Remote Sensing of Ice Cap and Glacier Mass Balance

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- Measurement of surface ice motion, improved knowledge of ice dynamics and ‘mass balance’.
- EO for cryospheric change

Overview: study of glacial ice reveals climate change. A warming climate will lead to, at present, a largely unknown contribution to sea level rise.

Overview process diagram 'borrowed' from a Bob Thomas paper.

Note that ice cores have also provided key information on past climate change. Ice cores can also give useful information on pollution transport.

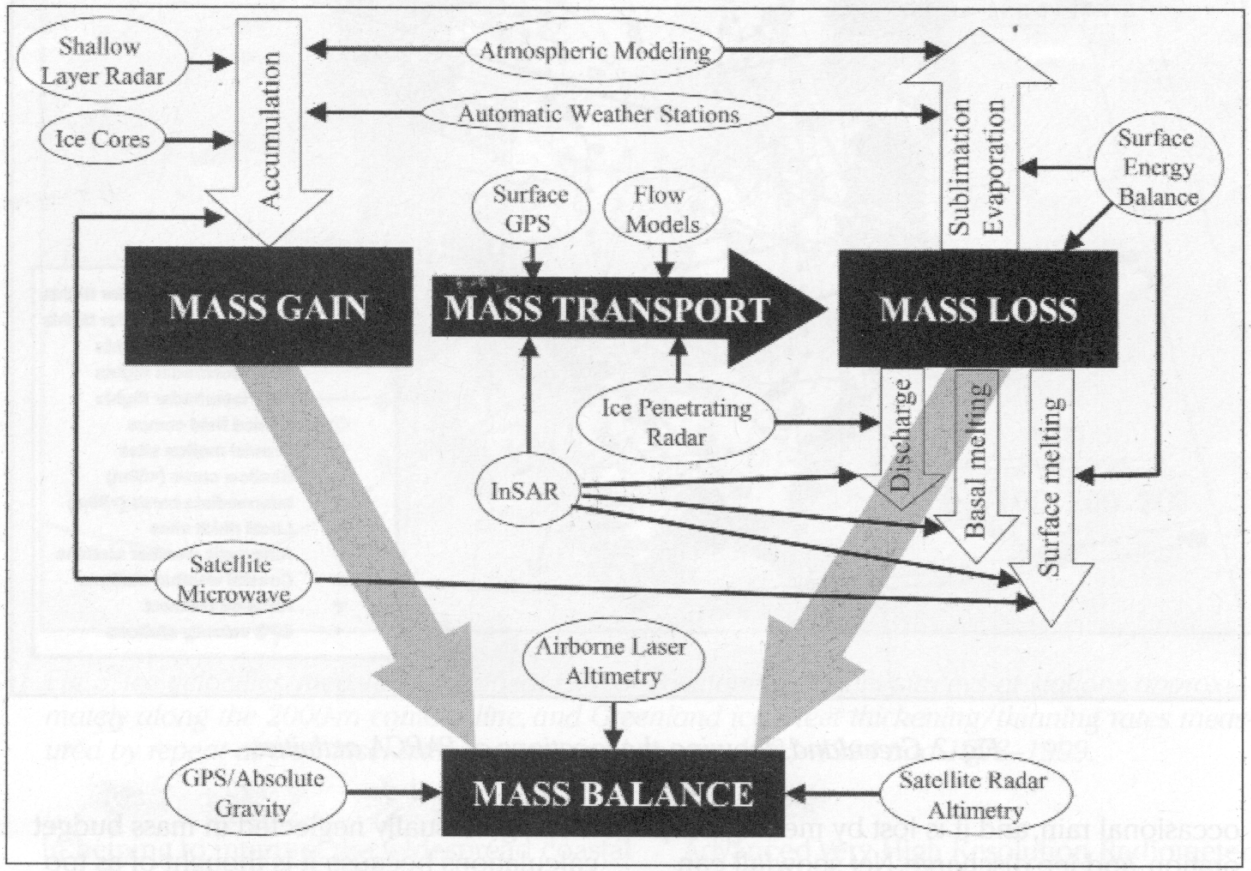
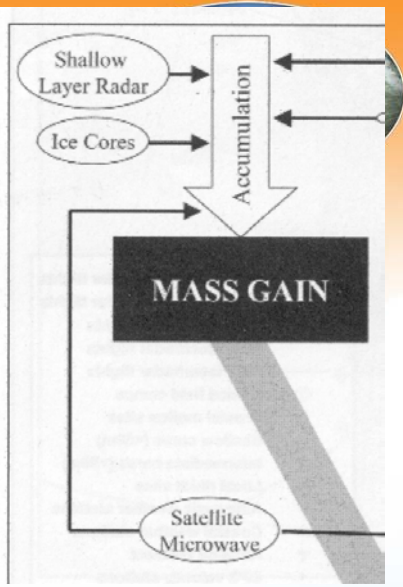


