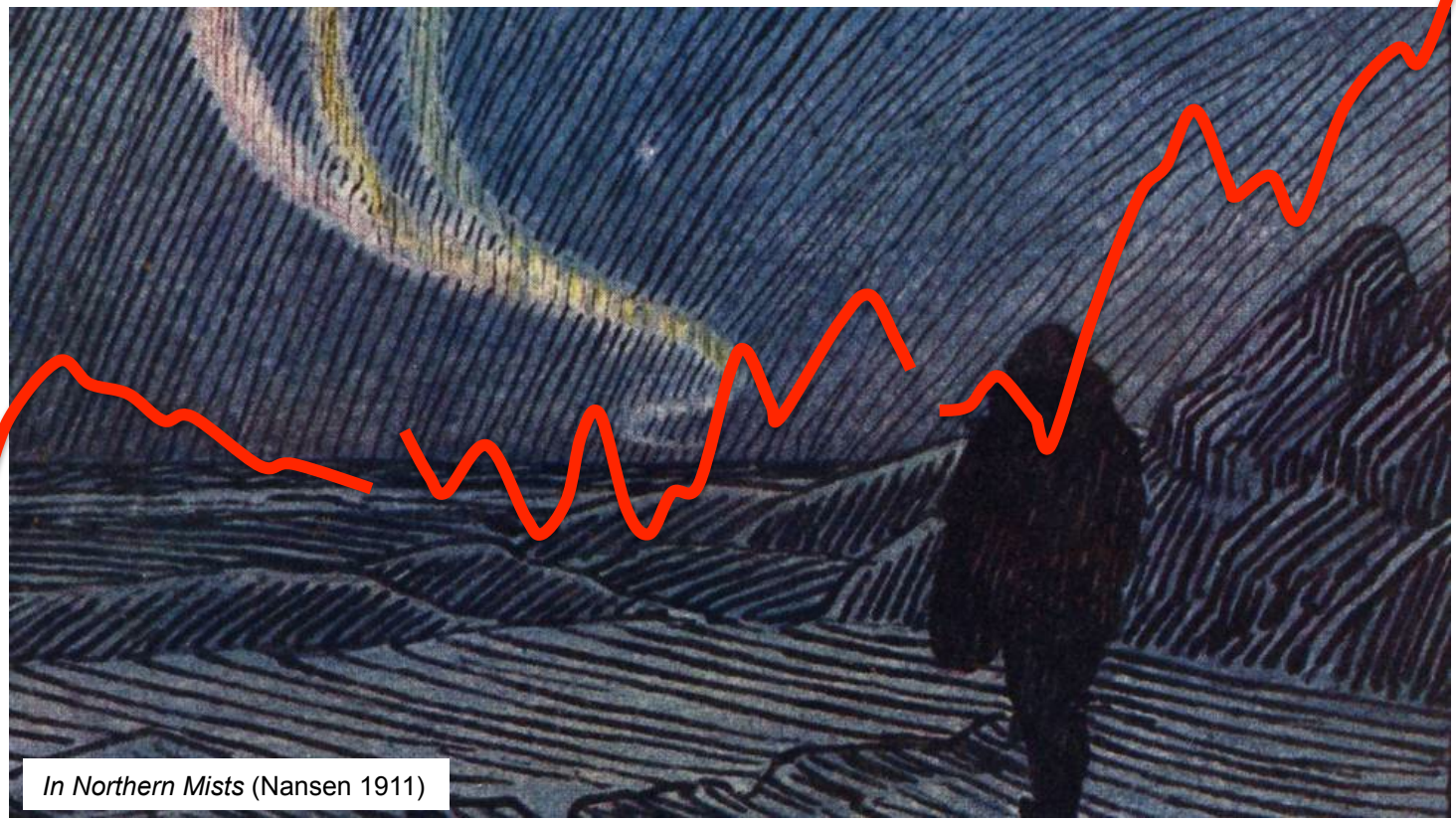
On observed northern climate change and predictability



In Northern Mists (Nansen 1911)

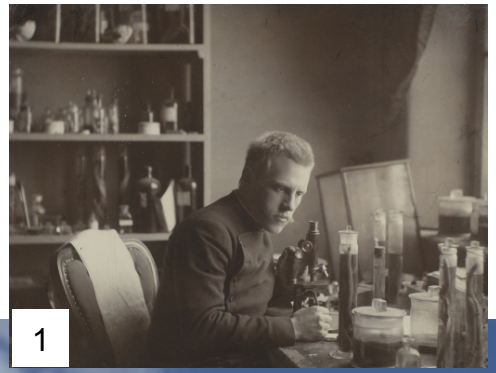
"A brief history of climate" (Eldevik et al. 2014)

Tor Eldevik, Marius Årthun, Ingrid Onarheim, et al.

Geophysical Insitute UiB / Bjerknes Centre for Climate Research

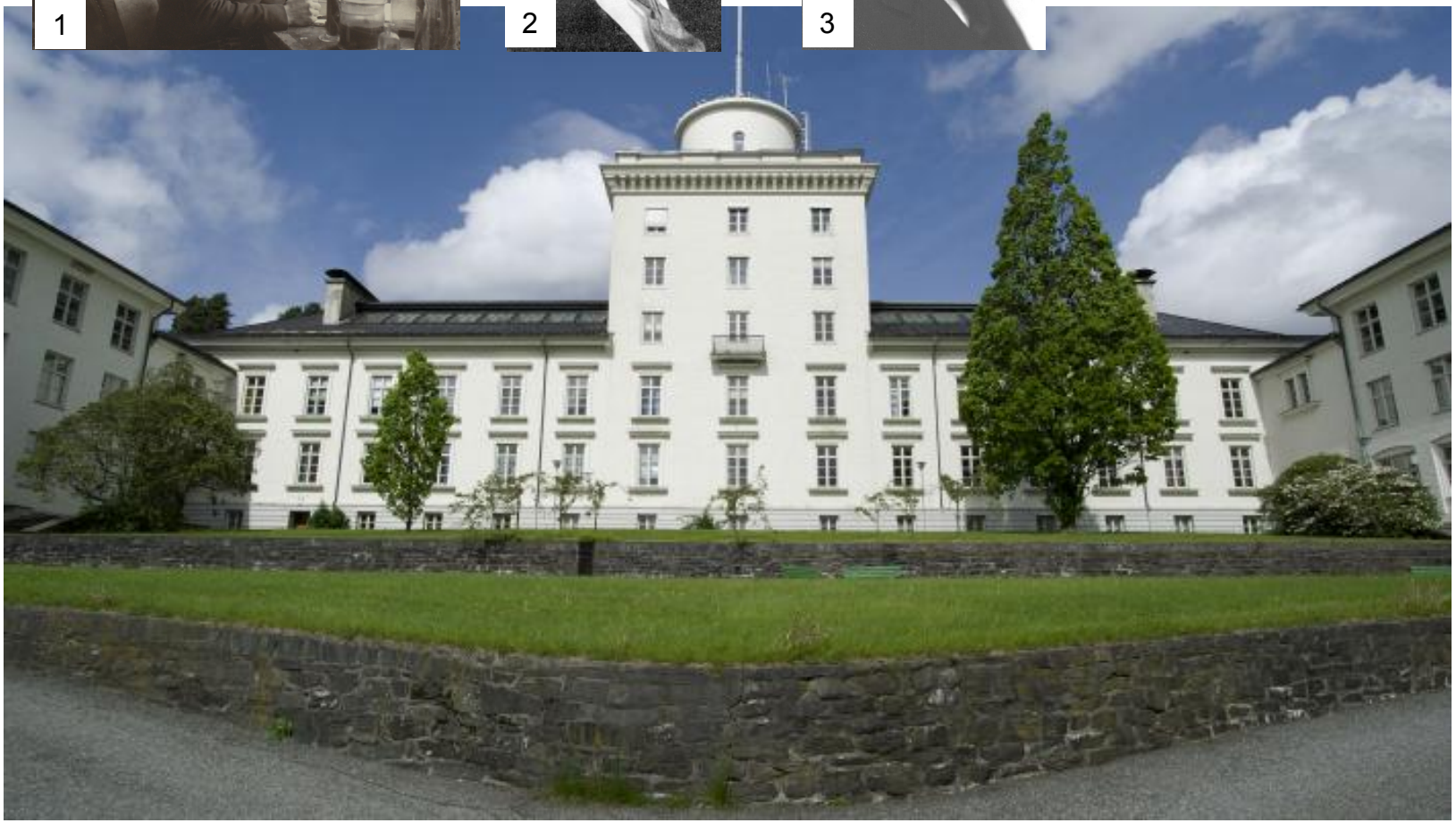
funding includes

- Research Council of Norway
  - NORTH, PATHWAY
- EU H2020
  - Blue-Action *Arctic Impact on Weather and Climate*

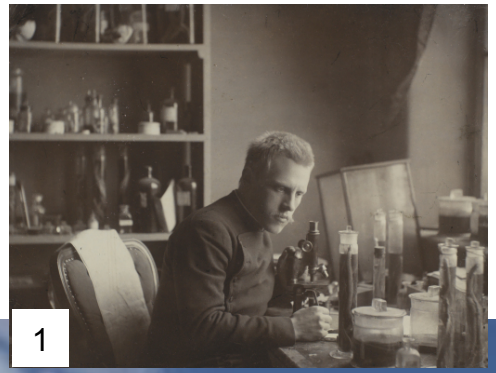

1


2


3



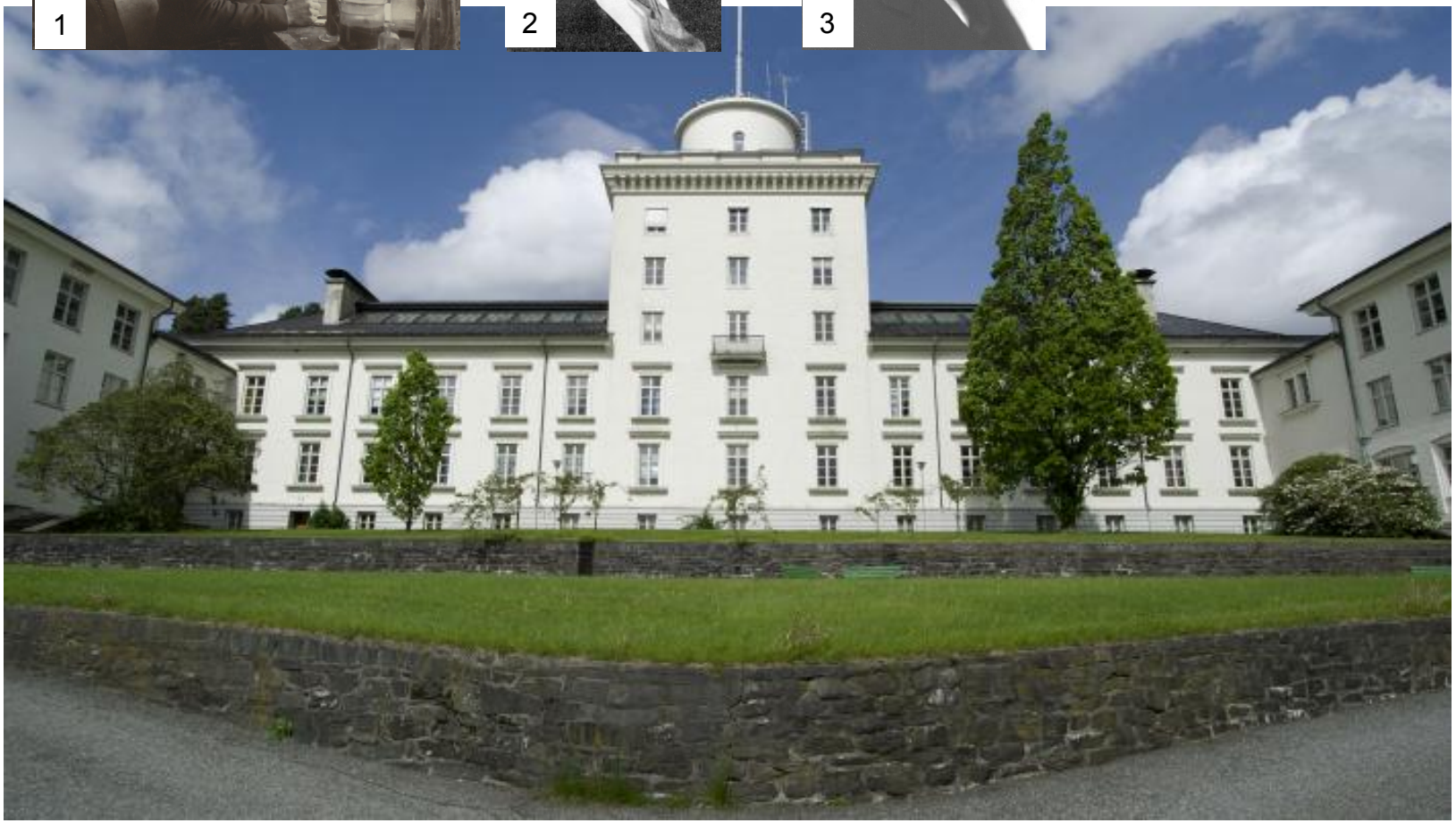
GFI established 1917 [building from 1928]


1


2


3

1. Fridtjof Nansen (1861–1930)
2. Bjørn Helland-Hansen (1877–1957)
3. Vilhelm Bjerknes (1862–1951)



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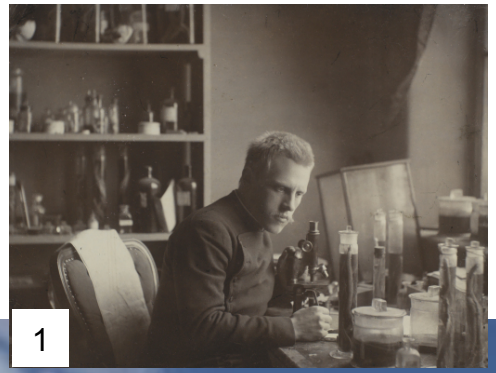

1


2


3

1. Fridtjof Nansen (1861–1930)
2. Bjørn Helland-Hansen (1877–1957)
3. Vilhelm Bjerknes (1862–1951)

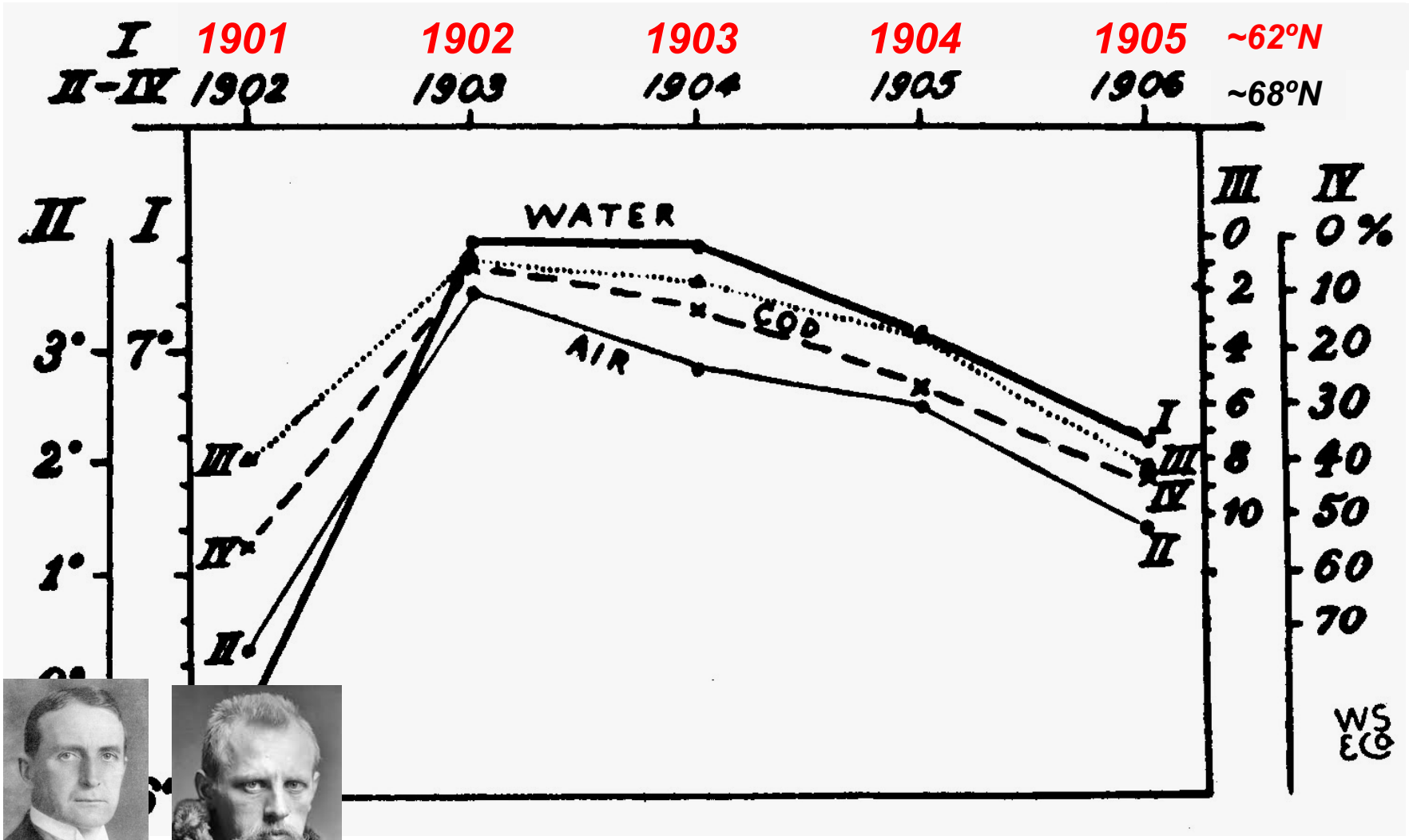
Bjerknes (1904)

1. diagnosis
2. prognosis

(3. reanalyses)

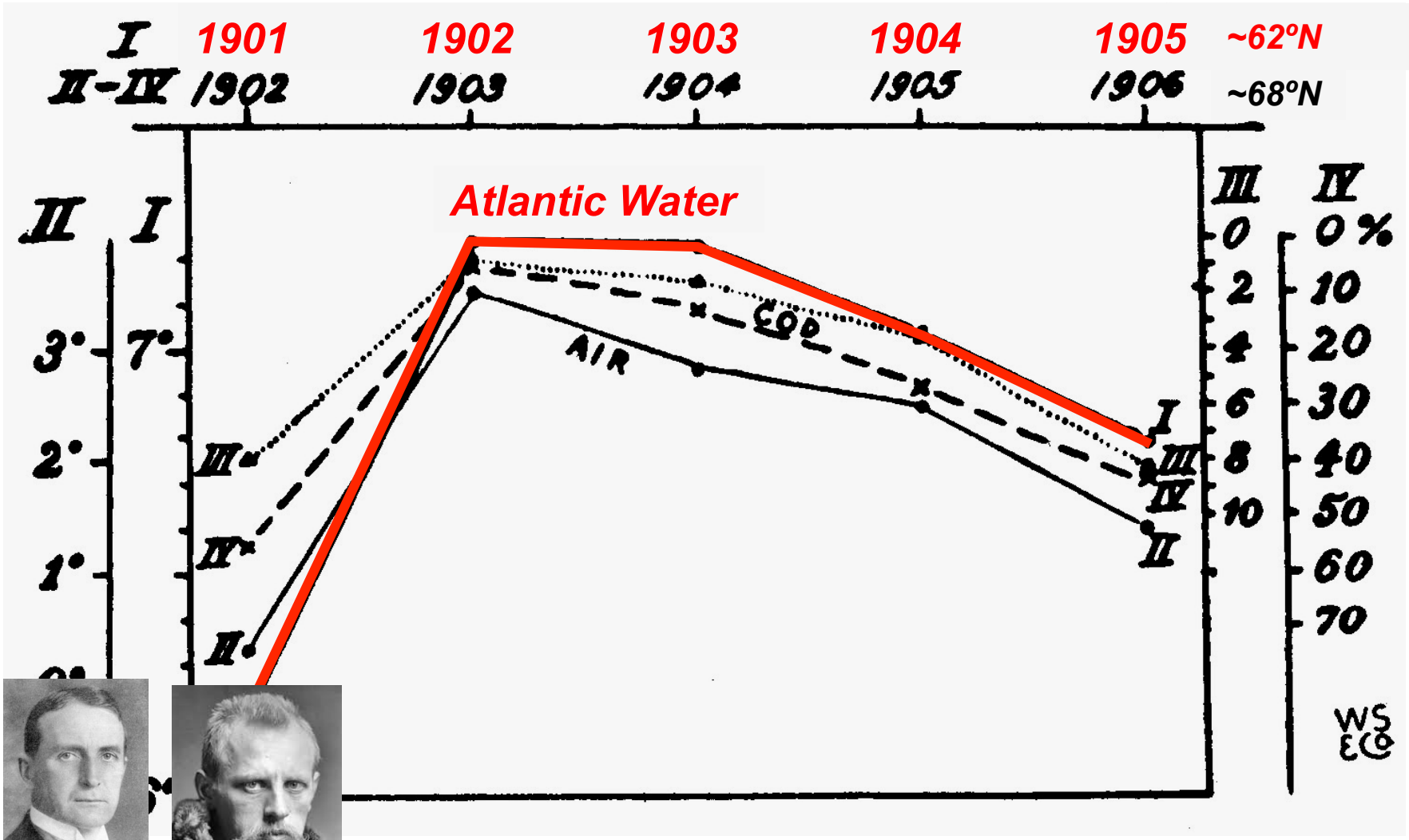
GFI established 1917 [building from 1928]

