Improvements to the COARE Bulk Flux Algorithm using OOI Surface Flux Data

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Introduction

The project utilizes six year of data from the NSF Ocean Observatories Initiative (OOI) combined with results from the CLIMODE, DYNAMO and SPURS research programs to:

- Improve bulk air-sea flux algorithms that parameterize the heat and momentum exchange at moderate to high wind speeds,
- Conduct process studies to investigate wind-wave interactions and the impact of wave-age, wave-steepness and wind-wave directional differences on momentum exchange.
- Use these investigations to test parameterizations of surface fluxes being used in coupled air-sea mesoscale models.

The flux packages shown in Figure 1 include a sonic anemometer and an IMU to motion correct the velocity components before computing the direct covariance fluxes and wave statistics.

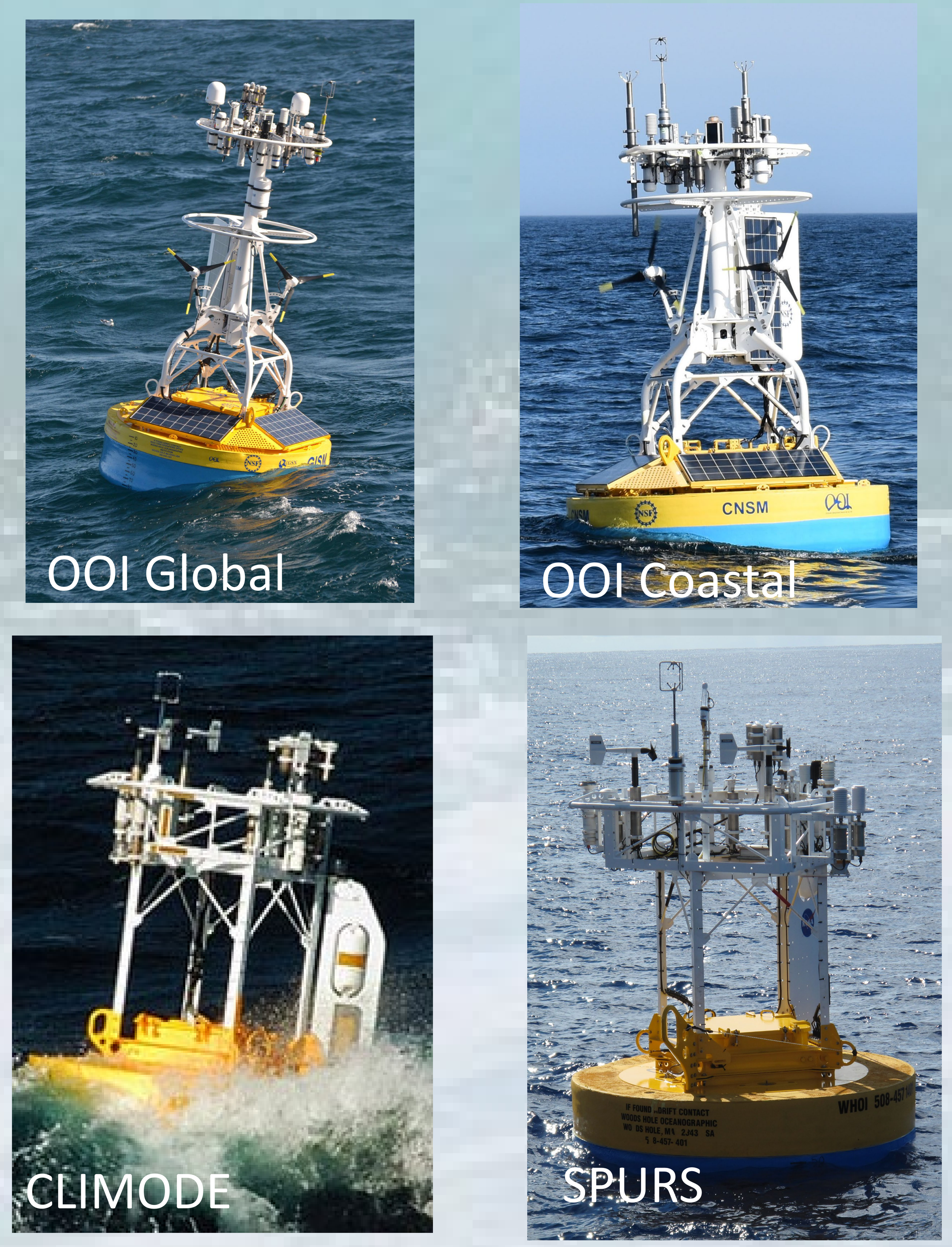

Figure 1 OOI Global and Coastal moorings and the CLIMODE and SPURS buoys. The OOI and CLIMODE buoys provide momentum and buoyancy fluxes. The SPURS buoy added an IRGA to directly measure the latent and sensible heat fluxes .

