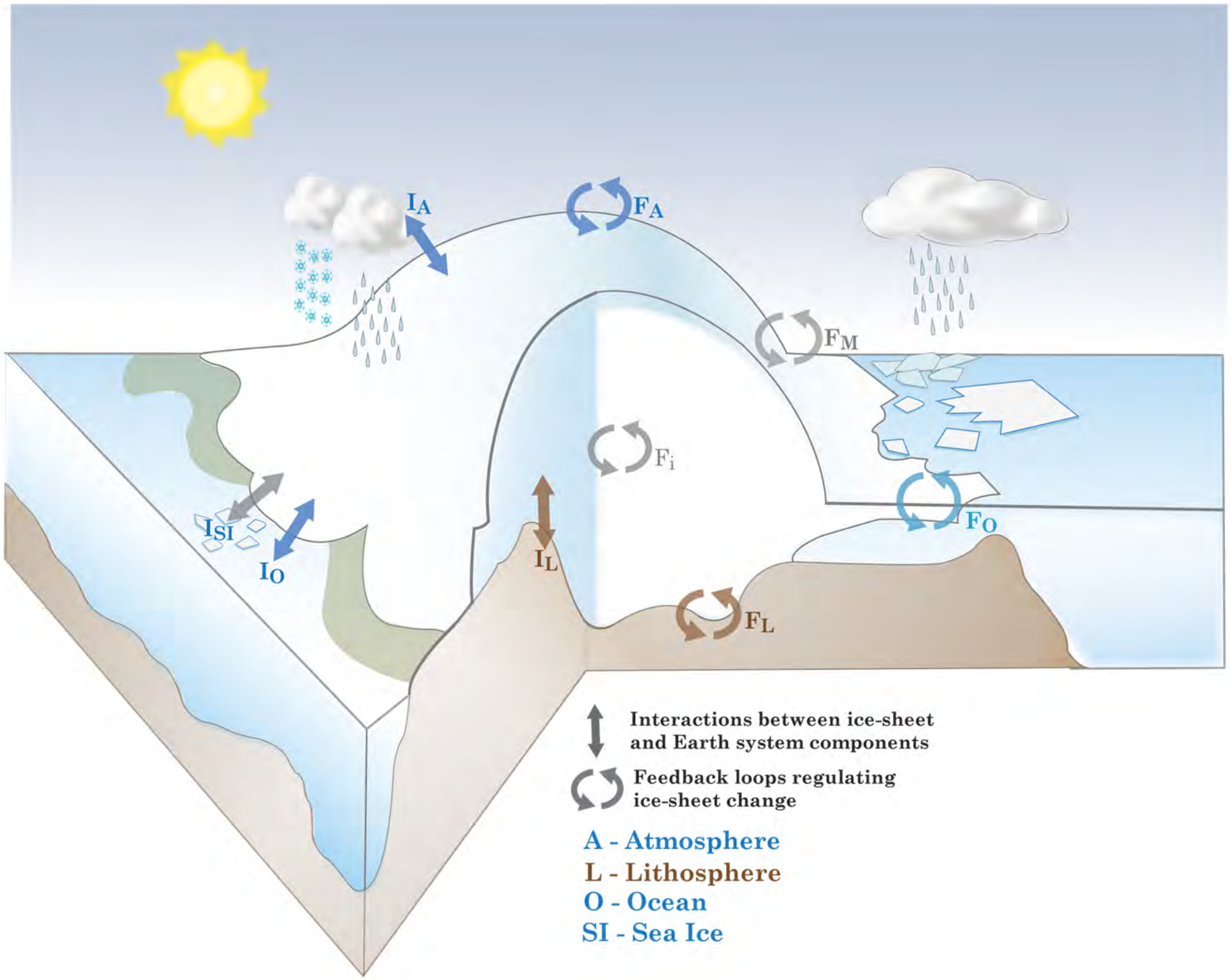
Ice sheets and their interactions with the oceans

