

Weather extremes and modes of large-scale variability

David Karoly

with inputs from Judith Perlwitz and Lisa Alexander

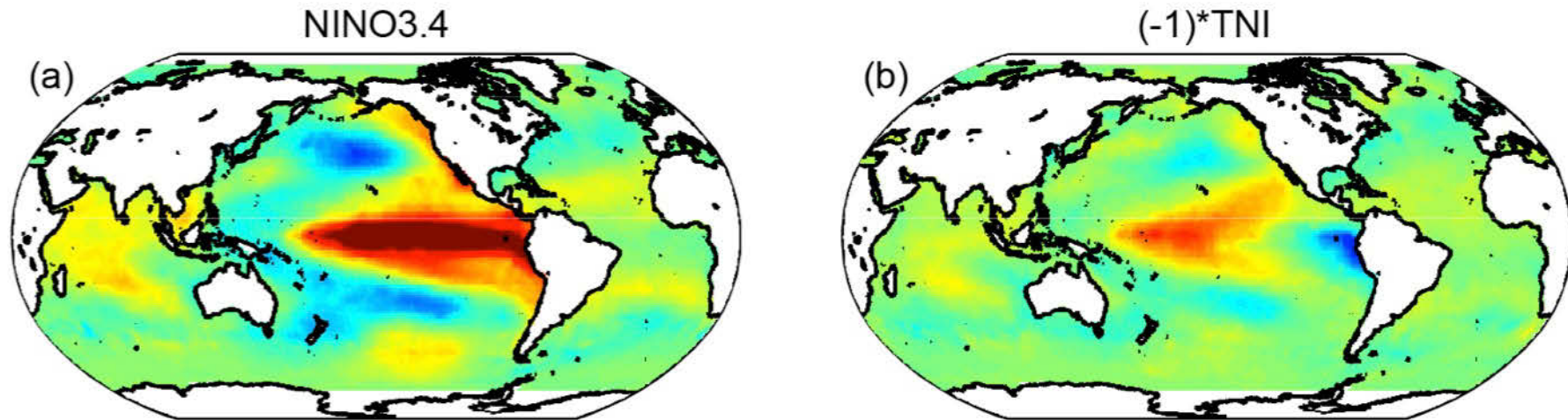
Overview

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

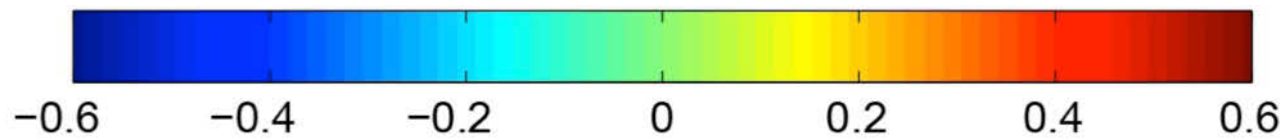
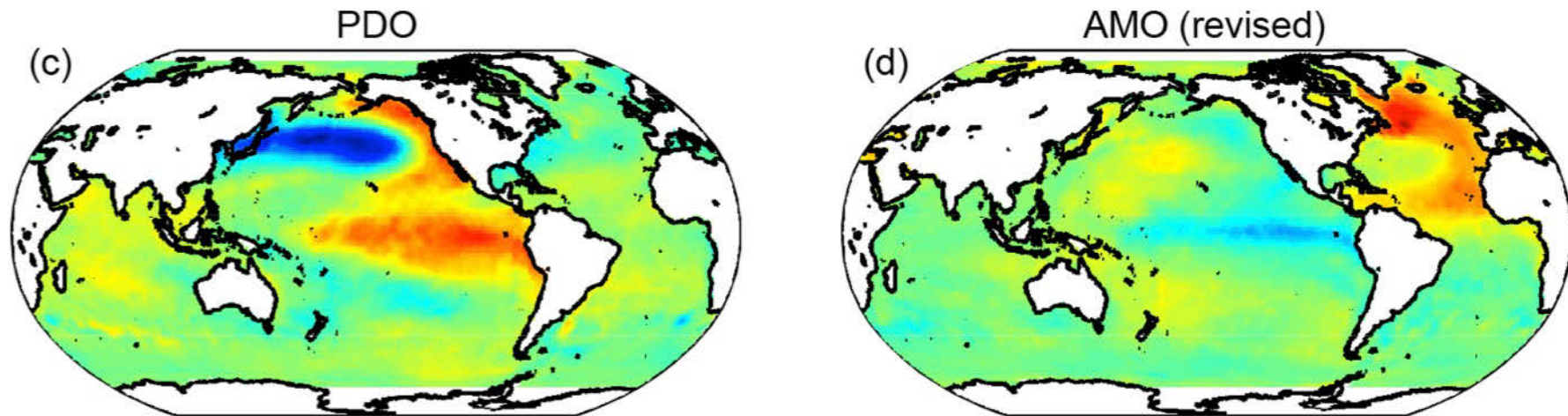
Modes of variability

- 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



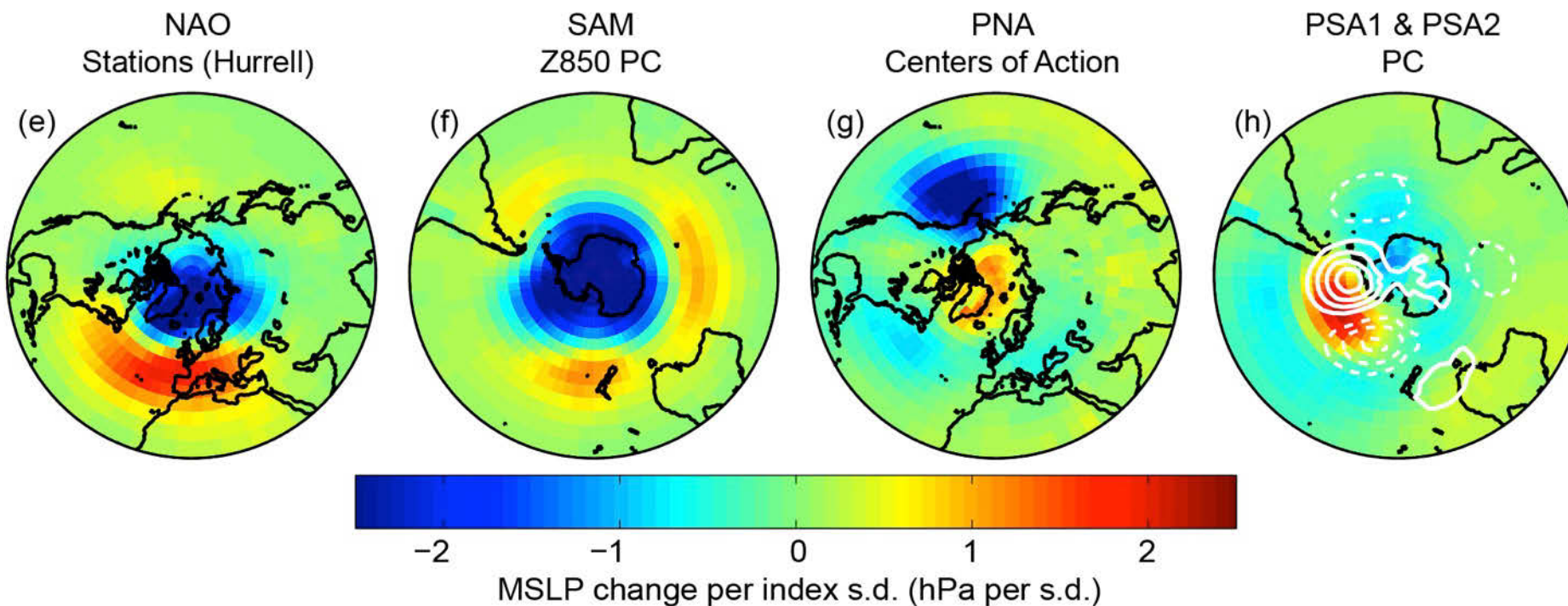
Decadal to Multi-decadal Variability of Pacific and Atlantic Oceans



SST change per index s.d. ($^{\circ}\text{C}$ per s.d.)

