

Quantifying surface melt in western Greenland from zigzag patterns in exposed stratigraphy.

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Acknowledgements: Chris Small for Landsat calibration, Ian Howat RISCO image compilation and GIMP DEM. Operation IceBridge and CreSiS shallow ice radar products.

Mass balance measurements

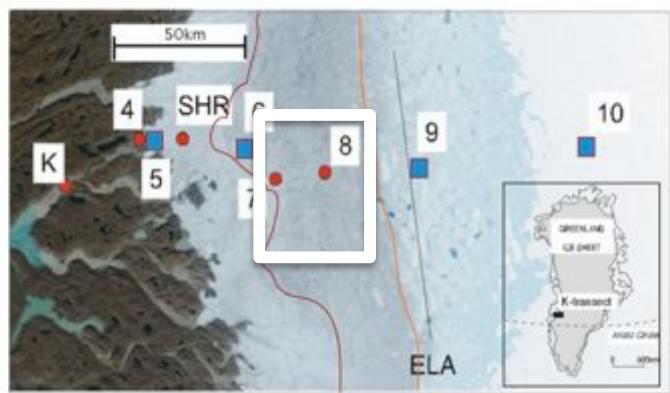


Fig. 1. The K-transect in West Greenland. The sites 4, 5, SHR, 6, 7, 8, 9 and 10 are mass balance sites. The blue squares indicate the position of the IMAU weather stations. The equilibrium line altitude is located close to site 9. The two coloured lines indicate the dark zone where albedo is lower than in the surrounding areas (Wientjes and Oerlemans, 2010; Wientjes et al., 2011).



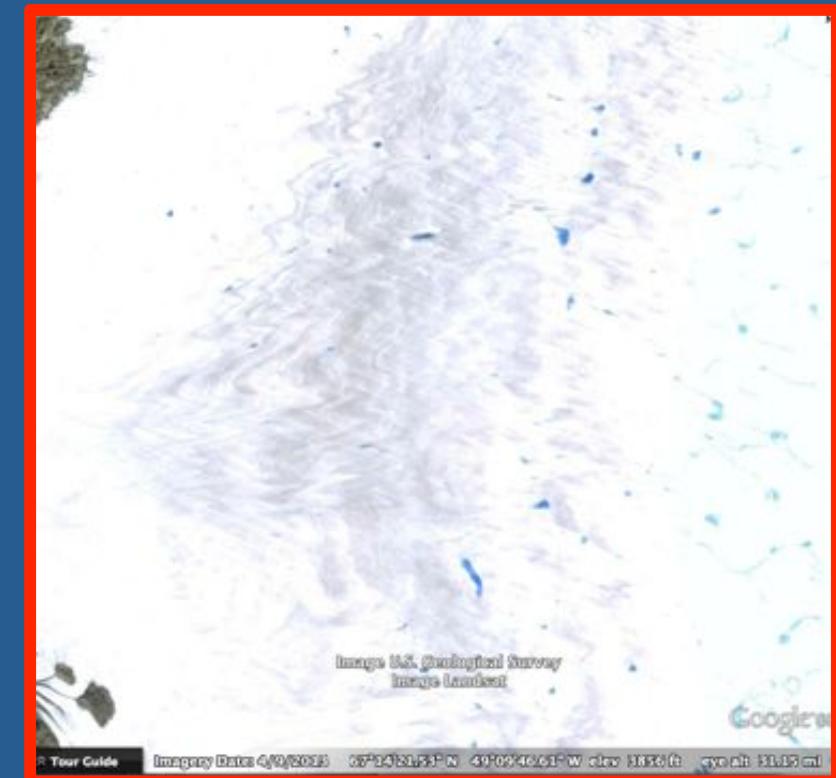
Exposed strata



300 km



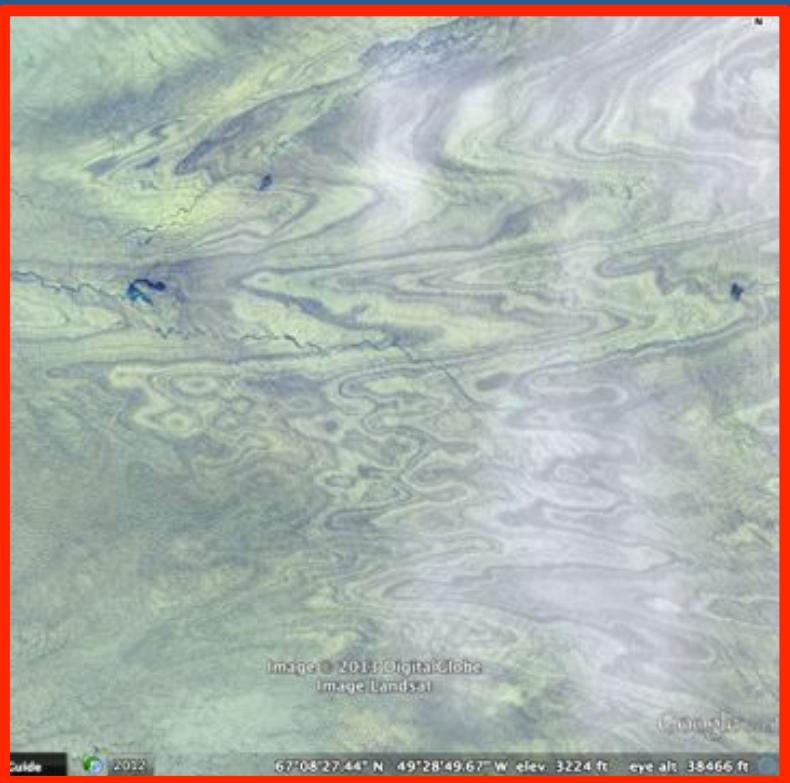
Exposed strata



50 km



Exposed strata



10 km



Exposed strata

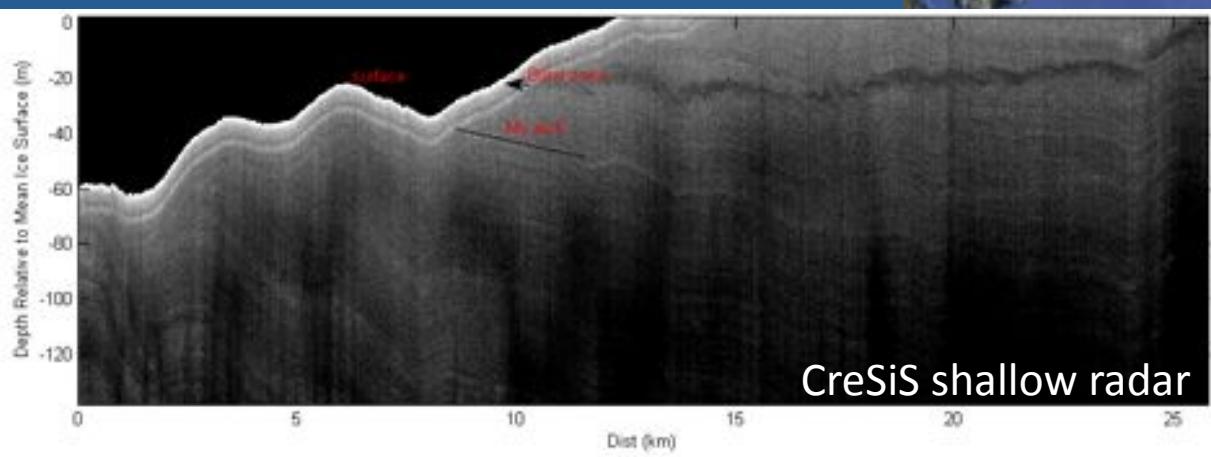


Image EBCO®
Image Lombok
NOAA, U.S. Navy, NGA, GEBCO
U.S. Geological Survey
6°49.35' N 46°31'22.40" W elev 7278 ft eye z

Rule of Vs

- Dipping strata on an incised surface produce V-shaped outcrops



<http://www.marlimillerphoto.com/Vblocks.html>

Rule of Vs

- Dipping strata on an incised surface produce V-shaped outcrops

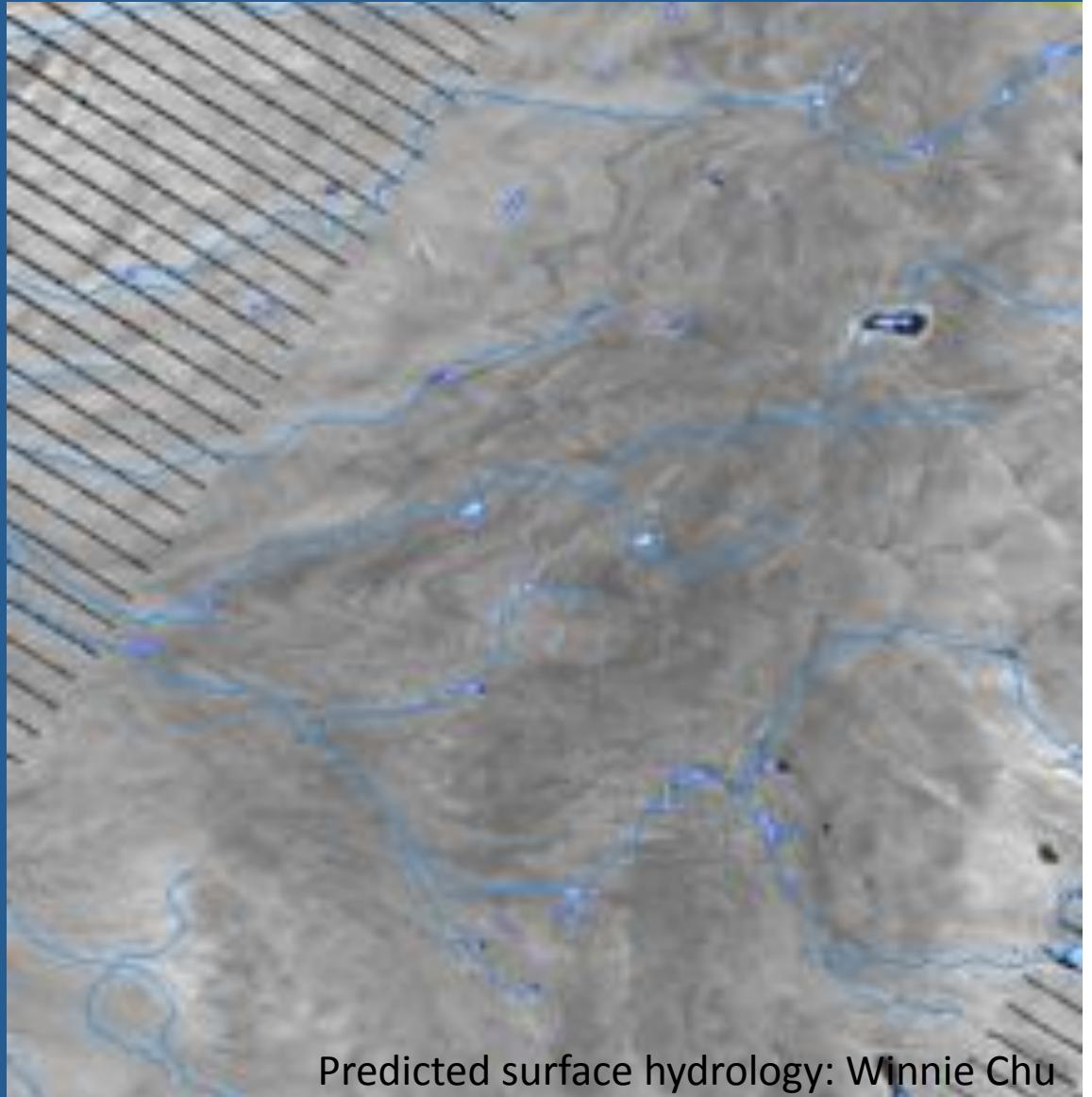
All photos © Arts Observer



Detail of "Cinderella Table," 2005 (CNC-cut birch plywood, 57 layers) by Jeroen Verhoeven of the Netherlands.

