# **Arctic Climate and Weather Extremes**: Polynya Events in the Last Ice Area (Wandel Sea)

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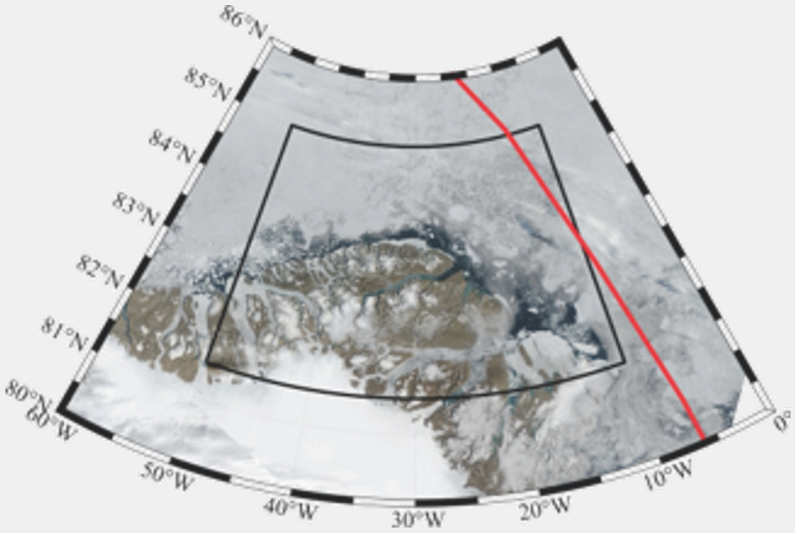
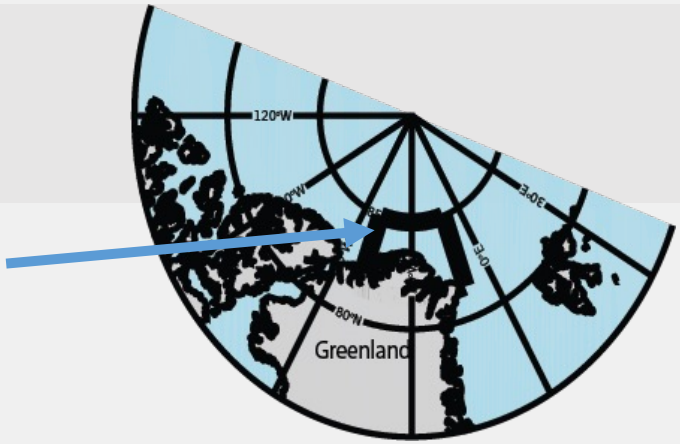
Last Ice Area (WWF)



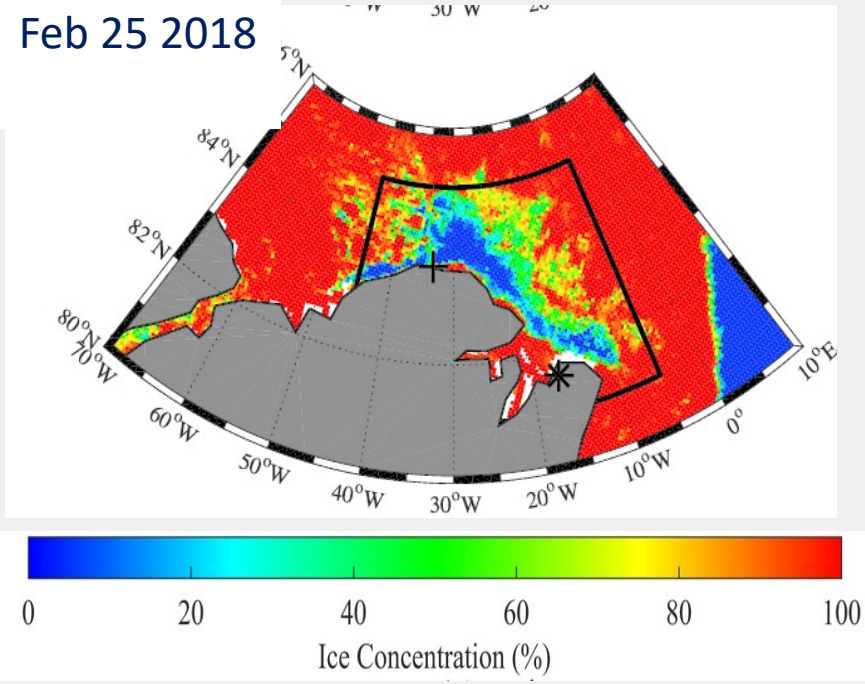

Wandel Sea

# Two Polynyas: Feb 2018, Aug 2020

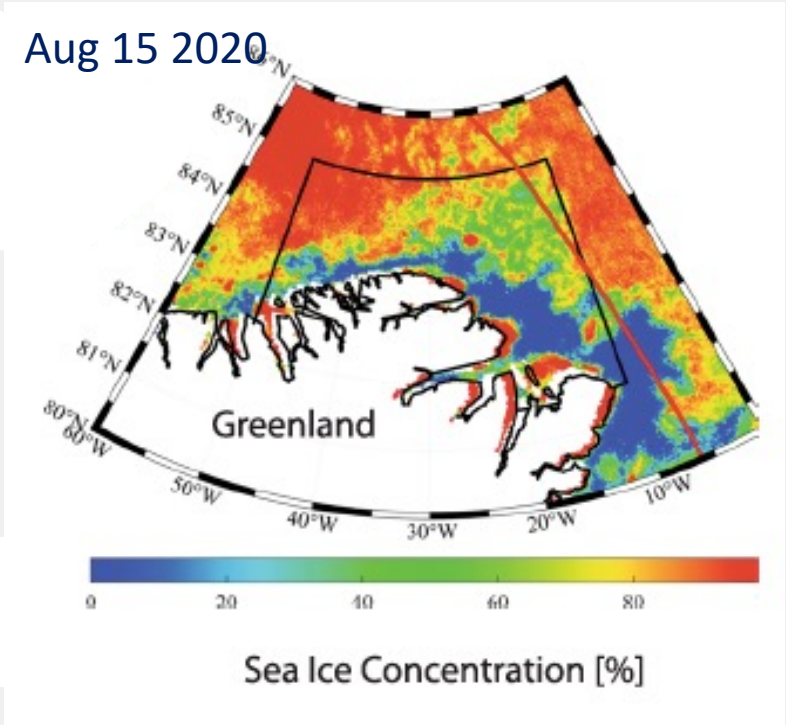



Wandel Sea

Feb 25 2018

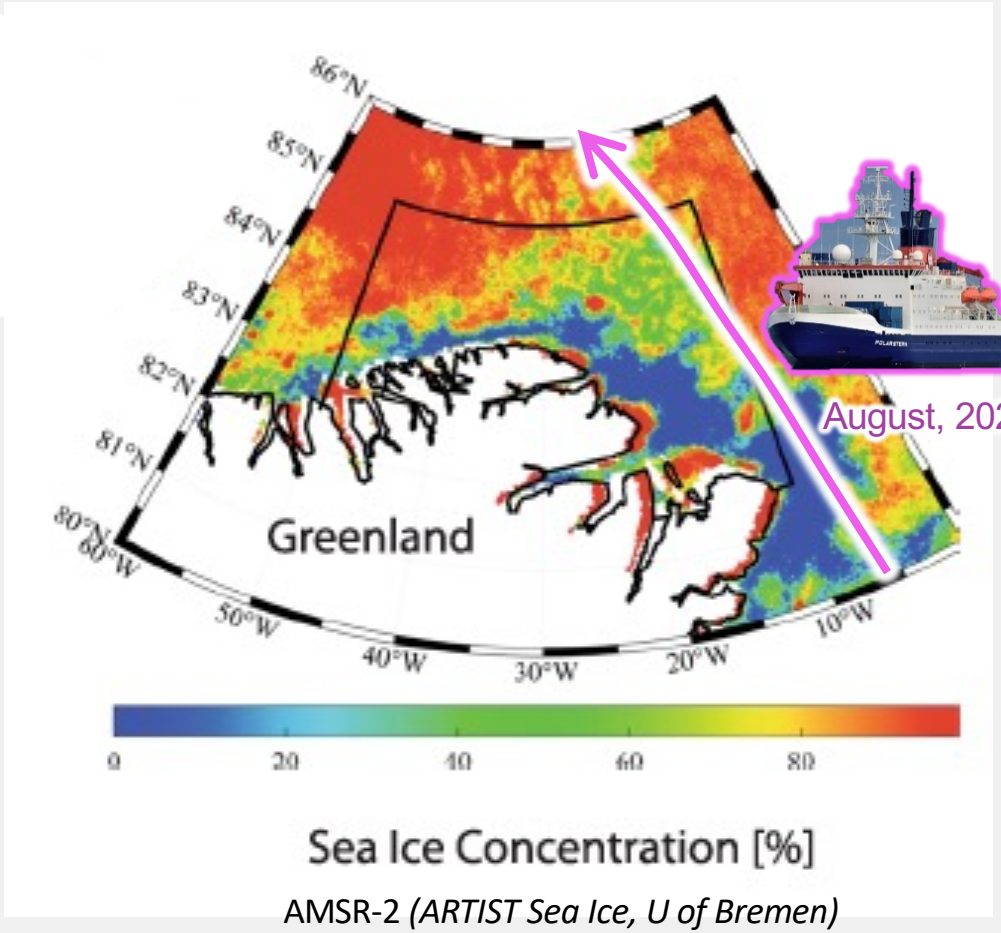



Aug 15 2020




AMSR-2 Artist Ice Concentration [%]

# MOSAiC route to reposition to the North Pole in August 2020




AMSR-2 *(ARTIST Sea Ice, U of Bremen)*

…via the Wandel Sea!

