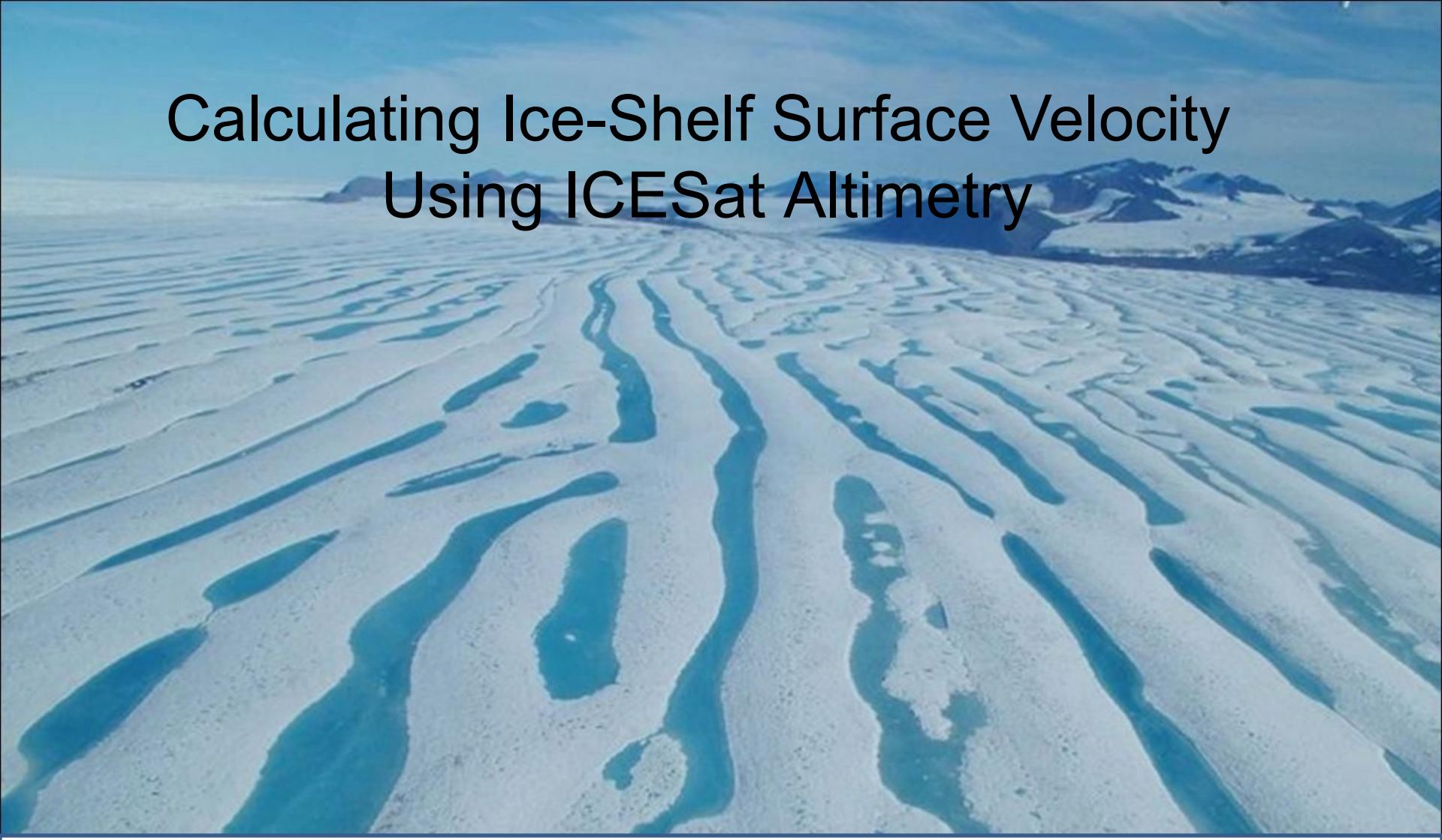
Calculating Ice-Shelf Surface Velocity Using ICESat Altimetry



GATEWAY ANTARCTICA

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Outline

1/ Introduction

2/ Background to ICESat

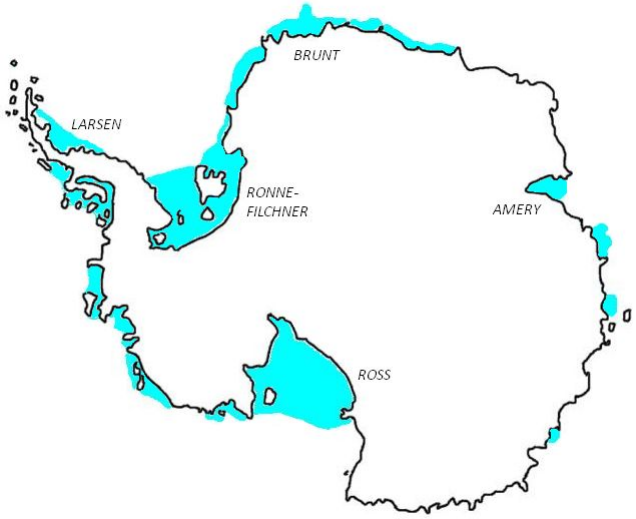
3/ Single Track Processing

4/ Grounding Line Identification

5/ Multi Track Processing

6/ Conclusions

Introduction



Why is measuring ice shelf velocity important?

- Ice shelf-stability
- Acceleration of grounded ice
- Mass-balance of outlet glaciers
- Basal melt rates

How can ice shelf velocity be measured using an altimeter?

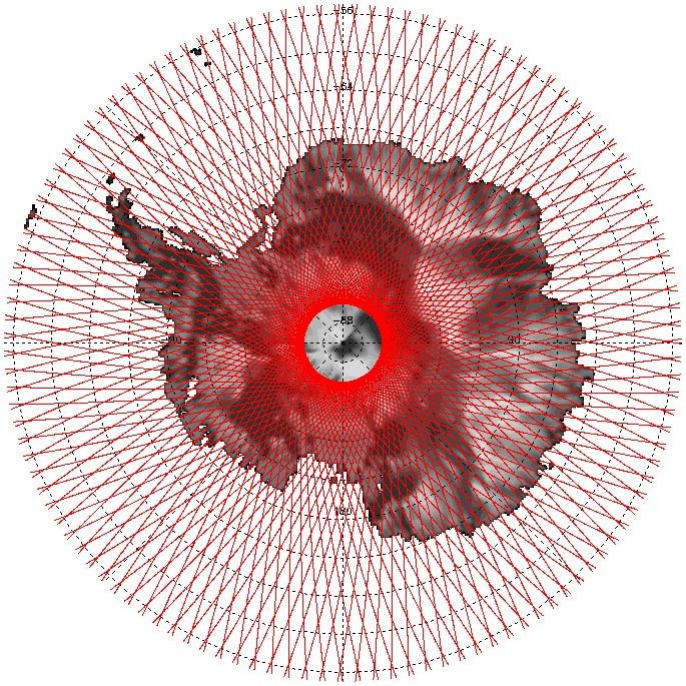
- Altimeter measures small elevation changes
- Surface undulations in the ice are preserved
- Features move with ice flow
- Repeat satellite passes monitor movement

ICESat

NASA satellite for measuring ice sheet mass balance, cloud and aerosol heights

Ice, **C**loud and Land **E**levation **Sat**ellite

Geoscience Laser Altimeter System (GLAS)



