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Projections of Directional Wave Climate Change in Australia Using Statistical-Synoptic Typing

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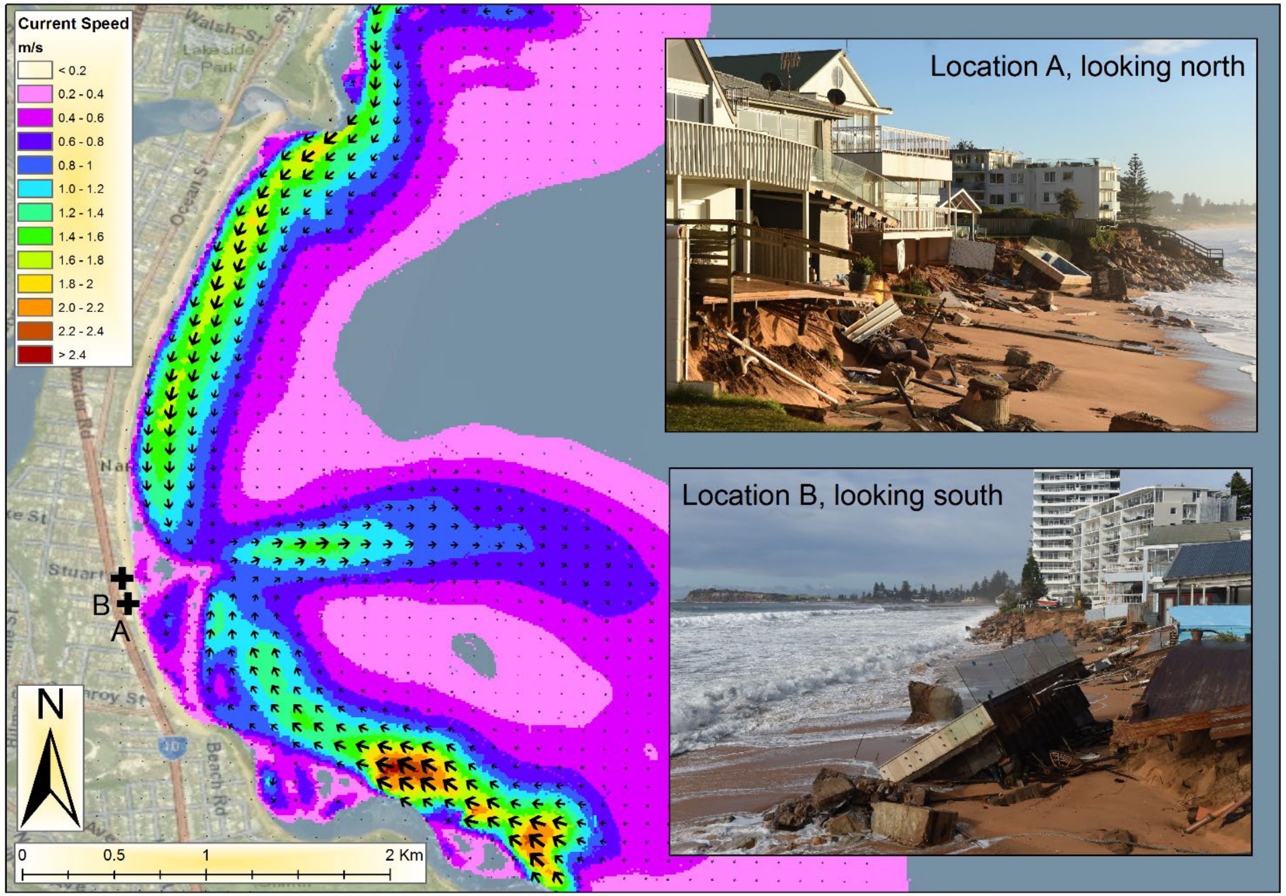
Introduction

- Changes to **directional wave climate** may be more significant than sea level rise for Australia outside of tropics
- Since IPCC AR4, an increasing number of wave climate change studies – most taking a **dynamical downscaling** (DD) approach
- DD provides good detail, but is time consuming and inherits climate model uncertainties related to physics and scale



Mortlock et al. (2017)

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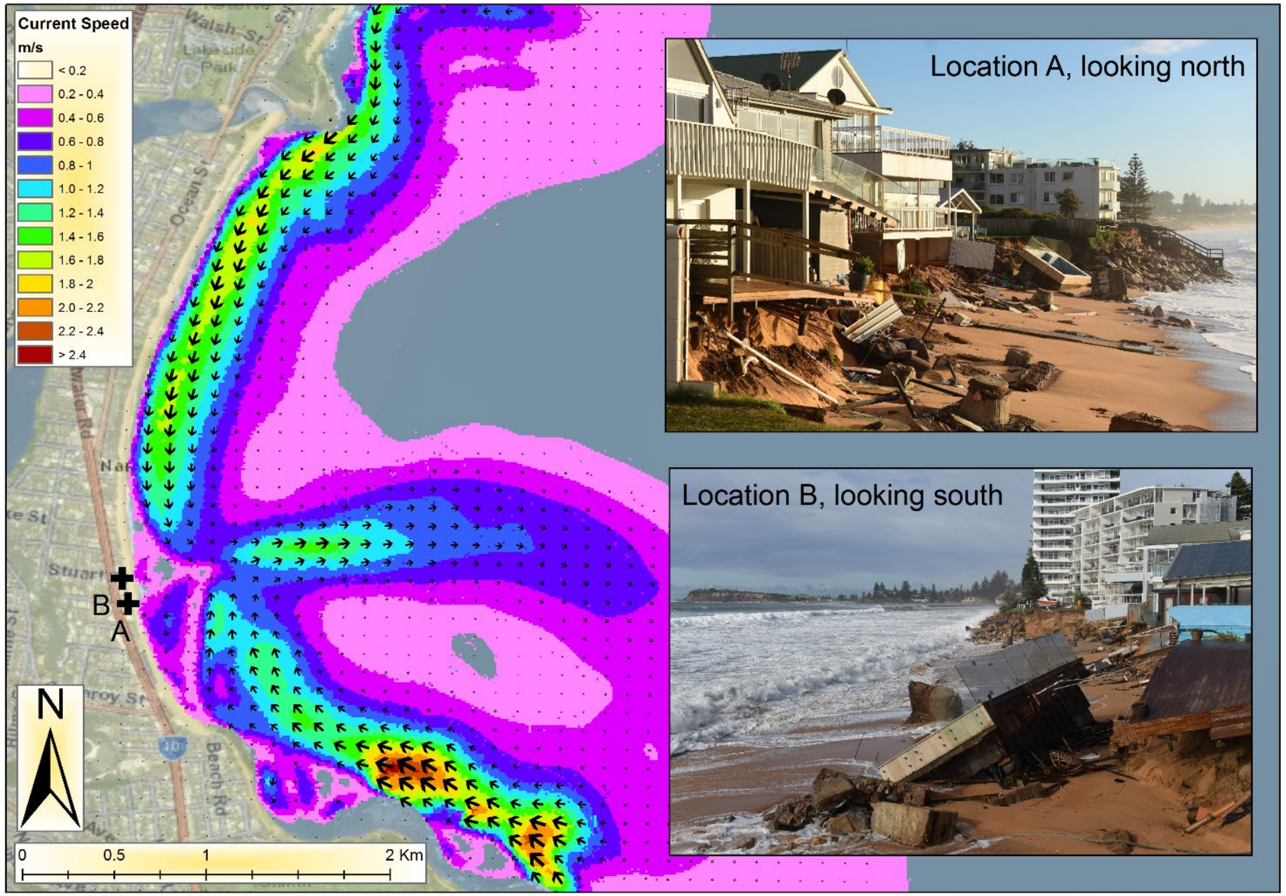
Introduction

