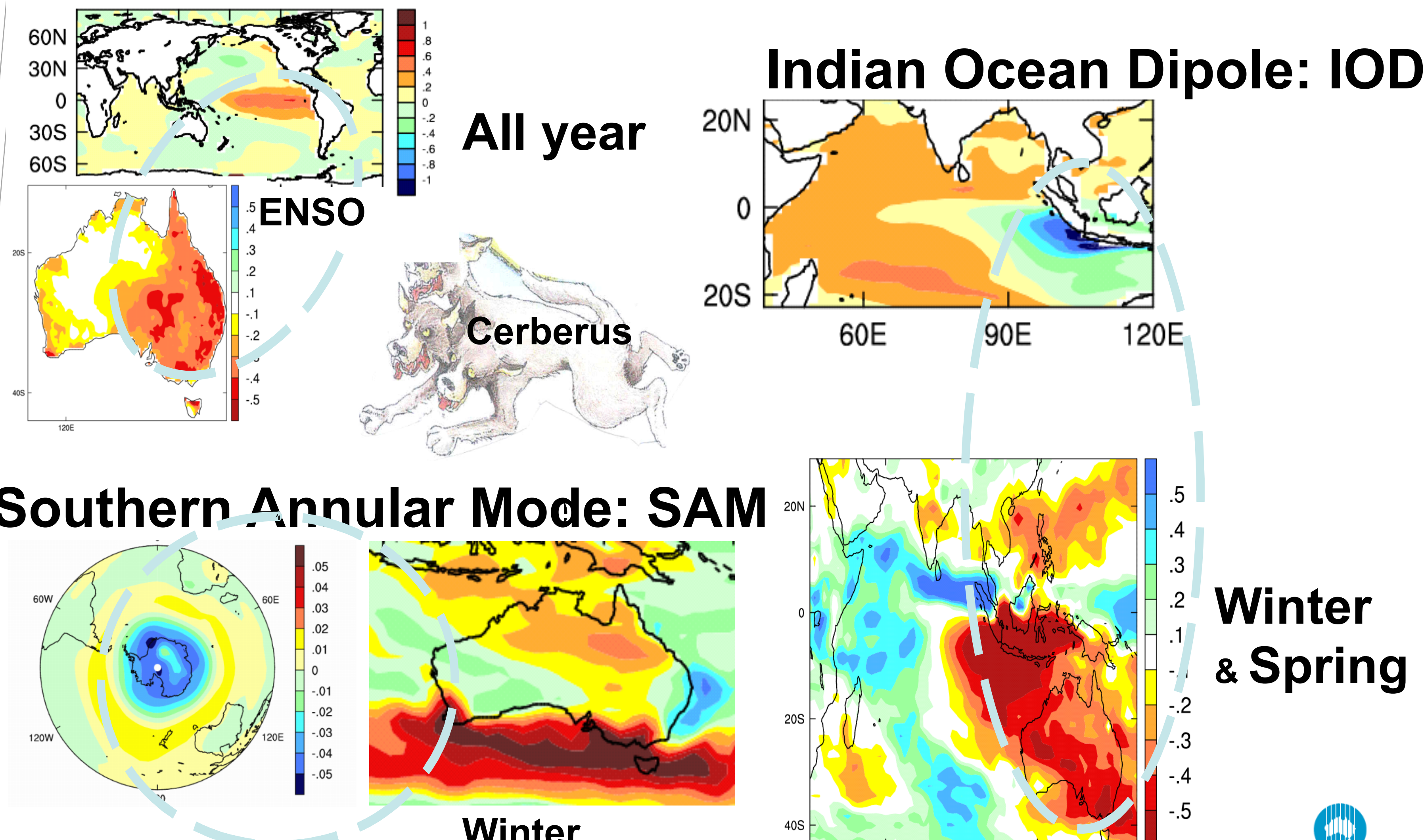
Australian Droughts

Wenju Cai and many colleagues at CSIRO

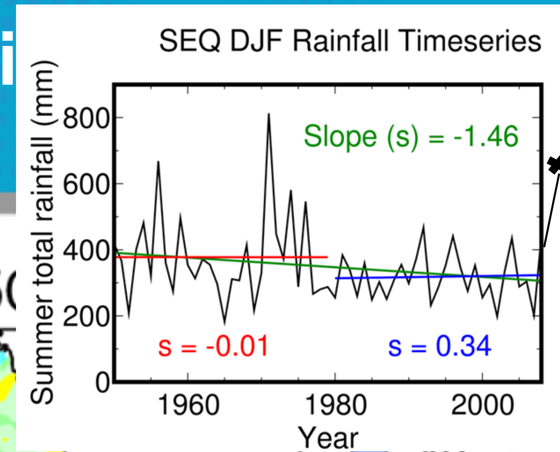
Droughts and climate change

- What causes droughts?
- Seasonality is important.
- Drivers of rainfall variability.
- What is the long-term outlook?

The three-headed dog of the Australian climate

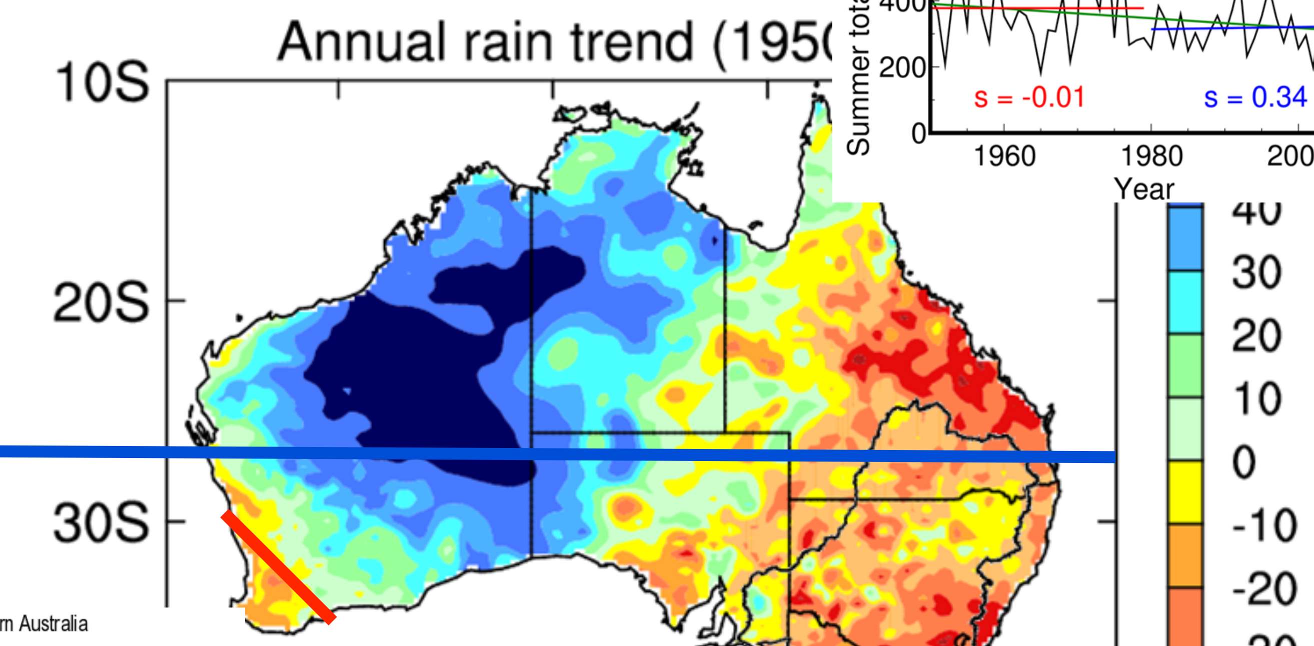


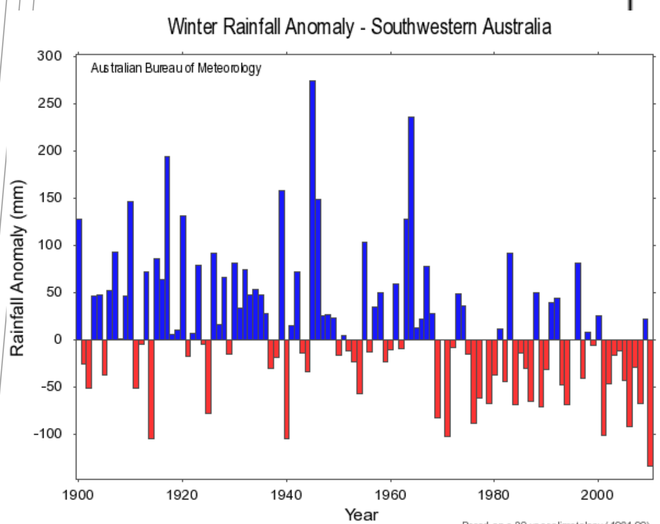
Focusing on Australia Annual rai since 1950 in % of climatology

