Sea-level trends in the Australian region
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Introduction

Sea-level variability differs between the open ocean and over the shelf due to the expression of different oceanographic processes [6,7]. This can result in different sea-level trends observed by satellite altimeters in the open ocean and tide gauges at the coast. Many sea-level reconstruction techniques [8–10] use tide gauge data as a proxy to reconstruct spatially coherent modes of open ocean sea-level variability and regional projections of sea-level change are calculated from global models.

We investigate the variability of sea-level trend between the open ocean and the coast around Australia, using recent improvements in coastal altimetry corrections (range waveform re-tracking, wet tropospheric correction and improved tide models).

Data

We derive sea surface height anomaly (SSH) time series from orbit to orbit by correcting altimeter range and geophysical altimetry data from Jason-1 and Jason-2/OSTM [11,12]. We focus on the Indian Ocean and a region close to the Australian coast [13].

Results

Sea level trend and its uncertainty

Trend (mm a−1; 2002—2015) n Mean Median

Ocean open, standard corr., white noise 10927 5.0 ± 2.0 4.9
Ocean open, standard corr., coloured noise 10927 4.9 ± 3.8 4.8
Coastal region, standard corrections 1709 4.7 ± 2.1 4.4
Coastal region, standard with FES tides 1709 4.7 ± 1.5 4.5
Coastal region, corrections with FES tides 1709 5.0 ± 1.5 4.9
Tide gauges with GIA VLM 63 6.5 ± 1.9
Tide gauges with SONEL VLM 23 6.2 ± 1.9

Table 1. Data sets compared in this analysis

Method

Linear trend in time

Periodic signals

(Climate indices: DCI, ICI)

Figure 1. Climate indices: PDO and ENSO indices (dots) and the filtered DCI and ICI (solid lines)

Linear sea-level trends from short observations can be affected by the interannual scale variability. We use the Multi-variate El Niño Southern Oscillation Index (ENSO M2) and Pacific Decadal Oscillation (PDO) index as proxies for Pacific climate variability and apply filters to expand the spatial climate index [13] and the local spatial climate index (Fig. 1). The standard SSHa time series six-level variance explains the entire range of variability correlated to ENSO (Fig. 2).

Influence of climate on sea level

Including climate indices in the regression highlights a strong negative relationship to both decadal and inter-annual variability from the Indian Ocean throughflow, along the North West Shelf and on the continental shelf to the Great Australian Bight. The sea-level reconstruction time series from the coastal region exhibits greater colour than non-Australian (1,1) noise, which is indicative of remnant periodic power in the signal. The FES correction results in a regionally-coherent change in the trend. It is notable that the trend in the ongoing trend across the continental slope (>5 km from the coast) is reduced (c.f. uncertainty; Fig 7), compared to GOT, extending out along the continental shelf.

Coastal altimetry corrections leads to a generally higher trend. The differences do not correlate with distance from coast or completeness.

The FES tidal correction and ALES range (coastal corrections) as a result.

Coastal altimetry corrections increase the spatial average trend in the coastal region by 0.3 mm a−1 (FES tides, ALES range and GPD+ wet corrections) as a result.

Tide gauges with FES tides; (b) difference (%) due to applying FES tidal corrections with FES tides (c) FES tidal correction leads to significant differences in the trend (and its uncertainty; Fig 7), compared to GOT, extending out along the continental shelf

Figure 3. Principal component analysis on the coastal region, standard altimetry data shows the leading mode of variability correlates well with the multi-variate ENSO index

Figure 4. Coefficients (mm) of the multi-variate regression for the coastal region, standard corrections with FES tides

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Table 2. Spatial latitude-weighted mean and median trend from the valid data set from each region and with different corrections applied. One standard error is given for the spatial mean.

Conclusions

Linear trend and uncertainty, determined by residual noise characteristics, are investigated around the coast of Australia for new, improved coastal altimetry data sets. The data covers a very short period (2002—2015) compared with major climatic variability, so we adjust our SSHa time series by multi-variate regression with the major PDO and ENSO modes of variability.

The FES 2014 tide model gives improved variability (lower standard deviations) in the SSHa time series. SSHa calculated with the GOT tide model exhibits greater colour but non-Australian (1,1) noise, which is indicative of remnant periodic power in the signal. The FES correction results in a regionally-coherent change in the trend. It is notable that the trend in the ongoing trend across the continental slope (>5 km from the coast) is reduced (c.f. uncertainty; Fig 7), compared to GOT, extending out along the continental shelf.

Trends are largest in the regions of high mesoscale activity, in the East Australian and Leeuwin Currents and around Macquarie Island. The coastal altimetry corrections increase the spatial average trend in the coastal region by 0.3 mm a−1 (FES tides, ALES range and GOI wet tropospheric correction). The trend uncertainty is reduced by the coastal corrections because the variance of the SSHa time series is reduced.

In this study, trend uncertainty increases when using the most appropriate coloured noise model; the choice of noise model changes from the open ocean region (the noise is best fit by a coloured but non-Australian (1,1) model) to the coastal region (where a white or AR(1) model fits best), consistent with tide gauge data. On the continental shelf, higher frequency variability can persist (due to shallow water effects and waves being supported by the coastal boundary) which lead to flatter noise profile in the power spectral density curve.

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