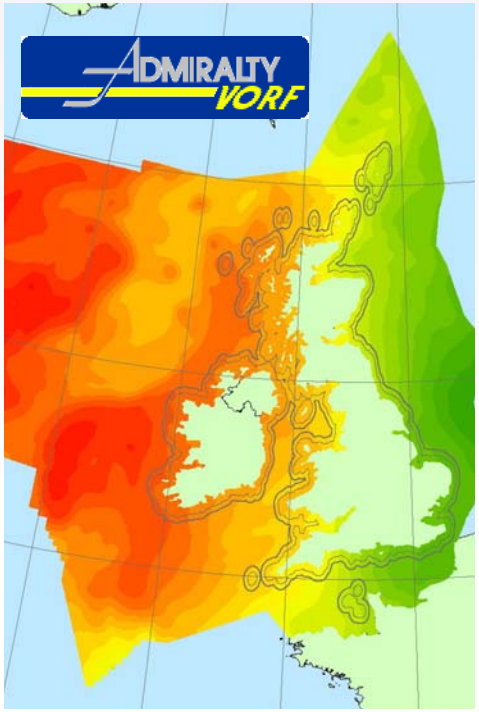
VORF: Concept and Current Status

Prof Marek Ziebart and Dr Jonathan Iliffe
Department of Civil, Environmental and
Geomatic Engineering
University College London



Hydrography and Marine Spatial Data Infrastructure, Bradfield College
27th October, 2009

Presentation structure

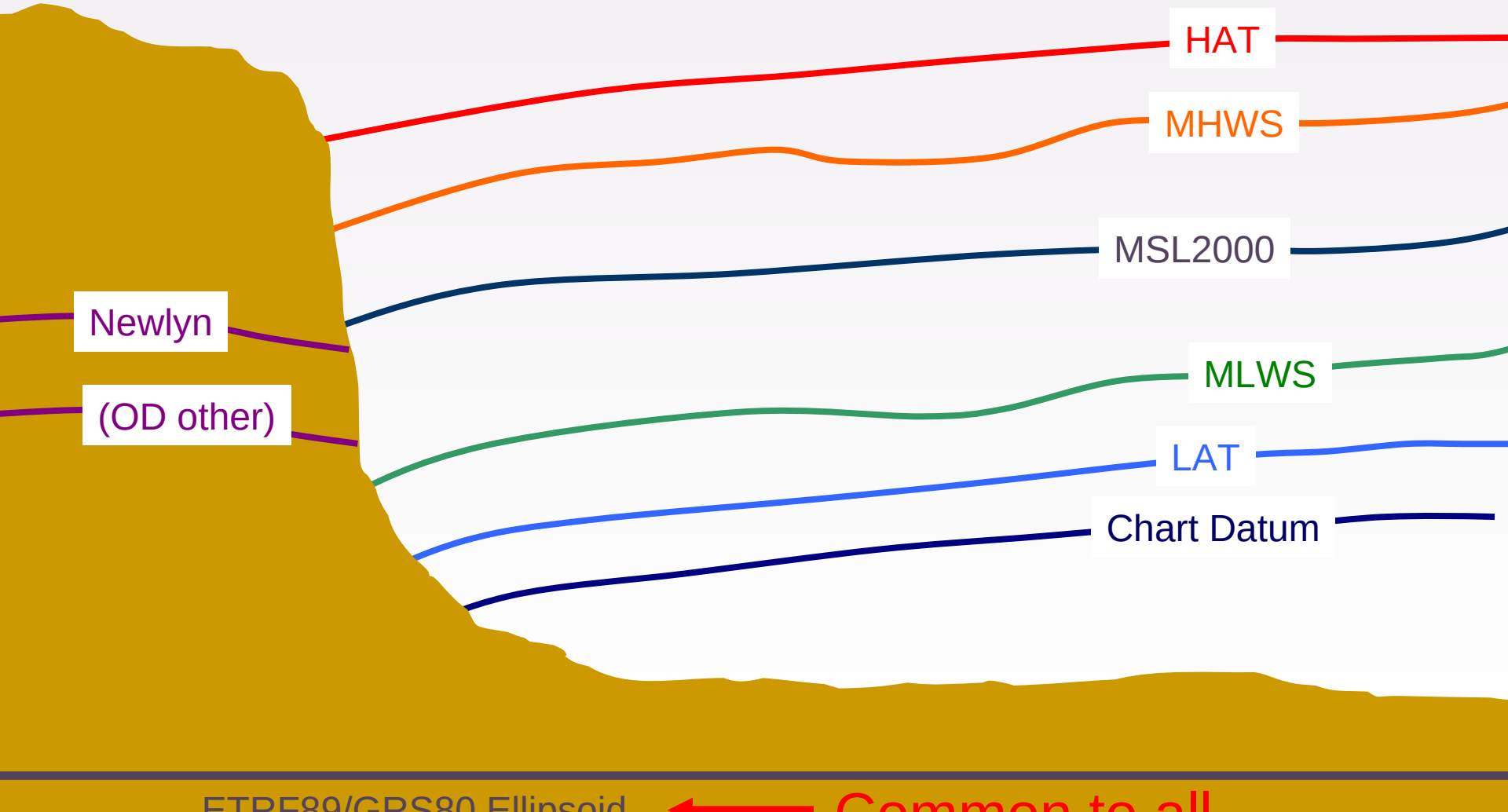
- What is VORF?
- Why do we need it?
- Model development
- Interface and software functionality
- Applications
- Results of model testing
- Status, trends in offshore satellite positioning
- Conclusions

What is VORF?

- A high resolution digital model of all the reference surfaces in all navigable waters of the British Isles. All surfaces are modelled with respect to the GPS global datum (WGS84/ITRF2000, ETRF89)

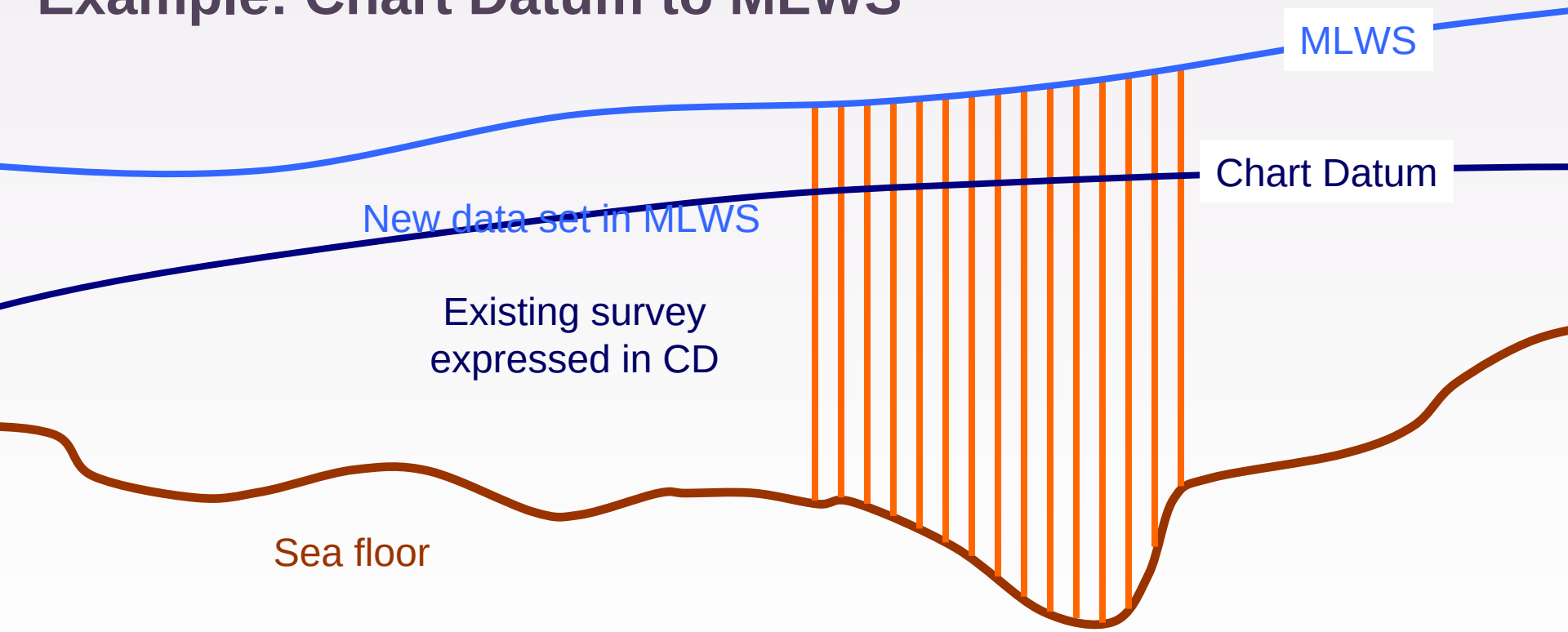
- The software to transform rapidly and robustly between these different datums.