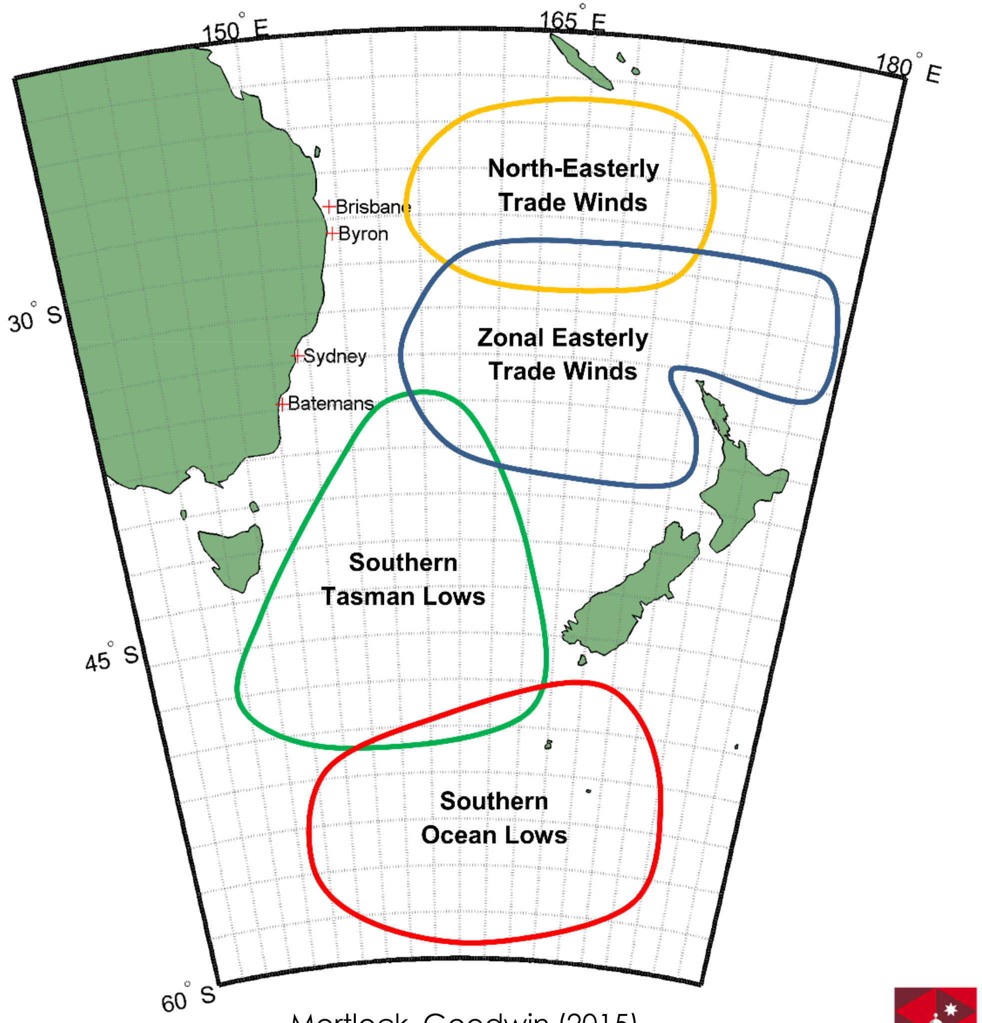
- **Statistical downscaling** uses relationships between large-scale climate configurations and wave conditions to make projections (e.g. Camus et al., 2014; 2017)
- This talk focusses on two parts:
  - Our approach to statistical wave climate decomposition
  - Potential impacts of **tropical expansion** on wave climate in Australia



Mortlock et al. (2017)

Statistical-Synoptic Wave Climate Typing

1. Statistical clustering of deep-water directional wave data
2. Composite sea level pressure anomalies of synoptic climate pattern for each cluster
3. Directional wave power of each cluster tracked and regressed against large-scale climate indices
4. Centroid wave parameters refracted to nearshore to investigate shelf gradients in wave power



Mortlock, Goodwin (2015)