Fig Box 2.5-2, IPCC AR5 WG1

Hemispheric-Scale Modes of Atmospheric Variability



Tropical Variability of Atlantic and Indian Oceans

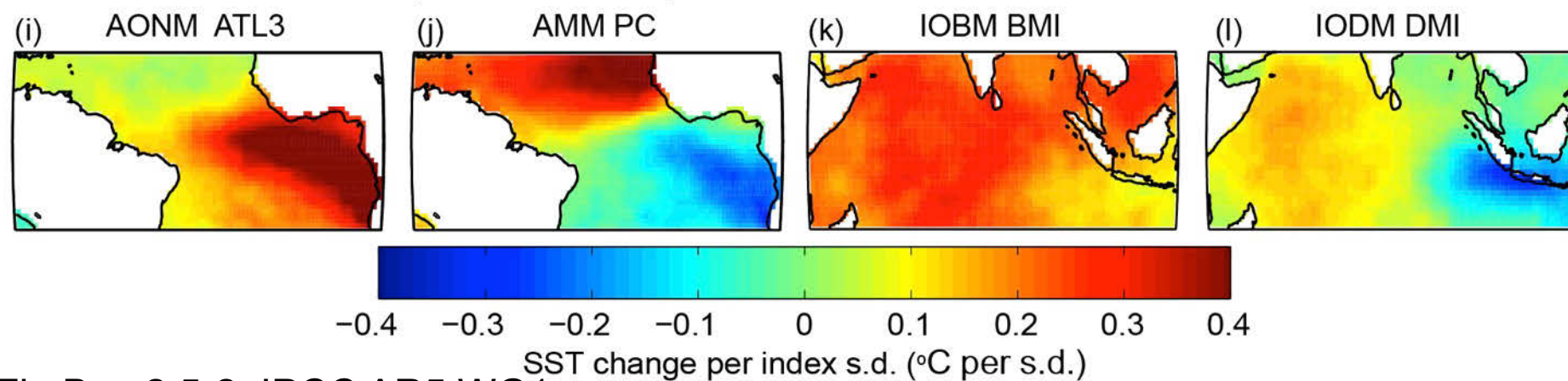
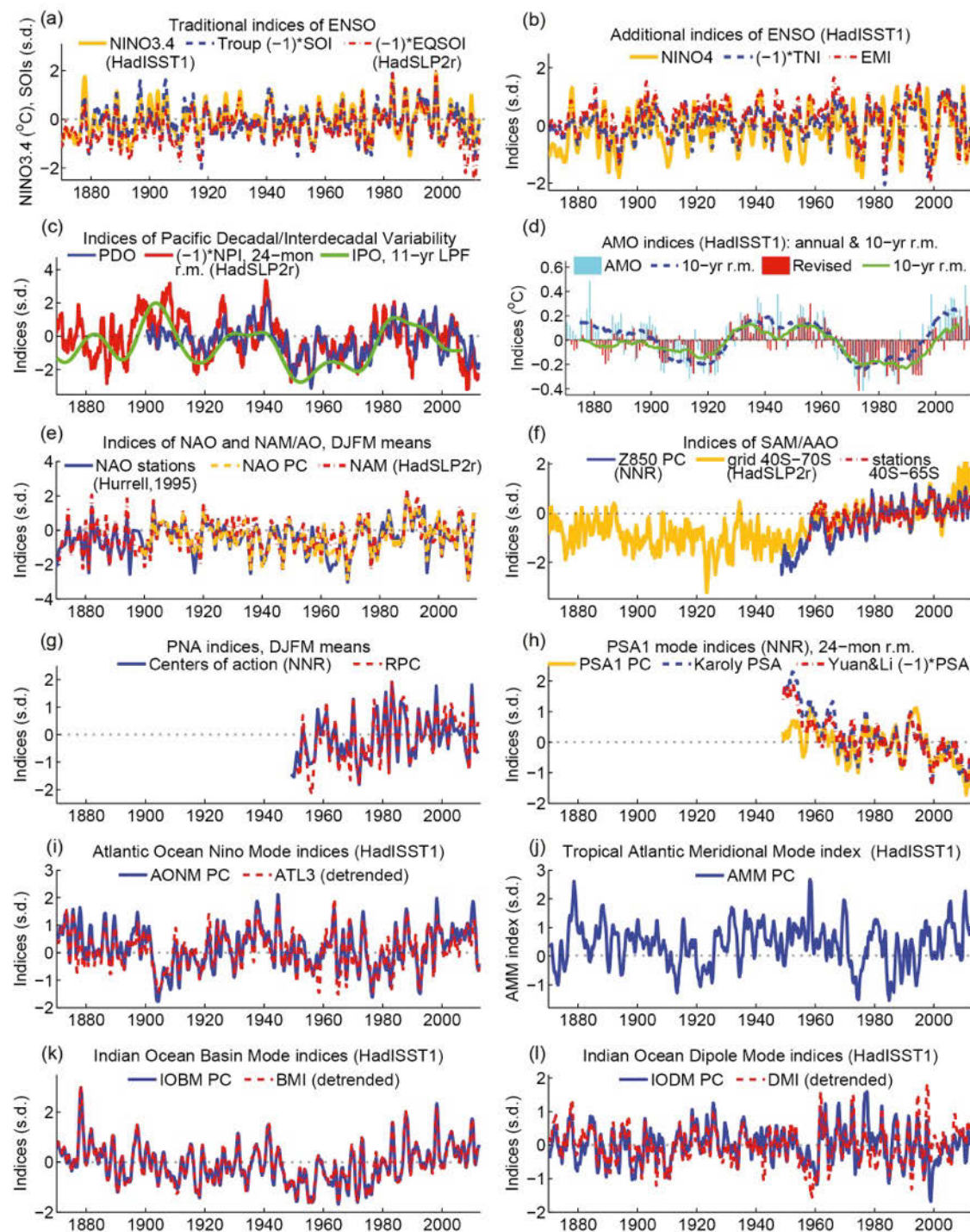


Fig Box 2.5-2, IPCC AR5 WG1

Modes of variability

Fig Box 2.5-2, IPCC AR5 WG1



Modes of variability and regional climate impacts

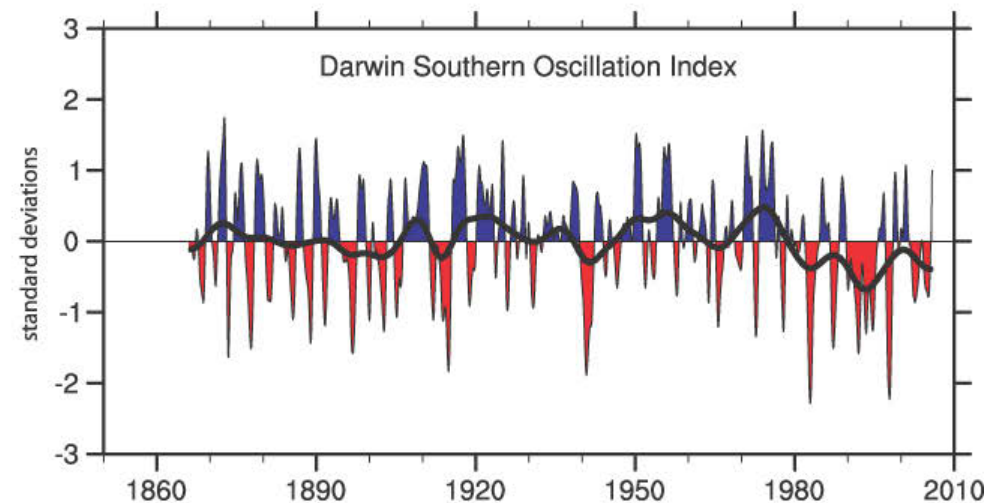
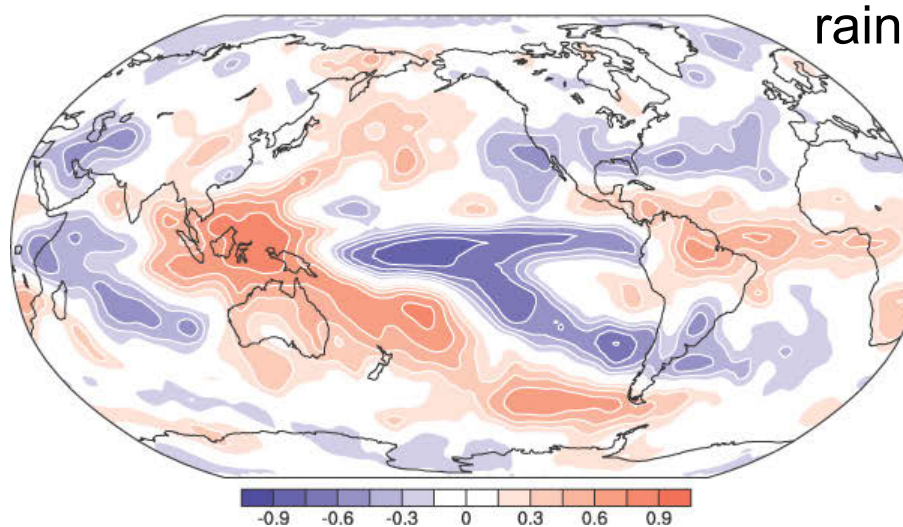
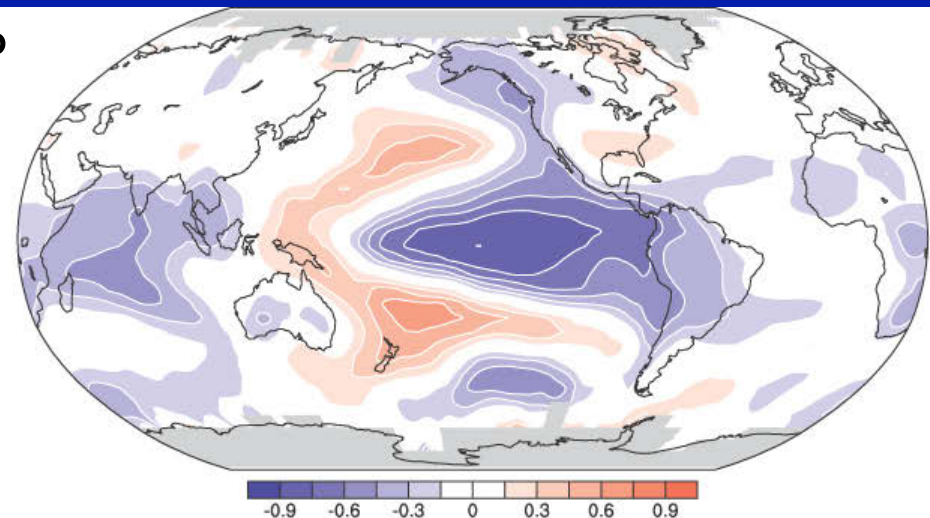
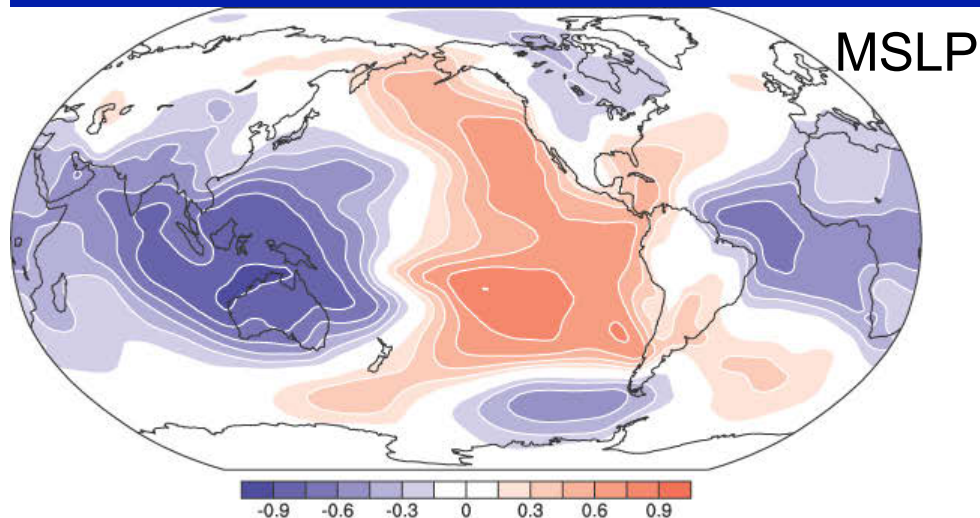
- The Climatedogs: the four drivers that influence Victoria (Australia) climate
<http://www.depi.vic.gov.au/agriculture-and-food/farm-management/weather-and-climate/understanding-weather-and-climate/the-climatedogs-the-four-drivers-that-influence-victoriaas-climate>
- The Pacific adventures of the climate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

