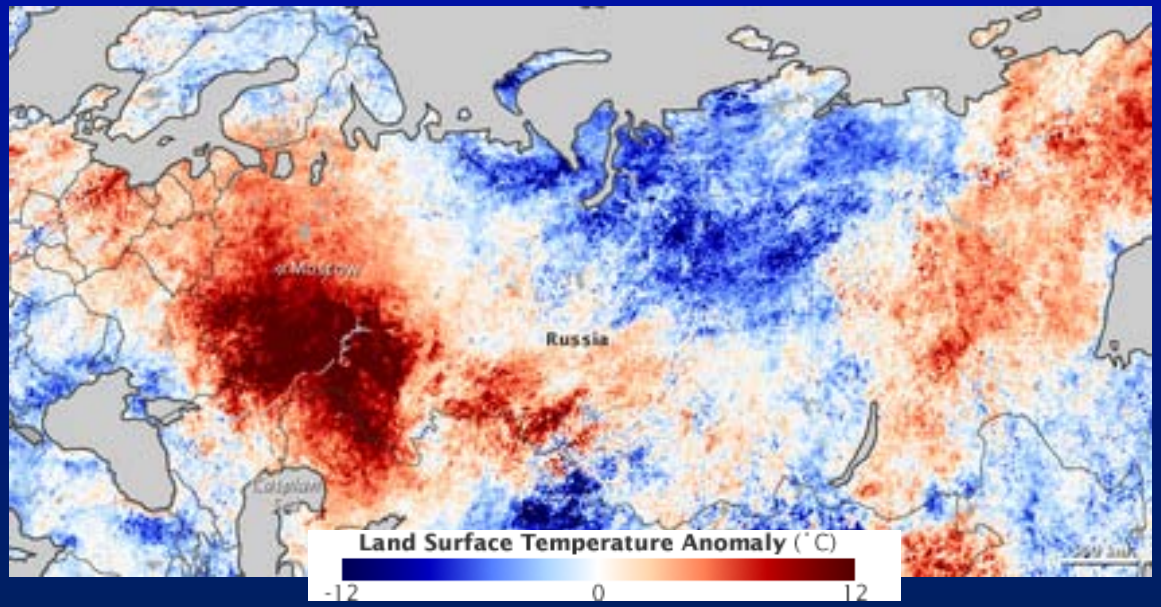
The Russian Heat Wave and other recent climate extremes

Kevin E Trenberth
NCAR

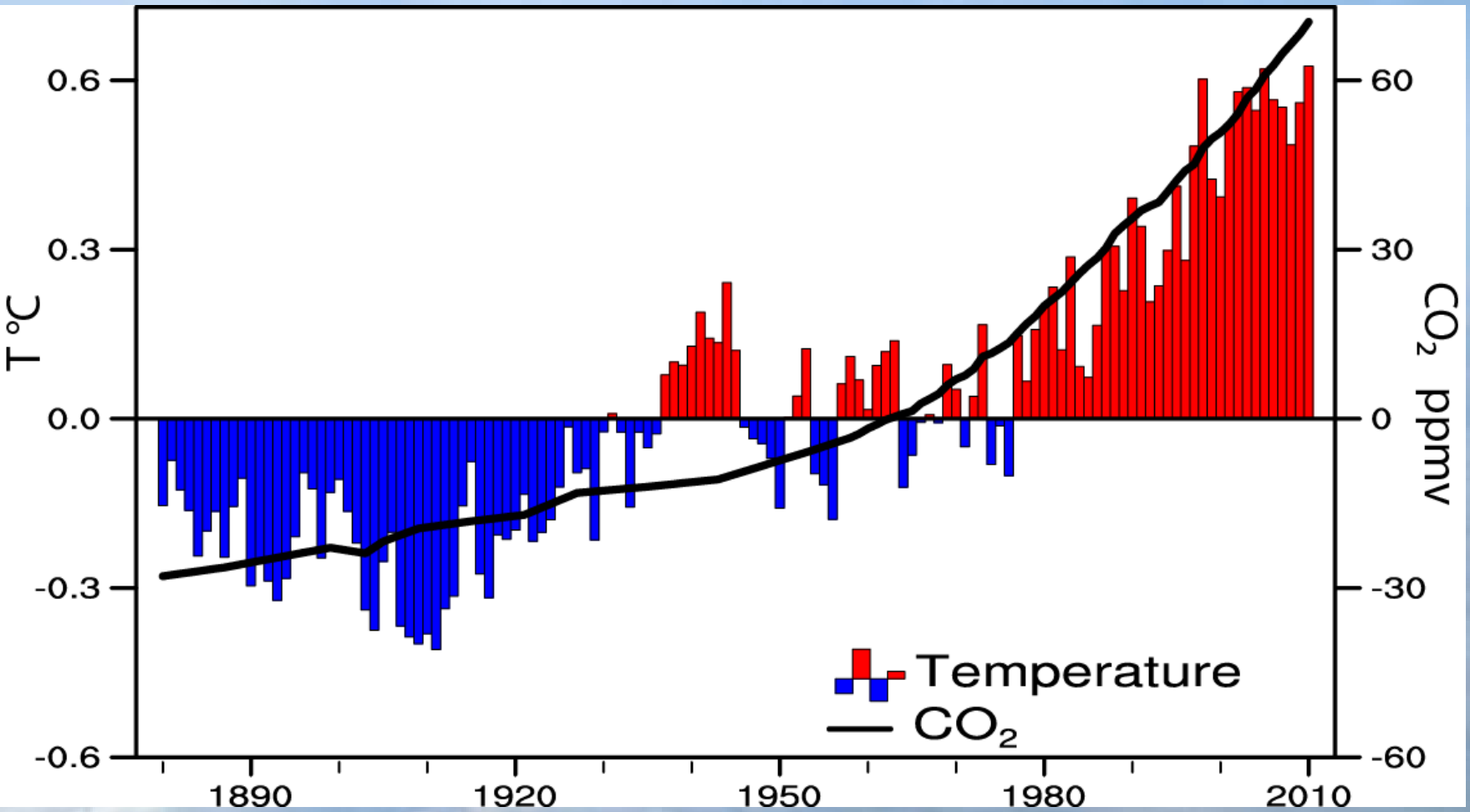


"Everybody talks about the weather, but nobody does anything about it."
— Attributed to Mark Twain, 1890s

"Now humans are doing something about the weather: global warming is contributing to an increased incidence of extreme weather because the environment in which all storms form has changed from human activities."

Kevin Trenberth
USA Today 3 June.

Global temperature and carbon dioxide: anomalies through 2010



Base period 1900-99; data from NOAA

Running a fever: Seeing the doctor

- **Symptoms**: the planet's temperature and carbon dioxide are increasing
- **Diagnosis**: human activities are causal
- **Prognosis**: the outlook is for more warming at rates that can be disruptive and will cause strife
- **Treatment**: mitigation (reduce emissions) and adaptation (planning for consequences)

Attribution wrt storms

Global warming is "**unequivocal**" and "**very likely**" caused by human activities (IPCC 2007).
So shouldn't the null hypothesis be that there is a human influence?

2 Effects:

1) **Direct radiative forcing**
   - 1-2% effect instantaneously
2) Effects of **cumulative past radiative forcing** such as increased ocean temperatures and ice melt.
   - 5-10% effect…

The environment in which all storms form has changed owing to human activities.

Global warming has increased temperatures, and directly related to that, is an increase in the water holding of the atmosphere.

Over the ocean, where there are no water limitations, observations confirm that the amount of water vapor in the atmosphere has increased by about 4%, consistent with a 0.55°C warming of sea surface temperatures (SSTs) since about the 1970s.

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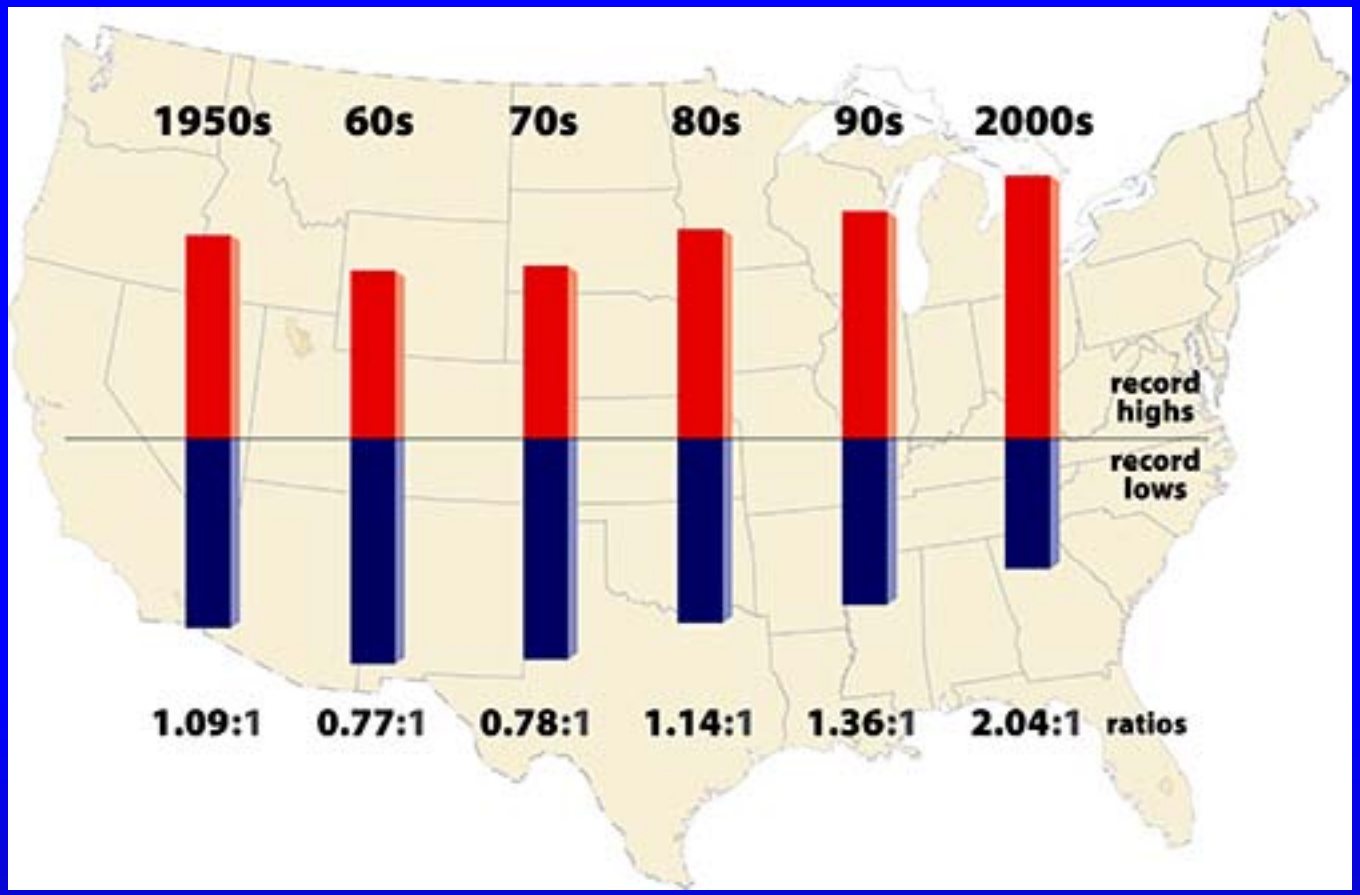
Climate change and extreme weather events

Changes in extremes matter most for society and human health

With a warming climate:

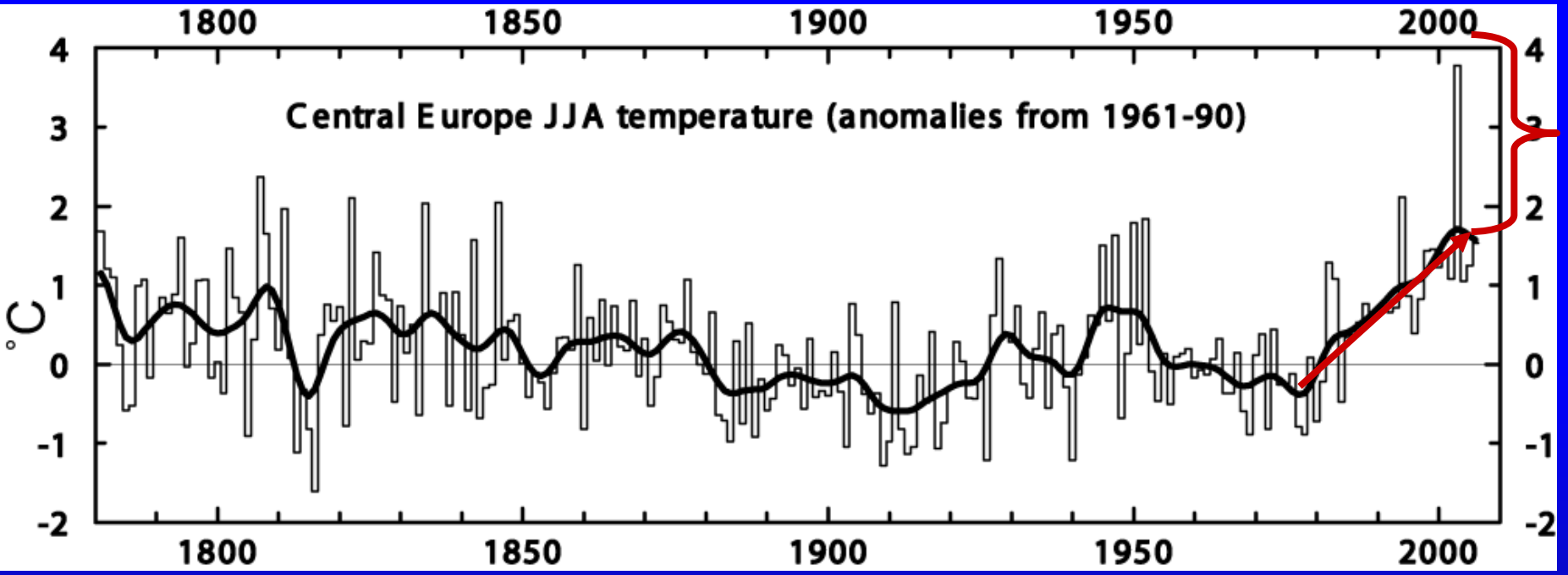
- More high temperatures, heat waves
- Wild fires and other consequences
- Fewer cold extremes.

