Stratospheric Influence on Surface Winter Climate and prospects for Seasonal Forecasting

Adam Scaife,
Jeff Knight, Sarah Ineson and Andrew Marshall

Hadley Centre, Met Office, Exeter, UK.

SPARC meeting, Sep 2007, Fields Institute, Toronto

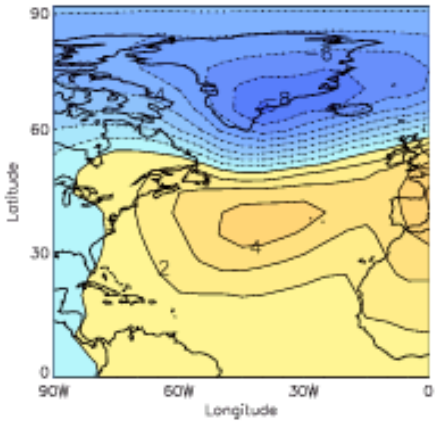
Multidecadal European winter warming

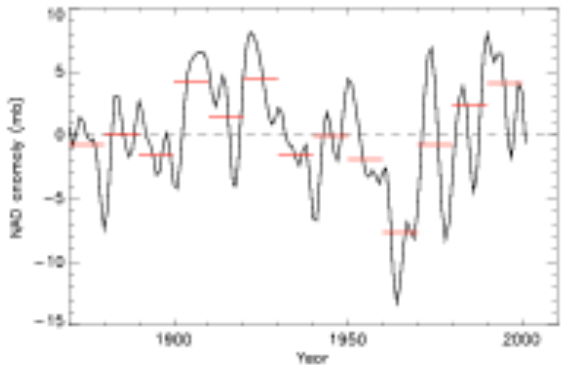
Cold European winter 2005/6

Remote response to El Nino

Seasonal forecast expts

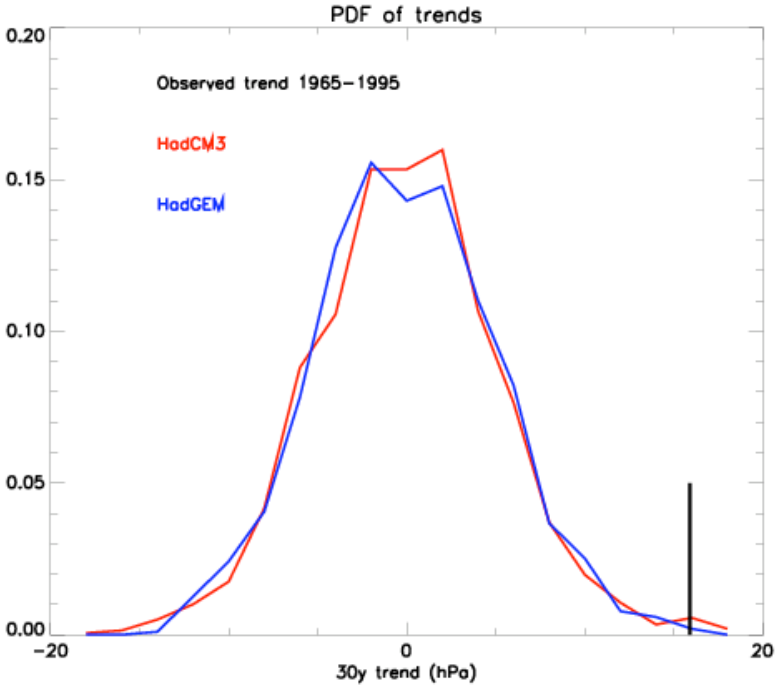
1: Multidecadal NAO trends





Note 1960s to 1990s change

"Tropospheric models" do not easily capture the observed NAO trend.

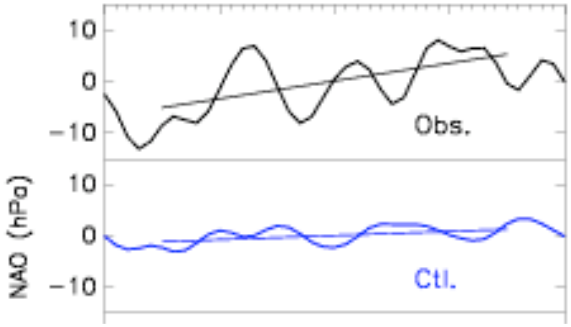


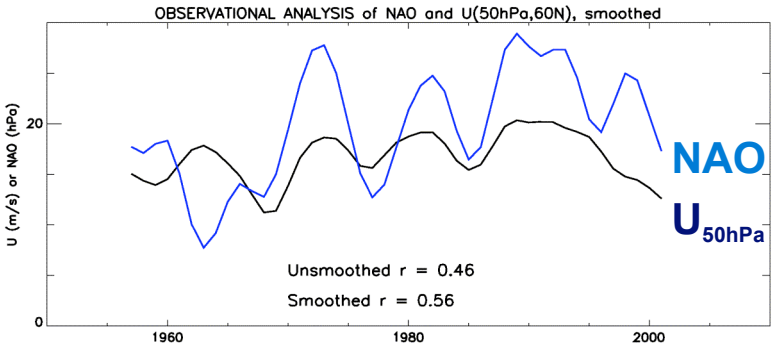
NAO change and the stratosphere

Observations have a large increase in NAO

Control run has very little increase in NAO
(includes GHG, aerosols, observed SST etc)

Change in NAO index





Both NAO and stratospheric wind increase

Decrease in recent years

Similar multiannual variability

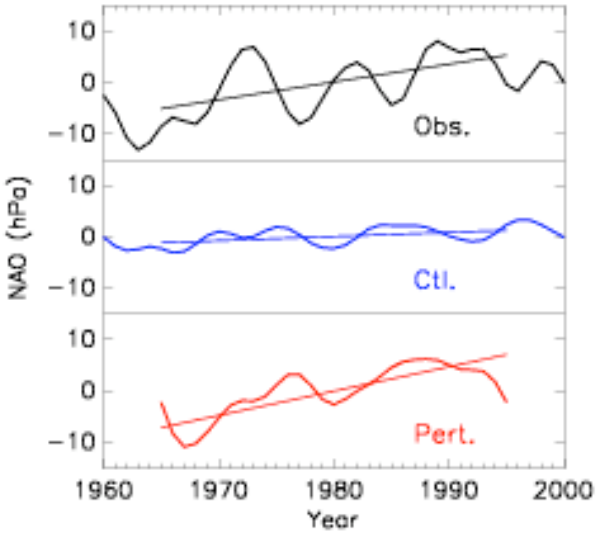
Stratospheric influences

Impose a body force in the model stratosphere (c.f. Norton 2003)

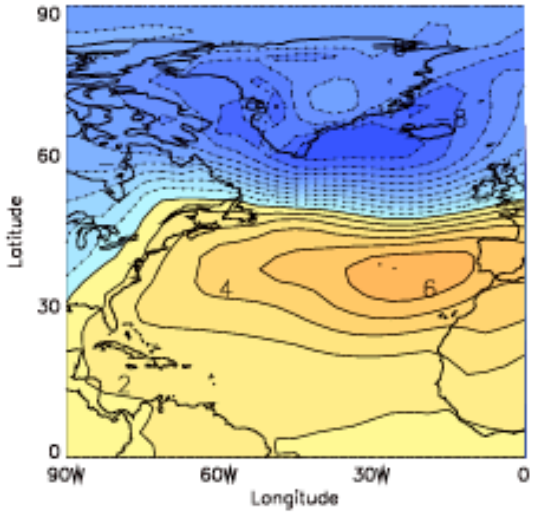
=> Increase in stratospheric wind from 1960s to 1990s

