2nd Tidal and Water Level Working Group Meeting

Norwegian Hydrographic Service, Stavanger, Norway
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Vertical Offshore Reference Framework (VORF)

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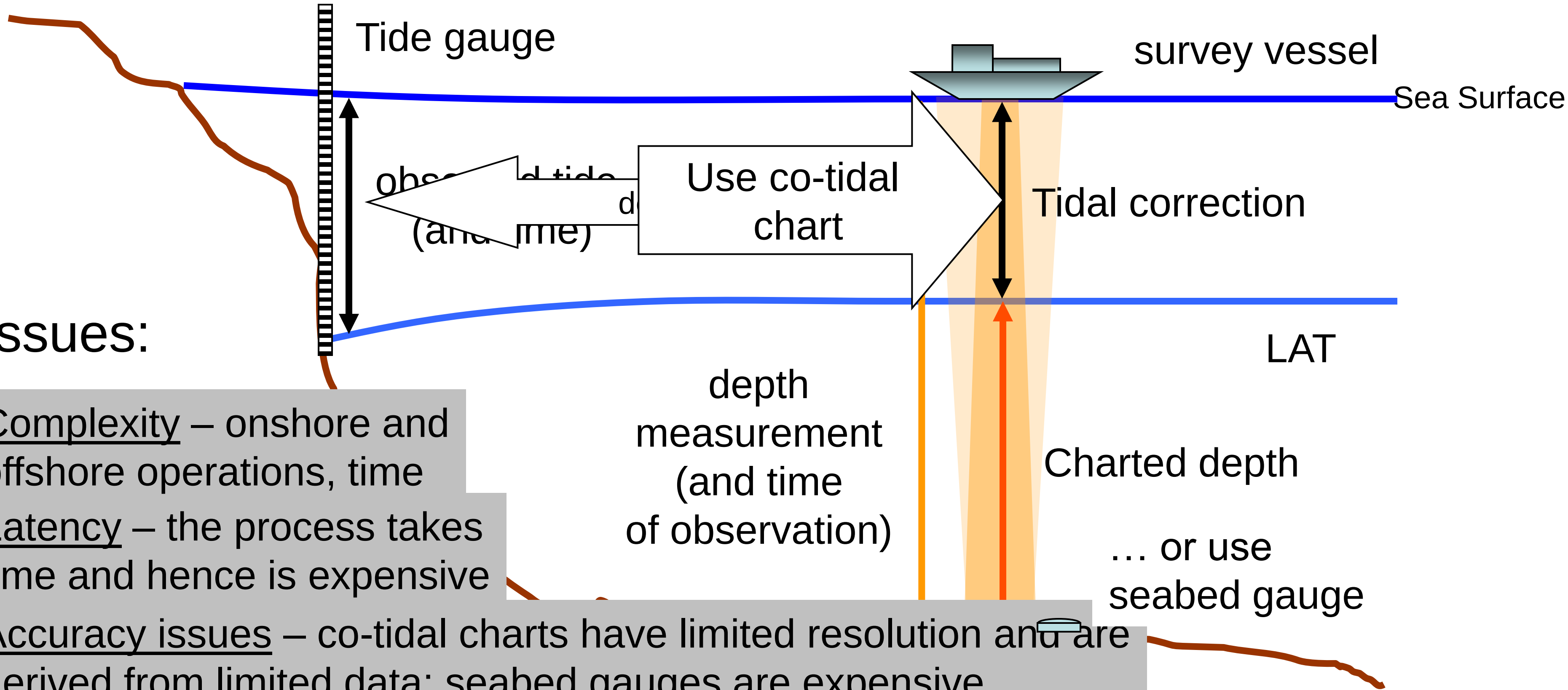
Presentation Structure

- What is VORF?
- Technical development
- Validation and Testing
- Summary

What is VORF?

- VORF = **V**ertical **O**ffshore **R**eference **F**rame
- A set of mathematical models of the major surfaces used in the current and future charting of UK home waters
- A suite of software utilities allowing the transformation of mapping and positioning data between the VORF surfaces

Current practice for bathymetric data processing



Issues:

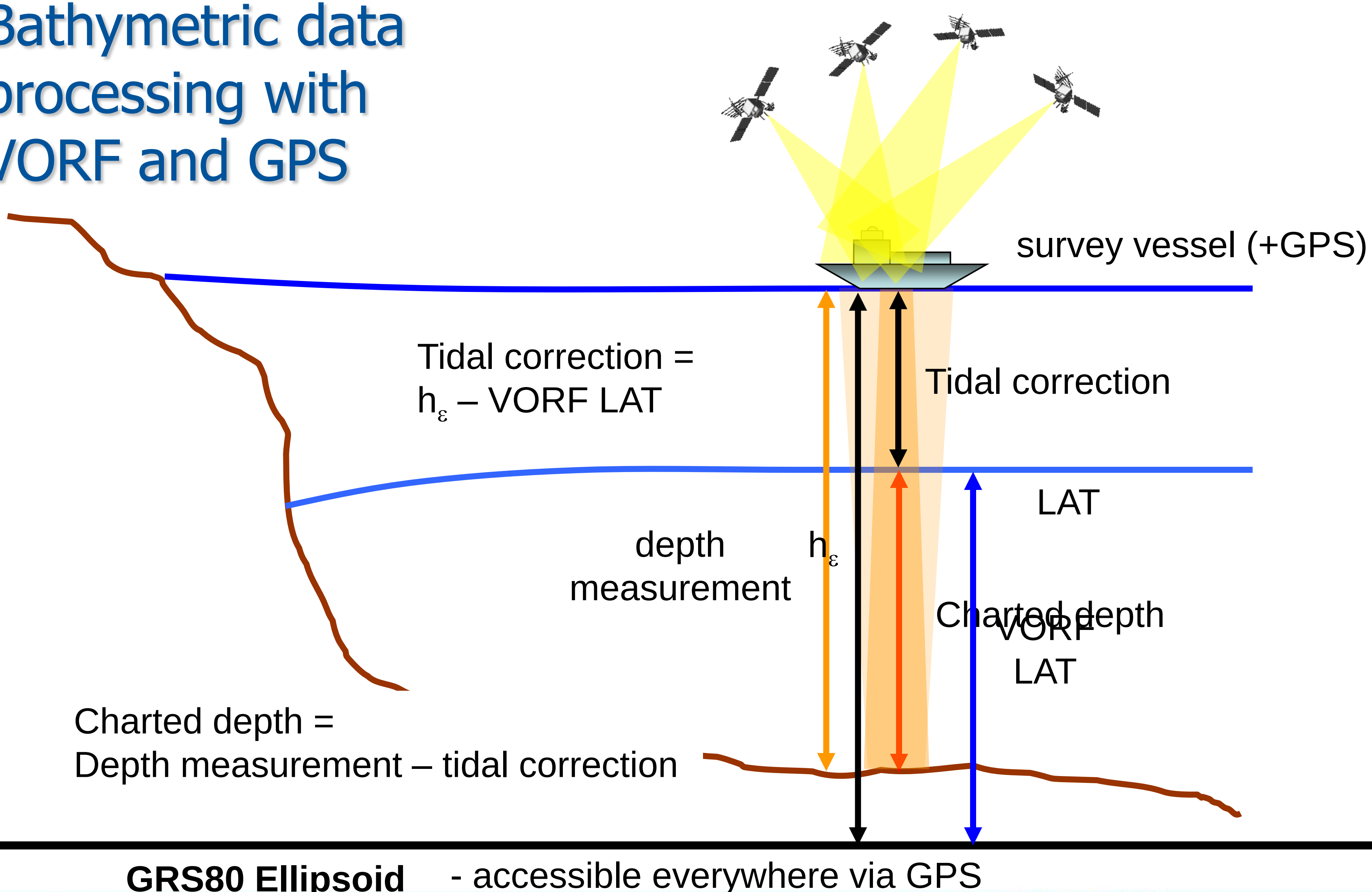
Complexity – onshore and offshore operations, time

Latency – the process takes time and hence is expensive

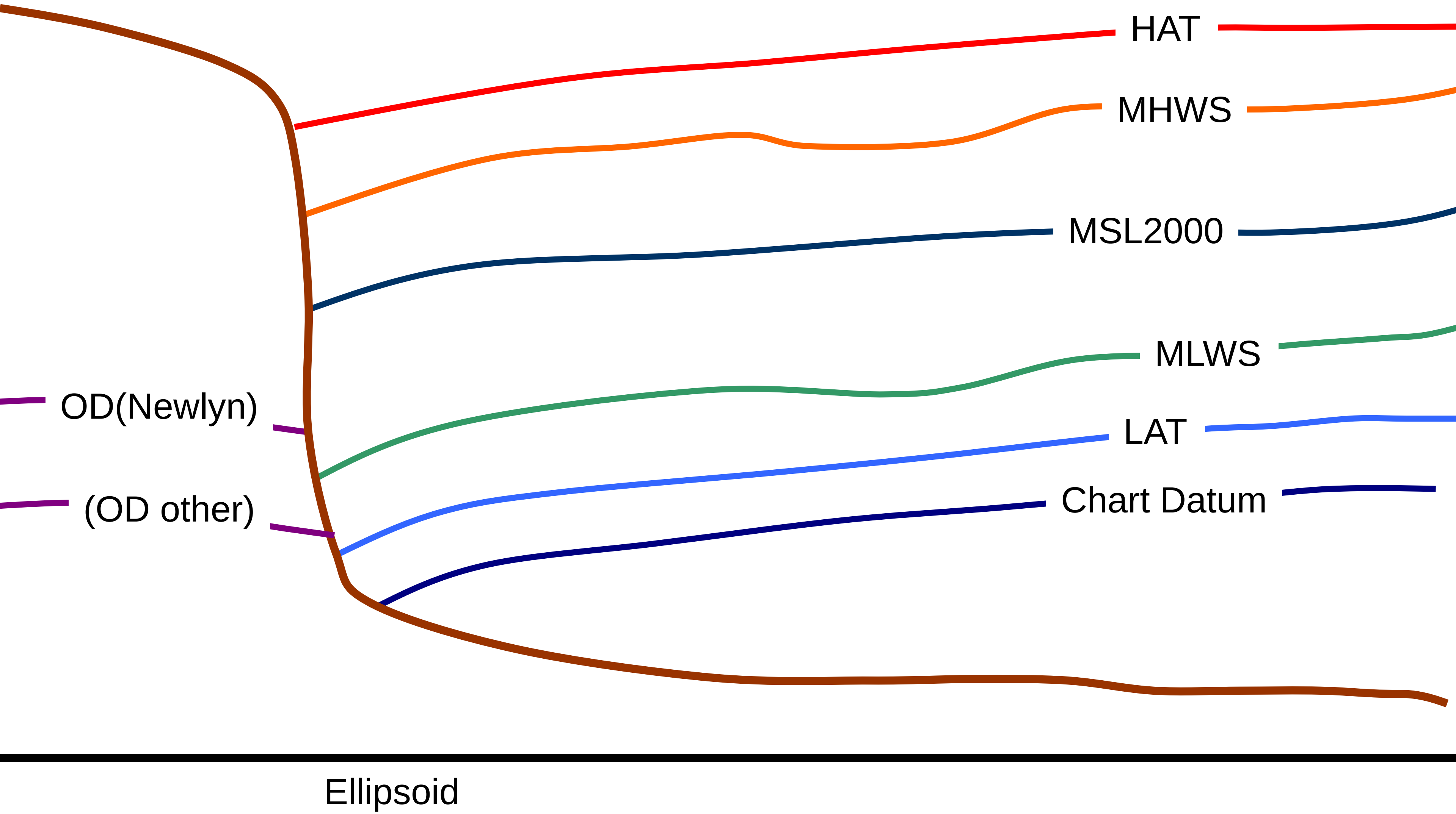
Accuracy issues – co-tidal charts have limited resolution and are derived from limited data; seabed gauges are expensive

