Sea-ice mass balance in the Arctic in a new ice—ocean coupled model: impact of sea ice deformations

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Introduction

- Sea ice is at the interface between the ocean and the atmosphere
- Sea ice cover is highly heterogeneous → leads, openings through which a large part of air-sea exchange takes place → needs to be quantified!
- For instance, leads likely contribute significantly to winter ice production→ How much?

Breakup event in the Beaufort Sea (Feb. 2013)

NERSC

Introduction

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To quantify this impact, we need to reproduce this heterogeneity in our models

Breakup event in the Beaufort Sea (Feb. 2013)

Introduction

Problem:

State-of-the-art sea ice models struggle to reproduce this heterogeneity

For resolution> 5km, **modelled** sea ice properties are very **homogeneous**

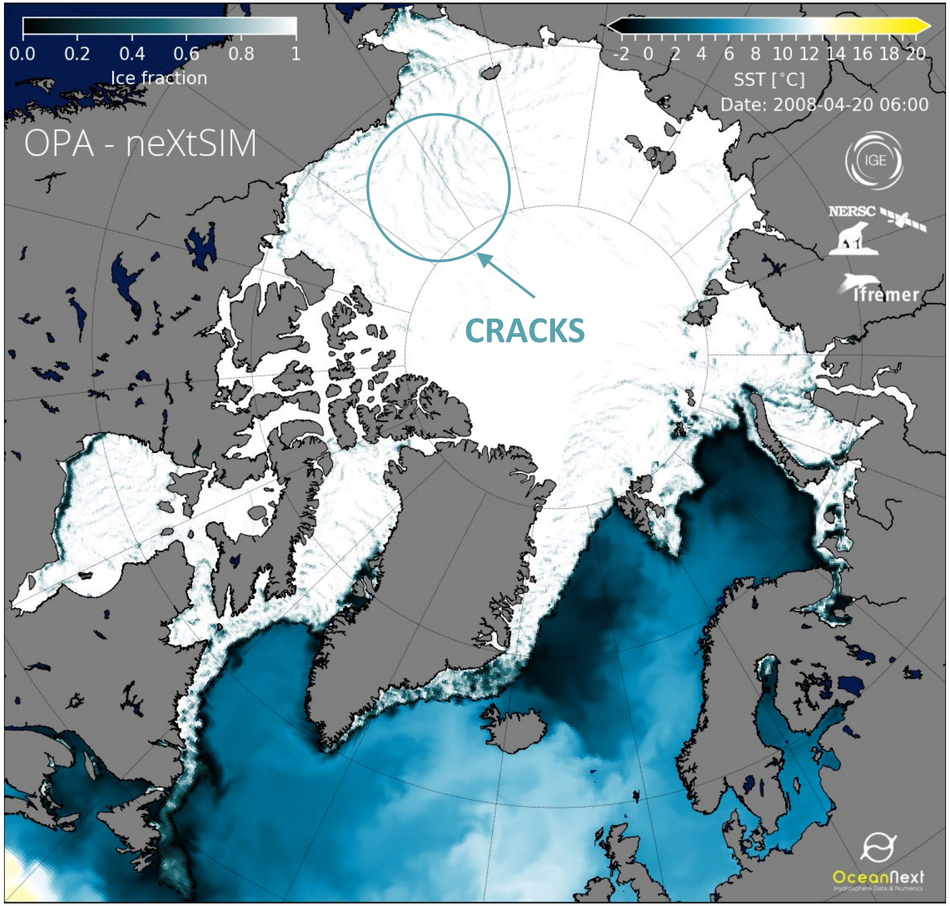
Solution:

Using a sea ice model with a brittle rheology

Sea ice model: neXtSIM
Ocean model: OPA (NEMO)

Simulations start in 1995 and stop end of 2018.

Horizontal resolution is 0.25deg (12km in the Arctic)



Plotting tools: Laurent Brodeau

Introduction

Changing rheology impacts:

- Large-scale motions (transport)
- Deformations (leads, ridges)
- Thermodynamics (indirectly)