Olga Sergienko

Geophysical Fluid Dynamics Laboratory Review

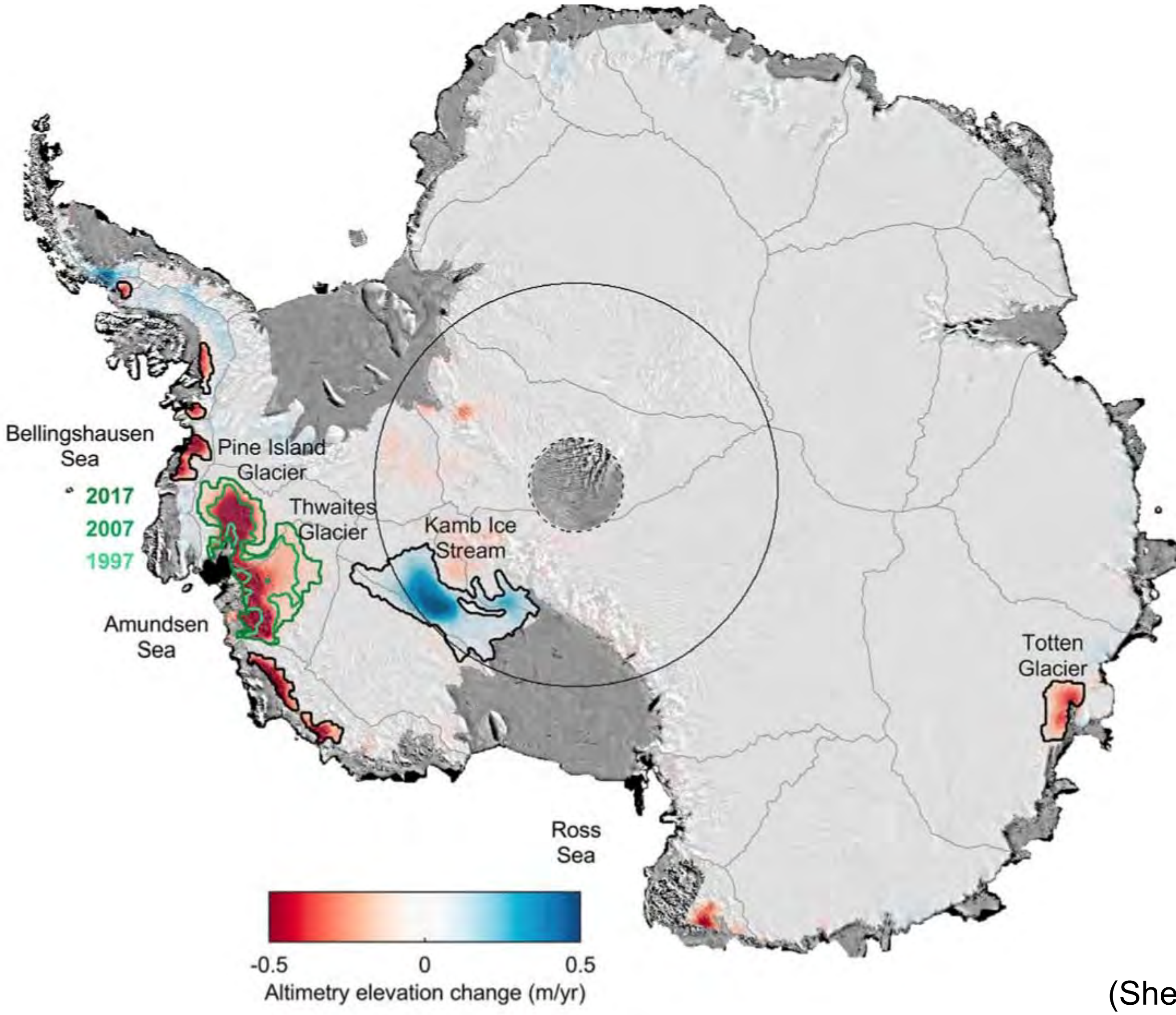
October 29-31, 2019

How ice sheets work



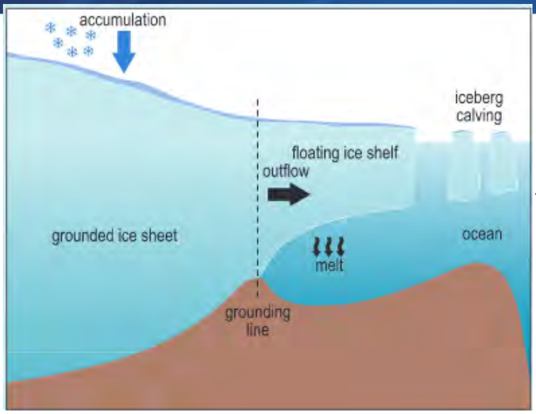
Fyke et al. (2018)

Antarctic surface elevation changes



(Shepherd et al., 2019)

Grounding line stability

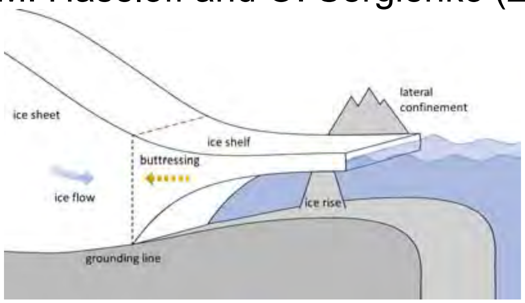


“Marine ice-sheet instability hypothesis”

J. Weertman (1974). **Stability of the Junction of an Ice Sheet and an Ice Shelf** *J. Glac.*

“…A stable ice sheet can occur if the bed slopes away from the center of an ice sheet. The generalization of our results is rather obvious.”

M. Haseloff and O. Sergienko (2018). **The Effect of Buttressing on Grounding Line Dynamics**. *J. Glac.*



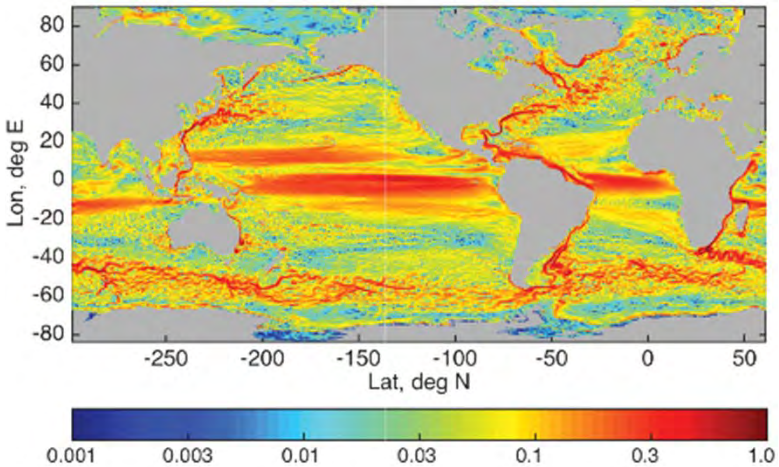
“…These results show that the stability of confined marine ice sheets is influenced by ice-shelf properties. Consequently, the marine ice-sheet instability hypothesis may not apply to buttressed marine ice sheets.”

