Bjerknes Centre for Climate Research

POLAR 2018 Open Science Conference

Observational Evidence for Predictive Skill from Arctic Summer Sea-ice Extent

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AC-6_AC-7b Across the Southern Ocean: Atmospheric and ice mass changes & Seeing the Future:
Predicting Variability and Change of the Polar Climate and Environment

23 June, 2018; Davos, Switzerland

UNIVERSITY OF BERGEN uni Research NERSC Nansen Center, Bergen HAVFORSKNINGSINSTITUTTET INSTITUTE OF MARINE RESEARCH

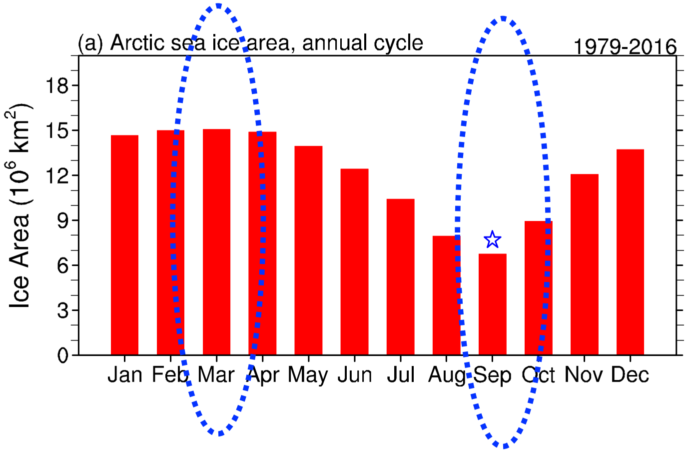
1 **Background**

2 **Data sets and methods**

3 **Results: observation and simulations**

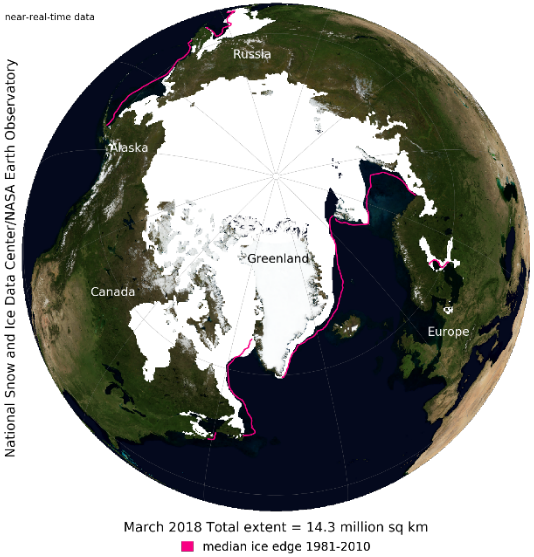
4 **Conclusions**

Highest in March

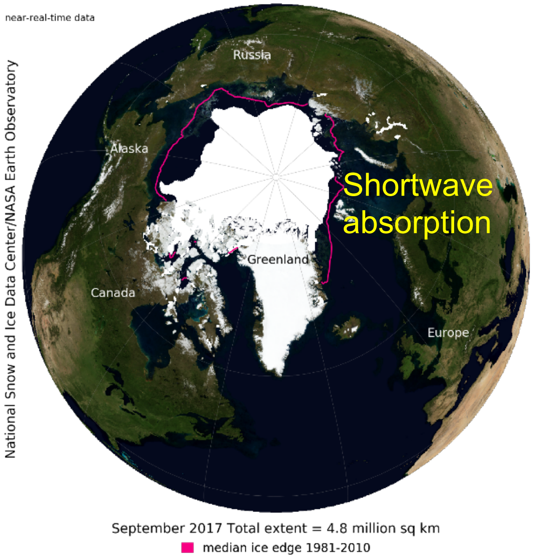


Lowest in September

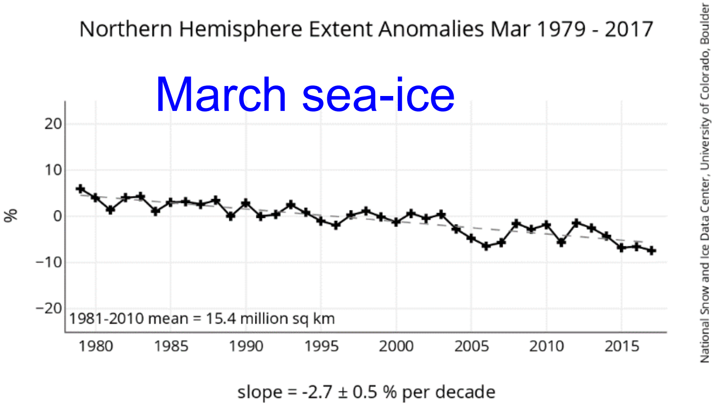
2018 March, mostly cover by sea ice

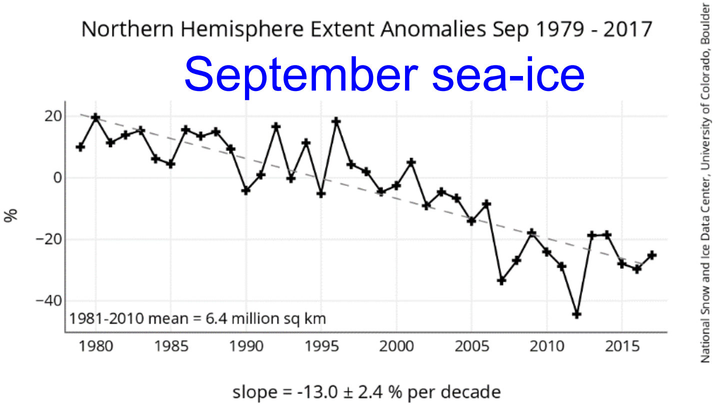


2017 September
More open water



Increasing focusing on the impact of autumn Arctic sea-ice





Source: ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/north/monthly/images/

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L08707, doi:10.1029/2008GL037079, 2009

Published in 2009, GRL

Influence of low Arctic sea-ice minima on anomalously cold Eurasian winters

Meiji Honda,[1] Jun Inoue,[2] and Shozo Yamane[3]

Published in 2012, PNAS

Impact of declining Arctic sea ice on winter snowfall

Jiping Liu[a,b,1], Judith A. Curry[a], Huijun Wang[b], Mirong Song[b], and Radley M. Horton[c]

