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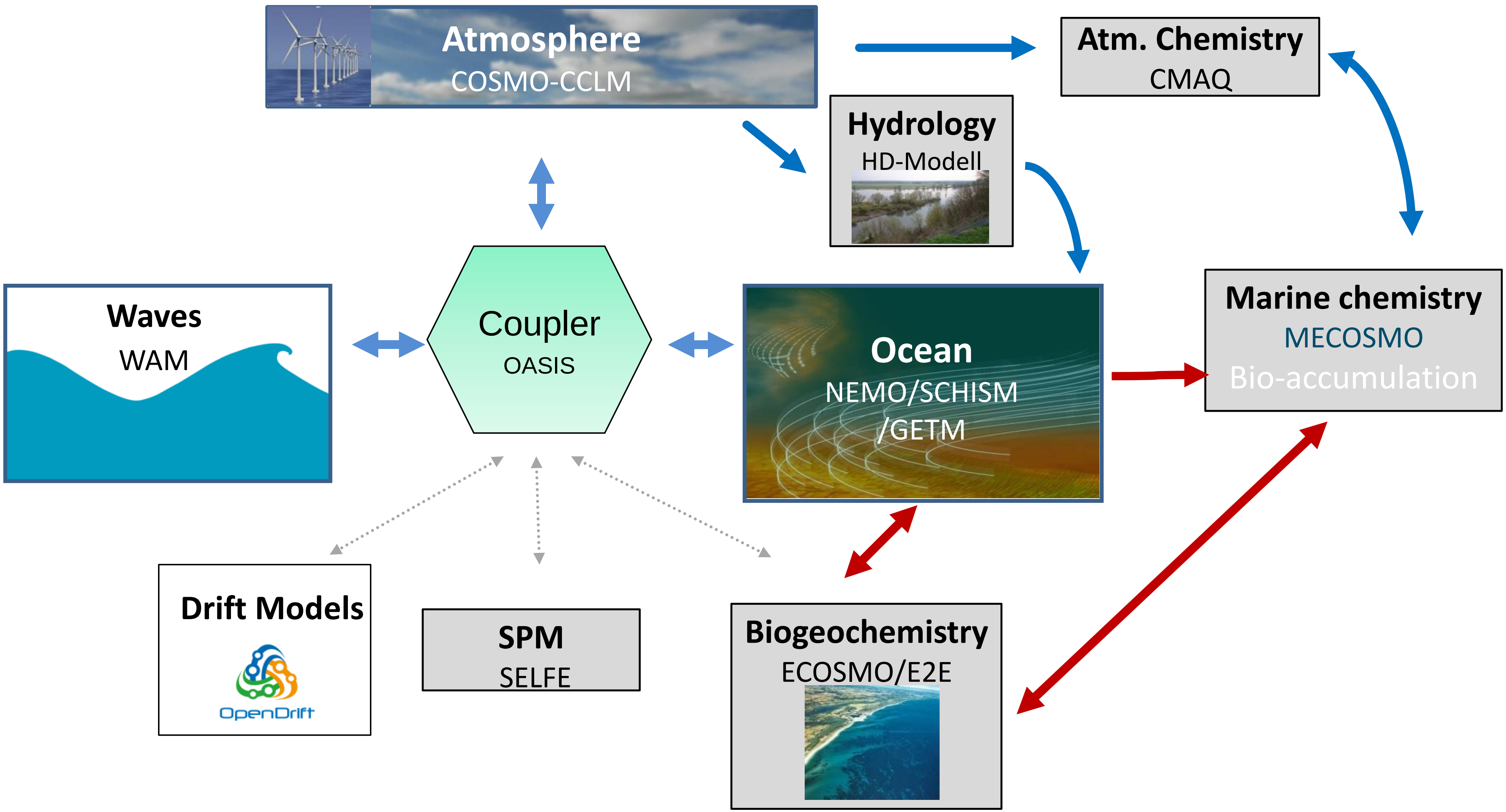
Zentrum für Material- und Küstenforschung

GCOAST Model System

Joanna Staneva & GCOAST TEAM

GCOAST Modell system



Relevance of ocean-wave coupling for coastal predictions

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- Increased interest in reducing prediction errors of state estimates at coastal scales, which in many cases are due to unresolved nonlinear feedback between wind-waves, circulation and atmosphere

- Assessment of the degree of regional coupling

- Study the impact of interaction processes between wind waves, atmosphere and ocean on the quality of coastal ocean simulations

- Substantial effects also on mean fields - energy and momentum transfer

- Extreme weather events in the marine realm

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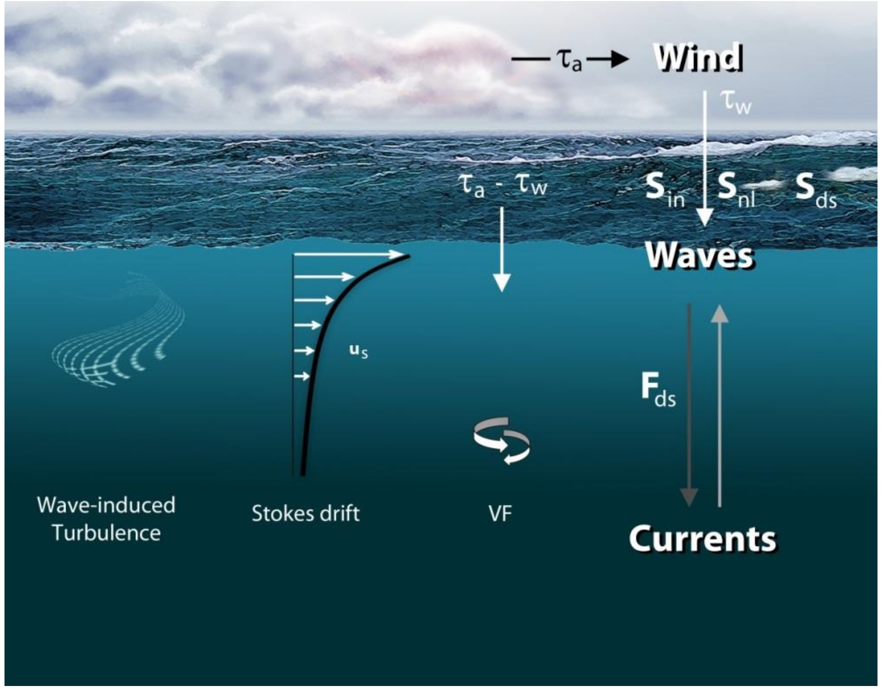
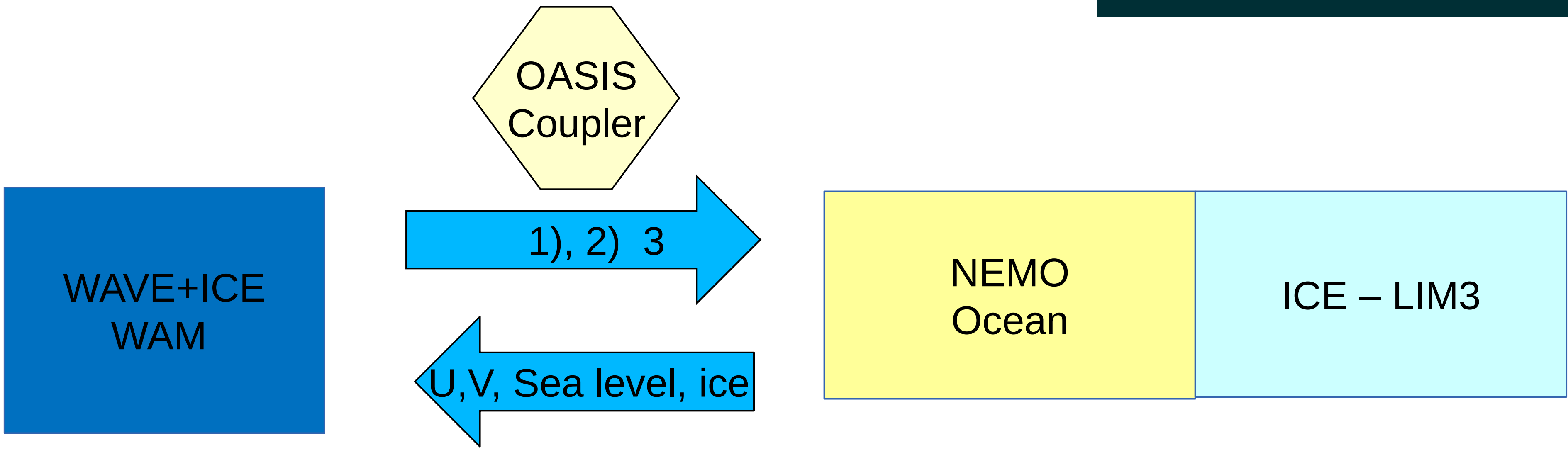
Wave-current interaction:

(1) The Stokes-Coriolis forcing incl, Stokes Coriolis contribution to the advection term
(2) Sea state dependent momentum flux
(3) Sea state dependent energy flux
(4) Wave-induced mixing
(5) Wave-induced bottom fluxes from WAM

Implementing two-way coupling with OASIS





Impact of wave-induced forcing on Sea Level
Different meteoconditions during 2016

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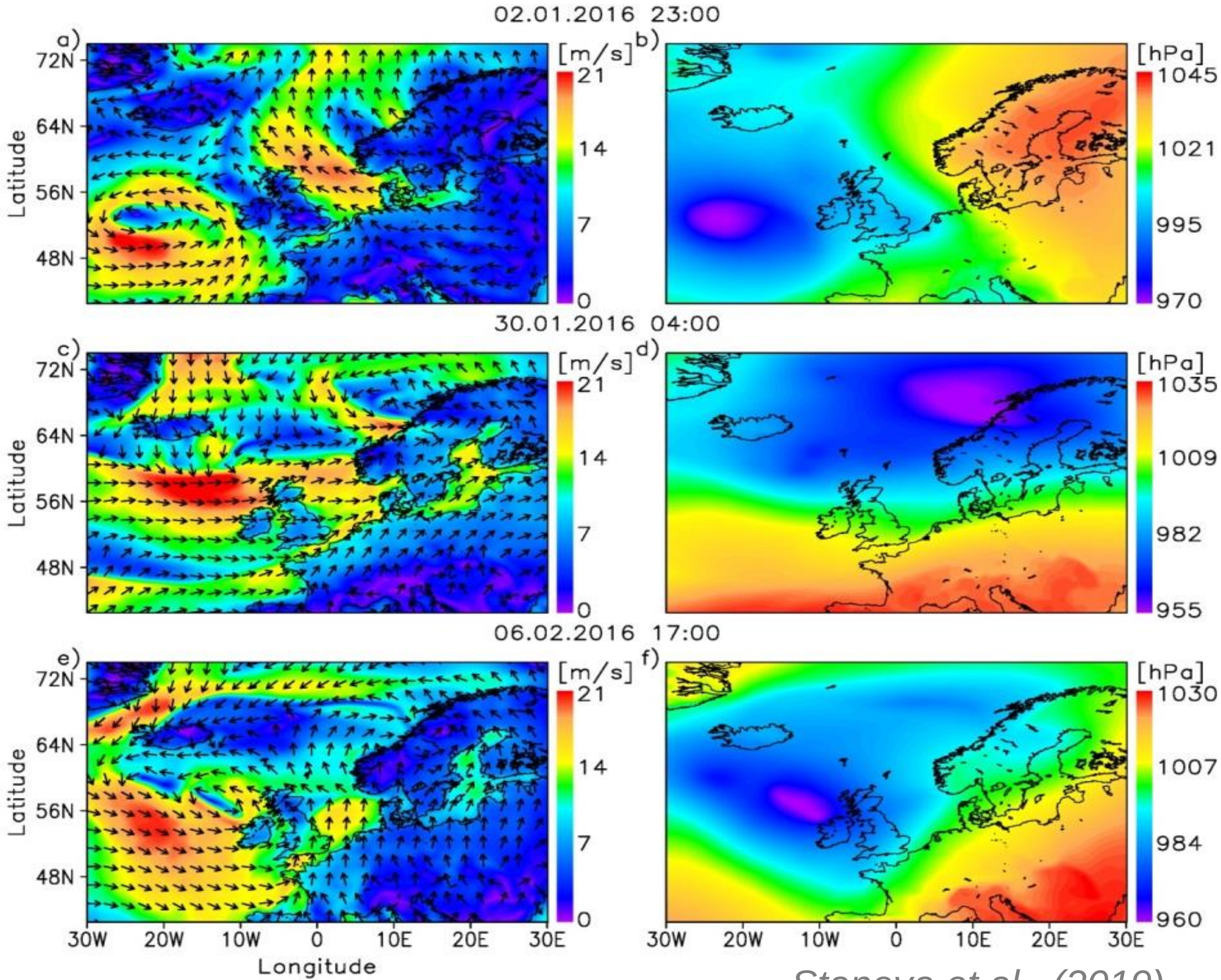

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Staneva et al., (2019)

