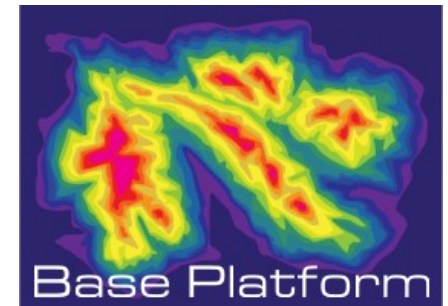




# On the modeling of vertical reference surfaces

Martin Verlaan, Firmijn Zijl,  
Maialen Irazoqui Apecechea,  
Sandra Gaytan Aguilar, Cornelis Slobbe

JONSMOD May 10-12 2016

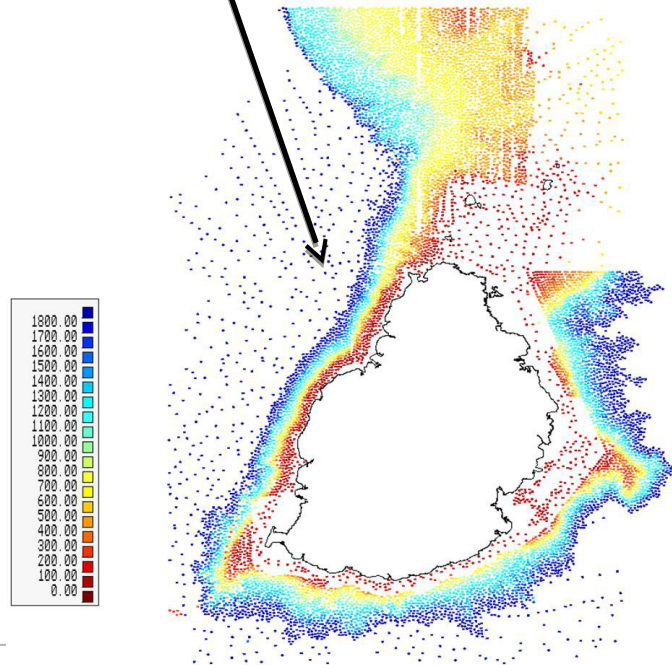
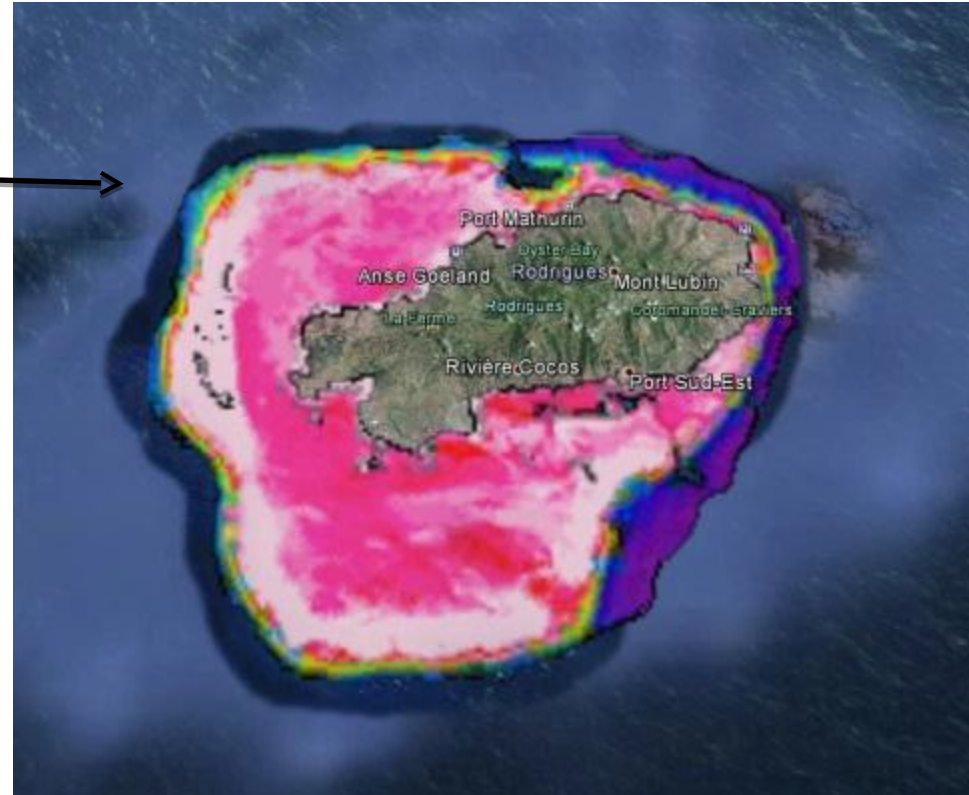
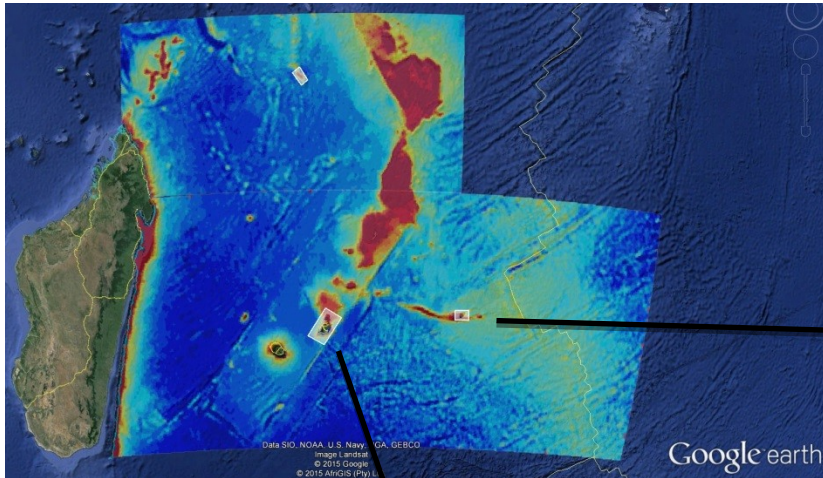
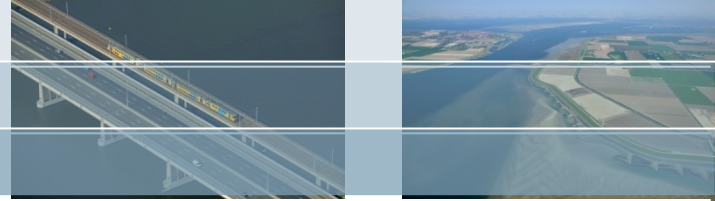


# Outline

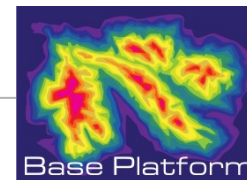


- Introduction – bathymetry measurements from space
- Lowest Astronomical Tide
- Geoid
- Vertical reference of model revisited
- Future work

# Mauritius

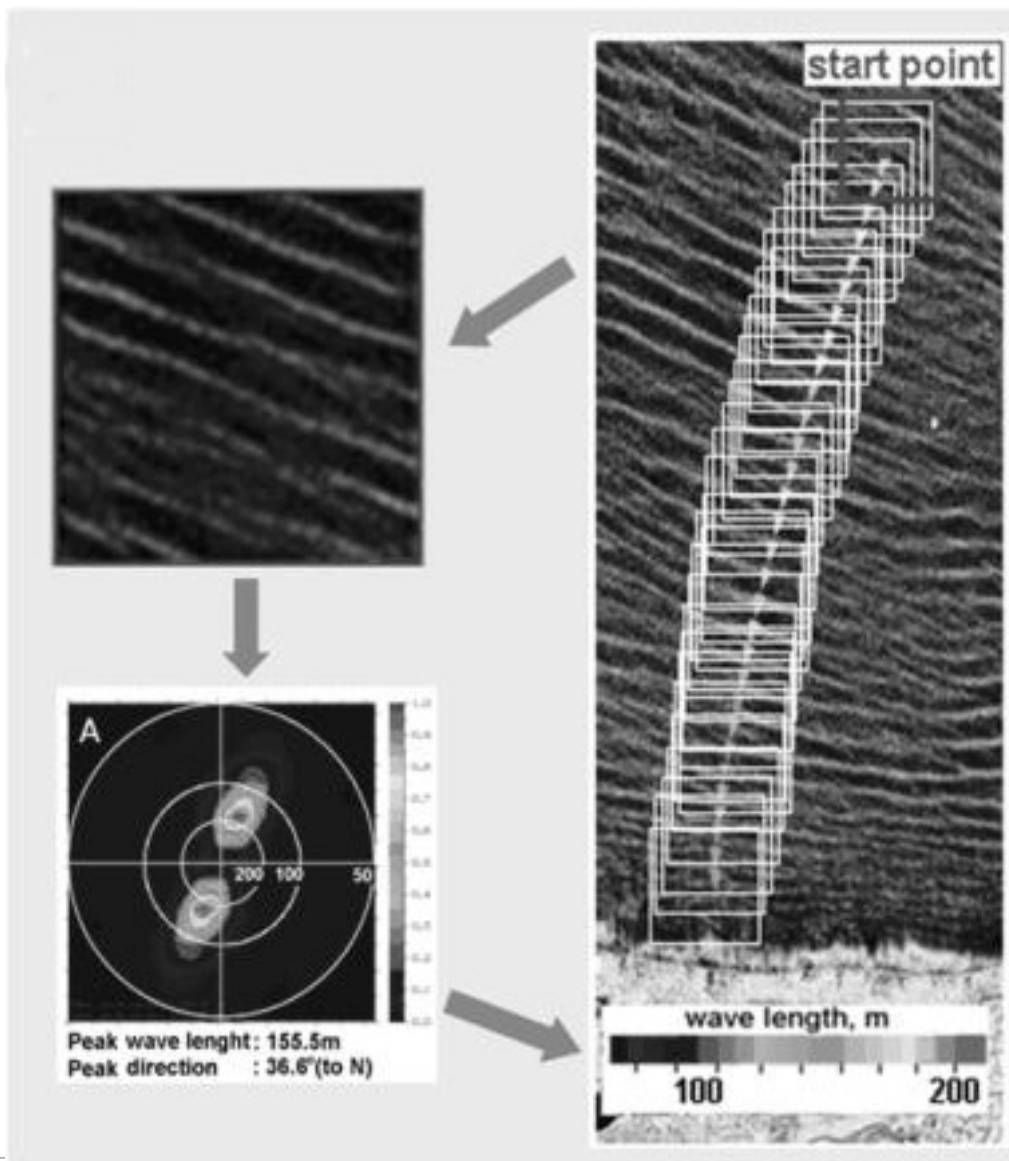
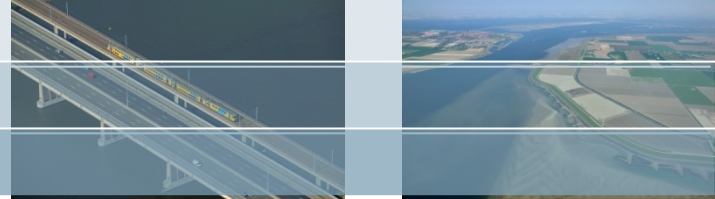


