Impacts of sea ice / SST changes for the observed climate change

— GREENICE project —

Fumiaki Ogawa[1,2], Yongqi Gao[2,3], Noel Keenlyside[1,2], Torben Koenigk[4], Vladimir Semenov[5], Lingling Suo[2,3], Shuting Yang[6], Tao Wang[7]

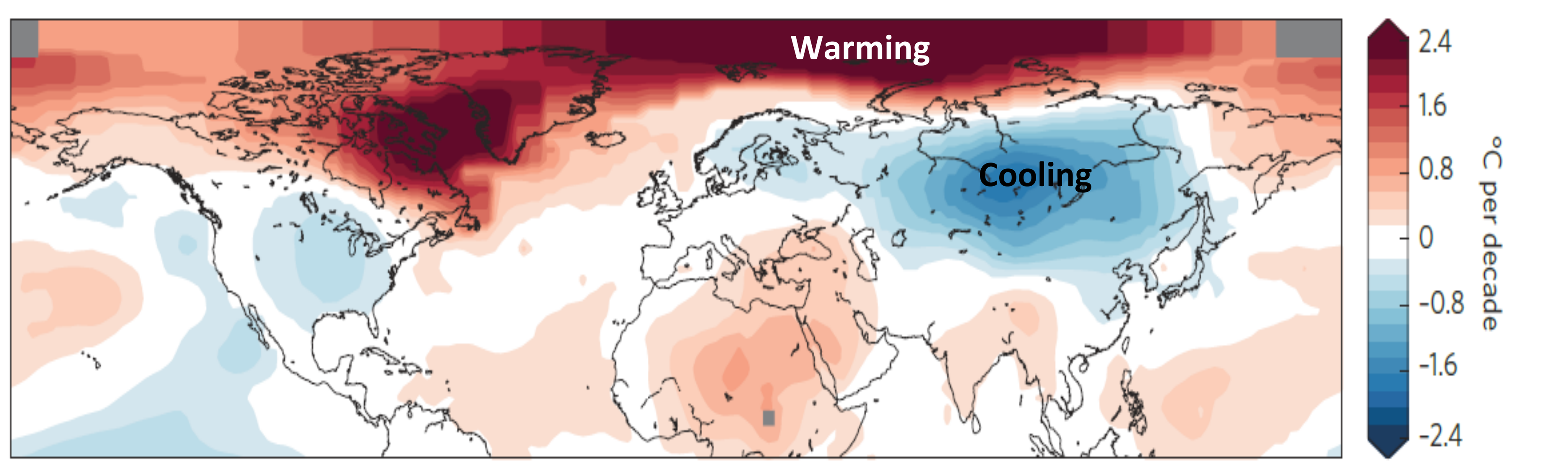
[1]Geophysical Institute, University of Bergen, Norway. [2]Bjerknes Centre for Climate Research, Norway. [3]Nansen Environmental and Remote Sensing research Center, Norway. [4]Swedish Meteorological and Hydrological Institute, Sweden. [5]Helmholtz Centre for Ocean Research Kiel, Germany. [6]Danish Meteorological Institute, Denmark. [7]Chinese Academy of Sciences, Institute of Atmospheric Physics, China.