Rule of Vs

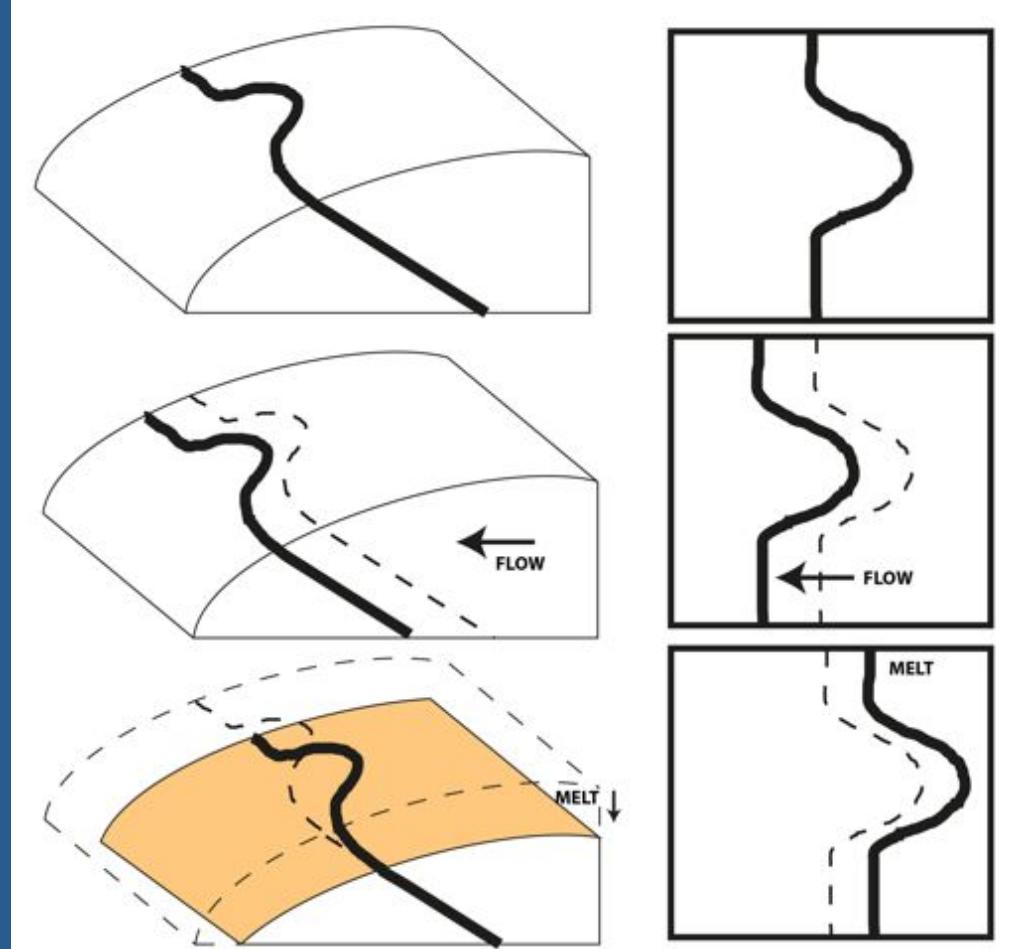
- Dipping strata on an incised surface produce V-shaped outcrops
- Undulating strata produce more complicated Vs



Predicted surface hydrology: Winnie Chu

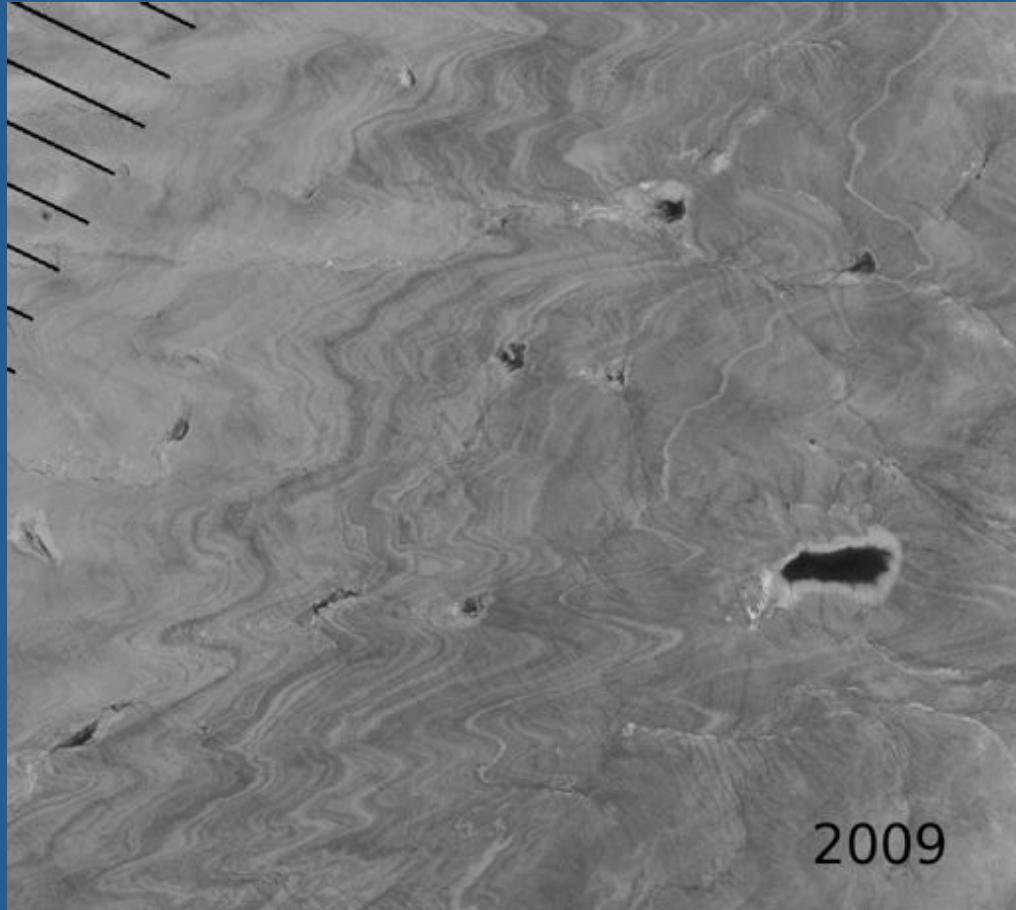
Rule of Vs

- Dipping strata on an incised surface produce V-shaped outcrops
- Undulating strata produce more complicated Vs
- Ice flow moves Vs towards the coast
- Surface melt moves Vs down dip

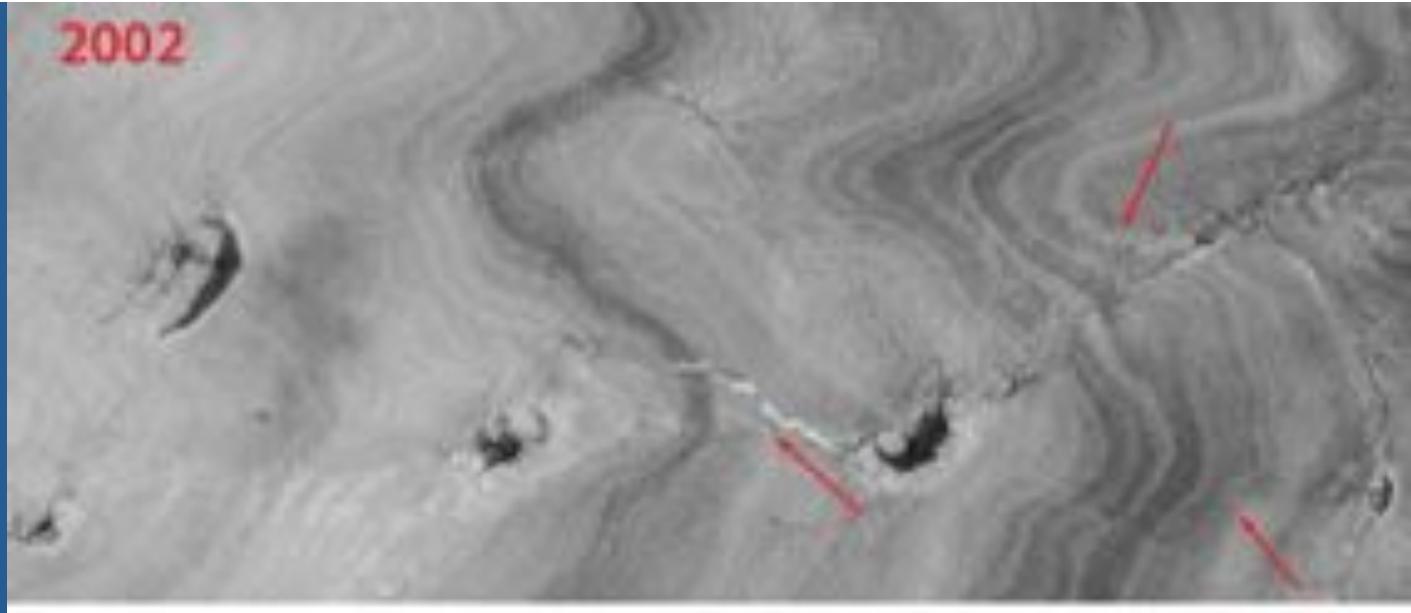


Rule of Vs

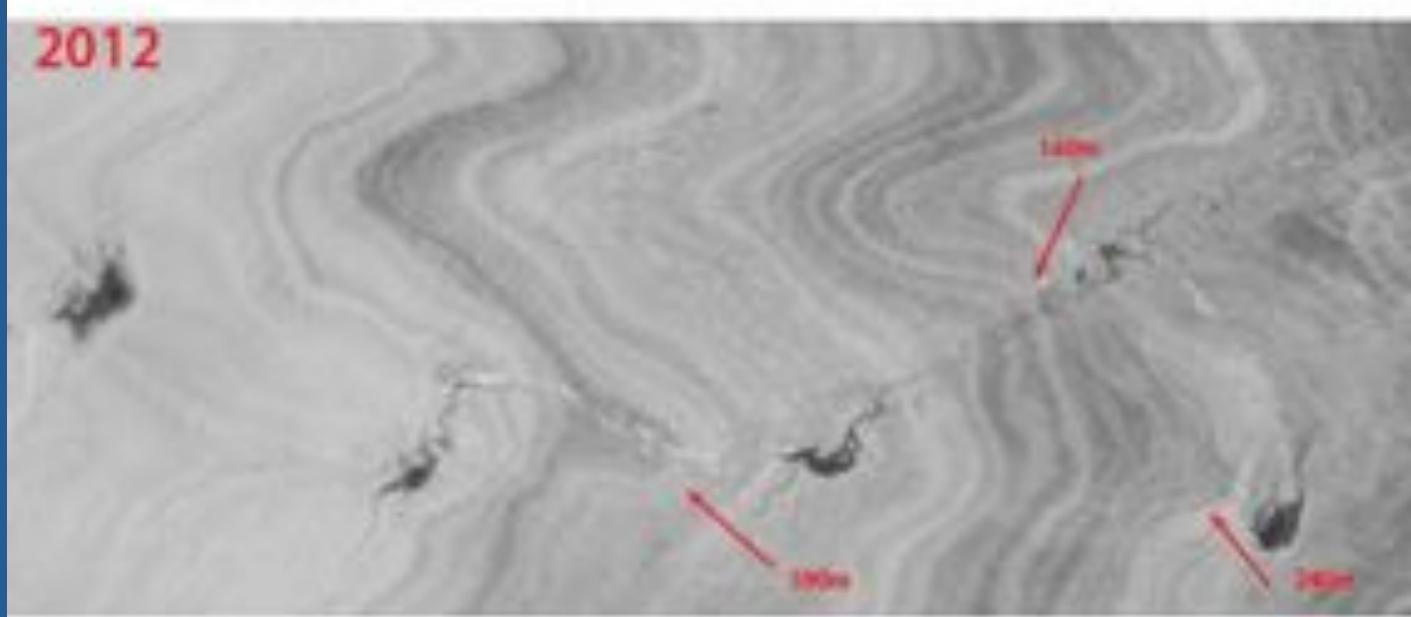
- Dipping strata on an incised surface produce V-shaped outcrops
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2002



