neXtSIM

Breaking up is hard to do – Simulating extreme sea-ice breakup events in the Arctic

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BCCR seminar, 29. November 2021

Partner in:

BJERKNES CENTRE for Climate Research

SFI Smart Ocean
SFI Climate Futures

MERCATOR OCEAN INTERNATIONAL

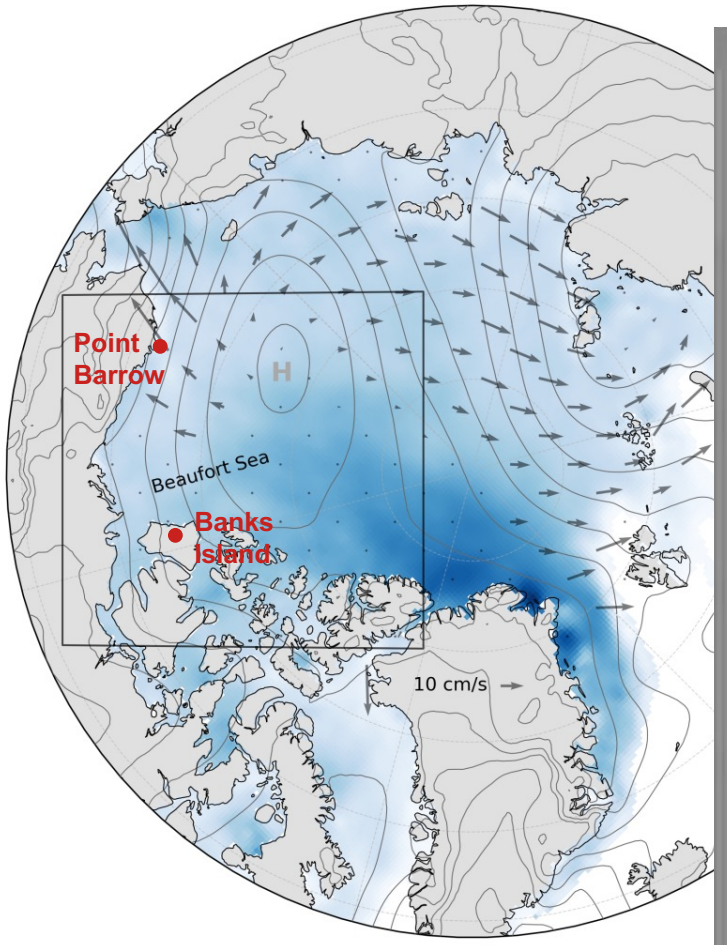
ONE OCEAN 2021-2023

NERSC

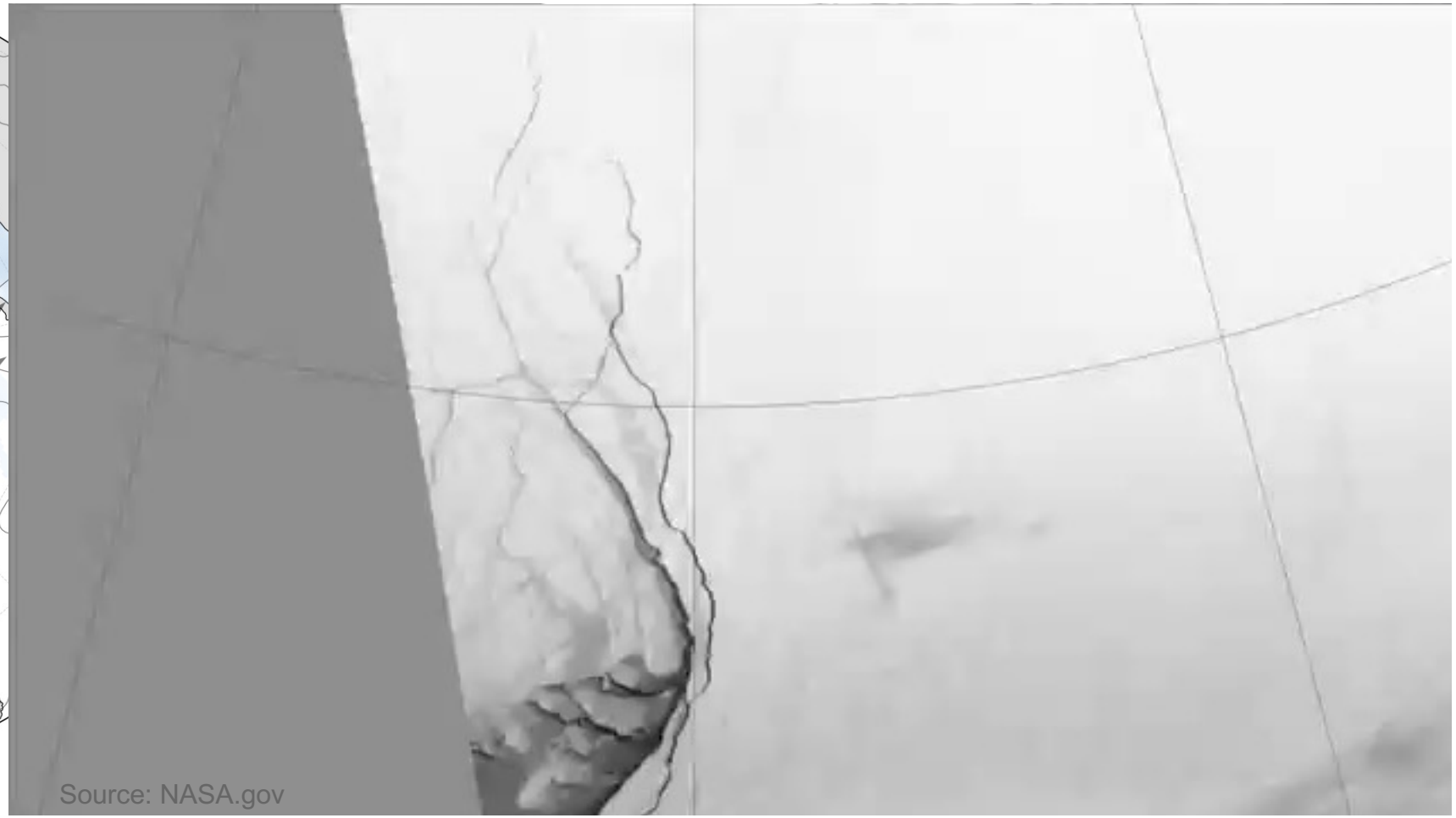
Arctic sea ice – broken up and full of leads and crags

Taken from a low-flying airplane on March 26, 2011. NASA Earth Observatory

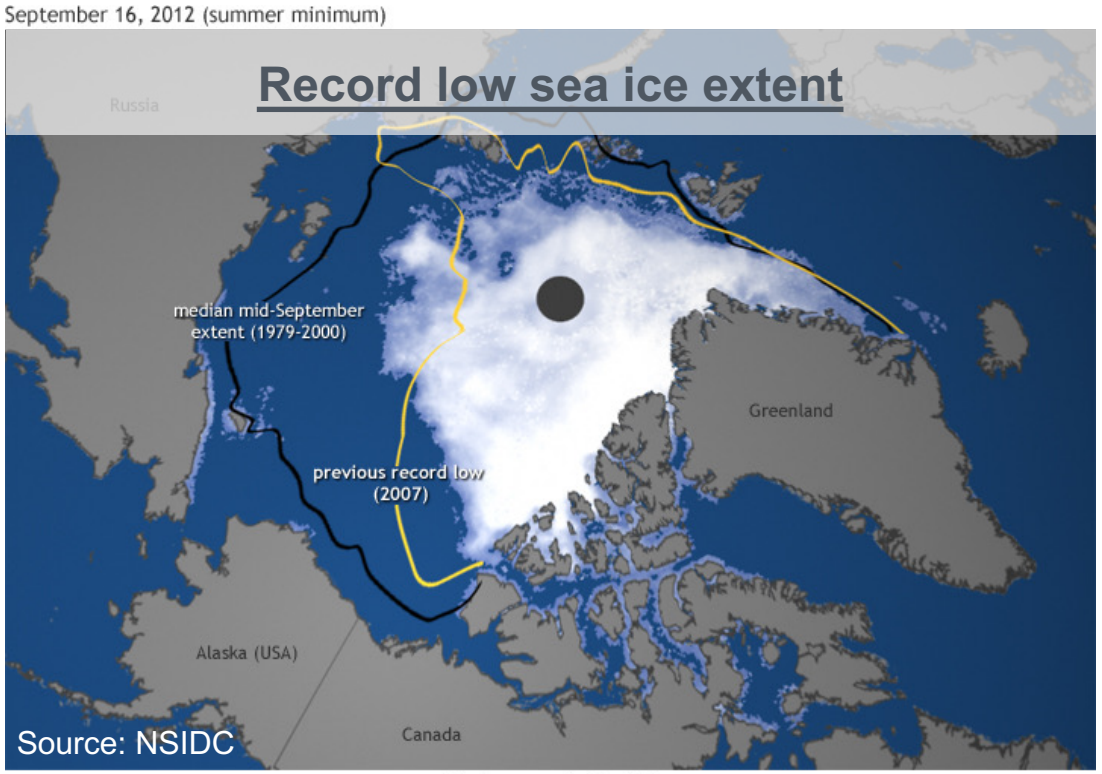
Case study: Breakup event - Beaufort Sea 2013



Breakup event seen from satellite January-March 2013



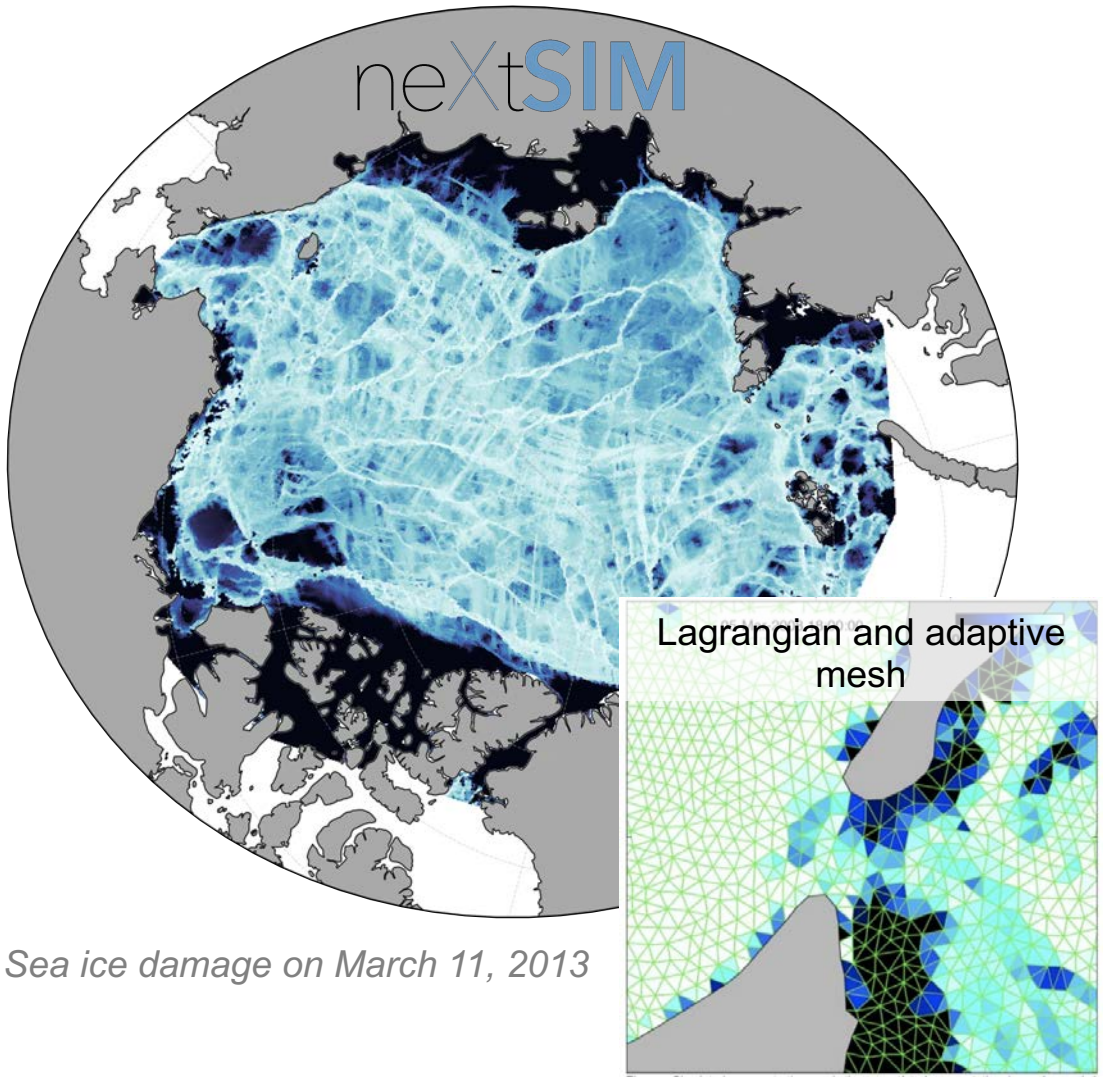
What factors influenced the 2013 breakup event?