Impact of wave-induced forcing on Sea Level
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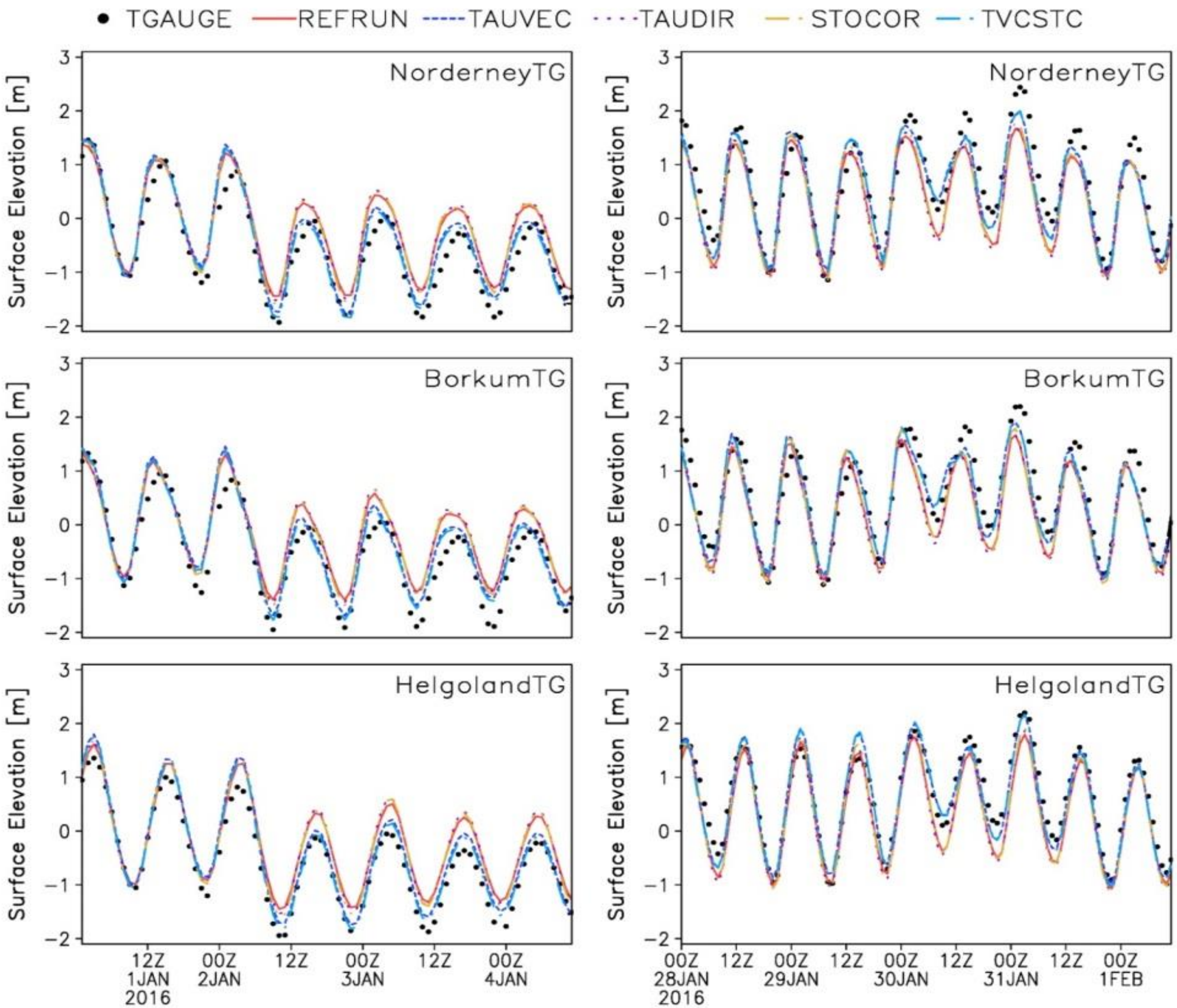

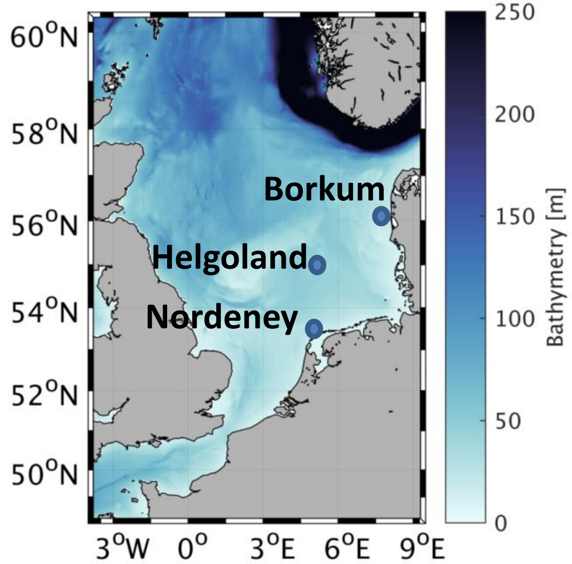

Staneva et al. (2019)

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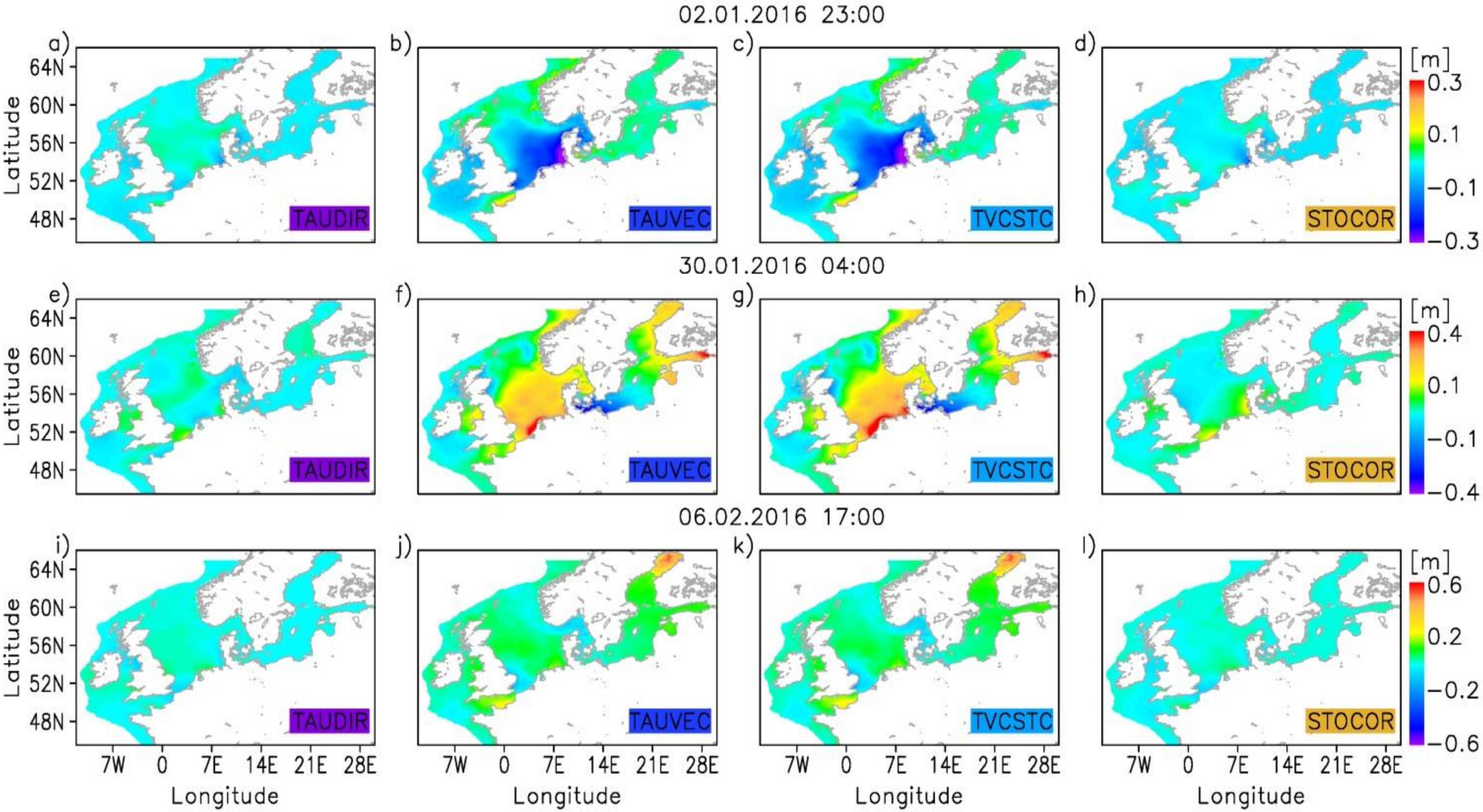

TAUOC **TAUVEC** **ALLWAVE** STCOR

Staneva et al. (2019)

Stokes-Coriolis forcing

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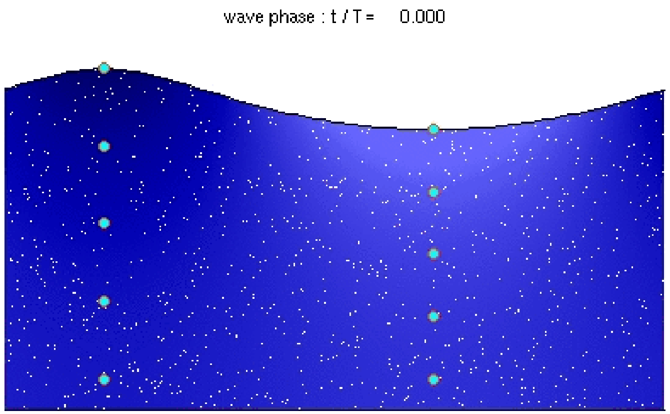
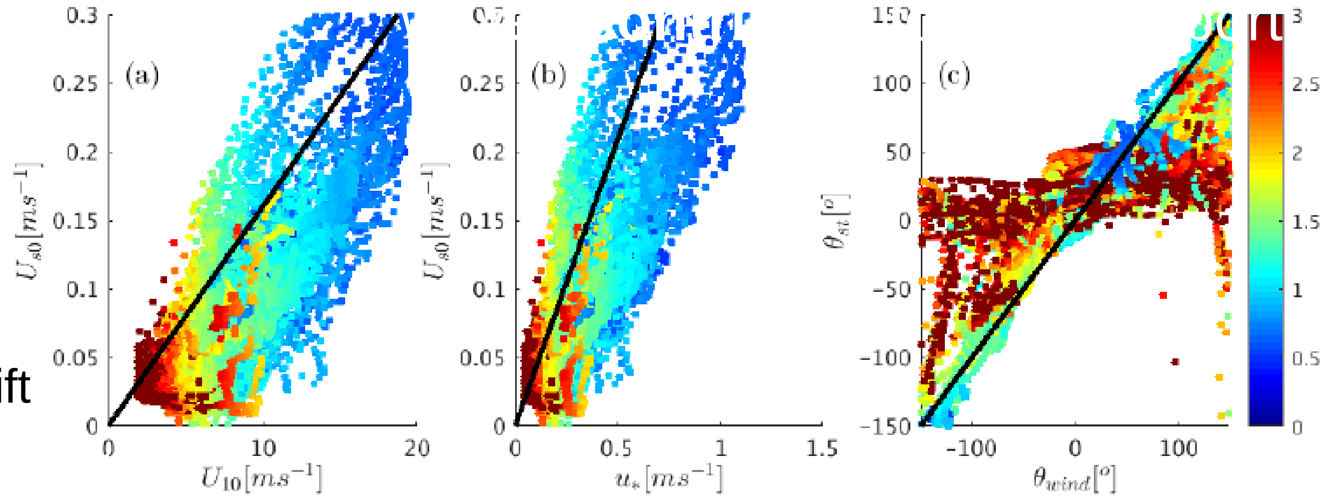


http://en.wikipedia.org/wiki/Stokes_drift



The Stokes drift –> WAM

Momentum equations in NEMO:

$$\frac{D\mathbf{u}}{Dt} = -\frac{1}{\rho_{\mathrm{w}}}\nabla p + \mathbf{u}\times f\hat{\mathbf{z}} + \mathbf{u_S}\times f\hat{\mathbf{z}} + \mathbf{D^u} + \mathbf{F^u}$$

New! Adding Ust in advection terms!

