ATM S 111: Global Warming

Floods and Droughts

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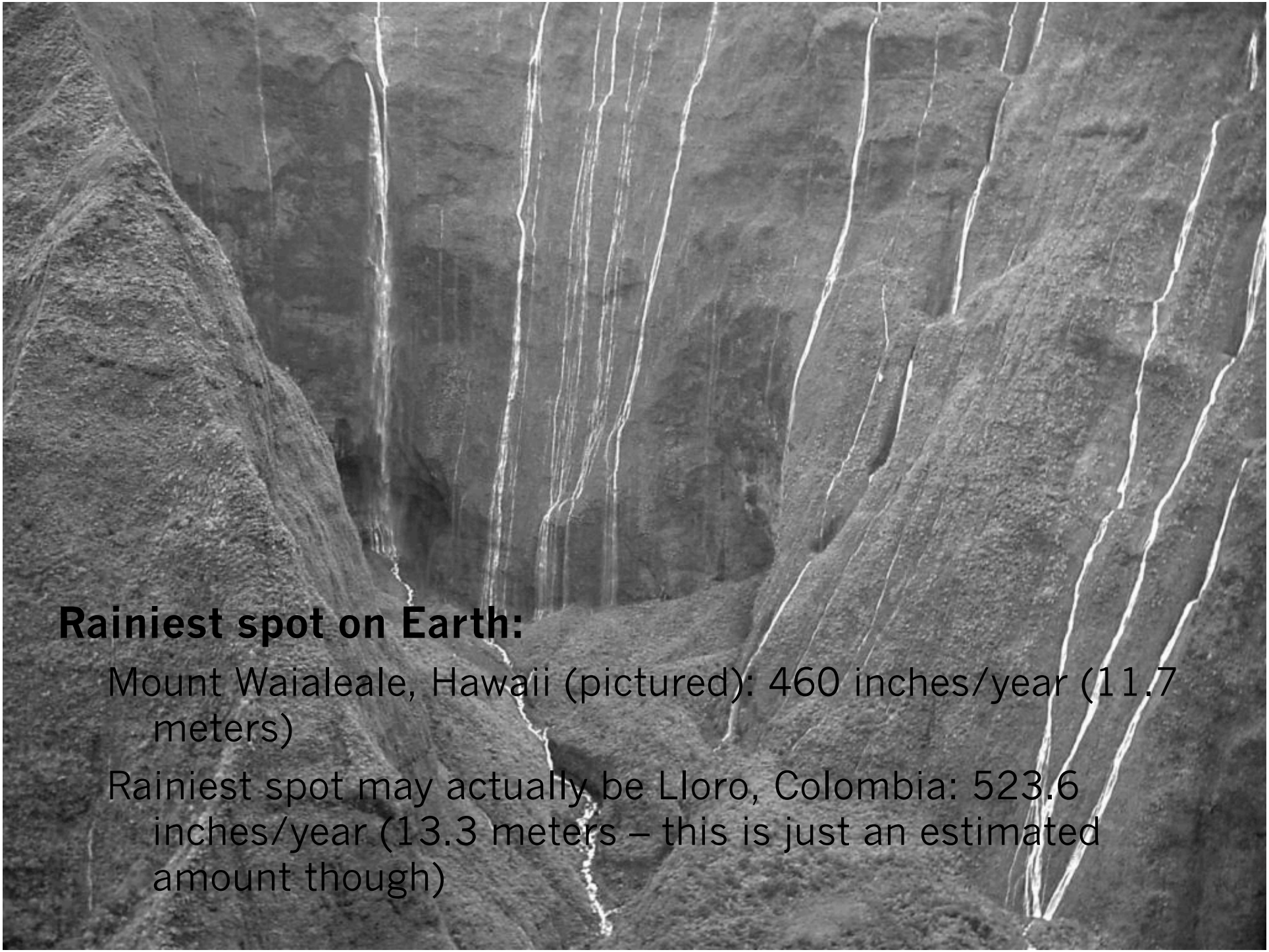
Day 13: July 8 2010

Outline

- Precipitation around the world
  - Rainy regions and deserts
  - Monsoons
- Changes that are expected in the future
  - **Wet get wetter**, **dry get drier**
  - Heavy rain events with more heavy rain
- Changes that have been observed
  - Increased rainfall?
  - Droughts in the Sahel
  - Droughts in Australia

Rainiest and Driest Places on Earth

- Again, these are just places that have weather stations
  - There are likely more extreme places that aren't being measured



Rainiest spot on Earth:

- Mount Waialeale, Hawaii (pictured): 460 inches/year (11.7 meters)
- Rainiest spot may actually be Lloro, Colombia: 523.6 inches/year (13.3 meters – this is just an estimated amount though)


Rainiest year on record:
905 inches (almost 23 meters) in Cherrapunji, India
on the foothills of the Himalayas

Rainiest day ever:

Reunion Island (500 miles off coast of Madagascar)

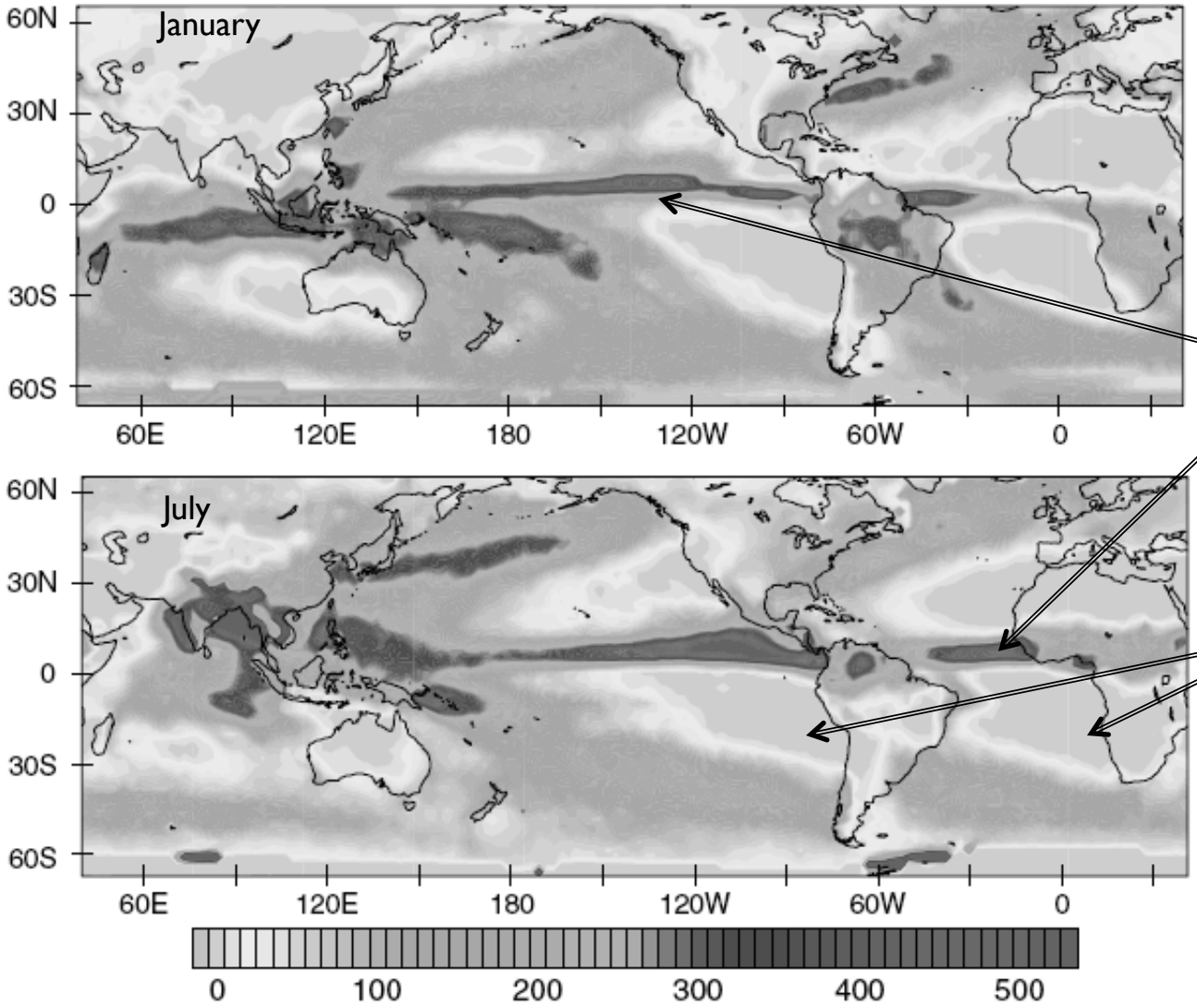
72 inches **(1.86 m) in** *24 hours***!!!**

Also just three years ago, Reunion Island set the record for 72 hour rainfall: 155 inches (3.9 m) during a tropical cyclone

Extreme Precipitation

- All of the above examples are associated with **mountains**
  - More rain on windward side of mountains
    - Rain occurs when **moist air rises**
    - Mountains can force air to rise over their slopes
  - These extremes are localized rainy areas
    - Just like the Olympic Peninsula here in Washington!
- Let's take a look at the average precipitation over the whole globe
  - There are also large scale patterns of rainy and dry

Observed **precipitation** in January and July



Observed precipitation in mm/yr

Rainiest spots are narrow bands near the equator

Some of the driest places are over the ocean!

