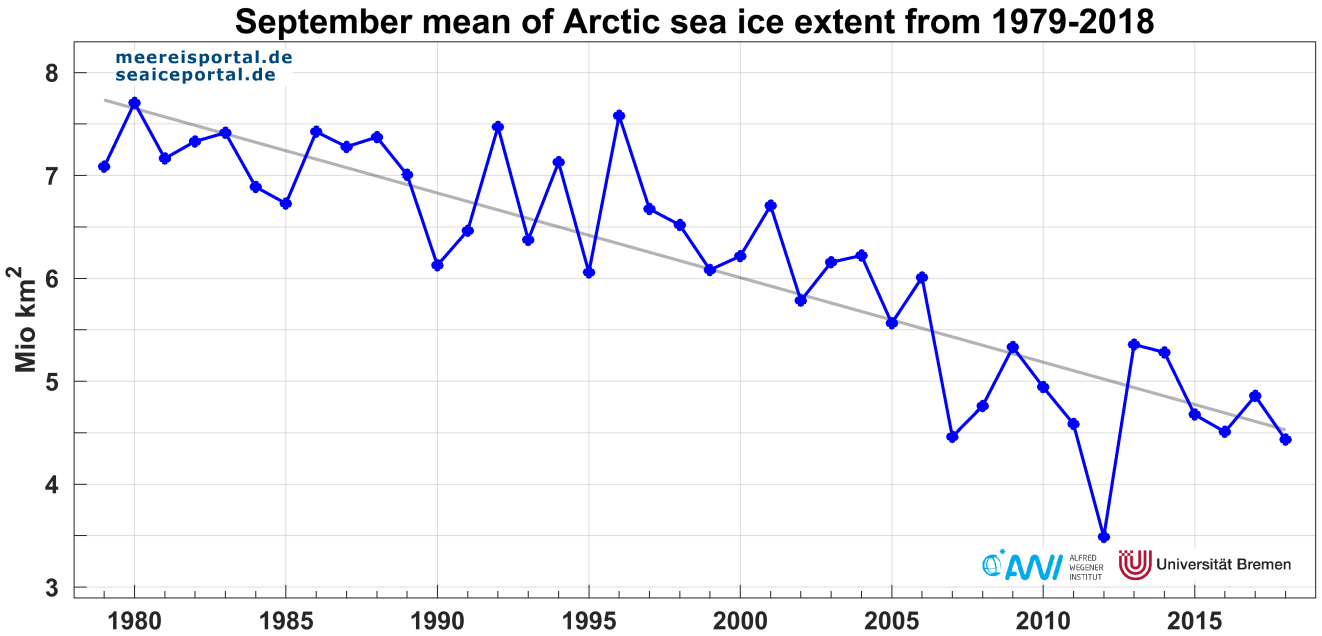
Mid-latitude and tropical drivers of Arctic climate change

Thomas Jung, Kunhui Ye, Felix Pithan and Tido Semmler

Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Bremerhaven, Germany

Motivation


September mean of Arctic sea ice extent from 1979-2018
meereisportal.de
seaiceportal.de
Mio km²
8
7
6
5
4
3
1980
1985
1990
1995
2000
2005
2010
2015
ALFRED WEGENER INSTITUT
Universität Bremen

Relaxation experiments

Take a model:

$$\frac{d\mathbf{x}}{dt} = F(\mathbf{x})$$

Add a relaxation term that “pulls” the model towards some reference field:

$$\frac{d\mathbf{x}}{dt} = F(\mathbf{x}) - \lambda(\mathbf{x} - \mathbf{x}_{ref})$$

- Make λ dependent on latitude, longitude and height (localization)
- Choose reanalysis data or model fields as reference fields

Method → Pull the model towards observations in certain regions, and study the impact elsewhere!