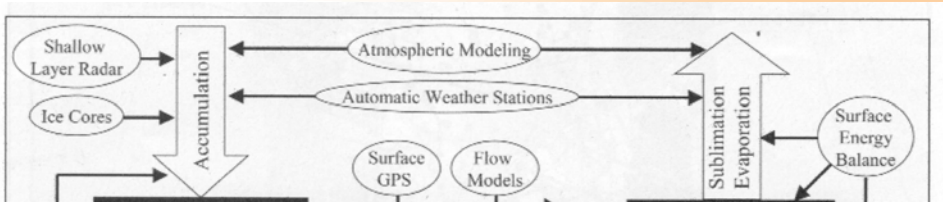
Fig. 1. Program for Arctic Regional Climate Assessment (PARCA), showing links between the various activities.

Mass gain



- Field data on snow accumulation from repeated measurements using stakes, snow pits, etc., is essential. Even with improvements in remote sensing techniques (surface, airborne and satellite), this type of data will remain very important.
- Surface ‘high bandwidth’ radar can resolve near surface layering and give information on accumulation. (however, it appears that dynamics may affect apparent layer thickness; this is current research).
- Satellite techniques for snow accumulation on large ice caps show promise, but as yet aren’t universally applicable.

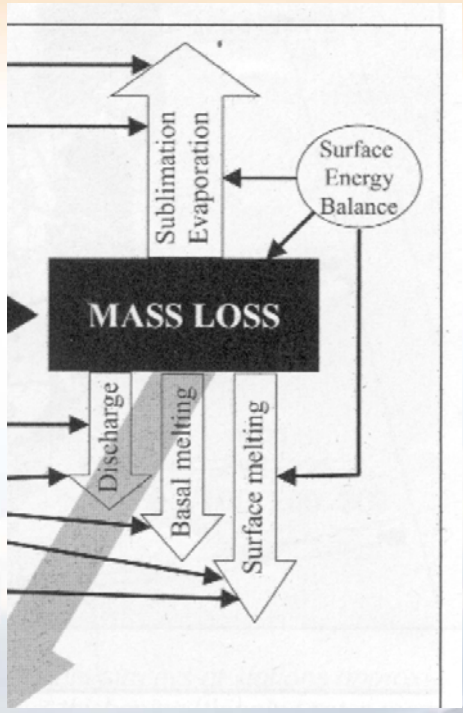
Mass gain/ loss



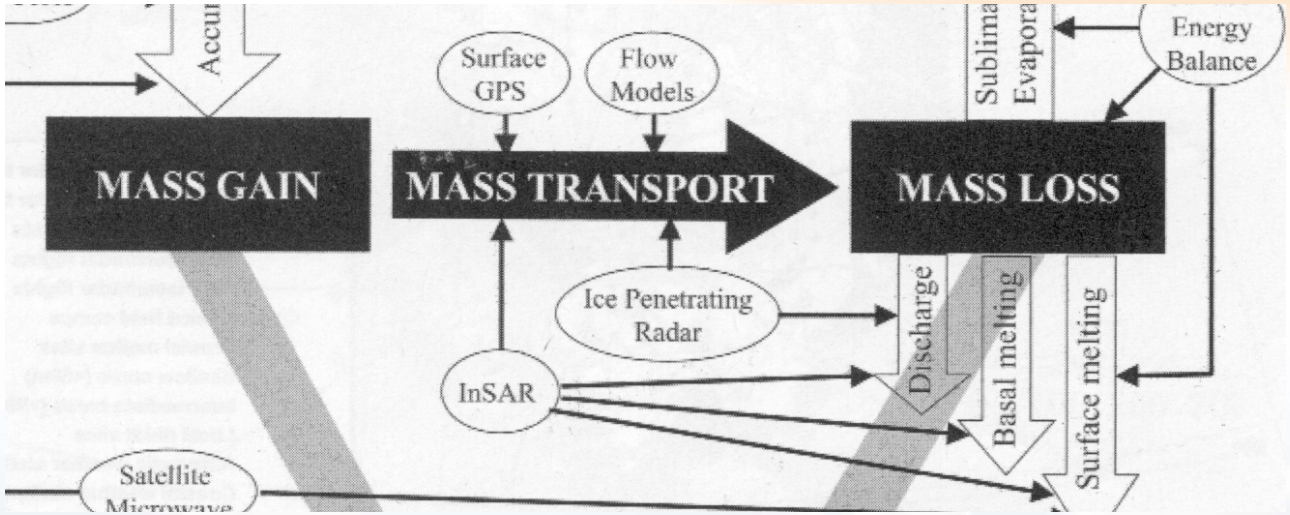
- AWS (automatic weather station) data coupled with weather models can provide information on both accumulation and sublimation/ evaporation. Also this type of data can be very important in the interpretation of remotely sense data.