An early vision of a predictable climate



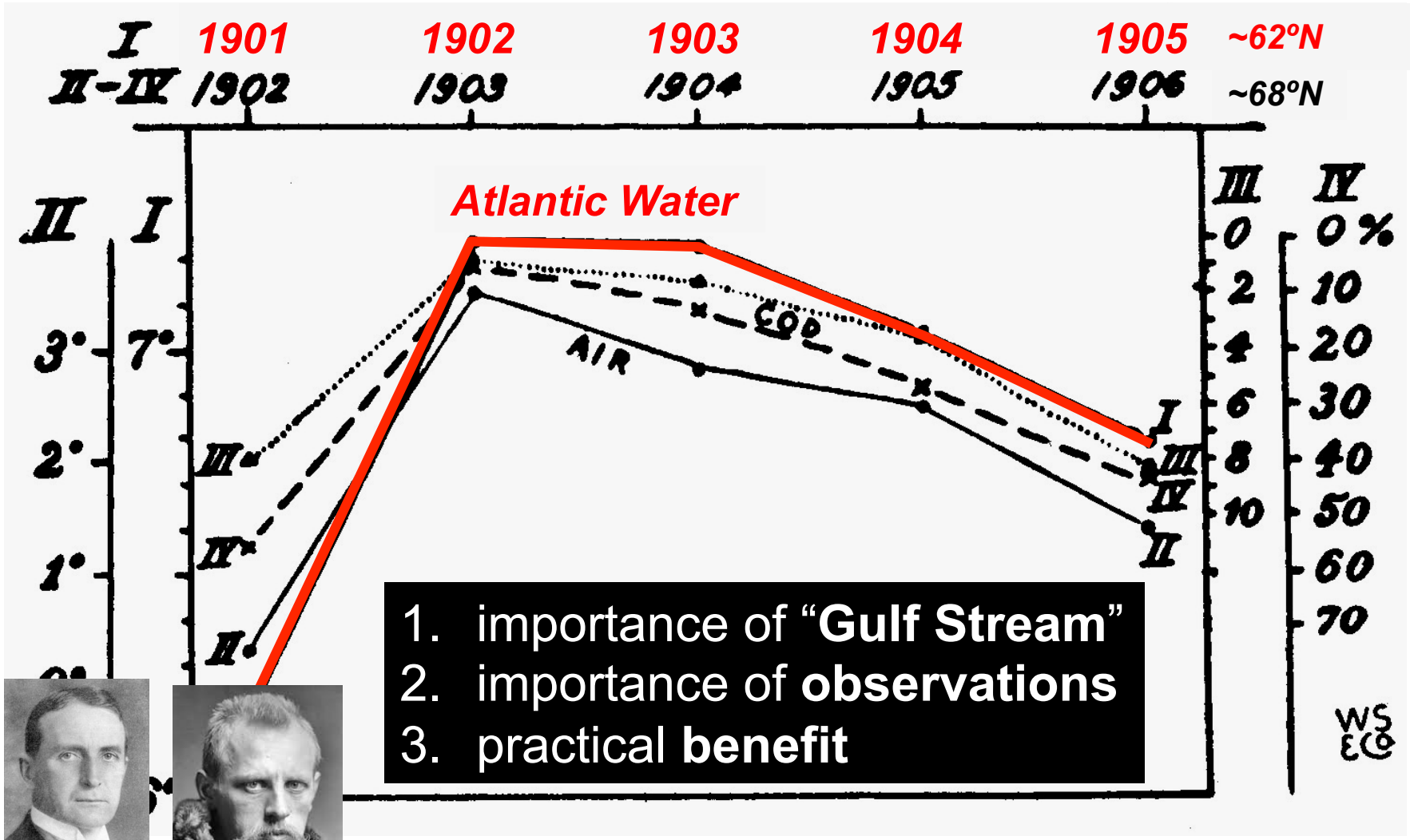
Helland-Hansen og Nansen 1909

An early vision of a predictable climate



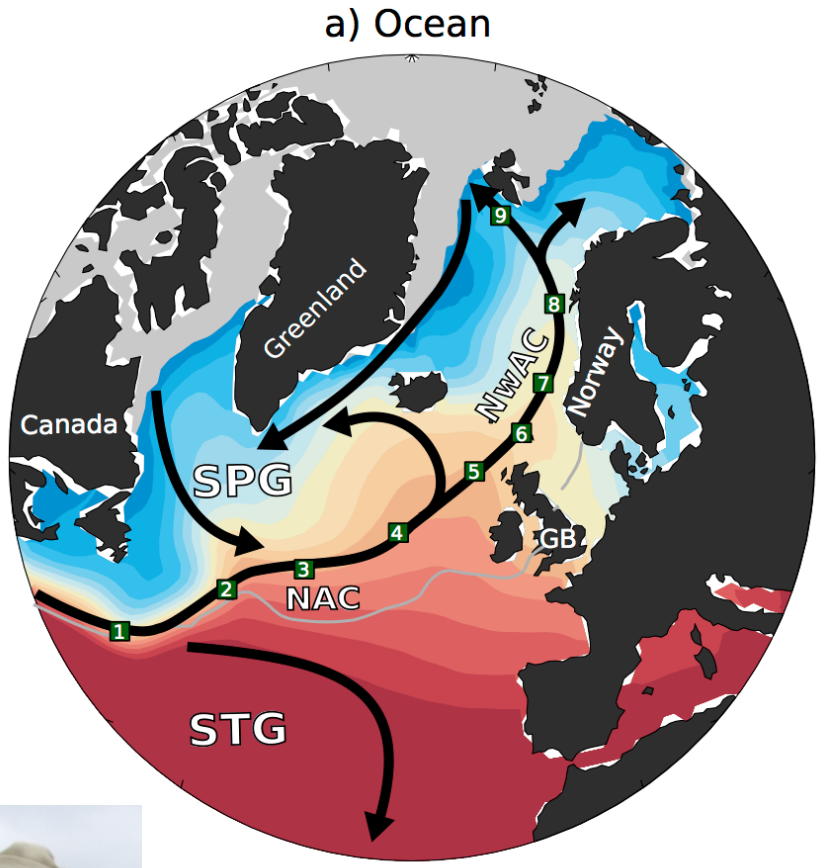
Helland-Hansen og Nansen 1909

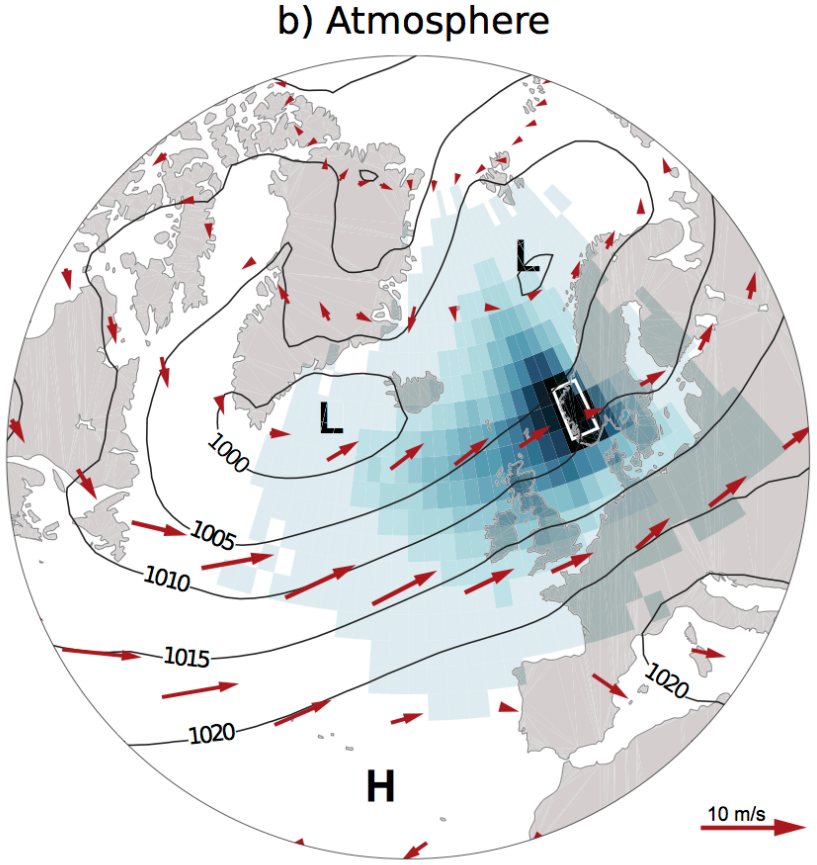
An early vision of a predictable climate



Helland-Hansen og Nansen 1909

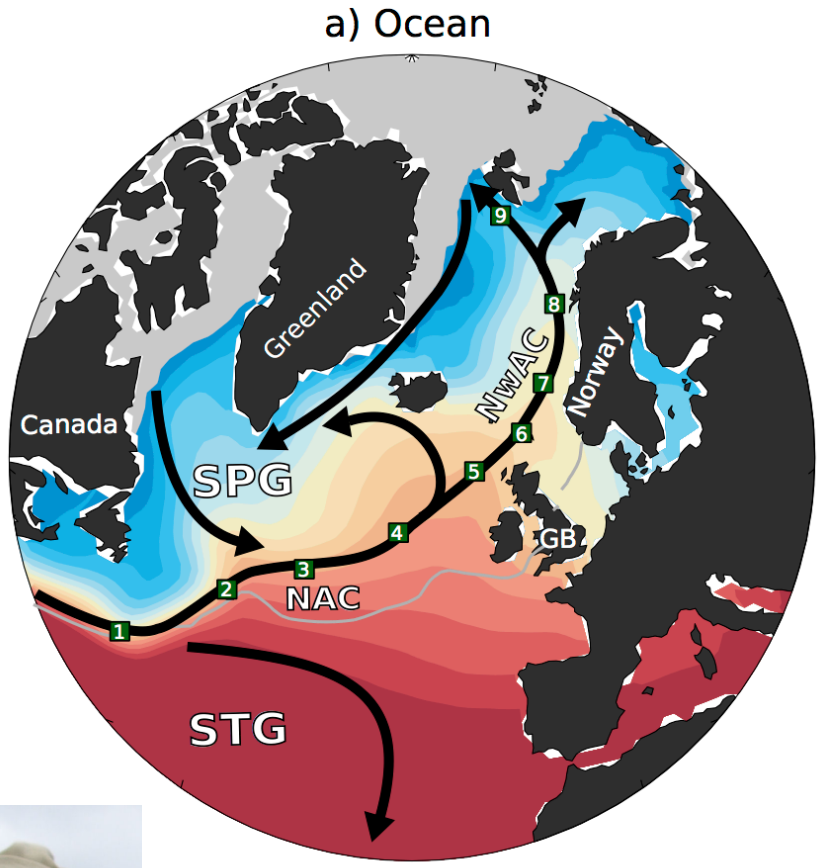
The “Gulf Stream” and the westerly winds

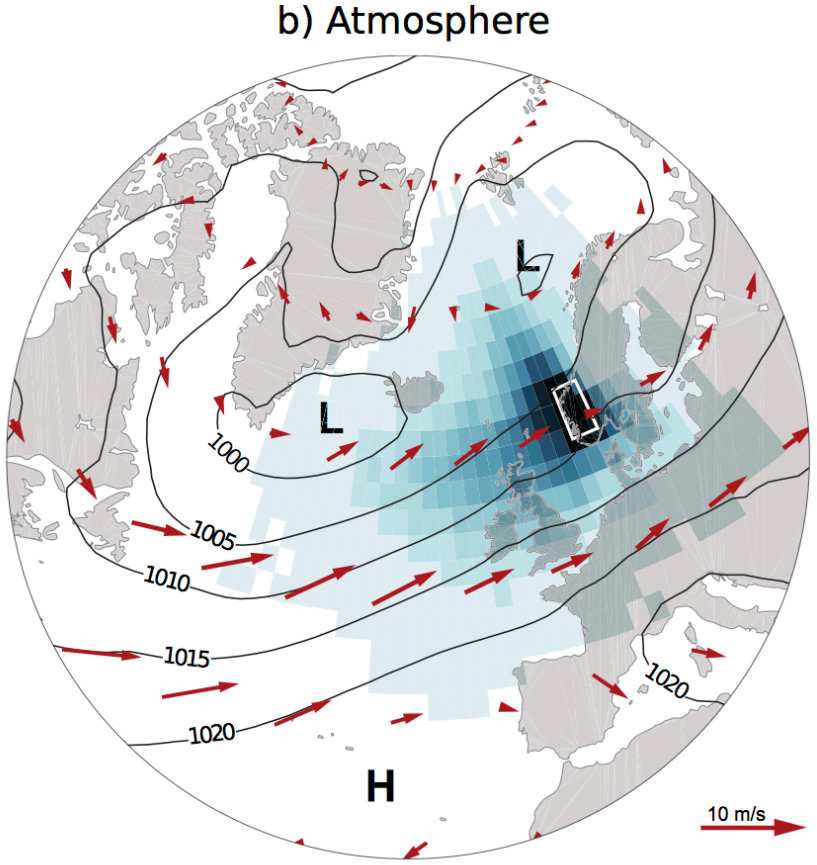




Årthun et al. 2017:
Skillful prediction of northern climate provided by the ocean.
Nature Comm.

The “Gulf Stream” and the westerly winds

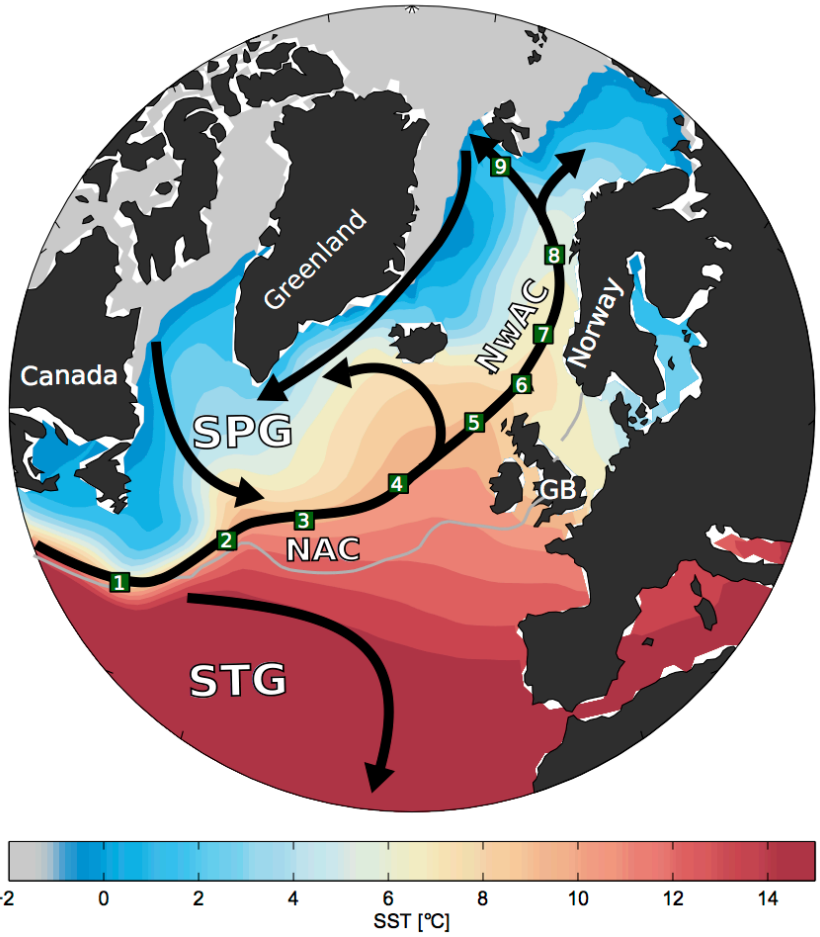


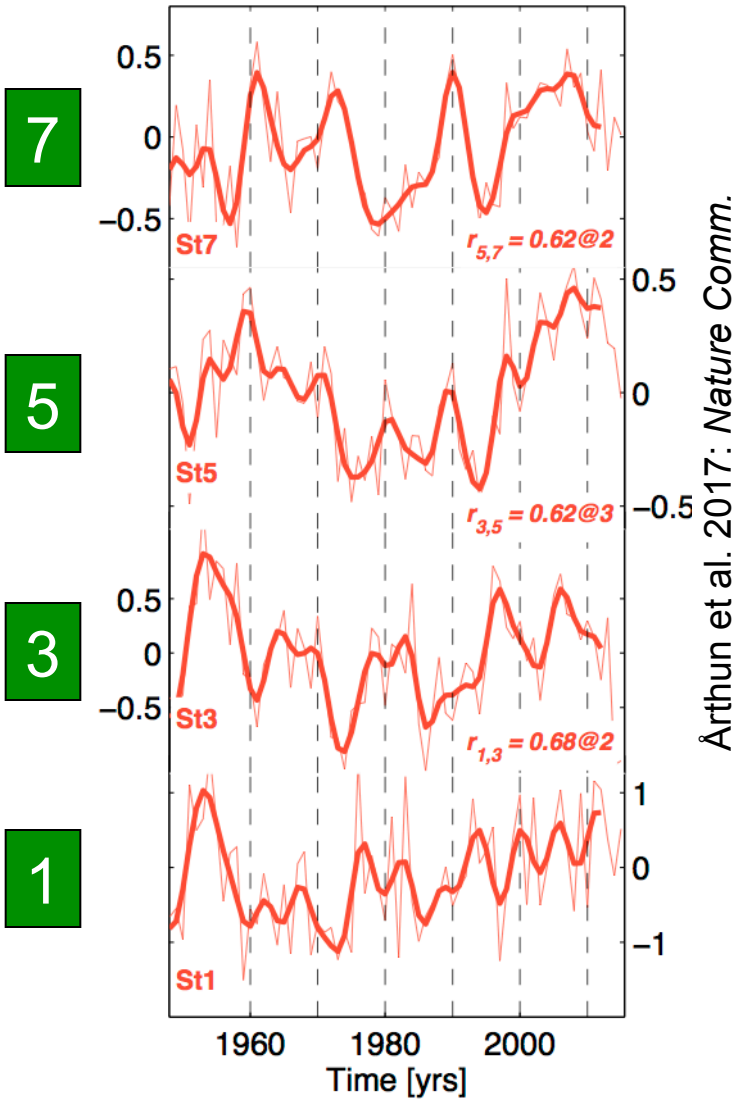


NAO + mean temperate ocean => *diagnostic*

“Gulf Stream” + mean westerlies => *prognostic?*

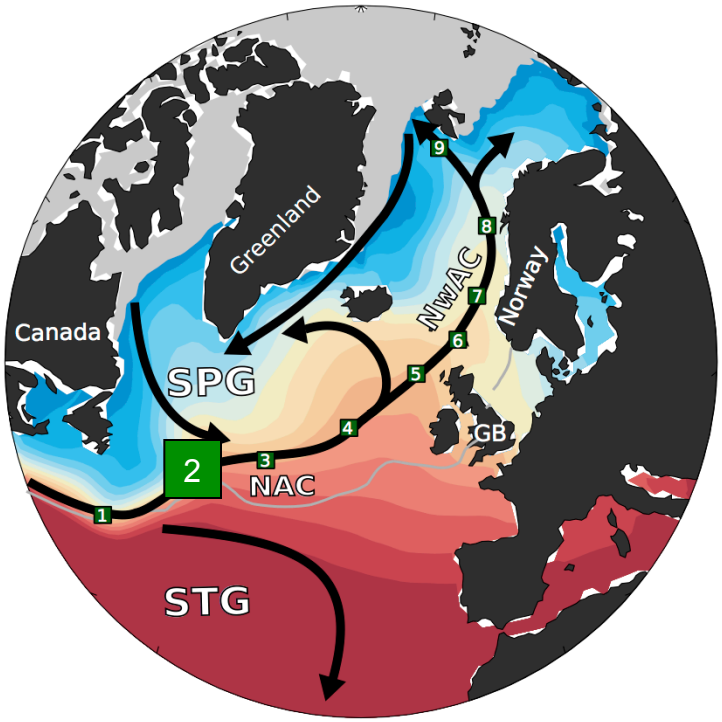
Observed SST propagation (HadISST)





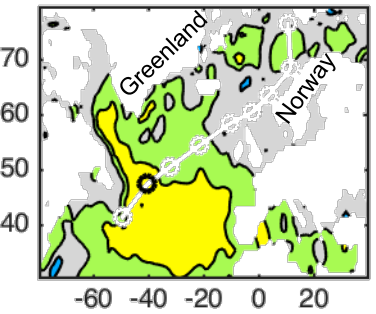
Propagating thermohaline anomalies, e.g., Sutton and Allen 1997, Holliday et al. 2008, Årthun and Eldevik 2016, +++

