

# Forecast system development: what next?

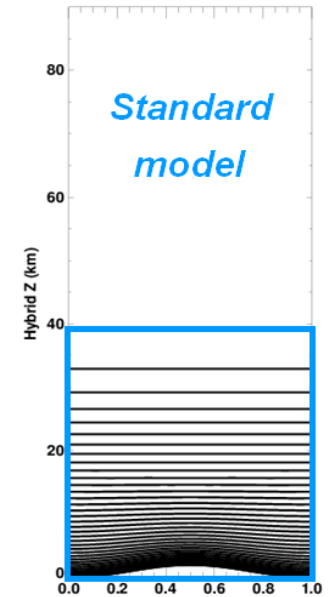
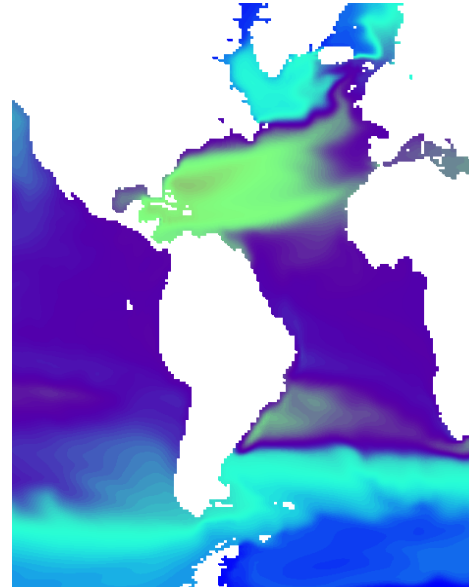
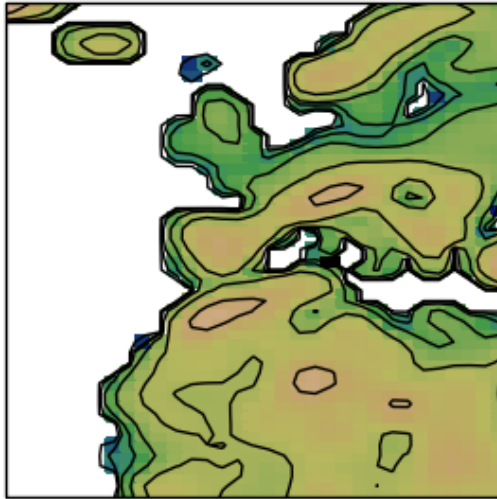
Doug Smith, Adam Scaife, Nick Dunstone, Leon Hermanson, Rosie Eade, Vikki Thompson, Martin Andrews, Jeff Knight, Craig MacLachlan, and many others



# Improved models

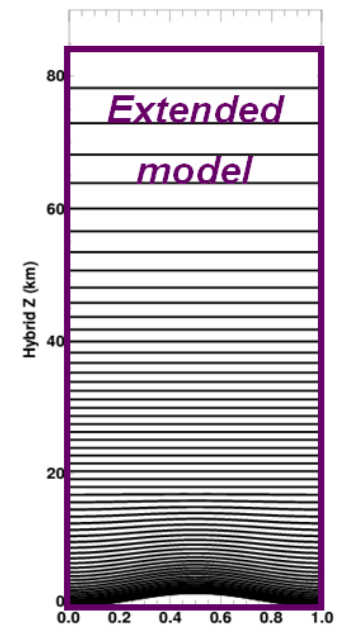
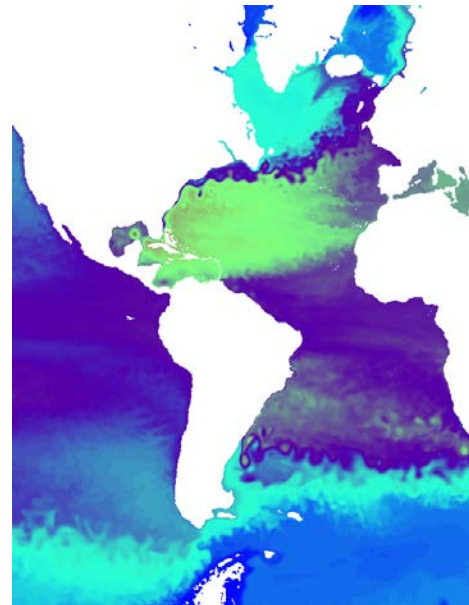
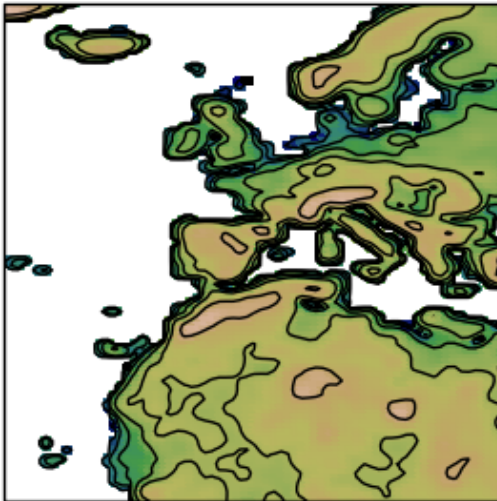
## Previous model

- 150 km atmosphere
- 1 degree ocean
- Poorly resolved stratosphere



## Latest model

- 60 km atmosphere
- 1/4 degree ocean
- Well resolved stratosphere







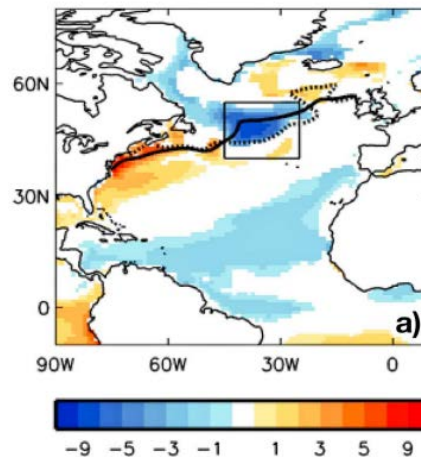
**Met Office**  
Hadley Centre

- Previous model: cold bias → blocking frequency too low
- Much improved with new model

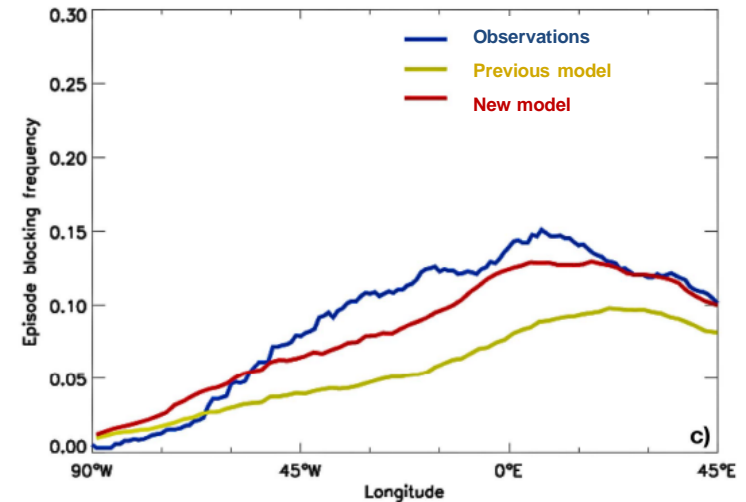
- Downward propagation of signals from the stratosphere to the surface
- Seen in ENSO and solar impacts on NAO
- Not represented in previous model with poorly resolved stratosphere

# Improved models

Previous model bias



Atlantic blocking frequency



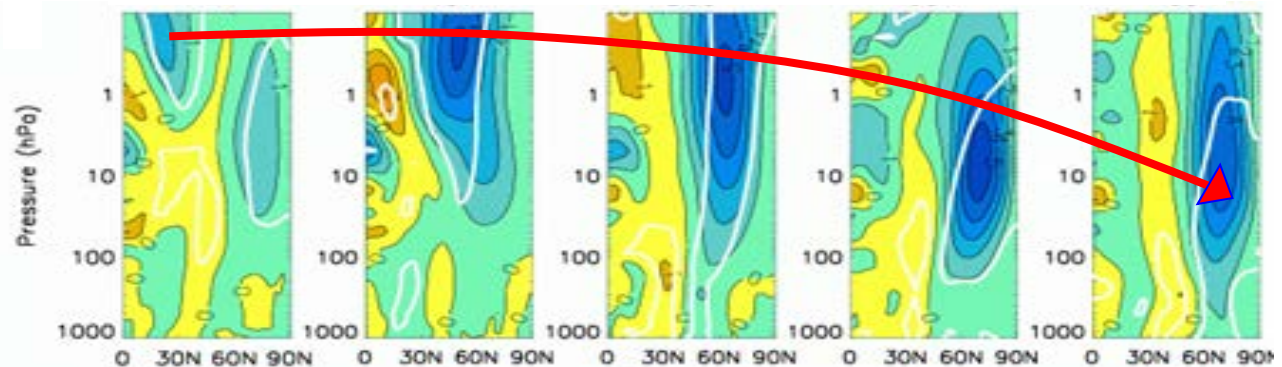
Oct

Nov

Dec

Jan

Feb



Zonal winds at 60°N



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Hadley Centre**

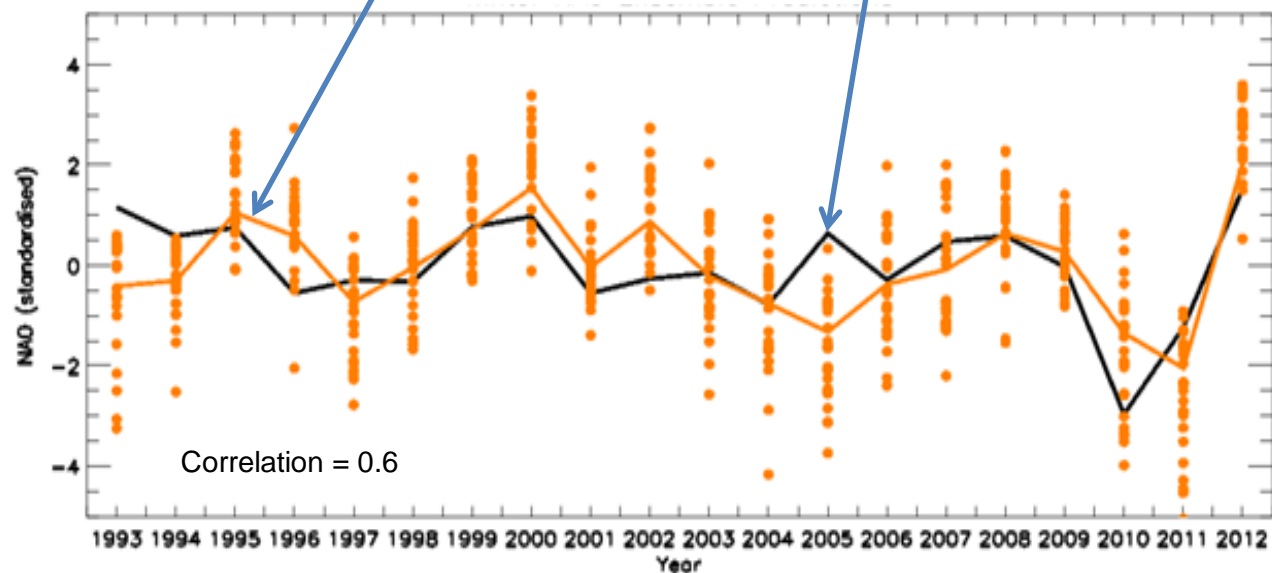
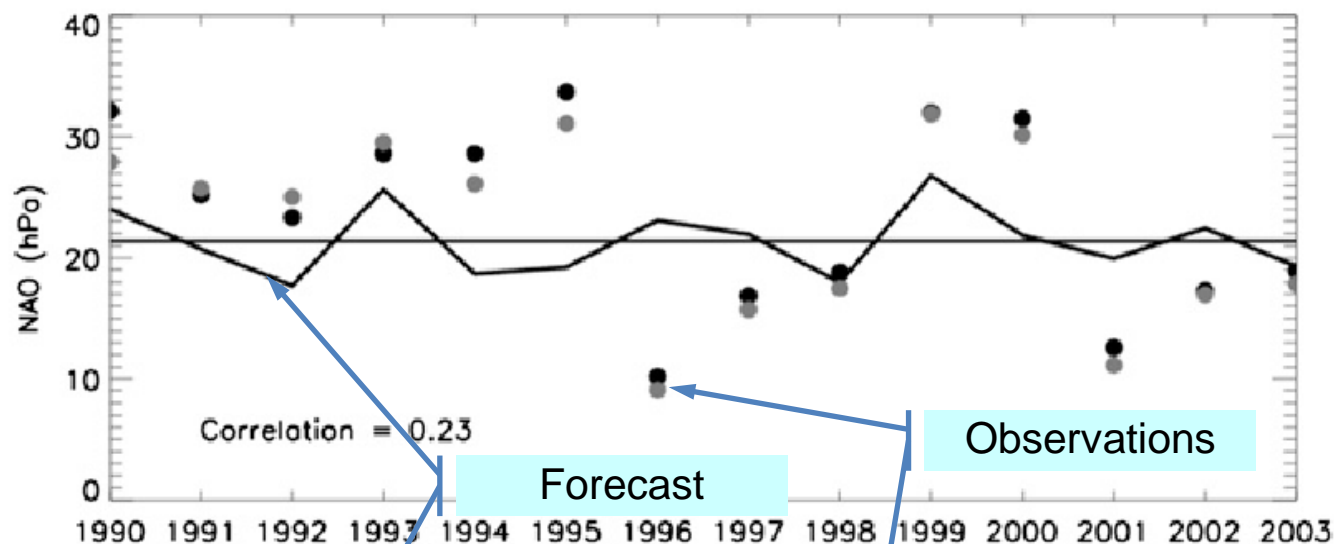
**Previous model**

- No significant skill

**Latest model**

- Good skill !

