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McMurdo Sound

An accessible laboratory for ice shelf / ocean processes

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Pat Langhorne, Inga Smith, Tim Haskell

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The University of Auckland New Zealand
CallaghanInnovation Business Technology Success
University of Otago Sapere Aude

Interactions at the boundary

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Tony Hisgett

Alison Lee

Significance of small-scale processes

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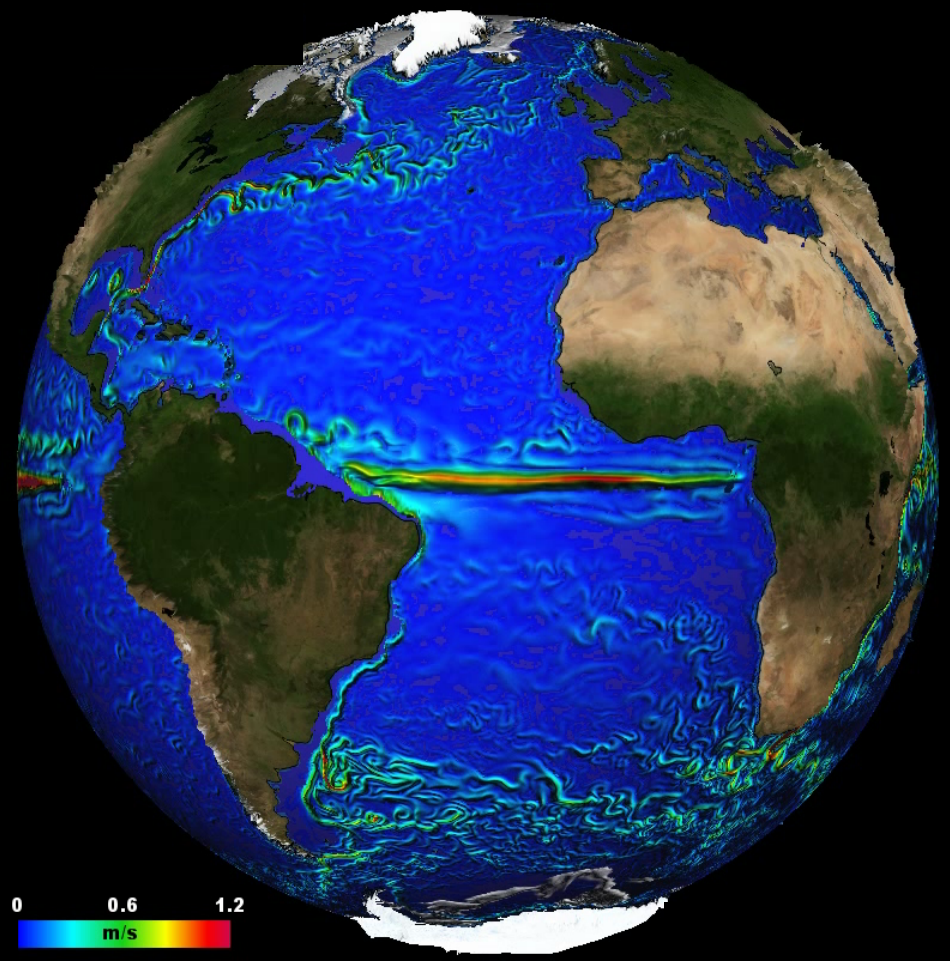
- Critical exchanges at boundaries
- Complex processes at phase-change margin
- Potential for large-scale impacts
- Assess quality of predictive tools

McMurdo Sound : A quantifiable scale

- Wide range of available ice-ocean processes
- Ice shelf + sea ice ocean regimes
- Develop tools, skills and understanding



Surface velocity and sea ice
Erik Behrens (NIWA)

McMurdo Sound

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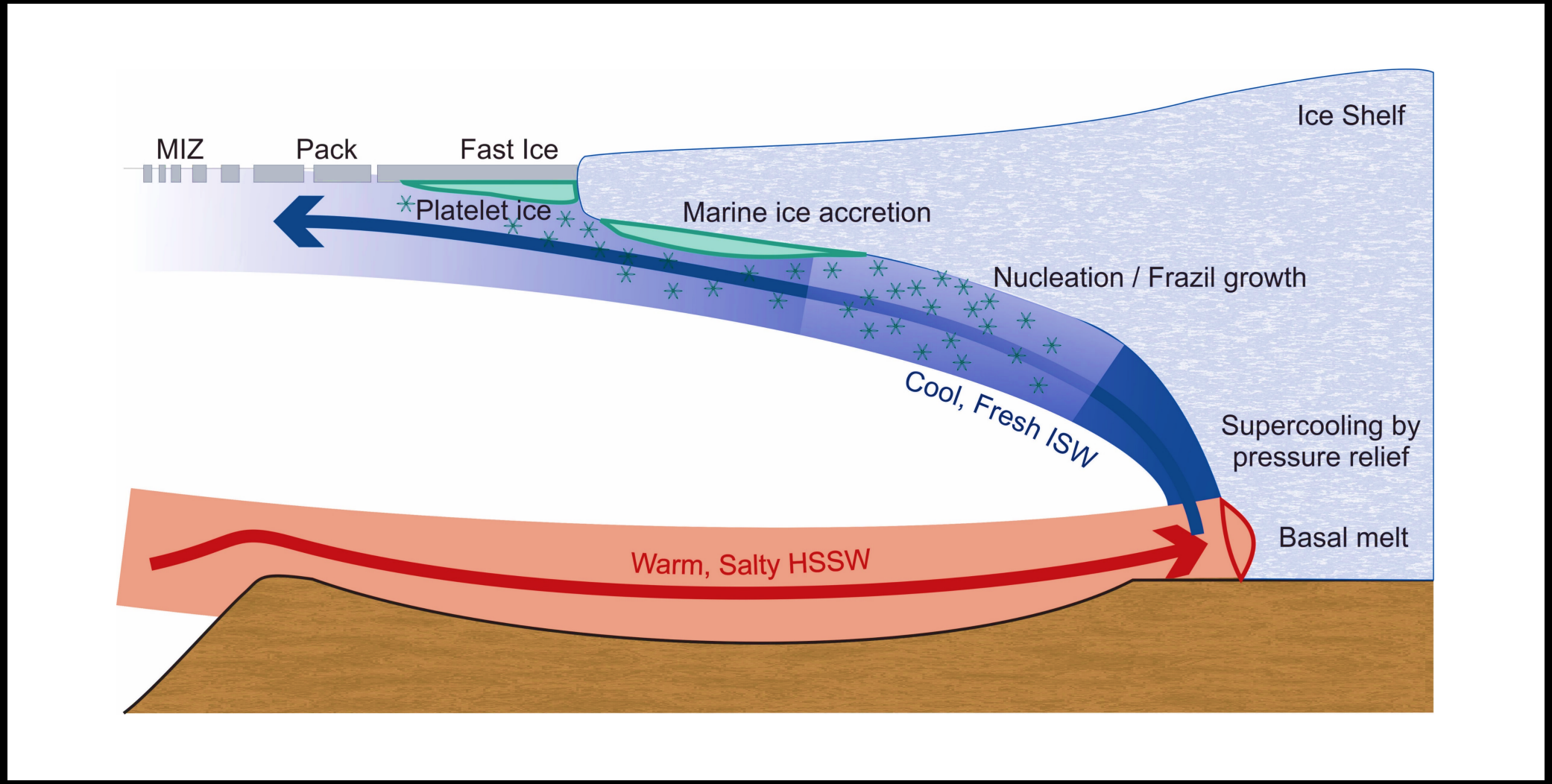

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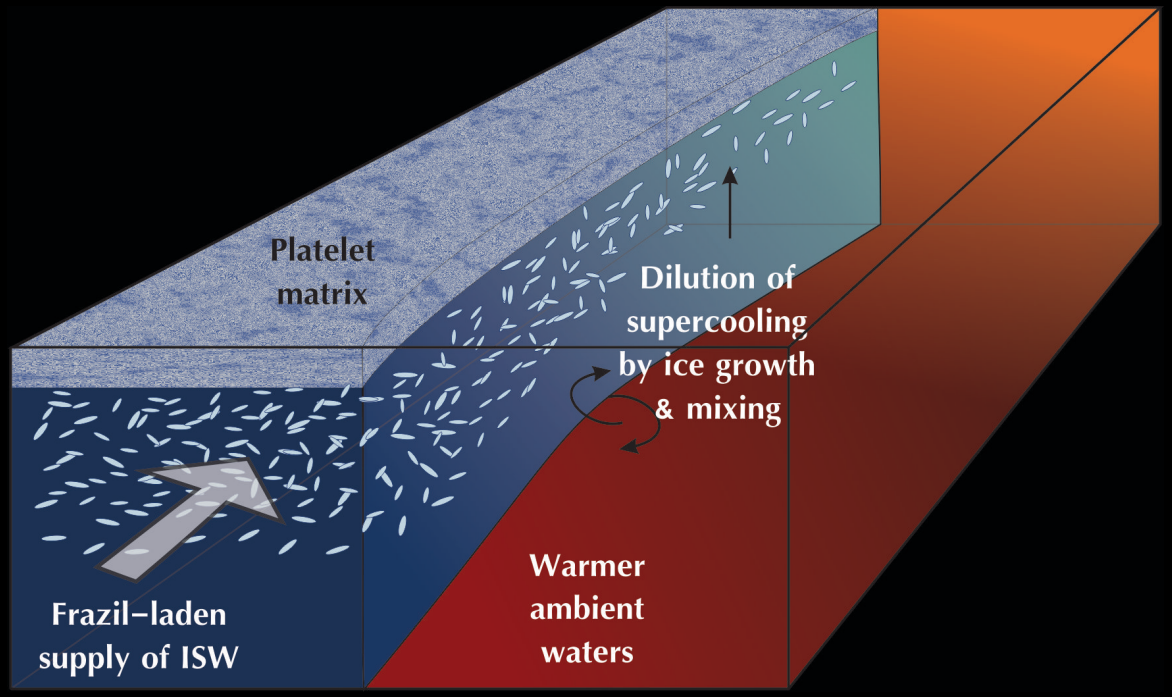

