

GCOAST regional ocean predicting system: impact of coupling of waves, circulation and atmosphere models

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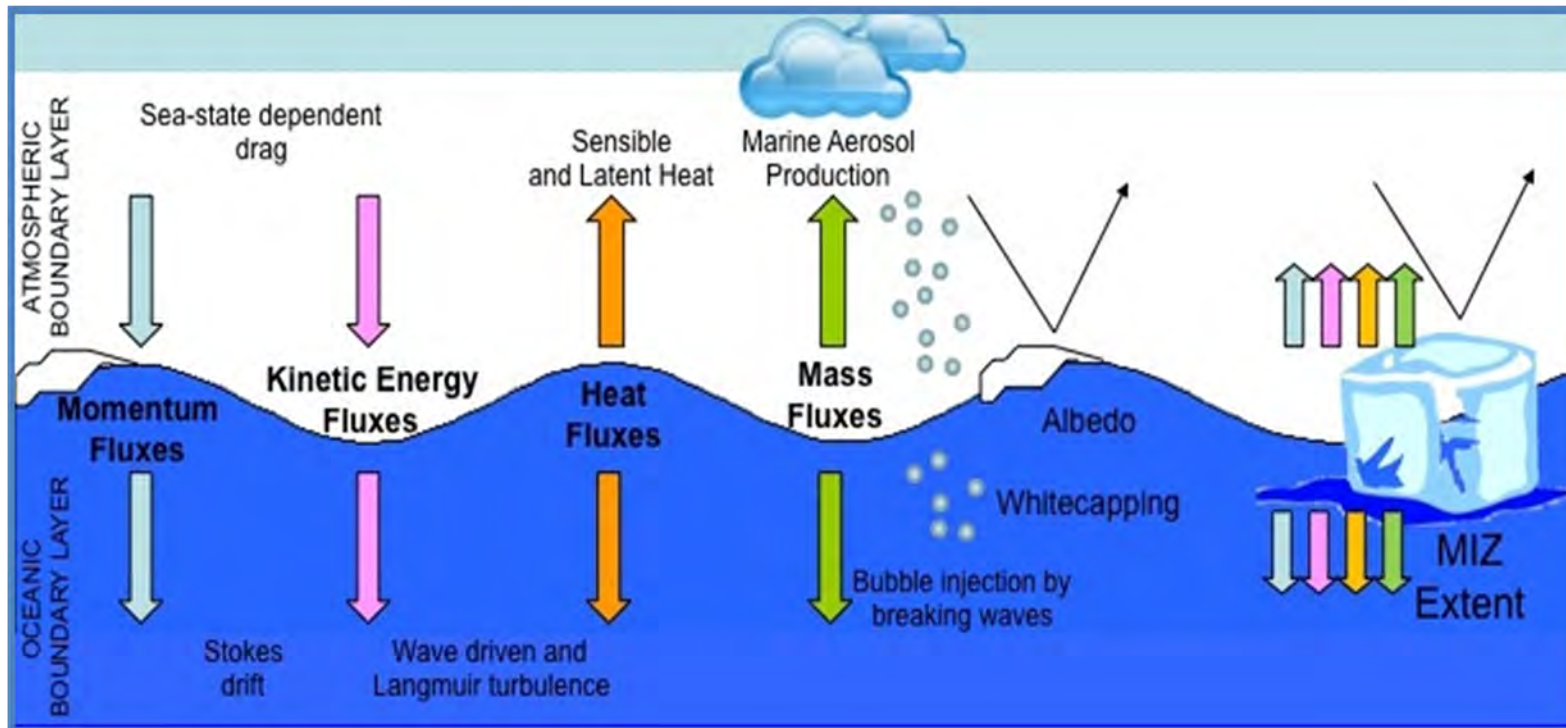
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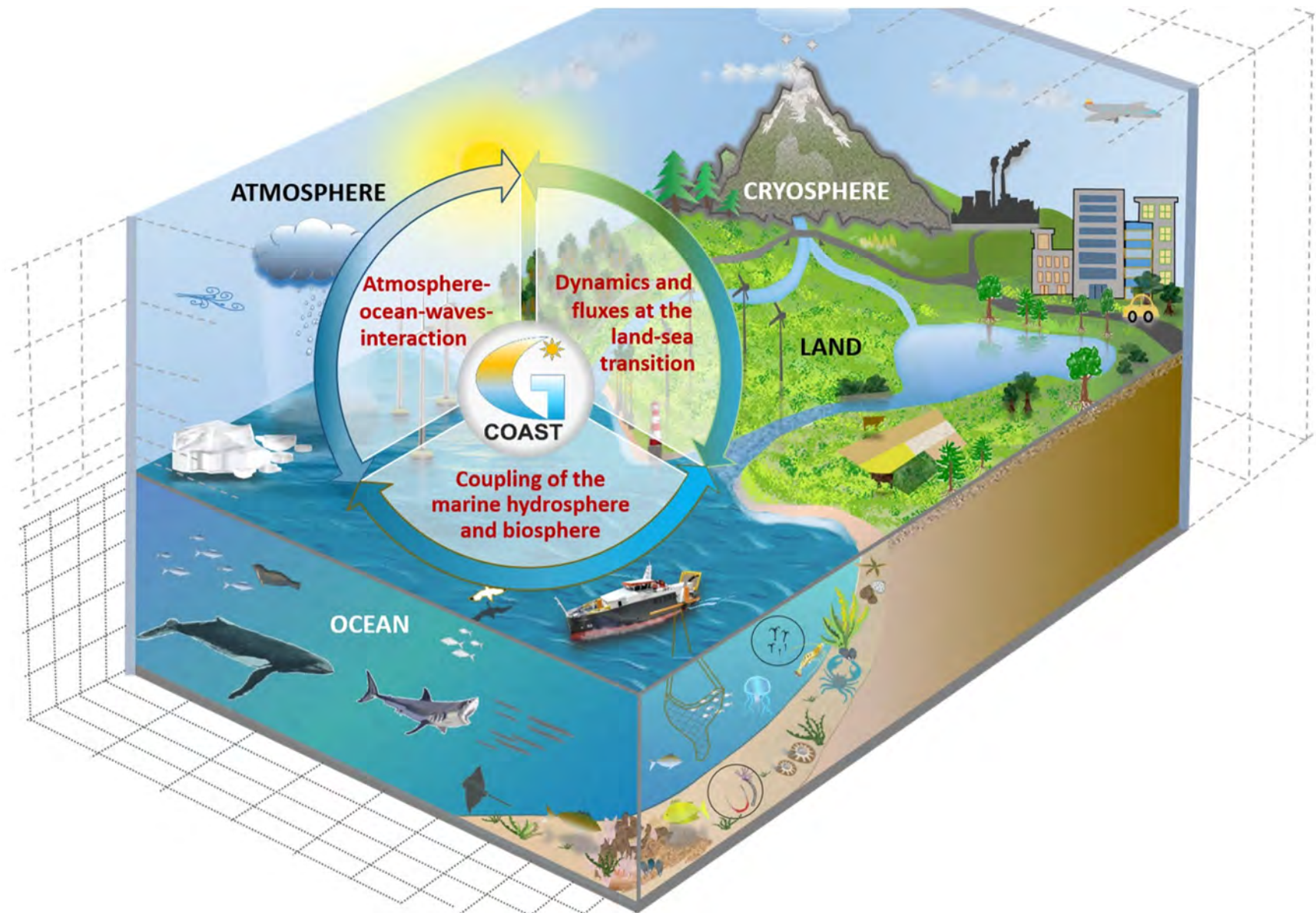