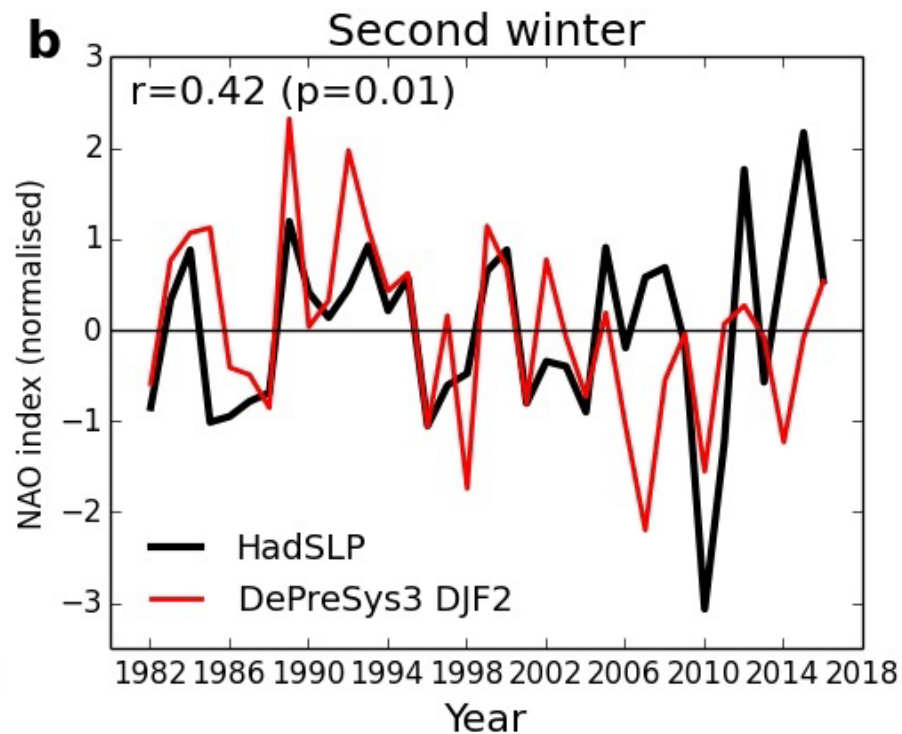
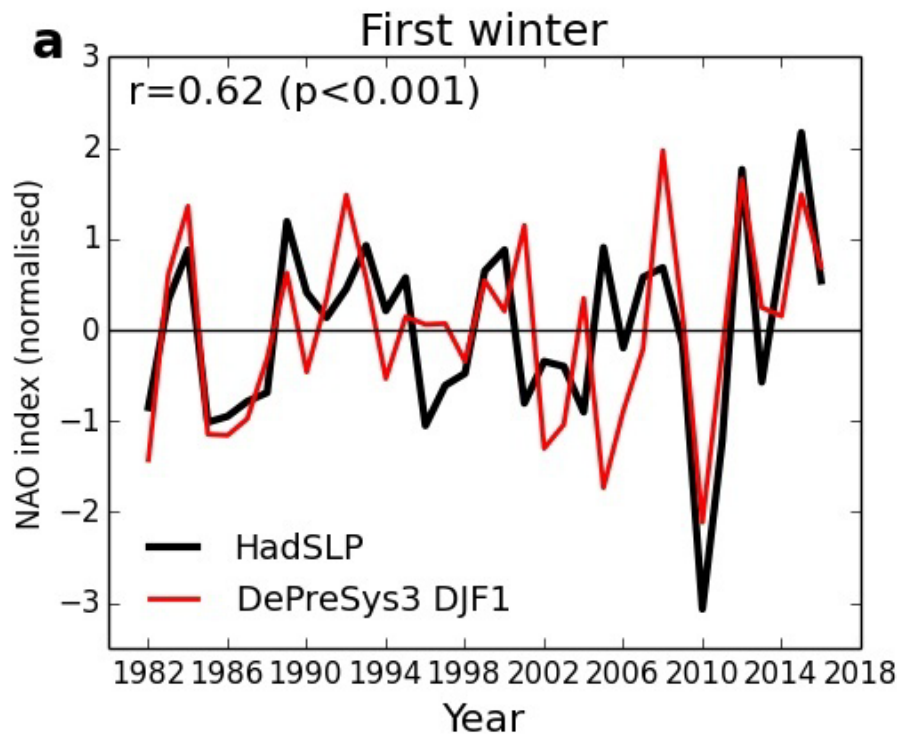
# Skilful predictions of European winter





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# Skilful predictions of European winter

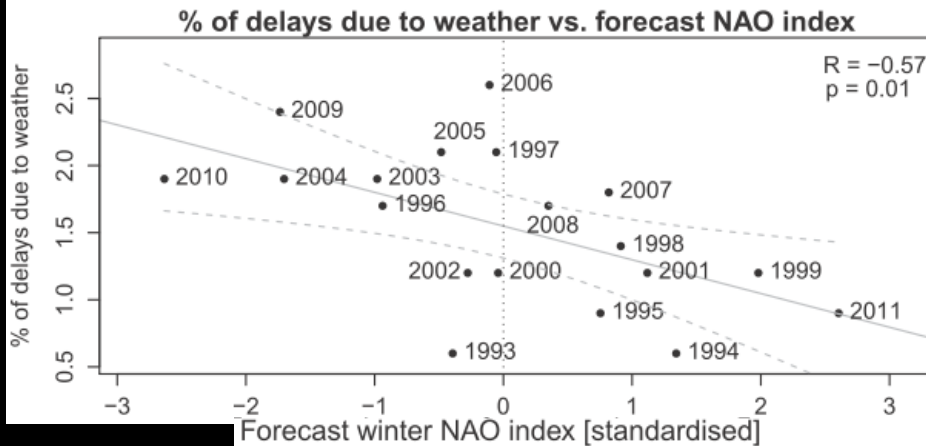


- Skill extends over the whole satellite era since 1980
- Recent large signals are captured
- Significant skill from more than a year ahead

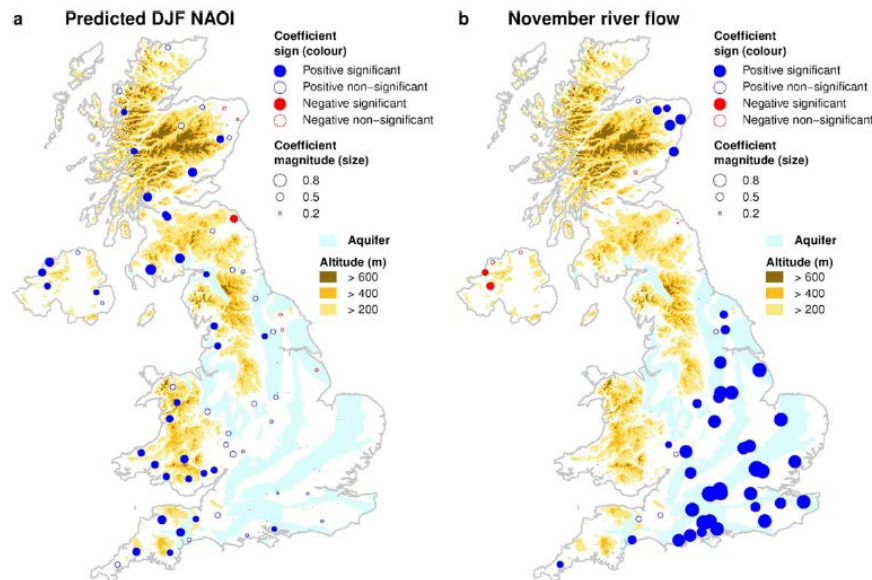
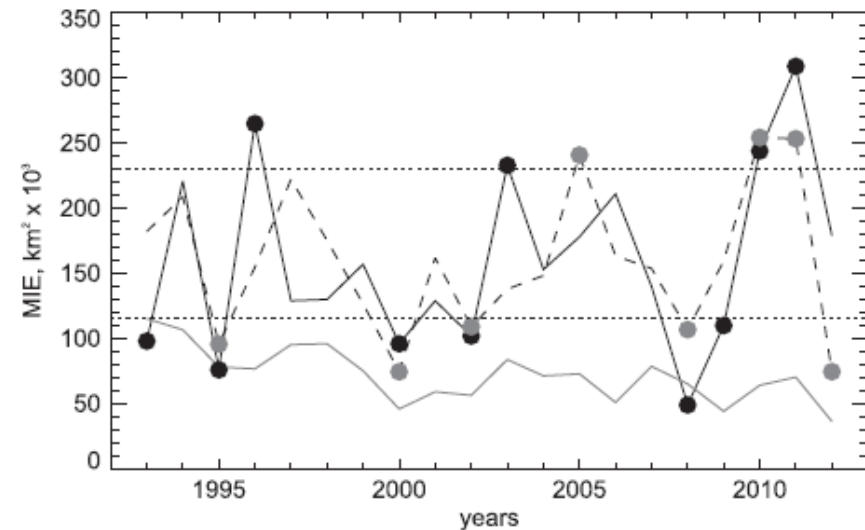


# Example applications of NAO forecasts

## UK transport: e.g. weather delays at Heathrow airport



## Baltic sea ice cover



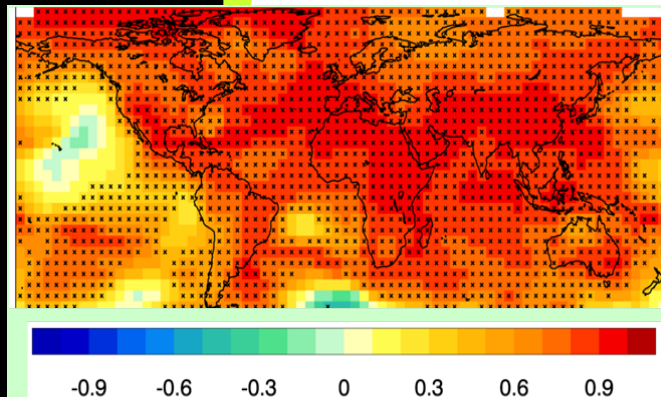
## UK river flow

Palin et al 2016, Karpechko et al 2016, Svensson et al 2015

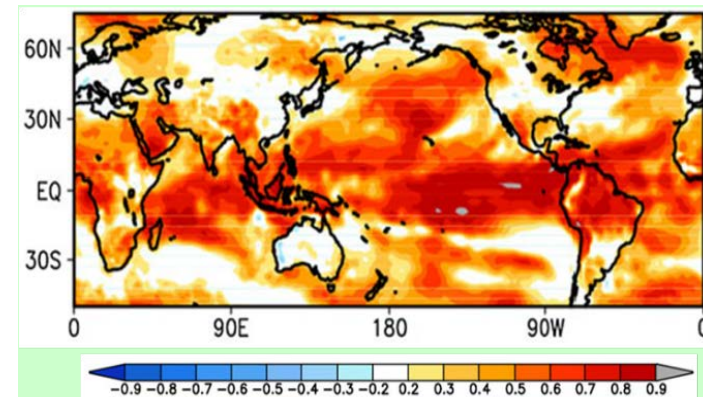


# Multi-year prediction skill

Skill for T in years 2-5



Skill for T in mths 2-4



Correlation skill over the period 1960 to 2005 from UKMO decadal predictions

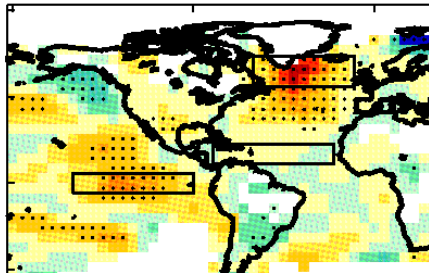
Correlation skill for DJF temperature from a typical seasonal hindcast.

