Is Recent Eurasian Winter Cooling Caused by Arctic Sea Ice Loss?

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1. Introduction

In recent decades, the Northern Hemisphere continent has undergone a significant cooling in the boreal winter. This cooling primarily appeared in central Eurasia and North America was sufficiently strong to weaken the annual-mean globally-averaged surface air temperature (SAT) trend, contributing to global warming. The relation between Eurasian cooling trend and SIC trend is not clear.

2. Data and method

 # Data

monthly SAT in HadCRUT4 and ERA-Interim reanalysis from 1979 to 2013
monthly Sea Ice Concentration (SIC) in HadISST from 1979 to 2013

 # Methods

1. Perron Yabu Procedure (linear trend with one time break) [Perron and Yabu (2009)]

$$y_t = \mu + \beta_1 t + \beta_2 DT_t^* + \tilde{y}_t\,, \qquad DT_t^* = t - T_B\ (t > T_B),\ = 0\ (t \le T_B)$$

2. Trend decomposition (linearly congruent component) [Thompson et al (2000)]

SAT = a*SIC ;a is a regression coefficient
SIC = b*time ;b is a time trend
SAT = a*b* time ;**a*b is the linearly congruent component** of SAT trend with SIC
SAT = c*time ;**c - a*b is residual component**

3. SAT trend in Observation

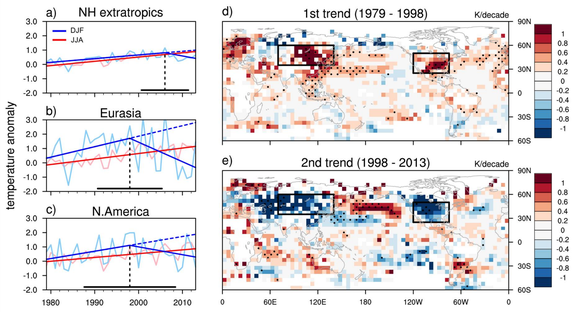


Figure1. Observed (blue) DJF- and (red) JJA-mean SAT and their linear trends in (a) North Hemispheric extratropics averaged over north of 20N, (b) Eurasia, (c) North America (boxed in d) in HadCRUT4. Dashed lines are extended trend in the absence of a breakpoint and the black solid lines running parallel to x axis are the 95% confidence interval of the estimated break point. The DJF-mean SAT trend (d) before and (e) after 1998. The values that are statistically significant at 5 % level are dotted.

DJF SAT in mid latitude started to decrease near after 2000s. Although the DJF SAT trend change appeared in 2006 in the northern extratropics, the breakouts of the trend changes are statistically estimated in 1998 both in Eurasia and North America. At the same time, the autumn and winter SIC over the BK seas started to sharply descend in 1998 (not shown)

→ This simultaneous change is just coincidence or a physically linked mechanism?

4. SAT trend associated with SIC

Table 1. Result of 1st mode from CCA analysis based on singular vector decomposition with Arctic sea ice concentrations (60N-90N and 0E-180E) and DJF-mean SAT (20N-90N and 0E-180E)

1st mode	Total variance (%)	SIC variance (%)	DJF SAT variance (%)
SON SIC	75.5	40.9	26.3
OND SIC	77.8	43.9	27.2
NDJ SIC	64.4	39.7	24.4

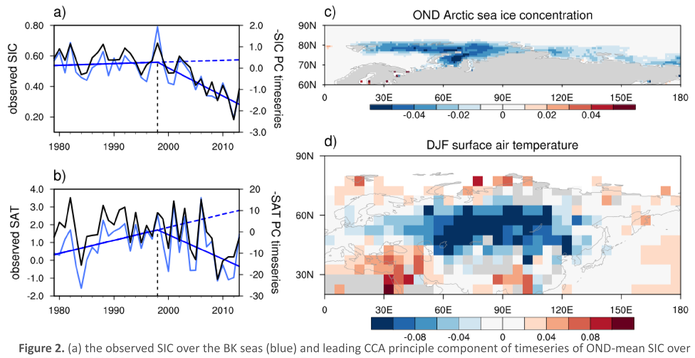


Figure 2. (a) the observed SIC over the BK seas (blue) and leading CCA principle component of timeseries of OND-mean SIC over 0E-180E and 60N-90N (black) and (b) the observed SAT over the Eurasia (blue) and leading CCA principle component of timeseries of DJF-mean SAT over 0E-180E and 20N-90N (black). The blue solid line is the estimated linear trend with the presence of a break point and the blue dashed line is the prolonged trend. The black dashed line indicates the statistically estimated break point. The leading CCA eigen vectors of (c) OND SIC and (d) DJF SAT

The OND SIC in the BK seas and the DJF SAT in Eurasia have high co-variability and the PC timeseries of the leading mode well reproduces the recent decreasing trend. It means not only in terms of the inter-annual variability, but the trend, they are highly related

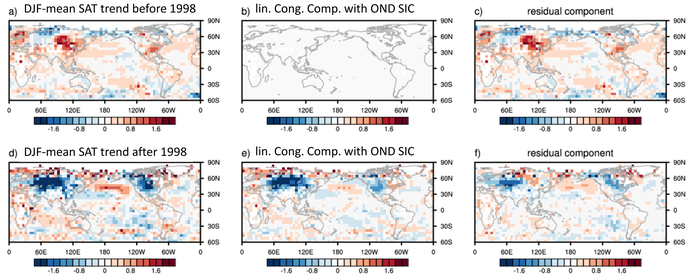


Figure 3. (a) the linearly regressed DJF-mean SAT trend before 1998, (b) the linearly congruent component of SAT trend with OND-mean SIC, and (c) the residual component of the trend before 1998. (d) the linearly regressed DJF-mean SAT trend after 1998, (e) the linearly congruent component of SAT trend with OND-mean SIC, and (f) the residual component of the trend after 1998.

