A model for waves-in-ice and sea ice dynamics in the marginal ice zone

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WAVES-IN-ICE FORECASTING
WIFAR
FOR ARCTIC OPERATORS

TOTAL

The Research Council of Norway

NERSC

Mohn-Sverdrup Center
Global Ocean Studies - Operational Oceanography

Outline

What is the marginal ice zone?

Definition of the problem and hypothesis

How do we model sea ice dynamics?

Representation of sea ice variables

Sea ice dynamics and rheology

The MIZ rheology

Tests in TOPAZ/HYCOM

Including waves in a sea ice model?

The proposed strategy

Early results and sensitivity studies

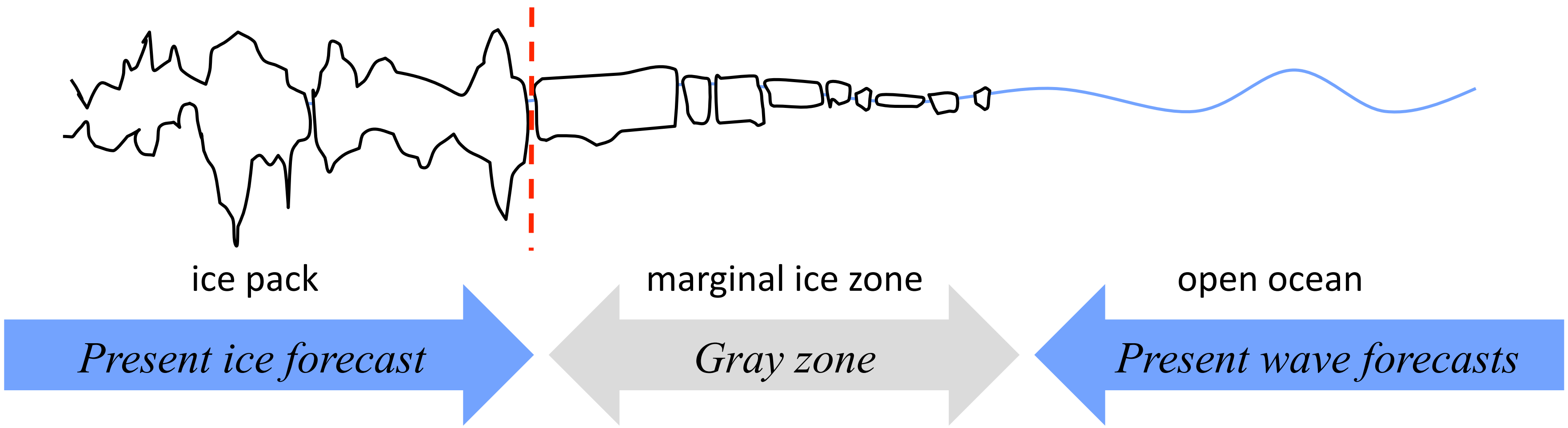
Field campaign

Passive listening experiment in the Fram Strait, Sept 2010.

Conclusions and perspectives

Motivation

- Increasing ship transport related to offshore activity on the Arctic Shelves
- Uncertain environmental conditions (sea ice, icebergs) pose problems for human safety, dimensioning of equipments and crisis management.
  - The oil & gas industry requires accurate and regular operational forecasts.
- With the gradual retreat of sea ice from the Arctic, wave fetch will increase, as well as the mechanical breaking of the sea ice.
- The models of sea ice need to be improved for operational forecasting of the Marginal Ice Zone (MIZ).



Waves in Ice Forecasting for Arctic operatoRs

The MIZ project

Post-doc funded 100% by TOTAL E&P (2007-2010)

Implemented a MIZ sea ice rheology in an operational ice-ocean model of the Fram Strait.

Follow-up:

WIFAR: A project from the PETROMAKS program

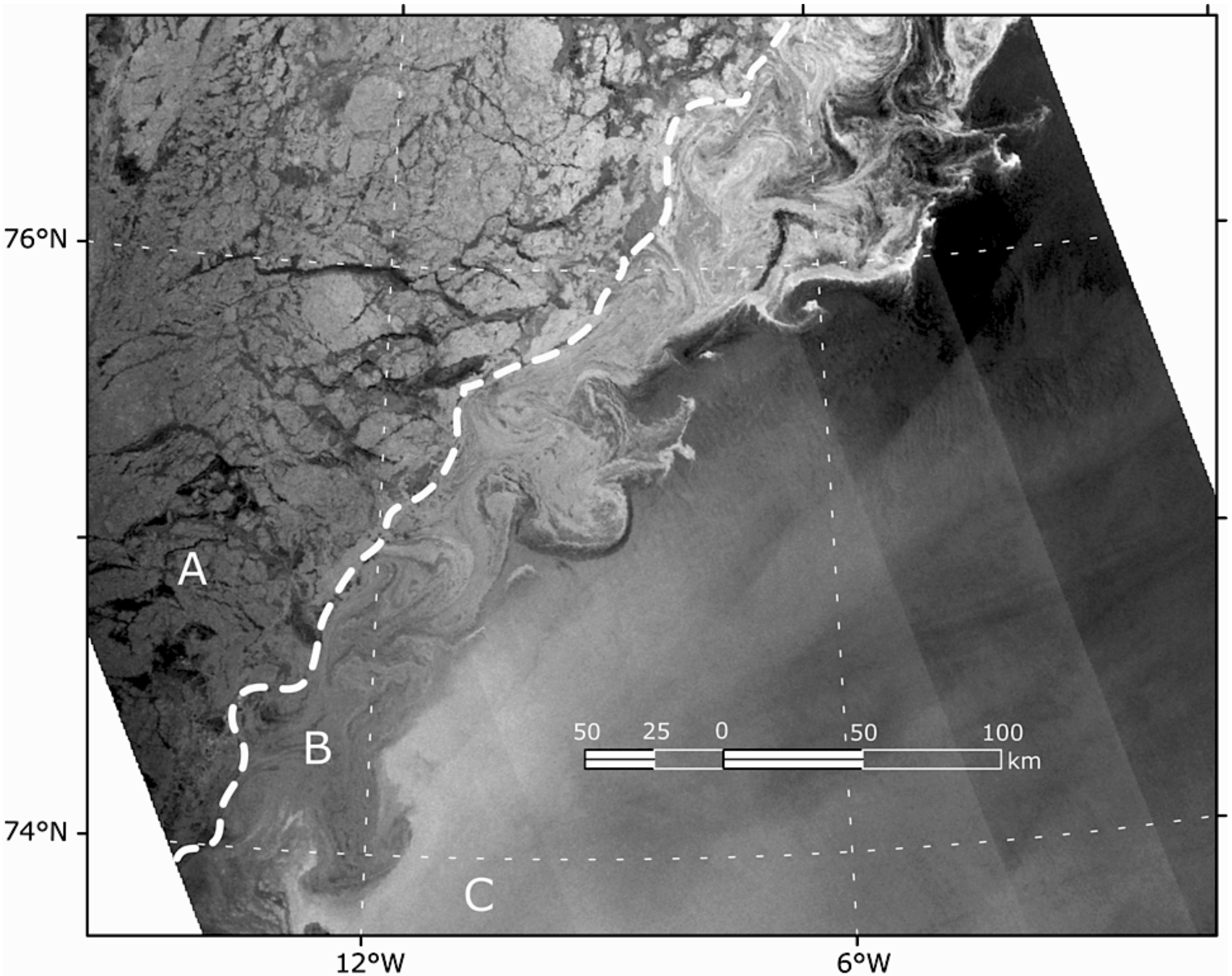
Co-funding by the Research Council of Norway and TOTAL E&P (2010-2013).