15 campaigns from Jan ‘03 to Oct ‘09

91-day repeat cycle

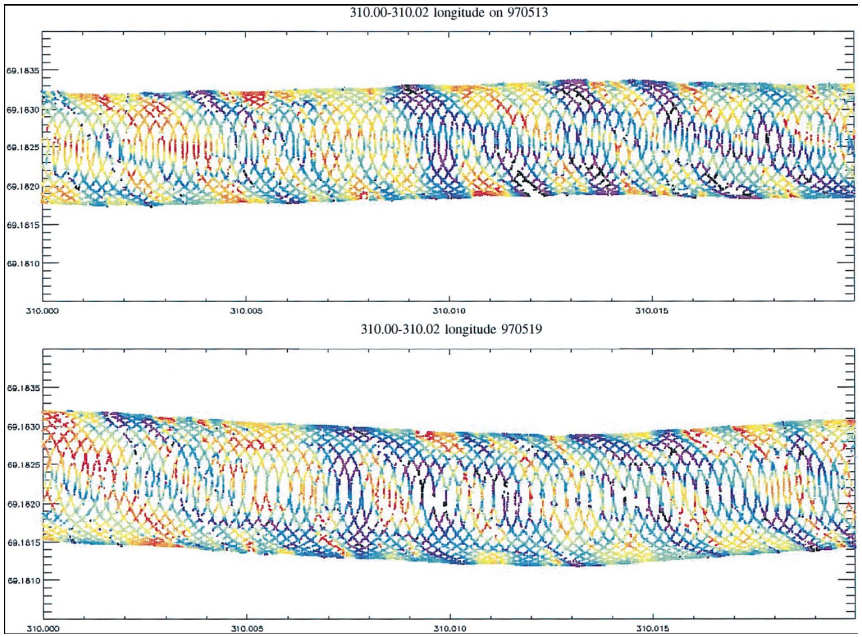
Laser footprint of ~65m

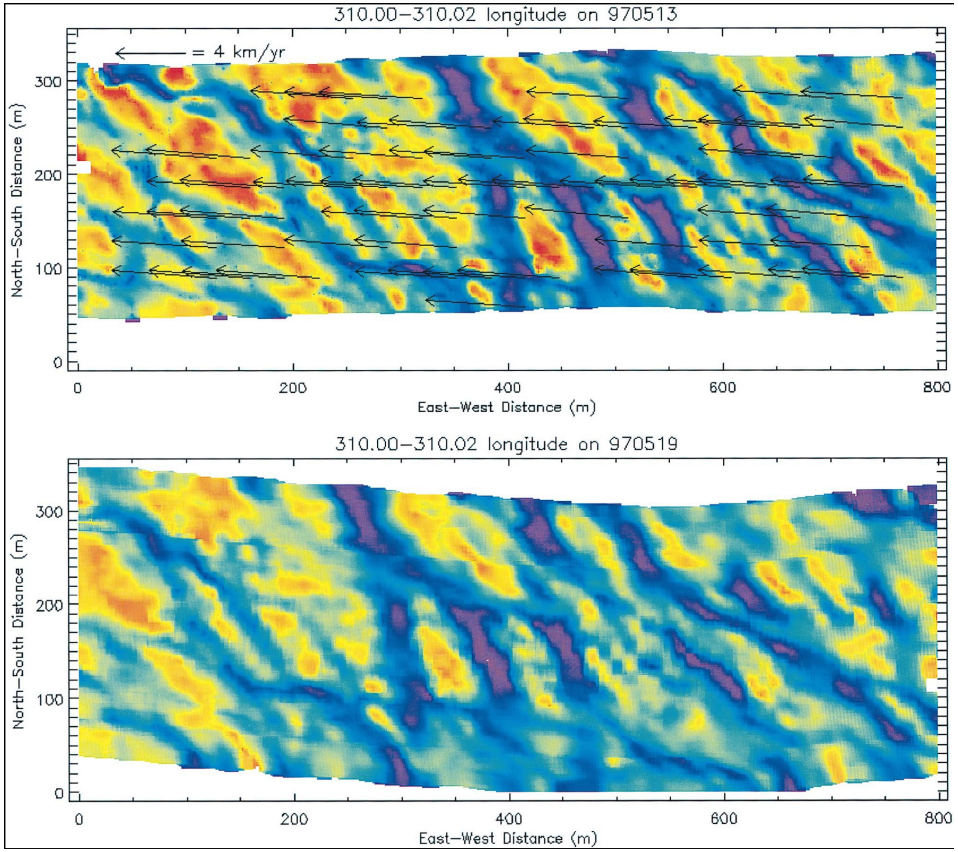
Separation of ~170m (Schutz et al., 2005)

Mean elevation of error of less than 1cm

Airborne Surveys

NASA study on Jakobshaven
(Abdalati and Krabill, 1999)





Works well on crevassed terrain on fast flowing outlet glaciers

Expensive with limited coverage for large ice shelves

Data Processing

1 – Convert unsaturated data into useable format

2 – Separate into tracks

3 – Interpolate individual ICESat points to continuous smoothed profile

4 – Calculate slope of profile

5 – Find the amount of offset required for peak correlation

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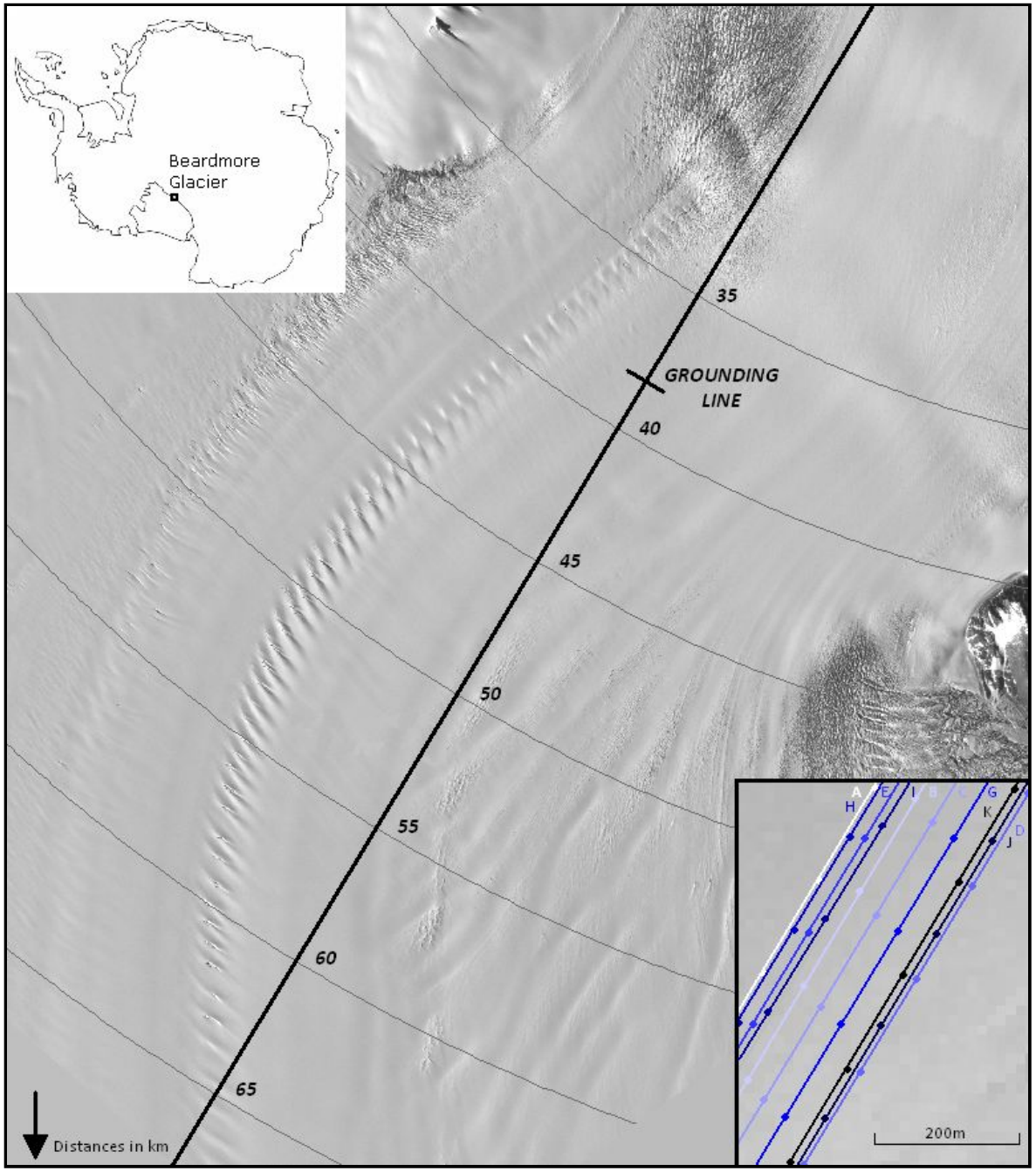