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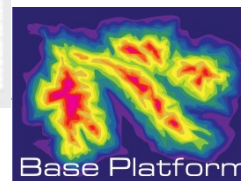


Deltares

# SAR derived bathymetry



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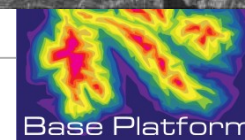


**Deltares**

# SAR waterline

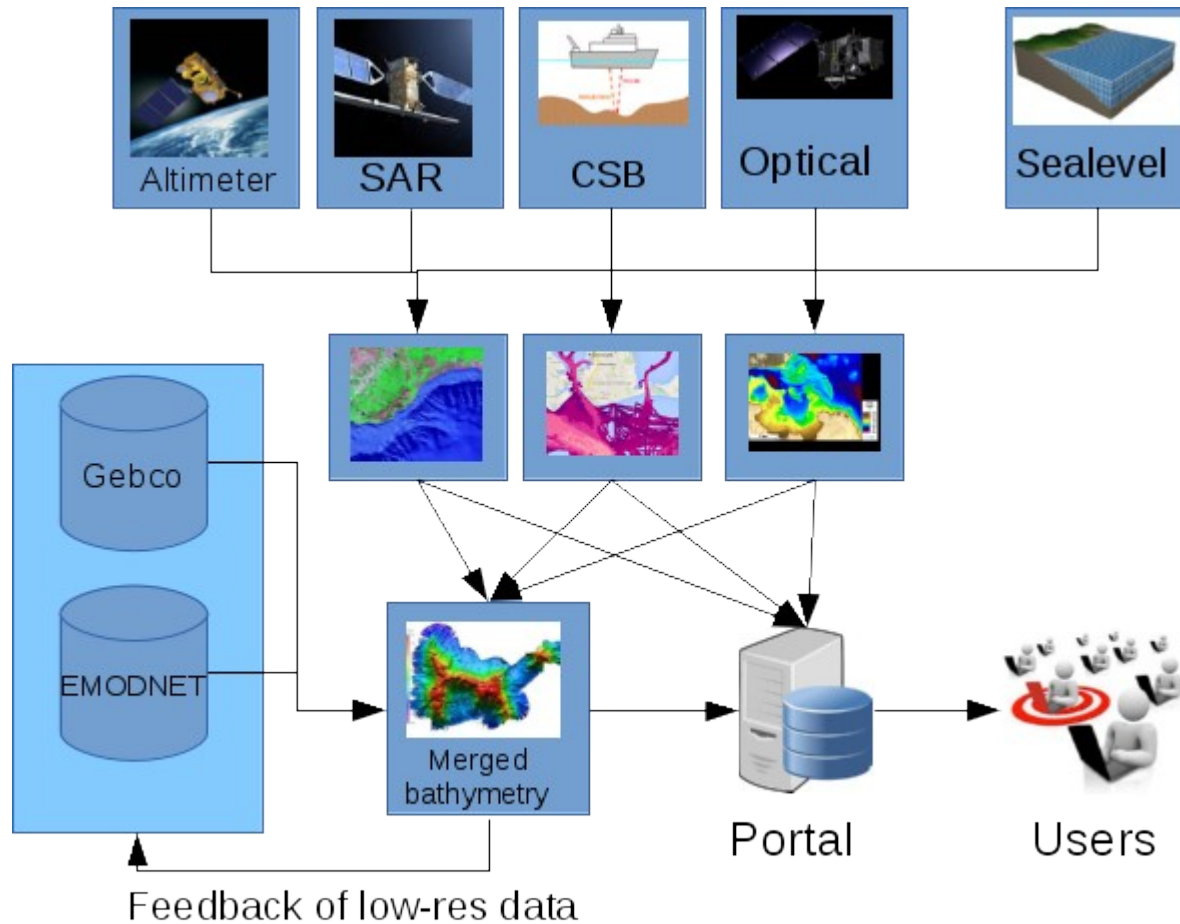


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**Deltares**

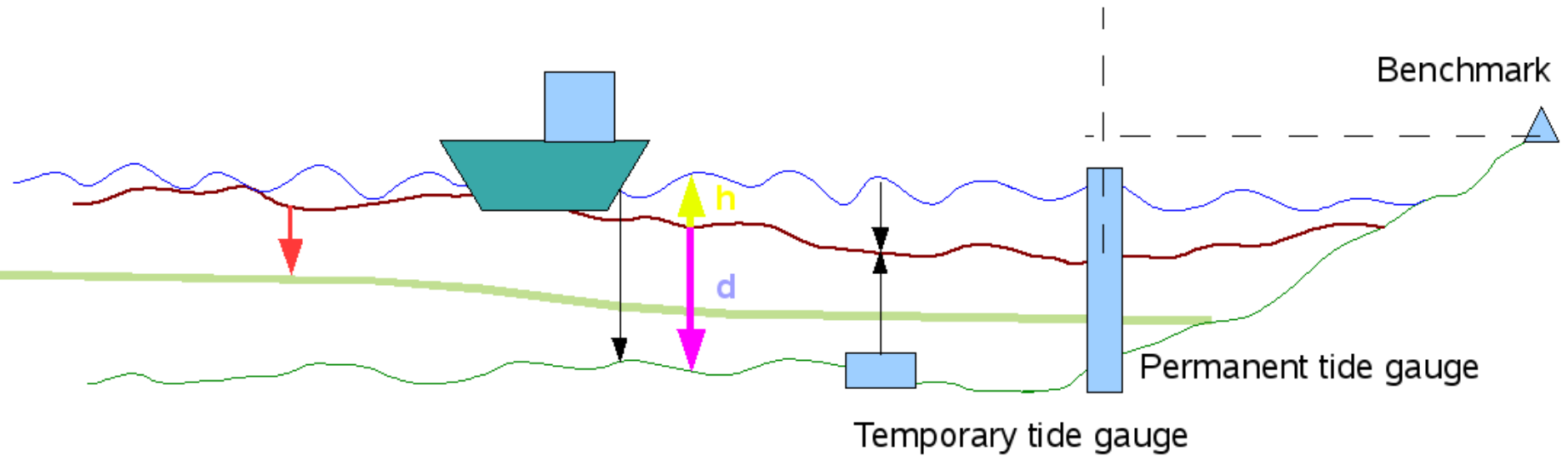
# BASE-platform Workflow



- Sea-level correction
- Vertical referencing
- Data-merging
- Validation
- Use cases:
  - Mauritius
  - Xynthia
  - ...

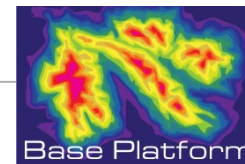


- MSL
- Sea Surface
- Bottom
- LAT



Source: [citg.tudelft.nl](http://citg.tudelft.nl)

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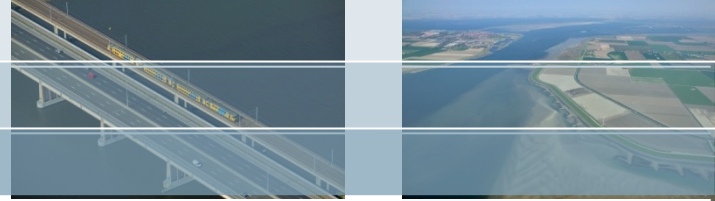
**Deltares**



