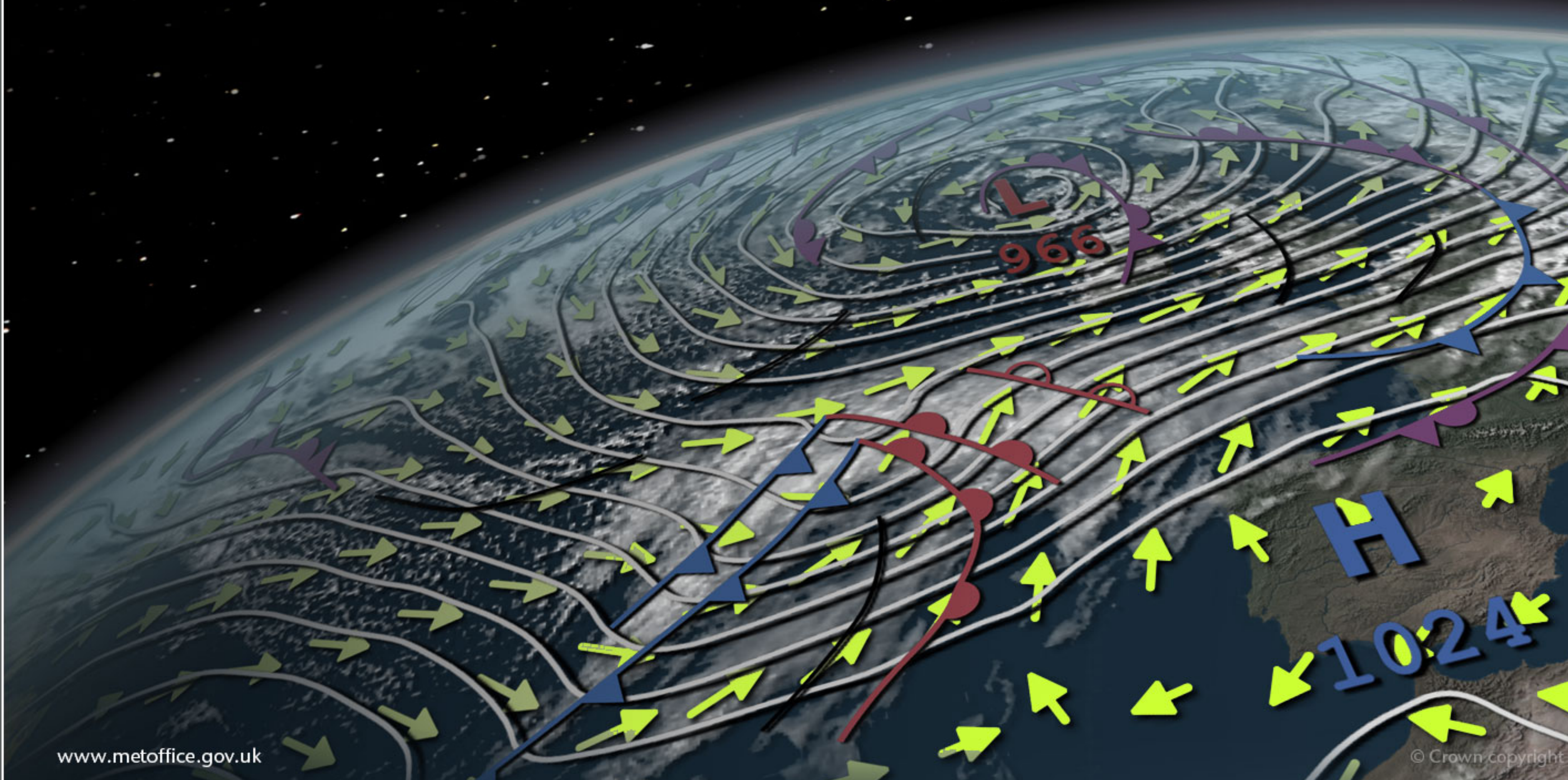
Met Office

Seasonal to decadal climate prediction: filling the gap between weather forecasts and climate projections

Doug Smith

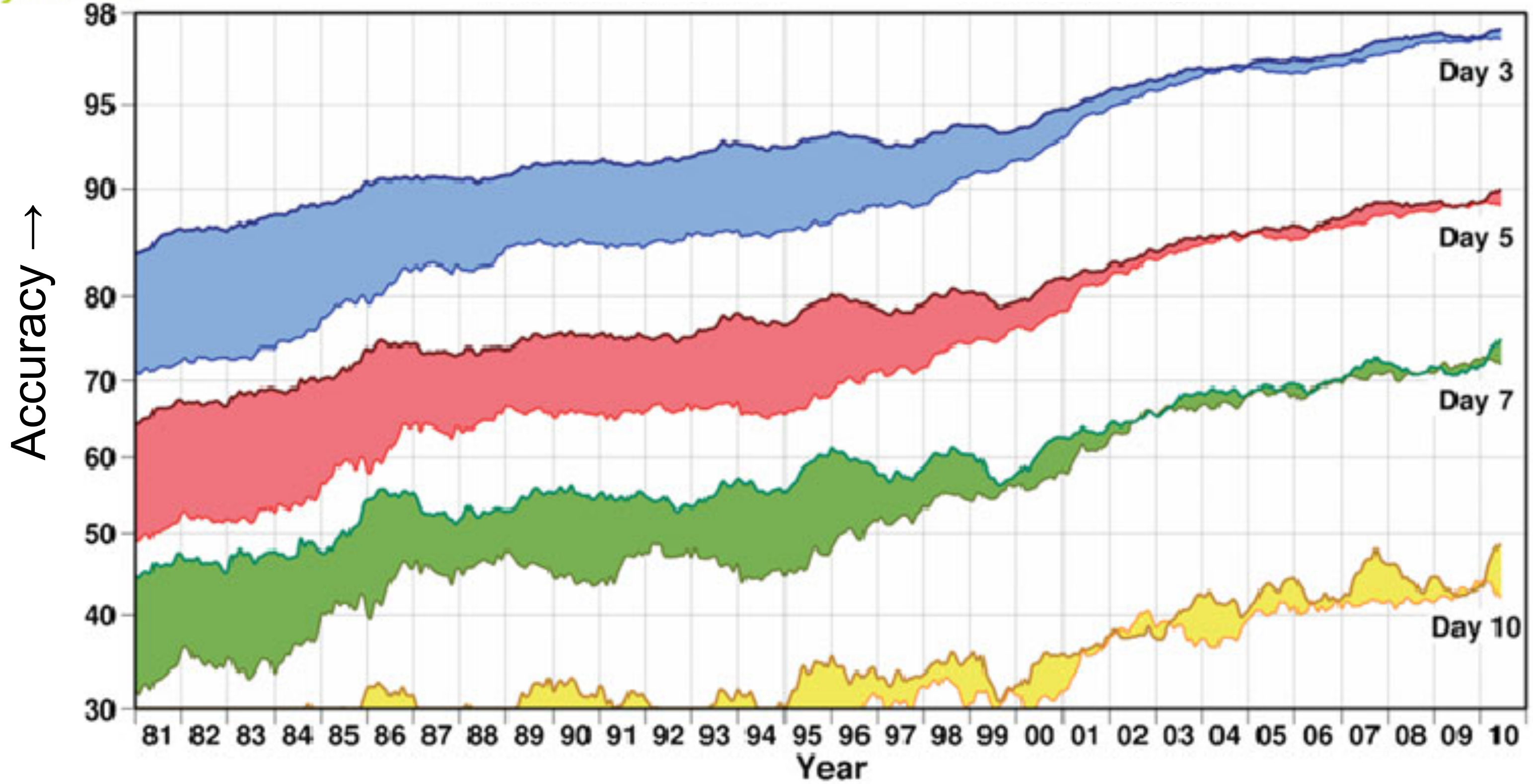
Walter Orr Roberts memorial lecture, 9th June 2015



Contents

- Motivation
- Practical issues
- What can we predict?
- What is the forecast?

Improved weather forecasts

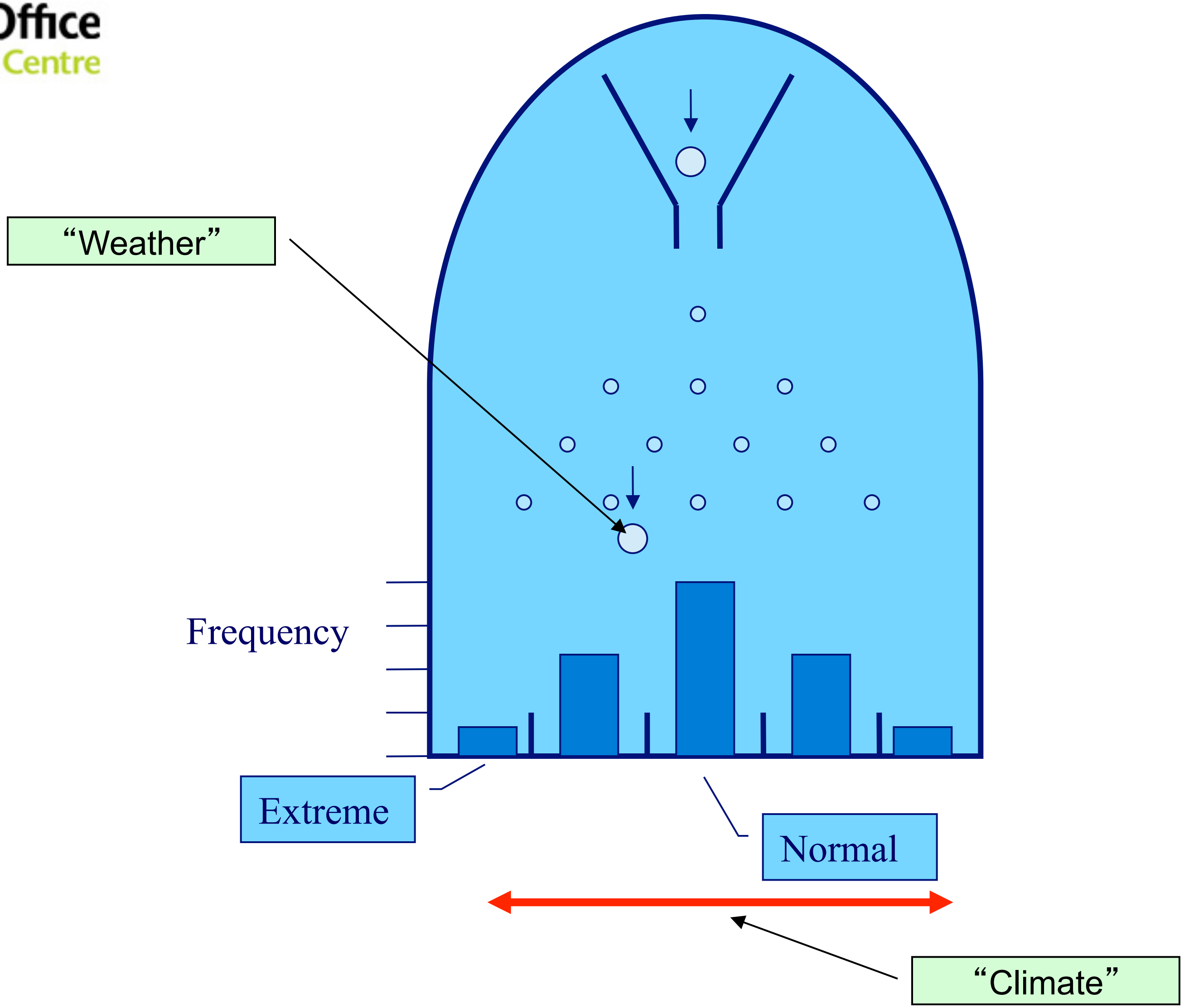


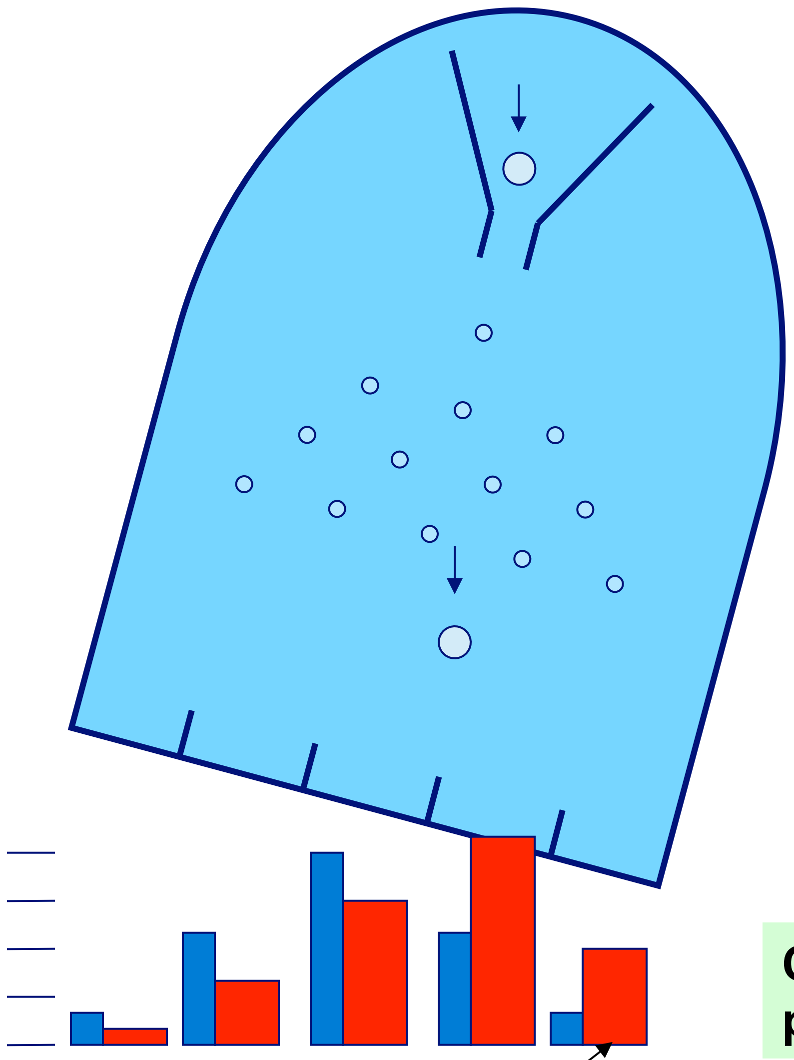
- **Weather forecasts much improved over last 30 years**
- **4 days ahead now as accurate as 1 day ahead in 1980**
- **BUT fundamental limits (weeks) due to chaotic atmosphere**

!