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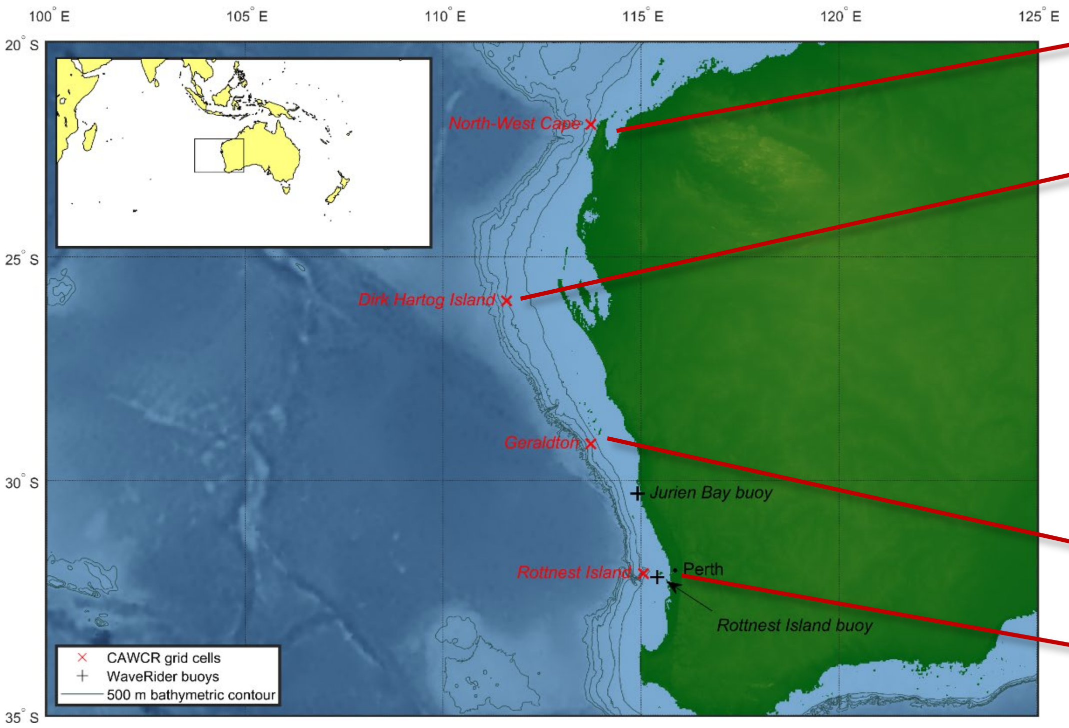
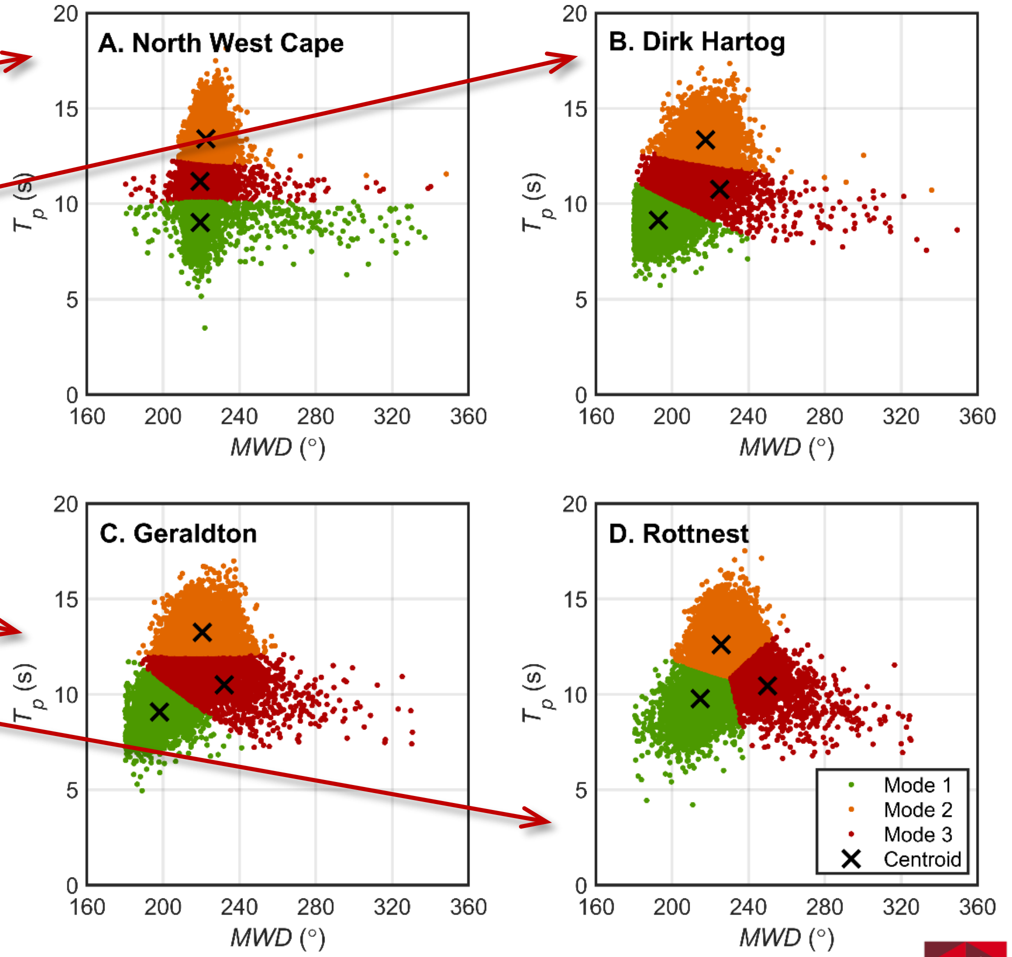
Statistical-Synoptic Wave Climate Typing



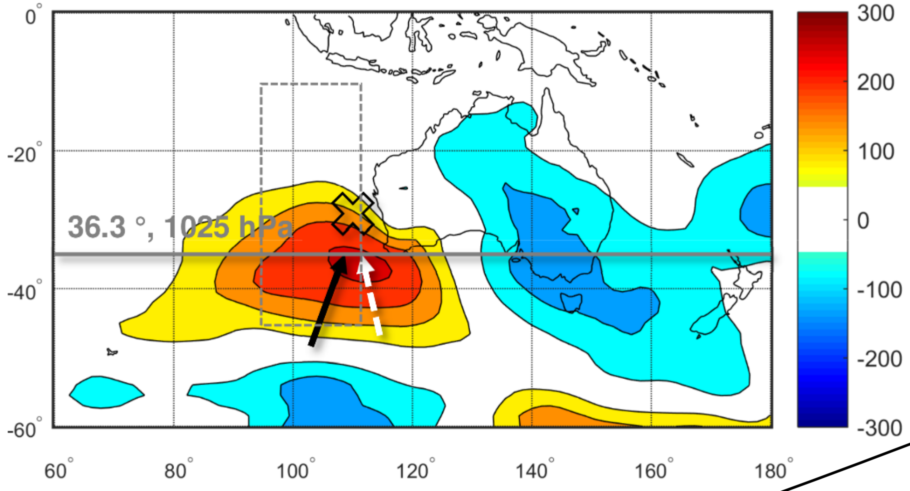
Mortlock et al. (in review)