Observed SST propagation (HadISST)

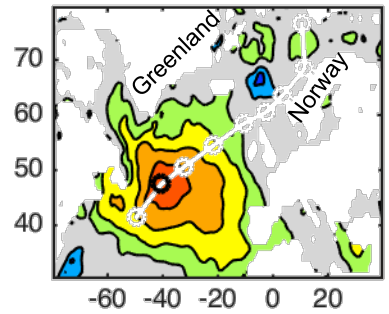


St: 2

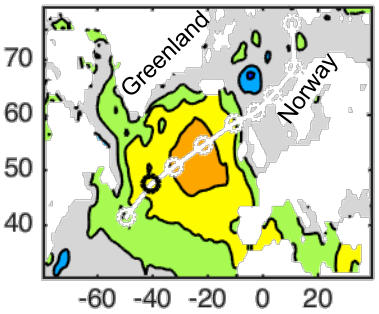
*interannual co-variance – **no** low-pass*



lag -1yr



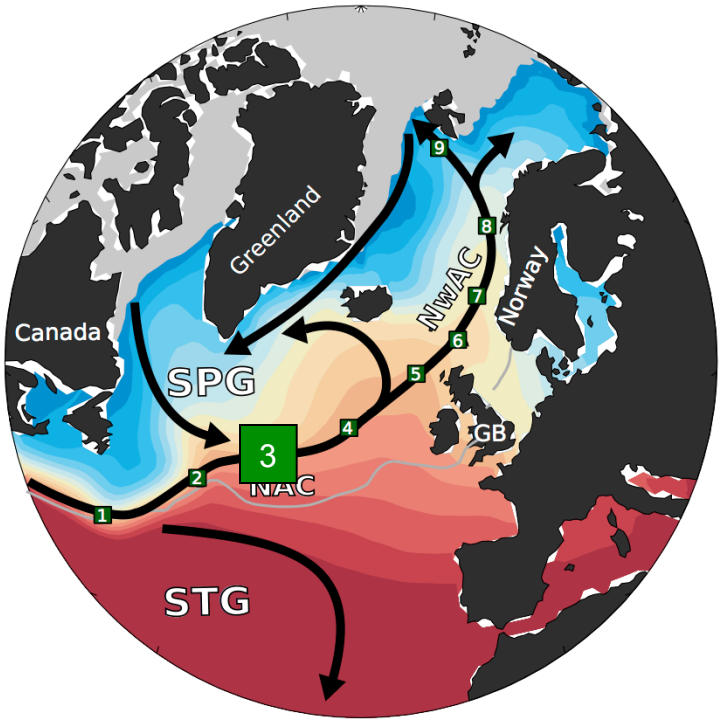
no lag



lag +1yr

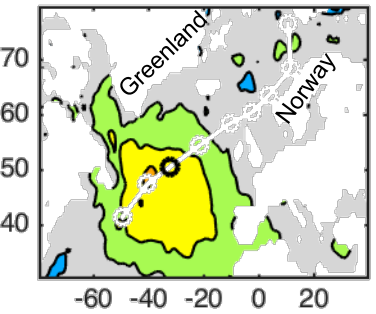
Århun et al. 2017: *Nature Comm.*

Observed SST propagation (HadISST)

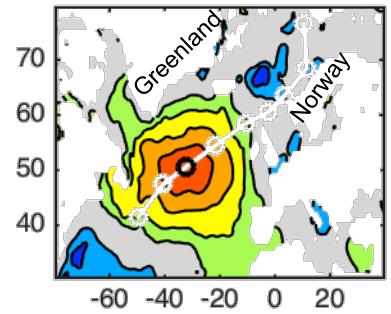


St: 3

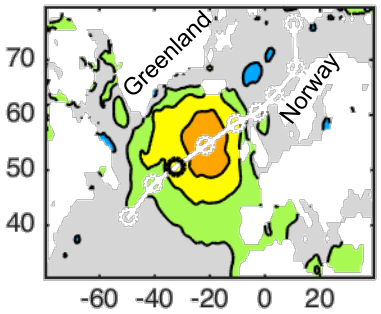
*interannual co-variance – **no** low-pass*



lag -1yr



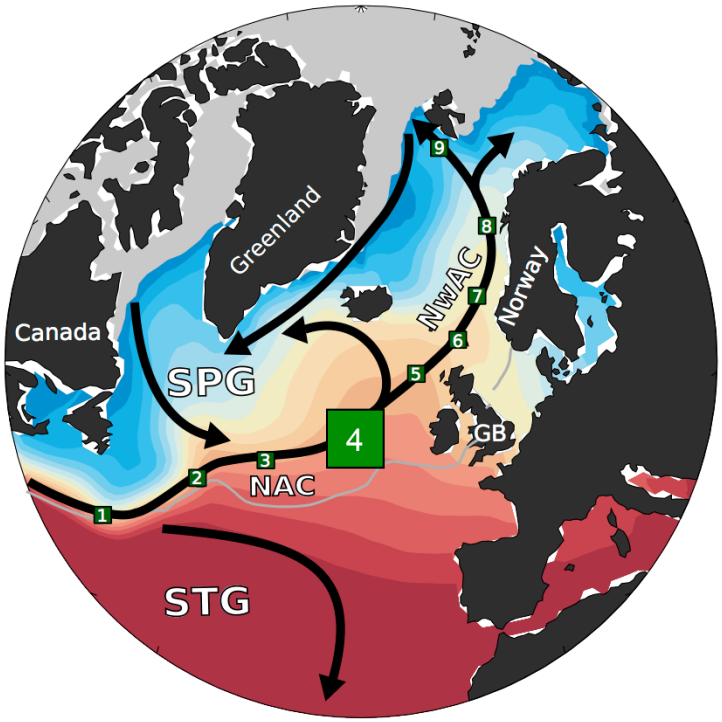
no lag



lag +1yr

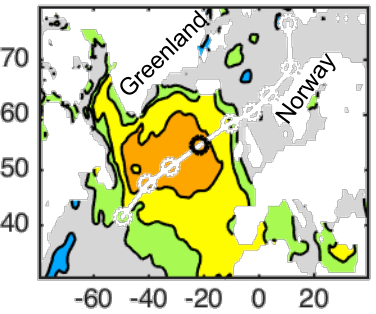
Årthun et al. 2017: *Nature Comm.*

Observed SST propagation (HadISST)

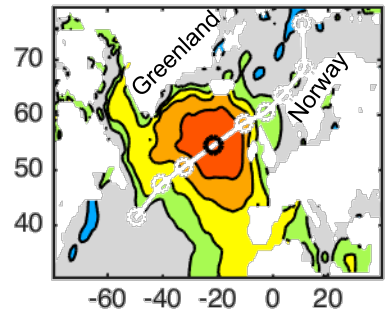


St: 4

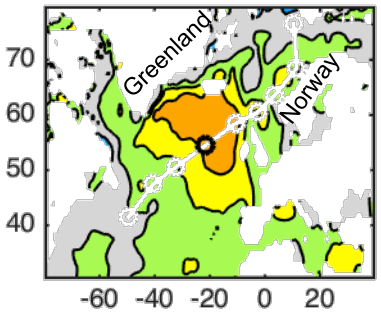
*interannual co-variance – **no** low-pass*



lag -1yr



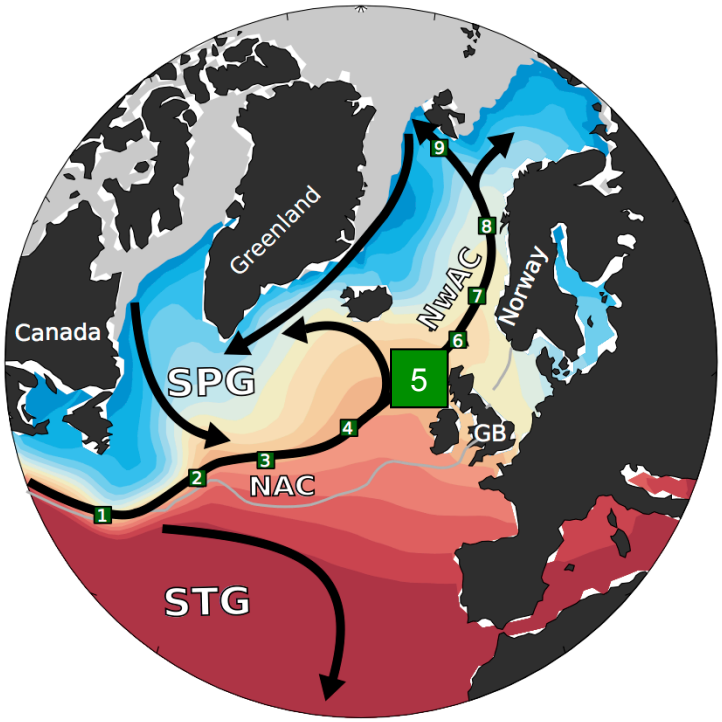
no lag



lag +1yr

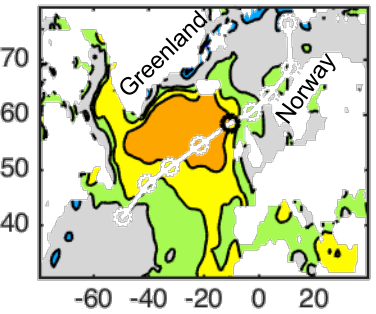
Årthun et al. 2017: *Nature Comm.*

Observed SST propagation (HadISST)

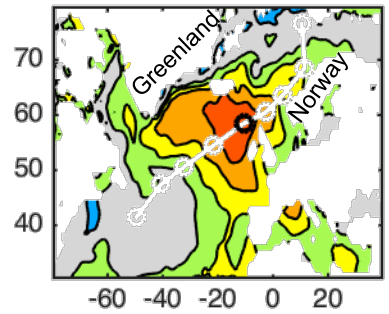


St: 5

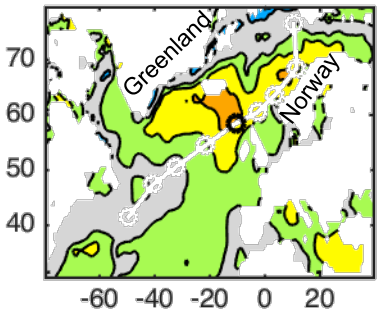
*interannual co-variance – **no** low-pass*



lag -1yr



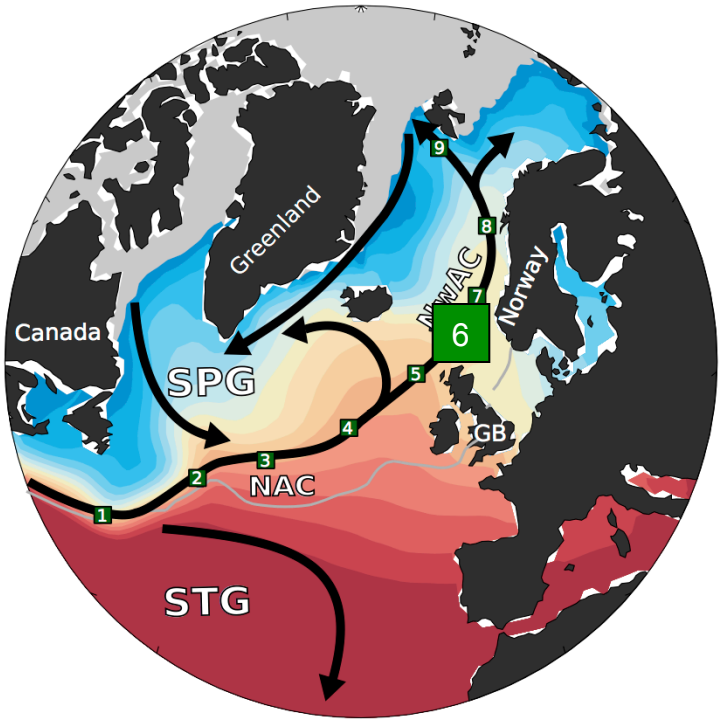
no lag



lag +1yr

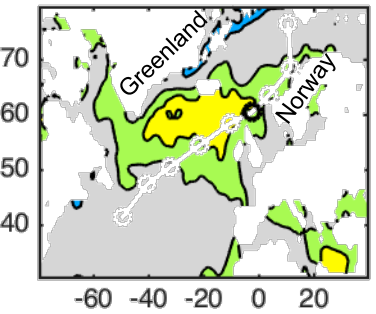
Årthun et al. 2017: *Nature Comm.*

Observed SST propagation (HadISST)

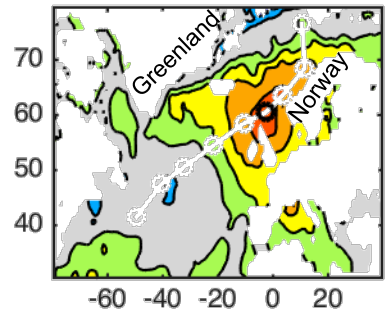


St: 6

*interannual co-variance – **no** low-pass*



lag -1yr



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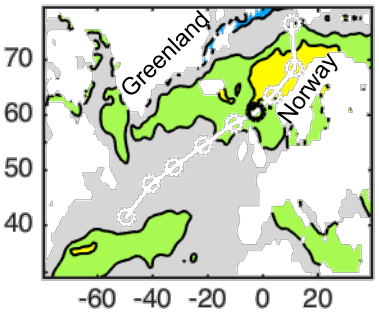
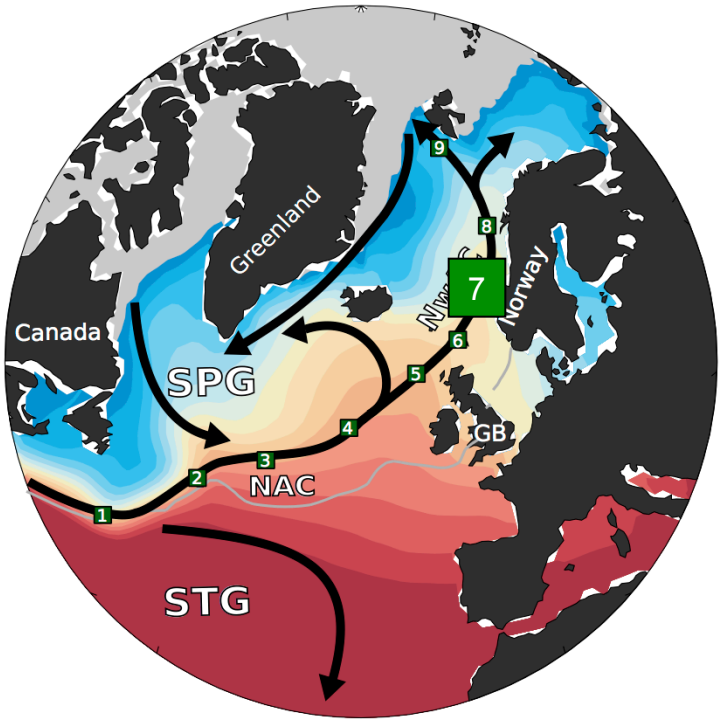


lag +1yr

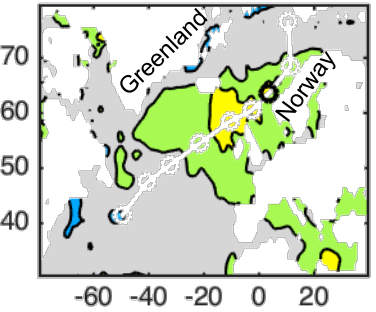
Århun et al. 2017: *Nature Comm.*

Observed SST propagation (HadISST)

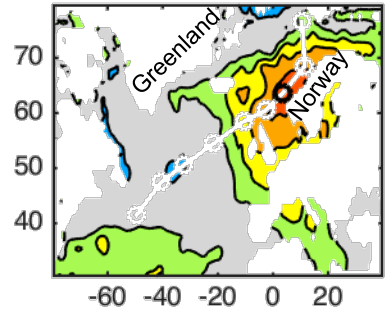


St: 7

*interannual co-variance – **no** low-pass*



lag -1yr



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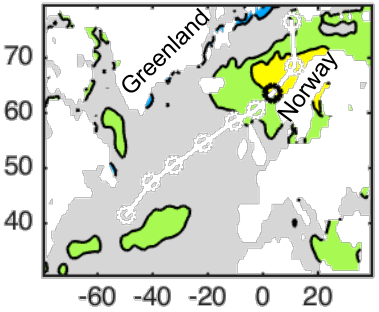
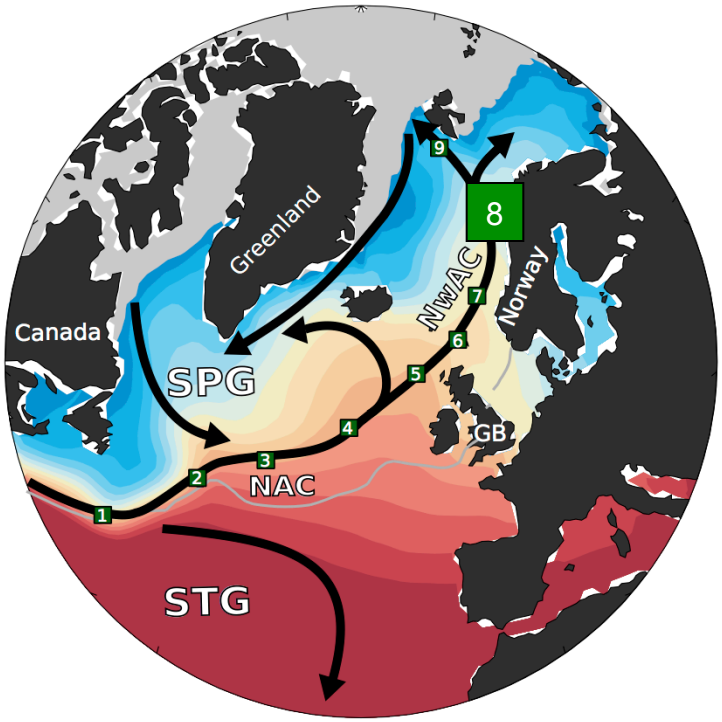


lag +1yr

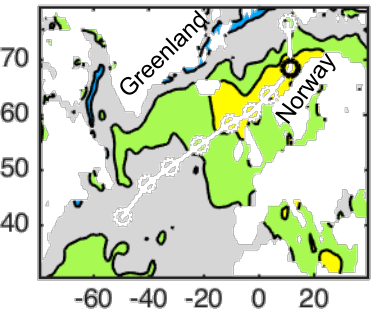
Årthun et al. 2017: *Nature Comm.*

Observed SST propagation (HadISST)

