From Ocean to Coast: Past and future marine climate changes off southeast Australia

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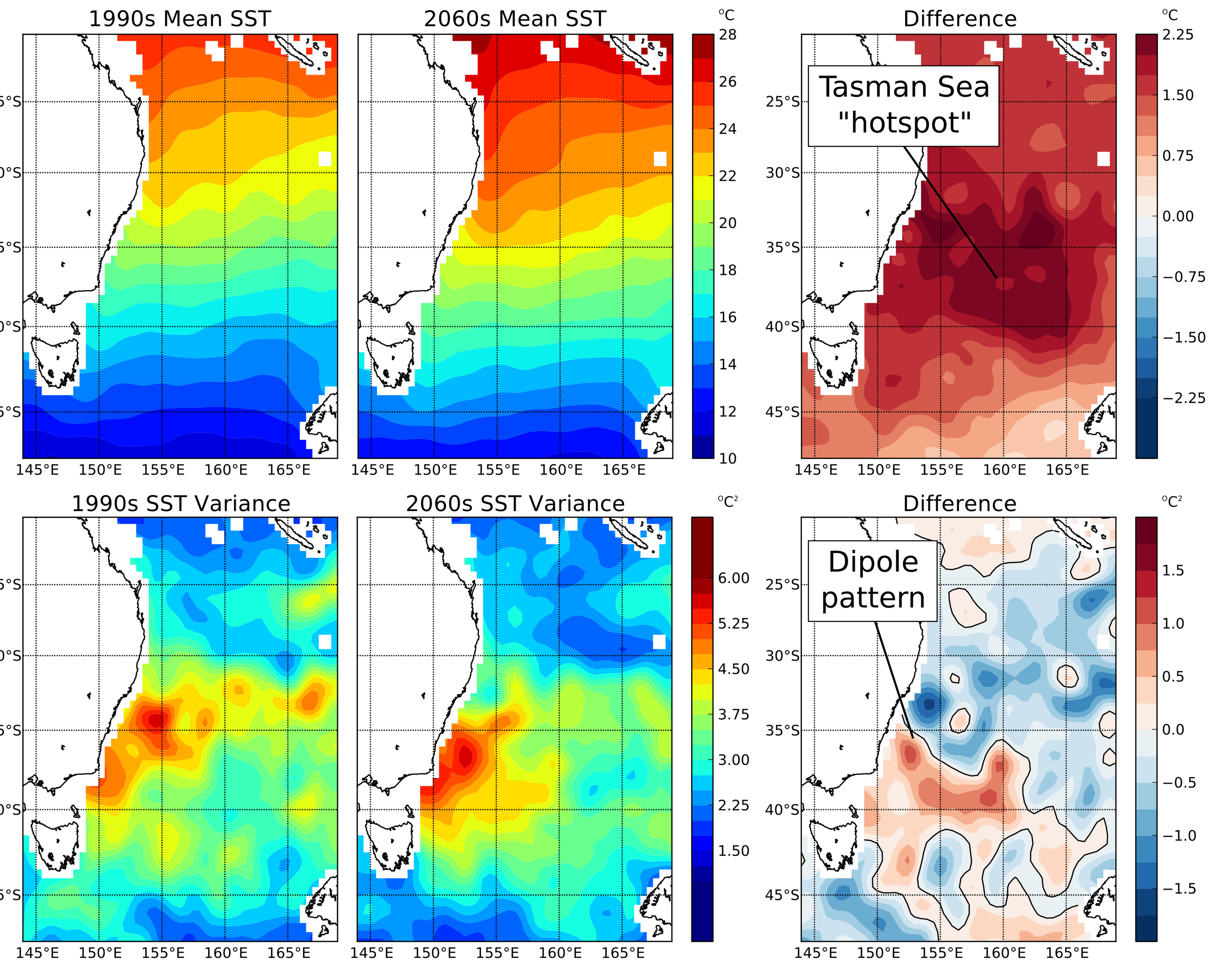
1 Introduction

- The surface waters of the western Tasman Sea are **warming** at almost **four times the global average** rate.
- Observational and modelling studies suggest that the increased sea surface temperature (SST) may be largely due to a **spin-up** of the **South Pacific Gyre** over recent decades.
- However, given the complex nature of the western boundary current in the South Pacific the **consequences** of the spin-up of the South Pacific Gyre in this region are **not obvious**.
- In particular, the enhancement of the EAC extension does not represent a simple change in the mean flow, but rather complex pulse and **eddy changes**, and is likely to affect higher order statistics such as the **frequency of warming or cooling events**. Extreme temperature events in particular can have catastrophic impacts on **fragile coastal ecosystems**.