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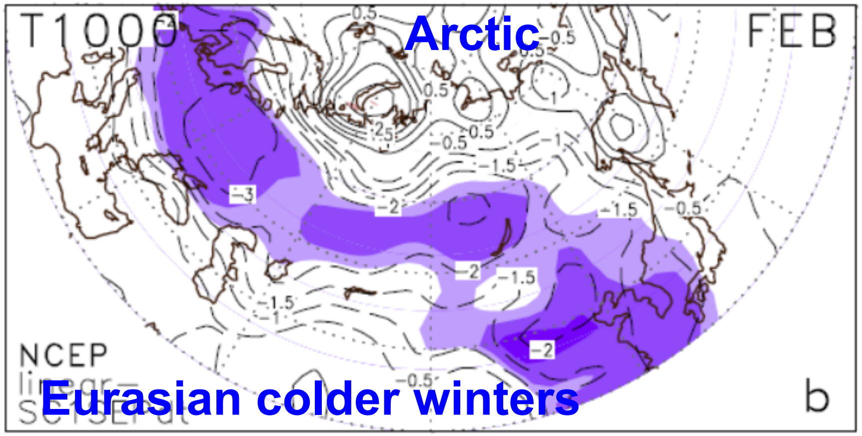
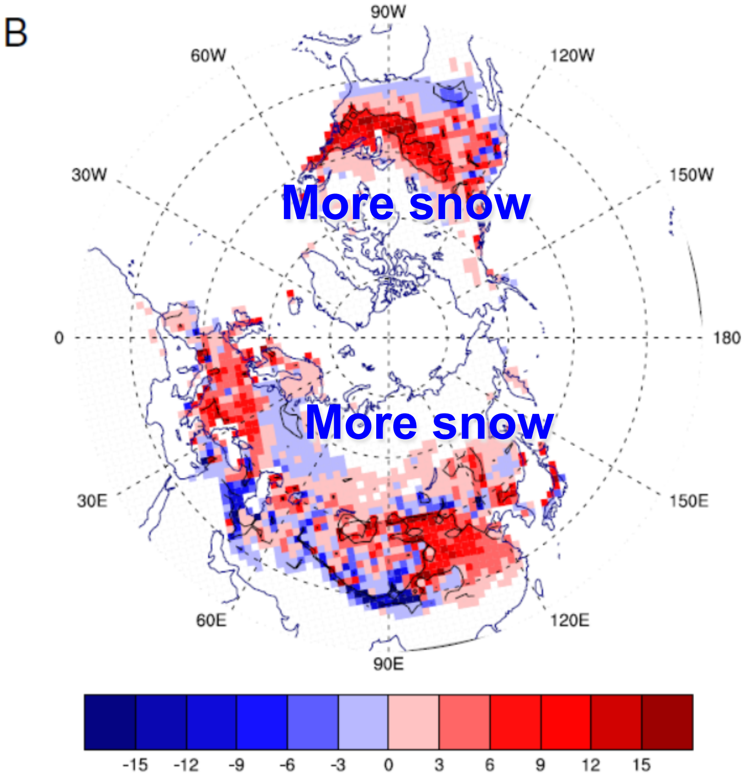


Arctic

Eurasian colder winters

Linear relationship between **reduced** September Arctic sea-ice and February temperature



More snow

More snow

Linear relationship between **reduced** Autumn Arctic sea-ice and winter snow cover

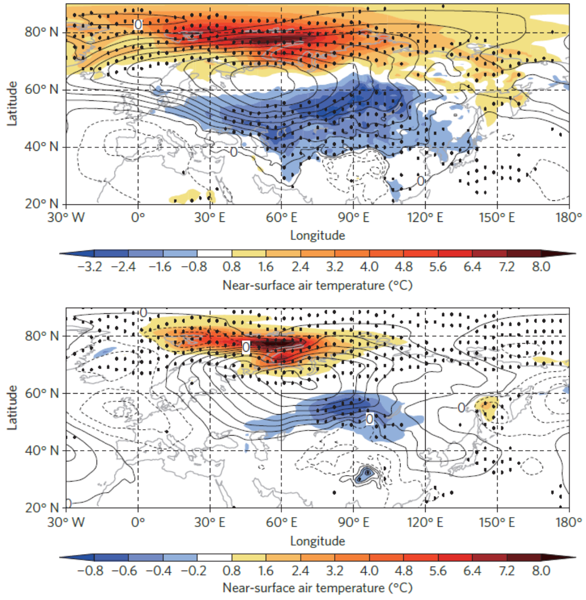
nature geoscience
LETTERS
PUBLISHED ONLINE: 26 OCTOBER 2014 | DOI: 10.1038/NGEO2277

Robust Arctic sea-ice influence on the frequent Eurasian cold winters in past decades

Masato Mori[1*], Masahiro Watanabe[1], Hideo Shiogama[2], Jun Inoue[3] and Masahide Kimoto[1]

Over the past decade, severe winters occurred frequently in mid-latitude Eurasia[1,2], despite increasing global- and annual-mean surface air temperatures[3]. Observations suggest that these cold Eurasian winters could have been instigated by Arctic sea-ice decline[2,4], through excitation of circulation anomalies similar to the Arctic Oscillation[5]. In climate simulations, however, a robust atmospheric response to sea-ice decline has not been found, perhaps owing to energetic internal fluctuations in the atmospheric circulation[6]. Here we use a 100-member ensemble of simulations with an atmospheric general circulation model driven by observation-based sea-ice concentration anomalies to show that as a result of sea-ice reduction in the Barents–Kara Sea, the probability of severe winters has more than doubled in central Eurasia. In our

Temperature & SLP



Observation:
Low *minus* High ice years
HadSST3

Simulation:
LICE *minus* HICE experiments

ARTICLES
PUBLISHED ONLINE: 10 OCTOBER 2016 | DOI: 10.1038/NGEO2820
nature geoscience

