The kick off workshop for the “Impact of initialized land temperature and snowpack on sub-seasonal to seasonal prediction” (ILSTSS2S) and “Third Pole Experiment Multi-Model Intercomparison” (TPEMIP).

Climate memory of the Eurasian land process associated with the Arctic amplification

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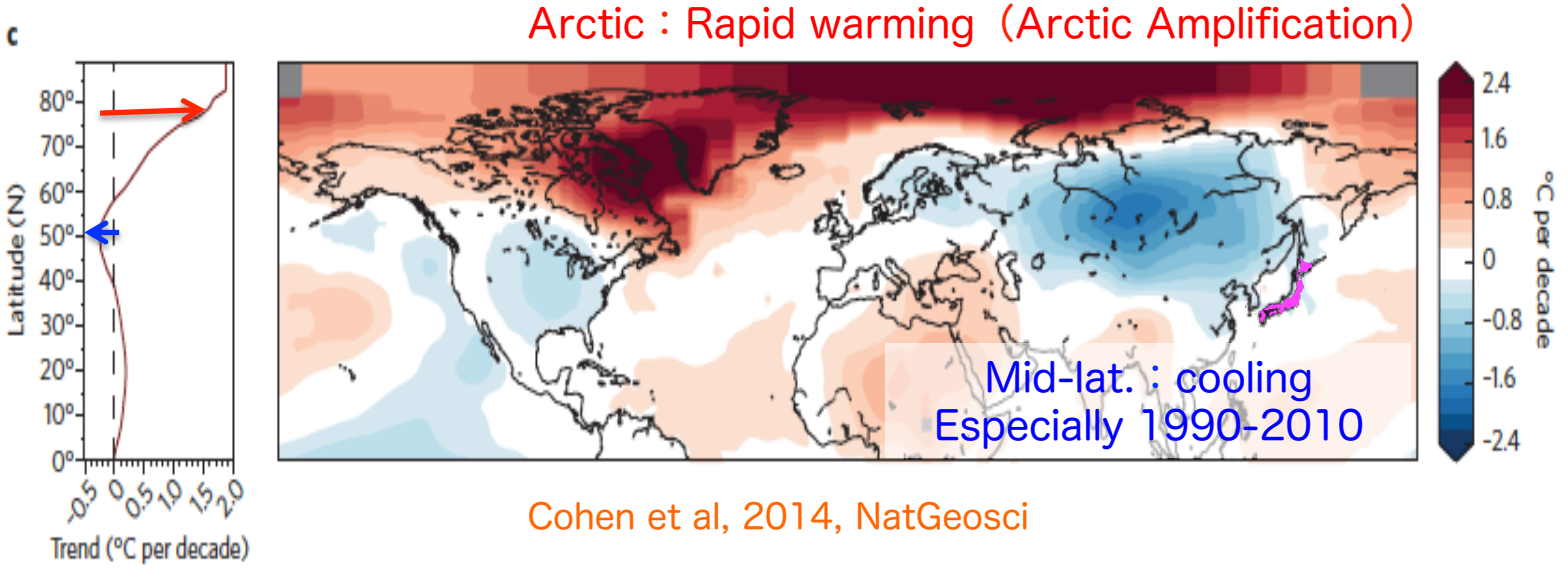
Surface temperature trend in boreal “winter”

