



# Challenges and Progress in Sub-Seasonal to Decadal Prediction on Regional Scales

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**Head Monthly to Decadal Prediction  
Met Office Hadley Centre**

**WCRP Open Science Conference 2011**

# Why monthly to decadal prediction?

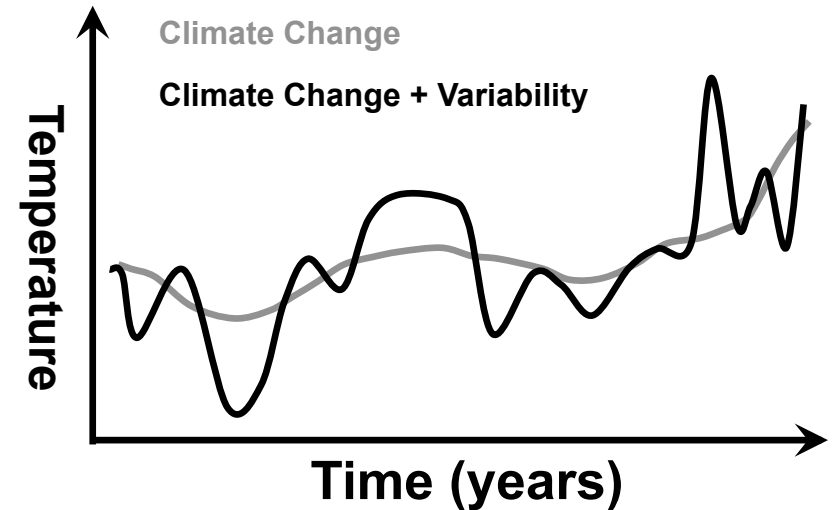
Climate varies a lot and this can greatly amplify or oppose any trend:

Tropical Floods during 2010/11

Russian heatwave 2010

African Drought 2011

Recent Cold European and US winters



Dry Water Pan, Kenya, 2011



Flooding at Toowoomba, Australia, 2011



Barcelona, Spain, March 2010

# If weather forecasts are poor after a few days how can we hope to do this?

**Initial Values e.g. ocean, land surface**

**Boundary Values e.g. GHG changes, volcanoes, solar variability**

## **OPTIONS:**

- **Initial values only:** weather forecasts: an accurate measure of the weather today is enough to predict the weather tomorrow
- **Boundary values only:** climate projections: the future level of greenhouse gases constrains the statistics of weather
- ❖ **Initial AND Boundary values:** climate predictions for months or years ahead

**But we need ALL the processes to be well represented if we are to maximise skill or accurately estimate predictability...**

# Forecast Capability

**Monthly**

**Seasonal**

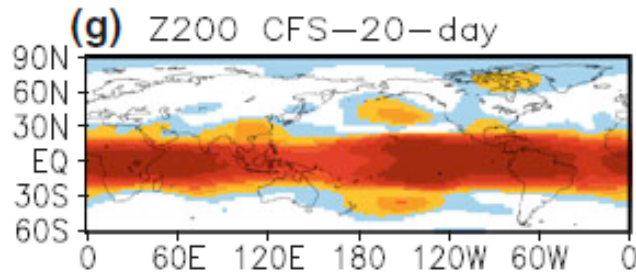
**Decadal**

# Future Developments

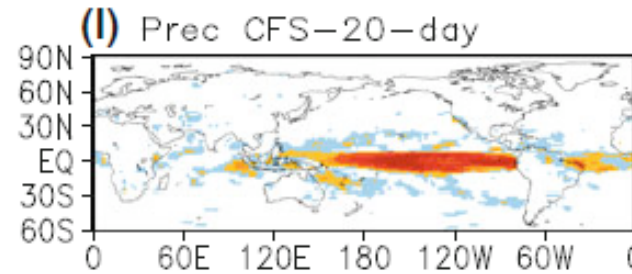
**Improved Models**

**Boundary Conditions**

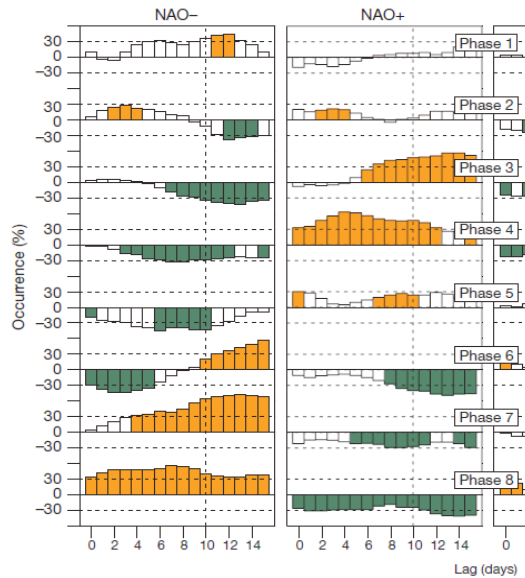
# Monthly Predictability



(Kumar et al, *Clim. Dyn.*, 2011)



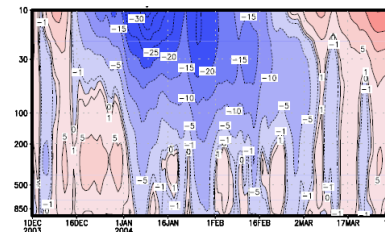
## MJO affects NAO



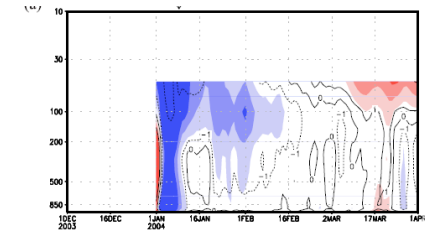
(Cassou, *Nature*, 2008, Vitart and Molteni, *QJRMS*, 2010, Lin et al, *GRL*, 2010)

## Stratospheric Sudden Warmings

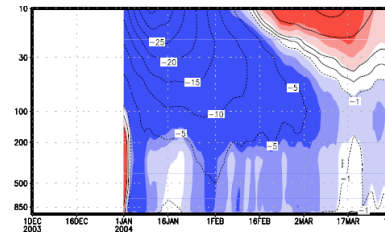
Observed wind 2003/4



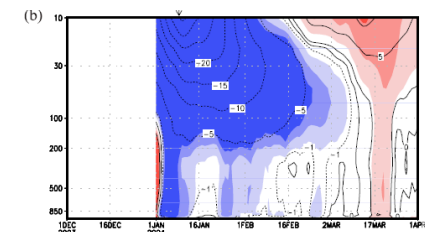
No Stratosphere



Predicted wind 2003/4



No Surface Init'