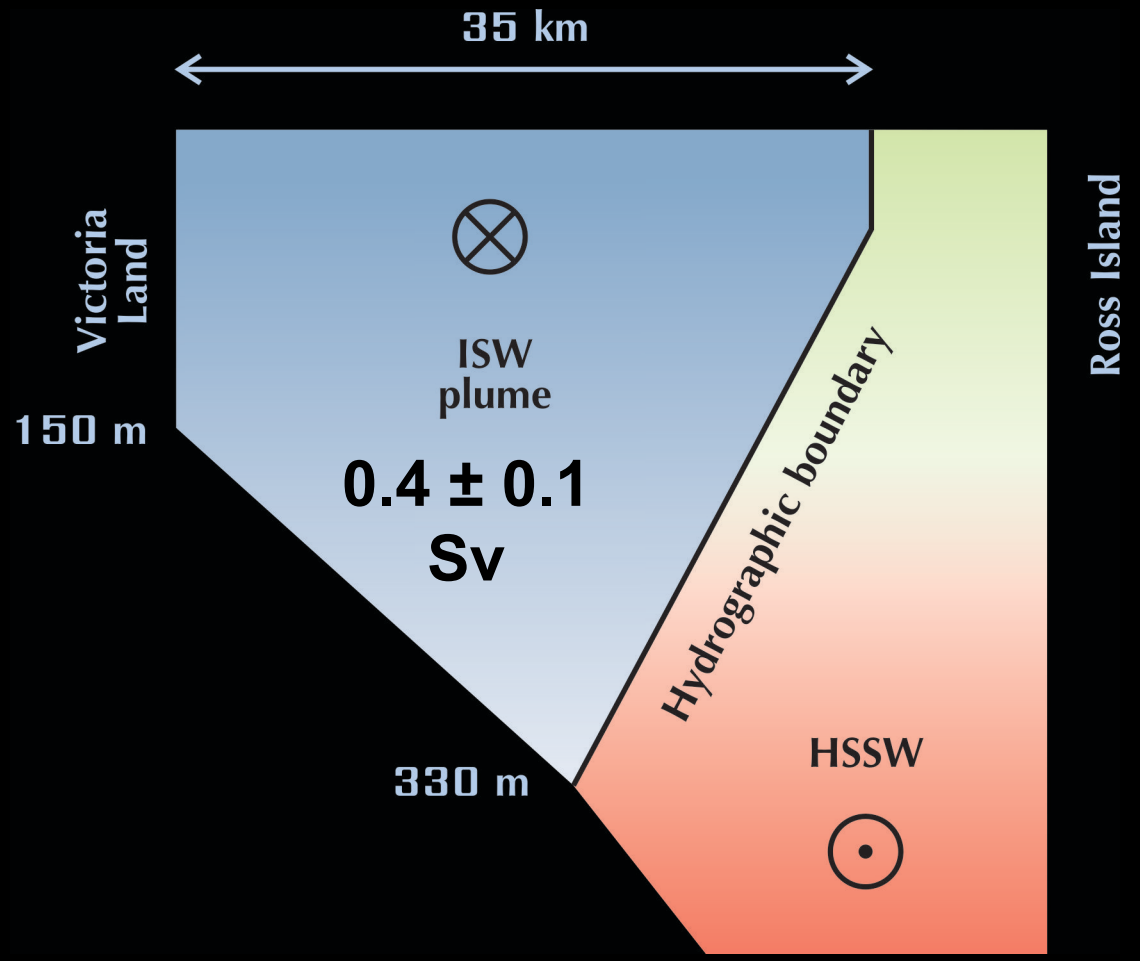

McMurdo Sound hydrography – looking Northwards
Robinson et al., 2014

Accessible ice-ocean processes

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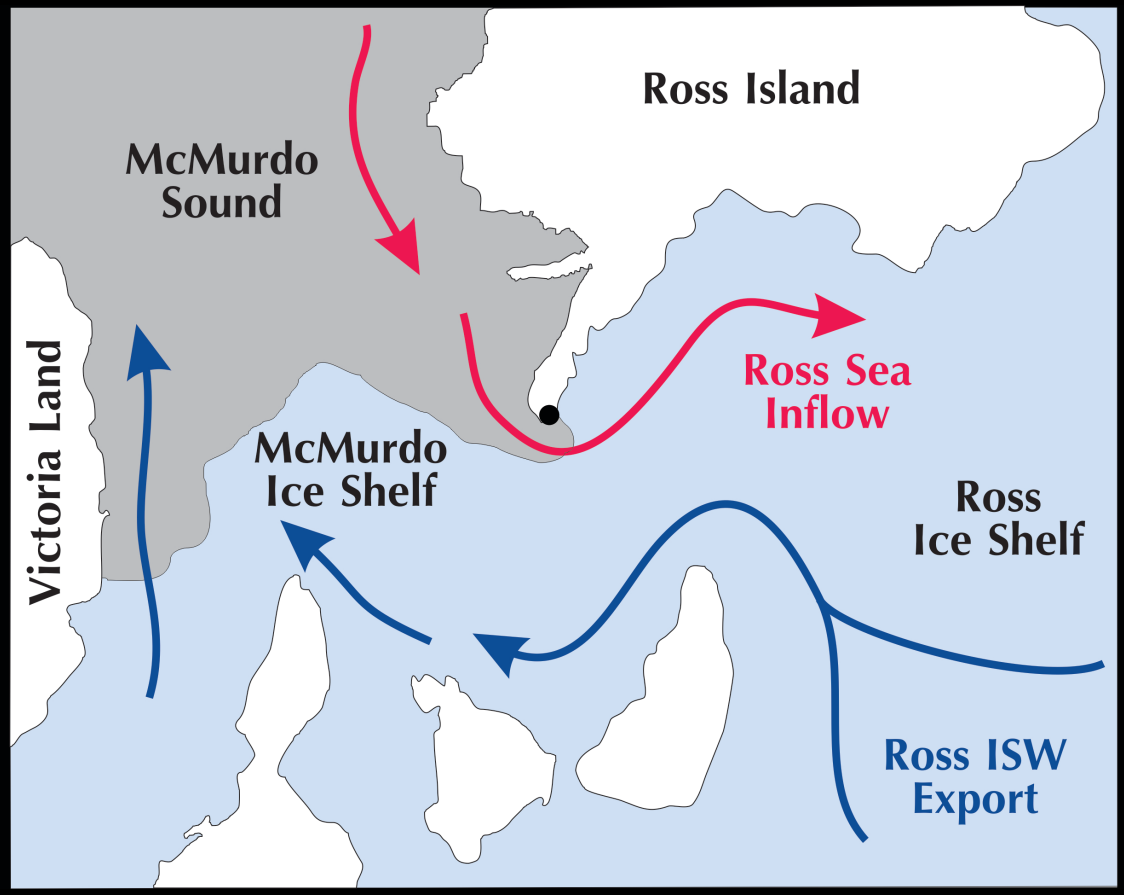
within 20 km of Scott Base

Ice shelf front exchange flow – both sea ice & ice shelf regimes
Episodic frazil-laden flow
Fast ice (as a temporary extension of ice shelf)
Vertical Ice walls: McMurdo Ice Shelf; Erebus Glacier Tongue;
Polynya: McMurdo;
Winter sea ice growth and evolution
Platelet layer formation & consolidation