Arctic：Rapid warming（Arctic Amplification）



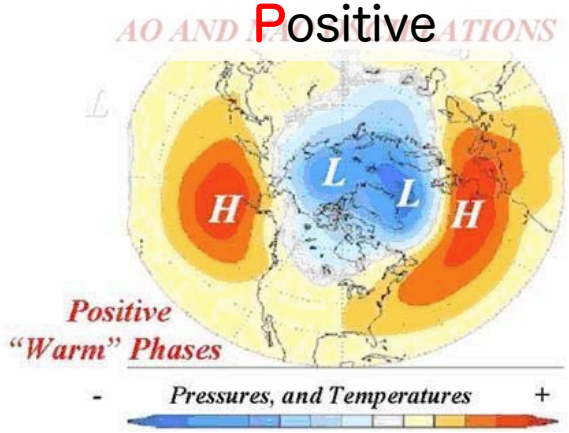
Cohen et al, 2014, NatGeosci

Arctic warming and mid-lat. cooling

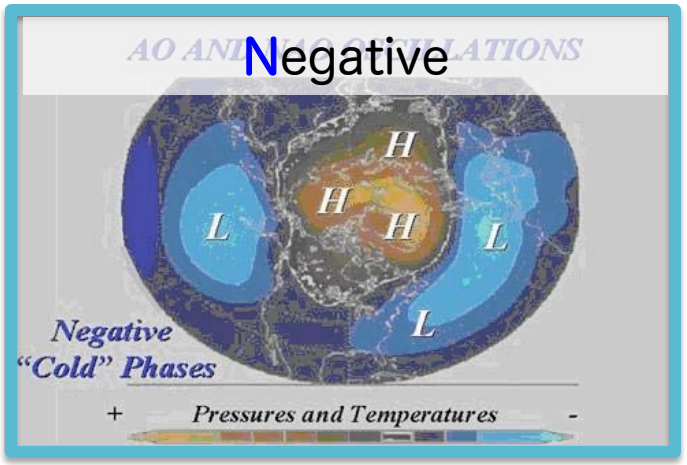
Arctic Oscillation

Thompson and Wallace, 1998, GRL

Positive



Negative

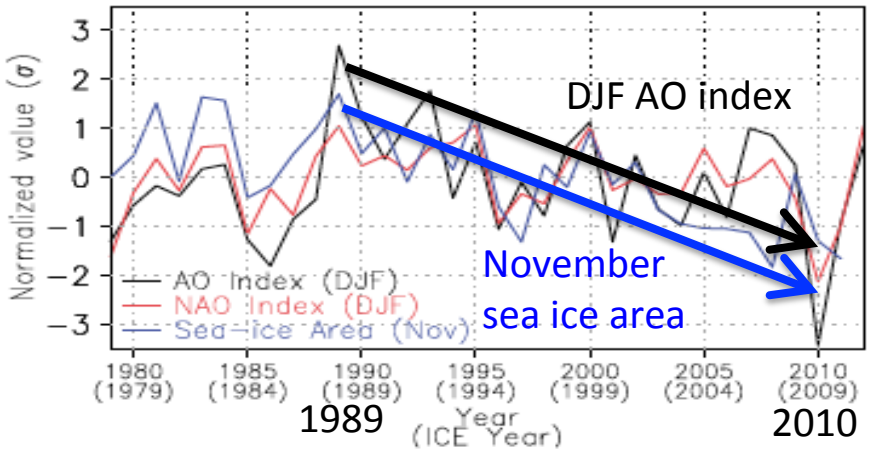


-> high pressure and warm anomalies in the polar regions

-> low pressure and cold anomalies over the mid-lat.

Caused by Arctic sea ice loss?

Rapid sea ice retreat & negative trend of AO



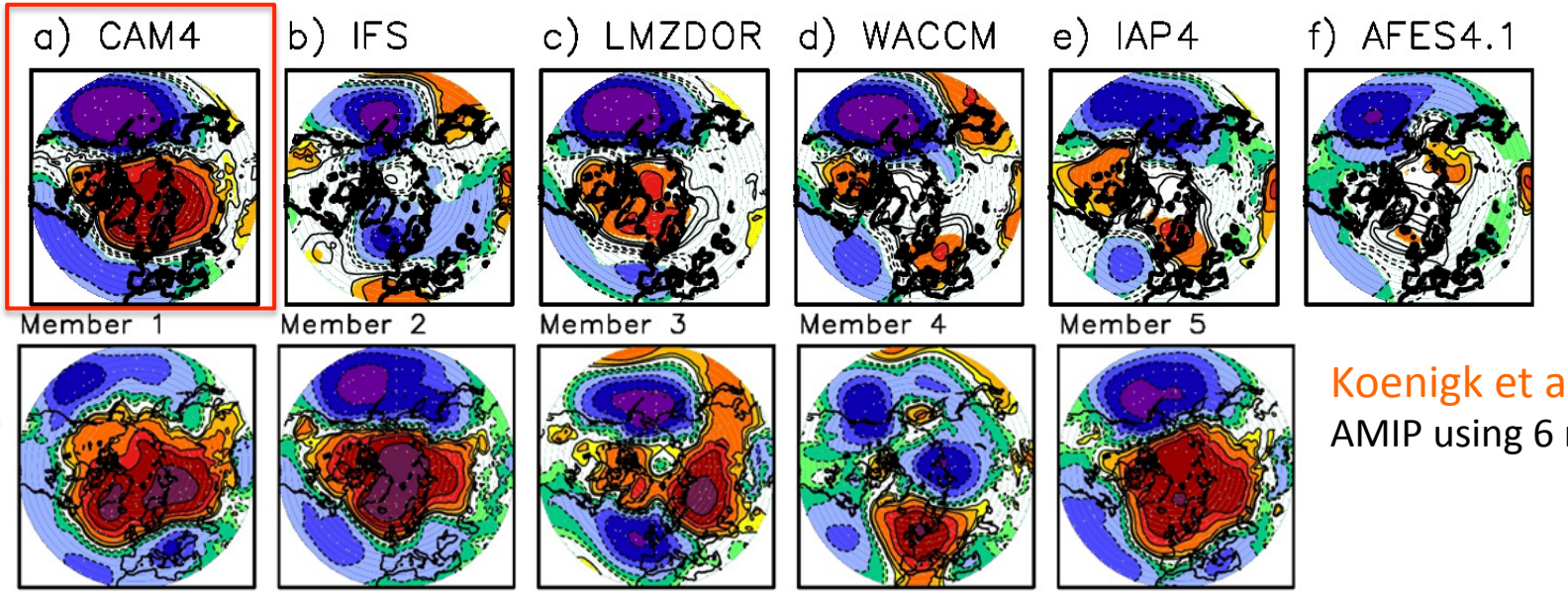
sea ice-AO/NAO papers

Liu et al., 2011; *Jaiser et al.,* 2012; *Nakamura et al.,* 2015; *Jaiser et al.,* 2016; *Ogawa et al.,* 2018; *Koengik et al.,* 2018 … etc

sea ice-Siberian cooling papers

Overland and Wang, 2010; *Cohen et al.,* 2012; *Hopsch et al.,* 2012; *Kim et al.,* 2014; *Mori et al.,* 2014; *King et al.,* 2015 … etc