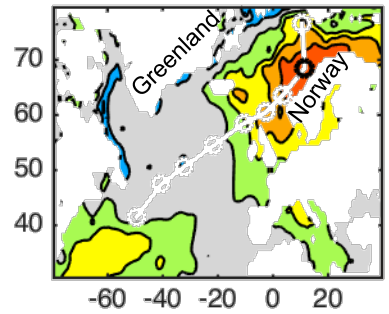


St: 8

*interannual co-variance – **no** low-pass*



lag -1yr



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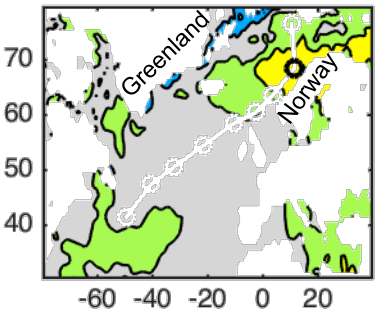
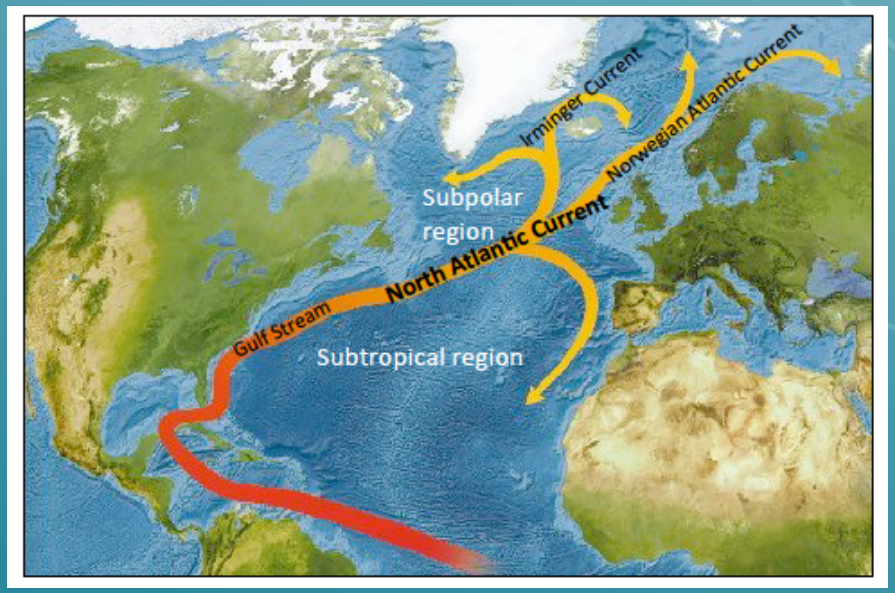


lag +1yr

Århun et al. 2017: *Nature Comm.*



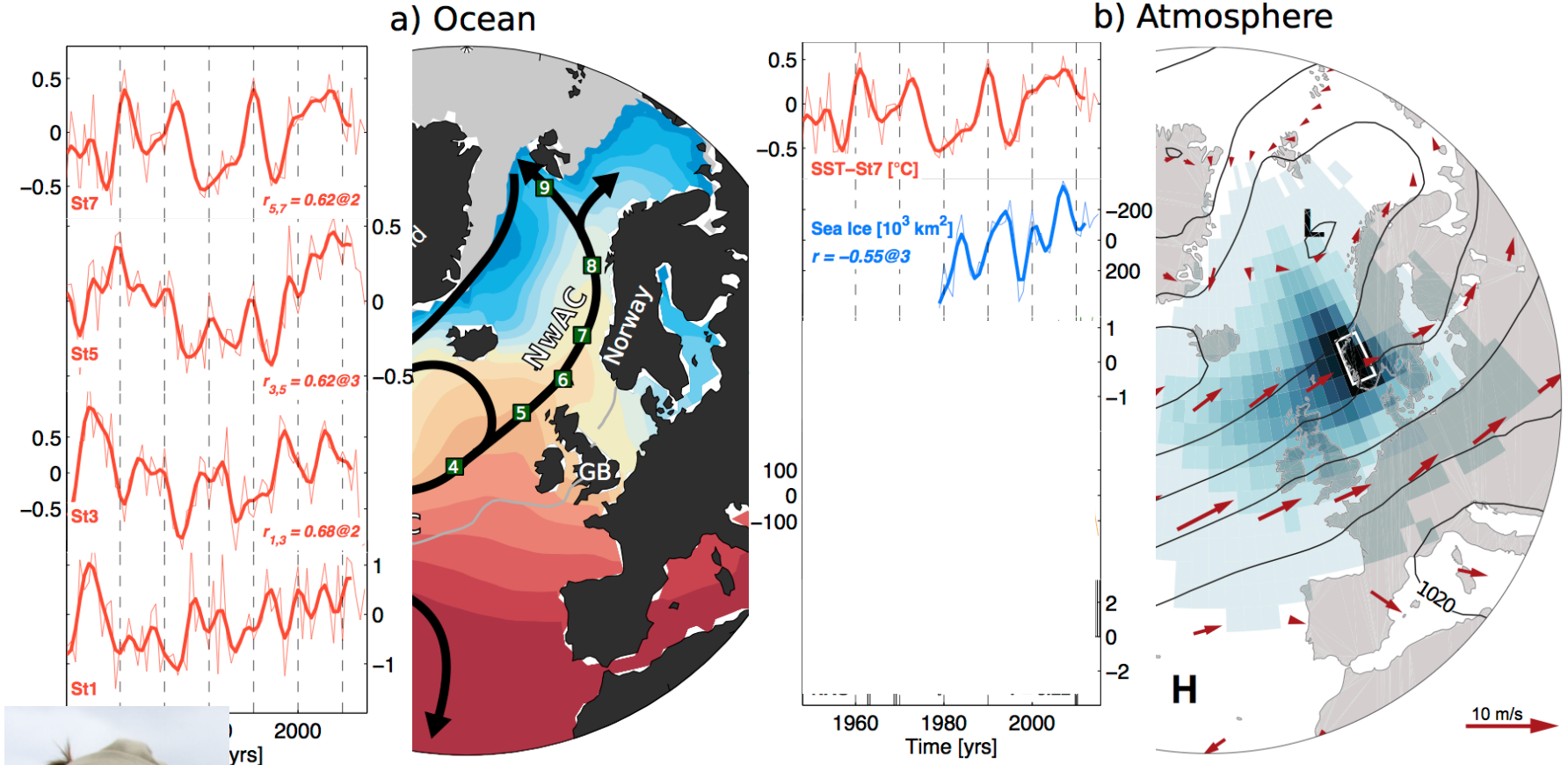
Helene's talk
Wed 17:20

Thermohaline variability along the Atlantic water pathway in the forced Norwegian Earth System Model

H. R. Langehaug, A. B. Sandø, M. Årthun, and M. Ilicak

In review in Climate Dynamics

How to get predictability beyond the ocean?

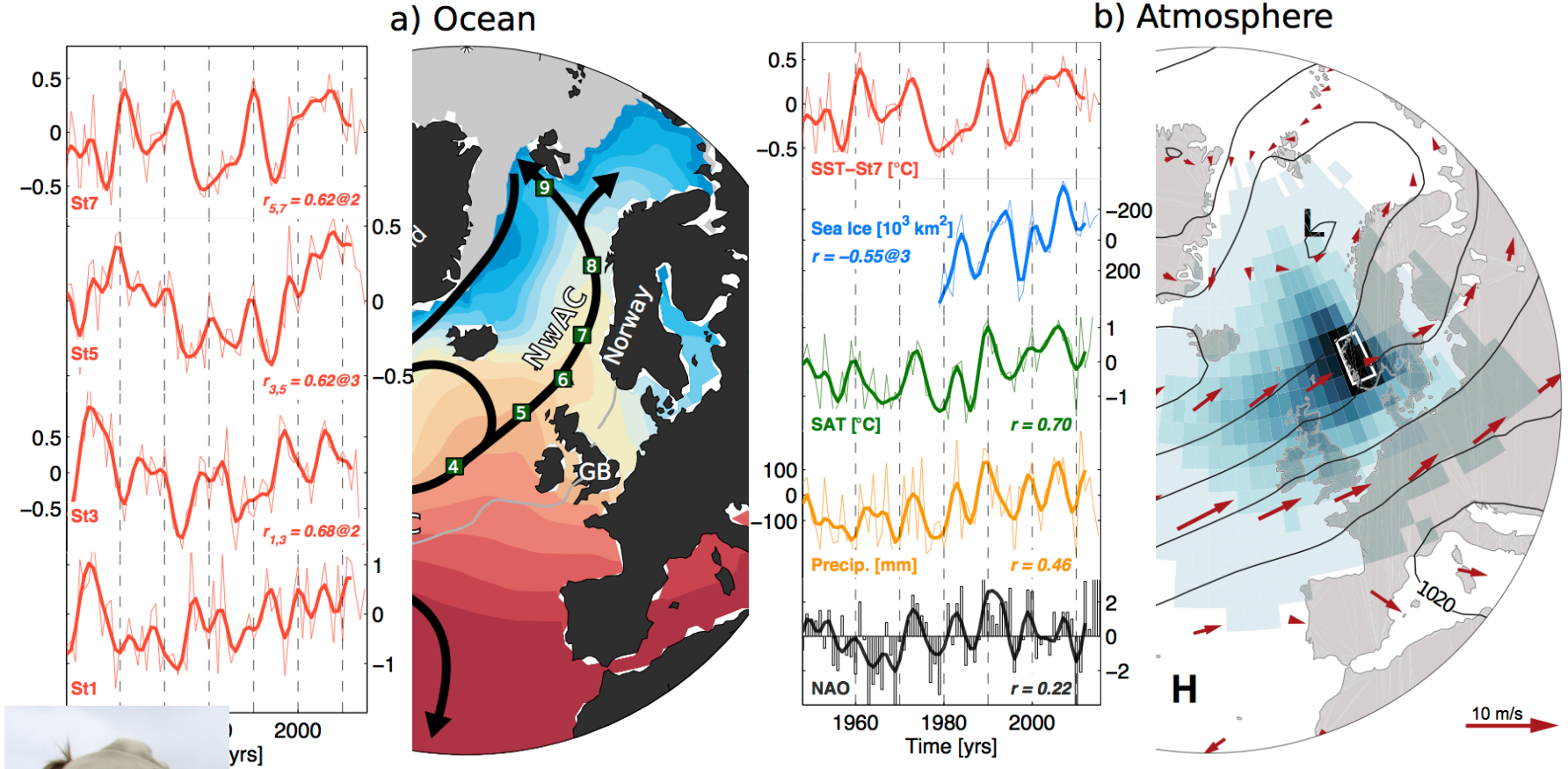


Årthun et al. 2017: *Nature Comm.*

Norwegian Sea heat (SST) is reflected in

+ Arctic winter sea ice cover (30% @3yr) – see also Yeager et al. (2016, GRL)

How to get predictability beyond the ocean?



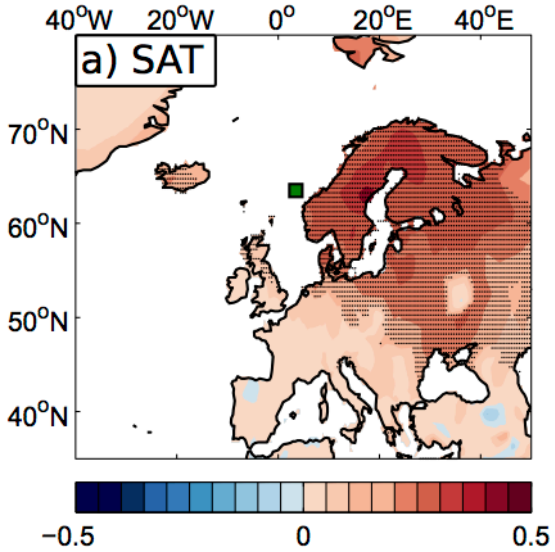
Årthun et al. 2017: *Nature Comm.*

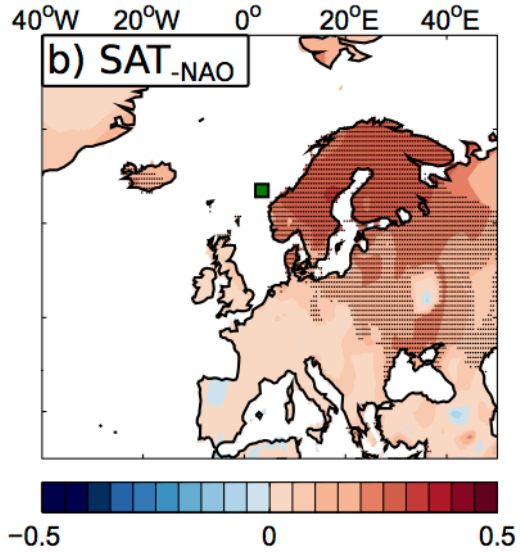
Norwegian Sea heat (SST) is reflected in

+ Arctic winter sea ice cover (30% @3yr) – see also Yeager et al. (2016, GRL)
+ Norwegian SAT (49%) and precipitation (21%) over land
+ practically *independent* from NAO (5%)

