Arctic Warming Impacts: Uncertainties, Implications and Prospects

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2 Nansen-Zhu International Research Center, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China

3 University of Bergen, Norway

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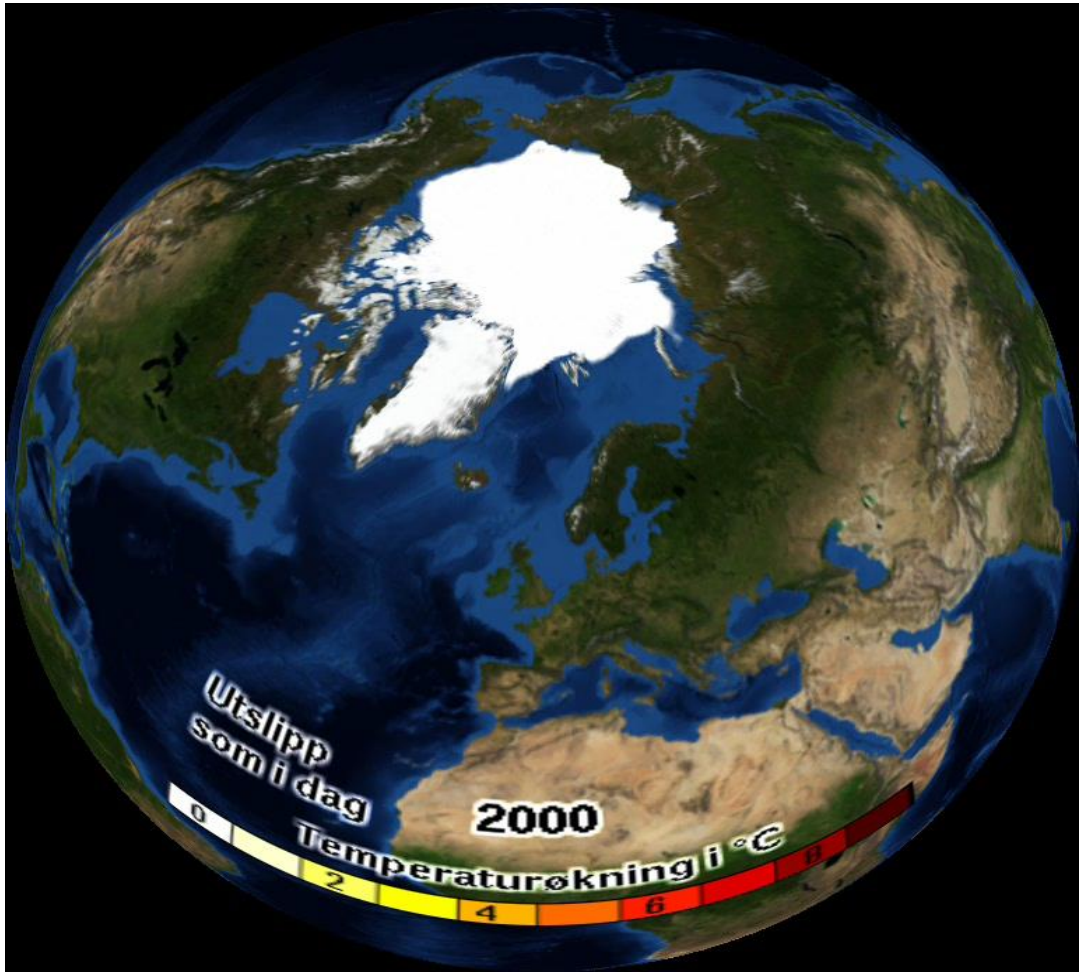
Projected Arctic Sea Ice



Courtesy of M. Bentsen

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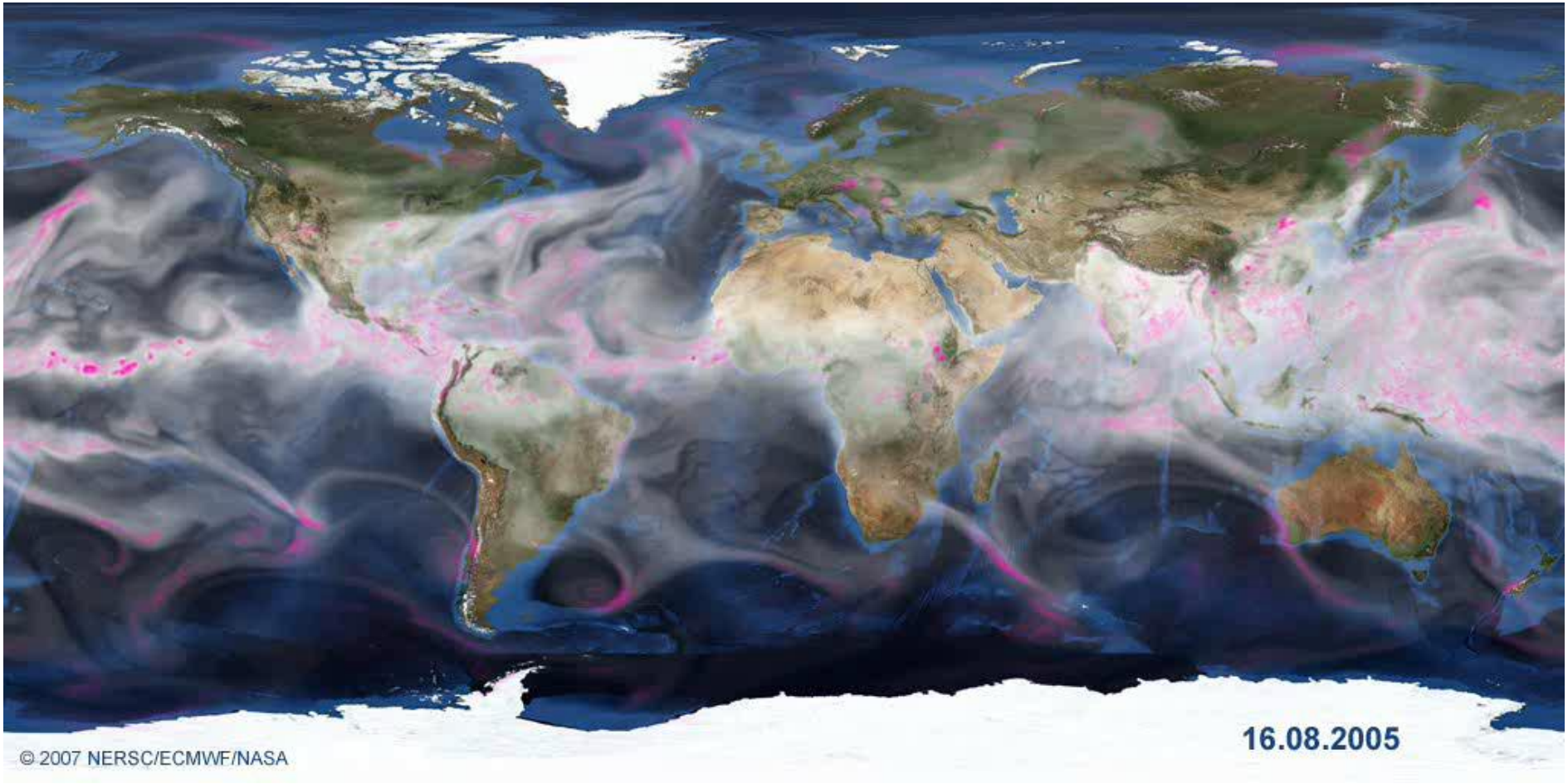
Water Vapor Transport



Courtesy M. Bentsen

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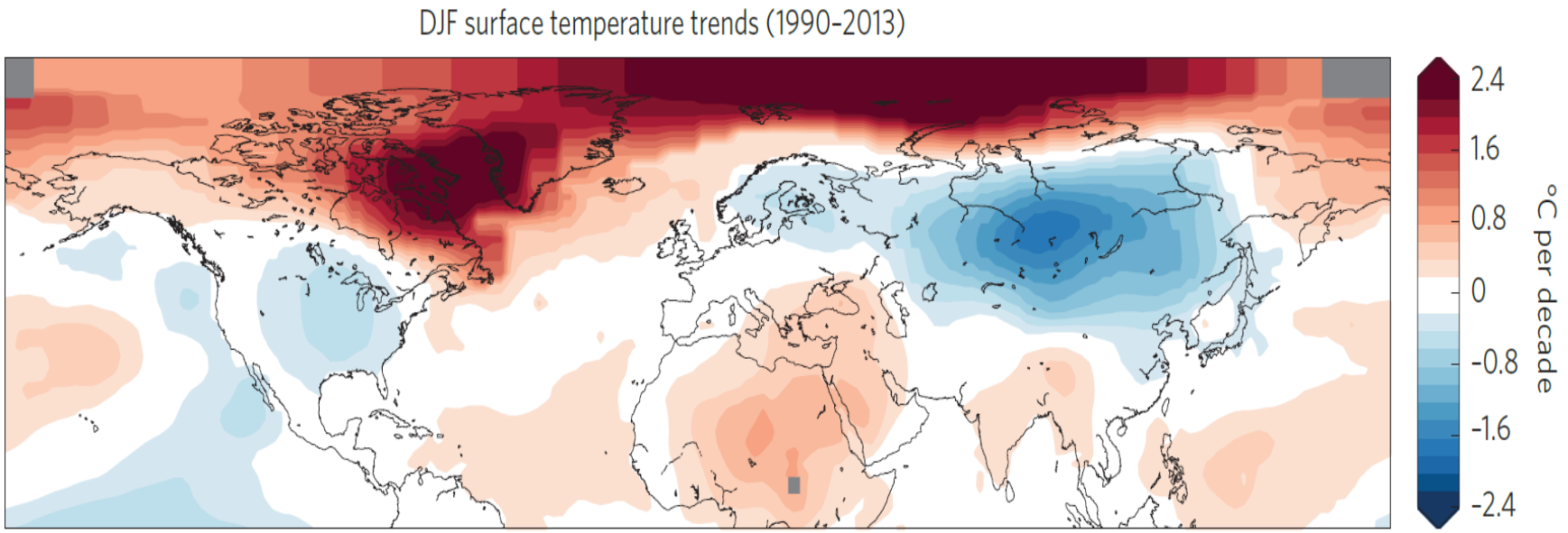
Arctic Warming and Eurasian Cooling



Cohen et al., 2014

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Northeast Passage

Travel time saved15 Days

http://news.sina.com.cn/c/2013-08-12/132027927515.shtml

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Arctic Warming (Amplification)

Concept of Polar/Arctic amplification of changes in Earth surface temperature induced by changes in concentration of gases in atmosphere was hypothesized in 1896 by Arrhenius

Courtesy of Leonid Bobylev

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On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground

Svante Arrhenius

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.