$$\frac{Dc}{Dt} = -\mathbf{u}_s\cdot\nabla c + \mathbf{D^c} + \mathbf{F^c}$$

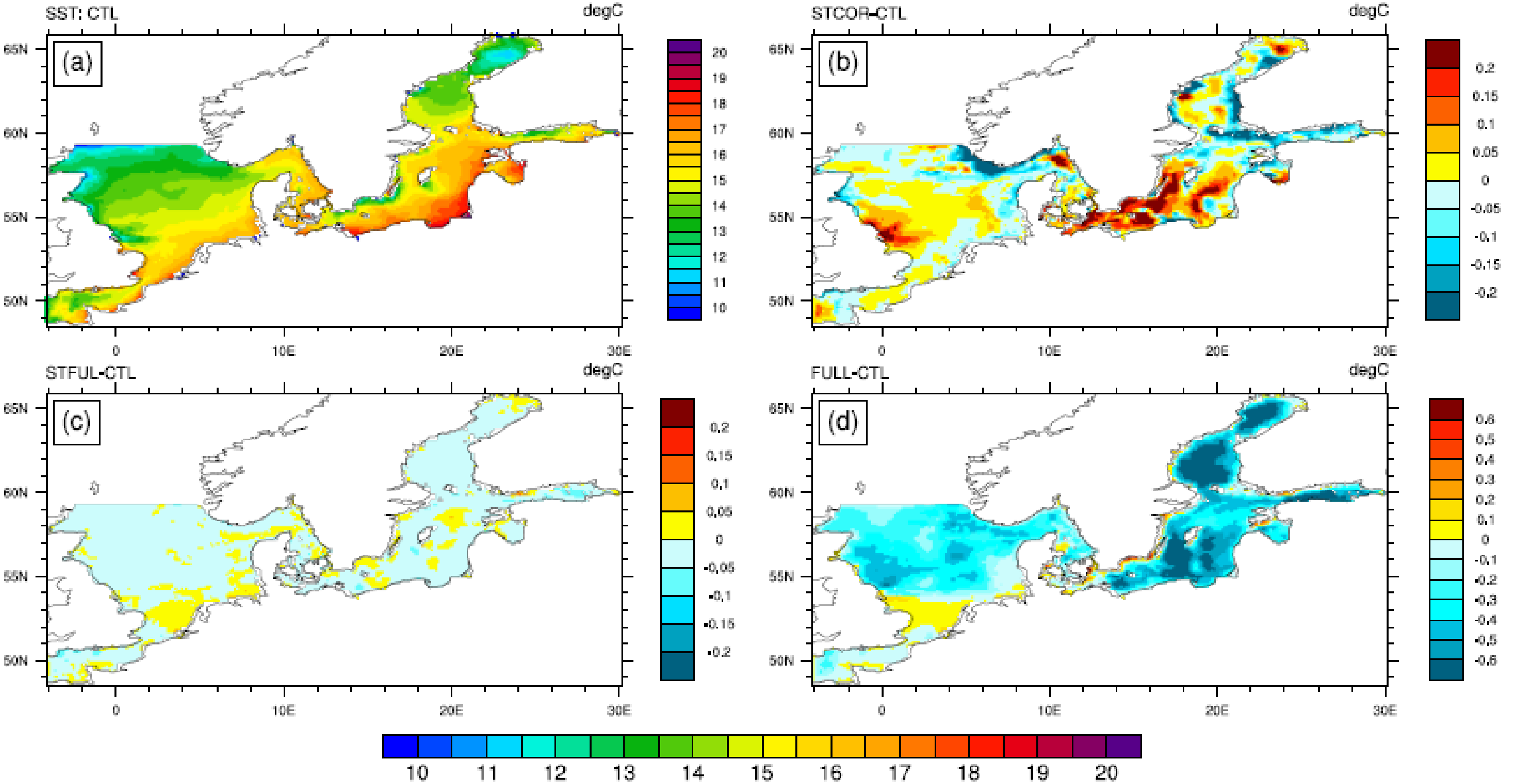
The relationship between U10 and the magnitude of the surface Stokes drift :

(a) black line represents the Ust =0:016 U10 (Li and Garrett, 1993);

(b) Ust = 0:377 Tau $^{1/2}$ (Madec et al., 2015);

(c) the surface Stokes drift direction and the direction of U10 The color represents the wave age

Impact of coupling with waves on SST (JJA)



Wu et al (2019)

Impact of coupling with waves on SST (NDJ)

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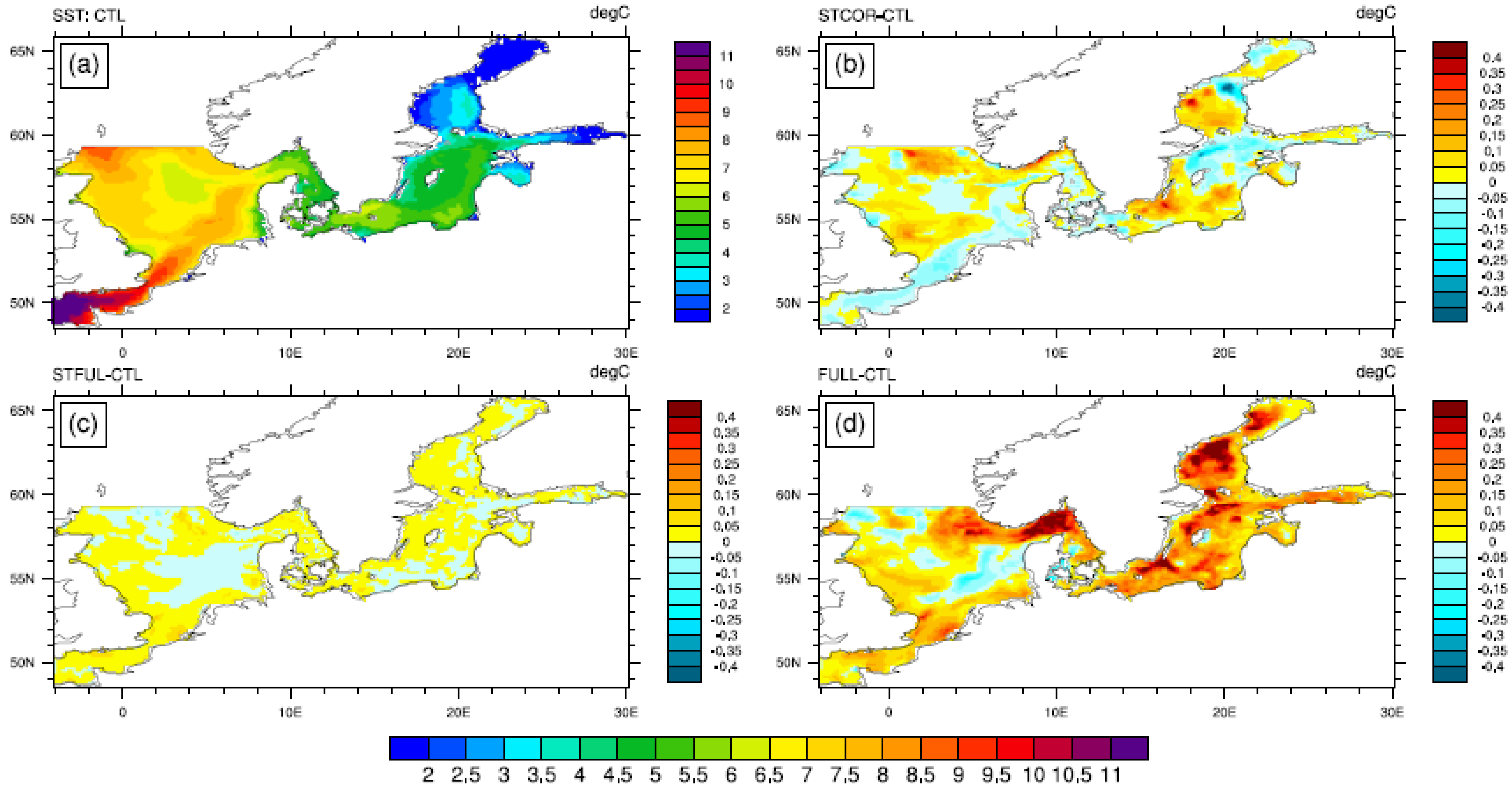
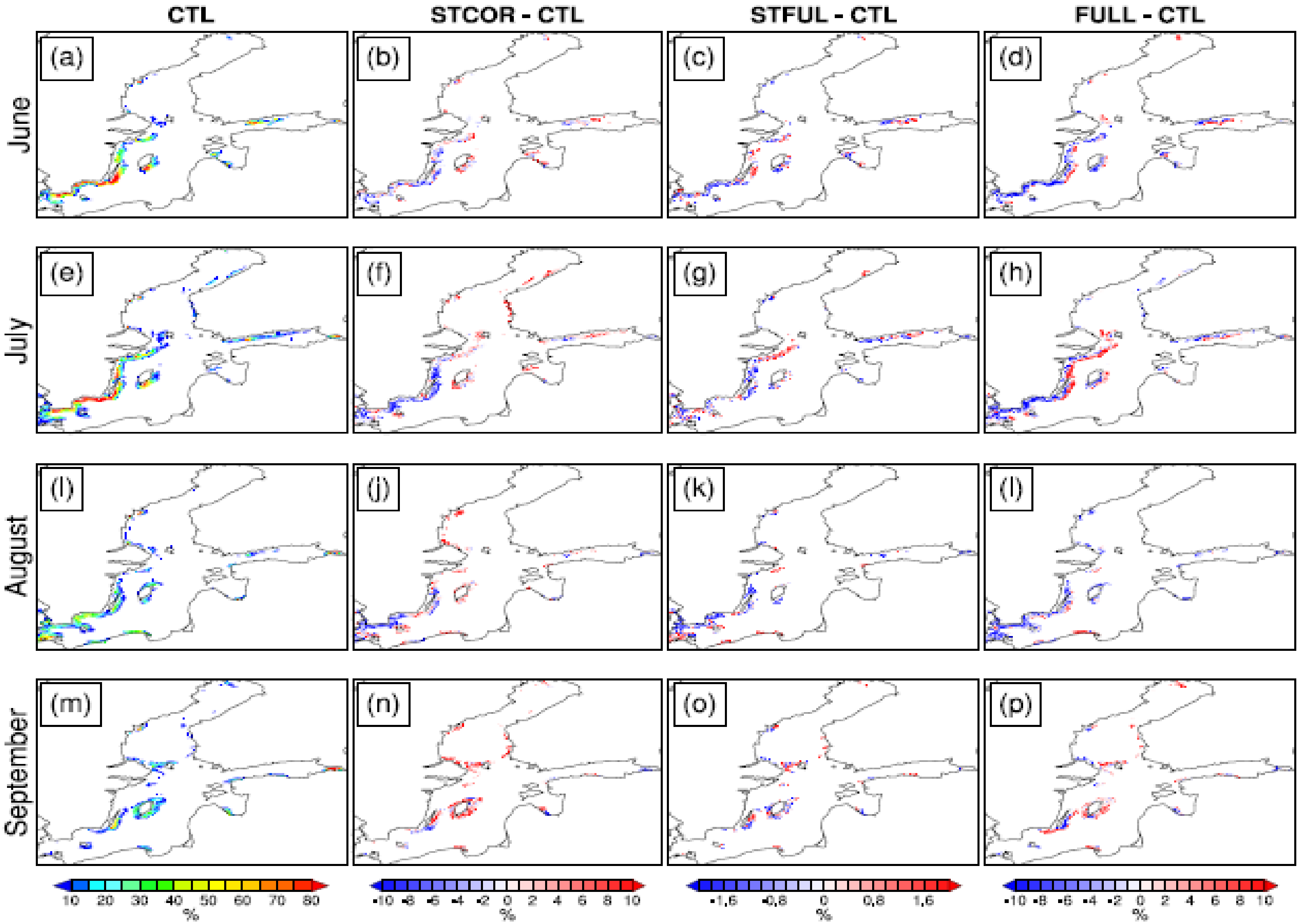


Wu et al (2019)

Impact of coupling on UPWELLING



The frequency of upwelling in the control experiment for the months of June, July, August and September, 2015. The criterion for upwelling are fulfilled when the SST difference from the zonal mean temperature is greater than 2.5 C.