Goal:

To develop new knowledge, observations and models of sea ice and waves in the Arctic.

Partners:

- Nansen Center, No (Lead, S. Sandven)
- University of Otago, NZ (V. Squire)
- NIWA, NZ (A. Kohout)



Fram Strait MIZ

16 January 2010

The Marginal Ice Zone:

- smaller ice floes
- no large scale cracks/leads
- ice filaments and bands
- ice vortices

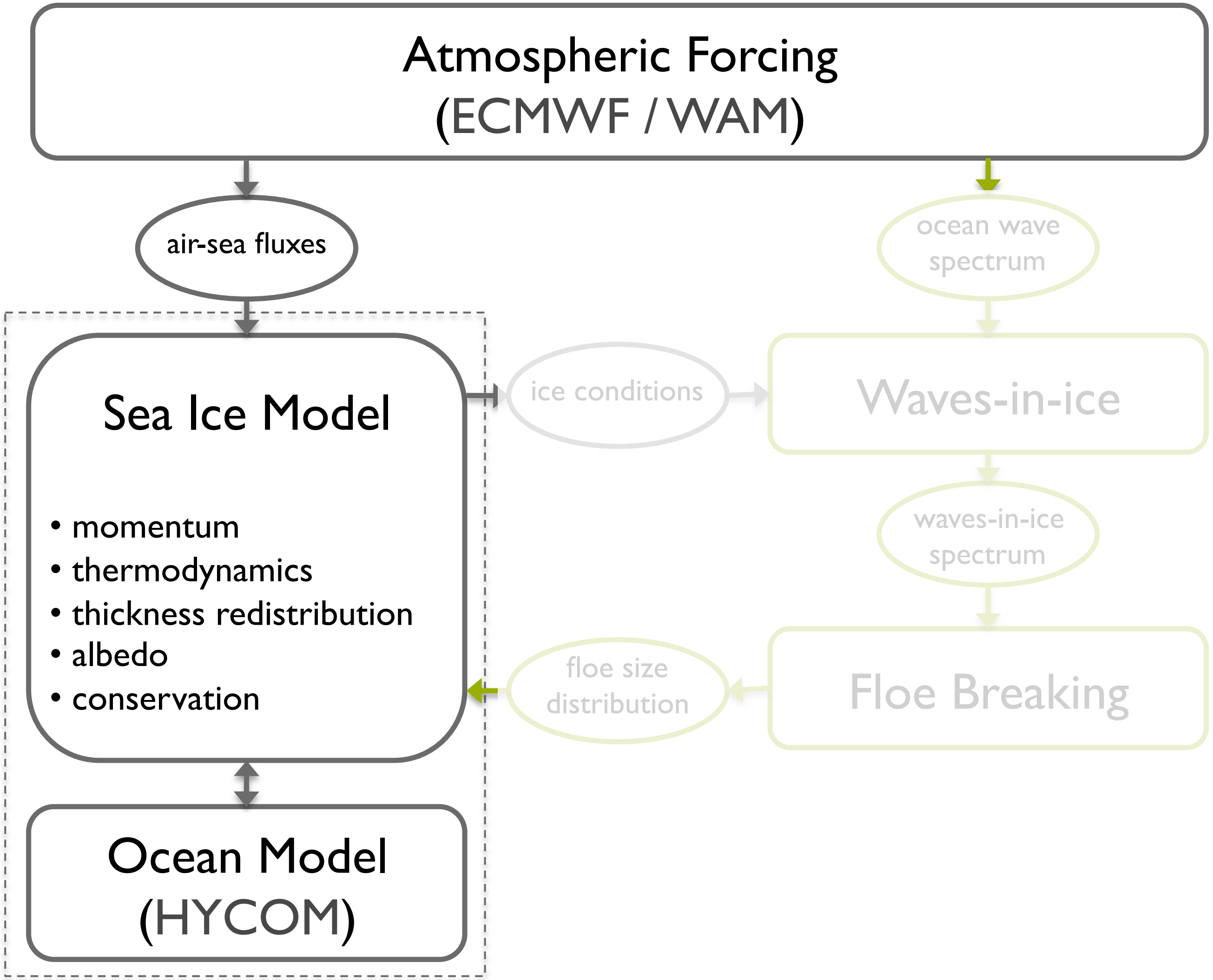
Two dynamical regimes separated by a (often) distinguishable boundary