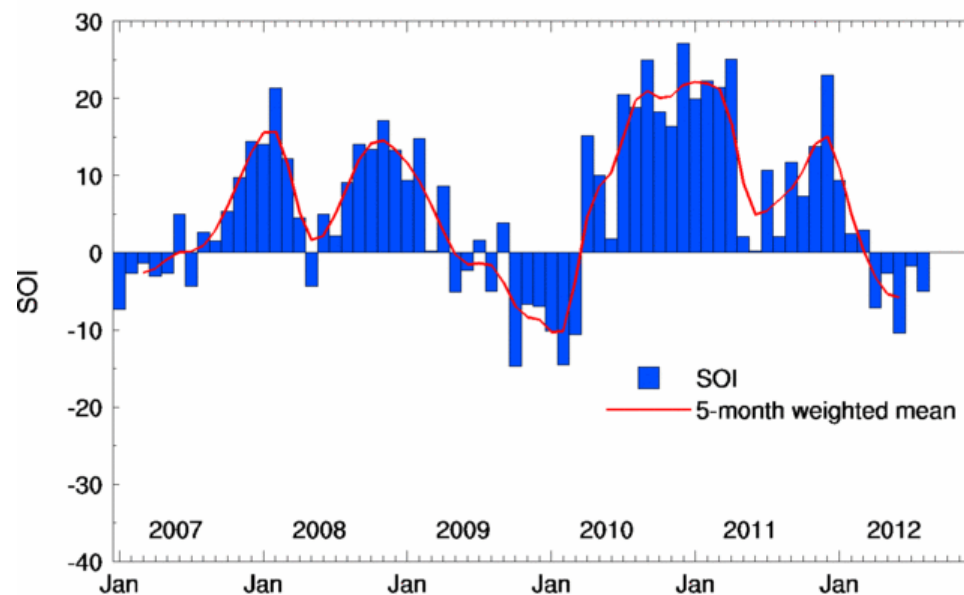
surface temperature



Australian floods Jan 2011

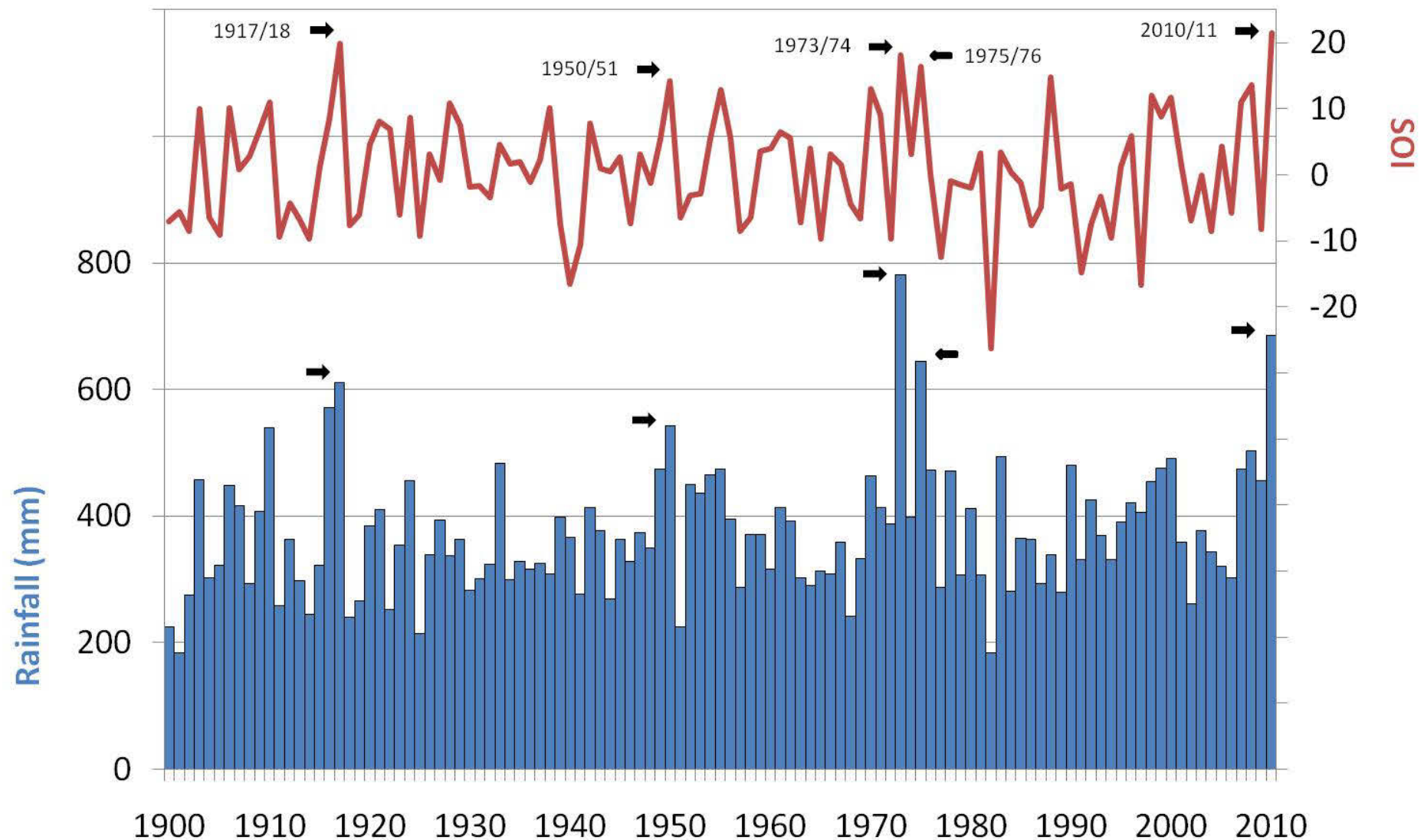


Southern Oscillation Index (SOI)