Inconsistency – practices using Chart Datum are sometimes poorly defined and can lead to discrepancies

Bathymetric data processing with VORF and GPS



VORF surfaces:



Technical development of VORF

Technologies applied in development of VORF

- Tide gauge data
- GPS data
- Satellite altimetry
- Gravity field models
- Tidal modelling

VORF Overall Approach

Find mean sea level

↓

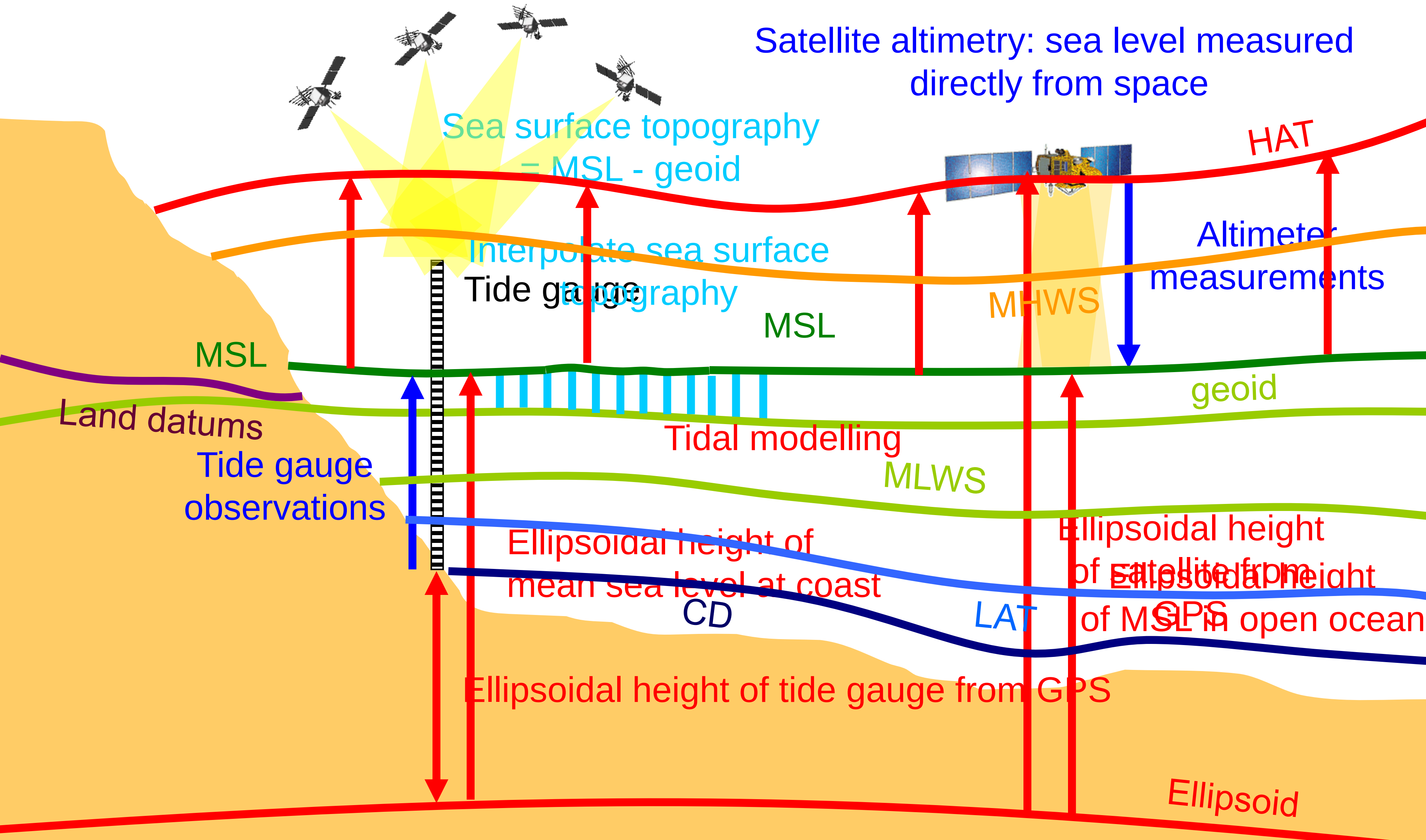
Model lowest astronomical tide

↓

Combine surfaces

Developing VORF (in one slide)

Interpolation (data merging) by least squares collocation and a covariance function derived from the characteristics of the tide gauge and altimetry data.

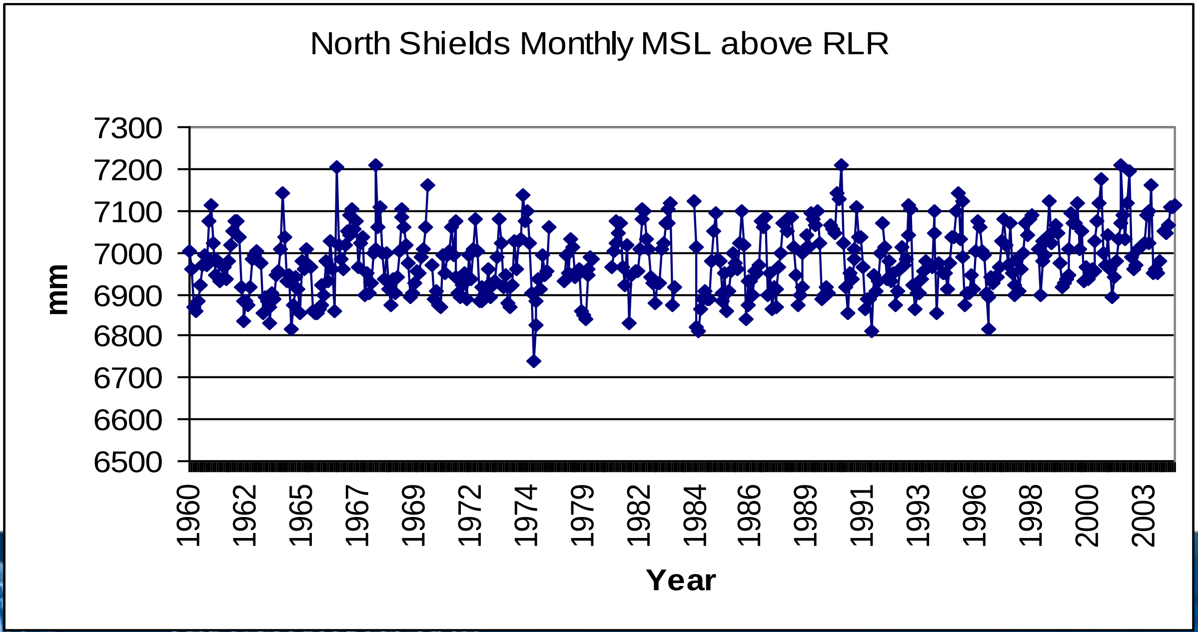


Monthly MSL Observations

Many tide gauge stations only have one month of observations.

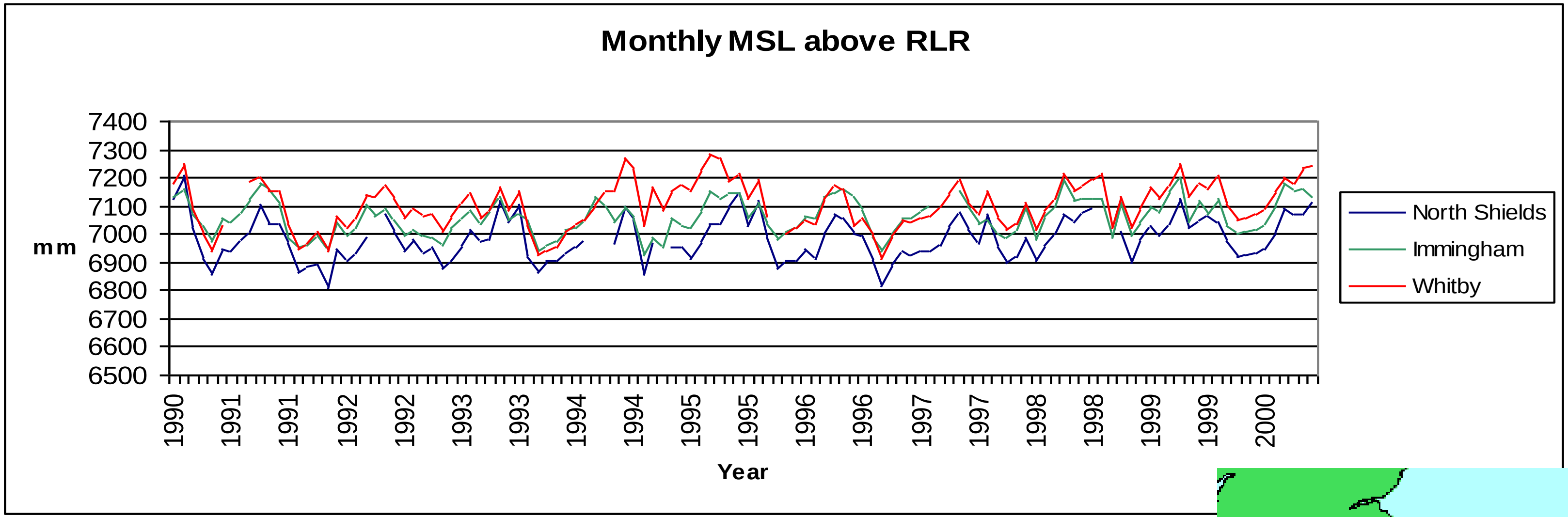
Variations due to winds, pressure, currents, etc.