You can't predict the weather in a couple of weeks time, so how can you say anything about the winter/summer/decade?

?

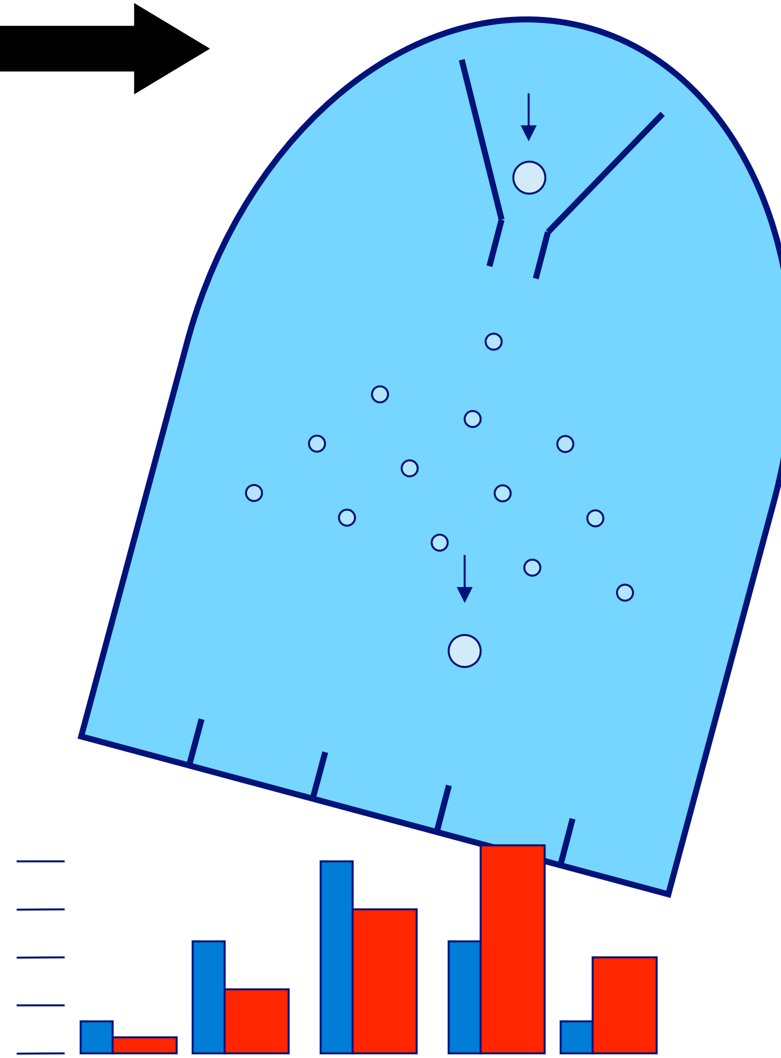

"Weather"
Frequency
Extreme
Normal
"Climate"

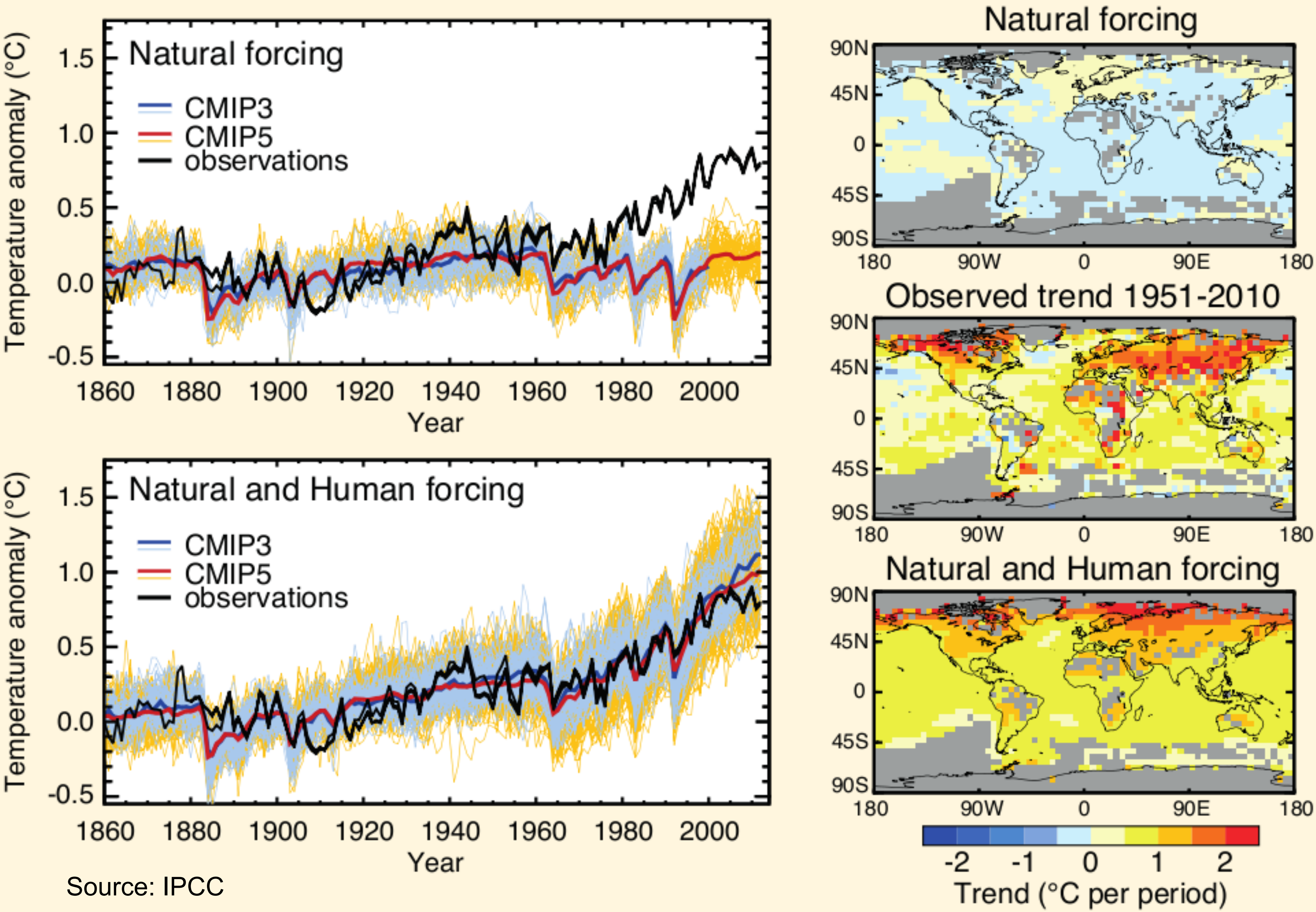


More extreme weather events

Can only forecast probabilities

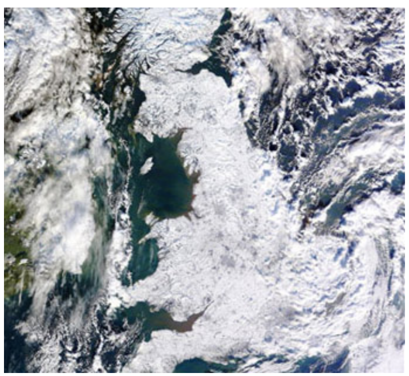
Greenhouse gases

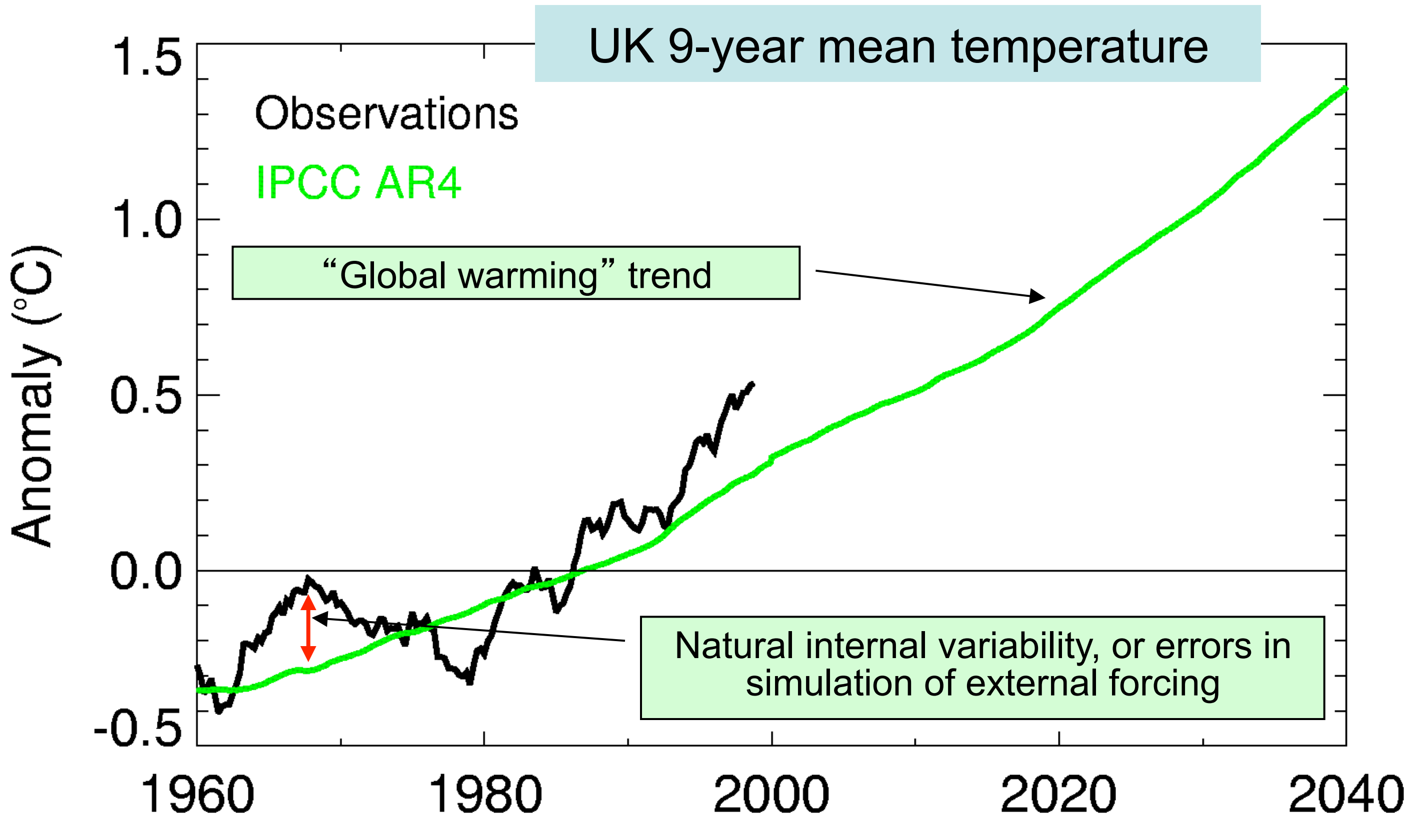



Natural forcing
CMIP3
CMIP5
observations
Temperature anomaly (°C)
Year
Natural and Human forcing
CMIP3
CMIP5
observations
Temperature anomaly (°C)
Year
Natural forcing
Observed trend 1951-2010
Natural and Human forcing
Trend (°C per period)

Source: IPCC

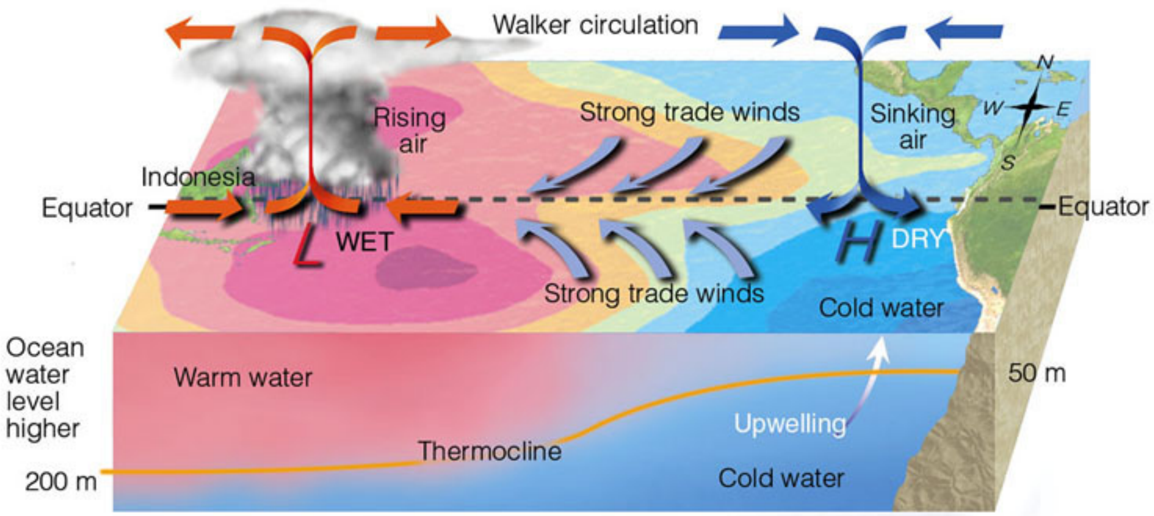
Want to predict variations and trend



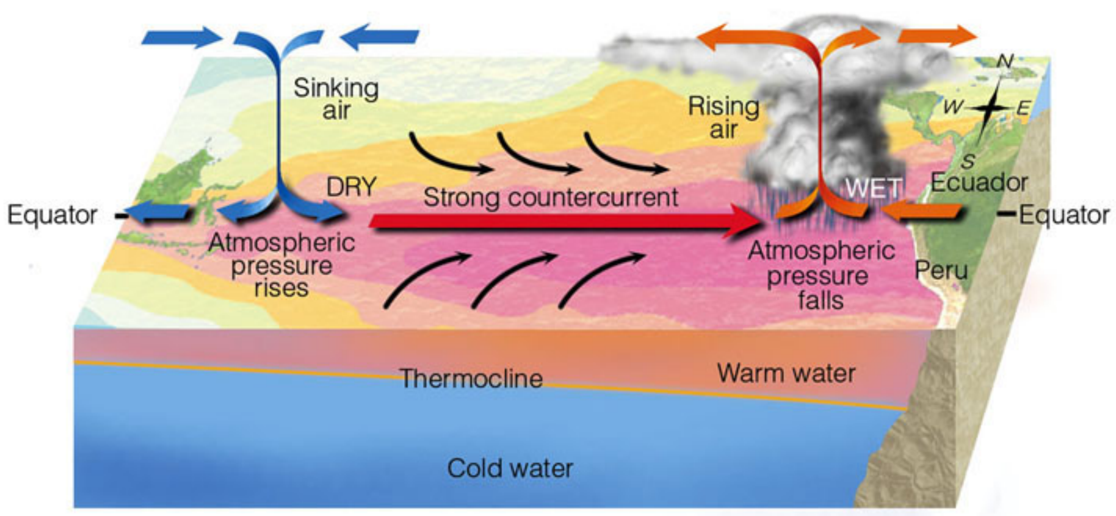


- **External forcing:** greenhouse gases, aerosols, volcanoes, solar
- **Natural internal variability** – need to start predictions from the current state of the climate system
- Climate varies **a lot** around the trend!