Relevance of atmosphere-ocean-wave coupling for coastal predictions

- Increased interest in reducing prediction errors of state estimates
- Study the impact of interaction processes
- Substantial effects also on mean fields -energy and momentum transfer
- Extreme weather events in the marine realm

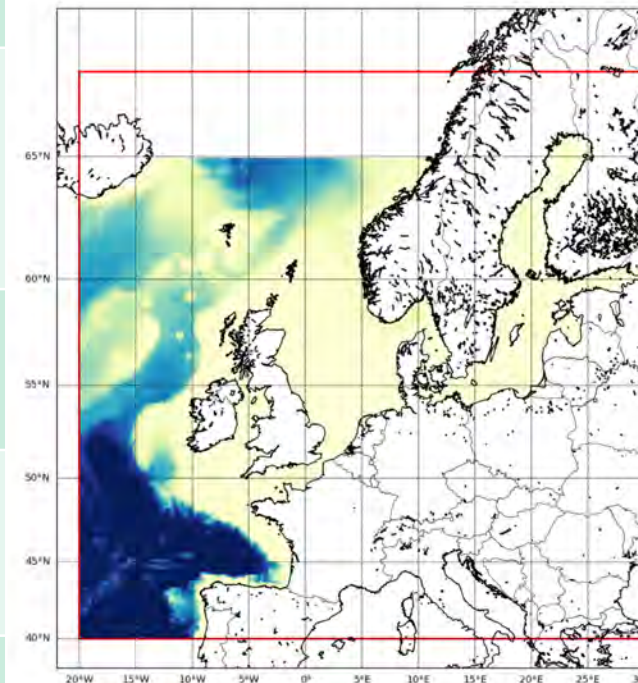
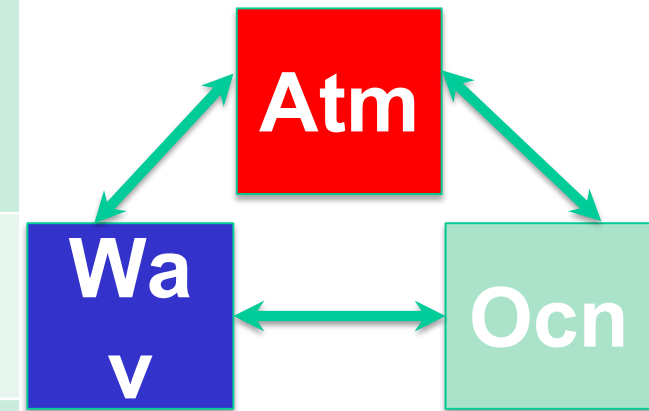


GCOAST Modell system



Coupled Model Setup

	NEMO 3.6	WAM 4.6.5	COSMO-CCLM
Horizontal grid	3.5 km covering North Sea and Baltic Sea, 900 m German bight	Same	7 km covering NW European seas
Vertical grid	56 s layers, emphasis on surface	N/A	55 levels
Initial field	CMEMS UKMO Data	EWAM wave data	COSMO-EU Model
Boundary condition	OSU tides, CMEMS UKMO Data for T,S, u,v, SLH	EWAM wave data	ERA-5 data
Forcing	DWD, ERA-I, ERA-5, COSMO	Same	ERA-5 Boundary data
Vertical diffusion scheme	GLS (<i>k-eps</i>)	N/A	
Ice	LIM-3	WAM ice parameterization	NA