Decadal prediction skill is higher than seasonal skill!

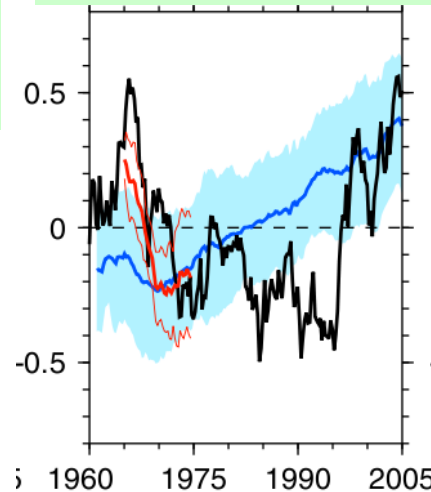


# Multi-year predictions

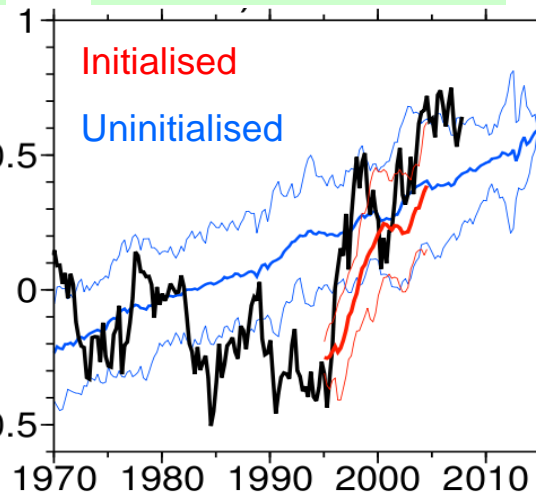
Improved skill from  
initialisation



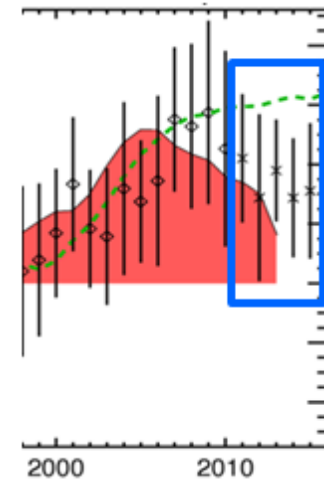
1960s cooling



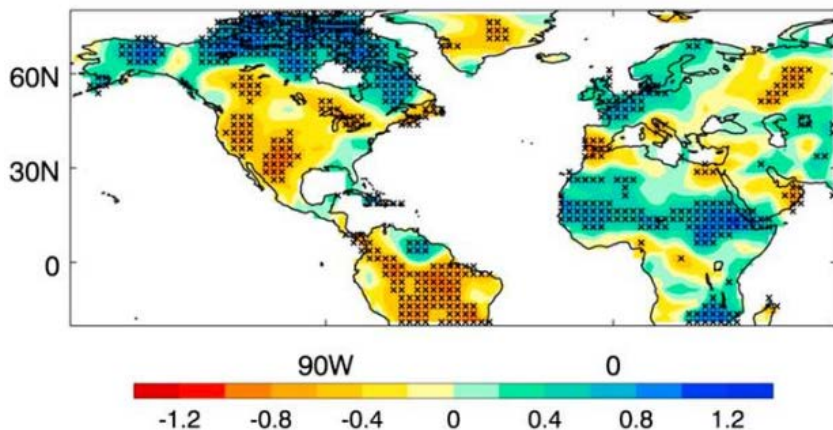
1990s warming



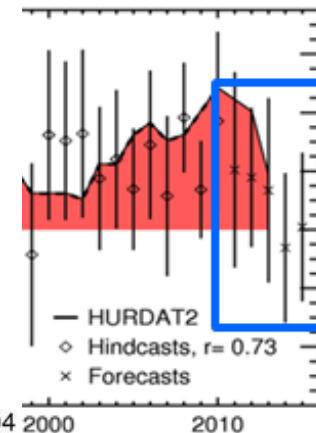
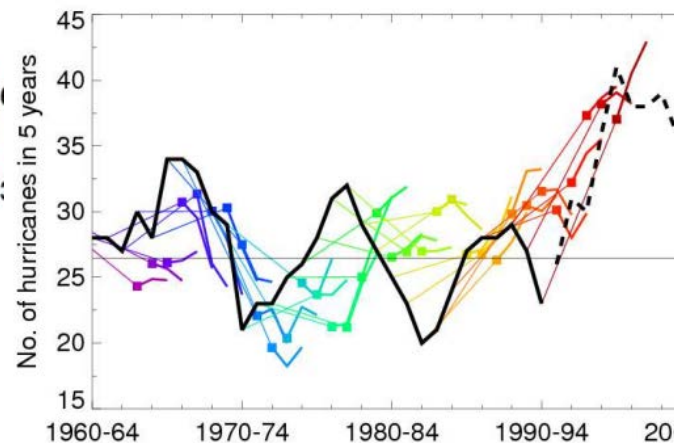
Forecast cooling



Impacts: rainfall



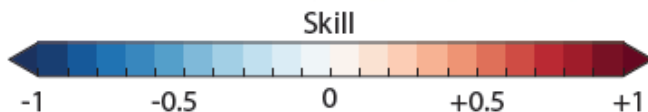
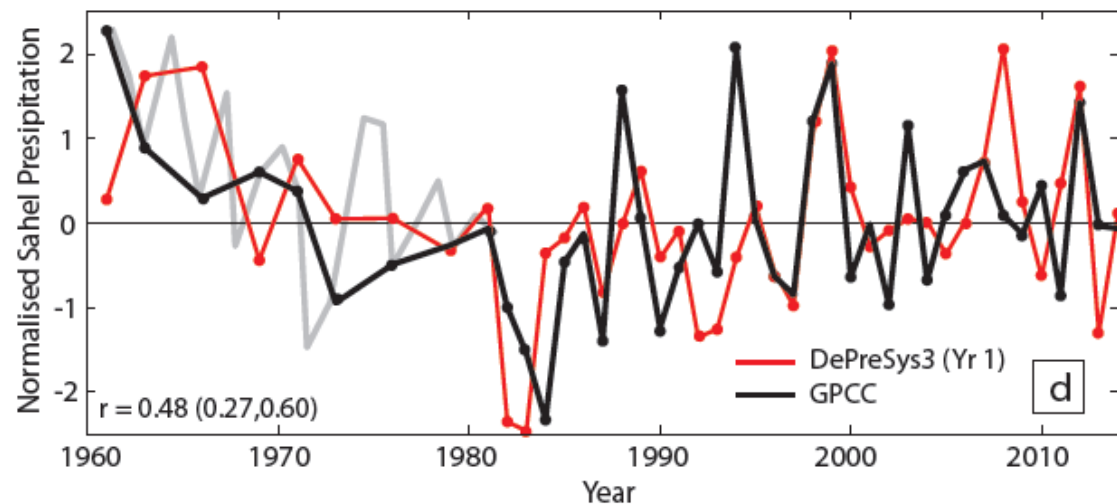
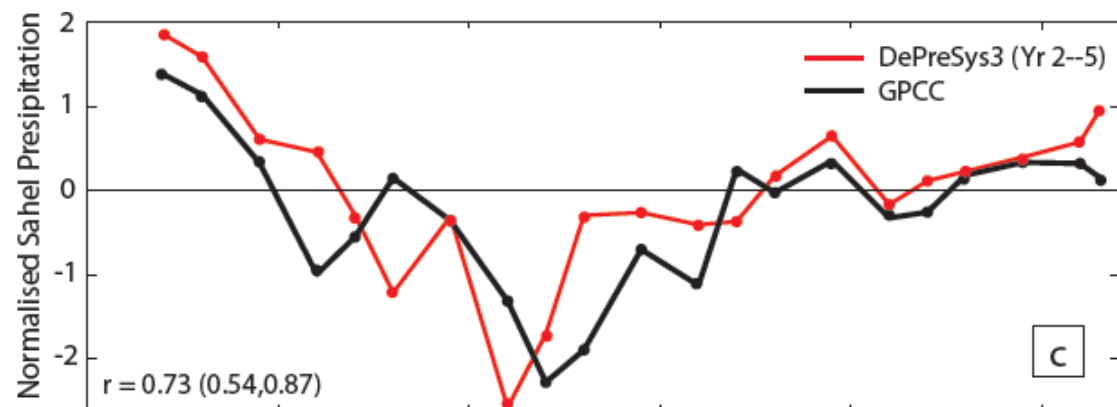
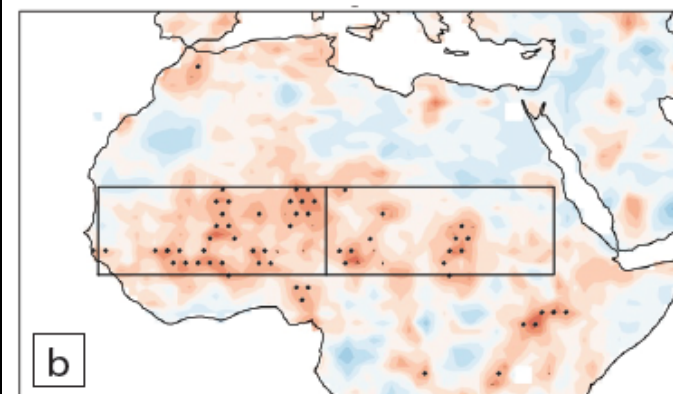
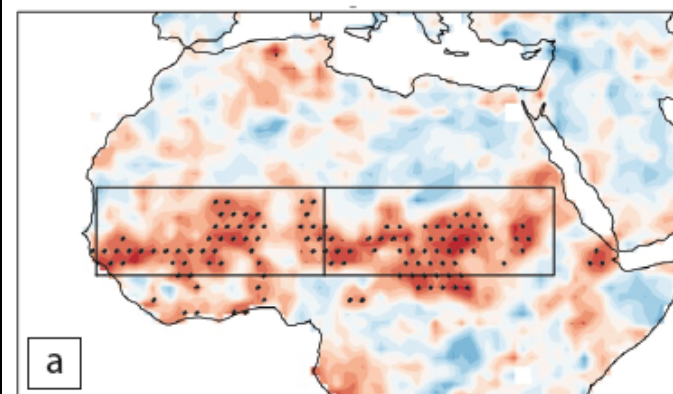
Impacts: hurricanes