VORF surfaces: Land and Sea datums related to each other



ETRF89/GRS80 Ellipsoid ← Common to all

Basic VORF functionality: Transforming data between vertical datums Example: Chart Datum to MLWS

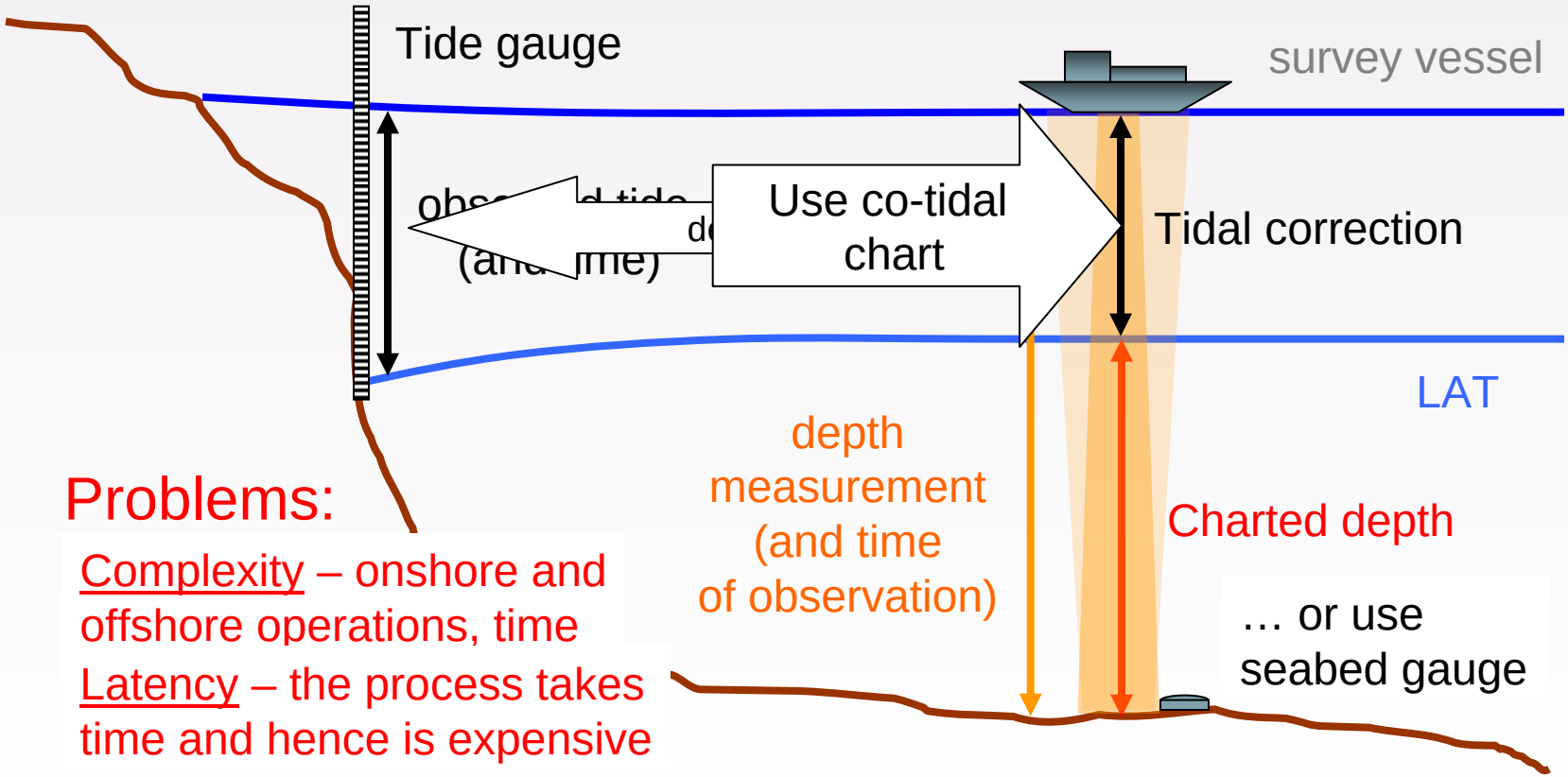


GRS80 Ellipsoid

Why is VORF needed?

- Continuing developments in GNSS
- LIDAR and multibeam technology
- Global trends in datum unification, harmonisation of charting, automation in navigation and data acquisition
- Data fusion (cf references from Rear Admiral Moncreiff)

Why is VORF needed:
Current practice for bathymetry data processing



Problems:

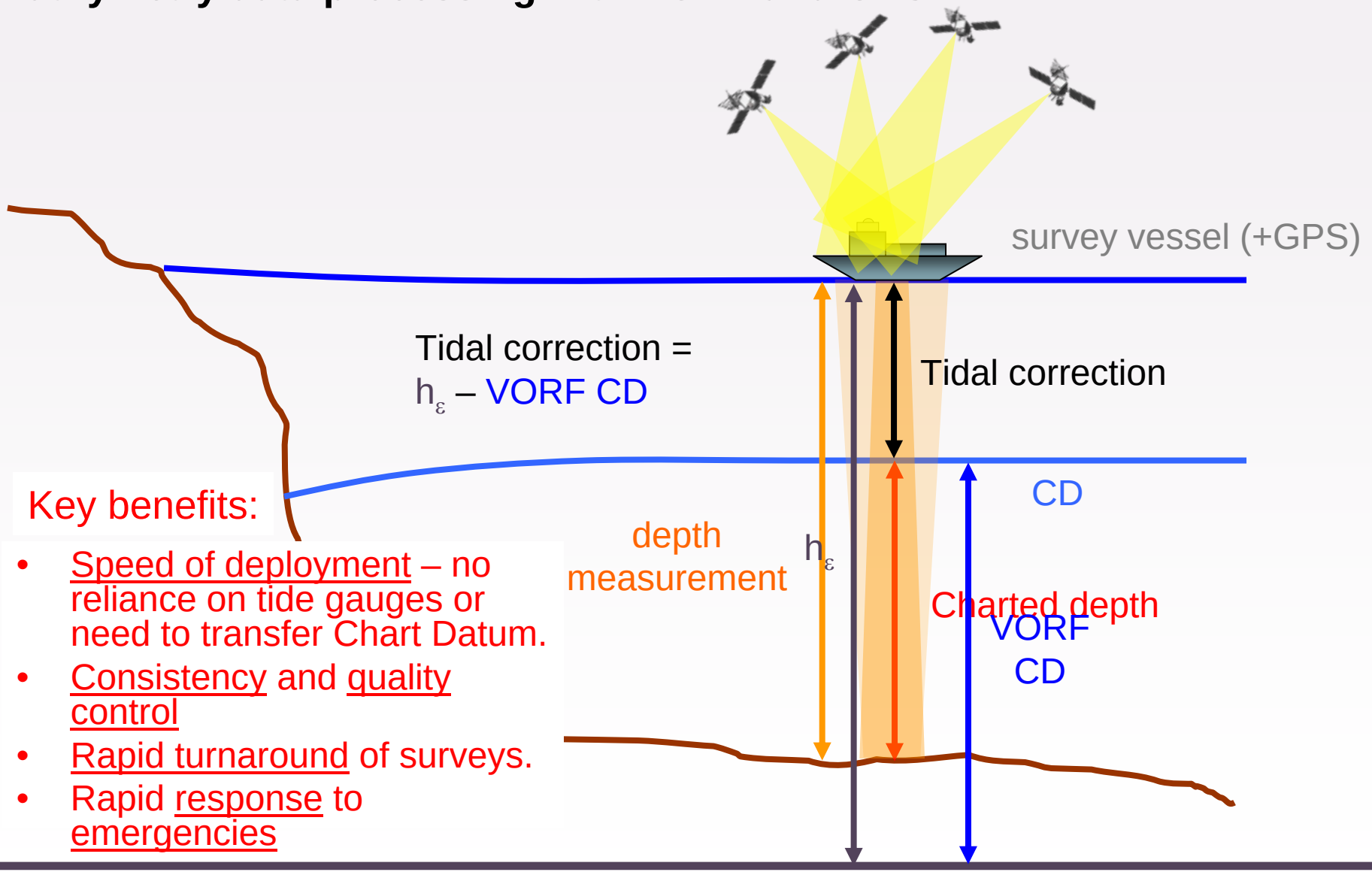
Complexity – onshore and offshore operations, time

Latency – the process takes time and hence is expensive

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

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

Bathymetry data processing with VORF and GPS



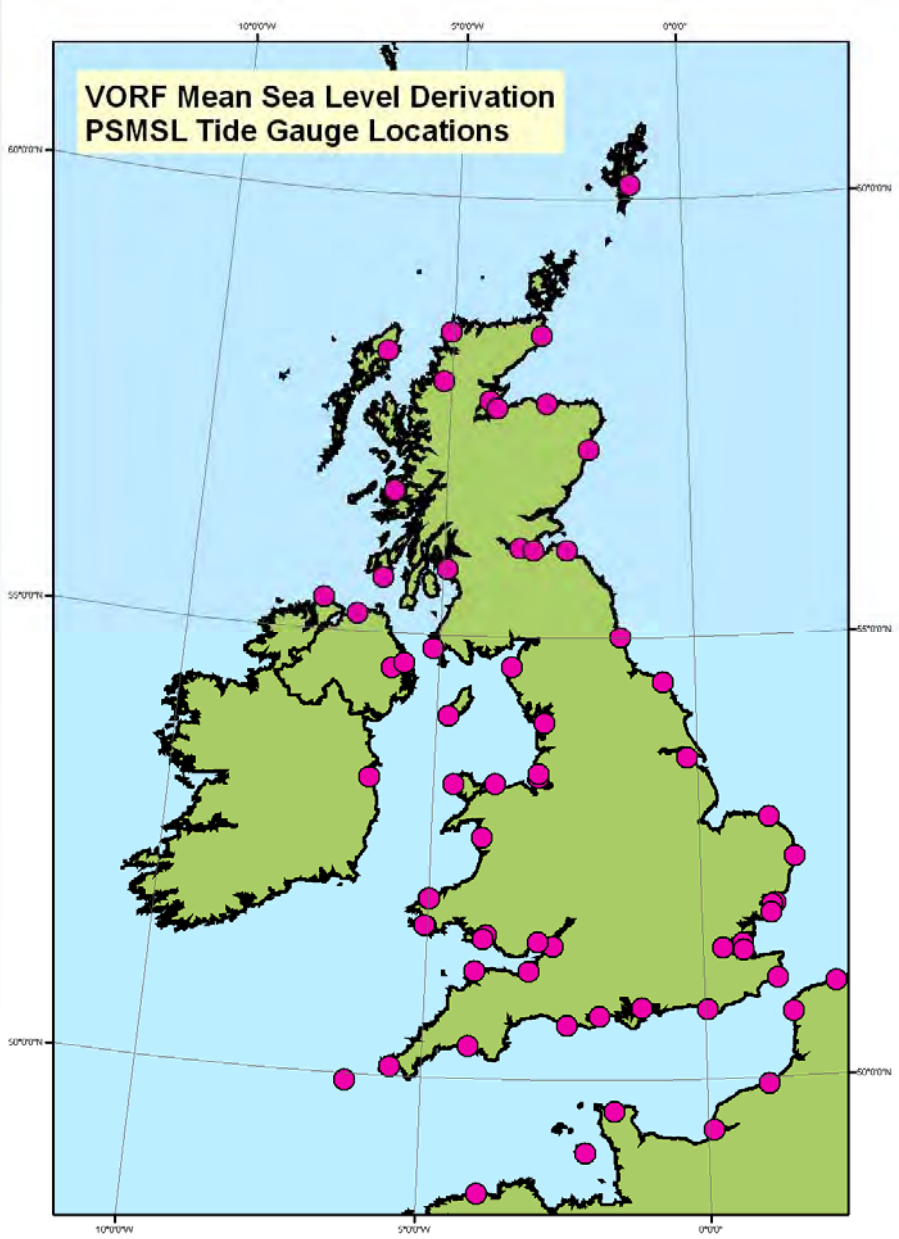
Key benefits:

- Speed of deployment – no reliance on tide gauges or need to transfer Chart Datum.
- Consistency and quality control
- Rapid turnaround of surveys.
- Rapid response to emergencies

GRS80 Ellipsoid - accessible everywhere via GPS

Data sources (1): Permanent Service for Mean Sea Level Tide Gauge data

- National Tidal and Sea Level Facility stations
- High quality continuous observations
- Low spatial density

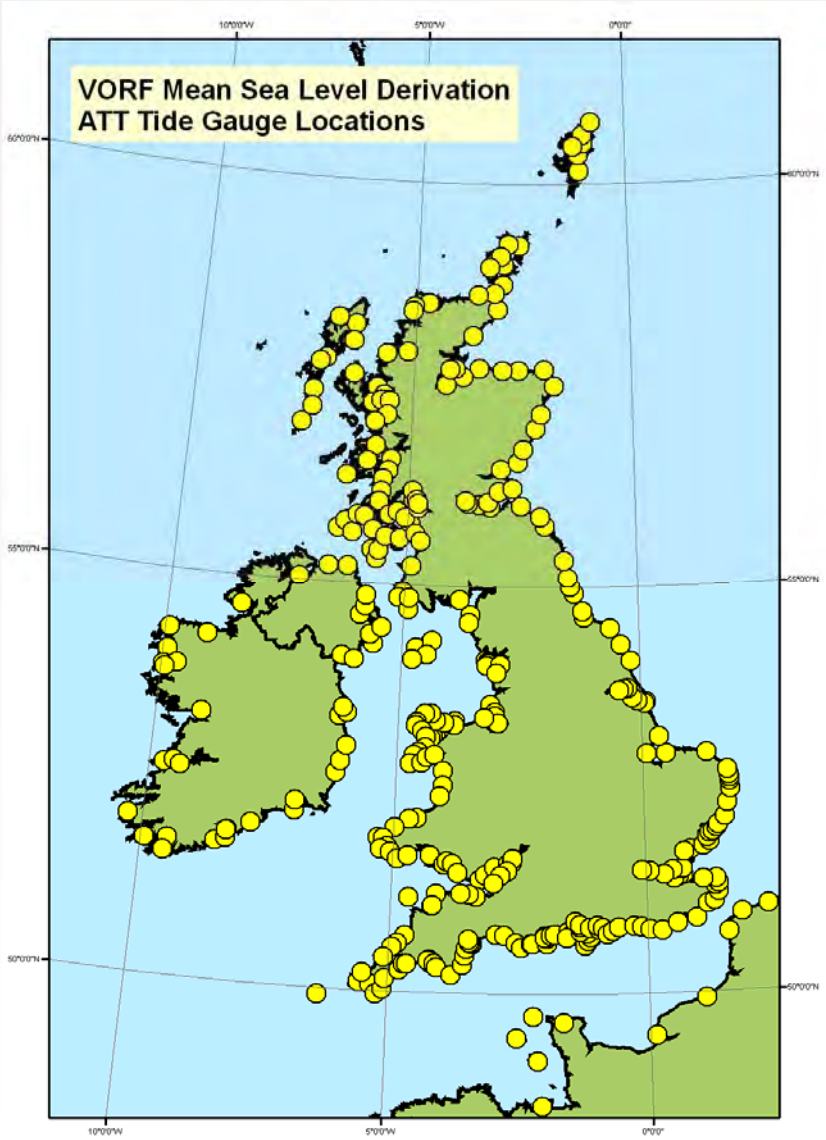


Data sources (2): Admiralty Tide Table Tide Gauges

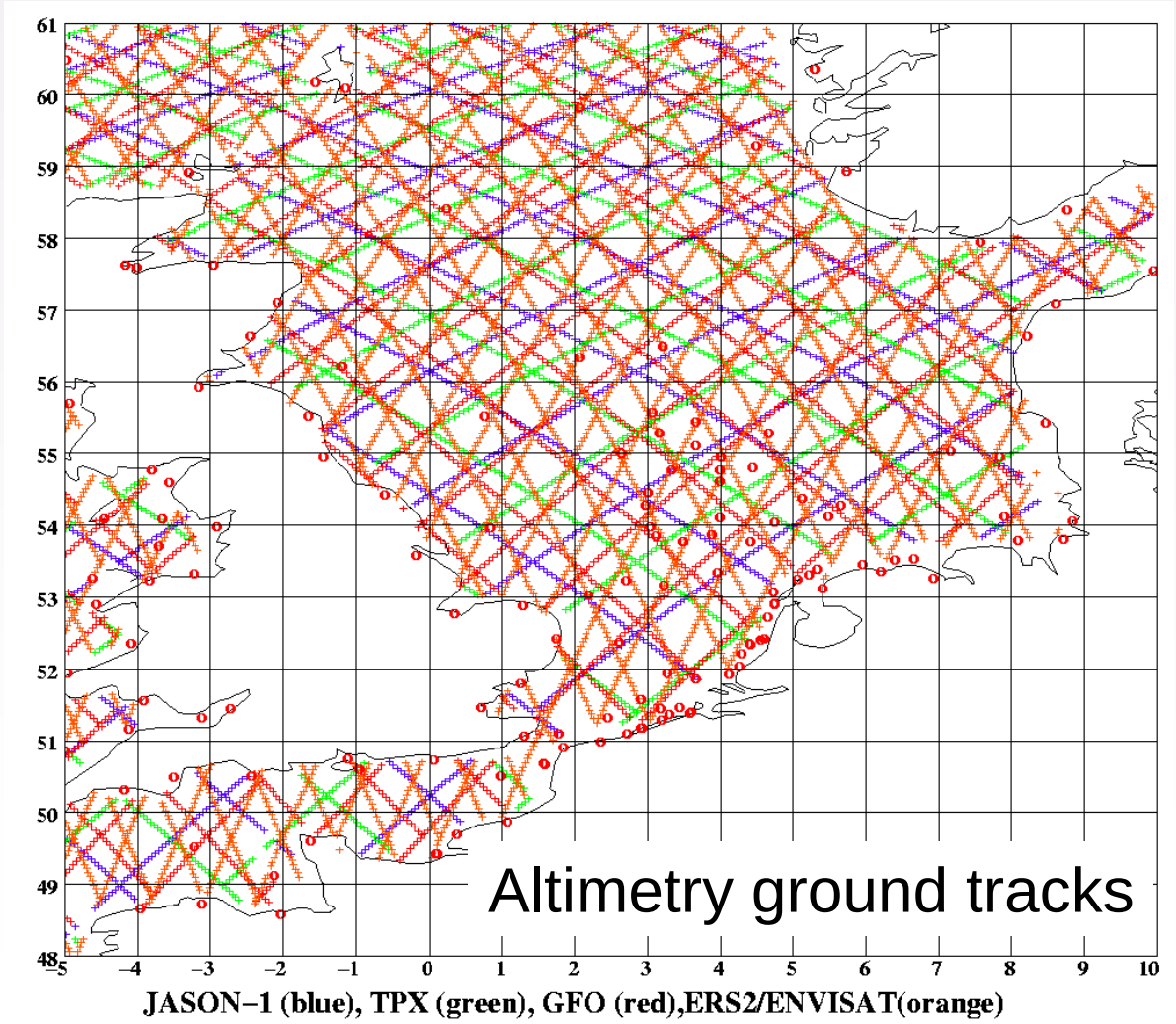
Primary and secondary tide gauge data.

Good spatial density.

Low precision due to short term data series.