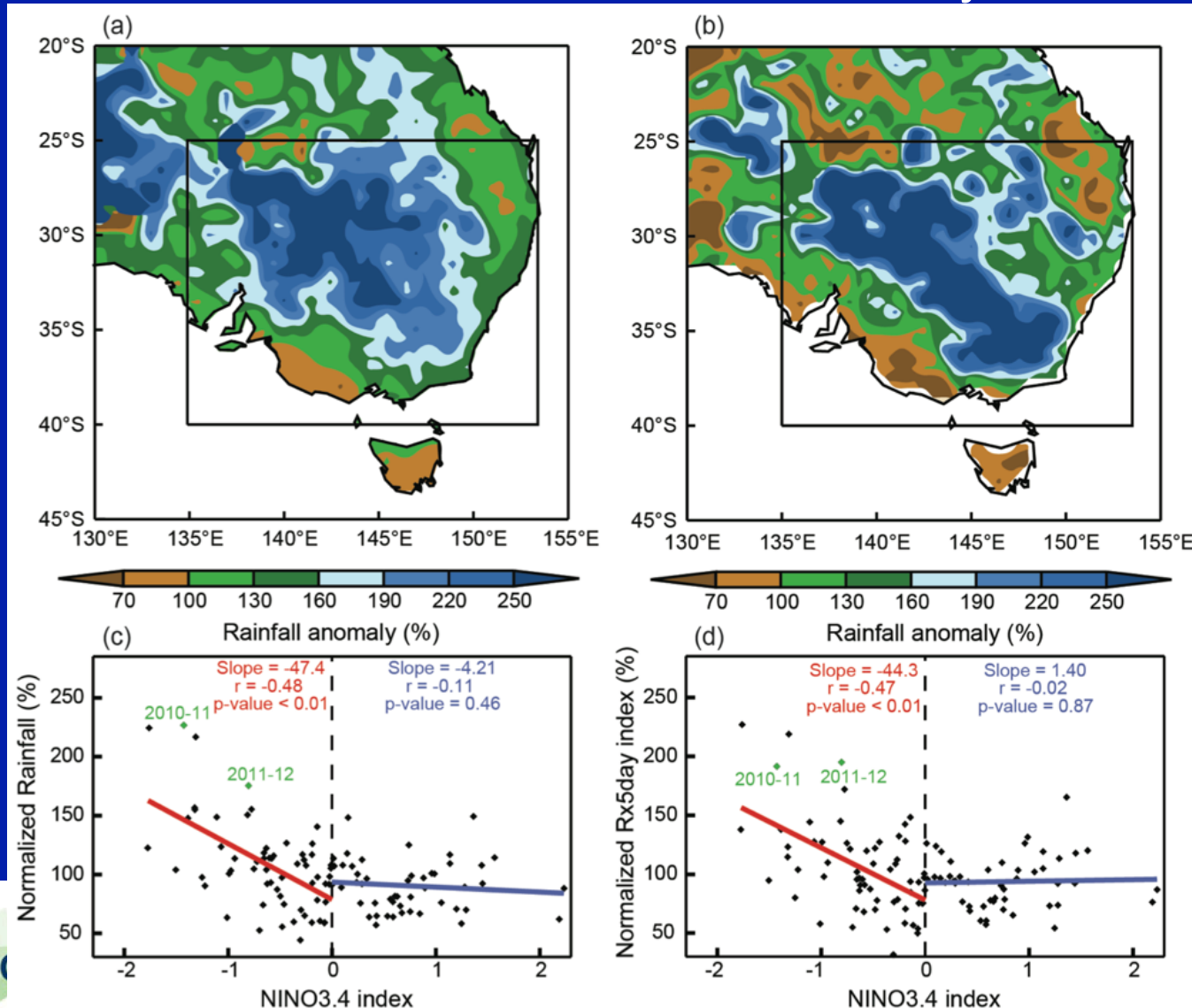
La Niña and eastern Australian rainfall

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

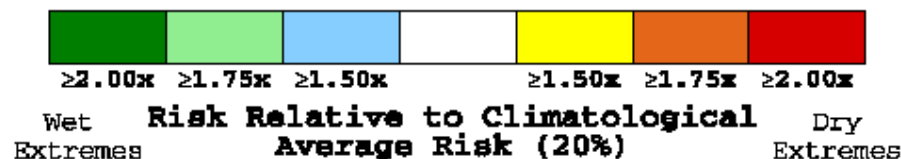
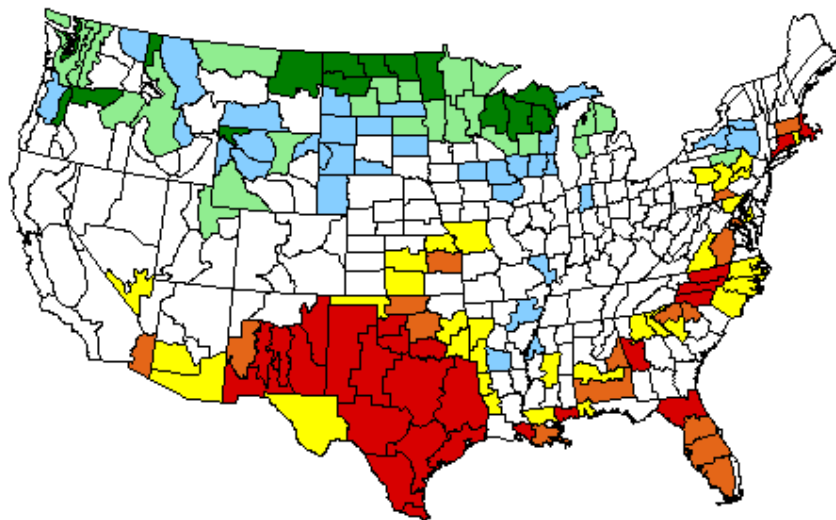
From King et al,
BAMS, 2013

THE UNIVERSITY OF
MELBOURNE

La Niña effects in the US

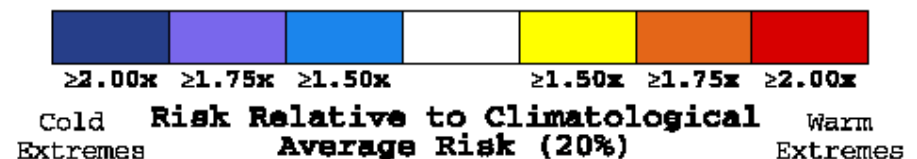
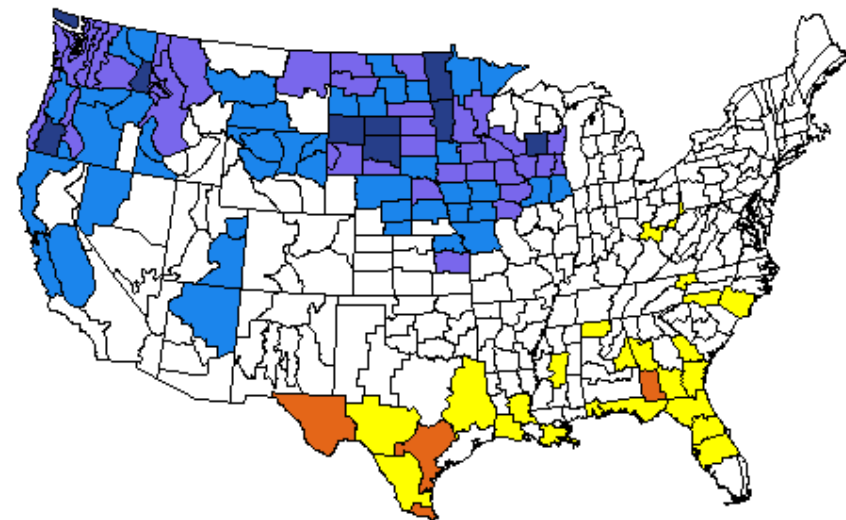
Changes in probability of extreme seasonal mean temperature and precipitation anomalies

