WGSIP 24th session
ECMWF, 27-29 March 2023

# An upcoming decade of rapid sea ice changes?

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Cecilia Bitz, Cécile Osy, Patricia DeRepentigny, Thierry Fichefet, Hugues Goosse, Alexandra Jahn, Marika Holland, Pasha Karami, Torben Koenigk, Bianca Mezzina, Makayla Ortiz, Daphne Quint, Francesco Ragone, Jerome Sauer, Annelies Sticker, Daniel Topal, Bruno Tremblay, Steve Vavrus, Jinfei Wang, Christopher Wyburn

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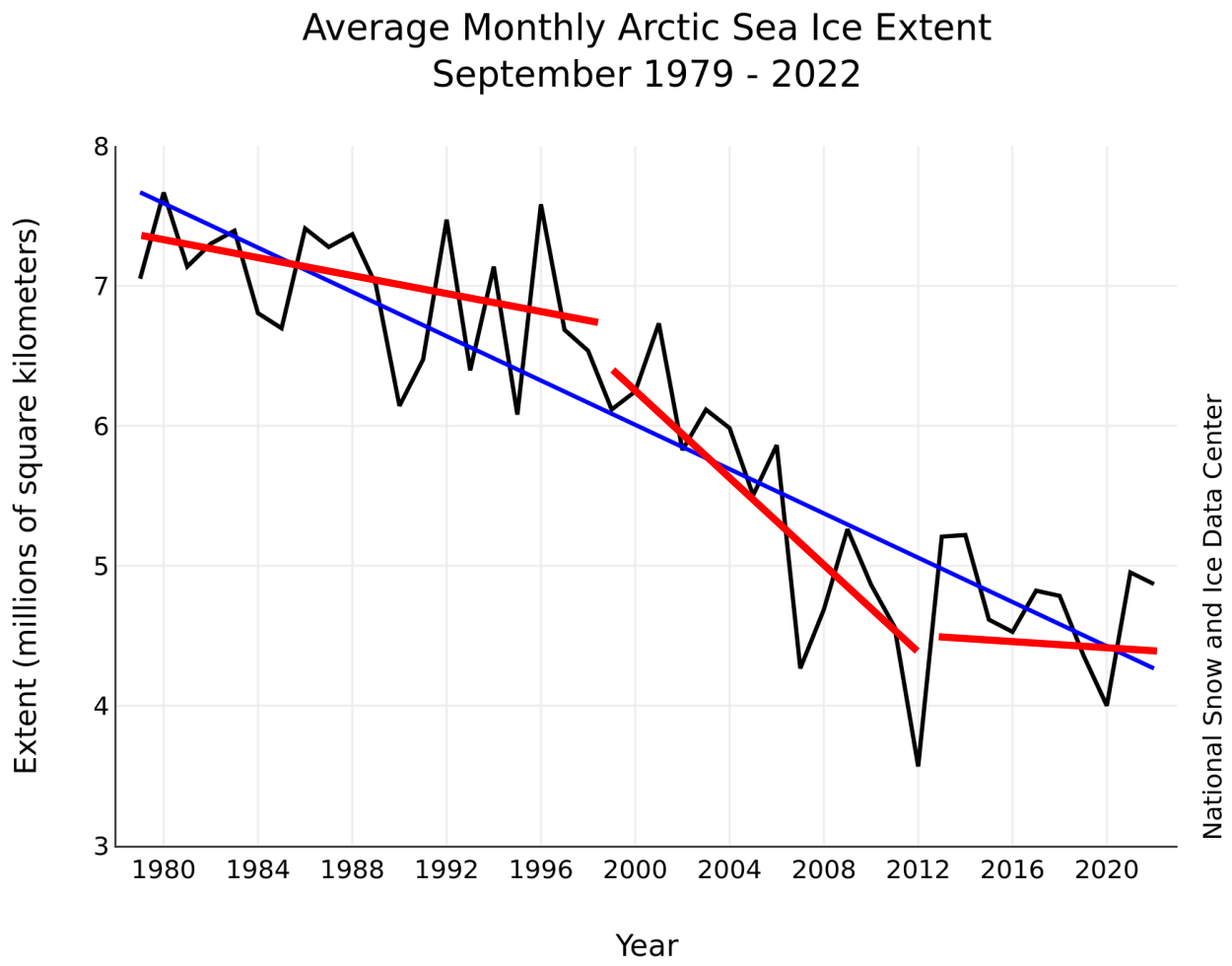
erc European Research Council Established by the European Commission

EARTH & LIFE INSTITUTE

# « Situation room »


Sep 18 2022
1981-2010 Avg Min

# The linear trend: worst model ever?



# Significant fluctuations in 1-10-yr September sea ice extent trends are expected in a warming world

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L15708, doi:10.1029/2011GL048008, 2011

**Inter-annual to multi-decadal Arctic sea ice extent trends in a warming world**

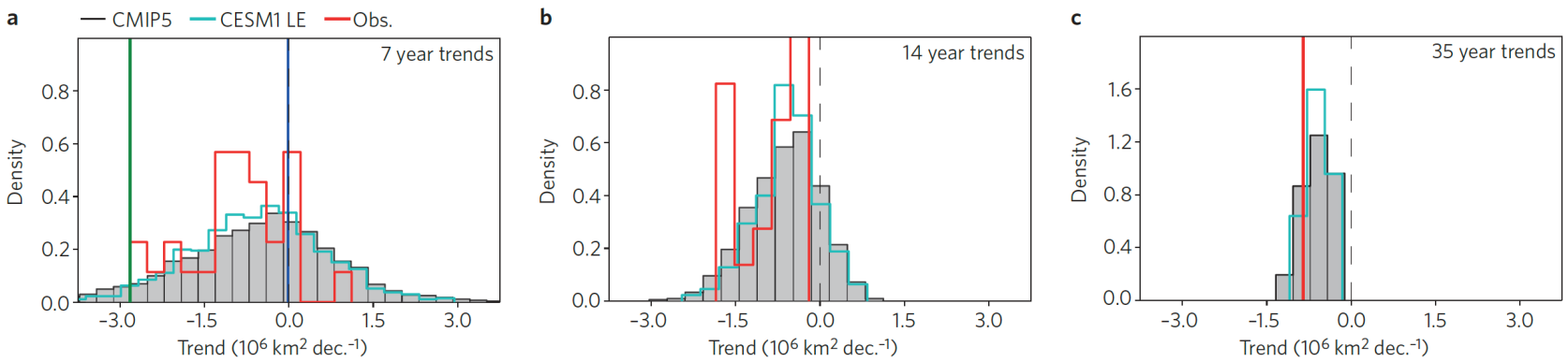
Jennifer E. Kay,[1] Marika M. Holland,[1] and Alexandra Jahn[1]

Received 2 May 2011; revised 1 July 2011; accepted 8 July 2011; published 11 August 2011.

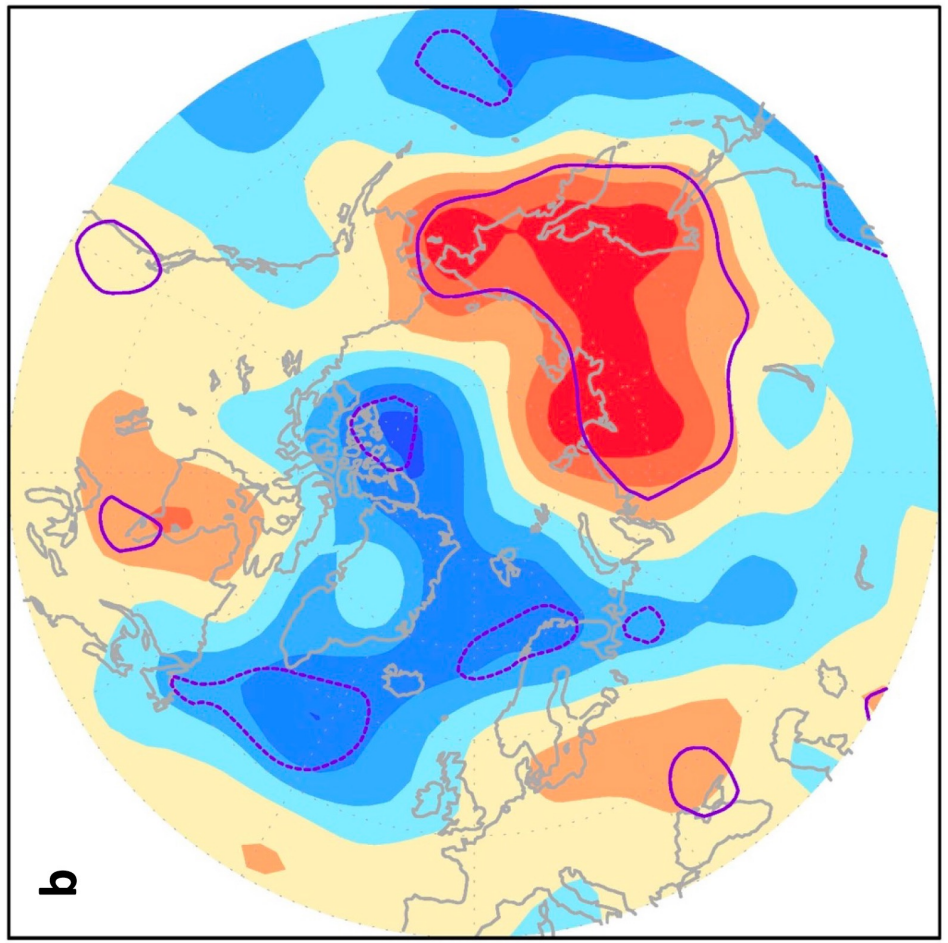
COMMENTARY:

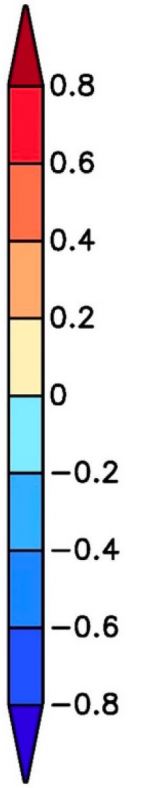
**Influence of internal variability on Arctic sea-ice trends**

Neil C. Swart, John C. Fyfe, Ed Hawkins, Jennifer E. Kay and Alexandra Jahn



# On the flat summer sea ice extent trend since 2012




Environmental Research Letters

**LETTER**

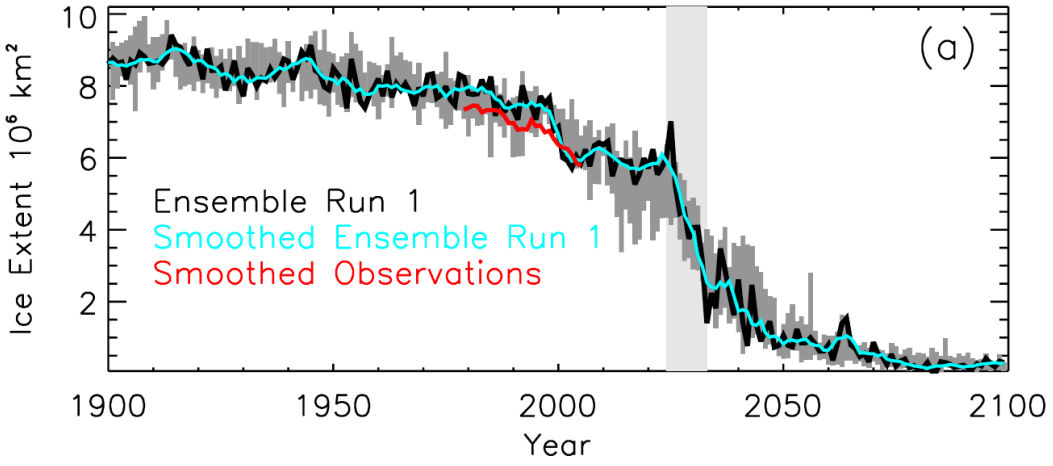
## Why has no new record-minimum Arctic sea-ice extent occurred since September 2012?