A : Central pack

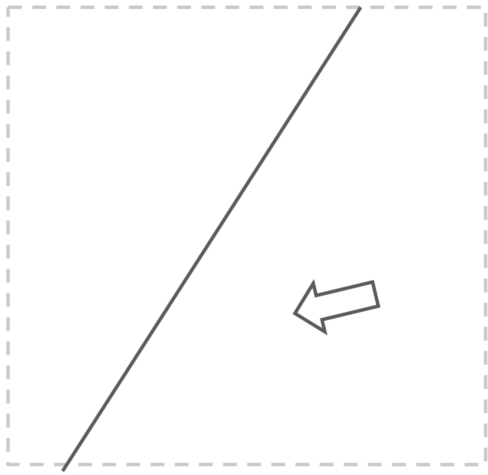
B : Marginal ice zone

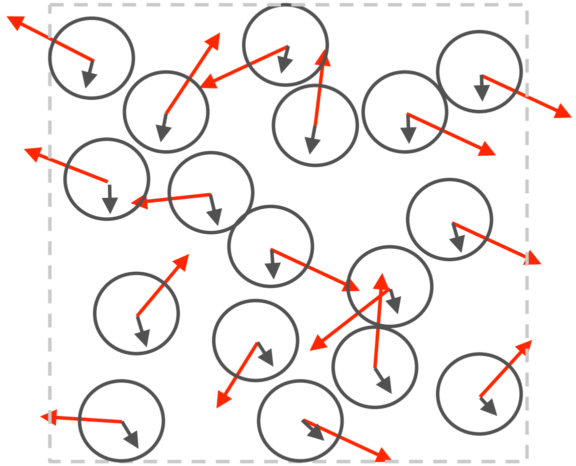
C : Open ocean

The ice-ocean modeling system



Two dynamical regimes





Viscous-plastic rheology (Hibler 1979)

• continuum
• plastic yield curve

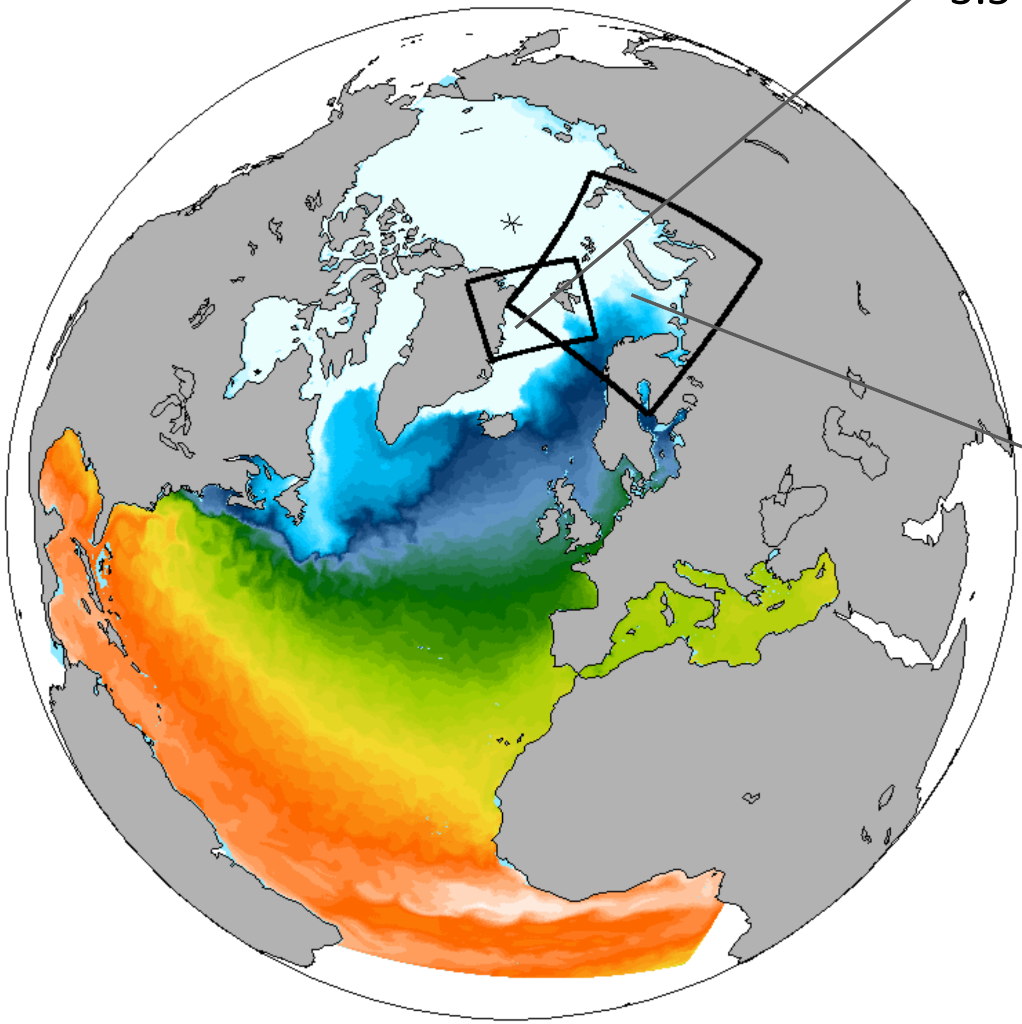
Collisional rheology (Shen et al. 1987)

• granular material
• floe-floe collisions
• non-newtonian fluid
• no yield curve
• low viscosity

TOPAZ - North Atlantic and Arctic Oceans

11 – 16 km resolution (800 × 880)