GCOAST Modell system

Atmosphere-ocean-waves interaction



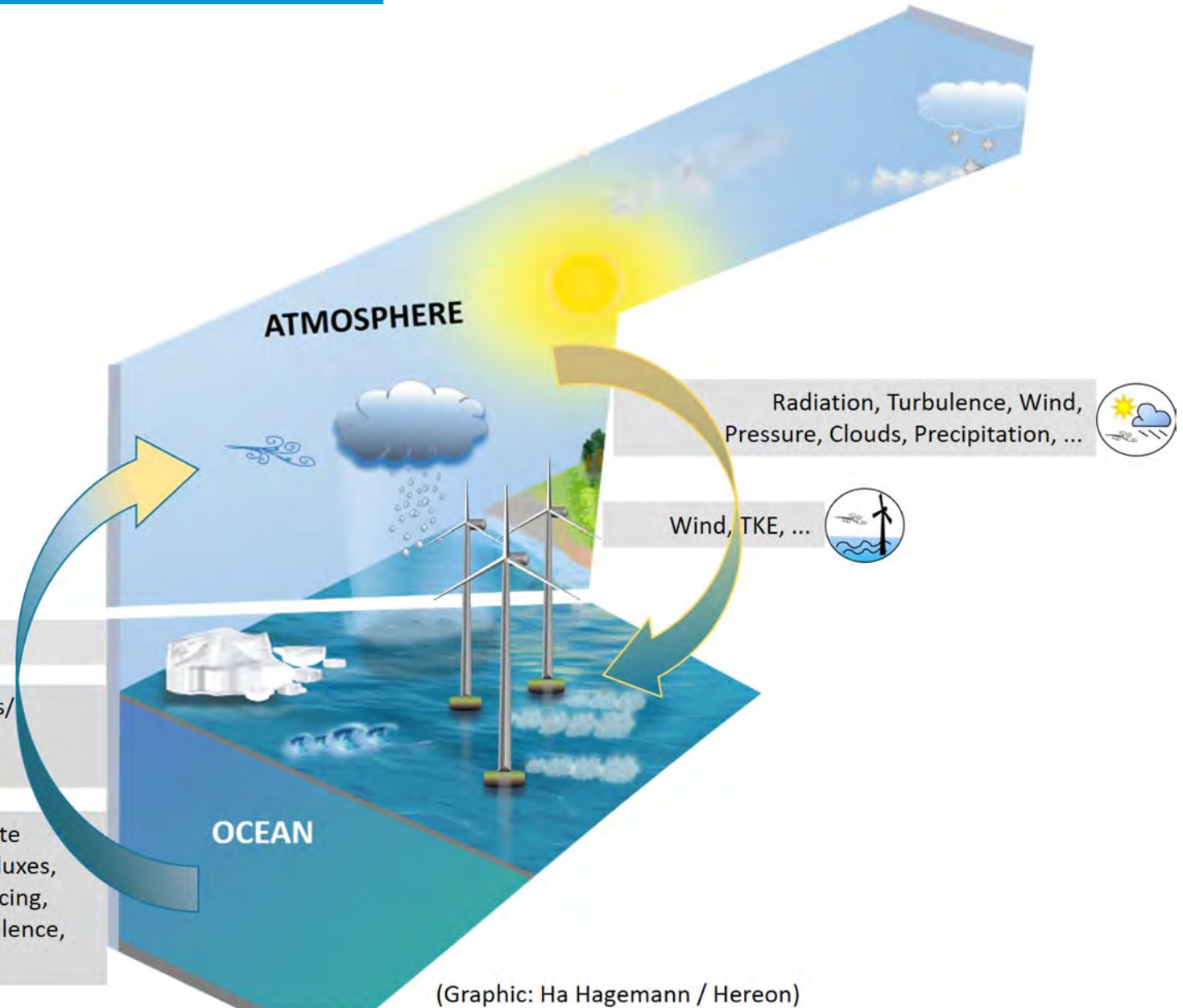
Sea ice cover, Temperature



Sea state modified bottom roughness/
wind interaction, Sea spray,
Wave-Ice-Ocean interaction, ...

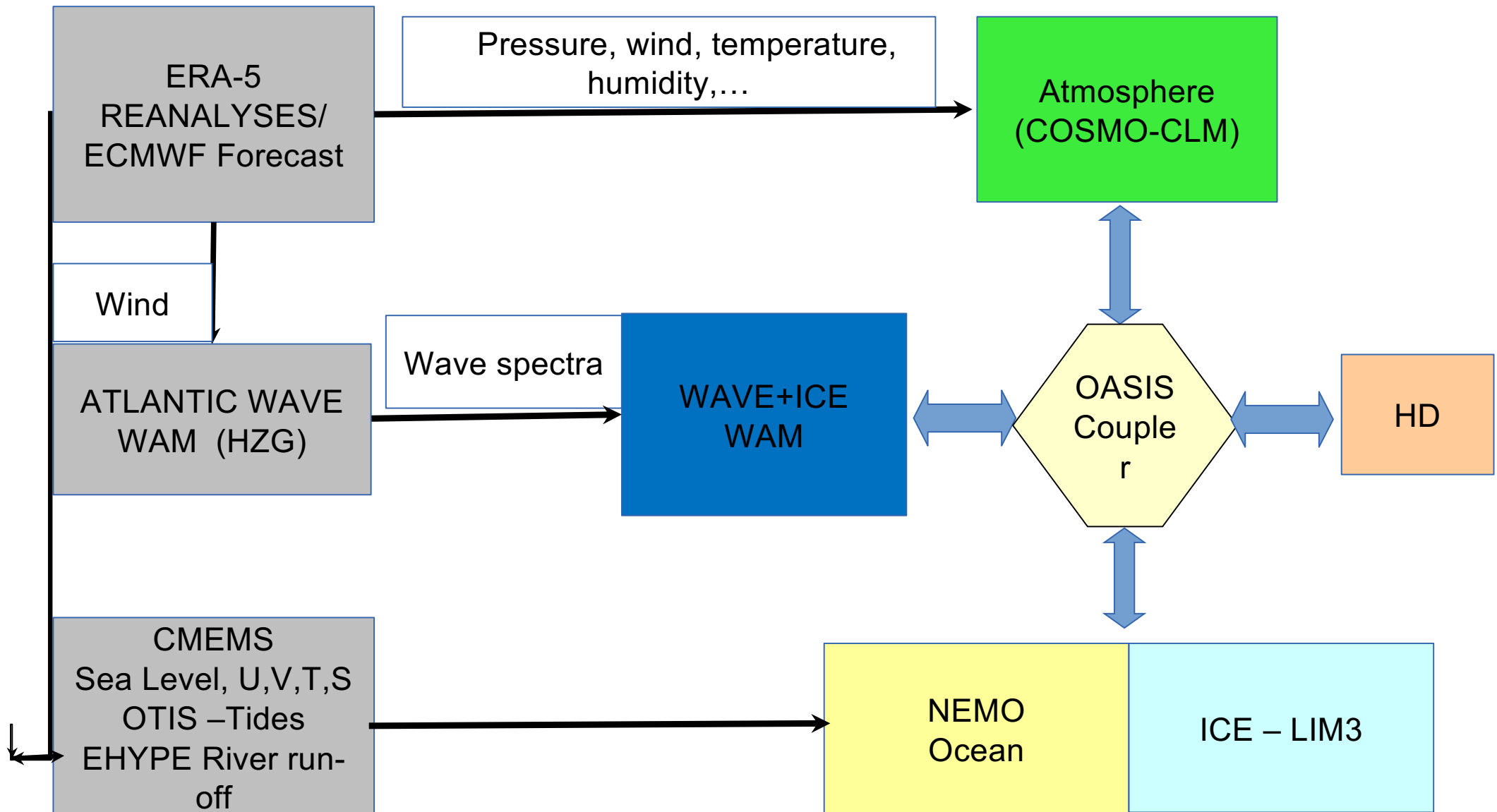


The Stokes-Coriolis forcing, Sea state
dependent momentum & energy fluxes,
Sea state bottom fluxes, Vortex forcing,
Ocean currents, SST, Salinity, Turbulence,
Mixing, Sea spray, Particles, ...