Mass loss

- Either through estimates of volume change (differencing DEMs, airborne and satellite laser data (Icesat) and/or satellite radar altimeters (Cryosat).
- Estimates of mass loss from estimates of ice and water flux, e.g. in Antarctica most of the mass loss is through iceberg calving so the flux of ice across the grounding line is a key required measurement.

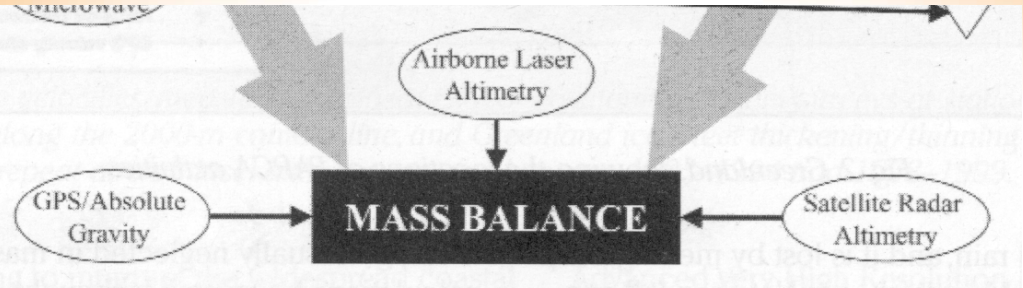


InSAR: a new tool in measuring ice transport

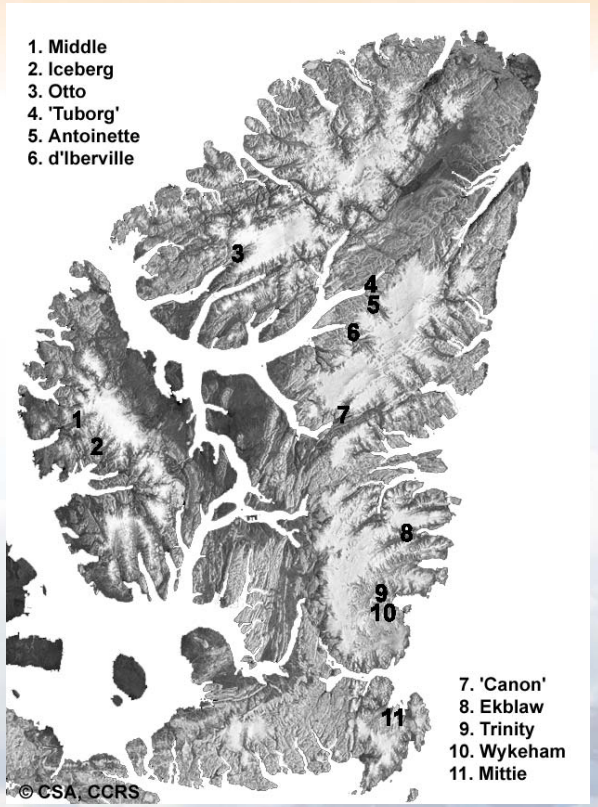


Satellite InSAR has improved ice flux estimates particularly in Antarctica, it has helped define grounding lines on ice shelves (and change), and provided new information on ice dynamics.

