0 Introduction

This report summarizes the quality of the surface meteorological data collected by the research vessel *Ronald Brown* (identifier: WTEC) IMET system during the last 5 cruises of 2003. These cruises began on 9 September and ended on 21 November of 2003. The data were provided to the Florida State University – Research Vessel Surface Meteorological Data Center in ASCII format by John Shannahoff and converted to standard RVSMDC netCDF format. The data were preprocessed using an automated screening program, which adds quality control flags to the data, highlighting potential problems. Next, the data are run through a newly implemented statistical Spike and Stair-Step Indicator, SASSI, which checks for spikes (V), steps (X), and other suspect values (U - fails threshold test, and Y – suspect between X's) and flags them accordingly. 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 preprocessors and the DQE.

2.0 Statistical Information

The *Ronald Brown* IMET 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 (14.12 m)	(PL_WDIR)
IMET Platform-Relative Wind Speed (14.12 m)	(PL_WSPD)
Earth-Relative Wind Direction (14.12 m)	(DIR)
Earth-Relative Wind Speed (14.12 m)	(SPD)
Platform-Relative Wind Direction 2 (25.5 m)	(PL_WDIR2)
Platform-Relative Wind Speed 2 (25.5 m)	(PL_WSPD2)
Earth-Relative Wind Direction 2 (25.5 m)	(DIR2)
Earth-Relative Wind Speed 2 (25.5 m)	(SPD2)
Atmospheric Pressure (15.56 m)	(P)
Air Temperature (12.98 m)	(T)
Sea Temperature (5.6 m in depth)	(TS)
Relative Humidity (12.98 m)	(RH)
Short-Wave Atmospheric Radiation (10.01 m)	(RAD)
Long-Wave Atmospheric Radiation (10.01 m)	(RAD2)
Precipitation	(PRECIP)

3.0 2003 QC Results

A total of 1,587,726 values were evaluated with 124,931 flags added by the preprocessors and the DQE resulting in 7.87 % of the values being flagged for these 5 cruises of the *Ronald Brown*. A breakdown of each cruise is provided in Table 1.

Table 1: Statistical Information

Cruise Identifier*	Cruise Dates	Number of Records	Number of Values	Number of Flags	Percent Flagged
03-J	9/09 – 9/19	14,425	302,925	21,839	7.21
03-K	9/21 – 10/03	16,350	343,350	32,580	9.49
03-L	10/05 – 10/11	8,554	179,634	8,656	4.82
03-M	10/17 – 10/18	1,153	24,213	1,078	4.45
03-N	10/27 – 11/21	35,124	737,604	60,778	8.24

3.1 Quality Control Information

The quality of the IMET data from the research vessel *Ronald Brown* collected in late 2003 was dependent on the cruise and the particular variable in question. Overall, the data were of fair quality with 7.87 % of the entire data set being flagged. The true winds were of poor quality: flagging 36.38 % of the true wind direction for the 14.12 m anemometer, 48.72 % of the true wind speed for the same anemometer, 10.21 % for the 25.5 m anemometer's true wind direction and 10.54 % of the 25.5 m true wind speed. In general, the second anemometer at 25.5 m, had considerably fewer quality control flags added to the data. The reason for the better quality at 25.5 m is unknown but may be due to less flow distortion from the deck cargo or other deck towers. Other variables with a high percentage of QC flags added were the relative humidity and the short-wave radiation. Around 5 % of the pressure and air temperature data were flagged. As displayed in the table above, the individual cruises' quality varied from good for 03-L and M, to fair for the 03-J, K, and N cruises. Table 2 details the distribution of the flags among the variables. A discussion of the flagged and removed variables follows.