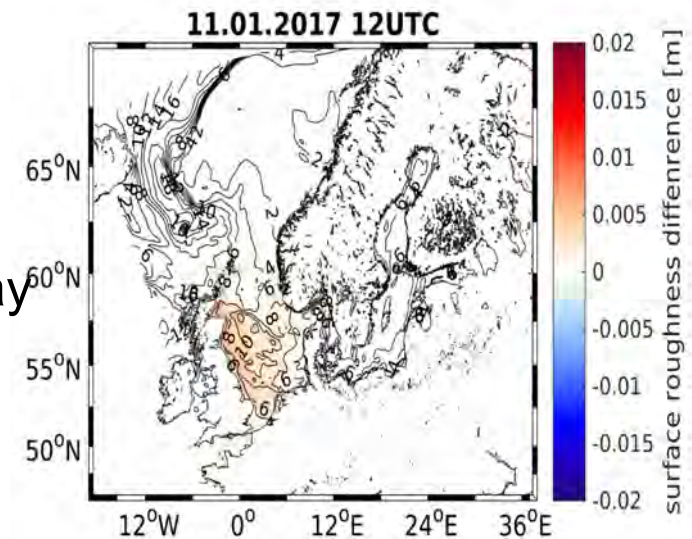
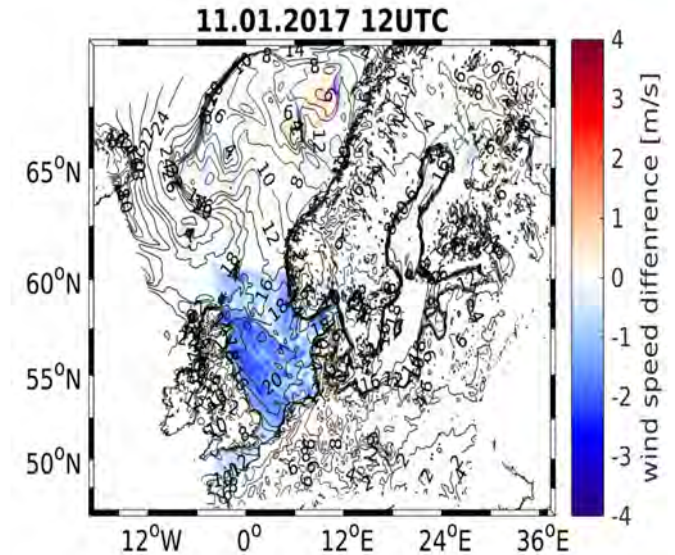
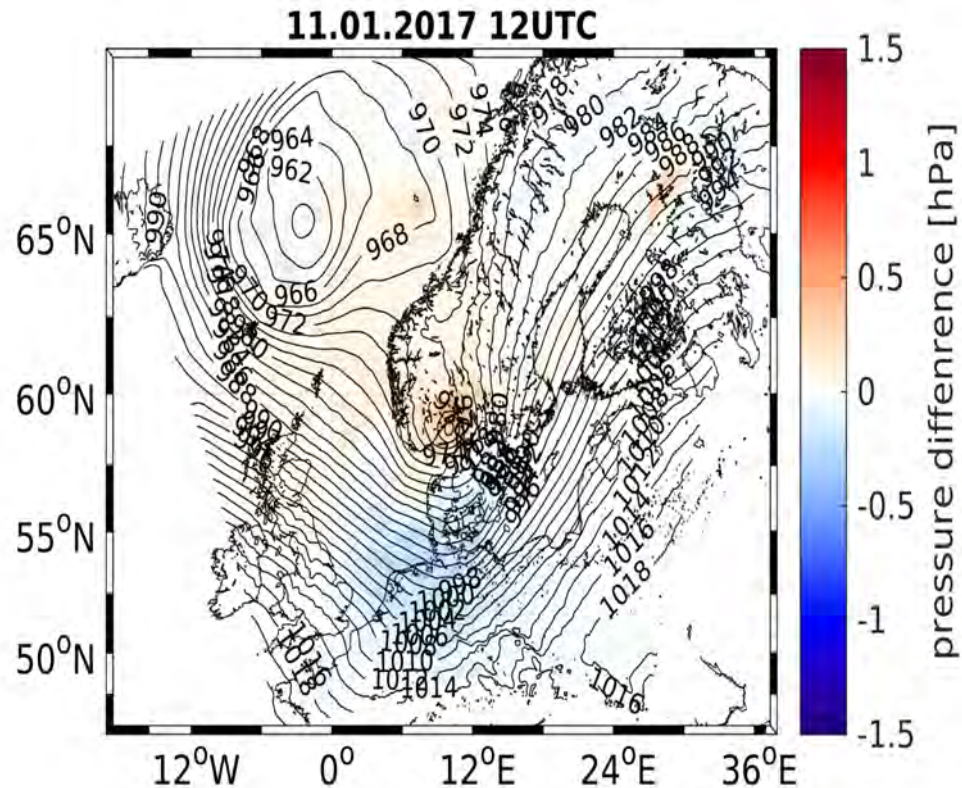


(Graphic: Ha Hagemann / Hereon)

External Forcing



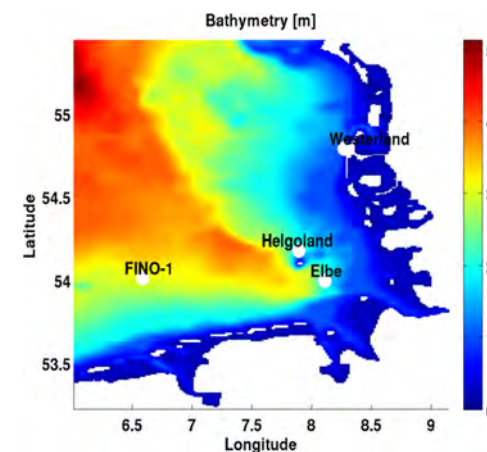
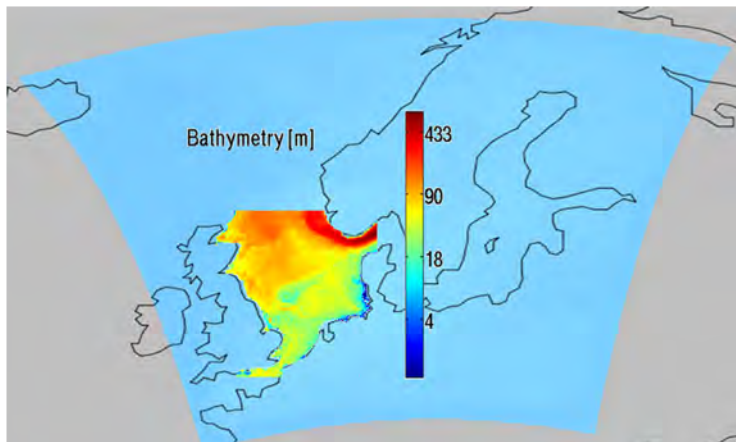
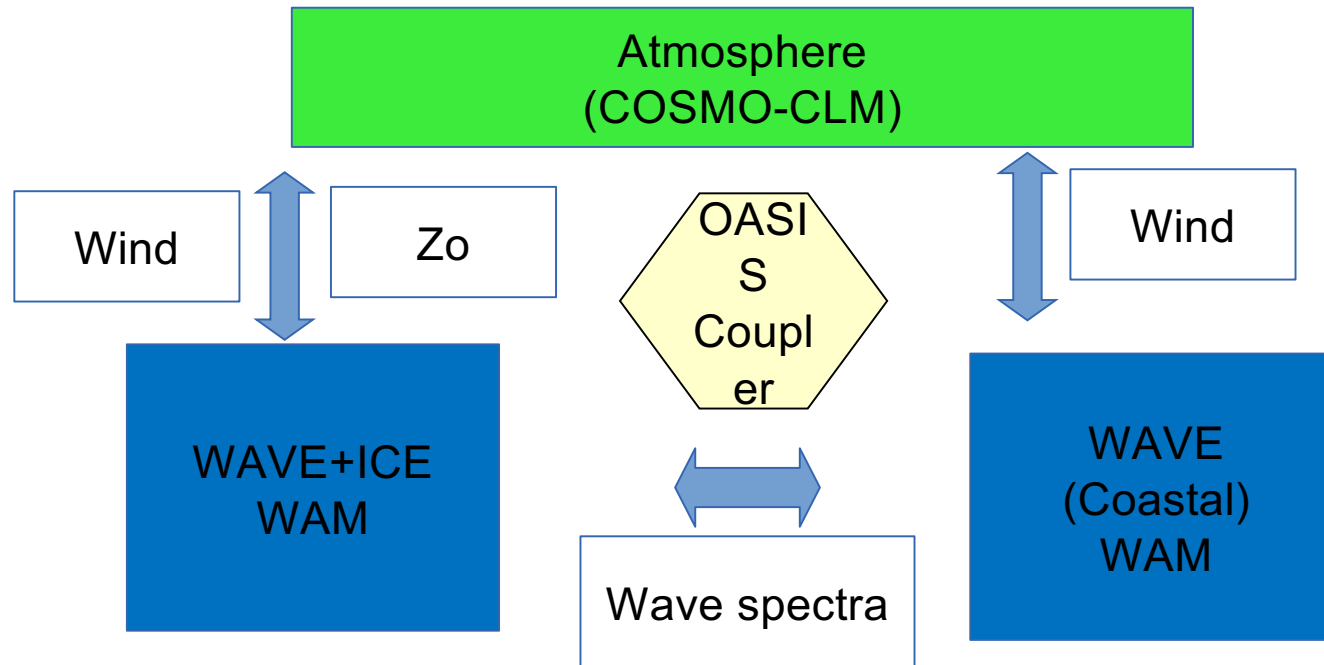
MSLP, 10m wind speed, surface roughness