# Wandel Sea Polynya Events: Summary of two papers, plus some new results

**Geophysical Research Letters**

**RESEARCH LETTER**
10.1029/2018GL080902

**Special Section:**
The Arctic: An AGU Joint

## What Caused the Remarkable February 2018 North Greenland Polynya?

G. W. K. Moore[1,2], A. Schweiger[3], J. Zhang[3], and M. Steele[3]

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Article | Open Access | Published: 01 July 2021

## Accelerated sea ice loss in the Wandel Sea points to a change in the Arctic's Last Ice Area

Axel J. Schweiger, Michael Steele, Jinlun Zhang, G. W. K. Moore & Kristin L. Laidre

*Communications Earth & Environment* **2**, Article number: 122 (2021) | Cite this article

**6942** Accesses | **4** Citations | **1318** Altmetric | Metrics

See also:

*V. **Ludwig** et al. (The Cryos., 2019): 2018 event (hi res sat, NAOSIM model)*

*Y. **Lee** et al. (The Cryos. Discussion , in review): Winter Polynyas (RASM model)*

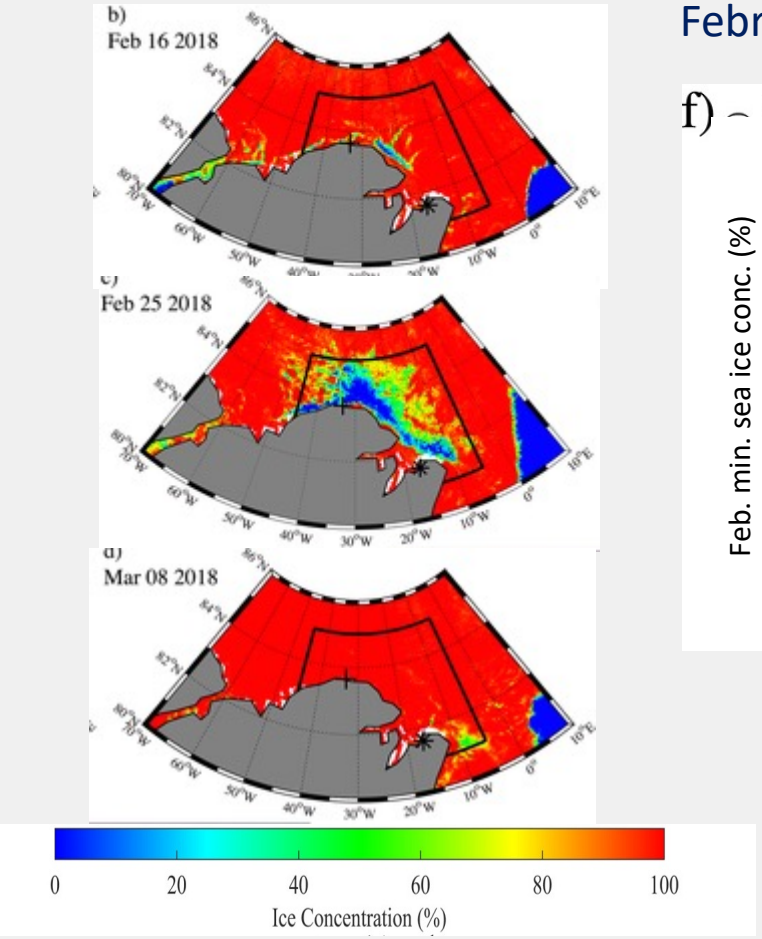
*Moore et al. 2021 (GRL) Spring 2020 Polynya north of Ellesmere Island*

Science Questions:

- Historical context. How special where they?
- What caused these events? Mechanisms
- What's the role of climate change (attribution)?
- What is likely to happen in the future?

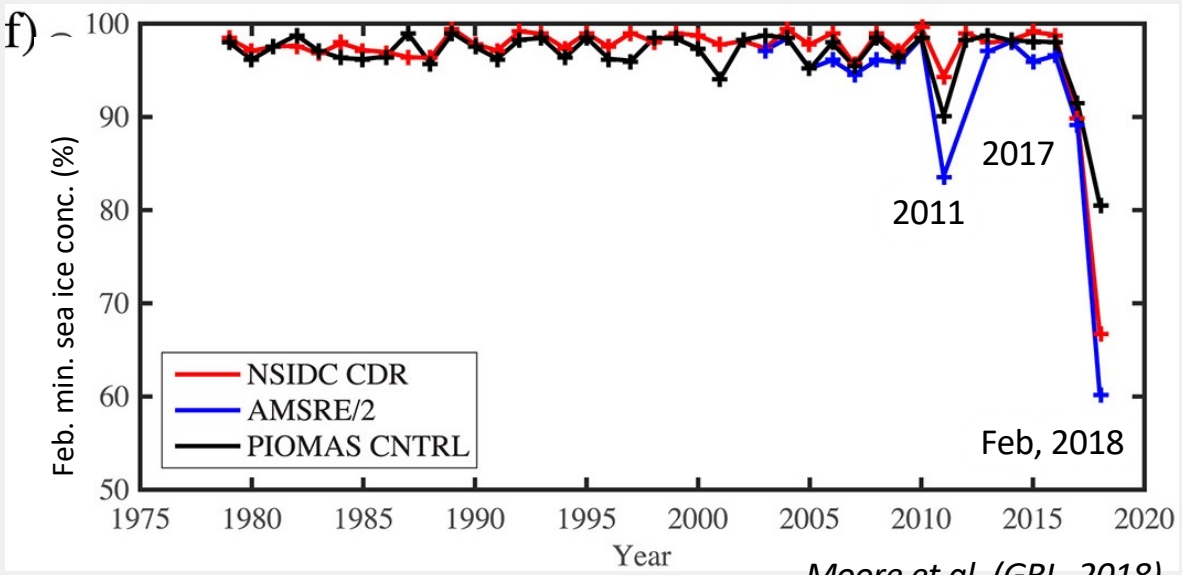
# The Winter Wandel Polynya: Feb 2018

late February 2018




AMSR -2 Ice Concentration

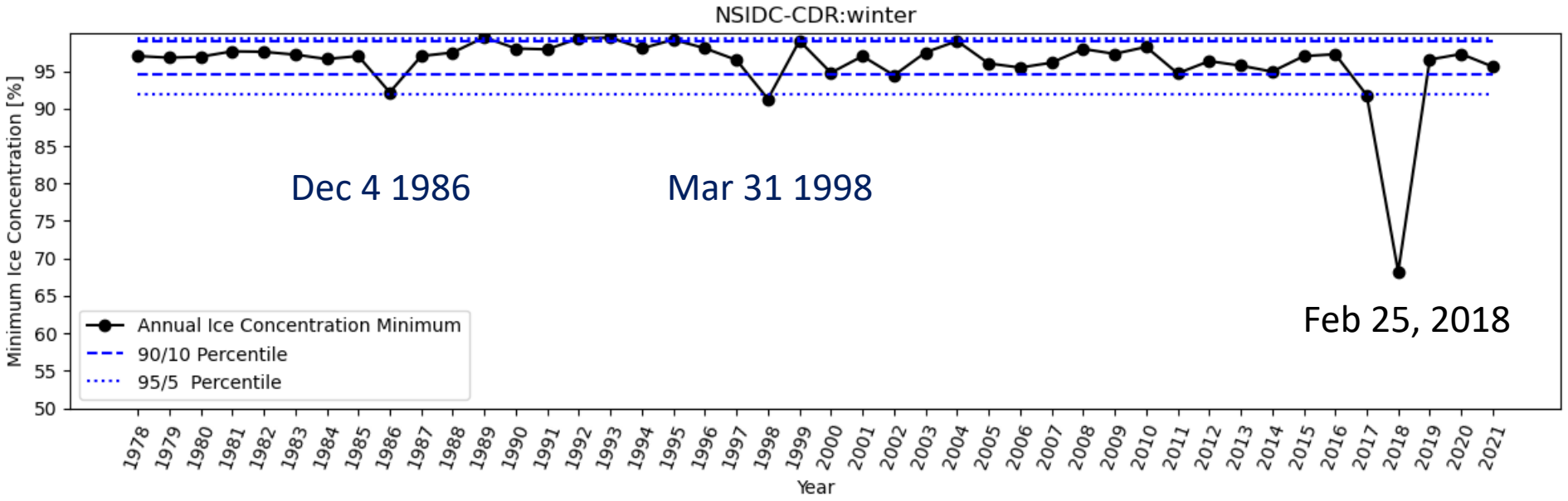
## February Ice Concentration [%]




*Moore et al. (GRL, 2018)*

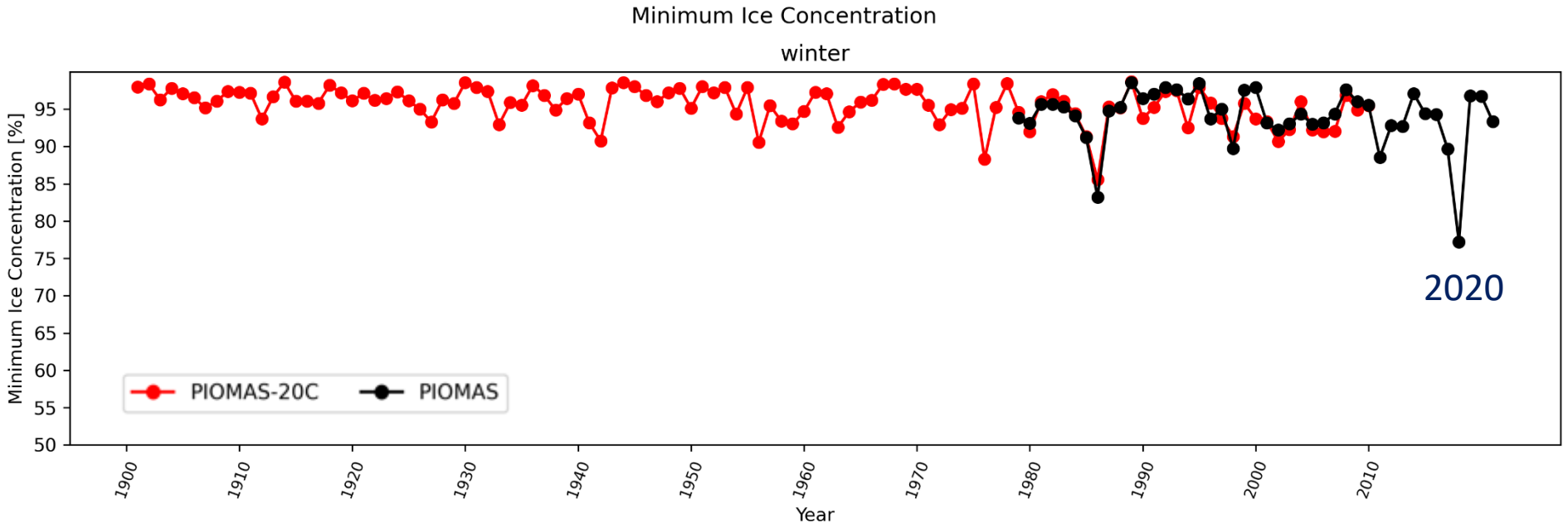
PIOMAS CNTRL: Ice-Ocean model forced with NCEP/NCAR, no Data Assimilation after January 1, 2018

# Winter Minimum (Dec-March) Ice Concentration




Data: NSIDC CDR

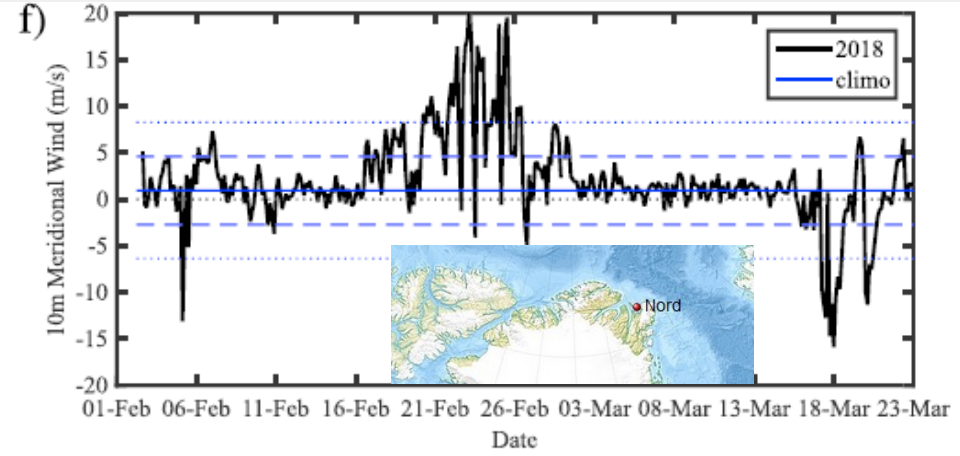
# The long view: 1901-2020




PIOMAS-20C : model-based reconstruction using ERA-20C atmosphere data to force ice-ocean model (HadISST 2 daily ice concentrations assimilated)
(see Schweiger et al. 2019 Journal of Climate)

