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Wind-wave and current interactions in the upper ocean

Mostafa Bakhoday Paskyabi (1), Ilker Fer (1), and Alastair D. Jenkins (2)

(1) University of Bergen, Geophysical Institute, Allégaten 70, 5007 Bergen, Norway, (2) Uni Computing, Geophysical Institute, Allégaten 70, 5007 Bergen, Norway

Observations were made of atmospheric forcing, surface waves and currents, and temperature, salinity and current profiles in the water column using a bottom-anchored mooring line equipped with densely-spaced oceanographic sensors and a Wavescan surface buoy fitted with a downlooking acoustic Doppler current profiler (ADCP) and a 5-m meteorological mast. The mooring was deployed on 16 June 2010 over the 277 m isobath on the continental shelf west of Trondheim, mid-Norway. Two-month long time series were recovered and analysed. The water column was strongly stratified, with the buoyancy frequency decreasing linearly from about 11 cycles per hour (cph) to 3 cph in the upper 100 m. The depth-averaged currents were dominated by the semi-diurnal tides. Frequency spectra of the baroclinic currents show a broad-band (between 24 and 6 h period) enhanced variance in the clockwise rotating component with a peak at the near-inertial frequency, suggesting that wind forcing energized the internal wave continuum. Cross-spectra between the wind speed and upper layer currents show high correlations. A significant peak is observed at the semidiurnal frequency in the counter-clockwise rotating component, suggesting the presence of internal tides. A storm with wind speed of about 20 m s^{-1} observed early in the deployment was associated with significant wave heights reaching 6 m, whereas the typical wave height was 1-2 m for the remaining of the record. The interaction of the near surface tidal current with the wind stress, and the modified wind-generated surface wave as a sea surface response to the atmospheric forcing are analysed. This Lagrangian surface current can be expressed as a vector sum of a quasi-Eulerian current, the wave-induced Stokes drift, and the tidal current. The observed wave energy spectrum is used to calculate the Stokes drift. The quasi-Eulerian current and Stokes drift are compared with the wind speed magnitude and direction. The contribution of the wave-induced Stokes drift to the vertical momentum transport is calculated numerically using the General Ocean Turbulence Model with modifications to include i) the effects of Stokes shear production on the conventional shear production, ii) revised Coriolis terms in the momentum equations, iii) an extra momentum source term associated with wave energy dissipation, and iv) an altered upper boundary condition due to wave energy input.