Particle transport model sensitivity on wave-induced processes in the coupled model system

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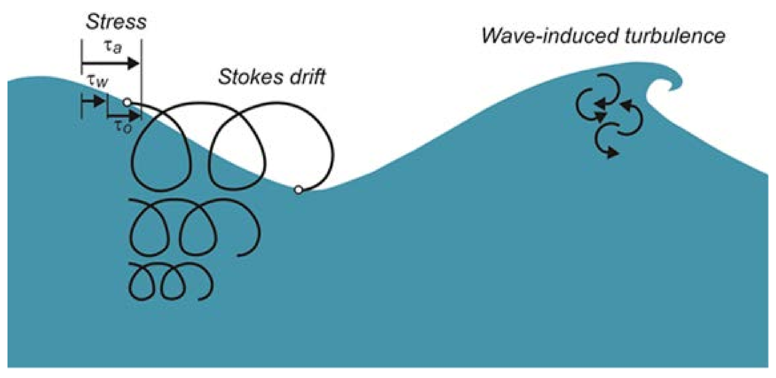
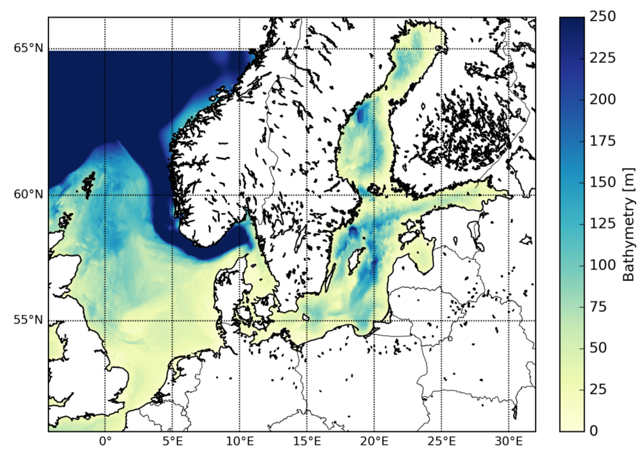
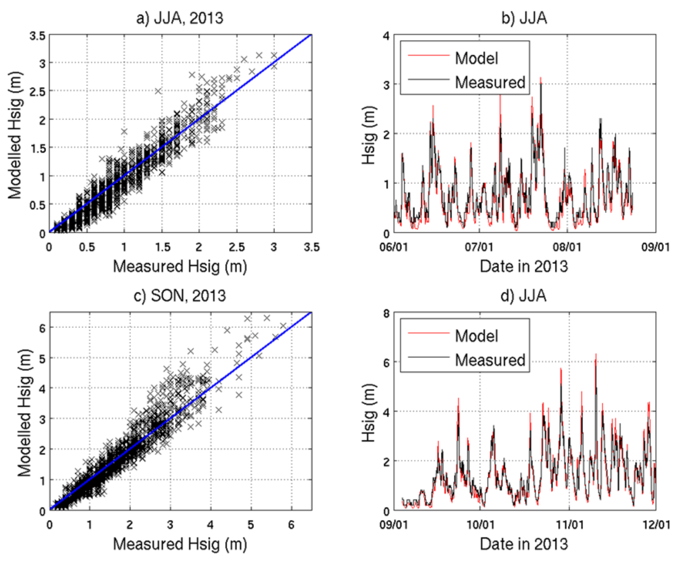
Overview



