



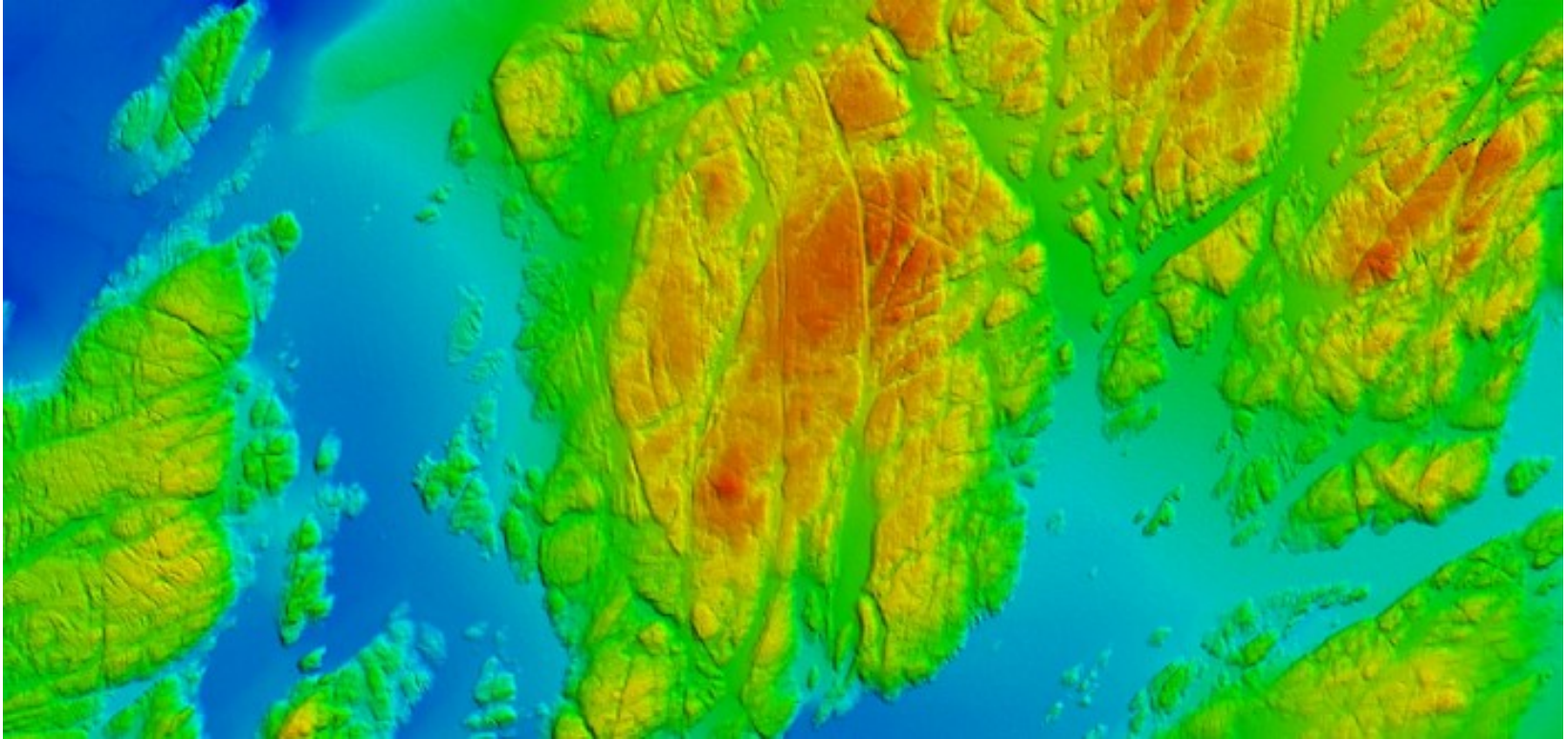
## MMT | Implementation of GNSS tides - a user perspective







# MMT | Implementation of GNSS tides

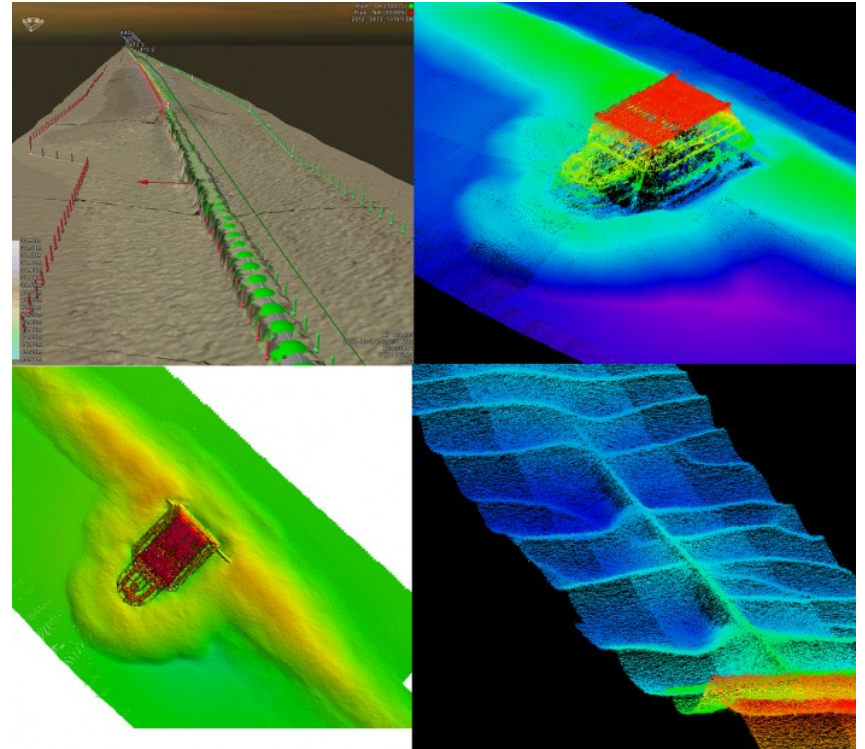


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# MMT | Outline

- History of GNSS tides at MMT
- Deriving Ellipsoid Heights
- Models
- Verification
- MSL
- Pros
- Cons
- Conclusion





