Coastal flooding: Impact of wave-current interaction in coastal ocean forecasting systems

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14TH INTERNATIONAL WORKSHOP ON WAVE HINDCASTING AND FORECASTING/ 5th COASTAL HAZARDS SYMPOSIUM and 2nd JCOMM Scientific and Technical Symposium on Storm Surges

Key West, Florida, USA, Nov 8-13 2015

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Motivation

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- In the last decade North Europe was affected by severe storms which caused serious damages in the North Sea coastal zones
- Precise coastal predictions of extreme events can contribute to avoid human and material losses
- The joint impact of surges, currents and waves cannot be considered separately for coastal predictions (non-linear feedback between strong currents and wind waves)

Outline

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- Model setup (hydrodynamic and wave model)
- Integrated Model System
- Impact of coupling on hydrodynamics (barotrop and barocline)
  - storm Xaver
  - storm Britta
- Summary and Conclusions

GETM - Nested models

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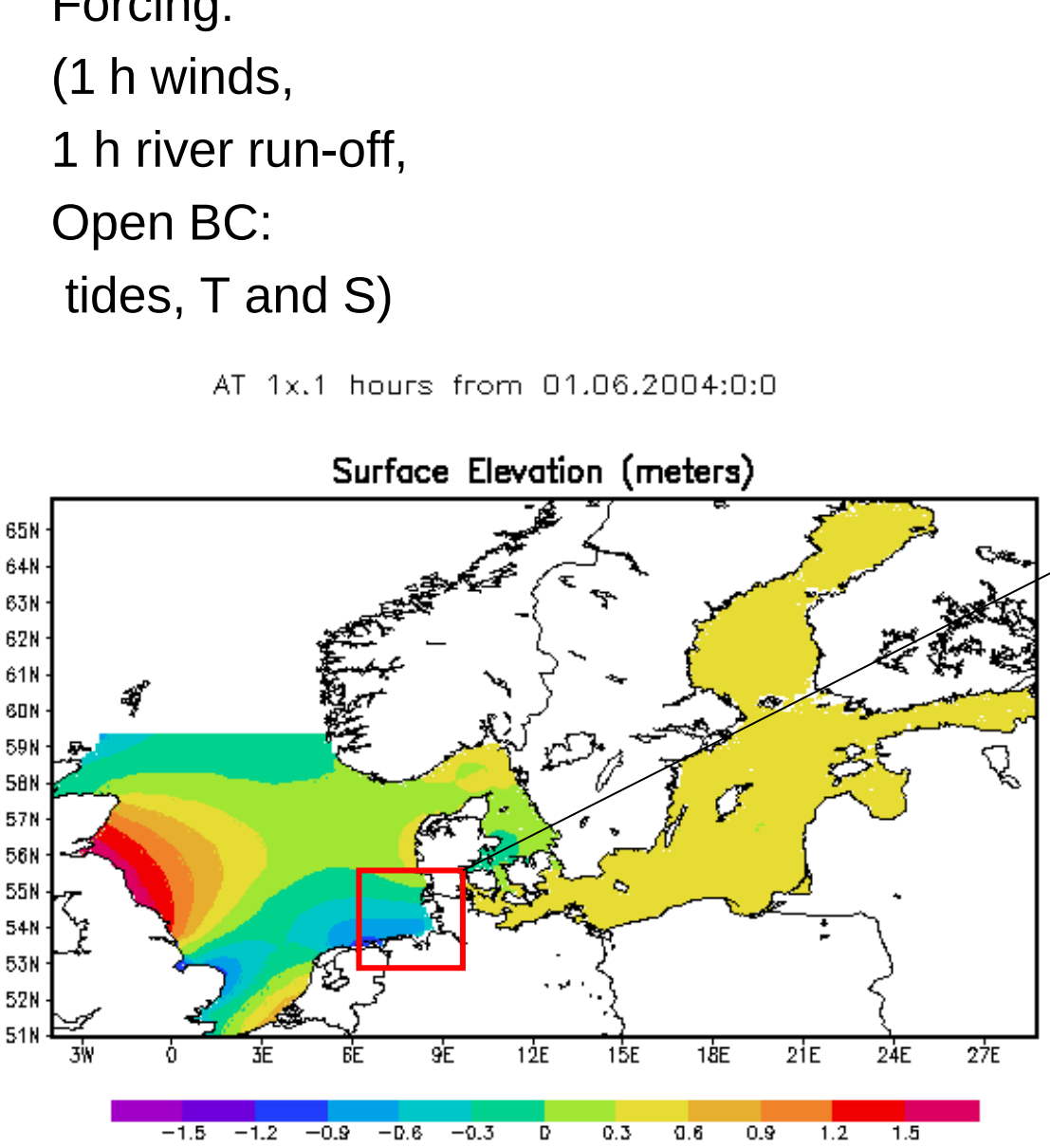
Forcing:

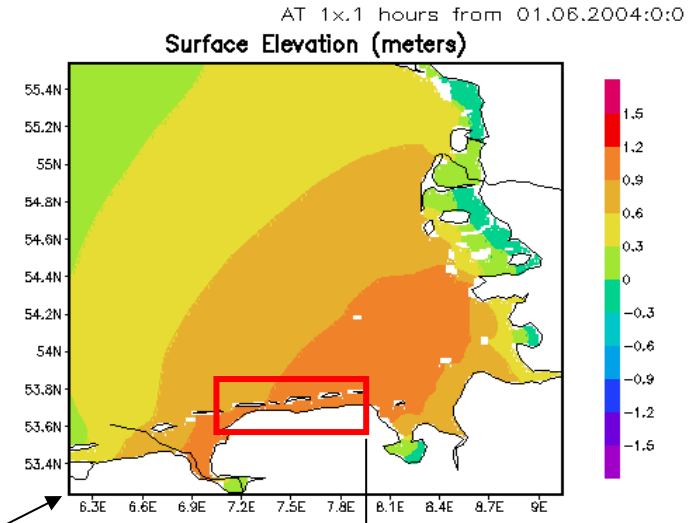
(1 h winds,

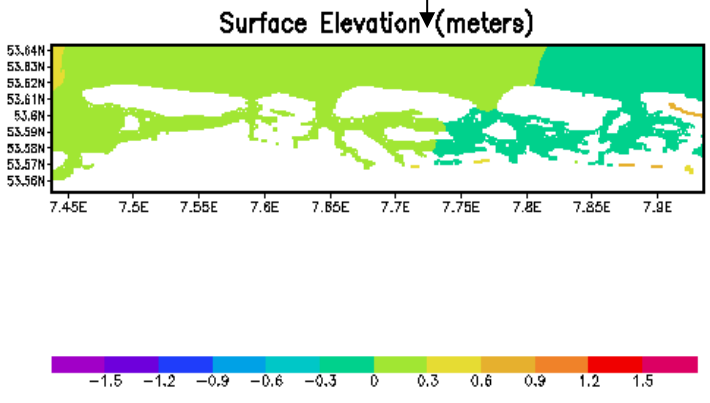
1 h river run-off,

Open BC:

tides, T and S)







