PARTICLE TRANSPORT MODEL SENSITIVITY ON WAVE-INDUCED PROCESSES

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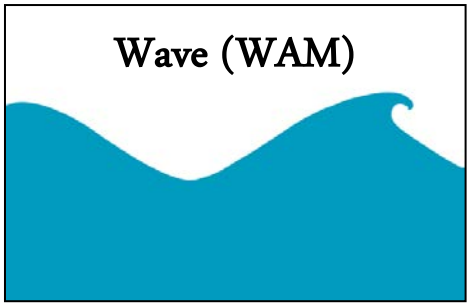
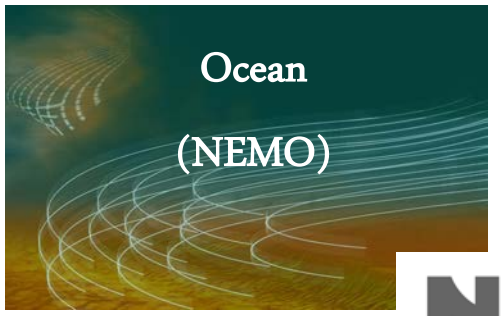
EGU General Assembly 2017, 23.-28.04., Vienna, Austria
OS2.3, Oceanography at coastal scales. Modelling, coupling and observations

GCOAST

Coupled Earth-System Model

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research



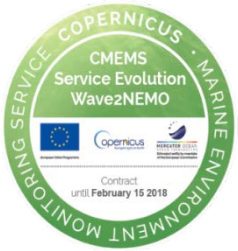


Drift Models

Land/Hydro

SPM/
Biogeochemistry

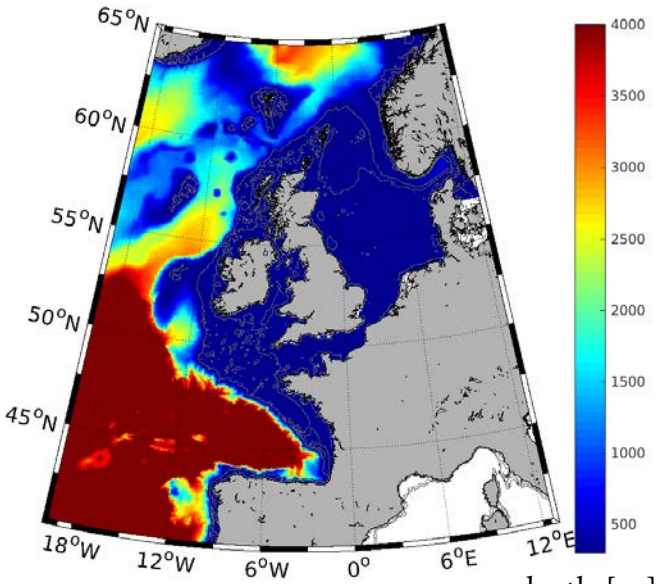
Outline



1. Wave-induced processes into NEMO
2. Comparisons with observations
    1. Effects of surface ocean waves on the model sea level
    2. Effects of wave processes on circulation
3. Drifter in the North Sea
    1. Transport model sensitivity to wave parameters
4. Discussion

Model setup

	NEMO 3.6	WAM 4.5.4
Modelling period	01.10.2013 - 31.12.2016	Switched on at 01.05.2013
Horizontal grid	2 nm covering North Sea and north west shelf	Same
Vertical grid	50 σ-layers; emphasis on surface	N/A
Initial field	CMEMS UKMO data	EWAM wave data
Boundary condition	OSU tides; CMEMS UKMO Data for T,S,u,v,SSH	EWAM wave data
Atmospheric forcing	UKMO Data (1 h)	Same
Vertical diffusion scheme	GLS (*k-eps*)	N/A
Bottom friction coef.	Log-layer	Const.