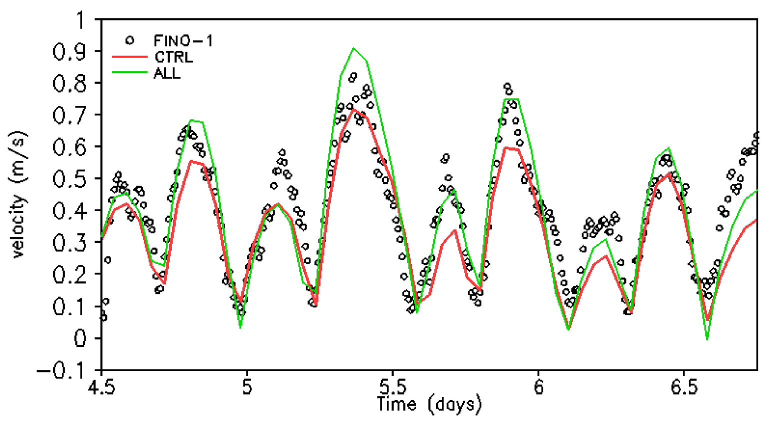
Wave-ocean interaction mechanisms included in this study (Alari et al., 2016).

Different effects of wind waves on the hydrodynamics in the North Sea and Baltic Sea are investigated using a coupled wave (WAM) and circulation (NEMO) model system as part of the Geesthacht Coupled cOAstal model SysTem GCOAST. The terms accounting for the wave-current interaction are: the Stokes-Coriolis force, the sea-state dependent momentum and energy flux. The role of the different wave parametrizations are investigated using a particle-drift model. Those particles can be considered as simple representations of either litter, oil fractions, or fish larvae. In the ocean circulation models the momentum flux from the atmosphere, which is related to the wind speed, is passed directly to the ocean and this is controlled by the drag coefficient. However, in the real ocean, the waves play also the role of a reservoir for momentum and energy because different amounts of the momentum flux from the atmosphere are taken up by the waves. In the coupled model system, the momentum transferred into the ocean model is estimated as the fraction of the total flux that goes directly to the currents plus the momentum lost from wave dissipation. Additionally, we demonstrate that the wave-induced Stokes-Coriolis force leads to a deflection of the current. During the extreme events the Stokes velocity is comparable in magnitude to the current velocity. So the resulting wave-induced drift is crucial for the transport of particles in the upper ocean. The performed sensitivity analyses demonstrate that the model skill depends on the chosen processes.


GCOAST model bathymetry.

