

# High-latitude processes in sub-seasonal to seasonal prediction

Steffen Tietsche

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ECMWF Annual Seminar 2019



## Talk outline

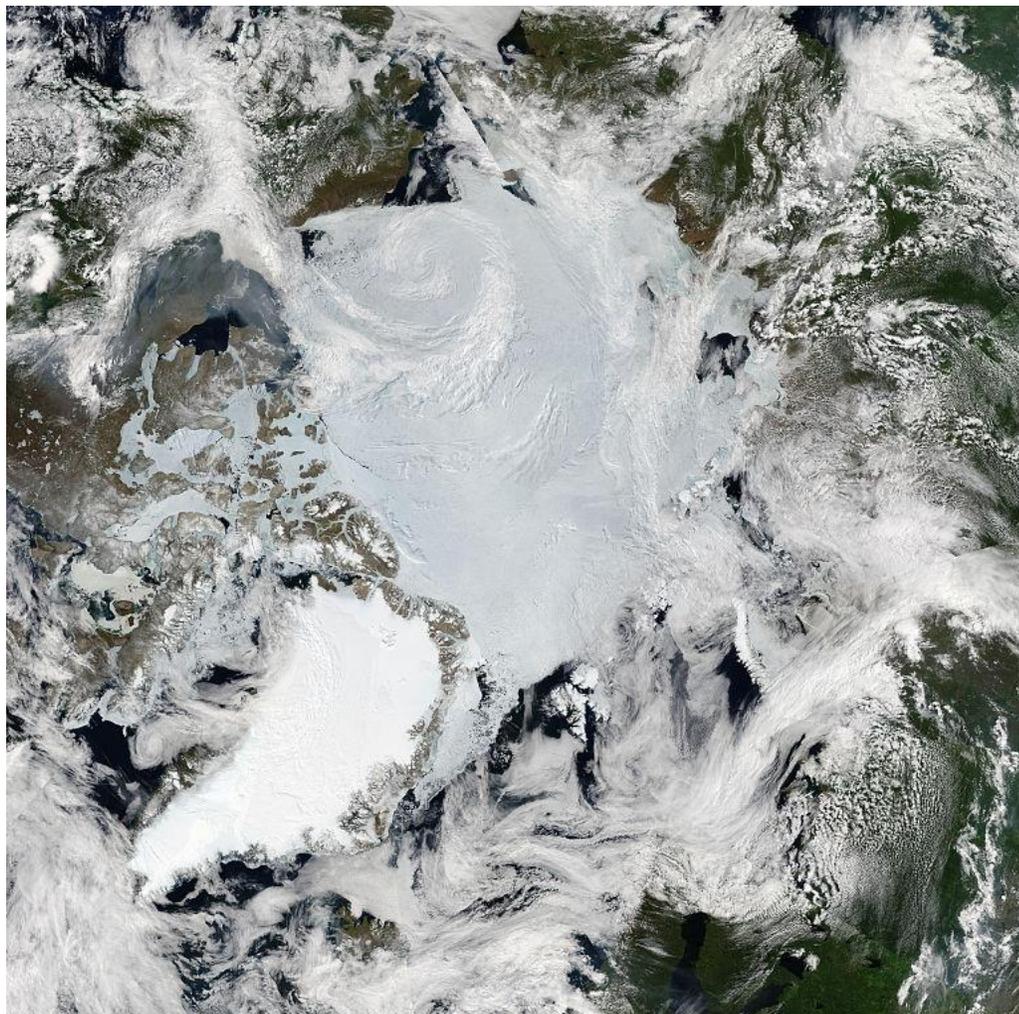
1. *What is special about high latitudes / polar regions?*
2. *Observations, modelling and initialization*
3. *S2S forecast skill and mid-latitude linkages*

## What is special about high latitudes / polar regions?

- Remote and sparsely observed
- Dominance of cryospheric processes
- Unique mass and heat flux patterns
- Polar amplification of climate change

## A view of the polar regions

The Arctic in MODIS visible, 12 July 2018



[Wikimedia Commons](#)

The Antarctic in MODIS visible, austral summer



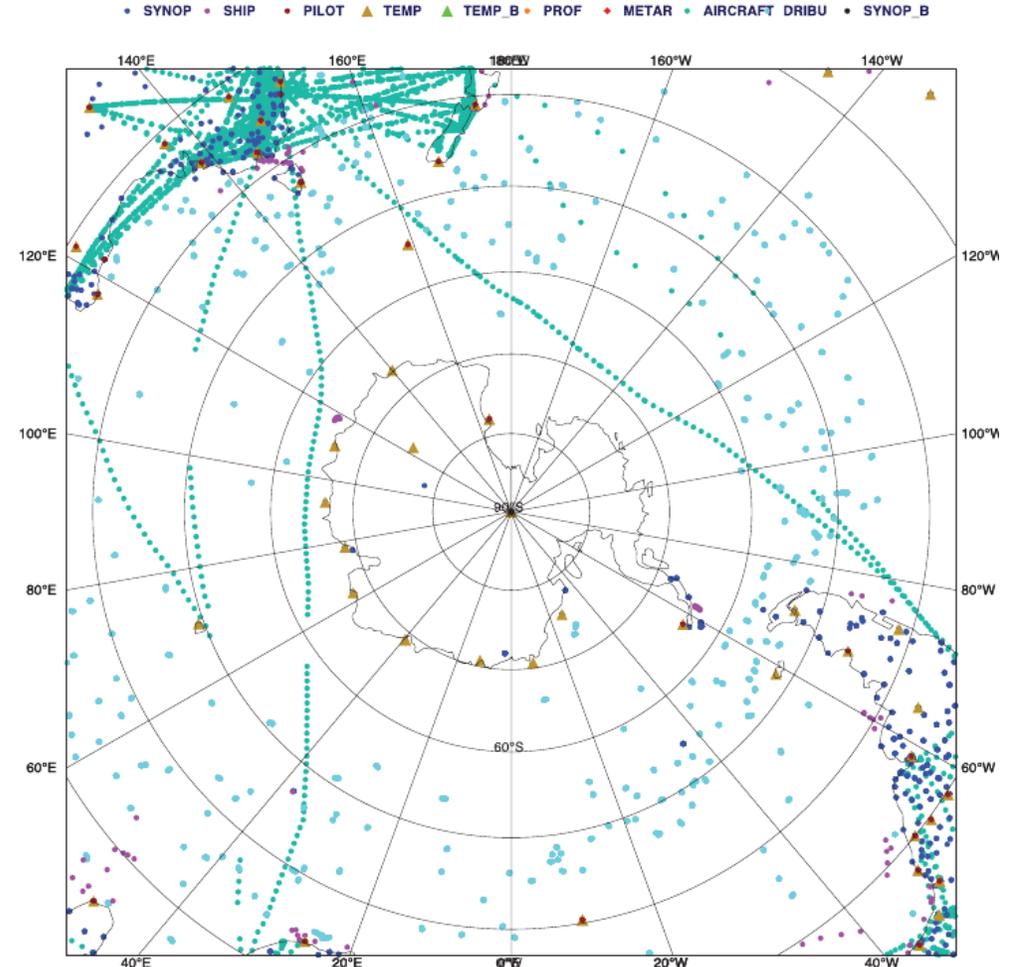
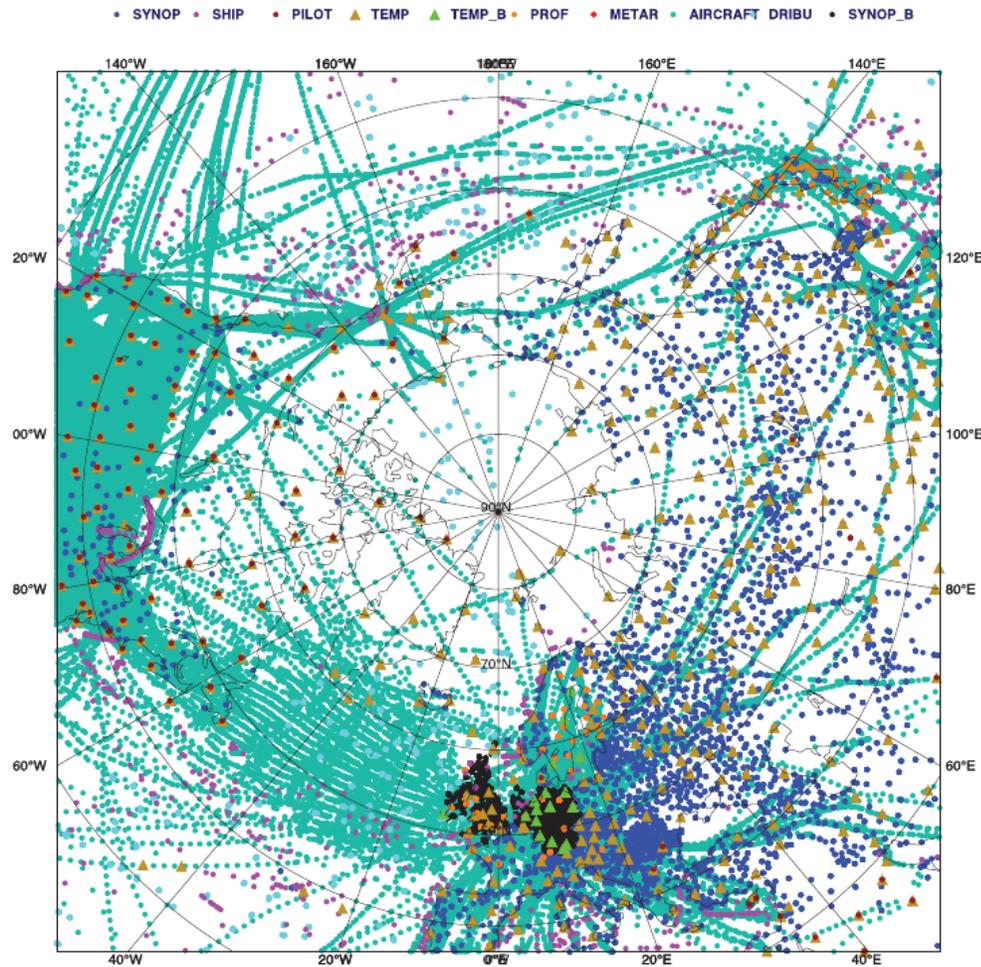
[Flickr / Scripps Institution of Oceanography](#)

