Impacts of sea surface temperature assimilation on heat budget estimates for the North Sea

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ESM Advanced Earth System Modelling Capacity

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Objectives and Research Questions

Objectives

- Apply assimilation techniques to a specific problem ("North Sea heat budget"), in which coupling processes play an important role

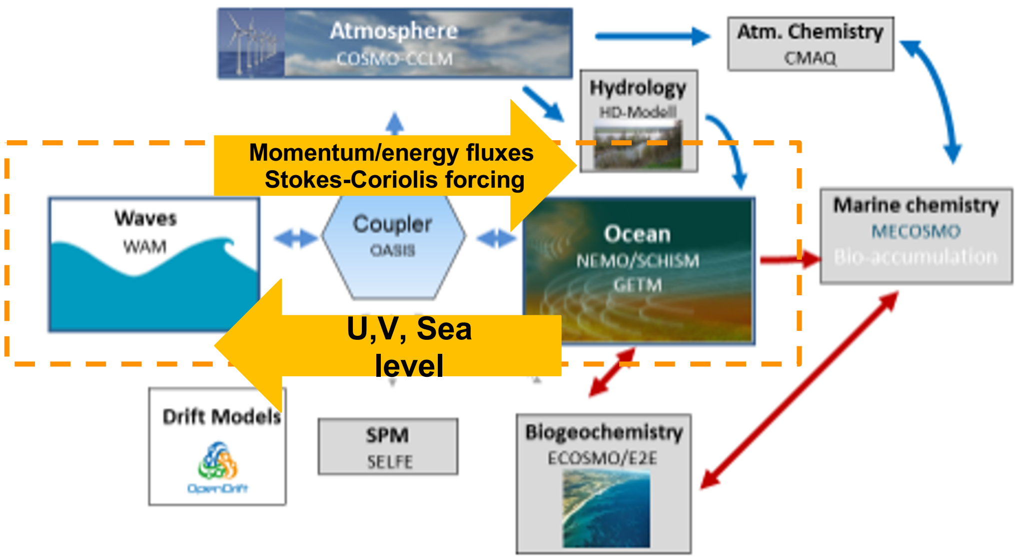
Research Questions

- How does the assimilation of SST observations change the simulated North Sea heat budget?

- What are the secondary effects of the temperature analysis on the remaining prognostic model variables, which are relevant for the heat budget ?

GCOAST system

Model components and flexible coupling interfaces (coupling of circulation model and wave model)



Experiments Setup

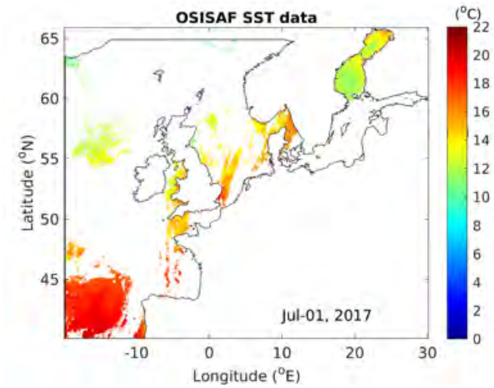
Experiment	NEMO-WAM coupled	Assimilation
1. Free Run	√	--
2. uncoupled DA Run	--	√
3. coupled DA Run	√	√

Observations and DA Tech.

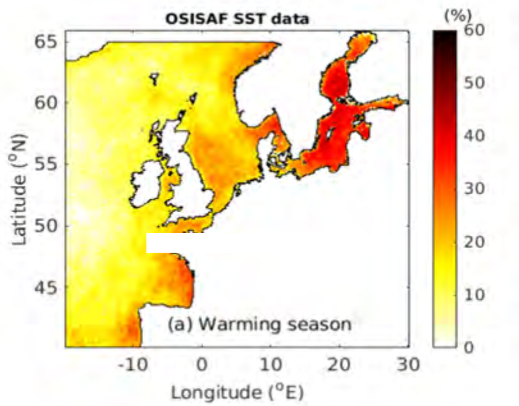
Satellite Observations

Temporal resolution: daily

Data apperence of a typical day



Data availability

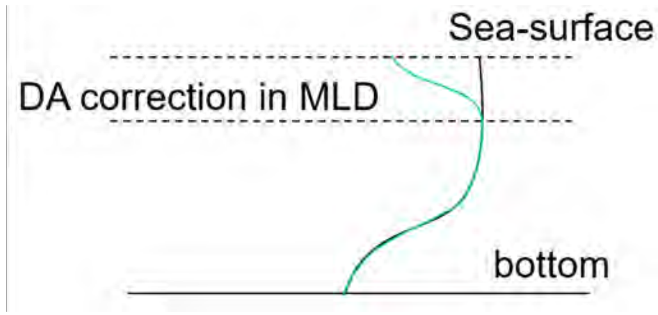


GALATON 3DVAR

3DVAR scheme with multivariate approach: balance of temperature and elevation adjustments