Data sources (3): Satellite Altimetry



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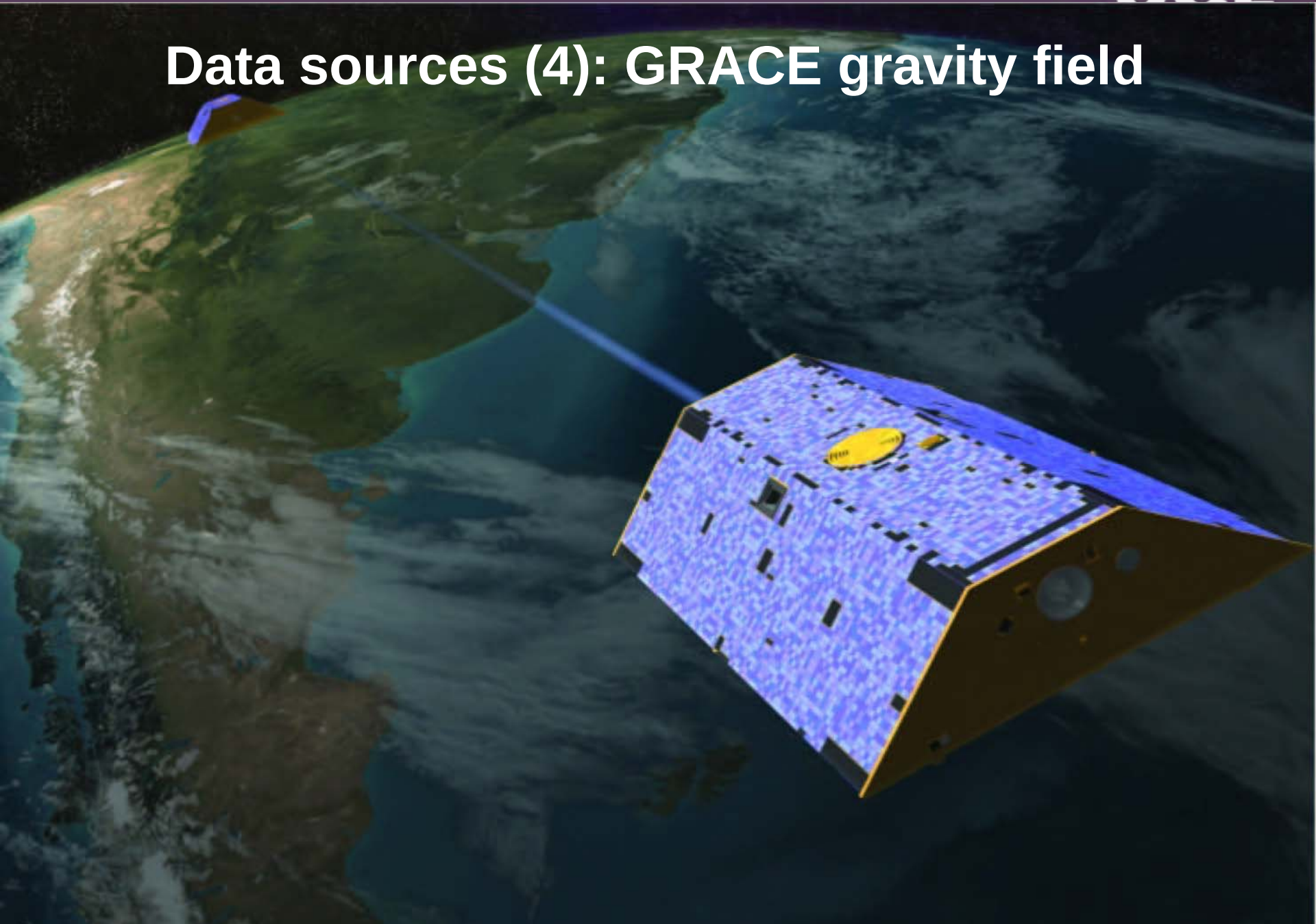
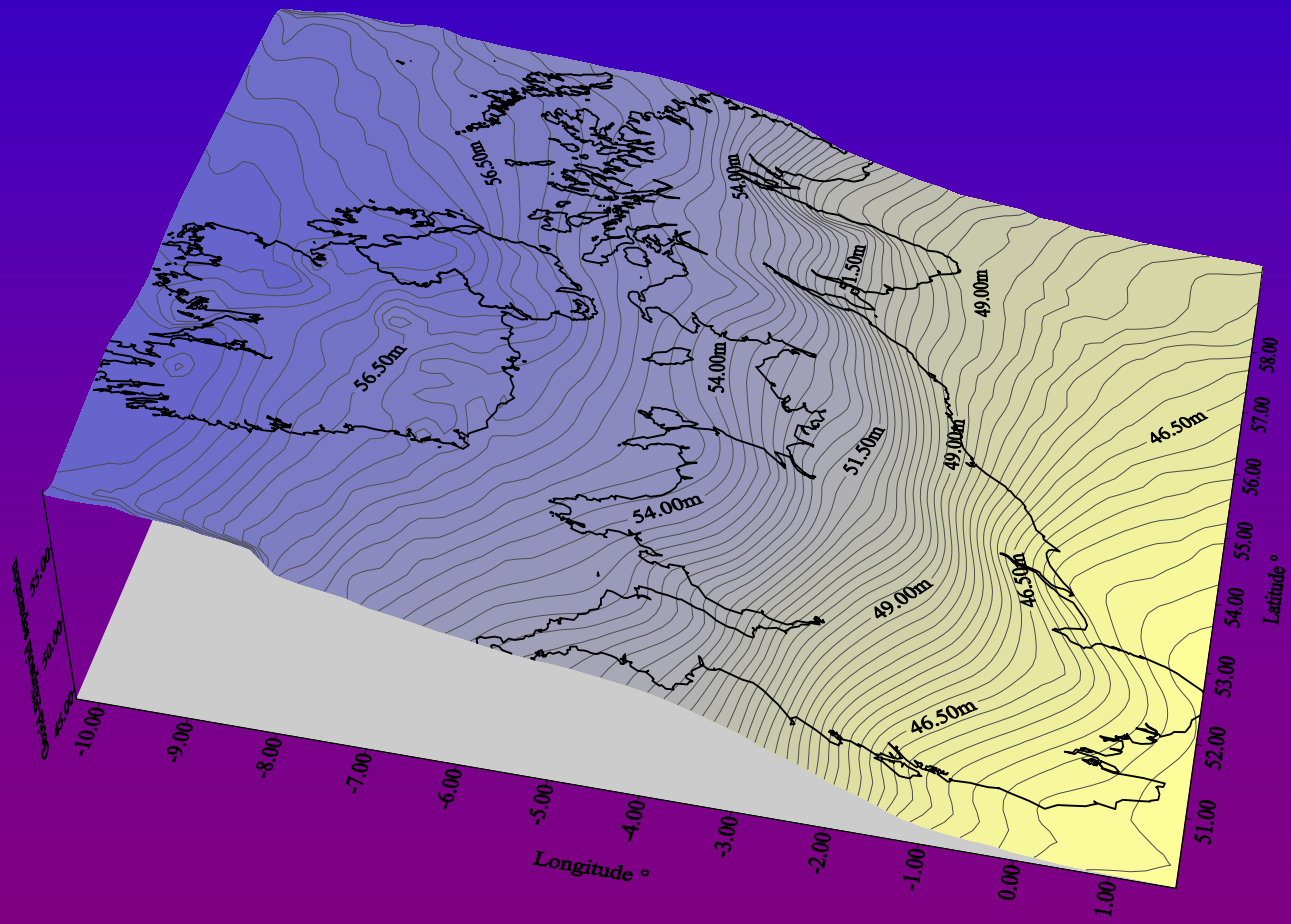
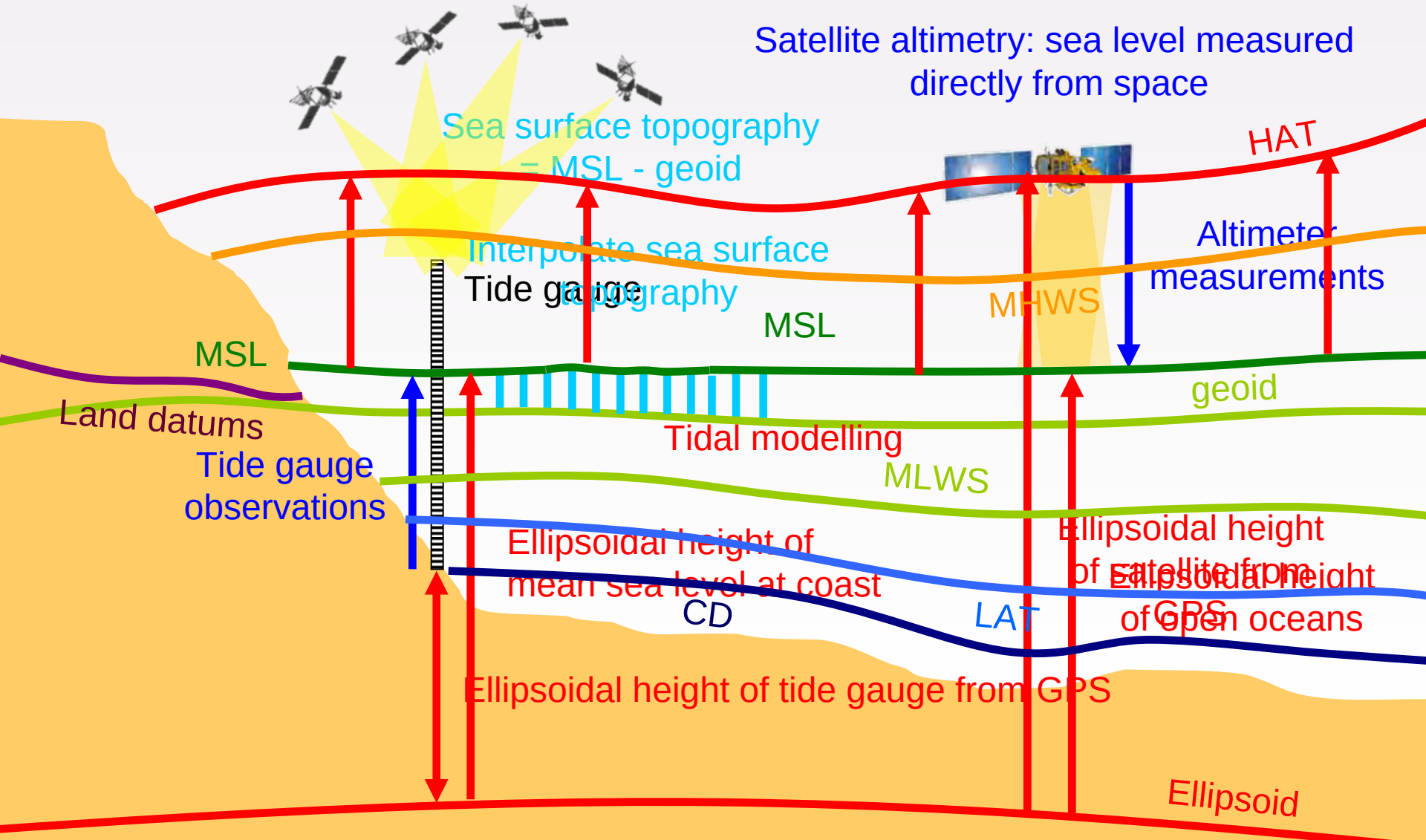
Data sources (4): GRACE gravity field