# The polar regions are sparsely observed

Conventional observations assimilated by ECMWF on 15 Apr 2015

Arctic

Antarctic

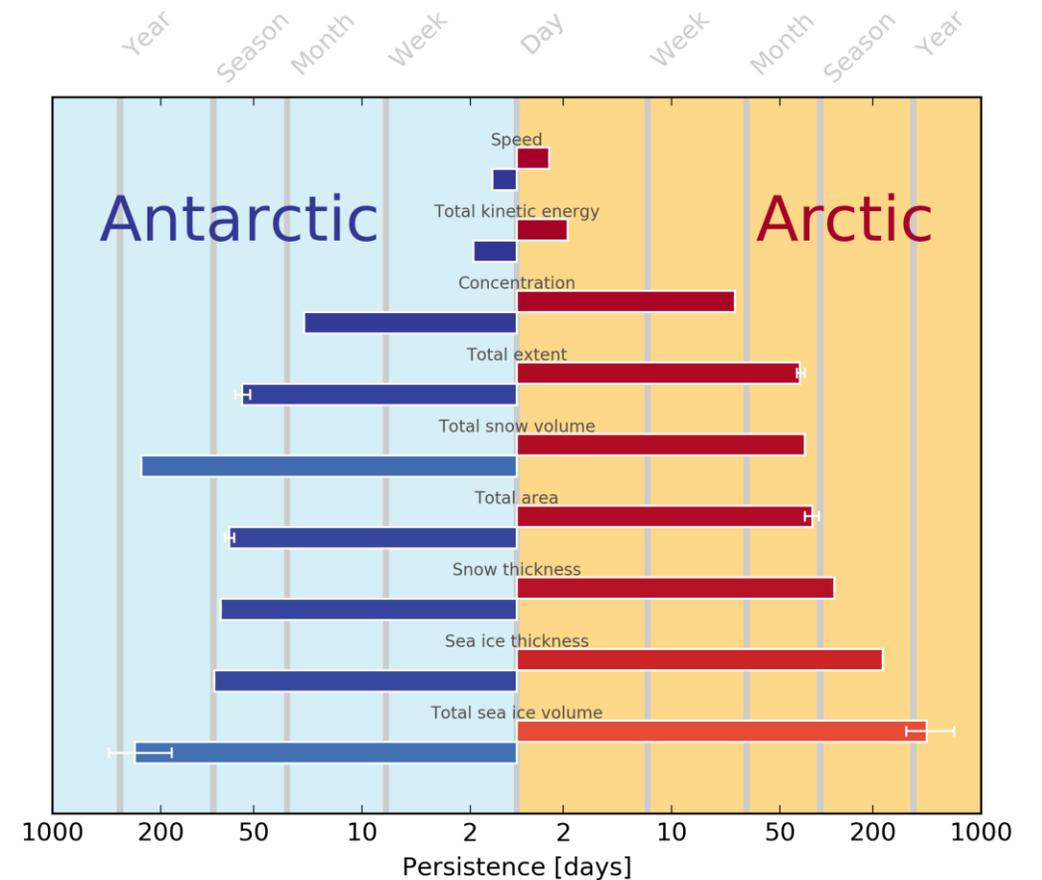


# Cryospheric processes

- Snow
- Sea ice
- Ice sheets, glaciers
- Ice shelves and ice bergs
- Permafrost

→ Specific challenges for modelling and observations  
→ Provide potential predictability

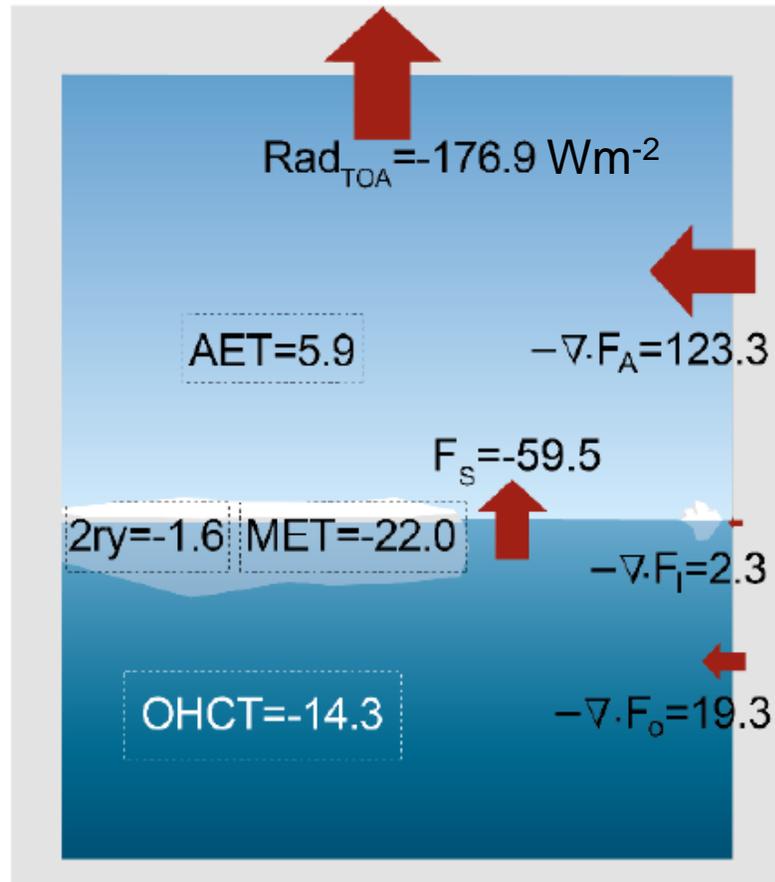
Example: persistence of sea ice properties