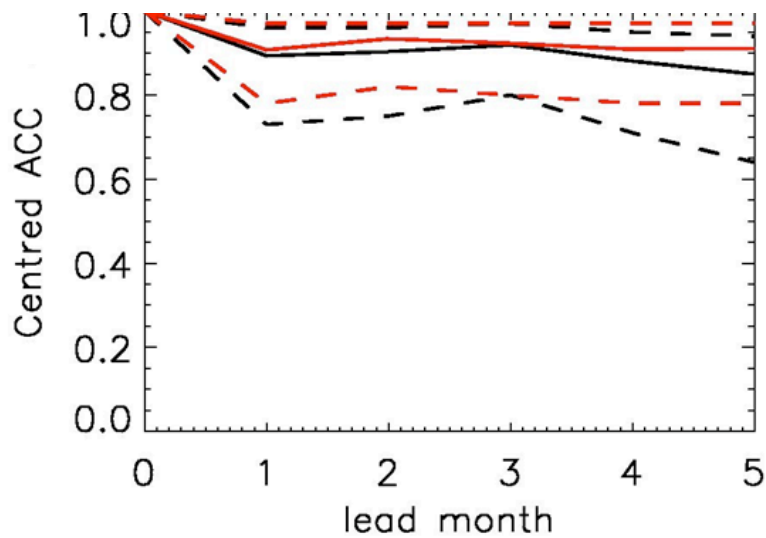
(Kuroda, *GRL*, 2008)

Monthly timescale predictability highest in tropics

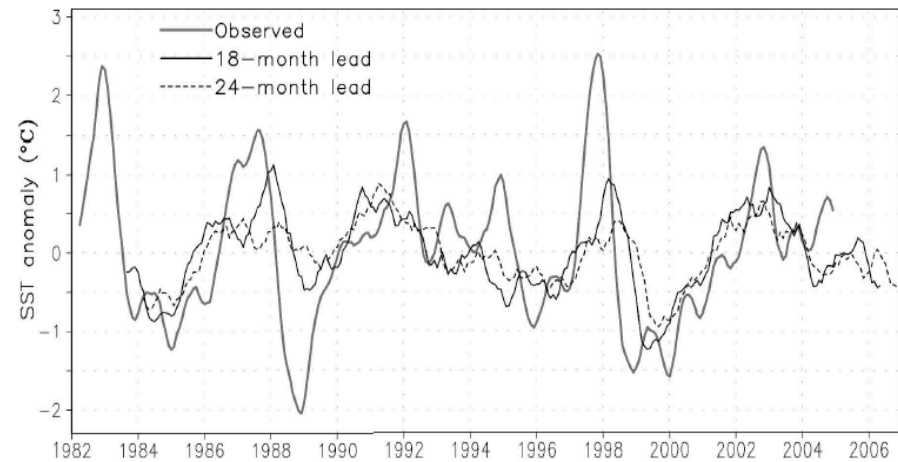
For extratropics MJO and SSWs => Conditional Forecast Skill

