# Projected changes in Tasman Sea marine climate, extremes, and circulation through the 21st century


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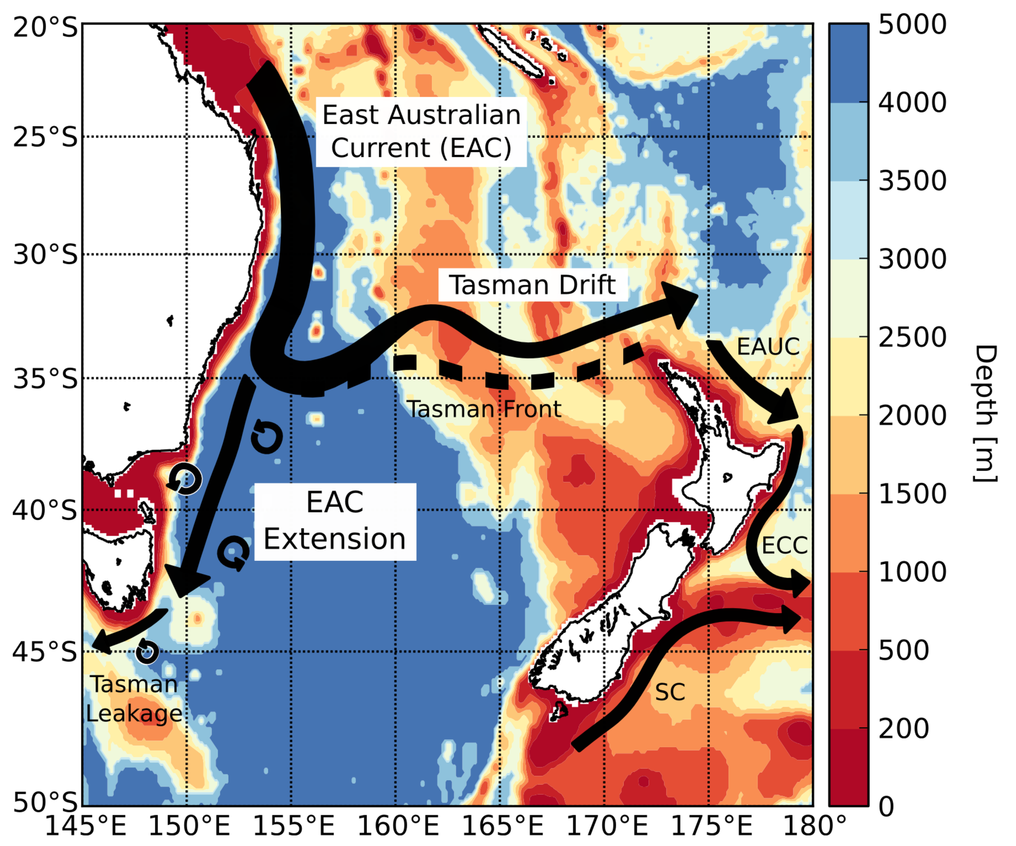
## 1 Introduction

- The surface waters of the western Tasman Sea are **warming** at almost **four times the global average** rate [1,2].
- 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 [3,4,5].
- 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**.