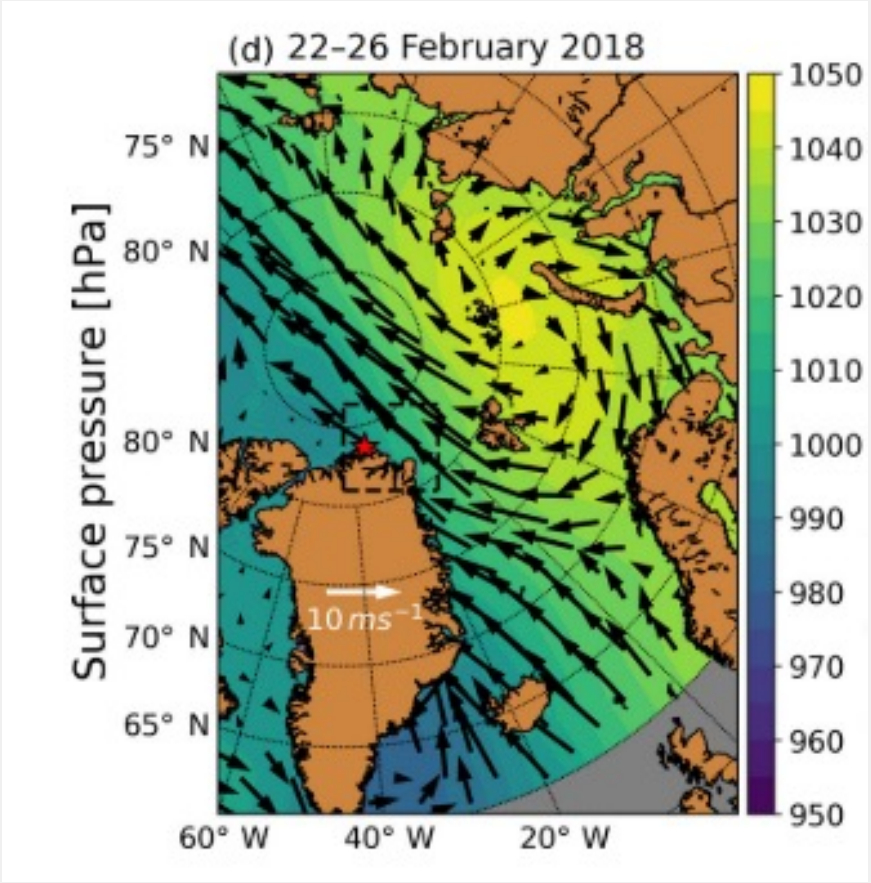
PIOMAS: Standard PIOMAS model

# 2018 February Event was caused by very strong southerly winds




Meridional Wind Speed at Station Nord (Moore et al. 2018). Dashed/dotted lines are one and two sigma of 1961-2017 climatology

The strong wind anomaly that created the Polynya was associated with a strong Stratospheric Warming Event in Early February

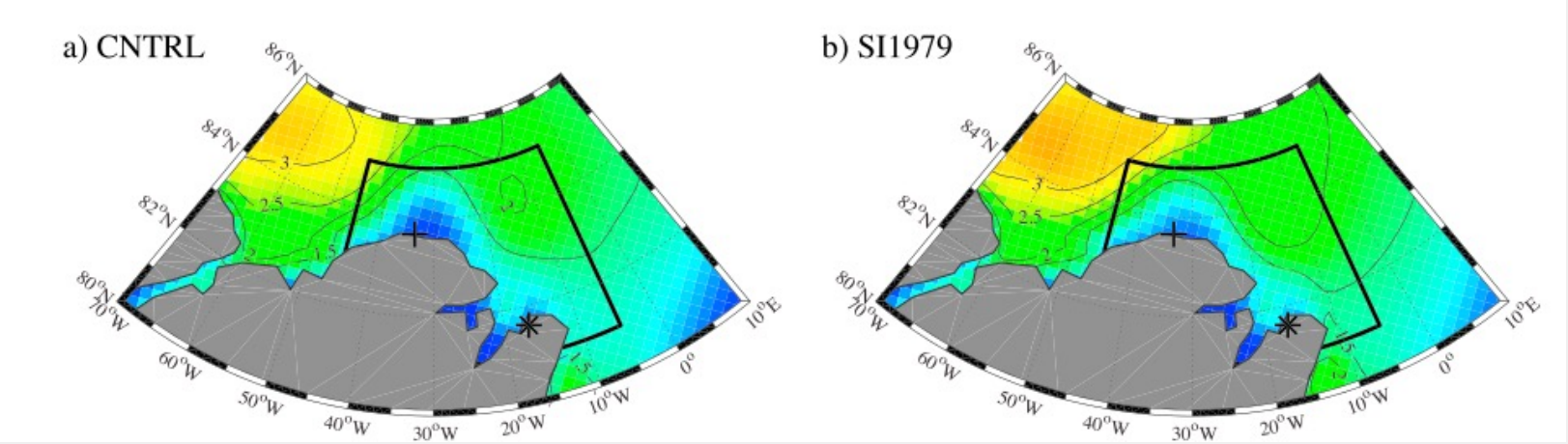



Surface Pressure and Wind Speed (ERA-5). From Ludwig et al. 2019

## Hypothesis: Thinning Ice made sea ice more susceptible to deformation and allowed Polynya formation

PIOMAS MODEL (SI1979) with

- 1979 initial conditions (ice thickness/concentrations)
- 1979 thermal forcing (radiation/temperature)
- 2018 Wind Forcing



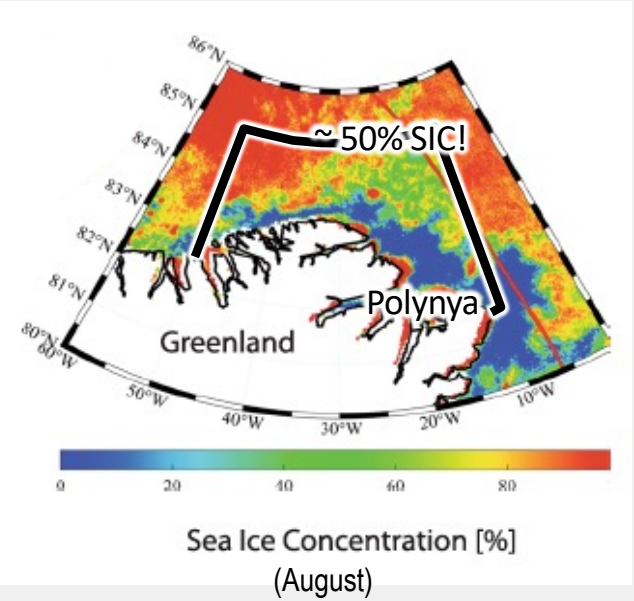

CNTRL: (Historical Forcing/no DA)

Thick and Cold but 2018 Winds

**Result:** Polynya would have occurred without thinning ice or warming (but size might have been a bit smaller)

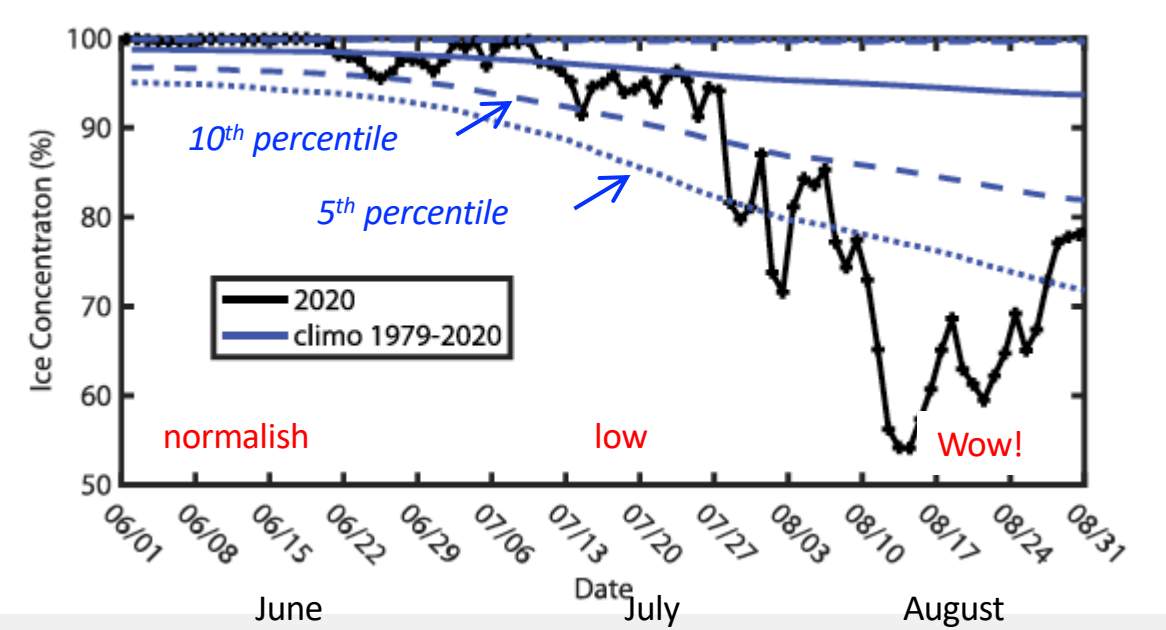
*Note: Lee et al. (TCD). Finds similar results with RASM (coupled) model*