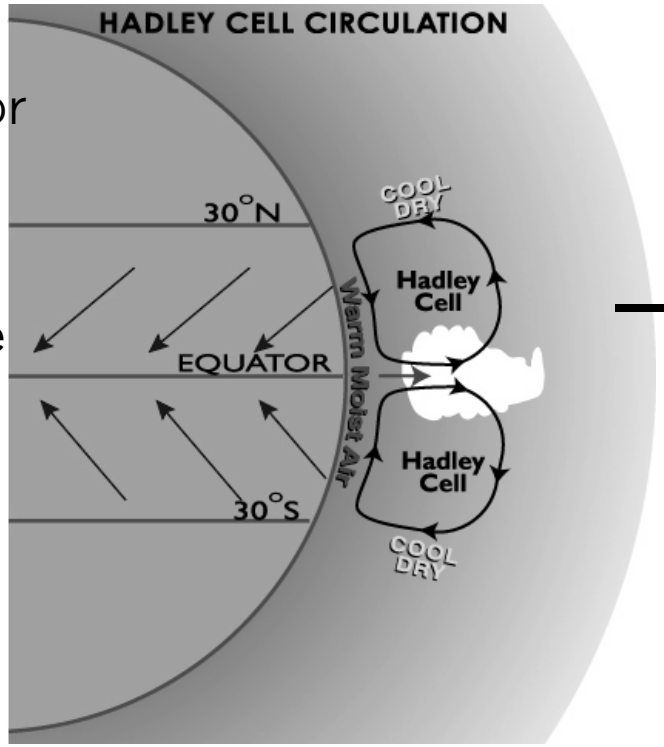
Most deserts are around 30 degrees latitude

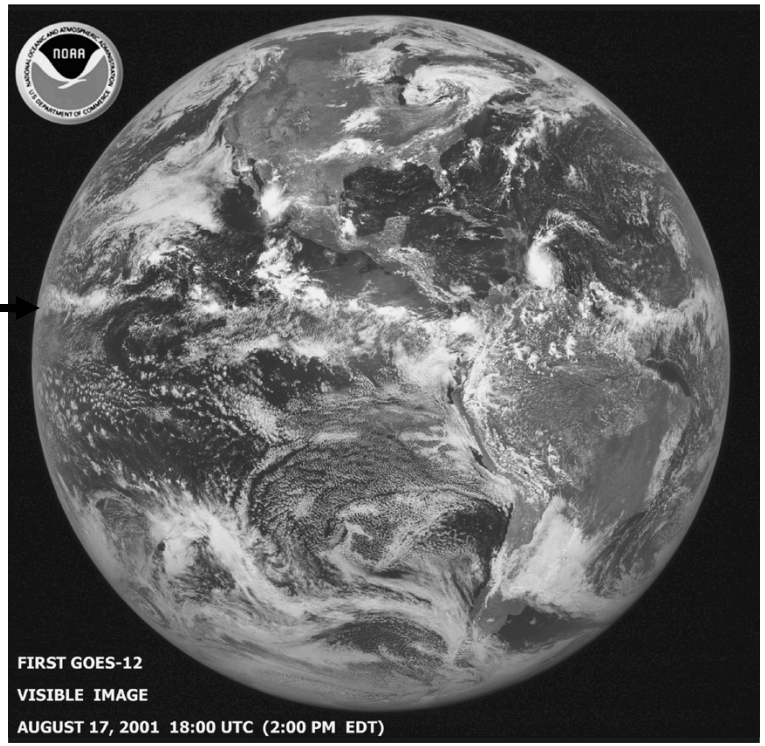
"Hadley Circulation"

Air rises above the warmest ocean surface (*hot air rises*)

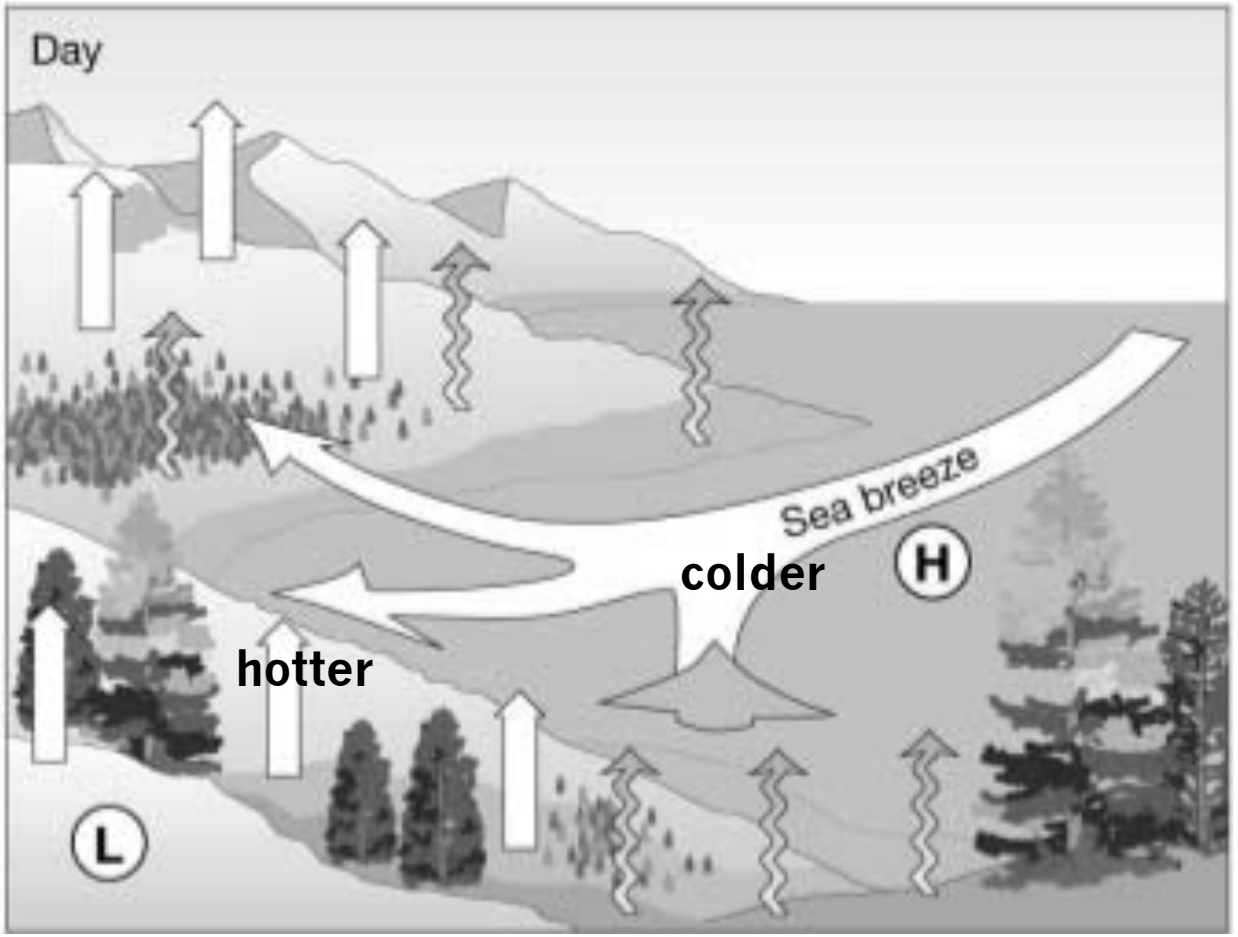
The circulation takes water vapor **away from** the **deserts** at 30 degrees and brings it **into** the tropical **rainy regions**