Arrhenius's paper is the first to quantify the contribution of carbon dioxide to the greenhouse effect (Sections I-IV) and to speculate about whether variations in the atmospheric concentration of carbon dioxide have contributed to long-term variations in climate (Section V). Throughout this paper, Arrhenius refers to carbon dioxide as "carbonic acid" in accordance with the convention at the time he was writing.

Contrary to some misunderstandings, Arrhenius does not explicitly suggest in this paper that the burning of fossil fuels will cause global warming, though it is clear that he is aware that fossil fuels are a potentially significant source of carbon dioxide (page 270), and he does explicitly suggest this outcome in later work.

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* *By* Prof. SVANTE ARRHENIUS *.

I. *Introduction : Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this : Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet § ; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.
† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).
‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.
§ *Comptes rendus*, t. vii. p. 41 (1838).

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Arctic Warming (Amplification)

- ✓ Sea ice
- ✓ Heat and moisture transport
- ✓ Inflows of Atlantic and Pacific waters
- ✓ Local radiative effect
- ✓ Increased emittance of blackbody
- ✓ Reduced air pollution
- ✓ Phytoplankton

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Arctic Warming (Amplification)

- ✓ Local Processes
- ✓ Remote Processes
- ✓ Combined

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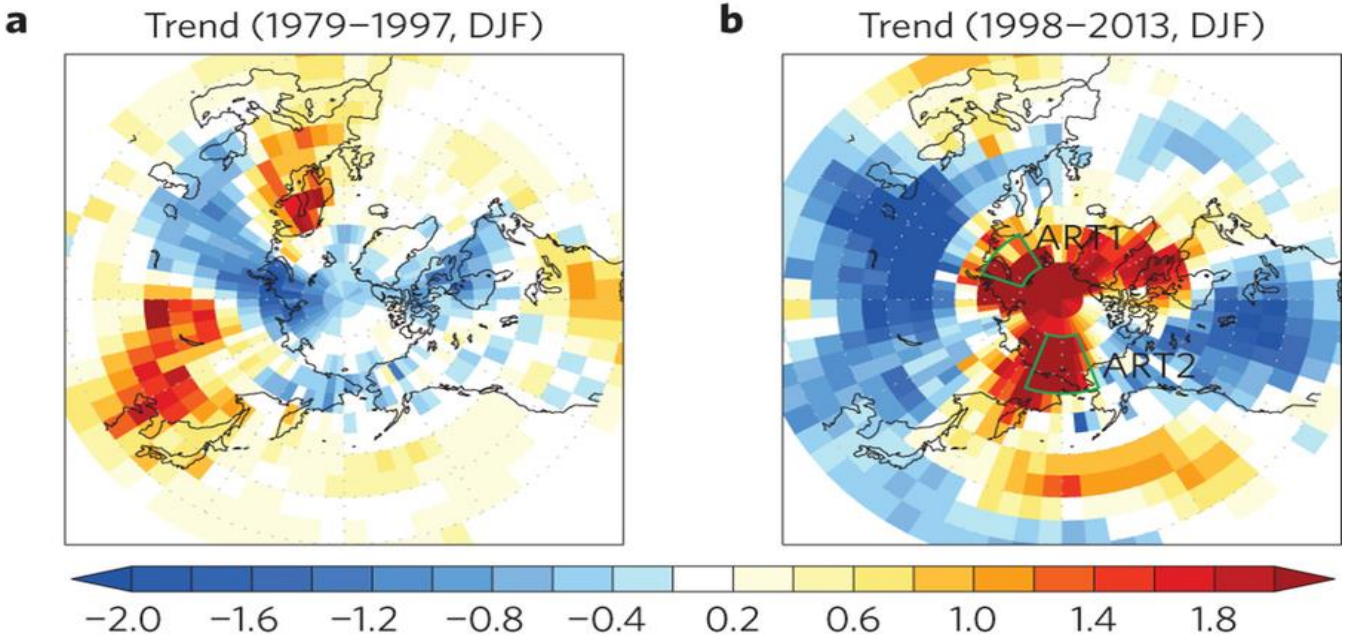
Arctic Warming



Kug et al. 2015

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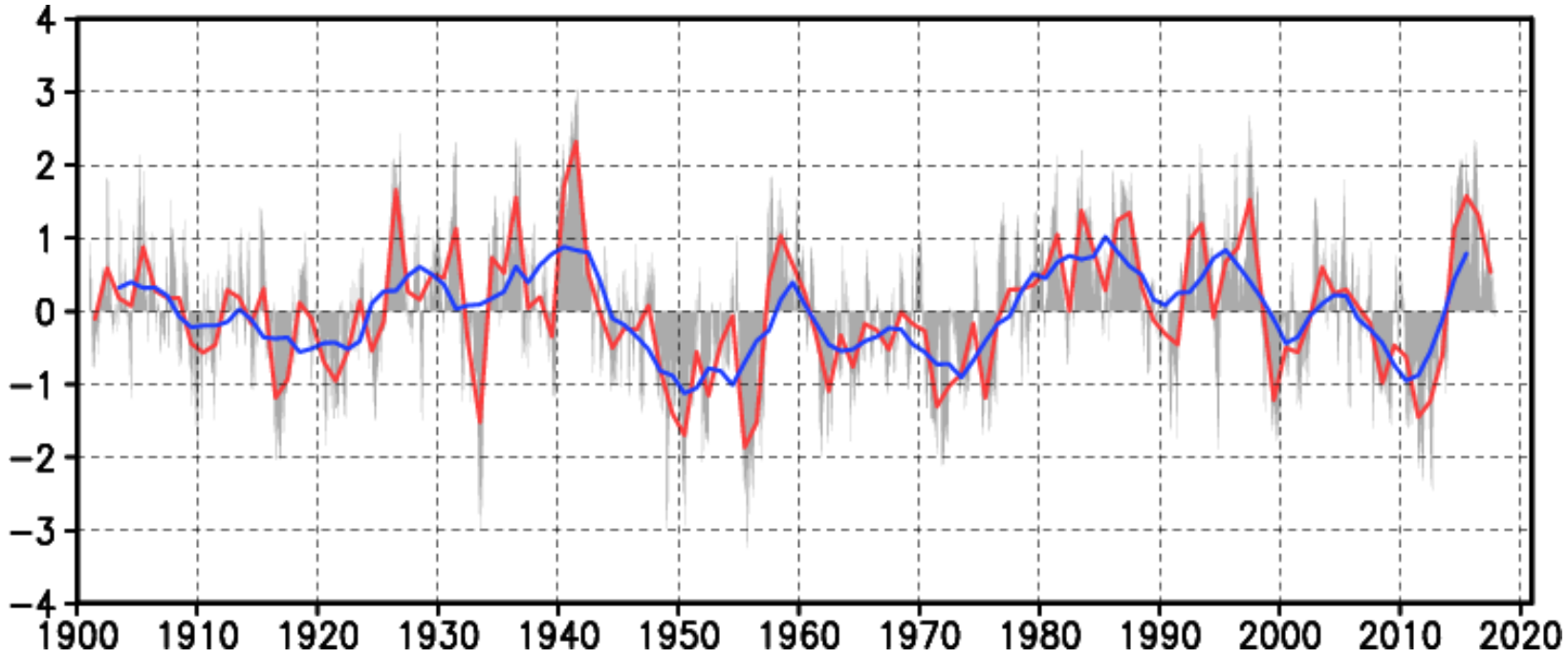
PDO (1901-2018)