Corresponding author: Fumiaki Ogawa email: fumiaki.ogawa@gfi.uib.no

1. Sea-ice reduction and its possible impacts

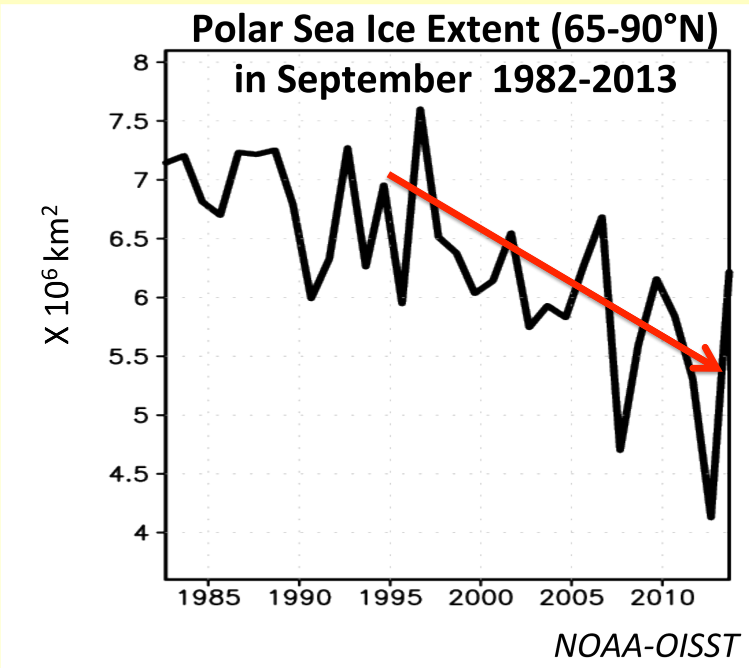
Arctic amplification of global warming

Winter-time (DJF) surface temperature trends 1990-2013



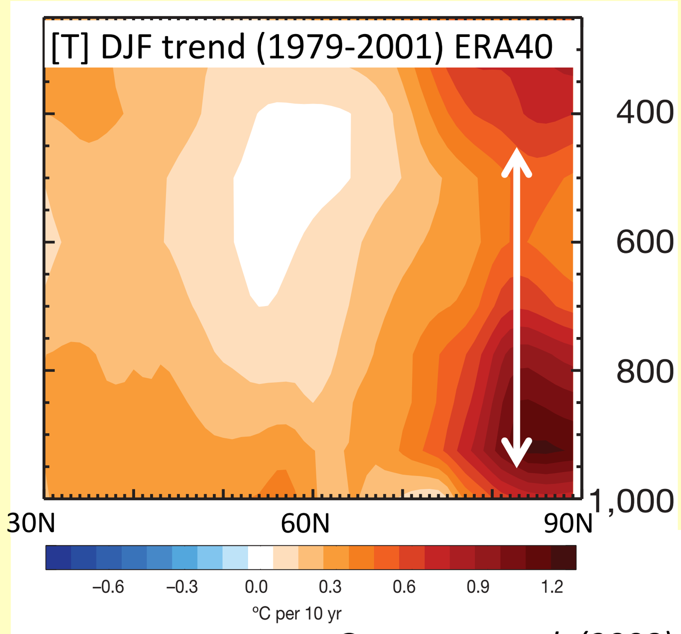
Cohen et al. (2014)

Sea Ice reduction



NOAA-OISST

Upward extended warming



Graversen et al. (2008)

- The arctic region has warmed more than twice as fast as the global average (*Cohen et al., 2014*)
  - Impact of sea-ice reduction (*Screen et al. 2012; 2013*)
  - Poleward energy flux by atmospheric internal dynamics (*Graversen et al., 2008*)
  - Greenland warming response to tropical SST change (*Ding et al., 2014*)
- Mid-latitude winter is getting severer (*Cohen et al., 2014*), especially in Siberia.
  - Sea-ice reduction may have influenced (*Mori et al., 2014*)
  - No evidence of sea-ice impact (*McCusker et al., 2016*)

... need to be addressed for sustainable-growth of society (= "green-growth").

2. Experiments and results from GREENICE project

Coordinated AGCM experiments to assess the robustness of atmospheric response to SIC & SST changes