# Summery Event: August 2020



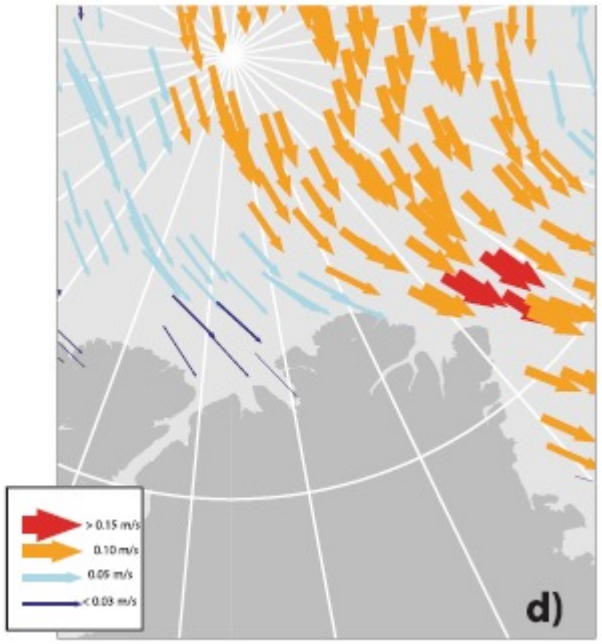

AMSR-2 *(ARTIST Sea Ice, U of Bremen)*

## Summer 2020



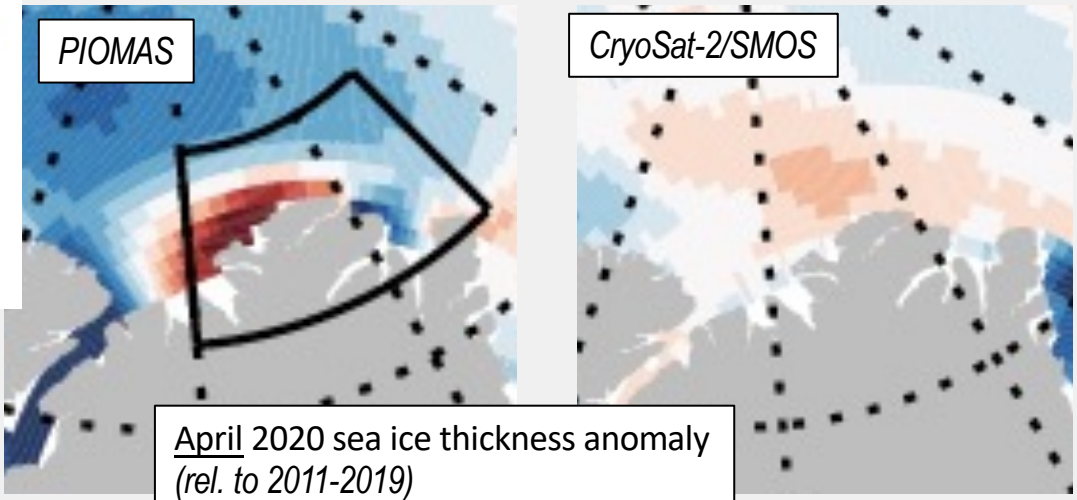

SMMR/SSMI/SSMIS *(NOAA/NASA CDR, NSIDC): 1979-2000*

# But the ice was thick in the spring of 2020?



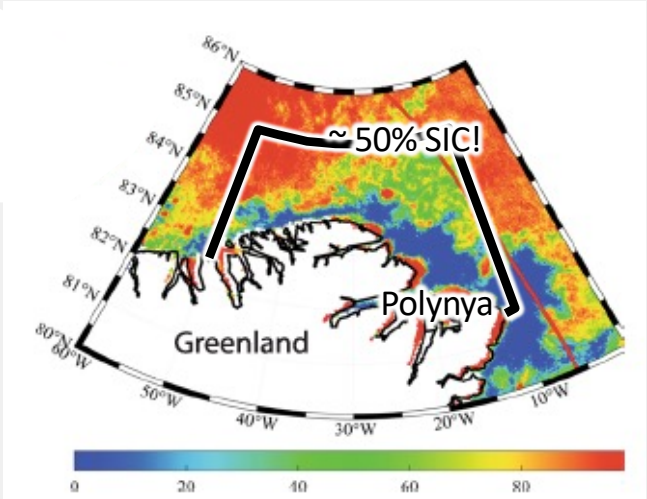

Ice Velocity Anomaly Feb 2020

Especially puzzling,
given relatively thick springtime ice!




April 2020 sea ice thickness anomaly
*(rel. to 2011-2019)*

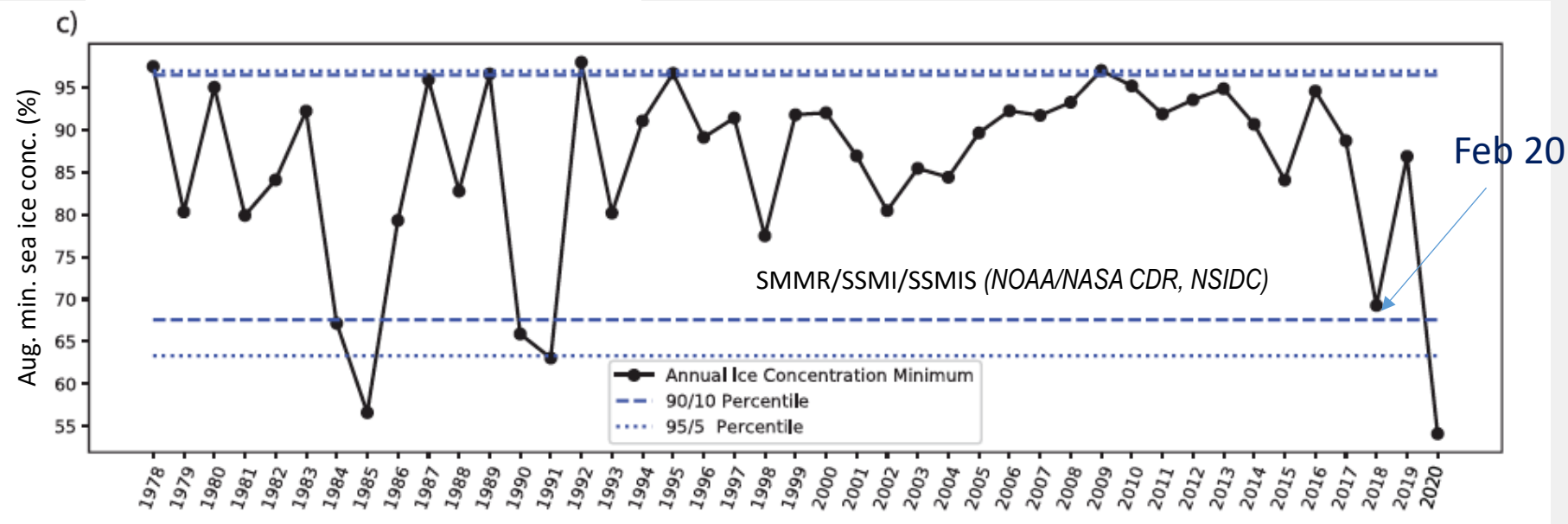
# August 2020 Polynya: 41 year context




August 2020

2020 was lowest

*…but other years were also low!*




Feb 2018

Minimum Ice Concentration for each year

# Why was August 2020 so low: Examining Ice Mass Budget

## Dynamics vs Thermodynamics

Modeled ice thickness Δ partitioned as:

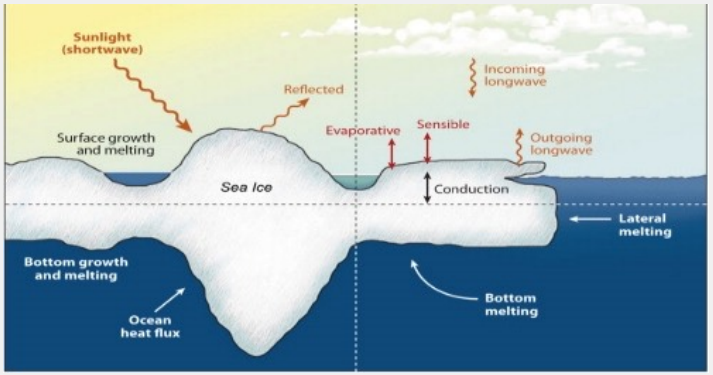
$$\Delta h_{ice}/\Delta t = F_{adv(ection)} + F_{prod(uction)}$$

$F_{adv}$ = thickness flux convergence

*( > 0 means thickening )*

$F_{prod}$ = net growth – melt

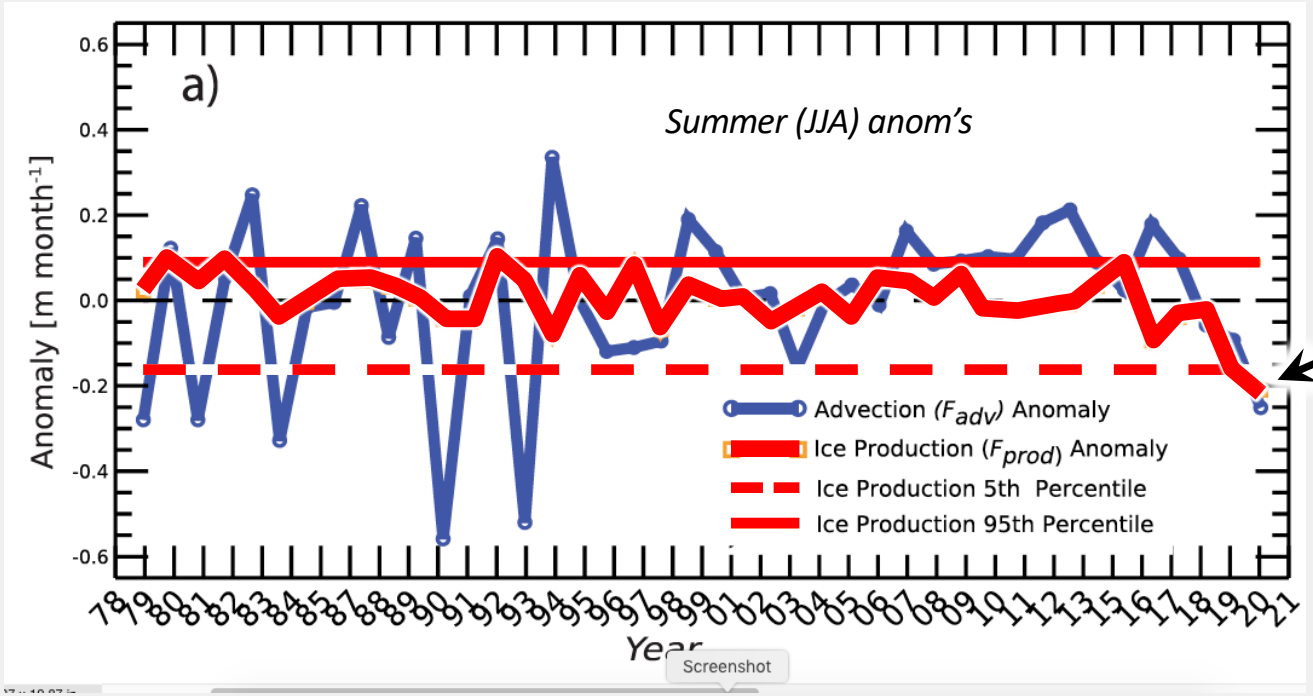
*( > 0 means thickening )*



# Summer (JJA) Advection and Production Anomalies

## Dynamics vs Thermodynamics

Data from PIOMAS model




Summer 2020:

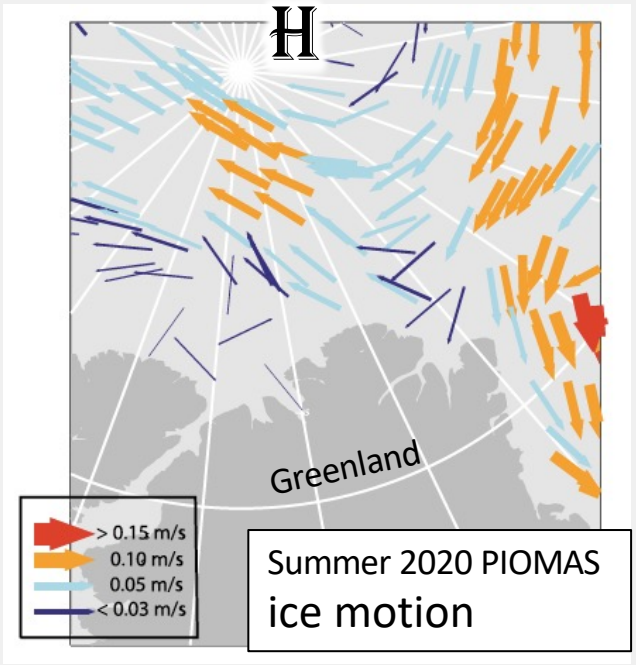
- Large divergence
- Large net melt

Strong Advection events earlier: 2020 both went downL

# Advection

Dynamics vs Thermodynamics

$$\Delta h_{ice}/\Delta t = F_{adv} + F_{prod}$$

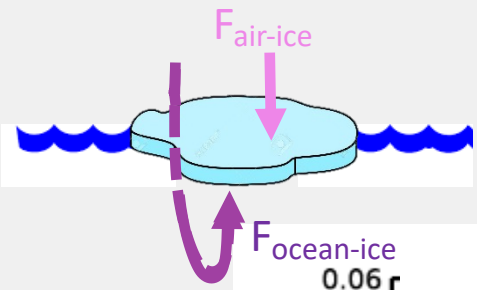



Big, strong high pressure cell
→ "giant Beaufort High"