Correct by cross comparison.



RLR = Revised Local Reference (a generic level for time series analysis).

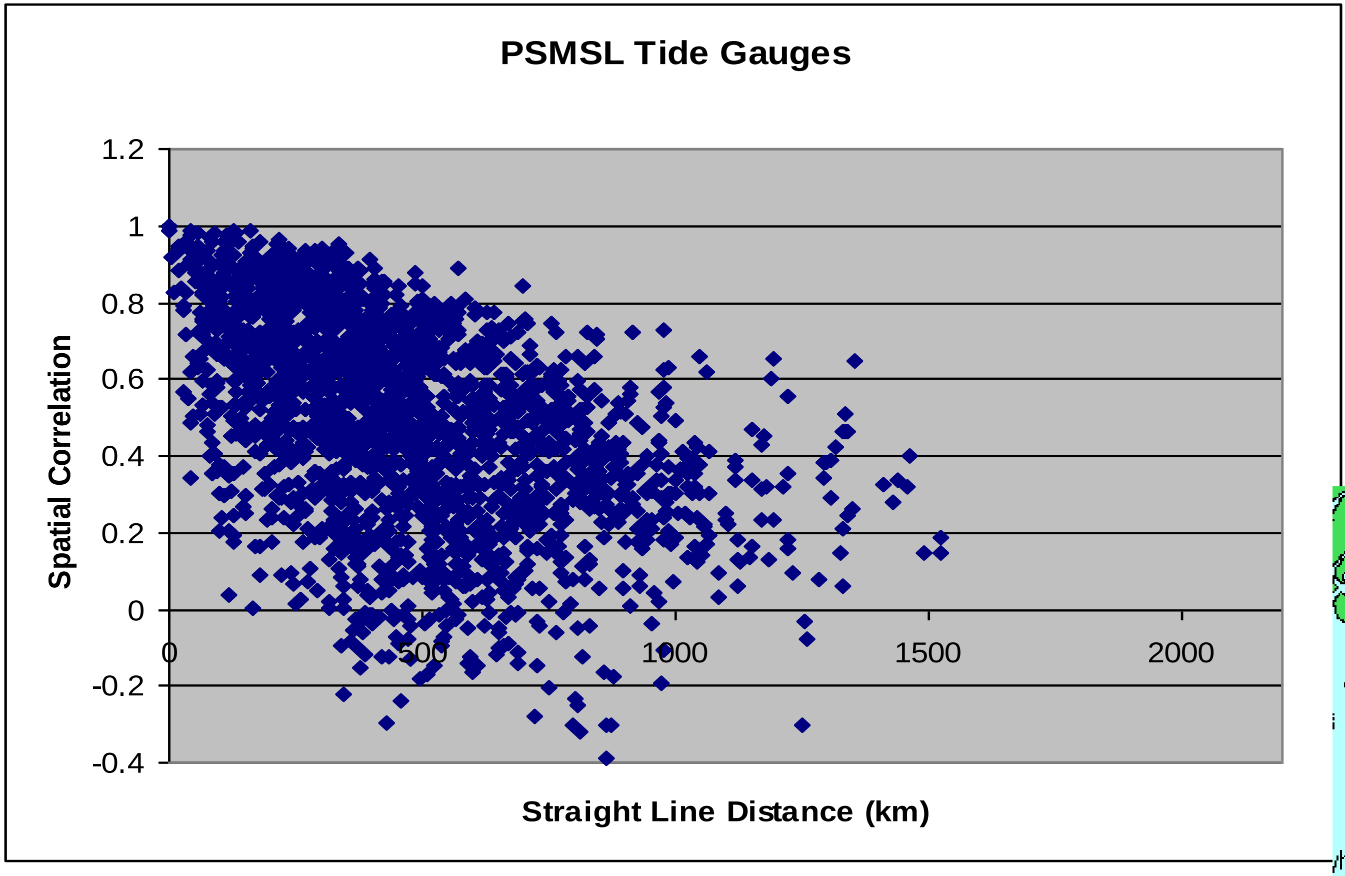
Spatial Correlation



Coefficient of correlation between pairs of tidal stations help to control the interpolation of MSL at stations where there are short series of data.

Spatial Correlation Scatter Plots

Coefficients of correlation in monthly means of MSL

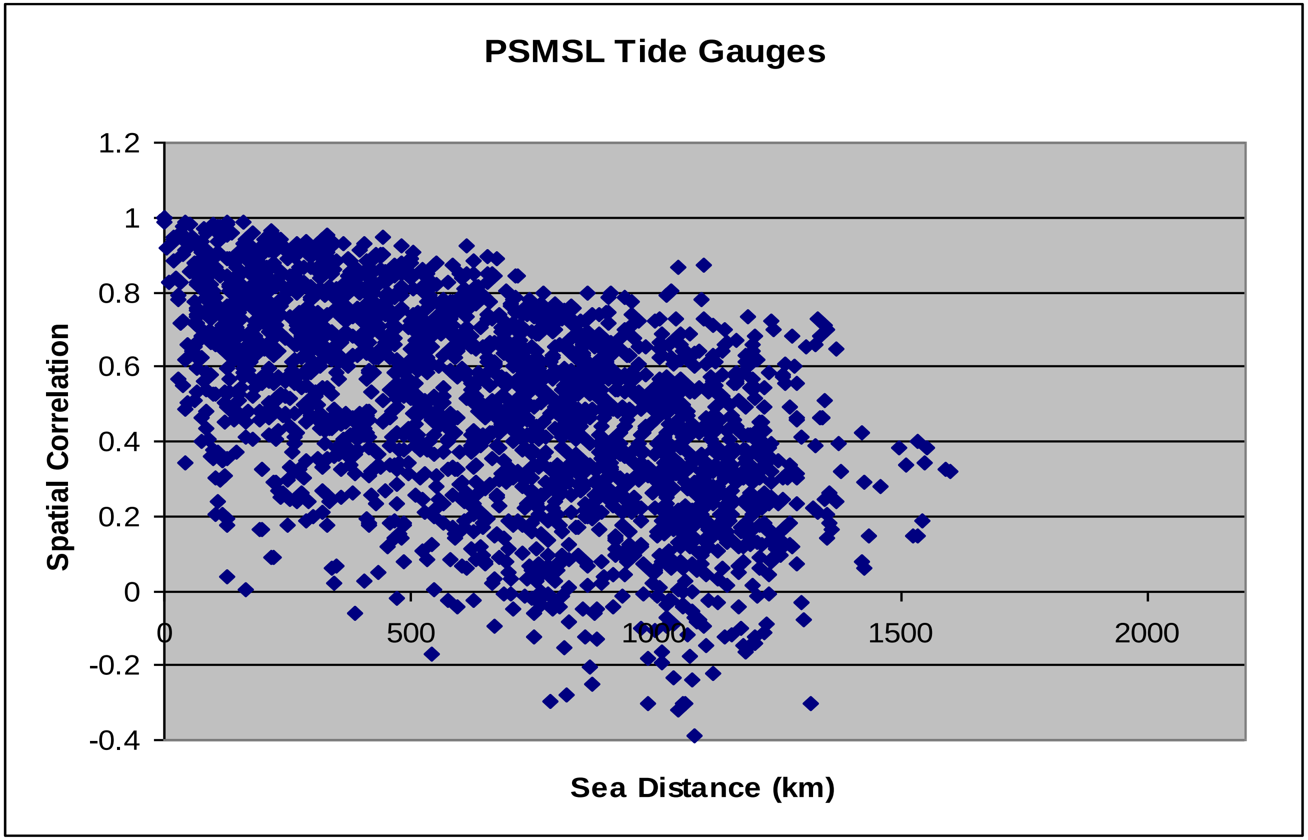


<u>Straight Line Distance</u>
Distorted by stations on opposite coasts which are relatively close to each other but have little correlation.

North Shields to Workington only 140km apart but the **coastal** distance is > 1000km

Spatial Correlation Scatter Plots

Coefficients of correlation in monthly means of MSL

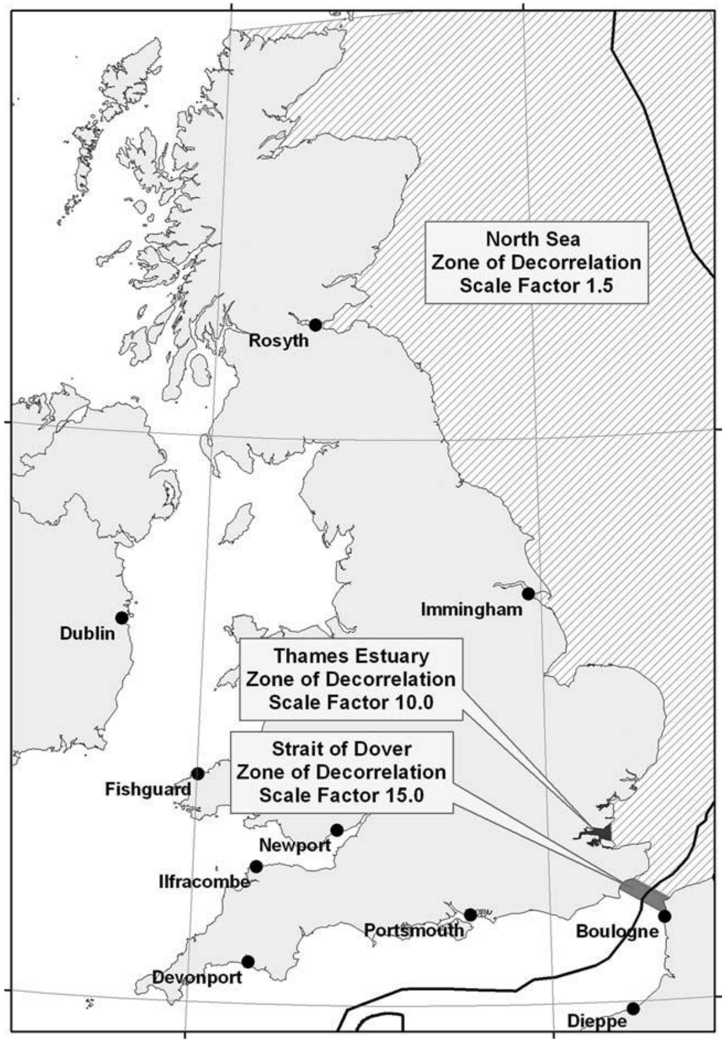


<u>Sea Distance</u>

Represents the shortest distance necessary to travel between the points by sea.

