Global warming and Extremes of Weather

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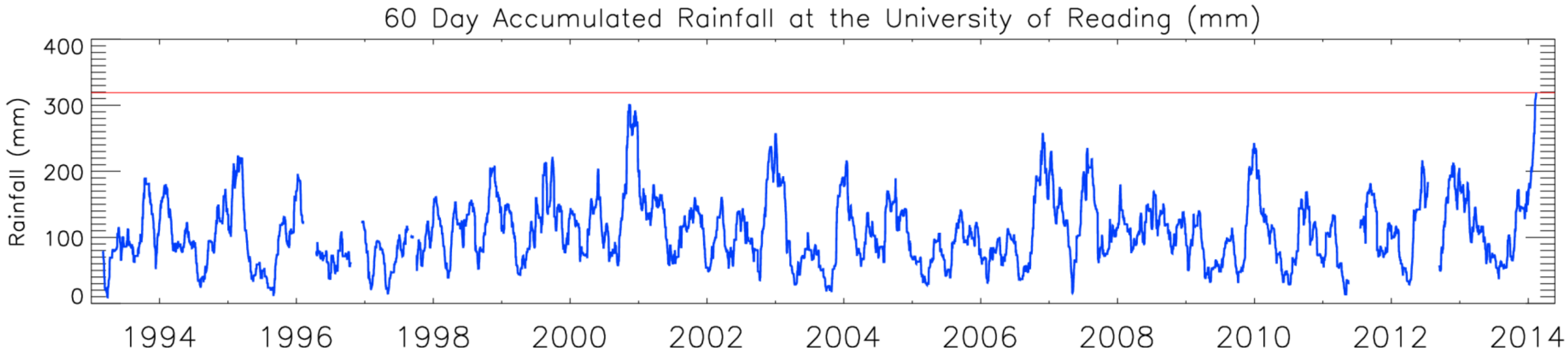
Extreme weather climate change

- Recent extreme weather focusses debate on climate change
- Can we expect more or worse in the future?
- First we need to establish what generates our weather extremes



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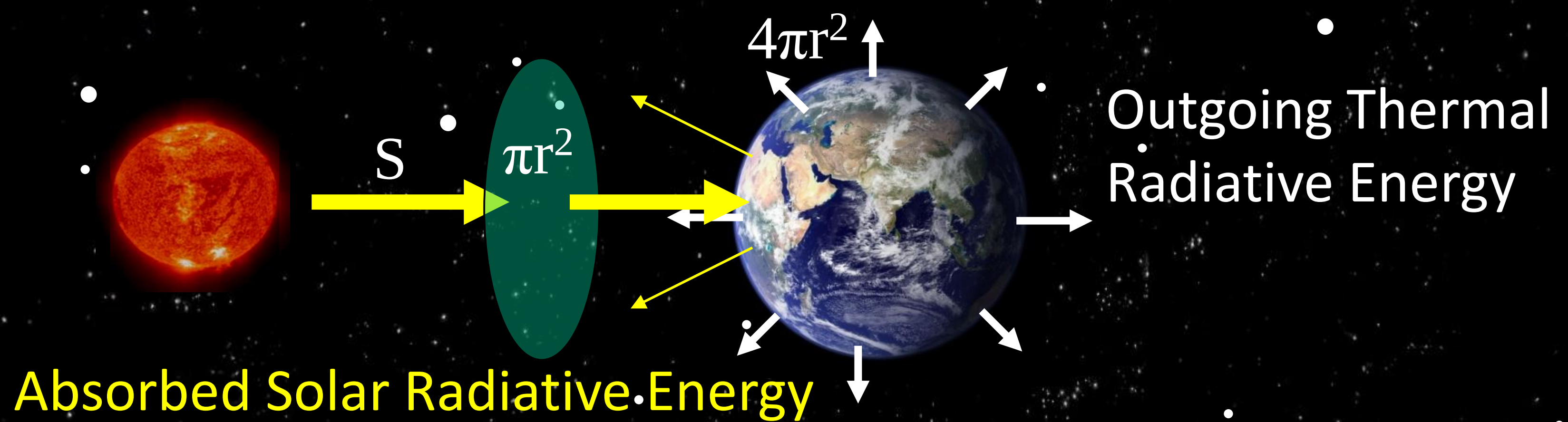
1) What determines our climate?

Earth's energy balance in space

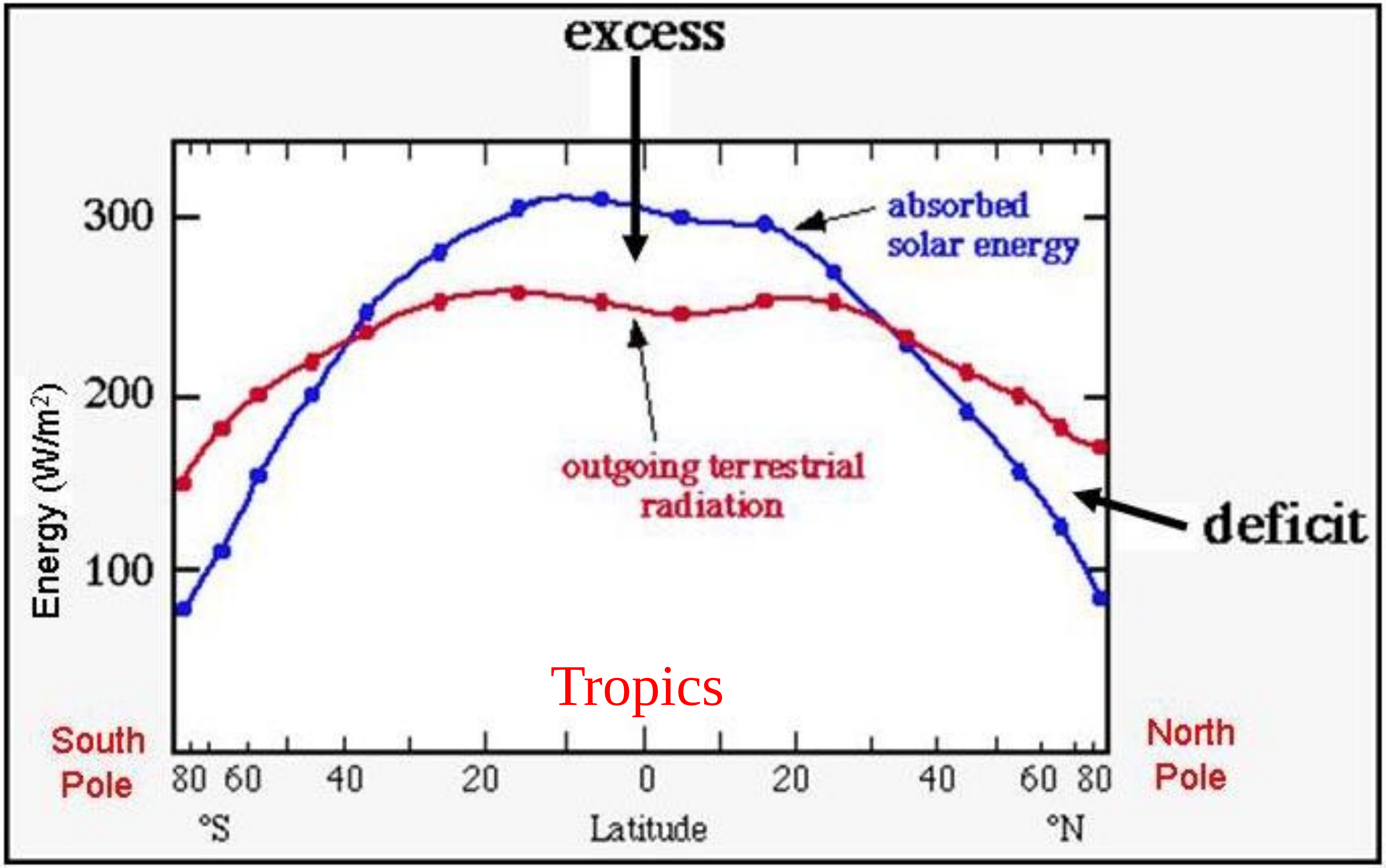


- There is a balance between the absorbed sunlight and the thermal radiative cooling of the planet
- Without the greenhouse effect, this balance would occur at a frigid global temperature of –18°C

Fourier (1824); Tyndall (1858); Arhenius (1896); Lacis et al. (2011)

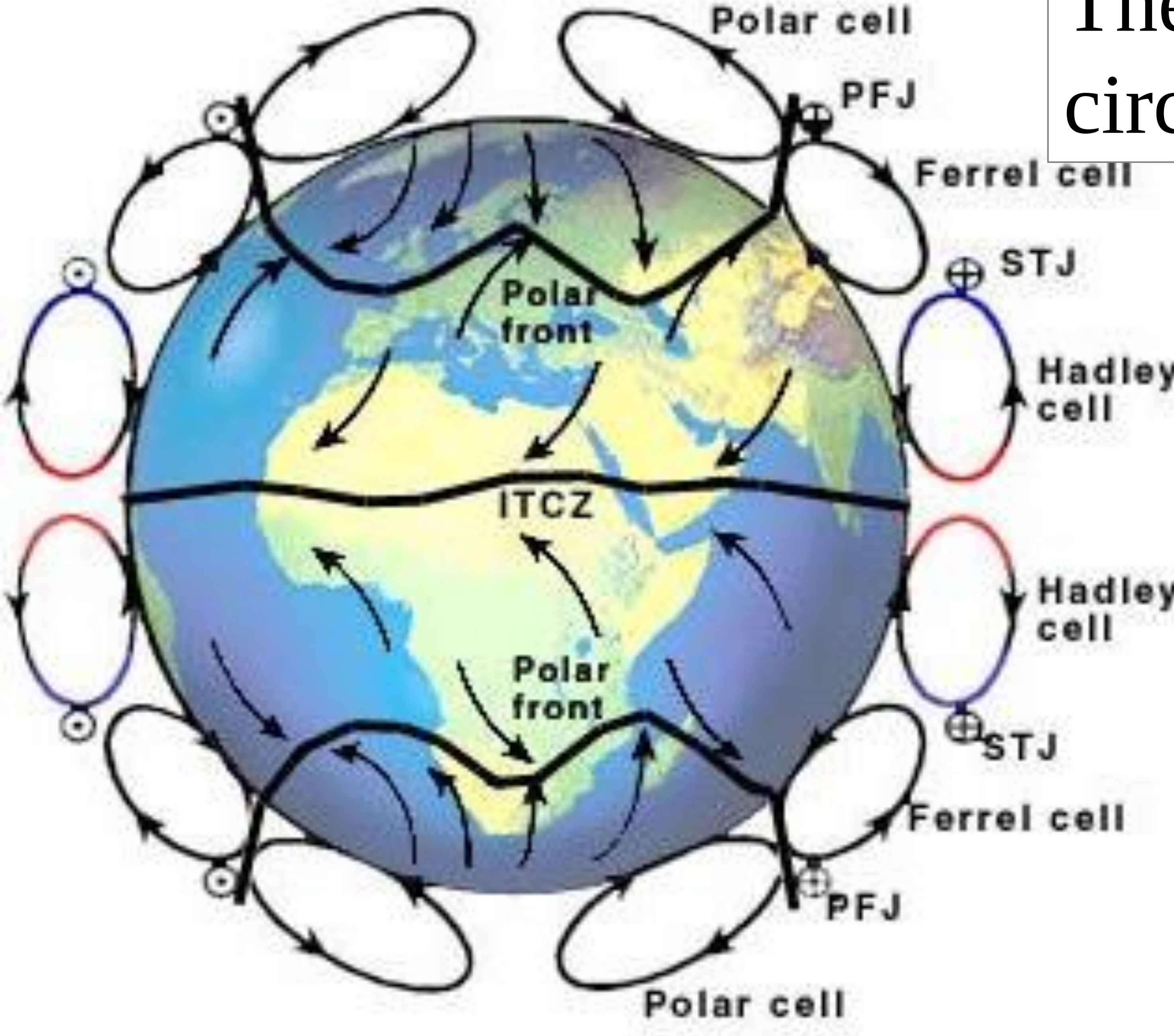
The Net Radiation Balance

Why don't the tropics get warmer and warmer and the poles colder and colder?