> 100 years of ocean & atmospheric observations

Robinson et al., 2014

Accessible ice-ocean processes

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within 50 km of Scott Base

Ice shelf front exchange flow – both sea ice & ice shelf regimes
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Polynya: McMurdo;
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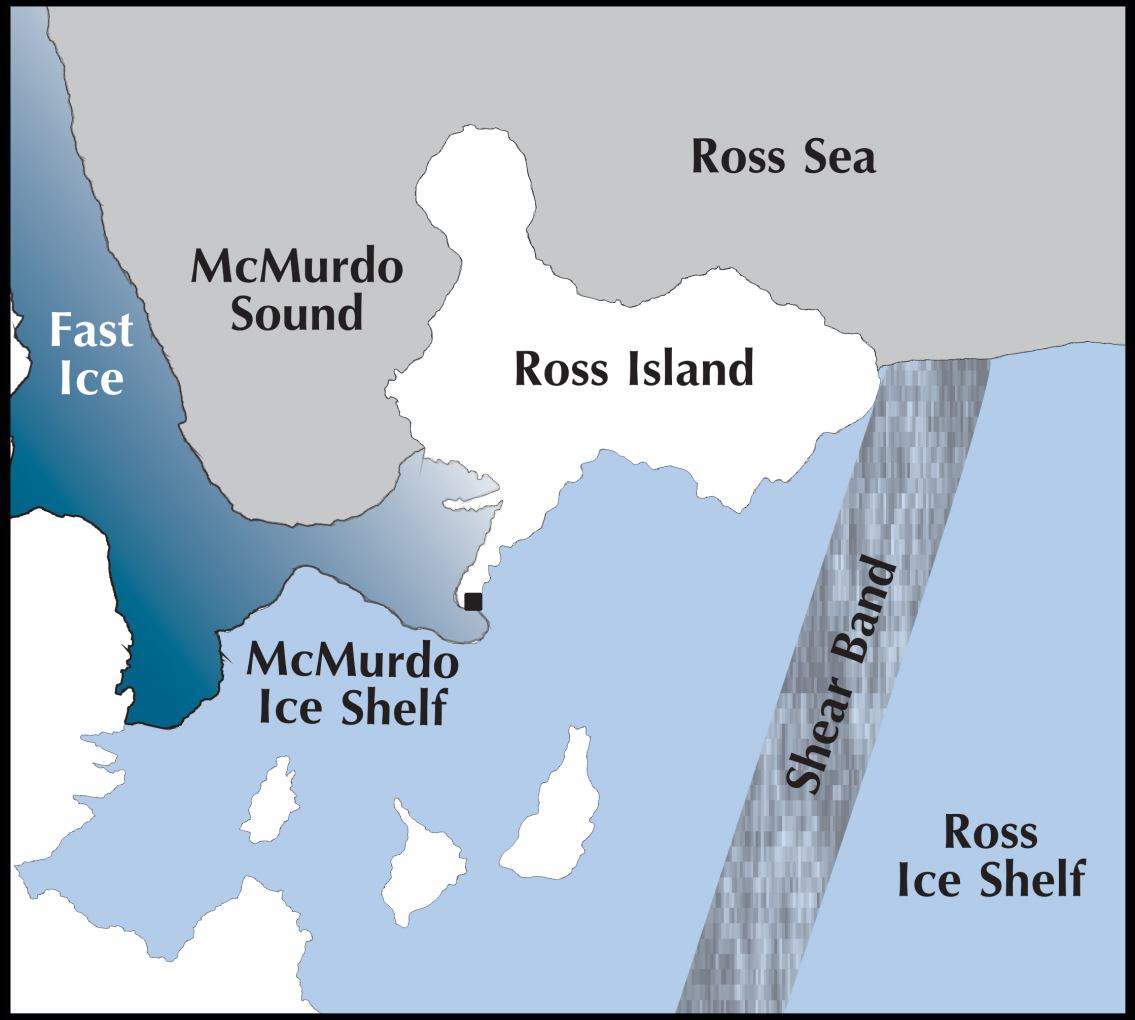
Marine Ice accretion and consolidation
Supercooling by pressure-relief
Quantifiable Ice Shelf Water plume



Accessible ice-ocean processes

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within reach of the NZ Programme

Ice shelf front exchange flow – both sea ice & ice shelf regimes
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Fast ice (as a temporary extension of ice shelf)
Vertical Ice walls: McMurdo Ice Shelf; Erebus Glacier Tongue; Ross Ice Shelf; Drygalski Ice Tongue
Polynya: McMurdo; Ross Sea
Winter sea ice growth and evolution
Platelet layer formation & consolidation
Marine Ice accretion and consolidation
Supercooling by pressure-relief
Quantifiable Ice Shelf Water plume
Ice Shelf / ocean interaction in space & time
Interactions at the grounding line
Linkages between sub-Antarctic & polar regions

Fixed-wing support
Deep Hot Water Drill
Ice Shelf traverse capability
Collaboration with national programmes

Supercooled Ice Shelf Water

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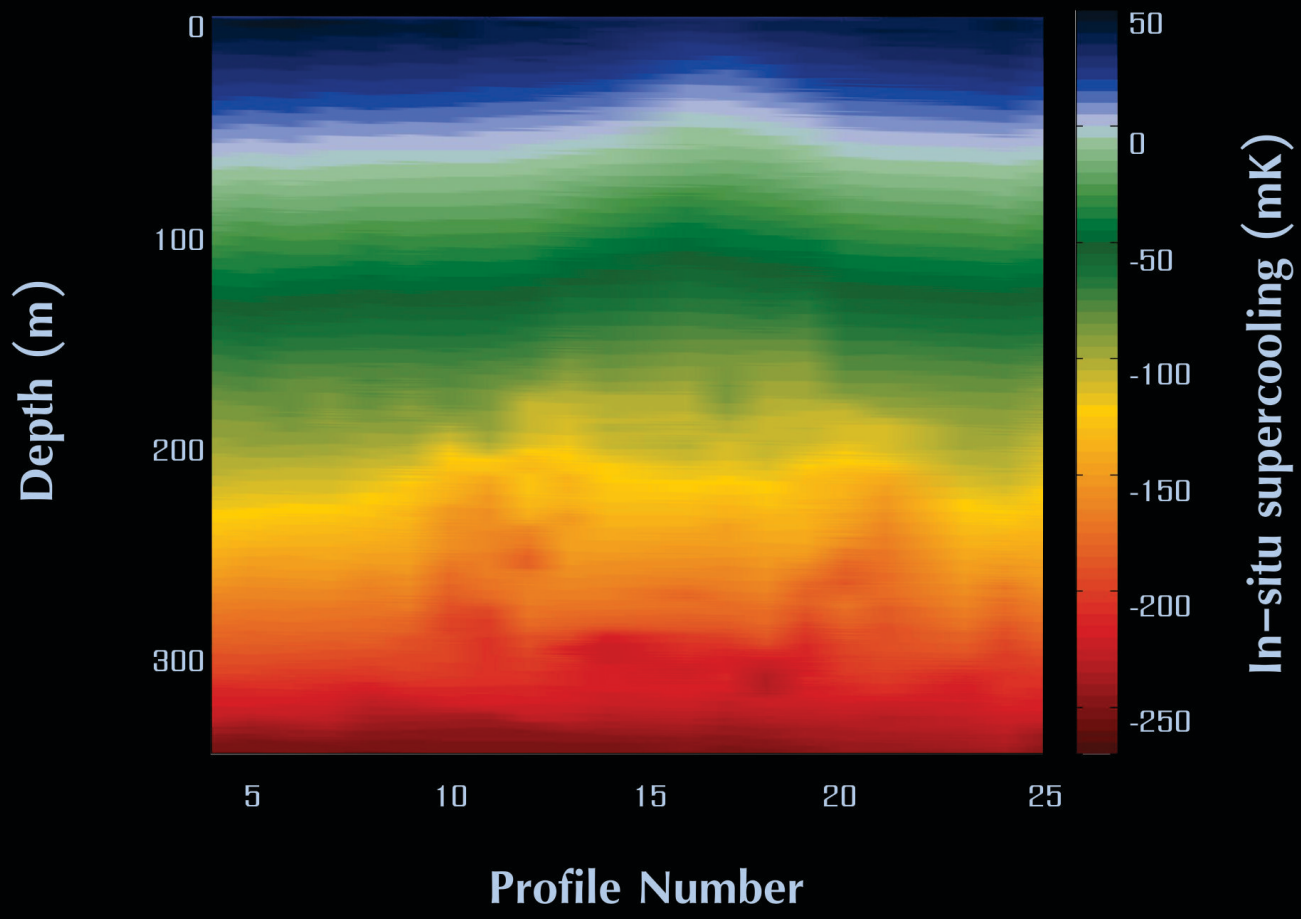
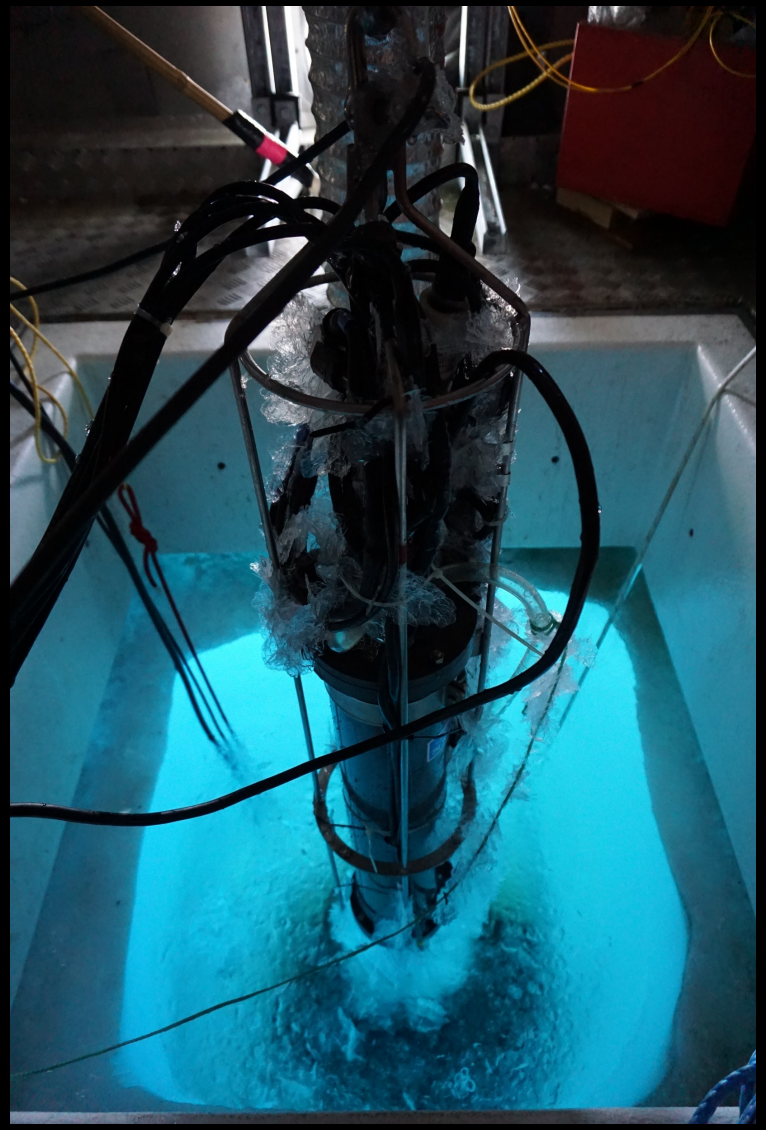