O. Sergienko and D. Wingham (2019). **Grounding Line Stability in a Regime of Low Driving and Basal Stresses**. *J. Glac.*

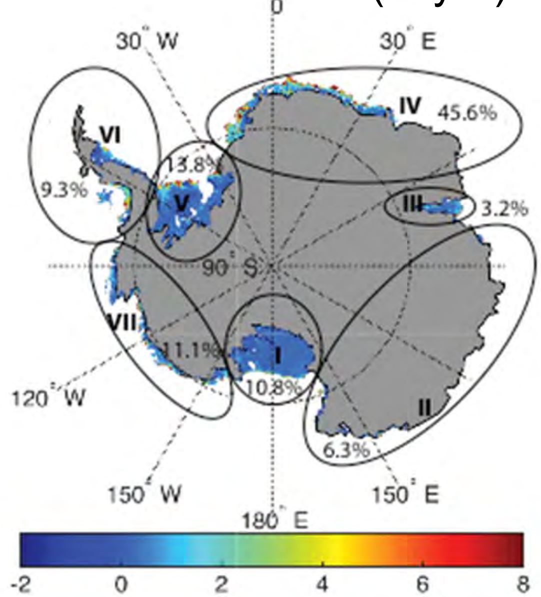
“…Our analysis suggests a more complex (in) stability criterion than ‘marine ice-sheet instability hypothesis’. We also determine characteristic timescales that can be used to determine whether particular configurations can be considered in isolation from other components of the climate system or whether their effects and feedbacks between the ice sheet and the rest of the climate system have to be taken into account .“

Global coupled ocean/sea-ice/ice-shelf model
($^1/_8$ degree)

Surface speed (m s^{-1})

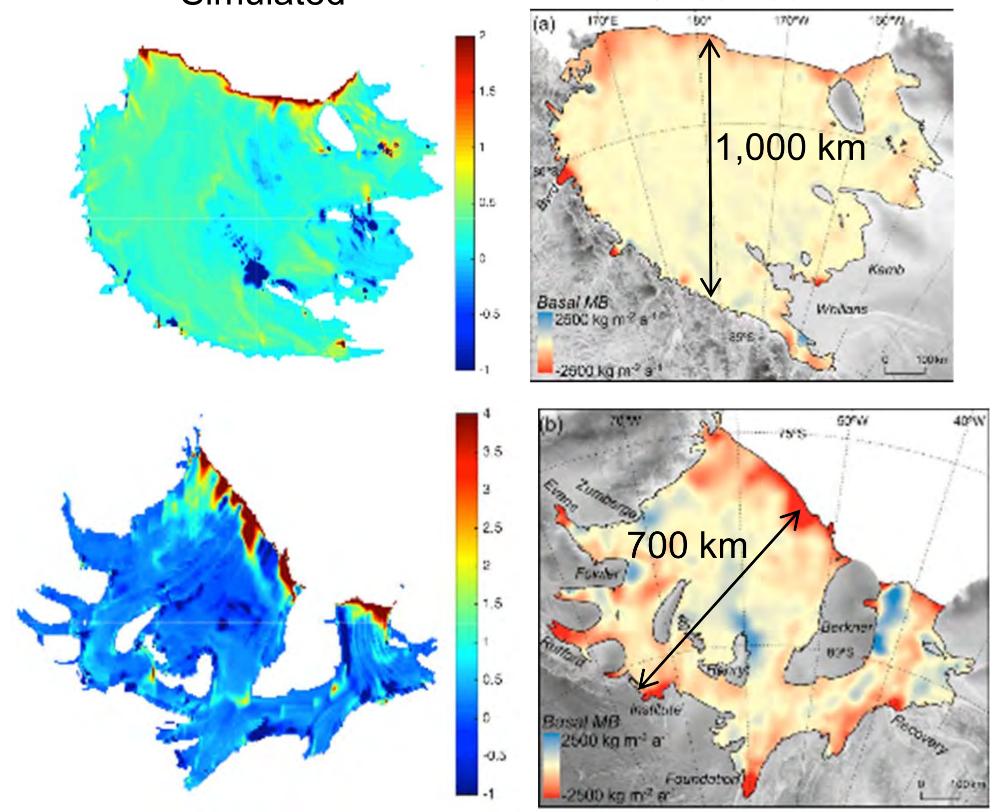


Ice-shelf melt rates (m yr^{-1})



Ice-shelf melt rates (m yr^{-1})

Simulated | Observed



(Moholdt et al., 2014)