"convergence zone": where winds come together

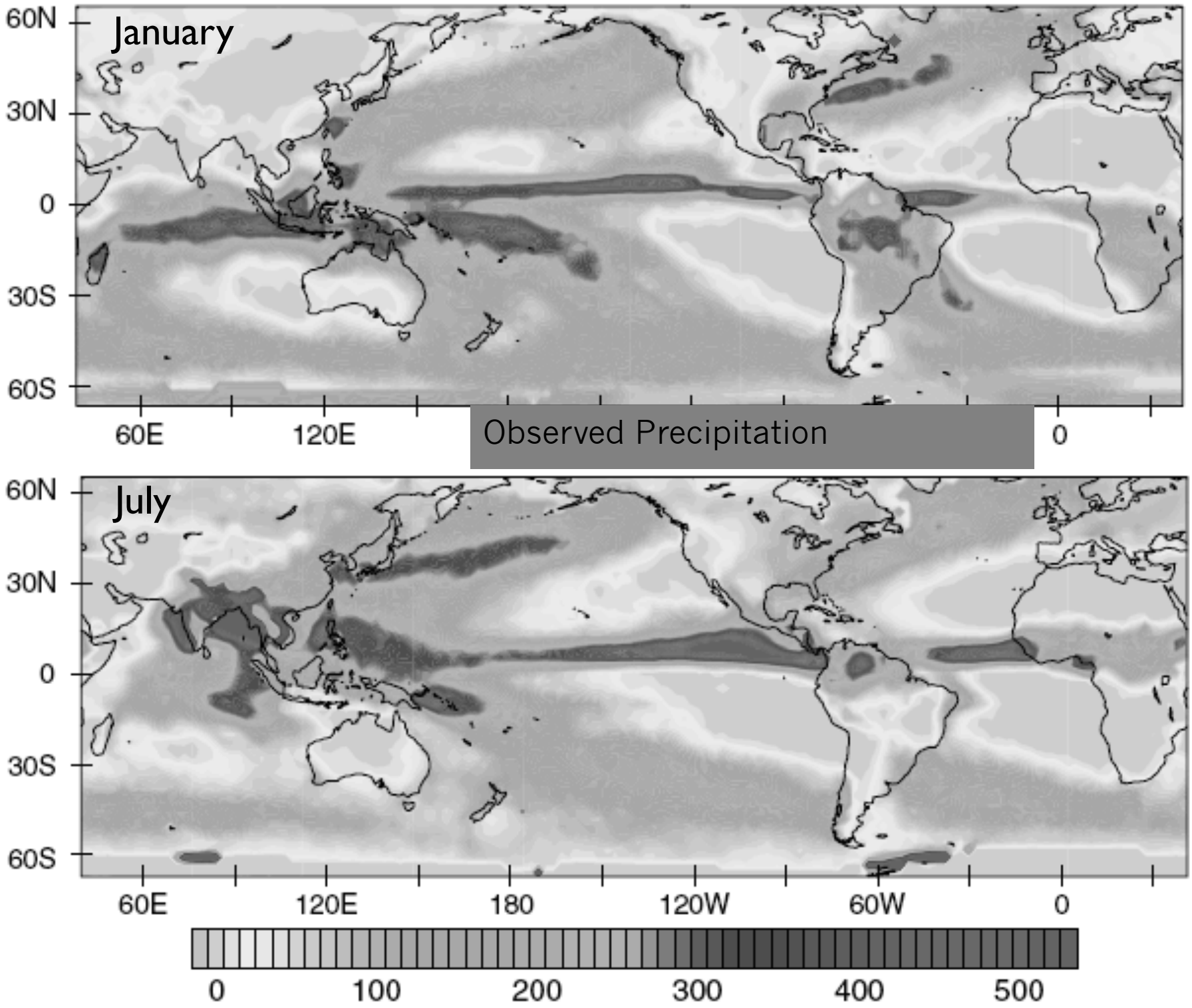




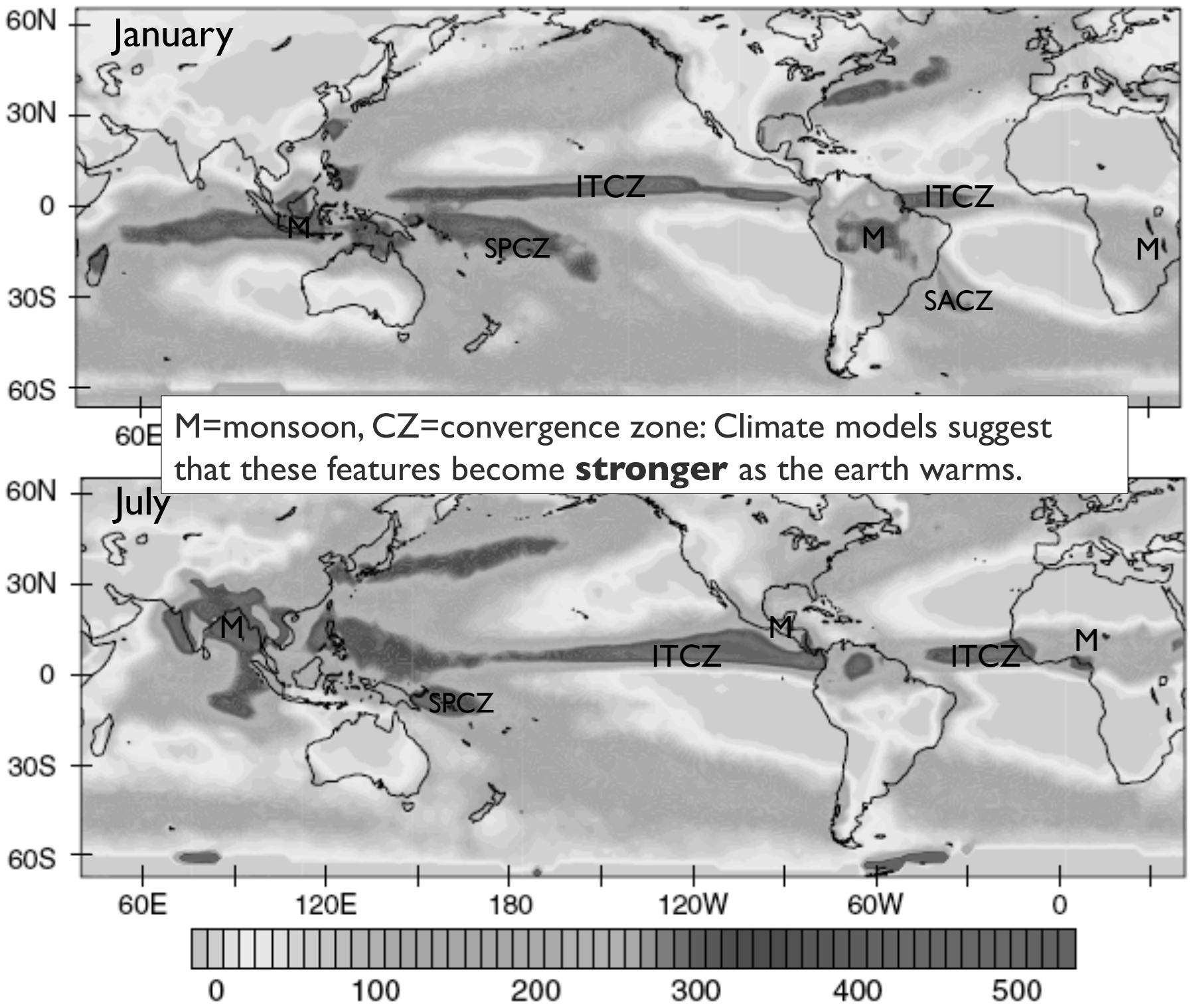
Monsoon Circulation



Daily = “Sea Breeze” caused by daily solar cycle
Seasonally = Monsoon (a persistent version of the sea breeze) caused by seasonal solar cycle
Heating of land is key: again hot air rises, and circulation brings in water vapor



Observed Precipitation

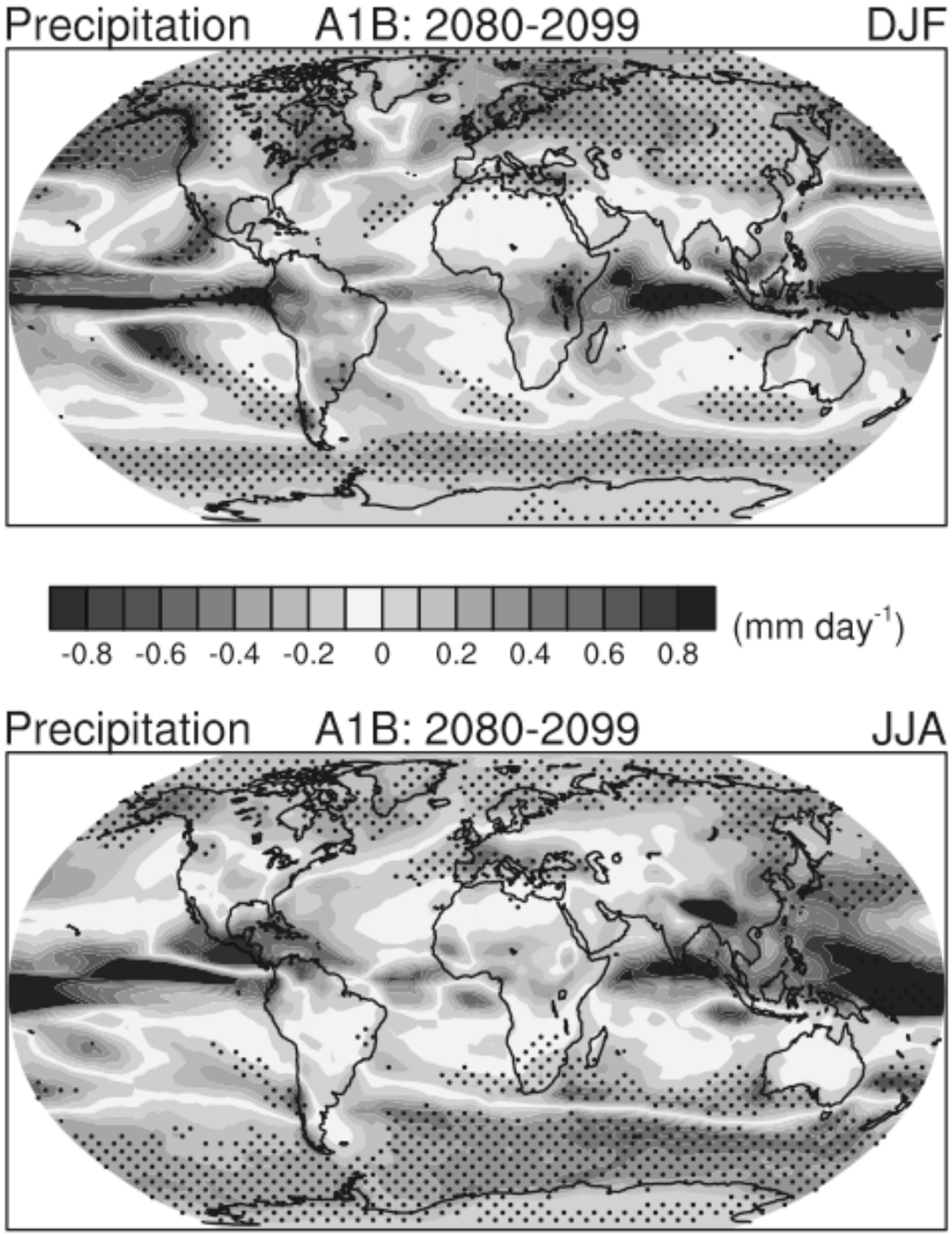


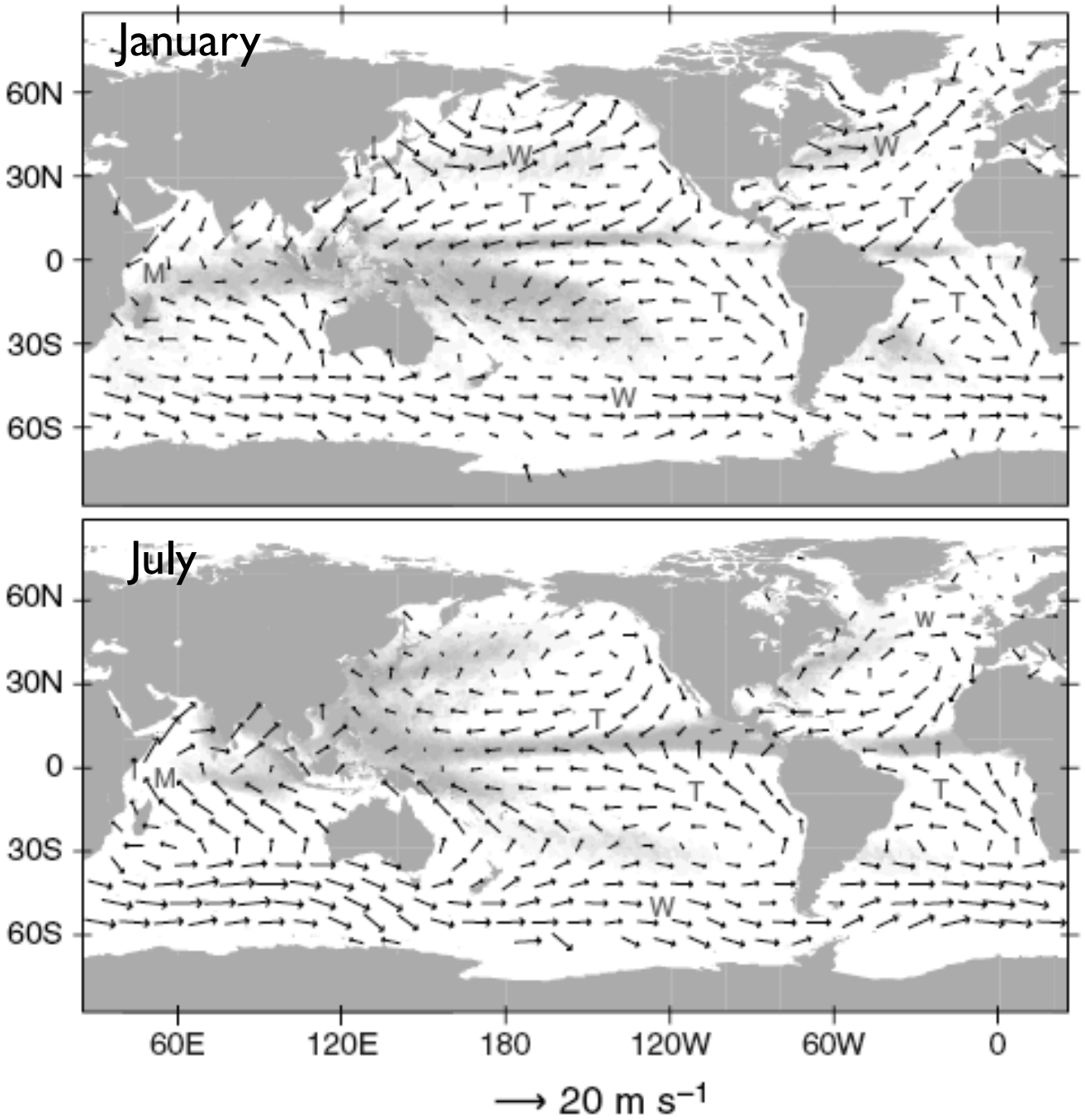
M=monsoon, CZ=convergence zone: Climate models suggest that these features become **stronger** as the earth warms.

