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Multi-decadal climate variability: Flood and Drought - New South Wales

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Overview

- Climate controls on variability in New South Wales
  - El Niño/Southern Oscillation (ENSO)
  - Inter-decadal Pacific Oscillation (IPO)
- Flood risk
- Drought risk (water supply)
- Pre-instrumental evidence of variability
- Implications and conclusions

Climate modes affecting Eastern Australia

El Niño-Southern Oscillation (ENSO)

- Sir Gilbert Walker, Indian Meteorological Office (1923)
- Southern Oscillation Index (SOI)

Each extreme occurs every 2-6 years – <u>however</u>, ‘chaotic’, irregular

El Niño

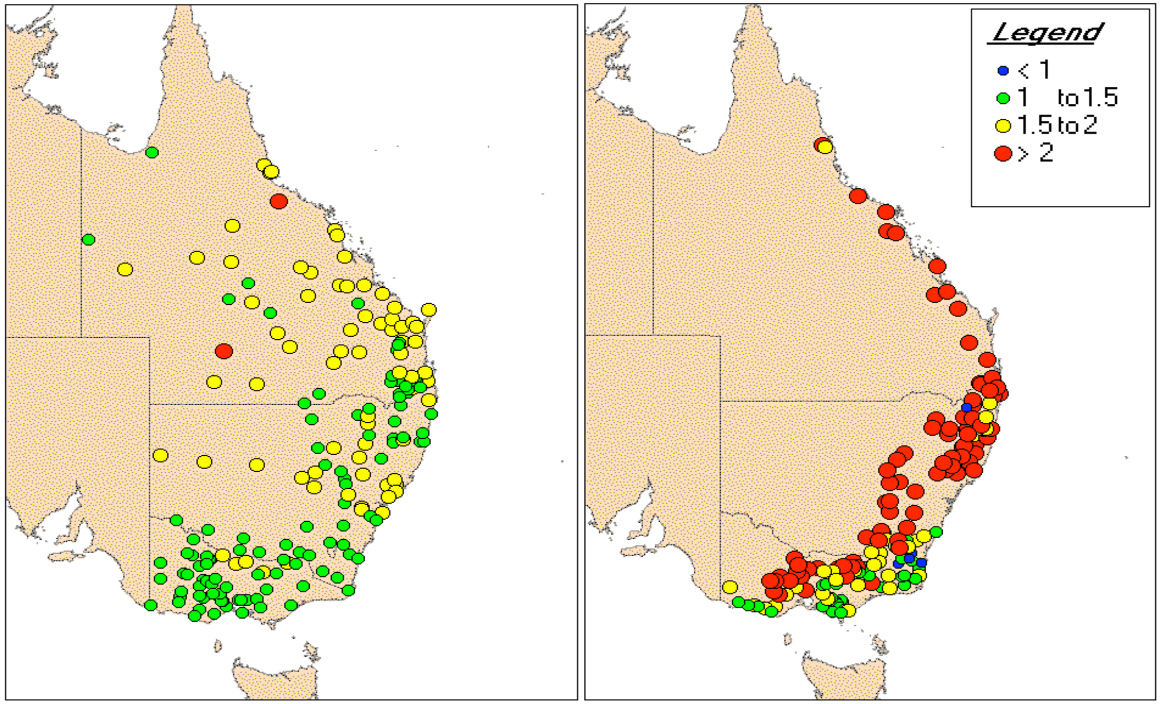
- anomalous warming in Eastern Equatorial Pacific Ocean
- associated with dry conditions across E. Australia

La Niña

- anomalous cooling in Eastern Equatorial Pacific Ocean
- associated with wet conditions across E. Australia

ENSO impacts - rainfall and streamflow

Ratio of La Niña to El Niño (a) rainfall and (b) streamflow



Verdon, Wyatt, Kiem and Franks, *Water Resources Research*, 2004

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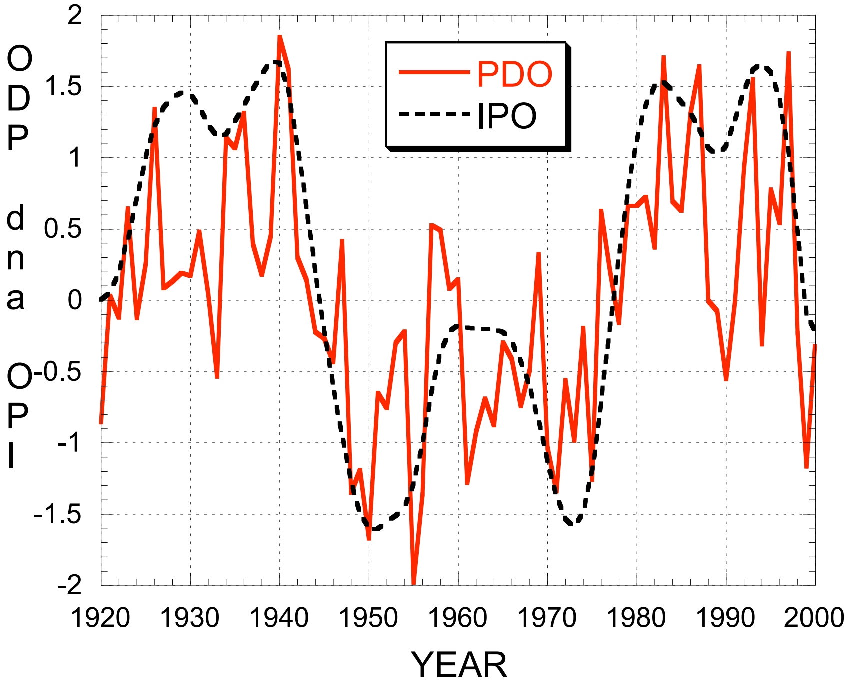
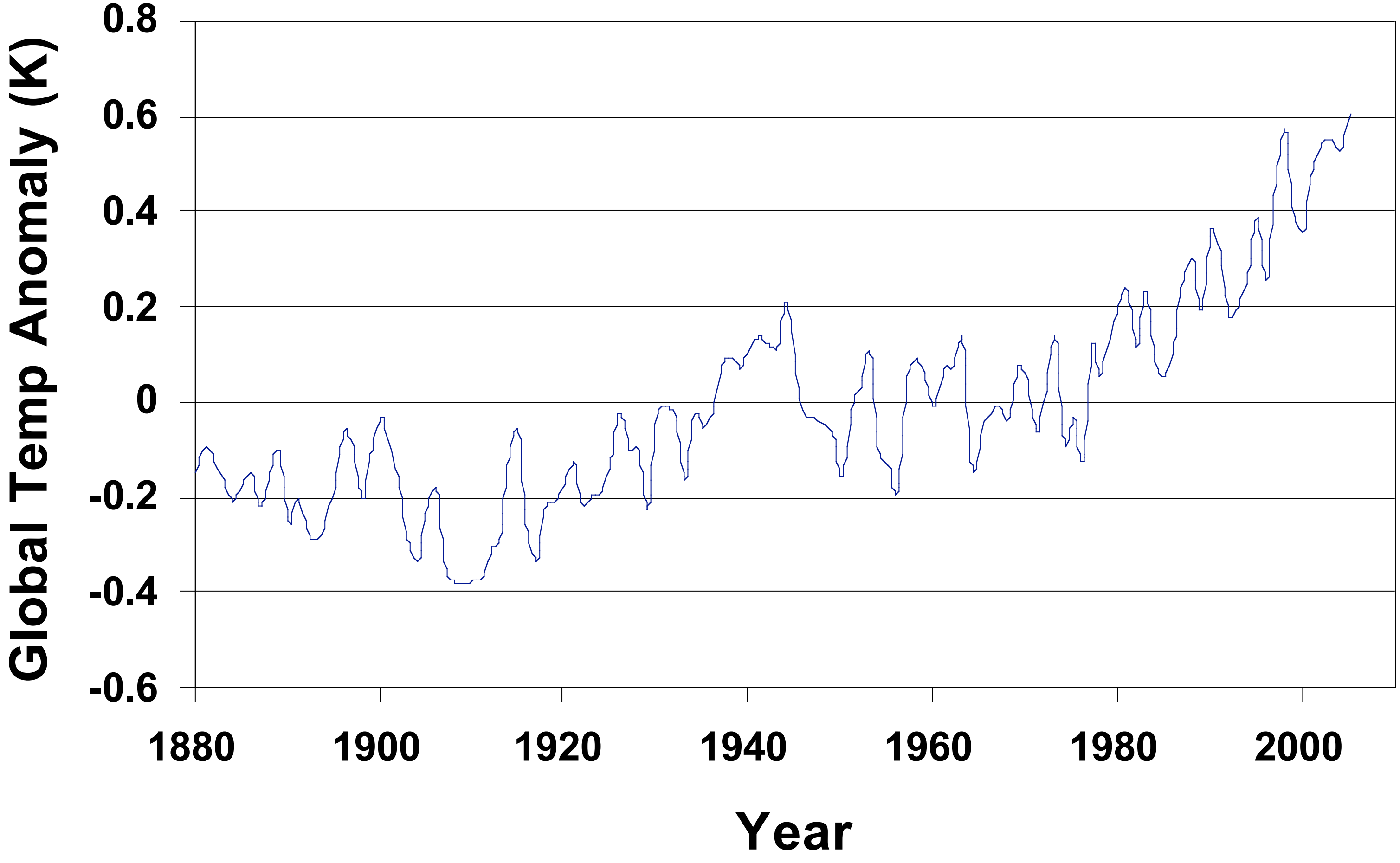
Climate modes affecting Eastern Australia