Timeseries of supercooled profiles in McMurdo Sound
Robinson et al., 2014



Processes at fluid-solid boundaries

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Alex Forrest, UBC

Roughness via crystal suspension & accretion

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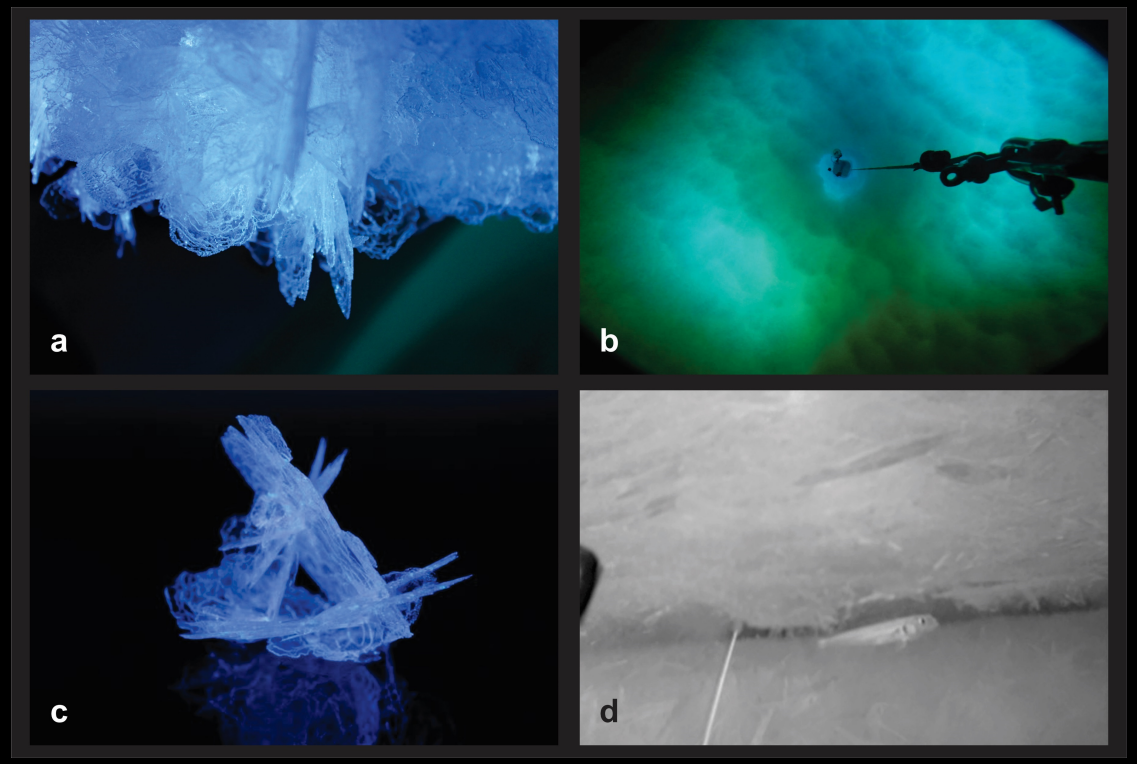

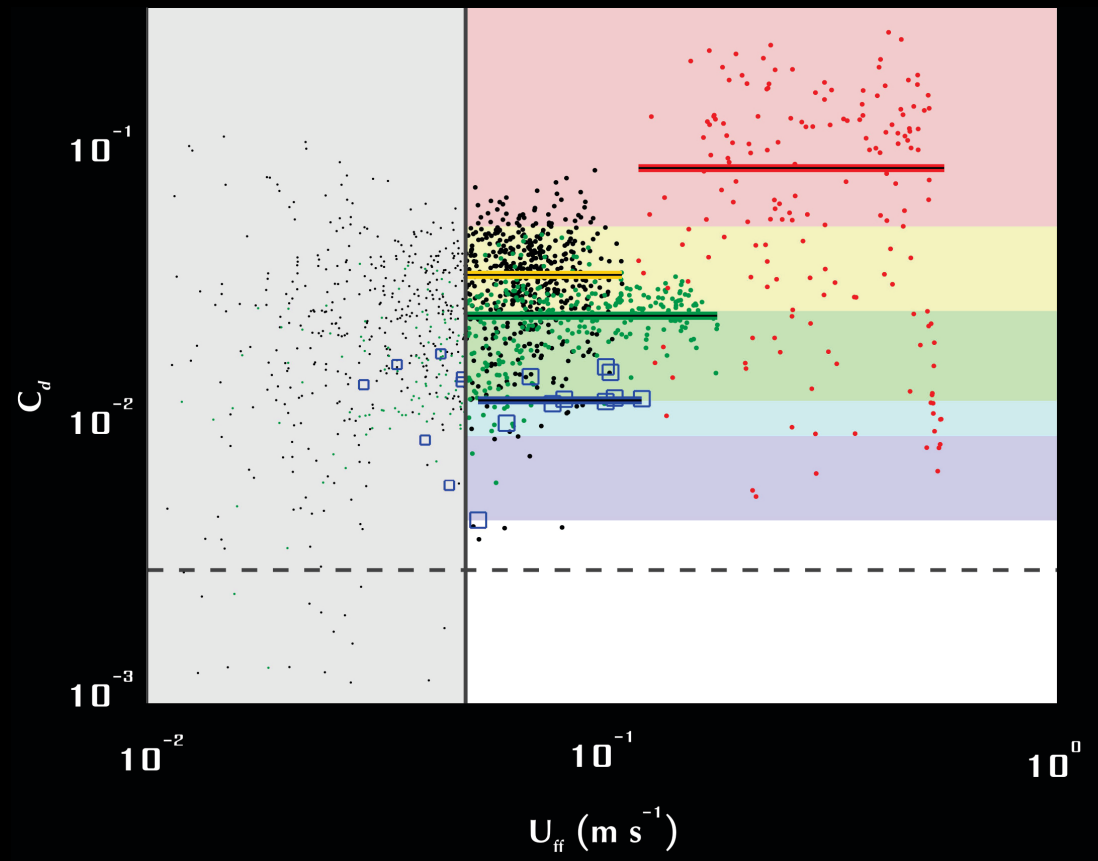

Modes of crystal-enhanced effective roughness

Robinson et al., 2017

Pressure-relief of Ice Shelf Water

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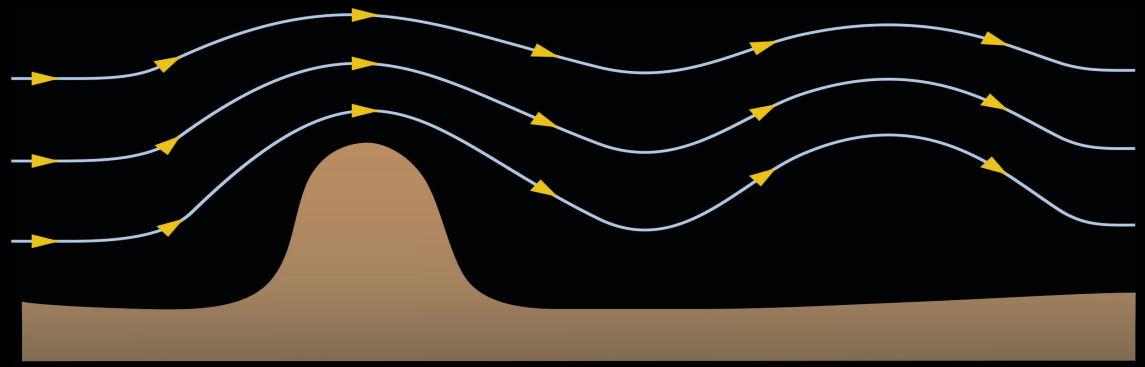
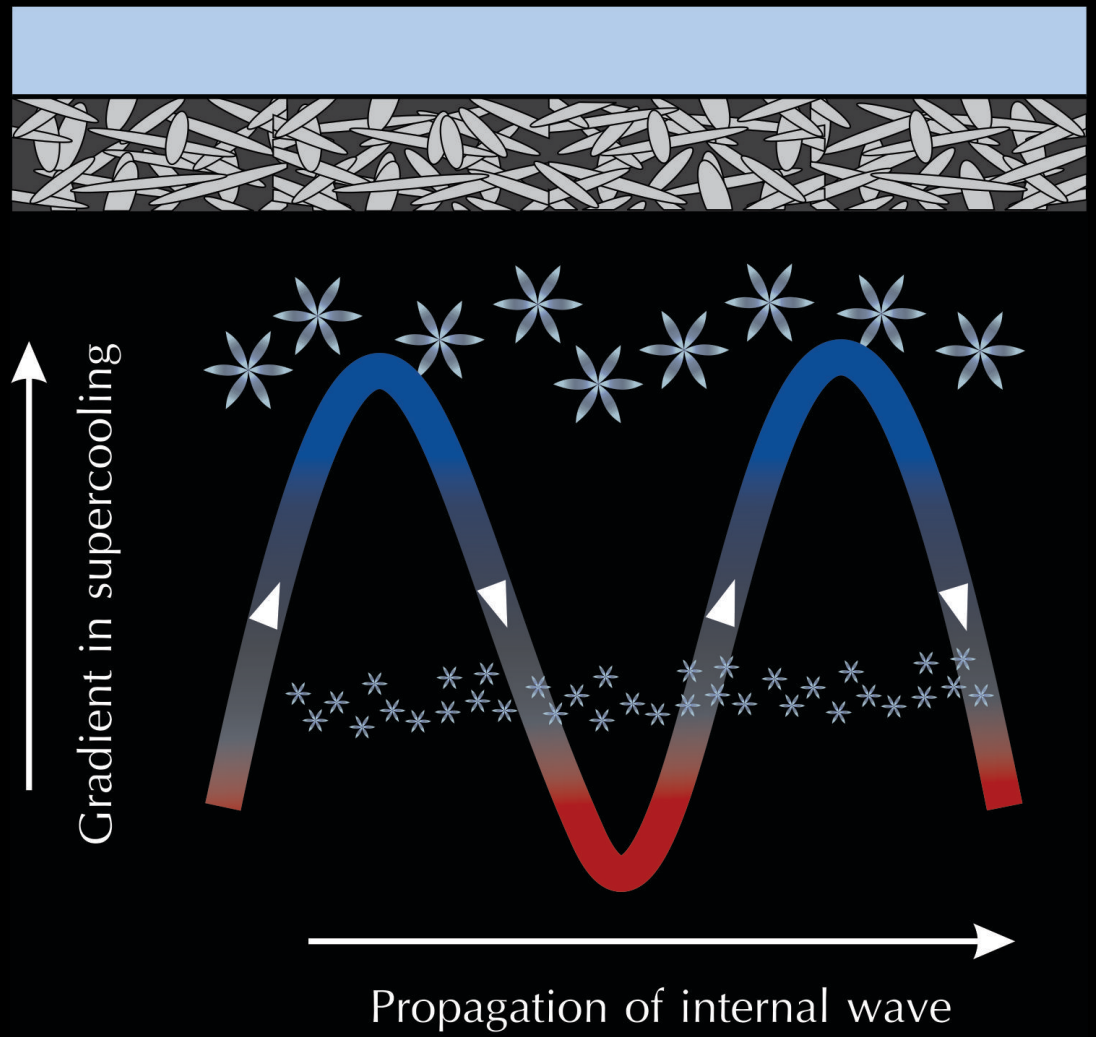
Interaction of internal waves with ISW