- More extremes in hydrological cycle:
  - Drought
  - Heavy rains, floods
  - Intense storms, hurricanes, tornadoes



The ratio of record daily highs to record daily lows observed at about 1,800 weather stations in the 48 contiguous United States from January 1950 through September 2009.
Each bar shows the proportion of record highs (red) to record lows (blue) for each decade. The 1960s and 1970s saw slightly more record daily lows than highs, but in the last 30 years record highs have increasingly predominated, with the ratio now about two-to-one for the 48 states as a whole. Meehl et al. GRL 2009

Heat waves are increasing: an example

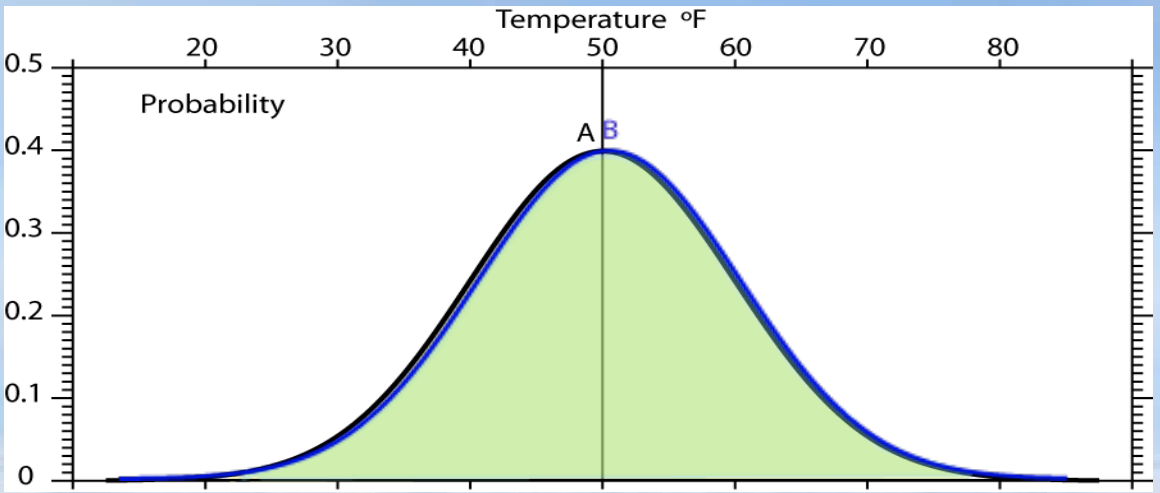


Extreme Heat Wave
Summer 2003
Europe
>50,000 deaths

Trend plus variability?

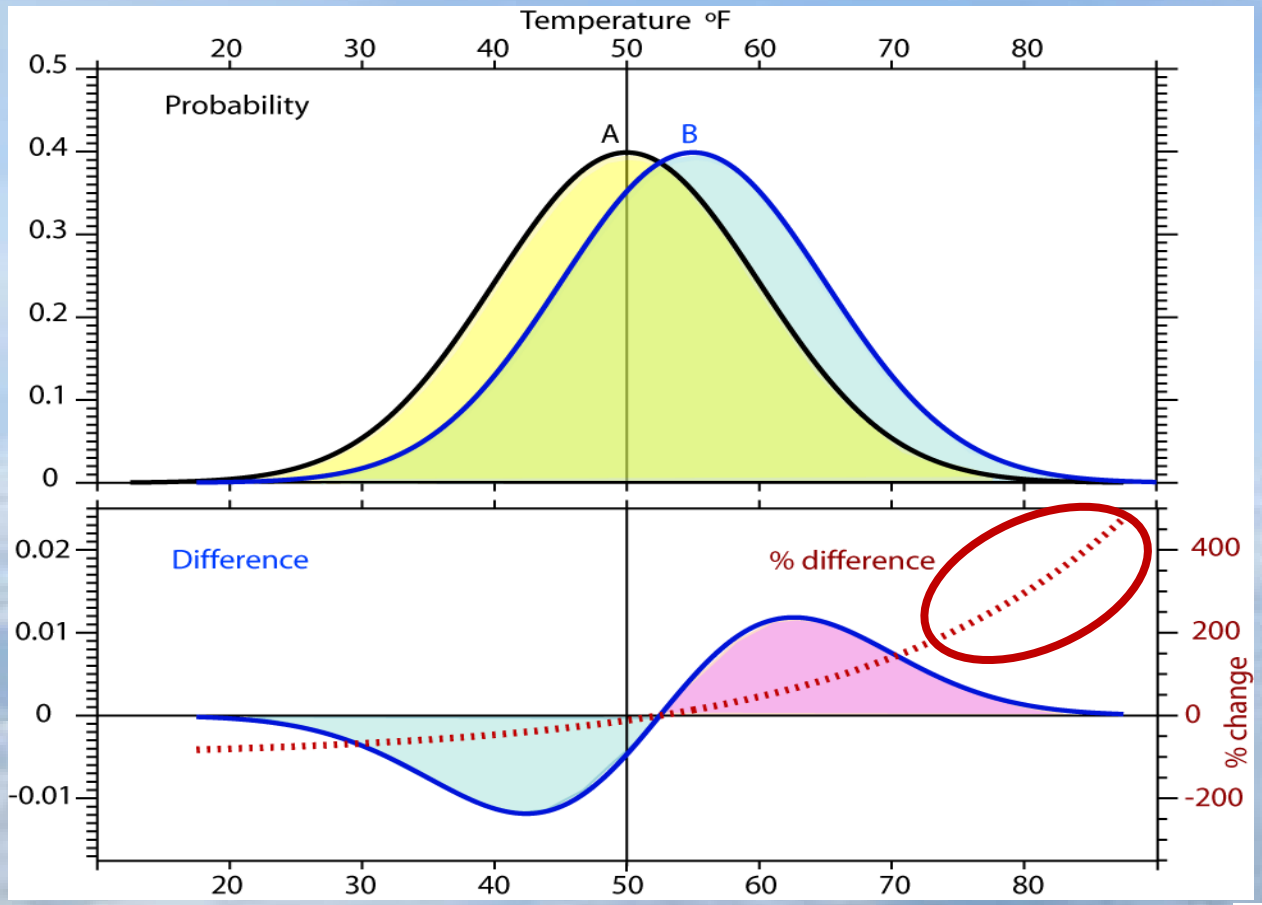
IPCC

Reason for focus on extremes



Mean A: 50°F, s.d. 10°F

Reason for focus on extremes



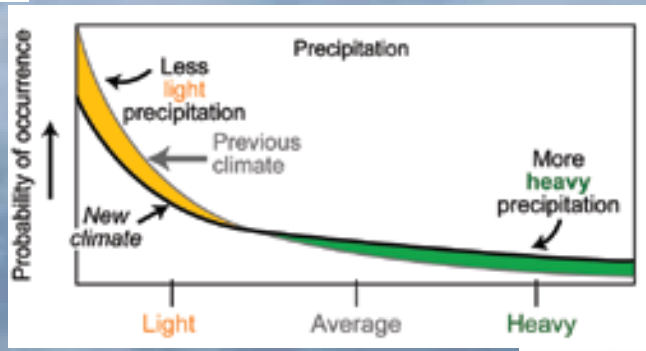
Shift in climate: from A to B

Most of time the values are the same (green).

Biggest changes in extremes: >200%

Mean A: 50°F, s.d. 10°F

Mean B: 55°F, s.d. 10°F



Human impacts on climate related to water

- Warming: more heat, higher temperatures
- The atmosphere can hold more water vapor
  - 4% per °F (7% per °C)
- Over wet areas (ocean) => more moisture

- More heat => more evaporation => more precipitation
- Longer dry spells, more drought (where not raining)

- More intense rains/snows
- More intense storms

- More rain instead of snow
- Accelerating snow melt, less snow pack in spring
- Earlier runoff, peak stream flow

More floods and droughts

Global warming: Controlling Heat

The presence of moisture affects the disposition of incoming solar radiation:

Evaporation (drying) versus temperature increase.

Human body: sweats

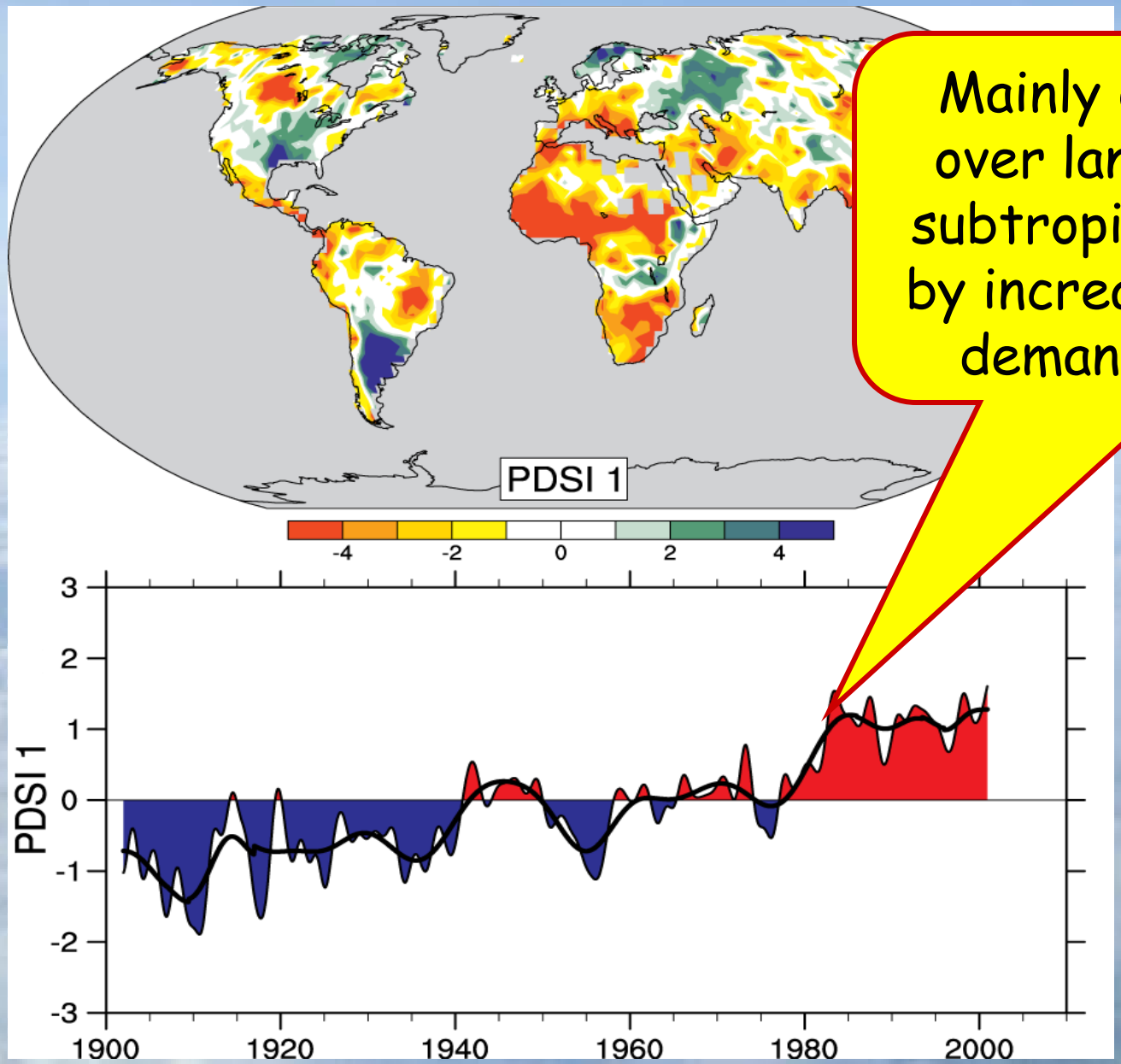
Homes: Evaporative coolers (swamp coolers)

Planet Earth: Evaporation (if moisture available)

e.g., When sun comes out after showers,

the first thing that happens is that the puddles dry up: before temperature increases.

Drought is increasing most places



Mainly decrease in rain over land in tropics and subtropics, but enhanced by increased atmospheric demand with warming

Severity Index (PDSI) for 1900 to 2002.

The time series (below) accounts for most of the trend in PDSI.

Dai et al 2004
IPCC 2007

Precipitation

How should precipitation change as climate changes?

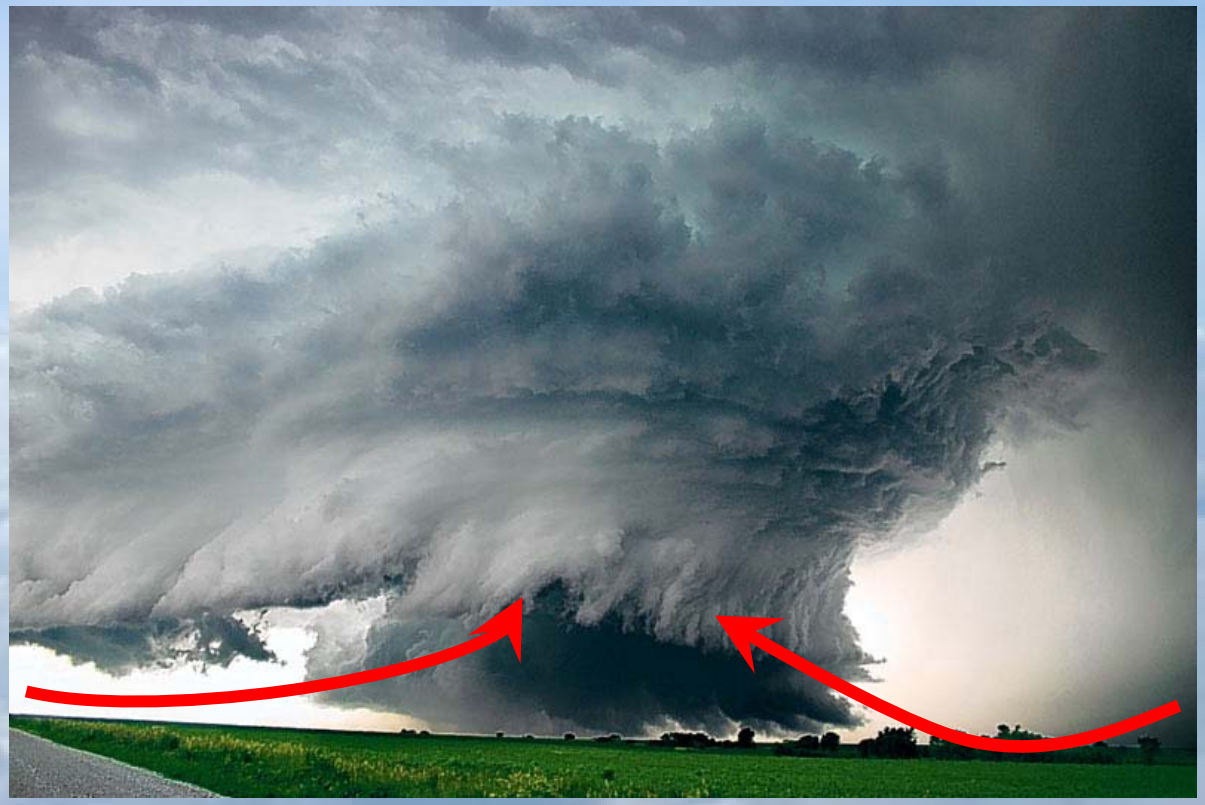
Usually only total **amount** is considered

- But most of the time it does not rain
- The **frequency and duration** (how often)
- The **intensity** (the rate when it does rain)
- The **sequence**
- The **phase**: snow or rain