Repeat acquisitions for one descending satellite orbit path (Beardmore Glacier)

Perpendicular offset from mean:

A	- 101
H	-90
E	-68
I	-43
B	-39
C	+3
G	+45
K	+89
J	+99
D	+109

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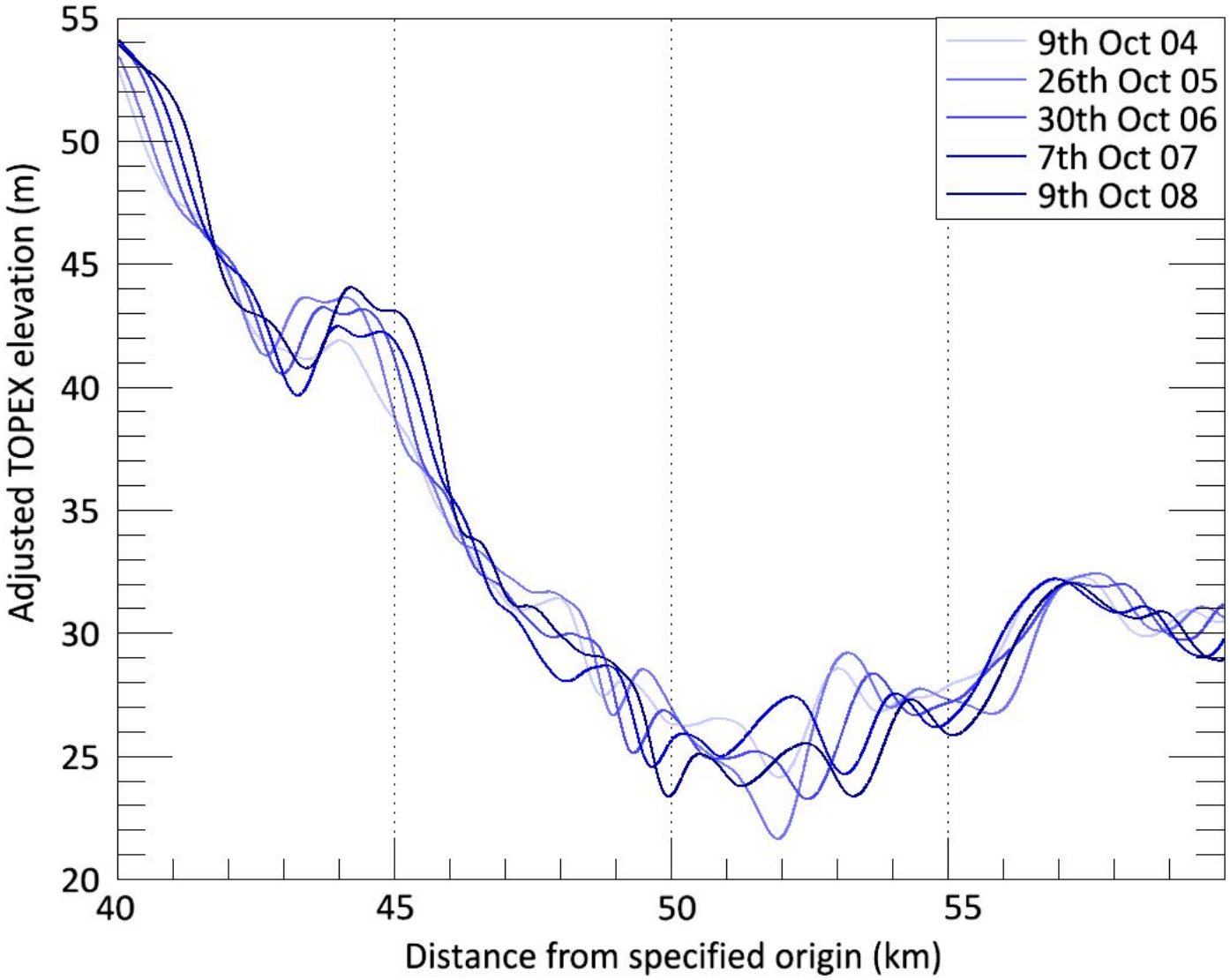

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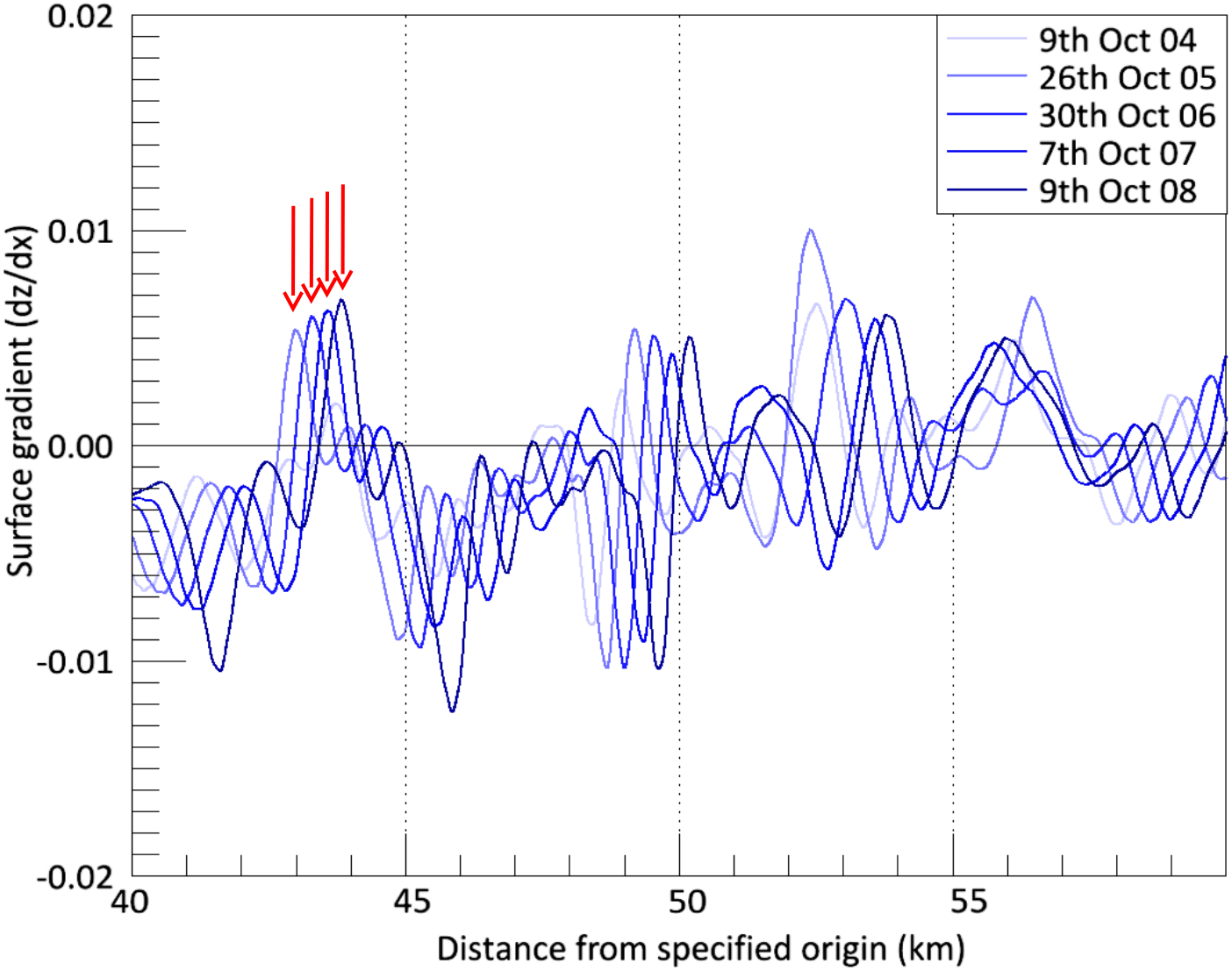