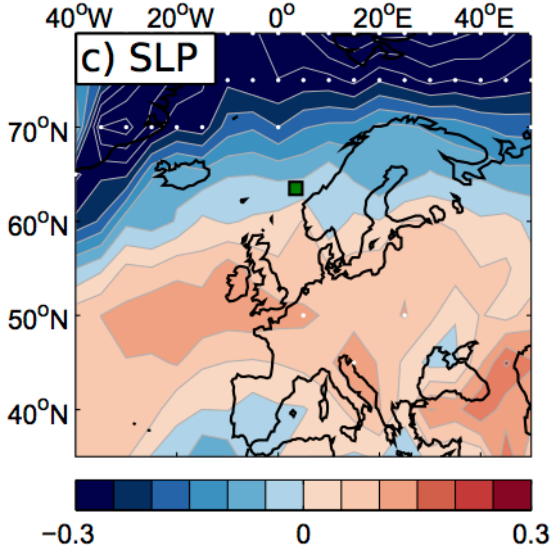
Spatial manifestation over land

Norw Sea SST@no lag





SST, *less* NAO

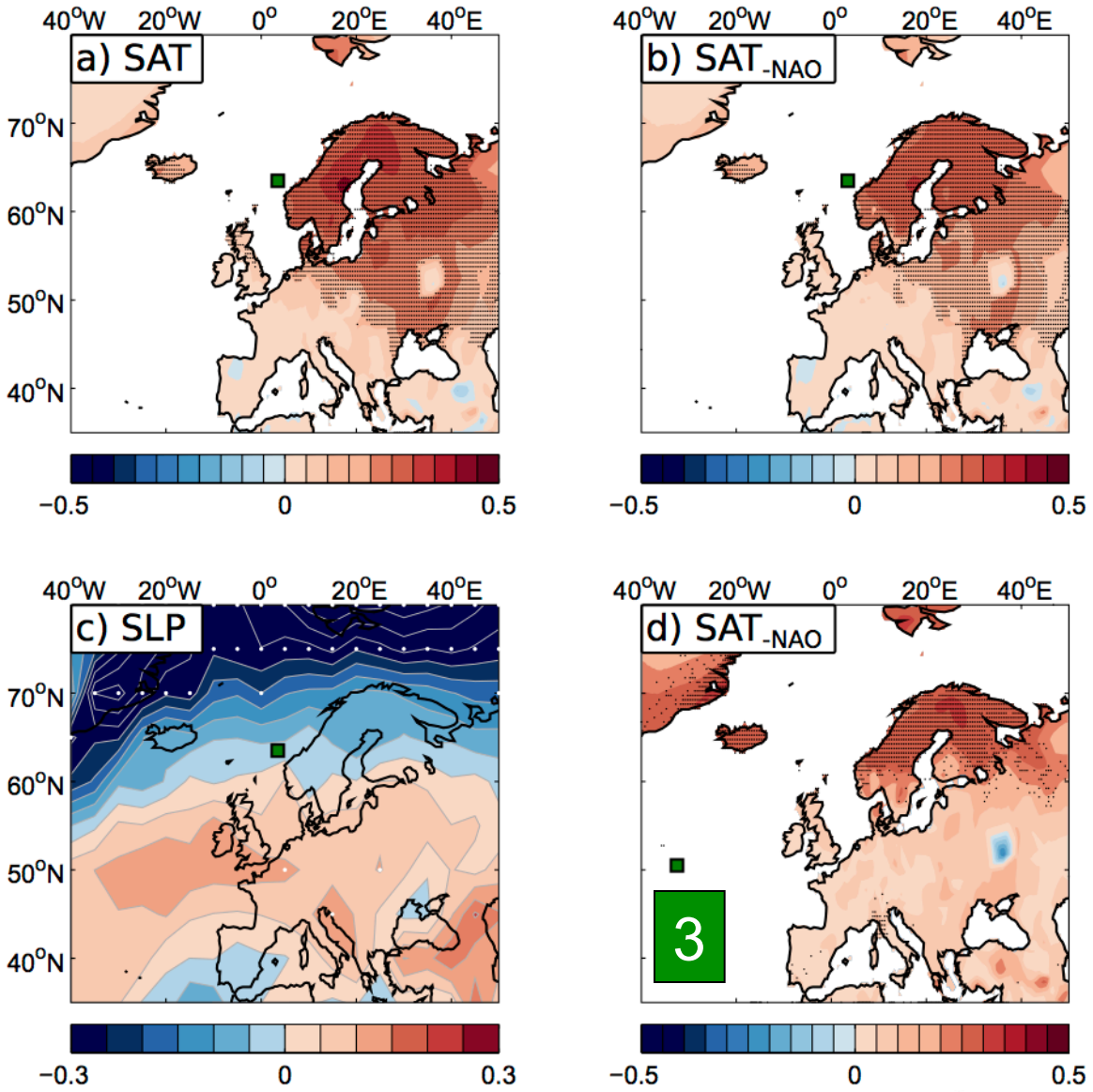


Årthun et al. 2017: *Nature Comm.*

HadSST / HadSLP2r / CRU TS3.23

Spatial manifestation over land

Norw Sea SST@no lag



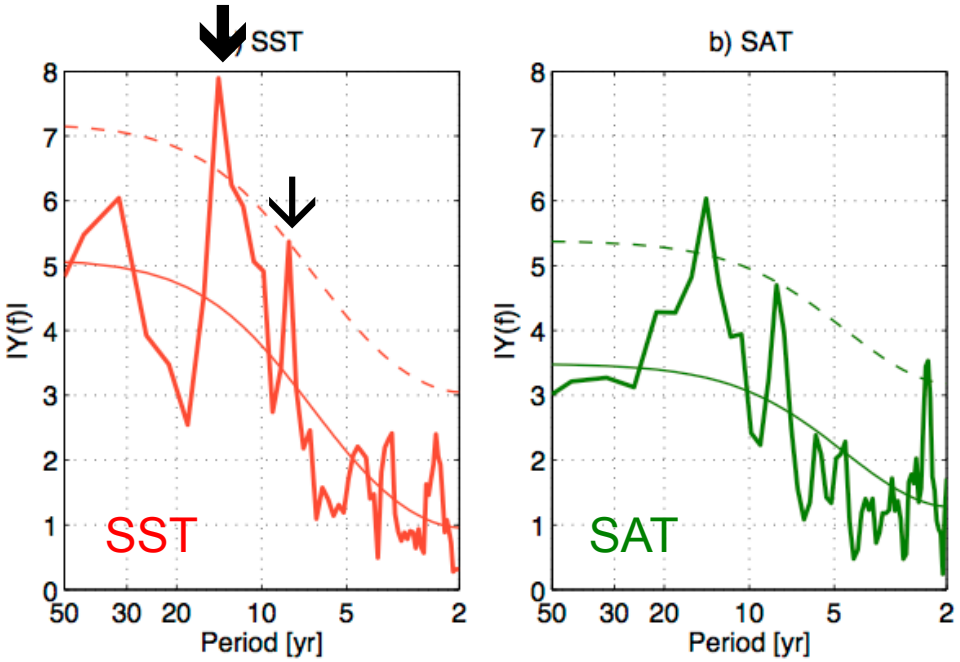
SST, *less* NAO

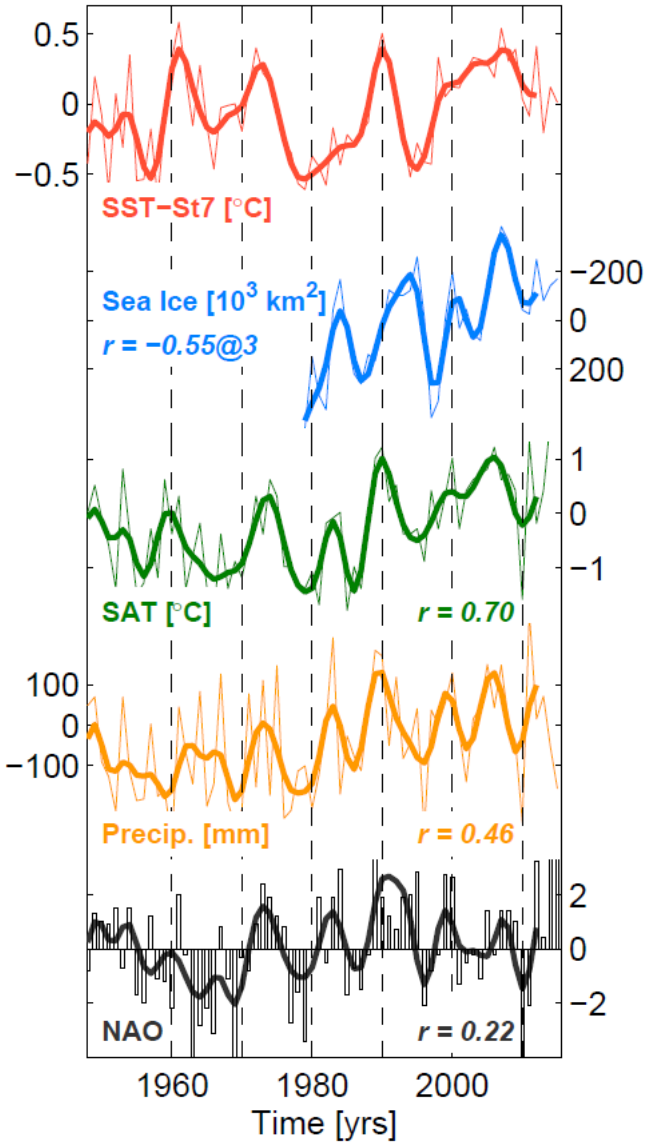
SP NAtl SST@7 yr

Årthun et al. 2017: *Nature Comm.*

HadSST / HadSLP2r / CRU TS3.23

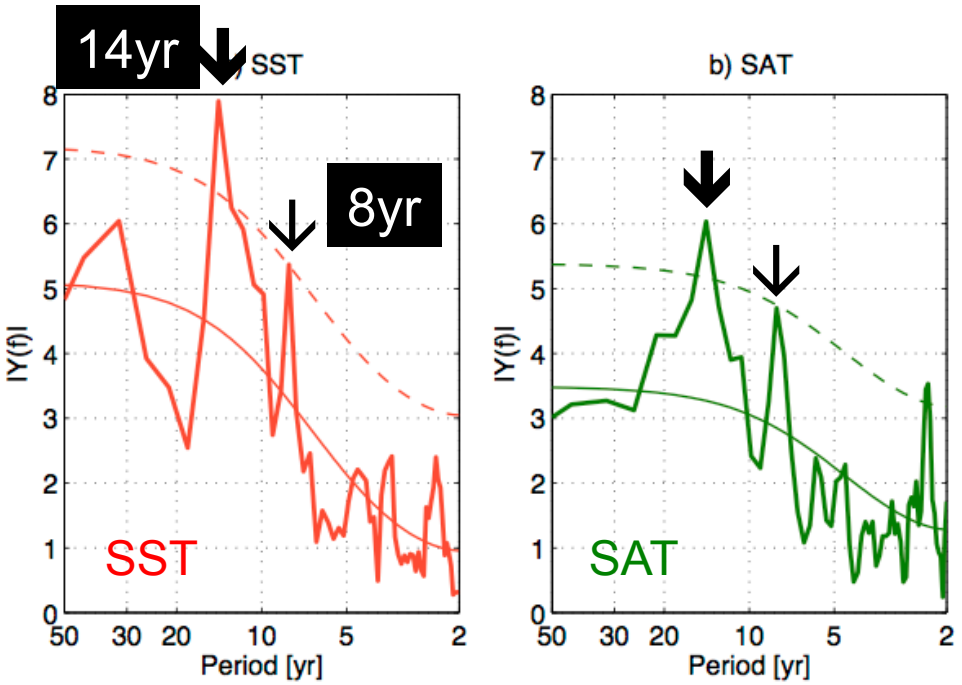
Dominant time scales





Årthun et al. 2017: *Nature Comm.*

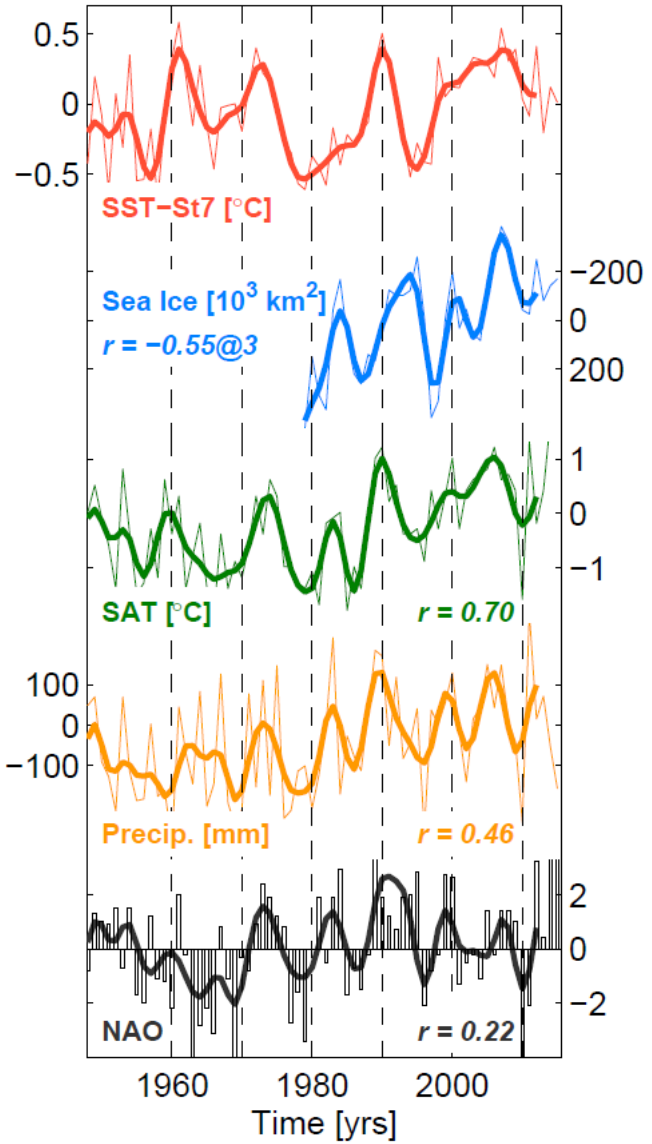
Dominant time scales



14-yr timescale ➔ ocean advection

8-yr timescale ➔ NAO

E.g., Moron et al. 1998; Häkkinen 2000; Marshall et al. 2001; Reintges et al. 2016.



Årthun et al. 2017: *Nature Comm.*

Marius' poster

T3-30

Wed afternoon

T3-30 Arctic-Atlantic Climate Variability and Predictability from Poleward Ocean Heat Transport

Marius Årthun*
Contributions from: Nora Loose, Tor Eldevik, Erik W. Kolstad
Bjerknes Centre for Climate Research, Bergen, Norway
*Email: marius.arthun@uib.no

Bjerknes Centre for Climate Research

1) Prediction of Arctic-Atlantic climate provided by the ocean *(Årthun et al., 2017. Nat. Commun.)*:

- **Ocean temperature** changes in the subpolar North Atlantic lead downstream temperature changes in the Nordic Seas by approximately 7–10 years.
- SST variations are subsequently **reflected in continental climate** over Norway and Arctic sea ice extent.
- SST and SAT variability pronounced on **interdecadal time scale**.

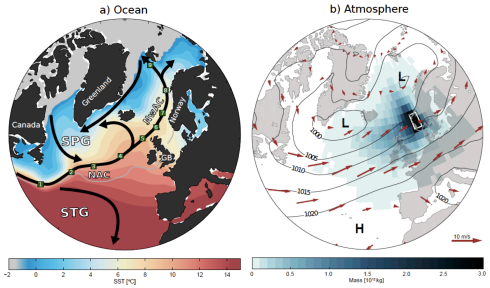


Figure: *Dominant ocean and atmosphere circulation in the North Atlantic and Nordic Seas.*

2) How does Nordic Seas SST influence northern SAT? *(Årthun et al., in prep.)*

- Dominant interdecadal time scale of SAT variability over the Nordic region.
- SAT variability **decomposed into dynamics and thermodynamics** (following O'Reilly et al., 2017).
  -> interdecadal variability rooted in thermodynamics
  -> thermodynamical component co-varies with SST.
- **Conclusion**: Multi-annual ocean temperature anomalies are advected eastward over Scandinavia by the climatological westerly winds

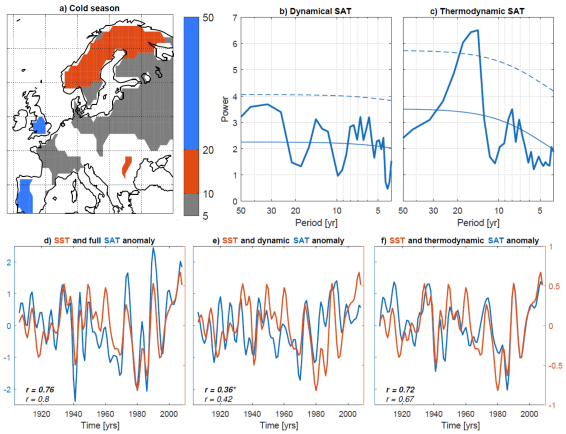


Figure: *(a) Dominant time scale (in years) of SAT variability during the cold season (Nov-April). (b,c) Power spectra for dynamic and thermodynamic SAT anomalies for western Norway. (d-f) Time series of Norwegian Sea SST anomalies and decomposed (dynamic + thermodynamic) SAT anomalies for western Norway. To highlight multi-annual variability the time series have been 5-year low-pass filtered. Correlations between filtered (bold) and unfiltered time series are given. Data are from CERA-20C.*

3) Origin of Nordic Seas heat anomalies: An adjoint sensitivity analysis *(Loose et al., in prep.)*:

- Use adjoint sensitivities from ECCOv4 to assess the relative importance of local and remote forcing of Nordic Seas heat content.
- **0-3 years:** Local air-sea heat fluxes trigger heat anomalies.
- **2-4 years**: Heat and freshwater fluxes along the NAC become important (warmer/saltier NAC -> warmer Nordic Seas).
- **7-8 years**: Densification of surface waters in subpolar North Atlantic lead to warm SST anomalies in the Nordic Seas.

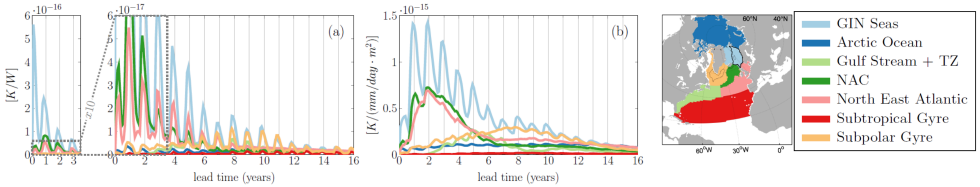


Figure: *Average absolute value of Nordic Seas winter heat content sensitivities to (a) surface heat and (b) freshwater fluxes as a function of lead time, where the average is taken over the regions shown in the map.*

CONTACT INFORMATION
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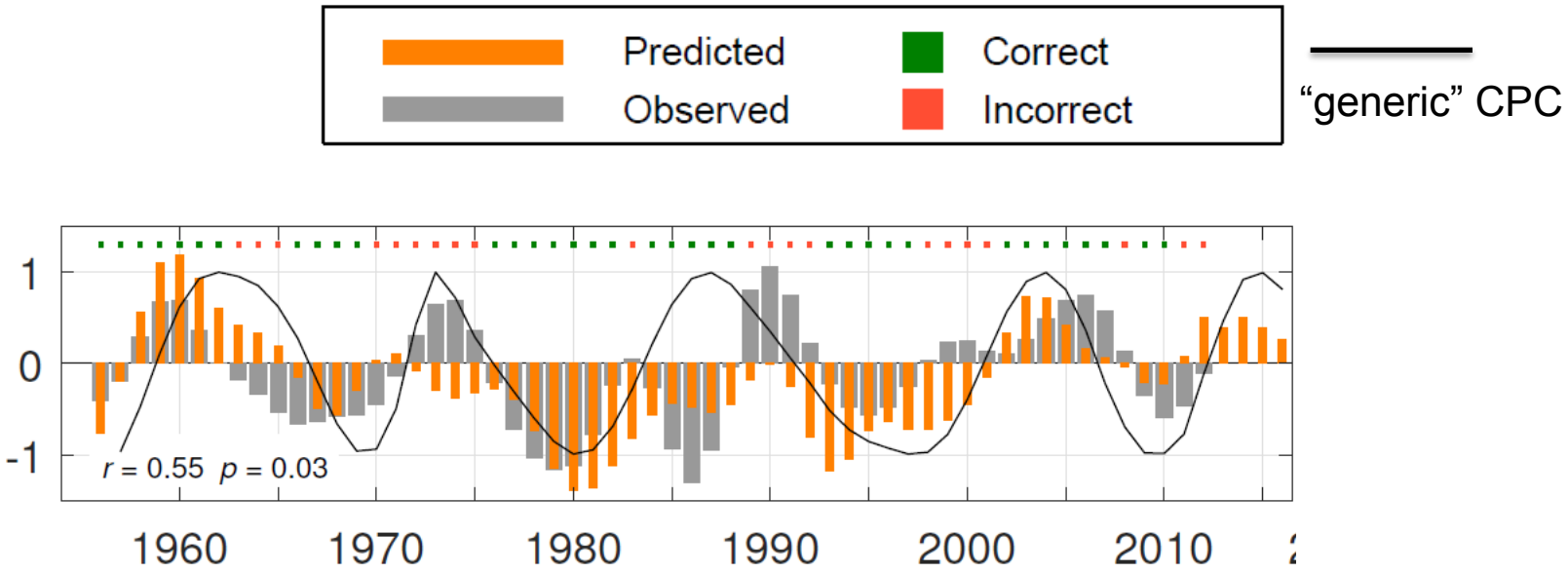
Basic prediction

Surface Air Temperature - Norway

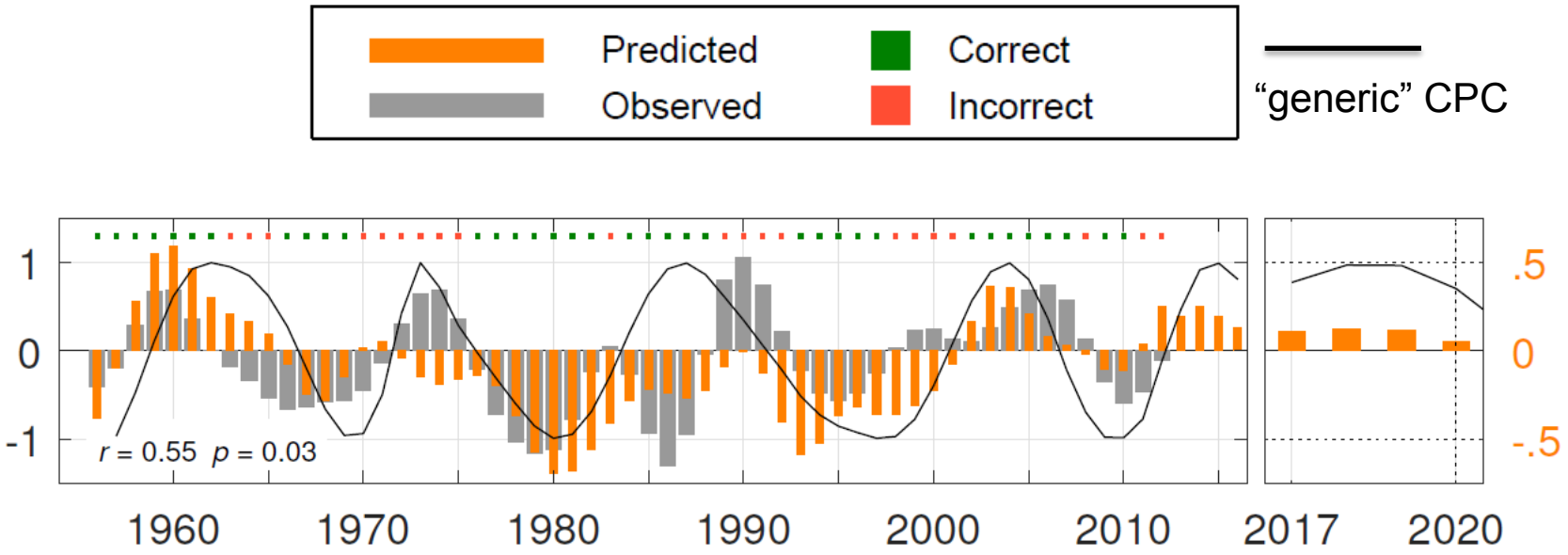


- Sign of prediction correct 67% of the time
- More skilful than random chance and climatology predictions

Årthun et al. 2017: *Nature Comm.*

Basic prediction 2017–2020

Surface Air Temperature - Norway



- Sign of prediction correct 67% of the time
- More skilful than random chance and climatology predictions
- Temperatures above long-term average toward 2020

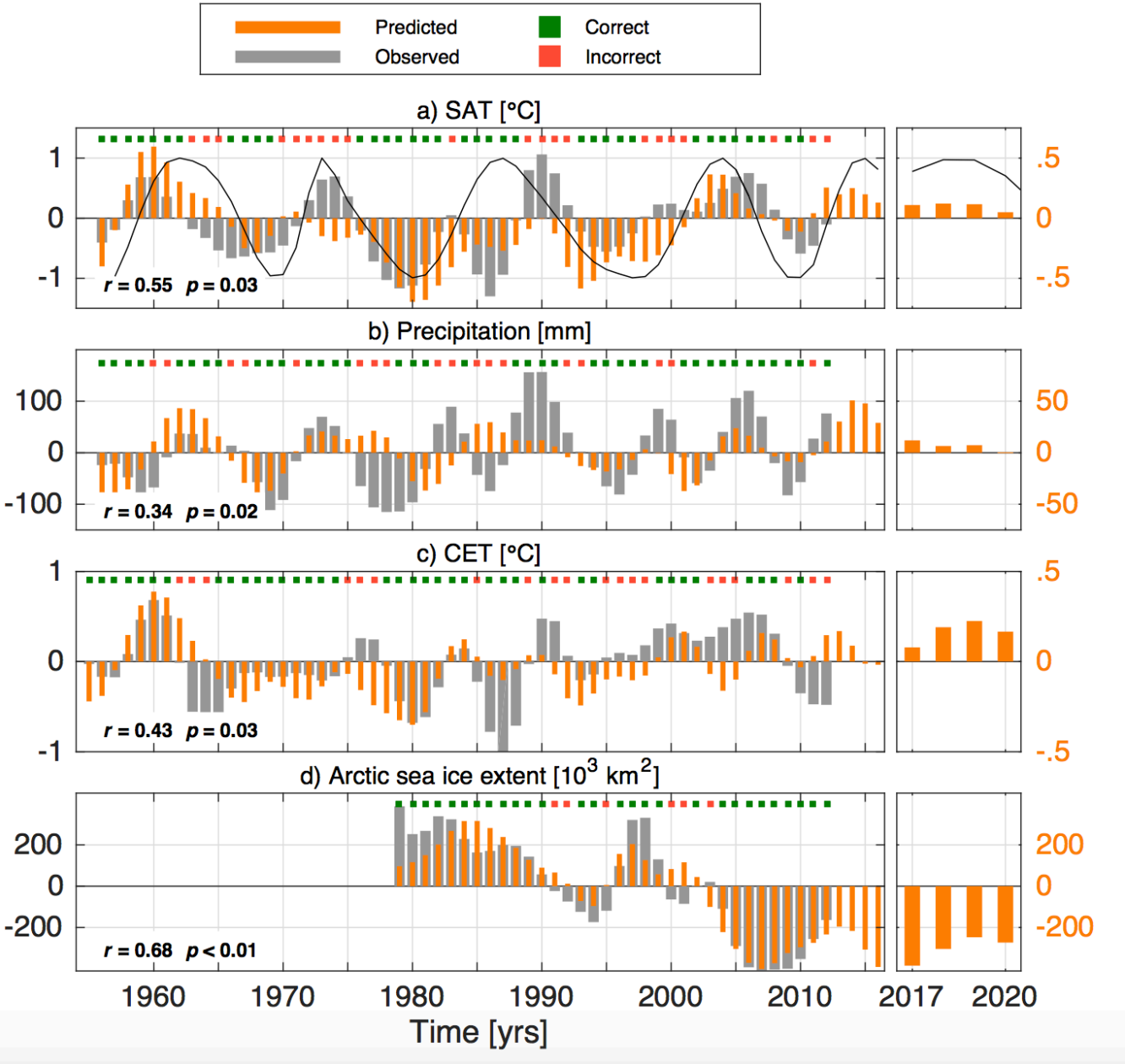
Årthun et al. 2017: *Nature Comm.*

Norway SAT

Norway precip

CET

Arctic sea ice



Årthun et al. 2017: *Nature Comm.*

anomalies wrt 1981–2010 climatology

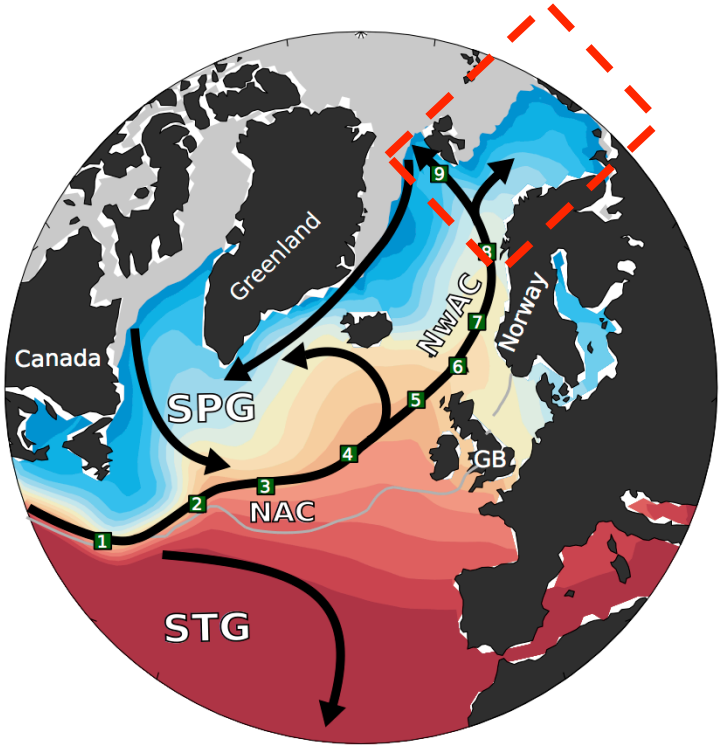
Statsminister Erna Solberg. FOTO: Audun Braastad / NTB scanpix