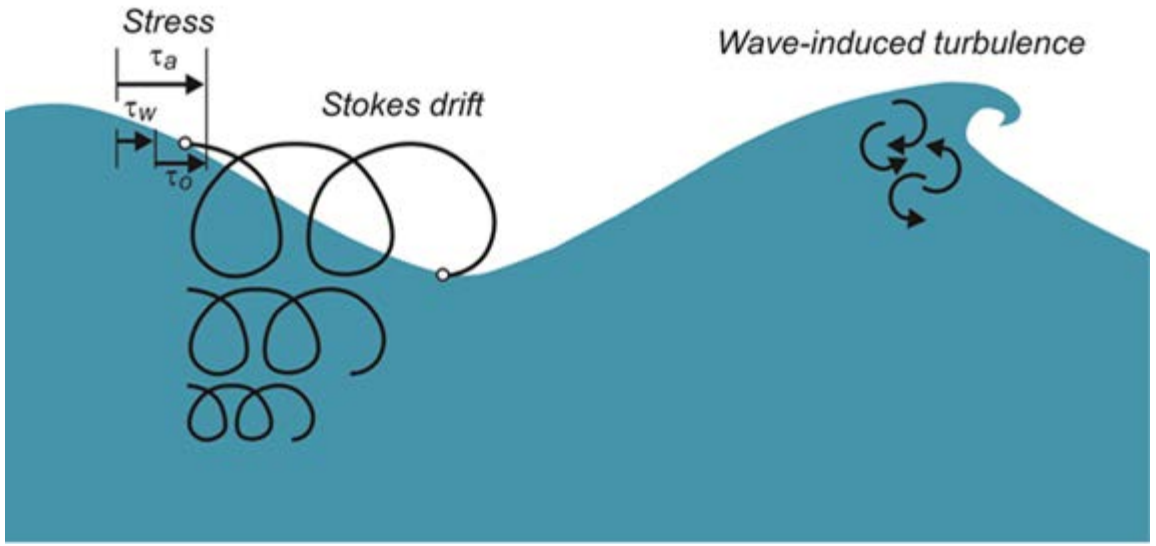


Model domain

Physical processes forming wave-circulation interaction

We will further develop and implement into the target areas NEMO ocean model that takes into account the following wave effects:

1) The Stokes-Coriolis forcing *(Hasselmann, 1970);*
2) Sea state dependent momentum flux *(Janssen, 1989; Janssen, 2012);*
3) Sea state dependent energy flux *(Craig and Banner, 1994).*



Alari et al. (2016)

NEMO Model modifications to include waves

Wave forcing variables of WAM 4.5.4:

$$\overrightarrow{v_s} = \int \mathrm{d}f\mathrm{d}\theta \frac{2gk}{\omega \tanh(2kD)} \vec{k} F(f,\theta)$$ ⟶ Stokes drift

$$\tau_{\mathrm{in}} = \rho_{\mathrm{w}} g \int_0^{2\pi} \int_0^{\infty} \frac{\boldsymbol{k}}{\omega} S_{\mathrm{in}} \mathrm{d}\omega \mathrm{d}\theta \,, \qquad \tau_{\mathrm{oc}} = \tau_{\mathrm{a}} - \tau_{\mathrm{in}} - \tau_{\mathrm{db}}$$ ⟶ wave induced stress

output of wave breaking parameter α for TKE ⟶ TKE

Implementation in NEMO 3.6:

$$\frac{D\boldsymbol{u}}{Dt} = -\frac{1}{\rho}\nabla p + (\boldsymbol{u} + \boldsymbol{v}_{\mathrm{s}}) \times f\,\hat{\boldsymbol{z}} + \frac{1}{\rho}\frac{\partial \tau}{\partial z}$$ ⟶ momentum eq.

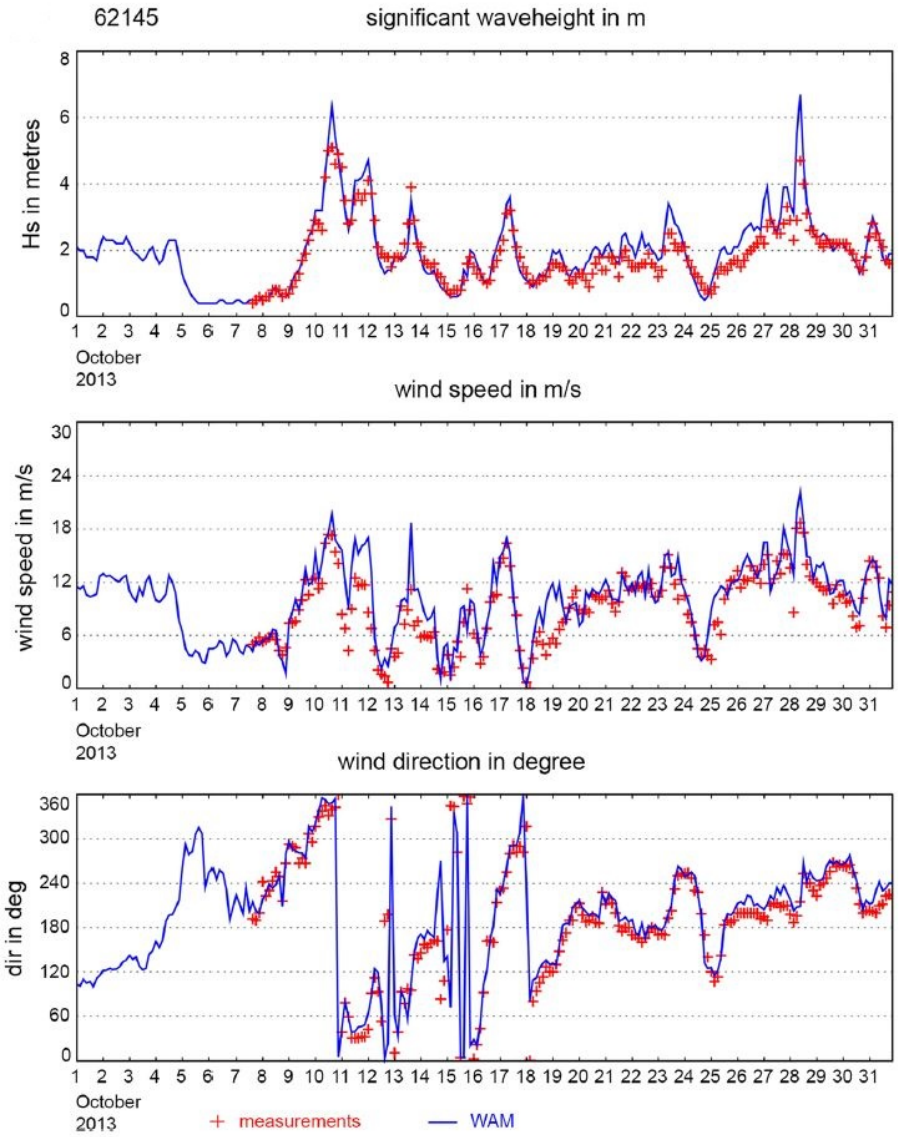
turbulent length scale for TKE scaled with wave heigth H_S ⟶ turb. length scale