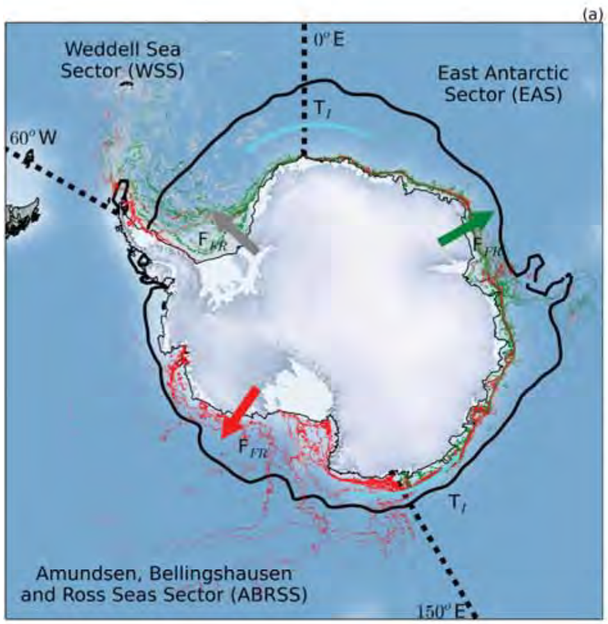
$^1/_8$ degree ~ 3 km @75^{o}S

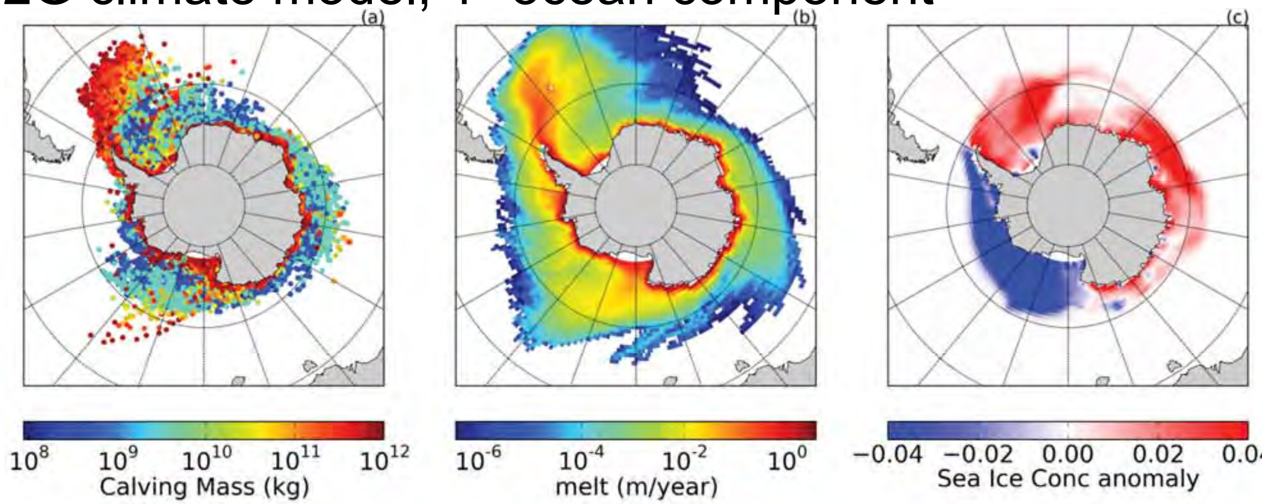
Sufficient for large ice shelves, but not small ones

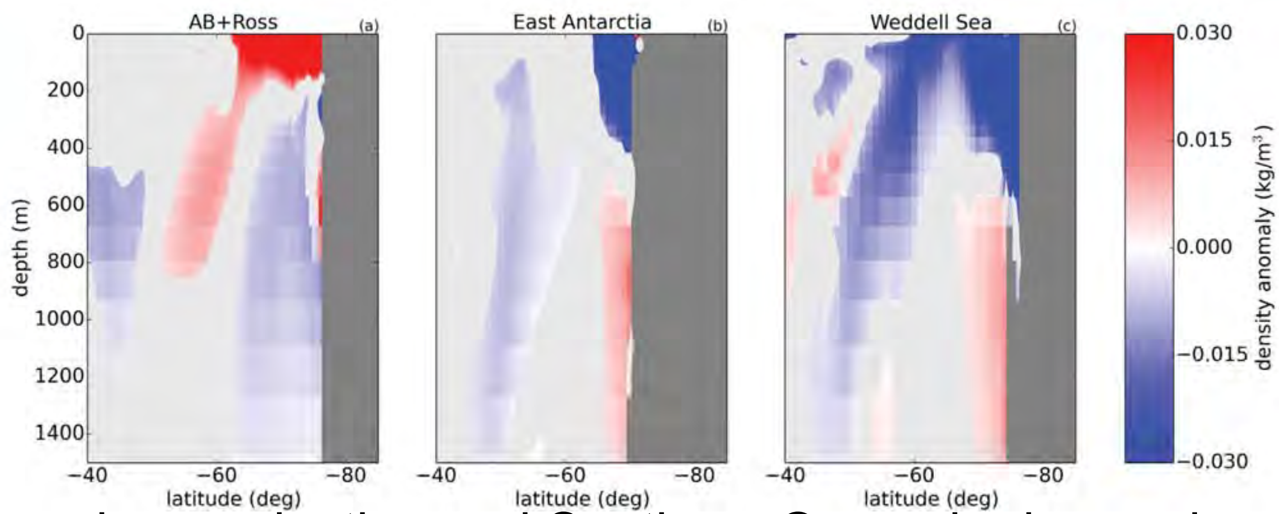
Harrison et al. (in preparation)

