

The main achievement of the project is the creation of a map of current vertical land movements in the UK based on an optimal combination of two geodetic surveying and monitoring techniques; the measurement of absolute gravity (AG) and the use of high precision, continuous GPS (CGPS). This meets specific objective (ii) of WP1.9 of the Oceans 2025 programme, which is related to priority topic area 4 (application of satellite geodesy to sea level science) of the NERC Strategic Ocean Funding Initiative (SOFI). Two other achievements are: (1) the results and outputs have already been used in the recent UK Climate Projections (UKCP09) reports, where vertical land movements are combined with model predictions of future changes in sea level to better assess future changes in sea level with respect to the land; (2) the research has acted as a proof-of-concept study, with the processing strategy and scripts developed, the results obtained and the experience gained from the processing and analysis all being transferred to NERC BIGF who will be responsible for the future refinement of the map.

These achievements were possible by meeting each of the four main objectives, as follows:

- (i) New coordinate time series were produced in ITRF2005 from a high level processing, resulting in 3 to 12 years of daily position estimates for 127 CGPS stations in the UK.
- (ii) New estimates of vertical station velocity and their uncertainty were produced for the 127 CGPS stations from an analysis of their time series. In terms of precision, the uncertainties were in the range of  $\pm 0.2$  to 1.1 mm/yr (1-sigma). In terms of accuracy, a comparison with AG vertical station velocities was carried out at two co-located sites (Lerwick and Newlyn) and, as seen previously, it was found that the CGPS vertical station velocities were too positive, this time by about 1.1 mm/yr.
- (iii) A rigorous assessment of the suitability of all 127 CGPS stations for the purpose of providing reliable estimates of vertical land movements was then carried out. Based on a study of the time series, 87 of the 127 were originally excluded due to unacceptably large (greater than 0.5 mm/yr) velocity uncertainties, mainly related to their time series being less than 6 years in length. However, 16 of those excluded were subject to a further, dual-CGPS analysis, and were then re-included, giving a new total of 56. Following this, from a detailed consideration of local environment, monument type and foundation, and local site geology, each CGPS station was given a site suitability rating. This led to 10 of the 56 being rejected, as having possible vertical motion not due to glacio-isostatic adjustment or natural compaction, resulting in a final total of 46 CGPS stations considered, at this stage, to provide reliable estimates of vertical land movement.
- (iv) The optimal combination of AG and CGPS was considered to be achieved by aligning the 'over positive' CGPS to the more realistic AG vertical station velocities, using the two co-located sites.

The new map of current vertical land movements was produced based on the AG-aligned CGPS vertical station velocities for the 46 CGPS stations and is presented in the figure on the right. This is generally consistent with maps of long term vertical land movements based on geological and geophysical studies, which have vertical land movements in the UK of the order of 1 to 2 mm/yr, with Scotland rising and the South of England subsiding, so that Great Britain is effectively 'tilting'. Furthermore, consistent with the maps of long term vertical land movements, the new map also shows the highest uplift centred around the area of Scotland with maximum ice at the last glacial maximum and a zero line running roughly between Liverpool and Newcastle. However, the map of current vertical land movements has a limit of 1.5 mm/yr of vertical land movement and a detailed comparison between the geodetic (current) and geological (long-term) estimates gives differences (geodetic minus geological) of between 0.7 and -1.3 mm/yr, with the geodetic estimates showing less uplift in Scotland, and less subsidence in South-West England.

The significance to the field is that this was the first attempt to create a map of current vertical land movements in the UK based on an optimal combination of AG and so many CGPS stations.

