Dual-frequency GPS survey for validation of a regional DTM and for the generation of local DTM data for sea-level rise modelling in an estuarine Salt Marsh.

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1. Background

Global average temperatures have risen by an average of 0.07°C per decade over the last 100 years, with a warming trend of 0.13°C per decade over the last 50 years. Temperatures are predicted to rise by 2°C - 4.4°C by 2100 leading to global average sea-level rise (SLR) of 2 – 6mm per year (20 – 60cms in total) up to 2100 (IPCC 2007) with impacts for protected coastal habitats in Ireland.

Estuaries are predominantly sedimentary environments, and are characterised by shallow coastal slope gradients, making them sensitive to even modest changes in sea-level. The Shannon estuary is the largest river estuary in Ireland and is designated as a Special Area of Conservation (SAC) under the EU Habitats Directive (EU 1992) providing protection for listed habitats within it, including estuarine salt marsh.

Trends in Shannon estuary tidal data from 1877 – 2004 suggest an average upward SLR trend of 4 - 5mm/yr over this period. A simple linear extension of this historical trend would imply that local SLR will be in the region of 40 - 45cm by 2100. However, this may underestimate actual SLR for the estuary by 2100, since it takes no account of predicted climate-driven global SLR acceleration (IPCC 2007) up to 2100.

2. Sea-level rise modelling in GIS

Much work has been done to model SLR in Geographic Information Systems (GIS) (Titus & Richman 2001, Hennecke & Cowell 2000) and additional work has been carried out to assess the significance of DTM error on SLR predictions (Cowell & Zeng 2003, Blomgren 1999). Opportunities exist however to consider DTM quality for Ireland and to develop reliable SLR prediction methods in an Irish context. The sensitivity of the Shannon estuary to SLR and its designation as a habitat conservation area suggests that it is a suitable location to develop techniques supporting reliable SLR modelling for coastal conservation in Ireland.

3. Scope of Shannon assessment

This paper discusses some of the questions that have been explored in terms of refining the accuracy of sea-level rise modelling in a salt marsh complex in the region of Shannon town. Predictions are based on the observed tidal data, and utilise Intergovernmental Panel on Climate Change (IPCC) predictions (IPCC, 2007) for global SLR up to 2100. The significance of regional post-glacial land-surface rebound (Devoy, 2000) predicted SLR acceleration (IPCC, 2007) and local deposition trends are also considered.

The generation of meaningful SLR prediction maps in a Geographic Information System (GIS) presupposes the existence of highly accurate Digital Terrain Model (DTM) data. The Ordnance Survey Ireland (OSi) 1:50,000-scale spot height and contours dataset provides the basis of the national coverage DTM dataset for Ireland. However, vertical errors in this dataset are quoted at ±5m, suggesting that it is unsuitable for SLR modelling. OSi vector mapping at larger scales does however provide some additional height-encoded coastal data that might be used to augment the national coverage DTM at the coastline. This question is examined using dual-frequency (i.e. survey-grade) Global Positioning Systems (GPS) survey. The OSi DTM for Ireland is currently being upgraded with aerial 'LIght Detection And Ranging (LIDAR) survey data (characterised by vertical errors of ±15cm) but coverage is as yet limited to major urban areas, and plans to extend surveys beyond these areas are at an early stage. Separate aerial LIDAR surveys of the coastline have also commenced, under the auspices of the Irish Department of the Marine, but as yet these surveys have not extended to include the Shannon estuary. The need for high-quality DTM for effective SLR modelling, coupled with the lack of accurate DTM data for the Shannon estuary study area, created a need for a newly generated local DTM from first principles.