Forced with observed SST and SIC changes, considered separately and together

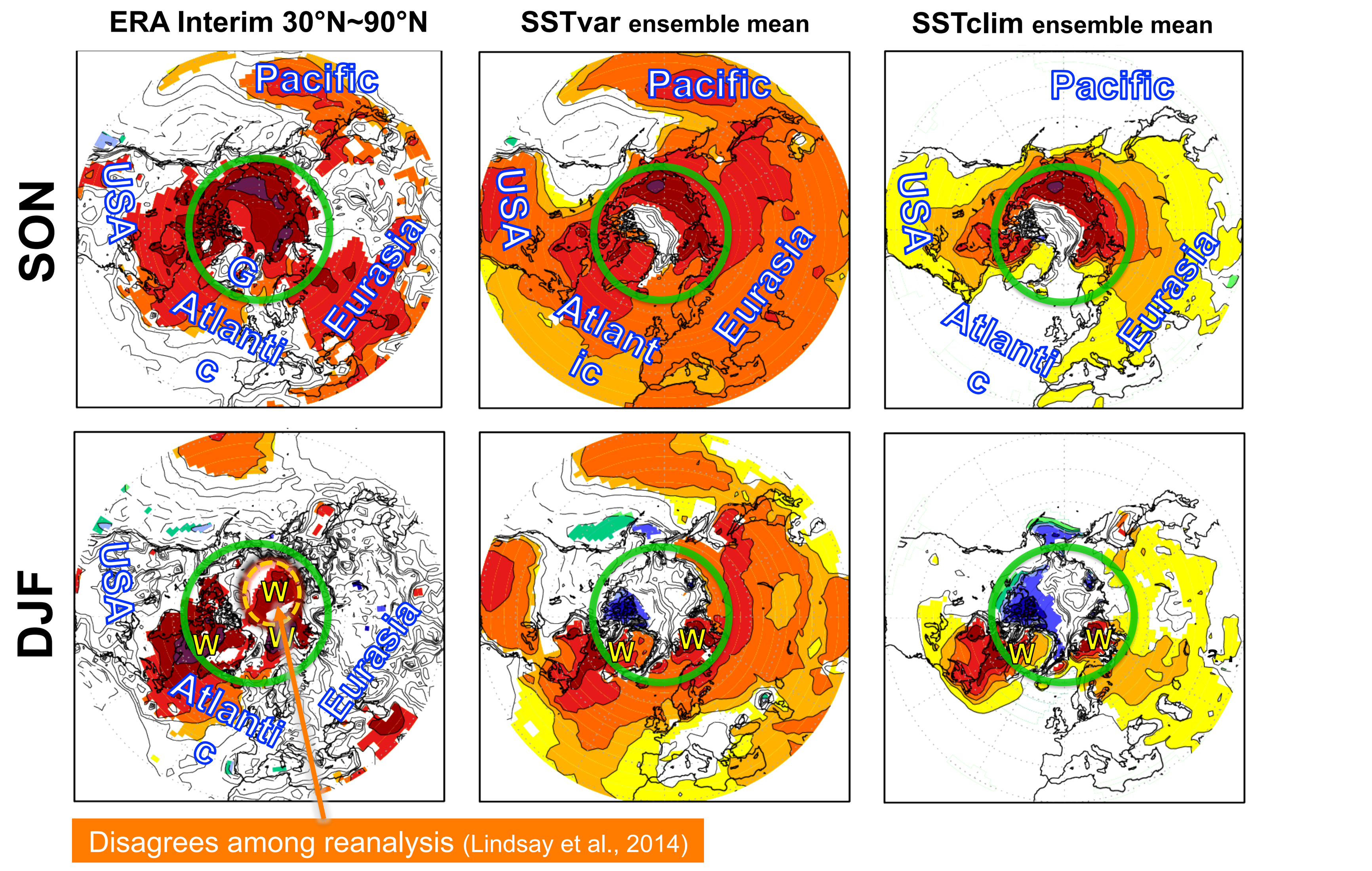
Two ensembles

– Hindcast experiment ("**SSTvar**")
- 1982-2013
- CMIP5 protocol (RCP8.5)
- NOAA OI satellite derived data
- Full daily variations in SIC and SST
- 7 different models

Model	Resolution	SSTvar	SSTclim
CAM4	1° x1 °, L26	20 members	20
WACCM	1° x1 ° L66	20	20
IFS	T255 L91	20	20
LMDZOR	2.5°x1.25°L39	20	20
IAP	T85L19	9	-
AFES	T79 L56	30	-