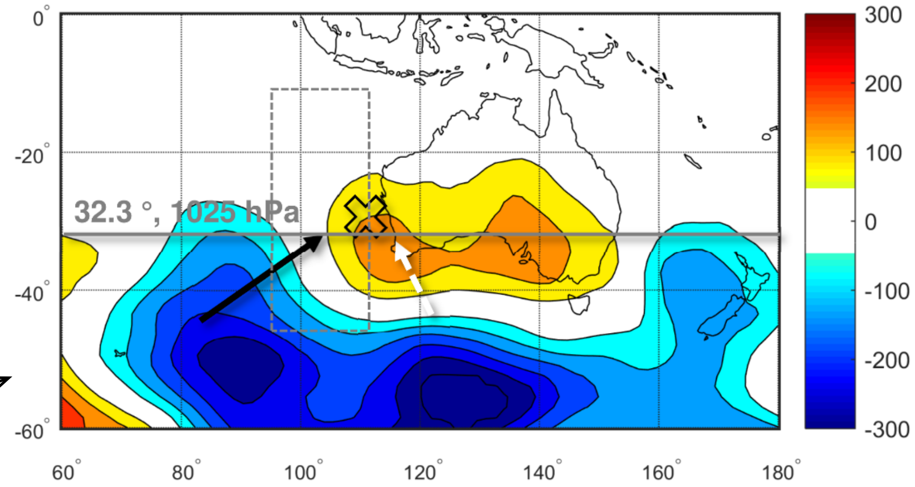


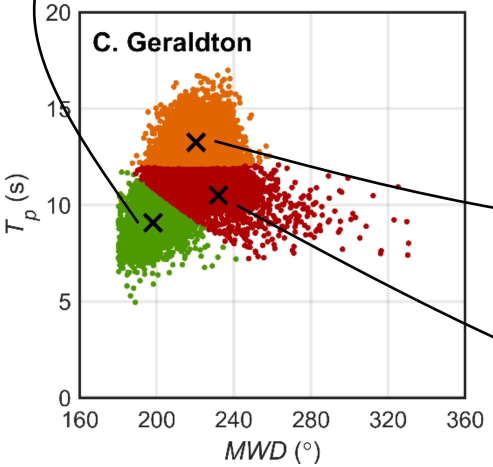
- CAWCR wave hindcast 1979 – 2014 (Durrant et al., 2014)
- Equidistant data points on shelf break ~ 1,000 m depth

Statistical-Synoptic Wave Climate Typing

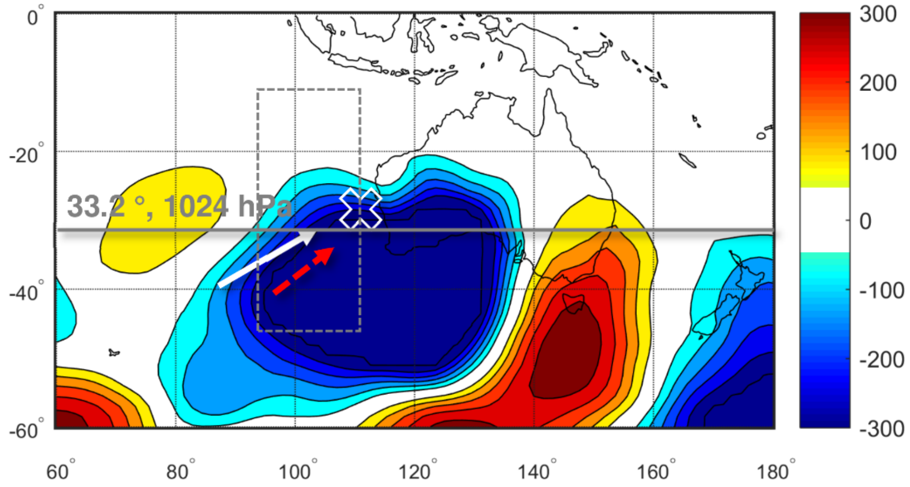
Mode 1: short-period, Southeast Indian Ocean anticyclone