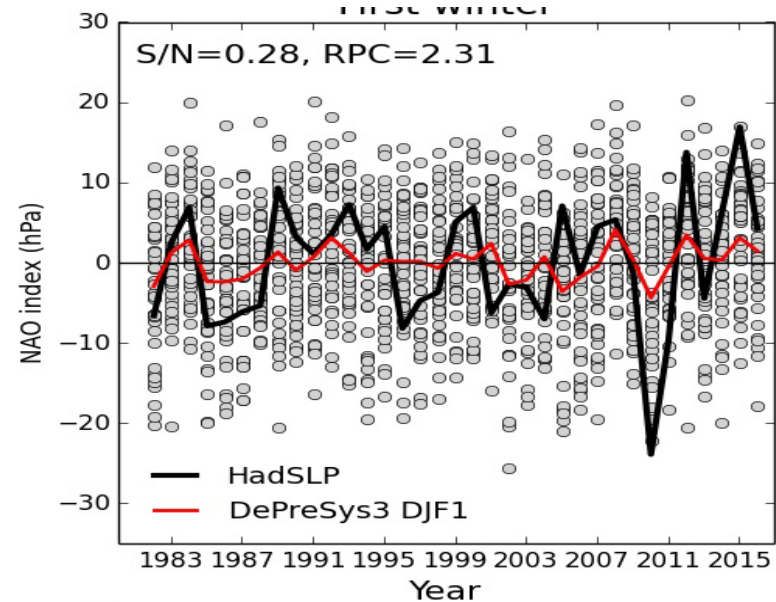
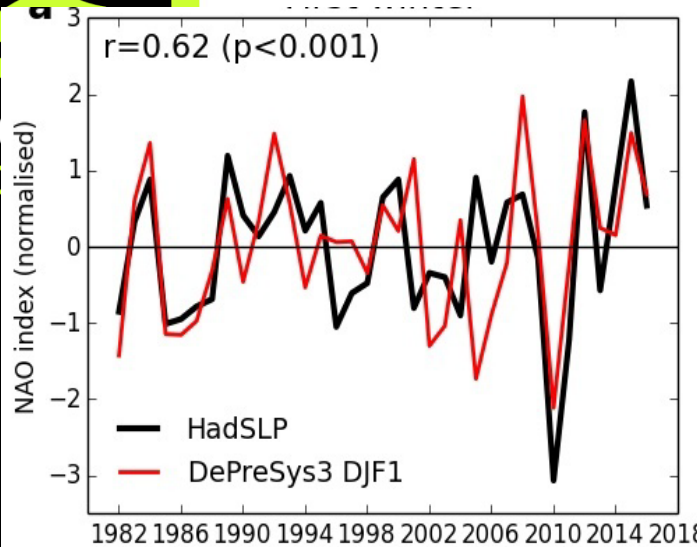
# Sahel rainfall



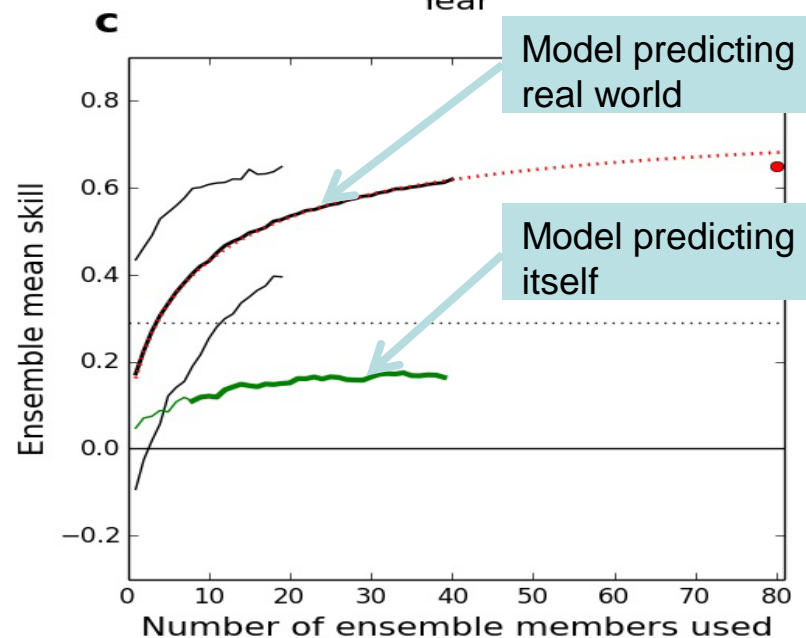
- Significant skill for both multiyear (years 2 to 5, top row) ...
- ... and inter-annual at 8 month lead (bottom row)

# The signal to noise paradox

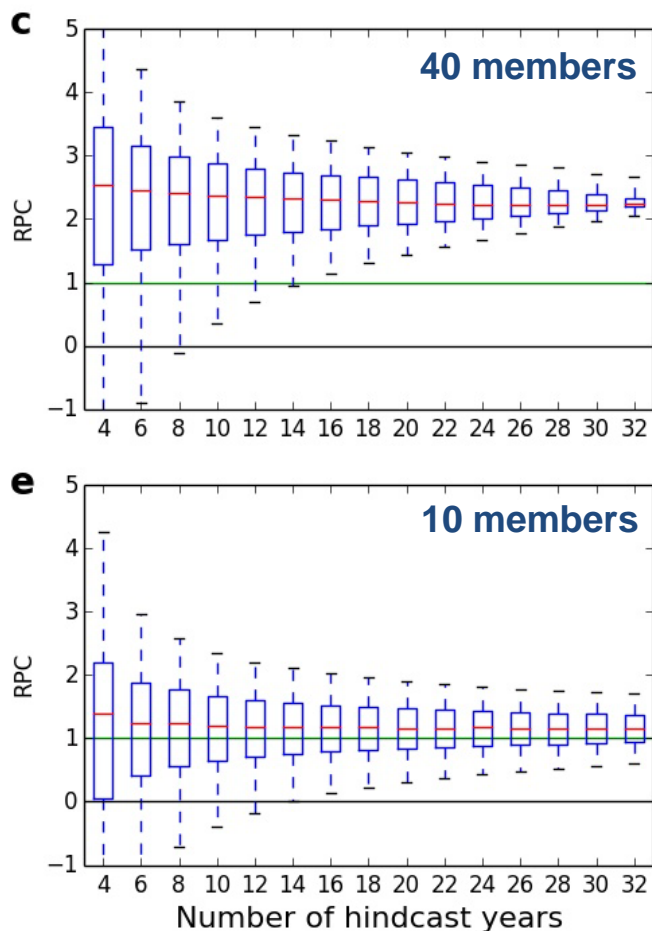
Met O  
Hadley C



- Skill (anomaly correlation) of seasonal forecasts of the NAO (DJF from Nov)
- Model ensemble mean predicts the real world better than individual model members!
- High skill despite low signal to noise in model → **“the signal to noise paradox”**
- **N.B.** You will not see this if you have a low skill score...



# The signal to noise paradox



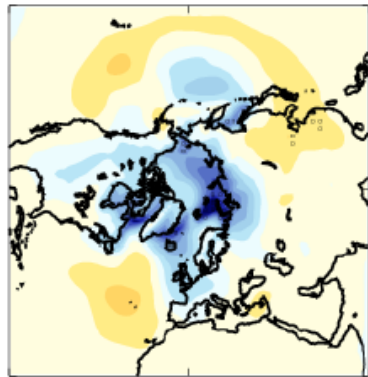
NAO signal-to-noise paradox now seen in multiple seasonal forecast systems. **Key research question to understand the deficiencies in current models.**