http://ds.data.jma.go.jp/tcc/tcc/products/elnino/decadal/pdo_doc.html

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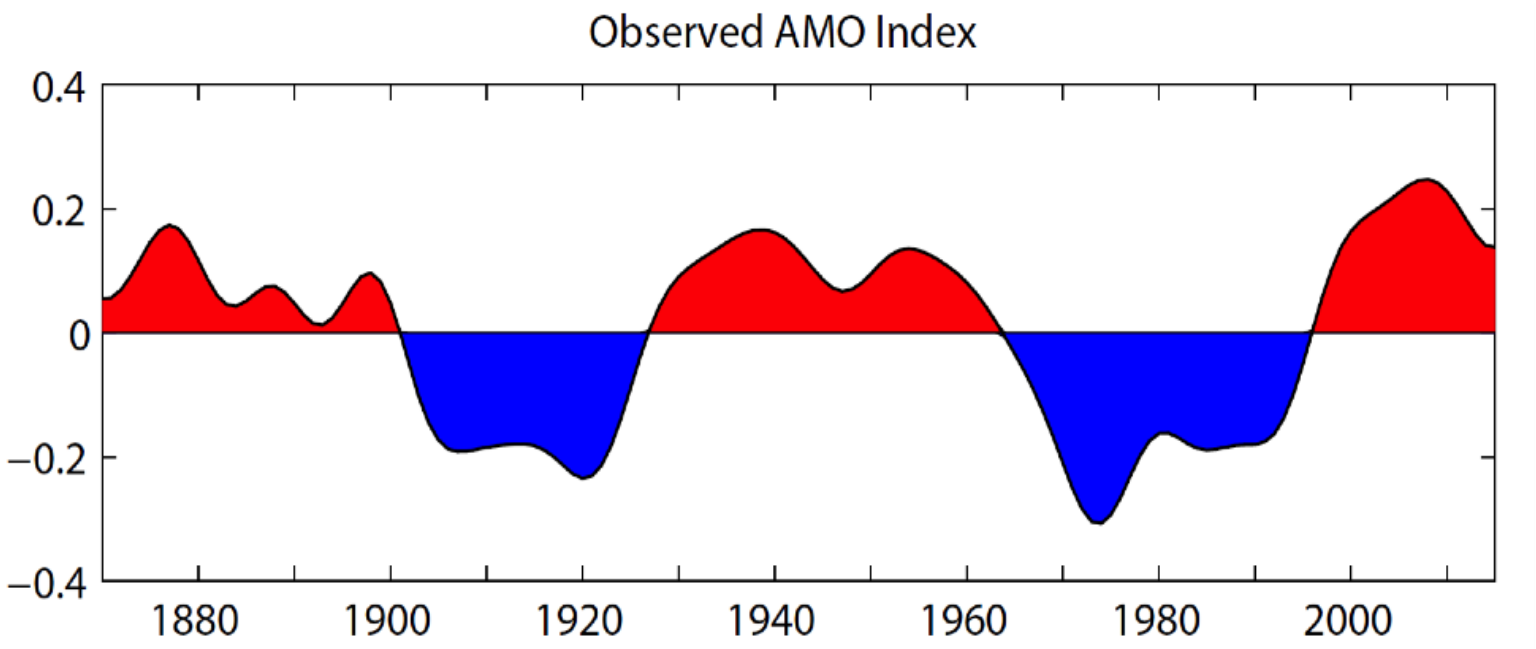
AMO (1870-2015)



https://climatedataguide.ucar.edu/climate-data/atlantic-multi-decadal-oscillation-amo

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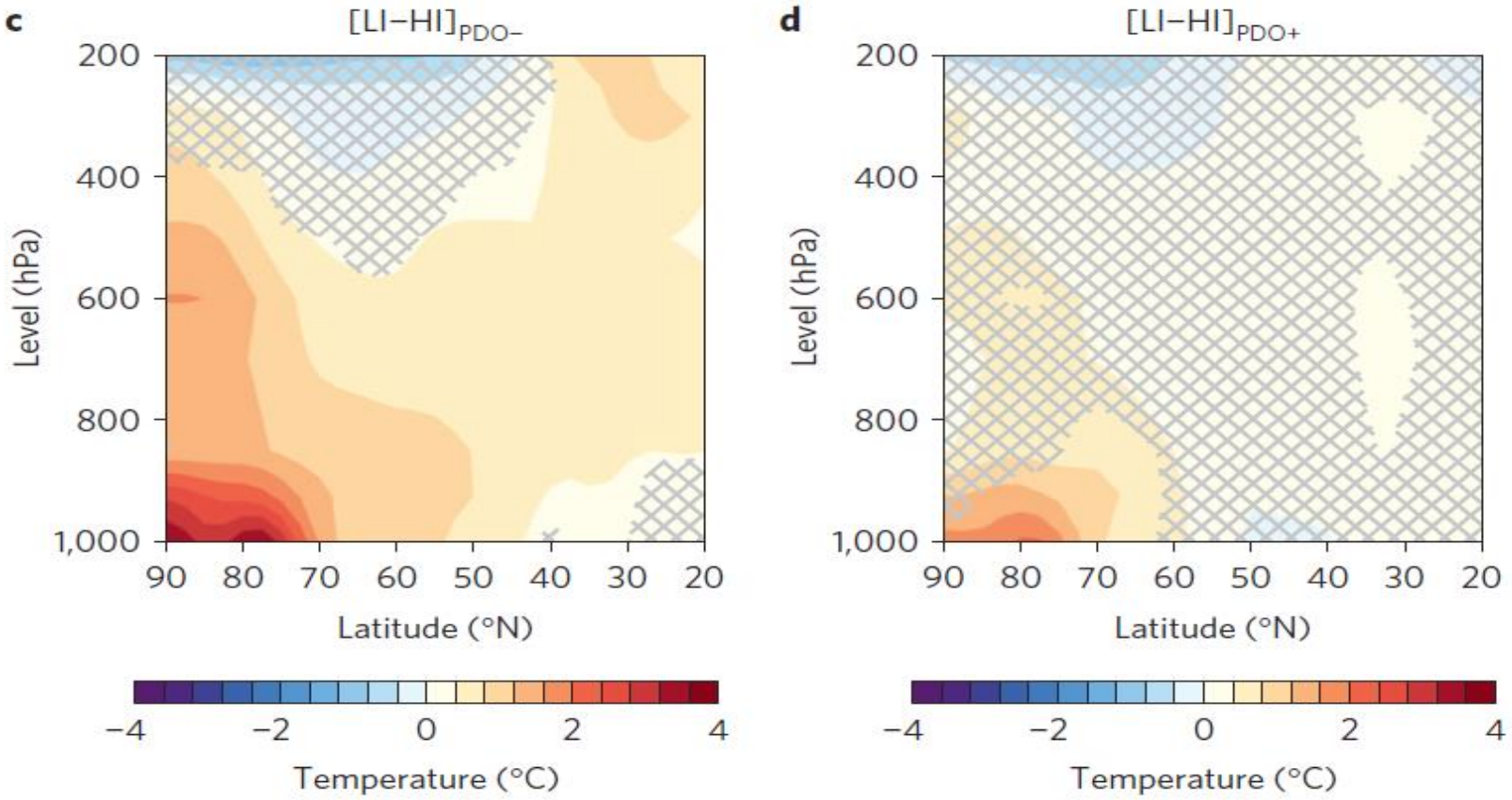
Arctic Warming (PDO)



Screen and Francois 2016 *Nature Climate Change*

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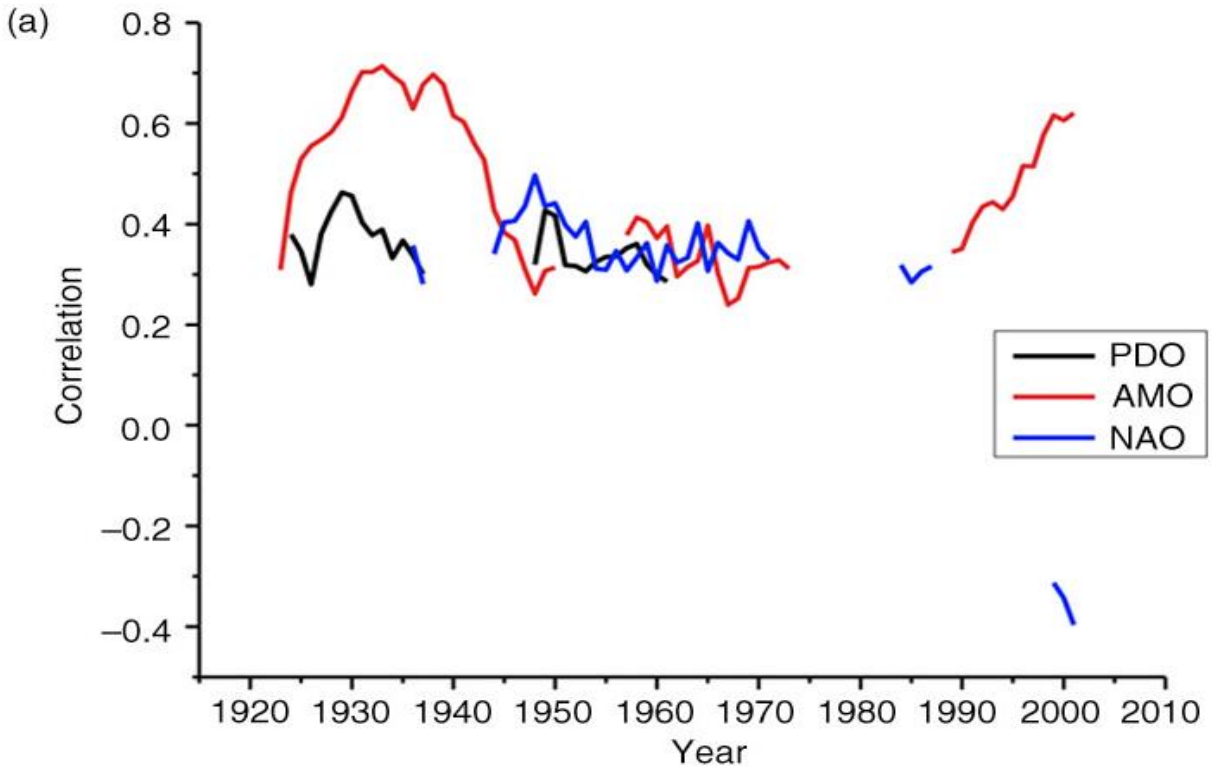
Arctic Warming (AMO)



