Recent anomalously cold Central Eurasian winters forced by Arctic sea ice retreat in an atmospheric model

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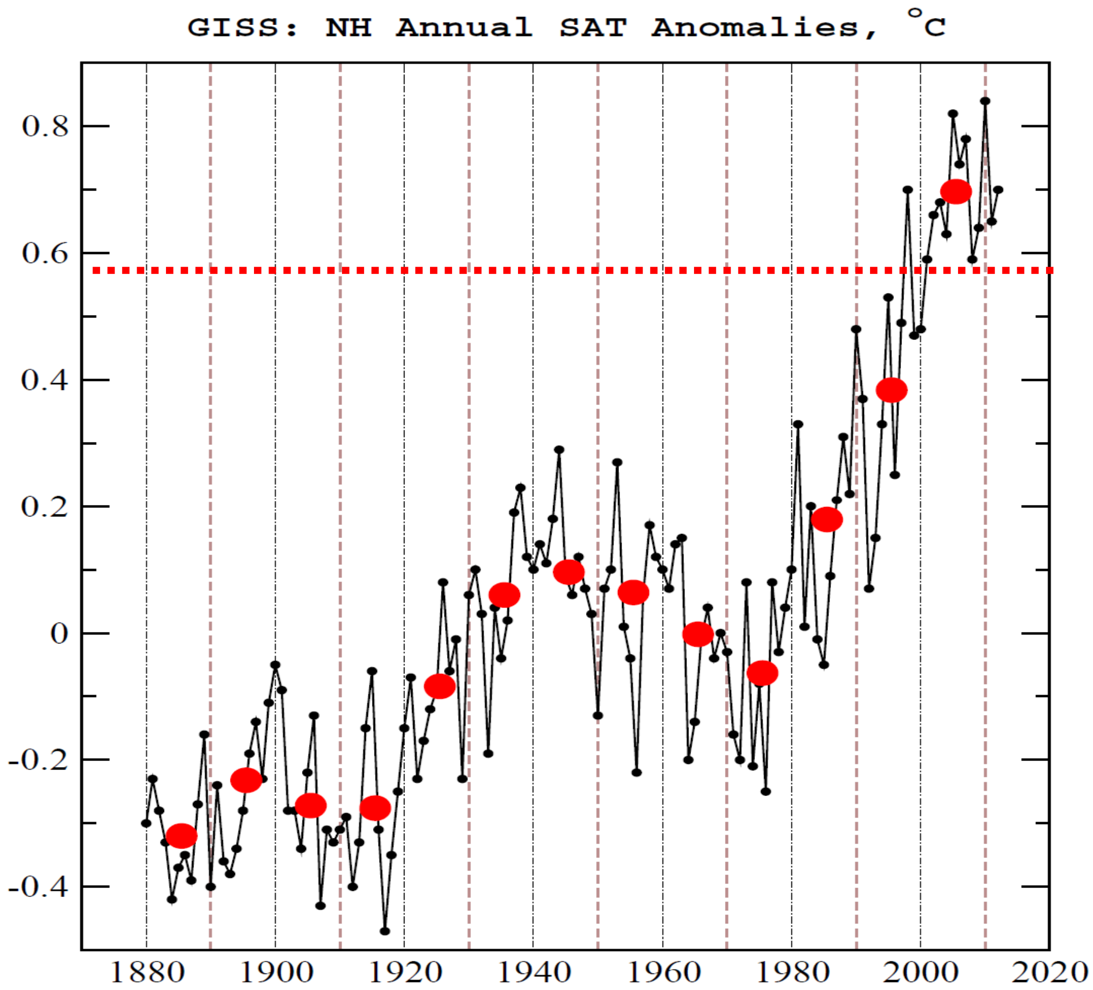
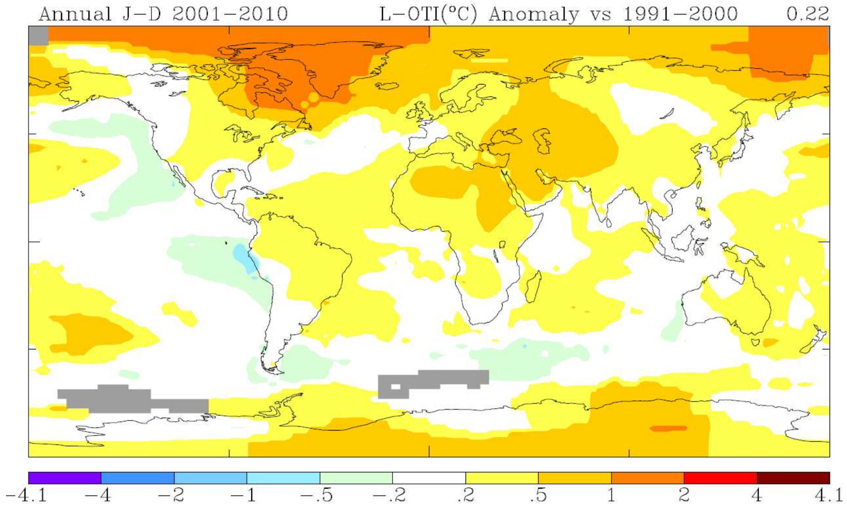
Northern Hemisphere surface air temperature (SAT) changes (GISS)

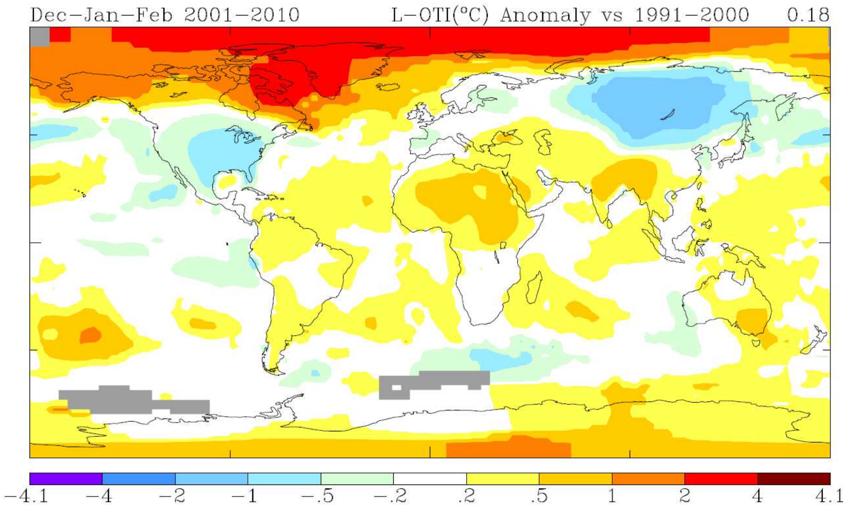


The first decade of the 21st century is the warmest during the last 150 years

Decadal SAT anomalies (GISS) 2001-2010 vs 1991-2000

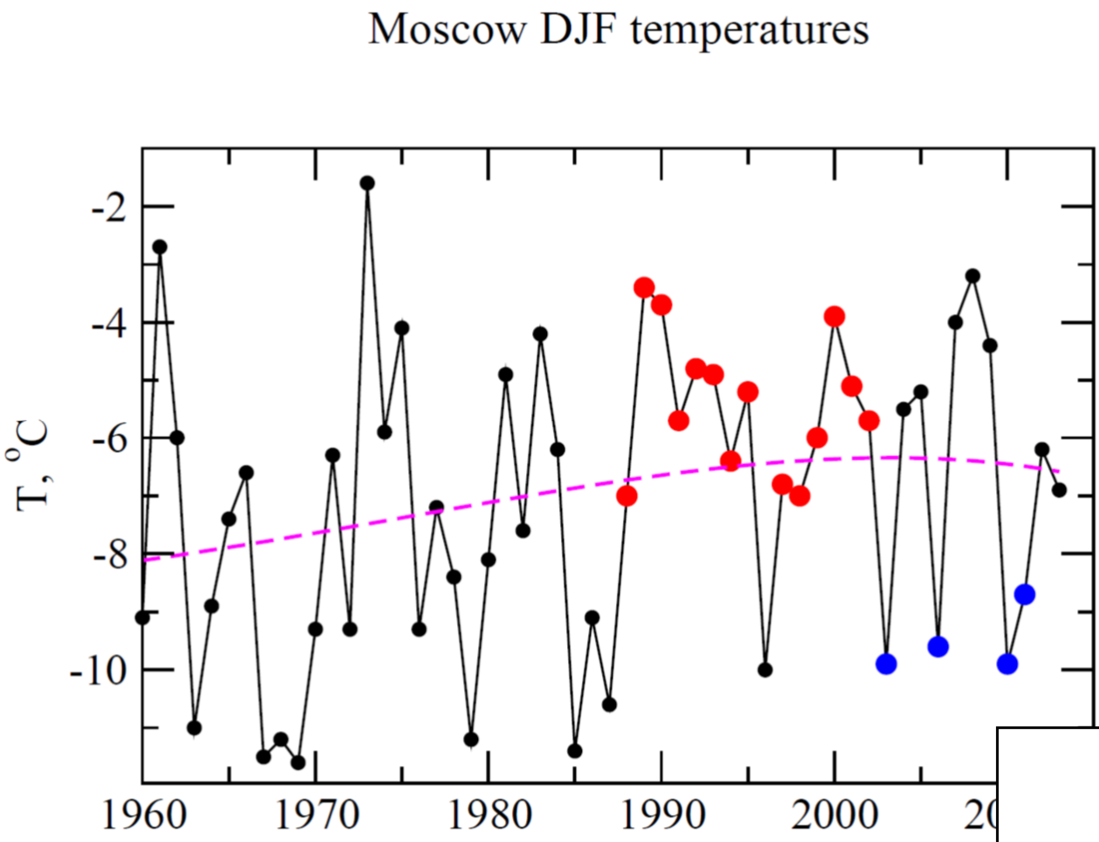


ANNUAL



DJF

Recent anomalously cold winters phenomenon

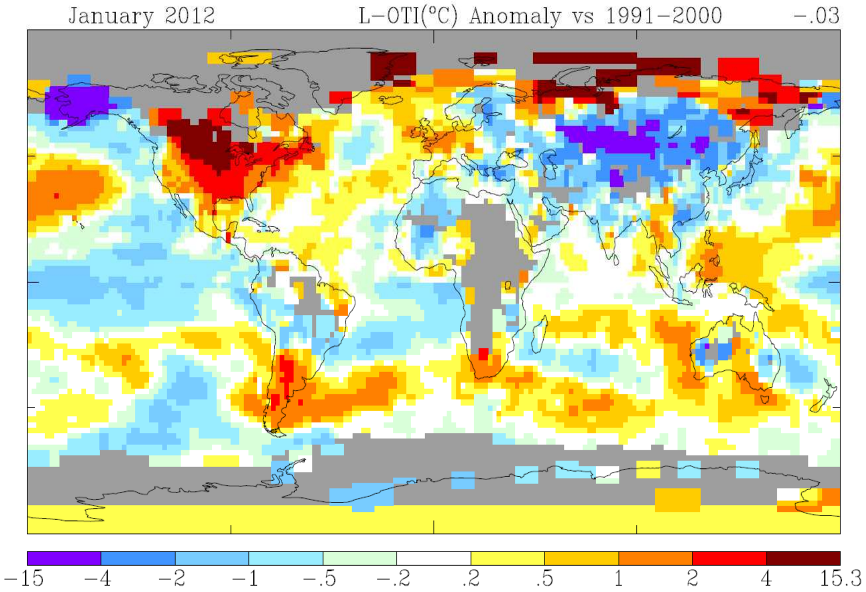


period	Hamburg "cold yrs" < 0 °C		Moscow "cold yrs" < -8 °C	
	N	Prob.	N	Prob.
1950-1987	11	0.29	18	0.47
1988-2002	1	0.07	1	0.07
2003-2013	3	0.21	4	0.36