## Company Profile

- High Resolution Seabed Mapping, Pipeline, Geophysical and Geotechnical Surveying
- MMT Sweden founded in 1976
- MMT UK (NetSurvey) founded in 2002
- Offices in Gothenburg, Sweden & Banbury, UK
- Privately owned
- 200 specialists
- 8 vessels
- 4 ROVs
- 2 ROTVs



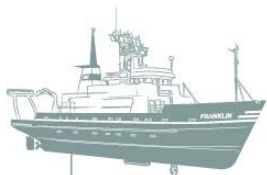
# MMT | History of GNSS tides at MMT



## Timeline:

- 2005 - RTK base stations
- 2007 - Filtered SBET
- 2009 - Full SBET
- 2014 - All clients convinced?





# MMT | Deriving Ellipsoid Heights

- Data collected with POS MV – RINEX and IMU
- Processed through POSPac
- ASB or PPP depending on location and availability of base station data
- Careful analysis of QC plots



# MMT | Tide Defenitions

## Mean Sea Surface

(**MSS**) represents the mean state of the ocean and therefore includes permanent effects of global currents

- MSS models are developed based on data provided by altimetry satellites. It is not an equipotential surface.

## Mean Sea Level

(**MSL**) refers to a 'level' water surface, which you would get if the sea was perfectly at rest

- It coincides with an equipotential surface, as for example the Geoid. MSL values are measured with respect to the level of benchmarks on land

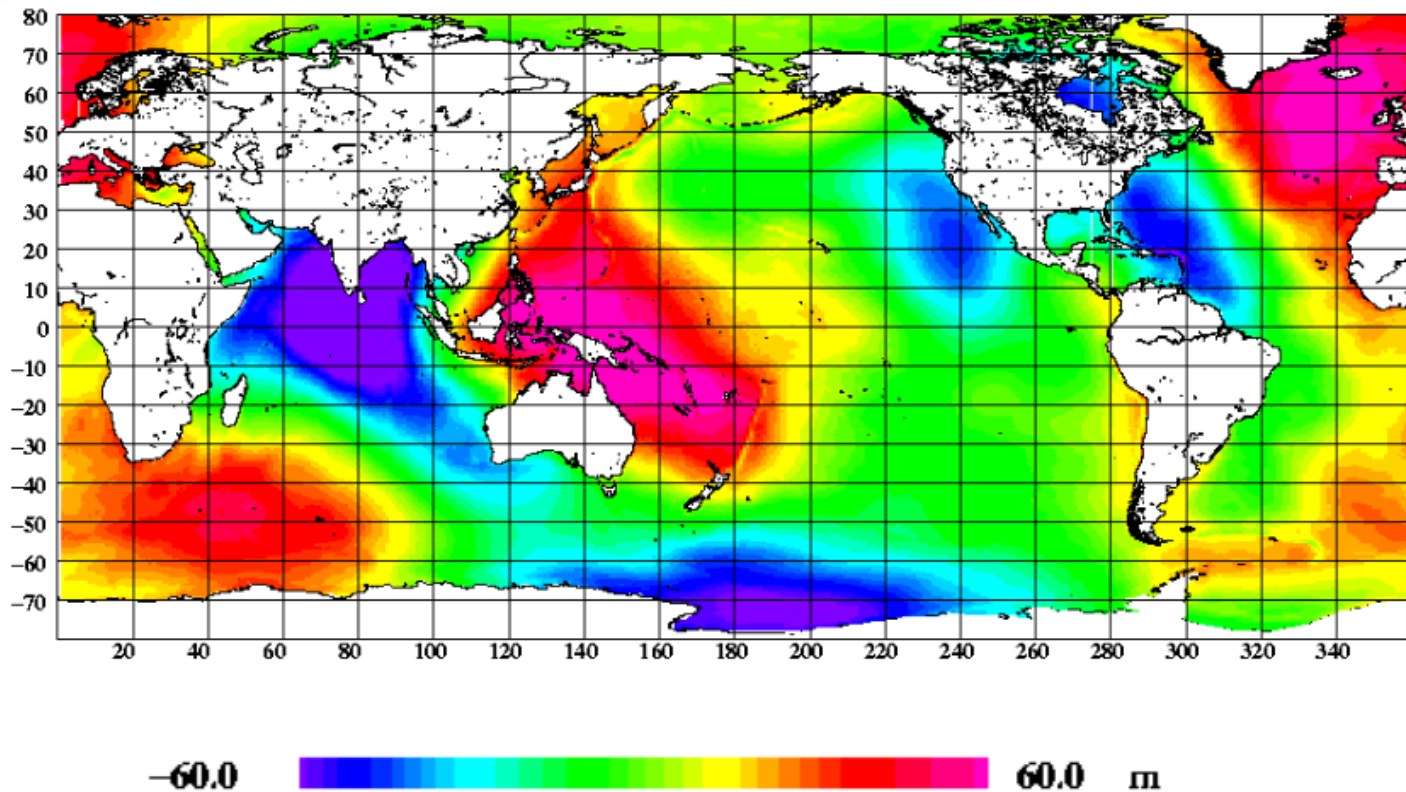
## Geoid

is an equipotential surface which would coincide exactly with the mean ocean surface of the Earth, if the oceans were in equilibrium, at rest, and extended through the continents

