Implications of sea ice uncertainties in simulating a stratospheric response

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Understanding of the Causes and Consequences of Polar Amplification
Aspen, 2017.06.12 (revised 2017.06.11)

Stratospheric Pathway of the Arctic-midlatitude Linkage

"A physical relationship between climate variations in the Arctic and NH midlatitude via stratospheric processes"

which can be understood within dynamical frameworks of

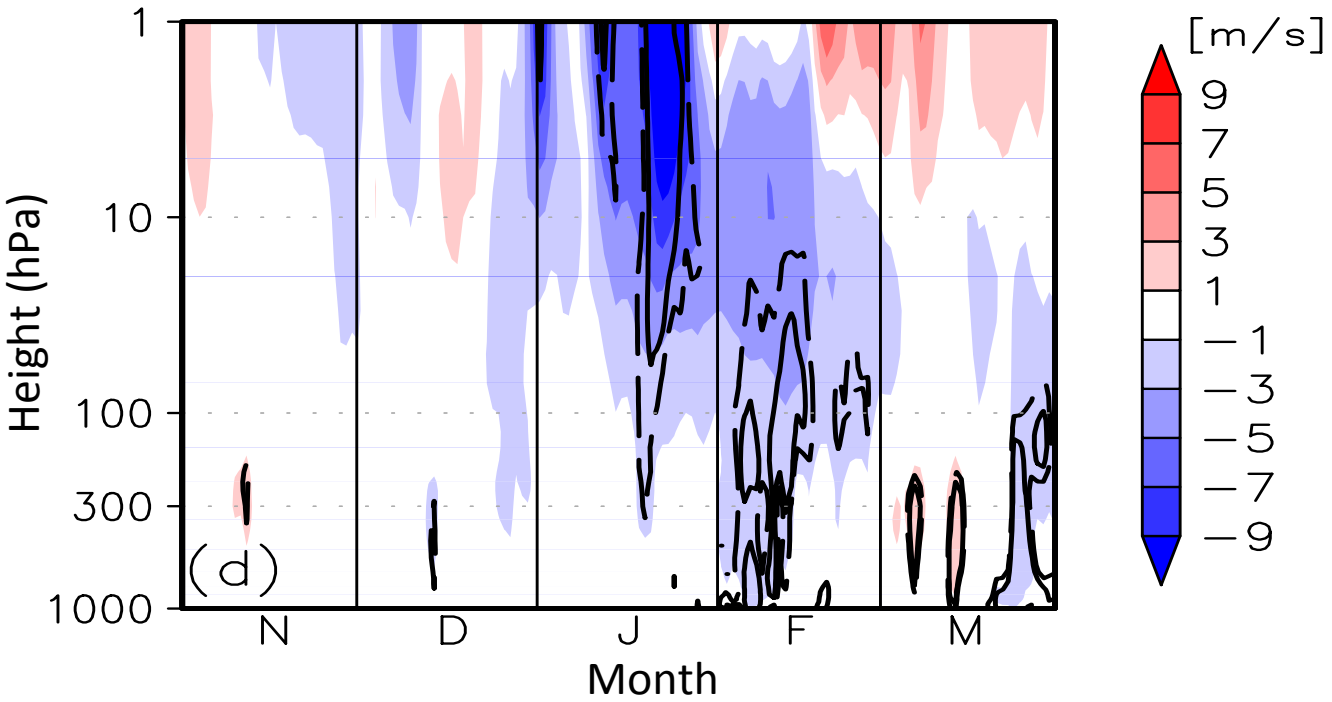
- upward propagation of planetary-scale Rossby waves
- constructive interference with the planetary wave field
- wave-mean flow interaction

Theory and observations : Matsuno (1971), Newman (2001), Baldwin and Dunkerton (2001), Polvani and Waugh (2004), Manney et al. (2008), Nishii et al. (2009), Smith and Kushner (2012),
Snow : Fletcher et al. (2009), Cohen et al. (2014),
Sea ice : Jaiser et al. (2012), Orsolini et al. (2012), Kim et al. (2014), King et al. (2015), Nakamura et al. (2015, 2016a, b), Sun et al. (2015), Hoshi et al. (2017) and many more

Wave-mean flow interaction from sea ice anomaly

Regression coeff on Dec-BK SI index (JRA-55, 1979-2015)

Zonal-mean zonal wind (60N)



- An interannual relationship of sea-ice with the strength of polar vortex and its evolution
- Weakened polar vortex is associated with Dec sea-ice loss of the Barents-Kara Seas (co-varying with other areas)