- Low pressure system between Island and Norway
- Secondary low around Oslo
- Reduced pressure gradient
- Enhanced surface roughness
- Reduced wind speed

Two-way coupling and Downscaling via OASIS

- Waves extract energy and momentum from the atmosphere.
- The effect is largest for young sea states and high wind speeds.

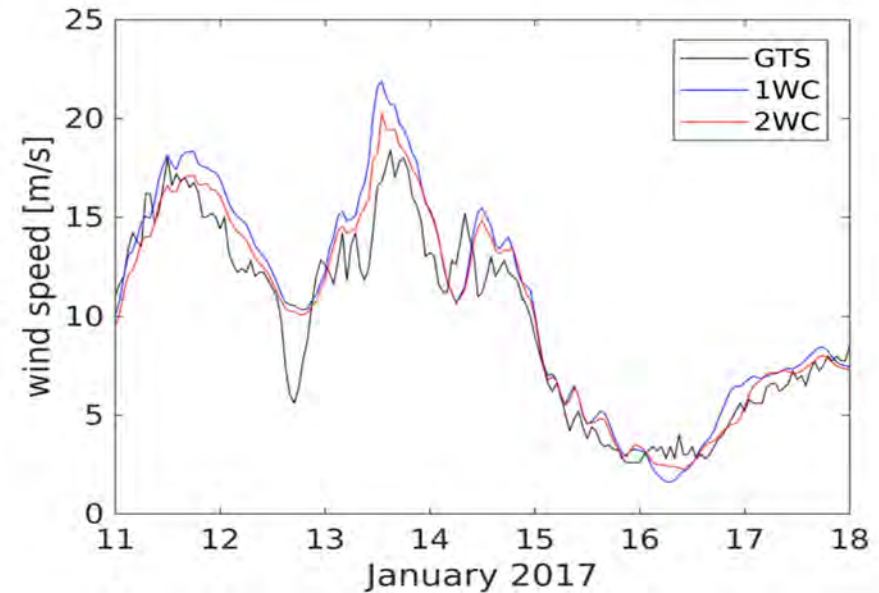
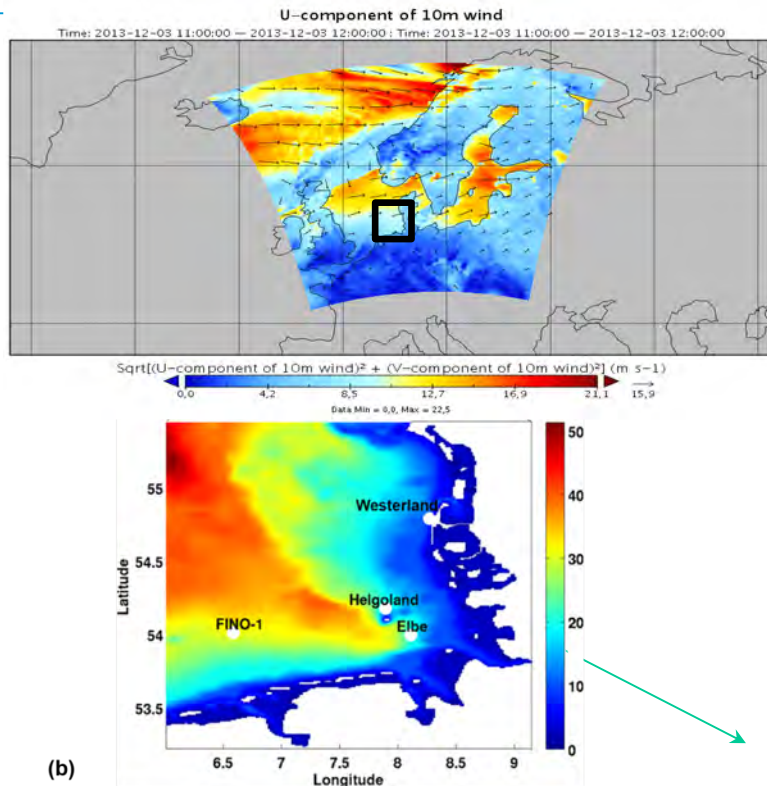


