

# Weather extremes and modes of large-scale variability

David Karoly

with inputs from Judith Perlwitz and Lisa Alexander

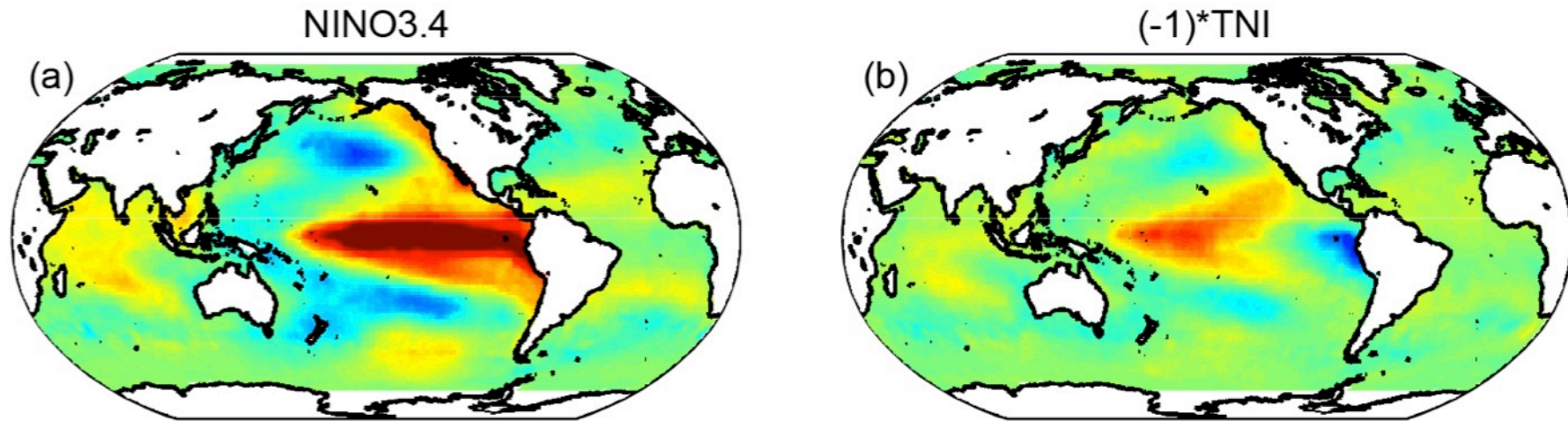
## Overview

- Some common modes of variability
- Links between modes of variability and extremes
  - El Niño-Southern Oscillation
  - North Atlantic Oscillation, blocking in Europe

# Modes of variability

- The global atmospheric circulation has a number of preferred patterns of variability, all of which have effects found in surface climate variations
  - Southern Oscillation: seesaw of pressure between the eastern and western tropical Pacific Ocean
  - North Atlantic Oscillation: seesaw of pressure between middle and high latitudes of the Atlantic
  - Northern Annular Mode: seesaw of pressure between middle and high latitudes of the Northern Hemisphere
  - Southern Annular Mode: seesaw of pressure between middle and high latitudes of the Southern Hemisphere
  - Pacific-North American pattern

## El Niño – Southern Oscillation



## Decadal to Multi-decadal Variability of Pacific and Atlantic Oceans

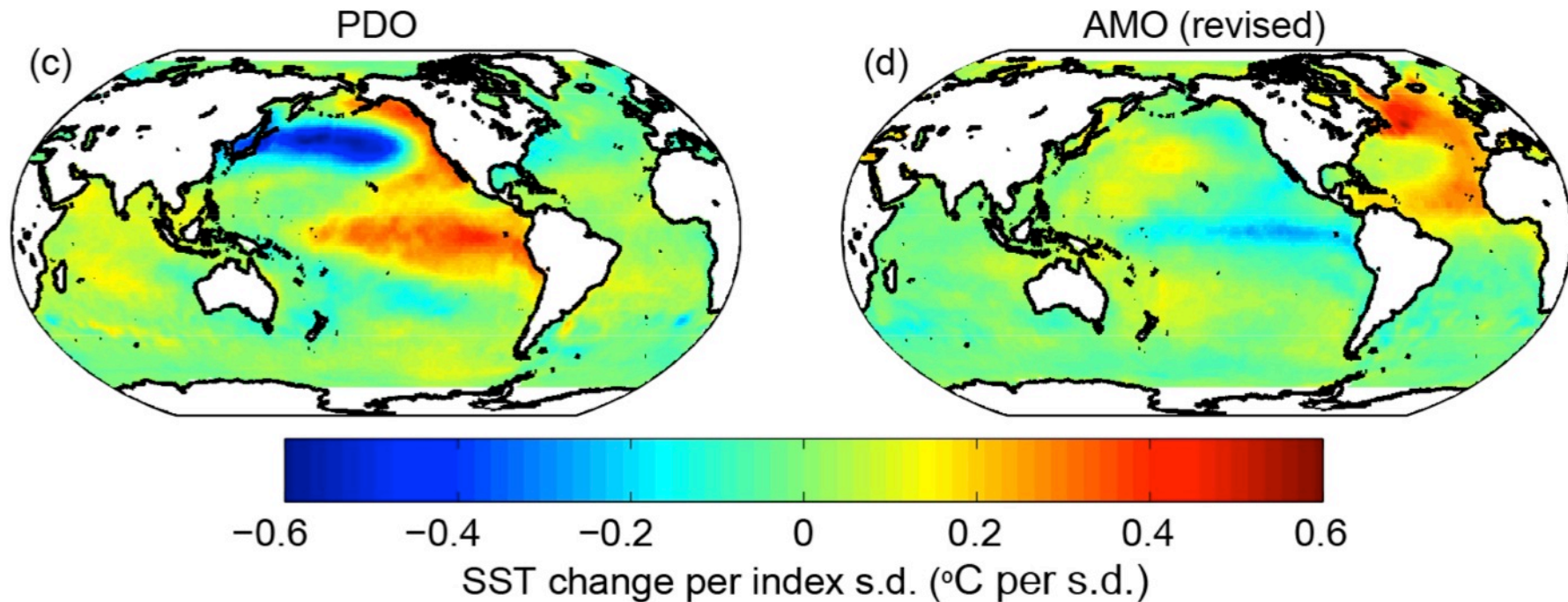
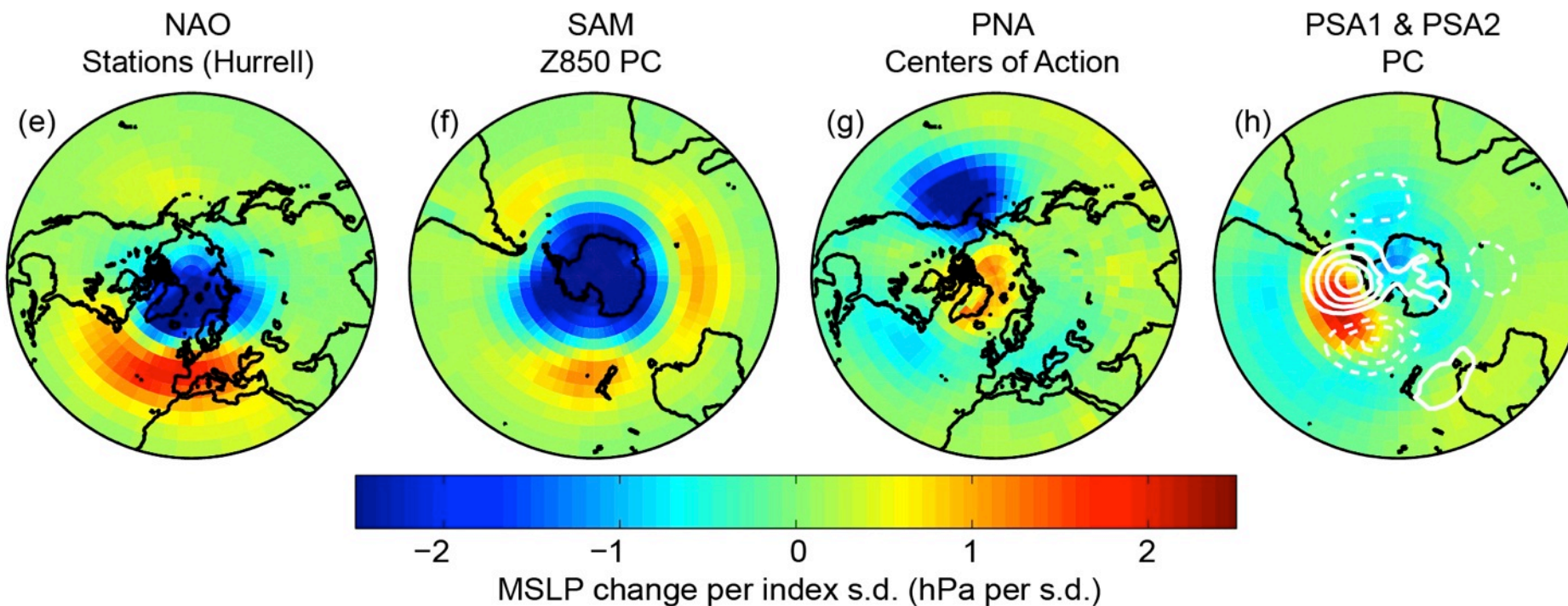