*Mallett et al. (Nature Comm. Earth & Environ, 2021)*
*Moore et al. (Nature Comm. Earth & Environ., 2021)*

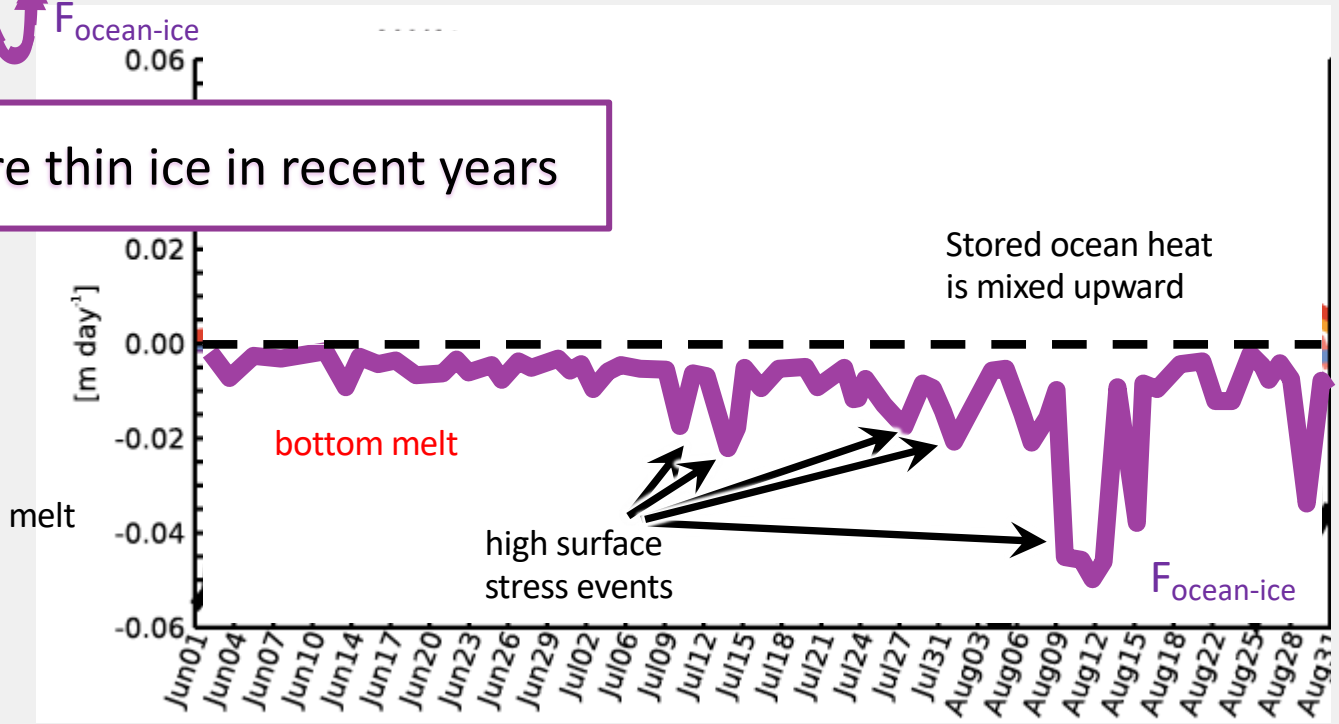
*Lots of divergence out of the Wandel Sea*

# Dynamics vs Thermodynamics

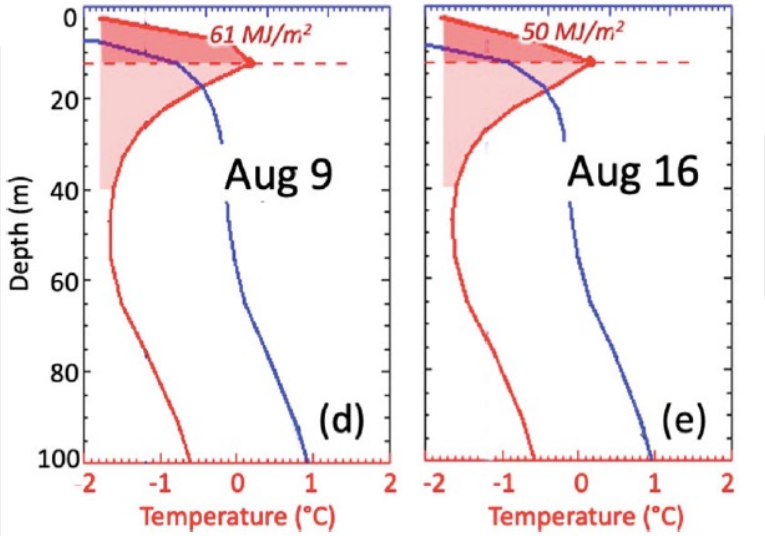



$$\Delta h_{ice}/\Delta t = F_{adv} + F_{prod}$$

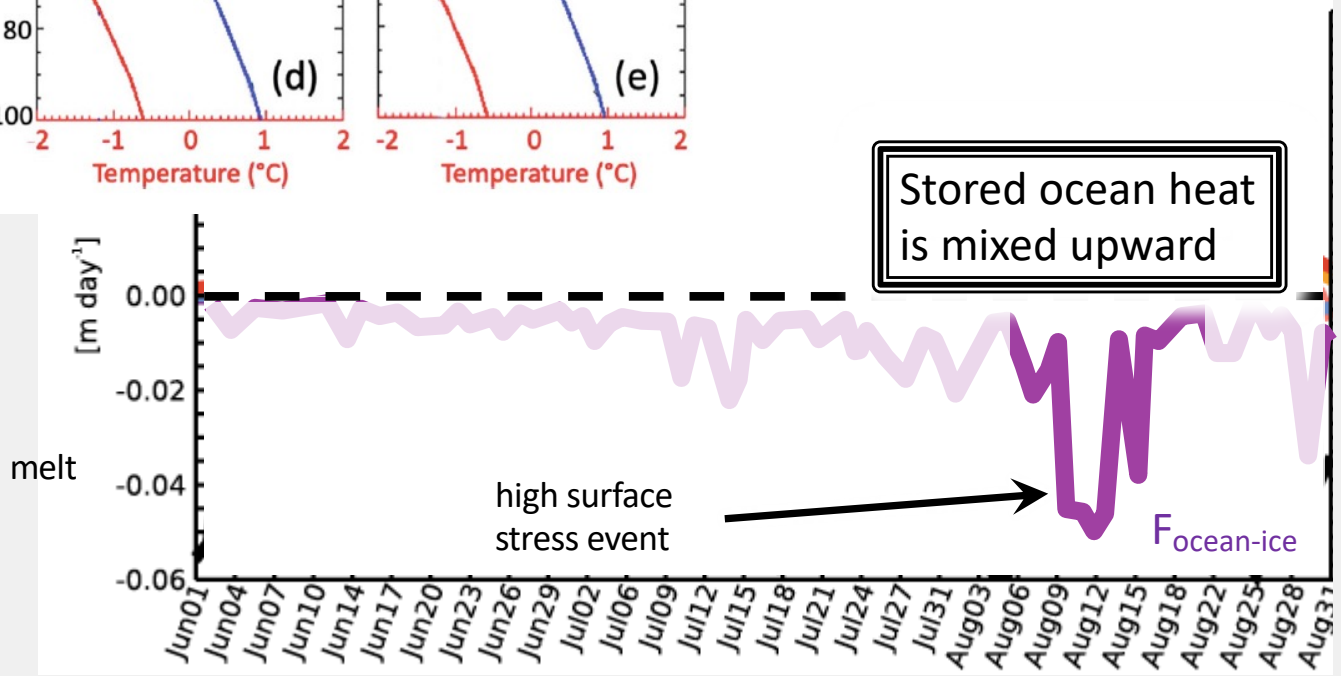
More thin ice in recent years



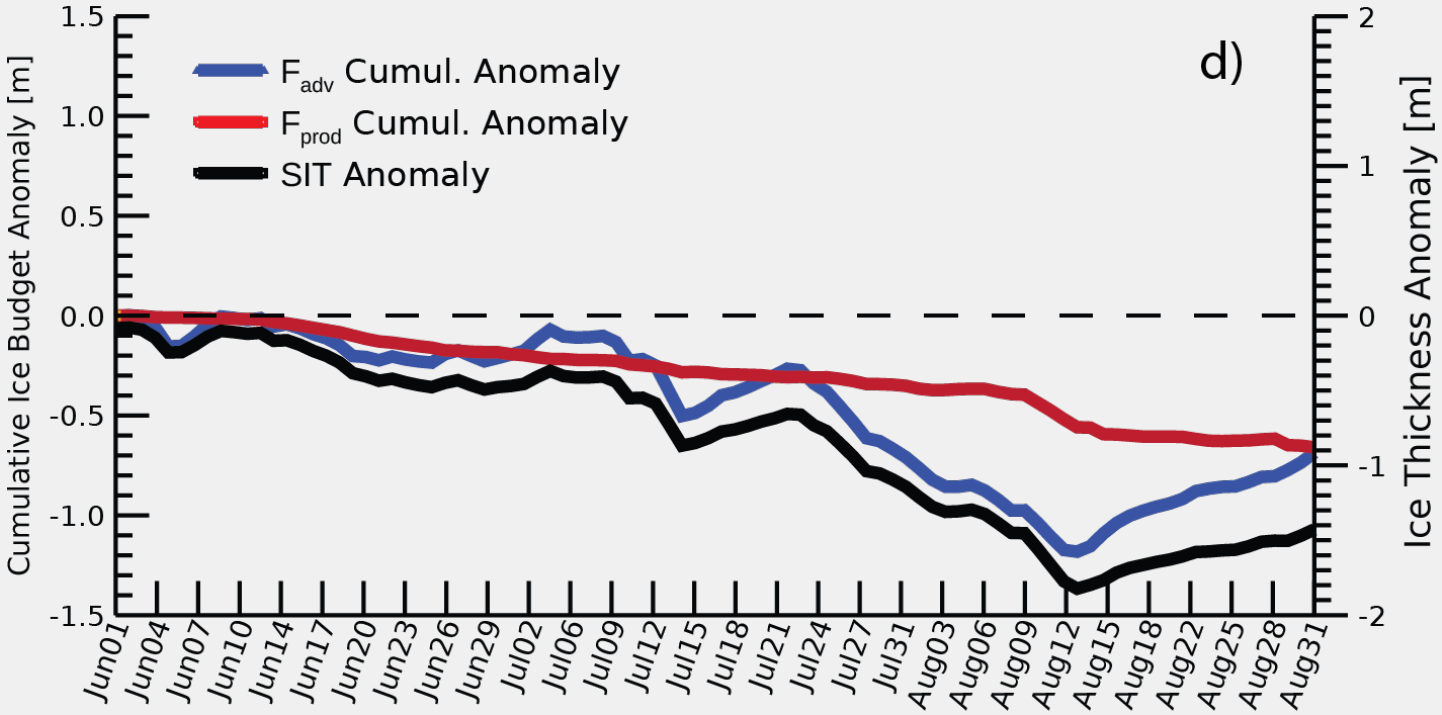
# Ocean Heat Melts Ice




Decrease in subsurface ocean heat
(NSTM = Near-Surface Temp. Max.)