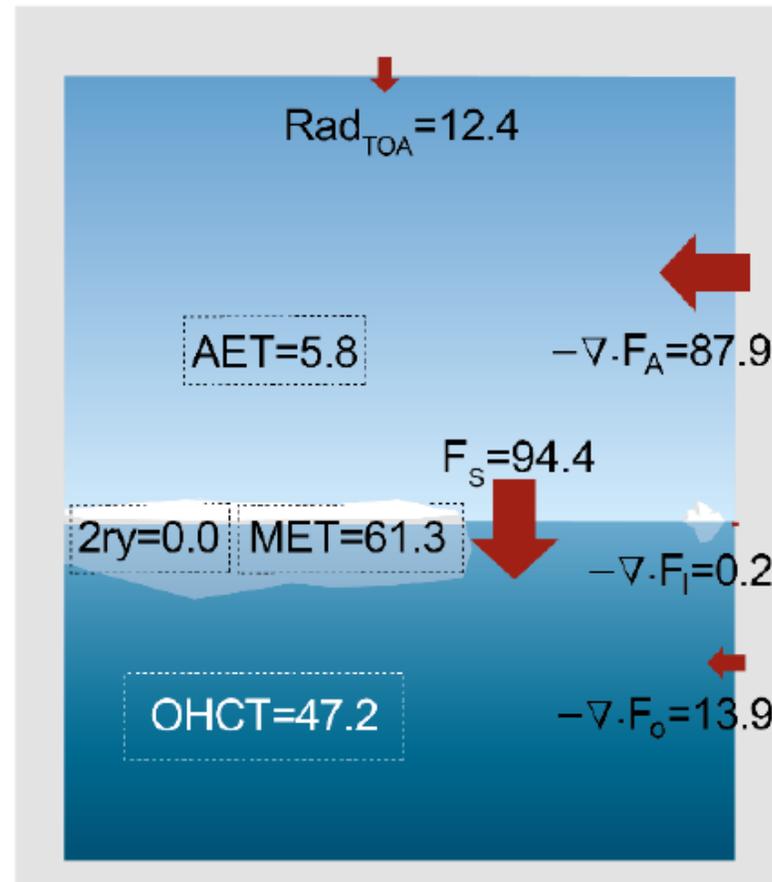
Chevallier et al. 2019

# The coupled energy budget of the Arctic

b) 2005-2009 Jan mean

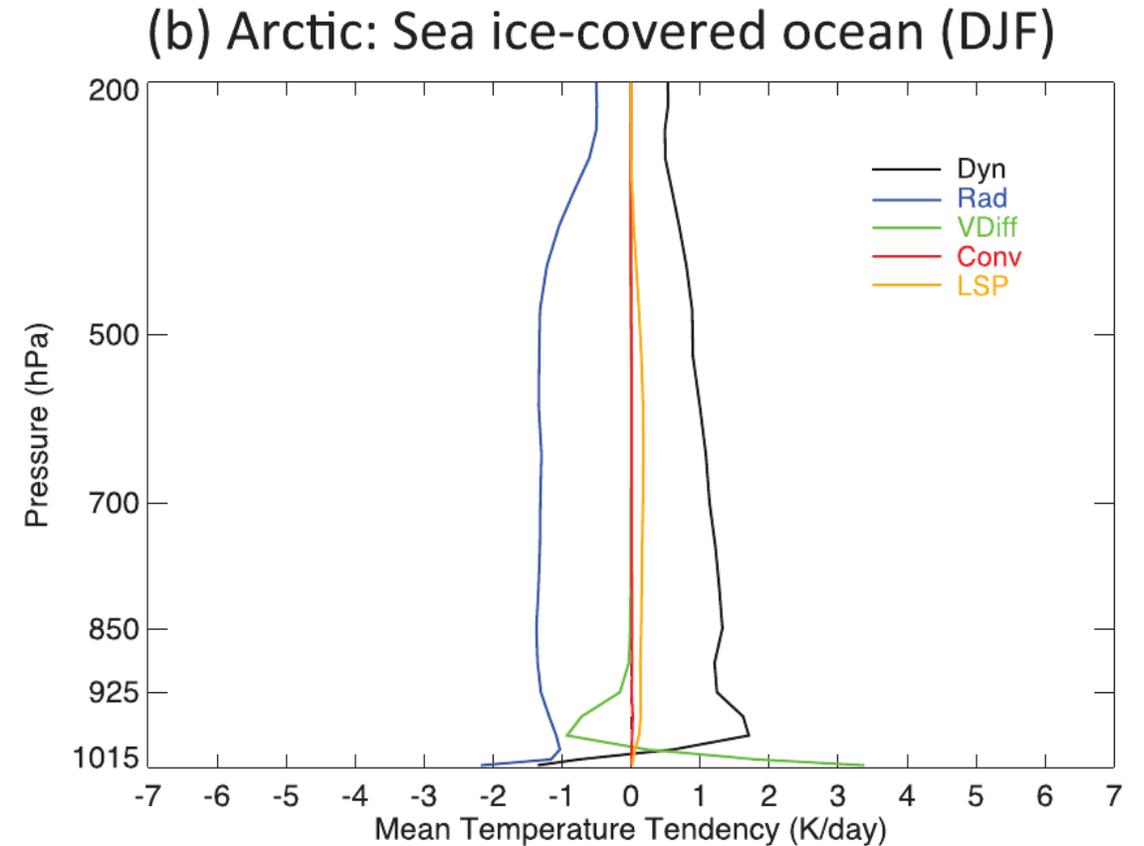
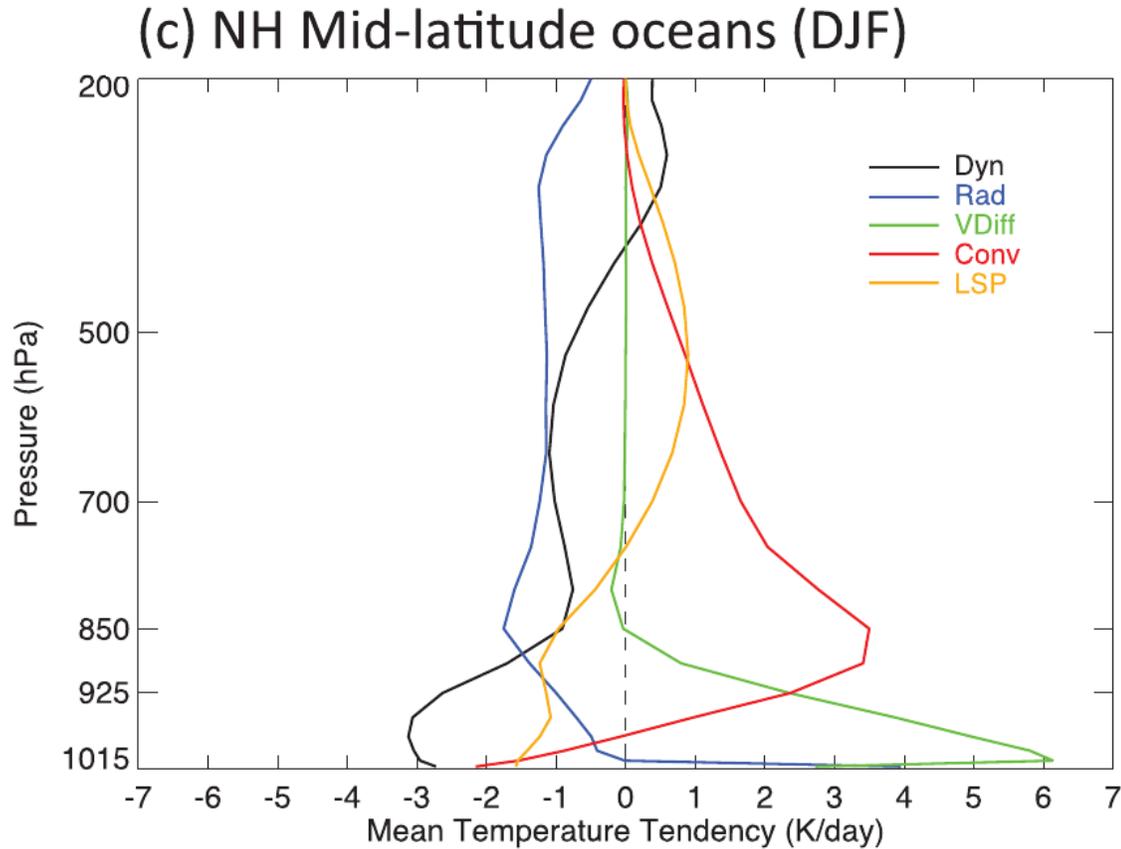