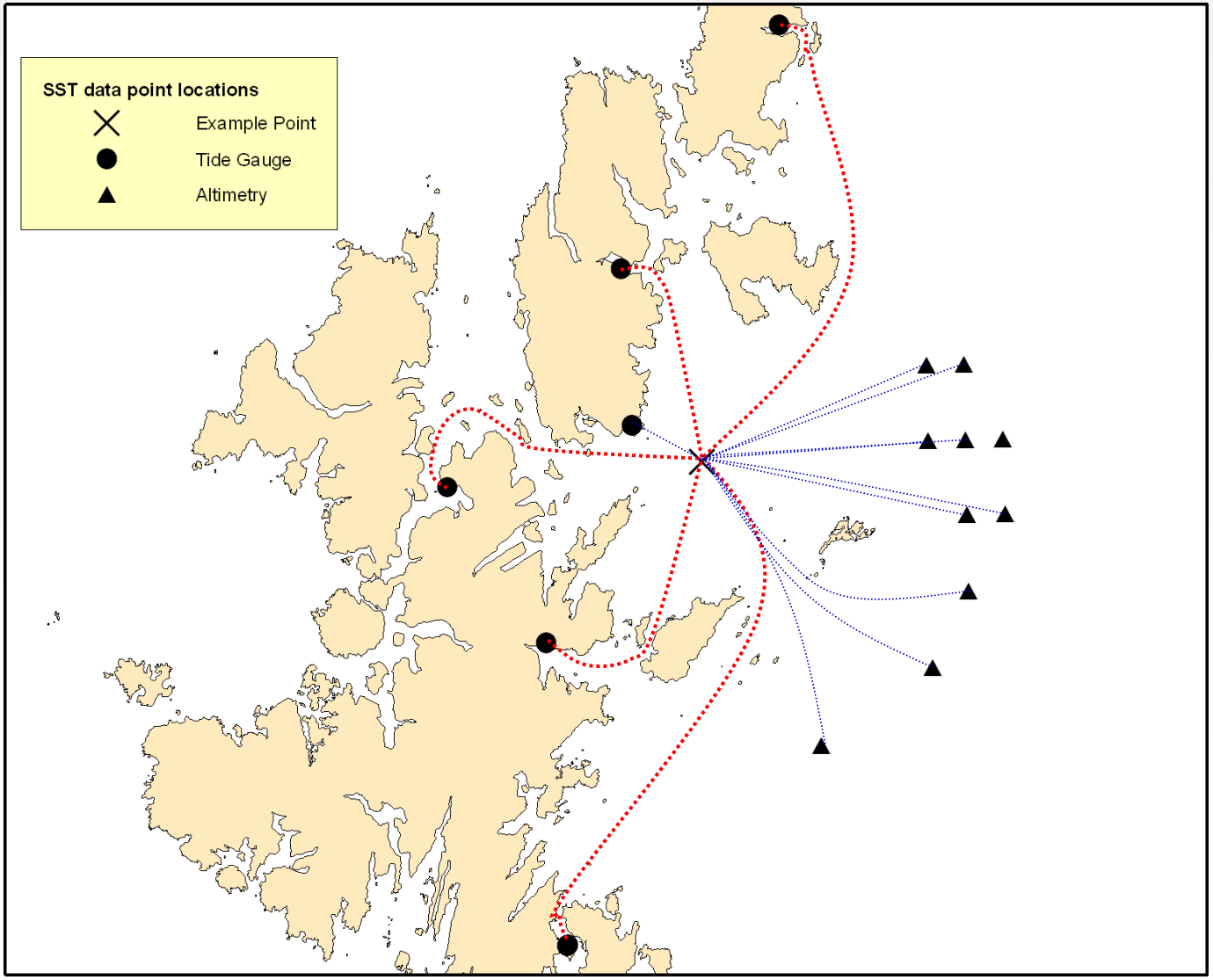
Data sources (5): OSGM05 – the latest UK gravity field model



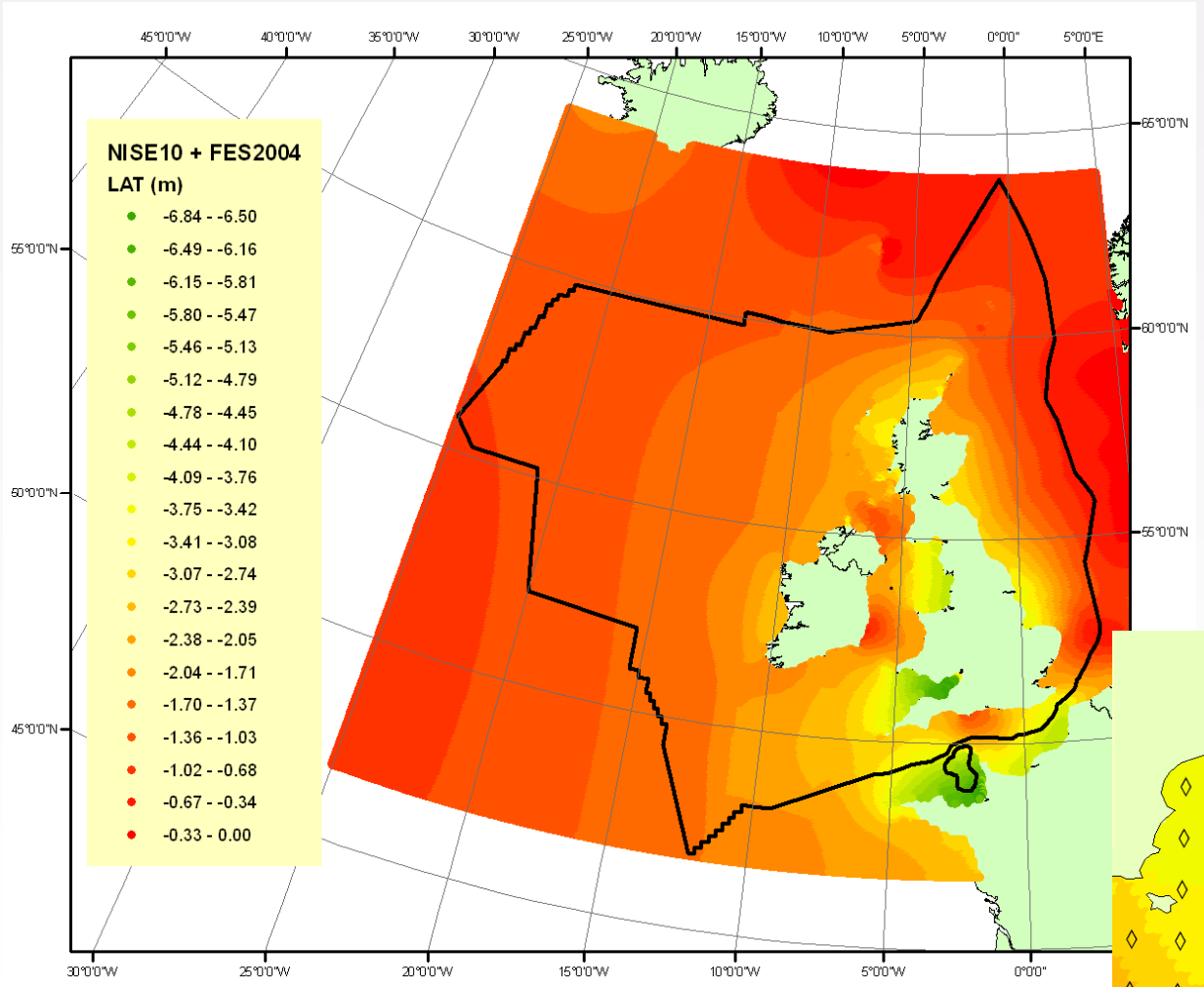
Developing VORF (in one slide)



Modelling: Interpolation of surfaces



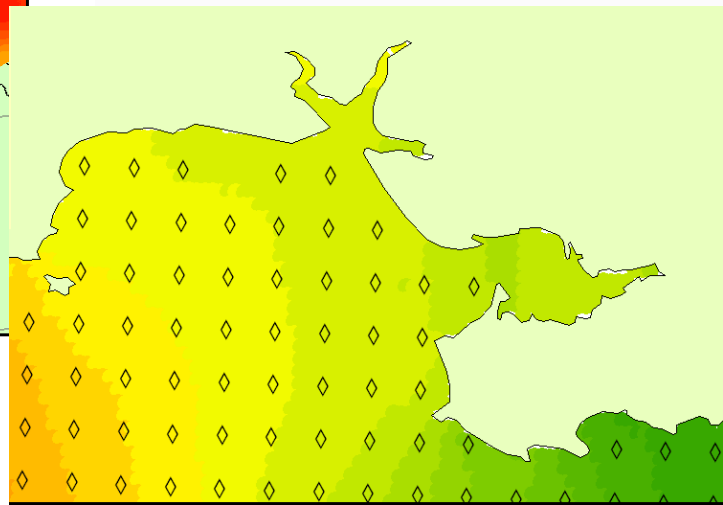
Tidal modelling



Numerical models assessed by comparison with tide gauges.

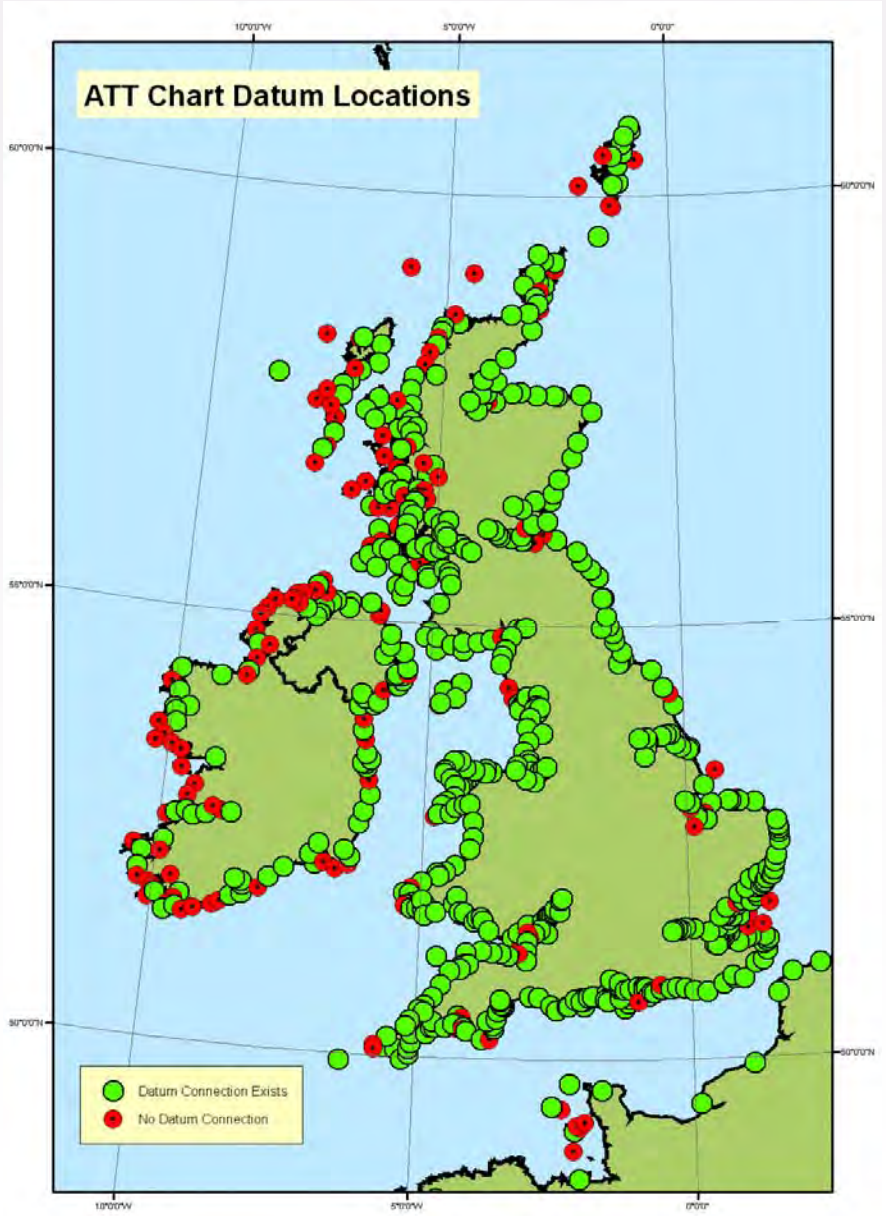
Best in open seas.