Fig Box 2.5-2, IPCC AR5 WG1



## Hemispheric-Scale Modes of Atmospheric Variability



## Tropical Variability of Atlantic and Indian Oceans

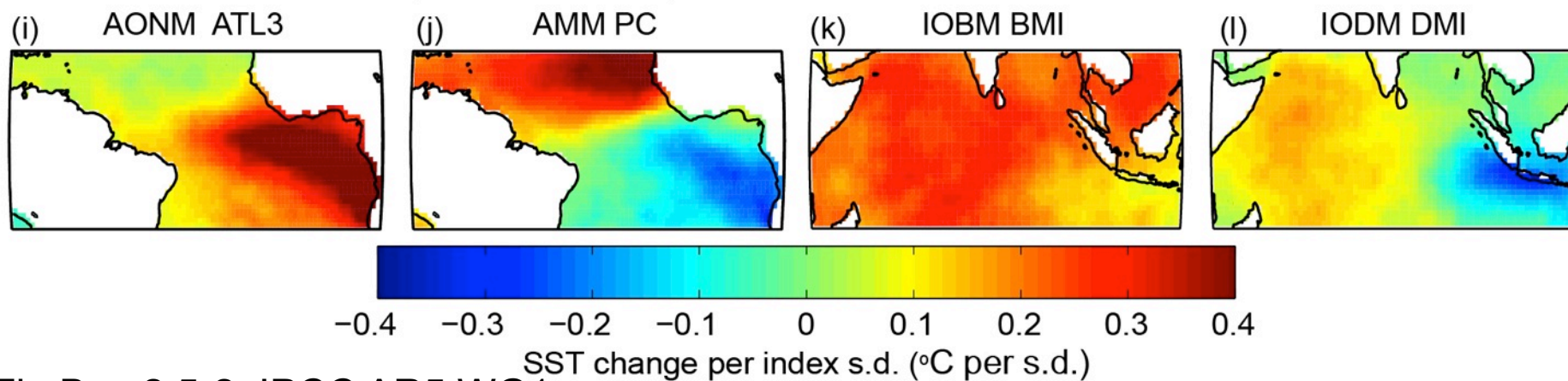
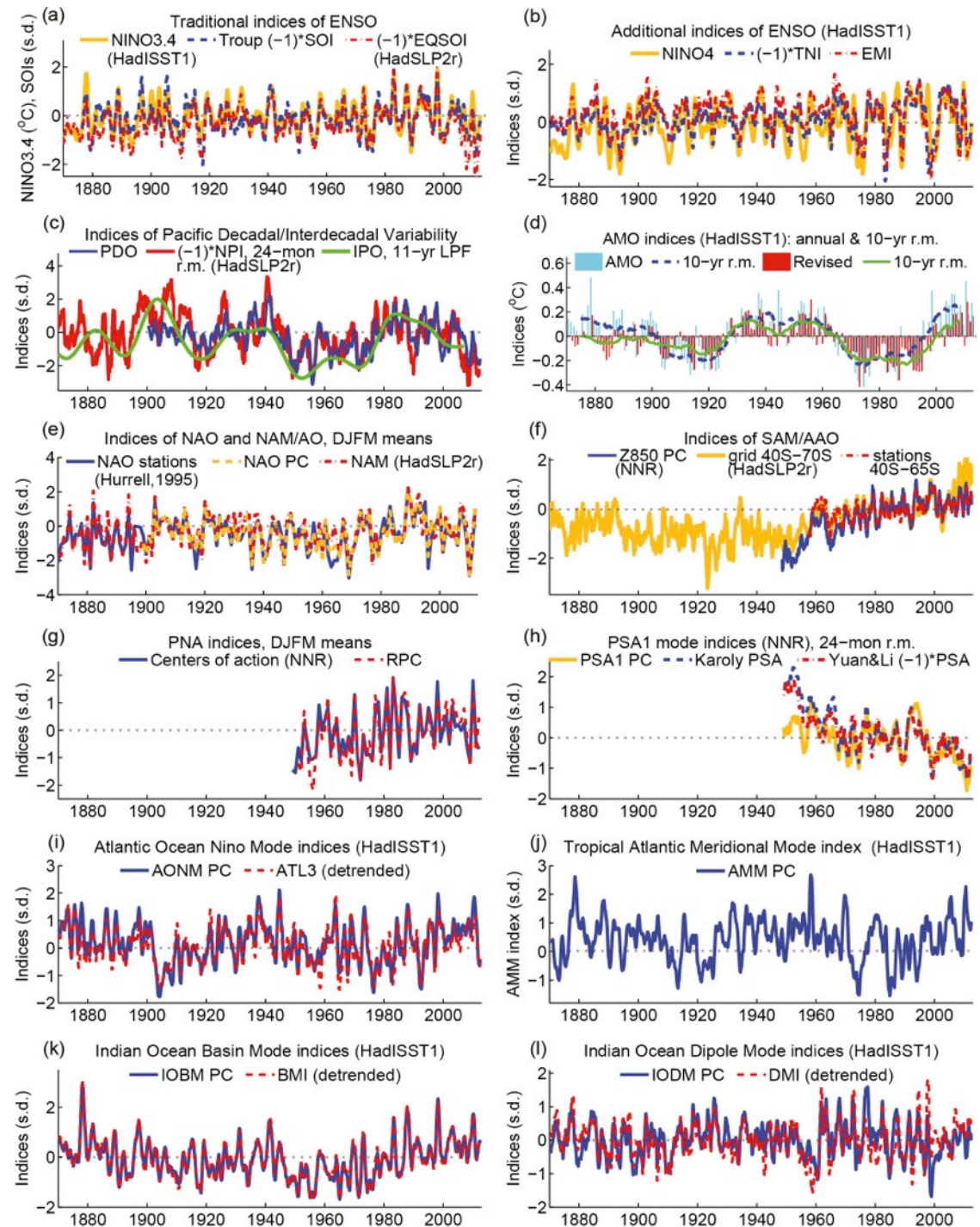


Fig Box 2.5-2, IPCC AR5 WG1

# Modes of variability

Fig Box 2.5-2, IPCC AR5 WG1



# Modes of variability and regional climate impacts

- The Climatedogs: the four drivers that influence Victoria (Australia) climate  
<http://www.depi.vic.gov.au/agriculture-and-food/farm-management/weather-and-climate/understanding-weather-and-climate/the-climatedogs-the-four-drivers-that-influence-victoriaas-climate>
- The Pacific adventures of the climate crab  
<http://www.pacificclimatechangescience.org/animations/climatecrab/>