=> Increase in NAO similar to observed value

Change in NAO index

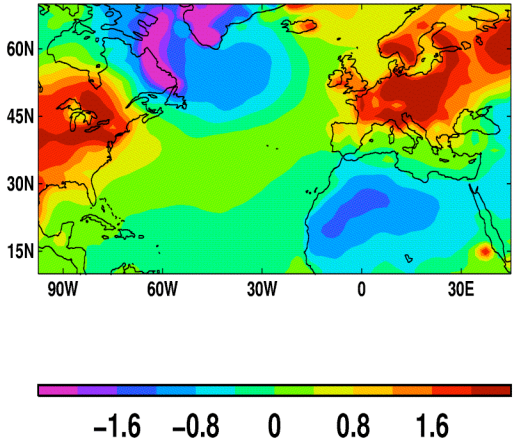


Change in surface pressure

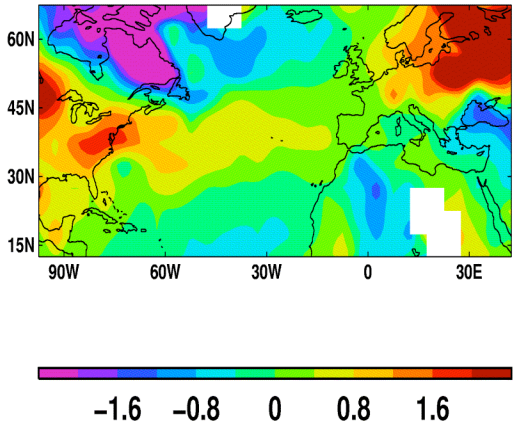


Winter surface climate response

Model Temperature



Observed Temperature



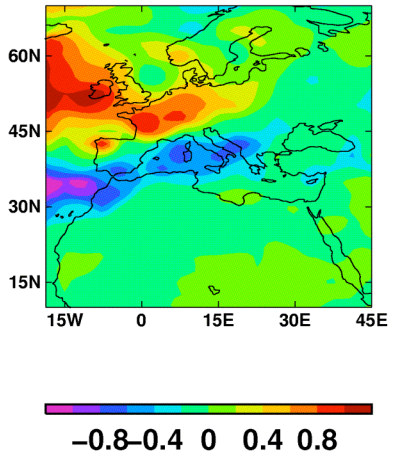
<u>European T trends 1960s-1990s</u>

HadAM3 ctl 0.15K/decade

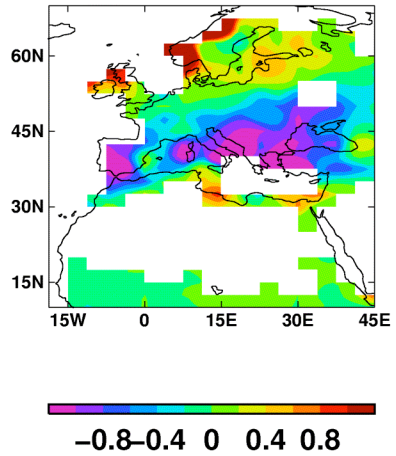
HadAM3 expt 0.59K/decade

Observations 0.53K/decade

Model Precipitation



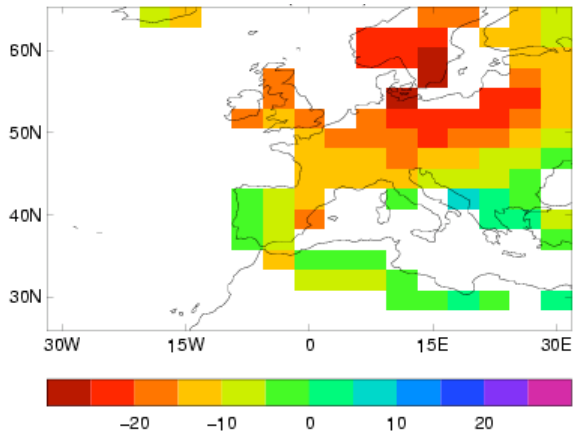
Observed Precipitation



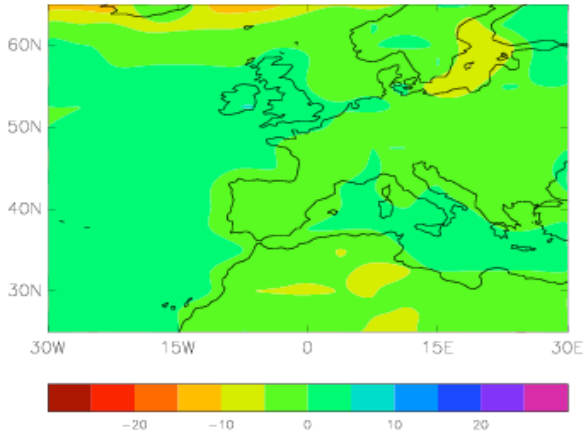
Scaife et al. GRL, 2005

Changes in extremes e.g. frosts

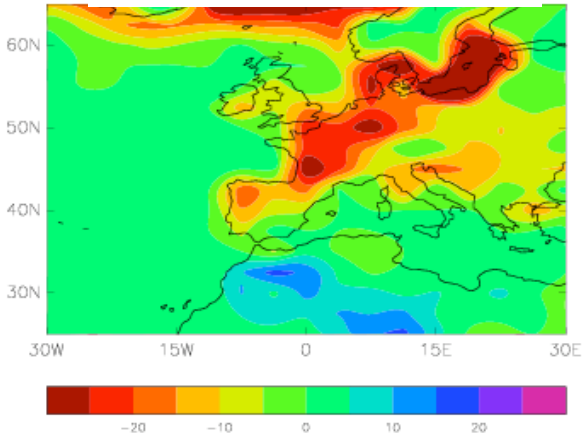
Observations



Model (forcings)



Model (forcings + NAO)



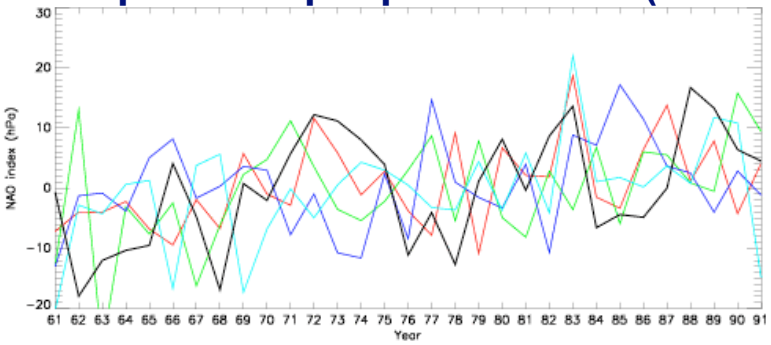
Observed changes larger than 30y modelled change with all anthropogenic forcings

Signs of dipole across Europe in observed data

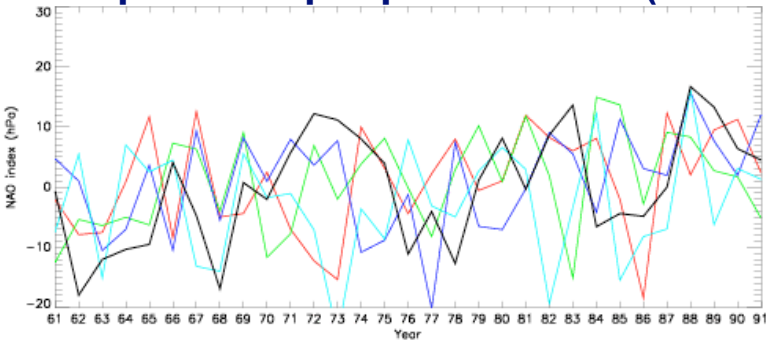
Scaife et al., J.Clim., in press

Decadal variability in strat-trop models

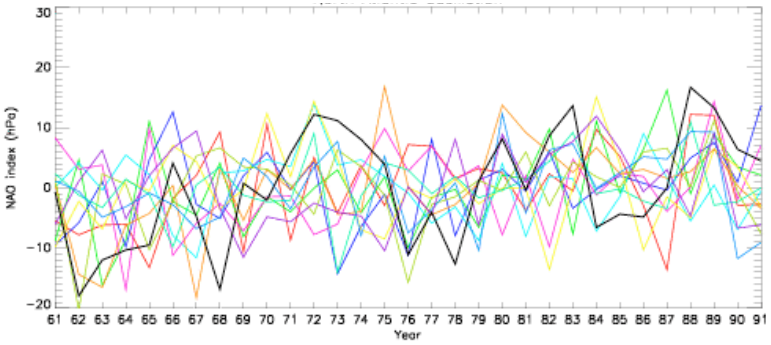
Stratosphere-troposphere Model (HadAM3)

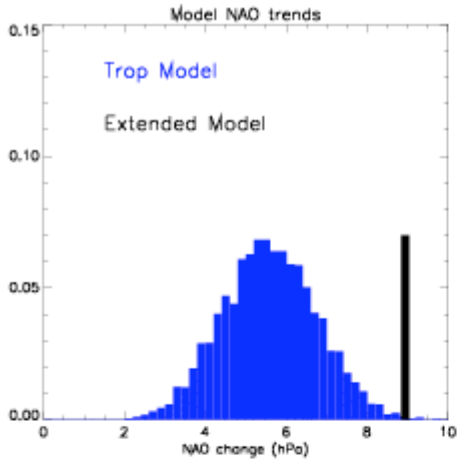


Stratosphere-troposphere Model (HadGAM1)



Troposphere Model (HadAM3)





<u>NAO TRENDS 1960/61-1990/91:</u>

Observations: 11.9 hPa

Strat-trop HadAM3: 10.3 ± 1.2 hPa

Strat-trop HadGAM: 7.8 ± 1.5 hPa

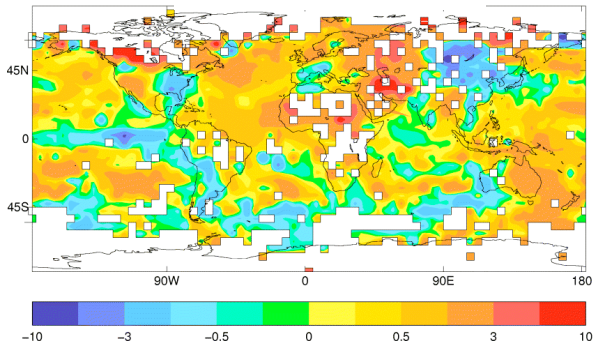
Trop HadAM3: 5.6 ± 1.4 hPa

Possibility of improved signal to noise ratio in ensemble decadal predictions

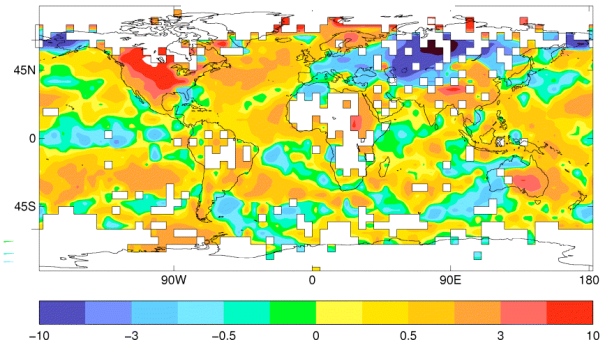
2: Winter 2005/6: a cold Europe case study

"The Met Office continues to predict … a colder-than-average winter … the balance of probability is for a winter colder than those experienced since 1995/96".
Met Office forecast issued November 2005, see also Graham et al., 2006, Scaife and Knight, submitted.

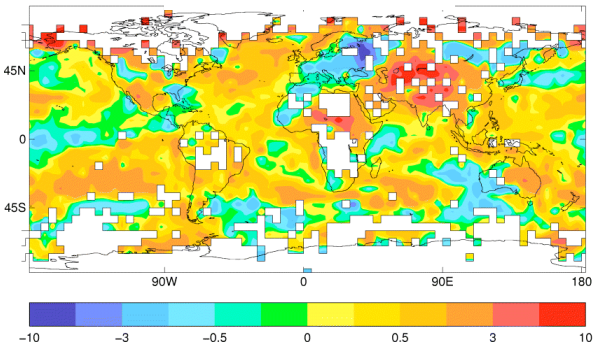
December 2005



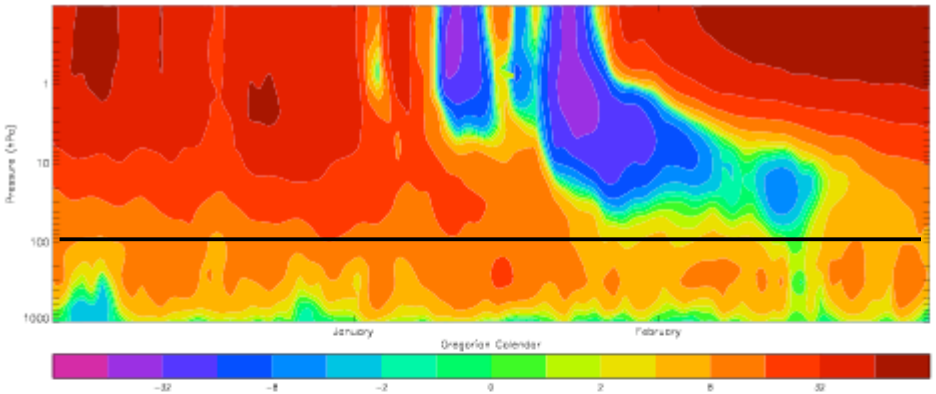
January 2006



February 2006



Zonal wind through the winter
(c.f. Baldwin and Dunkerton 2001, Charlton et al. 2004)

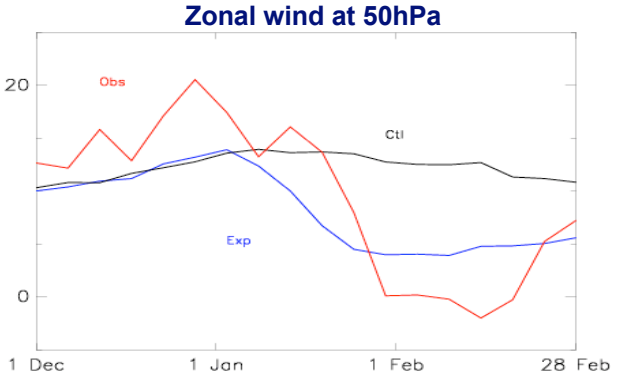


- **Colder than 1970-2000 over much of Europe**
- **2nd coldest in 10 years using area mean T**
- **Record snowfall in parts of central Europe**
- **Late winter colder than early winter**
- **Extreme stratospheric warming in January**

Winter 2005/6 ensembles

- Tropospheric models (HadAM/HadGAM)
  - 50/25 members
  - HadISST as a boundary condition