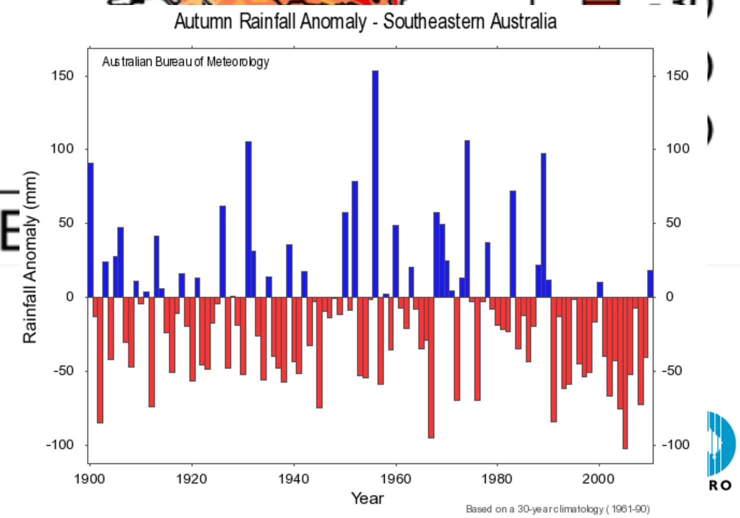


October-March

May-October

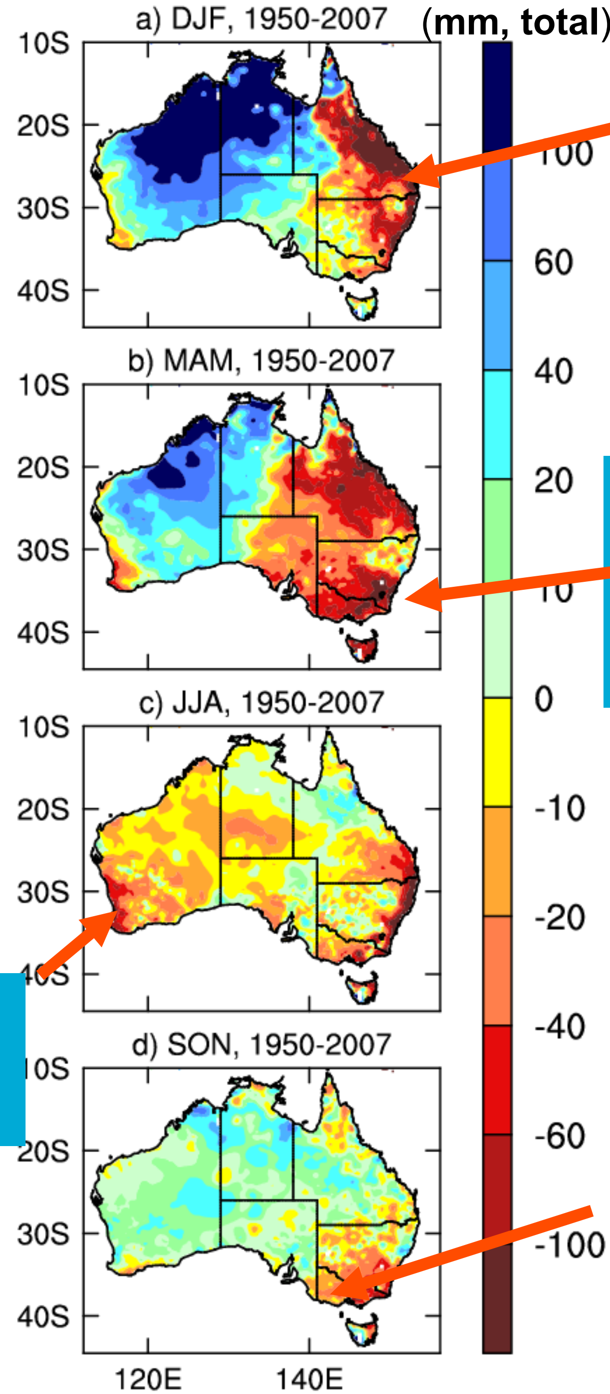






ENSO Impact asymmetry → the PDO & Climate Shift

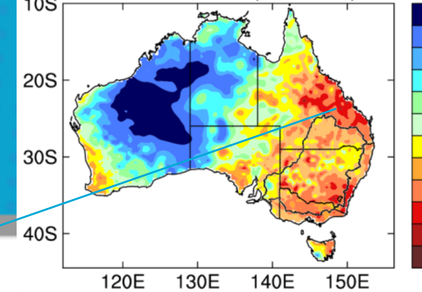
We don’t understand the dynamics

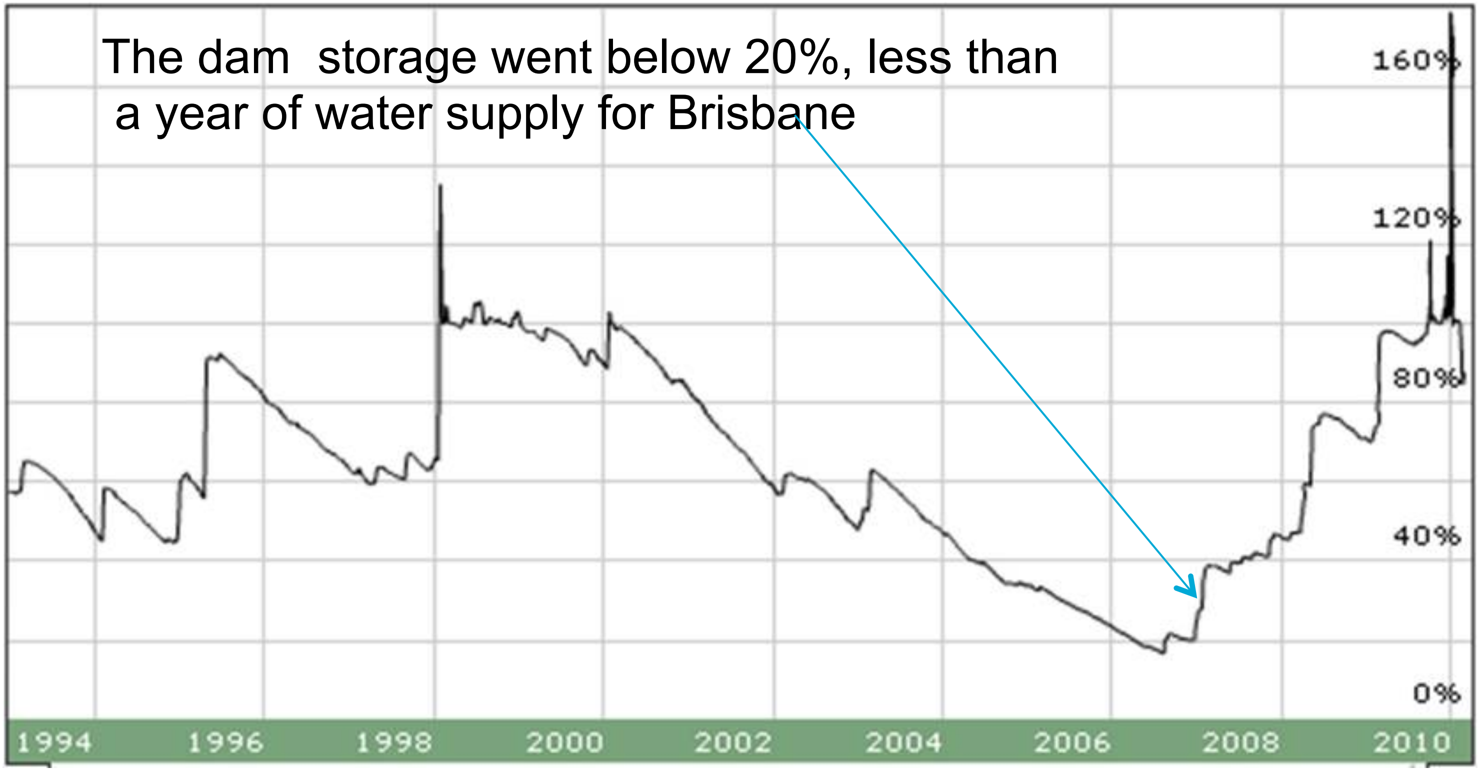


Positive SAM trend

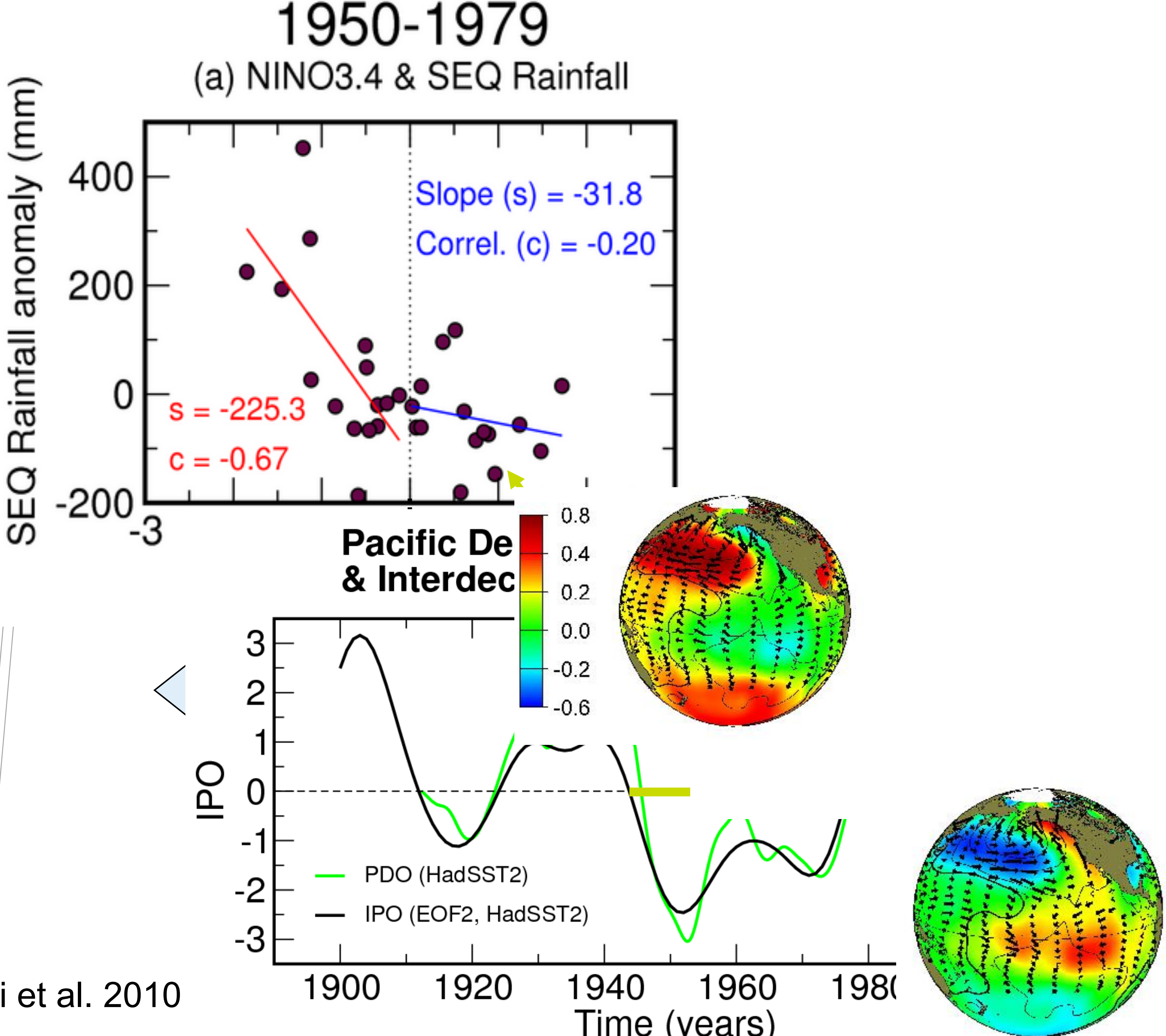
More positive IODs

A severe drought ..