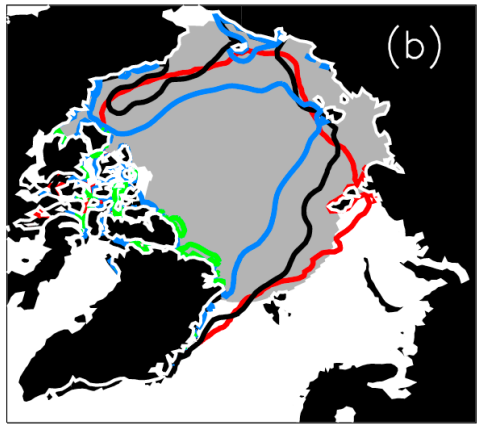
Jennifer A Francis[1] and Bingyi Wu[2]

[1] Woodwell Climate Research Center, Falmouth, MA, United States of America
[2] Department of Atmospheric and Oceanic Sciences, and Institute of Atmospheric Sciences, Fudan University, Shanghai, People's Republic of China

← August 2010-2020 SLP trends (NCEP/NCAR reanalysis)

# Evidence for rapid sea ice loss events in climate model simulations



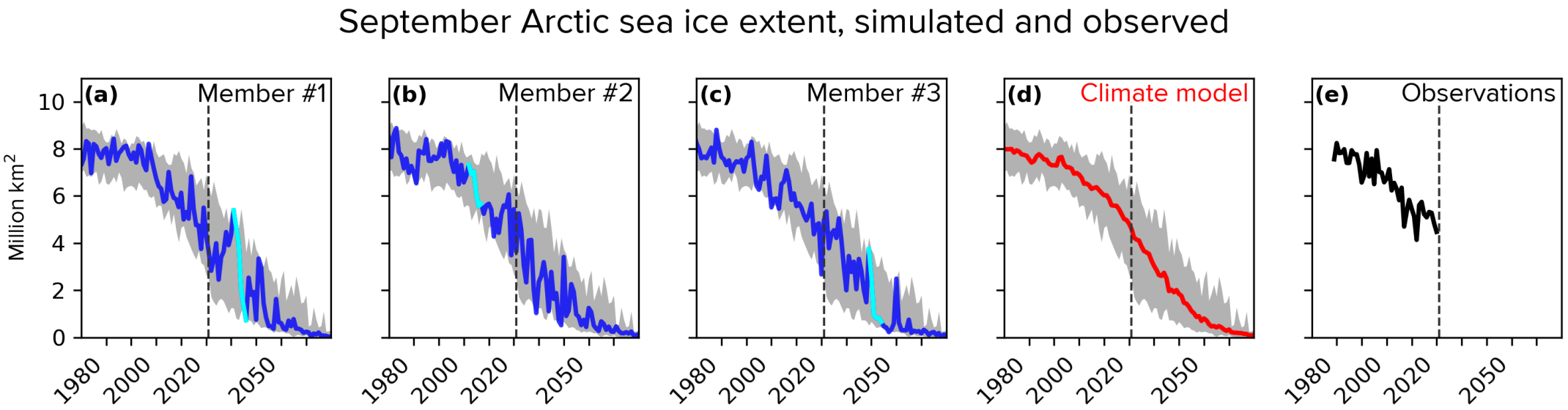

GEOPHYSICAL RESEARCH LETTERS, VOL. 33, L23503, doi:10.1029/2006GL028024, 2006

Click Here for Full Article

**Future abrupt reductions in the summer Arctic sea ice**

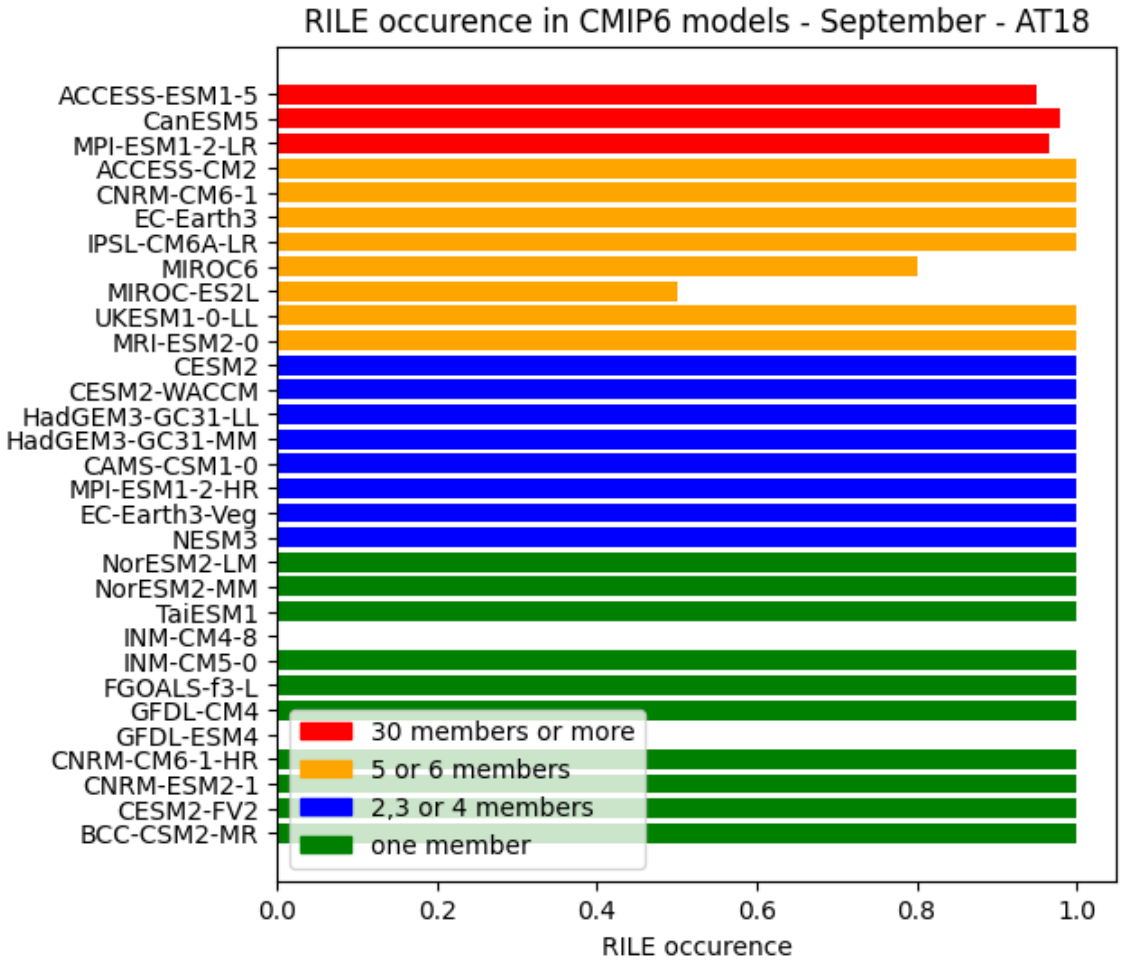
Marika M. Holland,[1] Cecilia M. Bitz,[2] and Bruno Tremblay[3,4]

# Evidence for rapid sea ice loss events in climate model simulations



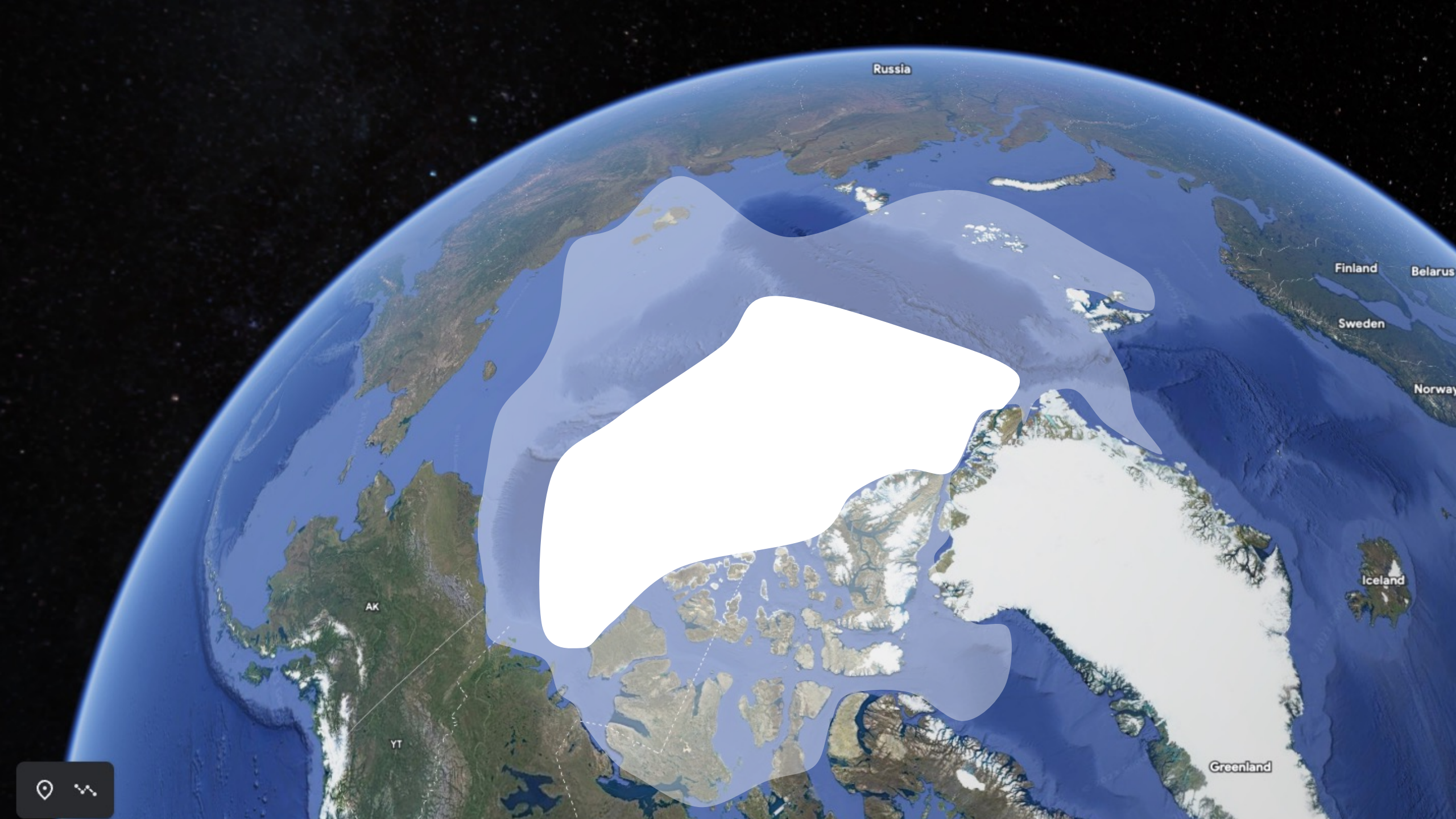

Data: CESM1-LE

# RILEs are ubiquitous in CMIP6 models




Courtesy Annelies Sticker

A RILE is identified when the derivative of the 5-yr running mean September sea ice extent is < -0.3 million km2/yr for at least 4 years (Auclair & Tremblay 2018 definition)


Russia
Finland
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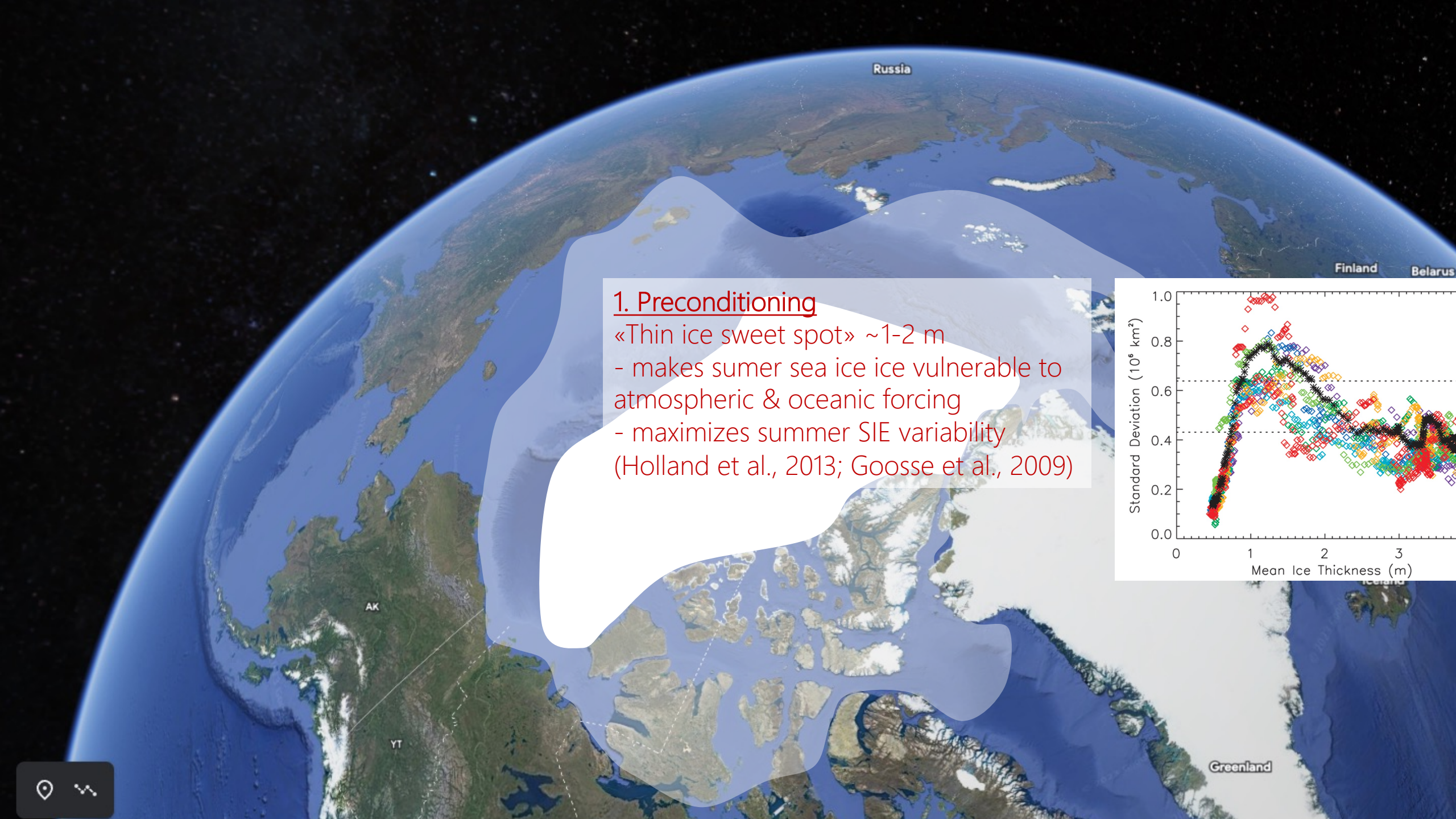
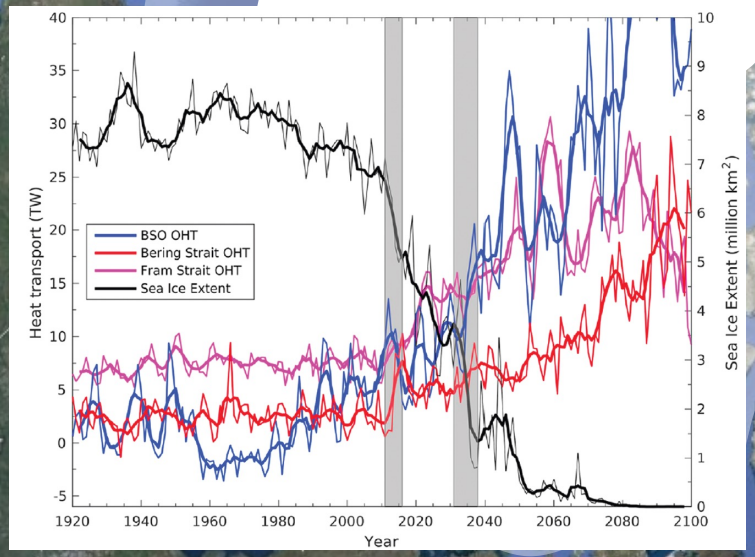