“Lagrangian point” icebergs in a climate model

CM2G climate model, 1° ocean component



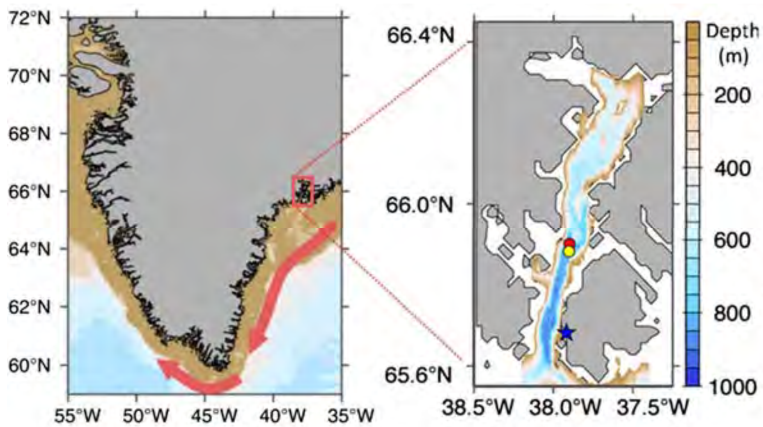


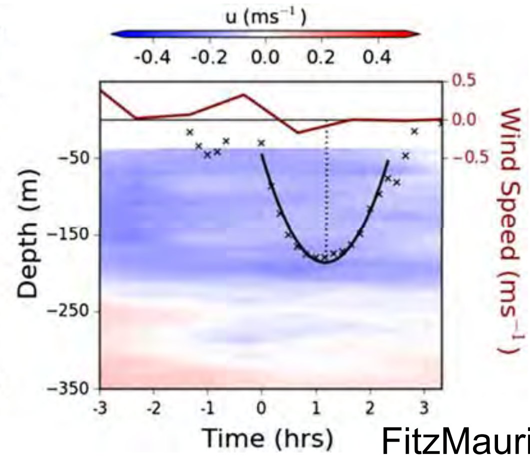


Stern et al. (2016)

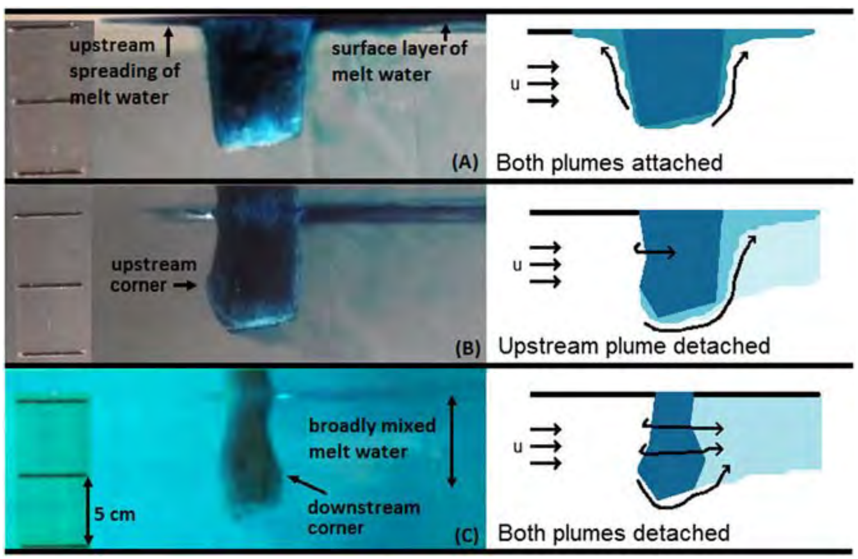
Icebergs have effects on sea ice production and Southern Ocean hydrography

Three-dimensional icebergs: melting parameterizations

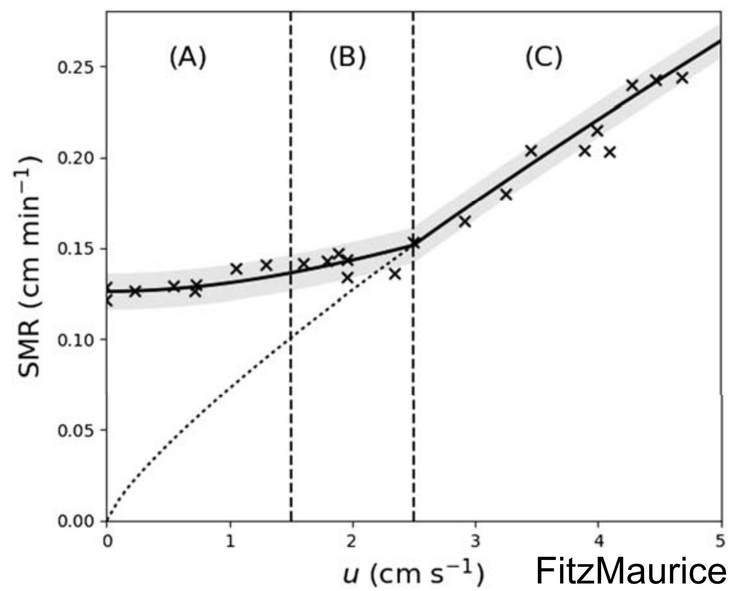




FitzMaurice et al. (2016)