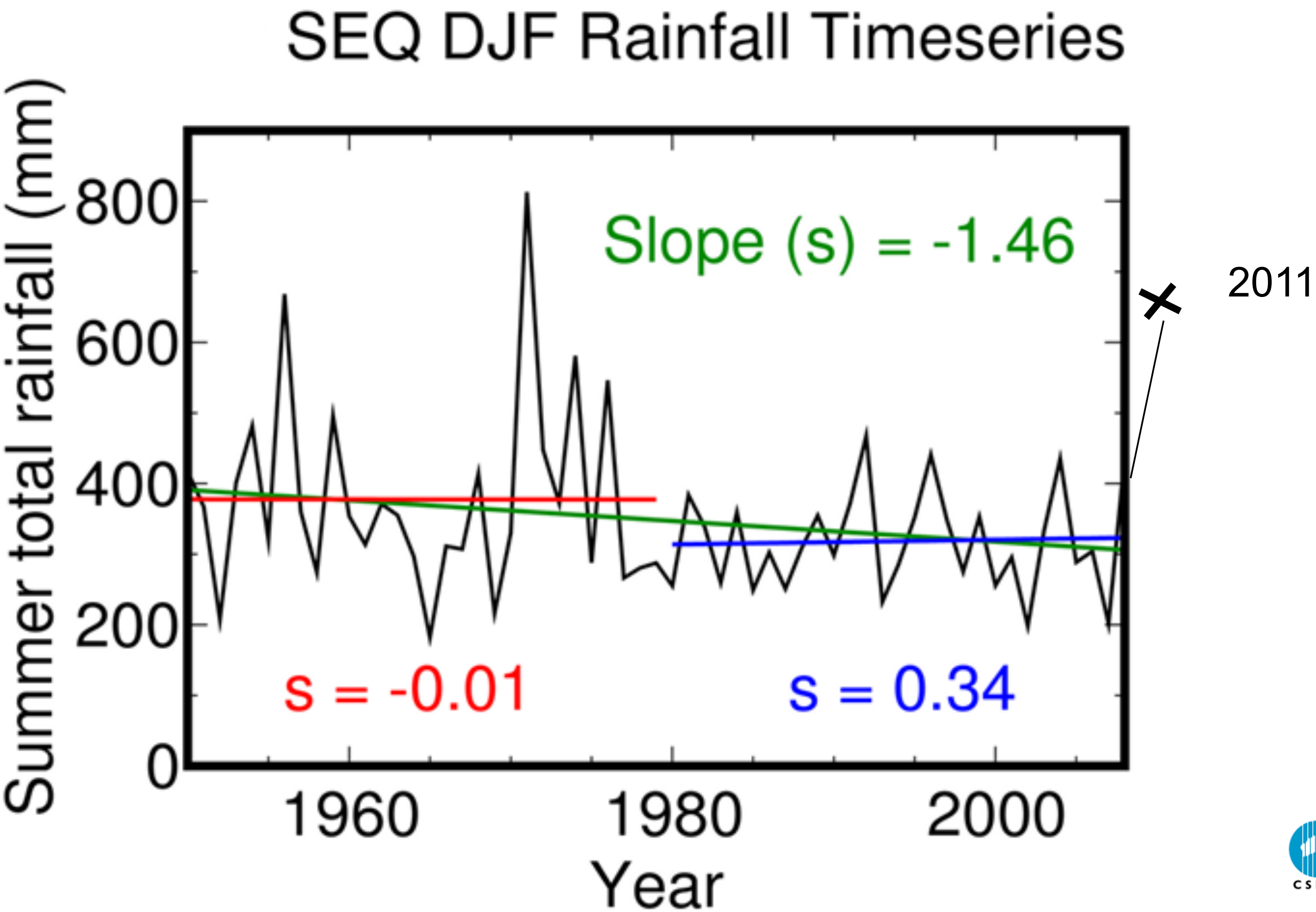


- Is climate change induced?

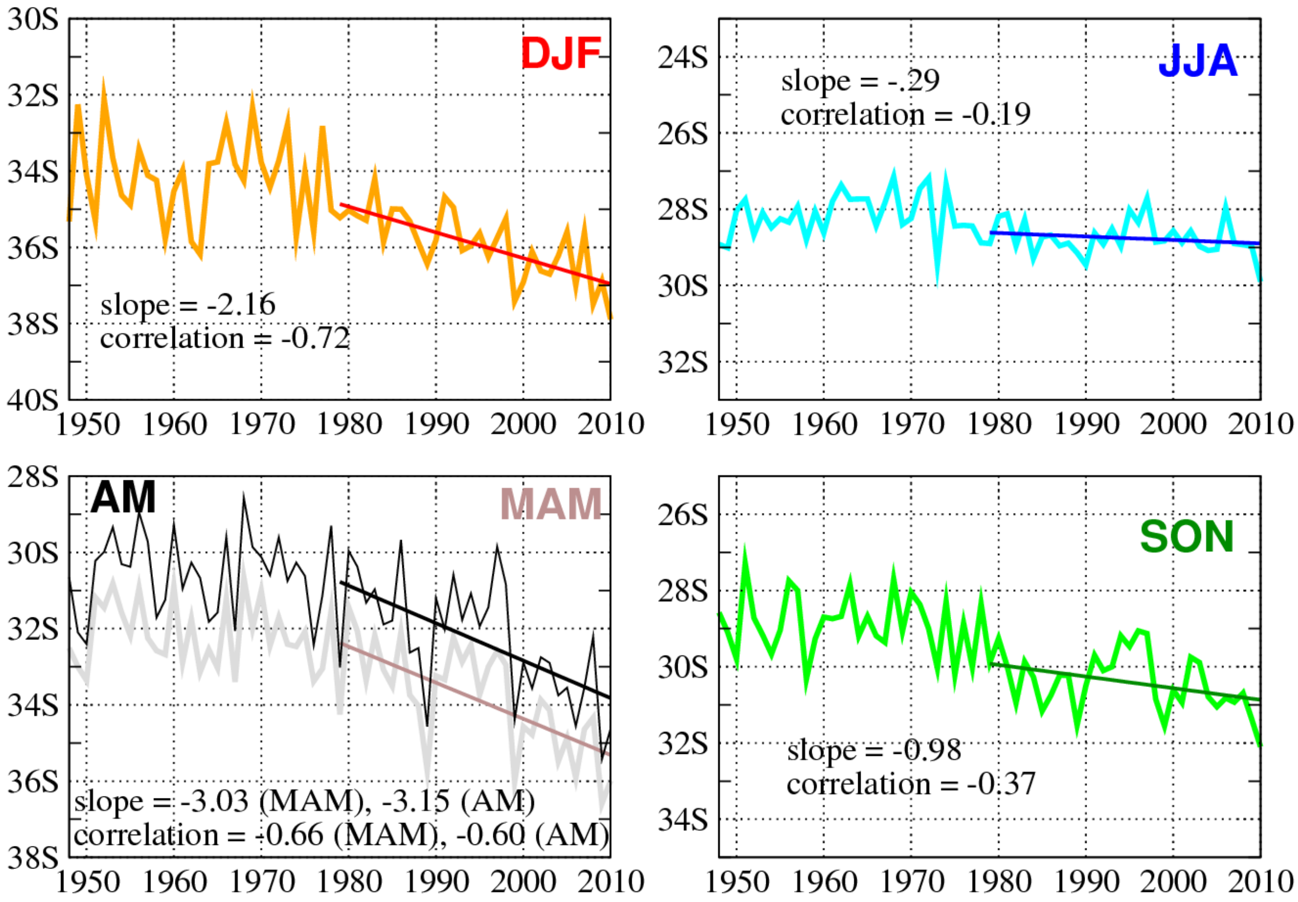


Cai et al. 2010

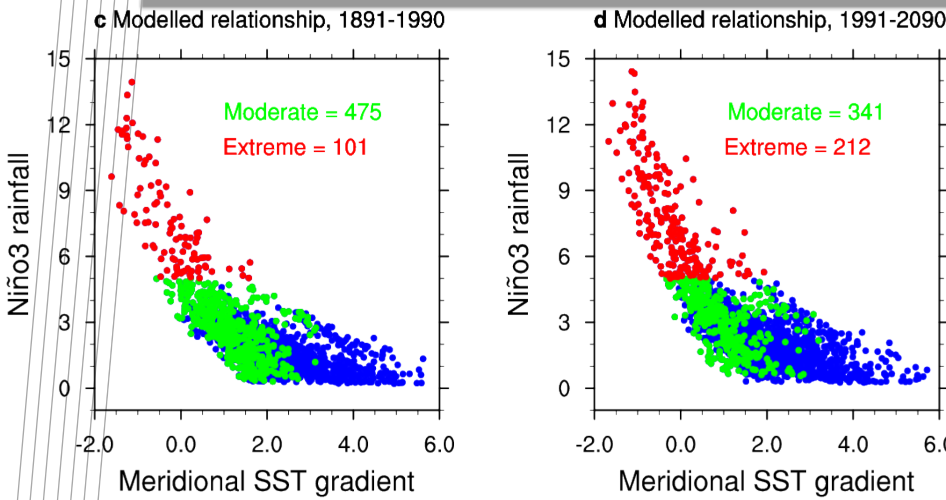
SEQ summer rainfall



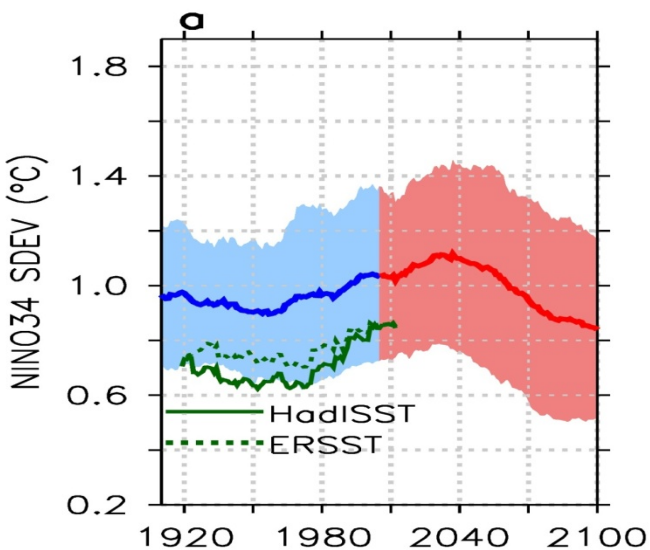
Extent of SH Hadley Cell (Zero zonal MMS_{500}, NCEP1)



