Implementation and Validation of Separation Models for use of GNSS Heights in Hydrographic Surveys

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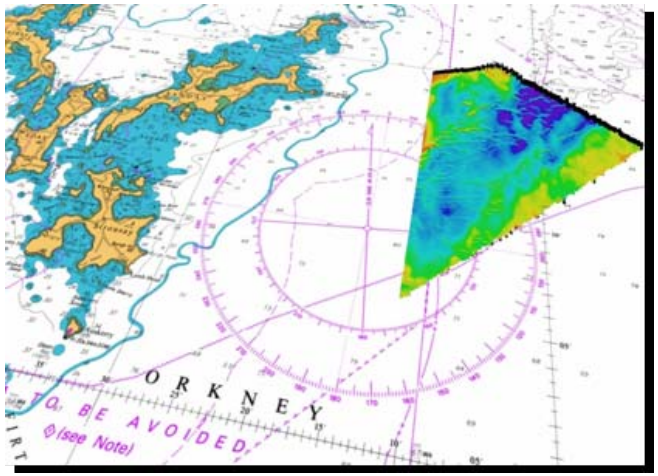
Company History

- Company created in 2002
- Currently employs 20 staff and a further 15 freelance multibeam specialists
- Viewed as ‘Multibeam Centre of Expertise’ in UK
- Over 20 projects completed in last three years utilising a GNSS Tidal solution
- Surveys have included:
  - SOLAS Surveys for the MCA
  - Dock Wall Structural Surveys
  - Combined Swathe bathymetry and Marine Laser Scanning Surveys



The Tidal Solution

- Bathymetric Surveys have traditionally used one of three solutions for reducing soundings to datum:
  - A local tide gauge - (generally within 10 miles of area)
  - A tide station and co-tidal corrections for areas further offshore
  - predicted tides based on the assumed tidal regime

A New Approach

In 2006 UKHO began development of the Vertical Offshore Reference frame.

The Aim

An accuracy of 0.2m (vertical) at 2 standard deviation (sigma) within 20Km of the UK coastline

An accuracy of 0.3m (vertical) at 2 standard deviation (sigma) or better for any point beyond 20Km of the coastline bounded by the UK Continental Shelf.

Why?

Modern charting surveys with 100% Swathe bathymetry quickly showed the issues with using tide gauges or co-tidal models at a distance from the gauge.

Illustrating what we had all known from or error budgets that our surveys were potentially not meeting specifications required

Error within 1-2nm of a gauge - 0.05m
2-10nm - 0.1-0.3m
Offshore - 1.0m

The Challenge - Development of the Model

Determine a continuous surface for CD. UCL adopted a multi-step procedure.

1. Compute a gridded surface of mean sea level at a new epoch (MSL2000) above the GRS80 ellipsoid from a combination of long and short term tide gauge data and satellite altimetry.

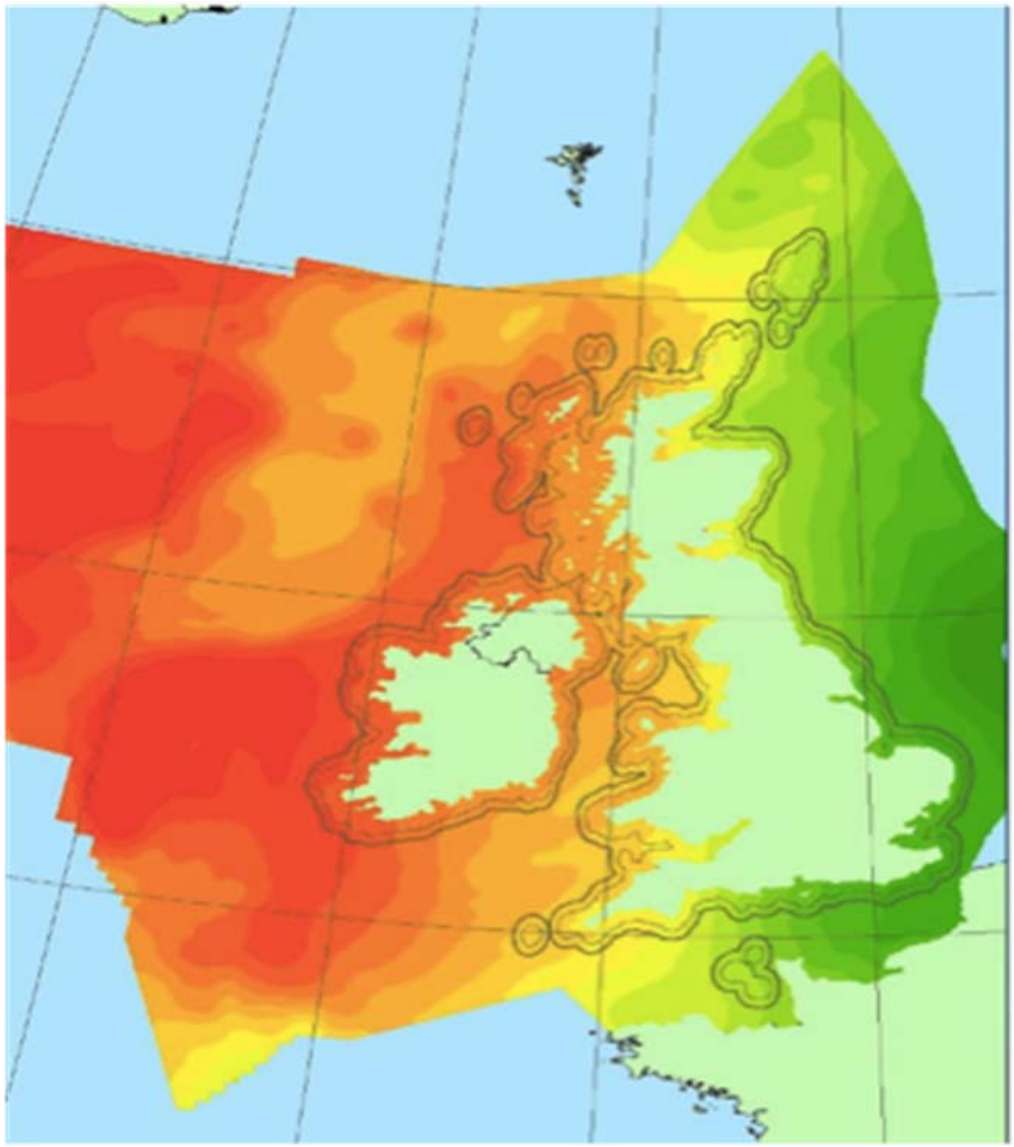
2. The tidal ranges of HAT, LAT MLWS, MHWS, and CD over the 18.6 year period centered on the epoch 2000 were calculated for each point in the grid.