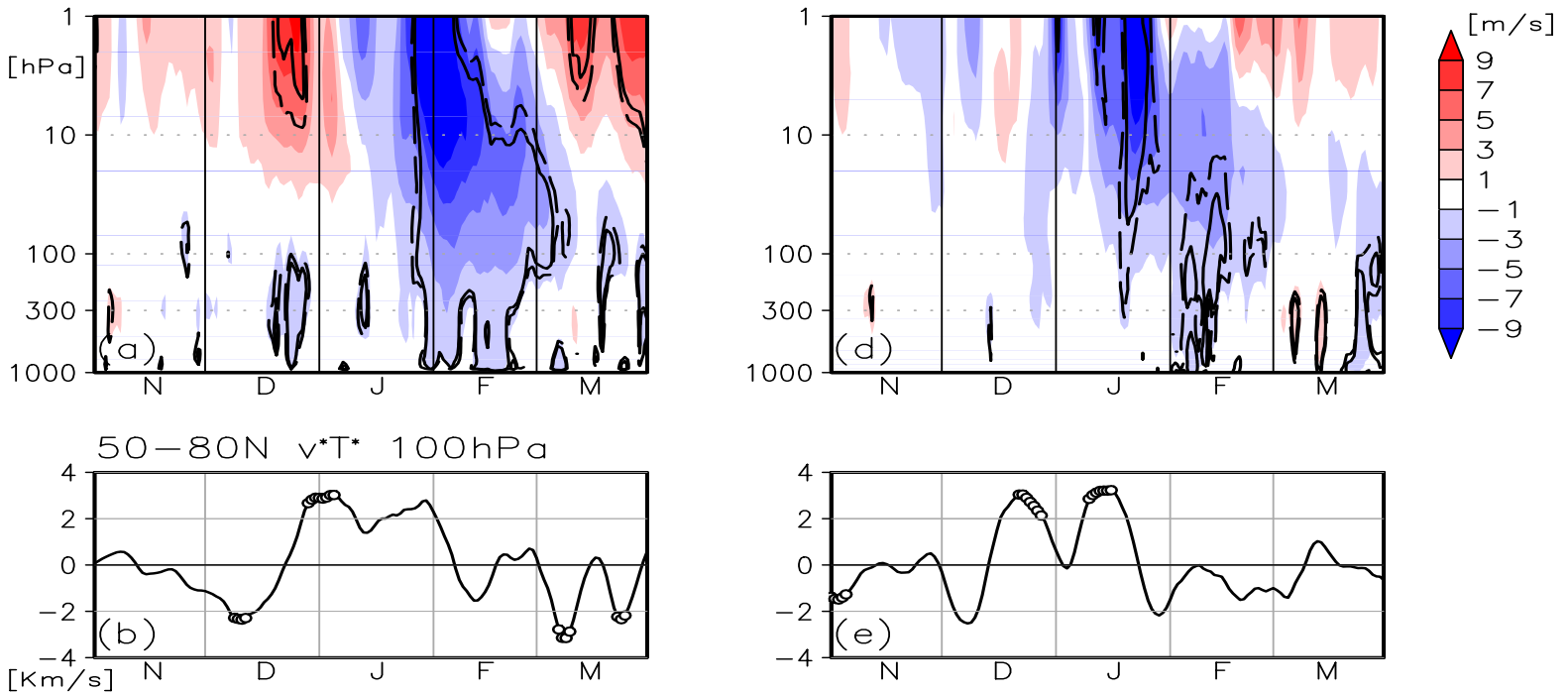
Comparison between model results and reanalysis data

Model Results

ΔU at 60N and
Δv*T* at 100 hPa ave >40N

JRA-55, 1979-2015

Regression coeff of U at 60N
and v*T* at 100 hPa



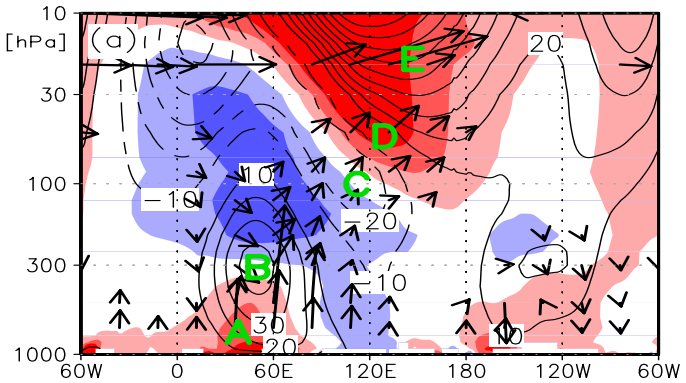
- Eddy heat flux increases prior to weakened polar vortex
- Sea-ice reduction experiments provide supporting evidence for stratosphere-troposphere coupling

Nakamura *et al*., 2015, 2016a, Jaiser et al. 2016, Hoshi *et al*. 2017

Comparison between model results and reanalysis data long-height cross section at 60N and PW modulation