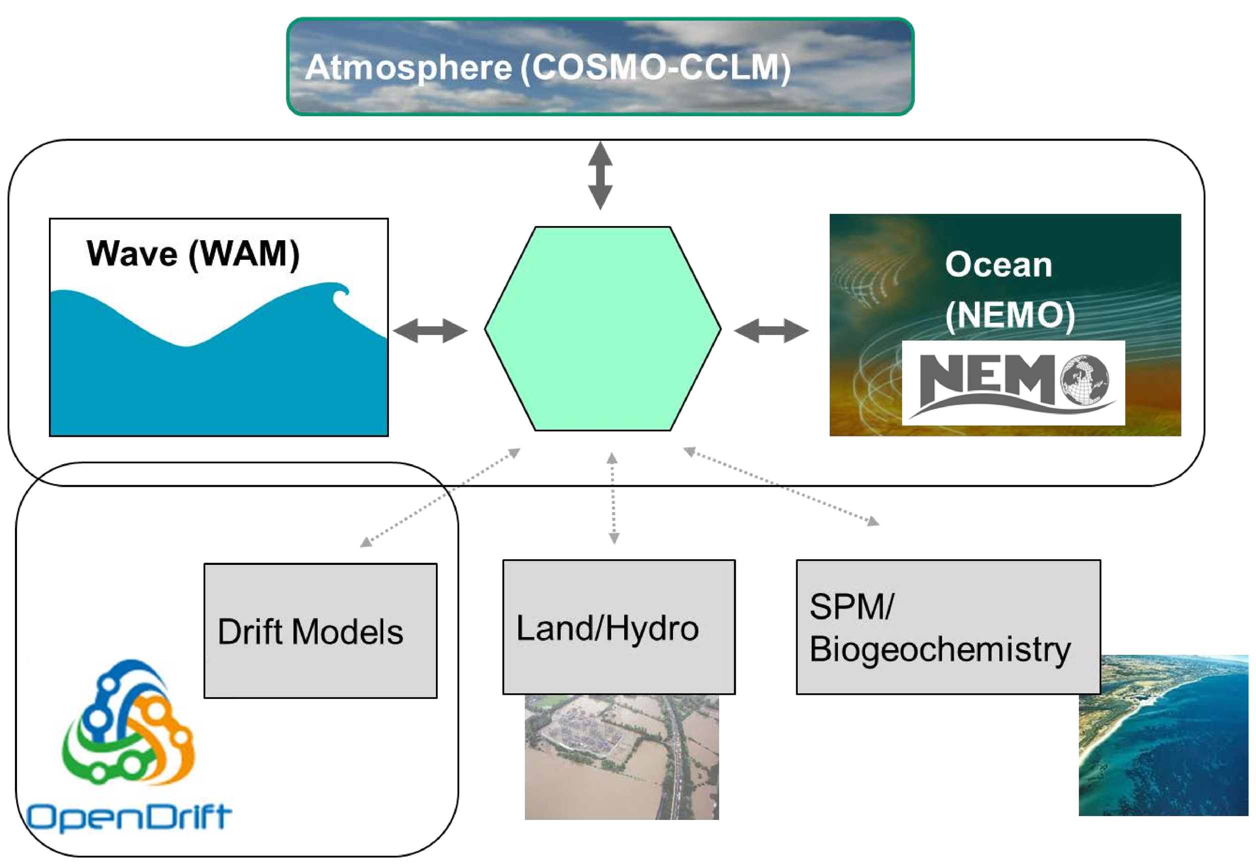


Significant wave height validation at a buoy station located in the Northern Baltic Proper. Scatter plot (left) and time-series (right) comparisons are presented.



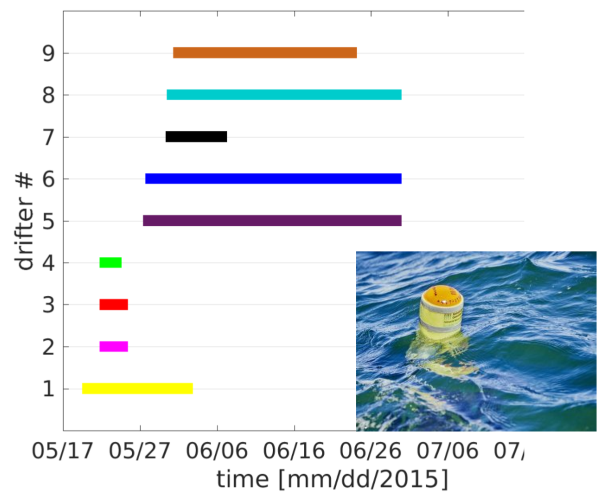
Time variability of velocity (m/s) at 4 m from ADCP data of FINO-1 station (circles) and for CTRL (red) and ALL (green line) model runs.

GCOAST Model System

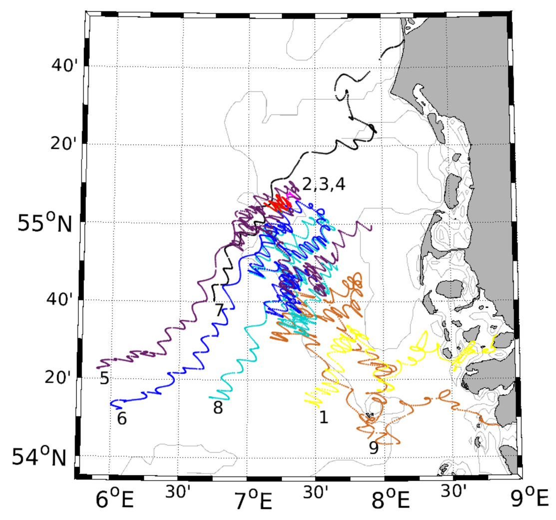


	NEMO	Stokes-Coriolis force	Sea-state dependent momentum flux	Wave breaking
CTRL (NOWAVES)	√			
STCOR	√	√		
TAUOC	√		√	
TKE	√			√
TAUST	√	√	√	
ALL	√	√	√	√