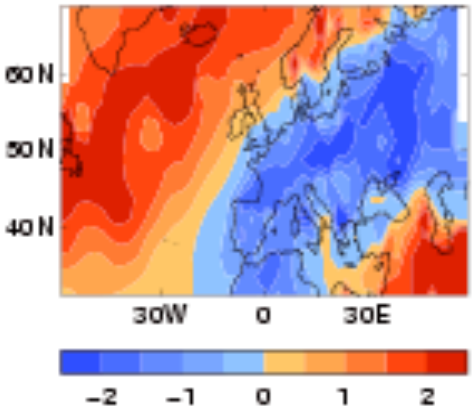
- Tropospheric Model + stratospheric perturbation
  - 25 members
  - HadISST as lower boundary condition
  - Perturbed stratosphere from 1st Jan



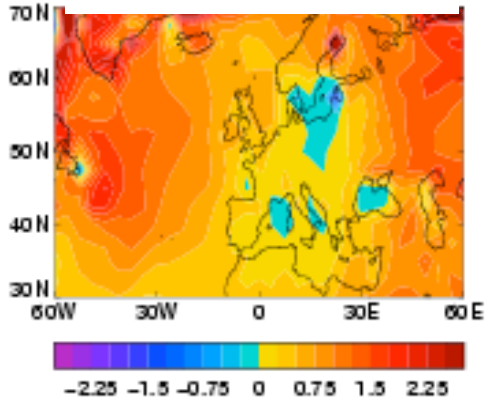
- Troposphere-stratosphere models (HadAM/HadGAM)
  - 25/25 members
  - HadISST as a boundary condition

Winter 2005/6 – SST played a part

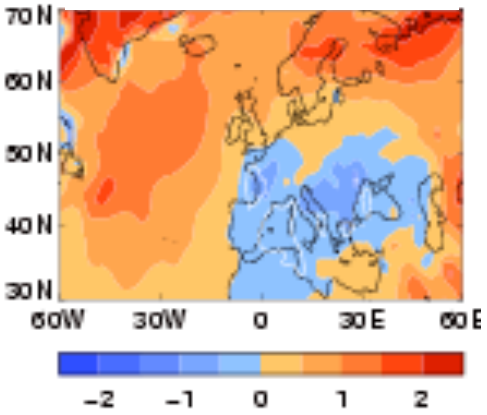
Observed Anomalies



Old model



New model



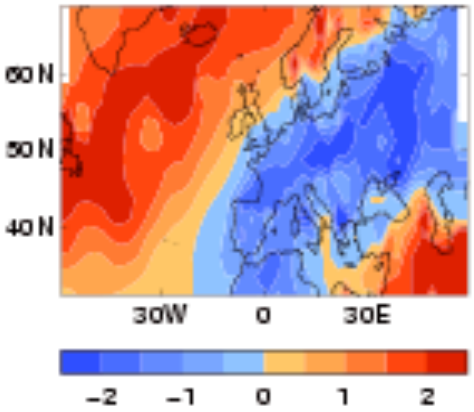
Cold European signal from SSTs

Clearest in new HadGAM model with increased horizontal resolution and improved storm track

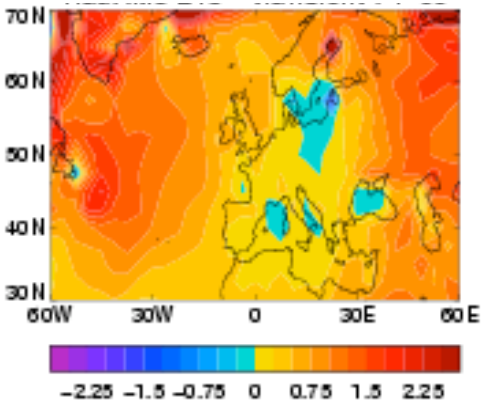
Scaife and Knight, QJ, submitted.

Winter 2005/6 – stratosphere played a part

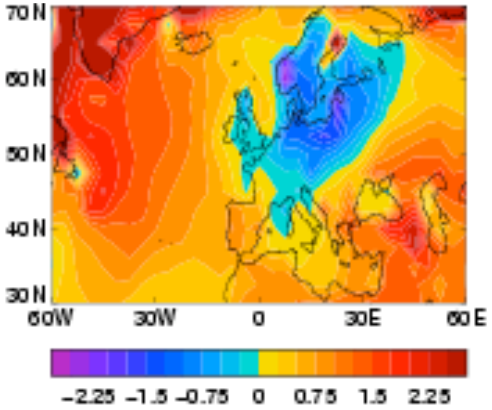
Observed Anomalies



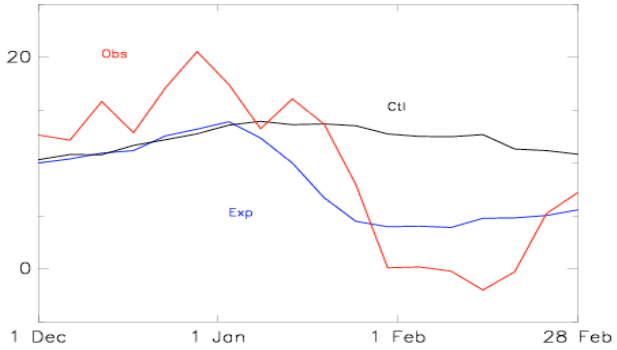
Old model



Old model + strat forcing



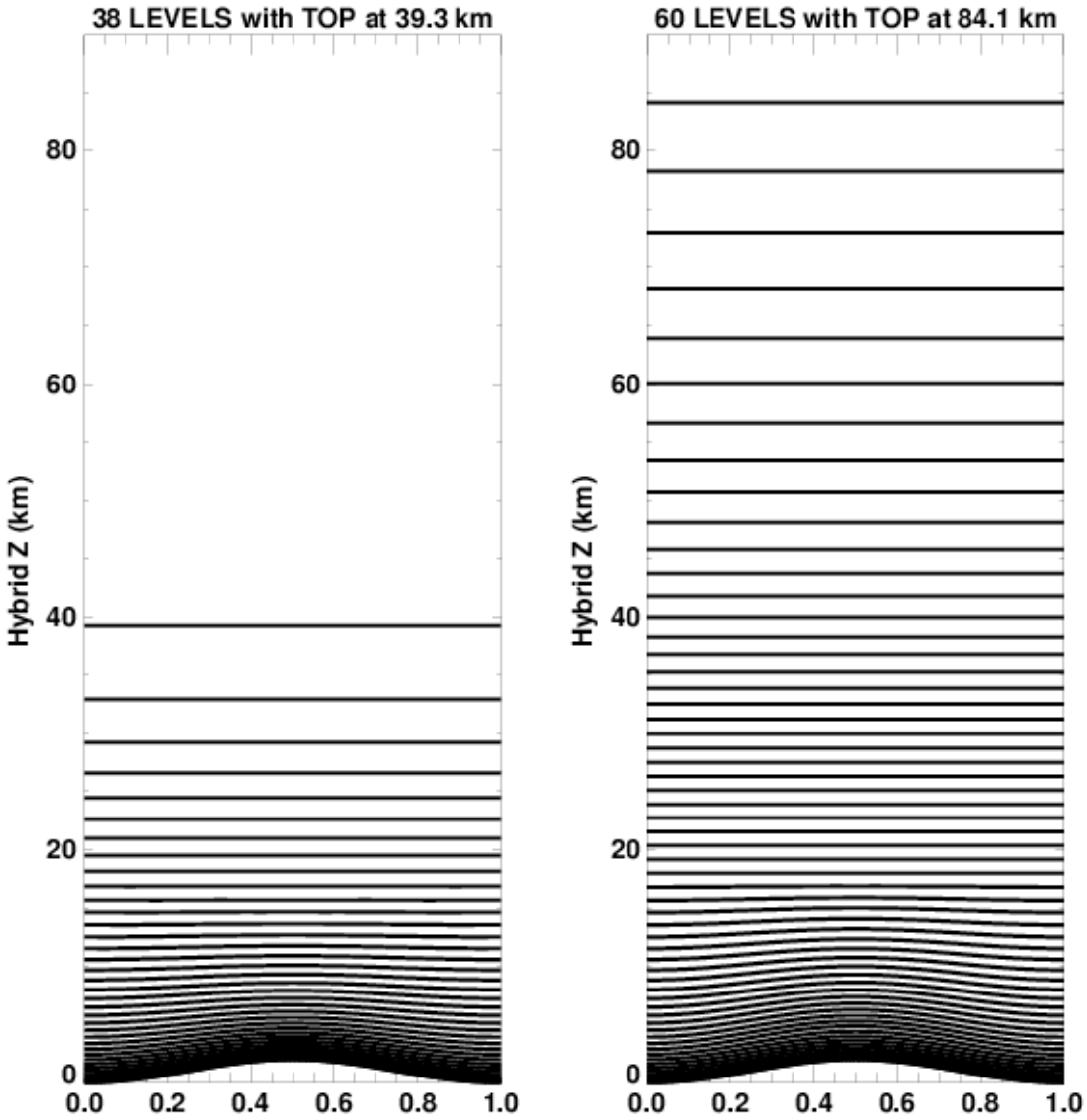
Zonal wind at 50hPa



Cold European signal from *IMPOSED* stratospheric warming

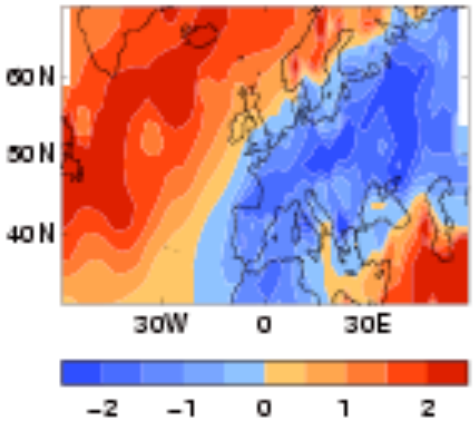
Scaife and Knight, QJ, submitted.