WAM – Nested models

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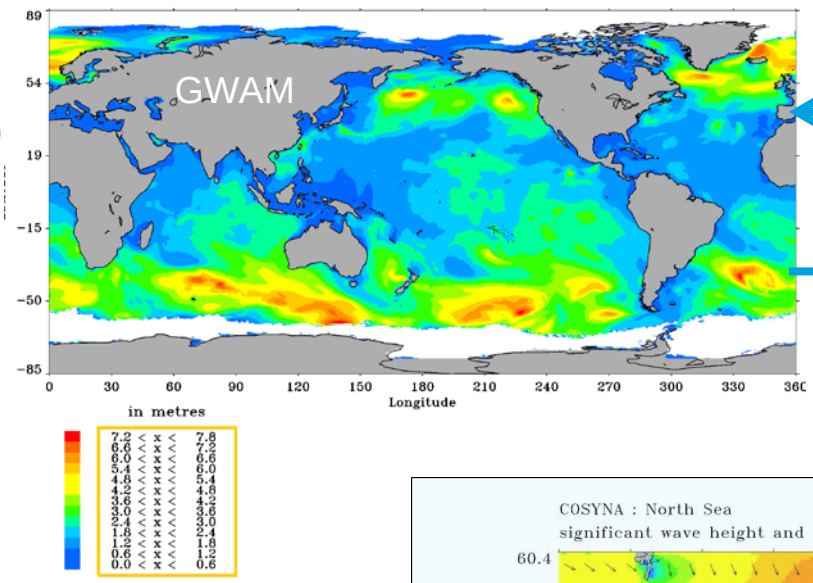
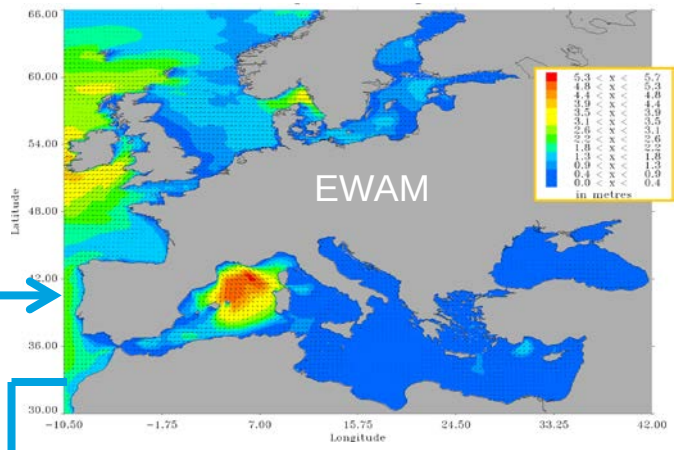
DWD

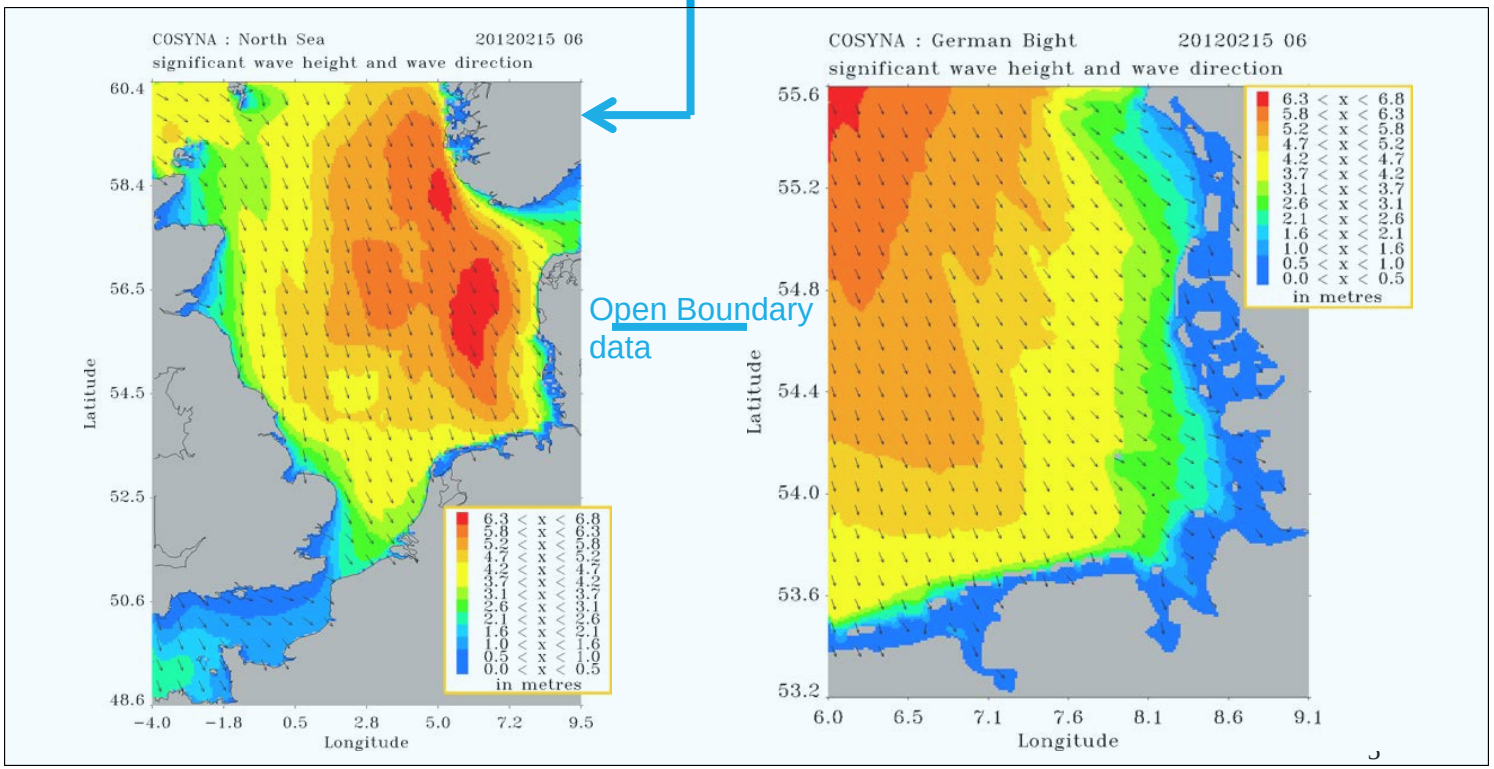


data assimilation

Jason2

Open Boundary data





Open Boundary data

HZG : pre-operational wave forecast since September 2009.
spatial resolution :
North Sea ~ 5 km,
German Bight ~ 900 m
(twice a day 72 hours forecast,
winds from DWD)

Integrated model system

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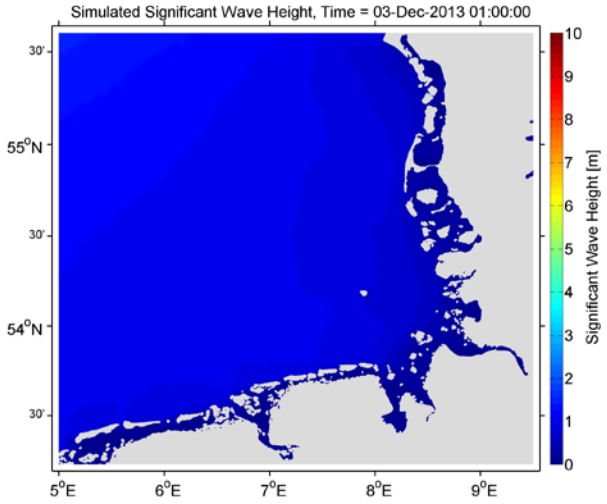
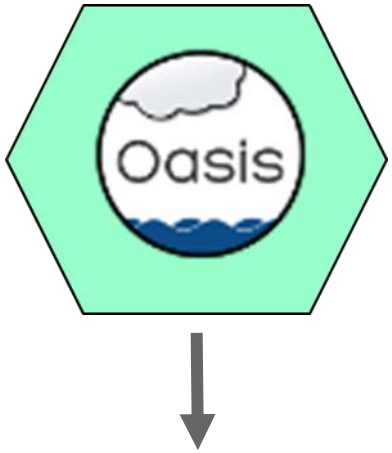
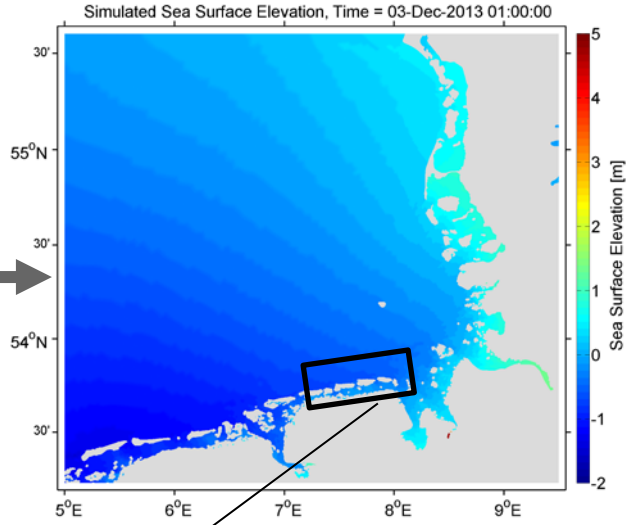
Wave Model (WAM)

