

a. Shipboard Instruments

The R/V Hi'ialakai (HA) is outfitted with sensors for air temperature (Ta), relative humidity (RH), barometric pressure (P), sea surface temperature (SST), wind speed (U), and wind direction (DIR).

Ta and RH is from an RM Young 41372 VC in an RM Young 43502 aspirated radiation shield mounted along the ship centerline on a short mast at the front edge of the pilot house roof, at an estimated height of 13.4 m.

Pressure is a Vaisala PTB 330 SPH10 mounted in the aft section of the bridge on the 03 deck at a height of 12 m. SAMOS metadata indicate the pressure is specified at measurement height, but based on a comparison with PSD pressure data it appears to be corrected to sea level.

Wind speed and direction are from an RM Young 85000 Ultrasonic anemometer, also mounted to the short mast on the forward edge of the pilot house roof. The SAMOS archive gives the wind measurement height at 15.88 m, but this cannot be correct as it is on the same mast with the T/RH sensor and only ~50 cm higher. We estimate the anemometer height at 14 m. This is not a desirable location for accurate wind measurements, and flow distortion may contribute to bias compared to wind measured from the bow tower. There is an RM Young prop-vane anemometer mounted to the top of ship's bow jack staff, but this is not being logged. The SAMOS dataset provides relative and true wind speed and direction; the latter is computed by the ship's SCS system.

Ship SST measurements are from an SBE-38 digital thermometer, TS2, at the 4 m seawater intake and the SBE-21 thermosalinograph, TS (SAMOS metadata indicates, incorrectly, that both TS2 and TS are the SBE-21). The SBE-21 receives water pumped from the forward intake to the wet lab, which may lead to temperature bias due to the length of the plumbing. All ship data used in this report are from the 1-minute SAMOS archive:

http://samos.coaps.fsu.edu/html/data_availability.php.

b. ESRL/PSD flux system

The ESRL/PSD/BLO air-sea flux group collected surface meteorology and sea surface temperature data during the cruise. The PSD met system deployed on WHOTS 2017 consists of five components:

1. Vaisala WXT520 weather station for U, Ta, RH, P and rain rate @ 17.15 m ASL on a PSD-supplied 10 m met tower, installed on the bow immediately behind the ship's (shorter) bow jackstaff.
2. Eppley PSP and PIR solar and infrared radiometers (2 each) located on the aft the pilot house roof.
3. Differential GPS unit measuring 2 Hz SOG, COG, heading and roll angle.
4. Floating thermistor sea surface temperature measurement (YSI 46040 thermistor, sea snake) deployed from a davit off the port bow.

5. Vaisala PTB220 digital barometer @ 13.3 m ASL on the aft pilot house roof.

These were all logged on a NOAA/PSD acquisition system. Measurements were continuous through the duration of the cruise. Raw motion and GPS data are 2 Hz. WXT data are 1 Hz. Others are averaged to 1 min.

The location for the sea snake was 2-3 m forward of an above-waterline water discharge on the ship's hull. The snake was adjusted as far forward as possible, and at most times on station the ship maintains at least 0.5 knots of forward way, which should keep the seasnake clear of temperature contamination from the discharge, but we cannot completely rule out the possibility. The starboard side has a similar discharge, with the addition of the ship's black-water discharge, and therefore provides no advantage. In general, the HA does not have an ideal configuration for deployment of the seasnake.

Additional details on PSD instruments are given in Table 1.

c. Additional notes on PSD and ship variables

Air Temperature: As has been the case for many years, HA air temperature is biased high by more than a degree compared to PSD and WHOI sensors. The sensor was recently calibrated, so the offset is likely due to a heat source near the measurement location.

Pressure: As mentioned above, the ship's pressure seems to be corrected to sea level, despite the information given in SAMOS metadata. As provided, the pressure is within 0.1 mb of the sea level-corrected PSD pressures. Pressure measured with the PSD digital barometer on the pilot house roof agrees with the WXT to within 0.1 mb, but shows greater variability at 1-min resolution from dynamic pressure effects of airflow over the bridge. WXT pressure is preferred.

Sea Surface Temperature: The ship's SBE-38 SST tracks the PSD sea snake measurements, with a mean offset of +0.1 °C. The seasnake sees a slightly larger diurnal warm layer signature (i.e. it cools off more at night), which seems reasonable given the difference in measurement depth. The seasnake temperatures exhibit a tendency to flat-line for many hours during the night, with hour-to-hour mean temperature variability less than 0.01 C. This is in the raw data and I'm not sure why we don't see more signal noise or variability in the SST at night. Interestingly, WHOTS-13 SST also flat-lines for a period of time at night on DOY 211 and 212, so the phenomenon may be real.

Radiation Measurements: Prior to the cruise, a month-long intercomparison and calibration was performed on the PSD radiometers at the NOAA/GMD roof-top radiation calibration facility. Solar radiometers (Eppley PSP S/N 28110F3 and S/N 34290F3) were calibrated against the sum of two GMD reference standards: a sun-tracking pyroheliometer for direct flux and a shaded Eppley model 848 pyranometer for the diffuse component. A direct comparison was also made to a secondary reference PSP maintained by GMD (S/N 73-36). The direct comparison before recalibration is illustrated by the time-series plot on p.8. The recalibration yields coefficients that are 4.6% and 3.7% smaller than the most recent Eppley coefficients for the two PSP instruments shown in Table 1. The mean measurement from the two PSD PSPs is used in this report for the reference solar flux. The updated calibration curve versus the reference

standard is shown in the lower plot on p. 8. The 95th-percentile of the difference between PSD and reference solar flux for 5-min measurements is $\sim 20 \text{ W/m}^2$ for both instruments.

The IR radiometers (S/N 30558F3 and S/N 30433F3) were compared to an unshaded, unventilated GMD PIR maintained by as a secondary standard, referenced to BSRN instruments as the primary standard. Following the recommendation of GMD, the PSD recalibration was determined from a 3-coefficient form of the Albrecht-Cox equation:

$$LWR = \frac{mV}{c_1} + c_2 \sigma_{sb} T_c^4 - c_3 \sigma_{sb} (T_d^4 - T_c^4)$$

where mV is the thermopile signal in millivolts, T_c and T_d are case and dome temperatures in °K and coefficients c_1 , c_2 and c_3 are determined from a multivariate regression to the reference measurement. The plot on p.9 shows the calibration curve and derived coefficients. The 95th-percentile of the difference between PSD and reference IR flux for 5-min measurements is $\sim 2.5 \text{ W/m}^2$ for both instruments. Of the two PSD PIRs, S/N 30558F3 (PIR1) shows less measurement variability and is used as the reference IR flux measurement in this report.

d. Comparisons with WHOTS-13 and -14

Tables 2 and 3 show the mean, median and standard deviation in measurement bias for ship and buoy systems relative to the PSD measurements. Pressures are adjusted to sea level ($z = 0$) for all systems. For the PSD-ship comparison, U, T and RH variables are unadjusted for measurement height. PSD wind speed is adjusted for mean flow distortion effects at the ship's bow: U is increased by 5% and V decreased by 15%. For the comparison with buoy systems, PSD data (U, Ta, RH) are adjusted to $z = 3 \text{ m}$ with the COARE bulk flux model (v.3.5). Comparison statistics for U, Ta and RH are restricted to hours when the relative wind direction at the ship is within $\pm 60^\circ$ from the bow and the hourly standard deviation in relative wind direction at the bow tower is less than 30° .

WHOTS-13 (W13) data are 1-hr averages from data logger 2. Logger 1 had failed prior to the cruise. Additionally, the wind measurement on logger 2 was not operating, so wind comparisons are not possible with WHOTS-13.

WHOTS-14 (W14) data are 1-hr averages transmitted from loggers 1 and 2 following deployment.

Table 1 shows a comparison over the entire period at station ALOHA (DOY 208.0–215.125).

Table 2 limits the comparison with each buoy to periods when the ship was near the mooring. Valid comparison data are selected by proximity to the mooring anchor, with additional relative wind direction restrictions mentioned above for U, Ta and RH comparisons. Position tolerance was set to $\pm 0.03^\circ$ of latitude and longitude from the anchor location ($\pm 3.33 \text{ km}$). The map plots show hourly positions near each mooring corresponding to valid comparison data (red markers).

Time series and correlation plots for each variable are shown on following pages and available as separate files in .png format. Time series plots show all measurements, unfiltered for relative wind direction or location. Correlation plots show only valid intercomparison measurements.

