

# Observations of Antarctic Grounding Line Migration with ICESat-2 Altimetry

living planet  
symposium

BONN  
23-27 May  
2022



British  
Antarctic Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL



UNIVERSITY OF LEEDS



**Bryony Freer**  
**SENSE CDT**

**Supervisors: Oliver Marsh,  
Anna Hogg, Helen Fricker**

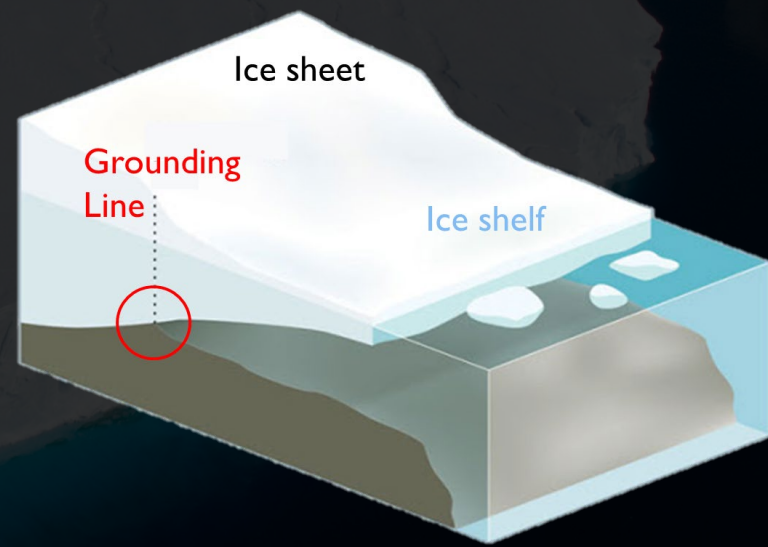




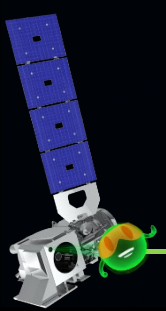
Ice Shelves  
(floating)



Grounding Line



Antarctic Ice Sheet  
(grounded)

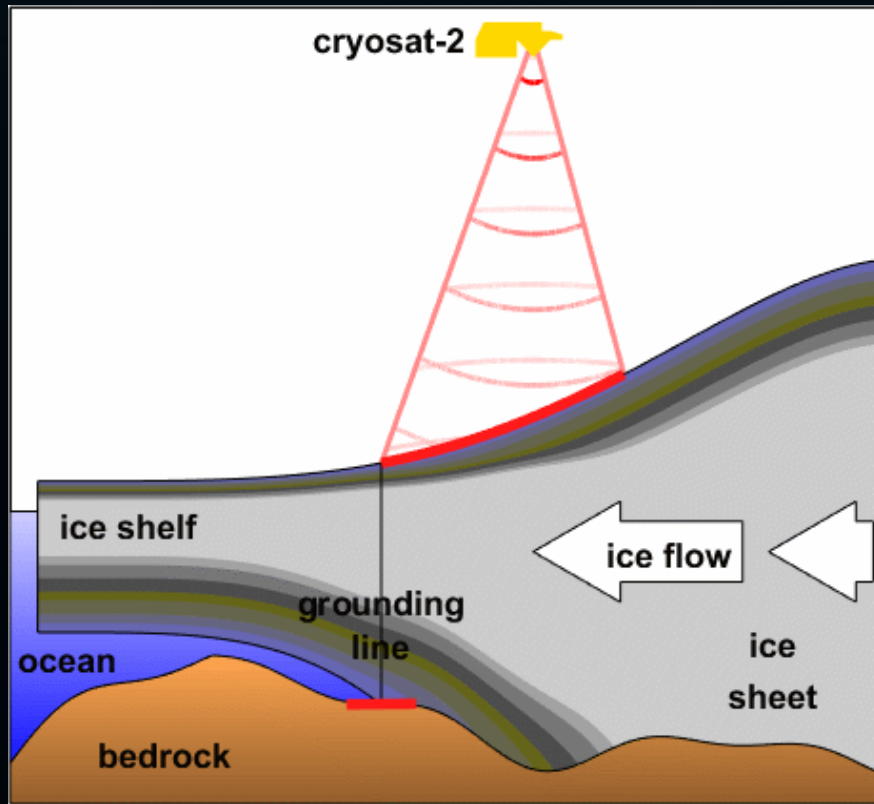


# Grounding Line Migration



The grounding line is a transitory feature within the grounding zone, that *migrates* on:

**Long time-scales** (years-decades):  
ice thinning, dynamic imbalance, MISI





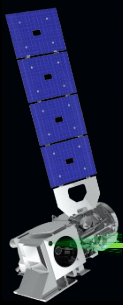
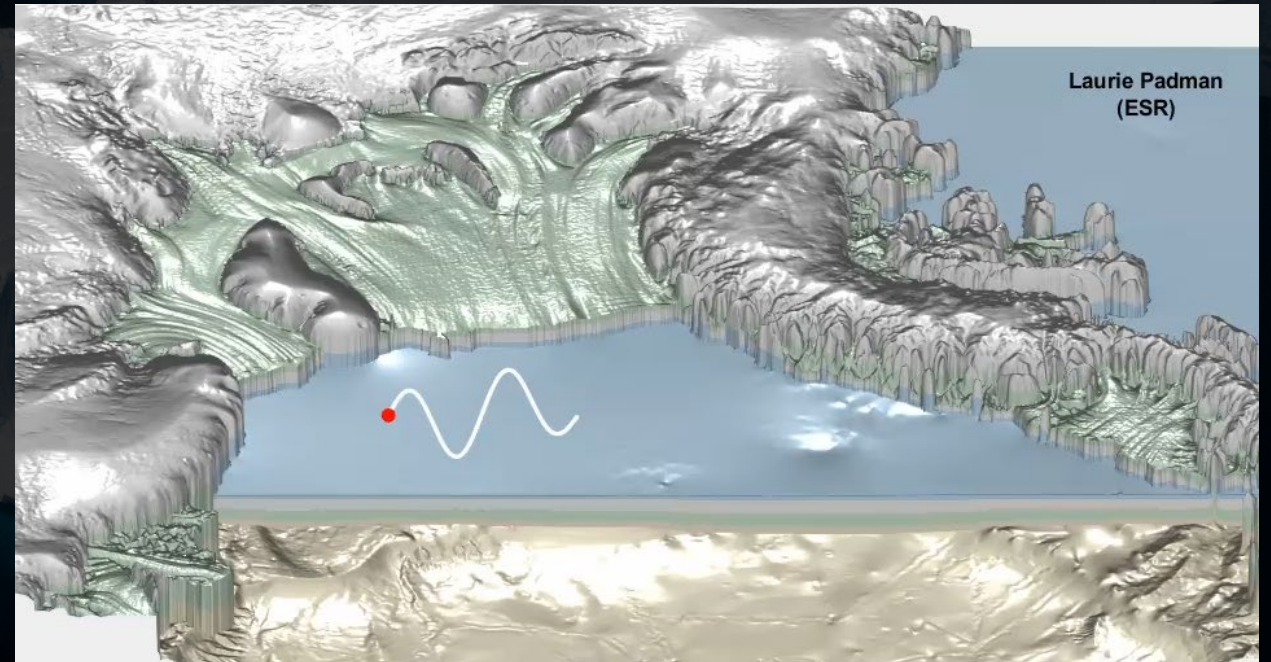
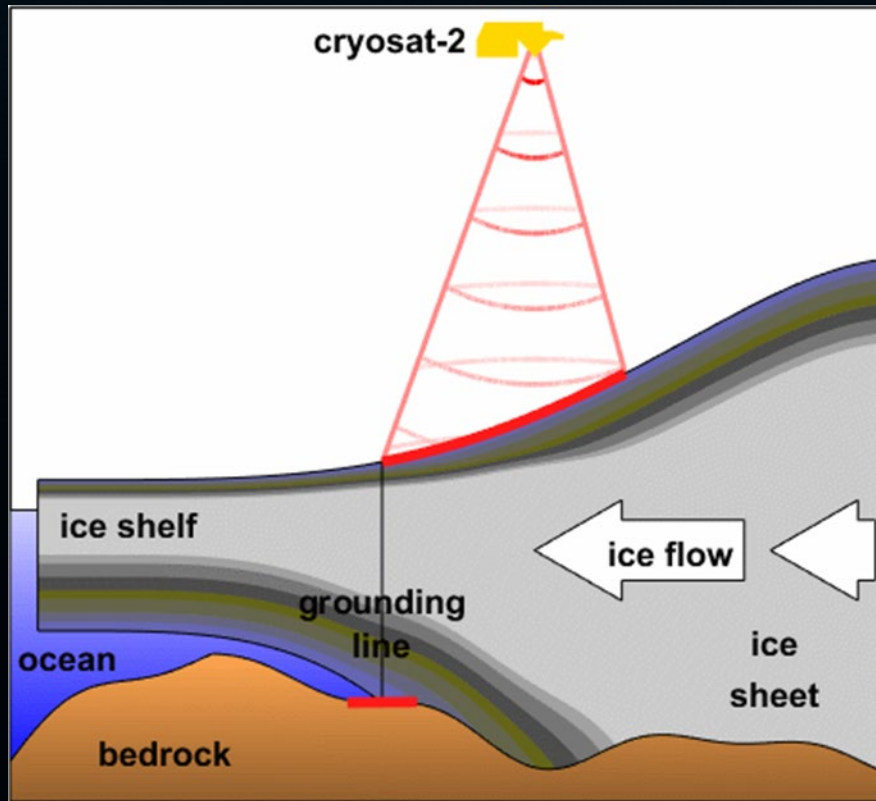
# Grounding Line Migration