LAT

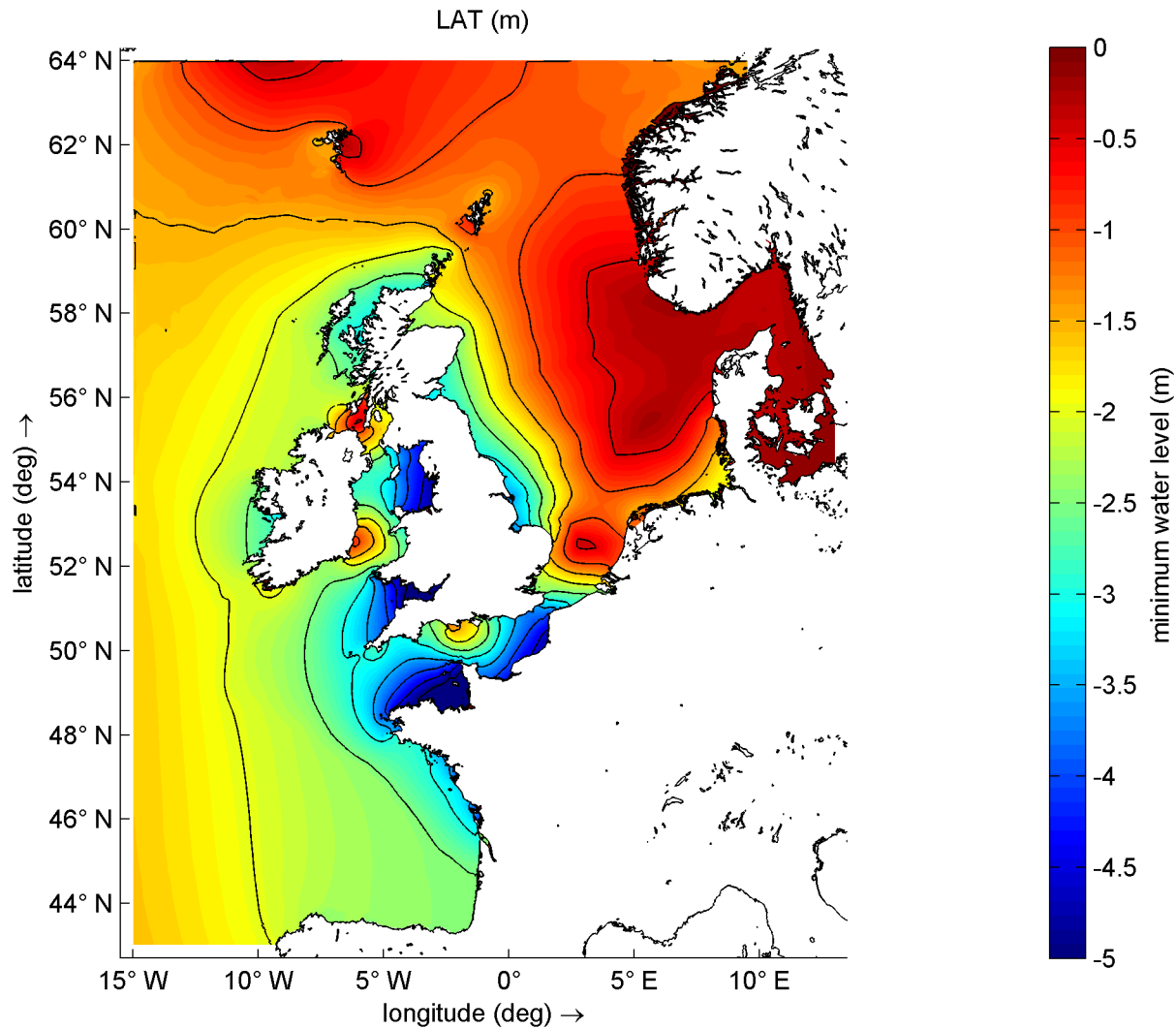


# Lowest Astronomical Tide

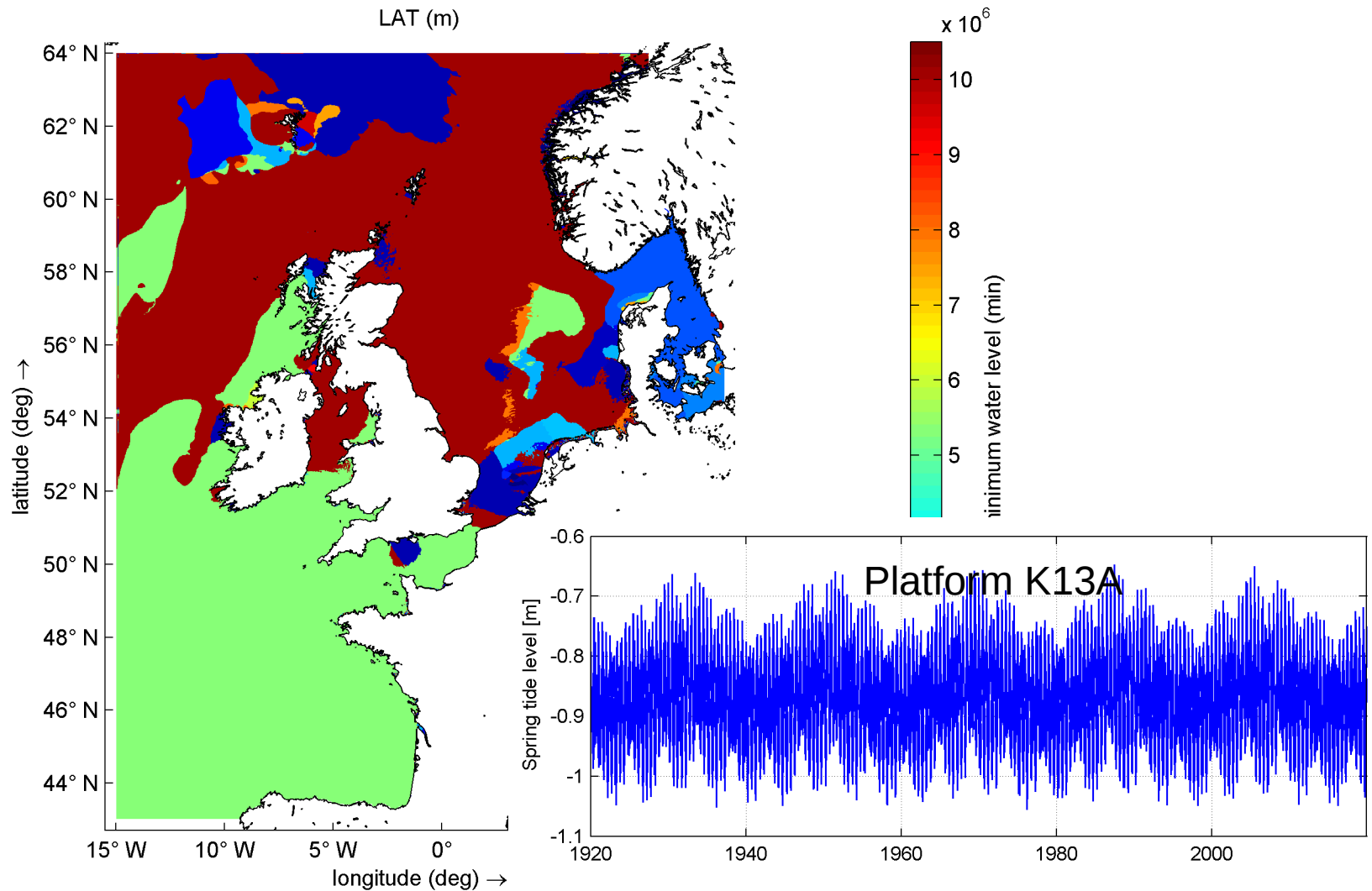
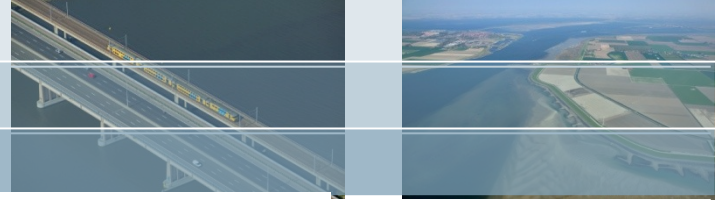


- IHO Resolution 3/1919 :
- “2a: ... It is further resolved that the Lowest Astronomical Tide (LAT), or as closely equivalent to this level as is practically acceptable to Hydrographic Offices, be adopted as chart datum where tides have an appreciable effect on the water level. ...
- Note i: LAT (...) is defined as the lowest (...) tide level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. ...
- Note ii: 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.”

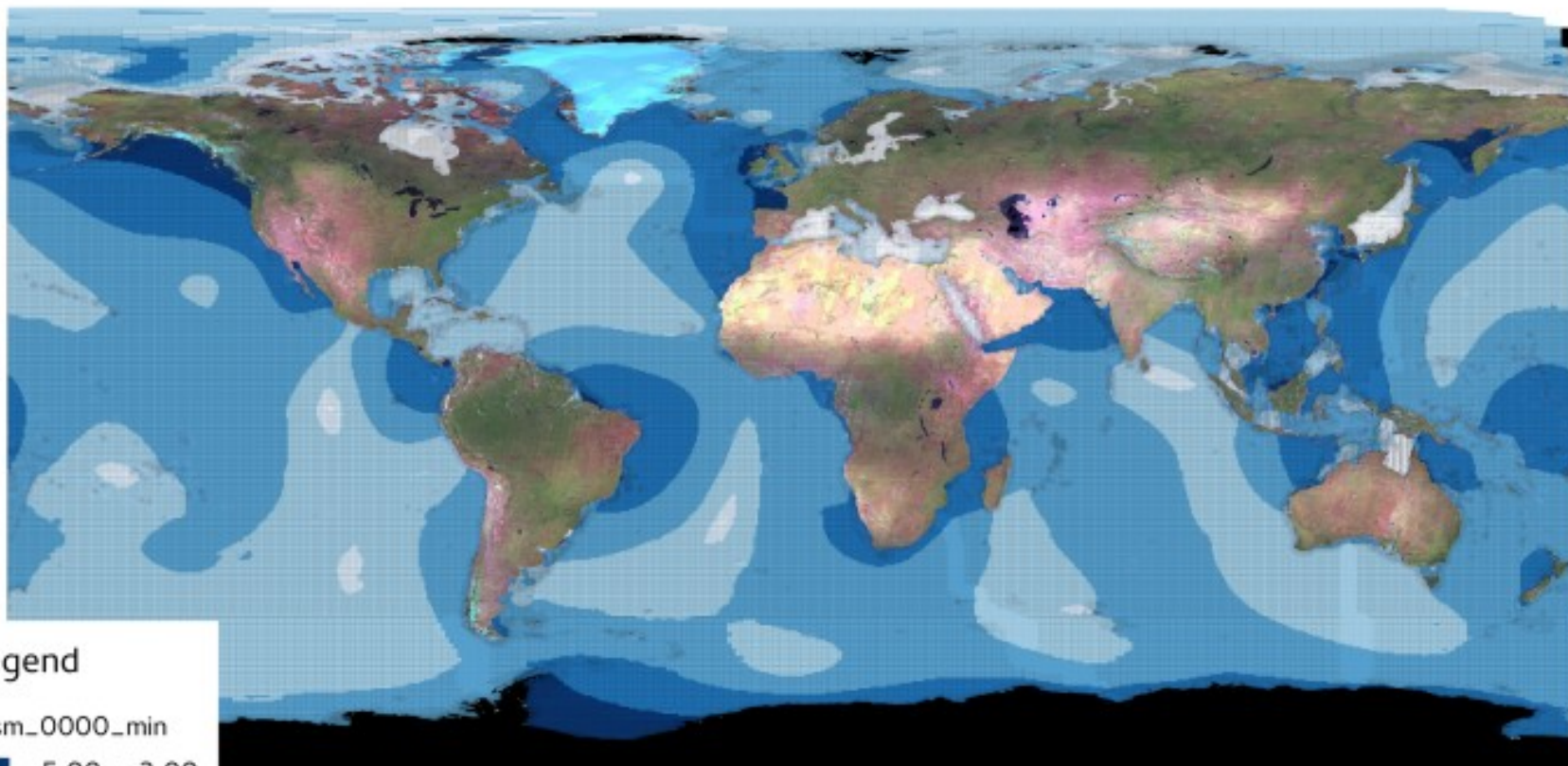
# LAT for North West Shelf



# Time of LAT



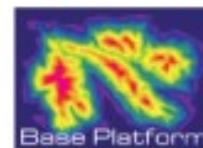
Lowest Astronomical Tide computed with GTSM version 1.0