I. Factors driving winter sea ice breakup – results from the neXtSIM model

II. Impacts of winter breakup events on Arctic sea ice

Introducing the neXtSIM sea-ice model



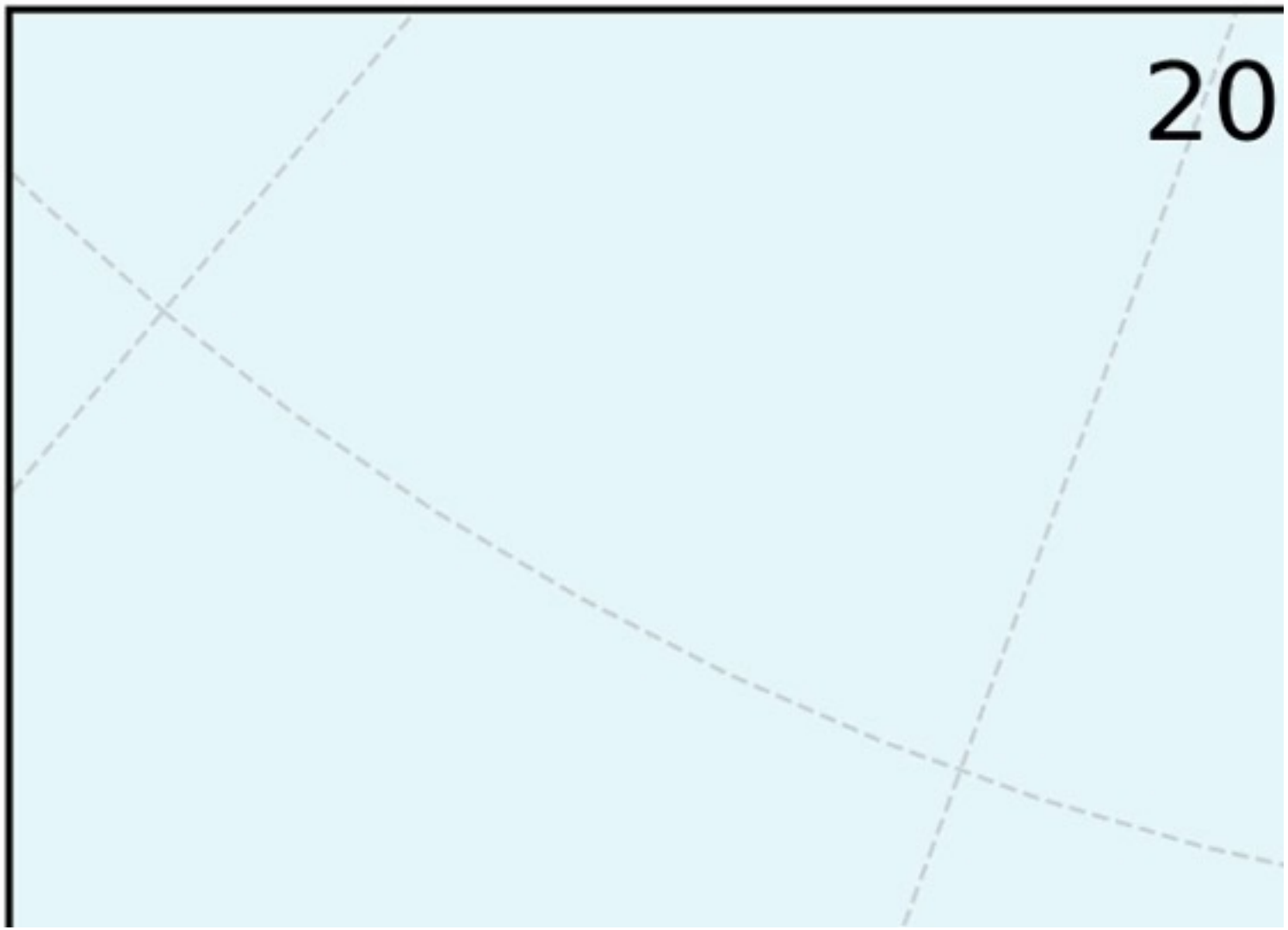
Sea ice damage on March 11, 2013

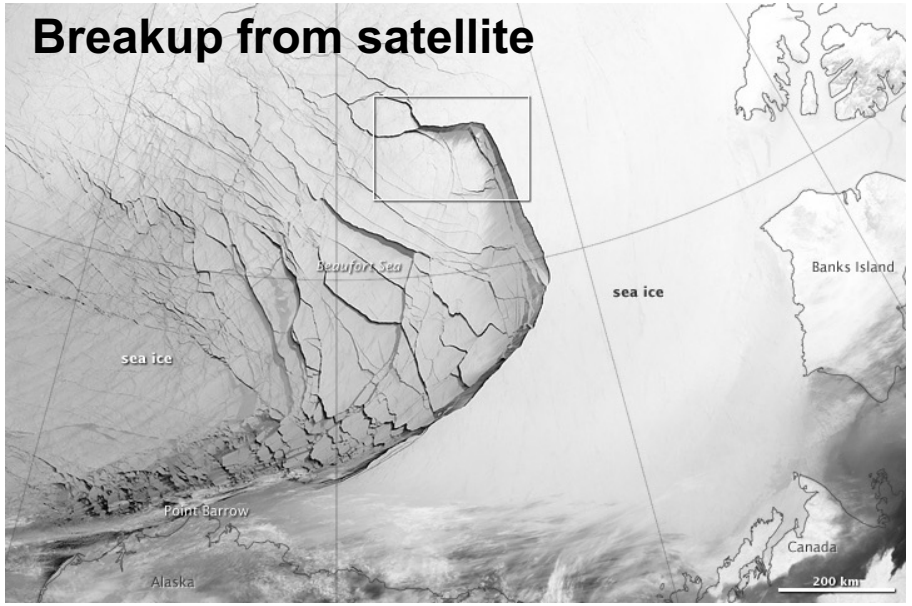
Methods

- Stand-alone version of neXtSIM [Rampal et al. 2016; Olason et al. 2021]
- Polar-WRF atmospheric forcing [Hines et al. 2015]
- TOPAZ4 ocean forcing [Sakov et al. 2012]
- Initial sea ice thickness and conc. from CS2SMOS [Ricker et al. 2017]

Simulating the 2013 breakup event

NeXtSIM simulation with Polar-WRF 10 km





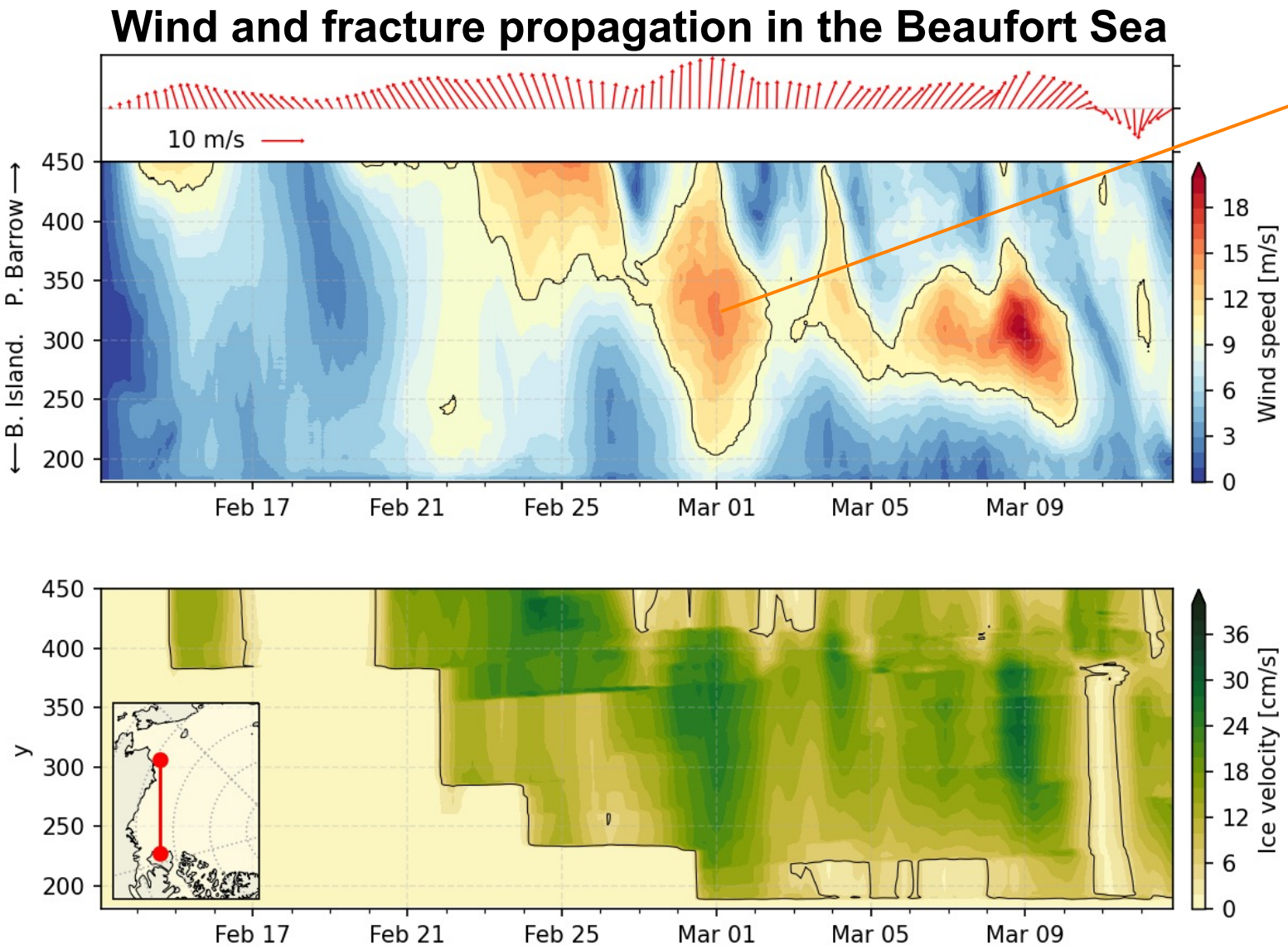
Key ingredients for simulating the breakup