Experimental setup

Atmosphere-only seasonal forecasting experiments with climatological SST and sea ice (ECMWF IFS)

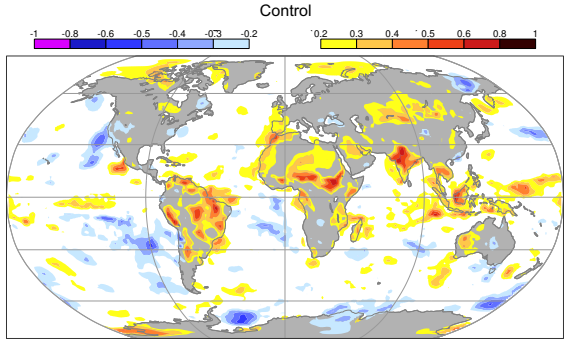
- Control experiment without relaxation
- Tropical relaxation (20S–20N)
- Non-polar relaxation (50S–50N)
- Arctic relaxation (70N–90N)
- Antarctic relaxation (70S–90S)

Comparable *coupled* seasonal forecasting experiments (ECMWF seasonal forecasting system)

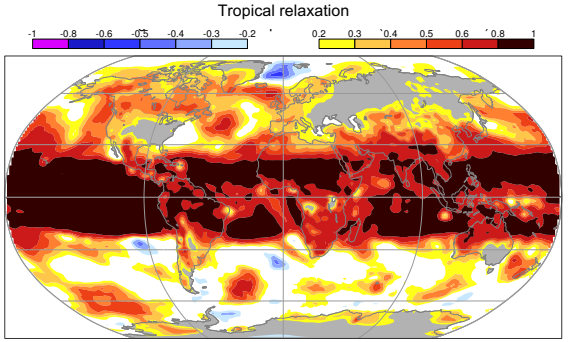
Seasonal experiments

Surface temperature correlations (DJF 1979–2013)