2 Marine Climate Change

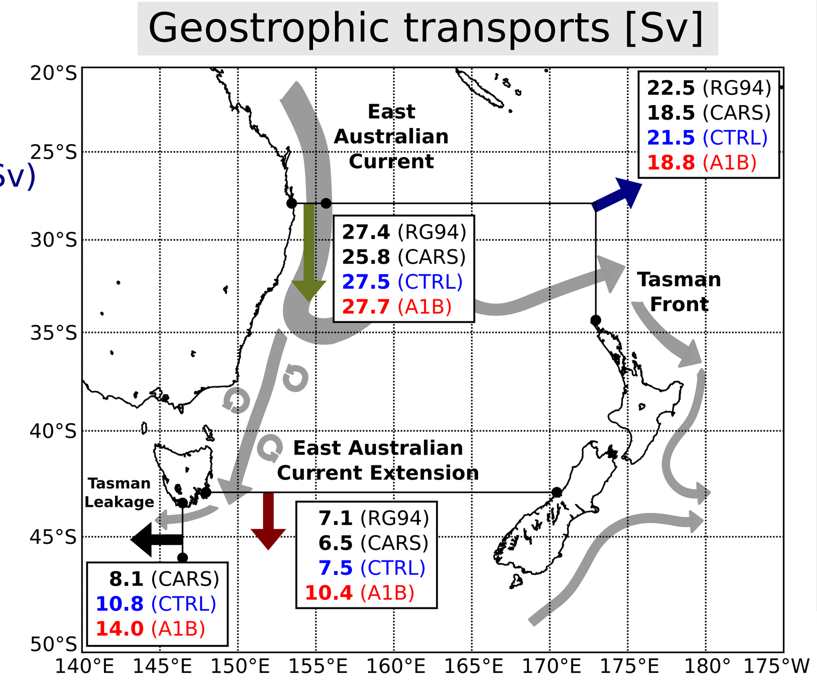
- We analyse control and projected **marine climate change simulations** of Australia from the dynamically downscaled Ocean Forecasting Australia Model (OFAM) through the **21st century**, forced by global climate simulations under the **A1B** carbon emissions scenario