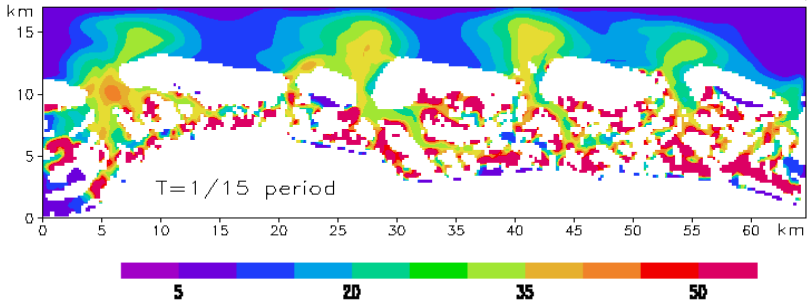




Circulation Model (GETM)



SPM Model (in GOTM)



Model developments

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GETM&GOTM Developments

The original versions of GETM and GOTM were modified to account for the following:

- 3D radiation stress (RS) due to the transfer of momentum by waves (Mellor 2011) Kummar et al (2011)-smooth vertical distribution, later criteria by Mellor (2013)
- Bottom friction modifications –as function of base roughness and wave properties (Styles and Glenn (2000)
- turbulent kinetic energy due to waves friction (wave breaking/white capping and bottom dissipation) - wave enhanced turbulence - in GOTM
- Stokes drift (transfer wave force to Eulerian framework)
- Vortex Force formulation (VF) (Ardhuin et al, 2008, Bennis et al., 2011) (on-going work)

➔ effects the tidal current profiles in shallow areas, deepens the surface mixed layer

➔ gradient of the radiation stress becomes important for the mean water level setup and for alongshore currents generated by waves in the surf zone

Storm Xaver on 06.12.2013

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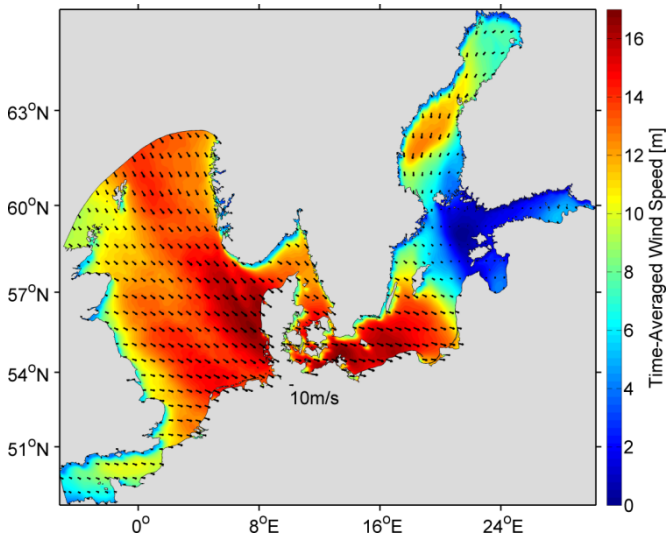
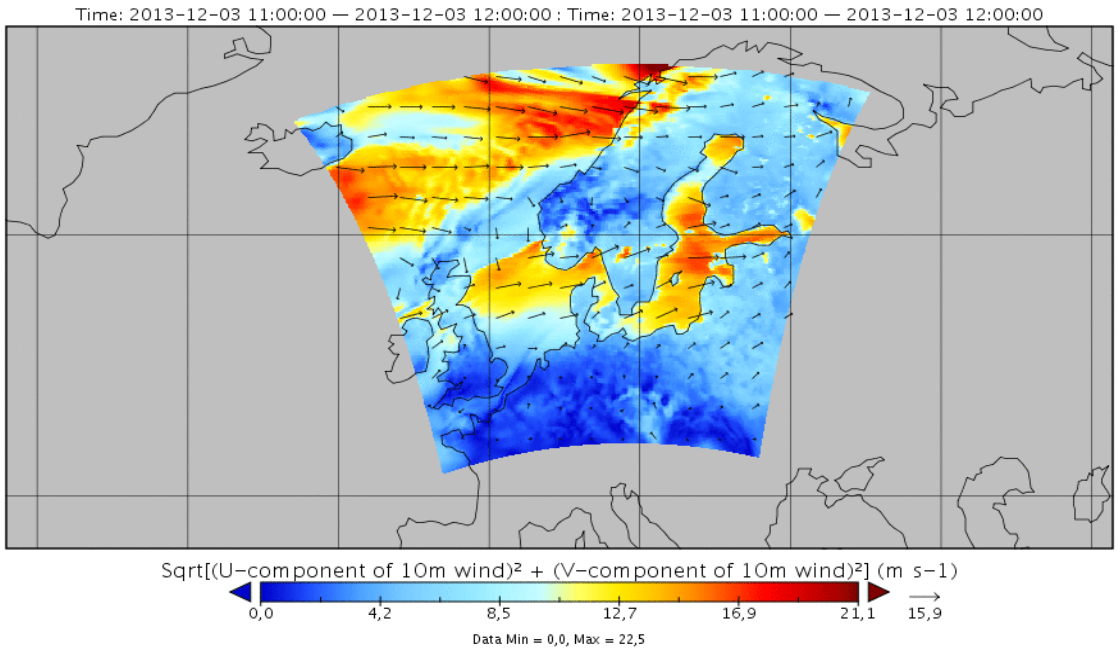


Wind speed averaged over two days of storm event

Wind speed at 10m (m/s)



Significant wave height (m) during Xaver

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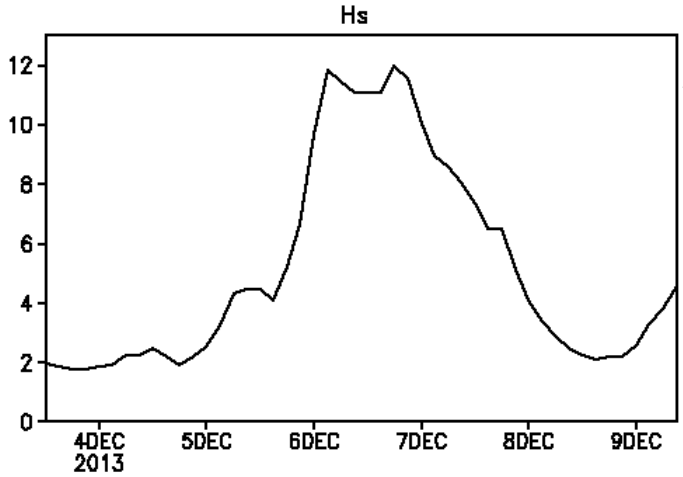