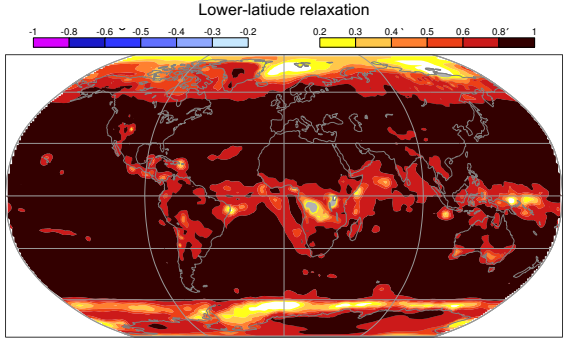
No relaxation



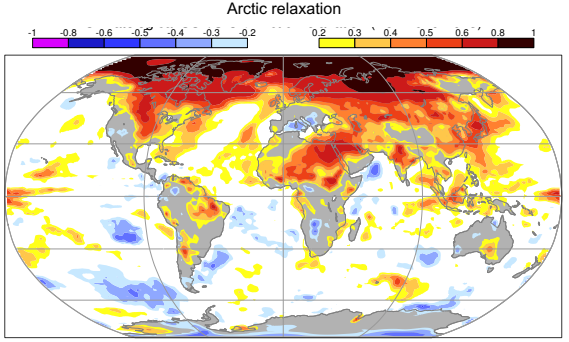
Tropical relaxation



Lower-latitude relaxation



Arctic relaxation



Jung et al. (2014), Ye et al. (2018) and others

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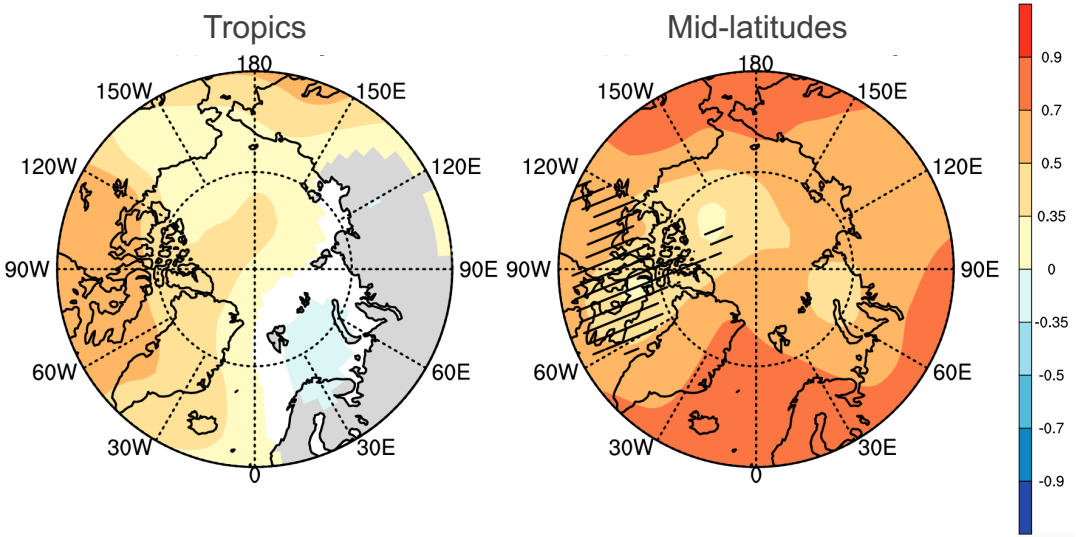
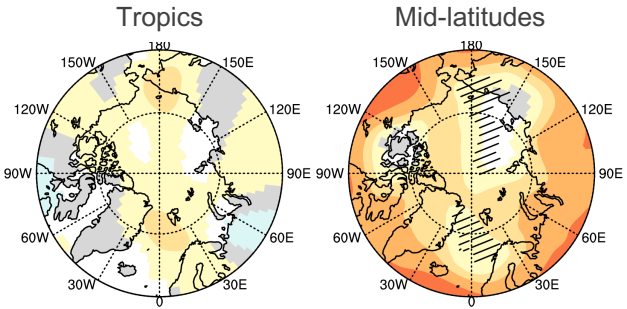
Impact on interannual Z500 variability

Winter



Summer



Ye and Jung, GRL, (2019)

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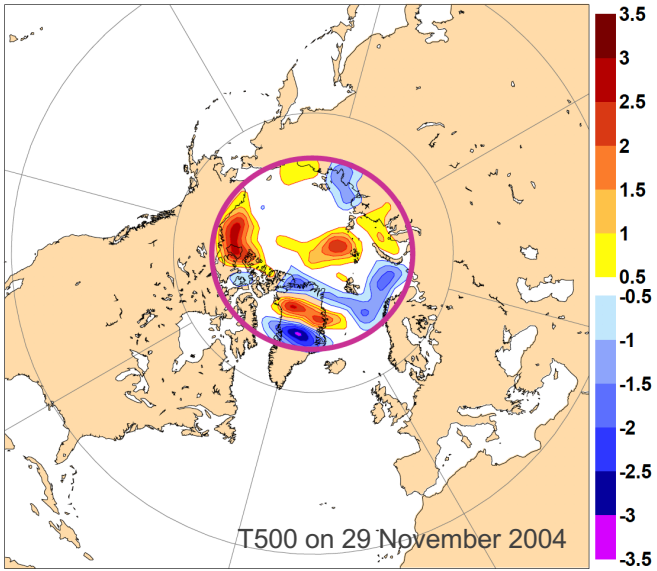
Preferred pathways

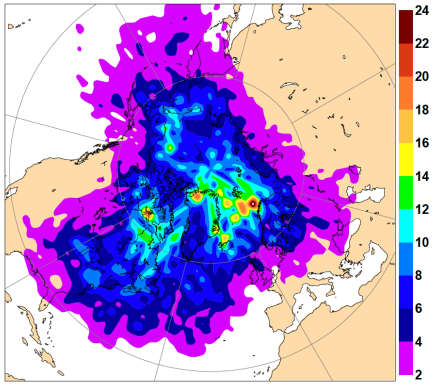
Insight from NWP using adjoint models

How to best perturb initial conditions to minimize D+2 forecast errors in the Arctic?