Robinson et al., In prep.





Pressure-relief of Ice Shelf Water

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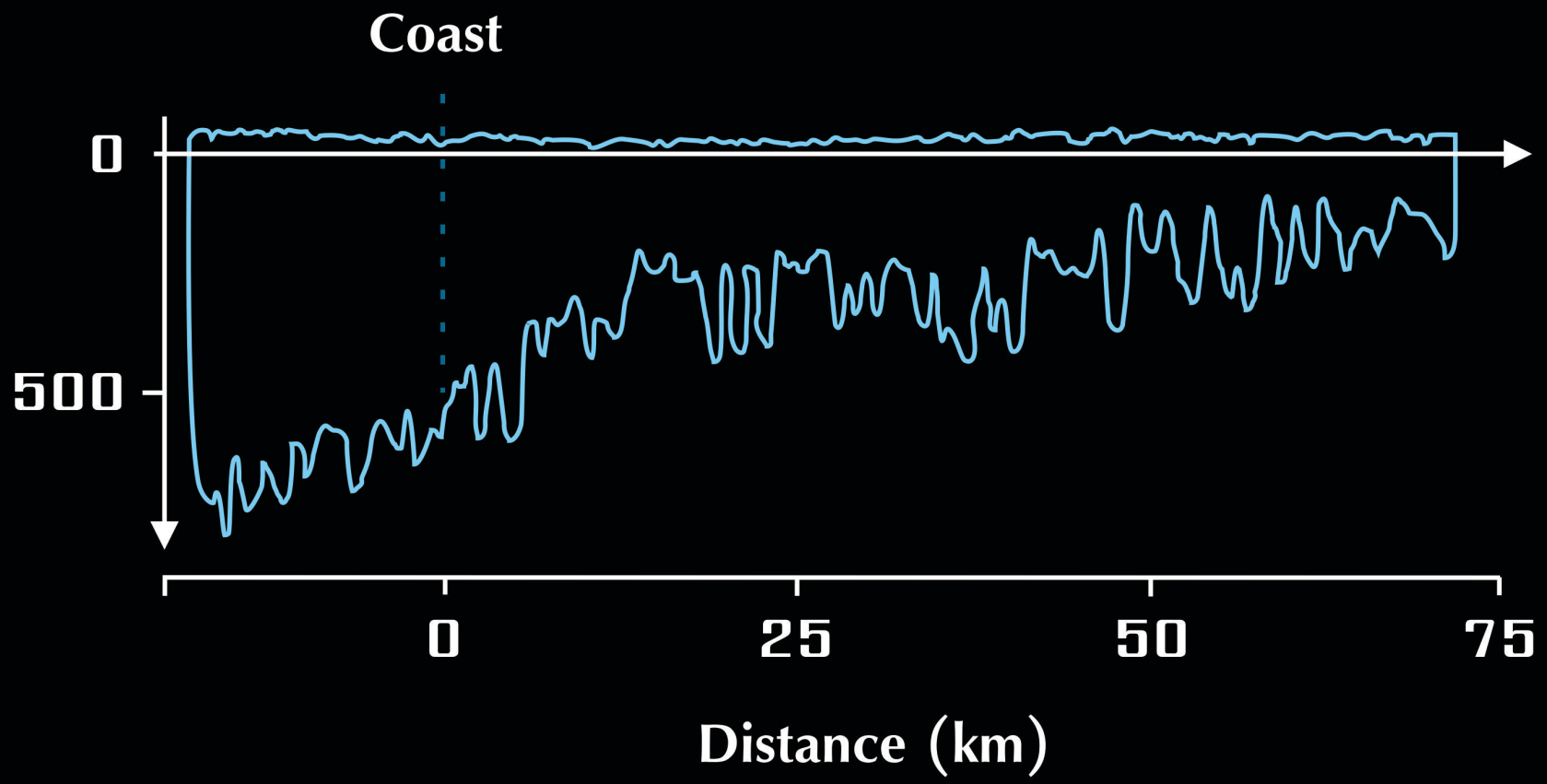

Morphology of bottom surfaces of glacier ice tongues in the East Antarctic region
Bianchi et al., Annali de Geofisica, 44 (1), 2001

