Comparison of Oregon State University turbulent fluxes with COARE 3.0 bulk fluxes

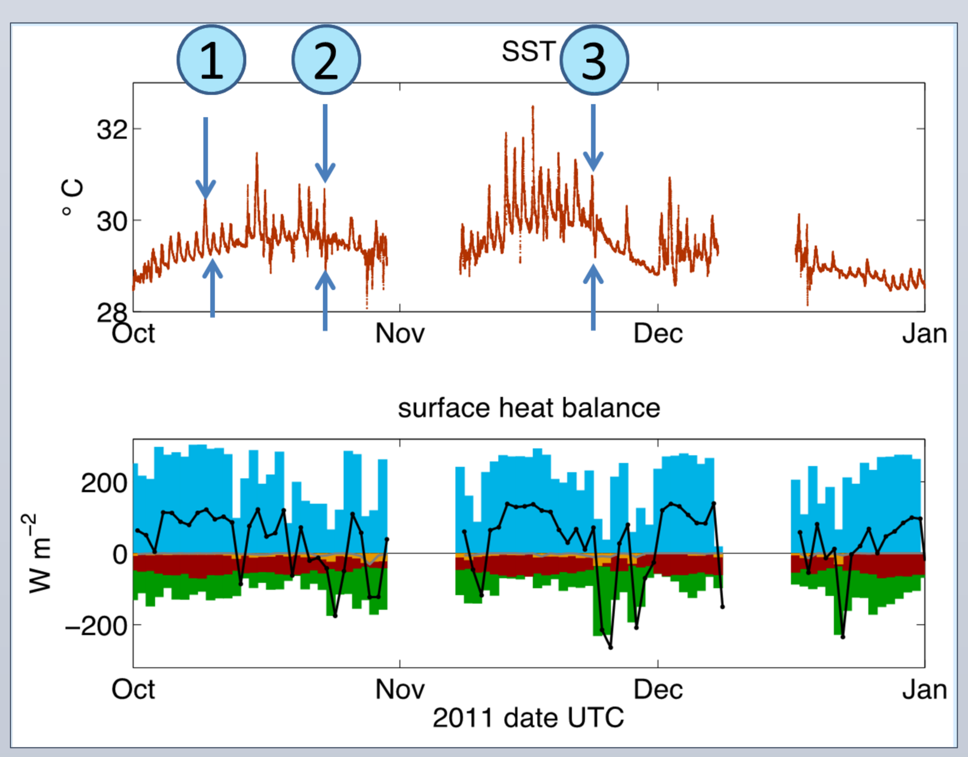
June Marion, Simon de Szoeke
Oregon State University , Corvallis, OR

Abstract

Three independent flux measurement systems were deployed on the research vessel *Revelle* during the DYNAMO 2011 field campaign. Oregon State University (OSU) launched a new flux system to provide independent measurements to compare with established NOAA/ESRL/PSD and University of Connecticut (U.Conn) flux measurements. Each system measured high frequency ship motion and position, temperature, humidity, winds, and solar and thermal infrared radiation. Covariance fluxes from OSU 20-Hz sonic anemometer data are found to be sensitive to low-frequency variance. In some examples covariances are sensitive to the direction of the mean steam velocity; in others they are sensitive to detrending the time series in each window. To see the contribution of larger scale circulations to the heat and moisture flux, we compute covariance fluxes with 10 min and 20 min averaging windows. Fluxes from each of these methods are compared with U.Conn/PSD/OSU consensus fluxes computed with the COARE 3.0 bulk flux algorithm.