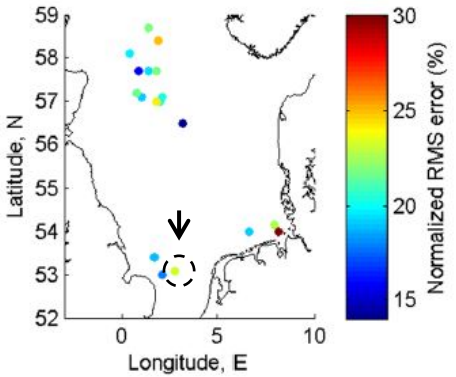
Alari et al. (2016)

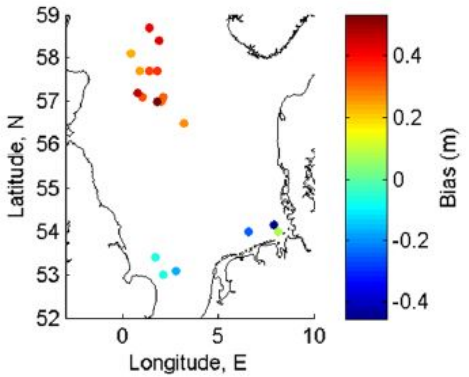
Experiments

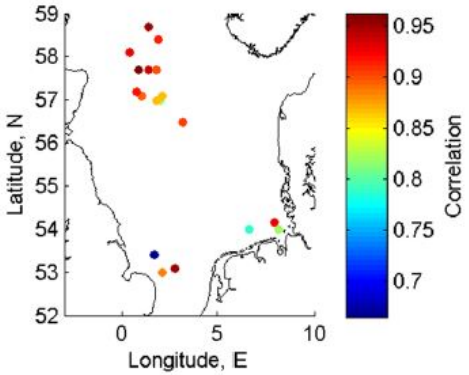
	NEMO	Stokes-Coriolis force	Ocean side momentum stress	Wave breaking
NOWAVE	√			
STCOR	√	√		
TAUOC	√		√	
TKE	√			√
TAUST	√	√	√	
ALL	√	√	√	√

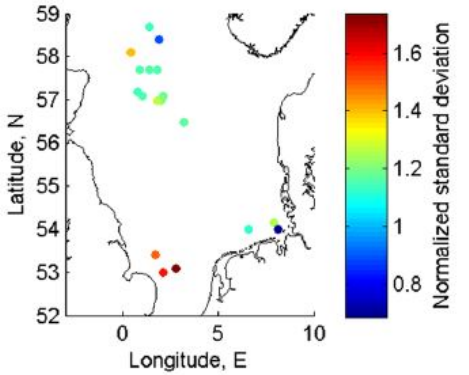
North Sea: Comparisons between the wave model simulations and observations





