Deltares

Enabling Delta Life

Computation of a consistent vertical reference datum in Europe using a Global Tide Surge Model

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15 november 2017

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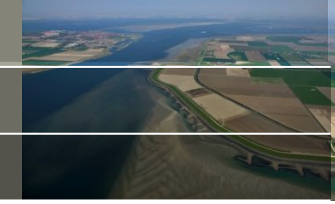

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EMODnet hrsm

EMODnet High Resoluton Seabed Mapping: 3 arc seconds DTM for European seas.

Lowest Astronomical Tide (LAT) has been designated by the International Hydrographic Organization (IHO) as the vertical reference surface for hydrographic charts

Issues :

- No vertical reference datum defined consistently across Europe
- Different methods for calculation in different countries.
- No easy way to convert between different reference levels.

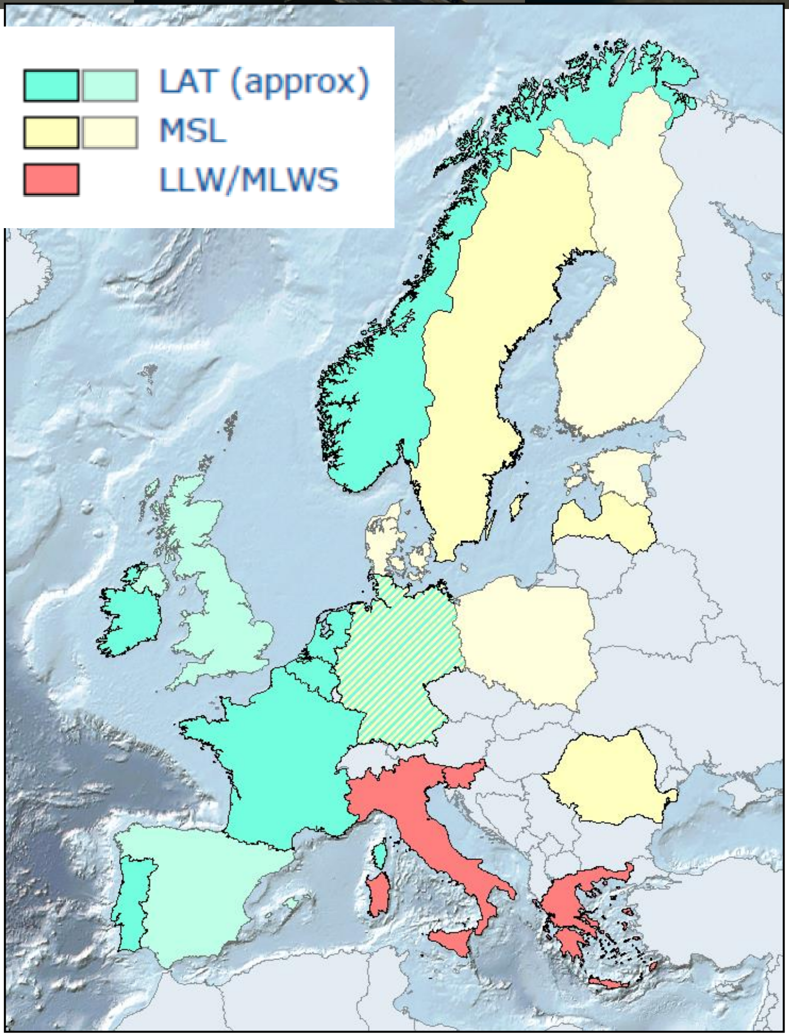
EMODnet hrsm

Role of Deltares:

- Compute a consistent LAT surface for Europe
- Derive conversion surfaces between the different reference levels

Methodology: Use the Global Tide and Surge Model (GTSM) to simulate water-levels in Europe (and elsewhere) and derive LAT.

→ What is LAT exactly?



Bas Alberts (EUREF 2016) .Presentation EMODnet initiative. Vertical reference surfaces used by consortium partners, after questionnaire.

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LAT definition

IHO definition: LAT (…) is defined as the lowest (…) **tide level** which can be predicted to occur under **average meteorological conditions** and under any combination of astronomical conditions.

…

*In non-tidal waters, in order to allow the development of regional solutions, it is recommended that an appropriate long term range of low (…) water definitions of the lower (…) 94-100 percentile be adopted."

- Common methodology based on pure astronomic tide: LAT = Minimum water-level reached in the nodal cycle of 18.6 years

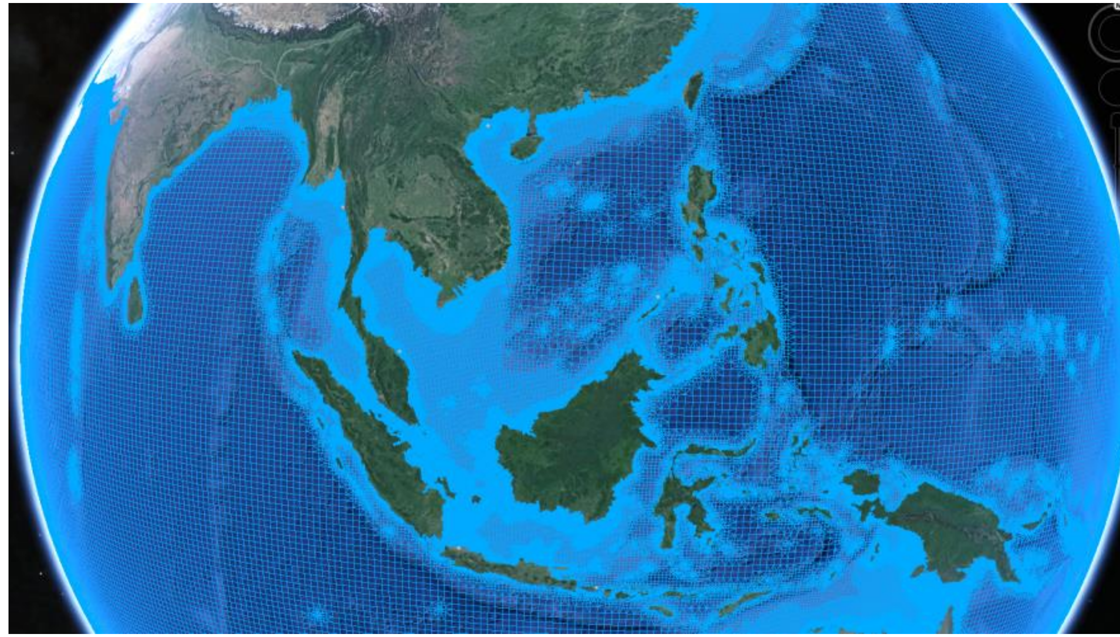
The GTSMv2.0 model

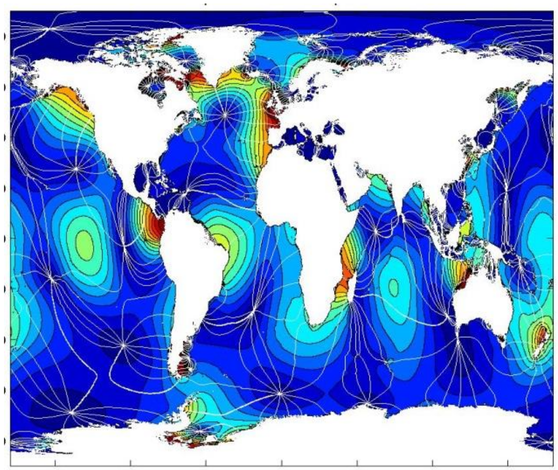
Global Tide Surge Model:

