Towards **Modelling the marginal ice zone**

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Australian Government
Australian Research Council

THE UNIVERSITY of ADELAIDE

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

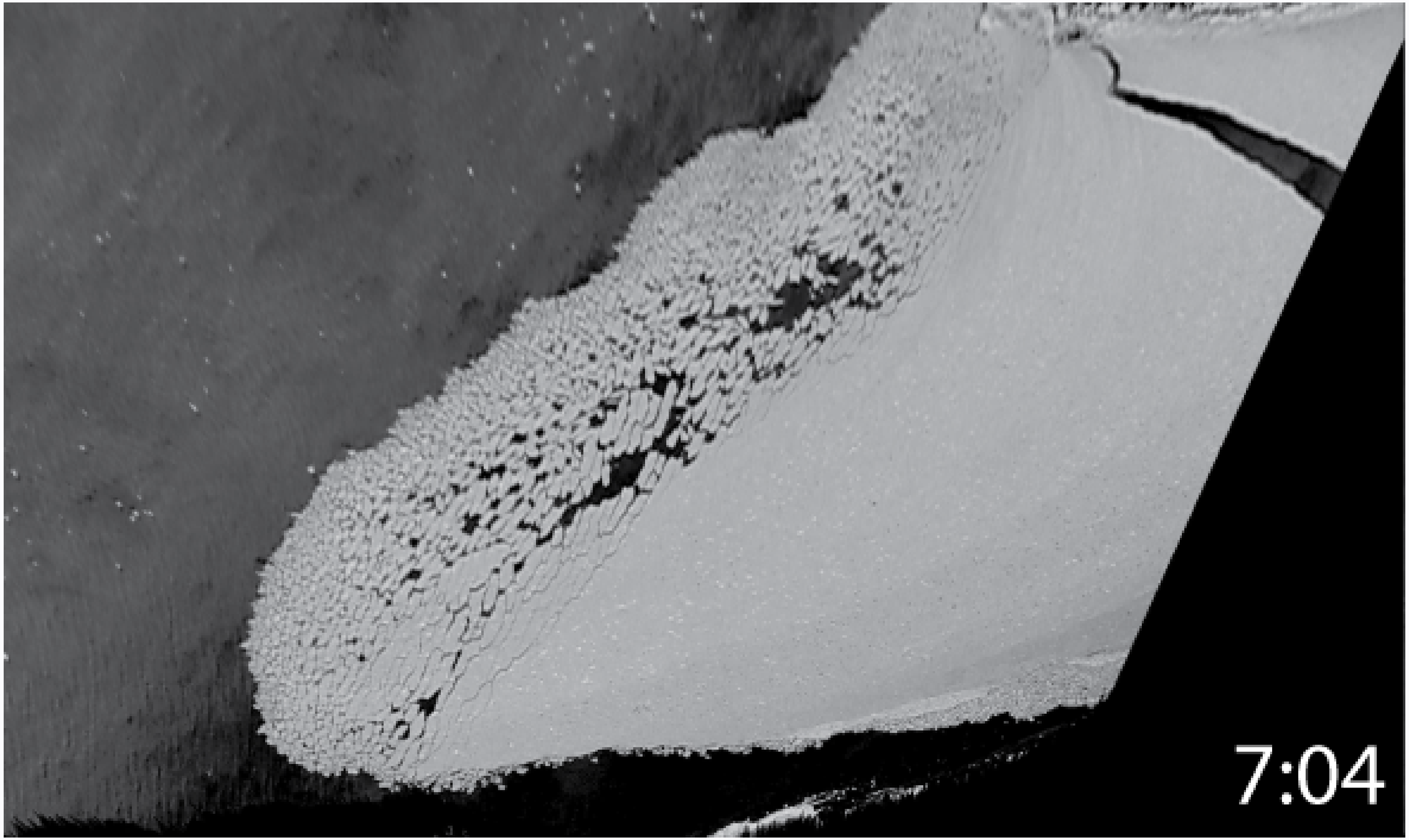
Marginal ice zone (MIZ): roughly. . .

. . . this. . .

. . . not this

Waves break up ice cover

St Lawrence Estuary, Québec, Canada



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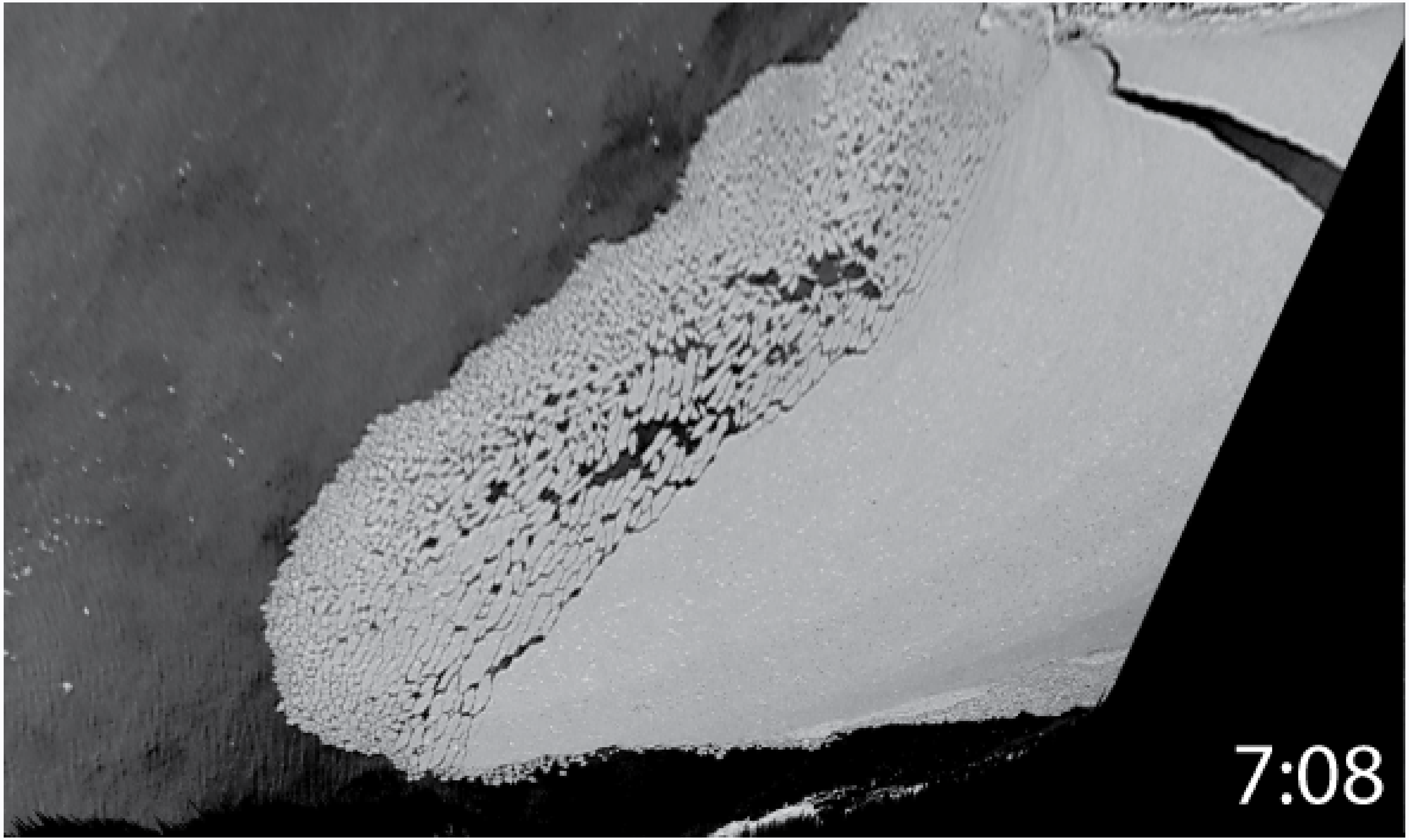