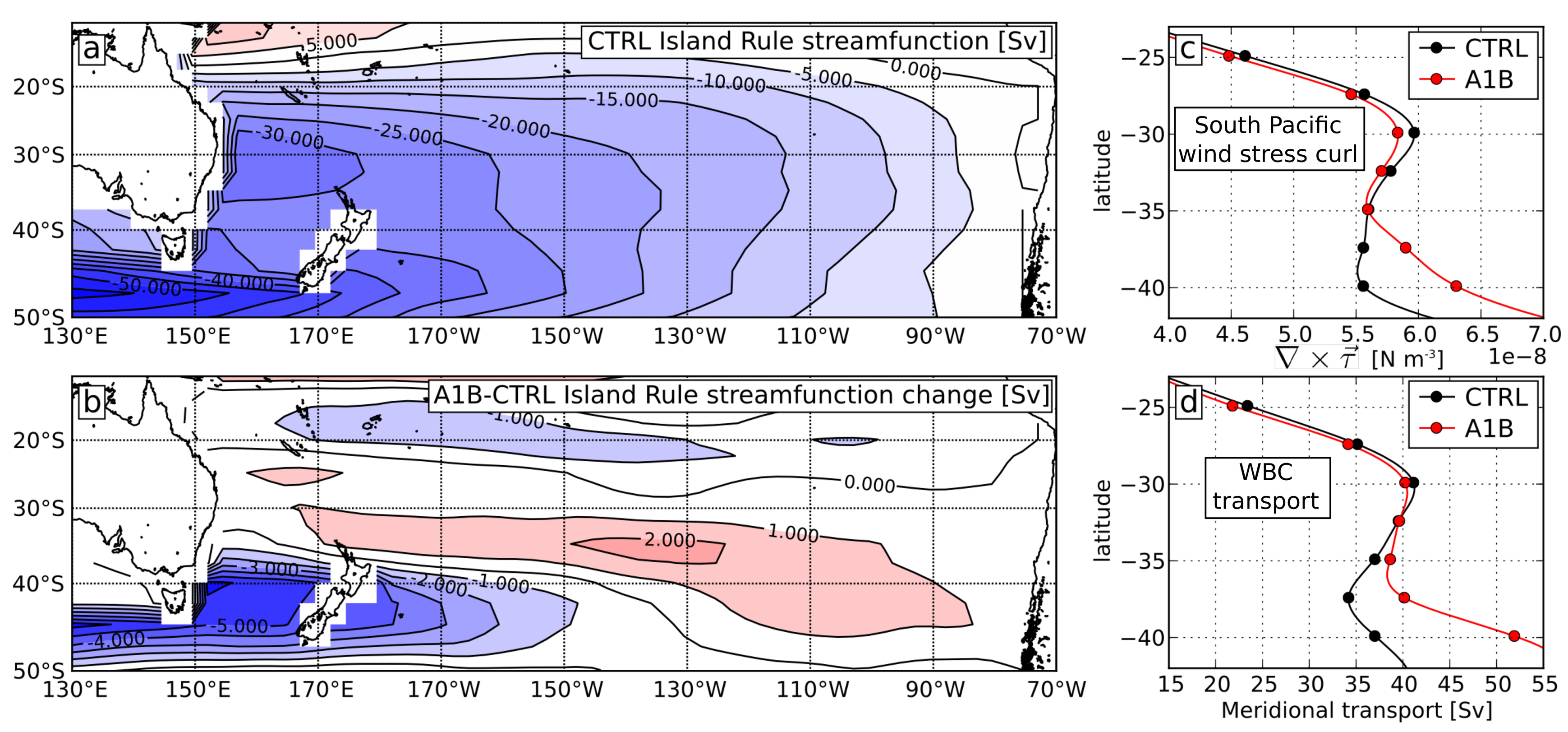


- Model estimations for the 1990s of **mean** and **variance** of SST compare well against observations
- Model predicts a **"hotspot"** of change in mean SST of up to 2.5°C in the Tasman Sea, and a dipole feature in the change of variance, indicating a **southward shift**

3 Tasman Sea Transports

- Projected changes to **mean flow**:
  - **increase** of EAC extension (+3.9 Sv)
  - **decrease** of flow along TasmanFront (-2.7 Sv)
  - **little change** in core EAC flow (+0.2 Sv)
- Relative changes in flow through Tasman Sea are consistent with predictions from **simple model** based on the Sverdrup transport and Godfrey [1989] Island Rule given change in wind stress fields:





5 Sea surface temperature extremes

- The ocean models **do not provide accurate predictions of extremes** but do provide **good estimates of large-scale circulation and climate statistics** (mean, variance, etc)

Concept: we model the observed extremes as a function of the ocean model 1990s climate, and then use the fitted model and the 2060s climate to predict future extremes