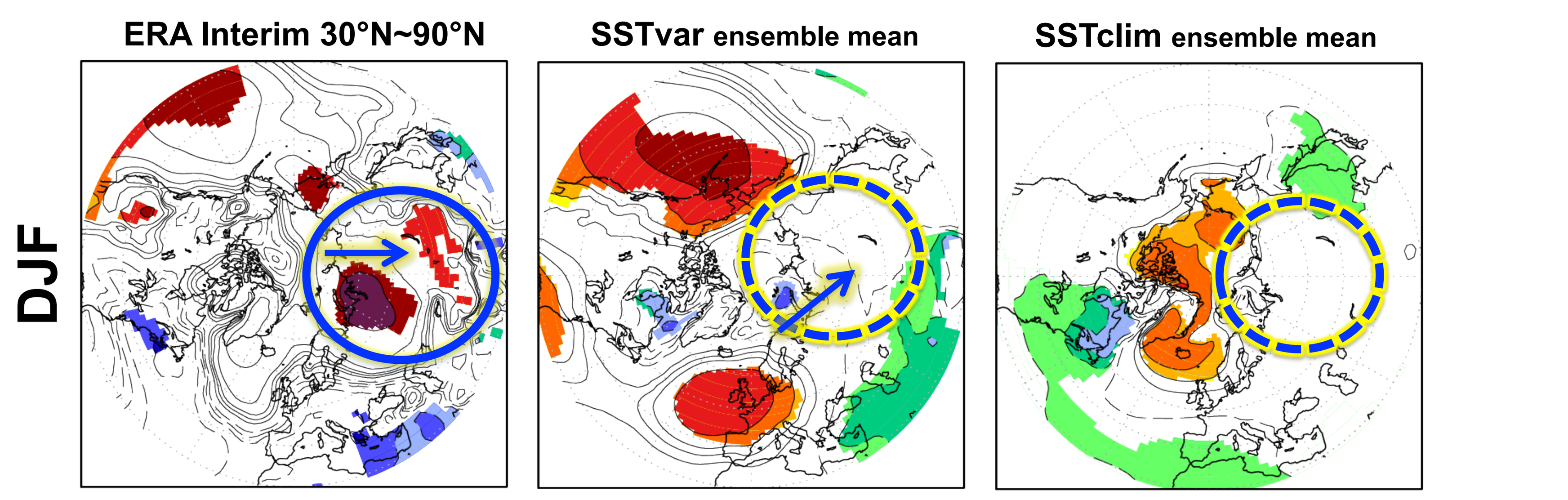
– SST climatology experiment ("**SSTclim**")
- Full daily variations in SIC (same as above)
- SST is replaced to daily climatology (adapted from *Screen et al., 2013*)

Trend of 2-m temperature [1982–2013]



- Significant polar surface warming pattern is similar to reanalysis in both experiments.
  → dominance of the sea ice impact.
- Greenland warming can be reproduced without SST change.
  → Tropical SST change (*Ding et al., 2014*) seems not required.
- Both of the experiments simulate warming trends in Siberia.
  → The siberian cooling is not likely to be driven by sea ice changes.