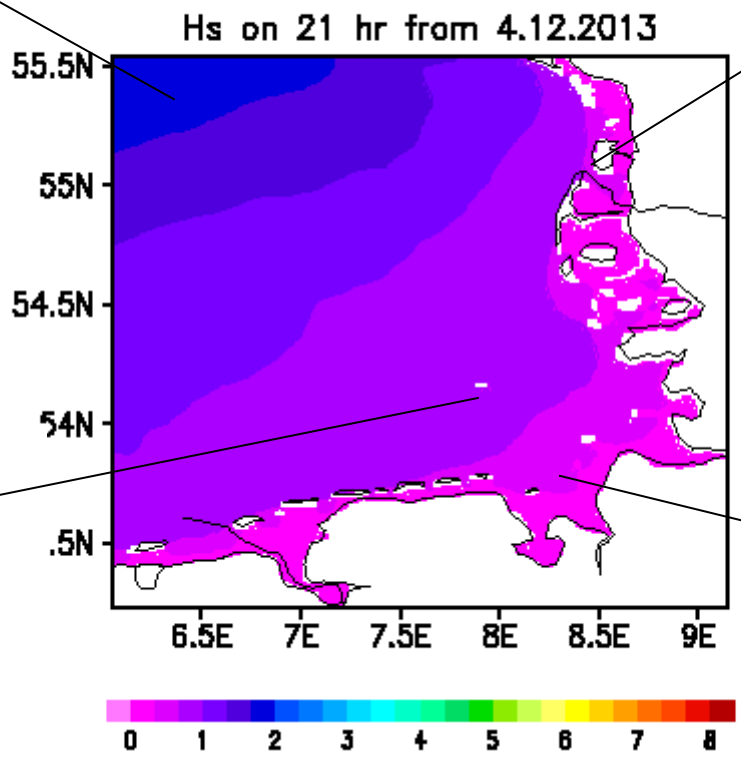

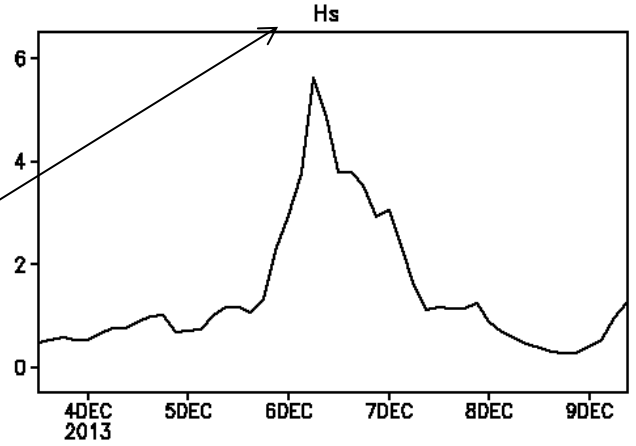

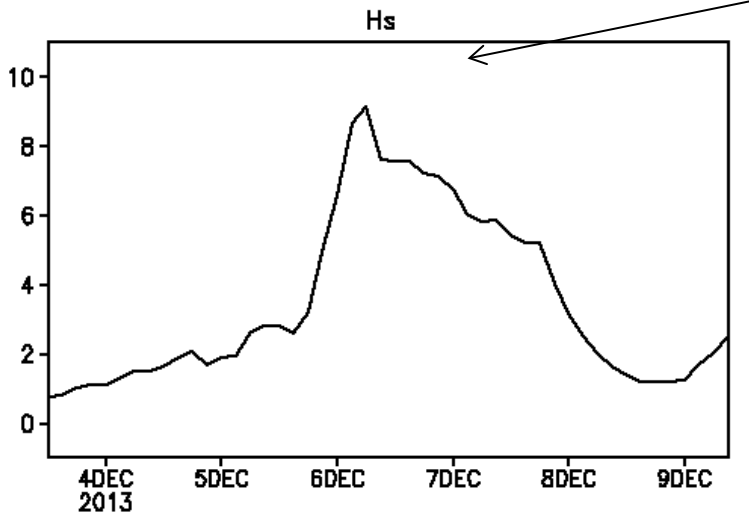

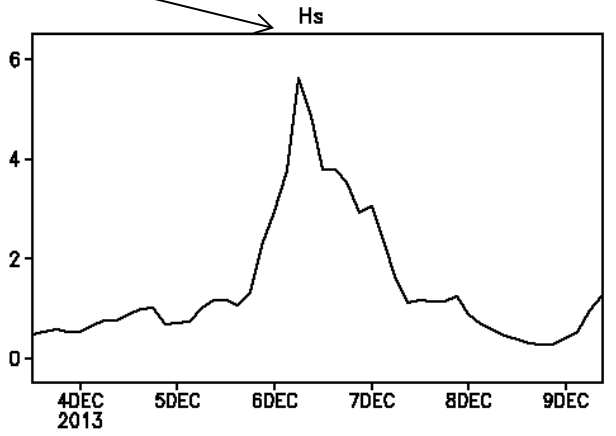

Impact of coupling with waves on hydrodynamics sea level elevation

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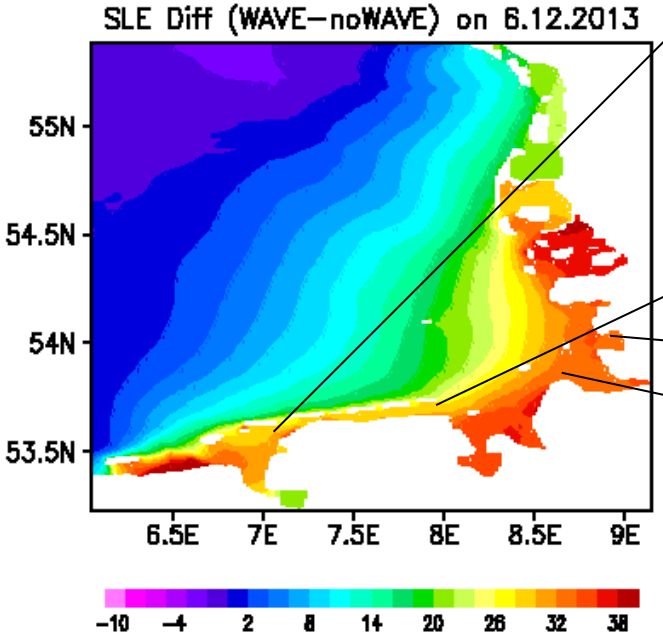
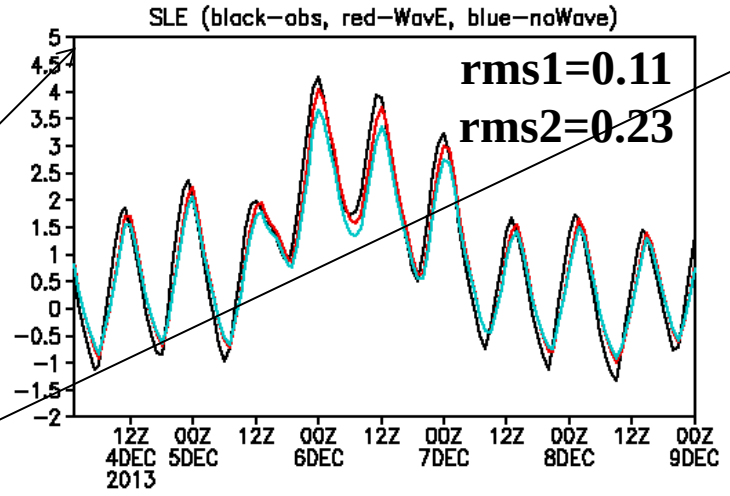
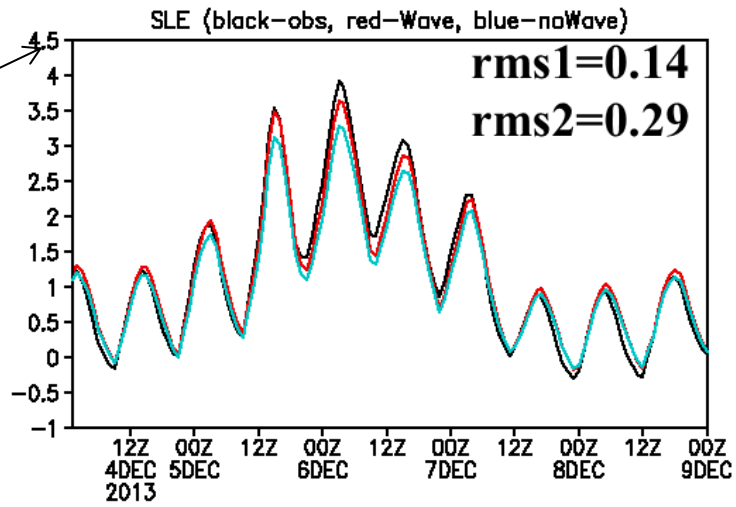
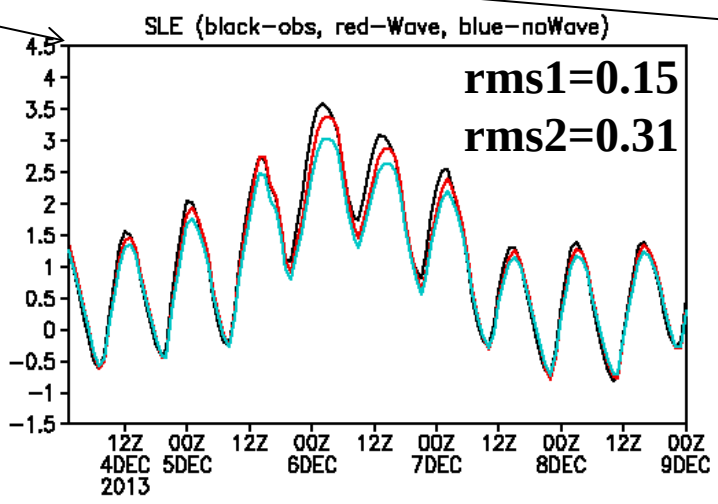
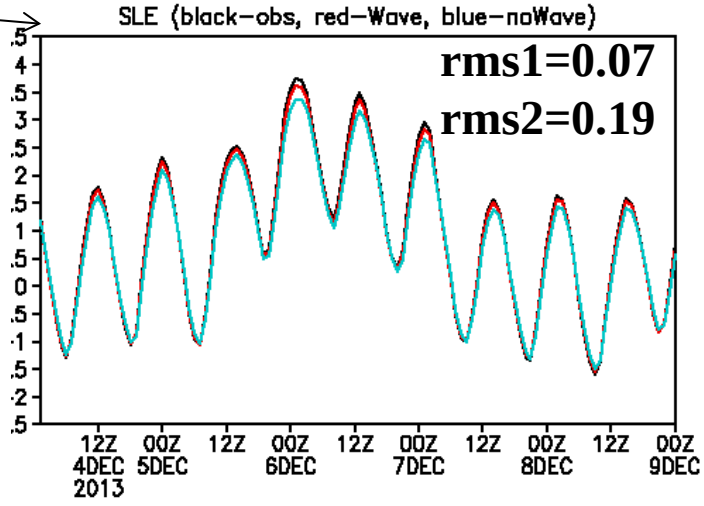


