The diversity in atmospheric response to Arctic sea ice reduction in EC-EARTH

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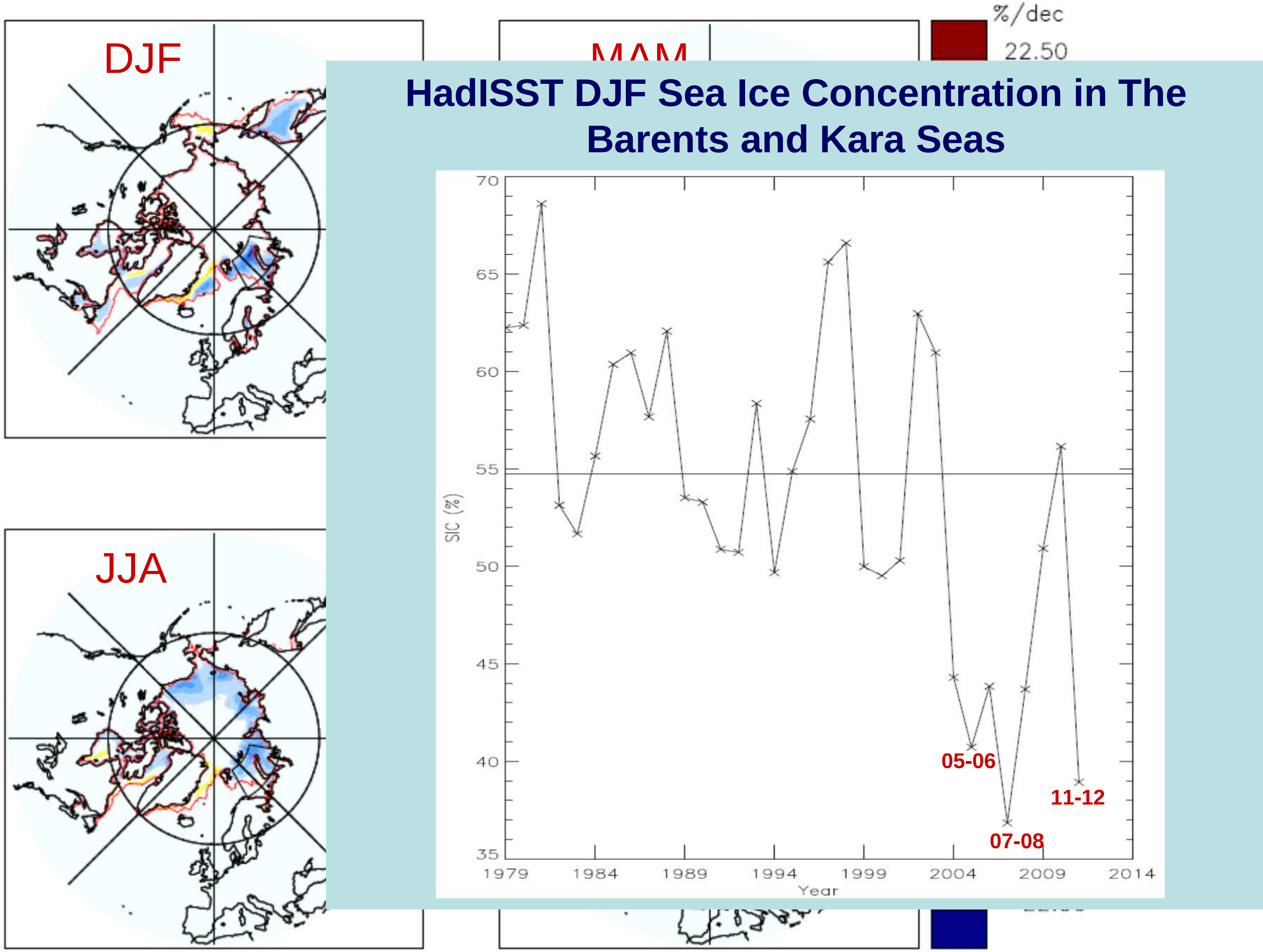
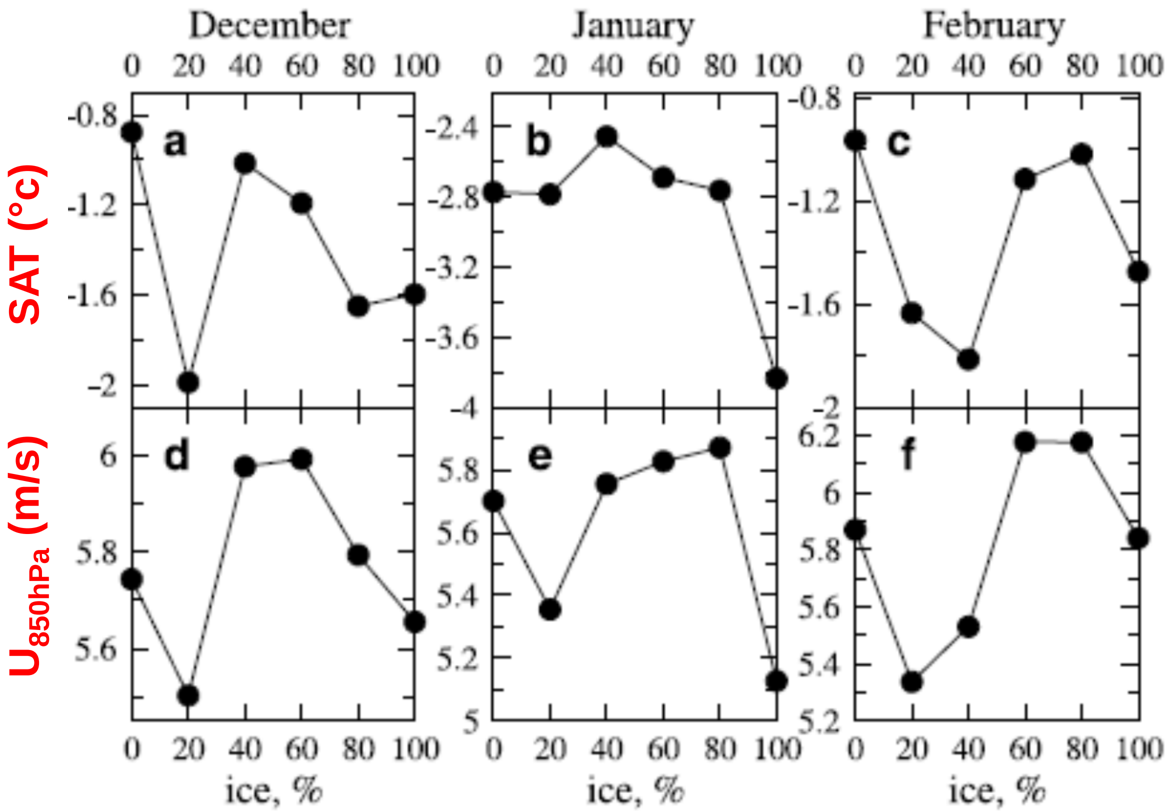
Recent Decline of Arctic Sea Ice