Aggregation over 20 models



The frequency doubles from one in 20 years to one in 10 years.



nature climate change

LETTERS

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Increasing frequency of extreme El Niño events due to greenhouse warming

Wenju Cai[1,2]*, Simon Borlace[1], Matthieu Lengaigne[3], Peter van Rensch[1], Mat Collins[4], Gabriel Vecchi[5], Axel Timmermann[6], Agus Santoso[7], Michael J. McPhaden[8], Lixin Wu[2], Matthew H. England[7], Guojian Wang[1,2], Eric Guilyardi[3,9] and Fei-Fei Jin[10]

El Niño events are a prominent feature of climate variability with global climatic impacts. The 1997/98 episode, often referred to as 'the climate event of the twentieth century'[1,2], and the 1982/83 extreme El Niño[3], featured a pronounced eastward extension of the west Pacific warm pool and development of atmospheric convection, and hence a huge rainfall increase, in the usually cold and dry equatorial eastern Pacific. Such a massive reorganization of atmospheric convection, which we define as an extreme El Niño, severely disrupted global weather patterns, affecting ecosystems[4,5], agriculture[6], tropical cyclones, drought, bushfires, floods and other extreme weather events worldwide[3,7–9]. Potential future changes in such extreme El Niño occurrences could have profound socio-economic consequences. Here we present climate modelling evidence for a doubling in the occurrences in the future in response to greenhouse warming. We estimate the change by aggregating results from climate models in the Coupled Model Intercomparison Project phases 3 (CMIP3; ref. 10) and 5 (CMIP5; ref. 11) multi-model databases, and a perturbed physics ensemble[12]. The increased frequency

extended to every continent, and the 1997/98 event alone caused US$35–45 billion in damage and claimed an estimated 23,000 human lives worldwide[17].

The devastating impacts demand an examination of whether greenhouse warming will alter the frequency of such extreme El Niño events. Although many studies have examined the effects of a projected warming on the Pacific mean state, El Niño diversity and El Niño teleconnections[18–21], the issue of how extreme El Niños will change has not been investigated. Here we show that greenhouse warming leads to a significant increase in the frequency of such events.

We contrast the characteristics between the extreme and moderate El Niño events using available data sets[22,23], focusing on December–January–February (DJF), the season in which El Niño events peak. During moderate events, which include canonical and Modoki El Niño[24], the eastern boundary of the warm pool (indicated by the 28 °C isotherm, purple, Fig. 1a) and the atmospheric convective zone move eastwards to just east of the Date Line. The ITCZ lies north of the Equator[25], and the rainfall anomaly over the eastern equatorial Pacific

nature climate change

LETTERS

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Response of El Niño sea surface temperature variability to greenhouse warming

Seon Tae Kim[1]*, Wenju Cai[1,2]*, Fei-Fei Jin[3], Agus Santoso[4], Lixin Wu[2], Eric Guilyardi[5,6] and Soon-Il An[7]

The destructive environmental and socio-economic impacts of the El Niño/Southern Oscillation[1,2] (ENSO) demand an improved understanding of how ENSO will change under future greenhouse warming. Robust projected changes in certain aspects of ENSO have been recently established[3–5]. However, there is as yet no consensus on the change in the

interest to determine how ENSO SST amplitude will respond to greenhouse warming.

Although recent studies have uncovered robust projected changes in ENSO-driven rainfall variability[3,4] and ENSO propagation characteristics[5], there is still no consensus on the change in ENSO SST variability[6–8]. Here we examine the issue using

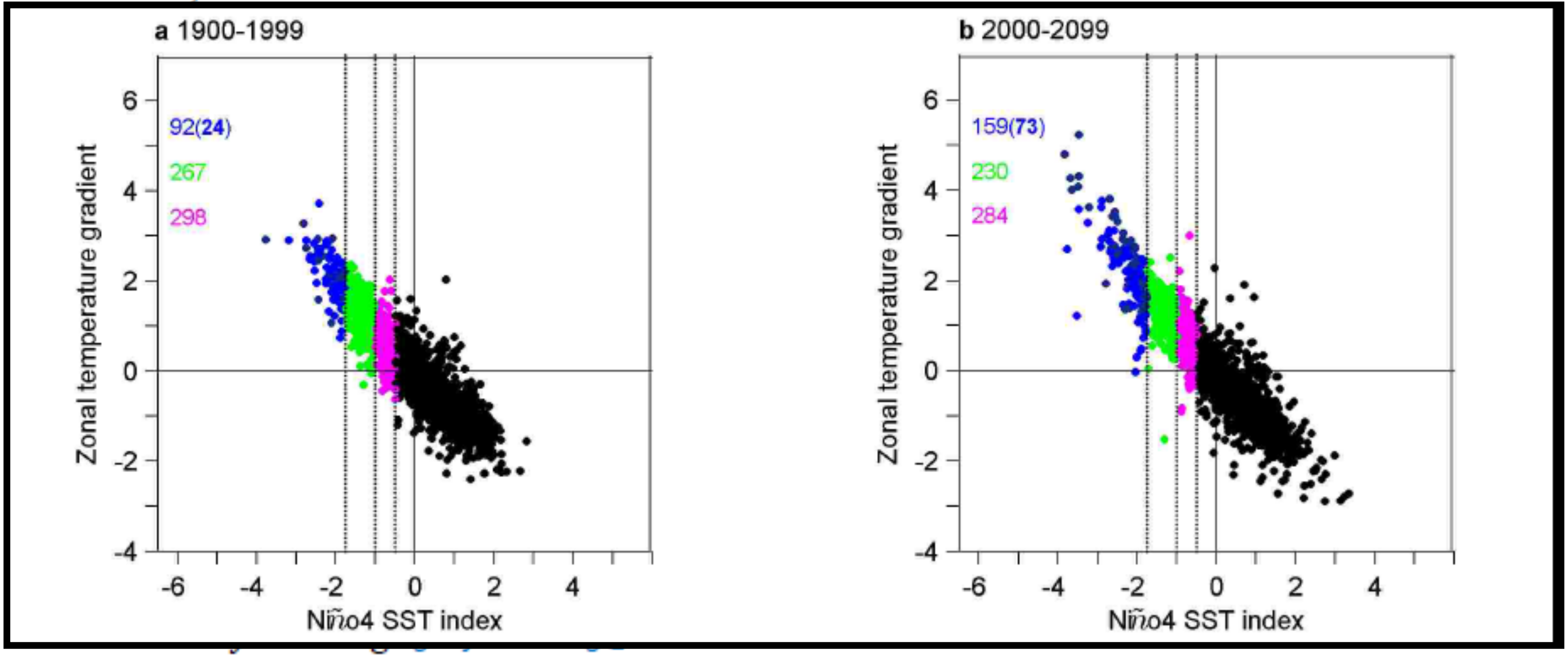
CSIRO

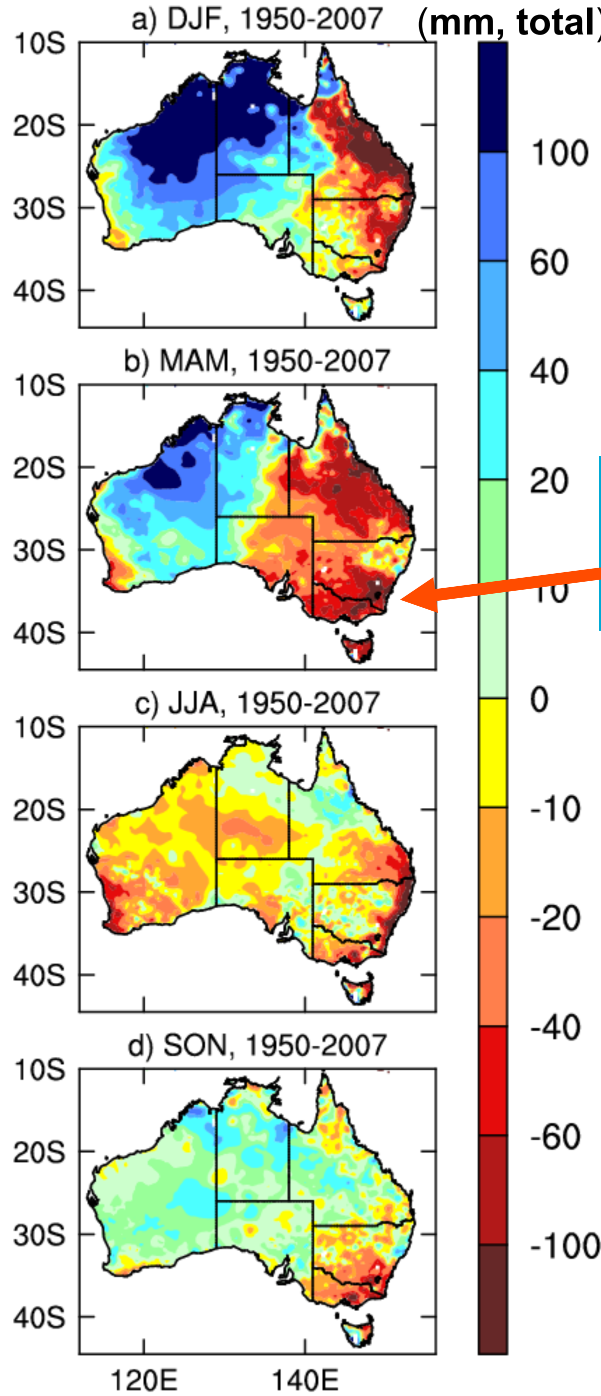
Nature CC to appear

More frequent extreme La Niña events under greenhouse warming

Wenju Cai[1,2], Guojian Wang[1,2], Agus Santoso[3], Michael J. McPhaden[4], Lixin Wu[2], Fei-Fei Jin[5], Axel Timmermann[6], Mat Collins[7], Gabriel Vecchi[8], Matthieu Lengaigne[9], Matthew H. England[3], Dietmar Dommenget[10], Ken Takahashi[11], Eric Guilyardi[9,12]