Improved pattern in the correlation but there are still regions where the correlation is weaker than others.

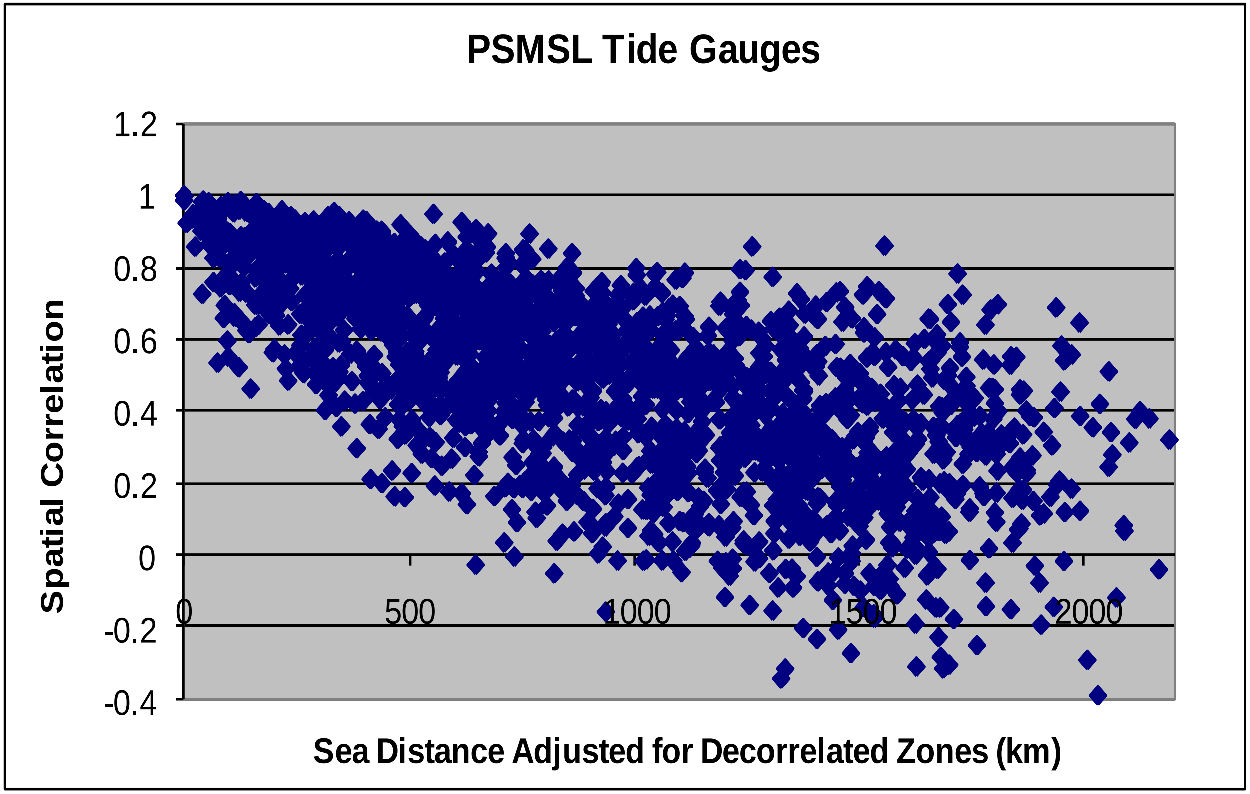
Zones of De-correlation



- Looked at sea distance routes of pairs of stations that had correlations less than the average for their distance apart.
- Three 'zones of de-correlation' were identified.
- Each zone has a single scale factor
- The proportions of any sea distance passing through the zone were multiplied by the factor to 're-calibrate' the distance.
- Example: 2 stations separated by a sea distance of 1000km, 500km of which passes through a zone with a factor of 1.5, then the two stations would be expected to behave as if they were 1250km apart.

Spatial Correlation Scatter Plots

Coefficients of correlation in monthly means of MSL

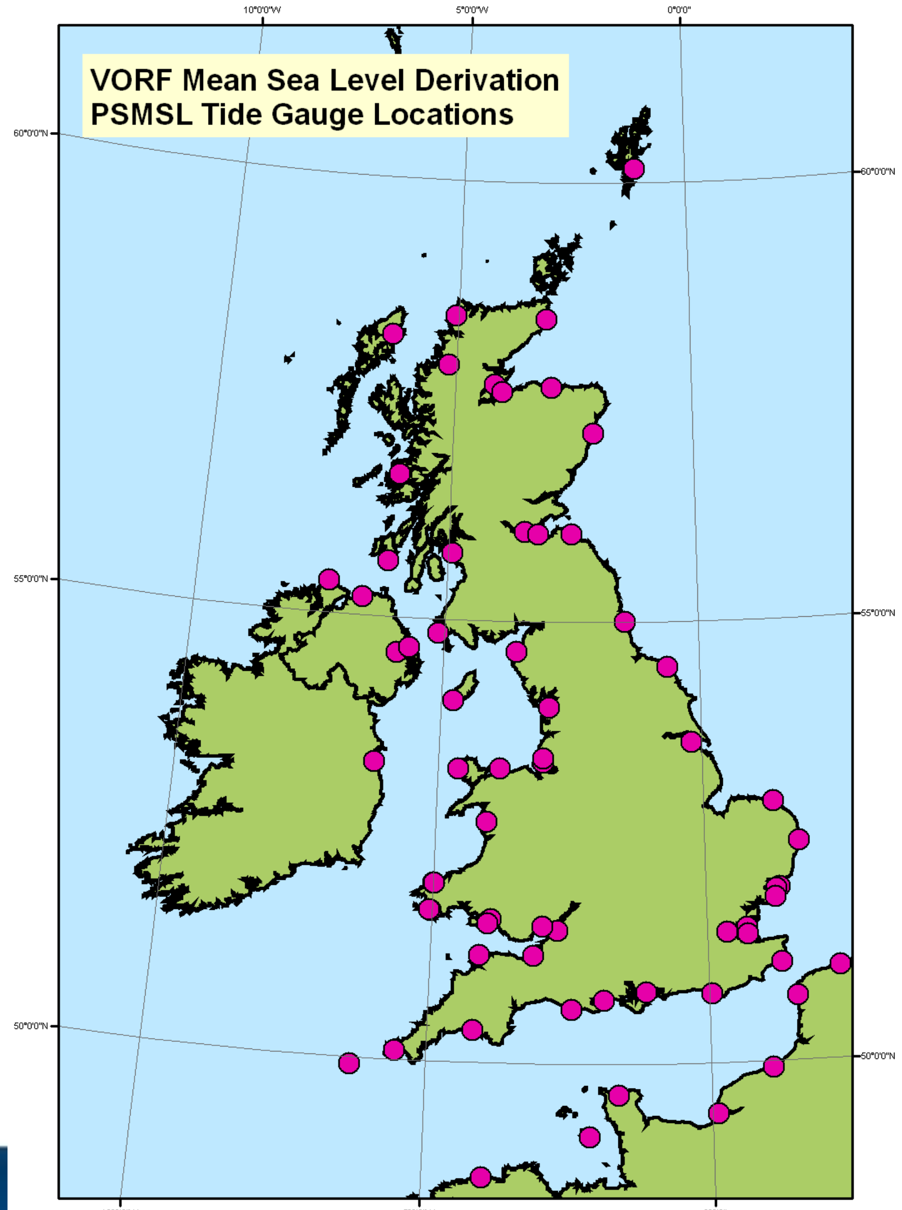


Sea Distance adjusted for "De-correlated" Zones

- **Great improvement in coefficient of correlation which, although falling away over larger distances, the most important interval [0-500 km] shows stronger pattern.**

Data sources:
Tide Gauge data via the Permanent Service for Mean Sea Level (PSMSL)

- National Tidal and Sea Level Facility (NTSLF) stations
- High quality continuous observations
- BUT low spatial density



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Data sources:
Tide Gauges Admiralty Tide Table (ATT)

- Around 700 Standard and Secondary Port locations
- Good spatial density
- BUT occasionally low precision due to short term data series