Mass balance



Satellite (Icesat) and airborne laser systems, and radar altimeters (Cryosat), are used to monitor surface height change and provide key information for mass balance. These data should be linked also to ice dynamics information because of the possible variability in ice flux. For example, many high Arctic glaciers are ‘surge type’.



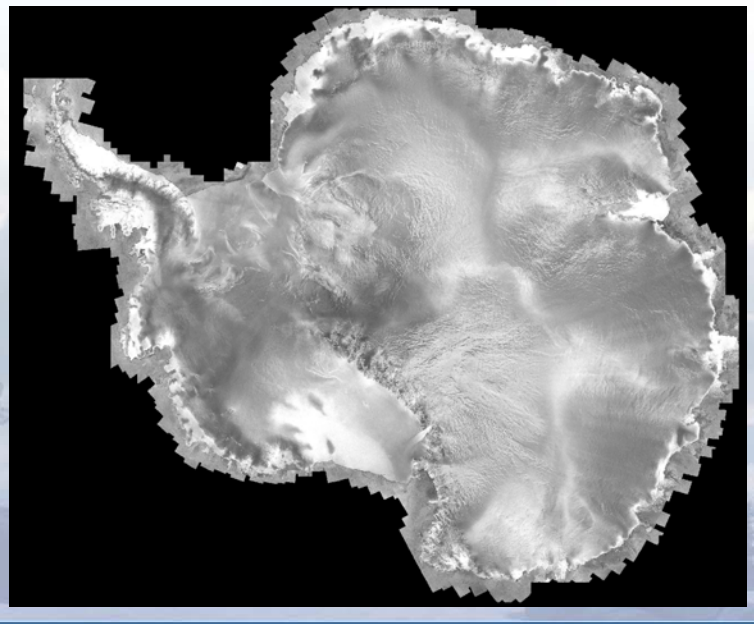
InSAR contributions

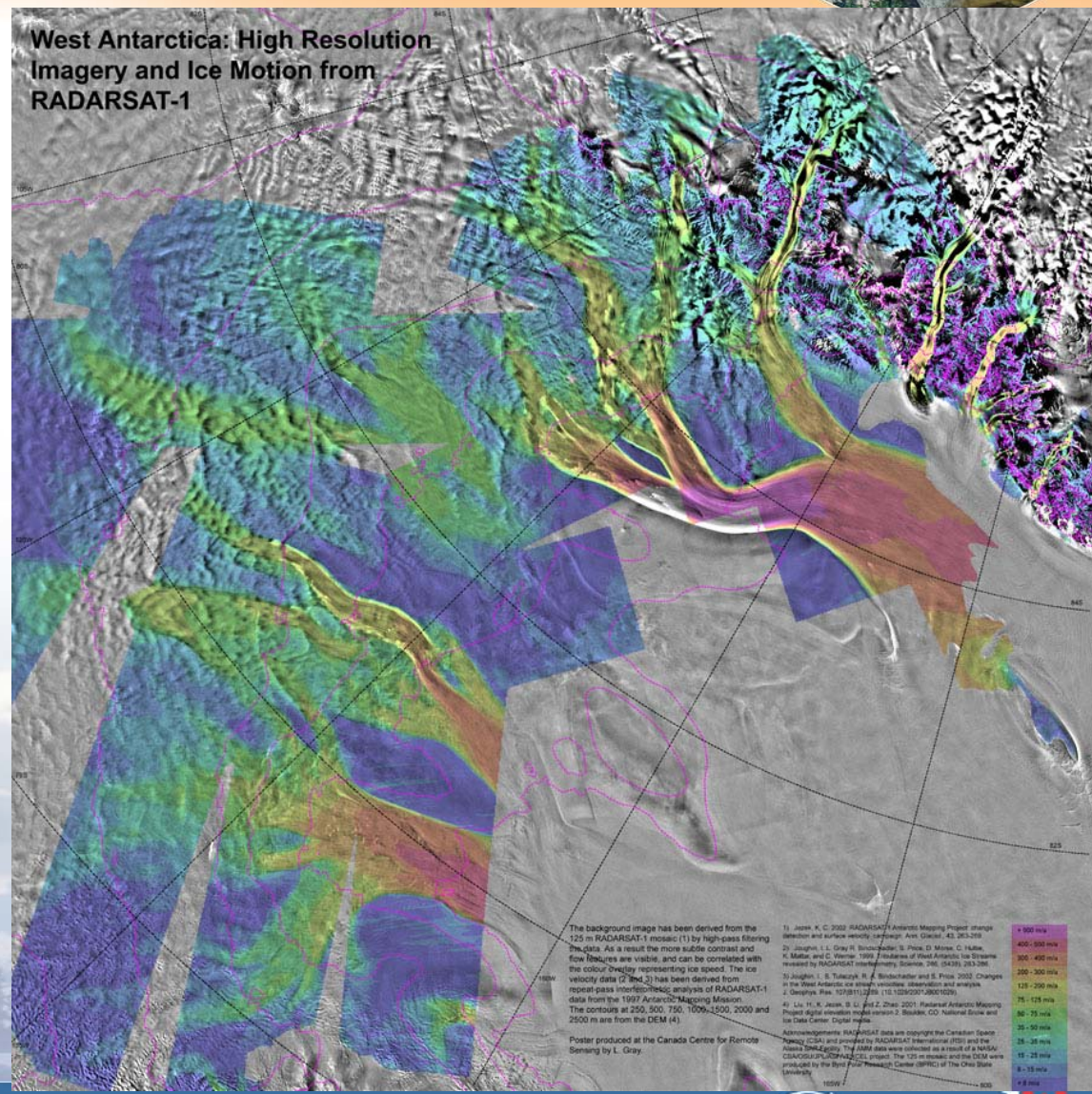
- SAR and InSAR (especially RADARSAT) has revealed Antarctic tributary flow, improved mass balance figures, and is making important contributions in relation to the subglacial hydrology, and melt on ice shelf bottom surface.
- RADARSAT 1 data has also been used to provide the first overview of Canadian high Arctic glacier ice motion. More glaciers are ‘surging’ than previously thought.
- However, InSAR requires reference data, e.g. knowledge that some points in the scene are stationary or have a known velocity.