El Niño Southern Oscillation (ENSO)

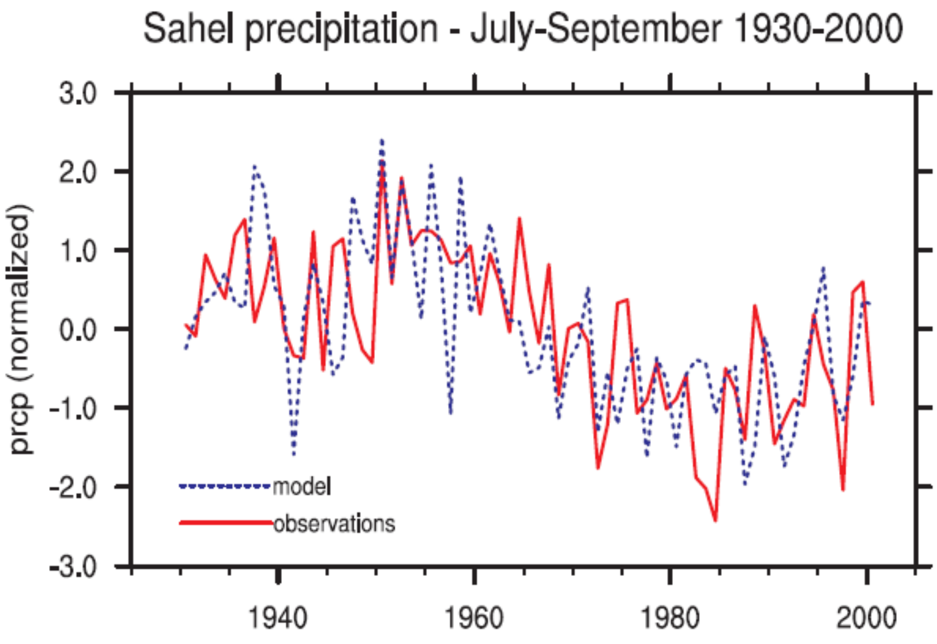


(a) Non-El Niño conditions



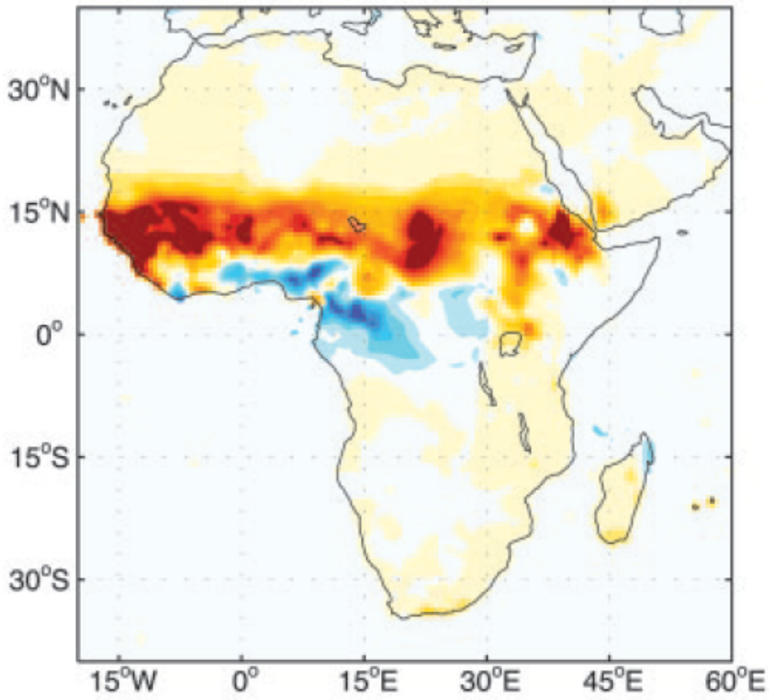
(b) El Niño Conditions

Sahel drought 1980s



Climate model forced by observed SST simulates Sahel rainfall variations.

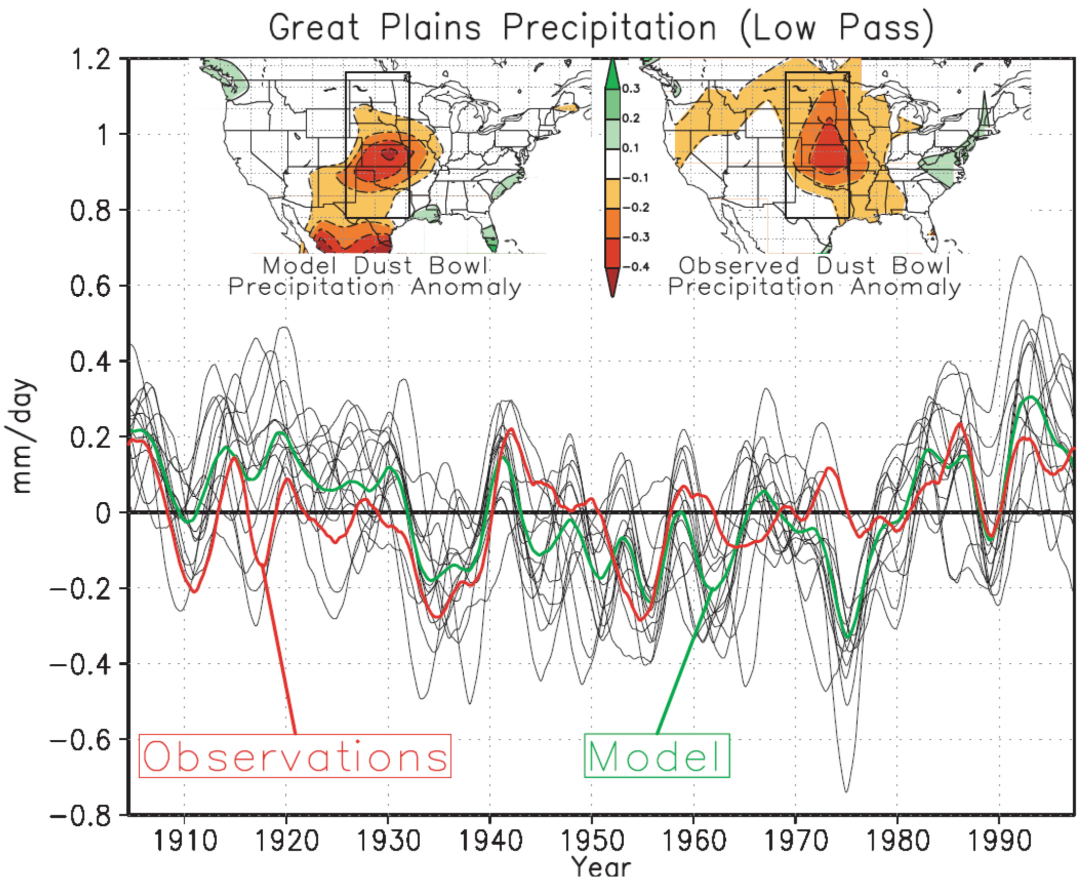
Giannini *et al.*, *Science*, 2003



Observed rainfall trend, 1950-2000

Held *et al.*, *PNAS*, 2005

US dust bowl 1930s

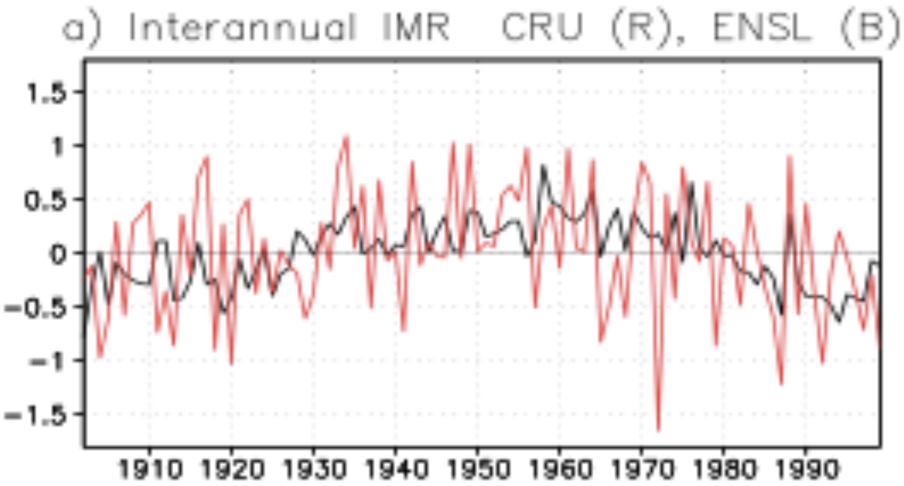


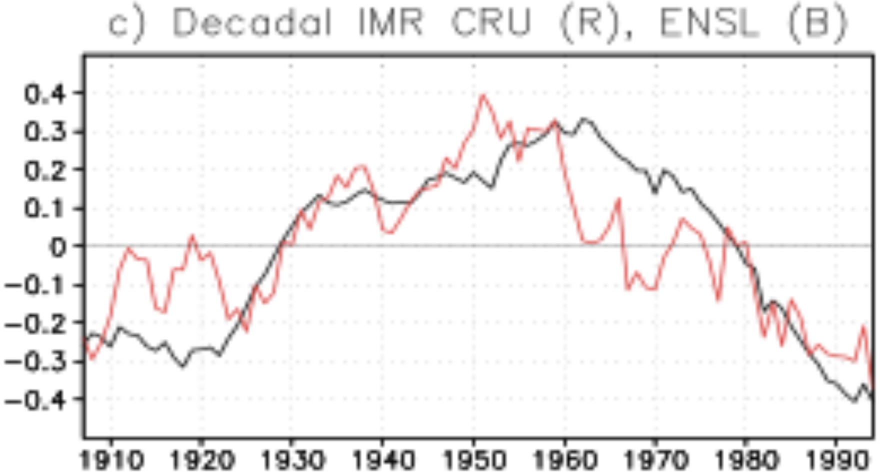
Dust Storm, Oklahoma, 1936

Climate model forced by observed SST simulates US great plains rainfall variations.

Schubert *et al*., *Science*, 2004

Indian monsoon rainfall



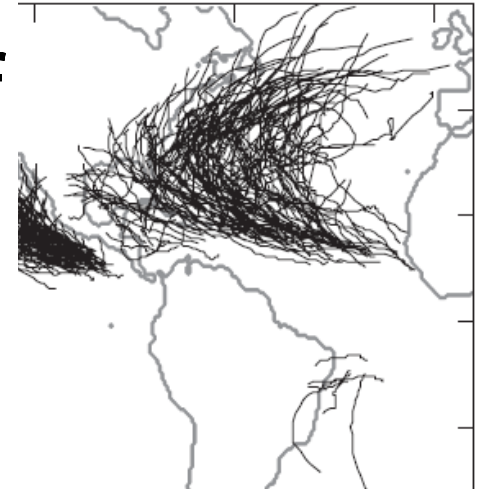


Year-to-year changes difficult to simulate.

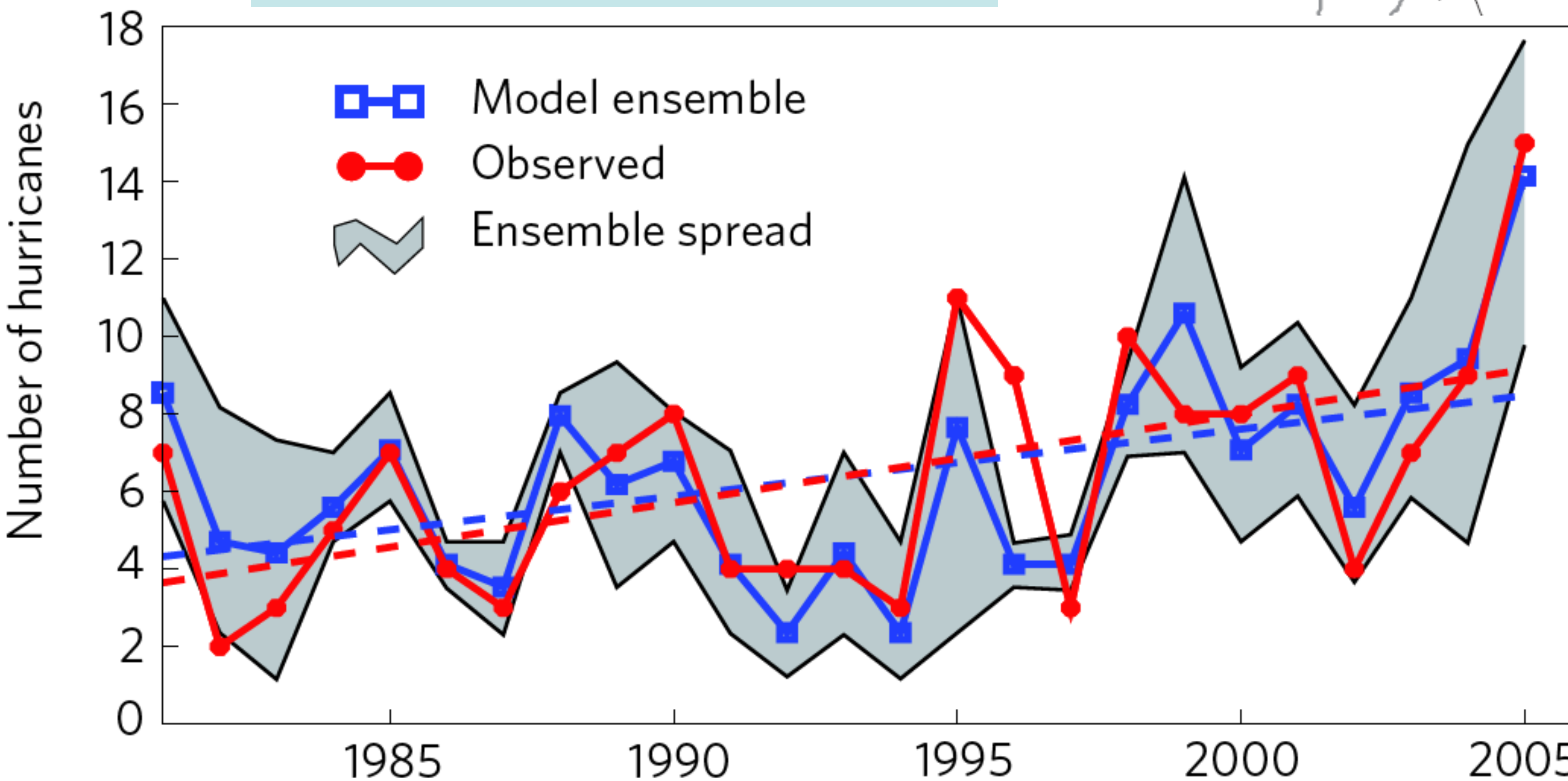
Modeled (black) and Observed (red) mm/day