- Climate model projections of precipitation change

  Wet gets wetter, dry gets drier

  Stippling: where models agree





Why?

As the atmosphere warms, **water vapor concentrations increase**

Winds bring in even more moisture into the rainy regions

Also more water vapor taken away from dry regions (and more evaporation there)

W = wind from west
T = wind from East (trade winds)
M = monsoon winds
blue = rainbelts

Global Warming Rain Responses

- Wet get wetter
  - More water vapor is brought into the regions that are already rainy
  - This extra rain is partially at the **expense** of dry areas
- Dry get drier
  - More water vapor taken out of the dry regions
  - And more evaporation from dry land surfaces
- There's a lot of uncertainty about specific precipitation responses though
  - Precipitation is much harder to predict than temperature
  - Regional responses could change significantly from changes in the winds

How about the **most intense storms**?

The intensity of downpours is believed to be proportional to water vapor concentration

Warmer temperatures → more water vapor

Thus, heavy rainfall events should become more extreme

1990-2000, Flood Impacts

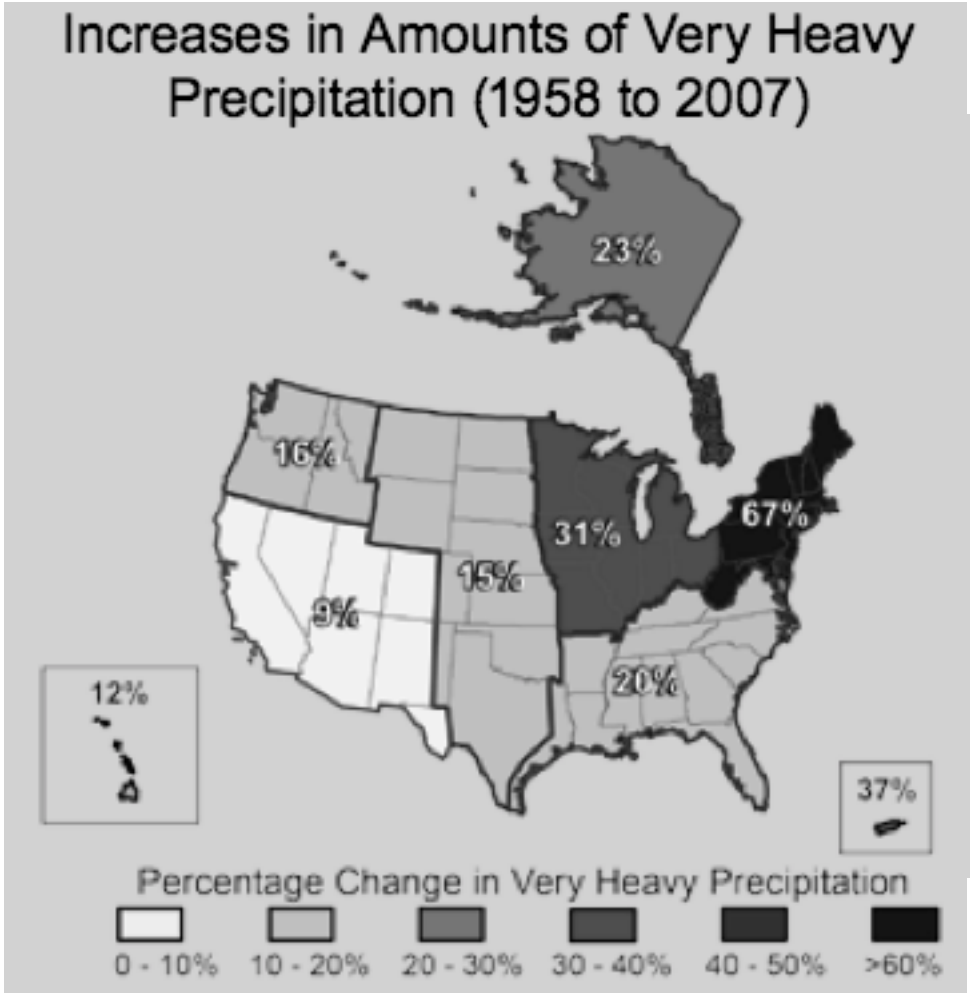
- Nearly 100,000 people were killed
- 320 million people were displaced by floods
- Total reported economic damages exceeding a trillion dollars

Bradshaw, et al. *Global Change Biol.* **13**, 1-17 (2007).

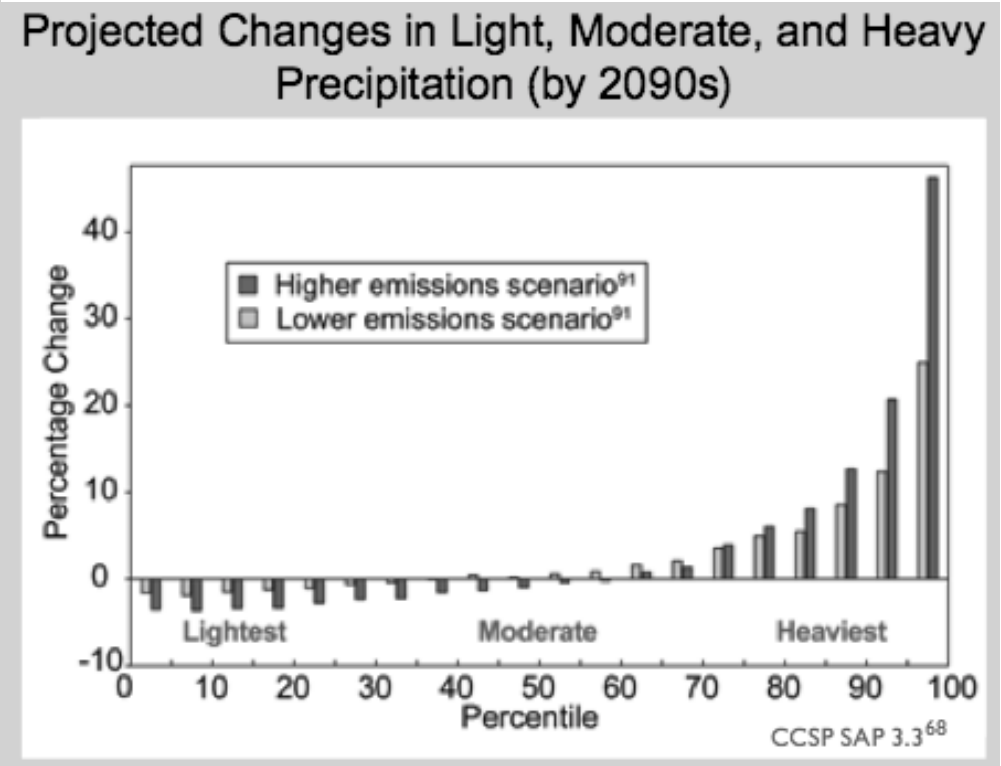
Do forests prevent flooding?

- A recent study says **yes**: Bradshaw et al., *Global Change Biol.* **13**, 1-17 (2007)
  - Analyzed broader scale data and found deforestation explained 14% of floods
  - They predict that decreasing forest area by 10% would increase flood frequency 4-28% and duration 4-8%

Are heavy rain events increasing?



Very heavy events have been increasing



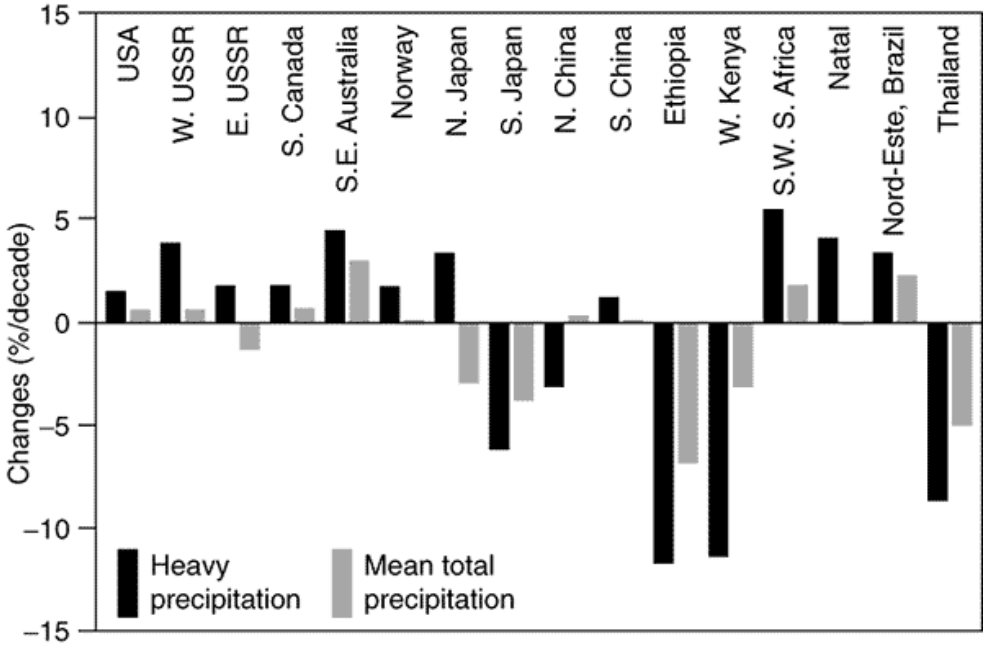
And heavy precipitation events in the US are **projected** to get worse

Are heavy rain events increasing?

Thus far, the changes are pretty small, but suggestive

Examples of observational results in the scientific literature that suggest an increase on the frequency of heavy rain events.

Note: places where heavy precipitation isn't increasing are places where the mean precipitation is decreasing



Are floods increasing?

Trends in the frequency of flood events are difficult to quantify because:

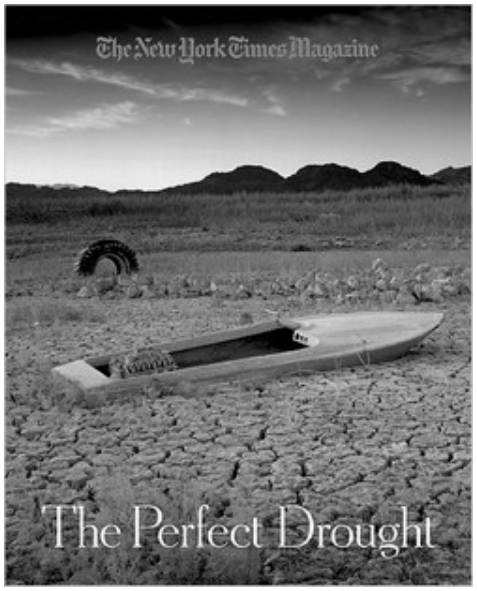
1. River configurations and land use are continually changing

2. Hourly rainfall data are available only over limited regions of the globe – the data are expensive and there are restrictions on their use

3. Rare events, especially when considered season-by-season – with rare events, it's difficult to rule out the possibility that random chance, not global warming, is to blame ("statistical significance").