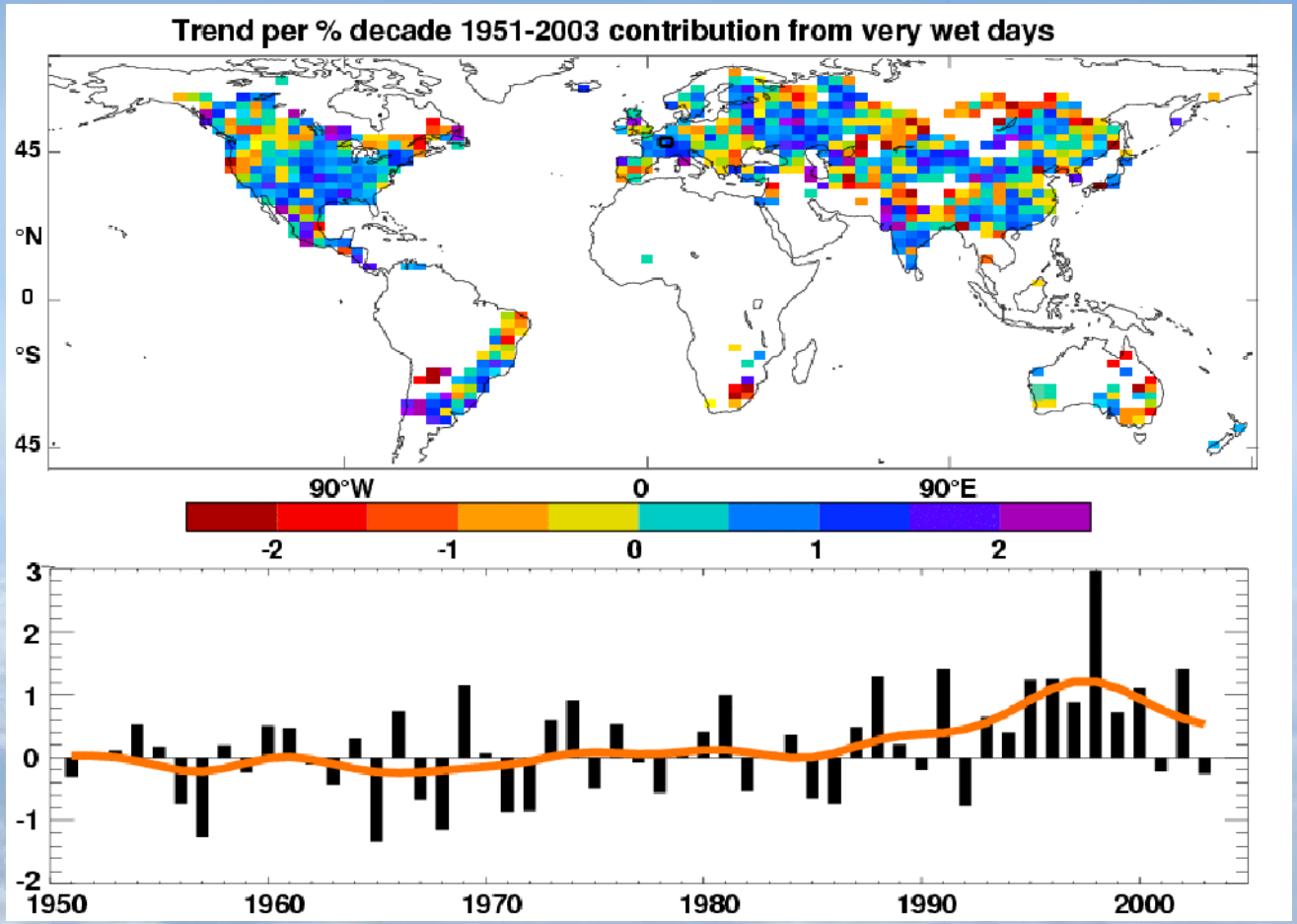
The intensity and phase affect how much runs off versus how much soaks into the soils.

Most precipitation comes from moisture convergence by weather systems

Rain comes from moisture convergence by low level winds:



More moisture means heavier rains



Precipitation

Observed trends (%) per decade for 1951-2003 contribution to total annual from **very wet days** > 95th %ile.

Alexander et al 2006
IPCC AR4

Heavy precipitation days are increasing even in places where precipitation is decreasing.

Some extremes in 2010 of concern

1. The flooding in Pakistan (August) and related earlier flooding in China and India (July)
2. The Russian drought, heat wave and wild fires (which is an event physically related to the Asian flooding via a monsoon circulation and teleconnections)
3. The flooding events in the US, notably the nor-easters in February-March and the "Snowmageddon" record breaking snows in Washington, Philadelphia and Baltimore.
4. Intense heavy rains in Nashville in May (over 20 inches in 2 days)
5. Wettest September ever in Australia, flooding since
6. The strong Atlantic hurricane season (19 named storms second after 2005 and tied with 1995 since 1944 when surveillance aircraft began monitoring, and 12 hurricanes). Only one storm made landfall in the US but 3 made landfall in Mexico and hurricane Karl caused extensive flooding in Mexico and Texas. Moisture from Hurricane Karl brought flooding rains to parts of southwest Wisconsin, southern Minnesota, and southeast South Dakota and contributed to Minnesota's wettest September in the 1895-2010 record.

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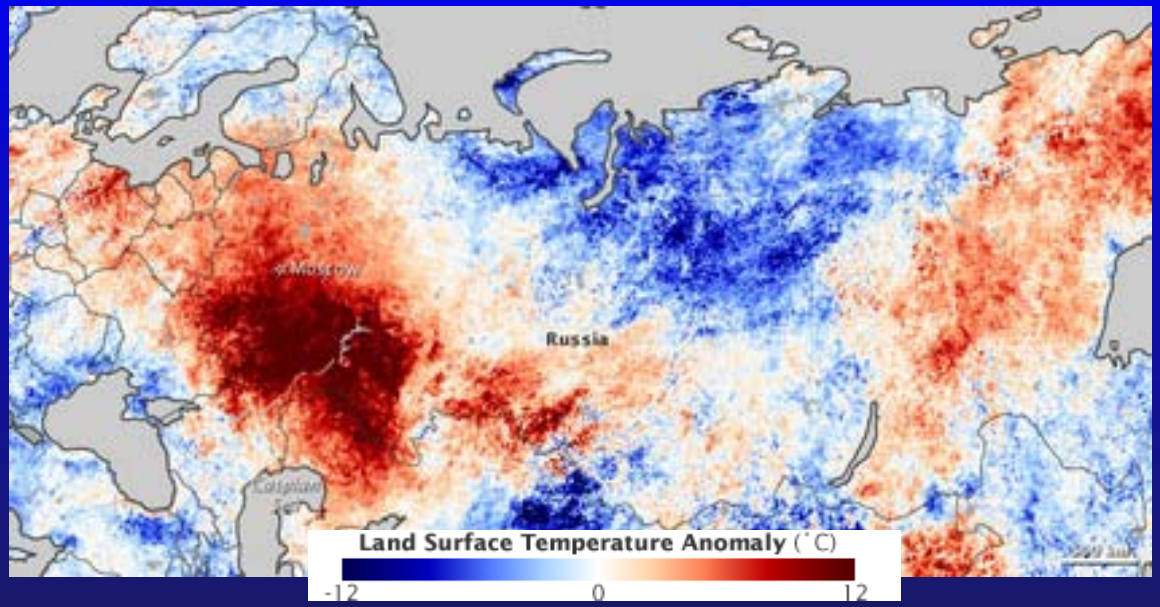
The Russian heat wave and wild fires of summer of 2010

- Hottest recorded summer in Russian history
- 56,000 deaths from smog and heat (Munich Re)
- US$15 billion in damages
- 2000 building destroyed
- Major crop failures, esp. wheat
- Russian regions (Eurasian Sakha Republic, as well as areas of partial taiga), had temperatures of 38–40 °C (100–104 °F)



http://en.wikipedia.org/wiki/2010_Russian_wildfires

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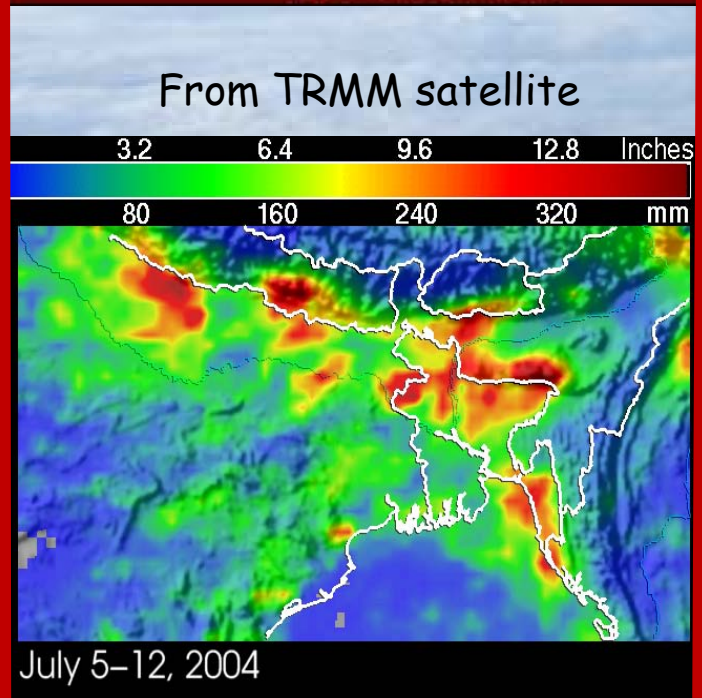
Russian heat wave attribution

Train of causation /evidence

There is a climate event, with observational evidence:

1) Record high temperatures in Russia, heat waves, wild fires, over a month
2) High SSTs in tropical Indian Ocean, western Pacific
3) Arctic sea ice loss: near record low
4) High precipitation, flooding in Pakistan, India, China: SE Asia
   - Distribution linked to La Nina