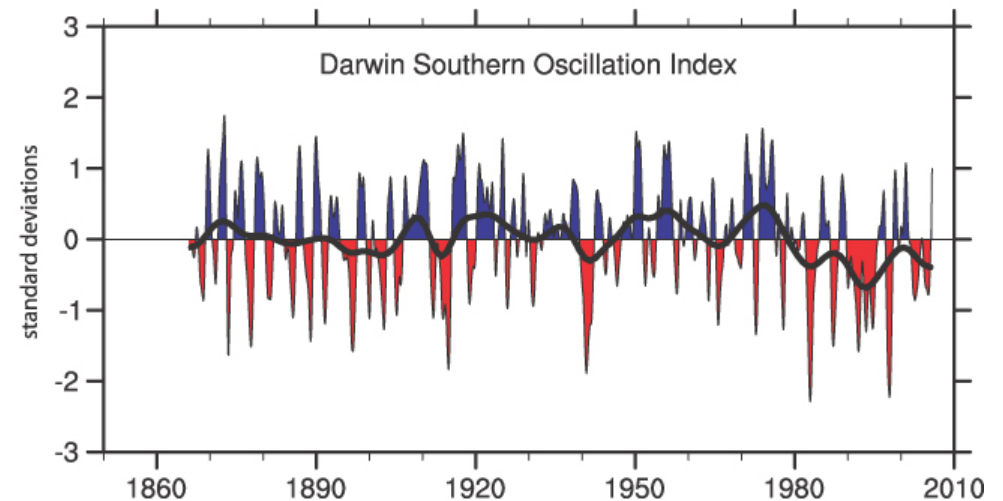
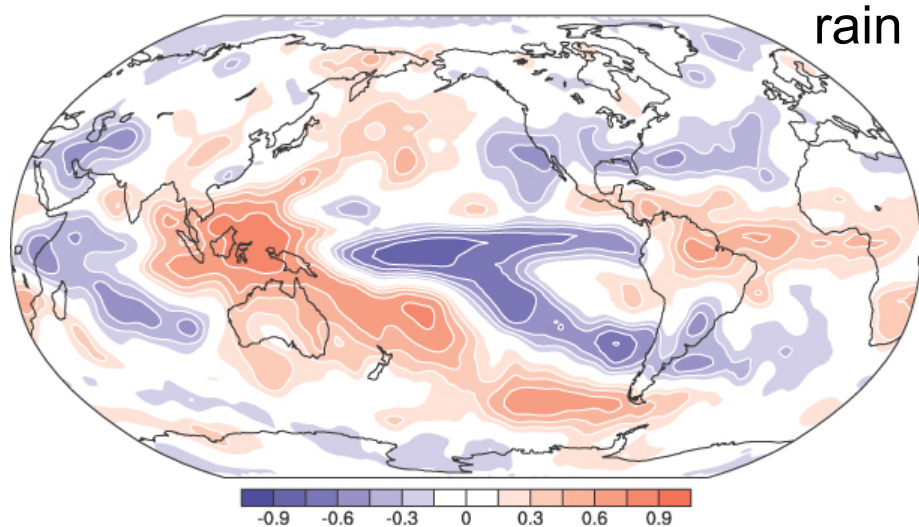
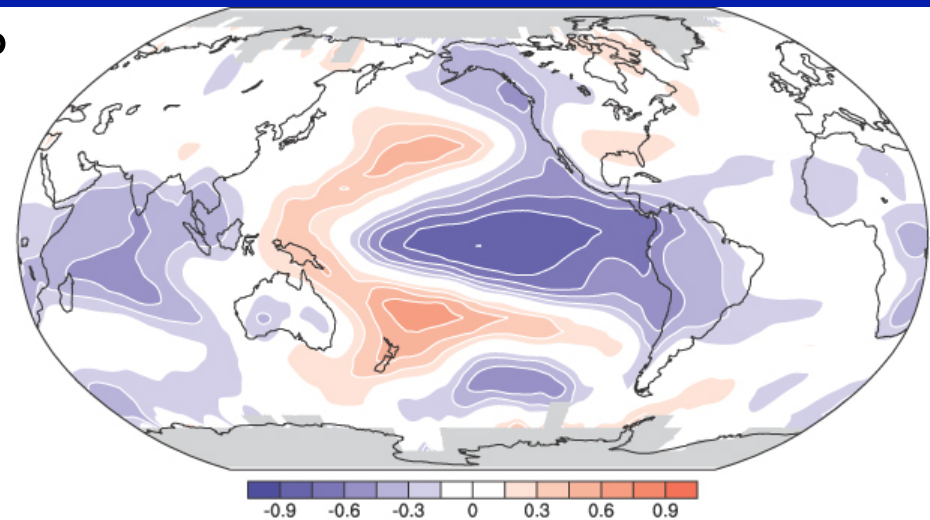
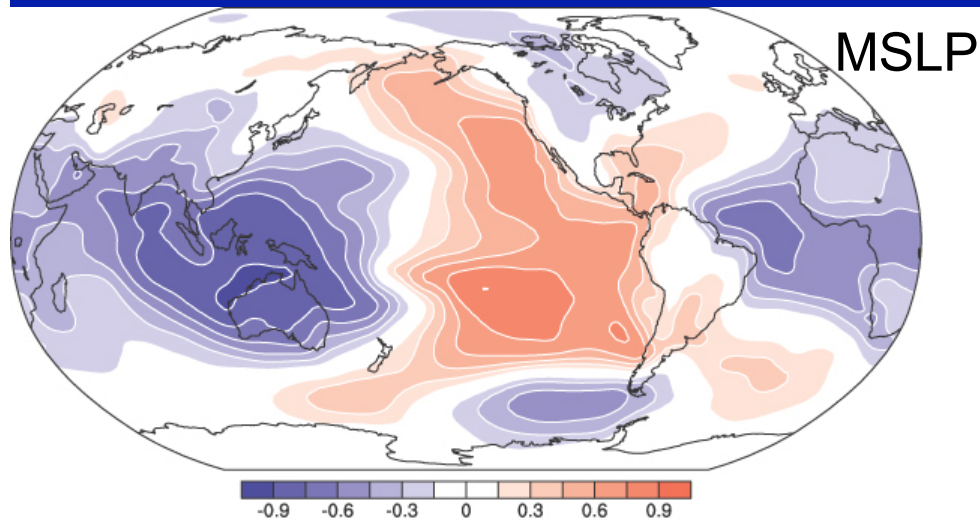


# El Niño-Southern Oscillation

Correlations of year-to-year variations with the Southern Oscillation Index for the May-April year

From Fig 3.27, IPCC AR4 WG1

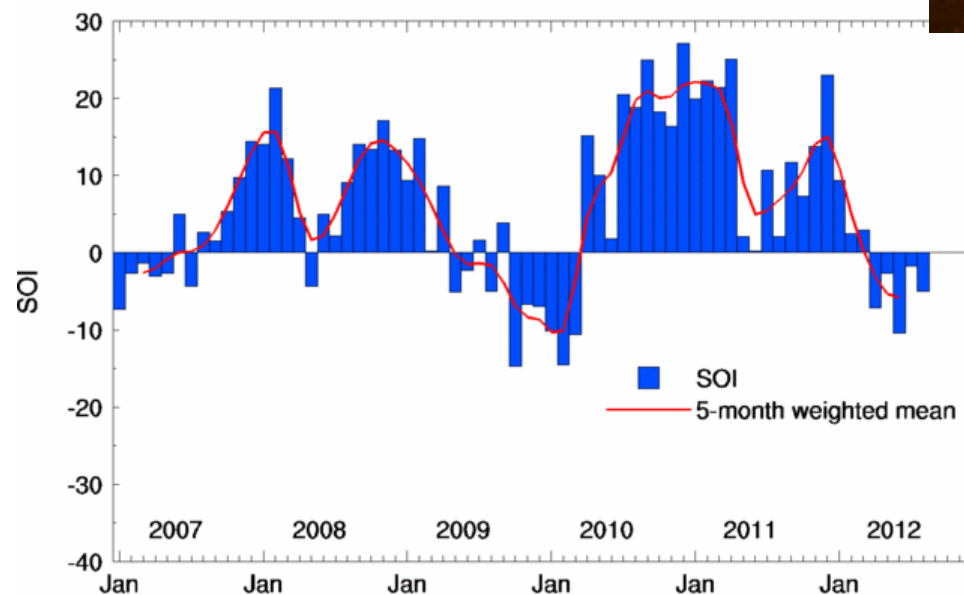
surface temperature



# Australian floods Jan 2011



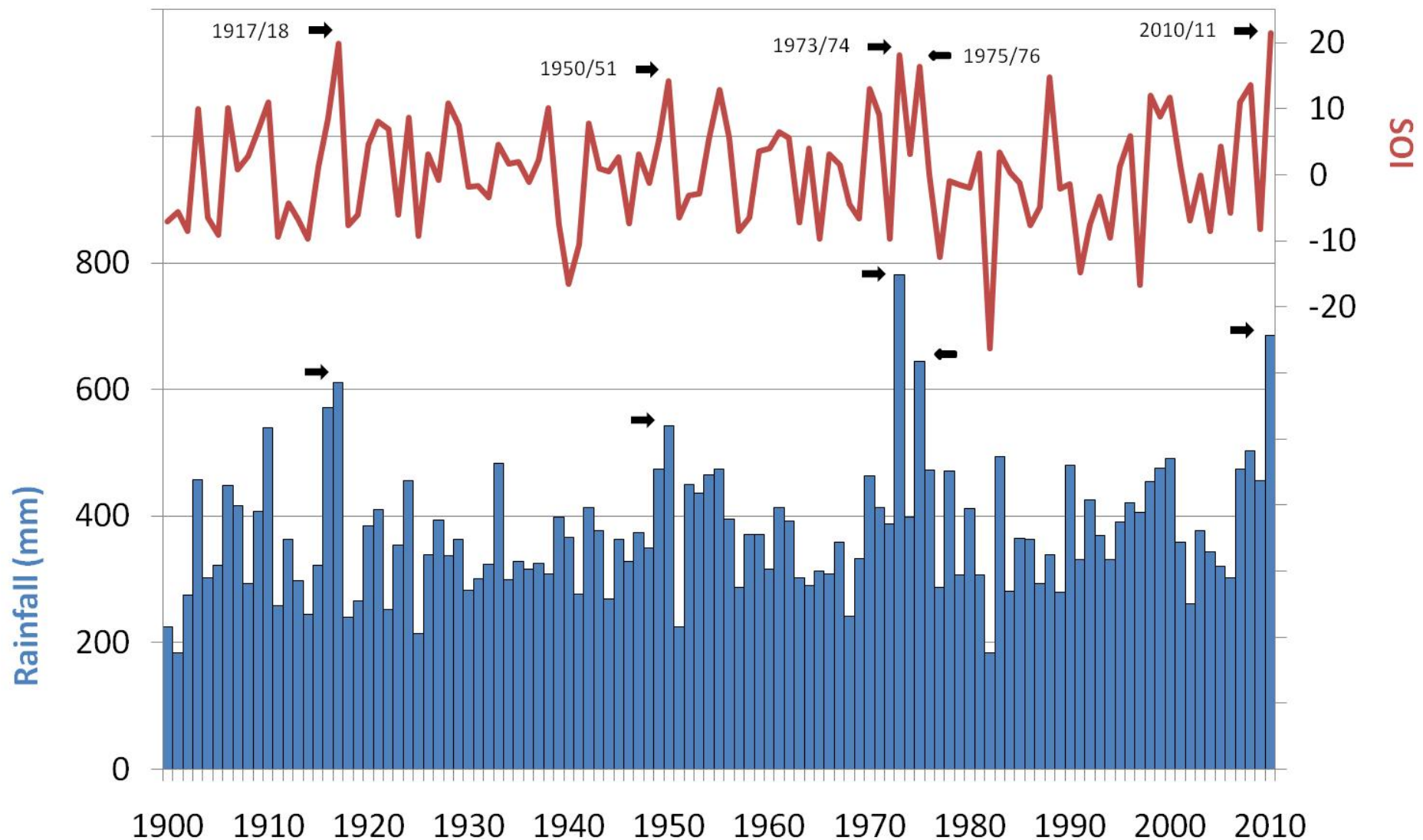
Southern Oscillation Index (SOI)