- Approximated by Geoid Models as for example EGM96 and EGM2008



# MMT | DTU 10 Model



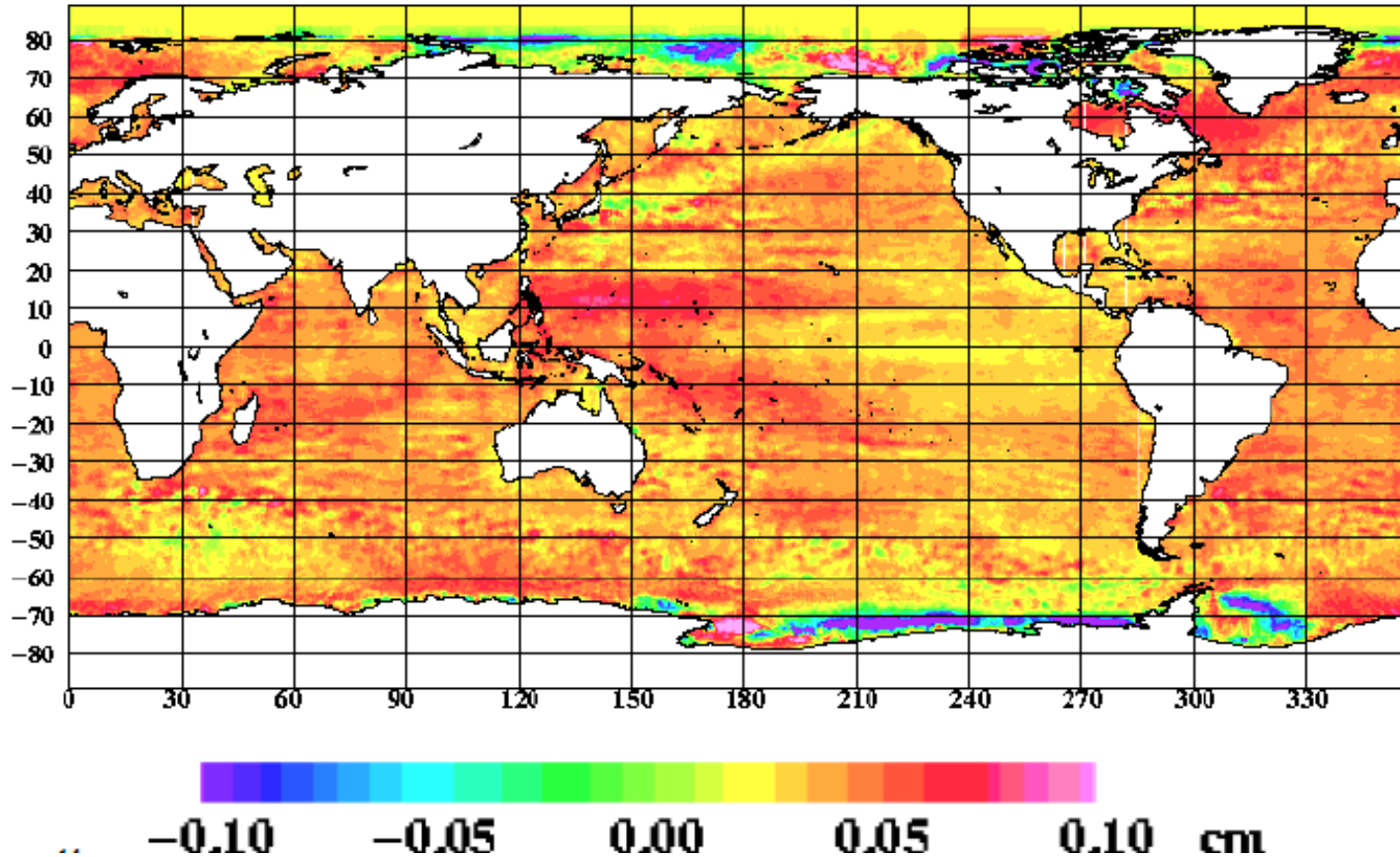
Global Coverage at 1x1 minute resolution

- Satellite Altimetry Data
- Gravity Field Models
- Tide Modeling



# MMT | DTU 10 Model

DTU10MSS – DNSC08MSS (3 cm average difference)