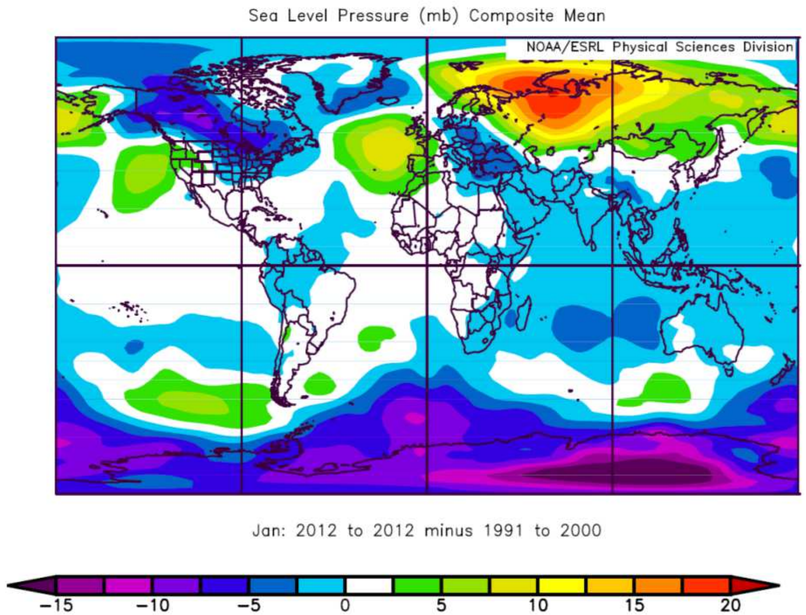
Recent anomalously cold winters phenomenon

January 2012

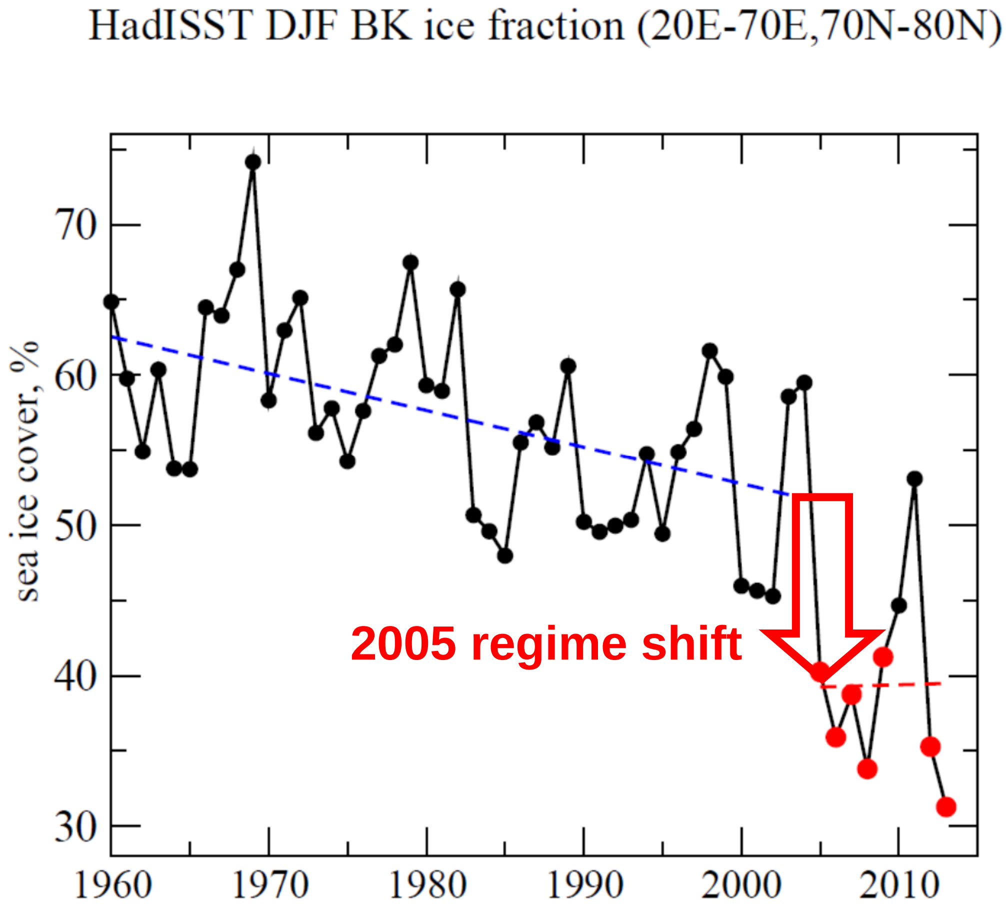
SAT anomaly, K



SLP anomaly, hPa



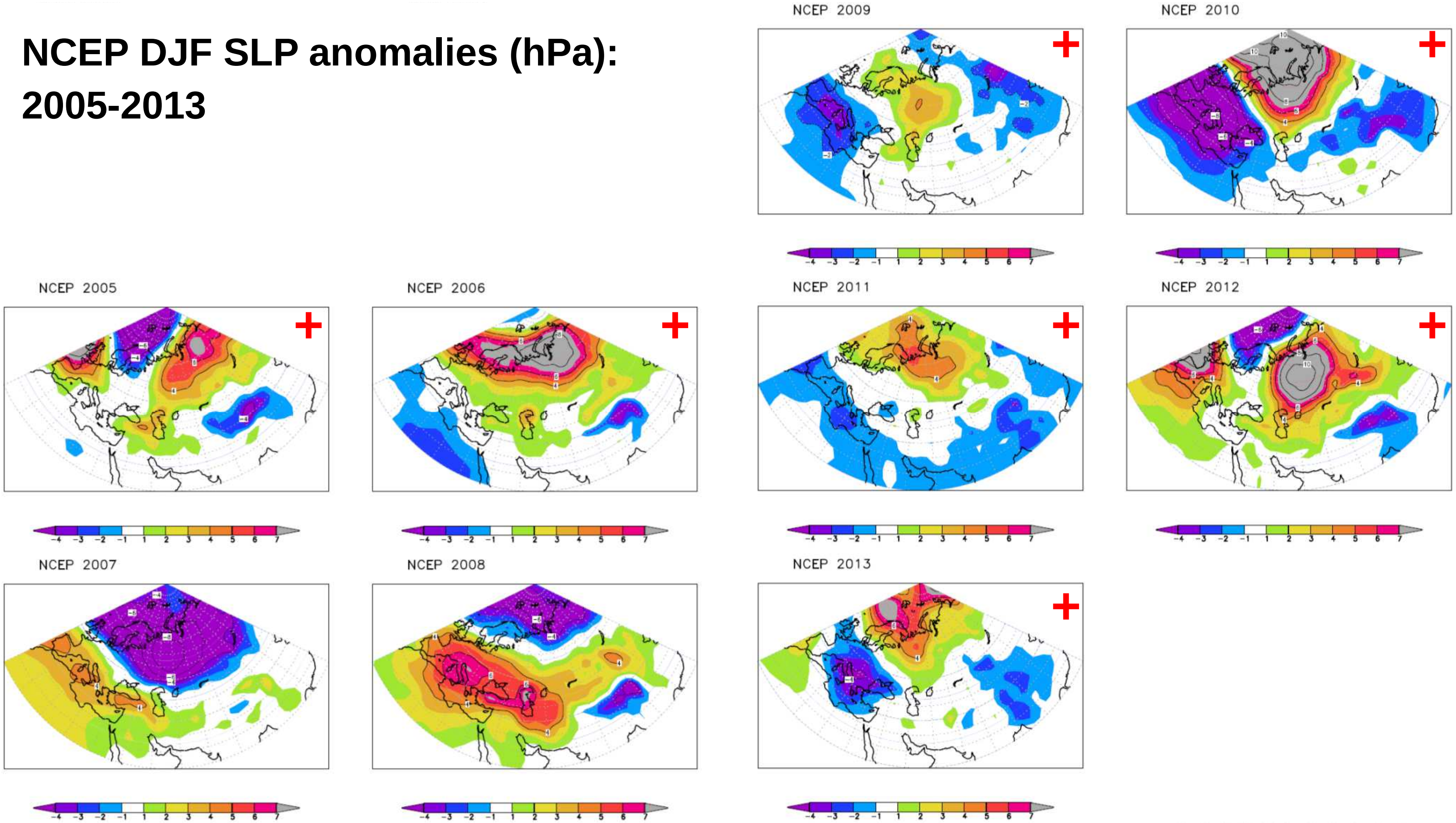
Recent anomalously cold winters phenomenon: Barents Sea ice



Has the Barents Sea ice cover played a special role?

Recent anomalously cold winters phenomenon: “Barents” anti-cyclone

NCEP DJF SLP anomalies (hPa): 2005-2013



Non-linear circulation response to gradual sea ice reduction

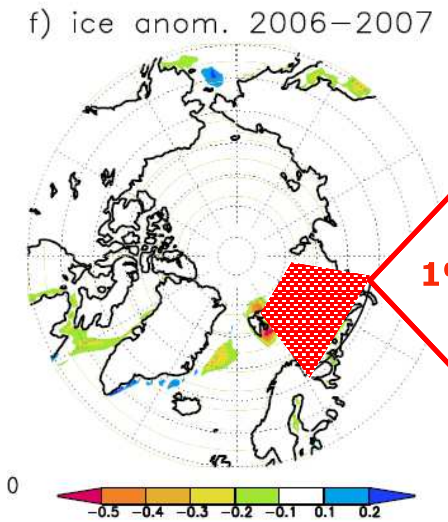
Petoukhov and Semenov 2010

ECHAM5 AGCM

6 x 100 yr simulations

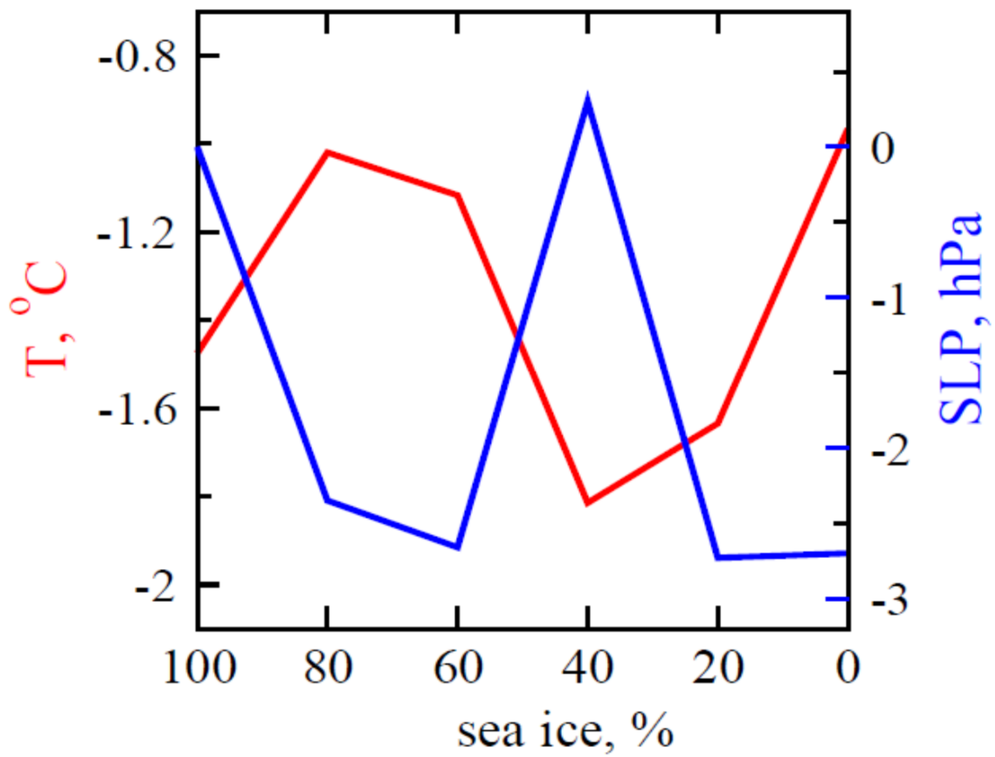
Same boundary forcing (SST/SIC) except for Barents and Kara Seas (see the sector), where the SIC In wintertime (Nov-Apr) set to