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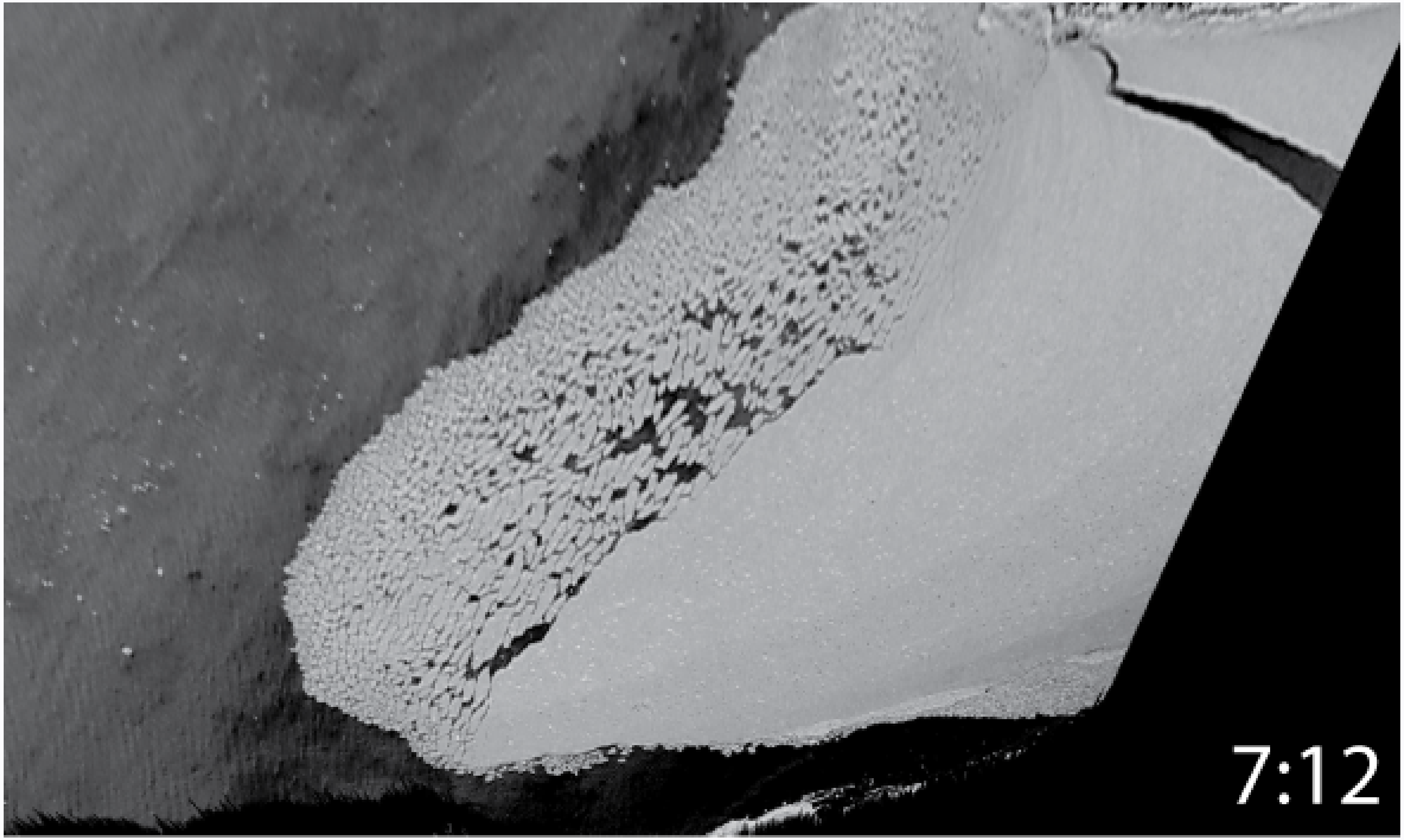