Atmospheric resolution L38 vs L60

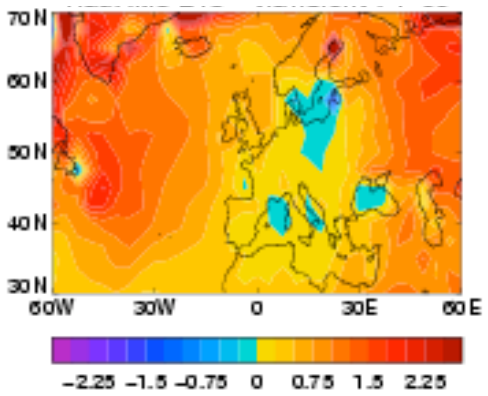


Winter 2005/6 - strat-trop models

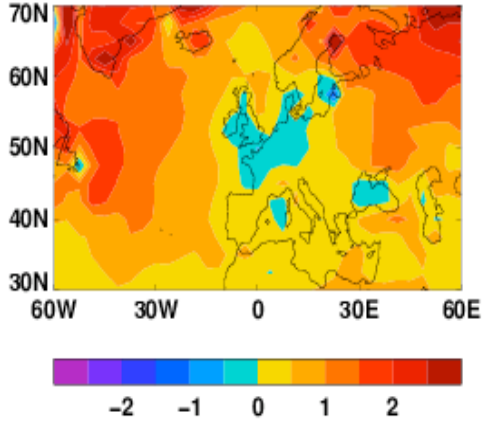
Observed Anomalies



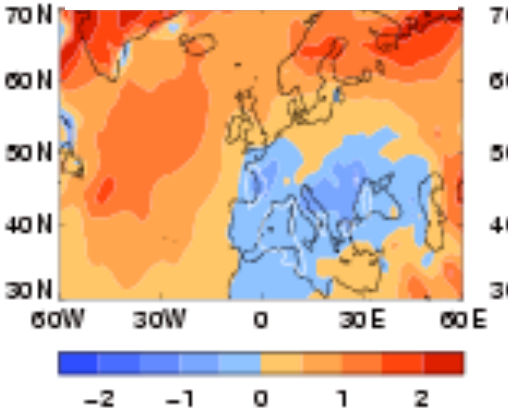
Old trop model



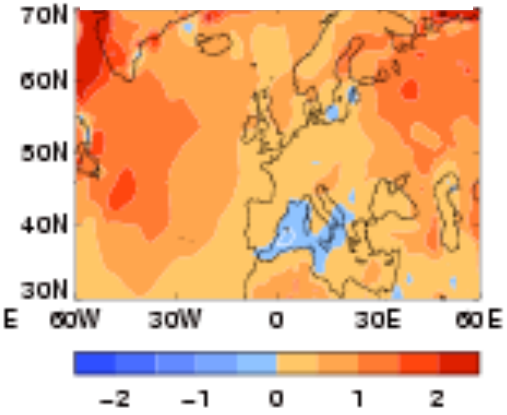
Old strat-trop model



New trop model



New trop-strat model



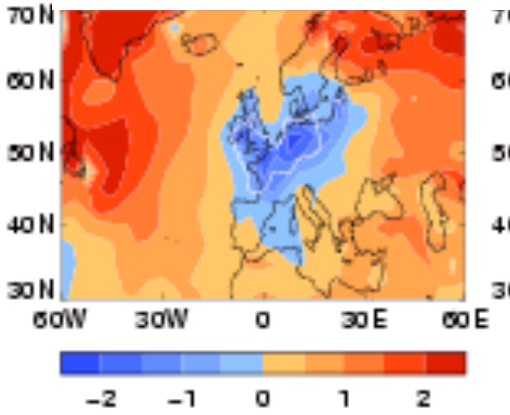
Stratospheric warming unpredictable from SST alone

Scaife and Knight, QJ, submitted.

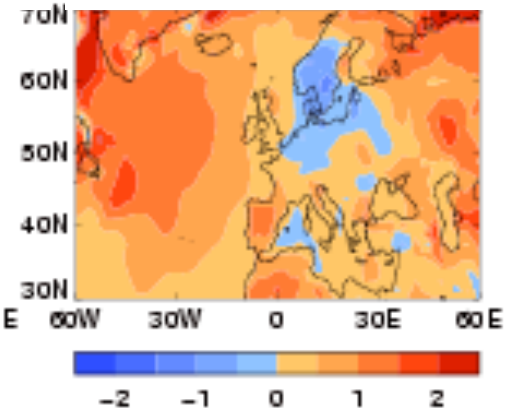
Winter 2005/6: stratospheric influence

Warming minus non-warming ensemble members gives another estimate of the region affected by the sudden warming:

Old strat-trop model

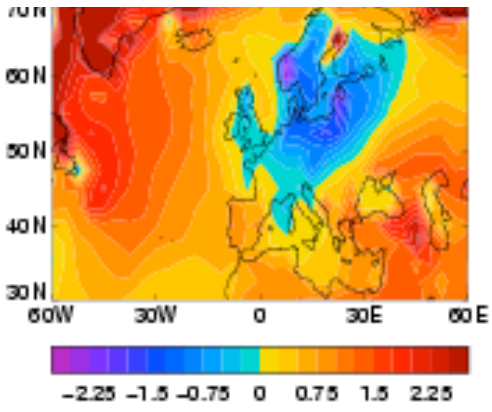


New strat-trop model



c.f.

Imposed strat warming

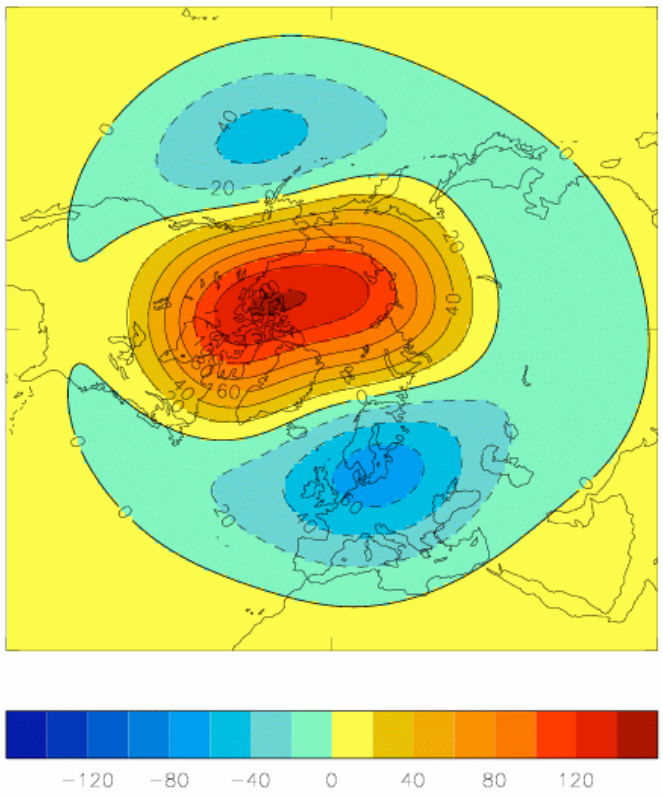


Imposed and simulated impacts of stratospheric warming in reasonable agreement

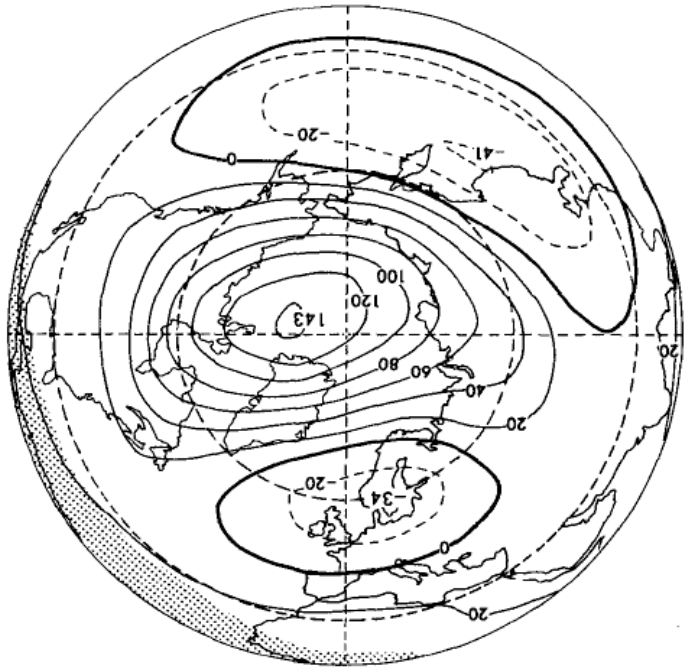
Scaife and Knight, QJ, submitted.

3: Remote El Nino effects

Model El Nino anomaly
(50hPa geopotential height)



Observations (Hamilton, 1993)



ENSO events produce a –ve NAO response (e.g. Bronniman et al. 2004)

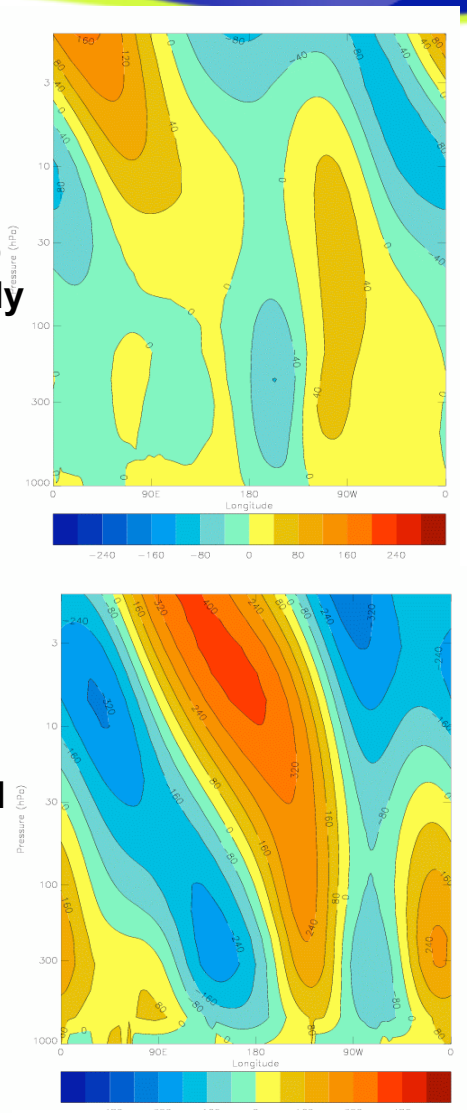
Clearly visible in 2/3 of observed El Nino events (Toniazzo and Scaife 2006)

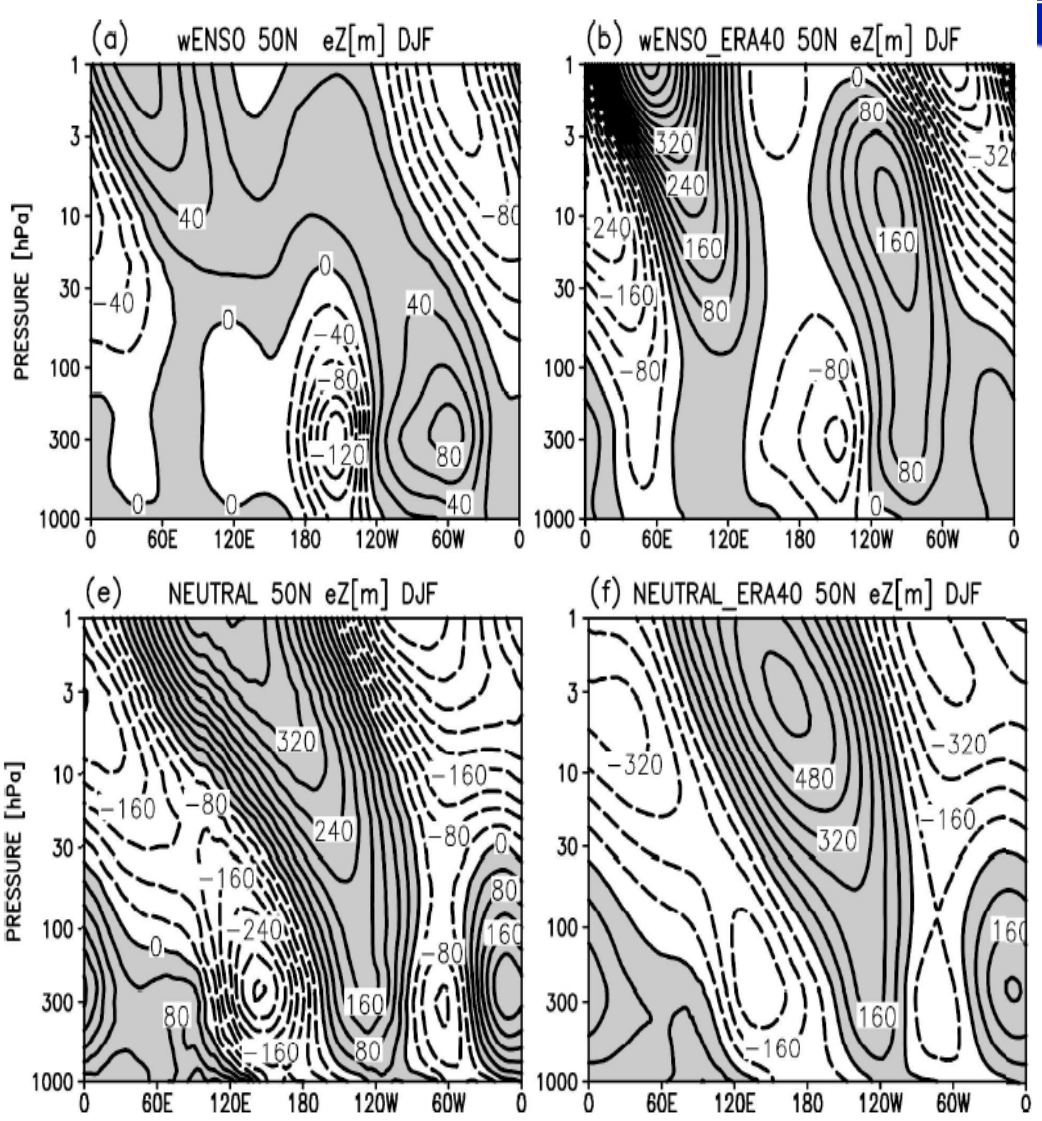
Stratospheric component appears in models (Van Loon and Labitzke 1987, Hamilton, 1993, Manzini et al. 2006)