Table 1: PSD instrument details

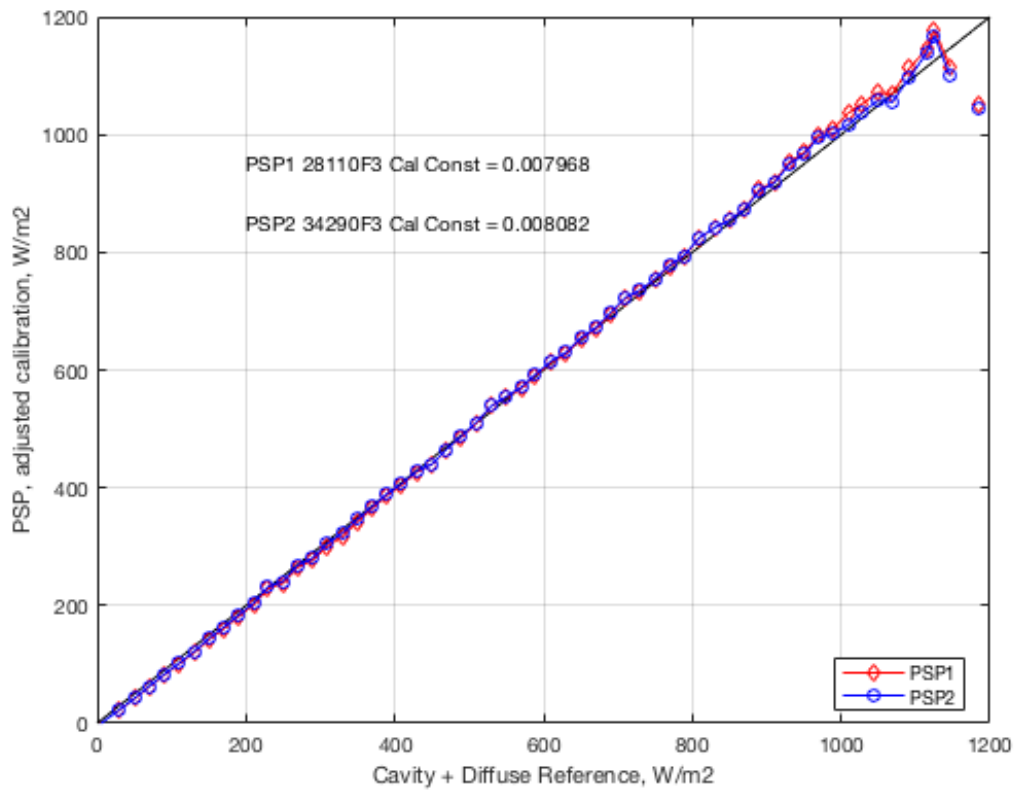
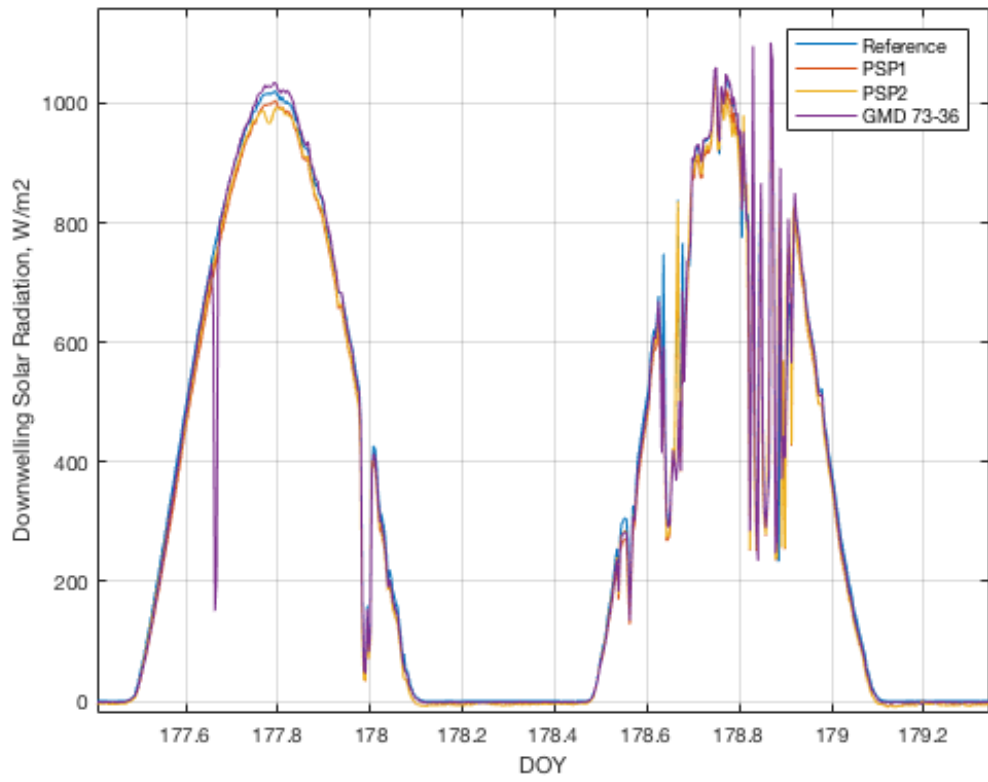
Sensor	Calibration coefficient	Make / Model	Serial Number	Date of calibration
Precision Spectral Pyranometer	0.00835	Eppley / PSP 1	28110F3	June 08, 2017
Precision Spectral Pyranometer	0.00839	Eppley / PSP 2	34290F3	June 08, 2017
Precision Infrared Radiometer	0.00416	Eppley / PIR 1	30558F3	June 06, 2017
Precision Infrared Radiometer	0.00325	Eppley / PIR 2	30433F3	June 06, 2017
Sea Snake thermistor 0C to 40C	C4=0.001399937 C5=0.00237854 C6=0.000000097	YSI 46040 series	n/a	
Class A Barometer	n/a	Vaisala/ PTB330	L2820128	Jun 07, 2017
Vaisala Weather Transmitter		WXT-520	E2850022	Jun 09, 2017

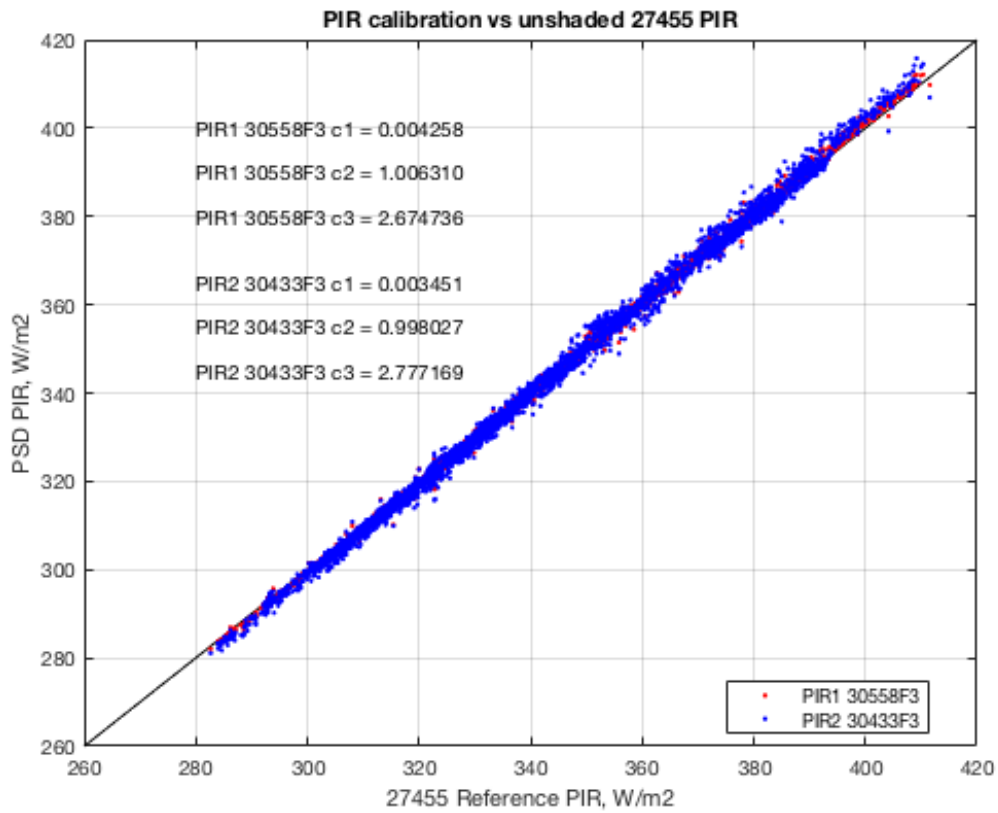
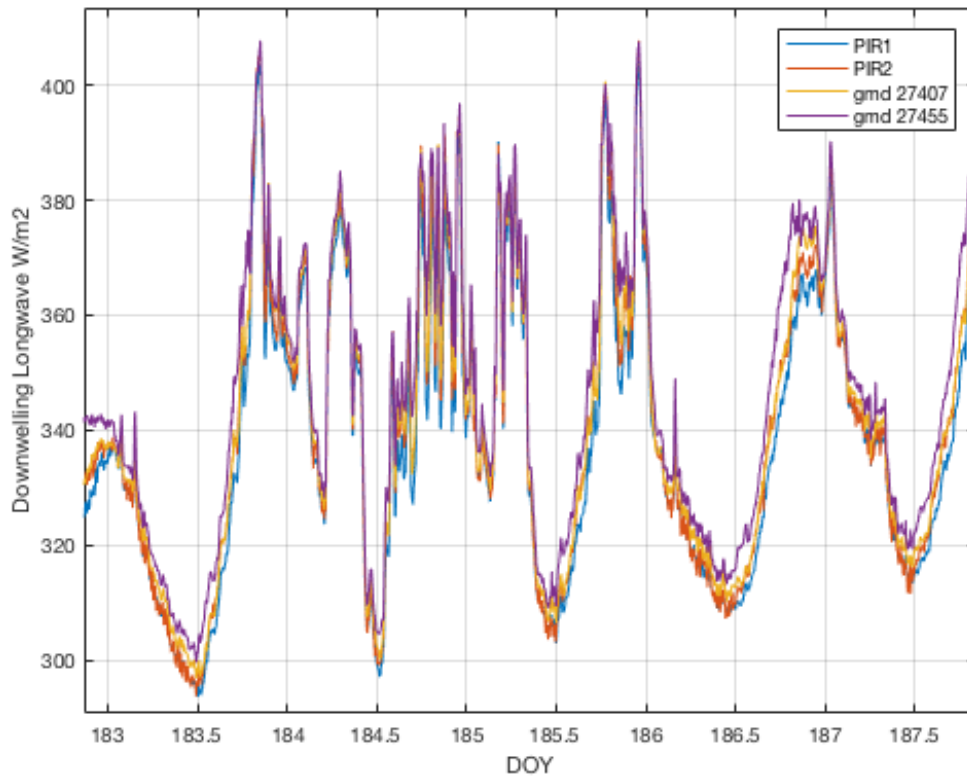
Table 1: Bulk met measurement bias relative to NOAA/PSD measurements for the entire period of time at Station ALOHA.