Satellite radar contribution

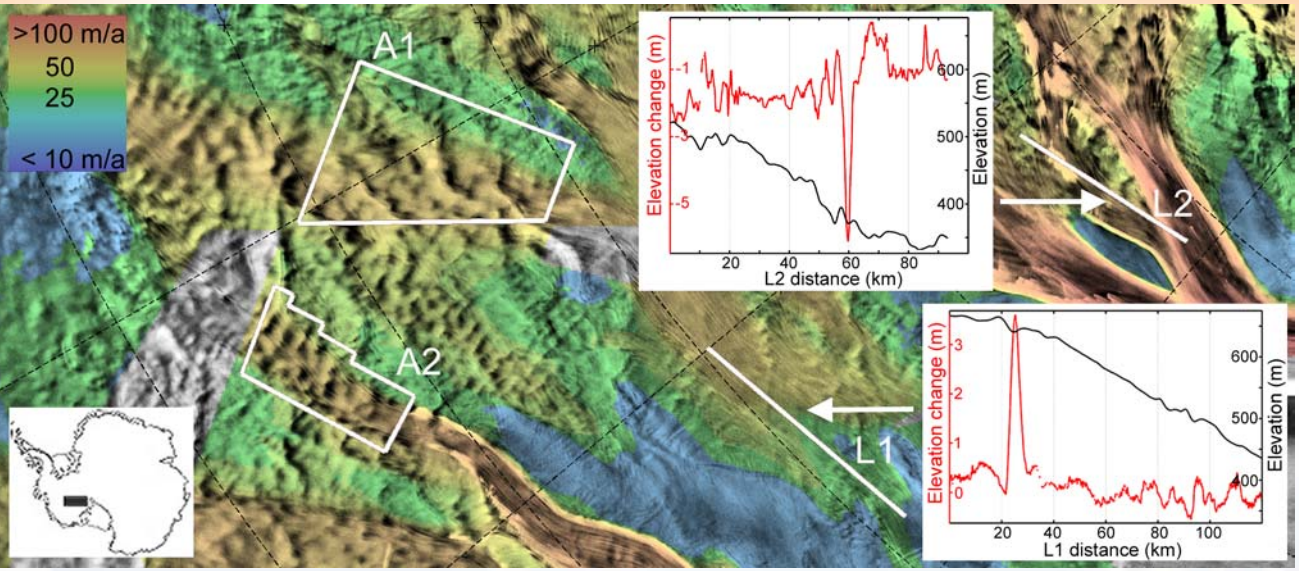
WAIS ice streams: more or less in balance. The Amundsen Sea sector and the Antarctic Peninsula are loosing ice.