Figure 2. The location of the data sets used in this investigation as indicated by the yellow circles.

Results: Momentum Exchange

Our investigations show that the COARE 3.5 wind-speed dependent algorithm is in good agreement with the OOI momentum fluxes as shown in Figure 3. This results again shows that a wind speed dependent parameterization is hard to beat because the wind waves are primarily responsible for supporting the surface stress.

$$\overline{uw} = C_D U_r S_r \qquad \overline{wT} = C_H S_r \Delta\Theta \qquad \overline{wq} = C_E S_r \Delta Q$$

$$C_{DN} = -\frac{\overline{uw}}{U_{rN}^2 G} = \left(\frac{\kappa}{\ln(z/z_0)}\right)^2$$

$$C_{HN} = C_{DN}^{1/2}\left(\frac{\kappa}{\ln(z/z_{0T})}\right)$$

$$C_{EN} =-= C_{DN}^{1/2}\left(\frac{\kappa}{\ln(z/z_{0Q})}\right)$$

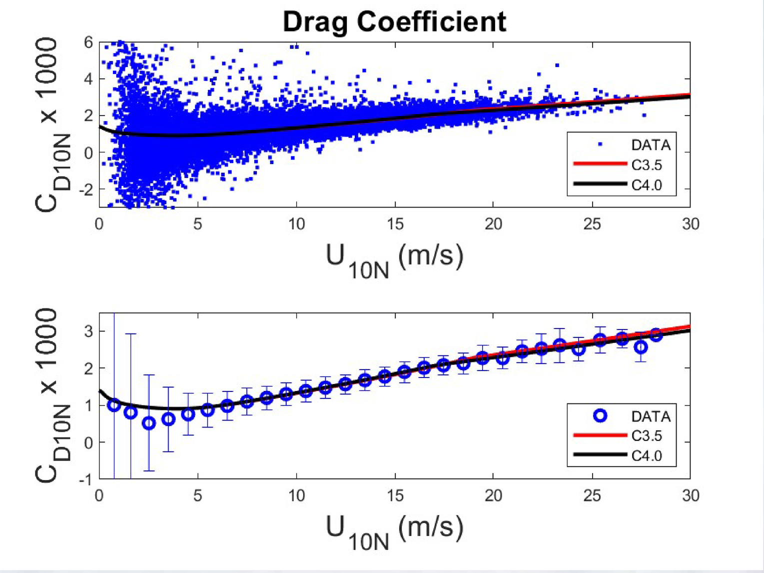

Figure 3. Drag Coefficient.

However, there are differences in the magnitude of the momentum flux, which appear to be a function of the longer wind waves. An example being the wave field from the Southern Ocean compared to the more fetch-limited region around the Pioneer Array as shown below.

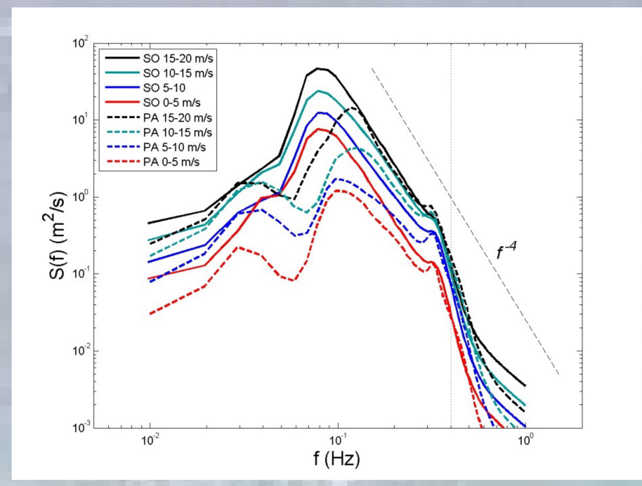

Figure 4. Wave spectra.