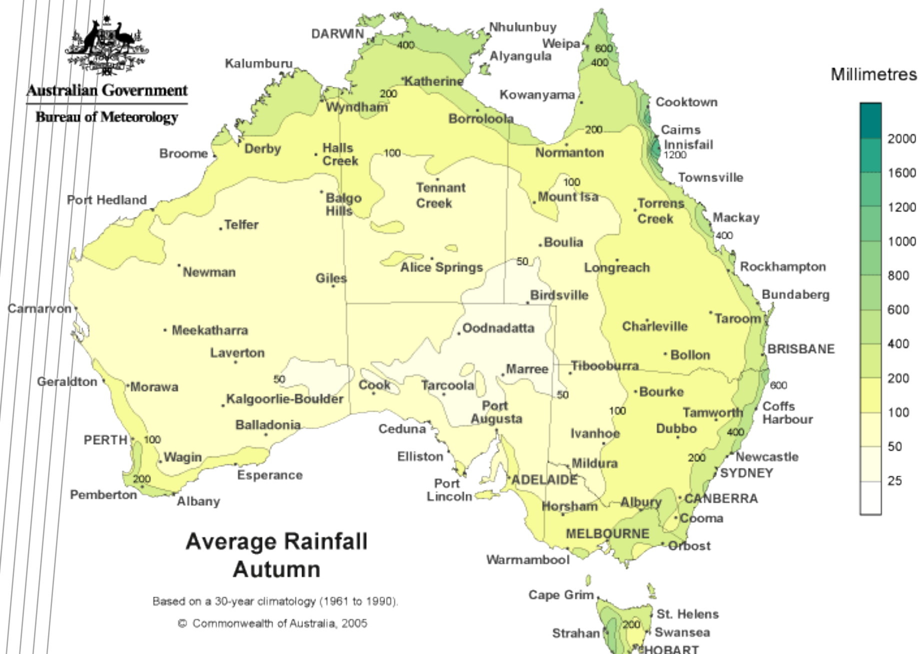
1. CSIRO Marine and Atmospheric Research, Aspendale, Victoria, Australia
2. Physical Oceanography Laboratory, Qingdao Collaborative Innovation Center of Marine Science and Technology, Ocean University of China, Qingdao, China
3. Australian Research Council (ARC) Centre of Excellence for Climate System Science, Level 4 Mathews Building, The University of New South Wales, Sydney 2052, Australia.