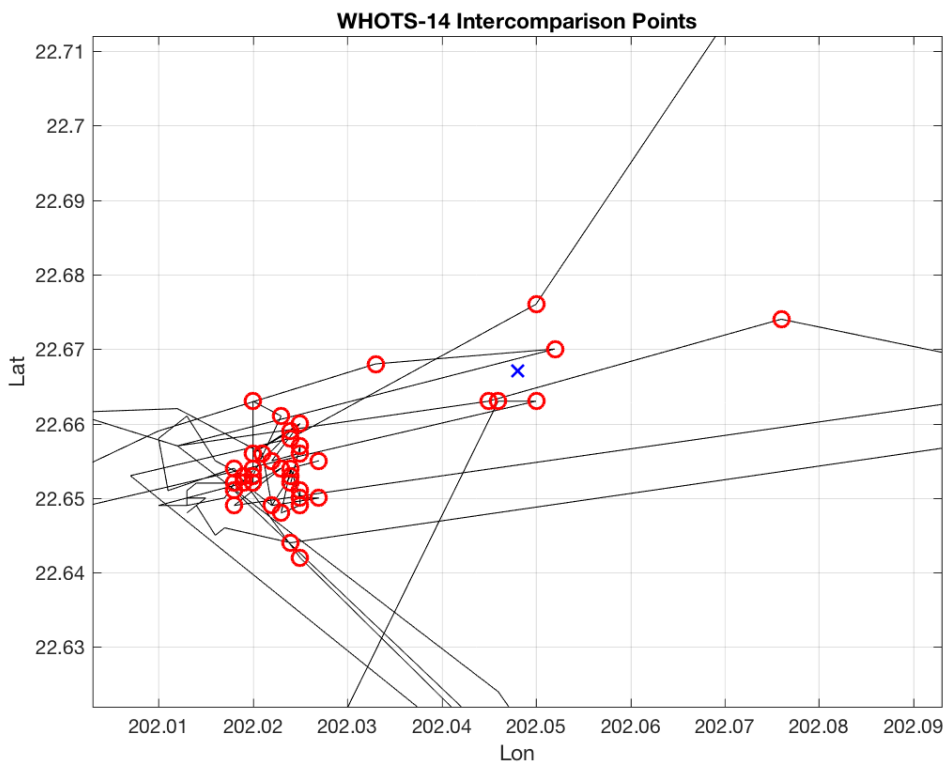
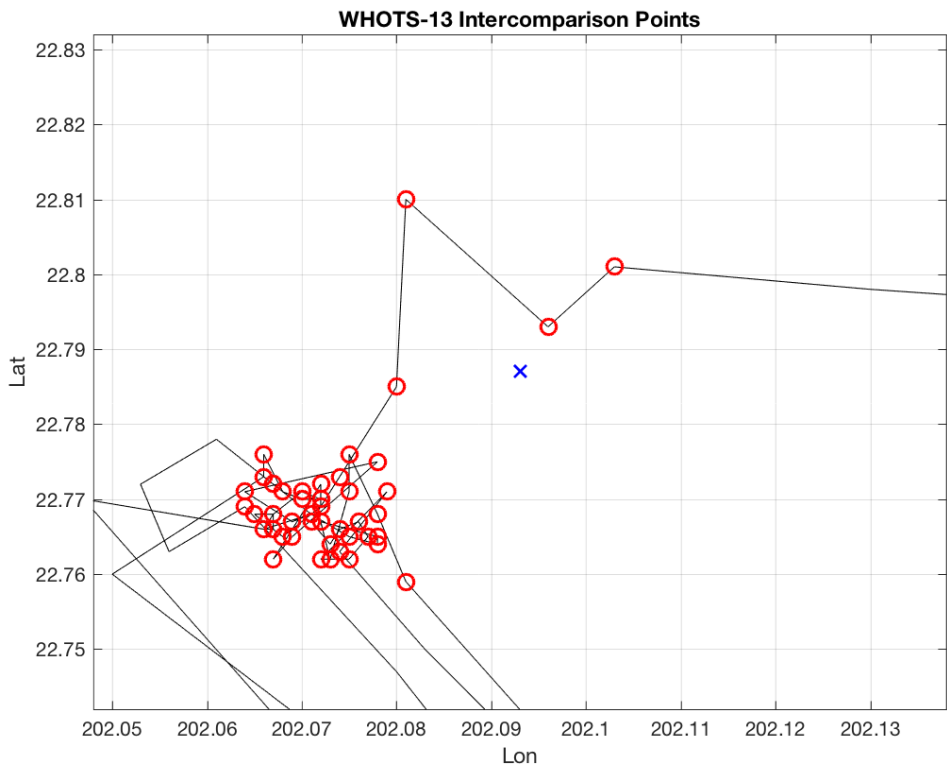
Bias	Ta C	RH %	SST C	U m/s	dir deg	Rs W/m ²	RI W/m ²	P mb
psd – ship								
mean	-1.58	-1.94	-0.11	1.37	-5.12	-	-	0.10
median	-1.49	-1.94	-0.11	1.36	-5.81	-	-	0.10
std	0.25	0.87	0.05	0.33	4.27	-	-	0.04
psd – W13-1								
mean	-	-	-	-	-	-	-	-
median	-	-	-	-	-	-	-	-
std	-	-	-	-	-	-	-	-
psd – W13-2								
mean	-0.04	0.71	0.08	-	-	6.44	-2.71	0.30
median	-0.04	0.62	0.08	-	-	-5.05	-0.92	0.30
std	0.15	0.77	0.03	-	-	32.02	5.68	0.07
psd – W14-1								
mean	-0.51	-1.74	0.16	0.87	10.03	2.24	8.02	-0.01
median	-0.50	-1.93	0.14	0.84	9.94	-2.95	6.70	-0.02
std	0.13	1.72	0.09	0.30	3.98	36.22	6.75	0.06
psd – W14-2								
mean	-0.42	-2.82	0.16	1.06	8.01	2.90	10.87	0.63
median	-0.42	-2.89	0.14	1.05	7.74	-6.23	9.86	0.65
std	0.13	1.64	0.09	0.32	3.92	33.97	6.91	0.30

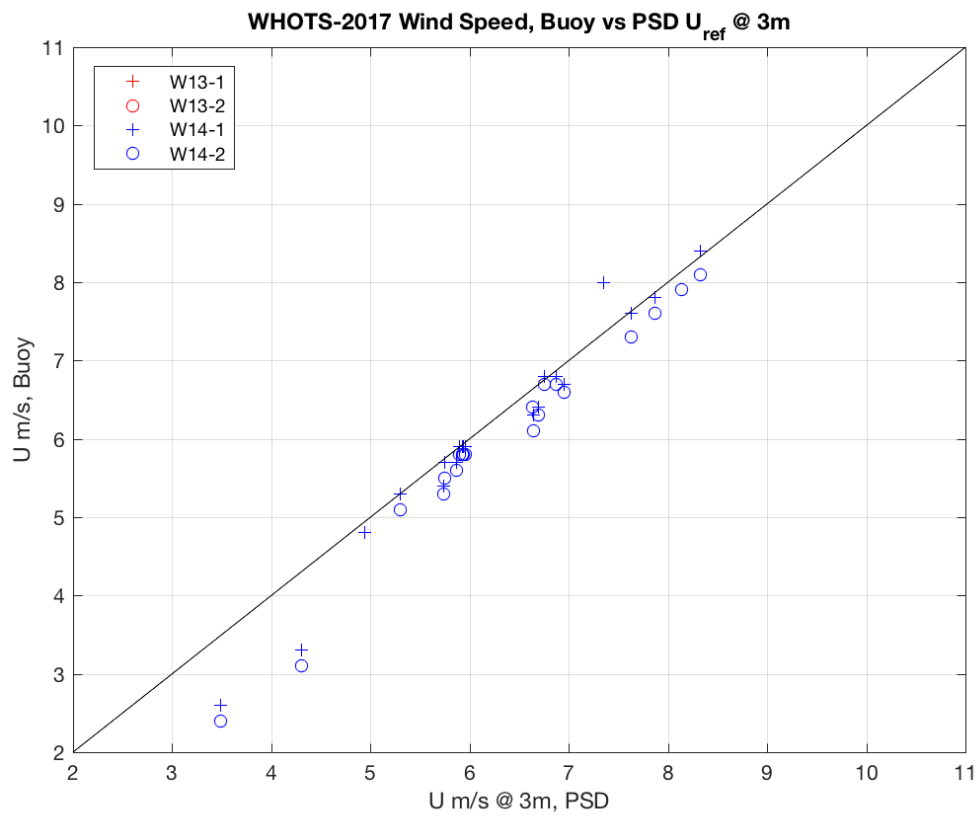
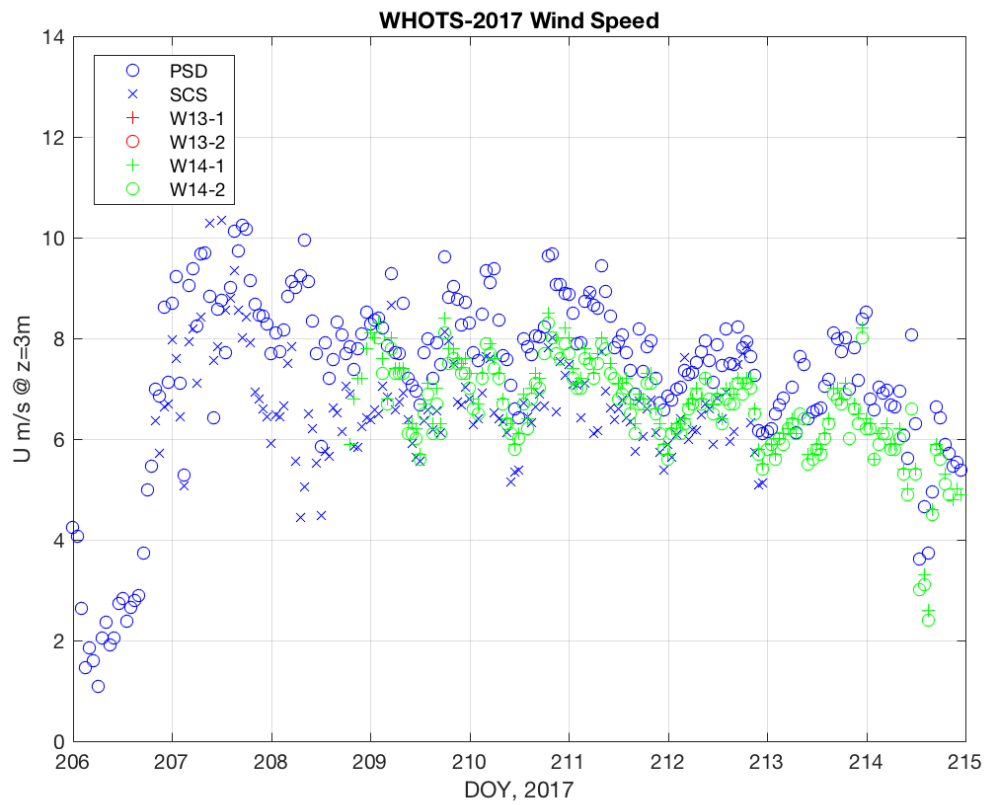
Table 2: Bulk met measurement bias relative to NOAA/PSD measurements for buoy intercomparison periods