Require modification in shallow water, coastal areas, etc.

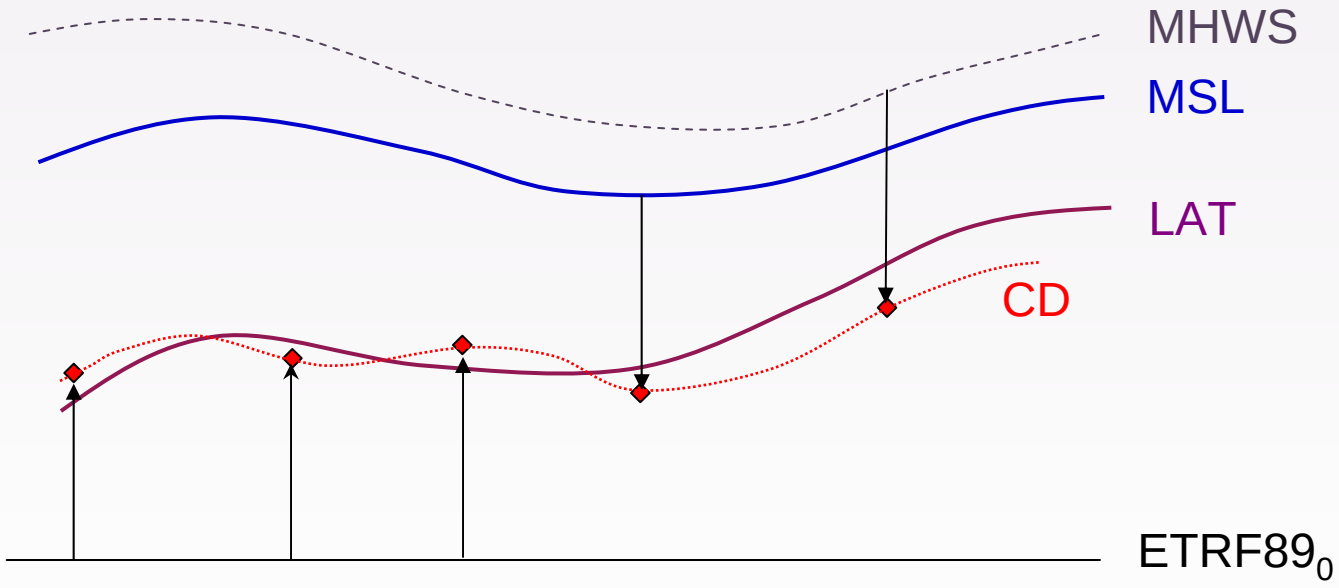


Modelling: Chart Datum

- VORF unifies all these separate datums into one, seamless surface
- Process involves verifying the link between CD and OD (the OS land height datum)

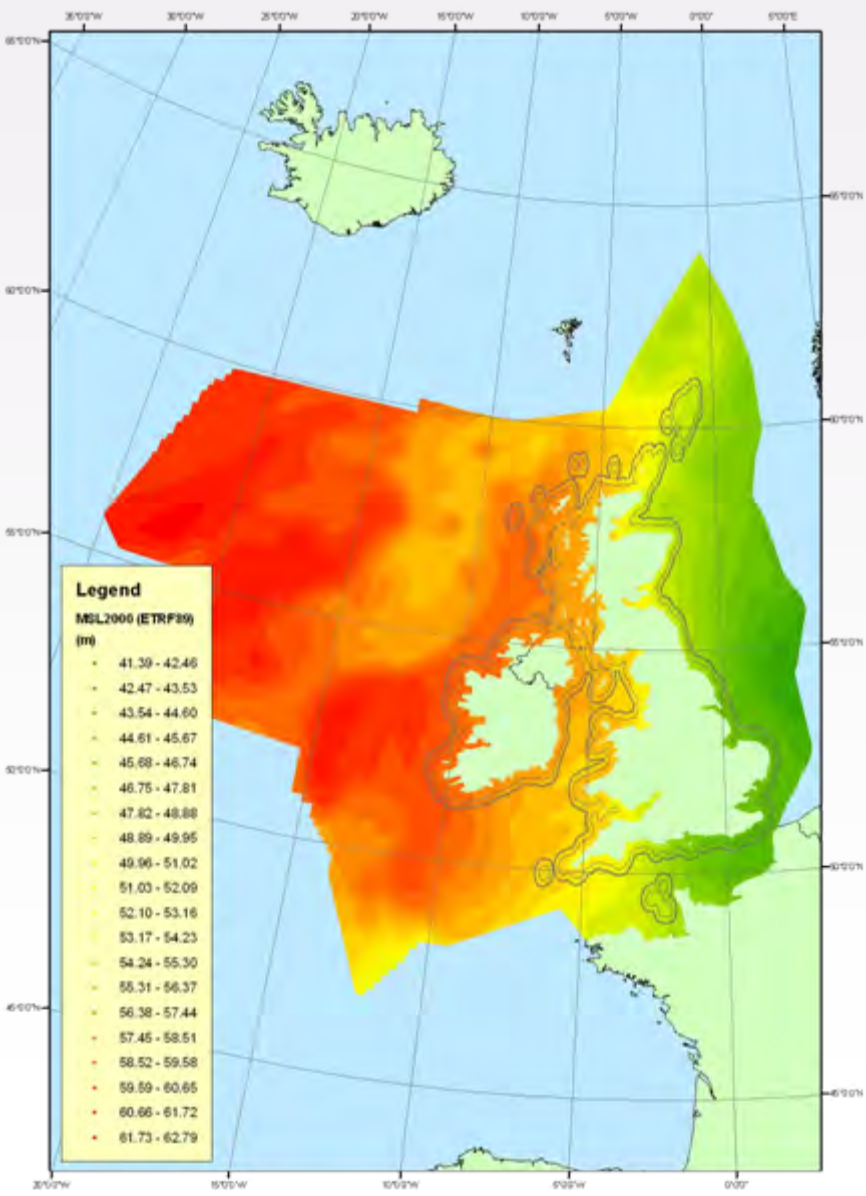


Modelling: Chart Datum interpolation



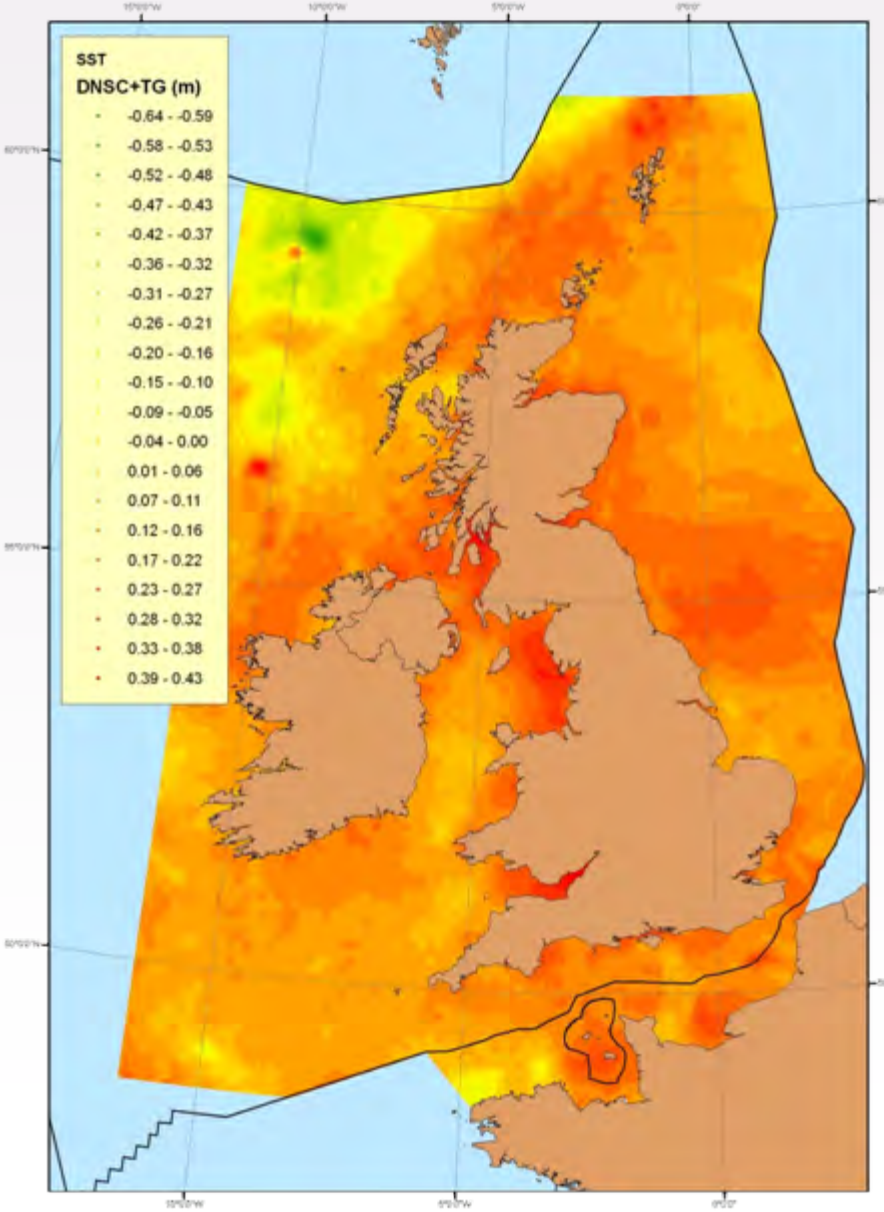
Science results (1): Mean Sea Level model 2000 above GRS80/ETRF89

