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Influence of Barents-Kara sea-ice reductions on Stratospheric Sudden Warmings

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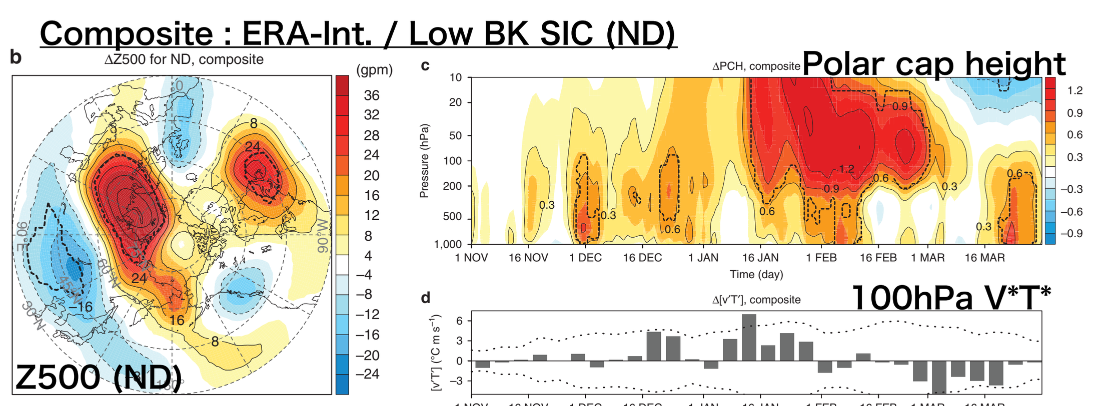
1. Introduction and Purpose

- Arctic sea-ice loss becomes more apparent after 2000
- Barents-Kara (BK) sea-ice reduction induces a negative Arctic Oscillation (AO) pattern and cold winter in mid-latitude though stratosphere-troposphere coupling processes (Kim et al., 2014)
- A higher frequency of Stratospheric Sudden Warming (SSW) occurrence after 2000



Purpose

To investigate influence of the recent Arctic sea-ice reduction on SSWs, particularly

- Characteristics of upward planetary wave propagation that induces SSWs
- Downward propagating SSW signals at the surface

Table 1. Central day (Day 0) of SSW events. The circle indicates events that 10 hPa zonal mean zonal wind at 60N reverses. Mark "L" indicates the year of low-ice condition in the BKS.

Events	D/M	Year	Major	BK-SIC
1	24 Feb	1980	○	
2	1 Feb	1981	○	
3	3 Dec	1981		
4	23 Jan	1982	○	
5	22 Feb	1983		
6	20 Feb	1984	○	
7	28 Dec	1984	○	L
8	18Jan	1987	○	
9	1 Dec	1987	○	
10	16 Feb	1989	○	
11	8 Feb	1990		
12	26 Jan	1991		
13	14 Jan	1992		
14	10 Feb	1992		
15	1 Jan	1994		L
16	23 Jan	1995		
17	30 Dec	1997		
18	19 Feb	1998		
19	13 Dec	1998	○	
20	22 Feb	1999	○	
21	16 Dec	2000		L
22	1 Feb	2001	○	L
23	23 Dec	2001	○	L
24	13 Feb	2002		L
25	16 Jan	2003	○	
26	13 Feb	2003		
27	27 Dec	2003	○	
28	27 Feb	2005		L
29	12 Jan	2006	○	L
30	22 Feb	2007	○	L
31	14 Feb	2008	○	L
32	21 Jan	2009	○	L
33	24 Jan	2010	○	L
34	13 Jan	2012		L
35	5 Jan	2013	○	L
36	4 Jan	2015		
37	26Jan	2015		