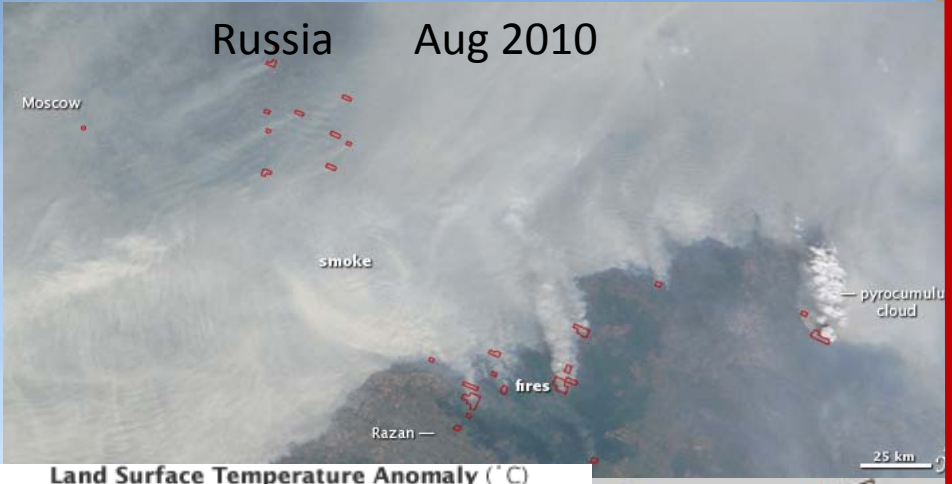
Jul-Aug 2010 India

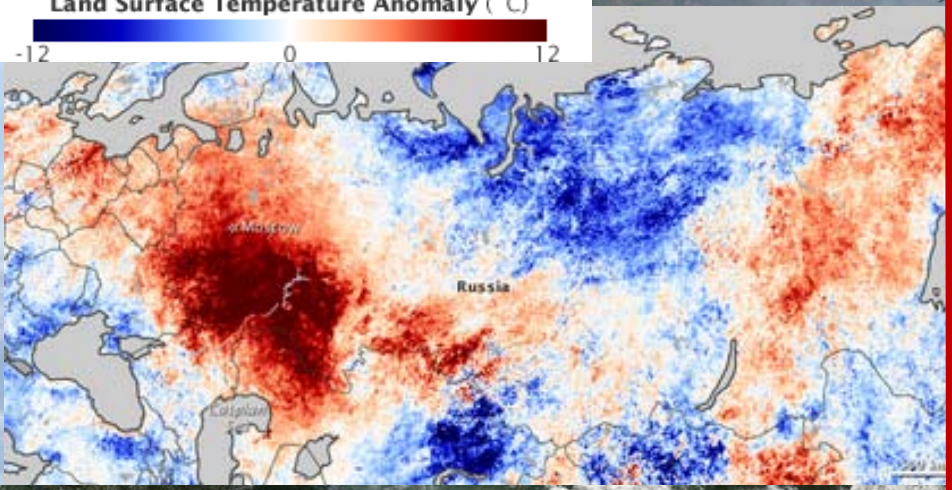


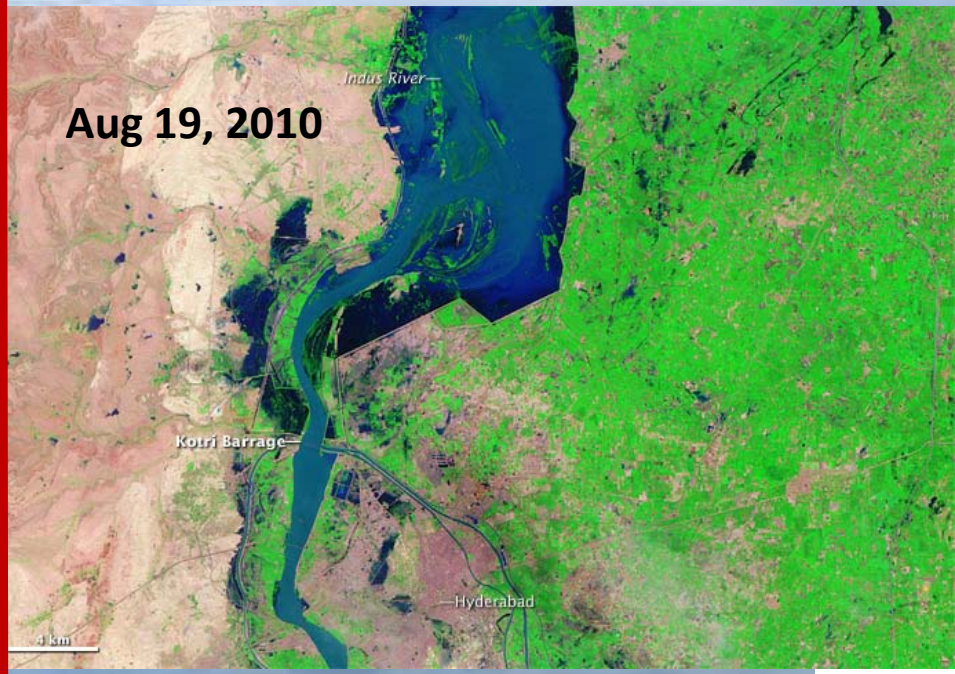
Aug 2010 Pakistan

Russia

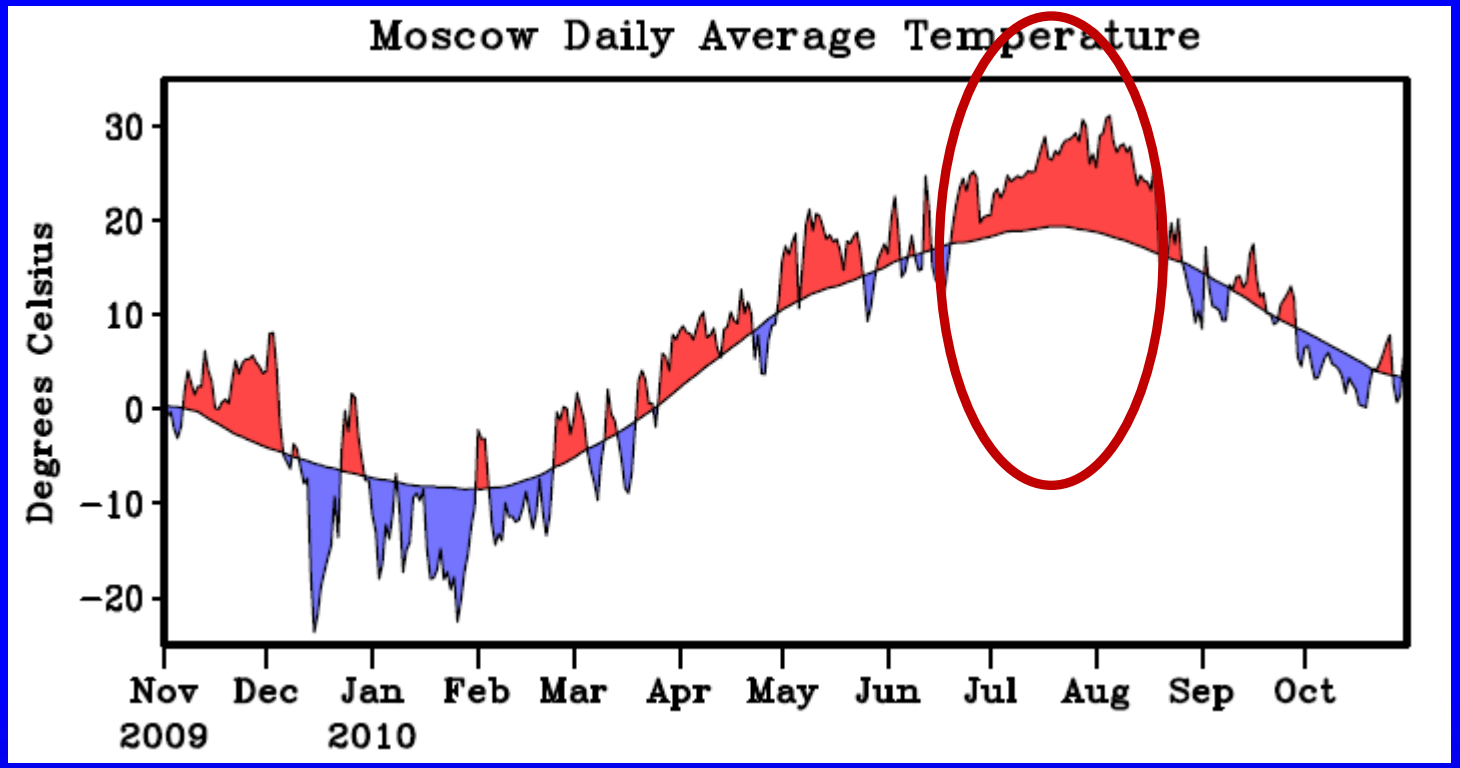
China



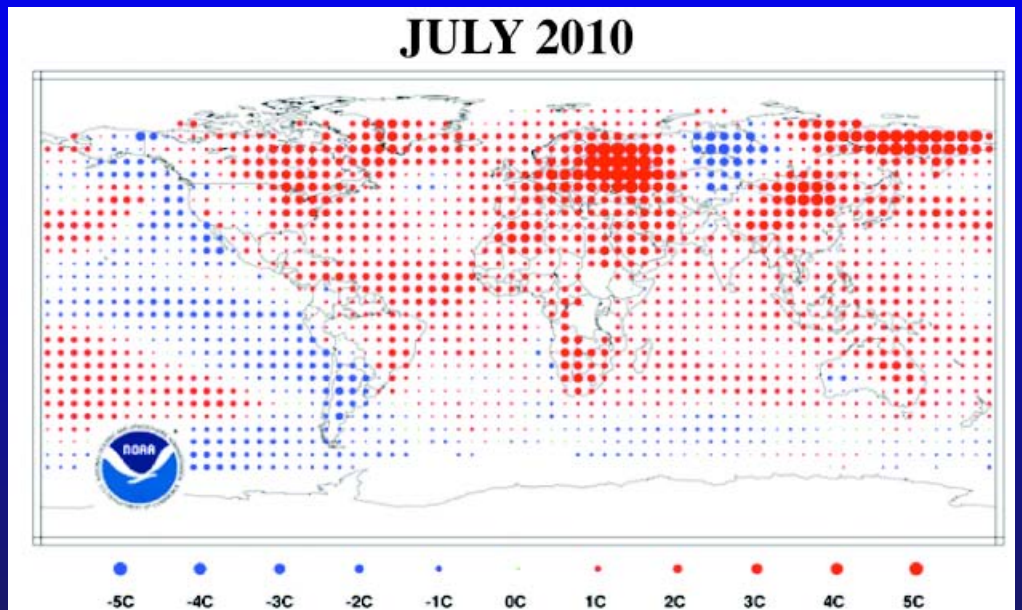




Courtesy NASA



Temperatures



From Dole et al 2011

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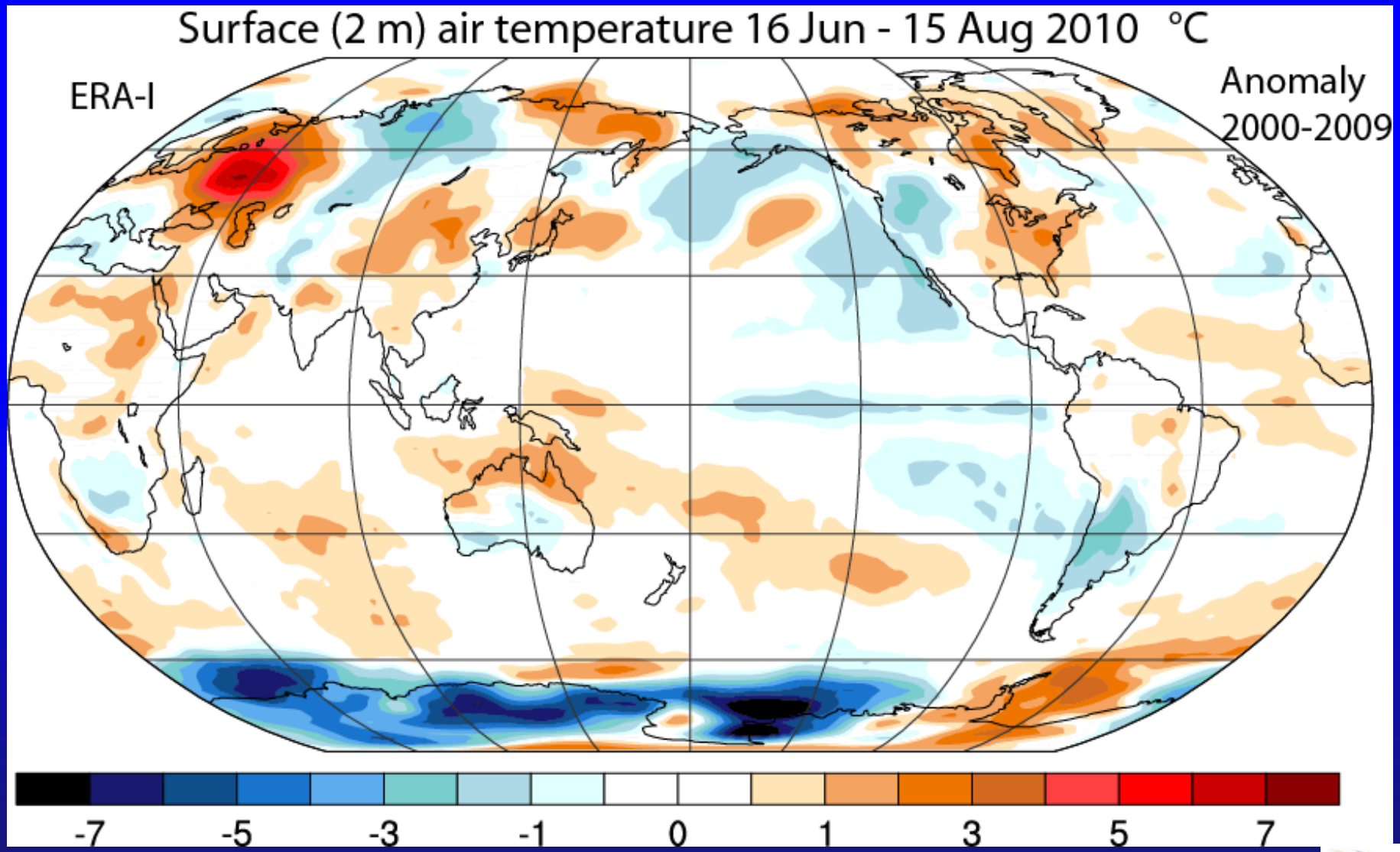
Surface air temperature (2m)



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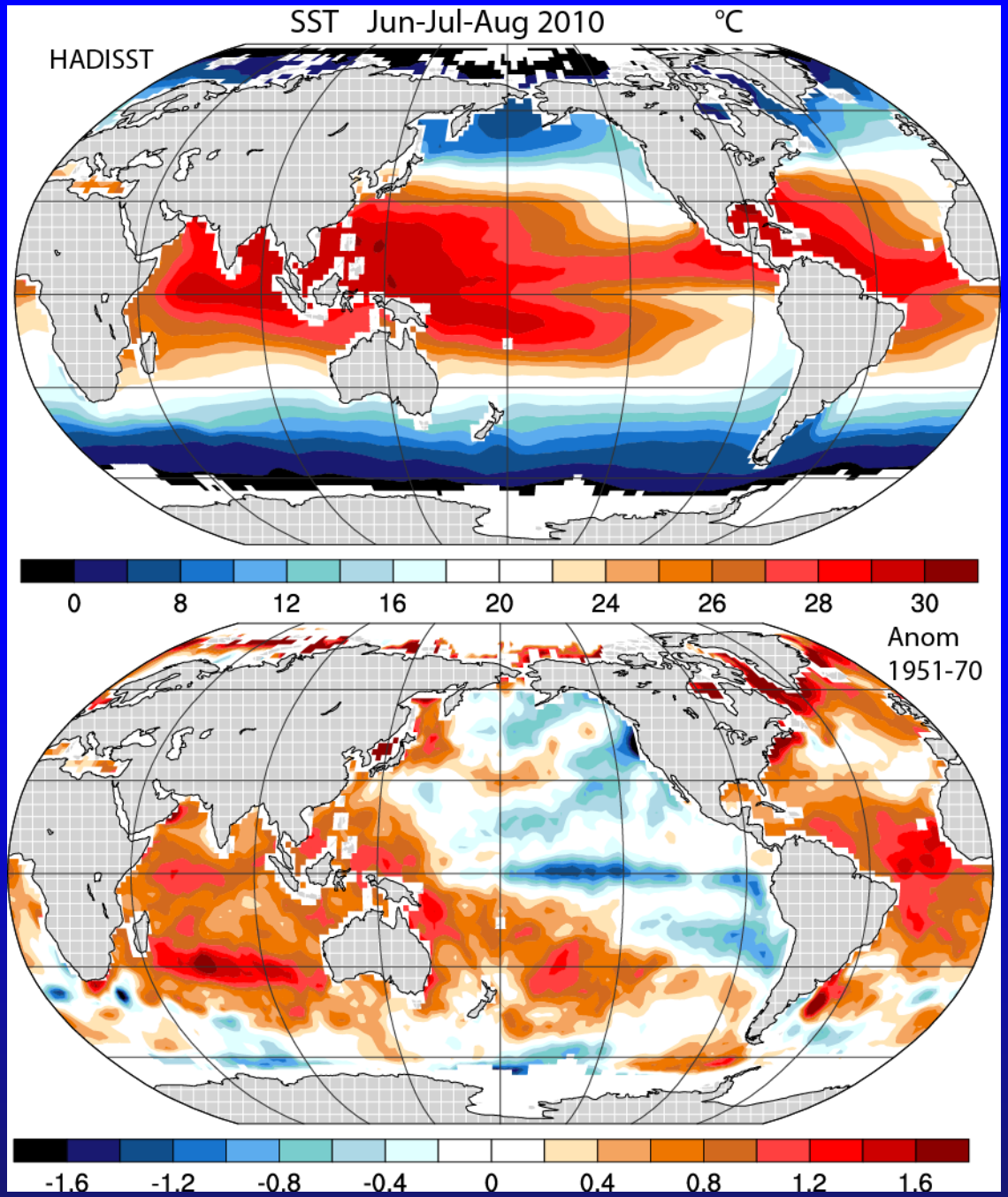

SSTs

Positive anomalies on top of normally high SSTs have extra impact owing to C-C

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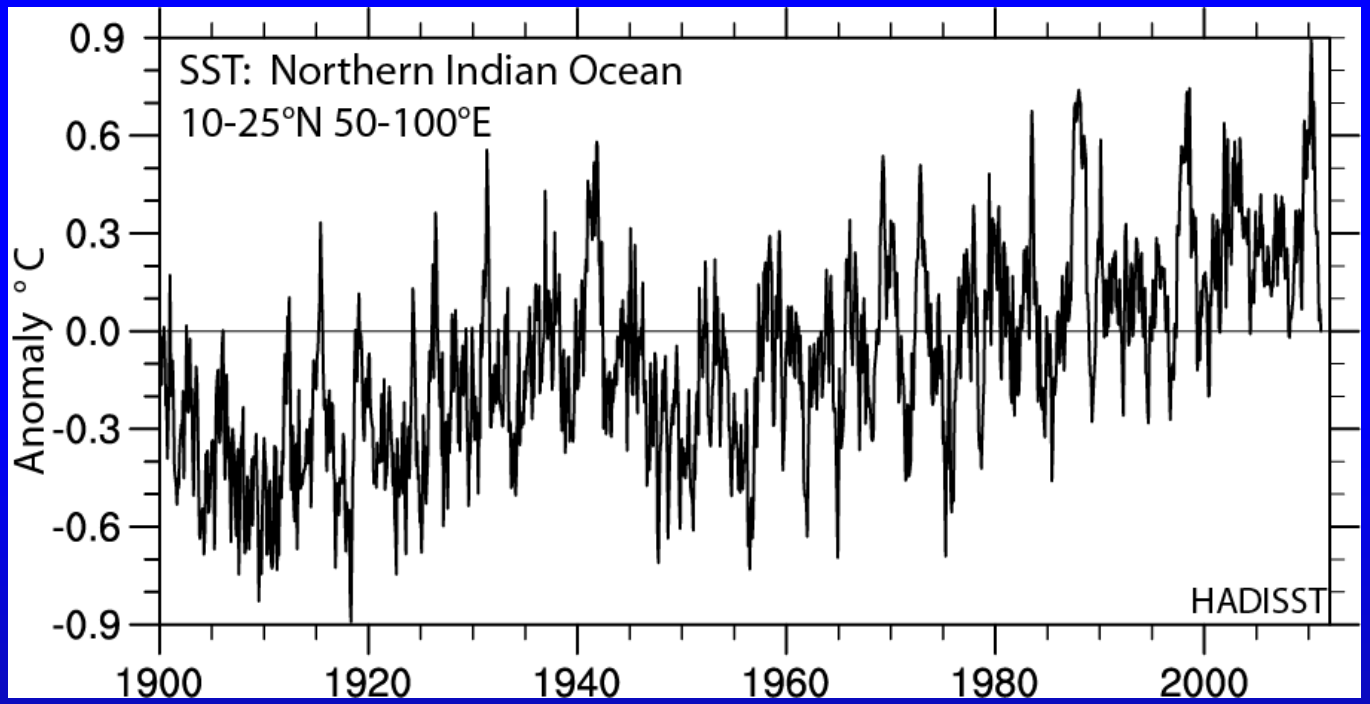
Northern Indian Ocean