Tasman Sea bathymetry and circulation

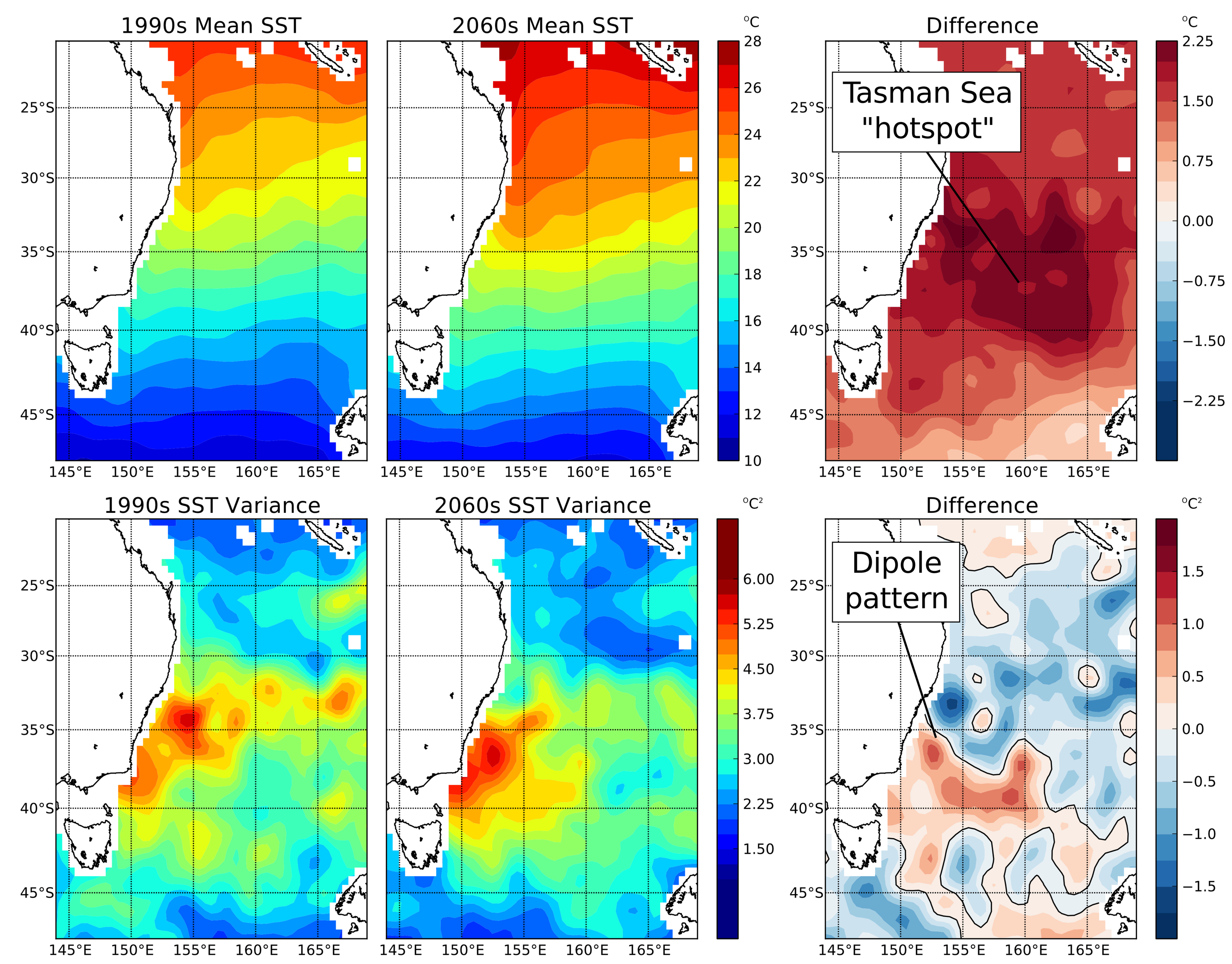



## References


[1] Holbrook, N. J. and N. Bindoff (1997), J. Clim, 10(5), 1035-1049
[2] Ridgway, K. (2007), Geophys. Res. Lett., 34(13), L13616
[3] Roemmich, D. et al. (2007), j. Phys. Ocean., 37, 162-173
[4] Cai, W. et al. (2005), Geophys. Res. Lett., 32, L23706
[5] Cai, W. (2006), Geophys. Res. Lett., 33, L03712
[5] Ridgway, K. and J. Godfrey, J. Geophys. Res., 99(C2), 3231-3248
[7] Thompson, K. R. and E. Demirov (2006), J. Geophys. Res., 111 (C5), C05005
[8] Oliver, E. C. J. and N. J. Holbrook, Extending our understanding of South Pacific gyre 'spin-up': Modeling the East Australian Current in a future climate, Manuscript submitted to J. Geophys. Res.
[9] Oliver, E. C. J., S. J. Wotherspoon, M. A. Chamberlain and N. J. Holbrook, Projected Tasman Sea extremes in sea surface temperature through the 21st century, Manuscript submitted to J. Clim.
[10] Oliver, E. C. J., S. J. Wotherspoon and N. J. Holbrook, Estimating extremes from global ocean and climate models: A Bayesian hierarchical model approach, Manuscript submitted to Prog. Ocean.