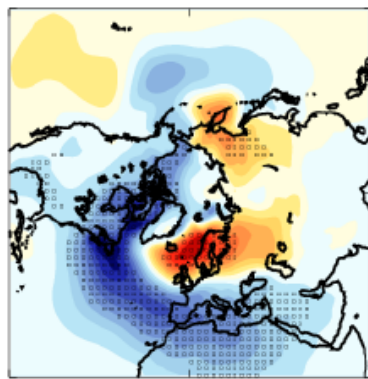


Met Office

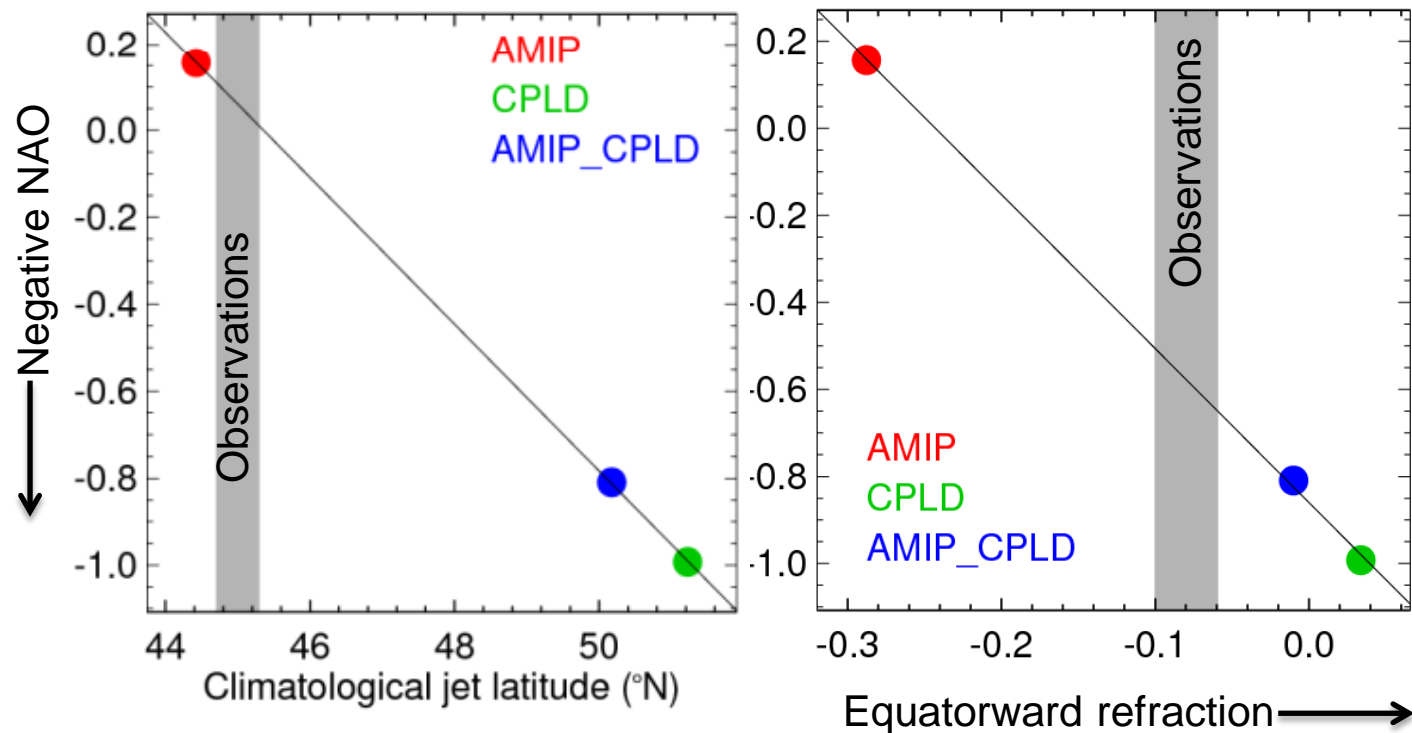
Atmosphere model



Coupled model



# Will the melting Arctic sea ice promote cold European winters?

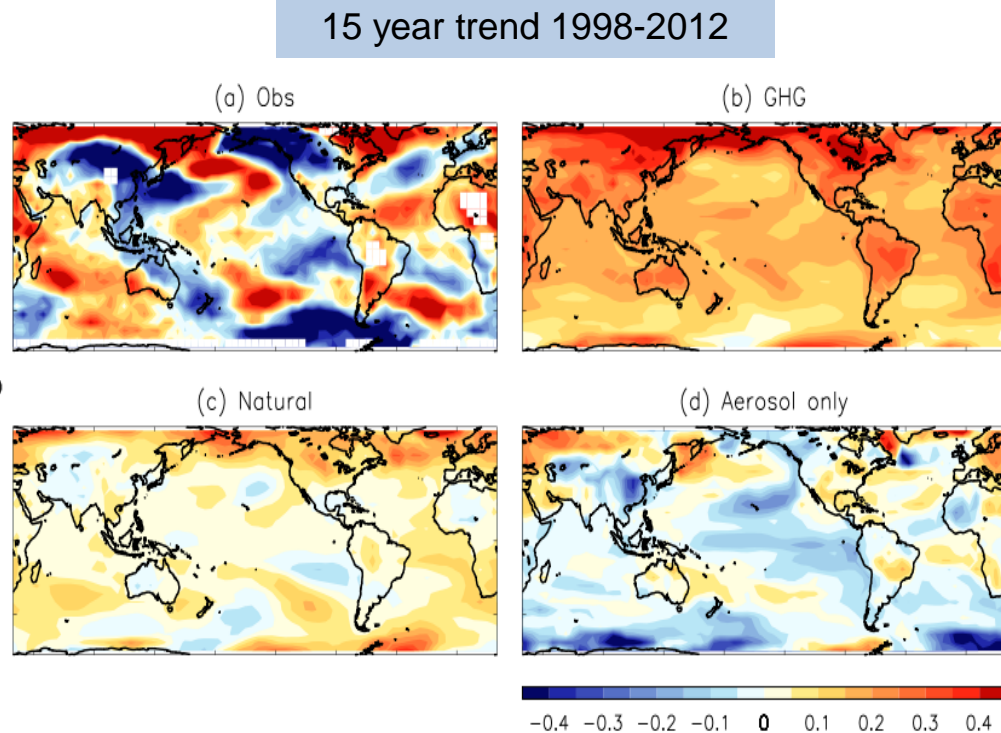
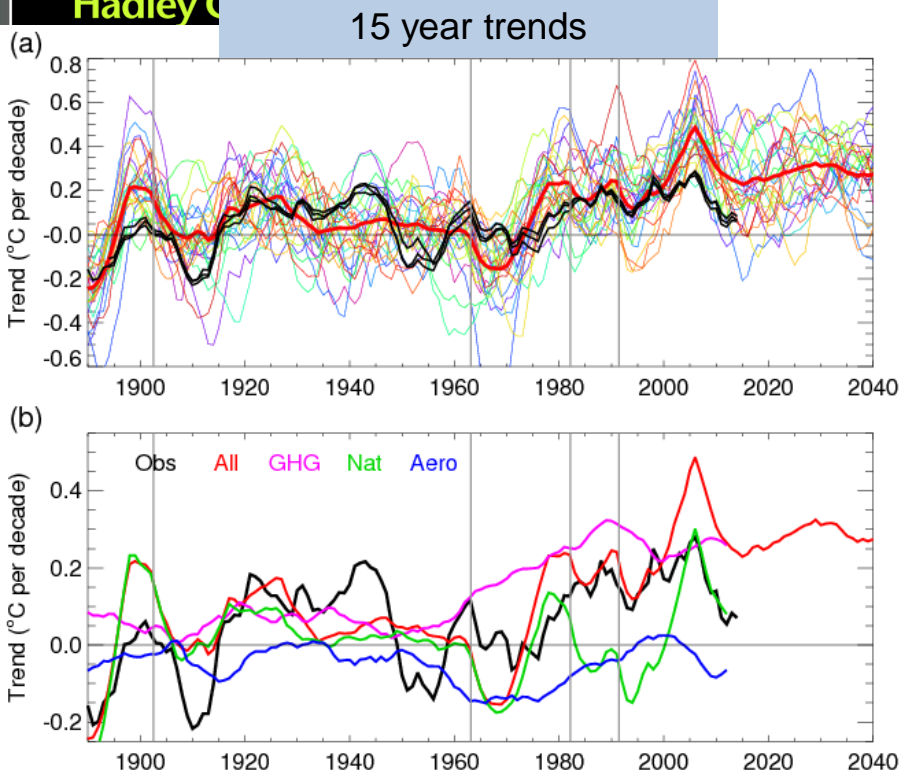


- Reduced ice → reduced Equator to pole temperature gradient → less wave activity
- Response depends on wave propagation, and hence background refractive index
- Observations (grey shading) suggest –ve NAO response
- Need more models → coordinated multi-model experiments (EU APPLICATE project)



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# Global warming slowdown: role of anthropogenic and volcanic aerosols



- Recent decrease in 15 year trends is simulated by CMIP5 models → externally forced
- Partly recovery from Pinatubo
- But anthropogenic aerosols produce cooling trend over most recent 15 years
- Pattern matches obs in many regions including the Pacific → negative PDO
- Slowdown was potentially externally forced by aerosols

# WCRP Grand challenge on Near Term Climate Prediction

## Aims:

- 1) Research and development to improve multi-year to decadal climate predictions (fundamental understanding of predictability, specification of forcing, forecast initialization and model bias/drift)
- 2) Collate and synthesize prediction output and tailor climate information (including assessments of uncertainty) to form the basis of a service addressing stakeholder needs.
- 3) Develop organizational and technical processes, including international coordination to underpin future routine provision of scientifically-sound prediction services.

The GC on Near-Term Climate Prediction will fill an important gap in **provision of seamless climate information, between seasonal climate predictions and long-term projections**, as recommended by the GFCS.

## Deliverables:

- Develop a **white paper** on the “Challenge of Near-Term Climate Prediction” with more details on the motivation, aims, existing and proposed research and implementation (Kushnir et al, in prep)
- The **production of standards, verification methods and guidance** for near term predictions which are seamless with long-term projections in collaboration with the WMO CBS/CCI Expert Team (Doblas-Reyes et al, 2018)
- Pursue **WMO recognition for operational decadal predictions** (Scaife et al, 2019)
- Initiate and issue a real-time **Global Decadal Climate Outlook** once each year (2016 onwards, with 2 years of dry running) in consultation with CBS-CCL, following the Global Seasonal Climate Update (Smith et al).





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# Decadal Climate Prediction Project (DCPP) : CMIP6

- **Component A: hindcasts**

- Start every year from 1960
- 10 ensemble members
- Much more robust assessment compared to CMIP5
- New improved models

- **Component B: ongoing forecasts**

- Input to WCRP Grand Challenge on Near Term Climate Prediction

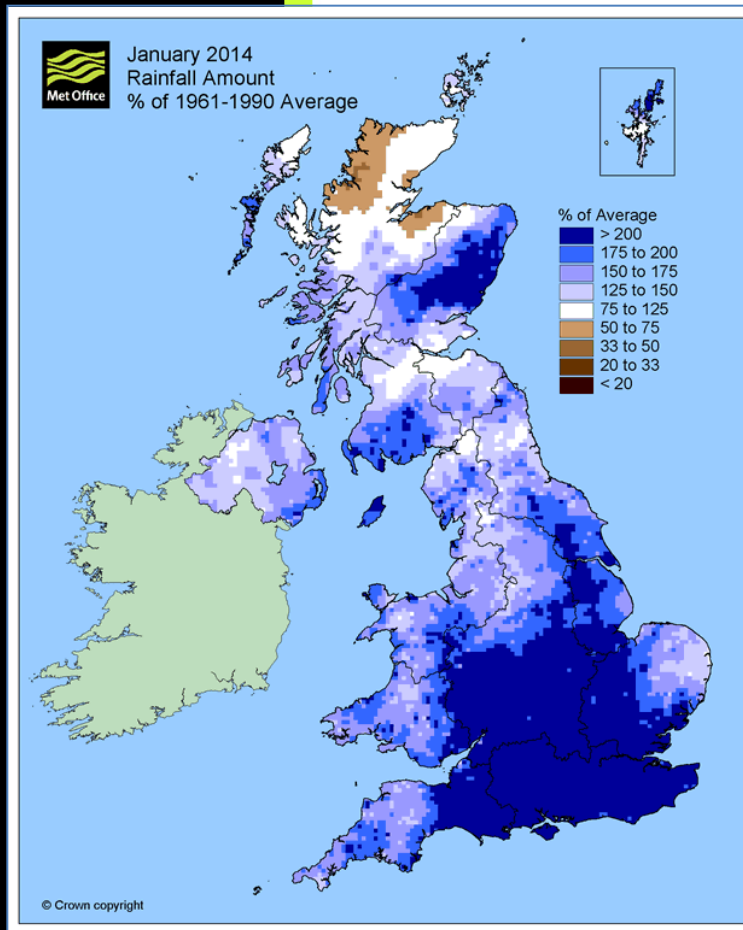
- **Component C: assessment of processes**

- Hiatus+: investigate ocean influence on decadal anomalies (including reduced and enhanced warming)
- Volcanoes: investigate the effects of volcanoes on climate and decadal predictions



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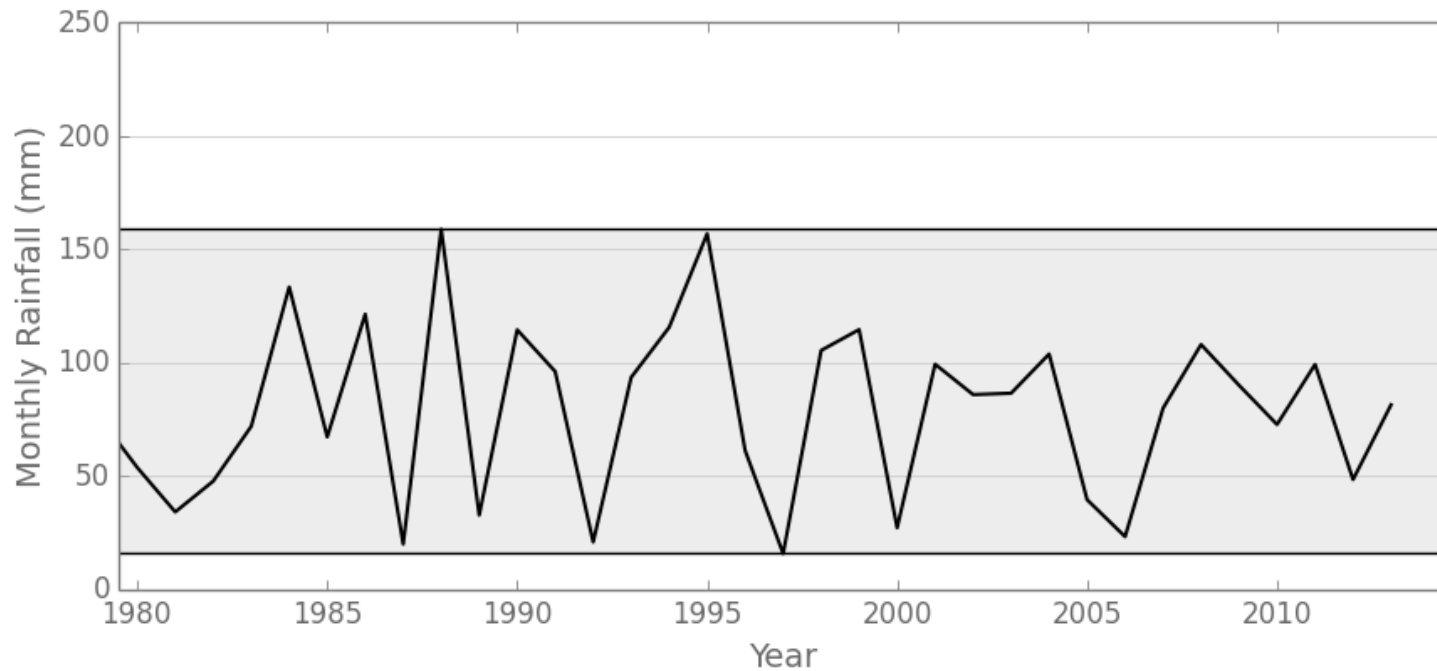
# Unprecedented rainfall



In south east England January 2014 saw the greatest monthly rainfall total on record