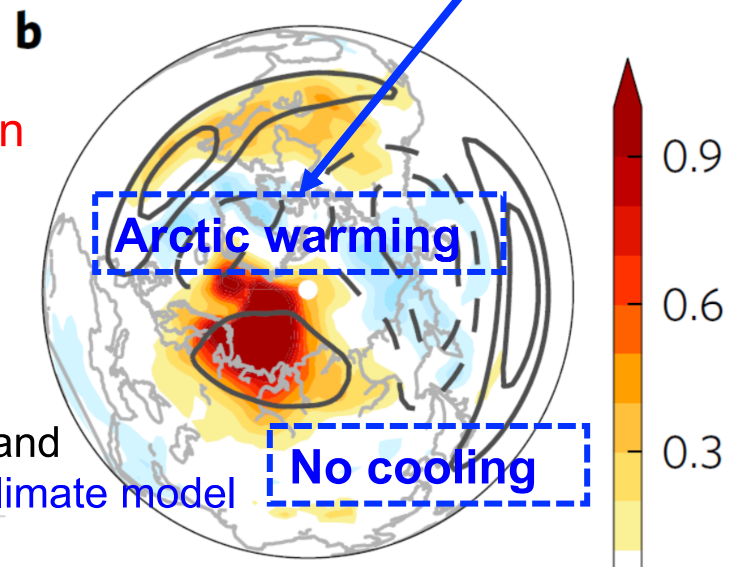
Twenty-five winters of unexpected Eurasian cooling unlikely due to Arctic sea-ice loss

Kelly E. McCusker[1,2]*, John C. Fyfe[2] and Michael Sigmond[2]

Surface air temperature over central Eurasia decreased over the past twenty-five winters at a time of strongly increasing anthropogenic forcing and Arctic amplification. It has been suggested that this cooling was related to an increase in cold winters due to sea-ice loss in the Barents-Kara Sea. Here we use over 600 years of atmosphere-only global climate model simulations to isolate the effect of Arctic sea-ice loss, complemented with a 50-member ensemble of atmosphere-ocean global climate model simulations allowing for external forcing changes (anthropogenic and natural) and internal variability. In our atmosphere-only simulations, we find no evidence of Arctic sea-ice loss having impacted Eurasian surface temperature. In our

The difference in these findings could be due to:

1. the particular nature of the boundary forcing pattern (HadSST vs. NSIDC);
2. the ability to capture the realistic exchanges of troposphere–stratosphere wave energy.



Linear relationship between **reduced** winter Arctic sea-ice and winter **surface** temperature from Atmosphere-only global climate model

- In spite of great effort devoted to understanding the Arctic-**midlatitude** linkages, the scientific community seem to have more controversies on this topic instead of converging on answers in recent years.
- Such intense debates from the scientific community easily lead the public to be confused on the research on the Arctic changes.
- With a focus on the **Arctic regions**, we analyze the lead/lag relationships between:
    1. Arctic sea ice extent and
    2. high-latitude atmospheric temperatures and circulation

Aim to support the point that the Arctic sea ice DOES exhibit pronounced potential predictability of the atmospheric circulation and temperature in the Arctic/high latitudes.

Observations:

- National Snow and Ice Data Center (**NSIDC**) observations:
  - Sea ice extent (SIE)
  - Sea ice concentration (SIC)
  - 1979-2016
- European Centre for Medium-Range Weather Forecasts (ECMWF) interim (**ERA-Interim**) reanalysis:
  - temperature
  - Atmospheric circulation
  - 1979-2016

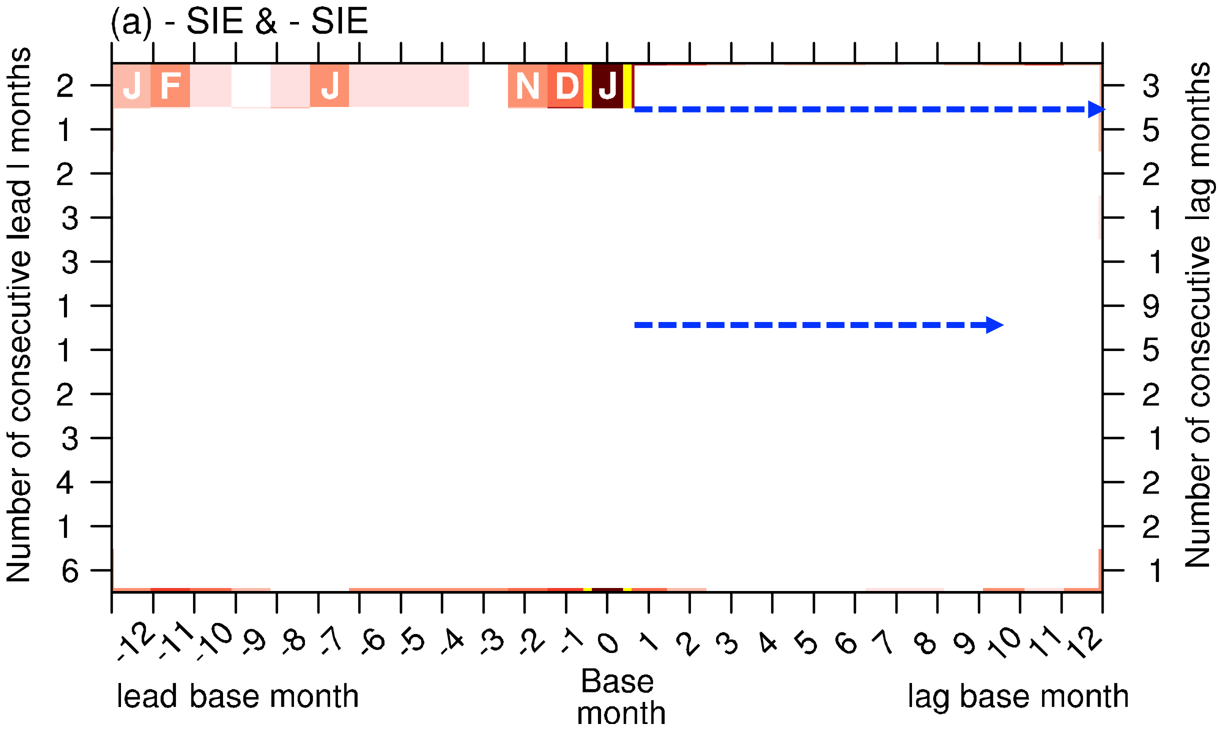
Simulations:

- 28 Coupled Model Intercomparison Project phase 5 (**CMIP5**) models:
  - Sea ice concentration (SIC)
  - 2-m temperature (T_{2m})
  - 1900-2005
- Arctic Predictability and Prediction on Seasonal to Inter-annual Timescales (**APPOSITE**) project
- Hindcast simulations (1982–2014) from **GREENICE project**