Sea ice rheology

Atmospheric forcing

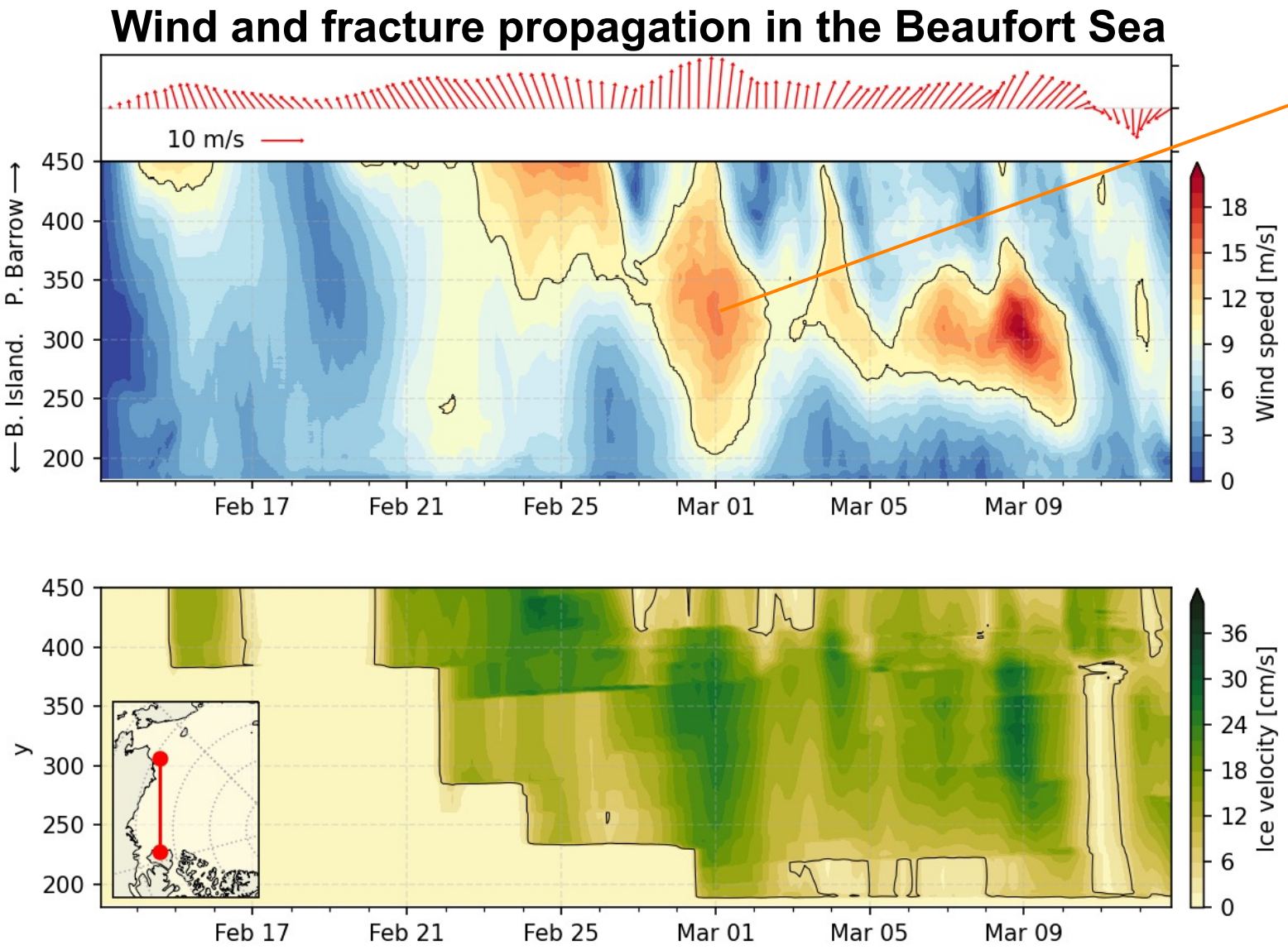
Sea ice thickness

Strong winds break the sea ice cover



Threshold for ice breakage:
~10 m/s

Strong winds break the sea ice cover



Threshold for ice breakage:
~10 m/s

https://doi.org/10.5194/tc-2021-279
Preprint. Discussion started: 29 September 2021

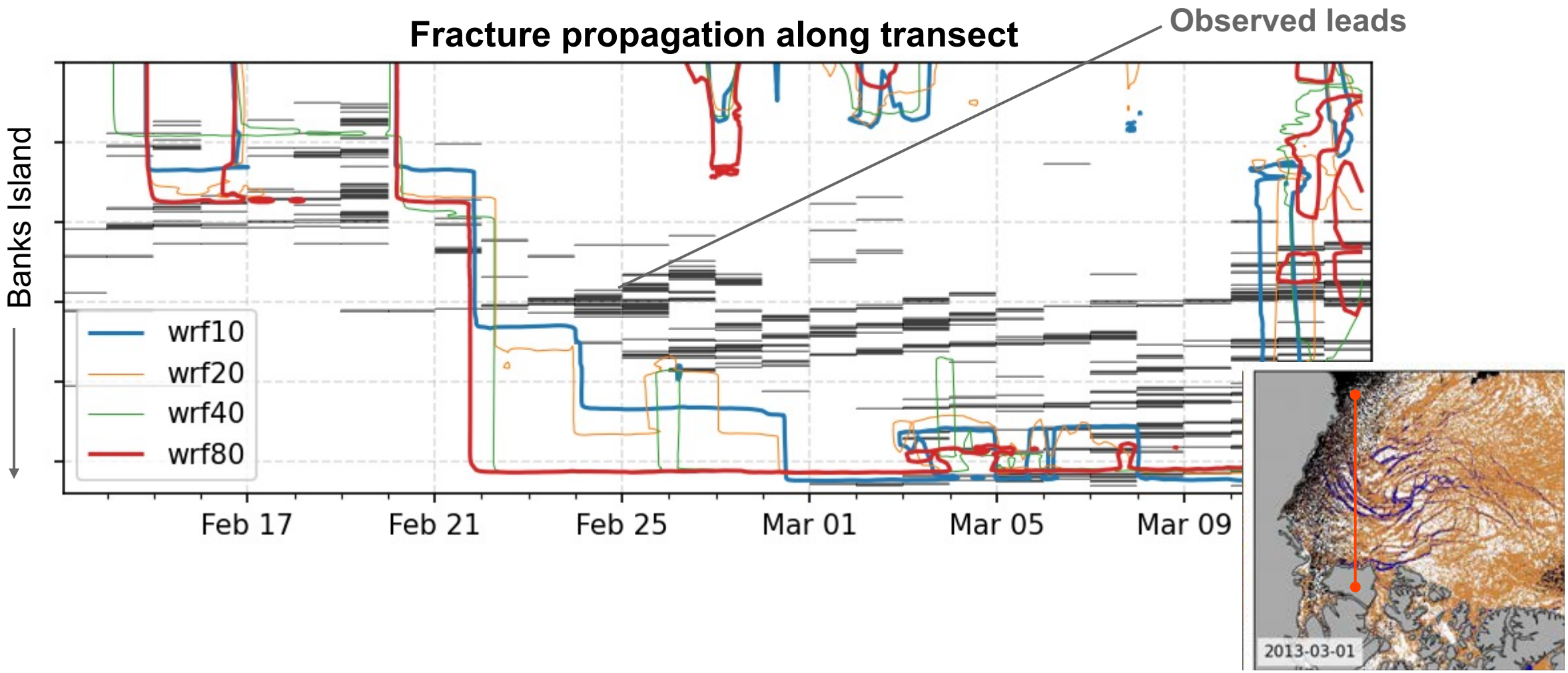
The Cryosphere Discussions
EGU

Causes and Evolution of Winter Polynyas over North of Greenland

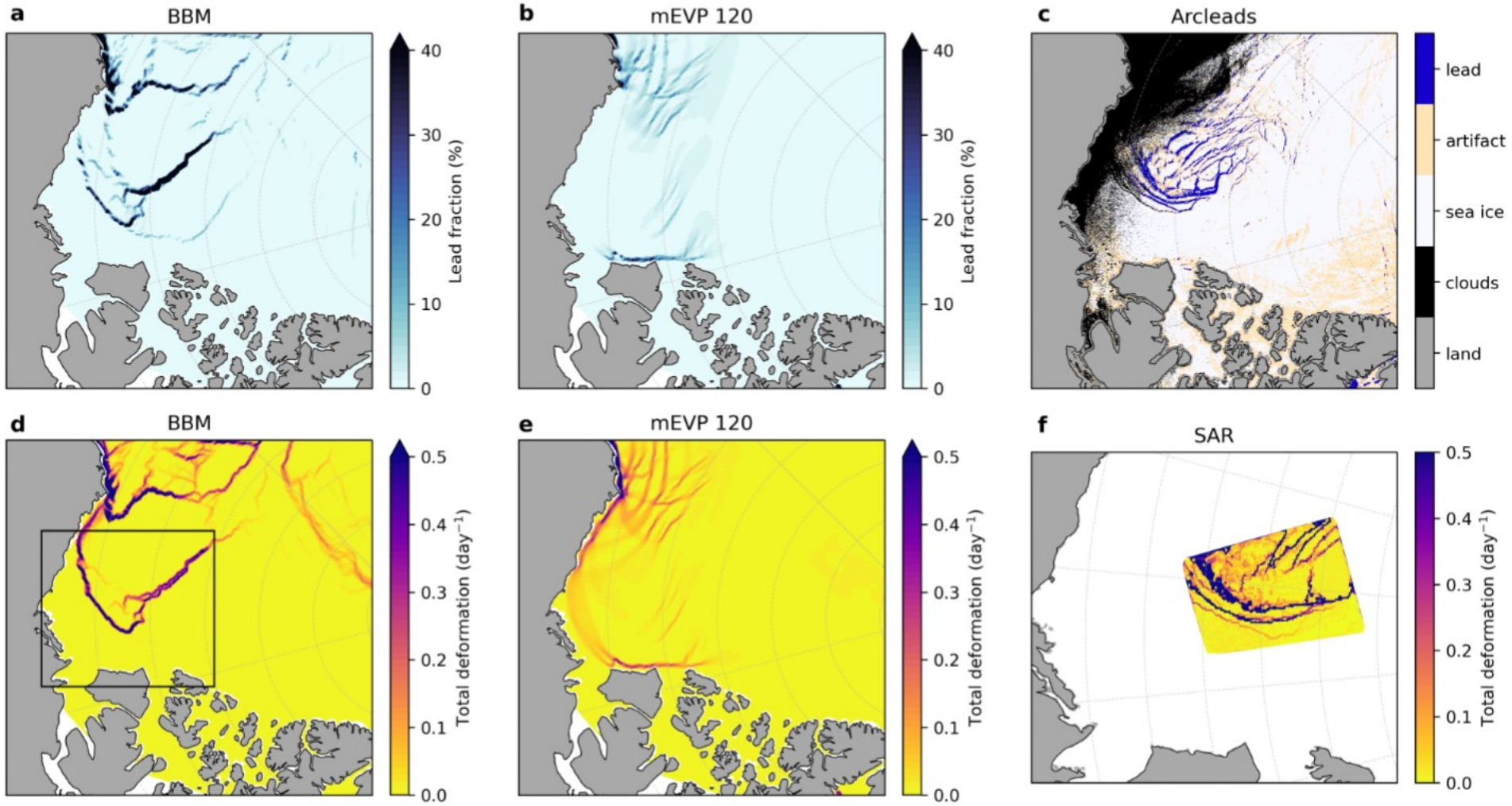
Younjoo J. Lee[1], Wieslaw Maslowski[1], John J. Cassano[2,3], Jaclyn Clement Kinney[1], Anthony P. Craig[4], Samy Kamal[5], Robert Osinski[6], Mark W. Seefeldt[2,3], Julienne Stroeve[2,7], Hailong Wang[8]

the majority of sea ice loss. Our analysis suggests that strong southerly winds (i.e., northward wind with speeds of greater than 10 m/s) blowing persistently for at least 2 days or more, were required over the study region to mechanically redistribute some of the thickest sea ice out of the region and thus to create open water areas (a latent heat polynya). In order to assess the role of internal variability versus external