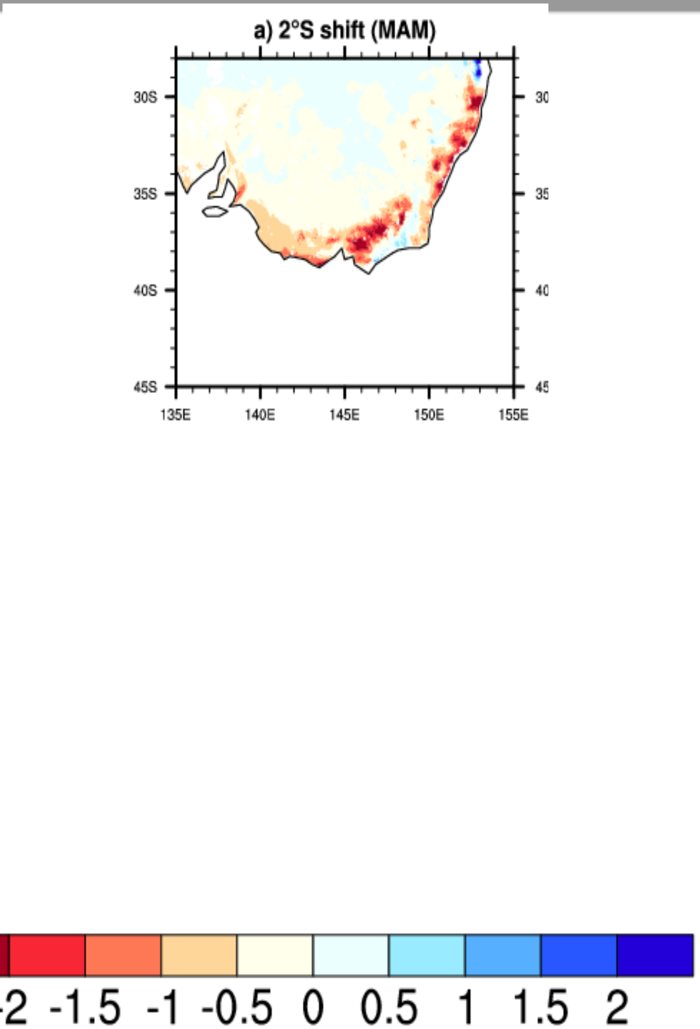


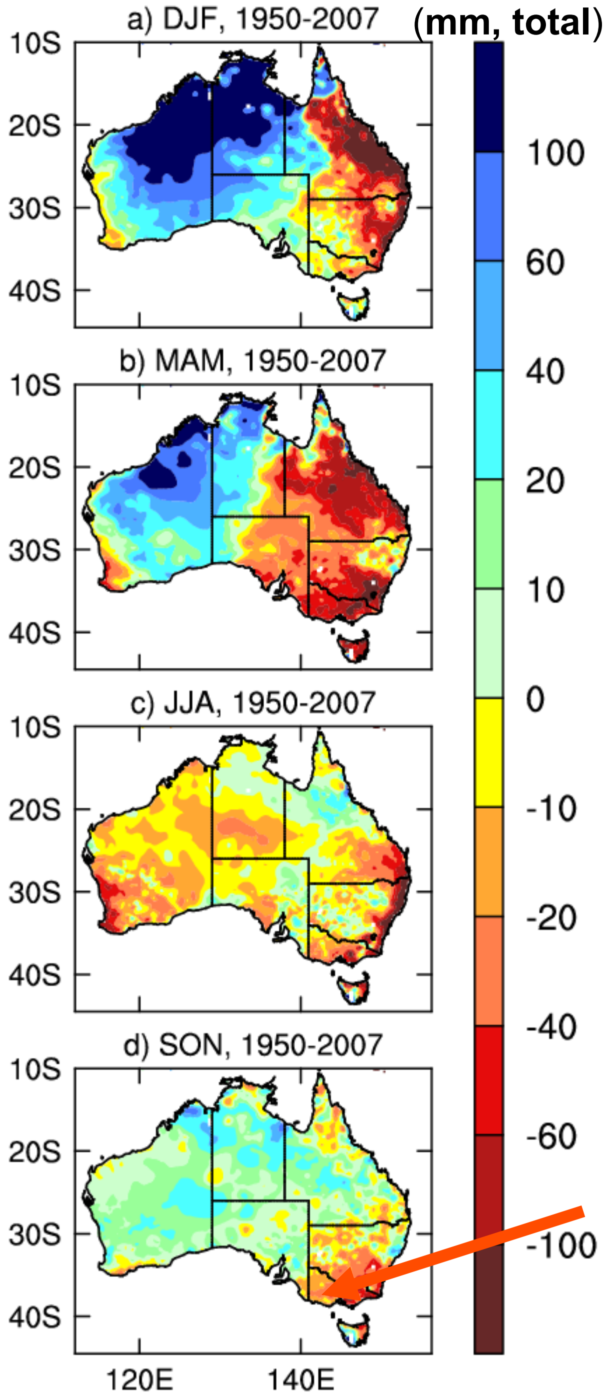


We don't understand the

Changes due to a 2º poleward shift of climatological MAM rainfall

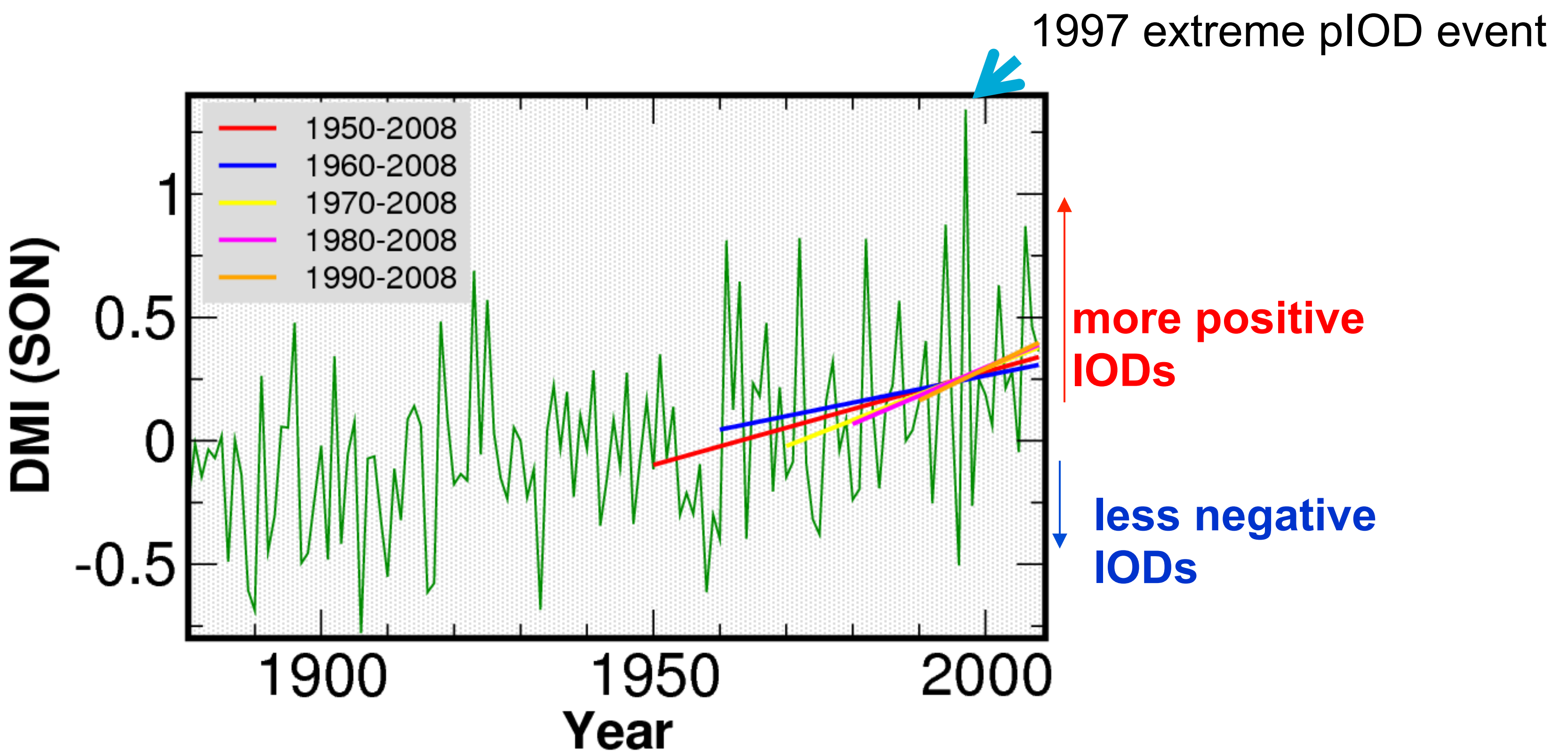






More positive IODs

The IOD is trending up

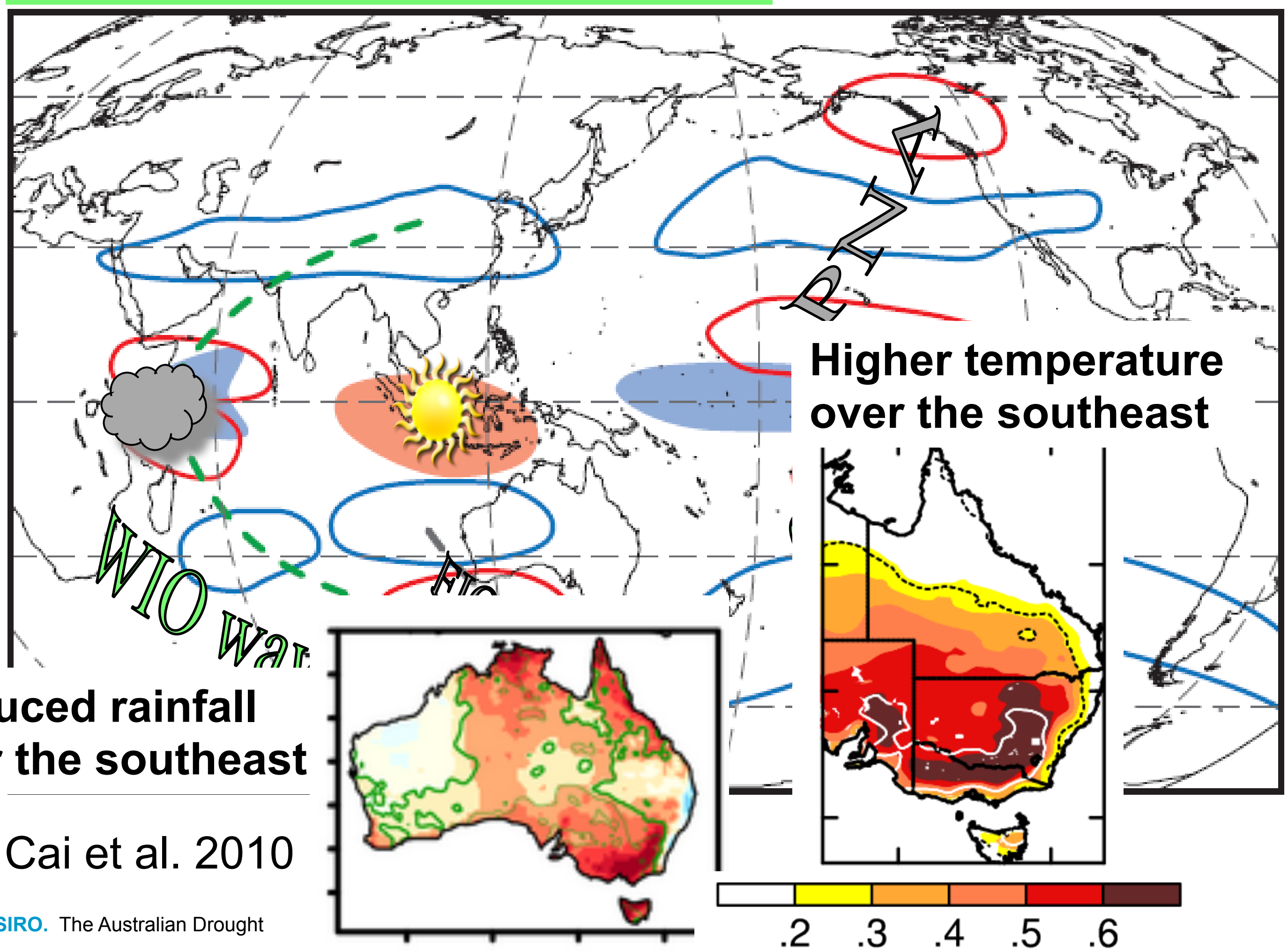


Recent positive IOD years: 2002, 2004, 2006, 2007, 2008

Cai et al. 2009b

Mechanism of the IOD and ENSO impact on Australia rainfall: SON

SON: IOD + El Niño



Cai et al. 2010

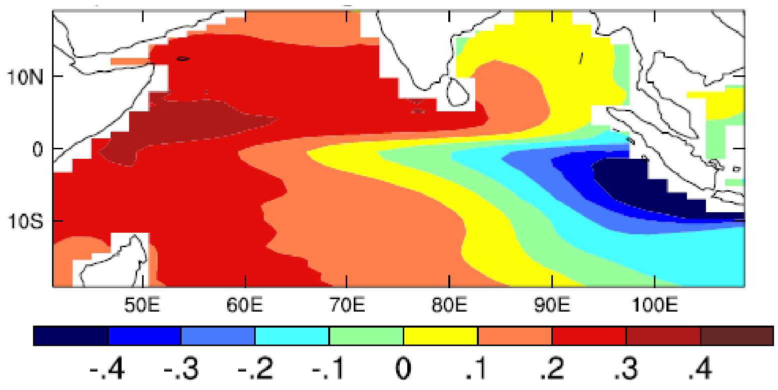
Drought: a great pre-condition for bushfires
See Tim Cowan's talk this afternoon

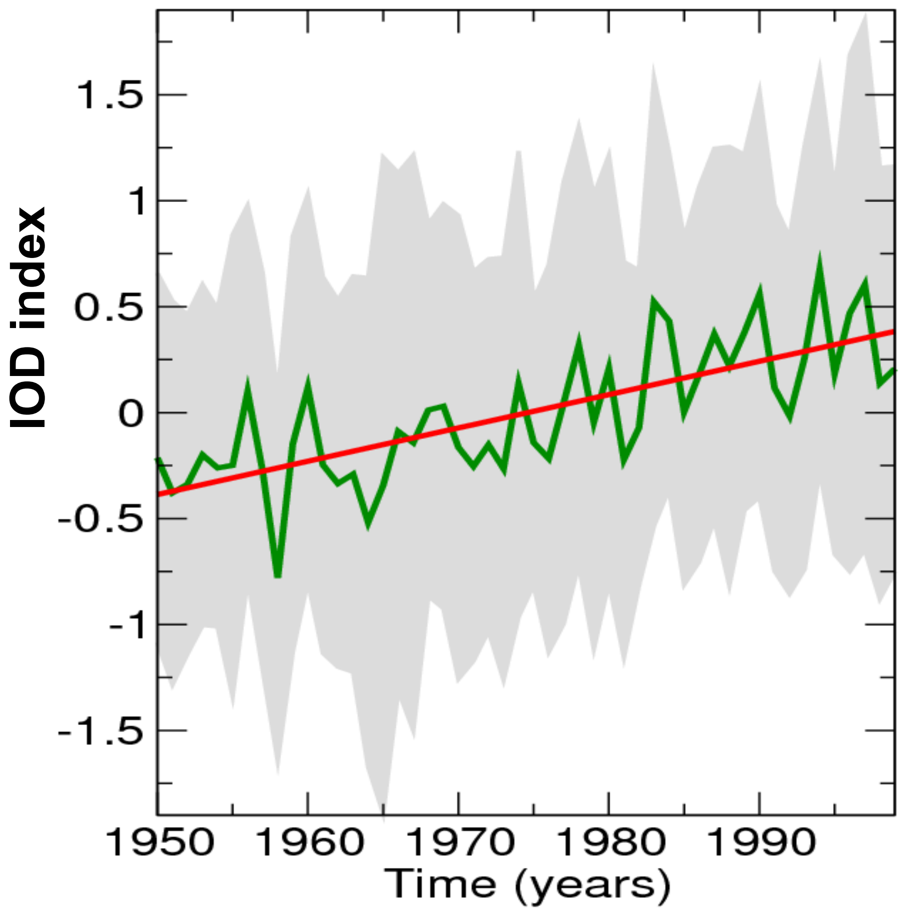
- **Black Saturday (7 February 2009)**
  - Temp = 46.4°C
  - Relative Humidity ~10%
  - Total death: 170+
  - ~2000 houses burnt

Cai et al. 2009a

Trend in the IOD: 19 climate models

- Some of the IOD trend is attributable to climate change





Cai et al. 2009c

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日本語要約

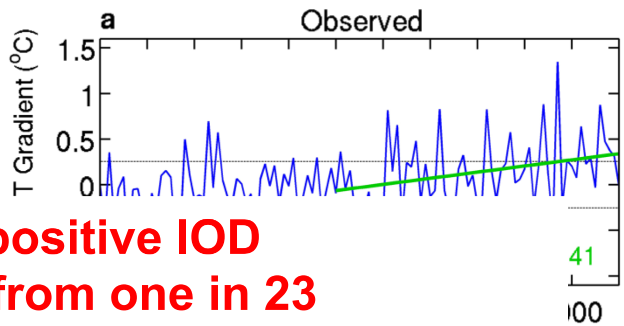
Increased frequency of extreme I... Dipole events due to greenhouse...