Trends of seasonal mean HadISST SIC since 1979

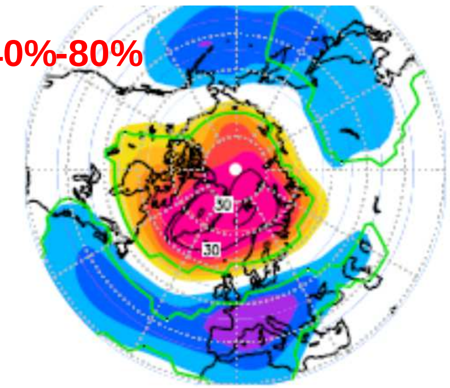


Petoukhov & Semenov (2010): The Barents-Kara sea ice reduction may results in cold winter extremes in Europe

- An idealized AGCM study using the condition of winter 2005-06
    - ECHAM5, T42 L19
- The atmospheric response to reduced sea ice concentrations
- Low level heating due to B-K SIC reduction results in strong anticyclone anomaly in the region, lead to a continental scale winter cooling



Z_{850} for SIC 40%-80%



Motivation

- Are the anomalous cold winters in Europe a robust response to the Arctic sea ice reductions?

- What factors play roles in determining the atmospheric response to Arctic sea ice reduction?

Experiments

- Idealized modelling studies
- Atmospheric module of EC-EARTH
- Forced with prescribed boundary conditions (SSTs and SICs):
  - Case with SSTs from year 2005-2006 (a ***cold*** European winter)
  - Case with SSTs from year 1989-1990 (a ***warm*** European winter year)
  - The role of North Atlantic SSTs (a ***mixed*** case)

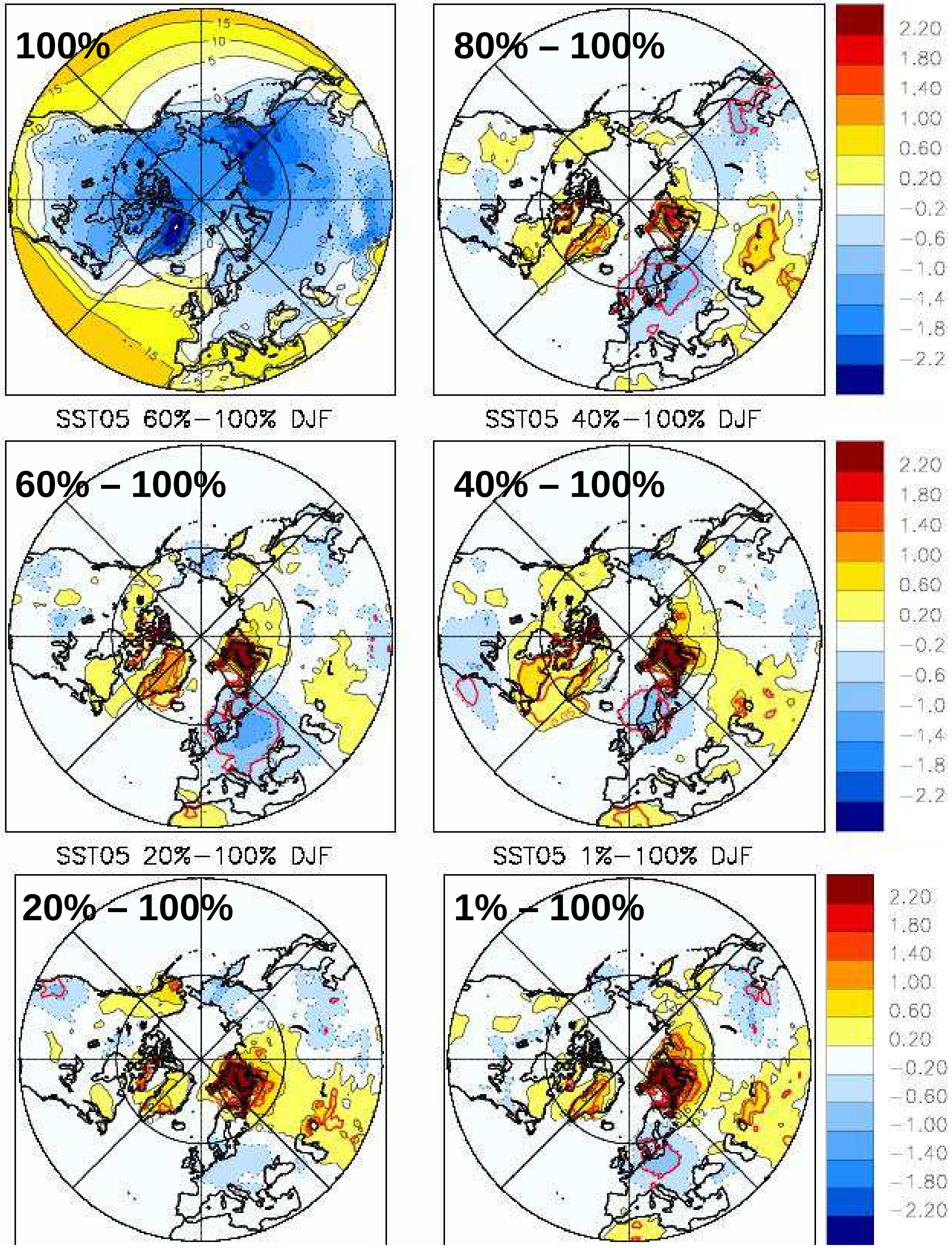
The *Cold* Case (1)