3. Wave-Mean Flow Interaction

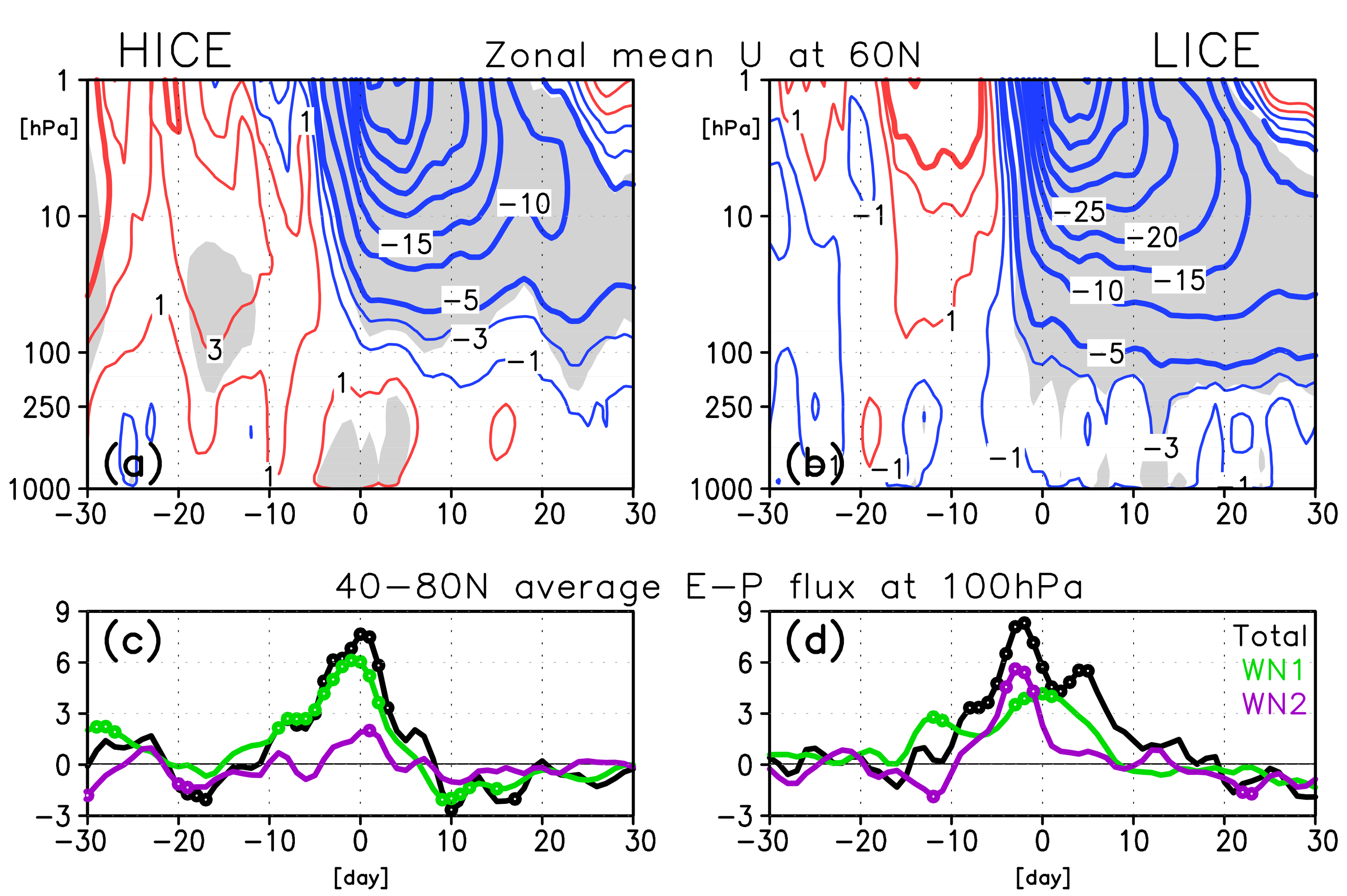


Figure 1. (top panels) Time-height cross-section of zonal mean zonal wind anomalies at 60N (contour; m/s) for the (a) Heavy-ice and (b) Light-ice SSW composites. (bottom panels) Time series of total (black), wavenumber-1 (green), and wavenumber-2 (purple) components of 40-80N averaged EP flux anomalies at 100 hPa (10^{-5} kg s^{-2}) are drawn for the (c) Heavy-ice and (d) Light-ice SSW composites. Shade in (a) and (b), and open circle in (c) and (d) indicate statistical significance at the 95% level.

Heavy-ice SSW

- An increase in E-P flux mostly from wavenumber-1 component

Light-ice SSW

- Larger contribution from wavenumber-2 component
- Possible pre-conditioning in zonal wind?
- Stronger downward propagating SSW signals and tropospheric easterly wind anomalies

2. Data and Methodology

Sea Ice Concentration : HadISST1 (Rayner et al,. 2003)
Horizontal resolution 1×1°

Atmospheric data : JRA-55 (Kobayashi et al., 2015)
Horizontal resolution 1.25×1.25°
37 vertical levels (1000-1hPa)

Period : 1979/80 - 2014/15 (36 years)

Sampling of SSWs

SSWs are detected when the daily stratospheric Northern Annular Mode (NAM) value falls below -1σ in DJF (central day)

Classification of SSW

Each SSW event is classified into either Light-ice (14) or Heavy-ice (23) year depending on a value of area-averaged December SIC of the BK Sea (15-90E, 70-85N)

