Comparison of Wind Vectors and Air-Sea Temperature Differences Measured during SHOWEX

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***Abstract*-During ONR's Shoaling Waves Experiment (SHOWEX) off the coast of North Carolina in November and December 1999, measurements of wind speed and direction as well as air and water temperatures were made using a variety of techniques. This paper shows a comparison of the measurements taken on December 3, 1999.**

During SHOWEX, wind speed and direction, air temperature, and water temperature were measured from Air Sea Interaction Spar (ASIS) Buoys, from the LongEZ aircraft flying at about 15 m, and from the Twin Otter airplane flying at about 300 m. Wind vectors were measured on the ASIS buoys using a sonic anemometer. On the LongEZ, wind vectors were obtained from a gust probe extending from the nose of the aircraft, air temperatures were measured by thermistors, and water temperature was obtained from infrared (IR) measurements. The Twin Otter carried a coherent, X-band radar (CORAR), a 5 mm radiometer, and an IR sensor, among other instruments. The rotating mode of CORAR was used to obtain wind vectors via scatterometry. The scanning 5 mm radiometer measured both water temperature and air temperature near the surface. The IR sensor gave a second measurement of water temperature from the Twin Otter. In addition, wind speeds were derived from the synthetic aperture radar (SAR) on RadarSat and high-resolution wind vectors were obtained from the SeaWinds scatterometer on QuikSCAT. All wind speeds were converted to neutral wind speeds at 10 m height.

Here we report comparisons of the winds and temperatures measured by this variety of sensors. Passes of the satellite-based sensors that occurred in the SHOWEX measurement area at times close to those of the other measurements were used in this comparison. Fig. 1 shows the locations of the three ASIS buoys and flight paths of the aircraft on December 3, 1999. Both RadarSat and QuikSCAT data were available on this day and these data were sampled along the aircraft flight paths as shown in Fig.1. The LongEZ first flew an L-shaped pattern in tandem with the Twin Otter, being lower, slightly behind, and about 300 m to the right of the Twin Otter. This put the LongEZ in the center of the antenna footprint of CORAR just a few seconds after the area had been sampled by CORAR. After this joint flight track, the LongEZ left the Twin Otter to fly some patterns very near the coast. RadarSat wind speeds and QuikSCAT wind vectors were determined along the joint LongEZ /Twin Otter flight track and QuikSCAT winds were determined along the subsequent flight track of the Twin Otter.

Note that the QuikSCAT winds were sampled in a very short time interval, essentially a snapshot, along this path, although they are displayed in the top part of Fig. 2 as a function of time at which the Twin Otter was at a particular location. These plots as a function of time vividly illustrate the effect of stratification on wind speeds derived from scatterometer measurements. Regions of stable stratification (positive values of Ta-Ts) correspond very well with lower wind speeds derived from both CORAR and the QuikSCAT scatterometer. This is because the microwave measurements yield the wind speed that would be measured under neutral stratification. This wind speed would be lower than the true wind speed under stable stratification and higher than the true wind speed under unstable stratification (negative Ta-Ts). For the switch from stable to unstable conditions between 2 and 2.5 hours after the start of flights, QuikSCAT shows a change in wind speed from about 5 m/s to about 10 m/s. CORAR measured a smaller change, from about 5 m/s to about 7.5 m/s. We can check the agreement of these changes against the Bussinger-Dyer relationship. This relationship predicts that for a measured wind speed of 6 m/s and a change of Ta-Ts from +2°C to -3°C, the neutral wind speed at 10 m will change from about 5.5 m/s to about 6.4 m/s, less than the measurements. A Ta-Ts change from +5°C to -5°C yields a change in neutral wind speed from 4.7 m/s to 6.5, in better agreement with CORAR's measurements.

The LongEZ flights were not in the same location as the Twin Otter flights after the first 30 minutes so the LongEZ winds near two to three hours into the flights are not measured at the same location as the CORAR and QuikSCAT winds shown near two and three hours after the flights began. Thus no independent wind speed measurements were available to check the scatterometer measurements around these areas of large stratification change.