Inter-decadal Pacific Oscillation (IPO)

- low frequency mode in mid-latitude Pacific Sea Surface Temps
- similar to north hemisphere Pacific Decadal Oscillation (PDO)
- related to (global) epochs of warming and cooling
- appears to modulate the <u>impact</u> and <u>frequency</u> of ENSO



- *IPO/PDO show major changes ~ 1945 & 1975 consistent with observed changes in Australian climate*



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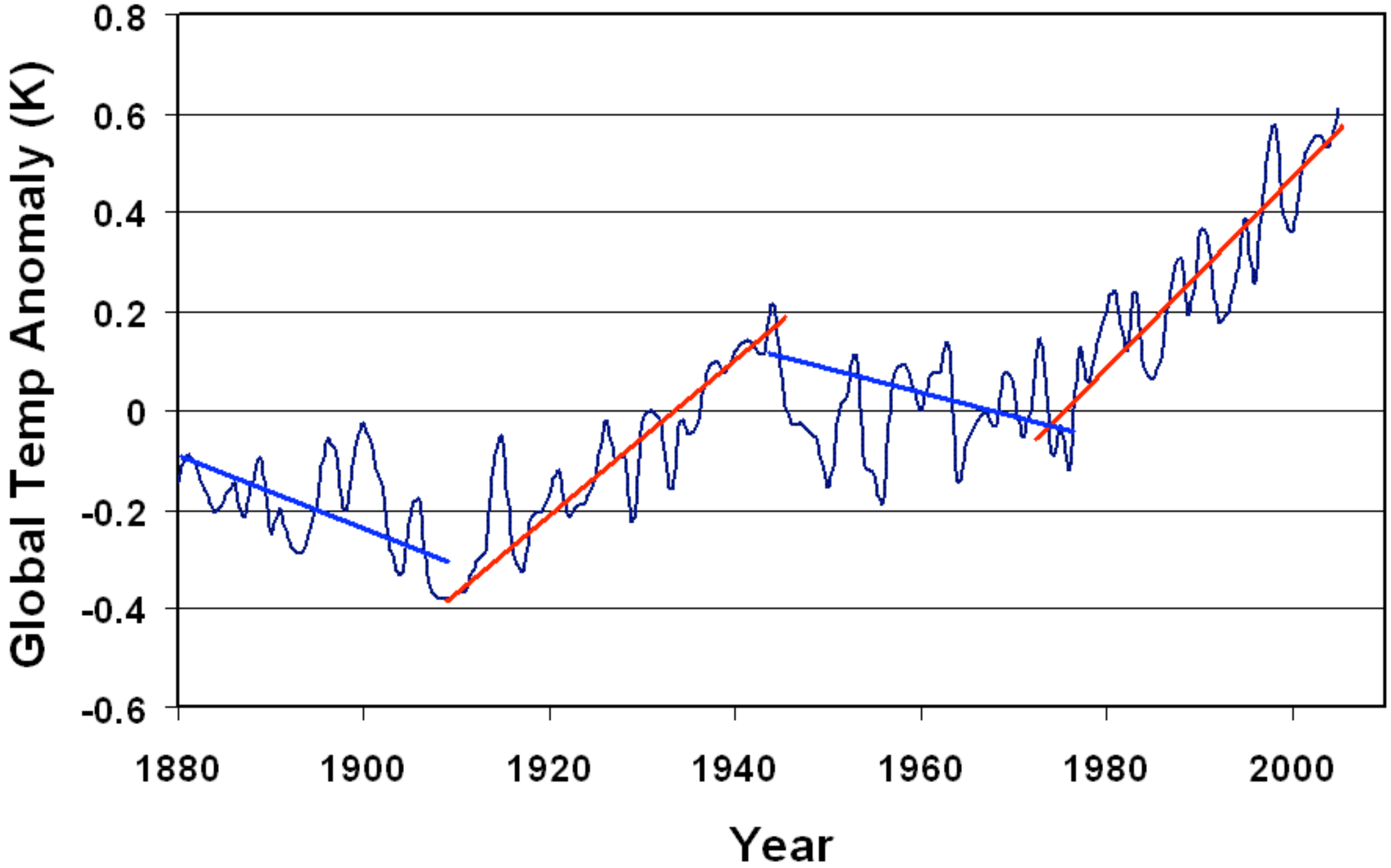

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ENSO/IPO impacts on Flood risk

Kiem, Franks and Kuczera, *Geophysical Research Letters*, 2003

- Annual Maximum Flood Volumes
- Key variable – practical importance

- 40 long-term records across New South Wales
- regional index after normalising records to mean log annual maximum

- individual years classified as El Niño, Neutral and La Niña
- Also IPO positive (1920-43;1974-present)
  and IPO negative (1944-1973)

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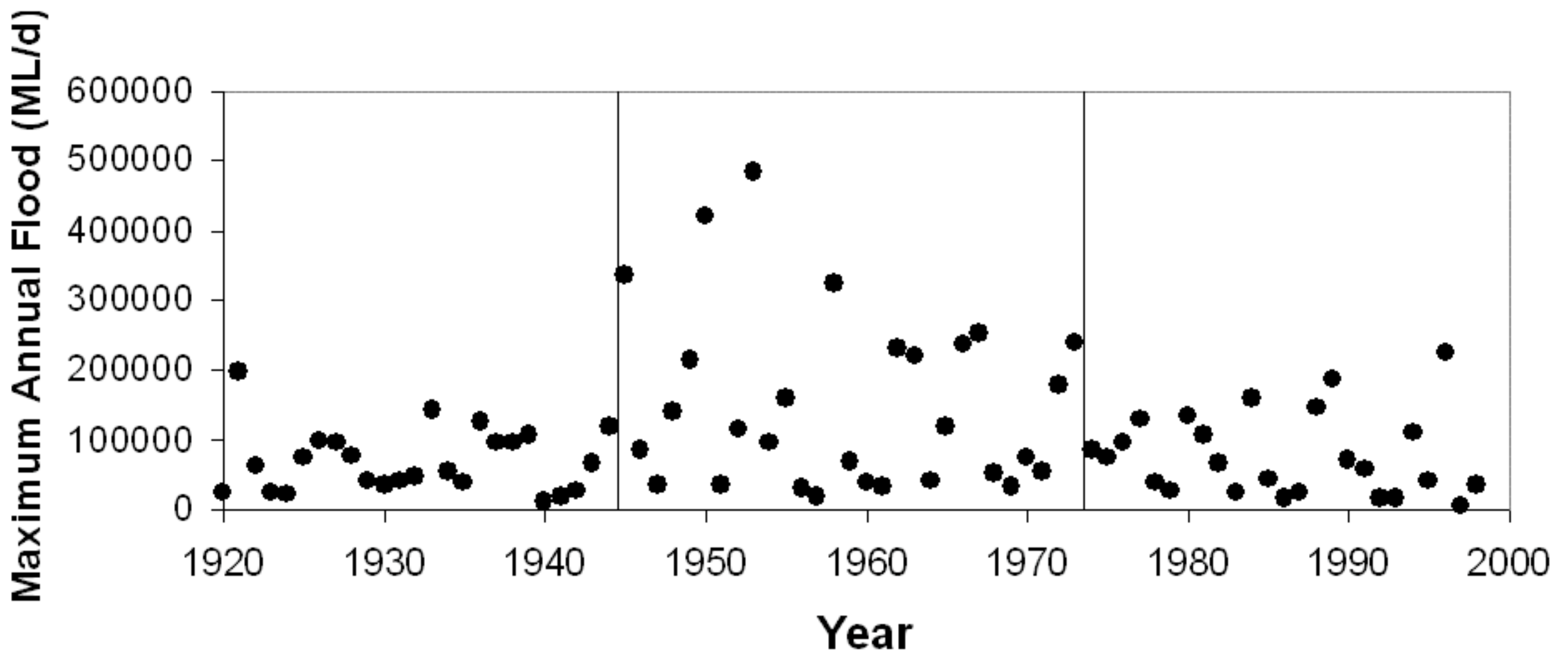
Typical annual maxima flood series