# El Niño-Southern Oscillation: a cornerstone of seasonal prediction

## Seasonal Forecast Skill



## Interannual Forecast Skill



Arribas et al., MWR, 2011

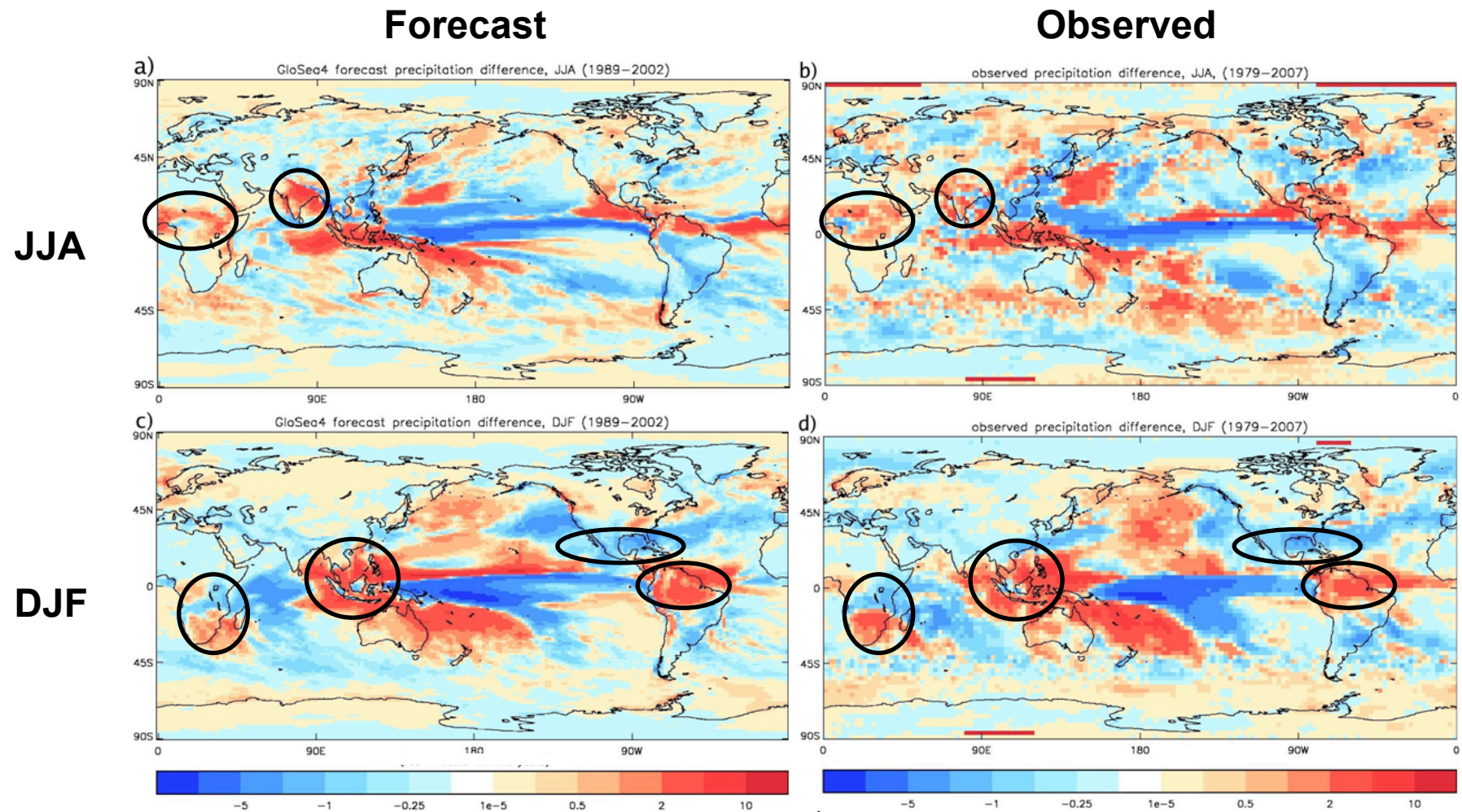
Luo et al., J. Clim., 2008

**ENSO peaks in winter**

**Remarkable predictability months ahead, some skill further ahead**

**Remote effects?**

# ENSO effects on rainfall

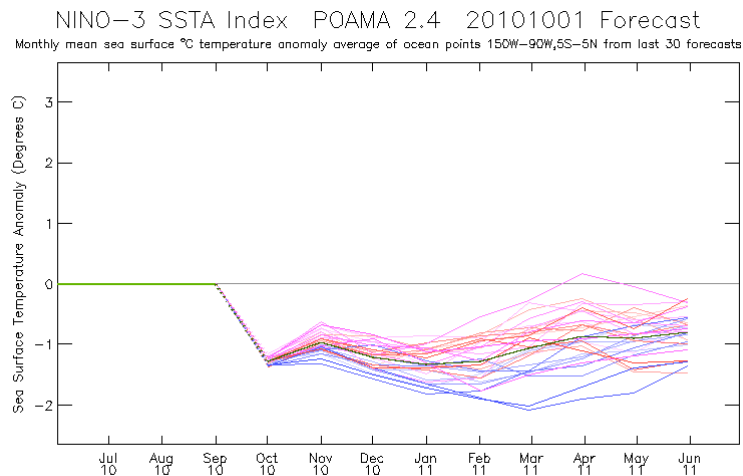


Arribas et al., 2011

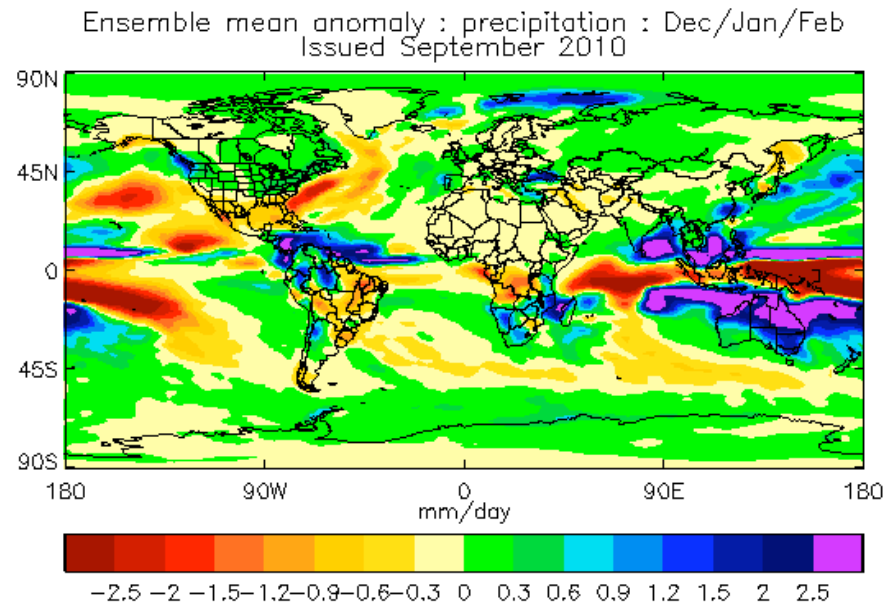
**Skilful forecast signals in the tropics – even for rainfall**

**e.g. Australia...**

# ENSO and Australian Floods (c.f. 1973/4)



BoM, 2010



Met Office, 2010

**Very wet signals for NE  
Australia due to La Niña**

**Increased risk predicted  
several months in advance**

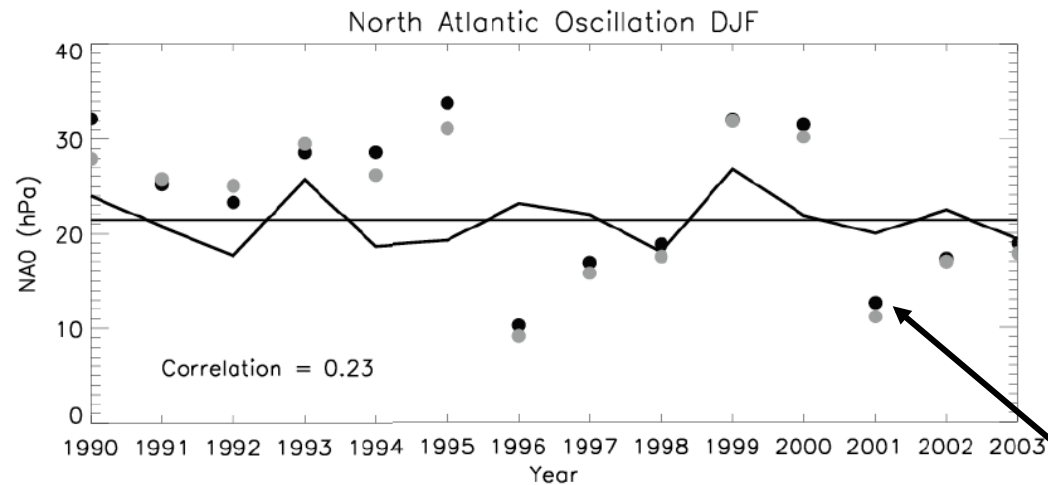
**Potential for adaptation**



**Flooding at Toowoomba, Australia, 2011**

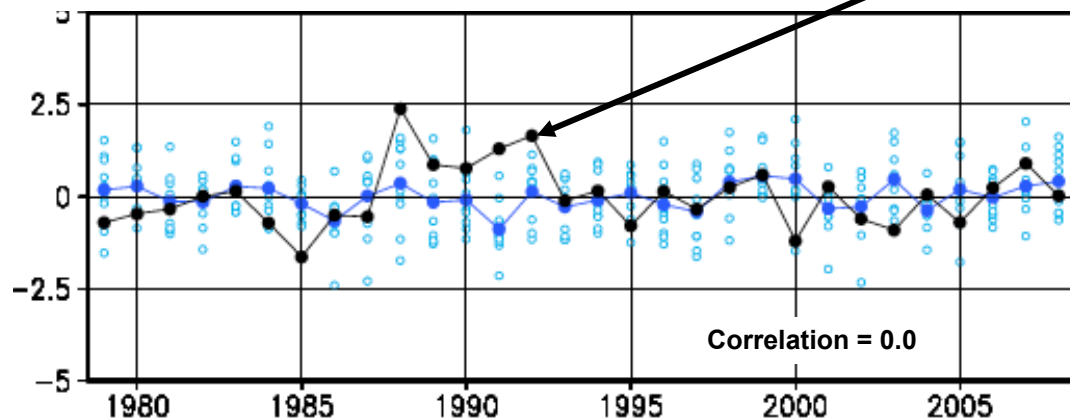


# BUT...long range predictability of the extratropics is often low:



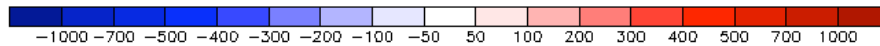
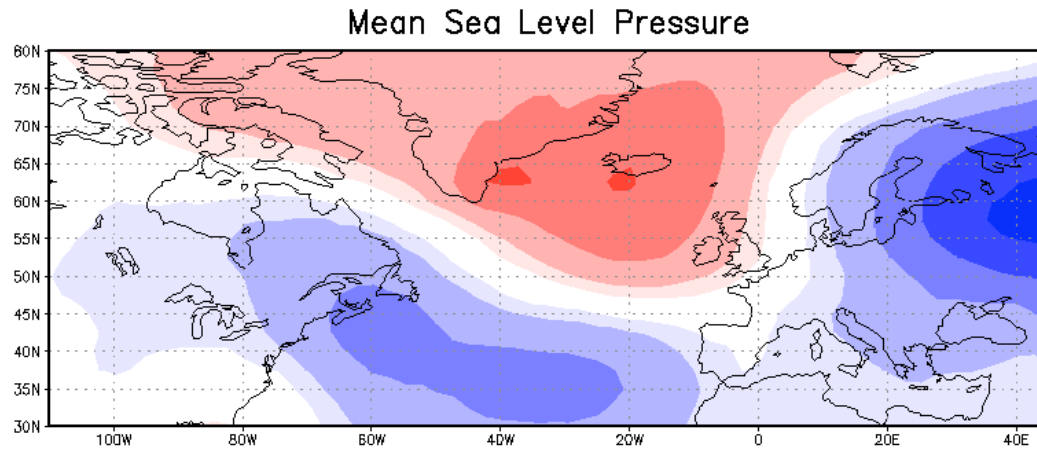
Seasonal Predictions of the NAO in UKMO system (Arribas et al., 2011, MWR)

observations



Seasonal Predictions of the AO in JMA system (Maeda, 2011, JMA)