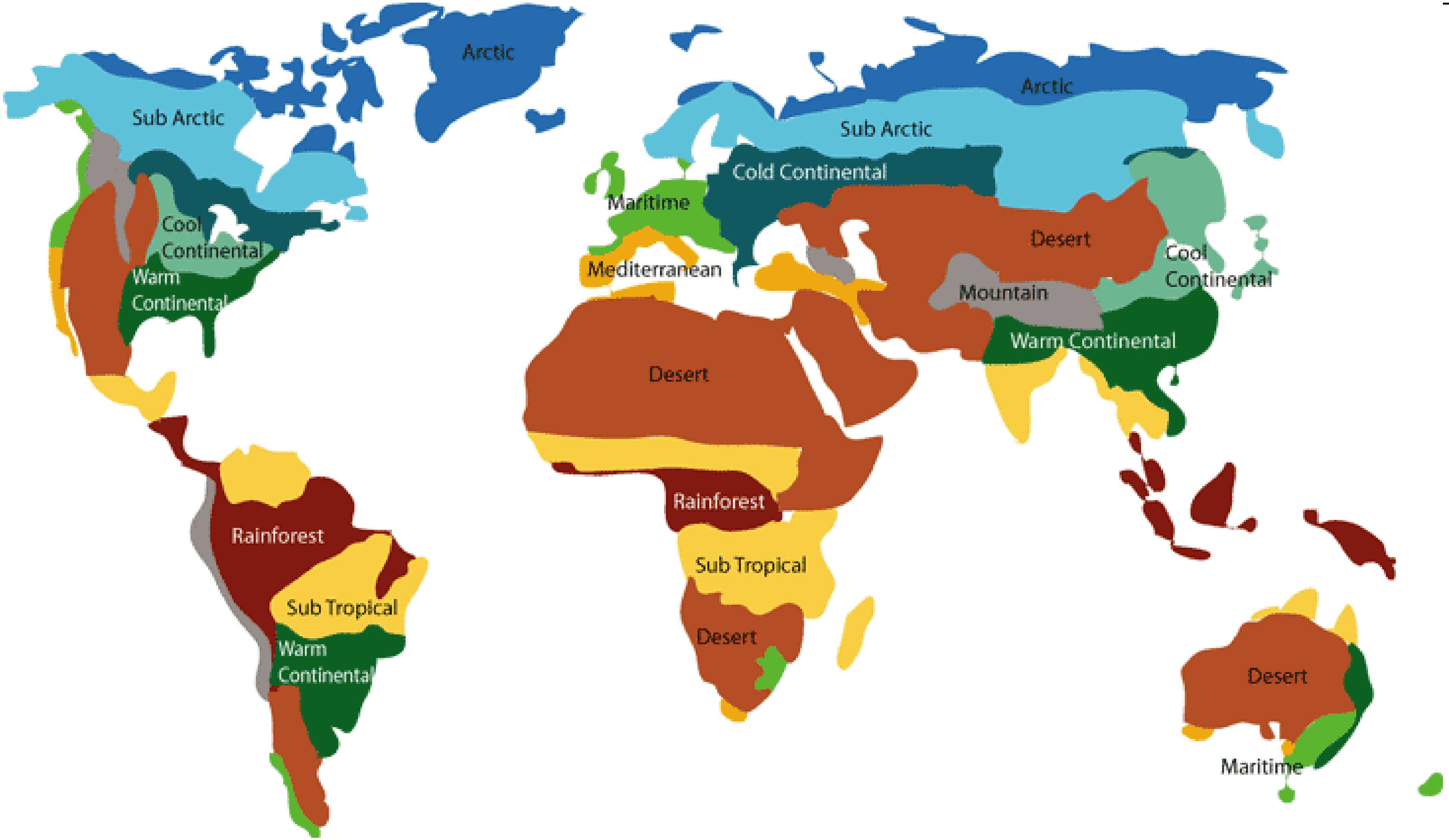


CLAUS movie

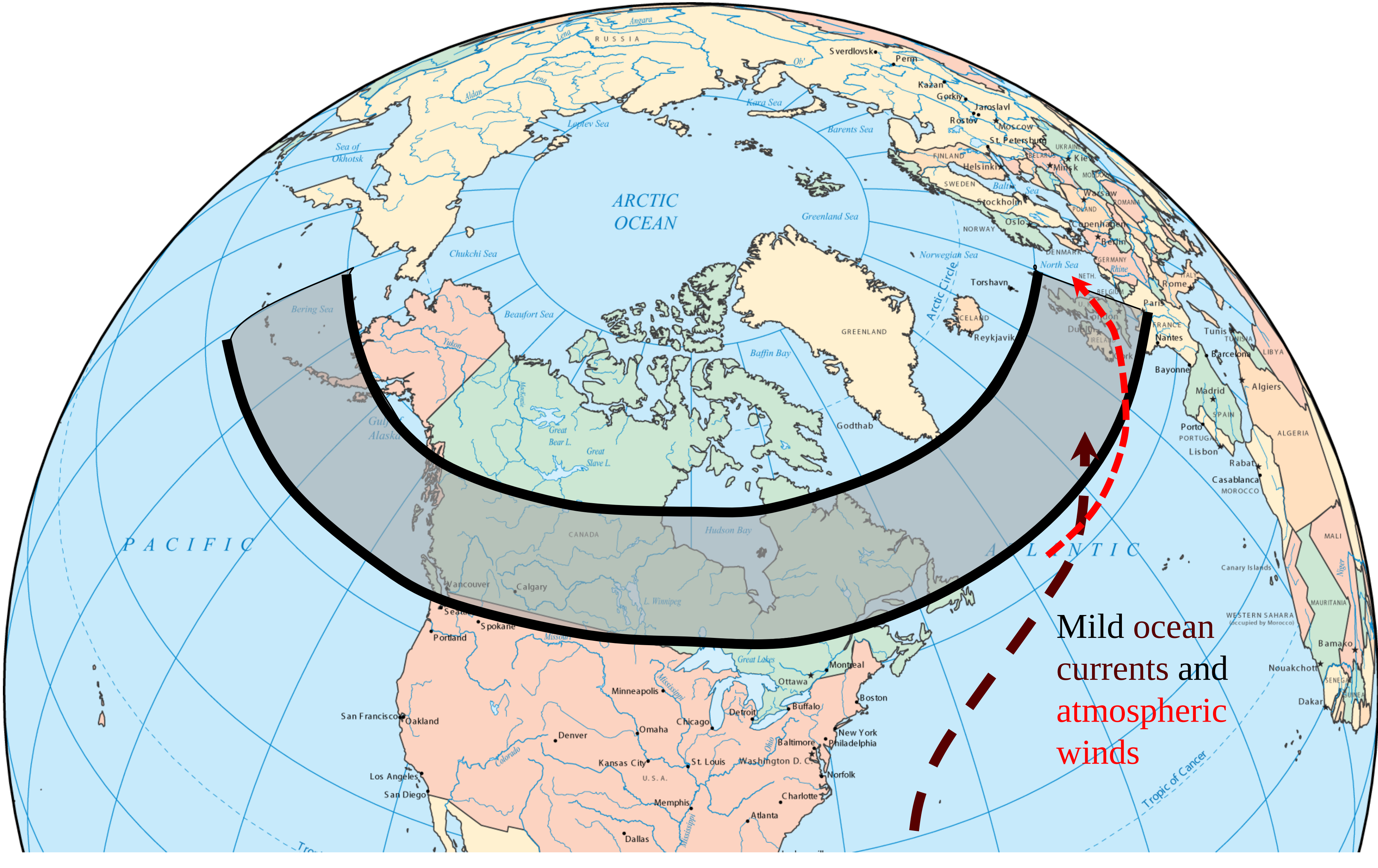
The global circulation



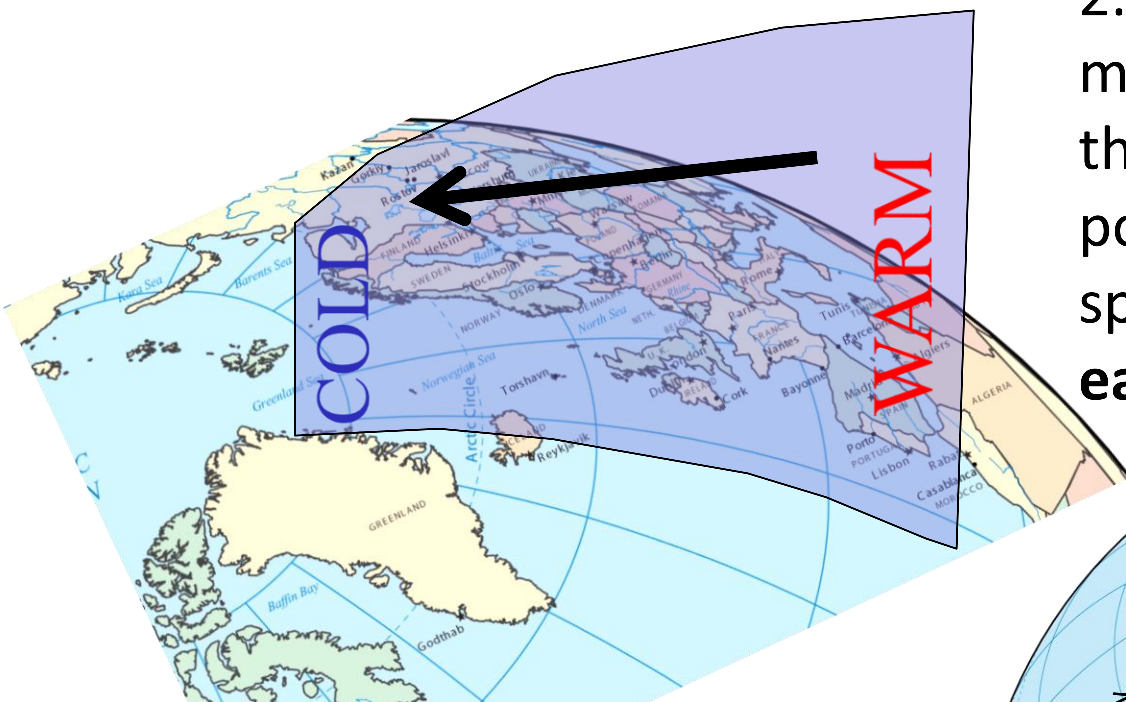
Climate Zones



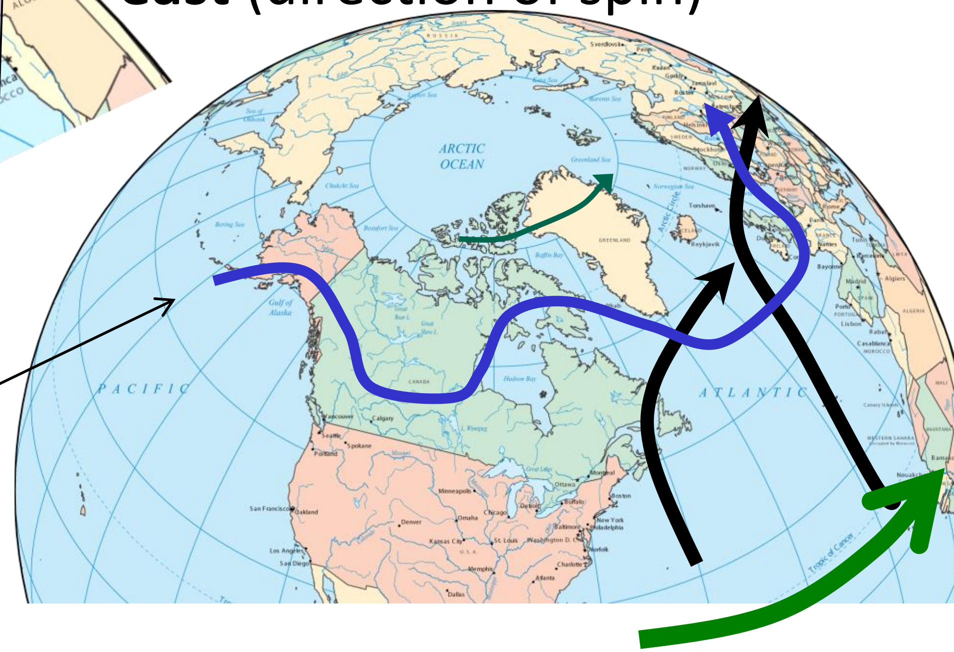
The UK's weather is sensitive to the circulation of the atmosphere and ocean



1. Air is warmer closer to the tropics (air expands) than at the poles (air contracts). This generates a **poleward flow of air** high up in the atmosphere

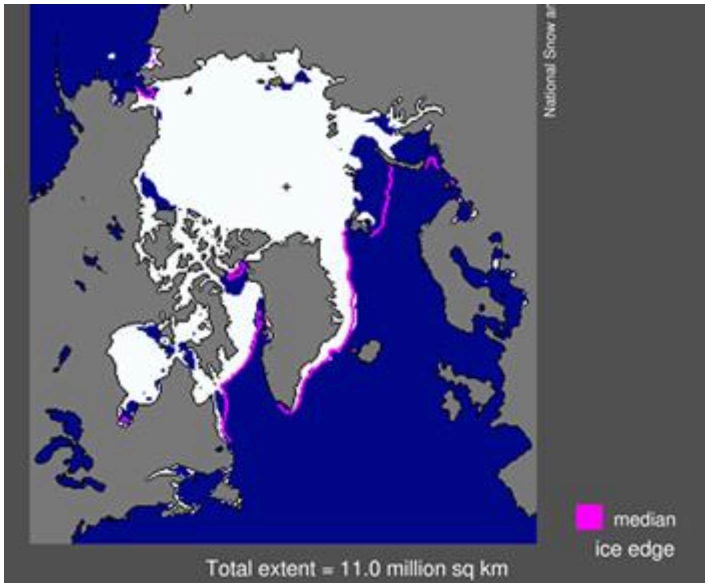


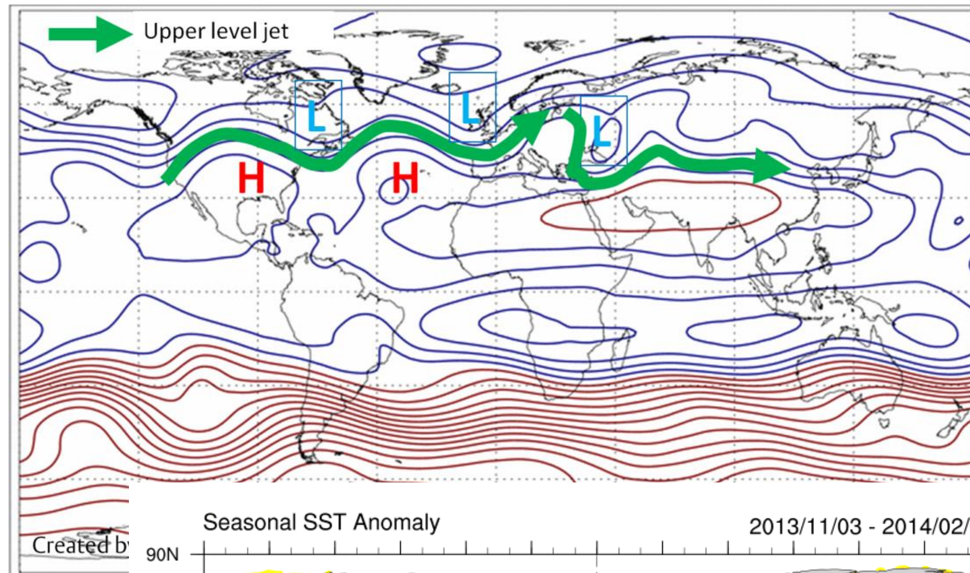
2. The Earth spins: the surface moves quicker near the equator than at higher latitudes. So poleward-flowing air retains this speed and is deflected to the **east** (direction of spin)

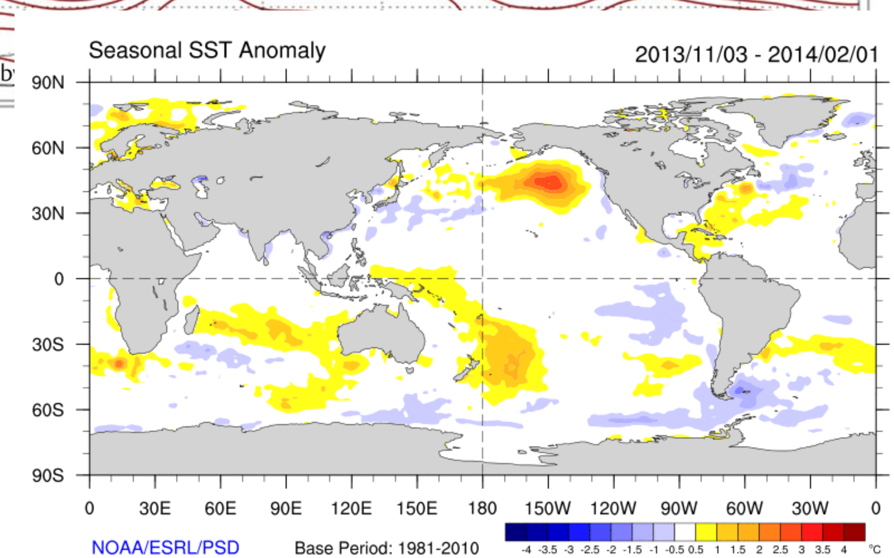


3. This high altitude (5-7km) fast moving ribbon of air is called the jet stream. It steers weather systems over or away from the UK.