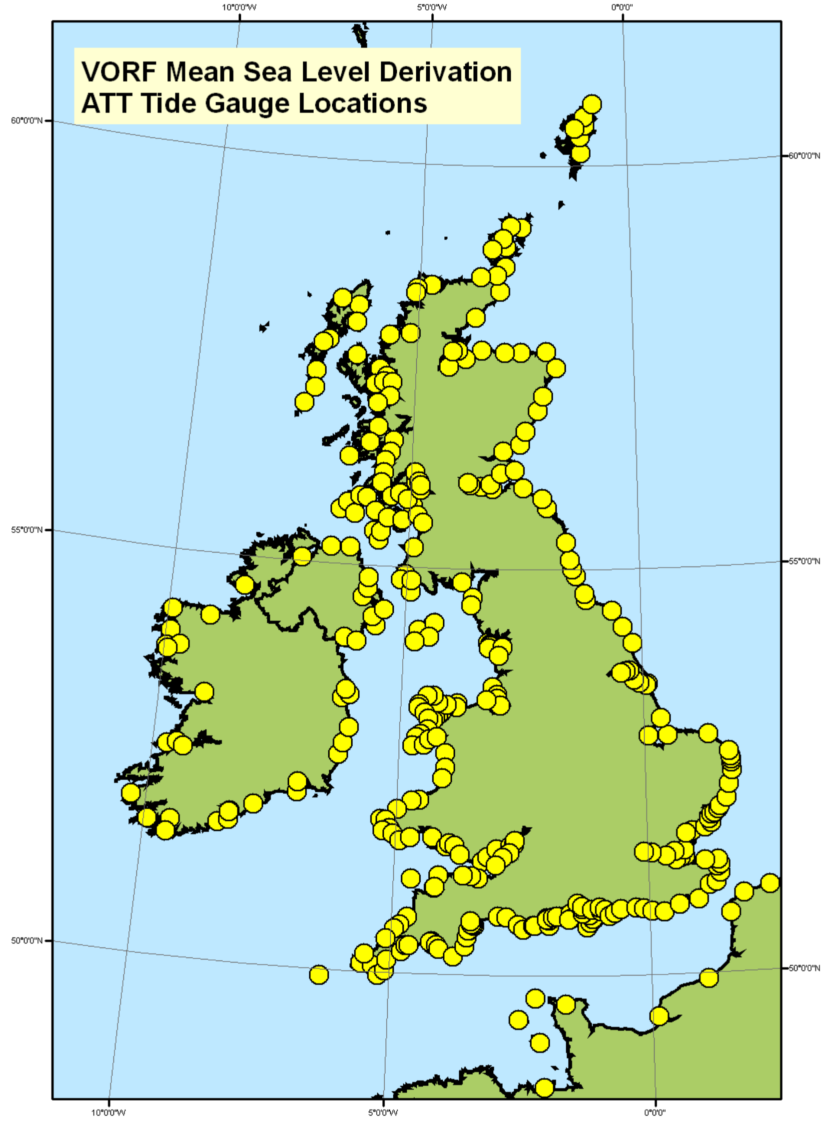
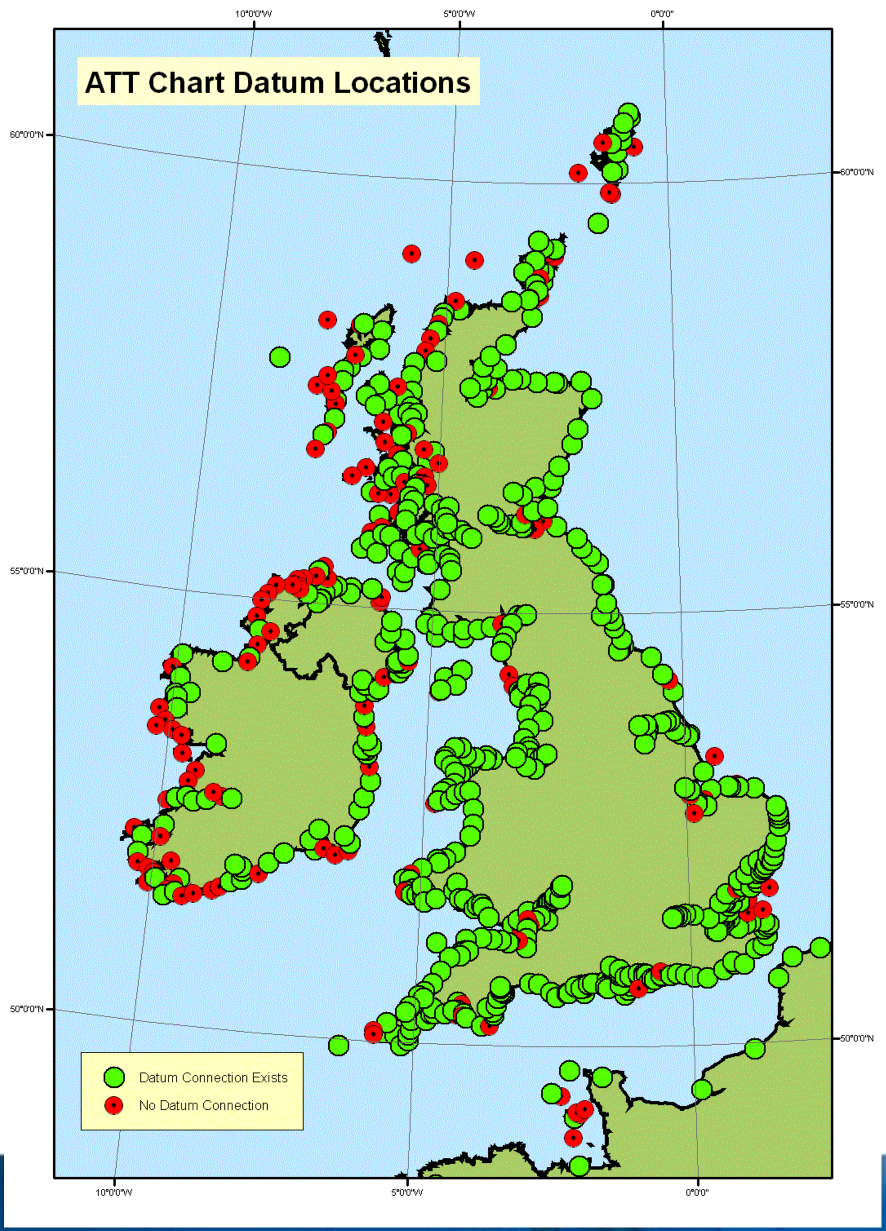
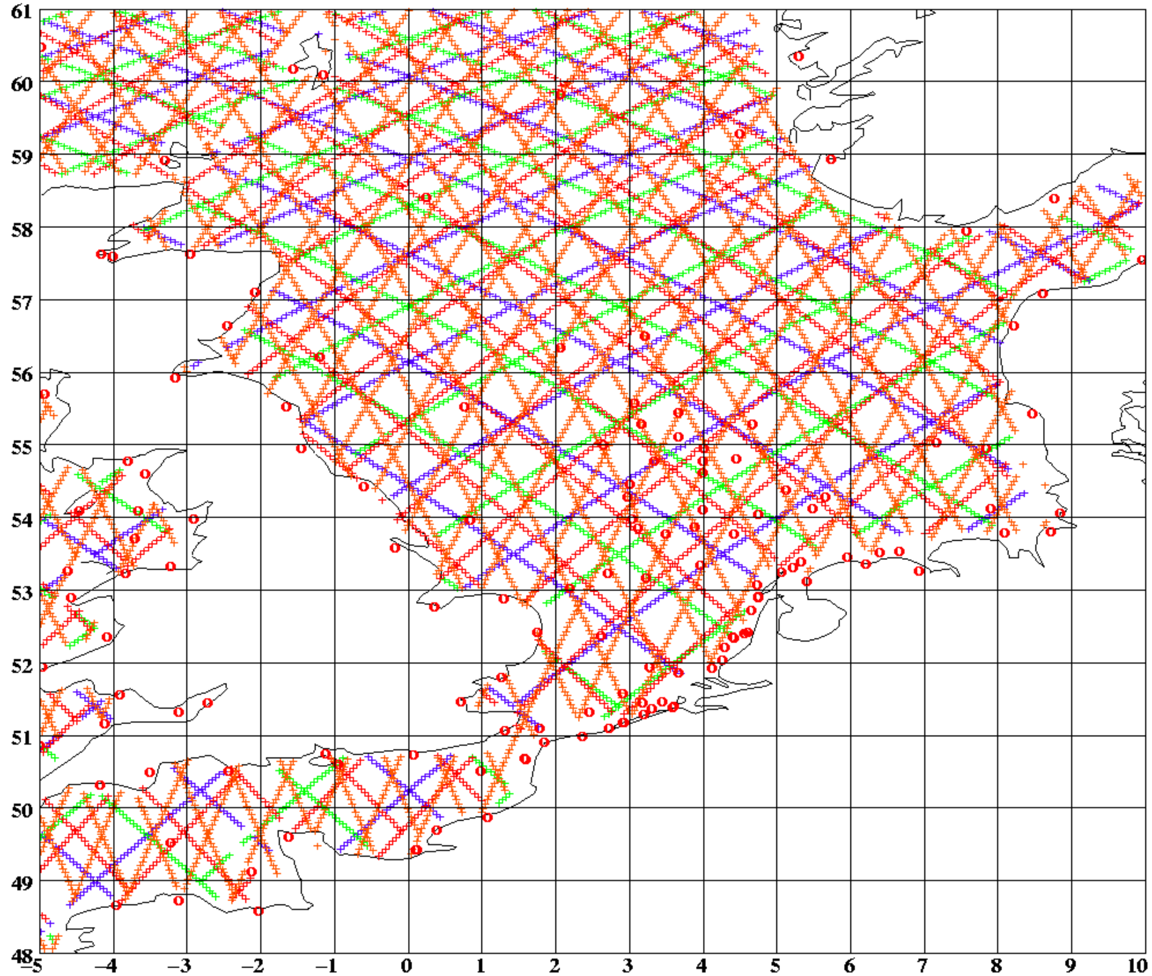


Chart Datum:



- VORF aims to unify all these separate datums into one, seamless surface
- Process involves verifying the link between CD and Ordnance Datum (the land-levelling height datum)

Technologies applied: Satellite Altimetry



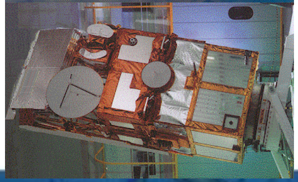
JASON−1 (blue), TPX (green), GFO (red),ERS2/ENVISAT(orange)

