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Woods Hole Oceanographic Institution

Recognizing Problems in Shipboard Logging Meteorology Systems

by

Richard E. Payne

Woods Hole Oceanographic Institution
Woods Hole, MA 02543

August 2002

Technical Report

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Approved for Distribution:

Nelson G. Hogg, Chair
Department of Physical Oceanography

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1. Introduction

This manual is an attempt to help assure the quality of meteorological data on UNOLS ships. It describes what the meteorological parameters should look like that are commonly recorded on UNOLS ships. It is hoped that this will be helpful to shipboard technicians, who have the responsibility of maintaining the meteorological sensors, to recognize sensor problems. Examples of typical records have been taken principally from data from the R/V *Oceanus*. An additional example of precipitation observations is from the R/V *Ron Brown.*

At the Woods Hole Oceanographic Institution it has been found that it is absolutely essential for the technician to be able to generate easily and quickly the daily plots of all the parameters and to be able to look at 1-7 days worth of data in a single plot. Otherwise, most sensor problems can go unrecognized.

A series of thirteen figures follows the text giving examples of data from two *Oceanus* cruises on Georges Bank during the GLOBEC experiment. Figures 1-6 are from *Oceanus* 354, an August cruise; and figures 7-13 are from *Oceanus* 317, a February cruise. They illustrate a variety of meteorological conditions and sensor problems. Detailed descriptions follow in sections 2 and 3.

A crude check of temperature, humidity, wind and short-wave radiation (solar radiation) can be made by stepping out on deck and is worth doing. Do the indicated temperature and humidity agree roughly with what you feel on your skin? If the ship is underway, is the relative wind from ahead and does the met system indicate that? If it was a clear, sunny day, does the plot of that day's short-wave radiation look like day 215 in figure 2?

The damp, salty, sunny atmosphere in which they are expected to perform is very hard on sensors. Sensor manufacturers have done a remarkable job of developing sensors, which will perform accurately and reliably, but they should be calibrated and refurbished at regular intervals. Relative humidity/air temperature sensors should be calibrated at six-month intervals. Beyond one year, their accuracy definitely cannot be relied on. R. M. Young propeller anemometers should have their propeller shaft bearings changed every six months and their direction shaft bearings changed as soon as they do not run smoothly and easily. Short- and long-wave radiometers and precipitation gauges should be calibrated once per year. Any sensors located where they will be subject to stack gases should be cleaned frequently.

2. General Comments on Meteorological Parameters

Barometric Pressure (BP)

Barometric pressure has a nominal range of 980 – 1040 mb. Values below 990 mb usually occur only under storm conditions. The range is less in the tropics where the succession of highs and lows that make life so interesting in mid-latitudes is largely absent. The tropics, however, have their own phenomenon--an atmospheric tide--which can amount to several hPa at the equator and can be quite visible as an oscillation in the record. Change of BP is generally slow but quite dependent on macro-scale weather conditions. A rapidly moving low can cause BP to change 20-30 hPa in 12 hours. Note that, in mid-latitudes, variations in barometric pressure, air temperature, relative humidity, and wind speed and direction can all be correlated when a front passes through. We can expect high frequency noise on top of the signal to be less than 1 hPa.

Air Temperature (AT)

The character of AT is different at sea than you would expect on land. The day-night difference is almost unnoticeable. The high frequency fluctuations also tend to be smaller. There can, however, be changes of 15-20°C in a 12-hour period. Usually these are correlated with changes in relative humidity and barometric pressure as a front goes through (mid-latitudes). See particularly days 215-219 on figure 2.

Relative Humidity (RH)

RH tends to be fairly high at sea, typically 70% RH or more. It is uncommon for values less than 50% RH to occur except off east-facing coasts. Often there are long periods when the RH can be close to 100% RH even with no fog. One thing to remember, however, is that the sensors used do not indicate accurately above 95% RH. Because their response curves have curvature at the high end especially, and the calibrations typically do not go above 95% RH, the calibration curves built into IMET (Improved METeorology) modules and other meteorological systems cannot represent the high RH values adequately. The result can be relative humidities indicated as higher than 100% RH, sometimes for hours or days at a time and even without any apparent fog. See days 43-44 in figure 7 for an example. The sensors can take several hours to recover from a period of high RH. As for air temperature, there can be large changes in short periods. A change of 40% RH in a day is reasonable off an east coast, but smaller changes would be expected as you get further from land.

Wind Speed and Direction (WS & WD, [TWS & TWD])

Several parameters contribute to the calculation of true wind speed and direction: speed and direction relative to the ship; ship speed and direction made good (usually obtained from a GPS receiver); and ship's heading (from the ship's gyro compass). The ship's direction made good should be very similar to the heading if the ship is underway; hove to they can be quite different. Assuming that your system logs all of these, it may compute true wind speed and direction. Figure 5, 6 and 11, 12, 13 show all the parameters from the R/V *Oceanus* cruises. Note the spikes in the true wind direction plot in figure 12. These occur because the time responses of the wind vane, gyro compass, and GPS are different. In figures 6 and 12, the ship speed shows when the ship is underway and when it is hove to on a station. You can see how the rest of the parameters change accordingly.

It is unfortunate that, because directions wrap around from 360 to 0 degrees, direction plots look very noisy when the direction is flipping around 360 degrees. This is especially apparent in the plots of true wind direction. Not all ships use the same direction convention. Some use the oceanographic convention: Wind direction is direction toward which the wind is blowing, since this agrees with current directions reported by oceanographic instruments. Others use the meteorological convention: direction from which the wind is blowing. The plots in this report are in oceanographic convention.

Note that on day 42 in figure 11, the true wind direction appears as if it might have shifted by about 180 degrees for several hours. If we look at the details in figure 13, we see that, during a period of low wind speeds, the direction swung through more than 360 degrees.

Precipitation (Precip)

The sensor used on most of the ships is the R. M. Young precipitation gauge. This gauge outputs a DC voltage proportional to the level of water in the reservoir. When the reservoir fills, it initiates its own siphon cycle and empties itself. When it is not raining, therefore, the output of the gauge is constant or slowly decreasing as the water inside evaporates. IMET precipitation modules output the level of the water in the reservoir, as well as the rates of change (the rainfall rate) averaged over the previous minute and hour. Rough weather will increase the noise in the gauge level due to the water in the gauge getting sloshed around. There was no precipitation module on cruise 354, but figures 8 and 10 show the precipitation gauge output on cruise 317. The high frequency noise in the early part of the record is due to an instrument malfunction as is the small maximum late on day 47. The expansion of the record in figure 10, however, shows typical behavior. Note the constant level for over a day followed by a sharp increase, self-siphon, and another increase almost to the point of self-siphoning again, all in the space of a little over half a day. This represents about 70 mm of rain, which is almost 3 inches.

One point to remember is that the gauge level should increase monotonically when there is rain. Bumps and dips of more than 1 mm or so indicate a malfunction of the gauge. Figure 14 from the *Ron Brown* is one example.

Short-wave radiation (SW)

Short-wave radiation has an obvious diurnal cycle. It is expected to be zero at night within the accuracy of the sensor and logger, i.e., within 2-3 W-m^{-2}, unless there are ship's lights shining on it. The maximum value to be expected in the tropics or summertime mid-latitudes, under a clear sky, with the sun directly overhead is about 1000 W-m^{-2}. It is possible to get brief peaks above this (or above whatever values are being recorded) if there are large cumulus clouds. Reflection from the clouds can have a focussing effect. Under partly cloudy conditions, the signal can be extremely noisy. Under a thick, solid overcast, the output and noise level will be low.

Long-wave radiation (LW)

Long-wave radiation emanates primarily from water vapor in the lower part of the atmosphere. Maximum values occur with low clouds since these tend to be warmer than clouds at greater altitudes. Conversely, a very clear sky, for example after a polar outbreak in mid-latitudes, is cold and lower values are observed under these conditions. The range to be expected is 200–500 W-m^{-2}. Expect it to be as noisy as the procession of clouds overhead. It will be noisier in partly cloudy conditions than under clear or totally overcast skies.