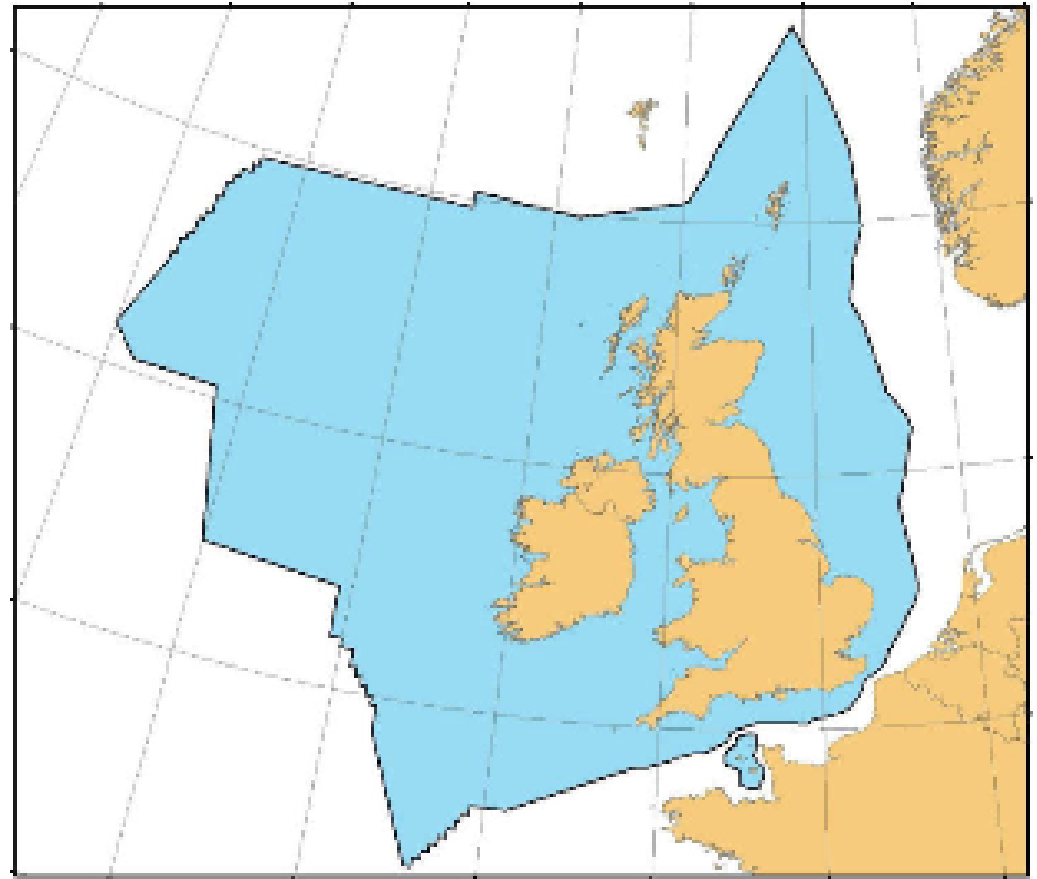


Improvement over DNSC08 – Observation period of 17 years



# MMT | VORF Model

- Covers the entire UK and Irish continental shelves
- Resolution Approximately 900m in Latitude and, depending on the Latitude, 500m in Longitude
- Tide Gauge Data
- GPS Data
- Satellite Altimetry Data
- Gravity Field Models
- Tide Modelling





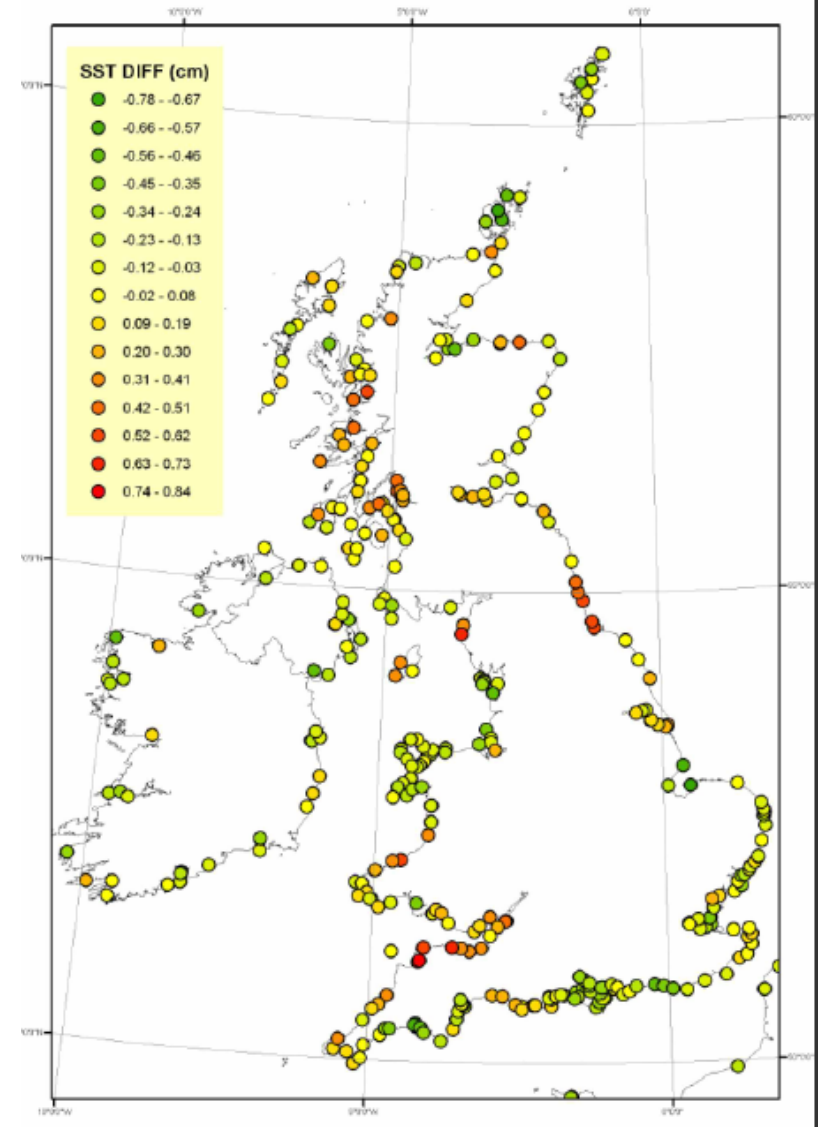
# MMT | Model Verification

320 GPS measured Tide Gauges  
Around Britain

TG -DNSC08MSS

Mean= 1.24 cm,  
Std= 6.8 cm

Comparison by  
Marek Ziebart, UCL London







# MMT | Model Verification VORF

Areas with large uncertainty were identified and MMT participated in the verification for UKHO with the following method:

- Sea floor tide gauge deployed for 60 plus days
- Deploying vessel records GPS height of water surface for 8 hours (including a high and low water event)
- Harmonic analysis used to generate MSL and LAT from tide gauge data
- GPS water level curve used to 'fit' MSL and CD to the ellipsoid





# MMT | Tide Verification

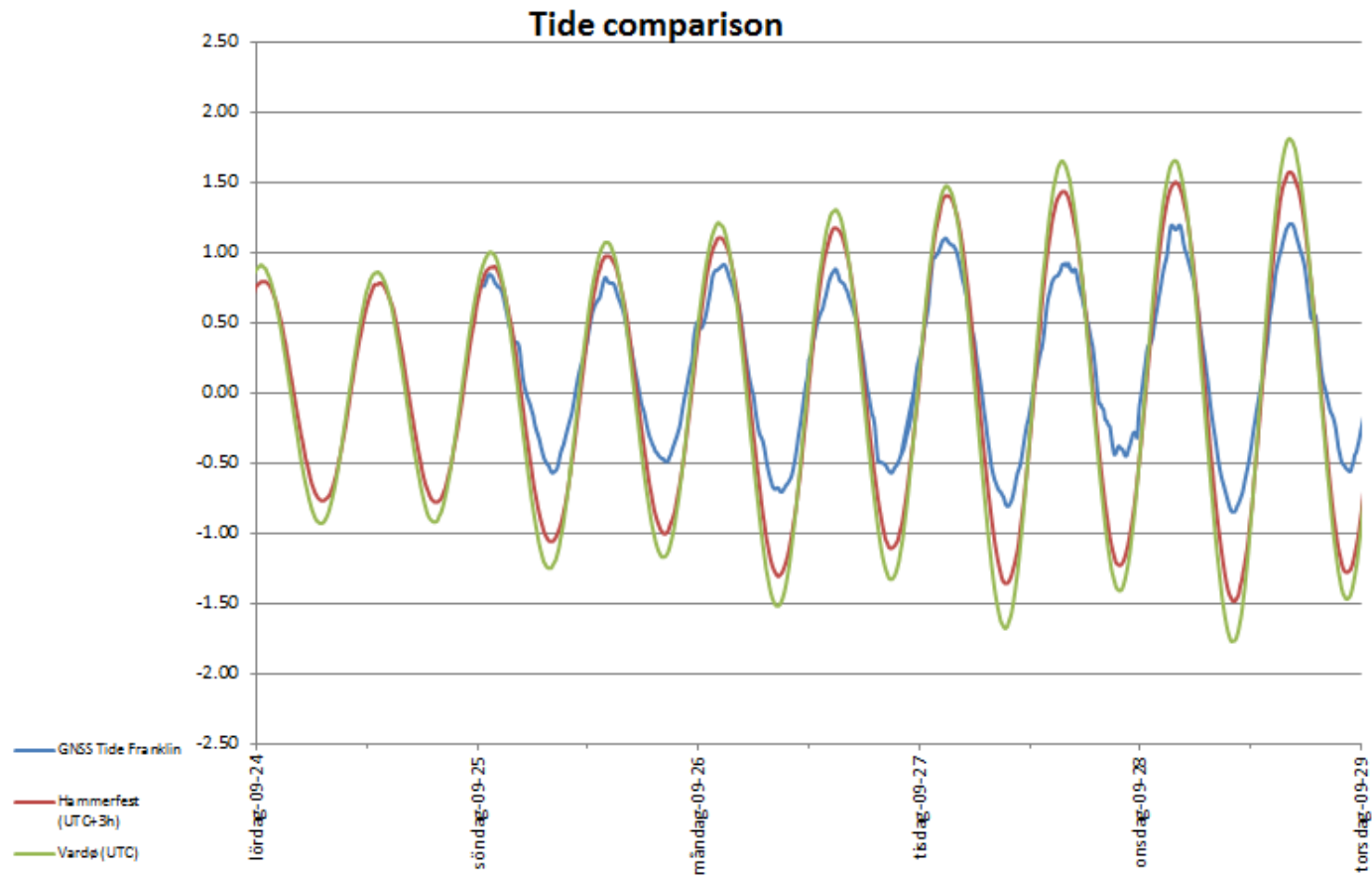
The derived tides need to be compared with tide gauge for QC. Following points are important while undertaking the comparison:

- Ellipsoid height contains all vertical changes
- Distance between reference point and water surface needs to be exactly determined
- Validity of comparison will decrease with distance from tide gauge, changes in phase and amplitude