3. Grid files for the required surfaces were derived by applying the tidal range estimates to the MSL2000 ellipsoidal heights.

CD and LAT are often not coincident around UK waters. CD was only ever a series of plane surfaces. Where different CDs overlapped, there would be an offset. This meant that on any one chart, soundings may be reduced to more than one CD.

The derived LAT surface was used inshore to create a continuous CD model by warping the surface to CD at known points. CD was gradually merged into LAT as you moved offshore.

The Result



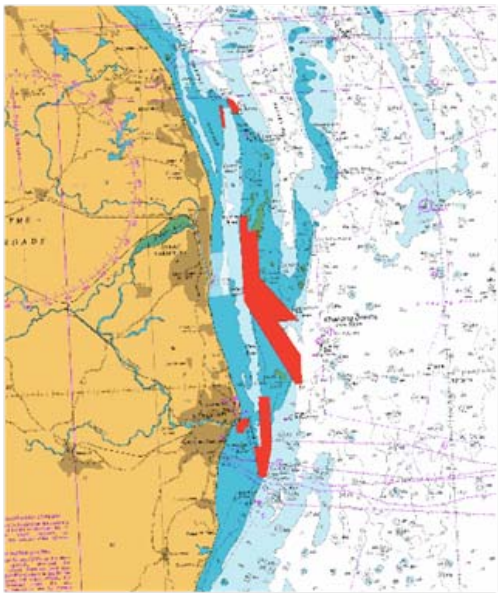
A UK Wide separation model of multiple surfaces

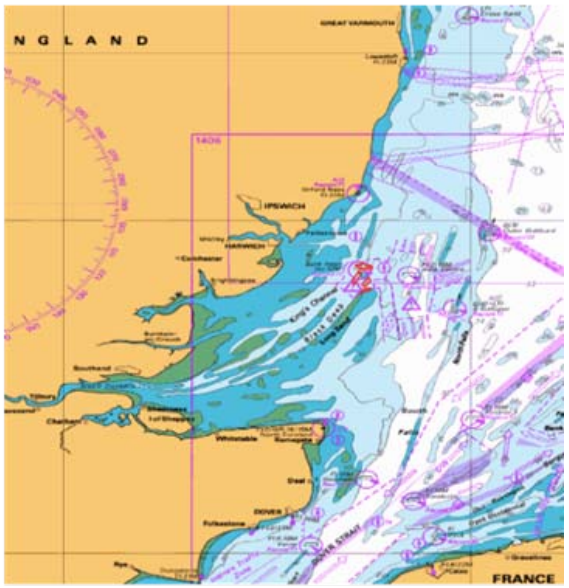
This was refined further following initial testing of the model by as series of observation campaigns around the UK in 2007

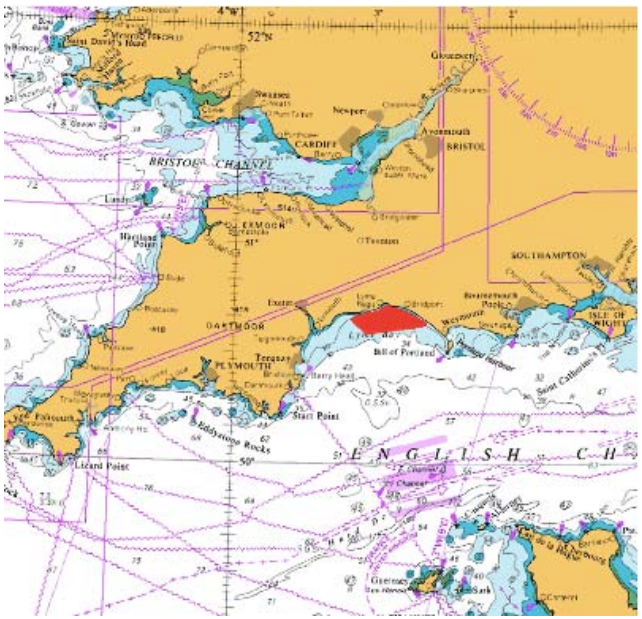
Further observations have continued up to 2010 to obtain data in offshore regions of the UK to refine the model further