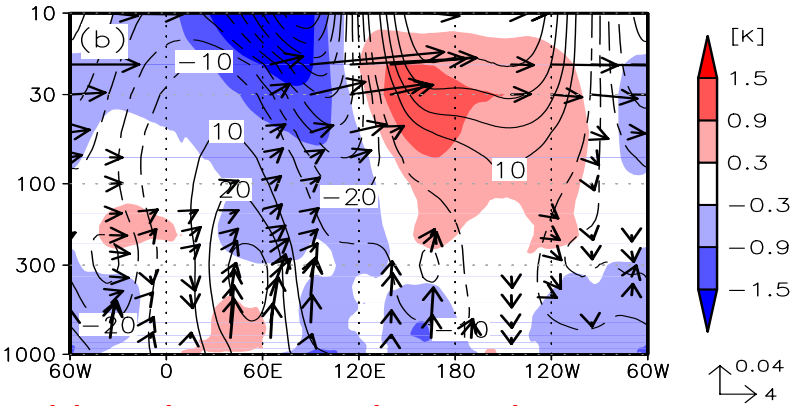
Model Results

Z, T, WAF anomalies
at 60N and Z at 100 hPa

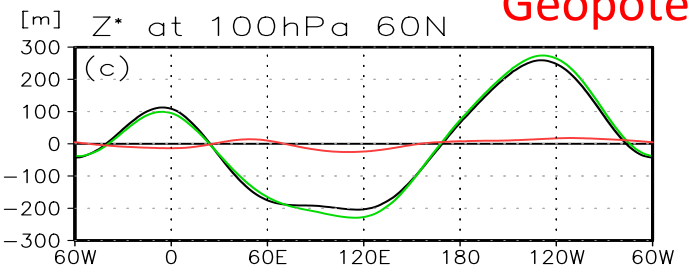


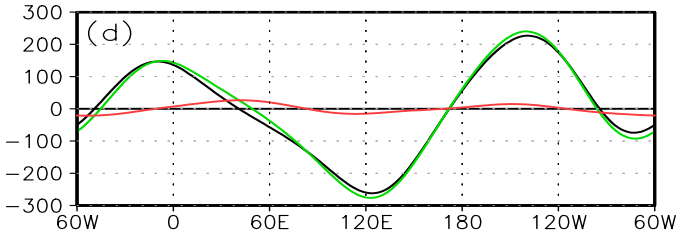
JRA-55, 1979-2015

Regression coeff of Z, T, WAF at 60N
and Z* at 60N 100 hPa



Geopotential height anomalies –planetary waves





- WAF shows upward propagation of Rossby waves from the Barents-Kara Sea region for both model results and reanalysis
- Deepening of Siberia trough and constructive wave interference

Possible factors for a range of sea-ice experiment results

- No impact thus no signal – then how do we interpret observations?
- Large internal variability thus a low signal-to-noise ratio
- Experimental design
  - Time scale of interest (months, years, decades and longer)
  - Repeated annual cycle/multi-single year vs. historical runs
  - Prescription of SIC (historical or fixed for when and where)
  - Prescription of SST (historical or fixed for when and where)
  - O3, QBO (important for stratospheric pathway), GHGs
- Model configuration (AGCM, CGCM, low vs high tops, resolution)
- Different metrics (trends, inter-annual variability, PDFs for parameters such as temp, height at different levels, zonal-mean zonal wind, circulation modes (e.g. NAO, AO), eddy heat flux, WAFs
- Sea ice parameterization (a transfer function from SIC to surface turbulent heat flux, including the question of sea ice thickness)

We assume sea ice data is at least good enough and consistent among different datasets and have treated as such, But…

SST-SIC combined datasets

- OI (NOAA, Optimum Interpolation SSTv2, Reynolds et al., 2007)
- HadISST (Hadley Centre Sea Ice and SST, Titchner et al., 2014)
- Merged OI (Merged Hadley-NOAA/OI, Hurrell et al., 2008)
- OSI-SAF (EUMETSAT, DMI/Nansen Centre for forcing ECMWF)
- COBE-SST (JMA for forcing JRA-55)