- 2D barotropic model
- Unstructured global grid: 50 km deep waters, 5km at the coast
- EMODnet – Europe
- GEBCO 2014 rest(~1km)
- TGF driven, no assimilation

Runtimes in 8 cores ~1hour/week

- Tidal Validation/Verification:
  - ~20cm for coastal stations (UHSLC)
  - ~ 7 cm in deep waters (FES2012)
- Surge Validation: *A global reanalysis of storm surges and extreme sea levels*(Muis et al. 2016)





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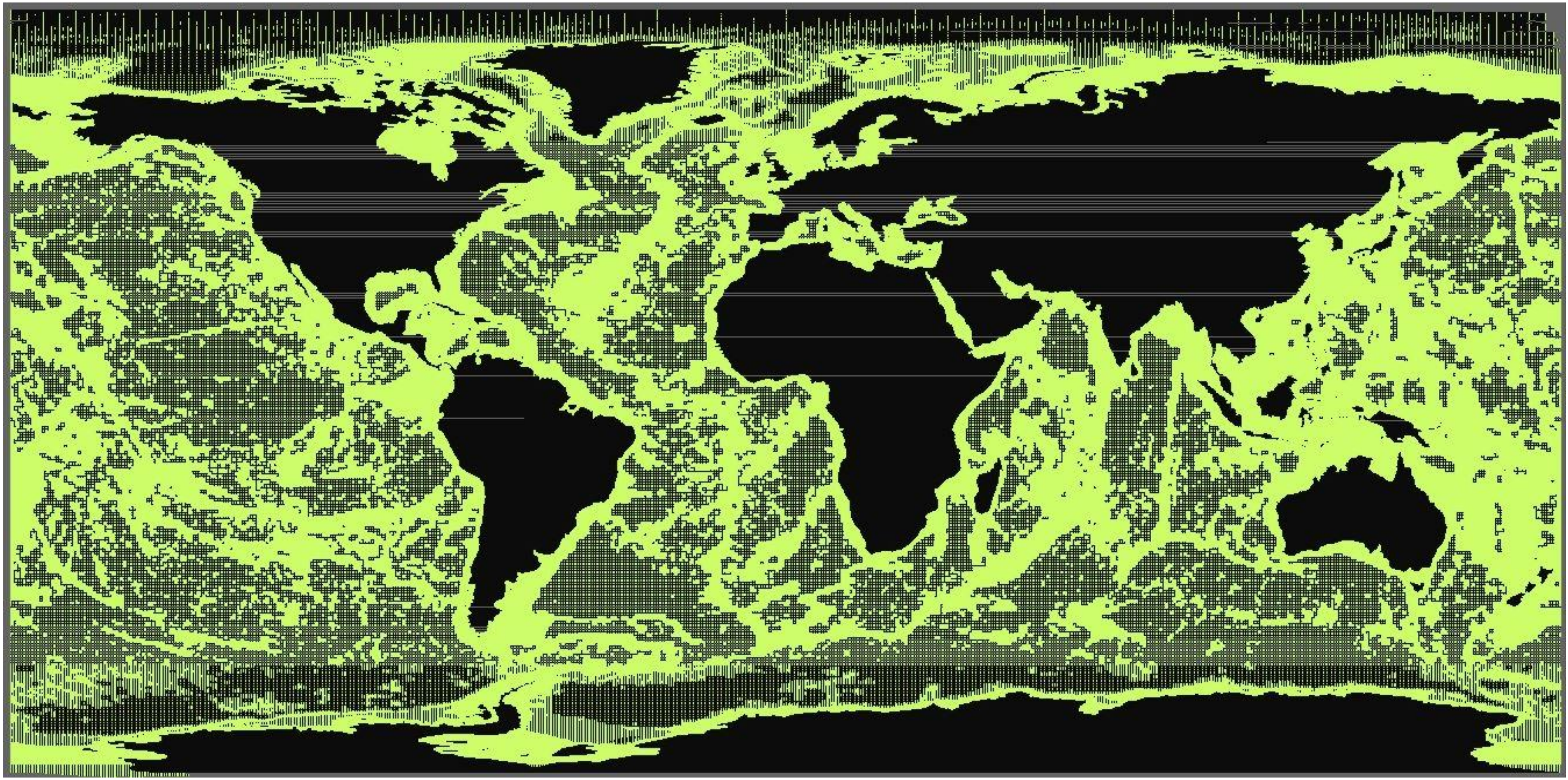
Grid

Depth and bathymetry gradient based refinement:



GTSMv2.0 5km – LAT (1998-2017)

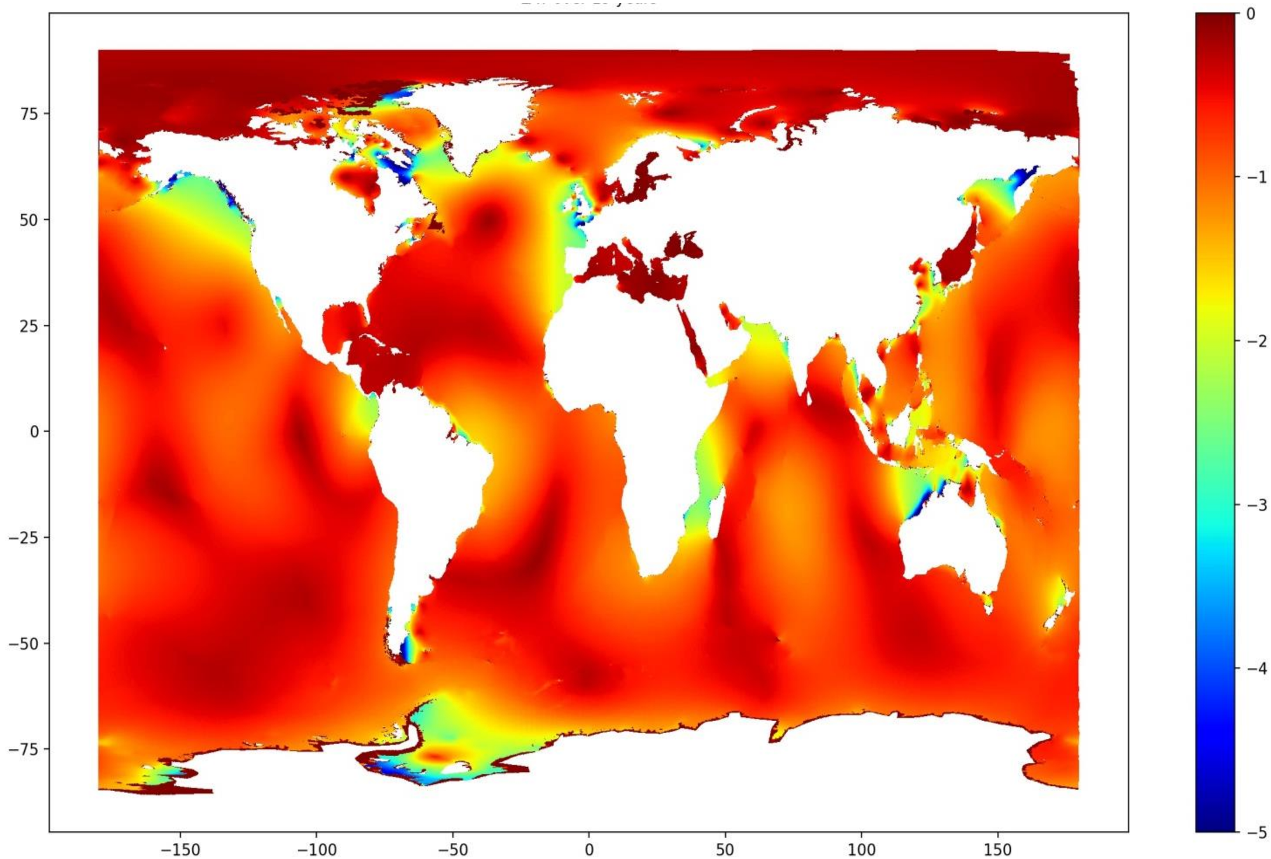
Previous calculations of LAT globally:

- Turner et al.(2013) – VORF project
- BASE-Platform (GTSMv1.0, FES2012)

Identified issues:

- Resolution for representation of coastal tidal dynamics
- Uncertainty on bathymetry and CD.
- No meteorological forcing or SA considerations

LAT using GTSMv2.0 (m)



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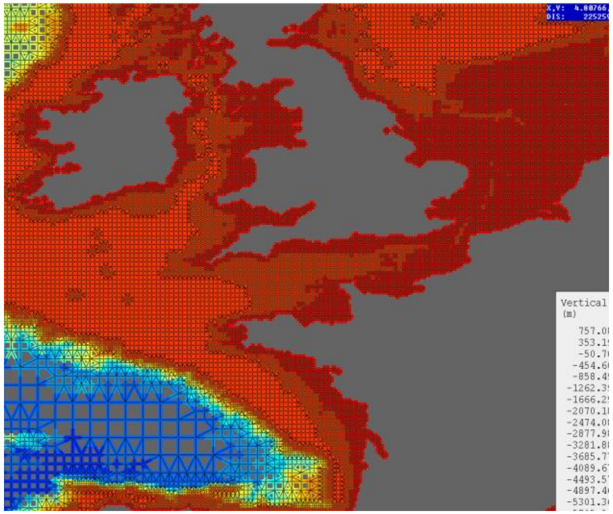
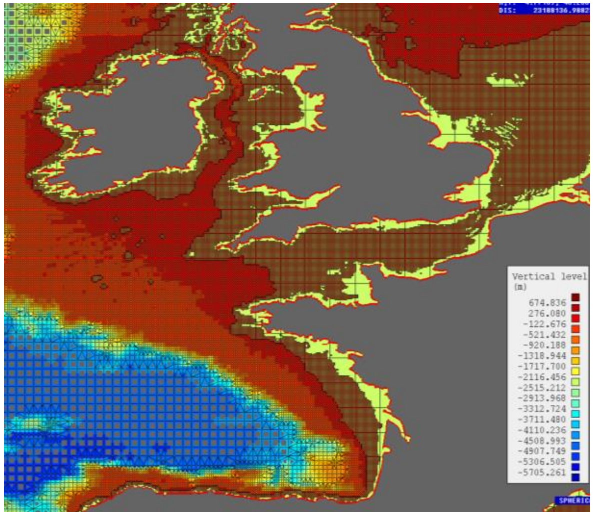
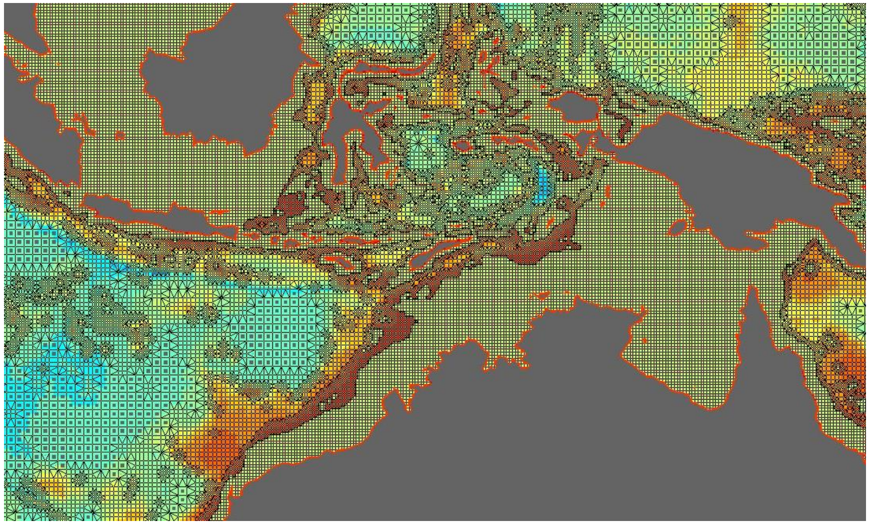
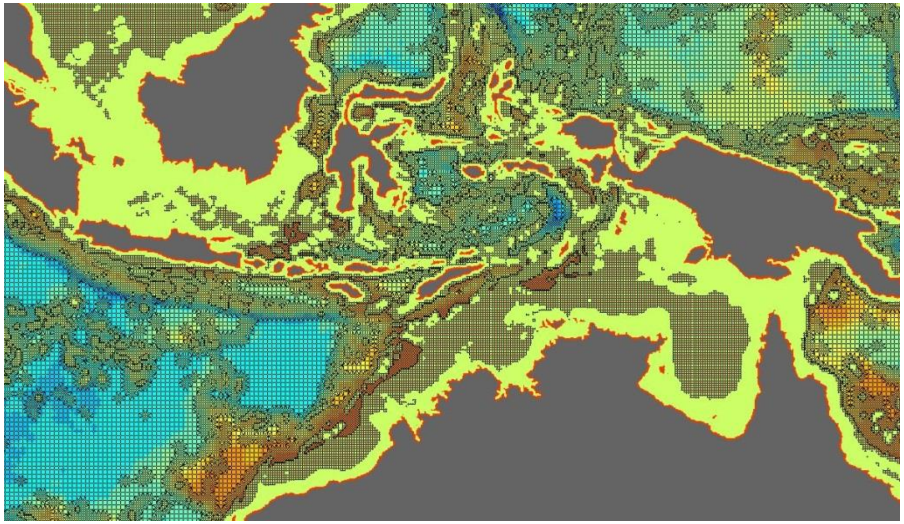
Towards GTSMv3.0: Increased grid resolution