The latter two are true for heat waves too

Defining drought



Months or years with below normal water supply.

Usually from below average precipitation.

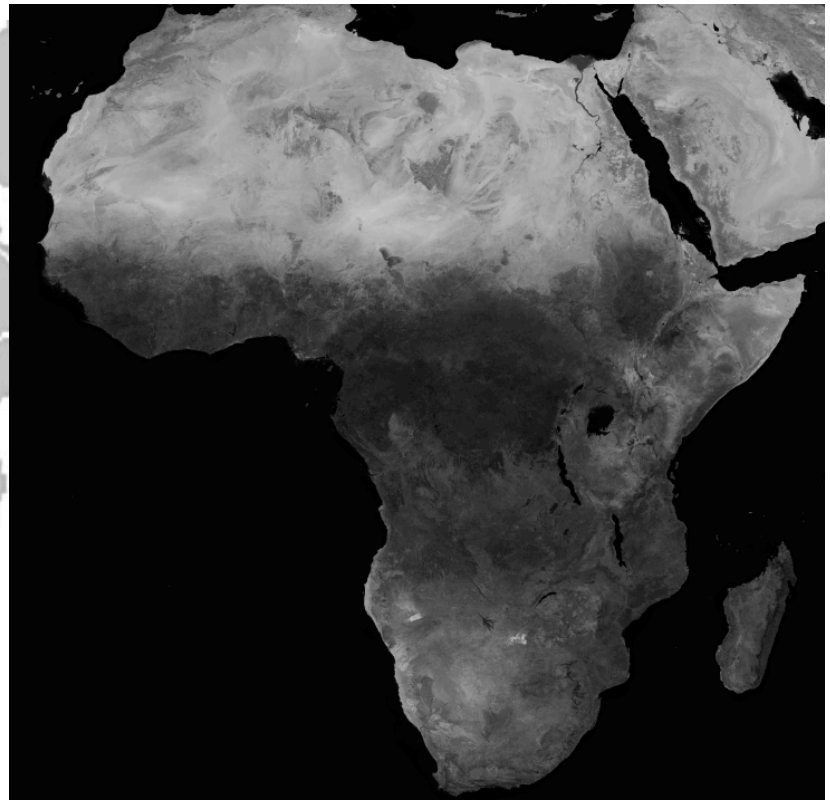
The definition is not quantitative.

Specific criteria (e.g., how long, how severe…) need to be specified.

Other factors such as population growth can create deficiencies in water supply

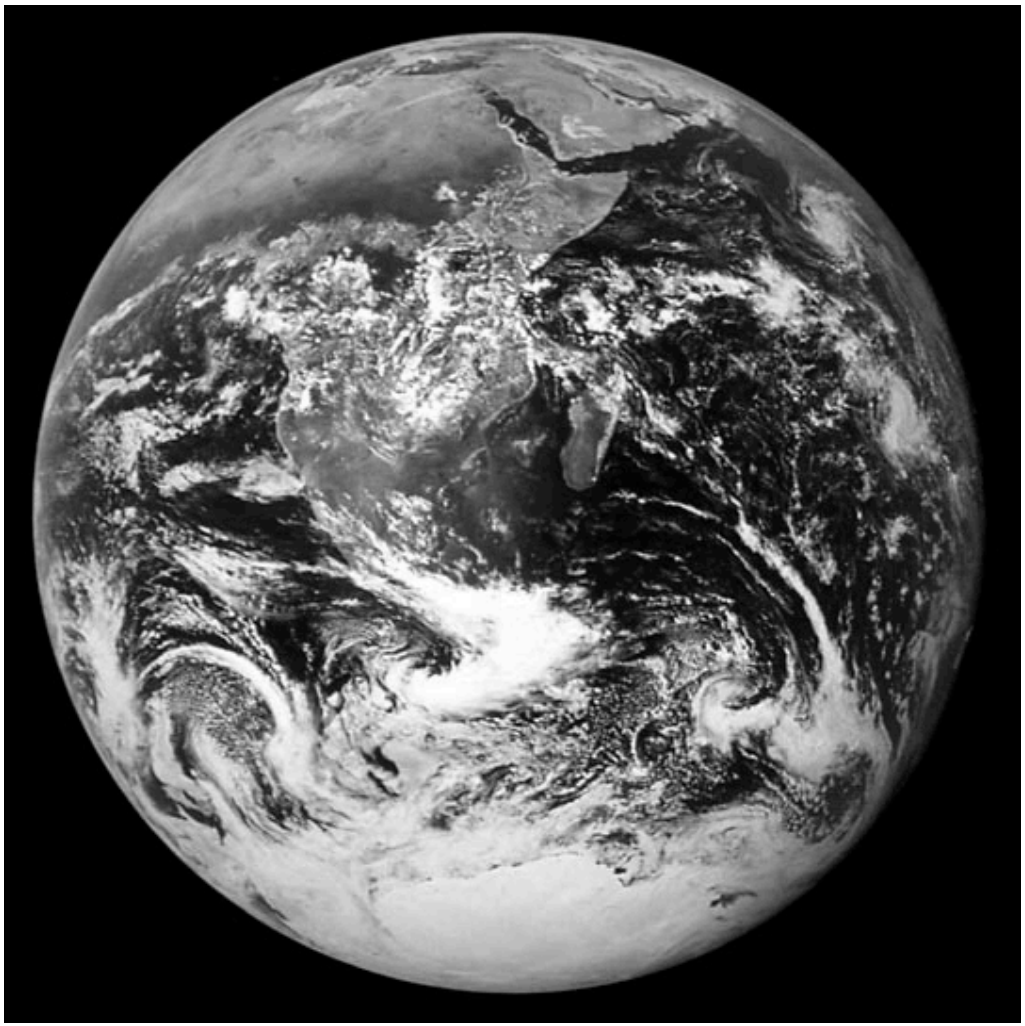
(ie Lake Chad)

Which way will the Sahel go?

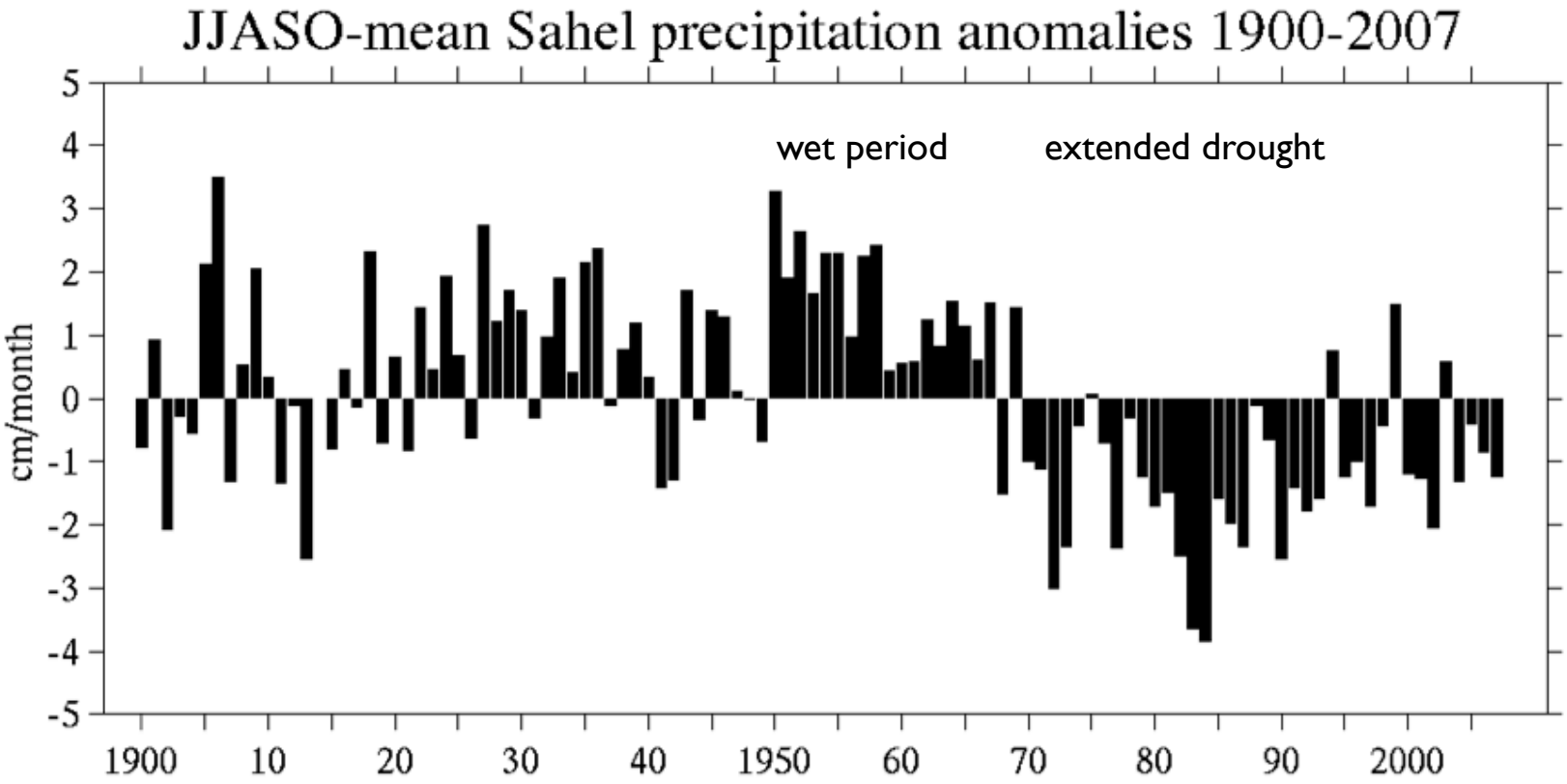


The Sahel is in between
desert and the region drenched by the African monsoon

The African Monsoon in full swing

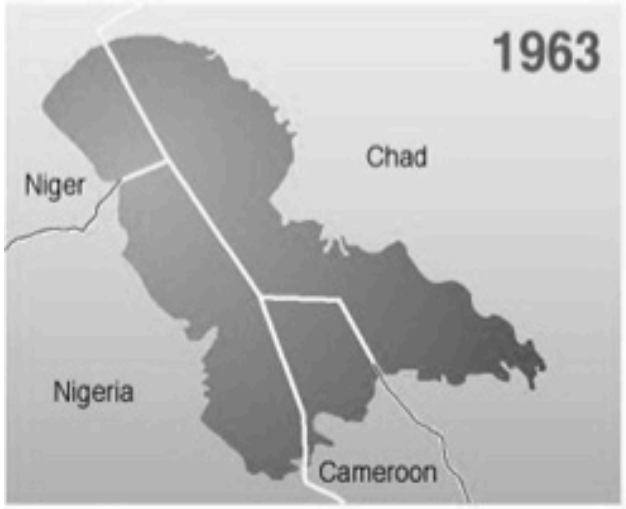


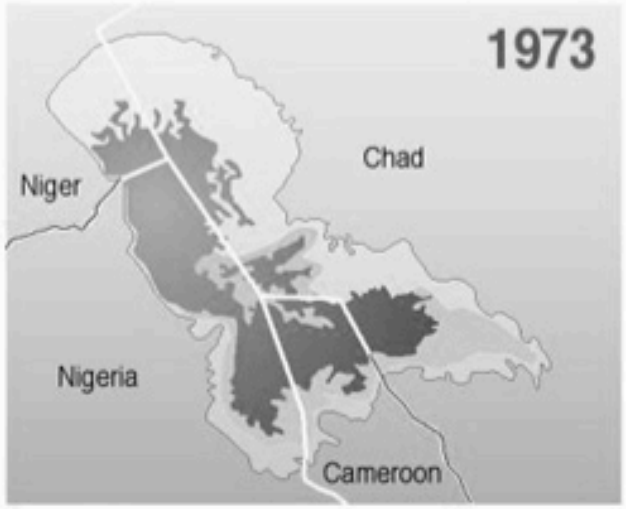
Which way will the Sahel go?