# Multimodel Forecast from the WMO Lead Centre for Winter 2010



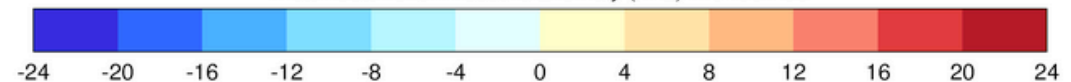
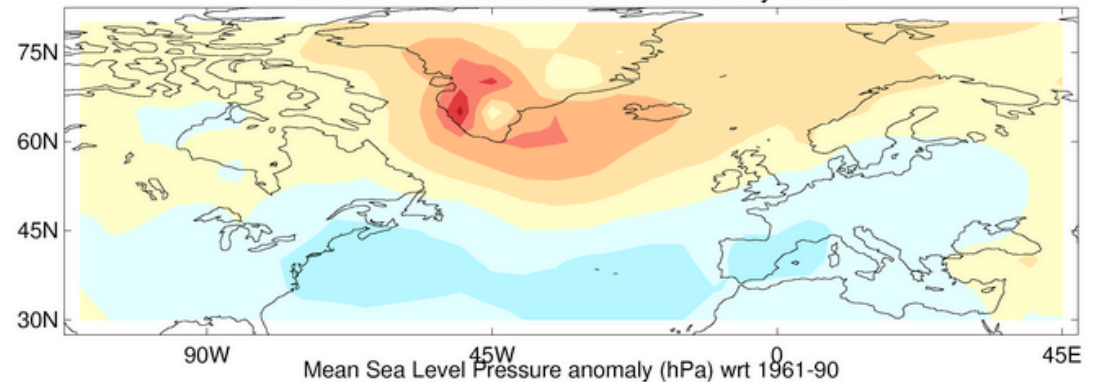
WMO Global Producing Centres			
Canada	Montreal	BCC	Beijing
ECMWF	HYDROMETEOROLOGICAL CENTRE OF RUSSIA	Moscow	
Seoul	Tokyo	Toulouse	Washington
Exeter	PCMAA	Melbourne	Pretoria
		CPTec	CPTec

**Blocked Atlantic flow predicted in early winter (12 GPCs)**

**Good match with observations**

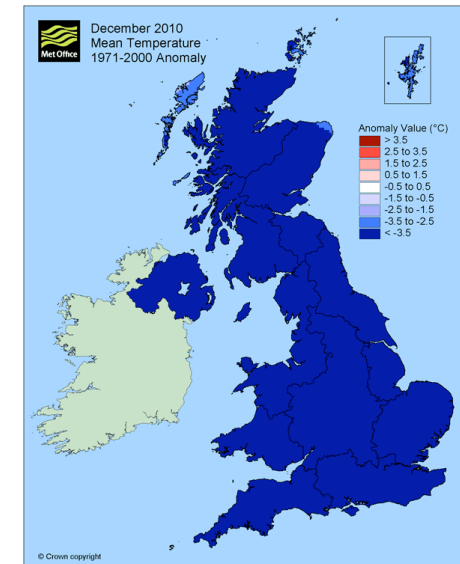
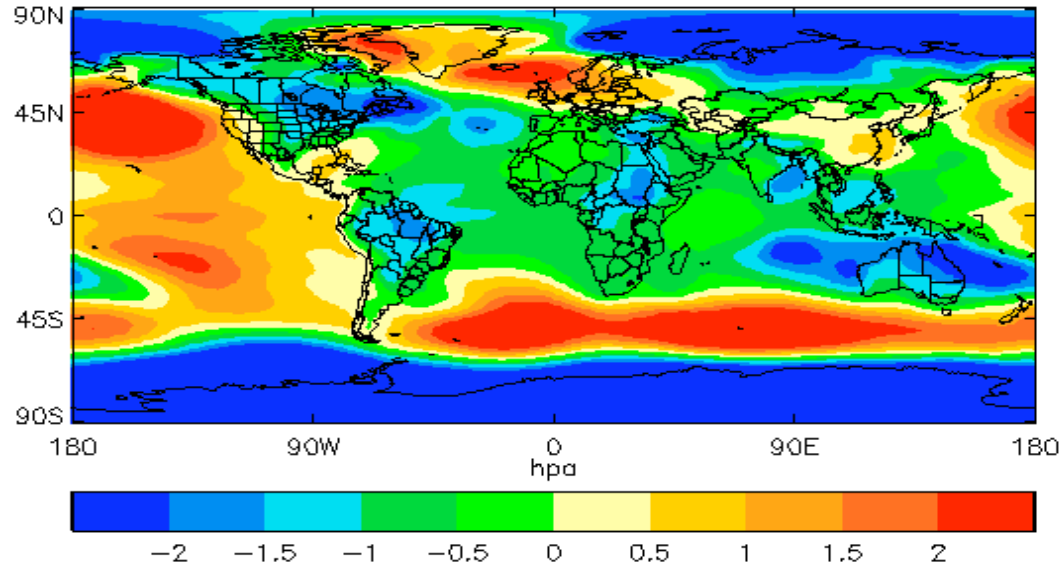
**Window of opportunity?**