SIC data

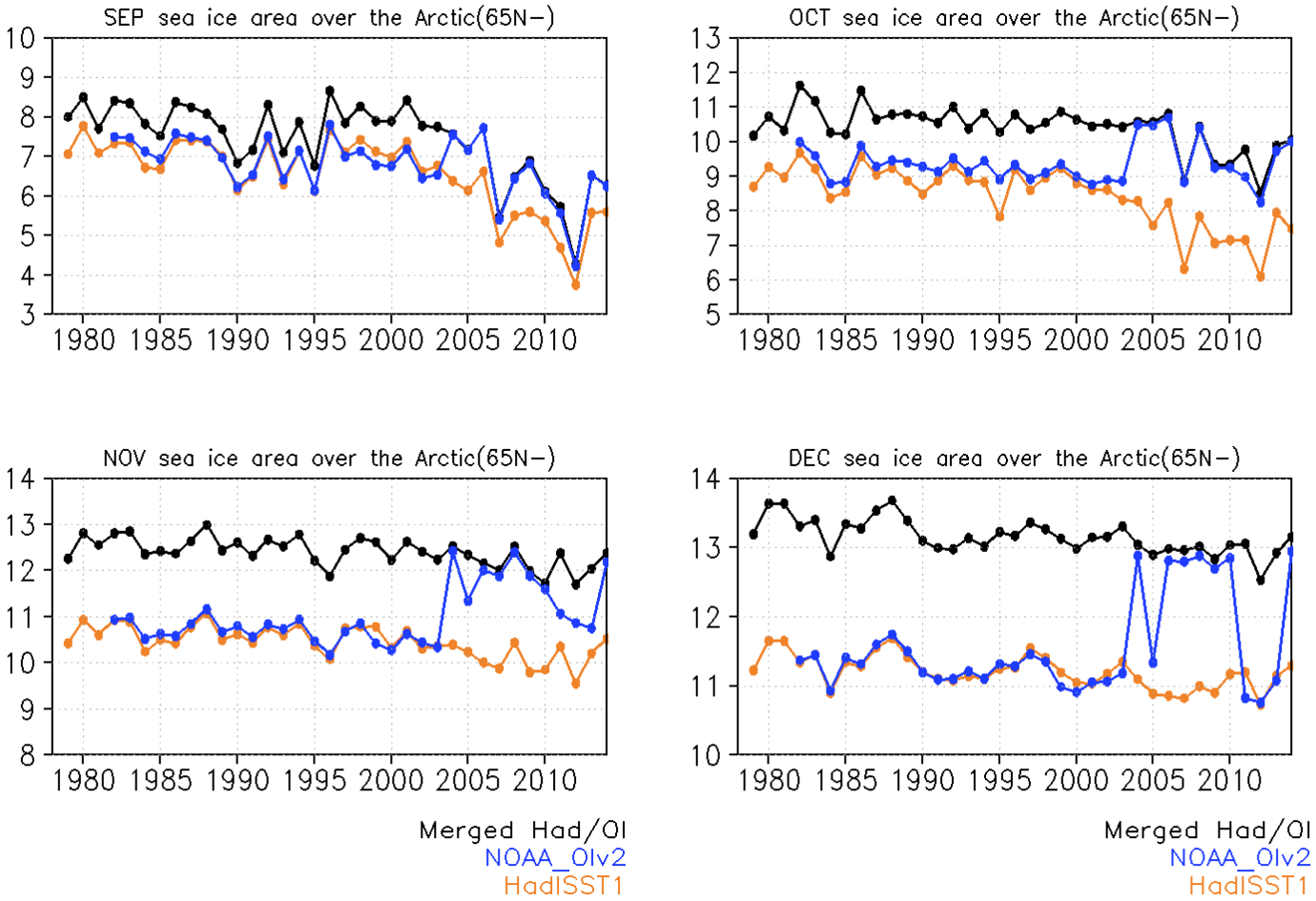
- NASA Team algorithm
- NASA Bootstrap algorithm (among at least 40+ products)

They are significantly different in estimated SIA trends over 1979-2015 as (Comiso and Meier, pers comm)

NASA Team algorithm 1 :	-4.5+-0.15 % per decade
NASA Bootstrap :	-4.4+-0.14
OSI-SAF :	-4.7+-0.15
HadISST :	-2.7+-0.17
HadISST v2 :	-3.8+-0.13

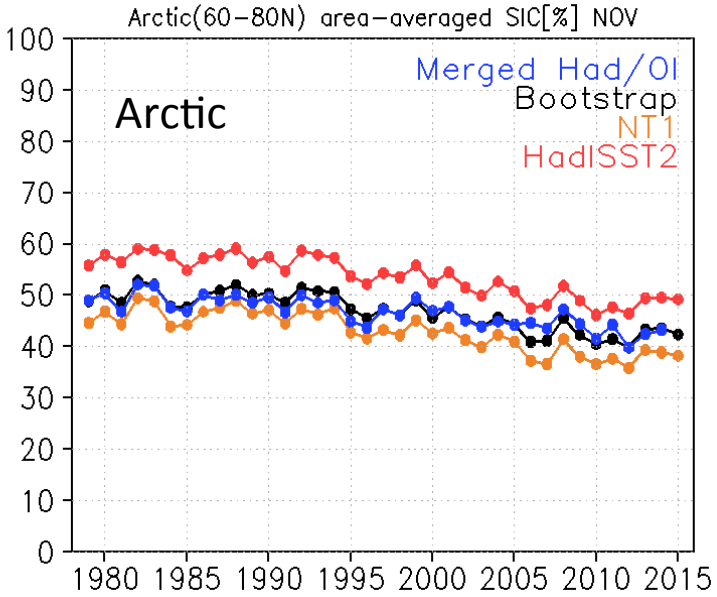
In the GREENICE AMIP Project (sea ice reduction experiment)
we used NOAA's OI as prescribed BC