# MMT | Tide Verification



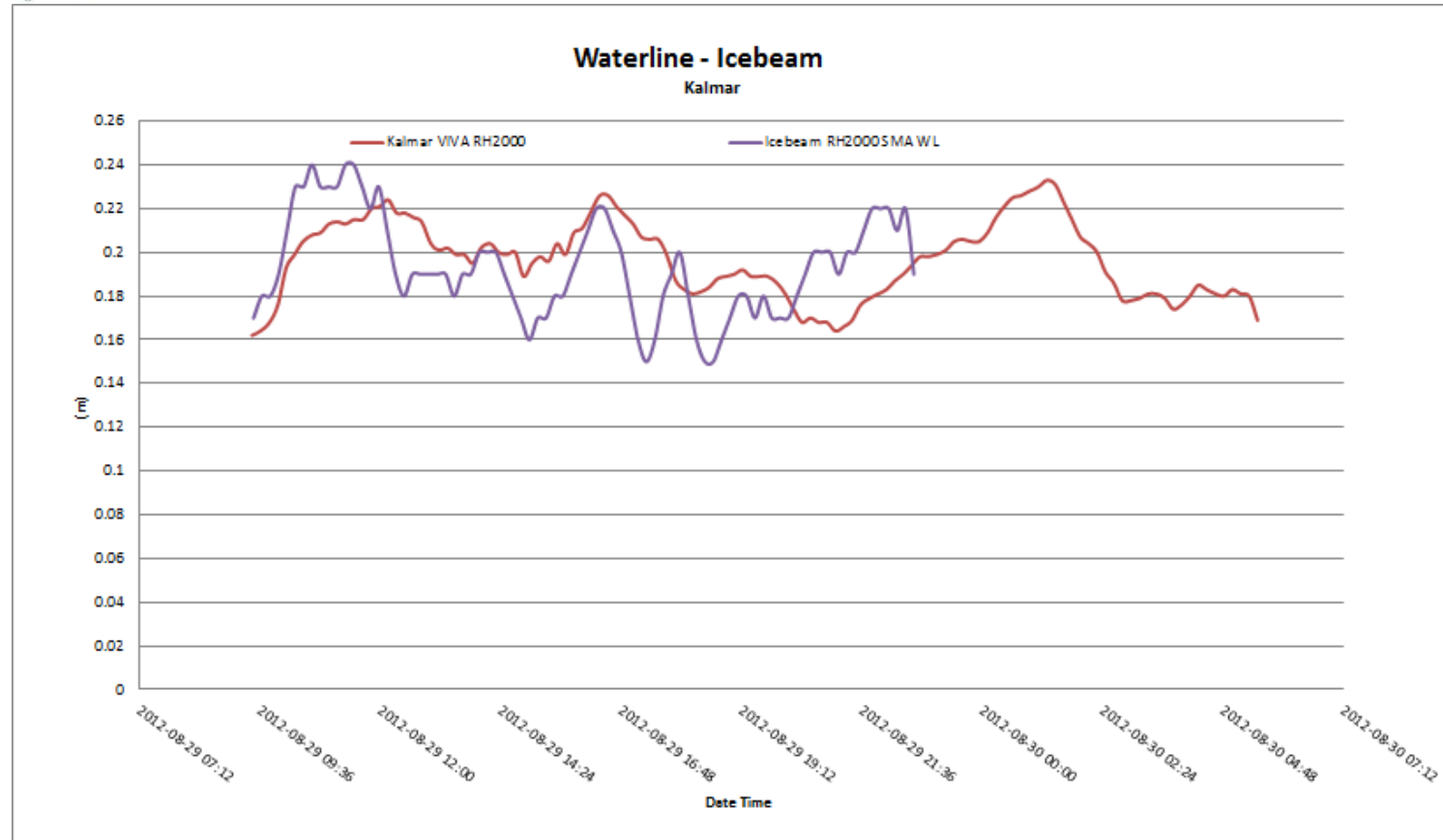
Working in the Barents Sea. Amplitude 3m







# MMT | Tide Verification



Working in Baltic Sea. Amplitude 0.08m





# MMT | Permanent tide

The sun and moon are causing a permanent deformation of the earth which are handled by three different systems for treating the 3D shape and gravity field:

- **Non-tidal or tide-free**

Effects from permanent tide removed from gravity field definition

- **Mean tidal**

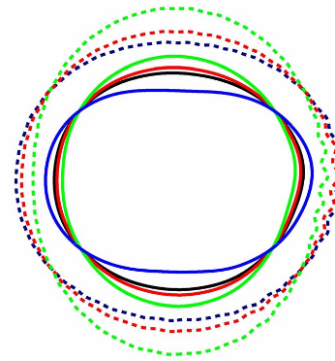
Permanent tide included in definition of Geoid

Ex. Satellite Altimetry

- **Zero tidal**

Effects both removed from Geoid definition and gravity field

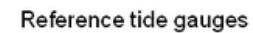
Ex. GPS heights



Solid line: geoid  
 mean at  $+W_z/g$   
 zero  
 conventional tide-free geoid at  $-kW_z/g$ ,  
 $k \approx 0.3$   
 fluid tide-free geoid at  $-kW_z/g$ ,  $k \approx 0.93$

$$W_z/g \approx -0.296 \sin^2(\phi) + 0.099 \text{ [m]}$$





	Alicante		Cascais		Kronstadt		Ostend
	Amsterdam		Constanta		Malin Head		Trieste
	Antalya		Durres		Marseilles		other
	Belfast		Genoa		Newlyn		no information