Winter stationary waves

El Nino anomaly

Control



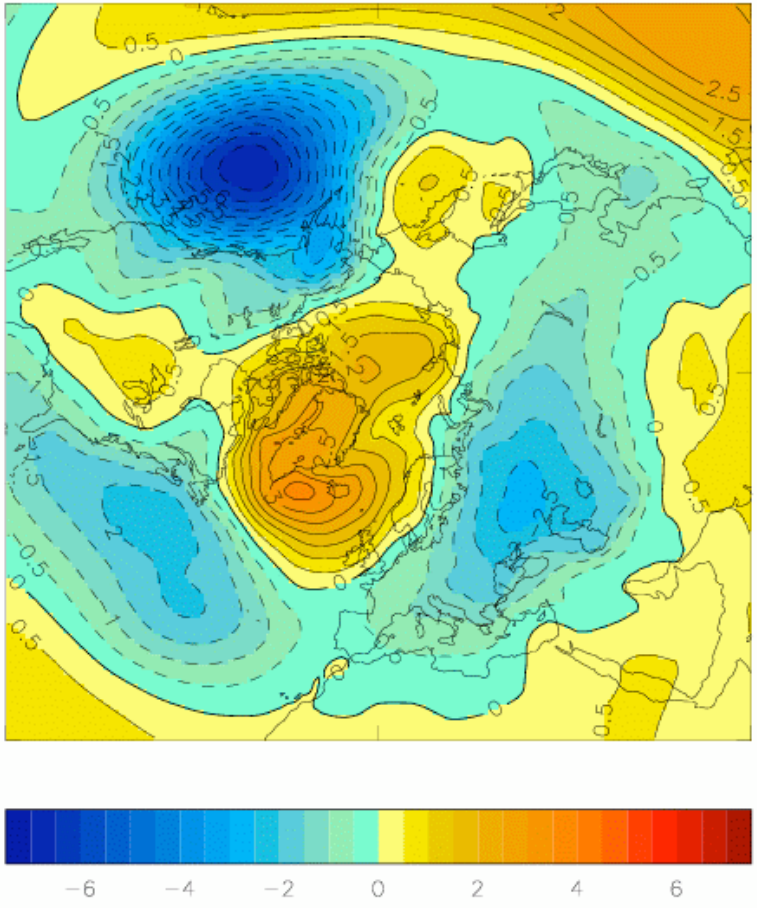


L60 HadGAM1 **ECHAMma** **ERA40**

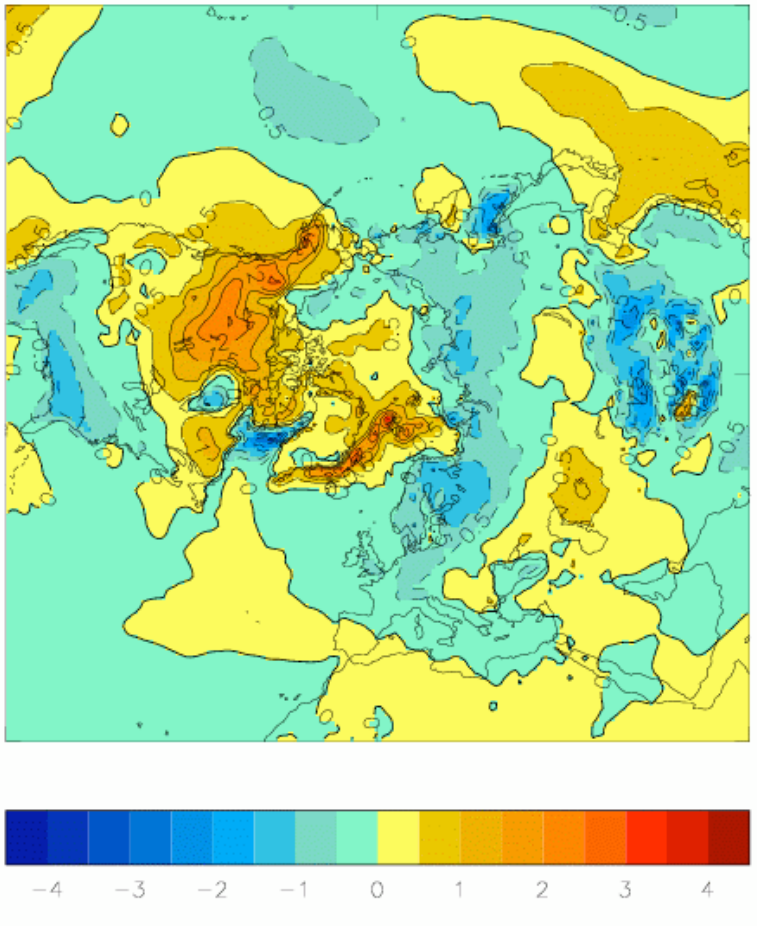
Manzini, 2006

Surface climate

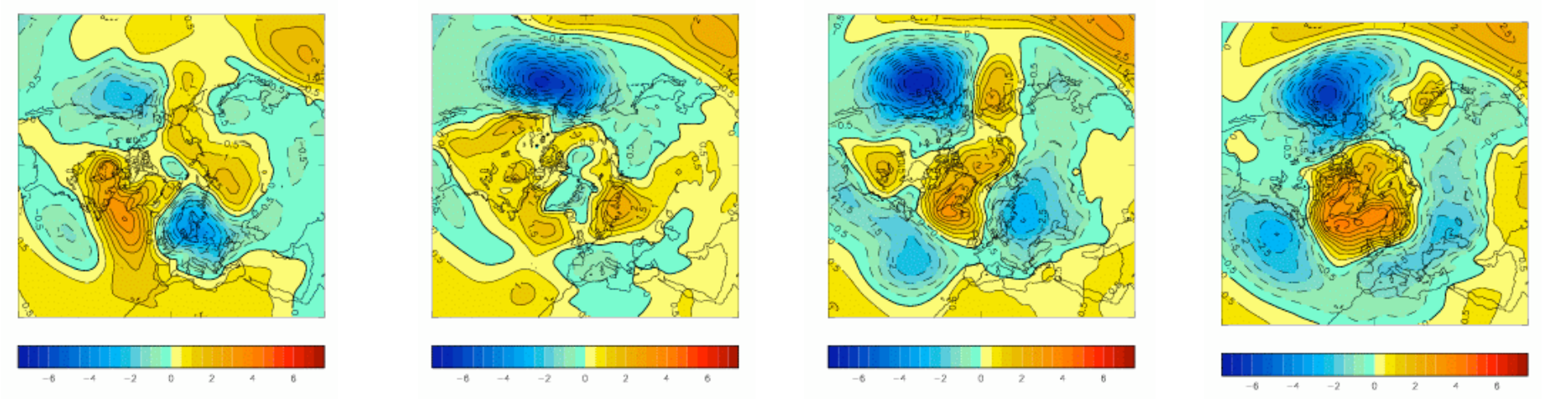
Jan-Feb PMSL



Jan-Feb T2m



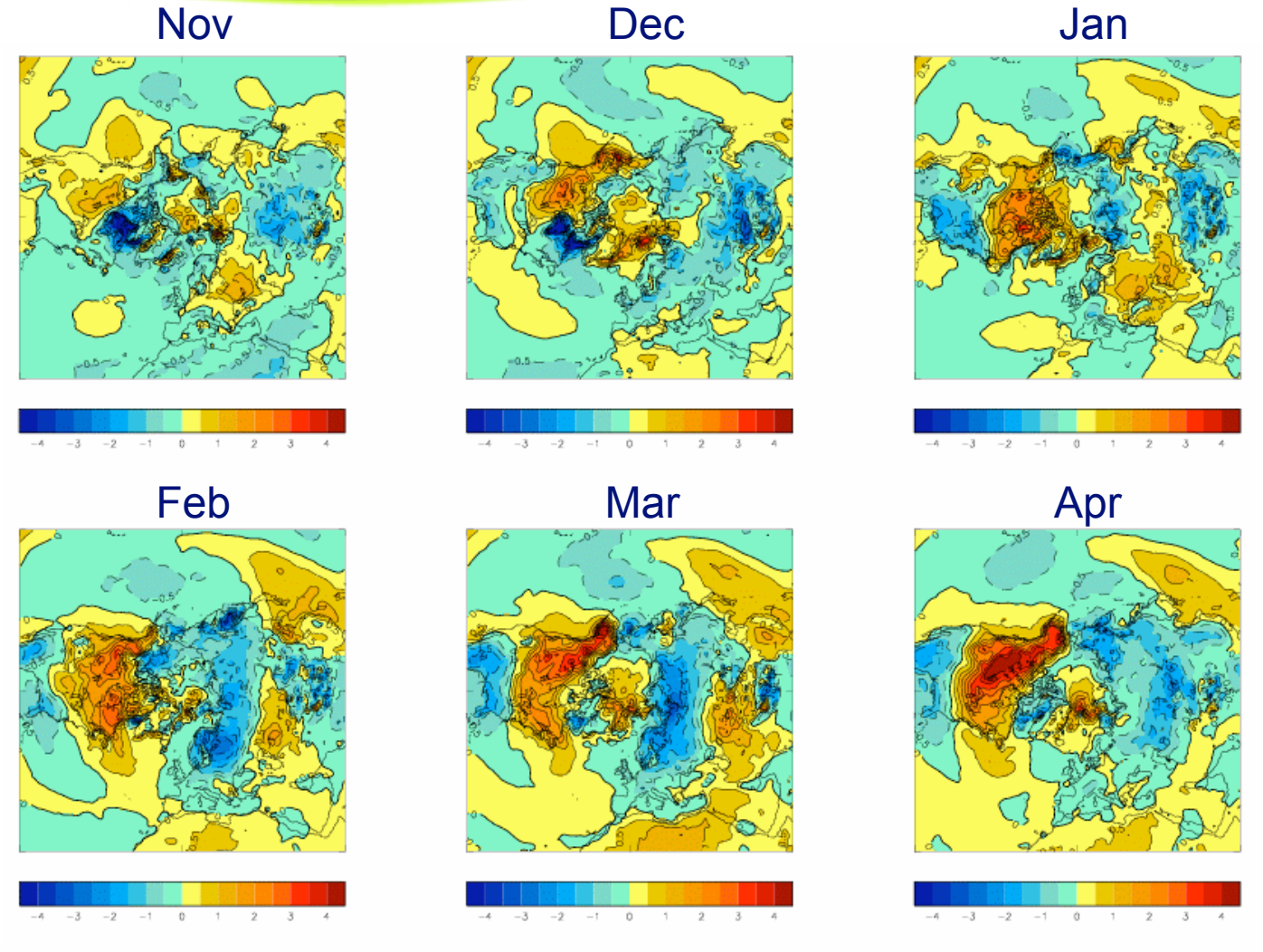
Intraseasonal signal



Moron and Gouirand, IJC, 2003

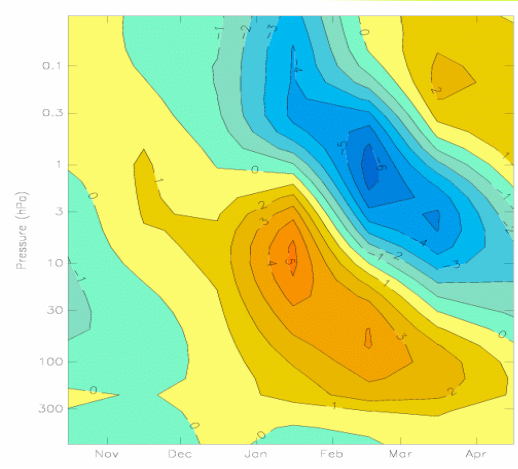