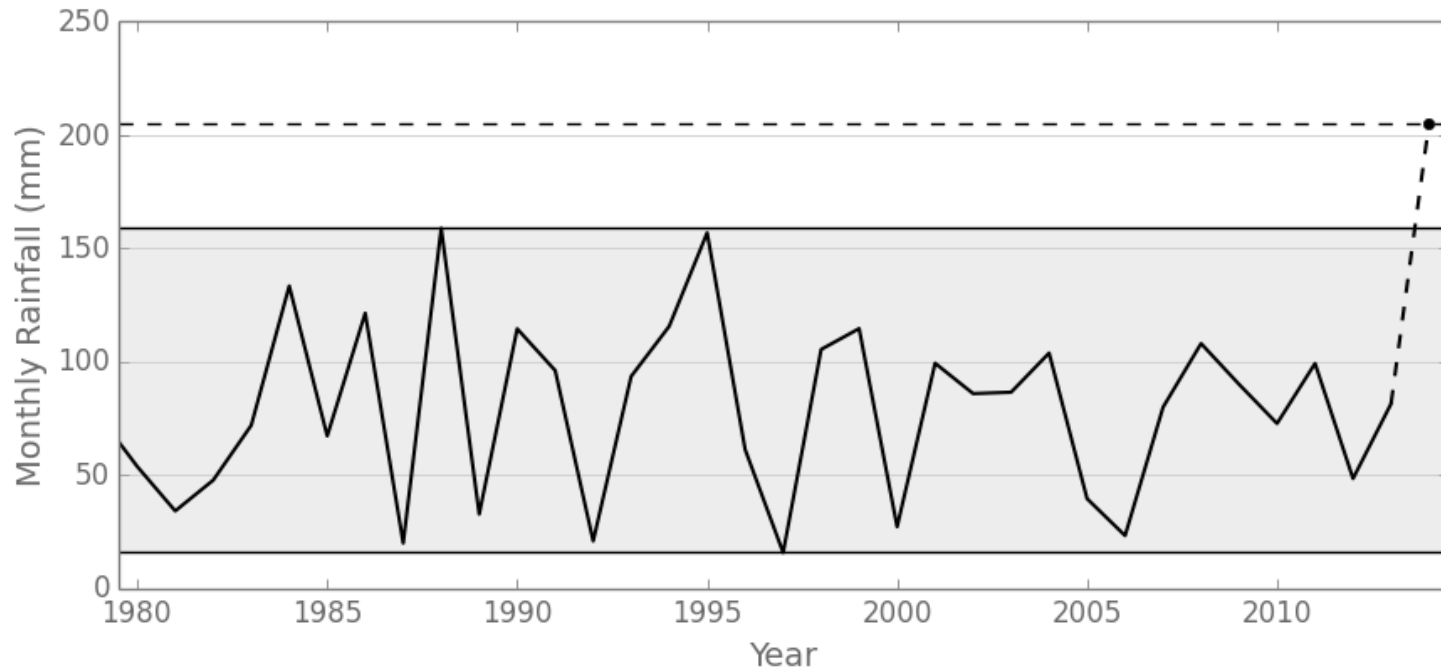
Should we be surprised?  
Could it be even worse?

# Unprecedented rainfall



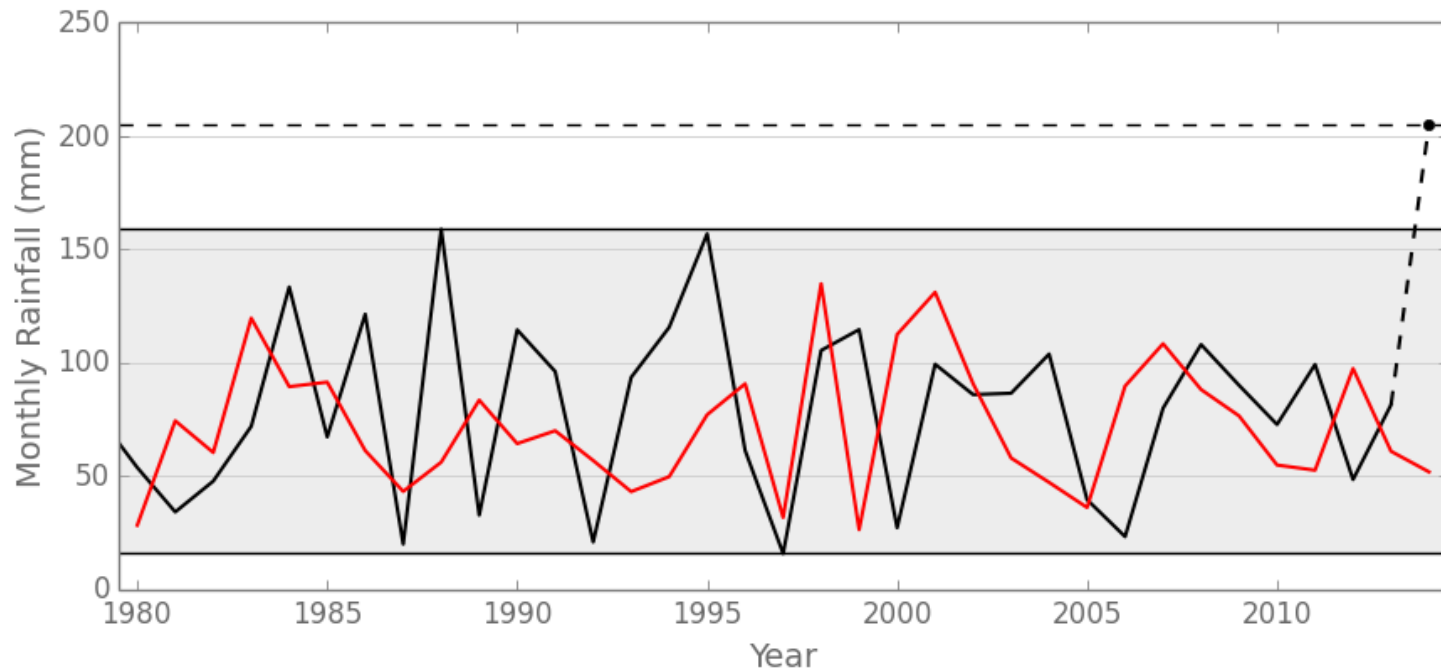


# Unprecedented rainfall



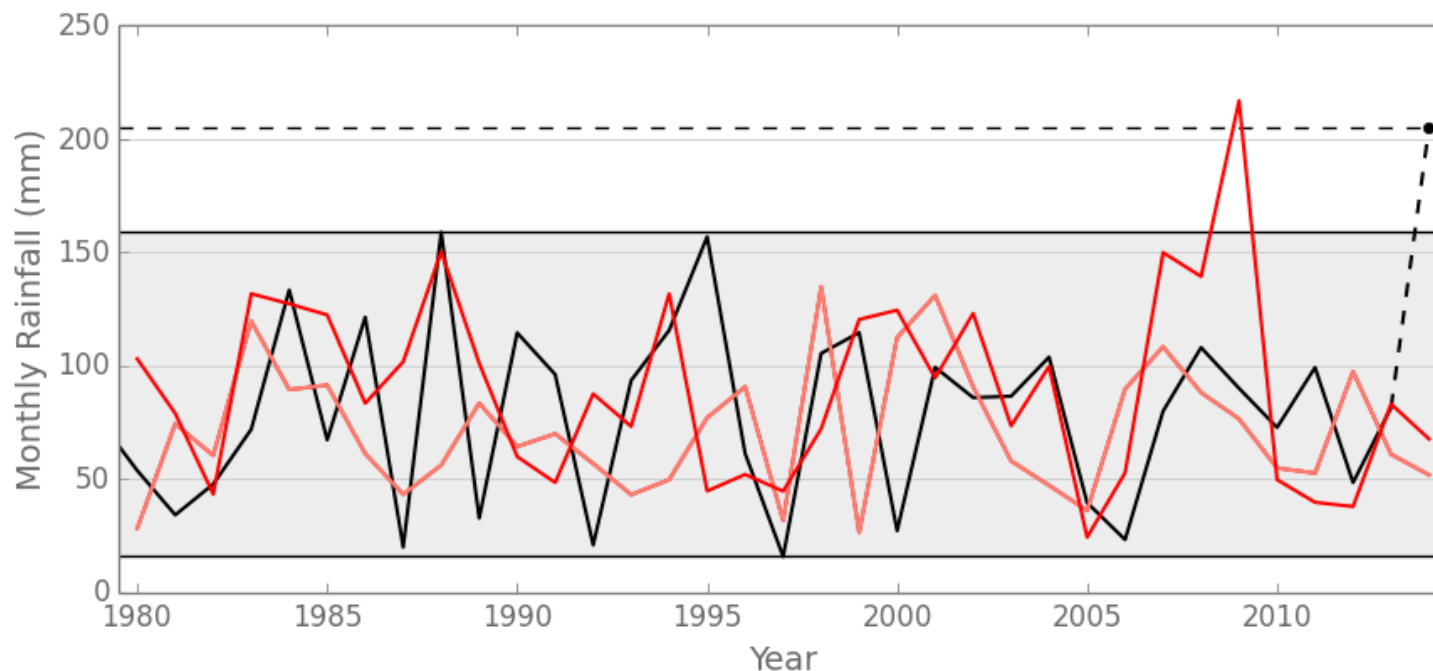
The monthly rainfall total of January 2014 exceeded previous records

# Unprecedented rainfall



The monthly rainfall total of January 2014 exceeded previous records  
In many model simulations the values are within the range of observations

# Unprecedented rainfall



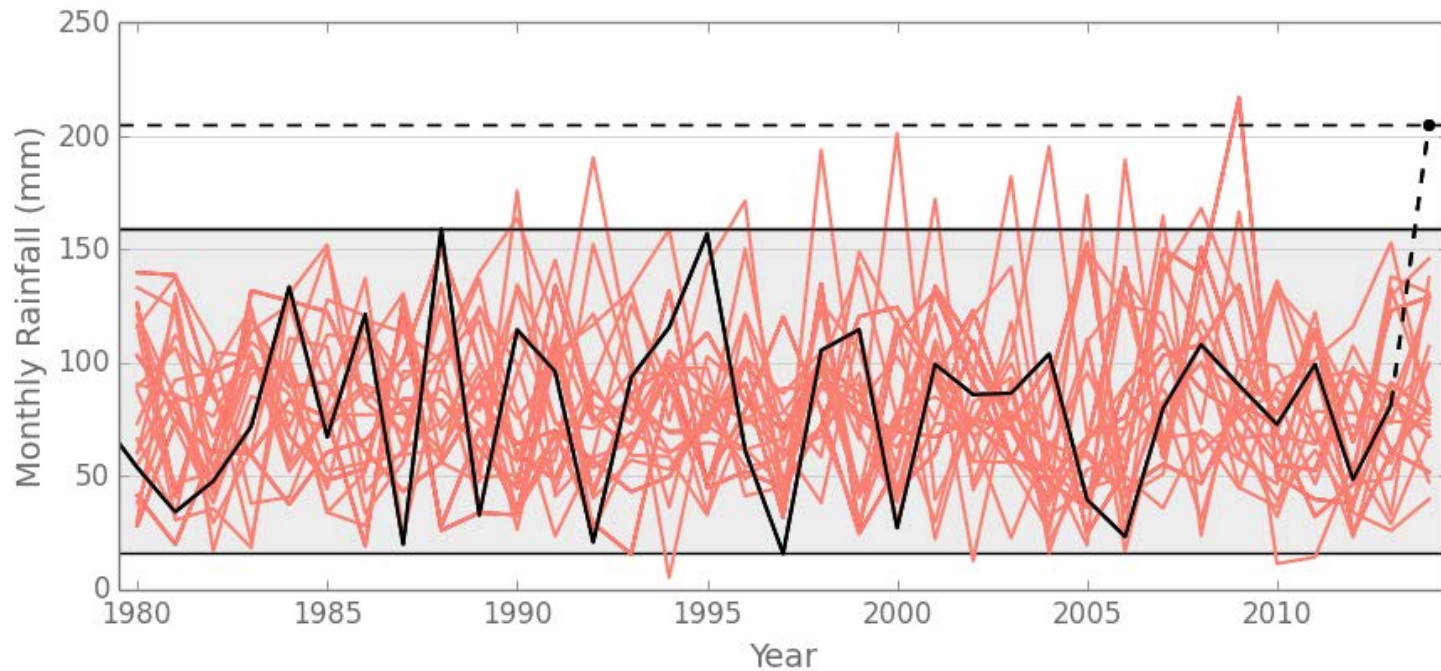
The monthly rainfall total of January 2014 exceeded previous records

In many model simulations the values are within the range of observations

However, in some the model exceeds the observed record



# Unprecedented rainfall



Observational record is too limited.