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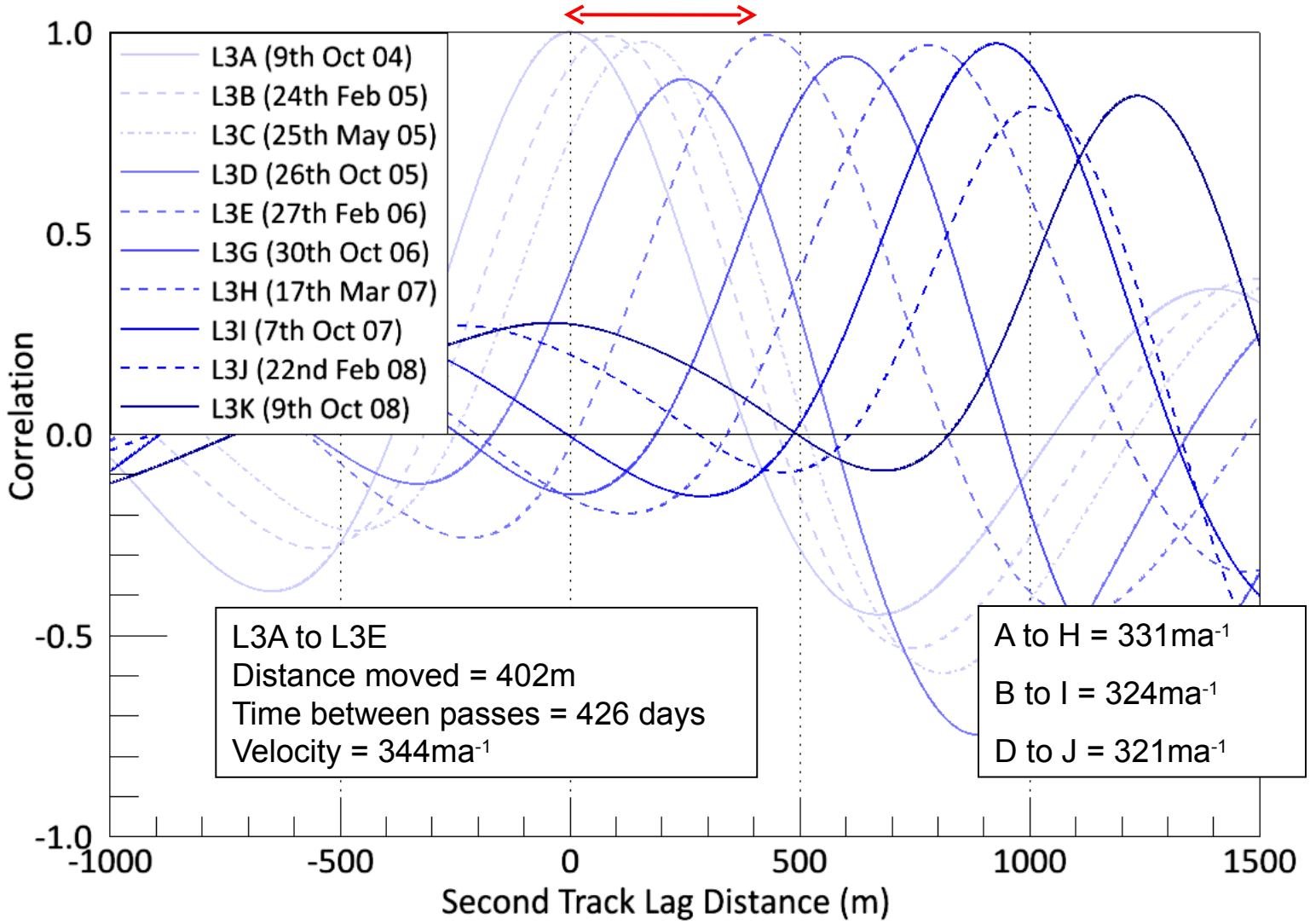