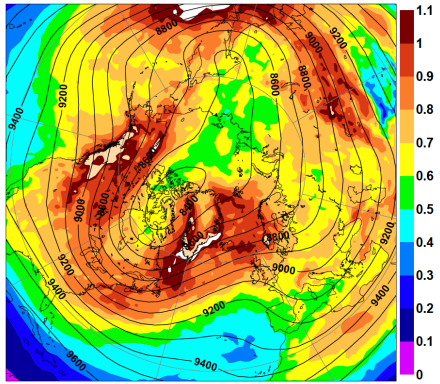


Seasonal average (DJFM, 2004/05)

Magnitude of optimal T500 perturbations



Eady index and Z500



Jung and Leutbecher, QJRMS, (2007)

Perfect model experiments with CESM

→ “We find that the tropics have modest impact on forecast skill in the Arctic or Antarctica both for sea ice and the atmosphere that is mainly confined to the North Pacific and Bellingshausen–Amundsen–Ross Seas”

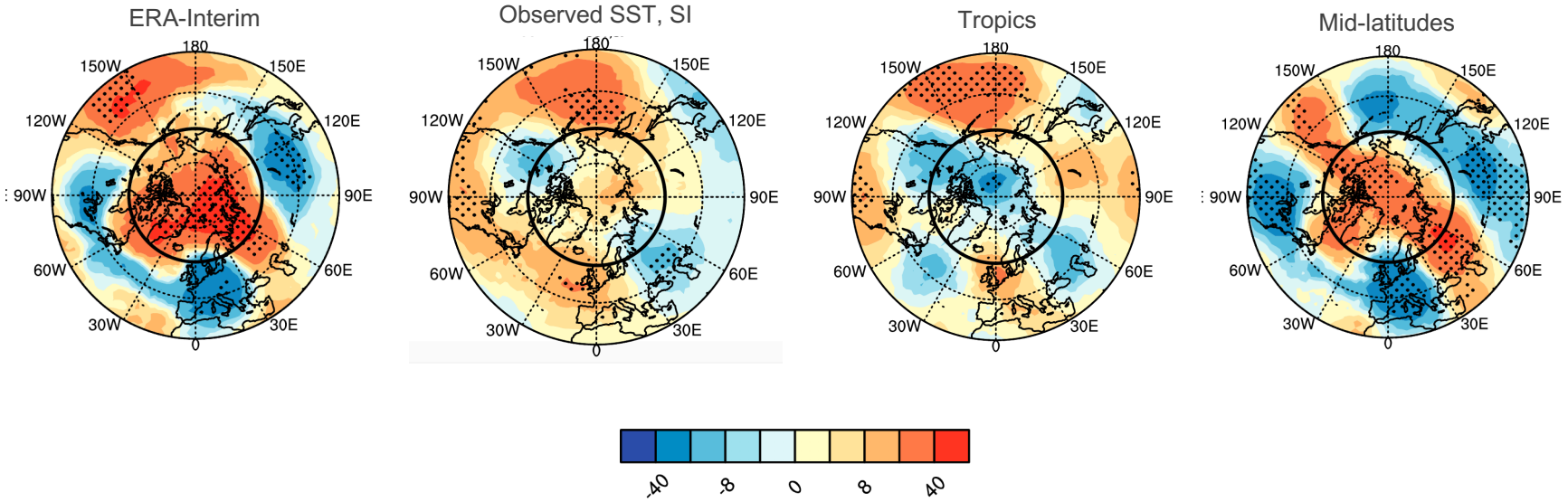
→ “The midlatitudes greatly improve Arctic winter and Antarctic year-round forecast skill”

→ “Arctic summer forecast skill from May initialization is not strongly improved in the nudged forecasts relative to the free forecast and is thus mostly a *local* problem”

Blanchard-Wrigglesworth and Ding, JCLIM (2019)