The grounding line is a transitory feature within the grounding zone, that *migrates* on:

**Long time-scales** (years-decades):  
ice thinning, dynamic imbalance, MSI

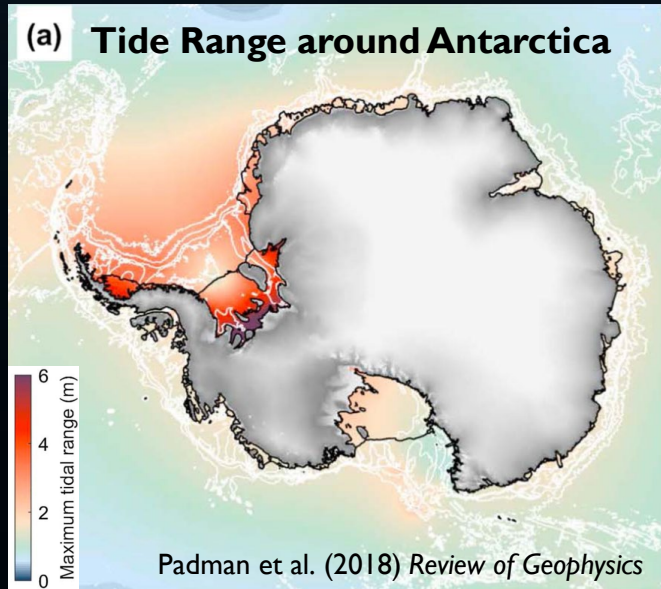
**Short time-scales** (minutes - hours - days)  
ocean tides, atmospheric pressure changes



# Tidal GL Migration: why do we care?



Tidal processes obscure signals of long-term change



Assumptions of GL position in large-scale ice sheet models:

- Determined by floatation conditions alone **✗**
  - Fixed (i.e. no tidal migration) **✗**
  - Zero melt **✗**
- Not realistic assumptions**

Also unknown impact of tidal GL migration on:

- Basal **shear stress**
- Upstream **buttressing** and **ice velocity**
- Basal **melt rate** (as seawater flushes across the GZ)

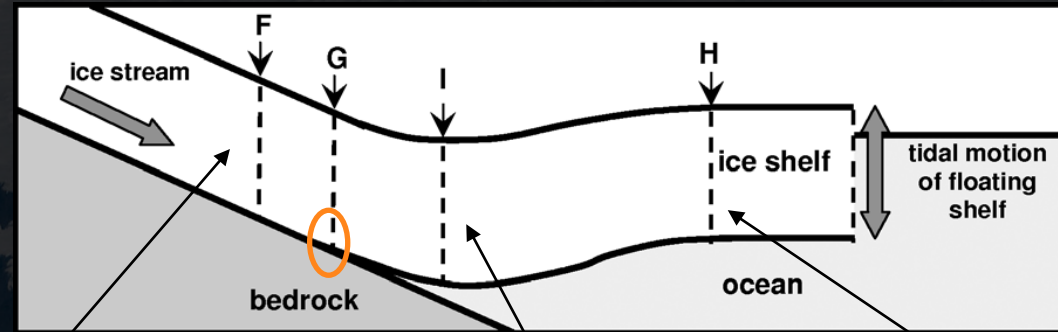
Hindered by lack of observations for testing and validation ...





# How do we measure grounding lines using satellites?

## Grounding Zone Features (idealised ice sheet):



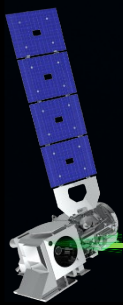
Fricker & Padman (2006)

**F:** landward limit of ice flexure

**I:** break-in-slope

**H:** inshore limit of hydrostatic equilibrium

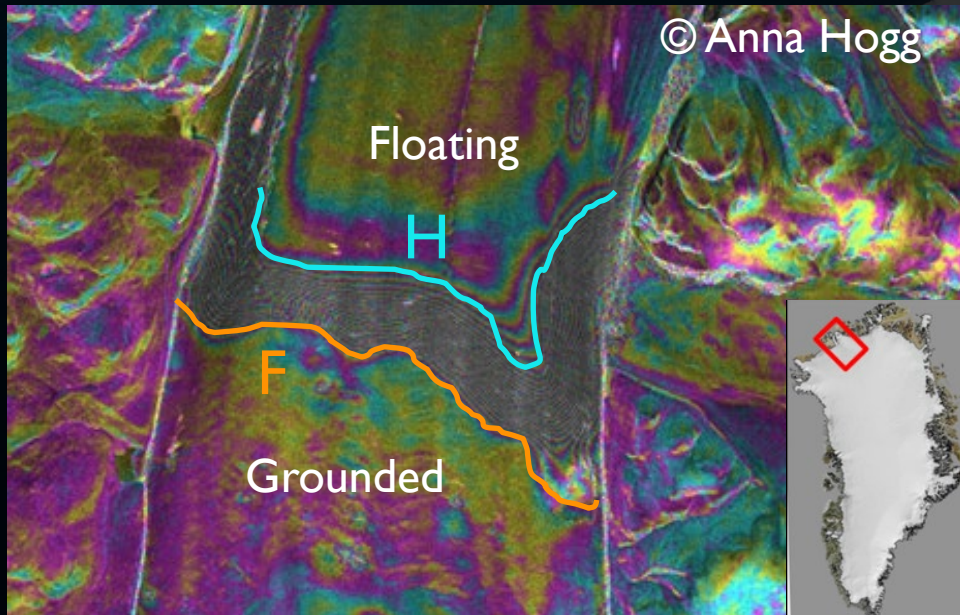
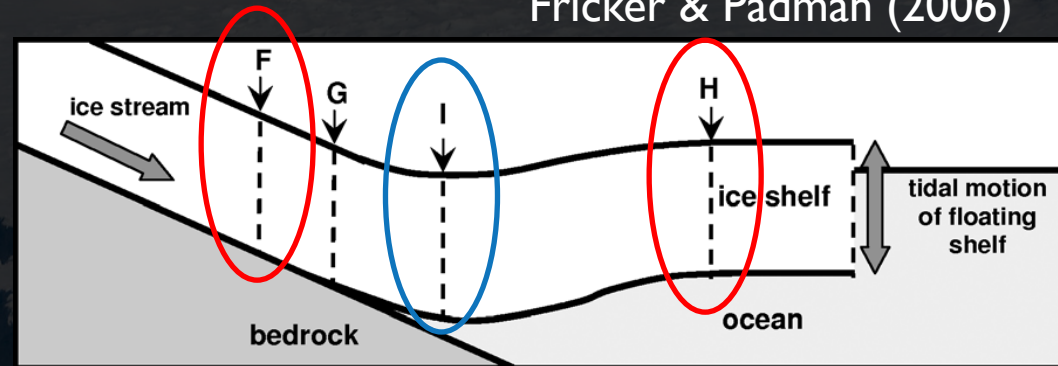
**G:** limit of ice flotation (what we want to know)