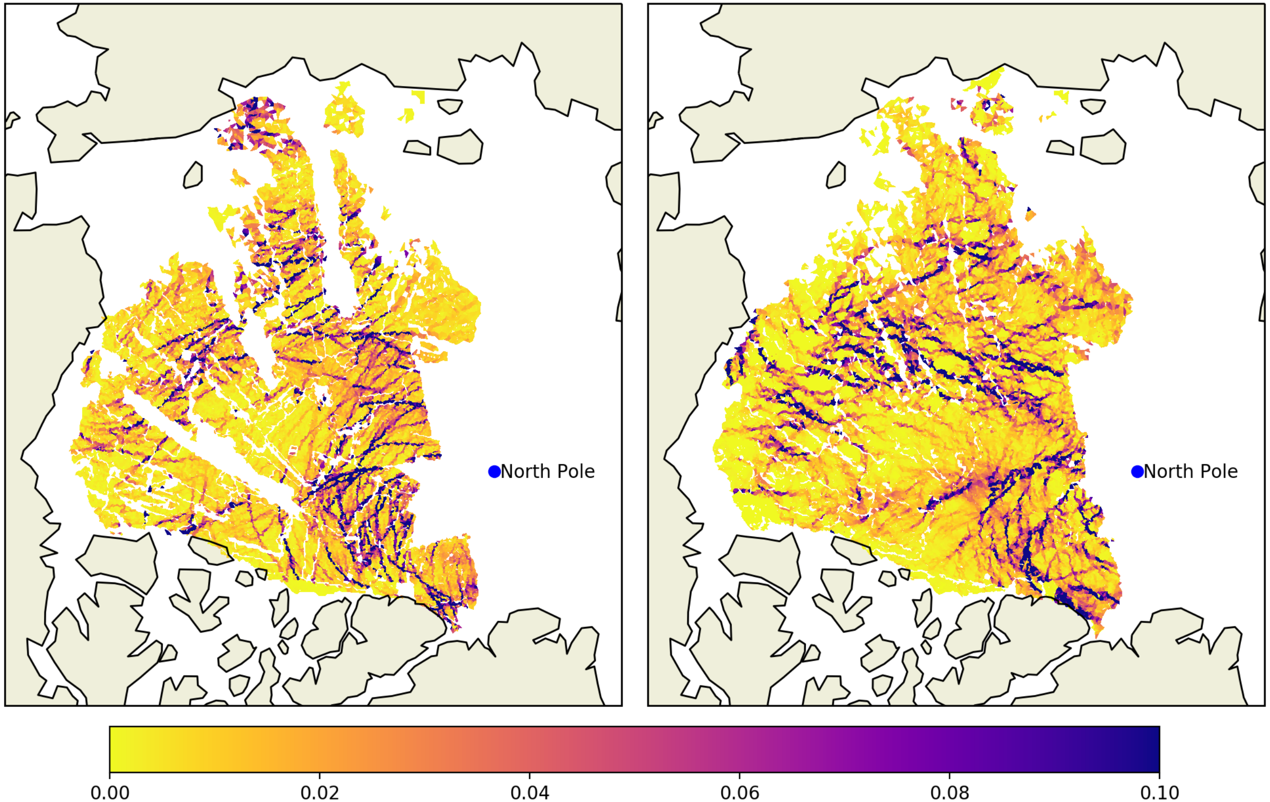
→ **First order importance in the mass balance**

Can we get a good Arctic sea ice mass balance using a brittle rheology?

If yes, what is the impact of small-scale dynamics on this mass balance?

Sea ice evaluation in the model

Sea ice deformations



Shear rate on April 16th, 2007. (1/day)

The model compares very well against sea ice deformations from RGPS

This was the original objective of neXtSIM developers.

Can we do more than that?

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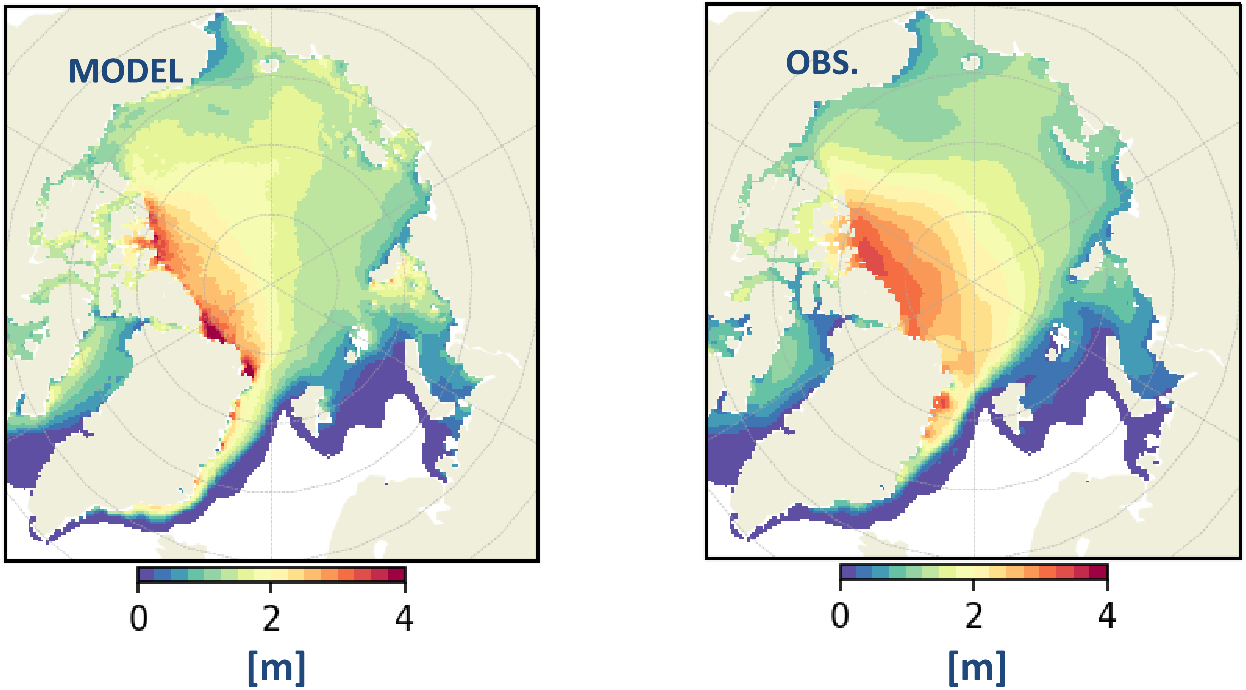
Sea ice evaluation in the model