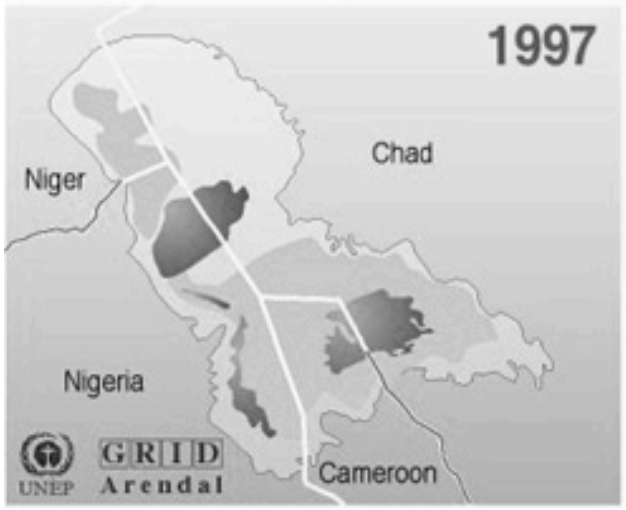


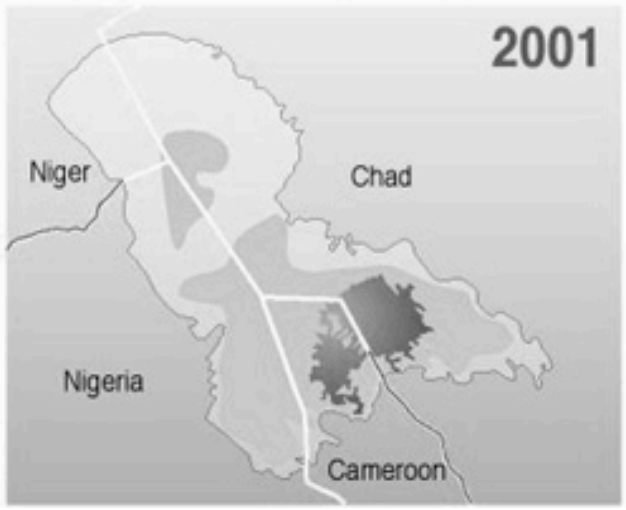
The shift around 1970 is believed to be due to changing sea surface temperature patterns in the tropical Atlantic (possibly driven by aerosol forcing).

