Coupling of wave and circulation models in coastal-ocean predicting systems: A case study for the German Bight

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Overview

This study addresses the coupling between wind wave and circulation models on the example of the German Bight. This topic reflects the increased interest in operational oceanography to reduce prediction errors of state estimates at coastal scales. The uncertainties in most of the presently used models result from the nonlinear feedback between strong tidal currents and wind-waves, which can no longer be ignored, in particular in the coastal zone where its role seems to be dominant. The individual and collective role of wind, waves and tidal forcing are quantified. Effects of ocean waves on coastal circulation and SST simulations are investigated considering wave-dependent stress and wave breaking parameterization. Also the effect which the circulation exerts on the wind waves is tested for the coastal areas using different parameterizations. The improved skill resulting from the new developments in the forecasting system, in particular during extreme events, justifies further enhancements of the coastal pre-operational system for the North Sea and German Bight.

Pre-operational wave and circulation models

The nested grid model system for the North Sea-Baltic Sea and the German Bight provides real time simulations together with a 3-day forecast. Atmospheric forcing and tides play an essential part in the synoptic and neap-spring variations of SST, stratification and tidal fronts. The response of wave-, hydro- and sediment dynamics to atmospheric and tidal forcing is studied as well. The pre-operation wave- and circulation model results for the North Sea and the German Bight are available under Coastal Observing System for Northern and Arctic Seas (COSYNA) web Site: http://www.coastlab.org.

Coupling between wave and circulation models

GETM/GOTM were modified to account for:
- 3D radiation stress due to the transfer of momentum by waves (Mellor, 2011) or Vortex Force formulation (Arduhin et al., 2008, Bennis et al., 2011)
- Bottom friction modifications —as function of base roughness and wave properties (Moghimi et al., 2013)
- Turbulent kinetic energy due to waves friction (wave breaking/white capping and bottom dissipation)

WAM Developments (Cycle 4.5.3):
- Source function integration scheme of Hersbach and Janssen (1999)
- Depth induced wave breaking of Battjes & Janssen (1978)

Wave impact on sediment dynamics

The spatial resolution of satellite observations is comparable with the one of the high-resolution numerical model, which enables identifying and validating new and so far unknown patterns of the sediment distribution such as the oscillatory behaviour of sediment pools to the north of the back-barrier basins and clear propagation patterns of tidally driven suspended particulate matter outflow into the North Sea. The improved skill resulting from the new developments in the forecasting system, in particular during extreme events, justifies further enhancements of the coastal pre-operational system for the North Sea and German Bight.

Impact of coupling between wave and circulation models.

Left: Sea Level Elevation (SLE) difference between coupled and circulation model only. Right: SLE variability in two locations shown above (black: tide gauge observations; blue line without wave effects, red line coupled wave-circulation models).

Impact of coupling between wave and circulation models.

Left: Spectral density from observations (top), WAM-only (middle) and coupled WAM-GETM simulations (bottom), WAM with coupled wave-circulation run (blue) and wave on (top) and wave off (bottom) for July 1999.

Impact of coupling between wave and circulation models.

Left: Vertical integrated SPM surface concentrations (top) high water, (bottom) low water. The fine SPM concentrations during high water are only half as large as during flood and ebb. Right: (top) MERIS derived surface images of SPM concentration (bottom) zoom into SPM concentrations (normalized with respect to the maximum) from simulations and observations.