Geophysical Research Abstracts
Vol. 15, EGU2013-11749, 2013
EGU General Assembly 2013
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Field PIV measurements reveal scaling trends of velocity and Reynolds stress profiles in the rough wall coastal ocean bottom boundary layer

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A submersible particle image velocimetry (PIV) system was deployed to characterize mean flow and turbulence in the inner part of the coastal ocean bottom boundary layer (BBL), and their interaction with the bottom roughness. This system consisted of two independent PIV sample planes with a field of view of 29x29 cm^2, which could be oriented at different angles to each other, thus enabling one of the light sheets to be aligned to the mean current direction, and the other to the dominant wave direction. High-resolution sonar was used to measure the bottom roughness characteristics. Data from a co-deployed ADV facilitated Reynolds stress calculations by filtering out wave-induced motions from the PIV data. A massive database was created under varying velocity, bottom roughness, as well as relative wave current orientation and magnitude. It consisted of 30-60 minute subsets of PIV data acquired over entire tidal cycles at 6 Hz, corresponding to 10800-21600 instantaneous 2D velocity distributions for each subset. After processing, velocity data was obtained at a resolution of 4.5 mm, from the seabed up to 29 cm above the bottom.

The presentation focuses on three datasets (referred to as **R3**, **R4** and **R9**), where the mean current (U_c) is higher than the rms value of wave-induced velocity (U_w), i.e. $U_c/U_w \sim 1.7 - 2$. The bottom roughness for **R3** and **R4** is characterized by relatively mild ripples with wavelength of 90 cm and height of 2 cm, whereas ripples corresponding to **R9** have similar wavelength, but are 5 cm in height. The mean velocity profiles for all the runs indicate the presence of a log layer above the roughness sublayer. To non-dimensionalize the profiles, the reference height is selected to maximize the log region, the friction velocity (u*) is matched with the peak value of the Reynolds shear stress, and the hydrodynamic roughness (z_0) is least square fitted to the log region of the velocity profile. Scaling of elevation with inner variable, i.e. $z^+ = zu^*/\nu$, where ν is the kinematic viscosity, shows that the momentum deficit increases with roughness height. When adjusted for this deficit, the non-dimensional profiles collapse within the log layer. The scaled momentum in the roughness sublayer is much lower when the current is perpendicular to the ripple crests (**R3** and **R4**), than that when the flow is parallel to the ripples (**R9**). Velocity profiles across different streamwise locations in the same PIV set collapse above the log layer, but diverge within one ripple height above the seabed. The velocity is lowest above the ripple crests, consistent with laboratory data. Shear stress profiles peak in the bottom portion of the log layer. Within the log layer, they decrease with increasing elevation. The stress profiles do not scale well with either z_0 or $z^+$and the appropriate scaling is a matter under consideration. One-dimensional spatial energy spectra ($E_{11}(k_1)$), ($E_{33}(k_1)$)), calculated at various heights above the seabed, reveal increasing anisotropy with decreasing elevations. An inertial range approaching a -5/3 slope develops only at low wavenumbers at the highest elevations.