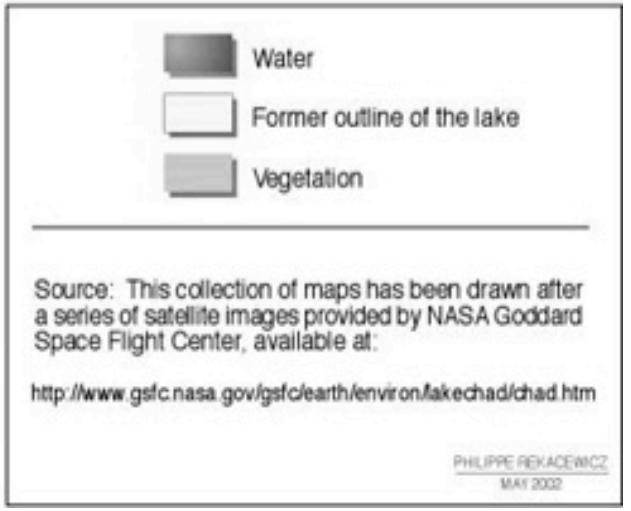
The disappearance of Lake Chad



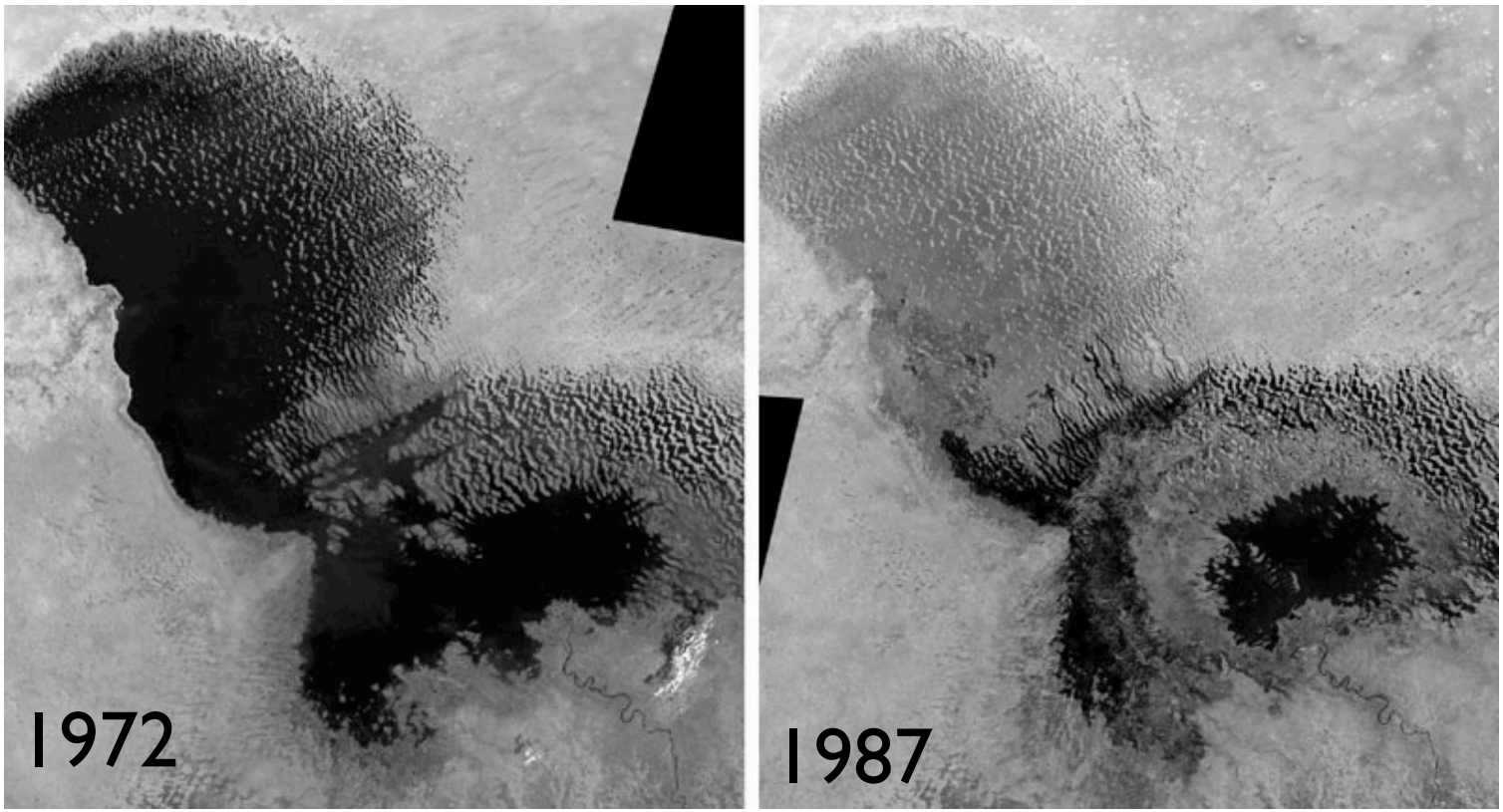






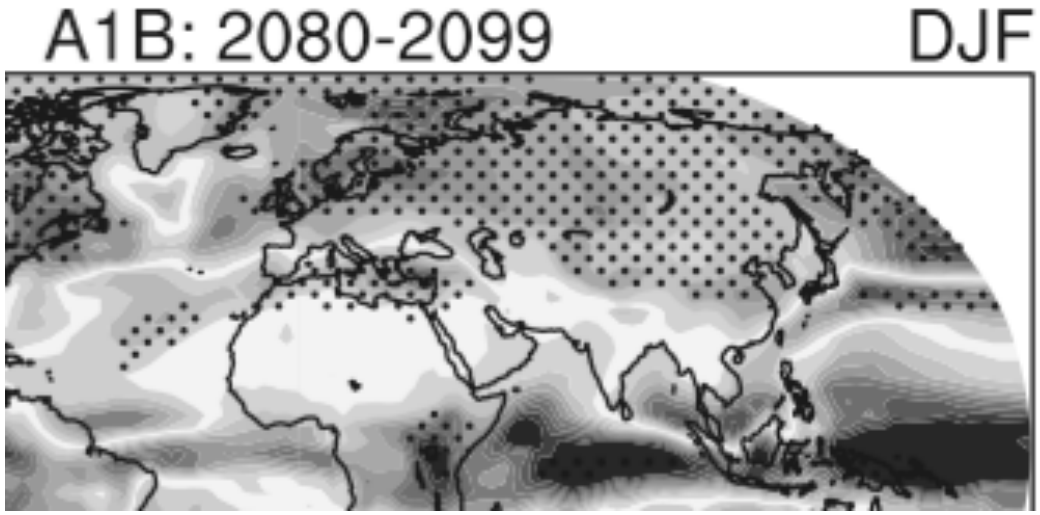


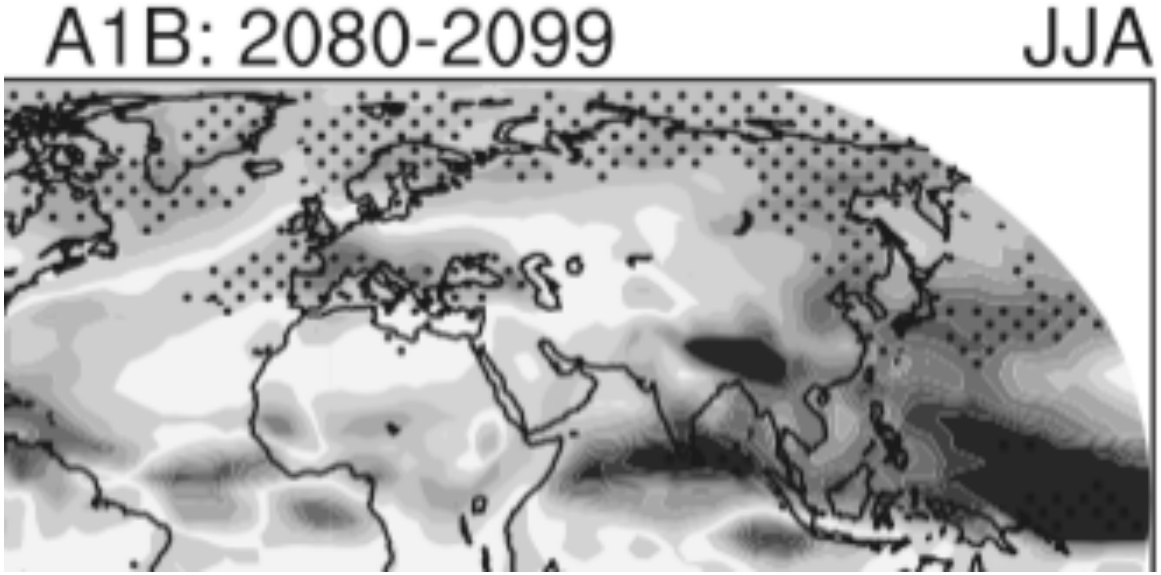
Lake Chad



Which way will the Sahel go? Climate model predictions

Drier in the winter

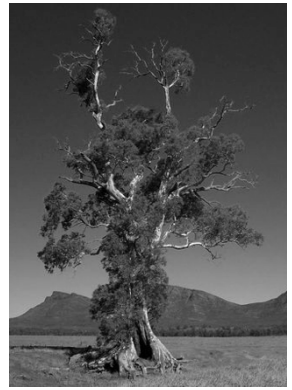


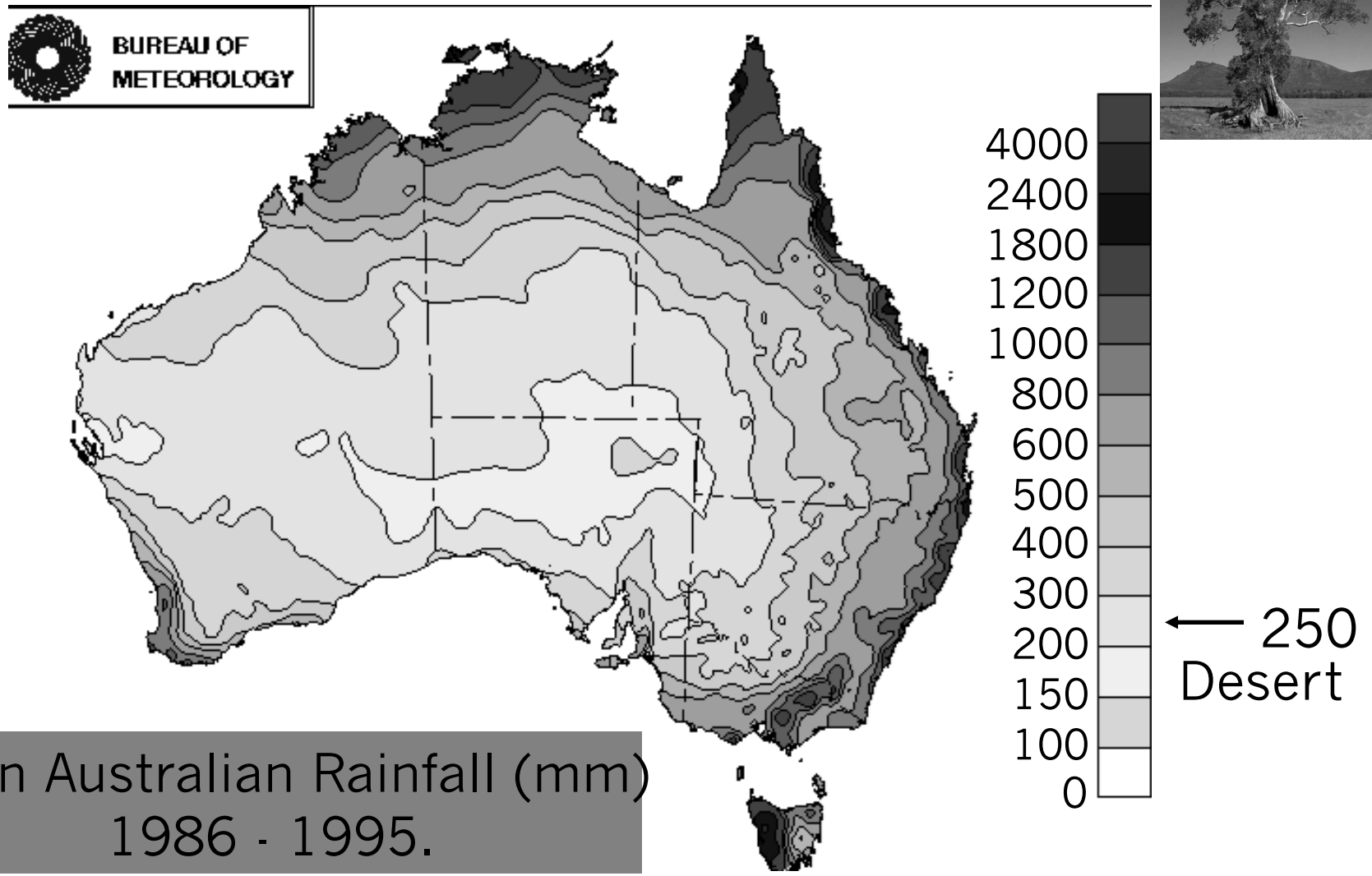


Wetter in the summer

But different models give very different answers: this is the average.

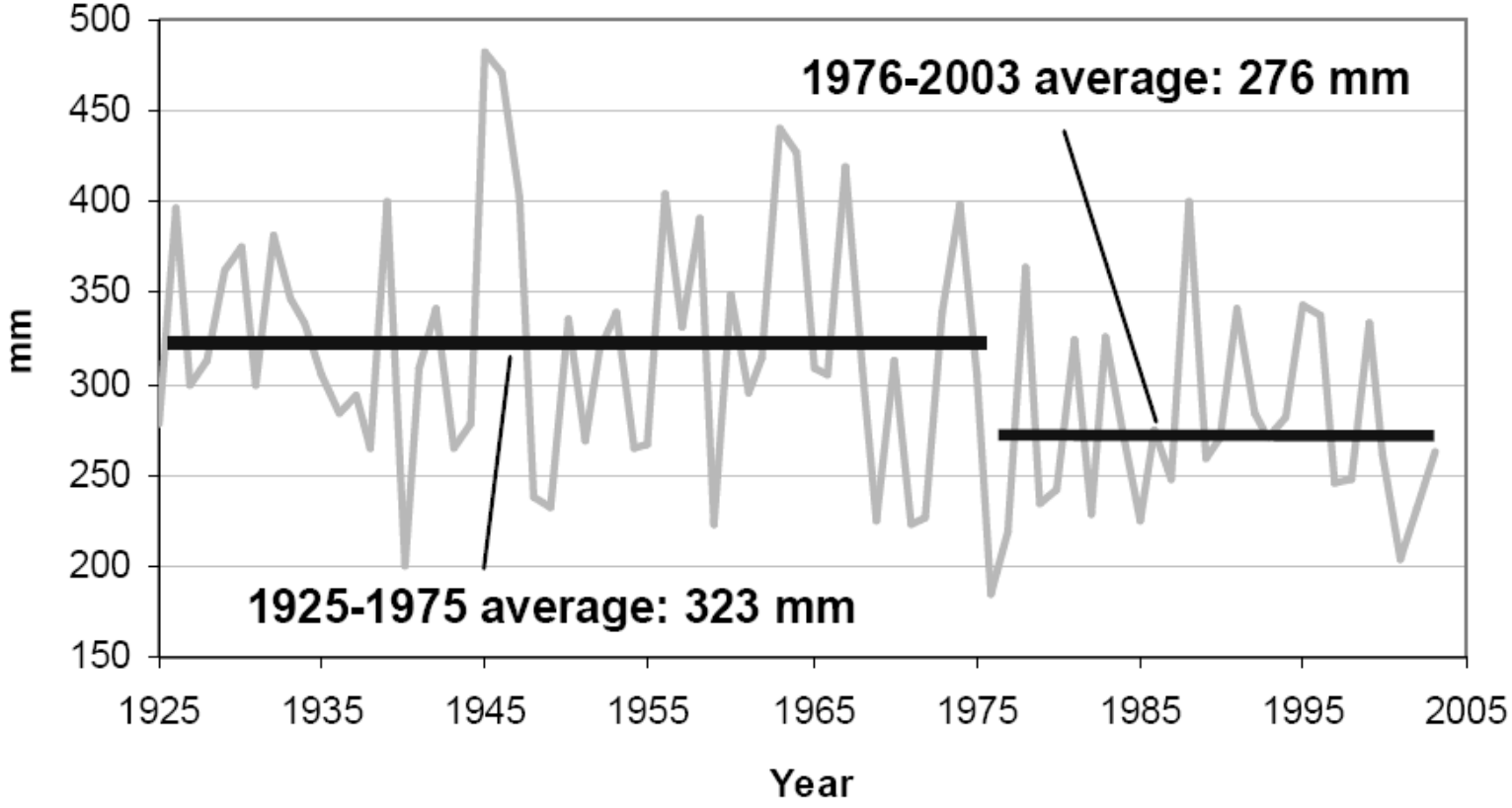
The drying of southern Australia





Mean Australian Rainfall (mm)
1986 - 1995.