Cases Studied

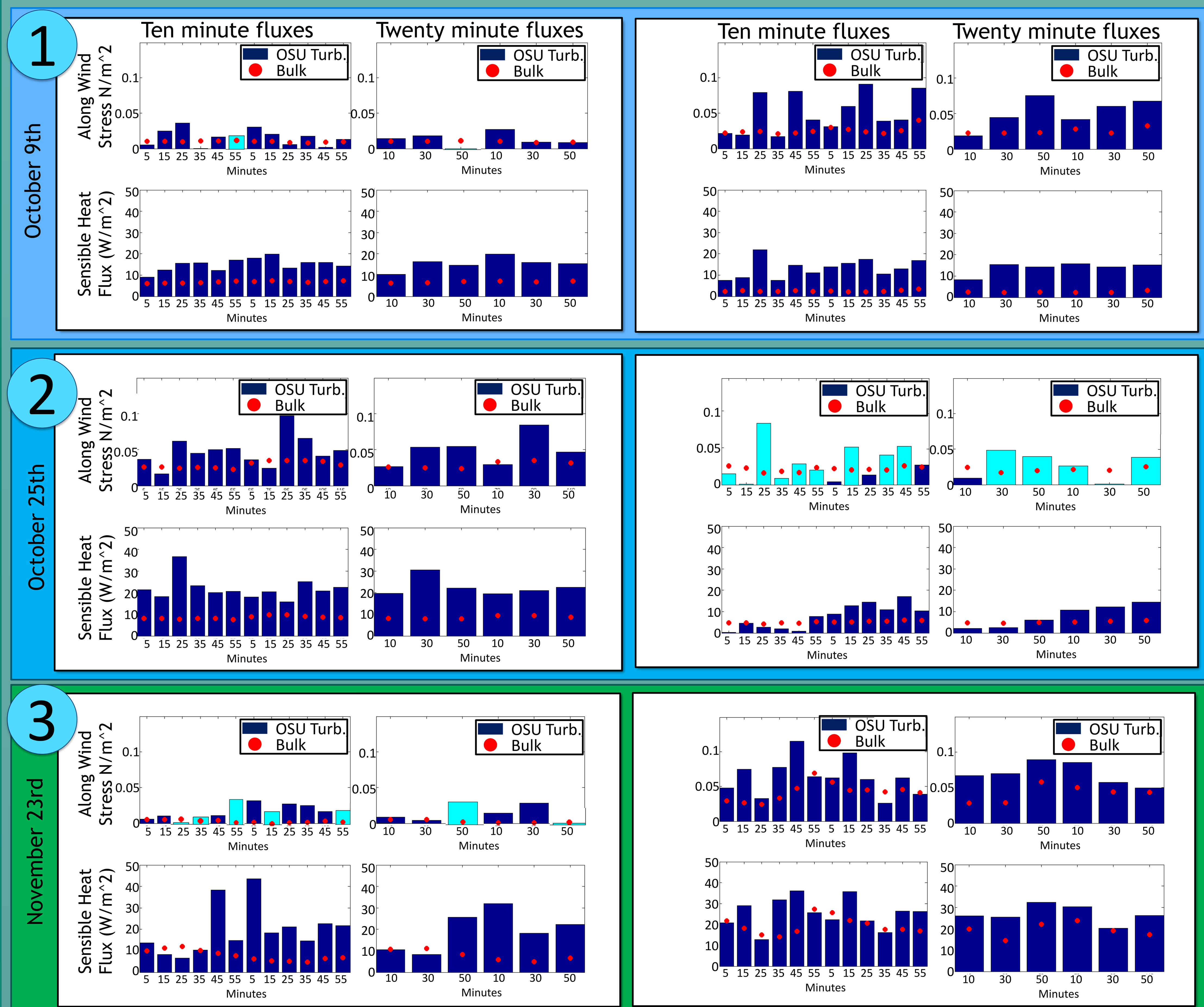
We chose three 2-hour cases to demonstrate the quality of our observations during different weather regimes: (1) a period of strong insolation and SST warming on leg 2; (2) a period of SST cooling on leg 2; (3) a case of high winds and sustained cloud cover but no rain, in the vicinity of the Thanksgiving Day westerly wind burst on leg 3. We compare flux calculations performed for both daylight and night. Below is a plot showing SST and the surface heat balance for the entire cruise with arrows indicating the approximate times compared.



Method

We adapted the U. Conn. flux methodology for use with the 20-Hz OSU data. This method adds the high-frequency platform motion (computed with an accelerometer) to the sonic anemometer winds, rotates into geophysical coordinates, and adds mean ship velocity to the wind. The high-frequency data are divided into 10- and 20-minute windows, rotated into mean stream coordinates to account for flow distortion, and finally detrended prior to covariance calculations. Two experiments were also conducted to determine the most robust processing techniques with respect to flow distortion around the ship (experiment 1) and the effects of removing the mean only, or the mean plus the trend (experiment 2).

