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

HadISST DJF Sea Ice Concentration in The Barents and Kara Seas
Petoukhov & Semenov (2010): The Barents-Kara sea ice reduction may result 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
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<1.5\(\sigma\))  (b) Prob(T>1.5\(\sigma\))  (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 winter SIC runs (80%, 60%, 40%, 20% and 1%).
The *Warm* Case (2)

Changes in: 
(a) T2M  (b) Prob(T<1.5\(\sigma\))  (c) Prob(T>1.5\(\sigma\))  
(d) MSLP (hPa)

- 80% – 100%
- 60% – 100%
- 20% – 100%
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:

1. **(a) T2M**
   - 80% – 100%
   - 60% – 100%
   - 20% – 100%

2. **(b) Prob(T<1.5σ)**

3. **(b) Prob(T>1.5σ)**

4. **(c) MSLP (hPa)**

Difference in Response: MSLP

**Cold case**

100%

**Warm case**

100%

**Warm - Cold**

100%

**Cold case**

60% - 100%

**Warm case**

60% - 100%

**Warm - Mixed**

100%
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

![Graph showing the correlation between NAO Index and $T_{eu}$](image)

Correlation coefficient $R = 0.87$