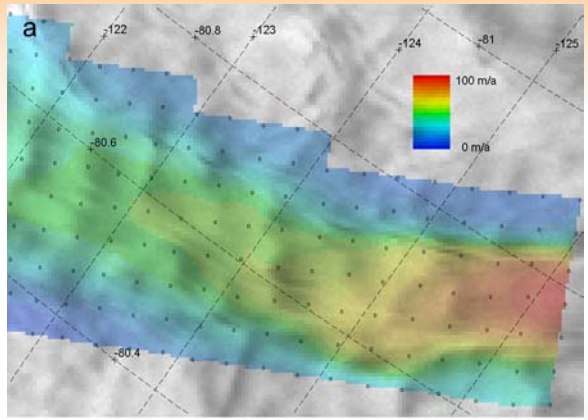
Most of the InSAR work assumes 'surface parallel' flow. We need to be able to measure the vertical component in the presence of large horizontal displacements.

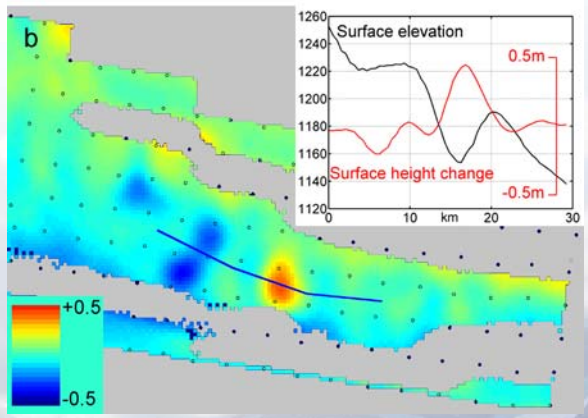