SLE difference (cm)









SLE (m) -- observations
-- coupled
-- uncoupled

Impact of coupling with waves on hydrodynamics bottom salinity difference (psu)

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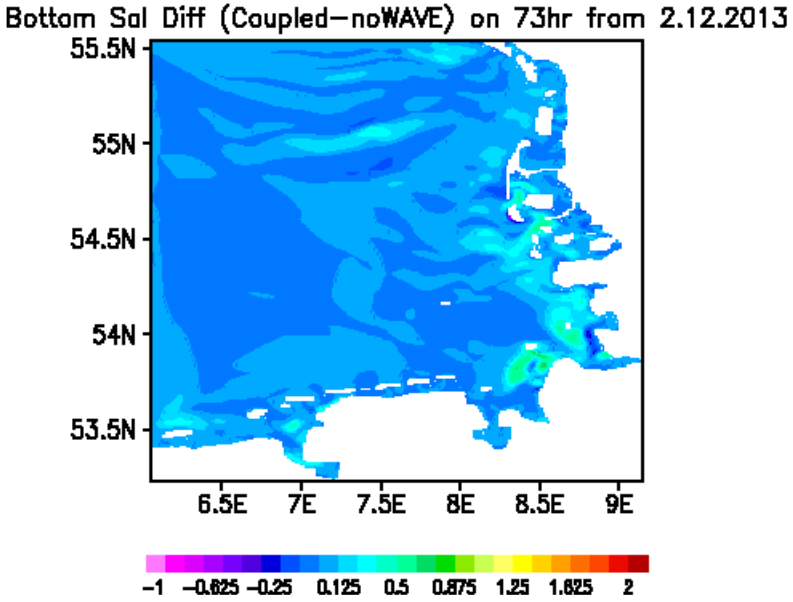

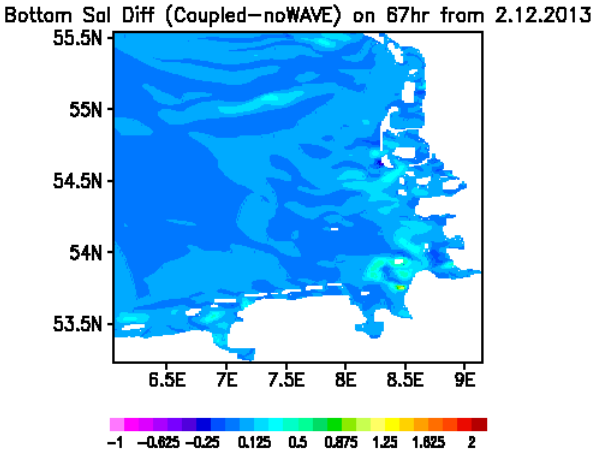

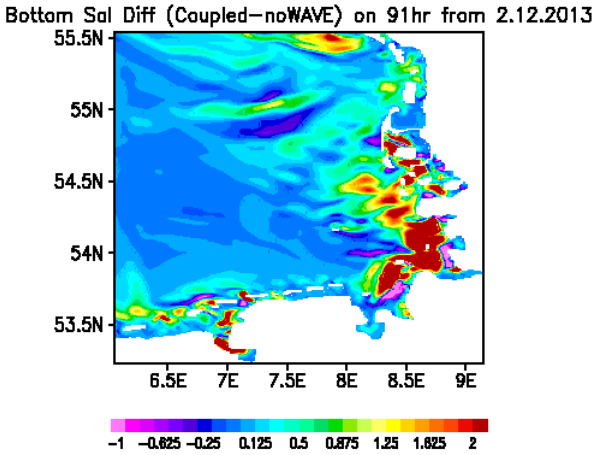

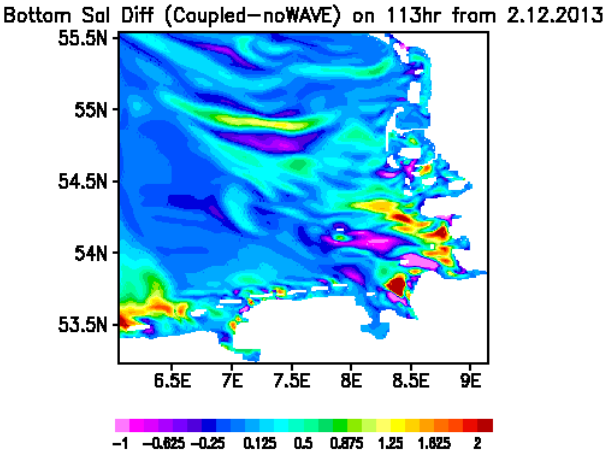

Storm Britta on 01.11.2006

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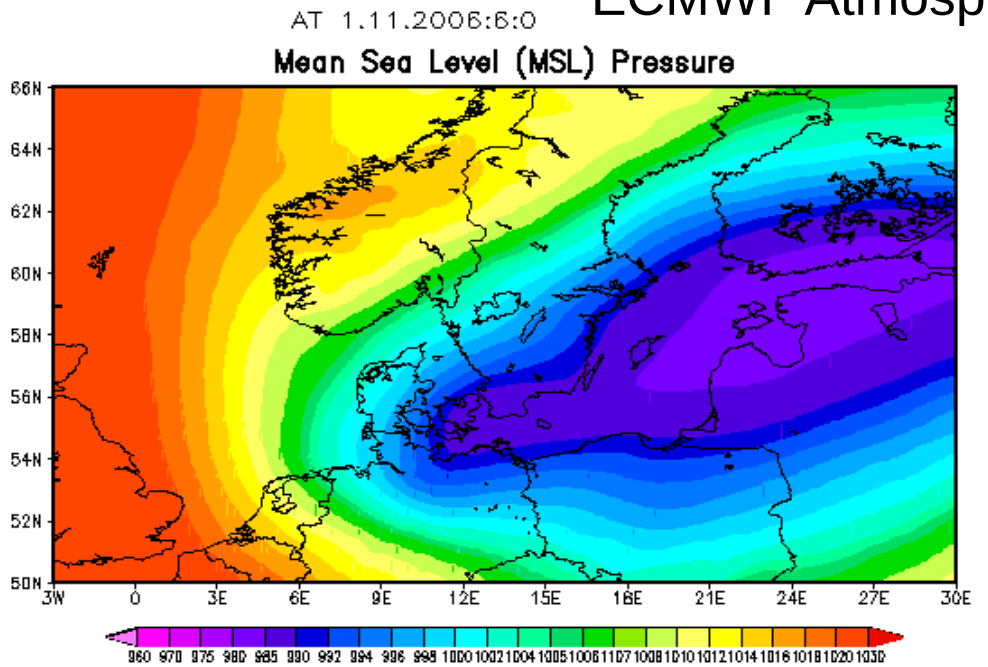
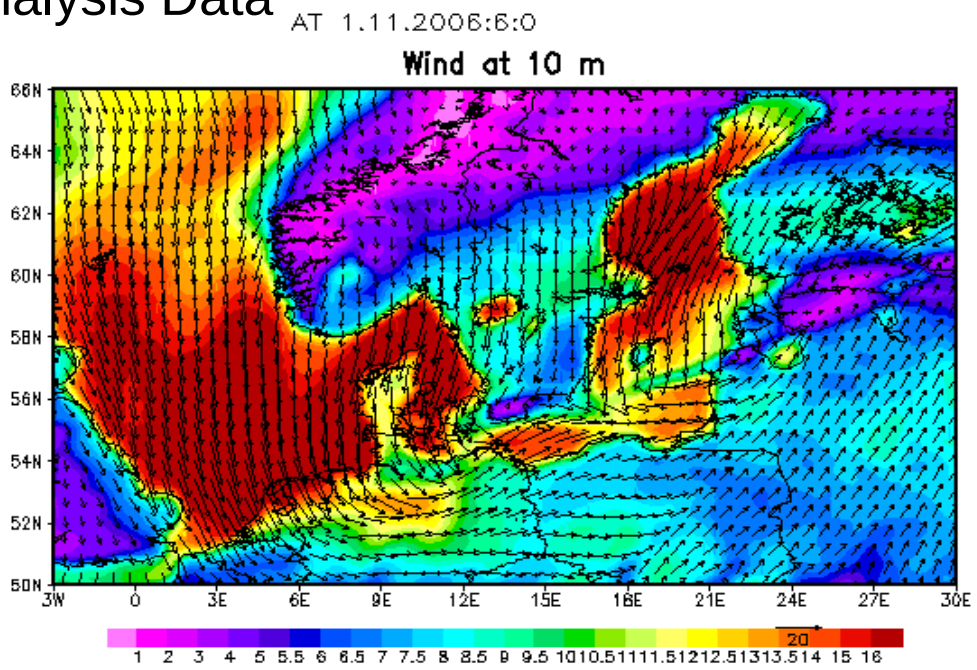
ECMWF Atmospheric Analysis Data