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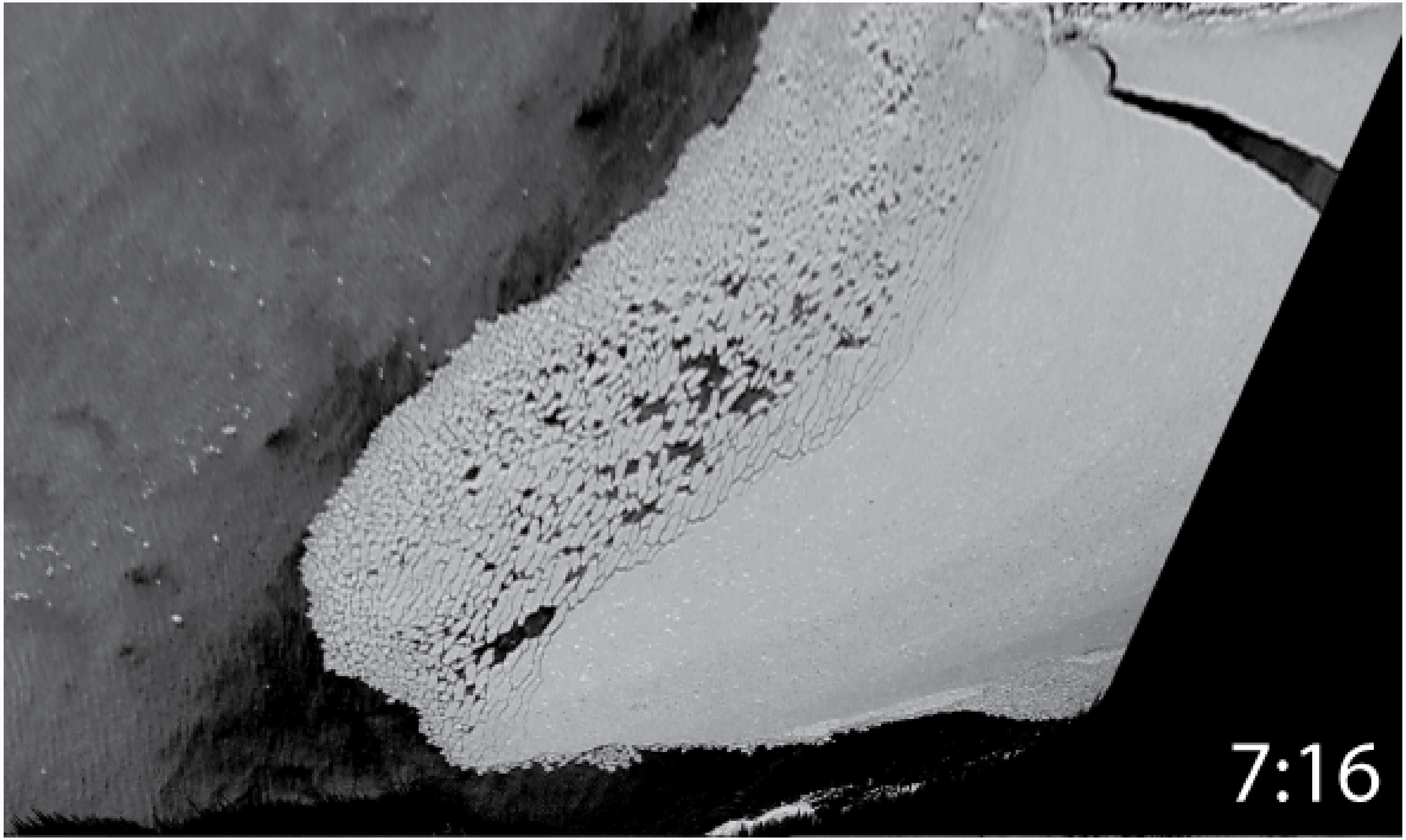

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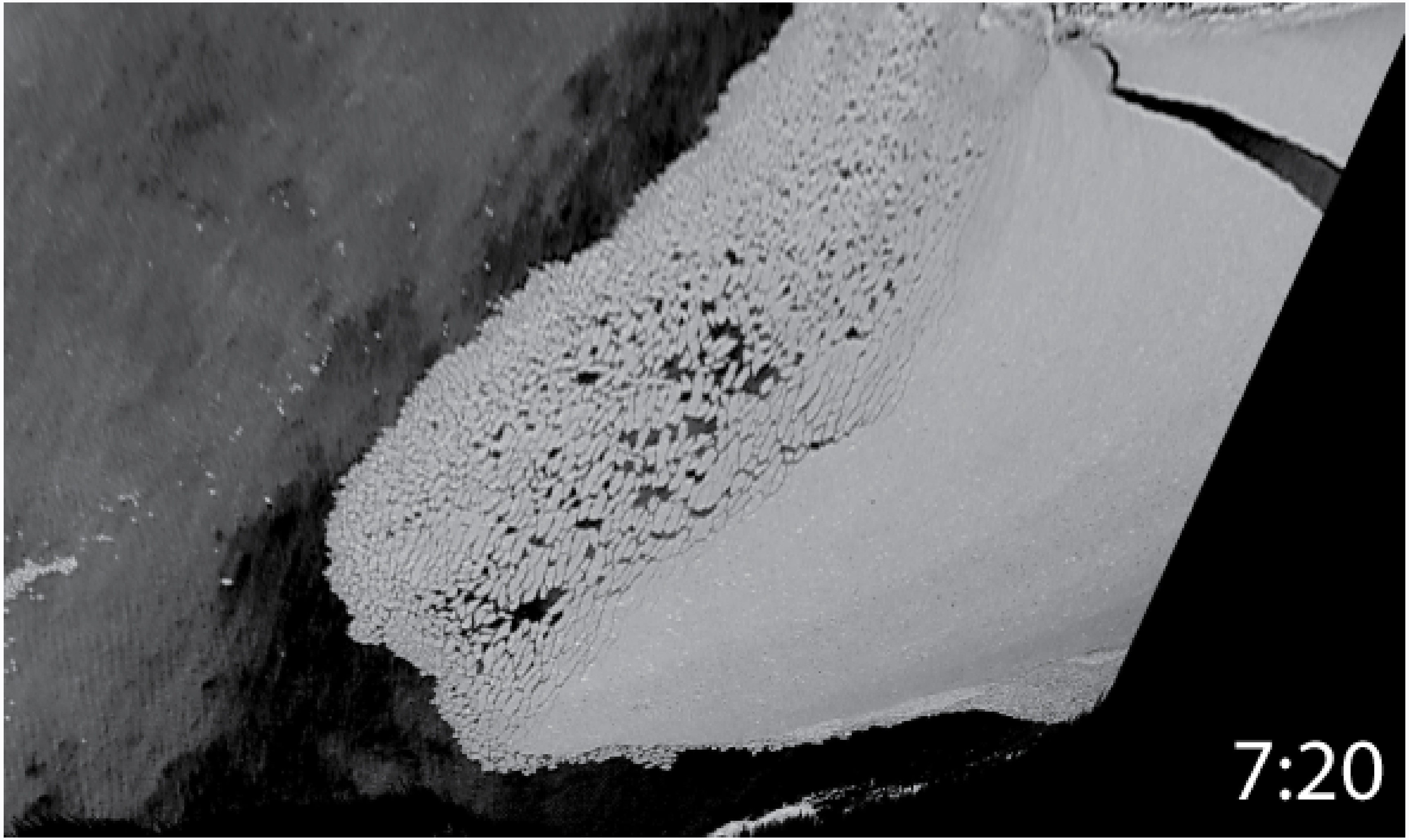