- Deep water 50km →25km
- Coast: 5km→2.5km globally, 1.25km Europe
- Smoothing at 2.5km resolution
- Larger coverage of refinement at steep bathymetry (5km)









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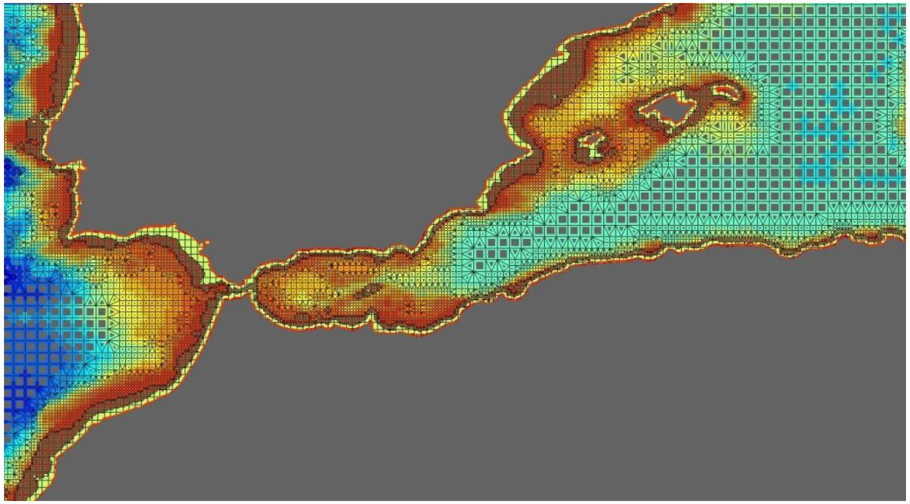
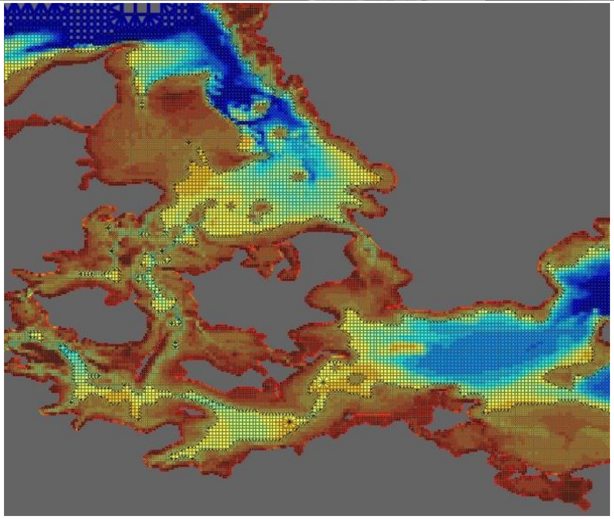
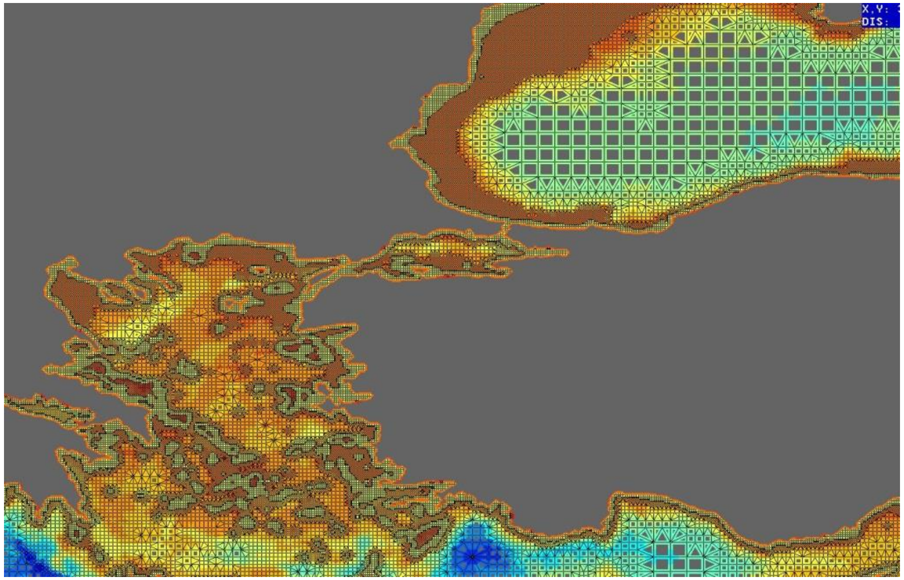
Increased grid resolution - Connections