3. Specific Comments on Figures

The parameters in figures 1,3,7,9 (BP, AT, RH, TWD, TWS) are plotted together because they are often correlated. For example, figure 3 represents a little more than one day extracted from figure 1. In this case, the pressure is recovering from a moderate passing low. As the barometric pressure recovers, the temperature increases and the relative humidity decreases, probably because some warm, dry continental air is filling behind the low. The wind direction swings as the low passes, but there is no signature in the wind speed in this case. Figure 9 is a similar example from the data of figure 7. In this case, although the correlation between air temperature, relative humidity, and barometric pressure is apparent, there is no obvious signal in either wind speed or direction. Note in figures 7 and 8 a period of several hours with no data is represented by a straight-line segment in each of the parameter plots.

In **Figure 1,** note the recovery in BP during days 213-216 from a low of 1004 hPa to a high of 1017 hPa. AT drops almost 4°C in the first day and then stays constant; RH also drops; and TWD shifts well over 90 degrees during day 217. This has some of the features of a cold front passage, except the wind speed was constant through the period. Since the period is in the summer, the AT has values of 18-26°C.

Figure 2 covers the same period as figure 1, except that short-wave radiation is substituted for BP. Note that the sky is quite free of clouds during days 215-216.

Figure 3 covers one day out of figure 1 to show details of what happened shortly after midnight on day 218. Note the sharp dip in BP, the sharp drop in AT, the slower drop in RH, and the sudden shift in wind direction and speed.

Figure 4 shows SW for the period of figure 3. All the excitement of the low happened during the previous night but you can see where the clouds cleared just after noon on day 218.

Figure 5 shows all the parameters that enter the computation of true wind speed and direction on a series of days when the ship was alternately steaming and hove to. Note that the only indication of the maneuvering in the true wind speed and direction are some spikes in the direction due to a mismatch in the time constants of the parameters used in the computation. This is a good test to determine if the algorithm used for computing TWS and TWD is calculating correctly on your system.

Figure 6 is a magnification of day 215 from the previous figure and shows in better detail the correlation between various parameters as the ship is steaming and is hove to.

Figure 7 shows an increase in temperature and relative humidity as a low-pressure area approaches. Note that the apparent RH increases above 100%RH and is clipped. TWD rotates 360° as the low passes. TWS drops almost to zero before the low arrives and rises to 15 $m\text{-}s^{-1}$ as it passes. AT is quite low except when it rises during the passage of the low. Since this is off the northeastern coast of the United States, the high AT and RH values indicate that the low was scooping up some southern air.

Figure 8 shows SW and Precip for the same period as figure 6. Note that SW is very low on the day the low passes, which indicates thick clouds. The negative spikes in the precipitation plot are one form of problem that has been seen, particularly in stormy conditions. They make the data difficult to edit for scientific use. Even though the SW was low on day 42, there was probably a good swell moving the ship.

The straight lines at the end of day 40 are a gap in the data. There is precipitation near the end of day 43, at the beginning of day 46 and during day 47. The drop just before the end of day 47 is probably a problem in the gauge. On day 49 there was a great deal of rain, leading to one self-siphoning and nearly filling the gauge a second time.

Figure 9 shows in detail the apparent sudden drop in RH just after the passage of the center of the low. Apparently, some moisture can accumulate inside the RH sensor shield, which keeps the apparent RH above 100%RH until it evaporates. It then drops quite suddenly to the true ambient value.

Figure 10 shows details of the data in figure 8. Thick clouds keep SW low and fairly steady. The large amounts of rain are obvious in the Precip plot.

Figure 11 is a plot of all the parameters, which enter into the TWS and TWD computations for the period of figure 7.

Figure 12 is an expanded view of day 44 from figure 11 and shows a very slowly changing TWD and TWS.

Figure 13 is an expanded view of day 42 from figure 11and shows details of what looked somewhat anomalous in the TWD early in the day.

Figure 14 shows details of what appears to be an instrument problem. The gauge level drops suddenly and then recovers. It would be well to be suspicious of a gauge that behaved like this and to replace it, if possible.

4. Conclusion

Meteorological sensors deployed on ships are subject to many sources of error, not the least of which are the environmental conditions under which they have to work. Too often the sensors are expected to return accurate data for very long periods of time with little attention given to them. In this report it was the goal to illustrate what good data looks like for all the common sensors and to show some of the problems for which to be on the lookout. Often, putting together the data from several sensors can illuminate an atmospheric source for what appears to be anomalous, and possibly bad, data.

5. Acknowledgments

Bob Knox, of the Scripps Institution of Oceanography, suggested the usefulness of a report of this sort. Funding for publishing the report came from National Science Foundation Grant OCE-9806381. Shawn Smith of the WOCE Surface Meteorology Data Center at Florida State University provided the R/V *Ron Brown* precipitation figure.

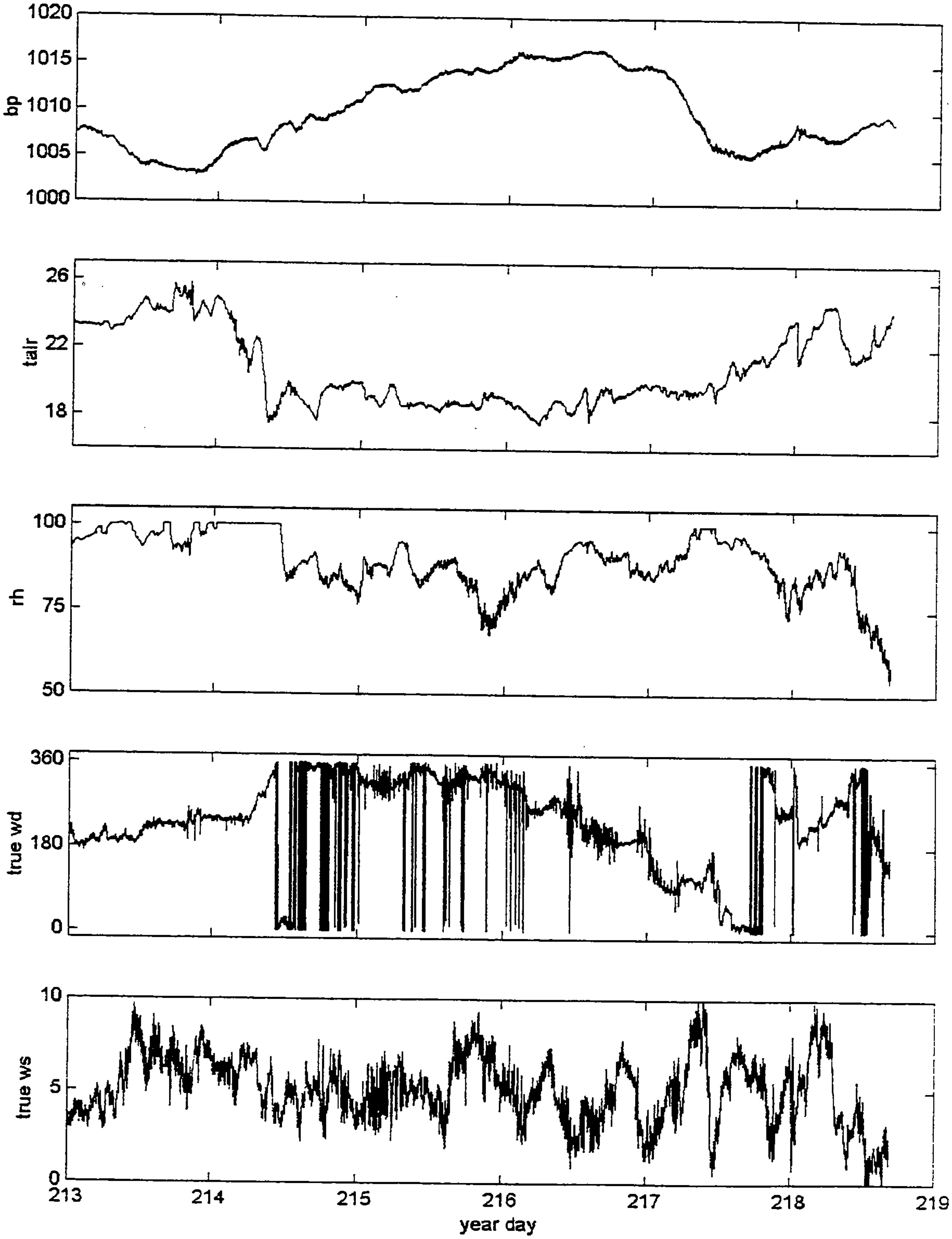

Figure 1: R/V *Oceanus,* Cruise 354, Georges Bank, August 1--6: Shows some features of a cold front passage.