$$U(z) = \sqrt{\frac{\tau}{C_D(z)}}$$

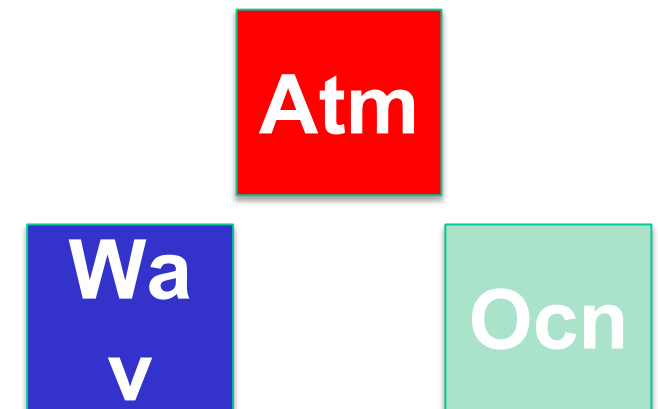
$$C_D(z) = \frac{\kappa^2}{\ln^2(z/z_0)}$$

$$z_0 = \frac{\alpha\tau}{g} = \frac{1}{\sqrt{1-\tau_w/\tau}}$$

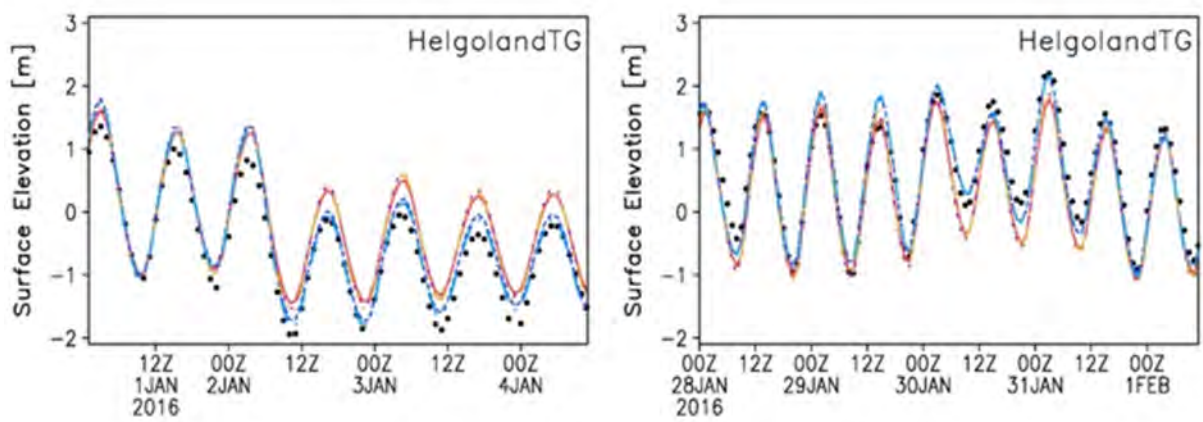
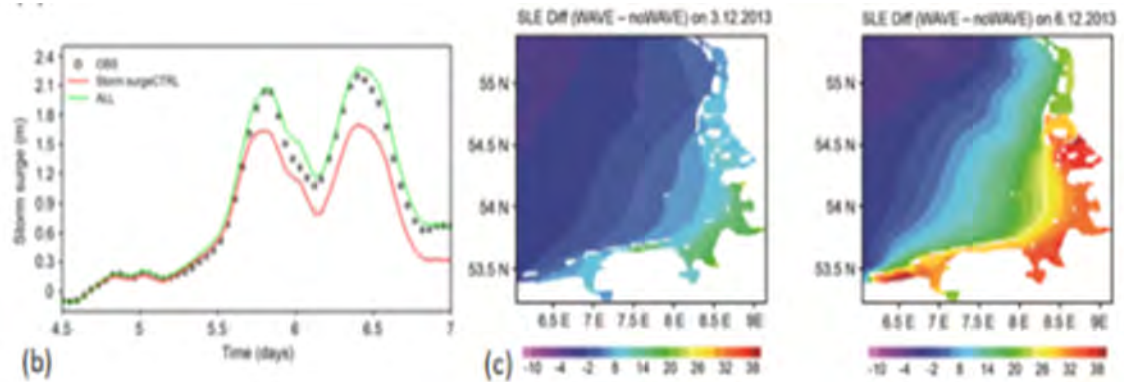
Impact on HiRes forecast wind and waves



mean hs	Hel:1.95		Fino-1:1.42		Wes: 1.63	
	1-way	2-way	1-way	2-way	1-way	2-way
bias hs [m]	-0.14	-0.03	-0.07	-0.01	-0.13	-0.03

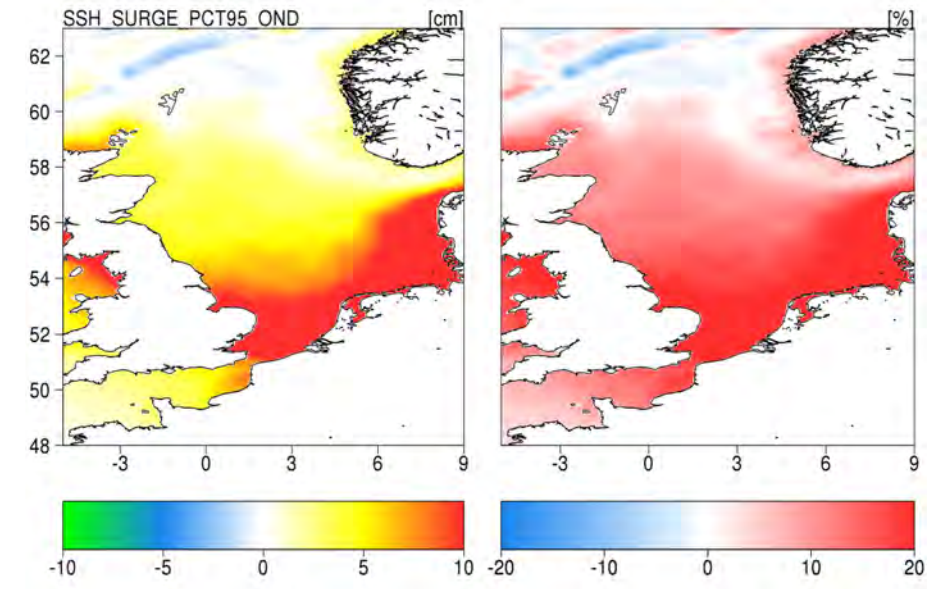


Impact on sea level predictions



Impact on surge and coastal ocean forecasting (Staneva et al. 2017, 2021)