A number of factors can influence the jet stream and therefore extreme weather







4. Changes in this temperature difference between equator and pole can alter the position and strength of the jet stream. This and other **natural** and **human-caused** effects influence our weather patterns and extremes.

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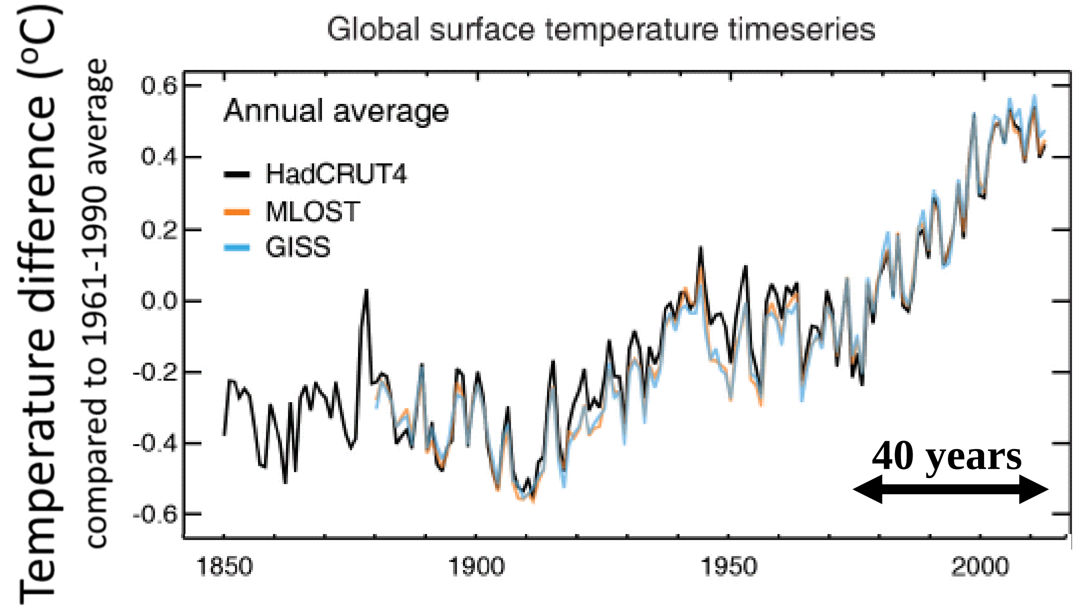
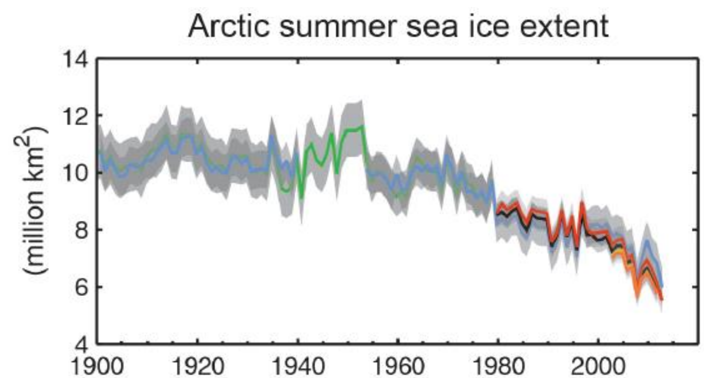
2) Is our climate changing?

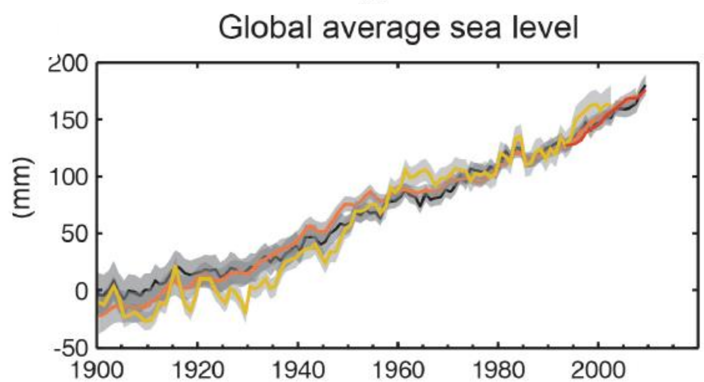
Evidence for current climate change

“Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.” IPCC (2013)



Top: Differences in global average surface temperature compared to the 1961-1990 average
Middle: Changes in the July-September average summer Arctic sea ice extent
Bottom: Changes in global average sea level compared with 1900-1905 average
Source: IPCC WGI (2013) SPM



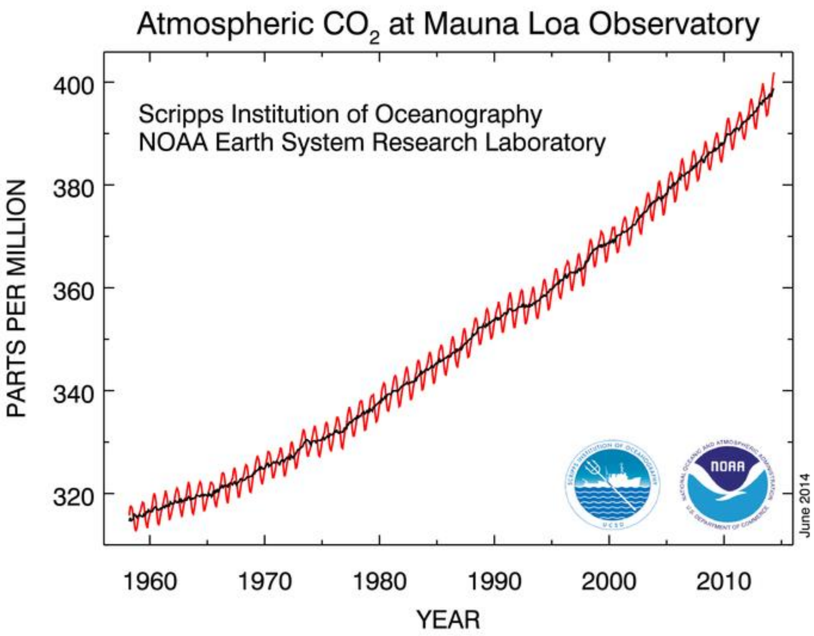


3)What is currently causing global warming?

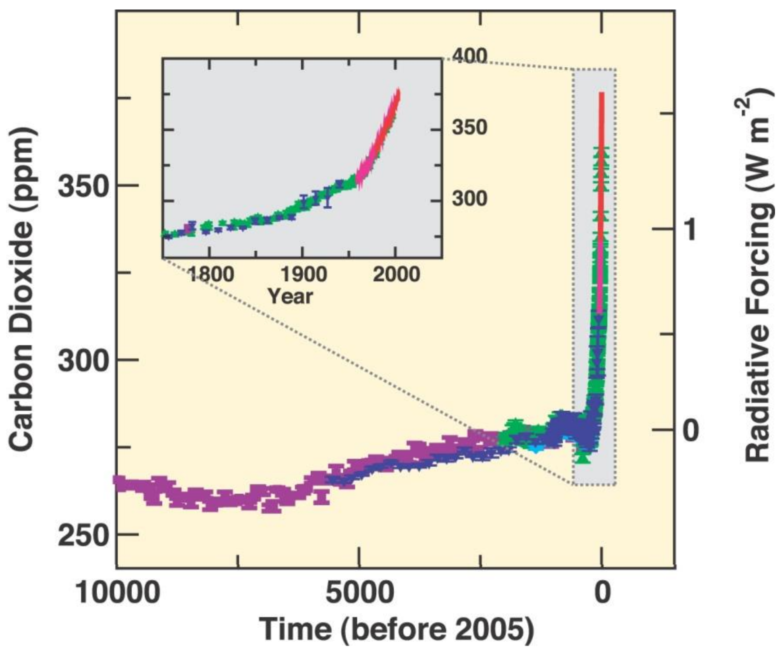
“Radiative forcing” of climate

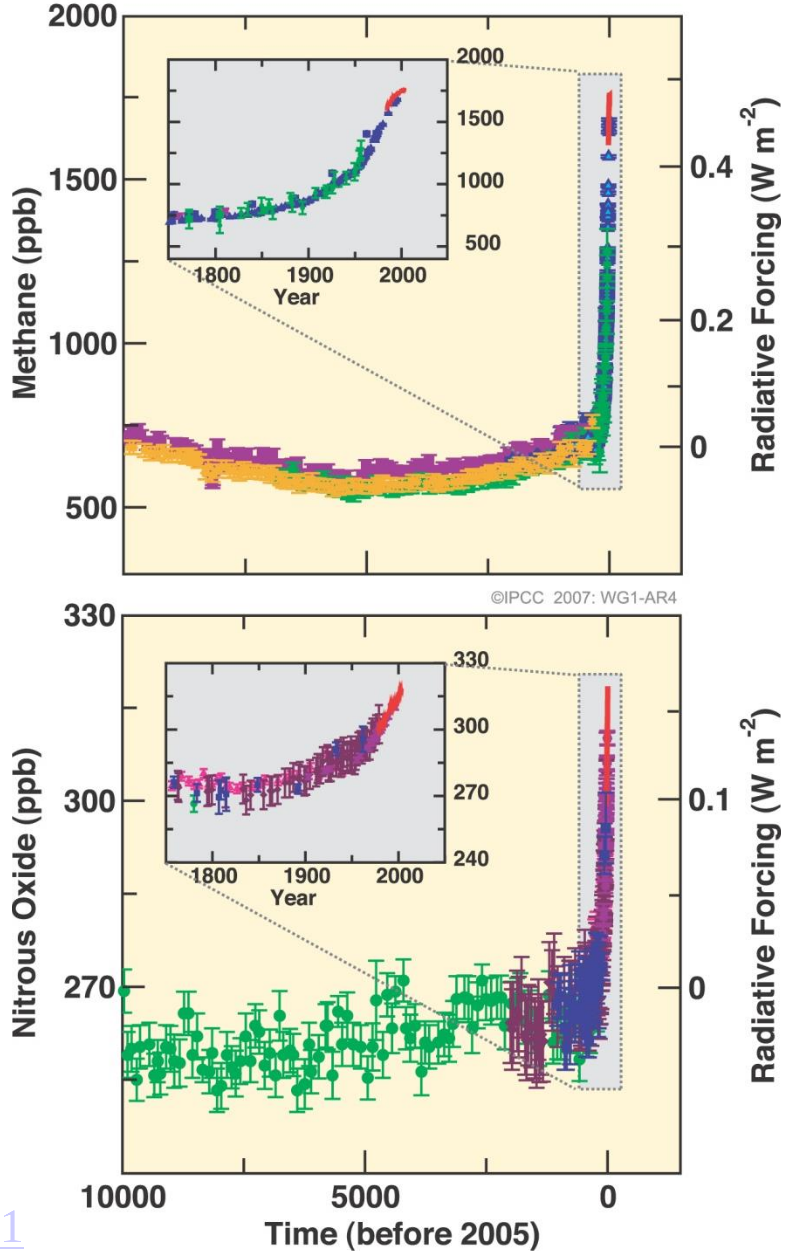
- Increases in greenhouse gases heat the planet by reducing how easily Earth can cool to space through infra-red emission
- Small pollutant aerosol particles cool the planet by reflecting sunlight
- If more energy is arriving than leaving the planet, the planet should heat up…

Currently energy is accumulating at rate equivalent to 300 billion electric heaters (1 kilo Watt) spread over the globe *(link)*