Johannessen et al. 2016 *Tellus*

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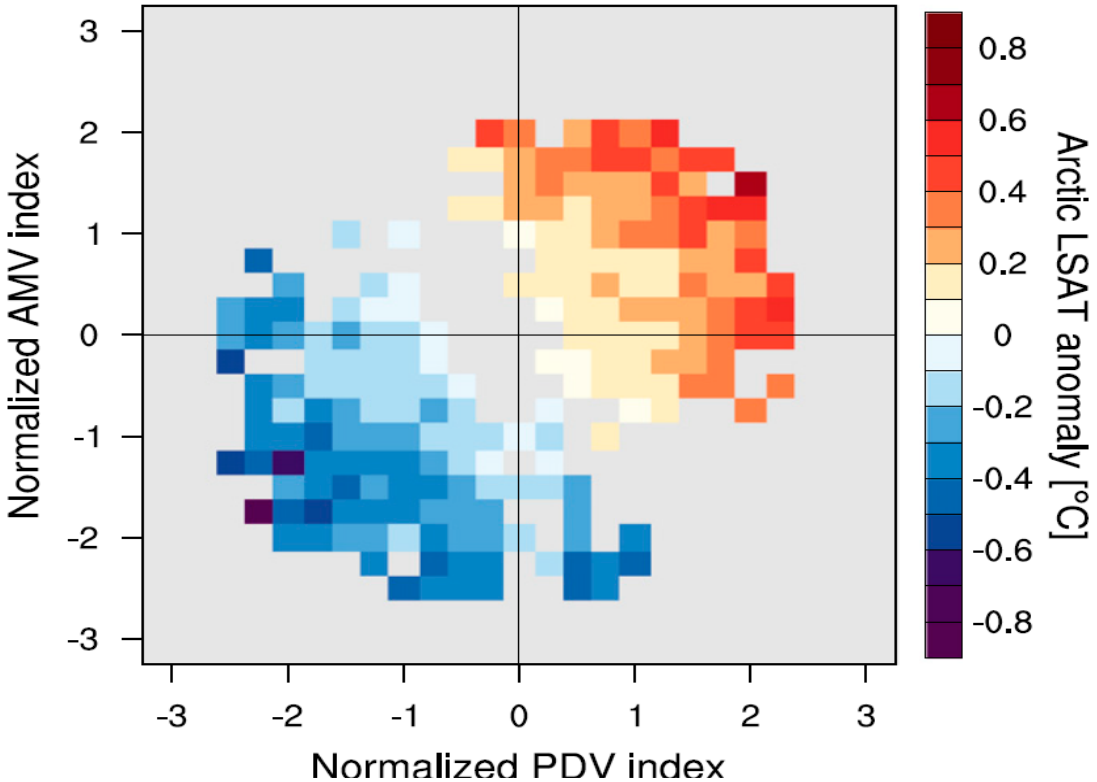
Early Arctic Warming
AMO and PDO



Tokinaga et al. 2017, PNAS

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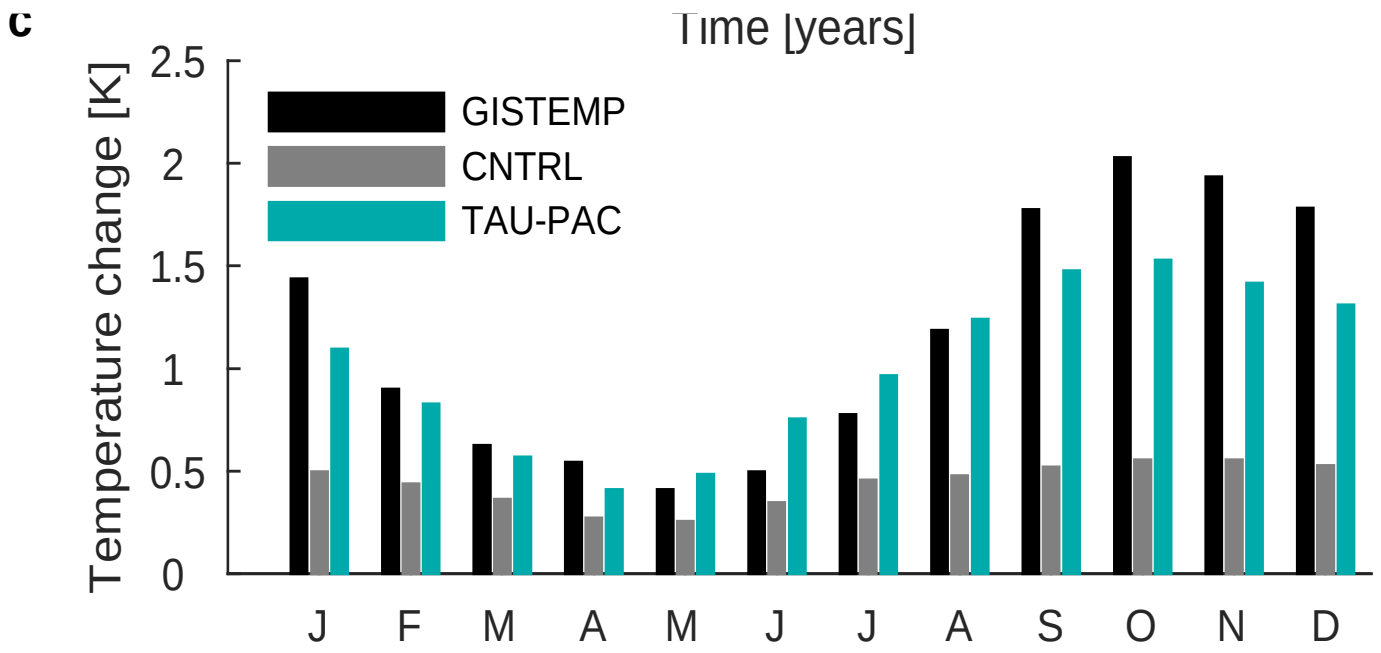
Early Arctic Warming
PDO

Svendsen, L., Keenlyside. N., Bethke, I., **Gao, Y.Q.,** Omrani, N.E. (2018): Pacific contribution to the early 20th century warming in the Arctic. *Nature Climate Change, http://dx.doi.org/ 10.1038/s41558-018-0247-1*



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Extratropical Ocean Warming since the 1990s

Li, F., Wang H.J. and Gao Y.Q. (2015), Journal of Climate

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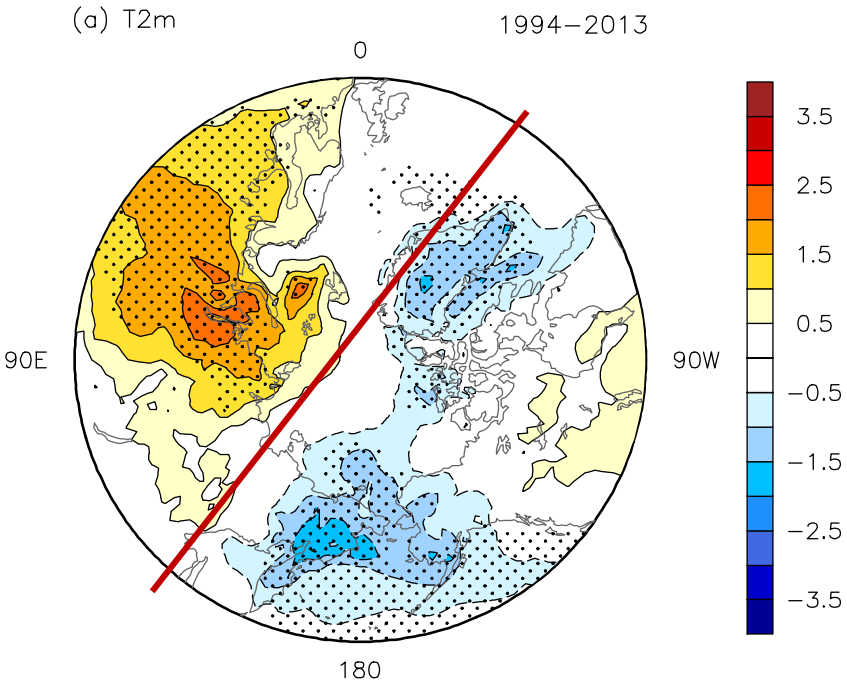
Teleconnection of ET warming