But decade-to-decade potentially predictable GIVEN ACCURATE OCEAN PREDICTIONS
Kucharski *et al*., *Climate Dynamics*, 2008

Model simulations of hurricane frequency



- 50 km resolution (GFDL model)
- Forced by observed SST



(Zhao et al. 2009)

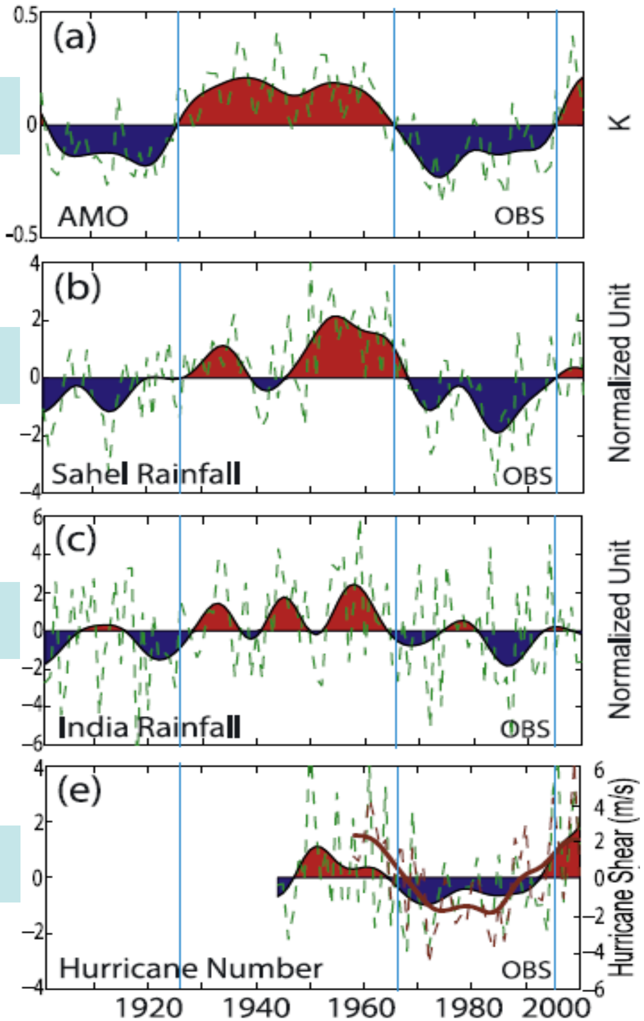
North Atlantic variability

North Atlantic SST

Sahel rainfall

India rainfall

Hurricanes

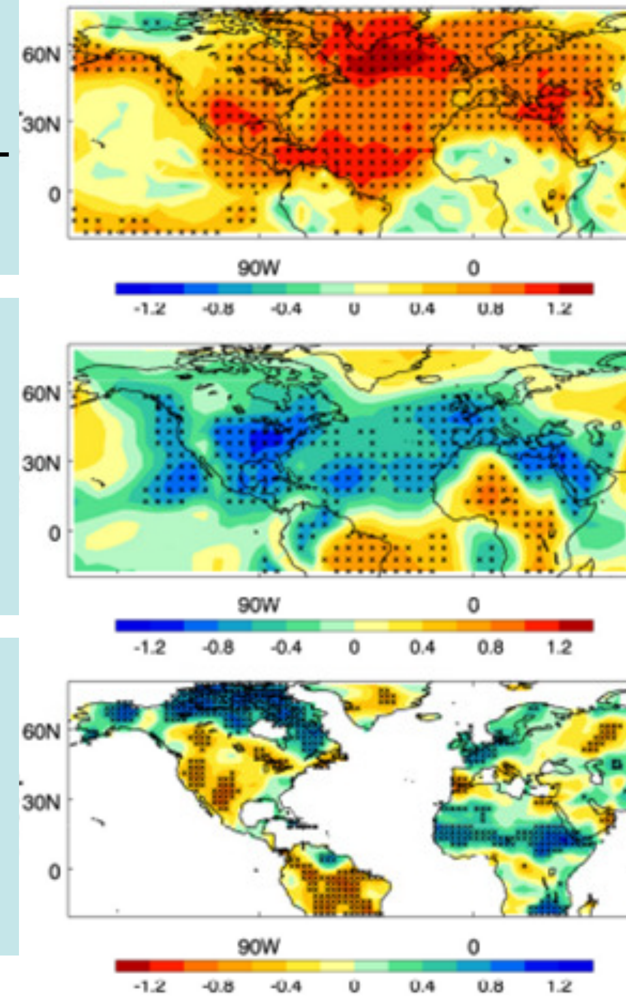


Warm – cold Atlantic: summer composite

Temperature

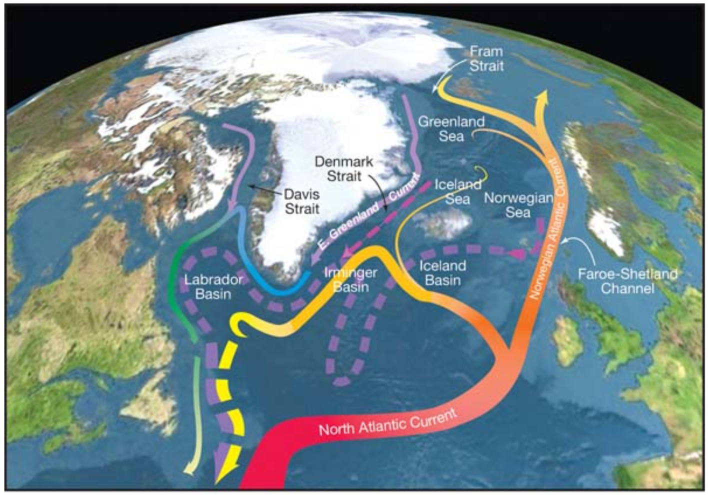
Pressure

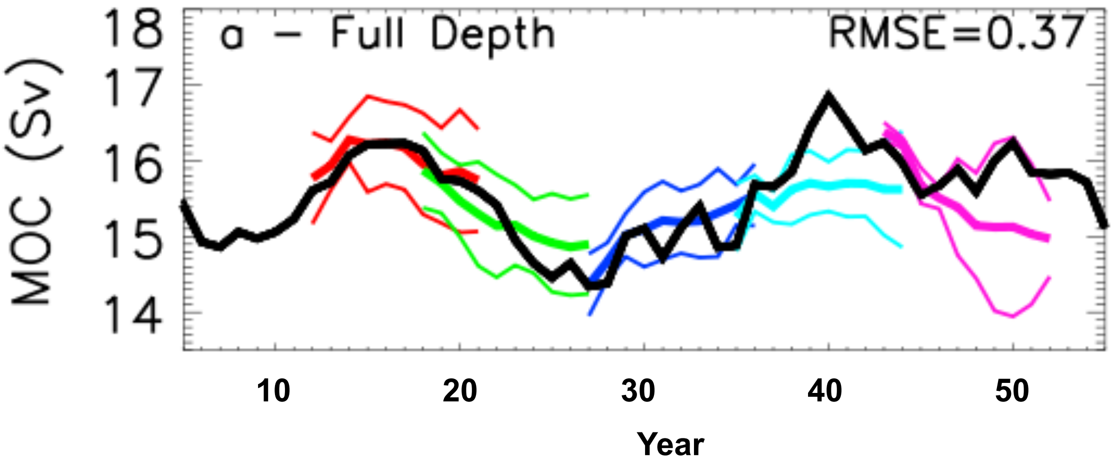
Rainfall



(Zhang and Delworth 2006; also Knight et al 2006 ...t al 2014)

Atlantic ocean circulation





Many idealised experiments suggest that North Atlantic ocean currents are potentially predictable on decadal timescales

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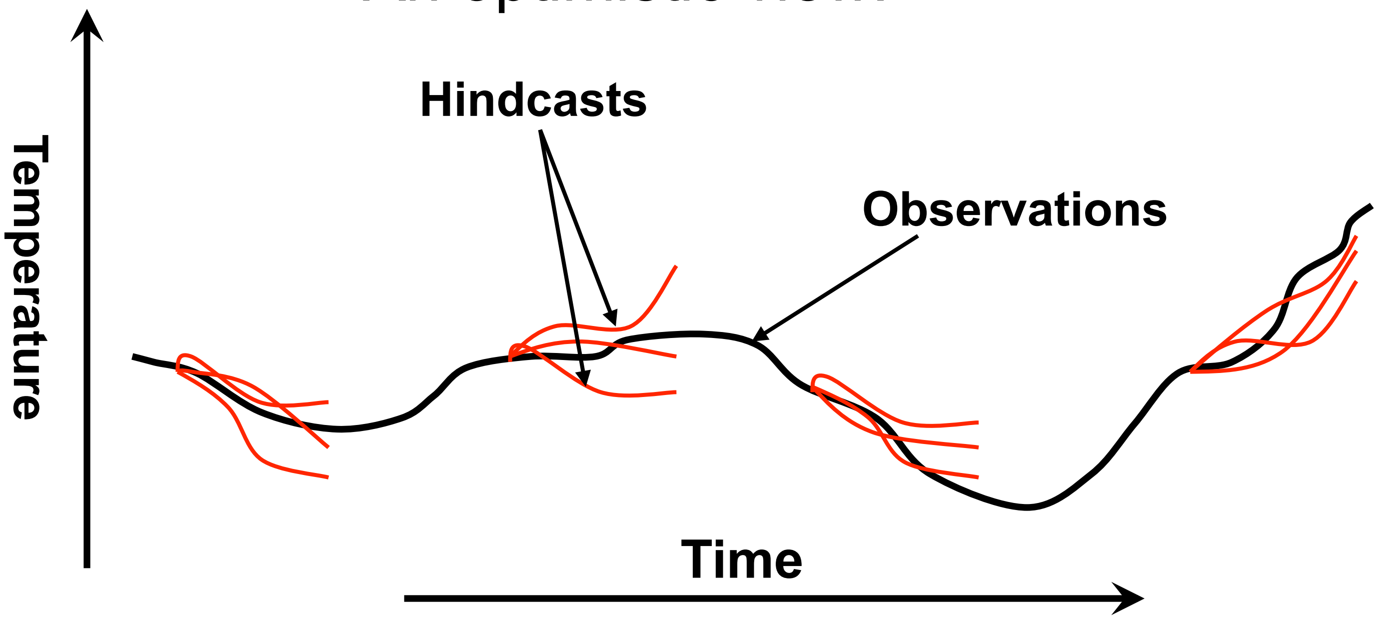
Hindcasts to assess skill

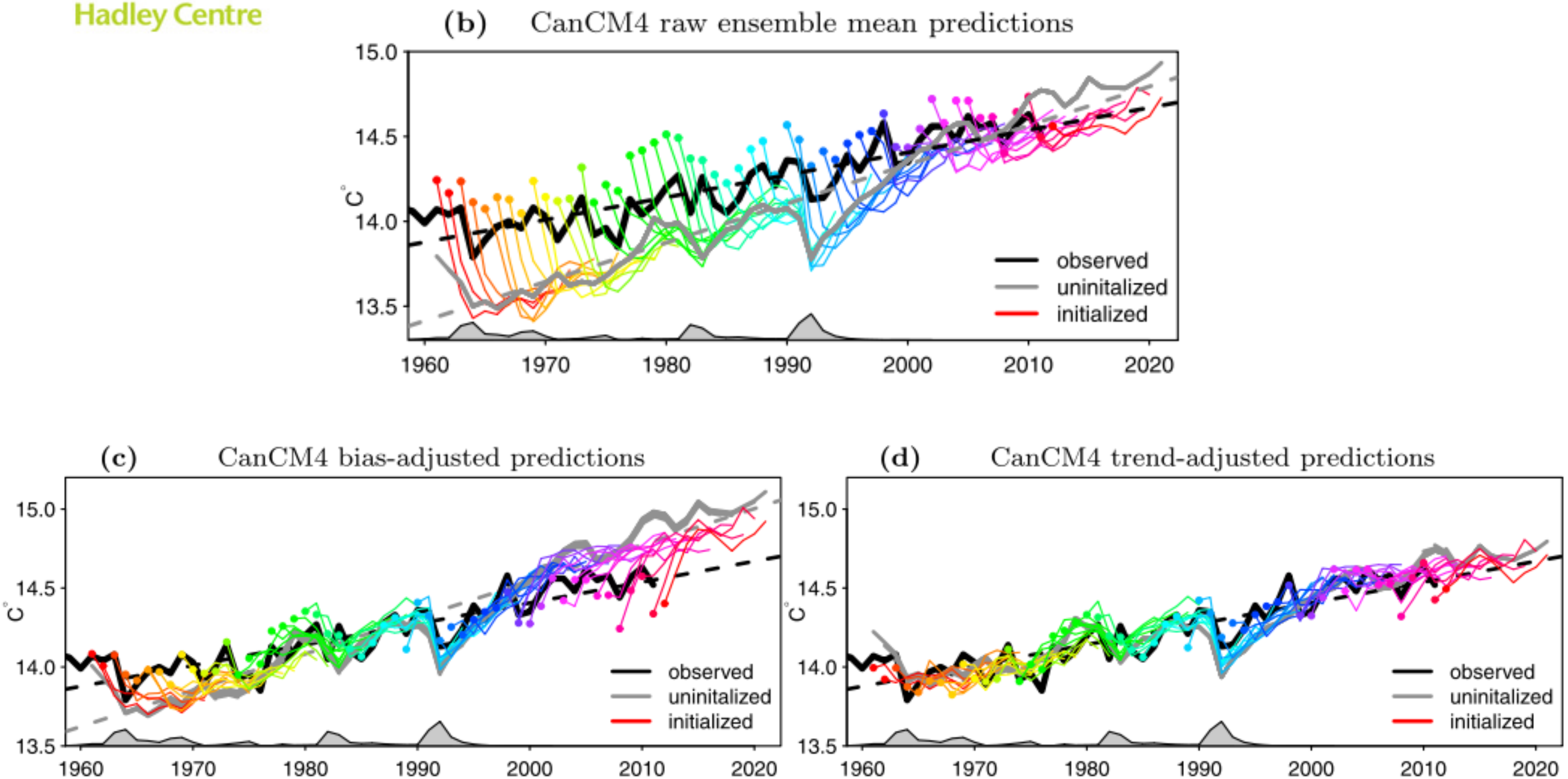
Ensembles to sample uncertainties:
- Uncertainties in the initial conditions
- Model errors