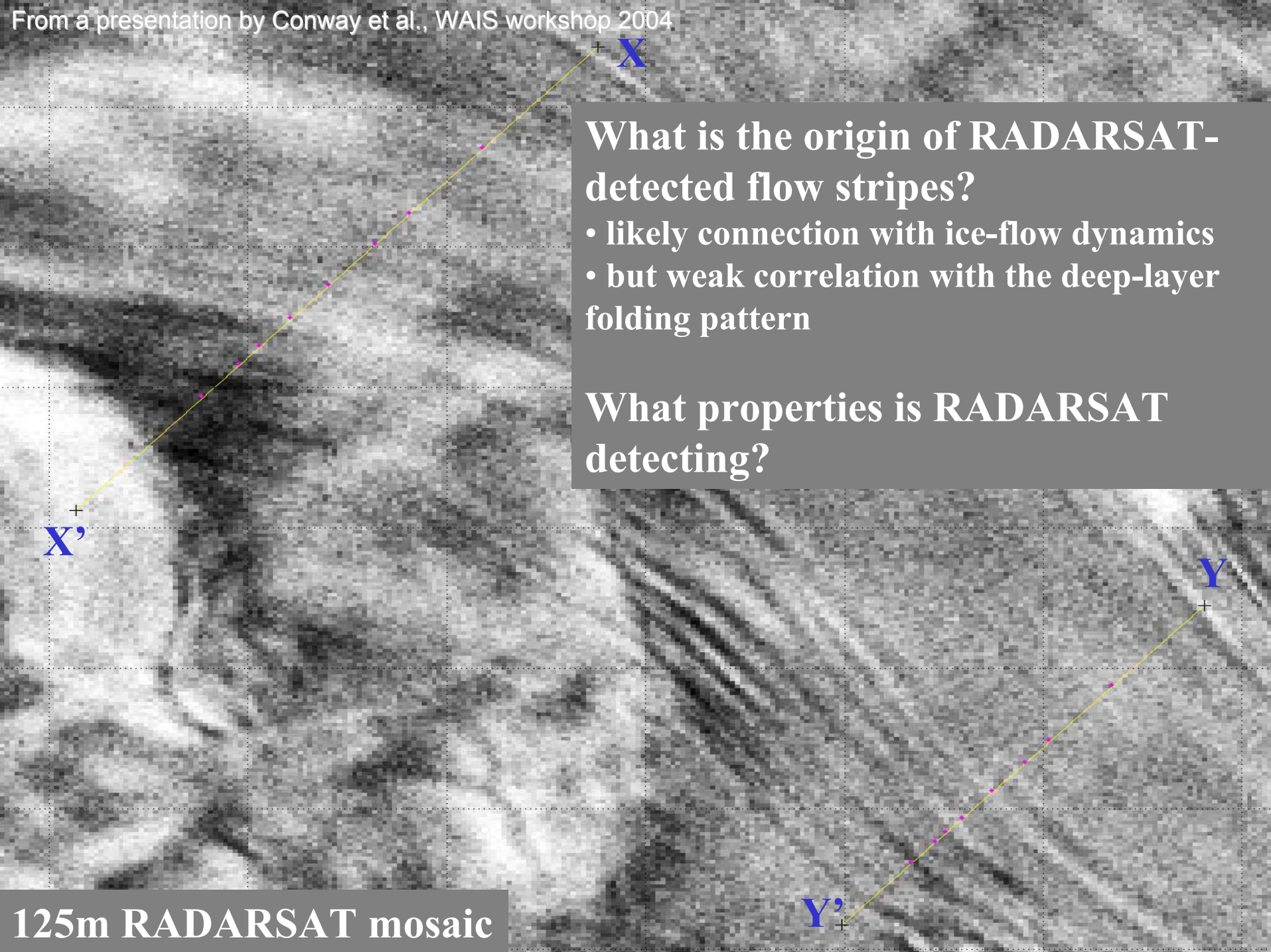
InSAR contributions cont'd



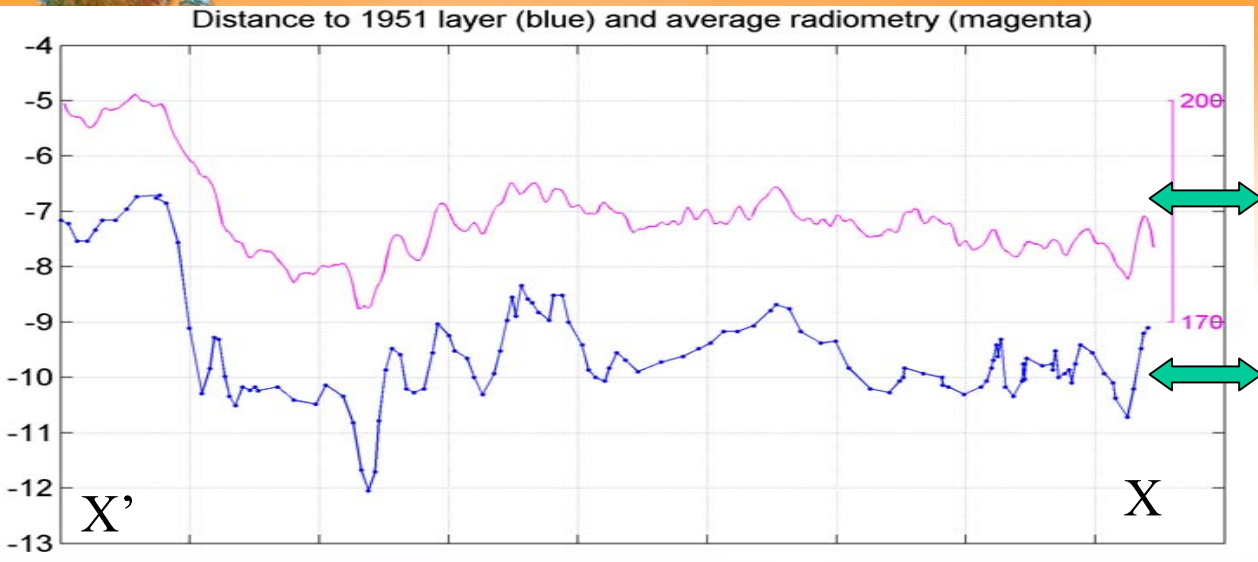




Interferometric techniques have shown unexpected vertical surface displacements (±2 cm/day). These have been linked to non-steady state transport of subglacial water.