c) 2005-2009 Jul mean



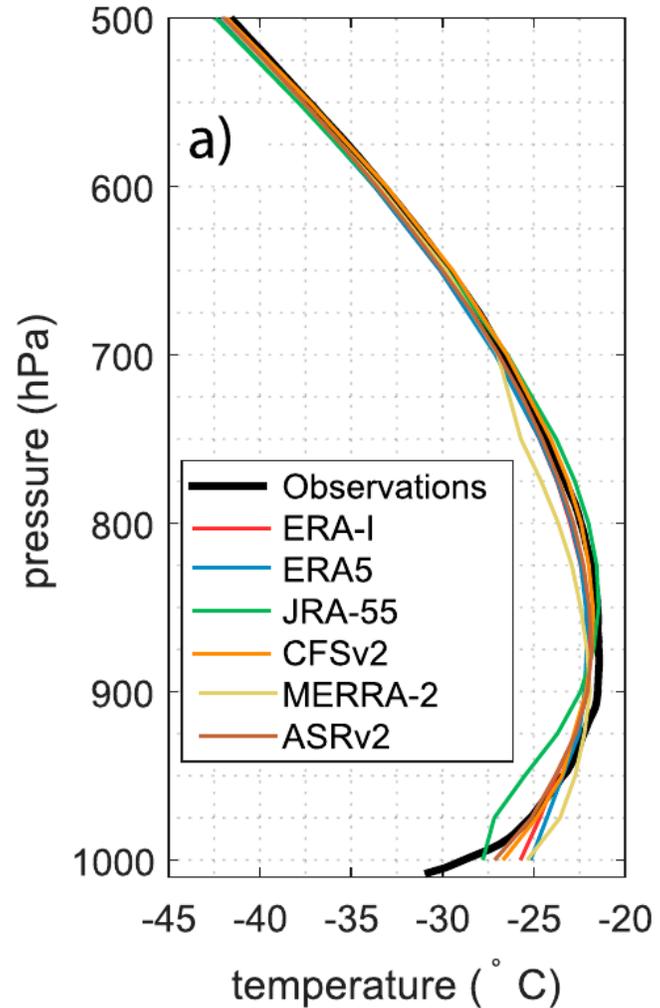
Mayer et al., J. Clim. 2019

# High latitudes have different balance of tropospheric processes

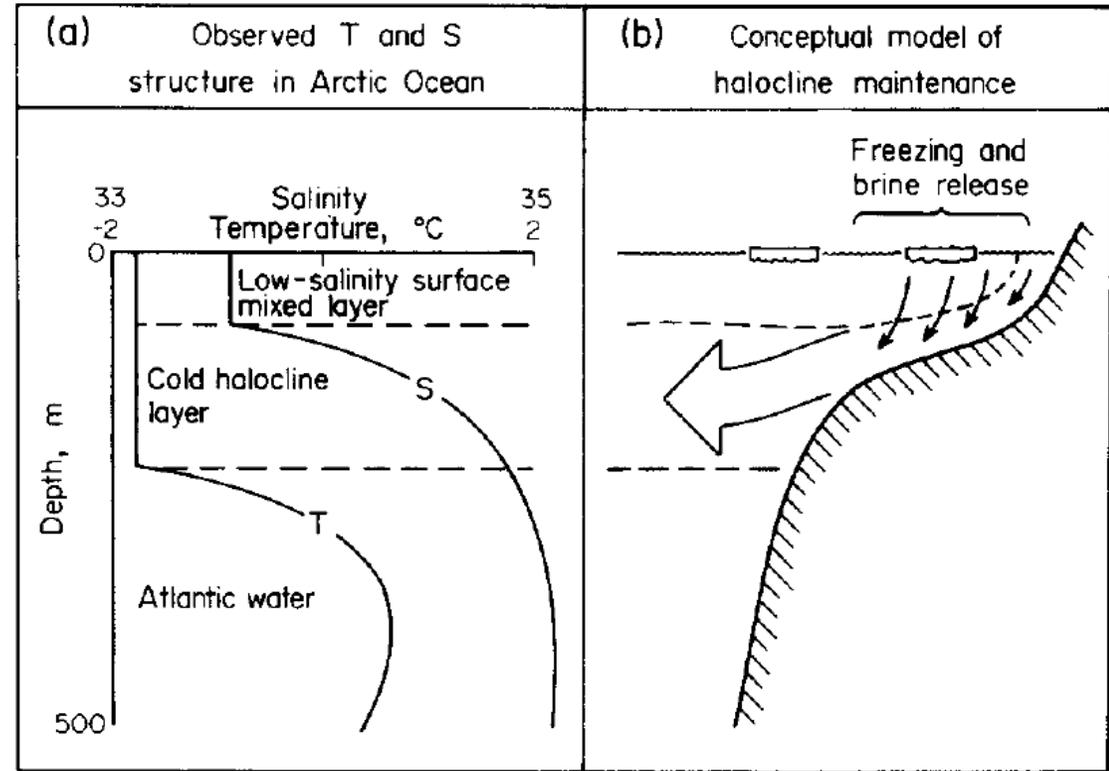


Jung et al., BAMS 2016

# Shallow stable boundary layers (esp. Arctic)

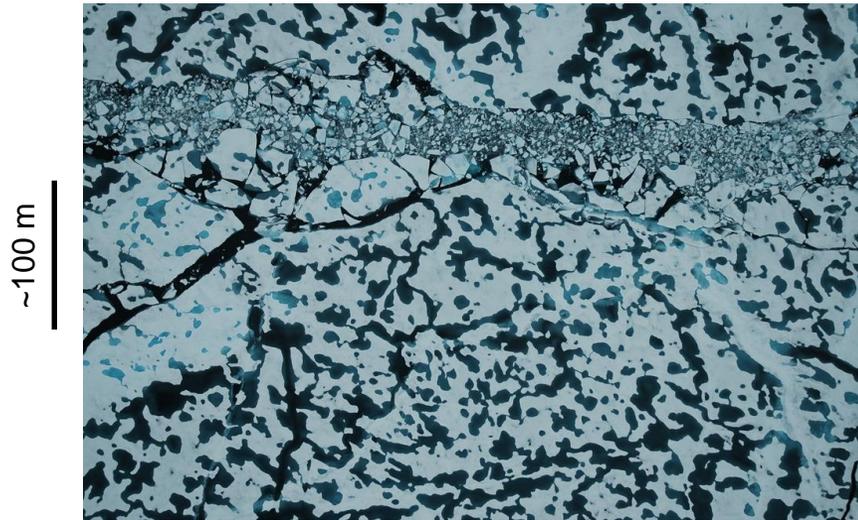


Graham et al., J. Clim. 2019

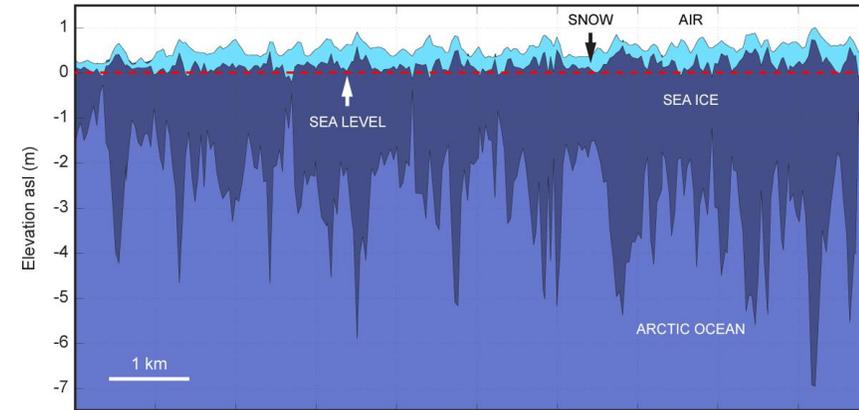


Aagaard et al., Deep Sea Res. 1981

# Sea ice



aerial photograph of broken sea ice with melt ponds



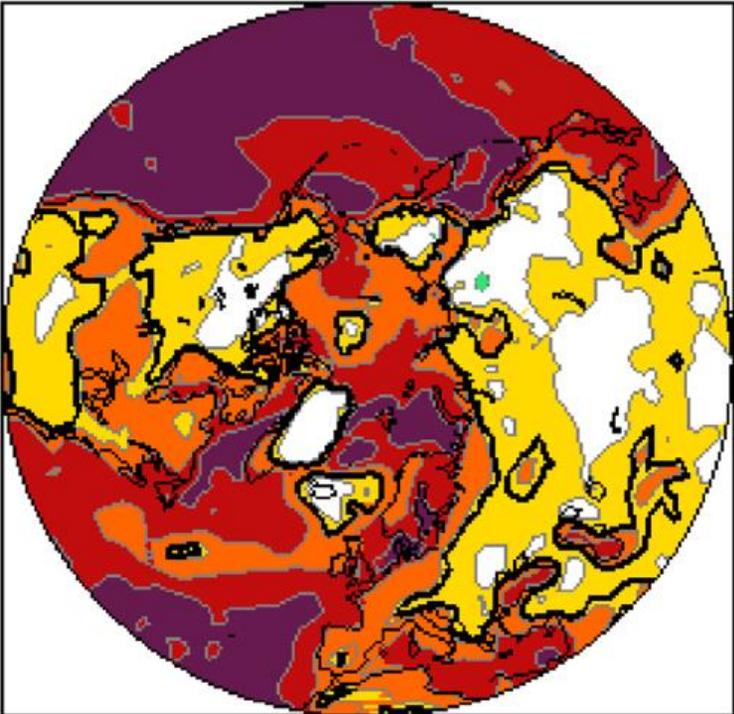
ice thickness transect from Operation IceBridge

Immediate (hours)	Delayed (days to seasons)
Surface cooling from albedo effect	Advection
Suppression of atmosphere-ocean heat fluxes	Timing of melt from ice thickness
Suppression of wind mixing in upper ocean	Melting: fresh water export

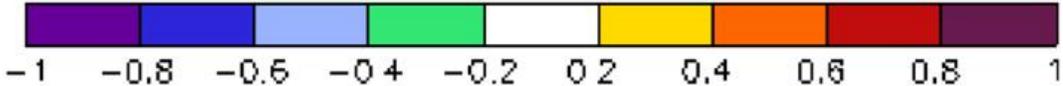
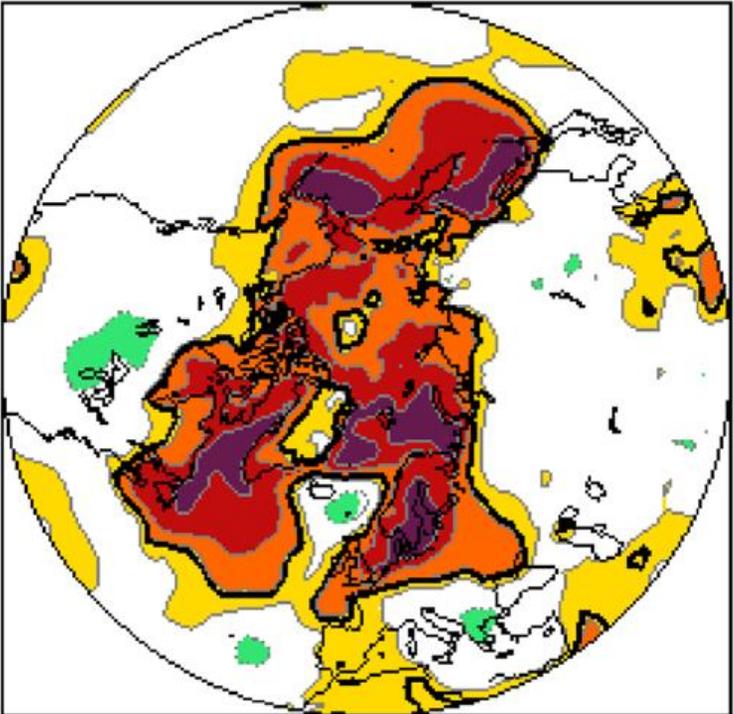
# Impact of sea ice on winter surface air temperature

Correlation of DJF SAT with reanalysis in atmosphere-only simulations (1982-2014):

observed SST and sea ice



observed sea ice but constant SST



Koenigk et al., Clim. Dyn. 2019

# Snow

Immediate (hours)	Delayed (days to seasons)
Surface cooling from albedo effect	Soil moisture from snow melt
Thermal insulation between soil and atmosphere	Timing of melt from snow depth

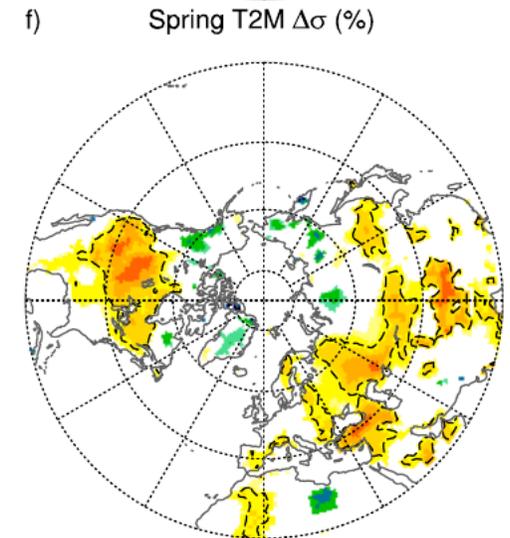
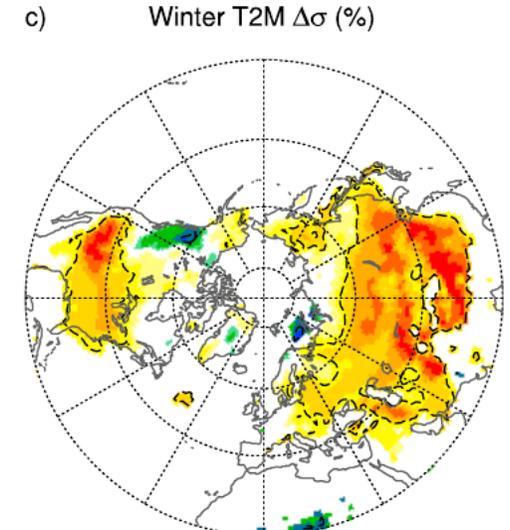
Also cf.