Clear evidence of multi-decadal variability

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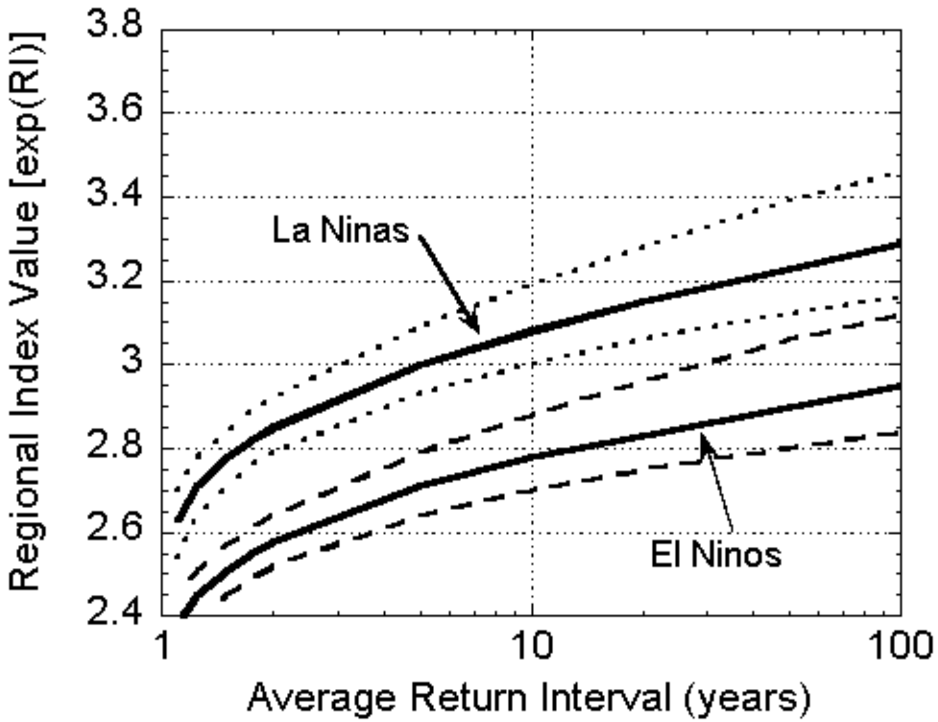
ENSO-dependent flood risk



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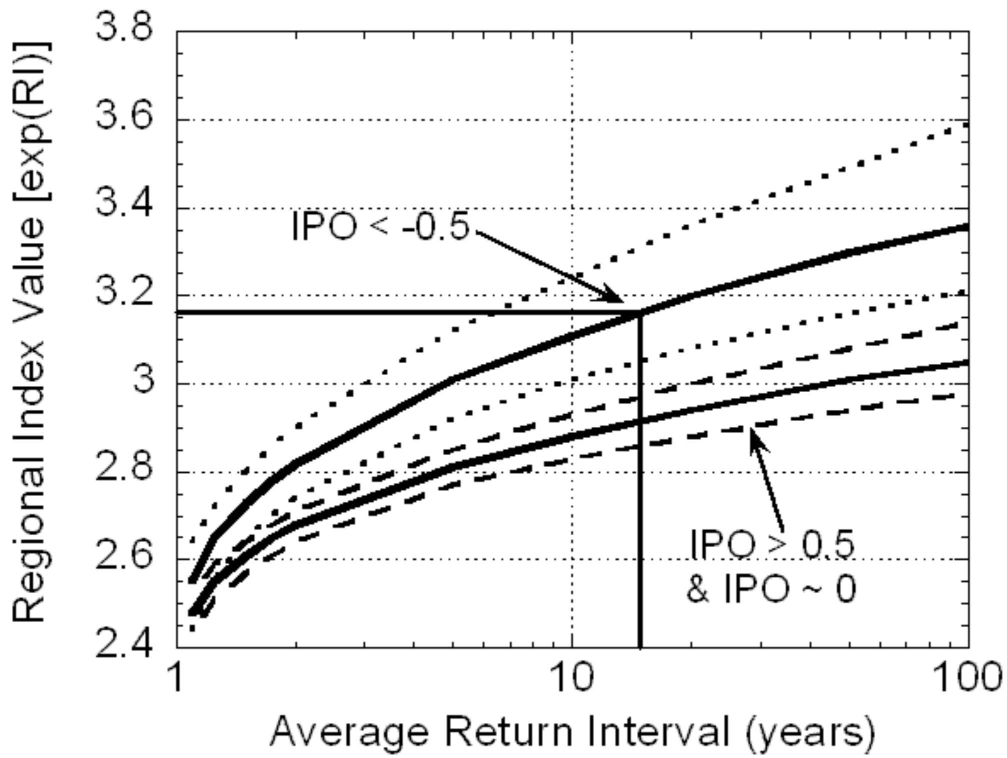
IPO-dependent flood risk

- 20-30 year persistent IPO epochs
- ie. Flood and Drought Dominated Regimes (FDR/DDR)



Flood risk summary

La Niña events are primary drivers of flood risk

100 yr flood by traditional analysis occurs every 15 yrs of IPO negative

Implications

Traditional risk assessment will be in error

Annual risk is dependent on ENSO state
- ENSO predictions can aid preparedness

Medium-term flood risk (20-30 yrs) is dependent on IPO climate state

Long-term flood risk depends on frequency of IPO

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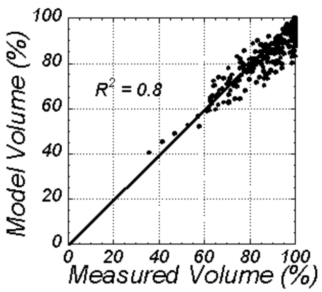
IPO impacts on water supply drought risk

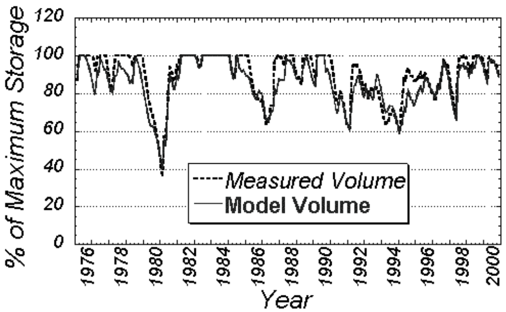
Kiem and Franks, Hydrological Processes, 2004

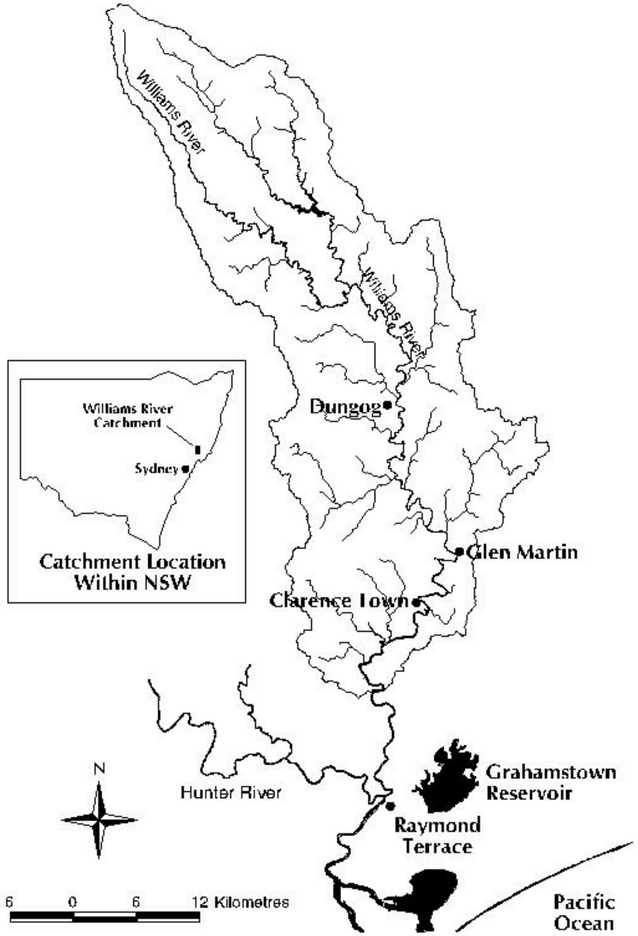
- Grahamstown Reservoir

- water supply drought
- services pop. 400,000
- 'critical event' at 30%

- different IPO states
  - El Niño/La Niña frequency







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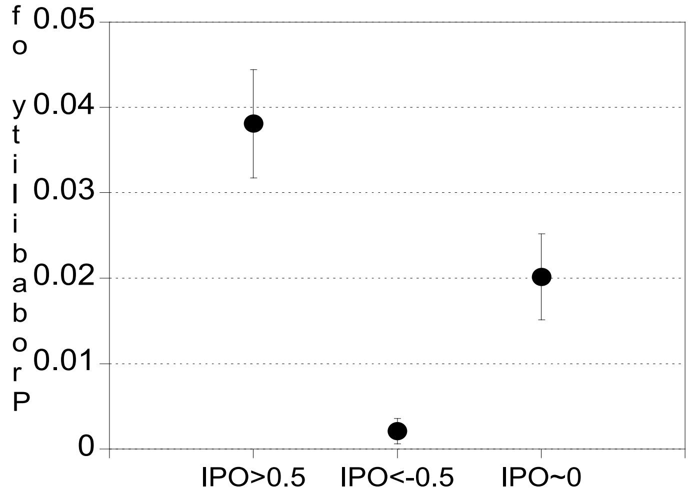
Multi-decadal drought risk results



IPO positive shows highest risk – 20 times higher than IPO negative

Why does IPO positive represent highest risk?