Experiment setup:

- EC-Earth atmosphere-only, T159 L31
- Follows the strategy of Petoukhov and Semenov (2010).
- **6 experiments** of 50 years A-GCM runs forced with the same prescribed SSTs but different SICs;
- The climatological run (**100%**):
  - SSTs from AMIP (observation) for year 2005 – 2006 (a cold European winter);
  - SICs from the climatological mean over period 1987-2006;
- 5 reduced SIC runs (**80%, 60%, 40%, 20% and 1%**)
  - The same SSTs as in 100%;
  - The SICs as in 100% everywhere except in the Barents and Kara (B-K) Sea sector (30°E - 80°E, 65°N - 80°N);
  - SICs in the B-K sector are set to 80%, 60%, 40%, 20% and 1% of the climatology from Nov. through April;

The ***Cold*** Case (2)

Mean T2M differences in winter (DJF) with respect to 100%



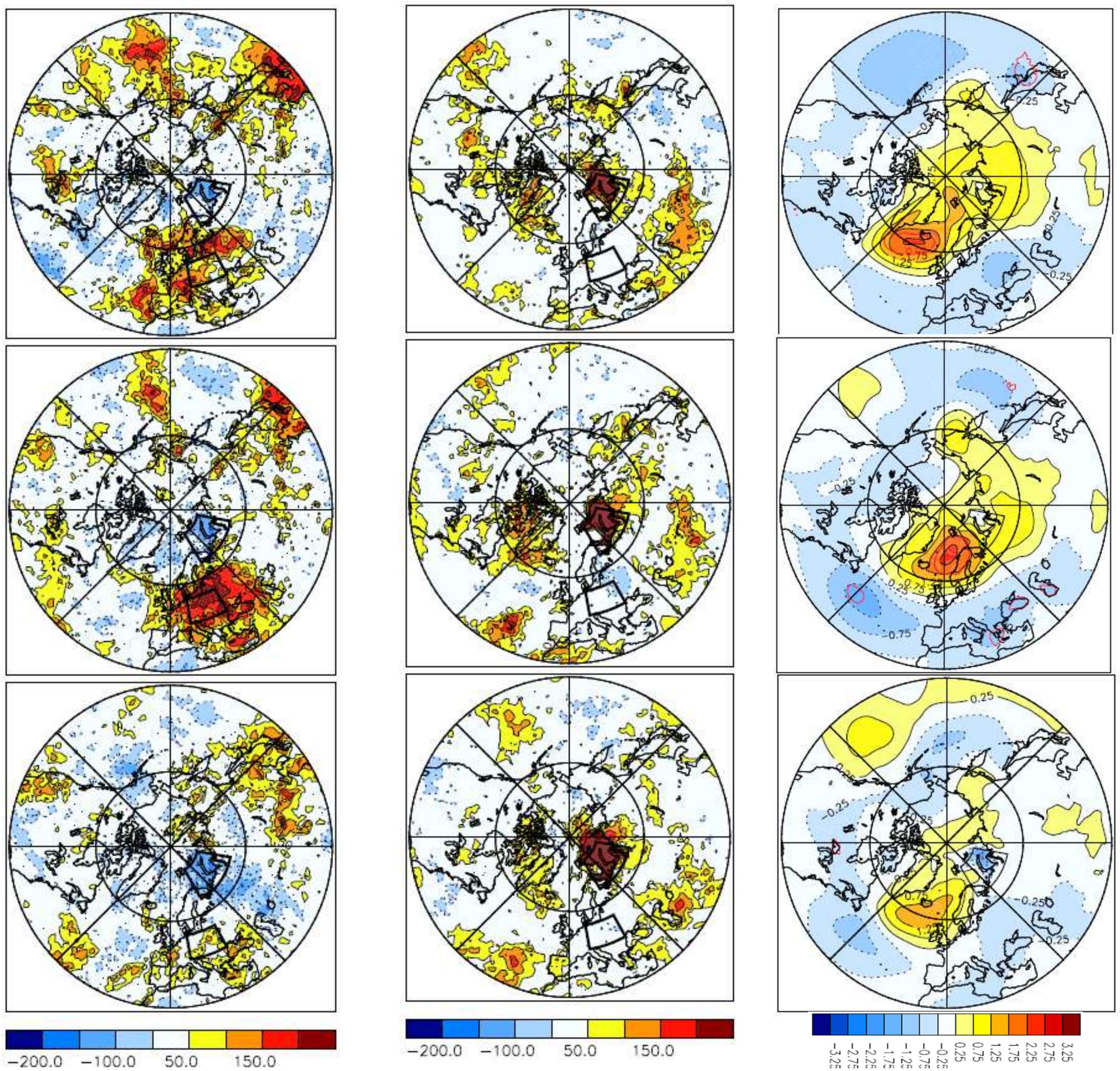
The *Cold* Case (3)

Changes in: (a) Prob(T<1.5σ) (b) Prob(T>1.5σ) (c) MSLP (hPa)

80% – 100%

60% – 100%

20% – 100%



The *Cold* Case summary

- The reduction of SIC at B-K sector can results in continental-scale winter cooling of more than 1K, with increased probability of cold winter months over Europe.

- Confirm the main results of Petoukhov and Semenov (2010) with another model at a higher resolution.

➔ Will sea ice reduction in B-K area always results in cold responses in European continent?

The *Warm* Case (1)

- **A warm winter year 1989-1990 for Europe;**
- **Experiment setup:**
  - Same as the **cold case** except the SSTs are from year 1989-1990;
  - 6 A-GCM experiments with
    - the climatological B-K SIC (**100%**), and
    - 5 reduced witner SIC runs (**80%, 60%, 40%, 20% and 1%**).