Lead/lag correlations between deseasonalized and detrended Arctic SIE and

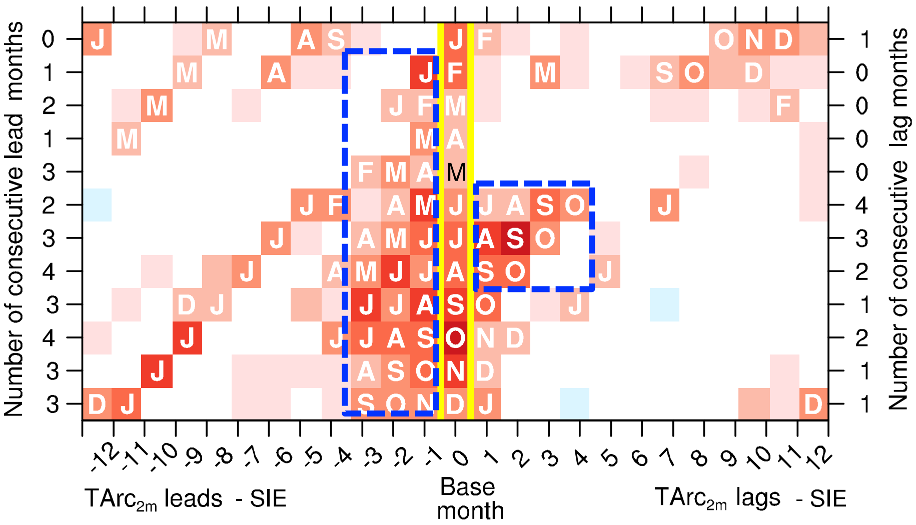
- Arctic averaged SIE, surface temperature, 500-hPa temperature
- Spatial atmospheric temperature over the Arctic
- Zonally-averaged mid- and high-latitude atmospheric temperature and zonal wind

- ☐ **Autocorrelation** of the Arctic SIE time series.
- ☐ Arctic SIE anomalies show at least one month significant memory throughout the year
- ☐ SIE anomalies exhibit continuous significant memory at positive lags up to 9 months midsummer
- ☐ SIE anomalies exhibit reemergence at least 12 months into the future during the growth season months of January and February

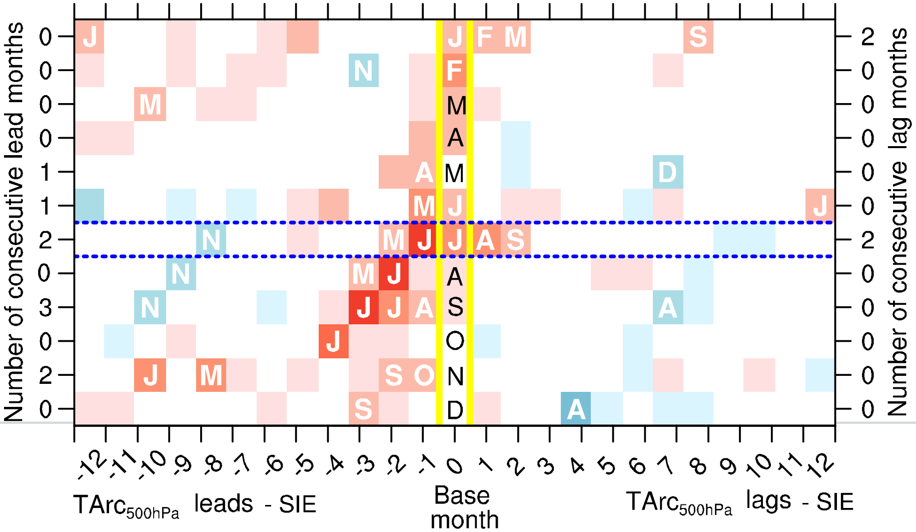


- **Lead/lag correlation** of (inverted) Arctic SIE with Arctic T2m.
- Periods of anomalously low SIE are preceded by anomalously warm surface conditions during most times of year
- Summer SIE anomalies exhibit robust and persistent correlations with Arctic surface temperatures at positive lags of **up to 4 months**, even stronger than that associated with September SIE
- The temperature anomalies linked to **midsummer SIE** are largest at the surface but also extend to the middle troposphere