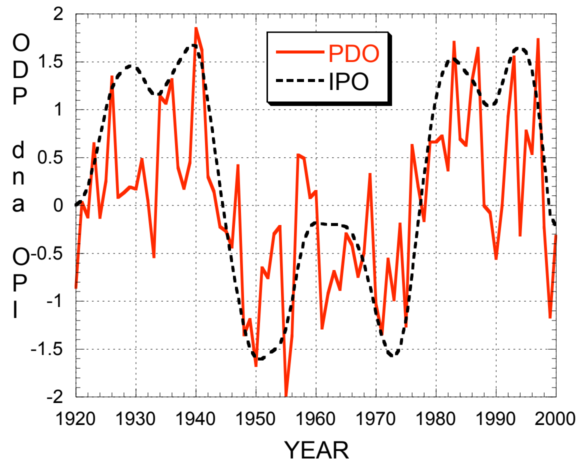
Reservoir has multi-year storage - El Niño lifecycle approx. 1 year

Drought risk is... often initiated by El Niño events

but… dictated by occurrence of recharging La Niña events

Relative frequency of La Niña events becomes important

	IPO +	IPO -
El Niño	10	7
La Niña	5	17
Neutral	24	13
Total	39	37



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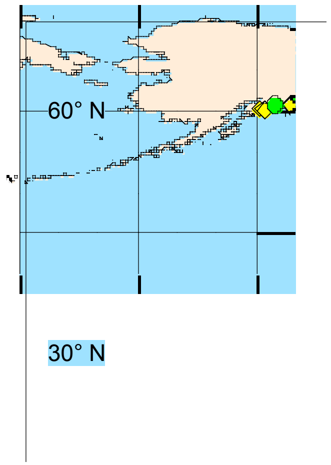
<u>Paleo-climate reconstructions of IPO/ENSO</u>

Verdon and Franks, *Geophysical Research Letters*, 2006

6 longterm IPO reconstructions from tree-rings and coral records



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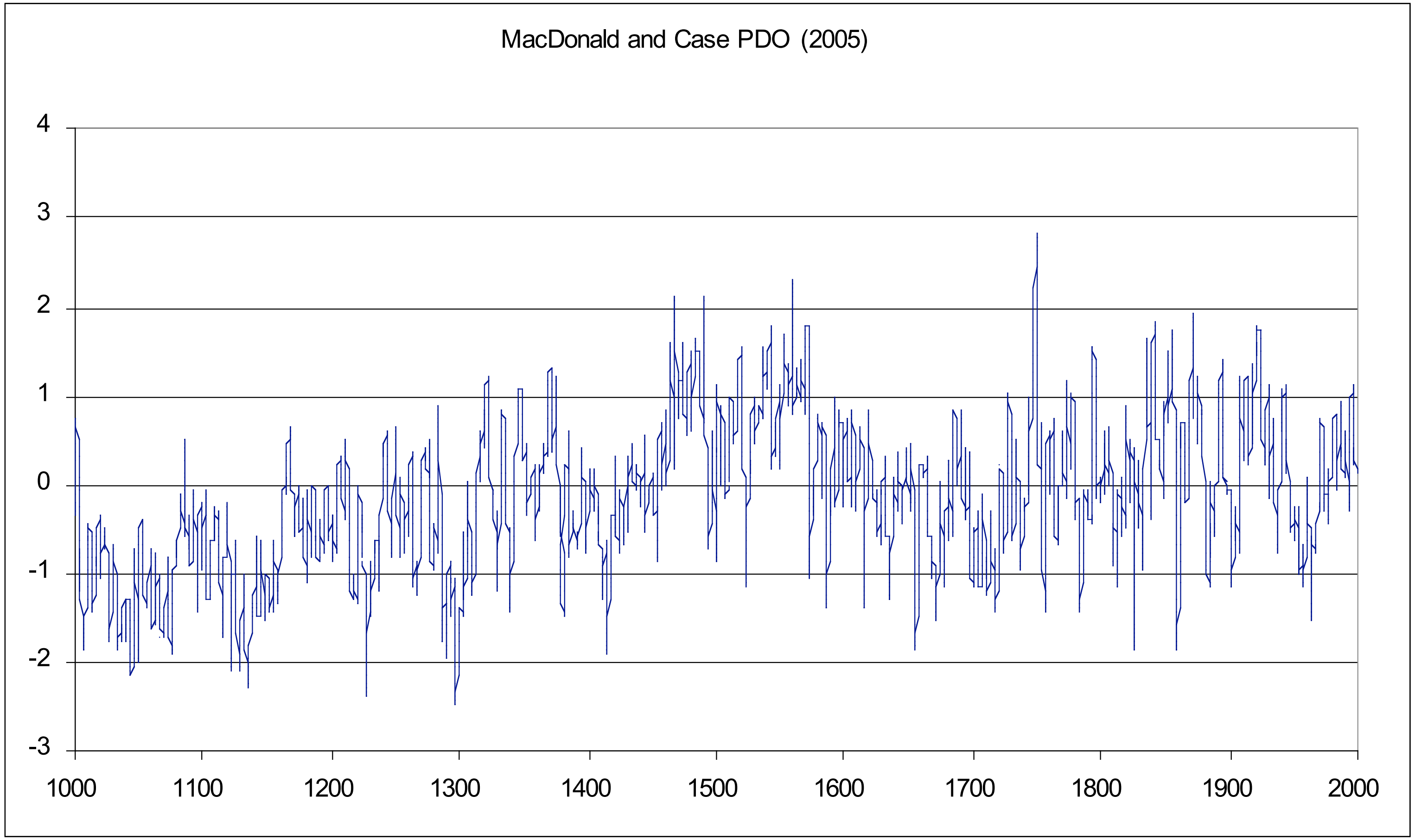
Example paleo-reconstruction



Identified step-changes in IPO

PDO	IPO	Biondi	D'Arrigo	Gedalof	MacDonald	Rarotonga
				1661 -	1662 -	
		1678 +		1681 +	1679 +	
		1703 -		1696 -	1696 -	
		1717 +**		1711 +	1717 +	
		1727 -	1723 -	1733 -		
		1765 +	1758 +	1759 +		1764 +
			1776 -		1776 -	1779 -
			1790 +		1791 +	1791+
		1806 -	1805 -	1805 -	1805 -	1805 -
		1825 +	1824 +	1821 +	1831+	1830+
		1839 -	1853 -	1848 -	1874 -	1857 -
		1883 +	1874 +			1875 +
	1908-	1893 -				
1922 +	1922 +	1907 +		1921 +	1908 +	
1942 -	1941 -	1947 -	1944 -	1945 -	1943 -	1943 -
1975 +	1976 +	1974 +			1968+	1979 +

- Mann-Whitney U test applied to 30 year moving windows
- identified step changes significant at the <5% level

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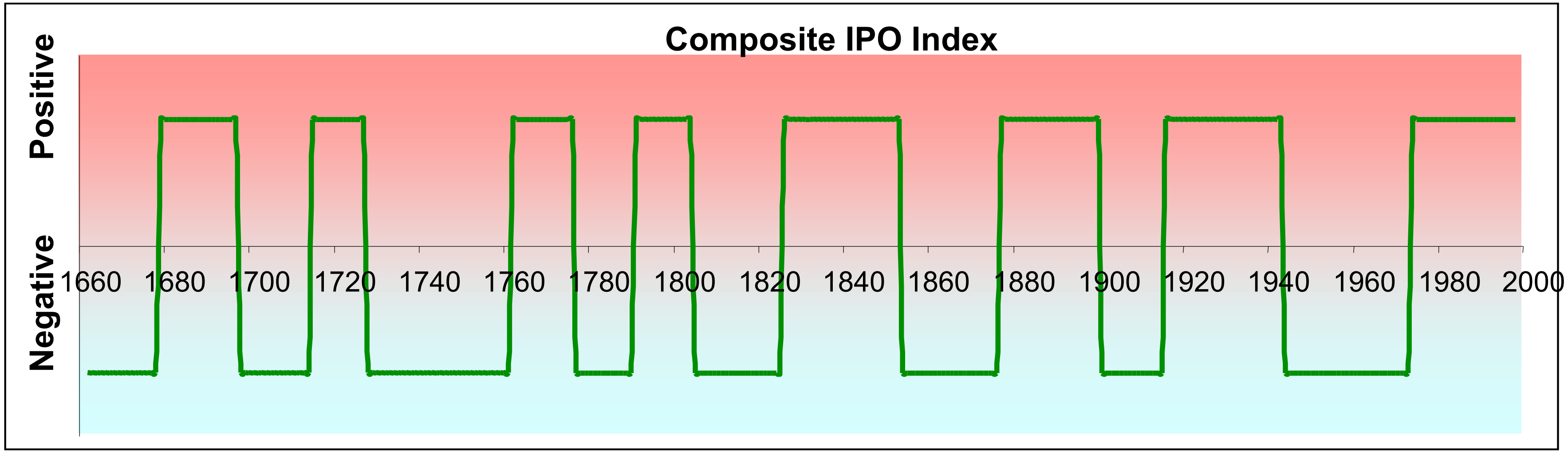
Assessing ENSO frequency modulation by IPO