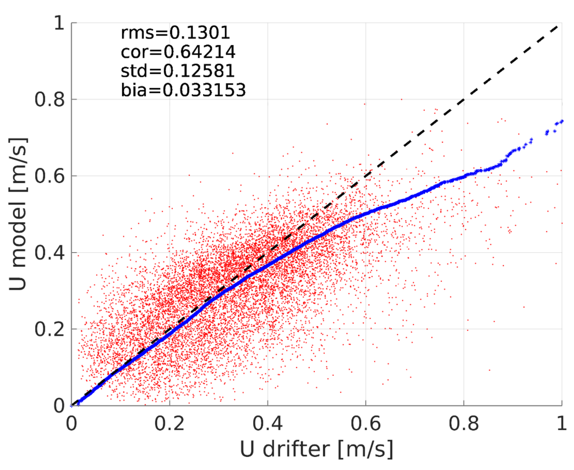
Model experiments.

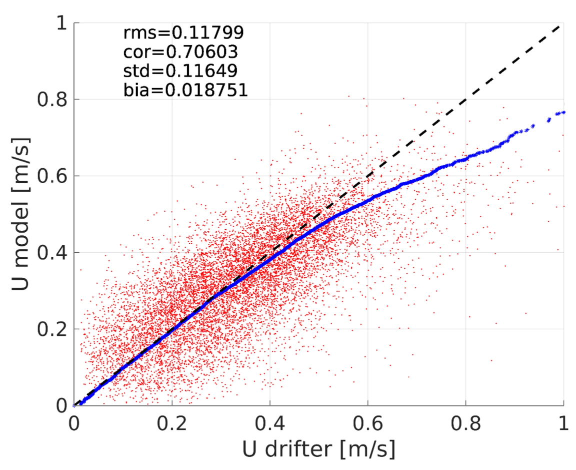


Deployment of HZG drifters.


HZG drifter trajectories.