Changes in greenhouse gases from ice core and modern data



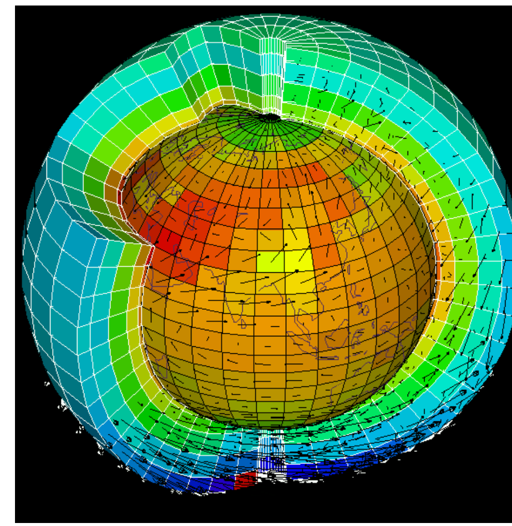


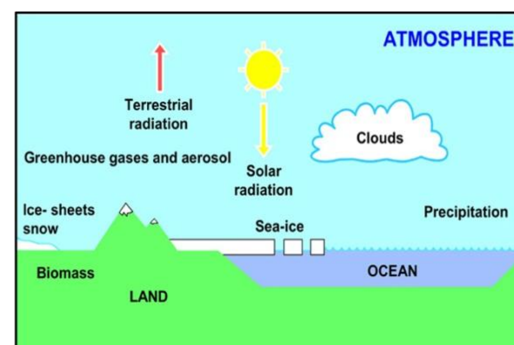
Carbon dioxide, **methane** and **nitrous oxide**

IPCC (2007) Summary for Policy Makers Fig. SPM.1

Computer simulations of climate

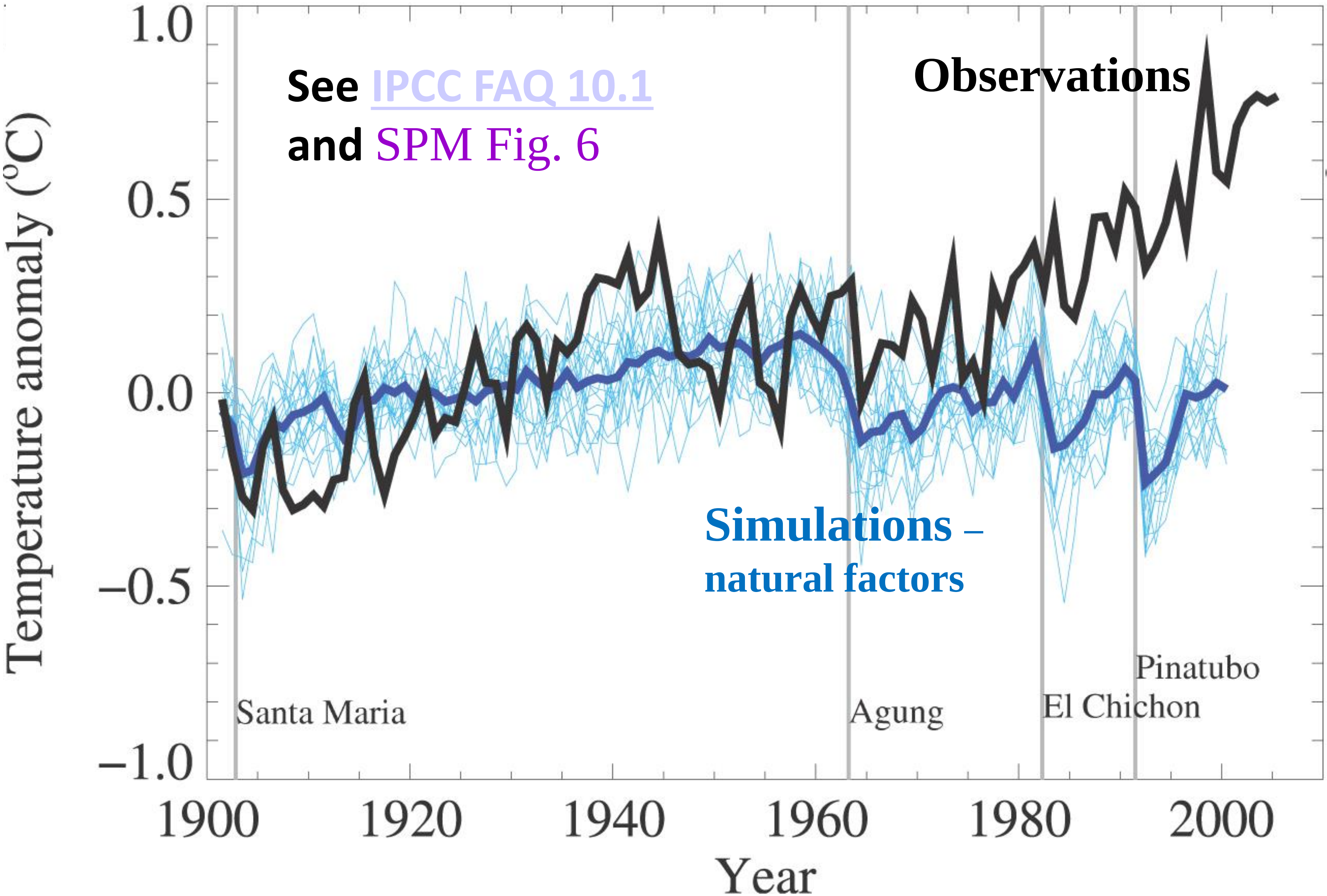
- Complex computer simulations of climate have been developed based on physics and observations
- These simulate weather patterns, ocean circulation, vegetation, chemistry, …
- We use these to make projections of the future
- They are also used to conduct experiments…
  - How much of recent warming is explained by natural effects?



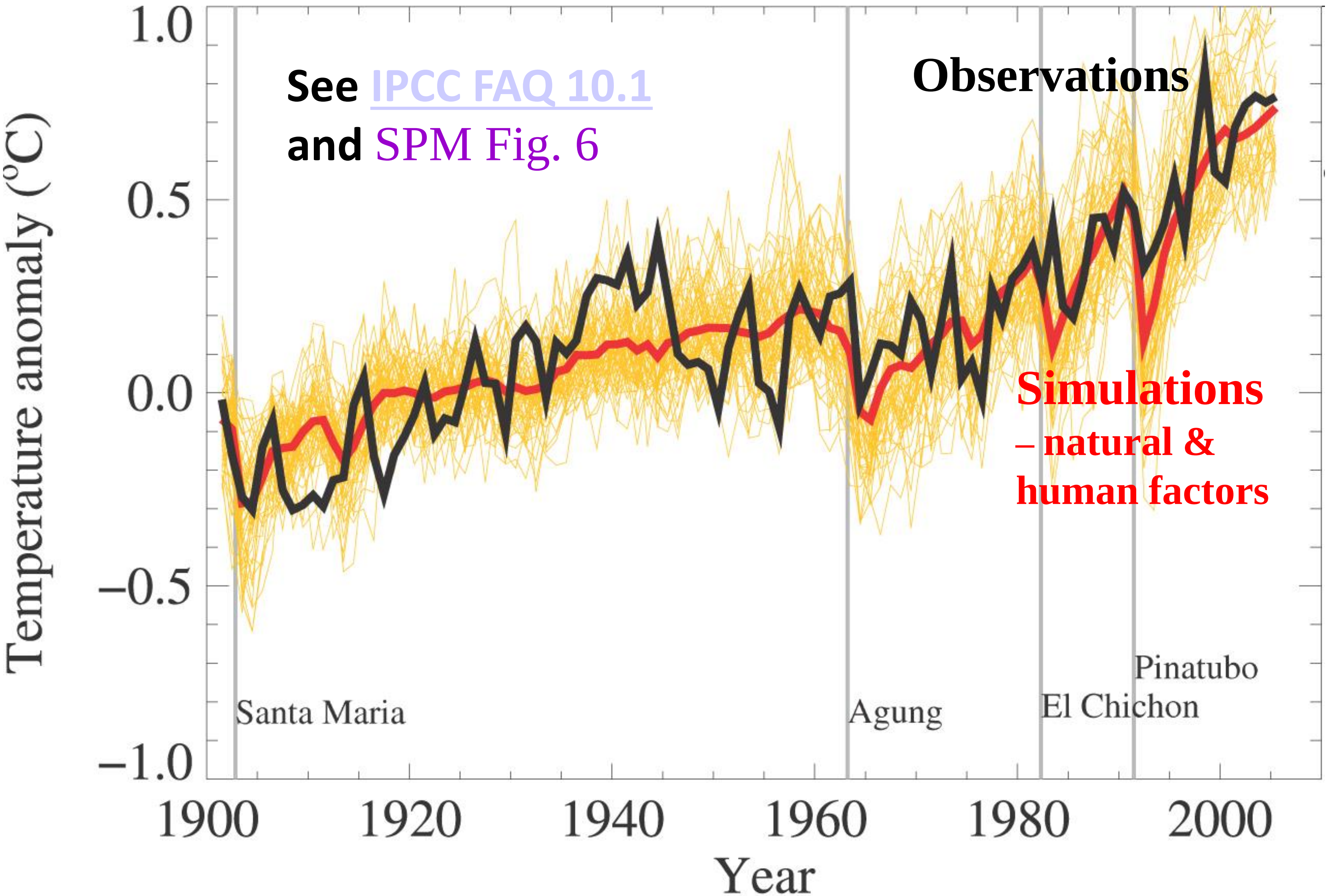


Met Office Hadley Centre

Recent warming cannot be simulated when only natural factors are included

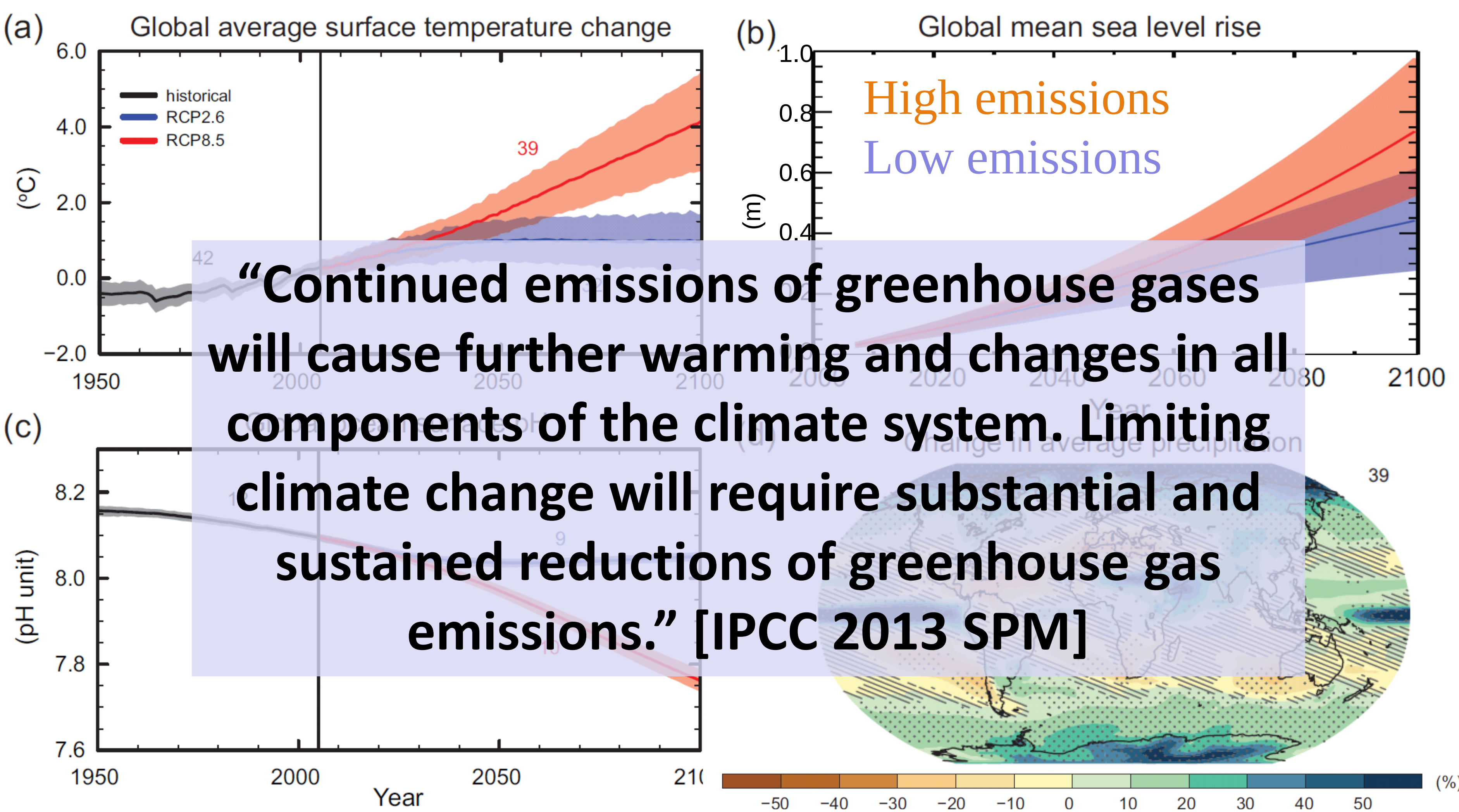


Recent warming can be simulated when man-made factors are included



4) What are the predictions for the future?