- composite IPO index developed from 6 independent proxies
- 2 NINO3 ENSO reconstructions (Mann and Cook) used
- frequency of EN and LN events in IPO+ and IPO- assessed



Results - ENSO event frequency

	Event	Fraction of events in IPO Pos	Fraction of events in IPO Neg	*P*-value
Cook NINO3	El Niño	0.36	0.24	0.01
	La Niña	0.28	0.37	0.04
	Neutral	0.36	0.39	0.29
Mann NINO3	El Niño	0.37	0.27	0.03
	La Niña	0.28	0.36	0.07
	Neutral	0.35	0.37	0.36

Evidence of variability of ENSO event frequency since 1600

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Case Studies - Summary

Flood, drought and fire risk – all impacted by ENSO and IPO

El Niño and La Niña event frequency varies on 20-40 year periods

Results in multi-decadal epochs of significantly elevated/reduced risk

Flood/Drought risk is a function of the prevailing climate state

- inter-annual – ENSO
- multidecadal – IPO

The 2001-3 El Niño and the current drought

September 2001

- significant trend towards El Niño
- reduced rainfalls across eastern Australia in summer months

April 2002

- initiation of full-blown El Niño event
- low winter rainfalls

September 2002

- mature phase of El Niño
- reduced summer rainfalls

April 2003

- El Niño fades

2004-2005

- largely average rainfalls, beneficial but not sufficient – NO LA NINA!

July 2006

- New El Niño event begins initiation

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<u>Summary</u>

Strong evidence of multi-decadal climate variability in NSW

Climate has never been static!

1920-1945

IPO+ El Niño dominates, low flood risk, high drought risk

1945-1975

IPO– La Niña dominates, high flood risk, low drought risk

1975-present

IPO+ El Niño dominates, low flood risk, high drought risk

Current drought cannot be directly linked to ‘climate change’

El Niño/La Niña variability due to <u>natural</u> processes

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Acknowledgements: Danielle Verdon, Anthony Kiem, Adam Wyatt, George Kuczera

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‘The analysis of 195 long time series of annual maximum flows, stemming from the GRDC holdings does not support the hypothesis of general growth of flood flows.’

‘Observations to date provide no conclusive and general proof as to how climate change affects flood behaviour.

There is a discontinuity between some observations made so far. Increases in flood maxima are not evident whilst model-based projections show a clear increase in intense precipitation.’

Kundzewicz et al. (2004)

Detection of change in world-wide hydrological time series of maximum annual flow

World Climate Programme – Water, UNESCO-WMO

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I LOOK AHEAD

Links to global climate variability

What causes multi-decadal SST variability (IPO and PDO)

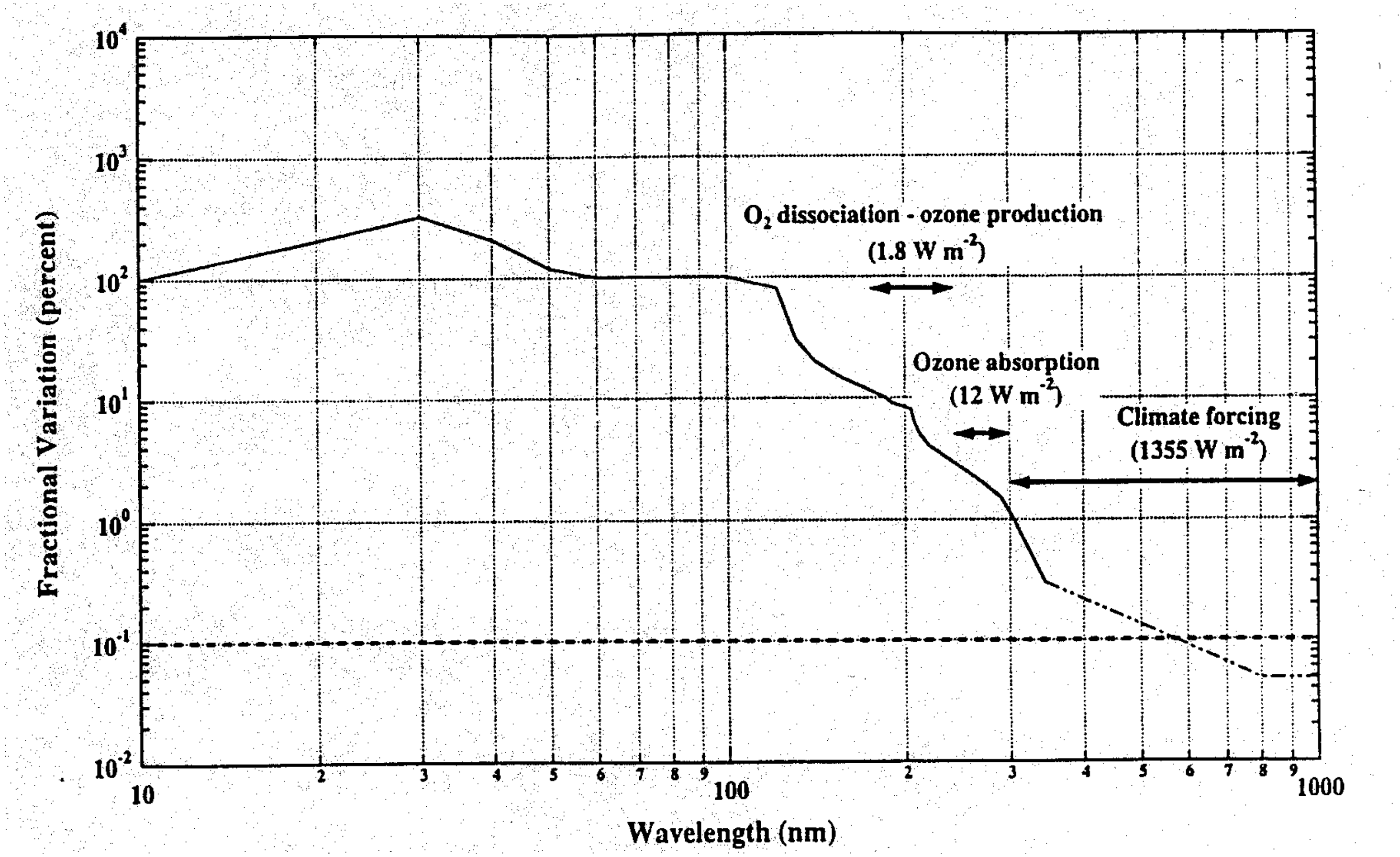
1. ENSO-like internal oscillation (ocean-atmosphere)
   (eg. Power, Latif and Barnett)

2. Tropical-extratropical exchanges (SST oscillation)
   (eg. Gu and Philander)

3. Solar-induced variability
   - direct uv irradiance (Lean, White)
   - uv-ozone interactions (Haigh)
   - solar modulation of cosmic wind