1%,20%,40%,60%,80%,100%



1% of the NH

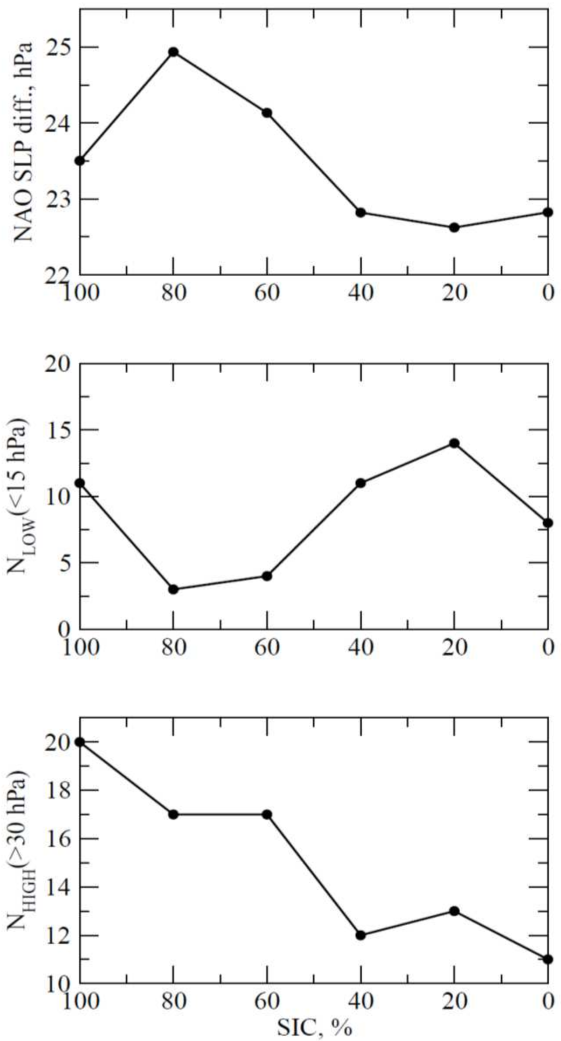
ECHAM5 results: winter SAT in Eastern Europe and SLP over the Barents Sea as a function of Barents SIC



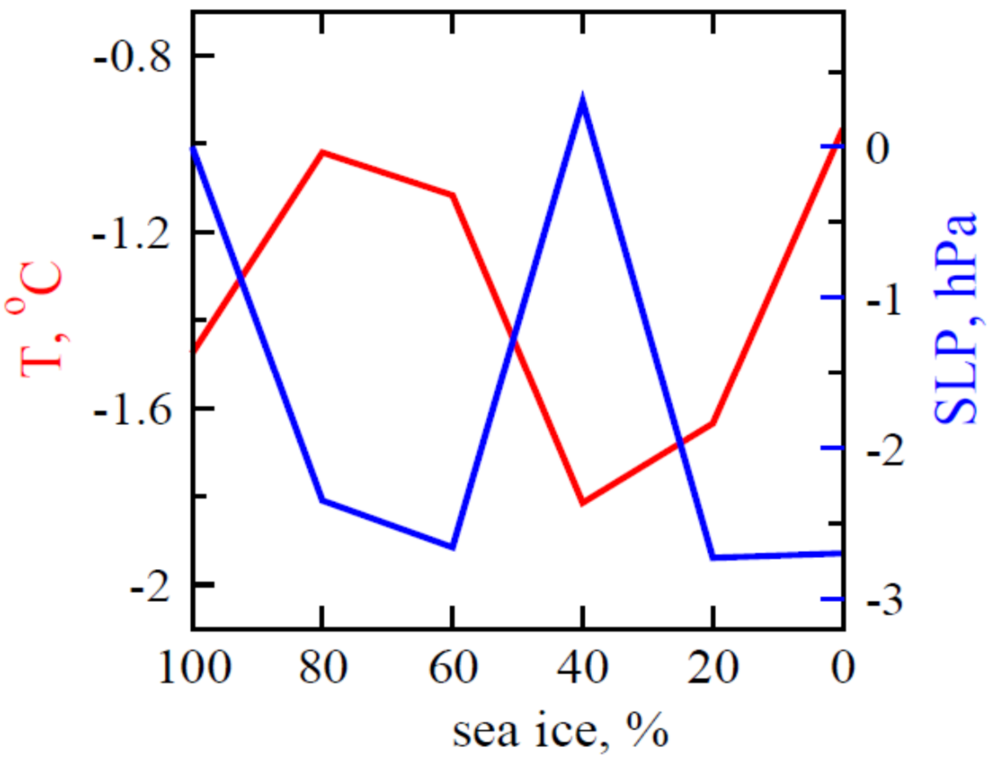
Non-linear circulation response to gradual sea ice reduction

Petoukhov and Semenov 2010

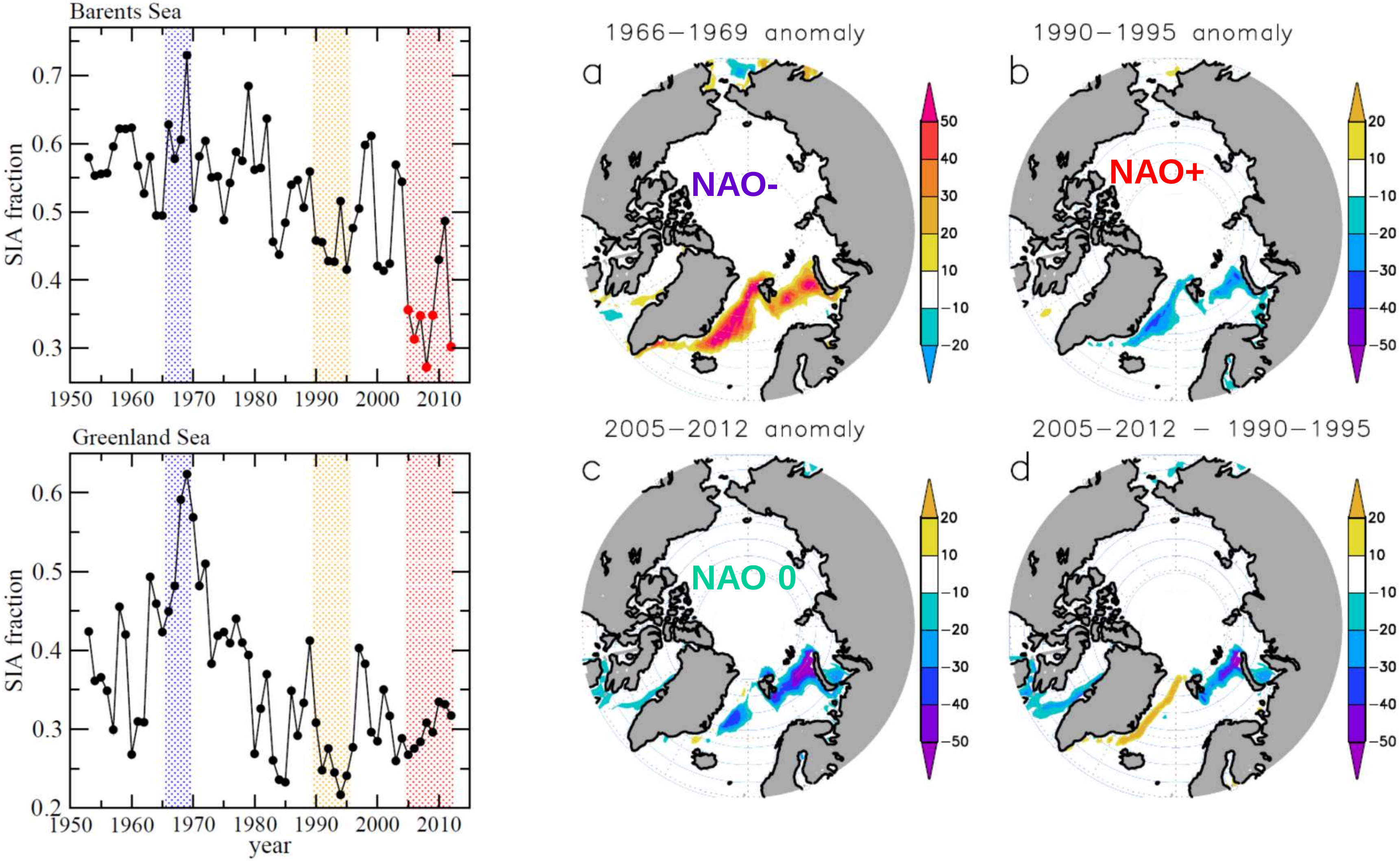
NAO extremes



ECHAM5 results: winter SAT in Eastern Europe and SLP over the Barents Sea as a function of Barents SIC