Impact of waves on Surge

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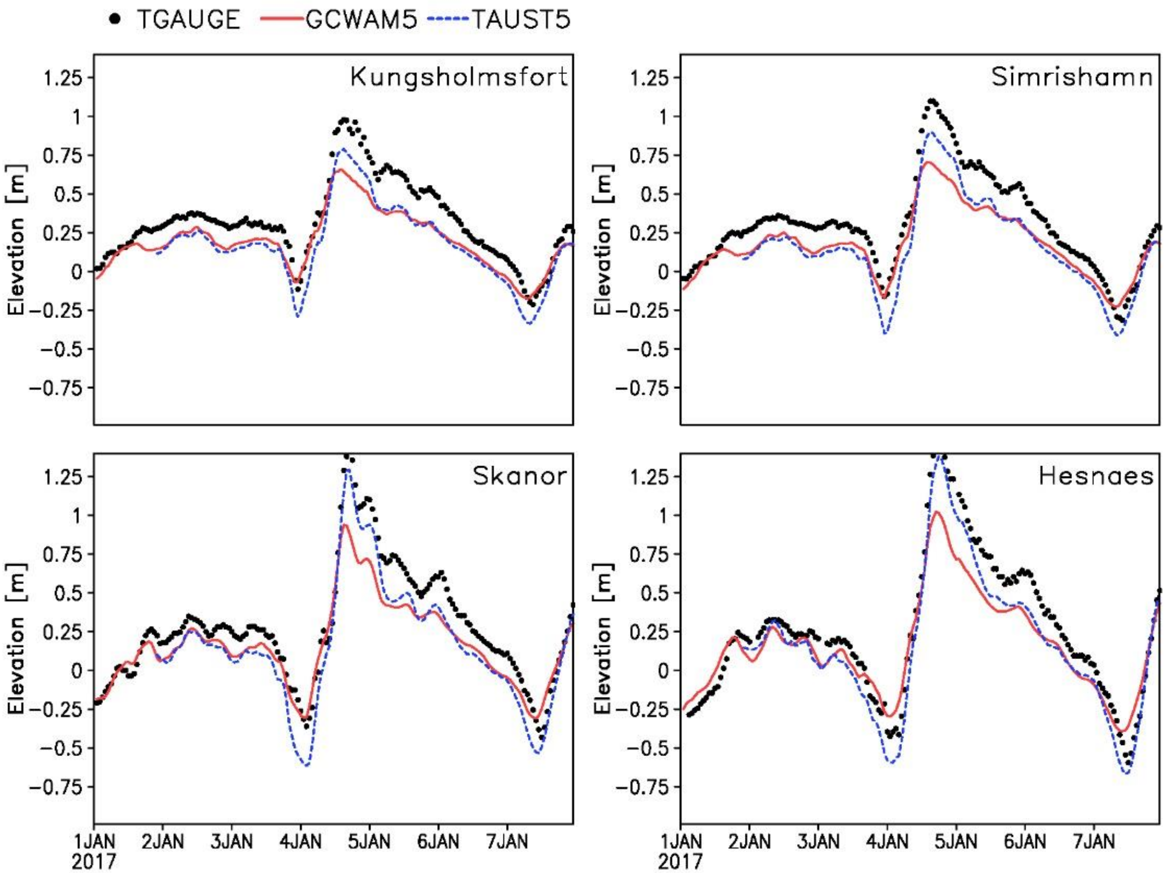
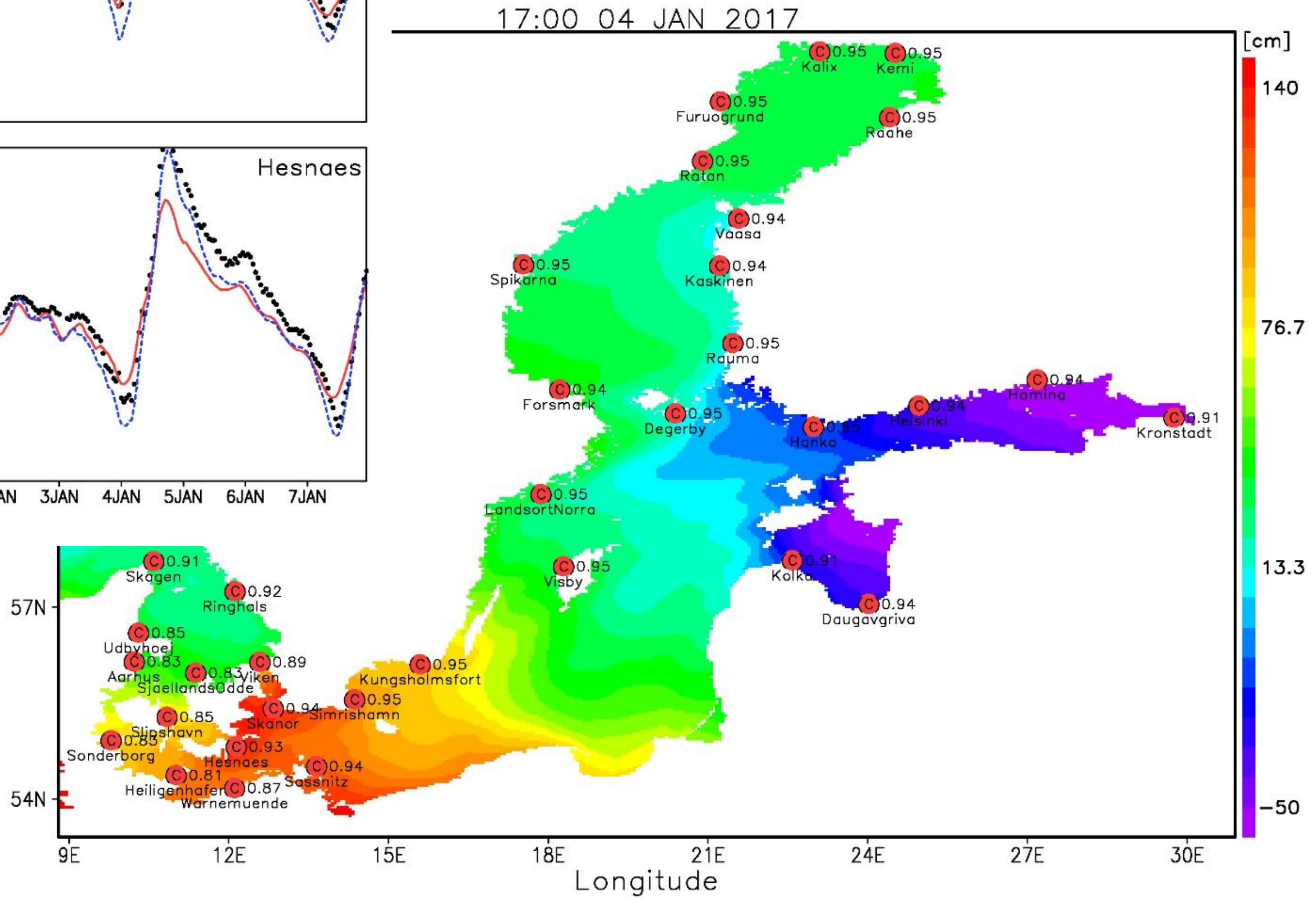
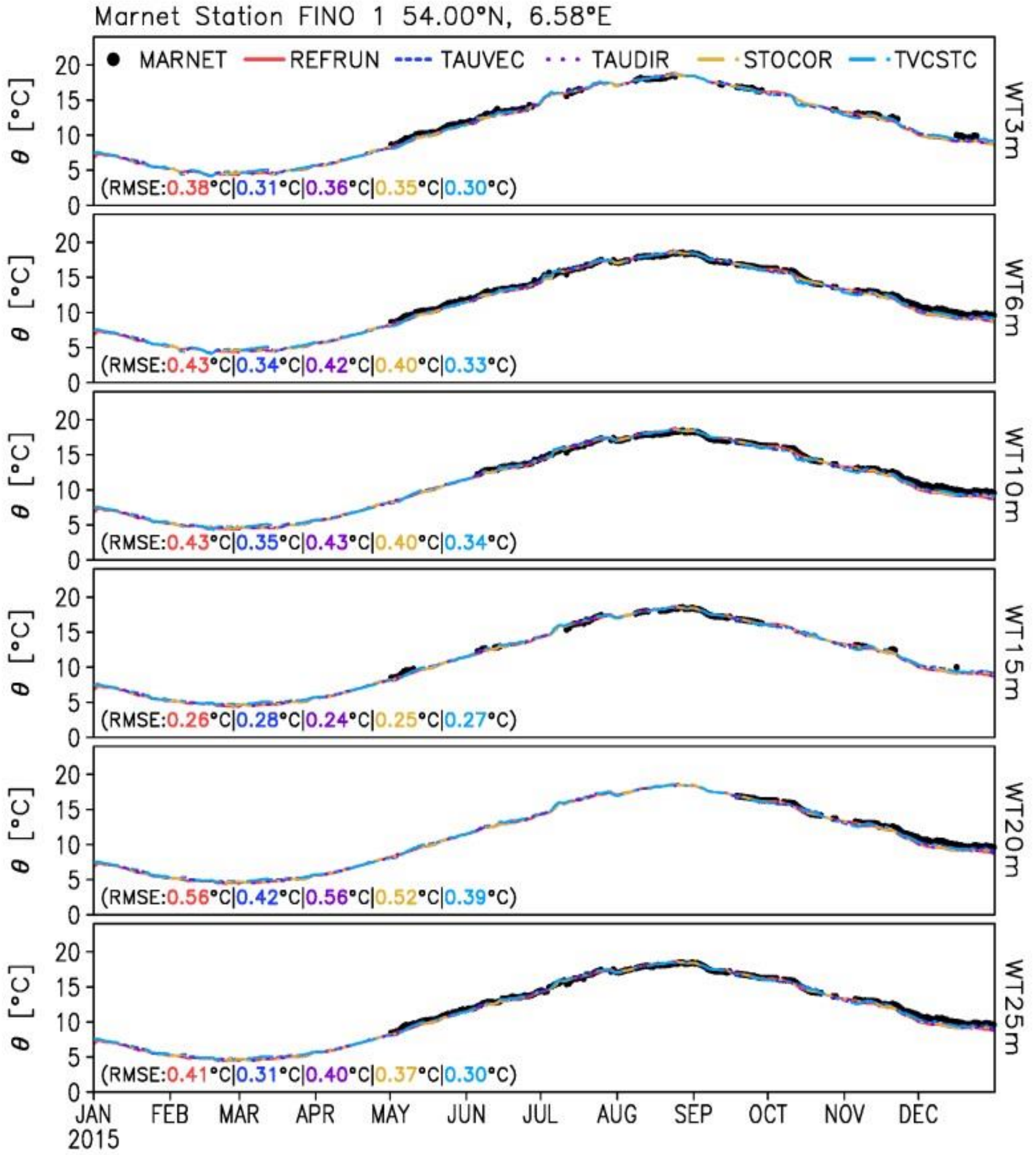
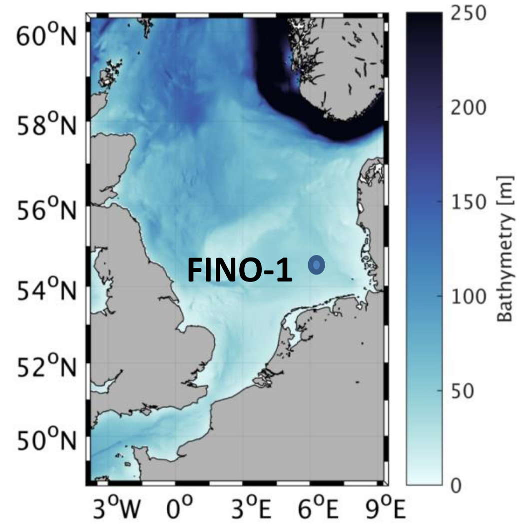
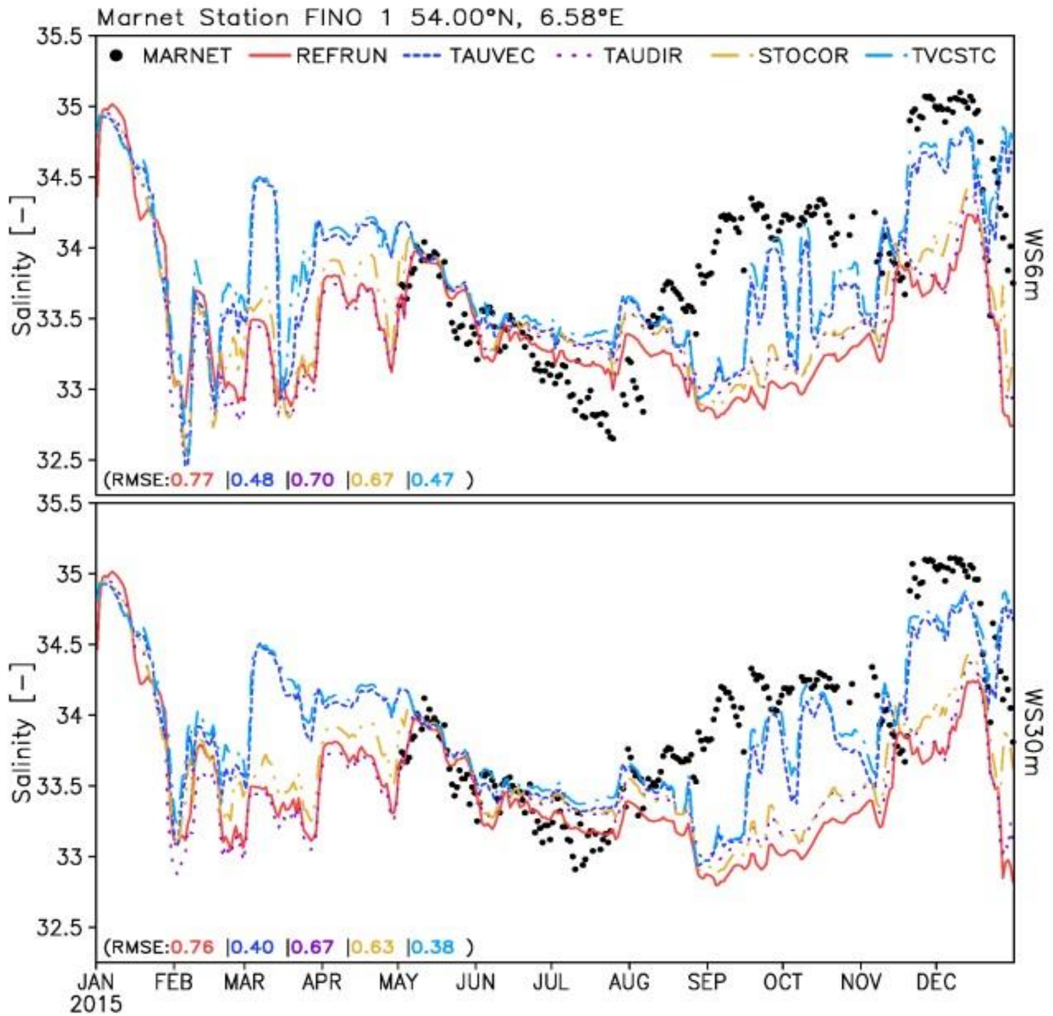