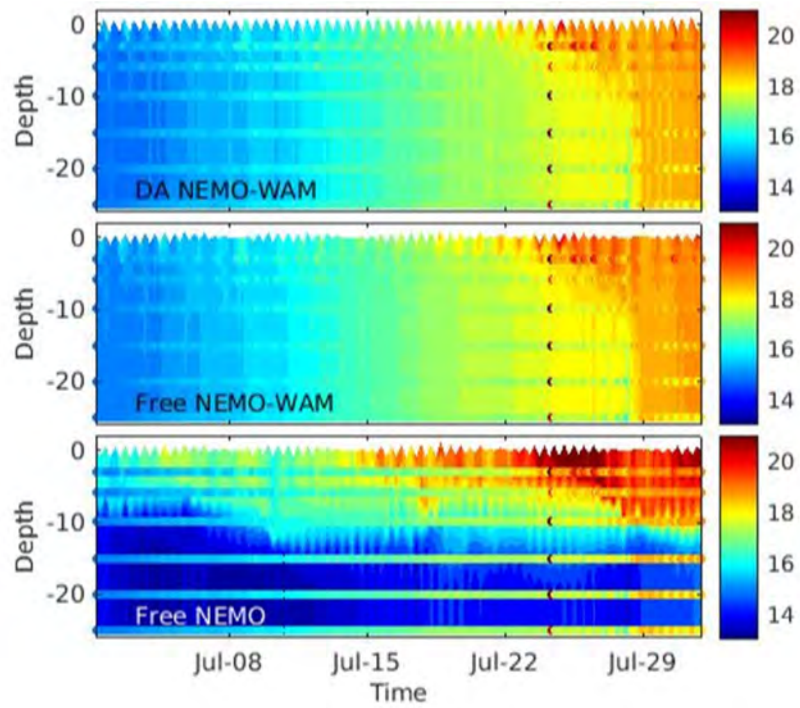
Coupling for DA

☐ **wave/circulation coupling plays an important role.**

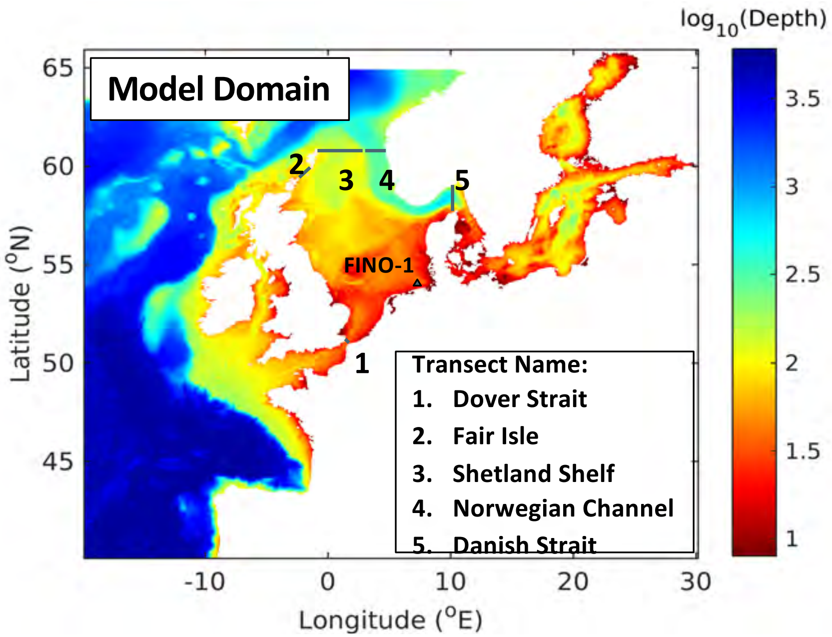


