Joining Up Land and Sea

The UKHO/UCL Solution – VORF, Vertical Offshore Reference Frame

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For over 150 years traditional bathymetric and topographic measurements have been collected independently to serve different purposes. Today depth and height data tend to be referred to different vertical datums which creates inconsistency across the land-sea interface. Depth datums, in particular are usually referred to local tidal datums (Chart Datums) connected to the local height datum at a limited number of discrete points. In this paper we discuss the development of a vertical surface separation model that will allow easier assimilation of land and maritime data sources resulting in seamless vertical data. The future possibilities of having data which can easily be output on different vertical datums are not to be understated. These applications range from the enablement of real-time bathymetric data reduction without the need for tide gauges to new concepts in marine navigation and safety. Will the imminent arrival of the United Kingdom Hydrographic Office Vertical Offshore Reference Frame (VORF) meet this challenge?

Commissioning

The requirement for VORF arose from earlier research and projects involving the creation of an integrated coastal dataset from existing data, such as ICZMap®. There was increasing difficulty in assimilating land and sea data in the vertical dimension due to poorly understood relationships between the datums and surfaces that cross the land-sea boundary. In July 2005, a contract was awarded to University College London to develop a technical demonstrator. Subcontracts were issued to Proudman Oceanographic Laboratory and the Danish National Space Centre. This is enabled by a mathematical model that underpins the VORF concept, focussed on home waters. Led by Dr Jonathan Iliffe and Dr Marek Ziebart of the Department of Geomatic Engineering with full time research fellows Dr James Turner and Mr João Oliveira, the first software demonstrator version will be delivered to the UKHO by the end of this year.

The Challenge

The aim is to refer vertical height/depth data to a consistent reference frame (such as ETRF89). On land this is (relatively) straightforward to resolve. At sea, however, data is referred conventionally to Chart Datum – which approximates to the tidal level of approximately Lowest Astronomical Tide. Chart Datum is not a seamless reference surface, it varies from location to location. It is established based on local water level measurements at discrete locations but its surface offshore is often less well known. Key elements of the challenge lie in developing a methodology for relating Chart Datum to the ellipsoid underlying the global datums used in GPS data acquisition. This will result in not only an accurate representation of Chart Datum, and its relationship with all other relevant surfaces, but also a system that runs efficiently whilst handling the vast amount of data acquired by modern survey instruments.

Seven Hundred Datums

On the horizontal datum front the UKHO has made great progress relating charts to WGS84 Datum (ETRF89 in UK Waters). However, for a full understanding of the
connections between datasets the relationships between vertical datums must be known. Heights on land in the UK are established to around a dozen different datums whilst depths at sea are given with respect to over seven hundred Chart Datums. Connecting land, sea and satellite datums needs to be established to achieve maximum interoperability between data sets and exploit the latest data acquisition technology. Integrating GPS technology into the acquisition of hydrographic data, using LIDAR in coastal zones and matching Ordnance Survey data on land with bathymetric data has important consequences. With increasing interest in the coastal zones with projects ranging from leisure developments to flood prevention schemes and offshore wind farms means this gap urgently needs plugging.

VORF Approach

To model the relationship between Chart Datum and other vertical reference surfaces UCL collected and validated a variety of sources including:

- A mean sea surface model in the open oceans derived from satellite altimetry
- Geoid model OSGM05. (Derived from the OSGM02 model combined with long wavelength gravity field data from the GRACE)
- Tide gauge data from the UK Permanent Service for Mean Sea Level (PSMSL) for all UK primary tide gauges, circa 60 data sets. This data consists of monthly mean sea level, typically spanning 10 years or longer (see Figure 1)
- Tide gauge data from Admiralty Tide Table (ATT) stations, comprising some 700 data sets. These observations typically span short periods of time (1-12 months), and go back as far as 1855 (also shown in figure 1).
- GPS derived ellipsoidal heights at specific tide gauge locations
- Bathymetric models for tidal modelling

![Figure 1: Sources of tidal data assimilated into VORF](image)
VORF Modelling

The two most significant steps in the VORF modelling process are (i) creating a model of the mean sea level at the reference epoch 2000 across the study area and (ii) determining lowest astronomical tide (LAT) with respect to this. The position of LAT in ETRF89 is fundamental to establishing the position of Chart Datum.

