Quantifying the Spatial and Temporal Variability of Wind-Stresses Across a Tidal Inlet

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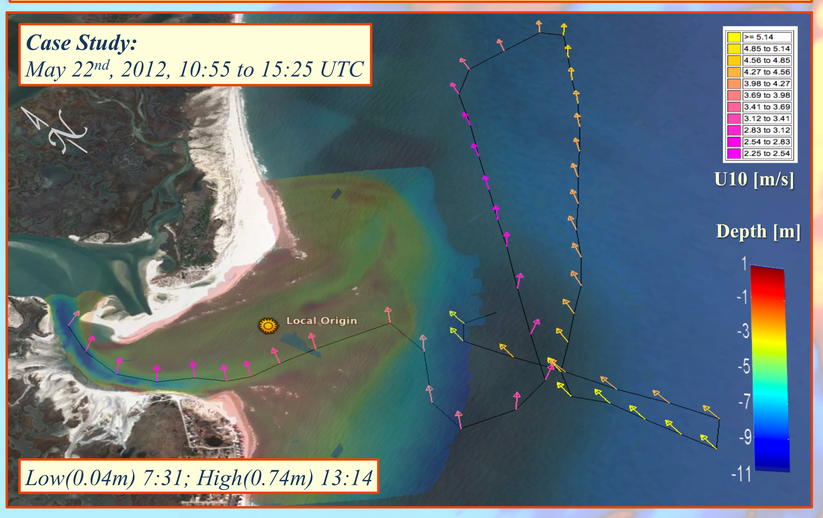
Introduction

Here we present a sub-set of data collected during the ONR-sponsored field campaign, Riverine and Estuarine Transport I (RIVET I). This inter-agency effort aims to gain a better understanding of the complex coupling of wind, waves, and currents in tidal inlets. Our research objective is to quantify the variability of the wind stress near the inlet and provide validation of coastal modeling efforts and satellite retrievals of wind and current fields.

Field Site: New River Inlet, NC

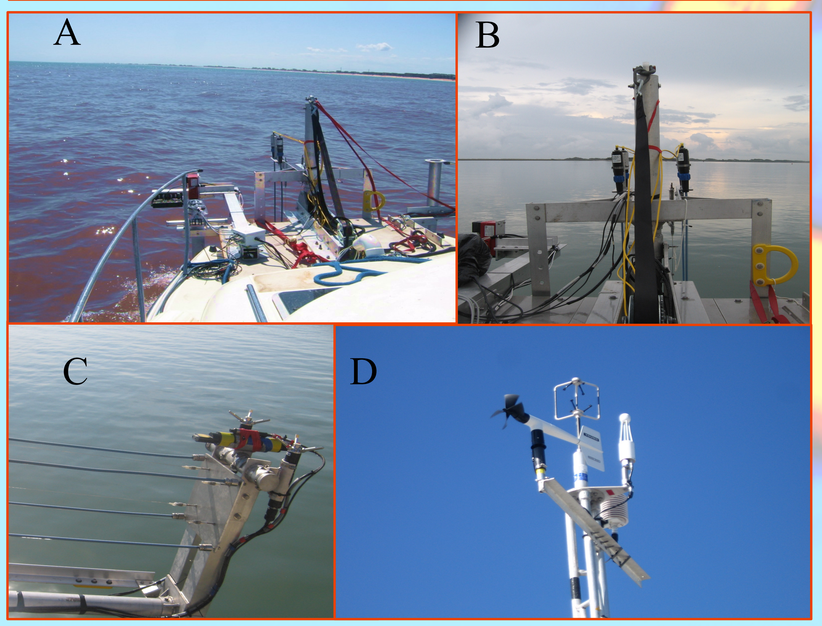


(above) Wind speed vectors (ref. 10m) along our vessel's GPS track. The dimmed bathymetry map is provided by the Army Corps of Engineers.

Surface Physics Experimental Catamaran

To achieve high spatial and temporal resolution, a mobile research catamaran, SPEC, was utilized. Among other instruments, SPEC was outfitted with:

- Meteorological mast, equipped with a flux package
- 1200 kHz RDI ADCP (downward orientation)
- 2 Son-Tek 10 MHz ADV's
- Infrared and Polarmetric Cameras
- 2 pairs of wave wires and 1 Ultrasonic Distance Meter (UDM)



A) Looking across bow of SPEC at a sea of rhodamine dye. **B)** Mechanical lift in the "sampling" position. **C)** Wave wires, paired ADV's, and turbidity sensor, raised out of water for transit. **D)** Flux package atop met-mast, height 5.99m (MWL)

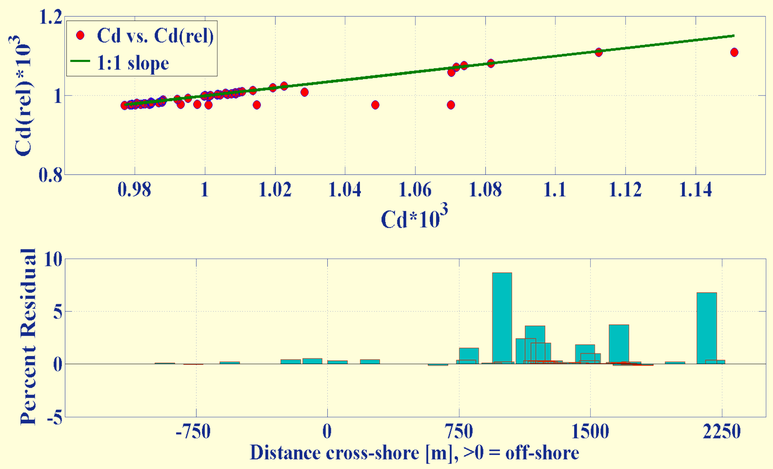
Methods: Motion Correction

A robust motion correction algorithm is necessary to accurately make direct measurements of the wind stress from a moving platform in a wavy environment. For this, we use the Anctil et al., 1994 method.