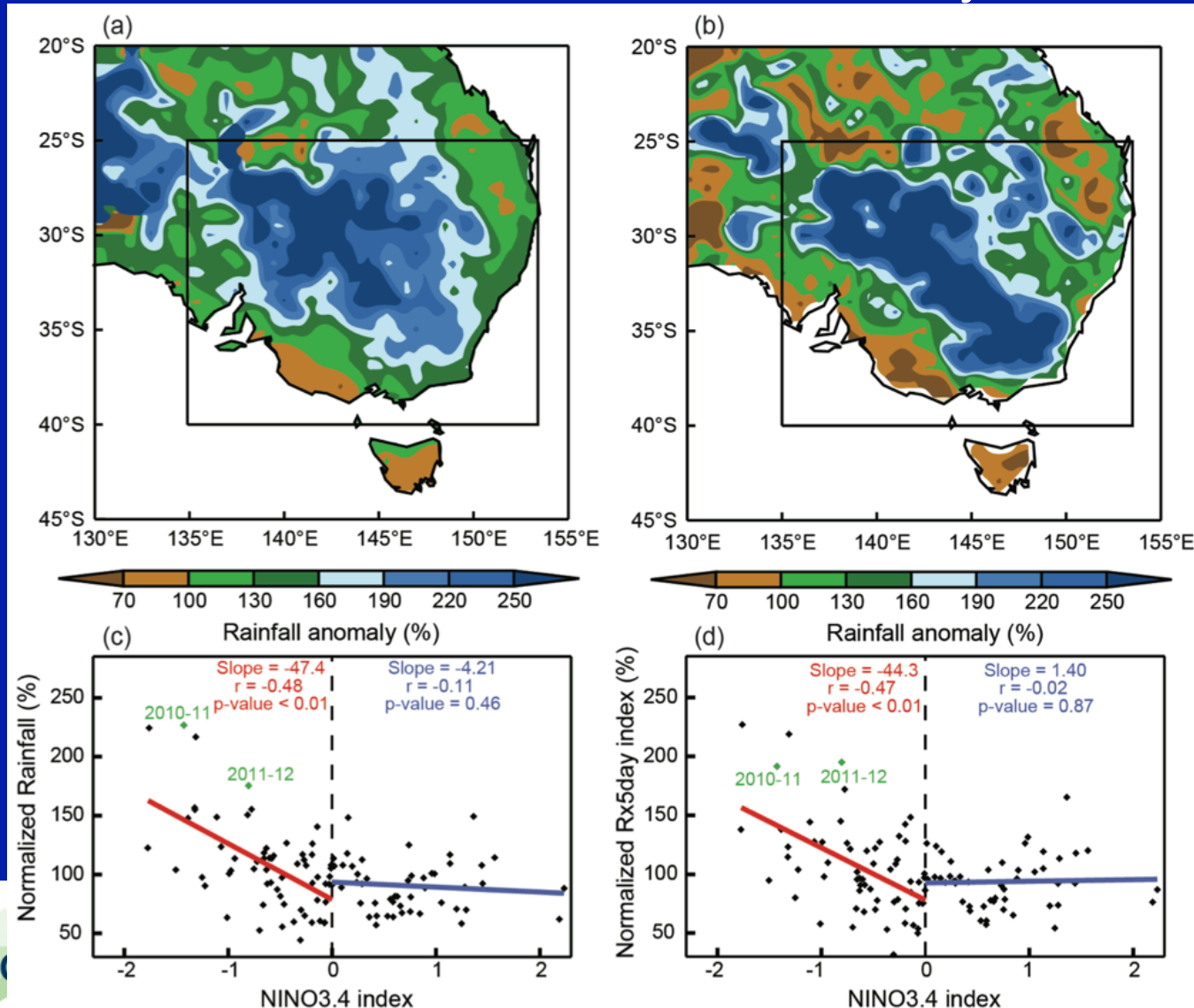
# La Niña and eastern Australian rainfall

Spring and Summer SOI and Eastern Australian Rainfall



# Heavy rainfall in Oct-Mar 2011-12 in SE Aust

Observed Oct 2011-Mar 2012 anomalies in  
total rainfall                      max 5 day rain



Impact of  
ENSO

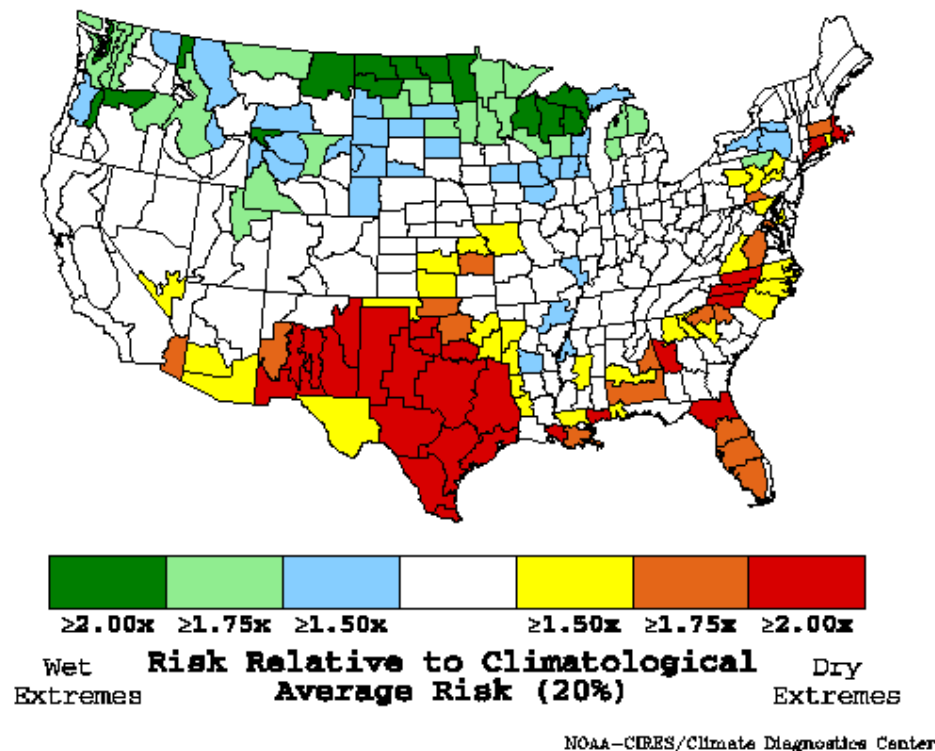
From King et al,  
BAMS, 2013

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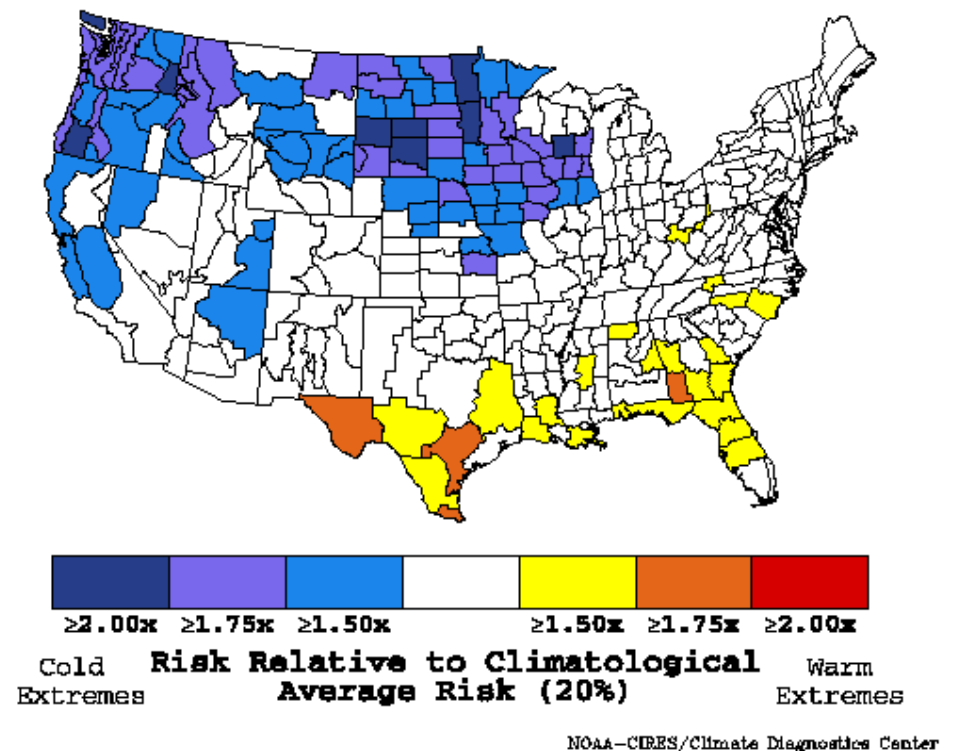
# La Niña effects in the US

Changes in probability of extreme seasonal mean temperature and precipitation anomalies