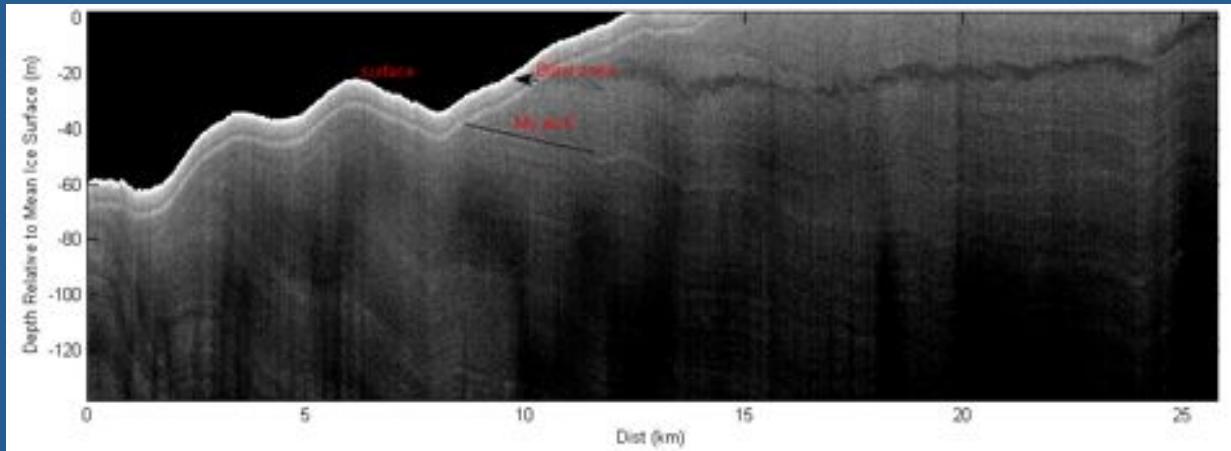
2012



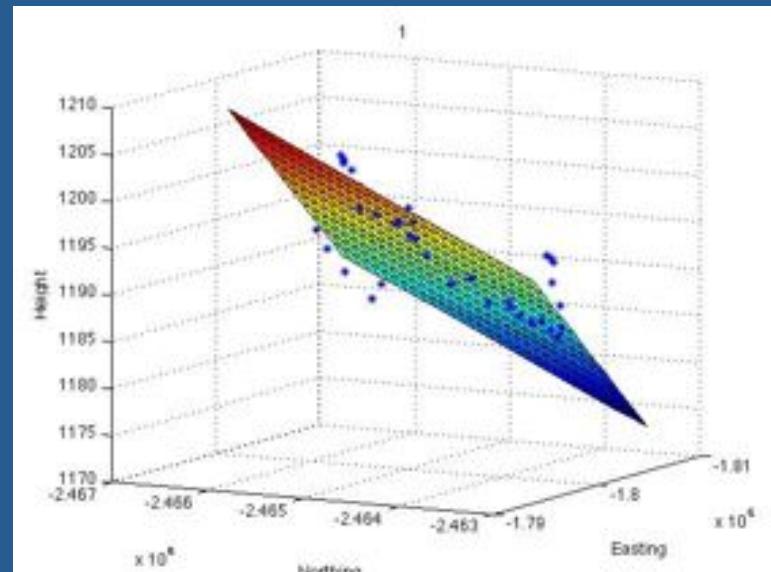
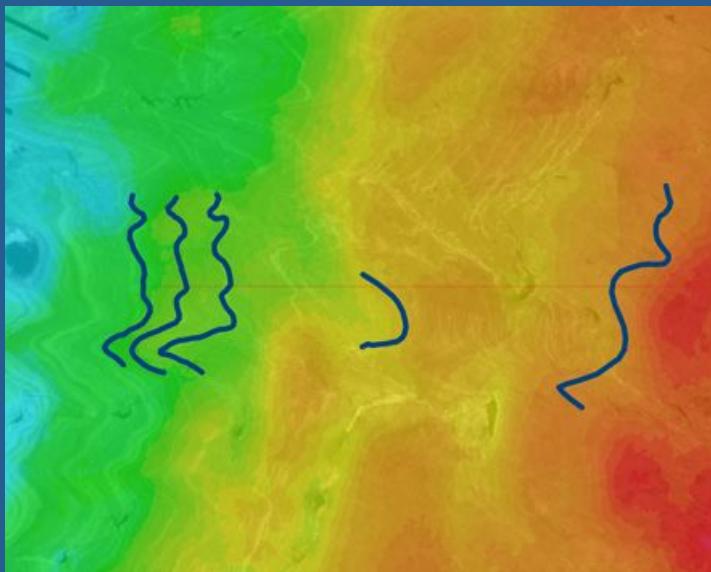
Inland Migration of Layers Along Meltwater
Channel and Downstream of Lake

Dip estimates $\sim 1^\circ$

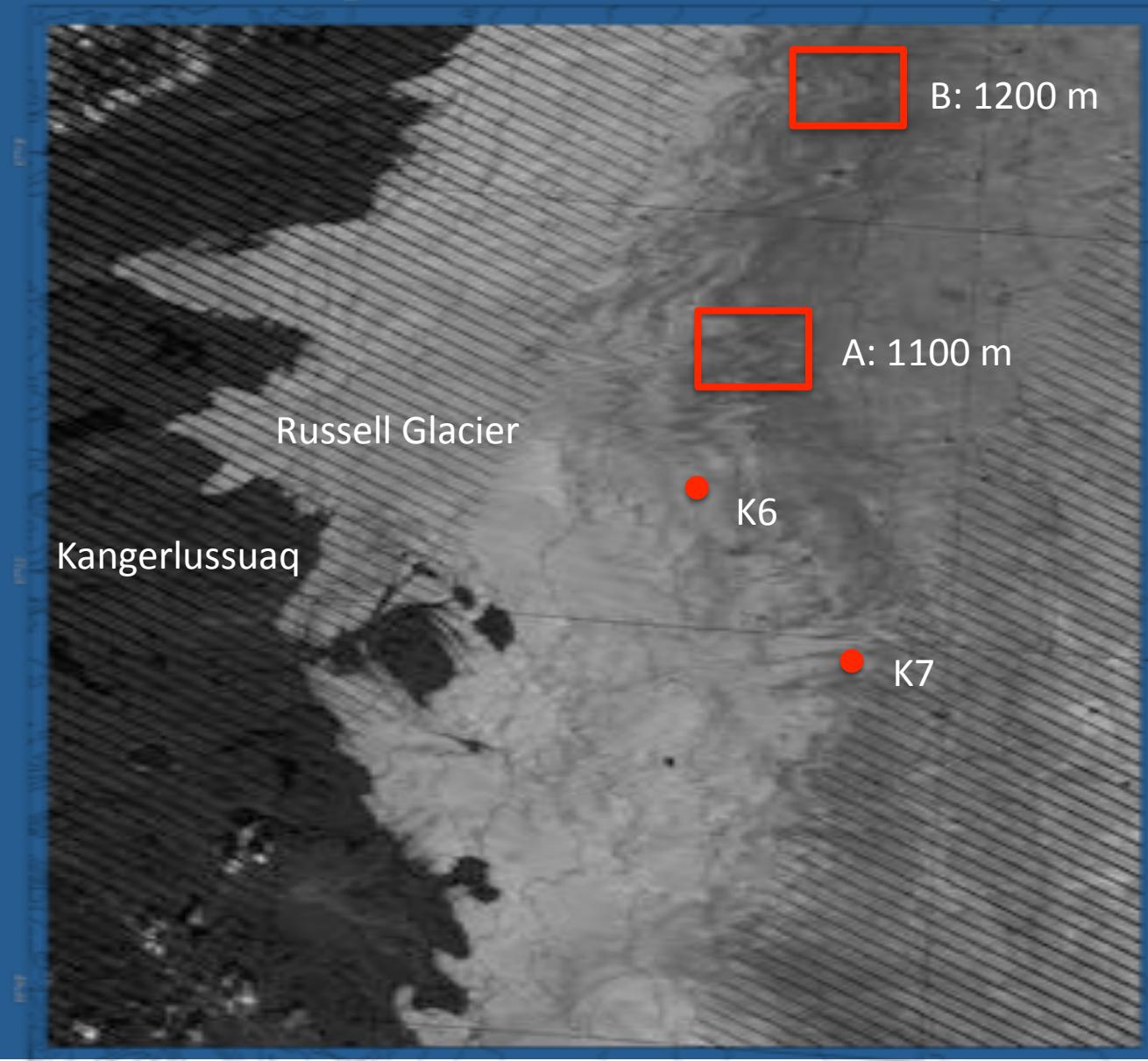
Radar profile



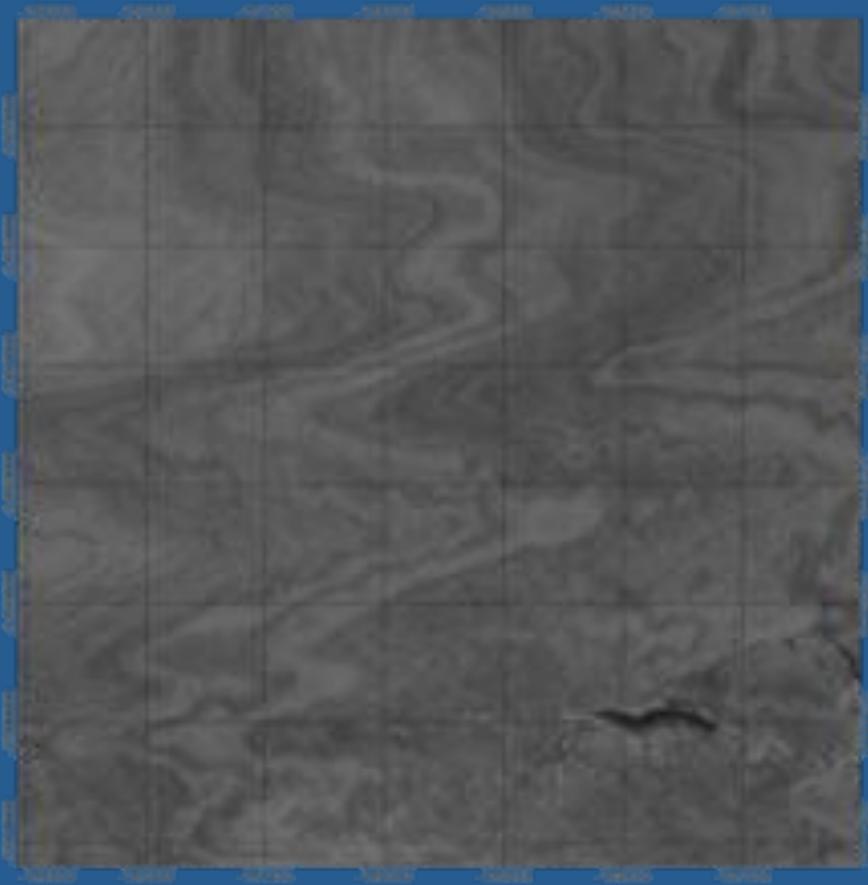
Structure contours/best fit a plane



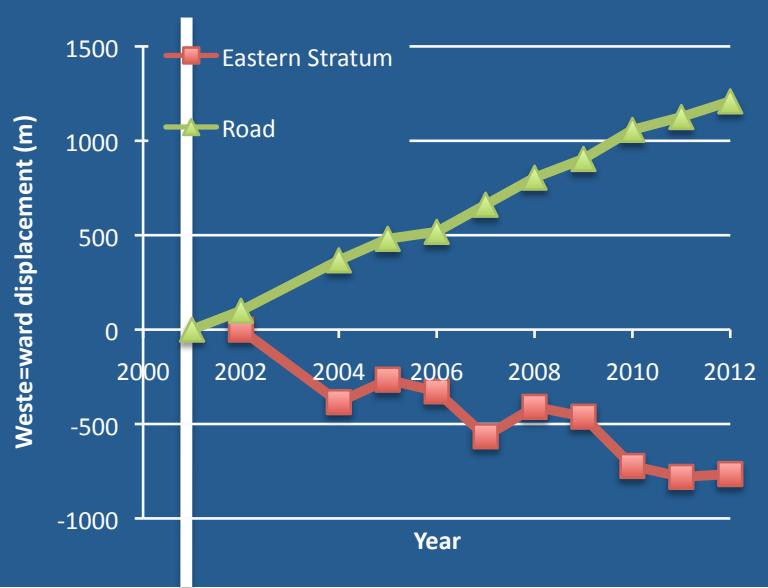
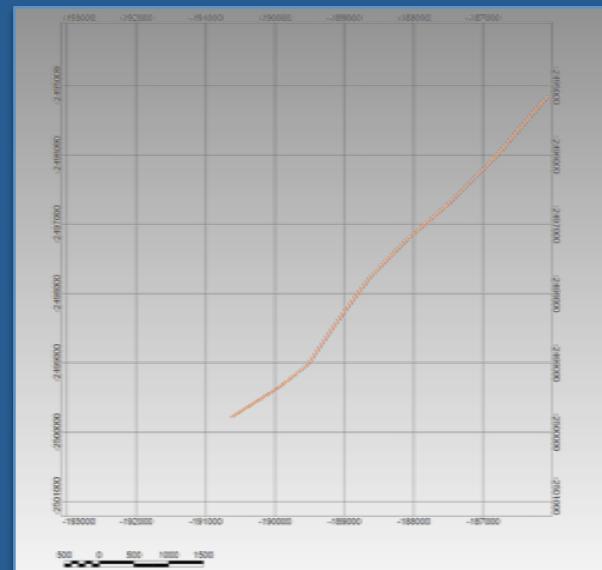
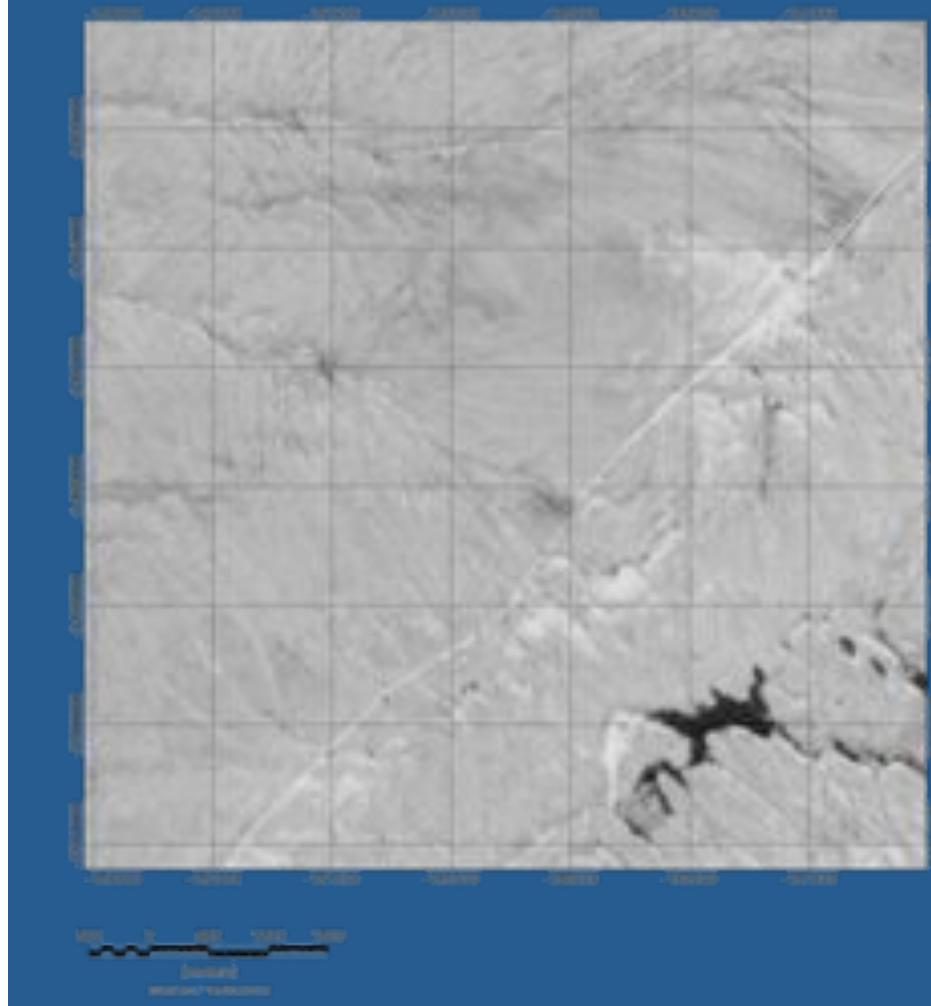
Location