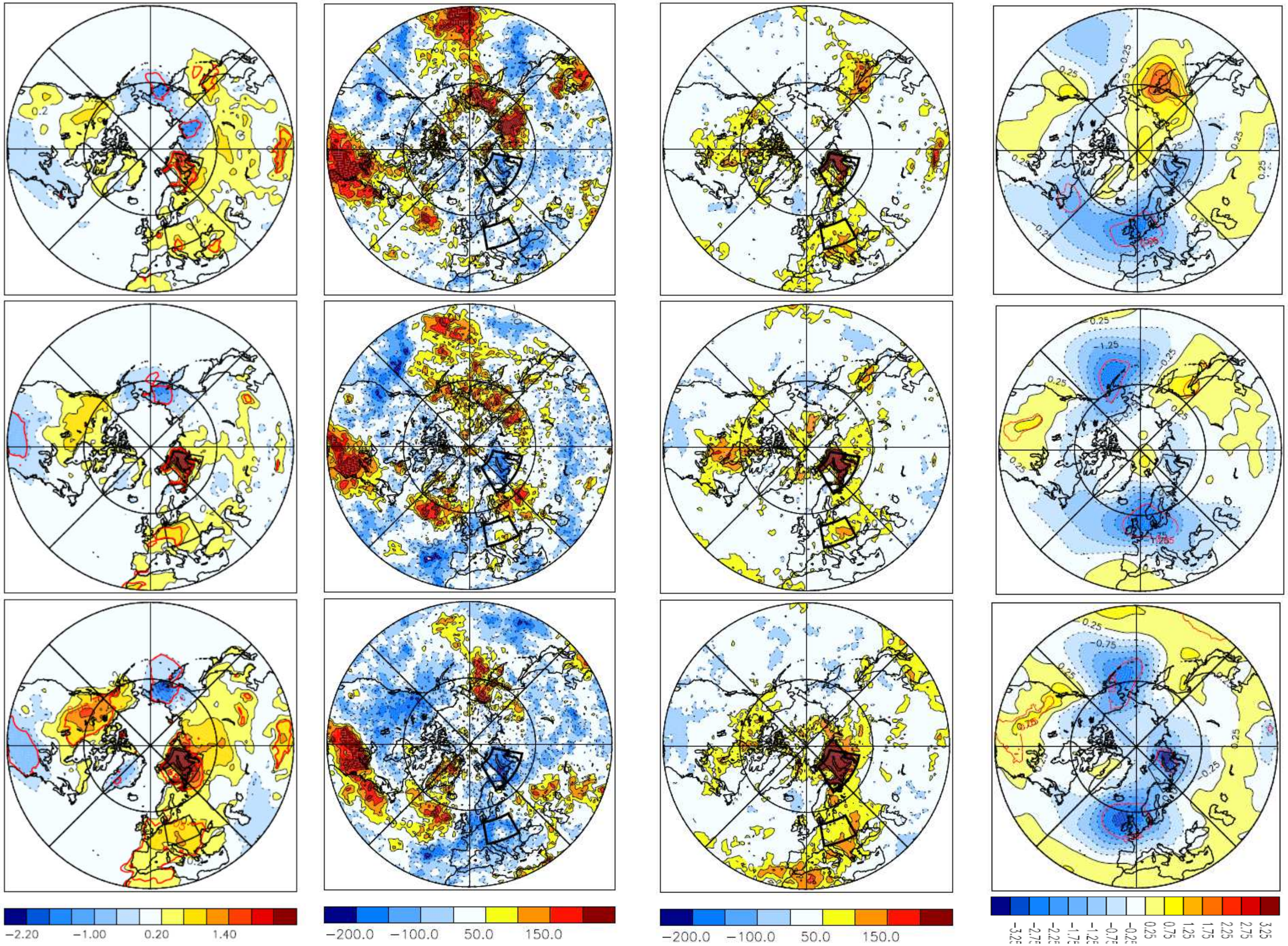
The ***Warm*** Case (2)

Changes in: **(a) T2M** **(b) Prob(T<1.5σ)** **(b) Prob(T>1.5σ)** **(c) MSLP (hPa)**

80% – 100%

60% – 100%

20% – 100%



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The ***Warm*** Case summary

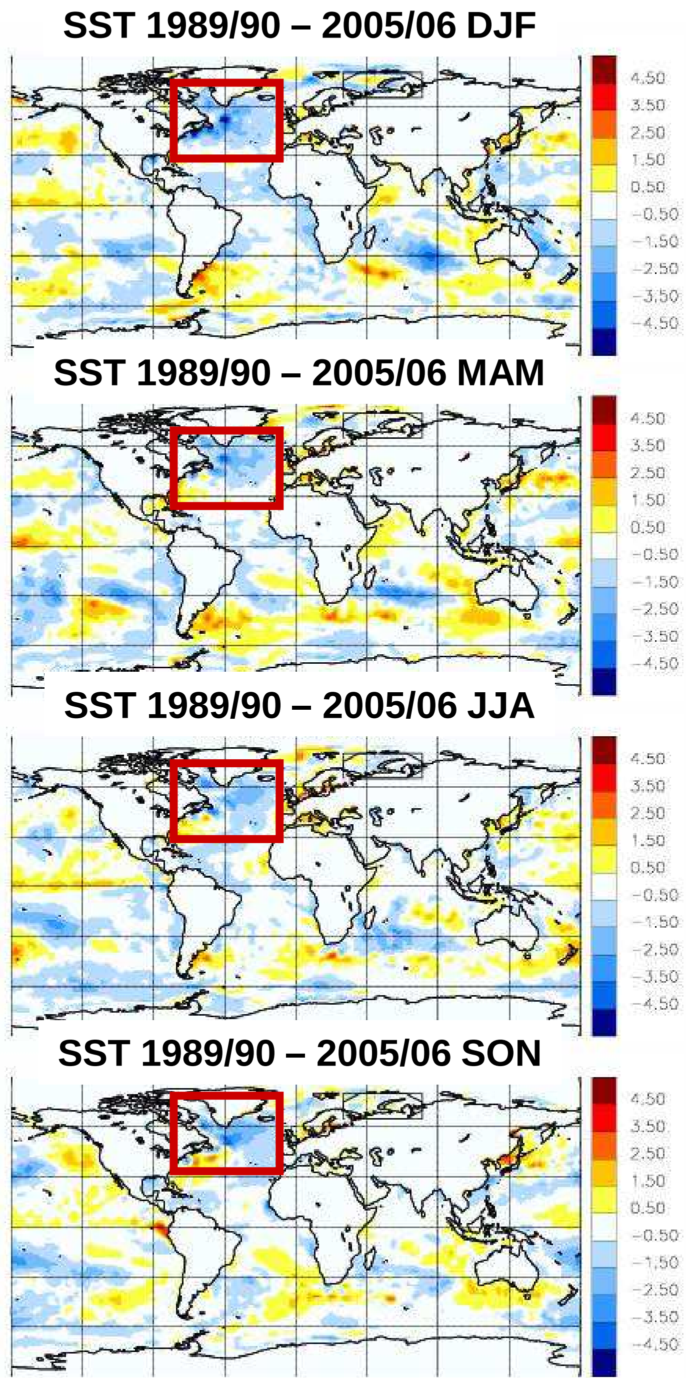
– In contrast to the ***Cold*** Case, under the ***warm*** winter condition, the sea ice reductions in the B-K sector lead to a general increase of winter temperature, and more extreme warm months in Europe.