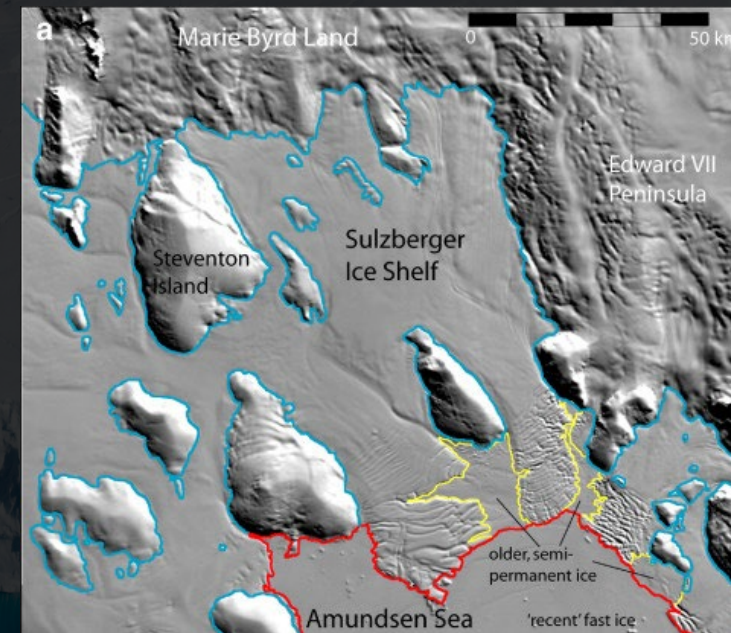


# How do we measure grounding lines using satellites?

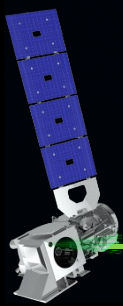
Fricker & Padman (2006)



1. QDInSAR hinge line  
(dynamic method)



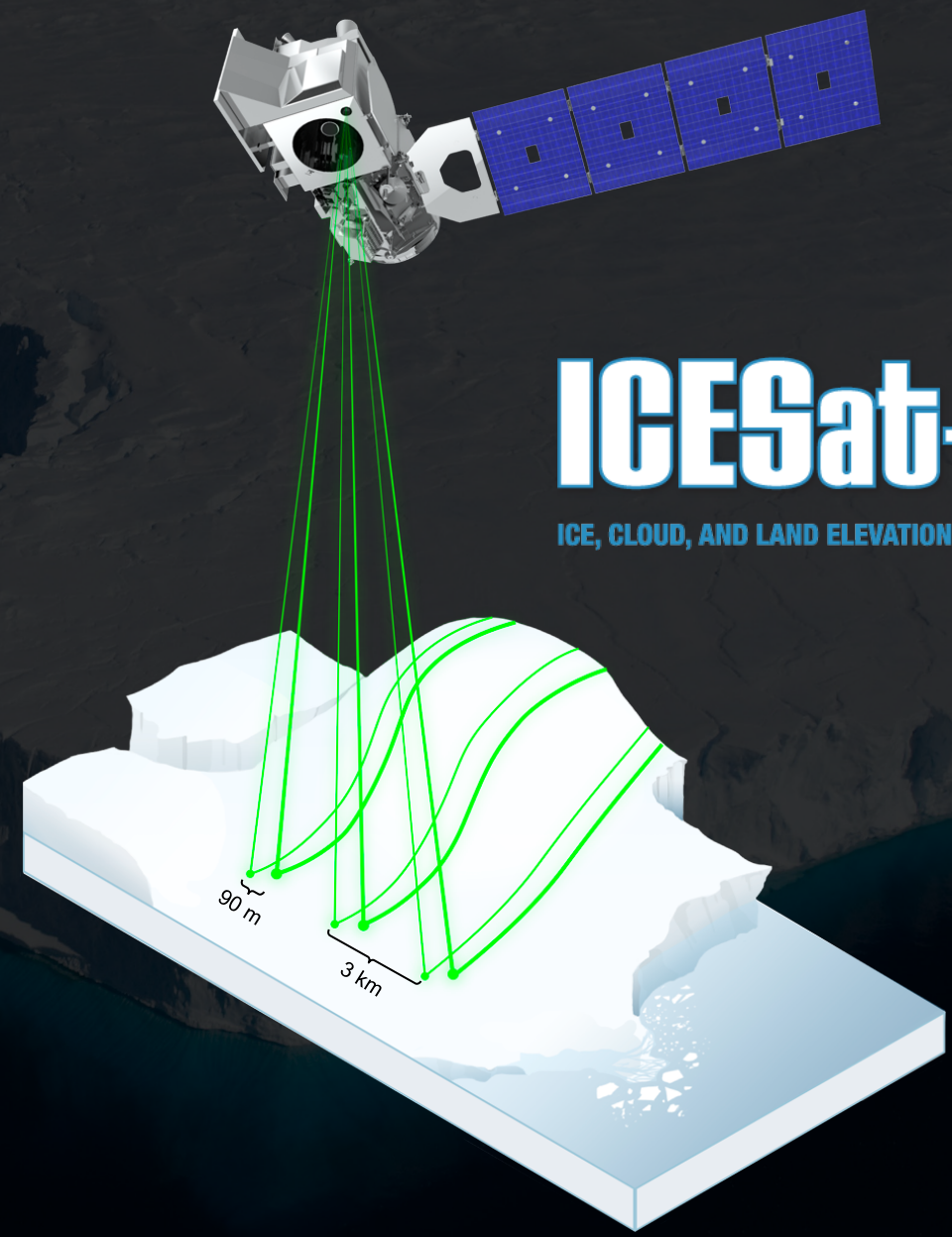
2. Optical shade  
(static method)





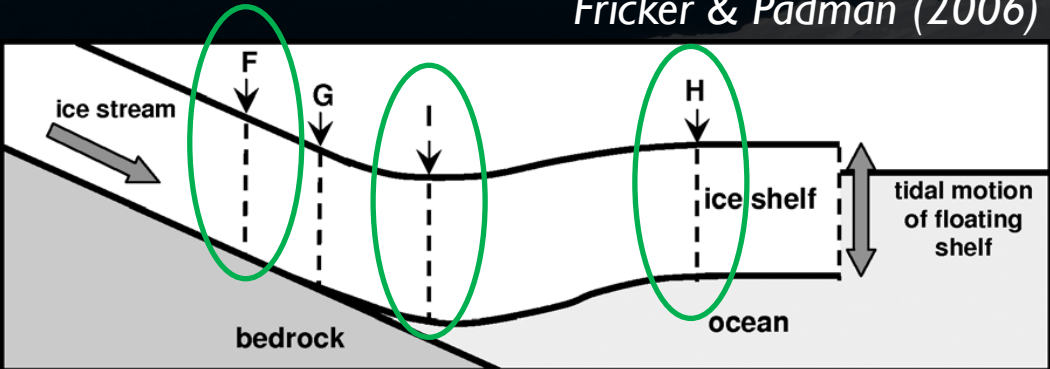
# 3. Repeat-track laser altimetry (RTLA)

(dynamic and static)