Incl: Bay of Bengal and Arabian Sea



May 2010 highest on record (30.4°C) and anomaly 0.9°C (2.9 σ)

(base period 1960-89)

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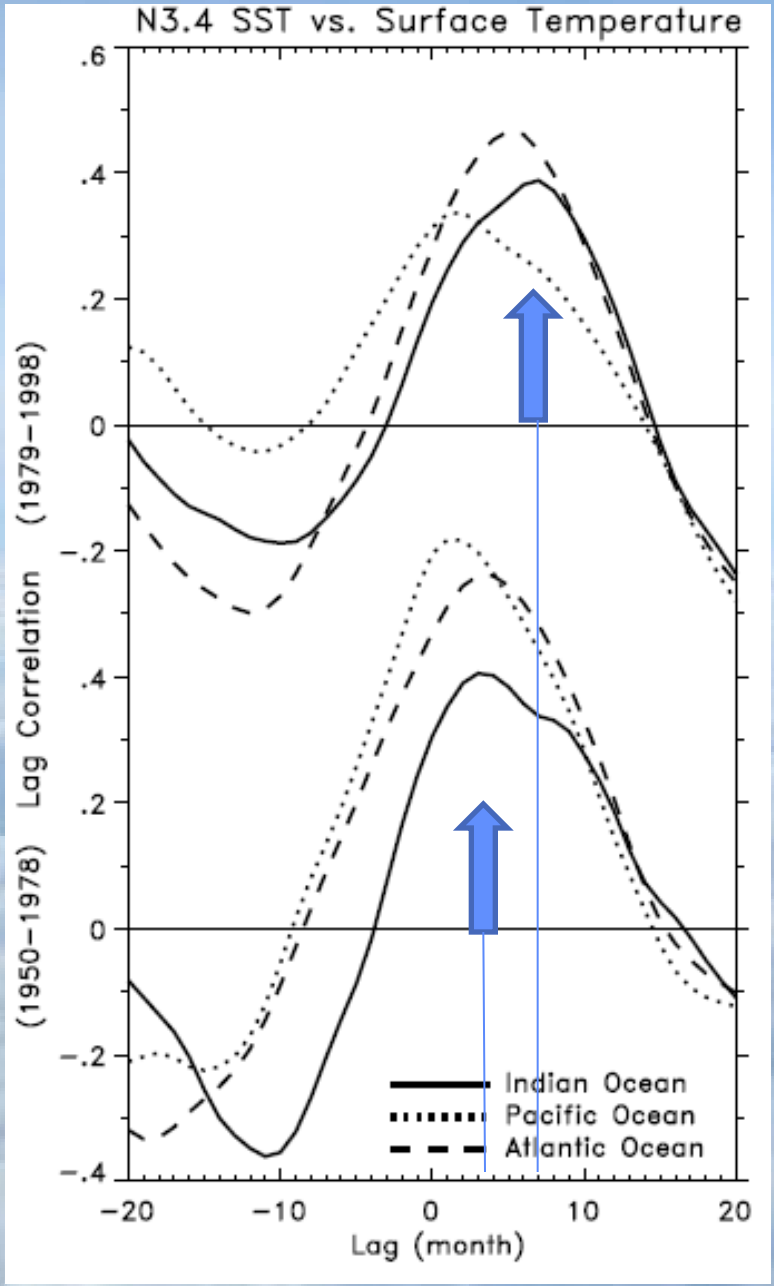
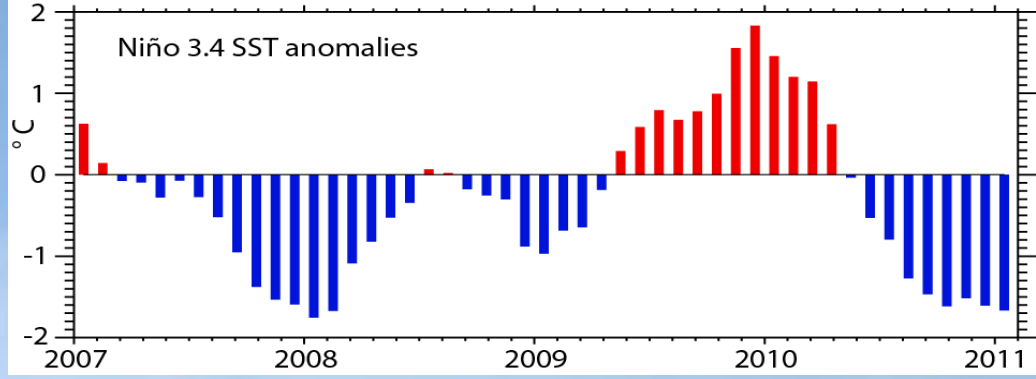


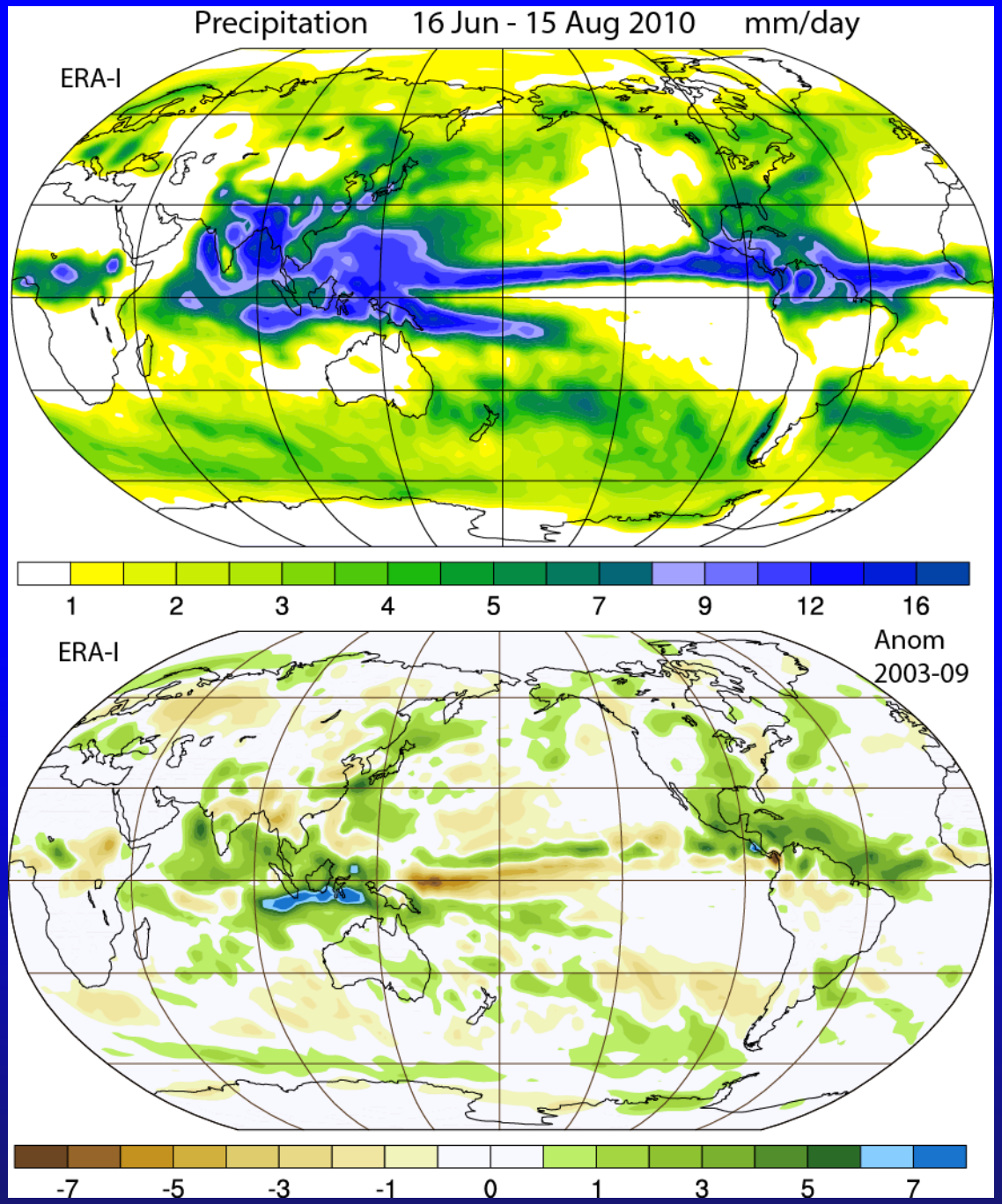


Indian and Atlantic Ocean SSTs lag Nino3.4 by 4 to 7 months:

the high SSTs in July-Aug 2010 are partly a response to the May 2009—May 2010 El Niño from light winds (less evaporative cooling) and sunny skies.

SSTs were also higher than pre-1970 values by about 0.5°C from global warming

Trenberth et al 2002



Precipitation

ERA-I

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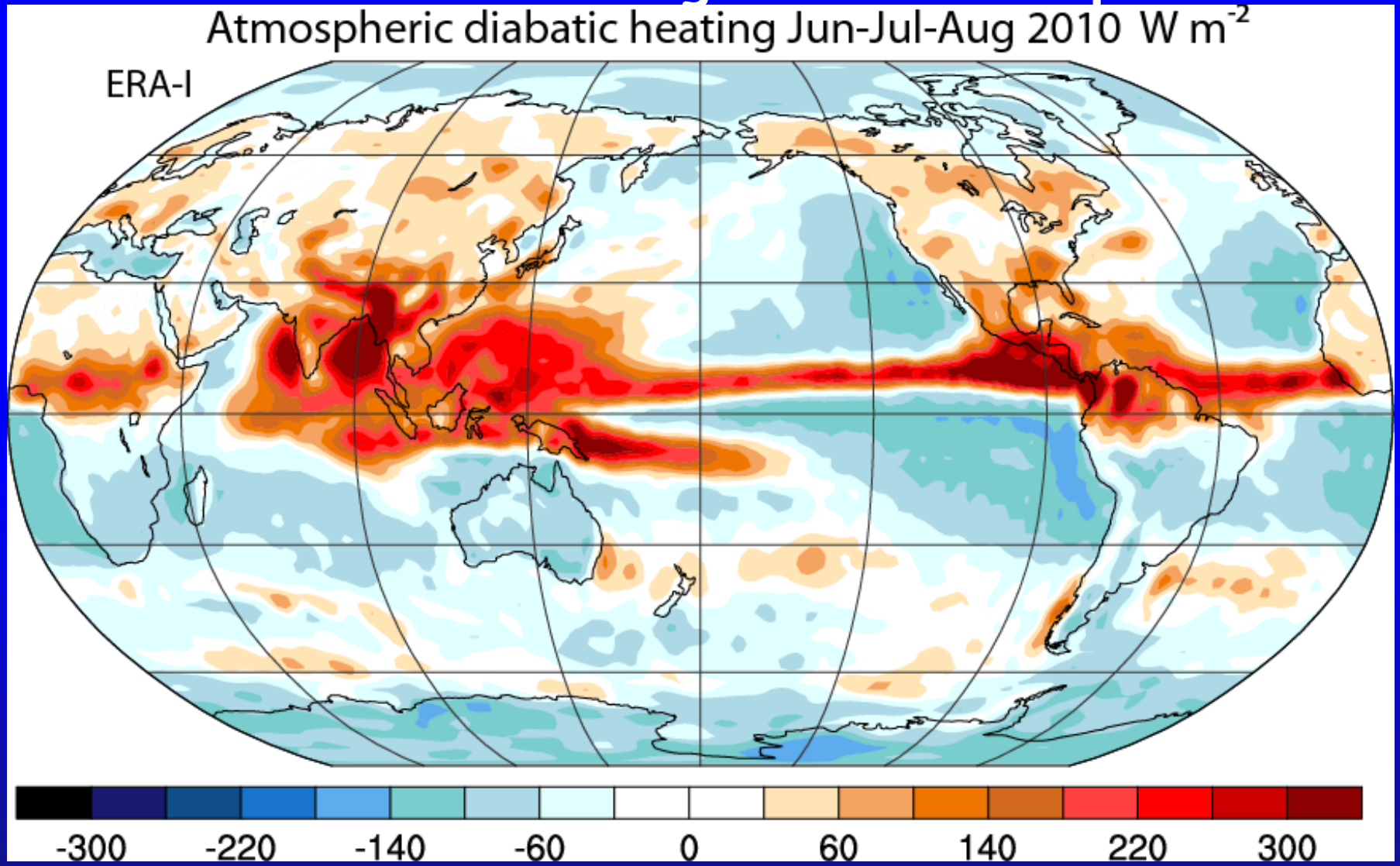
Diabatic heating in the atmosphere