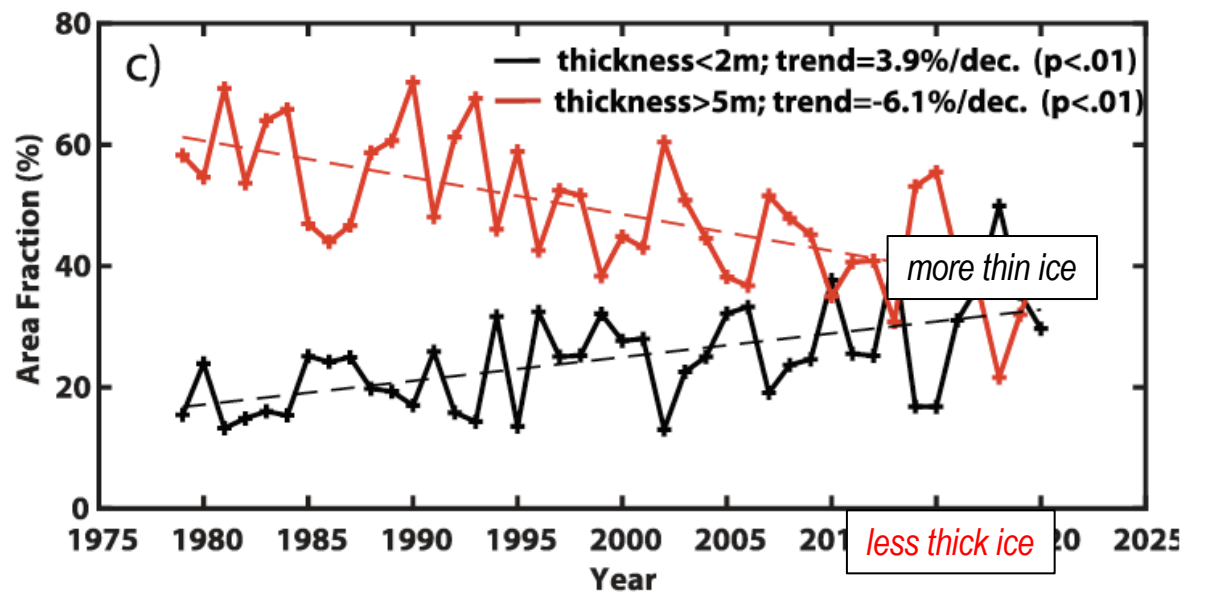
# Thermodynamics and Dynamics Cumulative Anomalies




Advection has the stronger impact on Ice Thickness

# Weather vs. Climate Change: "What if" Model Simulations

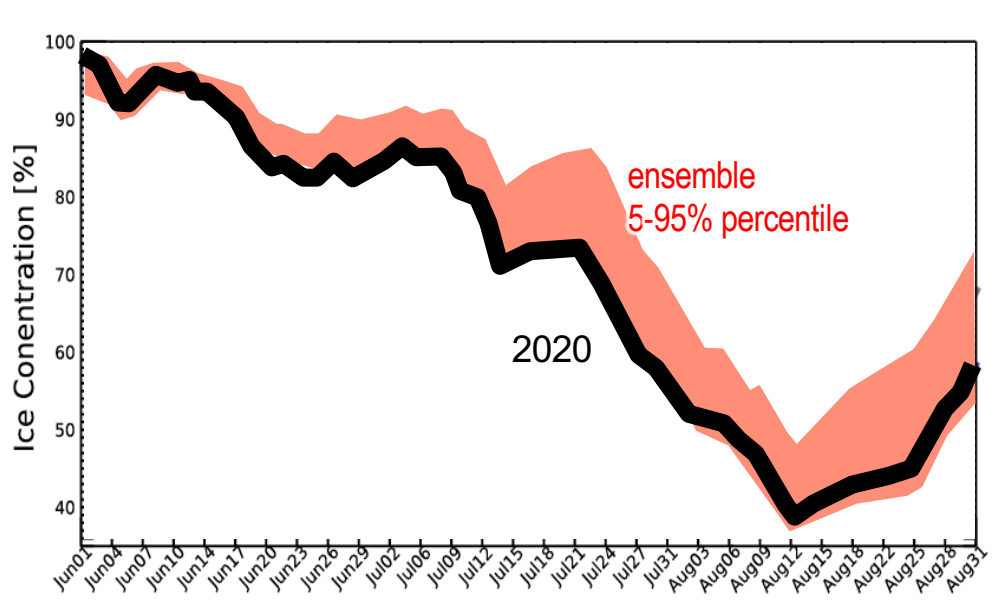
Assumption:
Thinning ice = climate change . Summer 2020 weather = internal variability




Q: What would have happened if Summer 2020 started with
ice-ocean conditions
*From another year….*

Testing the contribution " long-term ice thinning":

# The role of June 1, 2020 ice-ocean conditions (climate change)




INIT Experiment:

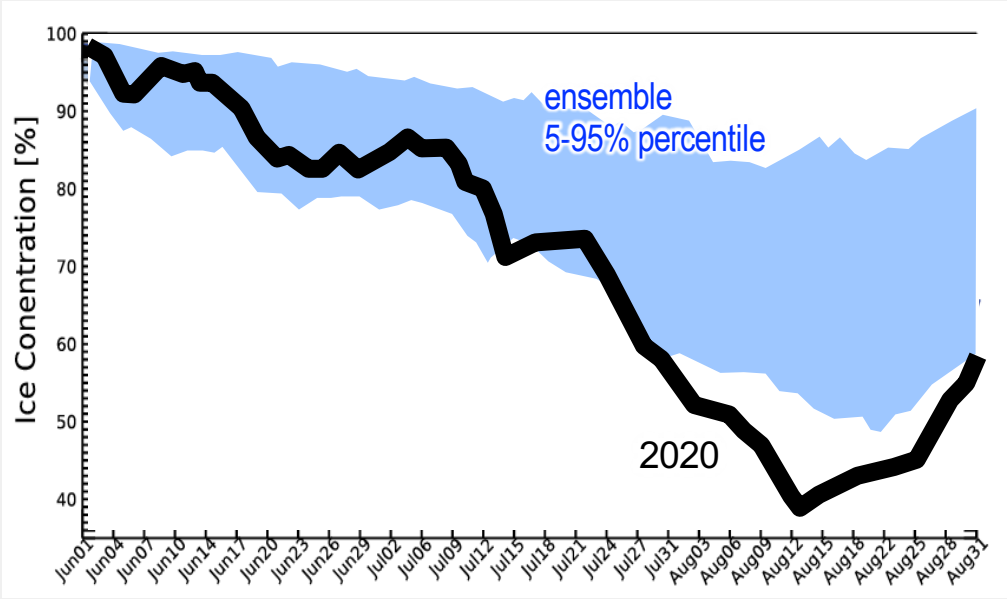
- June 1 ice-ocean conditions from June 1,1979, 1980, … 2019
- *2020 Atmospheric Forcings*

— Historical Simulation (2020 initial, 2020 Forcing)

- low SIC from the start
- not much change (relative to ensemble) over the summer

# The role of summer 2020 atmos. Forcing (weather)

Q: What if 2020 had different "weather"?




Historical Simulation
(2020 initial, 2020 Forcing)

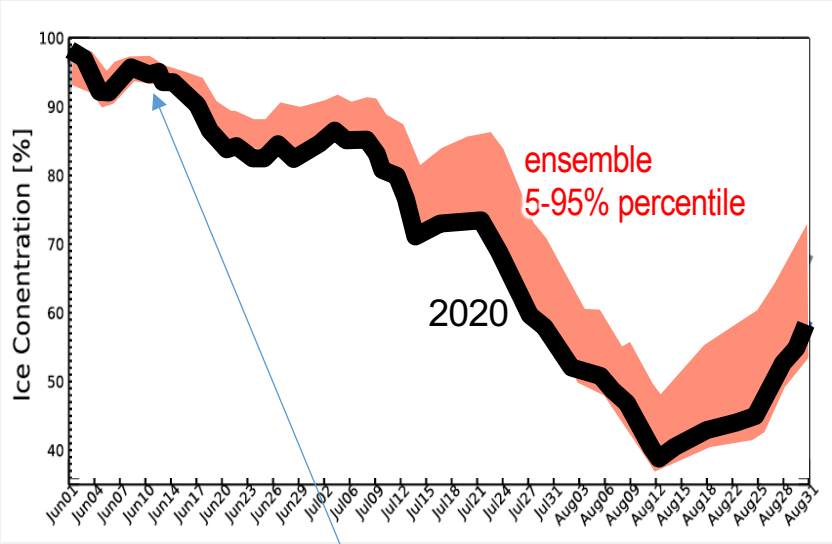
Experiment (Atmos)

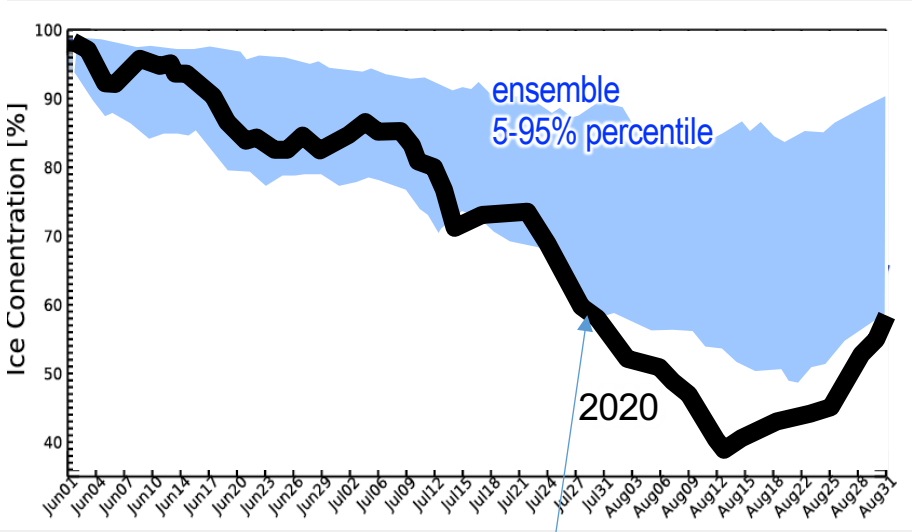
- Atmos. forcing from summer 1979, 1980, etc.
- *June 1, 2020 ice-ocean conditions*