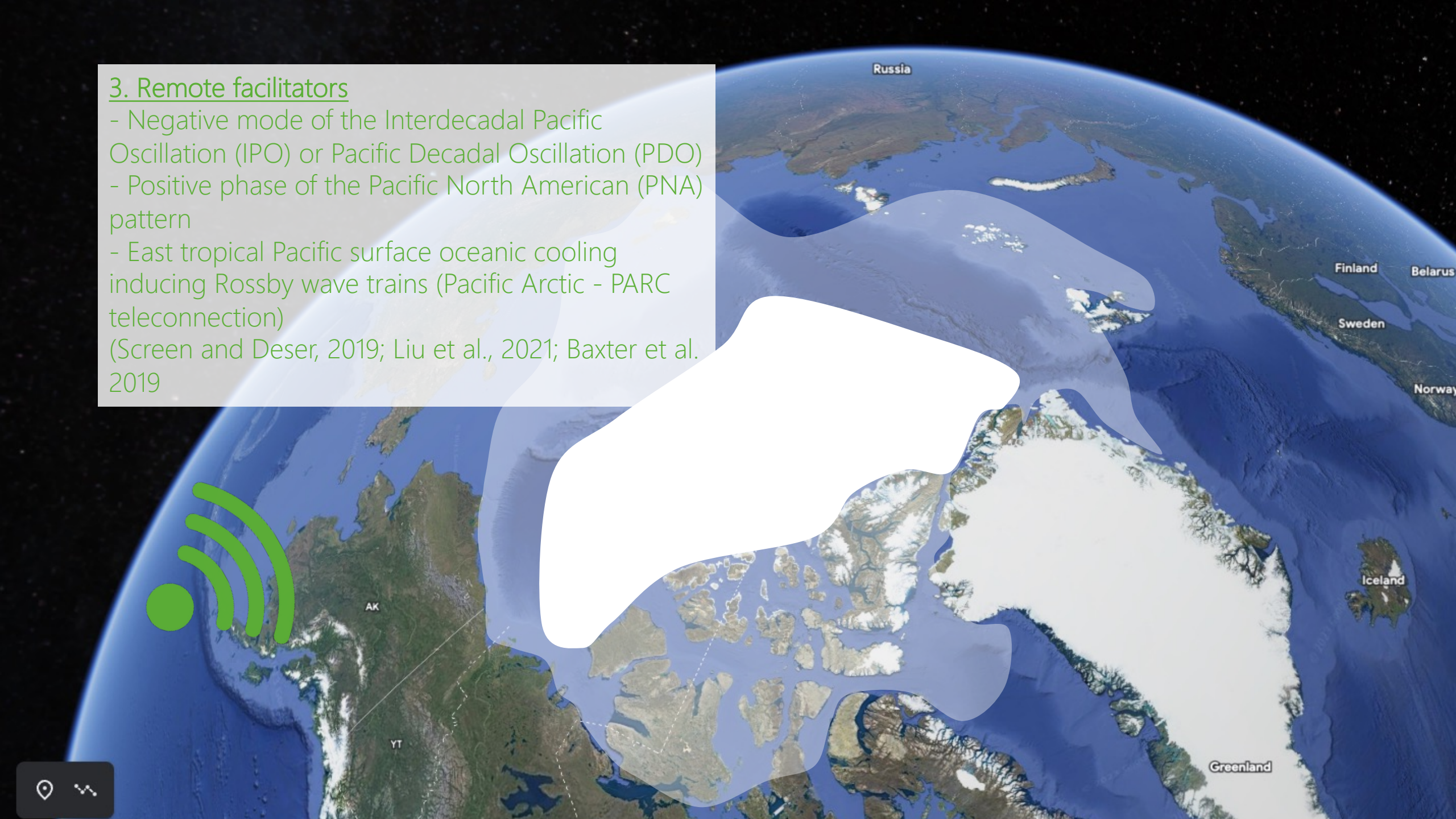

## 1. Preconditioning

«Thin ice sweet spot» ~1-2 m
- makes sumer sea ice ice vulnerable to atmospheric & oceanic forcing
- maximizes summer SIE variability
(Holland et al., 2013; Goosse et al., 2009)

## 2. Triggers

- mainly through Barents Sea and Bering Strait Openings
- pulses rather than gradual build-up
- effective to generate RILEs when sea ice covers shallow shelves (Auclair and Tremblay 2018; Holland et al., 2006)





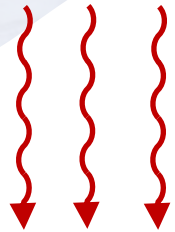

## 3. Remote facilitators

- Negative mode of the Interdecadal Pacific Oscillation (IPO) or Pacific Decadal Oscillation (PDO)
- Positive phase of the Pacific North American (PNA) pattern
- East tropical Pacific surface oceanic cooling inducing Rossby wave trains (Pacific Arctic - PARC teleconnection)

(Screen and Deser, 2019; Liu et al., 2021; Baxter et al. 2019

## 4. Radiative forcing

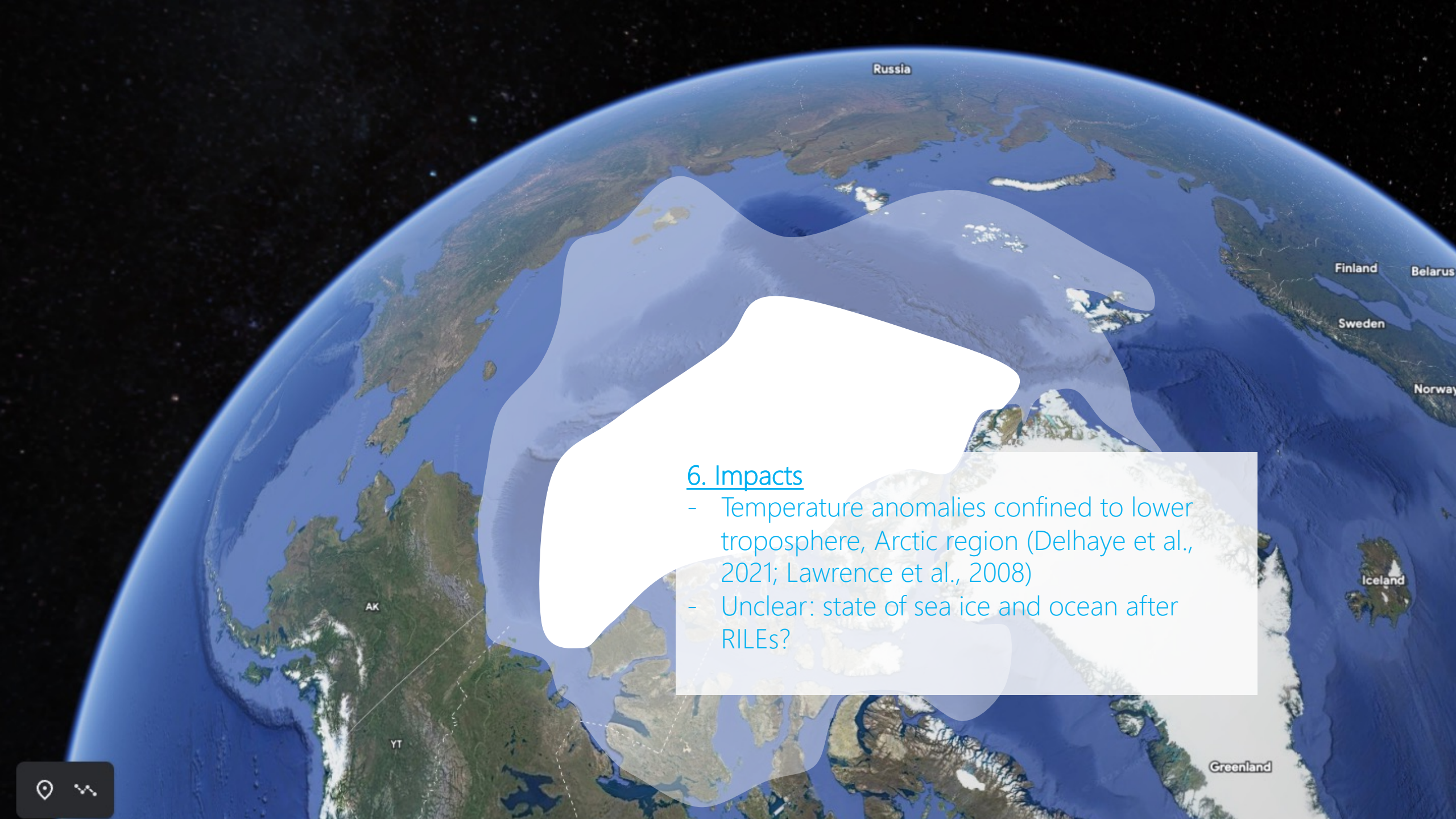
- Large background trend increases the probability of SIE loss exceeding a given threshold
- Aerosols and other short-lived climate forcers? (DeRepentigny et al., 2021)
- Clouds: drivers or responses to sea ice loss? (Vavrus et al., 2011)




## 5. Self—ampifying processes

- Ice-albedo feedback
- Open water formation efficiency
- Winter-to-summer reemergence
- Clouds ?