Future projections to 2100 from climate models



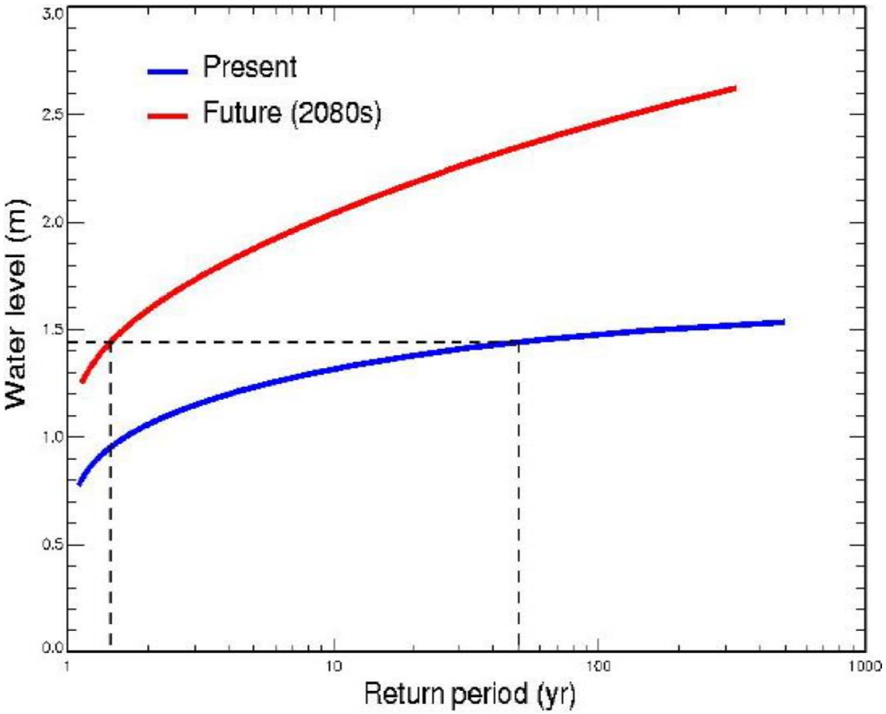
"Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system. Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions." [IPCC 2013 SPM]

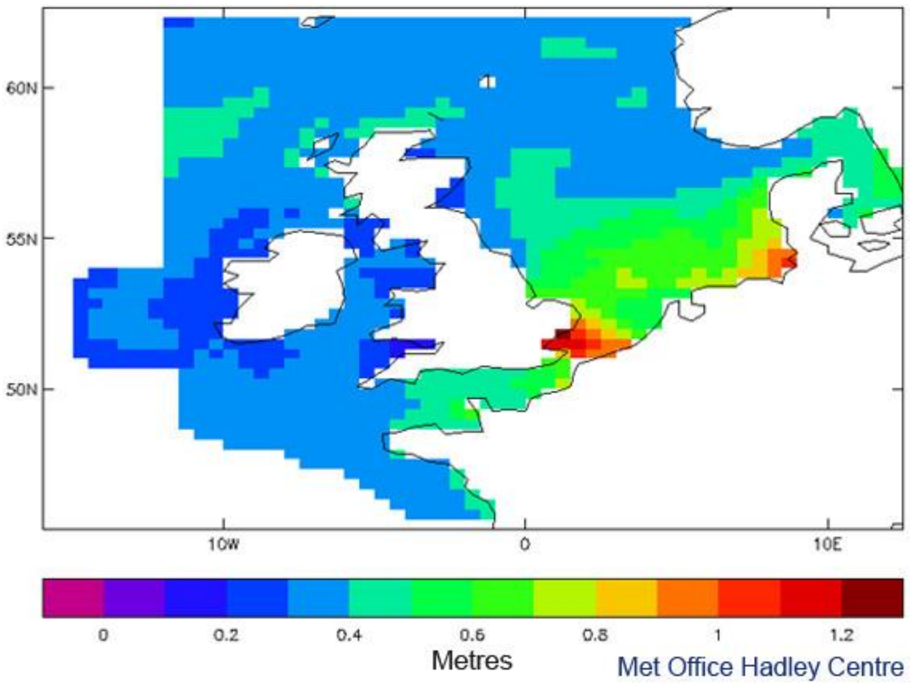
IPCC (2014) WG1 Summary for Policy Makers

N Sea storm surges could be a metre higher by the 2080s

Medium High Emissions with a 30 cm sea level rise

Return periods of extreme sea levels in the Thames Estuary

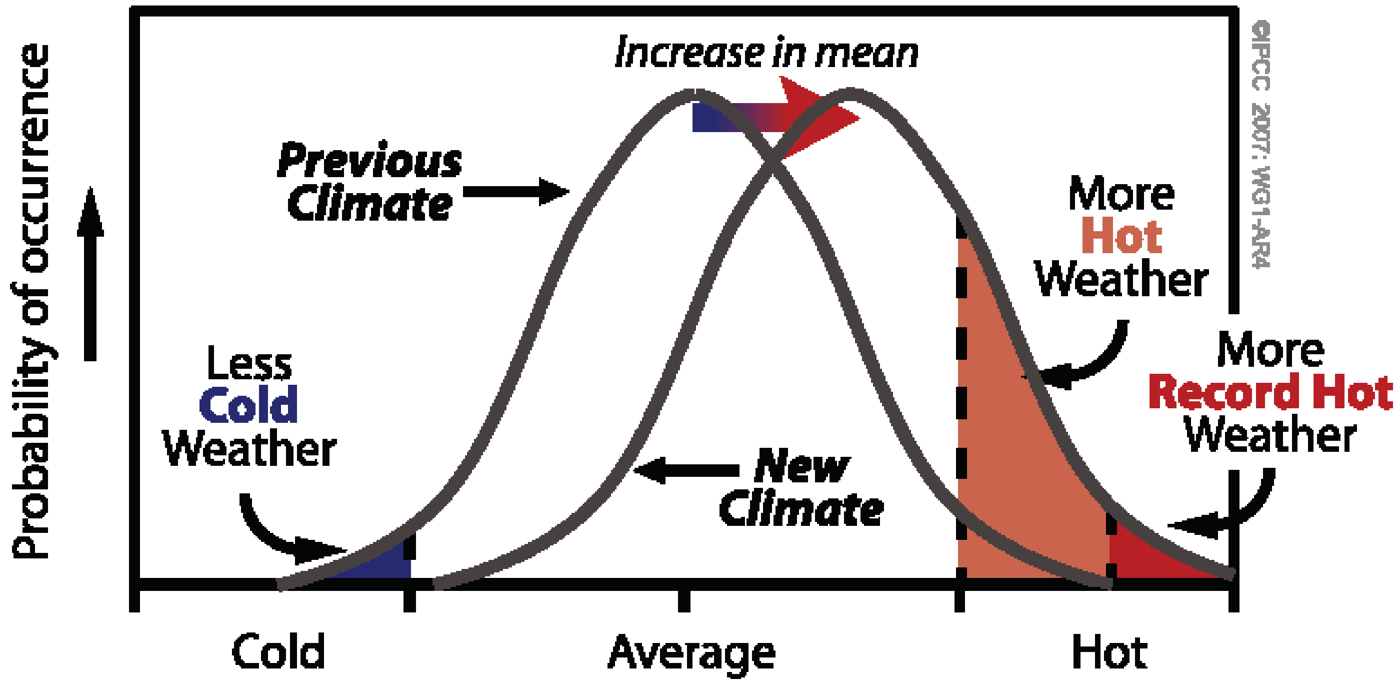




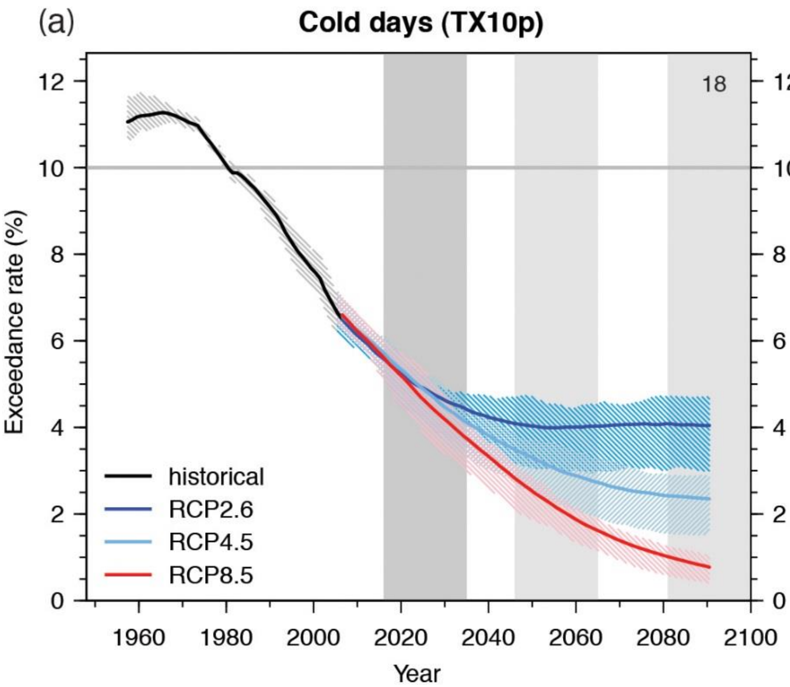
(courtesy of Jason Lowe)

Changing extremes

- Characterising change in variability?
- Characterising change in frequency of extremes?

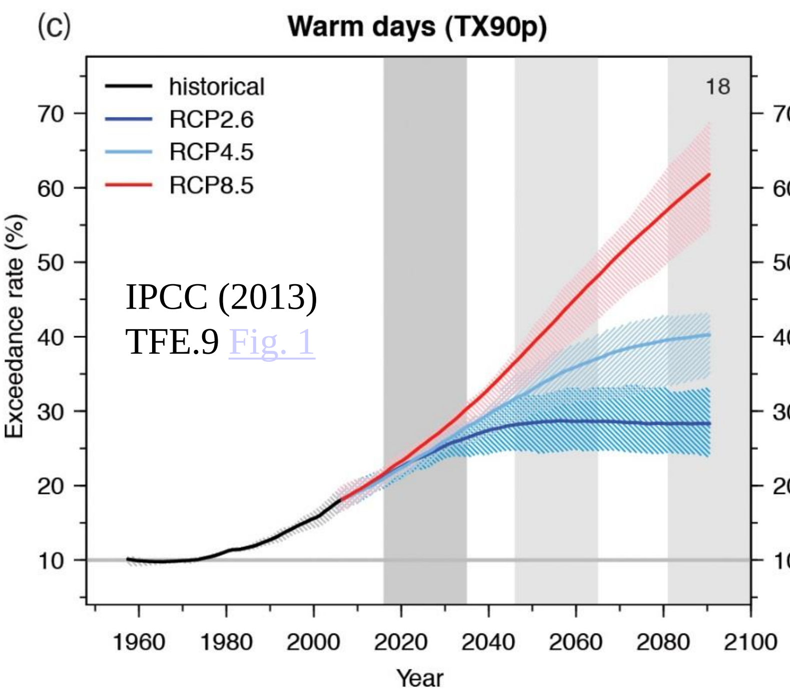


IPCC AR4 WG1 Box TS.5: **Extreme Weather Events**

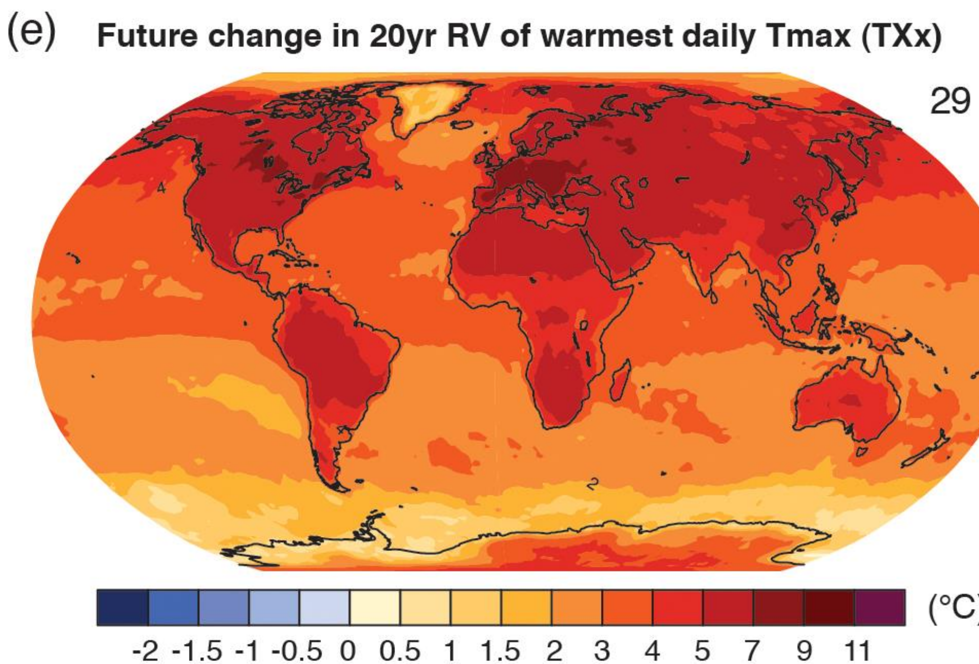


Extremes of temperature

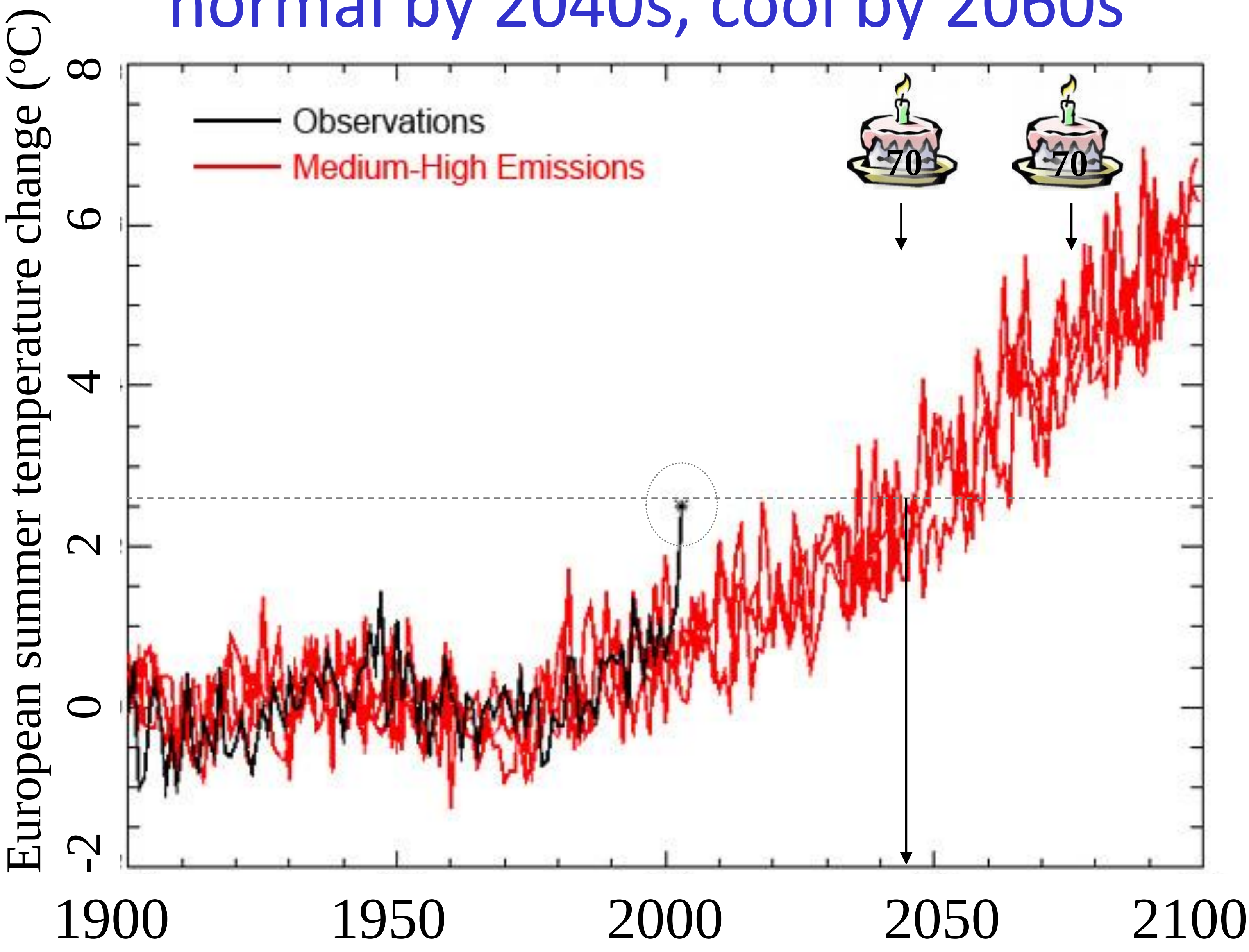
"It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is very likely that heat waves will occur with a higher frequency and duration. Occasional cold winter extremes will continue to occur." [IPCC 2013 SPM]