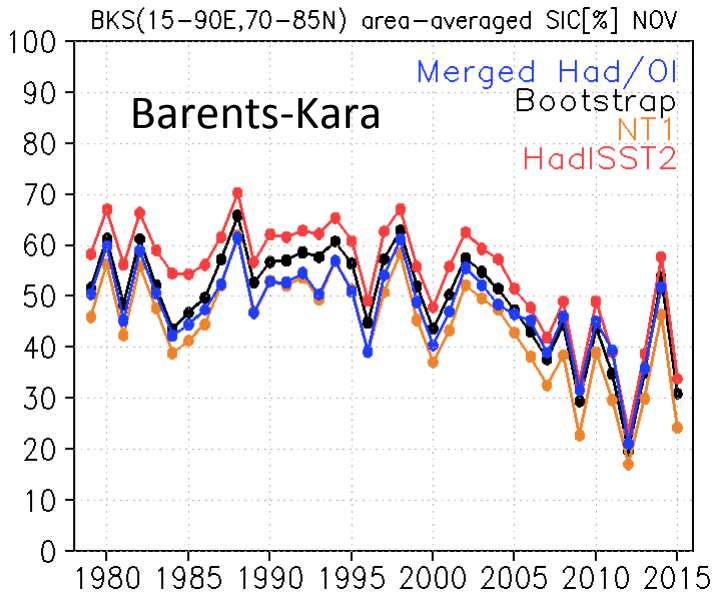
Sea ice area [10^6 km^2]; SIC>15% over the Arctic(65N-90N)

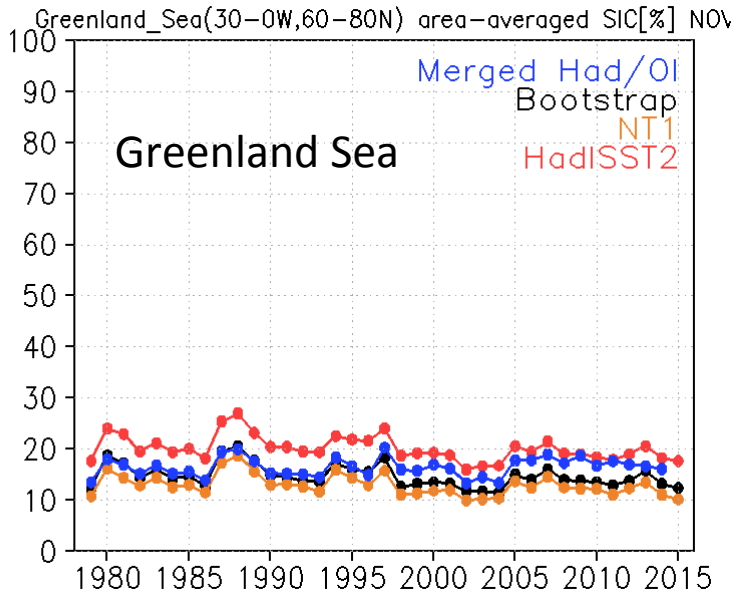


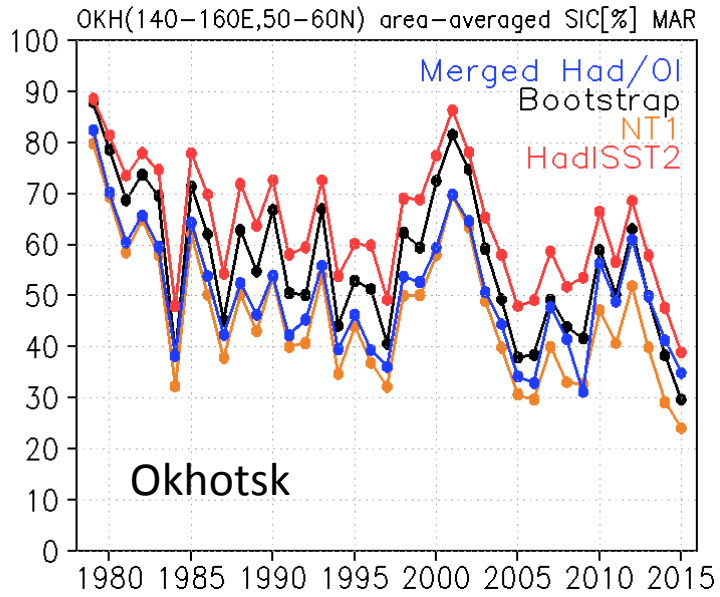
Courtesy of Ogawa, Hoshi and Nakamura

Comparison between sea ice datasets : area-averaged SIC









Differences in sea ice datasets

- There are different possibly due to
  - differences in SIC algorithm (NASA's Bootstrap and Team algorithm)
  - differences in how they are combined with SST data
  - landmask problem
- Retrievals of SST and SIC depend each other, yet not estimated jointly
  - Optimal Estimation Approach with RTF and inverse models
- Differences can be as large as 5 ~ 10% in SIC
- It my be significant in terms of surface turbulent heat flux depending upon a place and timing
- Do the differences matter, if yes, when and where?