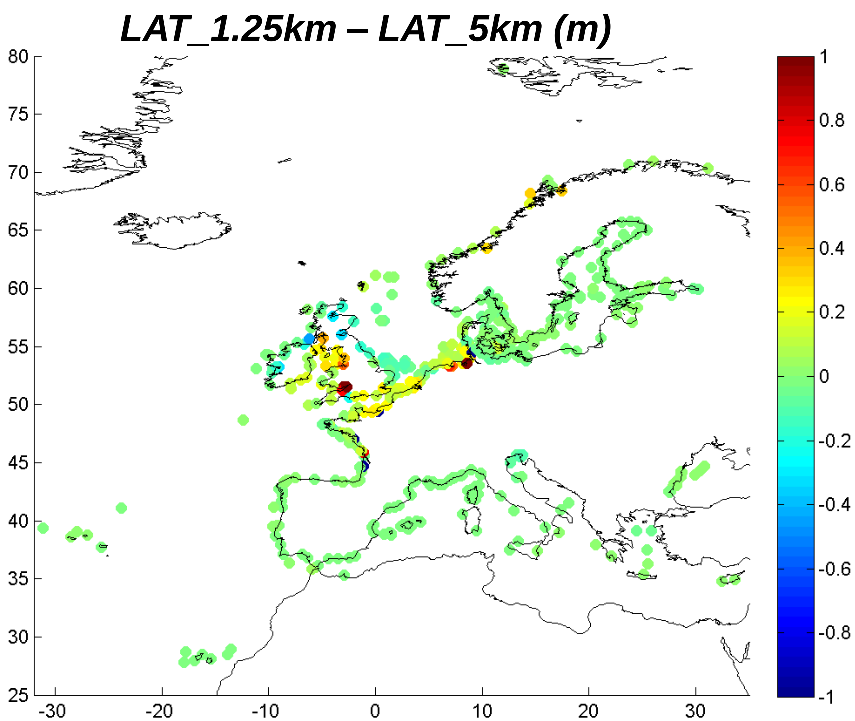




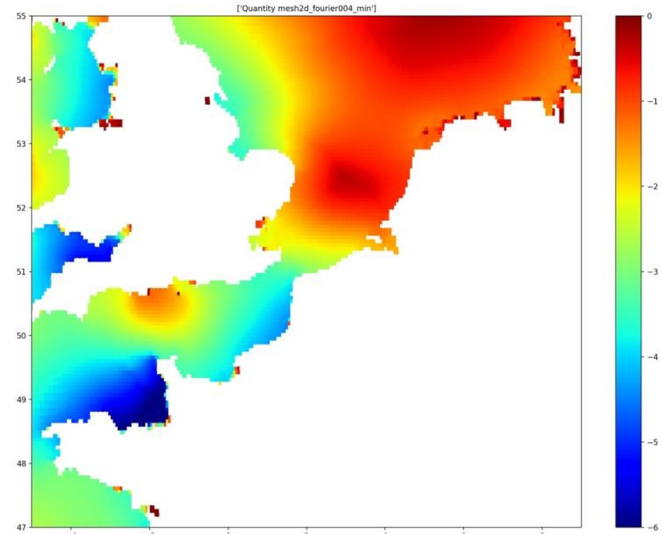


Area	no. stations	5km	1.25km EU
Deep ocean (FES2012)	347	7,8cm	7,4cm
Coast global (UHSLC)	292	20,5cm	18,3cm
Coast Europe (CMEMS)	327	21cm	16,7cm

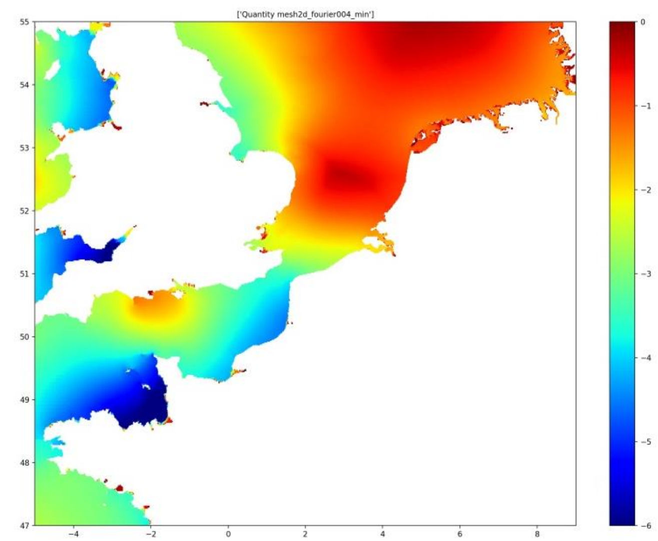
LAT 1.25km vs 5km (2015)



5km



1.25km



Places showing big LAT differences:

- Bristol Channel
- English Channel
- German Bight
- Irish Sea, Firth of Clyde

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Uncertainties and CD in bathymetry dataset

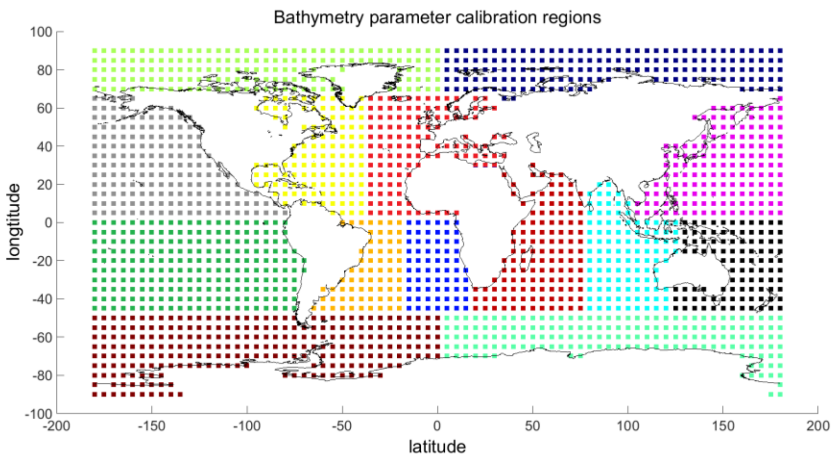
GTSMv2.0 results shown are uncalibrated
(untouched bathymetry, uniform friction coefficients)

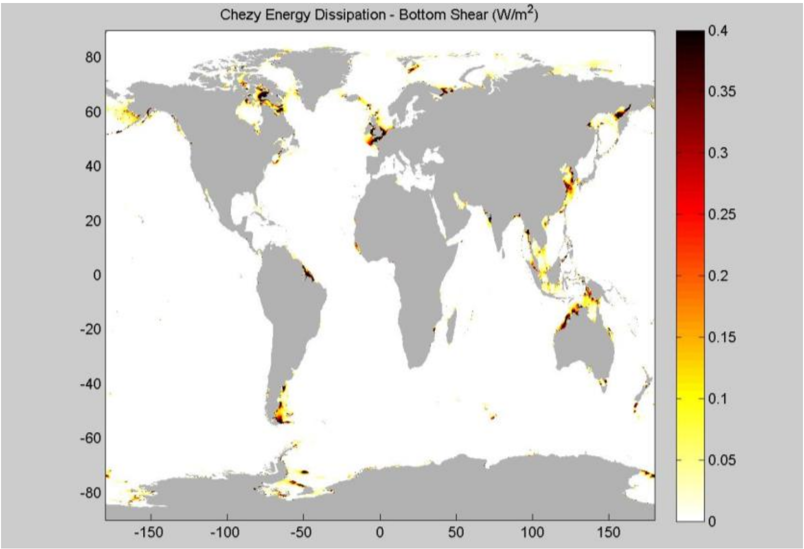
→Towards GTSMv3.0: Calibration using OpenDA

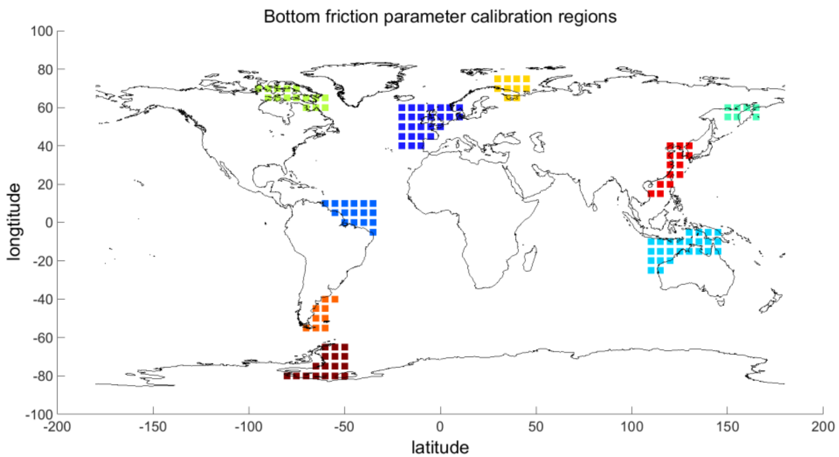
OpenDA: generic toolbox that allows for data assimilation and automated parameter calibration using observations