Impact of atmospheric resolution on breakup

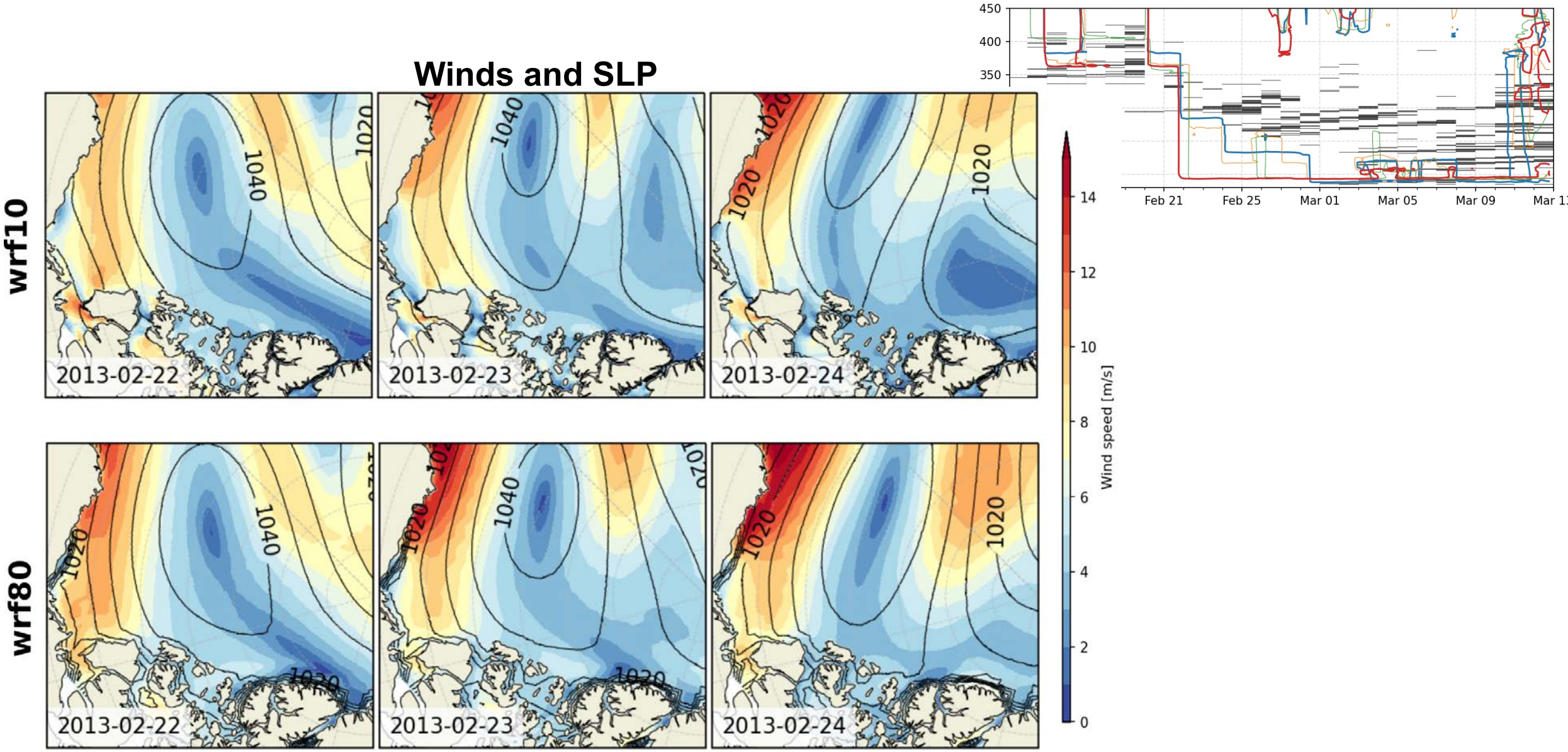


Comparison with optical and SAR data

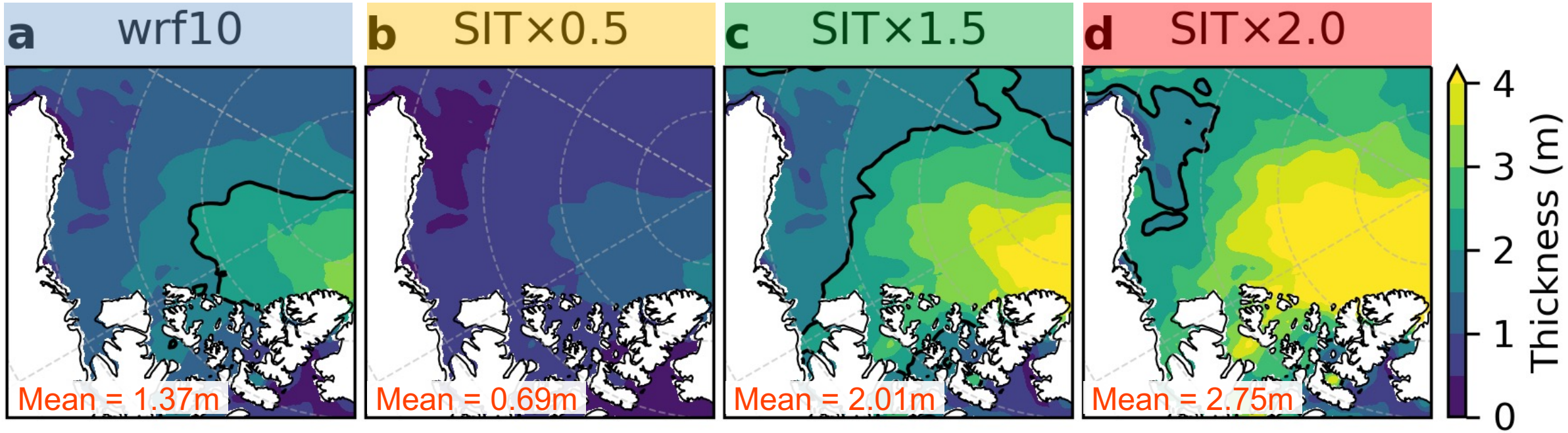


Simulated and observed lead fraction (a-c) and deformation rates (d-f) on February 25. The breakup is simulated using the (a,d) Brittle Bingham-Maxwell (BBM) and (b,e) the modified elastic–viscous–plastic (mEVP) rheology.

Impact of atmospheric resolution on breakup



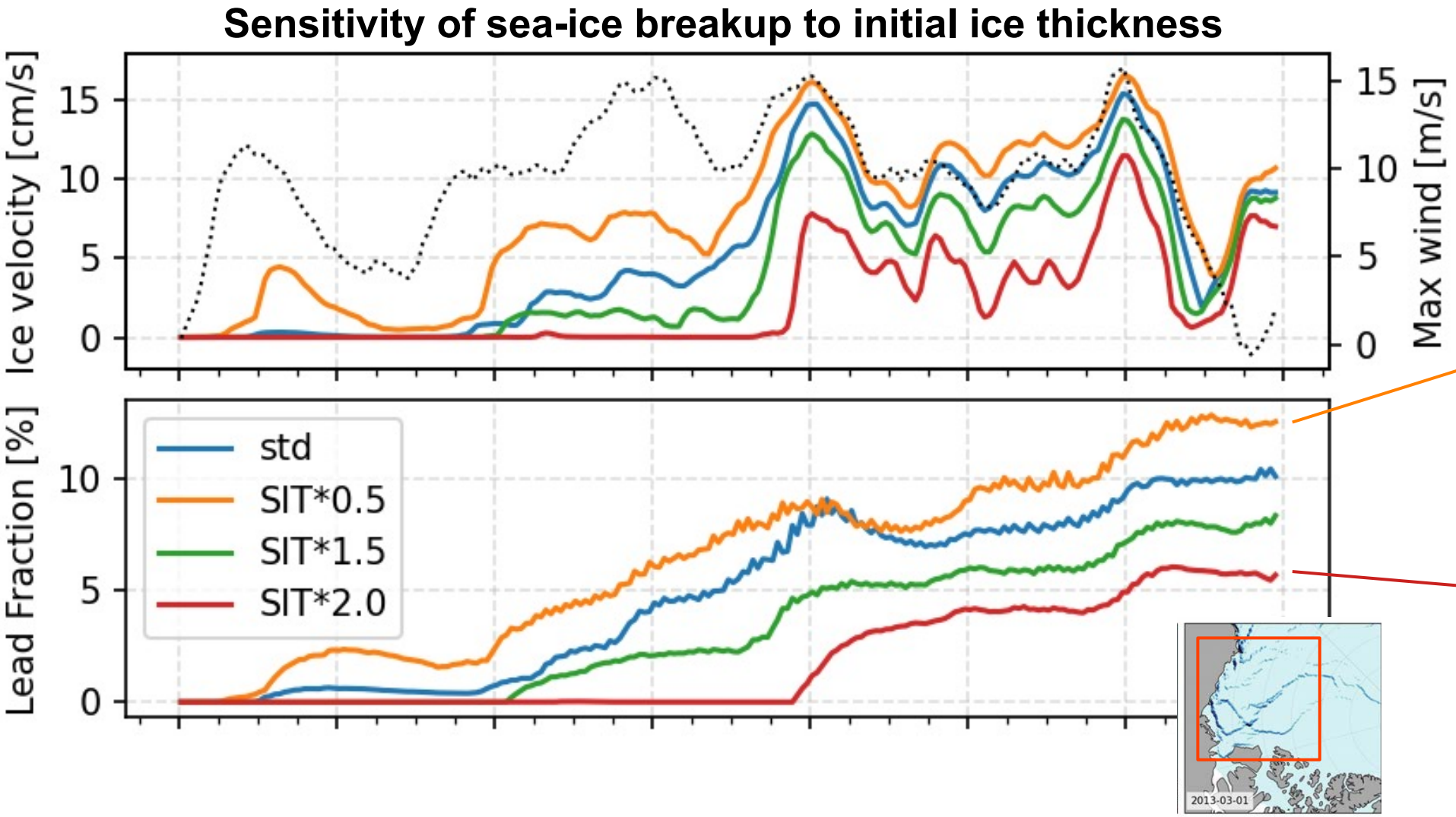
Impact of ice thickness on breakup



”Future scenario”

Conditions before the 2000’s

Impact of ice thickness on breakup



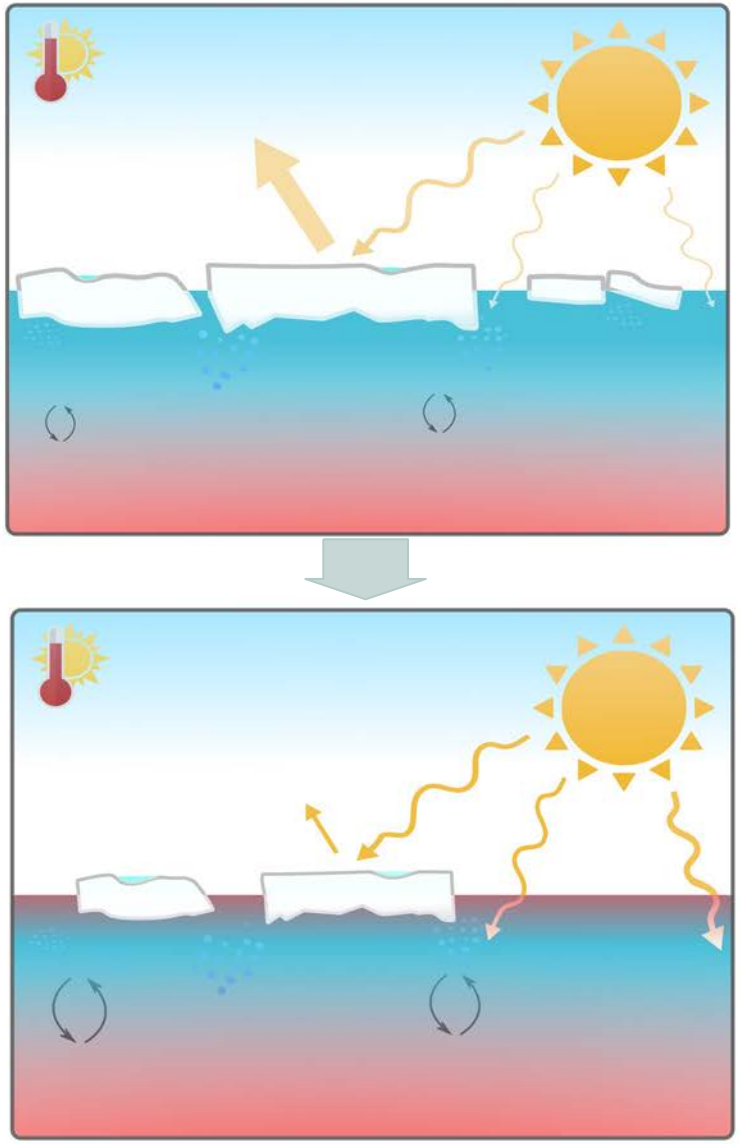
Thinner ice:
Easier to break + more leads