Experiment : no-brainer

Purpose: to evaluate an extent to which differences in SIC data would affect the way in which sea ice anomalies impact circulation, possibly?

- 100-member ensemble of 1 year integration under High- and Low-ice conditions
- In all runs, integration starts on July 1st using the output of the CNTL run in the Blue Arctic Ocean experiment (Nakamura et al., 2016b)
- Unlike Nakamura 2016b, global SIC data averaged for High- and Low-ice years are used as sea ice BC (i.e., including the Bering and Okhotsk Seas and SH)
- Prescribe climatological SST from Merged OI for the period of 1980-2010
- The only difference is SIC (O3 and QBO historical, fixed GHG)

Experimental Design

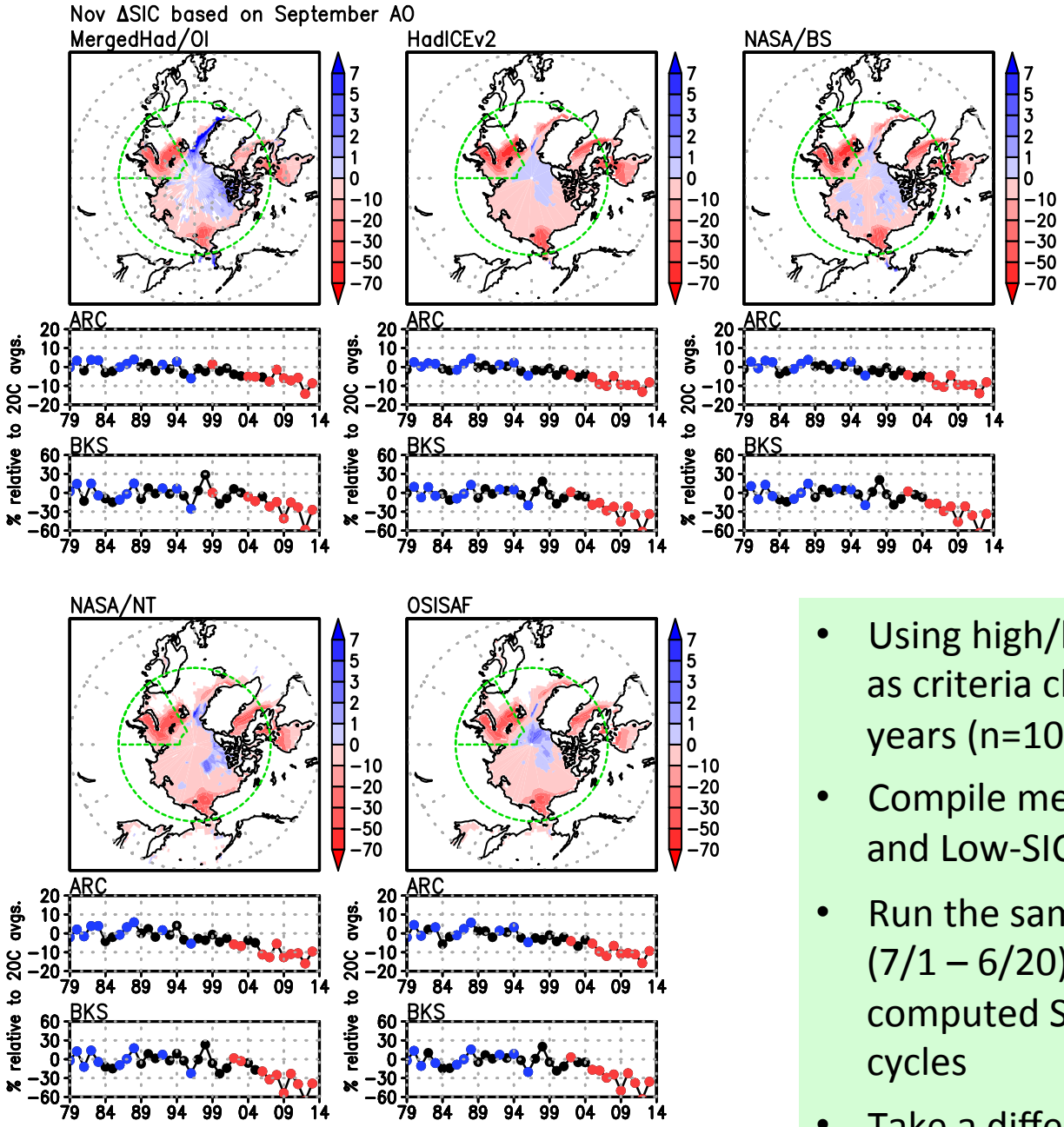
SIC dataset
Merged Had/OI
HadISSTv2
NASA/Bootstrap
NASA/NT1
OSI-SAF
COBE-SSTv2

×

A meta set of experiment. This meta set will be performed with five respective SIC datasets.