Simulation uncertainty



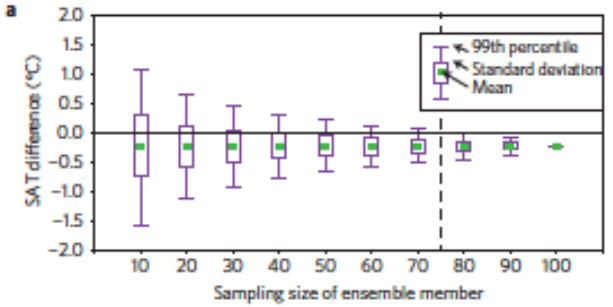
Koenigk et al., 2018
AMIP using 6 models

Simulations
Variant results among models
(Large uncertainties)

Observations (**20** samples or so)
Summer-autumn ***Arctic sea ice*** loss
→ winter *AO-* & Frequent ***cold wave***
(Robust, very significant)

"Gap"

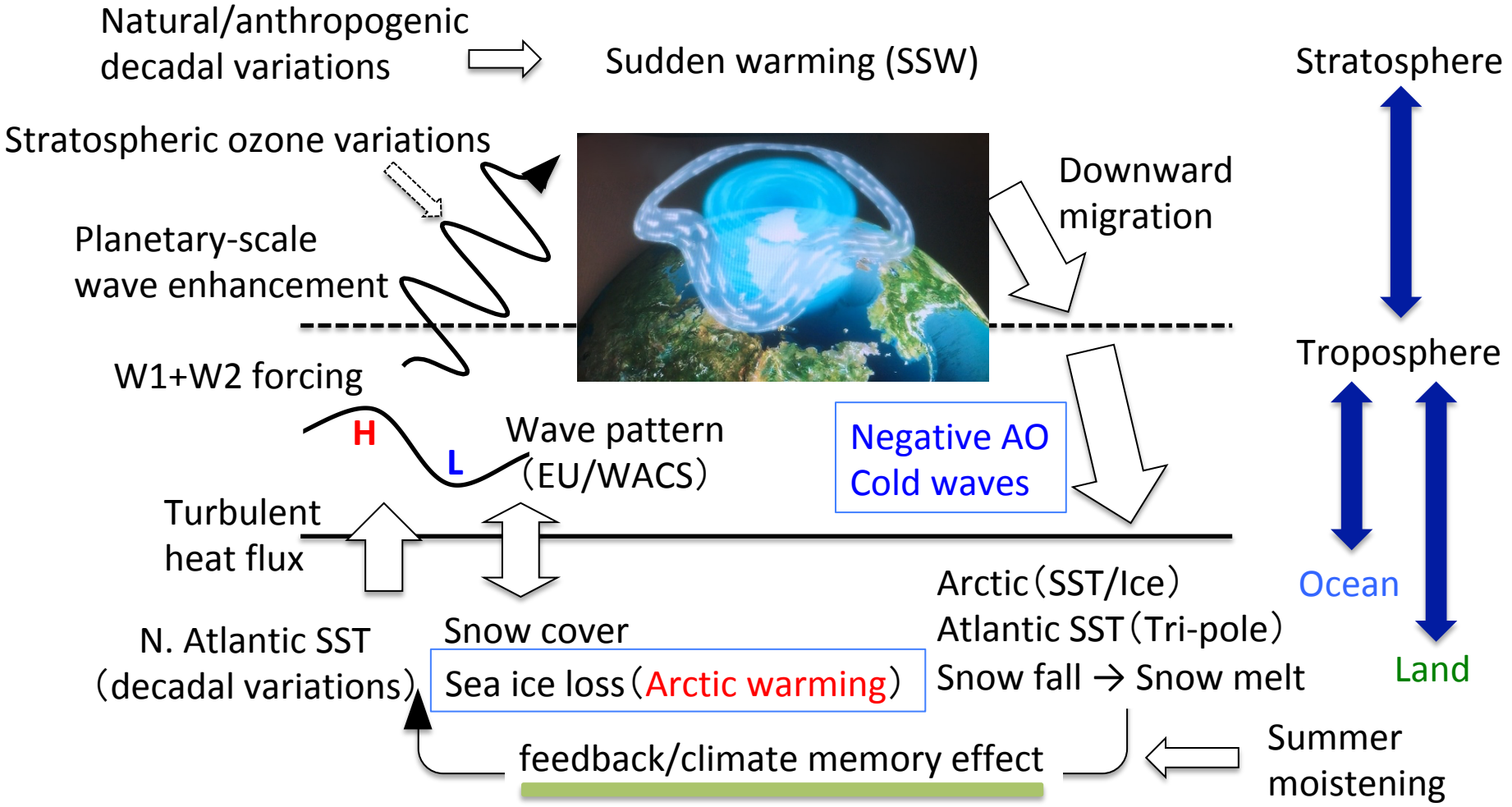
- **atmospheric internal variability**
  → **Low S/N suggested in many studies**
  e.g., Mori et al., 2014: 80 member is required



To fill this gap, we need to better understand the coupling/positive feedback processes in relation to the Arctic climate variability.