Thomas, *Clim. Dyn.* 2016

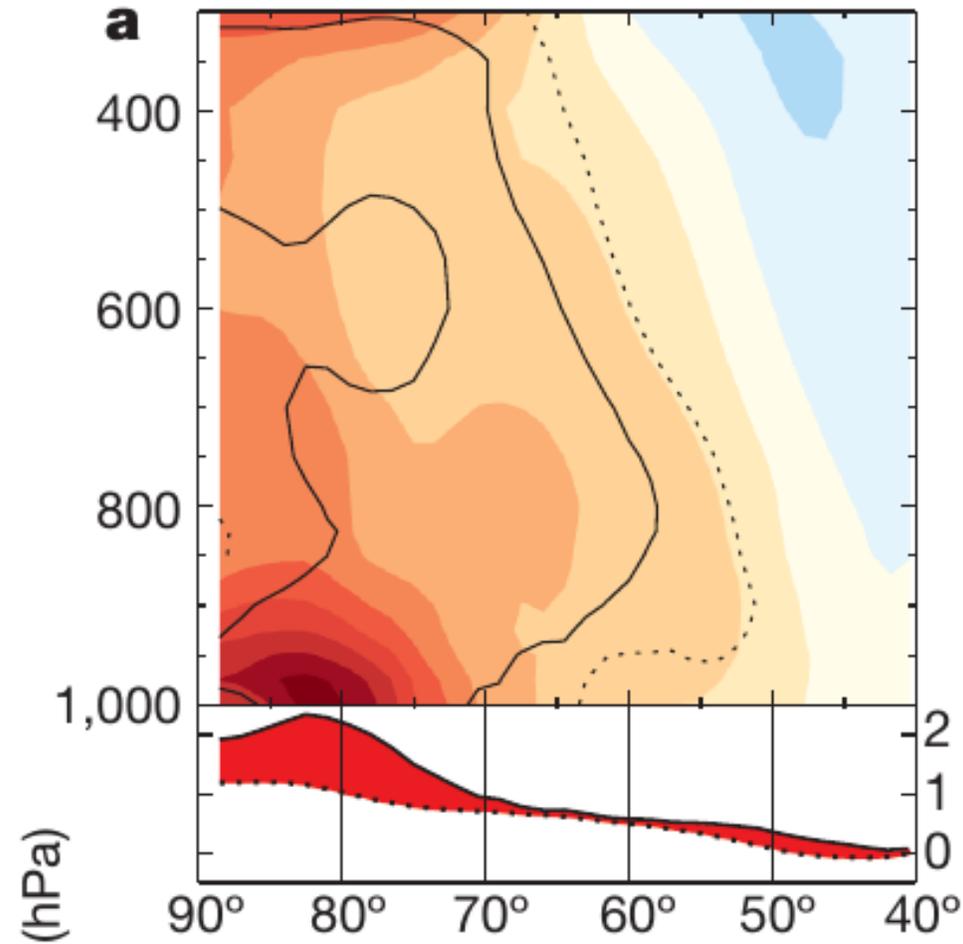
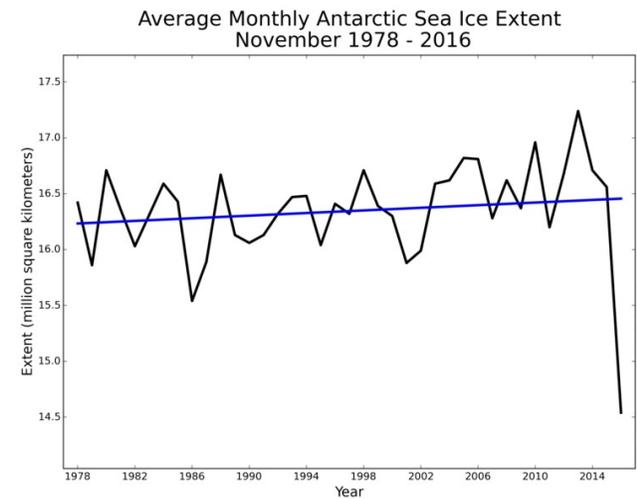
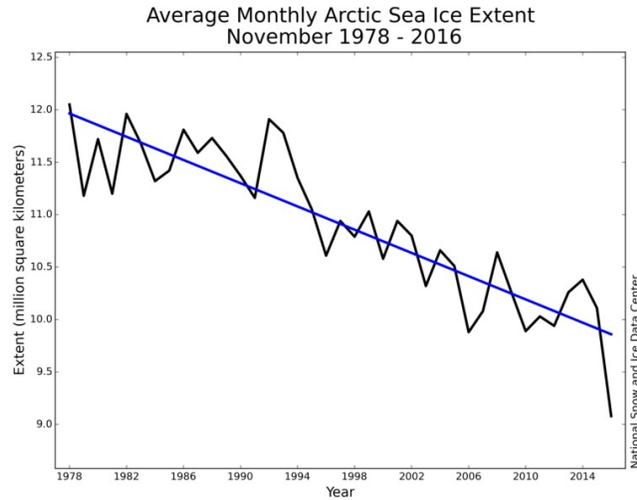
Kolstadt, *J. Clim.* 2017

Percentage of interannual variability of SAT closely related to snow cover

Dutra et al., *GRL* 2011



# (Arctic) amplification of climate change



Temperature trends 1989-2008 from ERA-Interim

Screen and Simmonds, Nature 2010

## 2. Recent progress in observing and modelling polar regions

# Satellite observations of the S2S-relevant cryosphere

## *Current state of the art*

- Mature data sets of snow and sea-ice extent with some inconsistencies
- Experimental data sets for (Arctic!) sea ice thickness, but rapidly improving
  - new types of satellite sensors since the 2000s:
  - thermal infrared (e.g. MODIS)
  - laser altimetry (ICESat and ICESat2)
  - radar altimetry (Envisat, CryoSat2, Sentinel3)
  - L-band radiometry (SMOS, SMAP, Aquarius)

## *Expected progress for the next years*

- New sensors like multi-spectral PMR (CIMR)
- Improved consistency between datasets through projects like ESA-CCI, SnowPEX
- More and improved assimilation into NWP analyses
- Field campaign data urgently needed for ground truth

## Model developments – ocean and sea ice

- Increasing horizontal ocean resolution:  
from  $\sim 1^\circ$  to presently  $\sim 1/4^\circ$ ; experimenting with  $\sim 1/12^\circ$ 
  - Resolve more eddies, esp. in Southern Ocean
  - Arctic currents topographically steered – bathymetry matters
  - Coastal effects important for sea ice
- Prognostic sea ice: finally in most operational S2S systems
- Pending: more sophisticated sea-ice physics
  - Subgrid-scale sea ice thickness distribution
  - melt ponds
  - land-fast ice

## Model developments – atmosphere and land surface

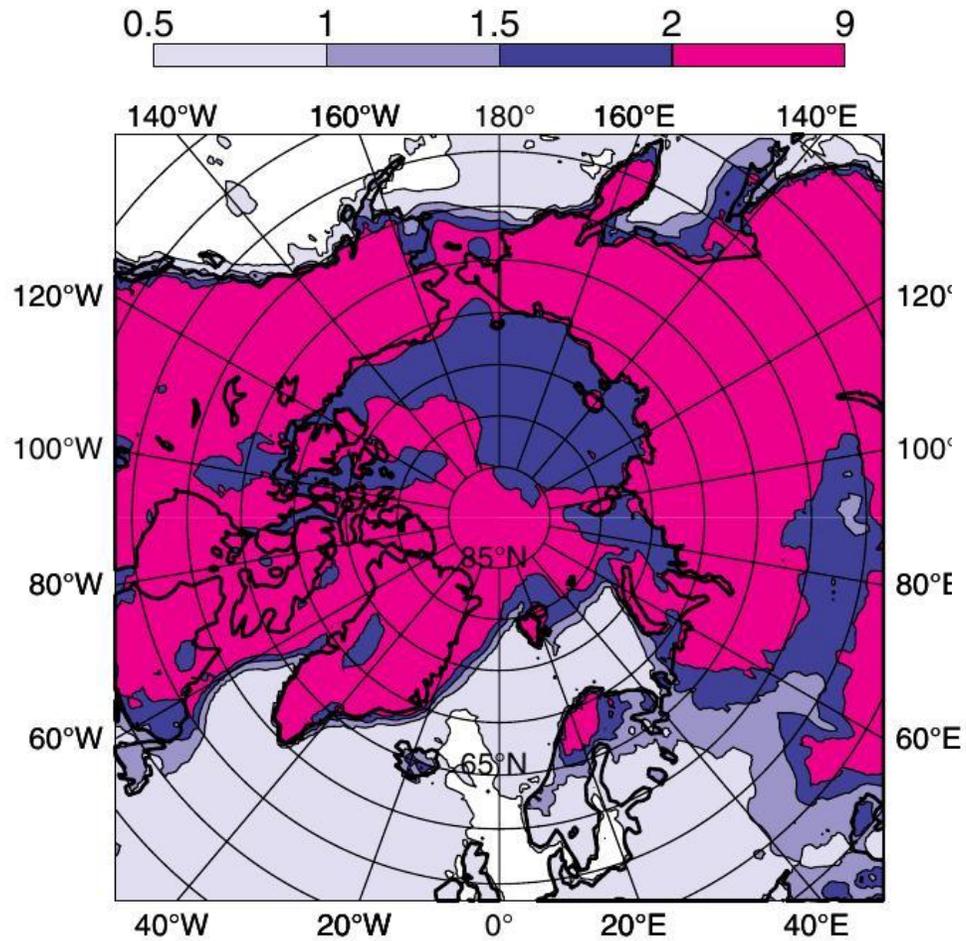
Some improvements, but major challenges remain:

- High-latitude clouds (cf. Forbes and Ahlgrimm, Mon. Weather Rev. 2014)
- Shallow stable boundary layers (Sandu et al., JAMES 2013)
- Snow/ice surface properties (e.g. Arduin et al, JAMES in rev.)

*Need consistent coupling between atmosphere, ocean and sea ice*

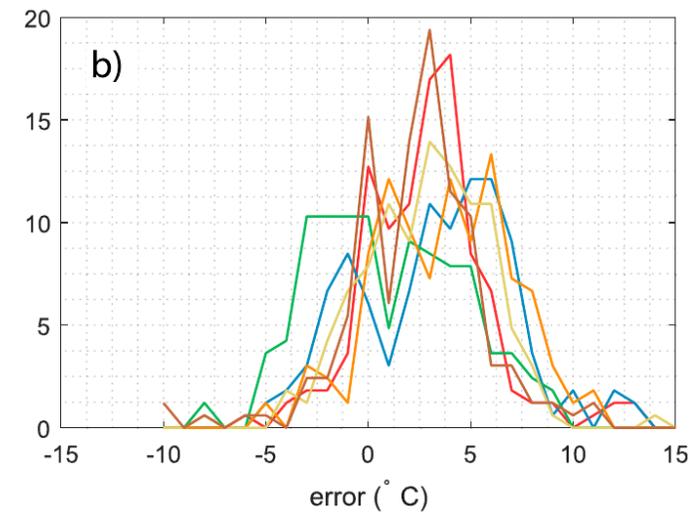
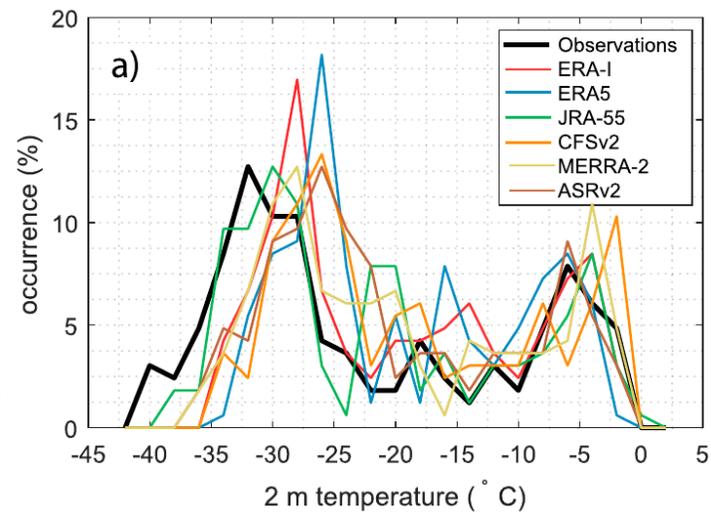
# Surface temperature uncertainty in atmospheric analyses over snow and ice