– The only difference in the experiments for the ***Cold*** and ***Warm*** Case is that the SSTs are taken from different years.

SSTs: the ‘*Warm*’ vs. ‘*Cold*’ case

The monthly mean SSTs in large area of North Atlantic are more than 1°C colder in year 1989-1990 than in 2005-2006.

=> The *Mixed* Case: with SSTs from the ‘***Cold***’ case every-where but from the ‘***warm***’ case for N. Atlantic



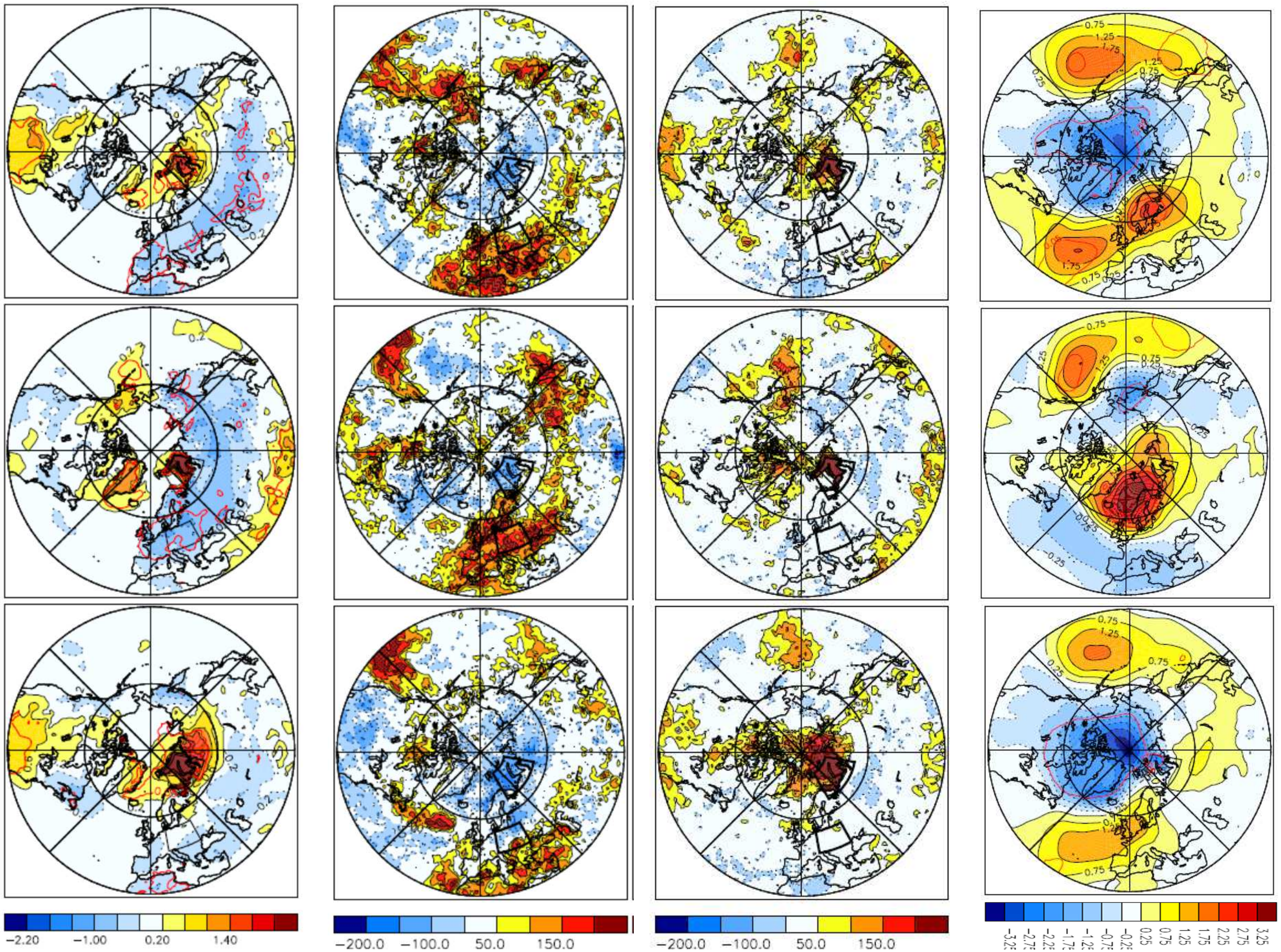
The *Mixed* Case (2)

Changes in: **(a) T2M** **(b) Prob(T<1.5σ)** **(b) Prob(T>1.5σ)** **(c) MSLP (hPa)**