Impact of waves on T&S
FINO-1 MARNET Station

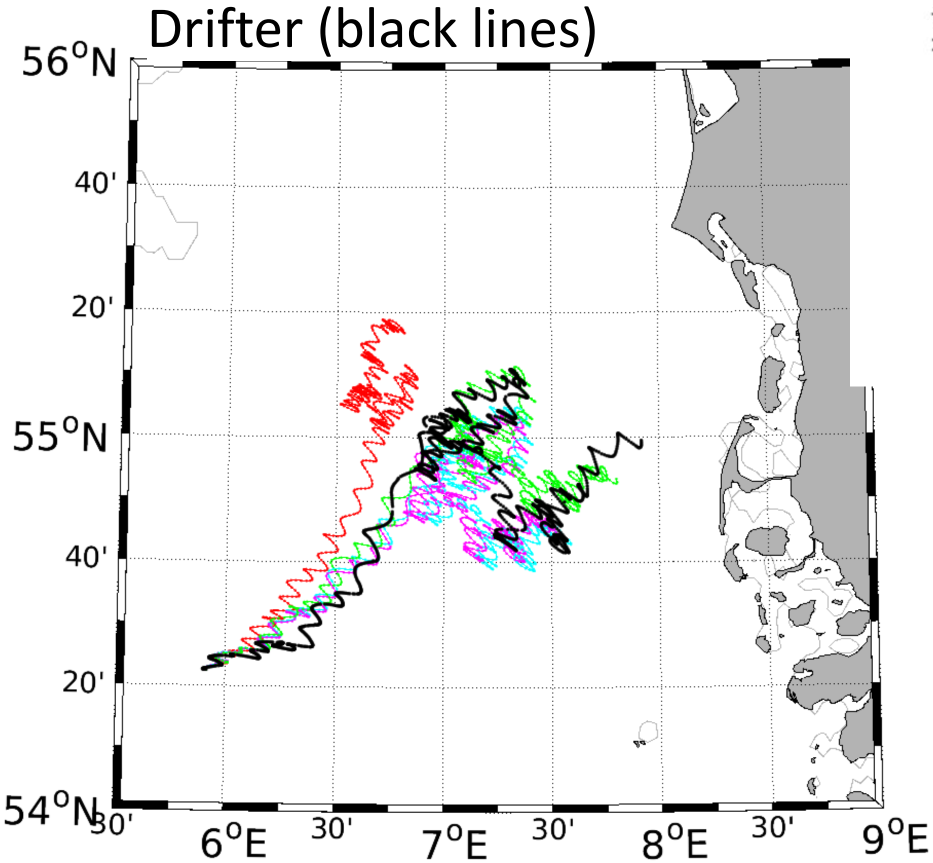


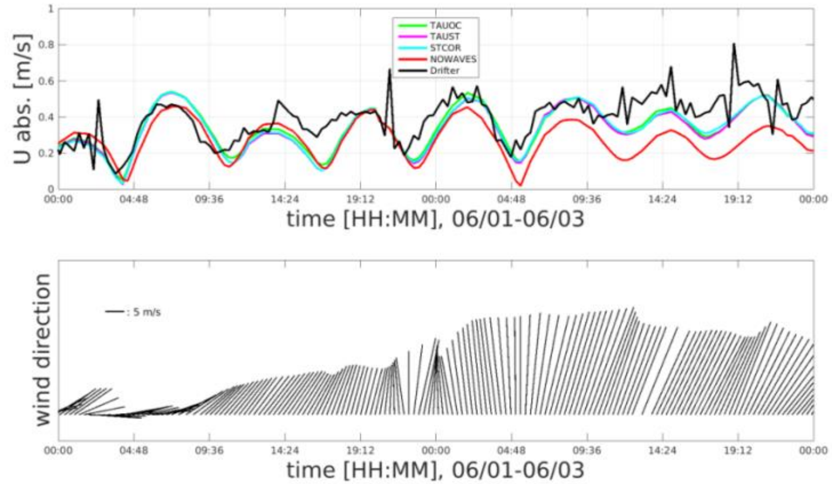


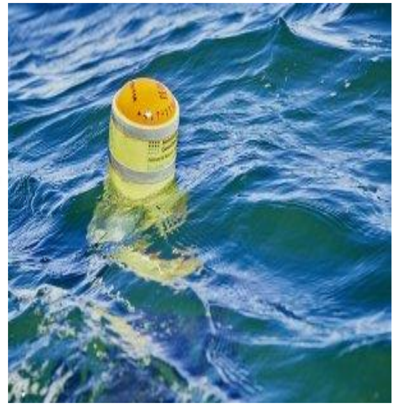


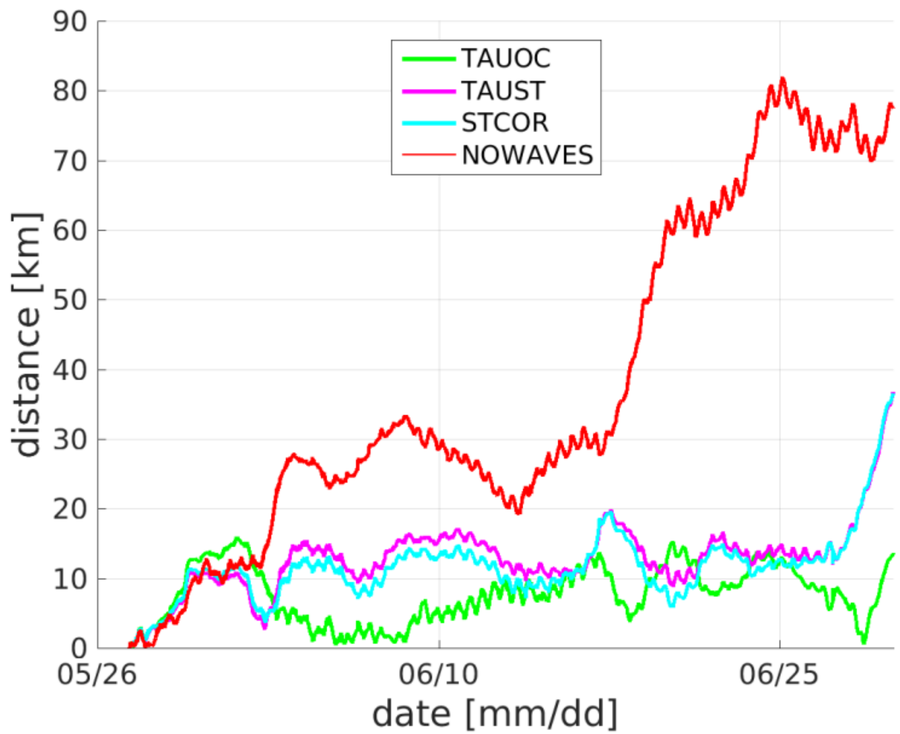
Sinergy with observations:

wave-circulation coupling for drift estimation









Example:

- Search&rescue prediction
- Oil spill

Staneva et al. (2019), ODYN

The Assimilation scheme

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Number of CPU requires:

- NEMO: 900
- WAM : 270
- COSMO: 720

NEMO (uncoupled) with PDAF
(16 ensembles) : 14400
(coupled) : 30240

Data storage requires:

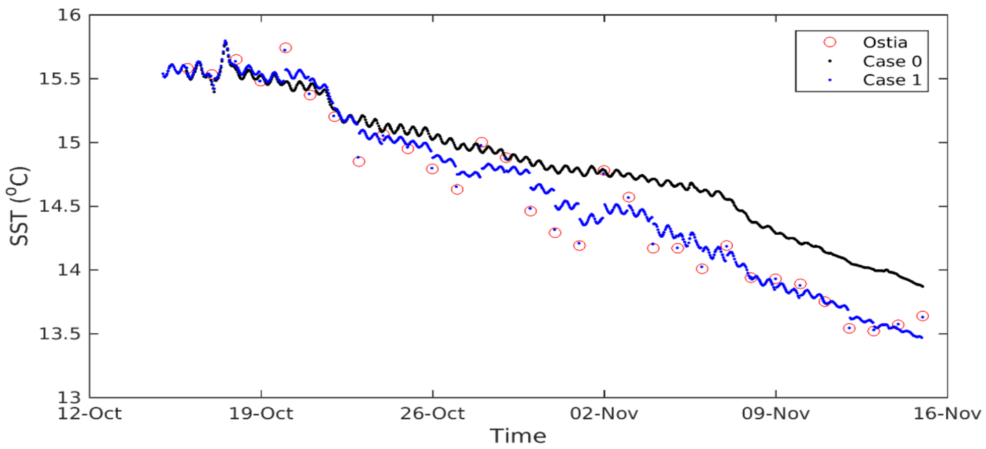
NEMO (uncoupled) with
PDAF (16 ensembles) :
1.4TB/month

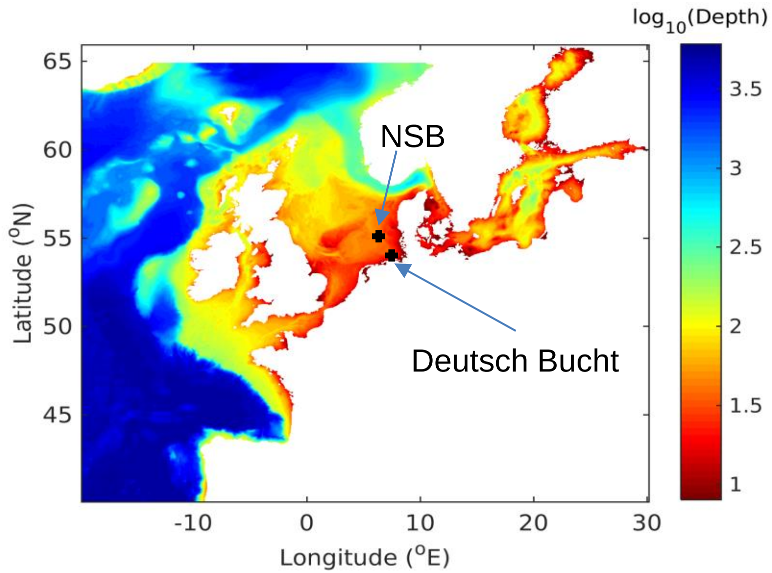
Alternative: Optimal Interpolation Data Assimilation

Test with uncoupled NEMO run: Cold start from 2013-10-15, run up to a stable state and continue.
Study periods start from 2014-10-15 to 2014-11-14