Connections between sea ice & ice shelf regimes

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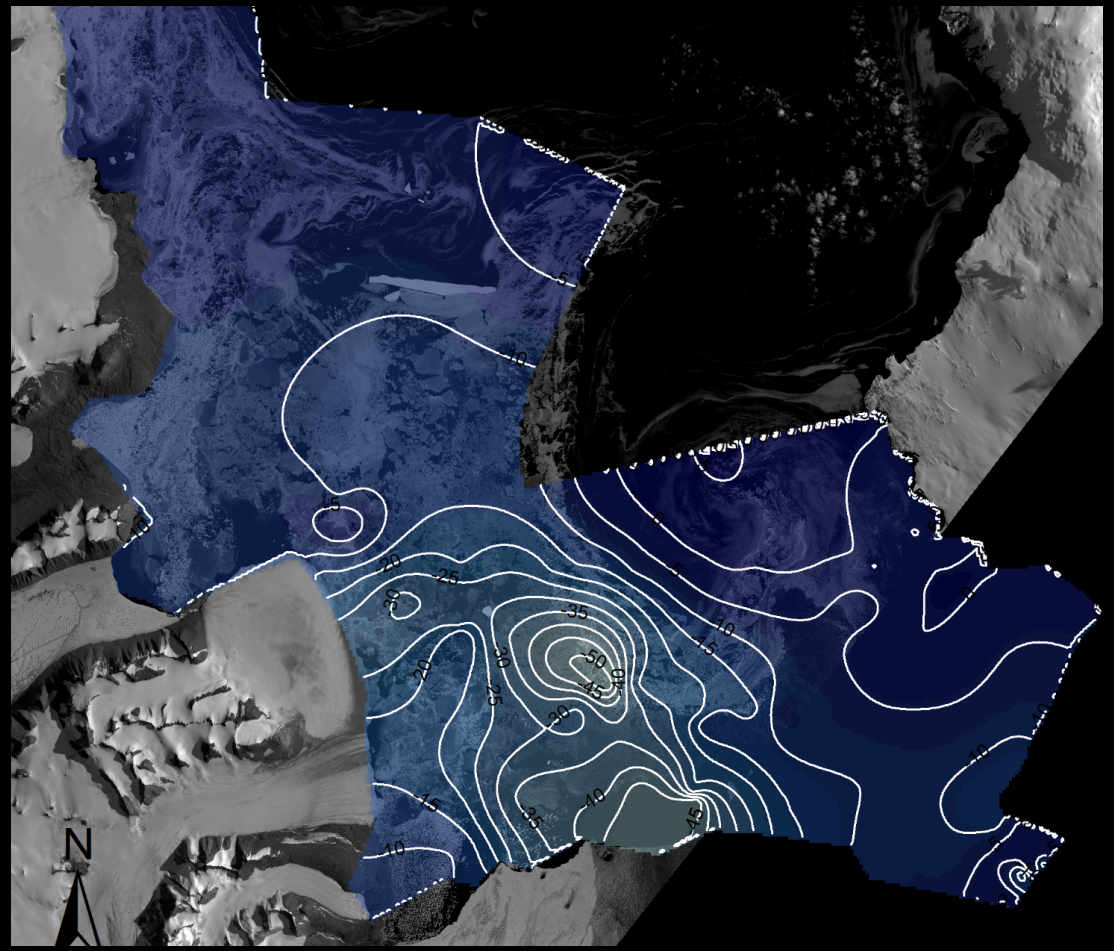
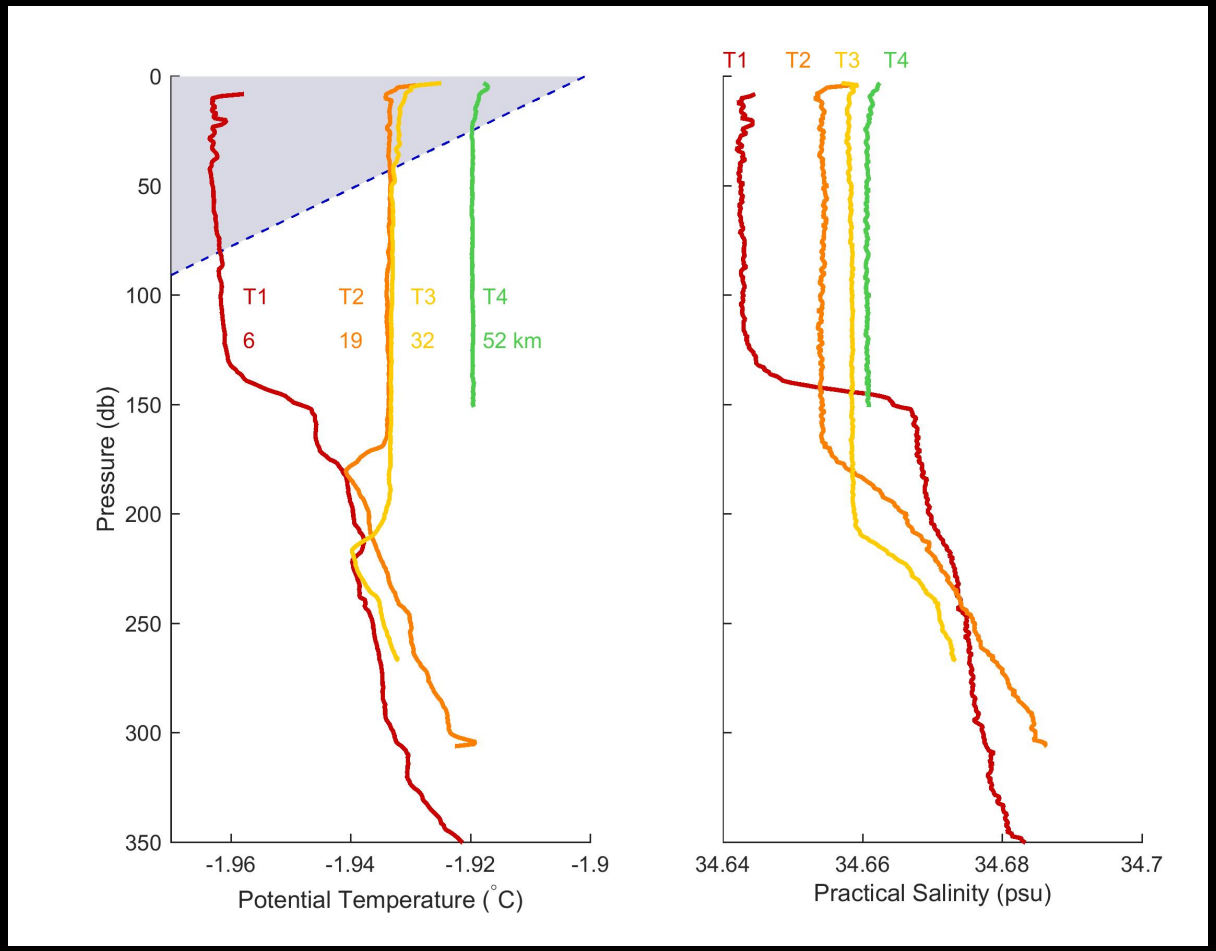


Langhorne et al., 2015



Robinson et al., In prep.

Testing parameterisations

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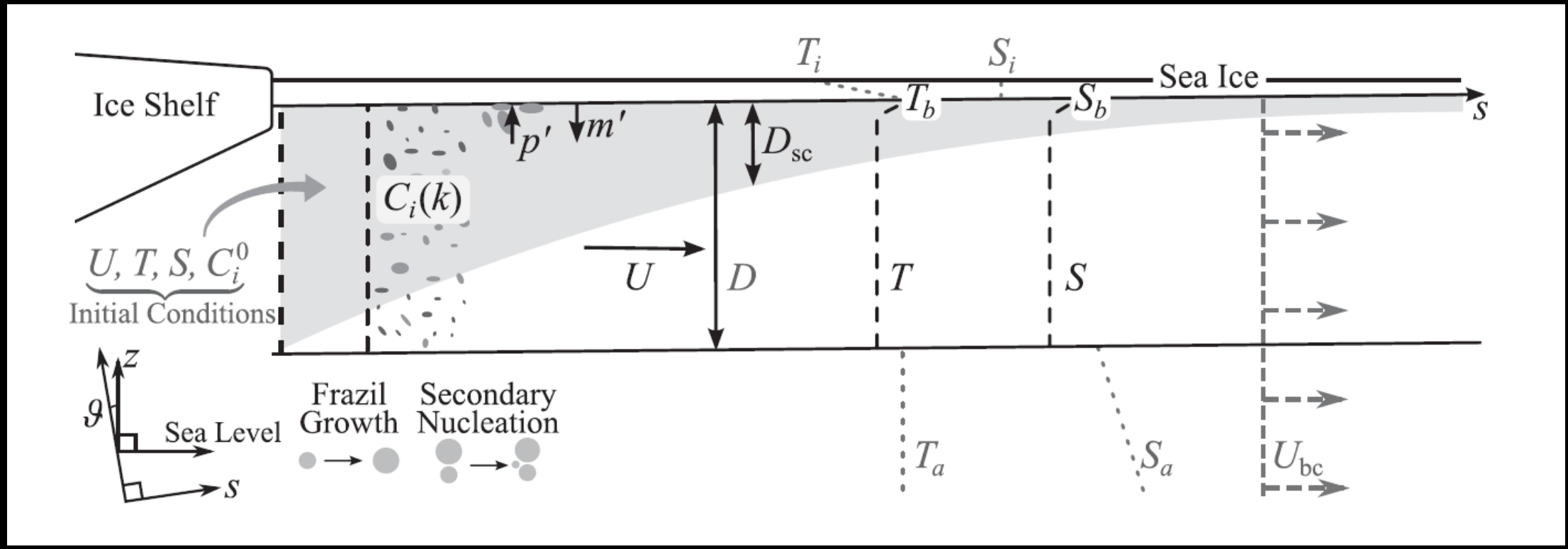