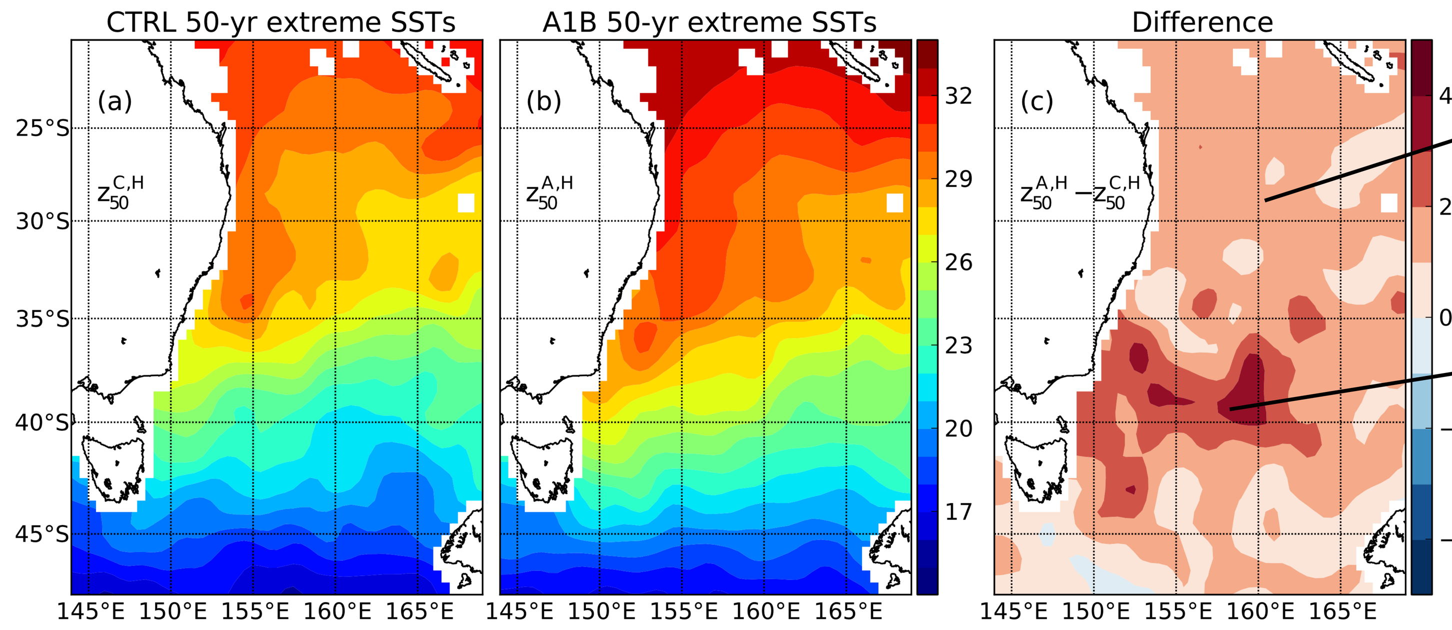
- Model the observed SST extremes **y** using an **extreme value distribution** (Gumbel) [Equation 1]

$$\boldsymbol{y}|\boldsymbol{a},\boldsymbol{\phi} \sim \mathrm{Gumbel}(\boldsymbol{a},\boldsymbol{\phi}) \quad (1)$$

$$\boldsymbol{a} = \boldsymbol{X}\boldsymbol{\beta}_a + \boldsymbol{\epsilon}_a \quad (2)$$

$$\boldsymbol{\phi} = \boldsymbol{X}\boldsymbol{\beta}_\phi + \boldsymbol{\epsilon}_\phi \quad (3)$$

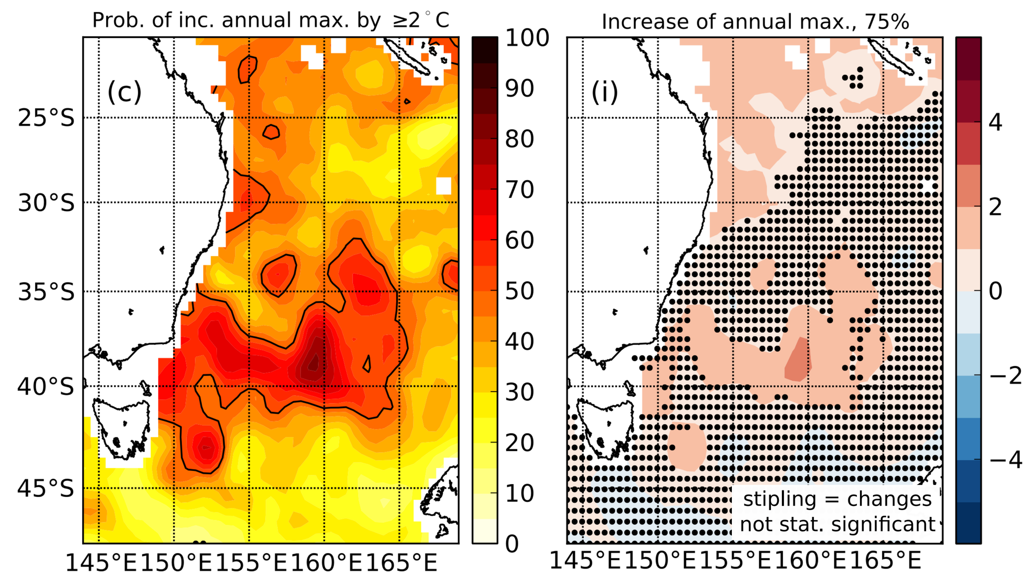
- Model the parameters of Gumbel distribution as a **linear regression** onto **X**, the marine climate statistics [Equations 2,3]. Then, given **X** from the 2060s simulation, use the fitted regression coefficients to **predict future extremes**.