ENVISAT

TOPEX

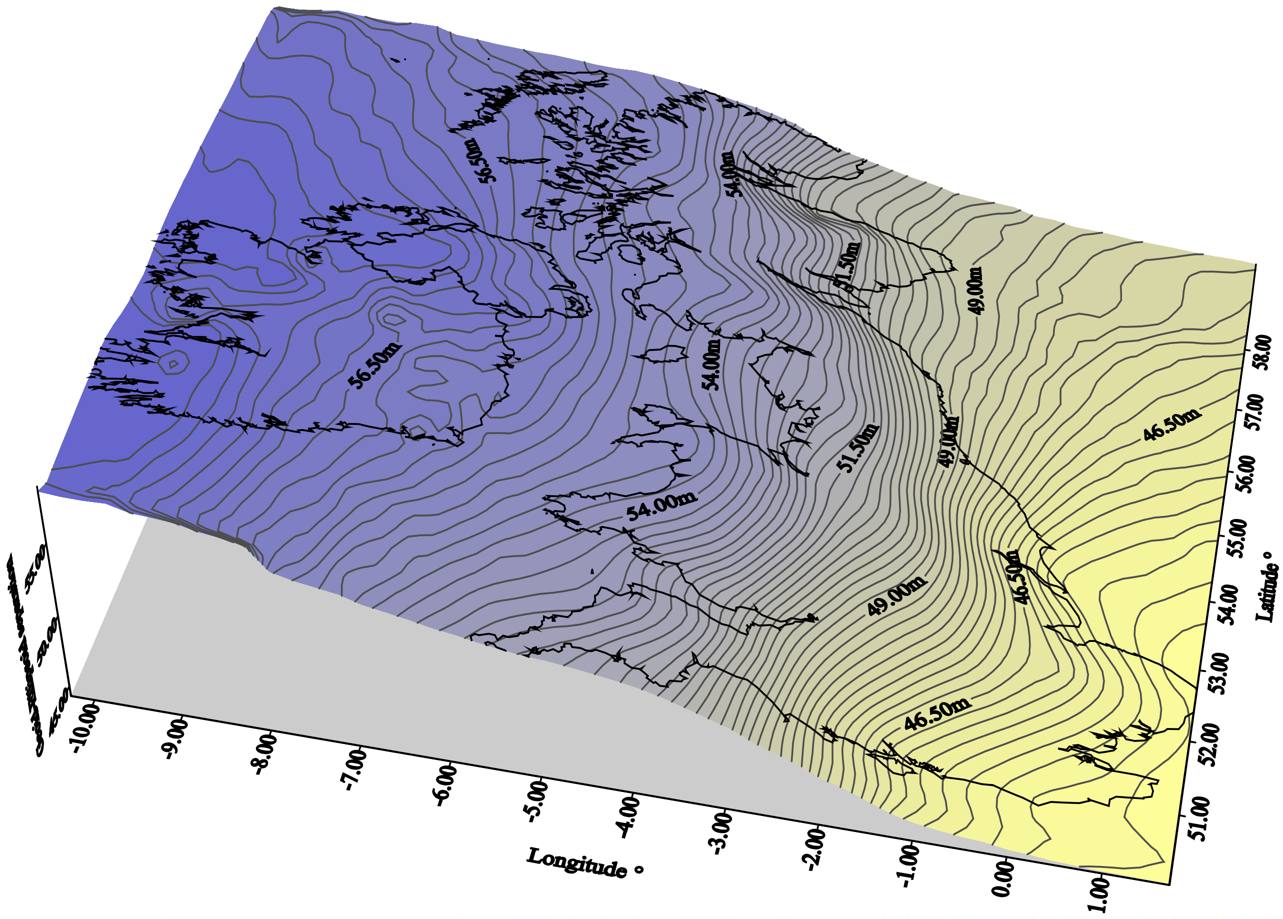
JASON

GFO

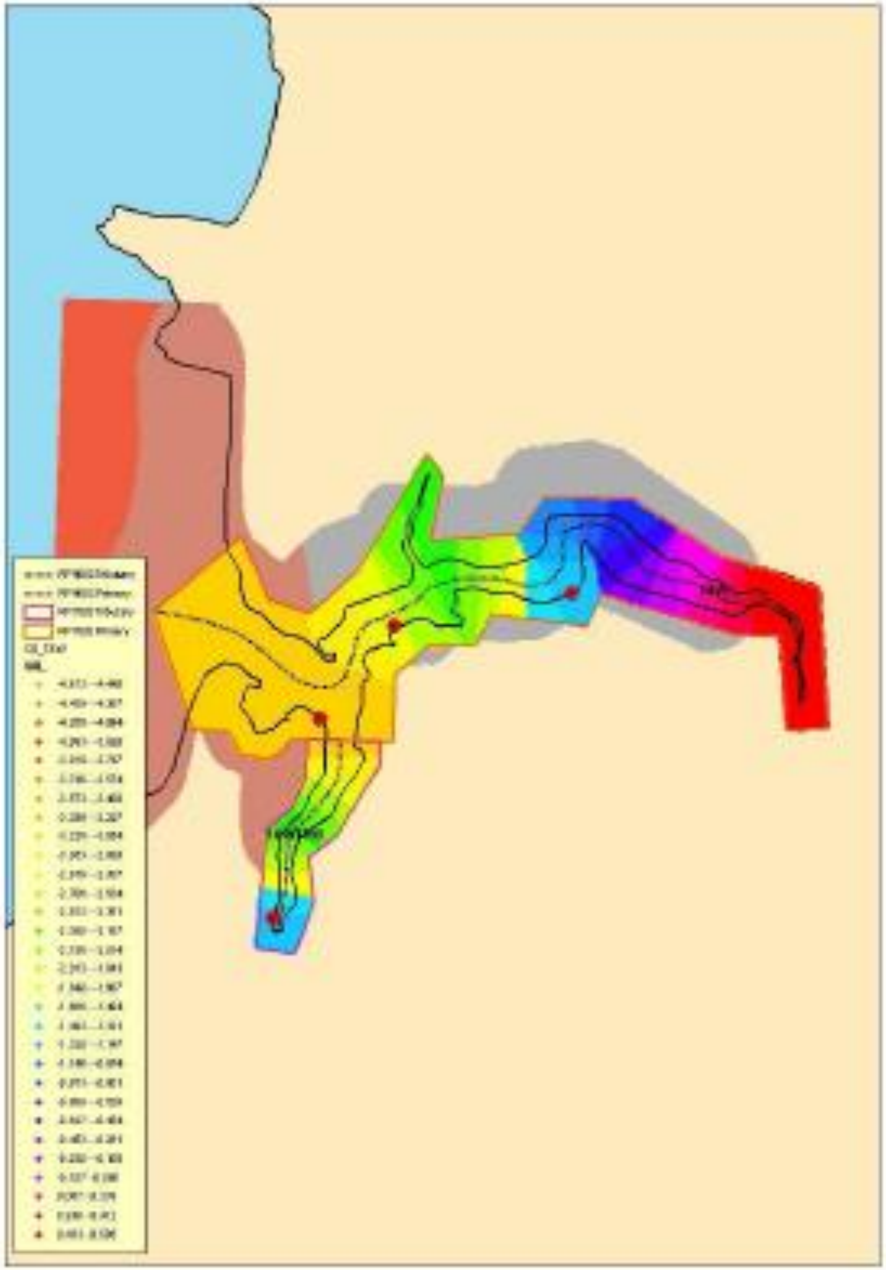


ERS1/2

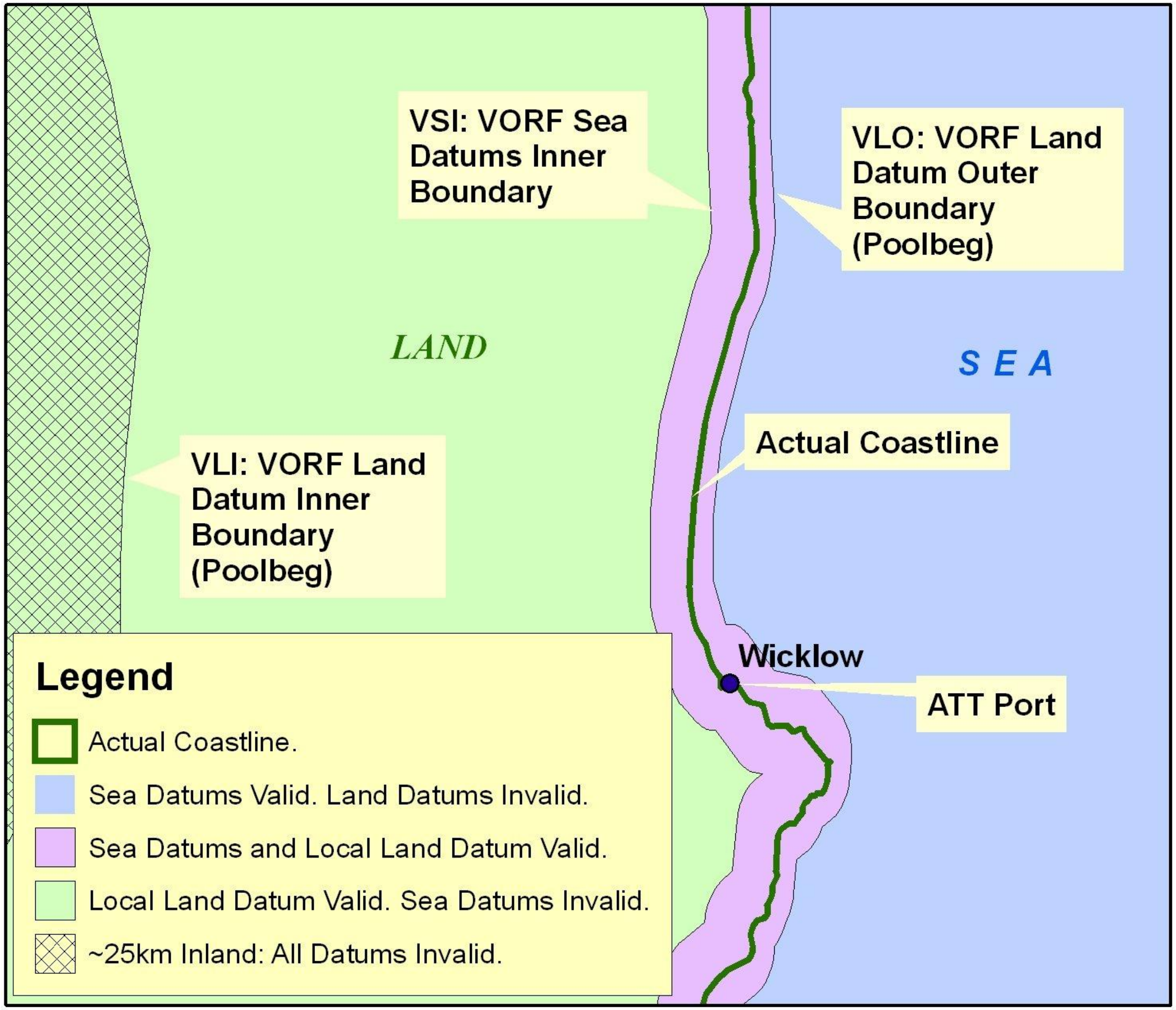
Technologies applied: OSGM05 – UK gravity field model (OSGM09 now available)