DJF SAT analysis spread from TIGGE archive (K)



Bauer et al., QJRMS 2016

Reanalysis SAT against in-situ observations  
(N-ICE campaign north of Svalbard in winter 2015)



Graham et al., J. Clim. 2019

# Upcoming MOSAiC sea ice drift expedition



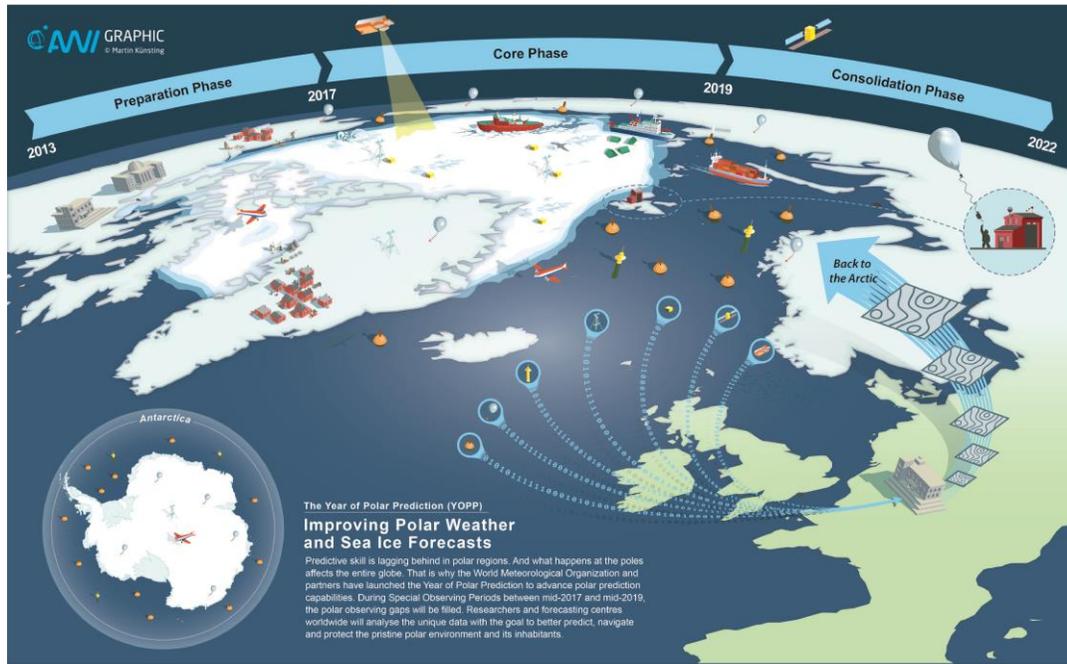
[www.mosaic-expedition.org](http://www.mosaic-expedition.org)

- **Largest** Arctic research expedition ever.
- **Integrates** between disciplines and between observations & models.
- Will lead to **breakthrough** in Arctic climate science.
- **Unique experience & network** for **next generation scientists**.

Sep 2019 – Sep 2020

### 3. Polar S2S forecast skill and mid-latitude linkages

# Year of Polar Prediction



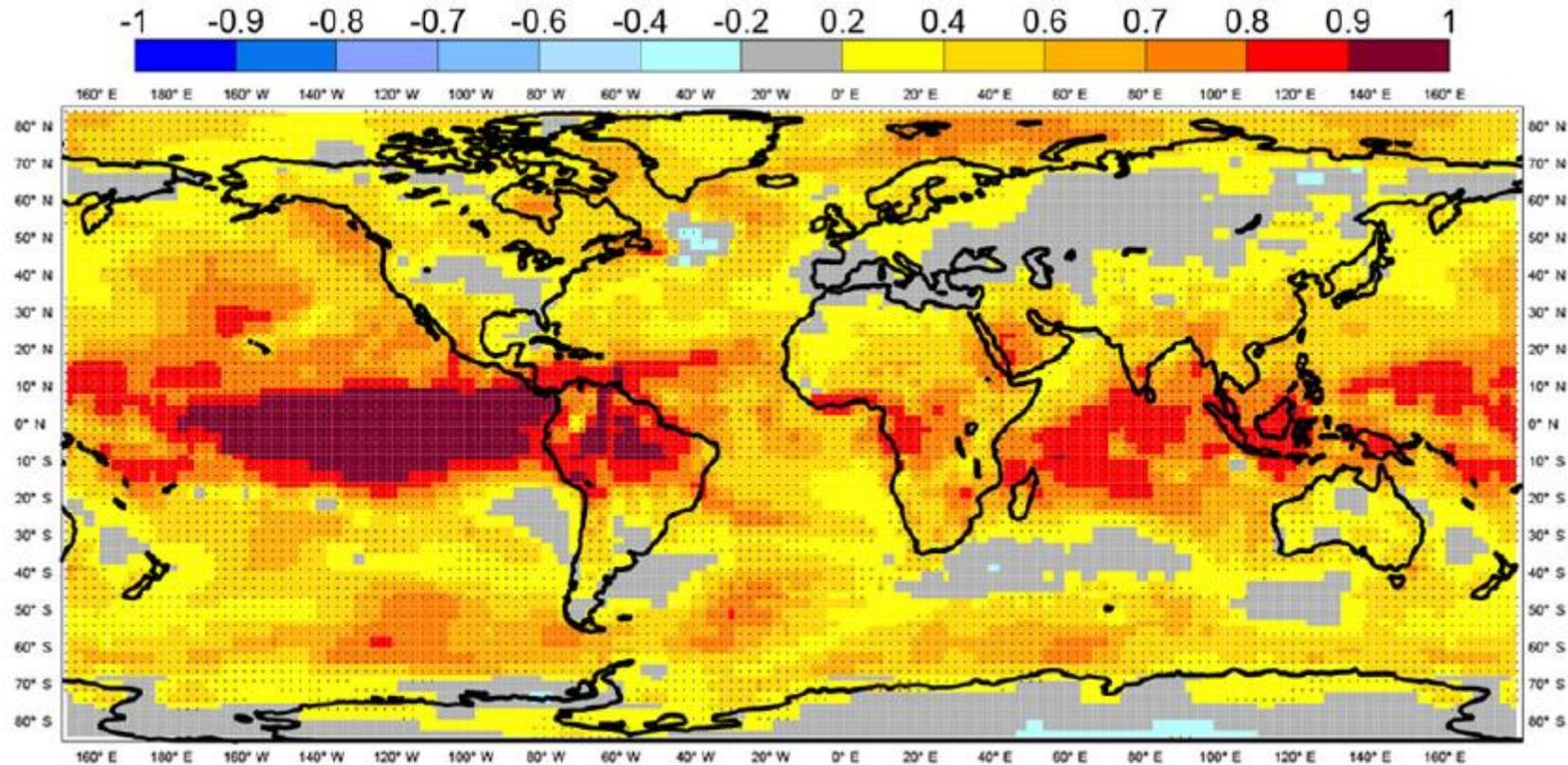
Coordinated by the  
World Meteorological Organization (WMO)

Period:  
mid 2017– mid 2019 (Launch: 15th May 2017)

- **Goal: Improving predictions of weather and environmental conditions in polar regions and beyond**
- International collaboration between academia, operational forecasting centres, and stakeholders
- Improving the polar observing system, as well as weather and climate prediction models in polar regions

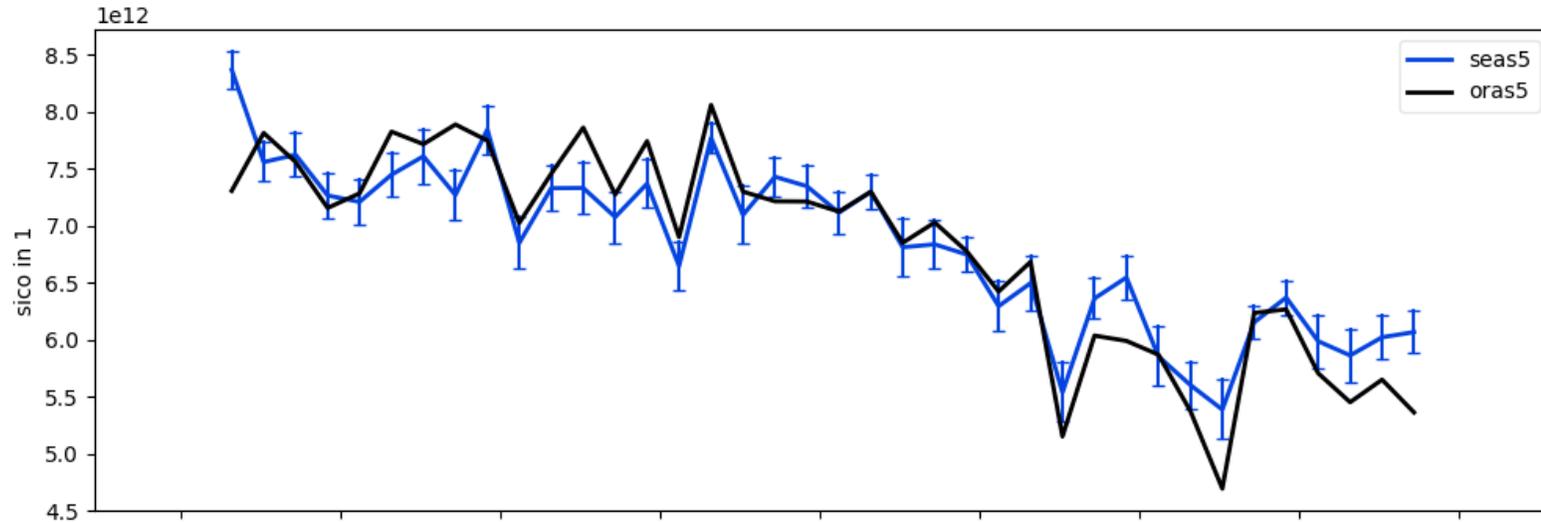
# How does forecast skill in polar regions compare with the rest of the world?