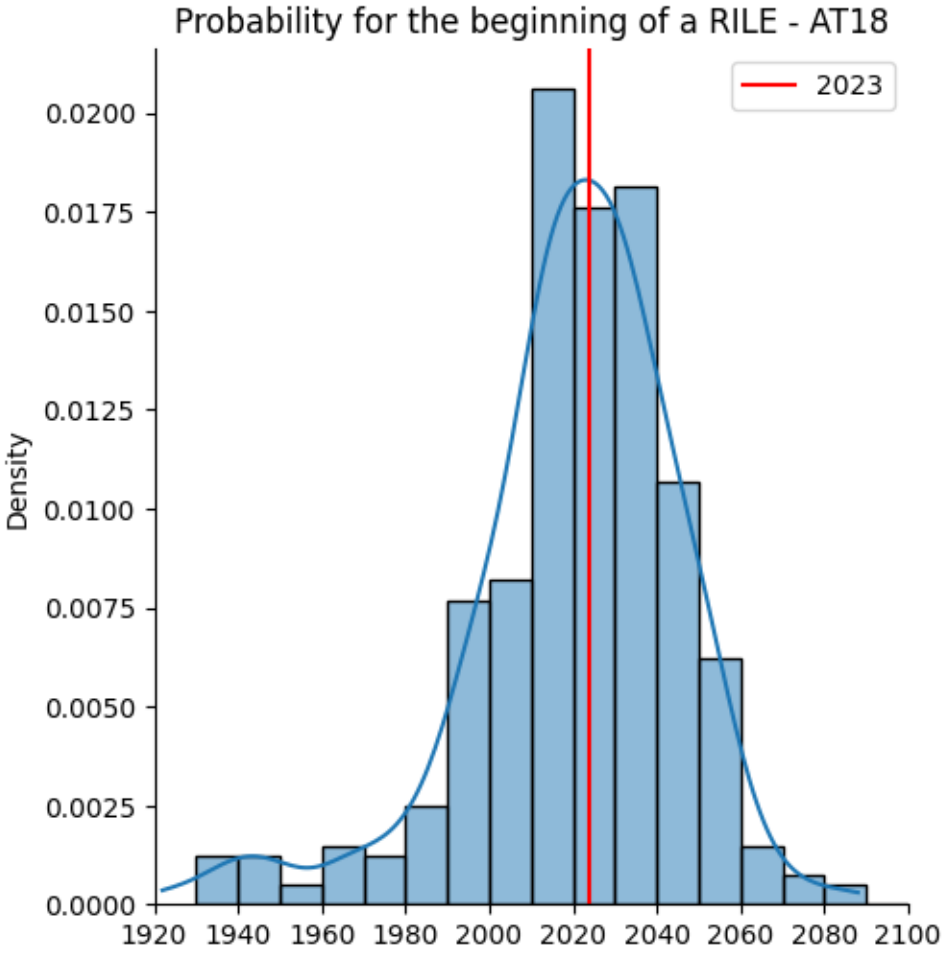
(Holland et al., 2006; Massonnet et al., 2018; Blanchard-Wrigglesworth et al., 2011)

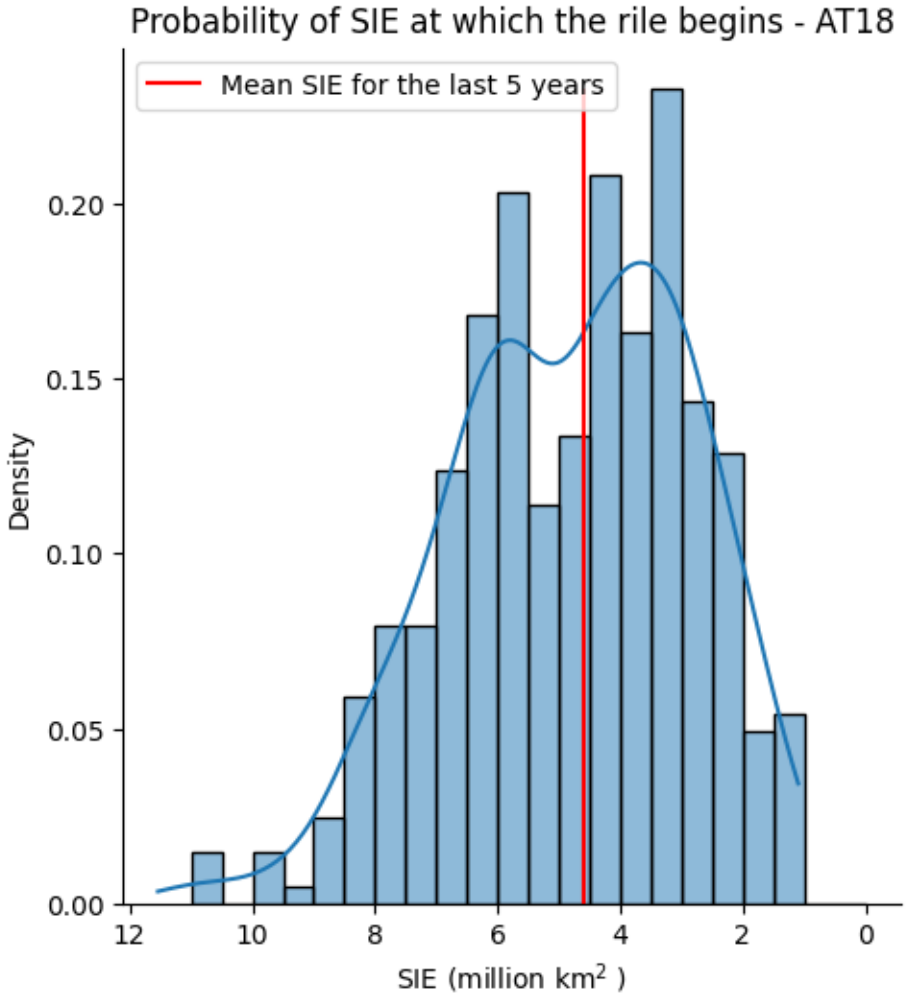



## 6. Impacts

- Temperature anomalies confined to lower troposphere, Arctic region (Delhaye et al., 2021; Lawrence et al., 2008)
- Unclear: state of sea ice and ocean after RILEs?

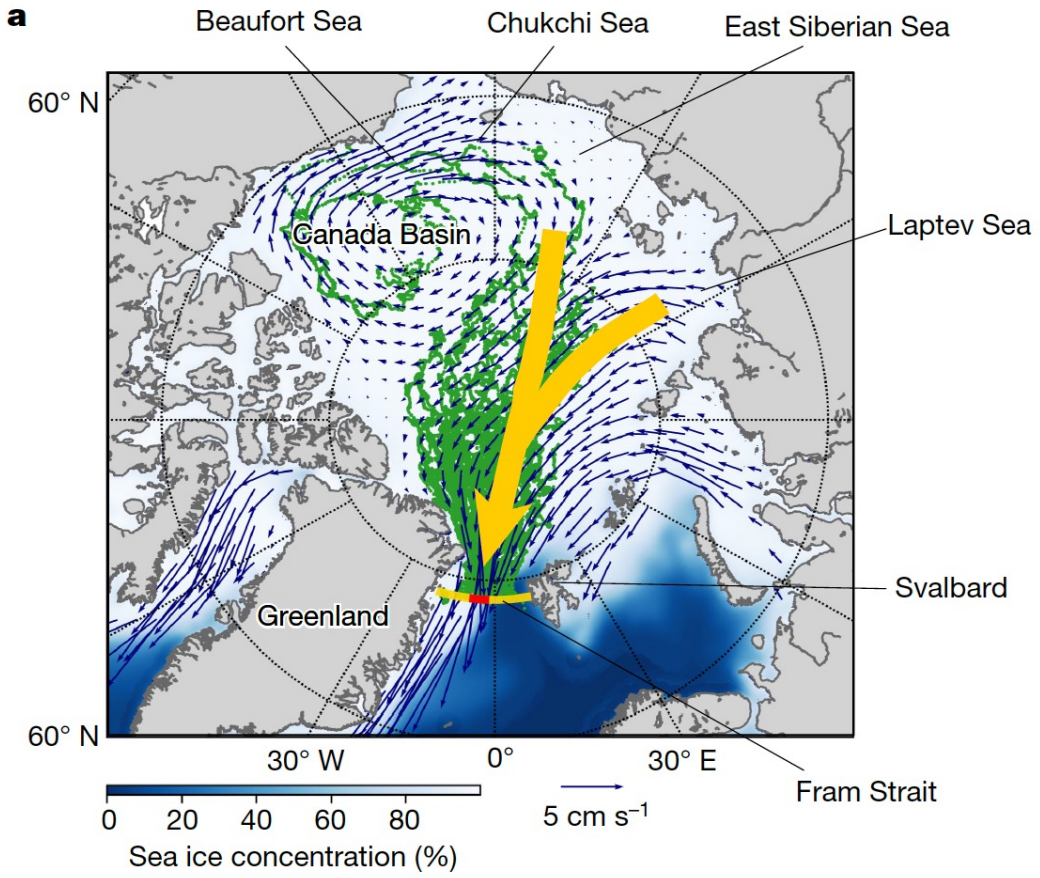
# RILEs are most likely to occur at the current observed state

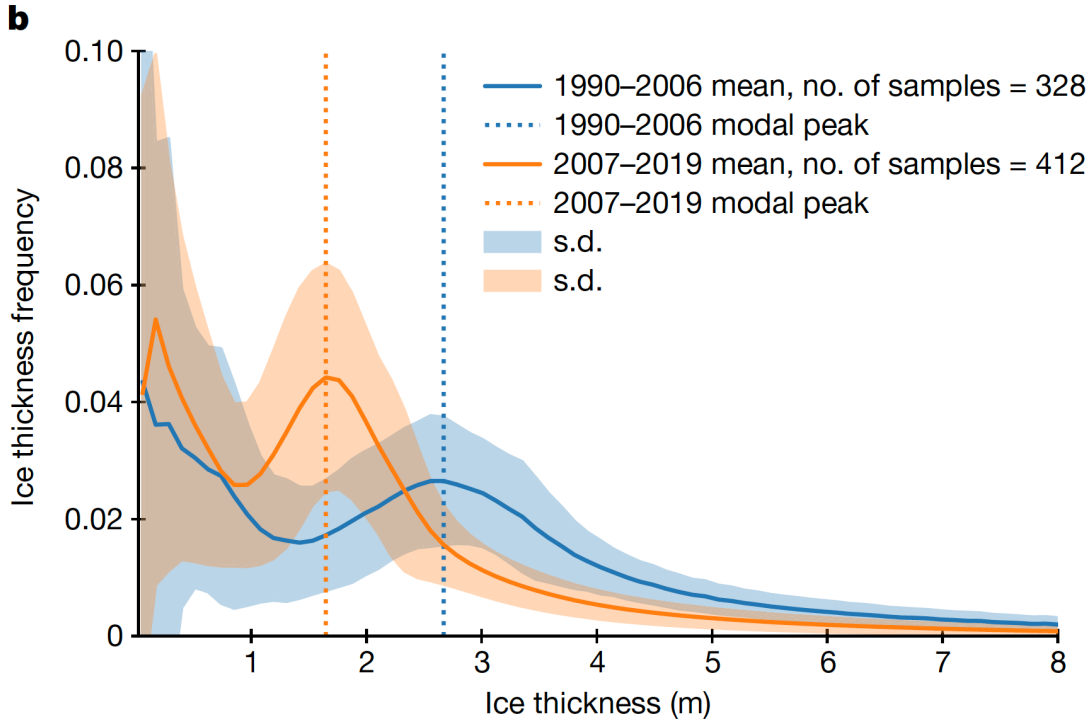



Courtesy Annelies Sticker

# A regime shift in Arctic sea ice thickness since 2007

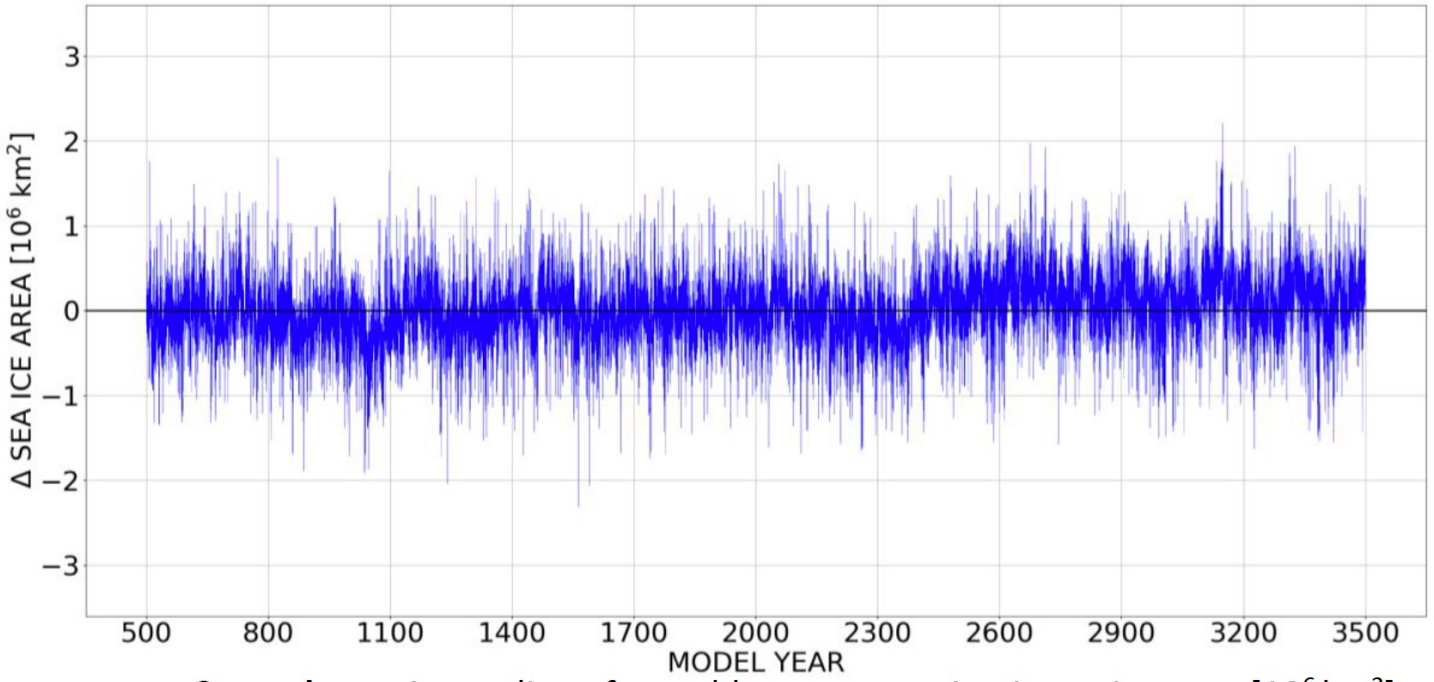



Sumata, H., de Steur, L., Divine, D. V., Granskog, M. A., & Gerland, S. (2023). Regime shift in Arctic Ocean sea ice thickness. *Nature*, *615*(7952), Article 7952. https://doi.org/10.1038/s41586-022-05686-x