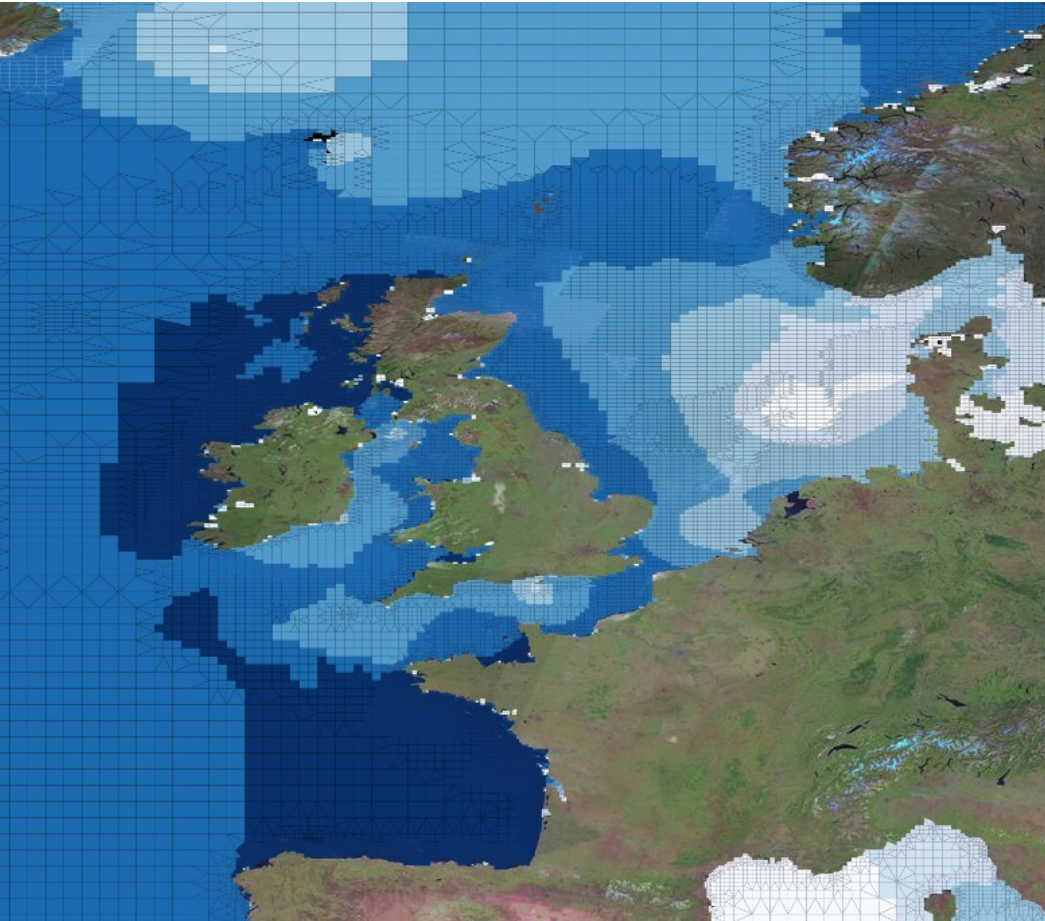
Legend

gtsm\_0000\_min

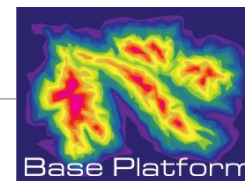
- 5.00 - -2.00
- 2.00 - -1.00
- 1.00 - -0.50
- 0.50 - -0.20
- 0.20 - -0.10
- 0.10 - 0.00



# Comparison of Global to Regional LAT

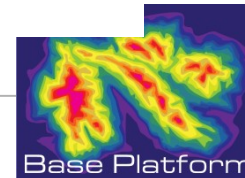
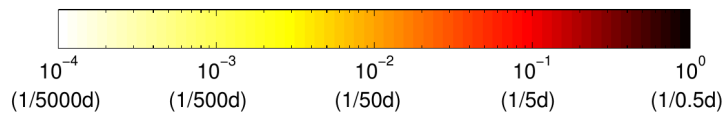
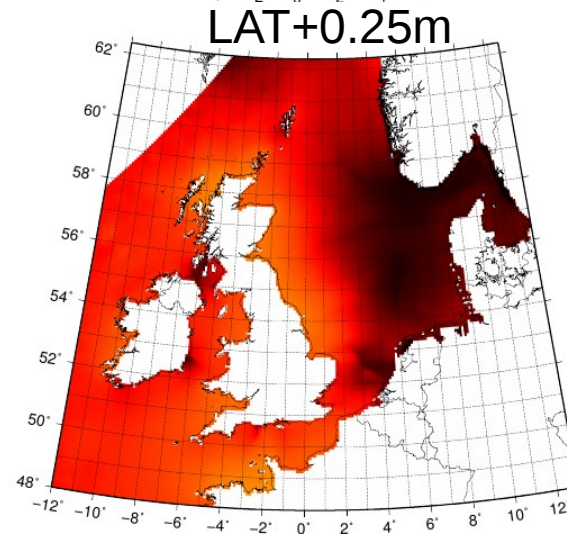
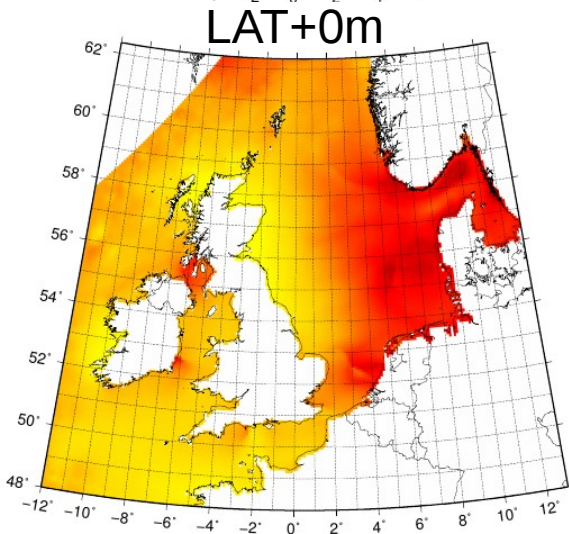
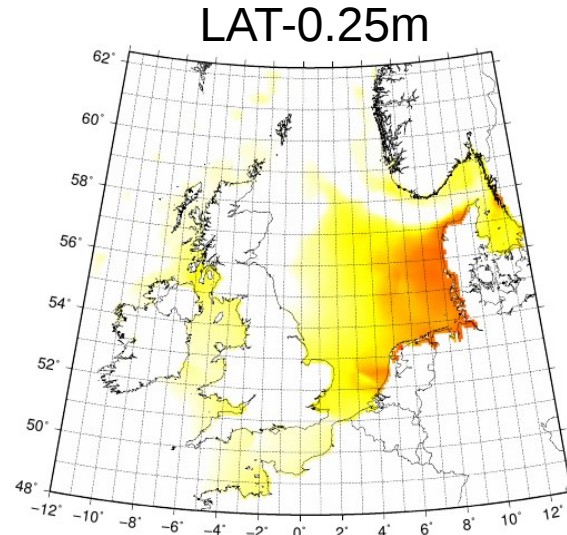
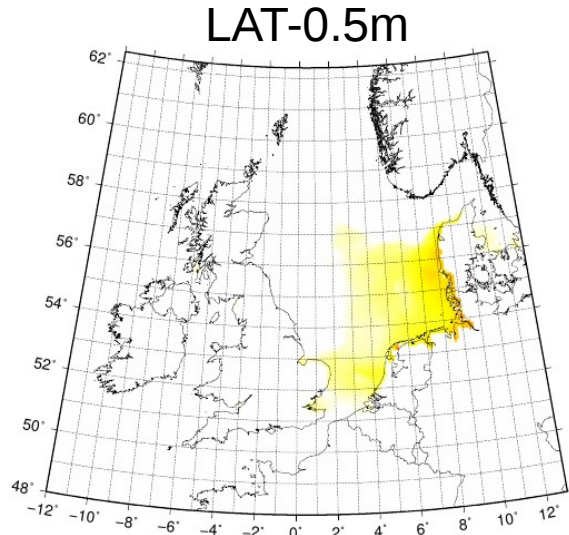


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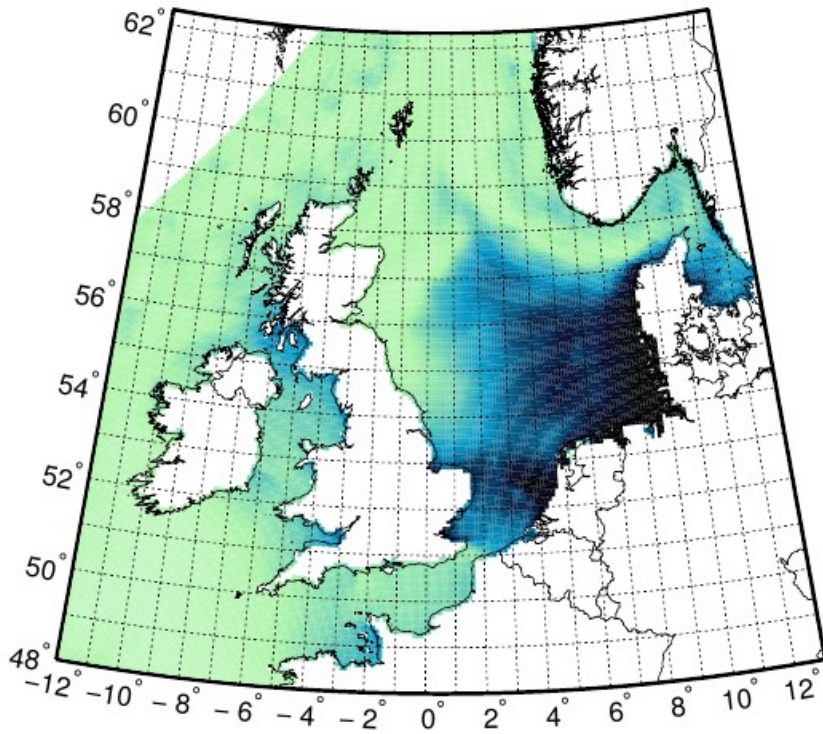
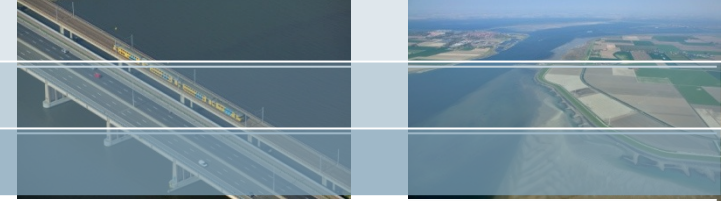
**Deltares**