HadSLP2r November 2010 to January 2011

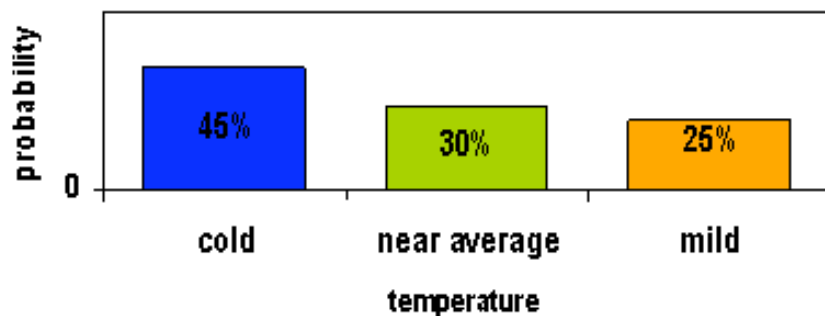


# Winter 2010

Sea level pressure forecast for NDJ: issued early Oct 2010

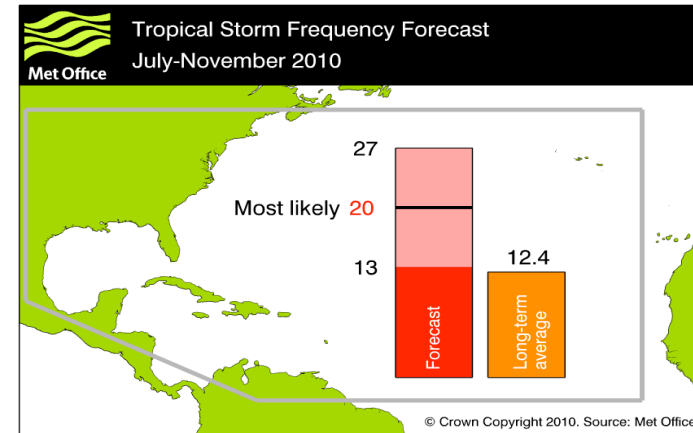
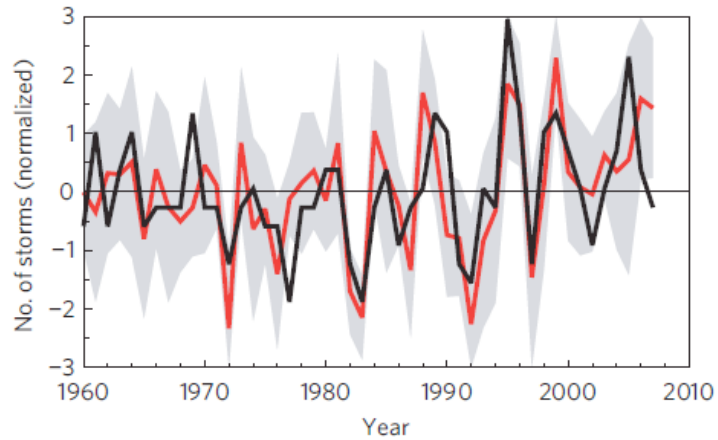


UK Government advised from October:

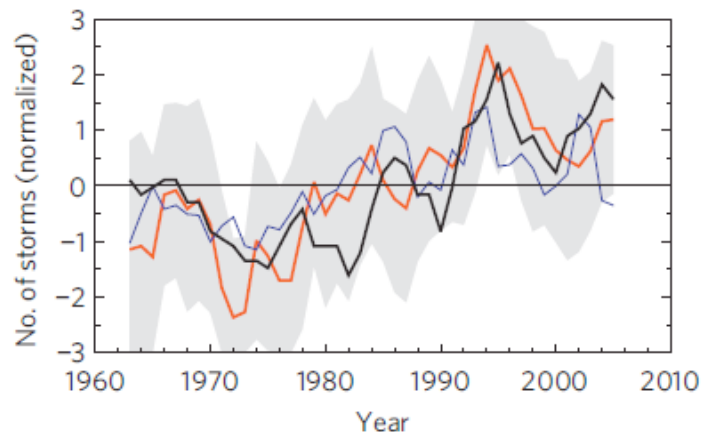


Coldest UK December for more than 100 years

# Extreme Events: Atlantic Hurricanes



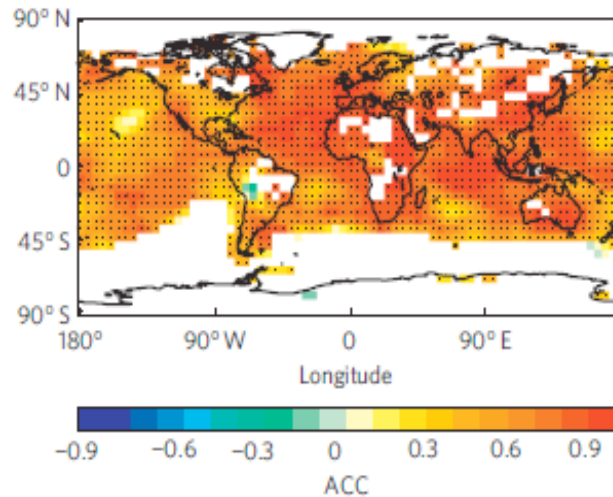
**Tropical cyclone numbers can be predicted months ahead**  
**Last year's *real time* forecast: Well above average vs 19 Observed**



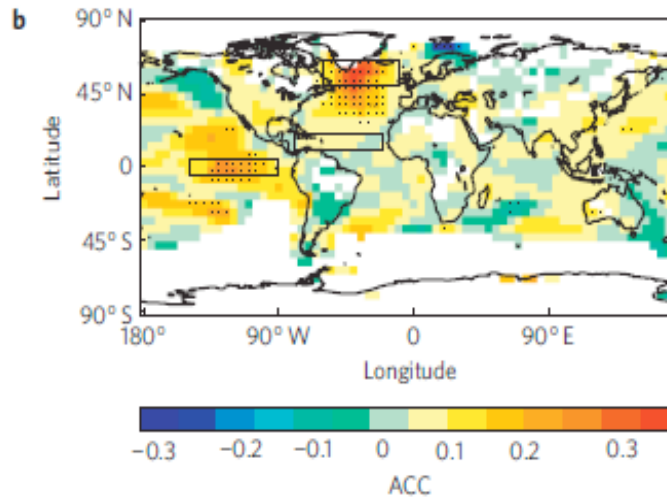
**Predictability several years ahead**  
**Originates in the North Atlantic**  
**(Doug Smith's talk on Monday)**