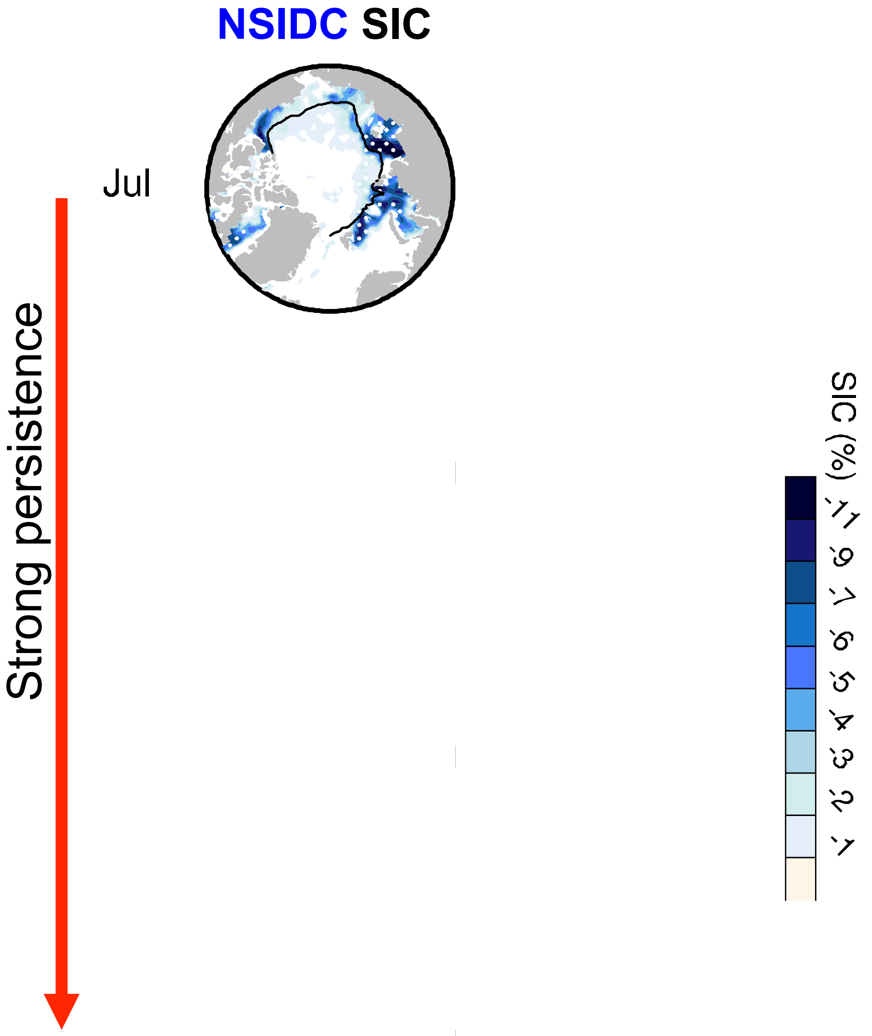
Arctic SIE (inverted) & Arctic T2m



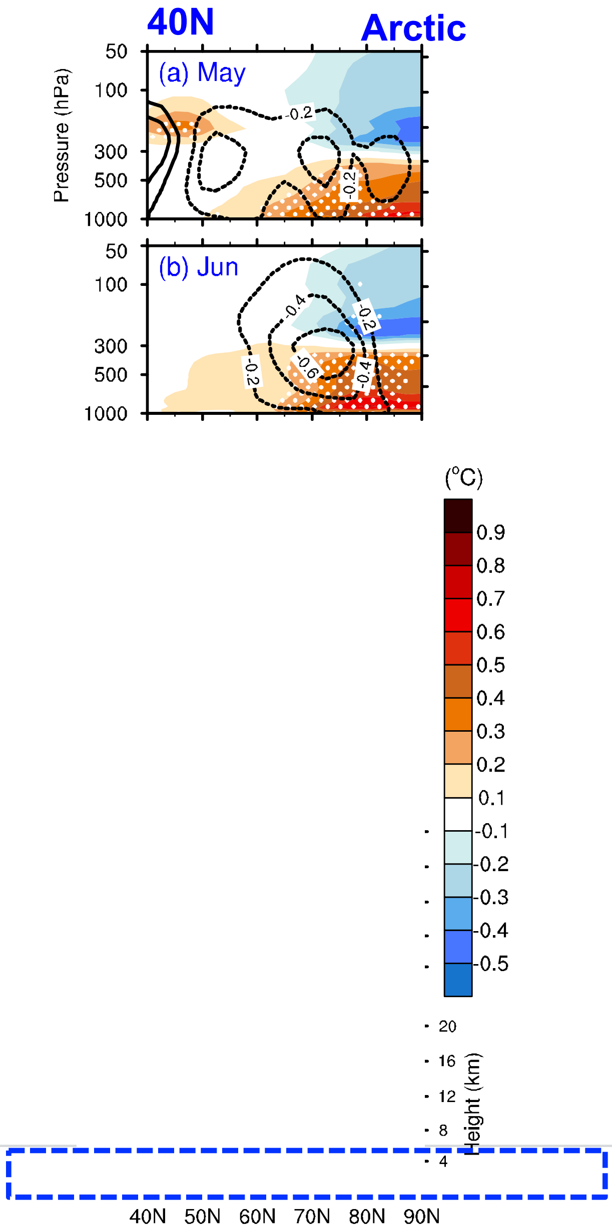
Arctic SIE (inverted) & Arctic T500hPa



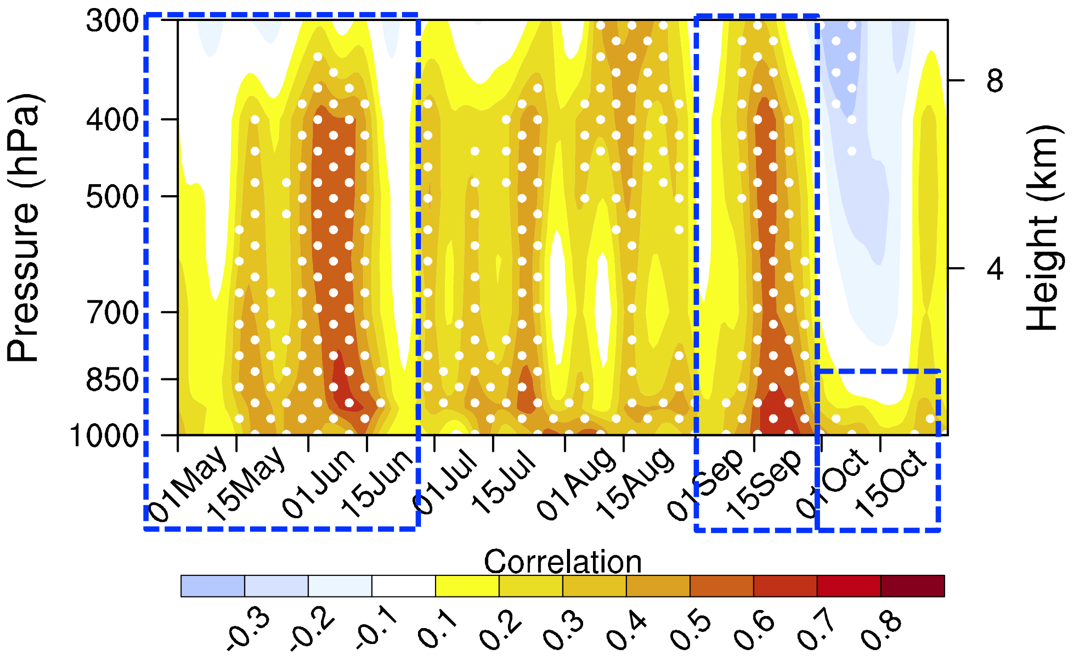
- ☐ **Regressions** of inverted July-mean Arctic ***SIE*** with the subsequent months' ***SIC***
- ☐ In **July**, anomalously low SIC anomalies emerge over the Barents, Kara, and Laptev seas;
- ☐ The regions of statistically significantly low SIC grow through summer and expand dramatically into the *Chukchi* and *Beaufort seas* in **August, September, and October**
- ☐ The spatial patterns of the SIC anomalies from CMIP5 outputs bear strong resemblance to the observations at all lags



- **Lead/lag regressions** between inverted July-mean Arctic **SIE** and monthly-mean zonally-averaged ***temperature & zonal wind*** from May to October
- Midsummers characterized by low sea-ice conditions are preceded by positive tropospheric temperature anomalies across high latitudes from May to June;
- In **July and August**, robust warm anomalies extend from the surface into the upper troposphere
- Arctic temperature anomalies associated with July Arctic SIE are significant through **September** but confined to the surface **into October**
- The positive temperature anomalies during August and September are associated with easterly wind anomalies of ~0.4−0.8 m s-1 centered at ~70ºN