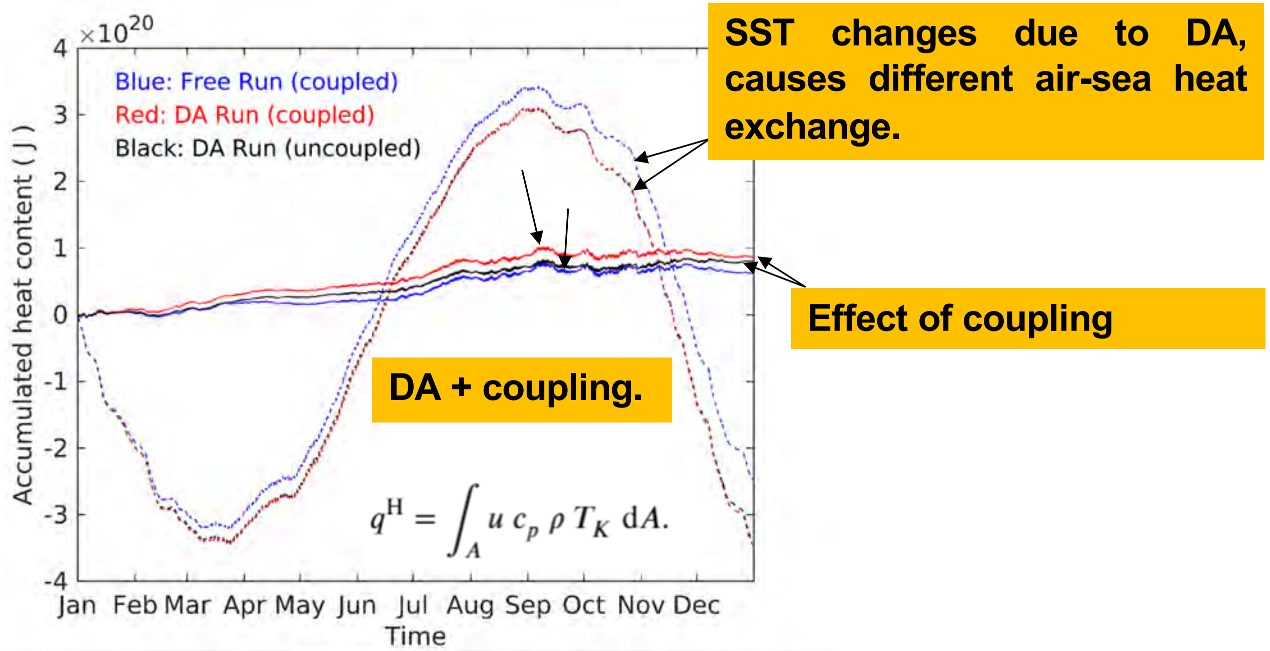
Model coupling provide a better mixing layer depth, thus a better vertical model error correlation length for DA.