Ex: Sea ice thickness vs CS2SMOS

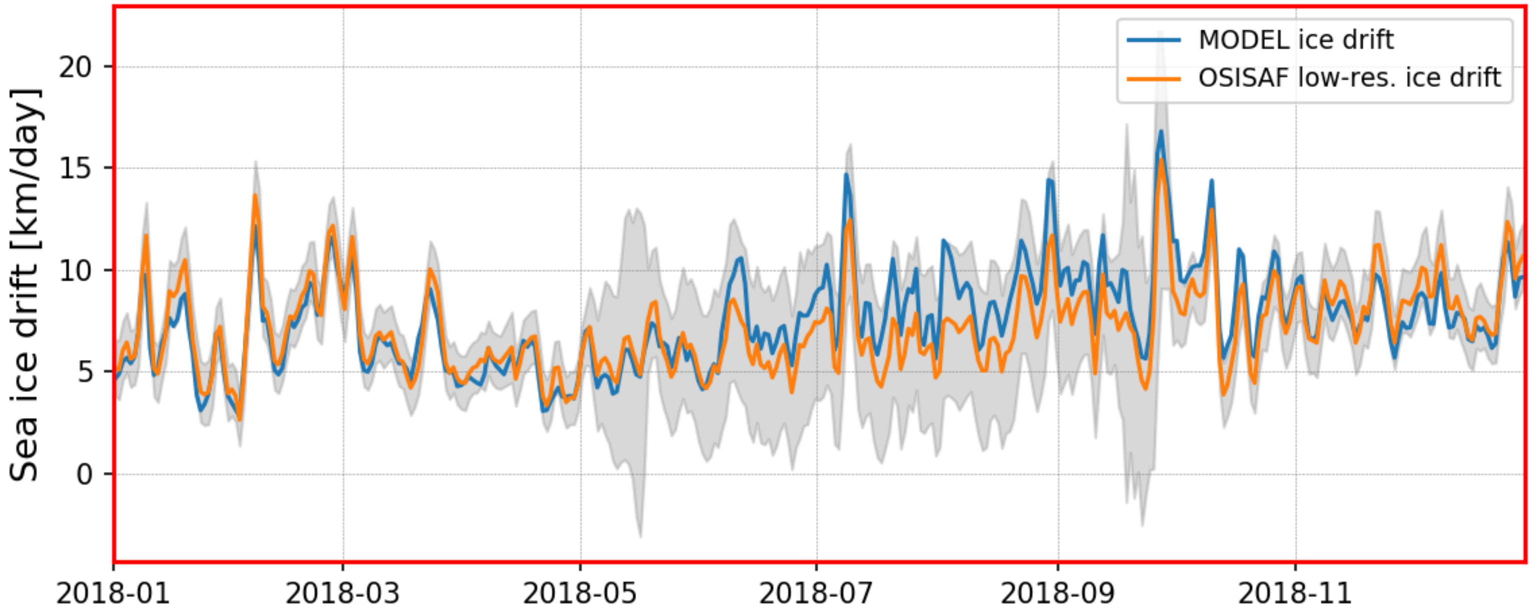


*Winter sea ice **thickness** 2011-2017 climatology*

Spatial distribution is consistent , thickness magnitude is well captured!