- ☐ **Correlation** of daily air temperature averaged over the Arctic (North of 65.0°N) from 1 May to 31 October (with 10-day low-pass filtered) with the inverted time series of July-mean Arctic SIE;
- ☐ Significant warm anomalies precede low sea-ice conditions in midsummer;
- ☐ **In September**, significant correlations extend from the surface into the free troposphere, indicating the potential influence of Arctic sea ice on atmosphere aloft.
- ☐ Confined to near-surface **in October**



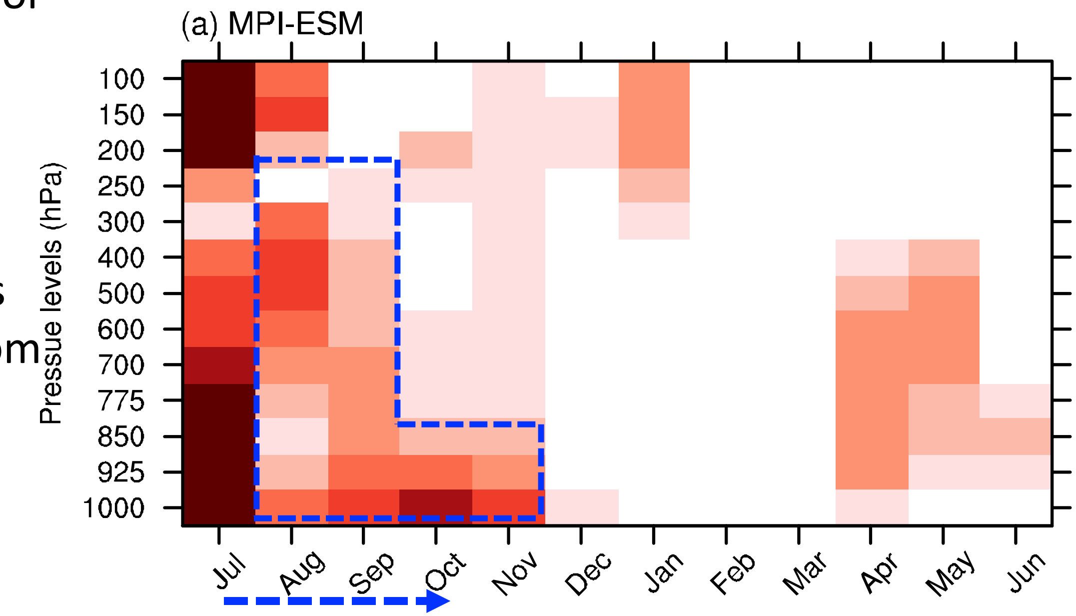
The above results indicate that the midsummer Arctic SIE anomalies offer potential predictive skills for the Arctic tropospheric temperature from August to September and near-surface temperature in October.

- Statistical correlations cannot induce a direct causal relationship
- Model simulations were used to confirm the effect of Arctic sea ice on the Arctic atmosphere

Prediction from Arctic Predictability and Prediction on Seasonal to Inter-annual Timescales (**APPOSITE**) project– *to test the importance of initialization from midsummer*.

- Long (multiple century) control experiments are run on a series of coupled ocean-atmosphere-sea-ice general circulation models (GCMs).
- The control simulations are then used as a baseline for assessing predictability in a series of initial-value (*initialized on July 1*) experiments run on the same models (i.e., the model predictions are verified against the respective model controls; the so-called "perfect model" approach).
- For the prediction experiments, between 8–12 individual years (the exact number varies from model to model) are chosen from the control simulation as start years for ensemble predictions.
- The predictability of various climate variables is then assessed using anomaly correlation coefficients (ACC).

- ☐ The anomaly correlation coefficient for Arctic-mean (north of 65°N) air temperature (*initialized on July 1*) derived from one model from the APPOSITE project;
- ☐ Arctic-mean air temperature exhibits persistent potential predictability from midsummer through autumn;
- ☐ The potential predictability of Arctic middle/upper tropospheric air temperature is **higher** in August and September than it is in October.
- ☐ APPOSITE project are consistent with our interpretation that midsummer conditions over the Arctic lead to predictive skill over the Arctic basin well into the autumn months



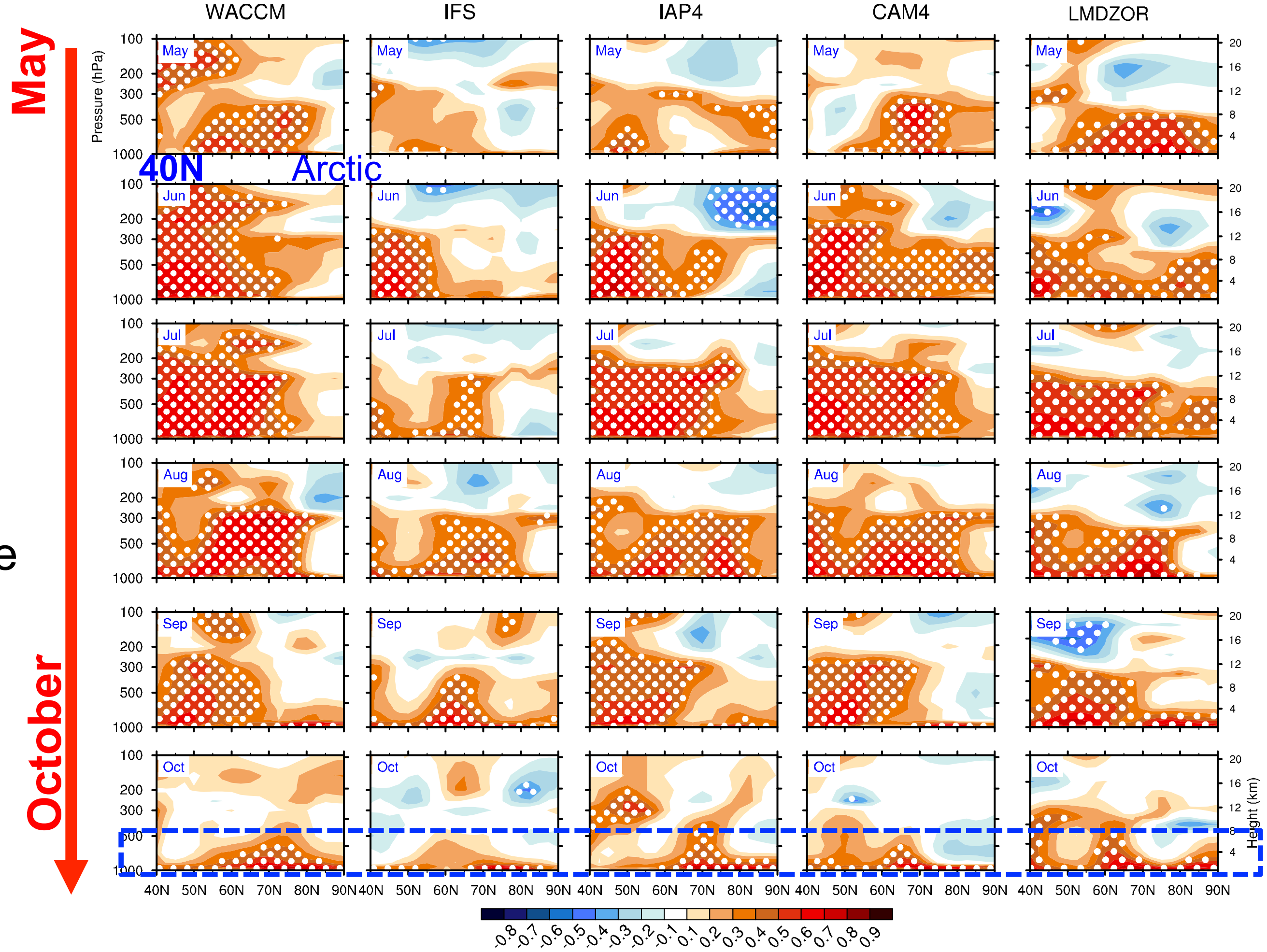
Shaded values indicate levels and months where coupled GCMs initialized July 1 exhibit significant predictive skill