The problem of non-identical flightlines

Track offset up to 200m

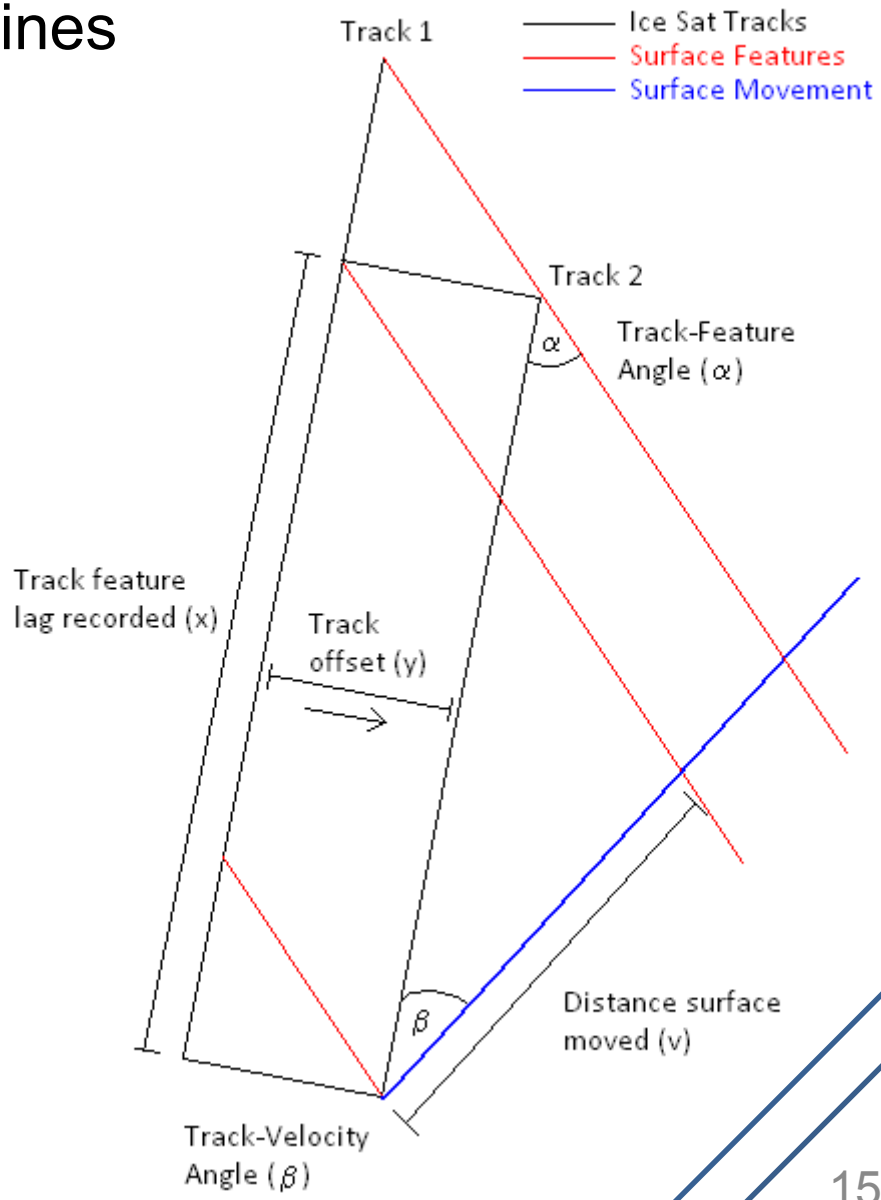
Surface profile may differ over this distance

Linear features can be accounted for if the angles are known:

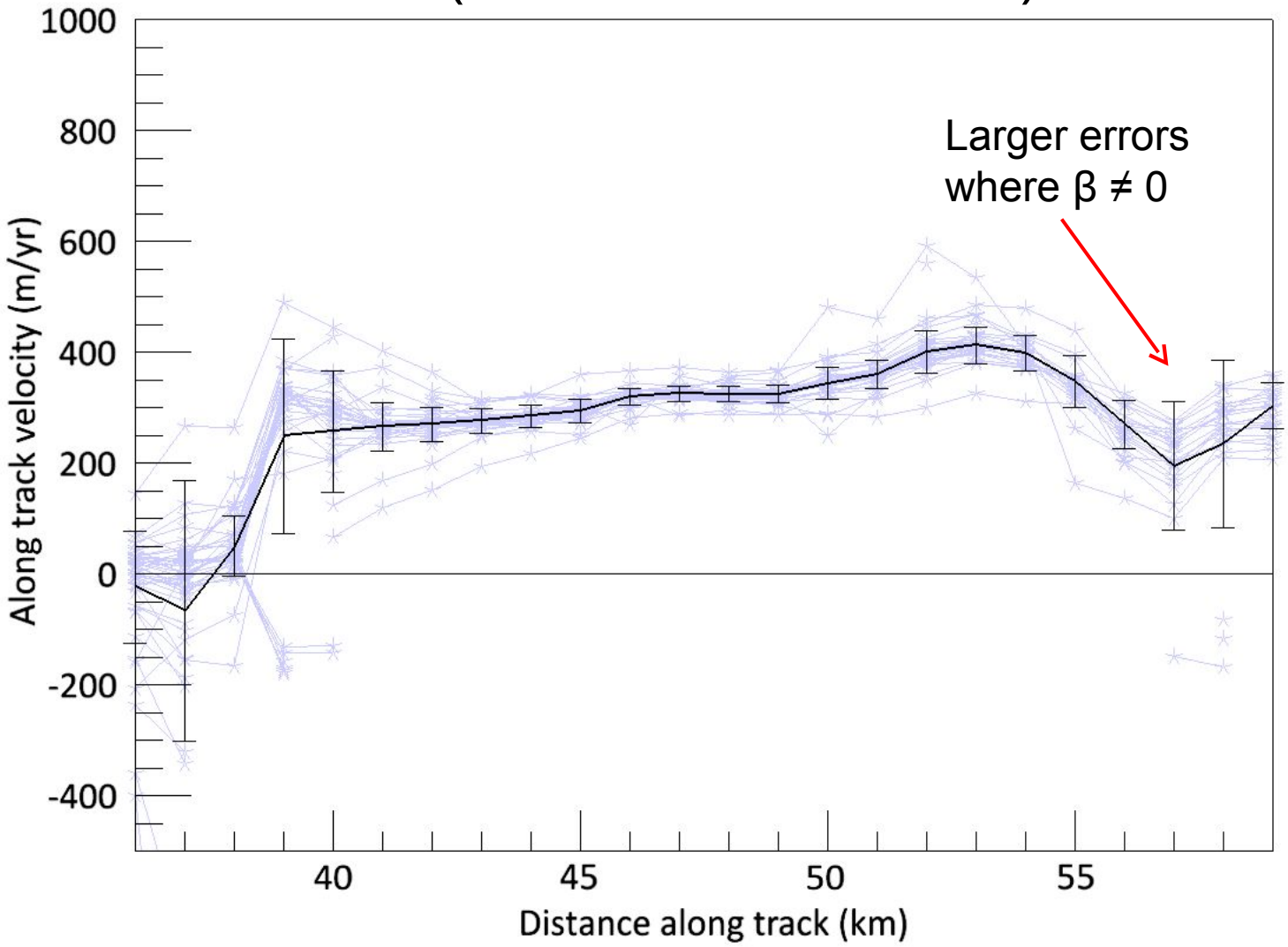
$$v\partial t = \frac{\partial x \sin\alpha - \partial y \cos\alpha}{\sin(\alpha + \beta)}$$