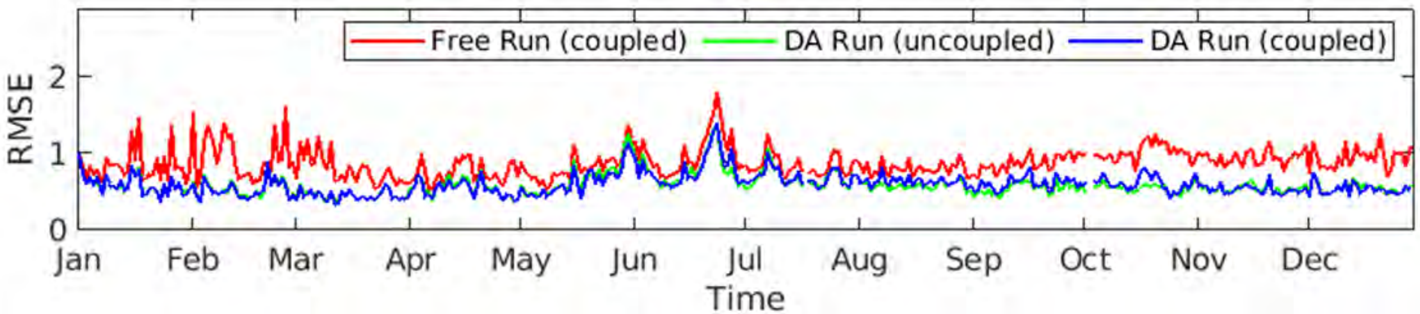
FINO-I



Advective transport & air-sea exchange







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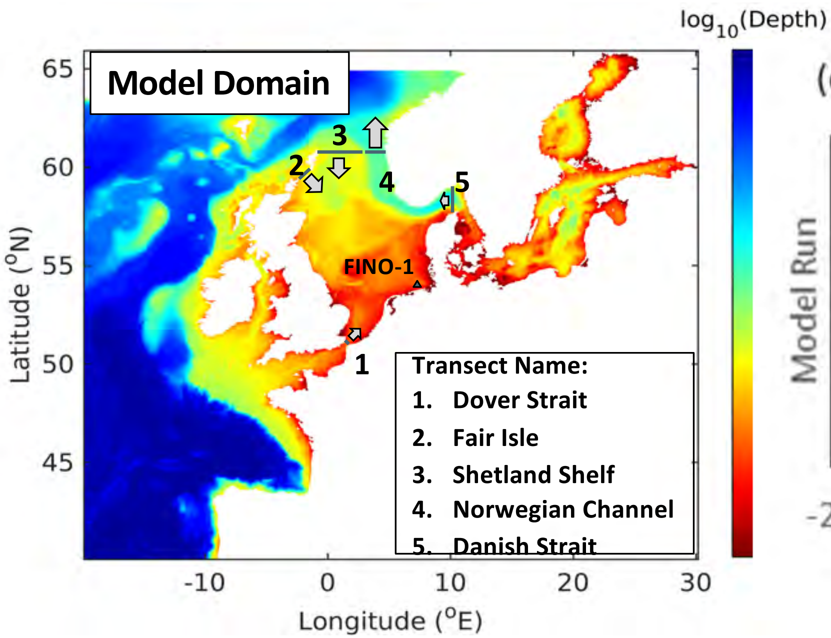
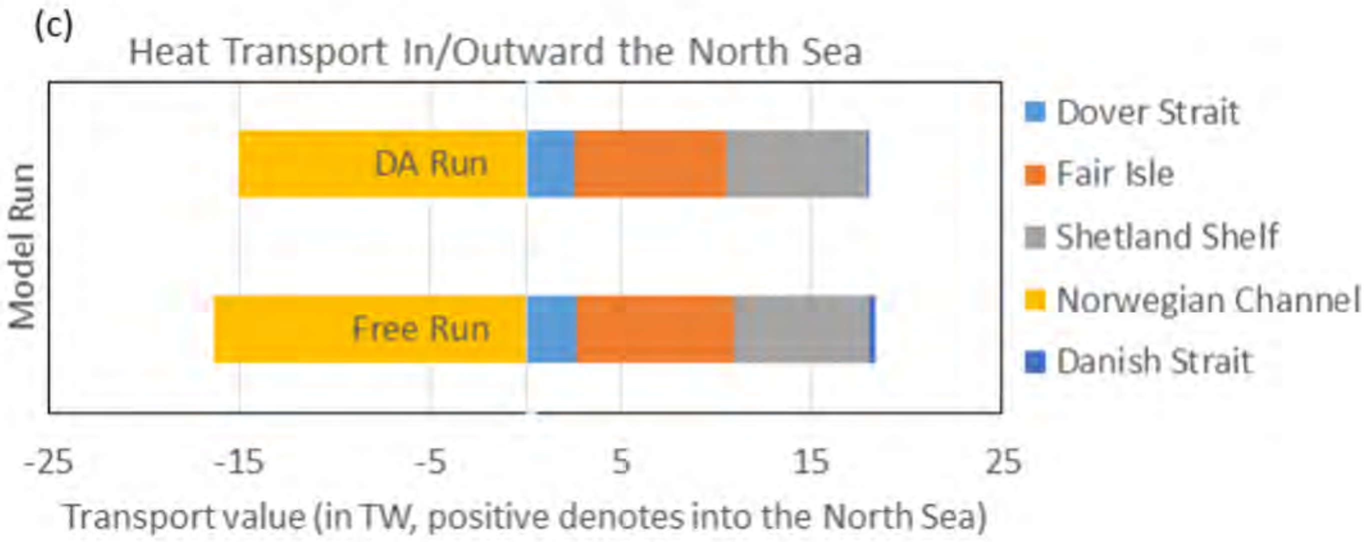
Heat transport at each boundary transect