- ☐ Statistical correlations cannot induce a direct causal relationship
- ☐ Model simulations were used to confirm the effect of Arctic sea ice on the Arctic atmosphere

Hindcast simulations (1982−2014) from multi-models: to test the force of Arctic sea-ice on atmosphere

- ☐ Simulations that were run with 1) daily and annually varying sea-ice but 2) *daily and annually repeating **climatological** mean SST*
- ➢ *variations in the models from year-to-year are due to either internal climate variability or changes in the boundary forcing from Arctic sea-ice anomalies*
- ☐ Five different Atmospheric General Circulation Models: CAM4, IAP4, IFS, LMDZOR, and WACCM
- ☐ Calculate the correlation between the observed & simulated air temperature over the Arctic

- Correlation between the observed & hindcast zonal-averaged air temperature in hindcast simulations
- The simulated Arctic air temperature is significantly correlated with the observed tropospheric temperature from May to September,
- but only with surface temperature in October.



Midsummer Arctic sea-ice may offer predictive skill for polar temperature throughout troposphere into September and at the surface into October.

- This study demonstrates pronounced predictive skill for Arctic climate that derives from midsummer Arctic sea-ice extent anomalies.
- Midsummer Arctic sea-ice is significantly linked to polar temperature throughout troposphere into September and at the surface into October.
- Observations and model output indicate that the predictability of Arctic climate arising from midsummer extends up to three months.

Thank you for your attention!

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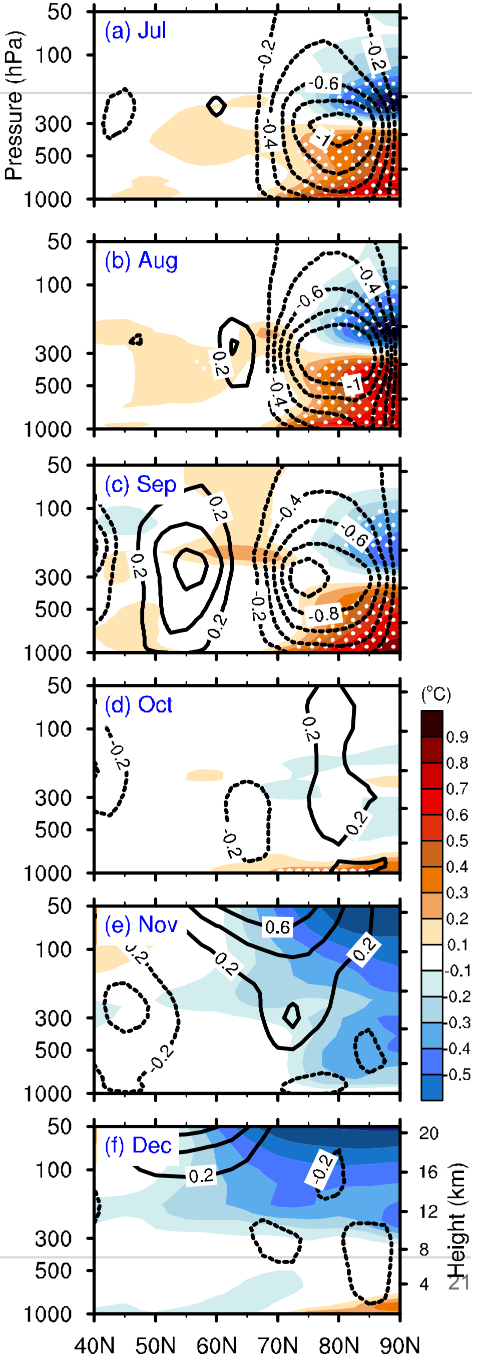
Support informations

- ☐ **Lead/lag regressions** between inverted September-mean Arctic **SIE** and monthly-mean values of zonally-averaged ***temperature & zonal wind*** for the base months
- ☐ Previous studies have emphasized the predictability of NH climate that derives from September SIE anomalies;
- ☐ An important distinction between our study and previous work is that the inferred predictability from midsummer SIE is ~2−3 months (Figures 1−3), whereas that associated with September SIE anomalies is only ~1 month;