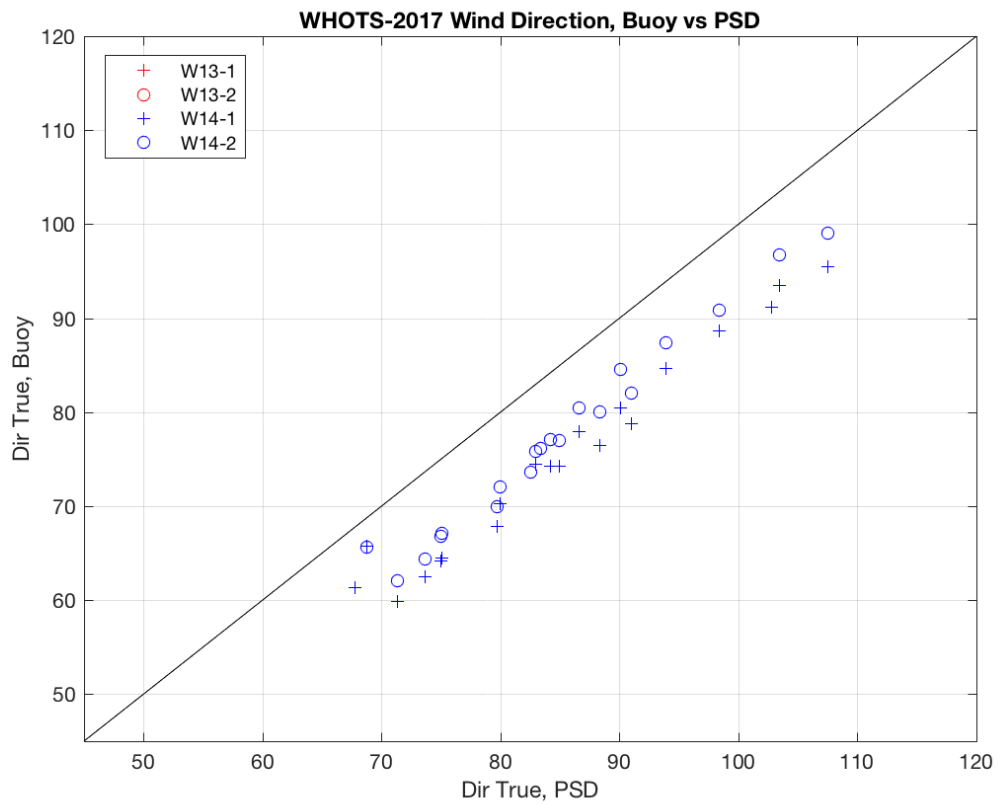
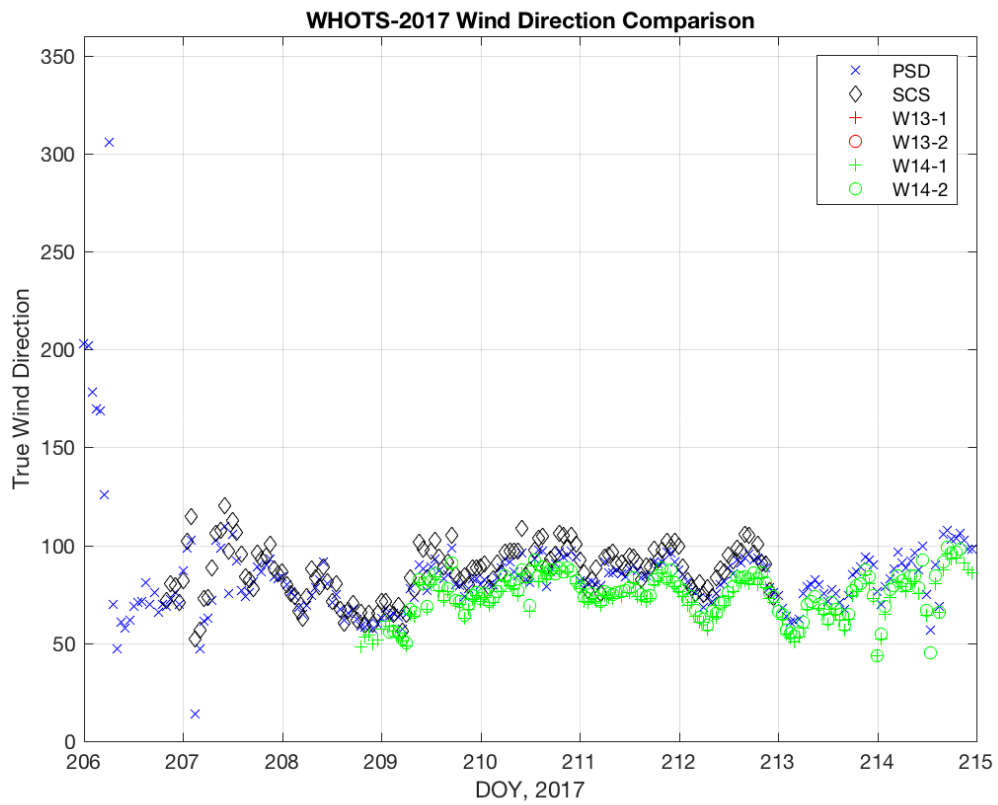
Bias	Ta C	RH %	SST C	U m/s	dir deg	Rs W/m2	RI W/m2	P mb
psd – W13-1								
mean	-	-	-	-	-	-	-	-
median	-	-	-	-	-	-	-	-
std	-	-	-	-	-	-	-	-
psd – W13-1								
mean	-0.35	-1.43	0.15	-	-	20.22	-5.13	0.70
median	-0.32	-1.60	0.12	-	-	-1.92	-5.08	0.72
std	0.08	1.00	0.07	-	-	41.25	1.83	0.27
psd – W14-1								
mean	-0.53	-0.98	0.19	0.91	9.96	4.91	9.44	0.03
median	-0.53	-1.24	0.18	0.88	10.32	-3.00	8.51	0.02
std	0.12	1.17	0.08	0.26	2.16	39.96	8.90	0.05
psd – W14-2								
mean	-0.43	-2.31	0.19	1.13	7.62	5.41	12.45	0.66
median	-0.42	-2.68	0.18	1.06	7.94	-6.46	12.18	0.70
std	0.11	1.12	0.07	0.27	1.53	40.66	8.61	0.27