3. Methods

Dual-frequency GPS survey data is capable of defining elevation to a precision of 1 – 2cm relative to the local OSGM02 geoid when post-processed against OSi GPS reference station data. Dual-frequency GPS survey data was collected for a salt marsh complex located to the south of Shannon town and post-processed against OSi GPS refence station data from the OSi GPS reference station at Limerick University. The results of this survey were compared with the national coverage DTM to quantify and classify the error ranges encountered within the OSi dataset, and to provide a high-quality point dataset for the generation of a local DTM for SLR prediction in GIS. The spatial extent of the GPS survey area was extended beyond the limits of the salt marsh complex to cover a range of OSi spot height and contour elevation values for the error assessment. Extension of the GPS point survey also offered an opportunity to map elevation in urban coastal areas landward of local coastal defence barriers. The area defined for these assessments was sub-divided into an initial network of 250 sub-blocks, measuring 100x100m, providing a sampling framework for the dual-frequency GPS survey. A Trimble R8 dual-frequency differential GPS receiver was used to capture 250 x,y,z coordinate points relative to the Irish WGS84/ETRS89 Ellipsoid and the local OSGM02 geoid at an average horizontal separation of 80m. GPS points were recorded in fast-static mode, which provides better elevation accuracies than is currently possible with the (beta version) OSi real-time GPS network. Trimble Geomatics Office (TGO) software v.1.62 was used to post-process the survey points against Receiver Independent Exchange Format (RINEX) data from the

OSi GPS reference station at Limerick University. The average vertical error in the GPS captured points after post-processing was 11mm, with a maximum vertical error of 35mm, and a minimum error of 4mm. Locations that corresponded with points on the OSi spot height and contour datasets were identified and surveyed with the Trimble R8. The difference between the GPS and OSi elevations at the spot heights and points sampled along the OSi 10m and zero contours were broadly within published OSi ranges. The vertical accuracies achieved across the entire GPS survey area suggest that dual-frequency GPS is a reliable source of base data for the generation of a DTM of sufficient quality for use in SLR prediction mapping.

It was possible to evaluate the accuracy of the OSi coastline definition by reference to GPS measurements relative to the geoid locally, but systematic vertical separation between the OSi definition of zero elevation and the measured elevations was observed. Local tidal regimes and a range of diverse definitions of zero are likely to account for the systematic separation observed (different methods typically include Mean tide mark, mean high-water mark, and highest astronomical tide mark). An additional problem exists however with definition of the absolute coastline using GPS. Collection of a network of elevation-encoded points is extremely accurate, but definition of a coastline using GIS would have required substantial offshore GPS surveying. This difficulty can be overcome with the use of Terrestrial LIDAR survey.

4. Additional work planned

Terrestrial LIDAR offers even greater scope for the generation of a high-quality local DTM data, typically returning vertical accuracies of less than 2cm, at an average horizontal ground-sampling density of better than 10cm. Terrestrial LIDAR surveying will be carried out using a Leica Scanstation instrument in a sub-section of the GPS survey area. This approach is expected to overcome difficulties in the definition of the salt marsh edge, and will provide a substantially more detailed DTM than the GPS survey. Final DTM products will be used as an input into a multi-variable model of salt marsh change in GIS.

A crucial question alluded to above is the degree to which local deposition rates might affect observed SLR in the estuary. Field observations suggest that sections of the salt marsh complex may be experiencing accretion, while other locations appear to be subject to erosion. In addition, the GPS survey reveals that salt marsh areas seaward of the reclamation barrier are approximately 1m higher than the land surface behind the reclamation barrier, suggesting that that existing salt marsh on the seaward side of the barrier has experienced significant build-up since the barrier was put in place approximately 100 years ago (dates derived from map and documentary sources). A network of 35 silt measurement pans was set up at intervals of approximately 500m along an 8km stretch of coast in the study area. Initial silt deposition survey results suggest variable rates of up deposition of 0 - 60mm/yr, suggesting geographical variation of erosion and deposition.

The final results of the silt measurement information (a six month period of measurement is half completed) will be used as reference data for the generation of a multi-variable grid model of salt marsh change in GIS. This model will attempt to predict the likelihood of salt marsh occurrence with SLR up to 2100, based on elevation and slope (as defined by the locally generated DTM) in addition to grid file definitions of coastal energy gradient and erosion/deposition ArcGIS Spatial Analyst.

The effectiveness of using the DTM-derived variables and the energy gradient model as predictors for salt marsh occurrence will be tested on existing marsh areas. Based on the success of this method, cell-by-cell predictions of possible salt marsh change up to 2100 will be postulated. Management recommendations will be made based on these results.

5. Acknowledgements

This research is funded entirely by the National Centre for Geocomputation at the National University of Ireland at Maynooth. Base Ordnance Survey Ireland digital data utilised in this project is provided under an OSi sub-contract agreement on the OSi digital licence for Clare county council.

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