Estimation of extreme sea levels from altimetry and tide gauges at the coast

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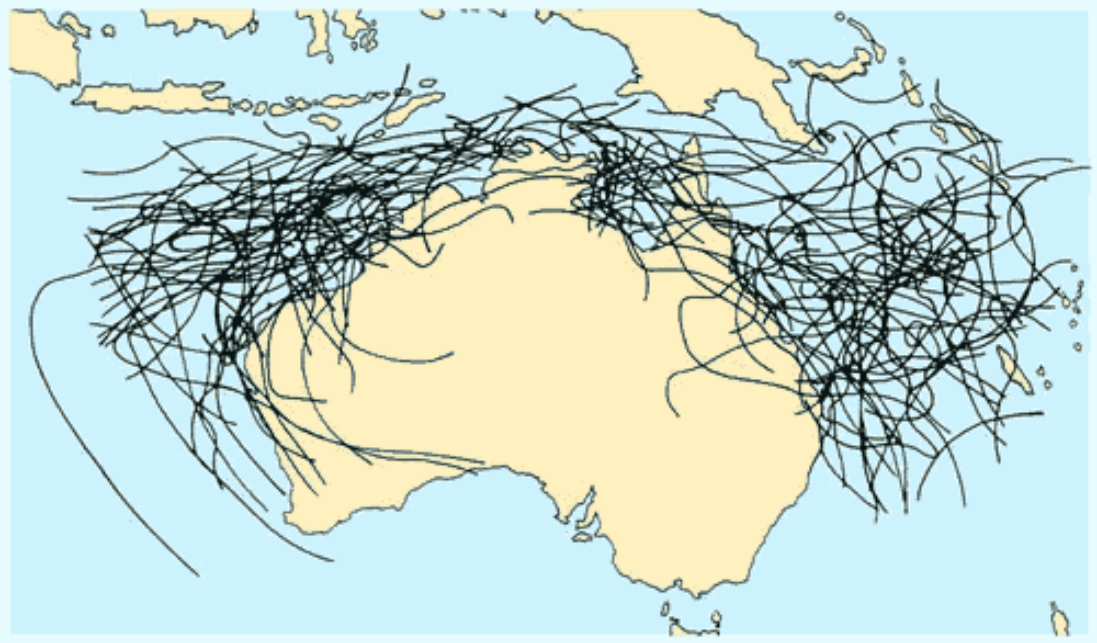
Introduction

- Sea-level rise will lead to more extreme sea level events
  - hence an increased likelihood of coastal flooding and erosion.

- Off the south-east coast of Australia, infrequently, the sea-level variations are associated with the East Coast Low (ECL) formed and intensified in a maritime environment near the coast.
  - The ECL is referred to a low-pressure system with closed cyclonic circulation at sea level
  - 5 times in June 2007

Introduction

- In the northern coast of Australia, sea-level rise has been found much faster up to 2.5 times than the global sea-level rise.
- Much of the coastline is more frequently affected by Tropical Cyclones. The region has cyclone frequency with averages 1-2 a year and period up to 7.7 days per season when a cyclone exists.