IPCC (2013)
TFE.9 Fig. 1

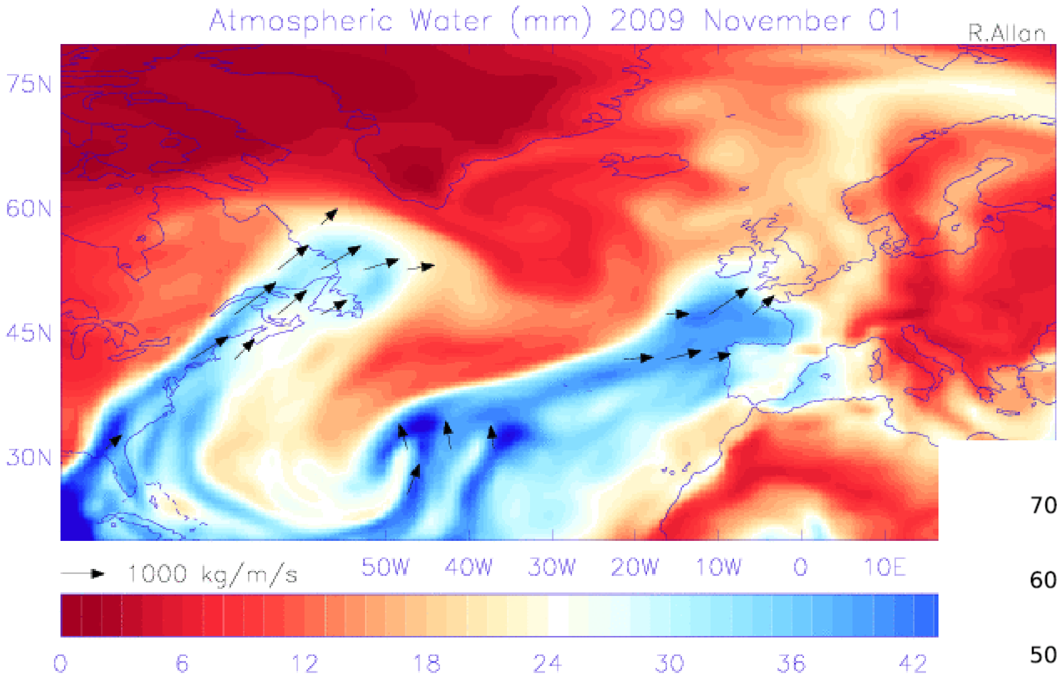


European 2003 summer temperatures could be normal by 2040s, cool by 2060s



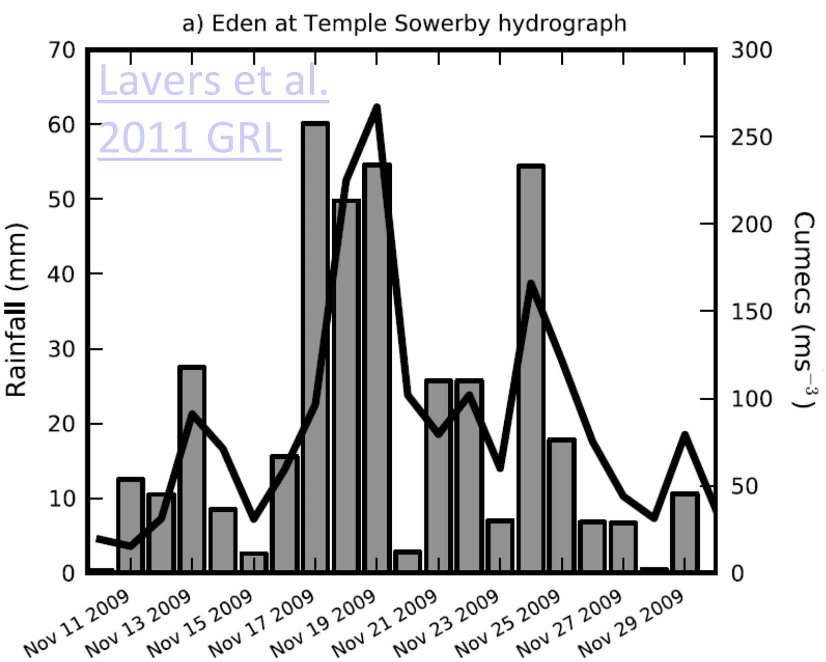
Rainfall extremes: Cumbria flooding 2009

An "atmospheric river" (see link)

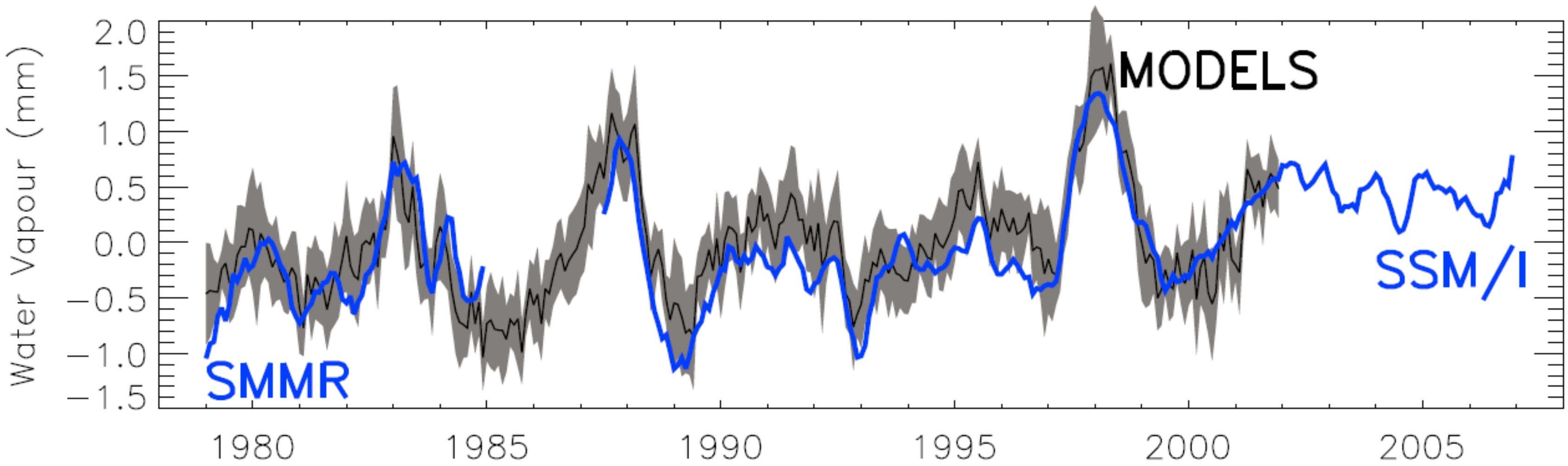


Lavers et al. (2013) ERL Also: click on image

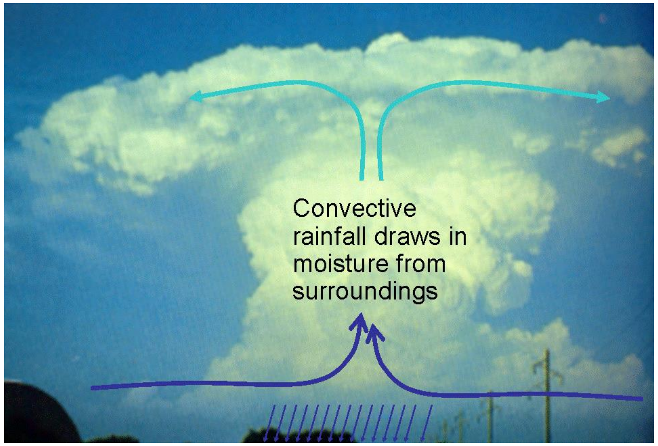
- Massive moisture transport
- Heavy rainfall over mountains
- River flooding



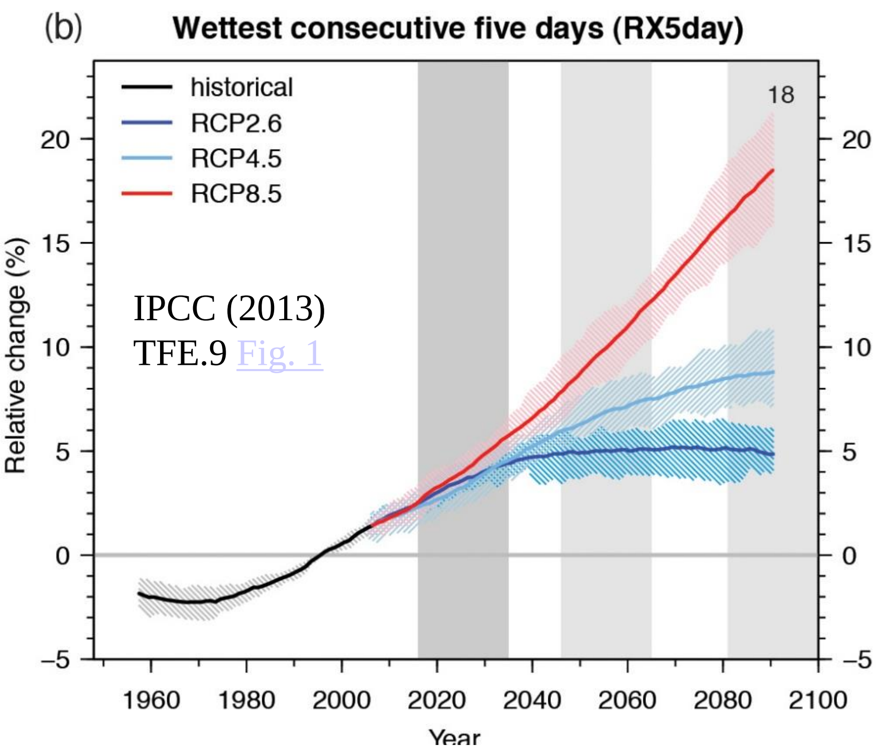
- Not only flood-generating mechanism
  - Summer flash flooding
  - Jet stream & wet seasons

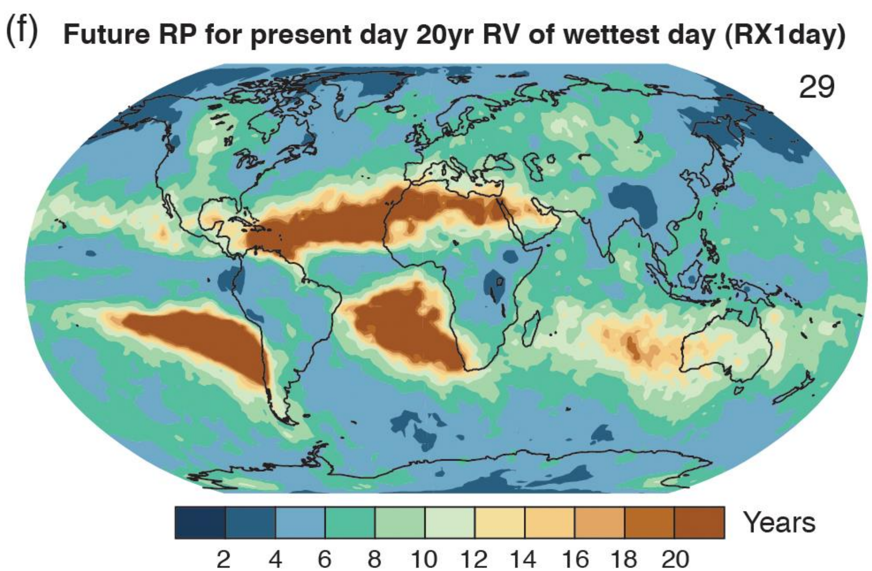


- Atmospheric moisture increases with warming in computer simulations and as detected by conventional and satellite observations



- The enhanced greenhouse effect amplifies climate change (+ve "feedback")
- Additional moisture also fuels a greater intensity of rainfall





"Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases."