Air temperature at 2 m



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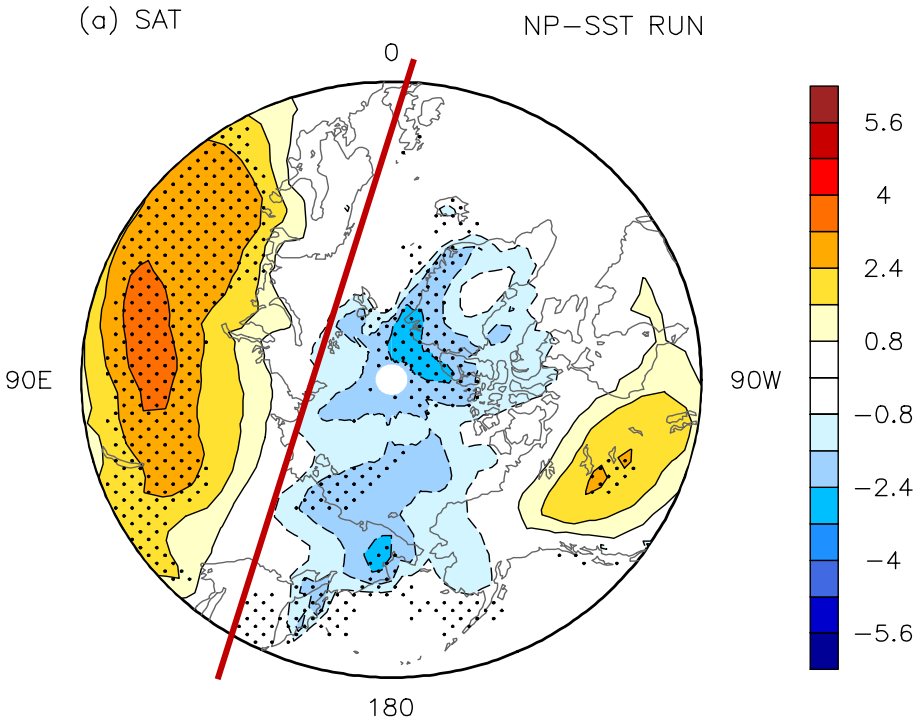
Simulated impact of NP-SST (Exp.4 minus Exp.2)



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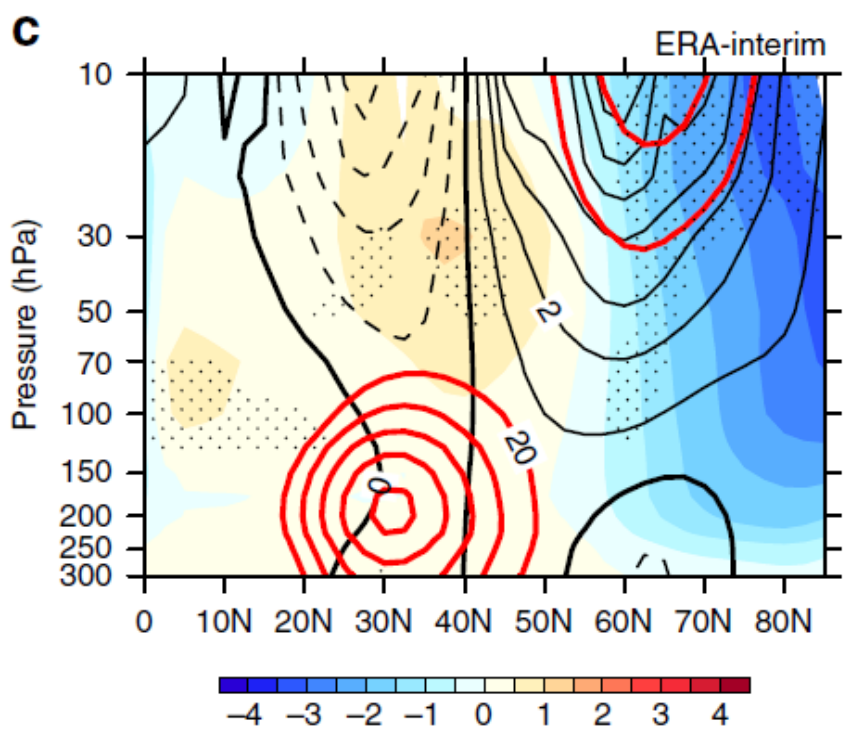
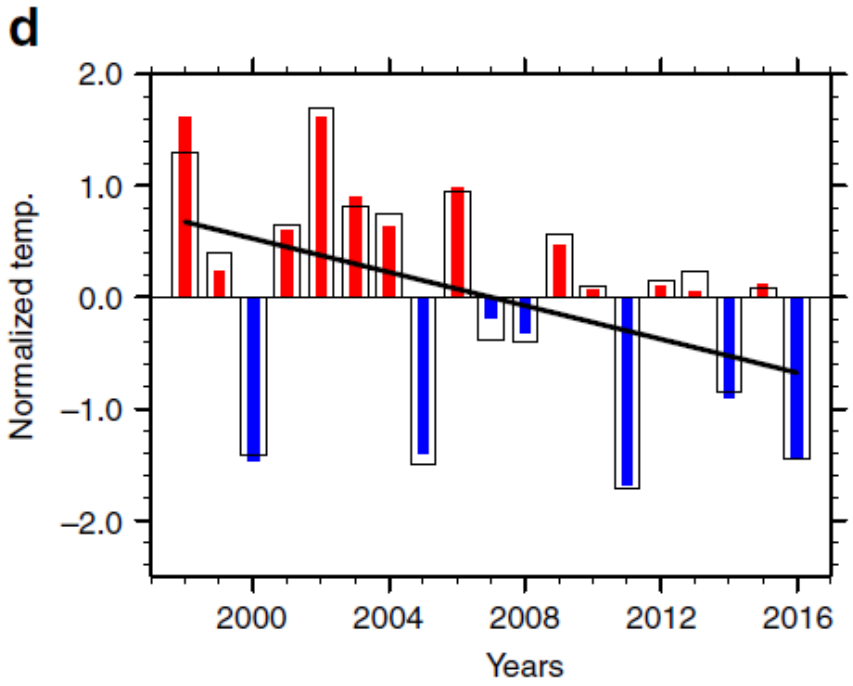
Strengthening of SPV

Hu, D., Guan, Z.Y., Tian, W.S., Ren, R.C. (2018): Recent strengthening of the stratospheric Arctic vortex response to warming in the central North Pacific. *Nature Communication*





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Arctic Sea Ice Impact

- Dating back in early 20th century…

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Cold Spells (East Asia)

Tao (1959) Almost all cold spells in China (East Asia) were originated from Arctic Ocean, particularly from the Barents/Kara Seas. When cold spells took place, there was an adjustment of planenary waves over the Eurasian continent.

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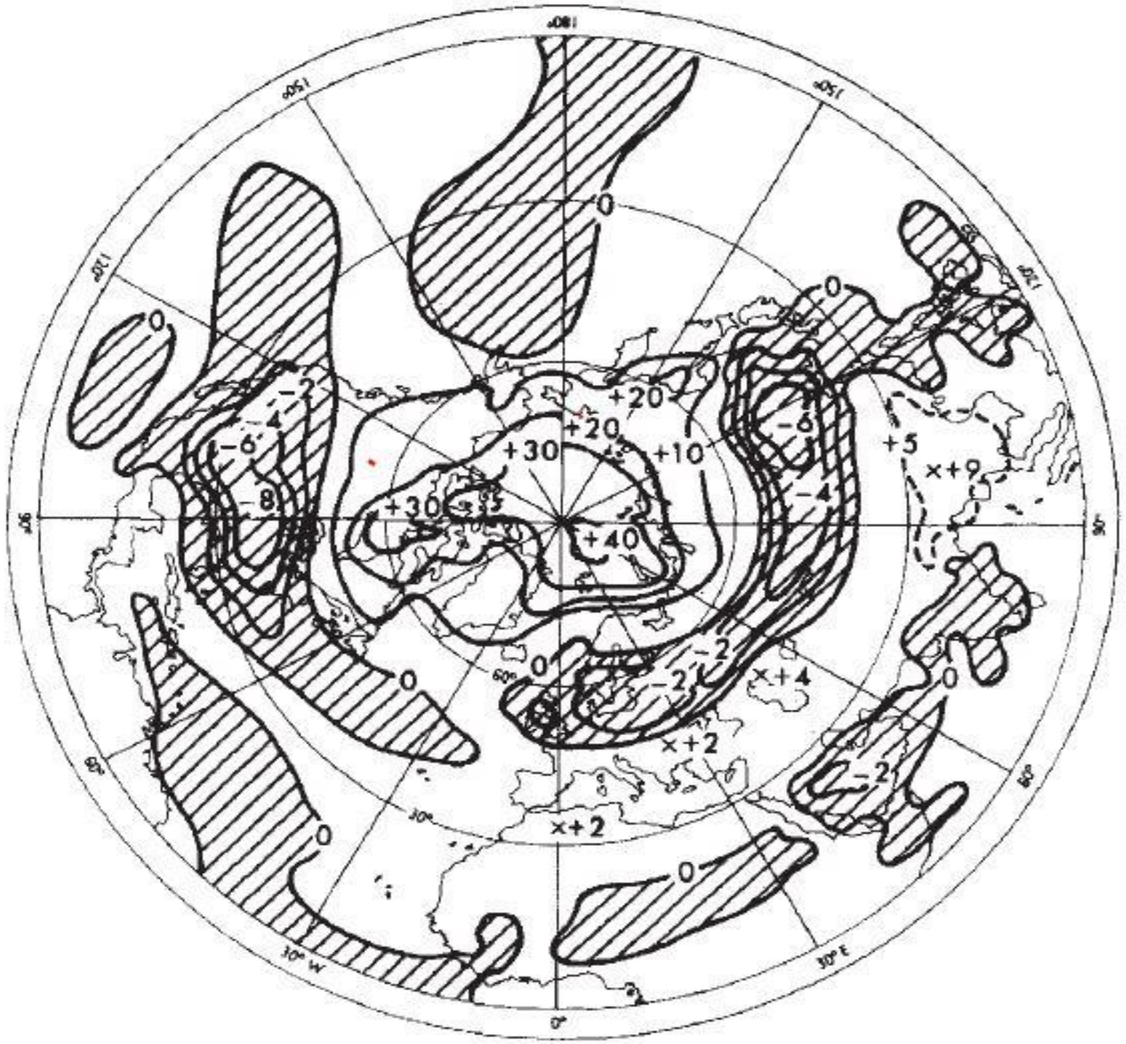
第30卷 第3期 气 象 学 报 Vol. 30, No. 3
1959 年 8 月 ACTA METEOROLOGICA SINICA August, 1959

十年来我国对东亚寒潮的研究

陶 詩 言
(中国科学院地球物理研究所)

解放后十年来,随着天气预报业务的建立, 天气预报的研究也有了迅速的发展,其中寒潮研究的論文占据相当大的数量.这是可以理解的,因为东亚的寒潮活动不但会引起災害性天气,而且寒潮的活动往往同許多重要天气系統的发生和发展相联系. 本文的目的,就想将最近十年来有关东亚寒潮活动的一些問題,例如寒潮的过程和爆发条件,寒潮冷鋒的結构,以及寒潮和天气等等,作一簡短的总結. 下面准备就五个方面来討論这个問題.