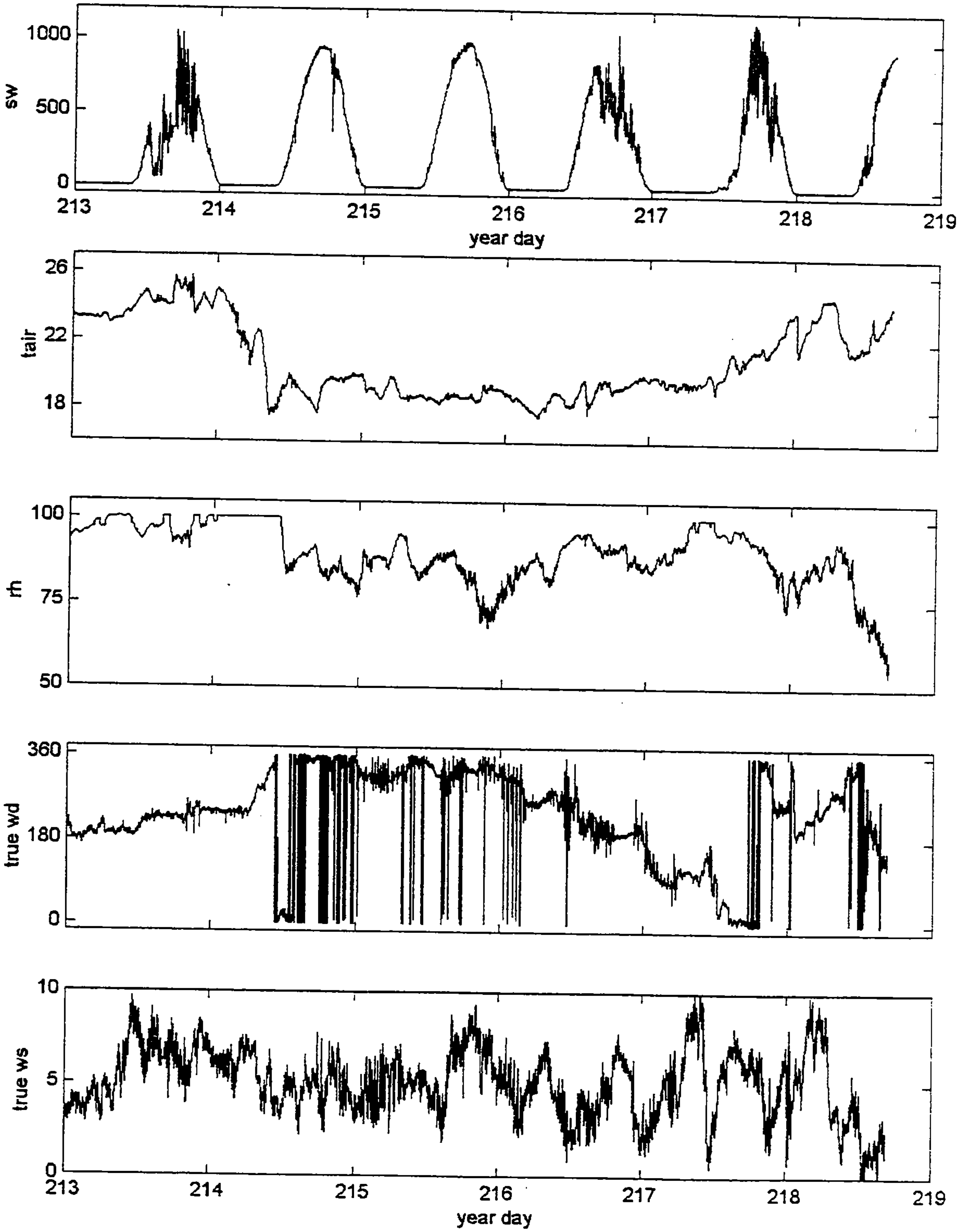

Figure 2: R/V *Oceanus*, Cruise 354, Georges Bank, August 1—6: Shows clear skies during high pressure period.

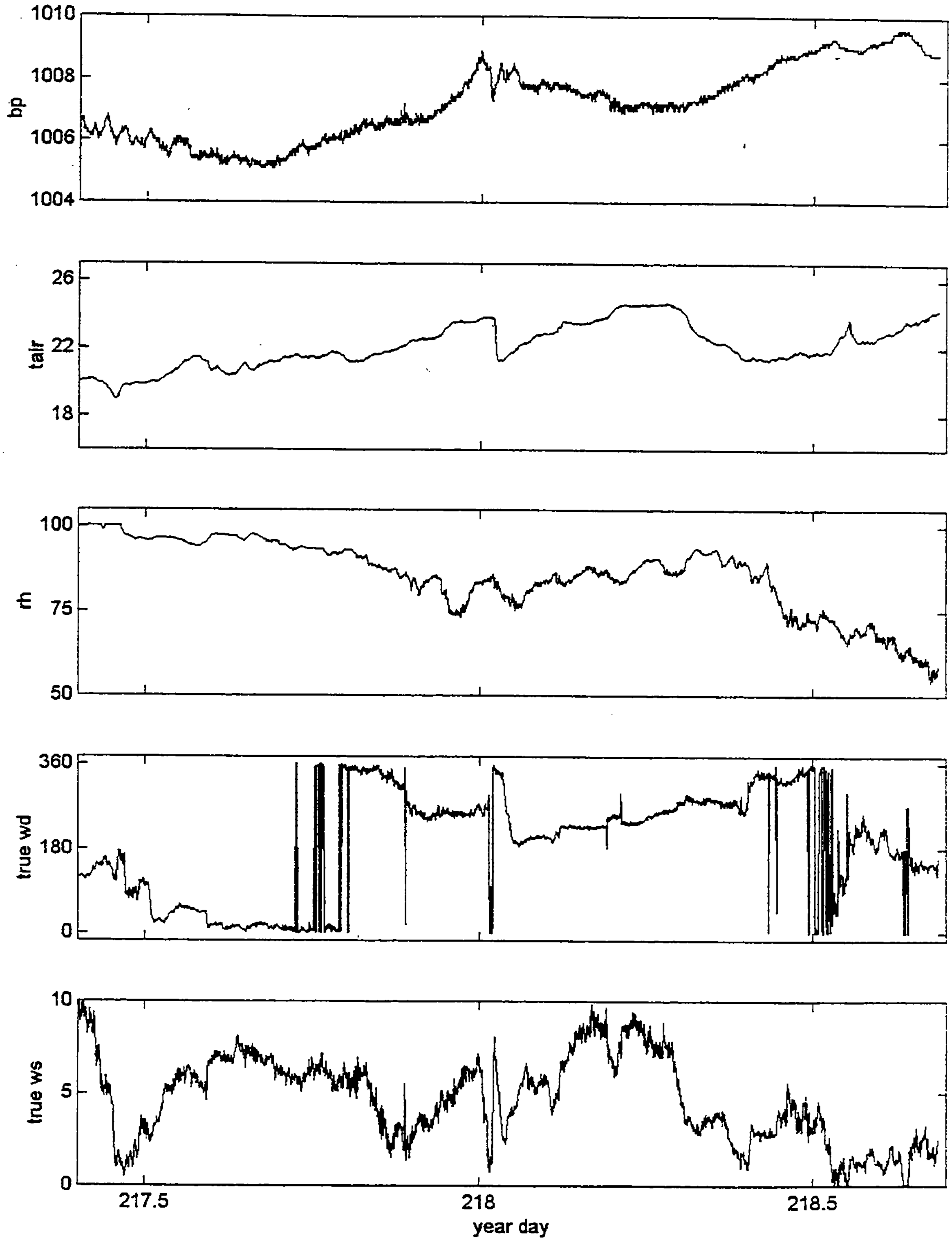

Figure 3: R/V *Oceanus*, Cruise 354, Georges Bank, August 5—6: Details of cold front passage from figures 1 and 2.