Arctic DJF sea ice anomalies



Simulation setup

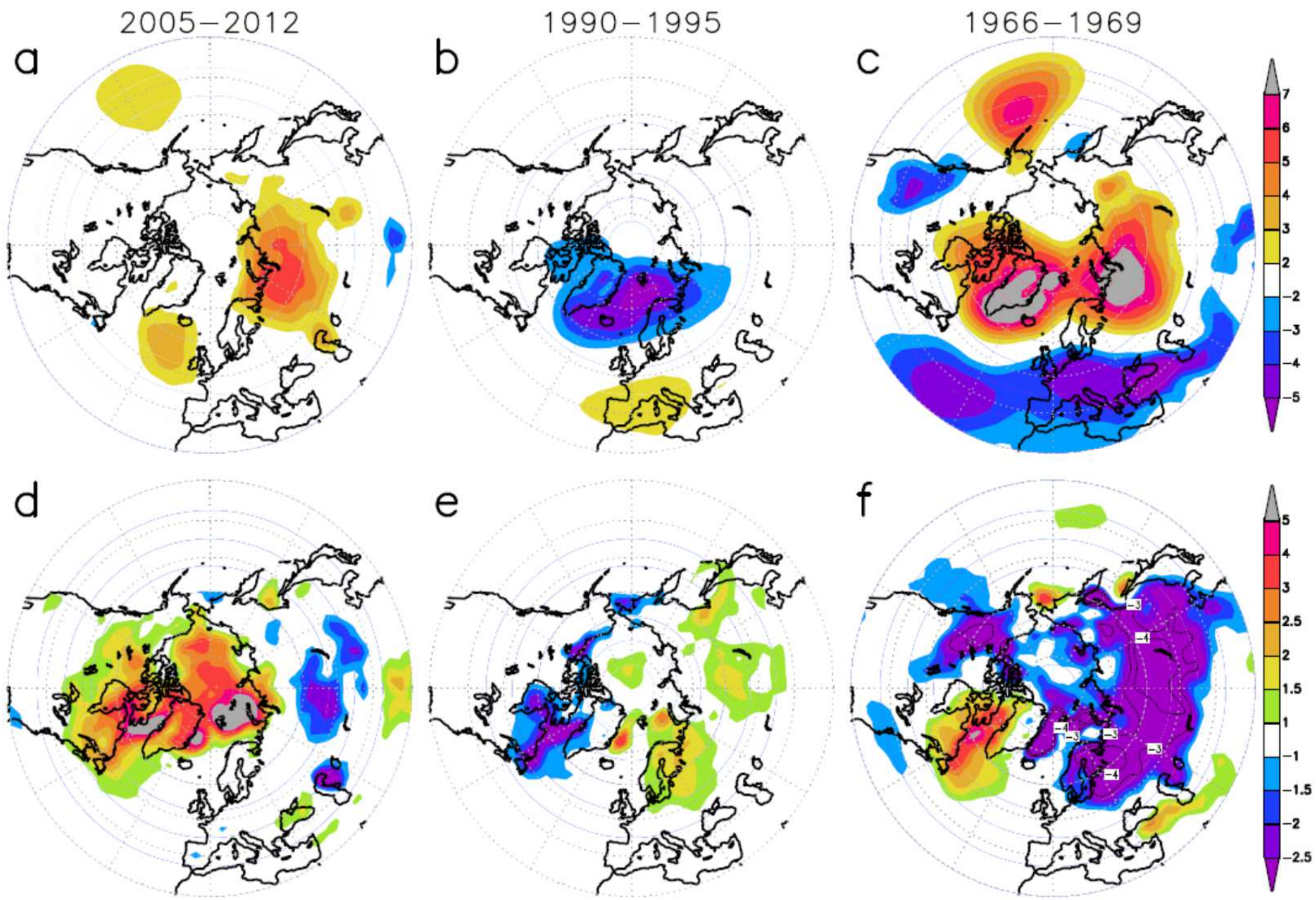
ECHAM5/T106/L31 model
50 year runs
SST fixed to 1971-2000

Sea ice from:
1966-1969: Negative NAO – high ICE (late 1960s) B&G
1990-1995: Positive NAO – low ICE (mid 1990s) B&G
2005-2012: Neutral NAO – very low ICE (2000s) B only
1971-2000: climatological run
2005-2012 sea ice from December through April

+same runs but at T31 resolution

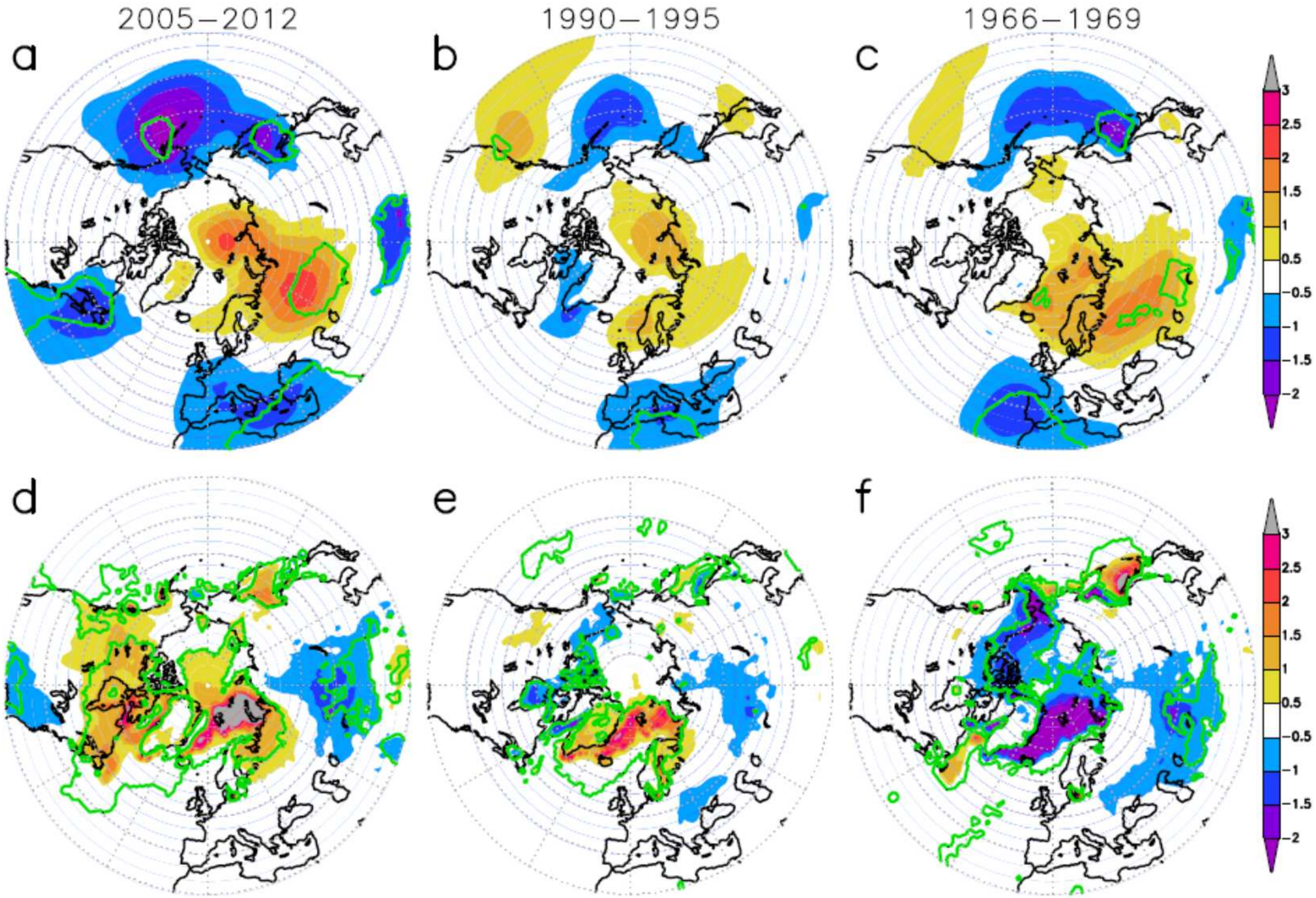
All results are anomalies relative to 1971-2000

Observed (NCEP) DJF SLP and SAT patterns (rel. 1971-2000)