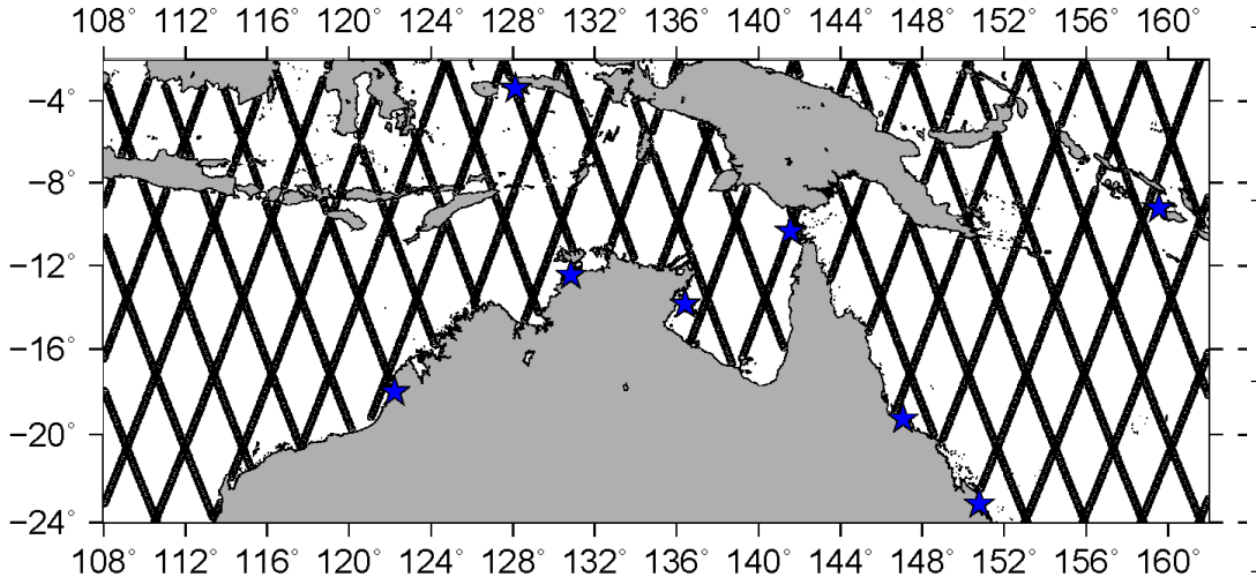
Objectives

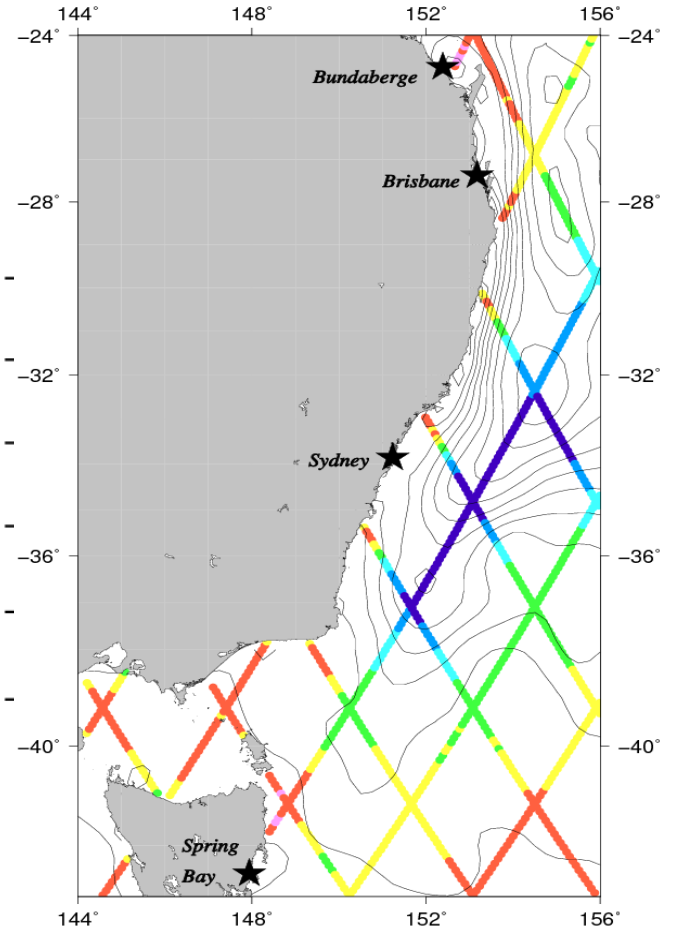
- To map coastal sea level through integrating altimetry and tide-gauge sea level measurements for monitoring of extreme sea levels associated with sea level rise.
- To capture high frequency sea-level variations within periods of 10 days.

Data and Areas

- The data used are sea level measurements (1992-2010) from both satellite altimetry and tide gauges
  - along the south-east Australian coastline (latitudes 43°S-24°S and longitudes 144°E-156°E), and
  - in the northern Australian coastal area (latitudes -24°S-2°S and longitudes 108°E-162°E).
- The along-track SSHs from multi-satellite altimeter missions (TOPEX/Poseidon, Jason-1 and Jason-2) are obtained from the RADS.
  - http://rads.tudelft.nl/rads/rads.shtml.
- The hourly tide-gauge sea level records are obtained from the University of Hawaii Sea Level Centre at 12 stations.
  - (http://uhslc.soest.hawaii.edu/home)