Atmospheric Impact (AGCM)



Newson, 1973
Nature

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Arctic Sea Ice and Climate (Weather)

- Bodikova (2009)
- Bader et al. (2011)
- Vihma (2014)
- Cohen et al. (2014)
- Gao et al. (2015)
- Overland et al. (2015)
- Coumou et al. (2018)
- Screen et al. (2018)

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Eurasian Cooling

- Arctic warming (sea ice decline);
- La Nina impact;
- AMO impact
- Natural variability

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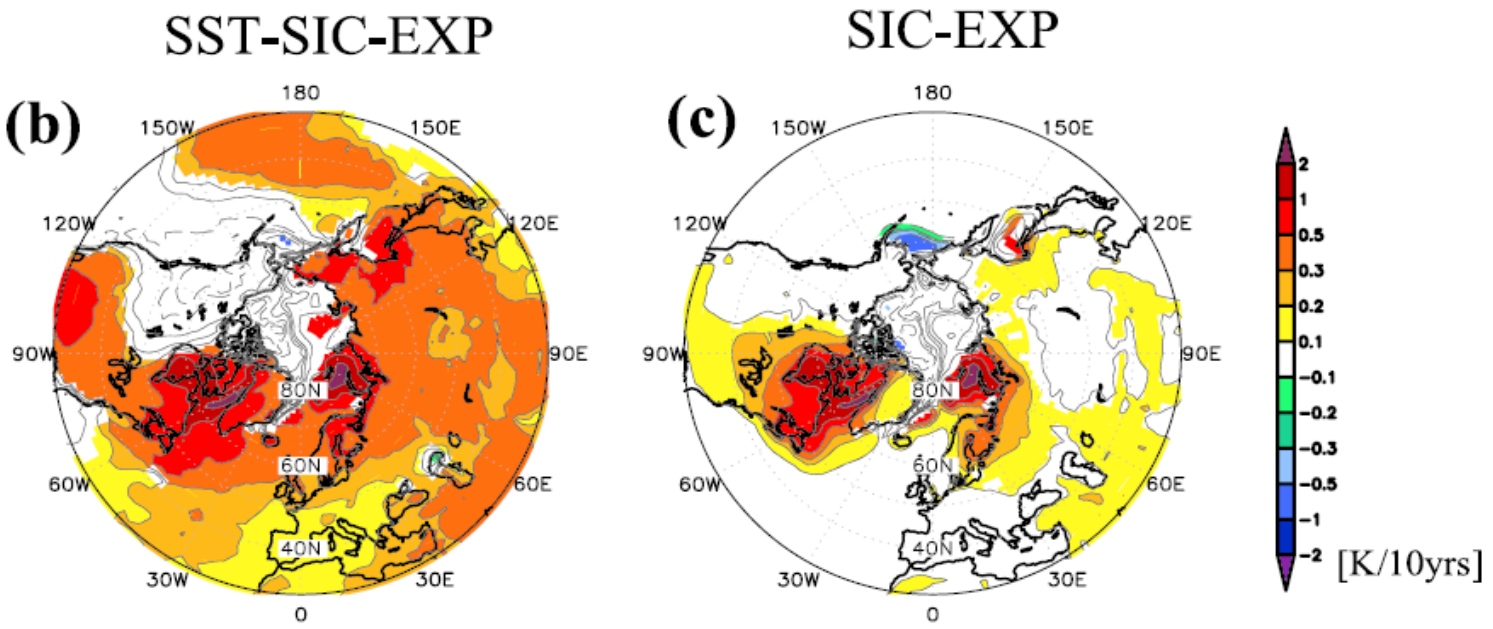
Evaluating Impacts of Recent Arctic Sea Ice Loss on the Northern Hemisphere Winter Climate Change

Ogawa, F., Keenlyside, N., **Gao, Y.Q.**, Koenigk, T., Yang, S.T., Suo, L.L., Wang, T., Gastineau, G., Nakamura, T., Cheung, H.N., Omrani, N.E., Ukita, J., Semenov, V. (2018): Evaluating impacts of recent Arctic sea-ice loss on the northern hemisphere winter climate change. *Geophysical Research Letters*, doi:10.1002/2017GL076502



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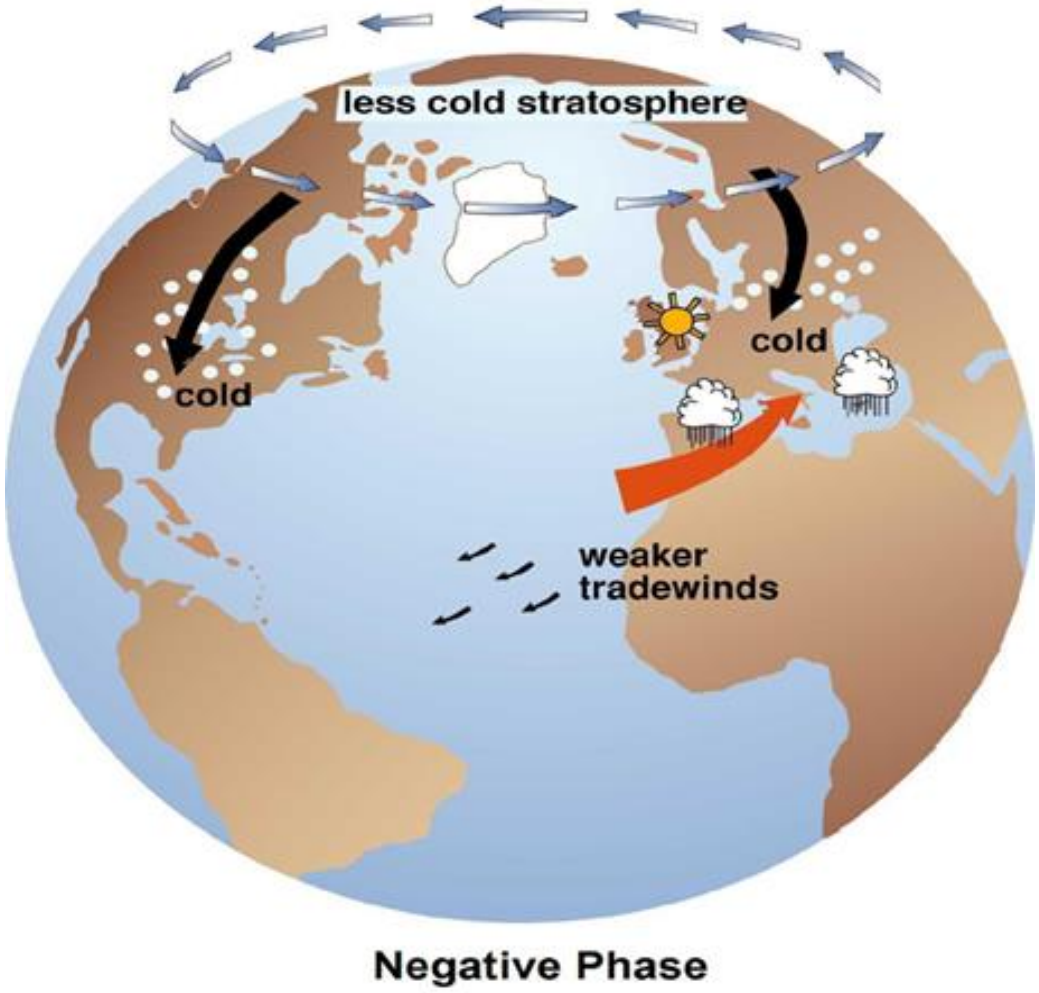
Arctic Oscillation



Courtesy of J. M. Wallace, University of Washington

http://www.weather.gov.hk/climate_change/ao_e.htm

Response of AO

1. **Negative AO**
2. **Positive AO**
3. **No Response**
4. **Forcing Dependent**
5. **Background climate dependent**