From energy balance as residual adjusted for mass balance
ERA-I

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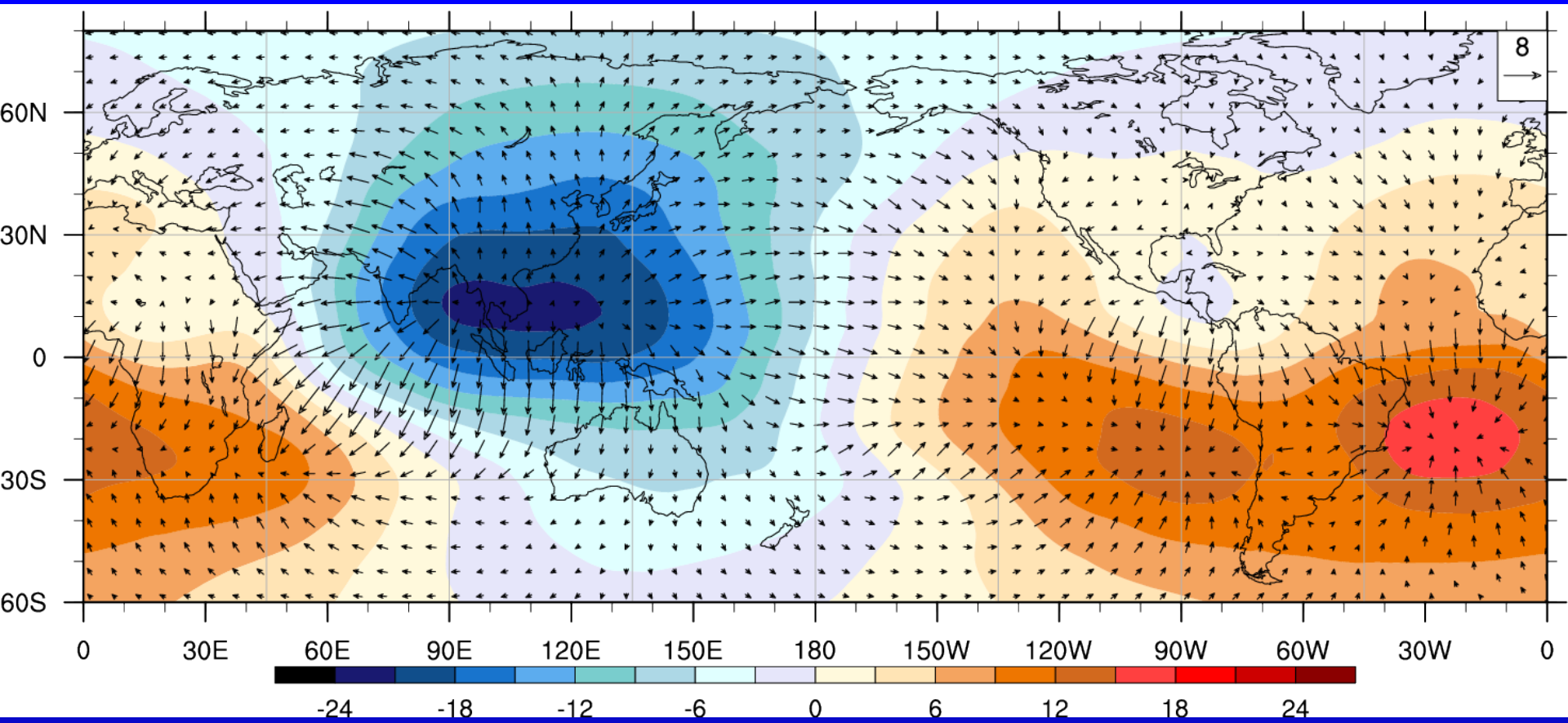
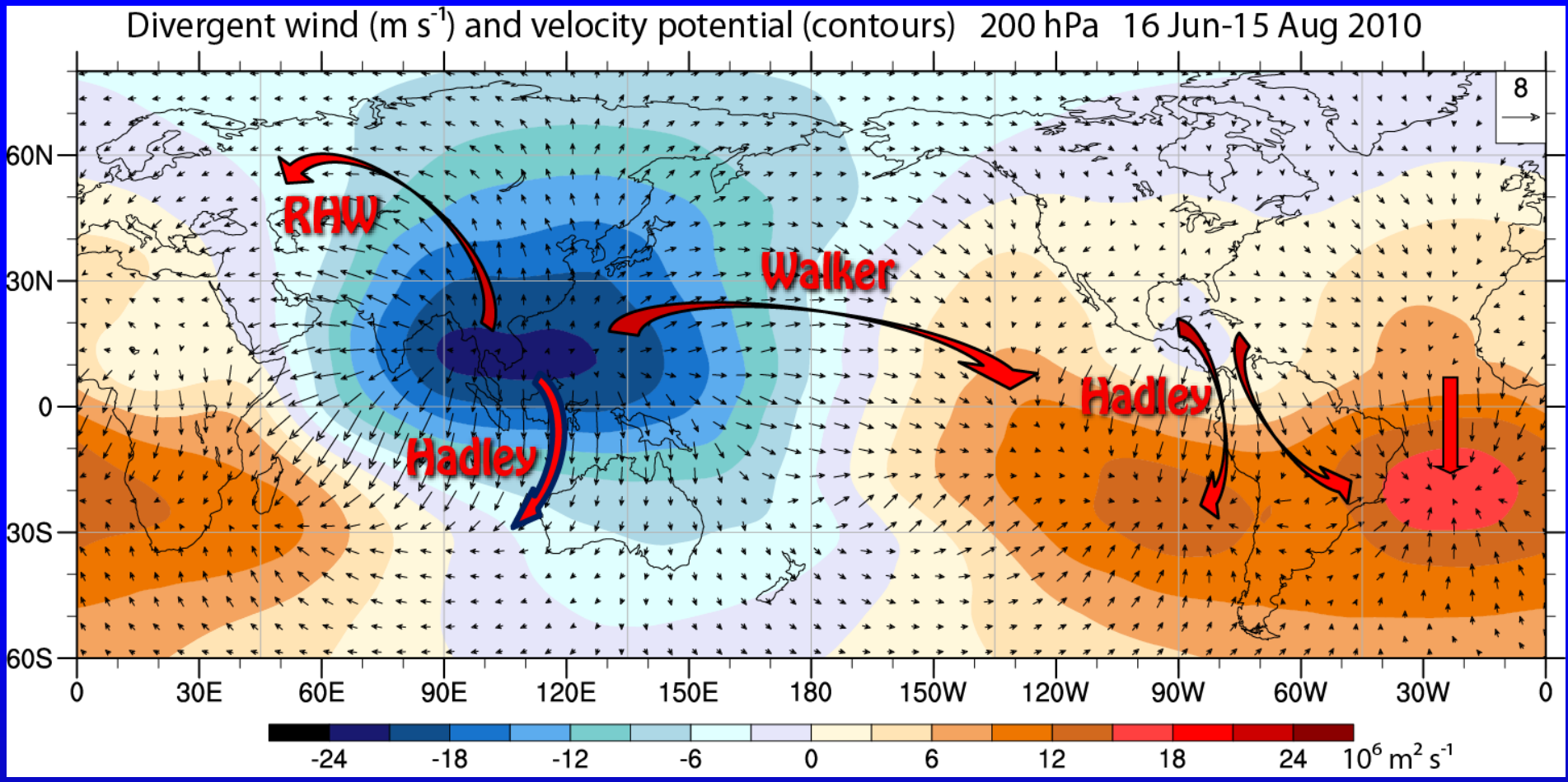
16 Jun – 15 Aug 2010 200 hPa



Upper troposphere outflow associated with monsoon overturning.



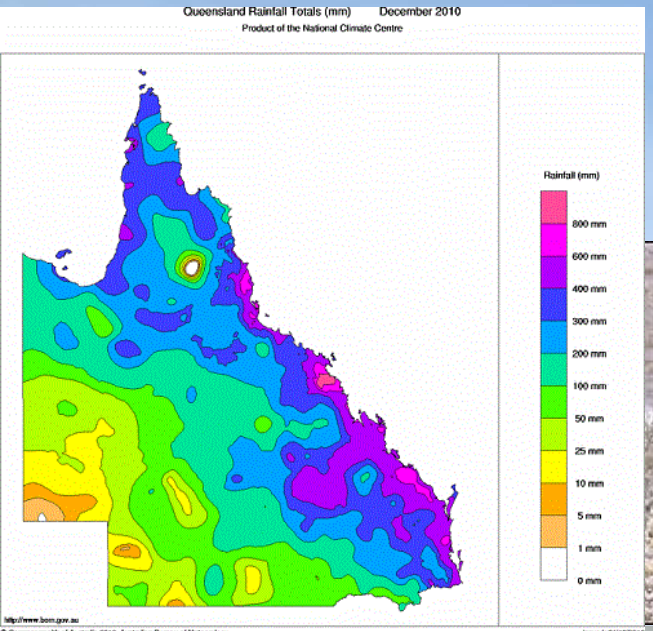
Record high SSTs in Caribbean and Gulf of Mexico Aug 2010
Record flooding in Columbia, 2nd highest activity in Atlantic tropical storms: 19 named, 12 hurricanes, 4 cat 4 or 5.
Drought in Brazil.

Russian heat wave attribution

Models are not good enough to test the null hypothesis that the blocking in the RHW was so persistent and strong because of the enhanced Asian monsoon.

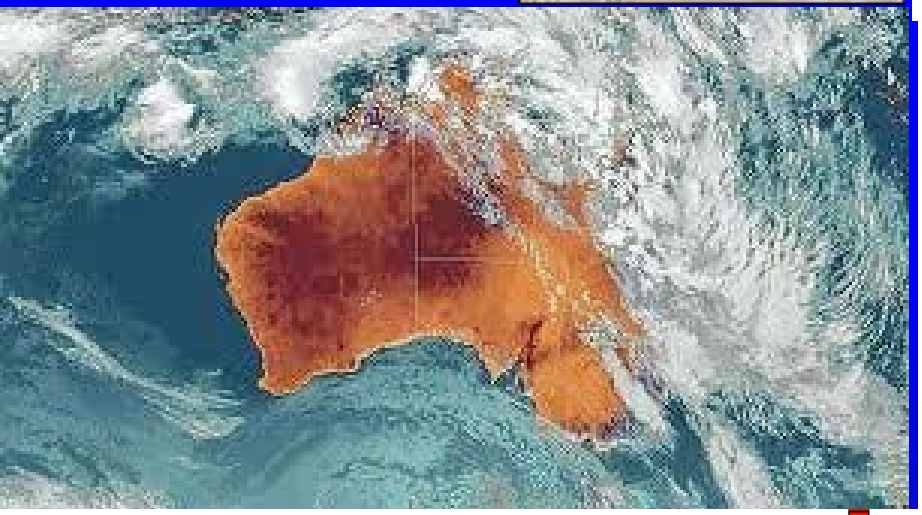
We conclude that it was.
Hence it was partly caused by record high SSTs that have a human component, as well as local radiative forcing.