80% – 100%

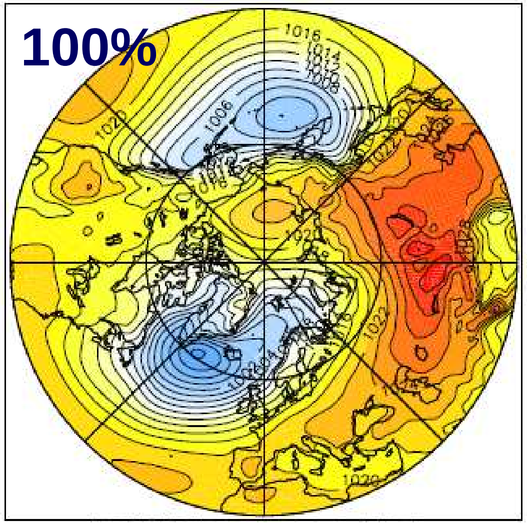
60% – 100%

20% – 100%

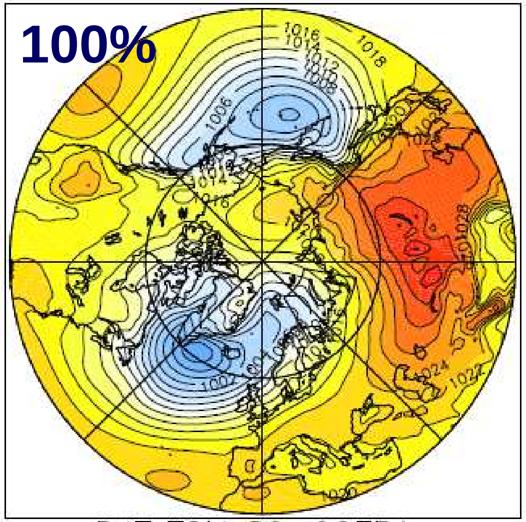


Difference in Response: MSLP

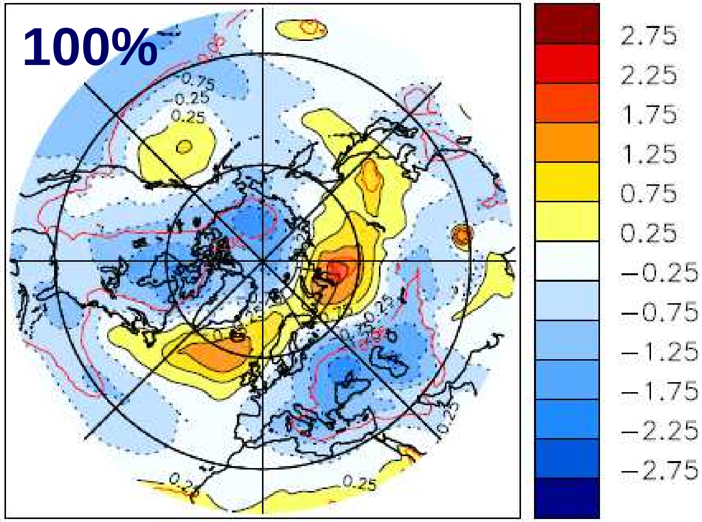
Cold case



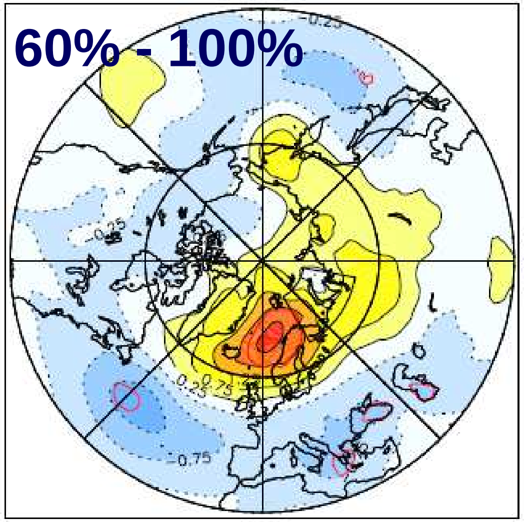
Warm case



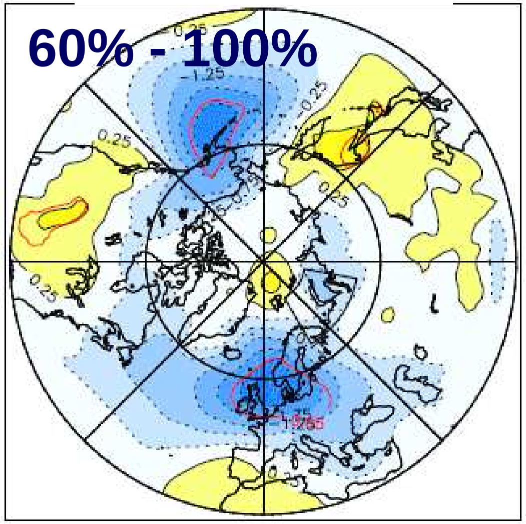
Warm - Cold



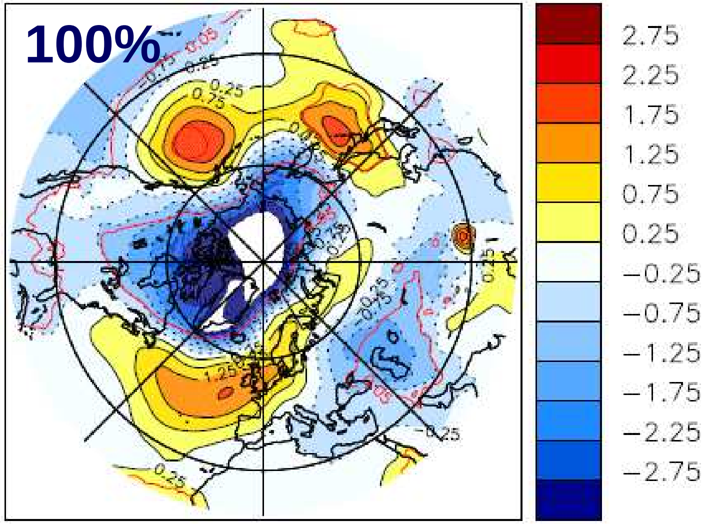
Cold case



Warm case



Warm - Mixed



Summary

- Wintertime sea ice concentration in the Barents-Kara seas is **a sensitive factor** for the atmospheric circulation patterns that influence the European winter temperature.