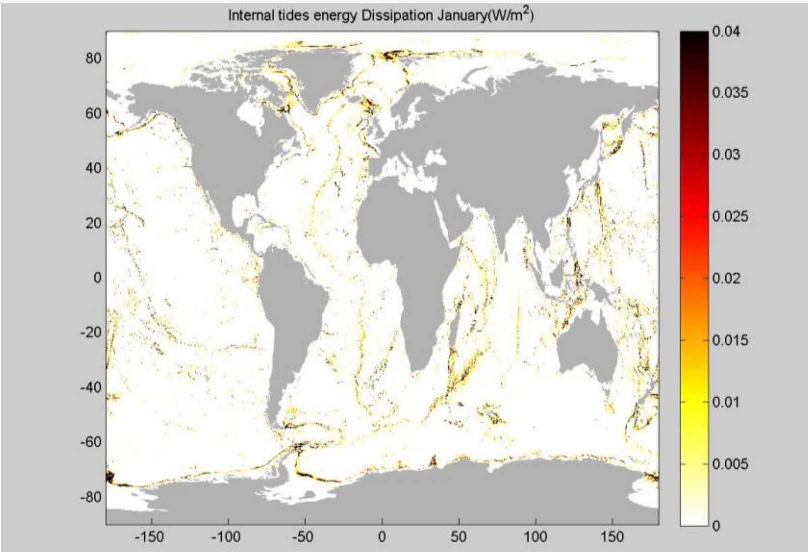
- Calibration of bathymetry as a means to identify possible systematic errors (e.g. from CD =~ LAT) and uncertainties in dataset.
- Deep water (FES2012) + coastal (UHSLC) stations
- Methodology: Minimize a cost function representing distance between model results and observation values given user defined
  - Uncertain parameters
  - Calibration regions (regions to which uniform changes are applied)
  - Num. of total parameters to be optimized= num. of regions x num. uncertain parameters

Uncertainties and CD in bathymetry dataset









Work in progress…!!

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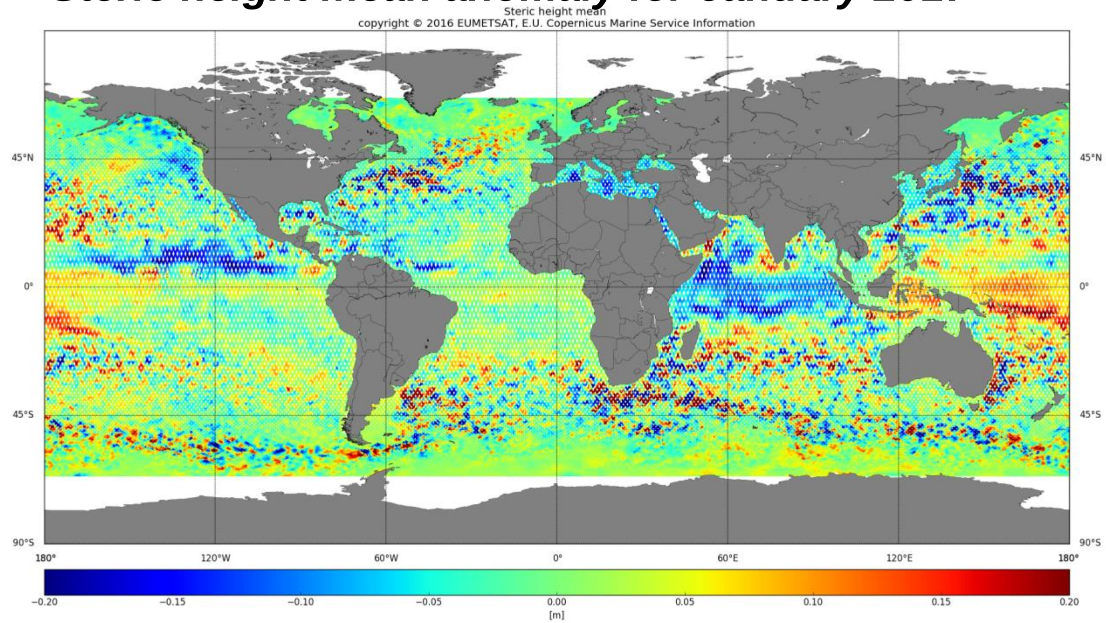
LAT non-astronomical components

Other signals at astronomic frequencies:

- Steric effects
- Water mass
- Atmospheric tides

Steric effects: Changes in sea-level due to thermal expansion and salinity variations (haline contraction).

Steric height mean anomaly for January 2017



They affect mean sea level, **annual** and semi-annual cycles of sea level

- 2D barotropic model (constant density) → Depth-averaged baroclinic pressure gradient can be introduced (Slobbe 2012);
- More fundamental: our models conserve **volume, not mass**! (Boussinesq models)

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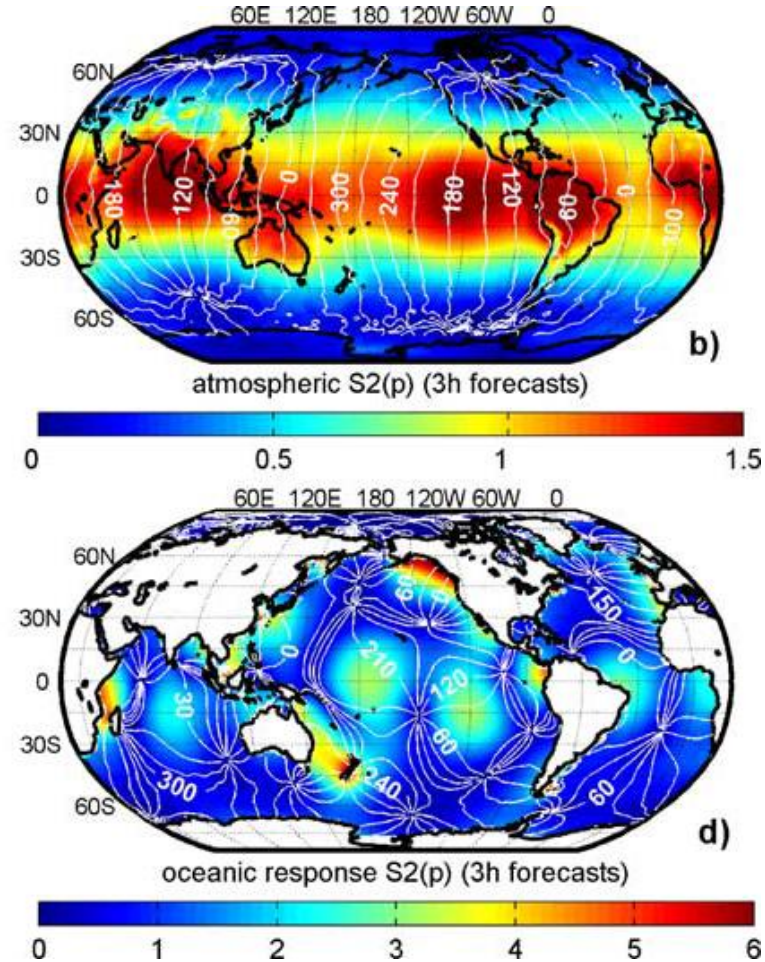
LAT non-astronomical components

- **Radiational tides**: Oceanic response to the atmospheric tides (“air tides”), resulting from solar radiation.
- At diurnal and semidiurnal frequencies → S1 (primarily radiational) and S2 (primarily astronomical).
- Mainly pressure loading, wind stress considered negligible.
- It also affects other frequencies (e.g. seasonal).