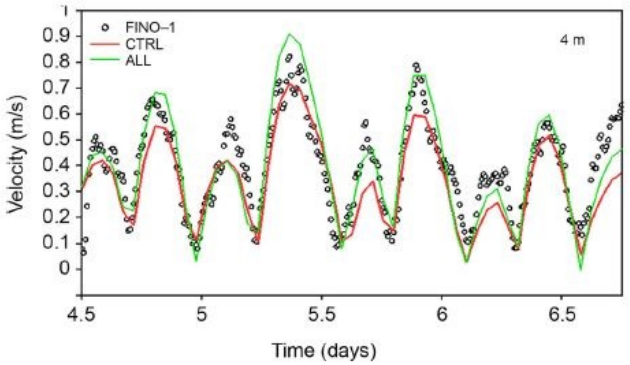


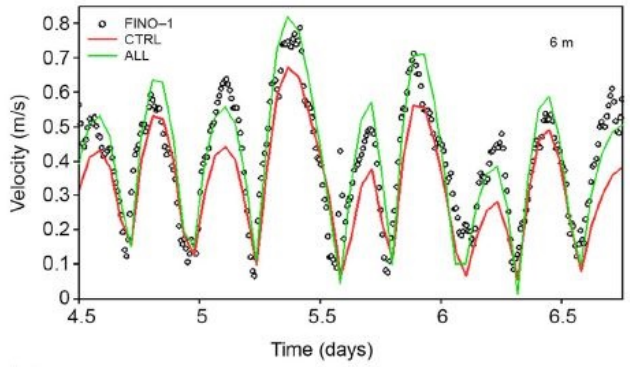


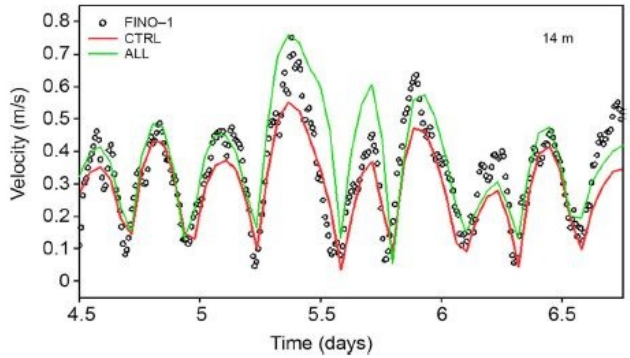


Staneva et al. (2017)