**DJF Precipitation Extremes During La Nina**  
**Risk of Extreme Wet or Dry Years**

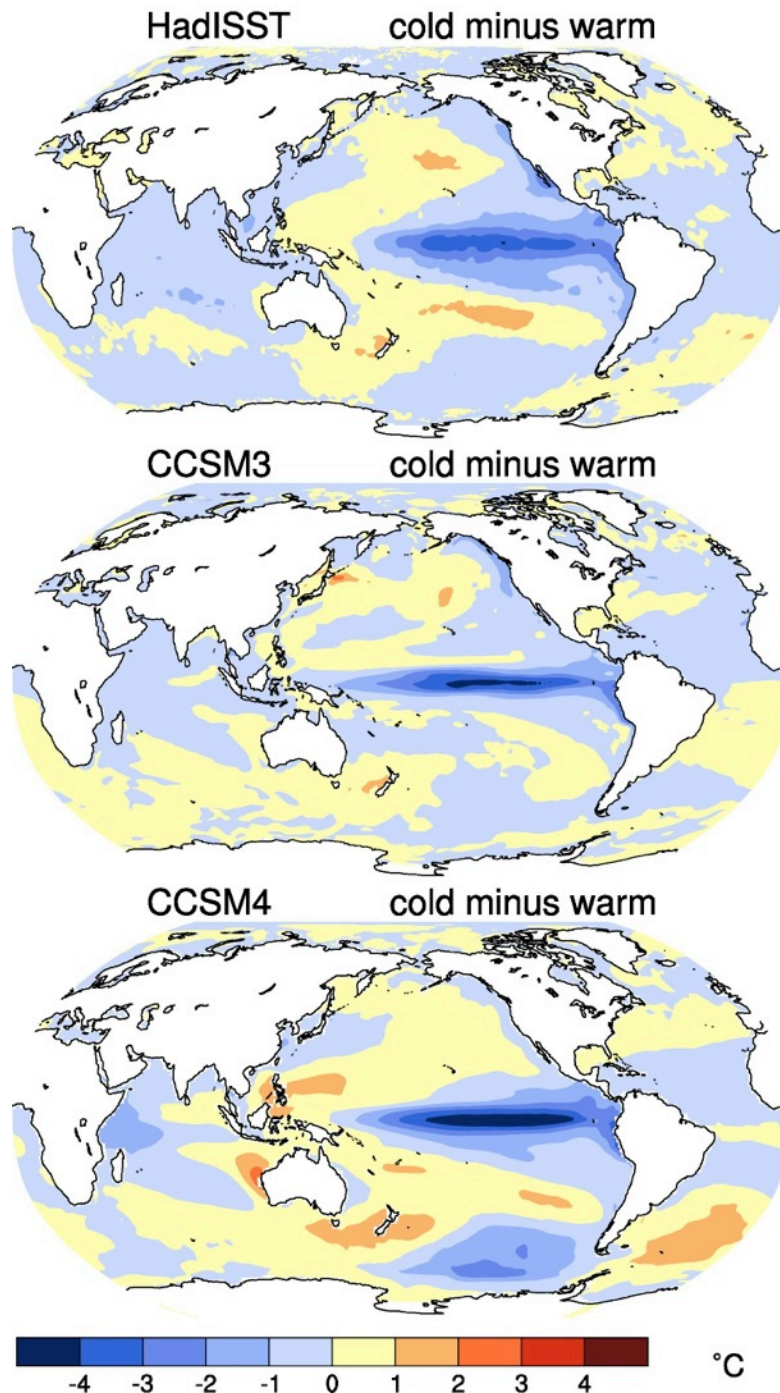


**DJF Temperature Extremes During La Nina**  
**Risk of Extreme Warm or Cold Years**





1950-1999 DJF composite of SST with Nino 3.4 events



# La Niña SST anomalies from observations and model simulations

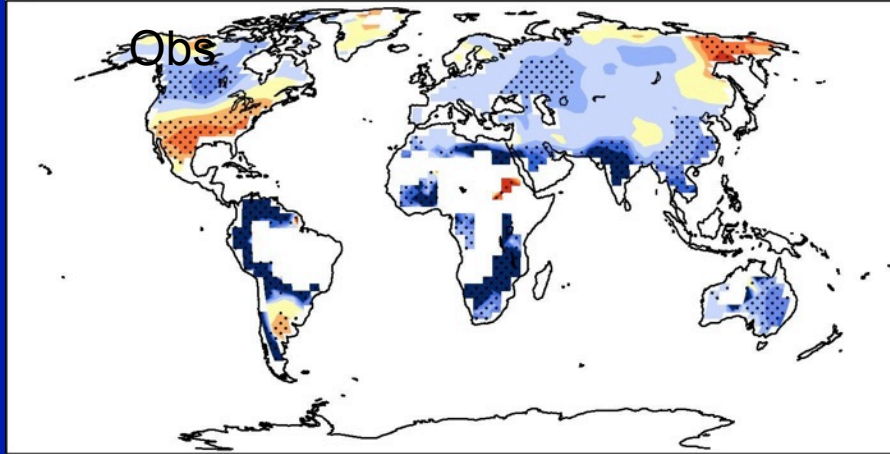
From Arblaster and Alexander,  
GRL, 2012

# Changes in temperature of hottest day in DJF season due to ENSO in observations and models

1950-1999 DJF composite of TXx with Nino 3.4 events

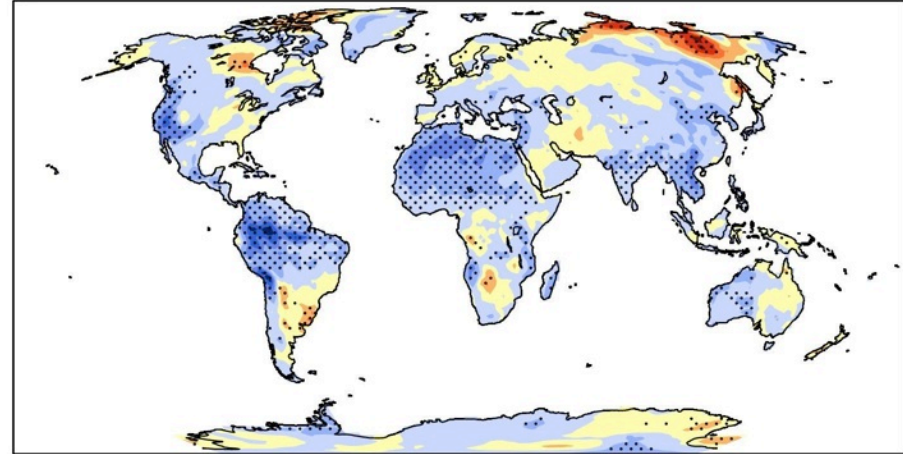
a) HadEX2 Obs

cold minus warm



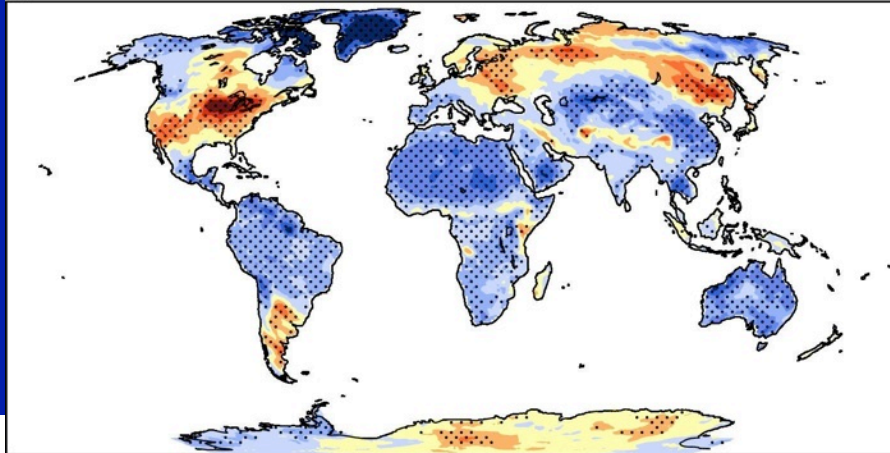
b) CCSM3 Historical

cold minus warm



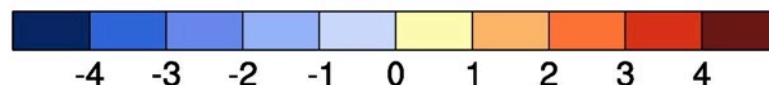
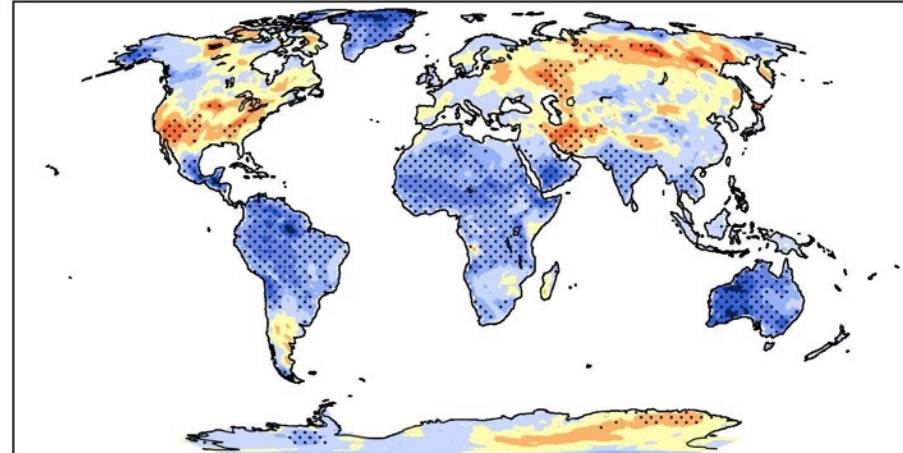
c) CCSM4 Historical