Solar correlations are no longer lacking mechanism

- variability is in UV bands



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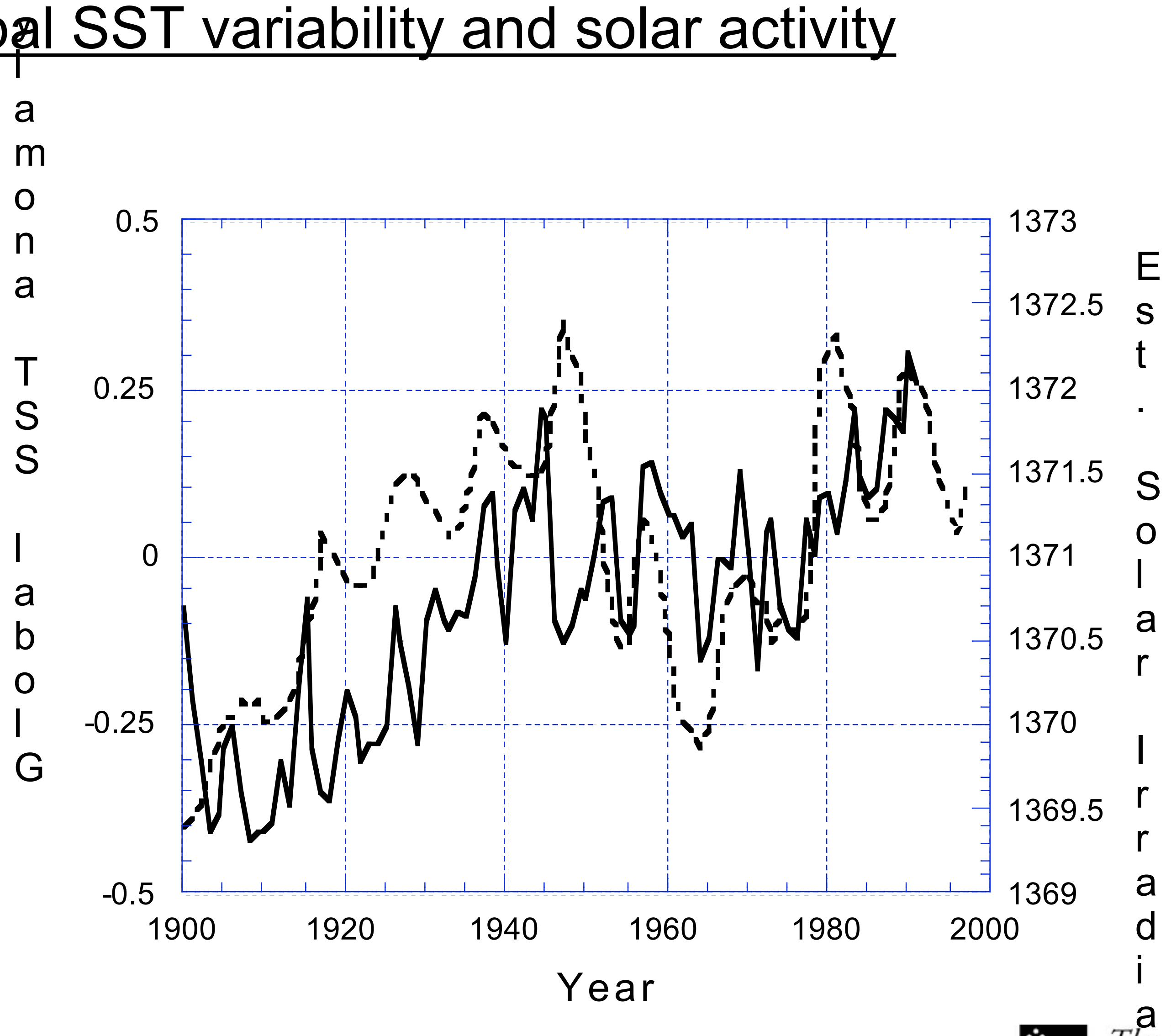
Global SST variability and solar activity



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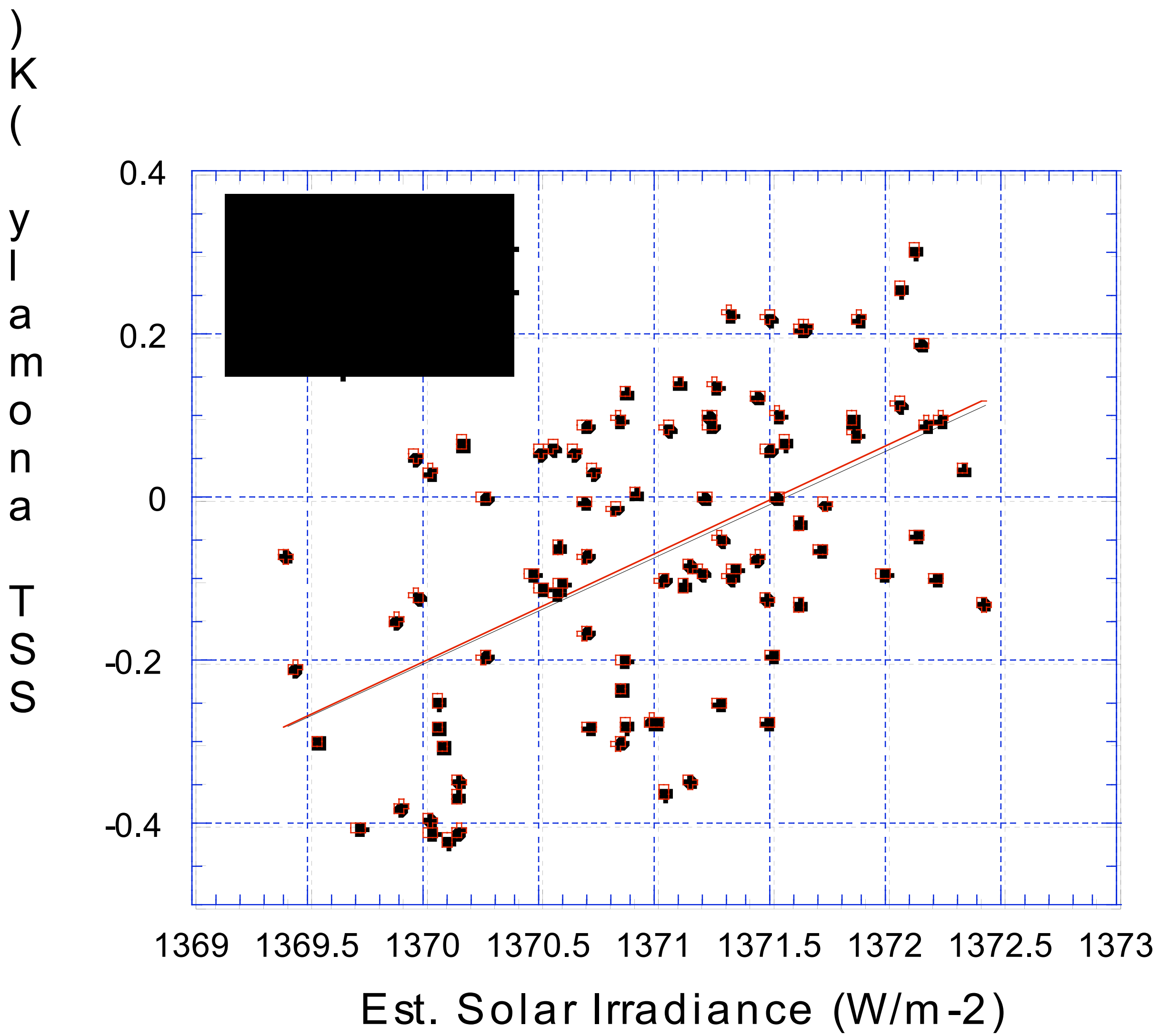

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A simple climate model

$$SST_t = \alpha_1 SST_{t-1} + \alpha_2 (I_t - I_{eq}) + \alpha_3 [CO_2] + \varepsilon_t$$

Where…

SST_t is the mid-latitude sea surface temperature anomaly at time t,
I_t is the irradiance at time, t,
I_{eq} is a notional equilibrium irradiance,
α_1 is a weighting coefficient related to the global storage capacity,
α_2 is the weighting coefficient for the solar influence
α_3 is weighting coefficient for the greenhouse effect
ε_t is the residual error.