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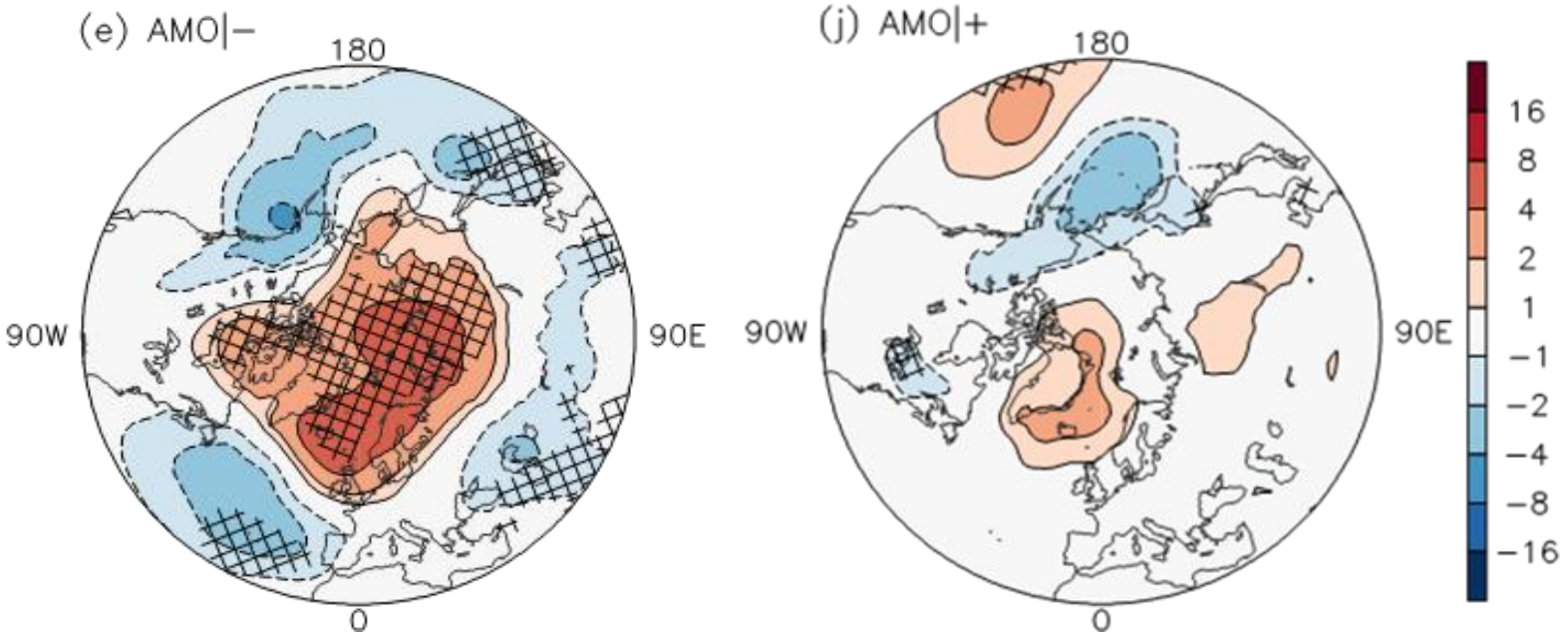
Atlantic Multidecadal Oscillation vs. Impacts of Arctic Sea Ice

Li, F., Orsolini, Y. J., Wang, H.,J. **Gao, Y.Q**., & He, S.P. (2018). Atlantic multidecadal oscillation modulates the impacts of Arctic sea ice decline. *Geophysical Research Letters*, 45. https://doi.org/10.1002/2017GL076210



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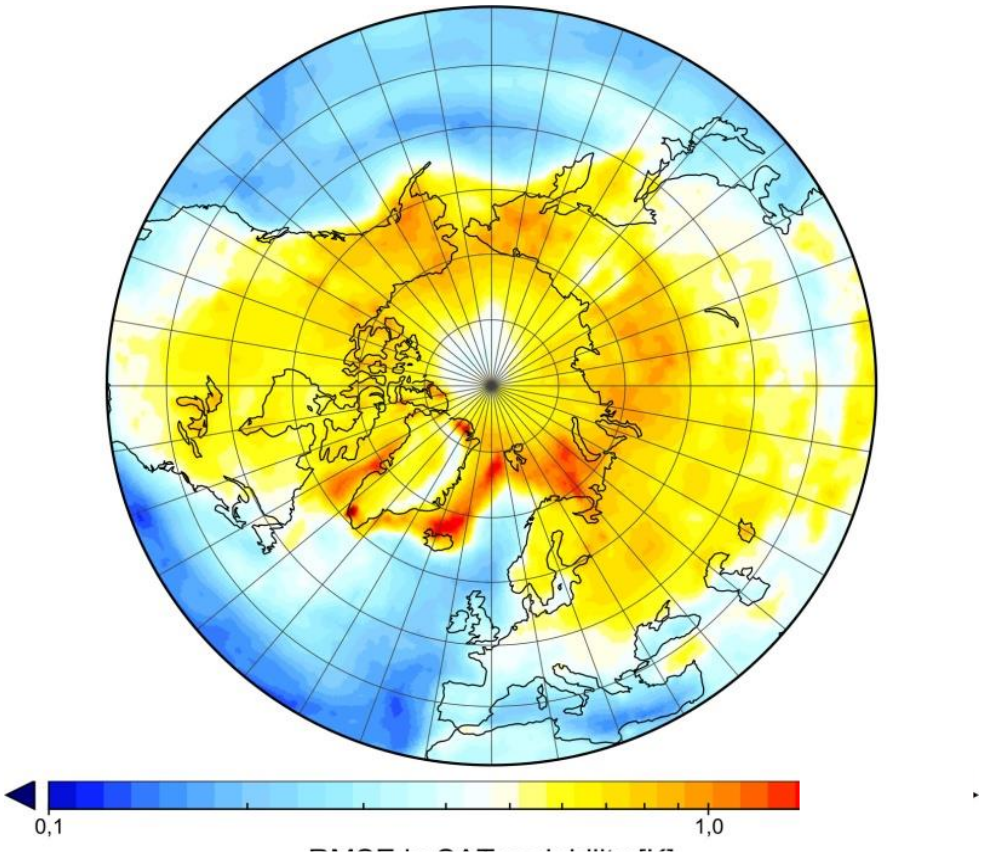
Global Climate Models (CMIP5)

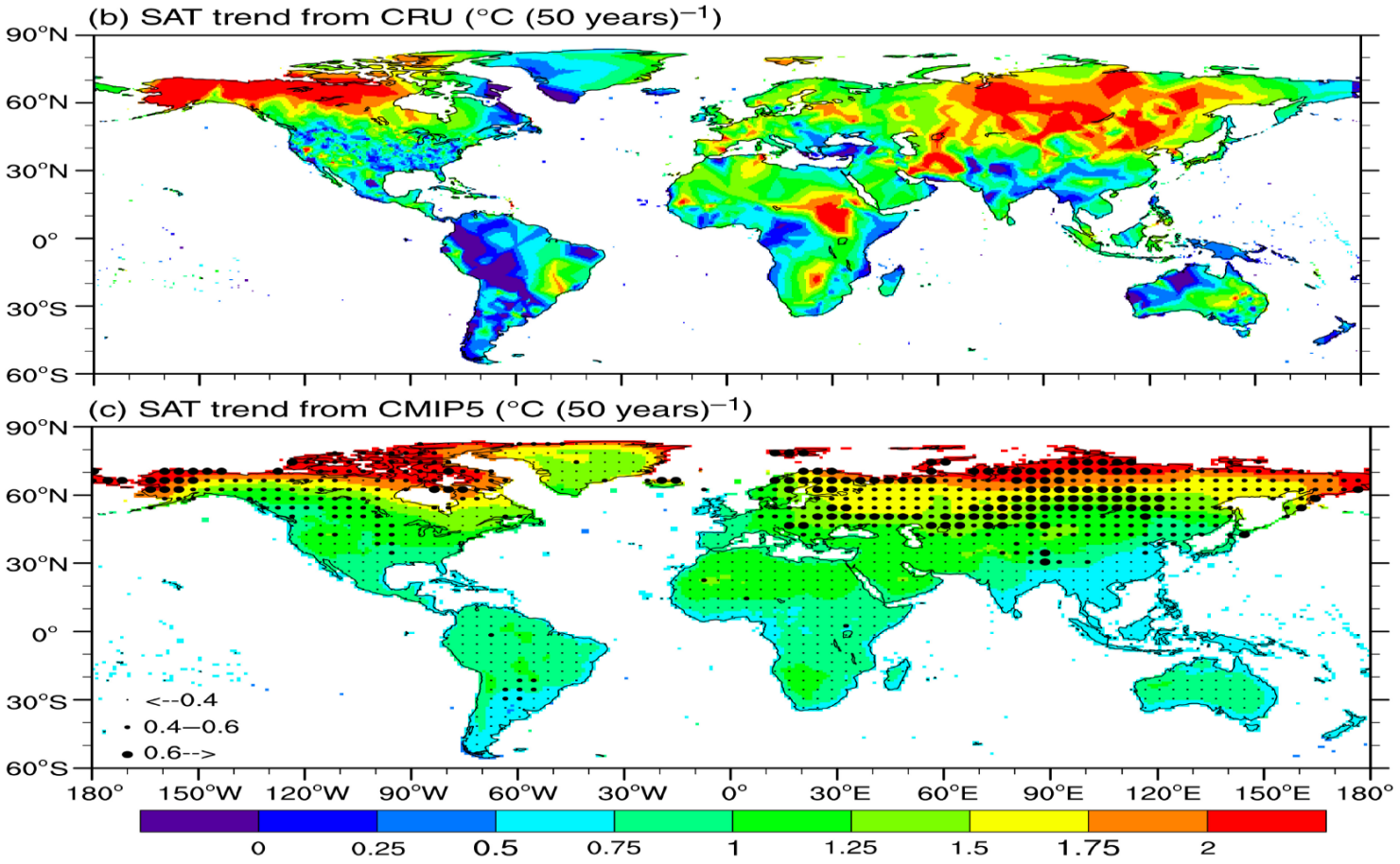


RMSE in SAT variability [K]