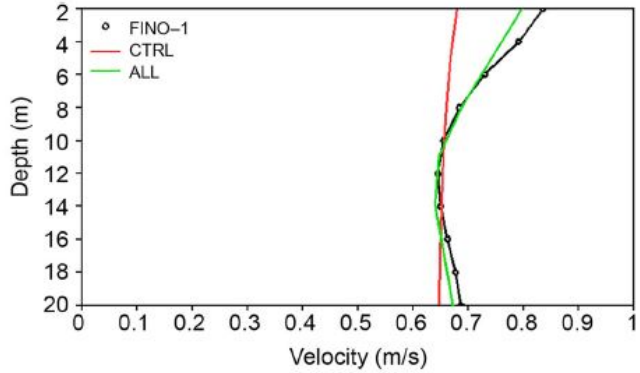
The impact of wind waves on currents





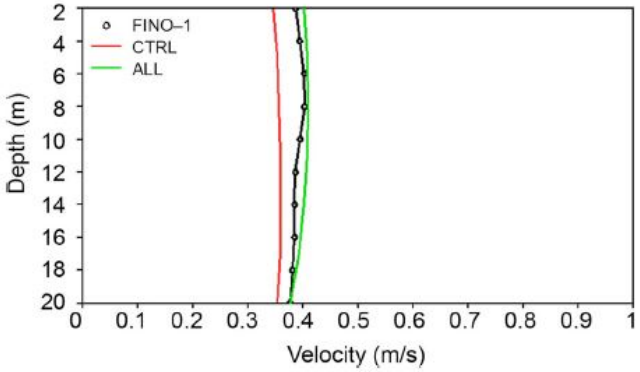


days from 12/01/2015



12/05/2015

09:00h



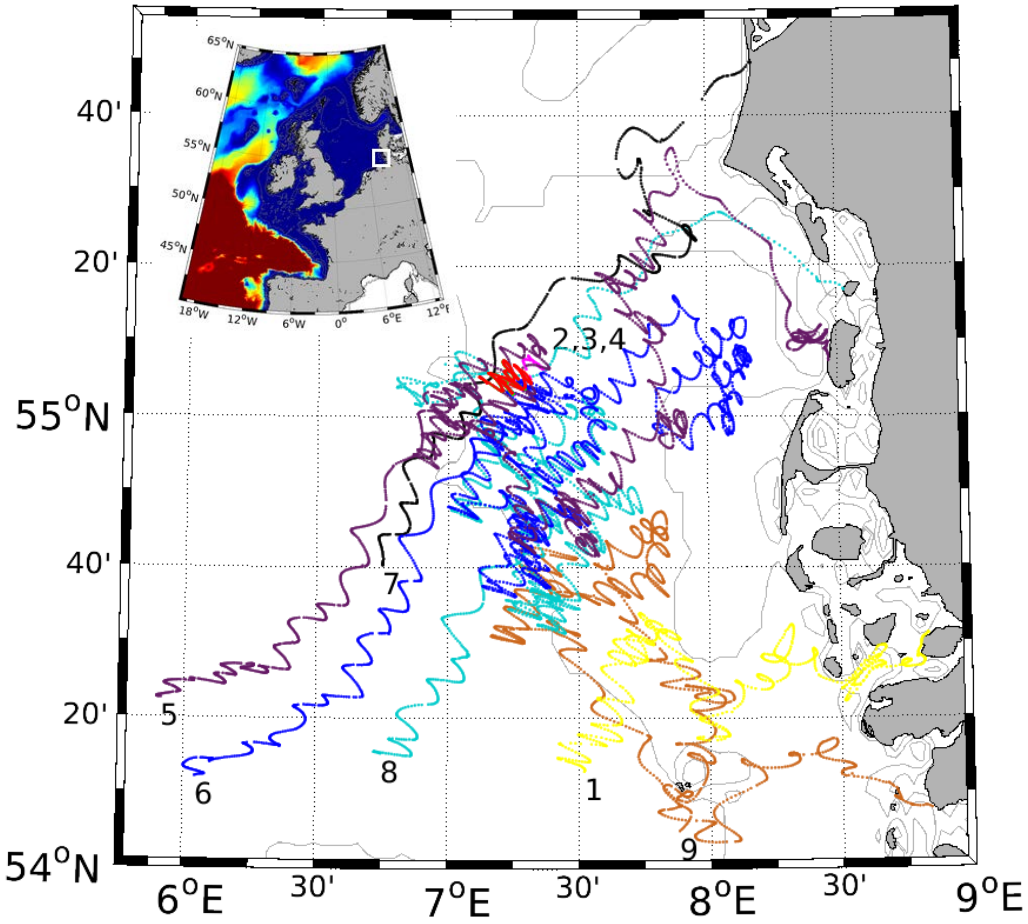
14:00h

Wave effects occur in extreme events in this order:

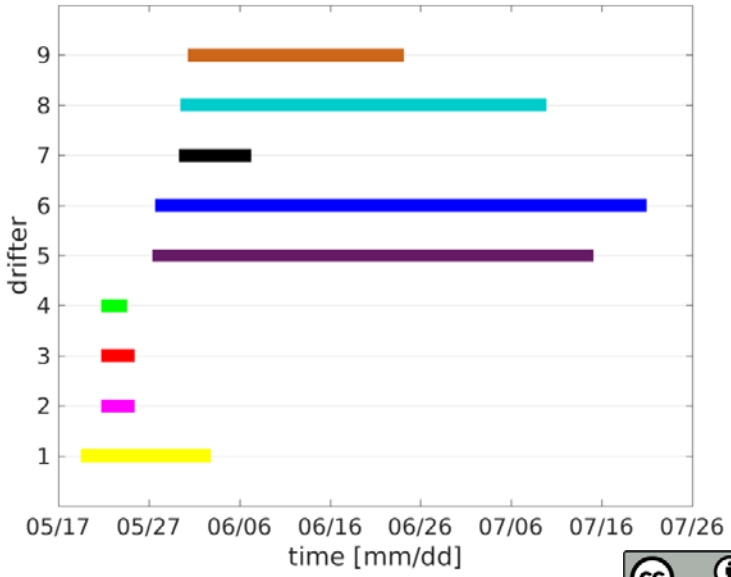
- momentum flux
- Stokes-Coriolis forcing
- changes in TKE.

Staneva et al. (2017)

HZG North Sea drifter



9 drifters deployed in the German Bight in 2015.



Courtesy of J. Horstmann, HZG, Germany.

RMS and correlation - Drifter v/s model runs

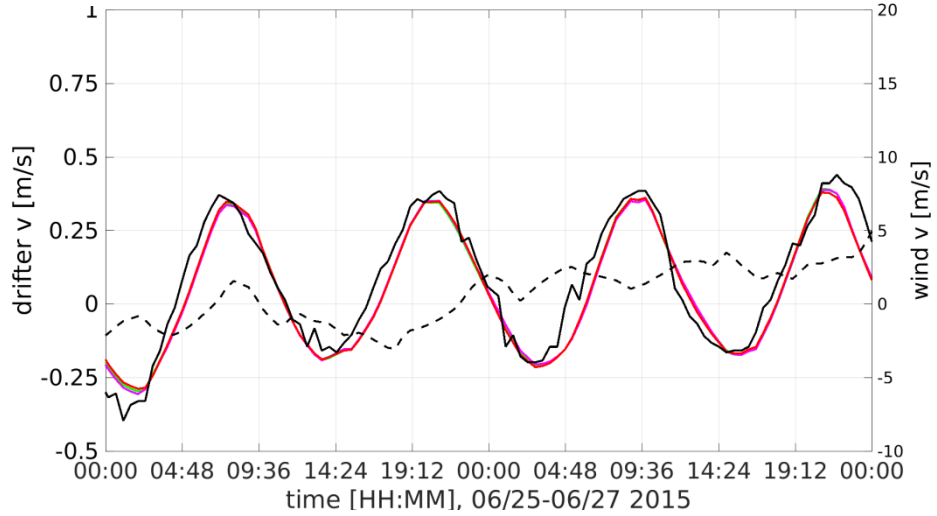
	RMSE			Correlation		
	U_{mag}	u	v	U_{mag}	u	v
NOWAVES	0.1279	0.1319	0.1252	0.6650	0.9024	0.8274
ALL	0.1170	0.1232	0.1157	0.7178	0.9129	0.8574

⟶ Reduction of RMSE and increase of correlation using the coupled model.