**ICESat-2**  
ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

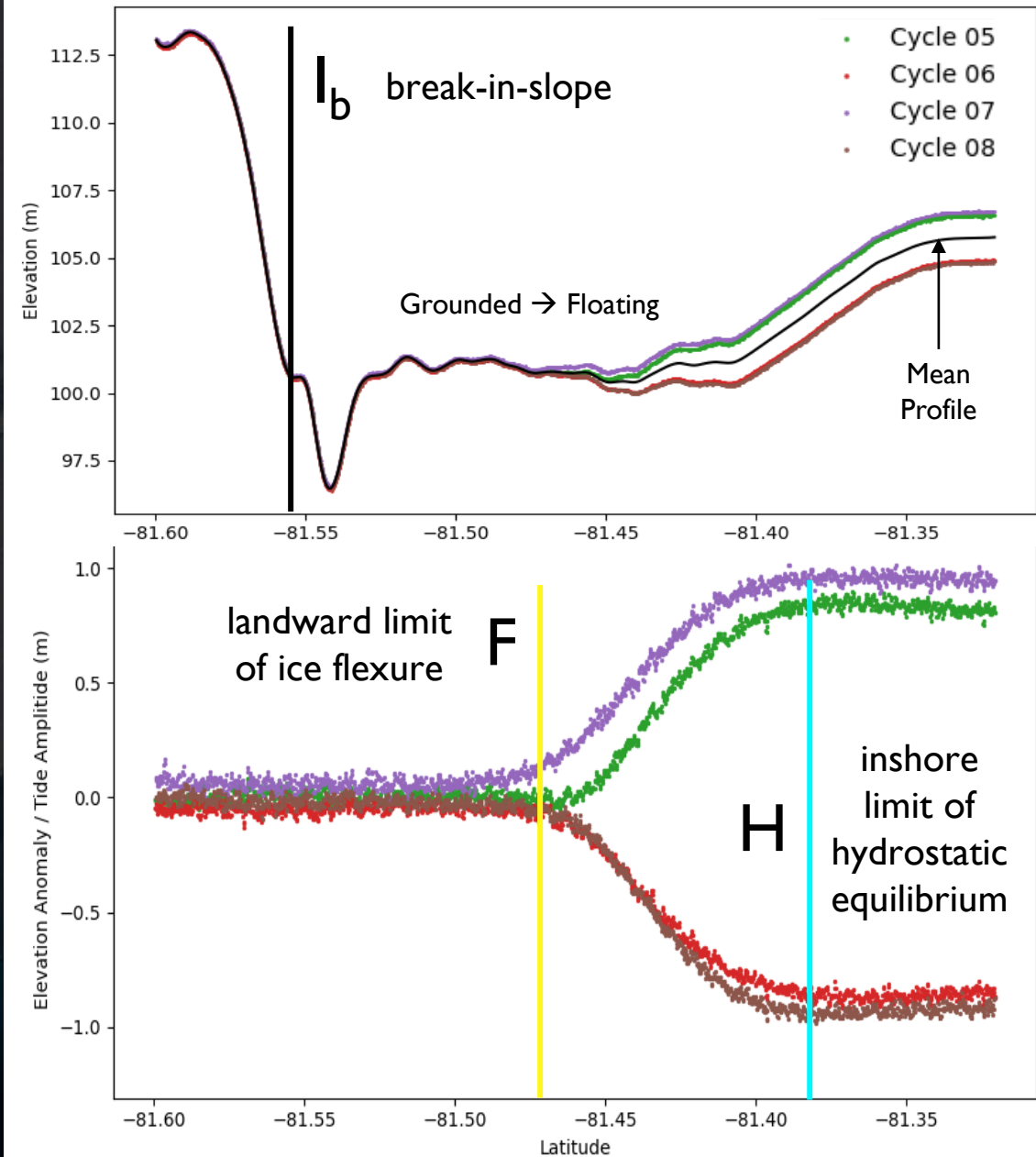
Fricker & Padman (2006)





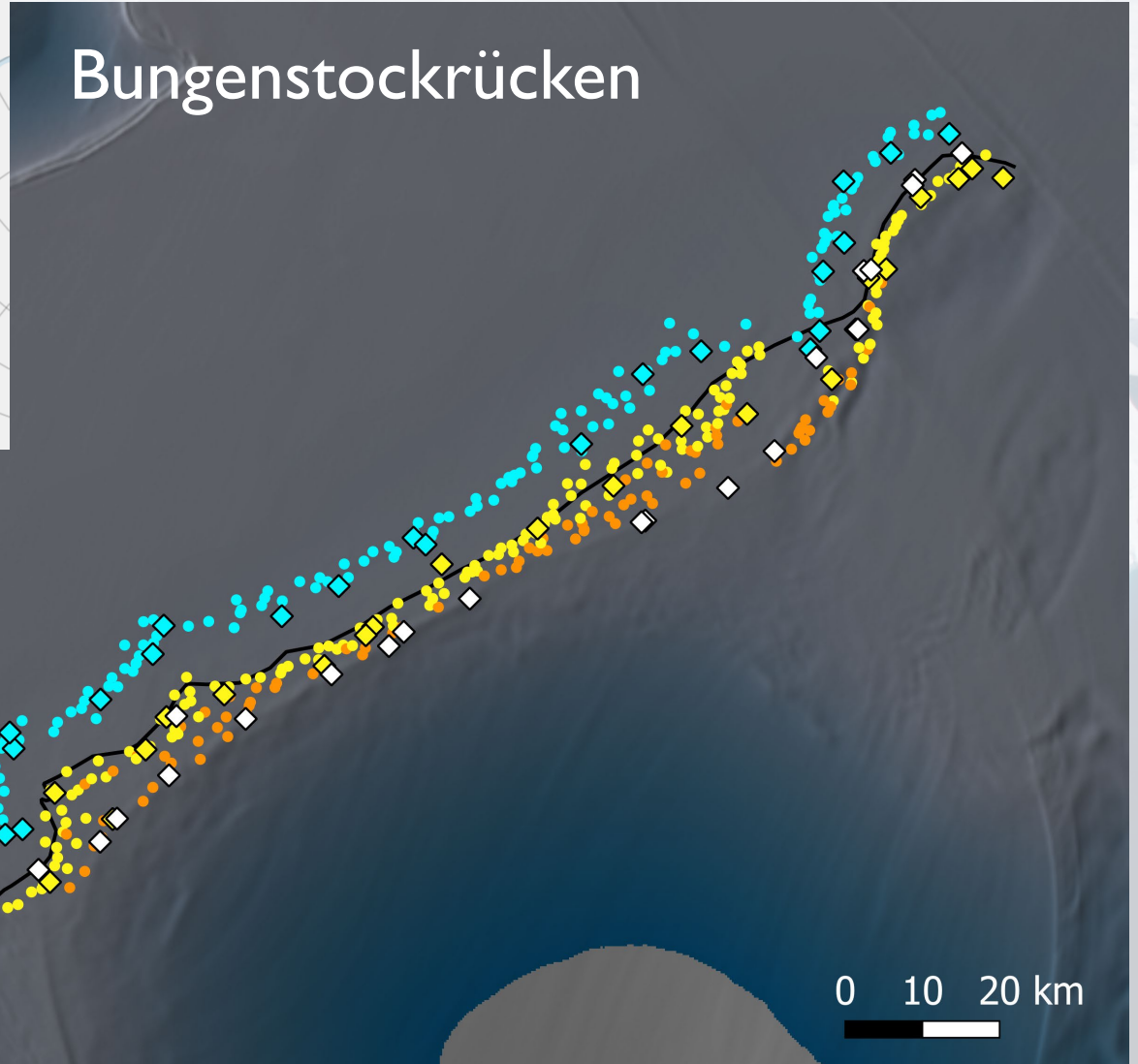
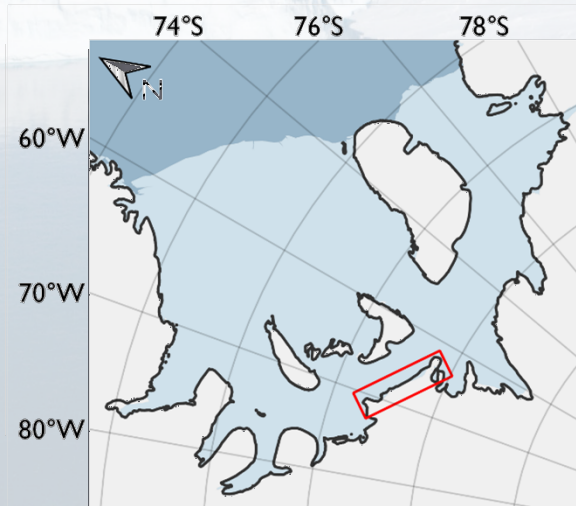
# 3. Repeat-track laser altimetry (RTLTA)

- a) Surface elevations per cycle
- b) Calculate mean surface profile
- c) Difference along-track elevations from the mean profile - **anomalies**
- d) Compare to predicted tides
- e) Identify GZ features:  $I_b$ , F and H