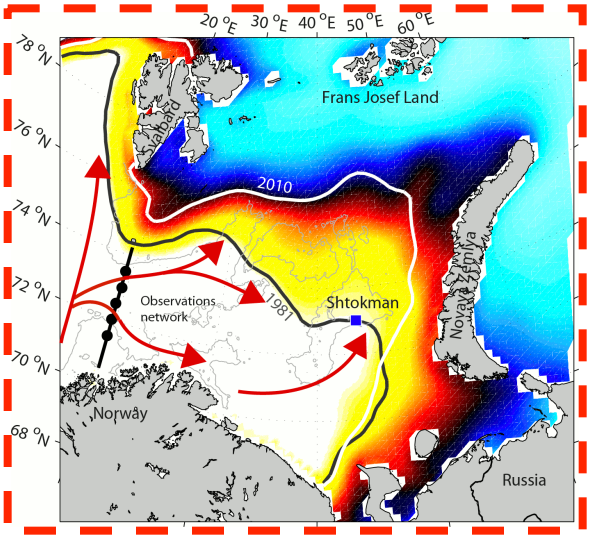
NTB/aftenbladet.no 20/1/2015

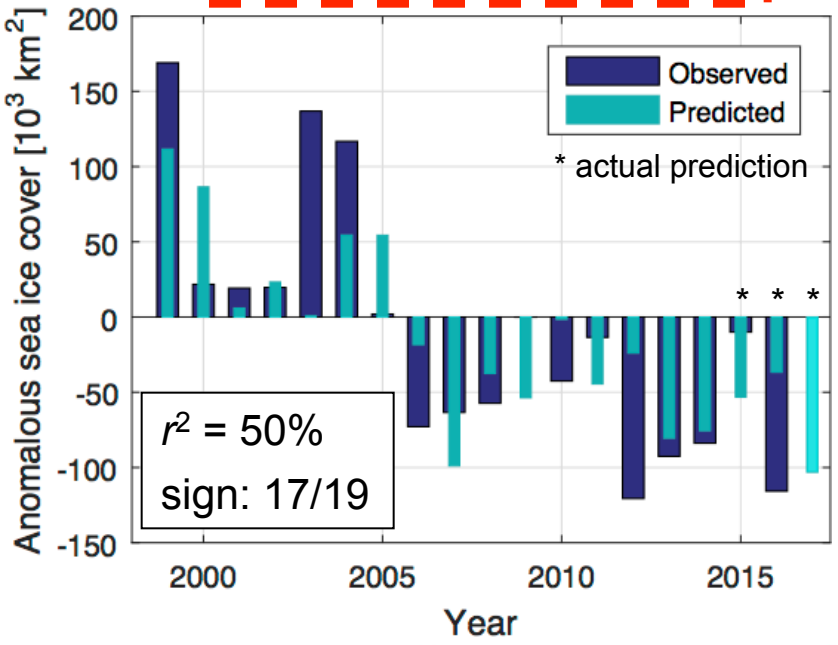
Solberg: - Iskanten har flyttet seg selv

(– The ice edge has moved itself)

Observed **Barents Sea ice** predictability





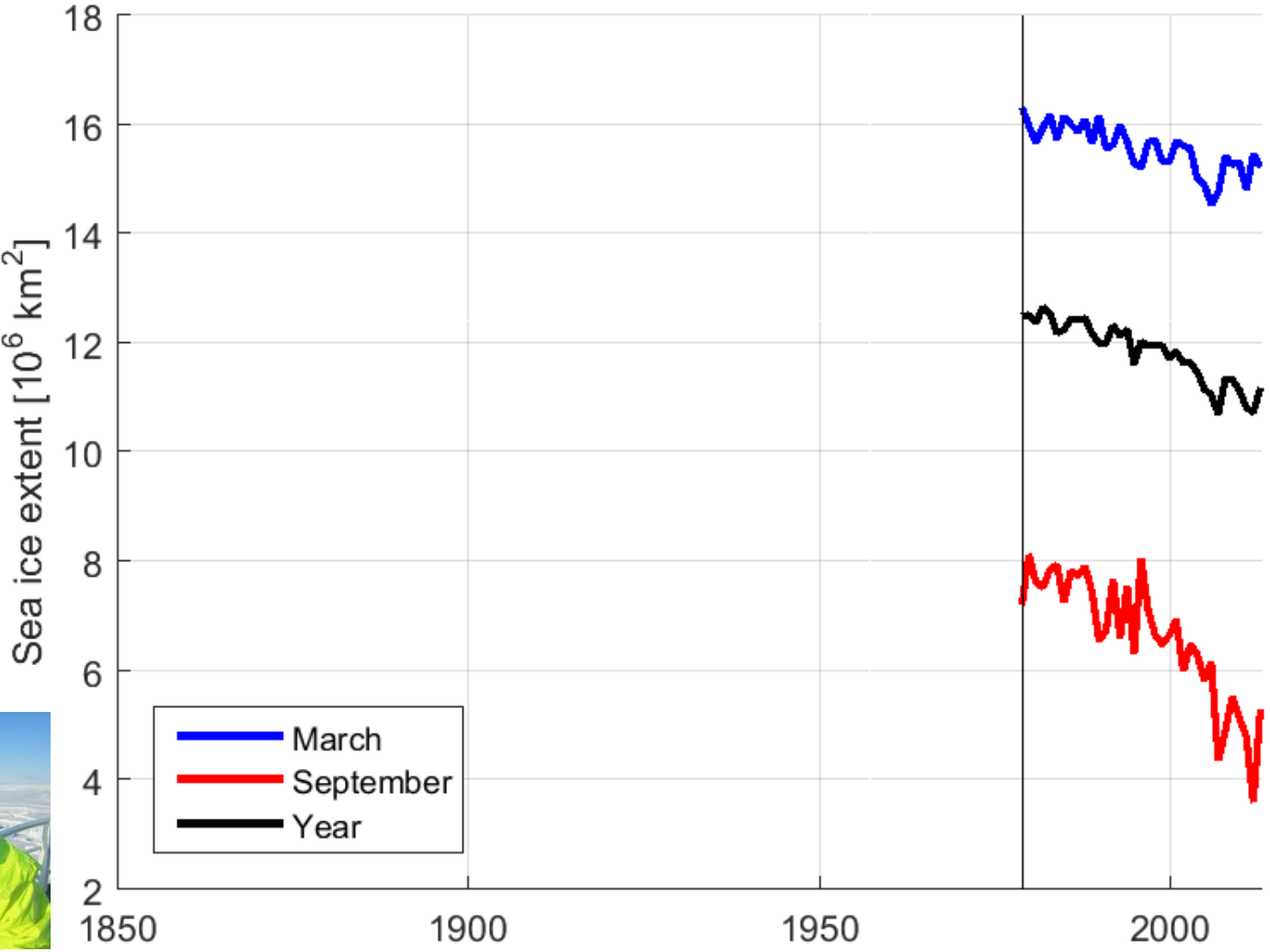


Onarheim et al. 2015: Skillful prediction of Barents Sea ice cover. ***GRL***

Onarheim et al. 2015: *GRL* – ***updated*** ; Årthun et al. 2012: *JClim*

Obs-based 1-yr prediction

Sea ice variability 1850-2013



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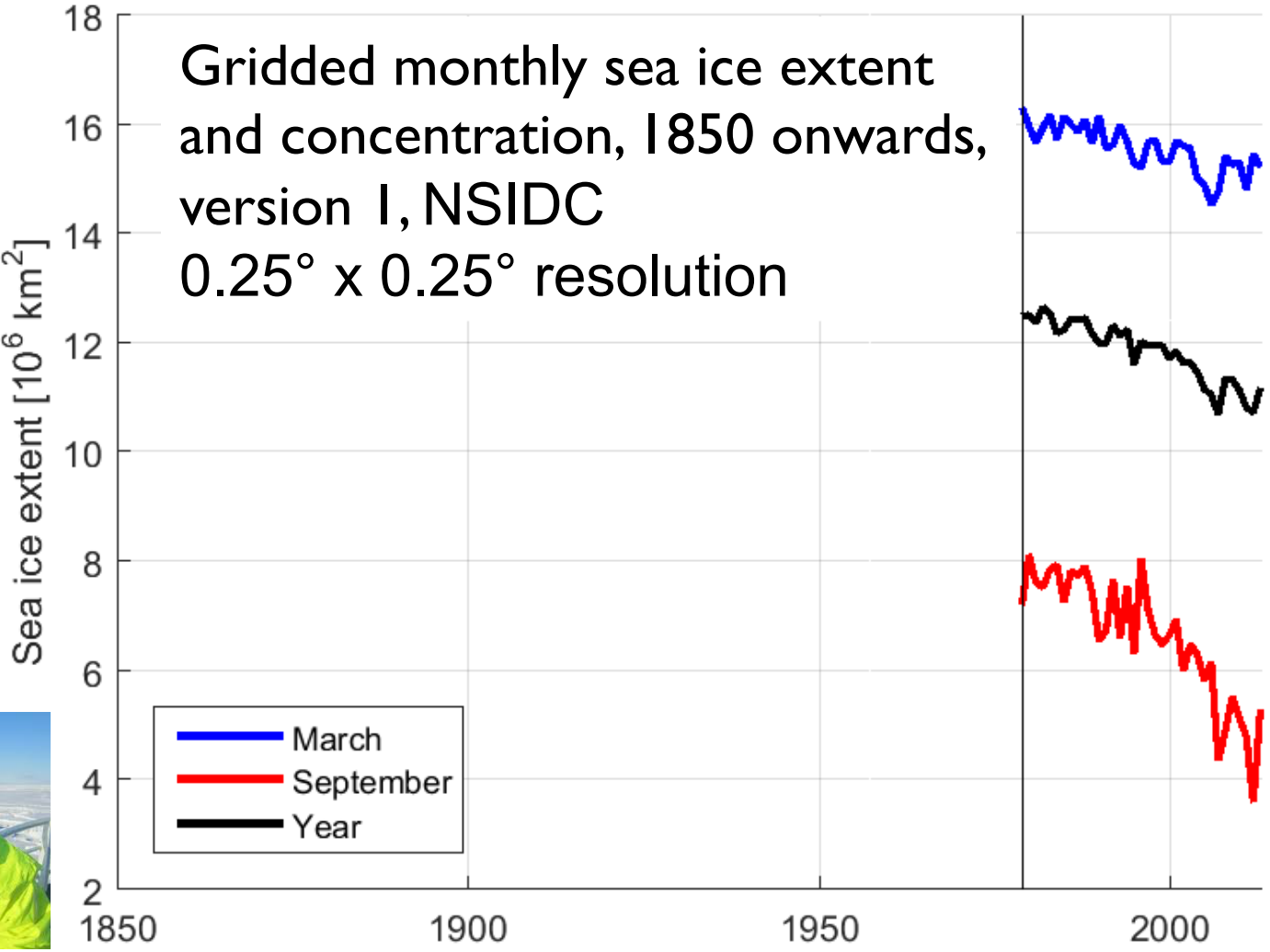
Onarheim et al., *J. Clim.*, in revision

Sea ice variability 1850-2013



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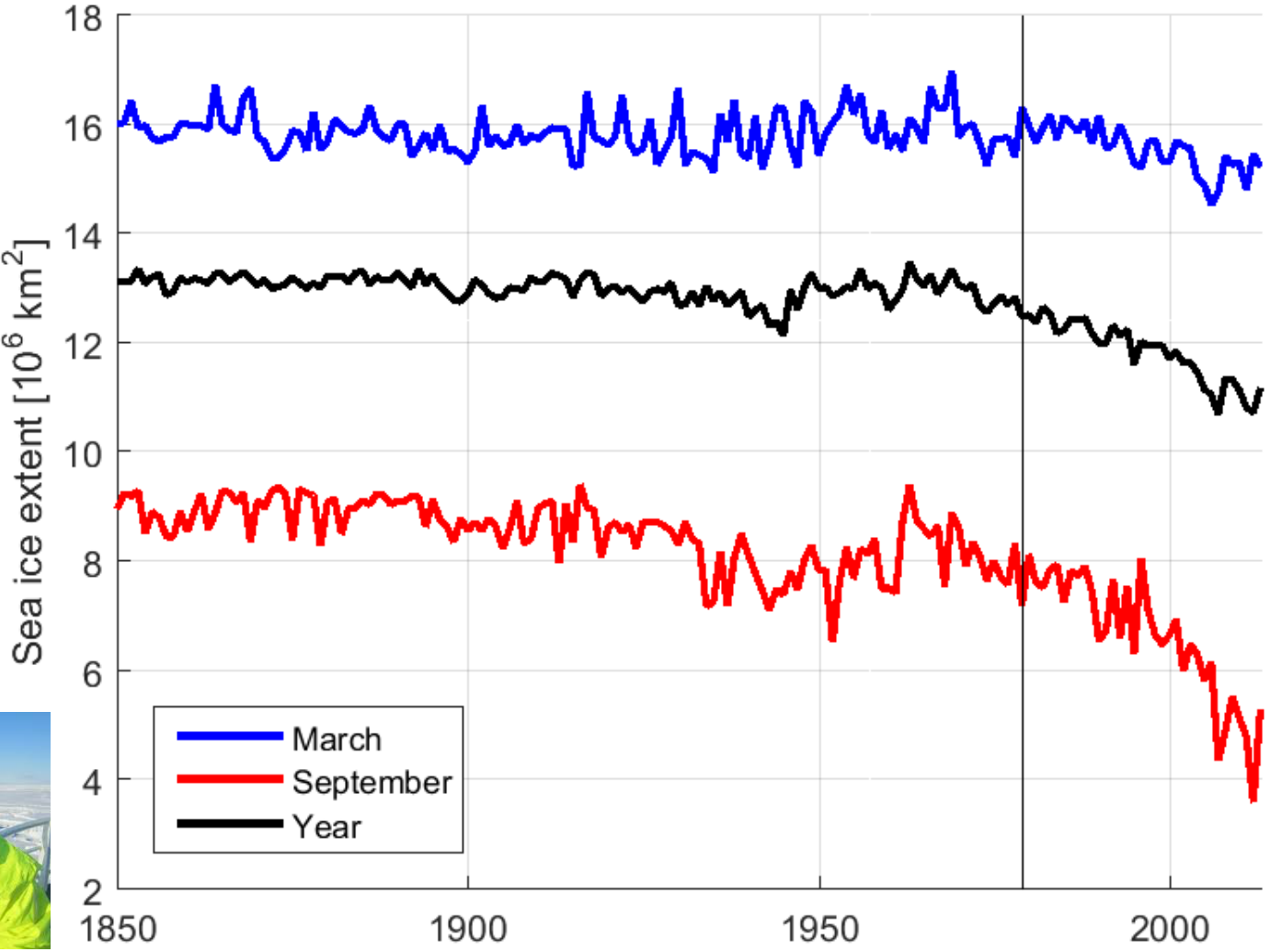
See also Walsh et al., 2016

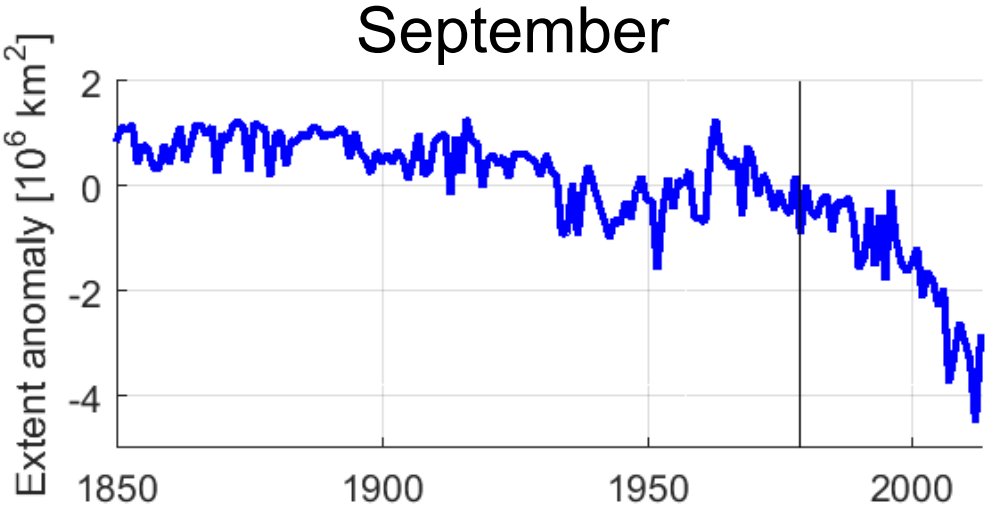
Sea ice variability 1850-2013



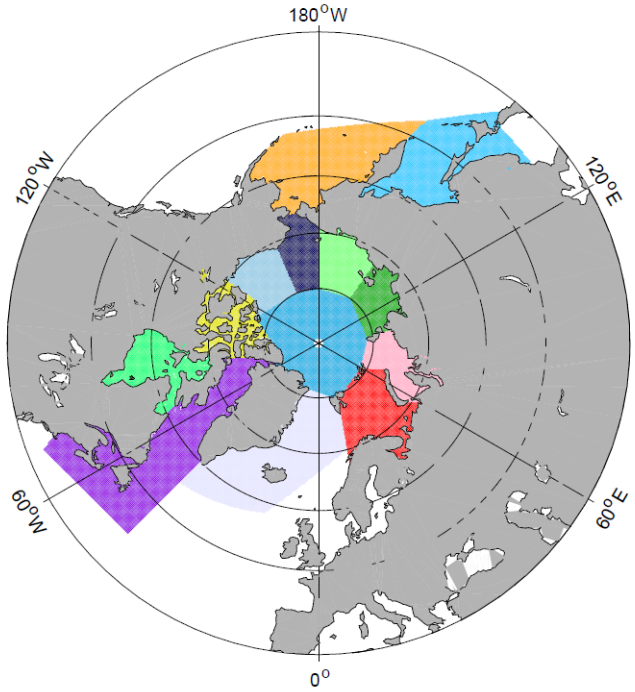
Bjerknes Centre for Climate Research

See also Walsh et al., 2016

Sea ice extent anomaly, 1850-2013



Blue: Northern Hemisphere



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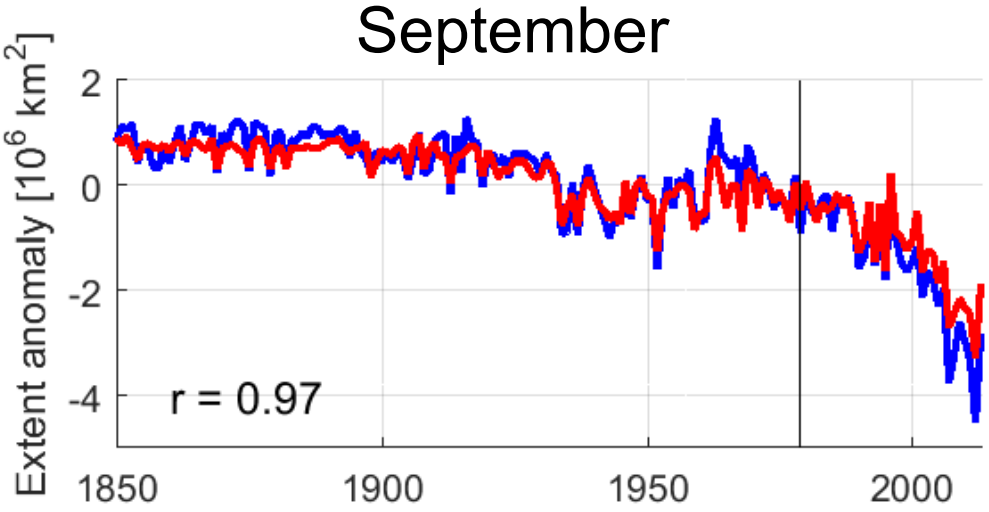
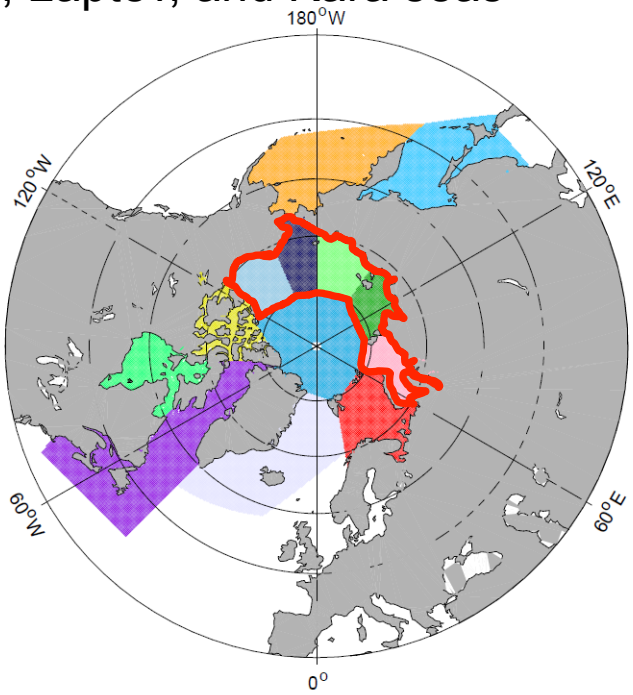
Onarheim et al., *J. Clim.*, in revision

Sea ice extent anomaly, 1850-2013



Blue: Northern Hemisphere
Red: Beaufort, Chukchi, East Siberian, Laptev, and Kara seas