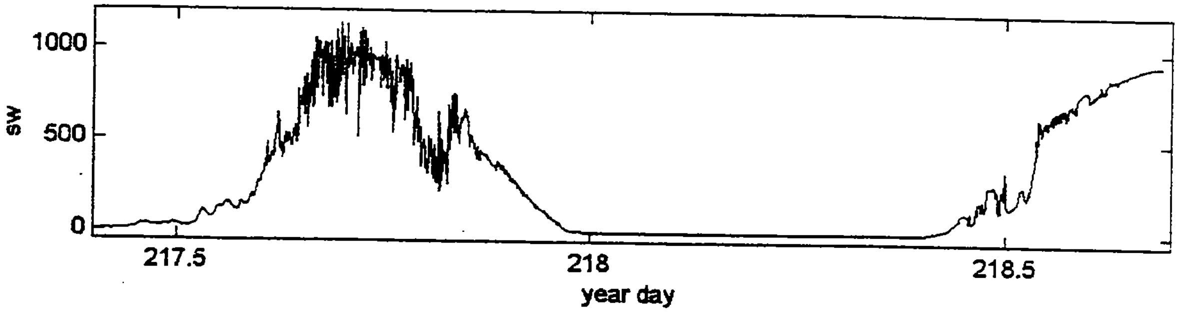

Figure 4: R/V *Oceanus*, Cruise 354, Georges Bank, August 5—6: SW details for figure 3

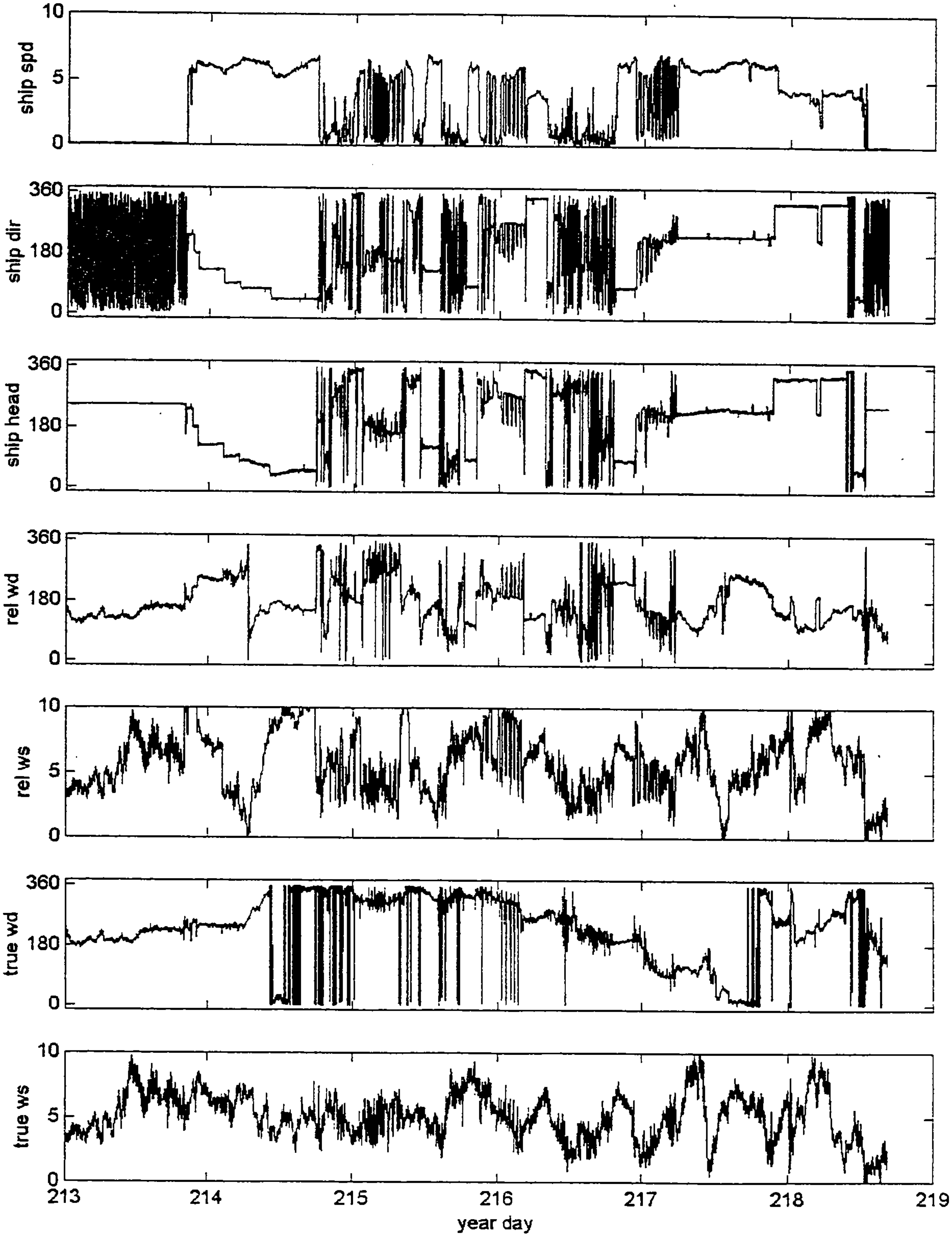

Figure 5: R/V *Oceanus*, Cruise 354, Georges Bank, August 1—6: Components of the true WS, WD computation during period of alternate steaming and hove to.