Athough the oscillations in the CORAR and QuikSCAT winds as a function of time are well correlated, QuikSCAT winds appear to be somewhat higher than CORAR's early in the flight. As the lower left plot in Fig. 2 shows, these data were taken well offshore where comparison measurements were not available. The wind speed from the Yankee ASIS

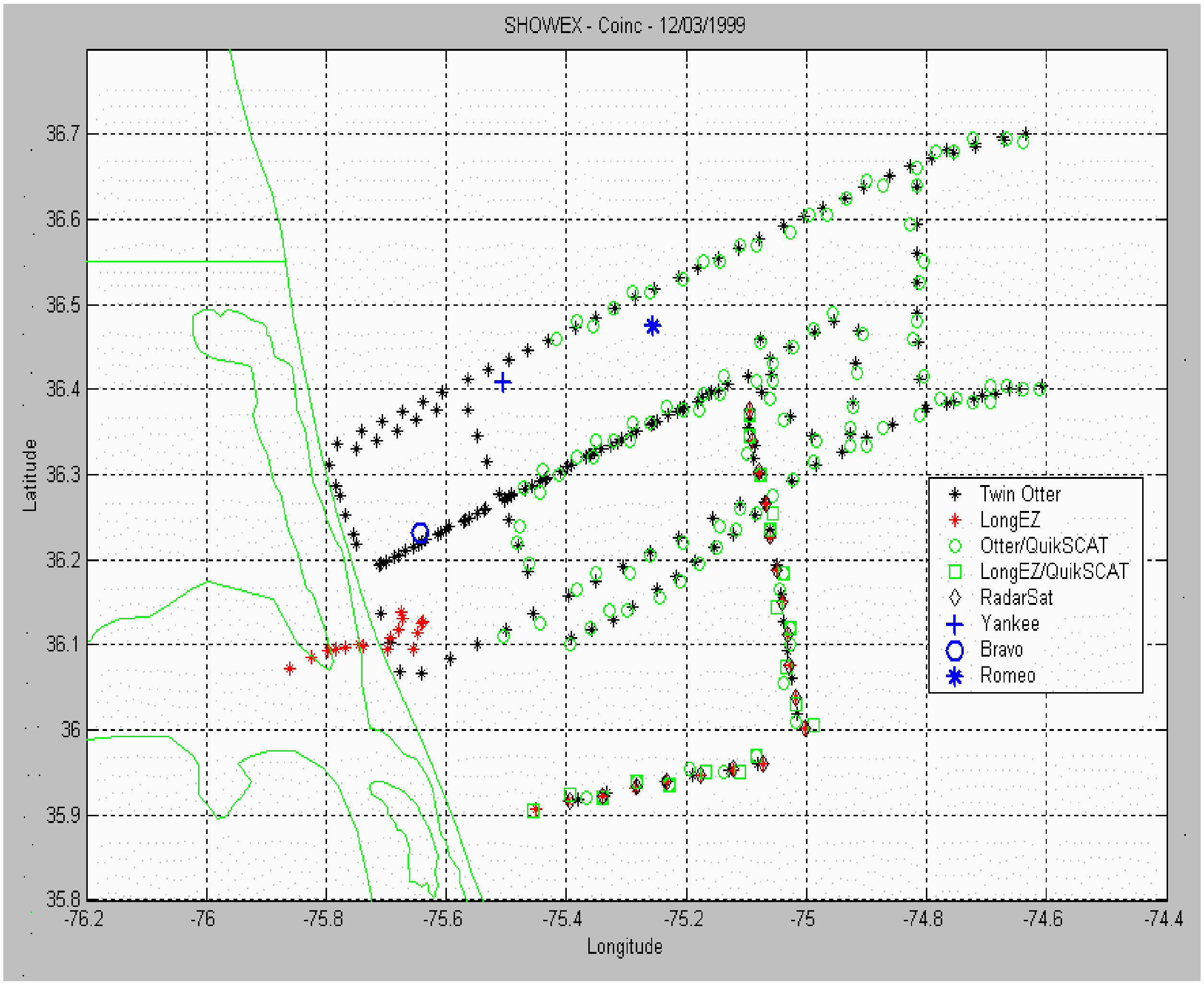

Figure 1. Locations of measurements on December 3, 1999 east of North Carolina, USA

buoy shown in this lower plot is an average over the entire time of the flights and is not collocated with these offshore locations. Thus it is not clear which measurement is more correct. Closer to shore, wind speeds measured by the different instruments are in better agreement with each other.

The data appear to be clearer for the wind directions. The QuikSCAT high-resolution wind directions are clearly biased low compared to the other sensors. However, this was not the case for all days that we analyzed. More frequently, all sensors agreed very well on the wind direction, to within about +- 10^{o}. It is not clear at present why this day was different.

Air-water temperature differences from the 5 mm radiometer on the Twin Otter seem to agree rather with those determined from the IR measurements onboard the same airplane. However, the Twin Otter flew in tandem with the LongEZ during the first 30 minutes on this day and the discrepancy between Ta-Ts measured on this aircraft and those measured on the Twin Otter is unexplained at this point.