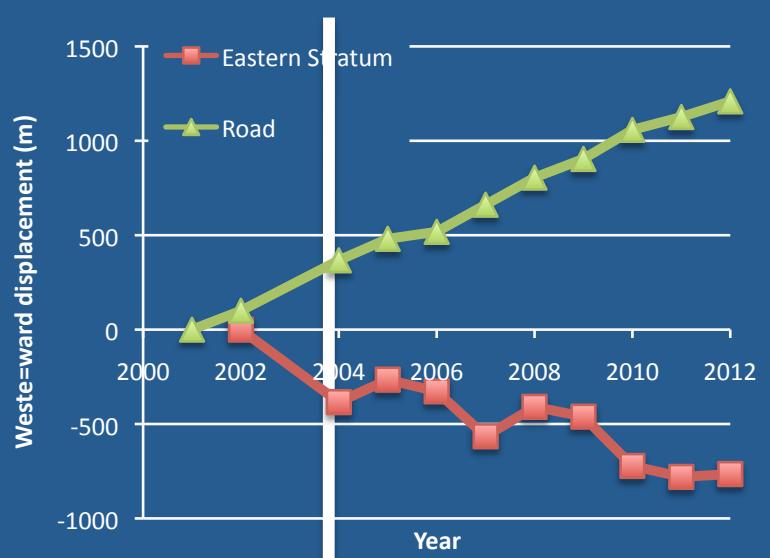
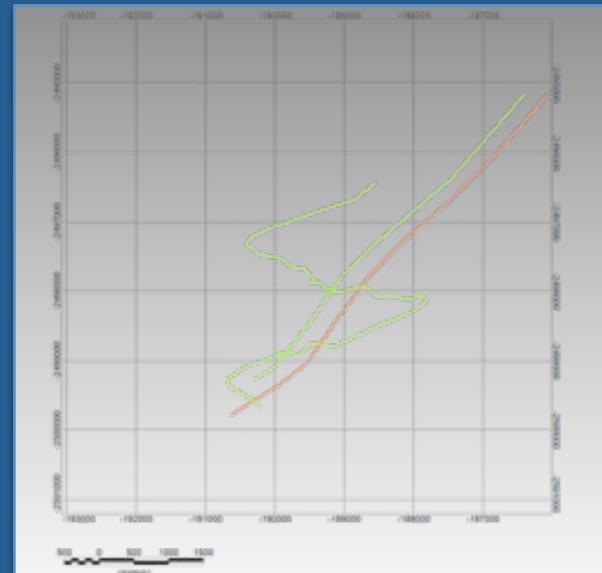
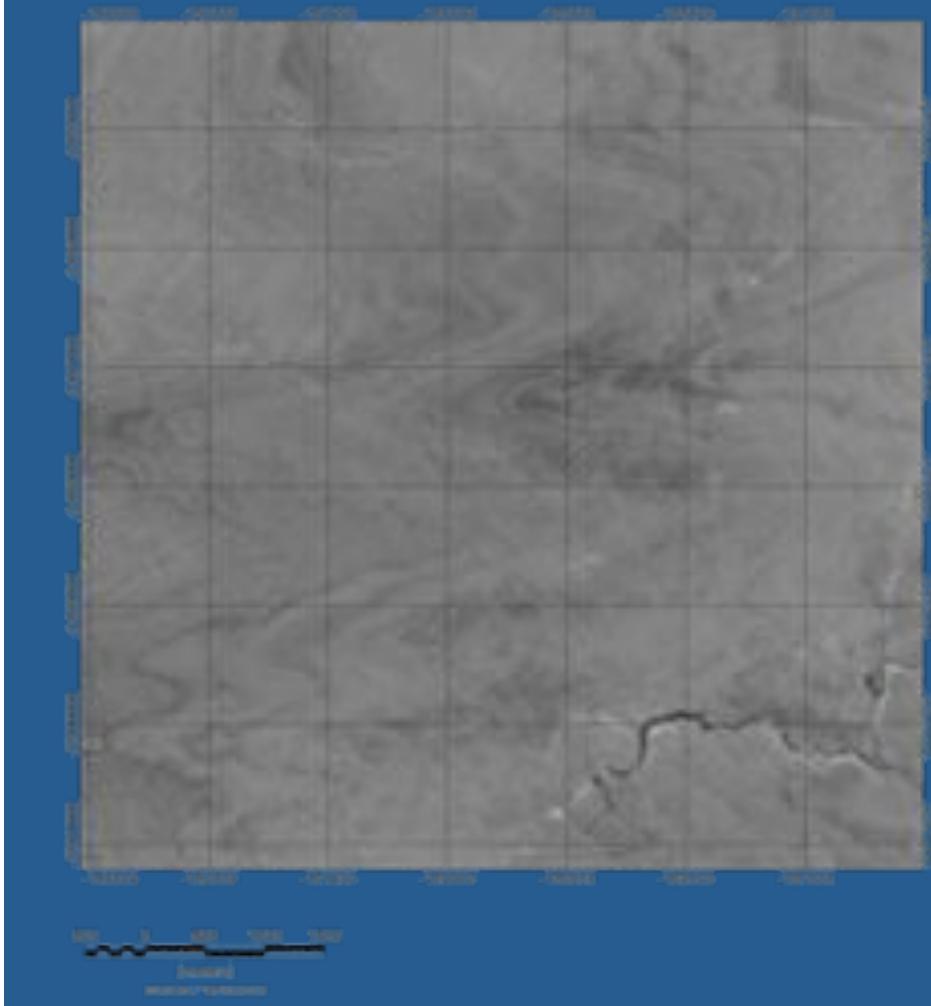
2000



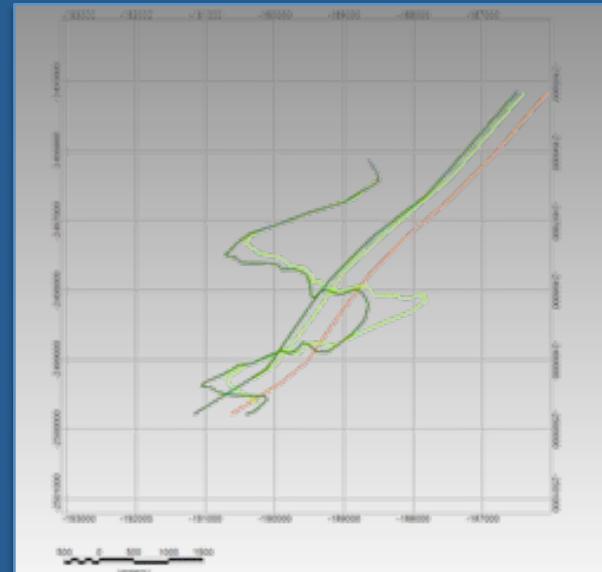
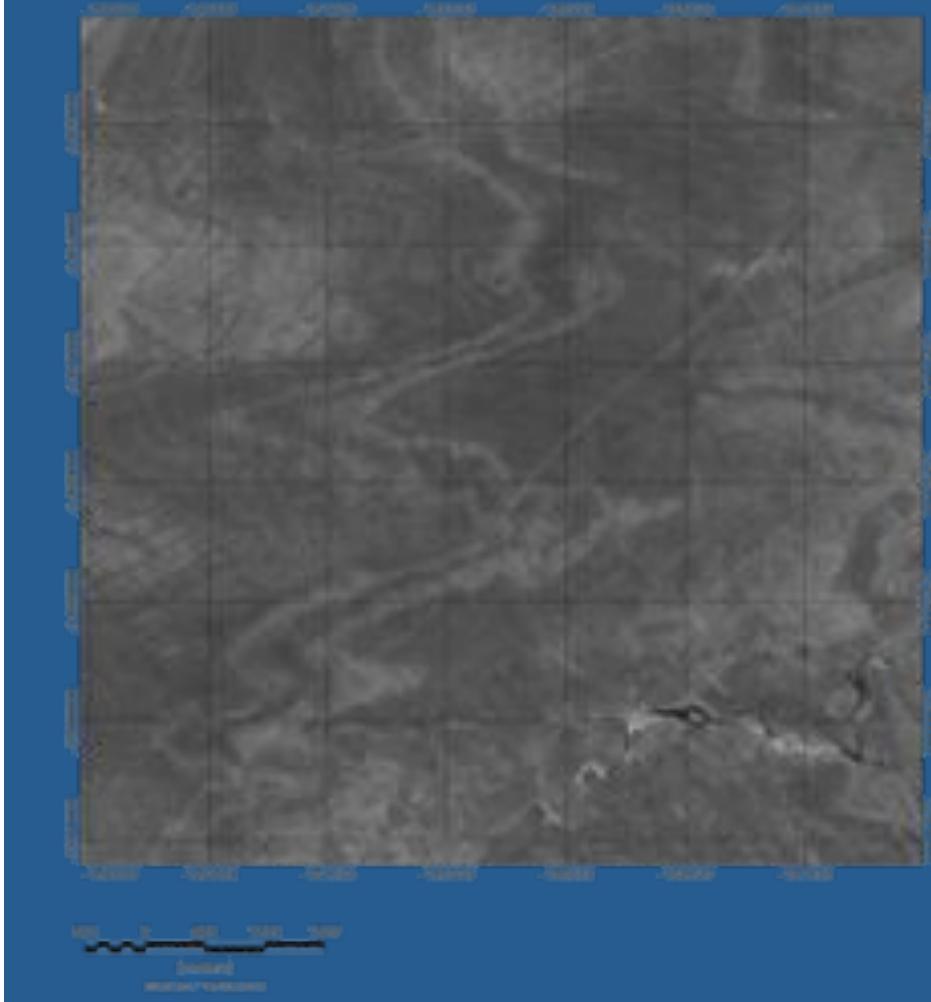
2001