Example: SEAS5 DJF ACC for 2m temperature

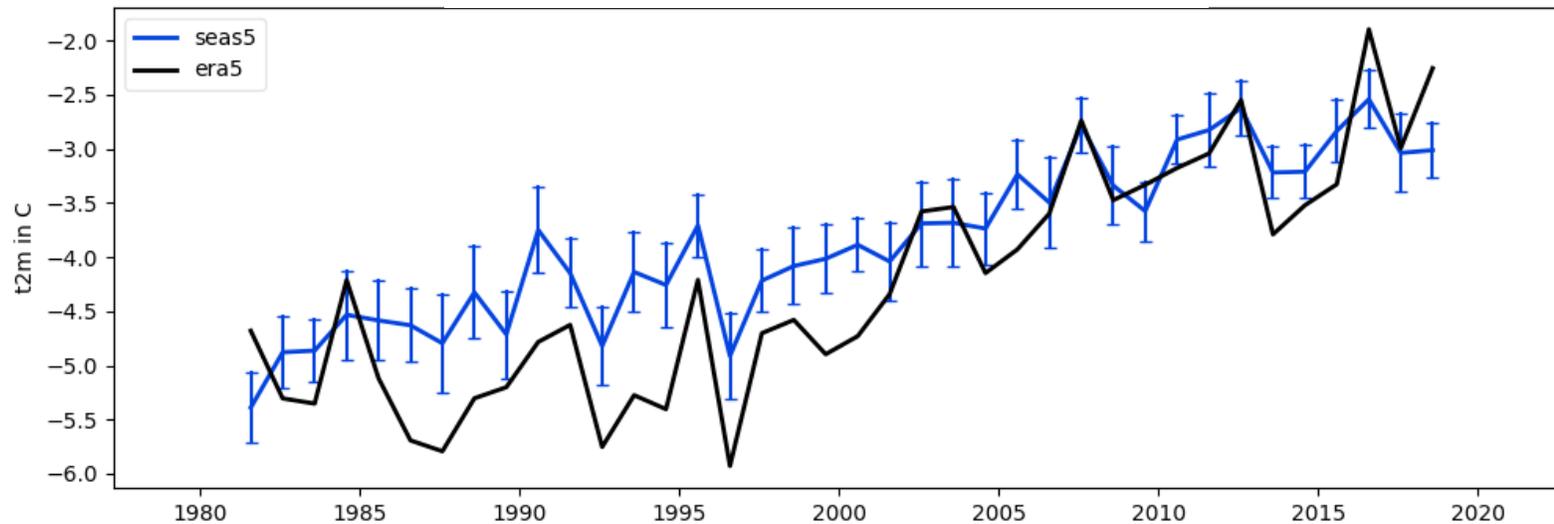


Johnson et al., GMD 2019

# SEAS5 Arctic sea ice and surface air temperature forecasts

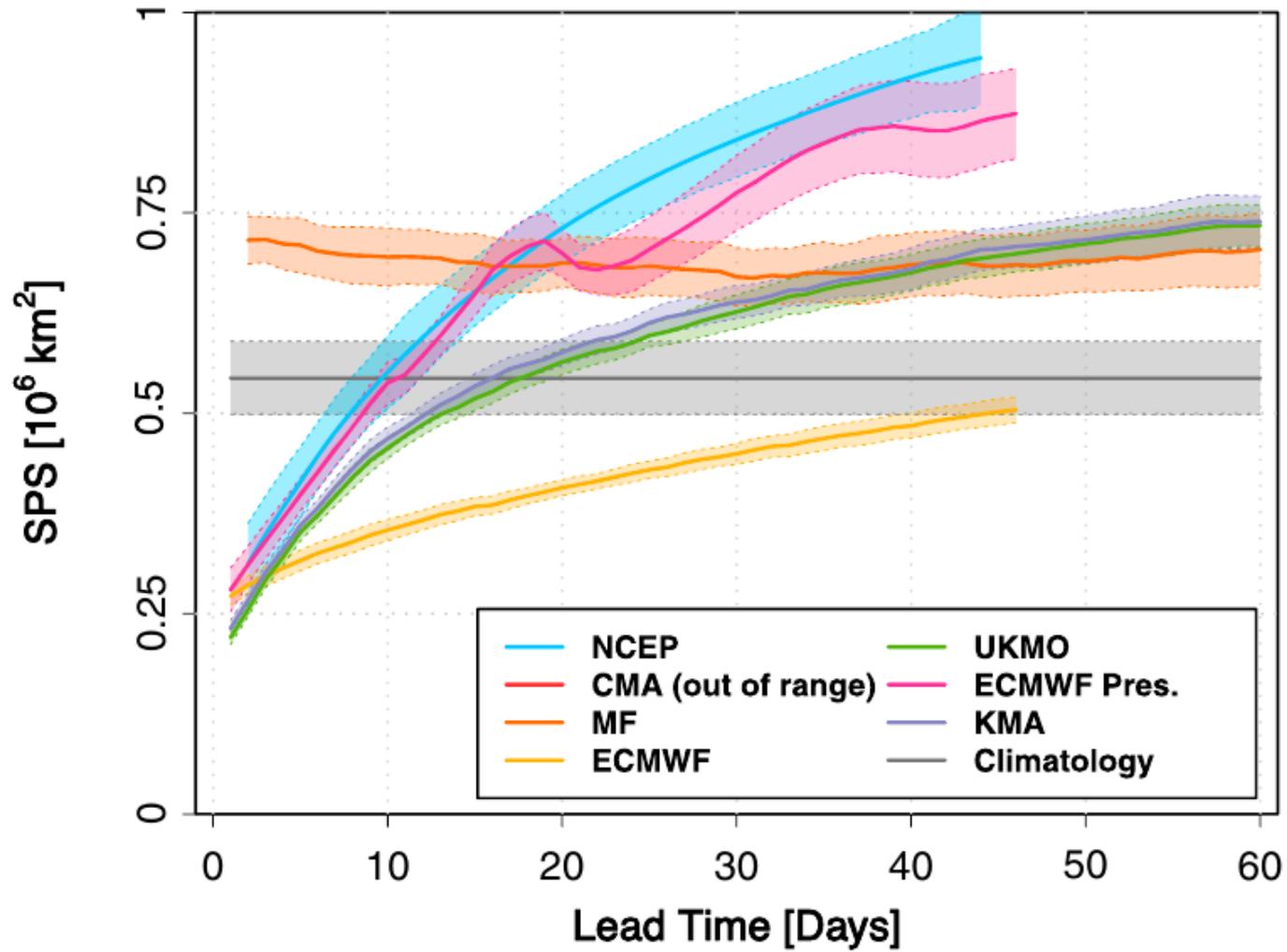


ASO Arctic sea-ice extent  
from July initialisation



ASO 2m temperature  
north of 70N  
from July initialisation

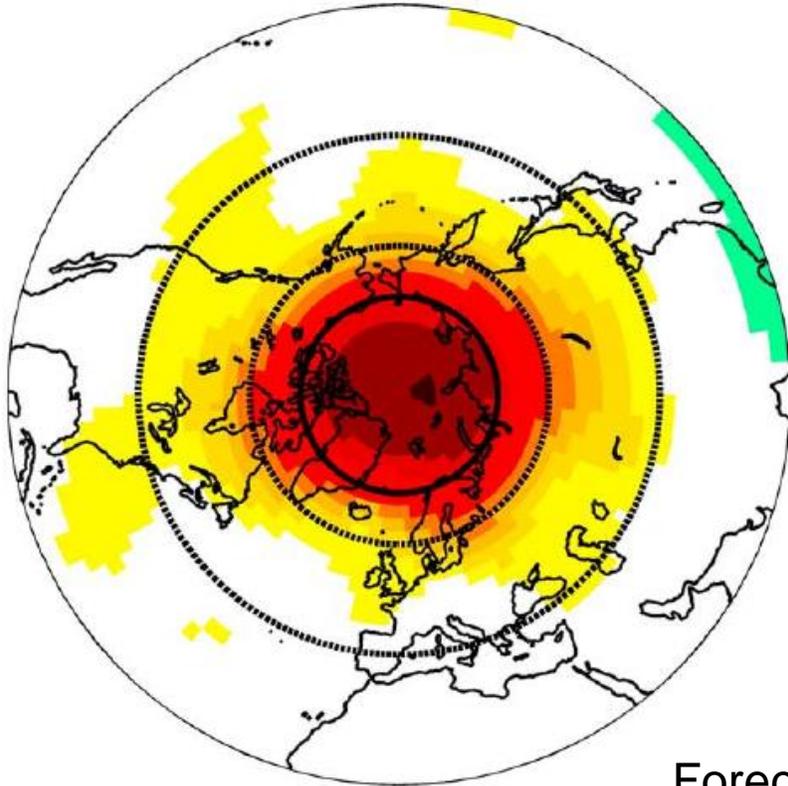
# Extended-range forecast skill for Arctic sea ice from the S2S database