Introduction into the Civil Hydrography Programme

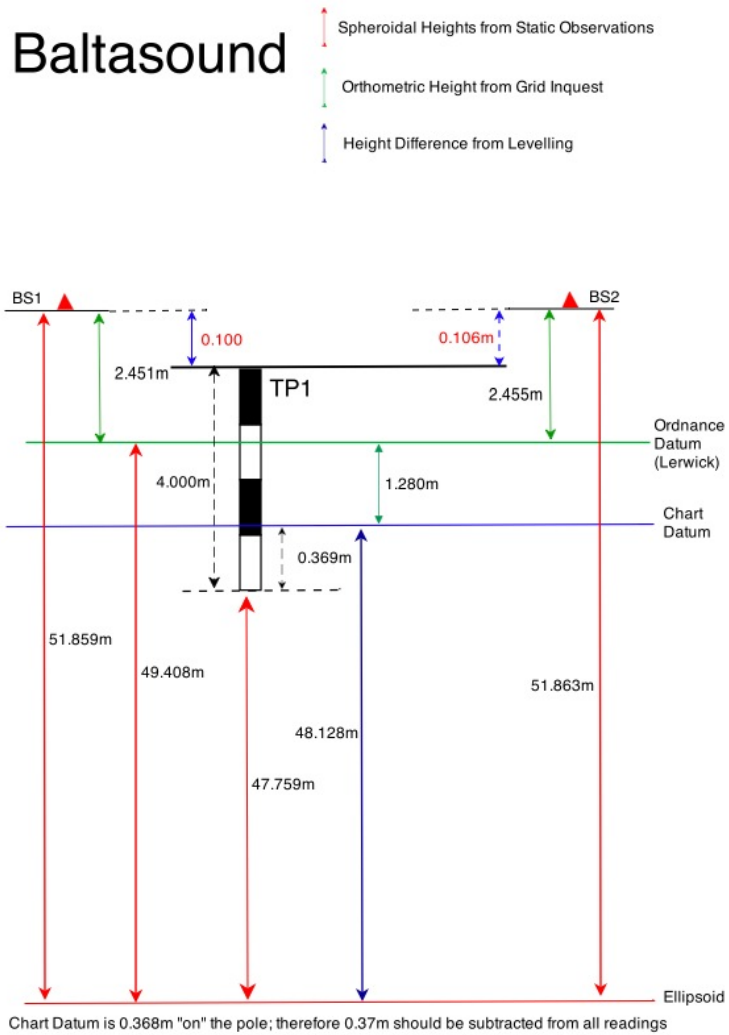
Stage 1- Ashore comparison with GPS Observations
Stage 2 - Low resolution Modeling in offshore areas
Stage 3 - Issue of full resolution model and increased validation requirements







Stage 1 Validation



Establish a tide station

Recovery or Establish new benchmarks using Static GPS Observations

Calculation of separation values between all surfaces

Derived values compared against VORF model

Single point Correction used for surveys based on the verified observations

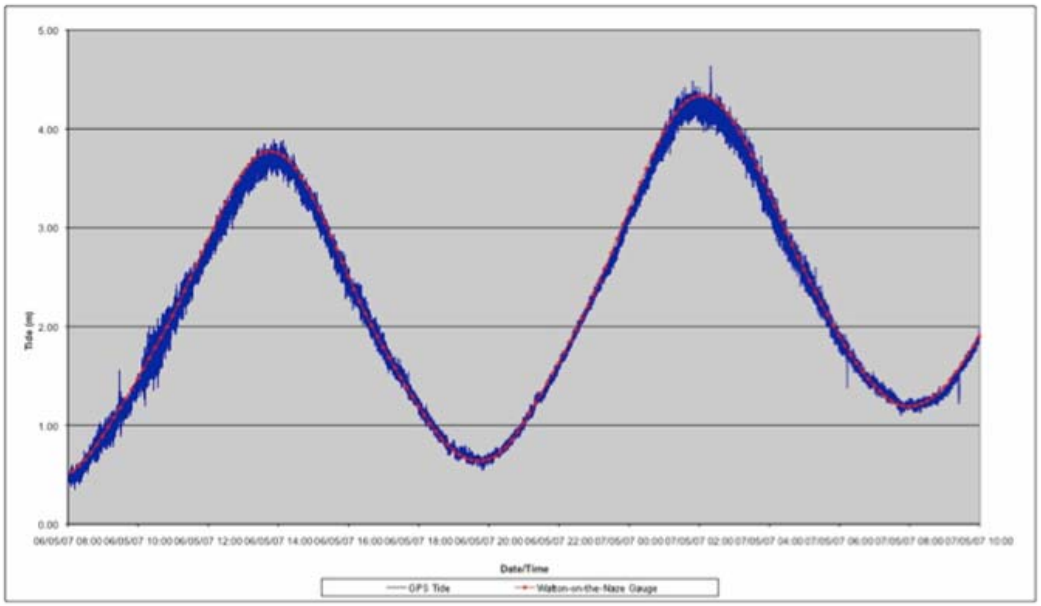
Location	Latitude	Longitude	Observed Separation Value	VORF Model	Difference
Great Yarmouth	52° 34' 18.65" N	1° 44' 05.13" E	42.77	42.76	0.01
Lowestoft	52° 28' 21.68" N	1° 45' 00.70" E	42.90	42.90	0.00
Felixstowe	51° 57' 28.55" N	1° 18' 04.58" E	42.76	42.69	0.06
Walton-on-the-Naze	51° 50' 37.17" N	1° 16' 46.28" E	42.46	42.48	-0.02
Fisherman's Gat	51° 28' 38.44" N	1° 23' 08.33" E	41.92	41.98	-0.05
Margate	51° 23' 29.96" N	1° 22' 57.37" E	41.90	41.90	0.00
Dover	51° 06' 51.95" N	1° 18' 53.67" E	40.60	40.62	-0.02