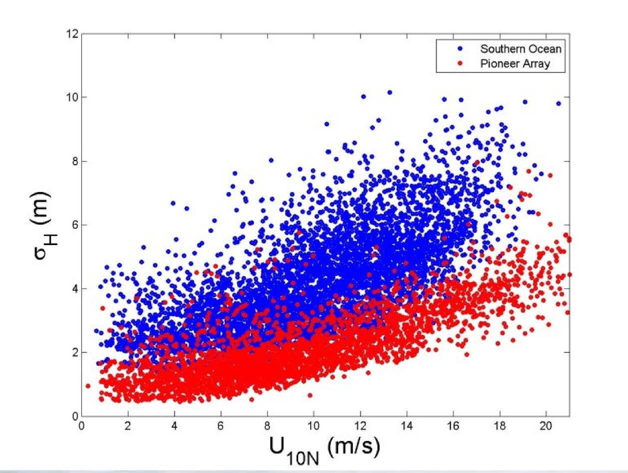

Figure 5. Wave height vs Wind Speed.

This suggests that a wind-speed dependent formulation will not be able to capture all of this variability. Instead, the wave steepness scaling used in COARE 3.5 continues to be the most promising approach for a wave-based parameterization as shown in Figure 6.

Wind speed dependent $\alpha = \frac{g z_0}{u_*^2} = f(U_{10N})$

Wave slope dependent $\alpha = \frac{g z_0}{u_*^2} = f(\sigma_H k_p)$

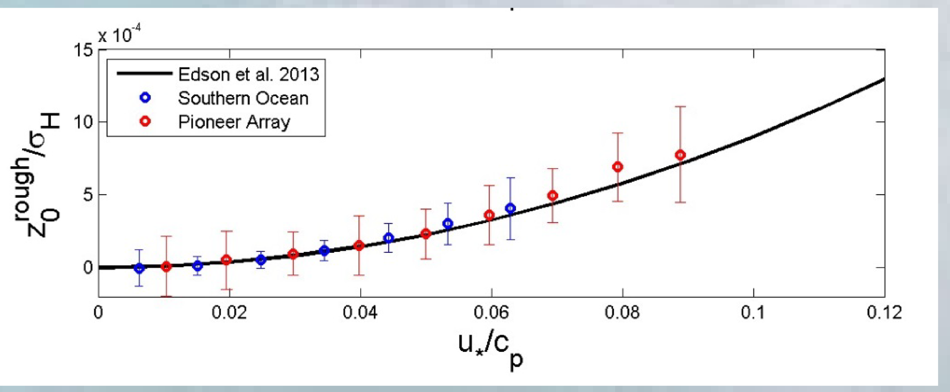

Figure 6. Wave steepness based parameterization

The wave-based parameterization is being used to investigate the impact of waves on air-sea exchange in a coupled-model. One important finding is that a wave-based parameterization based on the peak period experiences problems under moderate winds in the presence of swell. A formulation using the average period is being developed for COARE 4.0.

Results: Heat Exchange

A main objective of the research is to improve the heat flux parameterizations used in COARE 4.0 for the Stanton and Dalton numbers shown in Figure 7. Previous data sets are used to compute the transfer coefficient for moisture using data from SPURS. DYNAMO and CLIMODE. This is used to correct the buoyancy flux for moisture to compute the Stanton number. Our findings suggest that the transfer coefficients for sensible heat and moisture are not the same as shown in Figure 8.