An optimistic view:



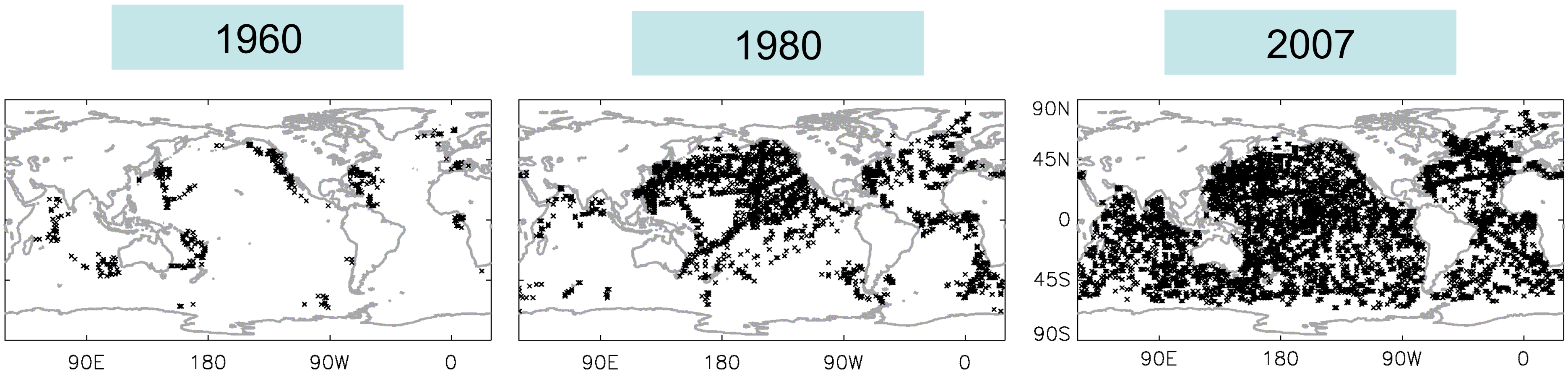
Perform historical tests (“retrospective forecasts” or “hindcasts” to assess likely skill and correct biases

Models are imperfect!



(Kharin et al. 2012)

Sub-surface ocean observations



- Need historical tests to assess likely skill of forecasts
- Far fewer sub-surface ocean observations in the past
- Could forecasts be more accurate than hindcasts?

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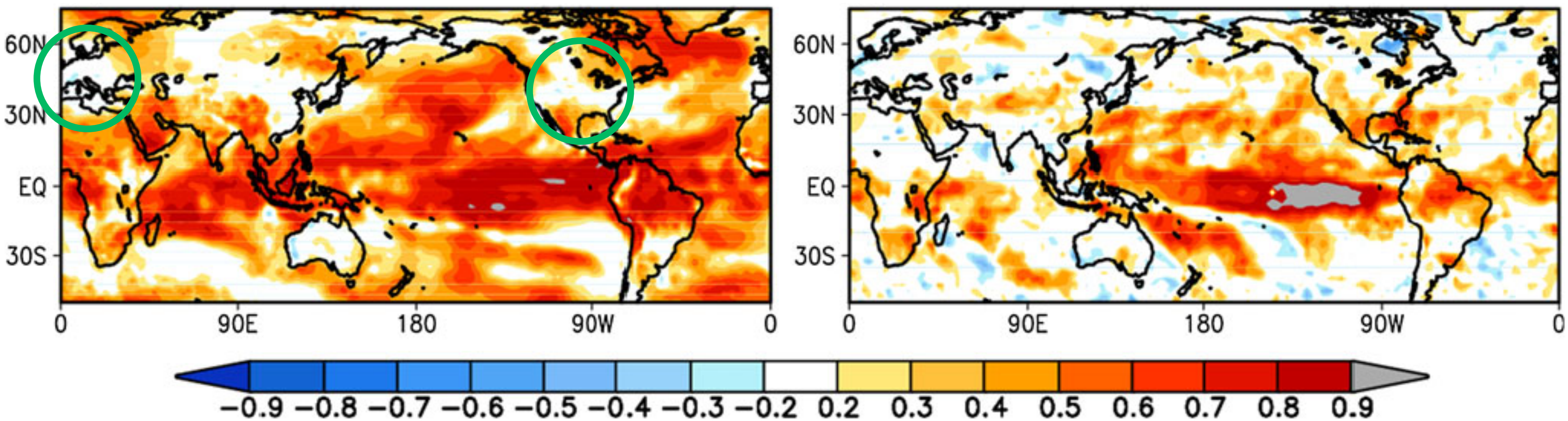
Seasonal forecast skill Dec-Feb (DJF, months 2-4)

Temperature

Precipitation



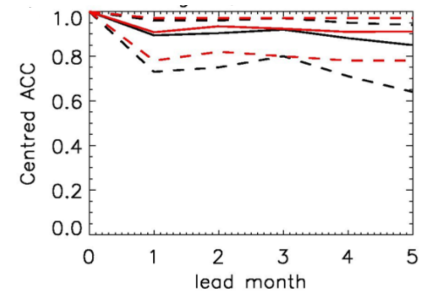
- High skill in tropics
- Much lower for mid-latitude land (Europe and USA!)
- Limited skill for precipitation