# Results I: Improved Mapping of Grounding Zone Structure with ICESat-2



**MEaSURES**  
Grounding Line  
(from InSAR)



**ICESat (2003-09)**

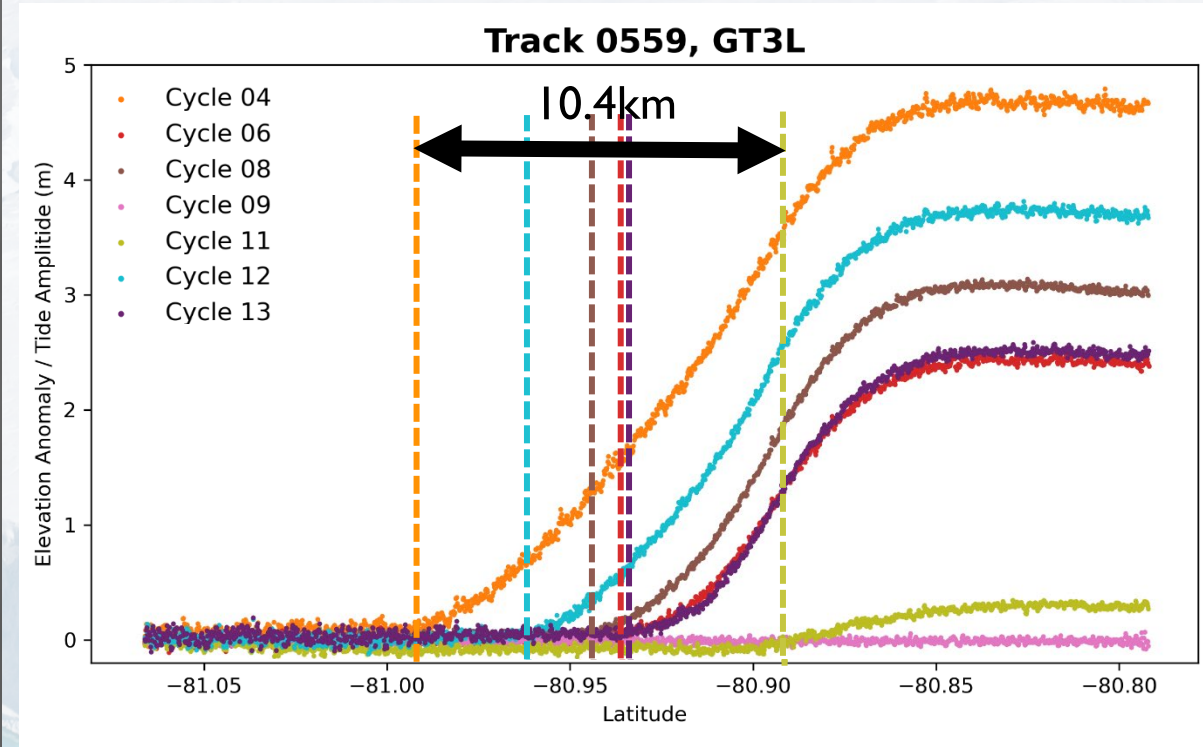
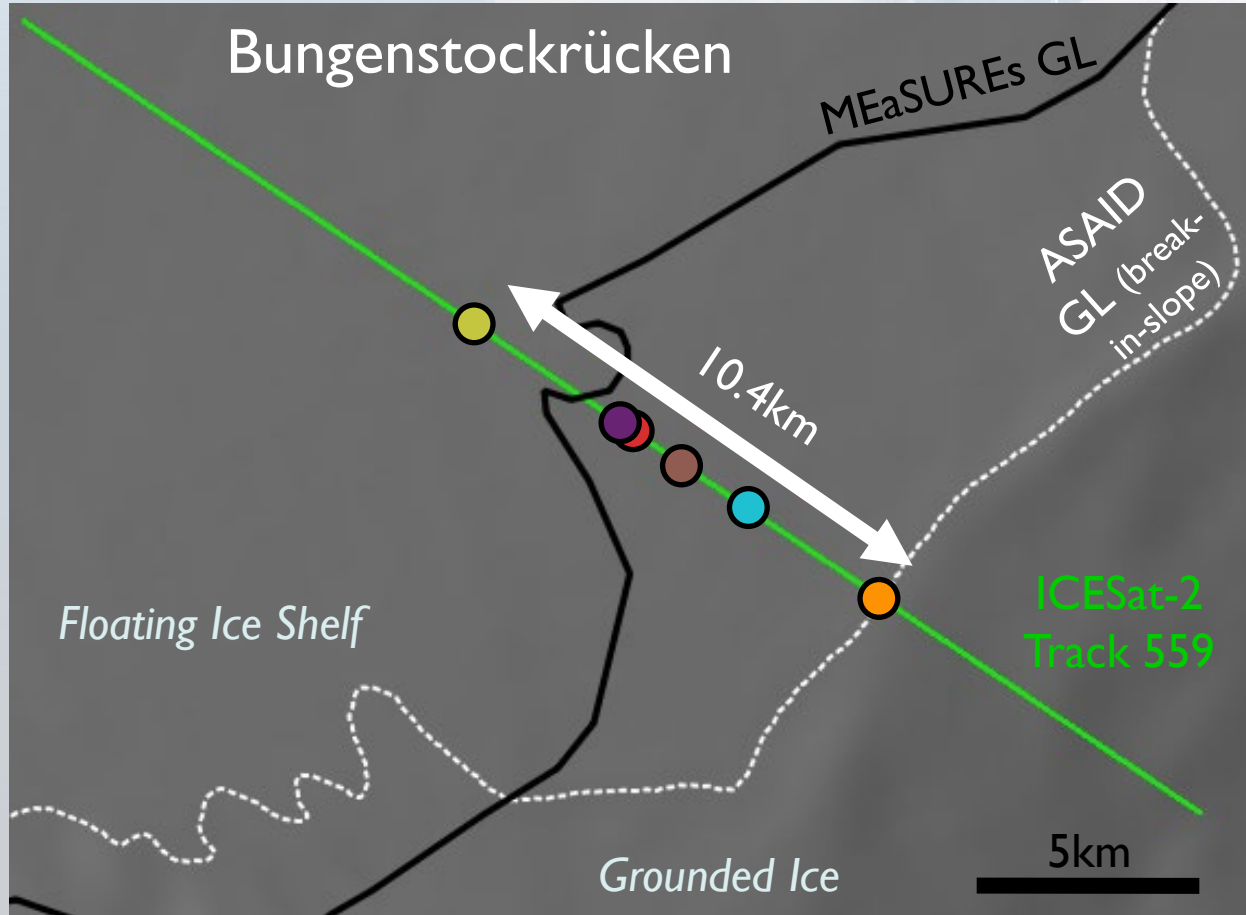