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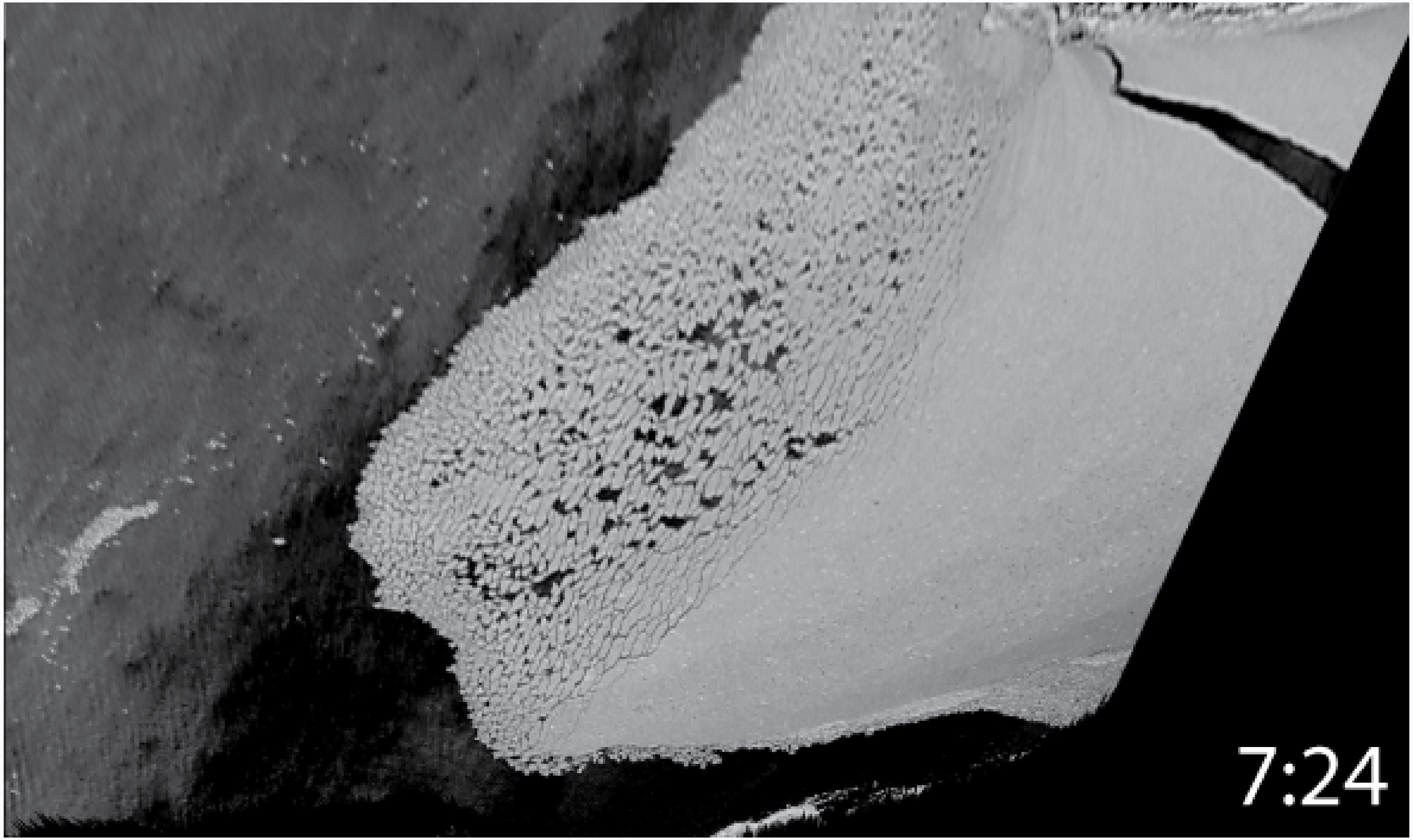
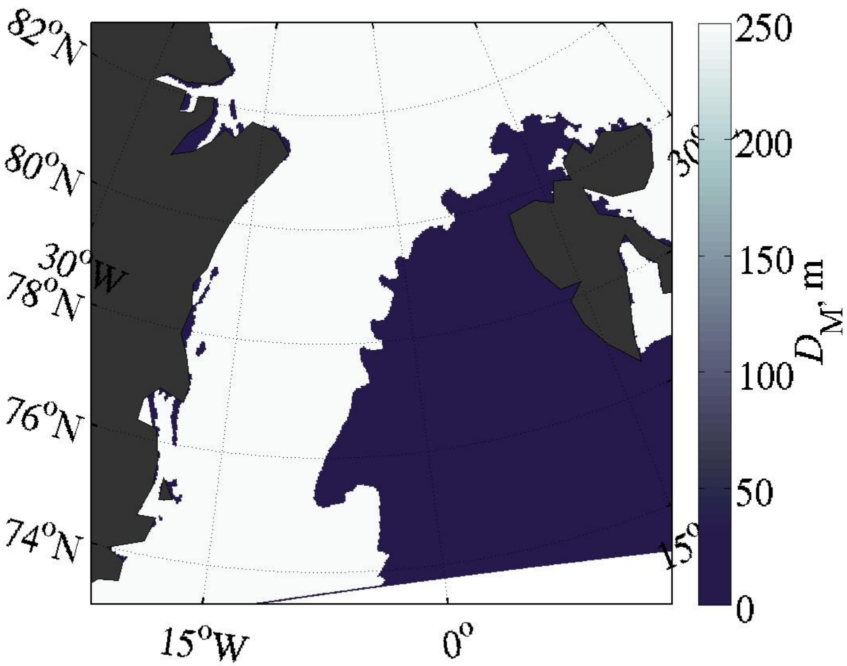
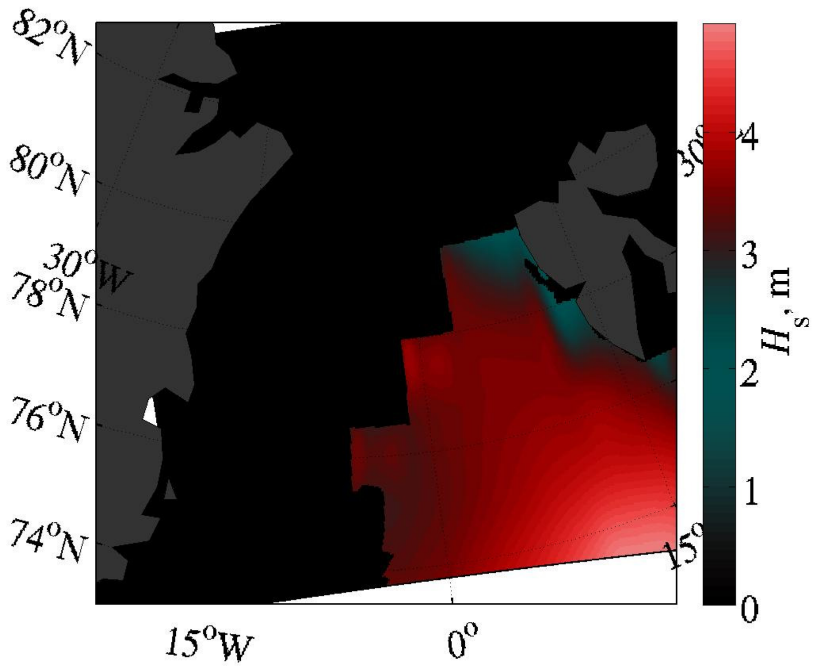