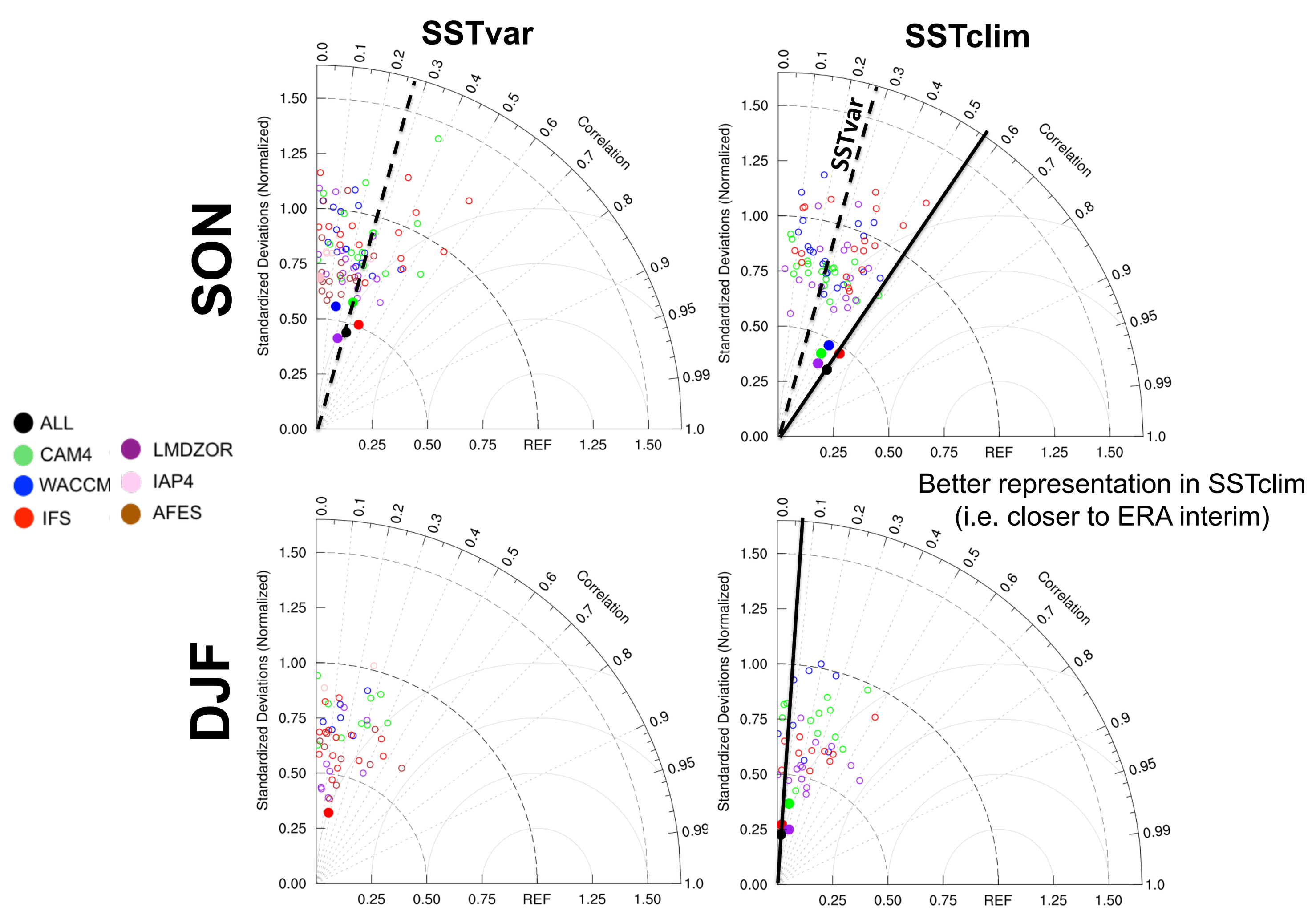
Trend of SLP [1982–2013]



- No positive SLP trend → No Siberian cooling (*McCusker et al., 2016*)

Similarity of t2m trend with ERAI (over 30°- 90°N Land)