Data and Areas





The Method

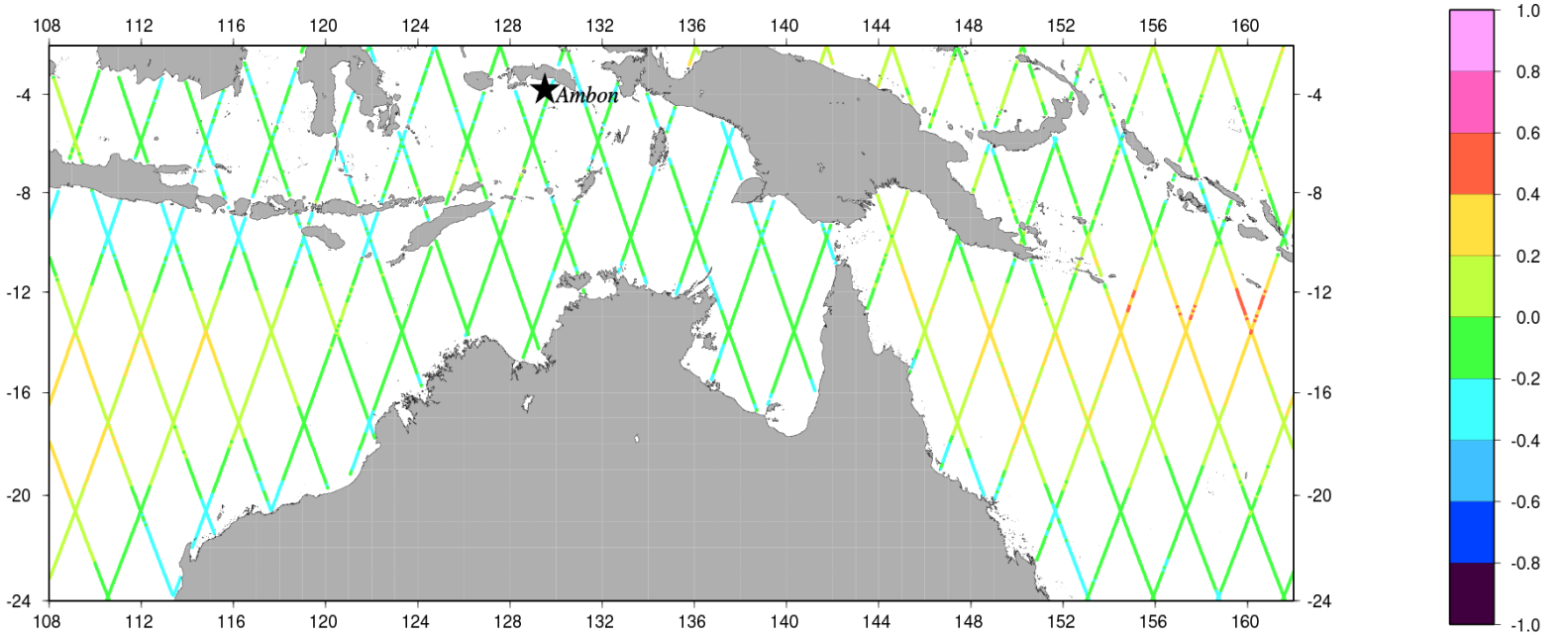
- Sea level time series at each point along-altimetry tracks is described by a multivariate regression model using sea level records from all tide gauges.

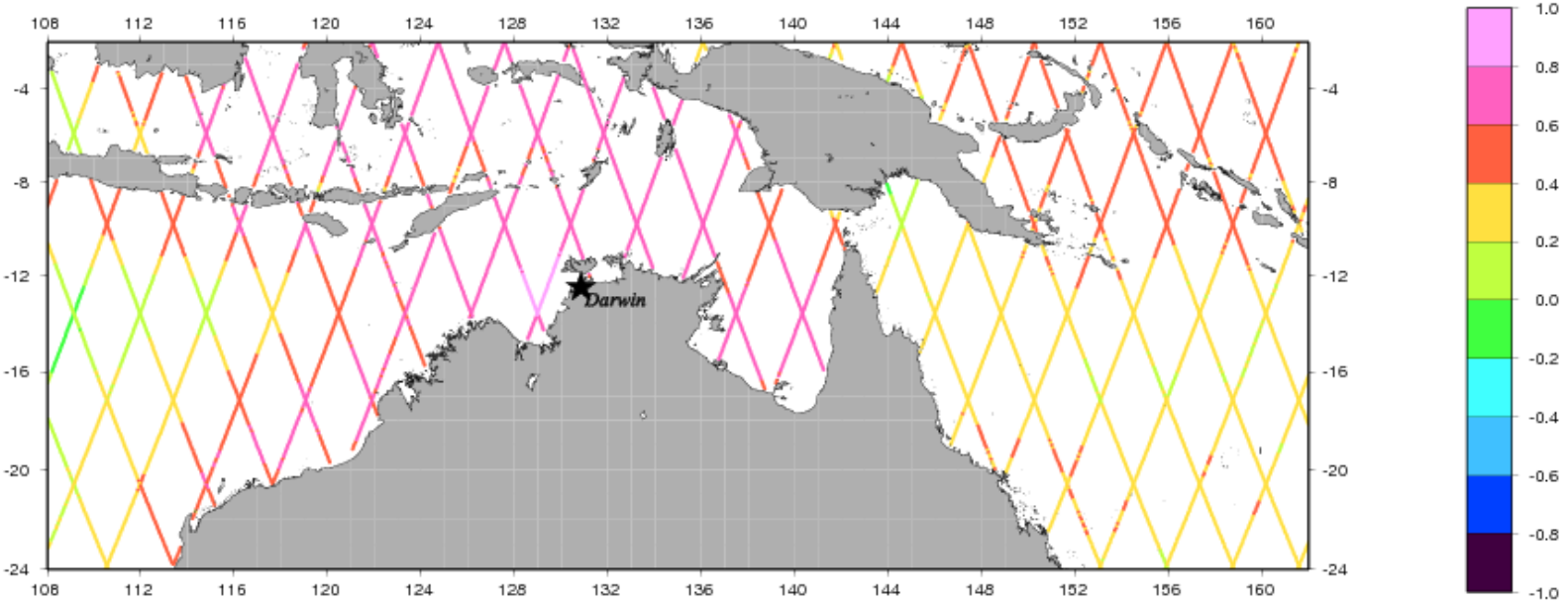
$$\underset{n\times 1}{\mathbf{y}} = \underset{n\times m}{\mathbf{X}}\ \underset{m\times 1}{\mathbf{b}} + \underset{n\times 1}{\boldsymbol{\varepsilon}}$$