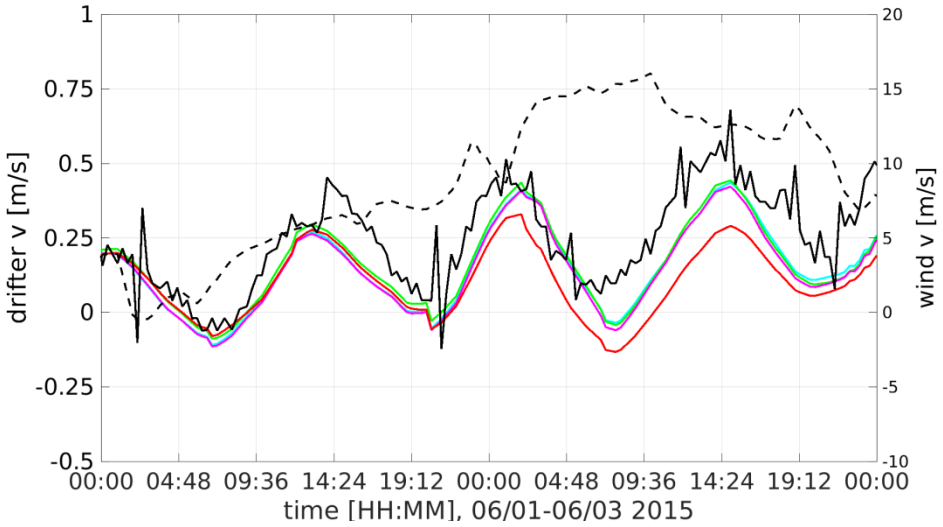
Meridional velocity:

model experiments v/s drifter

Drifter #5 (v-component):



calm wind condition



TAUOC

STCOR

ALL

NOWAVES

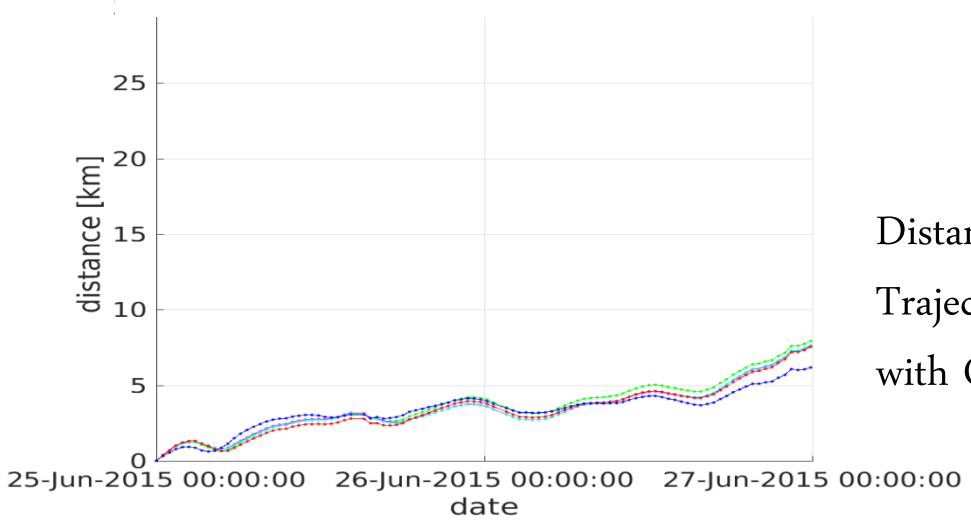
WIND

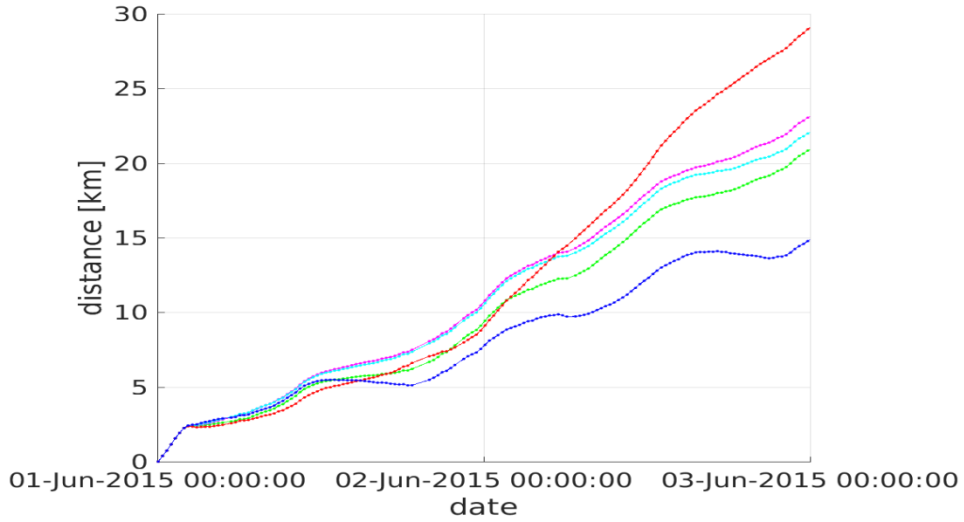
DRIFTER

strong southerly wind

Distances: model experiments v/s drifter

Drifter #5: calm wind condition





calm wind condition

Distances to drifter.