Multi-year analysis for a fair average amplitude and phases of atmospheric tides. 3 hour time-step needed for S2

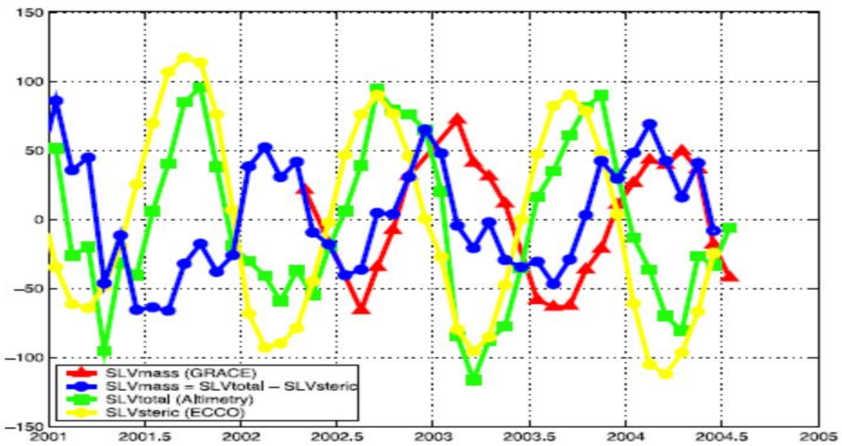
Possible with GTSM, different strategies considered.



Dobslaw and Thomas (2005). (b) S2 atmospheric tide in [hPa] from ECMWF forecast; (d) corresponding non-linear oceanic response [cm]

Example: Mediterranean Sea

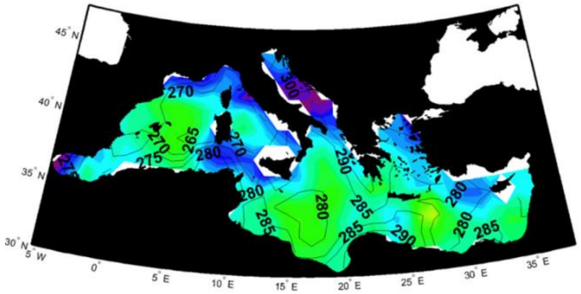
Garcia et al.(2005):
- Steric signal up to 16cm
- Remaining signal up to 10cm
- Wind signal average 2cm, up to 4cm.



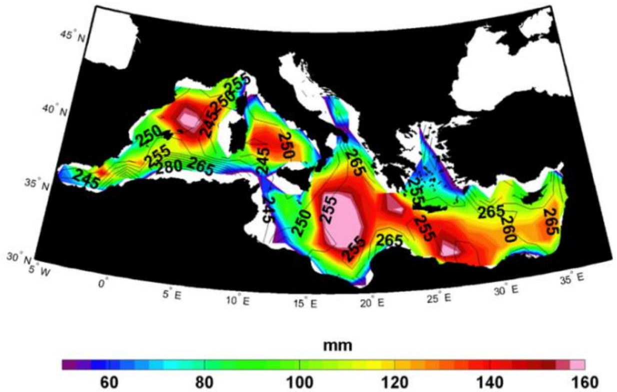
Garcia et al.(2005) The time series of monthly mean values over the Mediterranean Sea for several data sets

Need to:
- **Quantify (relative) effects (e.g. observations)**
- **How to account for these on a 2D hydrodynamic model?**

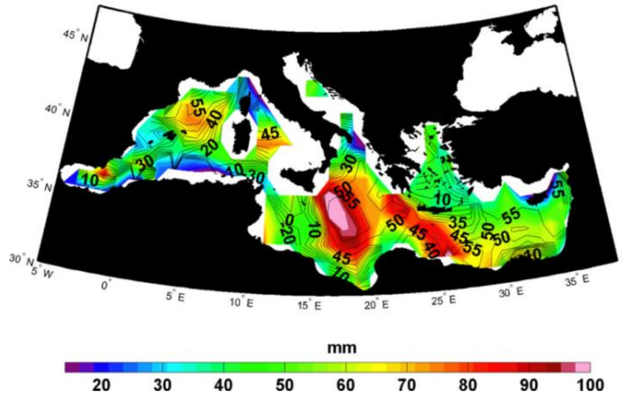
SA amplitude



Steric SA



Residual SA



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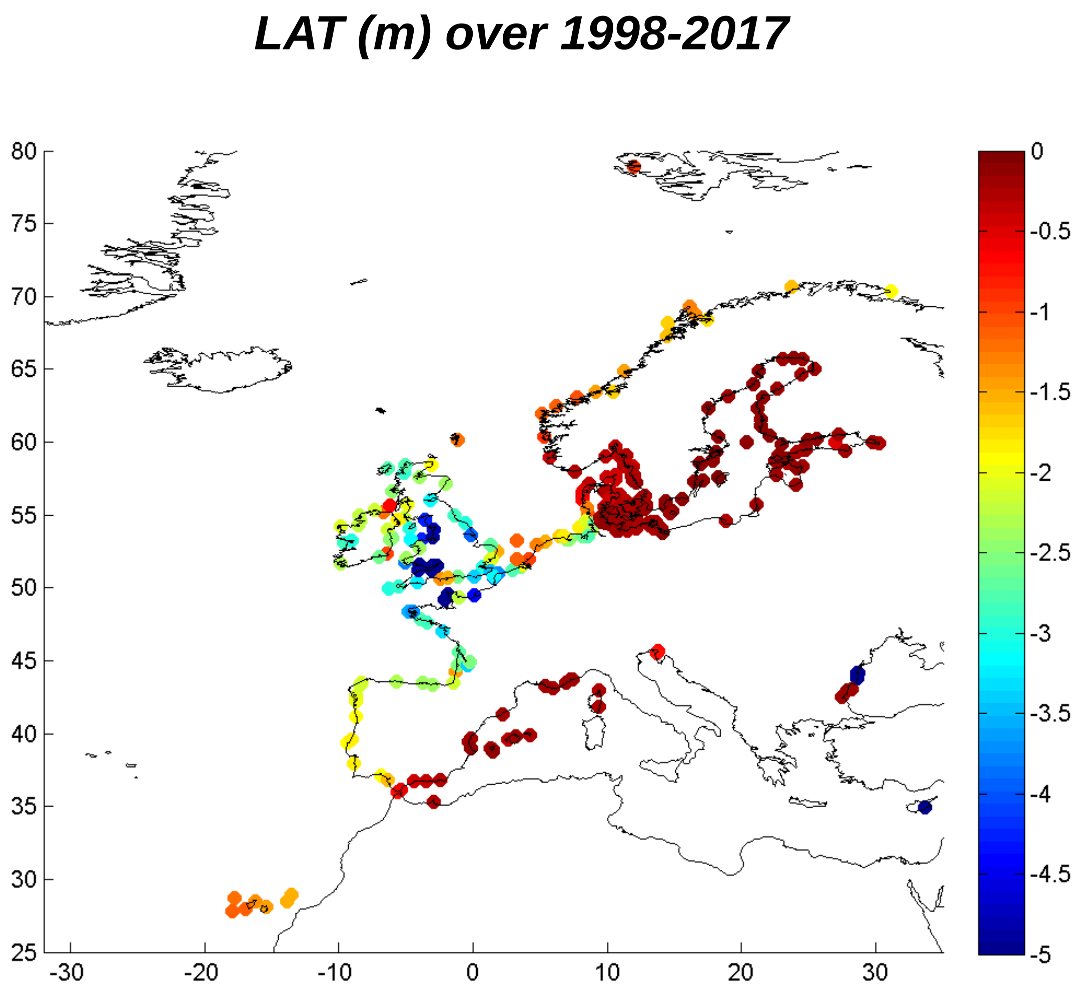
Calculation of LAT from observations (Europe)