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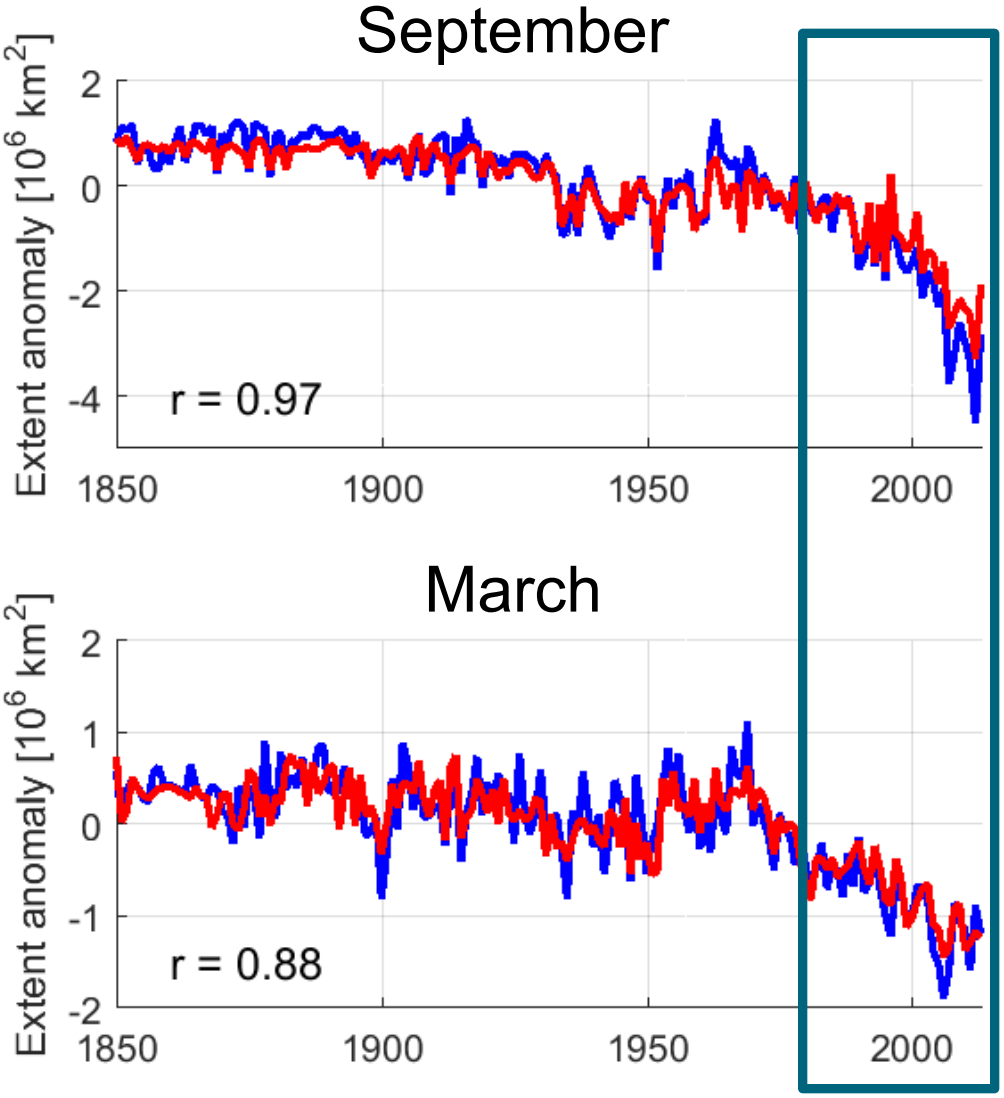
Onarheim et al., *J. Clim.*, in revision

Sea ice extent anomaly, 1850-2013



Blue: Northern Hemisphere
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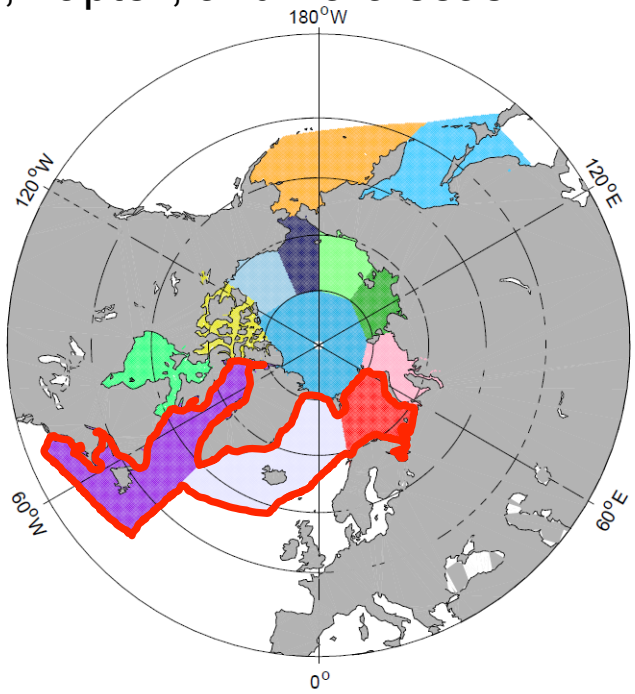

Blue: Northern Hemisphere
Red: Greenland Sea, Barents Sea, and Baffin Bay

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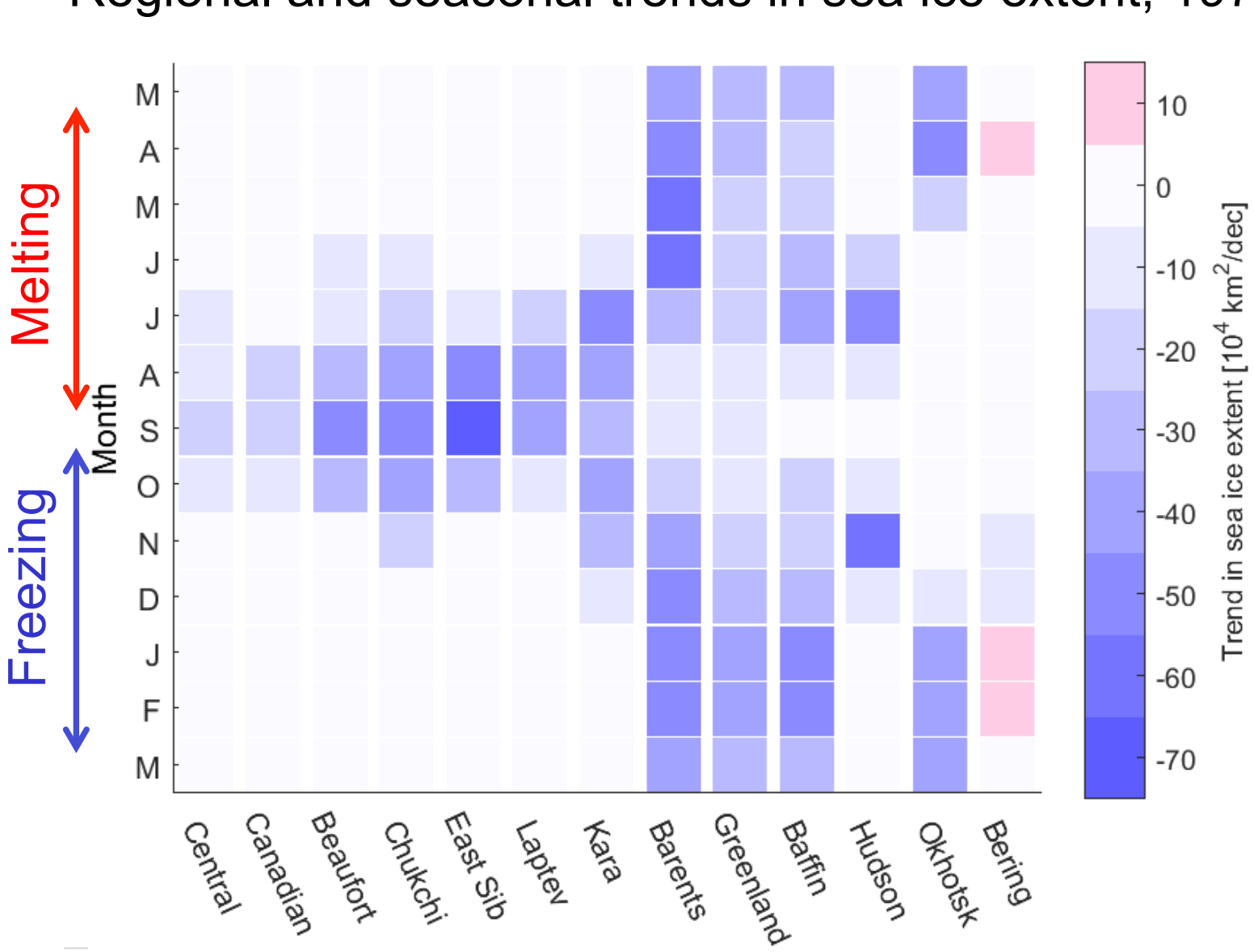
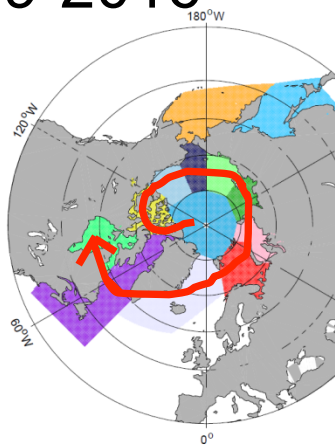
Onarheim et al., *J. Clim.*, in revision

Regional and seasonal trends in sea ice extent, 1979-2016





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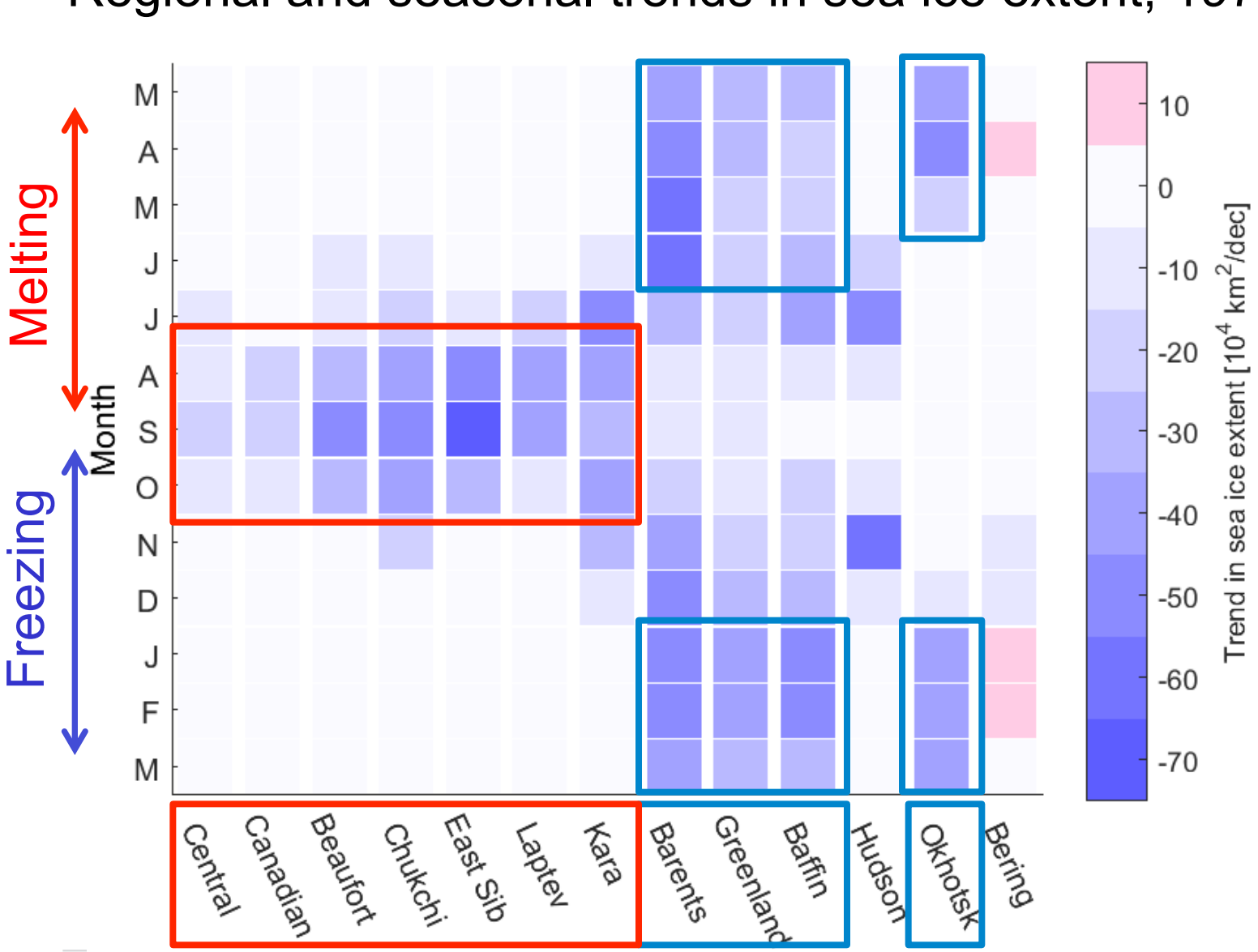
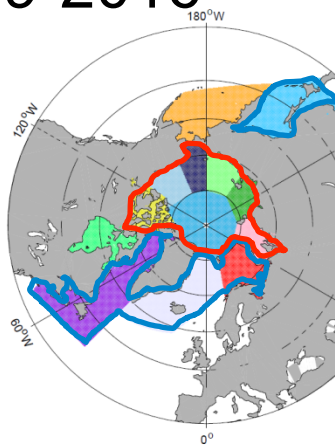
Onarheim et al., *J. Clim.*, in revision

Regional and seasonal trends in sea ice extent, 1979-2016





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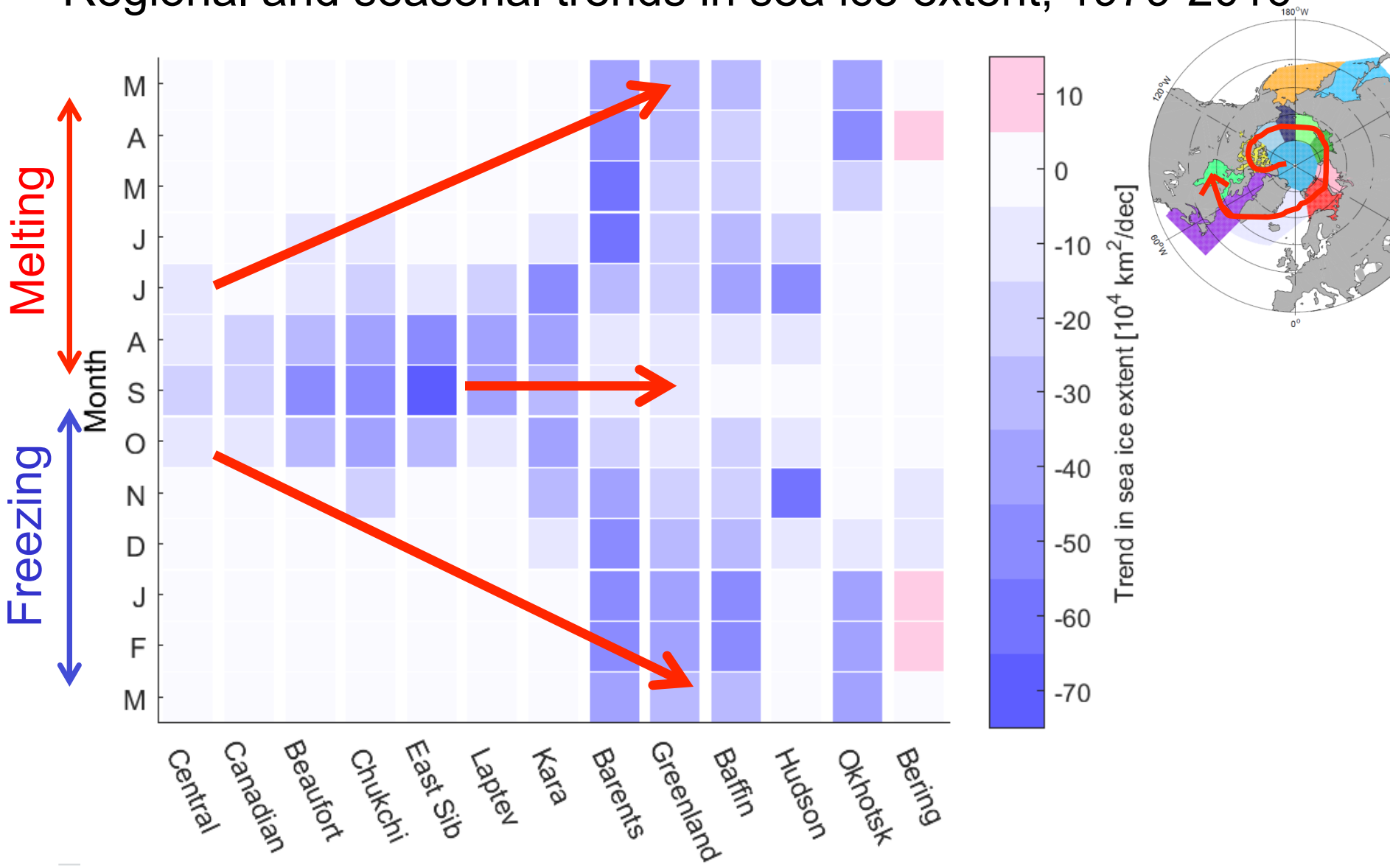
Onarheim et al., *J. Clim.*, in revision

Regional and seasonal trends in sea ice extent, 1979-2016



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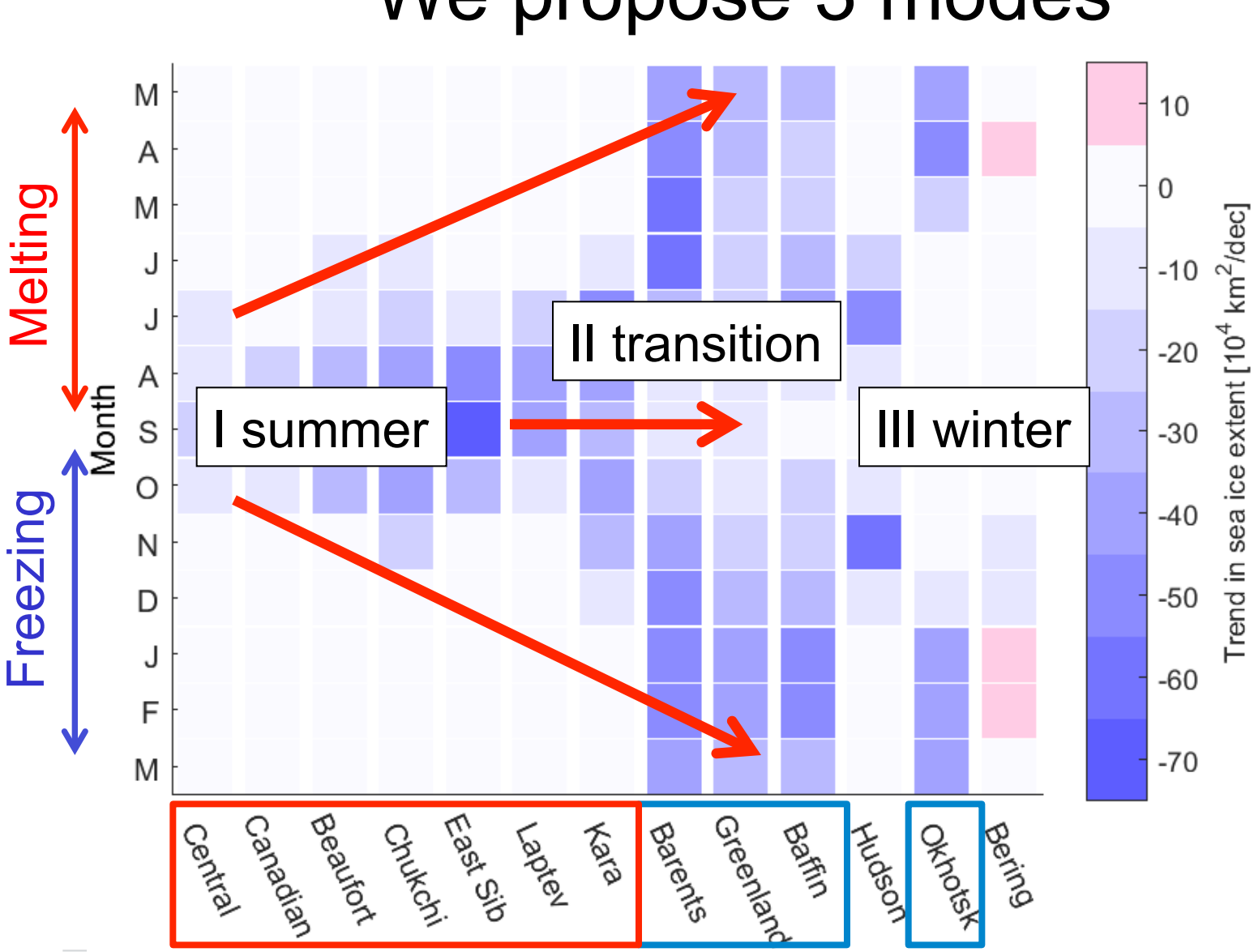
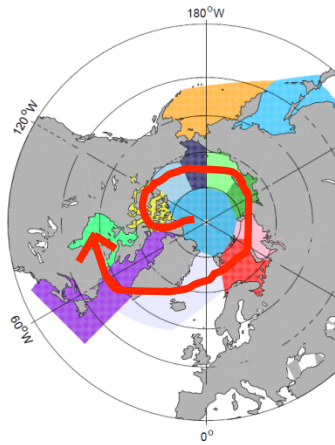
Onarheim et al., *J. Clim.*, in revision

We propose 3 modes





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Onarheim et al., *J. Clim.*, in revision