"The contrast in precipitation between wet and dry regions and between wet
and dry seasons will increase, although there may be regional exceptions" (link)

[IPCC 2013 WG1 SPM]

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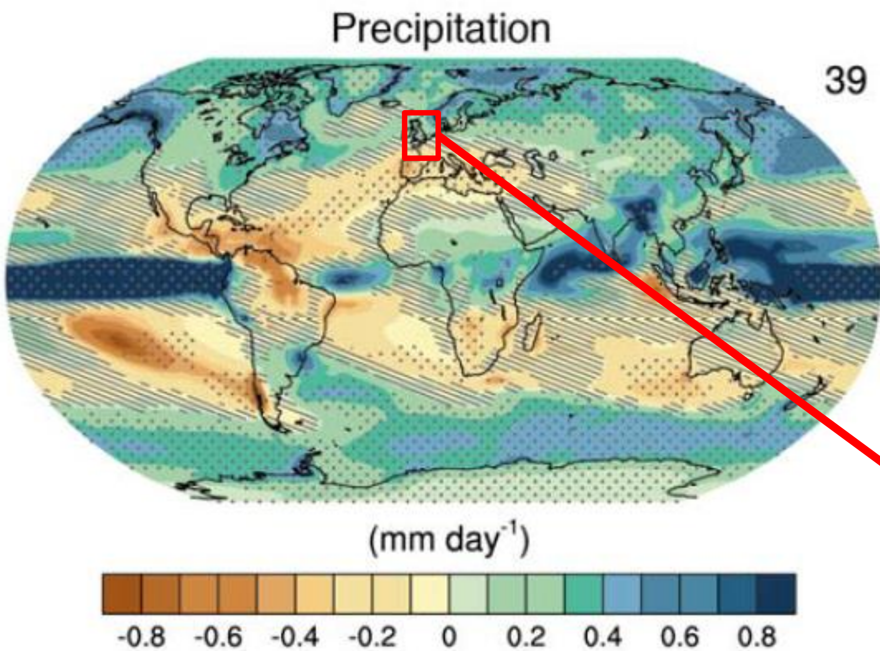
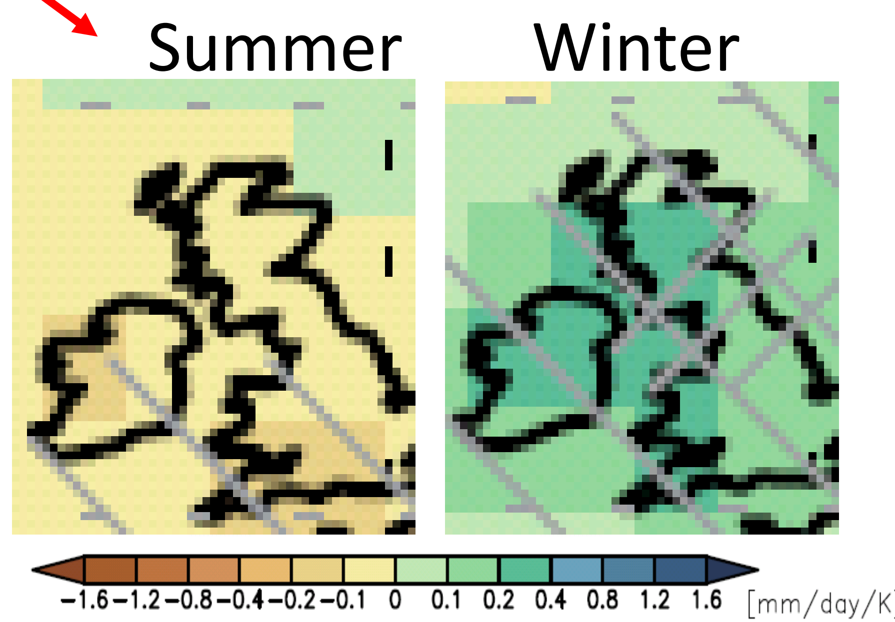
Challenge: Regional projections

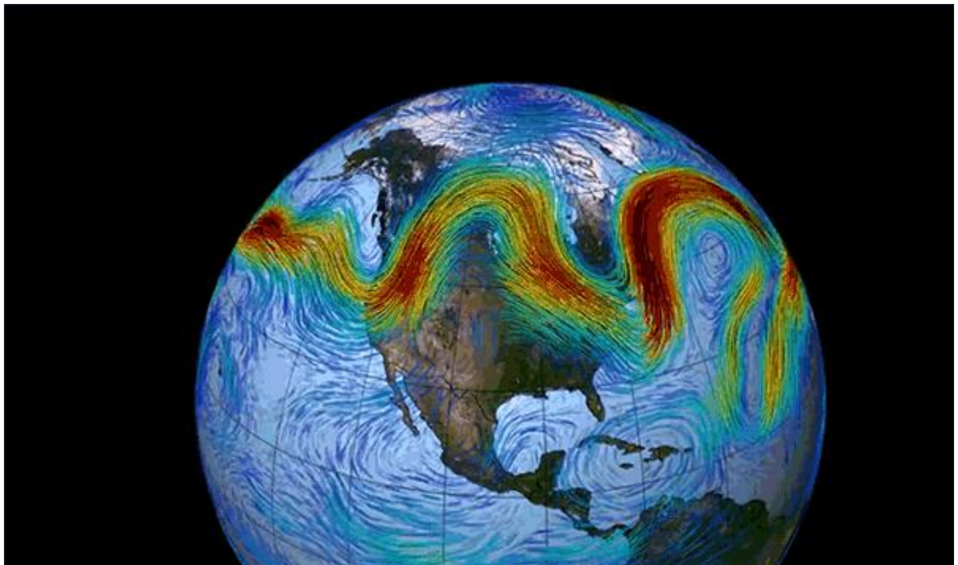


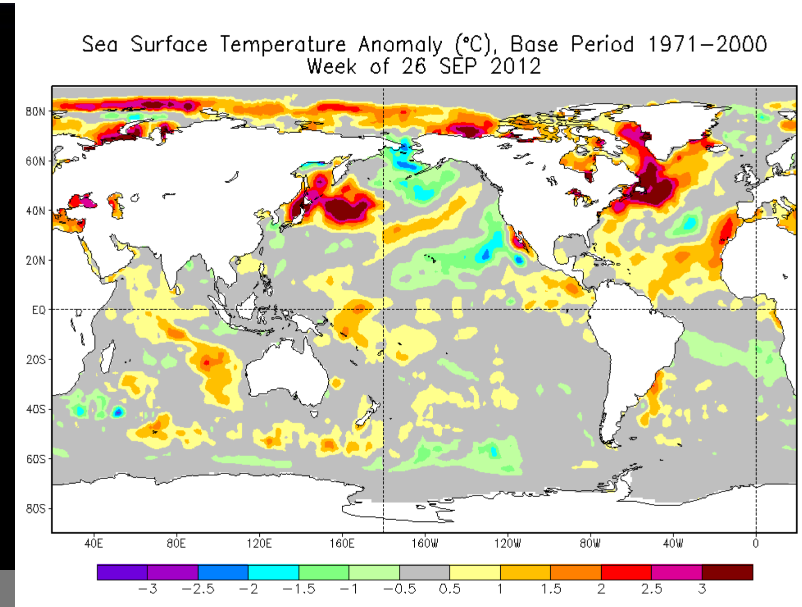
General changes in rainfall patterns are quite well understood **but** changes at regional scales – countries, even river catchments – are much less certain.

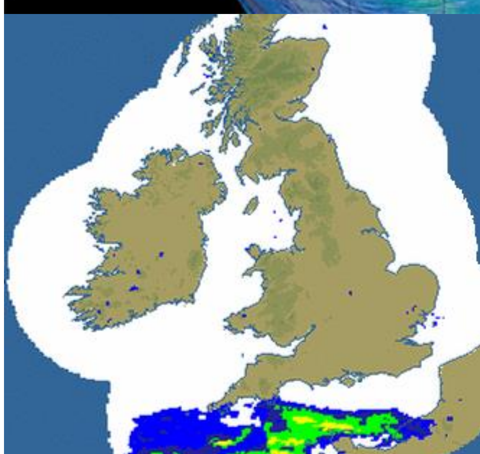


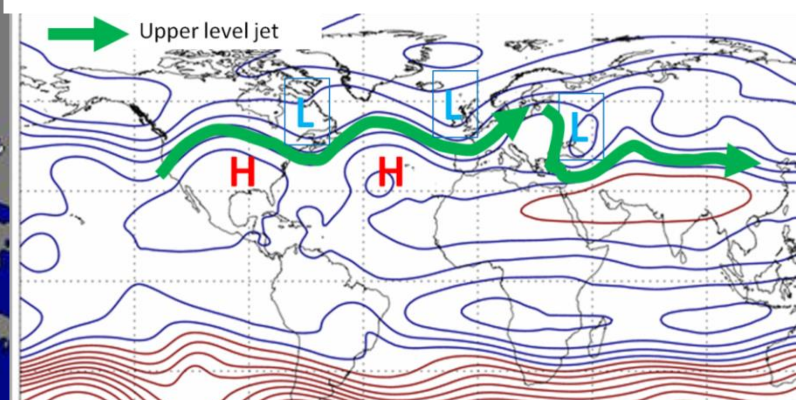
Small changes in the position and strength of the atmospheric circulation can have large influences on regional climate but are difficult to predict with any confidence.

How will atmospheric and oceanic circulations change?

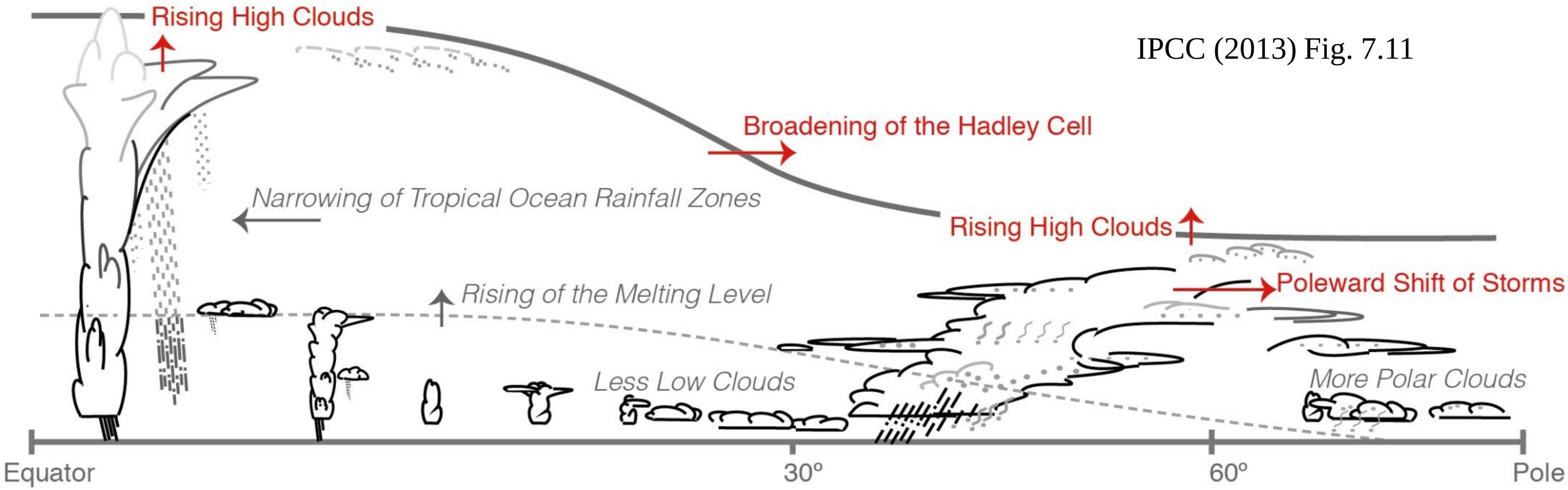








Changes in the atmospheric circulation



- Computer simulations indicate a poleward migration of the atmospheric circulation
  - Subtropical dry regions, mid-latitude storms
- The details of these changes are less certain

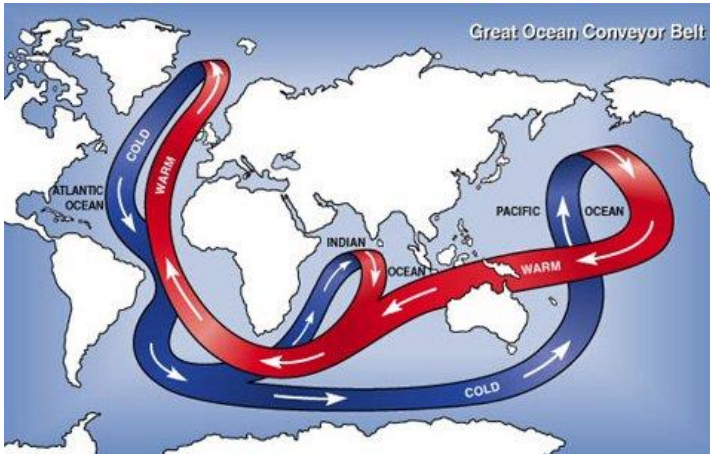
Summary

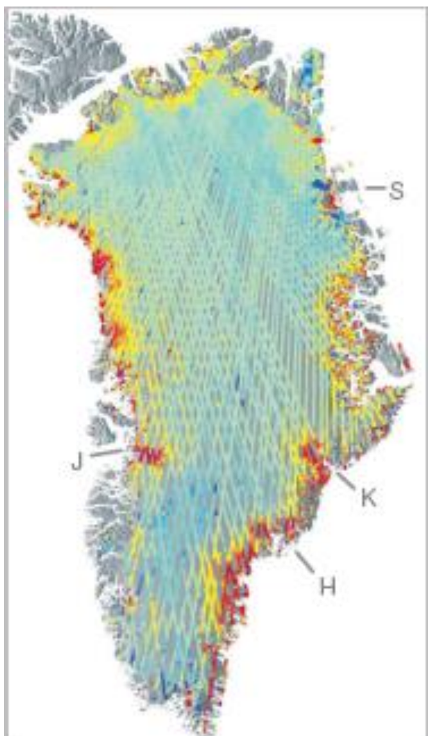
- The evidence for warming is unequivocal
- Much of recent warming caused by human activities
  - Greenhouse gases at highest levels for > 800,000 yrs
  - Physics of greenhouse effect well understood
- Substantial changes in global temperature and rainfall patterns are projected using computer simulations
  - more heatwaves, droughts and extreme rainfall & flooding
- Predicting regional climate change is a challenge…
  - How much more greenhouse gases will we emit?
  - Will "knock on effects" of the warming involving the land surface or clouds to amplify or oppose the warming?
  - How will atmospheric and oceanic circulations change?