**ICESat-2 (2019-21)**



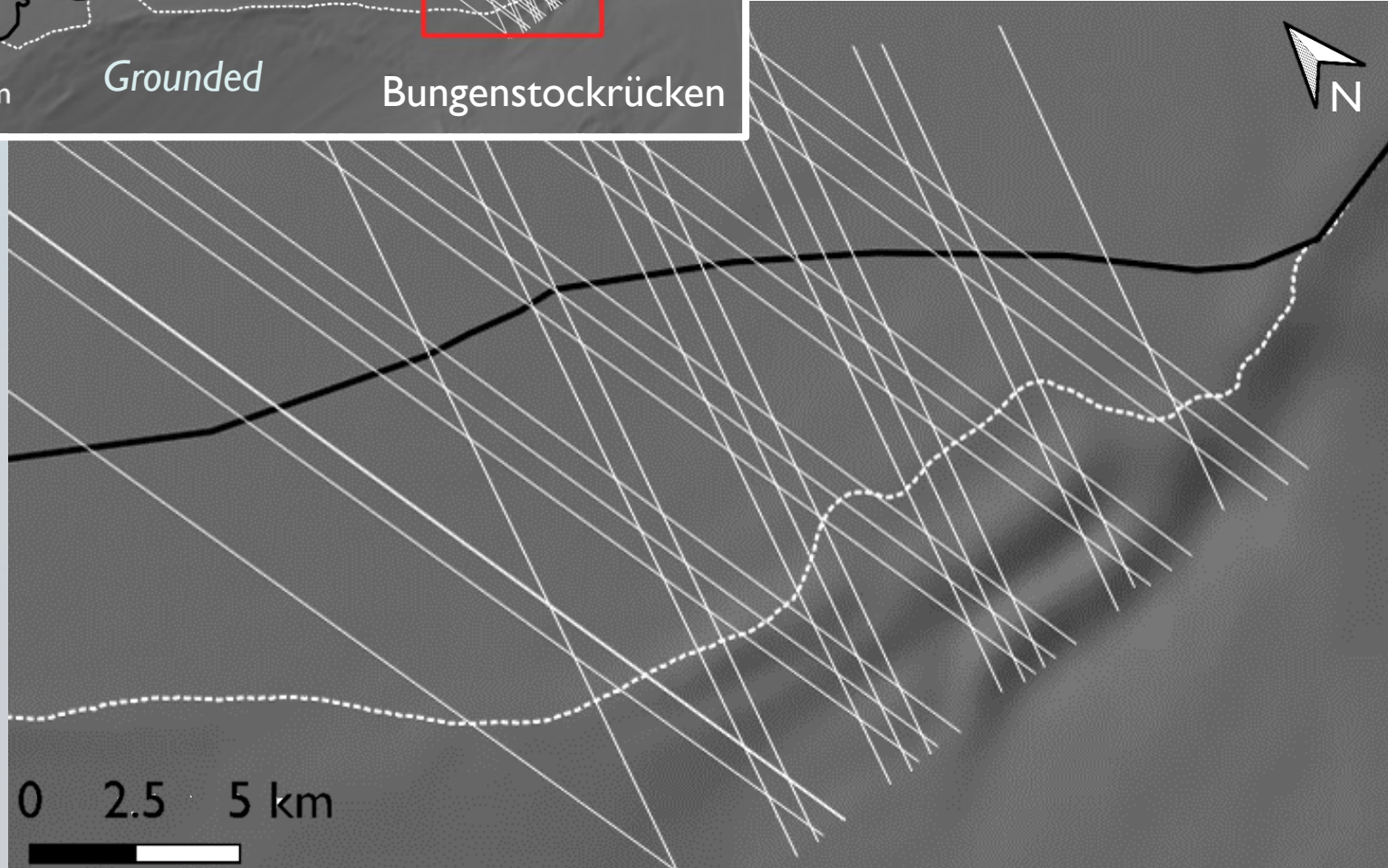
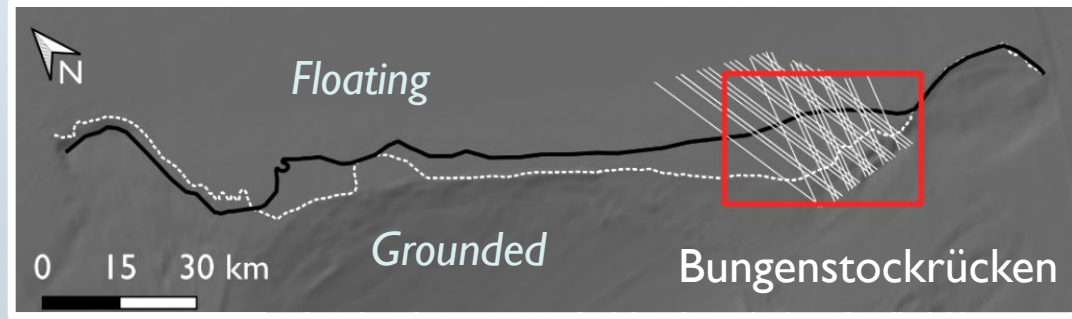


# Results II: Improved Observations of Tidal GL Migration with ICESat-2



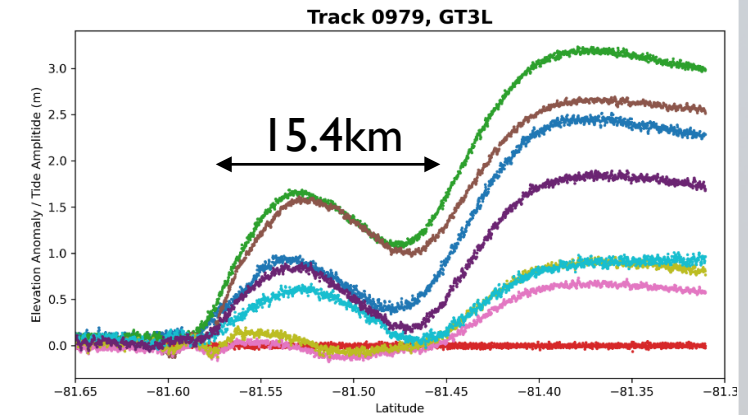
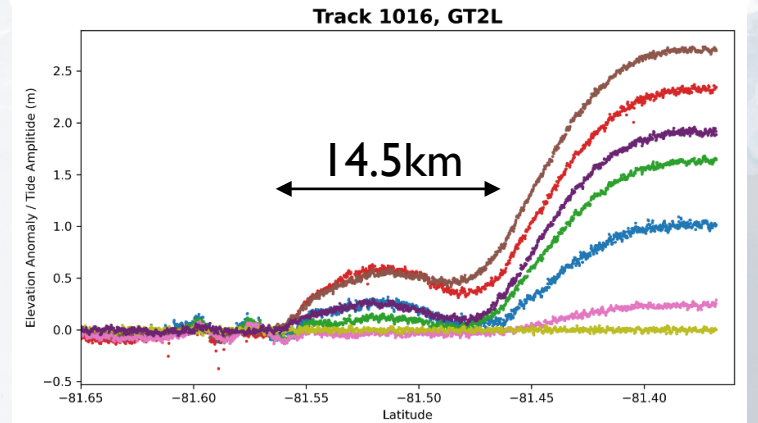
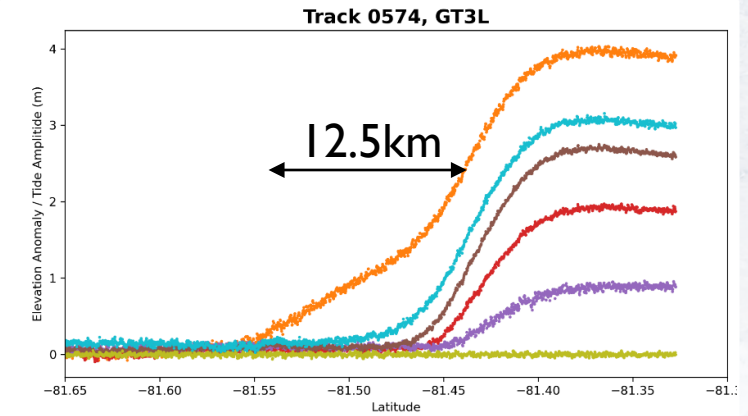
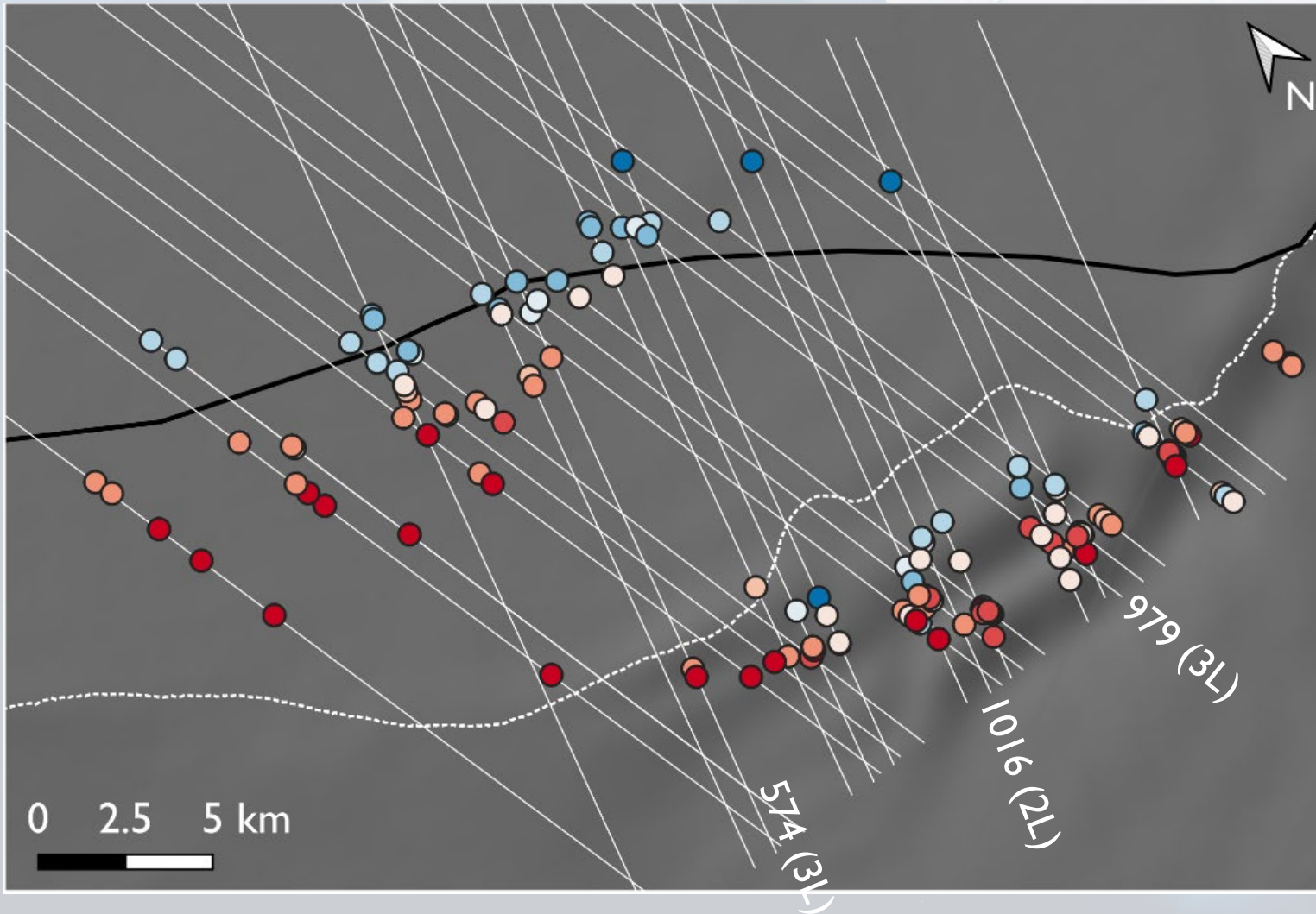