Sea ice evaluation in the model

Ex: Sea ice drift



***Daily Pan-Arctic sea ice drift** from MODEL and OSISAF (OBS) over 2018*

The model captures sea ice dynamics very well

Sea ice evaluation in the model

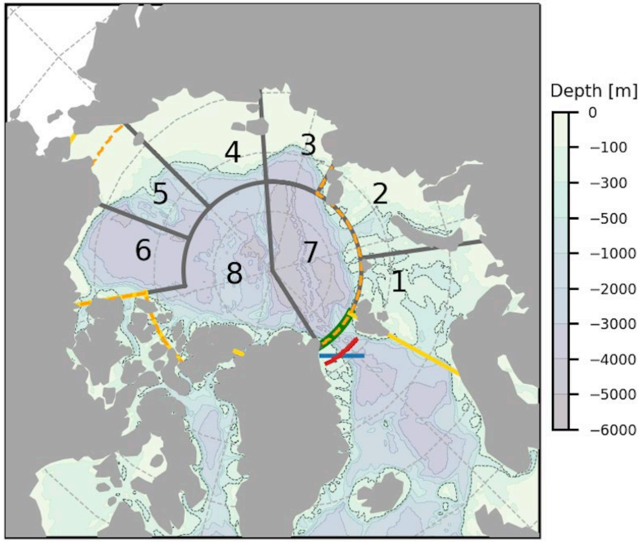
Winter mass balance:

Ricker et al., 2021

Total volume change = Dynamic change + Thermodynamic change

<u>Coverage:</u>

- 2003--2019
- November to March
- Regions 1→6



Sea ice evaluation in the model

Winter mass balance:

Ricker et al., 2021

Total volume change = Dynamic change + Thermodynamic change

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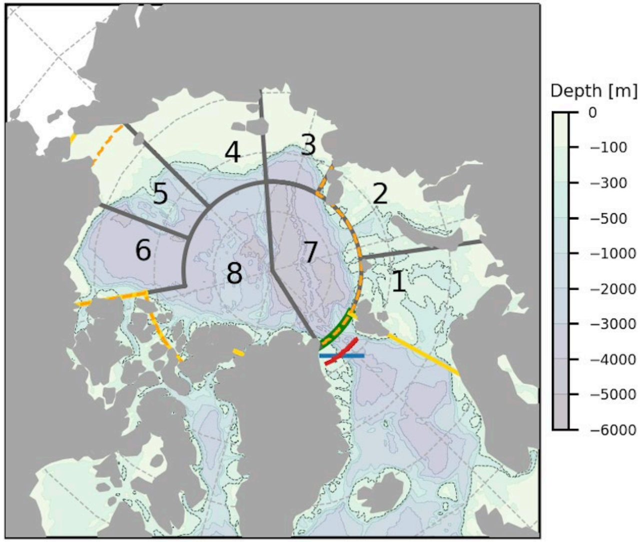


CS2/Envisat
(ESA CCI)

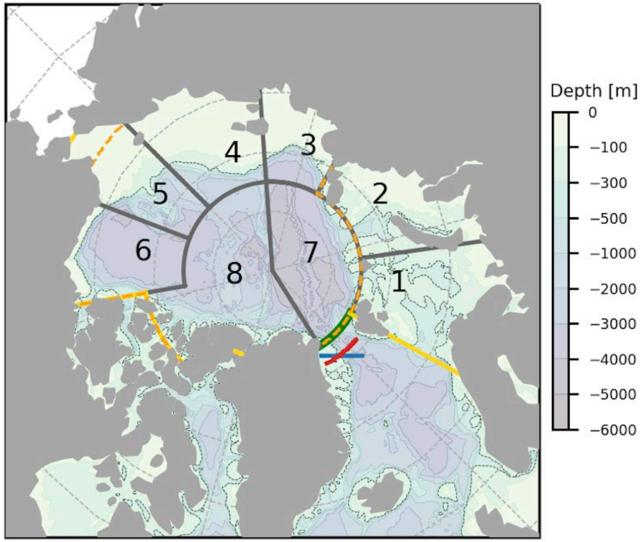
CS2/Envisat
+ monthly motions
from merged
radiometers &
scatterometers (from
CERSAT)