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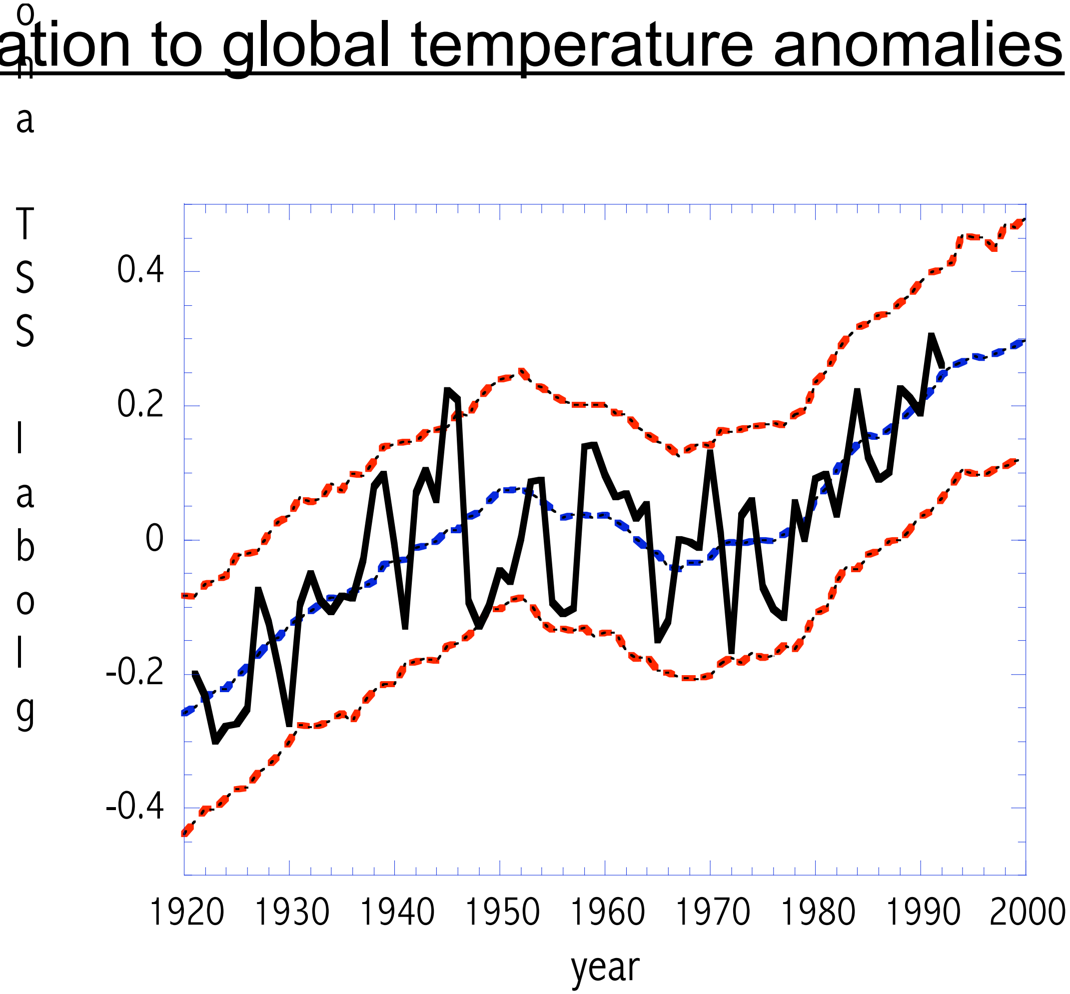
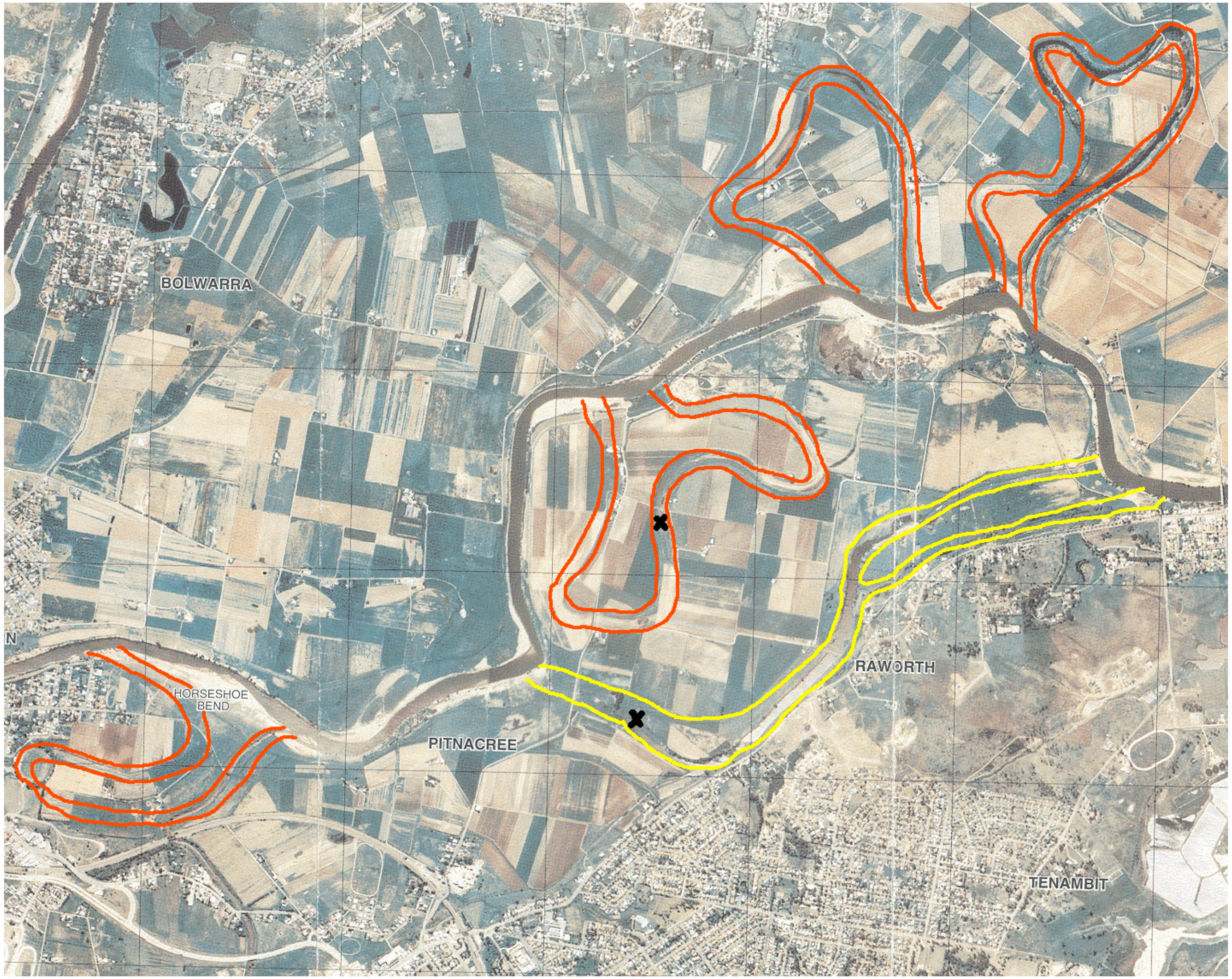
Application to global temperature anomalies



Note: Solar parameters are statistically significant at 99% level

‘Solar variation varies more substantially in the ultraviolet region and studies with climate models suggests that inclusion of spectrally resolved solar irradiance variations and solar-induced stratospheric ozone changes may improve the realism of model simulations of the impact of solar variability on climate’

Intergovernmental Panel on Climate Change, WG1



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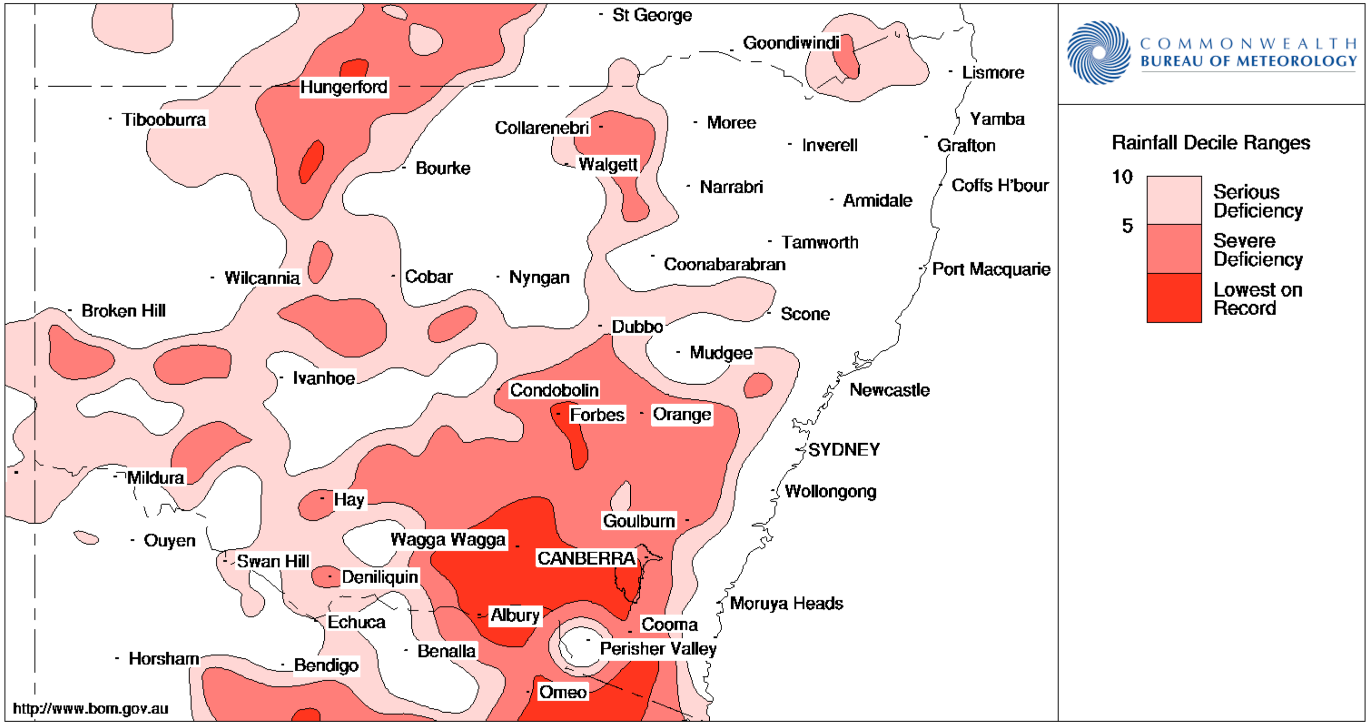
New South Wales Rainfall Deficiencies 1 July 2002 to 30 June 2003