We did not find that this discrepancy was present on all days on which comparisons could be made. Our general observation was that Ta-Ts was rather consistent among the three means of measuring it, although with some scatter. Wind speeds in general seemed to vary a bit among the sensors. We especially noted occasional differences between scatterometer wind speeds and those measured by more traditional means. The high-resolution QuikSCAT winds also proved to be too high within about 20 km of the coast and the directions were also incorrect in this region. This is not surprising given the approximately 25 by 6 km footprint of the instrument. The best agreement among the measurements was between wind directions measured by various sensors. Except for three occasions on which the high-resolution QuikSCAT wind directions disagreed badly with the others, wind directions measured by the various sensors agreed well. We will give more details on these results in our oral presentation.

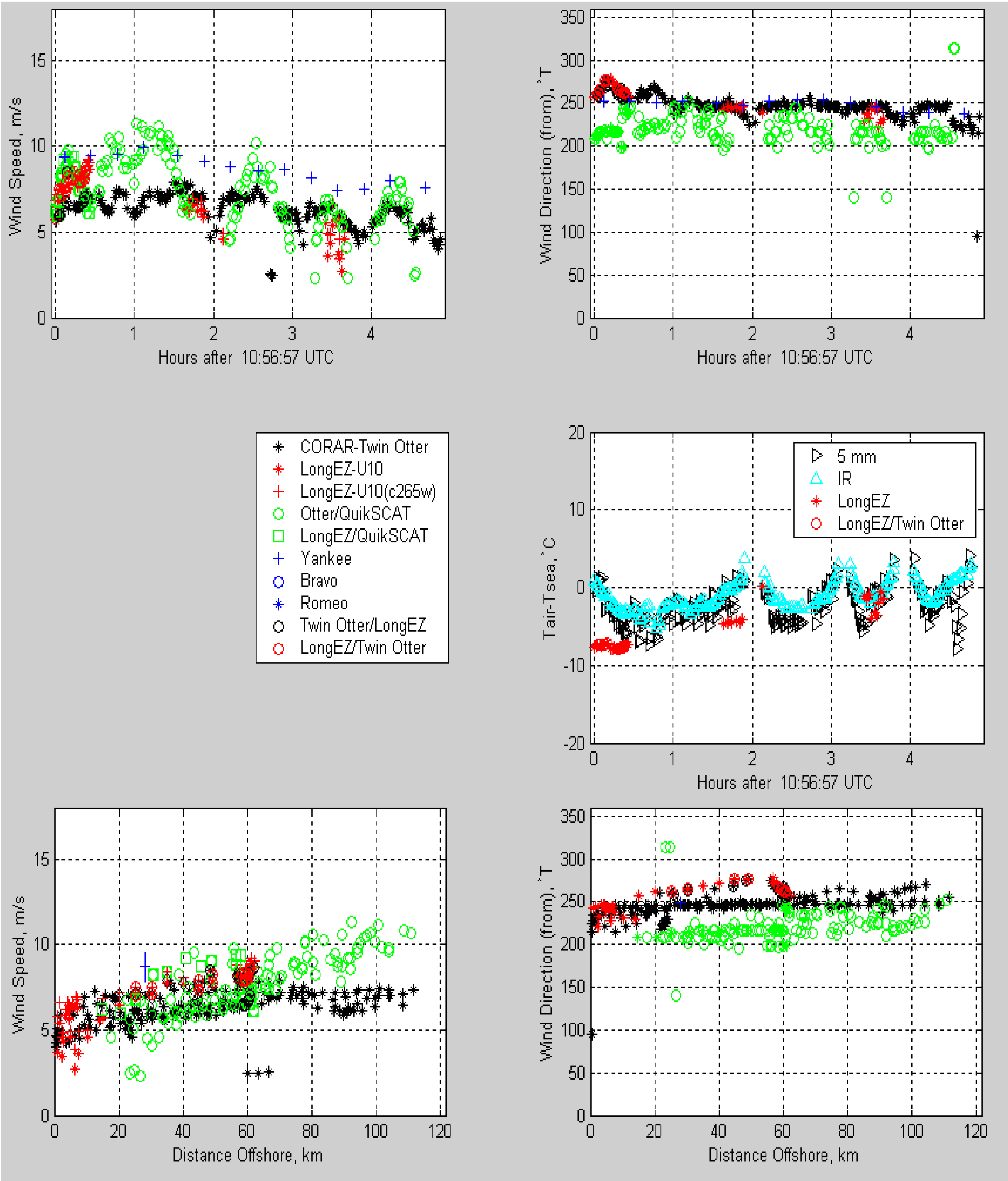

Figure 2. Wind speeds, directions, and air-water temperatures measured by the various sensors during SHOWEX plotted as a function time or distance offshore. Black circles indicate CORAR winds measured when the Twin Otter and LongEZ were flying in formation. Similarly, red circles are winds from the LongEZ when it flew with the Twin Otter.