Composite analysis

Conducting composite analysis with Day 0 as a reference

4. Atmospheric Circulation (Day-10~-1)

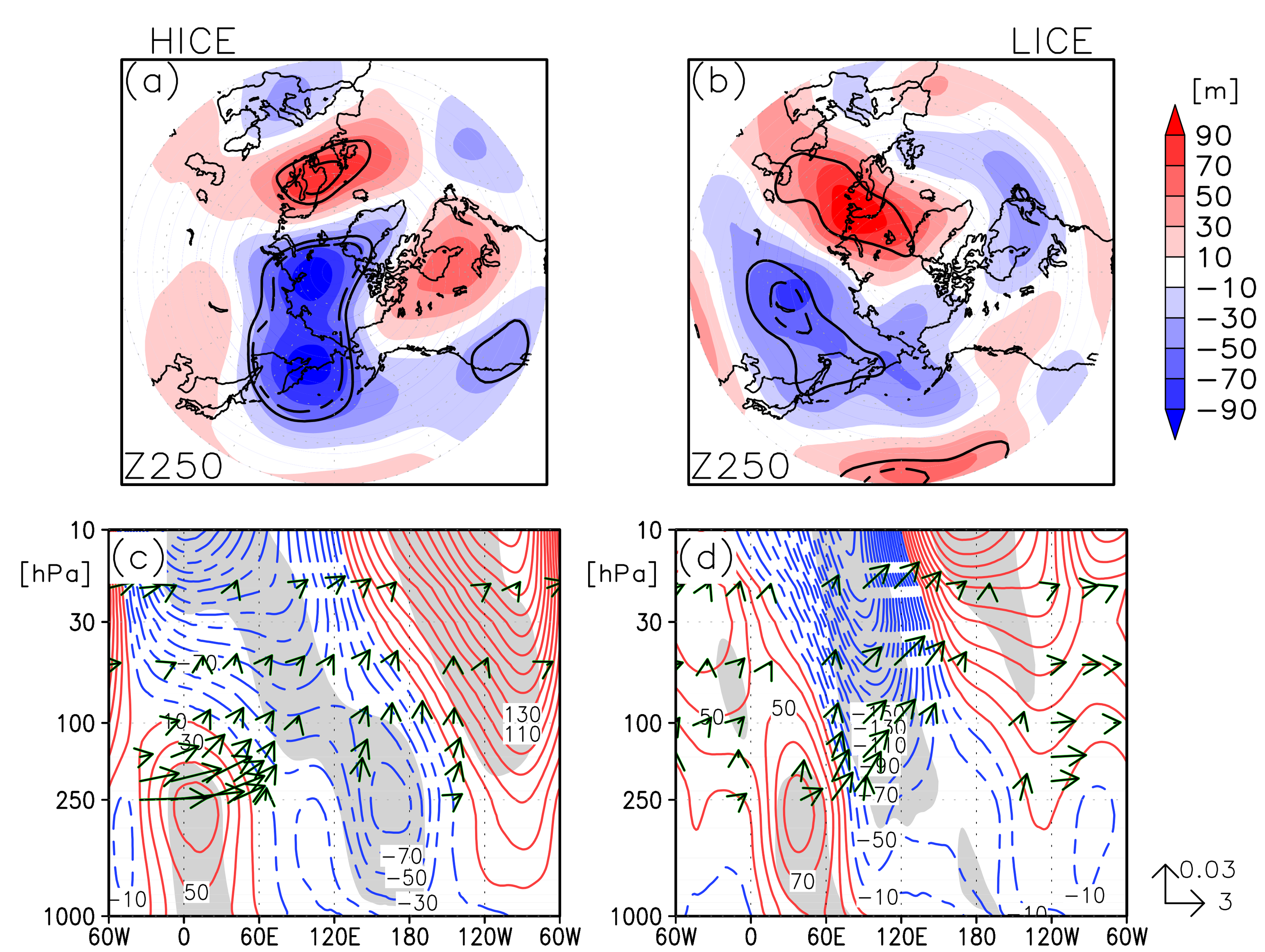


Figure 2. (top panels) Anomalies in geopotential height at 250 hPa (shade; m) averaged from Day -10 to Day -1 for (a) Heavy-ice and (b) Light-ice SSW composites. Solid and dashed lines indicate the statistical significance at the 95 and 99% levels, respectively. (bottom panels) Longitude-height cross-section of eddy component of geopotential height anomalies (contours) at 60N averaged from Day -10 to Day -1 for (c) Heavy-ice and (d) Light-ice SSW composites. Shade indicates the statistical significance at the 95% level. Arrows indicate anomalies of zonal and vertical components of the wave activity flux (m^2 s^{-2}) defined by Plumb (1985). Vectors which have positive vertical and zonal anomalies are plotted.