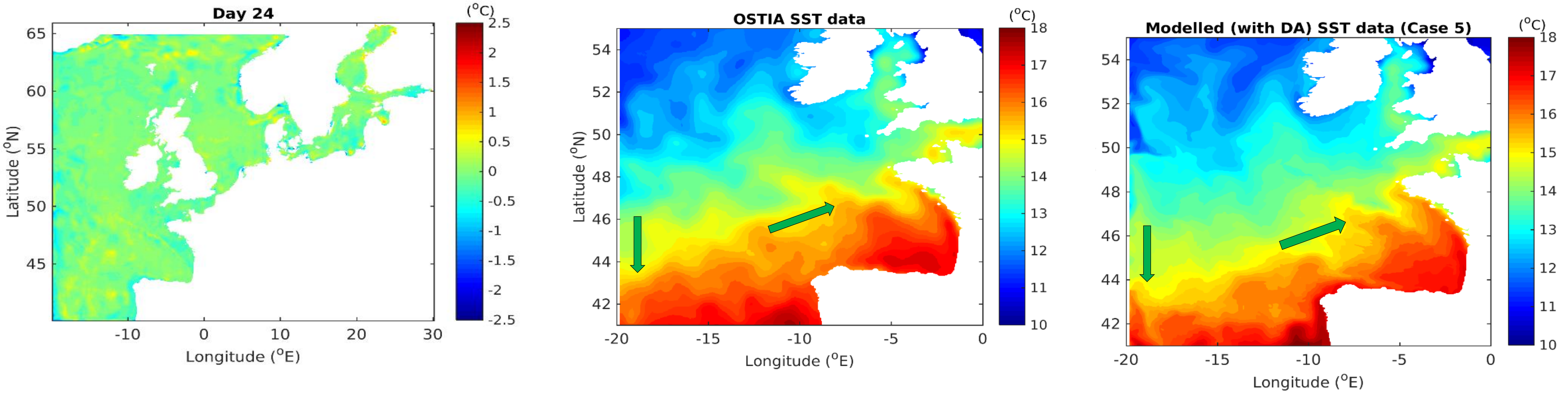
GCOAST DA Results

Station: NSB

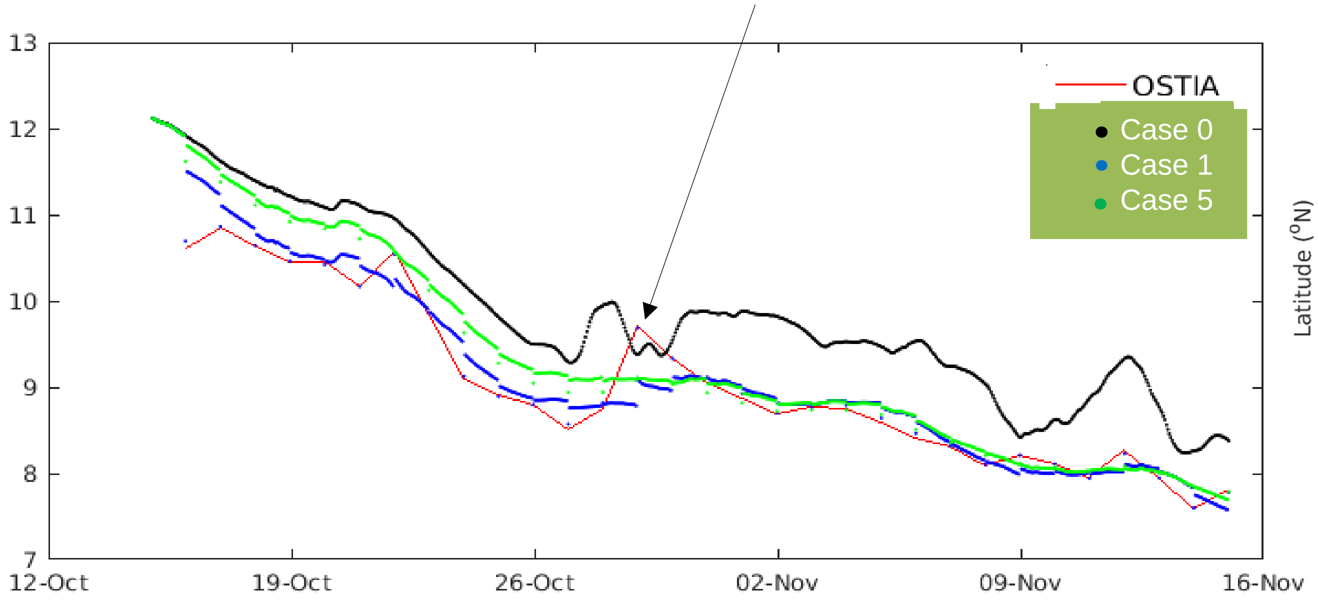


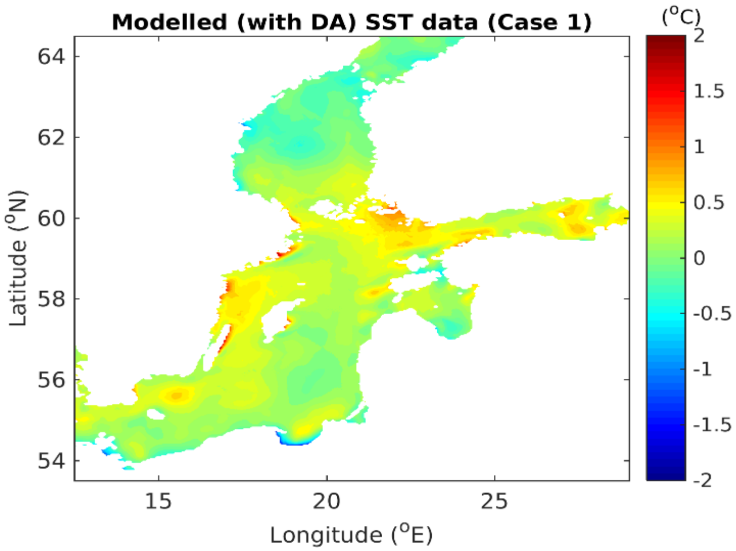


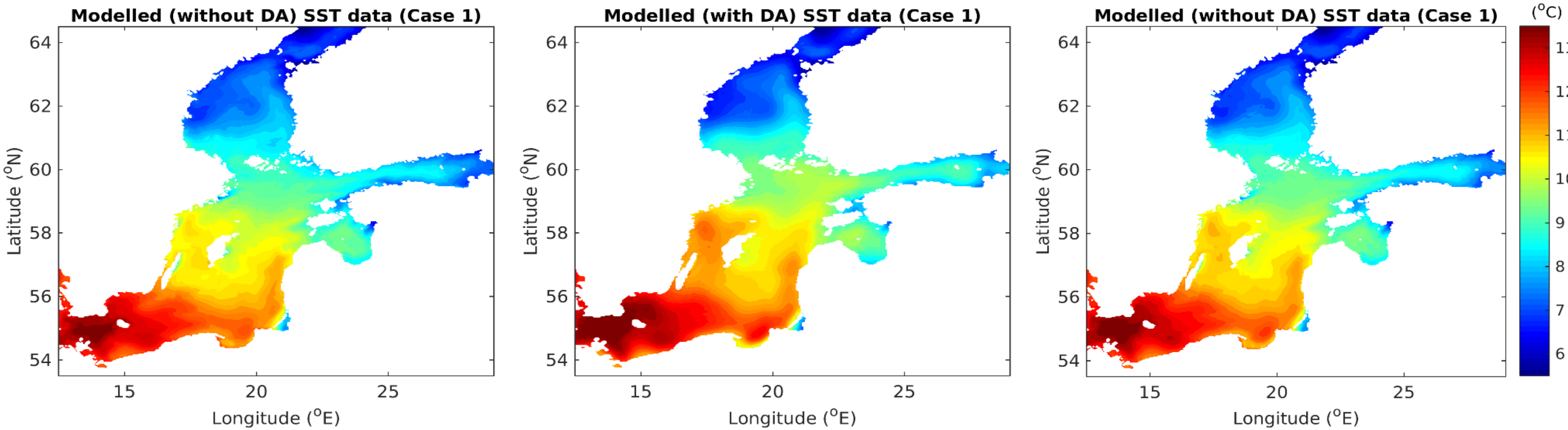
DA Run (Innovations)



Coupled with Atmospheric/Wave model?







METHODS

Model, grid, data sets etc.

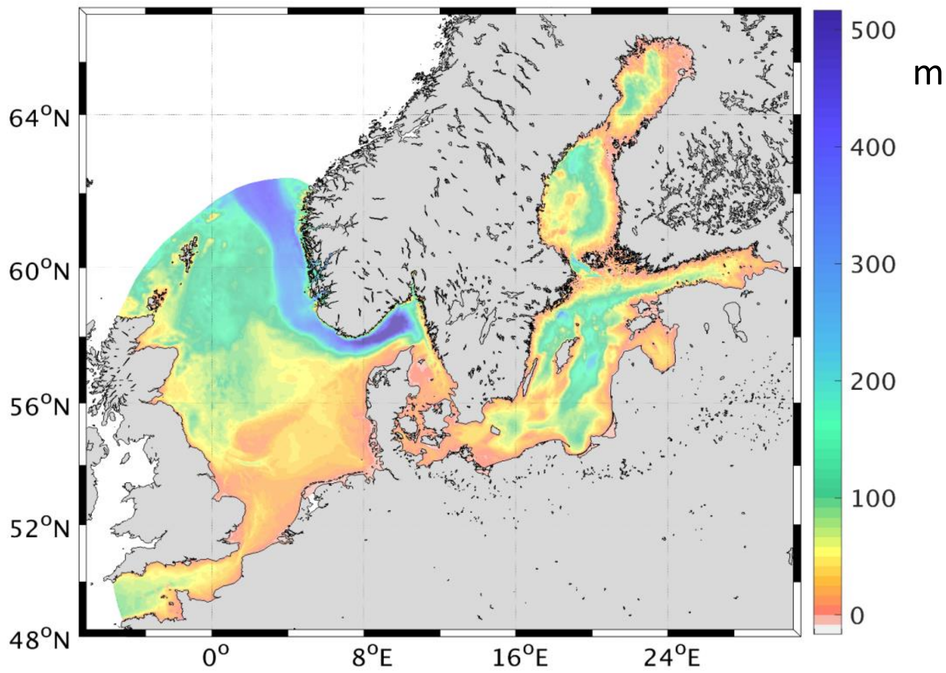
- SCHISM (Semi-implicit Cross-Scale Hydroscience Integrated System Model; Zhang et al. 2016)

- Regional North Sea - Baltic Sea grid (Stanev et al. 2018)
  - horizontal resolution 3 km to 100 m
  - variable # (max. 59) sigma layers with shaved cell technique (LSC^2; Zhang et al. 2015)

- Initialisation:
  monthly climatological temperature and salinity data (Janssen et al. 1999)

- Surface forcing:
  - hourly 7-km COSMO EU data from DWD
  - river runoff from EHYPE (SMHI)

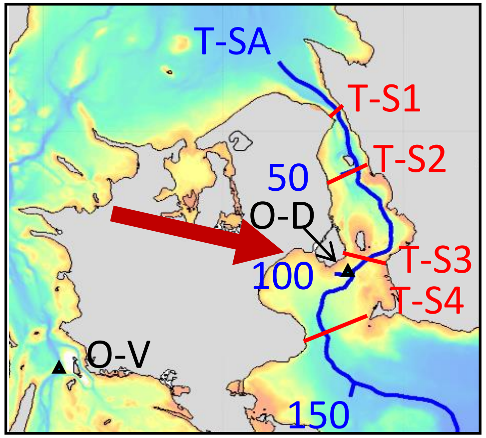
- Open boundary forcing:
  hourly Copernicus product

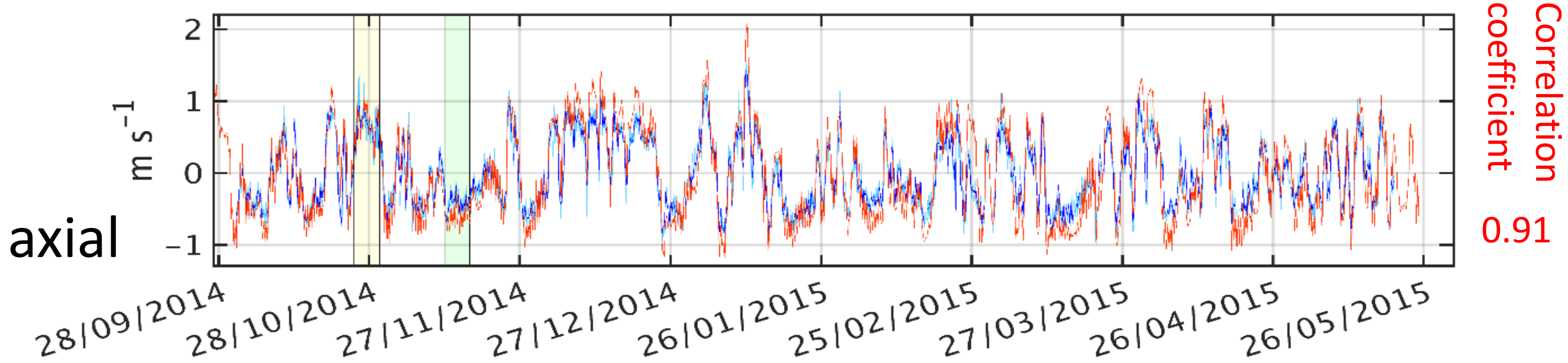


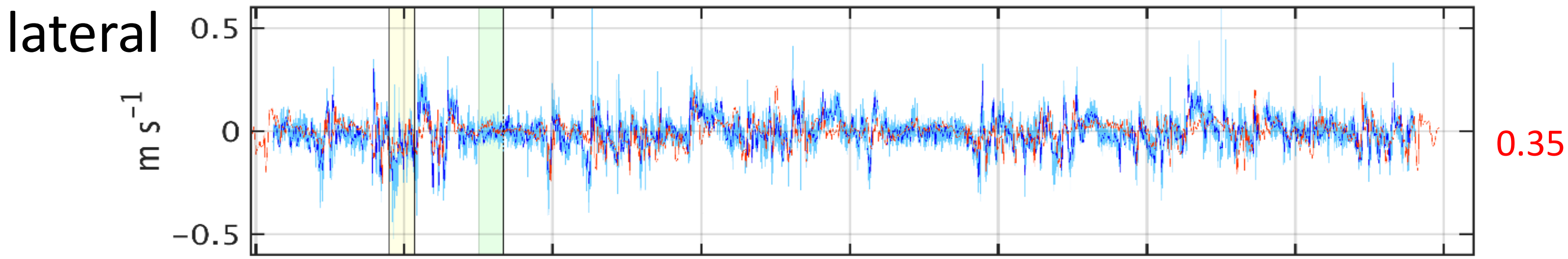
VALIDATION

Comparison with current meter data

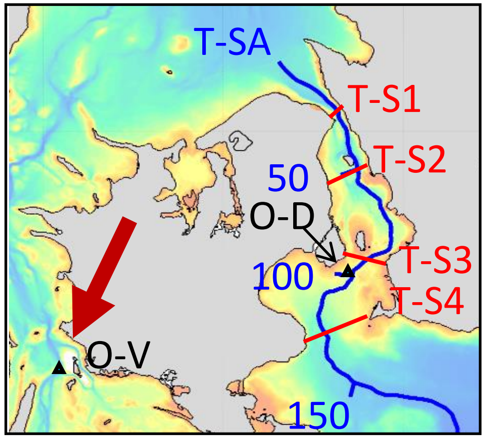
Drogden Fyr, 5m Velocities

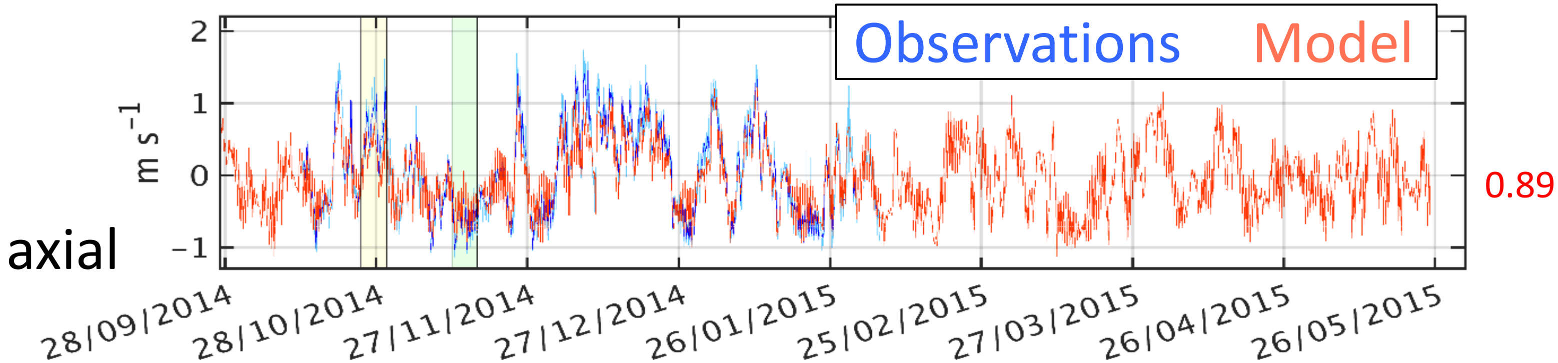


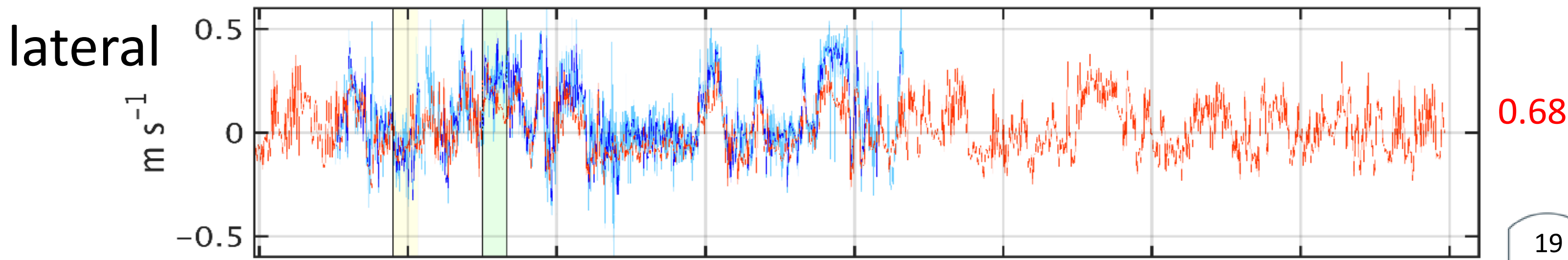




Vengeancegrund, 5m Velocities







Discussion

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- Several wave impacts on the upper ocean turbulence, i.e., Stokes-Coriolis forcing, sea-state-dependent momentum and TKE flux, and Stokes tracer and mass advection, are introduced into a high resolution regional GCOAST coupled system

- The sea-state-dependent fluxes (momentum and TKE flux) prove to be of greater importance than the Stokes drift influences in terms of Stokes-Coriolis forcing and Stokes tracer and mass advection.