Before 1998, the observed DJF SAT trend is not related with OND SIC over BK seas.
After 1998, the observed DJF SAT trend is highly explainable with OND SIC over BK seas.

→ Arctic SIC and the Eurasian SAT have statistically related in a viewpoint of both linear trend and interannual variability.

5. Model configuration

We used the GFDL CM2.1, the fully coupled climate model developed by the Geophysical Fluid Dynamics Laboratory. The observed SST (ERSST v3.) over the north of 70° N is restored to the pre-industrial simulation with 5 days timescale to give the only forcing of the sea ice loss in recent decades. 21 ensemble members are used. More details in Kug et al., (2015).

6. Coupled model experiments

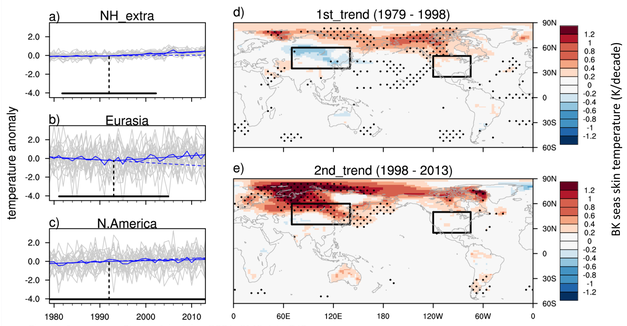


Figure 4. same as Figure 1 but for GFDL-CM2.1 in DJF

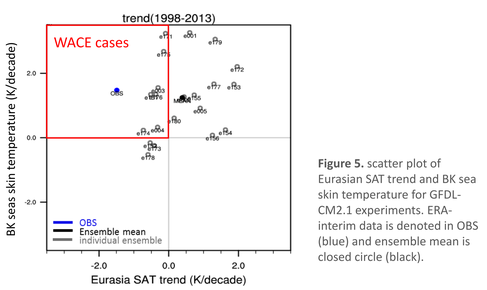
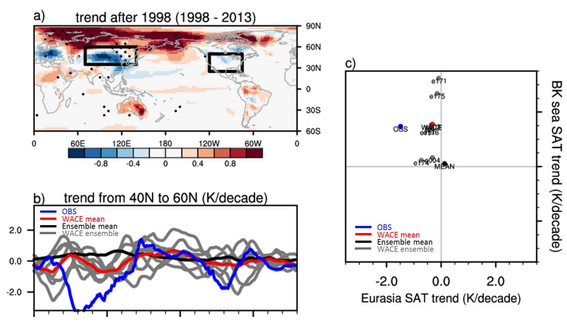


Figure 5. scatter plot of Eurasian SAT trend and BK sea skin temperature for GFDL-CM2.1 experiments. ERA-interim data is denoted in OBS (blue) and ensemble mean is closed circle (black).



The recent Eurasian winter cooling was not reproduced in coupled model simulation. But some ensemble members (7 in 21) show warm Arctic cold Eurasia (WACE) pattern and it is classified WACE cases.

The winter cooling over Eurasia represented in WACE cases are underestimated than observation (Fig. 6b)

WACE cases are accompanied with enhanced Ural blocking high, and the influenced Siberian high causes cold advection from Arctic.

Figure 6. (a) The DJF-mean SAT trend after 1998. The values that are statistically significant at 5 % level are dotted. (b) linear trend averaged from 40N to 60N. (c) scatter plot of Eurasian SAT trend and BK sea skin temperature for GFDL-CM2.1 experiments. ERA-interim data is denoted in OBS (blue) and ensemble mean is denoted closed circle.

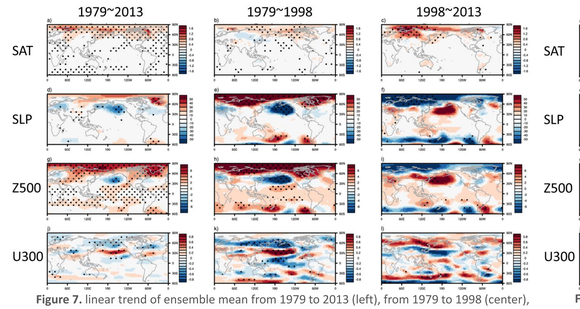


Figure 7. linear trend of ensemble mean from 1979 to 2013 (left), from 1979 to 1998 (center), from 1998 to 2013 (right)

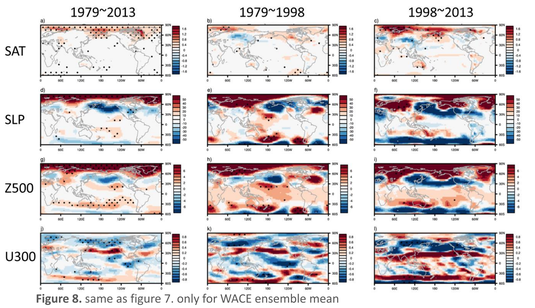


Figure 8. same as figure 7. only for WACE ensemble mean

7. Conclusions

In observation, the recent Eurasian winter cooling trend is mainly associated with late autumn sea ice loss. However, It is not well represented in polar restoring experiments in GFDL-CM2.1. In the WACE cases, the enhancement of Ural blocking and the Siberian high seems the main causes. In further study, we will analyze the leading mechanisms for the blocking intensity and frequency to understand the leading mechanism.

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