Global Changes in Long-Term Observed Tidal Range

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Introduction

Extreme high sea levels cause destructive flooding and erosion, while extreme low sea levels have implications for safe navigation and operation. Predictions of both are clearly of vital importance for coastal engineering, management and planning. Research has shown that extreme sea levels (ESL) generally increased at the same rate as mean sea level (MSL) through the twentieth century on a global scale, suggesting that the same mechanisms are driving both increases. However, the simplicity of this conclusion belies the fact that many mechanisms act on the different components of sea level, many of which have been found to have changed over long time scales (30-100 years) in a number of local and regional studies. This study investigates changes in the tidal component of sea level. Previous studies (Woodworth, 2011; Flick et al., 2003) have tended to focus on assessing changes in tidal constituents, but we primarily examine changes in tidal range around the world.

Data

The Global Extreme Sea Level Analysis (GESLA) dataset comprises 675 files giving a 'quasi-global' coverage (Menendez & Woodworth, 2010). The data has a sampling interval of 1 hour or less. High frequency data is essential for ESL analysis, since both the tide and surge components change over short time scales.

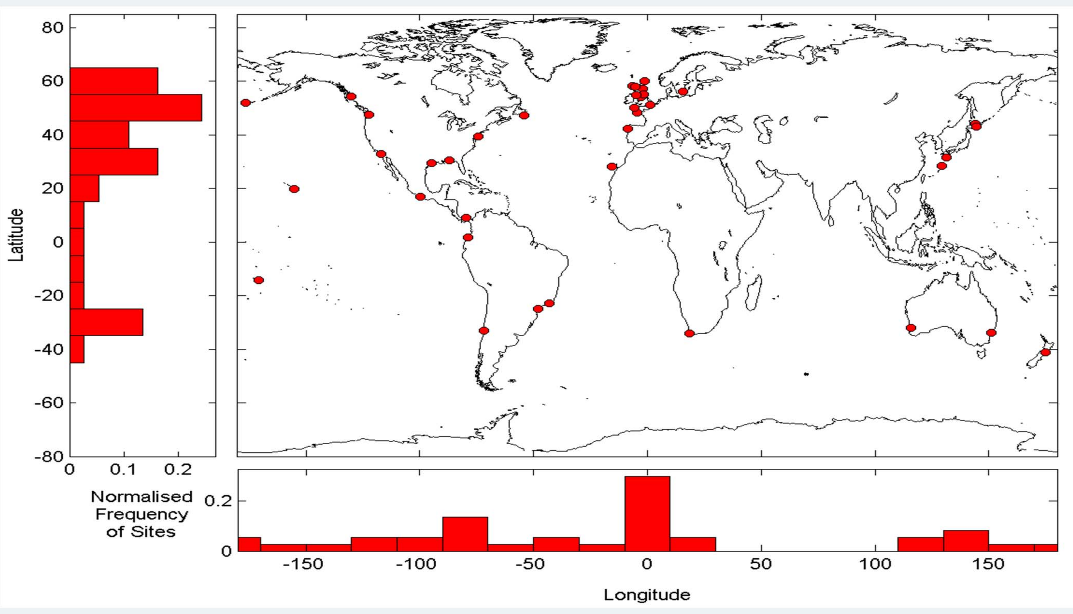


Figure 1: Position of 38 selected sites along with histogram of normalised frequency of latitude or longitude of the sites. The spatial coverage is shown to be poor in many regions.