# Results II: Improved Observations of Tidal GL Migration with ICESat-2





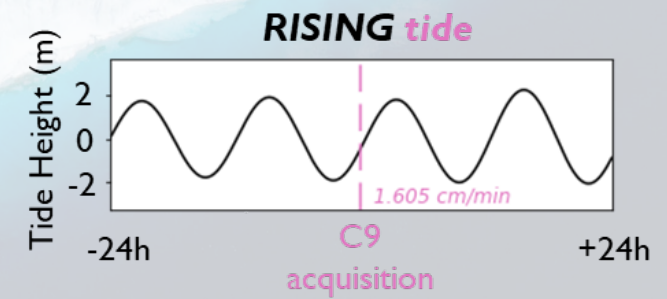
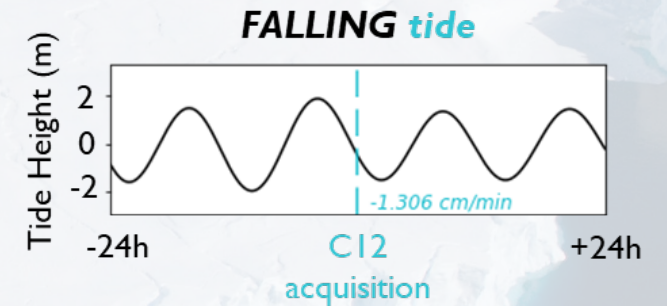
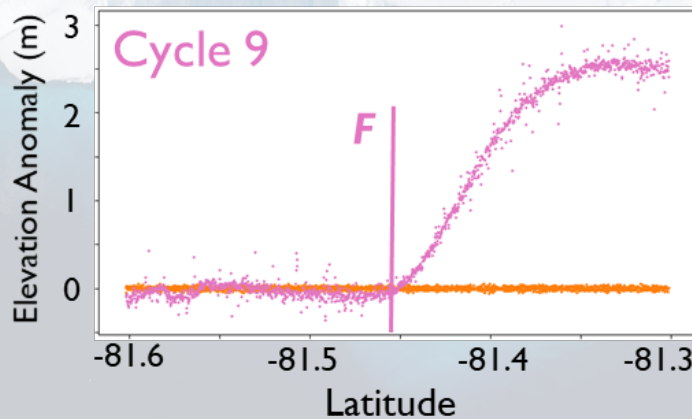
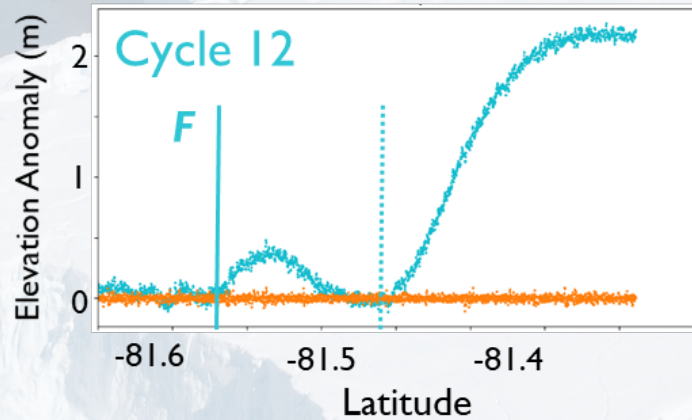
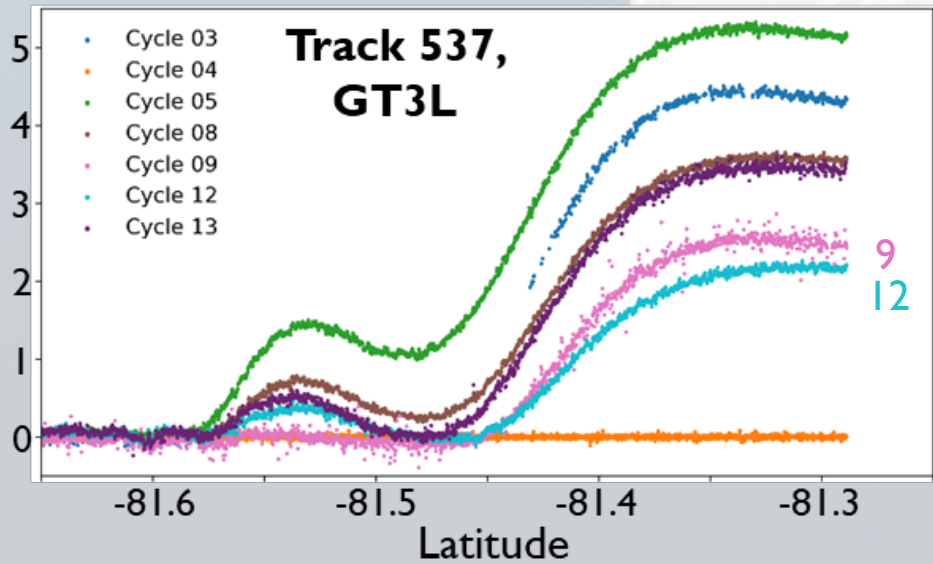
# Results II: Improved Observations of Tidal GL Migration with ICESat-2