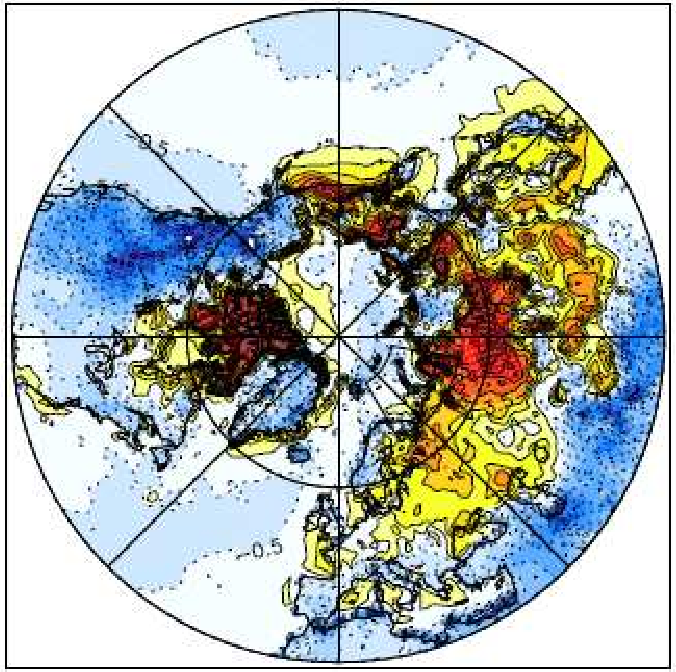
- The atmospheric response to the Arctic sea ice retreat is regulated by the **global SST pattern,** while the North Atlantic SSTs seem to be less important.

  - ➢ Indication of the importance of ‘background state’?
    - ▪ Response maybe different for subtle difference in the ‘background state’/other forcings
  - ➢ Mechanisms connecting the Arctic and the remote SSTs?
    - ▪ Stratosphere? Lag-response? etc.
  - ➢ Brings the uncertainty in predicting the response to the Arctic sea ice changes
    - ▪ Model biases?

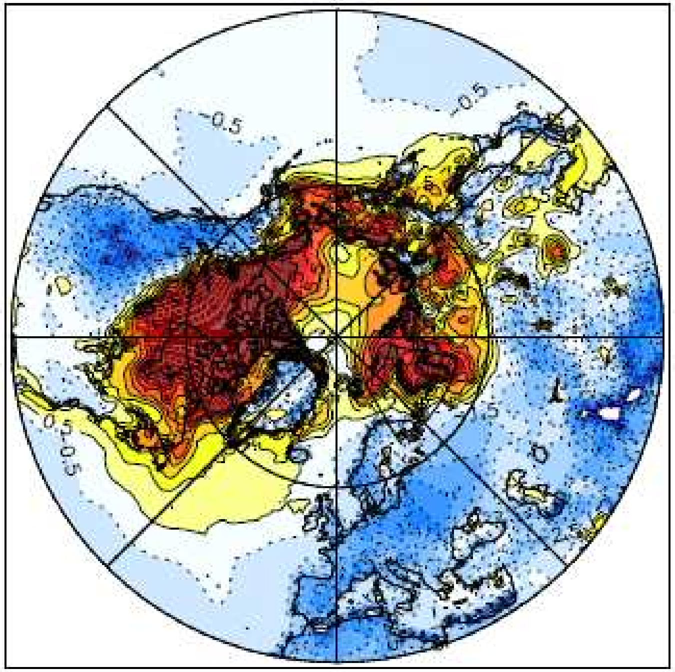
Thank you!

Model bias? T2M

Cold (100%) - ERA-I (05-06)

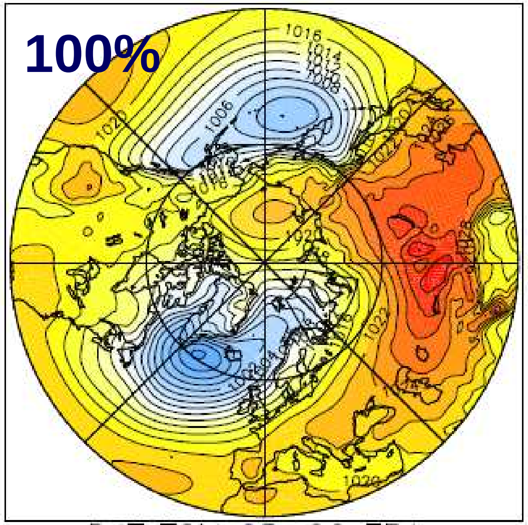


Warm (100%) - ERA-I (89-90)