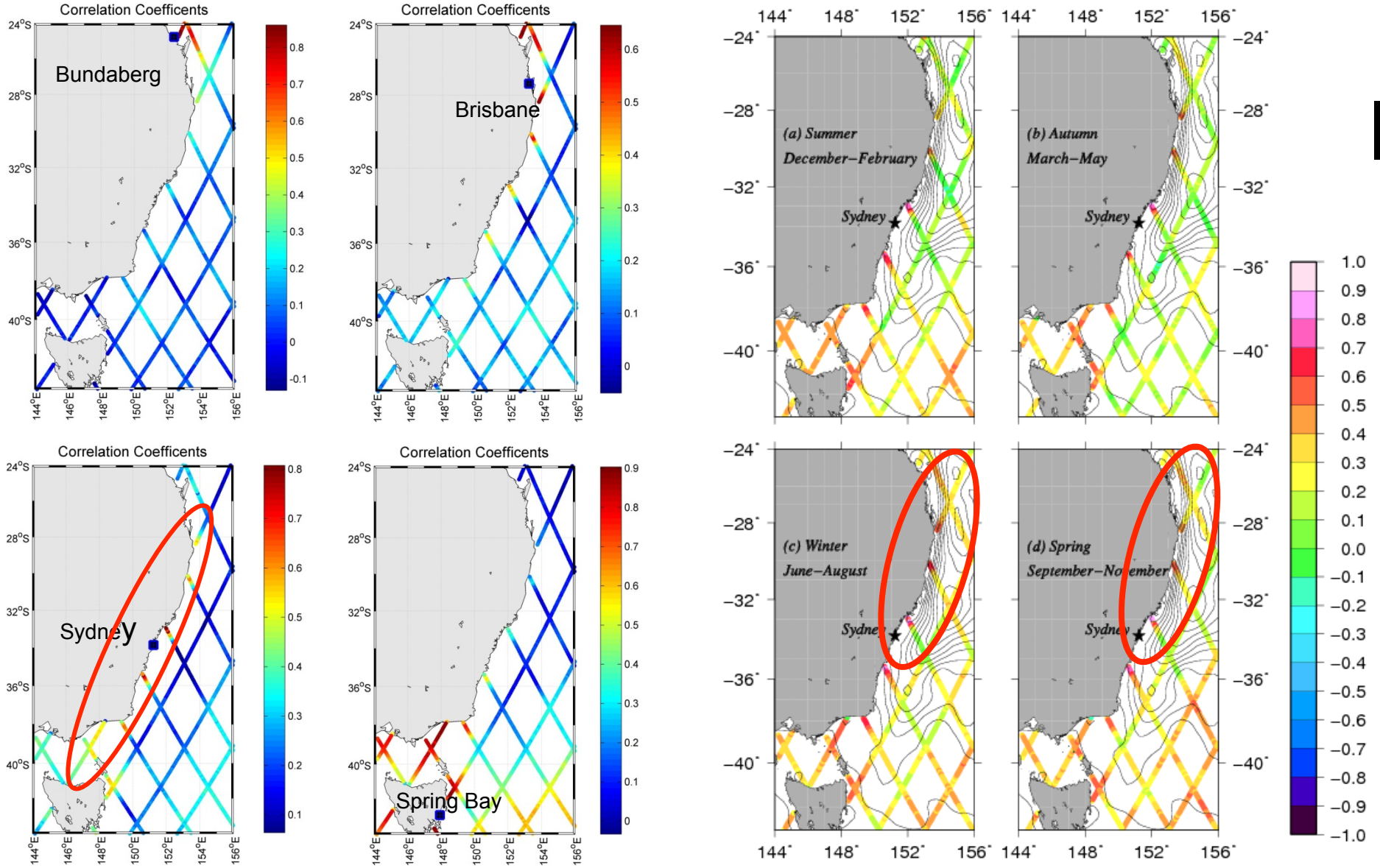
- The solution of the multivariate regression provides predictions at the time of interests, which can be used to monitoring extreme sea levels.
- Performance of the model is measured by the RMS of regression and hintcast skill (ie. R^2)

$$R^2 = \frac{\sum (y_i - \bar{y})^2 - \sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2}$$