Mode 2: long-period, Southern Ocean low



Mode 3: moderate period, Southeast Indian Ocean low

- ERA-Interim daily composite MSLP
- Subtracted from long term mean 1979 - 2014

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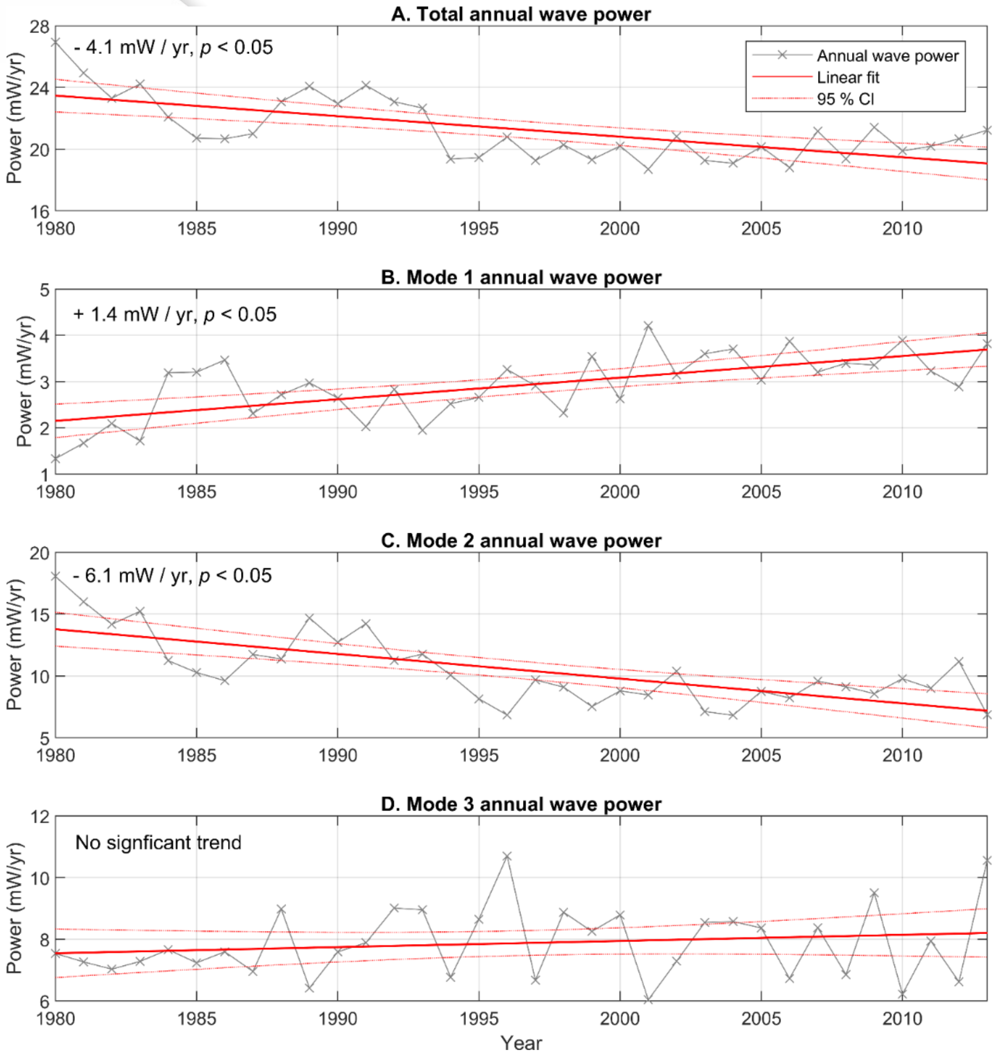
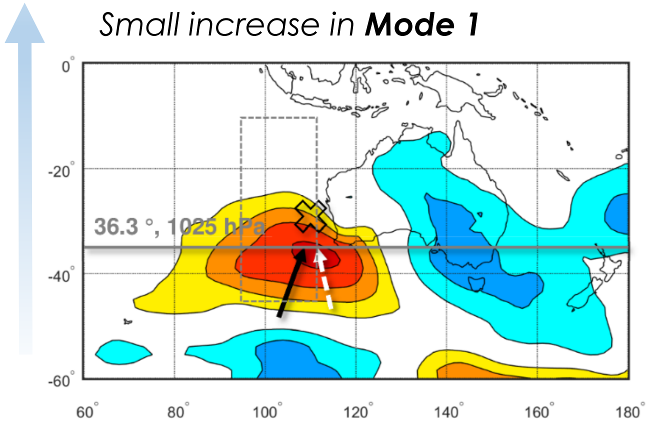
Wave Power and Climate Types

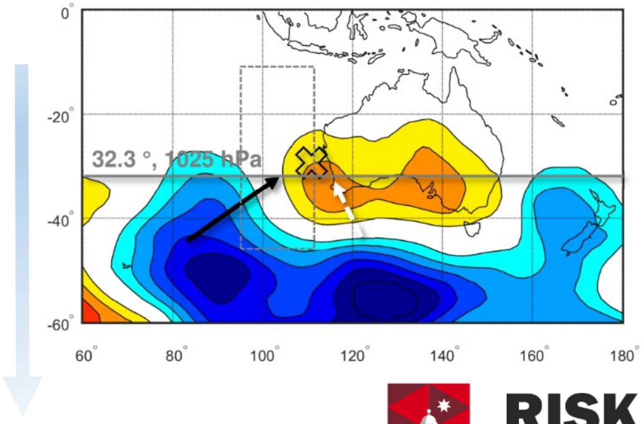


- 35-yr. wave power record indexed per wave climate type
- Total **wave power has decreased** along the Western Australian Shelf between 1979 and 2014
- Driven by a reduction in powerful Southern Ocean lows (Mode 2) with a small increase in Southeast Indian Ocean anticyclones (Mode 1)
- *What is driving this multi-decadal trend and can we expect it to continue?*

*Small increase in **Mode 1***



*Larger decrease in **Mode 2***



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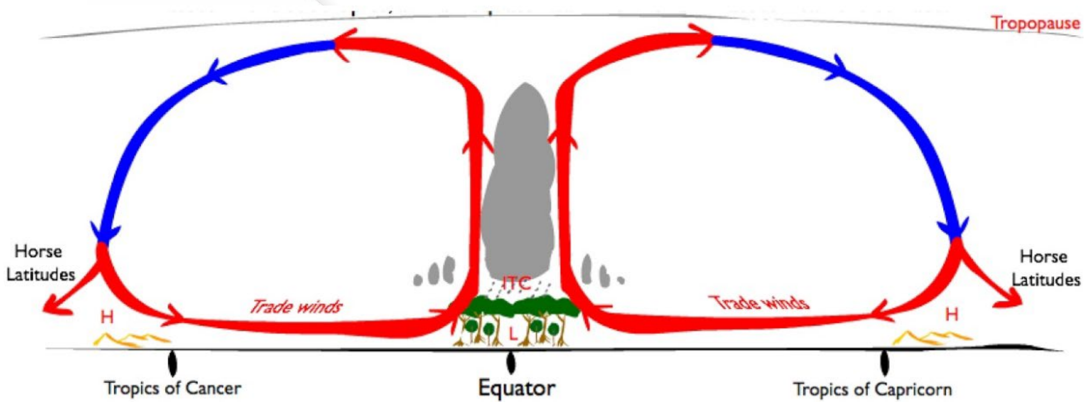
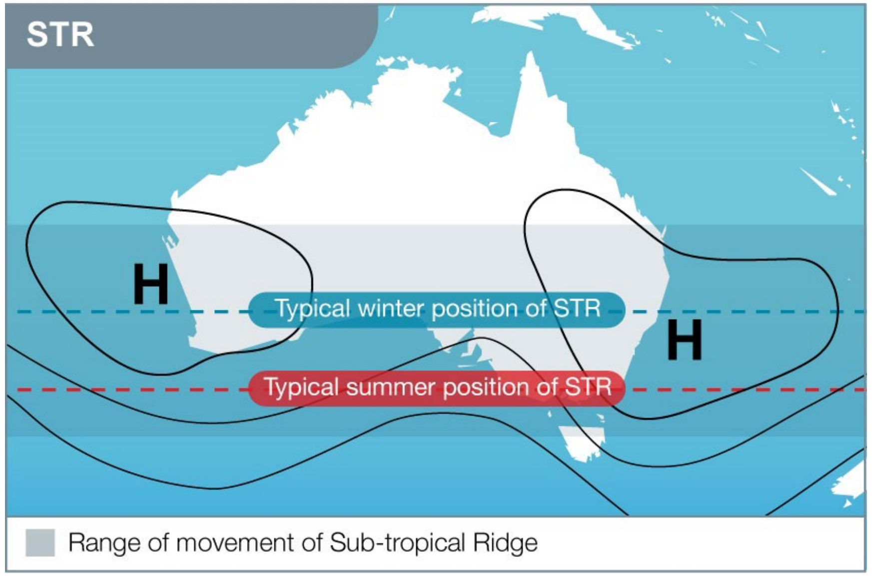
The Subtropical Ridge (STR)