Negative NAO signal appears in late winter in both model and obs.

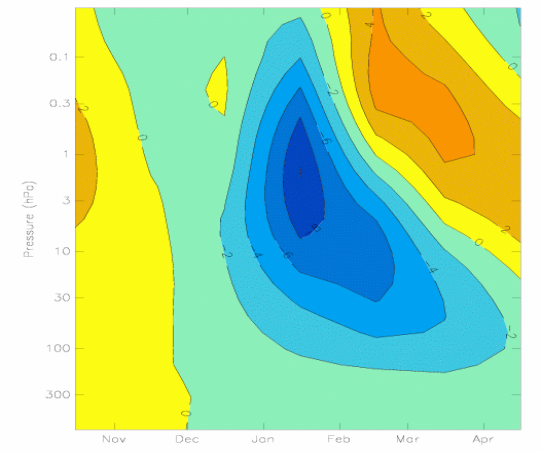
Intraseasonal signal

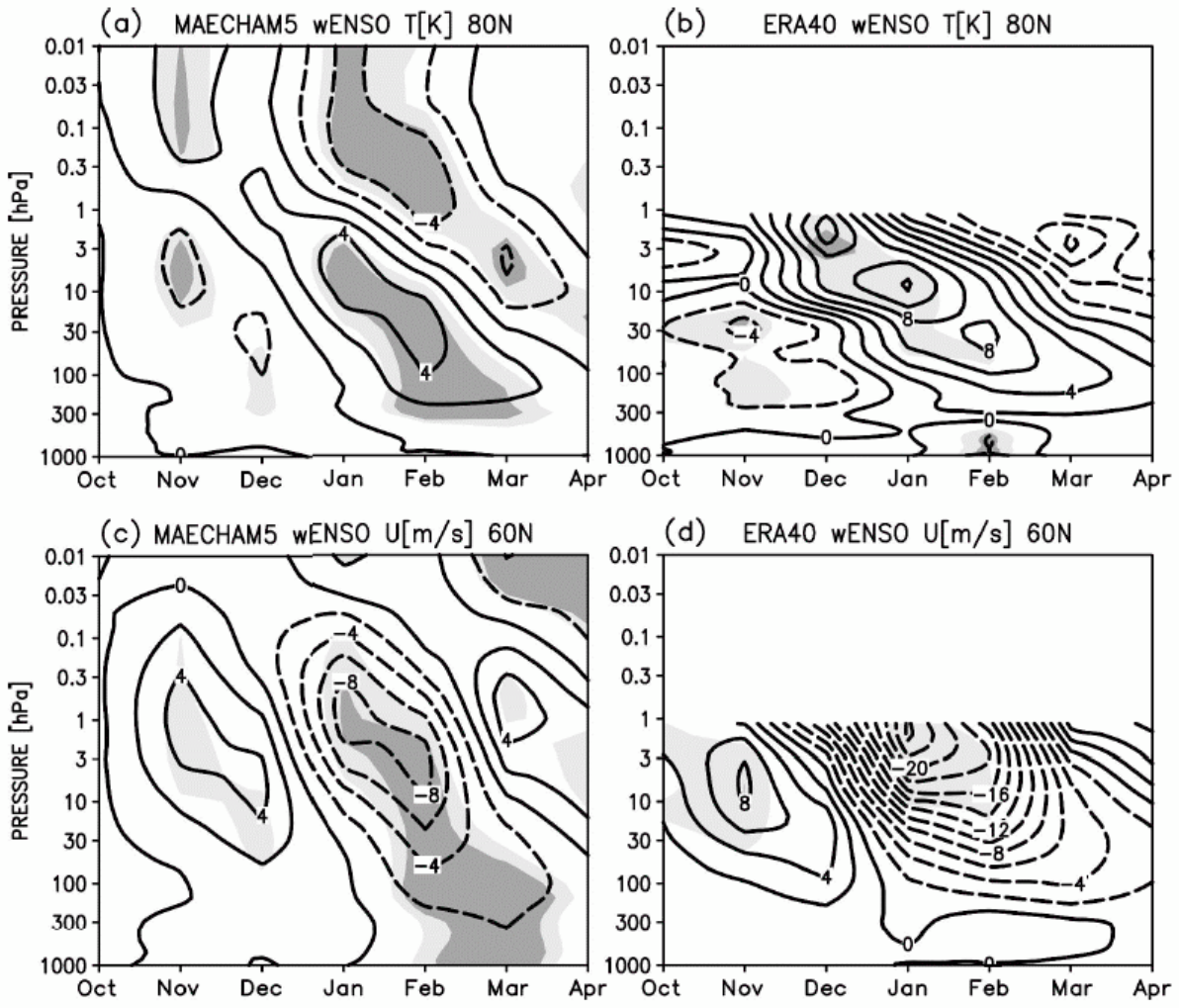


Corresponding surface temperature signal persists into Spring

Downward progression



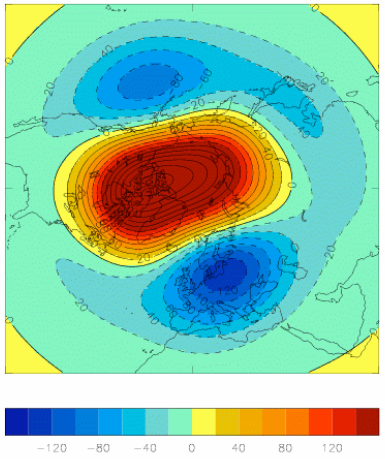
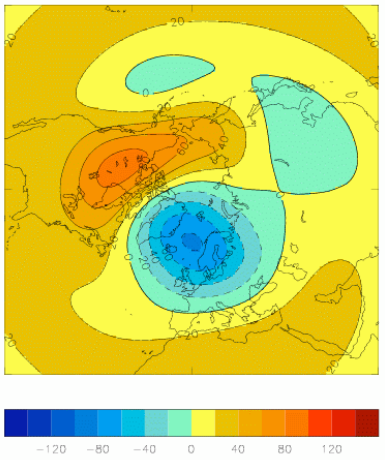
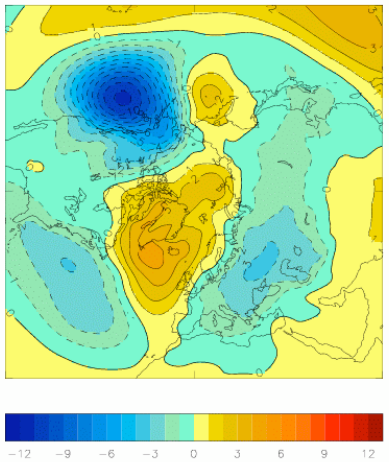
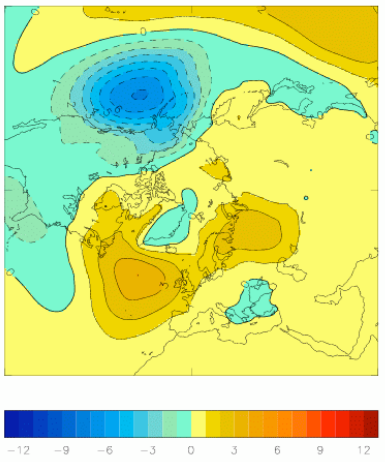