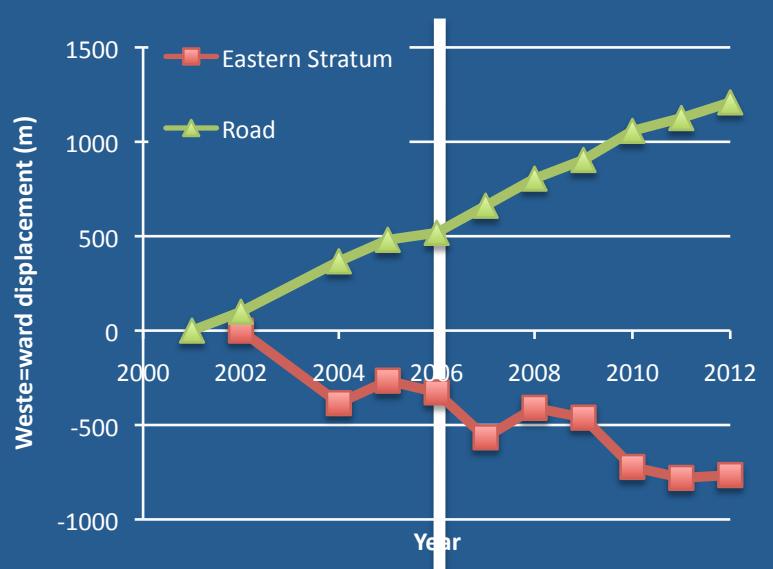
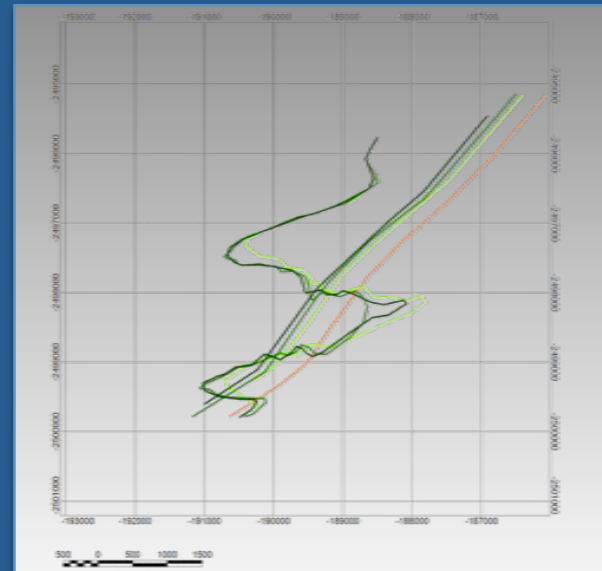
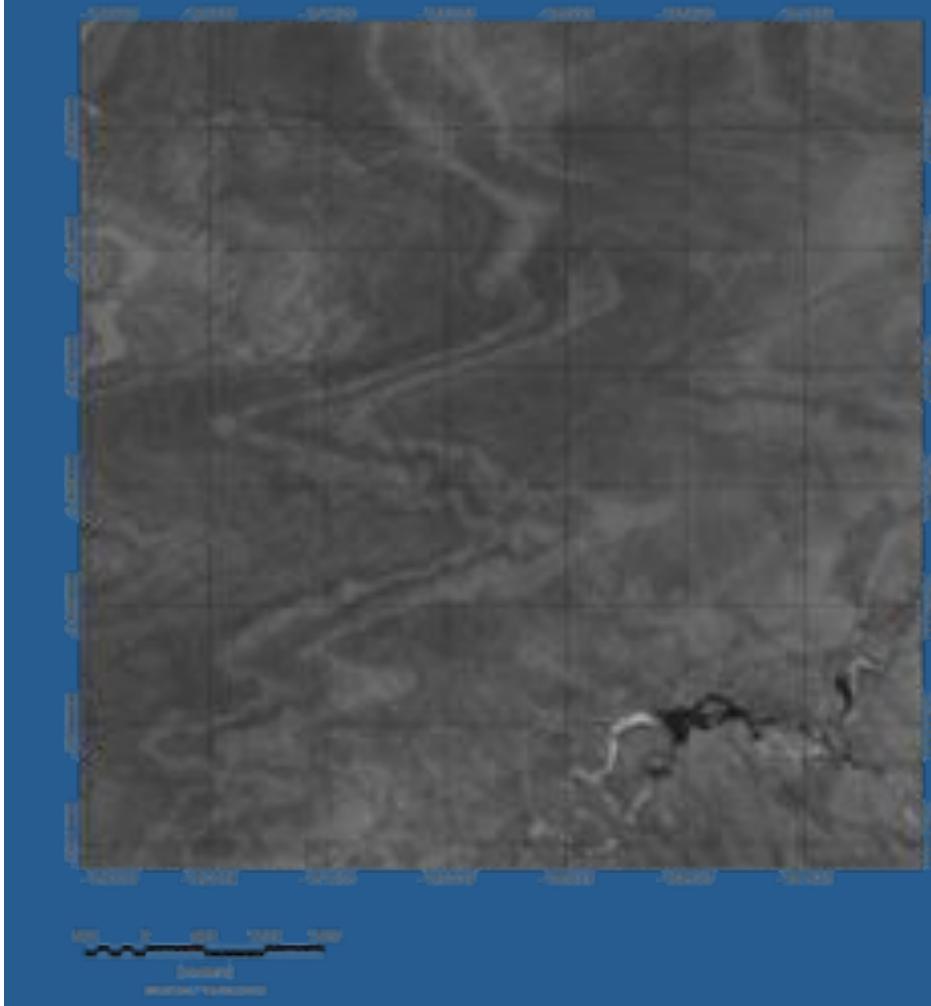
2004



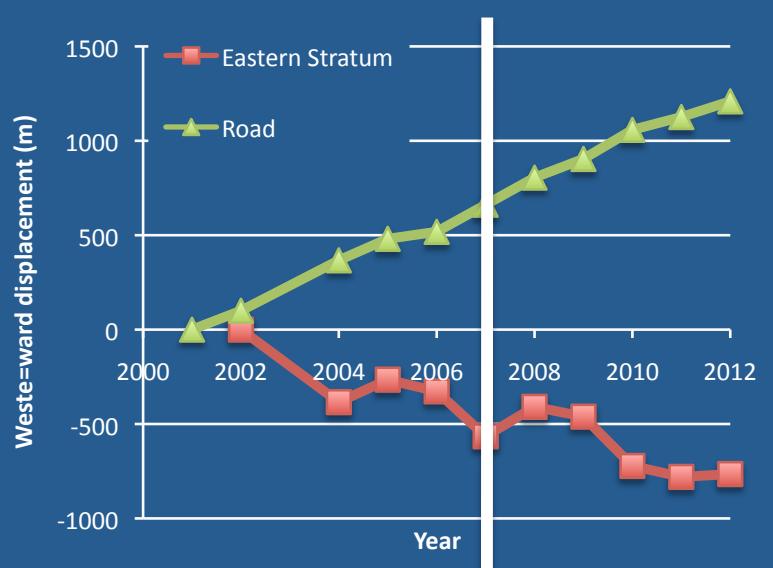
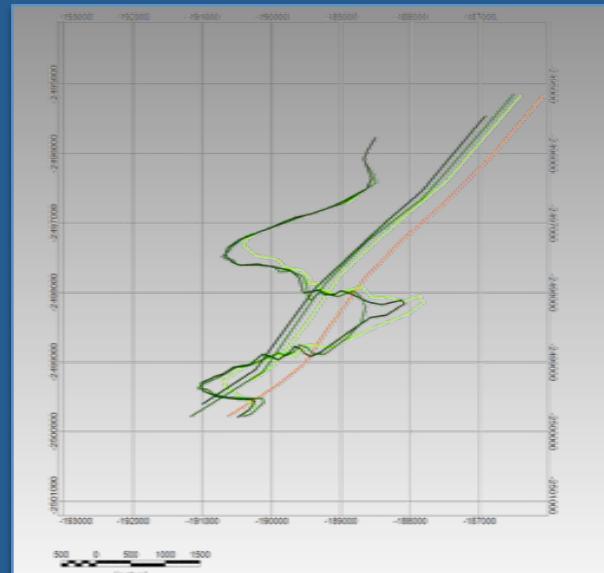
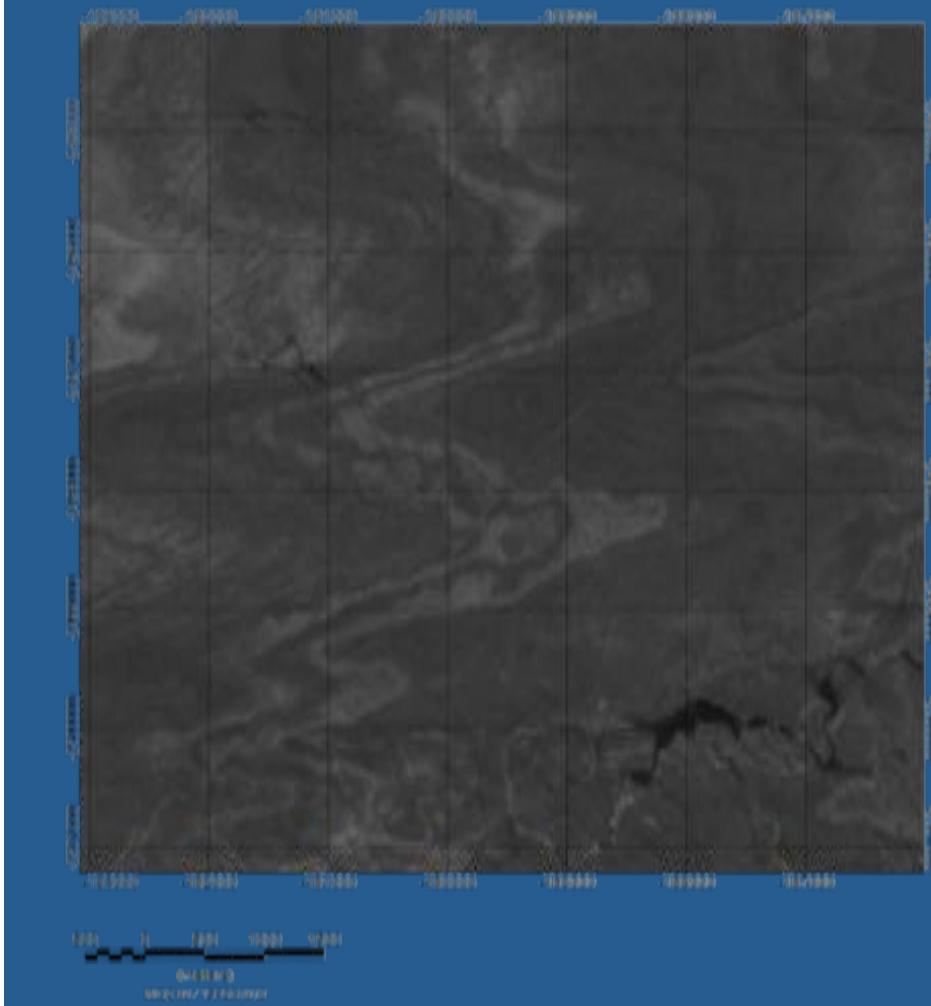
2005



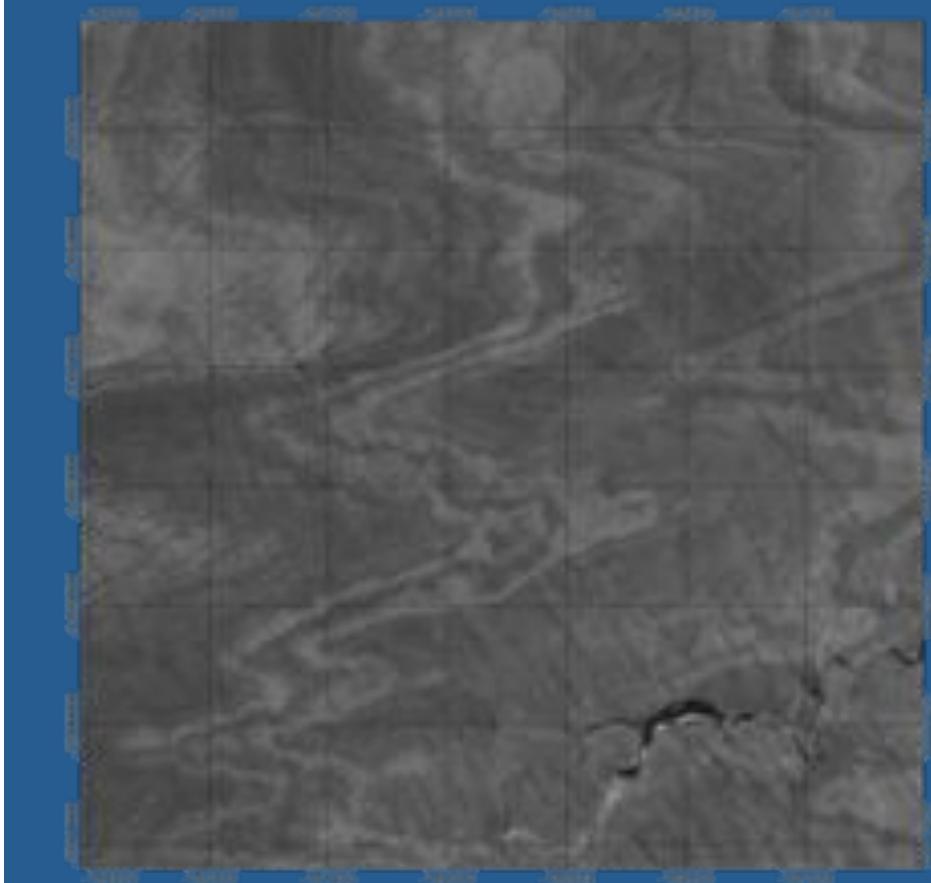
2006



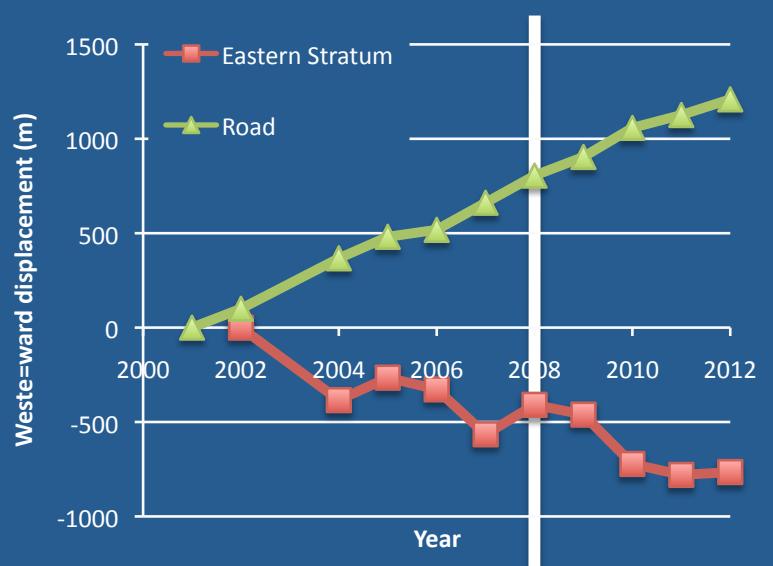
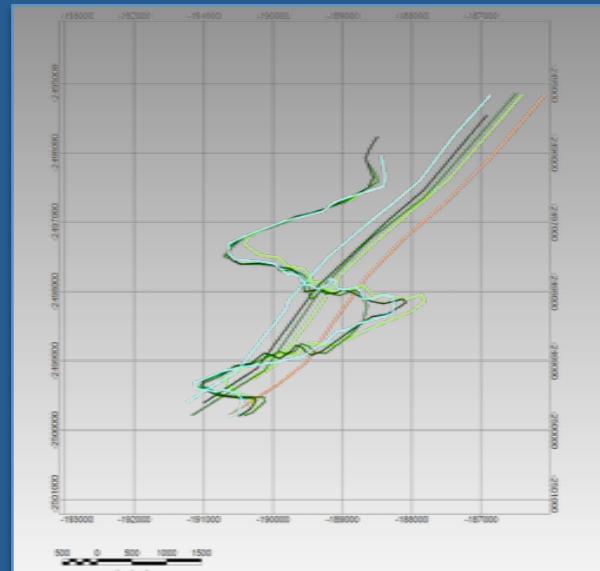
2007