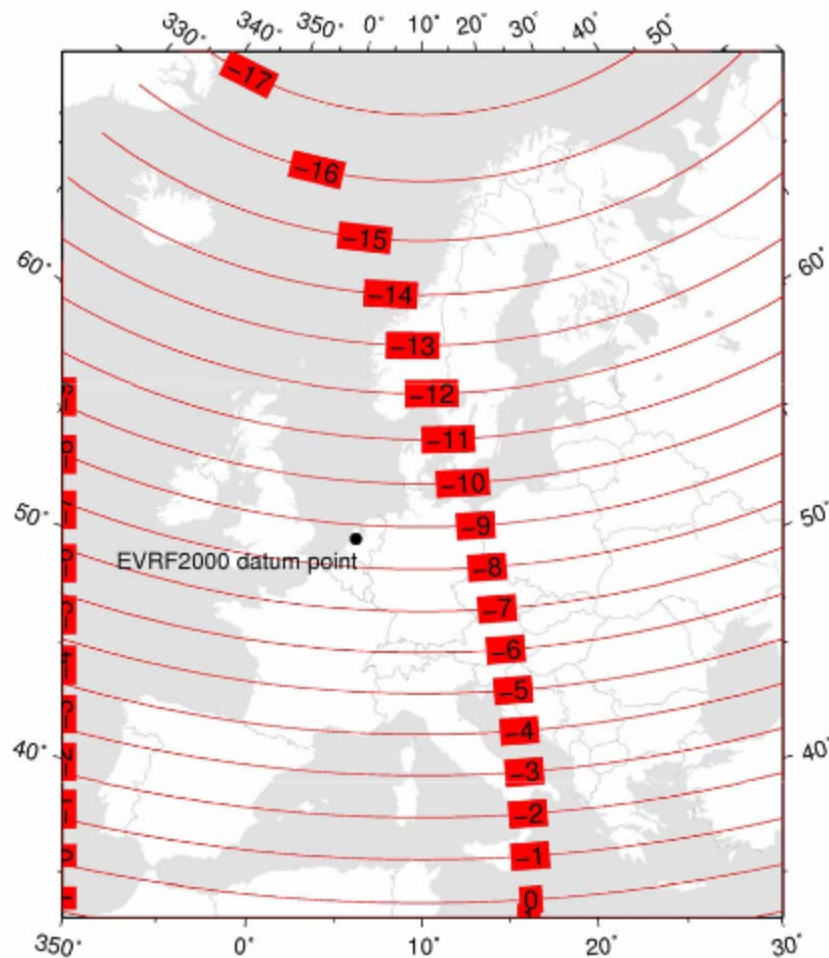
# MMT | Permanent tide

To summarize:

- Confirm the permanent tide system of your model
- Confirm the permanent tide system of the tide gauges to be used



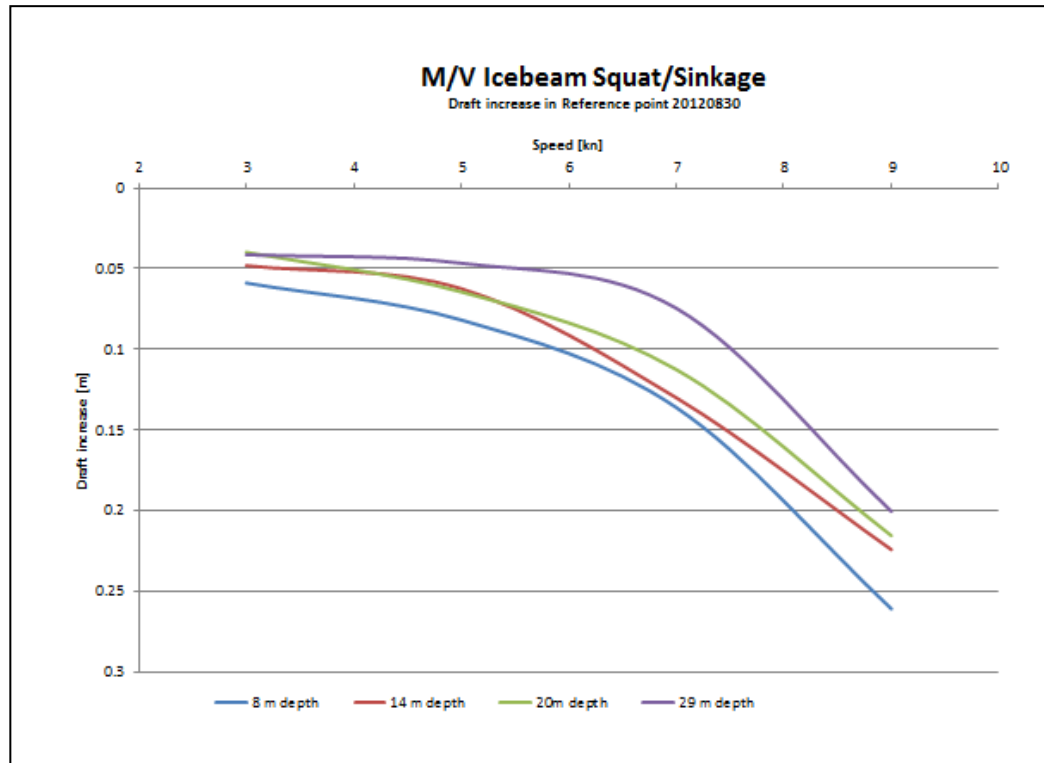
# MMT | Permanent tide



Correction from  
heights in the mean  
tide system to  
heights in the zero  
tide system  
in cm



# MMT | Pros - Compensate for sinking



Increase 15 cm in draft at 9 knots





# MMT | Pros - Compensation

- A difference from the average of 1mb can cause a difference in height of about 0.01 metre. Low pressure will tend to raise sea level and high pressure will tend to depress it.
- If the result is delivered as ellipsoidal heights it allows for the client to reprocess the data in the future with a better model or referencing the data to another reference level – Pioneered by NHS





# MMT | Pros

	Full SBET	Filtered SBET	Tide Gauge	Predicted tides	Approximate error
<b>Loading</b>	Yes	Yes	No	No	0-15cm
<b>Sinkage</b>	Yes	No	No	No	0-15cm
<b>Air pressure</b>	Yes	Yes	Partly	No	0-10cm
<b>Storm surge</b>	Yes	Partly	Partly	No	0-20cm
<b>Onshore/Offshore wind</b>	Yes	Yes	Partly	No	0-50cm