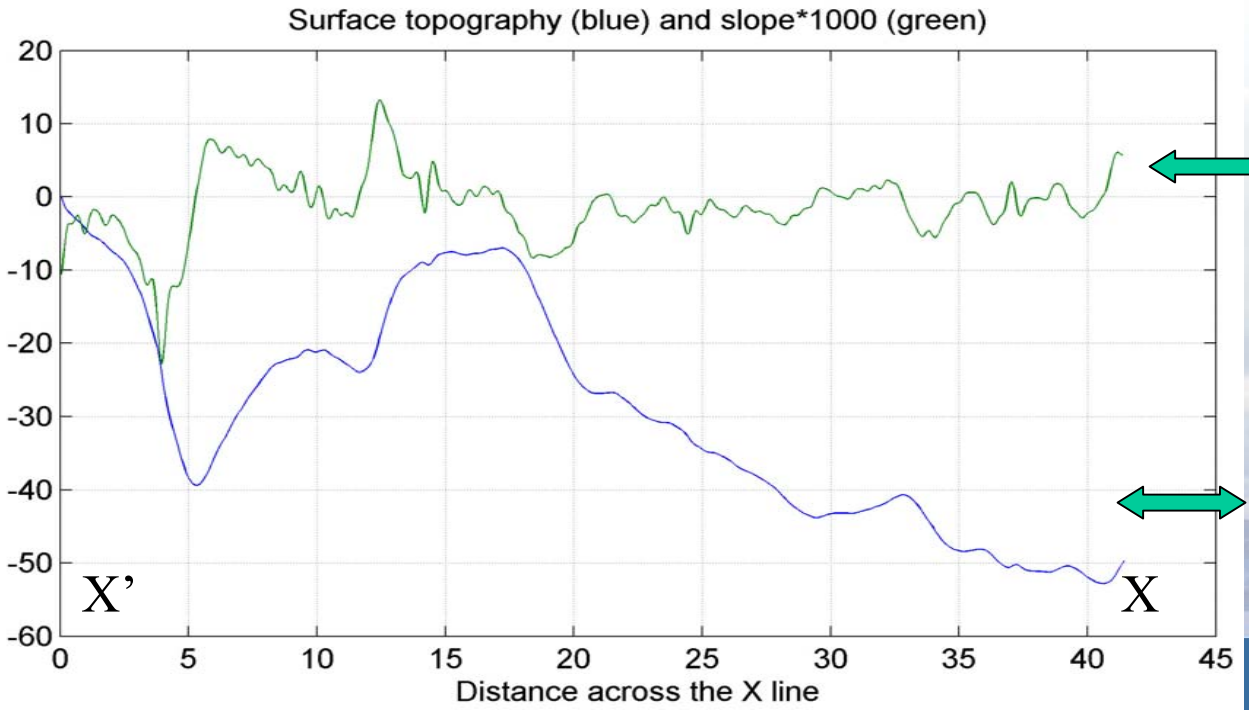

From a presentation by Conway et al., WAIS workshop 2004
X
X'
Y
Y'
What is the origin of RADARSAT-detected flow stripes?
• likely connection with ice-flow dynamics
• but weak correlation with the deep-layer folding pattern
What properties is RADARSAT detecting?
125m RADARSAT mosaic

Also from the presentation by Conway et al., WAIS workshop 2004



processed radiometry from 125m Radarsat mosaic data

near surface internal layer geometry (accumulation since 1951, data courtesy Ben Smith, U Washington).



surface slope

smoothed surface topography from barometric pressure

summary

Needs:

- ice volume and volume change
- ice area and areal change
- snow accumulation
- run-off
- sublimation/evaporation
- surface topography and topographic change
- ice thickness (subglacial topography)
- equilibrium line
- bottom surface melt
- subglacial water and water transport
- AWS met data

- A mixture of surface and remote data will be necessary, e.g. in-situ data essential for accumulation.
- Satellite imagers (e.g ASTER, SAR, etc.) and InSAR are significant contributors. A systematic approach to InSAR data collection is essential.
- Satellite and airborne profilers (laser and radar) are providing useful change data