Carolinensiel

Spikeroog

Wilhemshaven

Significant wave height and TKE dissipation

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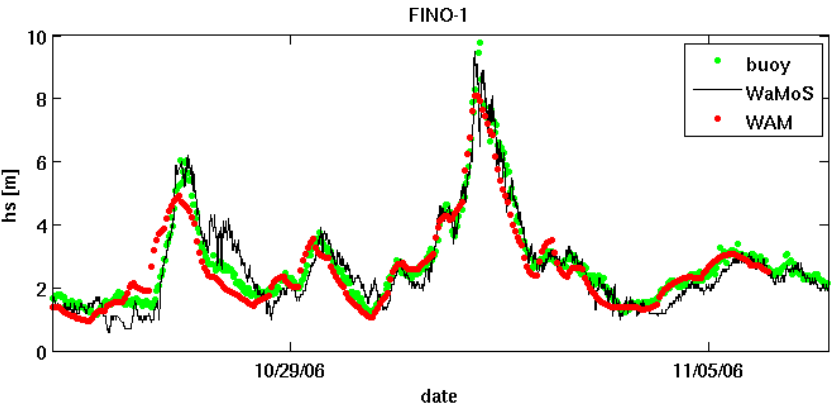

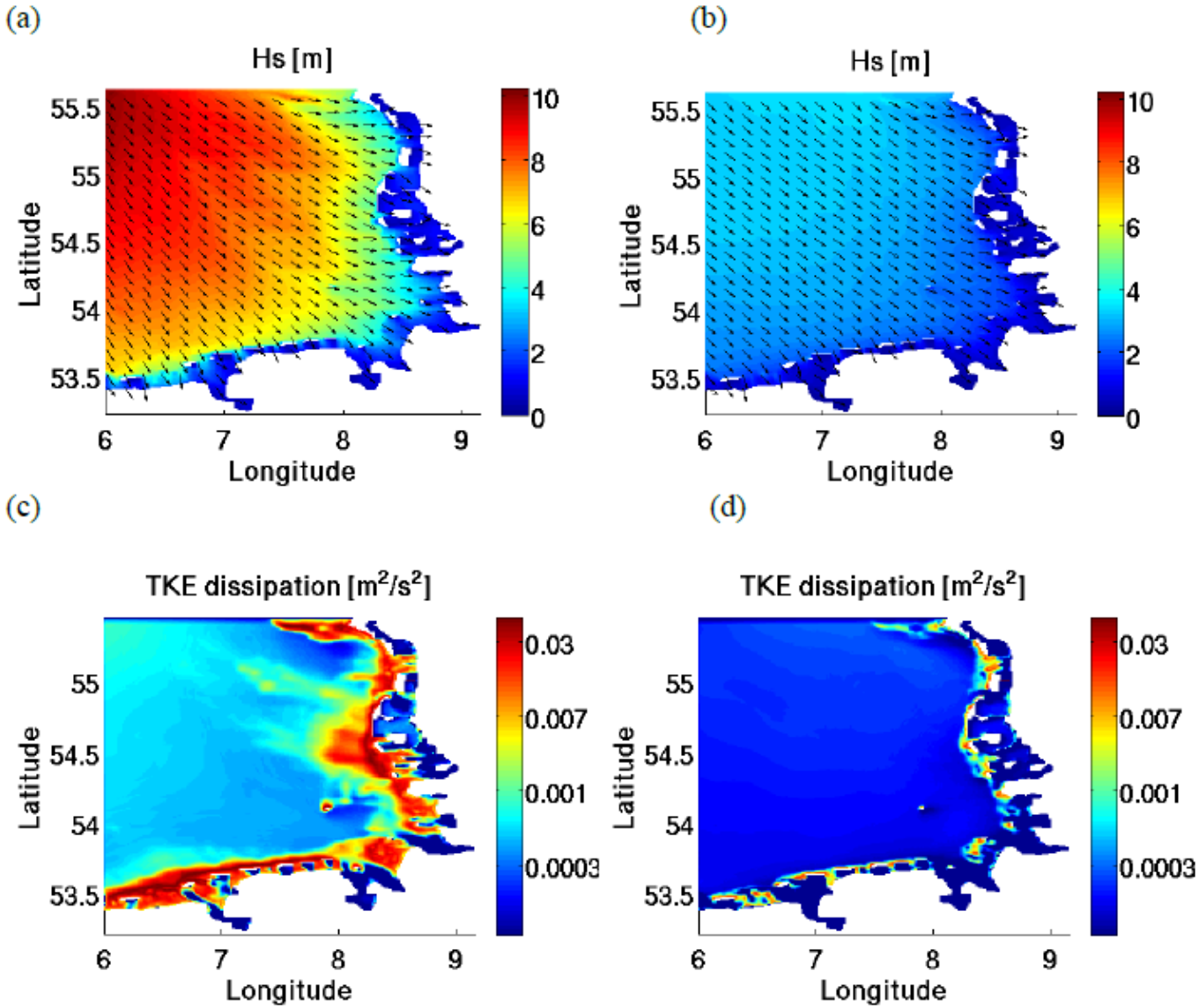

Impact of waves on circulation

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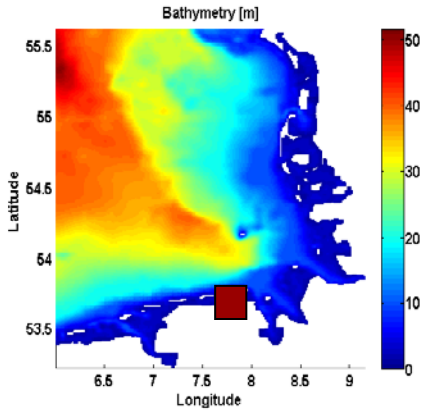
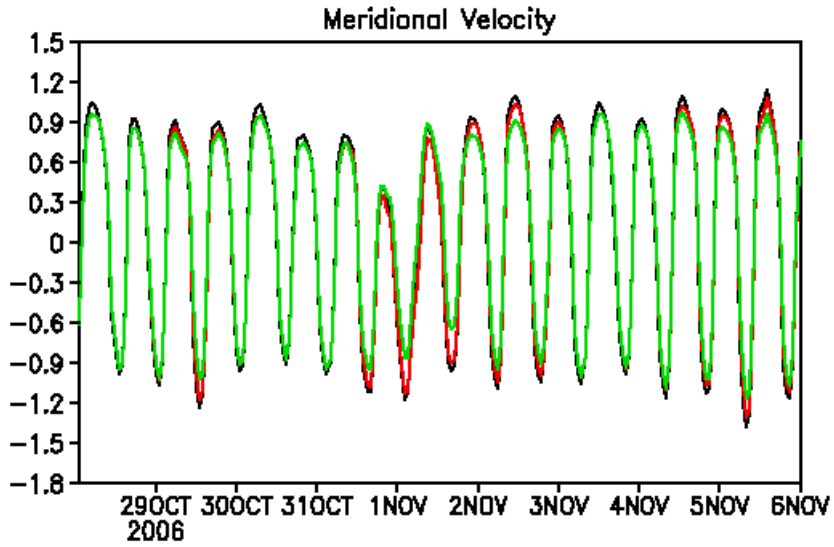