Methodology

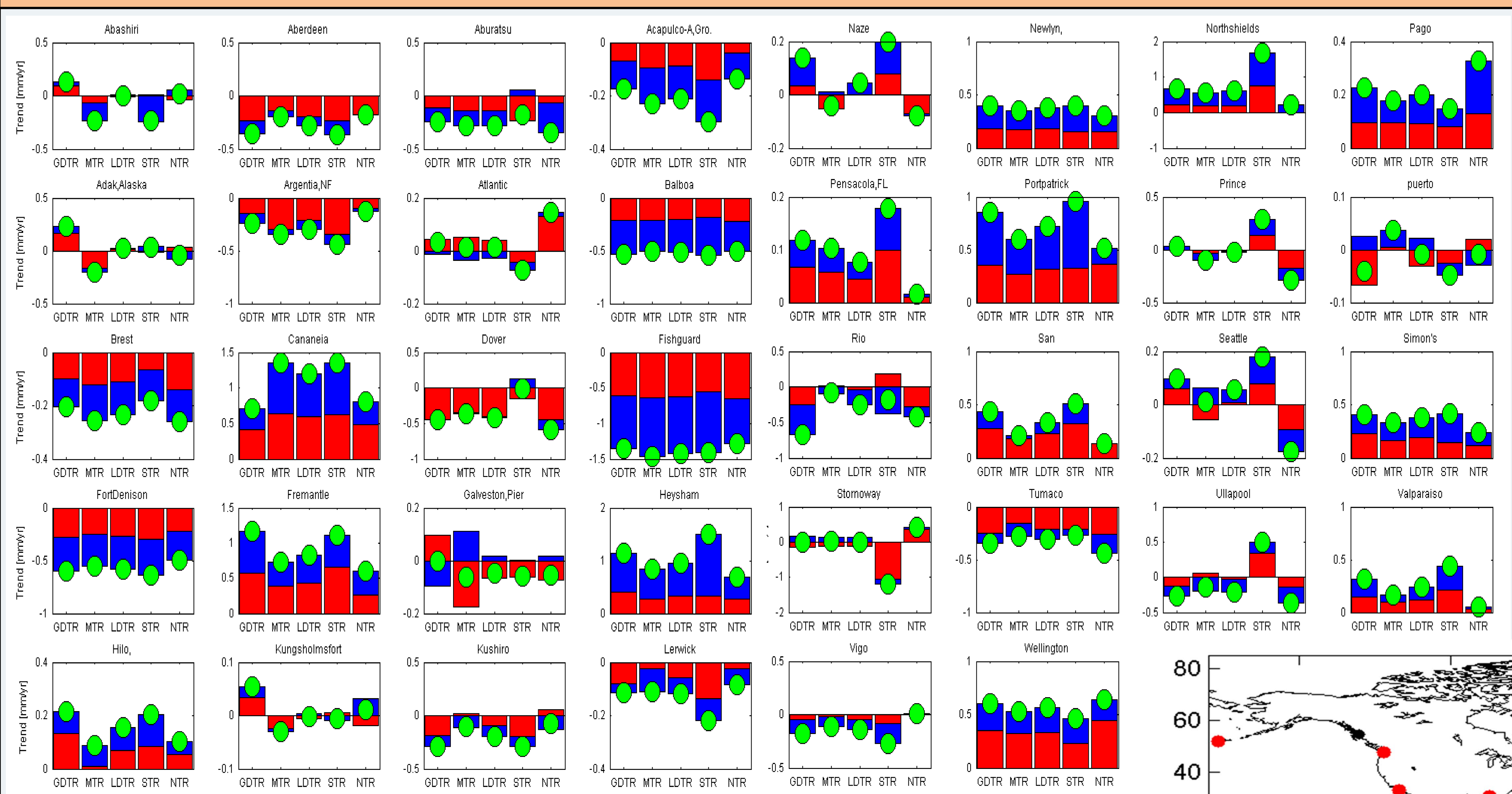
- Sensitivity tests will determine an effective threshold of data length for analysis of tides. For now datasets are required to be at least 28 years long, with 15 years data within that period (Woodworth et al., 1991). This paper presents data from the first 38 long datasets to be selected and pass this criteria (Figure 1).
- The data for each site was extended using data from UHSLC, BODC or NOAA, to the end of 2012, where possible. Data quality was checked beyond the quality control (QC) conducted by the respective data providers.
- Harmonic analysis was conducted using t_tide (Pawlowicz, 2002). This split the sea level data into its three components: MSL, tide and residual (often referred to as storm surge).
- Every high water (HW) and low water (LW) was extracted from the tide component, and from these turning points five parameters each of: tidal range, HW and LW were calculated per year (Table 1). Linear trends with a component accounting for nodal tidal signal were fitted to each of the fifteen total parameters.

Range Parameter	Calculation	Description
GDTR (Greater Diurnal Tidal Range)	MHHW – MLLW	Highest HW minus lowest LW each day.
MTR (Mean Tidal Range)	MHW – MLW	Average of all HW minus all LW.
LDTR (Lesser Diurnal Tidal Range)	MLHW – MHLW	Lowest HW minus highest LW each day.
STR (Spring Tidal Range)	MHWS – MLWS	Average of all HW minus all LW, over spring tide period.
NTR (Neap Tidal Range)	MHWN - MLWN	Average of all HW minus all LW over neap tide period.

Table 1: Abbreviations and descriptions of tidal range, HW and LW parameters calculated.

While the differences in trends of the different parameters are shown in Figure 2 and should be noted, both maps present GDTR, which is considered consistent, across semi-diurnal and diurnal tidal regimes and unambiguous in definition. Other parameters remain of use for comparison to previous research and in assessing changes in the tide.

Results



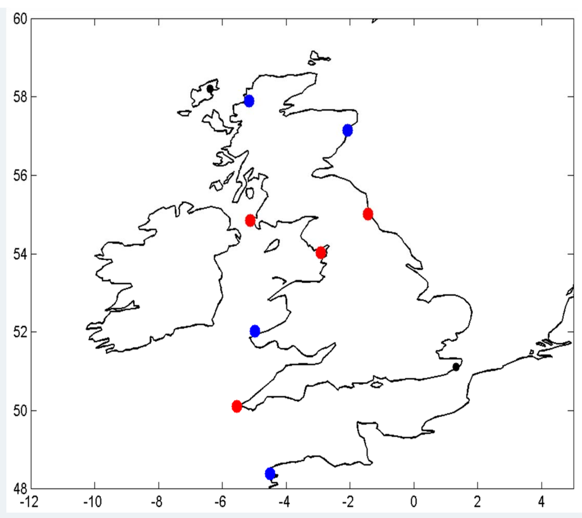
The selection of datum has a significant impact on the magnitude of the trend in some locations. At a number of sites STR is different to GDTR or MTR (Figure 2). STR is relevant parameter in this study, as ESL have a higher probability of occurrence during spring tides because a smaller storm surge is required to reach a certain threshold.