Impact on circulation trends

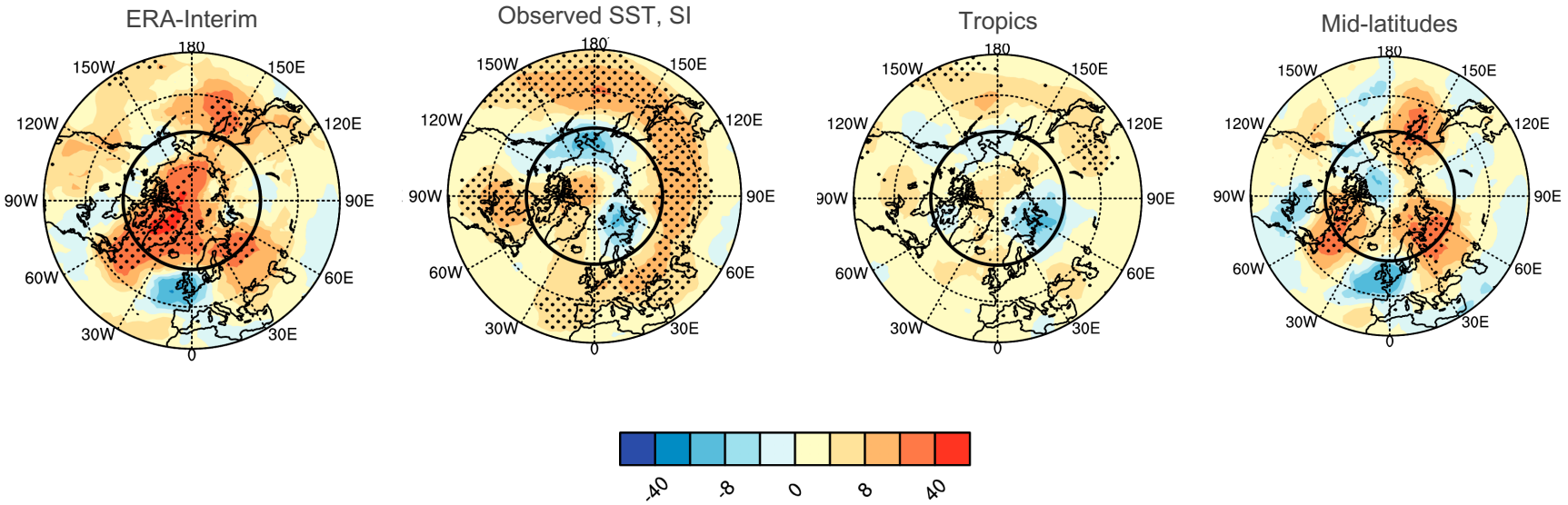
Z500 trends: Winter 1979–2013



Ye and Jung, GRL, (2019)

Impact on circulation changes

Z500 trends: Summer 1979–2013



Ye and Jung, GRL, (2019)