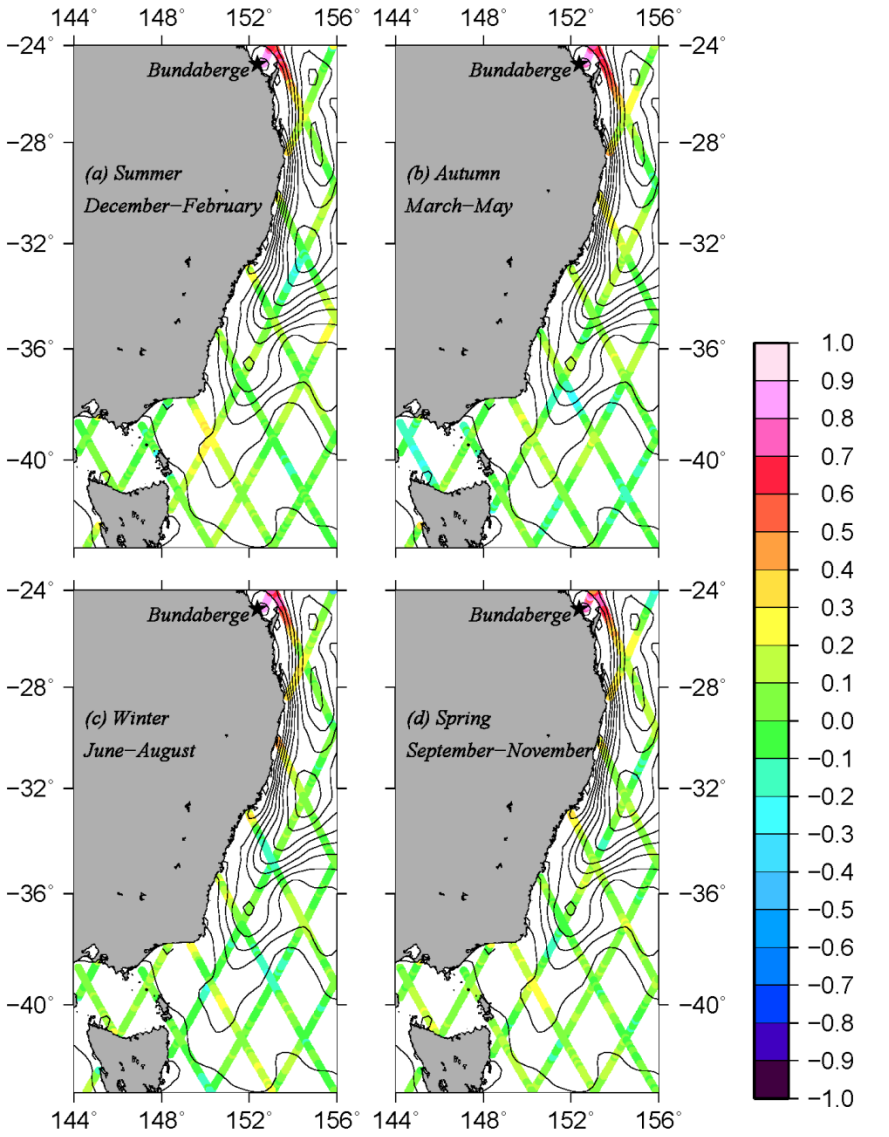
Results – Temporal Correlation

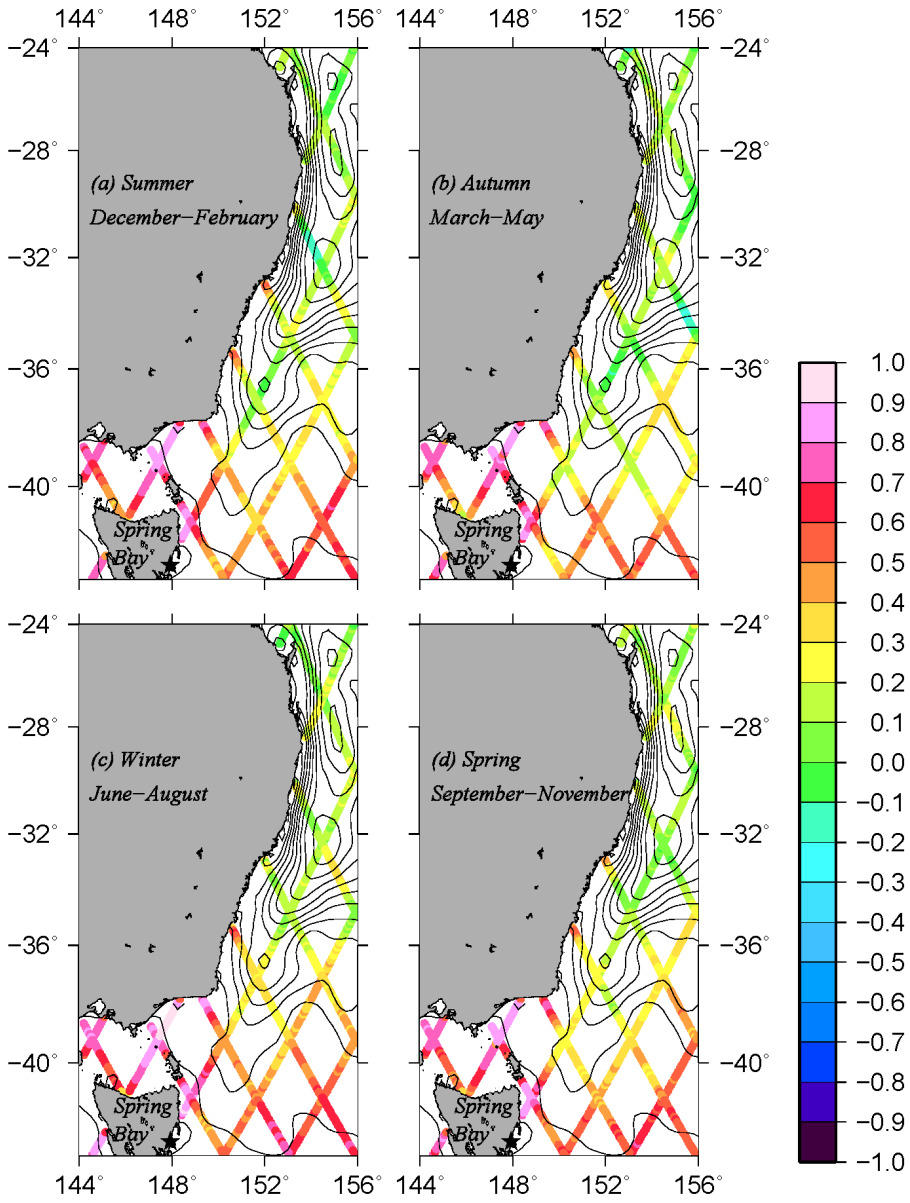






Distributions of temporal correlation coefficients between tide gauge and altimeter sea level measurements at four stations off the east coast of Australia.


144°
148°
152°
156°
−24°
−28°
−32°
−36°
−40°
Bundaberge
(a) Summer
December–February
(b) Autumn
March–May
(c) Winter
June–August
(d) Spring
September–November
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1.0