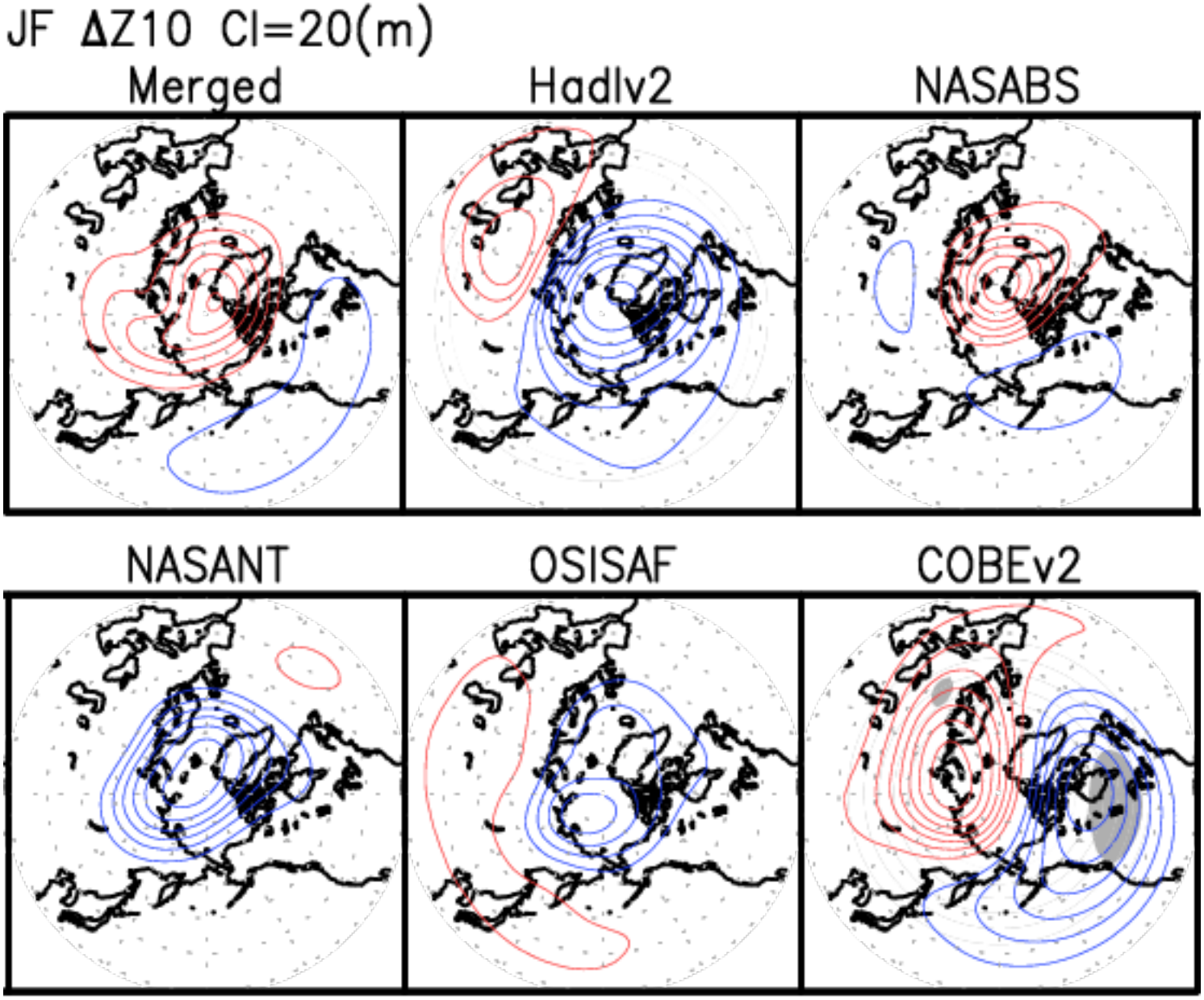
Definition	#m	SST	Sea ice
N15-H	100	Climatology of 1981-2010 of Merged Hadley/ OISST data	High ice period of 1979/80-1983/84
N15-L			Low ice period of 2005/06-2009/10
BKS-H			High-ice composite (n=10) November BKS SIC
BKS-L			High-ice composite (n=10) November BKS SIC
ARC-H			High-ice based on September Arctic SIC
ARC-L			Low-ice based on September Arctic SIC