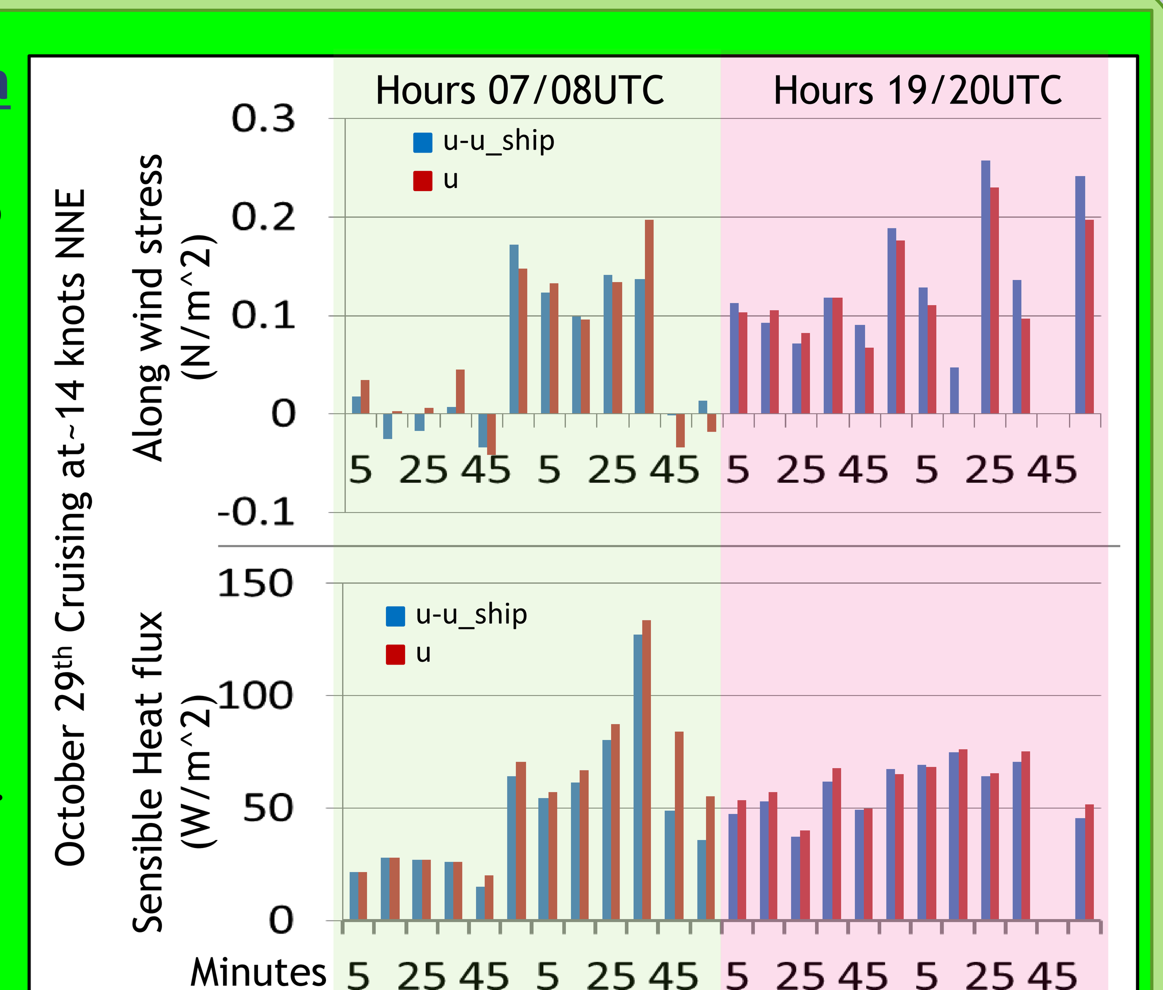
Hours 07 and 08UTC — Hours 19 and 20UTC



Fluxes for the three days are shown, hours 07/08UTC are shown on the left and hours 19/20 are shown on the right. For each two hour segment, ten and twenty minute fluxes are compared with COARE 3.0 bulk fluxes shown as red dots. Along wind stresses calculated using turbulent flux method are typically against the mean wind. Stresses that are with the mean wind are shown as light blue bars. COARE stresses are always positive as a result of the method of calculation.