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

Variable	B	E	G	H	K	N	S	U	V	X	Y	Total Number of Flags	Percentage of Variable Flagged
TIME												0	0.00
LAT						437						437	0.58
LON						437						437	0.58
PL_HD												0	0.00
PL_CRS							1					1	0.00*
PL_SPD												0	0.00
PL_WDIR							13					13	0.02
PL_WSPD							24					24	0.03
DIR		22,465			5,106		10					27,581	36.48
SPD		31,705			4,511		17	455	43	62	39	36,832	48.72
PL_WDIR2							12					12	0.02
PL_WSPD2							17					17	0.02
DIR2		1,666		4	5,895		155					7,720	10.21
SPD2		356	10		7,045		52	432	23	31	18	7,967	10.54
P					3,483			262	17			3,762	4.98
T					3,862		9	141	9	33	22	4,076	5.39
TS					595					6	1	602	0.80
RH			30		196			9,308	548	1,195	932	12,209	16.15
RAD	23,200											23,200	30.69
RAD2	23				1		14					38	0.05
PRECIP							3					3	0.00*
Total Number of Flags	23,223	56,192	40	4	30,694	874	327	10,598	640	1,327	1,012	124,931	
% of all Variables Flagged	1.46	3.54	0.00*	0.00*	1.93	0.06	0.02	0.67	0.04	0.08	0.06		

* - Percentages < 0.01%

3.1.1 Deleted Data

The DQE determined that there were no data in need of deletion for the *Ronald Brown* cruises from September through November 2003.

3.1.2 Missing Data

Several of the cruises in this set have days in which there is an isolated minute of data missing. The only cruises that had a substantial amount of data missing were the 03-K and N cruises. The 00-K cruise had data missing 22 through 24 September. For example, 22 September had all variables' data missing between 17:07 and 18:19 Z. On 23 September, anemometer 1 at 14.12 m, had loss of data from 00Z until 18Z. There were only 5 data points missing on the 24th. For the 03-N cruise, the data were missing on 6 November in all variables from 16:09 Z until 16:33Z. For those periods in which the platform-relative winds were missing, the calculated true winds were K-flagged for their uncertainty.

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 ship. Stair stepping of the meteorological variables in response to a change in the vessel's motion 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 newly implemented statistics based prescreener, and received the X-flag, usually in conjunction with the other flags used by the program. Nearly every day in the data set had X-flags added for steps by the prescreener, and K-flags added by the DQE for steps. Variables that were influenced by the motion of the vessel were the true winds, the air temperature and relative humidity, the air pressure and the sea temperature.

The true winds of the *Ronald Brown* often stair step and thus received the K-flag at these times. Some of the steps were not flagged, as there were no visible links in other variables to the steps. Examples of steps in the true winds are noticeable in each cruise. For example, 3 November, during the 03-N cruise, the true winds from both anemometers step with the navigation variables. The pressure and the air temperature also step with the changes in the vessel's platform-relative wind speed at the same time as the steps occur in the true winds. These values were K-flagged

The stepping of the temperature is likely related to the deck heating and ventilation problems discussed in section 3.2.4. The relative humidity is affected also, although not as frequently as the temperature. This is because the relative humidity has its own independent sensor with a different time constant.

As stated in the example of the true winds stepping, the air pressure is also affected by changes in the vessel motion resulting in stair stepping. The pressure stepped in the 03-J, K, and N cruises. The steps in the pressure ranged from 0.2 mb to 1.1 mb with an average step of 0.6 mb. Some of the steps were not flagged as no other variable looked to be related to the step. Another reason that steps may not have been flagged is the fact that they were only around a tenth to two tenths of a millibar. During the 03-J cruise the pressure stepped 5 times: 10, 12 (0.6 mb), 14 (no flags), 16 (0.4 mb), and 18 September. The average step during this cruise was 0.4 mb. The 03-K cruise had steps on 22 (1.1 mb), 25, 26-28, and 30 (1.1 mb caught by SASSI) September as well as 1 October (1.1 mb). The average step during this period was 0.7 mb with a maximum step of 1.1 mb and a minimum step of 0.3 mb. Finally, the 03-N cruise experienced pressure steps on 28 (1.0 mb), 30 (no flags), and 31 October and 1 (0.6 mb), 2, 3 (no flags), 4, 5 (0.7 mb) and 9 (0.7 mb) November. Here the average step was 0.57 mb. The exact cause of the pressure steps is unknown but may be due to the varying wind flow over the barometer.