# LAT exceedance frequency

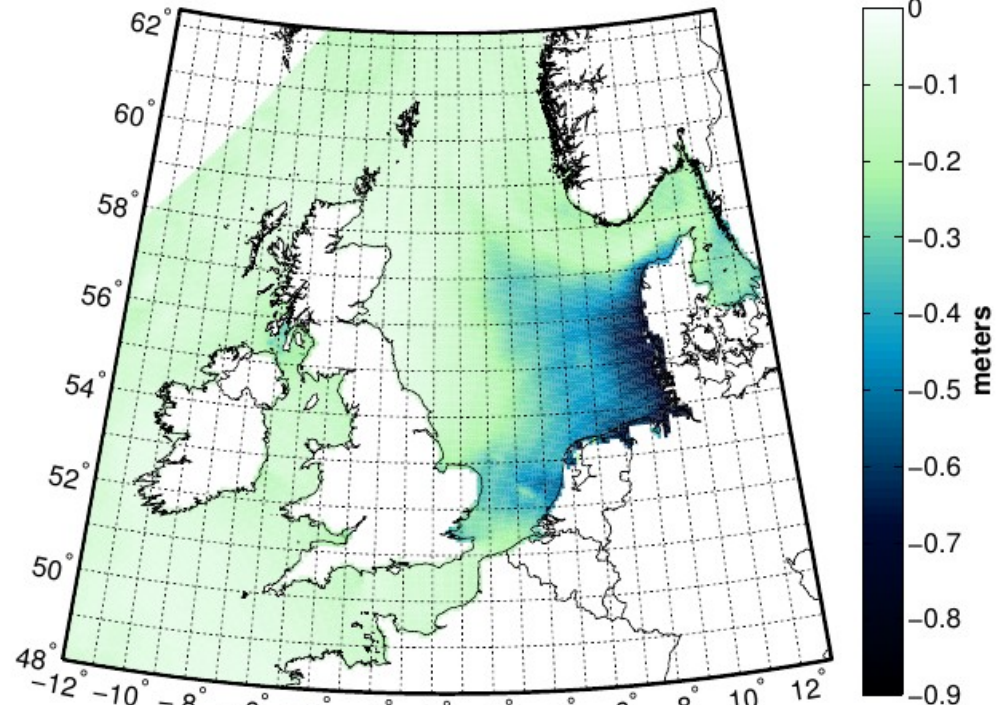


Deltares

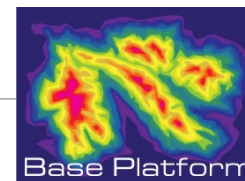
# LAT exceedance frequency



(b) Once per 10 years



(c) Once per year



# Discussion LAT



- IHO definition of LAT is open to multiple interpretations and existing implementations can differ significantly.
- Perhaps some of the differences could be overcome or compensated for if it were clear what are the dominant differences.
- It would be very useful for modellers if all hydrographic offices would publish their LAT implementation.
- In many locations the instantaneous sea level is frequently lower than LAT.





MDT

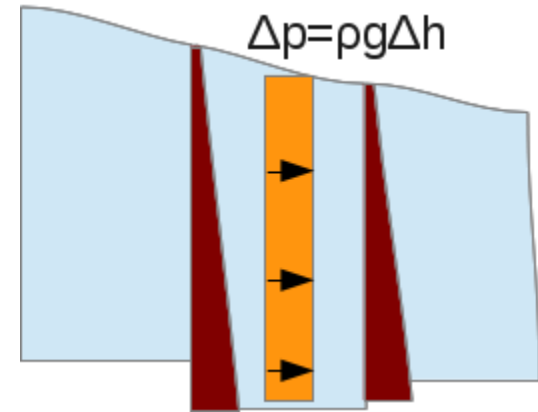
# Hydrostatic pressure



Surface slope

$$p = p_0 + \rho g(z - h)$$

$$F = \rho g H (h(x + \Delta x) - h(x))$$

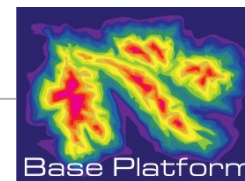


→ This assumes gravity only works in z-direction

$$\Phi = \frac{GM}{|x - x_m|}$$

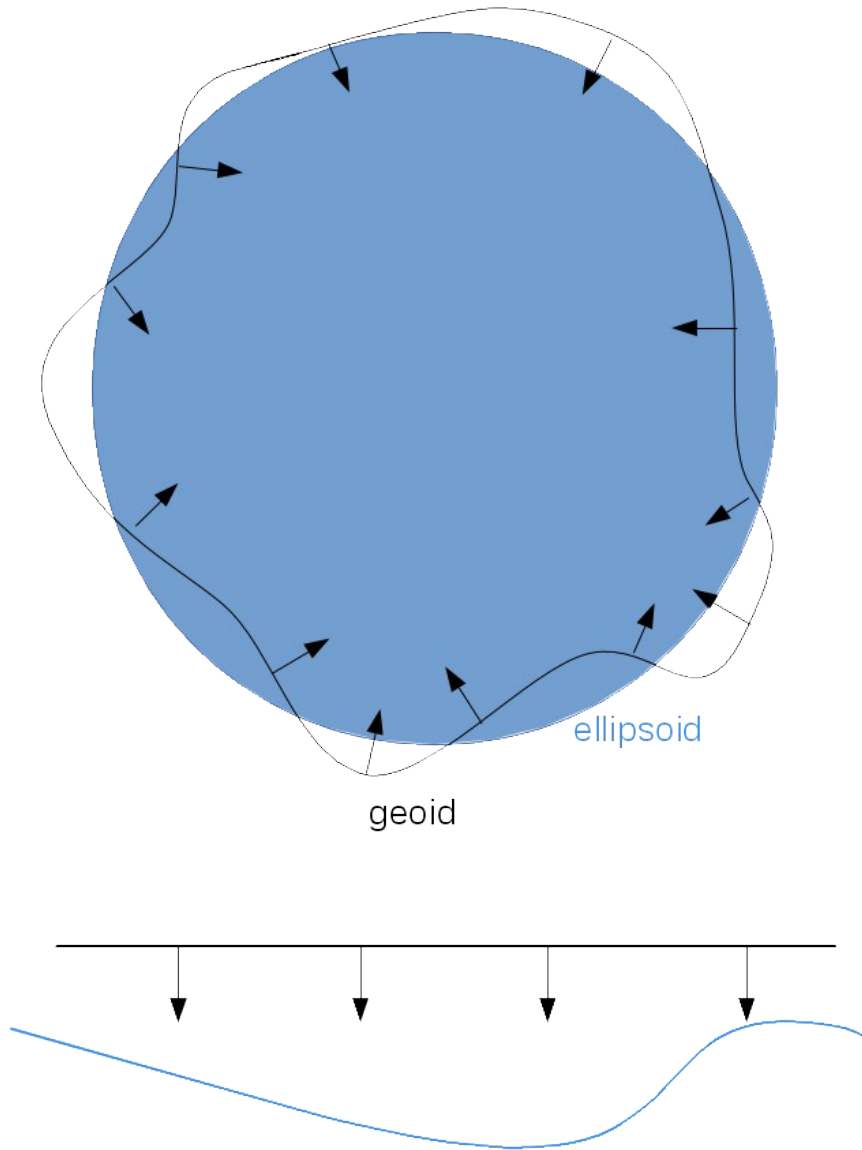
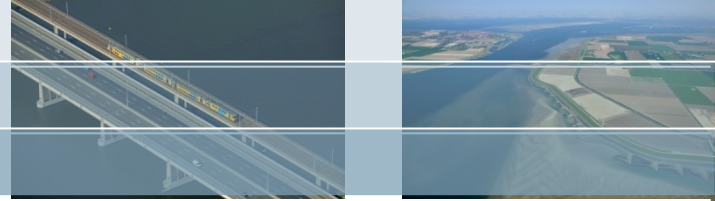
$$F = -\nabla \Phi m$$

$$g = -\nabla \Phi$$

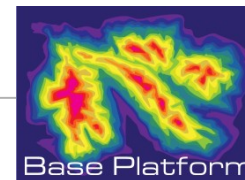


**Deltares**

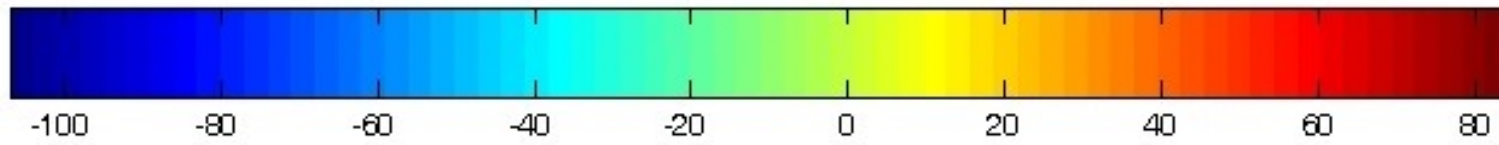
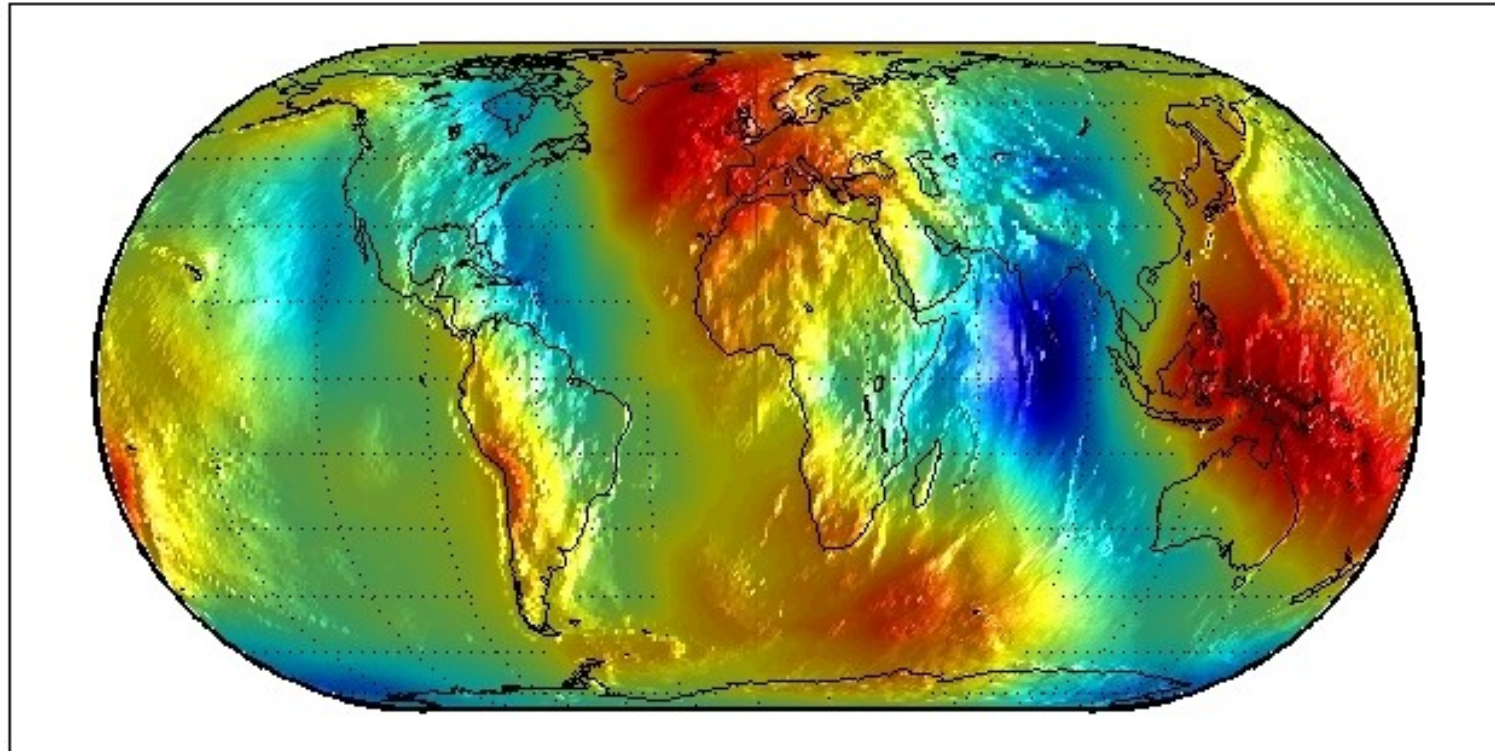
# Geoid in numerical model