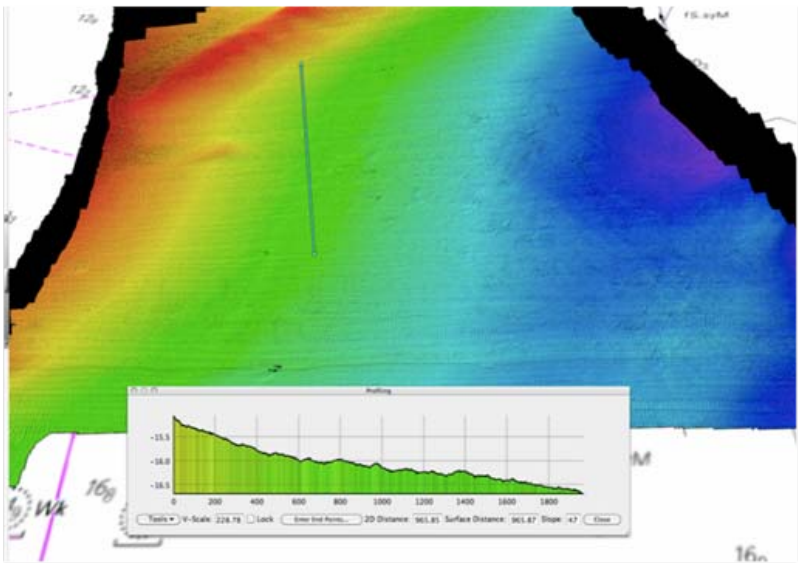
Stage 1 Validation

7125 Data Reduced with a single point correction - Differences of between 10-20cm between lines

Stage 2 Validation

- 2007 saw more data released in the areas where confidence in the model had built up.
- Tidal stations were still recovered and GPS observations were completed to verify model values at the coast
- Point Values were supplied for the survey area and used in deriving the GNSS tide - results were encouraging and resultant surfaces were showing that the seamless model had less artefacts





Stage 3 Validation and Use

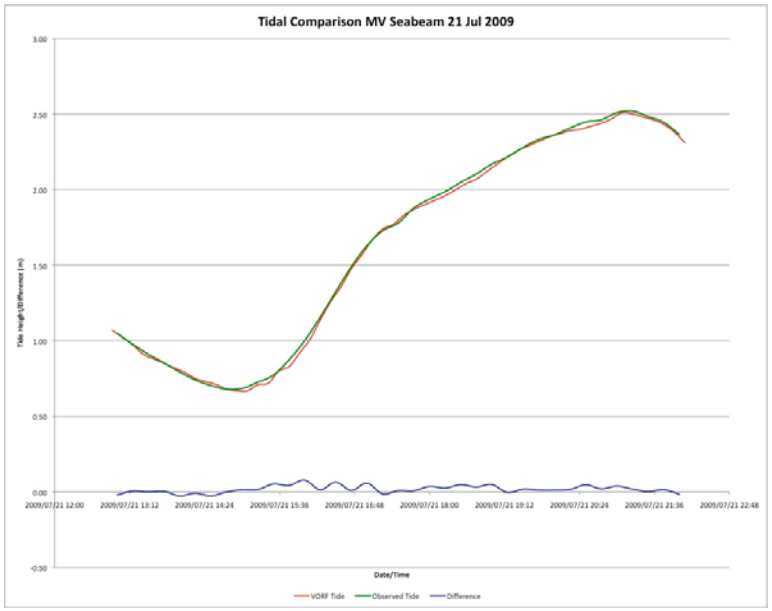
Data was released to more contractors and a new validation regime introduced