Hadley Centre Model

Manzini et al, 2006

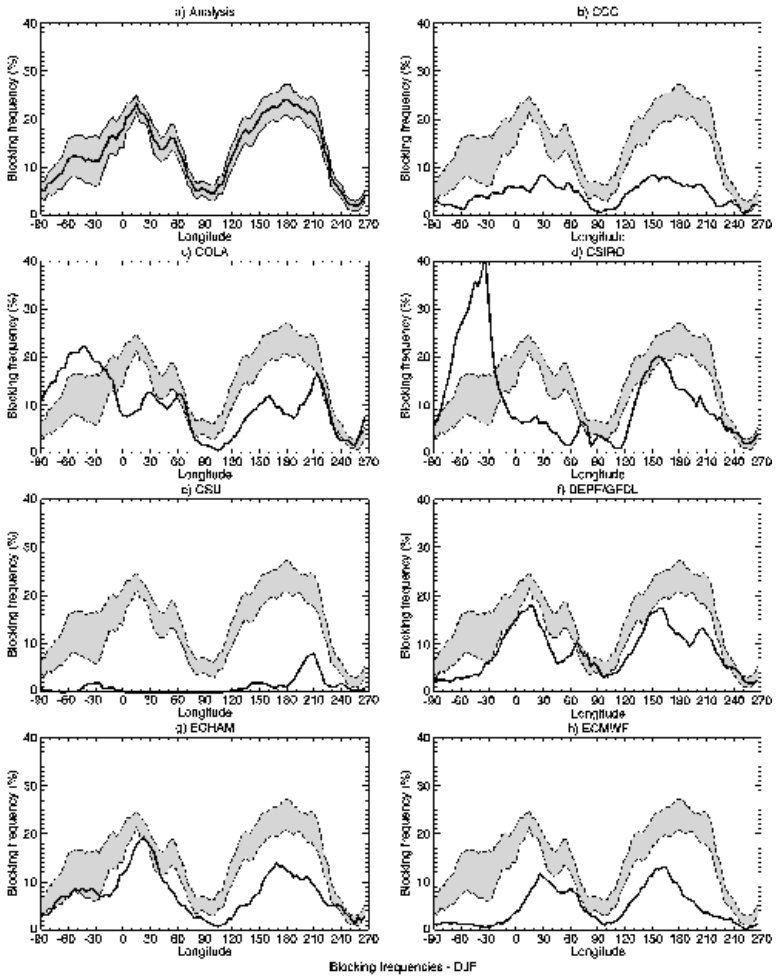
Model resolution effect

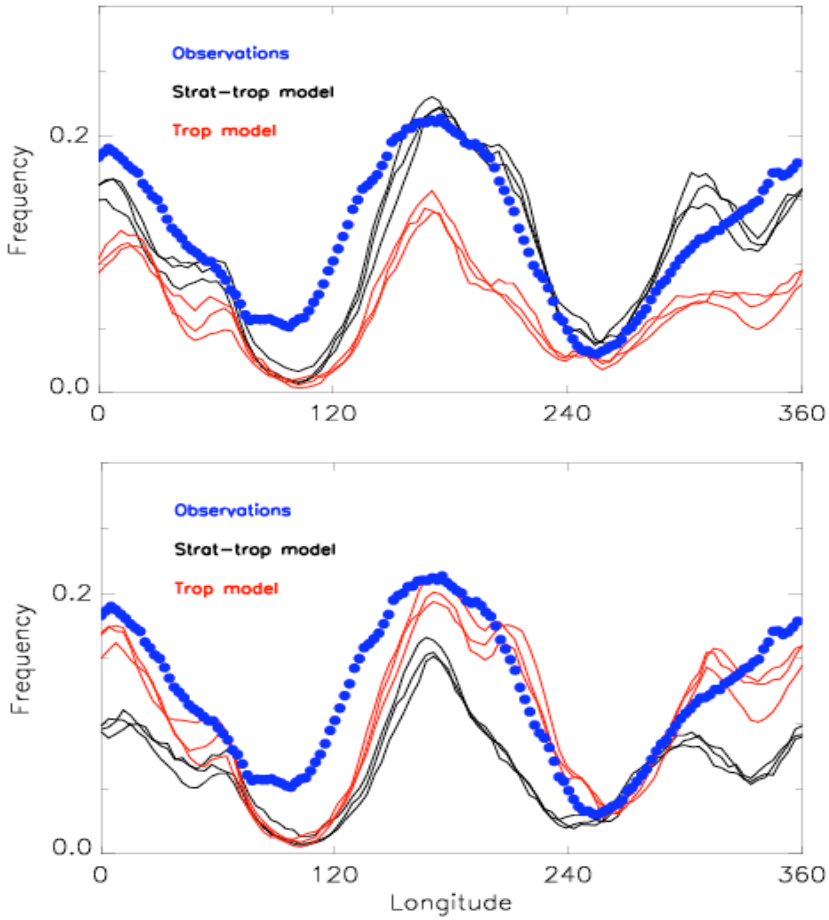
	L60	L38
50hPa gph		
PMSL		

Ineson and Scaife, in prep.

Atmospheric blocking

Climate model blocking frequencies
(D'Andrea et al. 1997, Tibaldi and Molteni 1990)

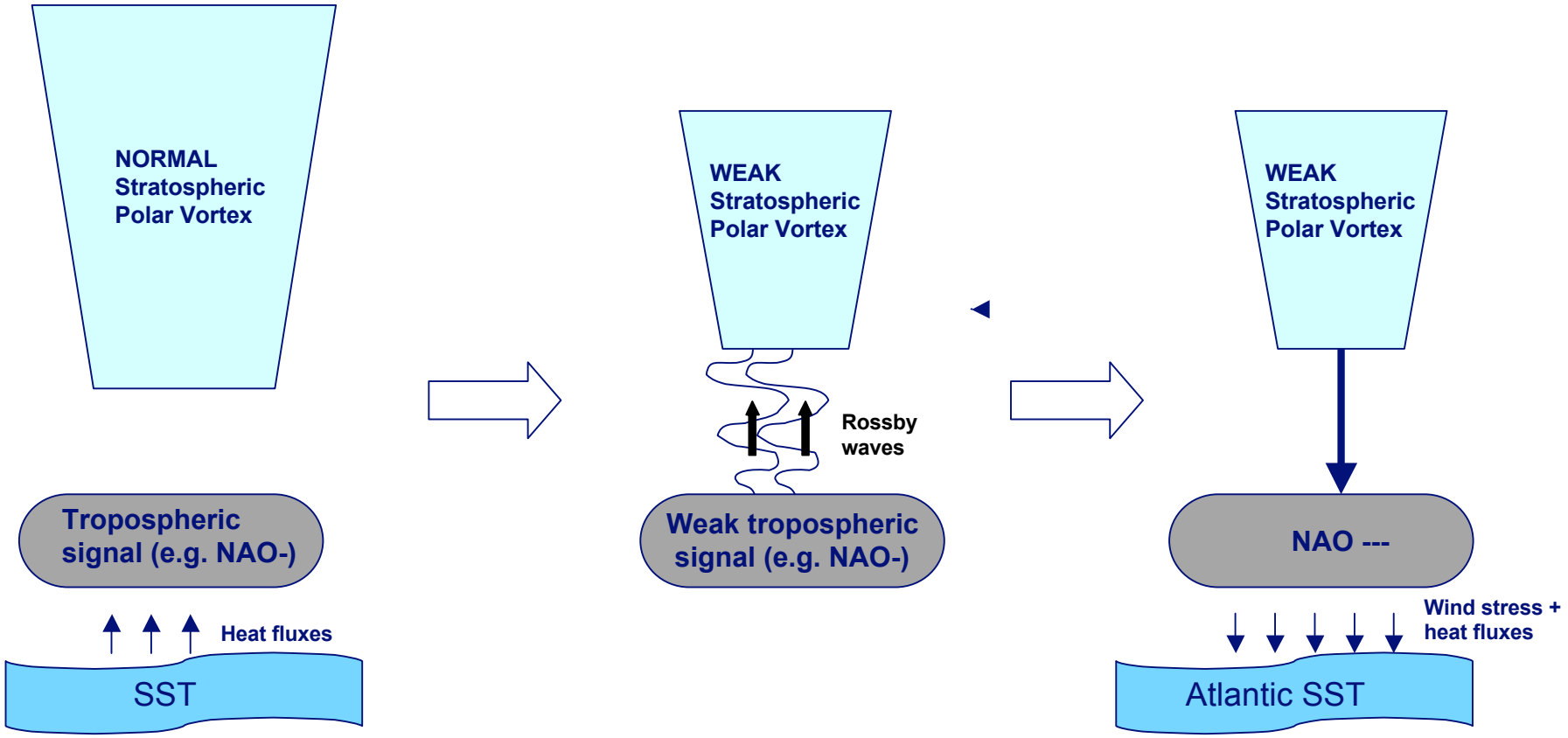




Climate models and weather forecasts underestimate blocking frequency after >5 days

Strat-trop HadAM3 model reproduces maximum blocking frequency in both Pacific and Atlantic sectors.

Possible mechanism



Seasonal Hindcast Experiments

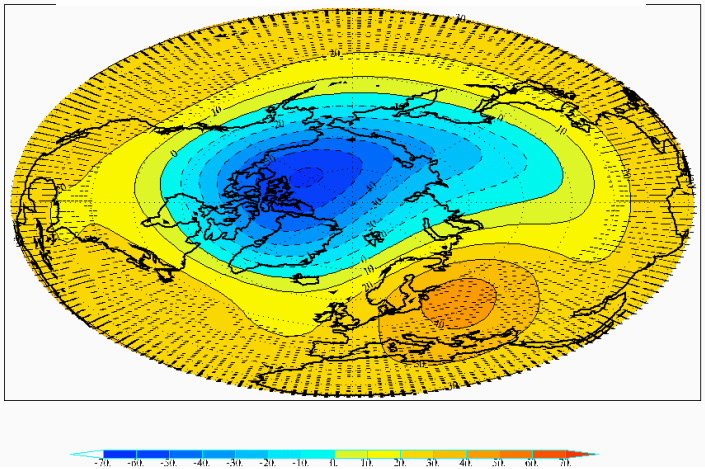
Currently running:

~10 selected winter case studies

15 member ensembles: L38 and L60 models

Initial conditions from 1st December

Volcanic response at 50hPa



To study:

- **El Nino effects**
- **Volcanic effects**
- **Atlantic SST influence**
- **Sudden warming effects**

To output:

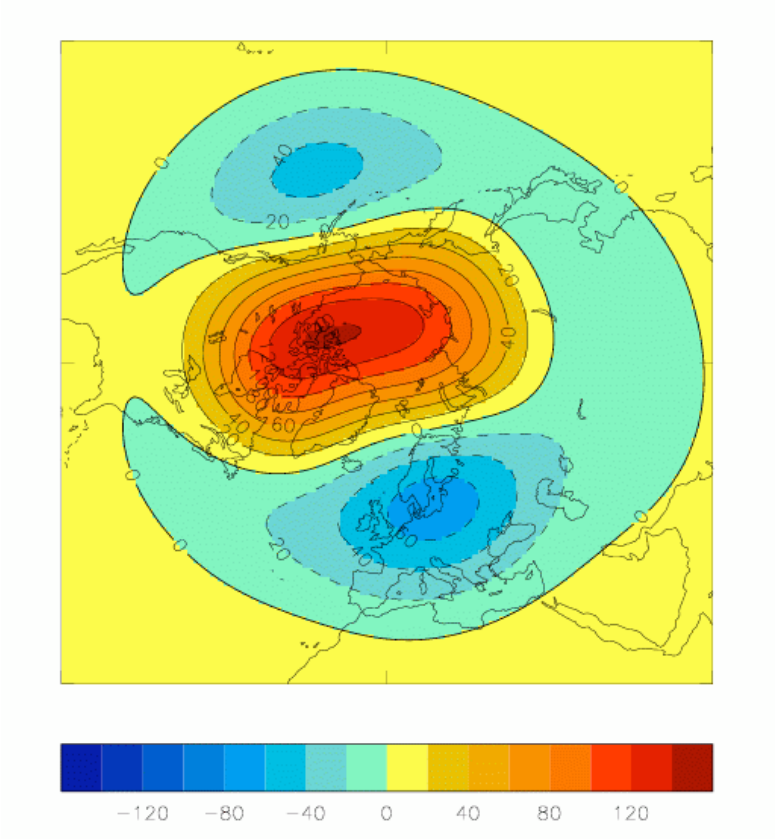
- **Understanding of sources of predictability**
- **Capability of models**
- **Recommendations for new Met Office seasonal forecast system due in 2009**

Conclusions

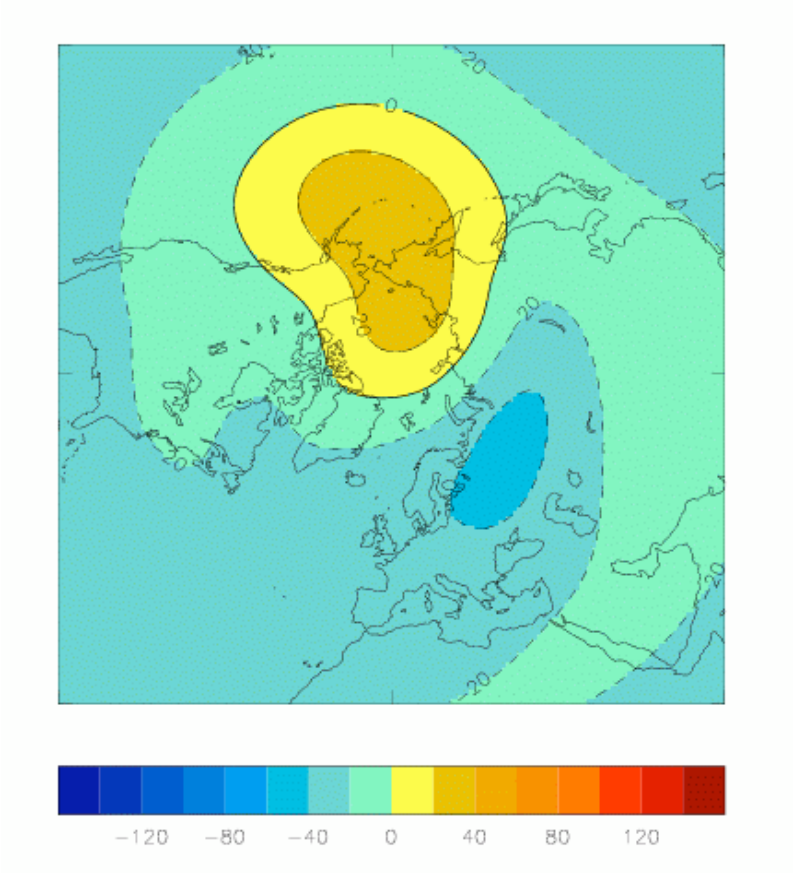
- The NAO dominated mean and extreme regional winter from the 1960s to 1990s and the stratosphere played an important part.
- A picture is emerging which links the stratosphere to the NAO (sometimes because of ENSO) and to cold, blocked European winters.
- Extended models produce a –ve NAO response to El Nino and decadal responses to SST but winter 2005/6 stratospheric warming is not predictable from SST and sea ice alone.
- Seasonal hindcasts are underway including initial atmospheric conditions for key winters.
- Trop-strat climate change experiments are needed to test whether current IPCC surface predictions are robust (e.g. Huebener et al. 2007).