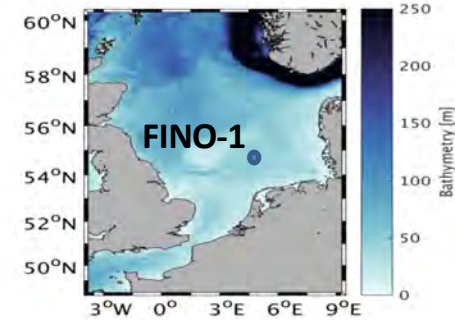
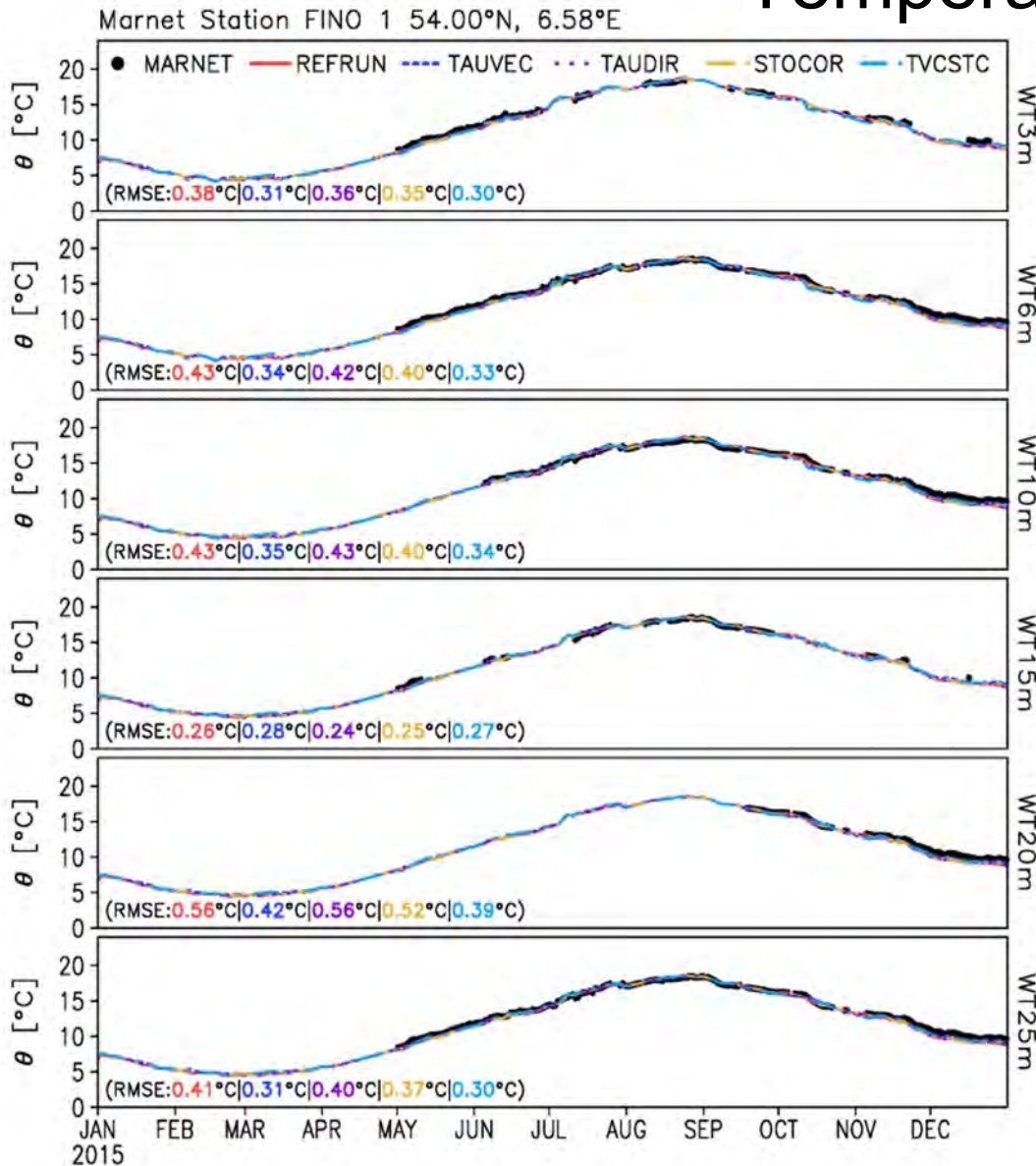
95th Percentile SLE (2009-2019)
Coupled – Uncoupled
Absolut and Relative differences



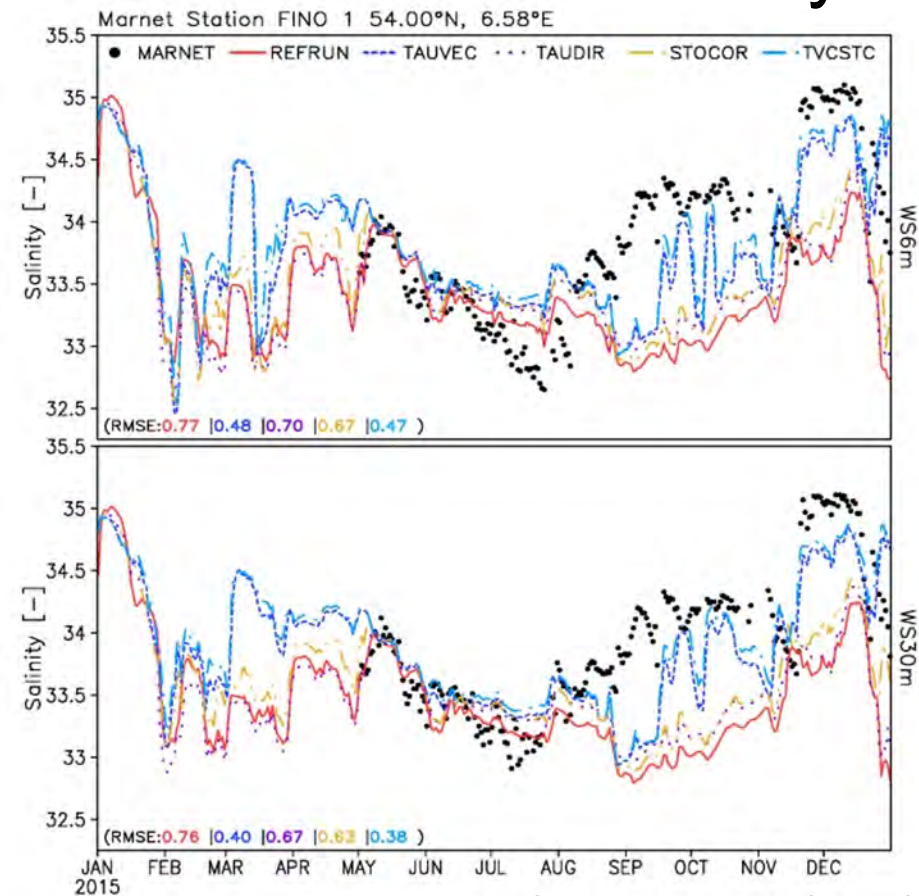
Positive (negative) differences show that surge is larger (smaller) due to wave-coupling
Bonaduche et al. (2020)