# Decadal Forecast Skill

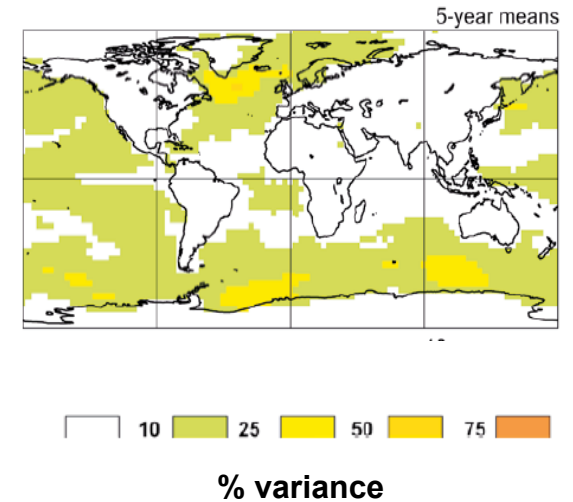
**Full Prediction Skill (5yr)**



**From Initial Conditions**



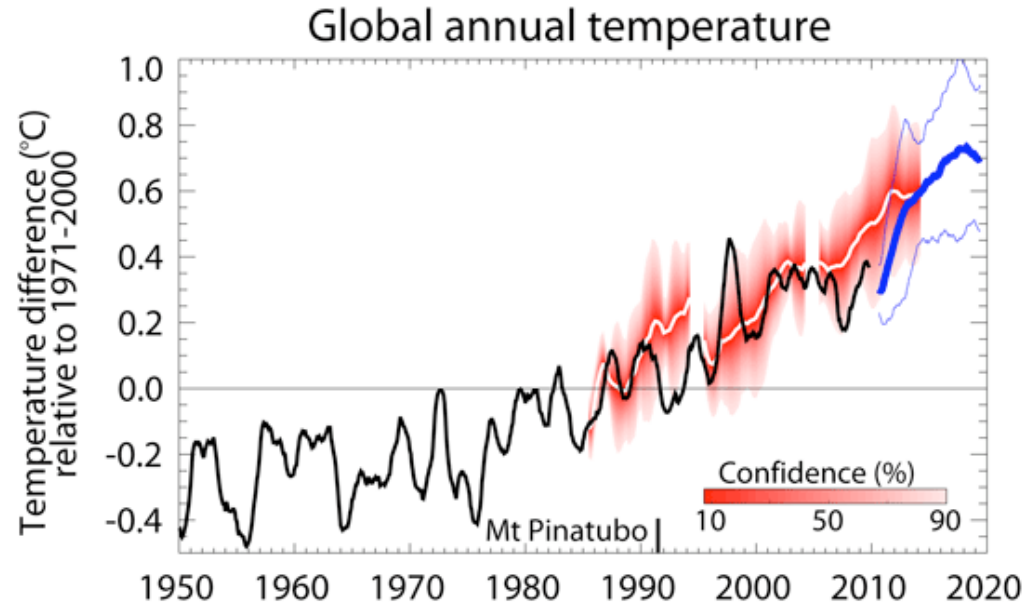
**Estimated**



**Decadal predictability from boundary conditions  
(GHGs, aerosols, ozone etc)**

***Additional* decadal predictability from initial conditions  
(North Atlantic and Equatorial Pacific)**

# Global Temperature from Year to Year



**Forecast for 2011: “unlikely to be a record year...”**  
**Issued Dec 2010**

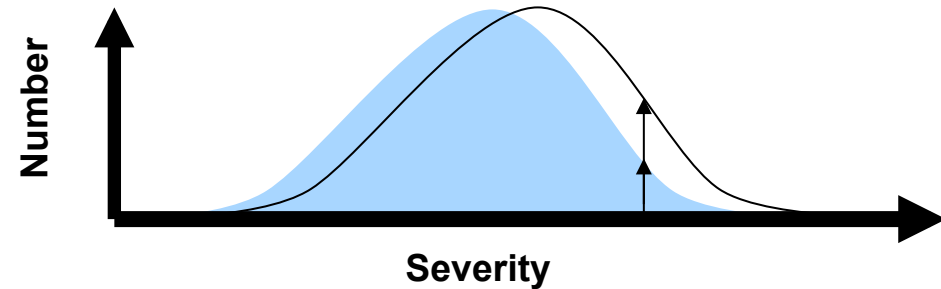
**1 yr lead time: correlation ~0.7**

**Forecast for 2010: “it is more likely than not that 2010 will be the warmest year in the instrumental record”**  
**Issued Dec 2009**

Rank	HadCRUT3		NOAA NCDC		NASA GISS	
	Year	Anomaly *	Year	Anomaly *	Year	Anomaly *
1	1998	0.52	2010	0.52	2010	0.56
2	2010	0.50	2005	0.52	2005	0.55
3	2005	0.47	1998	0.50	2007	0.51
4	2003	0.46	2003	0.49	2009	0.50
5	2002	0.46	2002	0.48	2002	0.49
6	2009	0.44	2006	0.46	1998	0.49

# Extreme Events: Hot Summer Days

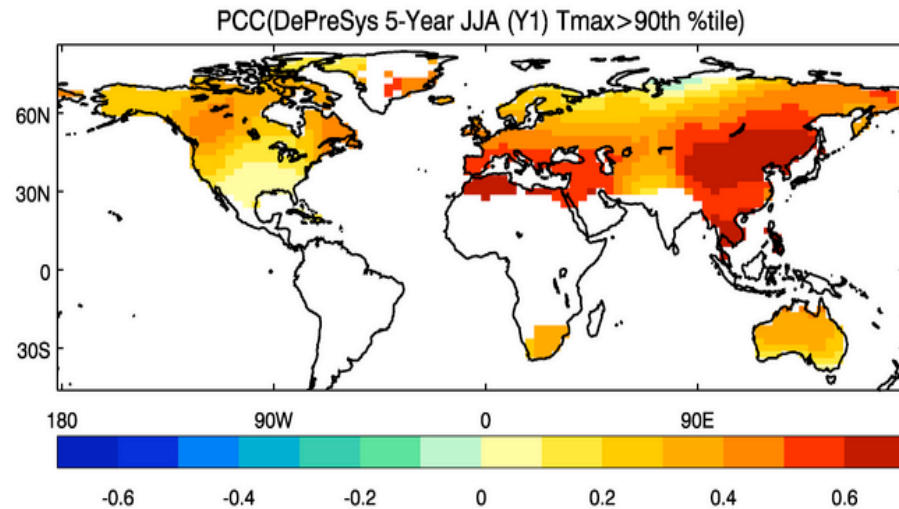
If we can predict the mean climate shift maybe we can predict extremes?



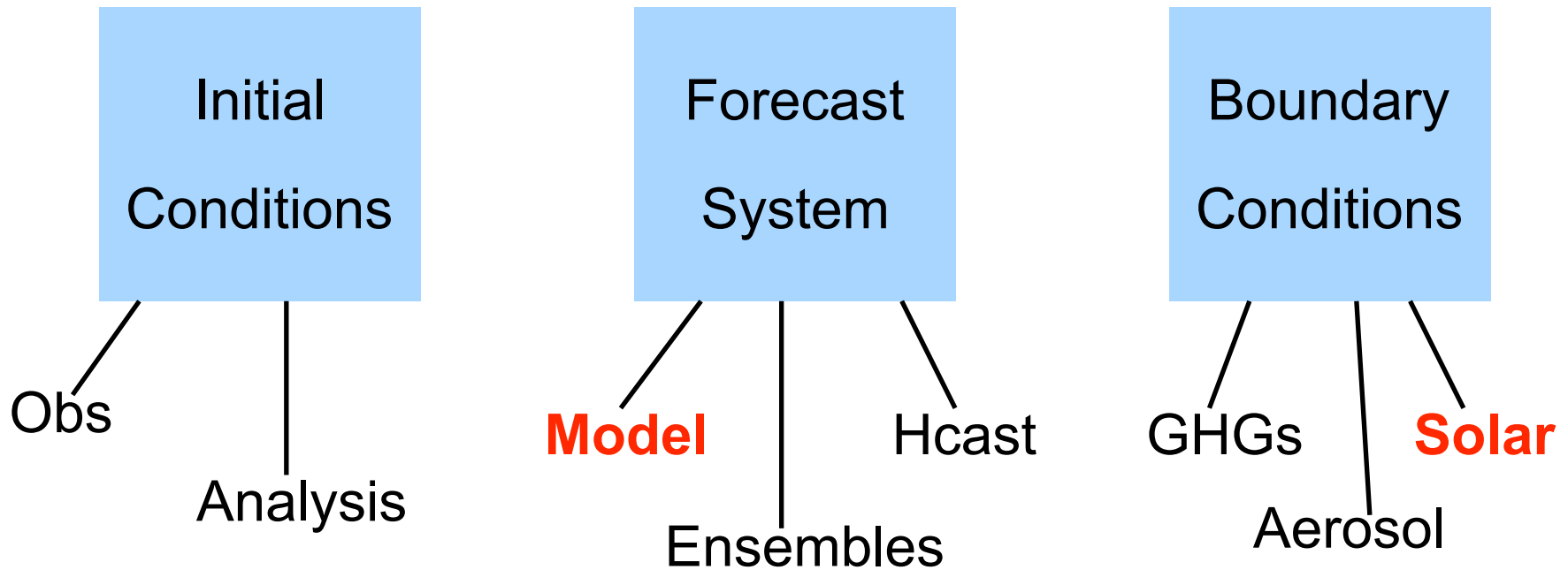
Predicting number of hot summer days for the coming 5 summers