Multi-sphere interaction of Arctic amplification

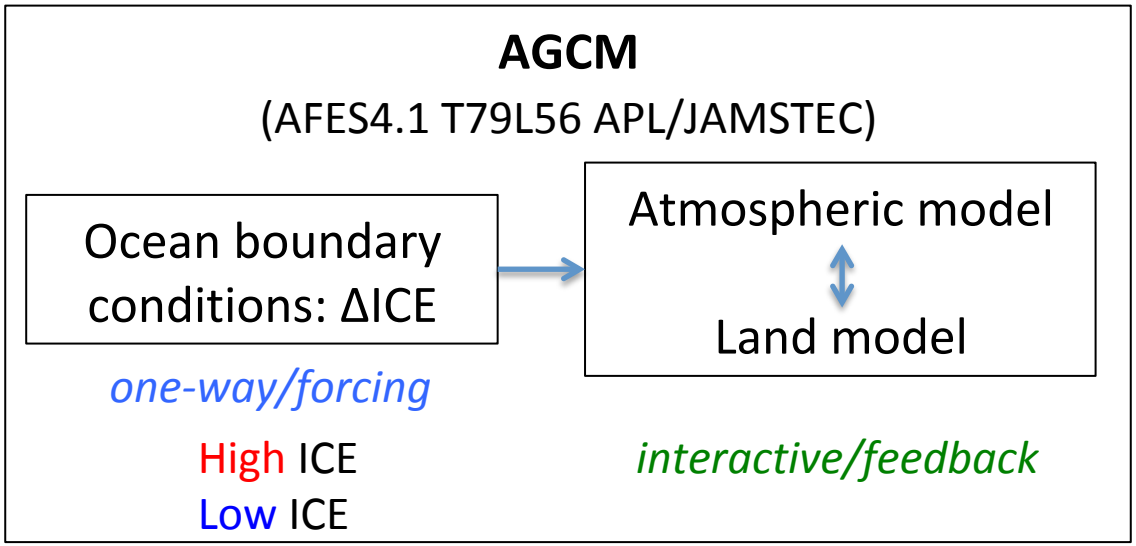
Various processes associate with Arctic climate



We here focus "***memory effect***" of the land process.

Memory effect in a framework of AGCM

Purpose: to examine memory effect of the land process and its role on the Arctic amplification.



In AGCM framework, memory effect of the land process can be evaluated.

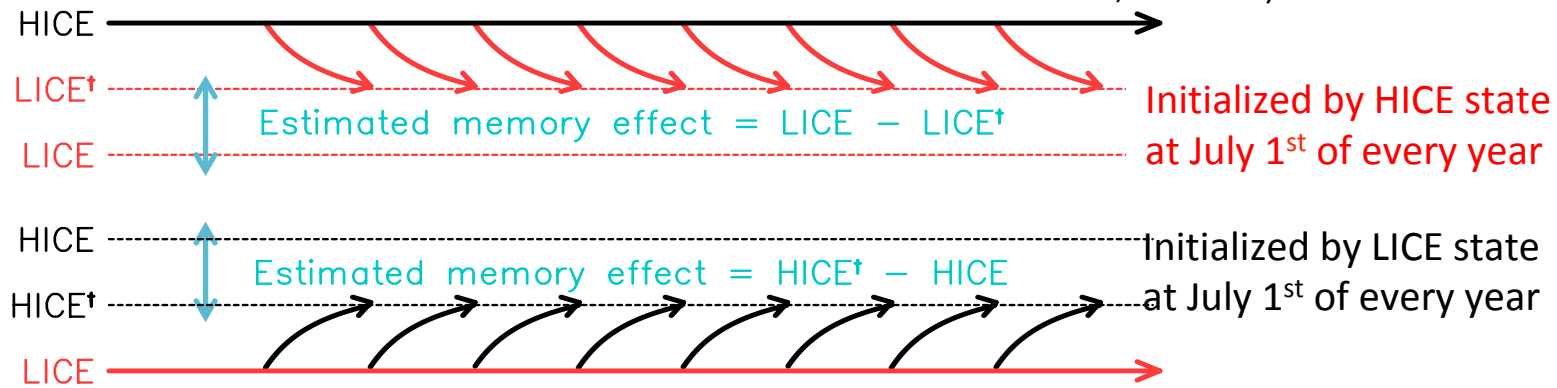
A new procedure to extract the memory effect is developed and applied it to sensitivity experiment driven by sea ice boundary forcing.