Heavy-ice SSW

- Enhanced climatological trough over Far East and climatological ridge over Europe
- Strengthened upward propagation of the planetary waves toward the stratosphere

Light-ice SSW

- Lower tropospheric baroclinic structure of anticyclonic anomalies over the BK Sea
- A wave pattern over Eurasia, which is similar to a stationary Rossby wave response to the BK sea-ice loss (Honda et al., 2009)
- Increased total upward wave activity along this anomalous wave pattern

7. Concluding Remarks

We conducted composite analysis on SSWs based on the classification of Light- or Heavy-ice events

Light-ice SSW (14 events)

- Stationary Rossby wave response to sea-ice reduction in the BKS
- Enhanced climatological wavenumber-2 pattern results in strengthening of the vertical EP flux at the lower stratospheric level
- Strong downward propagating SSW signals and Eurasian cooling

Heavy-ice SSW (23 events)

- Enhanced climatological trough over Far East and ridge over Europe, strengthens wavenumber-1 propagation

5. Wave 1 & 2 Components of Z250

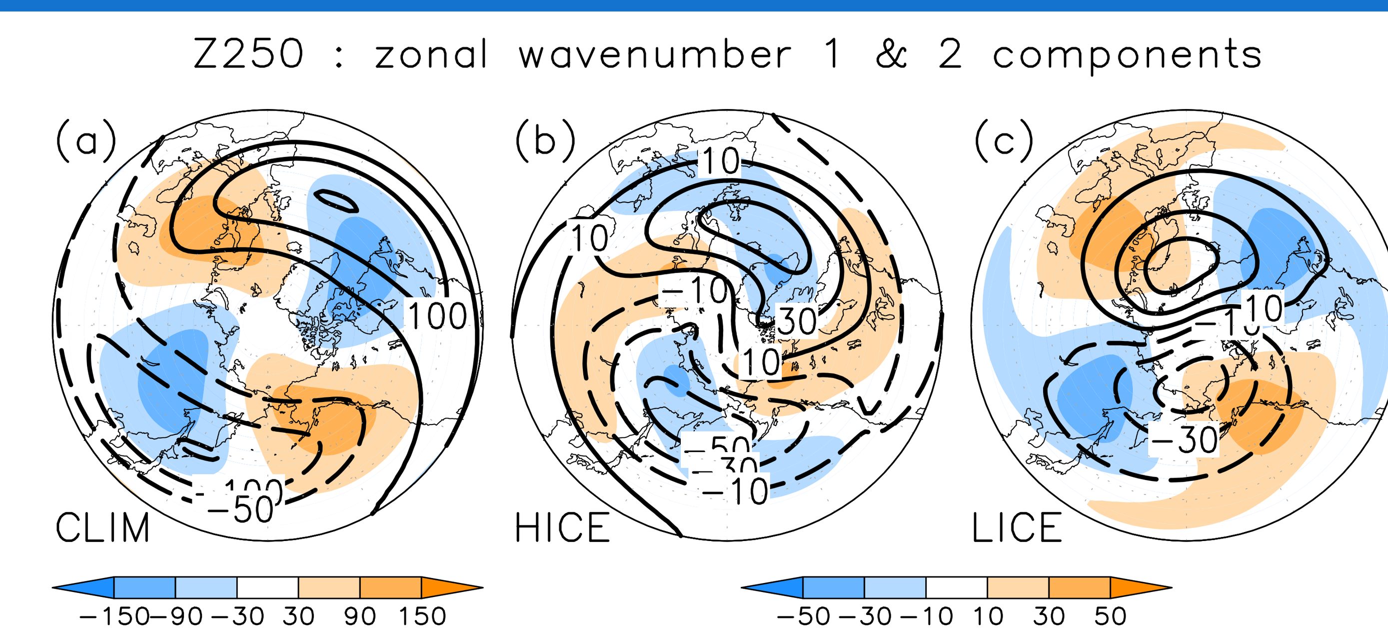


Figure 3. Zonal wavenumber-1 (contours) and -2 (shade) components of geopotential height (m) at 250 hPa for (a) winter (DJF) mean climatology and anomalies of (b) Heavy-ice and (c) Light-ice SSW composites averaged from Day -10 to Day -1.