Finally, the last meteorological variable to experience stair stepping during this set of cruises was the sea temperature. The sea temperature stepped during the 03-J, K, and N cruises on a total of 7 days. On 10 September, 03-J, the sea temperature stepped without a link to another variable. It was flagged because the sea temperature dropped from 29.5 °C to 29.1 °C in 3 minutes as the vessel was in the Gulf of Mexico west of Tampa. This is unlikely as the temperature in the Gulf is fairly uniform especially in the summer months. During the 03-K cruise, the sea temperature stepped 23, 24, and 25 September. The step on 23 September was indicated by SASSI. In this example the sea temperature dropped from 29°C to 27.9°C in 4 minutes as the vessel was southeast of the Mississippi River delta, which is feasible due to the close proximity to where the river flows into the Gulf of Mexico. The sea temperature also stepped on 24 and 25 September. On 25 September, the sea temperature stepped with the platform-relative wind speed and the platform speed over ground and was completely unexpected. As the platform-relative wind speed increased from 3.5 m/s to 7 m/s in one minute, the sea temperature rose 0.7°C to 29.3°C, then gradually fell back to 27.6°C all in the span of 2 hours and 20 minutes southwest of Louisiana. The stepping of the sea temperature with the speed of the vessel is very questionable, as noted by the flags. The instances of the sea temperature stepping during the 03-N cruise took place on 28 October and 3 and 12 November. On 3 November, the sea temperature went from 24°C to 21.75 in three minutes as the ship was west of the Galapagos Islands. It is possible that the vessel entered into the equatorial cold pool, thus lowering the sea temperature. Likewise, on 12 November, the vessel was near the equator, again west of the Galapagos Is., and began to move north and the temperature rose from around 23°C to 25°C in a short period of time as the vessel may have been exiting the equatorial cold pool. This step was noted by the X-flags from SASSI.

3.2.2 Flow Distortion

Flow distortion was, again, a major problem during the late cruises of 2003 of the *Ronald Brown*. Flow distortion is the result of the wind flowing over and around the cargo on the deck and the superstructure of the vessel relative to the location of the instrument sensors. Since the cargo varies from cruise to cruise, it is 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 and true wind speeds and directions of the anemometers. Another factor in identifying flow distortion is by the time series of the data, the trace will be different between the different anemometers at the same times. Flow distortion occurred on every cruise and almost every day of this set of data. This resulted in a high level of uncertainty of the true winds for the cruises.

During the 03-J cruise late on 9 September, for example, flow distortion was apparent in the 150° difference between the true wind directions from anemometer one and two. The platform-relative wind directions also differed by 150º from anemometer one to anemometer two. The true wind speeds and the platform-relative wind speeds also had an average difference of 2 m/s between anemometers indicating a flow distortion problem. On 27 September, 03-K cruise, the traces of the two instruments are different between the directions, both true and platform-relative, indicating flow distortion. For the true wind direction, the trace has a different shape from one anemometer to another. For the platform-relative wind direction, the values wrap around the 360° line in different places. In fact, the platform-relative wind direction from anemometer one recorded most of its values between 0 and 30° while anemometer two recorded most of its values between 330 and 360°. For the true wind speed on this day, the traces were different. For the platform-relative wind speeds, the magnitude of the anemometer at 25.5 m was around twice that of the anemometer at 14.12 m. For height changes around 10 m, there should typically only be about 5 % variability in the wind speeds at the different heights, not 100%. During the 03-L cruise, on 9 October, the platform-relative wind speed from the 25.5 m anemometer was again nearly double that of the 14.12 m instrument. The true wind speeds exhibit a different trace indicating flow distortion. The platform-relative wind directions have a very different trace, as do the true winds. The anemometer at 25.5 m has large steps in the true winds and the platform-relative winds that are not apparent in the other anemometer. These large steps take place at the same time and the data in these steps are much more variable than any other times indicating a flow distortion problem that affects the platform-relative winds and shows up in the subsequent, calculated true winds. An example of the problem in the 03-L cruise is the magnitude of the platform-relative wind speeds. Again, the 25.5 m anemometer is roughly twice the magnitude of the 14.12 m anemometer.