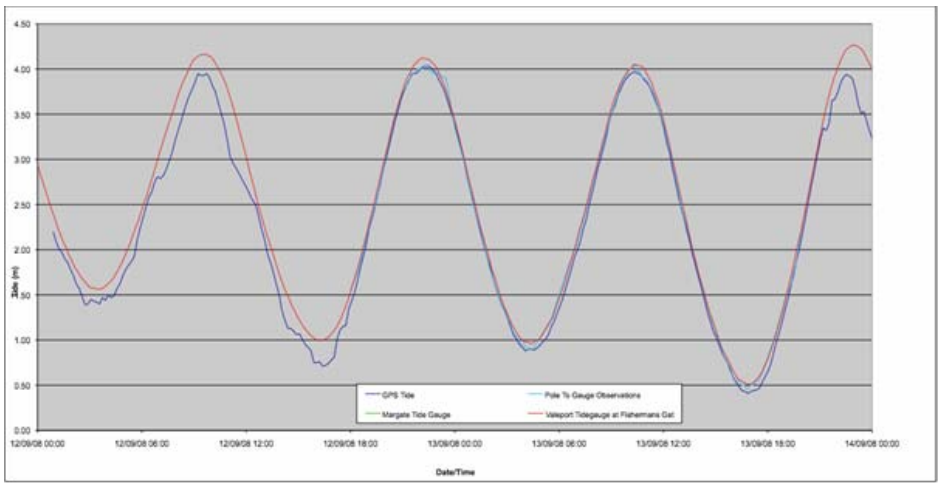
Continued Shore Observations

8 hour static comparison within 1km of gauge

Assessment of model offshore (using co-tidal models!)

Additional offshore tidegauges laid in key areas to assist in further modelling





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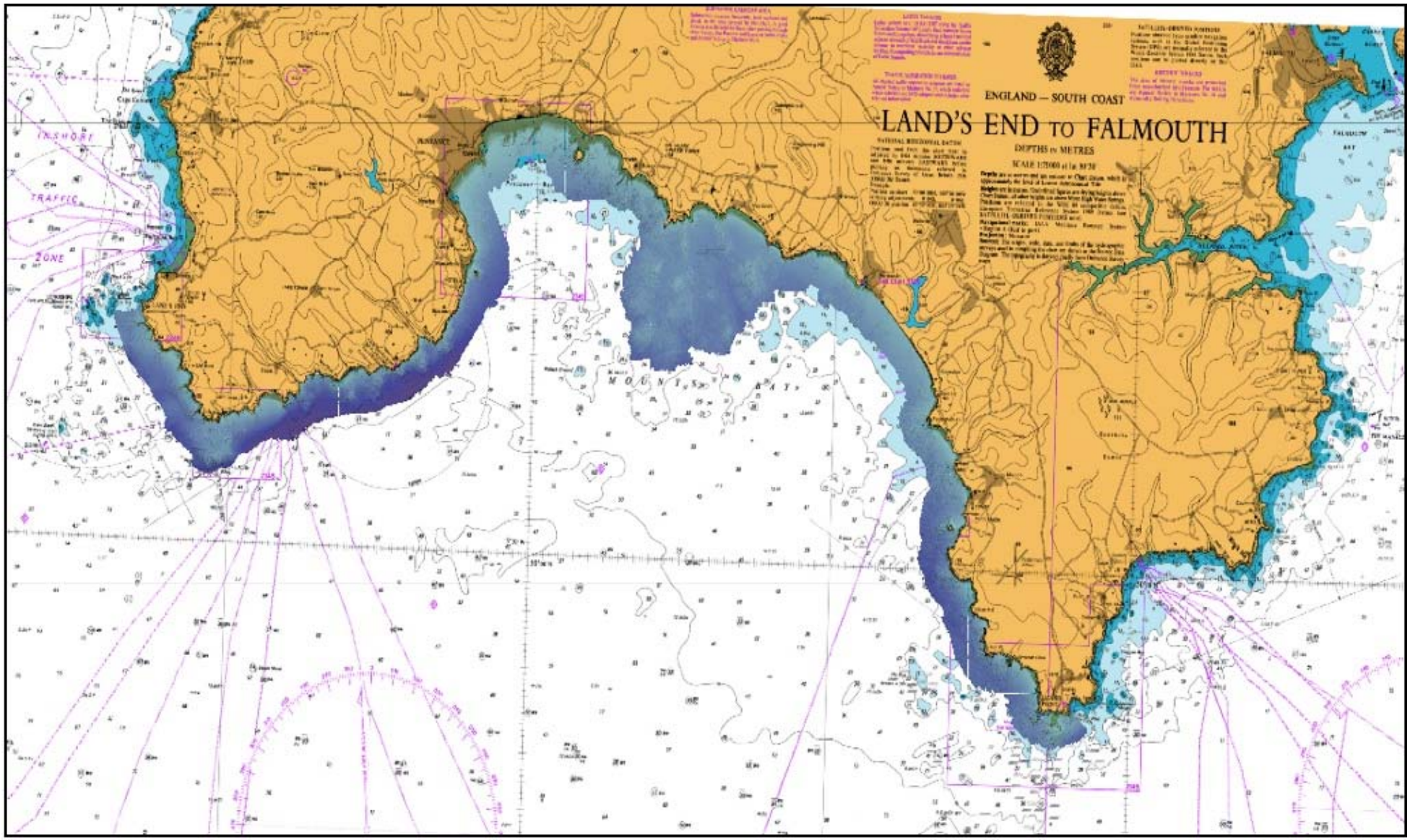
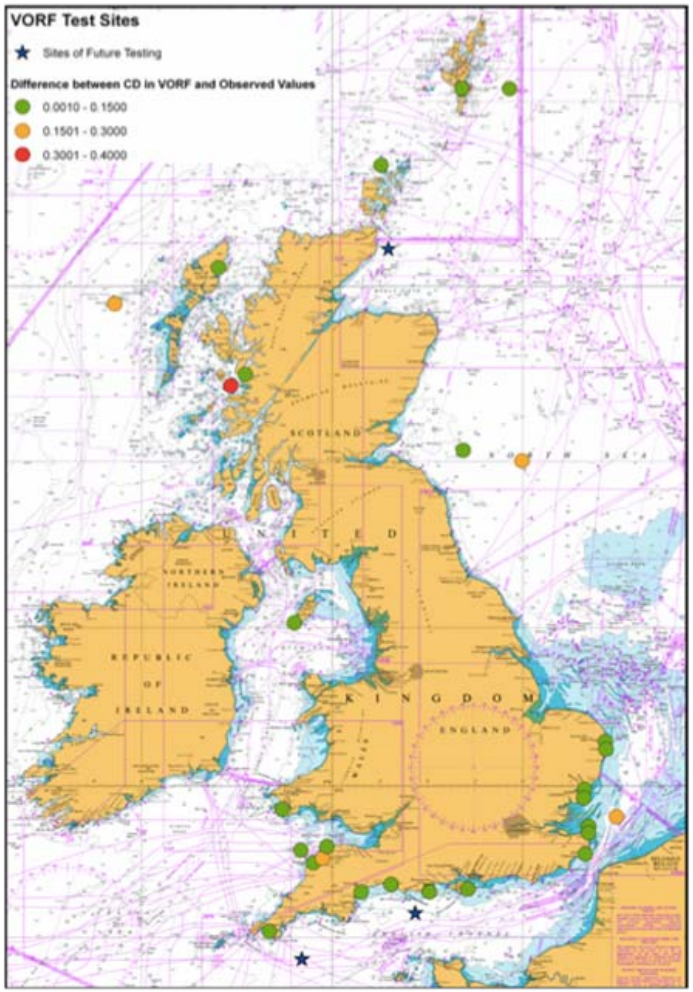