Heavy-ice SSW

- Enhanced climatological WN1 pattern

Light-ice SSW

- Enhancement of both climatological WN2 and WN1 patterns
- Eurasian wave pattern of anomalous field is directory associated with the enhancement of the anomalous wavenumber-2 pattern

6. SSW Impact to Surface (Day0~29)

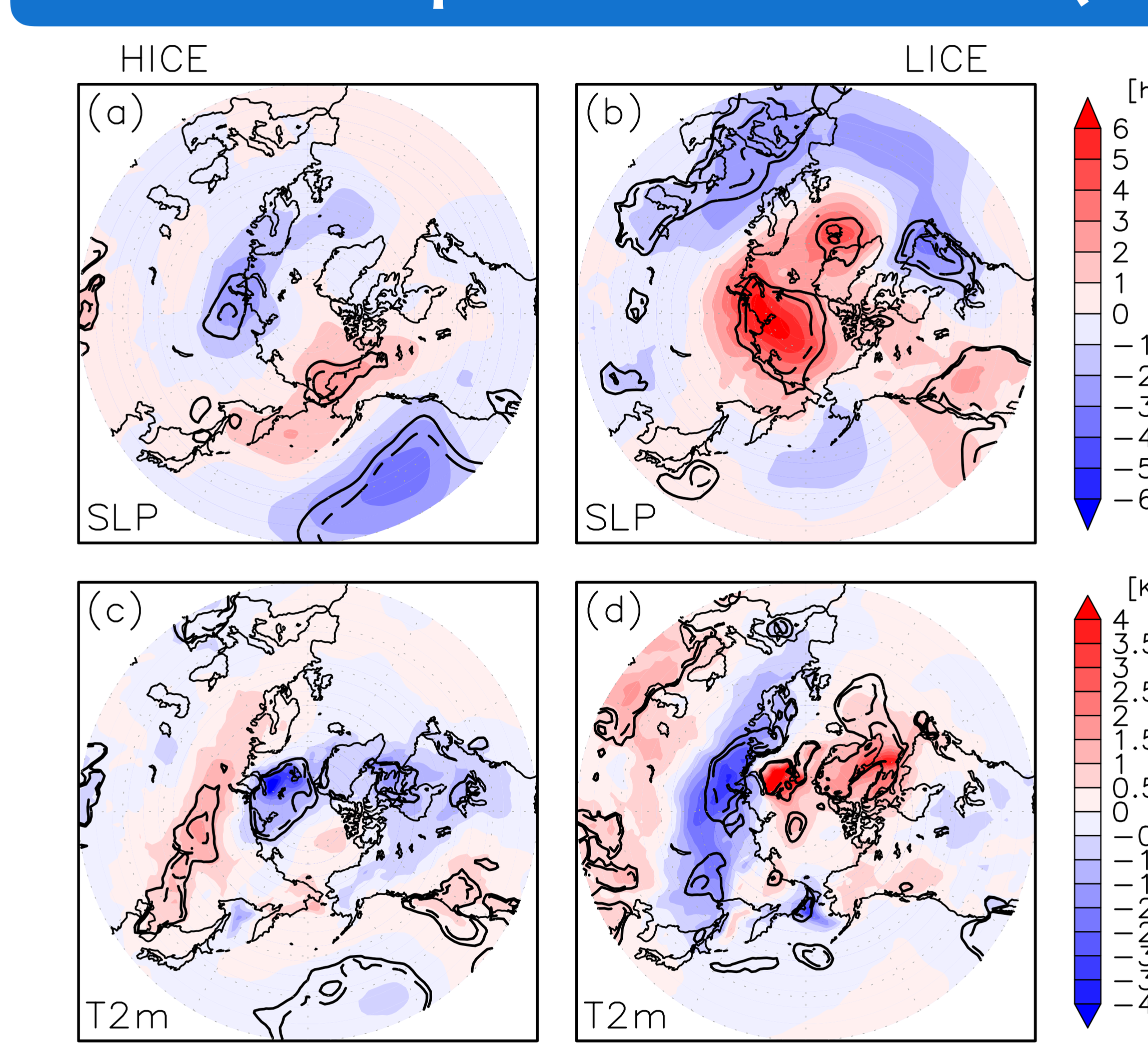


Figure 4. (top panels) Sea level pressure anomalies (shade; hPa) averaged from Day 0 to Day +29 for (a) Heavy-ice and (b) Light-ice SSW composites. (bottom panels) As in the top panels, but for 2 meter temperature anomalies (shade; K). Solid and dashed lines indicate the statistical significance at the 90 and 95% levels, respectively.

Light-ice SSW

- AO/NAO(-) like SLP anomalies
- Negative temperature anomalies over the Eurasia

Heavy-ice SSW

- No clean AO/NAO signals, nor Eurasian cooling