28 hybrid vertical levels

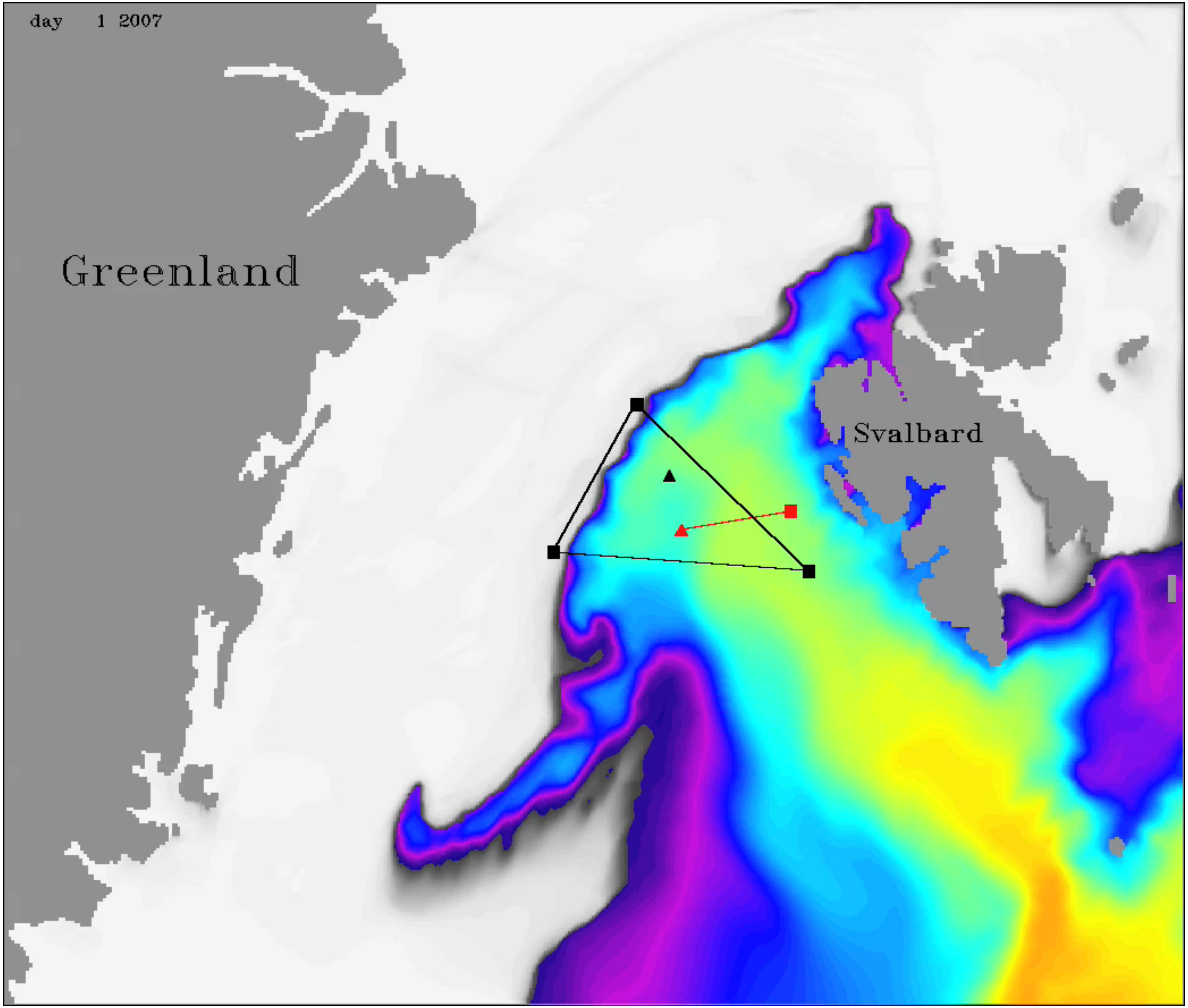


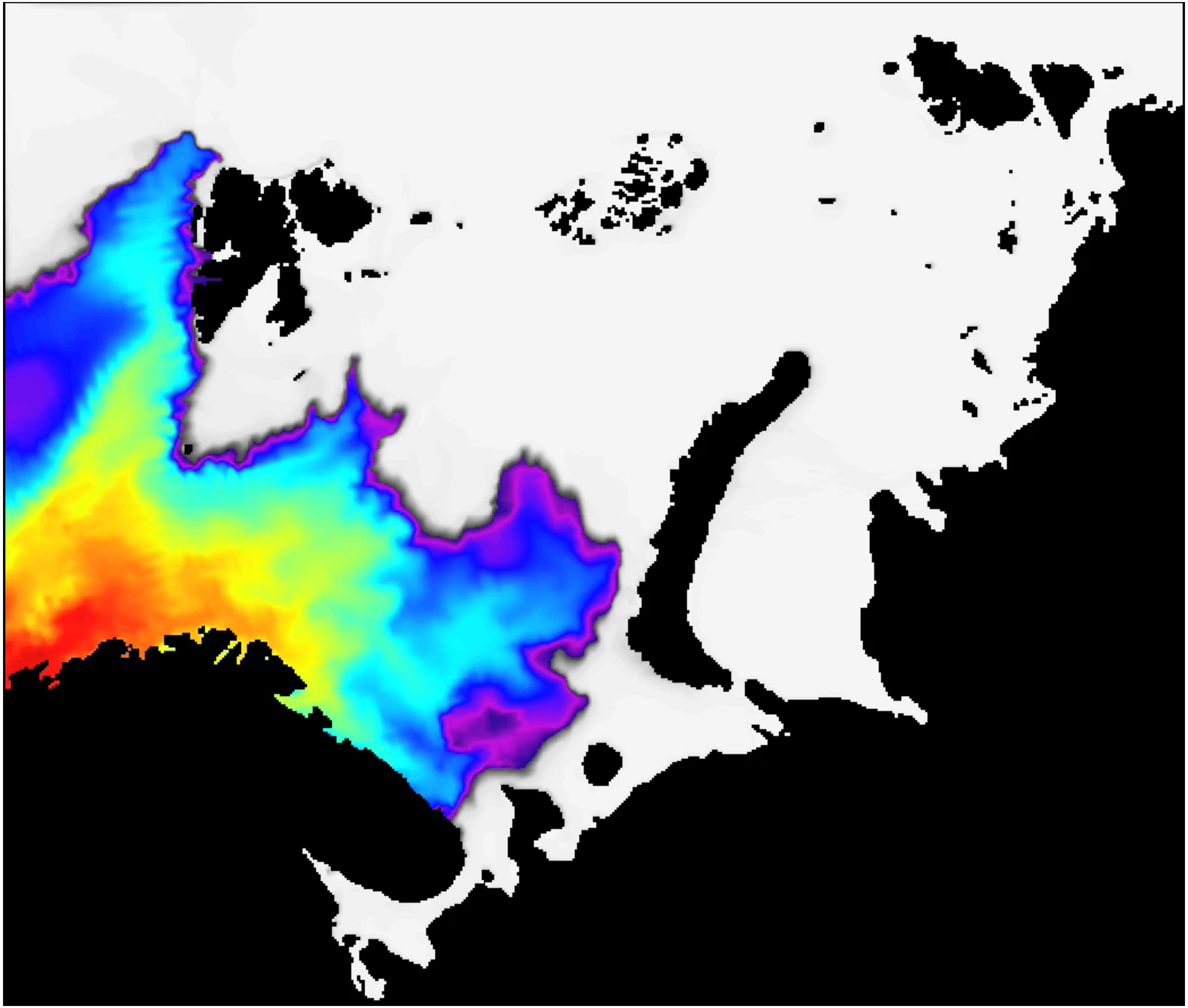
Fram Strait

3.5 km resolution (410 × 320)