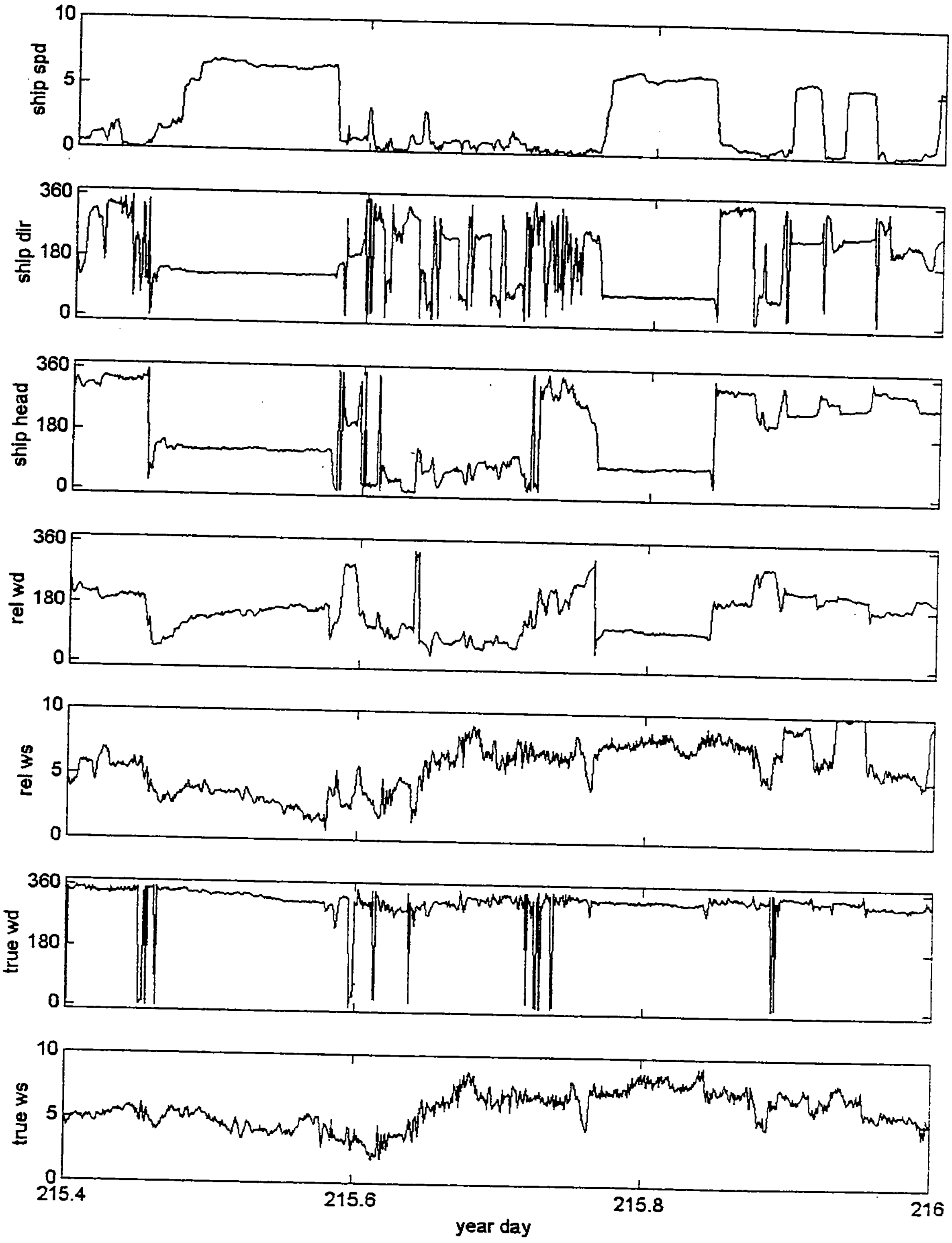

Figure 6: R/V *Oceanus*, Cruise 354, Georges Bank, August 3: Expanded view of day 215 from figure 5.

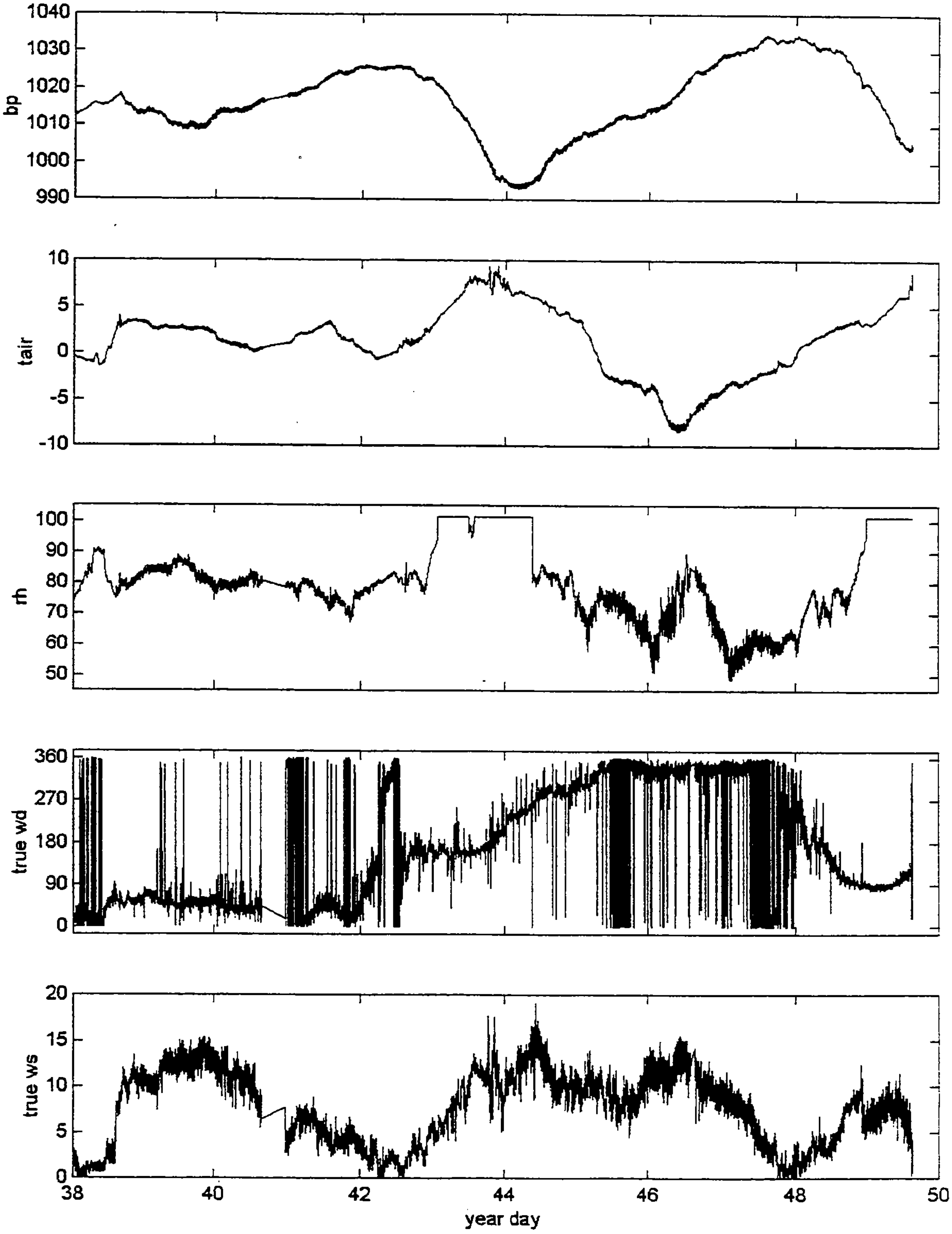

Figure 7: R/V *Oceanus*, Cruise 317, Georges Bank, February 7—18: Approach of low pressure area.

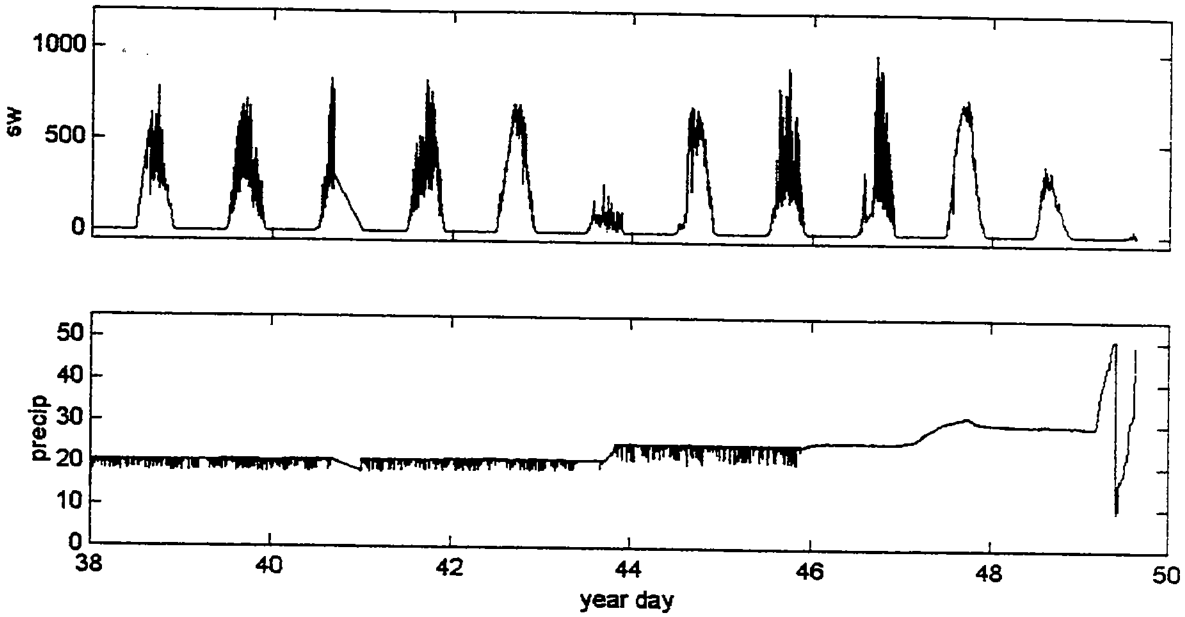

Figure 8: R/V *Oceanus*, Cruise 317, Georges Bank, February 7—18: SW and Precip for period of figure 7.