where β = 0,

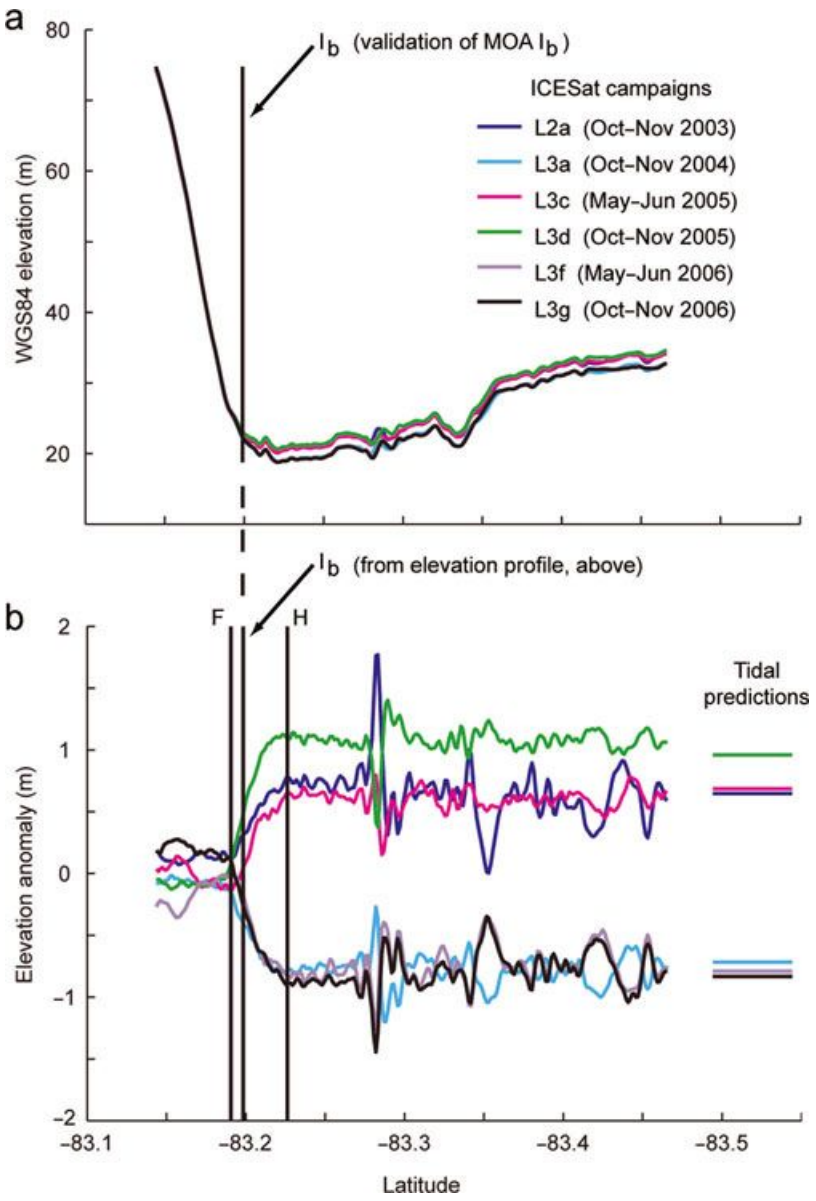
$$v\partial t = \partial x - \frac{\partial y}{\tan\alpha}$$



5-year single track velocity (Beardmore Glacier)



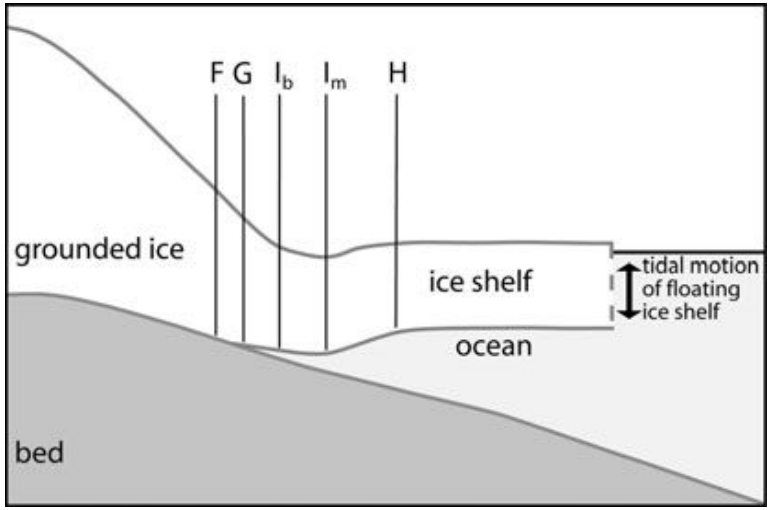
Identifying the grounding line



Previous work on grounding line identification (Brunt et al., 2010)