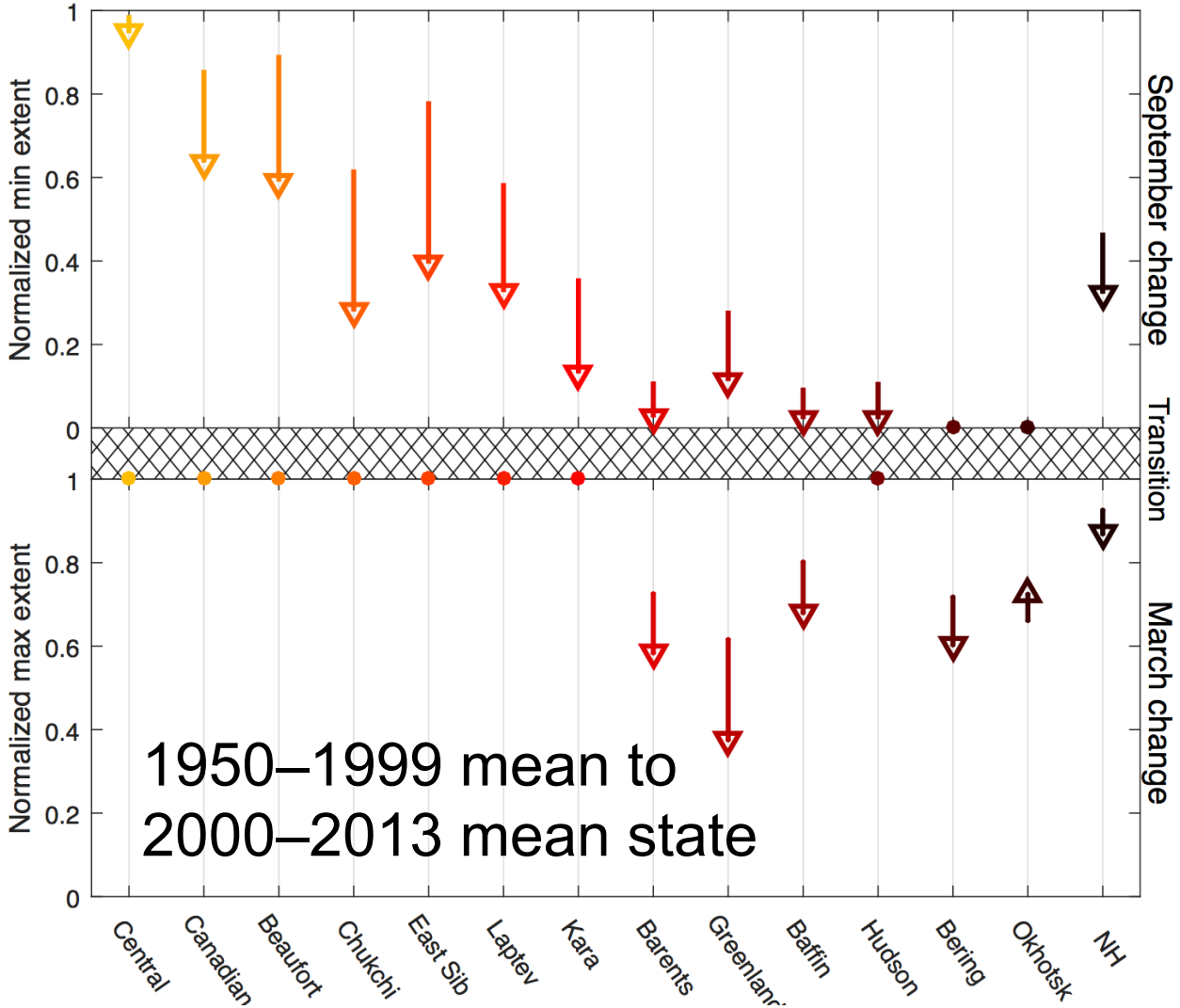
Space-for-time?

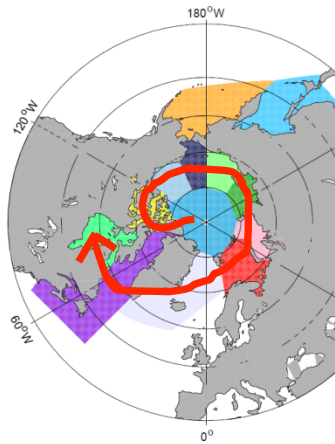
mode #

I

II

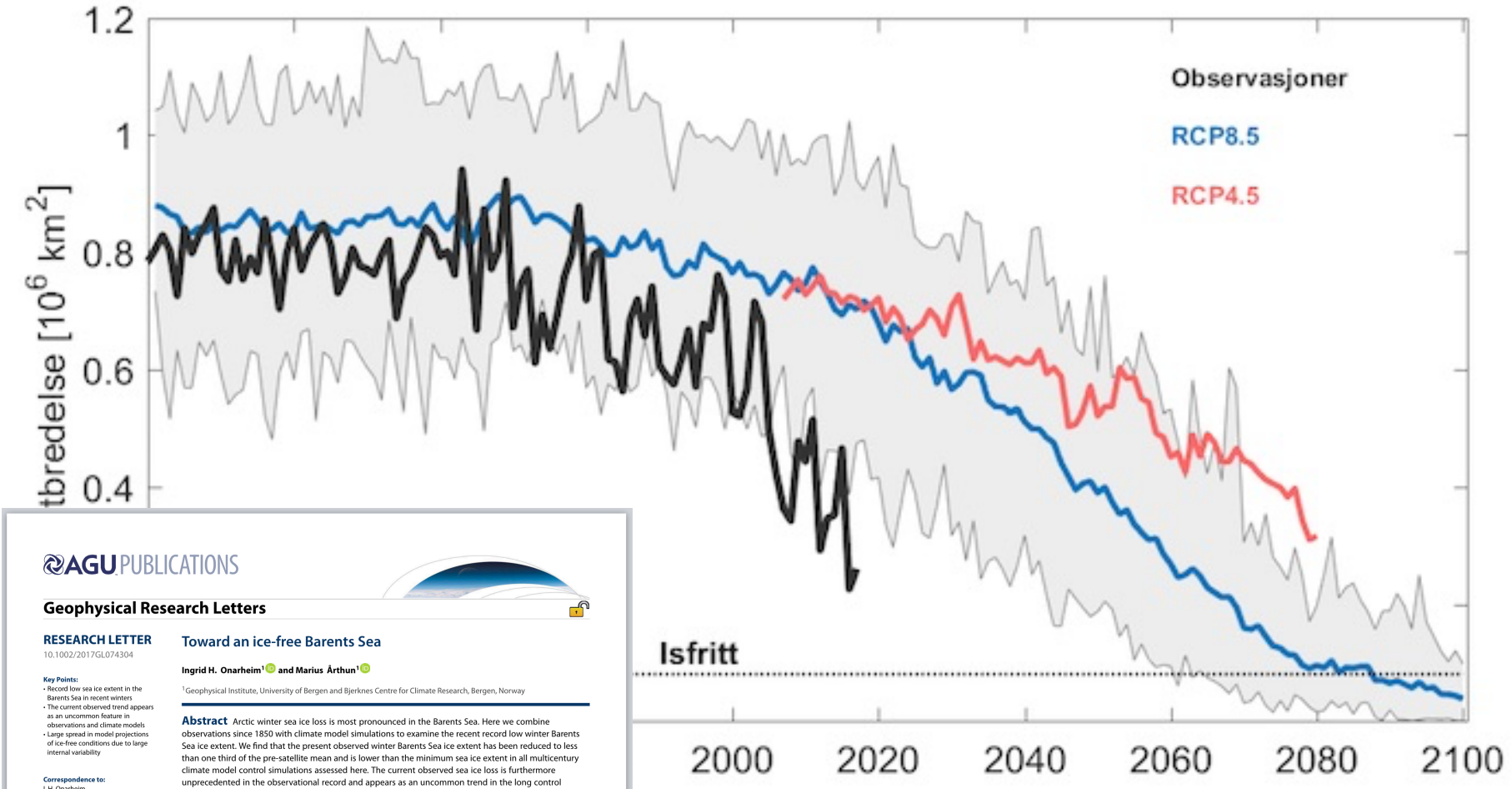
III





Onarheim et al., *J. Clim.*, in revision

Future Barents Sea: Onarheim and Årthun, GRL, 2017



AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL074304

Key Points:
- Record low sea ice extent in the Barents Sea in recent winters
- The current observed trend appears as an uncommon feature in observations and climate models
- Large spread in model projections of ice-free conditions due to large internal variability

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I. H. Onarheim,
ingrid.onarheim@uib.no

Citation:
Onarheim, I. H., and M. Årthun (2017), Toward an ice-free Barents Sea, *Geophys. Res. Lett.*, 44, 8387–8395, doi:10.1002/

Toward an ice-free Barents Sea

Ingrid H. Onarheim[1] and **Marius Årthun**[1]

[1]Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway

Abstract Arctic winter sea ice loss is most pronounced in the Barents Sea. Here we combine observations since 1850 with climate model simulations to examine the recent record low winter Barents Sea ice extent. We find that the present observed winter Barents Sea ice extent has been reduced to less than one third of the pre-satellite mean and is lower than the minimum sea ice extent in all multicentury climate model control simulations assessed here. The current observed sea ice loss is furthermore unprecedented in the observational record and appears as an uncommon trend in the long control simulations. In a warming climate, projections from the large ensemble simulation with the Community Earth System Model show a winter ice-free Barents Sea for the first time within the time period 2061–2088. The large spread in projections of ice-free conditions highlights the importance of internal variability in driving recent and future sea ice loss.

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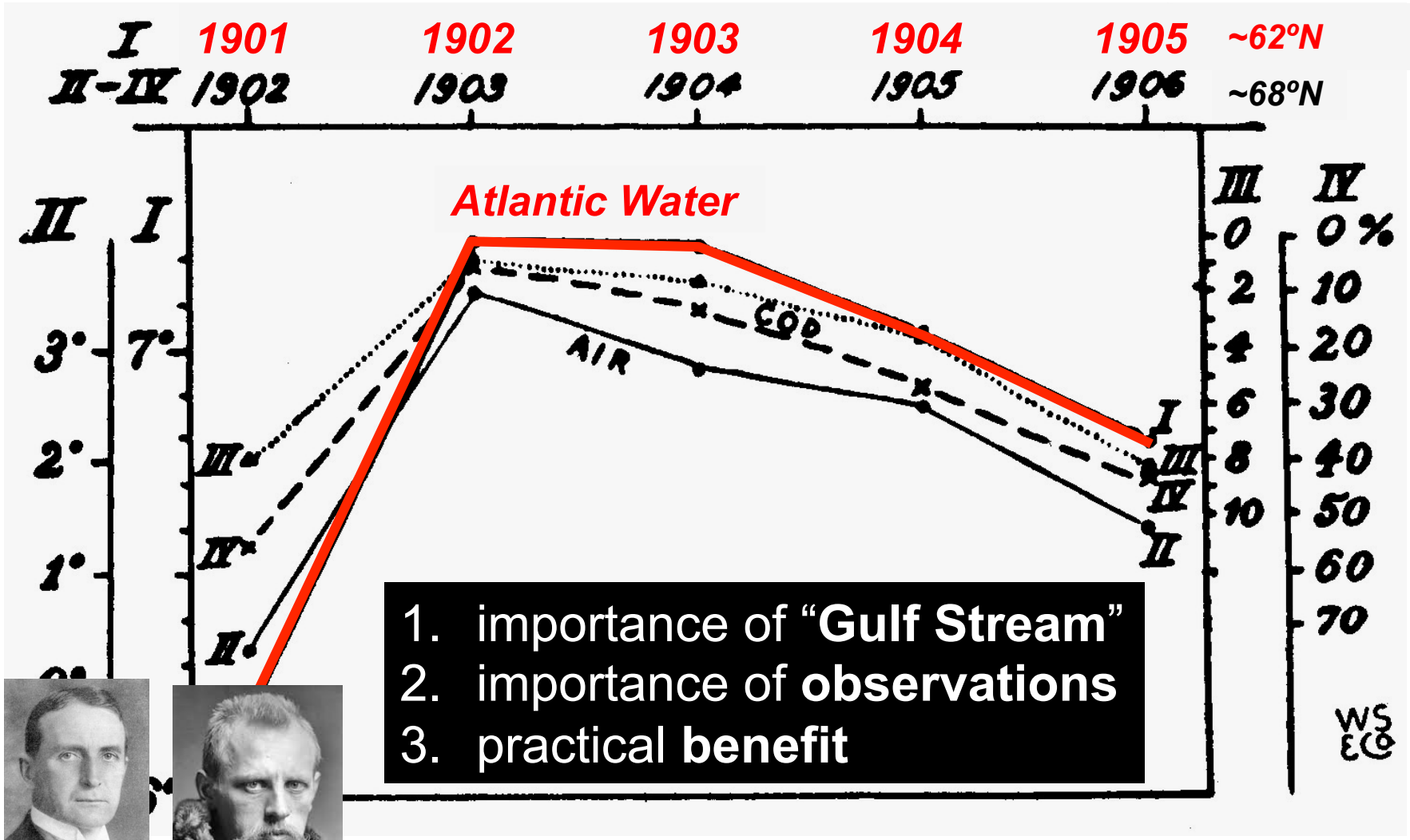
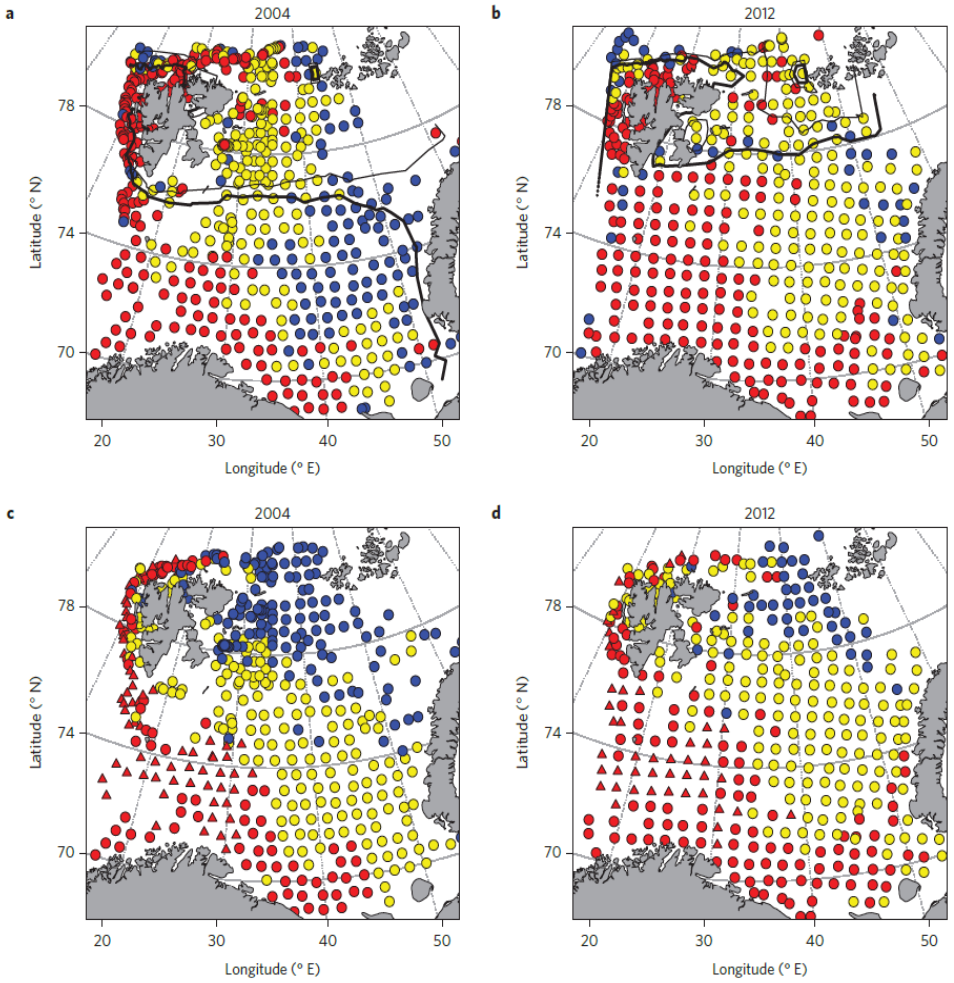
An early vision of a predictable climate



Helland-Hansen og Nansen 1909

Hydrography and Barents Sea fish stock



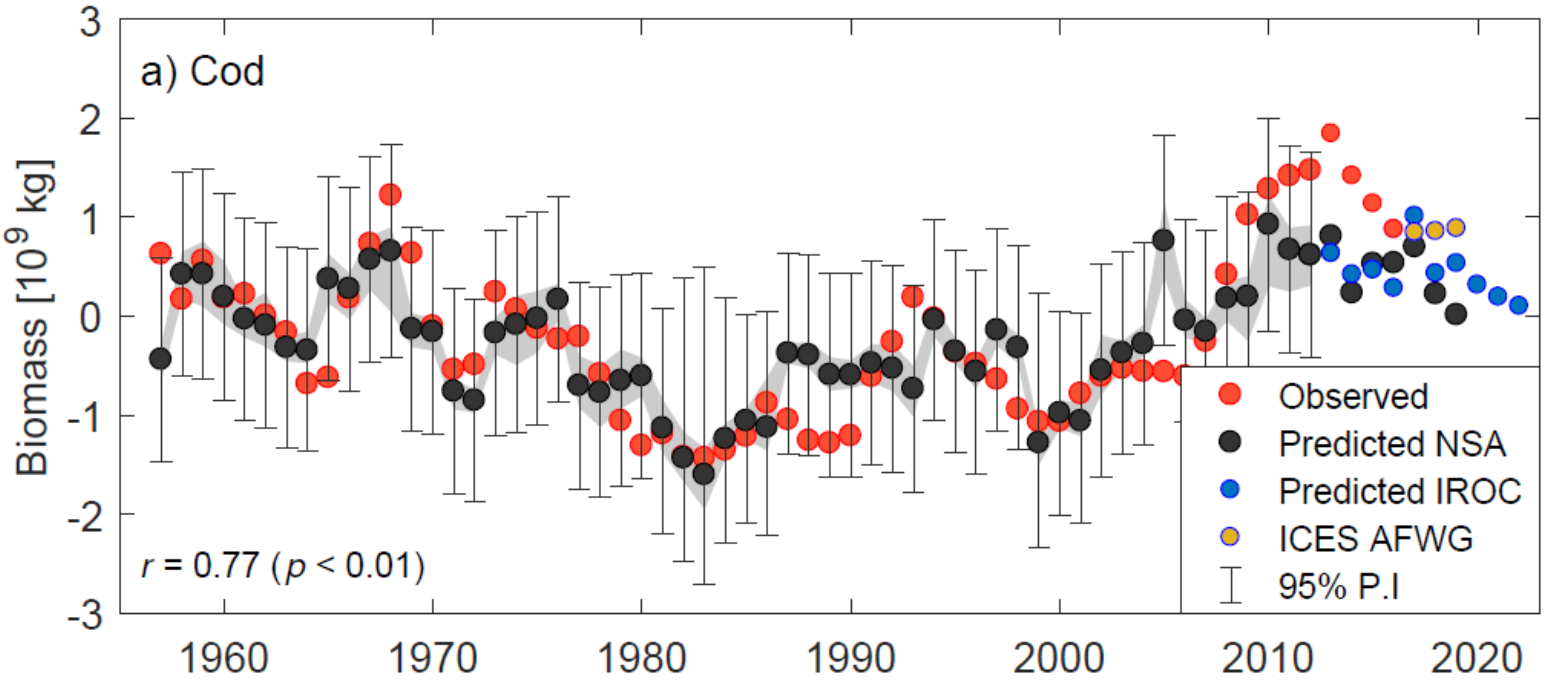
Fish stock variability reflects water mass distribution.

Upper: Distributin of Atlantic water (red) and Arctic water (blue)

Lower: Fish communities. Atlantic (red), Arctic (blue) and Central (yellow).

Fossheim et al. (2015).

Prediction of cod stock biomass based on upstream hydrography
7-year prediction horizon



Årthun et al., in prep

Northern climate change: *2 stories of 3 modes*

- **ocean–land climate predictability**

  I. NAO, **no lag, no predictability**

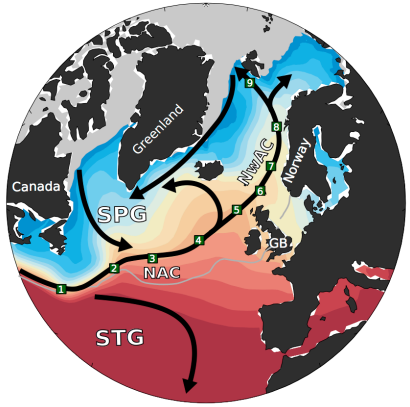
  NAO predictable? E.g., Dunstone et al. 2016

  II. variable ocean, mean wind; 14-yr cycle

  5–10yr predictive potential E.g., Årthun et al. 2017

  III. truly coupled, *the ultimate challenge*

  E.g., Frankignoul and Hasselmann 1977



- **the retreating Arctic Sea ice**

  I. summer, II. transition, III. winter modes

  space-for-time? Cf. *"Atlantification"*

  E.g., Reigstad et al. 2002; Årthun et al. 2012; Polyakov et al. 2017