In the open oceans the mean sea level model was derived from satellite altimetry observations. Near shore the most accurate data source is the network of permanent tide stations. Both the altimetry and tide stations refer MSL to GRS80, the satellite altimetry observations directly, and the tide stations usually through a geoid/datum connection. To cover the 20/30km gap between the offshore altimetry data and the onshore tidal information, UCL developed new mathematical models of the relationship between the tide gauge measurements and the altimetry that capture the way in which the coastal morphology influences their interdependence, and this includes interpolating the sea surface topography (SST) this being the difference between mean sea level and the geoid (see Figure 2). As well as modelling LAT and MSL against ETRF89, tidal surfaces have been created for Mean Low Water Springs (MLWS), Mean High Water Springs (MHWS) and Highest Astronomical Tide (HAT) giving increased functionality to VORF.

Benefits

The VORF project is a fundamental step in allowing UKHO to assimilate data from suppliers and customers in vertical reference frames other than the currently used Chart Datum. It will also aid high accuracy surveying with GPS and LIDAR to determine the tidally-defined shorelines such as Mean Sea Level (MSL), storm surge modelling, sea level rise studies, ecosystem studies, coastal zone management and proactive disaster mitigation planning. Additionally, further developments in global positioning and 3-D navigation may require the presentation of hydrographic information on reference frames other than Chart Datum. The demonstrator is scoped to cover the UK Continental Shelf, the Channel Islands and Republic of Ireland and is designed to solve the datum anomalies such that each data set can be run through the transformation software and all brought into one common reference frame.

Assessment
VORF’s full capability as an operational application will not be determined until, at a minimum, a full appreciation of the safety implications of the tool is understood. It will be extensively tested for accuracy and functionality by the UKHO Geodesy section. This assessment of the demonstrator is scheduled for completion early 2007, at which time a decision will be made on the way forward. As well as providing a key tool to the assessment of incoming survey data to the UKHO, it is likely that it could be incorporated as an additional feature to GIS packages or integrated into electronic navigation and charting systems. The VORF project is part of the Production Systems Programme which involves ongoing work to develop cutting edge data management and production facilities within UKHO. 117/150

**Future Applications**

Once VORF is fully available how can it be applied?

For those involved in hydrographic surveying, survey vessels equipped with kinematic GPS and VORF navigation will be more precise. It should negate the need to depend on remote tidal readings, dynamic vessel draught and, depending on the accuracy of the technology, will aid in the measurement of vessel heave. For example, a super-tanker with GPS and VORF, making its way through the Dover Strait with a tight under keel clearance, will effectively be its own tide gauge and know to a few centimetres its position over obstacles and shoals. Consider also the benefit to environmental systems, coastal zone management and marine boundary delimitation, with LIDAR being used to acquire new data of the inter-tidal zone prior to modelling storm surges and their impact on the coast. 137/150

Finally, the additional cost savings to surveyors compared with existing time consuming and expensive methods of data collection cannot be ignored. The land and the sea may be two totally different environments, but more and more people want to know how they interact. The VORF concept is the vital link between the two. 53/150

**Biographies**

Ruth Adams is a programme manager for the Maritime Systems section delivering projects to meet the needs of the Mariner. Before this she was Head of Additional Military Layers, Staff Officer and Head of Geodesy and Imagery.

She has a first class degree in Surveying Sciences from the University of Newcastle upon Tyne and is a Fellow of RICS. Until recently she was heavily involved in FIG Commission 4, Hydrography. She is vice-chair of the RICS Geomatics Faculty. 68/50

Jonathan Iliiffe is senior lecturer in geodesy at the Department of Geomatic Engineering, University College London, with research interests in datums and coordinate systems.

Marek Ziebart is a reader in Space Geodesy at the same institution. His research involves spacecraft orbit determination, reference frame definition, and modelling of GNSS observables.

Jim Turner is a research fellow at UCL Geomatic Engineering with a background in mathematical modelling of spacecraft orbits.

Joao Oliveira is also a GE research fellow with long experience in various aspects of computer science research.

*Extracts from THE VORF PROJECT – JOINING UP LAND AND MARINE DATA and A guide to Developing a vertical reference surface for hydrography – RICS/FIG.*