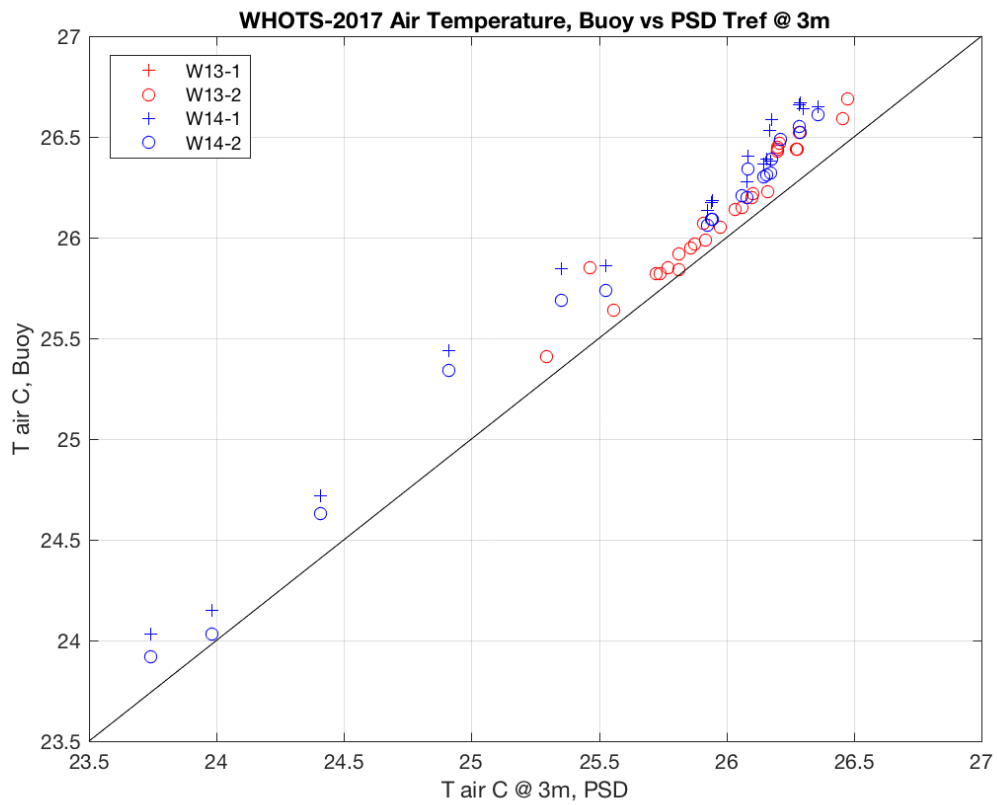
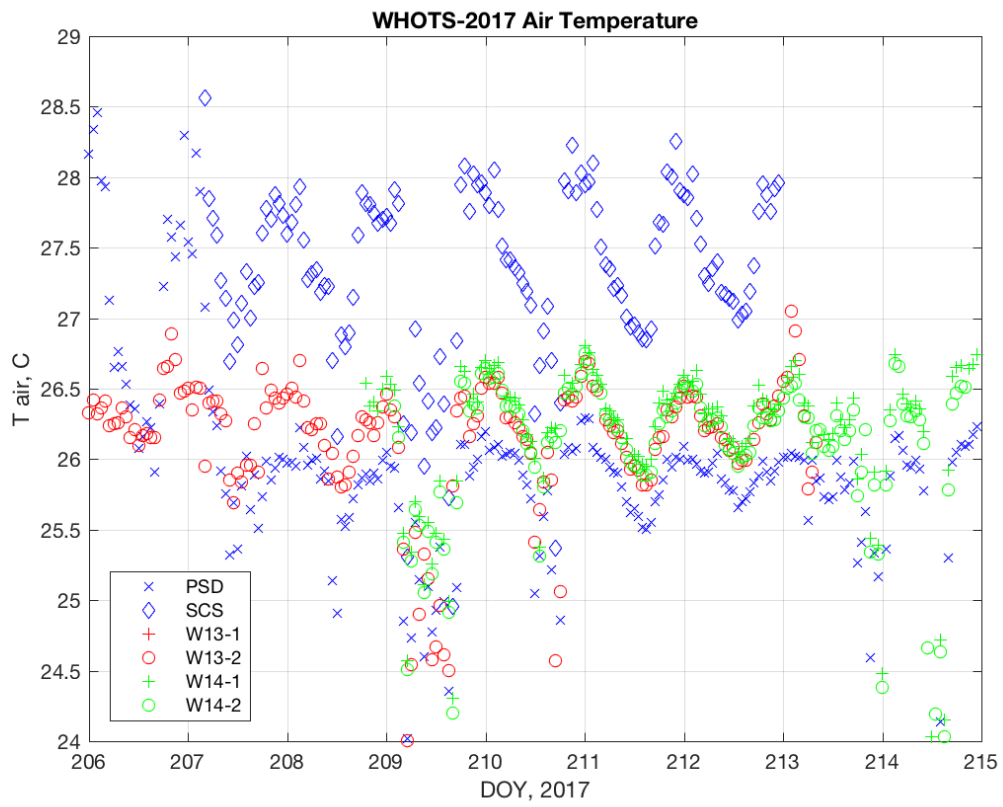


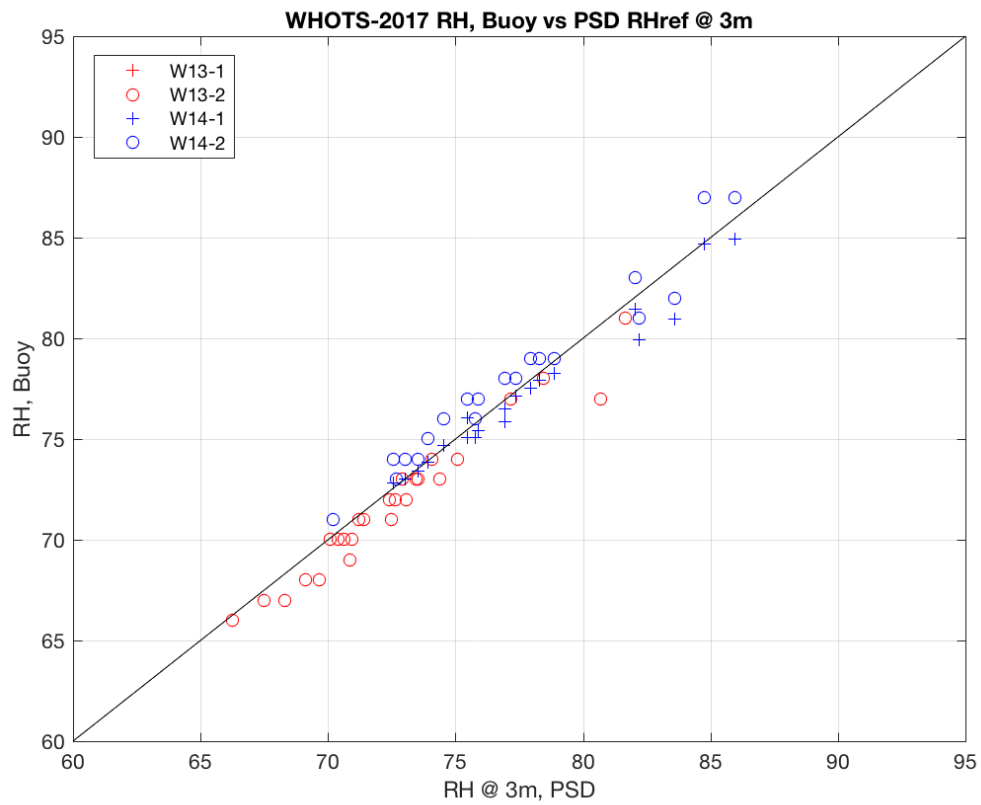
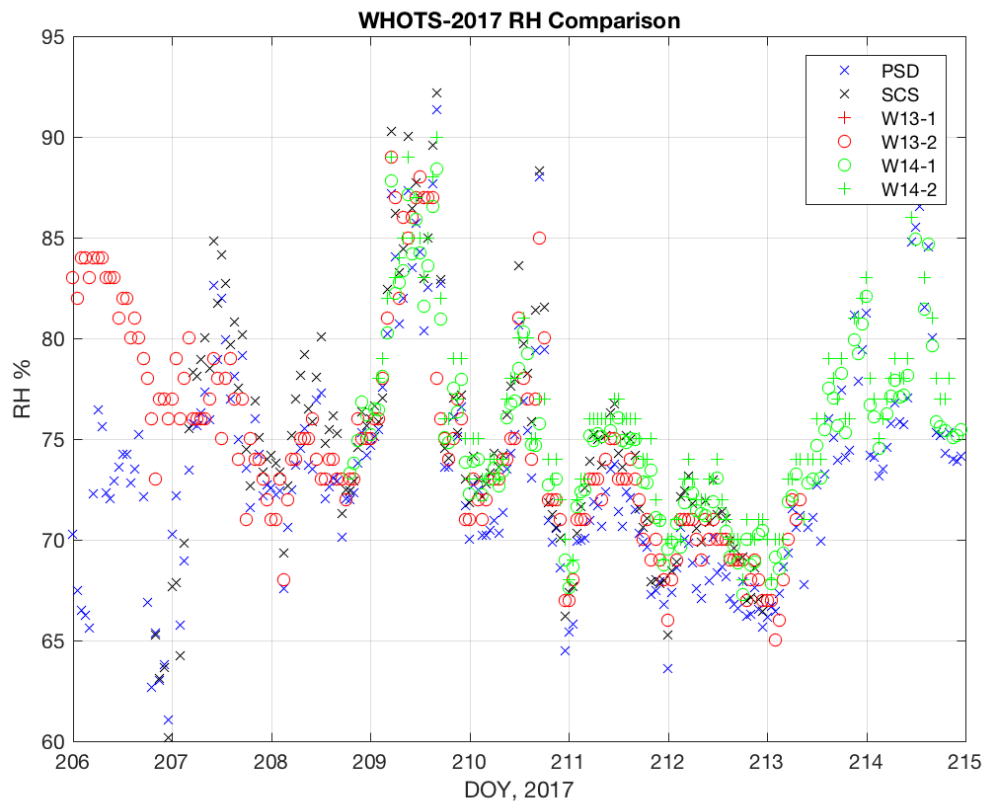