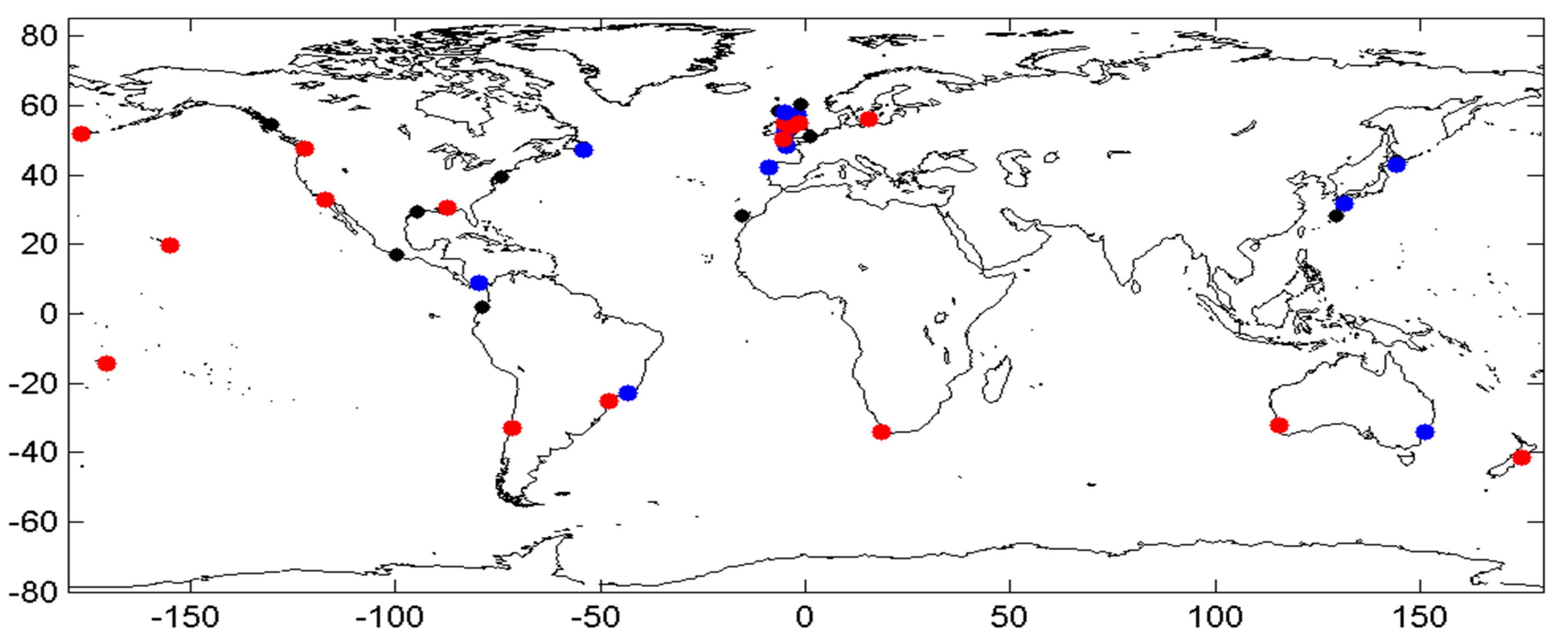
The global picture (Figure 4) shows 27 sites (16 positive and 11 negative) have significant trends in GDTR. Significant trends are detected in more than half the sites for both MTR and STR. Although, significant trends occur around the globe no clear global pattern emerges from the data. Regional patterns are difficult to detect on a global map and without a high spatial density of data it is not possible. The UK has good spatial coverage but from the selected datasets (Figure 3) no clear pattern is observed.

Figure 2 (top): One plot for each selected site showing linear trend for tidal range (green dots) for 5 tidal range parameters. Stacked bar charts show the contribution towards the tidal range trend of changes in HW subsets (blue) and LW subsets (red). For example, at Dover the contribution to STR from HW is positive (i.e. trend in MHWS is positive) while the contribution from LW is negative (i.e. positive trend in MLWS).

Figure 3 (bottom left): UK map showing whether trends of GDTR are significant positive (red), significant negative (blue) or not significant (black).

Figure 4 (bottom right): Global map showing whether trends of GDTR are significant positive (red), significant negative (blue) or not significant (black).





Conclusions & Further Work

- High frequency datasets required for analysis of ESL and tides are not uniformly distributed and therefore 'global' analysis is heavily biased towards data rich regions.
- The different tidal range datums can vary considerably and should not be interchanged. Each datum describes the tide differently and as such all are useful in assessing changes.
- At many sites the trends are often significant, but there is no clear global or regional pattern.
- Extension of the dataset is required, to give both a credible global dataset as well as regions of high data density. From this global and regional analyses of changes in tidal range can be conducted.
- Findings of changes in tide will feed into to a more complete understanding of changes in ESL.

References

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