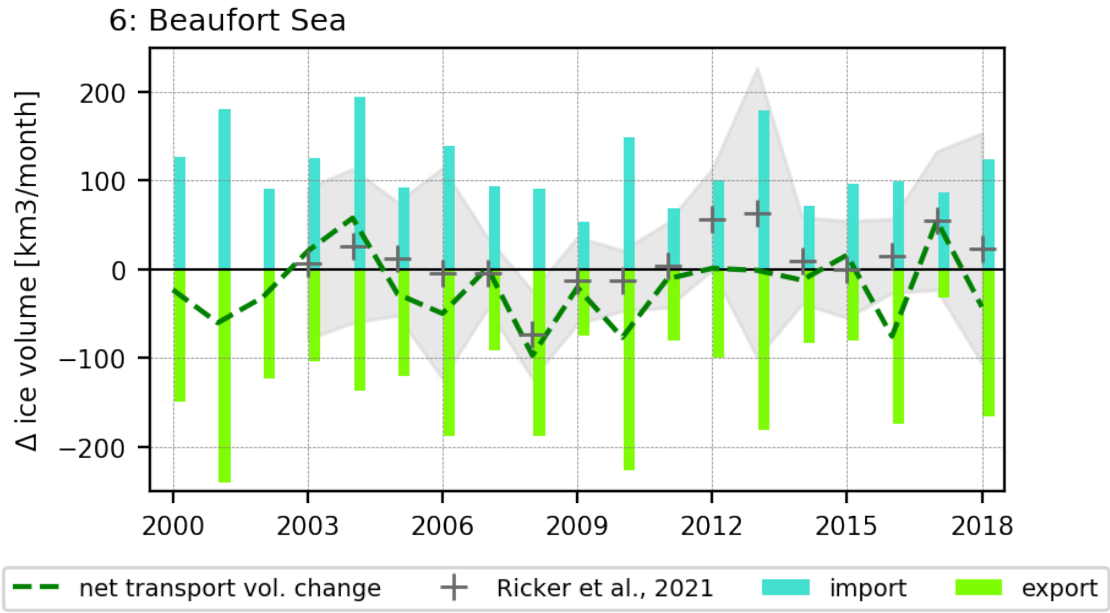
Sea ice evaluation in the model

Winter mass balance: dynamic change (import/export)

Ricker et al., 2021

Coverage:
- 2003--2019
- November to March
- Regions 1→6





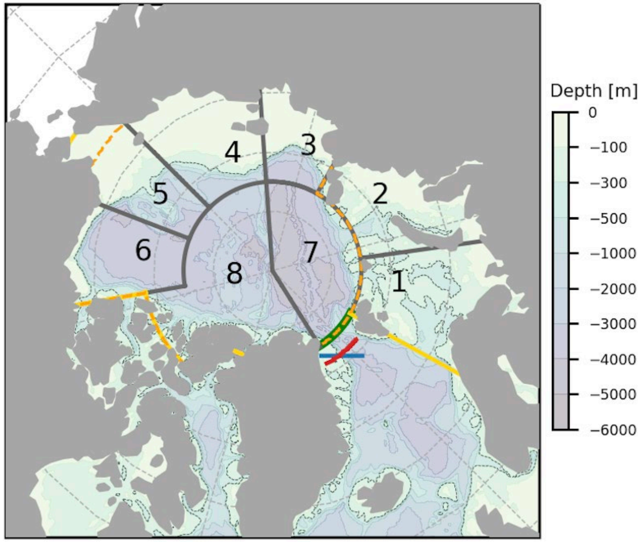
Variability is (generally) well captured!