Numerical model of Fram Strait

Max Floe Diameter

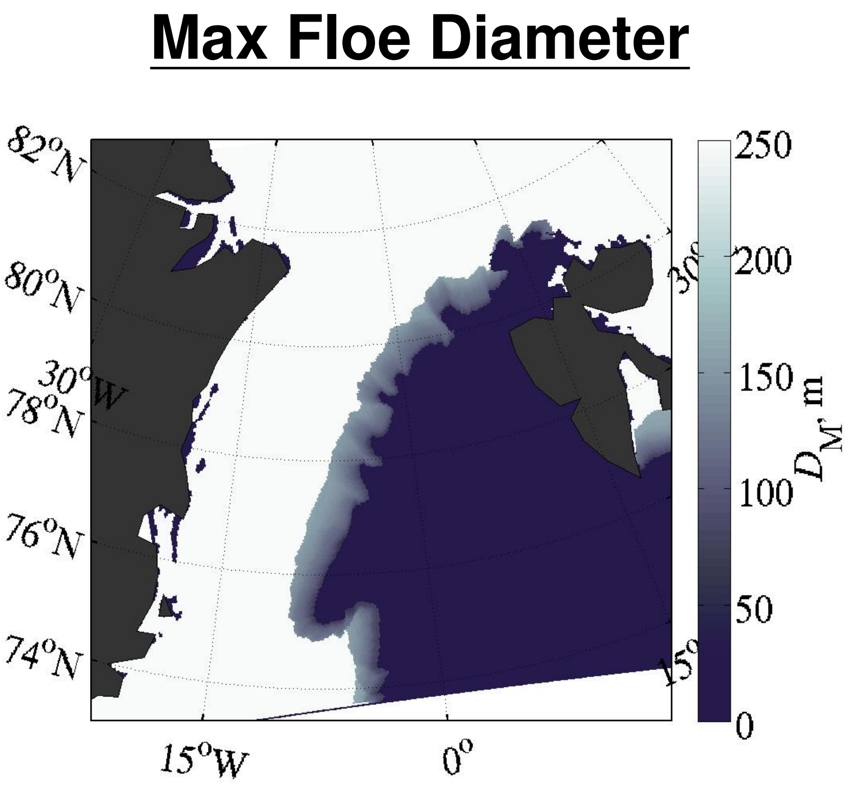


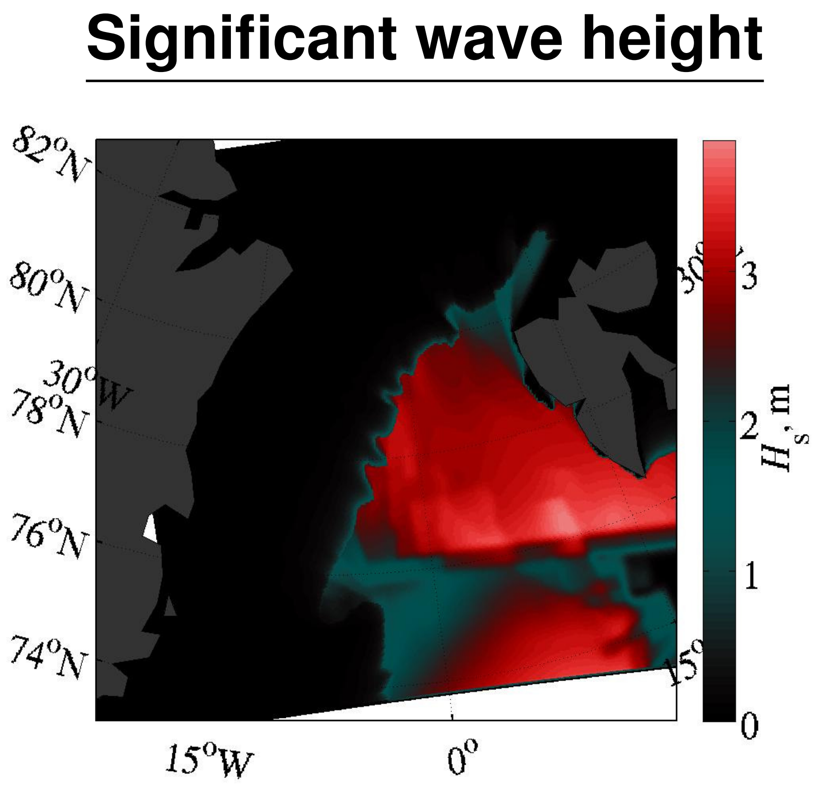
Significant wave height



- 10 wave directions and 22° resolution
- Maximum floe diameter is initially set to 250 m.