Validations

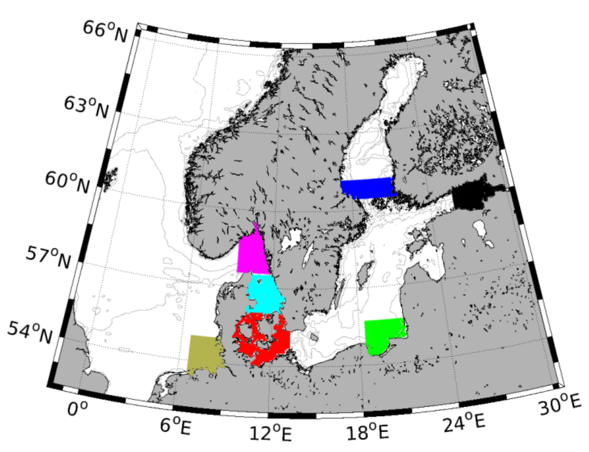


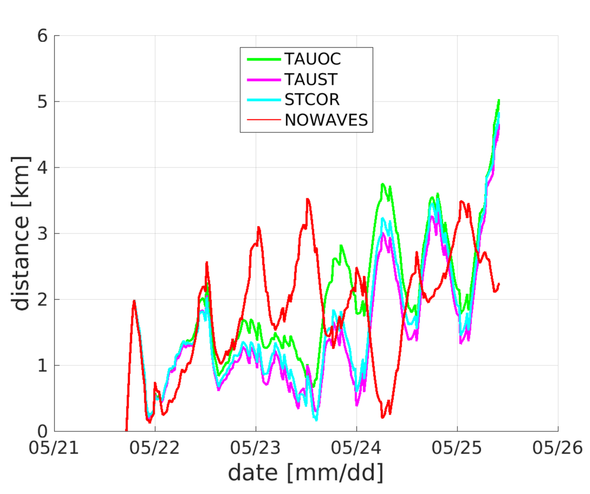


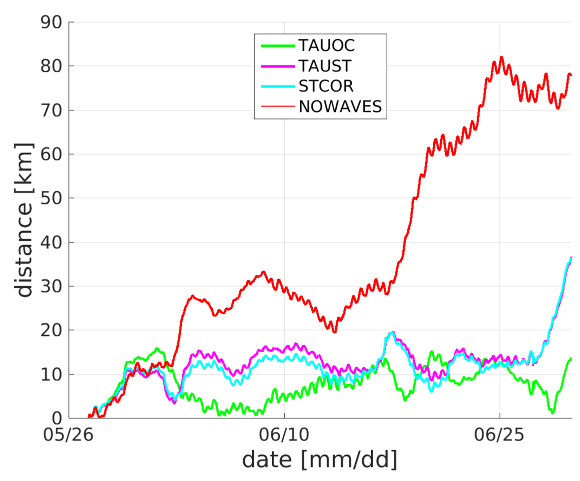
Scatter plots of surface velocity magnitude (m/s) between observed (drifter) data (x-axis) *versus* CTRL (left) and ALL (right) model runs.

Particle Transport Model Results

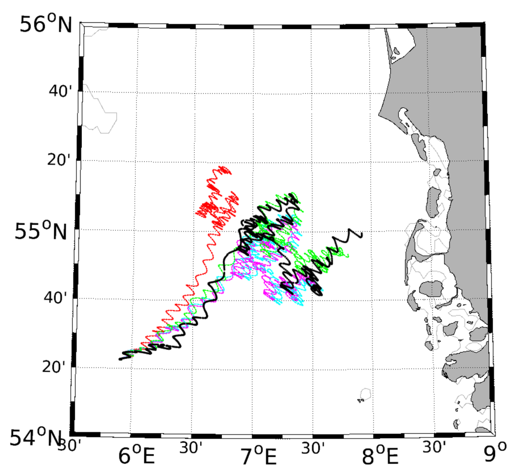
Initial condition – Seed on 01.10.2013 and 04.12.2013

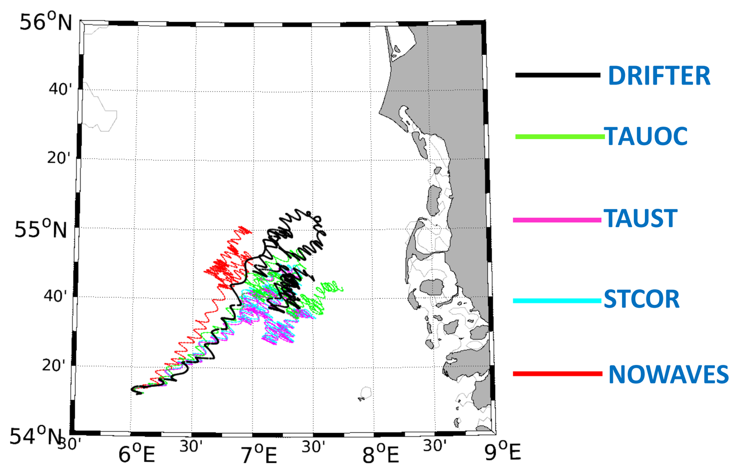






Time series of the distance (m) between the observed and model drifter trajectories.