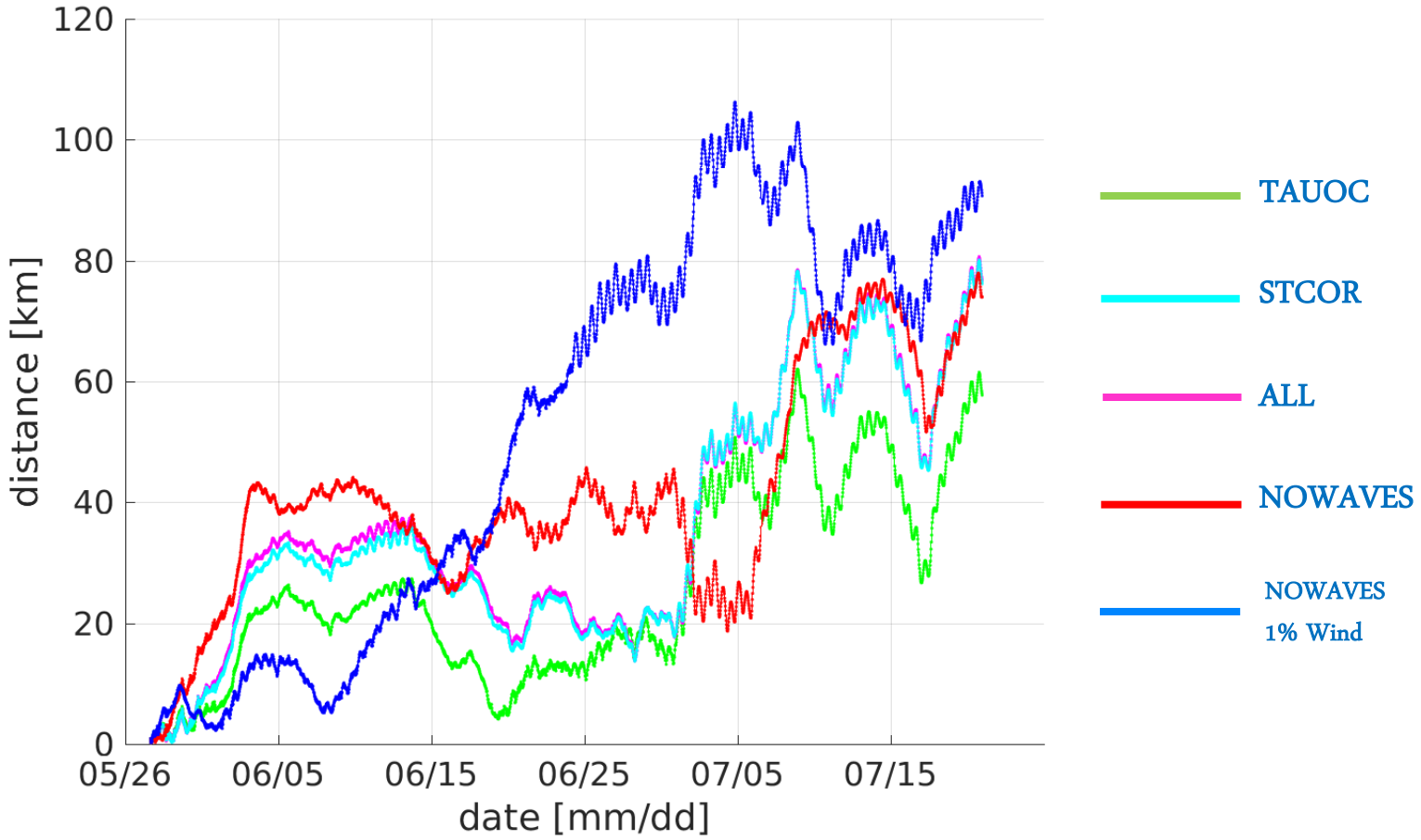
Trajectories modelled with OpenDrift.