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



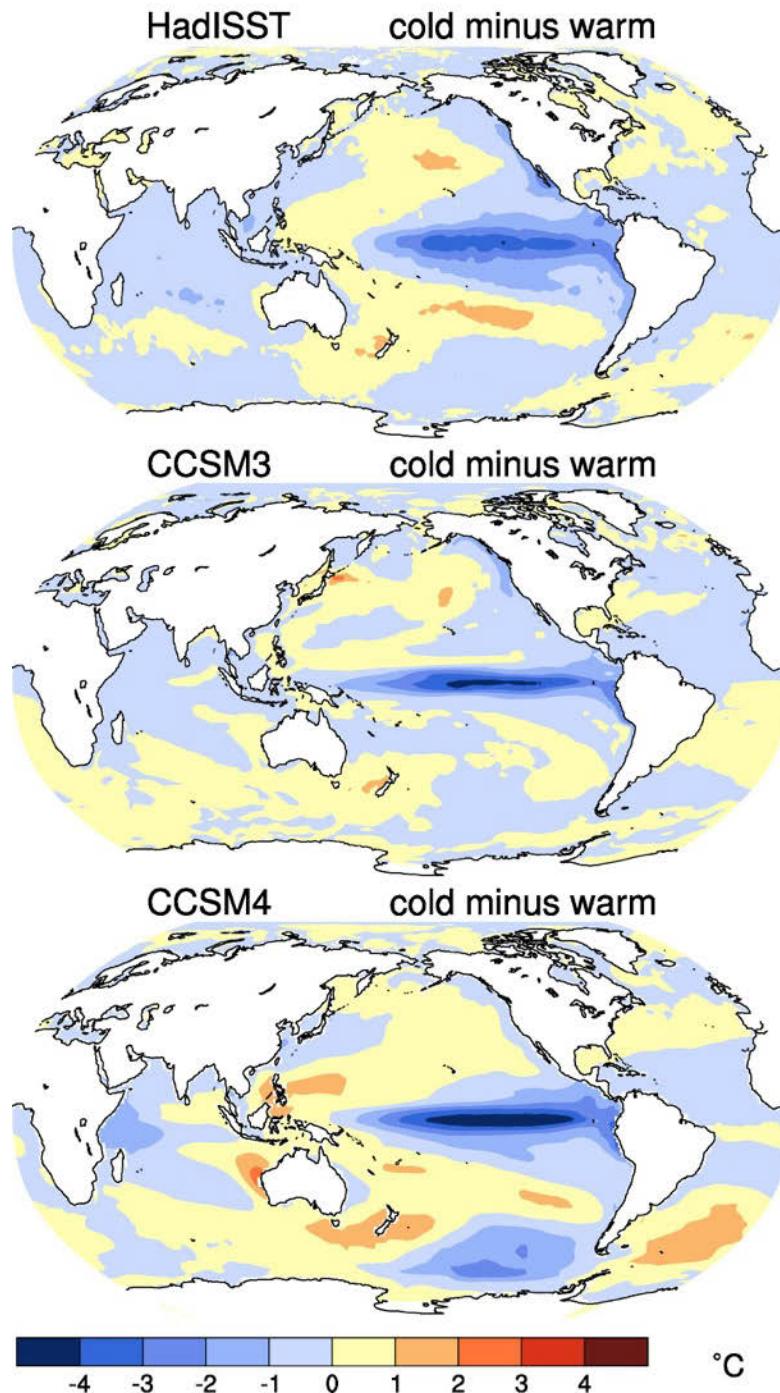
NOAA-CIRES/Climate Diagnostics Center

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



NOAA-CIRES/Climate Diagnostics Center

1950-1999 DJF composite of SST with Nino 3.4 events



La Niña SST anomalies from observations and model simulations

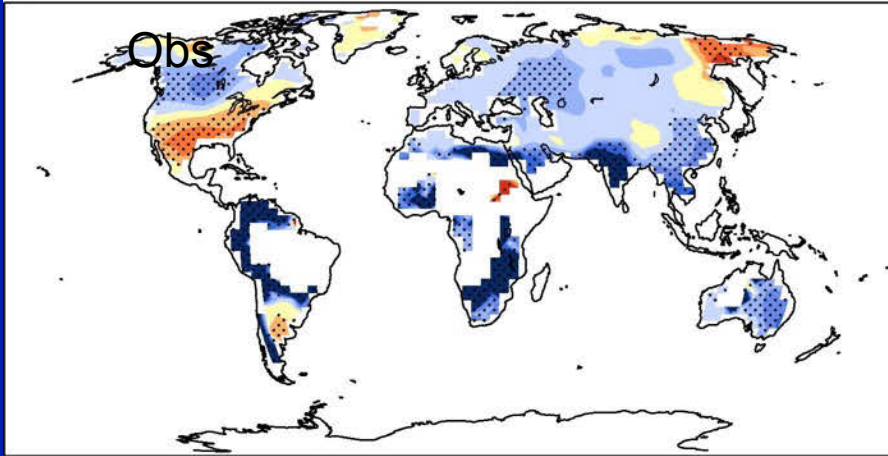
From Arblaster and Alexander,
GRL, 2012

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

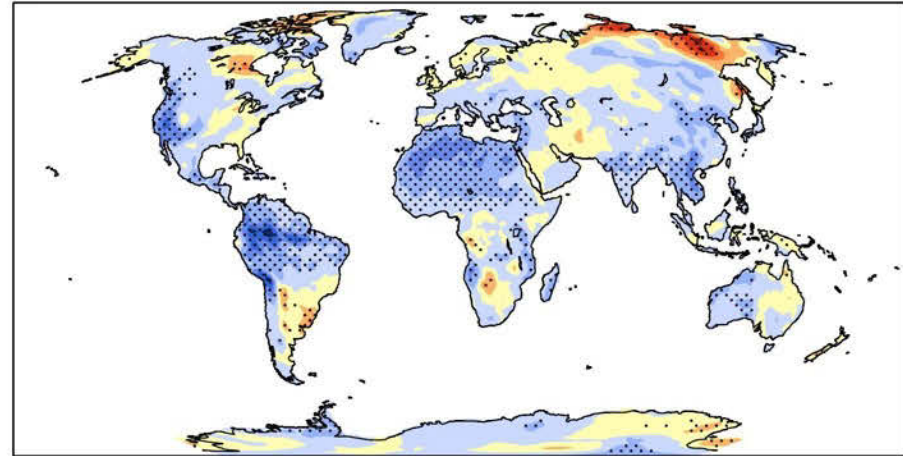
a) HadEX2 Obs

cold minus warm



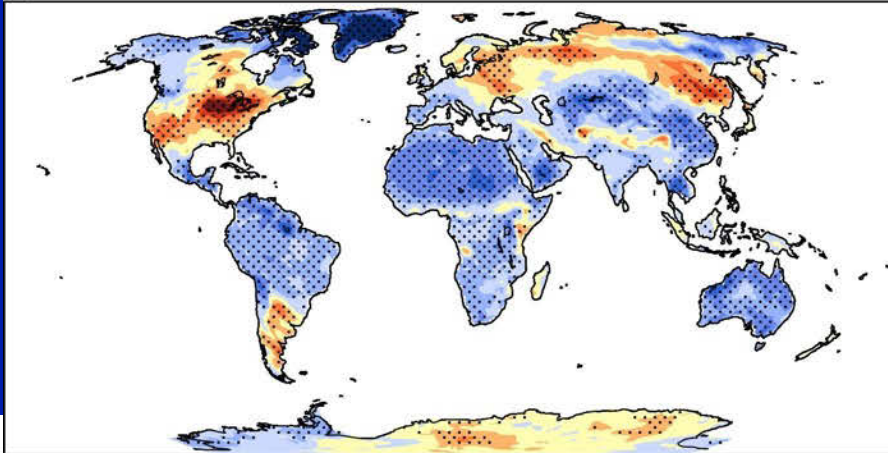
b) CCSM3 Historical

cold minus warm



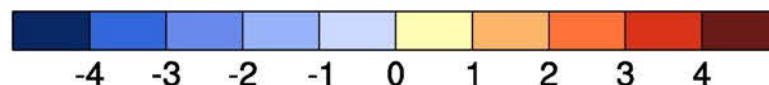
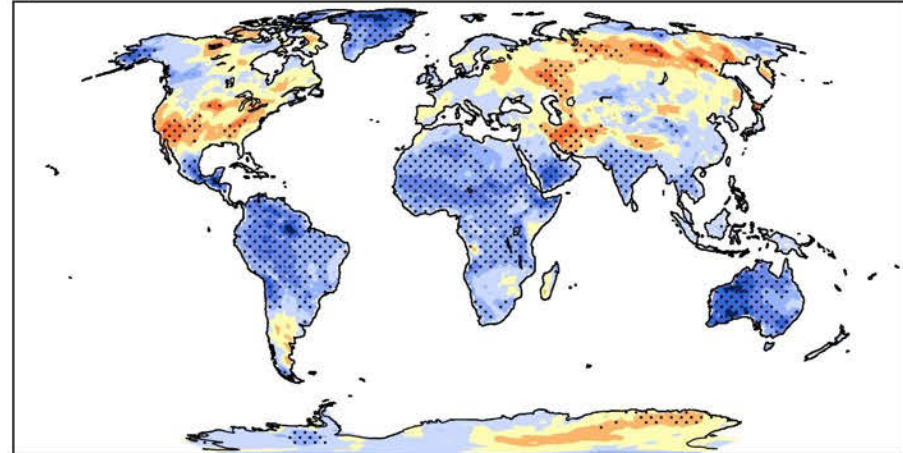
c) CCSM4 Historical