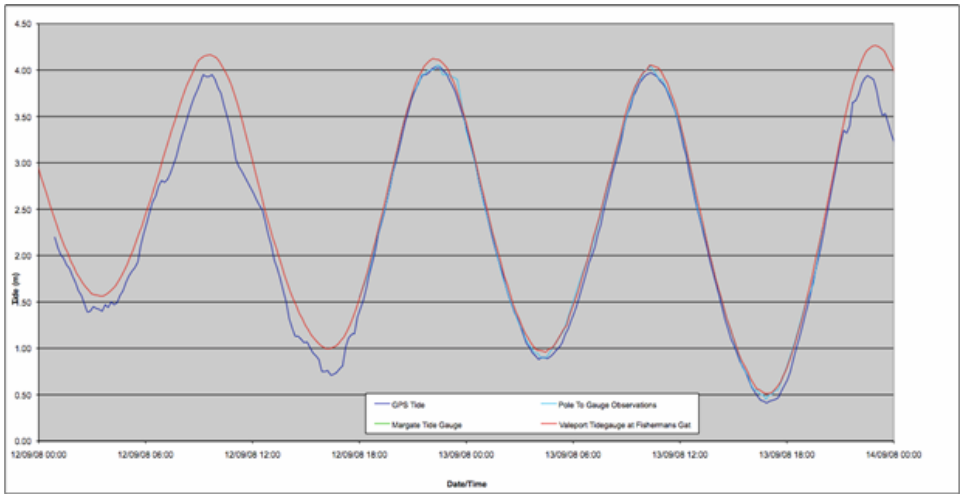
Current Assessment of the Model

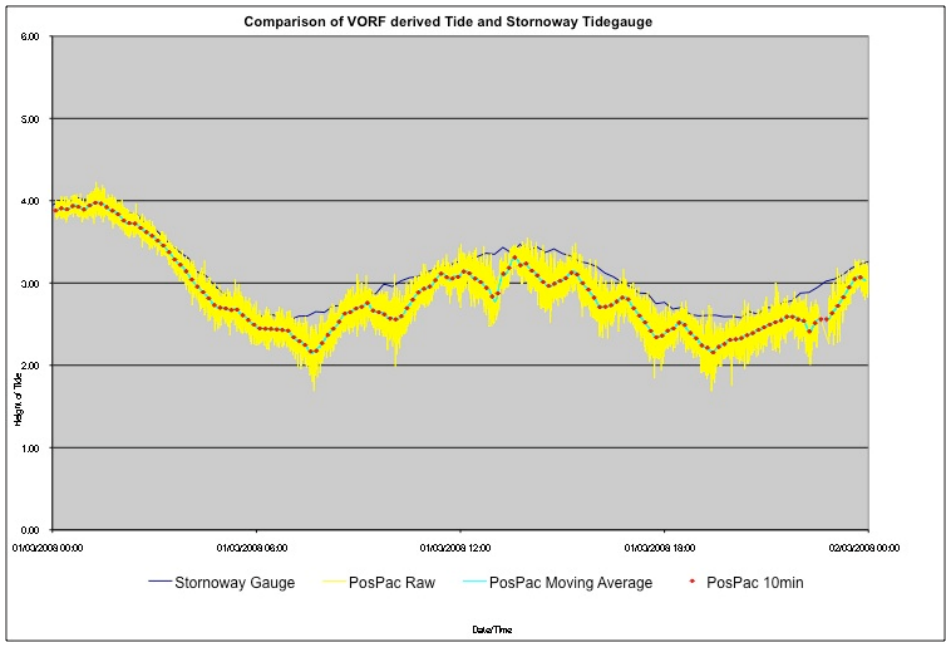


- Analysis of the results from all contractors in the Civil Hydrography Programme are encouraging
- Model is performing better than expected in many areas.
- Poorer coverage in areas where the tidal regime is less well understood

Implementing the GNSS Tidal Curve

- In its simplest from a 10 minute averaged tidal curve was applied to collected data.