- The Stokes drift affects the mass and tracer advection largely balances the influence of the Stokes-Coriolis forcing.

- The Baltic sea upwelling frequency changes by more than 10% along the Swedish coast when adding wave-related effects.

- Adding wave-related processes improves the model performance

Thank you for your attention!

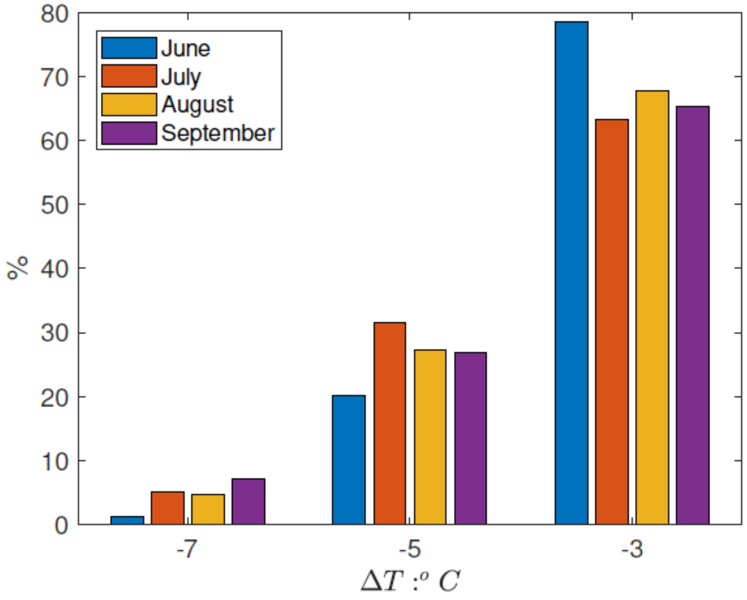
Publications:

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

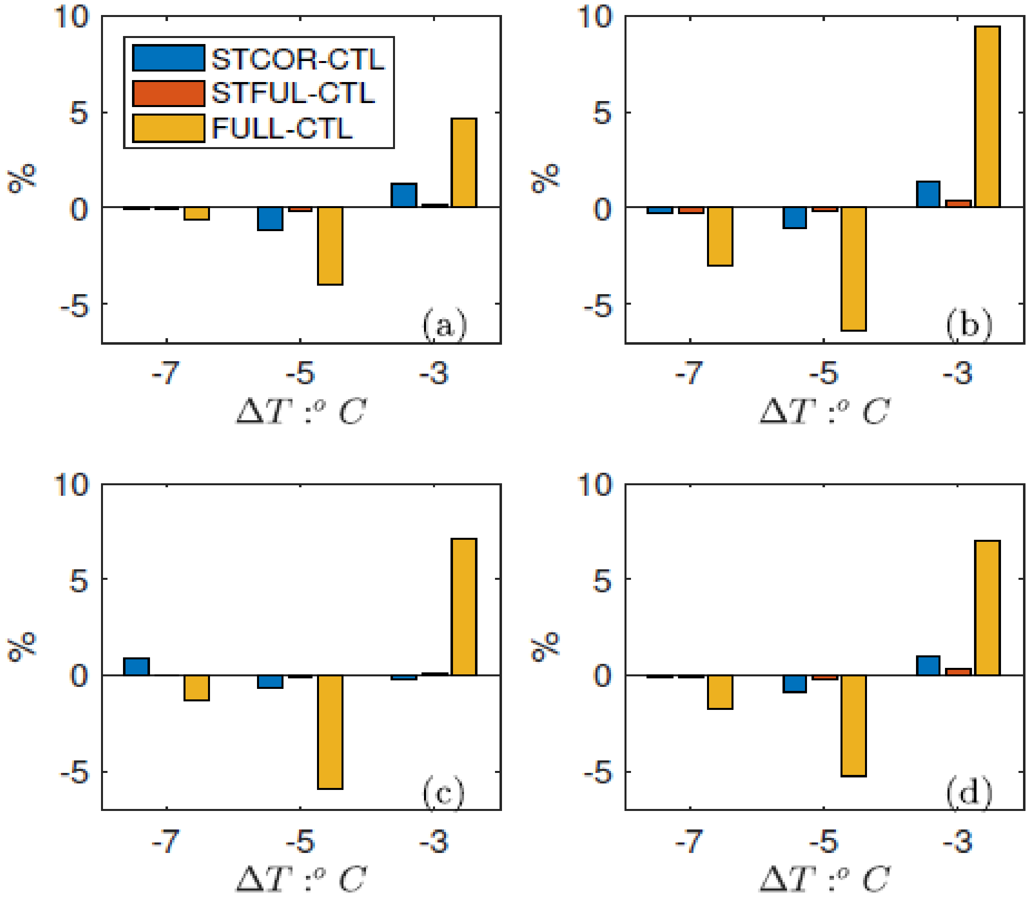
- Alari V, Staneva J, Breivik O, Bidlot JR, Mogensen K and Janssen PAEM (2016). Response of water temperature to surface wave effects in the Baltic Sea: simulations with the coupled NEMO-WAM model. Ocean Dynamics, DOI 10.1007/s10236-016-0963-x
- Breivik, O, J-R Bidlot, P A Janssen (2016). A Stokes drift approximation based on the Phillips spectrum, Ocean Model, 100, pp 49-56, doi:10.1016/j.ocemod.2016.01.005
- Stanev E., Schulz-Stellenfleth J., Staneva J., Grayek S, Grashorn S., Behrens A, Koch W., and Pein J. (2016). Ocean forecasting for the German Bight: from regional to coastal scales, Ocean Sci., 12, 1105–1136, 2016, doi:10.5194/os-12-1105-2016
- Staneva J., Alari V., Breivik O, Bidlot J.-R. and Mogensen K., (2016). Effects of wave-induced forcing on a circulation model of the North Sea. Ocean Dynamics, DOI 10.1007/s10236-016-1009-0
- 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, 2373-2389, doi:10.5194/nhess-16-2373-2016
- Wahle K., Staneva J, Koch W., Fenoglio-Marc L., Ho-Hagemann H., and Stanev E. (2016). An atmosphere-wave regional coupled model: improving predictions of wave heights and surface winds in the Southern North Sea. Ocean Sci. Discuss., doi:10.5194/os-2016-51, 2016

Impact of coupling on UPWELLING

The normalised distribution of the upwelling intensity (with 2 C bins) in June, July, August and September 2015.

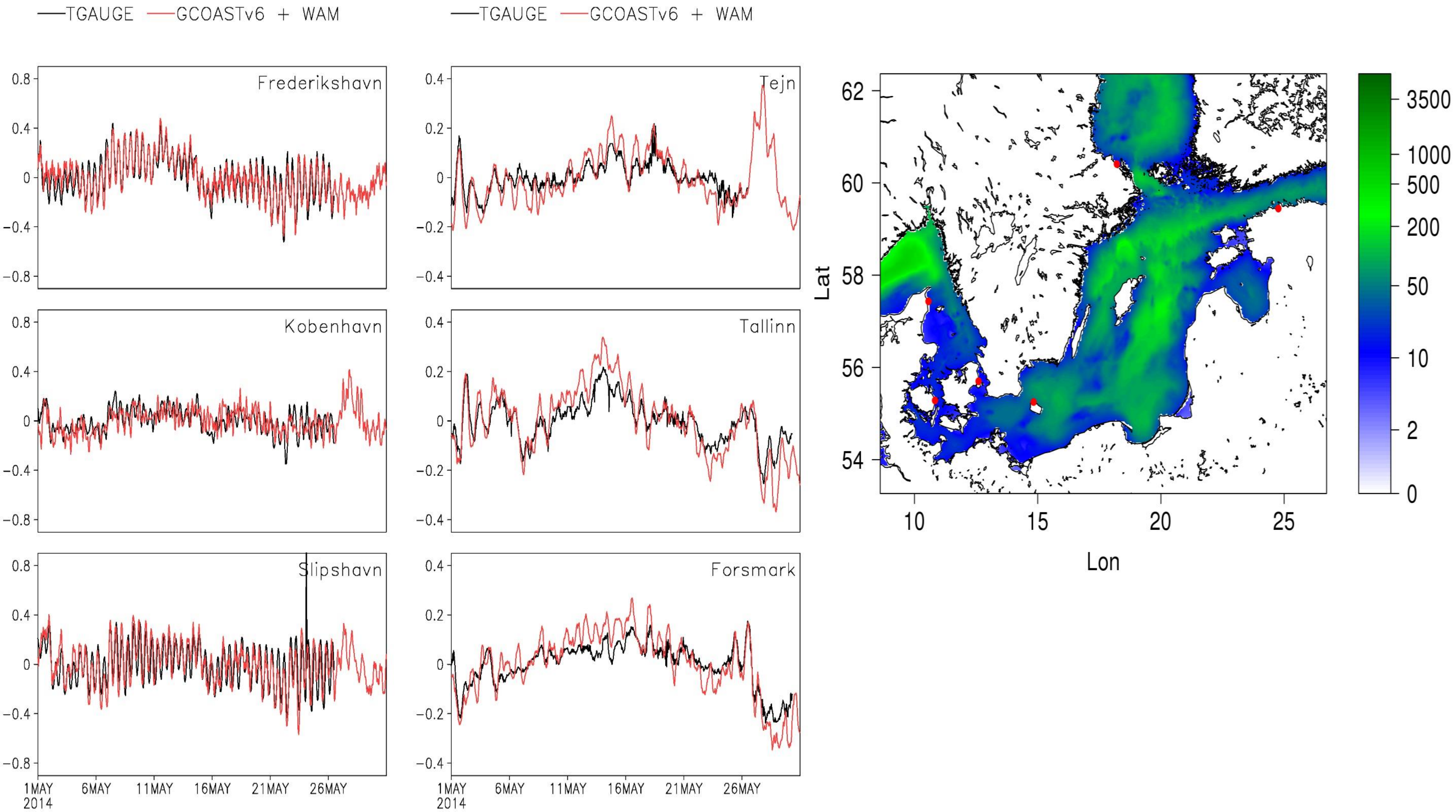


The wave effect on the distribution of the upwelling intensity in (a) June, (b) July, (c) August, and (d) September 2015.



Wu et al (2019)

Validation:Tide gauge



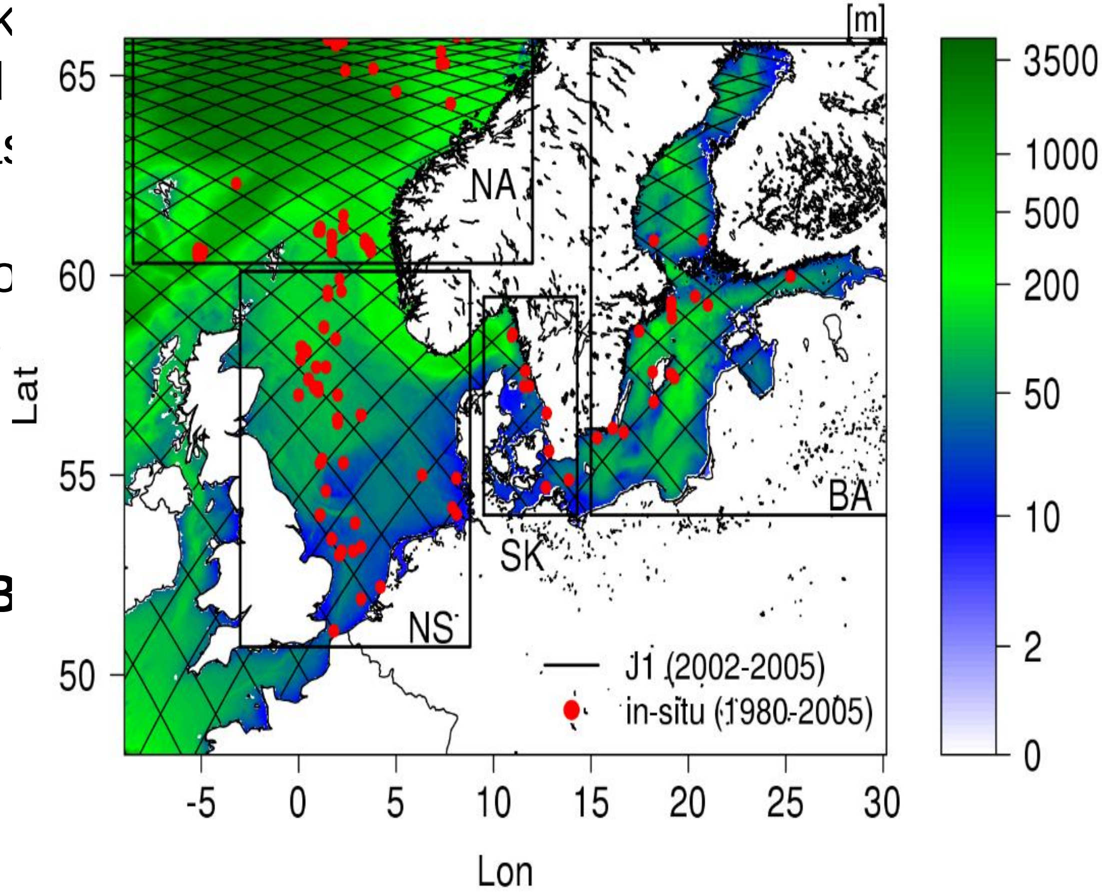
Wave Climate Change

- **Objective:** assess the skill of historical (**1980-2005**) regional wave climate simulation and use it as a reference to evaluate the wave climate projection by the end of the 21st century (**2075 – 2100**).