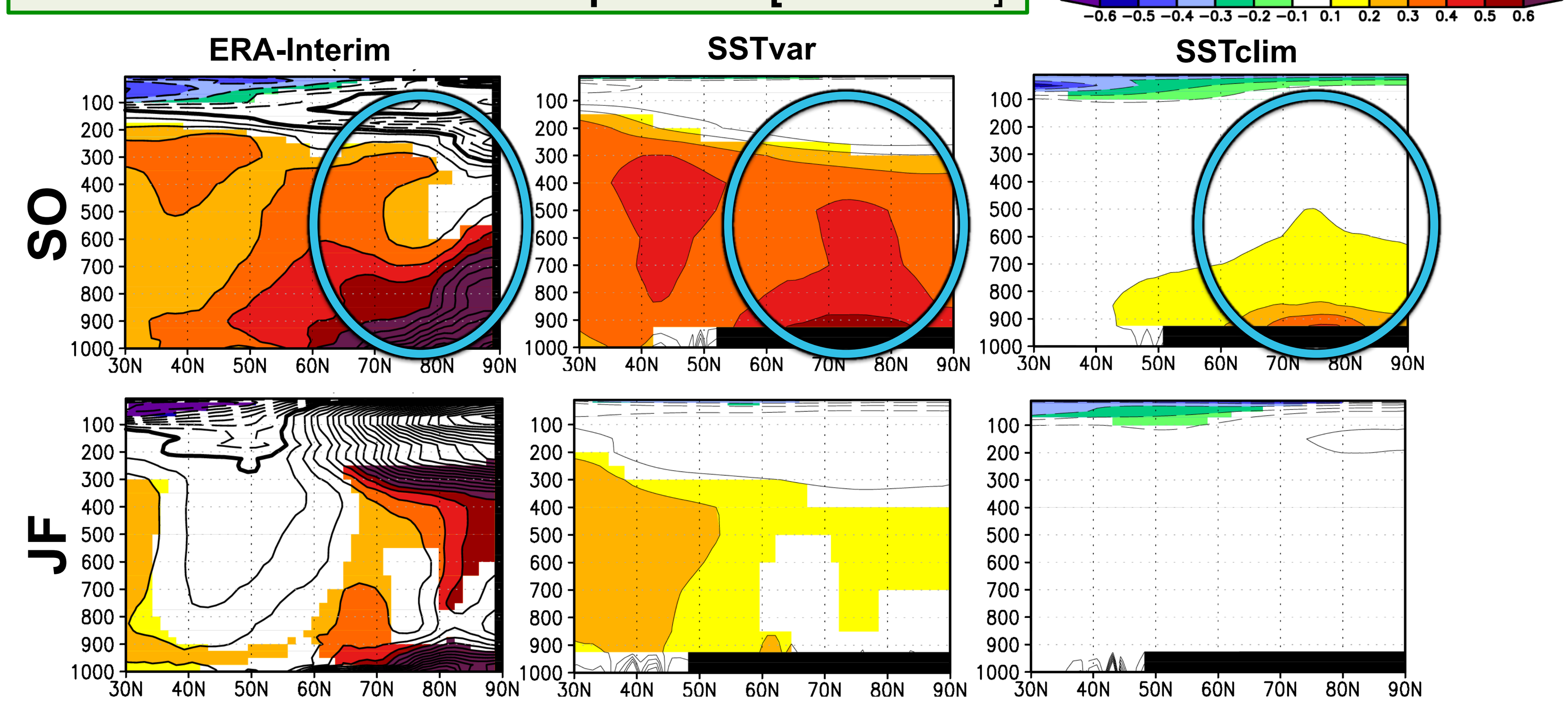
*** Observation is one realization



3. Summary

- The arctic amplification of the surface temperature warming in polar latitudes seems mostly due to the sea Ice changes both in autumn and winter.
- In winter, the Greenland surface warming can occur without tropical SST changes. (opposing to Ding et al., 2014)
- Siberian cooling seems to be caused by internal atmospheric variability instead of SIC and SST. (supporting McCusker et al., 2016)
- The impact of sea ice changes on arctic amplification is confined near the surface; warming aloft is mainly due to SST (supporting Screen et al., 2012; 2013).

Trend of zonal mean air temperature [1982–2013]



Observed arctic amplification extends upward.

The upward extention was reproduced with SST changes.

The extention reduced without SST changes. (*Screen et al., 2012*)

References

*Cohen et al., 2014, NGEO, **7**, 627-637.*
*Ding et al., 2014, Nature, **509**, 209-212.*
*Graversen et al., 2008, Nature, **451**, 53-56.*
*Lindsay et al., 2014, J. Climate, **27**, 2588-2606.*
*McCusker et al., 2016, NGEO, **9**, 838-842.*
*Mori et al., 2014, NGEO, **7**, 869-873.*
*Screen et al., 2012, GRL, **39**, L10709.*
*Screen et al., 2013, J. Climate, **26**, 1230-1248.*