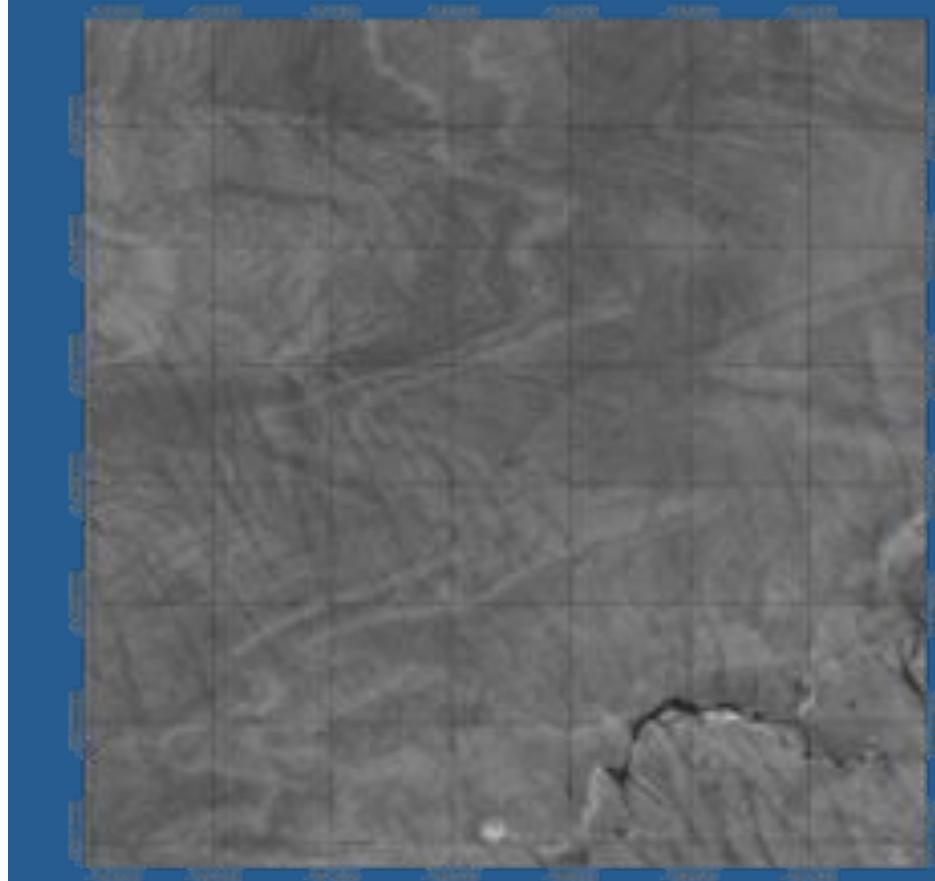
2008



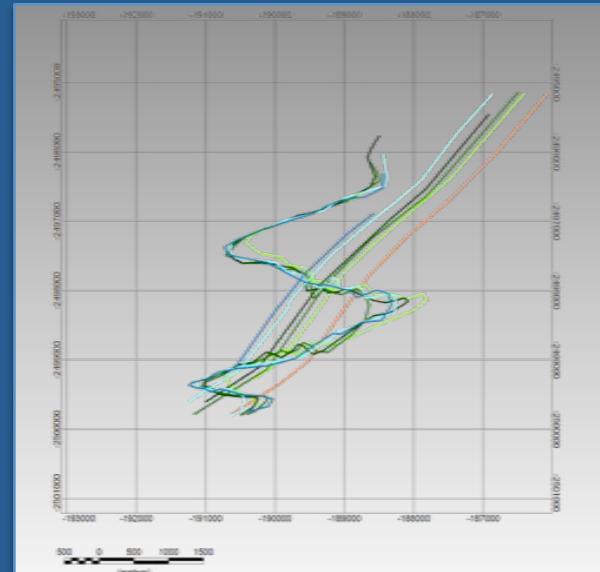
W.E. = Westward
E.E. = Eastward



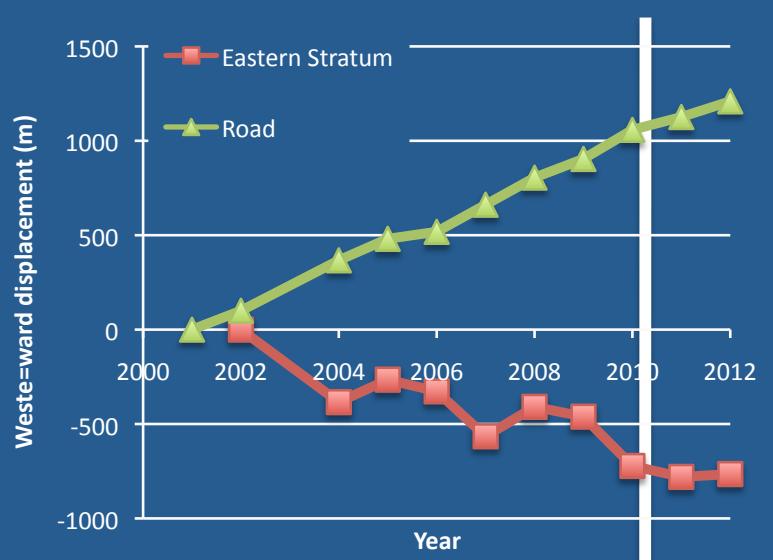
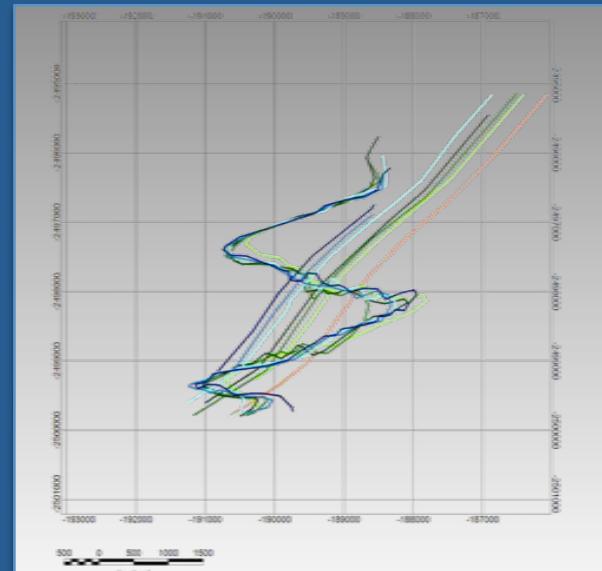
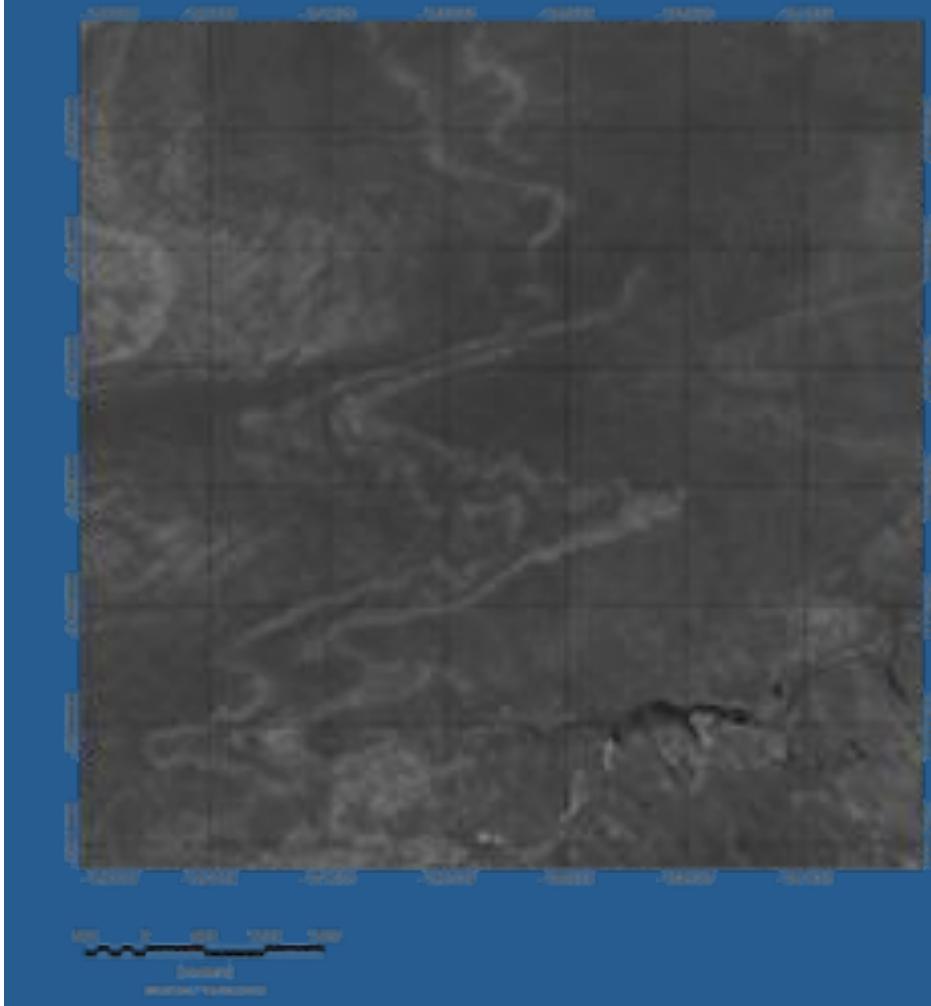
2009



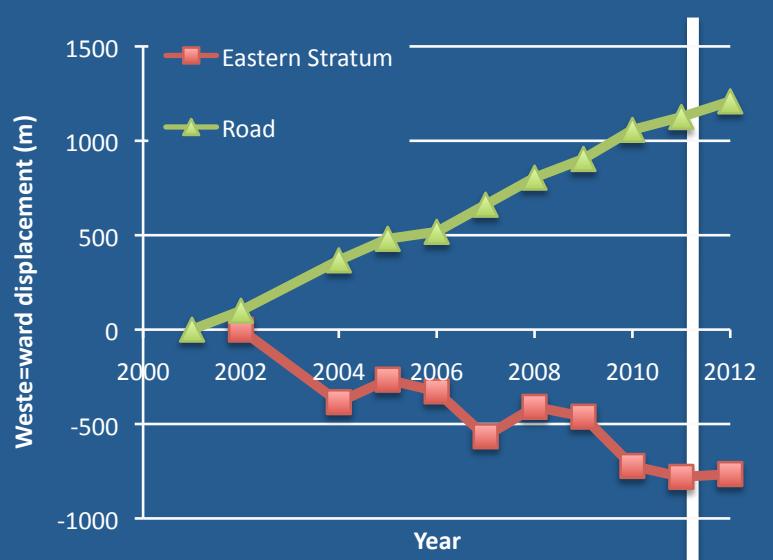
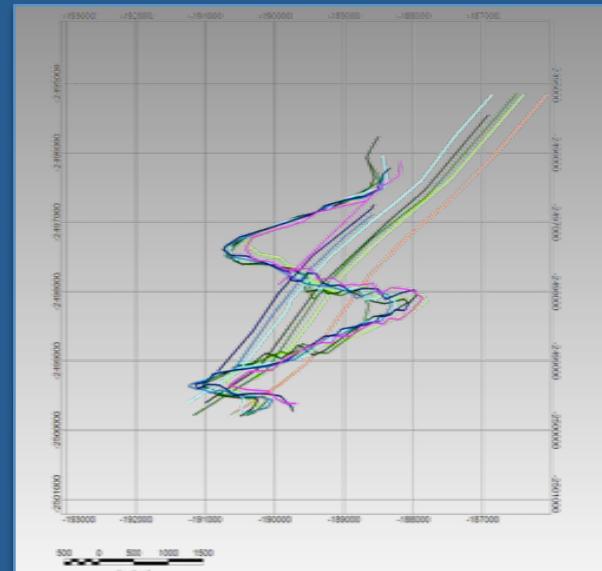
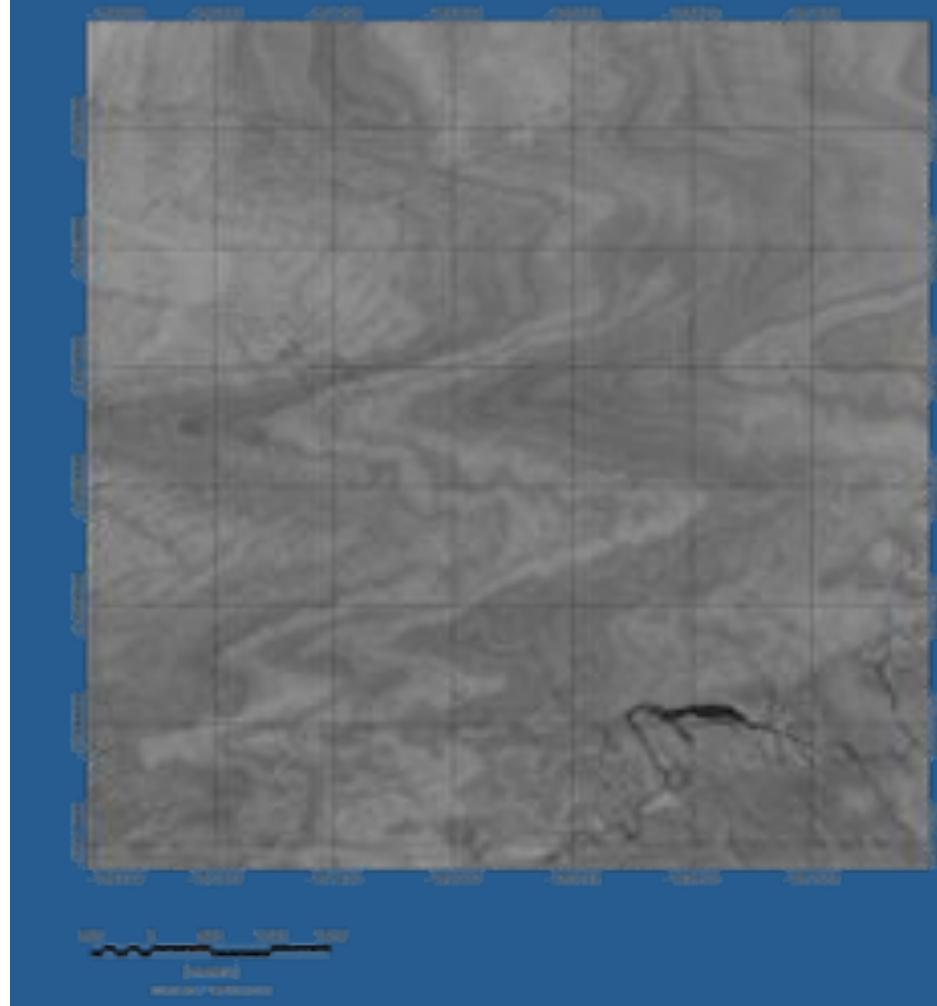
0 500 1000 1500
Easting
Metres