Thicker ice:
stronger winds required to break ice

Local impacts of sea ice breakup and their wider implications for Arctic sea ice

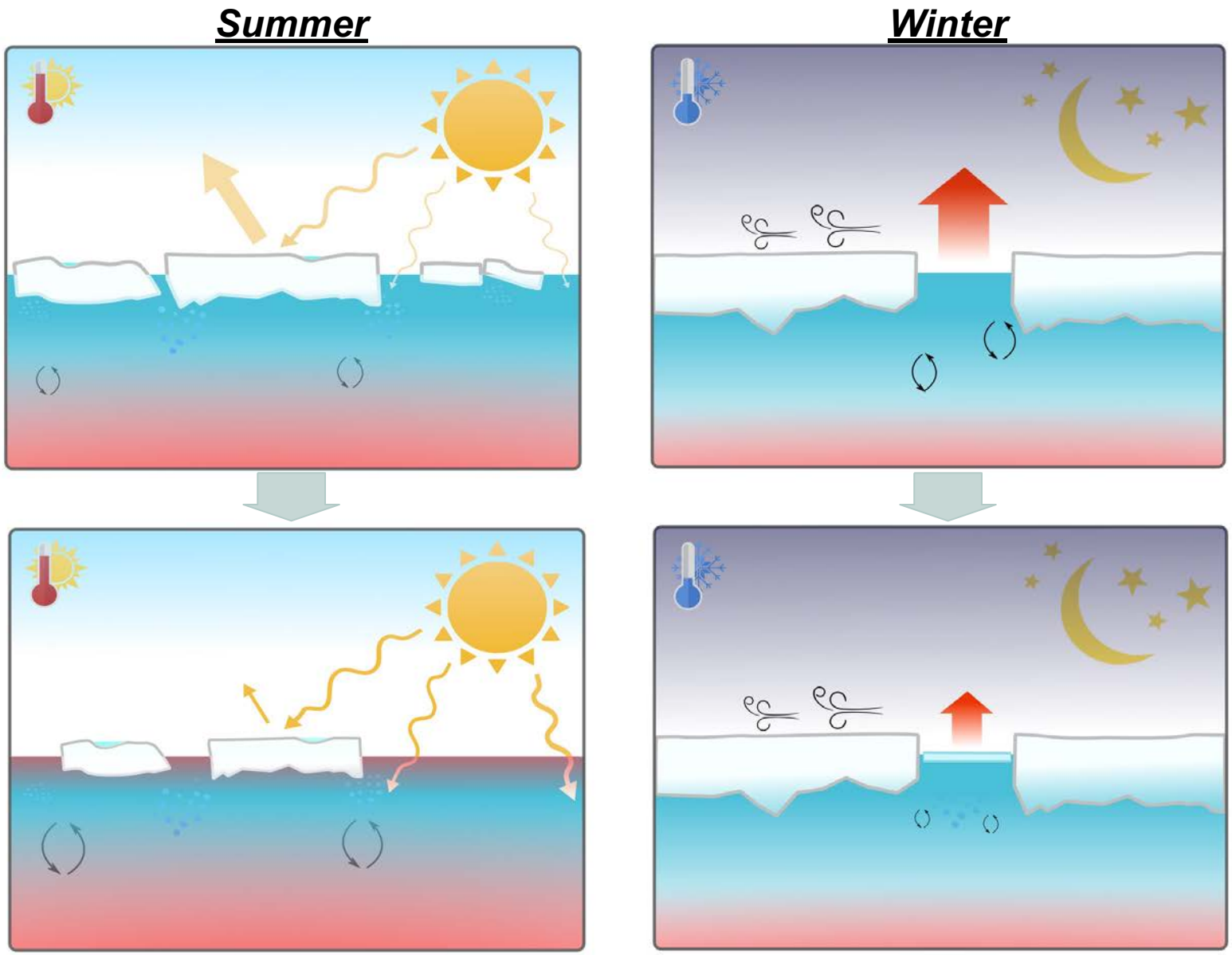
Impacts of winter breakup events

Summer



- More solar energy absored by ocean
- Accelerates sea ice melt

Impacts of winter breakup events

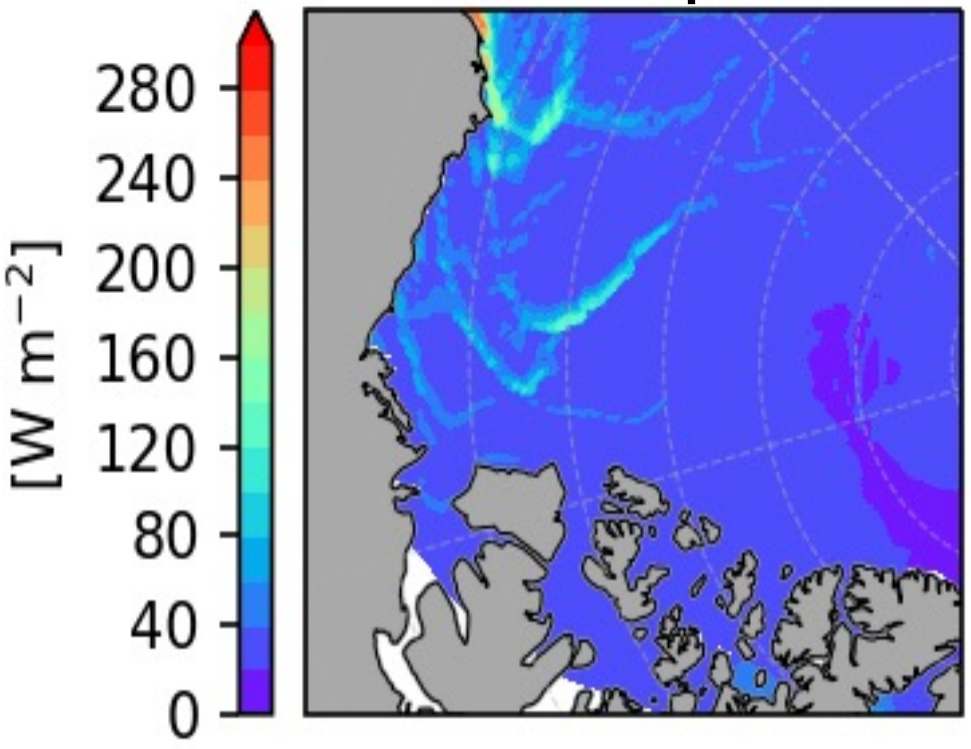


- More solar energy absored by ocean
- Accelerates sea ice melt

- Intense heat loss in open sea-ice leads
- Promotes new ice formation

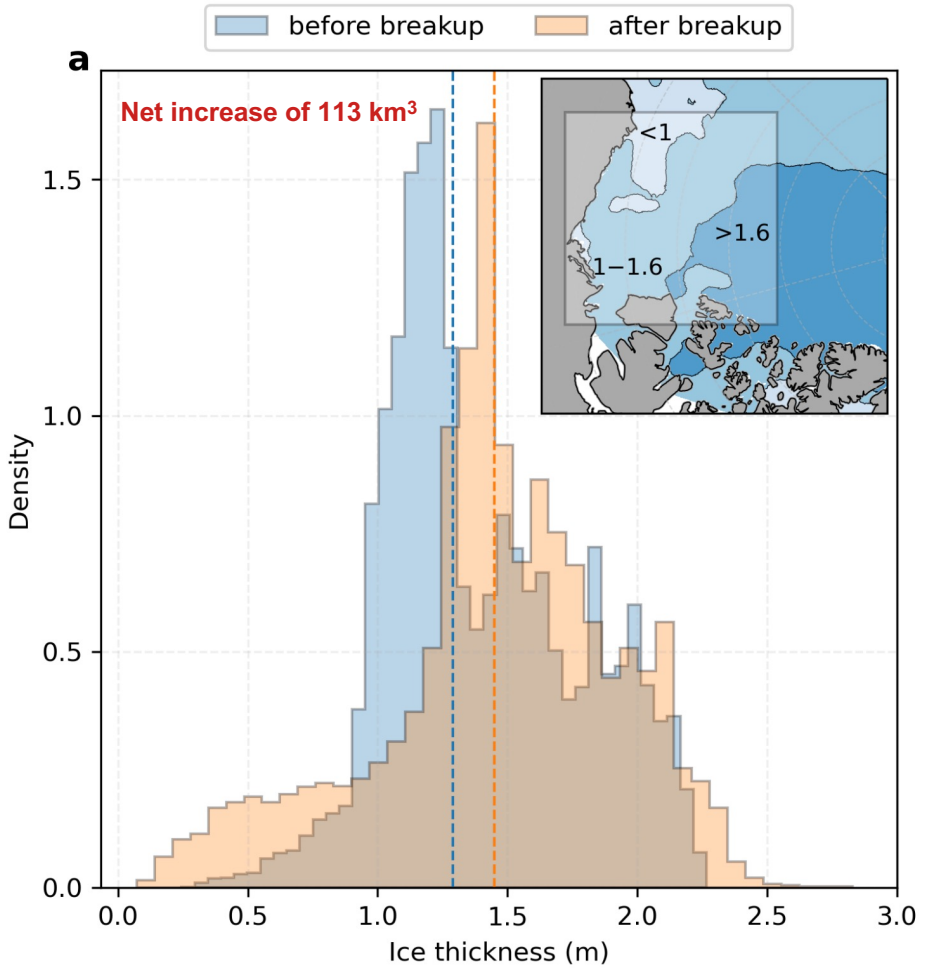
Breakup enhances local ice growth

Heat loss in open leads



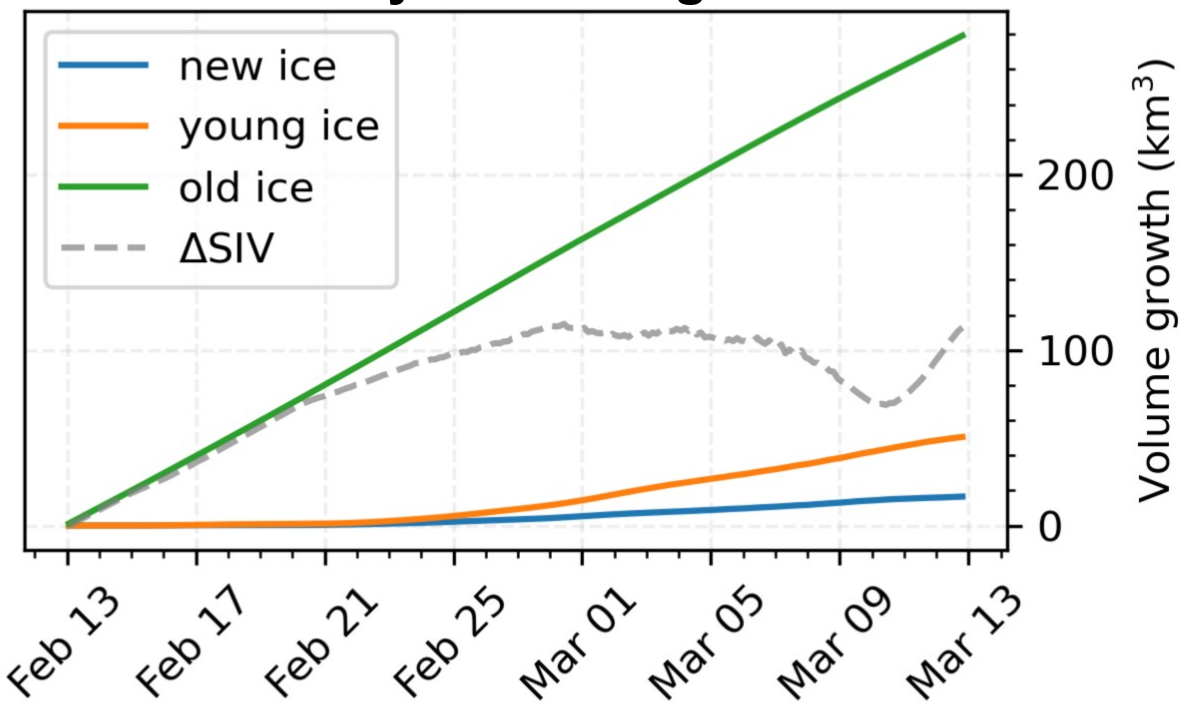
$$\Delta SIV = \Delta SIV_{thermo} + \Delta SIV_{dynamic}$$