- High spatial resolution model of mean sea surface directly compatible with GPS navigation
- Tightly controlled and estimated using multiple observation types



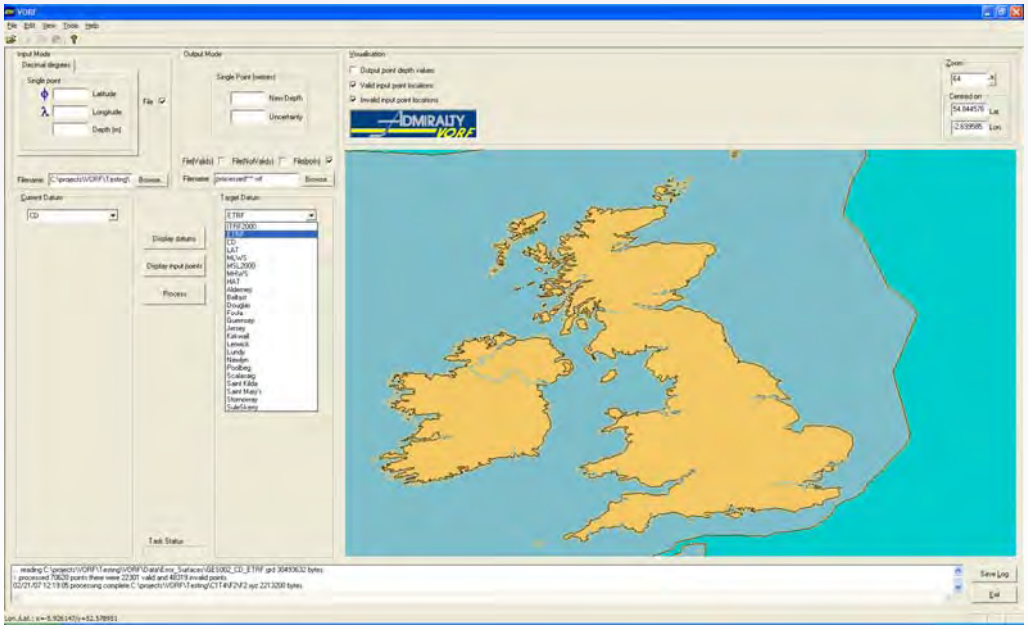
Science results (2): New UK Sea Surface Topography Model

- Sea surface topography model for inshore and offshore waters
- Successful conclusion of the largest ‘research’ element of project



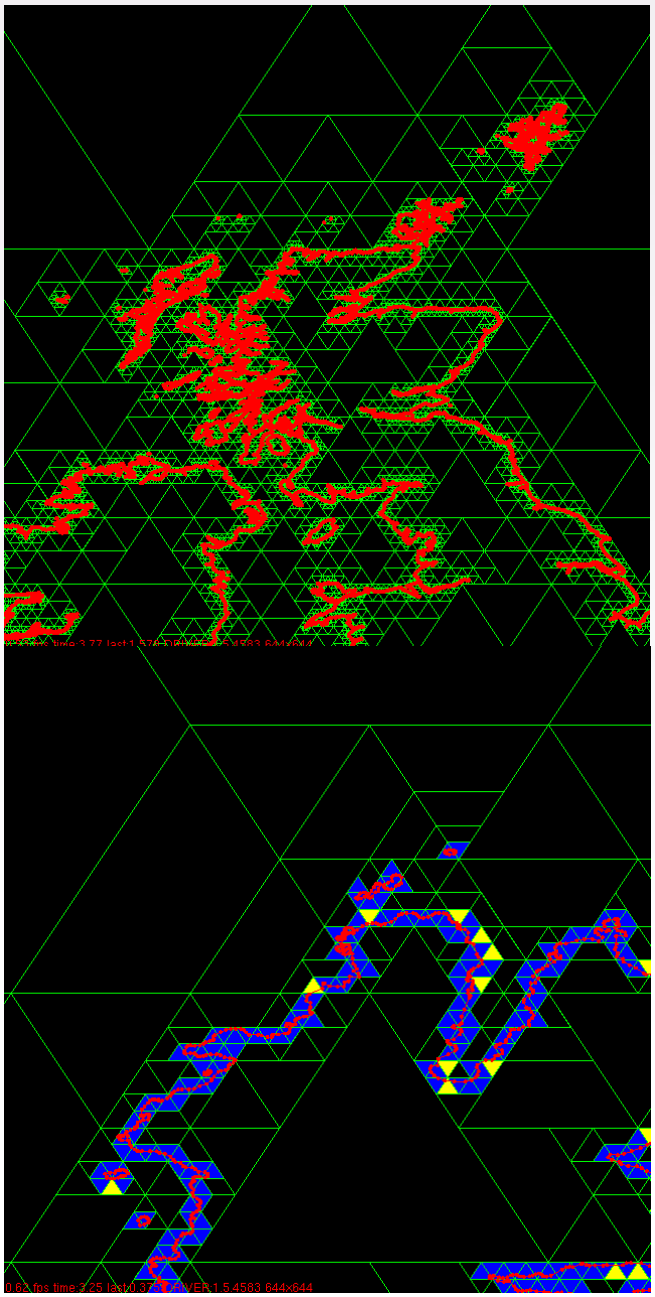
VORF software functionality

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



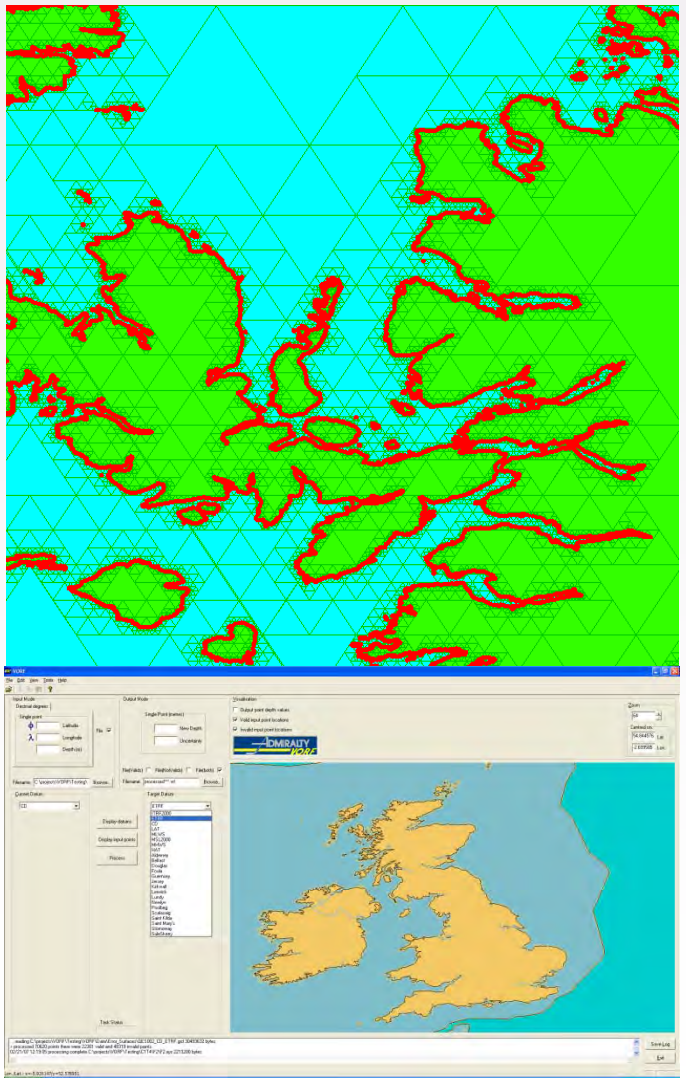
Point in Polygon (PiP) Test Requirements

- Transformation process requires PiP validation of allowable transforms
- Hydrographic data => huge data volumes (multi Gb)
- Conventional approach could make VORF unusable
- UCL has developed new concept in high performance PiP tests
- Technique based on quadtree subdivision of analysis space



Ultra Rapid Point in Polygon (PiP) Benchmark Tests

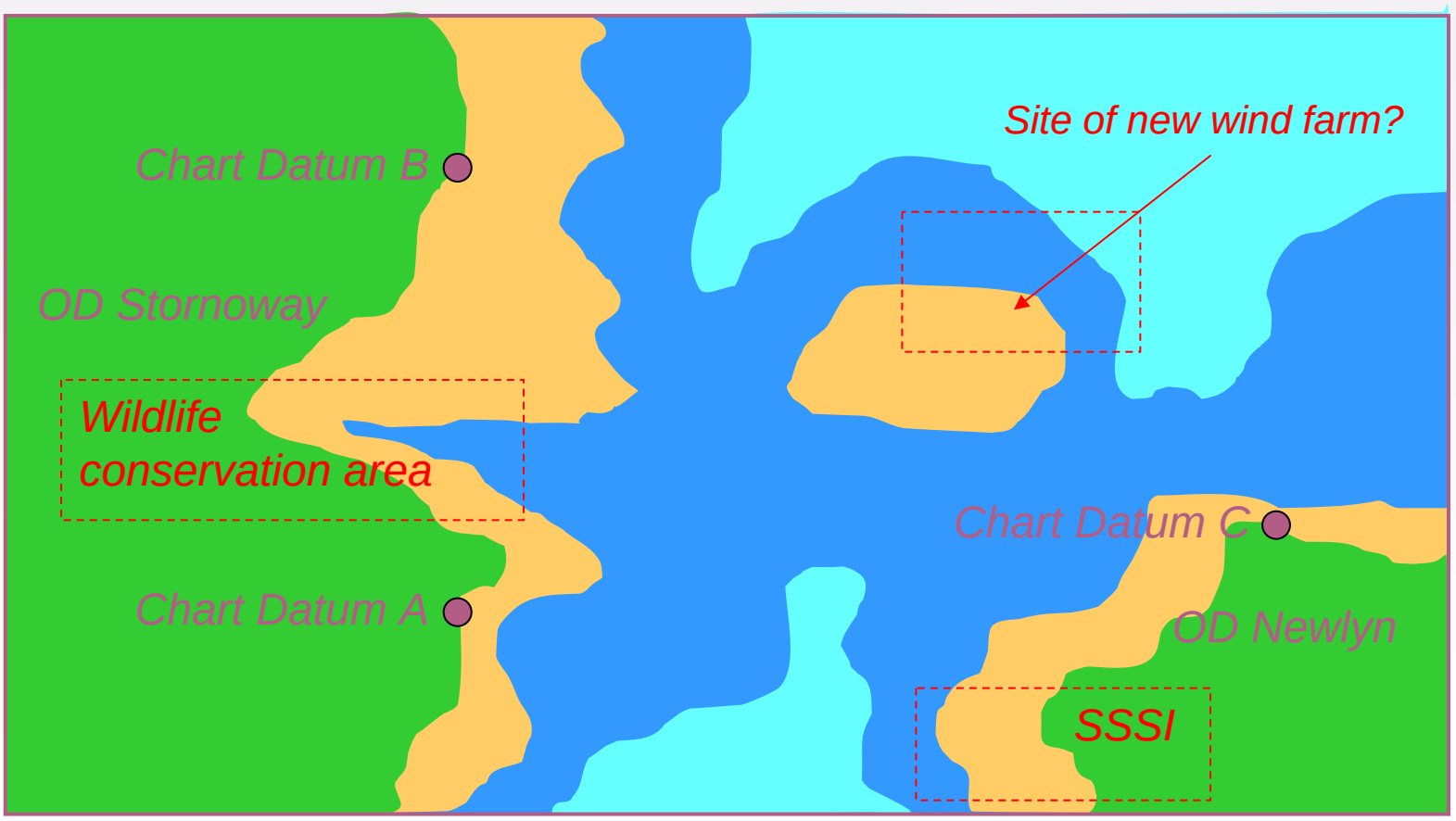
- 400,000 line segment polygon set
- Conventional desktop PC (1 Gb RAM, 3 GHz processor)
- 8,000,000 queries carried out correctly in 16 seconds (including file reading)



