UK Sea Level Space Watch – Monitoring Regional Sea Level Variability around the UK from Satellite Altimetry

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Sea Level Space Watch: Introduction

- Operational sea level monitoring service for UK seas, sea level variability from space-borne altimeter data, combined with tide gauge data.
- Support for national flood defence planning, supplementing UK Climate Projections with information on seasonal, regional variability
- Developed with funding from the UK Space Agency's "Space for Smarter Government Programme"

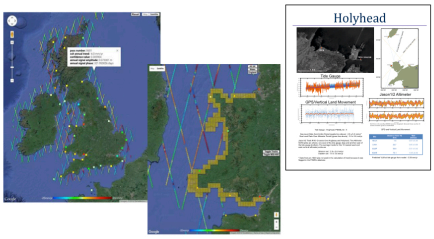

Figure 1 Screenshots from Sea Level Space Watch Web Service

What do we know about UK Sea Level Variability?

- Existing knowledge on UK sea level variability is based on analysis of tide gauge data.
- Long term trend (1900-2000) in UK Mean Sea Level is 1.4 mmyr^{-1}.
- Main source of UK regional variability in long term trends is geology – glacial isostatic adjustment
- Other regional variability on shorter scales (decadal, inter-annual) related to atmospheric variability and oceanography

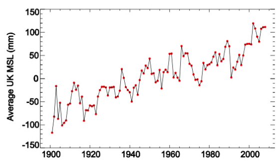

Figure 2: Average UK Mean Sea Level Change: 1.4 mm/year for the 20th century (updated from Woodworth et al., 2009)

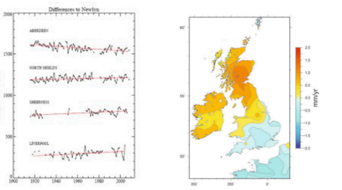

Figure 3: (left) Annual mean sea level differences with respect to Newlyn (Woodworth et al., 2009) (right) Land level movement in mmyr^{-1} (Williams, 2016)

Satellite Altimeter Data and Processing

- 14 years' satellite altimeter data processed (2002-2015):
  - Jason-1 and Jason-2 (2002-2015)
  - Envisat (2002 – 2010) and AltiKa (2013-2015)
- Altimetry data in the coastal zone need specialized waveform processing (retracking). The solution adopted in SLSW is to use a specialized coastal retracker (ALES - M. Passaro et al., Rem. Sens. Env., 2014)
- Co-located measurements on nominal ground tracks, generated (14 yr) time series
- Computed two sea level quantities:
  - TWLE - Total Water Level Envelope i.e. the actual level including tides and atmospheric forcing.
  - SSHA - Sea Surface Height Anomaly, i.e. anomaly w.r.t. the mean sea surface, with tides/atmospheric effects removed - used to derive Sea Level Rates
- Statistics for altimeter and Tide Gauge data (annual cycle amplitude and phase, long term trend, errors).
- Comparison of derived statistics from altimeter and tide gauge data showed good general agreement (Figure 7)

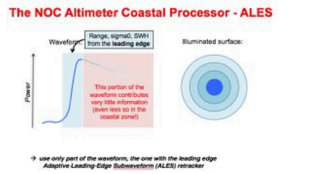

Figure 5: Operation of the NOC "ALES" altimeter coastal processor

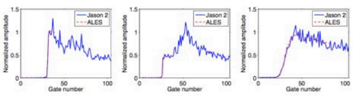

Figure 6: Examples of Jason-2 re-tracking by ALES, for SHW = 0.7m (left), 1.65m (centre), and 9.5m (right) (from Passaro et al., 2014)

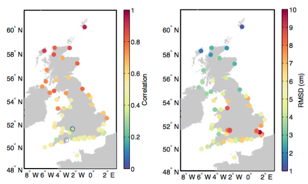

Figure 7 Comparison between de-trended, de-seasoned sea level from altimetry and tide gauges, (left) correlation, and (right) root mean square difference. Filled circles denote significant correlation at the 95% confidence level

Coastal Managers' Needs for Sea Level Data:

- Mean Sea Level Change will strongly govern future flood probabilities
- Improved information on sea level trends will support decisions on timing of (expensive) investment decisions, need to take action in time to avoid unacceptable risk.
- How will sea level rise impact on shoreline management plans and coastal habitat?
- Many 100s hectares coastal habitat potentially at risk, high cost of providing compensatory habitat.