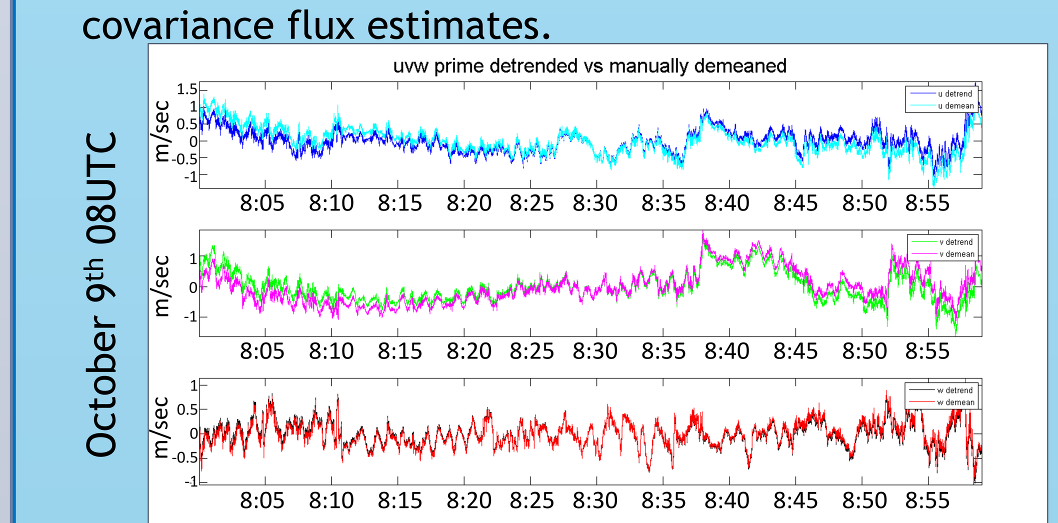
Experiment 1: ship-relative flow distortion

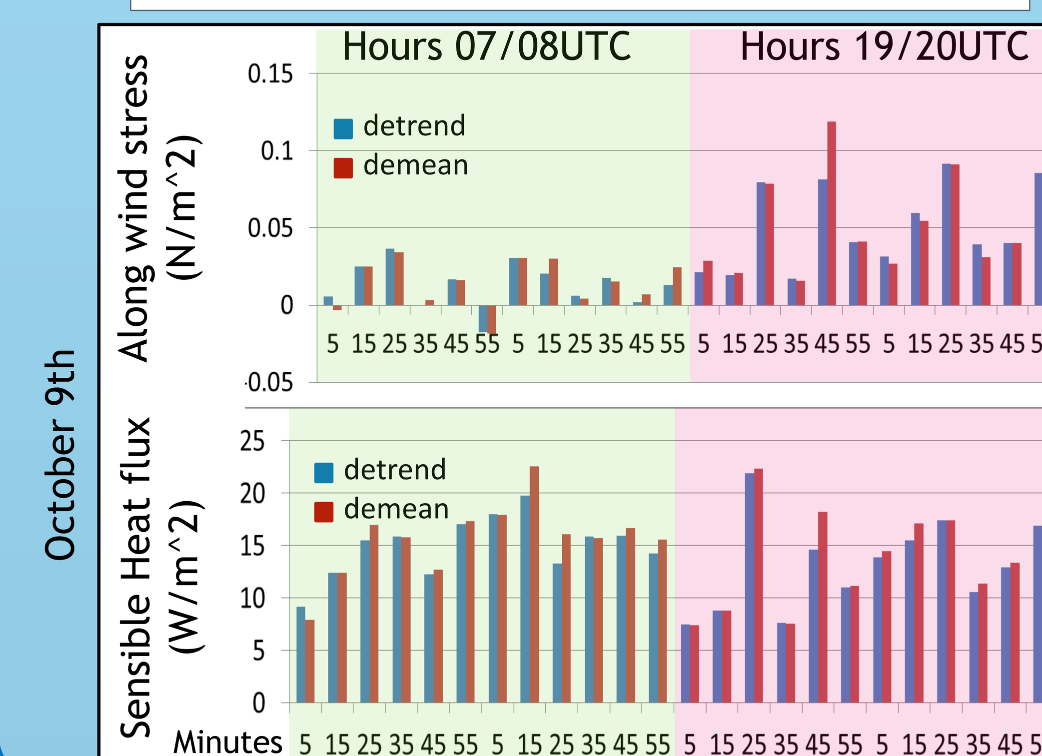
Earth-relative winds are calculated from sonic anemometers on the ship by adding the ship velocity to the anemometer winds. These winds are still distorted by flow around the ship superstructure. To account for flow distortion the winds are rotated into the mean stream direction. In our first experiment, we rotated into the mean stream two ways: using (1) the wind relative to the mean motion of the ship, and (2) the wind relative to the earth. Mean along wind stress and sensible heat fluxes were 6% and 9% lower respectively when rotating into the earth-relative stream on October 29 for hours 07,08,19,20UTC, when the ship was moving with a relatively constant velocity. This experiment had no effect when the ship was stationary. We believe that since the flow is distorted *around the ship*, wind velocity relative to the ship should be used for the flow distortion adjustment when the ship is moving.