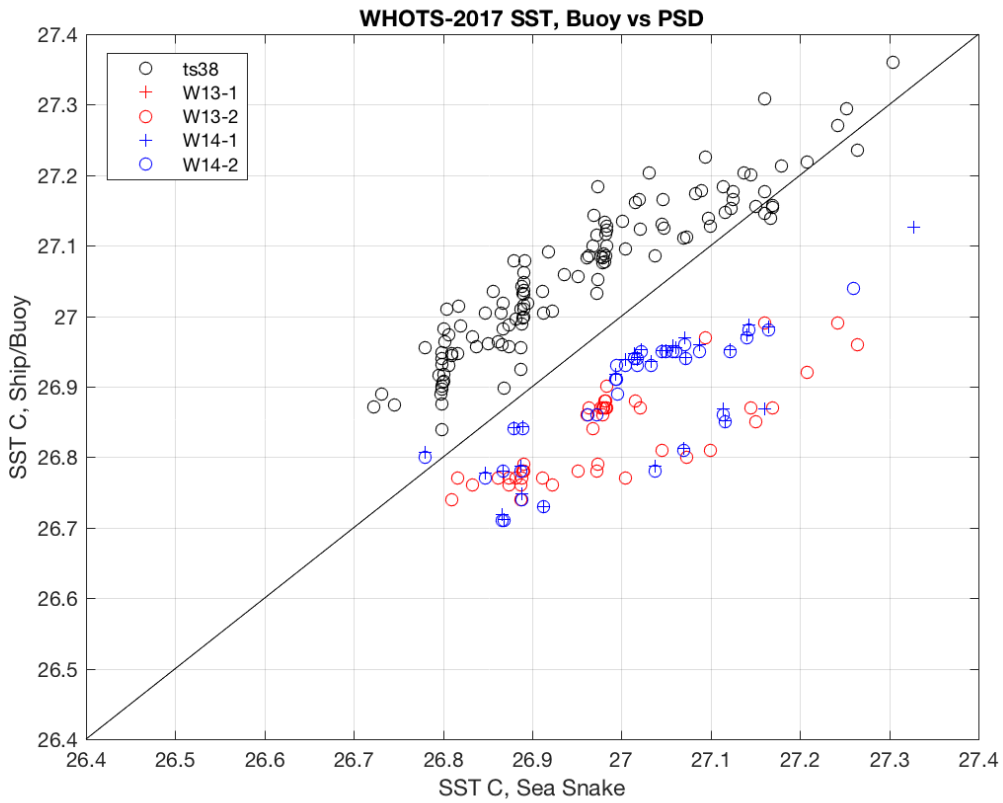
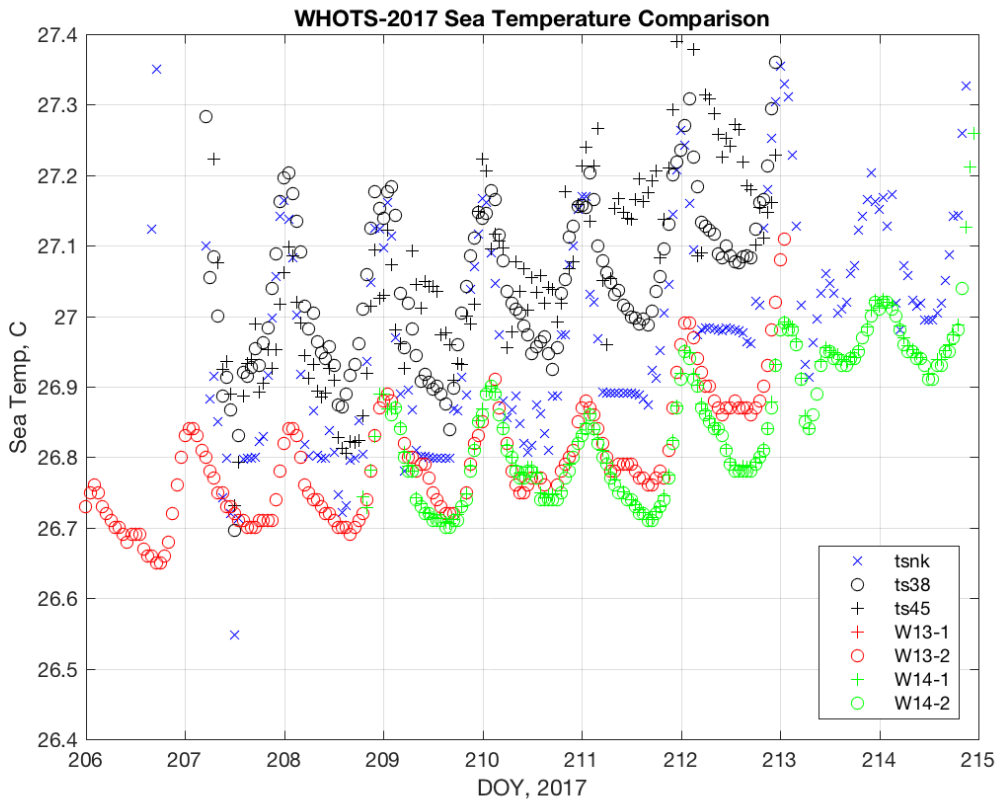


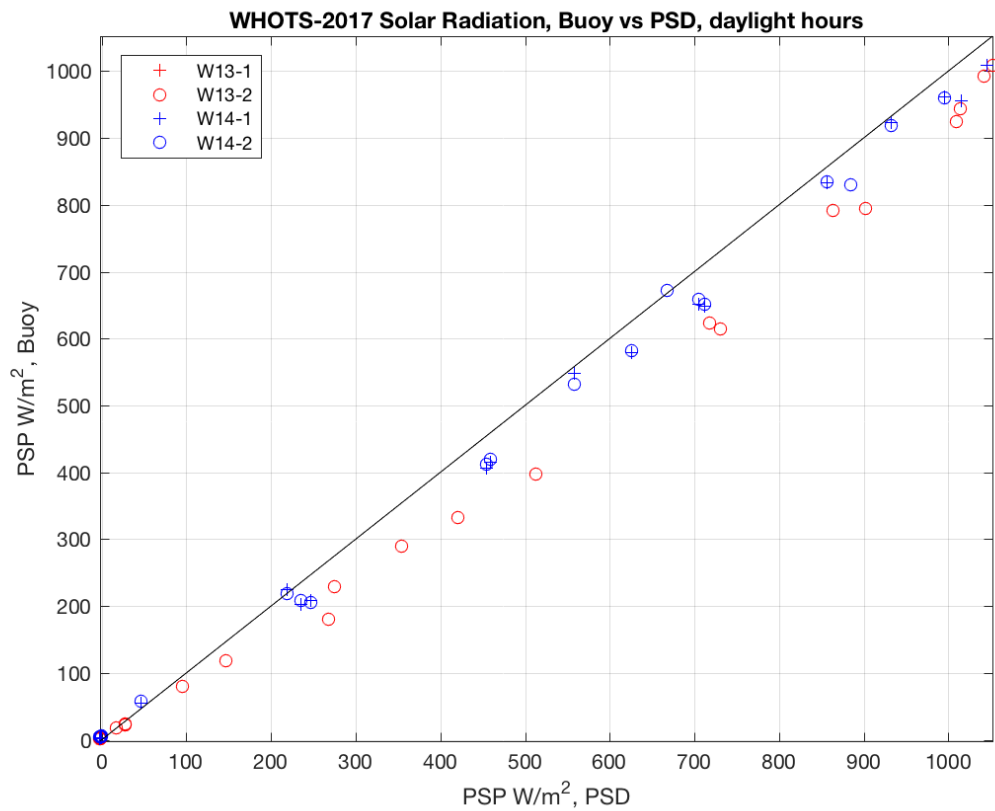
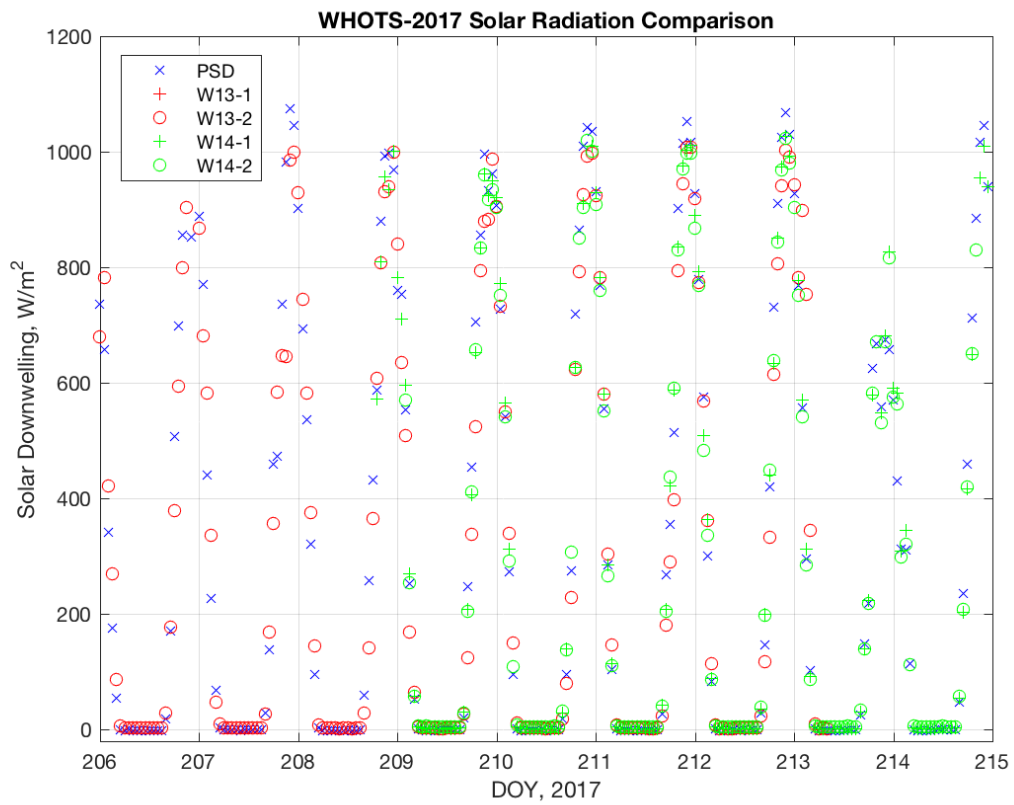