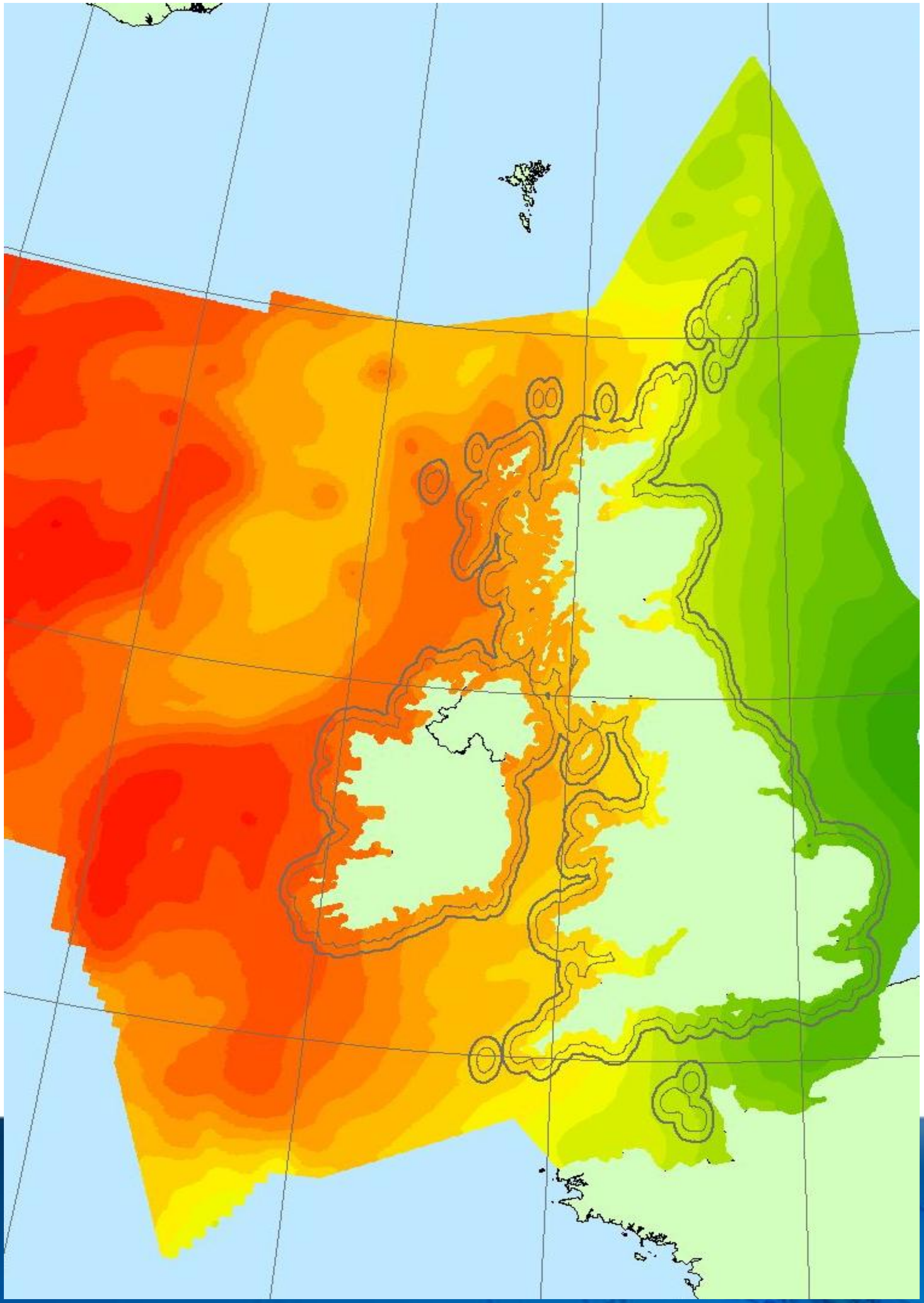
River Datums



Use of Areas of Applicability

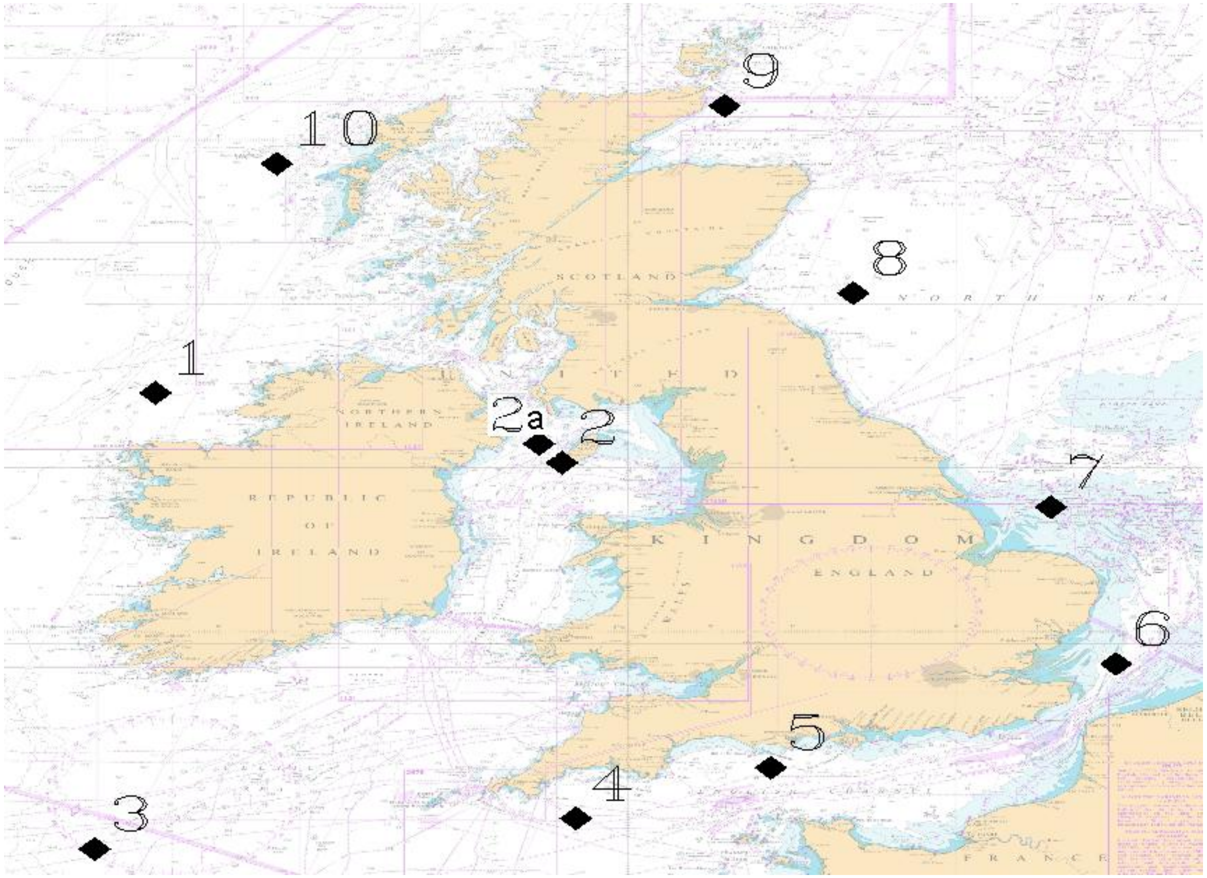


Boundaries of VORF Model:
UK Continental Shelf



Testing and validation of VORF

Locations for testing



Objectives of testing

• Obtain the necessary data at each location to allow for the separations available in the VORF model to be derived independently.

• The derived values will then be compared with the VORF output to ensure that they fall within the error budget.

Method of Data Gathering

- Deploy a tide gauge at a test location.
- Leave the gauge recording data for at least 2 months (seabed mounted gauge, or in some instances a fixed structure such as a jetty or platform).
- Ensure the gauge is logging using times that are synchronised with the GPS logging described below. Data is to be corrected for atmospheric pressure factors.
- Vessel must record water level height relative to the ellipsoid to within 5cm accuracy (for example by RTK, post-processed dual frequency GPS etc.). Great care must be taken to ensure that it is the water level height that is resolved (i.e. the reference point to water level value must be regularly determined). Therefore vessel draft (which affects antenna height) may need to be controlled.

Method of Data Gathering

- Position the vessel directly above (or within 500m of) the recording tide gauge position.
- Log the water level height from the GPS solution onboard the vessel for at least 8 hours. The vessel should be stationary (at anchor) during this procedure to reduce squat and settlement influences.
- Data should be logged from at least 1 hour before until 1 hour after high/low water (or longer as necessary) so that 1 peak and 1 trough of the tide curve are resolved.
- Leave the tide gauge logging data for 2 months.
- Repeat the vessel logging procedure before recovering the tide gauge.

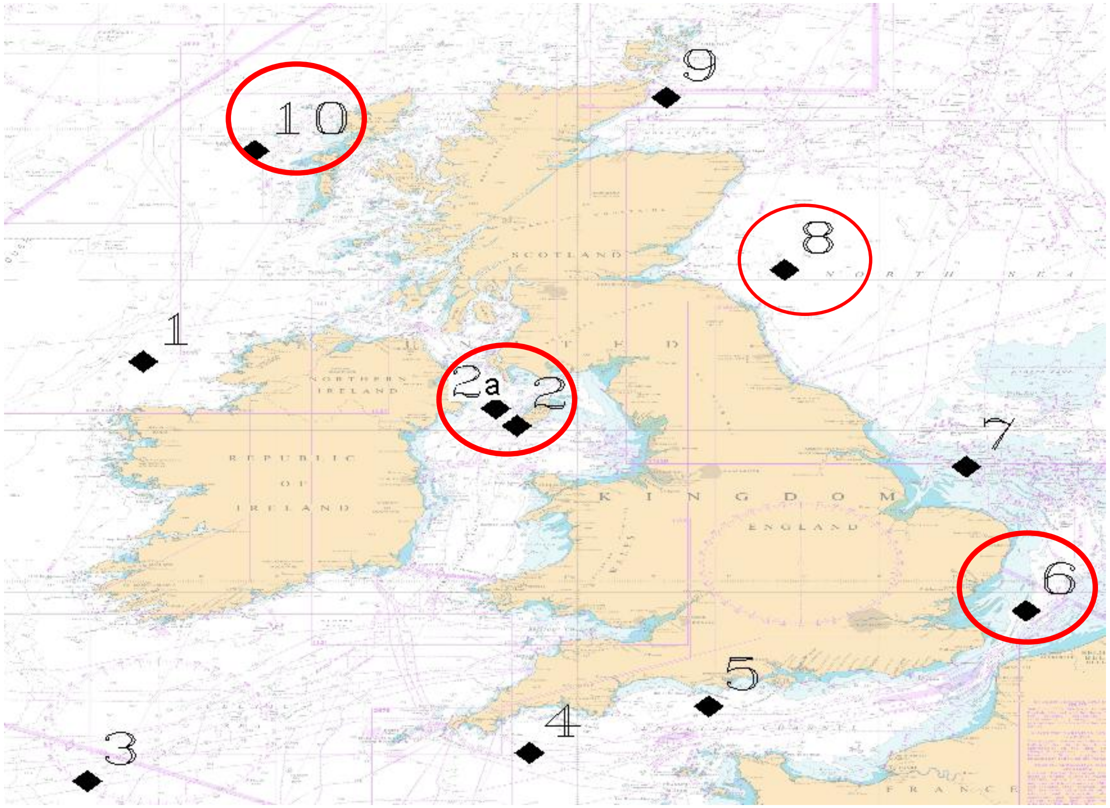
Analysis of Gathered Data – Tide Gauge

- Conduct harmonic analysis on the tide gauge observations.
- Derive Chart Datum (CD) at the location, by:-
    - Transfer Datum from an established location.
    - Use Co-Tidal Chart.
    - Use harmonic constituents to compute Lowest Astronomical Tide (LAT) using a Mean Sea Level value of 0 (zero).
- Once CD has been established, compute the various tidal planes (Mean High / Low Water Springs [MHWS / MLWS] etc.)
- The next step is to then establish these planes with respect to the ellipsoid.