Comparison of ice shelf elevation at different stages of the tidal cycle

Identification of the topographic break of slope



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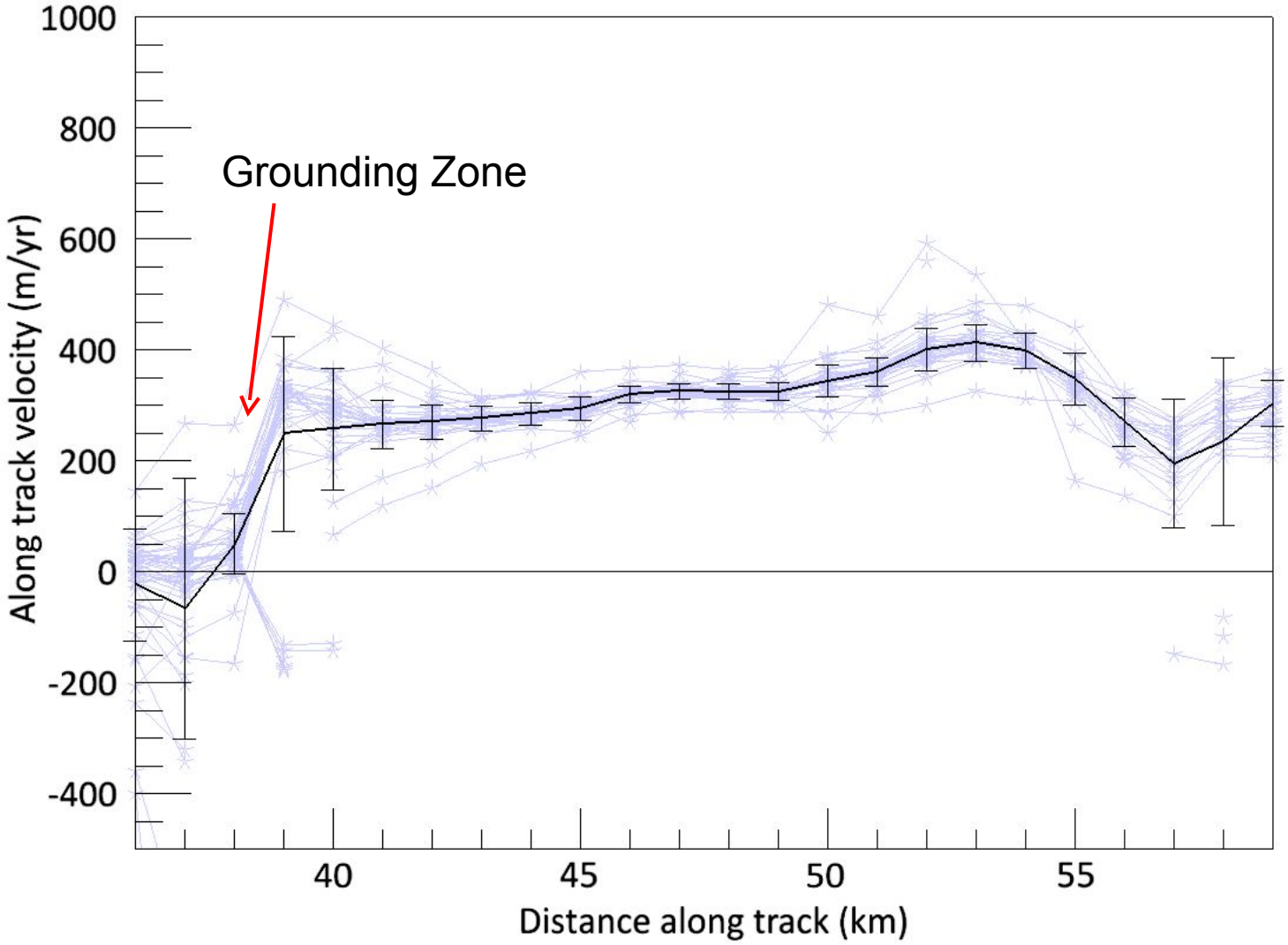
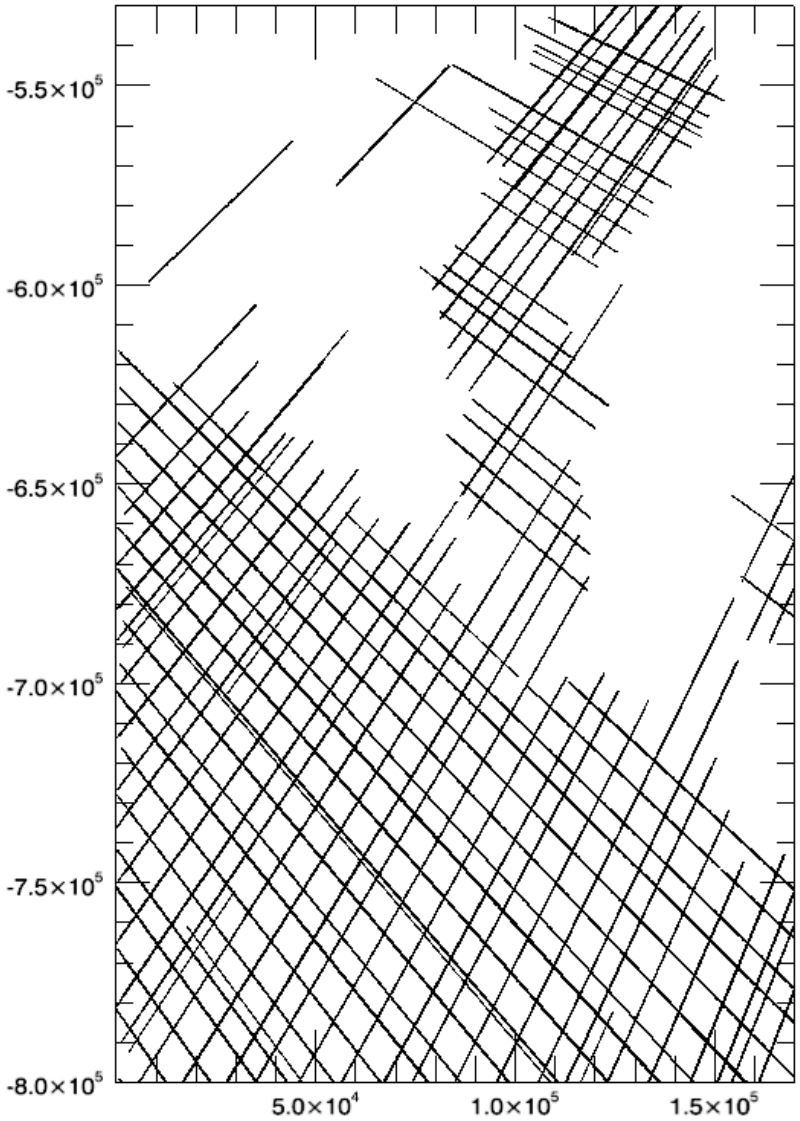
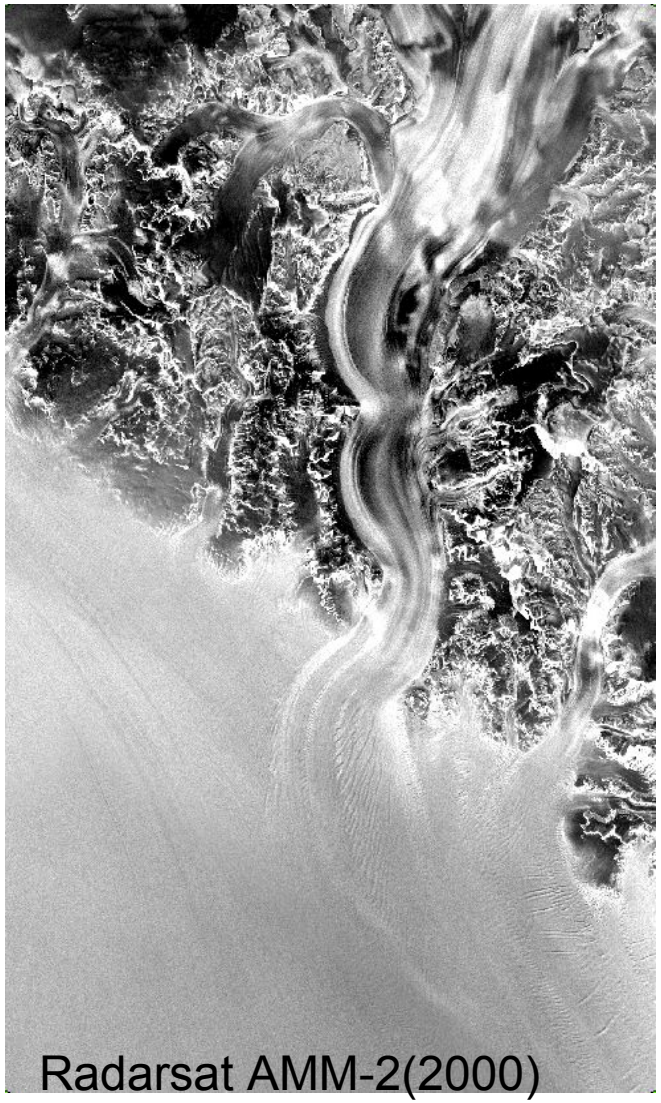