Physical processes driven advective transport

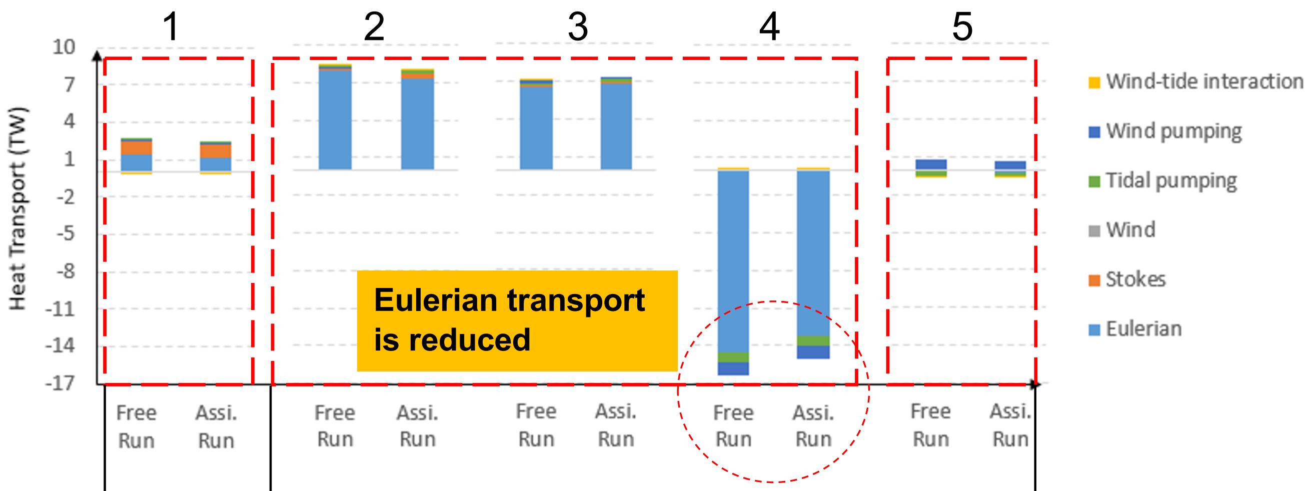
$$q^{\mathrm{H}} = \int_A u \, c_p \, \rho \, T_K \, \mathrm{d}A.$$

$$u_{\mathrm{n}} = \overline{u}_{\mathrm{n}} + u_{\mathrm{n}}^{\mathrm{t}} + u_{\mathrm{n}}^{\mathrm{w}},$$

$$\mathrm{d}A_{\mathrm{n}} = \overline{\mathrm{d}A}_{\mathrm{n}} + \mathrm{d}A_{\mathrm{n}}^{\mathrm{t}} + \mathrm{d}A_{\mathrm{n}}^{\mathrm{w}}.$$

annual mean   Tidal variation   Wind variation

$\overline{q^{\mathrm{H}}}$ = Euleria n + Stokes + Wind +
Tidal pumping +
Wind pumping +
Wind-tide interaction



Wind and tidal pumping dominate the east boundary;

Mean transport dominates the north boundary;

Mean transport and Stokes transport dominates the west boundary;