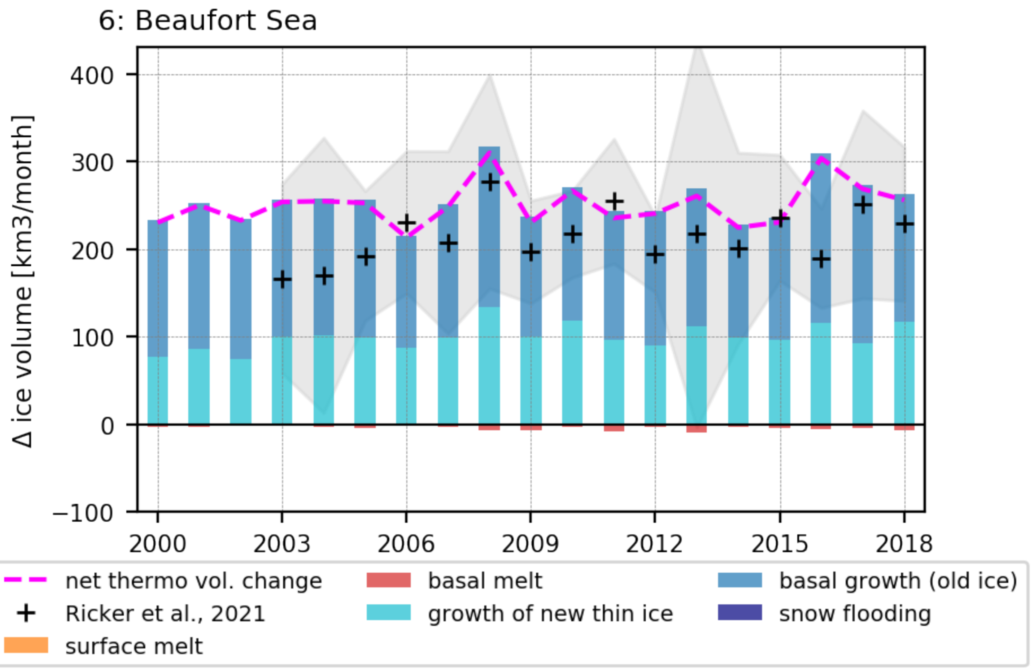
Sea ice evaluation in the model

Winter mass balance: thermodynamic change

Ricker et al., 2021

Coverage:
- 2003--2019
- November to March
- Regions 1→6



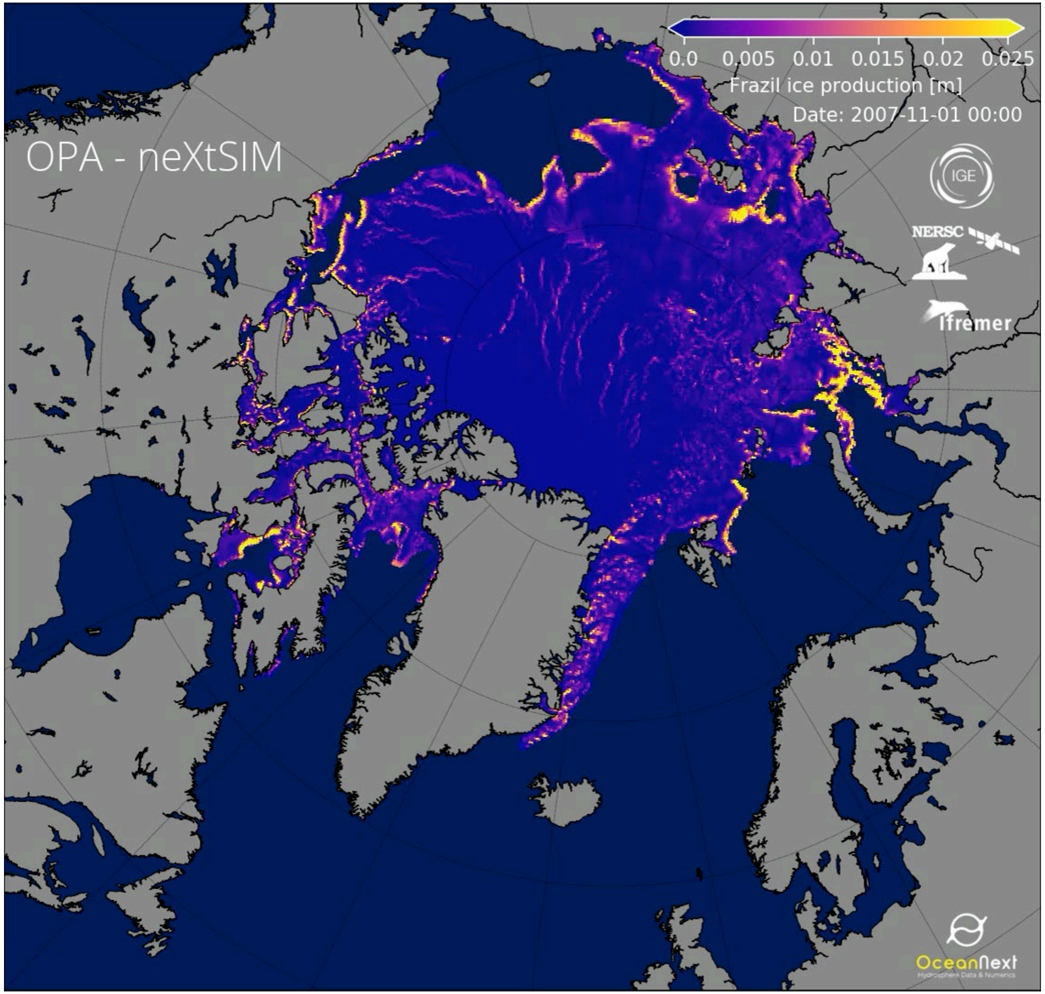


The model does well for thermodynamics, and very well for dynamics!