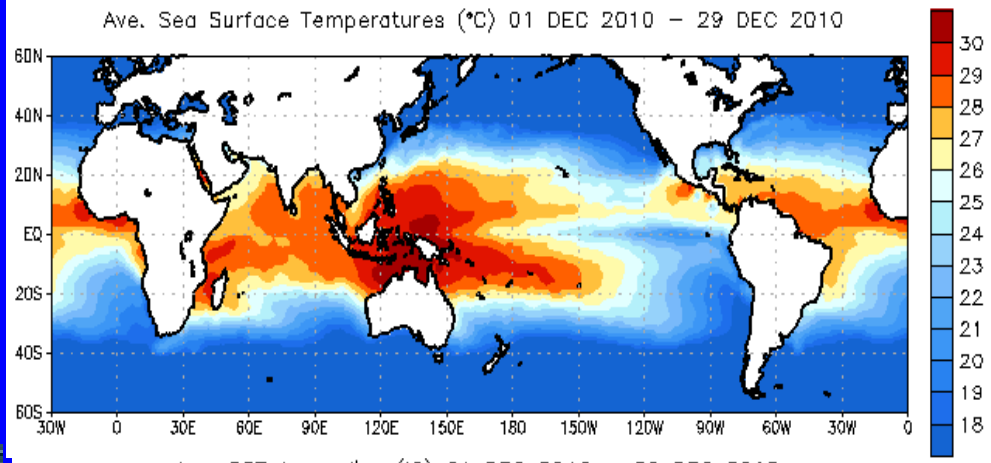
Flooding
Queensland Early Jan 2011

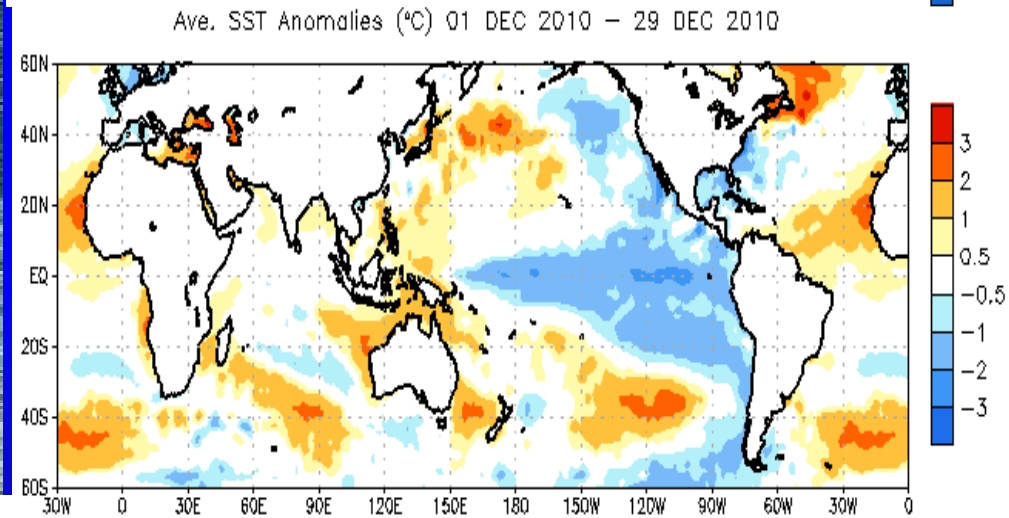


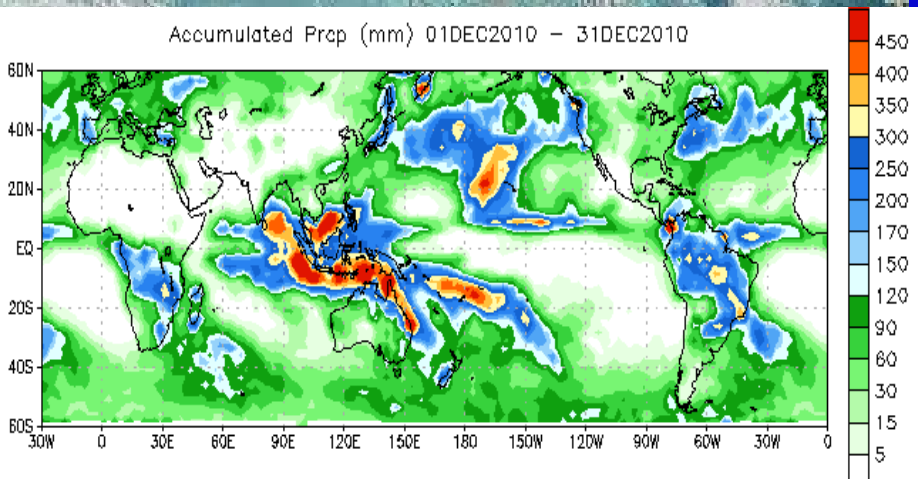
Flooding
Queensland
Early Jan 2011

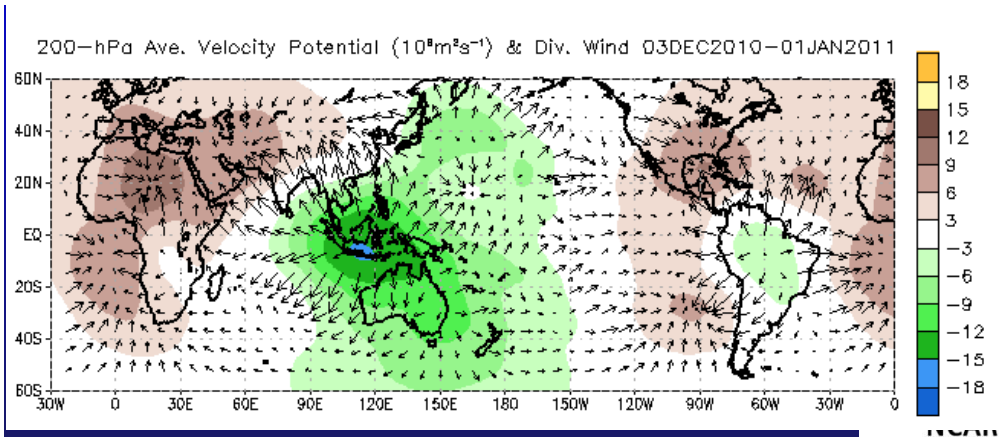
La Niña

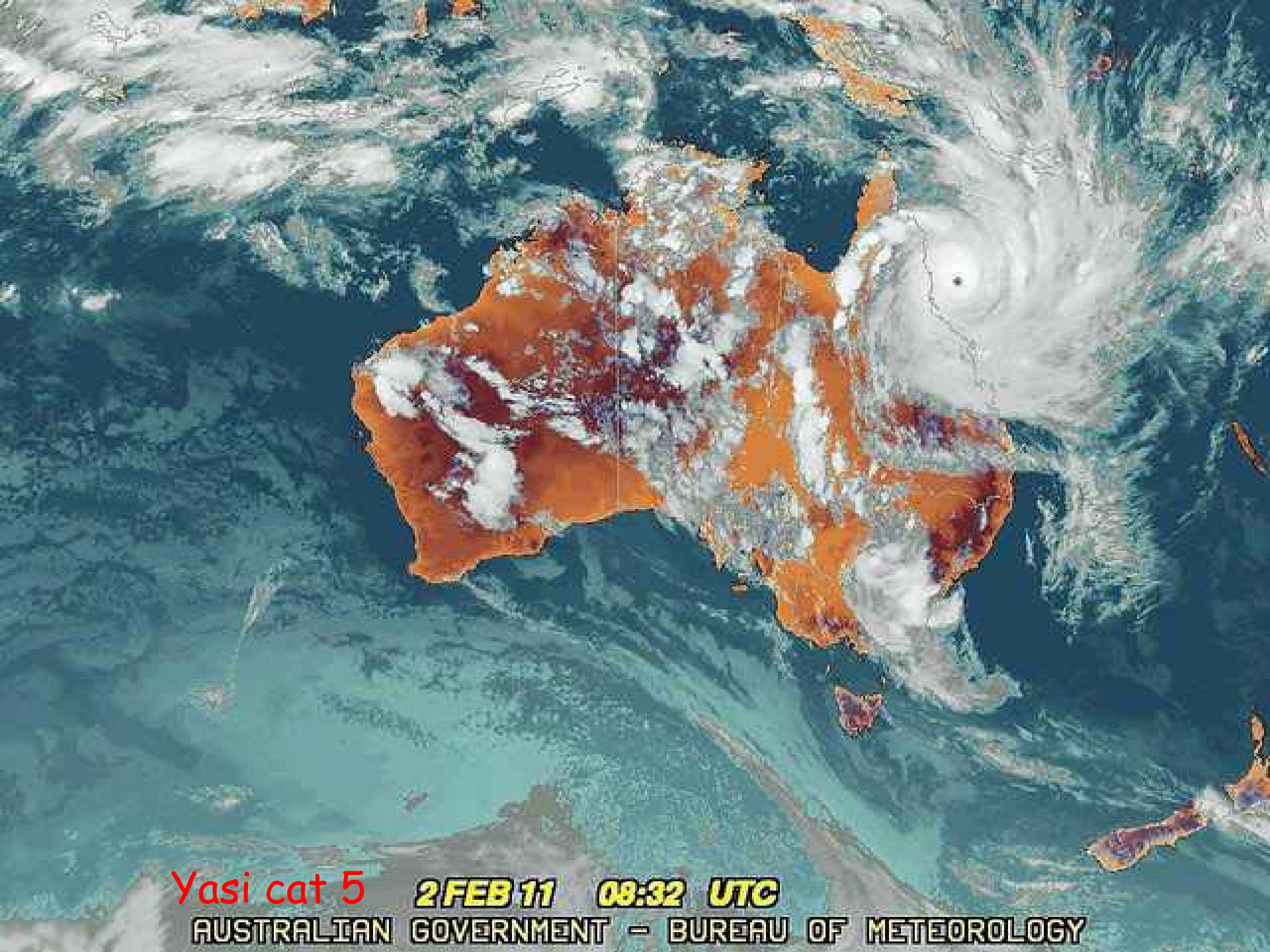











Yasi cat 5
2 FEB 11 08:32 UTC
AUSTRALIAN GOVERNMENT - BUREAU OF METEOROLOGY

Mississippi River

May 11 (below) and at Memphis

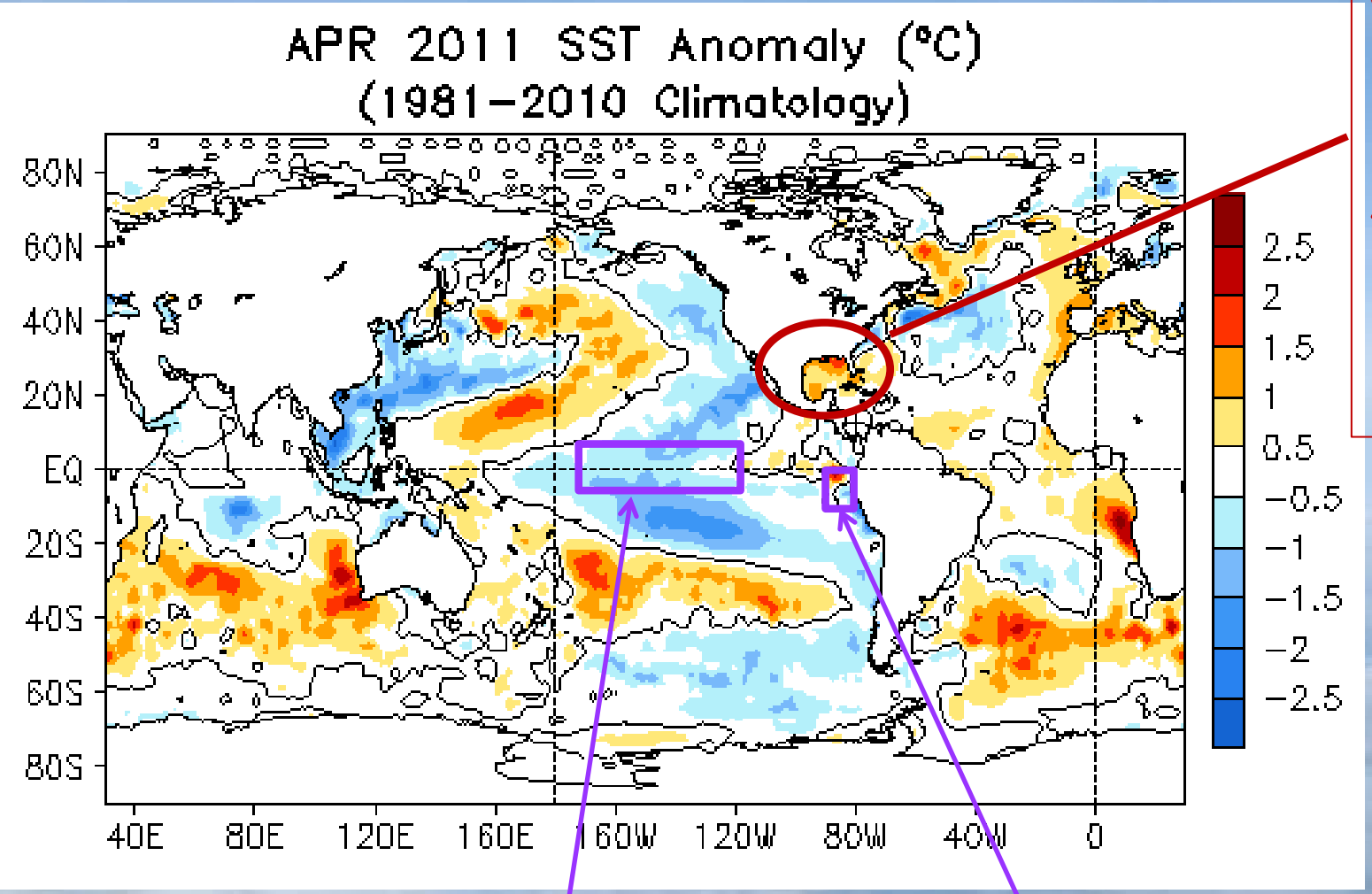
Tornado

Flooding on the Mississippi:

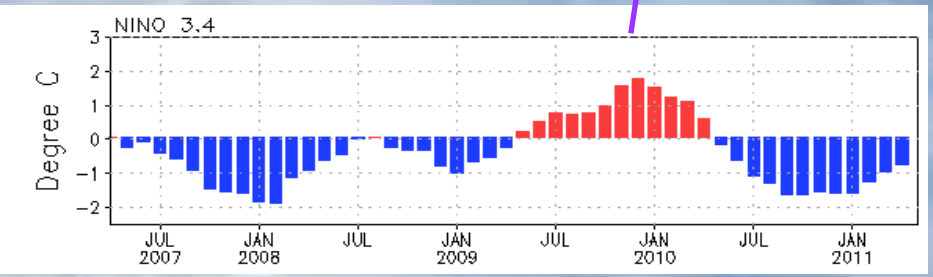
There were multiple "1-in-500 year" or "1-in-100 year flood events within a few years of each other in parts of the Basin…

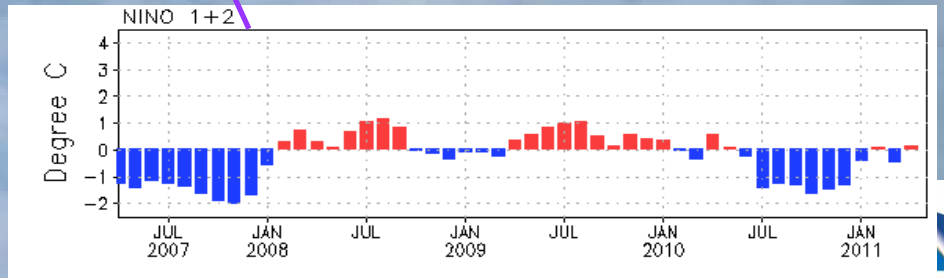
1993
Then again in **2008**.
And now: **2011**

AP 2000; NYT 2011 Peter Gleick

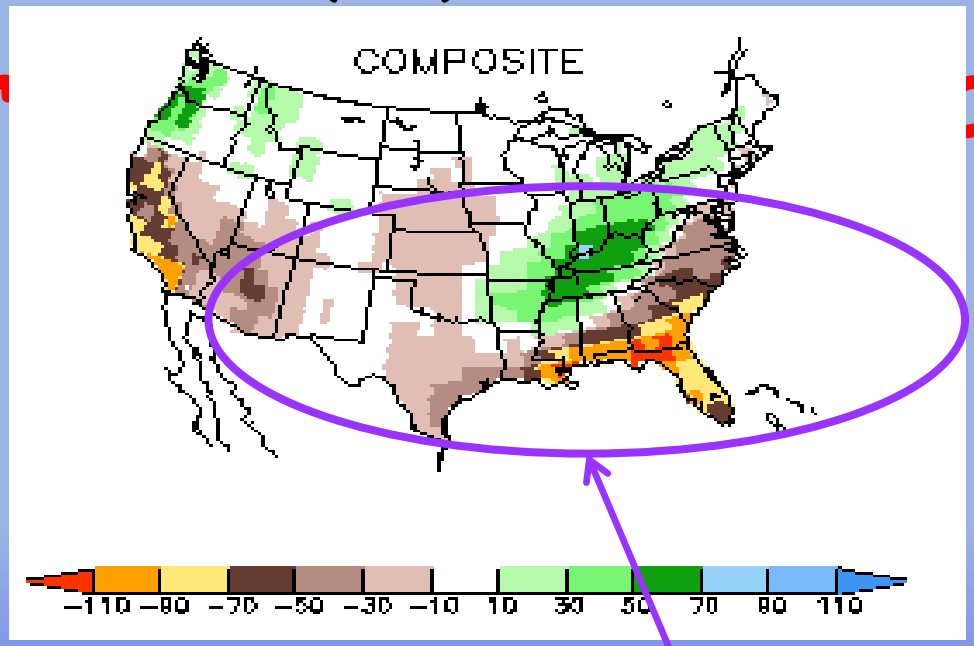


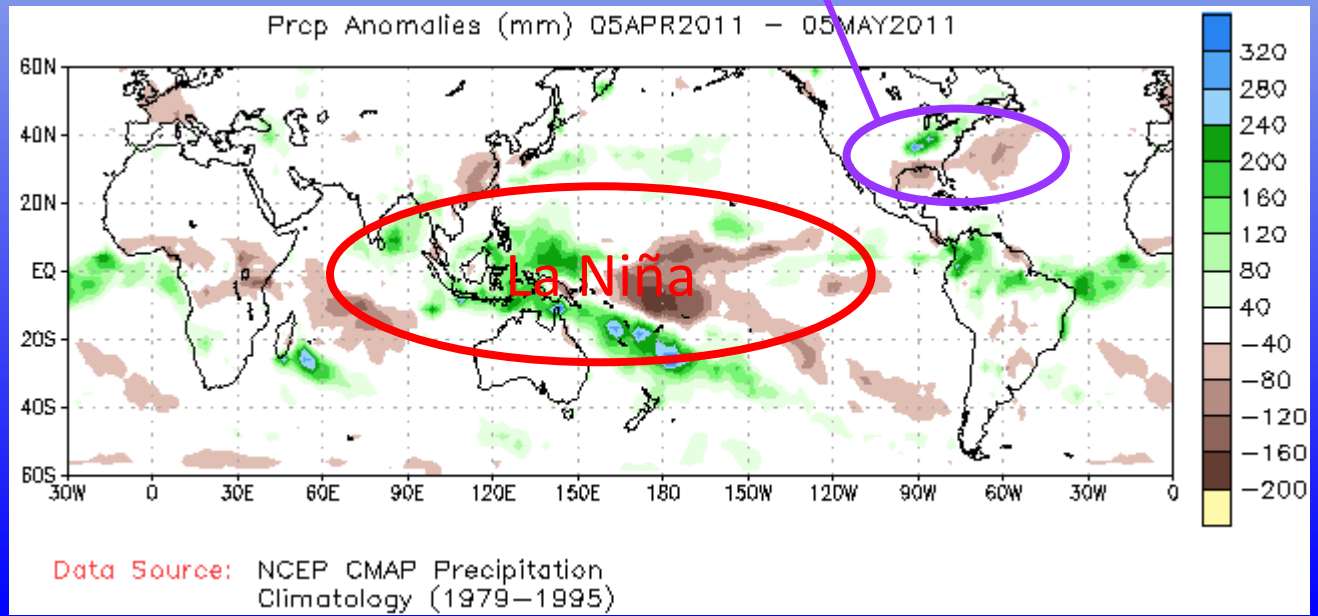
SSTs in Gulf 0.5 to 1.5°C above 1981-2010 values: ~1.5°C above pre-1970 values