Changes in thickness distribution



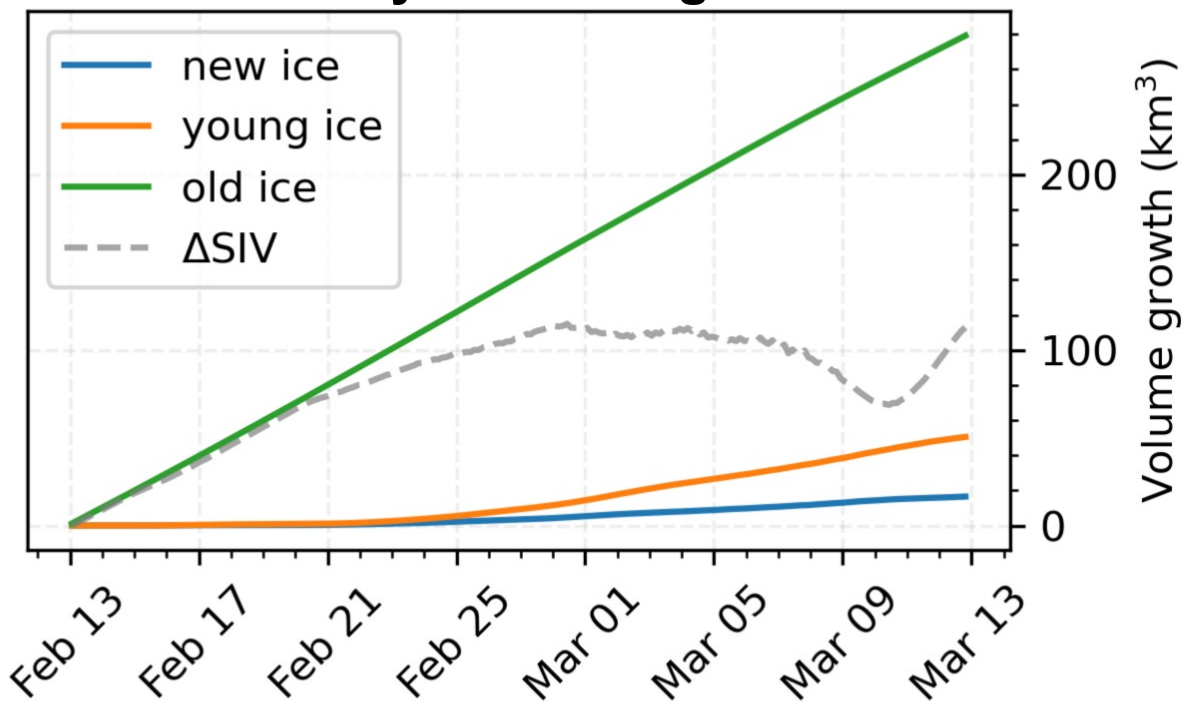
Impact on ice growth and volume budget

Thermodynamic ice growth

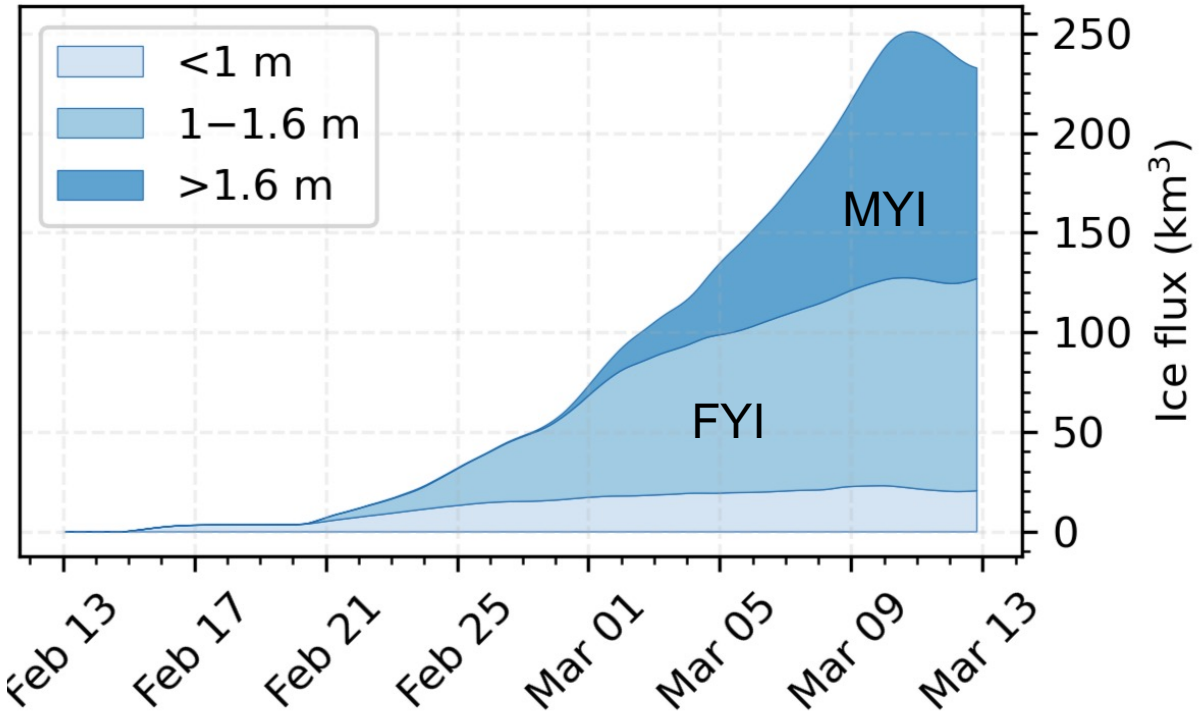


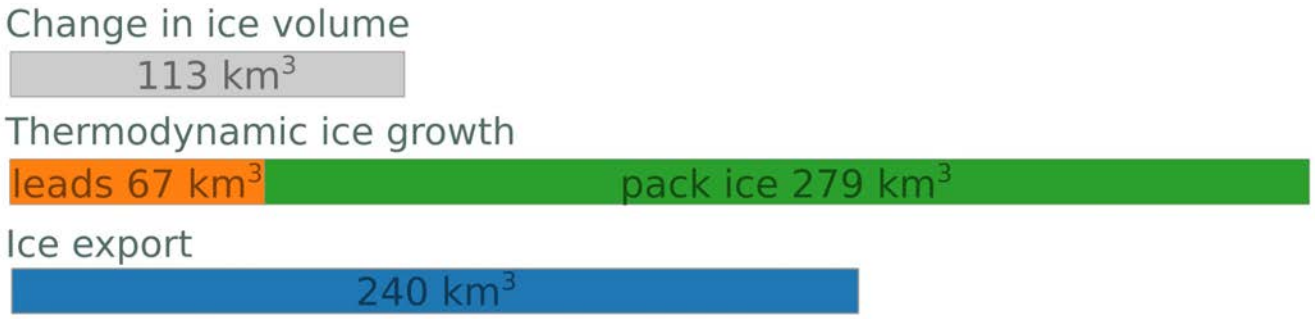
Impact on ice growth and volume budget

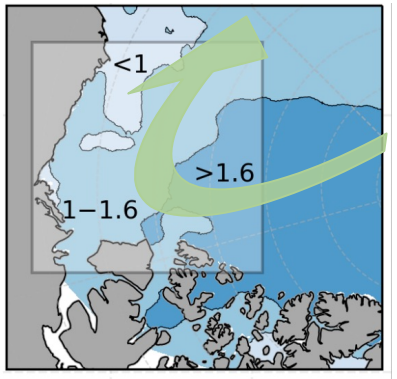
Thermodynamic ice growth



Sea ice export out of the Beaufort Sea

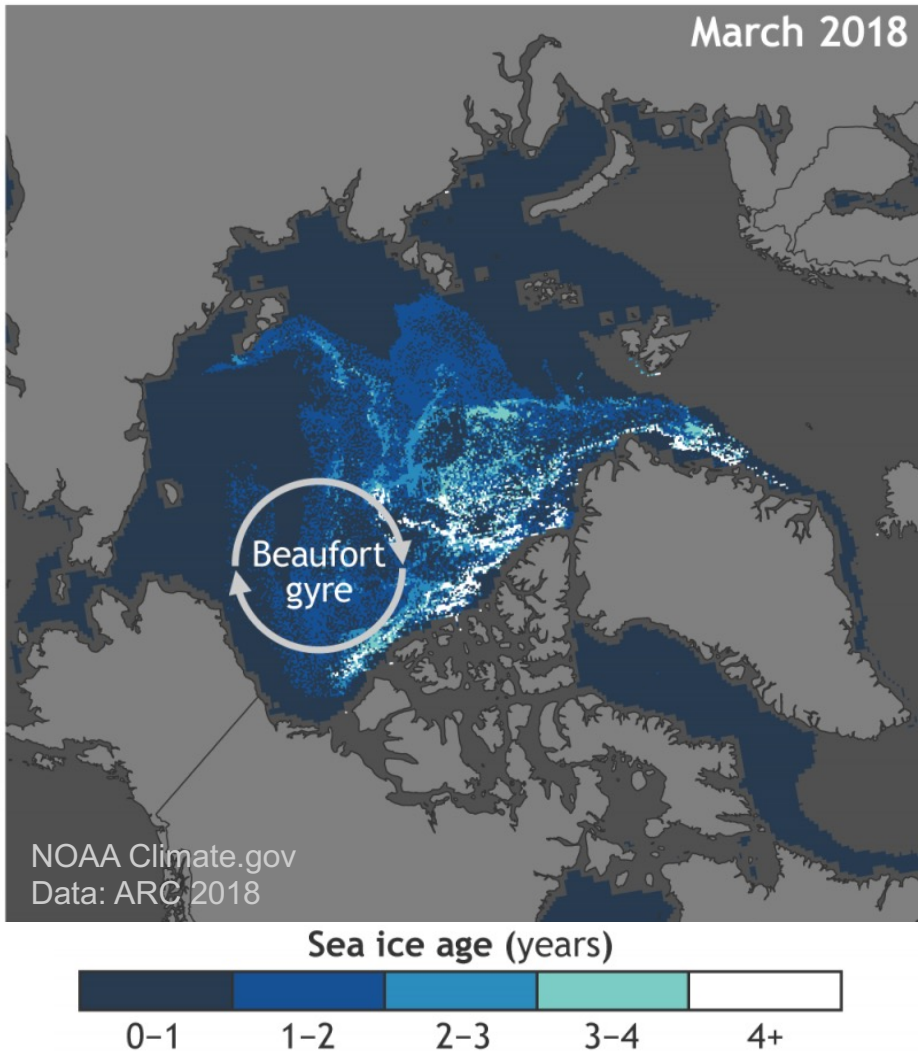






Implications for Arctic sea-ice loss

Accelerated loss of MYI?