Impact of leads on winter ice production

Ice formation in open water (lateral growth)

November 2007 to March 2008

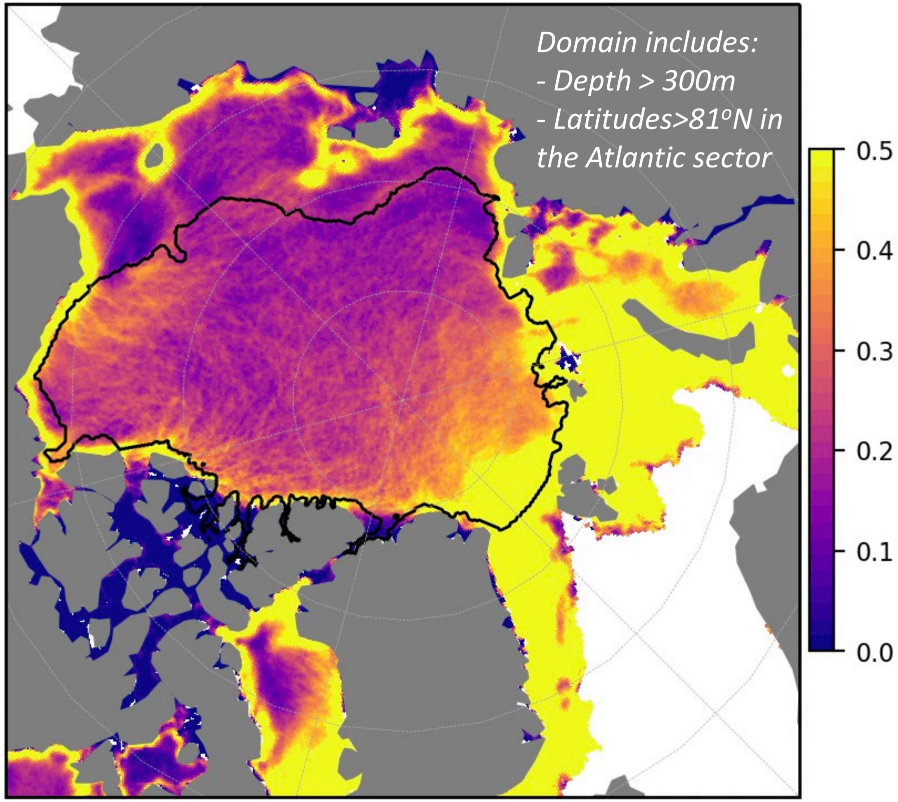


Impact of leads on winter ice production

Methodology:

- Model can distinguish different type of ice growth (frazil, basal…)
- In winter (January →March): domain ice is ~100% ice covered; frazil growth is only possible if divergence occurs

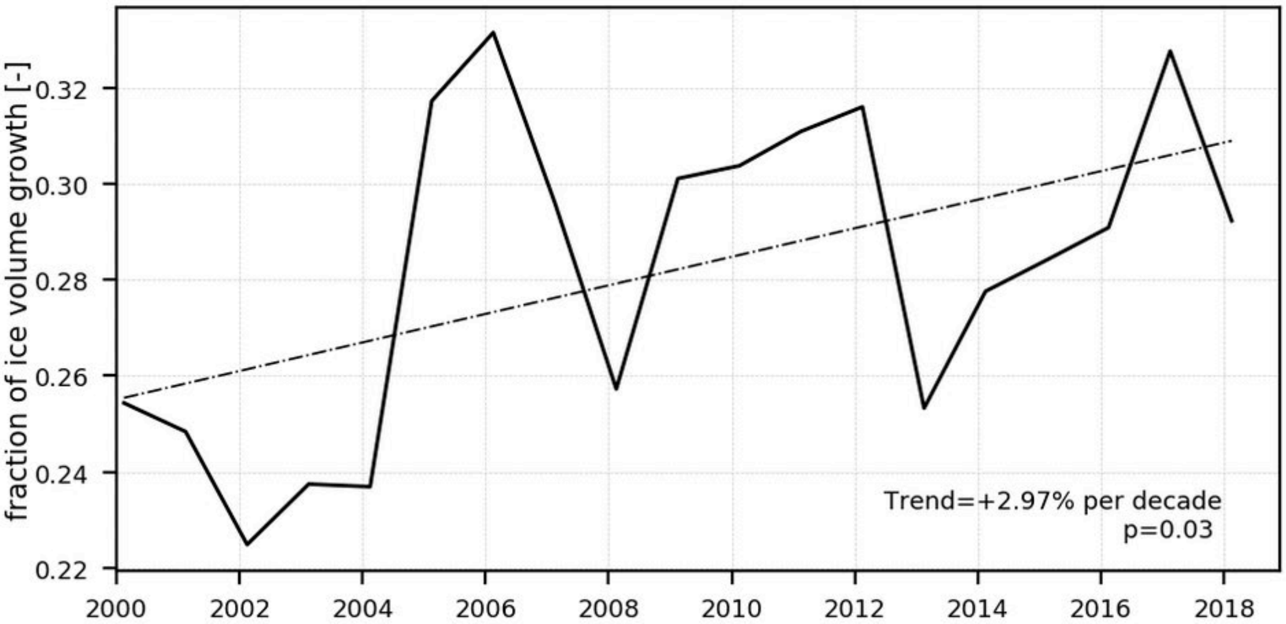
Impact of leads is clearly visible in 18-year long climatology of winter ice production