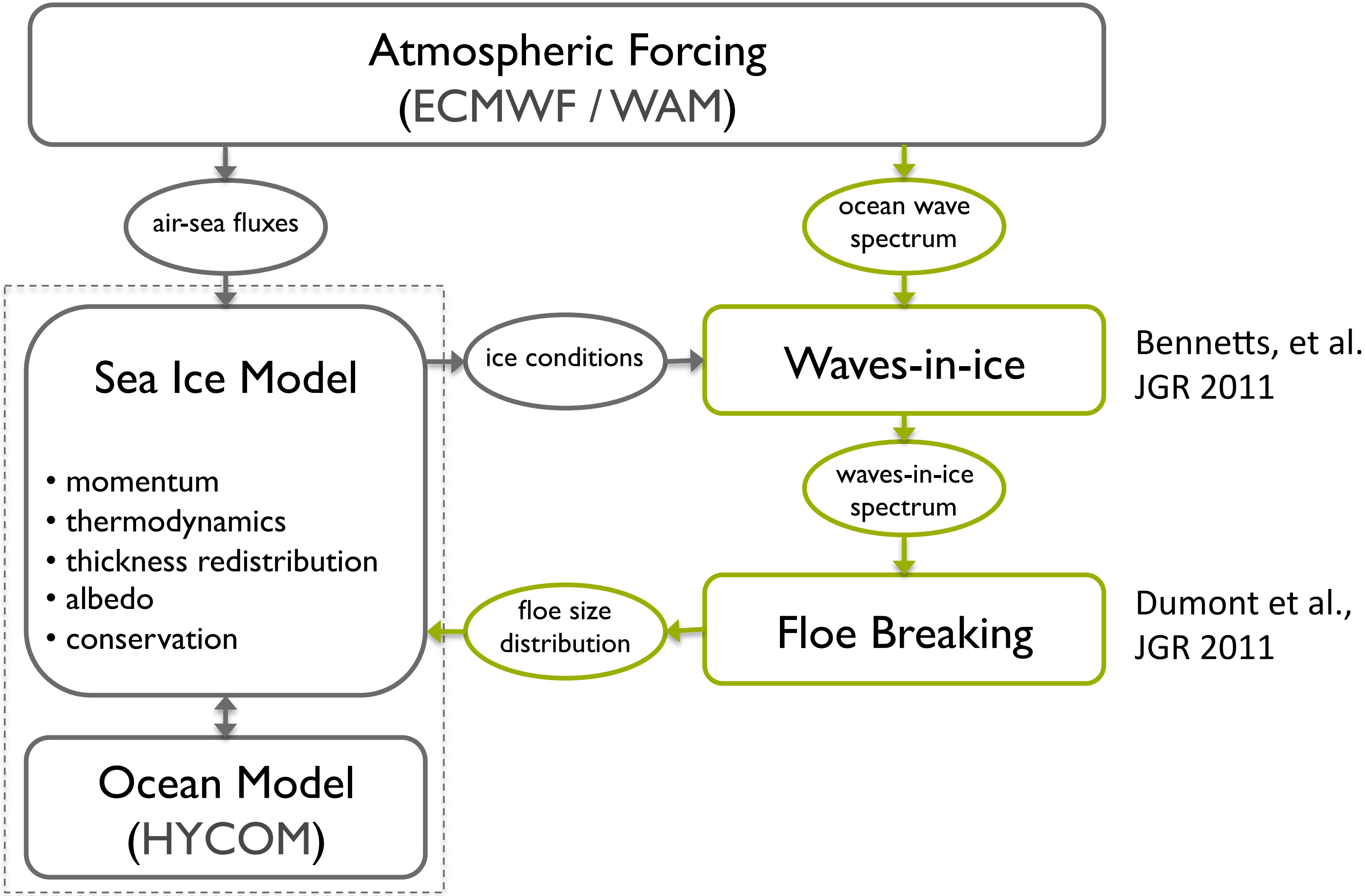
Barents Sea

5.0 km resolution (520 × 410)