Kim et al., 2012

Tropical Rains - seasonal

El Niño minus La Niña composite

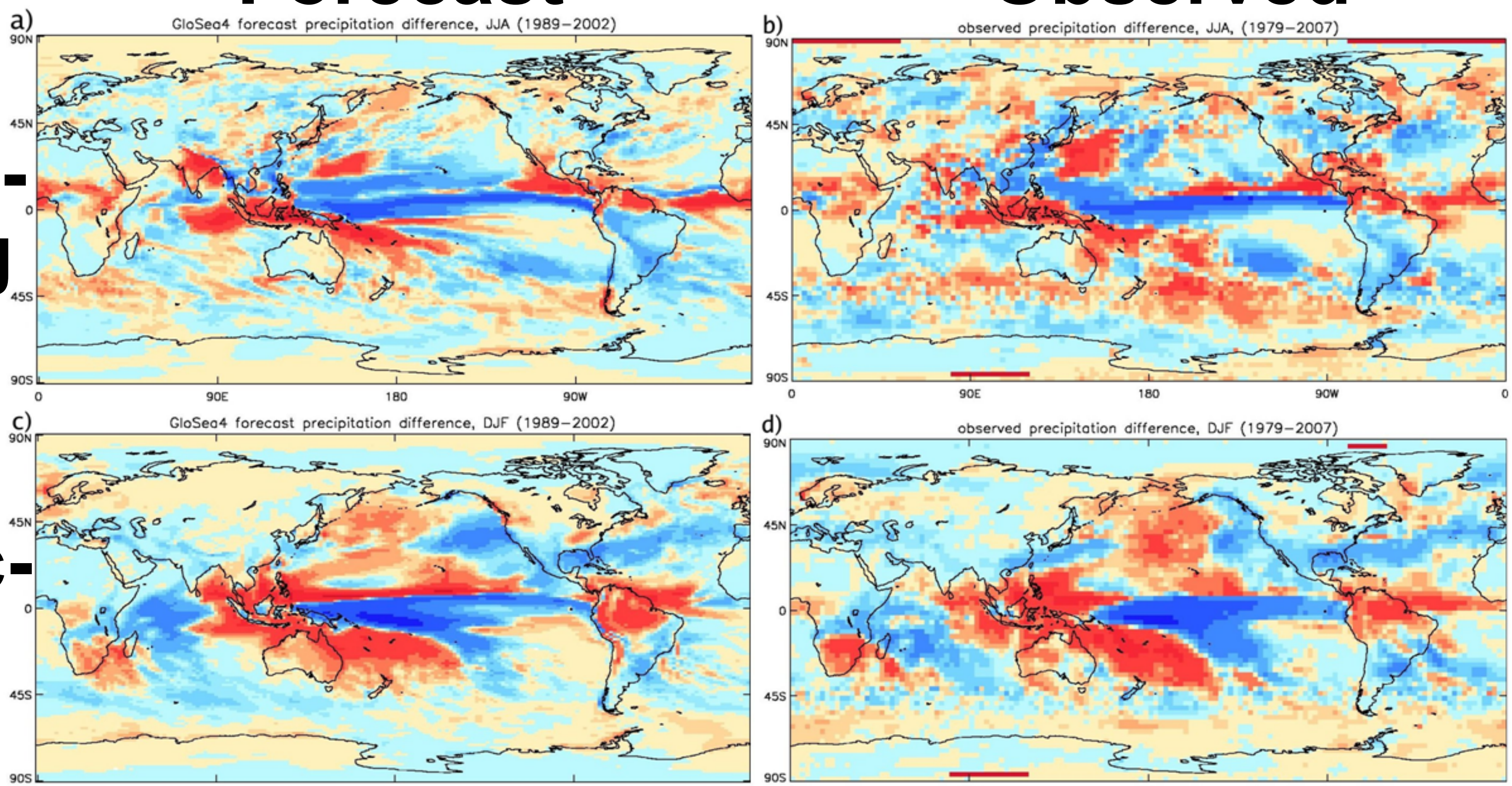
El Nino/La Nina Forecasts



Forecast **Observed**

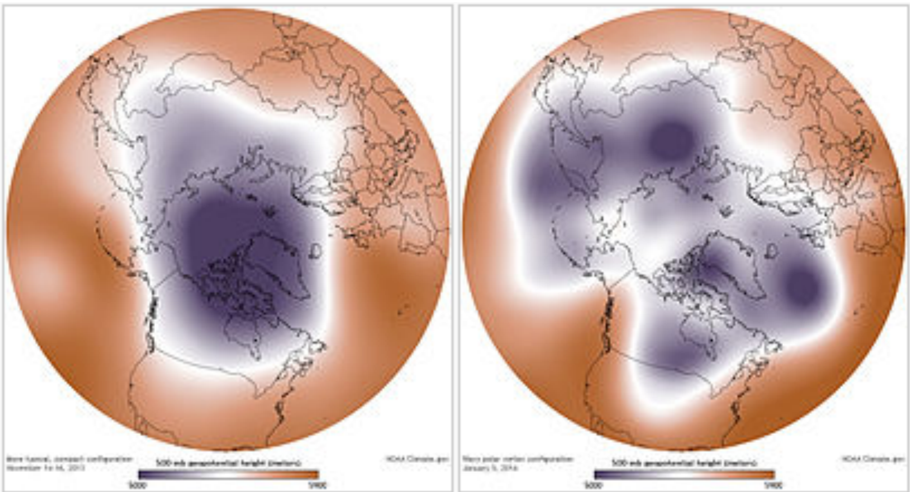
Jun-Aug

Dec-Feb

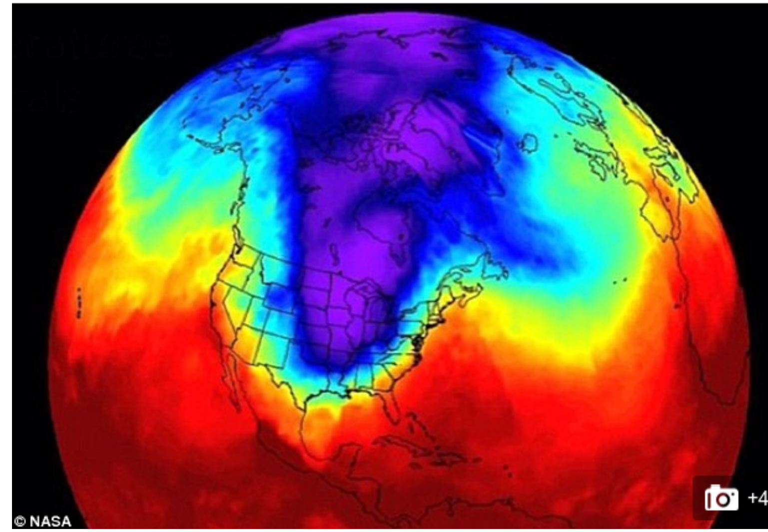


Arribas et al., MWR, 2011

The Polar Vortex

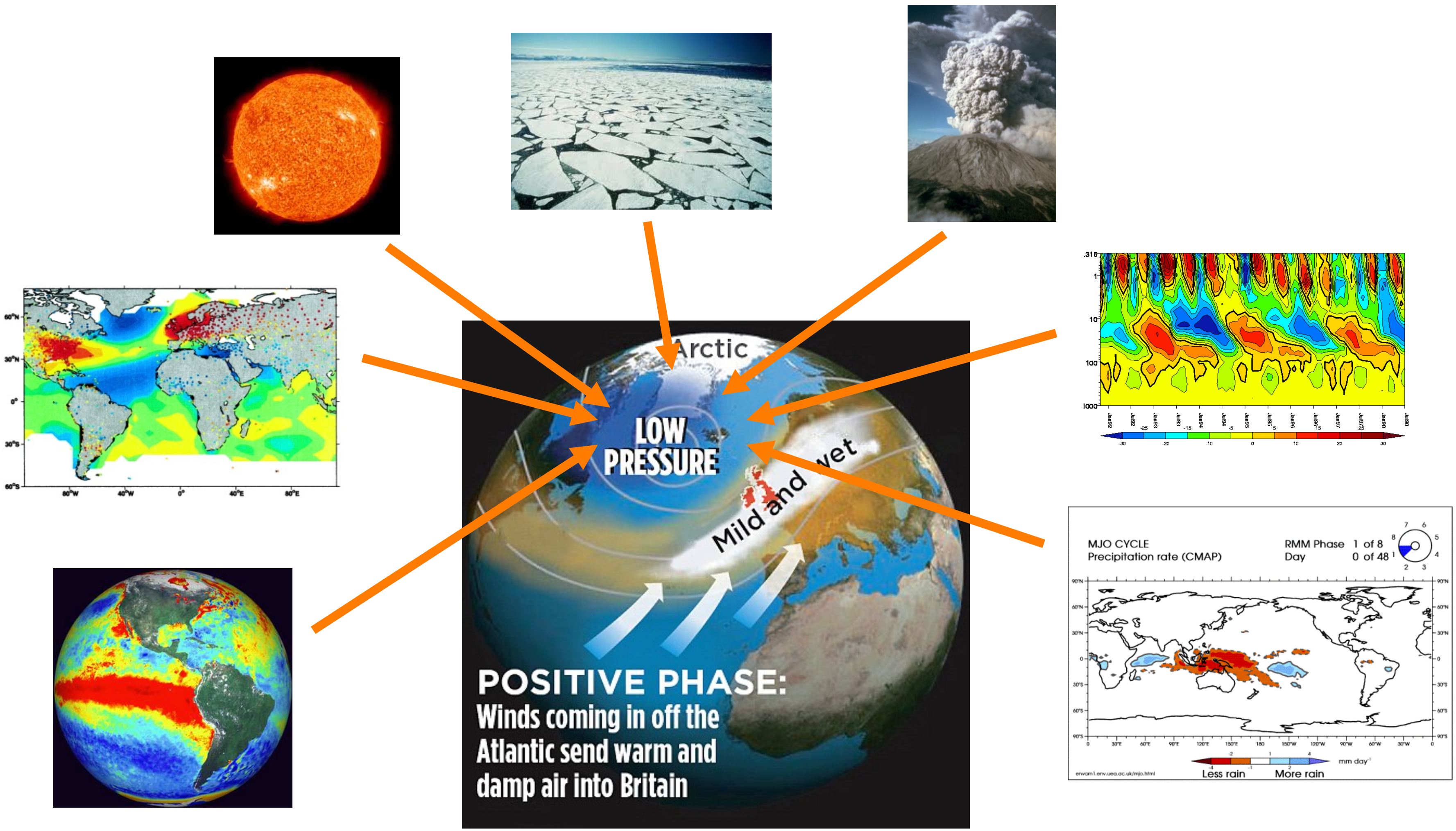


The typical polar vortex configuration in November 2013. ...A wavy polar vortex on January 5, 2014.

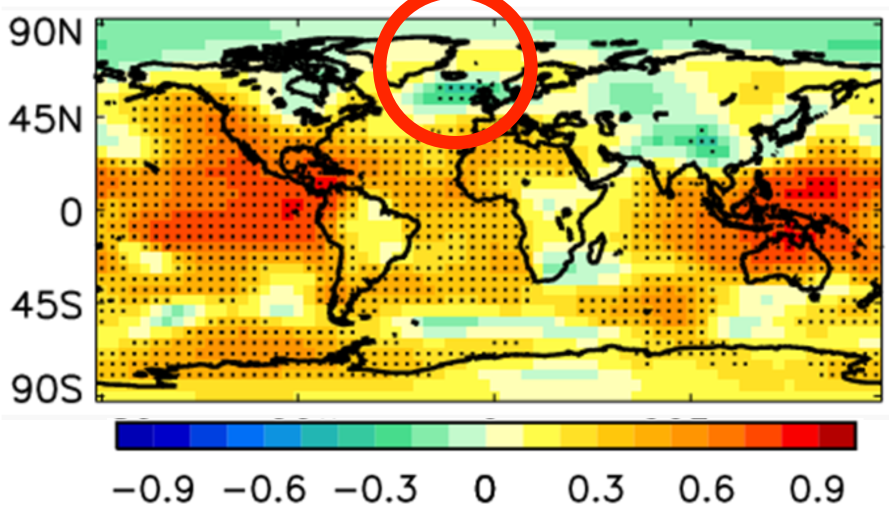


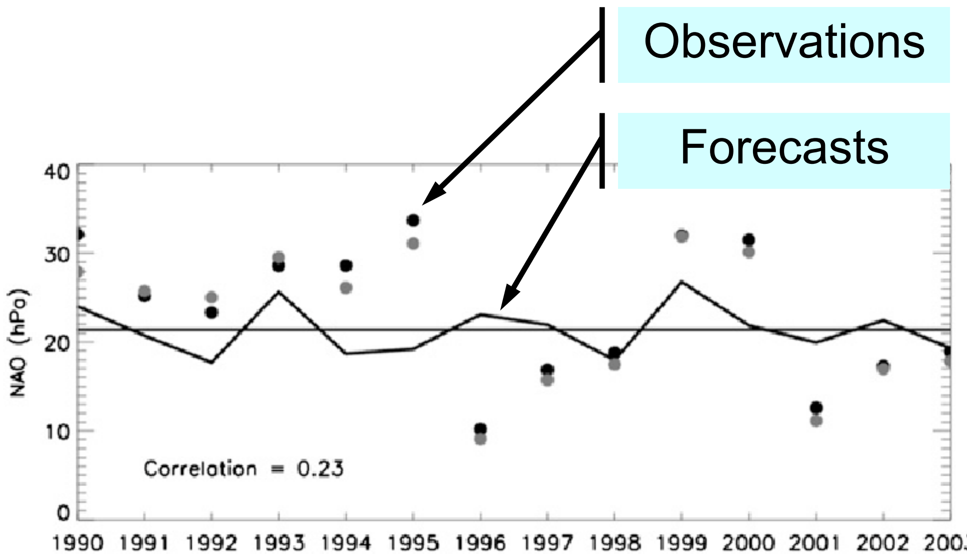
- Winter in USA and Europe depends on the wind direction
- Influenced by the Polar Vortex
- Sometimes breaks down → wavy
- Cold northerly winds e.g. 2014

Atlantic winter climate: the North Atlantic Oscillation (NAO)



2012: capability for predicting NAO is very low

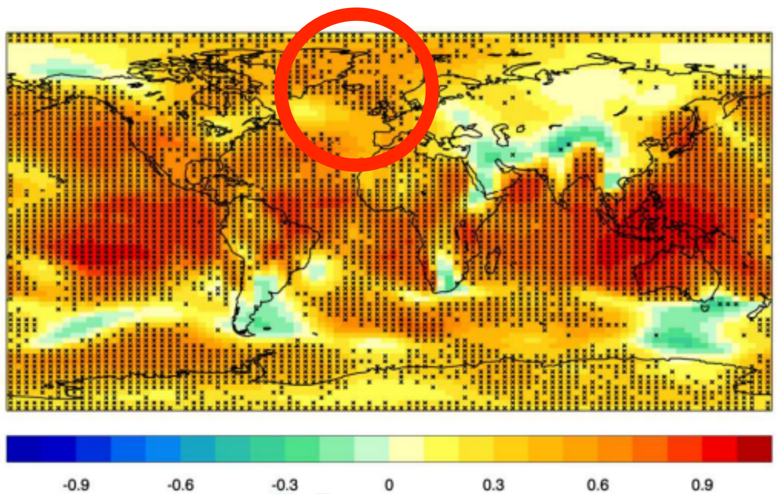


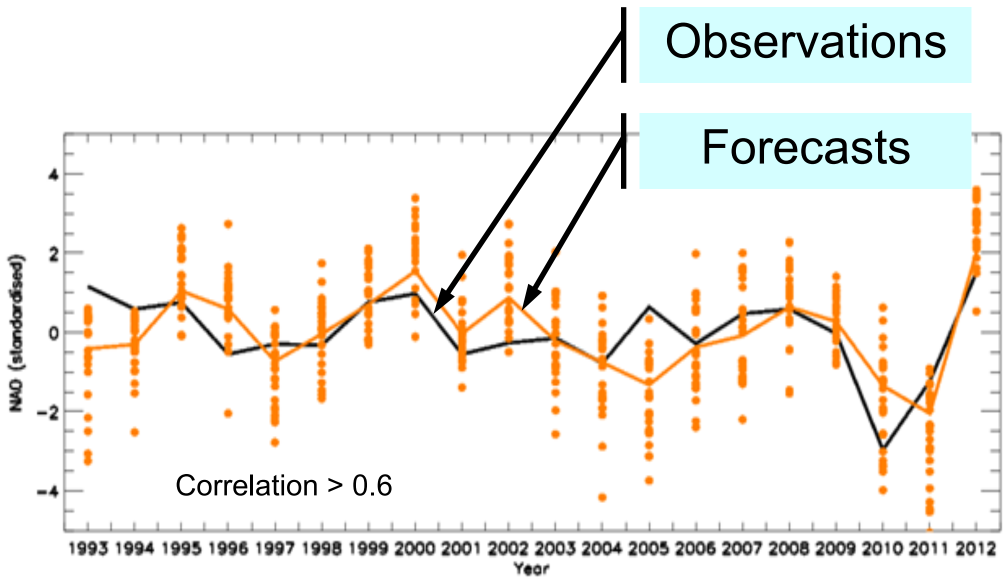


Skill (correlation) for predicting DJF sea level pressure starting on 1st November

Time series of observed (circles) and seasonal forecast (solid line) of the NAO

2014: capability for predicting NAO is high!





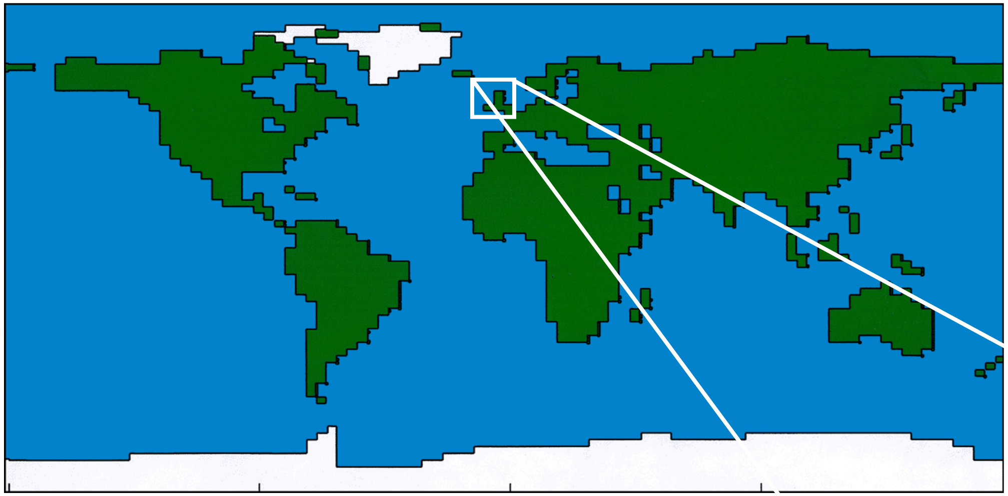
Skill (correlation) for predicting DJF sea level pressure starting on 1st November

Time series of observed (black) and seasonal forecasts (orange) of the NAO

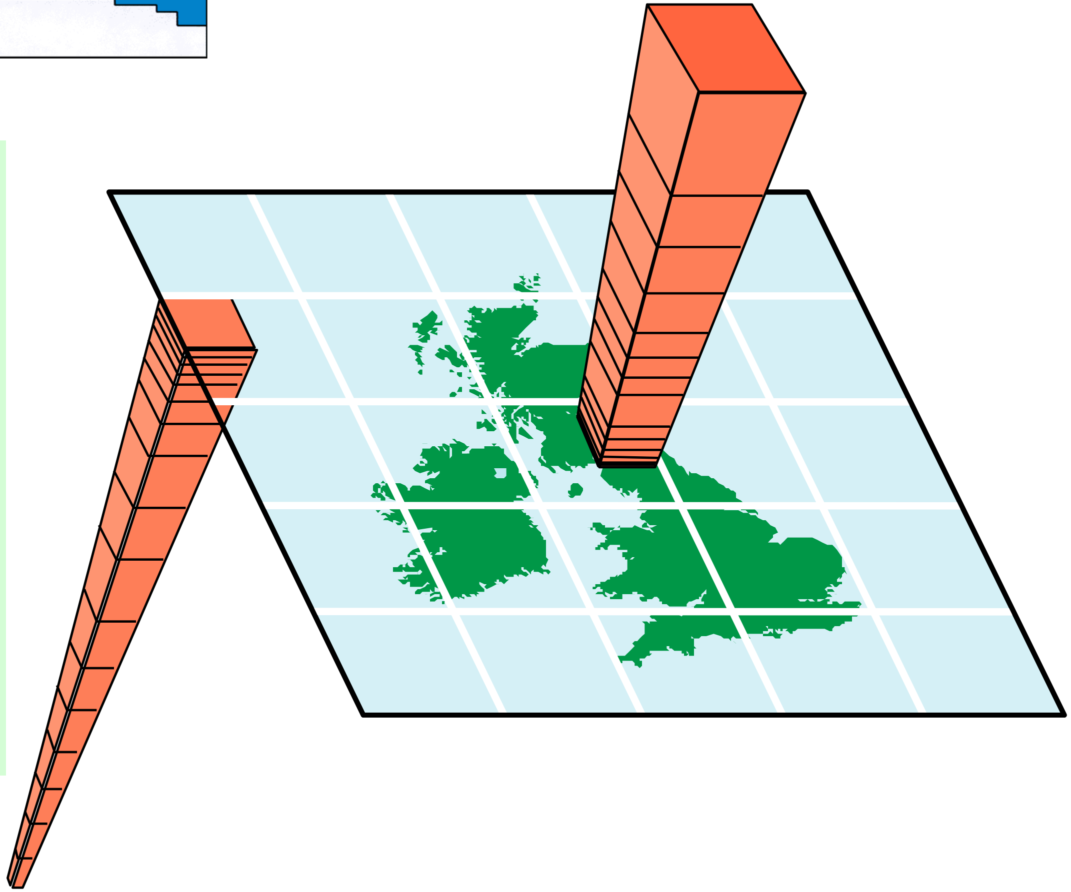
New model is 10 times more expensive
But now very skilful for European winters!