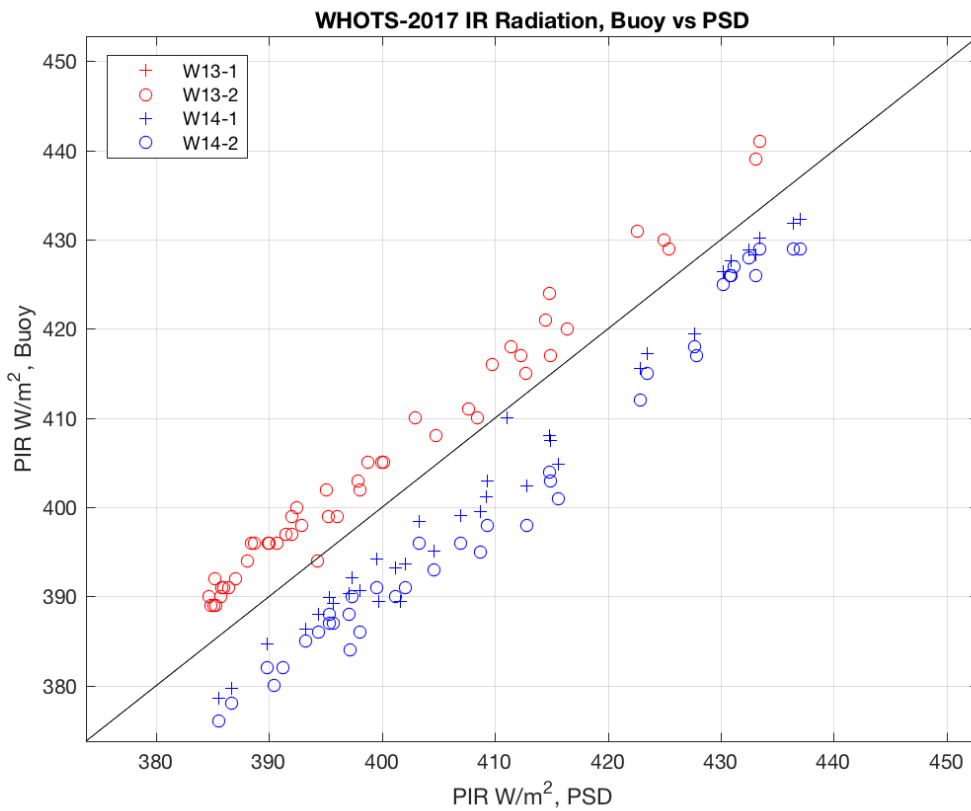
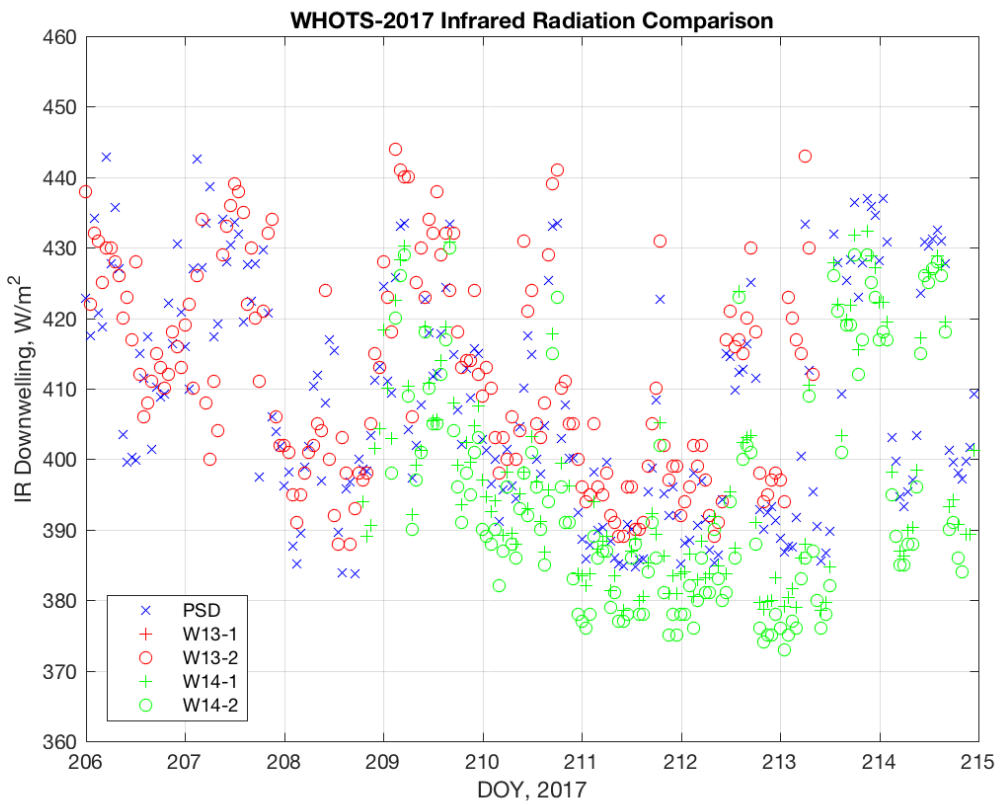