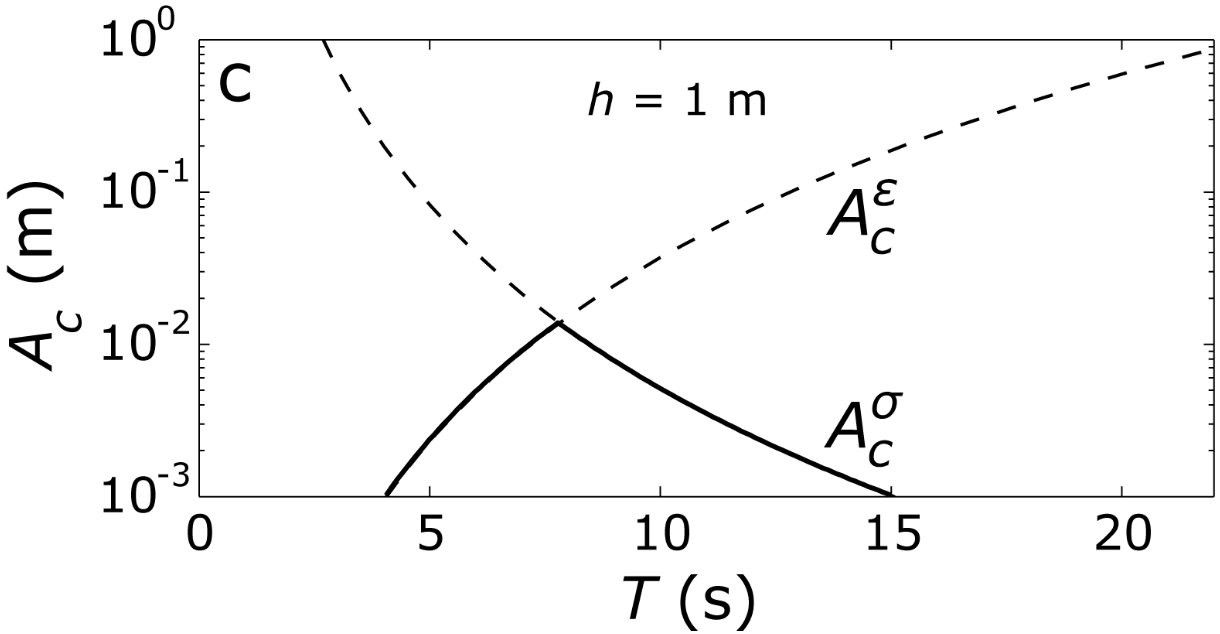

day 1 2007
Greenland
Svalbard



Including waves in a sea ice-ocean model



A flexural yield criterion



Flexural stress yield

$$A_c^\sigma \propto h^2/T^4$$

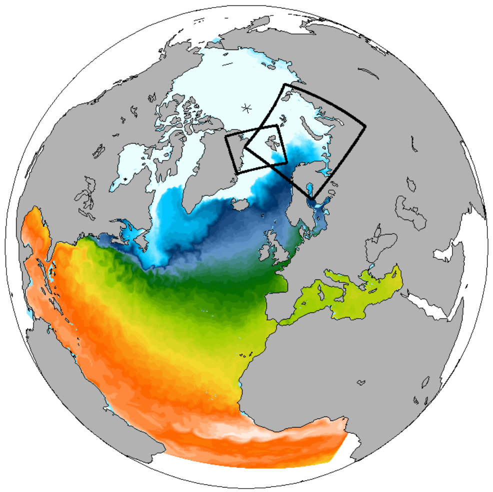
Flexural strain yield

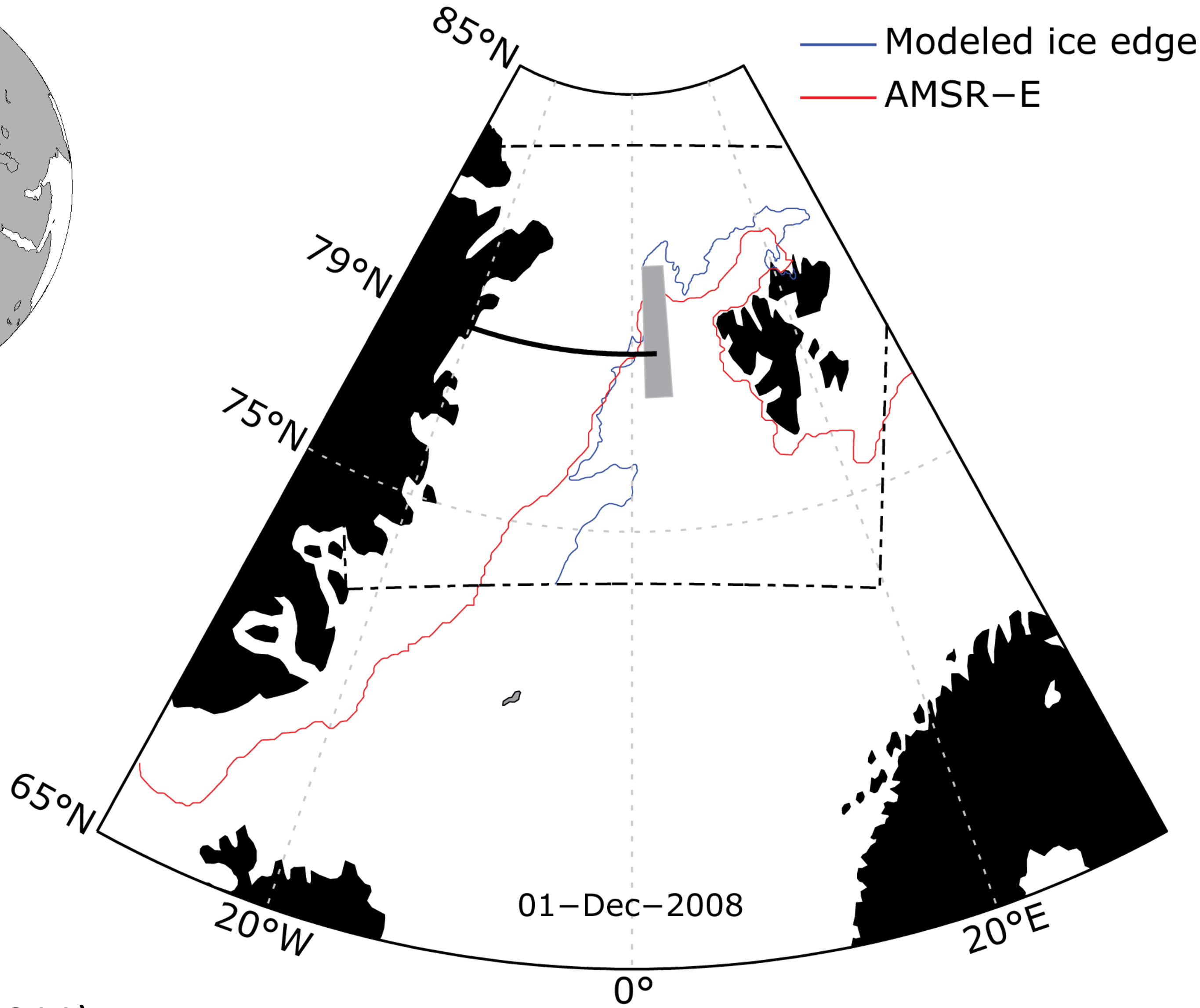
$$A_c^\varepsilon \propto T^4/h$$

The floe breaking parameterization determines the **maximum floe size** $D_{\max}$ of the floe size distribution.