Multi-Track Processing





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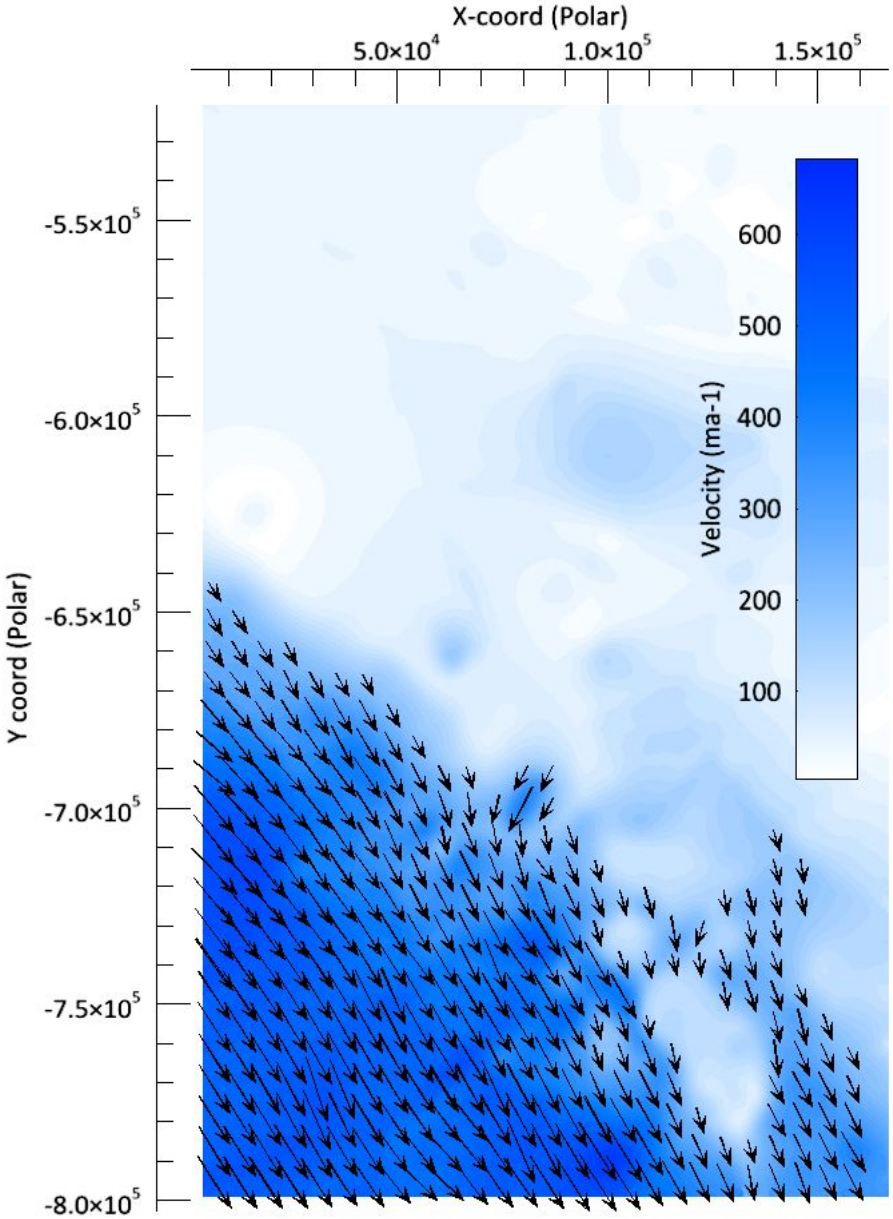
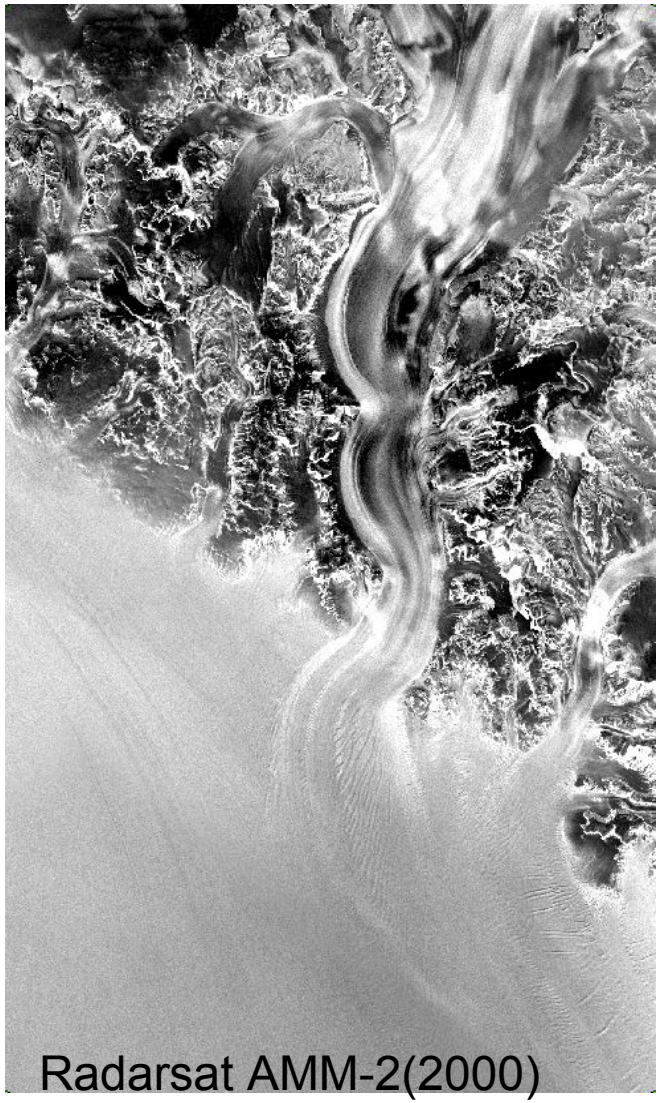
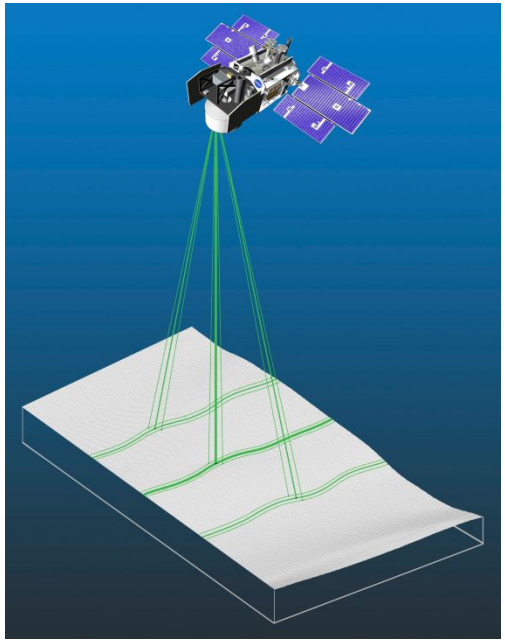


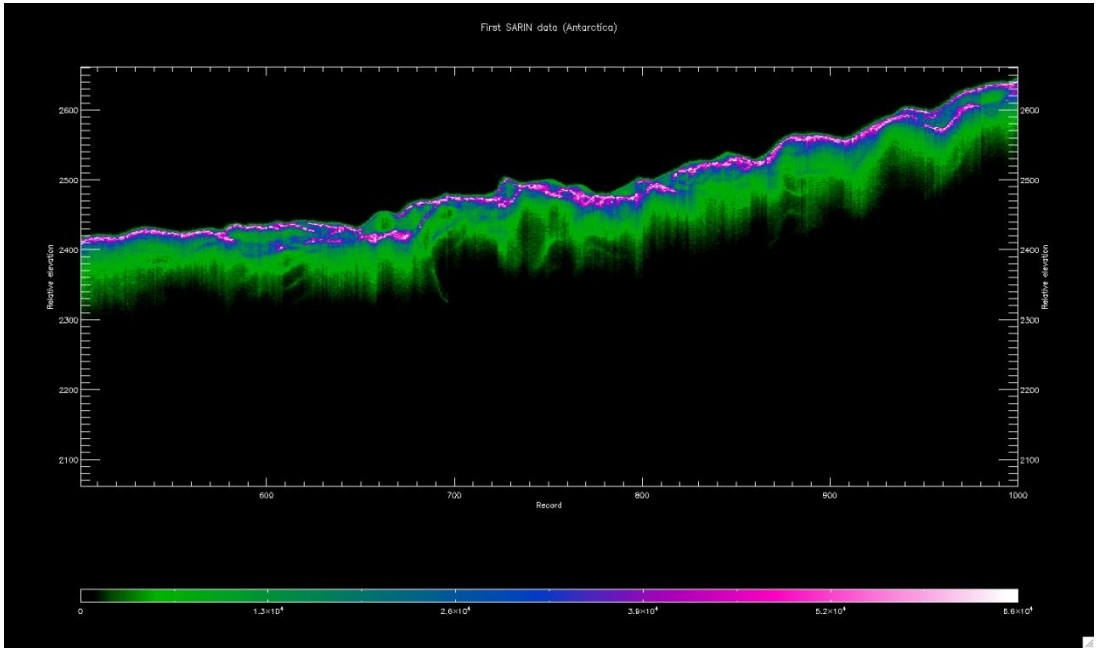


Method Development

- Iterative refinement of velocity at crossing points
- Estimation of errors
- Application to entire Ross Ice Shelf
- Validation using alternative remote sensing methods
- More advanced satellites



ICESat 2 ~ 2015
Multi-beam altimeter



Cryosat 2 – 2010
SAR Altimeter

Conclusion

- Previously undeveloped application of altimetry
- Large datasets available
- High spatial coverage
- Computationally inexpensive
- Calculation of a number of ice shelf parameters including grounding-line location, ice shelf thickness and surface velocity using a single sensor
- Ice flux at the grounding line

Questions?