Applications: Cost and Efficiency of Surveys

- Reduces complexity in survey operations
- Enables easier access to a consistent, seamless datum
- Enhances quality control
- Reduces costs

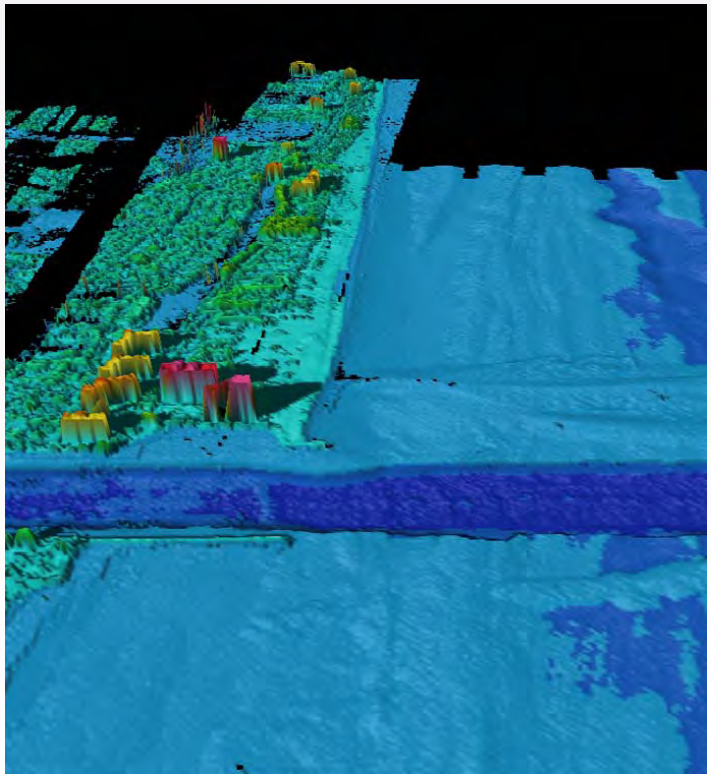
GIS applications – coastal zone projects



Linking land and sea data

Applications: Dealing with non-Chart Datum source data

- Some modern data acquisition systems present data directly in GPS datums
- SHOALS LIDAR data records coastline and shallow water topography
- VORF enables direct merging of LIDAR data with hydrographic databases



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 GNSS technology, and is the basis for future accuracy enhancements.

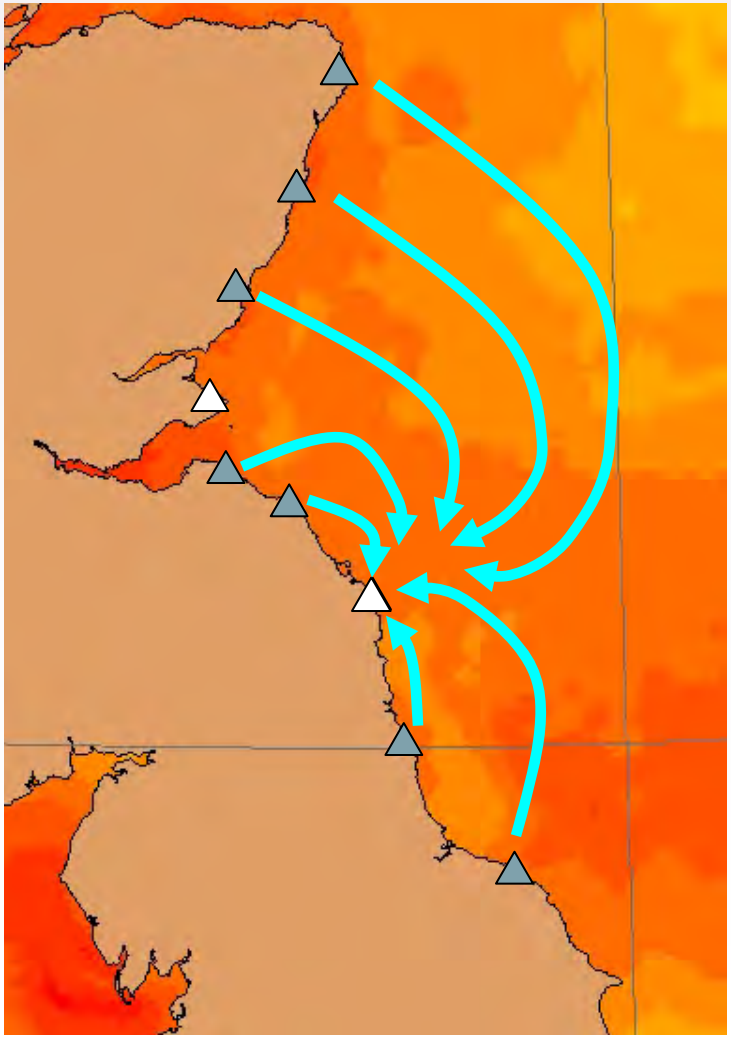
Progress to date

- Technology demonstrator delivered to UKHO December 2006
- Proof of concept established
- Tests of precision, stability, functionality and performance all complete
- Operational surfaces computed and delivered to UKHO
- Interest shown by GPS receiver manufacturers
- Initial sea trials carried out

Accuracy – how well has all this worked so far?

- Tests of interpolating and extrapolating sea level
- Initial sea trials

Interpolating/predicting sea level at a point



Knowing sea level at these points ▲
we needed to work out the sea level
at some other point △

Fundamental mathematical
building block in VORF

Test:

1. Remove known stations from dataset
2. Use the others to predict the value
3. Compute *known – predicted*
4. Repeat this all around coast
5. Compile statistics

RMS prediction error around whole UK coast = 7 cm

Initial Sea Trials

- Survey carried out off Thames estuary
- Conventional approach used: Tide gauge at coast and co-tidal charts used to reduce soundings
- Soundings also reduced using GPS/VORF
- No significant bias between two surveys
- RMS scatter in differences ~ 7 to 9 cm
- Strong validation of concept

Offshore Height from GPS/GNSS?

- For survey applications VORF is ineffective without accurate ellipsoidal height estimates of the vessel
- Conventional DGPS gives low precision height, but:
- C-NAV capabilities (height uncertainty ~10 cm)
- Long range RTK modelling (height uncertainty <10 cm)
- Ordnance Survey OSNet technology
- Explosion in new GNSS constellations and signals

What's happening to GNSS?

- GPS is being 'modernised'
  - Started in 2005
  - Civilian code on L2, new L5 signal
- GLONASS is being 'refurbished'
  - Will probably add CDMA (when?)
- Galileo is fully funded and going ahead
  - Two test satellites in orbit, 4 IOV currently in clean room at Astrium, Portsmouth
- Compass signal structure released
  - One MEO and several GEOs in orbit
- Several new SBASs

Features of some or all new GNSSs

- Separation of civilian and military functions
  - Good and bad!
- New signal structures
  - Short/long codes, BOC modulation, pilot signals
- Built-in integrity (SoL) – protected frequencies
- Increased power
- Three (at least) ‘open service’ frequencies
- Better clocks

GNSS into the Future

- 120(?) MEO satellites
  - Four interoperable and compatible systems
- 20(?) GEO satellites
- Extensive ground networks
  - With free and commercial services
- ‘Amazing’ new signal characteristics
  - Massive choice of ‘methodologies’
  - Separate and combined solutions

Next generation GNSS receivers

- 100+ tracking channels
- Forwards compatible with all future constellations
- Multi-frequency
- NTRIP enabled
- Commercially available now

Latest developments

- Scoping study for Royal Navy on VORF for the Arabian Gulf
- EU funding (INTERREG) for North Sea model – at least to assess complications such as fjords and other hydrodynamic regimes
- New OS network solution and GPS corrector surface (aligned to EUREF)

Conclusions

- VORF: as a research and technology demonstrator – concept has been proven to work
- Operational models have now been supplied to UKHO
- GNSS – new constellations and signals will improve real-time accuracy offshore dramatically
- VORF links UKHO data and products directly to GNSS measurement technologies – and copes with vast data volumes
- VORF is an enabling technology:
- Surveying without tide gauges – cheaper, faster, more accurate
- Lidar data – transform directly from WGS84 to CD/Newlyn
- Management and integration of legacy datasets
- Access to a common datum
- Most importantly: VORF joins the land and the sea – data sets/measurement techniques/services, all can be integrated