Dumont et al. (JGR 2011)

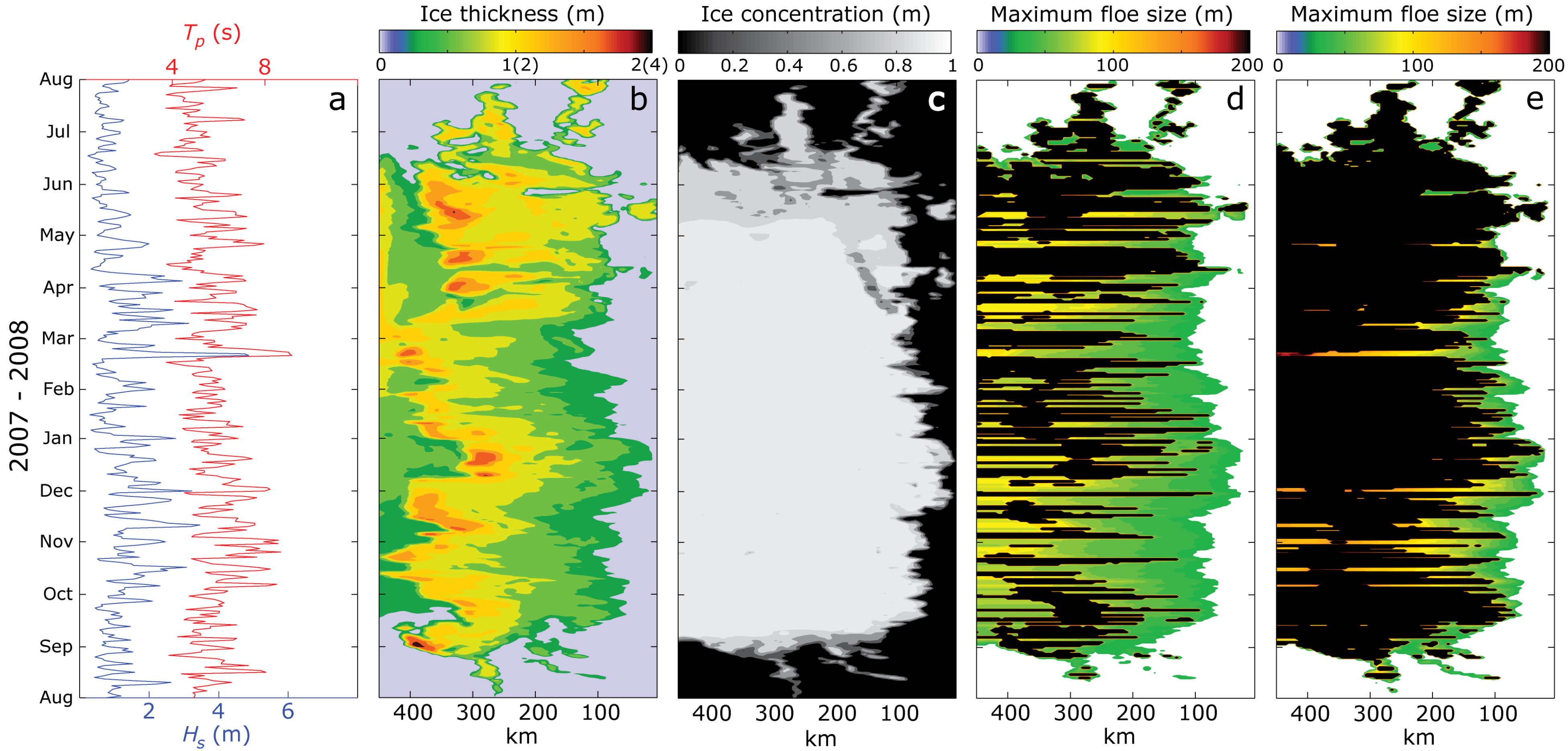
1-D Application to the Fram Strait





Dumont et al. (JGR 2011)

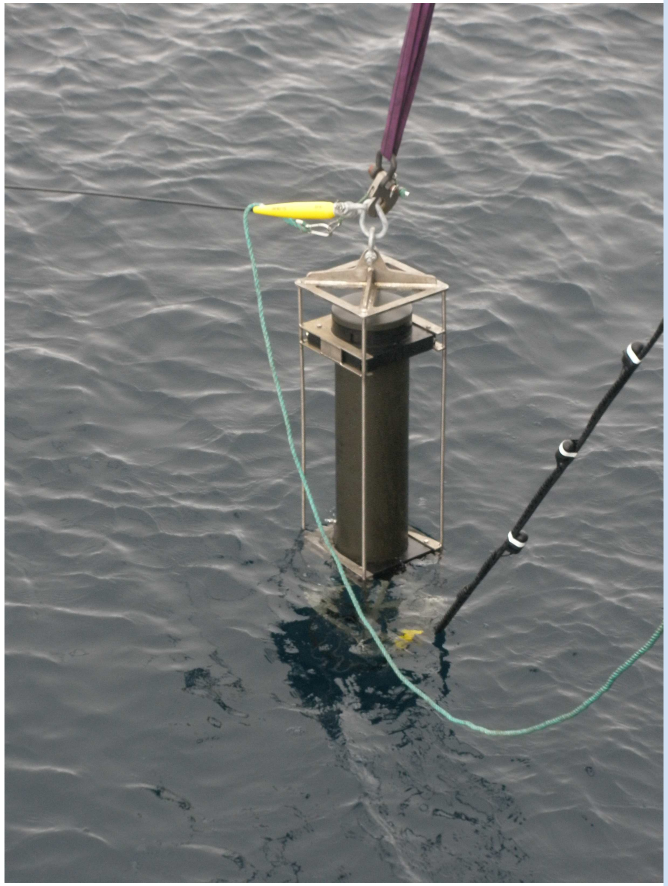
1-D Application to the Fram Strait



Dumont et al. (JGR 2011)

=> Validation?