Source: Agriculture Vic (2019)

- Subtropical anticyclones are major drivers of wave climate in Australia (Mortlock and Goodwin, 2015; Wandres et al., 2017)
- The **Subtropical Ridge** (STR) is the descending branch (poleward extent) of the tropical **Hadley Cell**
- At the surface, the STR is manifest as a quasi-stationary ridge of high atmospheric pressure
- The Hadley Cell in both hemispheres is expanding – "**tropical expansion**" (Lucas et al., 2014)
- While there is no clear latitudinal shift, the **STR is intensifying** over Southeast Australia (Drosdowski, 2005; Timbal and Drosdowski, 2013)

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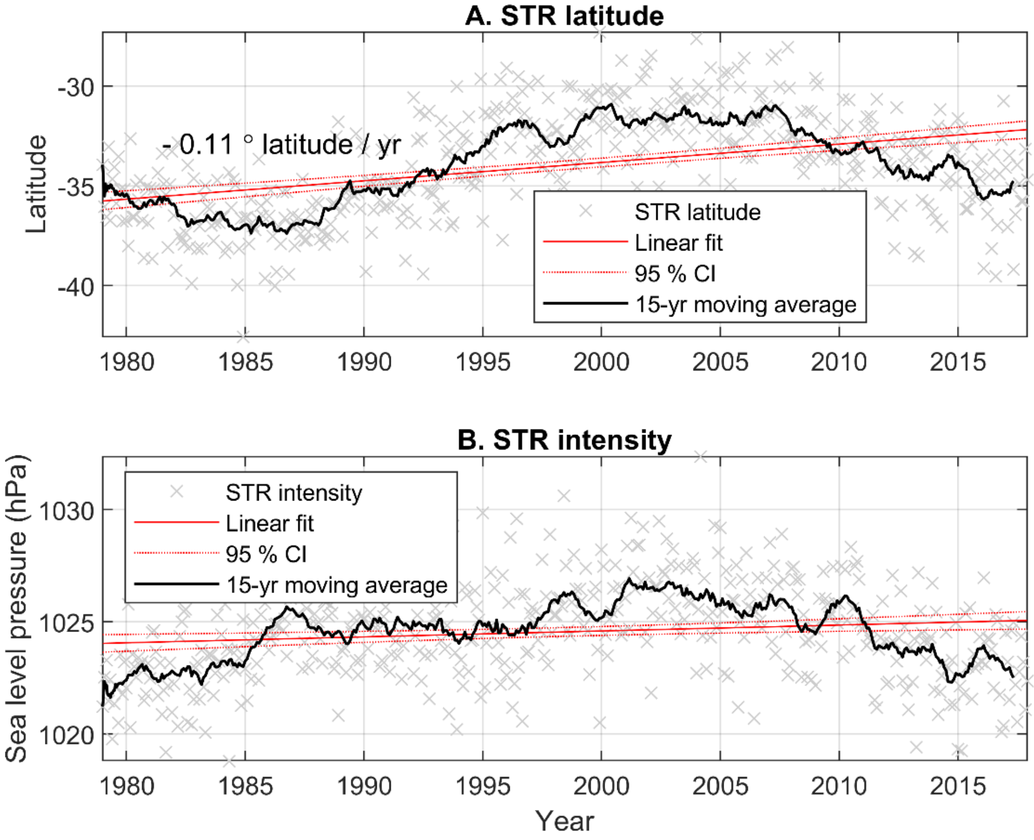
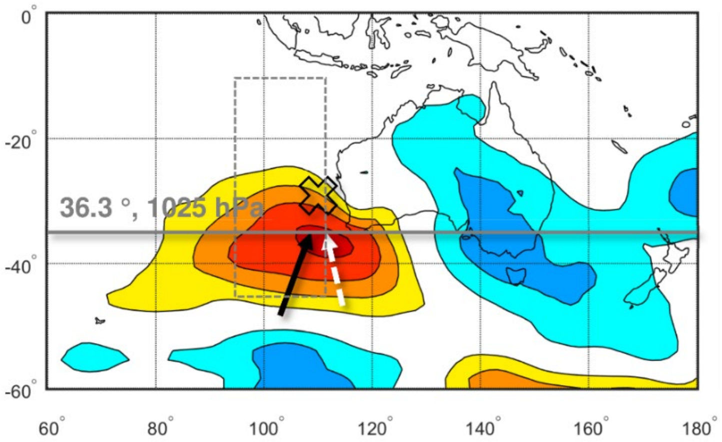
The Subtropical Ridge (STR)



- STR on the Western Australian coast exhibits **multi-decadal variability** in latitude and intensity
- There was a period of **intensification** for 25 of the 35 years analysed (~1985 to 2010)
- Synonymous with **blocking conditions**; reduction in Southern Ocean lows (Mode 2), increase in weaker anticyclonic waves (Mode 1), overall decrease in wave power