Zampieri et al., GRL 2018

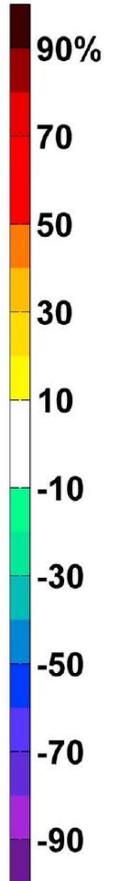
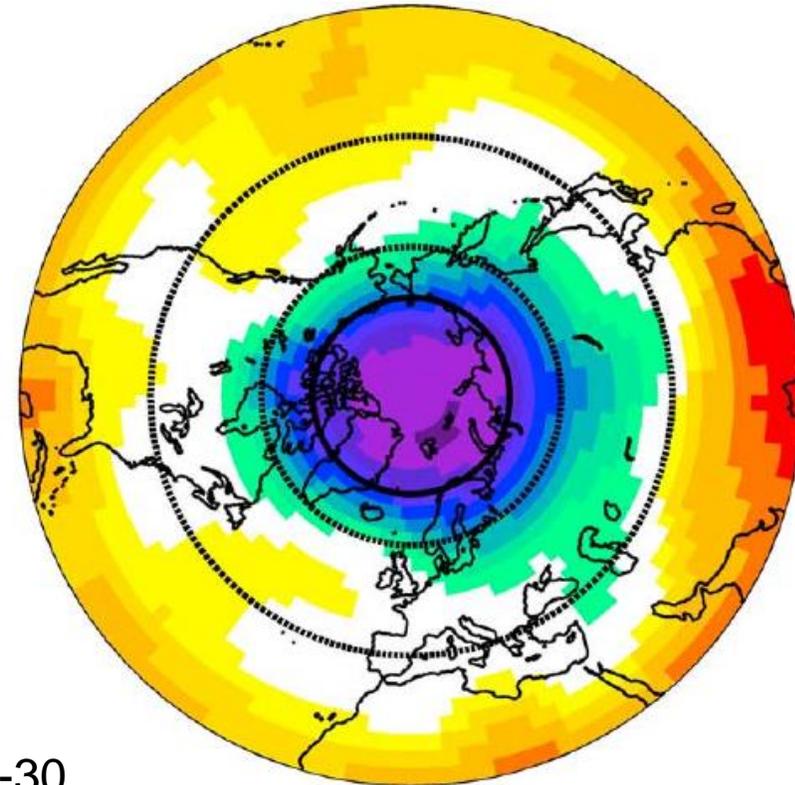
# Impact of Arctic atmosphere on subseasonal forecasts in mid-latitudes

Relative reduction (in %) of the z500 forecast error during wintertime through Arctic relaxation



Forecast days 11-30

Difference in the relative error reduction between experiments with tropical and Arctic relaxation



Jung et al., GRL 2014

## Arctic-mid-latitude linkages – a few thoughts

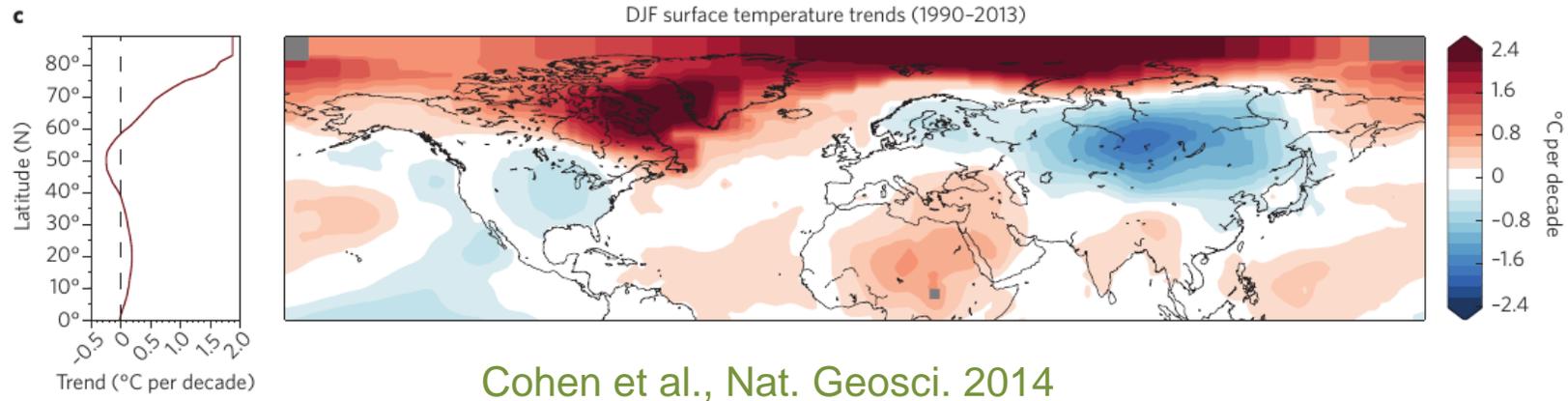
- Plenty of potential mechanisms have been proposed
- Episodical and regional strong impact evident (cf. "Polar Vortex" media hype)
- However, robust generic statements hard to come by
  - Mid-latitude variability high
  - Signal strength is moderate at best
  - Observational records are short
  - Results often model-dependent

*"Can it? Has it? Will it?"* Barnes and Screen, Wiley Interdiscip. Rev. Clim. Change 2015

*A workshop in Barcelona in Dec. 2014 concluded that the science is still in "pre-consensus" phase.* (Jung et al., BAMS 2015)

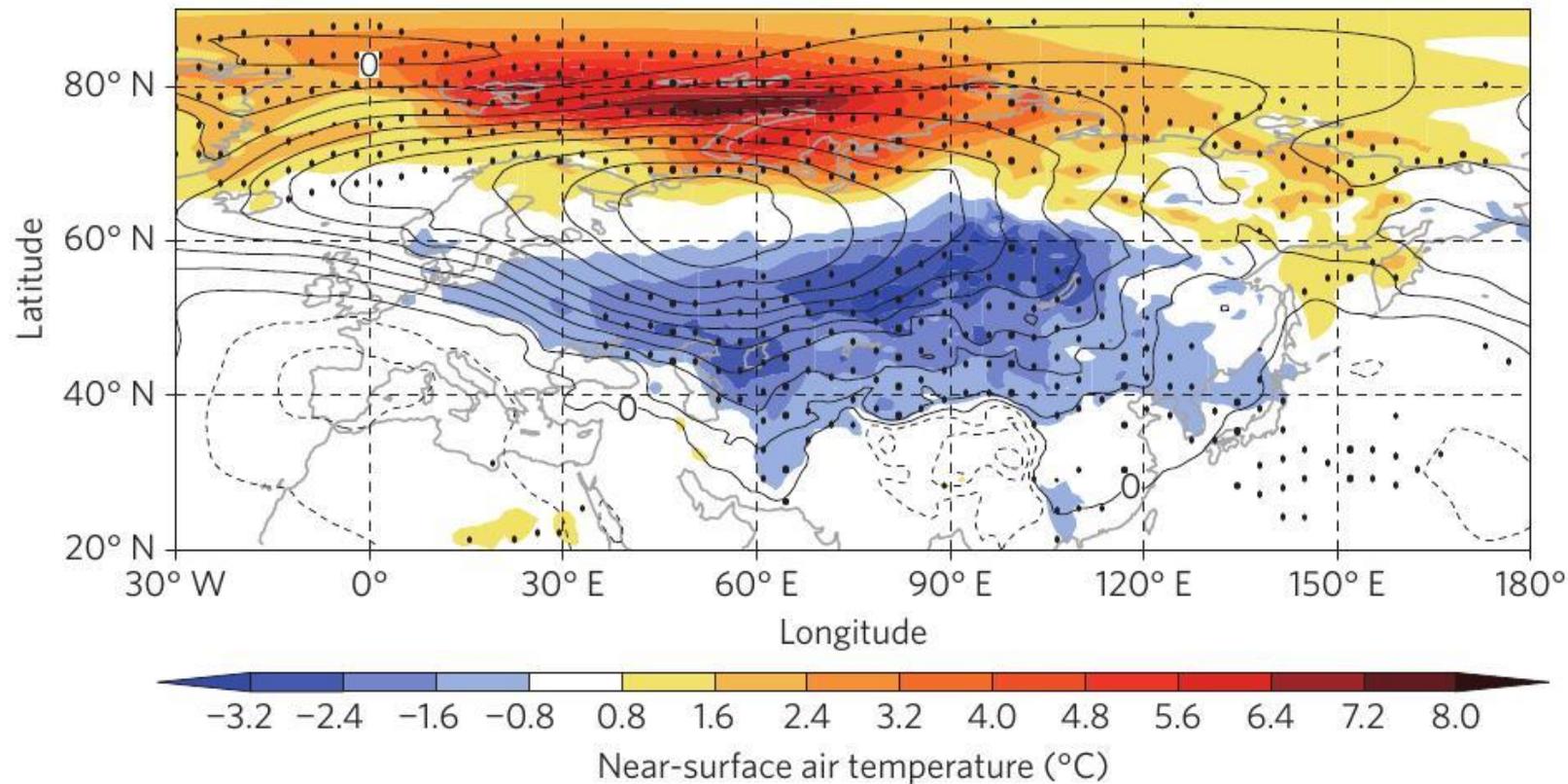
→ *Consensus still outstanding in 2019 (?)*

# An example linkage: Warm Arctic Cold Continents (WACC) pattern



- Cohen et al. suggest a dynamical interpretation: consequence of reduced sea ice and snow cover
- Confirmed by some modelling studies, but others argue this pattern might be mainly due to natural variability (e.g. Li et al., GRL 2015, Koenigk et al., Clim. Dyn. 2019)

# Cold Eurasian winters forced by Arctic sea-ice loss



Composite of DJF 2m temperature difference between years with low and high sea-ice cover in the Barents and Kara Seas (ERA-Interim 1979-2013)

Mori et al., Nat. Geosci. 2014

# Summary

- Polar Regions provide specific challenges for observations and modelling (remote, surface cryosphere, climate change)
- Impressive S2S-related progress in recent years, but major challenges remain at the surface
- Linkages to mid-latitudes present, but not obvious
- Future:
  - Improve surface modelling and coupling (boundary layers, snow and ice)
  - Better initialization of cryosphere through better observations
  - High-latitude clouds are still a major challenge
  - Strategies to cope with changing observing system and climate