Numerical model of Fram Strait

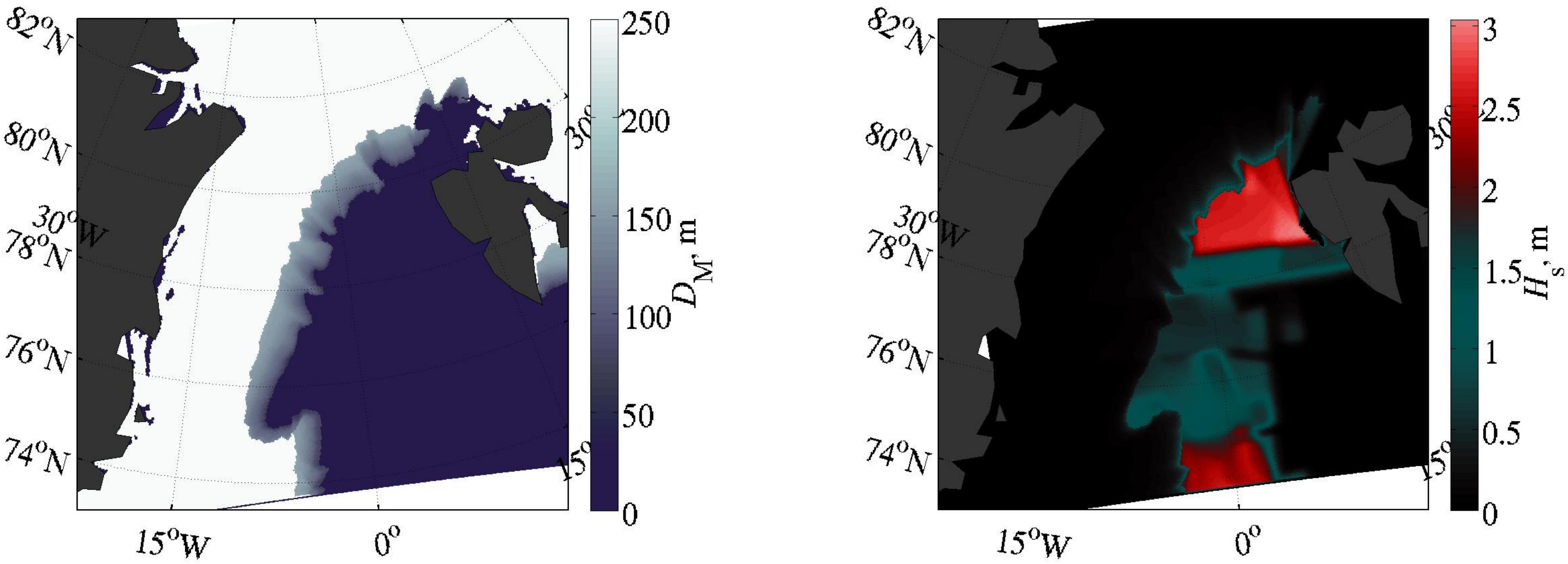




- Waves propagate into the ice-covered region and
  - break ice into smaller floes (left panel);
  - are damped by the ice-cover (right panel).

Numerical model of Fram Strait

Max Floe Diameter | **Significant wave height**



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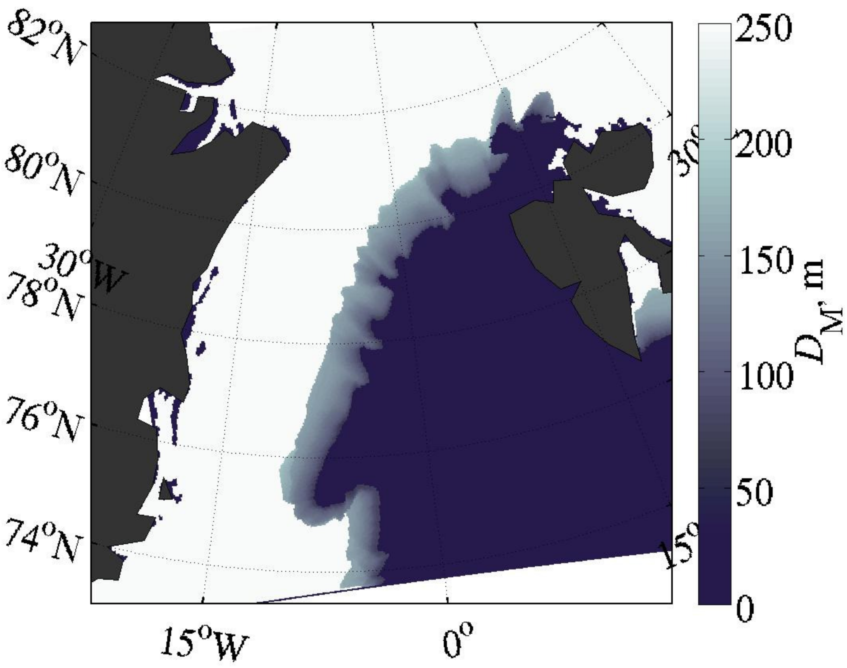

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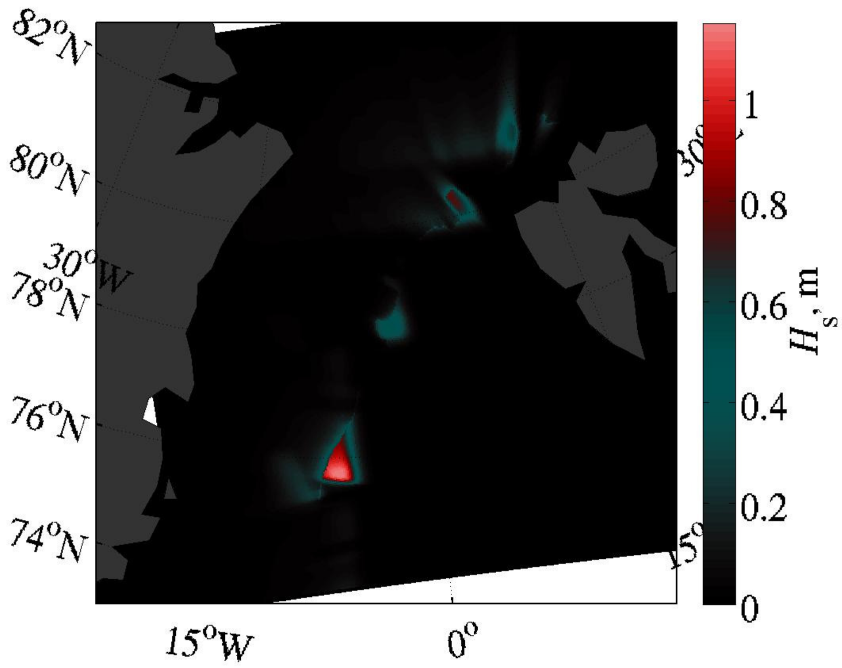

- Until the waves are damped to a degree that they can no longer break the ice.

Integration into CICE v4.1

Introduce wave-ice interactions using:

1. Floe size distribution.
2. Incident wave forcing.

CICE algorithm

```
do t=dt,2dt,...
  Thermodynamics
    · heat conduction, vertical growth/melt,
      lateral melt, new ice, melt ponds, snow
  Dynamics
    · elastic viscous plastic rheology,
      transport, ridging
end do
```

Integration into CICE v4.1

Introduce wave-ice interactions using:

1. Floe size distribution.
2. Incident wave forcing.

CICE algorithm

```
do t=dt,2dt,...
  Thermodynamics
    · wave-ice interaction code
     → damping and breakage
    · heat conduction, vertical growth/melt,
      lateral melt, new ice, melt ponds, snow
  Dynamics
    · elastic viscous plastic rheology,
      transport, ridging
end do
```

Integration into CICE v4.1

New wave and ice variables

1. Floe size distribution parameter $D(\mathbf{x}, t)$
   - In-cell average.
   - $D = D_{\mathrm{lg}} = 300\,\mathrm{m}$ initially for consistency with old version.
   - $D = D_{\mathrm{bk}} = 30\,\mathrm{m}$ if breakage occurs and $D > D_{\mathrm{bk}}$.