very low ice NAO"0" **low ice NAO"+"** **high ice NAO"-"**

Simulated (ECHAM5/T106) DJF SLP and SAT patterns

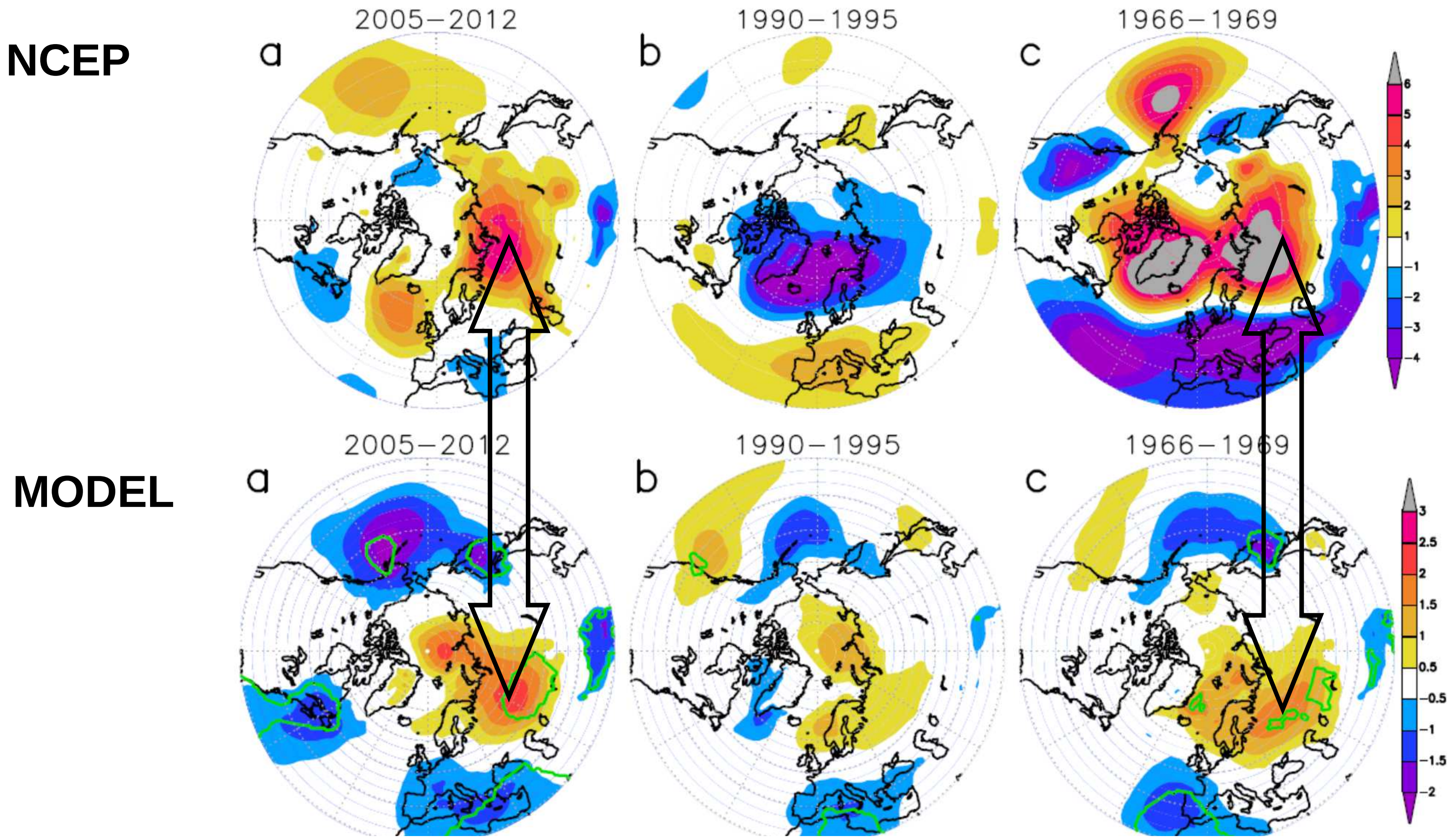


very low ice / **NAO negative FB**

low ice / **NAO negative FB**

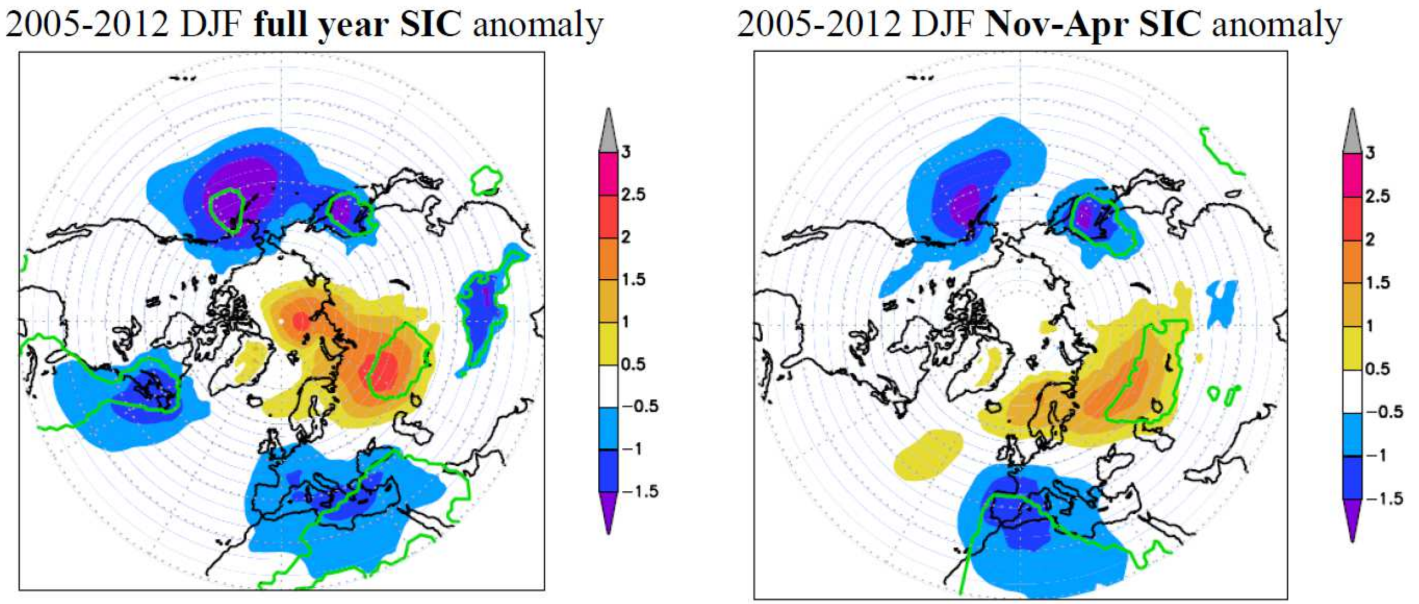
high ice / **NAO positive FB**

Simulated (ECHAM5/T106) DJF SLP and SAT patterns



The recent Barents anti-cyclone may be caused by strong sea ice decline.
The response to realistic SIC reduction is non-linear.

Indications for response mechanism (sensitivity to SIC anomalies in autumn)



Simulated DJF SLP response (in hPa) in the experiment with 2005-2012 SIC anomaly prescribed for all months (left) and for November through April only (other months have the same SIC as the reference climate 1971-2000 simulation).

The response is forced by contemporary sea ice anomalies

Indications for response mechanism

Which questions need to be addressed in order to understand the response?

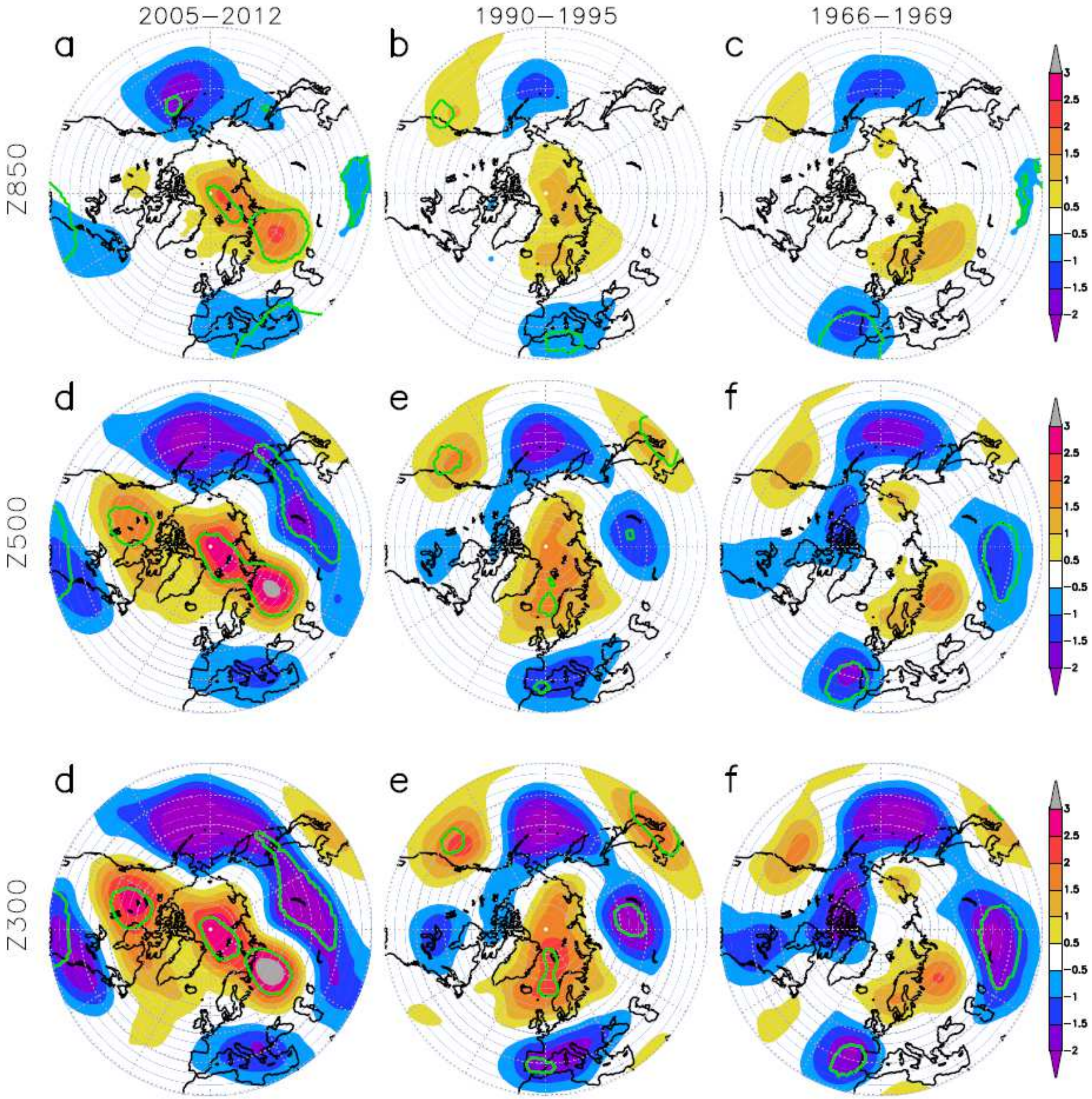
Is the DJF response preconditioned by preceding autumn SIC anomalies?

Is the response delayed or “simultaneous”? (atm. state, Rossby waves, troposphere-stratosphere interaction)

What is the structure of the response: local baroclinic versus large-scale barotropic response?

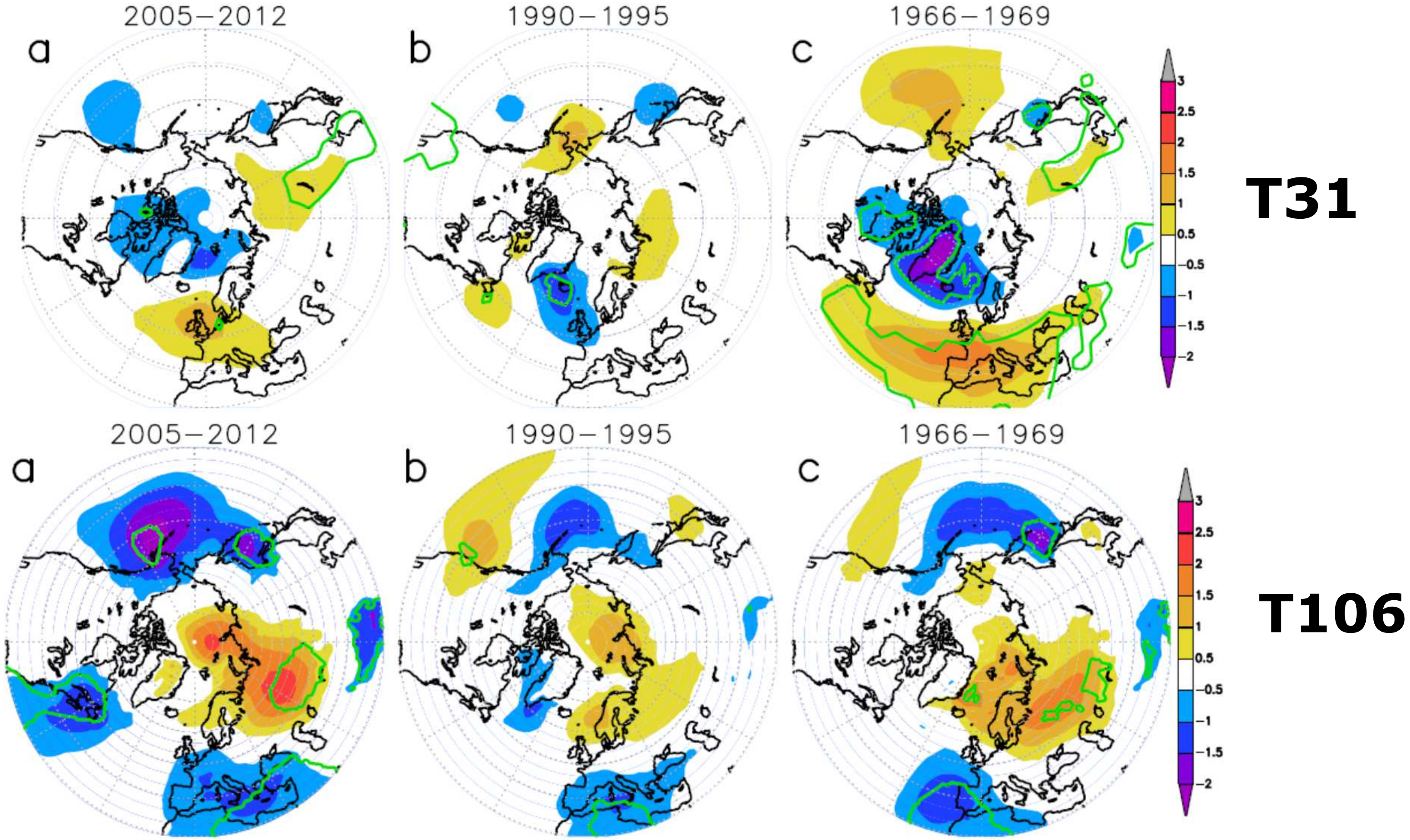
What is a role of eddies, local gradieints, convection (resolution issue)?