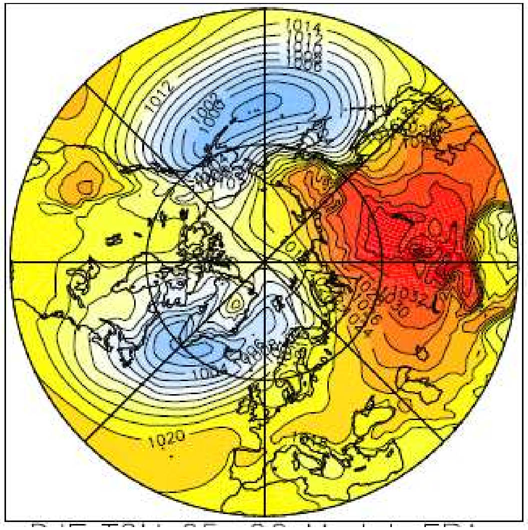


Model bias? MSLP

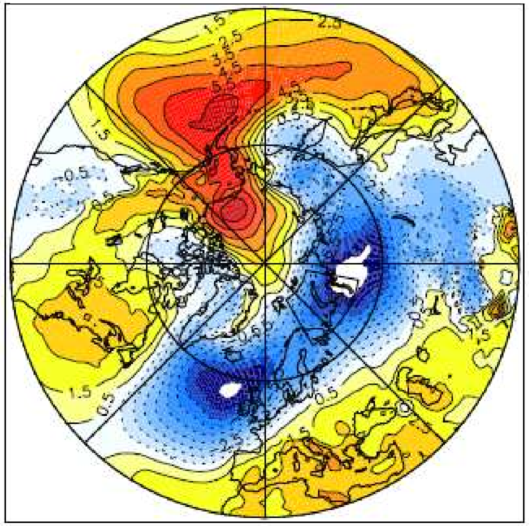
Cold case



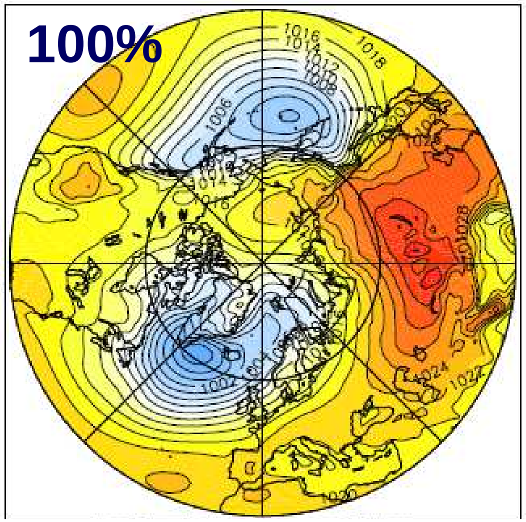
ERA-I 2005-06



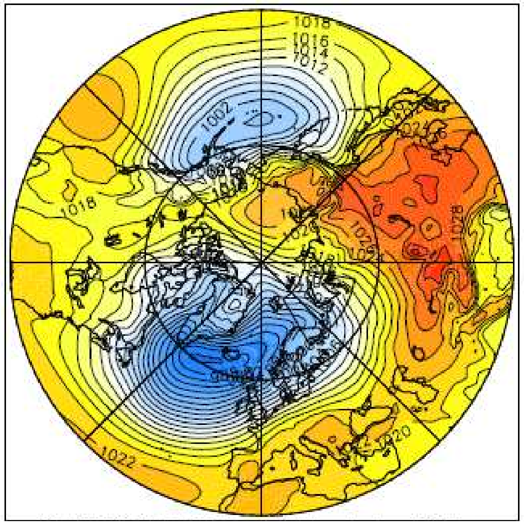
Cold - ERA-I



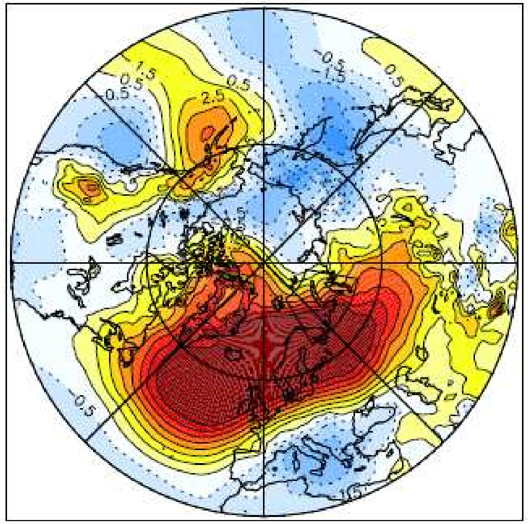
Warm case



ERA-I 2005-06

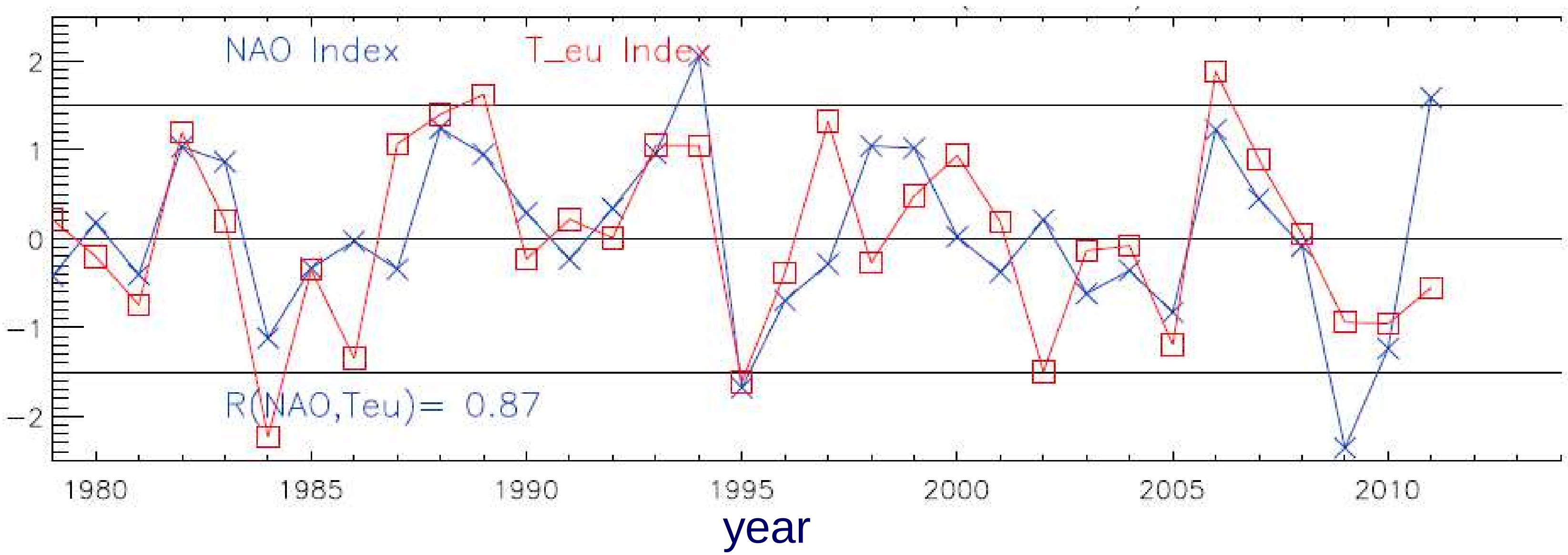


Warm - ERA-I



Winter T in Europe and NAO index is highly correlated

ERA-Interim NAO index and normalized T_{eu} (de-trended) in DJF



Correlation coefficient R = 0.87