# The rare event algorithm: designed to dynamically sample a model's extreme state

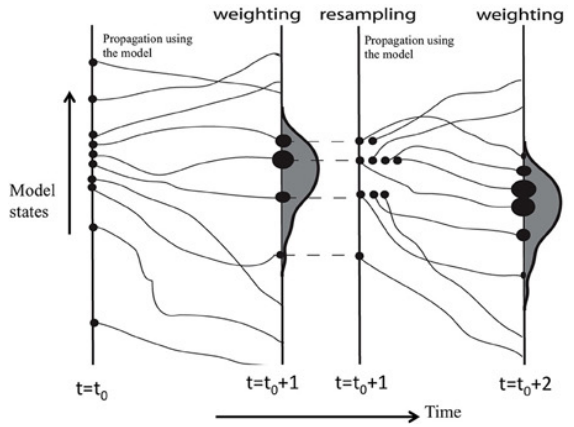
PLASIM climate model (T21)



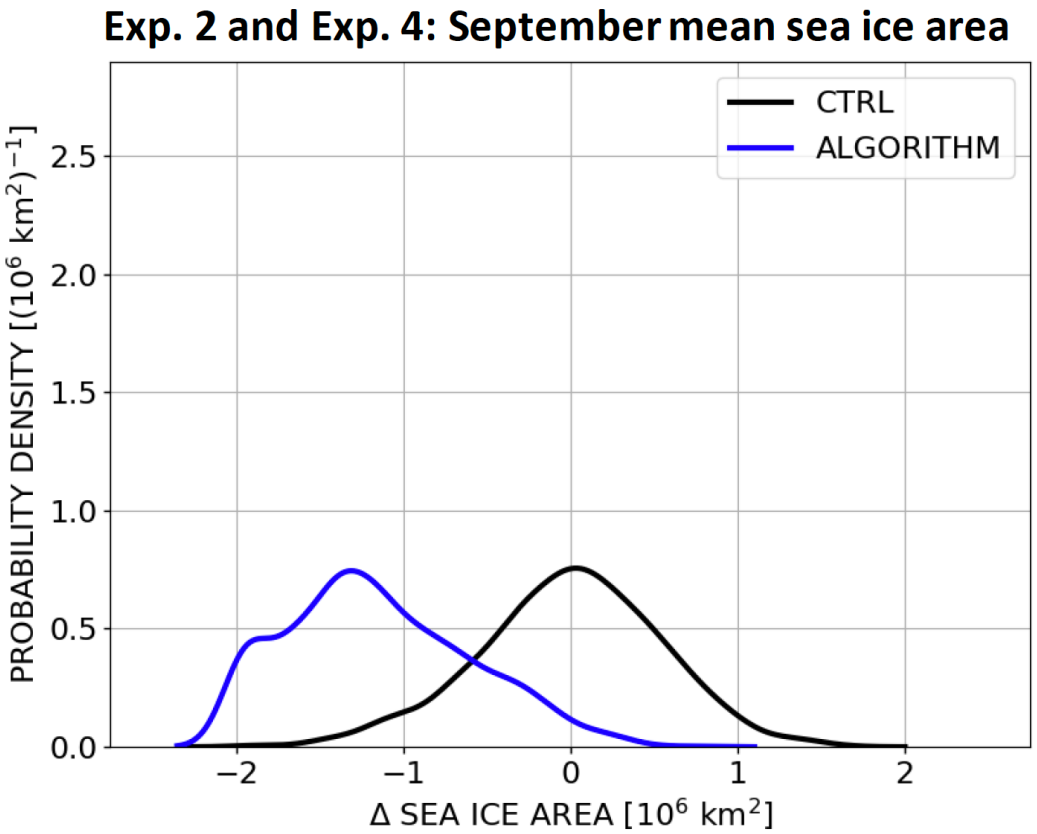

**Control run:** Anomalies of monthly mean pan-Arctic sea ice area [$10^6$ km$^2$]

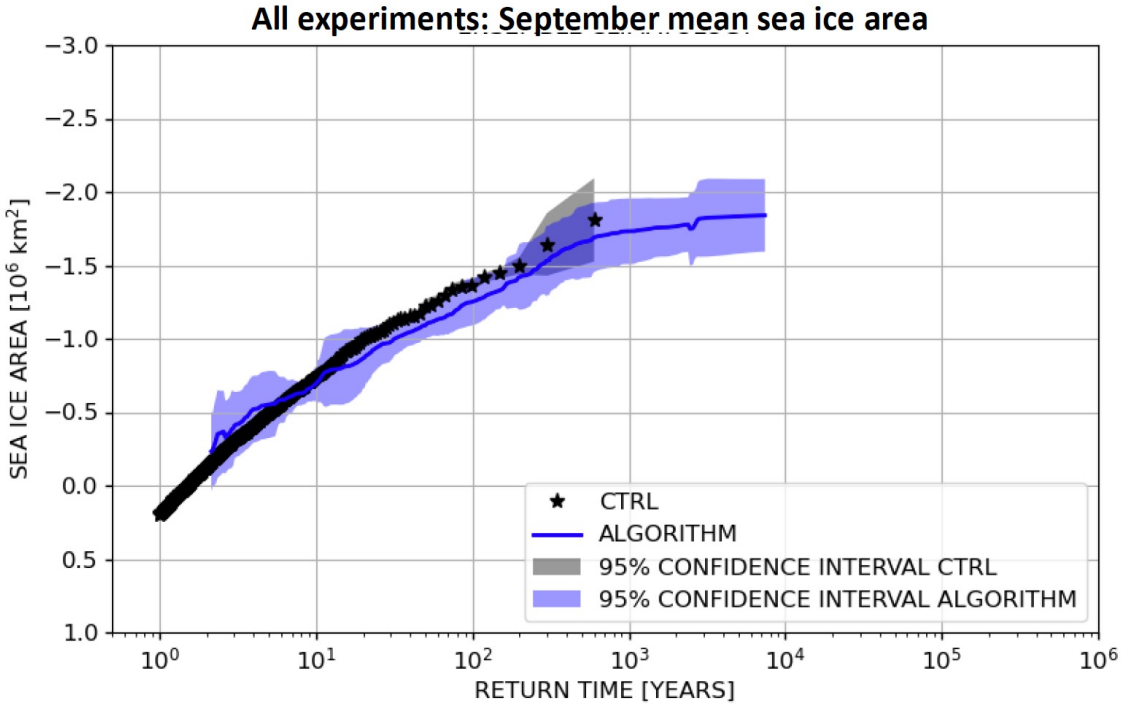
| Exp. | Model years for initial conditions | k [$10^{-6}$ km$^{-2}$ day$^{-1}$] |
|---|---|---|
| 1 | 501,506,…,3496 | -0.06 |
| 2 | 502,507,…,3497 | -0.05 |
| 3 | 503,508,…,3498 | -0.04 |
| 4 | 504,509,…,3499 | -0.05 |
| 5 | 505,510,…,3500 | -0.04 |

**N = 600 ensemble members, $\tau_R$ = 30 days, Simulation period: February-September**

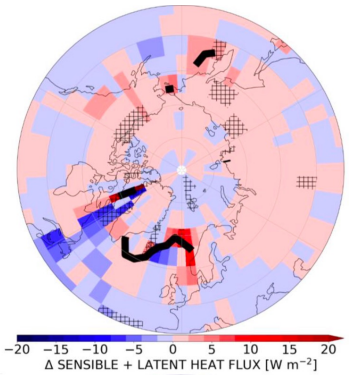


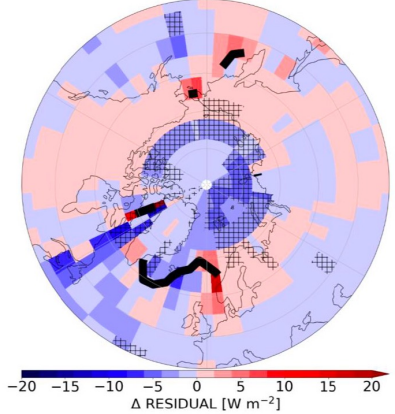
# Robust estimation of extreme Arctic sea ice extent states