## MMT | Cons

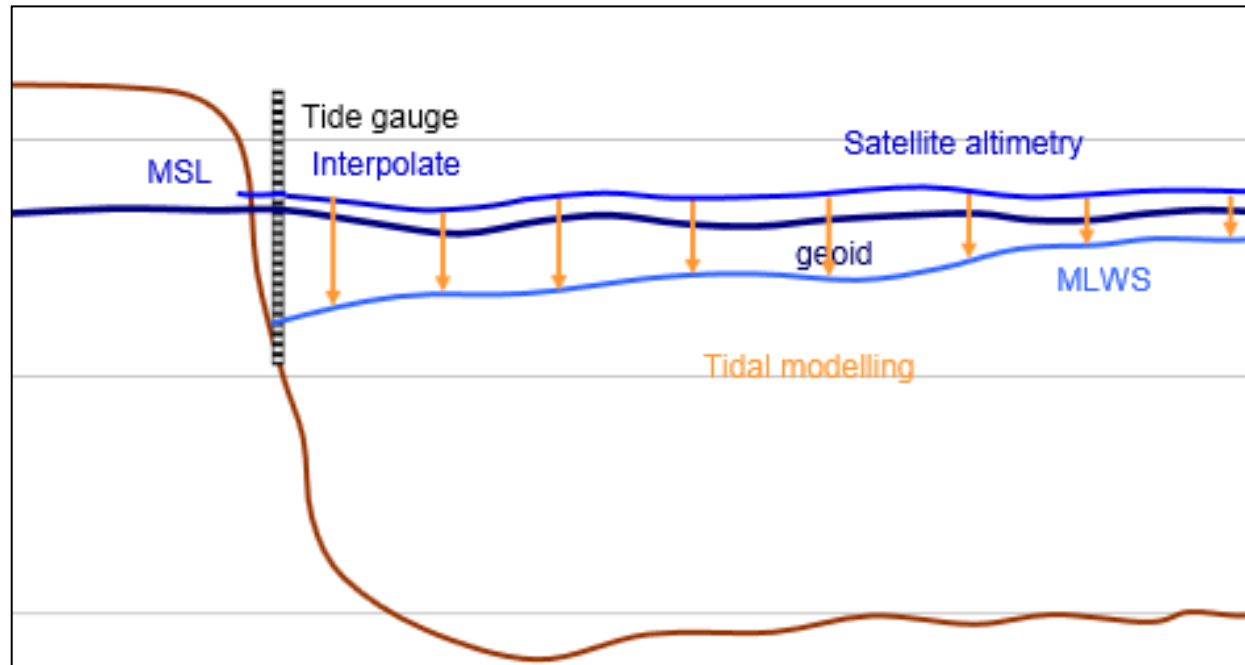
- The produced result is only as good as the processed ellipsoidal heights and the model used
- It requires good knowledge about the local tide gauges available in order to verify the derived solution
- Requires post-processing for a accurate result





# MMT | Cons

Satellite altimetry leaves around a 15km gap around any land. This gap needs to be interpolated and verified.

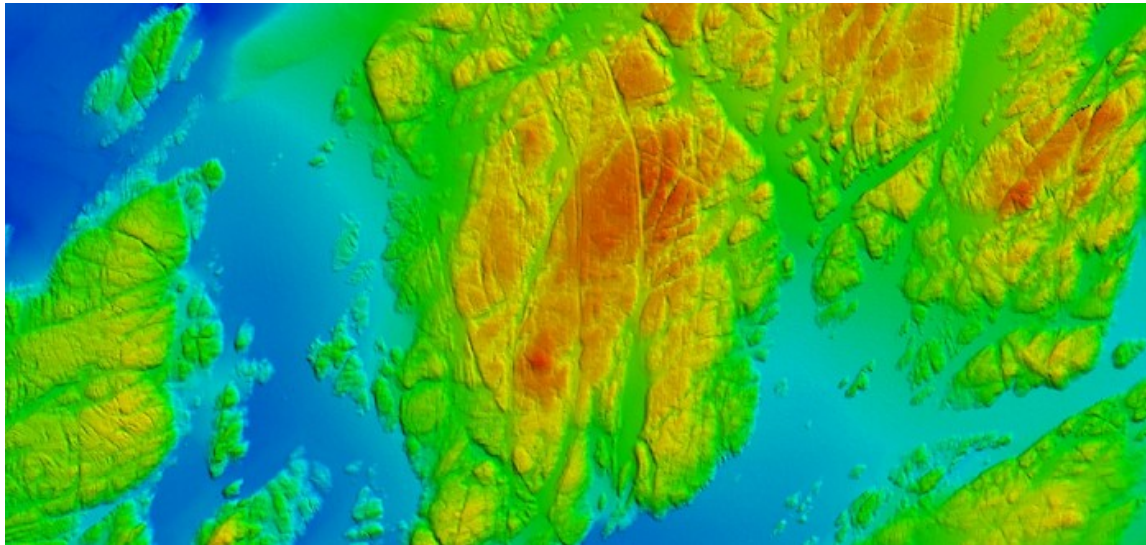




# MMT | Conclusion

GNSS derived tides are here to stay!

- Continuous developments are made by incorporating several GNSS and not only GPS
- Processing and importantly QC are improved
- Available models are refined and contains longer data series
- The national vertical reference systems are getting harmonized





# Questions?



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