Model response to warm and cold ENSO composites

DJF geopotential height, Z, 46hPa



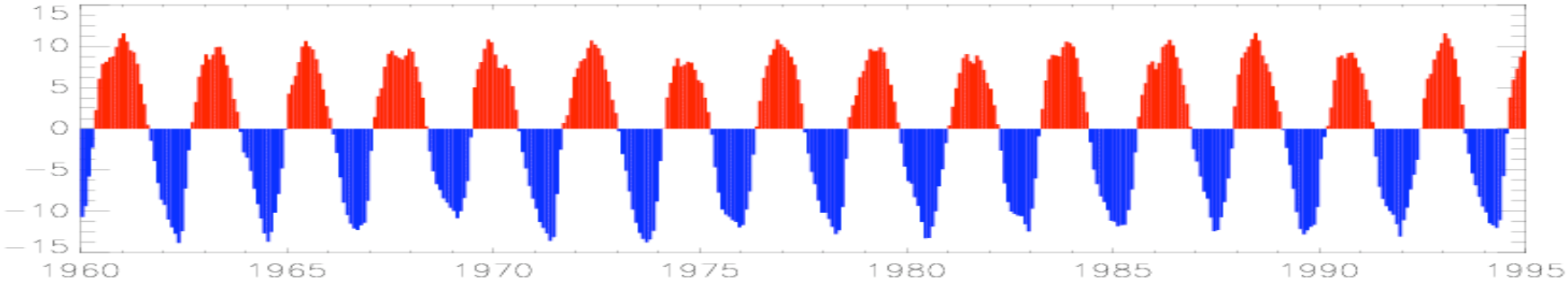
Warm



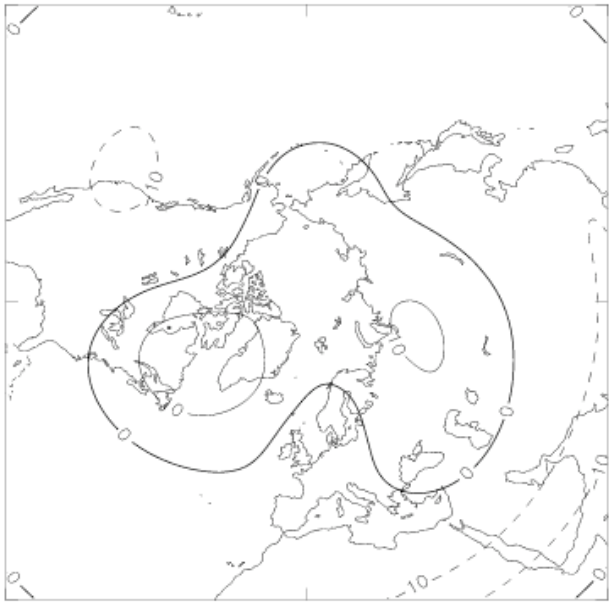
Cold

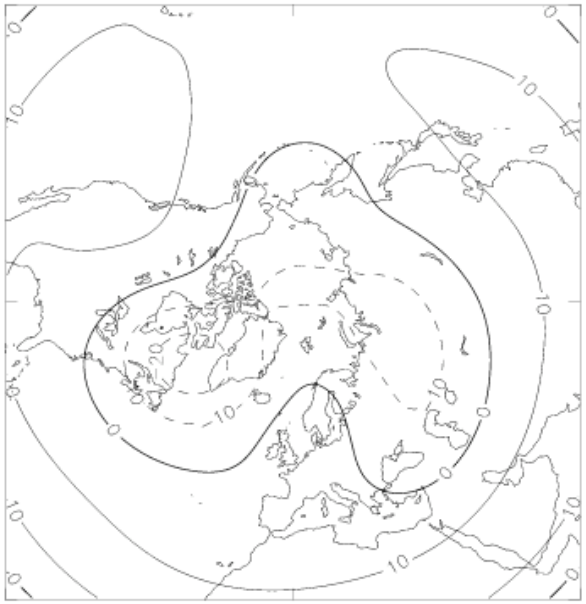
Model NH stratospheric response to QBO

U46 hPa (10°N -10°S)



Z46 hPa



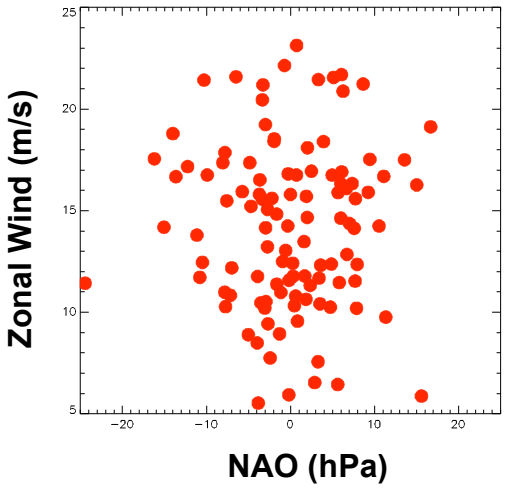


+ve QBO

-ve QBO

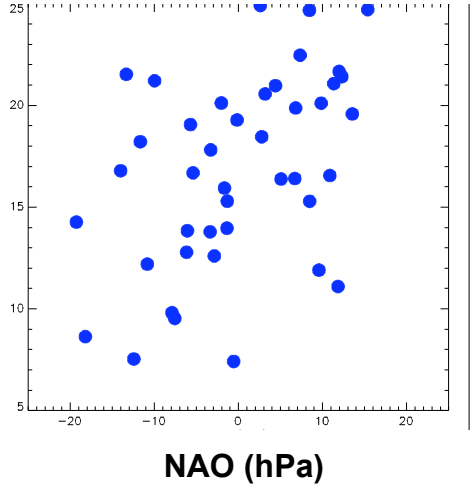
A simple metric to judge models:

HadAM3



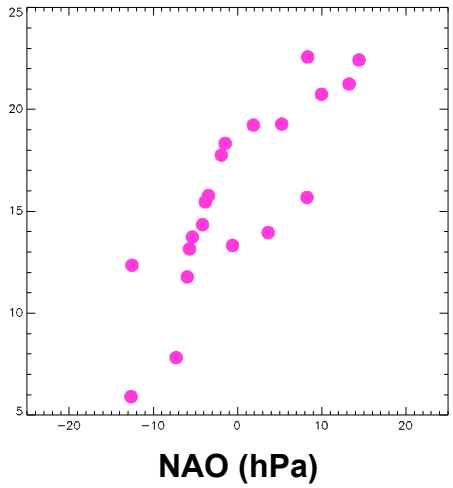
r(U50,NAO) = 0.0

Observations



r(U50,NAO) = 0.5

HadGAM

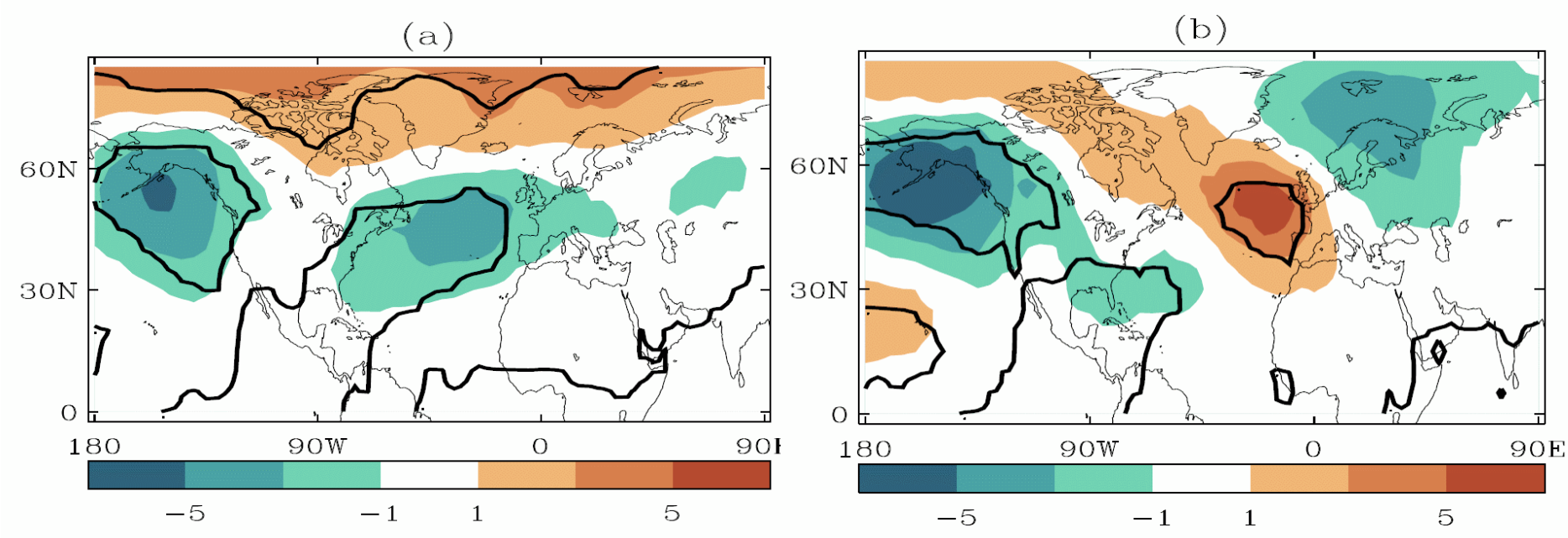


r(U50,NAO) = 0.8

	NAO (hPa)	U50 (m/s)	Ratio
HadAM3	10.3	0.5	**21.0**
HadGAM	7.8	3.2	**2.4**
OBS	11.9	5.6	**2.1**

Impact of El Niño on North Atlantic climate

January-February PMSL anomaly



Moderate

Strong

Toniazzo and Scaife, 2006