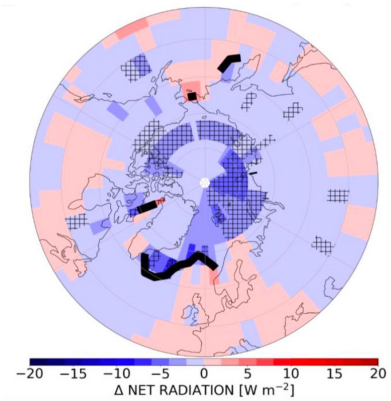


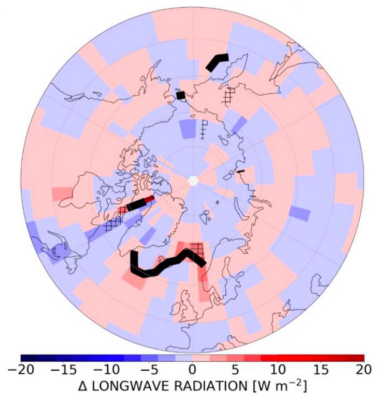



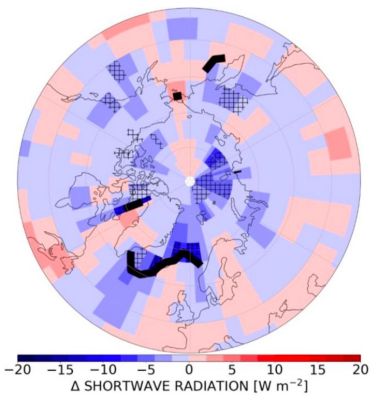
# Fluxes positive upwards

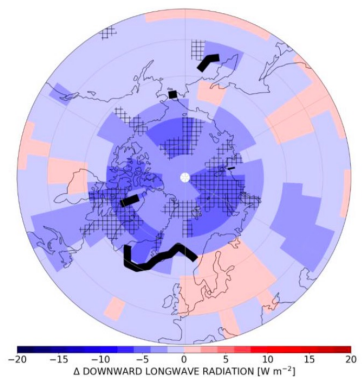


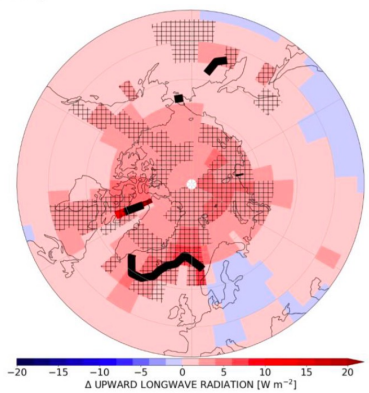



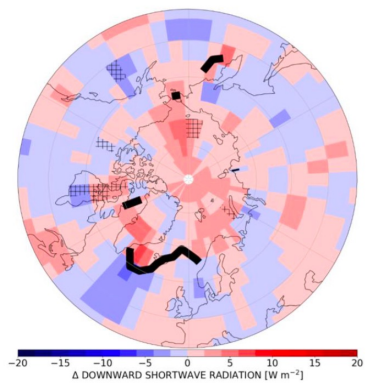



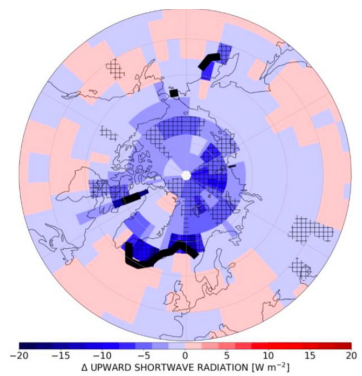



## Understanding

1 Characteristics of rapid sea ice loss events

2 Precursors, predictability and drivers

3 Process-based climate model predictions

4 Data-driven predictions

5 Impacts of rapid ice loss events

Climate model projections & predictions

Satellite & in-situ observations

Atmospheric & ocean-sea ice reanalyses

**Input datasets**

European Research Council
Established by the European Commission

Arctic WATCH

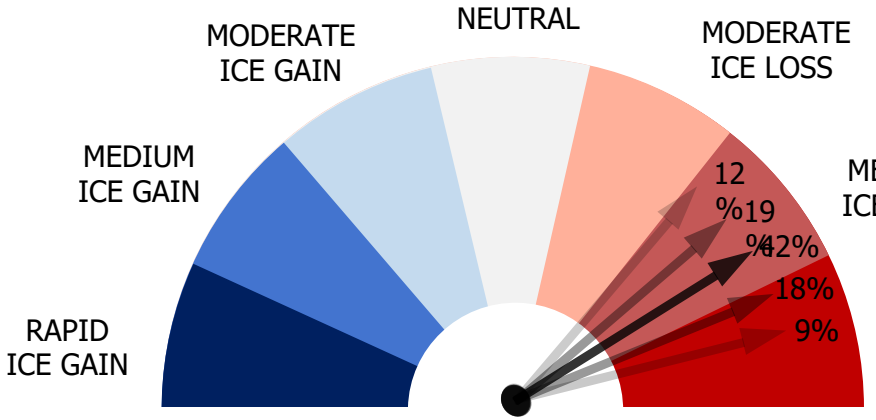
PhD PhD

PostDoc PostDoc

## Prediction

*In 2025*

Early-warning system of future rapid Arctic sea ice loss




Predicted Arctic sea ice change 2025-2030

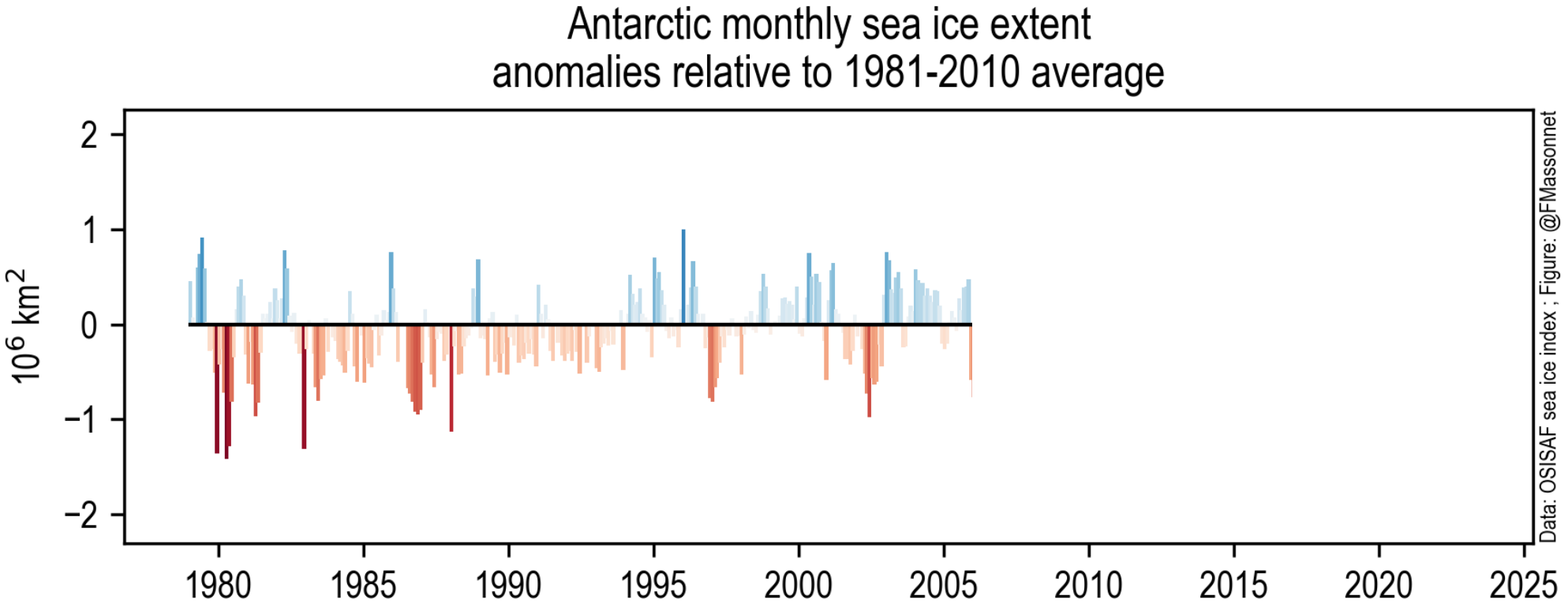
« What happens in the Arctic, does not stay in the Arctic »

# Rapid Arctic sea ice loss in the coming decade: a distinct possibility

- Current average sea ice thickness maximizes the summer extent variability
- As of now, September sea ice extent is large enough to allow significant future reductions
- There is ample evidence of abrupt reductions in sea ice in ESMs (1 / member at least) and none has occurred yet in observations
- Current understanding of precursors, drivers, and impacts of RILEs is superficial
- More insights on output from interannual prediction systems is needed
- For the record: Based on literature review and current state of the Arctic, and future emissions, I give a 70% chance that at least one RILE will have been initiated by 2030 (included).

# « Situation room »

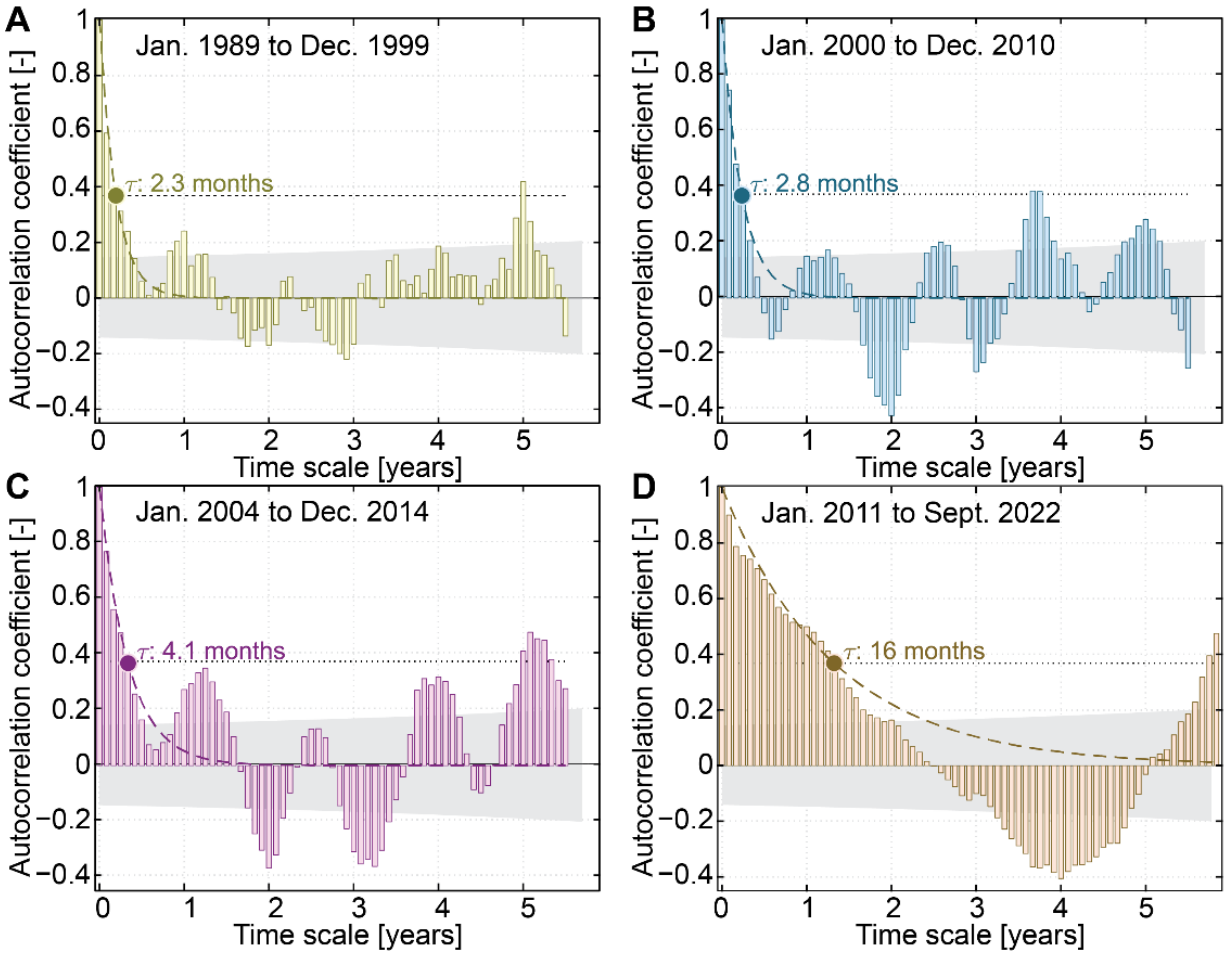
# Antarctic sea ice, are you trying to tell us something?




Data: OSI-SAF

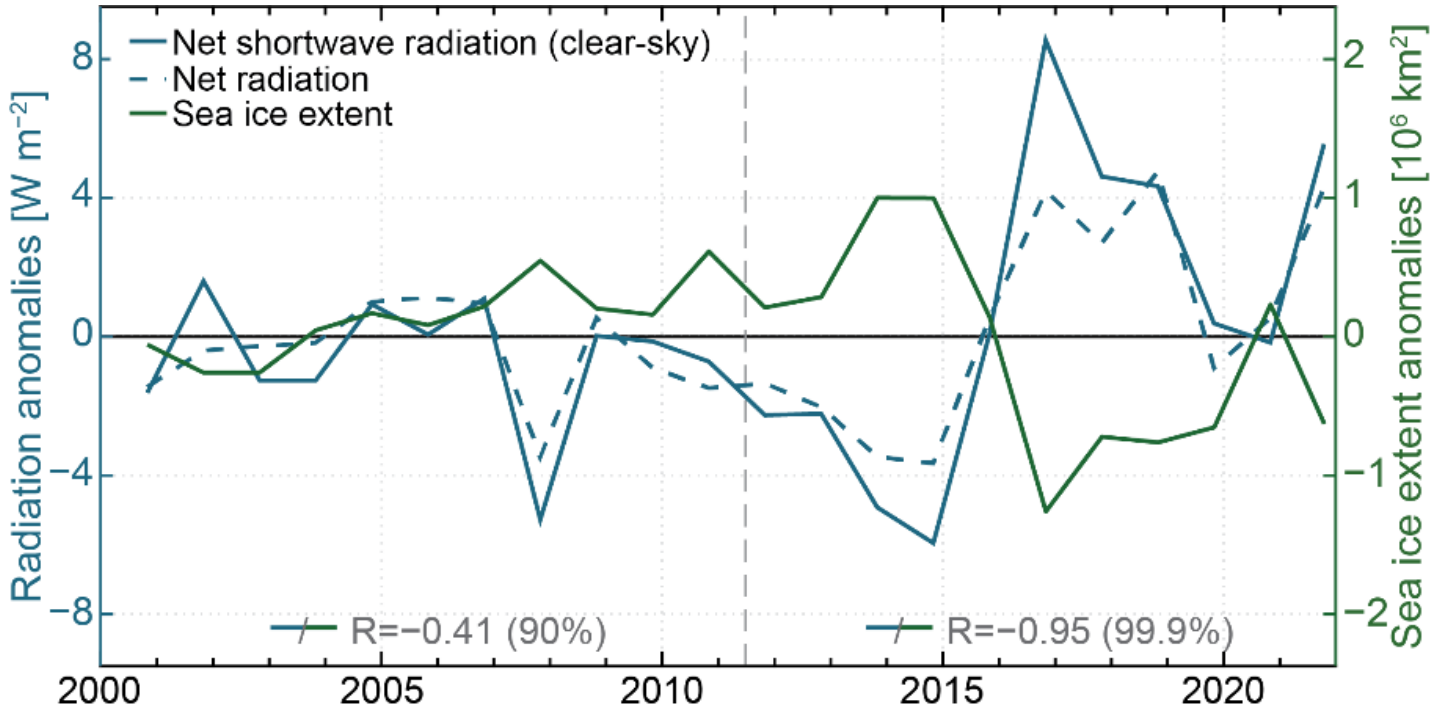
# A sudden change in Antarctic sea ice persistence since early 2010

Autocorrelation of observed monthly sea ice extent anomalies




Haumann et al., in prep.