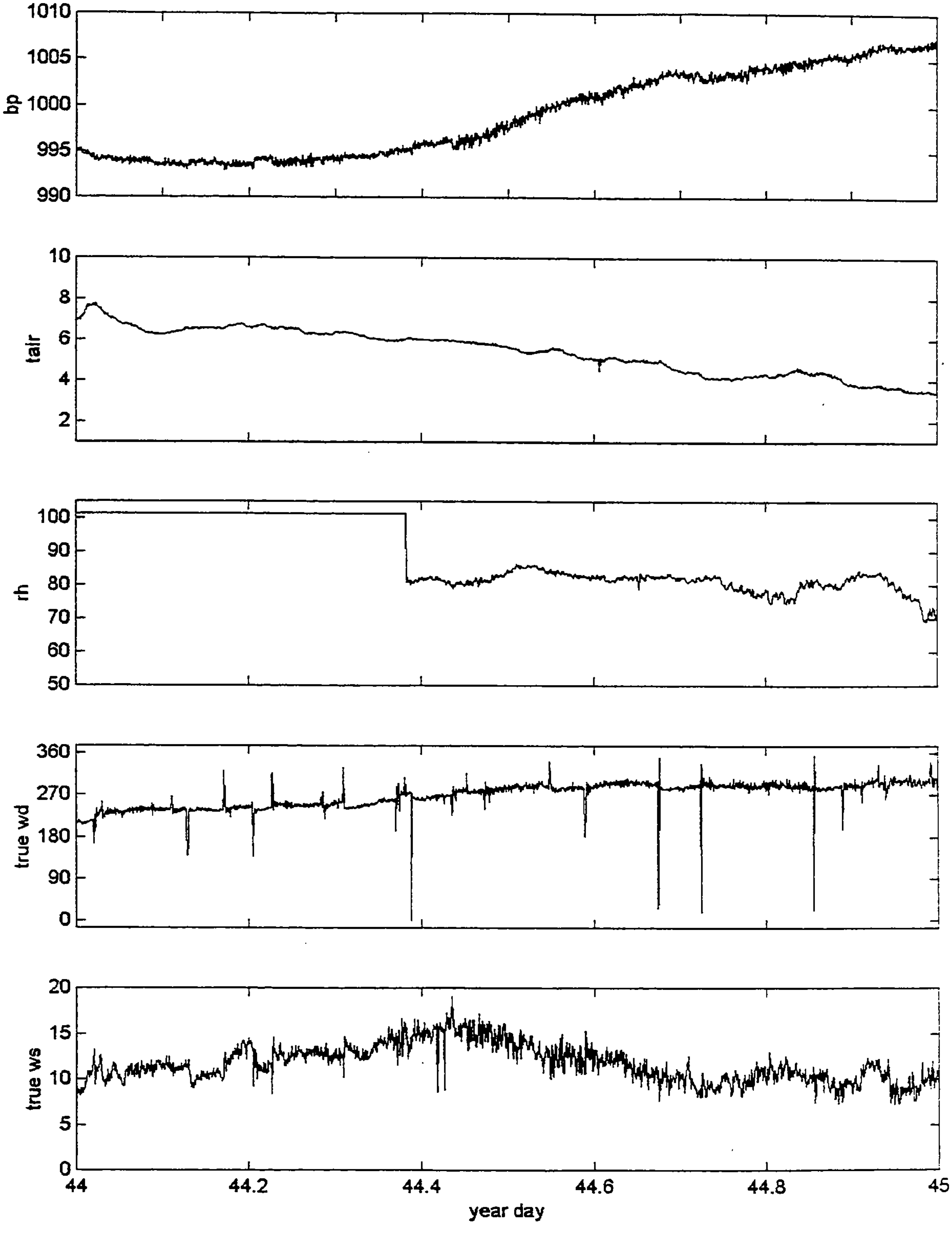

Figure 9: R/V *Oceanus,* Cruise 317, Georges Bank, February 13: Details of passage of low pressure.

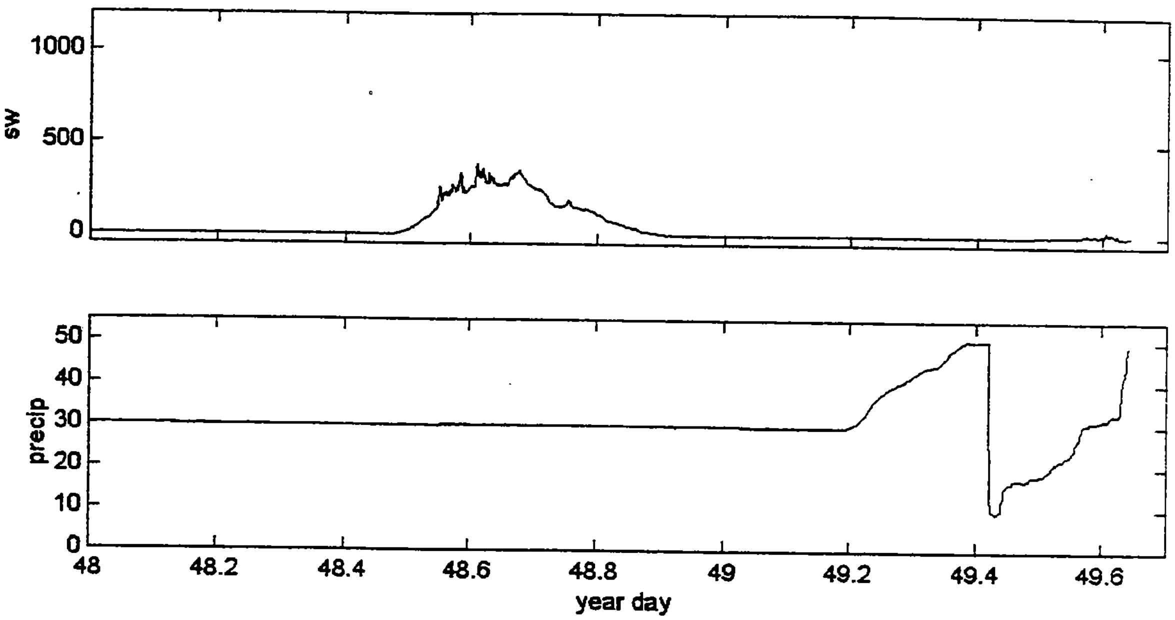

Figure 10: R/V *Oceanus,* Cruise 317, Georges Bank, February 1—18: Details for figure 8.