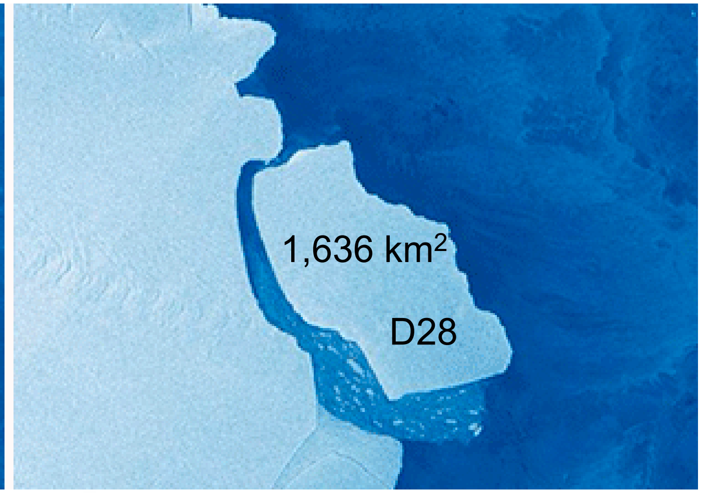
FitzMaurice et al. (2018)



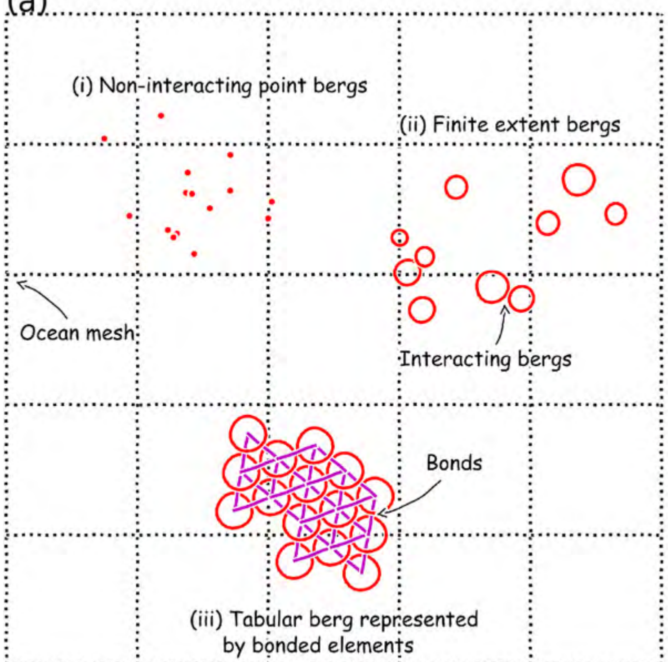
FitzMaurice et al. (2017)

Lateral melting parameterization based on observations and lab experiments

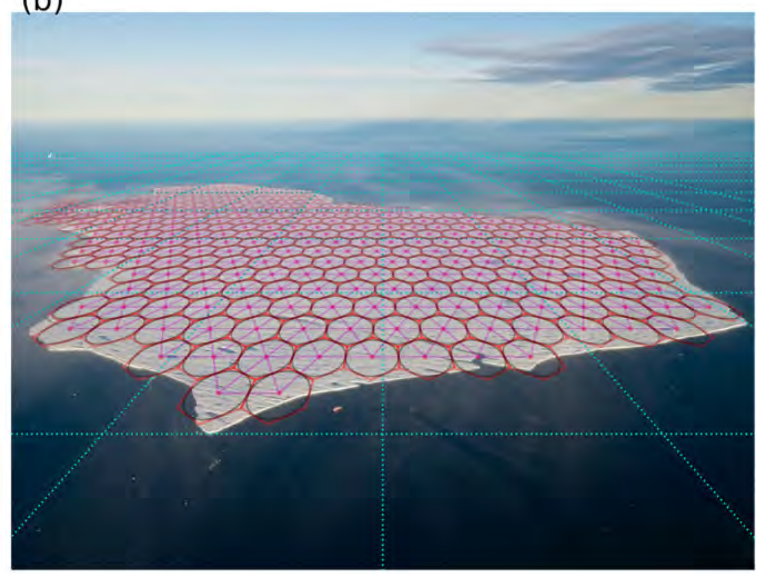
Three-dimensional icebergs: interactions with the ocean



(a)