Experimental design

Run	Integration	Sea ice boundary condition	Initial condition	
HICE	Serial 100 years	1979-1983 average	10-year spin-up	Merged Had/OI dataset Clim. SST is prescribed.
LICE		2005-2009 average		

a) "***Serial***" time-slice Exp.: Total responses to sea ice loss (Nakamura et al., 2015; Sun et al., 2015; Wu and Smith, 2016 etc)

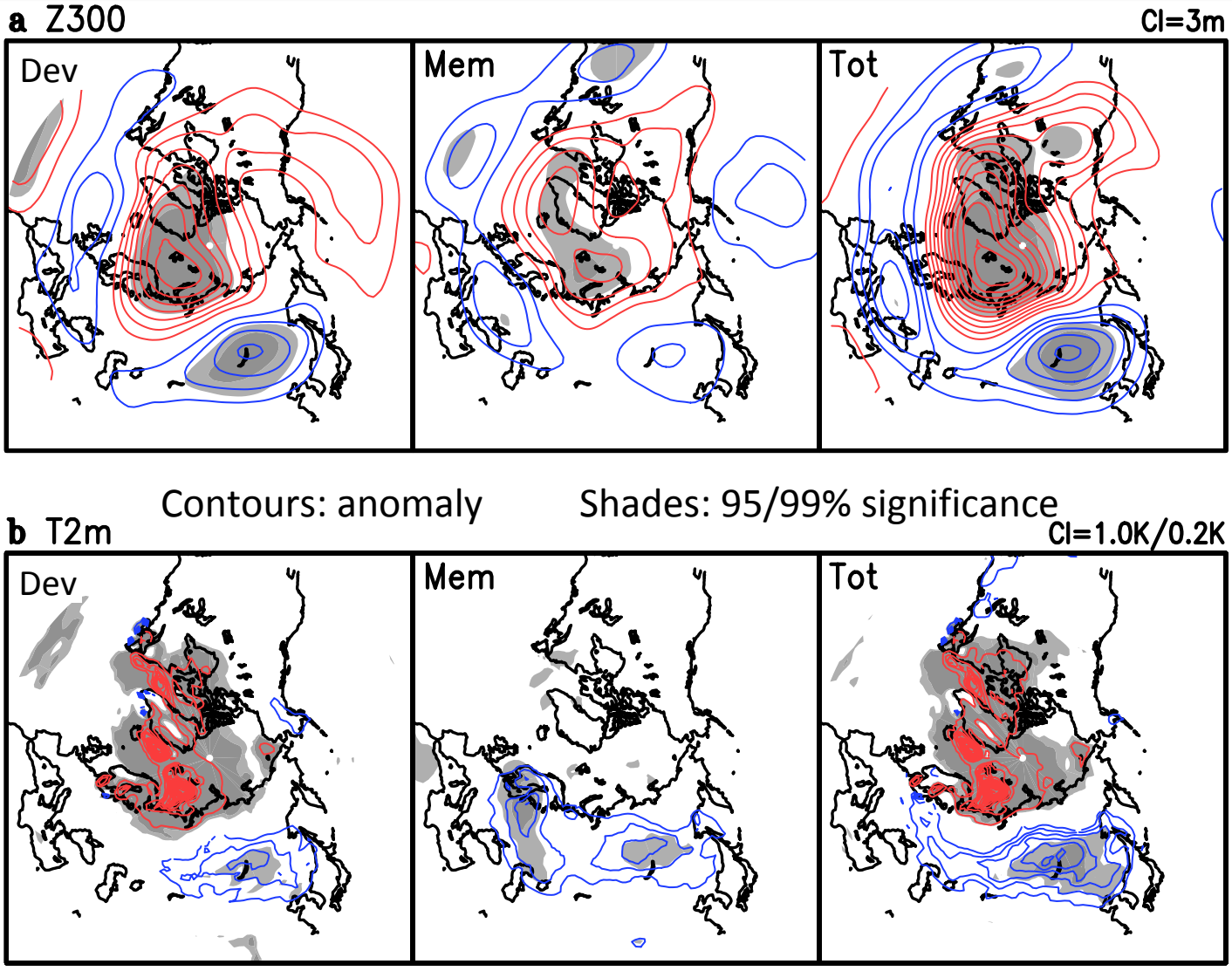
b) "***Initialized***" Exp.: Seasonal evolutions of responses (Deser et al., 2007; Honda et al., 2009; Mori et al., 2014 etc)



Residuals of a) minus b) are memorized anomalies that persist beyond annual cycle

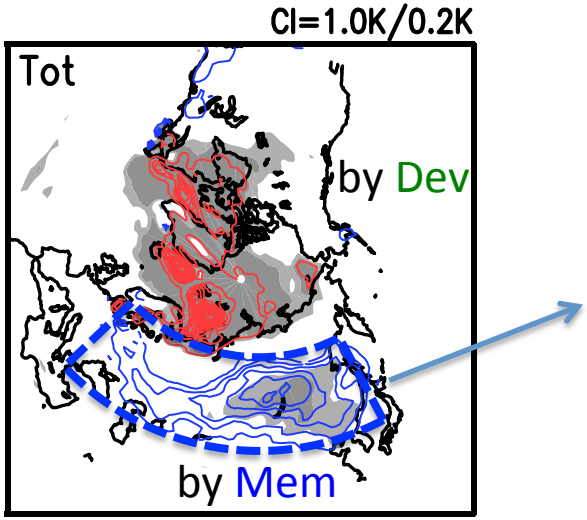
a) Total: $L - H$
b) Development : $((L^{\dagger} - H) + (L - H^{\dagger}))/2$
a) − b) Memory effect: $((L - L^{\dagger}) + (H^{\dagger} - H))/2$