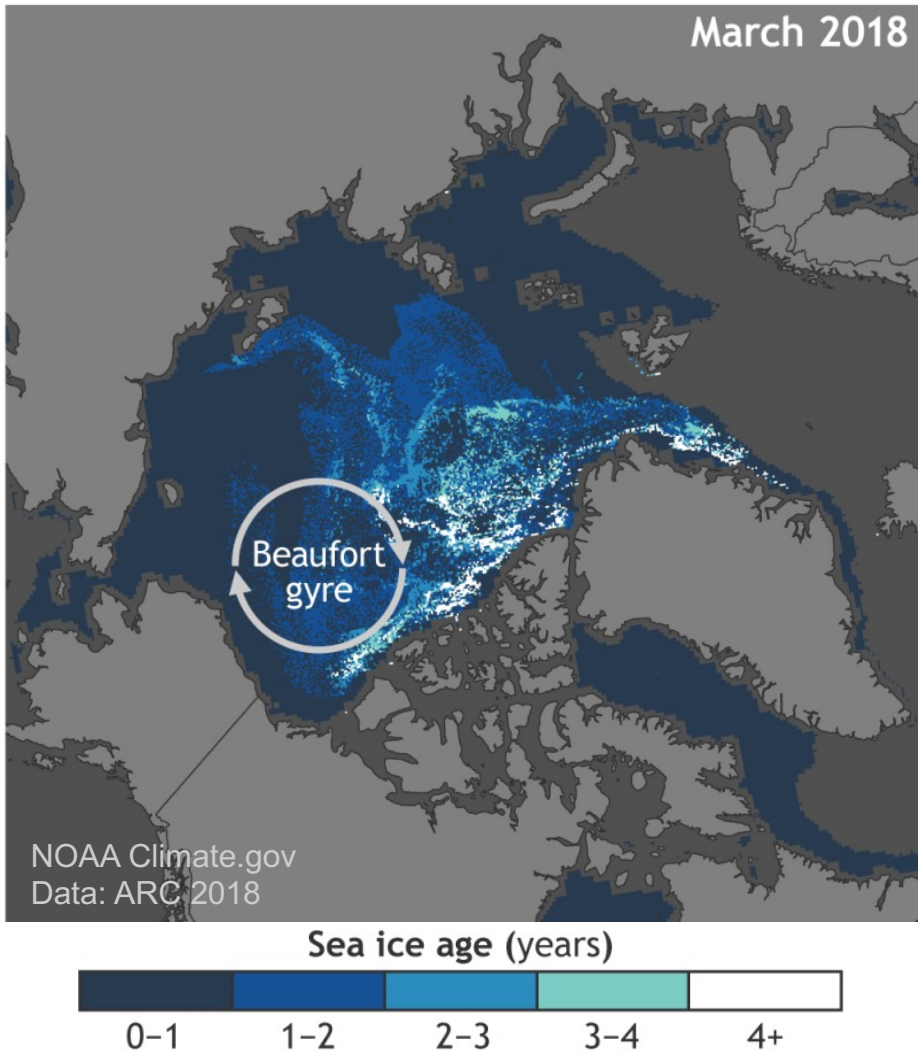


« ... we are seeing the Beaufort Sea go from a nursery to a graveyard for older ice»

Walt Meier, scientist at NSIDC

Implications for Arctic sea-ice loss

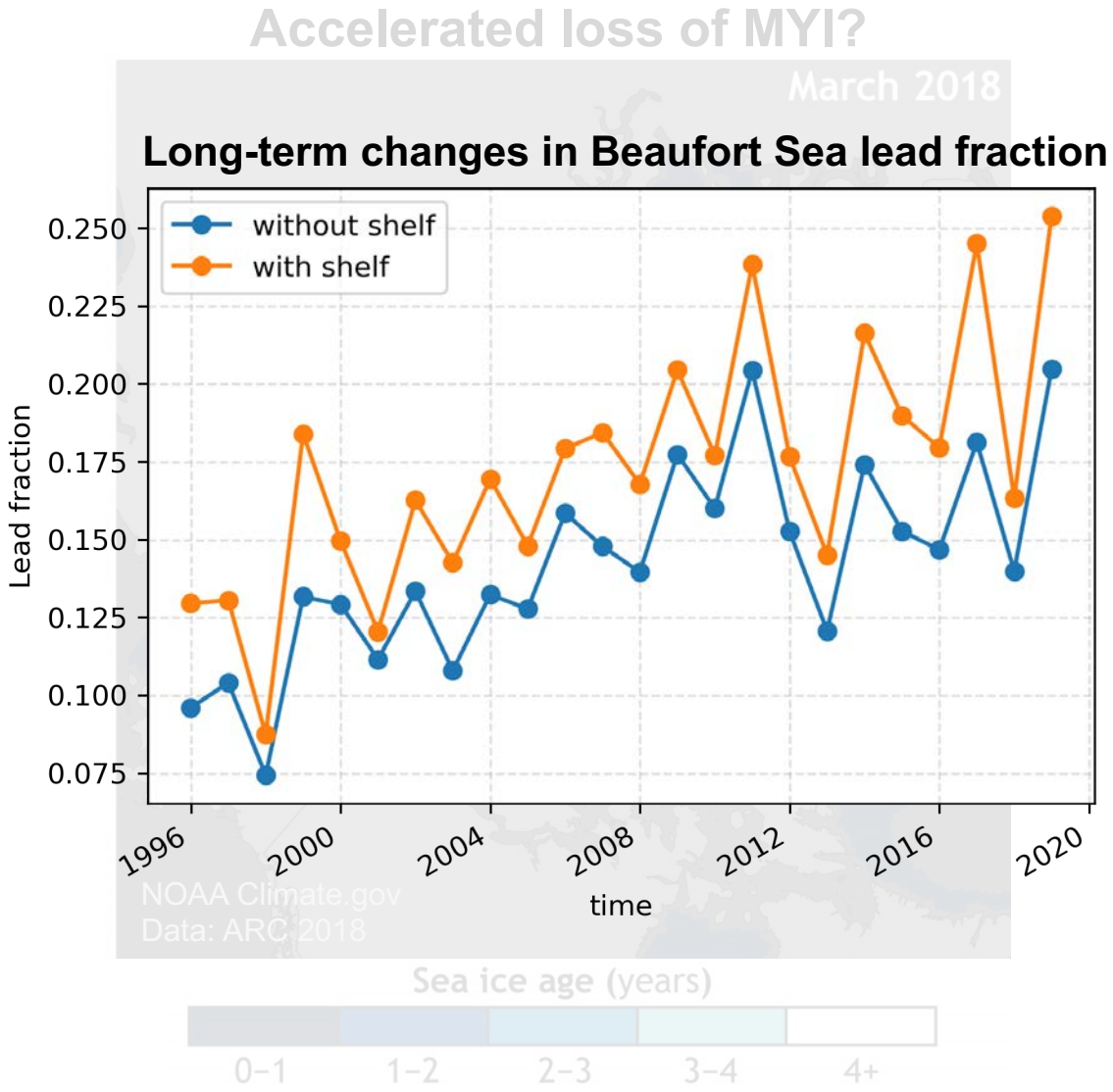
Accelerated loss of MYI?



OPEN QUESTIONS

- How does winter breakup events impact the timing of *spring break-up* and affect long-term Arctic sea-ice mass balance?
- Missing ocean/atmospheric feedbacks?
- Has the frequency of breakup events changed over time?

Implications for Arctic sea-ice loss



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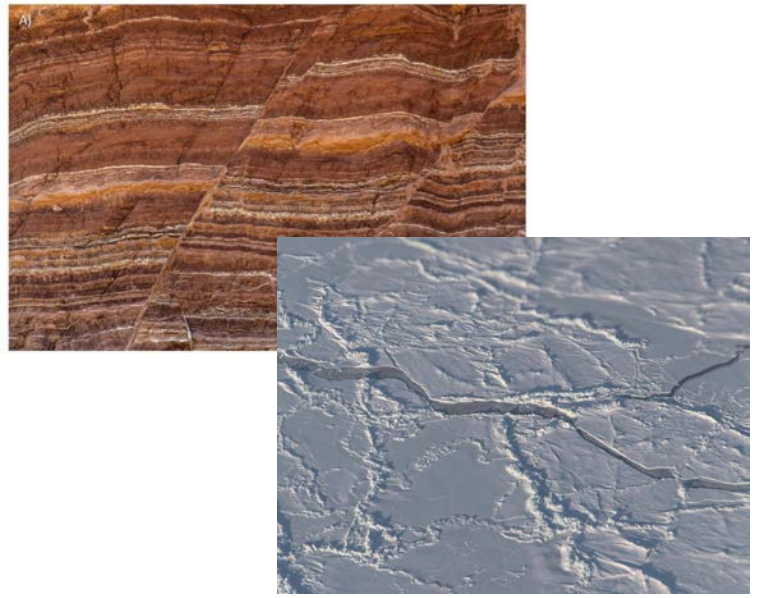
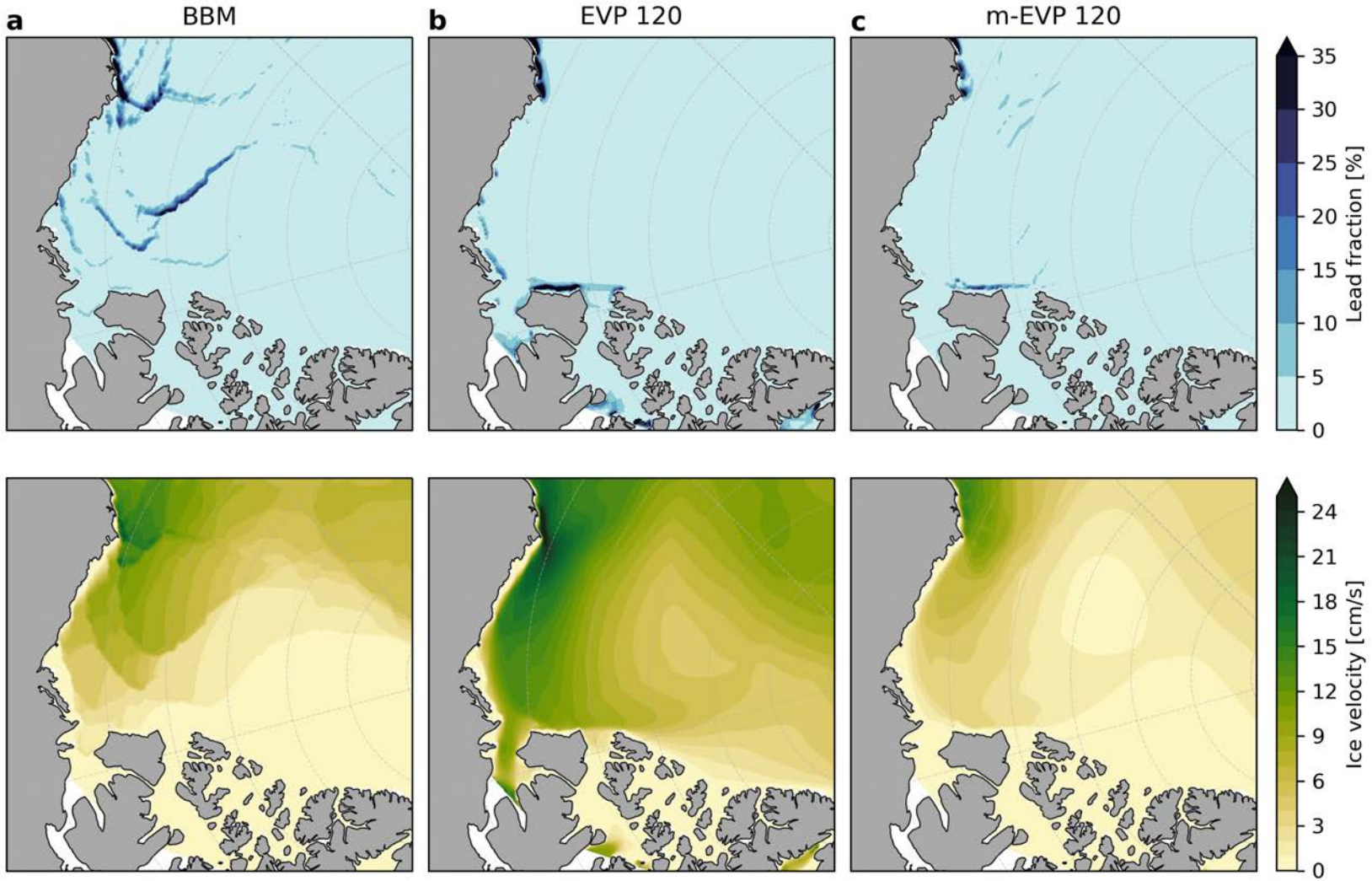
Ridges in sea ice*, Disko Island, Grønland*