3.2.3 Winds

The quality of the wind data for this set of cruises varies from anemometer to anemometer and cruise to cruise. There were some data of good quality collected. The true wind data of good quality that was collected during the 03-L cruise came from the anemometer at 25.5 m. For the 03-M cruise, good data were provided for both true wind speeds and the true wind direction from the anemometer at 25.5 m. There was fair quality wind data collected on the 03-J (SPD2), and 03-L (true winds from anemometer at 25.5 m). The rest of the true wind data was of poor quality. Overall, the true winds from the anemometer at 14.12 m were of poor quality with 36.48% of the direction flagged and 48.72% of the speed flagged. The true winds for the anemometer at 25.5 m were of much better quality but still fell in the category of poor data with 10.21% of the direction data flagged and 10.54% of the speeds flagged. Many of the flags that were added to the true winds were added by the preprocessor for failing the true wind recomputation test, which resulted in E-flags. Most of the flagging of the true winds was due to flow distortion and stair stepping with the vessel. Almost every day had flags added due to stair stepping. The use of the true winds should be done with caution.

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 reflected in the temperature 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 the ventilation problem is a relative temperature maximum during a period of platform-relative wind speed minimum. 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 X-flags added marking the steps.

Each of the cruises of this data set had instances of ventilation issues. The average increase in temperature was just over 1°C and the average change in relative humidity, when affected, was around a 10% decrease. Examples during the 03-J cruise include: 10 (+0.3°C), 13, 16, and 19 September. The 19th may be indicative of the flow over the instrument being blocked as no other link to the step is apparent and the radiation is recording negative values. For the 03-K cruise, the issue with the ventilation took place on 22, 24, and 27 September. The example on the 22 has the platform relative wind speed decrease and the temperature increases 3°C, and then accelerates back up and the temperature then decreases by the same amount; later in the day, another example, the platform-relative wind speed drops about 10 m/s and the temperature rises a half of a degree. The change in the relative humidity for the first example is around 15 %. There are several steps on the 24th in the temperature and the relative humidity. The first step, at about 15 Z, has the temperature rise from 27.0°C to 28.5°C and the relative humidity drops about 10% as the platform relative wind speed is near 0 m/s. The second step at around 21 Z has the temperature rise from 27.5°C to 28.5°C and the relative humidity fell about 7% as the platform-relative wind speed was again near 0 m/s. On 6 October the platform-relative wind speed fell 4 m/s and the temperature then rose 1.4°C. Examples of ventilation problems during the 03-N cruise were 31 October and 4, 5, 9, 10, and 14 November, among others. On 31 October, the first temperature rise was 1°C as the platform-relative wind speed fell 2 m/s, and the second increase in temperature was 2°C when the speed fell 0.5 m/s. On 5 November, the temperature rose 1.75°C as the speed fell 6 m/s. The tenth saw an increase of 2.5°C as the speed fell 4 m/s between 18:40 and 20:30 Z.

3.2.5 Navigation Data

The navigation data for the vessel experienced only one noticeable problem. During the 03-N cruise the platform course shifted from 90° to 75° in one minute on 15 November. This is not a drastic change in course, but, it is out of the trend of the rest of the data, and thus received the S-flag for the spike.

3.2.6 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 atmospheric radiation and the long-wave atmospheric radiation for recording negative values. The short-wave radiometer most likely detected negative values because the instrument was not tuned to detect low values of radiation. Negative values from the long-wave radiometer indicate a clear problem with the sensor. Long-wave values typically range from 300-500 Wm-2.
There were a total of 23,300 B-flags added to the short-wave radiation and 23 added to the long-wave radiation. There were 5,462 B-flags added to the short-wave radiation during the 03-J cruise, 6,100 during the K cruise, 2,831 during the L cruise, 440 for the M cruise, and 8,367 for the N cruise. The long-wave radiation received 8 B-flags during the 03-K cruise, 1 during the L cruise, and 14during the N cruise.