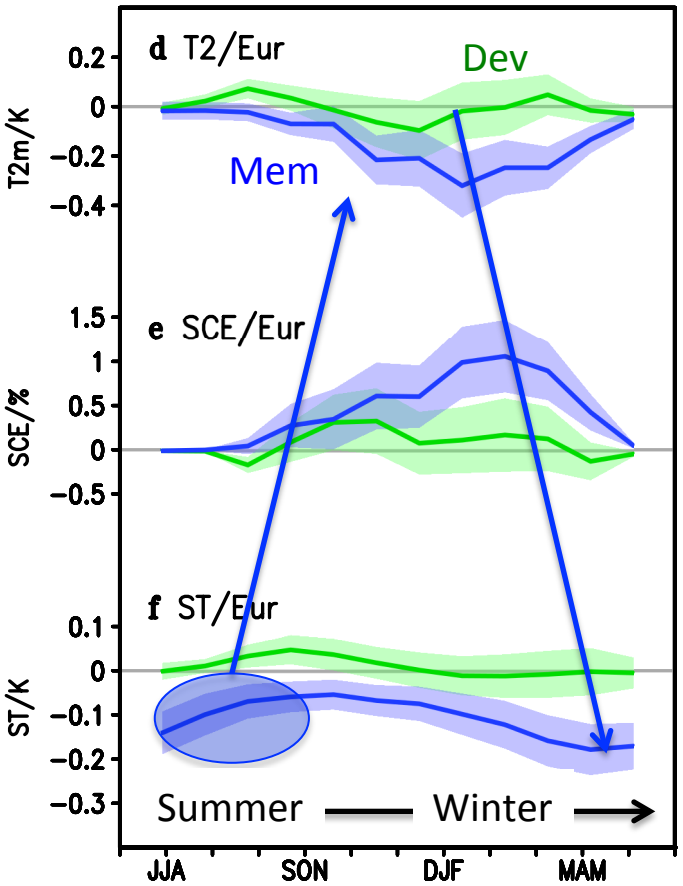
Winter (DJF) averaged responses



- Anomalies of negative AO-like pattern and Siberian cooling look like comparable between Ins and Mem

Seasonal evolutions of anomalies





Memorized coldness over the Eurasian continent

winter coldness

more snow in spring

sfc. cooling forcing & early snow in autumn

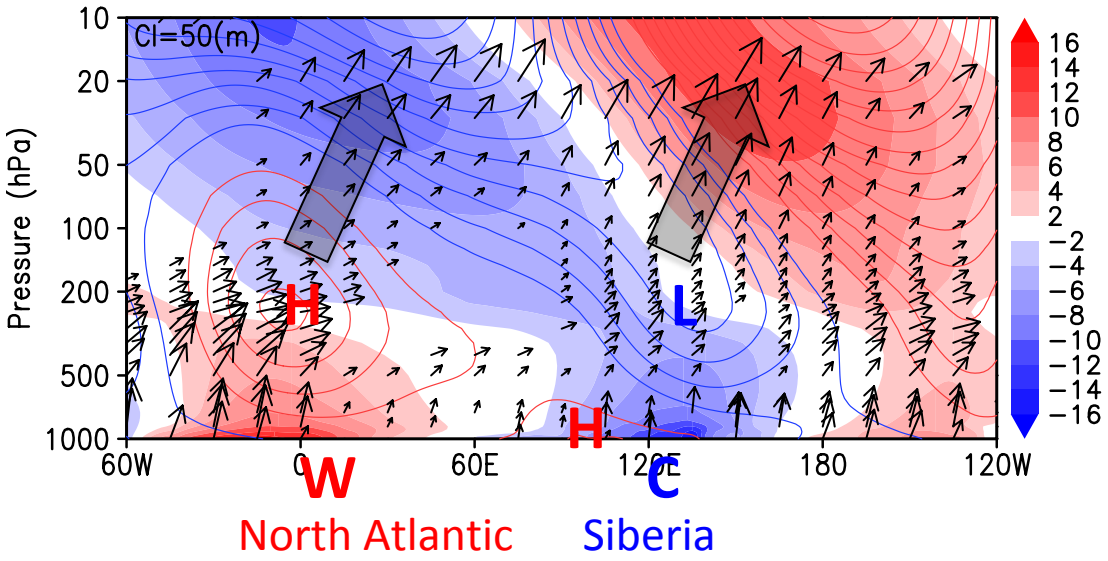
preventing soil warming in early summer

Shades: denominator of t-value (= $\sigma/N^{1/2}$)