Gravity perpendicular to geoid

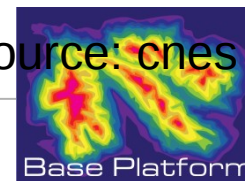


# Geoid relative to ellipsoid



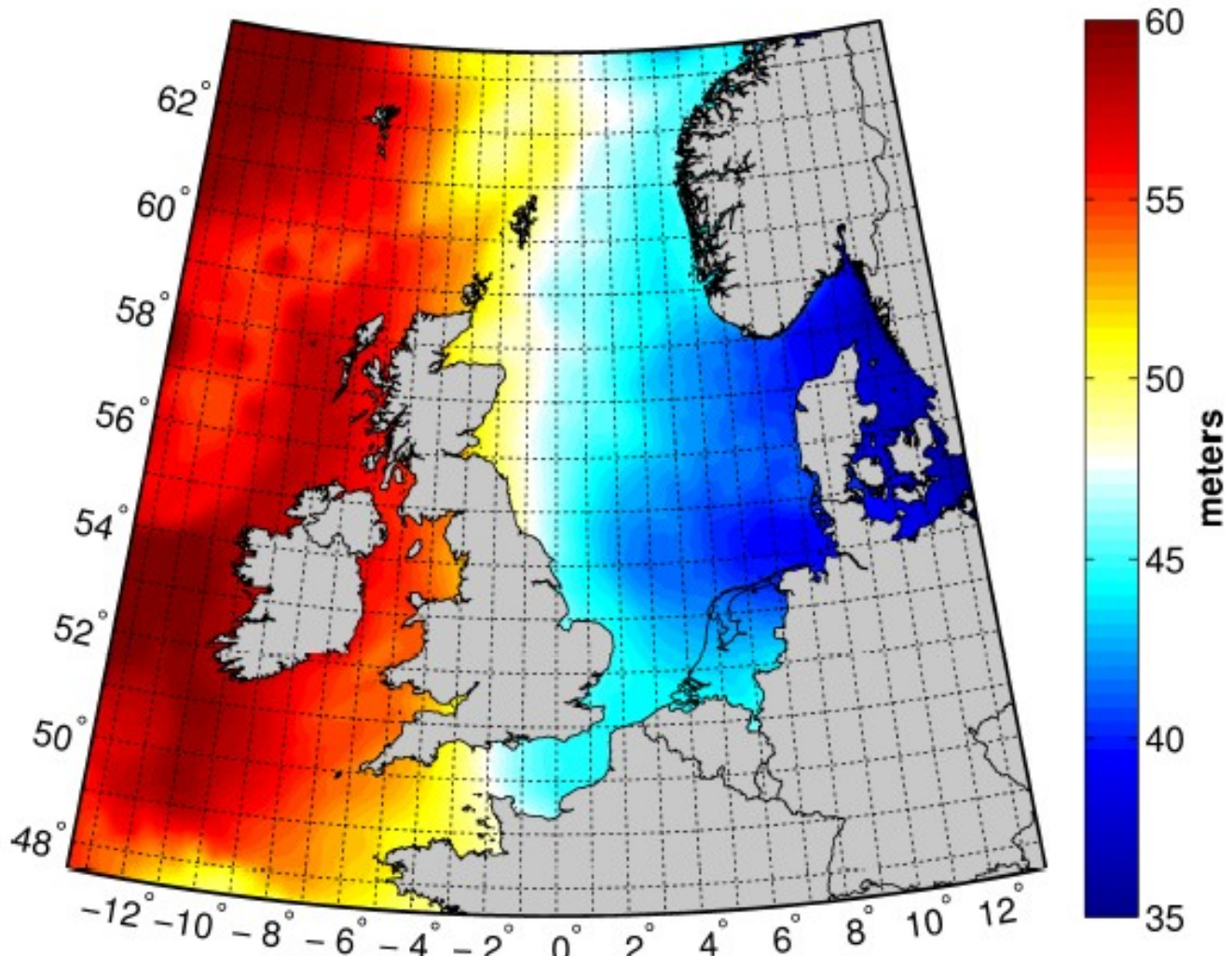
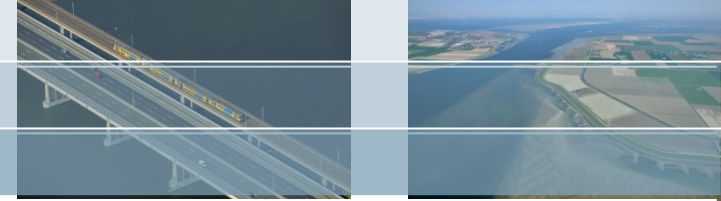
EGM96 altezza del geoida rispetto all'ellissoide

Source: cnes



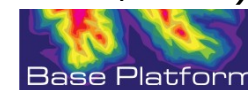
**Deltares**

# Absolute vertical referencing



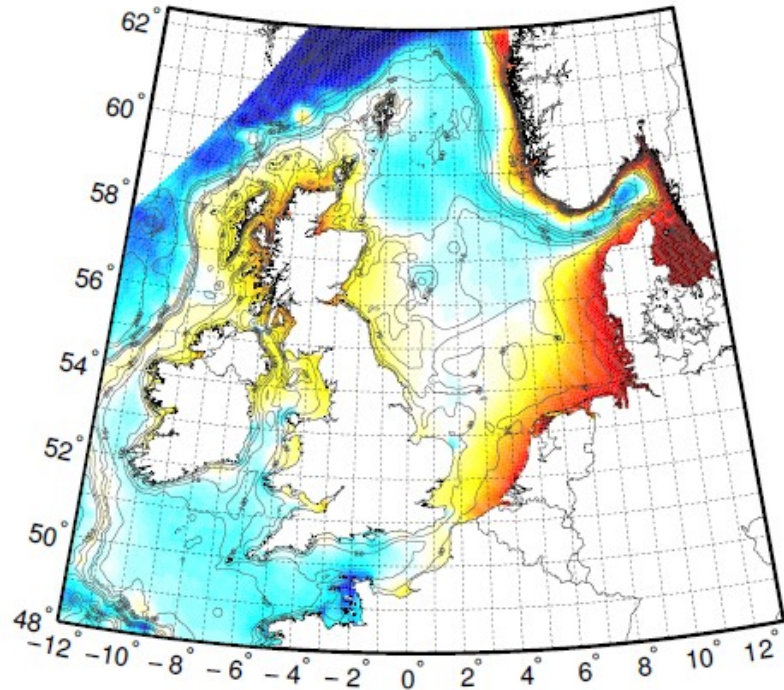
NLGE02013 Quasi-geoid relative to ellipsoid (Slobbe 2012,2013)

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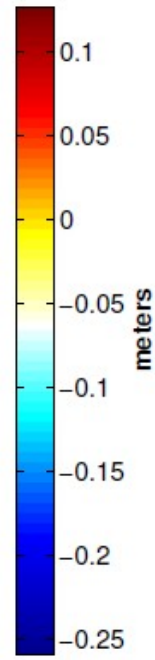


**Deltares**

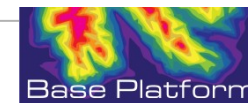
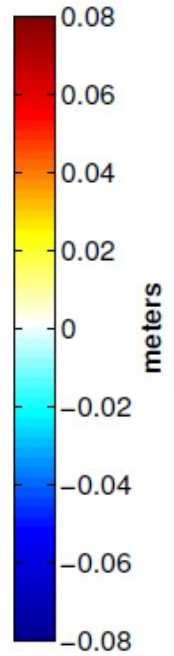
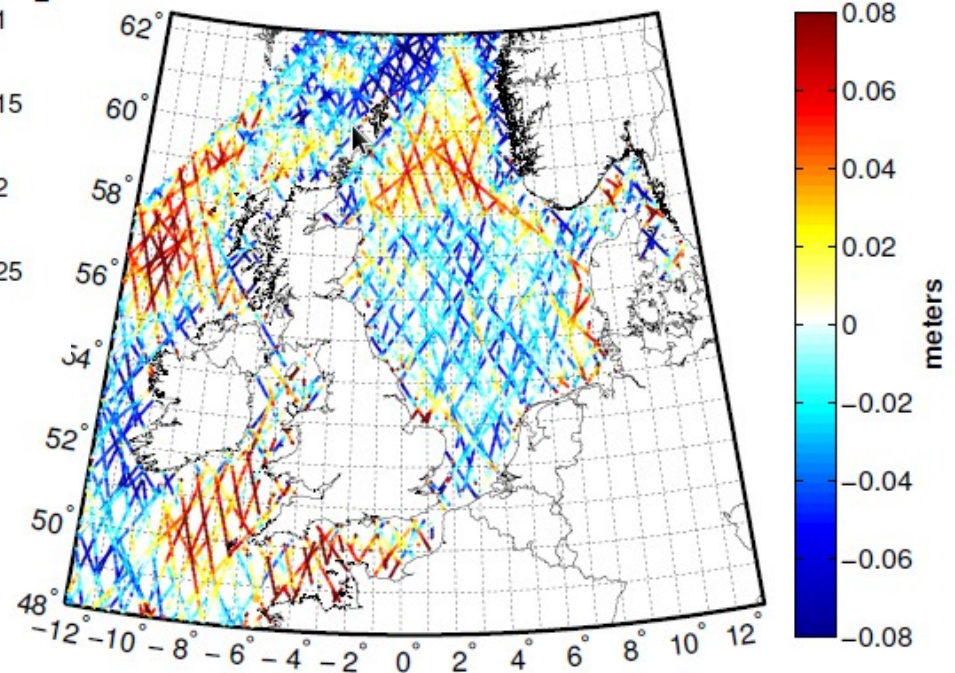
# Absolute vertical referencing