- Scaife *et al*, 2014

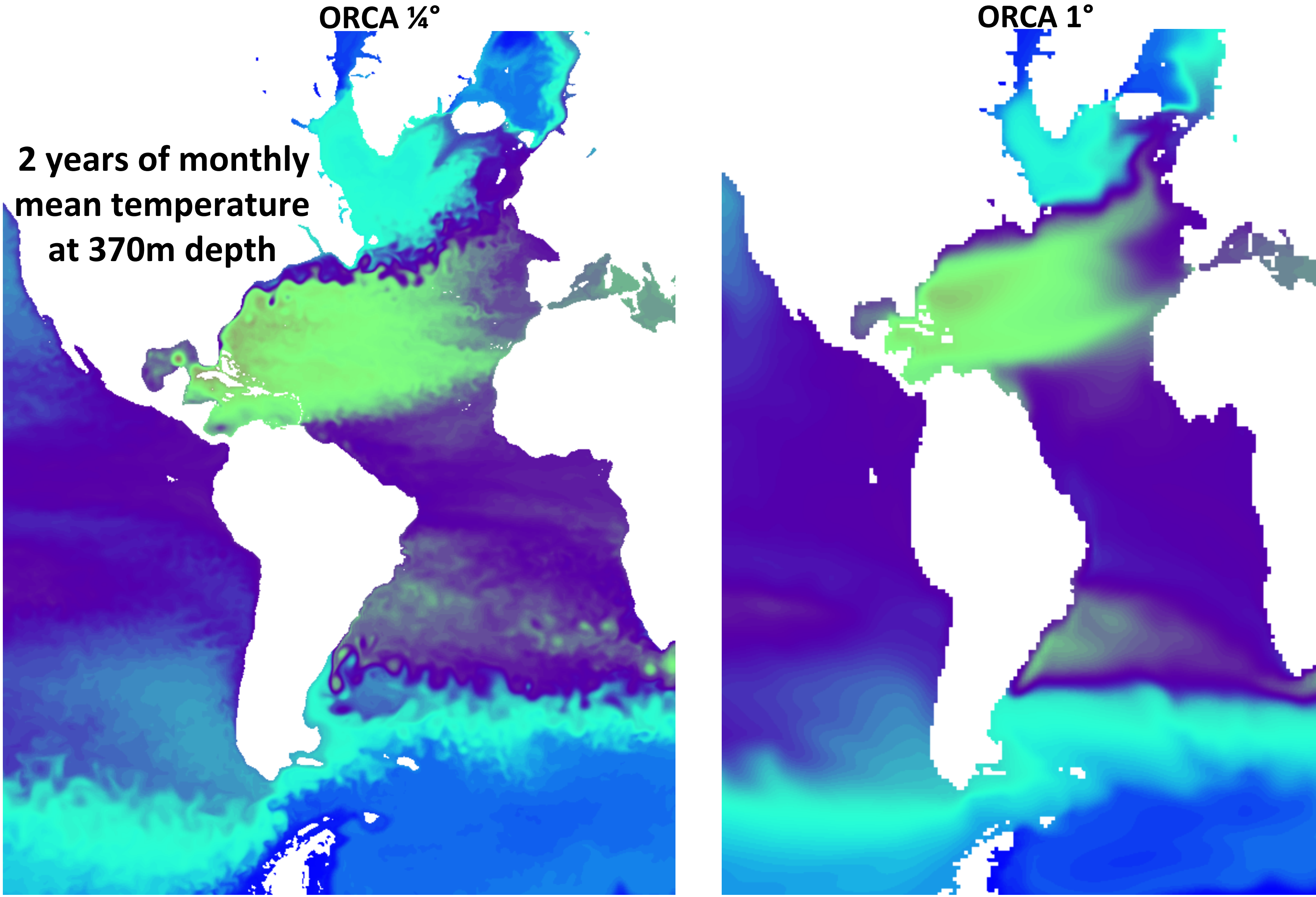
Modelling the climate



- Split the world into boxes
- For each box, ensure fundamental laws of physics are satisfied:
  - Conservation of mass, momentum and energy
- Small scale processes (e.g. Clouds) must be parameterised
- The smaller the boxes the higher the accuracy
- ...but more expensive (need large supercomputers)



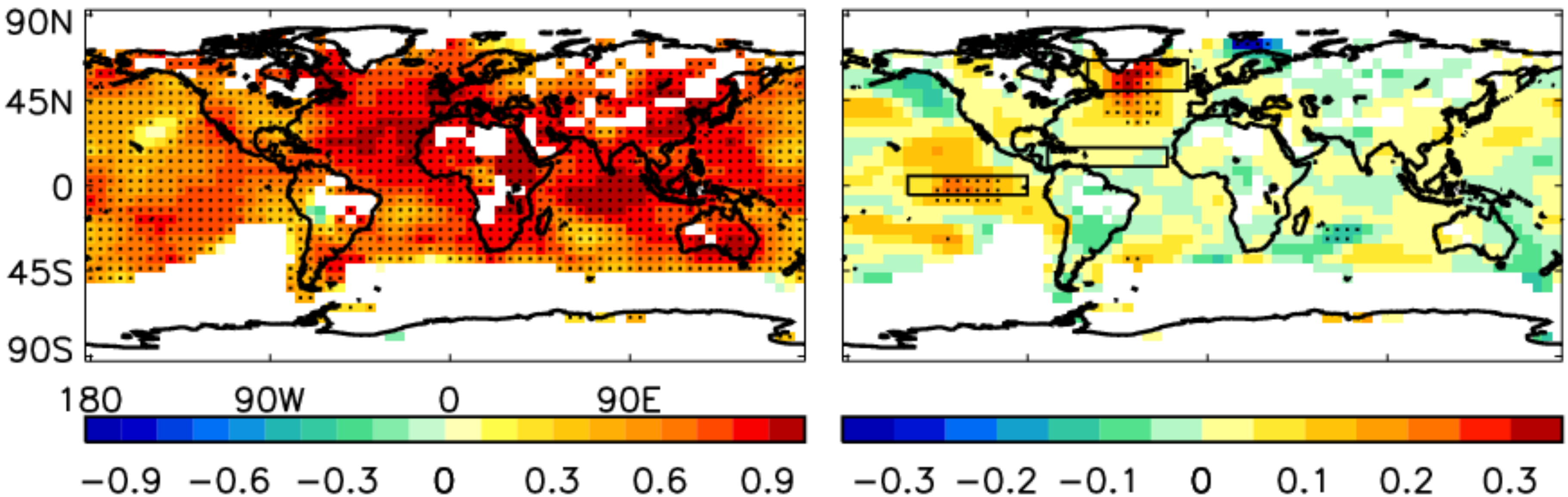
Higher resolution



The next 5 years

Skill of initialised predictions

Initialised - Uninitialised



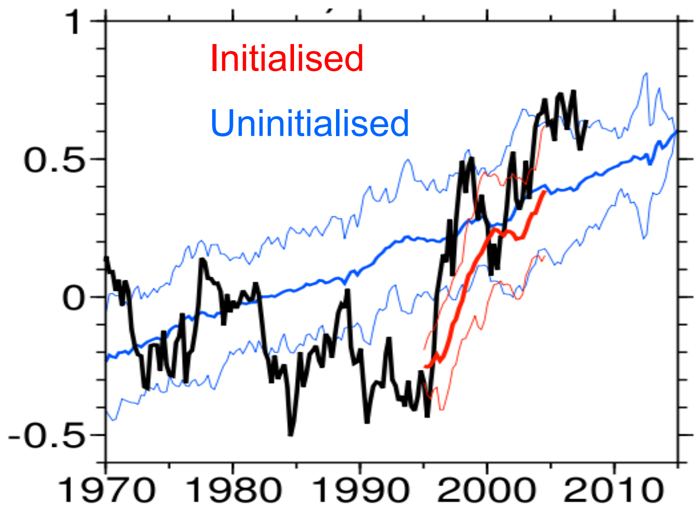
- Skilful almost everywhere (positive correlations)
- Mostly due to external forcing
- Initialisation gives improved skill mainly in North Atlantic and tropical Pacific

(Smith et al. 2010)

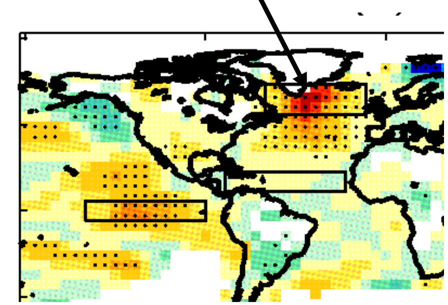
Case study: sub-polar gyre

Met Office
Hadley Centre

Predictions of sub-polar 1990s gyre warming



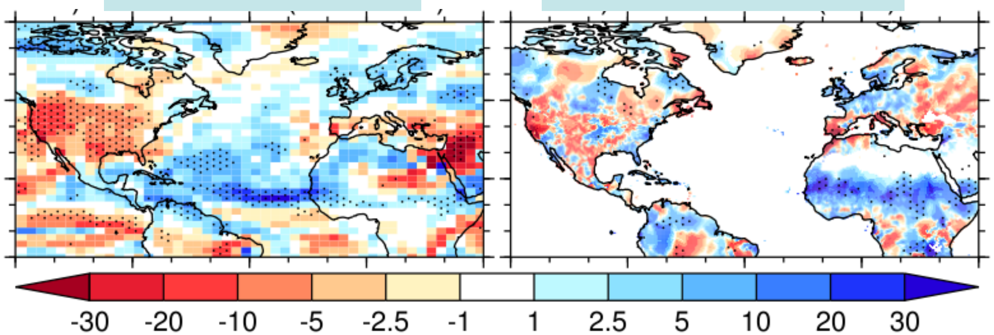
Sub-polar gyre



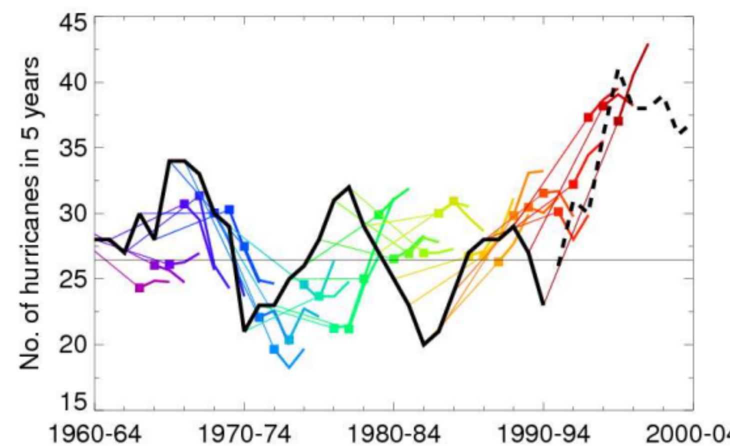
Impacts: rainfall

Model

Observations



Impacts: hurricanes



• Low skill in general, but some impacts captured over land for specific events

(Robson et al. 2012, 2013, Smith et al 2013)