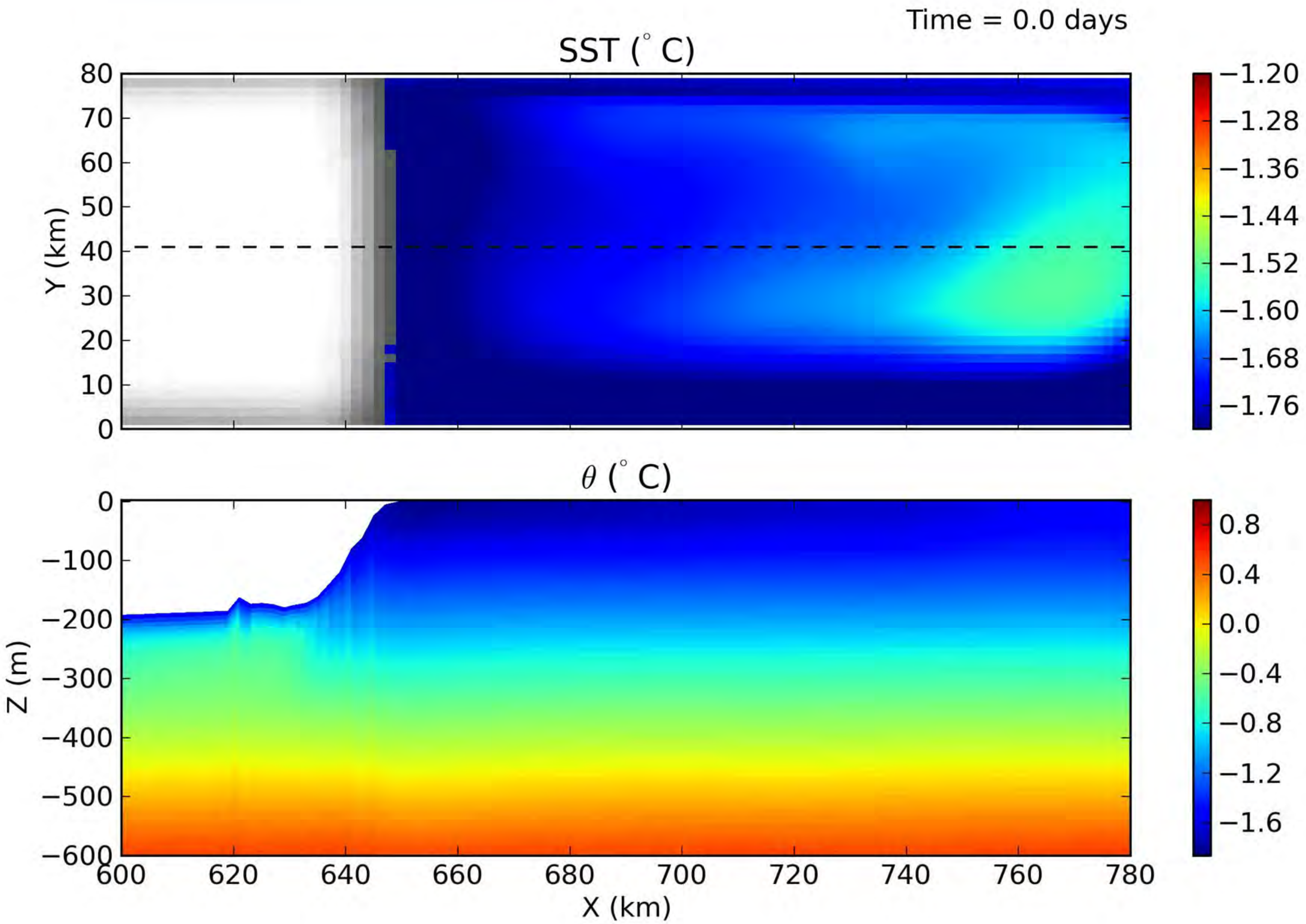


(b)



Stern et al. (2017)

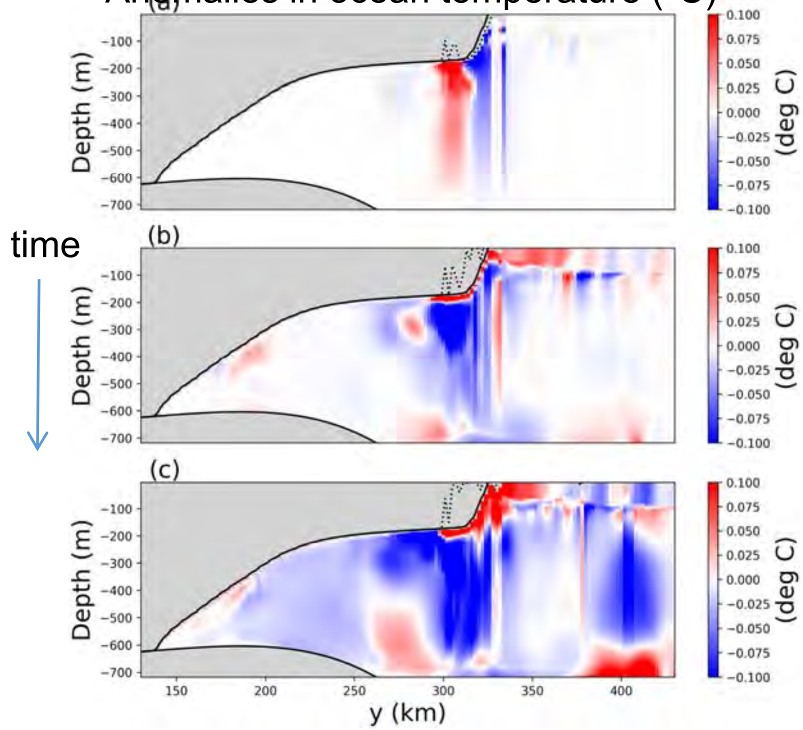
Three-dimensional icebergs: interactions with the ocean