- Tidal data derived from Post Processed GNSS Data which had been reduced to datum using the accepted VORF values
- In complicated coastal areas a number of artefacts were still appearing
- Examination of the tidal curves revealed data that did not follow the normal accepted rise and fall of tide





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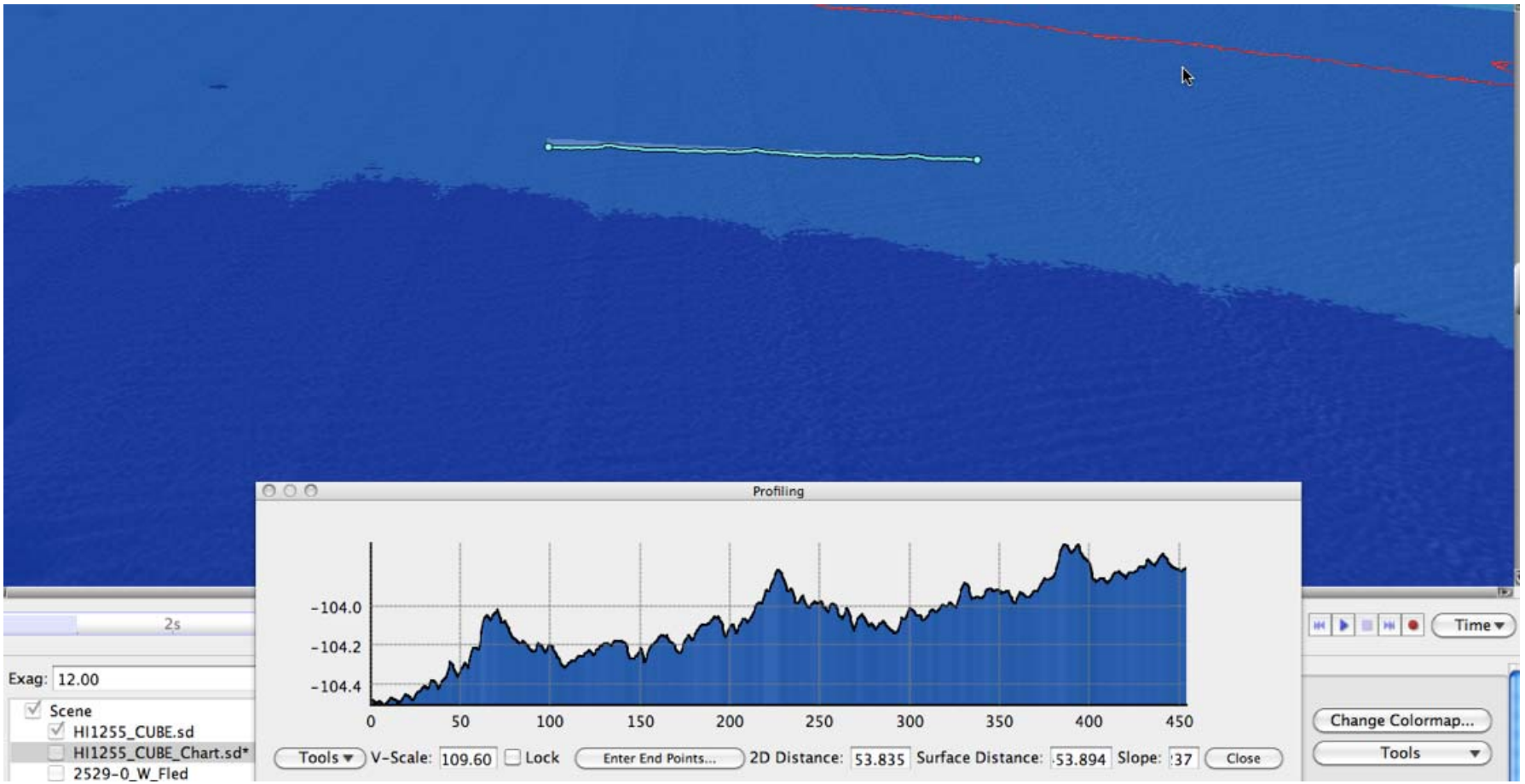