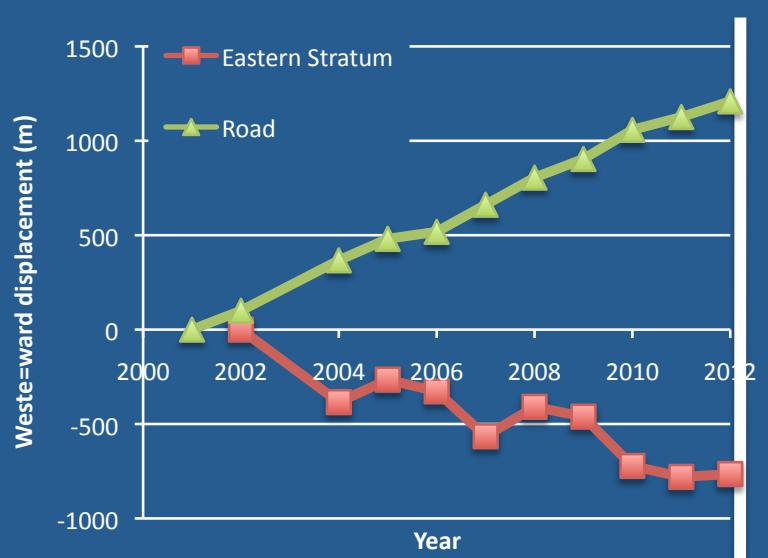
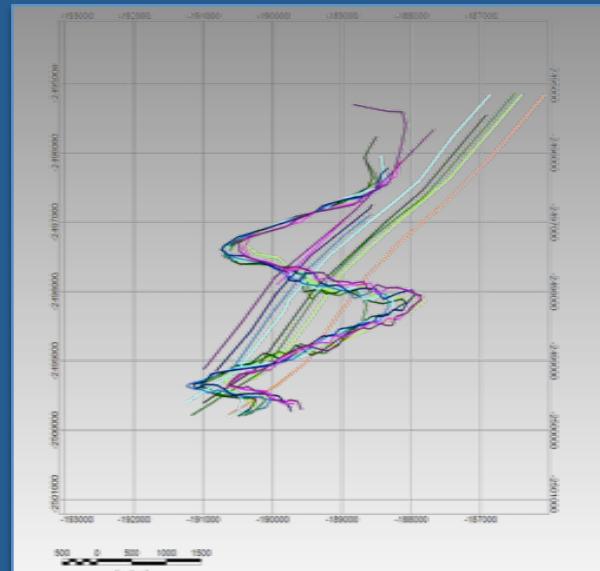
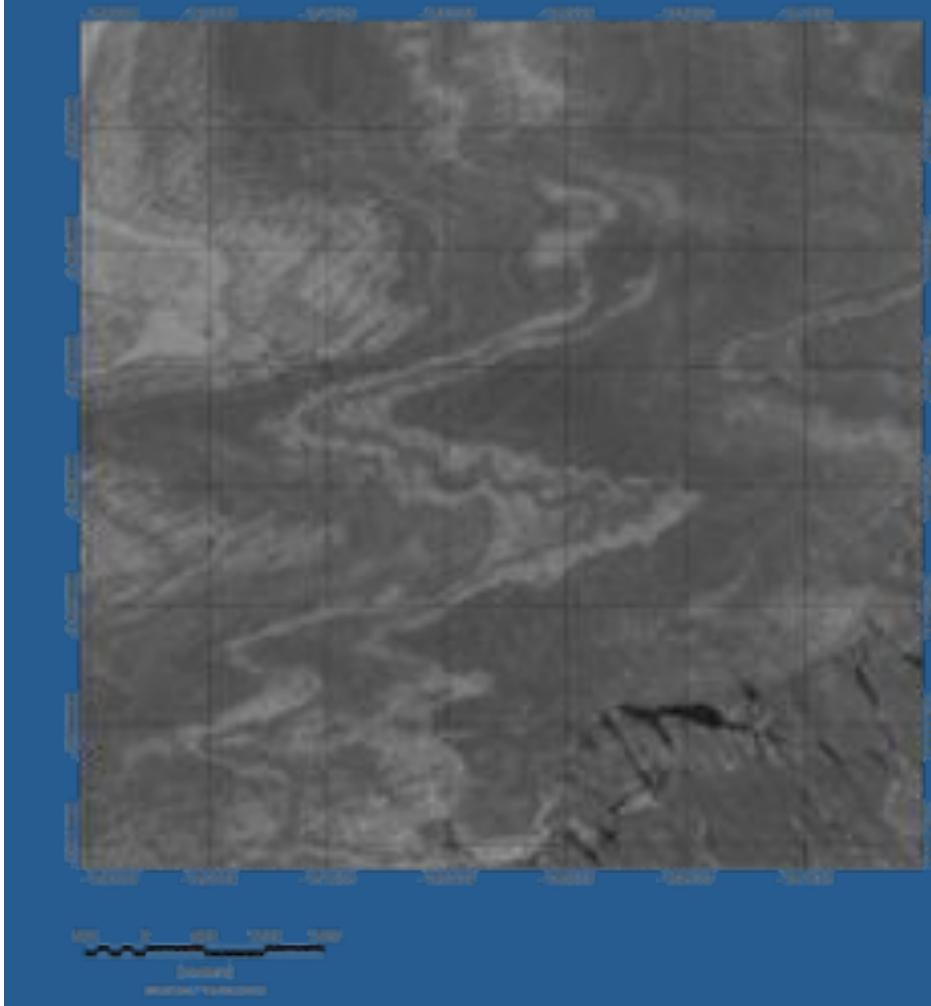
2010



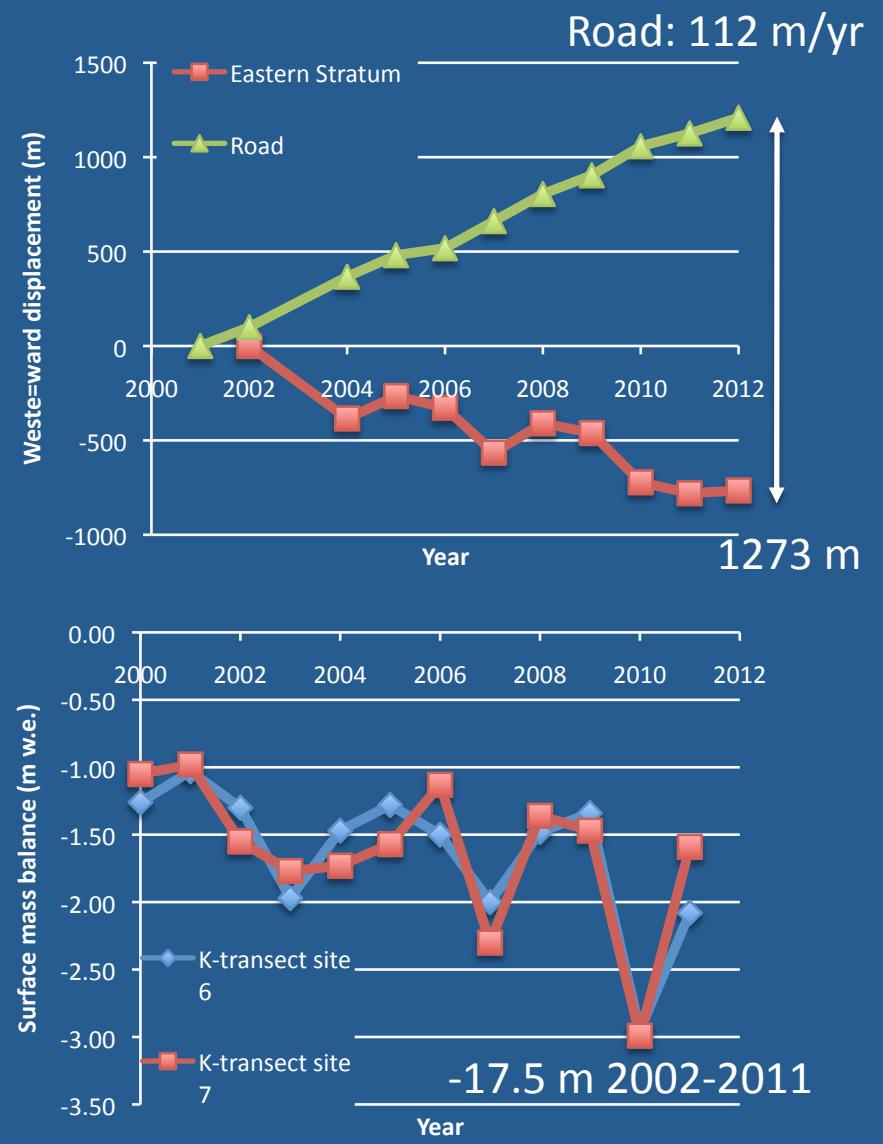
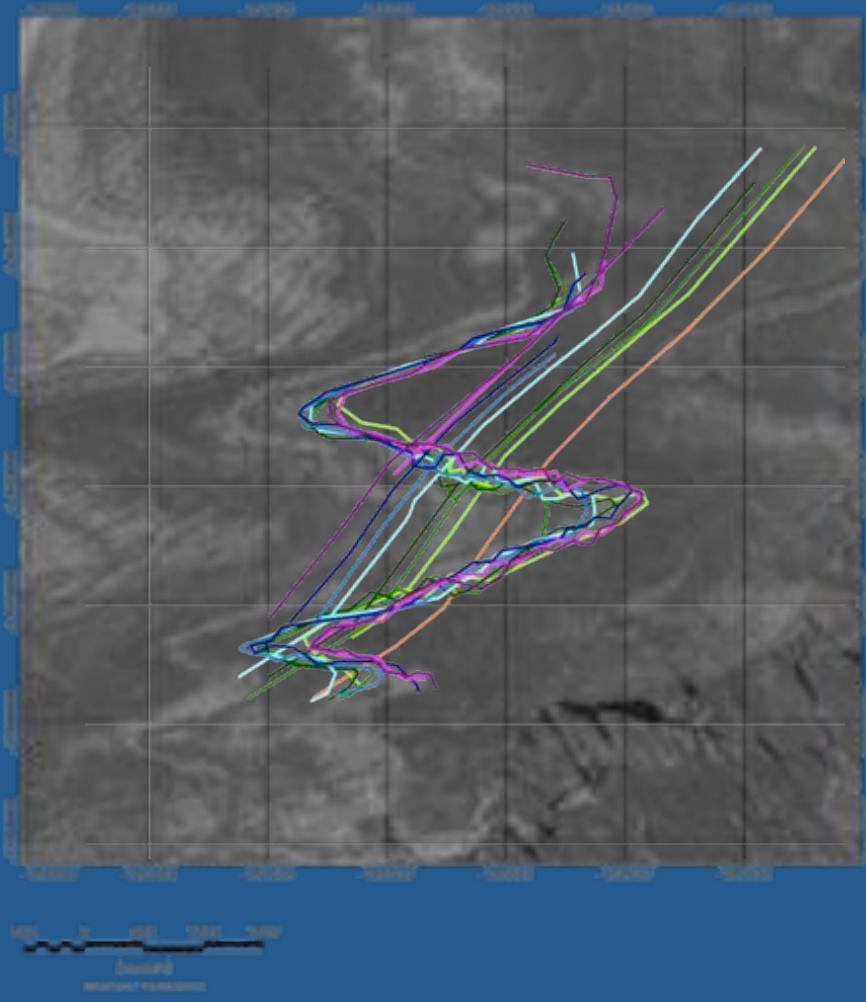
2011