cold minus warm



d) CCSM4 RCP8.5 Future

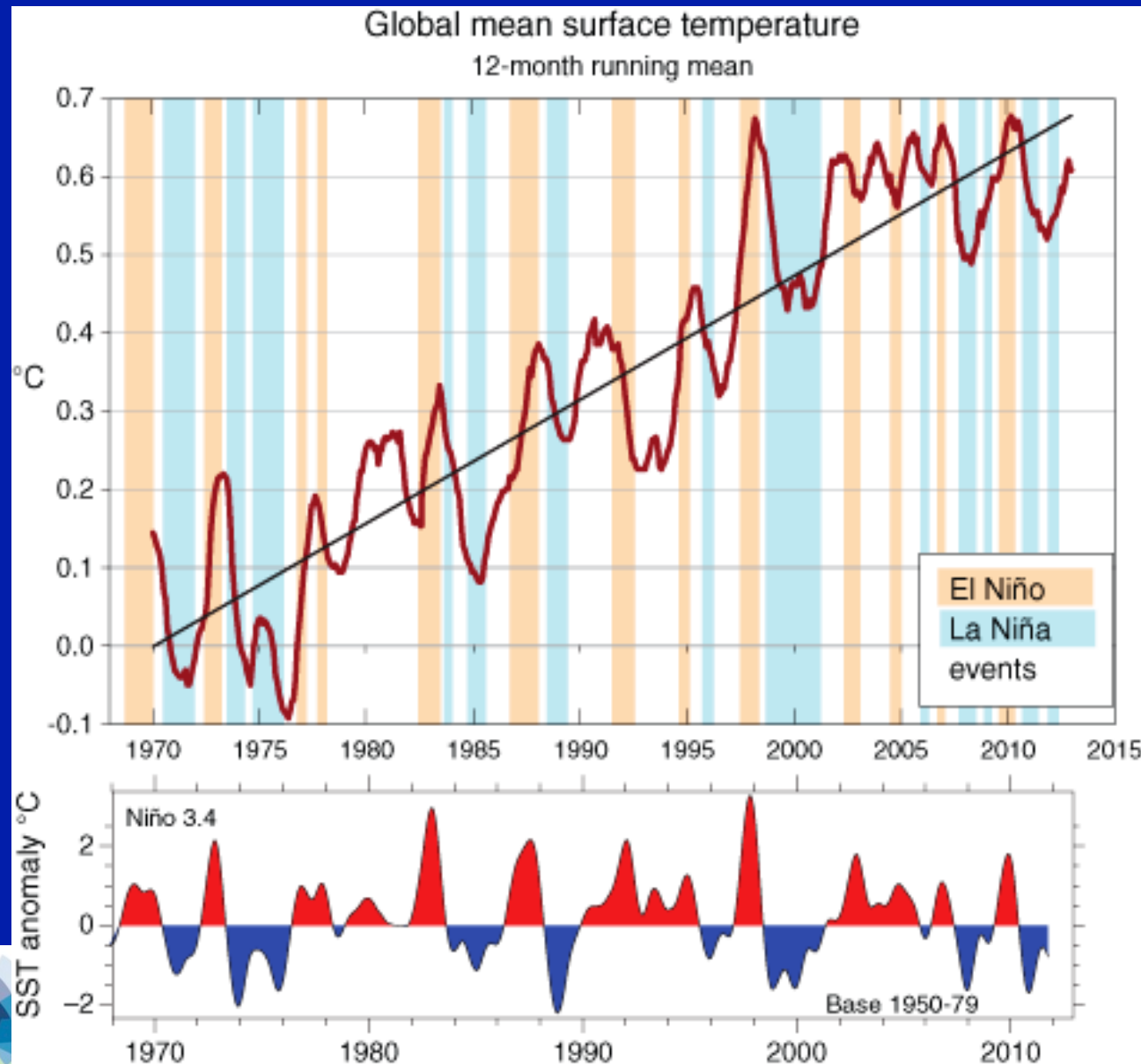
cold minus warm



°C

From Arblaster and Alexander, GRL 2012

# El Niño and global mean temperature



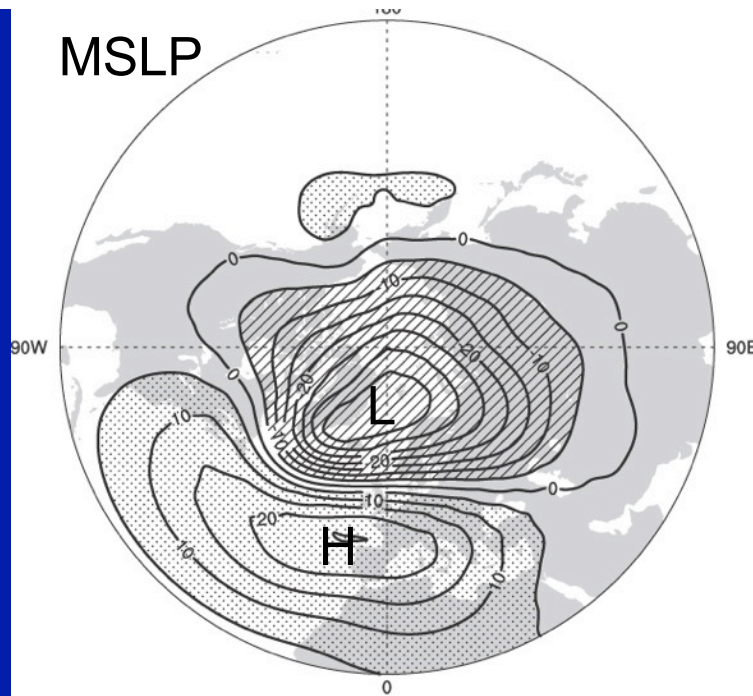
From Trenberth and Fasullo, *Earth's Future*, 2013



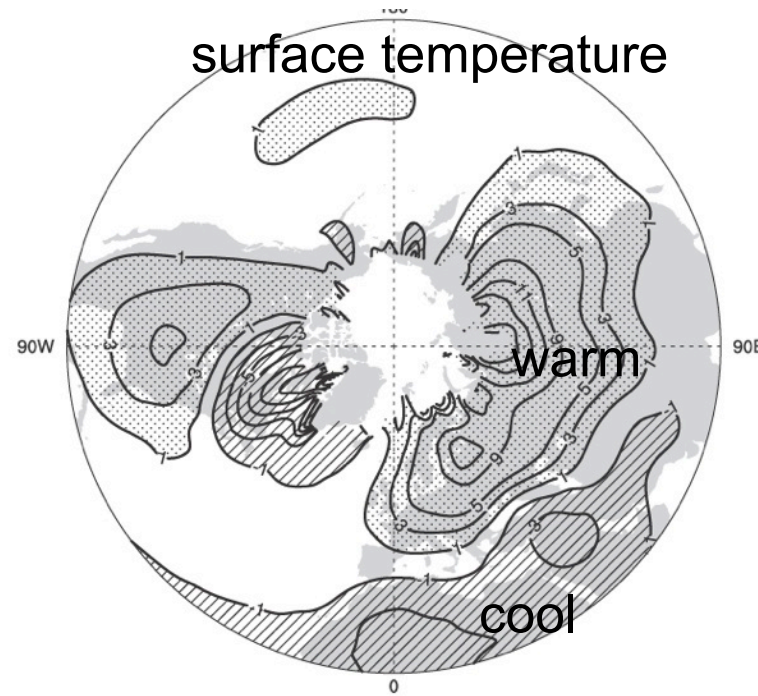
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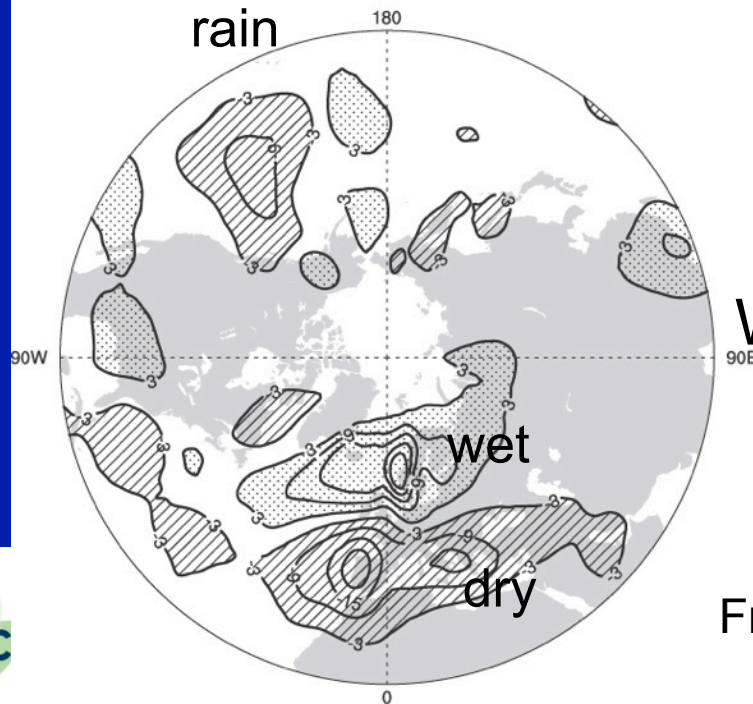
MSLP