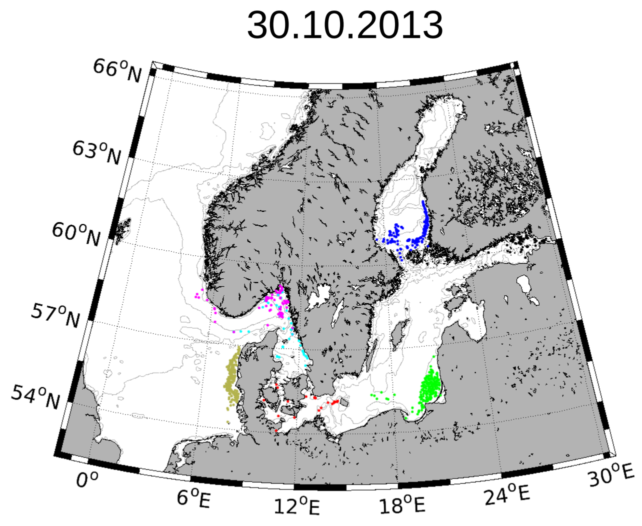




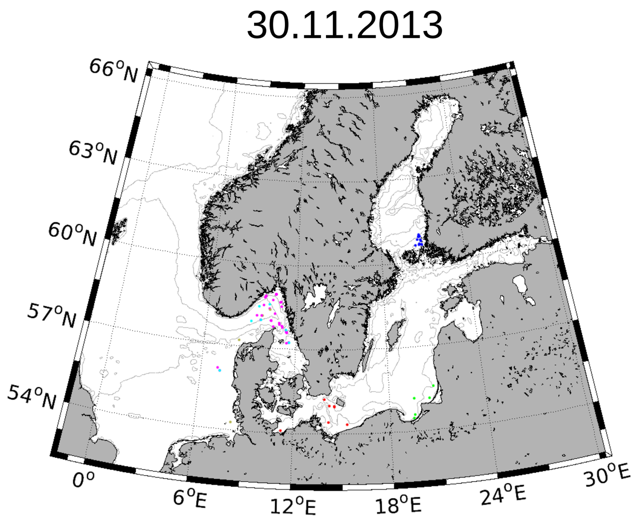
Drifter trajectories: observed (black line) and modelled (the colors of the different experiments are given in the legend).