Take advantage of model hindcasts (7000 years) to better quantify the risk of extremes

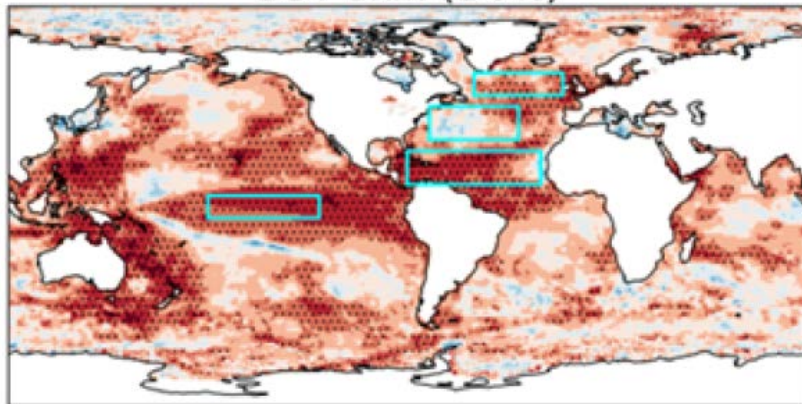
# Summary

- Very good progress in the last 4 years
- Important issues to overcome
  - signal to noise paradox
  - atmospheric response to Arctic sea ice
  - role of aerosols (and other external drivers)
- Need to keep improving the models
- Essential to understand the physical processes
- New WCRP Grand Challenge
  - Build on CMIP6 DCPD results
  - Begin to make operational decadal forecasts
- New use of hindcasts to quantify risks of extremes

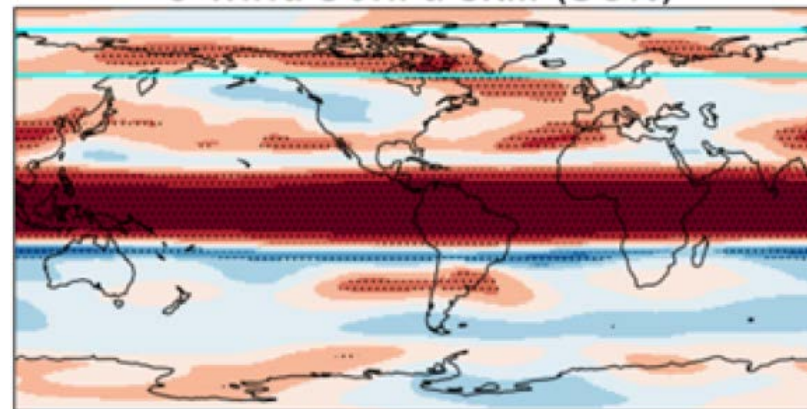


# Sources of NAO skill

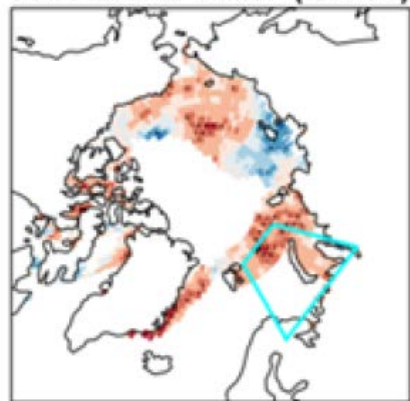
SST skill (SON)



U wind 50hPa skill (SON)

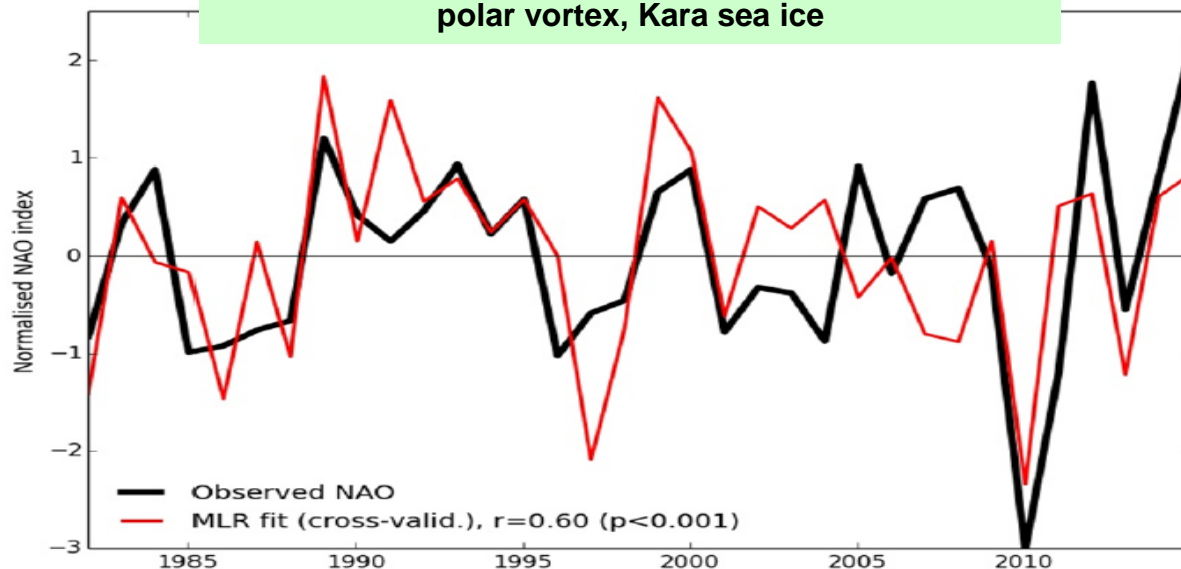


Ice area skill (SON)



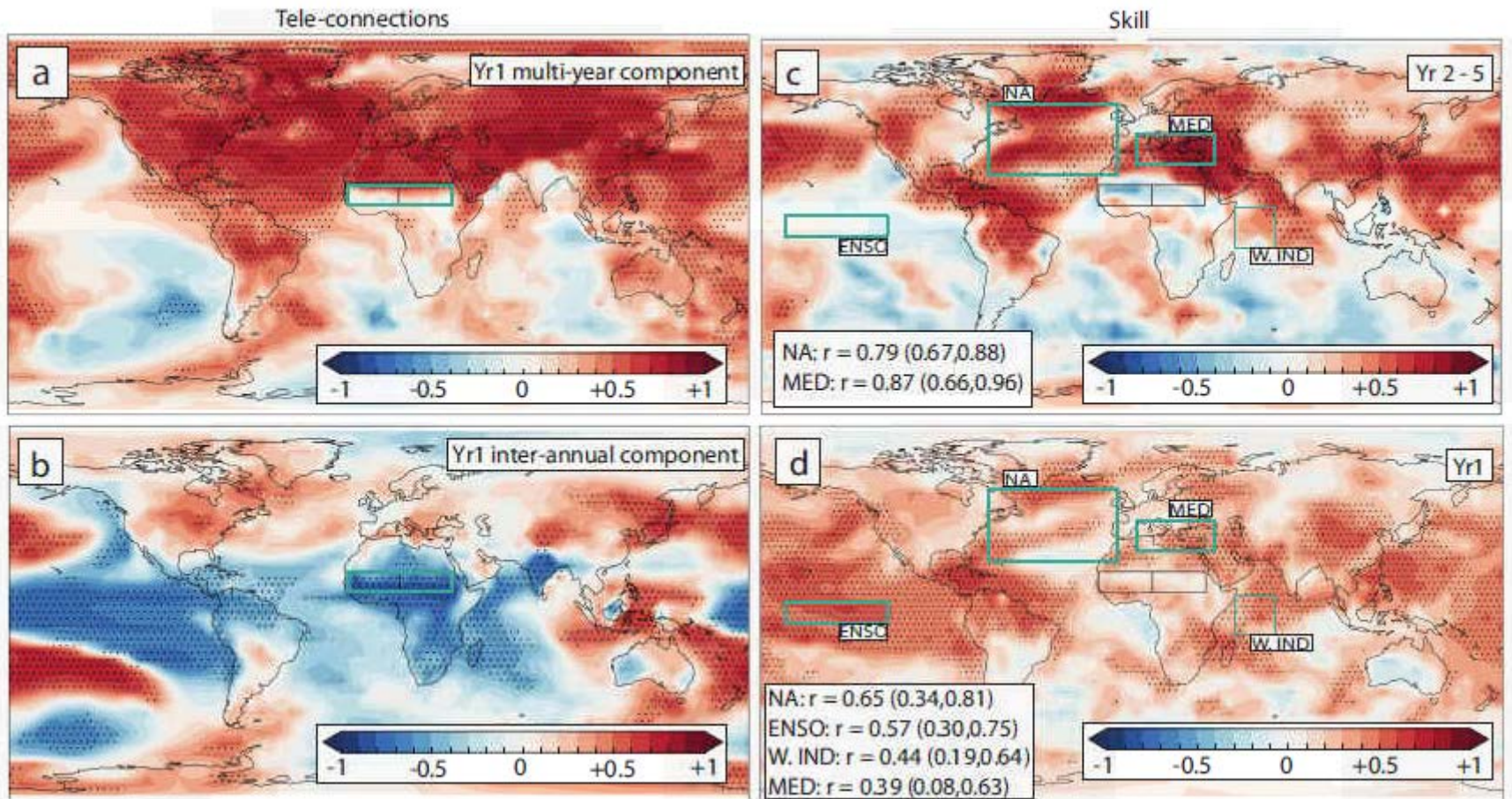
**a**

Multiple linear regression: Atlantic tripole, ENSO, polar vortex, Kara sea ice





# Sahel rainfall: drivers



- Multiyear driven by hemispheric temperature gradient which shifts the ITCZ
  - anomalous Hadley (meridional) circulation
- Interannual driven mainly by ENSO
  - anomalous Walker (zonal) circulation





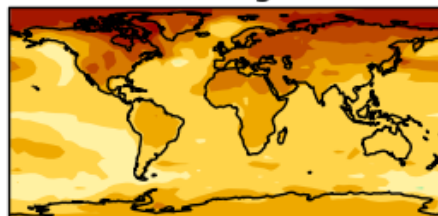
**Met Office**  
**Hadley Centre**

- Every year since 2010
- About 10 systems
- Dynamical and empirical
- Now have temperature, precipitation, sea level pressure and Atlantic overturning
- Currently ad hoc
- Aim to formalise under WMO
- Will be used to provide decadal climate outlook for WCRP Grand Challenge on Near Term Prediction

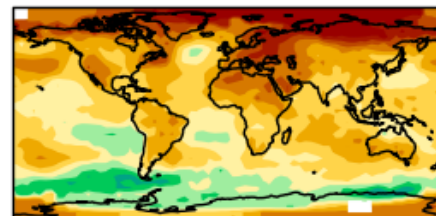
# Exchange of decadal predictions

2010 predictions for 2011-2015 surface temperature

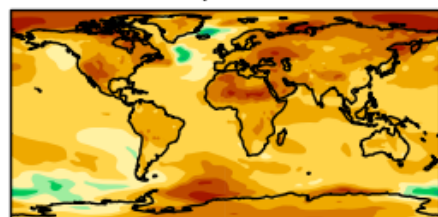
Average



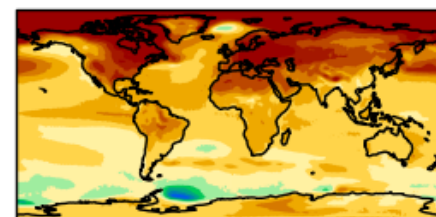
Observations



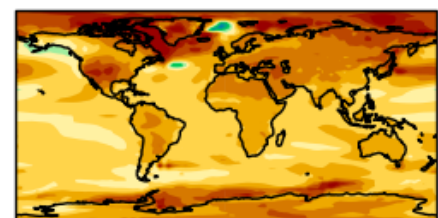
IC3/KNMI



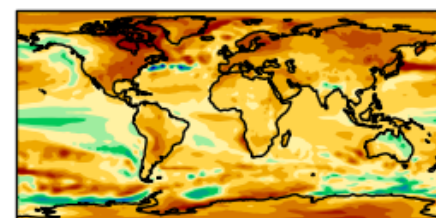
MIROC5



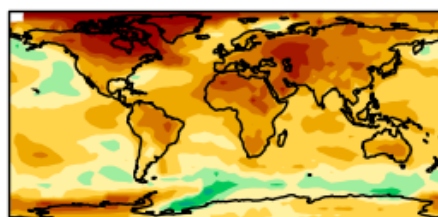
MOHC



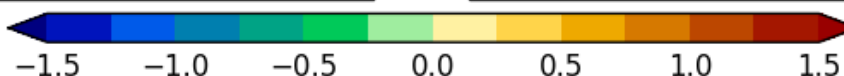
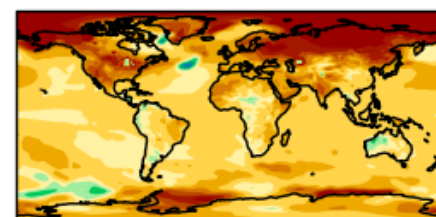
MPI