The drying of southern Australia



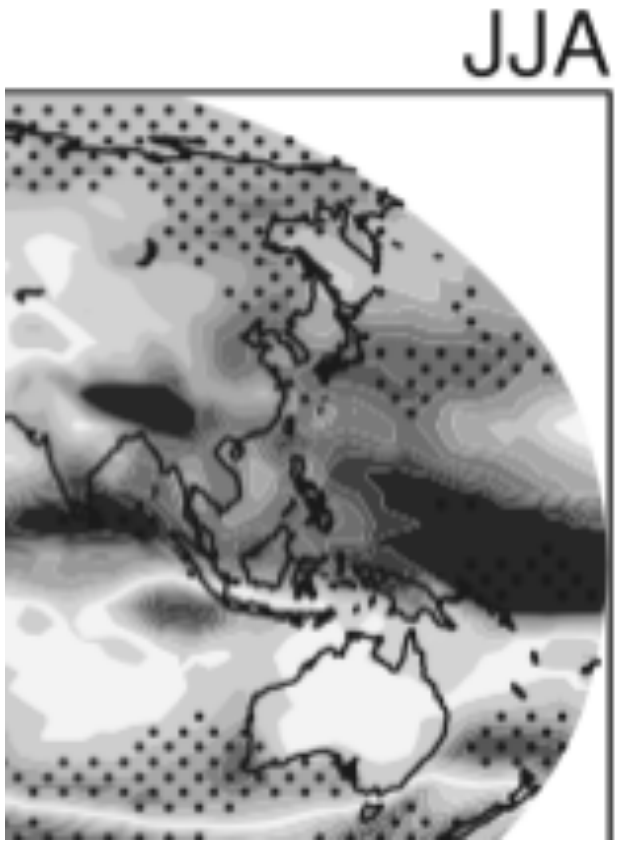
The decline in rainfall in south-western Australia since the 1960s.
Source:http://www.ioci.org.au/publications/pdf/IOCI_Notes_Series2.pdf.

The drying of southern Australia

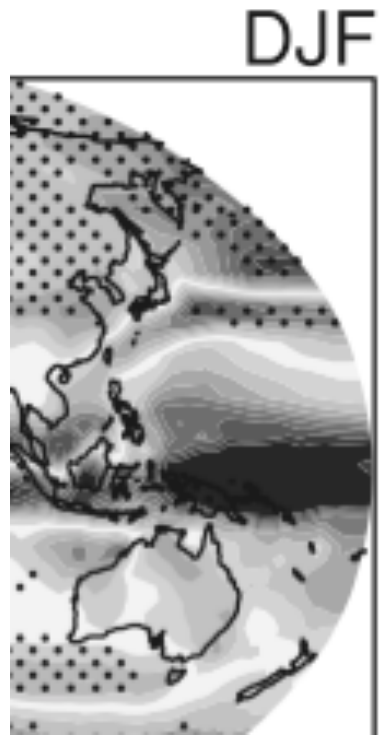
Other factors that may be playing a role:

- winter storms are, on average, a bit further south than they used to be – this is due to the ozone hole!
- increased water demand due to rising temperatures
- increased water demand due to population growth

The drying of southern Australia: climate model predictions



West: drier in summer.
East: Wetter in Summer

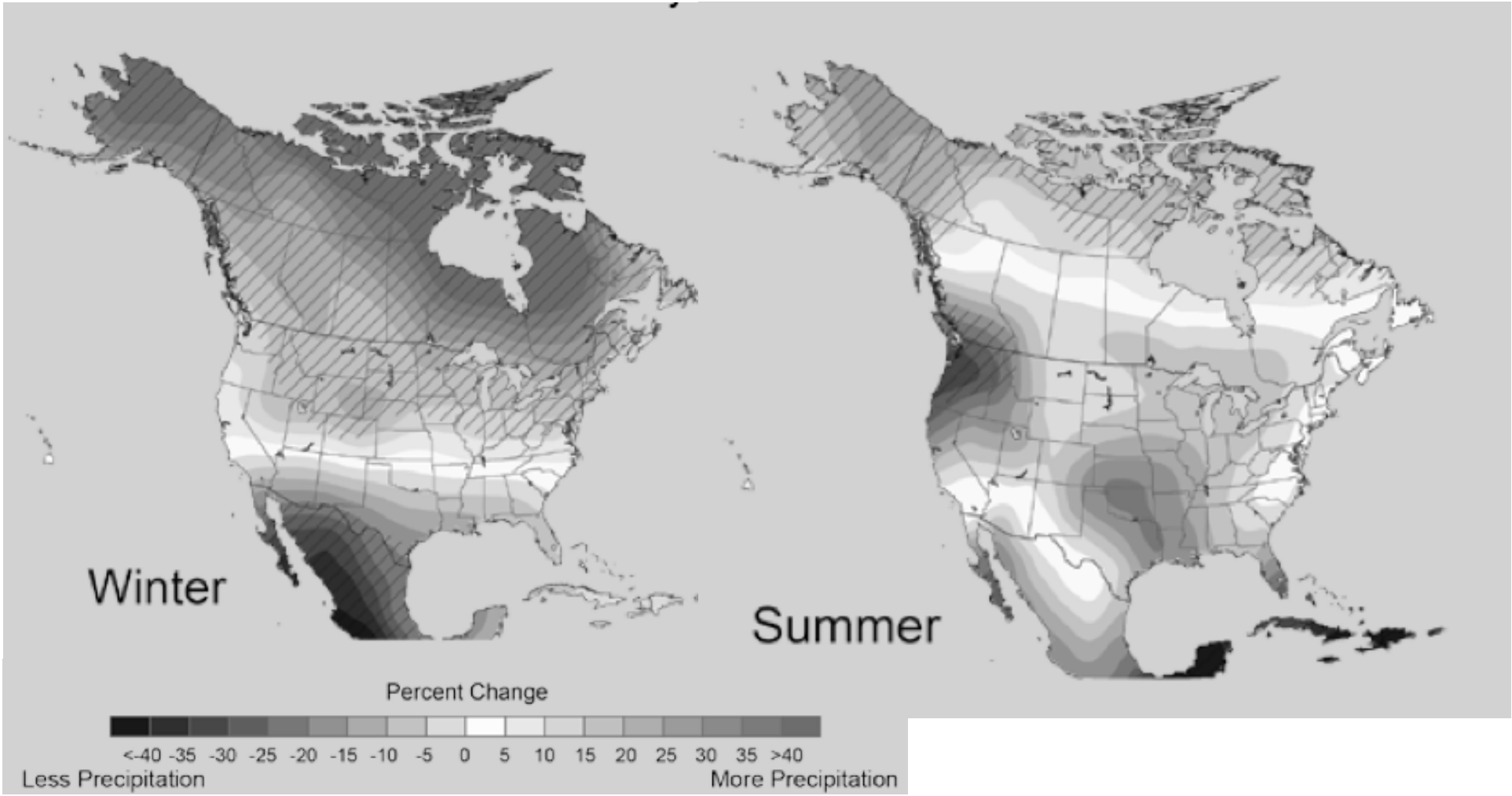


Everywhere drier in winter

Again, lots of disagreement among climate models

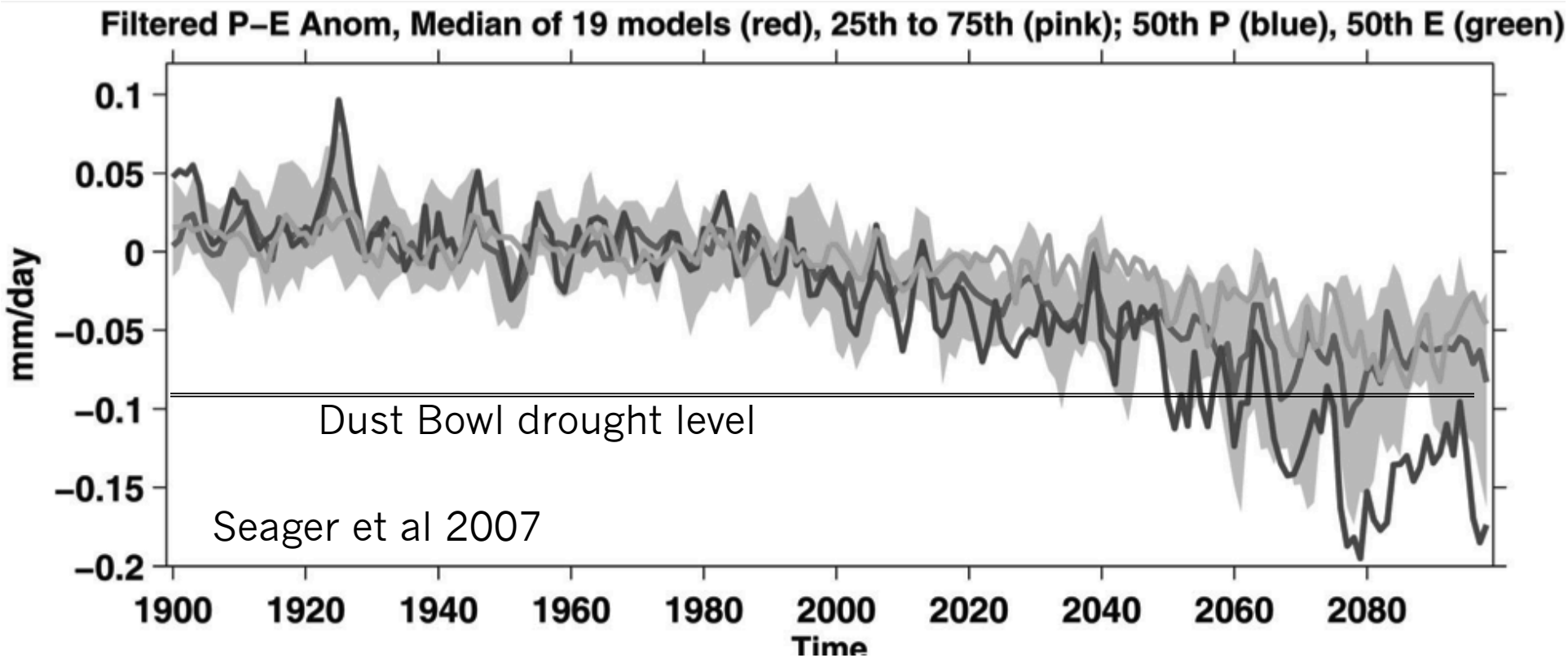
US Predictions

- US predictions



Some Additional Predictions

- Southwestern North America predicted to dry dramatically
  - As bad as the Dust Bowl by 2060 in some models



Precipitation changes

- Some increase in global precipitation might be expected just because there's more water vapor in the air. But changes in atmospheric circulation can have a big impact.
- A lot of the expected changes in precipitation are due to shifts in convergence zones or monsoons.
- The subtropics as a whole will probably get less precipitation as more of their moisture gets transported to the deep tropics and the convergence zones there.

Shifts are Hard to Predict

- **Shifts** in rising motion or midlatitude storms could happen **due to**:
  - Differences in **forcings** in different regions
    - E.g., aerosols cooling the oceans in places
  - Differences in **feedbacks** in different regions
    - E.g., cloud responses
  - Changes in **ocean currents**
    - A natural example that messes with rain patterns is **El Niño**