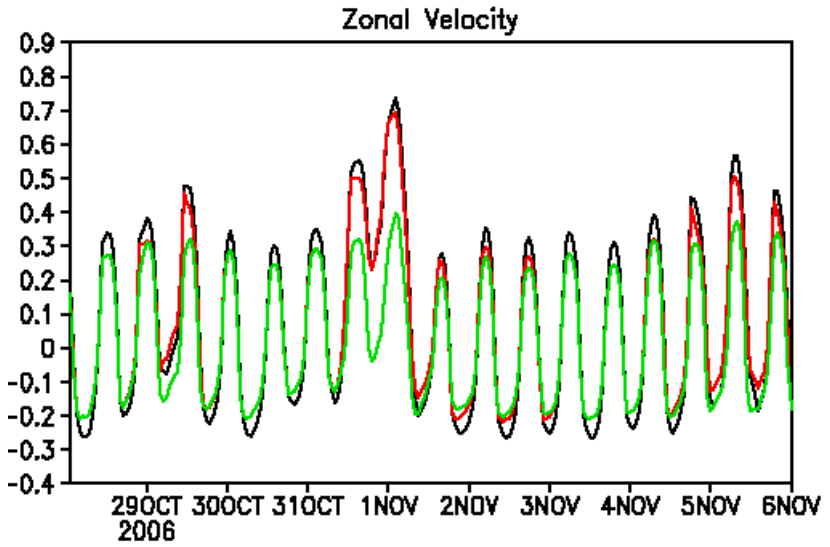
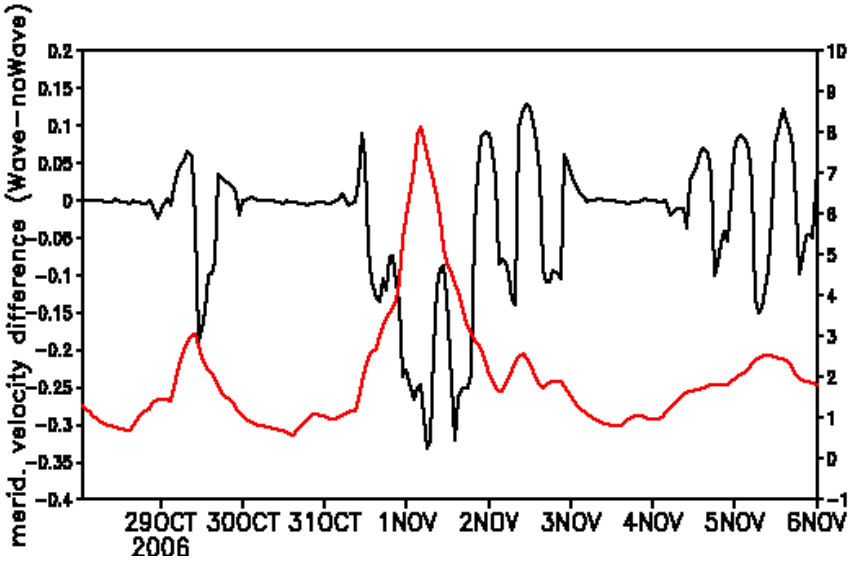
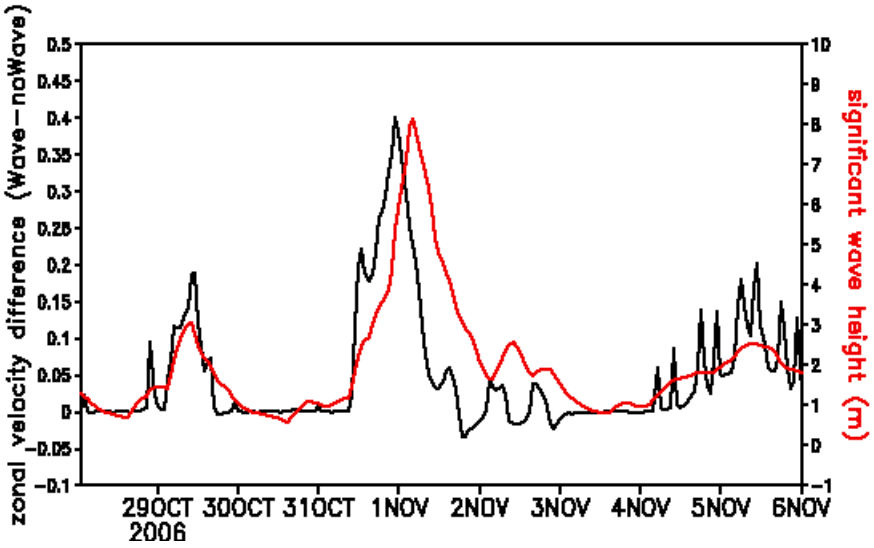






velocity (m/s) -- observations -- coupled -- uncoupled





-- velocity difference (coupled-uncoupled)(m/s) -- Hs (m)

Impact of waves on circulation

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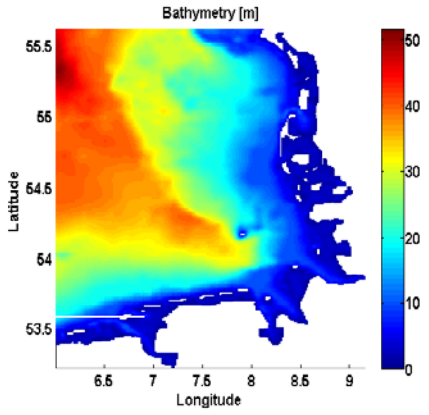