- **Wave Climate Simulation:** WAM model (5 k North East Atlantic (NA) North Sea (NS) and Baltic Sea (BA) considered as connected ba

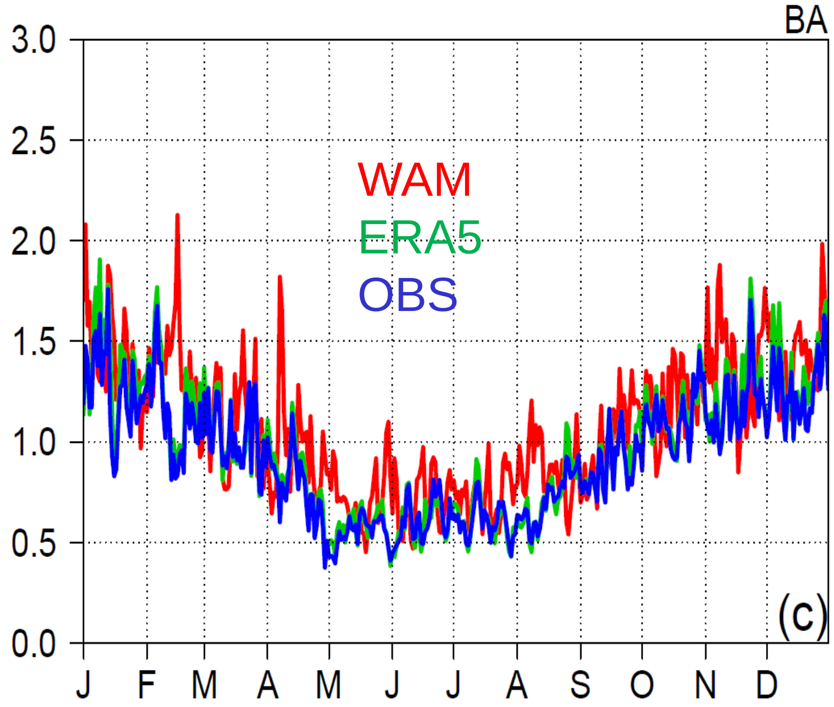
- **Scenario**: high emission scenario **RCP8.5** to investigate the maximum range of variations in the wave climate.

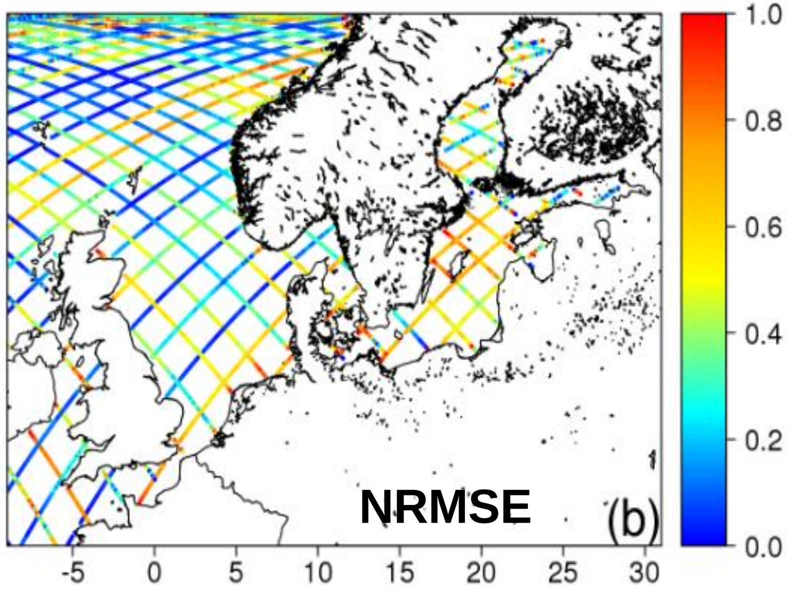
- **Data-sets**
  in-situ: GTS and CMEMS (Baltic Sea from **B**
  remote sensing: Jason-1;
  hindcast: ERA5-h;



(Bonaduce et., 2019)

Wave Climate: Baltic Sea





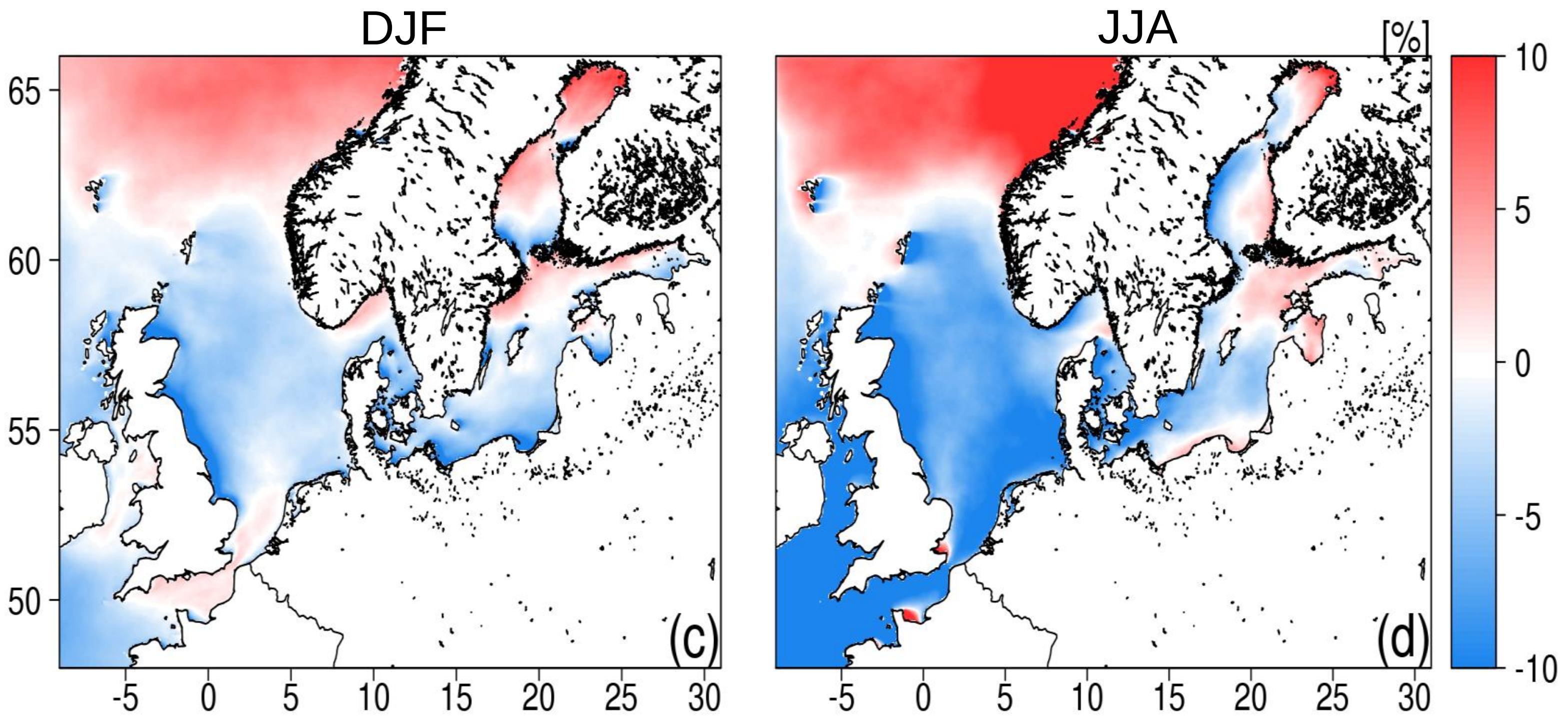
Julian year daily means of **Hs (m)**, at the observation positions during the historical run **(1980–2005).**

Discrepancies between the **observations and the WAM historical run (NRMSE 31%).**

ERA5-h was significantly **more reliable** (NRMSE 8%), due to observations assimilated during the reanalysis integration.

Similar results obtained comparing with satellite altimetry data (**Jason-1**) over a relatively short period (**2002 – 2005): NRMSE > 30 %** (considered as an average over the Baltic Sea).

Wave Climate Change: Baltic Sea



Annual 95th percentile Hs normalized difference between the future run (2075-2100) and historical run (1980–2005)

The **range** of variation in the **projected extremes: ± 10%**

- Interesting features were observed in the **Baltic Sea**
- **DJF**: **decrease the southern part of the basin**, which was associated with **increased extreme values in the Gulf of Bothnia**.
- **JJA:** a **decrease along the Swedish** coast and an **increase along the Finnish coasts** and Gulf of Finland were observed, probably due to changes in dominant meridional winds.

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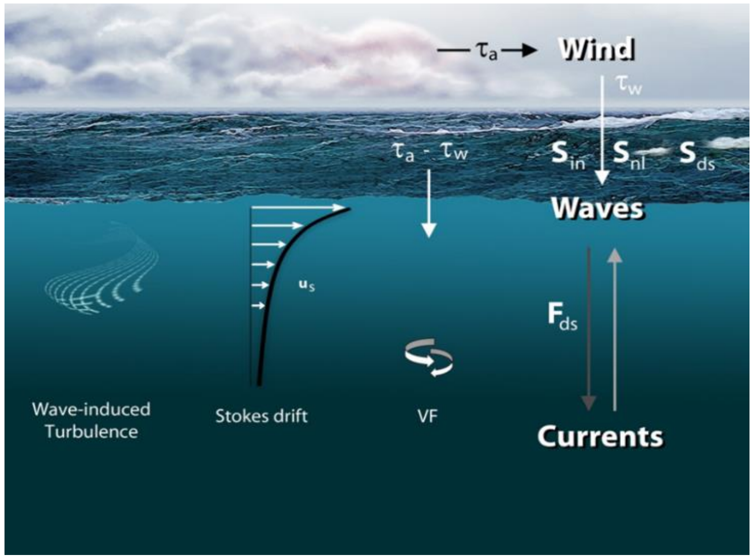
KSD Activities

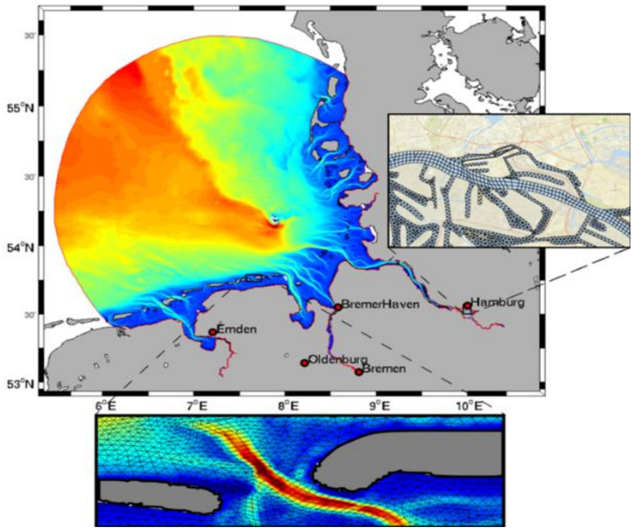
Wave model (WAM)

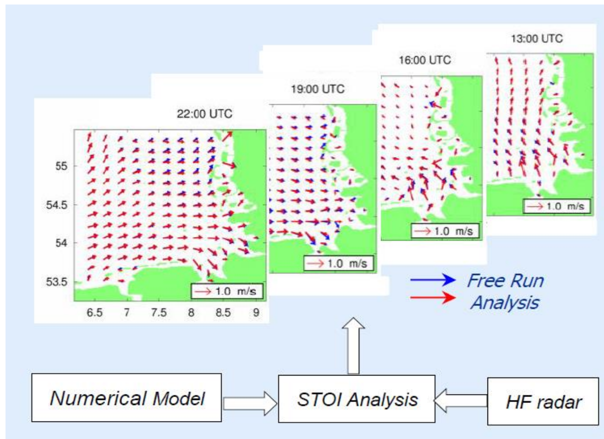
Regional Coupled model (NEMO)

Estuarine/ Coastal model (SCHSIM/GETM)

Data Analyses and Data Assimilation







Hydrodynamics and Data Assimilation

Modeling is an integrative part of the work of GCOAST, triggered by the need for yet not existing modelling capacity e.g. understanding of estuarine and coastal dynamics, resolving the dynamics of air-sea interaction, coastal extremes, land-ocean continuum, ocean predictability, impacts of offshore windfarms, marine liters, etc.

It involves evelopment, advancement and application of

- novel numerical modeling concepts, including unstructured grids and processes;
- modern **data analyses and assimilation** techniques integrating a wide spectrum of newly available observations;
- **coupling frameworks** for the coastal environment with focus on extremes.