Hughes et al., 2014

Testing parameterisations

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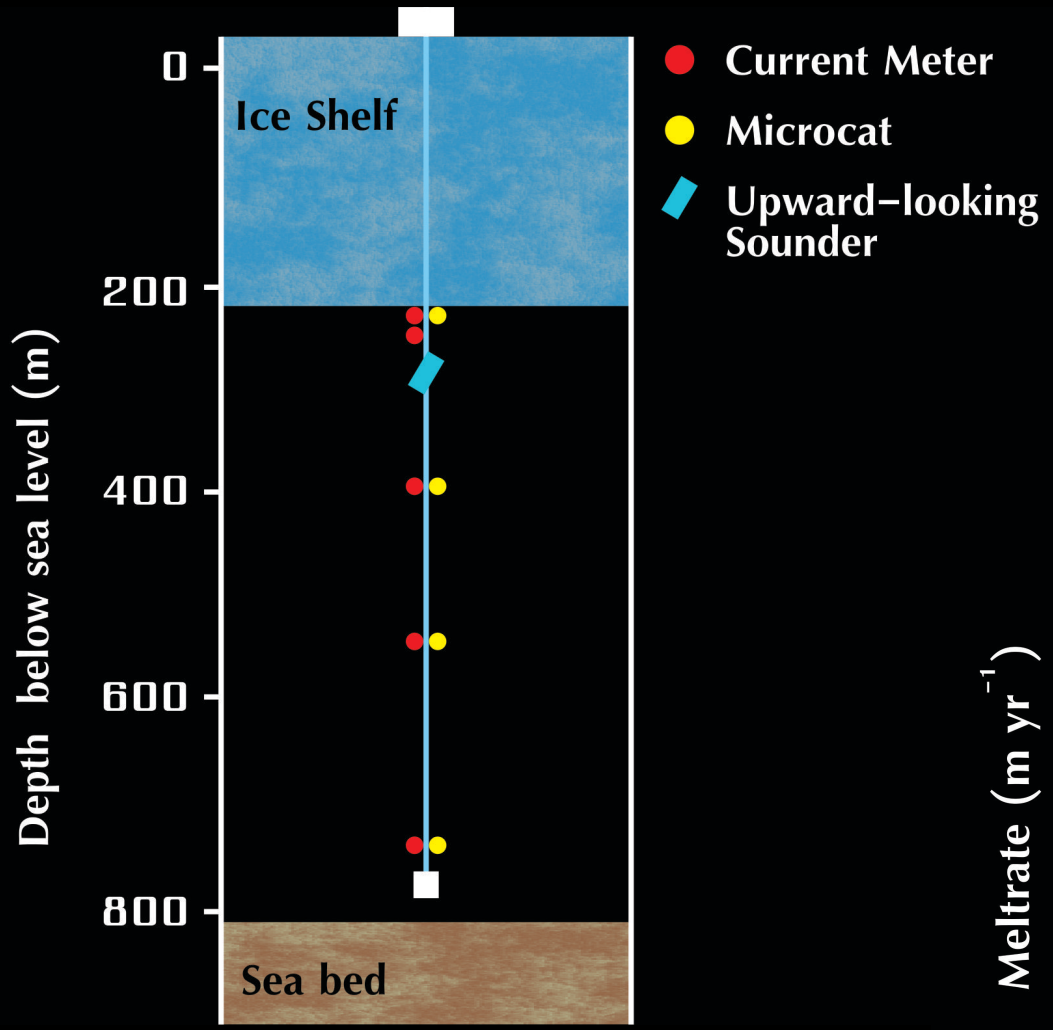
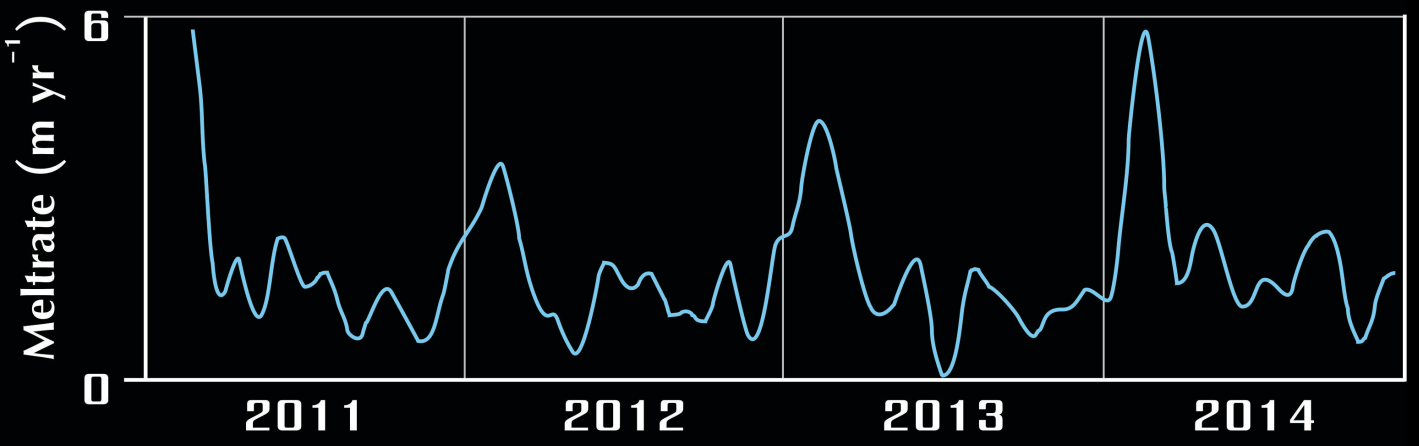


Stewart, 2017
Malyarenko, in prep.



Implications for ice shelf observations

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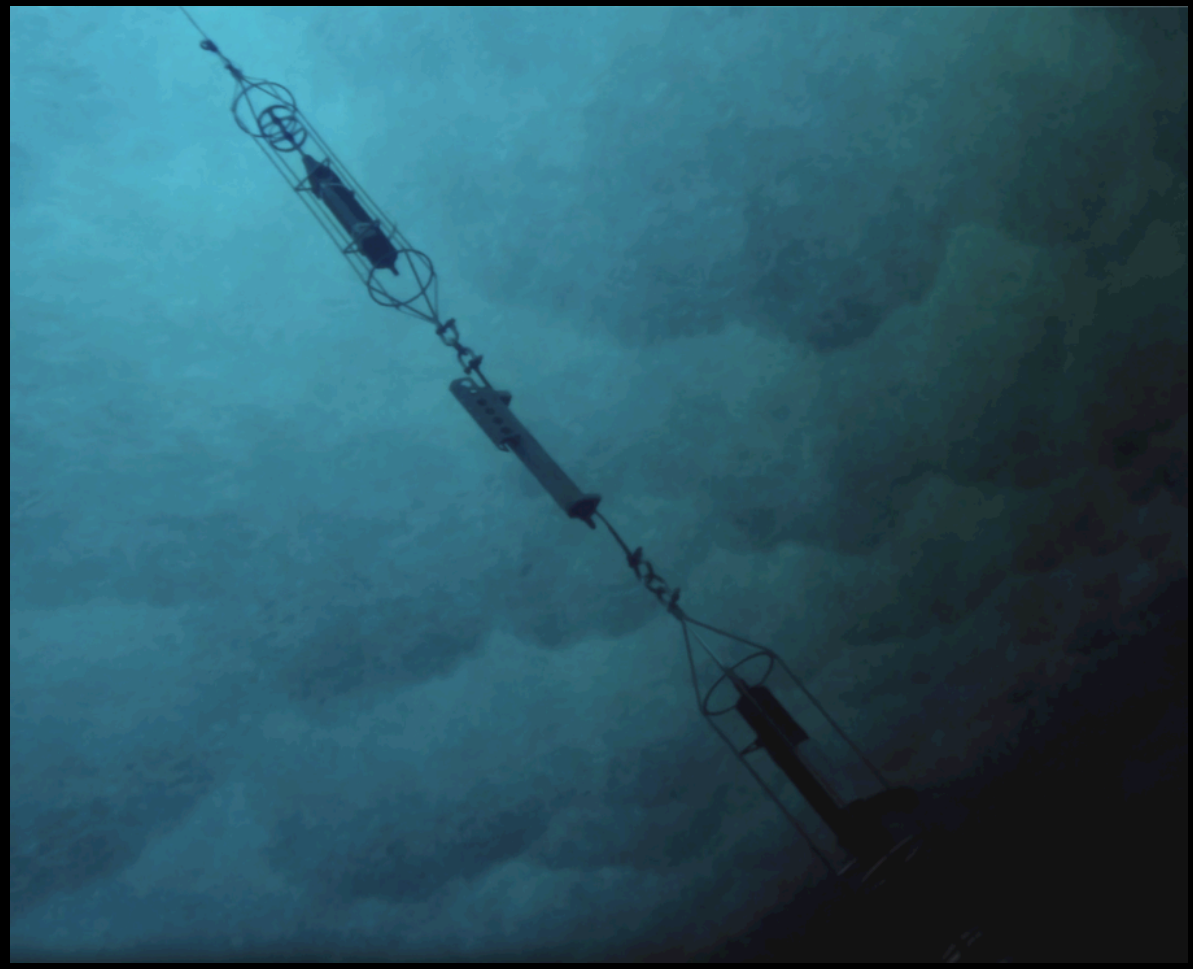
An opportunity to

- Develop observational tools, experience & understanding
- Inform process parameterisation
- Observe changes over quantifiable spatial scales

Implications for ice shelf / ocean observations

- Boundary roughness and interactions
- Basal topography
- Correspondence between platelet & marine ice layers



Representation of small-scale processes

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Parameterisation of sub-grid processes