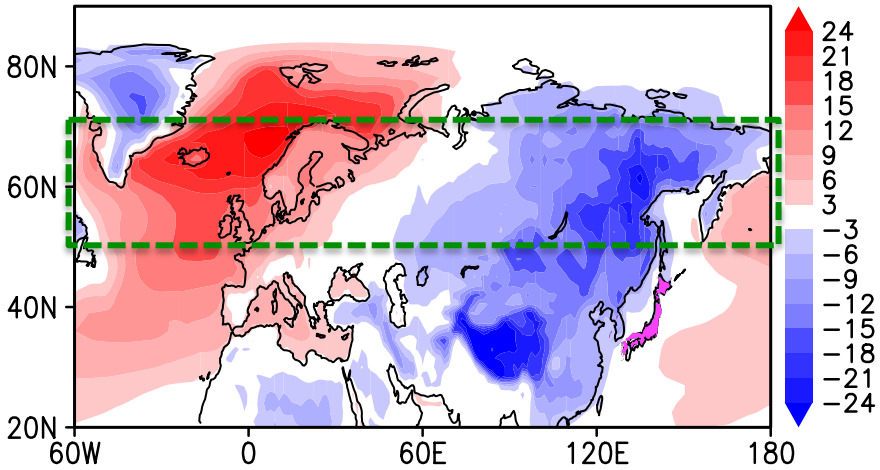
Dev: Arctic warming → AO-
Mem: Memorized coldness → AO-
suggesting the ***different pathways*** induce similar atmospheric forcing

Intensifications of climatological planetary wave

Zonal eddies in the climatological mean state



Contours : geopotential
Shading : temperature
Arrows : wave activity flux



Surface air temperature (eddy)

Arctic warming (Atlantic side) and continental coldness "**both**" Intensify land-sea contrast

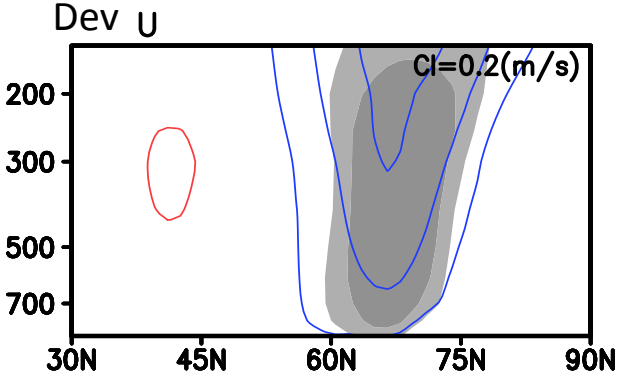
→ Intensified planetary wave

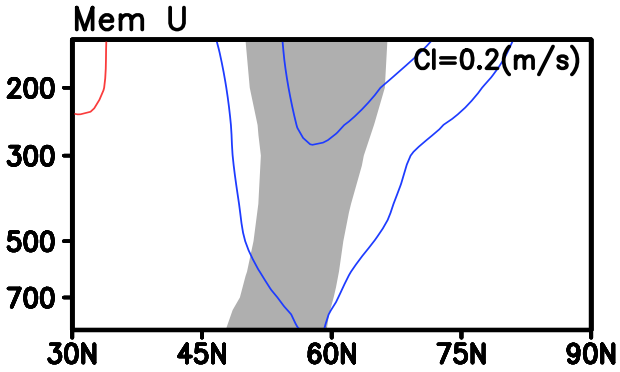
Wave-mean flow interaction is one of the typical dynamics of AO

→ Induce AO-like circulations

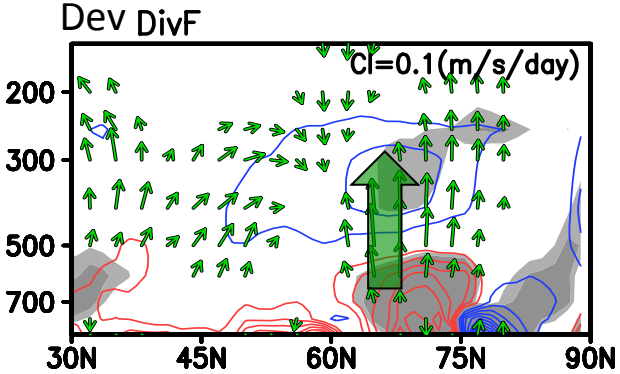
Wave activity from different sources

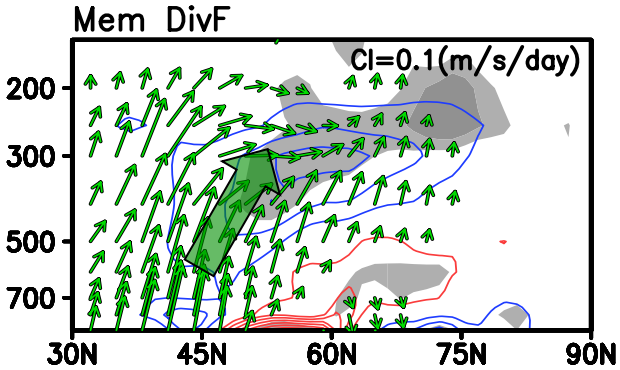
Zonal mean zonal wind





Zonal acceleration due to wave forcing





Contours: anomaly

Shades: 95/99% significance

Arrows:
Wave activity flux
(EPy, EPz)

- Deceleration of circumpolar zonal wind by wave forcing.
- Due to waves emanated from different wave sources
  - (Dev, left) polar warming due to sea ice loss
  - (Mem, right) cold anomalies memorized in the continent