~1000 waterlevel observations from CMEMS

For LAT calculation:

1. Harmonic analyses of most recent 4 years
2. Prediction for a 19 year period (1998-2017)
3. Minimum waterlevel

Even using any available year-data, usable stations drop to 336 → Lack of coverage in places



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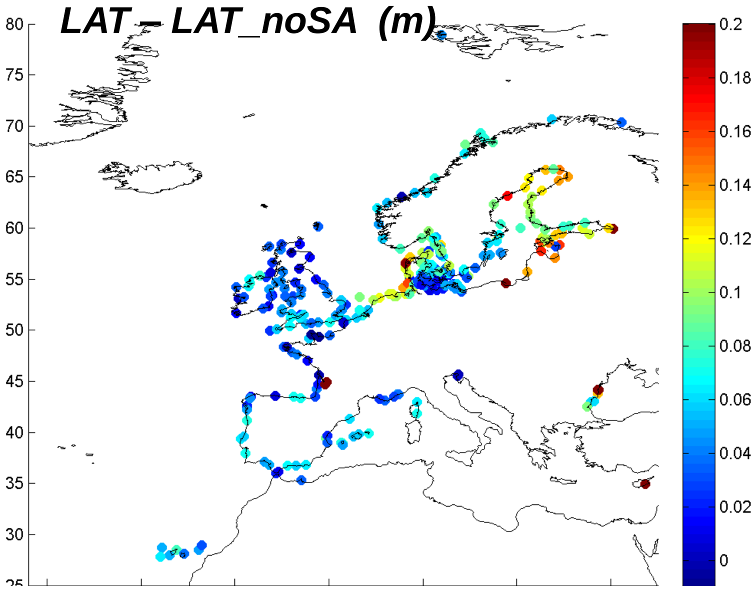
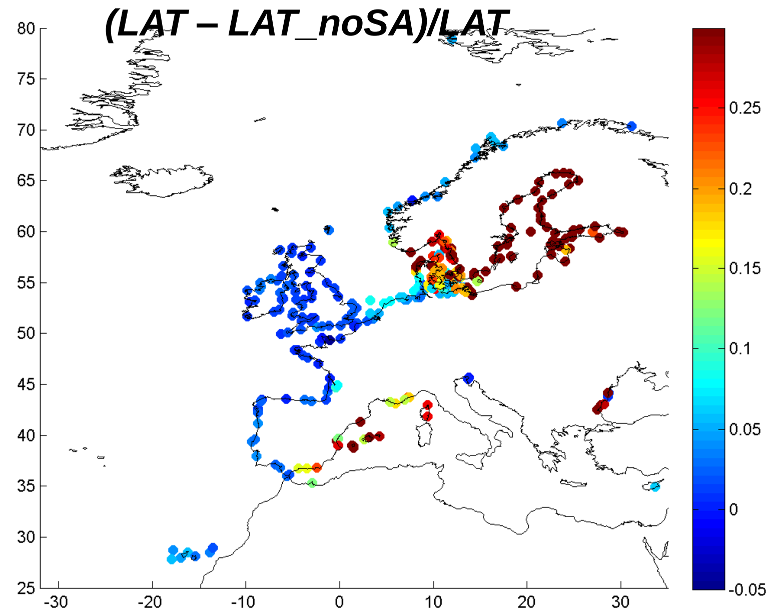
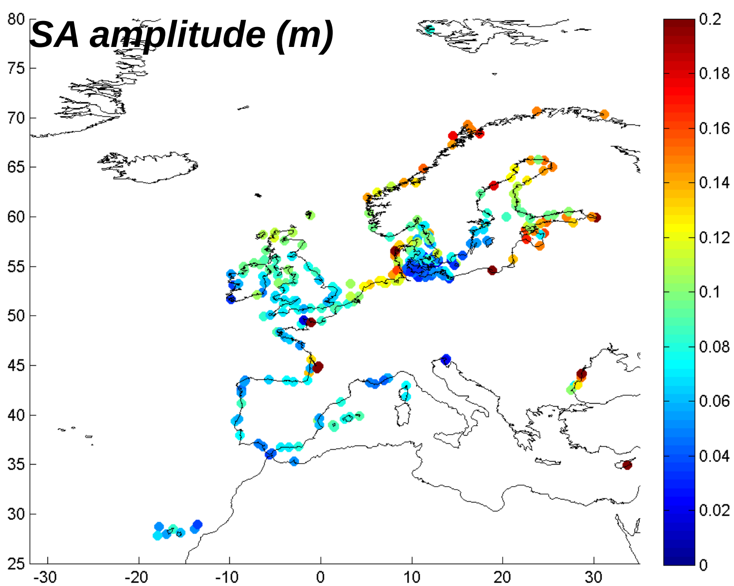
Calculation of LAT from observations (Europe)







Effect of SA in LAT from observations:

- Significant differences in LAT(German Bight, Baltic Sea)
- SA main contributor to LAT in Mediterranean and Baltic

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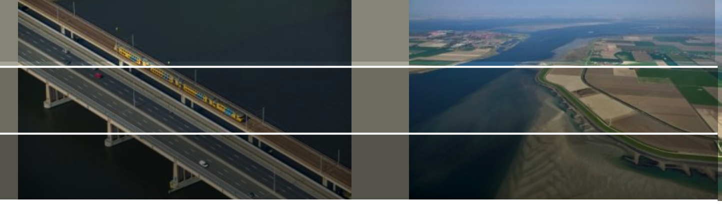
Future work



GTSMv3.0 model

- Calibration using OpenDA (bathymetry, friction coefficients)
- Investigate possible errors in bathymetry based on results from calibration

Validation dataset (observations):

- Work on additional data for validation with good spatial coverage
- Investigate also accuracy in LAT timing

Methodology for LAT calculation with GTSMv3.0

- Effect of meteorological forcing – Periodic? Full harmonic analysis?
- Introduce steric effects – E.g. calculate amplitude at seasonal frequencies and add on the fly.

Thank you

Questions?

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