Extremes **increase nearly everywhere**, due to increase of mean SST

"hotspot" of change due to combination of change in mean and variance of SST

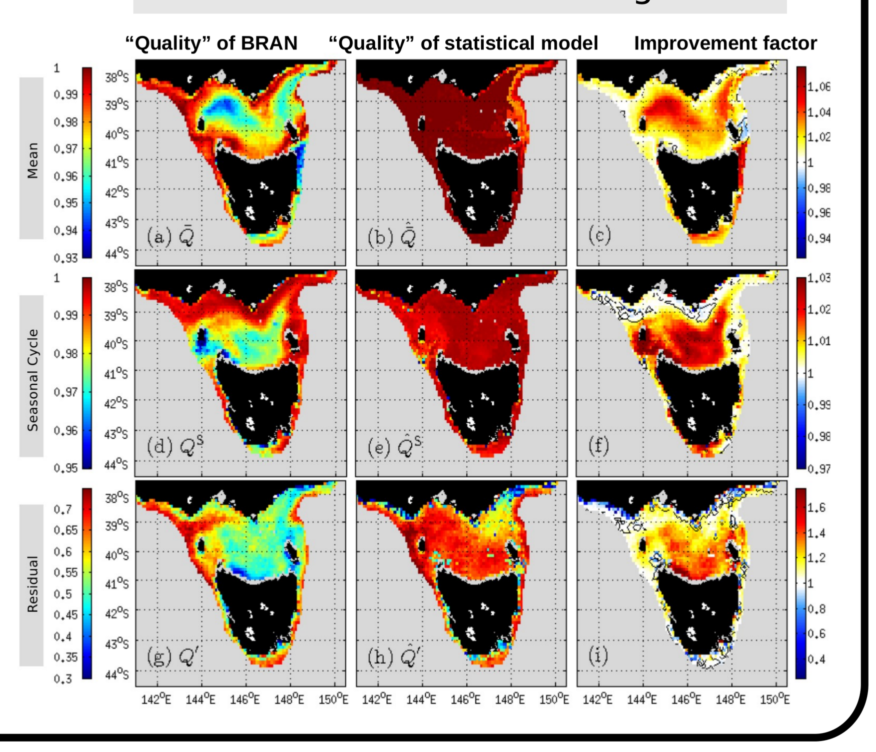
- Model is fit in a **Bayesian framework**
- Probabilistic approach allows for an estimation of **model error** and the assignment of **confidence limits** based on comparison with changes due to **randomness** in an unchanged climate, e.g.,
  - The **probability** that the maximum SST in a given year will **change by at least 2°C** is over 50% in the hotspot region (left panel):
  - Changes in maximum annual SST of ~2°C in much of the hotspot region are **statistically significant** at a confidence level of 75% (right panel):