Accelerated Arctic warming due to heat transport

Mass stream function of residual mean circulation

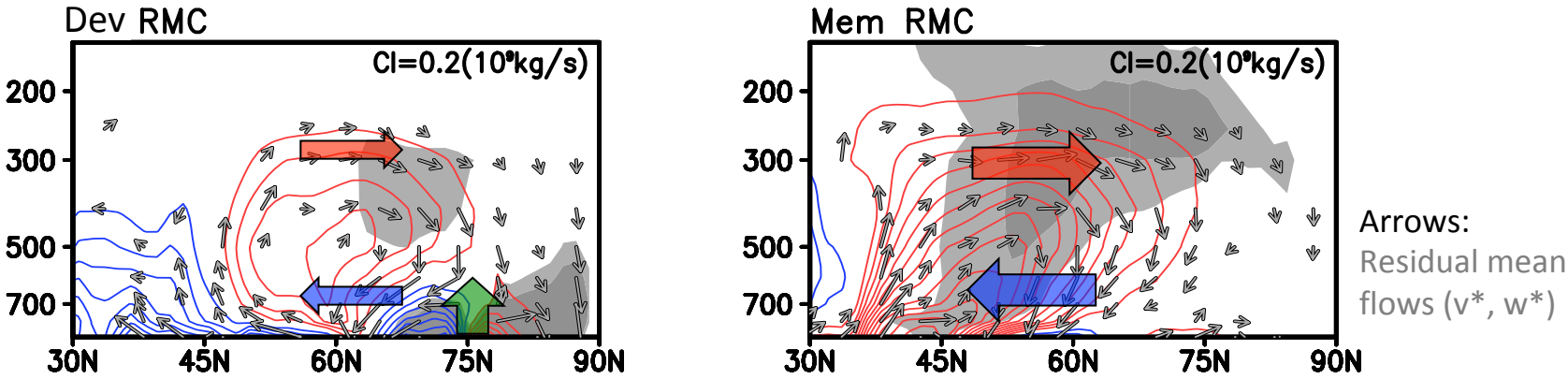


Table 2. Column heating rate in unit of W m^{-2} due to atmospheric heat transport

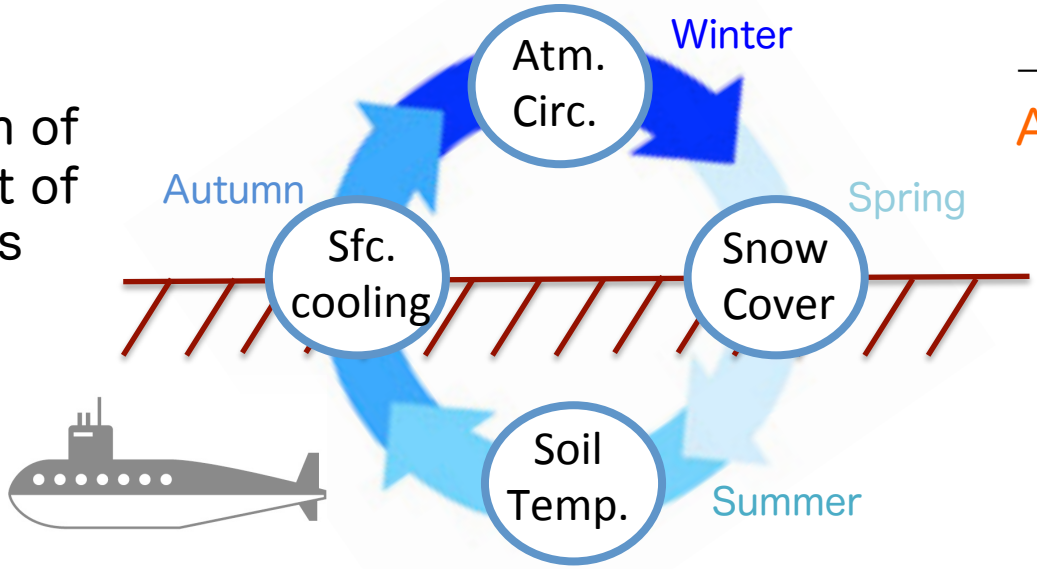
	Transport into mid-lat. Mid-latitudes† ⇐	Transport into high-lat. High-latitudes†† ⇒		Sfc. turbulent heat flux High-latitudes (Ice) ⇑	
Dev	−0.41	0.77	20%	2.86	
Mem	−0.35	0.92	20%	−0.24	
Tot	−0.76	1.69	40%	2.62	60%

- Circulation-induced column heating over the Arctic and cooling over the mid-lats. are comparable between Dev and Mem.

→ Arctic warming could be more accelerated by “Memory effects” by about 20% increase of heating.

Summary

(Our) Model's representation of memory effect of land processes



→20% increase of Arctic amplification

- Discussions
  - In reality, Eurasian summer has experienced marked warming and moistening.
  - Other forcing (e.g., ENSO, MJO, etc) should have larger impacts on land process than sea ice loss.
  - Therefore, we have some difficulty to apply the results of this study to the real world.
- Implications
  - Land process possibly has impacts on the recent Arctic climate change, with its amplitude comparable with sea ice impacts.
  - Model errors/dependencies of land process are expected large. Different intensity of memory effect can be a cause of the simulation uncertainty.