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Observations of momentum fluxes in the wind-wave boundary layer during Tropical Cyclone Olwyn

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In-situ measurements of ocean wind stresses are complicated by the fast size of the oceans and the atmospheric boundary layer. A common method to approximate the wind stress is by measuring the turbulent momentum flux directly and assuming that turbulent stresses dominate the total stress at these instrument heights. However, when wind speeds increase, the height at which these instruments are mounted (typically at 5-10 m from the ocean surface) becomes of similar order of magnitude as the wave height. As waves disturb the wind field close to the ocean surface, and hence impose stresses on the air, observations of the turbulent momentum flux during high wind speeds are expected to be considerably smaller than the actual local wind stress. In this study, high frequency measurements of wind speed (at 8.8 m and 14.8 m above the ocean surface) and ocean surface elevations during the near passage of Tropical Cyclone Olwyn are presented. The measurements allow for an independent comparison of the total wind stress and turbulent stresses in the wind-wave boundary layer up to wind speeds of 22 m/s (at 10 m height). The wave-induced stress during Tropical Cyclone Olwyn is estimated using the parameterization of Donelan et al. (2006). Our results confirm for increasing wind speed, the discrepancy between the total stress and the turbulent stress increases as well. The difference between the measured total stress and the turbulent stress at the two instrument heights compares well to the predicted wave-induced stress at these corresponding heights. Thus, measurements of wind stresses based on turbulent stresses alone will underestimate wind stresses during high wind speed conditions. Through a basic shear stress balance, we show that the wave-induced stress can be approximated through a simple predictive model using only observations of the turbulent stress and the significant wave height.