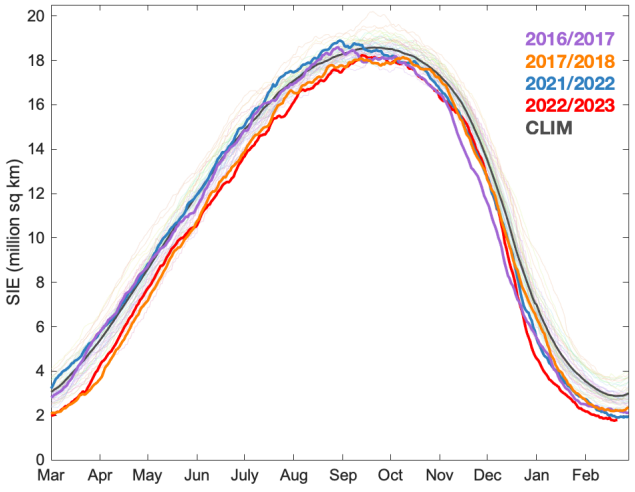
# Important role of the ice-albedo feedback…



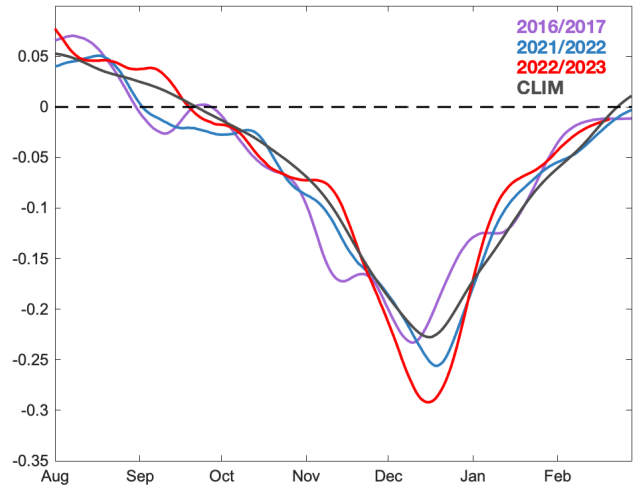

Haumann et al., in prep.

# … and preconditioning?

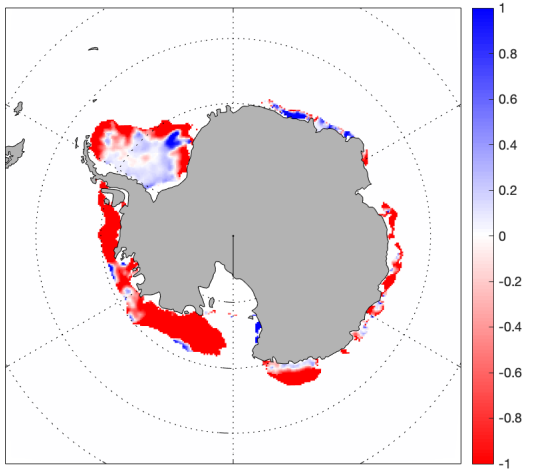
Sea ice extent




Melt rates

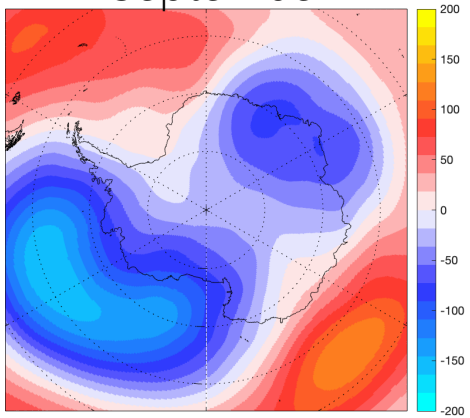



Observed February 2023 sea ice concentration anomalies

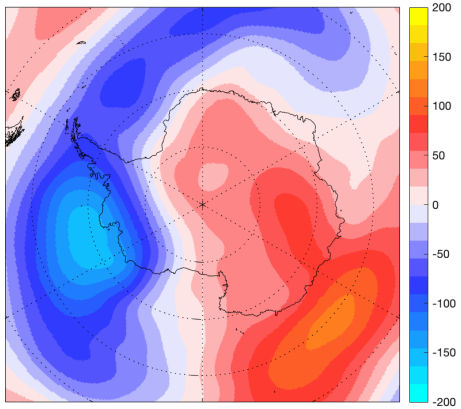


Z500 anomalies

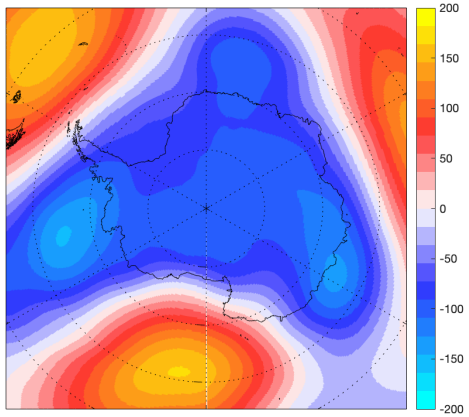
September



October

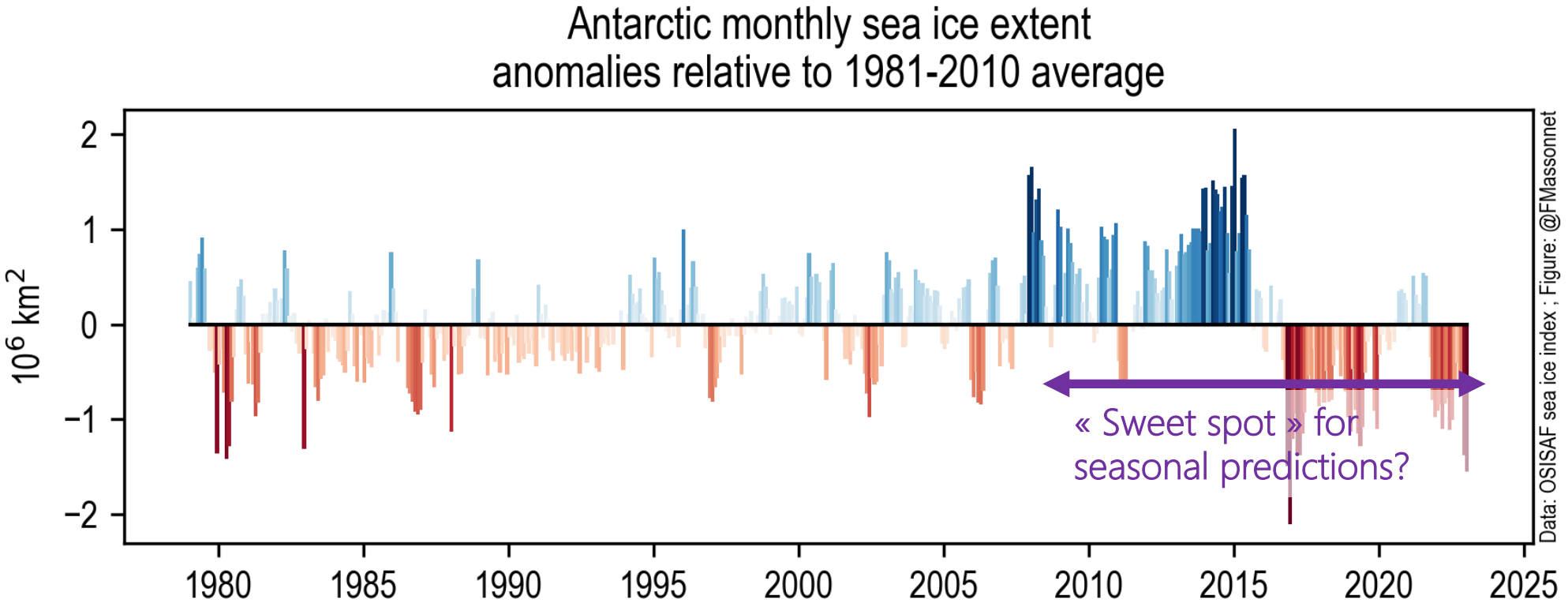


November



*Jinfei Wang*

# Antarctic sea ice, are you trying to tell us something?

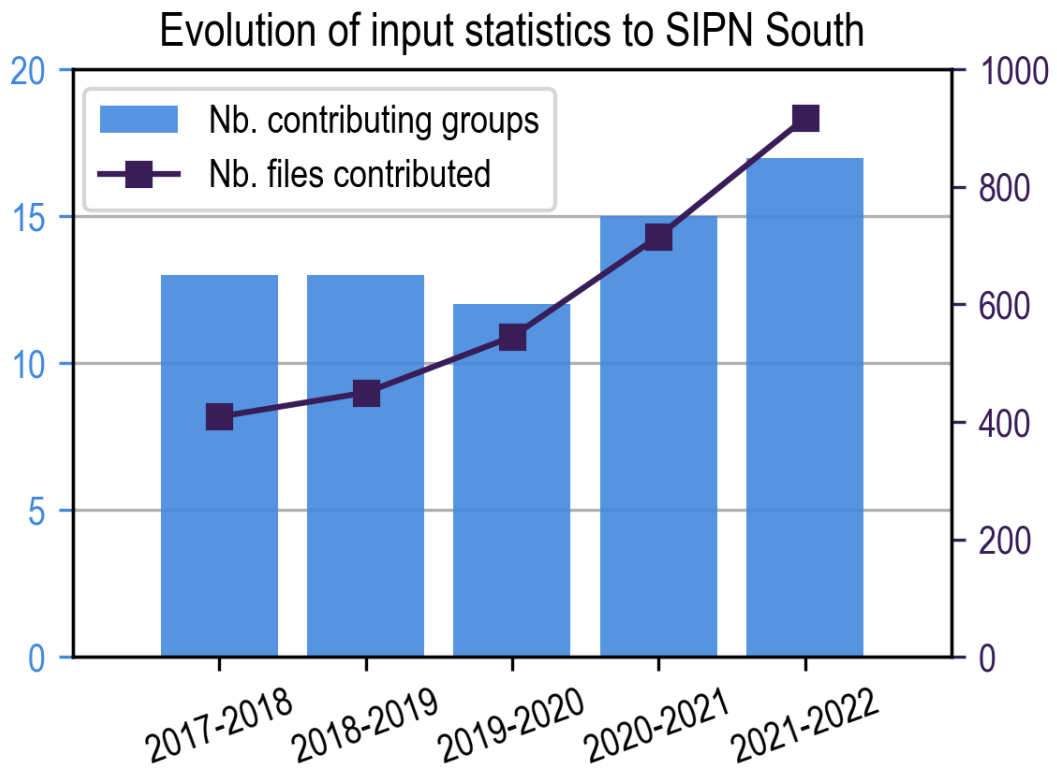



Data: OSI-SAF

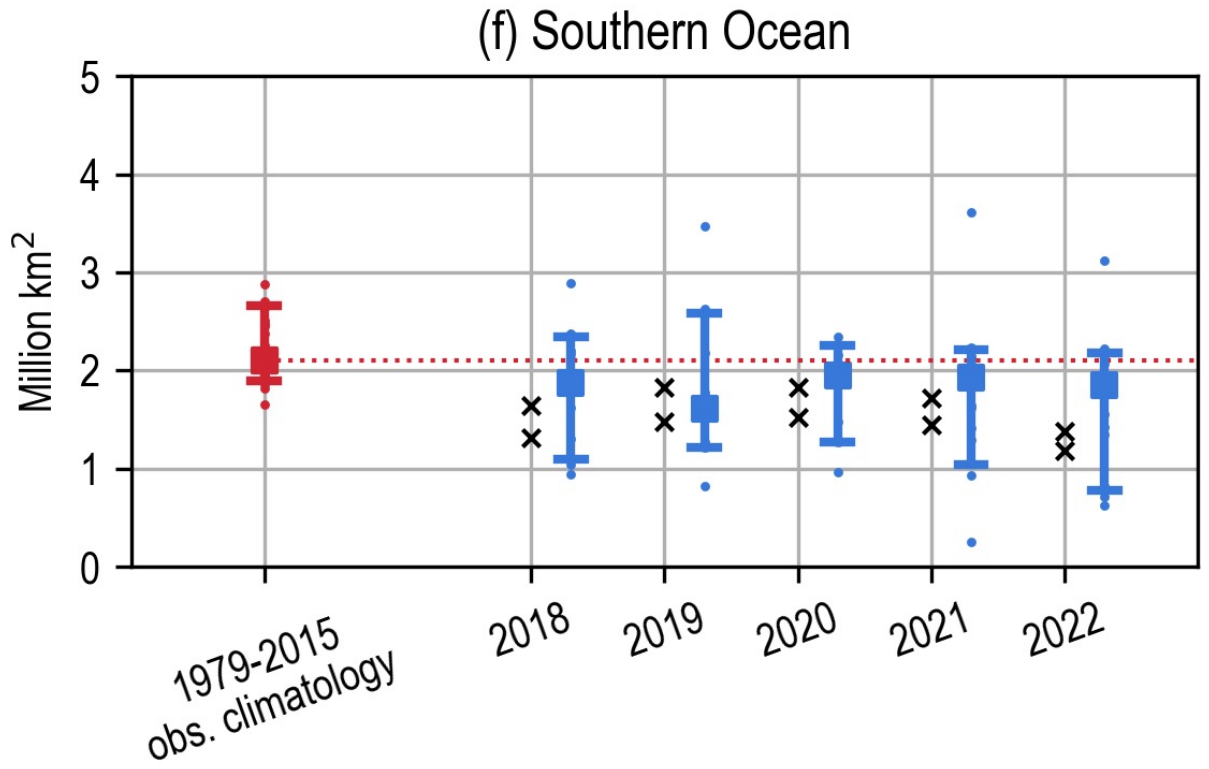
# SIPN South: The rules of the game

- Initialize before < 1 Dec
- Submit at least total sea ice area
- Provide daily temporal output

