UKHO/UCL VERTICAL OFFSHORE REFERENCE FRAME

Joining Up Land and Sea

Development of a vertical surface separation model will allow easier assimilation of land and maritime data sources, resulting in seamless vertical data. The future possibilities of having data that can be easily output on different vertical datums cannot be overstated. The imminent arrival of the United Kingdom Hydrographic Office Vertical Offshore Reference Frame (VORF) may meet this challenge.

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, creating 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. The UKHO/UCL Vertical Offshore Reference Frame project will provide the capability to seamlessly join land and sea surfaces across the shore, extend the knowledge of vertical datums and reference surfaces offshore and enable the transformation of height and depth between a number of vertical datums and reference surfaces, without the need for tide gauges.

The Commission
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, focusing 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 JoÃ£o 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 conventially 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 and 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 ised 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 in a system that runs efficently whilst handling the vast amout 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 datasets and to exploit the latest data-acquisition technology. Integrating GPS technology into the acquisition of hydrographic data, using Liddar in coastal zones and matching Ordnance Survey data on land with bathymetric data, has important consequences. With increasing interest in coastal zones and projects ranging from leisure developments to flood-prevention schemes and offshore wind farms, 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:

- mean sea-surface model in the open oceans derived from satellite altimetry
- Geoid model OSGM05, derived from 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 sixty datasets; data comprising monthly mean sea-level, typically spanning ten years or longer
- tide-gauge data from Admiralty Tide Table (ATT) stations, comprising some seven hundred datasets; observations typically span short periods of time (one to twelve months) and go back as far as 1855

- GPS-derived ellipsoidal heights at specific tide-gauge locations
- bathymetric models for tidal modelling.

VORF Modelling
The two most significant steps in the VORF modelling process are (1) creating a model of the mean sea level at the reference epoch 2000 across the study area and (2) 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 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 directly to GRS80, the satellite altimetry observations, and the tide stations usually through a geoid/datum connection. To cover the 20/30km gap between the offshore altimetry data and the on-shore 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 independence, and this includes interpolating the sea-surface topography (SST) this being the difference between mean sea level and the geoid. As well as modelling LAT and MSL against ERTF89, 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 represents 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 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. Addition-ally, further developments in global positioning and 3D-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 datum anomalies such that each dataset can be run through the transformation software and all brought into one common reference frame.

Assessment
The full capability of VORF 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 in early 2007, at which time a decision will be well on the way. As well as providing a key tool for the assessment of incoming survey data to the UKHO, it is likely that VORF could be incorporated as an additional feature in GIS packages or integrated into electronic navigation and charting systems. The VORF project is part of the Production Systems Programme that involves ongoing work to develop cutting-edge data management and production facilities within UKHO.

Future Applications
Once VORF is fully available how might 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 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 for the inter-tidal zone prior to modelling storm surges and their impact on the coast.

Finally, the additional cost savings to surveyors as compared to existent 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.