Distribution Based on Gridded Data
Product of the National Climate Centre



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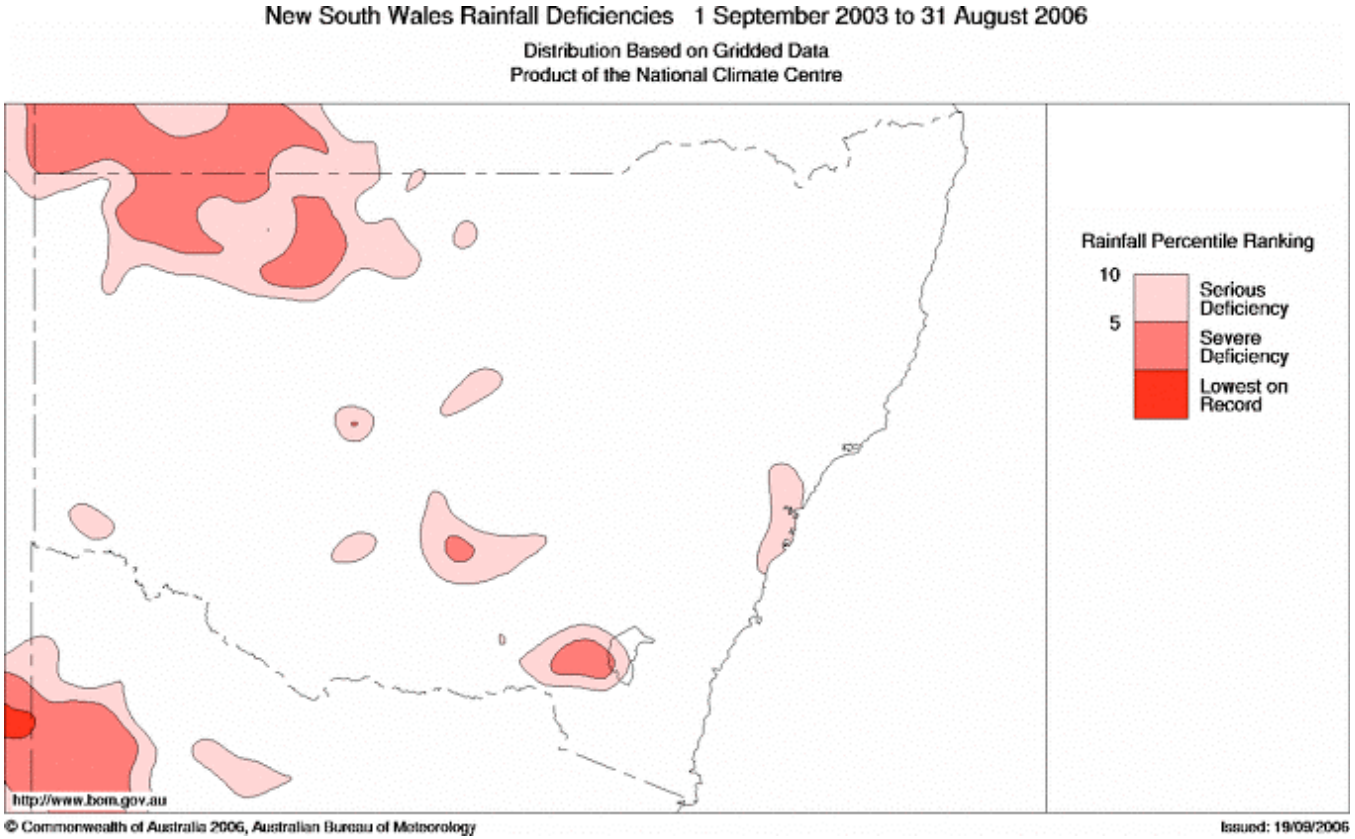

New South Wales Rainfall Deficiencies 1 September 2003 to 31 August 2006
Distribution Based on Gridded Data
Product of the National Climate Centre
Rainfall Percentile Ranking
10
Serious Deficiency
5
Severe Deficiency
Lowest on Record
http://www.bom.gov.au
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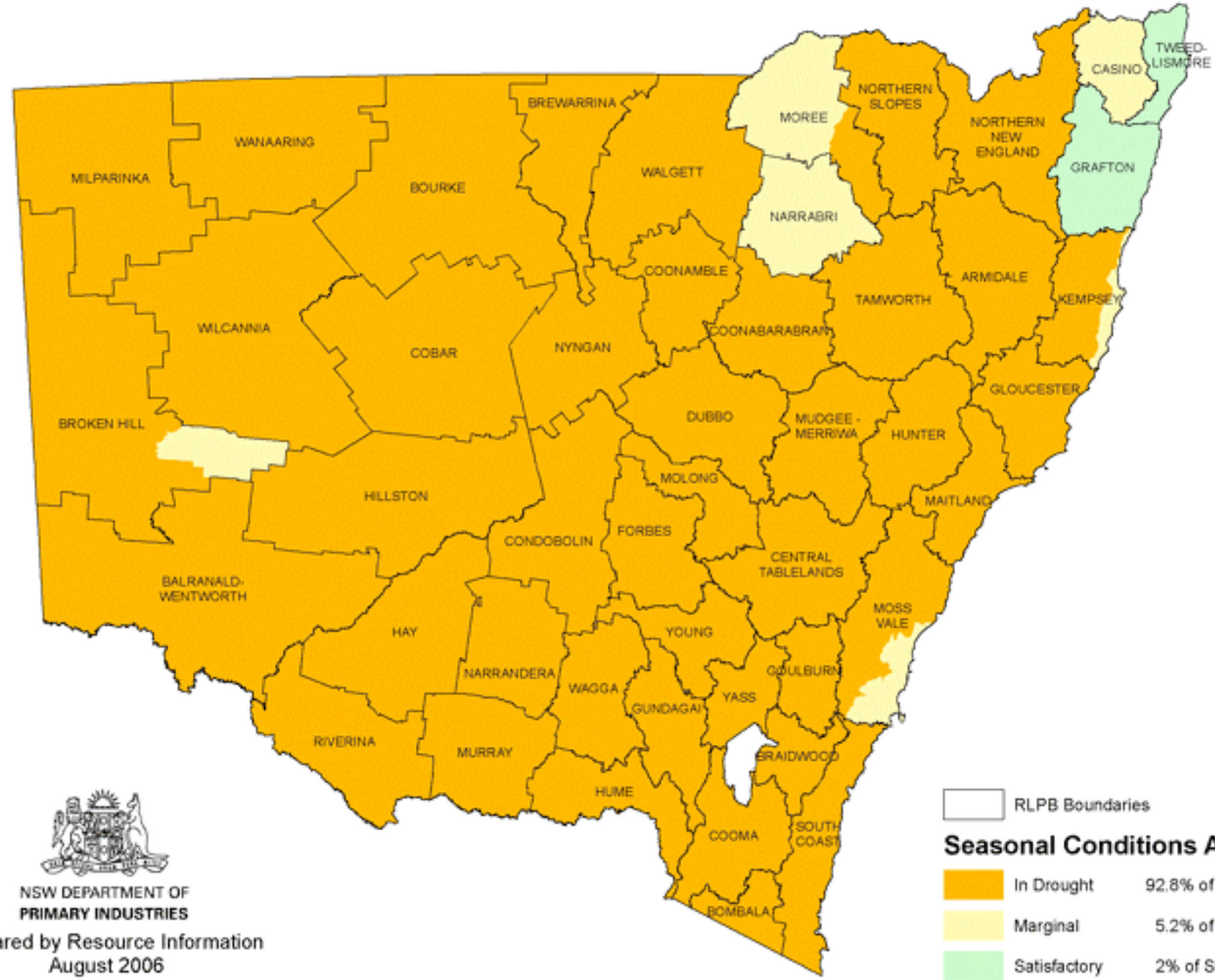
Issued: 19/09/2006



RLPB Boundaries

Seasonal Conditions August 2006

In Drought	92.8% of State
Marginal	5.2% of State
Satisfactory	2% of State

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Prepared by Resource Information
August 2006

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