Smoothed 10 minute GNSS tide using VORF

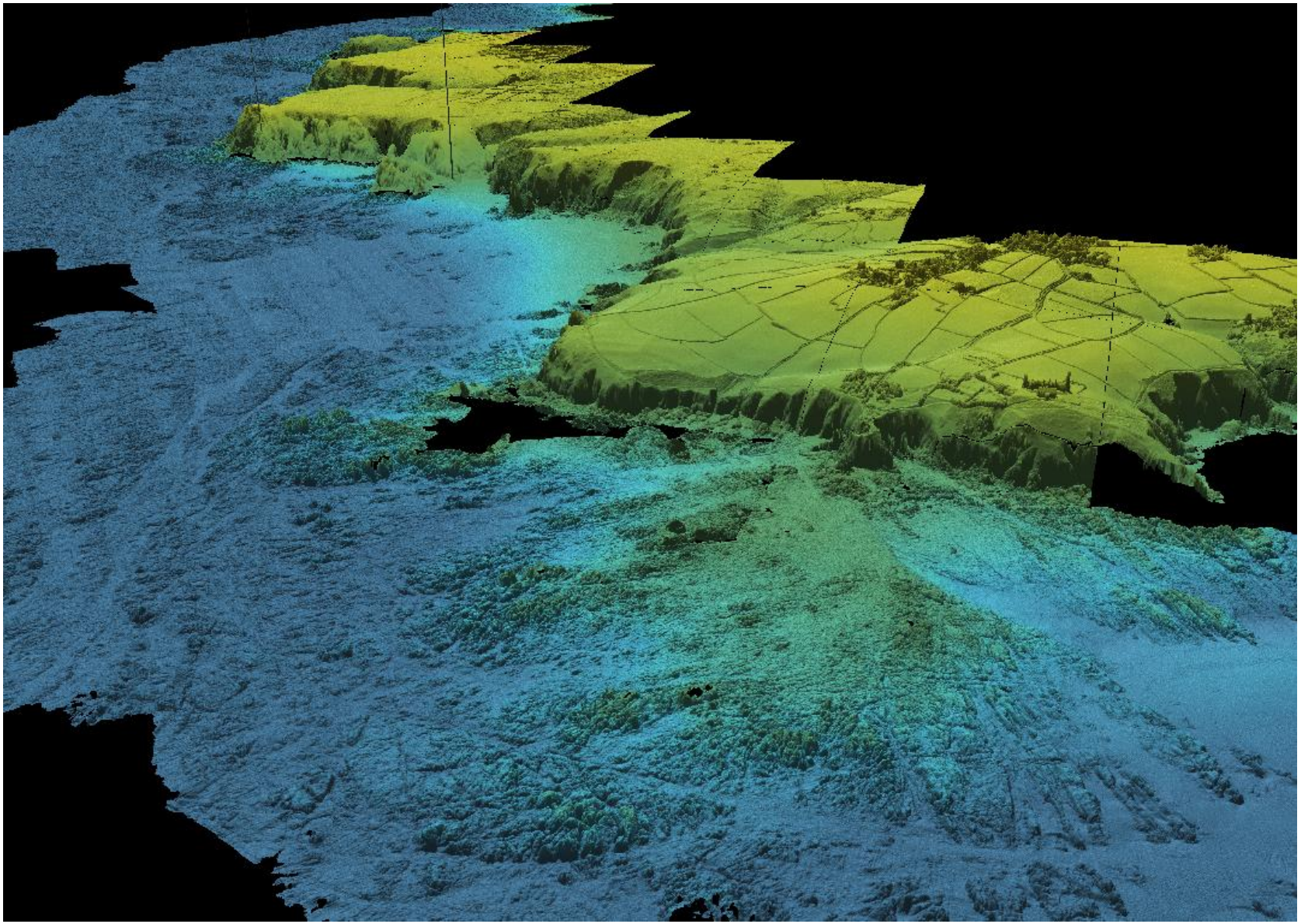
The solution

- Application of the full resolution GNSS tide using a post processed 3D solution on a ping by ping basis

- Current Processing packages are allowing the application of the Smoothed Best Estimate of Trajectory (SBET) to gathered data along with the the VORF model

- This application of tide on a ping by ping basis at point of sounding has for the first time allowed a true application of tide, irrespective of the vessels position in relation to the flooding or ebbing tide, which was effectively smoothed out in a traditional 10 minute sampled curve.

Advantage of Full Resolution GNSS Tide



Conclusions

VORF comprises a 500m to 1km resolution models of Mean Sea Level, CD and other tidal surfaces. 39 major surveys in support of navigational safety have been completed in UK waters using the VORF model to reduce data to a single common datum.

Advantages

Speed of processing increased due to the lower vertical uncertainty at point of sounding when using statistical cleaning methods

Surveys to be conducted in validated areas without having to establish a tide station or lay offshore gauges

Step change in the accuracies achieved in operations and opening new markets up to contractors

Allowing greater integration of land and marine data sets with easy transformations between different vertical datums

Questions?