# Novel Observations from ICESat-2:

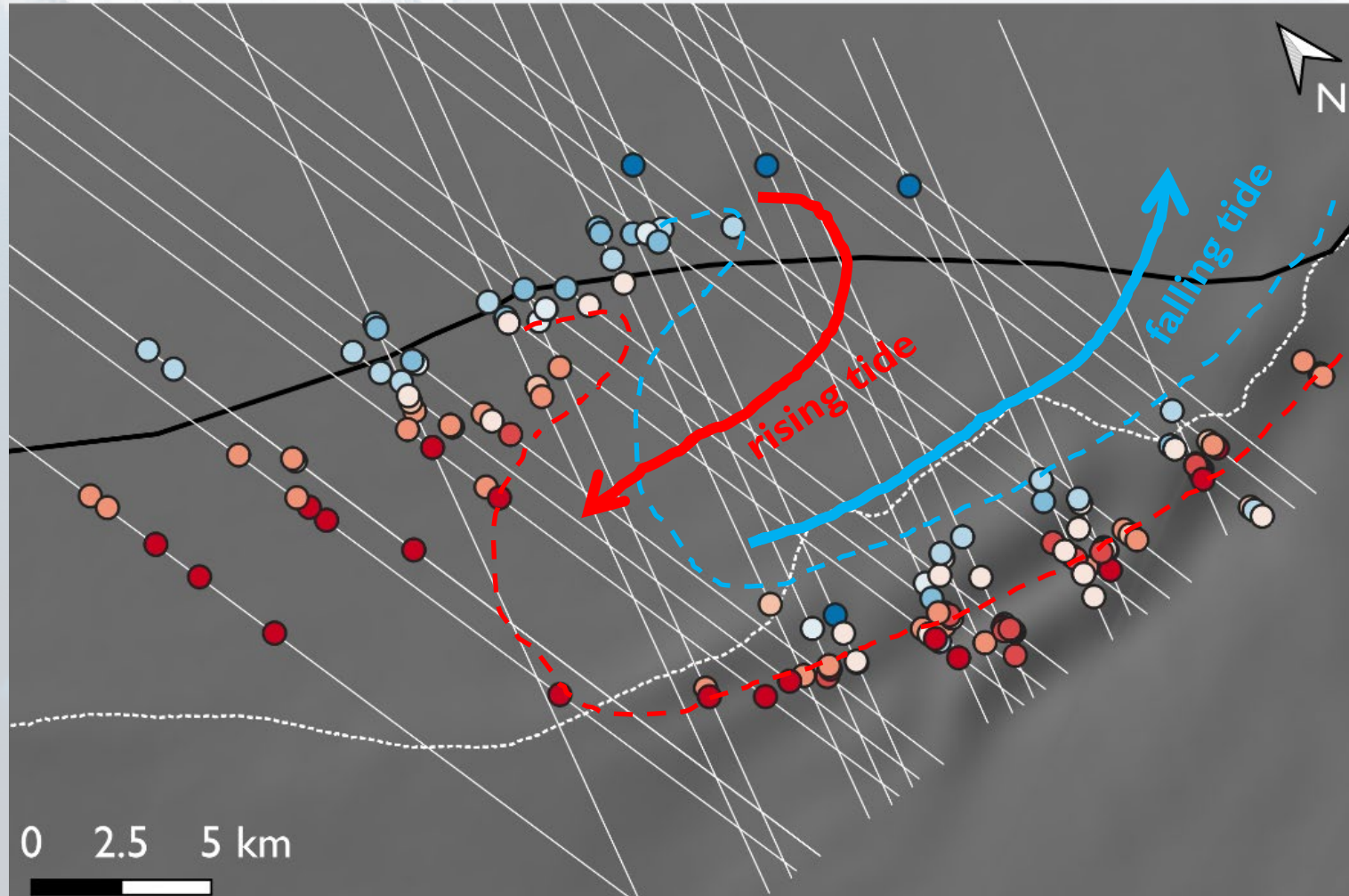
## Can we learn something about the viscoelastic response of ice shelves to tides?

The tides are changing so rapidly in this region that in some data we are able to see a clear delay in the response of the ice shelf surface to the change in sea surface height with the tides.

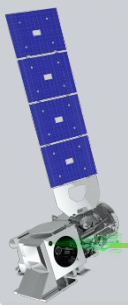




# Novel Observations from ICESat-2: Ocean Circulation in the Ice Shelf Cavity



Insights into ocean circulation within the ice shelf cavity?



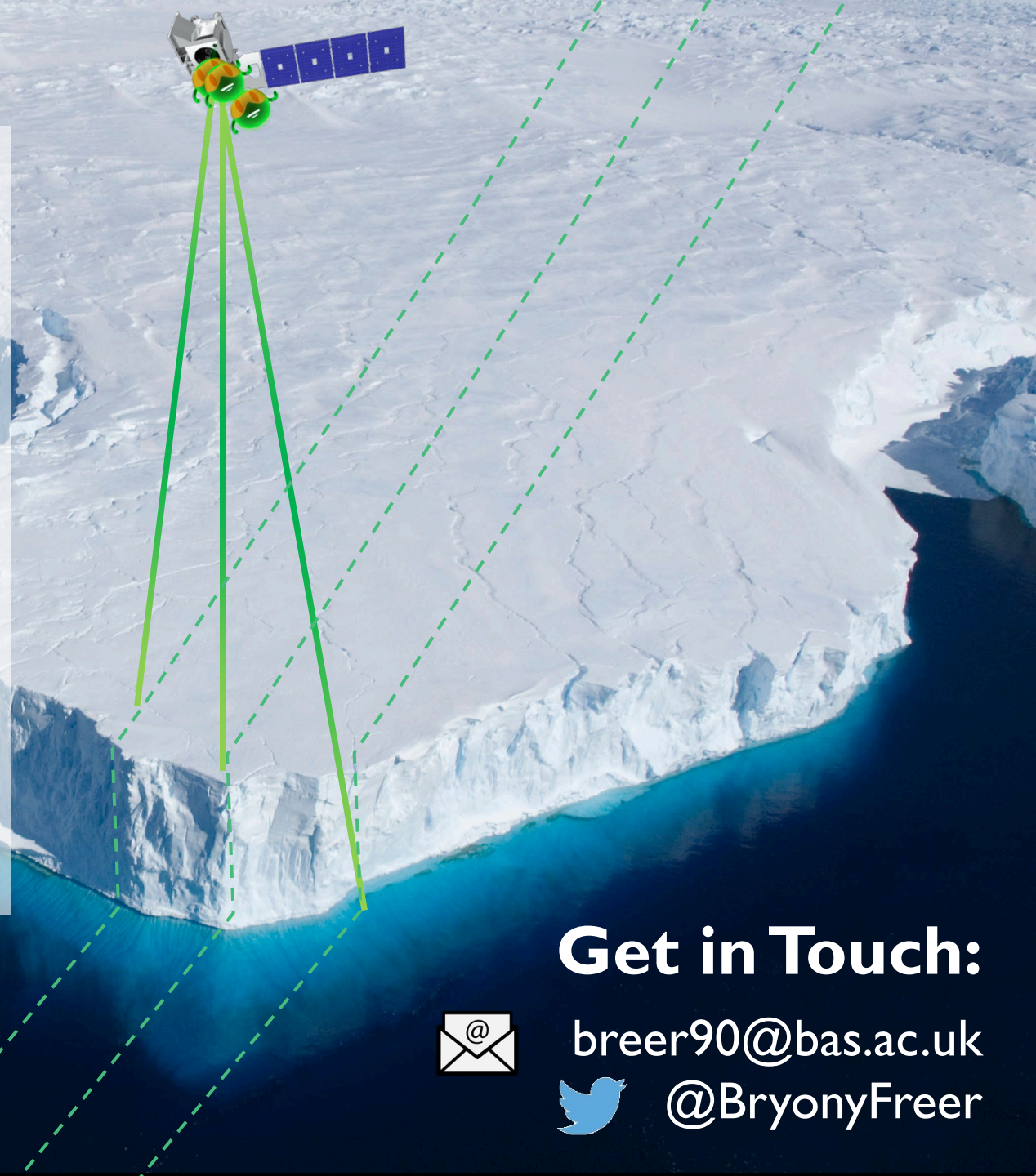


## Summary

It is very important to consider the extent of tidal grounding line migration around Antarctica when assessing long-term change.

ICESat-2 provides an excellent dataset to address this, providing:

- Improved mapping of grounding zone structure
- Improved observations of tidal grounding line migration
- Novel observations that allow us to ask more interesting questions about grounding zone processes



**Get in Touch:**

[breer90@bas.ac.uk](mailto:breer90@bas.ac.uk)

[@BryonyFreer](https://twitter.com/BryonyFreer)







**Fig 9.** A cartoonist view of what is encountered near the grounding line (Cartoon by Michael Dormer)

*“But there is the challenge to learn about this last piece of unknown ocean. The cavern near the grounding line will be low, cold, dark and noisy. What else will we find?”*

**Walter Munk (2011)**

**Get in Touch:**



breer90@bas.ac.uk



@BryonyFreer



**Track 0559, GT3L**