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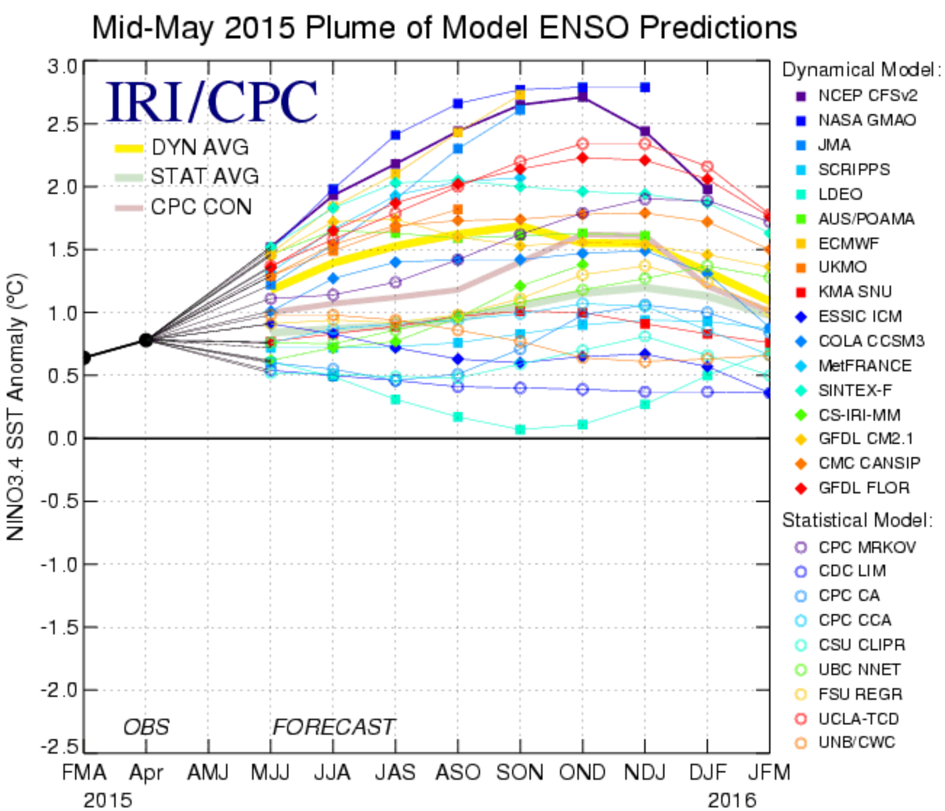
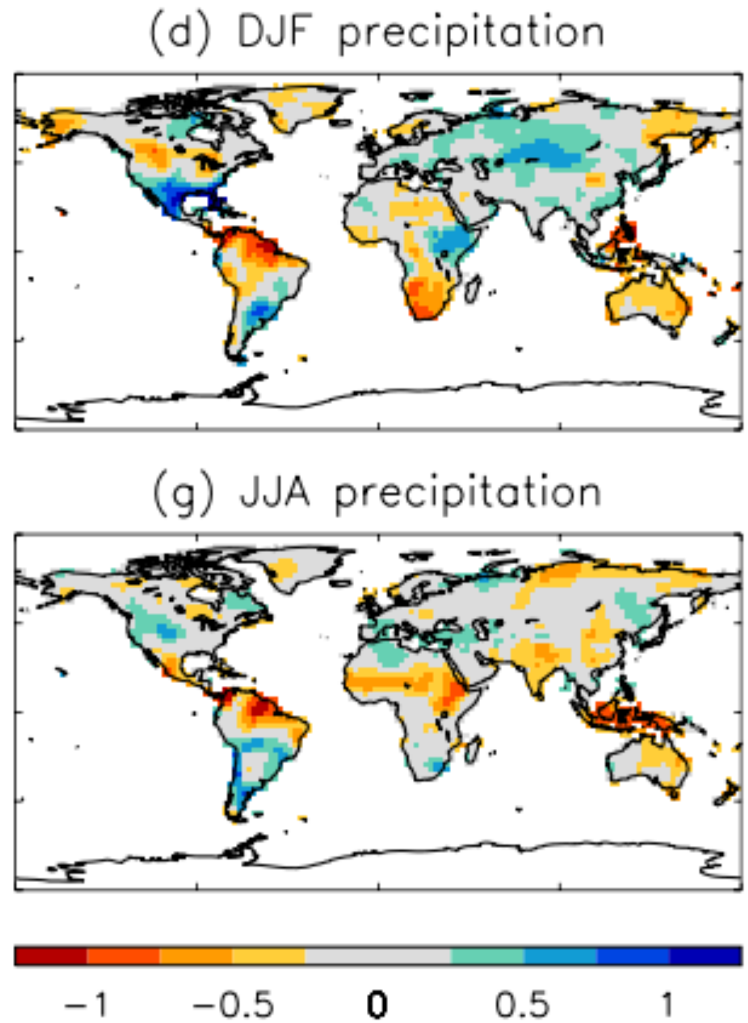
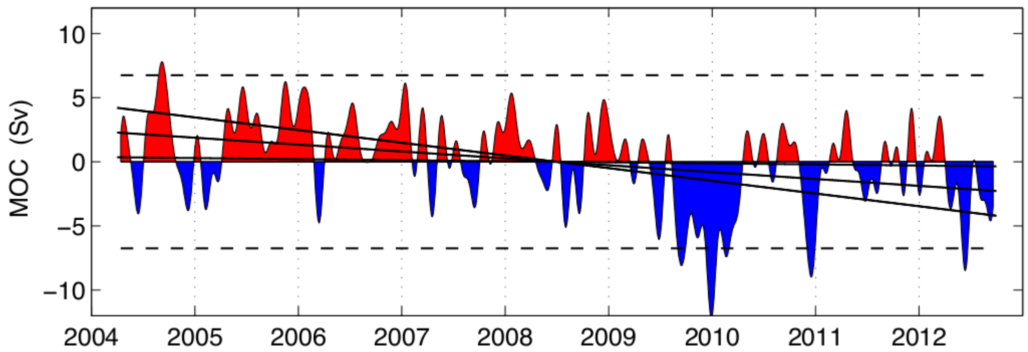
El Niño forecast



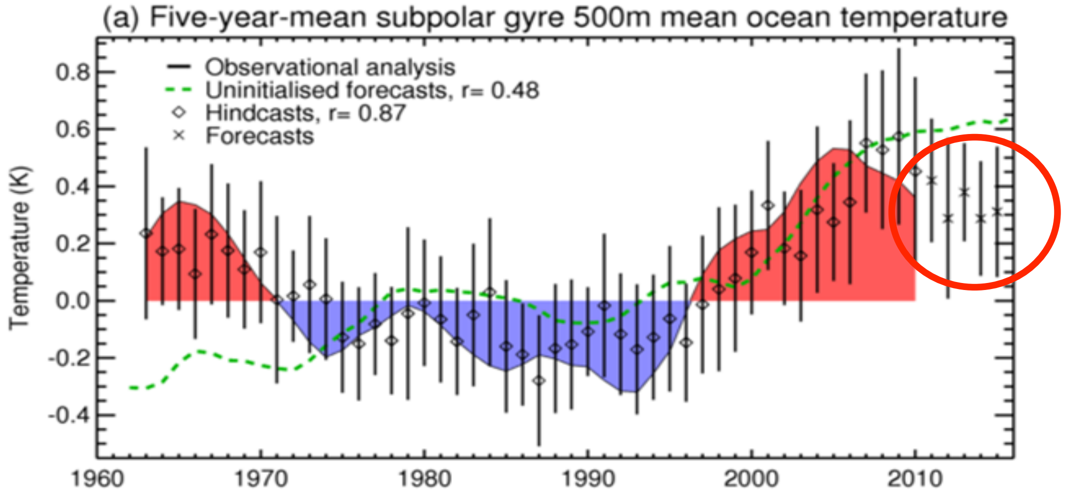


What next?

Observed Atlantic overturning circulation



Decadal forecasts of Atlantic temperature



- Atlantic predicted to cool…
- …in response to weakening of Atlantic overturning
- Not a reversal (yet), but impacts associated with warm Atlantic less likely:
  - cold winters and wet summers in Europe less likely
  - fewer hurricanes than recent peaks
  - reduced Sahel rainfall
  - reduced risk of drought in SW USA

- Smeed *et al*, 2013; Hermanson et al 2014

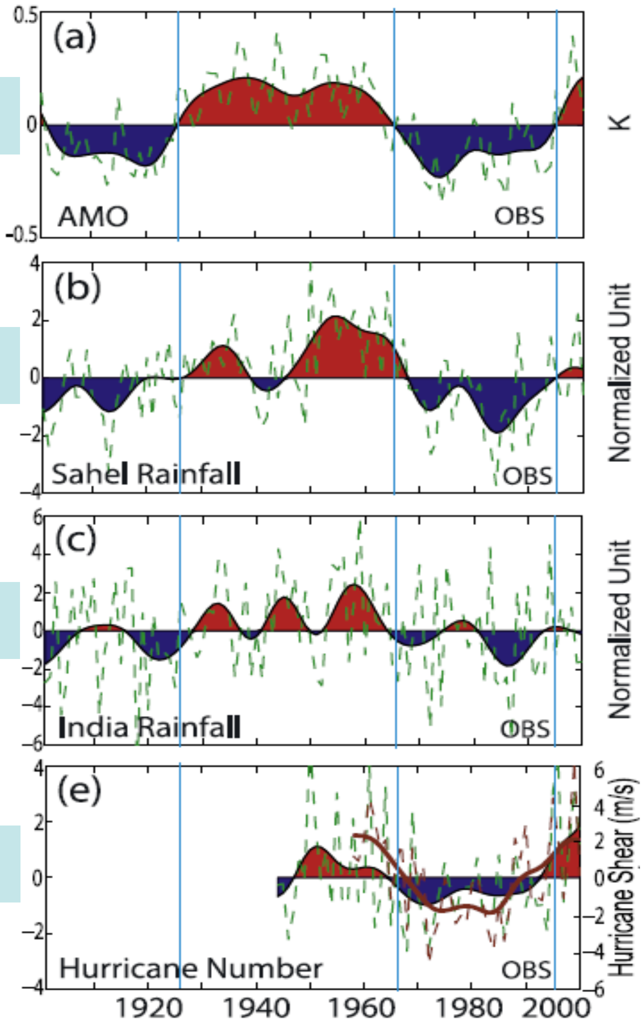
North Atlantic variability

North Atlantic SST

Sahel rainfall

India rainfall

Hurricanes

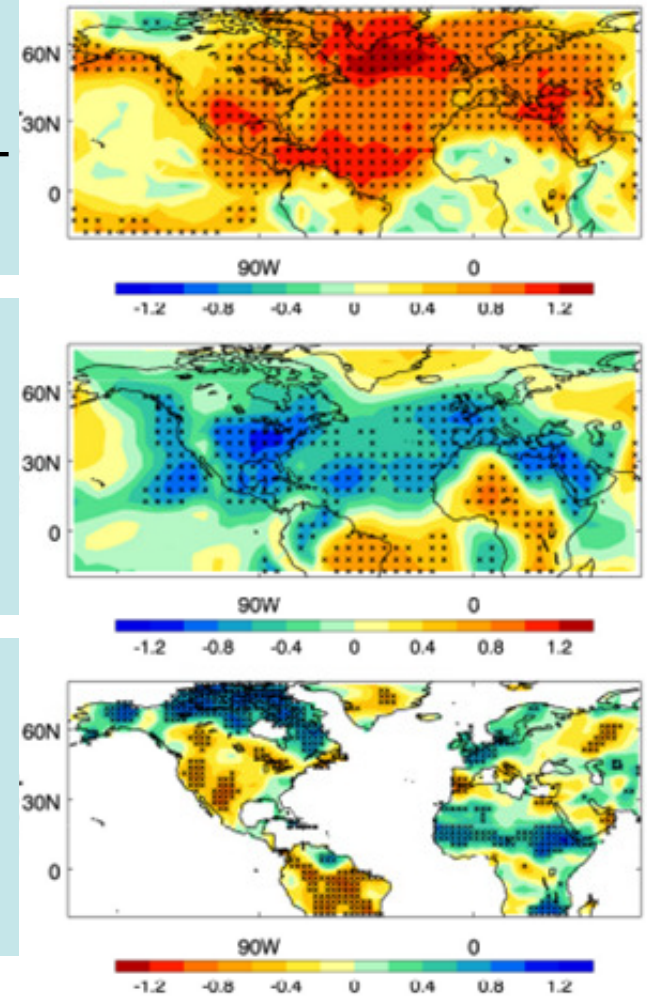


Warm – cold Atlantic: summer composite

Temperature

Pressure

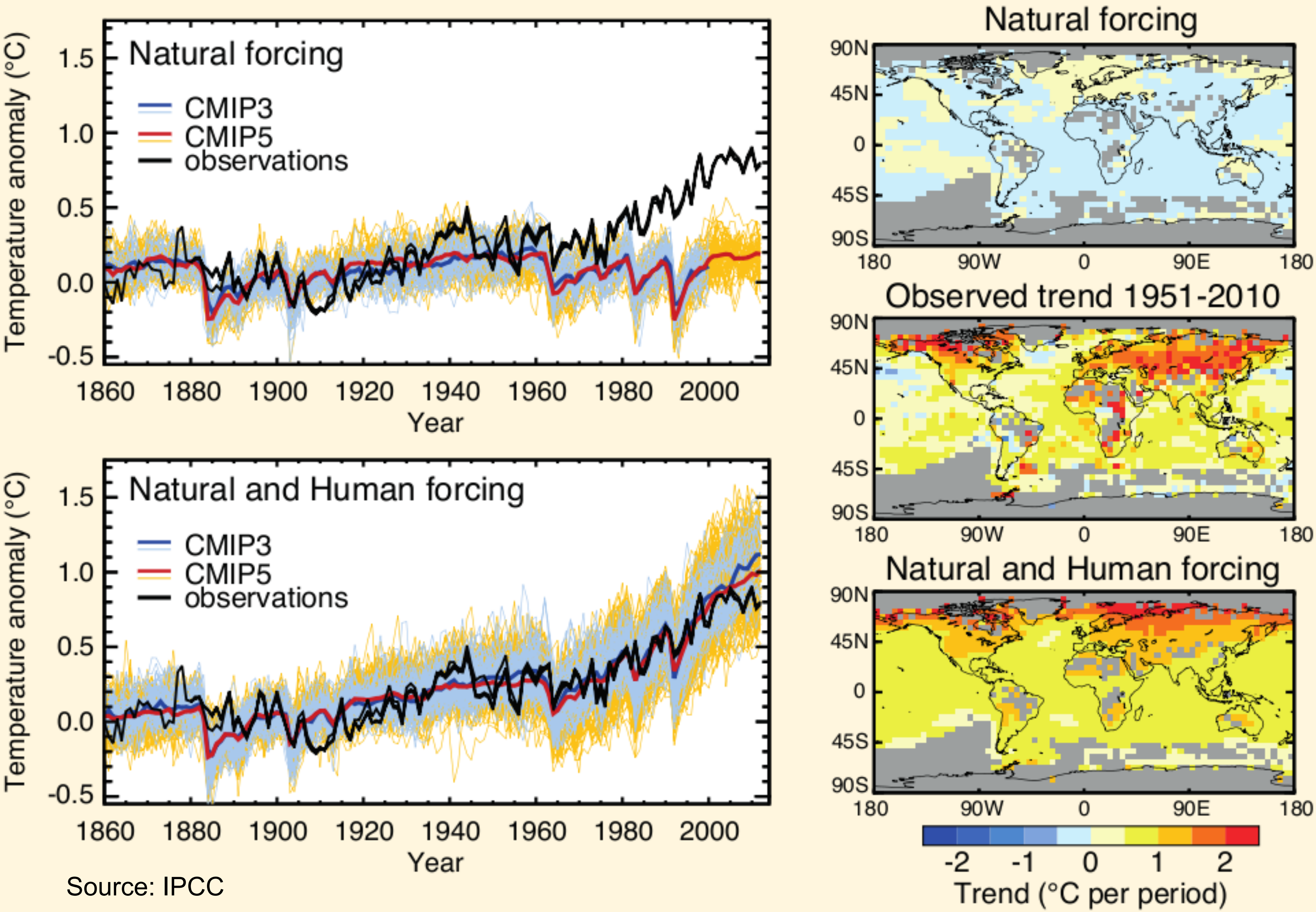
Rainfall



(Zhang and Delworth 2006; also Knight et al 2006 t al 2014)

Summary

- Many people are vulnerable to changes in climate over the coming seasons to decades
- There are good physical reasons why we may be able to predict some aspects of climate on these timescales
- ...though there will be uncertainties that need to be carefully communicated!
- This is a new and rapidly developing area
- Much recent progress...
- ...but also many issues still to overcome


Natural forcing
CMIP3
CMIP5
observations
Temperature anomaly (°C)
1.5
1.0
0.5
0.0
-0.5
1860
1880
1900
1920
1940
1960
1980
2000
Year
Natural and Human forcing
CMIP3
CMIP5
observations
Temperature anomaly (°C)
Year
Natural forcing
Observed trend 1951-2010
Natural and Human forcing
90N
45N
0
45S
90S
180
90W
0
90E
180
-2
-1
0
1
2
Trend (°C per period)

Source: IPCC