Impact of coupling – T&S

Temperature

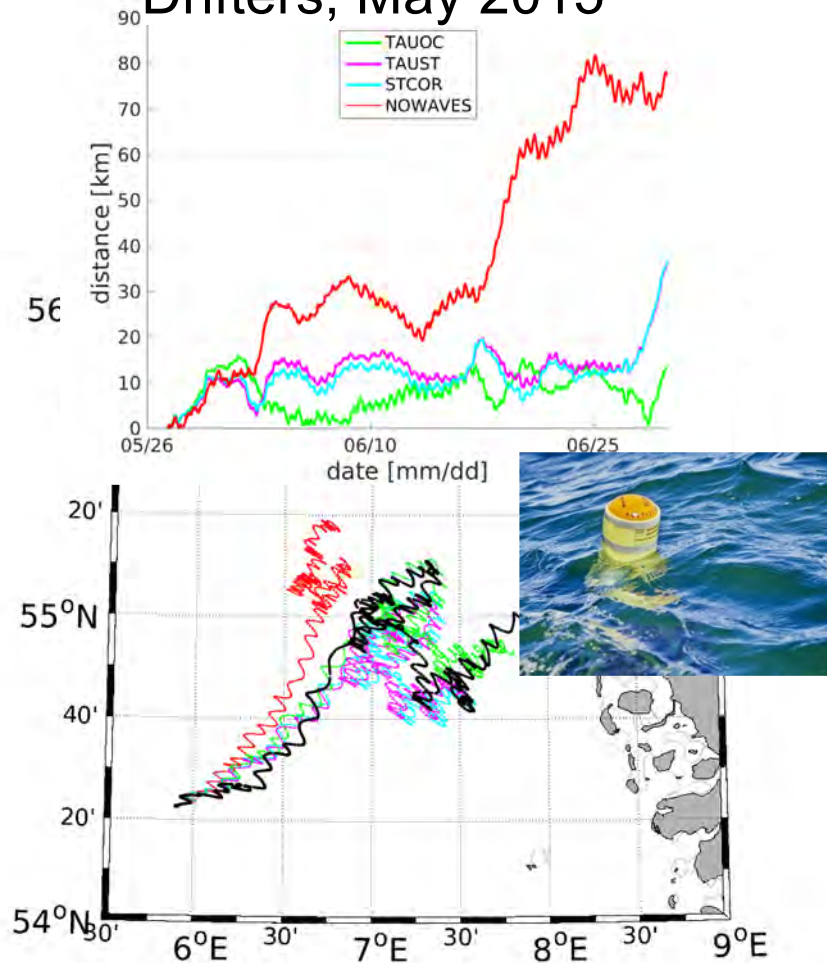


Salinity

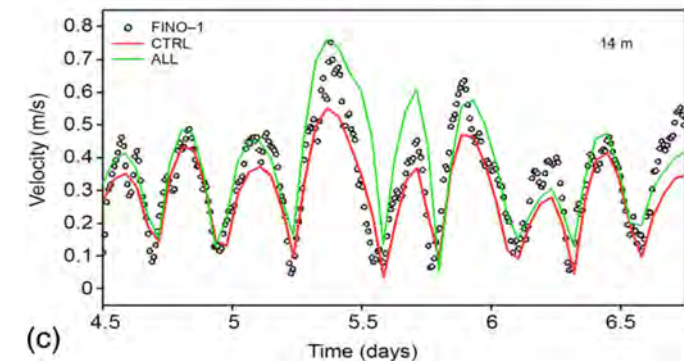
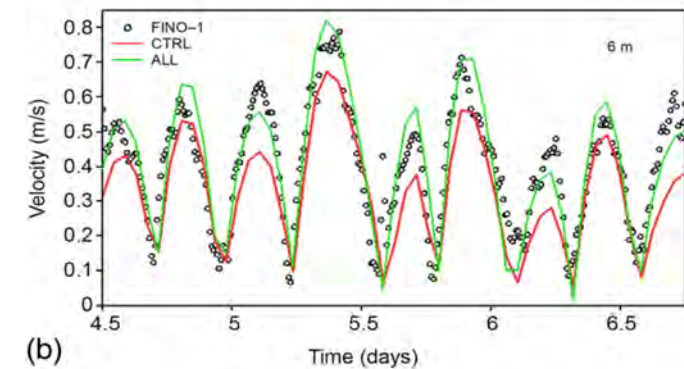
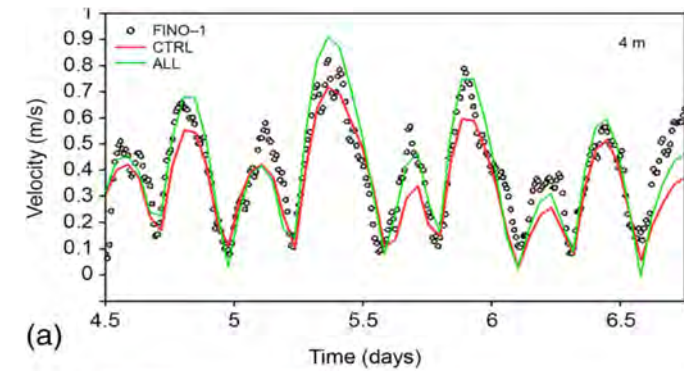


Impact of coupling on circulation and drifter modelling

Drifters, May 2015



Velocity at different levels



Staneva, J.; Ricker, M.; Carrasco Alvarez, R.; Breivik, Ø.; Schrum, C (2021). Effects of Wave-Induced Processes in a Coupled Wave–Ocean Model on Particle Transport Simulations
<https://doi.org/10.3390/w13040415>

Conclusions



- A coupled WAM-COSMO-NEMO model has been implemented for the NE Atlantic, North Sea and Baltic Sea and new parameterizations tested.
- Coupling of COSMO-WAM-NEMO showed better agreement with observations during extremes, especially in the coastal areas
- Effects of considering sea state and introducing wave-induced forcing on simulated temperature are not negligible and the skill has been improved.
- Storm surge, circulation, drifter simulations of the coupled model showed better agreement with observations than the stand-alone NEMO.
- Paves the road to more realistic simulations in both operational forecasting systems and climate studies

**Thank you
for your attention!**

Publications:



- Staneva, J.; Ricker, M.; Carrasco Alvarez, R.; Breivik, Ø.; Schrum, C (2021). Effects of Wave-Induced Processes in a Coupled Wave–Ocean Model on Particle Transport Simulations. *Water*, 13, 415. <https://doi.org/10.3390/w13040415>
- Staneva J., S. Grayek, A. Behrens and H. Günther (2021): GCOAST: Skill assessments of coupling wave and circulation models (NEMO-WAM). *Journal of Physics: Conference Series*, Vol. 1730, 012071, doi:10.1088/1742-6596/1730/1/012071
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- 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