Experiment 2: detrending anomalies

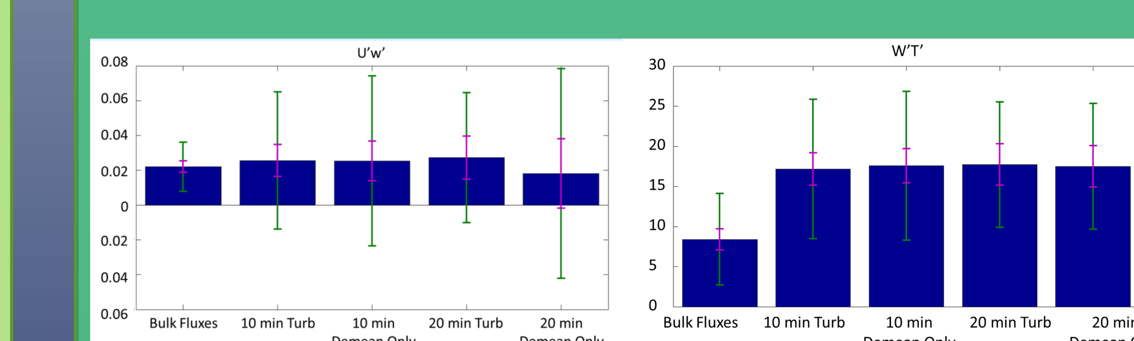
In a second experiment, within the stream coordinate system, we removed the 10 or 20 min mean but did not detrend the wind before computing the covariances <u'w'> and <v'w'>. This methods produced different results. A significant trend in the flux window indicates that the time series of turbulent velocities is not stationary. The trend represents variance at time scales longer than the window. Though true physical flux may result from this longer time scale variance, we decided that detrending yields more robust windowed covariance flux estimates.





Summary

We found that while turbulent fluxes were always higher than bulk fluxes, using a 20 minute window instead of a 10 minute window reduced the variability among the windowed flux estimates. When averaged over the 12 hours chosen for this study, turbulent along-wind stresses <u'v'> agree remarkably well with the bulk stresses, but the individual turbulent stress estimates are more variable. Averaged over the 12 hours studied, bulk heat flux <w'T'> is about half strength of the turbulent <w'T'>. We normally detrend the turbulent anomalies. Subtracting only the mean and not the trend increases the variability among flux estimates. For the 20 min <u'w'> the mean was diminished by 33% when the window anomalies were not detrended. Subtracting the mean ship velocity from the winds before rotating into the wind stream has little effect on the mean flux but affects individual estimates slightly when the ship is in motion.



Fluxes averaged over all 12 hours compared. 10min fluxes have 72 estimates, and 20min averages have 36. Green error bars are standard deviations, purple error bars are the standard deviation of the mean.