Analysis of Gathered Data – Linking the Tide Gauge data to the GPS data

- Using the simultaneous GPS and Tide Gauge records, subtract the raw tide gauge readings from the GPS heights (for each corresponding record over the length of available GPS observations) and obtain the mean of these differences.
- Add this mean difference to all raw tide gauge readings
- Obtain the mean of the adjusted tide gauge readings – this gives a value which can be considered to be MSL above the reference ellipsoid.
- The tidal planes derived from the tidal analysis can now be referenced to the reference ellipsoid.

Results so far....



POS 2			
Surface	**VORF**	**Observed**	**Difference**
LAT	51.9496m	51.78m	0.1696m
CD	51.9466m	52.06m	-0.1134m
MSL	54.9916m	55.14m	-0.1484m

POS 8.1			
Surface	**VORF**	**Observed**	**Difference**
LAT	44.249m	44.448	-0.199
CD	44.249m	44.448	-0.199
MSL	46.080m	46.089m	-0.009

POS 6			
Surface	**VORF**	**Observed**	**Difference**
LAT	41.8020m	42.03m	-0.2280m
CD	41.8020m	42.03m	-0.2280m
MSL	44.1764m	44.37m	-0.1936m

POS 8.2			
Surface	**VORF**	**Observed**	**Difference**
LAT	43.3910m	43.52m	-0.129m
CD	43.3910m	43.713m	-0.129m
MSL	46.1100m	46.093m	-0.017m

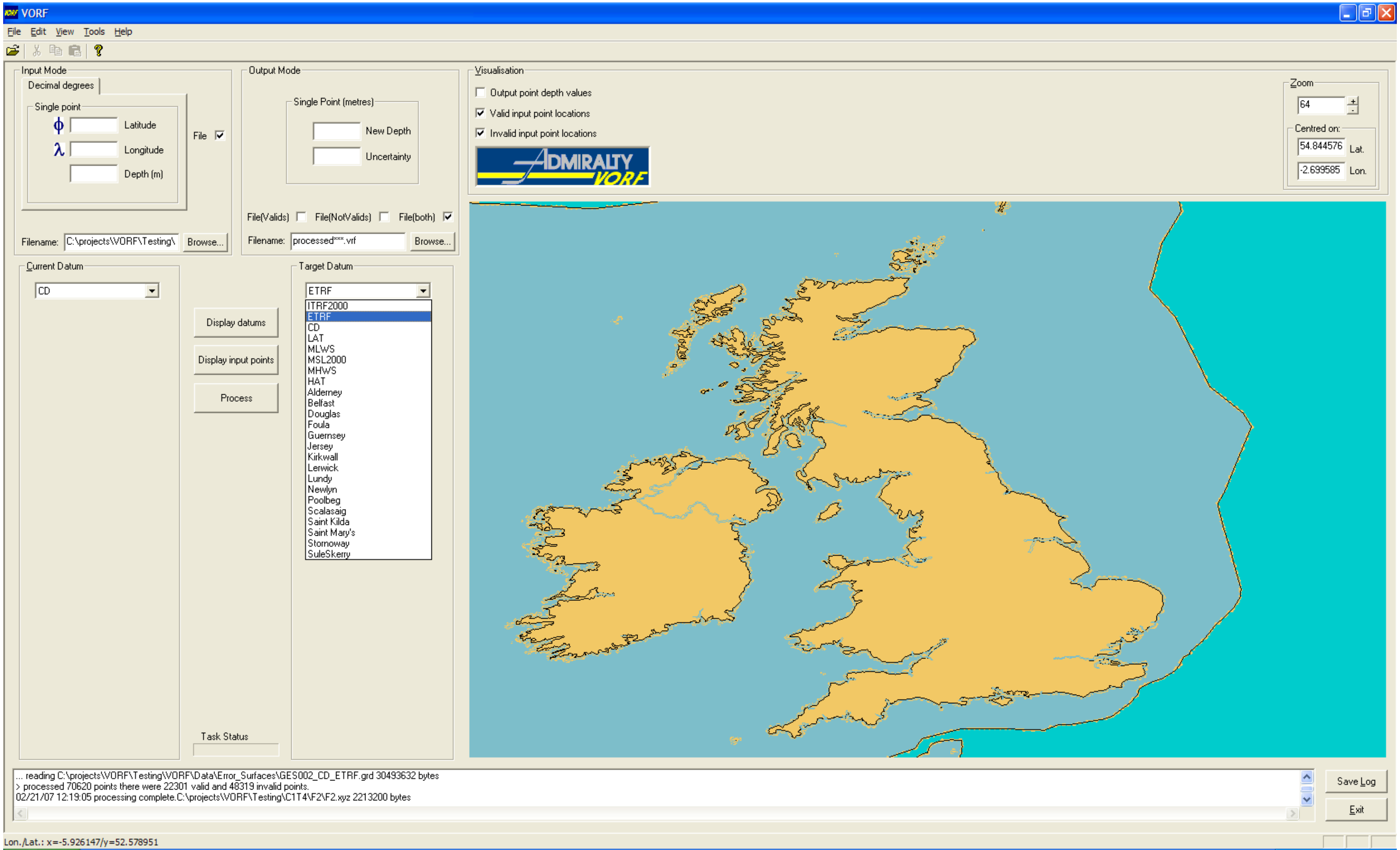
POS 10			
Surface	**VORF**	**Observed**	**Difference**
LAT	56.1386m	56.082m	0.0566m
CD	56.2442m	56.082m	0.1622m
MSL	58.1354m	57.952m	0.1834m

Average Differences	
Surface	
LAT	0.156m
CD	0.166m
MSL	0.110m

VORF software functionality

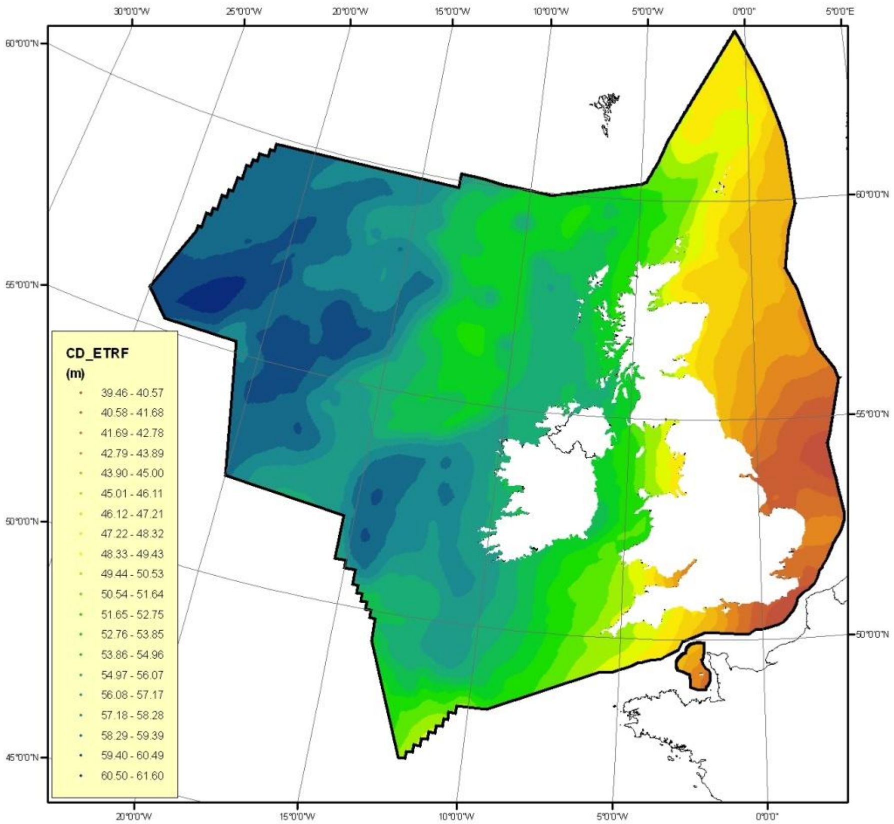
- Transformation between datums
- Estimated error in transformations
- Visualisation
- User error detection
- Point/file mode data import
- Deals with complexity of searching for special cases such as rivers and impounded datums.
- High speed data retrieval and processing.

VORF Application



Current progress:

- V2.0 delivered to UKHO Jan 08.
- Now to do:
- Stakeholders to be revisited
- Needs full testing
- Needs to be developed into robust software
- Safety case



How can VORF benefit the UKHO?

- Cost and efficiency of surveys
- Quality control
- Enabling new technologies
- Developing new products

Summary of VORF advantages

- VORF derives continuous surfaces, with fixed reference to ETRF89.
- It provides a consistent interpolation between Chart Datums, and methodology for extrapolation offshore.
- It eliminates some of the reliance on remote or expensive tidal observations.
- It has the potential to be built in to real-time applications.
- It fully exploits current and future GPS technology, and is the basis for future accuracy enhancements.

Conclusions

- VORF is an enabling technology
- Surveying without tide gauges – cheaper, faster, more accurate
- New navigation and space management concepts
- Fully integrated data products
- SOLAS – improved navigation in critical areas
- VORF will help UKHO in its development of marine charting and navigation products

References and Further Reading

General descriptions:

Iliffe, Jonathan, Marek Ziebart, James Turner, Joao F Oliveira, and Ruth Adams. The VORF project Joining up Land and Marine Data . GIS Professional. Issue 13, November/December 2006, pp 24 26.

Adams, Ruth, Jonathan Iliffe, Marek Ziebart, James Turner, and Joao F Oliveira. Joining up Land and Sea the UKHO/UCL Vertical Offshore Reference Frame . Hydro International Volume 10 Number 10, December 2006.

More detail on the methodology :

Iliffe, Jonathan C., Marek K Ziebart and Jim F Turner. "The derivation of vertical datum surfaces for hydrographic applications". The Hydrographic Journal, No. 125, 2007, pp 3 - 8.

Further details on the methodology of deriving sea surface topography around the British Isles as part of the project can be found in:

Iliffe, J. C., Ziebart, M. K. and Turner, J. F. (2007) 'A New Methodology for Incorporating Tide Gauge Data in Sea Surface Topography Models', Marine Geodesy, 30:4, 271 - 296.

Future uses::

Ziebart, M., J.Iliffe, J.Turner, J.Oliveira and R.Adams (2007), VORF - The UK Vertical Offshore Reference Frame: Enabling Real-time Hydrographic Surveying, proceedings of ION GNSS2007, Fort Worth, Texas, USA, September, 2007.