$$u = T_{BE}u_B + T_{BE}\int(a_B+g_B)dt + \Omega \times T_{BE}L_B$$

- **u** = Motion corrected and Earth referenced wind speed
- $\mathbf{u_B}$ = Platform referenced wind speed
- $\mathbf{T_{BE}}$ = Platform to Earth reference rotation matrix
- $\mathbf{a_B}$ = axial accelerations in platform reference frame
- **Ω** = angular velocity matrix
- $\mathbf{L_B}$ = instrument location in platform reference frame

Methods: Drag Coefficient Estimates



(above) **Upper:** Comparisons of *bulk* drag coefficient estimates (see below) using solely the wind speed and using wind speed relative to the depth-averaged current. **Lower:** Percent difference between Cd and Cd(rel), here plotted as a function of cross-shore distance.

We compare 2 methods for estimating the neutral drag coefficient, C_D, the bulk method used in Smith, 1988 and a direct covariance method (eddy correlation), as given in Anctil and Donelan, 1996. Before calculating stress, all wind data was despiked, corrected for all 6 degrees of platform motion, and corrected for translational motion. A 5-minute averaging interval was used for all stress estimates.

***Bulk Estimate*:**

$$z_o = au_*^2/g + R\nu/u_*$$

$$\tau = \rho C_D|U_{10}|$$

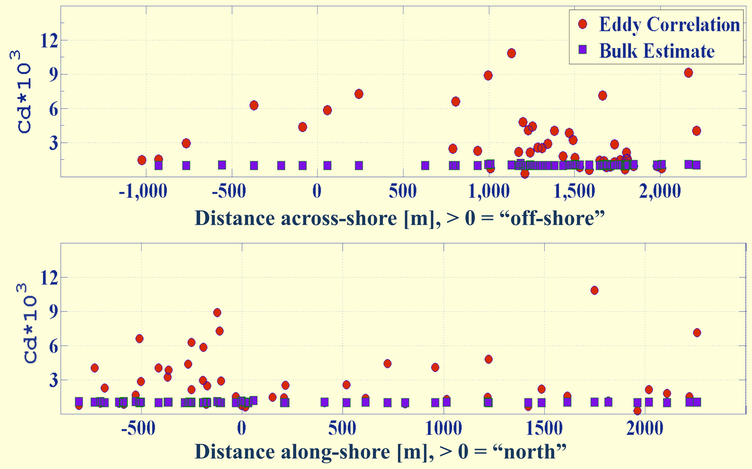
***Eddy Correlation*:**

$$u_*^2 = -\langle u'w' + v'w' \rangle$$

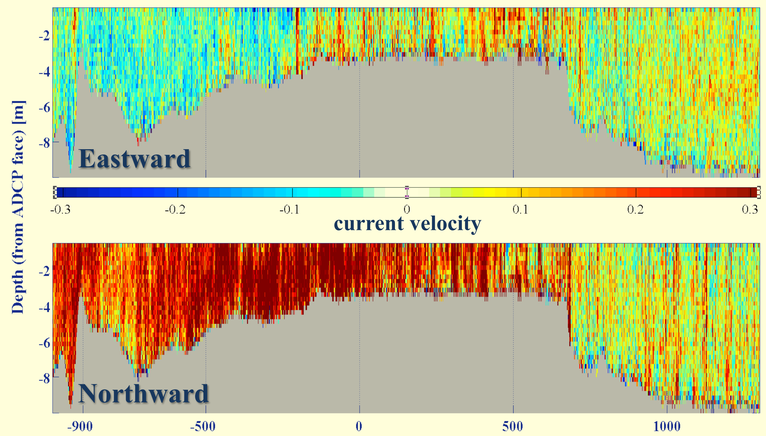
$$C_D = [u_*/U_{10}]^2$$

z_o = roughness length
u_* = friction velocity
g = 9.81 m/s^2
a = 0.011, Charnock's constant
U_{10} = neutral wind (ref. 10m)
R = 0.11, limiting aerodynamic Re
C_D = neutral drag coefficient
ν = 1.4138e-5 m^2/s
ρ = air density kg/m^3
τ = Wind shear stress

Results



(above) Drag coefficient estimates are shown as functions of the local coordinate system. *Note: 10% of eddy correlation estimates flagged as >10^{-2}, not included.



(above) Current profiles as a function of cross-shore distance [m].
(below) Coincident wind velocity and stress vectors along SPEC track.

Future Work

- Investigate the dependence of the wind stress on local wave conditions.
- *Use flux footprint methods to determine the "source" of the atmospheric drag (e.g. waves, houses along beach, marsh, etc.)
- Explore the sensitivity of a coastal model (Delft 3D) to a varying methods of wind stress parameterization
- Work with satellite remote sensing groups to validate retrieval of wind fields and surface currents from SAR images acquired during campaign.