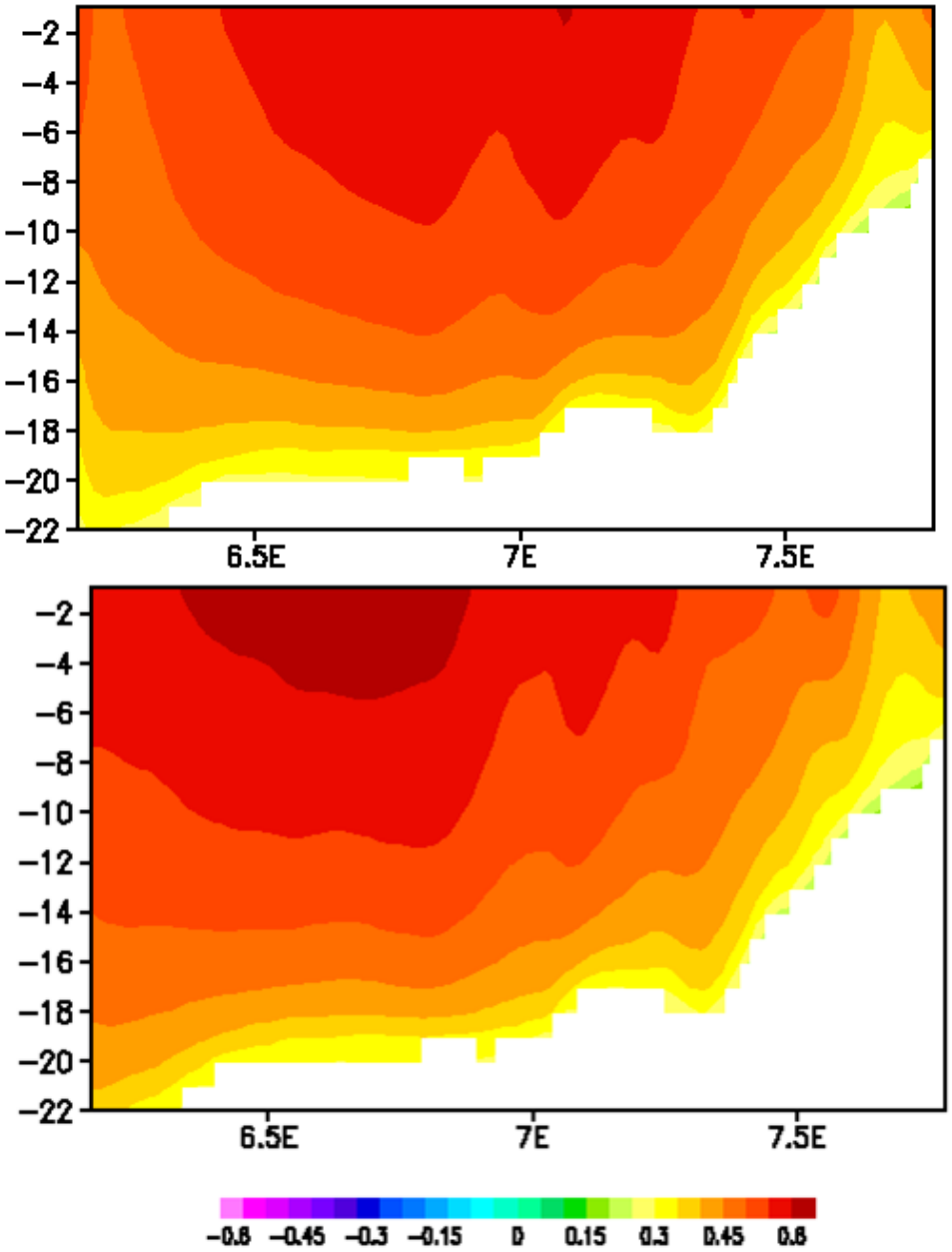

zonal velocity profiles (m/s)

uncoupled

coupled

Impact of wave forcing on SPM – surge Britta

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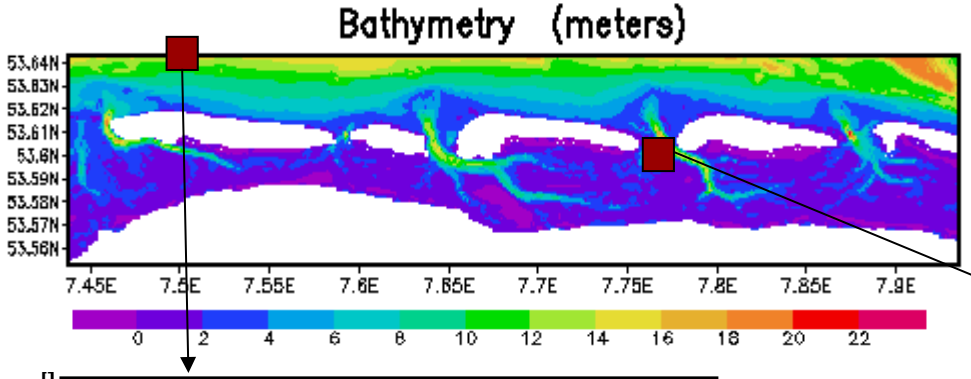
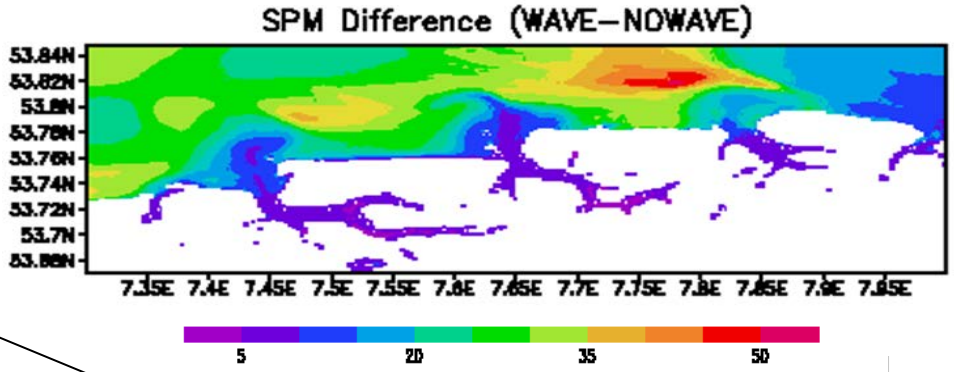
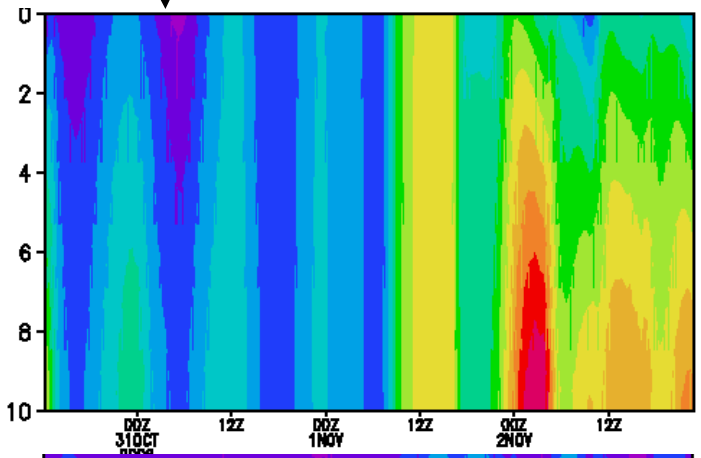
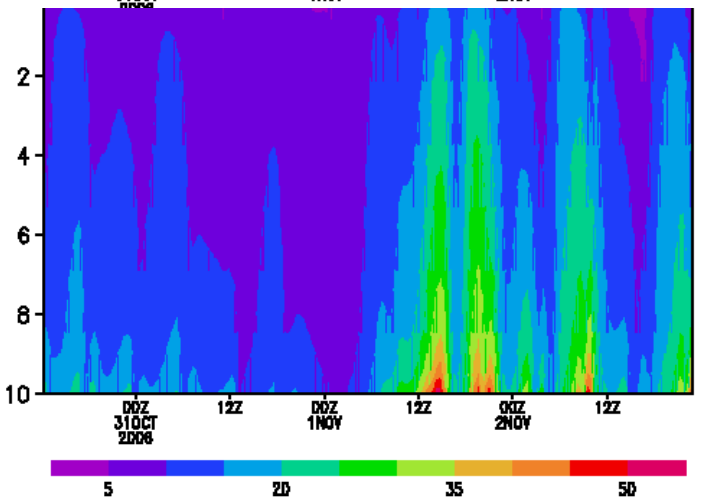




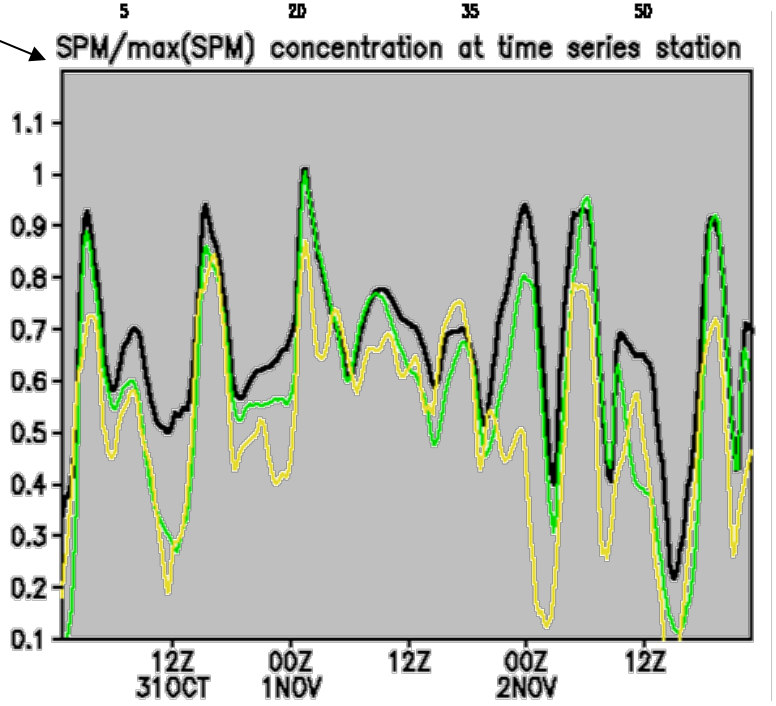


SPM conc. (g/m^3)

coupled



uncoupled



SPM/max(SPM) -- observations
-- coupled
-- uncoupled

Summary

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significant impact of coupling on:

- sea level in shallow water areas (Wadden Sea, tidal inlets)
- currents (longshore currents)
- bottom salinity concentration
- vertical and surface SPM concentration

➔ coupling between waves and circulation improves forecast statistics