## 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

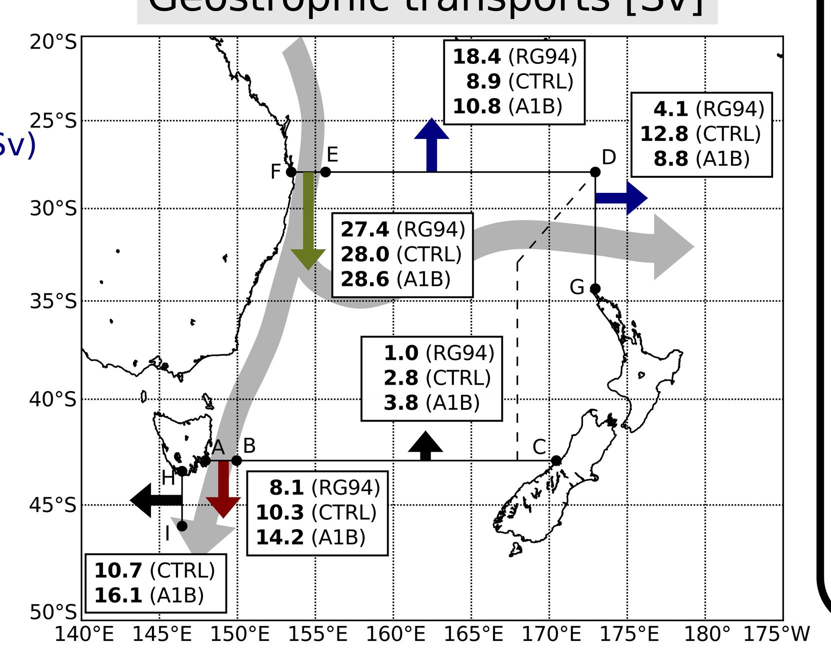


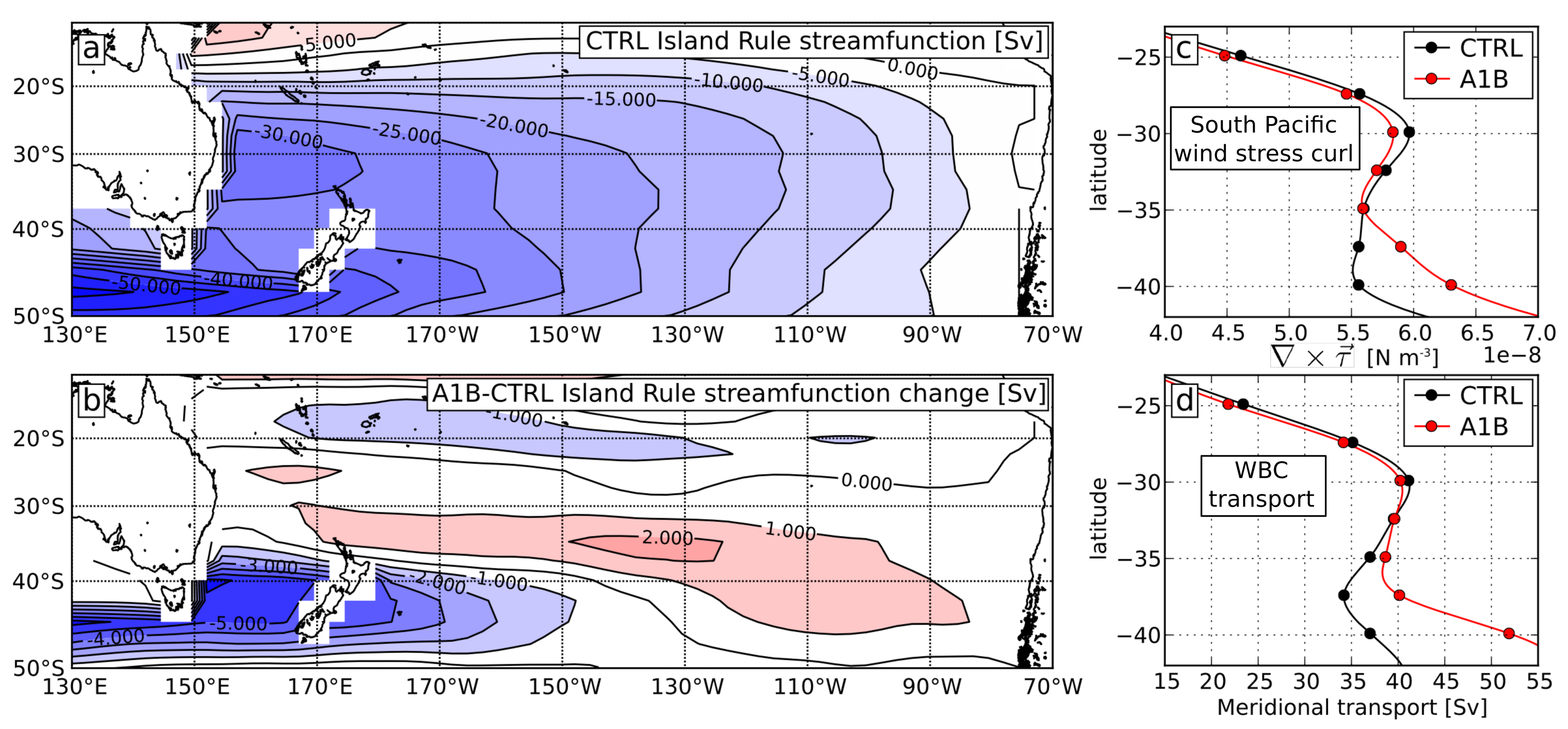

- Model estimations for the 1990s of **mean** and **variance** of SST compare well against observations
- Model predicts a **"hotspot"** of change in mean SST of up to 2.5$^{O}$C in the Tasman Sea, and a dipole feature in the change of variance, indicating a **southward shift**

## 3 Tasman Sea Transports

- Projected changes to **mean flow**:
  - **increase** of EAC extension (+3.9 Sv)
  - **decrease** of flow along TasmanFront (-2.1 Sv)
  - **little change** in core EAC flow (+0.6 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:

Geostrophic transports [Sv]




## 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

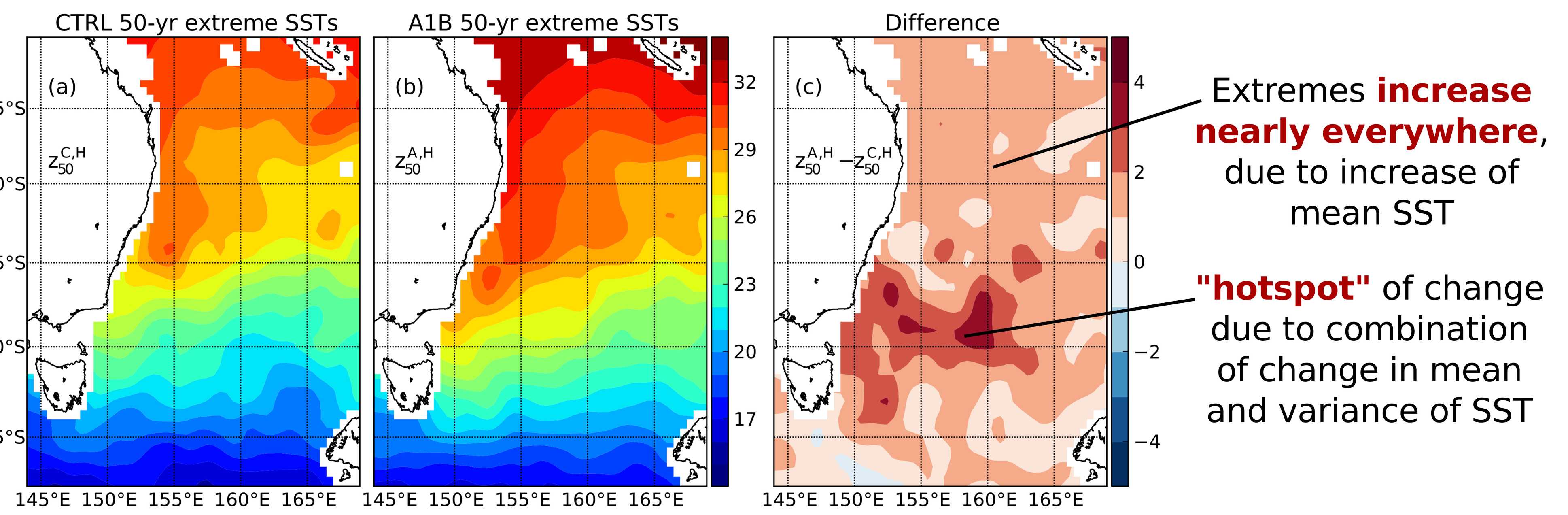
- Model the observed SST extremes ***y*** using an **extreme value distribution** (Gumbel) [Equation 1]