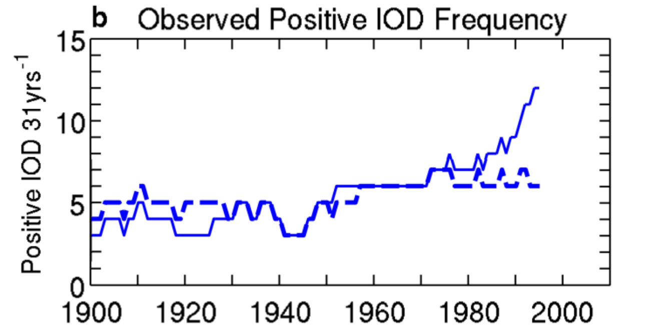
Wenju C...
Masumo...

nature geoscience
REVIEW ARTICLE
PUBLISHED ONLINE: 28 NOVEMBER 2013 | DOI: 10.1038/NGEO2009

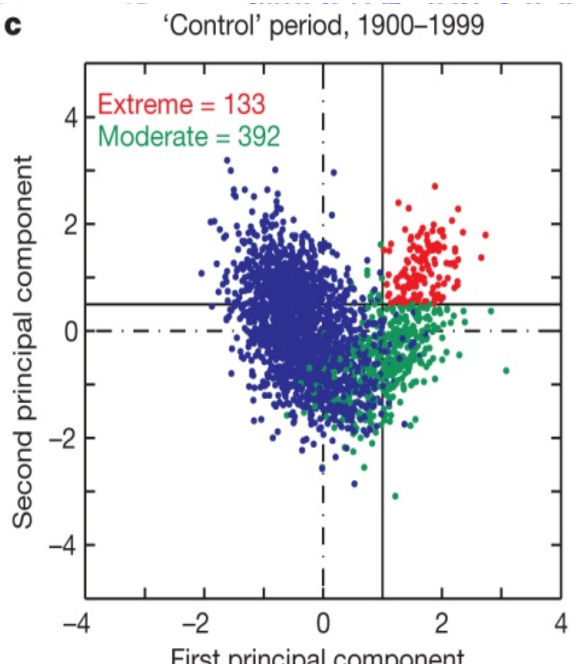
Projected response of the Indian Ocean Dipole to greenhouse warming

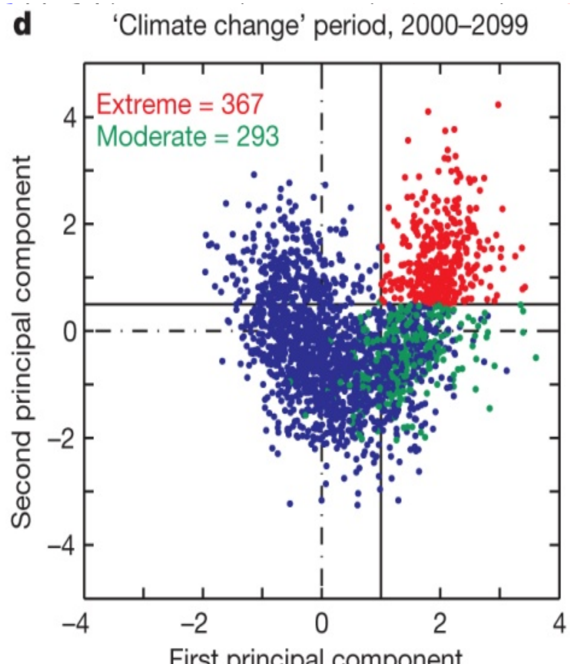
Wenju Cai[1,2*], Xiao-Tong Zheng[2,3], Evan Weller[1], Mat Collins[4], Tim Cowan[1], Matthieu Lengaigne[5], Weidong Yu[6] and Toshio Yamagata[7]

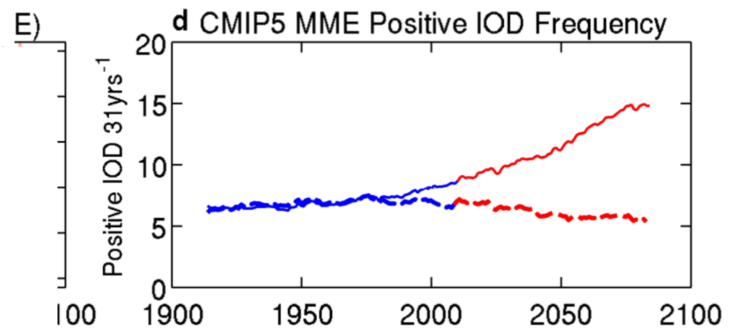


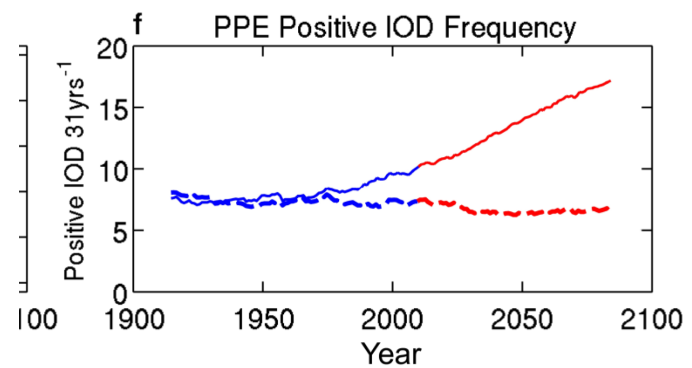


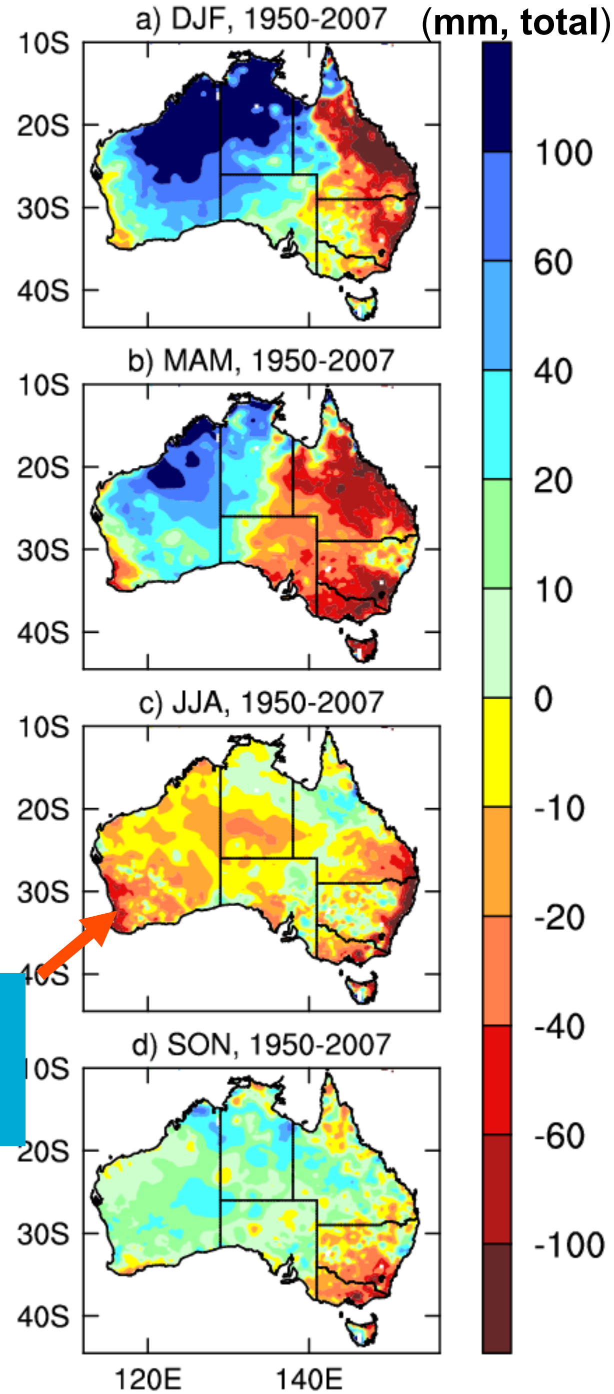
The frequency of extreme positive IOD increases by a factor of 3 (from one in 23 years to one in 7 years).