Assumption: This is the weather/internal contribution

SIC moves outside ensemble spread in late summer

# June 1 conditions vs. summer atmos. forcing




SIC at low end of ensemble starting in Early Summer

SIC Moves to low end of ensemble in Late Summer

Climate Change Contribution

~20%

Weather Contribution

~80%

# June 1 conditions vs. summer atmos. forcing

20% June 1 vs. 80% atmos. → 2020 SIC min.
*(mid-August)*

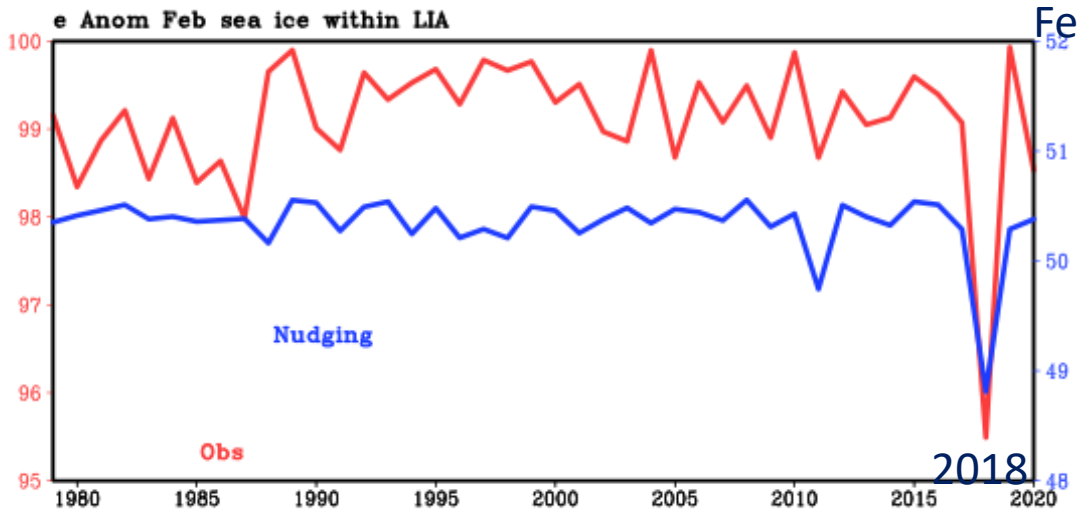
climate change signal *(i.e., ice thinning)*

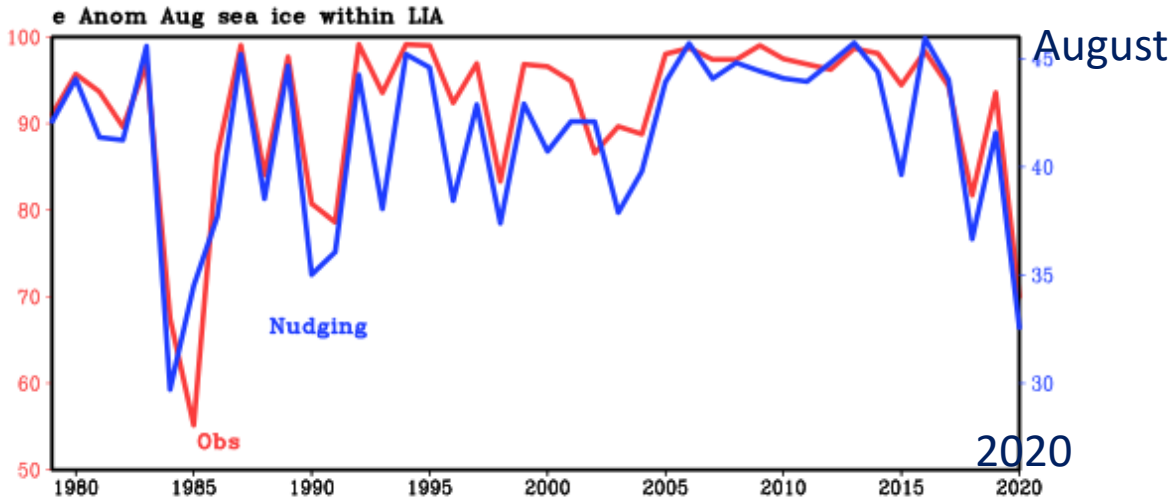
~ NYC flooding from

*Swain et al. (One Earth, 2020)*

Superstorm Sandy
*October, 2012*

# Wandel Sea Ice Concentration: Replication with a fully coupled Global Model.



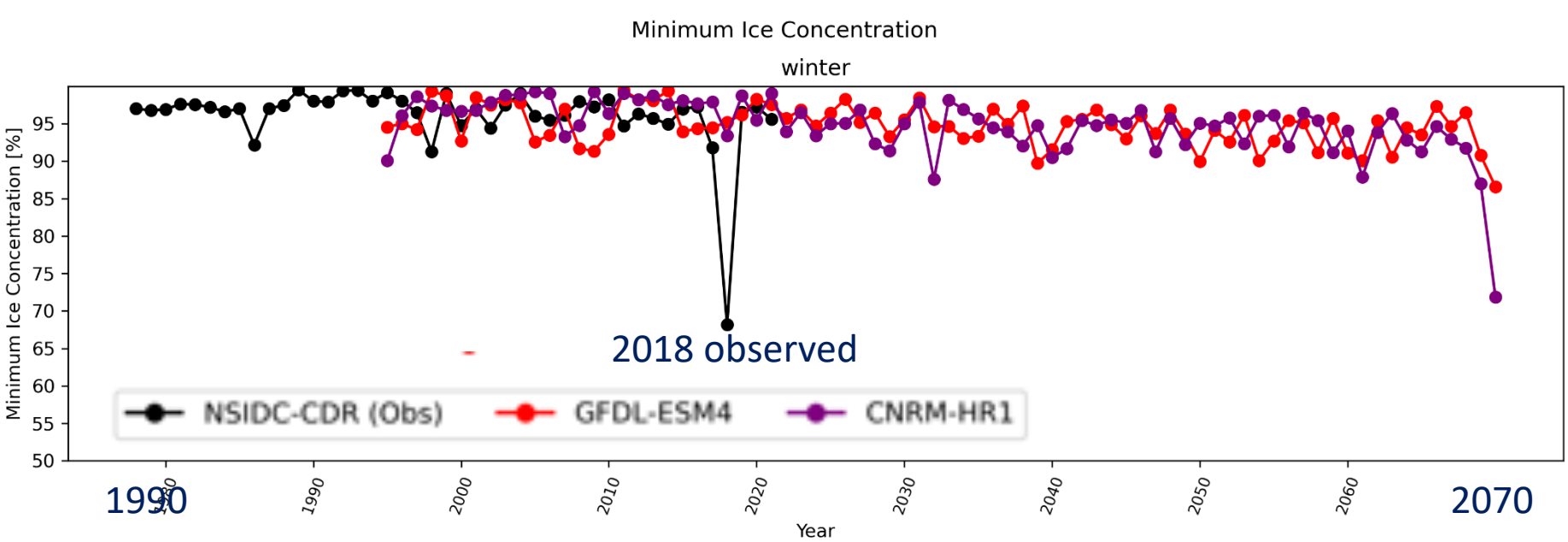

Note: Monthly Data.
Y-axis compressed!

Satellite Observed Ice Conc.

NCAR CESM Model in “replay mode” nudged with reanalysis (ERA-5) winds north of 60N

(Ding et al. Journal of Climate in review)

# What will happen in the future: winter




How do we generate daily ice information at suitable resolution:

GFDL-ESM4 IPCC AR6 historical + ssp585 atmosphere forcing for PIOMAS-like model

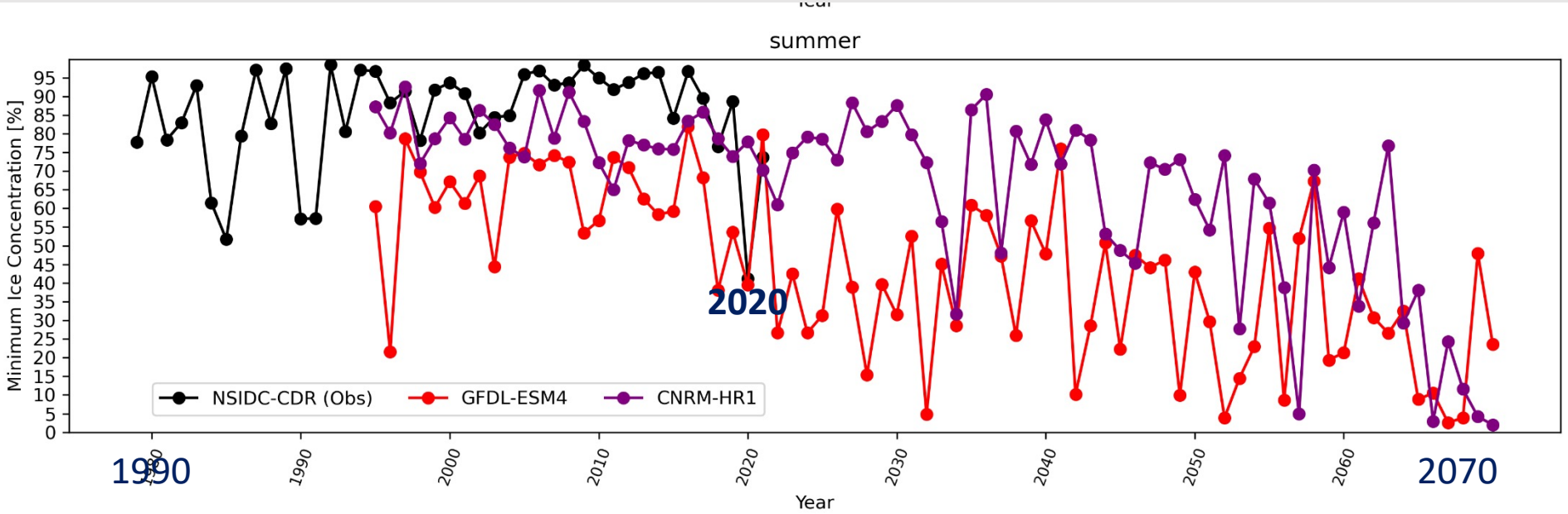
CNRM-CM6-1-HR IPCC AR6 historical + ssp585 atmosphere forcing for PIOMAS-like model

**-some calibration of forcing to ERA-5 reanalysis**

**-model tuning**

**Result: Winter event (Feb 2018) was a really "out of the park" event. Not likely to be seen before 2070 (model caveats apply)**

# What will happen in the future: summer




GFDL-ESM4 IPCC AR6 historical + ssp585 atmosphere forcing for PIOMAS-like model

CNRM-CM6-1-HR IPCC AR6 historical + ssp585 atmosphere forcing for PIOMAS-like model

Result:

- Likelihood of 2020-like summer events will increase over the next 50 years but will remain rare through 2050
- Model differences/calibration over historical period make interpretation difficult

**Summary**

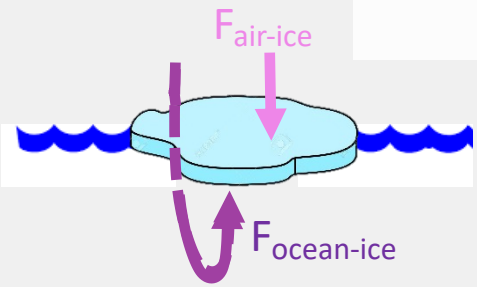
- Both Polynya events were primarily wind driven
- 2018 winter event was an extreme stochastic event with climate change playing no clear role
- Climate change, via thinning sea ice, is responsible for about 20% of the 2020 summer event. Weather accounts for about 80%.
- Winter events like 2018 will remain unlikely through 2070
- Summer events –like 2020- will remain rare but will become more likely over the next 30 years or so.
- Sea ice thickness distribution is important (mean thickness alone doesn't tell the story)

**Future work/Recommendations/Thoughts:**

- Need more, better calibrated climate model simulations for future (daily output, more scenarios, not just ssp585). Nudged (replay simulations)
- 42-year observed record is still relatively short for extreme events. Improved long term 150+ year reconstructions would be helfpul. Resolution, algorithms relevant for smaller scale events.
- Attribution likely model sensitive. Replication is needed.