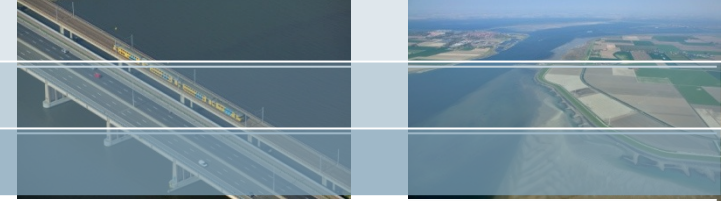
Mean Dynamic Topography



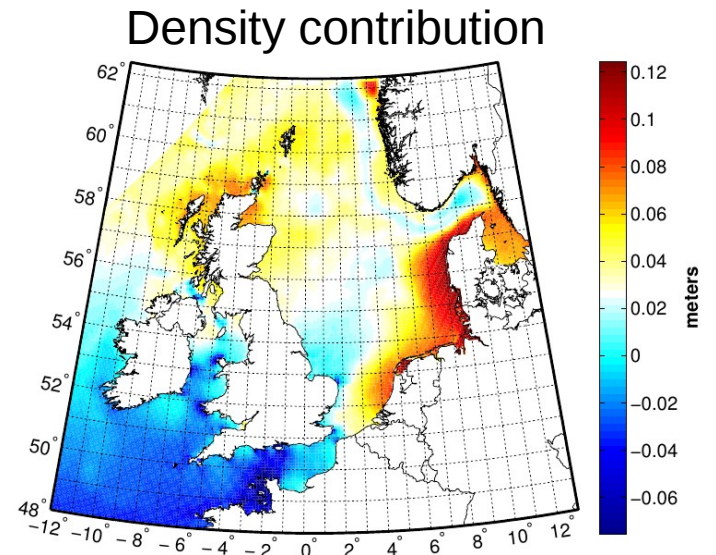
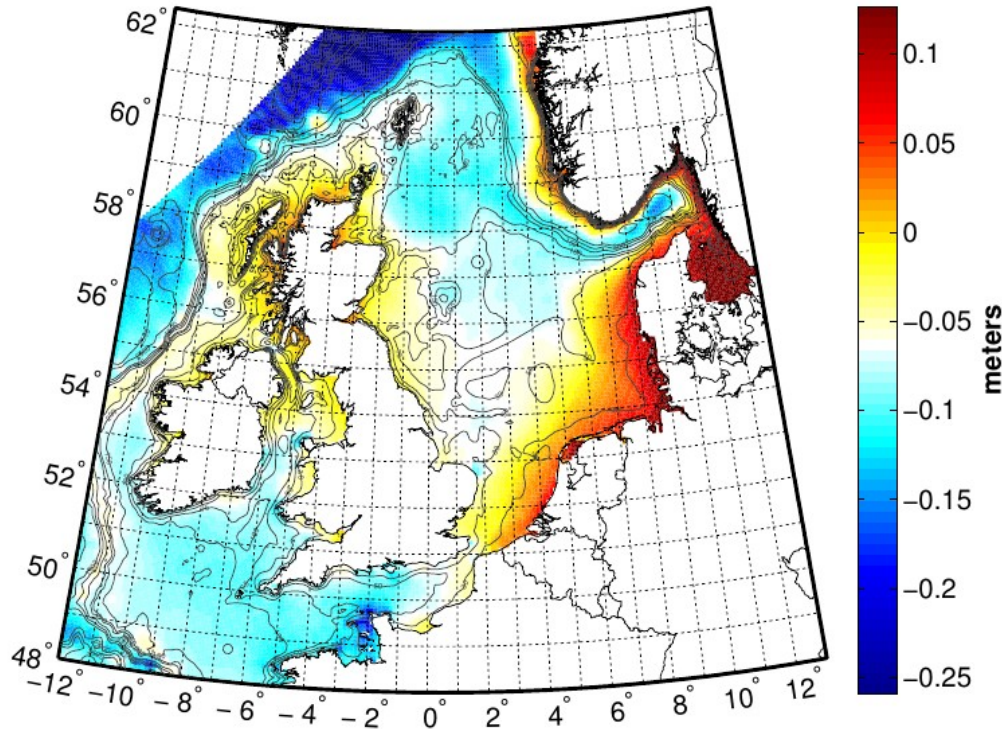
Mean difference MDT between Model and Altimeter



# Mean dynamic topography

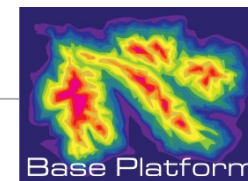


MDT wrt EGG08



Source: Slobbe et. al. 2012

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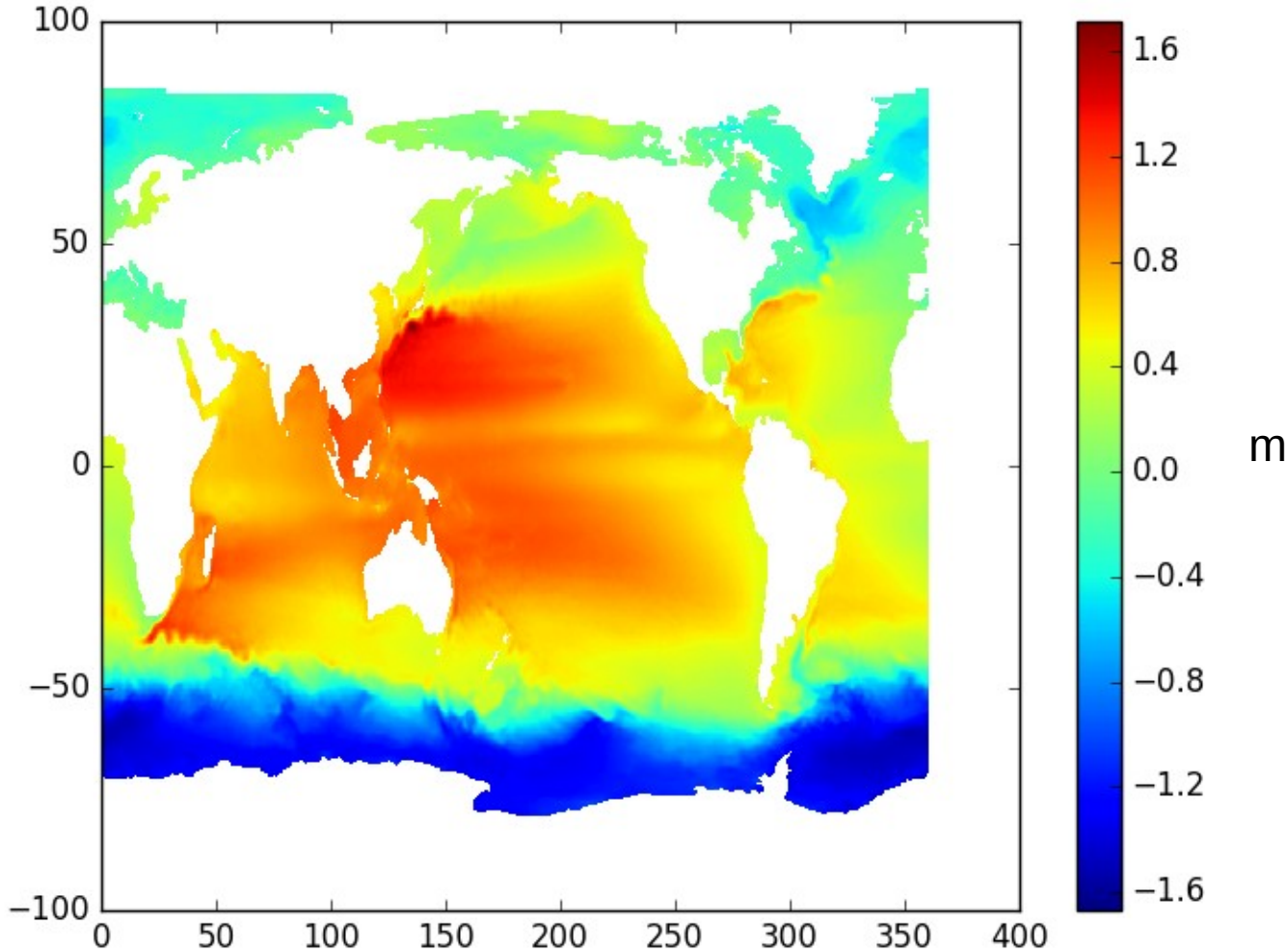