ALL

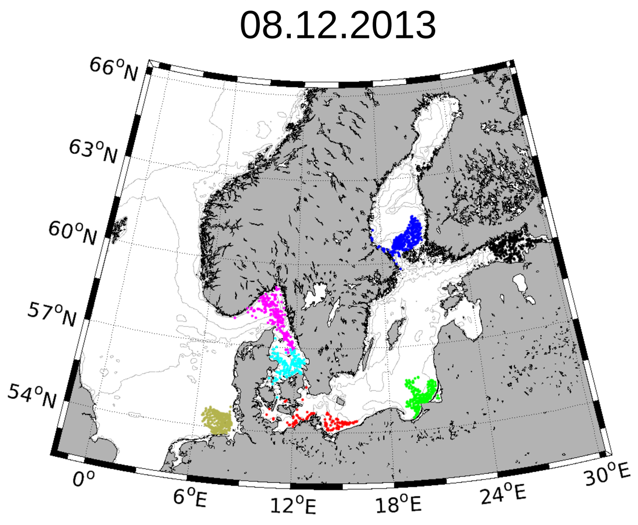
1 month after release 30.10.2013



2 months after release 30.11.2013

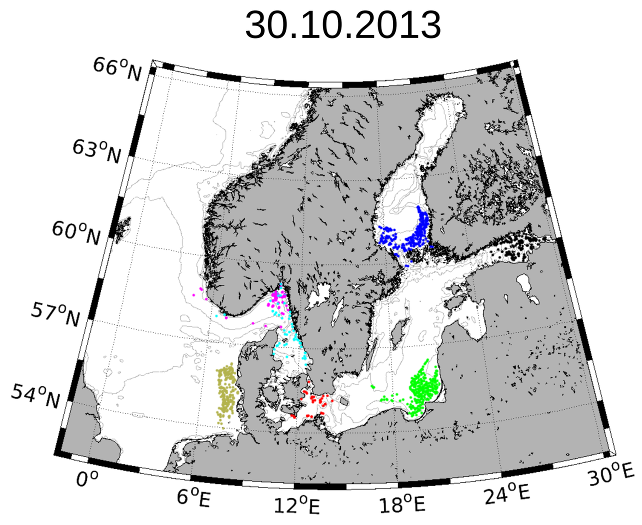


4 days after release 08.12.2013

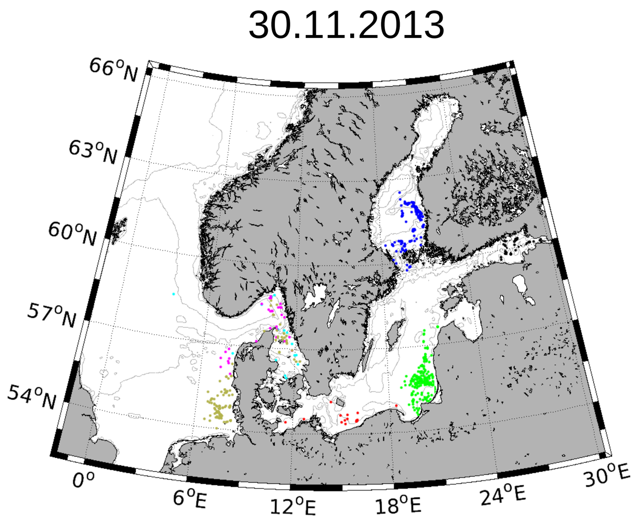


NOWAVES

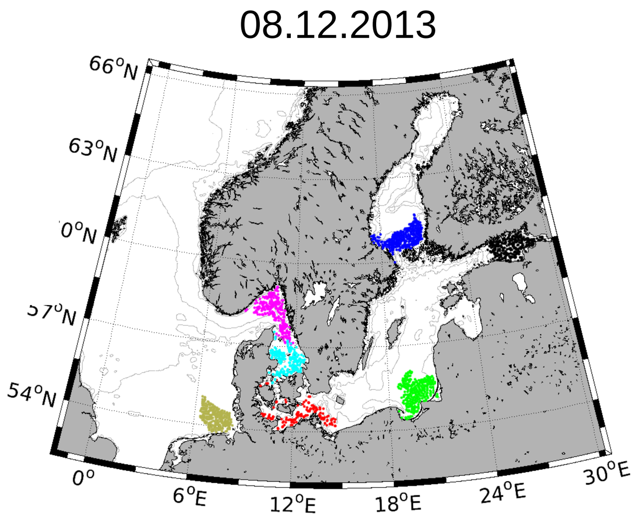
1 month after release 30.10.2013



2 months after release 30.11.2013



4 days after release 08.12.2013



Particles transport distributions: initial data (top pattern), ALL run (middle patterns) and NOWAVES run (bottom patterns). To investigate the coupling effects and the influence of extreme events, a longer period (3 months) including 1 powerful storm and several weaker storms and a shorter period including 1 powerful storm was chosen

Conclusions

The analyses of modelling results and available observations reveal a closer match with observations for the circulation model forced by sea state dependent fluxes and Stokes-Coriolis force, especially during extreme events. The performed sensitivity analyses demonstrate that the model skill depends on the chosen processes. The using of a coupled model system reveals that the newly introduced wave effects are important for the drift-model performance, especially during extremes. Those processes cannot be neglected by search and rescue, oil-spill, transport of biological material, or larva drift modelling.

References:

Alari V., Staneva J., Breivik O., Bidlot J.-R., Mogensen K. and Janssen P. (2016). *Surface wave effects on water temperature in the Baltic Sea: simulations with the coupled NEMO-WAM model*. Ocean Dynamics (66), doi:10.1007/s10236-016-0963-x.

Staneva J., Wahle K., Koch W., Behrens A., Fenoglio-Marc L. and Stanev E. (2016). *Coastal flooding: impact of waves on storm surge during extremes – a case study for the German Bight*. Nat. Hazards Earth Syst. Sci. (16), doi:10.5194/nhess-16-2373-2016.

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