Brittle sea ice rheology as a key factor

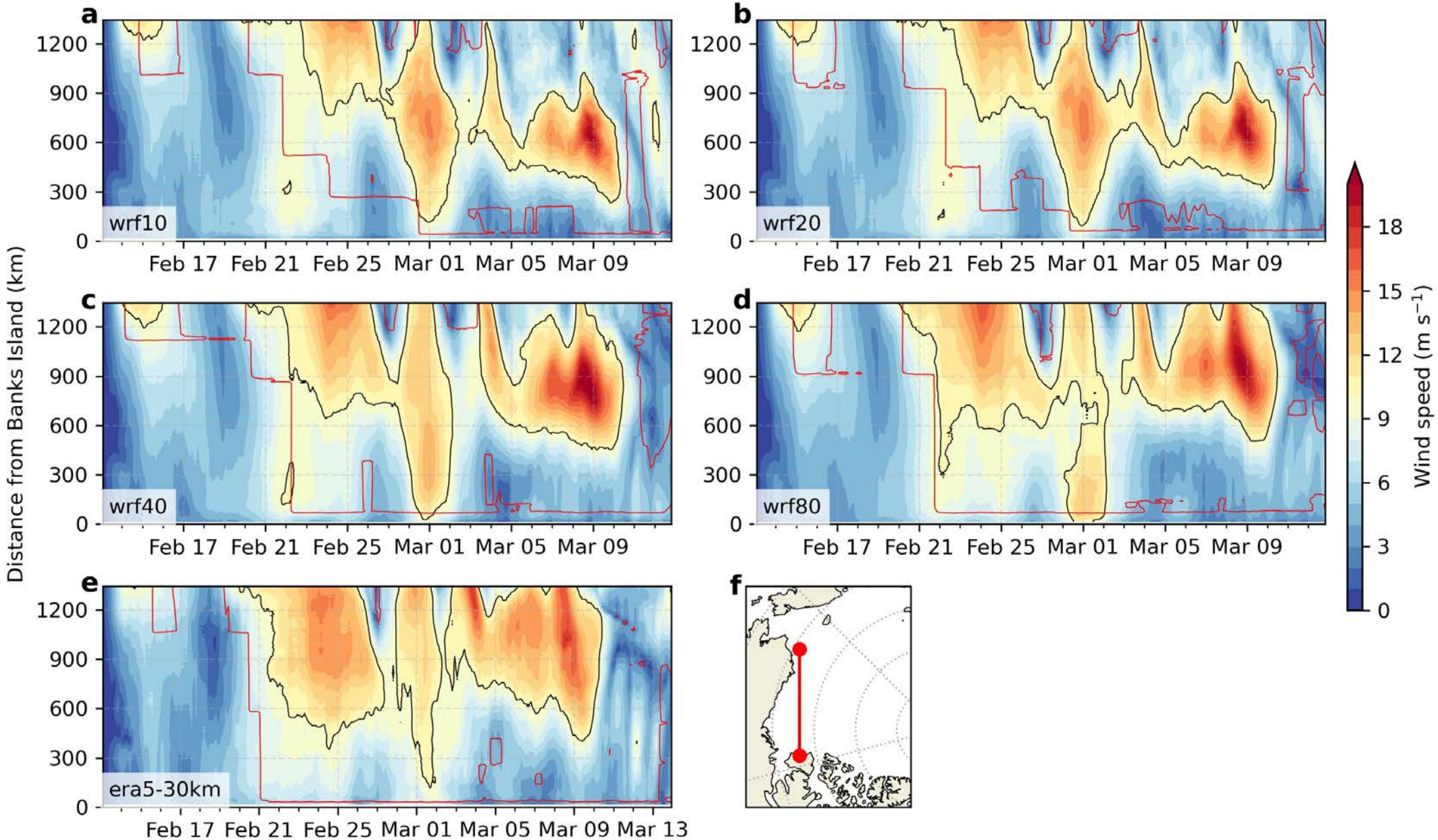


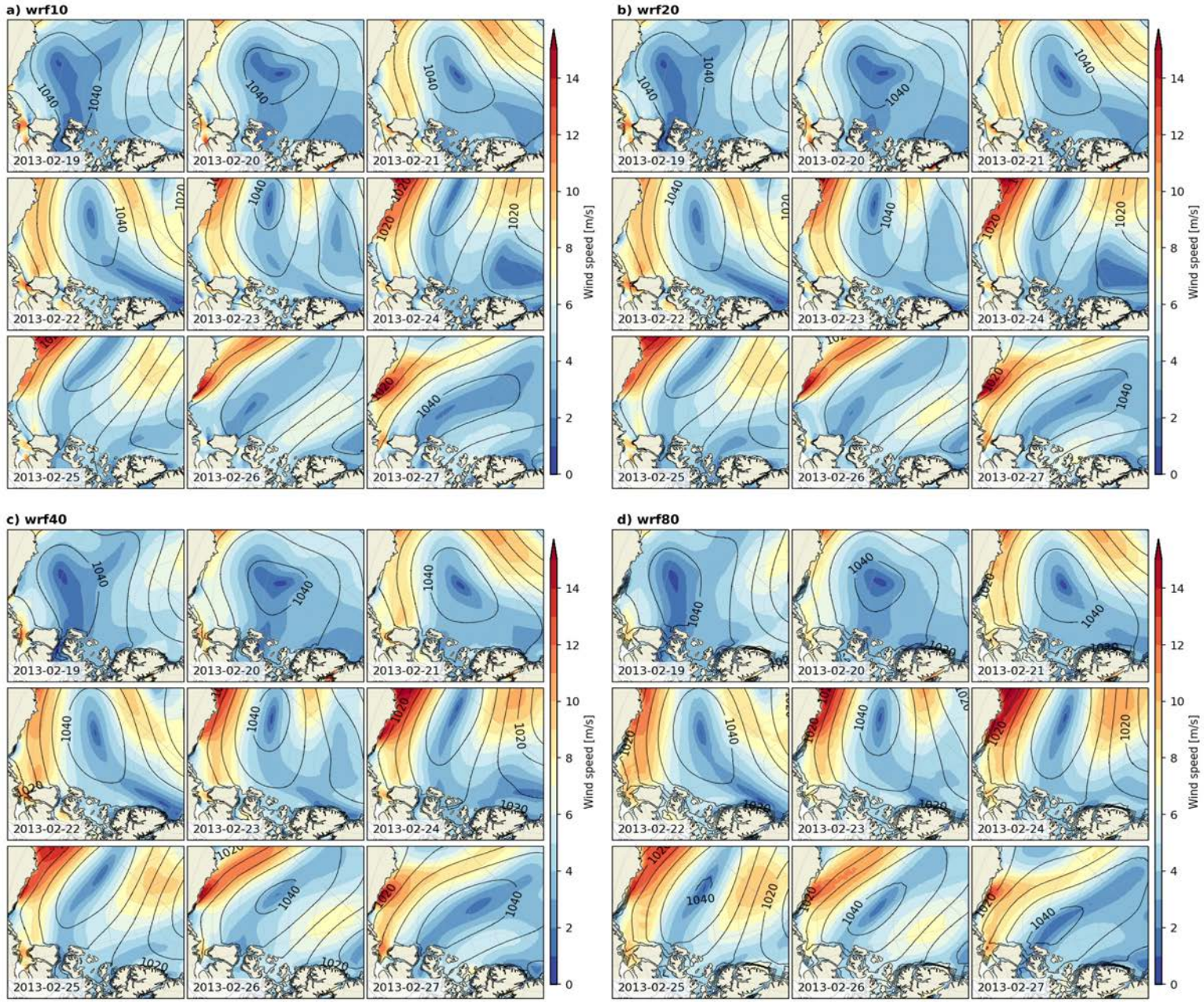
Sensitivity to different sea ice rheologies

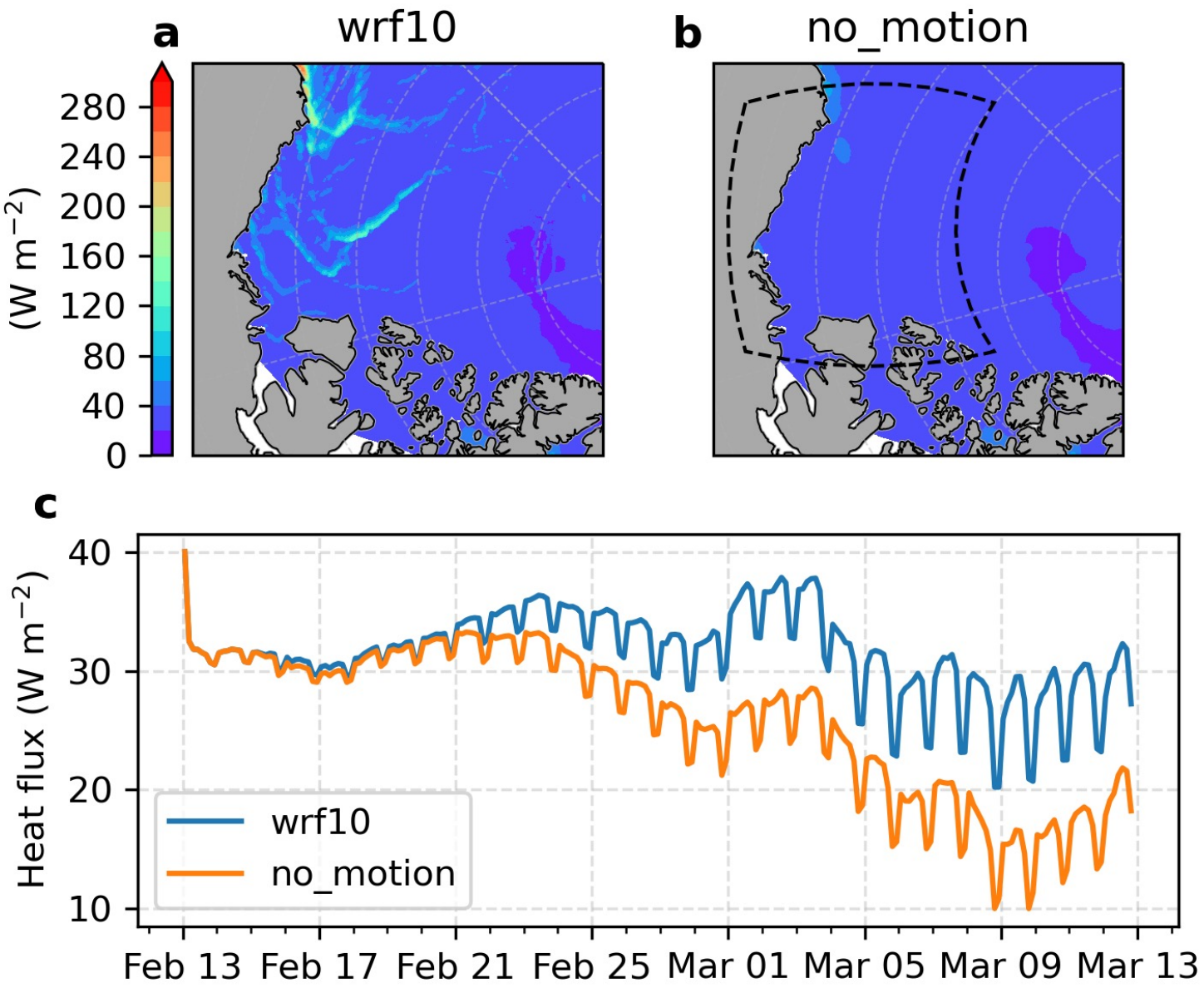


- Same model resolution
- Same atmospheric forcing (*WRF10*)
- **Only rheology is changed**

Brittle Bingham-Maxwell (BBM)


a
b
c
d
e
f
wrf10
wrf20
wrf40
wrf80
era5-30km
Distance from Banks Island (km)
0
300
600
900
1200
Feb 17
Feb 21
Feb 25
Mar 01
Mar 05
Mar 09
Mar 13
Wind speed (m s^{-1})
0
3
6
9
12
15
18


a) wrf10
b) wrf20
c) wrf40
d) wrf80
2013-02-19
2013-02-20
2013-02-21
2013-02-22
2013-02-23
2013-02-24
2013-02-25
2013-02-26
2013-02-27
1040
1020
Wind speed [m/s]
0
2
4
6
8
10
12
14


a
wrf10
b
no_motion
280
240
200
160
120
80
40
0
(W m^{-2})
c
Heat flux (W m^{-2})
40
30
20
10
wrf10
no_motion
Feb 13
Feb 17
Feb 21
Feb 25
Mar 01
Mar 05
Mar 09
Mar 13