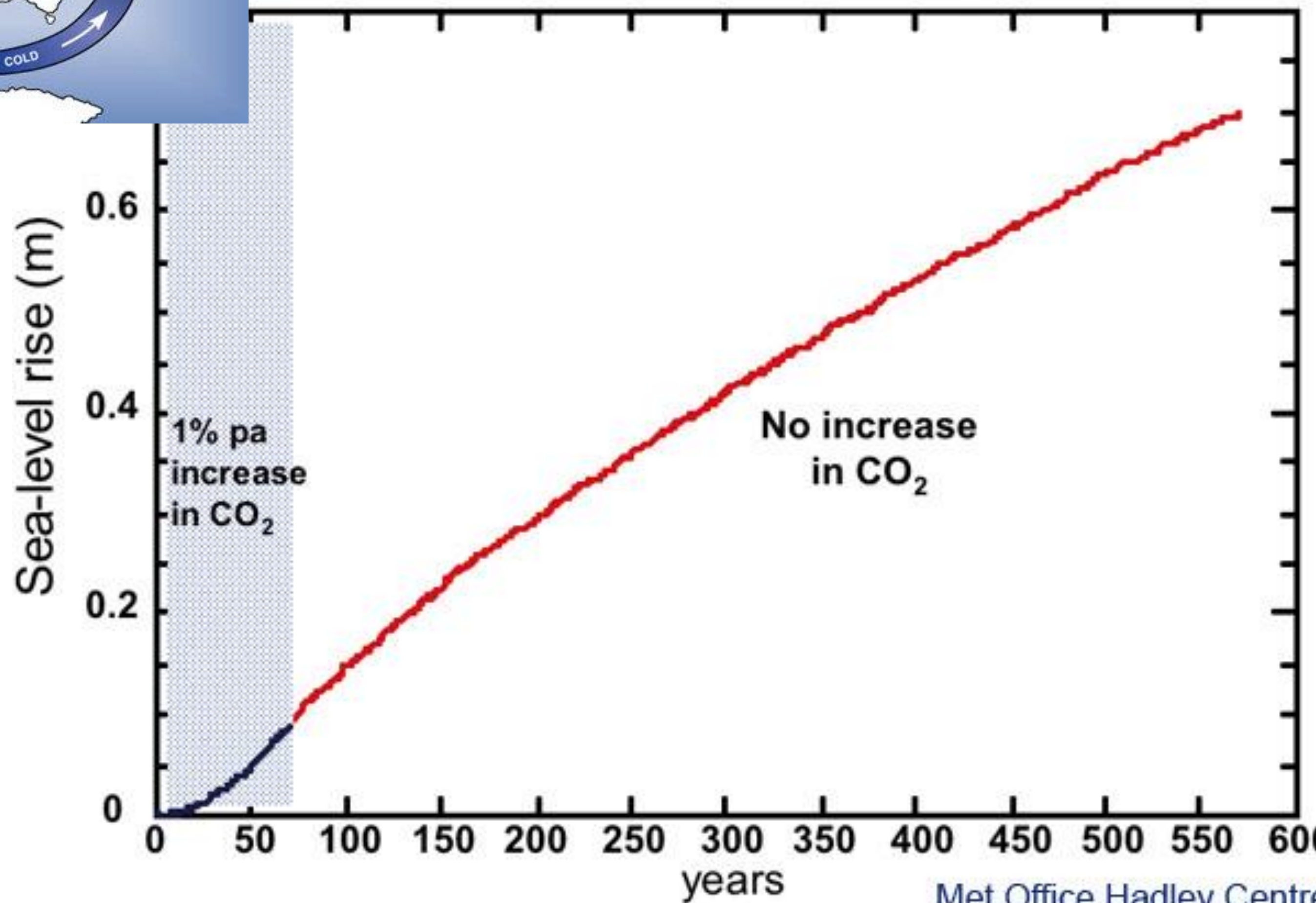
  Poleward migration of jet? Stronger/weaker jet? More/less blocking?

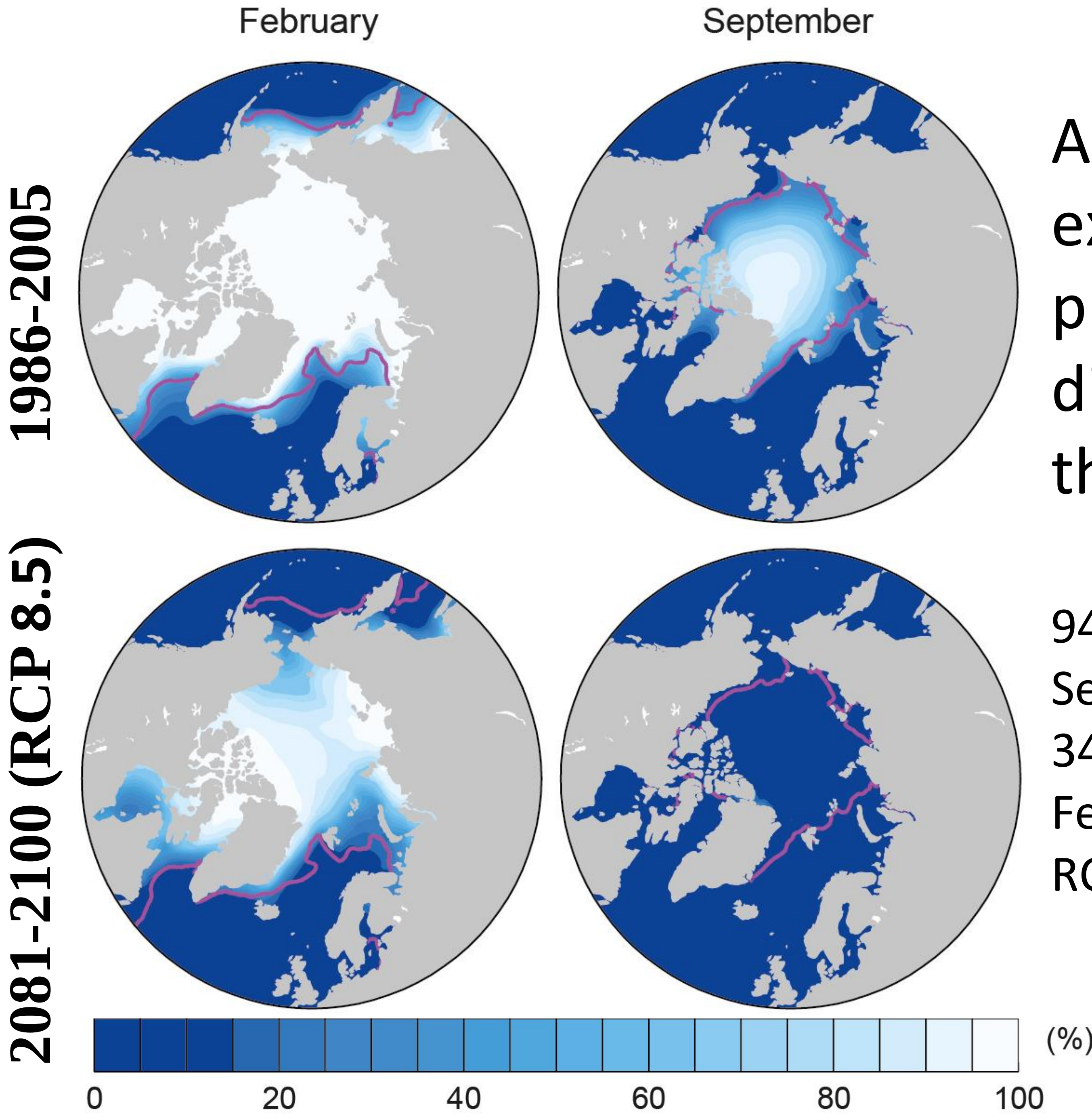
Extra slides

Long-term commitment to sea-level rise







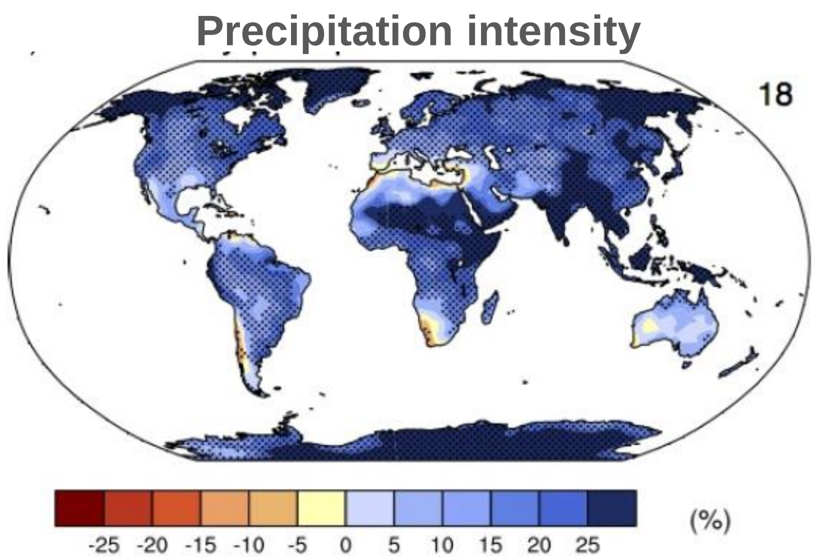


Arctic sea ice extent is projected to diminish over the 21st century

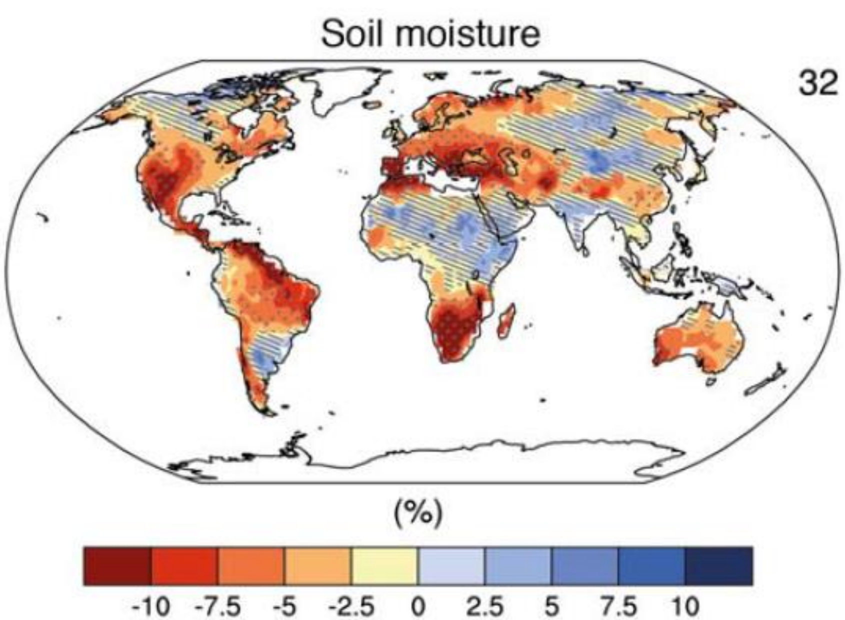
94% decrease in September and 34% decrease in February for the RCP8.5 scenario

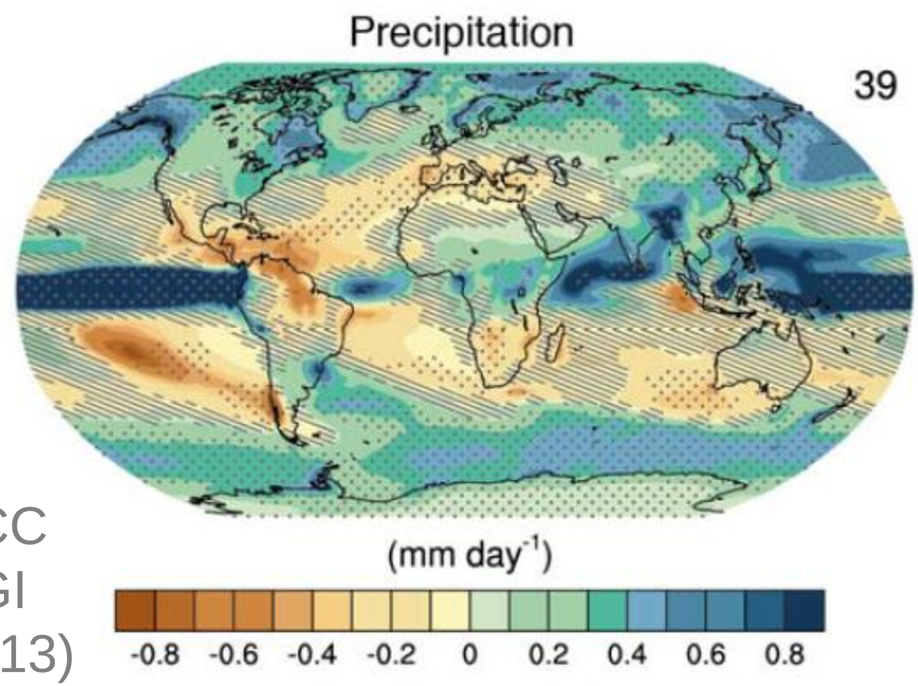
IPCC (2013) WG1 Fig. 12.29

Projections of the water cycle



- Increased Precipitation
- More Intense Rainfall
- More droughts
- Wet regions get wetter, dry regions get drier?
- Regional projections??





IPCC WGI (2013)

Change in average surface temperature (1986–2005 to 2081–2100) RCP 8.5 Scenario