November December January February March

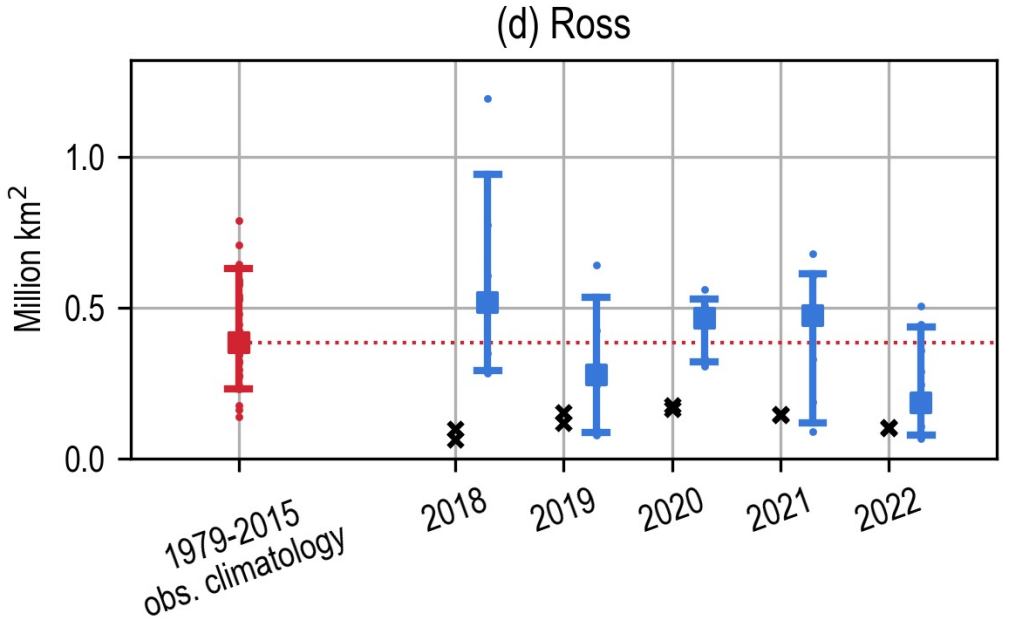

Evolution of input statistics to SIPN South
Nb. contributing groups
Nb. files contributed
20
15
10
5
0
1000
800
600
400
200
0
2017-2018
2018-2019
2019-2020
2020-2021
2021-2022

# The SIPN South ensemble captures reasonably the recent negative anomalies



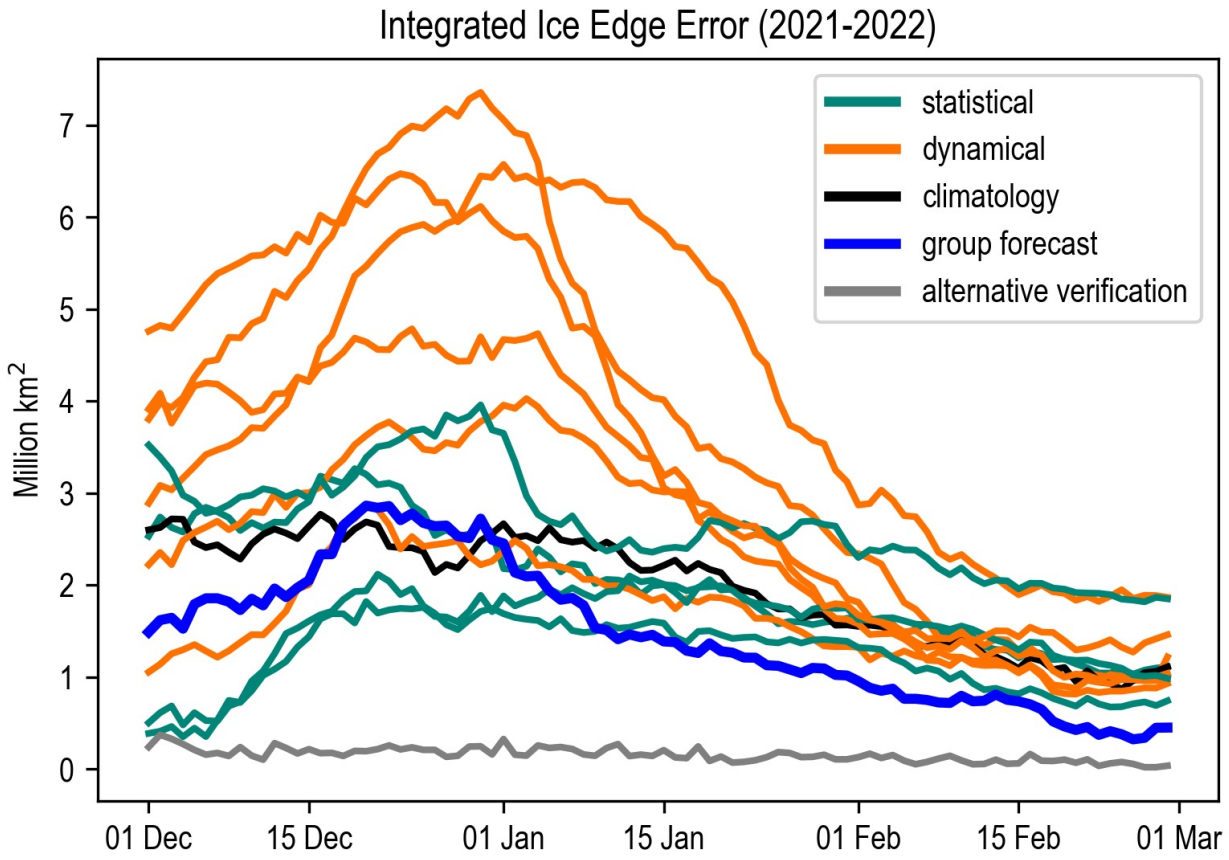

Massonnet et al., 2023: SIPN South: five years of coordinated seasonal sea ice prediction in the Southern Ocean, in revision

# The Ross Sea is the most challenging region to forecast

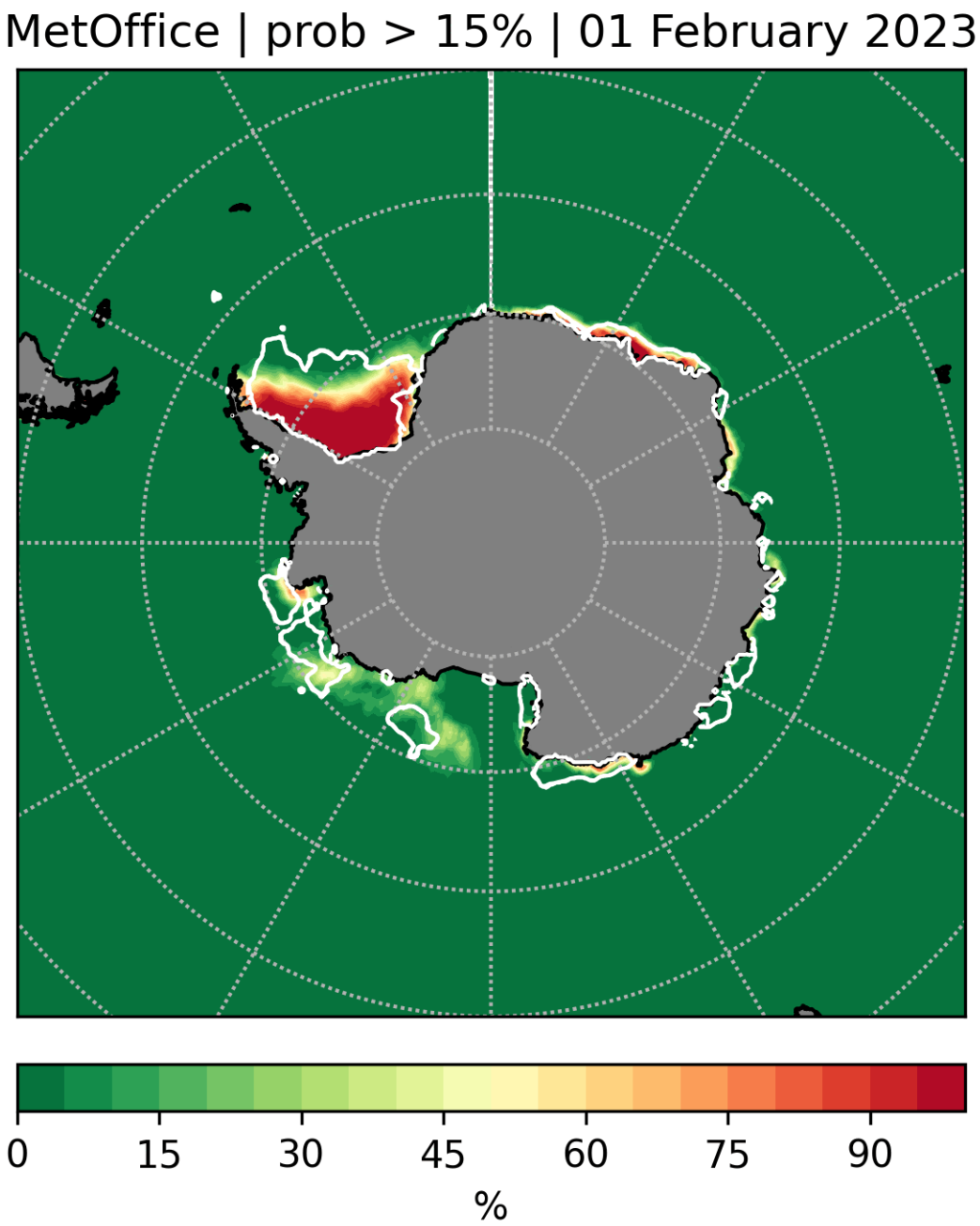



Massonnet et al., 2023: SIPN South: five years of coordinated seasonal sea ice prediction in the Southern Ocean, in revision

# The group forecast, a safe bet



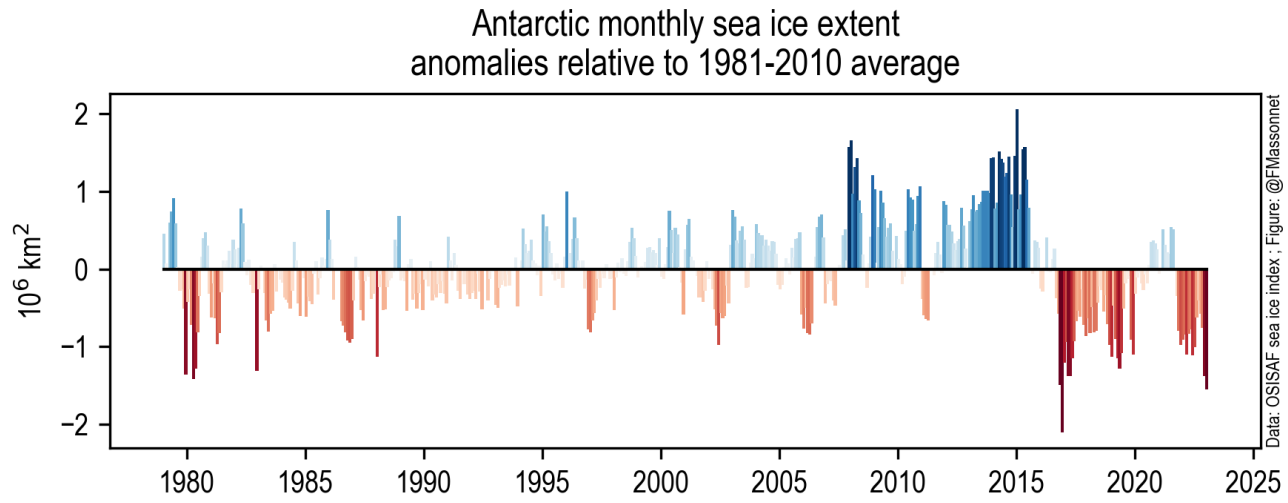

Massonnet et al., 2023: SIPN South: five years of coordinated seasonal sea ice prediction in the Southern Ocean, in revision




Probability of sea ice presence in the MetOffice seasonal prediction

# Rapid Antarctic sea ice loss in the next years: a distinct possibility?

- Apparent changes in the properties in sea ice extent time series are suggestive of possible shifts in the background state
- Identical atmospheric patterns seem to lead to different summer sea ice responses before and after 2015
- I would not dare to make any prediction at all ☺



# Thank you

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