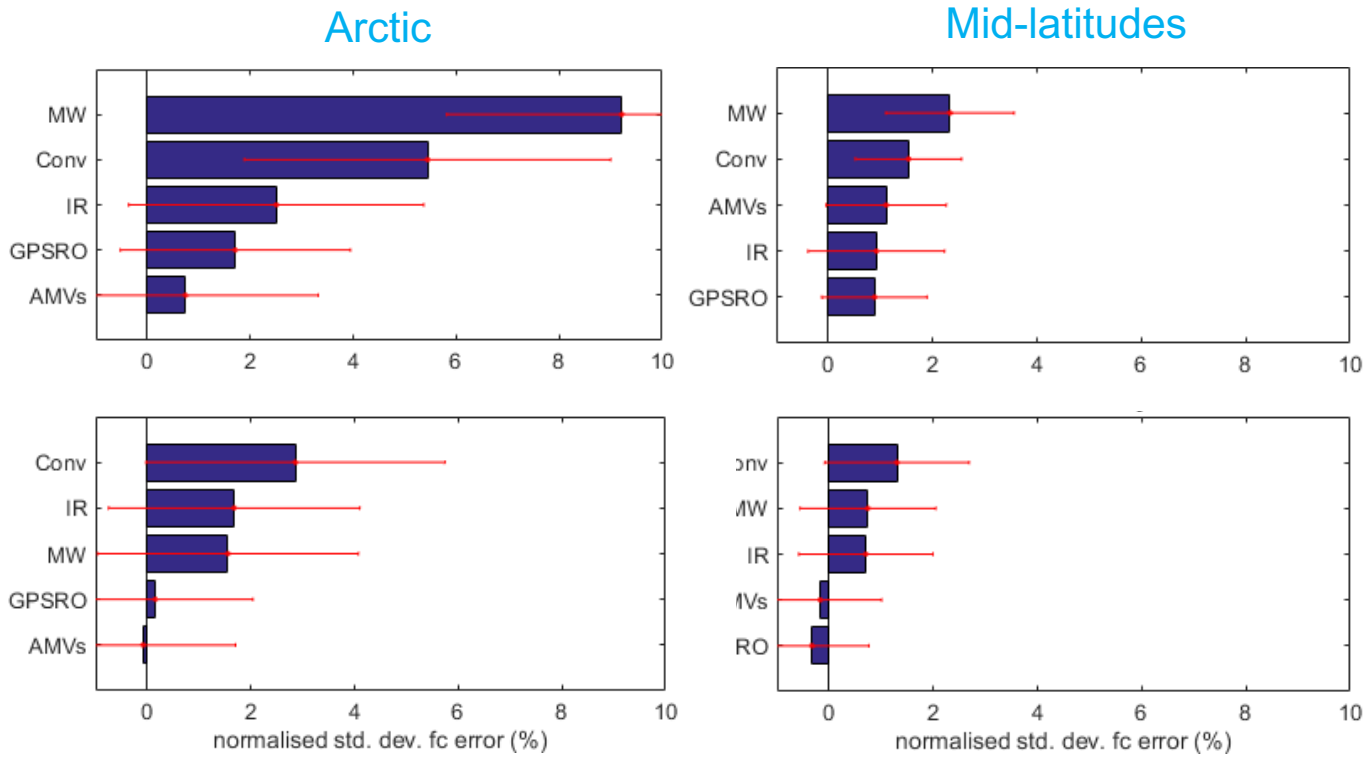
Observing system experiments

Remove observations during the data assimilation cycle in a certain region ➜ study the impact on forecast skill in “remote“ regions

Observing system experiments

Summer

Winter



Lawrence et al., submitted (2019)

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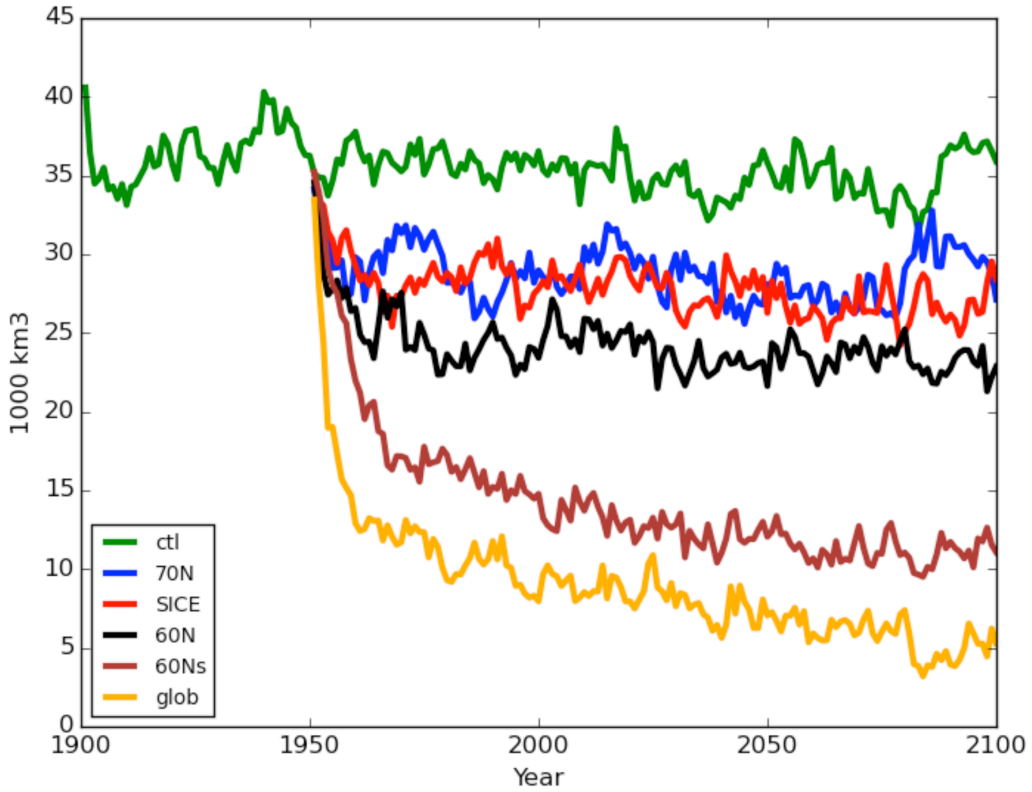
Regional CO_2 quadrupling