surface temperature



rain



## North Atlantic Oscillation

Winter variations associated with unit deviation of the NAO index

From Fig 3.30, IPCC AR4 WGI



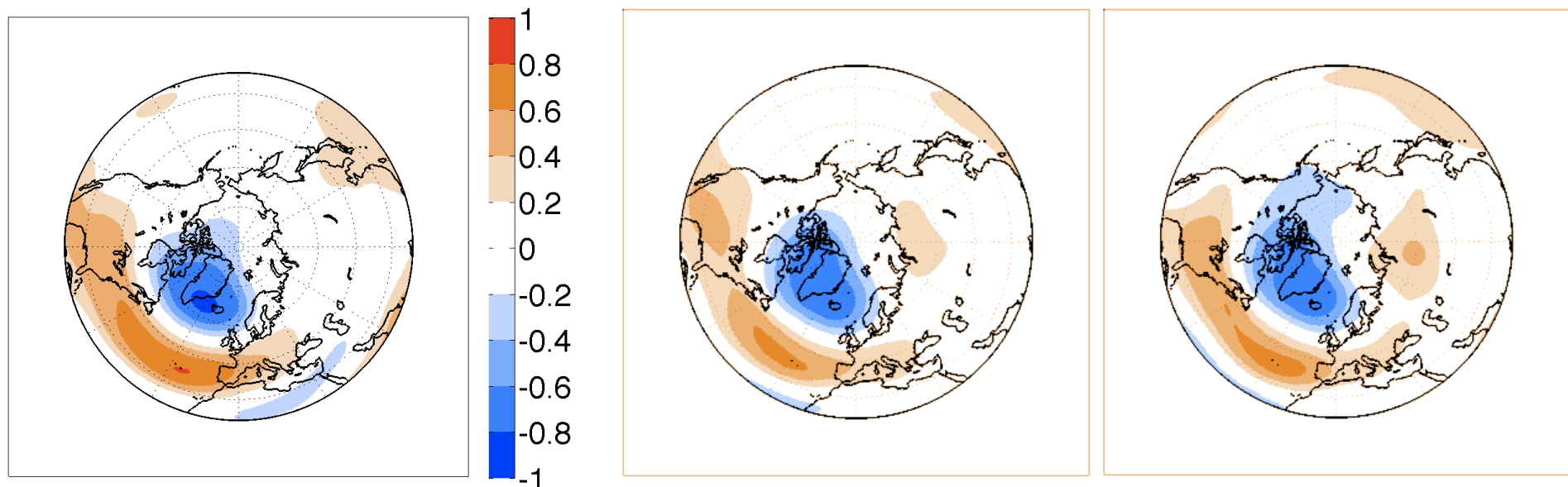
# Observed and simulated NAO

Correlations of winter 500hPa height anomalies with NAO index  
from observations and CMIP3 20C3M simulations

CPC

CGCM3.1(T63)