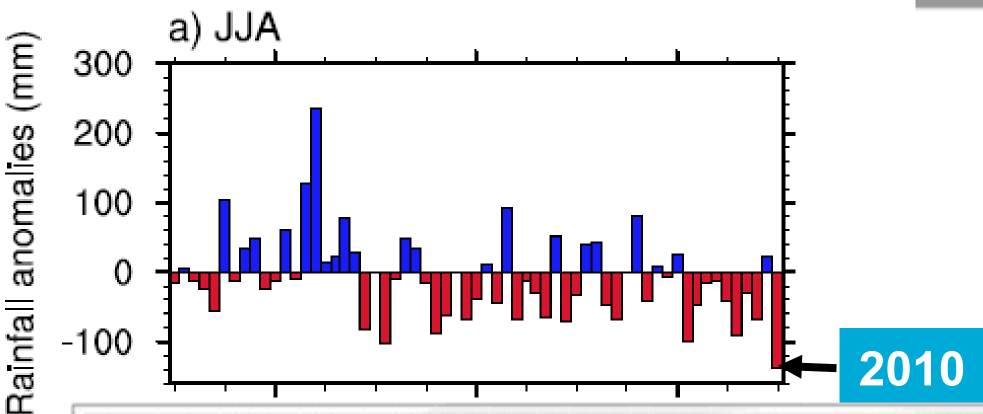


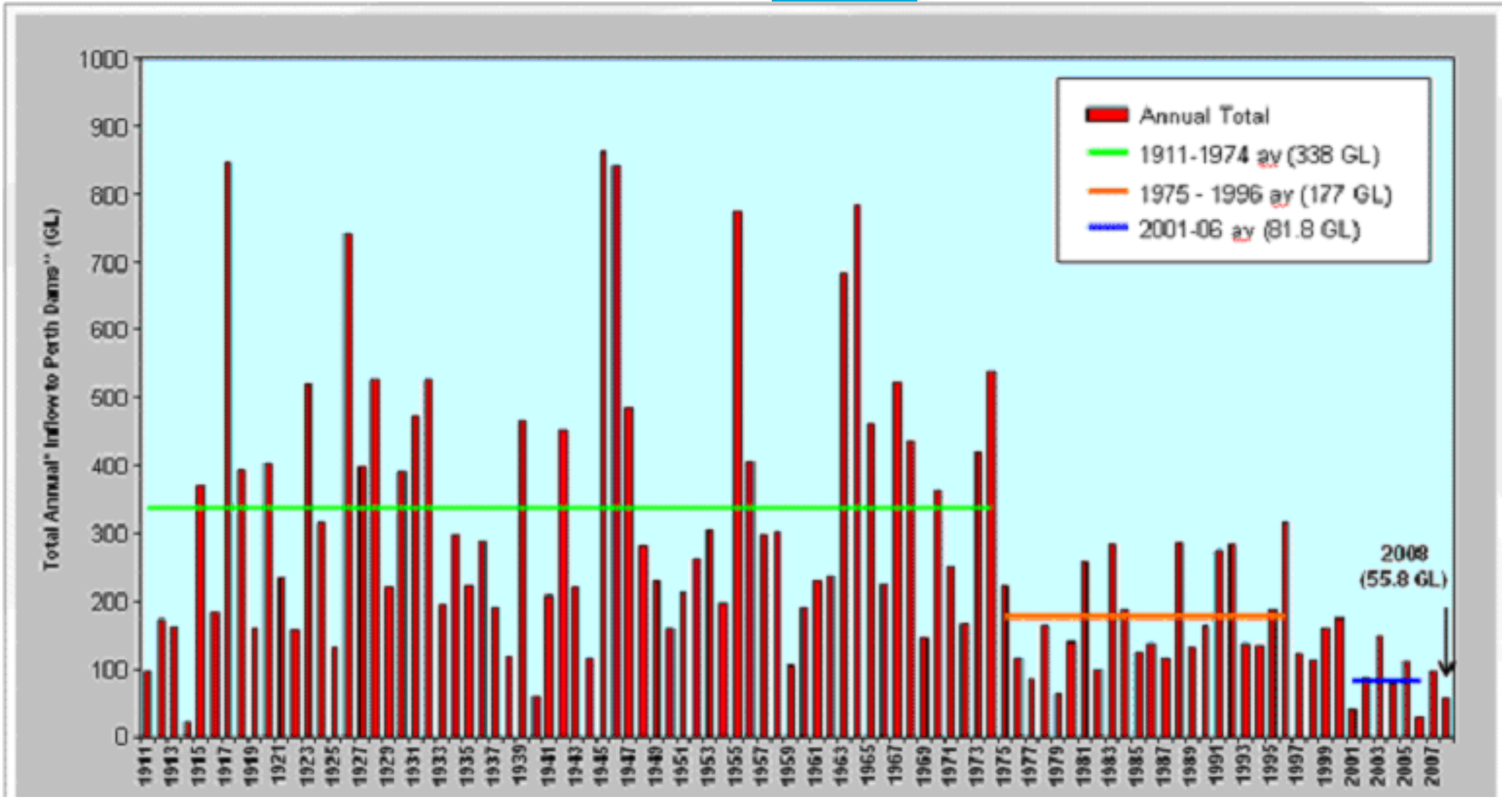




Positive SAM trend

The SWWA drought continues and there is a significant reduction in inflows to dams





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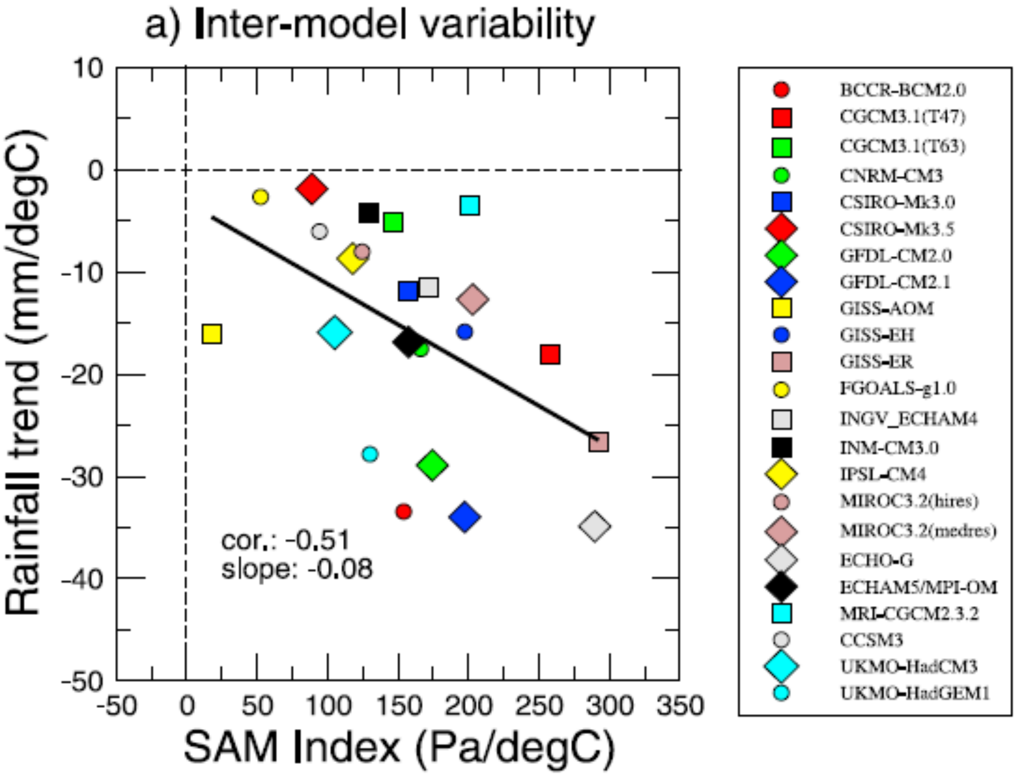
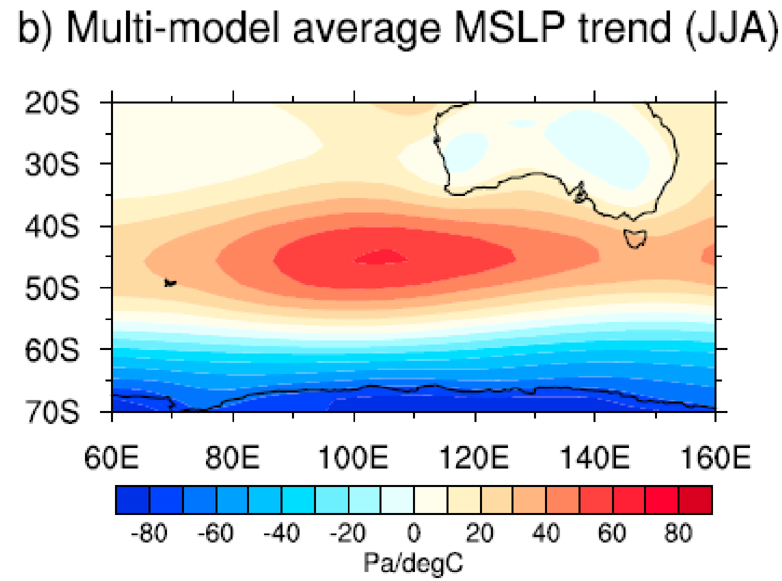
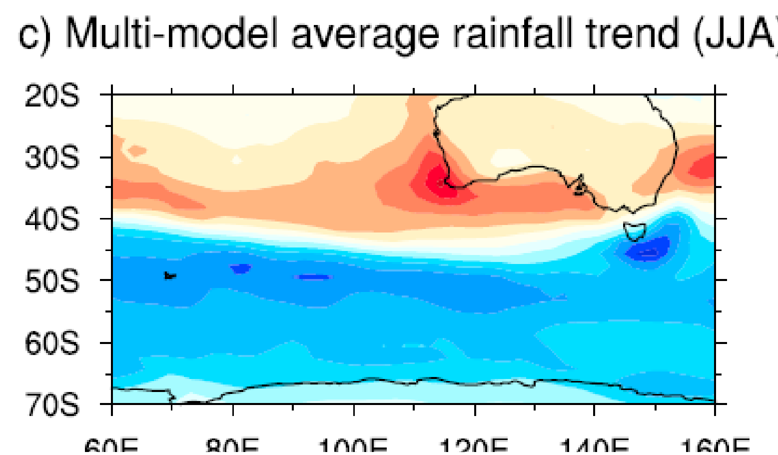






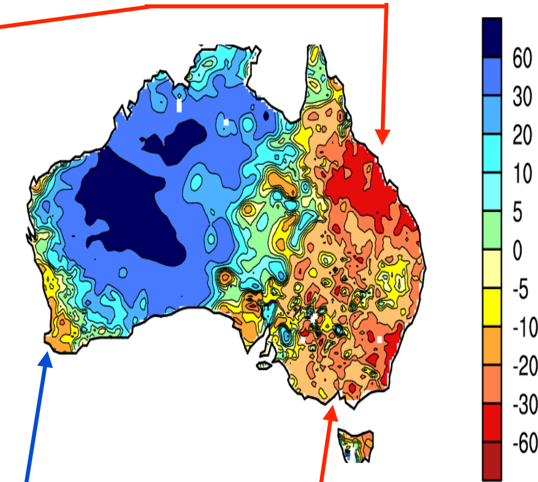
Cai, W., P. van Rensch, S.Borlace, and T. Cowan (2011), Does the Southern Annular Mode contribute to the persistence of the multidecade-long drought over southwest Western Australia?, Geophys. Res. Lett., 38, L14712, doi:10.1029/2011GL047943.

We are telling four stories

Story 1: The IPO/PDO influences the impact of ENSO on eastern Australia. When the PDO is positive (since 1980), La Niño no longer brings rainfall to east Australia, leading to a severe drought.

Story 2: The Indian Ocean Dipole is trending up, contributed by climate change, and is contributing to spring rainfall decrease, rising temperature, and severe bushfires over Southeast Australia.

Story 3: The SAM trends up (with increasing pressure over Australia) leading to a long-tern rainfall reduction



Poleward expansion of dry zone in a warming climate, contributes to the autumn rainfall reduction.

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End