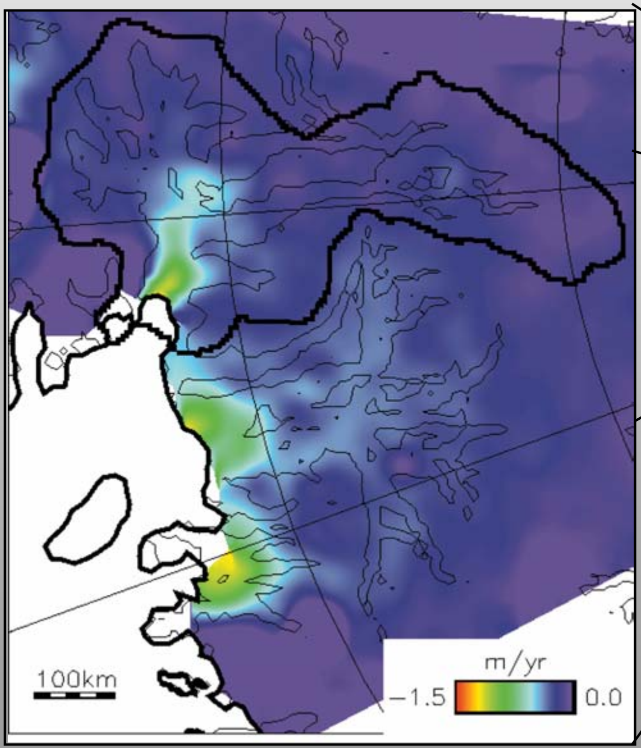
Recent Advances In Ice Altimetry
&
Implications for CryoSat

Prof. Duncan Wingham

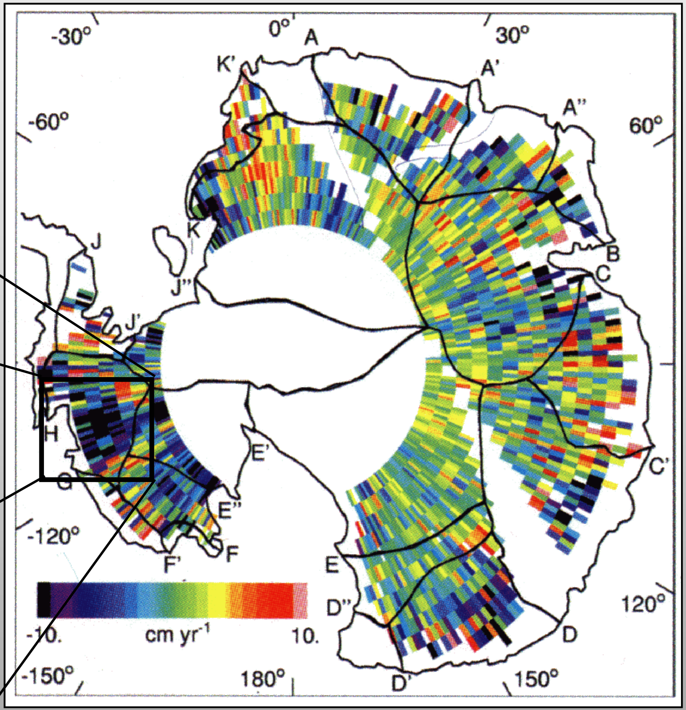
cpom

First evidence of WAIS inland thinning

1992-1999



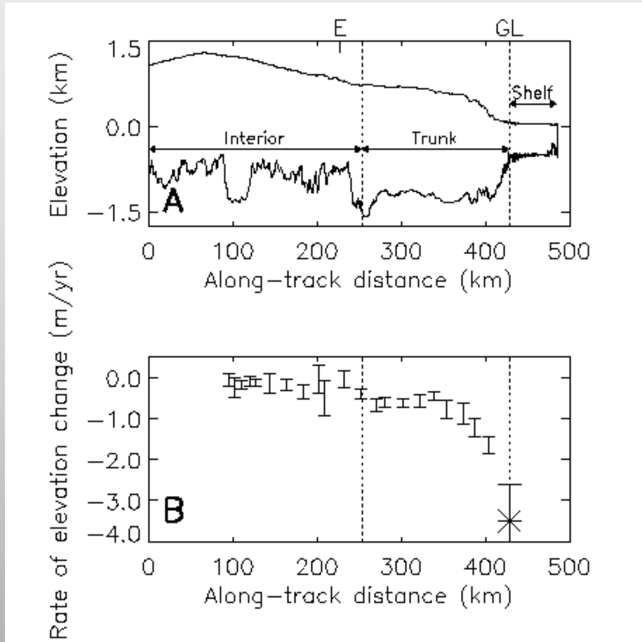
WAIS thinning is dynamically linked



Wingham *et al.*, *Science*, 1998

Shepherd *et al.*, *Science*, 2000

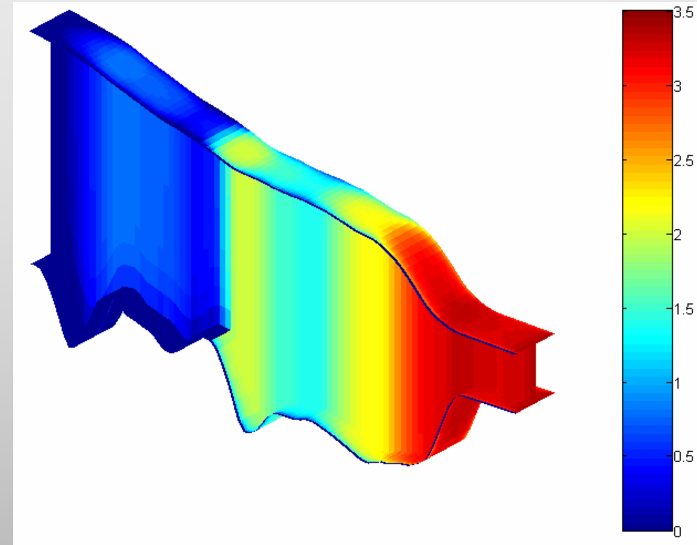
New generation of Ice Sheet Models

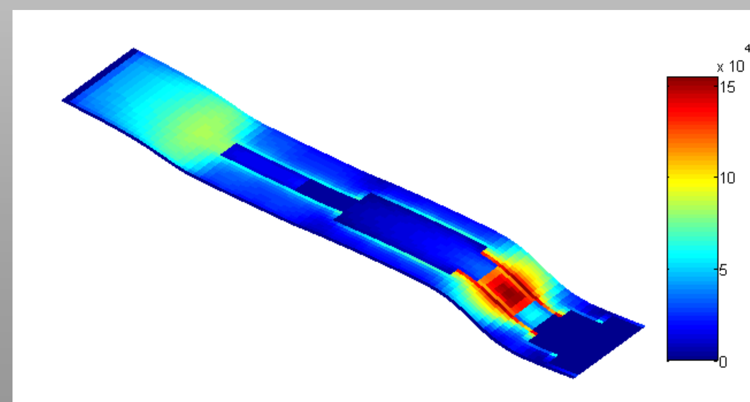


$$2\frac{\partial \sigma'_x}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}+\frac{\partial \tau_{xz}}{\partial z}=-\rho g\frac{\partial s}{\partial x}$$

$$2\frac{\partial}{\partial x}f\frac{\partial u}{\partial x}+\frac{1}{2}\frac{\partial}{\partial y}f\frac{\partial u}{\partial y}+\frac{1}{2}\frac{\partial}{\partial z}f\frac{\partial u}{\partial z}=-\rho g\frac{\partial s}{\partial x}$$

$$f=A^{-1/n}\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{1}{2}\frac{\partial u}{\partial y}\right)^2+\left(\frac{1}{2}\frac{\partial u}{\partial z}\right)^2\right]^{(1-n)/2n}$$





Pine Island: Internal or External Dynamics?

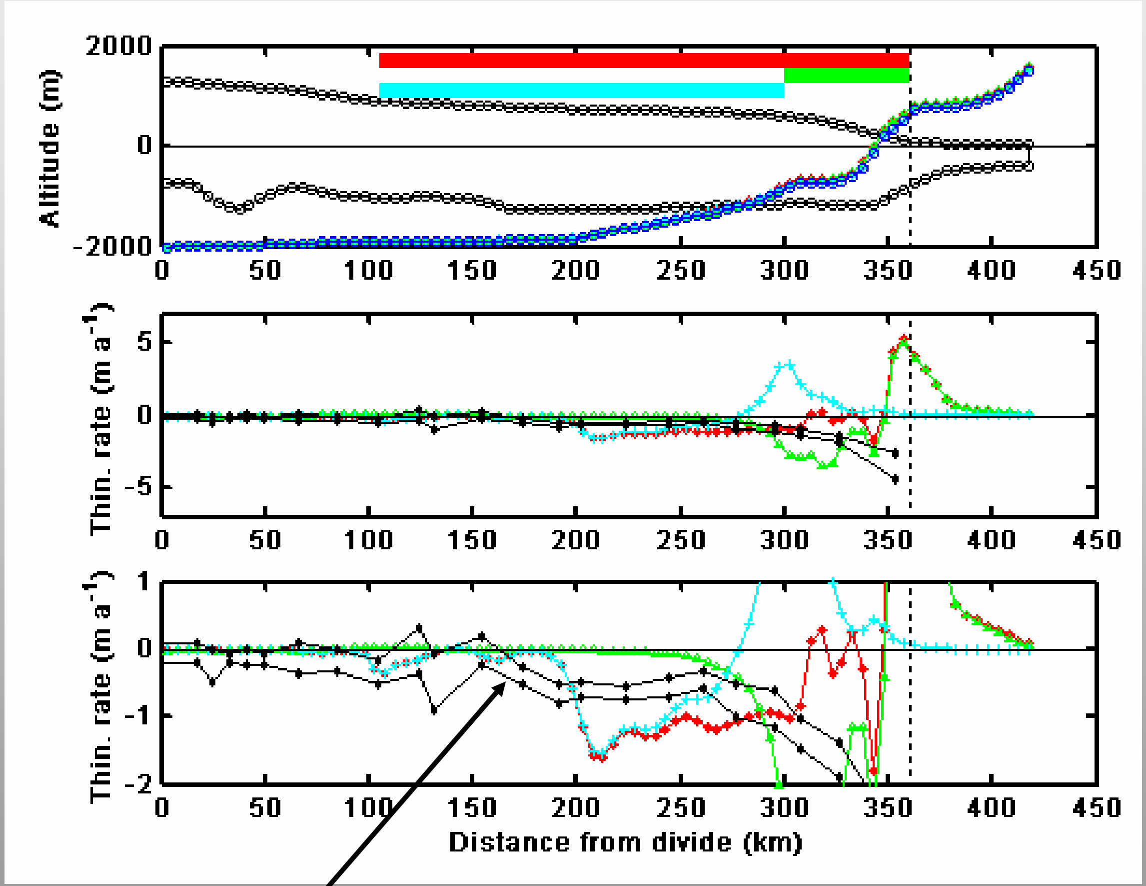
decrease drag coefficient by 10%

whole ice stream (red), just main trunk (blue) and just steep section (green)

local thinning rates of ~ 1 m yr^{-1} generated throughout

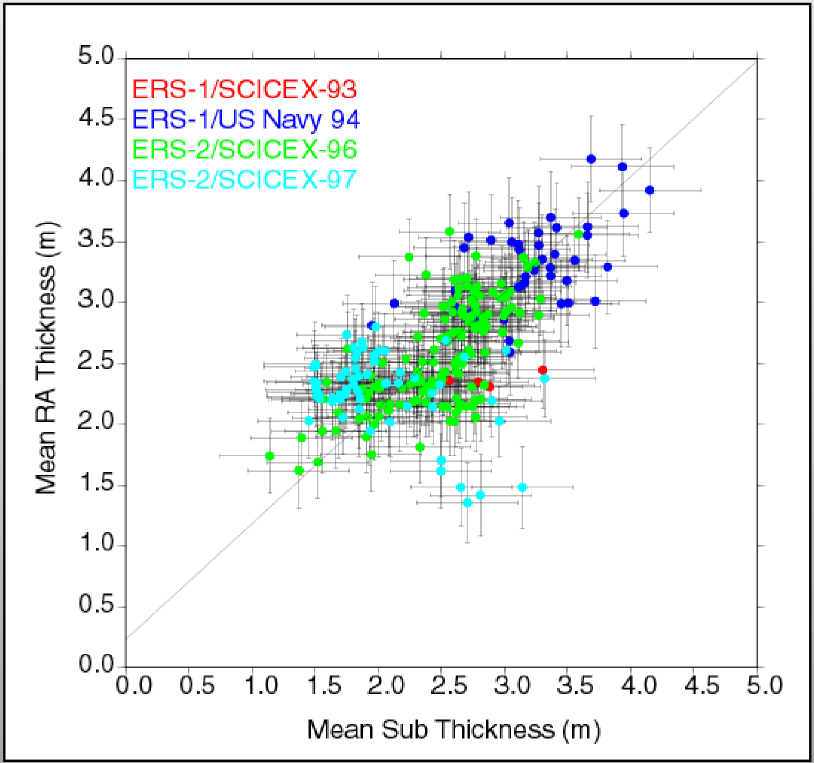
changes in steep section propagate

~ 110 km upstream of grounding line

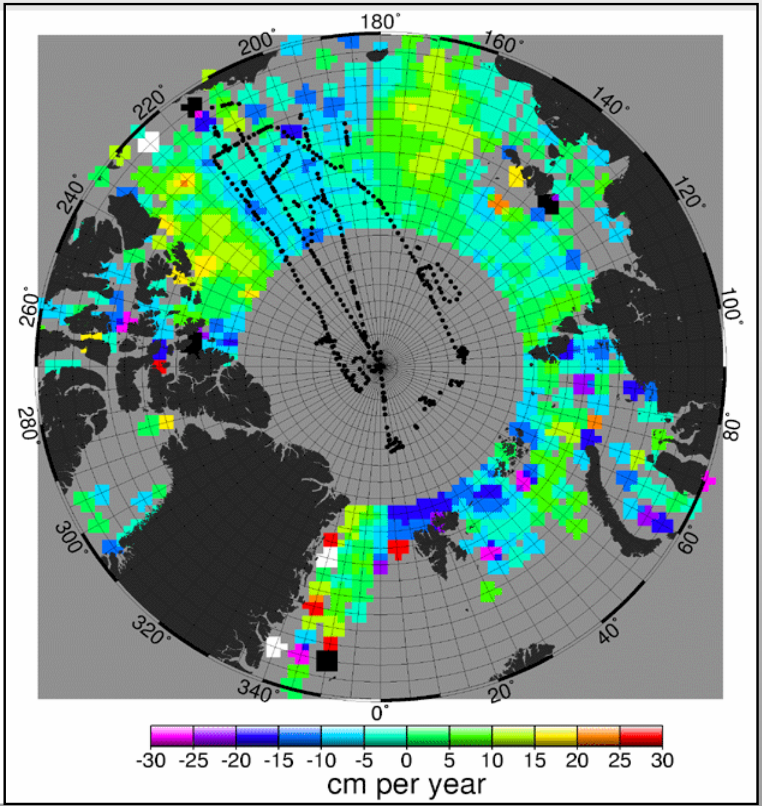


Observed thinning rates

Arctic Sea Ice Change 1992-1998



Comparison of satellite and submarine thickness measurements '93 to '97

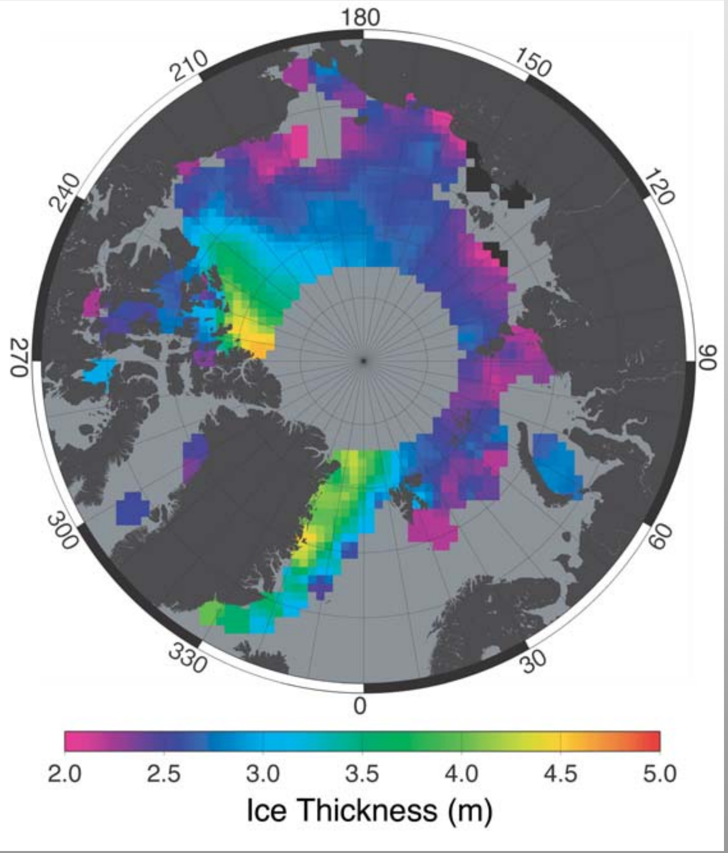


ERS reveals highly variable pattern of Arctic ice change

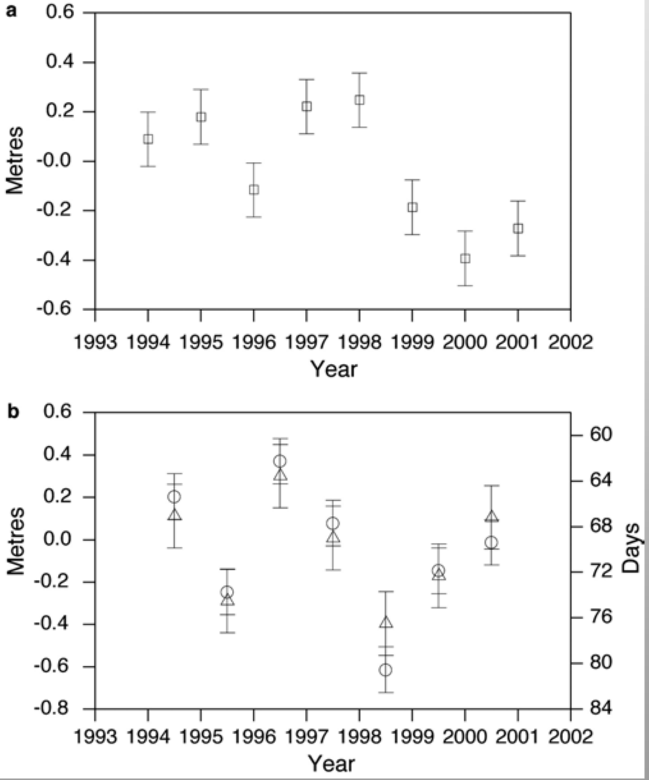
Laxon *et al.*, *Nature*, 2003

First Synoptic Observations of Arctic Sea Ice Thickness and Interannual Variability

Mean thickness

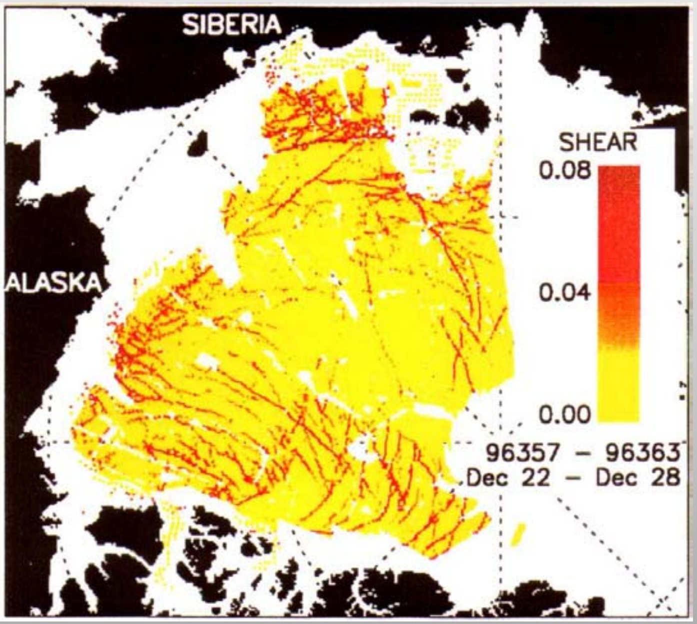


Inter-annual Variability

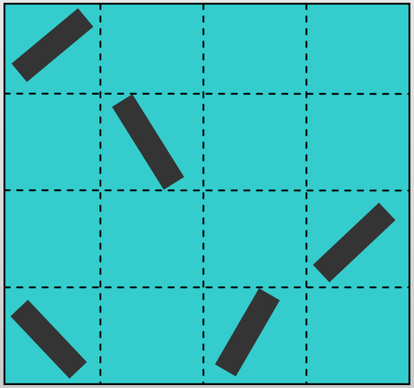


Laxon *et al.*, *Nature*, 2003

New generation of sea ice models

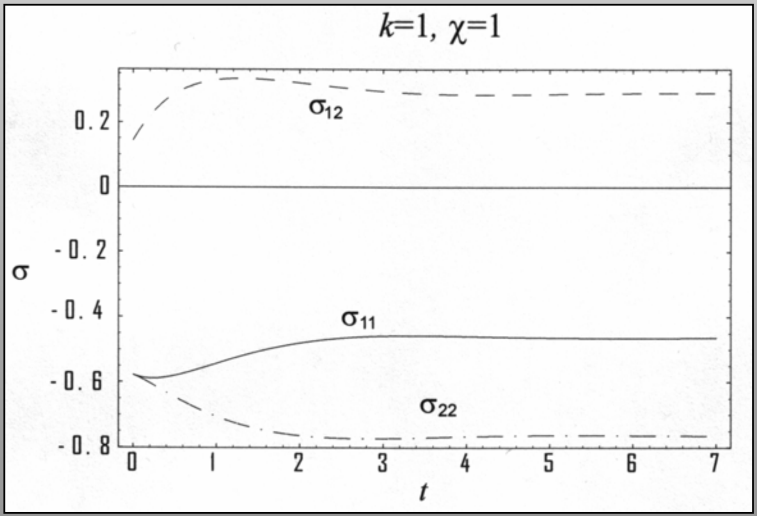


Satellite imagery shows sea ice mechanics to be highly anisotropic and dominated by fractures (leads)



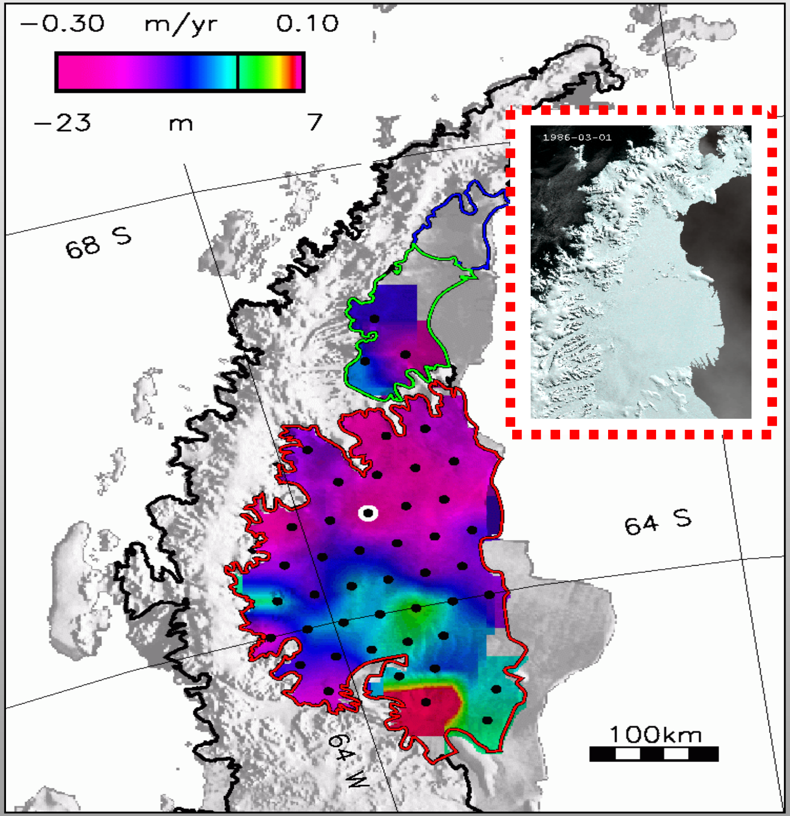
Deformation mostly occurs in thinner and weaker leads

Under deformation leads rotate, widen, narrow and close.



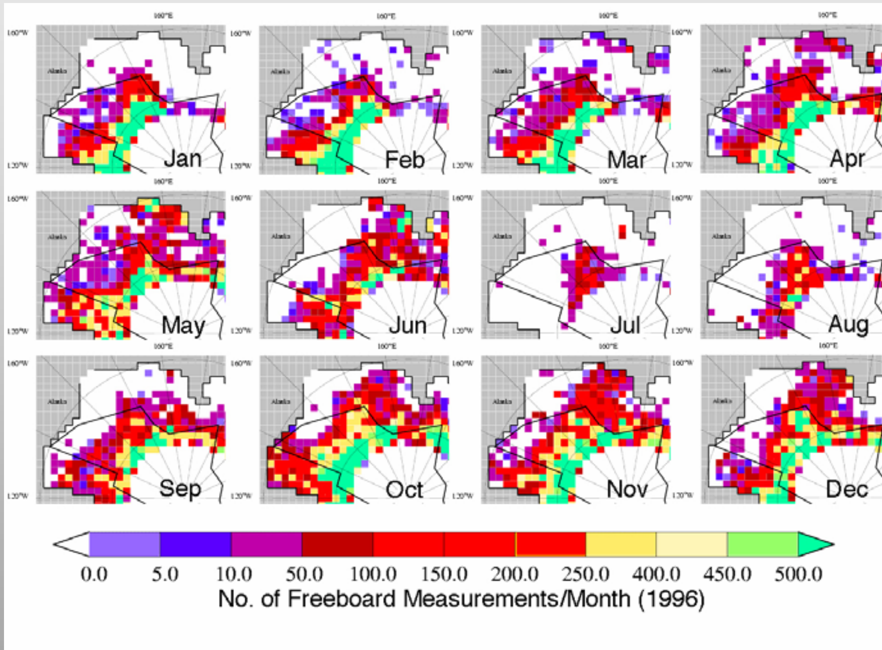
Ocean warming reaches the Antarctic?

Secular thinning preceded collapse of Larsen Ice Shelf

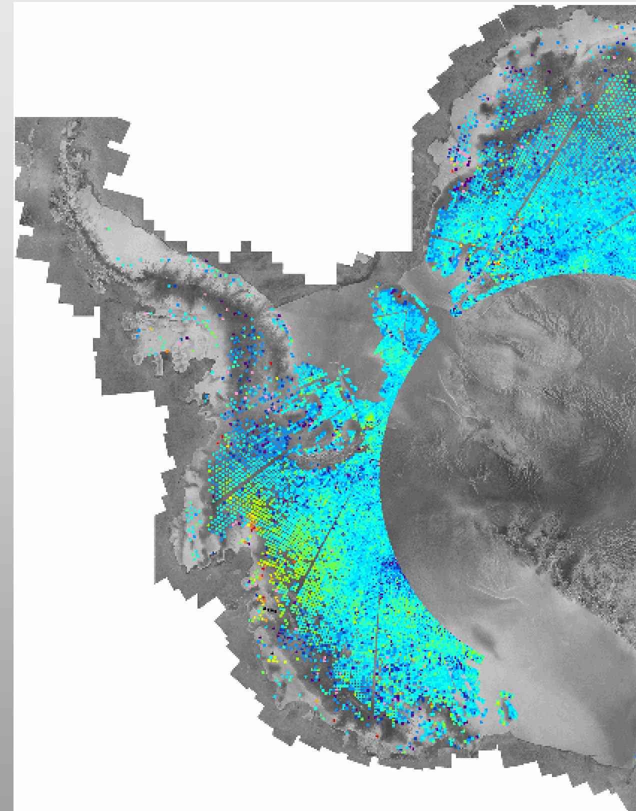


Shepherd & Wingham, *Science*, 2003

Implications for CryoSat: Sampling & Coverage

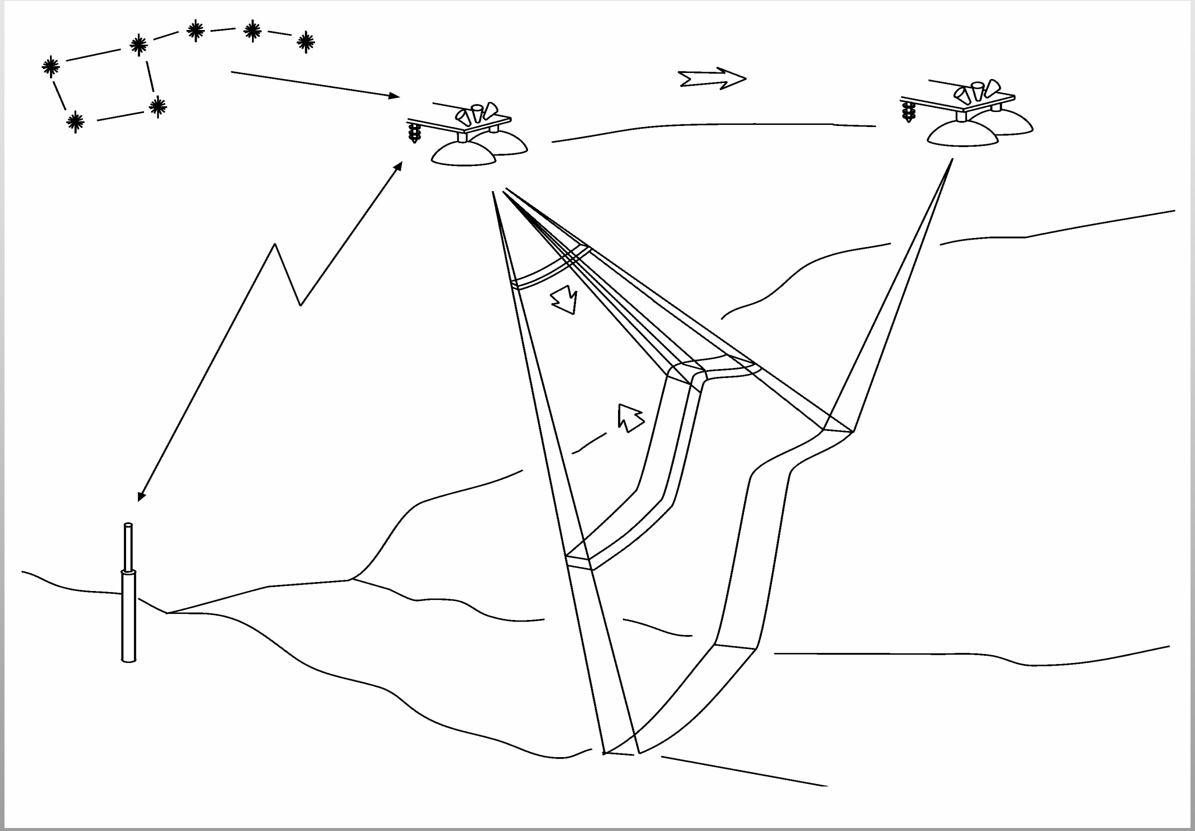


ERS sea ice sampling density



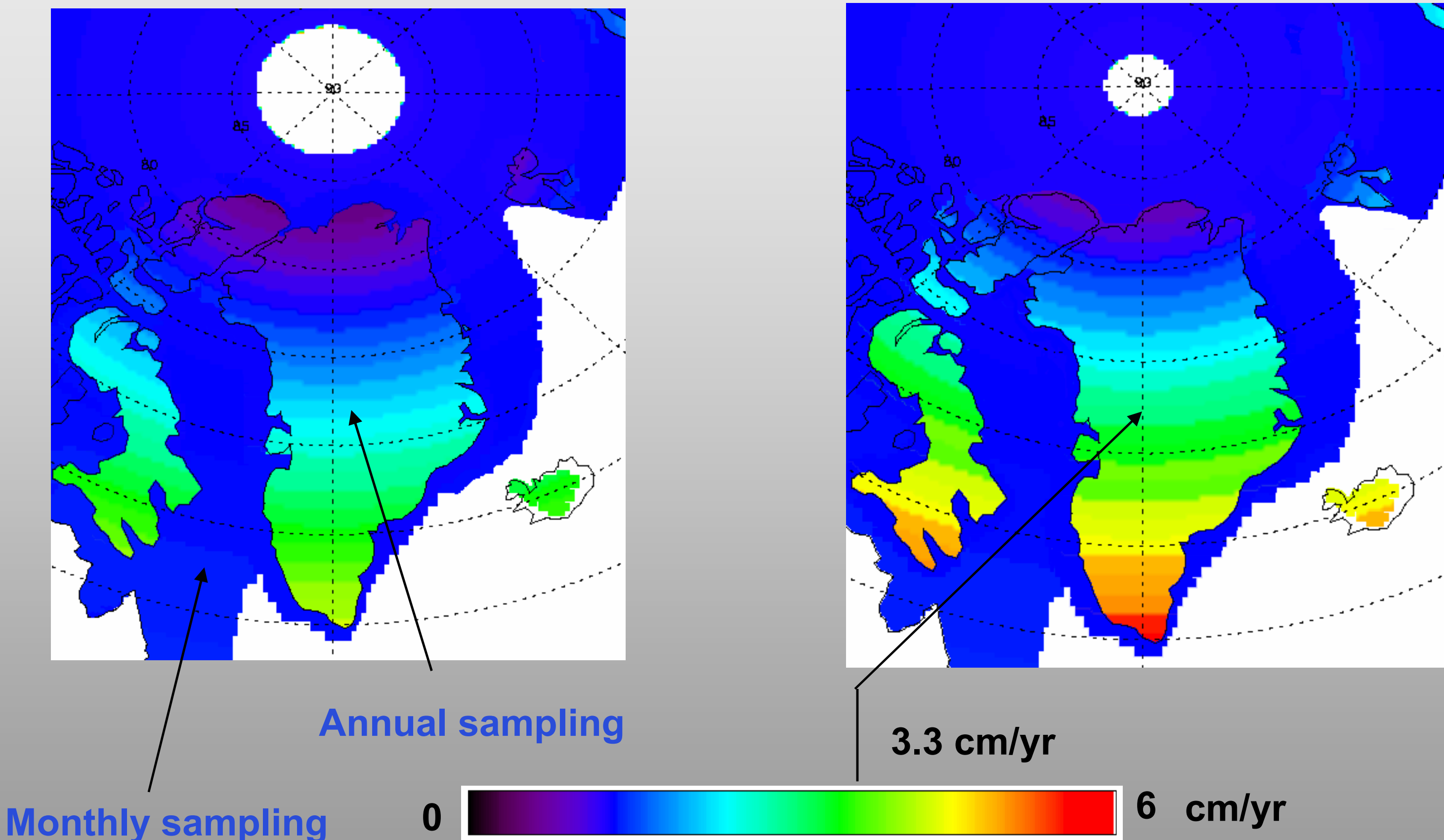
ERS coverage

CryoSat Measurement Concept

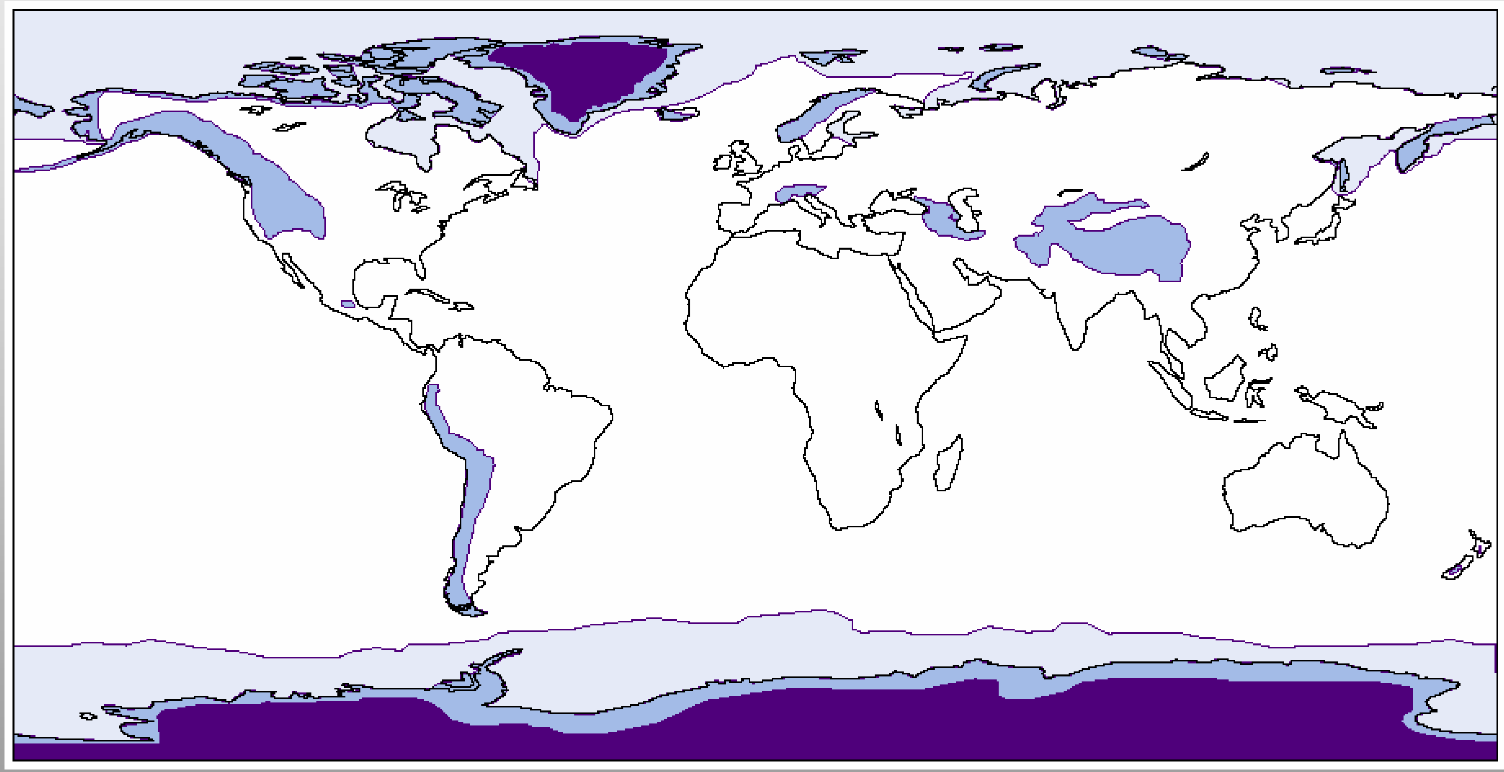


SIRAL 'SARIn' Operational Mode

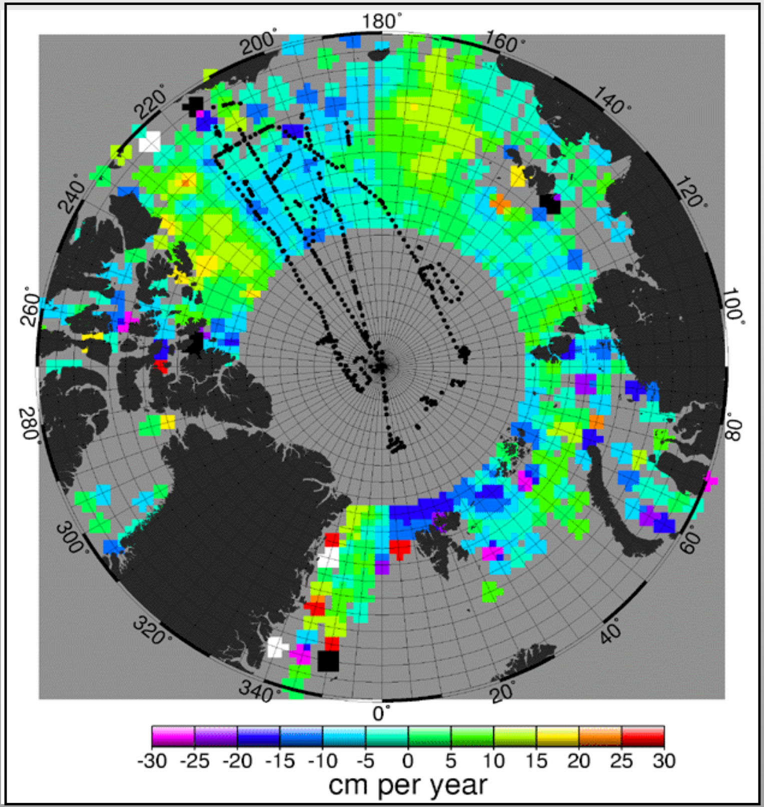
CryoSat Orbit Selection



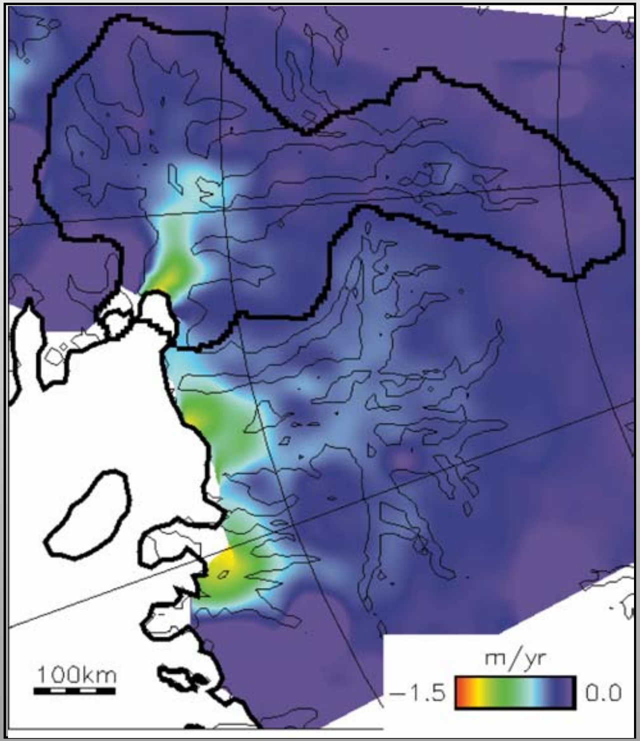
Implication of Mission Constraints: Mode Use



Implications for CryoSat: Validation



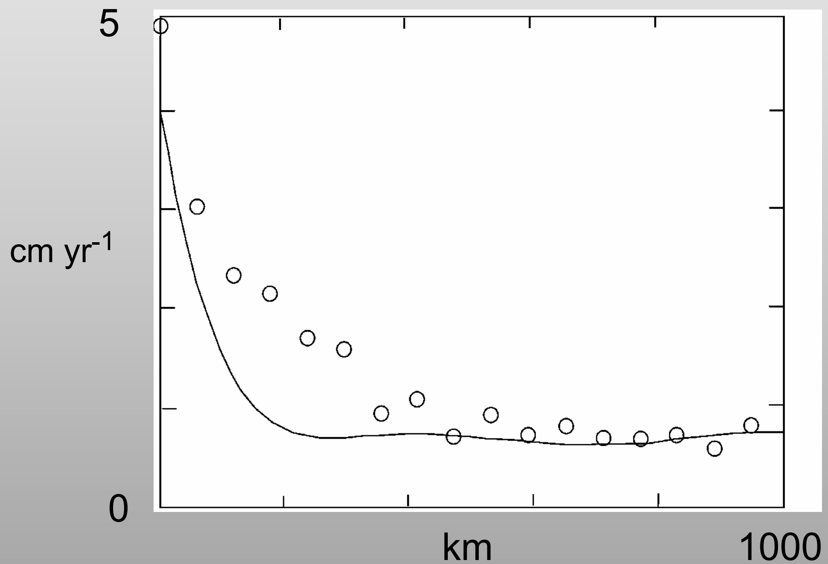
ERS reveals highly variable pattern of Arctic ice change



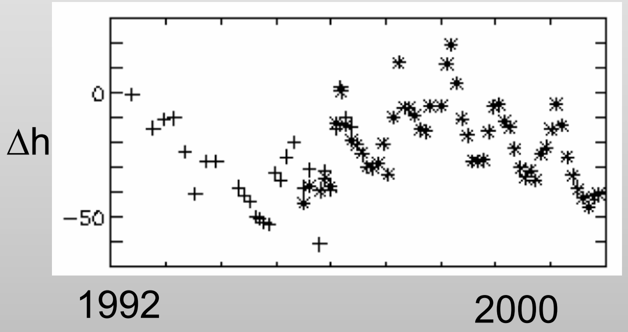
WAIS thinning is dynamically linked

Implications for CryoSat: Magnitude, Spatial and Temporal Scales & Geographic Distribution of Errors

Example: Level 2 Land ice geometric and penetration model error



Antarctica ERS elevation change covariance



E. Antarctic ERS elevation change

- ~ 2 cm yr^{-1} at 10^4 km^2
- Annual cycle, maximum range Spring-Autumn
- Dominated by Level 1b error at ~ 1 km^2
- Distinction between wet and dry firn

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Implications for CryoSat: Conceptual Validation Design

Example: Level 2 Sea ice geometric and penetration model error

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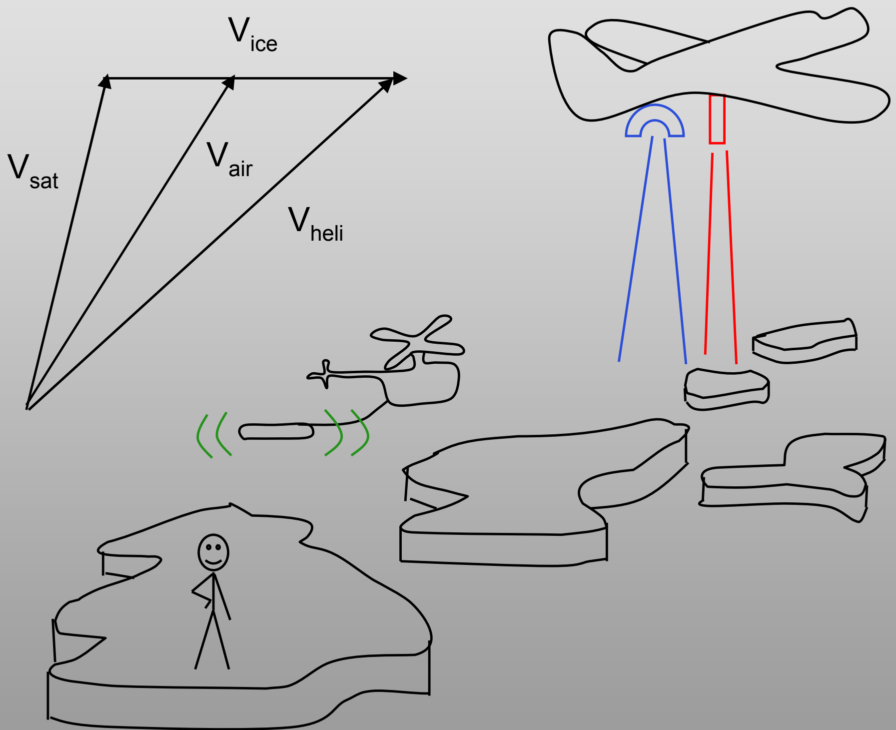
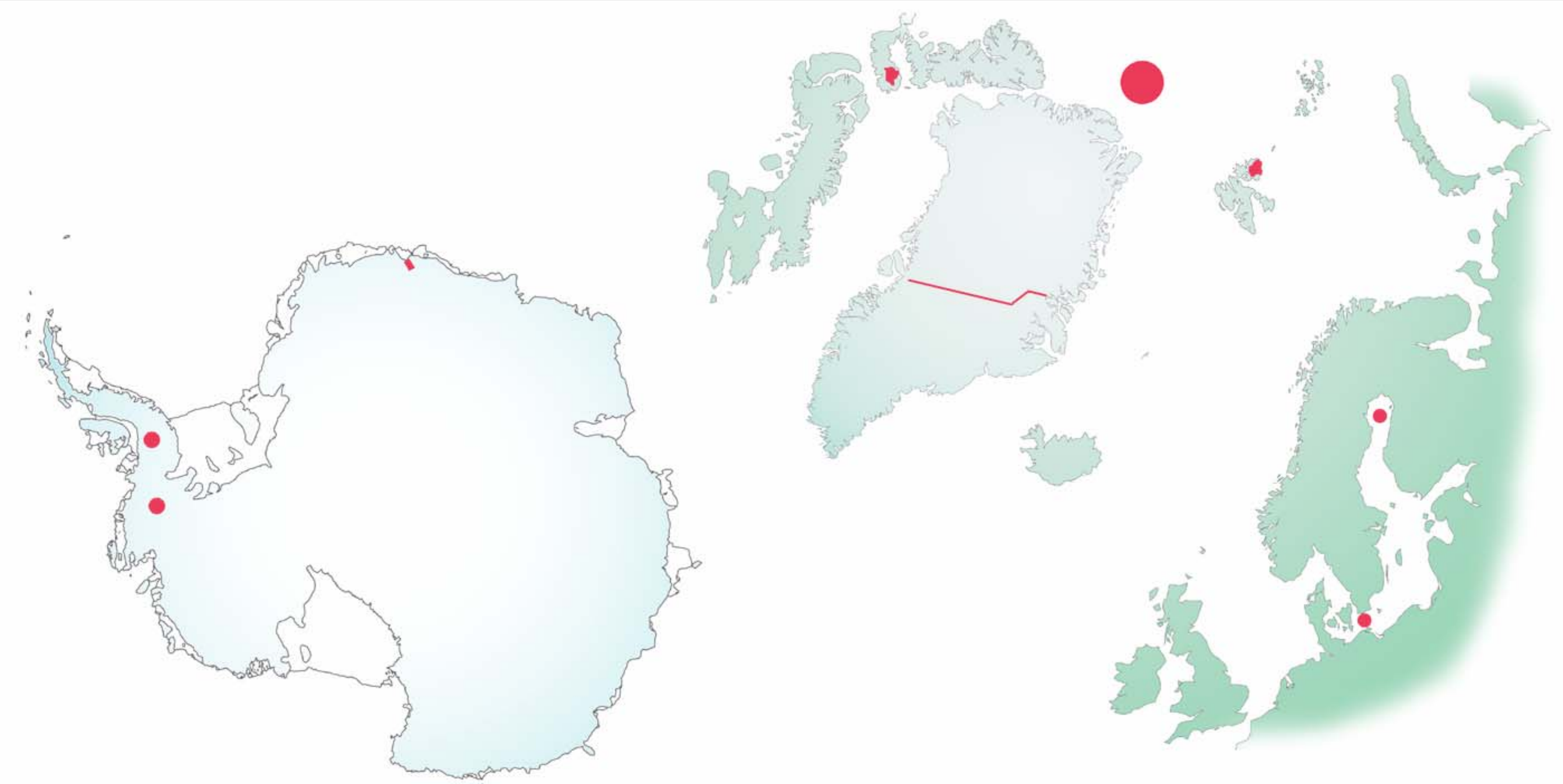


- Assess practicality and identify missing capability *e.g.* ASIRAS.
- Identify and contact important groups and planning time-scales *e.g.* Alfred Wegener Institute; 2-3 year planning horizon for polar activity.
- Identify practical locations *e.g.* Arctic Ocean N. and W. of Greenland is accessible and gives access to strong ice concentration variations.
- Identify experimental complexity and novelty and assess need for pre-launch trials *e.g.* LARA (2002) and CryoVEx (2003) campaigns.
- Identify and implement requirements on ground-segment capability.

Implications for CryoSat: Validation Experiments



Implications for CryoSat: Validation & Data Respinning