NCAR

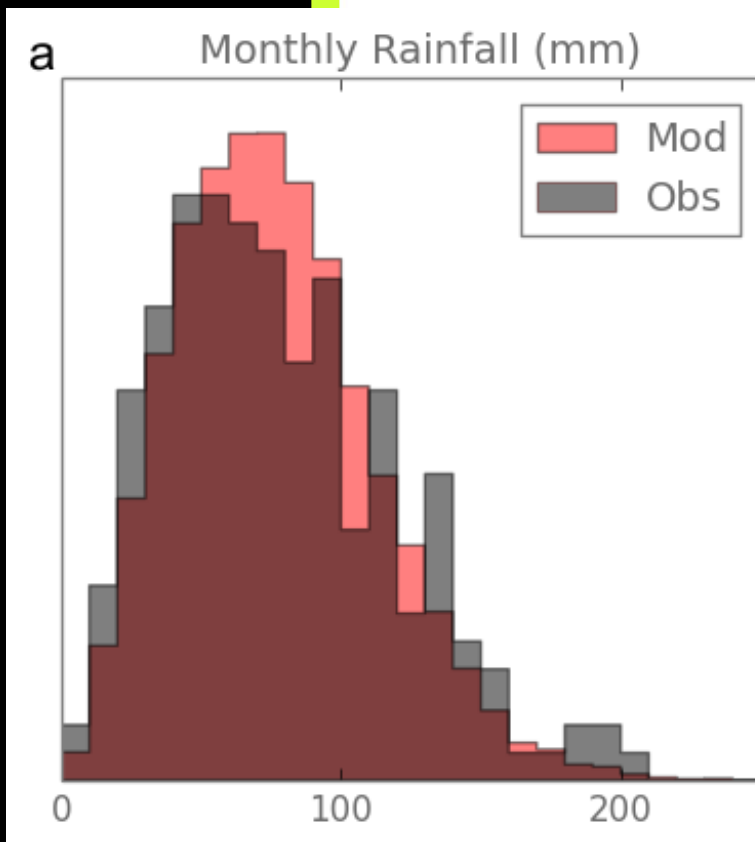


SMHI

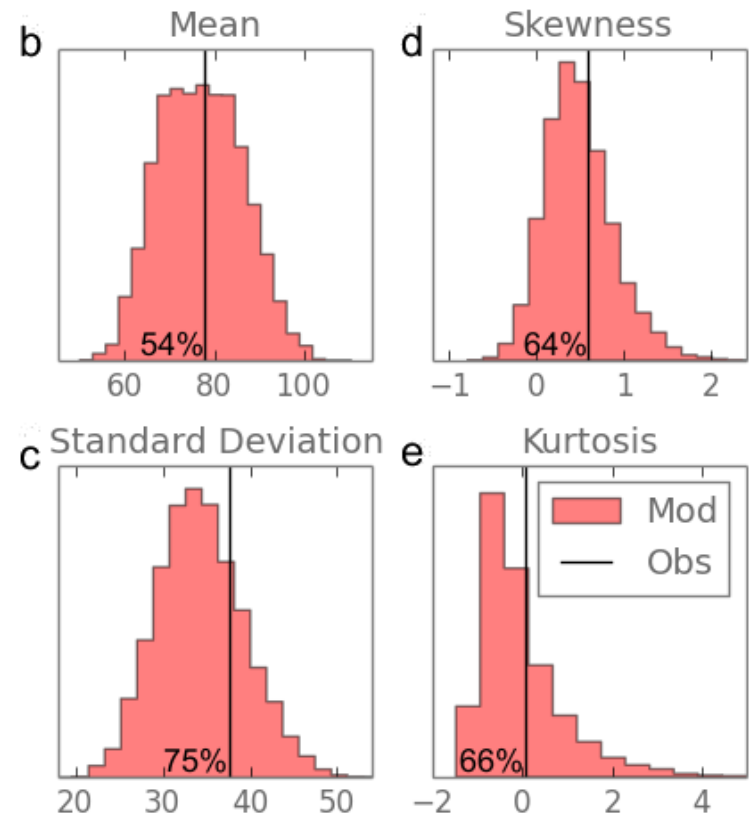


# Model fidelity

We resample the model 1000x and compare to the observations



Model and observations  
distributions appear similar

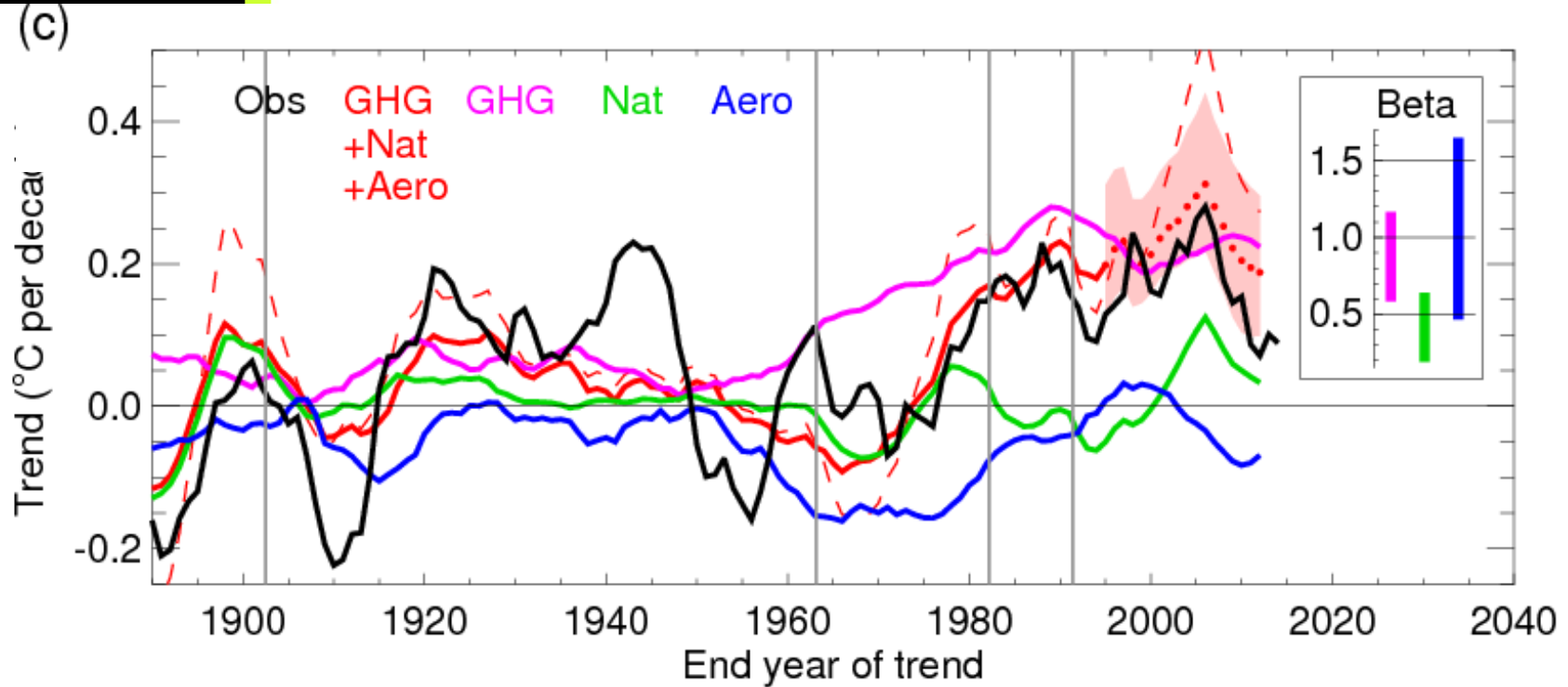


All measures agree to the 95% level

# Slowdown in surface warming: recalibration of models



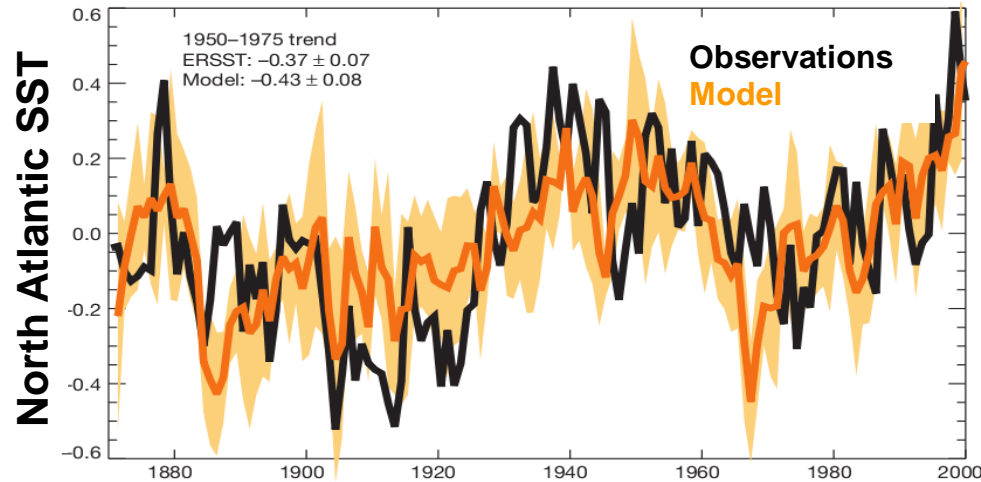
M  
Ha



- Detection and attribution analysis to obtain scaling factors (beta)
- Use data before 1995
- Scaling for Nat significantly less than one → models over-sensitive to volcanoes
- Scaled projection (red dotted) in much better agreement with obs than unscaled (red dashed)
- Need to understand response to external forcing better even for near term predictions

# External forcing of N. Atlantic

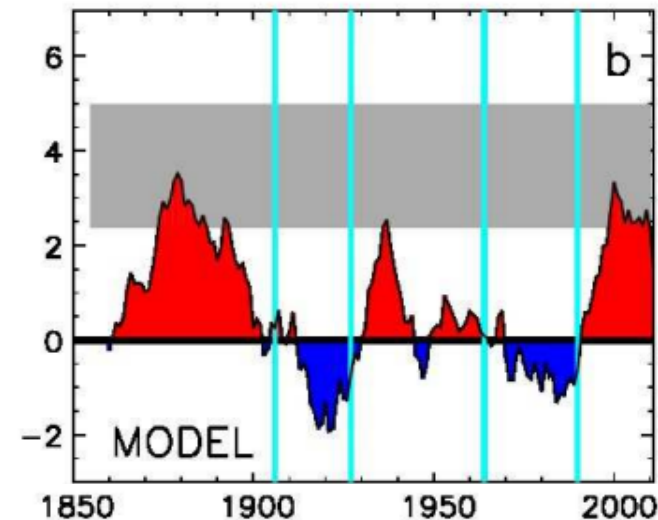
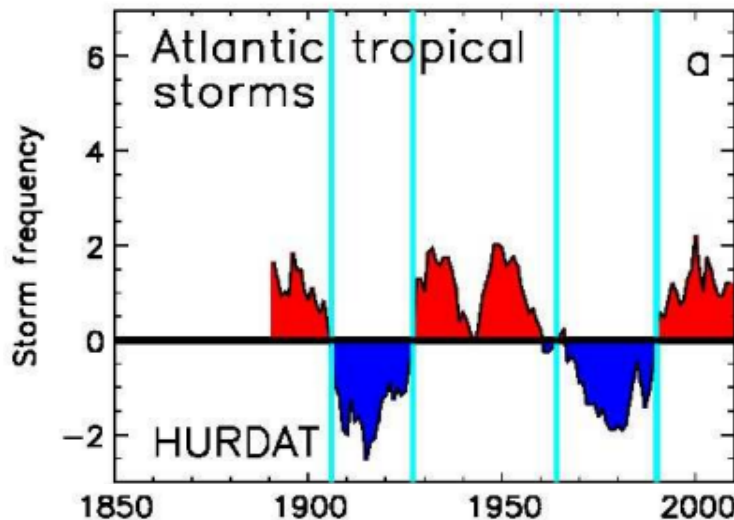
“AMO”



Booth et al.,  
2012

Observations

Model



Multi-decadal variability driven by **anthropogenic aerosols**