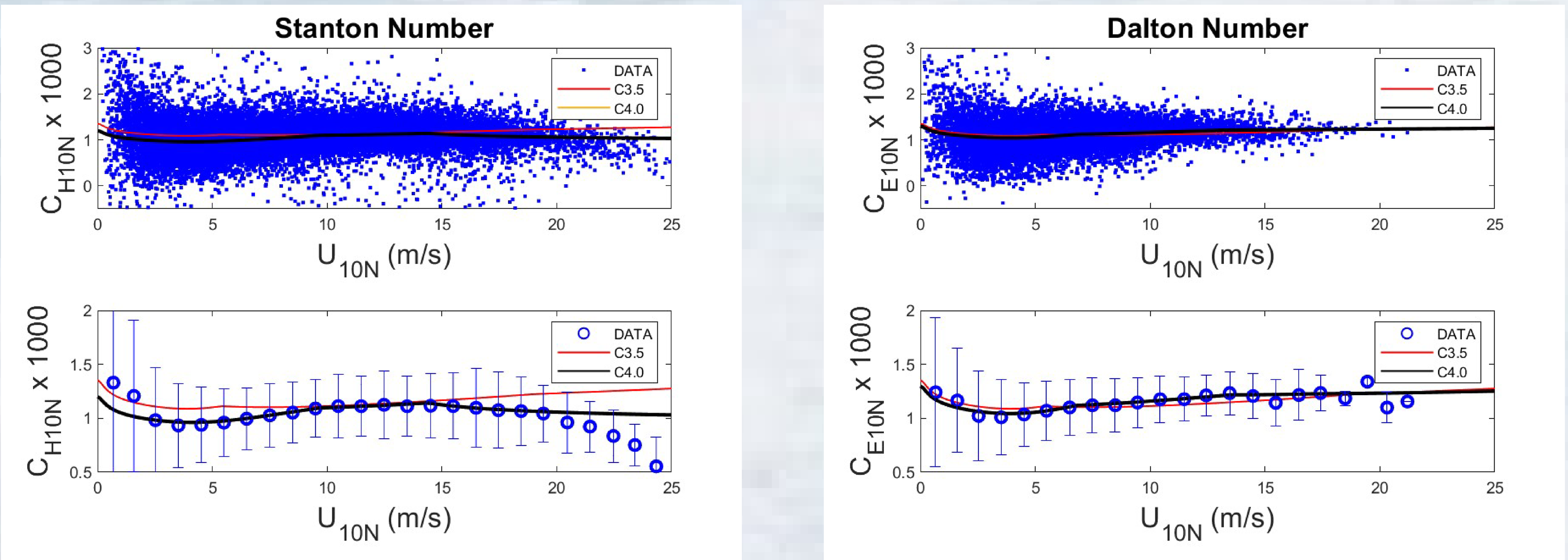

Figure 7. Heat Transfer Coefficients.

$z_{0T} = f(z_0 u_*/\nu)$ $\qquad z_{0Q} = f(z_0 u_*/\nu)$

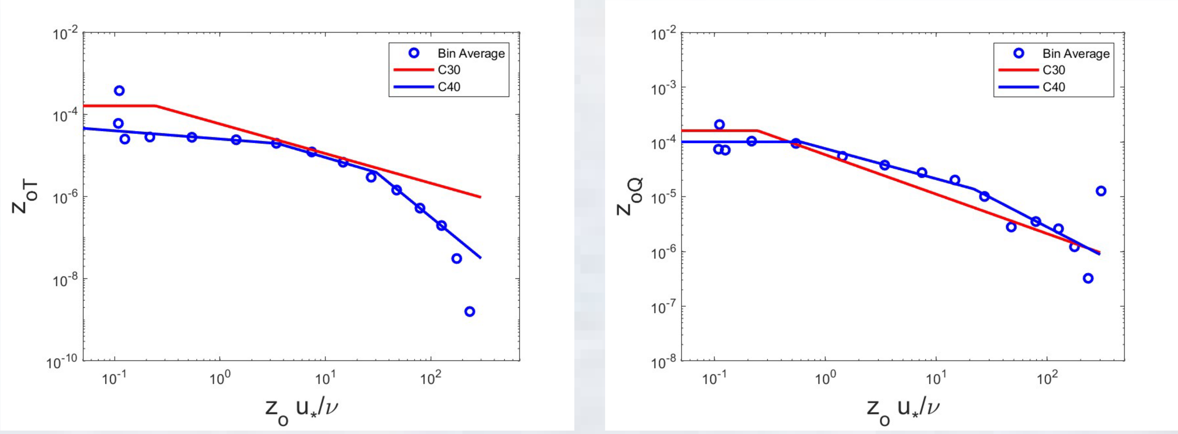

Figure 8. Thermal Roughness Lengths for temperature and humidity