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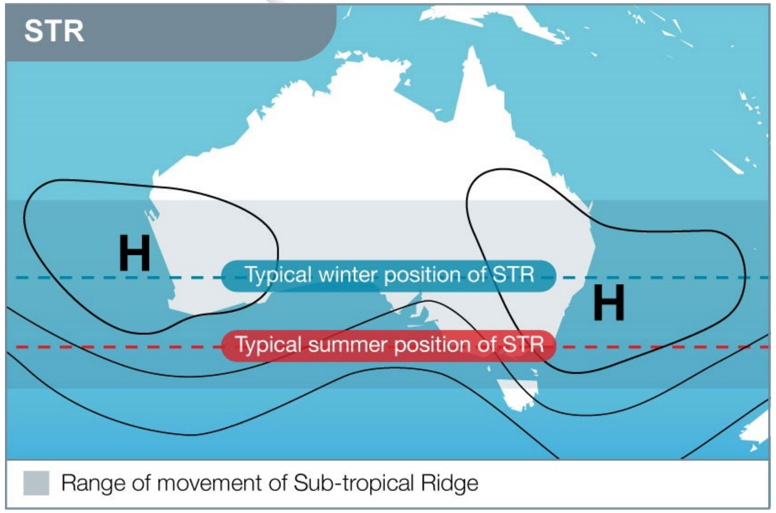
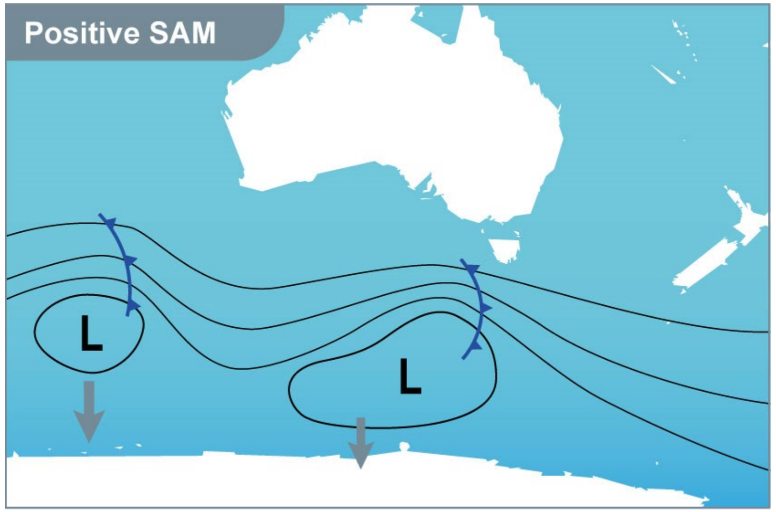
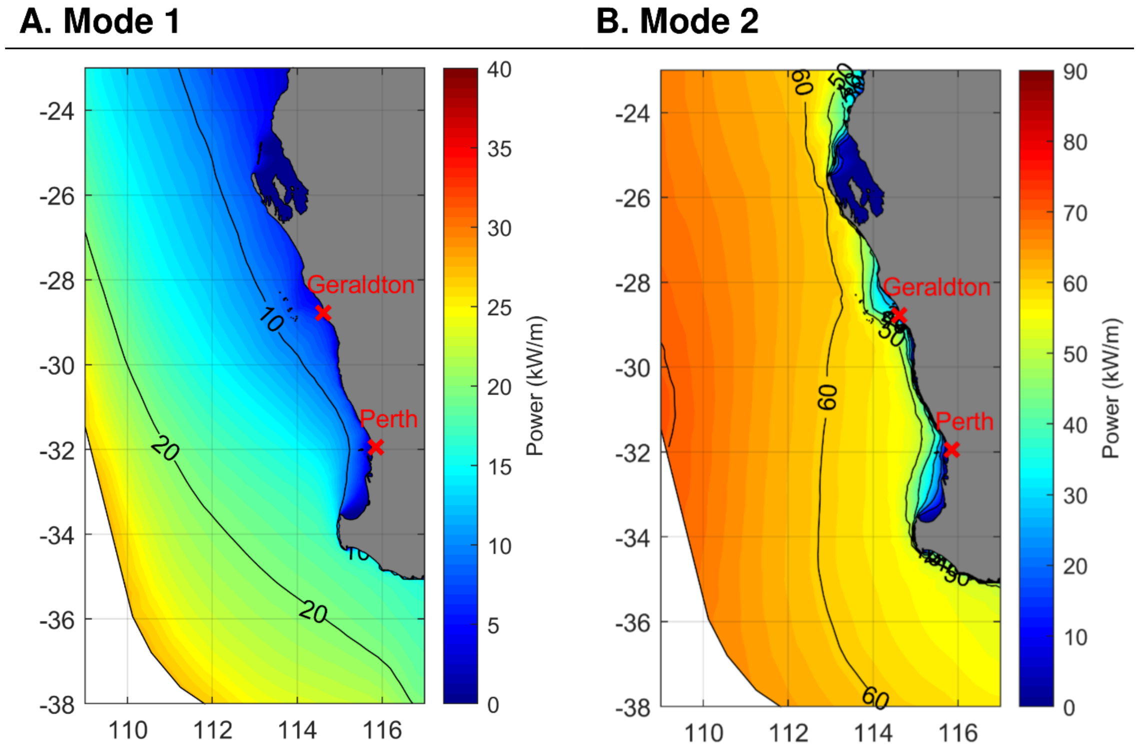
The Subtropical Ridge (STR)





Source: Agriculture Vic (2019)

- This is despite wave power in the Southern Ocean increasing over this period (Young and Ribal, 2019; Ruguero, 2019)
- Synonymous with **positive SAM** (Marshall et al., 2018) over past few decades; wave generation is more distal for Western Australia