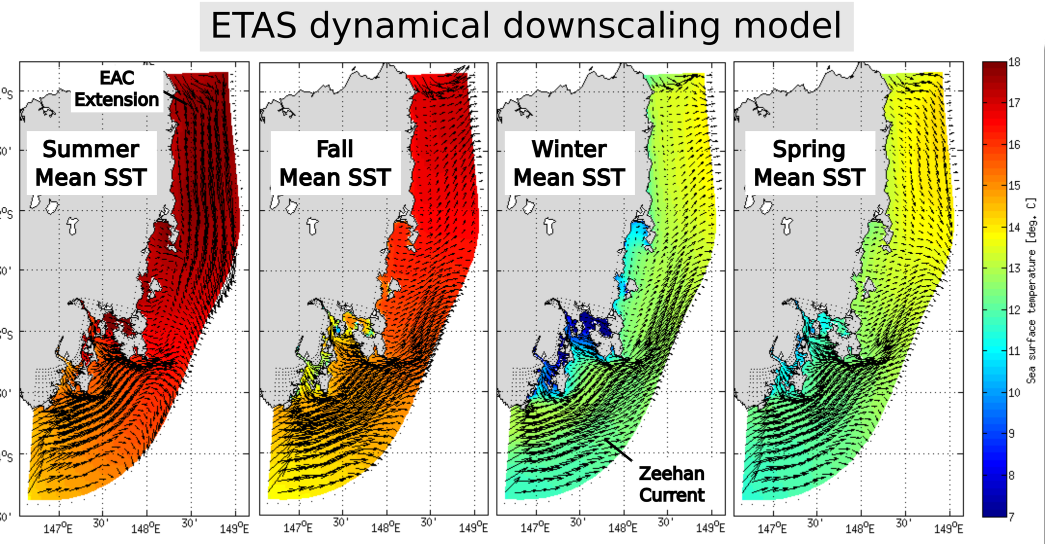
6 Downscaling to the shelf and coast

- Large-scale models **not designed for near-shore studies** and so provide poor estimates of marine climate variability over the continental shelf and in the coastal zone.
- Alternatives include **statistical downscaling** and **dynamical downscaling**.
- **Statistical downscaling** technique uses (i) accurate offshore estimates off SST and (ii) the observed shelf-ofshore statistical connection to improve model estimates of SSTs on the Australian continental shelf.
- **Dynamical downscaling** performed using Sparse Hydrodynamic Ocean Code (SHOC) at high-resolution for eastern Tasmanian continental shelf forced by BRAN and NCEP CFSR over 1993-2013 period.

OH14 statistical downscaling model



ETAS dynamical downscaling model



- Downscaling model can capture seasonality of influence of **Zeehan Current** and **EAC Extension**

7 Conclusions

Projected changes in Tasman Sea mean state include an **SST hotspot** and a **redistribution of transport**, consistent with linear a wind-driven barotropic model, occur in tandem with **changes to the mesoscale eddy field** and **SST extremes**. Future work will downscale these projections onto the continental shelf and the coastal zone.

Oliver, E.C.J. and N.J. Holbrook (2014), Extending our understanding of South Pacific gyre 'spin-up': Modeling the East Australian Current in a future climate, JGR, 119, 6078-6100

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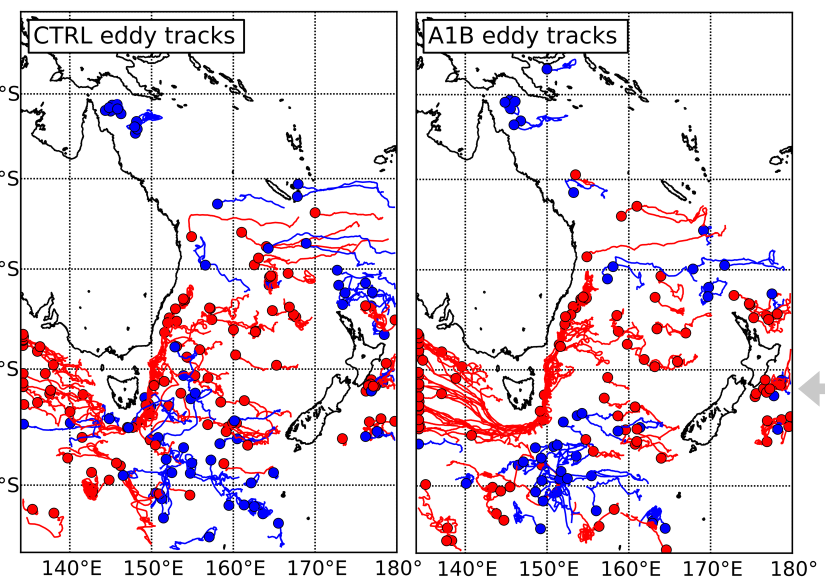
4 Eddy Field

- Changes in **eddy field** projected to occur in tandem with changes to mean circulation



Dramatic increase in **eddy kinetic energy** in Tasman Sea and EAC extension region in particular

Cyclonic (blue) and **anticyclonic (red)** eddies tracked using the Chelton et al. (2011) sea level algorithm

Significant increase in number of long-lived anticyclonic (warm-core) eddies in EAC Extension