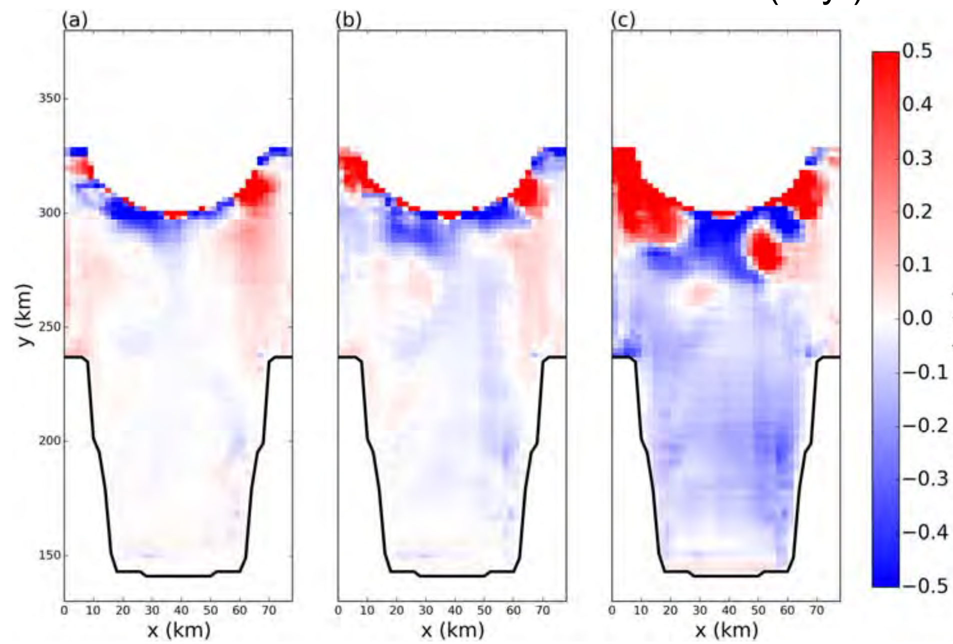
Stern et al. (2017)

Three-dimensional icebergs: interactions with the ocean

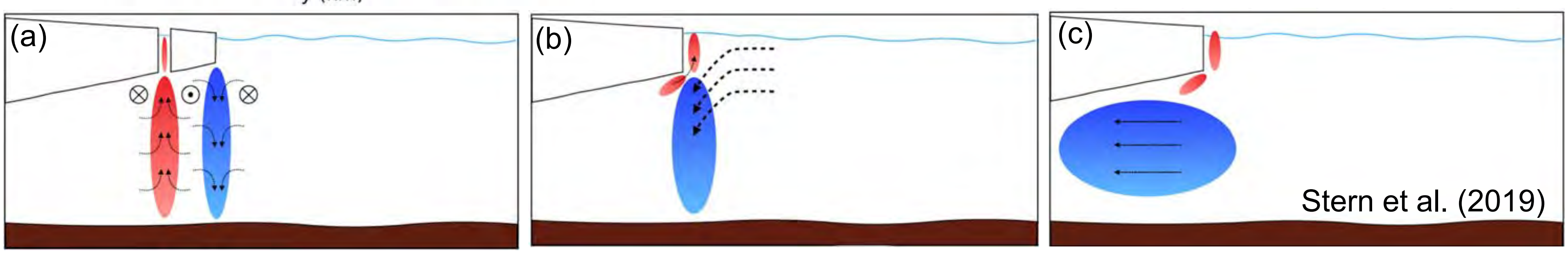
Anomalies in ocean temperature (°C)



Anomalies in sub-ice-shelf melt rate (m/yr)



time →



Iceberg calving and drifting causes: (a) upwelling of warm and downwelling of cold water; (b) subduction of cold water ; (c) propagation of cold water into the ice-shelf cavity

Future Plans & Challenges

Future Plans:

- Development of a two-way interactive ice-sheet component of a climate model
- Implementation of three-dimensional icebergs in a global climate model

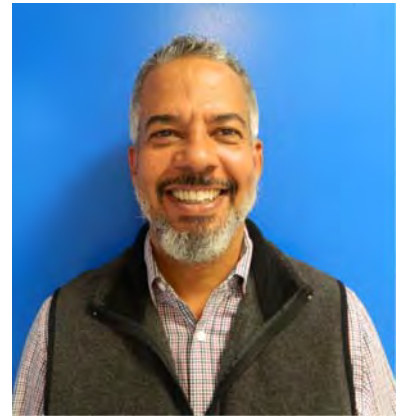
Challenges:

- Dealing with moving boundaries
- Recruiting talented team-members
- Sustaining collaborations with a diverse and distributed international team

Alistair Adcroft
UK

Anna Fitzmaurice
UK

Robert Hallberg
USA



Matthew Harrison
USA

Marianne Haseloff
Germany

Gustavo Marques
Brazil

Olga Sergienko
Ukraine

Alon Stern
South Africa

Summary

- Simulations of a global ocean/sea-ice/ice-shelf ocean model indicate that **$^{1}/_{8}$ degree is a minimal resolution** required for representation of ice-shelf/ocean interactions.
- Developed treatments of the marine ice-sheet grounding line dynamics suggest that **stability of marine ice sheets is more complex** that what is suggested by the "marine ice-sheet instability hypothesis", and its use as a basis for parameterizations in ice-sheet models is inadequate.
- Icebergs have local, regional and global effects on the state of the ocean. Developed Lagrangian-particle framework allows to represent **three-dimensional icebergs** in climate models and account for their effects and feedbacks between calving and sub-ice-shelf melting.