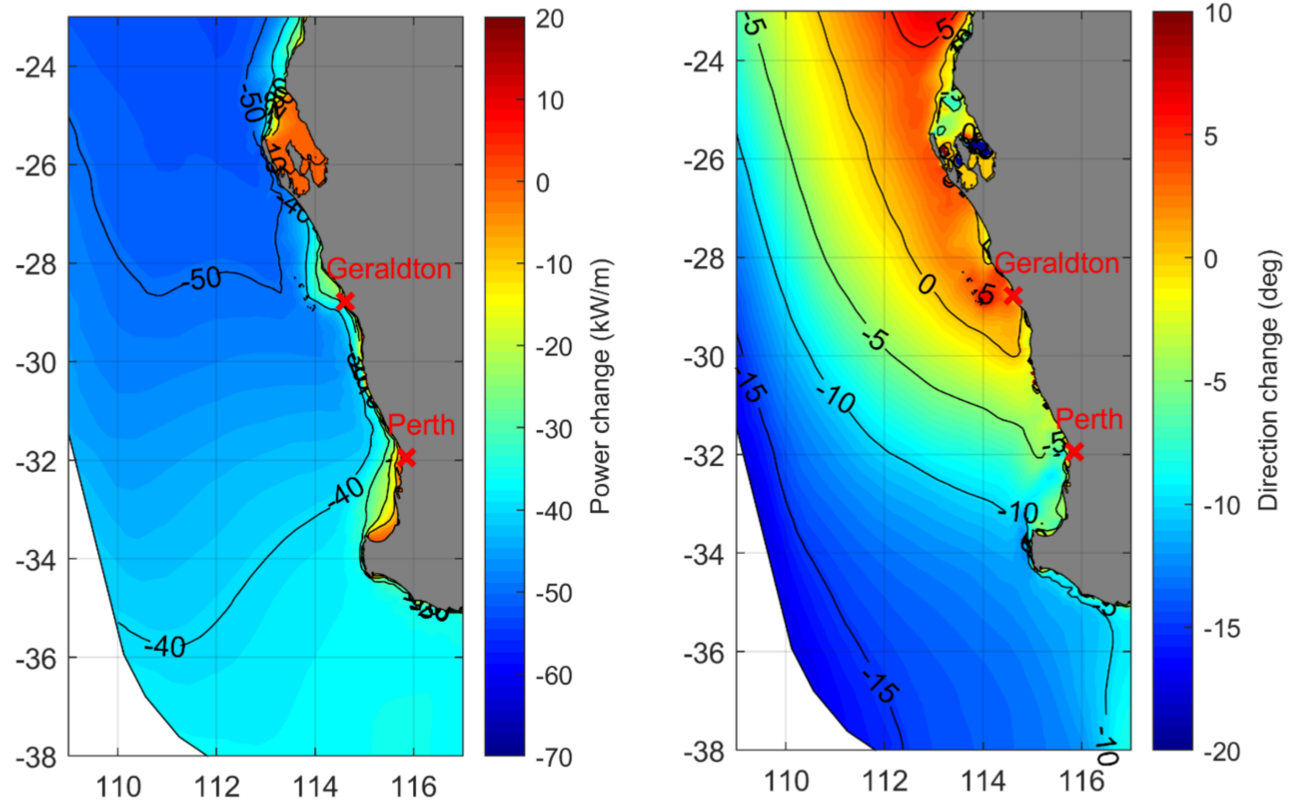


Left: Refraction of centroid wave parameters using MIKE21 SW with 1 km mesh at coast

What can we expect for the future?

- Tropical expansion projected to continue with anthropogenic warming
- An associated intensification of the STR may lead to a **reduction in total wave power** across the shelf (40 to 50 kW/m)
- And, an **anti-clockwise (southerly)** rotation in wave direction (- 5 to 15 degrees)
- While this is a high-level estimate, it is in agreement with DD studies of CMIP projections (Hemer et al., 2013; Morim et al., 2019)
- Statistical-synoptic typing is a powerful tool to build scenarios of wave climate change and relate these to changes in large-scale atmospheric parameters

A. Change in wave power **B. Change in wave direction**



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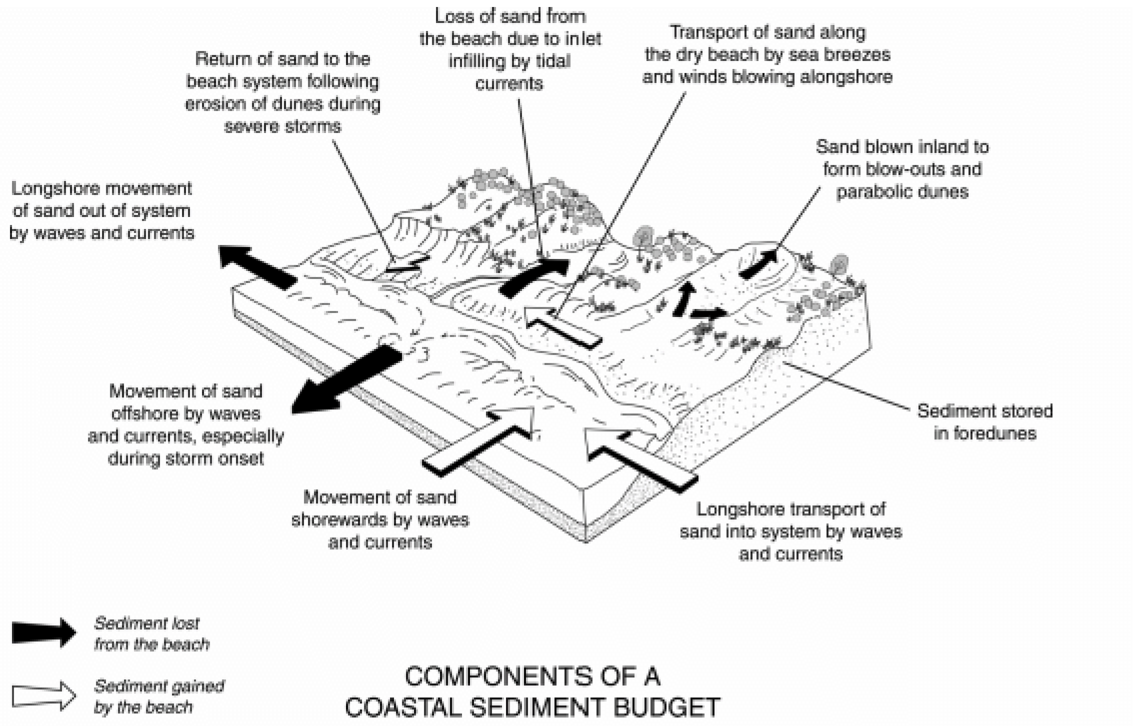
Unanswered questions

- How do these potential changes impact the **long-term sediment budget**; long-shore vs. cross-shore ratio; ability of coast to keep pace with a rising tidal prism
- Sustained high atmospheric pressure is also suppressing sea level; what does the combined effect of **lower-than-global-average sea level rise** and **lower constructive (modal) wave power** mean for net coastal response?
- The STR/SAM are changes in zonal climate – the response of meridional patterns like **ENSO and IOD** to warming may complicate the story
- On the Western Australian coast, changes in the **Leeuwin Current** and **sea-breeze** will also influence the net coastal response



Source: WAPC (2003)

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See Poster "*Directional Wave Changes Induced By The Expanding Tropics*", Itxaso Oderiz et al.

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