cold minus warm



d) CCSM4 RCP8.5 Future

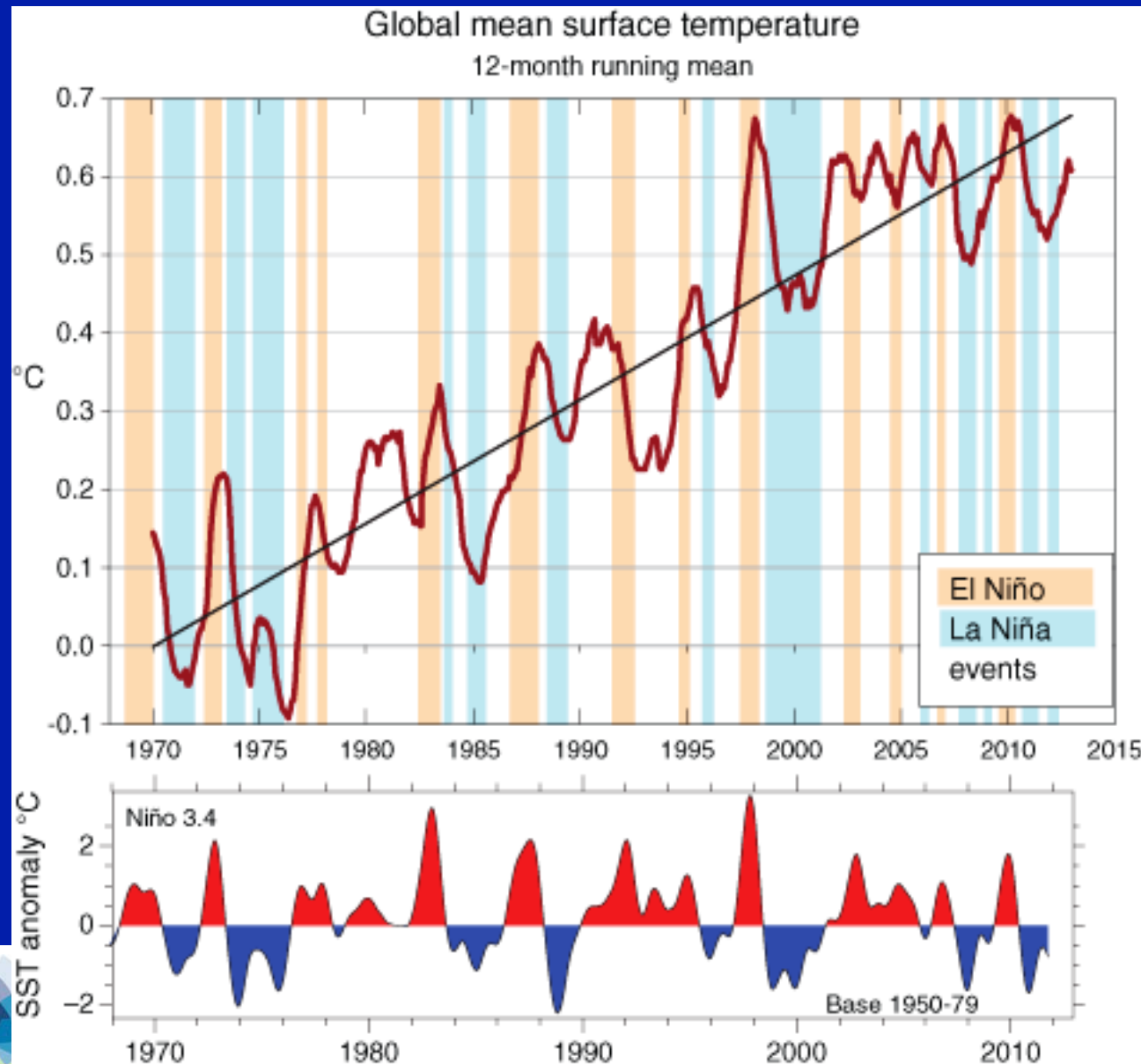
cold minus warm



°C

From Arblaster and Alexander, GRL 2012

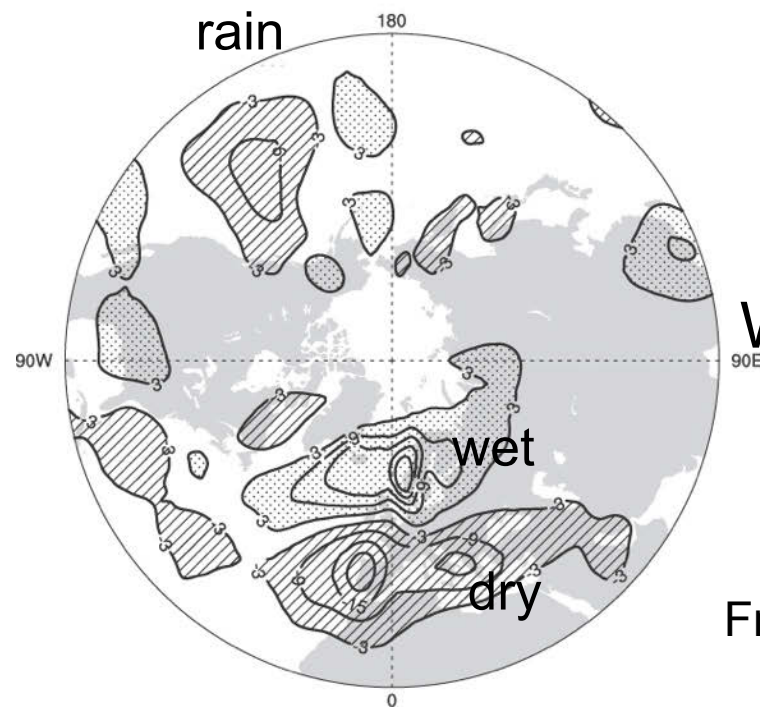
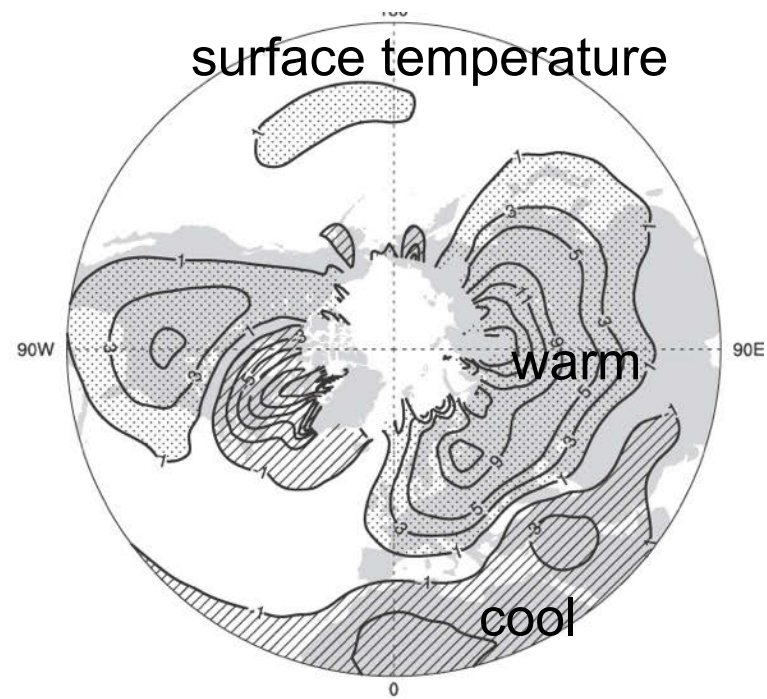
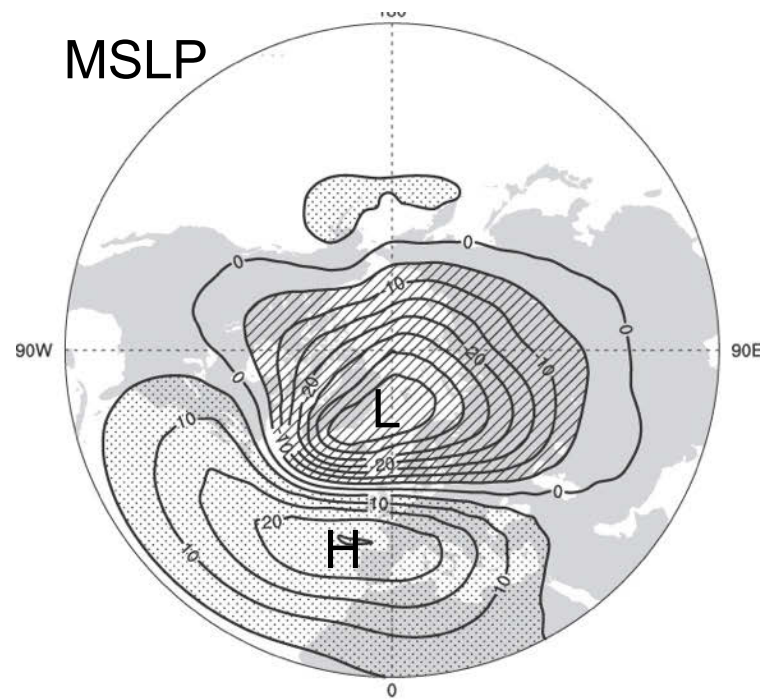
El Niño and global mean temperature