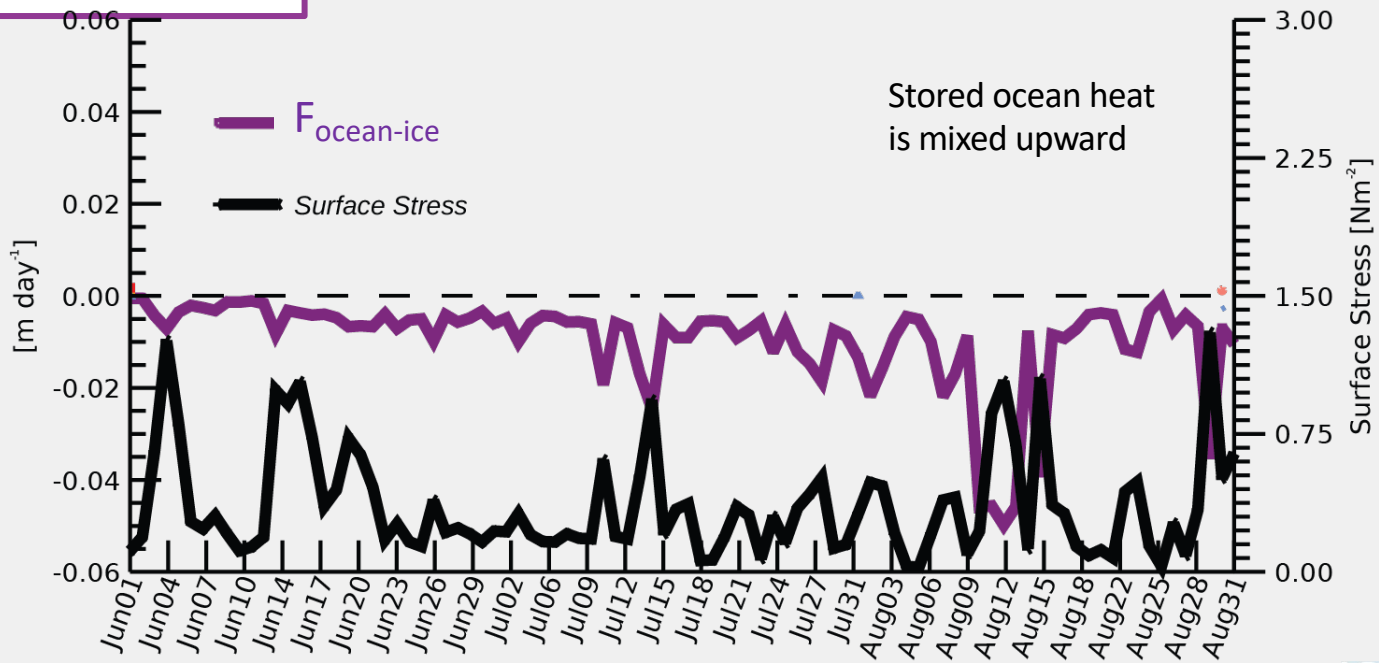
Thank You

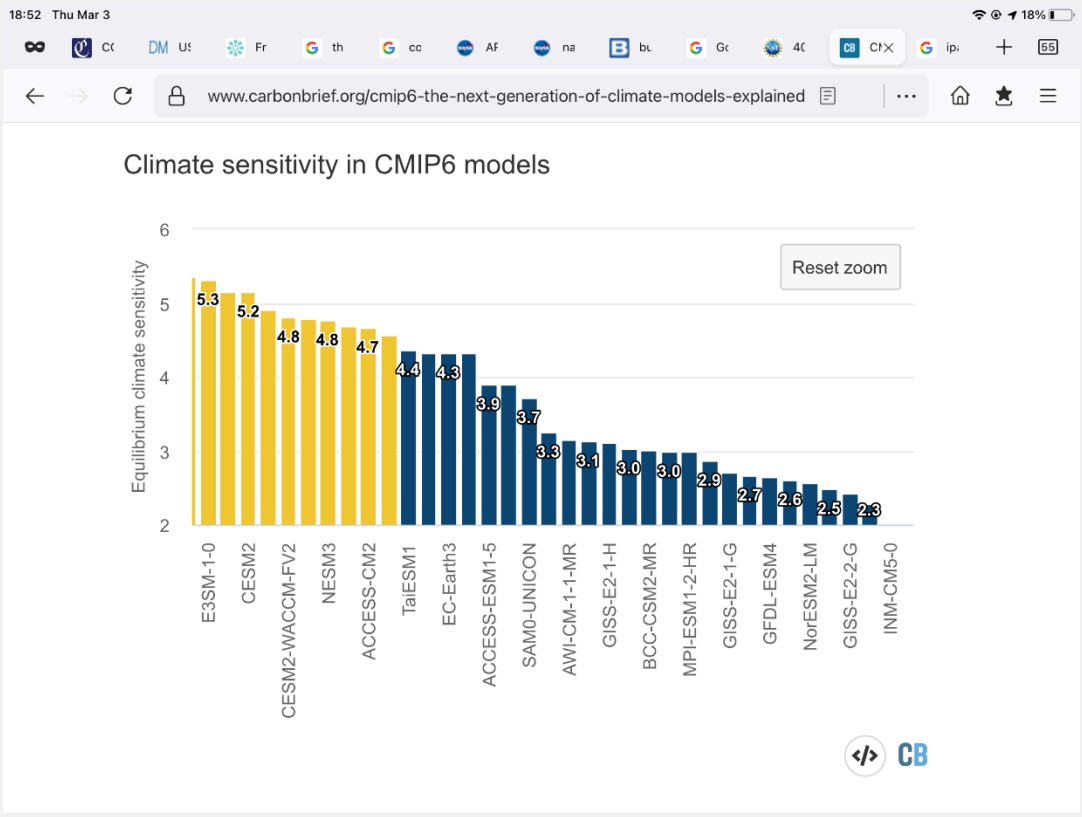
# Dynamics vs Thermodynamics

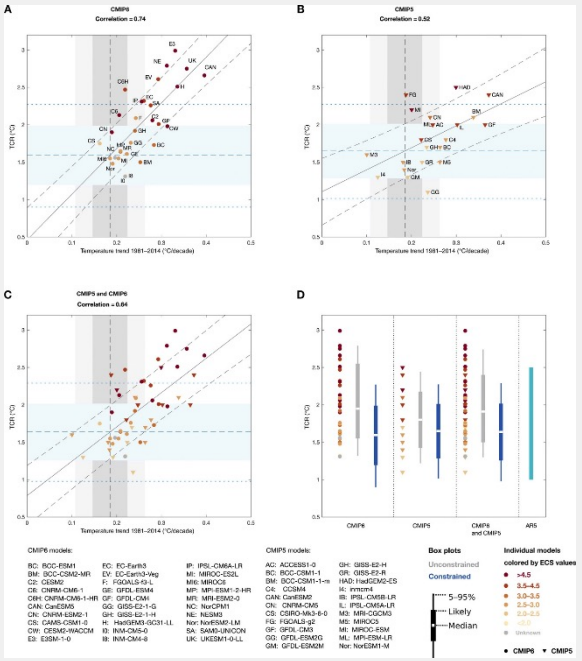



$$\Delta h_{ice}/\Delta t = F_{adv} + F_{prod}$$

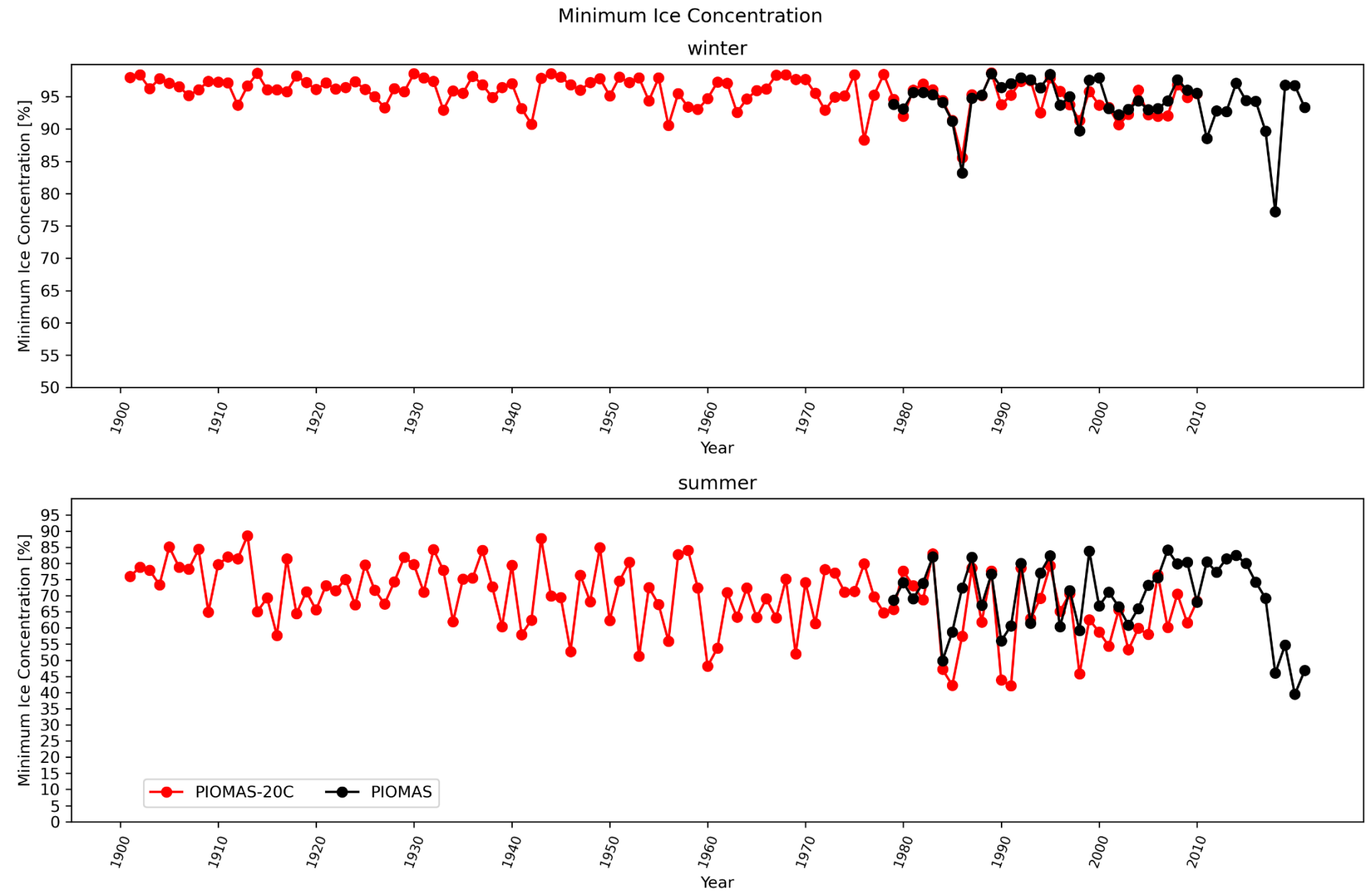
More thin ice in recent years






C6H : 4.3, GFLD-ESM4: 2.7


Minimum Ice Concentration
winter
Minimum Ice Concentration [%]
Year
summer
Minimum Ice Concentration [%]
Year
PIOMAS-20C
PIOMAS