A moored passive acoustic system

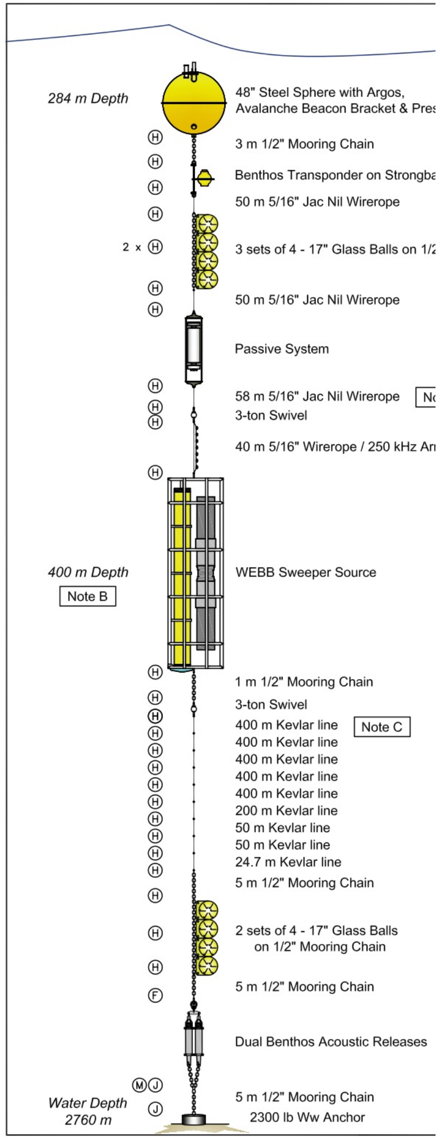


Bjørge Naxys system is integrated with the tomography instruments @ 350 m in 2580 m water depth.

The Autonomous Acoustic Logger monitors acoustic emissions in the low- to medium frequency range, spanning from ~1Hz to 6250Hz

The system was deployed
10th of September 2010
@ 79°39.984'N 000°14.211'W
Records 5 min every 3 hours

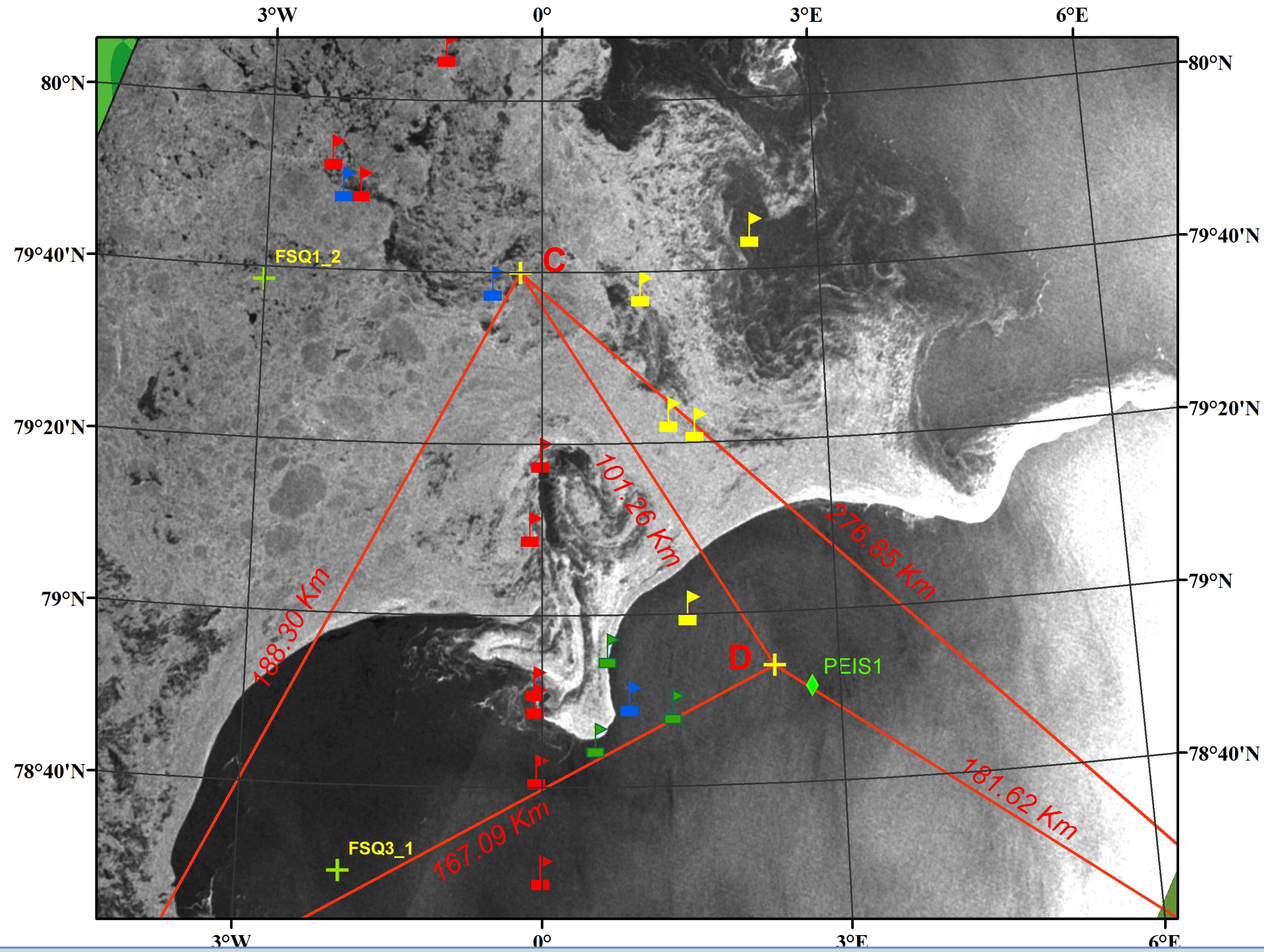
Planned recovery in 2012.



Sonobuoy drop 4th October 2010

A 9 hour aircraft mission provided by the Royal Norwegian air force.

Listening and recording both ambient noise and acoustic sources



Red/green flags – hydrophone at 305 m, Yellow flags hydrophone at 122 m, Blue flags AXBTs C&D is tomographic moorings, FSQ moorings are RAFOS sources, and PEIS is inverted echo sounders. This is work carried out with FFI in Horten.

Summary and conclusions

Sea ice dynamics

- The MIZ collisional rheology has been implemented as a module in the HYCOM code used by the TOPAZ system
- A 3.5 km HYCOM model of the Fram Strait runs in real-time forecast mode at NERSC.
- Ice motion near the ice edge has improved qualitatively, but the extent of the MIZ is not well reproduced.

Waves-in-ice

- A strategy was developed to implement waves-in-ice in a sea ice model code, tested and sensitivity in one dimension.
- The 2D implementation in HYCOM is under way.
- In-situ data are being analyzed for model validation.

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