144°
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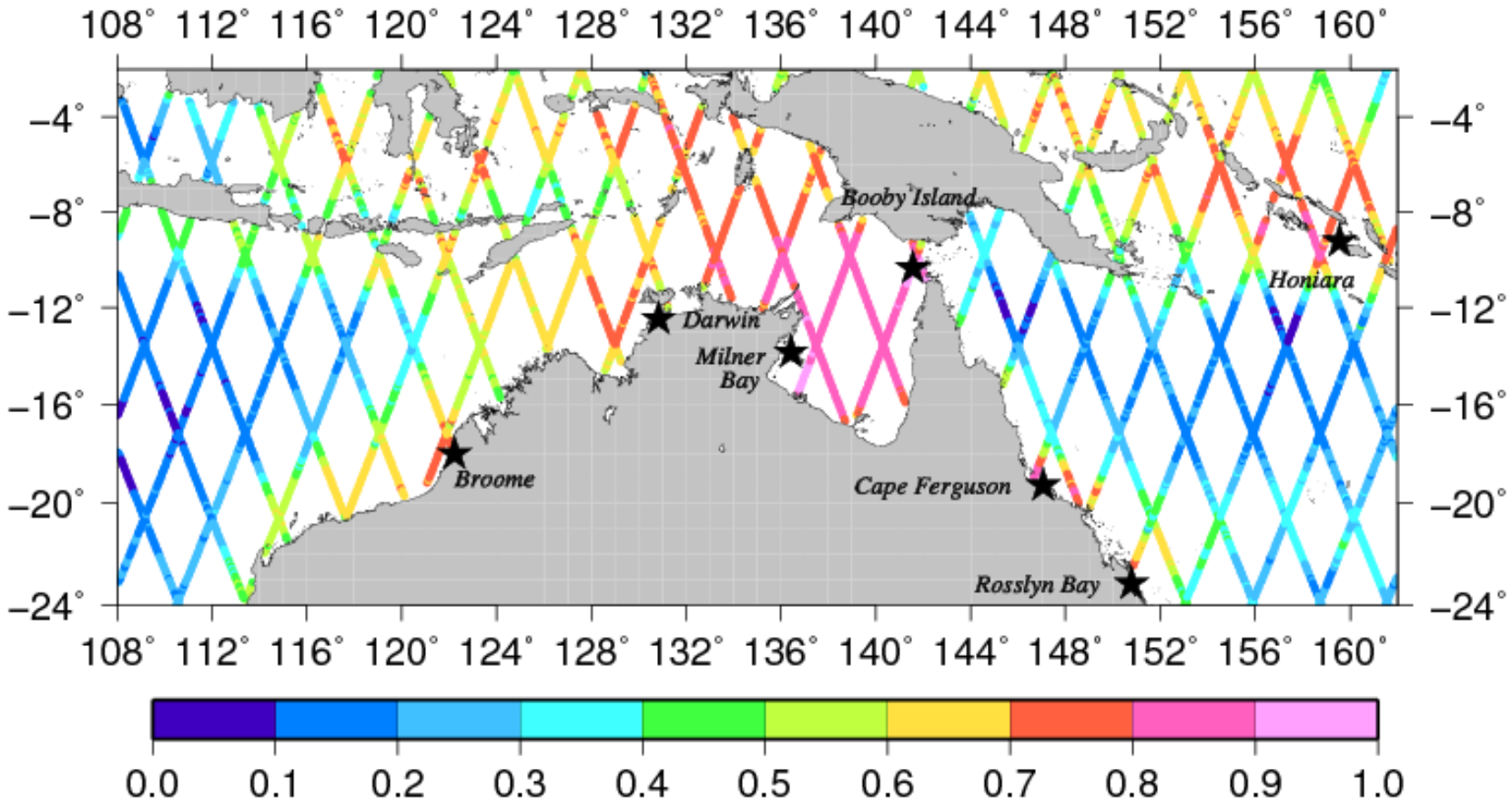
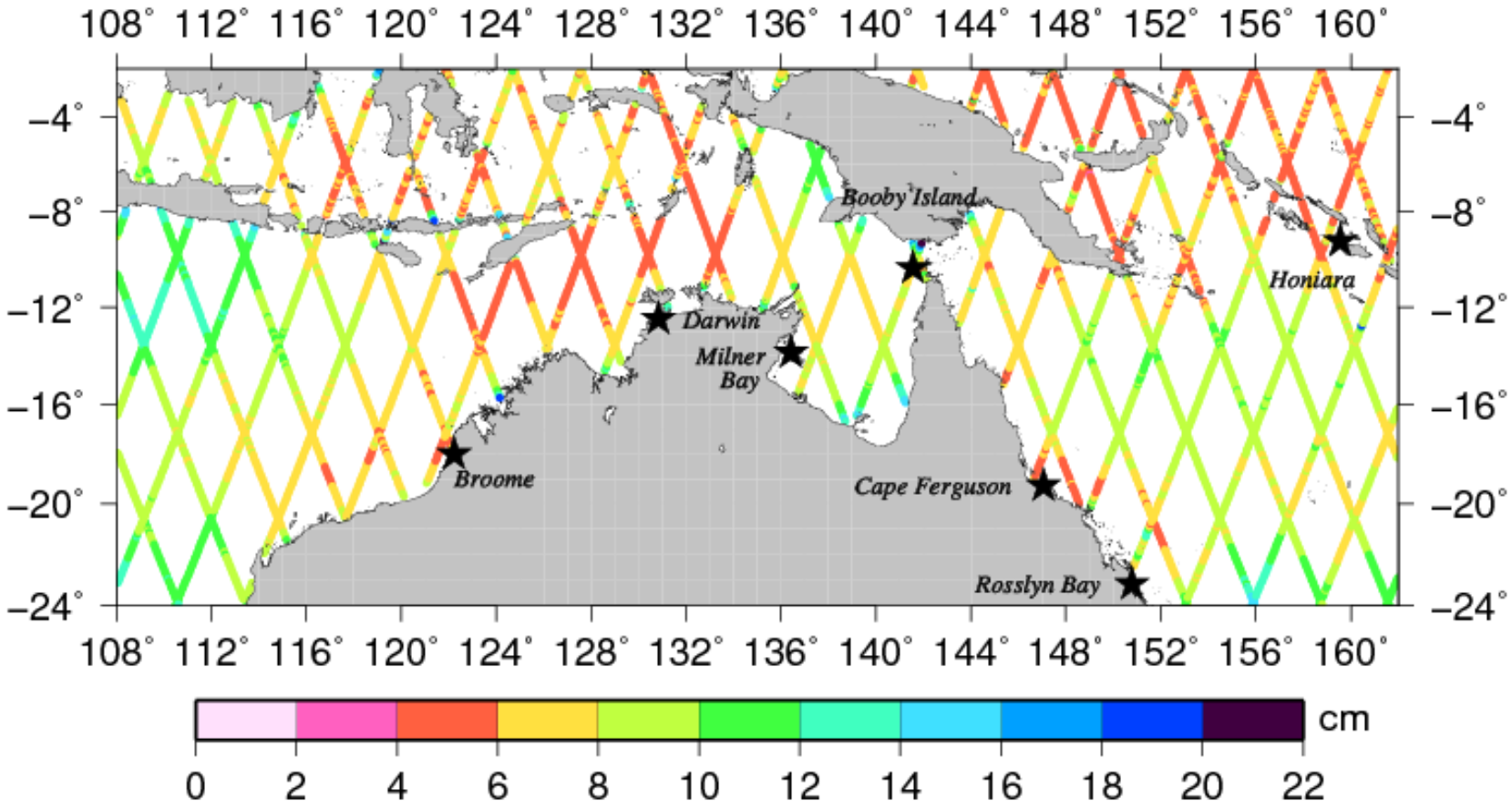
June–August
(d) Spring
September–November
Spring
Bay
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1.0