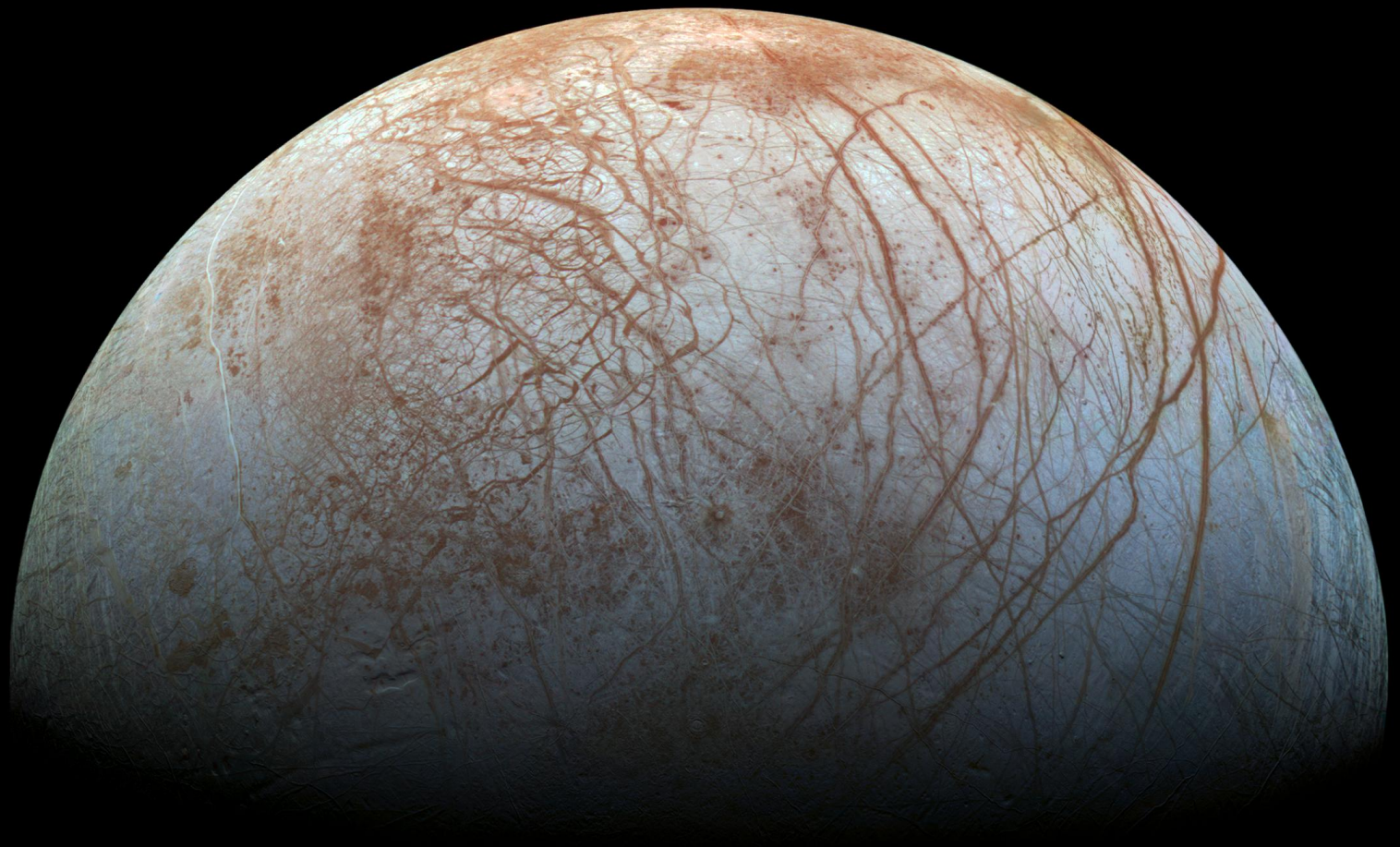
Galton-Fenzi & Gwyther

ESM – Improving sea ice performance

Behrens et al.

Relevance for other worlds

Schmidt et al.



Thanks to …

MARSDEN FUND
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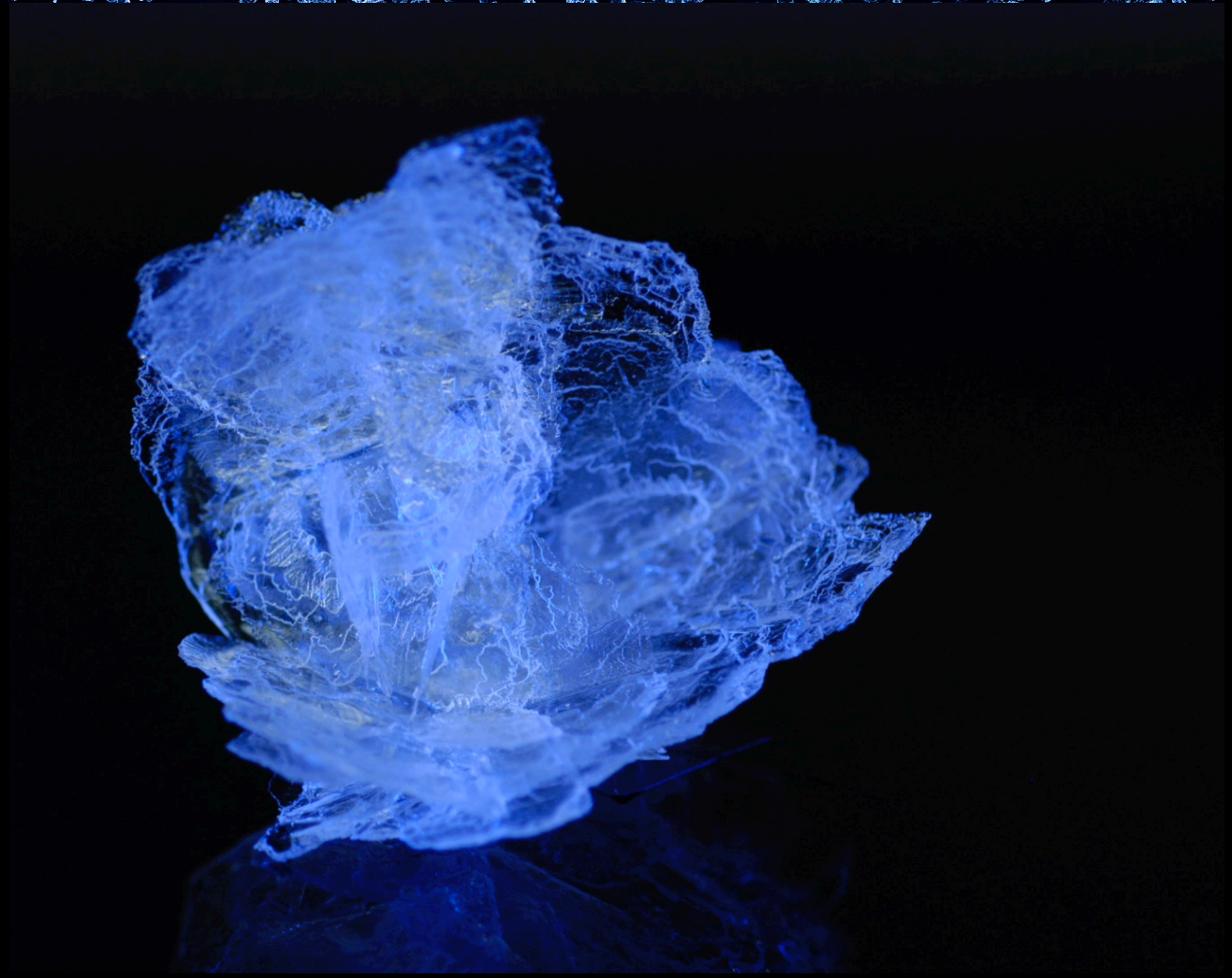

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Dave Dempsey
Madi Rosevear
Eamon Frazer
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References

Bianchi et al., Morphology of bottom surfaces of glacier ice tongues in the East Antarctic region, Annali de Geofisica, 2001

Hughes et al., Extension of an Ice Shelf Water plume model beneath sea ice with application in McMurdo Sound, Antarctica, 2014

Langhorne et al., Observed platelet ice distributions in Antarctic sea ice: An index for ocean-ice shelf heat flux, GRL, 2015

Robinson et al., Evolution of a supercooled ISW plume with an actively growing sub-ice platelet matrix, JGR, 2014

Robinson et al., Observations of amplified roughness from crystal accretion in the sub-ice ocean boundary layer, GRL, 2017

Robinson et al., Longevity of Ice Shelf Water with distance from the Ice Shelf front (In prep.)

Robinson et al., Supercooling by interaction of internal waves with Ice Shelf Water (In prep.)

Stewart, Ice-ocean interactions under the north-western Ross Ice Shelf, Antarctica, PhD thesis, 2017

Ice-ocean processes
Water mass formation / advection / circulation
Waves in sea ice – fast ice to MIZ
Supercooling
Frazil / Platelet ice
Ice shelf / sea ice connection
Flow under and around ice tongues
Melt / dissolve / Freeze processes
Under-ice boundary roughness
Connection to climate scales via Deep South ESM

Theme: The importance of small-scale interactions in large-scale processes

McMurdo Sound as a process laboratory for ice shelf processes – what processes can be accessed?

Set the scene – hydrography of McMurdo Sound (Robinson PhD)
McMurdo Sound represents a physical connection between Ice Shelf & Sea Ice regimes… it is filled with platelet ice, which is a manifestation of this connection.

Specific benefits of ready access
Early winter observations (preparing for 3rd)
Fast ice means there is very little (oceanographic) distinction between ice shelf & sea ice… or fast ice is an extension of the ice shelf.
Access to both SI & IS (e.g. for airborne studies)
Containerised set-up

We have / can / are investigate

Processes / longevity of supercooling relief with distance from the IS cavity
Suspended frazil & enhanced under-ice viscosity
Internal waves / lee waves / interaction with headland / rapid pressure-relief of SC water
Frazil / platelet accretion into layers (slush => semi-rigid matrix)
Interstitial freezing to consolidation
Under-ice boundary layer with various scales of roughness
Assessment of melt / freeze parameterisations (Hughes et al., Alena)
Sea ice growth processes, through winter
Test / develop supercoolometer
Connection to icy worlds – via Britney et al
Rapid pressure relief (internal waves, flow beneath glacier tongues, basal topography of ice tongues / shelves)
Processes at ice walls (DIT, EGT, McMIS, RIS)

Develop tools, understanding and skills in preparation for sub-IS investigations…
RIS vulnerability (interactions at the boundary)
Marine ice initiation & development

- Processes at the phase-change margin
  - Suspension & growth/melt of frazil
  - Implications for buoyancy-driven circulation (on many scales)
  - Development of the supercoolometer
  - Relief of supercooling & ISW influence on sea ice growth / trends with space (& time) from the ice shelf front
  - Crystal accretion and enhanced roughness
  - Convective overturning

- Pressure relief of ISW
  - Export of supercooled water, greater in depth and degree than elsewhere, direct from Ross / McMurdo IS
  - Interaction with headland produces large-amplitude waves in unstratified water
  - Basal topography of Ice Tongues (and crevassed ice shelves)

- Connections between ice shelf and sea ice regimes / processes

- Physical processes at fluid / solid boundaries
  - Melt / freeze / dissolve and an opportunity to assess existing parameterisations
  - ISW plume flow

- Implications for ice shelf / ocean observations
  - Boundary roughness at various scales (i.e. skin friction, morphology, ripples, billows)
  - Basal topography (i.e. inverted crevasses for marine ice initiation)
  - Marine ice initiation / development / consolidation / influence & susceptibility

- Modelling – small scale processes and climate scale