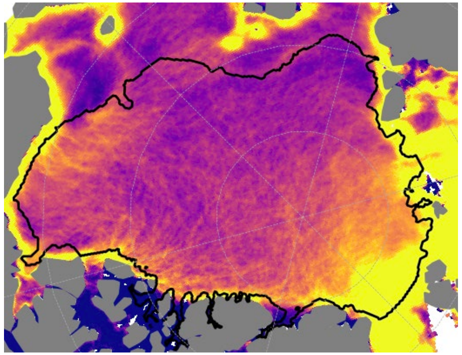
2000-2018 climatology of the ratio of ***winter new thin ice production*** *in open water to total ice production*

Impact of leads on winter ice production

We integrate in the Arctic Basin:



Selected domain:



Evolution of contribution of leads to total ice growth in winter (January to March)

20 to 30% of ice production takes place in leads! (and it's going up)

Impact of leads on winter ice production

- This estimate is consistent with previous estimates (Kwok, 2006 ; von Albedyll et al. 2022)

- No trend in total ice production, no trend in wind, but ice is thinning and drifting faster.

→ **More deformations, hence more leads? Wider leads? Longer lifetime?**

→ **How does it impact the ocean underneath?**

There is more to explore!

Conclusion

Can we get a good Arctic sea ice mass balance using a brittle rheology?

Yes, we can (and we do).

If yes, what is the impact of small-scale dynamics on this mass balance?

From January to March, ~30% sea ice production takes place in leads.

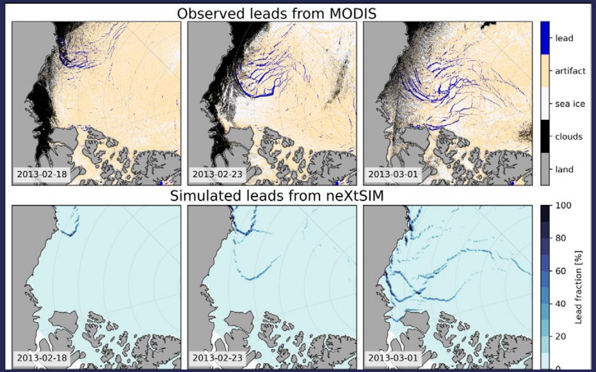
This contribution is increasing (whereas total ice production is not)

Conclusion

- We analyze 18 years of simulation from a coupled ocean—sea-ice model using a brittle rheology
- The model shows sea ice deformations and a mass balance consistent with observations
- We find that ice production in leads represent ~30% of ice production in winter

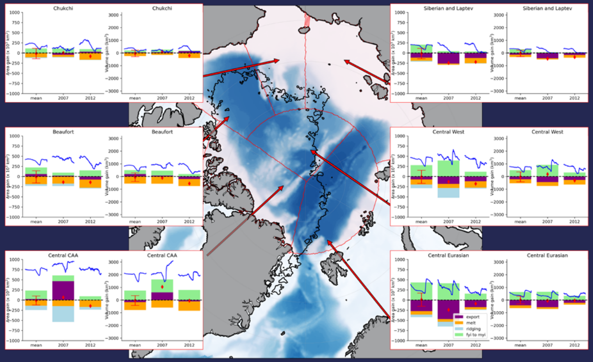
Interested in our work? Check out posters from our team!

Today, C2.01:

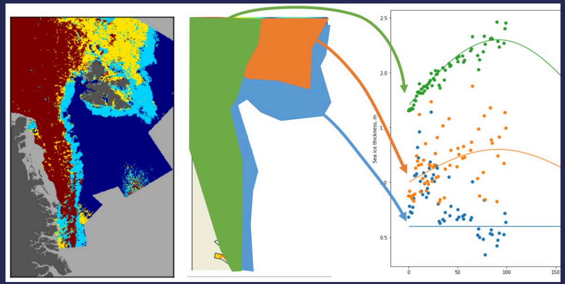


J. Rheinlænder et al.: Simulating extreme **sea-ice breakup events** in the Arctic

Tomorrow, A9.06:



H. Regan et al.: Drivers of **multiyear ice evolution** in the Arctic



A. Korosov et al.: Retrieval of sea ice type and deformation from Sentinel-1 SAR, and assimilation into a sea ice model