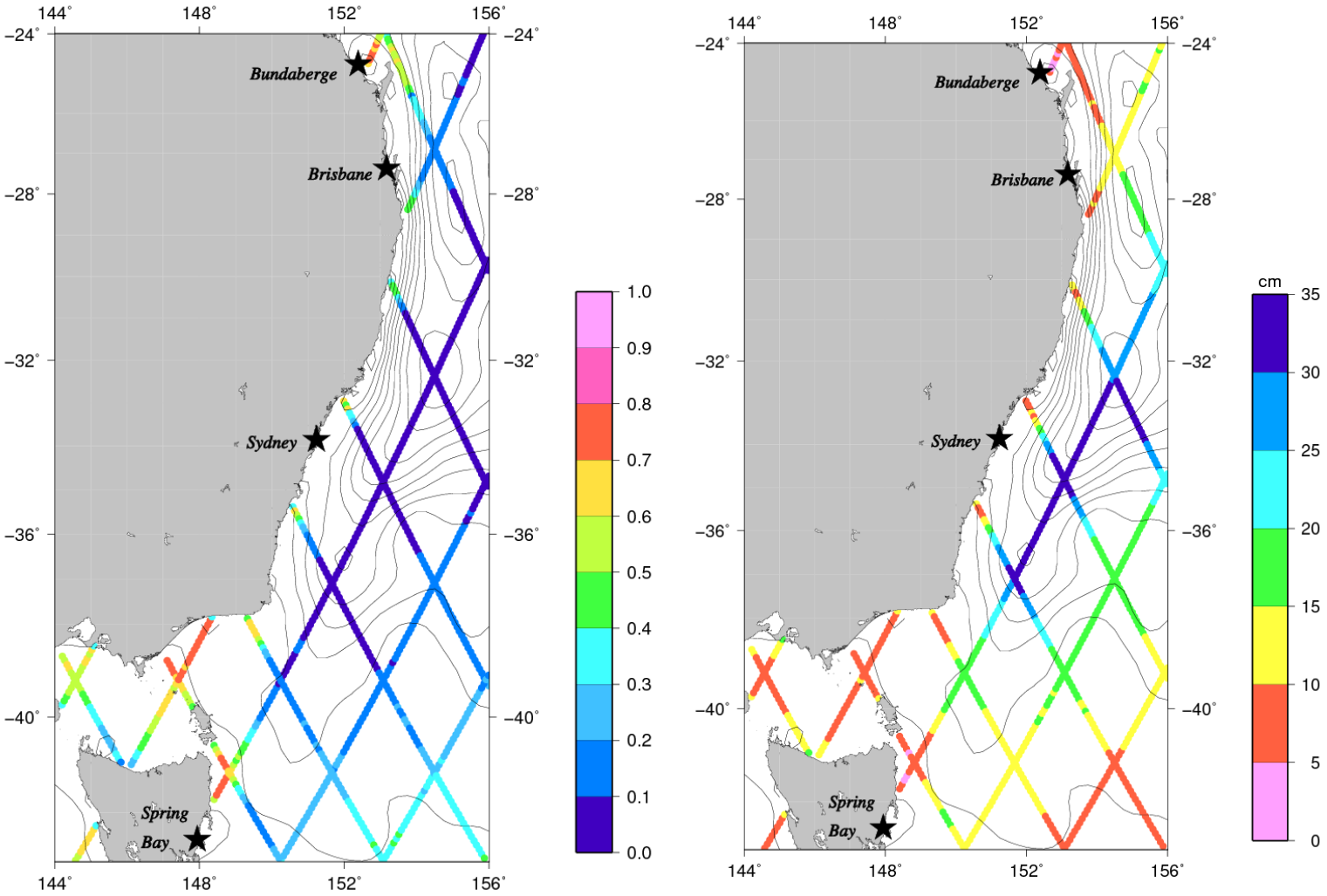
Results – Multiple Regression Coefficients



Results – RMS of Multiple Regression



Results – Multiple Regression Coefficients and RMS



The hindcast skills (left) and RMS of regression off south-east Australia. Background contours are the mean surface height field of the area from the CNES-CLS09 Mean Dynamic Topography.

Measures of Regression Model Performance

Coast	Measure	min	max	mean
South-east	R^2	0.01	0.80	0.24
North	R^2	0.03	0.96	0.40
South-east	RMS (cm)	4	35	16
North	RMS (cm)	4	21	8

Conclusions

- The multiple regression model can in generally explain >40% and >24% of sea level variations in the northern coast and south-east coast of Australia, respectively.
  - >60% of R^2 near the coastline
- Off the south-east coast, the model performs well only along the coastline within in a narrow strip (~60 km), due to the effect of EAC system.
- The results, especially in the northern coast, suggest that integrated mapping and predicting of the coastal sea level is a possibility, which opens the way for further research into monitoring of extreme sea level events.
- The validation of the multiple regression model is continuing.

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Thanks and Questions

A presentation to the 6rd Coastal Altimetry Workshop, 20 – 21 September 2012, Riva del Garda, Italy