Projected UK Sea Level Change

For long-term planning of coastal defence management, UK agencies use UK Climate Projections programme: http://ukclimateprojections.metoffice.gov.uk. UKCP09 projections show differences of up to 8cm in predicted sea level change by 2050.

The models used have limited input in terms of local oceanography, regional variability is primarily assigned to glacial isostatic adjustment.

- Can we get a better understanding of regional inter-annual sea level variability?
- Can satellite sea level data provide us with useful information on the long-term trajectory of sea level change?

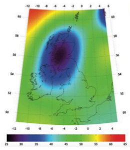

Figure 4 Projected changes in mean sea level from UKCP09: Relative sea level change around UK from 2000-2095 (medium emissions).

	London	Cardiff	Edinburgh	Belfast
2000	2.5/3.0/3.5	2.5/2.9/3.5	1.2/1.6/2.2	1.3/1.7/2.3
2020	8.2/9.7/11.5	8.2/9.7/11.5	4.3/5.7/7.5	4.6/6.0/7.8
2050	18.4/21.8/25.9	18.4/21.8/25.9	10.5/13.9/18.0	11.1/ 14.5/18.6

Table 1. Projected overall sea level rise 1990 onwards from UKCP09 L / M / H scenarios

Sea Level Space Watch Results: Sea Level Annual Cycle

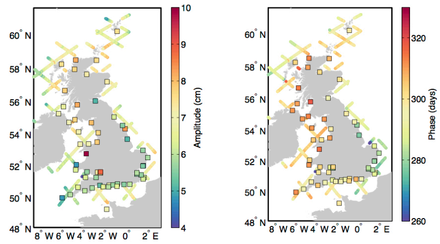

Figure 8: Amplitude and Phase of Annual Cycle in Sea Level from 2002-2015, Jason-1, and Jason-2 and UK National Tide and Sea Level Network of Tide Gauges (from Cipollini et al, Surveys in Geophysics, 2016)

An annual cycle was fitted to the SSHA data from the altimeter and tide gauge data. The amplitude and phase are shown above.

- The annual cycle peaks between early October in the south-east and early November in the west coast, the amplitude ranges from 5 to 9 cm.
- There is good agreement in the characteristics cycle fitted to the tide gauge and altimeter data

Sea Level Space Watch Results: "Long Term" Trend

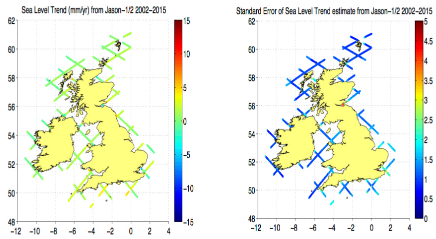

Figure 9: Annual trend and standard error in sea level for the period 2002-2015, Jason-1 and Jason-2 data

- A "long-term" trend was calculated over whole data set
- Sea level trend ~0.5 - 3.0 mm/yr. Largest at the South Coast.
- This only for 14 years, and most likely affected by shorter term inter-annual variability. A longer time series (~25-30 years) is needed

Project Outcomes and Recommendations

Results

- Estimates of the amplitude and phase of the annual cycle from altimetry and the tide gauges are consistent at most stations.
- The annual cycle peaks between early October in the south-east and early November in the west coast and has an amplitude ranging from 5 to 9 cm.
- Good agreement between the de-trended de-seasoned sea level from altimetry and tide gauges, mean correlation and RMSD of 0.57 and 5.3 cm, respectively
- Inter-annual variability highly coherent along UK coast with a std deviation of 2 to 4 cm.
- Preliminary evidence of a geographical structure in the long-term trend, larger on the South and East than in the North-West.

Recommendations

- Apply IB correction to the tide gauge data for consistency with altimetry, and to reduce uncertainties in the estimates of the trends.
- Apply consistent corrections across different altimeter data sets.
- Selection of tidal model for altimeter data is important: for UK FES 2012 seems to give lower errors than GOT410

http://www.satoc.eu/projects/sealevelsw/test.html

SatOC Satellite Oceanographic Consultants · National Oceanography Centre, Natural Environment Research Council · Space for Smarter Government Programme · Environment Agency · Cyfoeth Naturiol Cymru Natural Resources Wales · Committee on Climate Change