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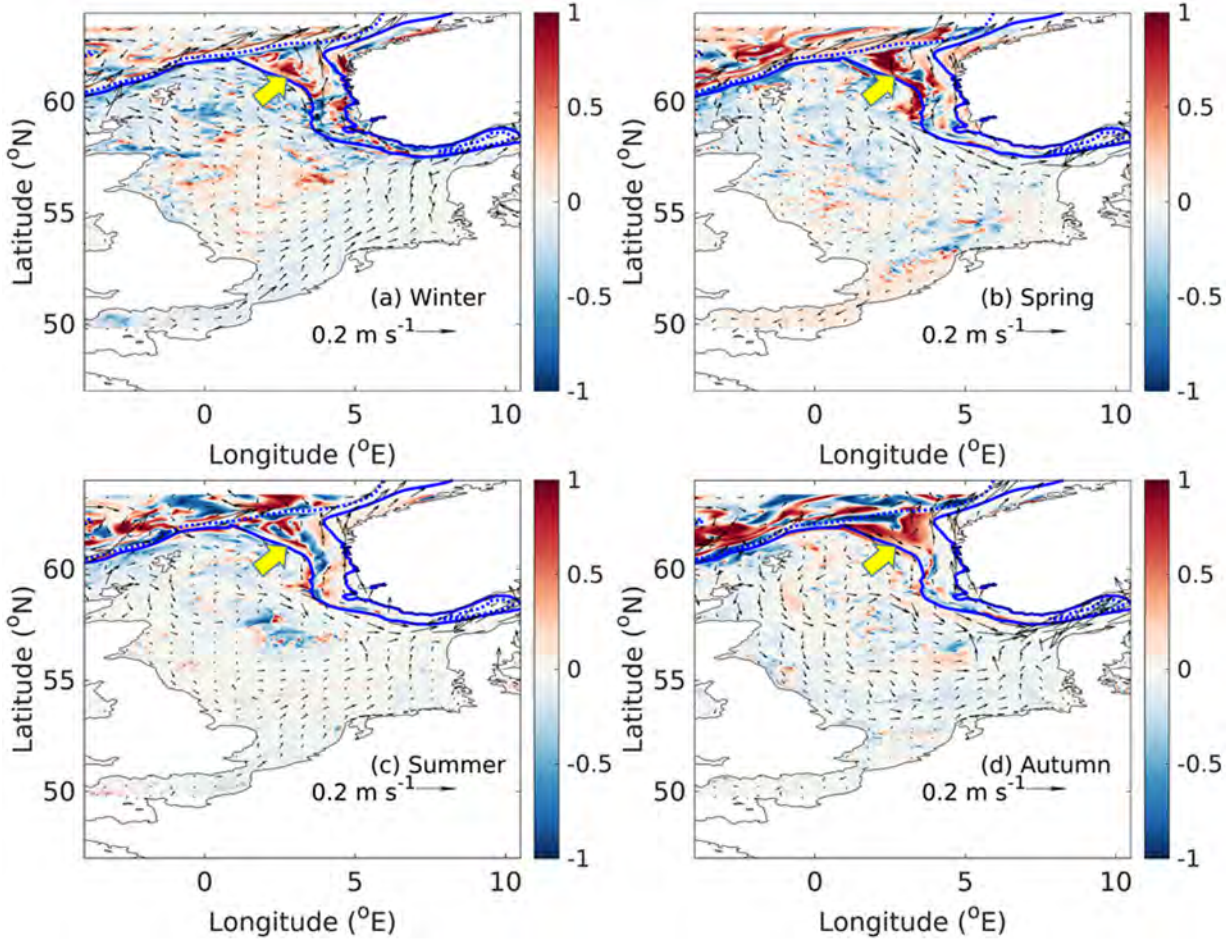
Hydrodynamic reaction to DA



Relative changes in kinetic energy per unit water mass:

$$\varepsilon = \frac{1}{2}(u_{\mathrm{DA}}^2 - u_{\mathrm{Free}}^2)/\frac{1}{2}(u_{\mathrm{DA}}^2 + u_{\mathrm{Free}}^2)$$

ε < 0, DA removes kinetic energy

ε > 0, DA adds kinetic energy

Enhanced along shelf inward kinetic energy at the entrance of the Norwegin Channel.

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Conclusions

How does the assimilation of SST observations change the simulated North Sea heat budget?

- **Direct changes of SST->air-sea heat exchange;**
- **Direct changes of temperature in water columns -> advective heat transport;**
- **Indirect changes of flow velocities -> advective heat transport;**

What are the secondary effects of the temperature analysis on the remaining prognostic model variables, which are relevant for the heat budget ?

The acceleration of the along-shelf current at the northern edge of the North Sea reduces the mean volume transport, thus the advective heat transport, from the North Sea to the Atlantic through the Norwegian Channel.

Vielen Dank.

Reference:

Chen, W., J. Schulz-Stellenfleth, J. Staneva, S. Grayek. 2021. Impacts of the assimilation of satellite sea surface temperature data on volume and heat budget estimates for the North Sea. Journal of Geophysical Research: Oceans.

Appendix

GALATON 3DVAR

- FORTRAN90 implementation of 3DVAR scheme
- Parallised via MPI using the domain decomposition given by model
- Multivariate approach is used: balance of temperature and elevation adjustments exactly following the NEMOVAR structure in the analysis scheme.

$$J(x) = 0.5(x - x_f)^T B^{-1}(x - x_f) + 0.5(Hx - y)^T G^{-1}(Hx - y)$$

- x_f: prior state
- B: the model error covariance matrix (In vertical: mixing layer thickness, varied in space and time)
- H: the observation operator
- G: the observation error covariance matrix

Appendix

Model setups

	NEMO 3.6	WAM 4.6.2
Horizontal grid	3.5 km North Sea & Baltic Sea, 0.9 km German bight	as NEMO
Vertical grid	51 z-s layers	N/A
Initial field	CMEMS UKMO Data	EWAM wave data
Boundary condition	OSU tides, CMEMS UKMO for T,S, u,v, SLH	EWAM wave data
Forcing	DWD, ERA-I, ERA-5, COSMO	Same
Diffusion scheme	GLS (*k-eps*)	N/A
Ice	LIM-3	WAM ice parameterization

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