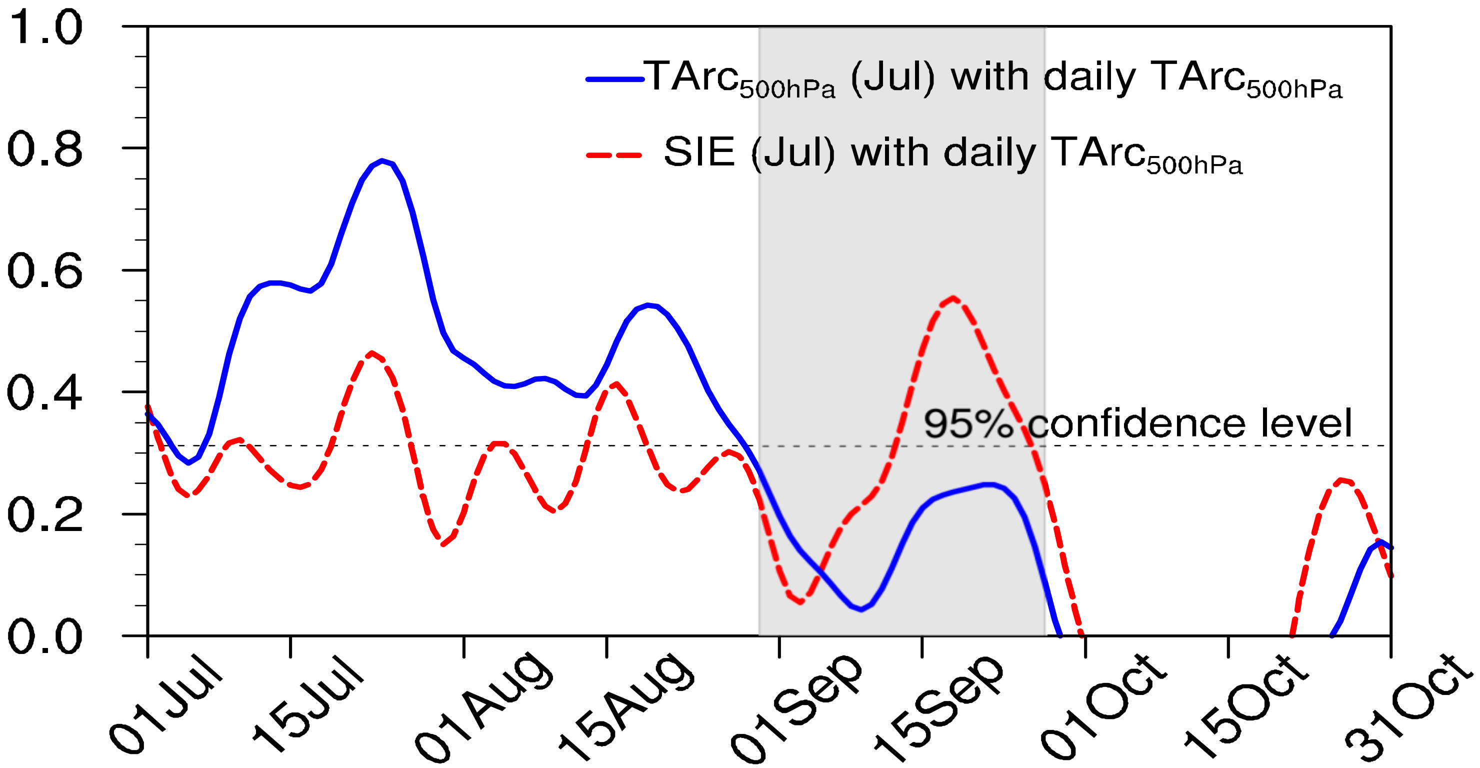
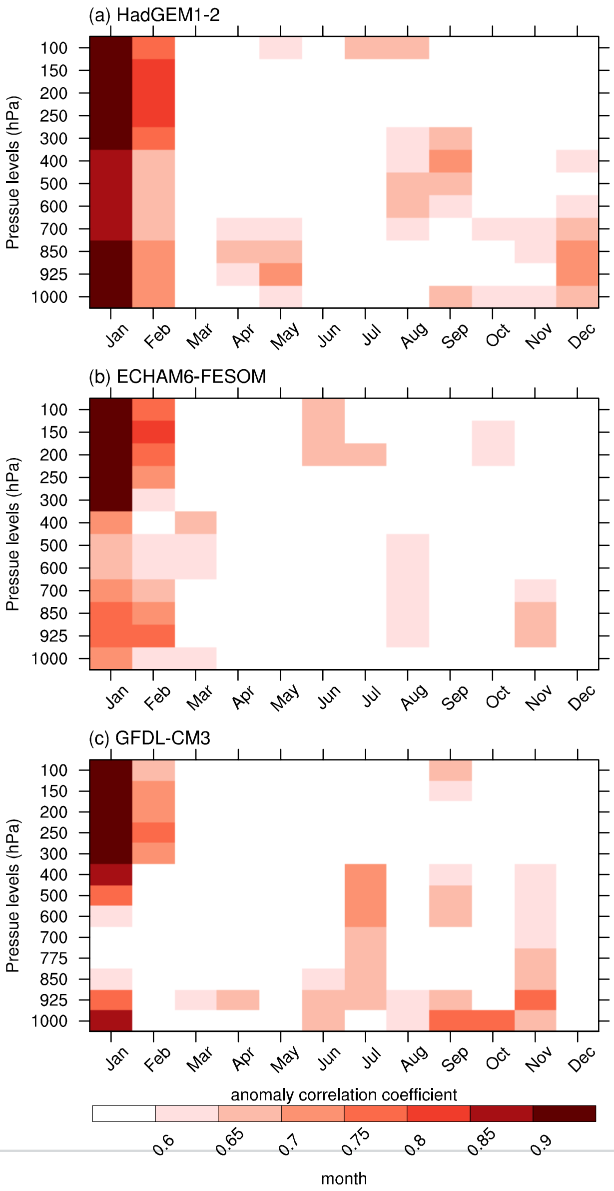


Figure S3. Correlation coefficients of daily Arctic 500-hPa temperature (TArc500hPa) from July to October with the July-mean Arctic sea-ice extent (SIE) (red curve) and July-mean TArc500hPa (blue cure). TArc500hPa is area-averaged over the Arctic (65.0°–90.0°N). The horizontal dashed line indicates the 95% confidence level. The SIE index is inverted (i.e., negative values correspond to reduction of SIE). All data is deseasonalized and detrended. Shading indicates the time from 1 September to 30 September. Daily data is smoothed with a 10-day low-pass filter.

- The anomaly correlation coefficient for Arctic-mean (north of 65°N) air temperature (*initialized on January 1*) derived from four models from the APPOSITE project;
- Similar predictive skill is not found for results initialized January 1



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