3.2.7 G Flag

There were G-flags assigned by the preprocessor to values greater than four standard deviations from the climatological mean (da Silva, et al., 1994). The flagged values were typically just greater than the four standard deviation limit and may represent extreme, realistic values. There were G-flags added to two cruises, 03-J and K. The variables affected were the true wind speed from the 25.5 m anemometer (10) and the relative humidity (30). For the 03-K cruise, the true wind speed at 25.5 m received 10 G-flags on 29 September for values greater than 18 m/s. For the relative humidity, 26 were added to the 03-J cruise on 17 September for values less than 40% off the coast of New Orleans, LA. There were 4 G-flags added during the 03-K cruise on 29 September, again for relative humidity values less than 40% south of the Louisiana/Texas coast.

3.2.8 H Flags

The H flag is used to identify discontinuities; large sudden shifts in the data time series. These 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 four discontinuity flags added among the cruises. They occurred during the 03-L and N cruises. The variable that experienced discontinuities was the true wind direction at 25.5 m. This occurred on 11 October during the 03-L cruise. It was discontinuous as the direction went from 330° to 85° in one minute at 10:25Z. This is capable of happening in nature, but the rest of the data is not supportive of this event taking place. For the 03-N cruise, on 9 November, the wind shifted from 190-110° at 5Z, again unsupported by the other data.

3.2.9 S Flag

Isolated spikes commonly occur with automated data and can be caused by various factors such as electrical interference. Isolated spikes occurred in most of the variables in the data set. These points were assigned the S-flag. Spike flags were added to all of the variables with the exception of time, latitude, longitude, platform heading, platform speed, atmospheric pressure, sea temperature, relative humidity, and short-wave atmospheric radiation. The pressure (17) and relative humidity (548) did have spike flags (V) added by SASSI. All of the cruises had spike flags added to them except 03-M.

There were also acceleration spikes in the data as well. Acceleration spikes are due to the movement of the vessel and therefore the instrument. They are often found as the vessel is changing speed and/or direction (Smith et al., 1999). They are visible as spikes where the time series levels off, yielding continued accelerating motion, i.e. turning, speeding up or slowing down. The main variables are with acceleration spikes are the platform speed, platform heading, platform course, and platform-relative winds. The true winds do exhibit acceleration spikes, but to a lesser degree. The spikes are propagated into the true winds since they are calculated from the navigation data and the platform-relative winds, which often have acceleration spikes.

3.2.10 Precipitation Data

The precipitation data was of excellent quality in regards to the amount of flags in the data. There was, however, a leak or evaporation taking place in the collection bucket. This was made apparent by the slow decline in the amount of water in the bucket. The instrument should not leak nor should significant evaporation take place. Total rainfall amounts should be calculated with caution due to these problems.

3.3.0 Final Comments

3.3.1 Winds and Overall Quality

The majority of the flagging of the cruises of this *Ronald Brown* data set was due to the large amount of stair stepping done by the meteorological data, flow distortion and negative radiation values recorded. The high number of E and K-flags for the winds and B-flags for the radiation demonstrated this. Even though all of the meteorological data experienced stair stepping, the entire set as a whole was of fair quality with 7.87% of the data having flags added. The winds were of particularly poor quality for the first anemometer as 36.48% of the true wind direction and 48.72% of the true wind speed were flagged. The second anemometer was of considerably better quality with 10.21% of the true wind direction and 10.54% of the true wind speed receiving flags. The difference in the wind quality may be due to the differing locations of the anemometers, bow and above the superstructure, which varies the amount of flow distortion affecting the anemometers.

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 pressure data for example, due to insufficient meteorological backing because of the lack of other data. In some cases, there was not enough evidence to say whether certain questionable data should have been flagged. It is very possible that some of the data left unflagged on these cruises are suspect and should be used with caution.

References:

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