Deltares

# Mean Dynamic Topography



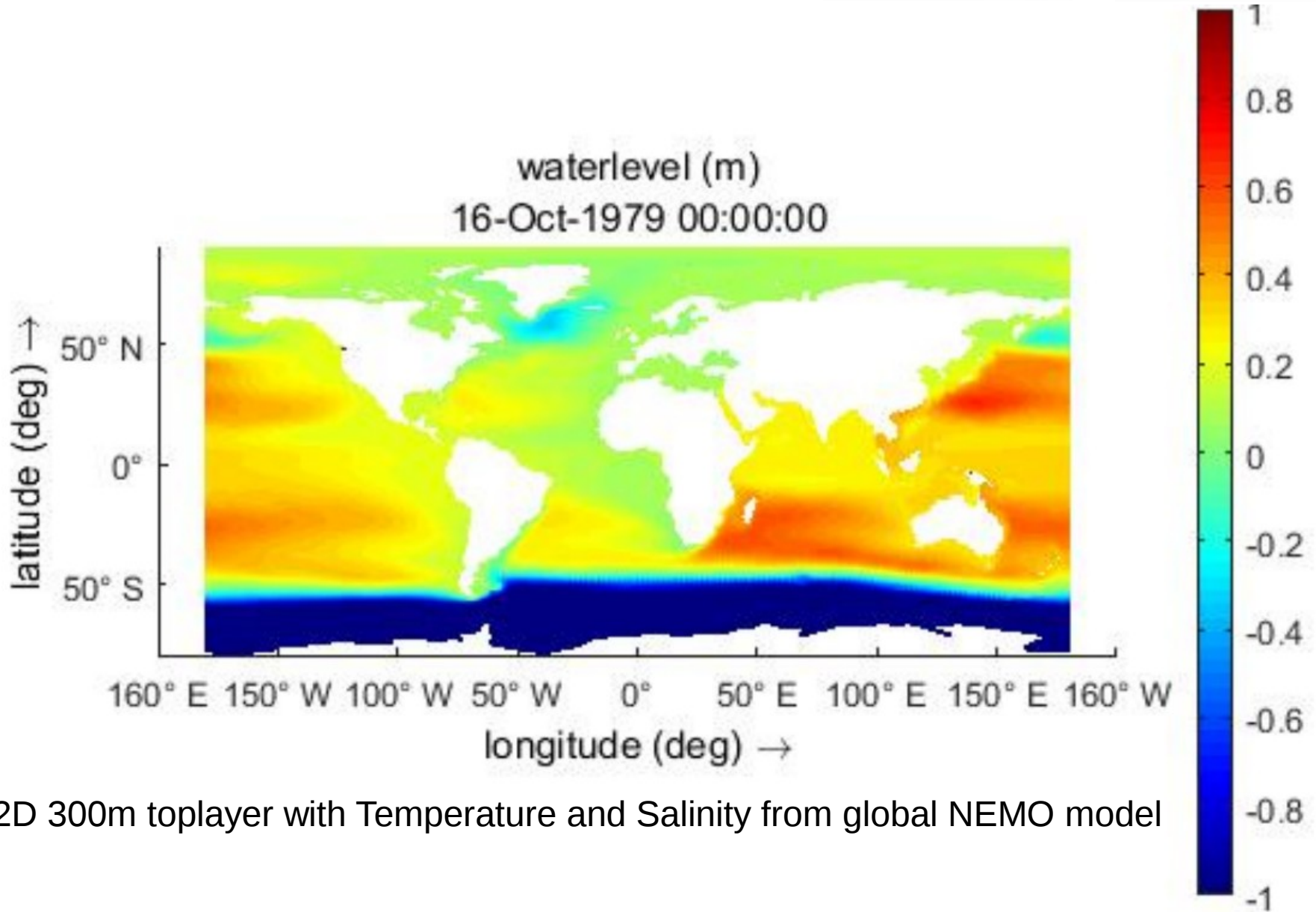
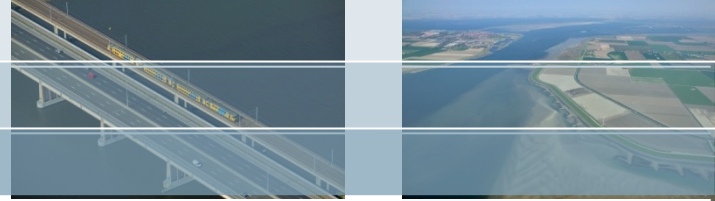
Satellite derived MDT



Source: aviso

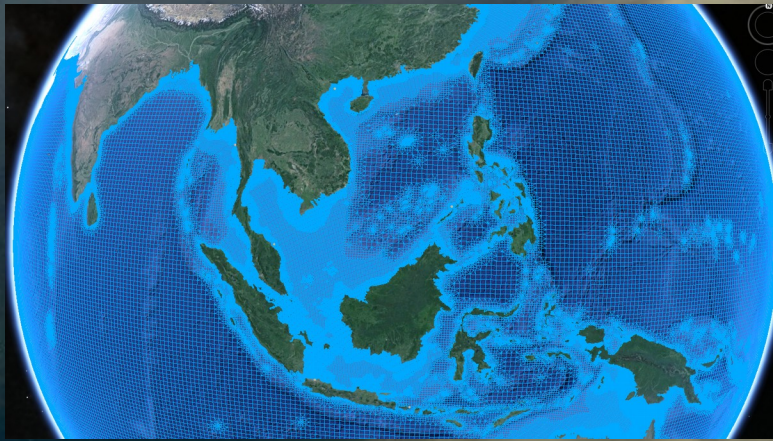


# GTSM MDT test



2D 300m toplayer with Temperature and Salinity from global NEMO model

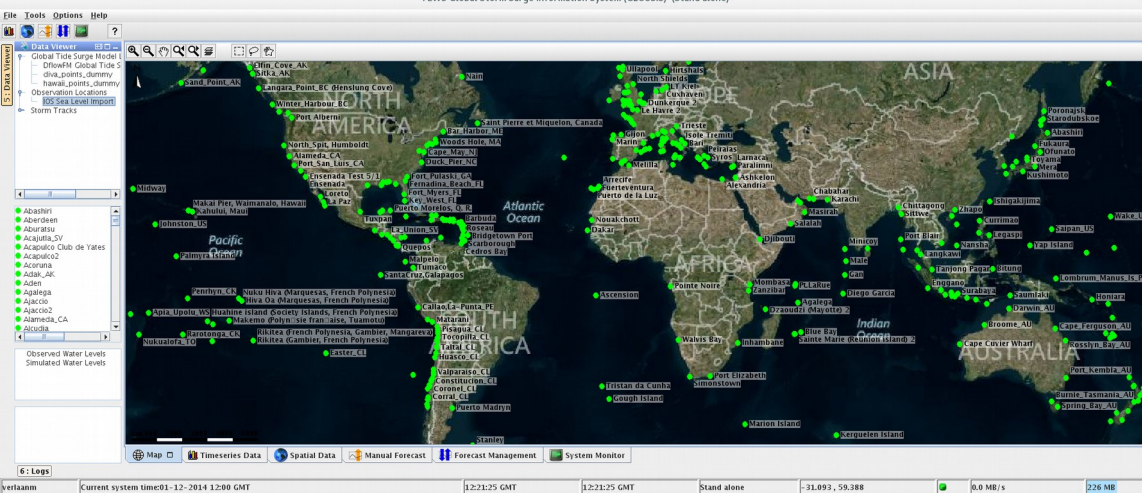
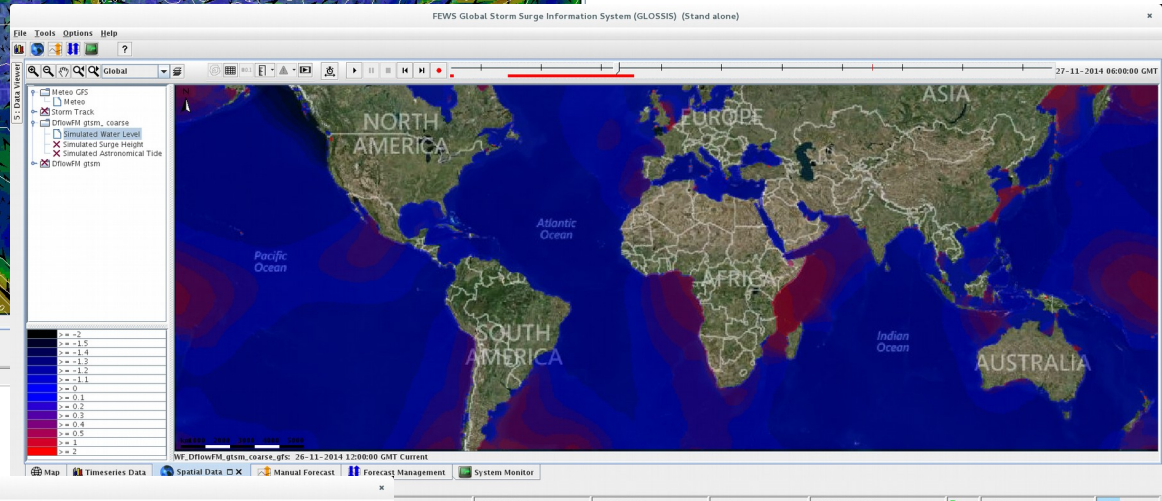
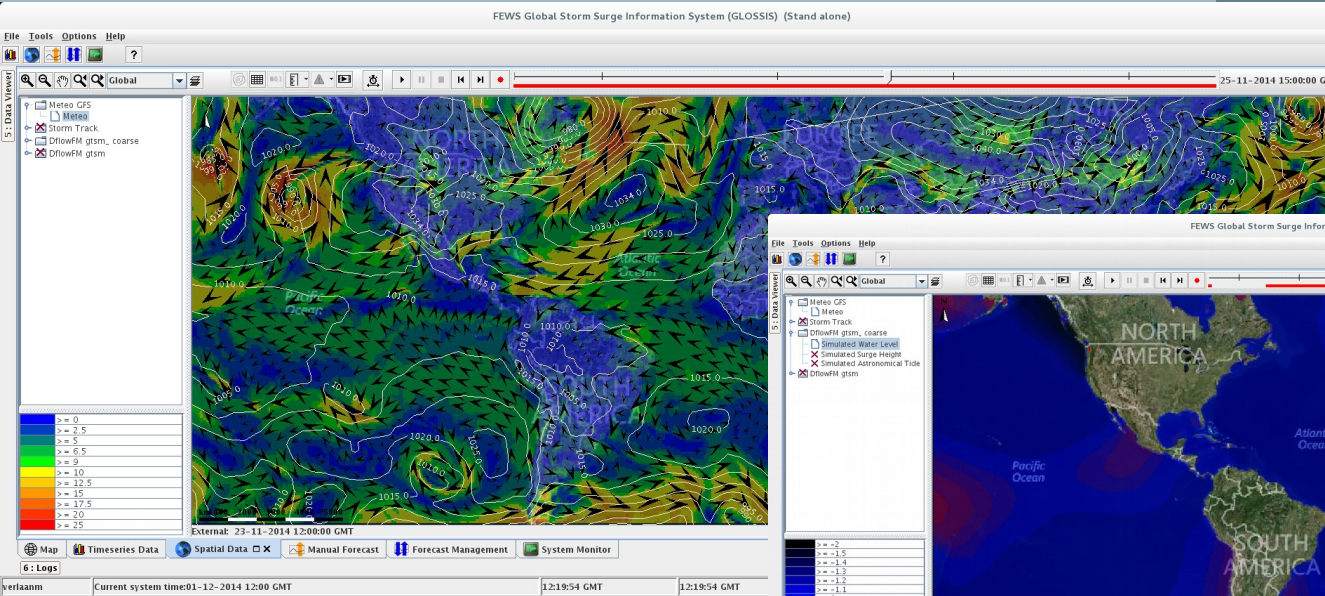
# Instantaneous sea level



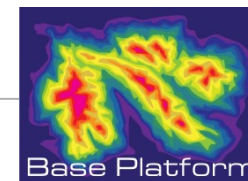
# GLOSSIS – global operational storm surges



Running in ID-Lab



Real-time observations from IOC



**Deltares**

Base Platform

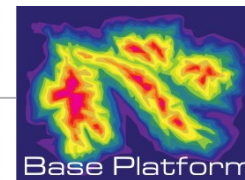
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# Future work



- Validate models for LAT and MDT
- Quantify errors of LAT procedures
- Compare 2D vs 3D modelling approaches for MDT

*Acknowledgments:* This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 687323. Part of the work is funded by the NEVREF project, funded by STW (Netherlands applied science funding)





Questions?