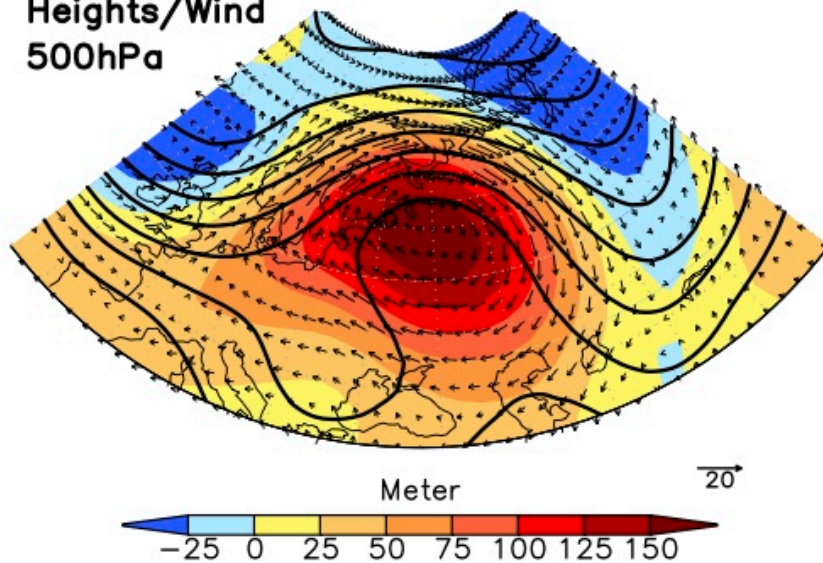
HadGEM1



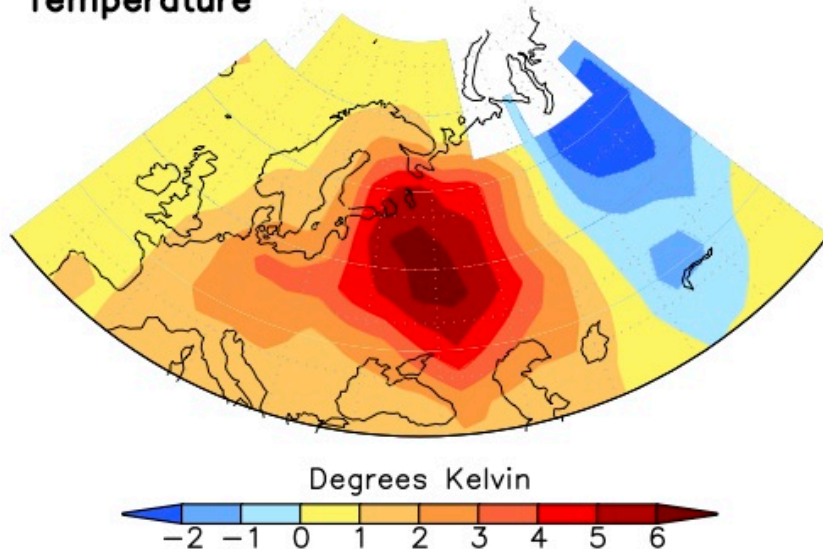
from Gonzalez-  
Reviriego et al, 2010

Reanalysis/OBS 2010

Heights/Wind  
500hPa



Temperature



## 2010 Russian heat wave

associated with blocking

Observed 500 hPa geopotential heights and winds

Observed temperature anomalies

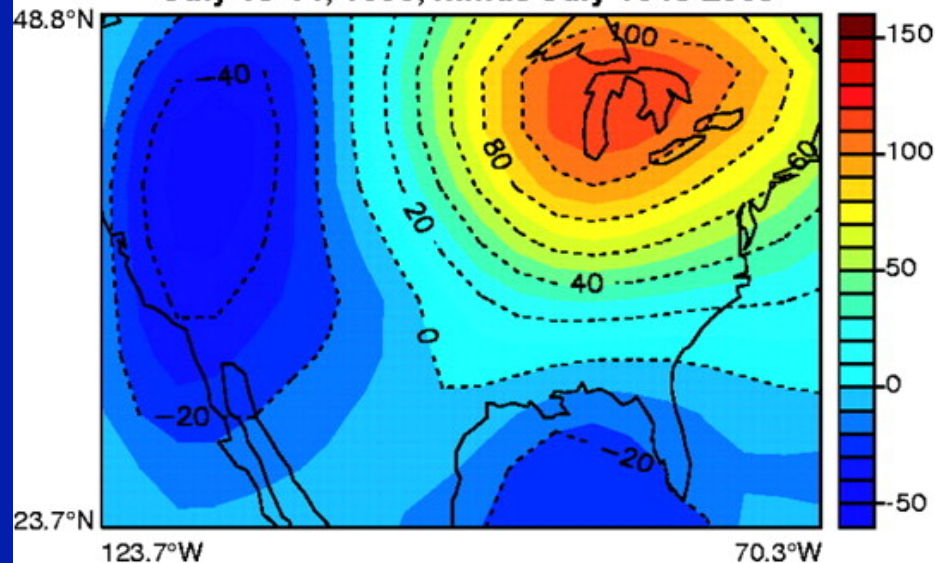
From Judith Perlwitz



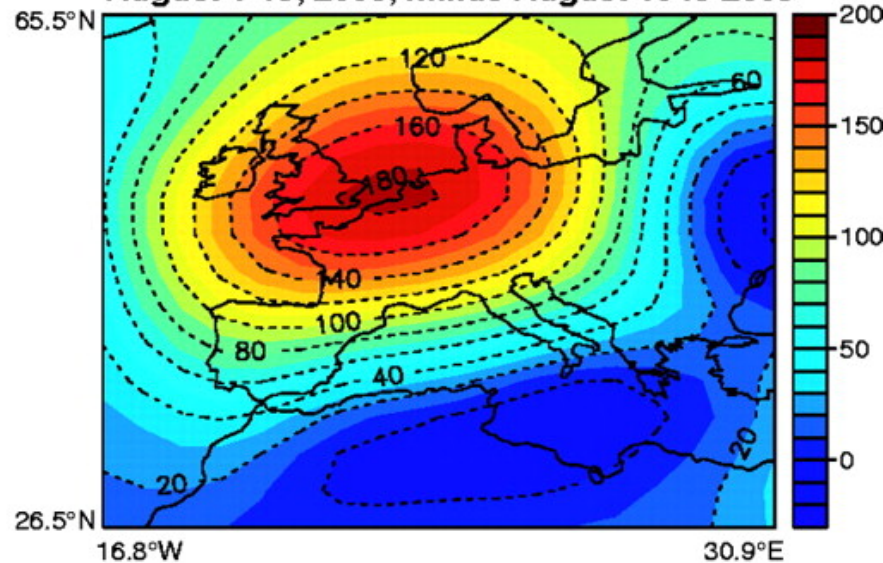
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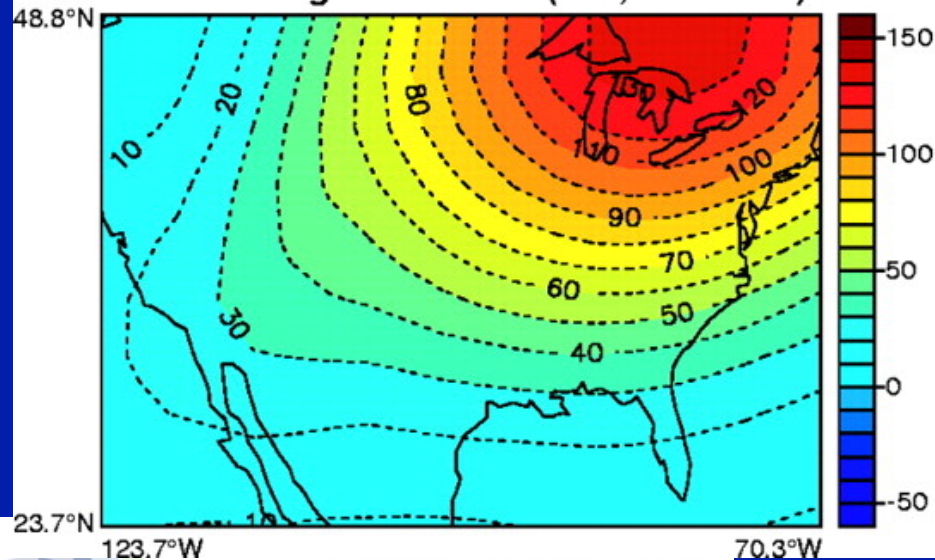
**A** Observed Heat Wave 500hPa Height Anomalies  
July 13-14, 1995, minus July 1948-2003



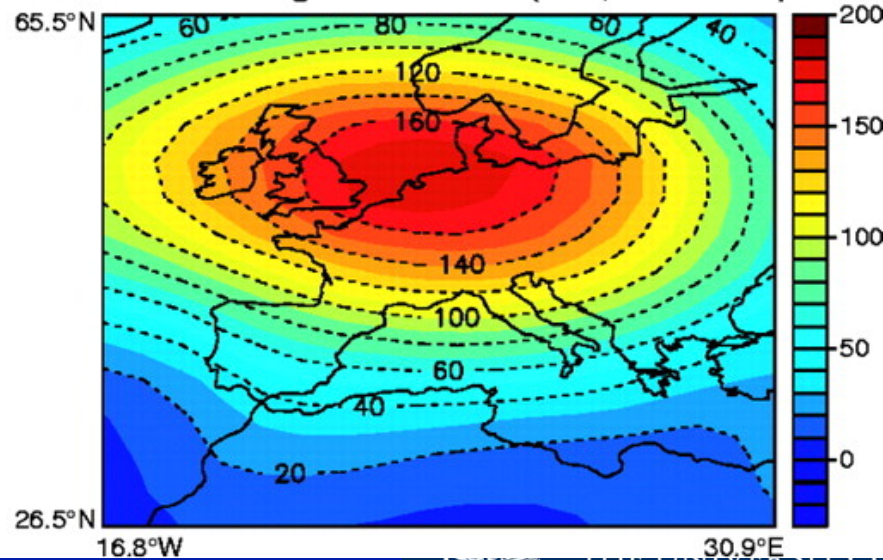
**B** Observed Heat Wave 500hPa Height Anomalies  
August 1-13, 2003, minus August 1948-2003



**C** Simulated Composite Heat Wave  
500 hPa Height Anomalies (JJA, 1961-1990)



**D** Simulated Composite Heat Wave  
500 hPa Height Anomalies (JJA, 1961-1990)



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**CLIMATE SYSTEM SCIENCE**

from Meehl et al 2004

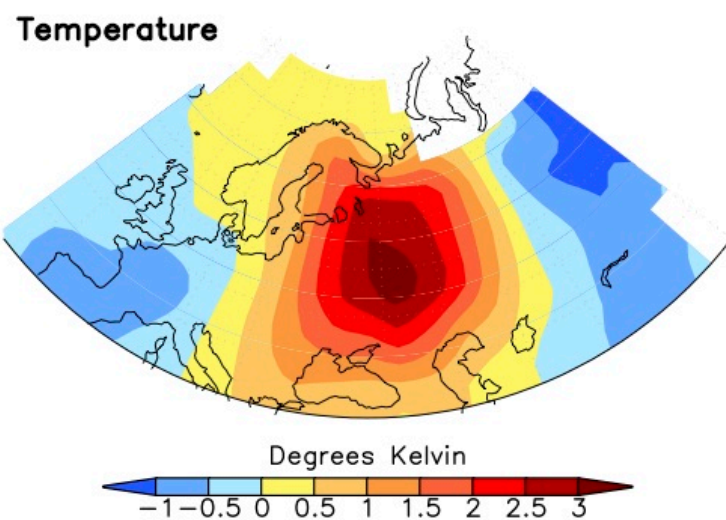
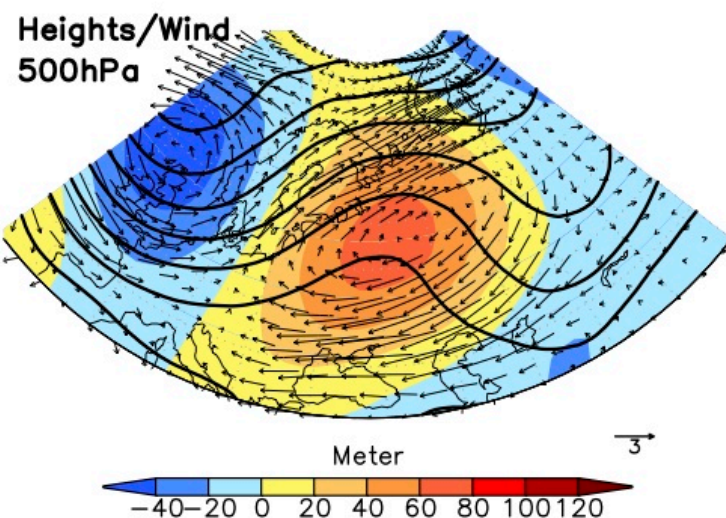


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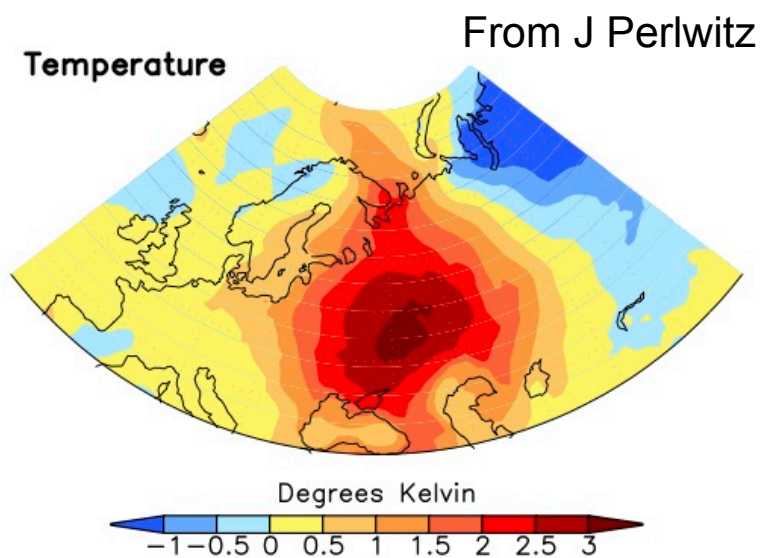
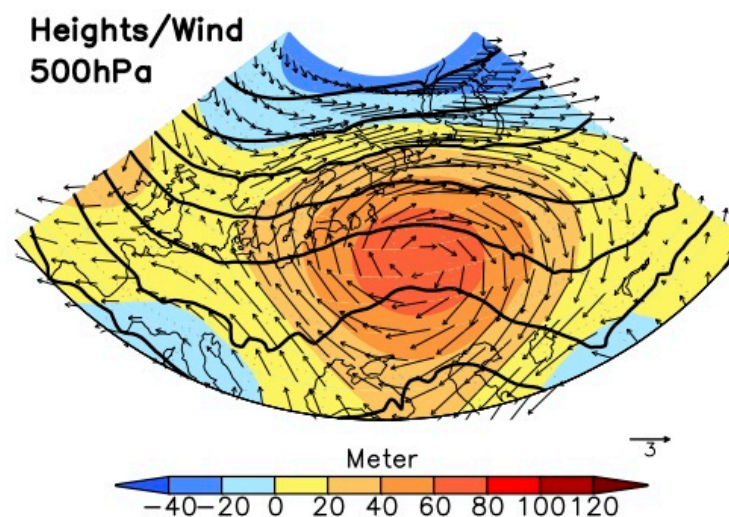


# Observed and simulated events

Reanalysis/OBS  
Top 10 events



CCSM4 1900–1999  
Top 10% >1.7K



# Summary

- Common modes of variability affect seasonal climate variations and the likelihood of weather extremes in many regions
- Large-scale climate variations associated with modes of variability can be simulated reasonably well by climate models
- Details of the spatial structure and temporal persistence of modes, such as blocking, is key to the representation of extremes and is not as well simulated