Indications for the response mechanism (GPH anom. in troposphere)



The response is barotropic

Indications for response mechanism (DJF SLP low res. T31 experiments)

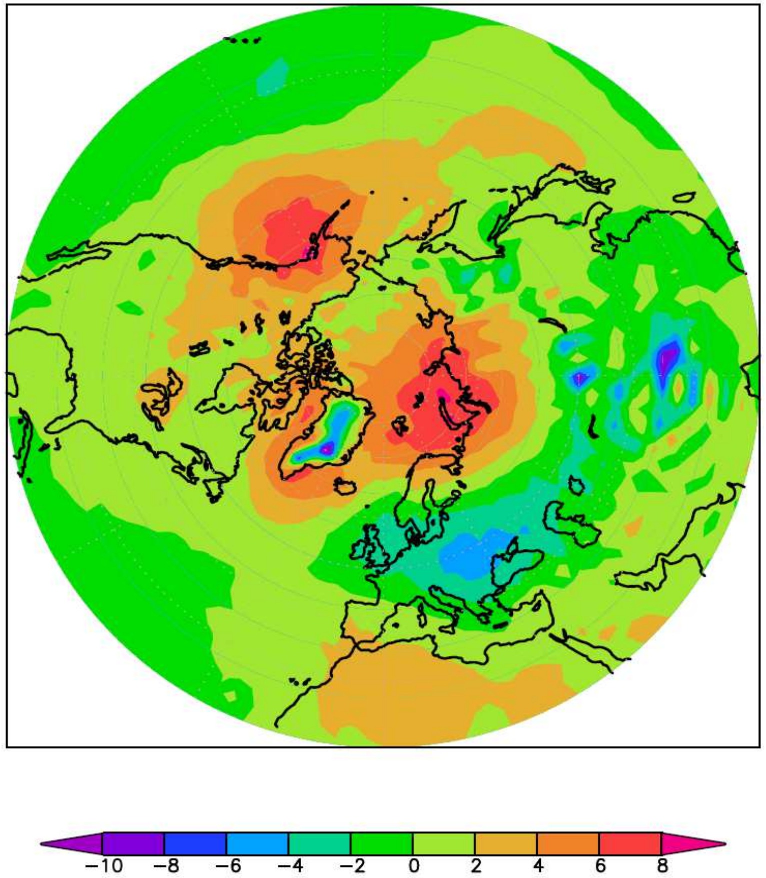


Recent response is not captured. Other responses are reversed! Eddies? Waves? Local low level gradients?

The last but not the least: Biases

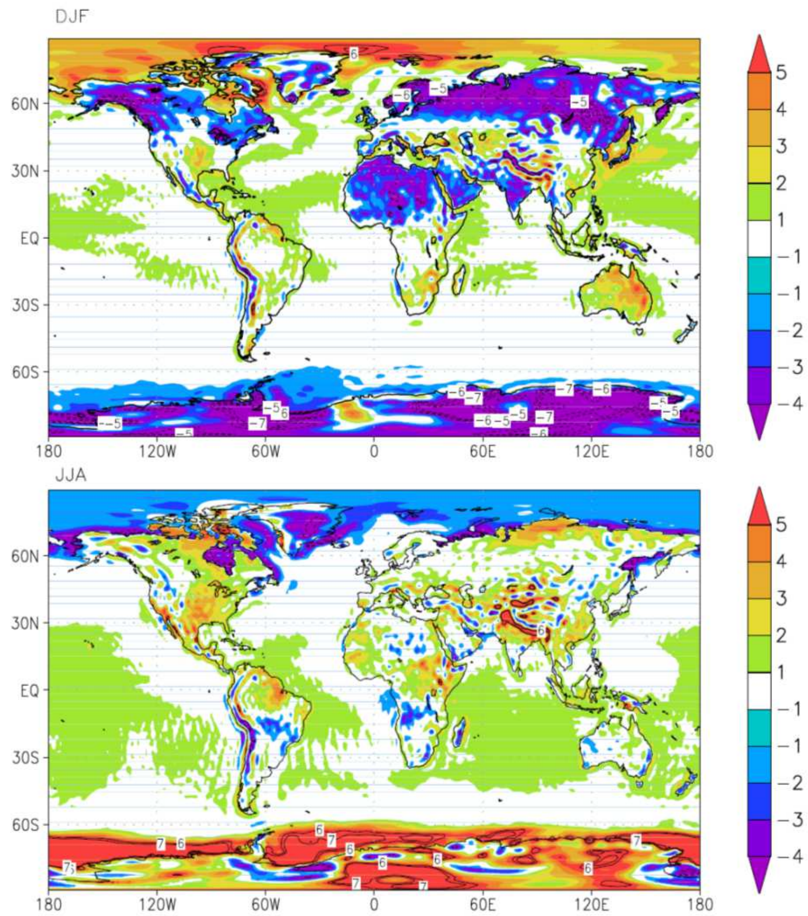
DJF SLP

ECHAM5–NCEP DJF SLP bias, hPa



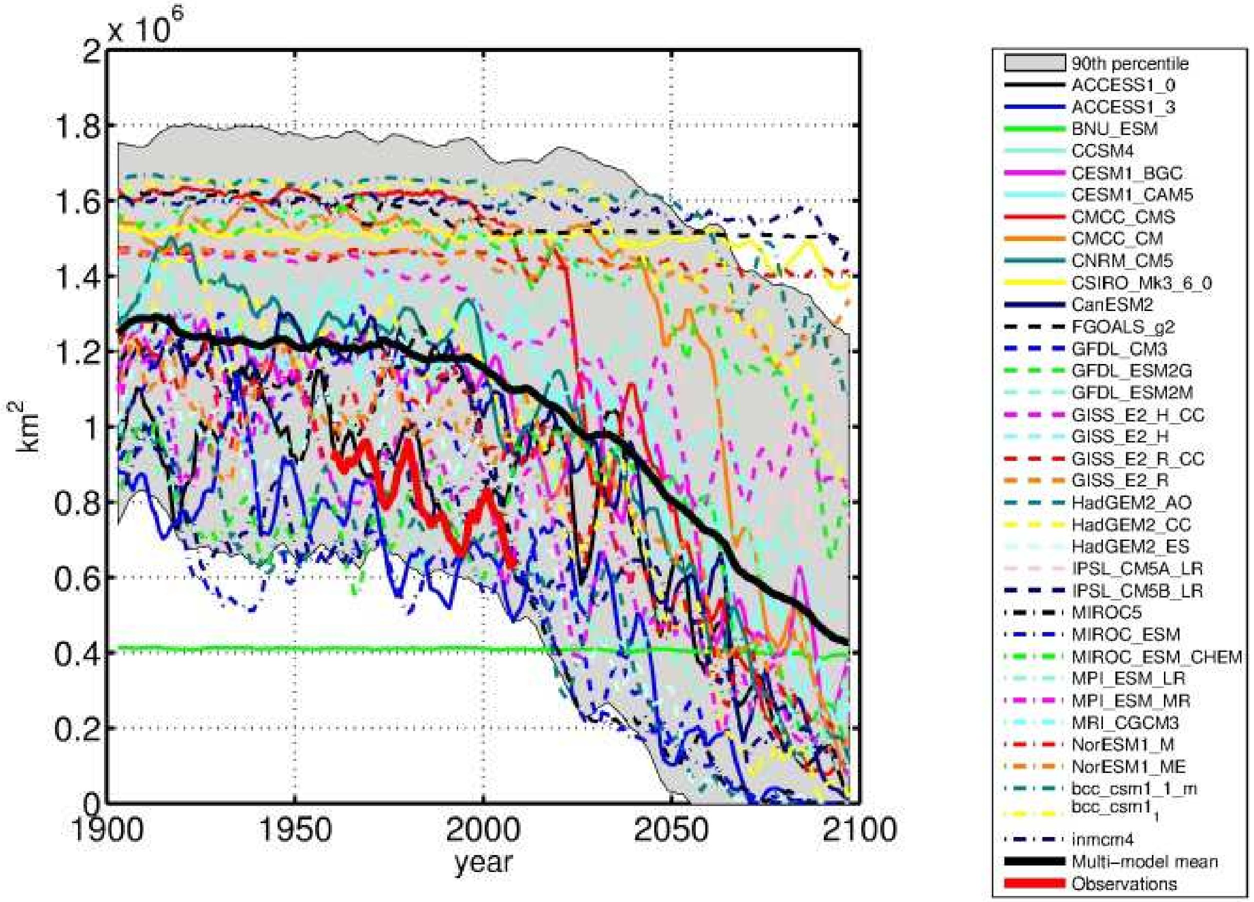
SAT

ECHAM5–T106 – NCEP SAT bias, K (1971–2000)



The last but not the least: Uncertainties

CMIP5: Barents Sea sea ice area in March



Conclusions

Recent anomalous cold winters over Eurasia are linked to anti-cyclonic circulation anomaly over and south to the Barents Sea

Numerical simulations with AGCM at relatively high resolution (~1°) reproduce the observed cooling and formation of the anti-cyclonic anomaly south to the Barents Sea when forced by prescribed sea ice concentrations

The simulated response to the observed SIC during the last 4 decades is essentially non-linear

The response to SIC consists of large-scale (NAO) and local (Barents Sea) responses

Results for the recent DJF SIC anomalies seem not to depend on preceding (autumn) SIC anomalies

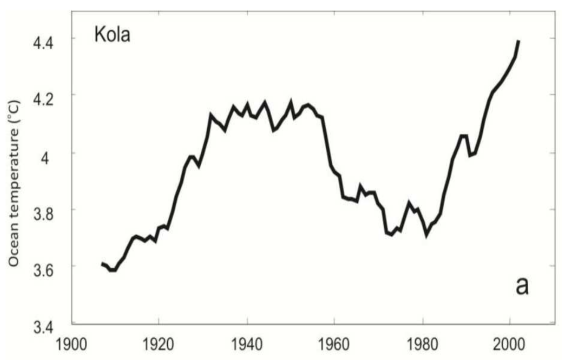
The model results are very different (even with opposite sign) in low resolution simulations

Thank you for your attention!

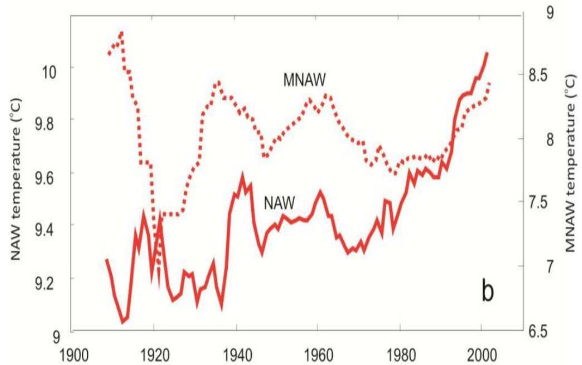
Multi-decadal climate changes in the Arctic

Smedsrud et al., 2013, Rev. Geophys.