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



THE UNIVERSITY OF
MELBOURNE



North Atlantic Oscillation

Winter variations associated with unit deviation of the NAO index

From Fig 3.30, IPCC AR4 WGI

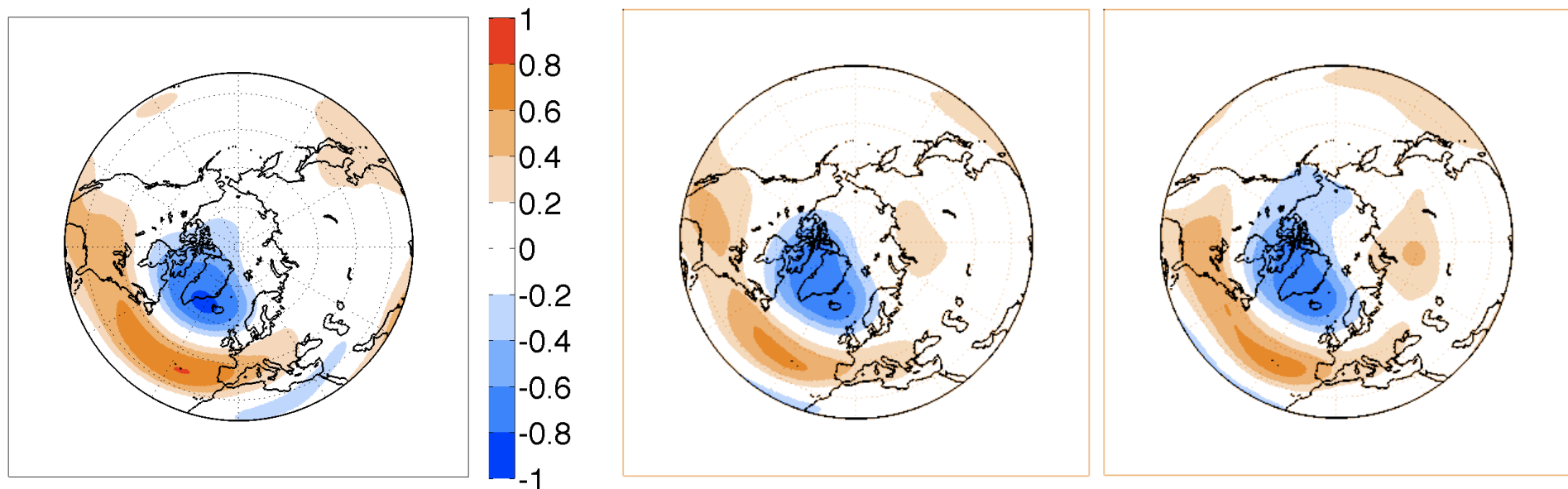
Observed and simulated NAO

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

CPC

CGCM3.1(T63)