     $\rightarrow$ Weighted average if breakage only in a proportion of cell.
   - $D = D_{\mathrm{sm}} = 5\,\mathrm{m}$ if thickness $< 0.1\,\mathrm{m}$ or concentration $< 1\,\%$
   - Transported with concentration.
2. Incident wave forcing from Wavewatch III.
   - At constant latitude outside ice cover $\rightarrow$ can vary in time.
   - Reset each timestep.
3. Simple floe bonding scheme implemented.
   - Floes double in size without waves and if freezing.
   - Stops small floes near coast in summer persisting through winter.

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Simulation: Antarctic, standalone, 1979–89

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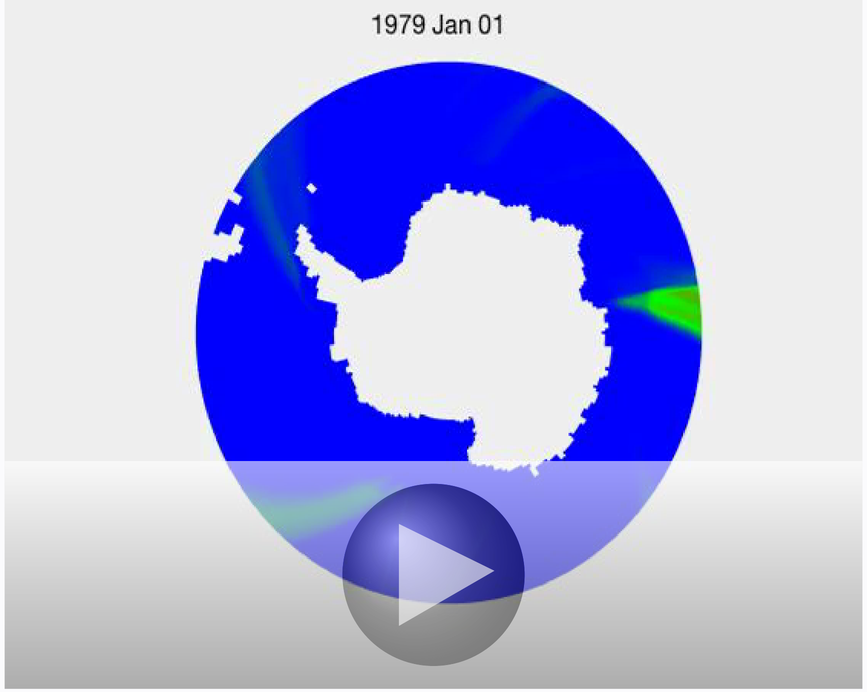
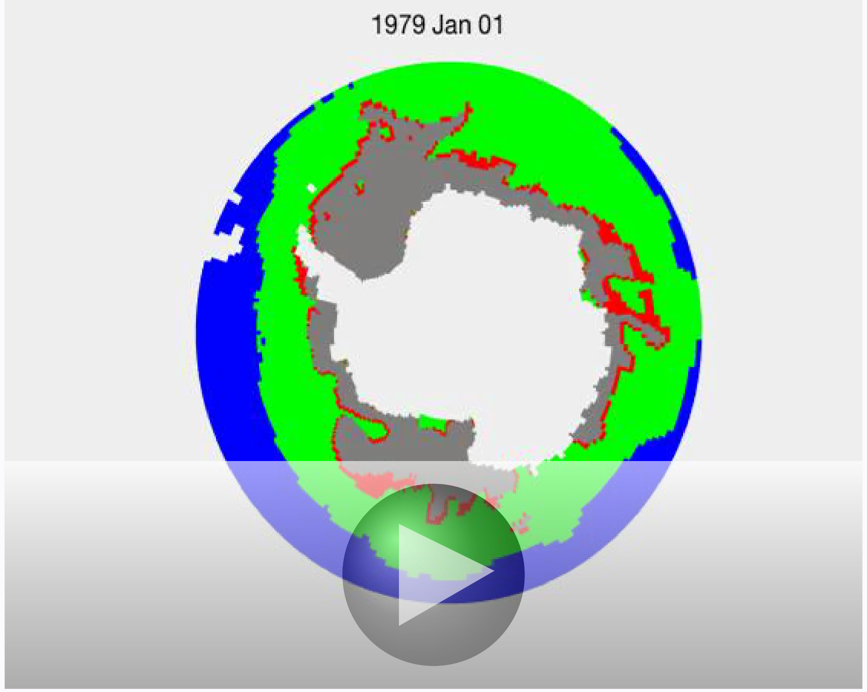