Control

4*CO_2 north of 70N

4*CO_2 north of Jan ice edge

4*CO_2 north of 60N

4*CO_2 south of 60N

4*CO_2 globally

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Conclusions

- The atmospheric circulation in both the tropics and mid-latitudes has a strong impact on the Arctic atmospheric circulation
- There seem to be preferred pathways *into* the Arctic
  - North Pacific (tropical forcing)
  - East of Greenland (mid-latitude forcing)
- Linkages are weaker in summer than in winter
- Conclusions are consistent with lessons learnt from NWP
- Thermodynamic forcing from non-polar regions associated with enhanced CO_2 has major impact on Arctic sea ice volume

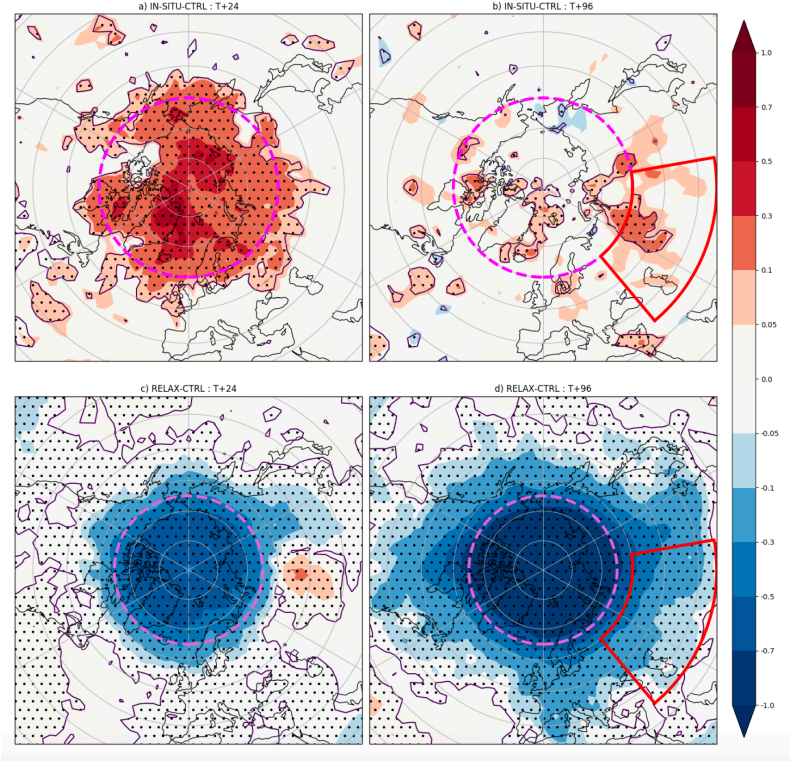
OSE vs relaxation

D+1

D+4

OSE (no-conv)

Relaxation



Normalized change in Z500 RMSE

Day et al., QJRMS, submitted (2019)

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