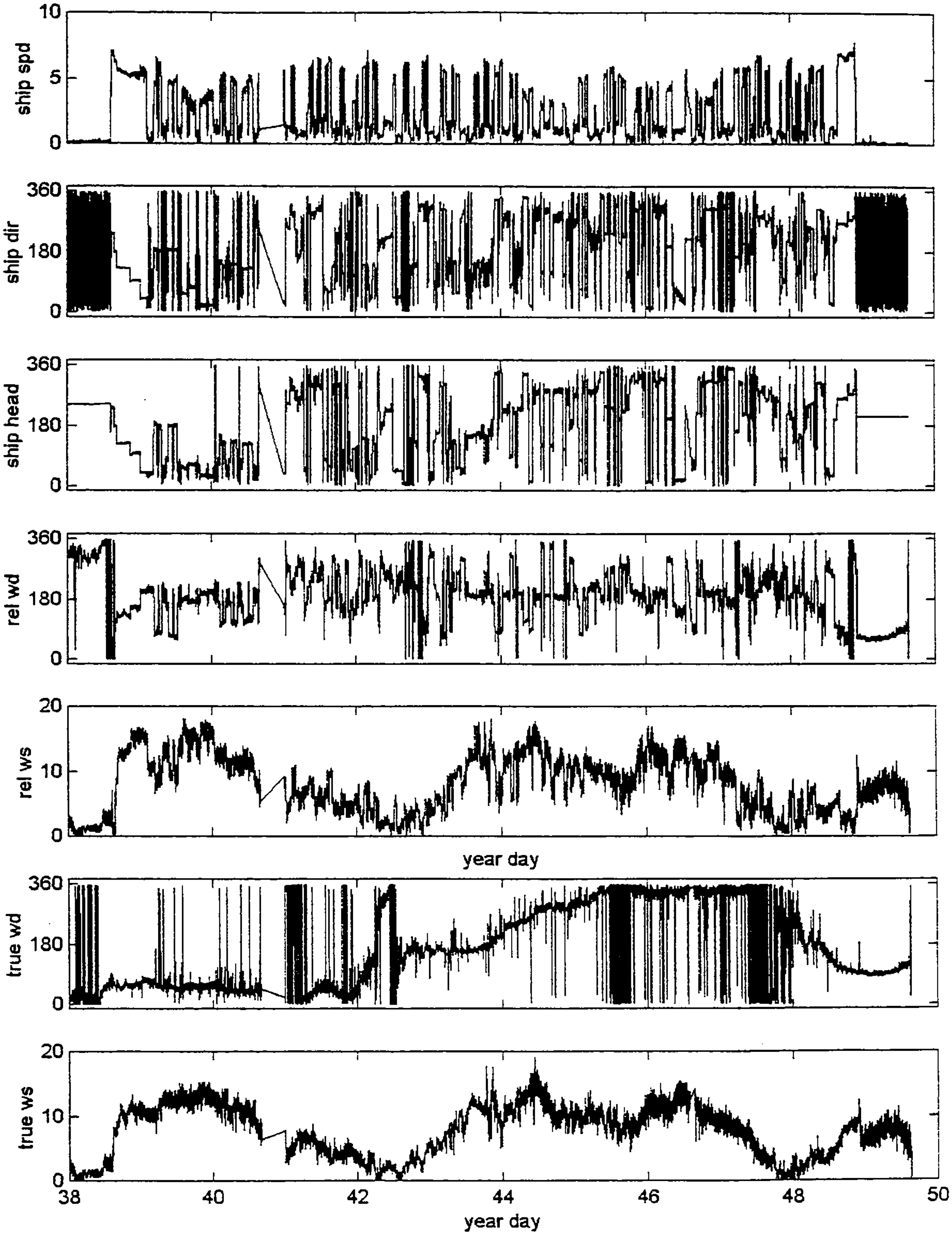

Figure 11: R/V *Oceanus,* Cruise 317, Georges Bank, February 7—18: Component of true WS, WD computation for period of figure 7.

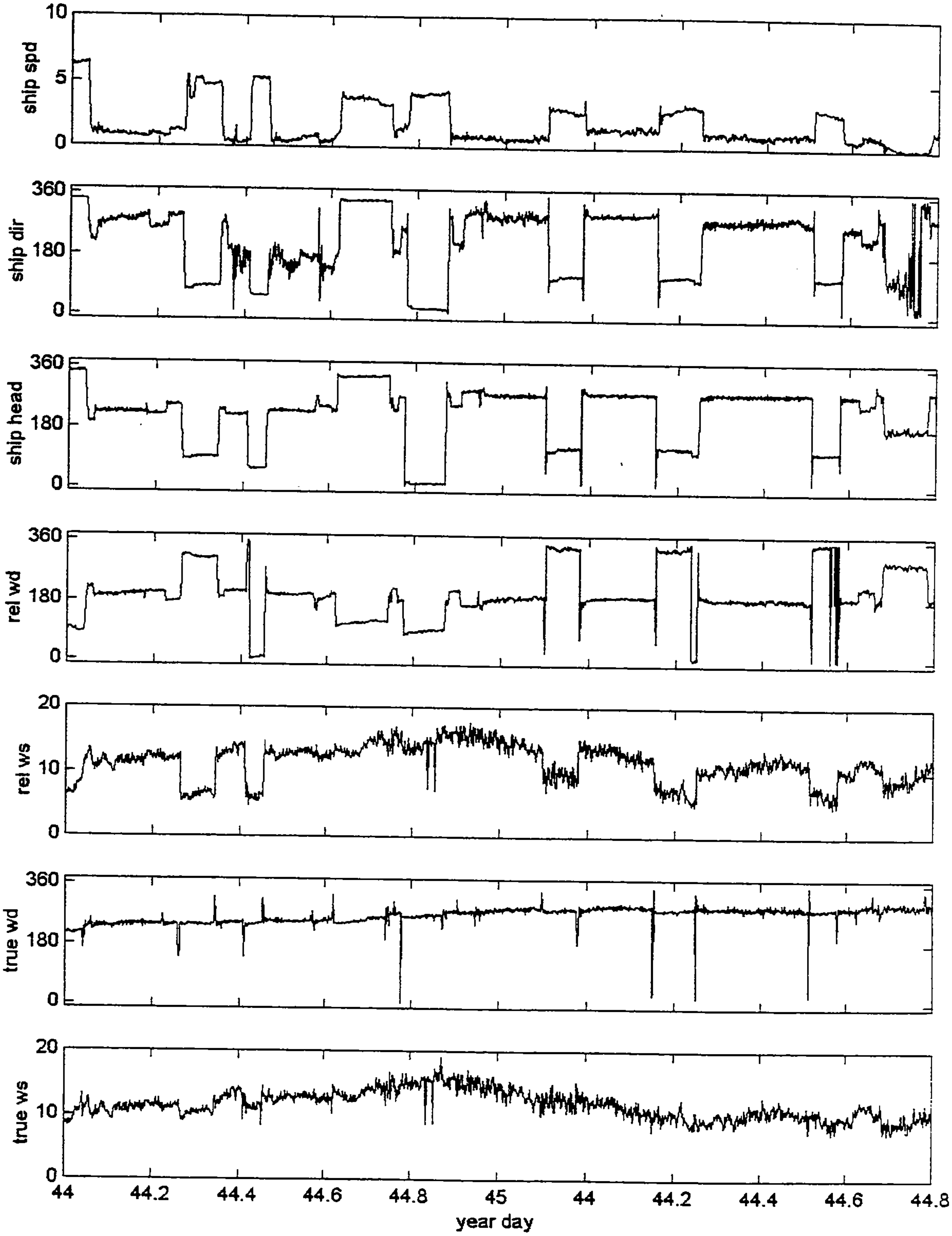

Figure 12: R/V *Oceanus*, Cruise 317, Georges Bank, February 13: Expanded view of day 44 from figure 11.

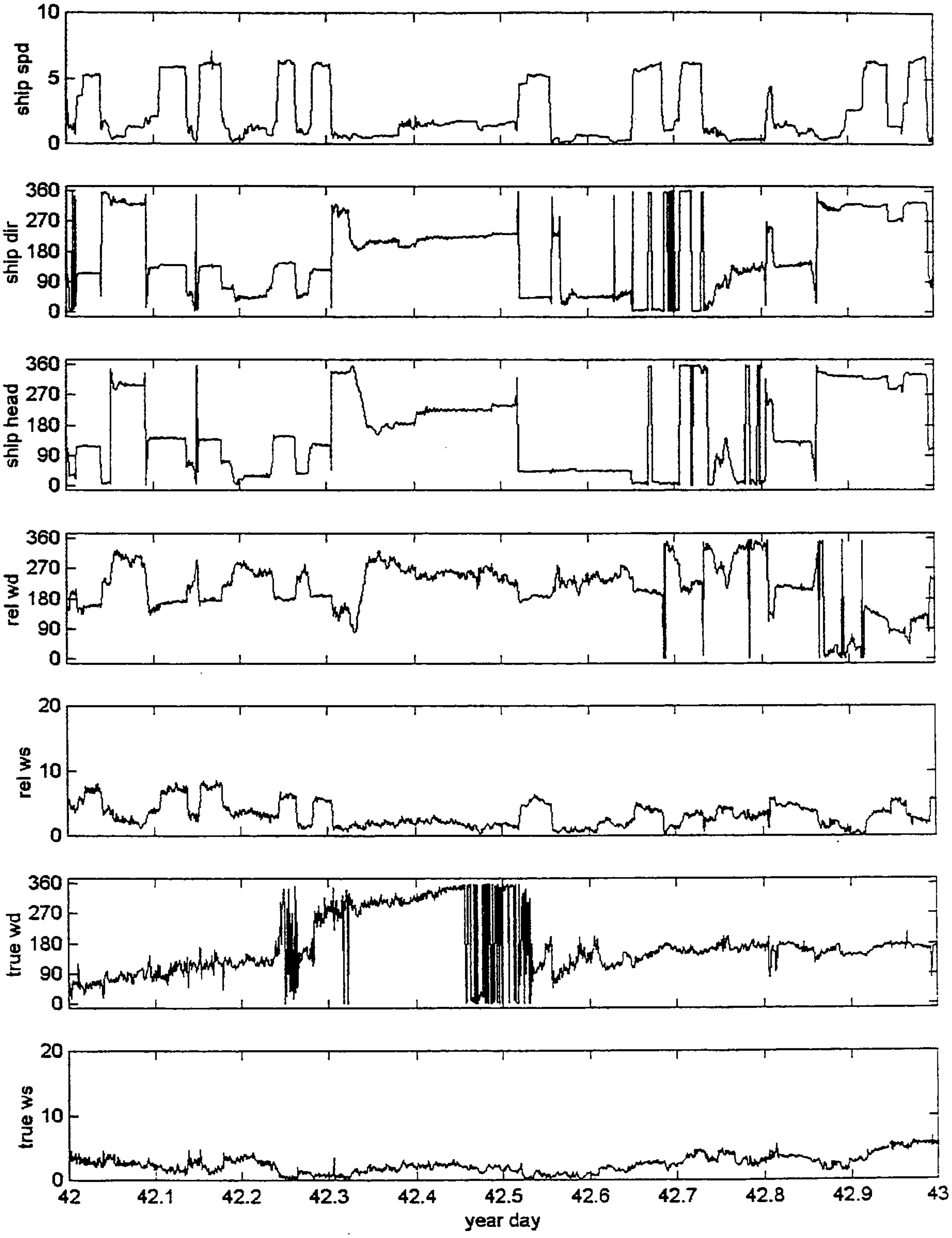

Figure 13: R/V *Oceanus*, Cruise 317, Georges Bank, February 11: Expanded view of day 42 from figure 11.

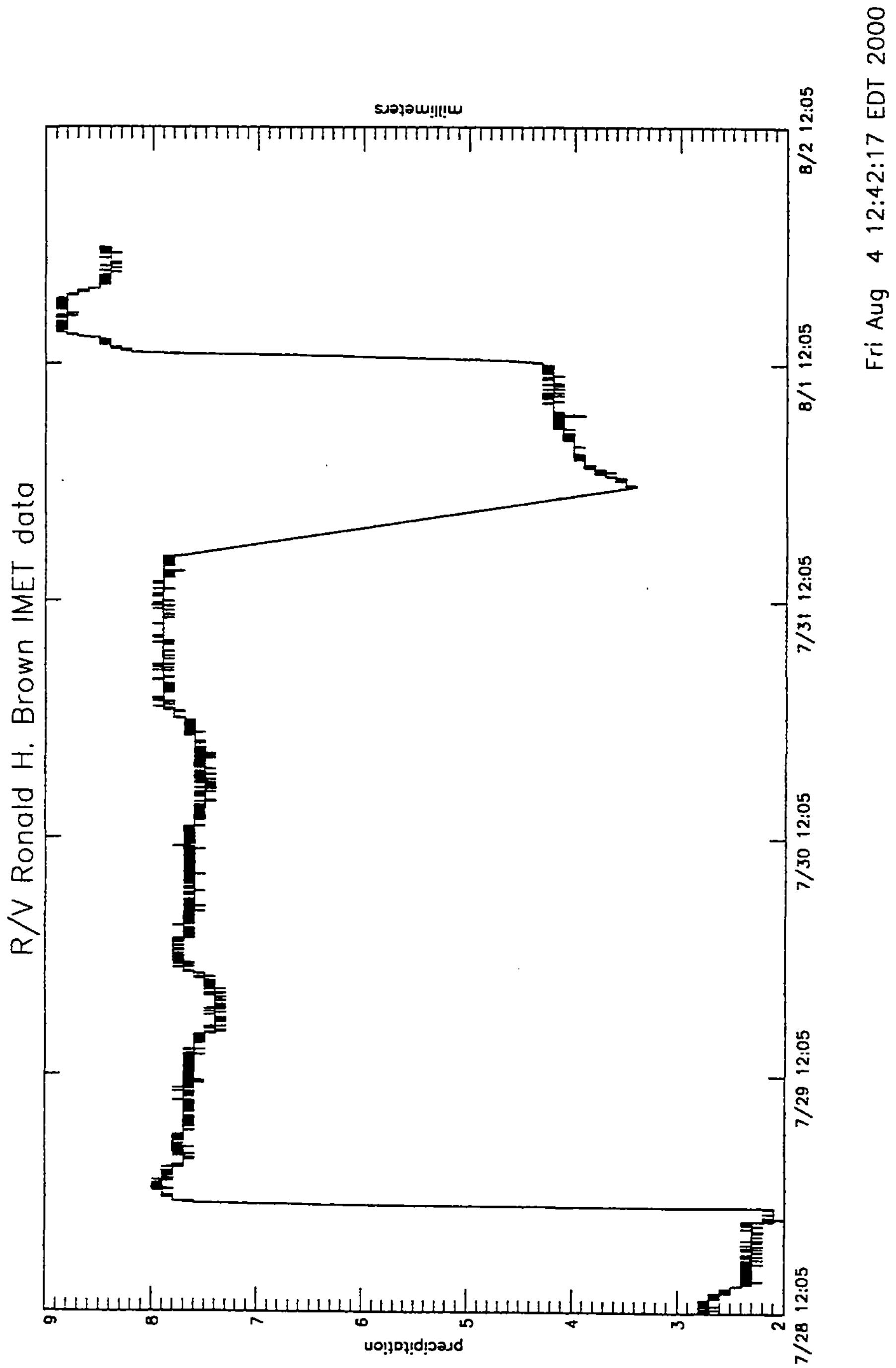

Figure 14: R/V *Ron Brown*, July 28--August 1: Details of precipitation gauge problem.

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16. Abstract (Limit: 200 words)

This report is to assist shipboard technicians whose responsibilities are maintaining digital logging meteorological systems. Examples of good and bad data recorded on ships by IMET (Improved METeorology) systems are given, as well as general comments on how various parameters should appear when plotted against time.

Parameters included are: wind speed and direction, air temperature, relative humidity, barometric pressure, short- and long-wave radiation, and precipitation (R. M. Young gauges).

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