- TAUOC
- STCOR
- ALL
- NOWAVES
- NOWAVES 1% Wind

strong southerly wind

Distances: model experiments v/s drifter (long time scale)

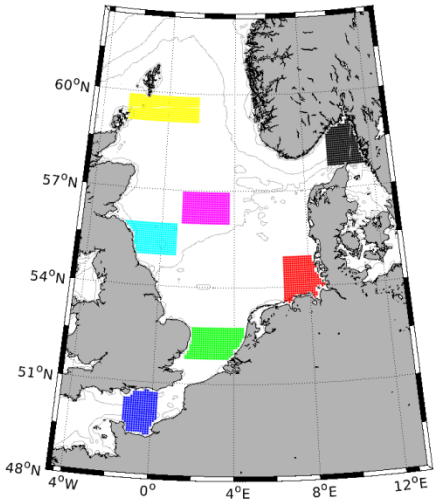
Drifter #6:



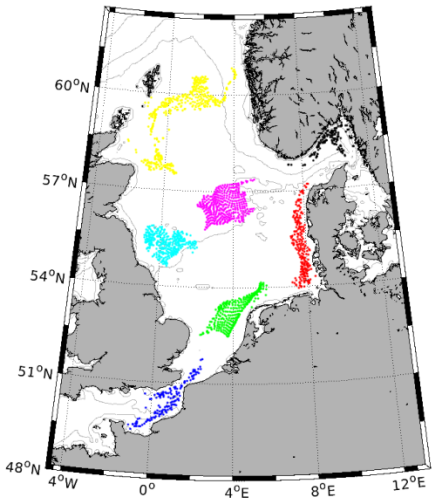
Distances to drifter.

Application of particle tracking

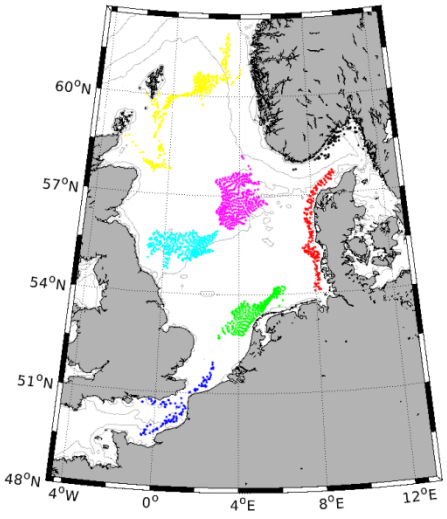
INITIAL DISTRIBUTION



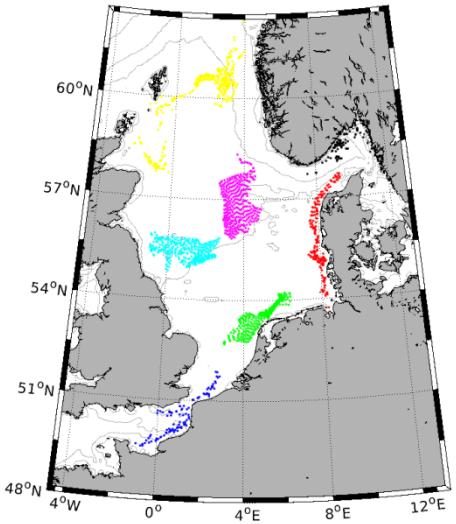
NOWAVES



TAUOC



STCOR

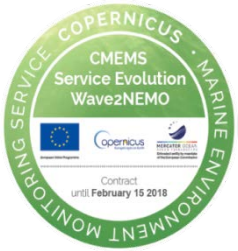


Seeding on: 10/01/2014.

Distribution on: 10/23/2014 (after Ex-Hurricane Gonzalo)

Important for biogeochemical models, SAR models, oil spill models.

Discussion



- A coupled NEMO-WAM-Lagrangian model has been set up and applied for the North Sea and new wave-induced parameterizations have been added.

- Effects of considering sea state and introducing wave-induced forcing on model simulations are not negligible.

- Storm surge and circulation of the NEMO-WAM coupled model showed better agreement with the observations for the coupled model compared with stand-alone circulation model only.

- Particle tracking applications benefit from the newly developed wave-induced processes in the coupled model system.

- The coupled system paws the road to more realistic simulations to be used for both ocean forecasting and long-term simulations.

Publications

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.

Breivik O., J.-R. Bidlot and Janssen P. (2016). *A Stokes drift approximation based on the Phillips spectrum.* Ocean Model (100), doi:10.1016/j.ocemod.2016.01.005.

Breivik O. (2016). *Shear and depth-averaged Stokes drift under a Phillips type spectrum.* arXiv preprint, arXiv:1603.06532.

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), doi:10.5194/os-12-1105-2016.

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.

Staneva J., Alari V., Breivik O., Bidlot J.-R. and Mogensen K. (2017). *Effects of wave-induced forcing on a circulation model of the North Sea*. Ocean Dynamics (67), doi:10.1007/s10236-016-1009-0.

Wahle K., Staneva J., Koch W., Fenoglio-Marc L., Ho-Hagemann H. and Stanev E. (2017). *An atmosphere-wave regional coupled model: improving predictions of wave heights and surface winds in the Southern North Sea*. Ocean Sci. (13), doi:10.5194/os-13-289-2017.

Thank you for your attention!

Questions?