Davy and Esau 2014

Average RMS error in SAT in 36 CMIP5 GCMs

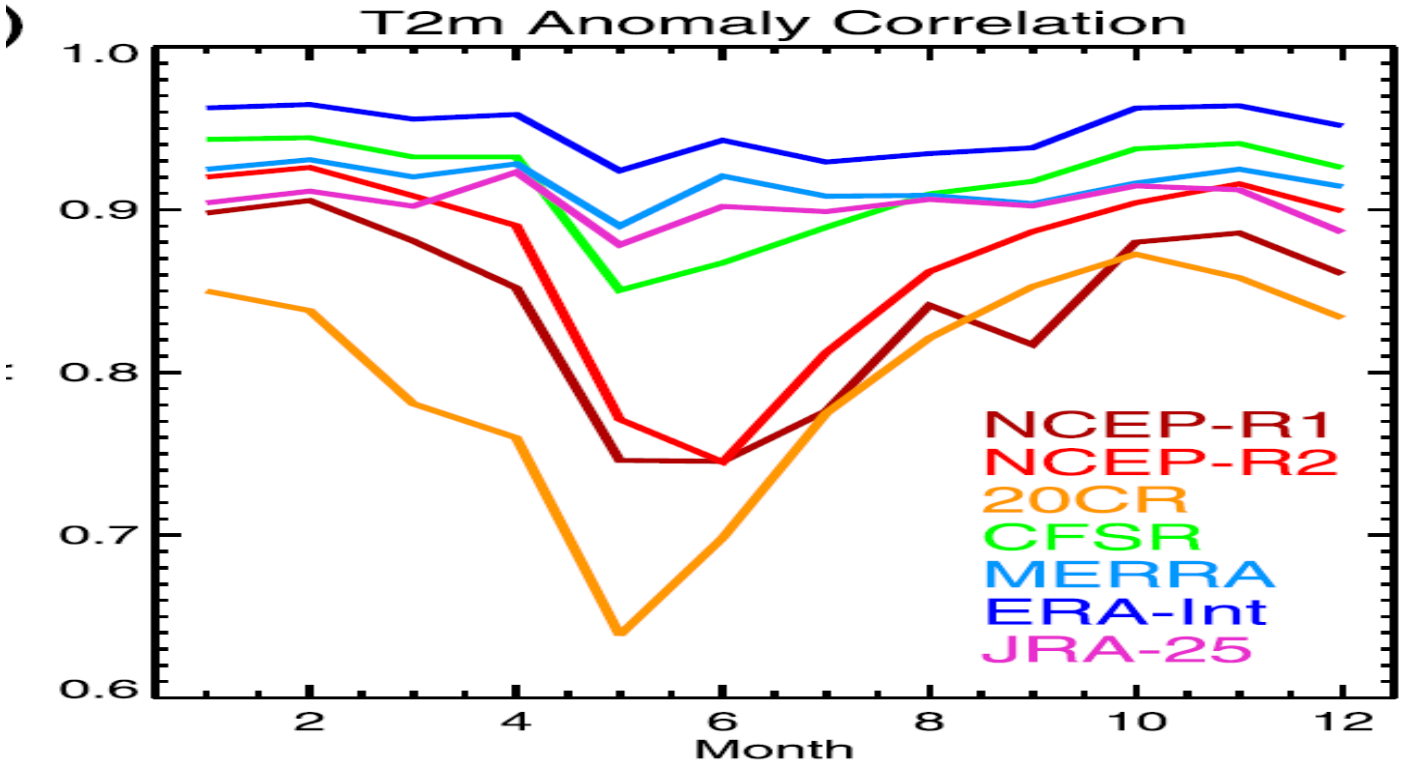
CMIP5



Xie et al., 2016

Assessment of seven atmopsheric reanalysis products in Arctic

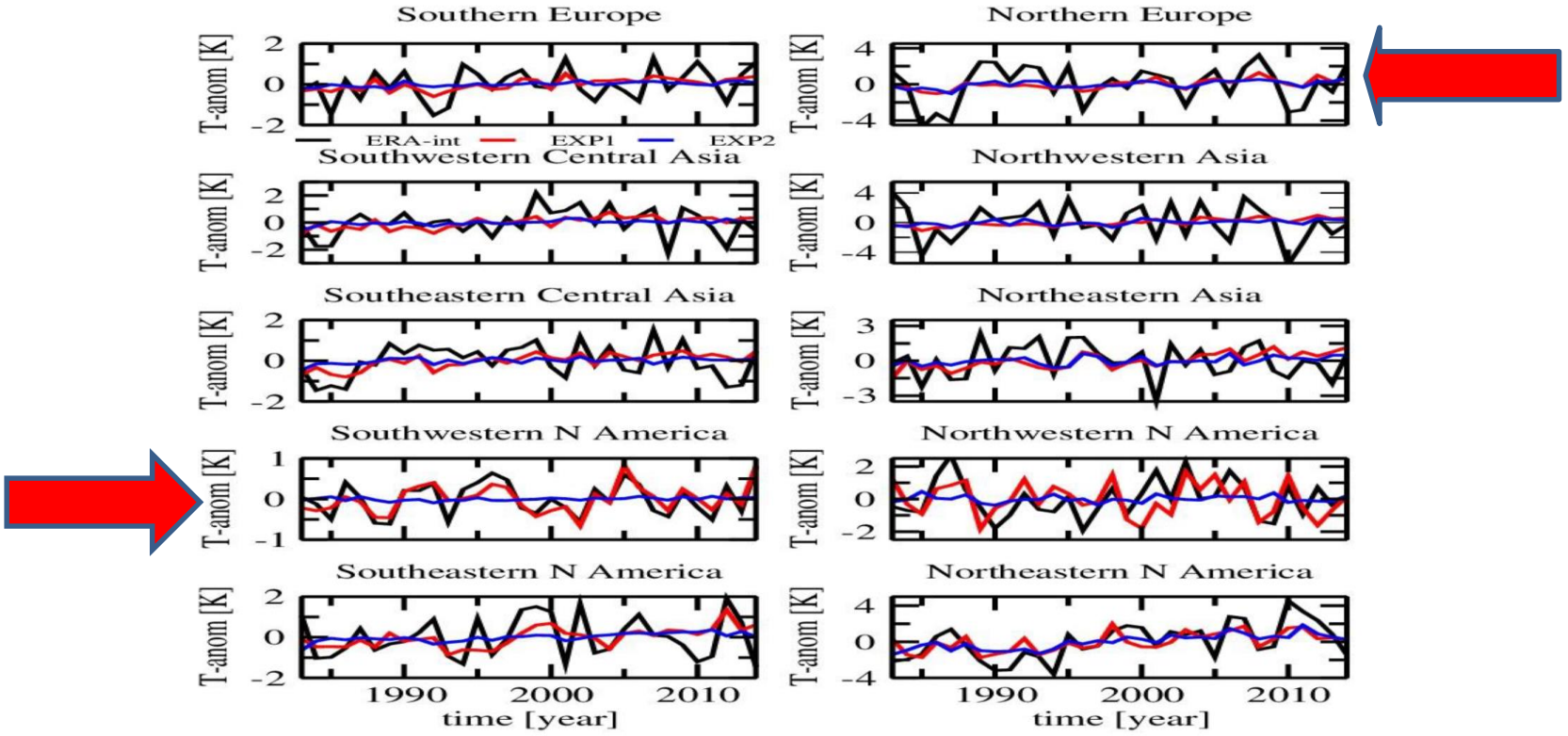
NCEP1, NCEP2, CFSR, 20CR, MERRA, ERA-Interim, JRA25



Lindsay et al. 2014

Impact of Arctic sea ice variations on winter temperature anomalies in northern hemispheric land areas

Koenigk, T., **Gao Y.Q.**, Gastineau G., , N. Keenlyside, N., Nakamura T., Ogawa F., Orsolini Y., Semenov V., Suo L.L., Tian T., Wang T., Wettstein J.J., Yang S. (2018): Impact of Arctic sea ice variations on winter temperature anomalies in northern hemispheric land areas. *Climate Dynamics* (in press)



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Concept

- Sea ice decline ≠ Arctic surface warming
- Arctic surface warming ≠ Arctic troposphere warming

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Implications and Perspect

- Responsible process for Arctic Warming
- Arctic-lower latitude linkage versus Ocean State
- Call for long-term and well-designed observation, multi-model coordinated experiments, improvement of models
- Forecast, Predictions, Climate Service
- Past and Future (Projections)

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EU H2020 Blue-Action (2016.12-2021.02)

Model	NorESM	IPSL-CM	EC-Earth	CMCC-CM	ECHAM5	IAP-AGCM	HadGEM	ICON	EC-Earth
Hor. (km)	100	100	100	100	100	100	40	40	40
Part.	NERSC	CNRS-LOCEAN	DMI	CMCC	IAP-RAS	IAP-NZC	UoS	MPI-M	NLeSC

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Thank you !

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