Skilful over continental scales using 1960-2003 data

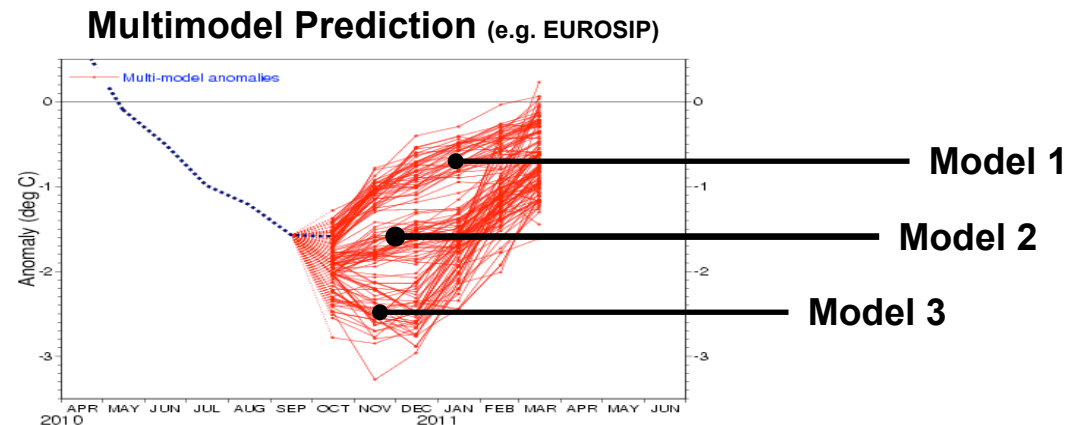
Same skill as shifting distribution



# Sources of Forecast Error



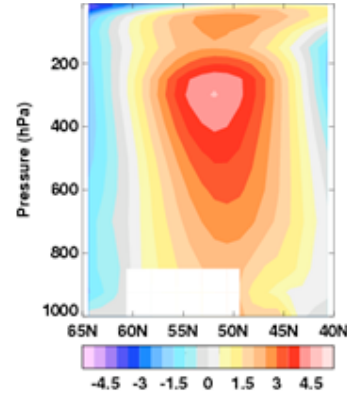
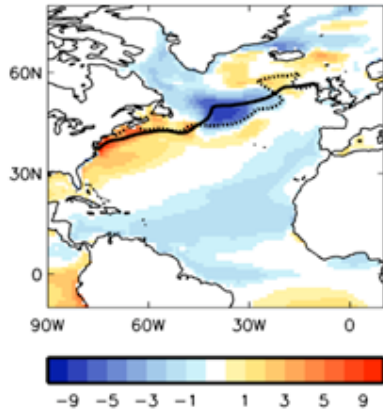
Could perturb models but need model improvements





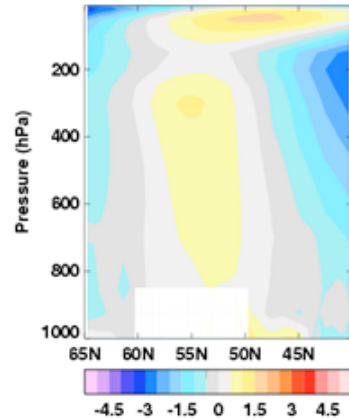
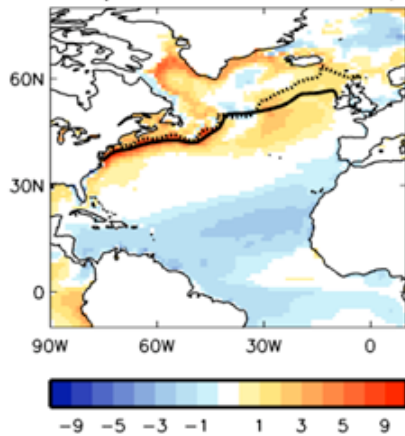
# Ocean Biases and Blocking Errors

## Current Model



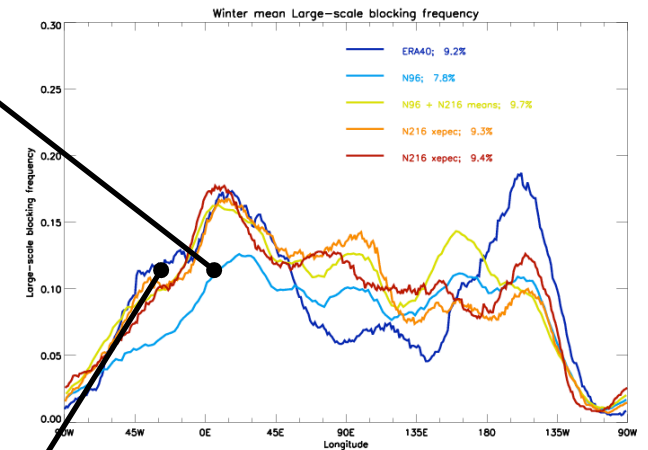
Gulf Stream Bias  
Wly wind bias  
=> Blocking Deficit

## New Model



No Gulf Stream Bias  
No Wly wind bias  
=> Good Blocking

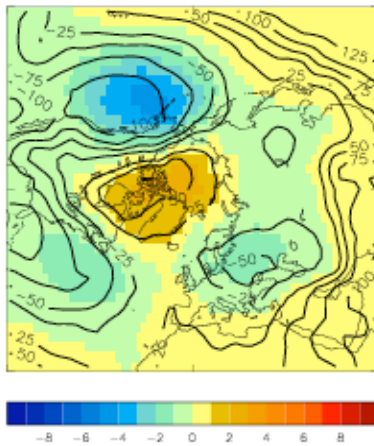
## Blocking Frequency



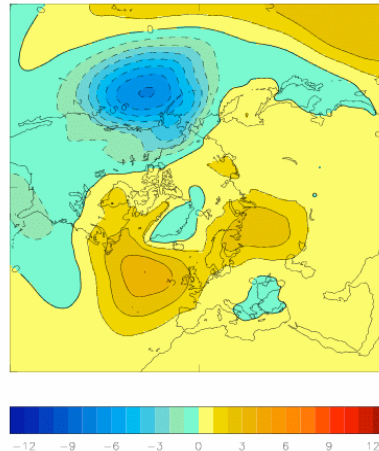
# Vertical Resolution

El Nino => negative Arctic Oscillation/NAO  
 Cold European Winter signal  
 Only works in high vertical resolution model