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

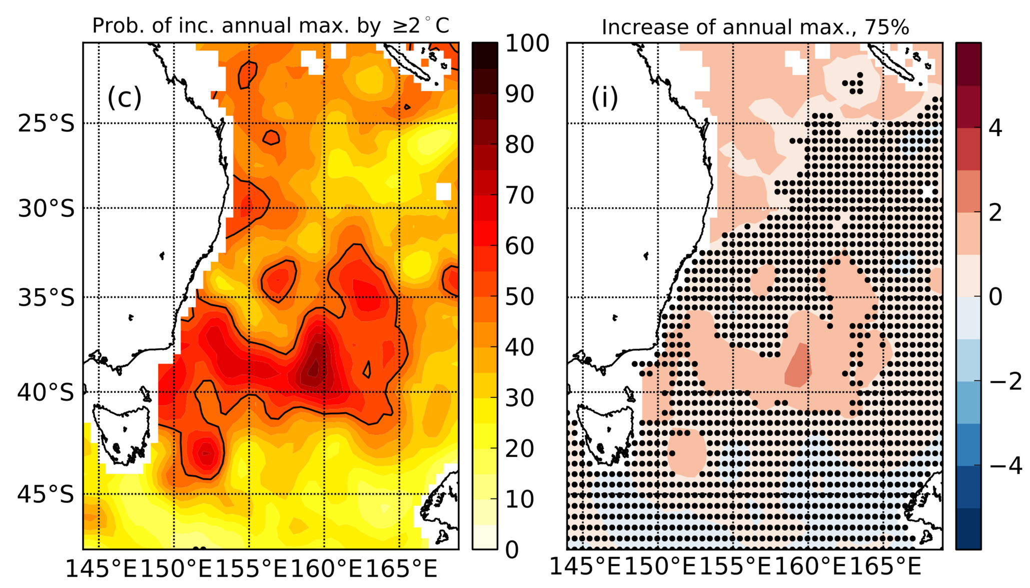
$$\boldsymbol{a} = \boldsymbol{X\beta}_a + \boldsymbol{\epsilon}_a \quad (2)$$

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

- 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**.




- 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$^{O}$C** is over 50% in the hotspot region (left panel):
  - Changes in maximum annual SST of ~2$^{O}$C in much of the hotspot region are **statistically significant** at a confidence level of 75% (right panel):




## 6 Conclusions

- Mean **Tasman Sea SST warming** (1-3$^{O}$C) is projected to occur in tandem with an **increase of SST variance** south of the EAC separation point [9]
- **EAC extension** is projected to **strengthen** a the expense of flow along the Tasman Front, and the EAC core flow (north of the separation point) is projected to change very little [8]
- These transports occur alongside a **southward shift** (~1$^{O}$ latitude) of the **EAC separation point** [8]
- **Extreme SSTs** respond to changes in both the **mean** and the **variance** of SST (and other higher order moments) [9]. We have developed a **general technique for estimating extremes** from climate projections [10], which can also be applied outside the marine context.

## 4 EAC Separation Point

- Sea level skewness ($m_3$) can be used to determine the **mean path of WBCs** [7], and its intersection with the **continental shelf** can be used to estimate the mean location of the **EAC separation point**
- Models runs predict a 0.9$^{o}$ (94 km) **poleward shift** in mean separation point location: