SHIPBOARD Meteorological Measurements: Interpretation and Quality Assessments

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Fig. 1 USCGC Healy with sensor locations

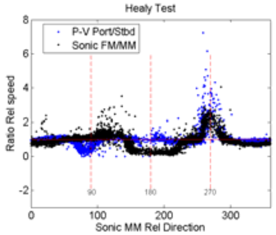

Fig. 3 Ratio of FM to MM sonic relative speed and P-V Port to Stbd vs sonic MM relative direction.

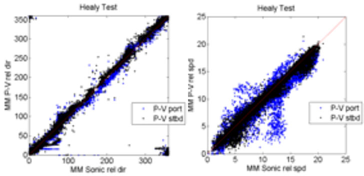

Fig. 4 MM Port and Stbd prop-vane relative direction vs MM relative direction (left) and prop-vane relative speed vs MM relative speed (right)

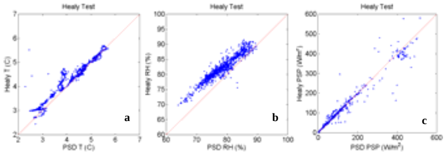

Fig. 5 Air temperature (a), Relative Humidity (b), and downward solar flux (c) comparisons between ESRL and Healy sensors.

Quality shipboard meteorological measurements are critical for understanding air-sea interactions over the oceans. Several of the main goals of the SAMOS (Shipboard Automated Meteorological and Oceanographic System) program are:

- Identify meteorological sensors installed on various research ships that are reliable and accurate
- Improve data collections systems eliminating problems encountered in the past
- Improve access to quality assured data.

NOAA's Earth Systems Research Laboratory (ESRL) has developed a shipboard flux standard and been tasked with evaluating how well the UNOLS and NOAA research vessels providing data to the SAMOS program are working. ESRL's flux standard was recently deployed on the USCGC */Healy/* and the Woods Hole Research Vessel */Knorr/* (Figs. 1 & 2). This poster presents preliminary results from data collected during two cruises and attempts to address what Bradley and Fairall (2007) *call "thoughtful location" where even the best instruments can have measurement errors due to the influence of the measurement platform itself.*

HEALY

During a short */Healy/* test cruise (February 2-4, 2008), ERSL took the opportunity to install only a few (temperature {T}, relative humidity {RH}, and incoming short and long-wave solar radiation {LW, SW}) of their flux standard package and not co-located with the ship's instrumentation. Particular attention was paid to four wind sensors deployed on the */Healy/* and how they performed based on operational characteristics of the sensors, location of the sensor on the ship, and wind direction relative to the ship. Figure 1 shows two prop-vanes (P-V) and a sonic anemometer (SA) mounted high on the main mast (MM) and a second SA mounted on the forward mast (FM). At first glance, the data represented in Fig. 3 show two expected effects of the ship. First, the MM blocks the P-Vs for winds from the port (270^0) and starboard (90^0). Second, the ship's super-structure blocks the FM-SA for winds from the aft (180^0). Closer analysis of Fig. 3 reveals several more subtle; yet still important differences in the comparisons of the P-Vs and SAs. If the MM were symmetrical, one would expect the ratio of the port to starboard P-V relative wind speeds to have matching yet inverse peaks at 90^0 and 270^0. There are two peaks, but shifted ~10^0 suggesting a possible alignment error of the MM-SA. Non-symmetrical MM shadowing, light and variable winds from 270^0, or limited data could be causing increased scatter in one peak. Comparison of the FM/MM SA is even more complicated than the P-Vs because of the added spatial separation (40m horizontal/ 16m vertical). There is considerable reduction (70-80%) in the FM-SA speed compared to the MM-SA shown in Fig. 3 for aft relative winds over a 70^0 sector. For ship-relative winds from ~300-30^0 the MM-SA is higher (20-30%) than the modeled difference (6%, not shown) for sensors with a 16m height difference. The peak at ~260^0 reflects shadowing by the MM on the MM-SA and again suggests a MM-SA alignment error. Direct comparison of the three MM wind sensors (Fig. 4) shows very good agreement. The scatter plots in Fig 5 a-c are comparisons of T, RH, and SW. Note; the LW data from the ship are still being analyzed to make sure that the conversion equations are correct. The ESRL T/RH sensors were mounted on the flying bridge in an aspirated shield. T and RH (Fig 5 a & b) show offsets with the RH offset increasing with lower RH. Even before any comparisons between the SW radiometers were analyzed, it was determined from photographs (Fig. 1) that ship's radiometers were positioned too close to other sensors. Repositioning was recommended before the next scientific cruise. Taking into account these affects and despite having only 3 days of data, the results in Fig. 5c show very good agreement. Additional comparisons over a wider range of temperatures, RH, and sky conditions with co-located sensors are needed to better understand some of these results.

KNORR

Data comparisons from the International Chemistry Experiment in the Arctic LOwer Troposphere (ICEALOT) cruise on board the */Knorr/* show that the data are of a high quality but still require a careful understanding of how the data were collected. For this cruise the entire ERSL flux standard was installed and flux standard sensors were co-located with ship sensors as best possible (Fig 2). Figure 6 shows comparisons of three technologically different, but closely located wind sensors. The mechanical nature of the P-Vs lends itself to smoothing out some of the variability. On the other hand, the ESRL SA is designed to measure atmospheric turbulence, which means it also captures ship-induced turbulence very well. The Vaisala Weather Transmitter (WXT) is a multi-sensor package whose wind sensor uses sonic technology, but with a limited response rate compared to the ESRL SA. The WXT also includes T, RH, pressure, and precipitation measurements. The ship's P-V sensor was compared to both the ESRL SA and the WXT. No quality control has been done to any of these data. The top two panels (Fig. 6) are the WXT vs. P-V wind speed and direction comparisons and the bottom two panels are the ESRL SA vs. P-V comparisons. Both the SA and WXT wind speeds read high compared to the P-V. In the wind direction comparisons, the WXT vs. P-V has more scatter. Looking at daily time-series plots of wind speed and direction for all three sensors (not shown), there is a tendency for spiking in the WXT data primarily at wind speeds less than 10 ms^{-1} with no correlation to the relative wind directions. The spiking causes increased scatter in both the wind direction and speeds, top two panels compared to bottom two panels Fig 6. On several days, there are periods where the WXT unexpectedly shows larger variability (not spiking) and an offset of ~$2ms^{-1}$ compared to either of the other two sensors. It is unclear at this time what the cause of the larger variations, the spikes or the sudden offset is. Figure 7 is a time series of the Knorr's and ESRL's SW sensors. Finding a suitable place to mount radiometers is always a challenge. It is not practical to try and mount them at the very highest point on the ship, so the next best thing is to move them as far away horizontally from the superstructure as possible to avoid shadowing. As discovered during ICEALOT in higher latitudes, low sun angles combined with the ever-changing orientation of the ship relative the sun's angle, adds additional factors to bear in mind. Examples of these effects appear just after sunrise and just before sunset for year day 84 (Fig. 7). It should be noted that the ESRL sensor was located such that it could be checked and cleaned daily; while the ship sensor was on top of the forward mast and not accessible while at sea. Moisture and/or frost were found regularly on the ESRL sensor. Figure 7 and daily time series (not shown) of the two sensors show very good agreement for all types of sky conditions despite these, at times, unfavorable conditions. Figure 8 contains comparisons of the sea surface temperature (SST), T, and RH. The /Knorr/ has two SST measurements. The Sea Bird SST is measured further aft and likely affected (warmer) by the ship, while the sea water intake for the TSG is in the bow and much closer to the ERSL SST sensor. The ESRL SST uses a system by which the temperature sensor hangs from a boom extending out horizontally from the ship and floats just below the surface. It can be affect by the bow wake of the ship, ocean waves, and winds relative to the ship. During ICEALOT there were times the SST sensor would skip out of the water or almost fly due to weather and sea conditions. Without careful quality control and understanding of the measurements, questionable, data not as subtle as the ESRL sensor being on deck (blue circle Fig 8), will be mixed in with good data. The T/RH comparison show offsets even though all three sensors were mounted in close proximity on the forward mast. For RH >80% the IMET and WXT measurements also begin to drop off by as much as 5%. The ESRL T/RH was the only one of the three to be aspirated. Additional analysis of these data and other measurements not show in this poster are continuing.

Conclusions:

As no surprise, shipboard measurements provide a challenge to the research community. Results from the */Healy/* suggest a limited sector for acceptable winds when measured on the forward mast. Winds on the MM are influenced considerably by the ship's super structure. Experience has shown this to be true on most ships and consistent with Bradley and Fairall. Using the relative wind directions should always be a first step in quality control of the data. Wind comparisons from the */Knorr/* imply that purchasing a sensor based solely on required accuracies and precisions doesn't guarantee the sensor is appropriate. The WXT was being tested with the hope that it could eventually replace the existing IMET sensors currently operating on the */Knorr/*. Comparisons of just a few of the other measured parameters also shows how even co-located and similar sensors can produce different results. SAMOS provides an excellent platform from which the user can begin to understand measurements made at sea. What these two data sets reveal is the need for even more information in addition to tables of numbers and instrument names. This first time user found the SAMOS web site useful, but lacking in some of the important information necessary to analyze the ship's data. Not found on the SAMOS web site were Computational Fluid Dynamics (CDF) flow models (Fig. 9) for the */Healy/* or */Knorr/* or a list of field tested sensors. As can be seen in Figs. 1, 2 & 9, ships come in all shapes and sizes making measurements on each unique.

Bradley, F. and C.W. Fairall 2006, A Guide To Making Climate Quality Meteorological and Flux Measurements At Sea, NOAA Technical Memorandum OAR PSD-311

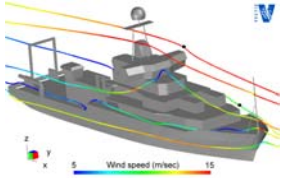

Fig. 9 Computational Fluid Dynamics simulation of wind flow patterns for R/V Ronald H. Brown.

Fig. 2 R/V Knorr as configured for ICEALOT 2008

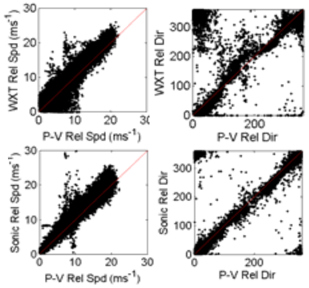

Fig. 6 Comparison of 3 wind sensors mounted on the forward mast: Prop-Vane, Vaisala Weather Transmitter, ESRL sonic.

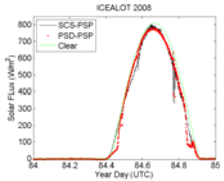

Fig. 7 Short-wave radiation comparison and modeled clear-sky

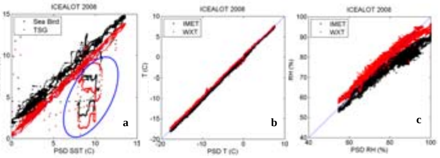

Fig. 8 SST (a), RH (b), and T (c) comparisons between PSD and Knorr sensors. Blue circle is where PSD SST is out of the water.