Variability in sea-level trends from open ocean to the coast: An Australian case-study

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Introduction
Short- to medium-term forecasts of sea-level rise at the coast tend to be
informative by present linear trends in sea-level in the surrounding open
Some methods of sea-level reconstruction, such as those that use
spatial basis functions3,6,7, assume that tide gauge sea-level variability is a
direct proxy for sea-level variability observed by satellite altimetry.
Sea level varies across the continental shelf from the open ocean to the
cost due to complex responses to forcing. Shallowing bathymetry increases
vicious effects and enhances tides.
Therefore, we investigate the sea-level variability across the continental shelf
using newly derived coastal altimetry data.

Method
Following [1], we use the RADS database to process the raw 1 year
sea surface height anomaly from Jason-1 and OSTM/Jason-2 to along-track
tracks at coarser spaced grid points, every 5 km from the point of
closest approach (or crossing) of the coast. This results in time series at around
2,000 comparison points within 50 km of the Australian coast, from 2002-2015.

For the coastal altimetry we use:
• Replace the standard MLE waveform re-tracker range measurement
with ALES range16.
• The FES 2014b tide model15 replaces the standard GOT model16.
• The GDP-wat tropospheric correction10 is used.
The 2002-2015 linear trend is calculated by a maximum likelihood
estimation with automatic noise controller (ANC) noise, using Héctor software4.

The trend in time and annual and semi-annual signals are calculated on
the full time series (standard single-variable linear regression, SVLR) and
the time series including climate indices (multi-variable linear regression, MVLR).

The climate indices of the Pacific Decadal Oscillation (PDO) and
ENSO are used in our analysis. The PDO is calculated based on
standard products, while the ENSO is calculated based on
ENSO (3C).

Coastal Altimetry
Range (waveform retracker)
For coastal regions, we make use of seawater altimetry data from the
ALES re-tracker16 against standard (MLE) waveform from Jason-1 and
• The ALES re-tracked range results in slightly more data gaps than the
standard MLE. Time series are less complete on average (by 6%),
although within 10 km of the coast, MLE is slightly more data gaps and
ALES provides 10% more time series with 67% completeness.
• The variance of the time series is different between the standard
and ALES-tracked data.
• Sea-level trends derived from ALES re-tracked data are larger,
in the mean, than those from standard data (by 0.4 mm yr^-1 mean),
but within the observational uncertainty.

Tides
Comparing the standard GOT tide model against the FES tide model17,16,
designed for open oceans:
• The standard GOT model fails to provide data in some channels and
shelves to the land, whereas the FES tide model has better coverage.
• The sea-level variance standard deviation is changed, on average reducing by
21 mm.
• In regions of high tidal range, shallow bathymetry and
land/ocean boundaries, the difference in the estimated trend from 2002-2015
can be as large as 20%.

Across the shelf
The variance of the satellite altimetry time series changes
within the shelf (Fig 1a), but within the observational
uncertainty. There is much higher variance on the tropical
(north and north-east) shelf than the mid-latitude
(southern) shelf. These tropical shelves show the largest
impact of using the FES tide model. This region shows a
sharp decline in variability at the shelf break (Fig 2a)
on the continental slope, which corresponds with shallow oceanographic
processes dominating here.

The linear trend from 2002-2015 does not significantly vary
across the shelf for any particular region, when
analysed by the EOF pattern and climate
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Conclusions
Applying waveform re-tracking and corrections specifically
designed for coastal applications to satellite altimetry affects the trend observed in a 14-year time series.
Improved tide modelling on average reduces variance and reduces power at aliased tidal frequencies (not shown). Although the standard deviation of the time
series is unaltered by the ALES re-tracker, there is a persistent change in the trend that is within the observational uncertainty.

The trend observed on the Australian coast is dominated (19.3% variability explained, Fig 3) by an ENSO / PDO mode. The MVLR used here aims to
remove this signal to look at cross-shelf variability in trends. However, there remains a strong gradient in the trend between eastern and
western Australian coasts (Figs 4,5).

The trend around the Australian coast is dominated (19.3% variability explained, Fig 3) by an ENSO / PDO mode. The MVLR used here aims to
remove this signal to look at cross-shelf variability in trends. However, there remains a strong gradient in the trend between eastern and
western Australian coasts (Figs 4,5).

Fig 4. The mean linear trend (mm yr^-1) for each satellite pass ground-track, with distance around the coast of Australia. The position of the
individual tracks are shown in Fig 3.

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The trend is due to single-variable (tidal) and multi-variable (climate indices) re-tracking and corrections specifically designed for coastal applications to satellite altimetry. The results are presented in magneto.

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References
13. Legresy, Watson, Passaro, Royston and ALES provides 10% more time series with 67% completeness.

Data Sources
• MLE: CMEMS Marine Copernicus portal: https://www.marine.copernicus.eu
• RADS: Tides page (with coasts of interest noted): github.com/remser/RADS

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Fig 3. The EOF pattern and principal component (5-year running mean) of the coastal time series from following (3), we use the RADS
EOF. It is based on the FES 2014b tide model and the principal component from the
coastal time series is unaltered by the ALES re-track.

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