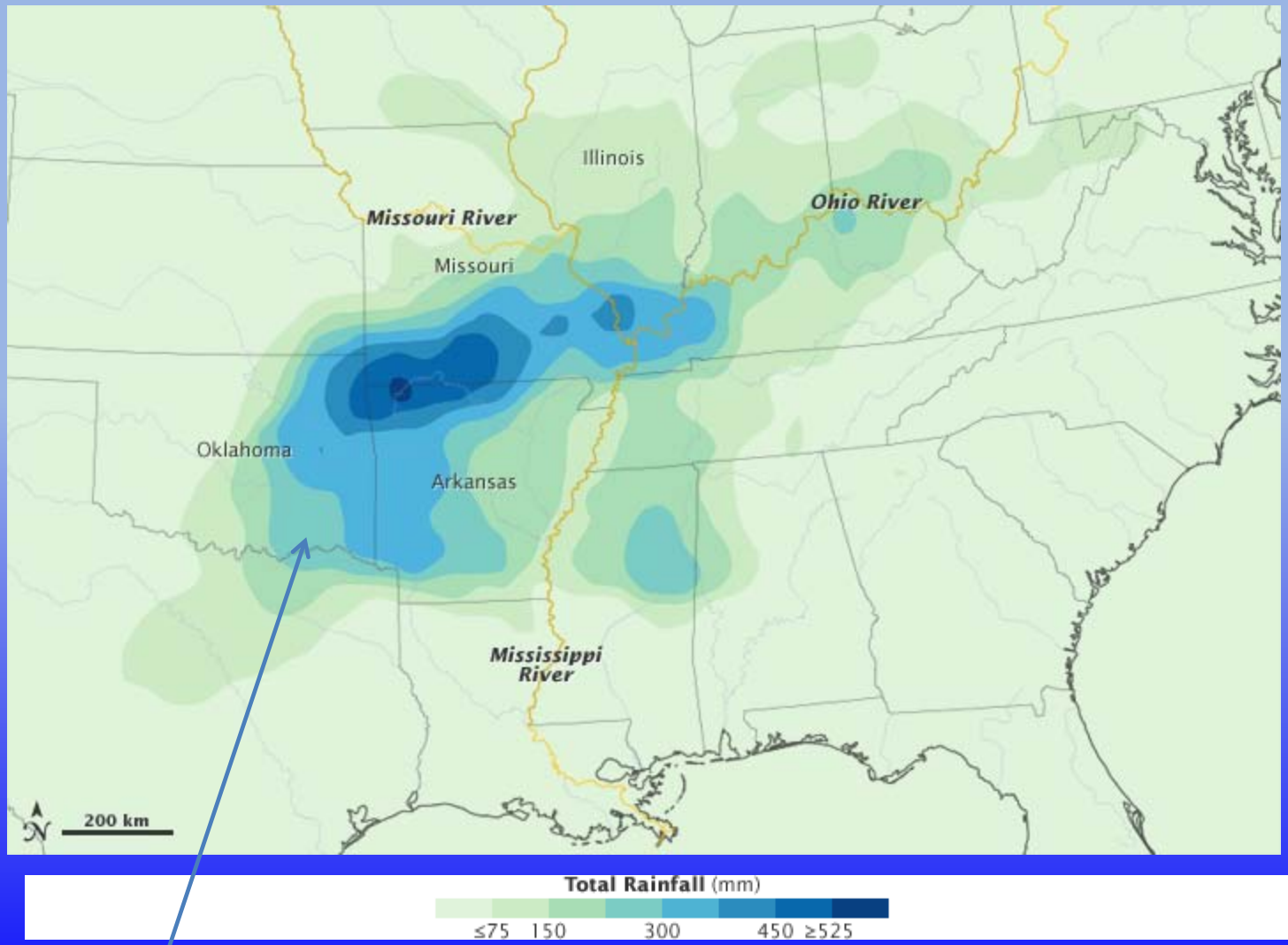


La Nina precipitation anomalies for JFM anomalies (mm)

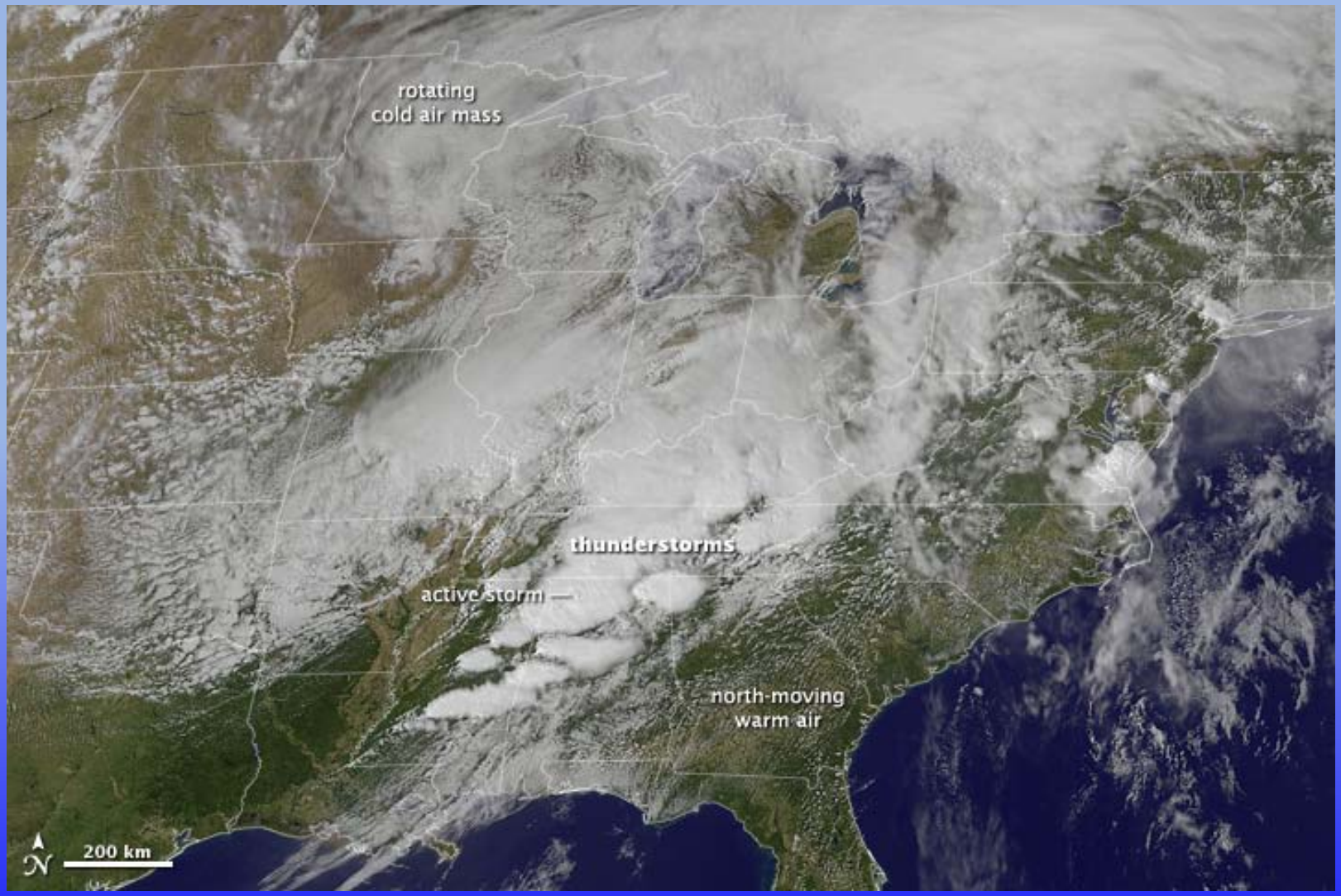




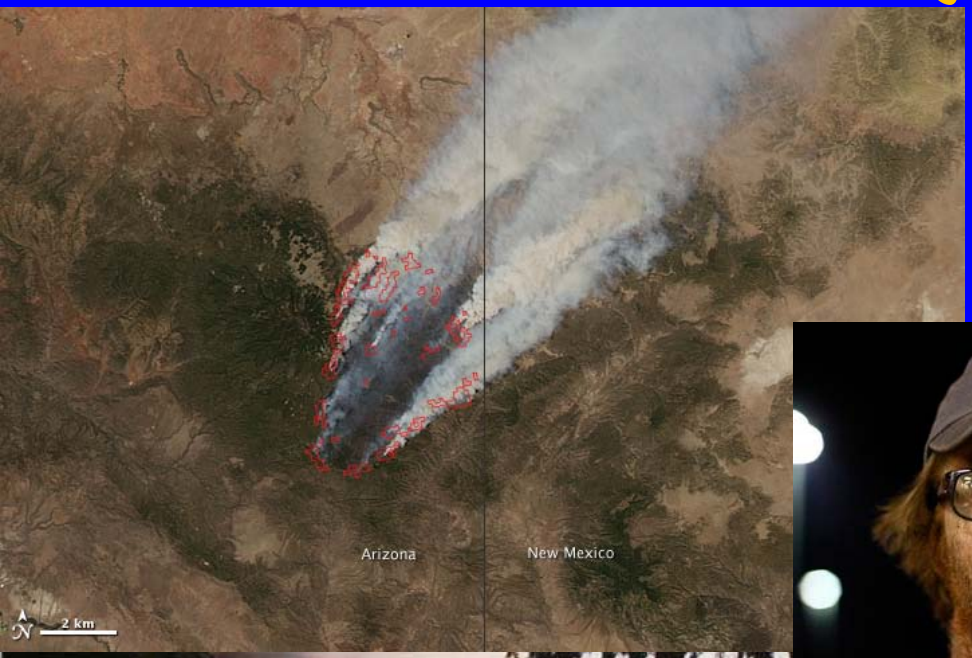
19-25 April 2011



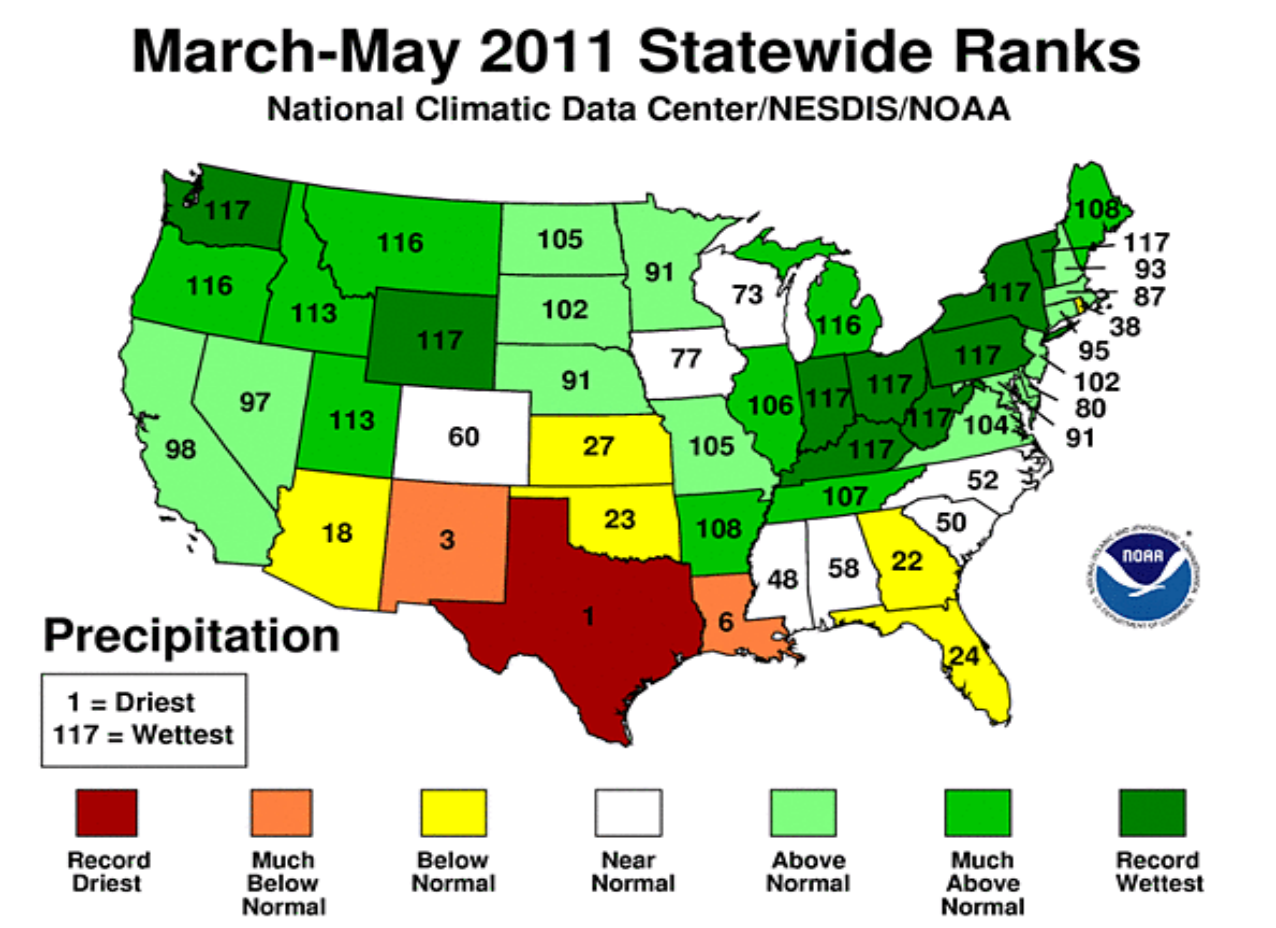
10 inches


rotating
cold air mass
thunderstorms
active storm
north-moving
warm air
200 km
N

Arizona on fire
June 7-25, 2011
Biggest on record



Spring 2011 in the USA



- The greatest flood in recorded history to the Lower Mississippi River
- An astonishingly deadly tornado season
- The worst drought in Texas history
- The worst fire season in recorded history

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Spring 2011 in the USA

The US has recently experienced (or is experiencing) some of the worst climate extremes in history: from drought and wild fires to floods, powerful storms and deadly tornadoes. When natural variability is compounded by human influences on climate, this is what we get. **Records are not just broken, they are smashed!** It's as clear a warning as we are going to get about prospects for the future.

Of course it won't happen this way every year, the regions most affected shift (last year Russia, this year Arizona; last year the Indus in Pakistan, this year the Mississippi and Missouri…), and some times will be benign, but the kinds of changes being recorded are just what we expect and have been predicted for the human influence on climate.

Kevin Trenberth
14 June 2011

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Extremes attribution

While it we can not say that these events were due to global warming (poorly posed question), it is **highly likely** that they would not have happened without global warming!

Munich Re:

(one of the world's leading reinsurers)

" The only plausible explanation for the rise in weather-related catastrophes is climate change. The view that weather extremes are more frequent and intense due to global warming coincides with the current state of scientific knowledge".

http://www.munichre.com/en/media_relations/press_releases/2010/2010_09_27_press_release.aspx

Courtesy Peter Gleick

Many things you can do:

Going Green!

Climate and Earth System observations and models will contribute to environmental justice by assessing the impacts of climate change on food production, flooding, drought, sea level rise, and health.

Who is going to be most affected by climate change?

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