Kola section annual 0-200m T (PINRO)



NAW temperature (Yndestad et al. 2008)



NAO and Novaya Zemlya annual SAT

Barents T (100m-150m) *(Levitus et al. 2009)*

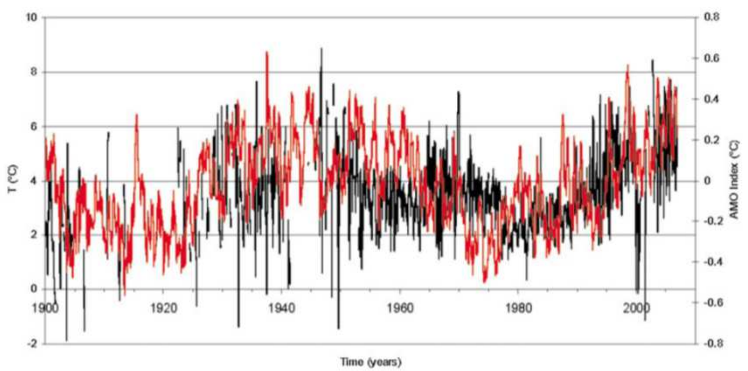
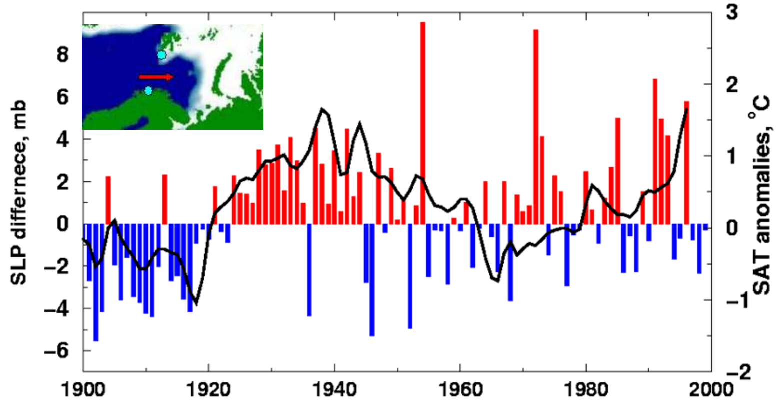


Figure 2. Monthly temperature (°C) in the Barents Sea for the 100–150 m layer, from 1900 to 2006. Years without all 12 months of data are not plotted. The red line is the Atlantic Multidecadal Oscillation Index.

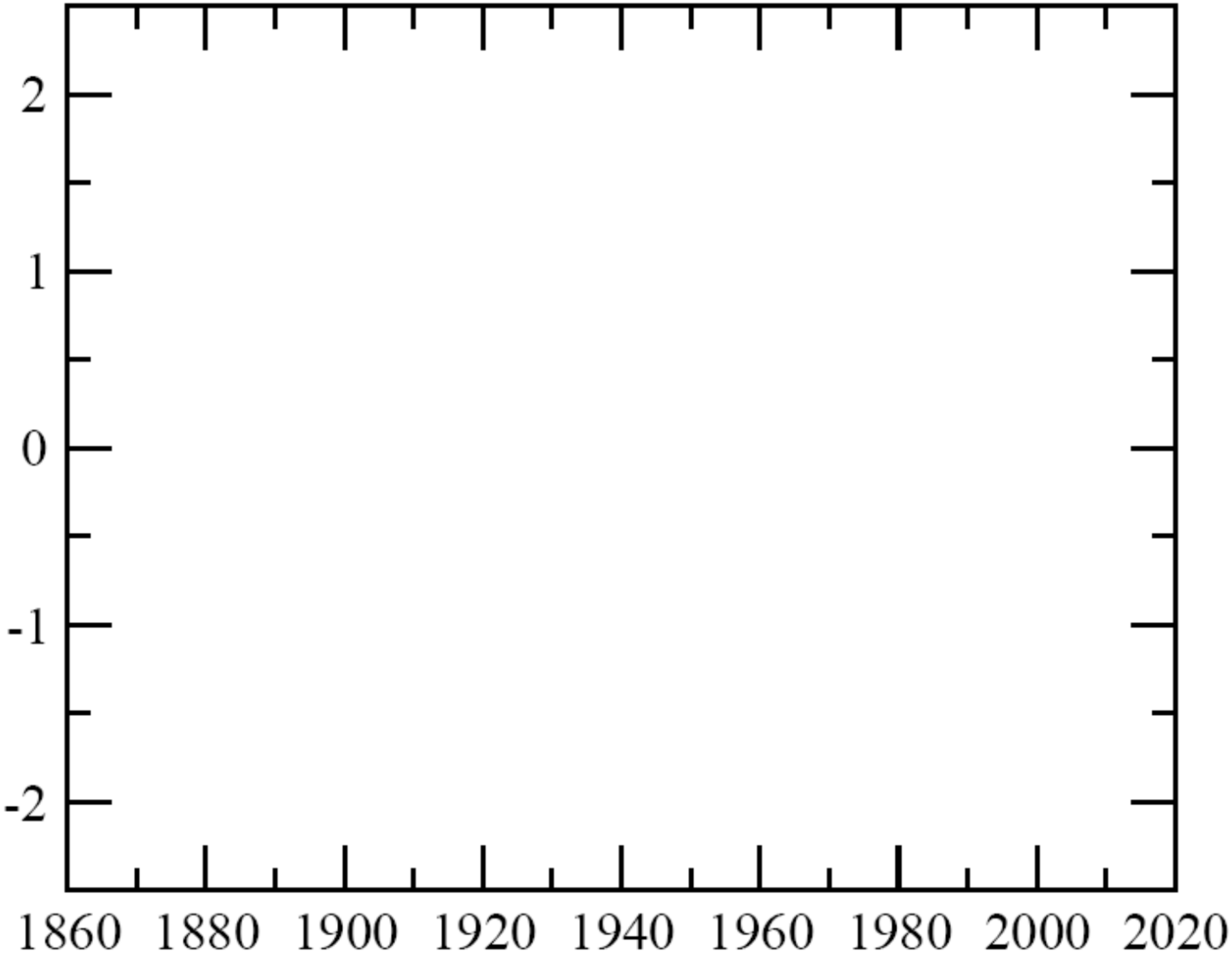
DJF SLP gradient *(Bengtsson et al. 2004)*



Multi-decadal climate changes in the Arctic

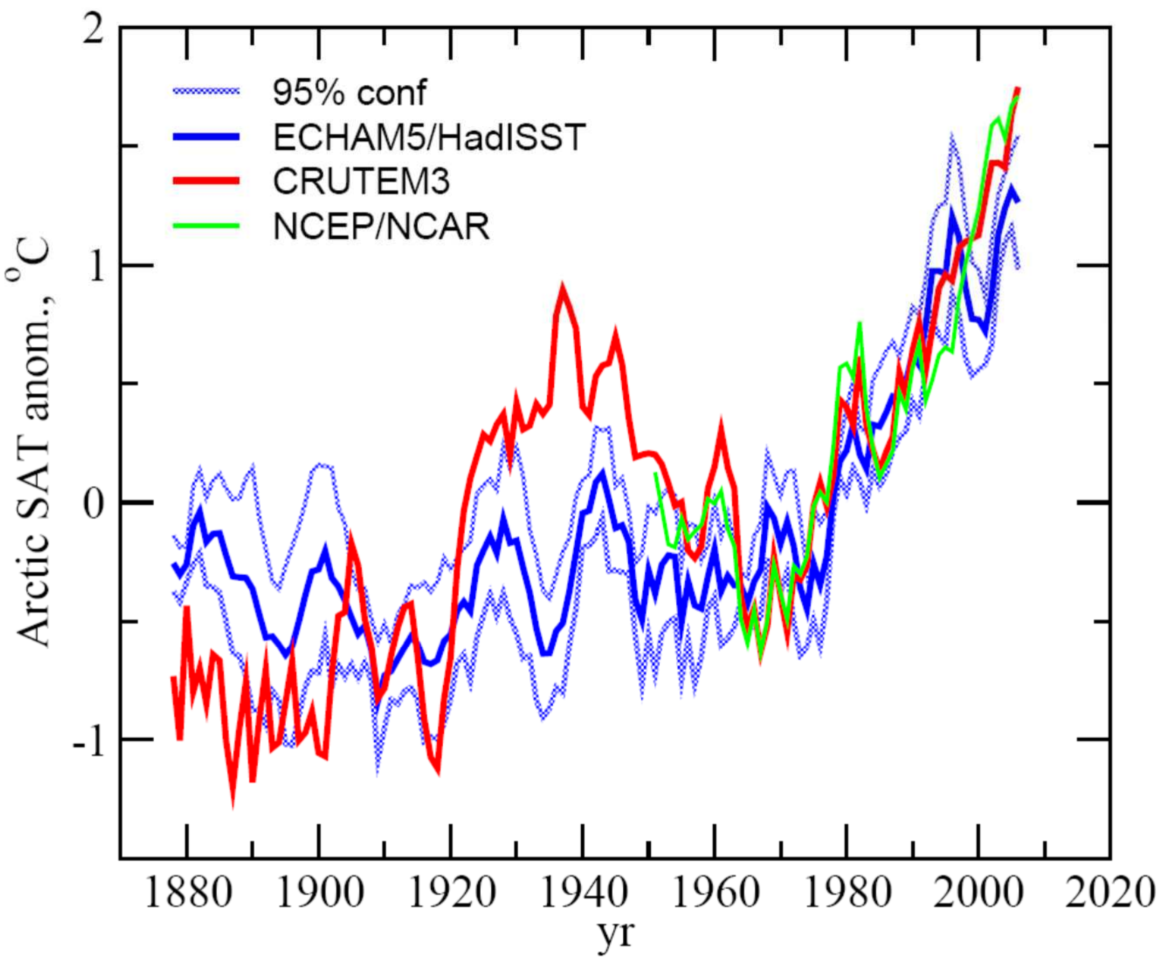
The Early 20th Century Warming in the Arctic is a key for understanding present and predicting future climate changes