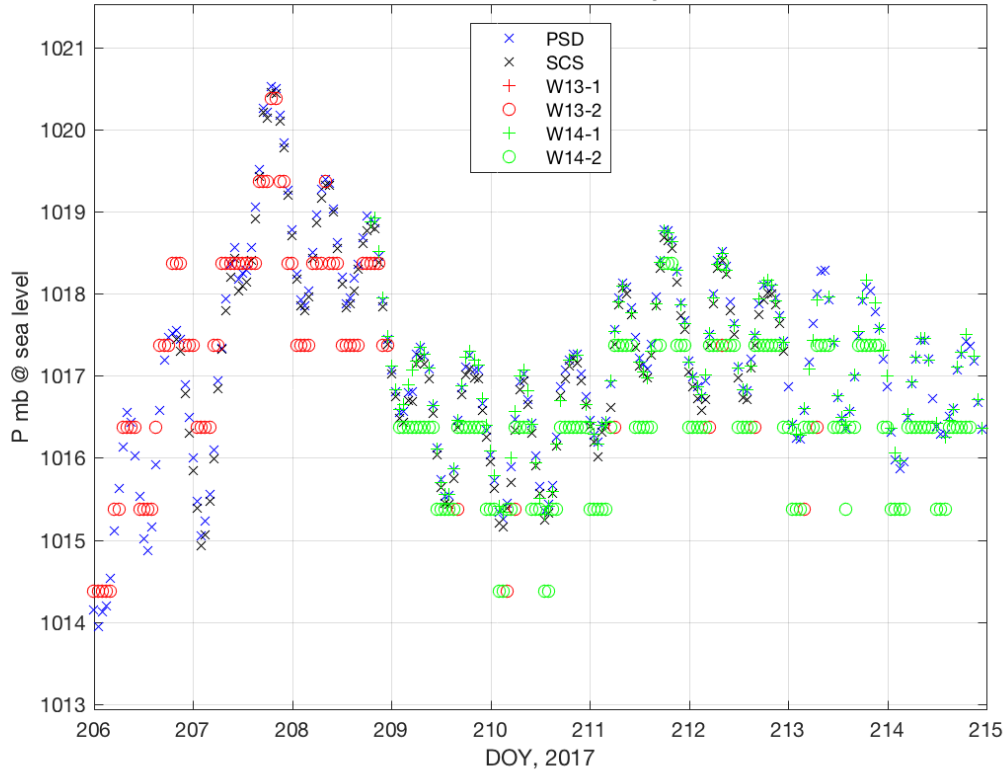




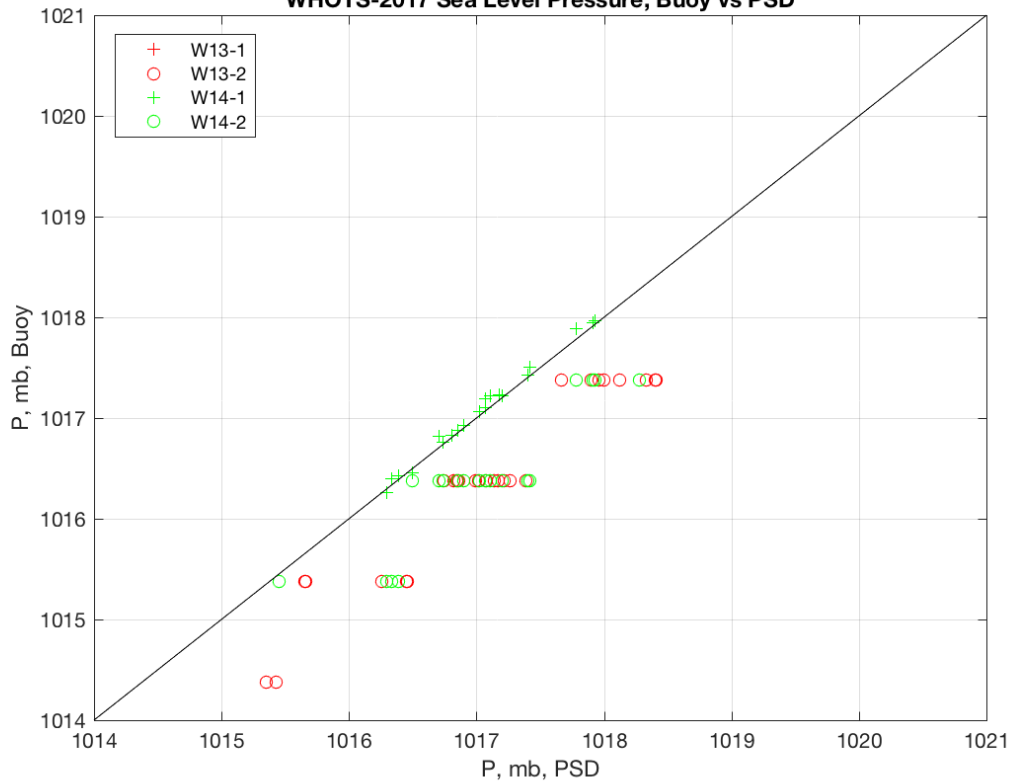


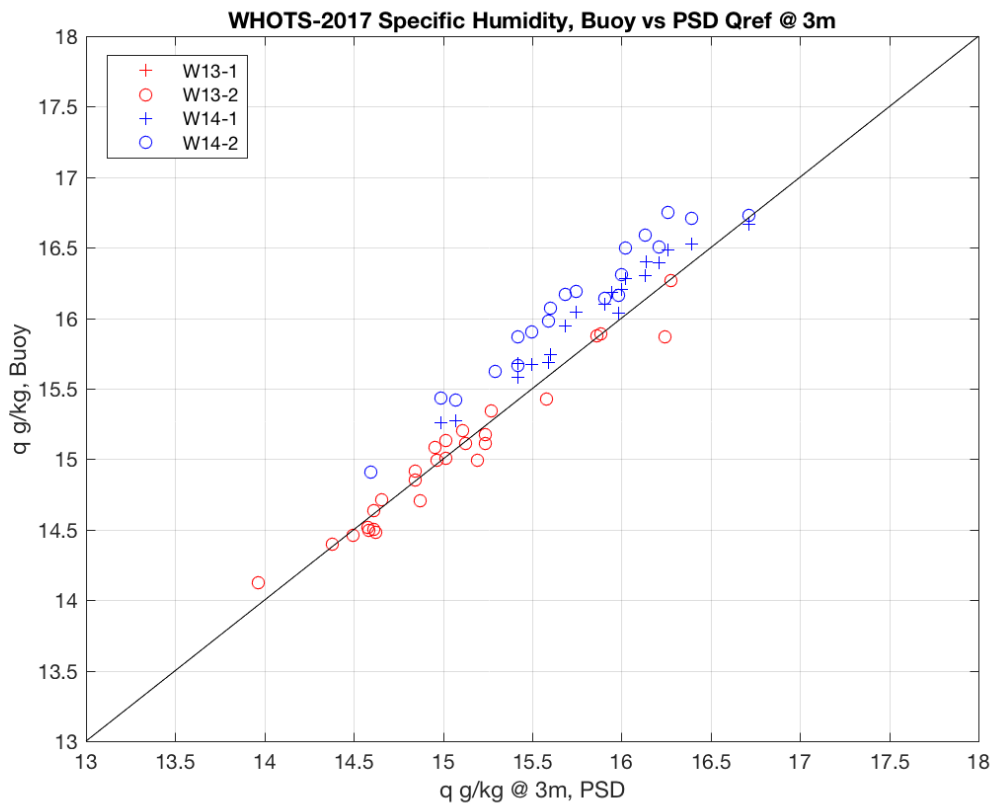
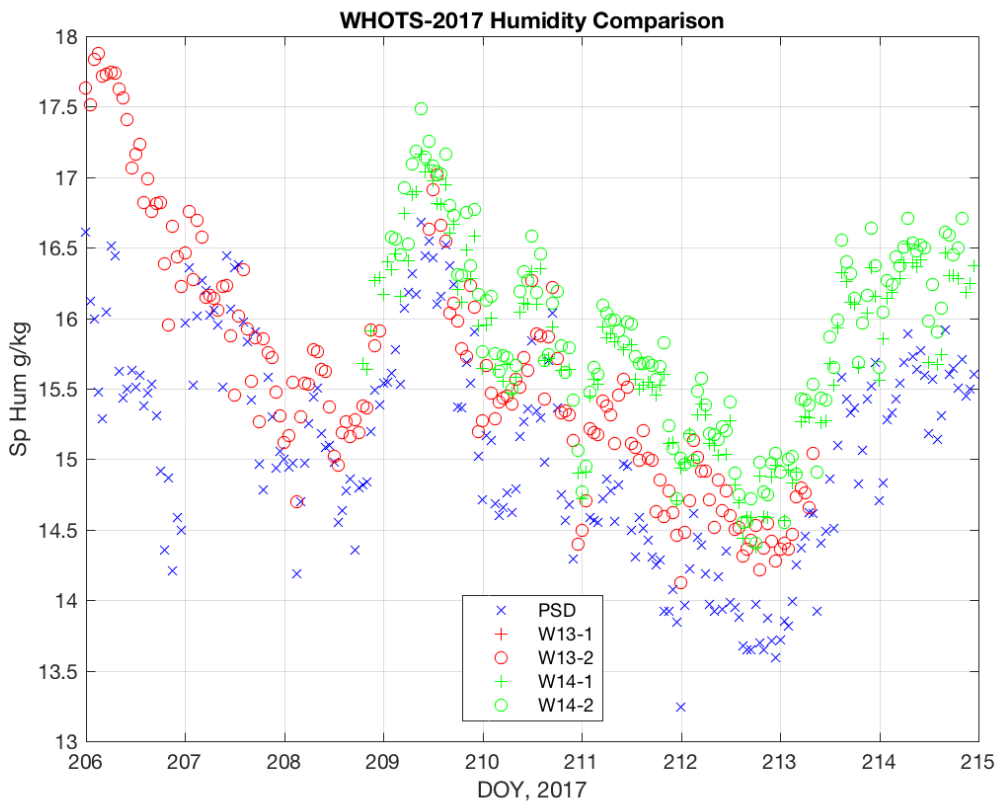


WHOTS-2017 Pressure Comparison



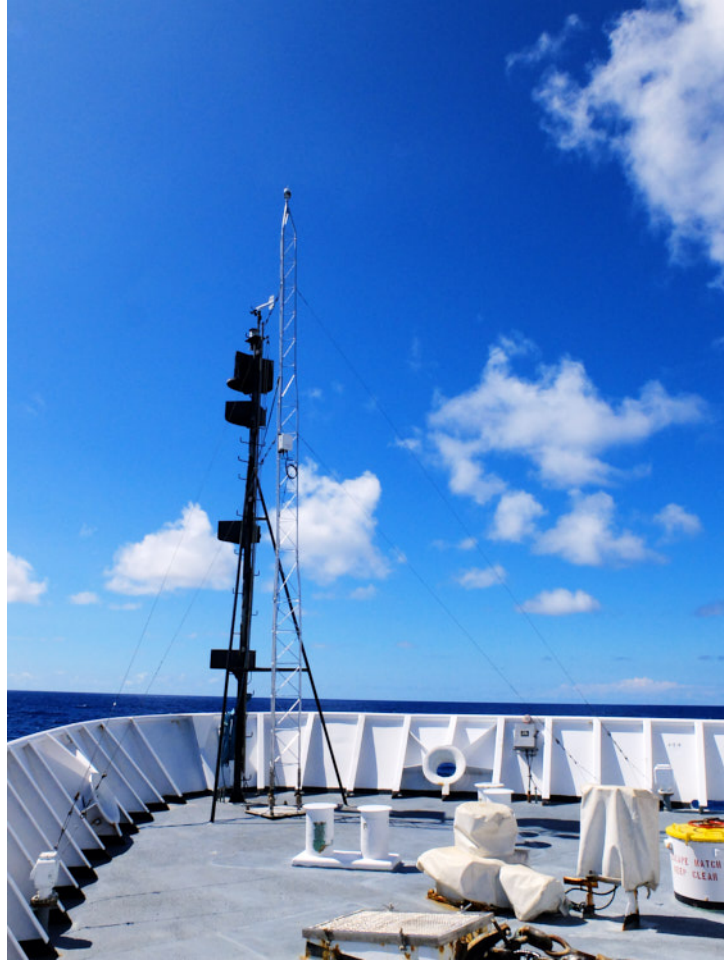
WHOTS-2017 Sea Level Pressure, Buoy vs PSD







PSD seasnake and port-side overboard discharge.



PSD met tower and ship jackstaff.



Ship T/RH and sonic anemometer on short mast at bridge roof centerline.