- Tentative results from the first-50 years integration
- 6 datasets based on September Arctic sea ice conditions (Low-ice minus High-ice)



- Using high/low Sep Arctic Ocean SIA as criteria chose High- and Low-ice years (n=10)
- Compile mean annual cycles of High- and Low-SIC
- Run the same model for a single year (7/1 – 6/20) 100 times using thus computed SST+SIC combined annual cycles
- Take a difference for sea-ice response

Preliminary results (Based on September Arctic)

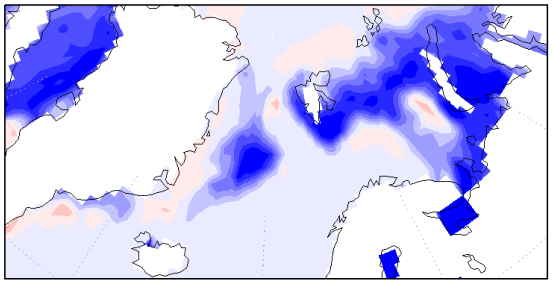


Concluding Remarks

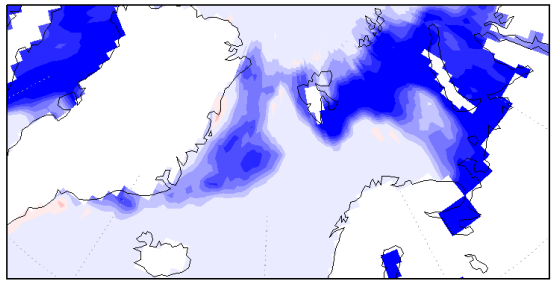
- There are differences in SIC datasets, which appear to be large enough to influence outcomes of sea-ice sensitivity experiments
- How do we design numerical experiments knowing this type of uncertainty in forcing data?
- Do we really want to venture into creation of yet another SST-SIC dataset?
- Speculation: SIC and SST in the GIN Seas (upstream region of the Barents-Kara Seas) may be critical in setting up different sea-ice responses

Differences in ΔSIC (Low – High, NOV) over the GIN-BK Seas

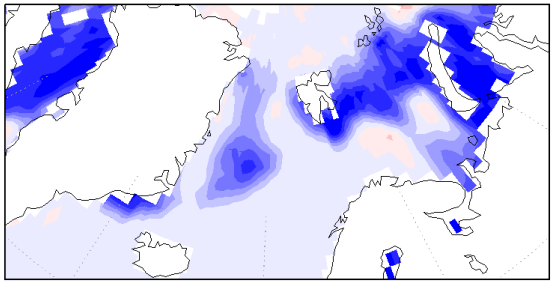
HadISST2



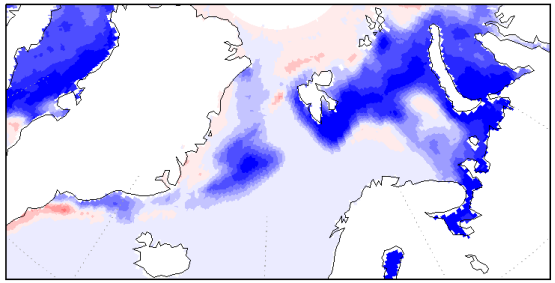
Merged-OI



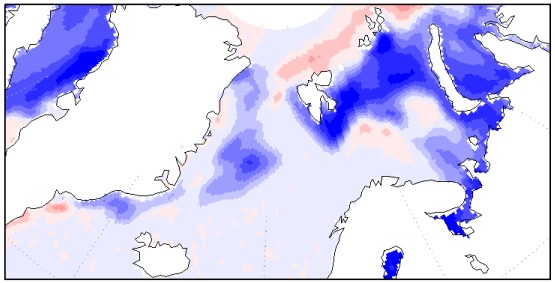
COBE-SST

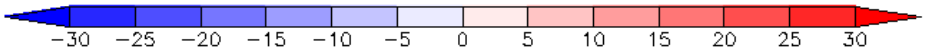


NASA Bootstrap



NASA Team





Questions and issues

- Physical understanding of stratospheric impacts on weather
- Hierarchical experiment strategy for AGCM and CGCM
- Tropospheric processes, e.g. inter-basin teleconnection
- Joint influences from sea ice and snow (how to model?)
- Joint influences from SIC and SST, especially tropical SST
- Summer linkages – soil moisture?
- Eddy heat flux is modulated so is residual mean meridional circulation; what impact does this have on material transport (e.g. O3)?

Other issues

- Model top (how high? GW parameterization) and resolution
- Heat and momentum fluxes at high seas
- Need coordinated observations and modeling for the Arctic ABL
- 3D visualization tools for planetary waves and polar vortex