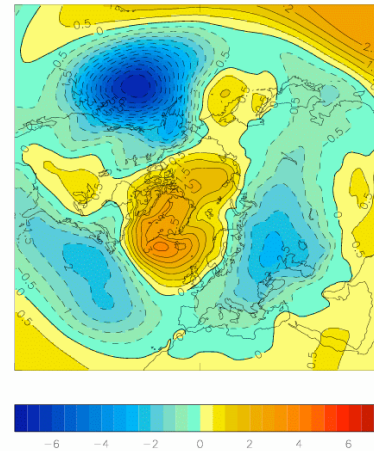
Observations



Old Model

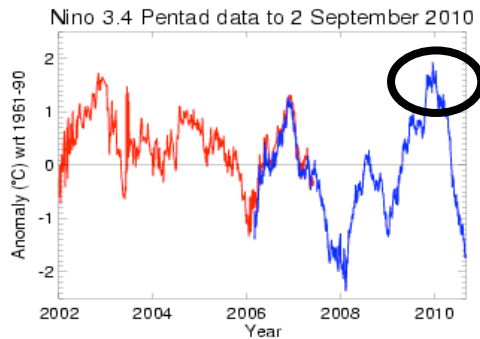


Current Model

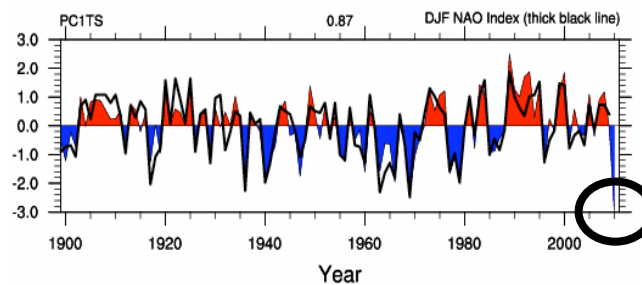


Ineson and Scaife 2009,  
 Cagnazzo and Manzini 2009  
 and others...

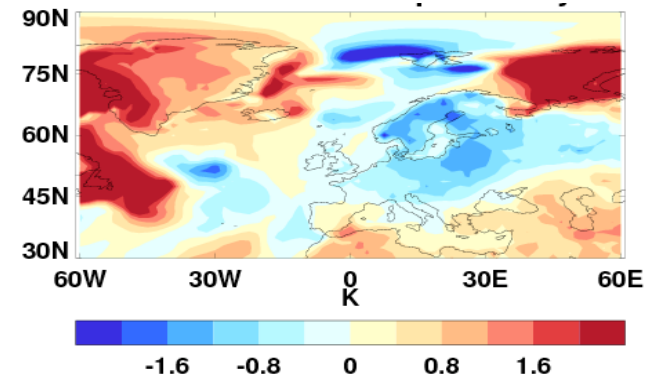
Winter 2009/10



Record low NAO

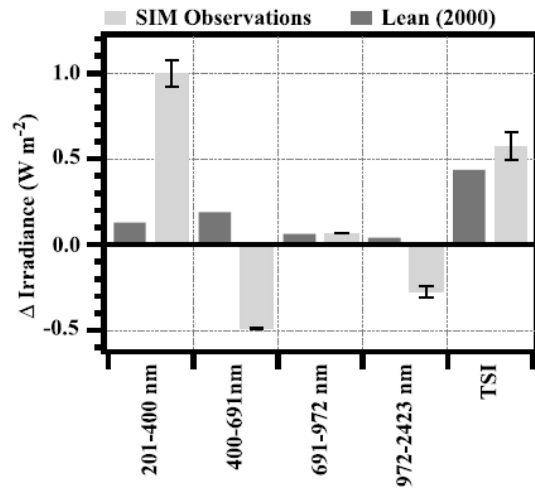


UKMO GloSea4

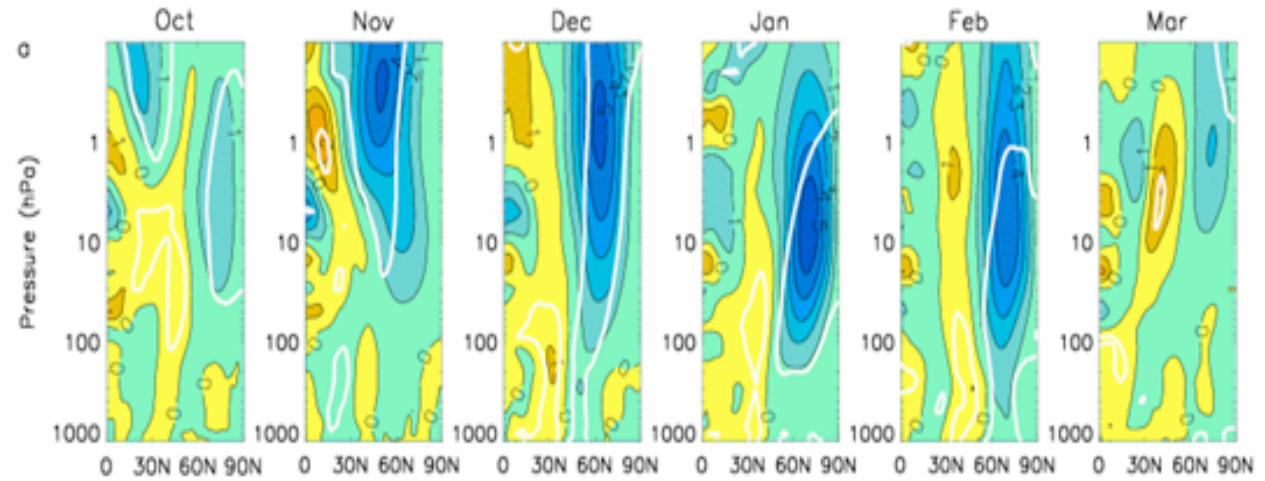


# Solar Variability Effects?

Solar Irradiance Variation



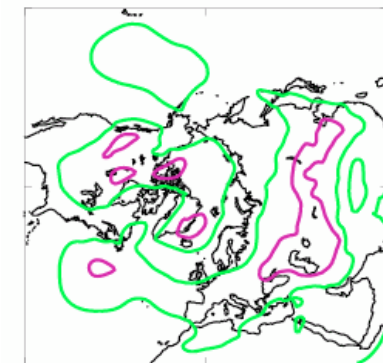
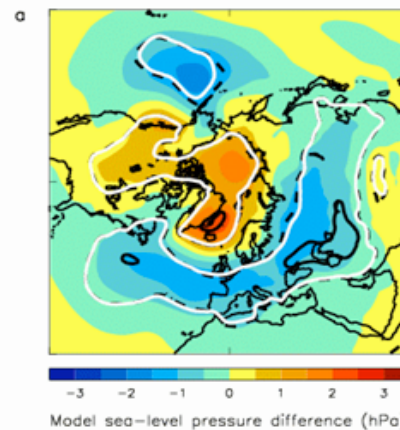
Climate Model Response in Zonal Wind



Large differences in spectral solar irradiance variability

Descending easterlies in Winter  
 $\Rightarrow$  negative AO

Potentially useful surface signal



purple (green) indicates 50 (25)% of interannual st. dev.

# Summary

- **Initialisation improves prediction months to years ahead**
  - Monthly to seasonal forecasts: tropics higher skill.
  - Interannual to Decadal: more uniform skill
- **Conditional skill => intelligent use of forecasts**
- **Some key extremes such as hurricanes or frequency of hot days show skill**
- **Improvements come from models, initialisation, ensemble generation and boundary forcing – some way to go but understanding mechanisms gives confidence**
- **Rapidly growing international activities: CMIP5 decadal hindcasts, CLIVAR WGSIP/WGCM, WMO Lead Centre for Long Range Forecast input to the Global Framework for Climate Services etc**