Floe size regions



Open water: $D = 0$

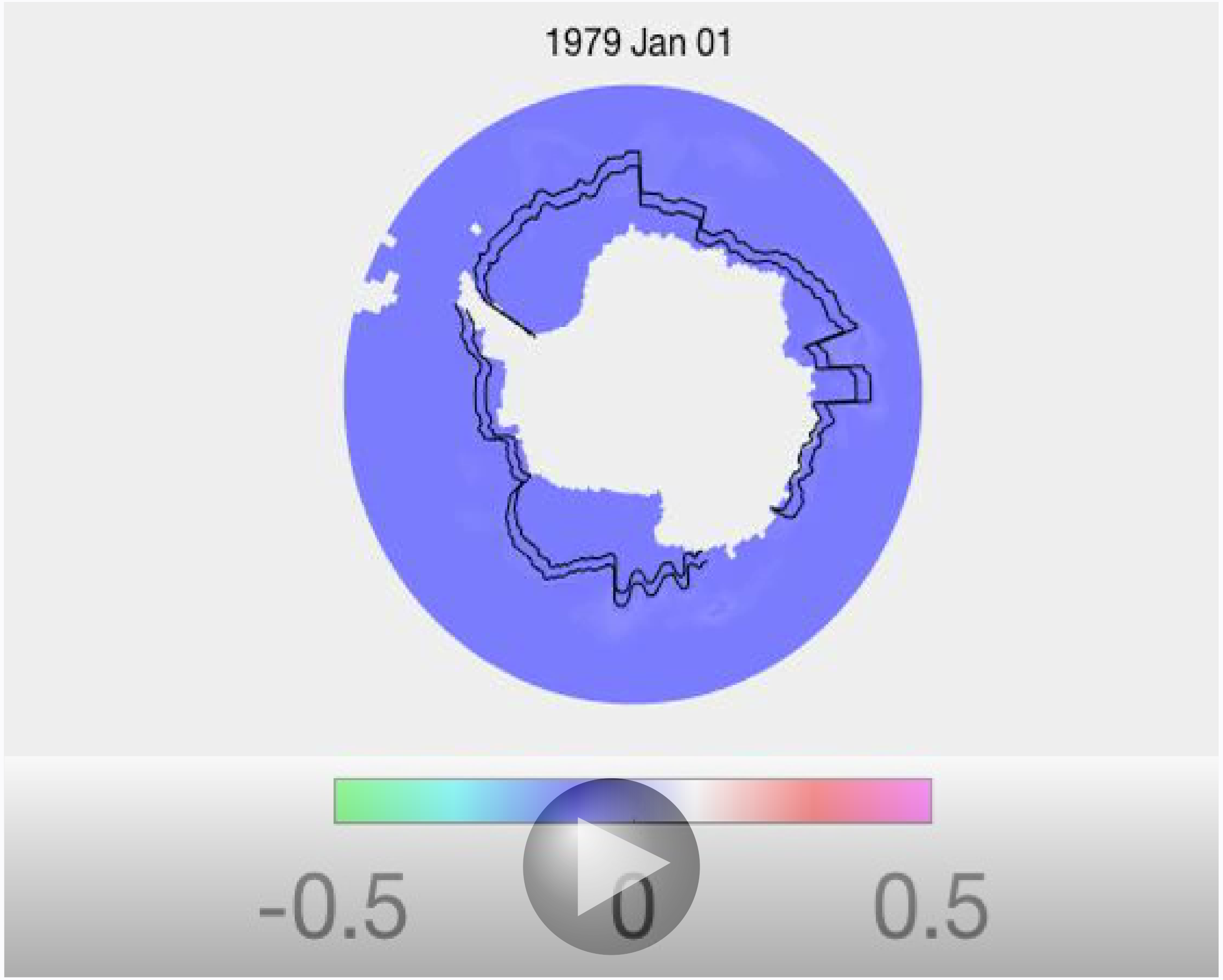
Small floes: $0 < D \leq 5\,\mathrm{m}$

Broken floes: $5\,\mathrm{m} < D \leq 250\,\mathrm{m}$

Unbroken floes: $250\,\mathrm{m} < D$

Simulation Antarctic, standalone, 1979–89

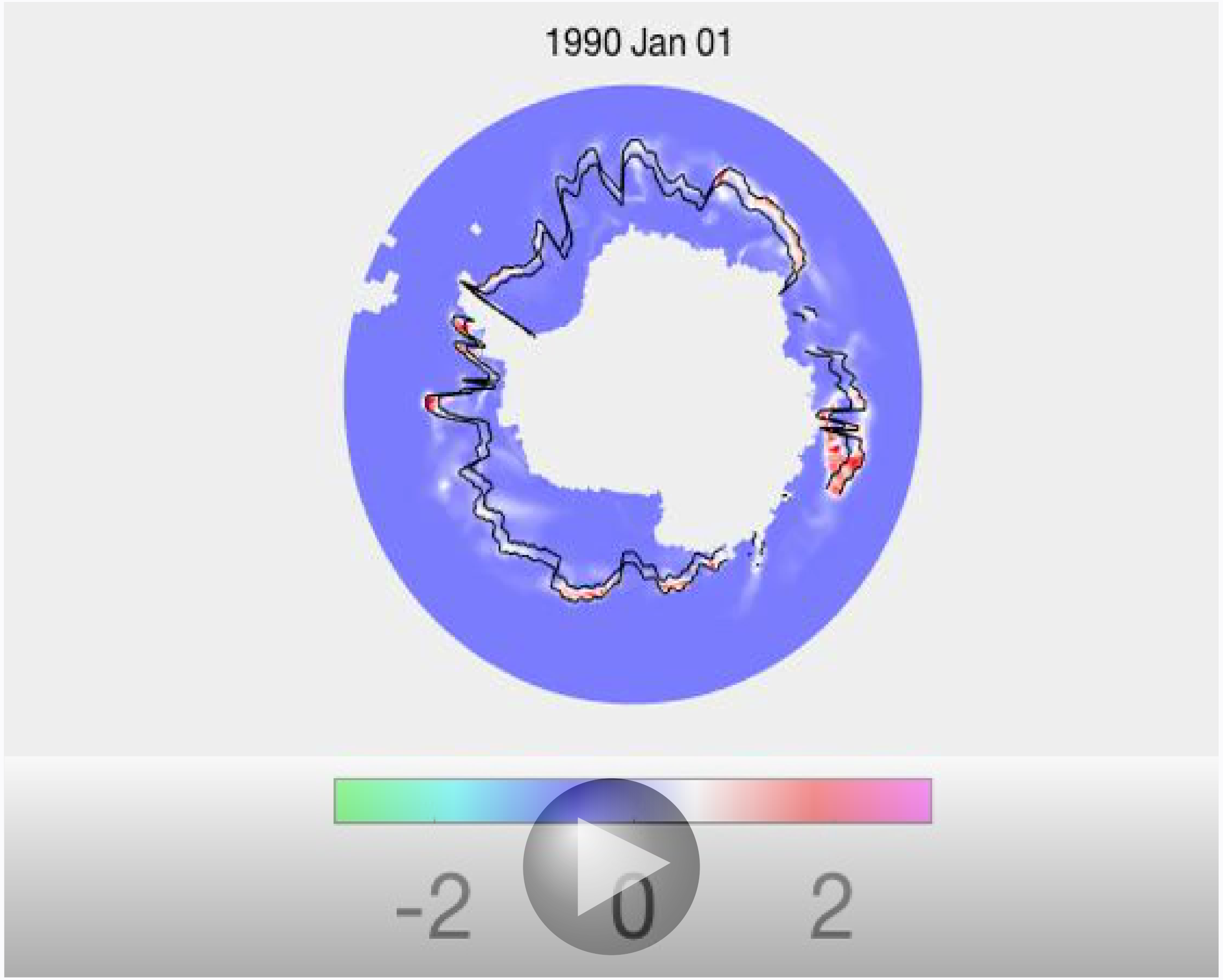
Concentration: no waves − with waves



less ice ↔ more ice

Simulation Antarctic, standalone, 1990–95

Volume [km^3]: no waves $-$ with waves



less ice $\longleftrightarrow$ more ice

Future

Fully coupled model

- Where?!?

Floe-size dependent dynamics

- Drag in CICE 5 (Feltham group model)
- Modified rheology (Aksenov group integrating Feltham's granular rheology into CICE)
- Transport (models by Washington and Harvard groups)

More???

- Pancake ice
- Landfast ice
- Ice shelves