Arctic temperature and winter sea ice

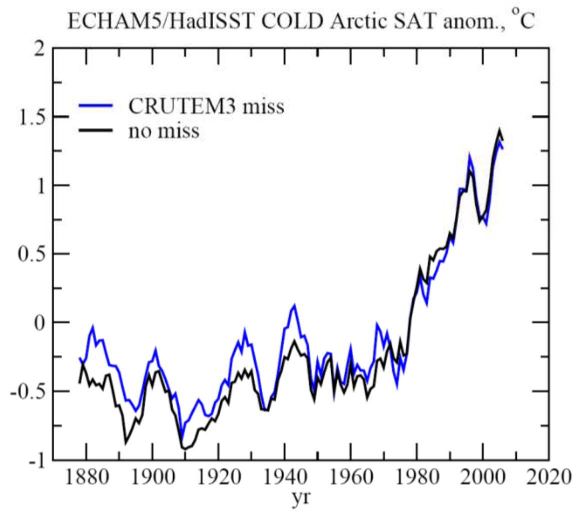


Results: wintertime Arctic SAT anomalies

ECHAM5-T31 HadISST1.1 + All forcing



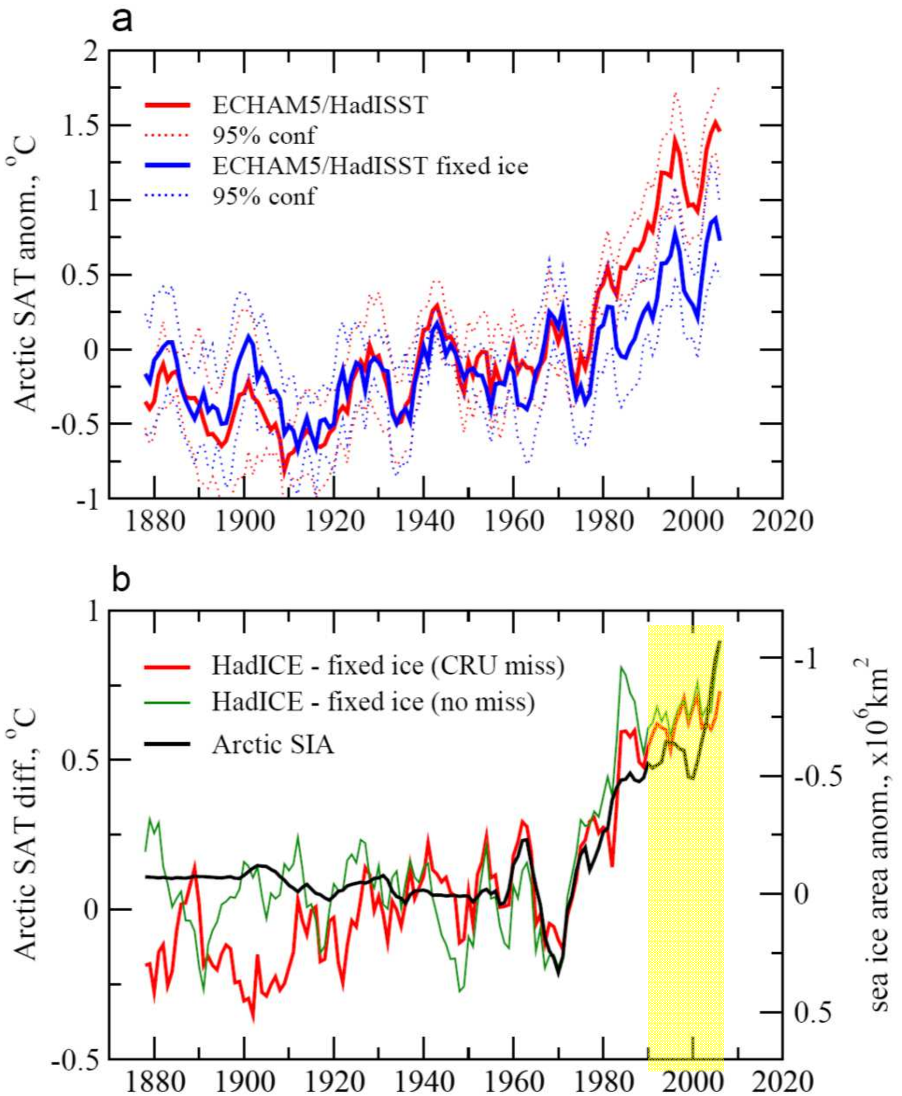
Sampling effect on winter Arctic SAT



***Semenov and Latif*, 2012**

Cryosphere

Results: wintertime Arctic SAT sensitivity to sea ice

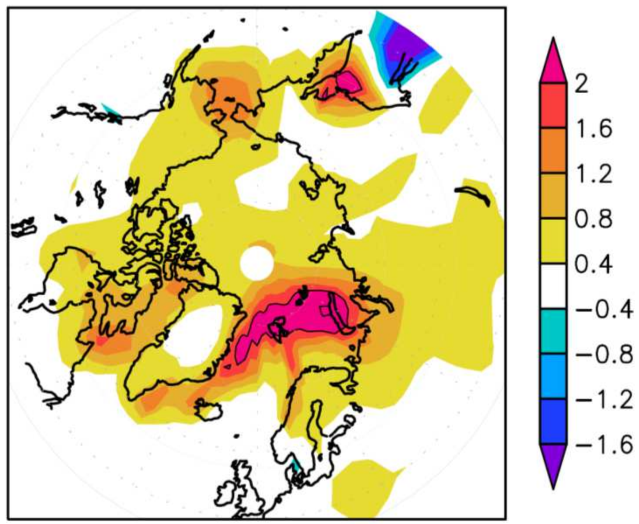


Differences between
HadISST (red) and HadISST_**fixed ice** exp. (blue)

Sea ice is responsible for ~40% of the SAT trend since 1970s with sensitivity of -0.8 °C/Mkm²

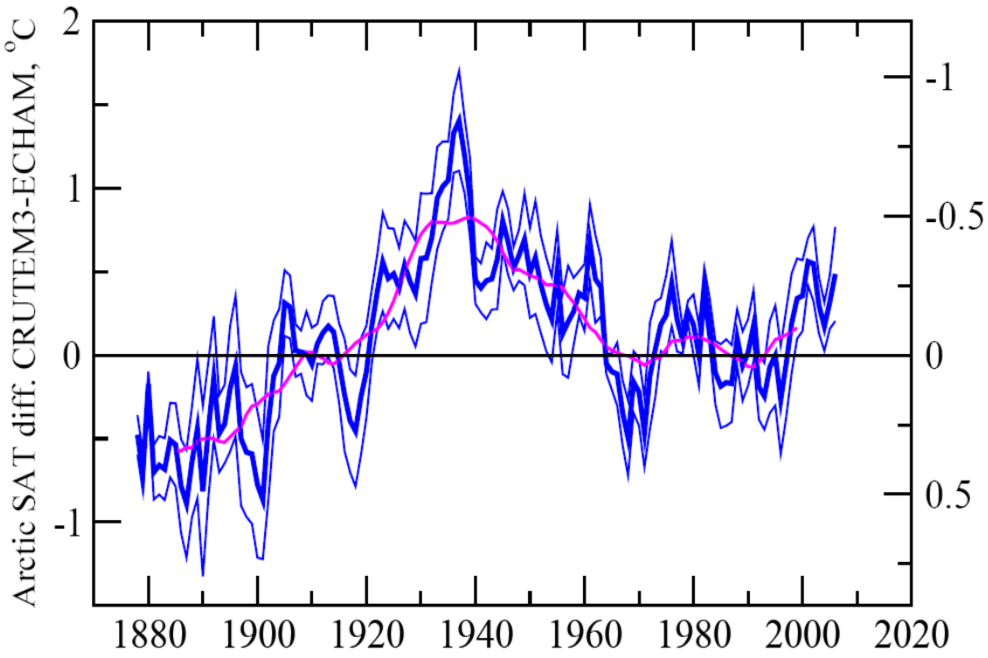
This suggests about **-0.7 Mkm²** sea ice anomaly for the ETCW from 1920-1940

1989-2008 COLD SAT difference

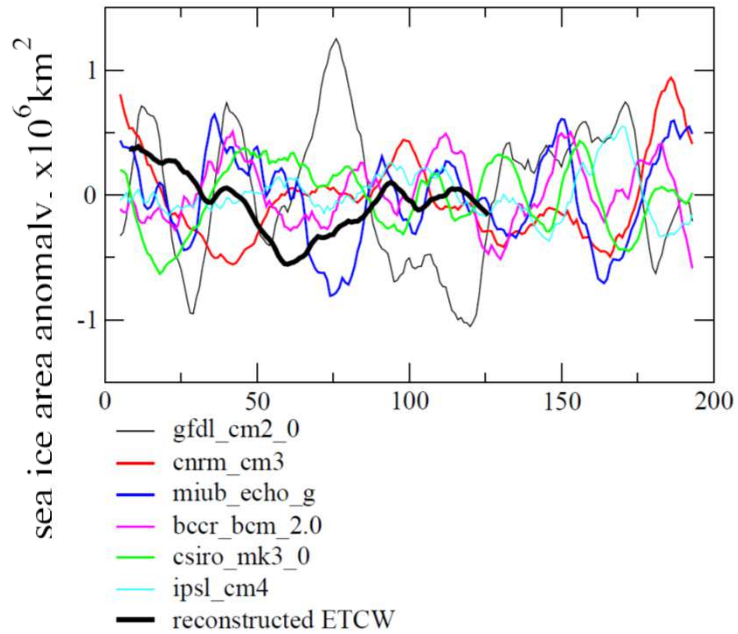


Arctic SAT/Ice sensitivity

Differences between CRUTEM3 and HadISST Arctic COLD SAT



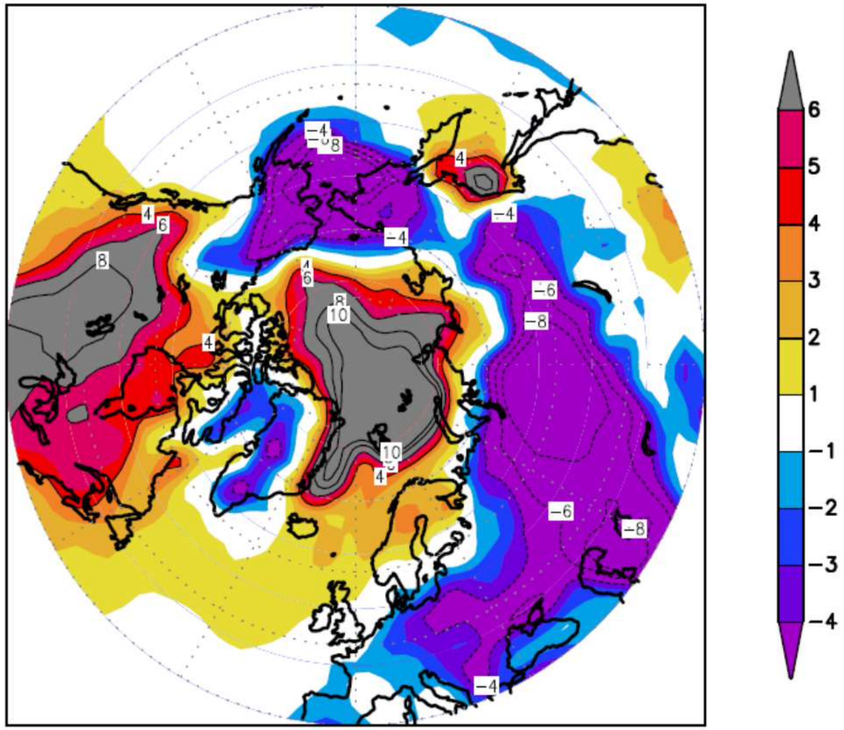
CMIP3 control simulations: winter ice area



Ensemble-mean difference (°C) between Arctic cold season land SAT from the ECHAM5 (HadISST) ensemble (thick blue line) and the observations (CRUTEM3). The thin blue lines show the 95% confidence interval. A 5-year running mean was applied. The magenta line is ensemble-mean difference smoothed with a 15-year running mean. Left axis is for SAT anomalies, right axis represents sea ice area anomalies (10^6 km^2) associated with the temperature difference as estimated from sensitivity experiments.

Hot Arctic – Cold Continents pattern

Jan 2006



- NAO **DJF SAT pattern**