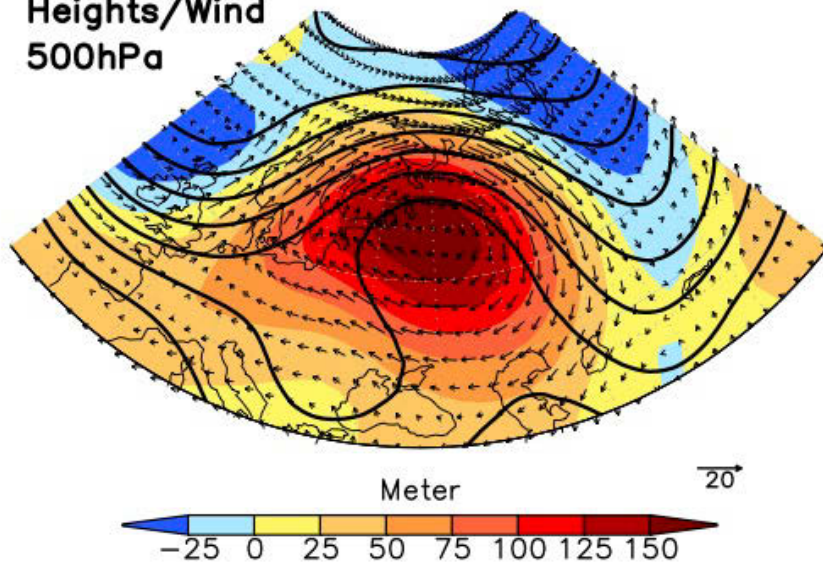
HadGEM1



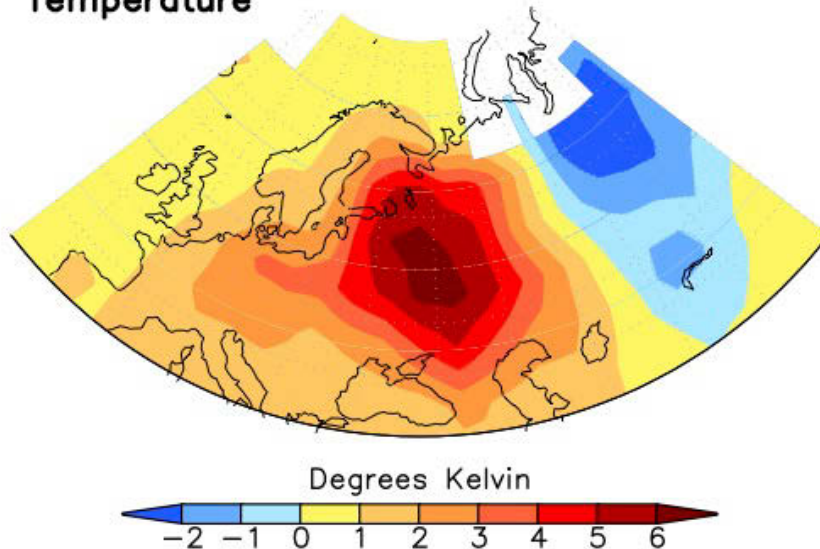
from Gonzalez-
Reviriego et al, 2010

Reanalysis/OBS 2010

Heights/Wind
500hPa



Temperature



2010 Russian heat wave

associated with blocking

Observed 500 hPa geopotential heights and winds

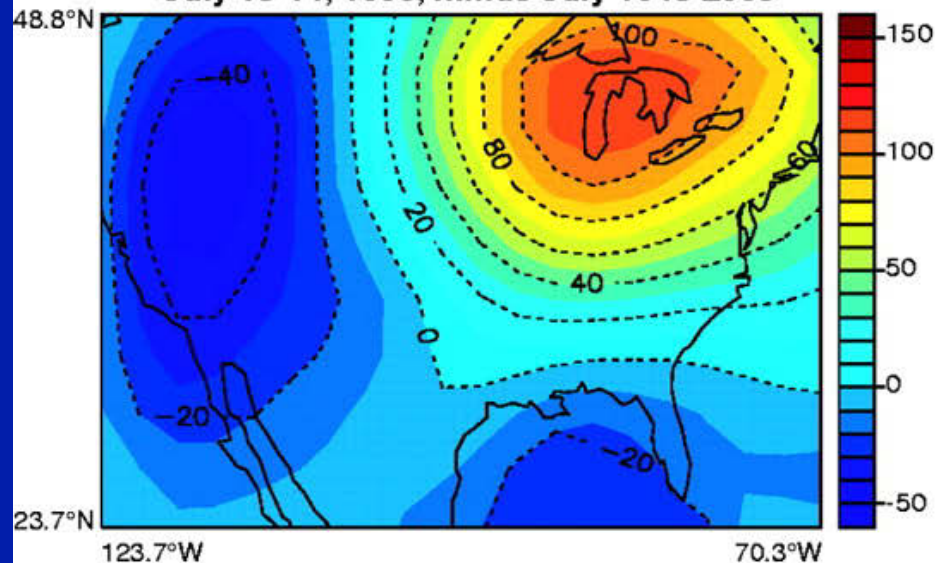
Observed temperature anomalies

From Judith Perlwitz

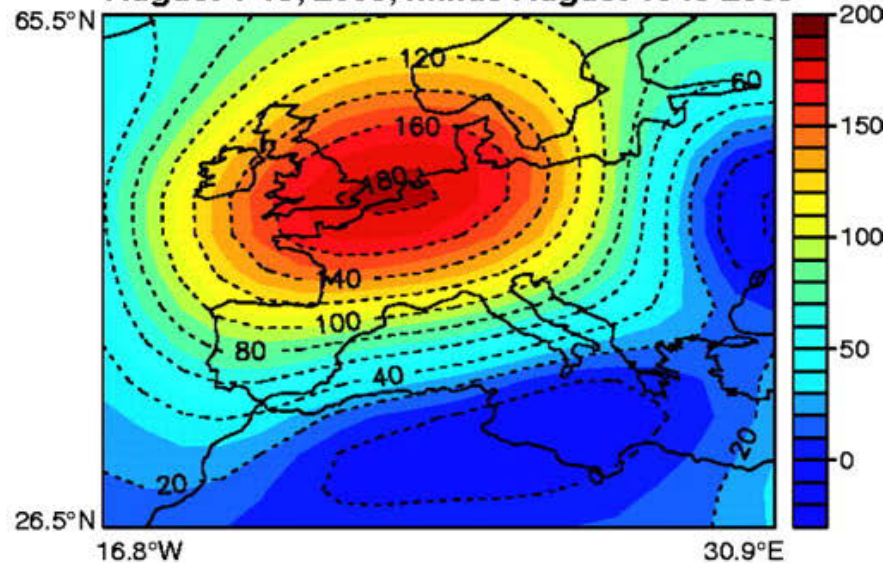


THE UNIVERSITY OF
MELBOURNE

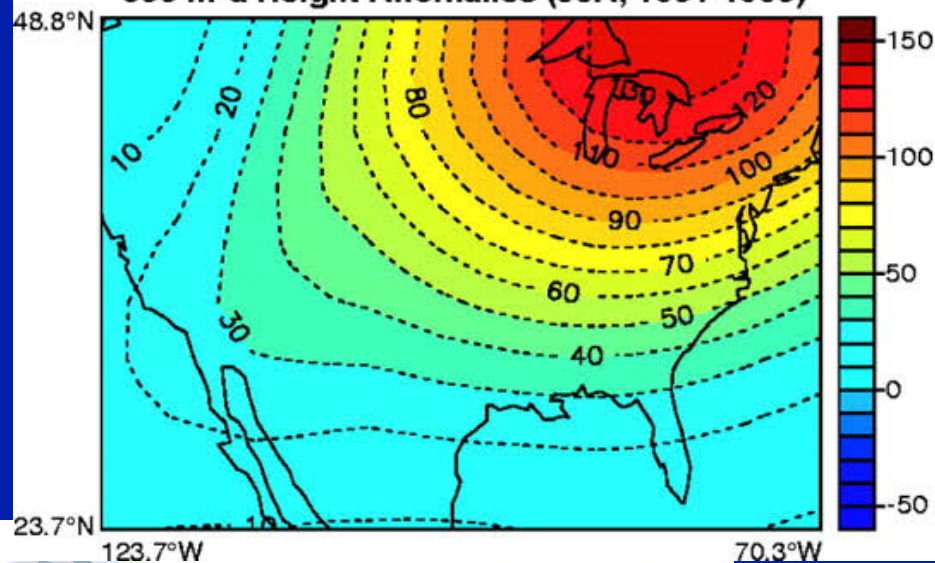
A Observed Heat Wave 500hPa Height Anomalies
July 13-14, 1995, minus July 1948-2003



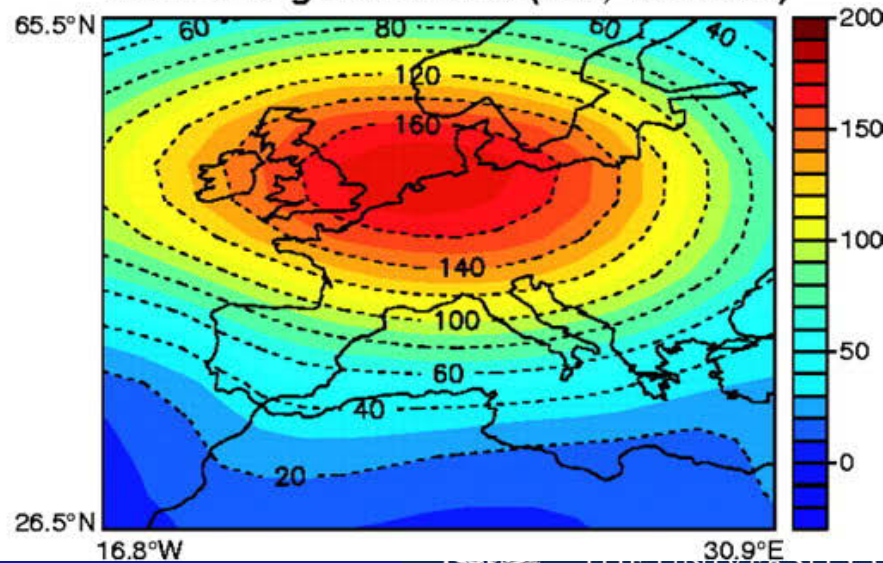
B Observed Heat Wave 500hPa Height Anomalies
August 1-13, 2003, minus August 1948-2003



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



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



ARC CENTRE OF EXCELLENCE FOR
CLIMATE SYSTEM SCIENCE

from Meehl et al 2004

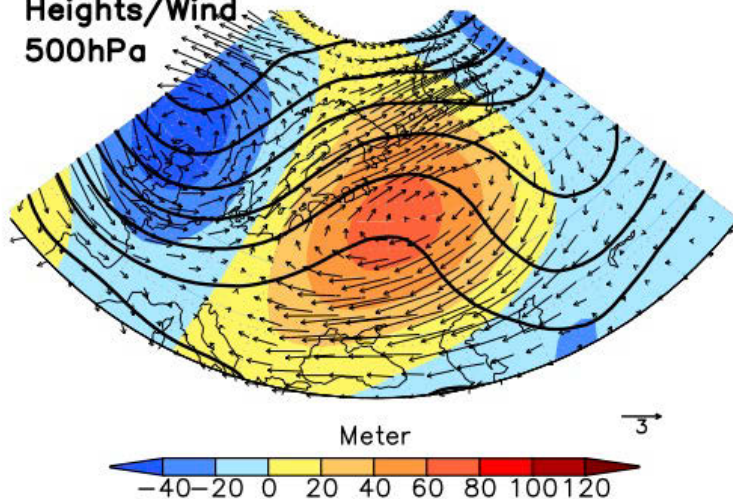


THE UNIVERSITY OF
MELBOURNE

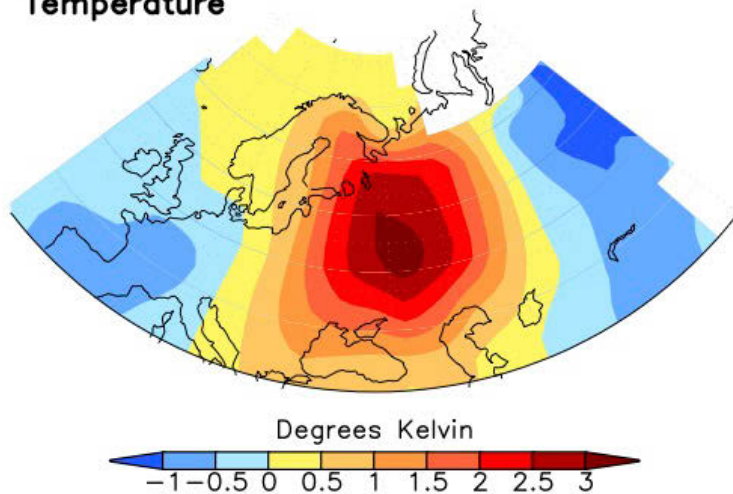
Observed and simulated events

Reanalysis/OBS
Top 10 events

Heights/Wind
500hPa

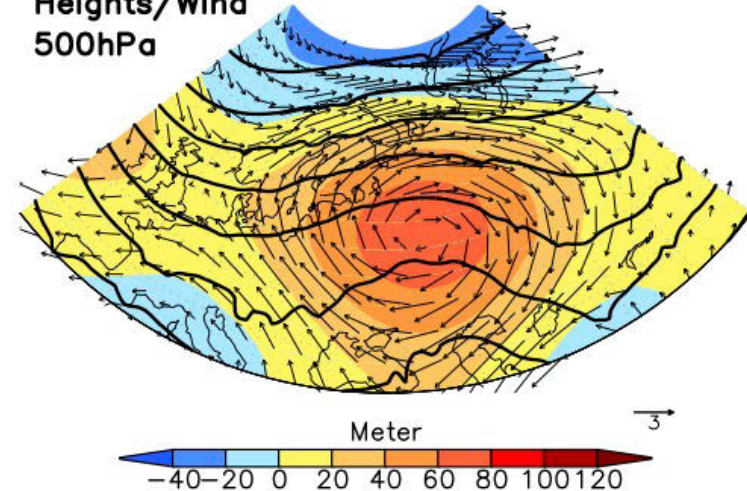


Temperature

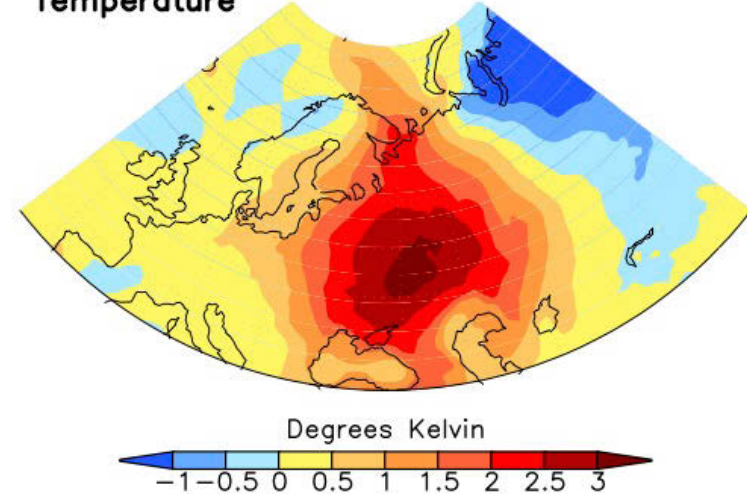


CCSM4 1900–1999
Top 10% >1.7K

Heights/Wind
500hPa



Temperature



From J Perlwitz

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