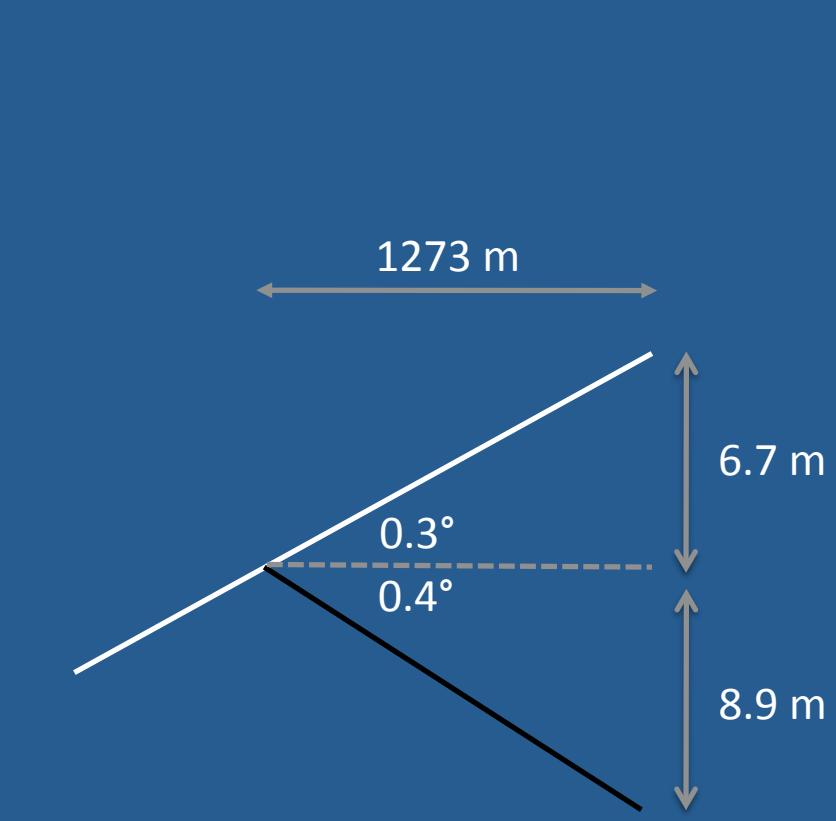
2012



Rivers and Roads

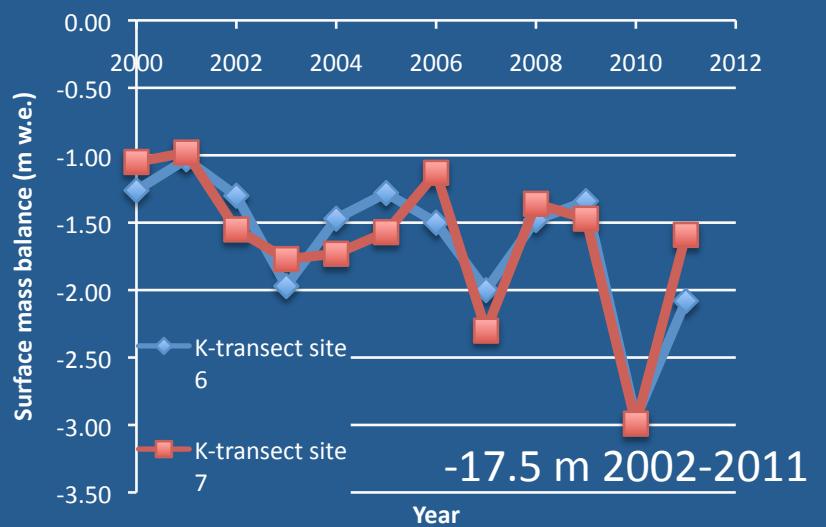
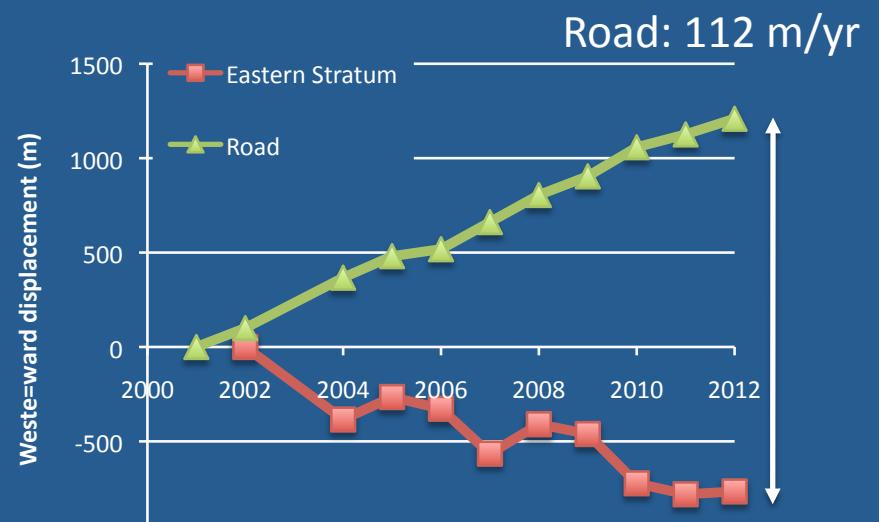


Rivers and Roads

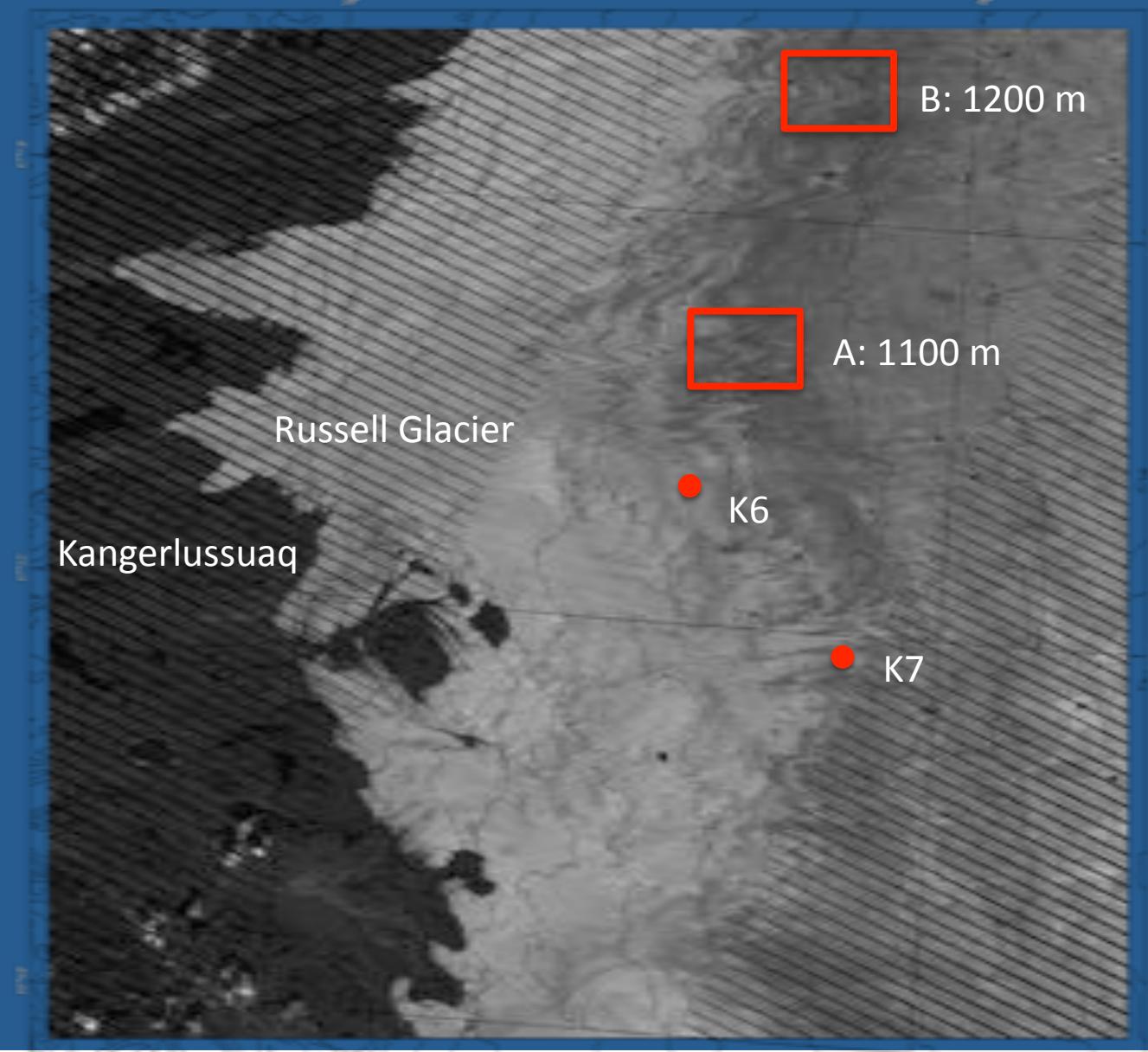


$$6.7 + 8.9 = 15.6 \text{ m lowering} = 14 \text{ m w.e.}$$

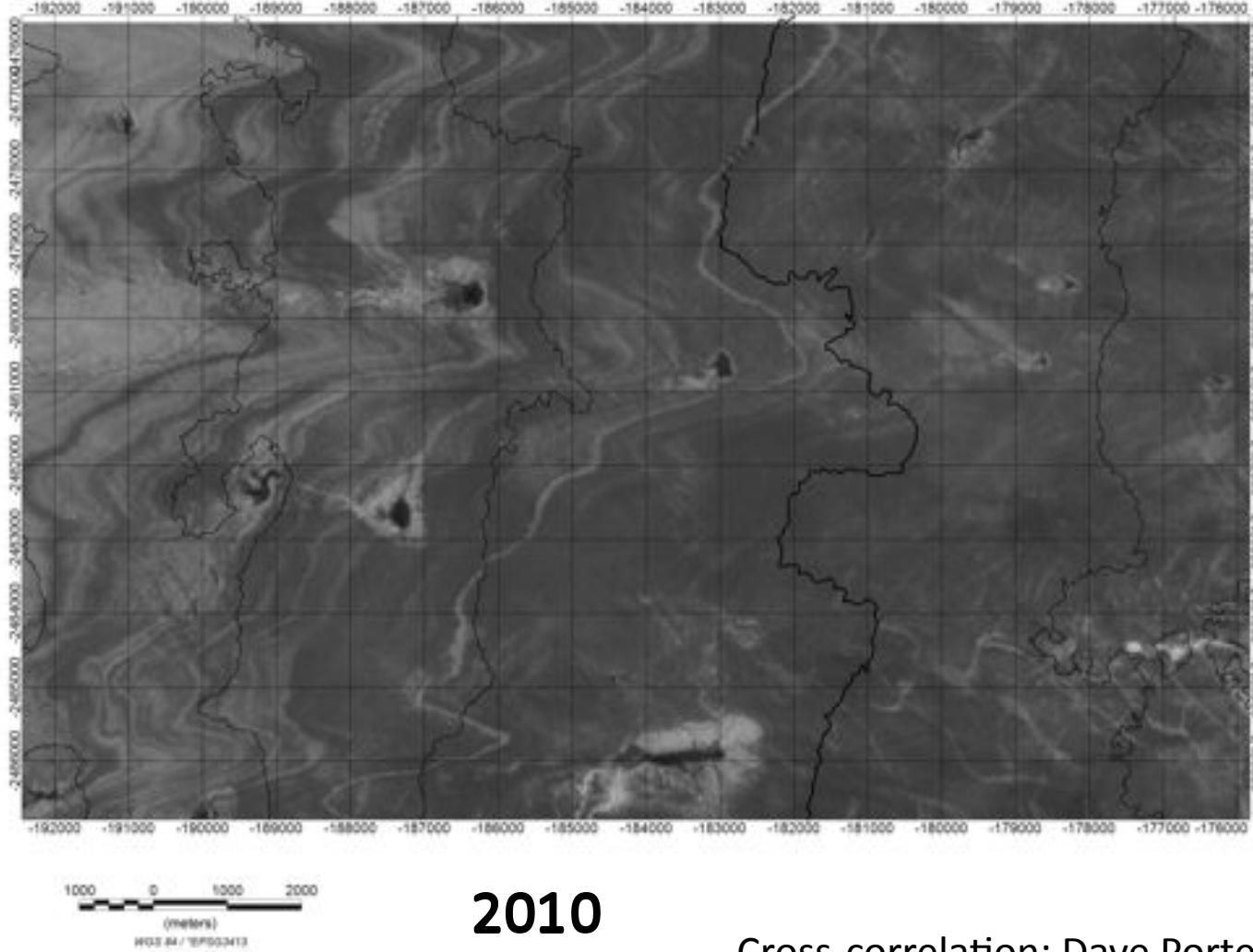
(c.f. K-transect 17.5 m)



Location

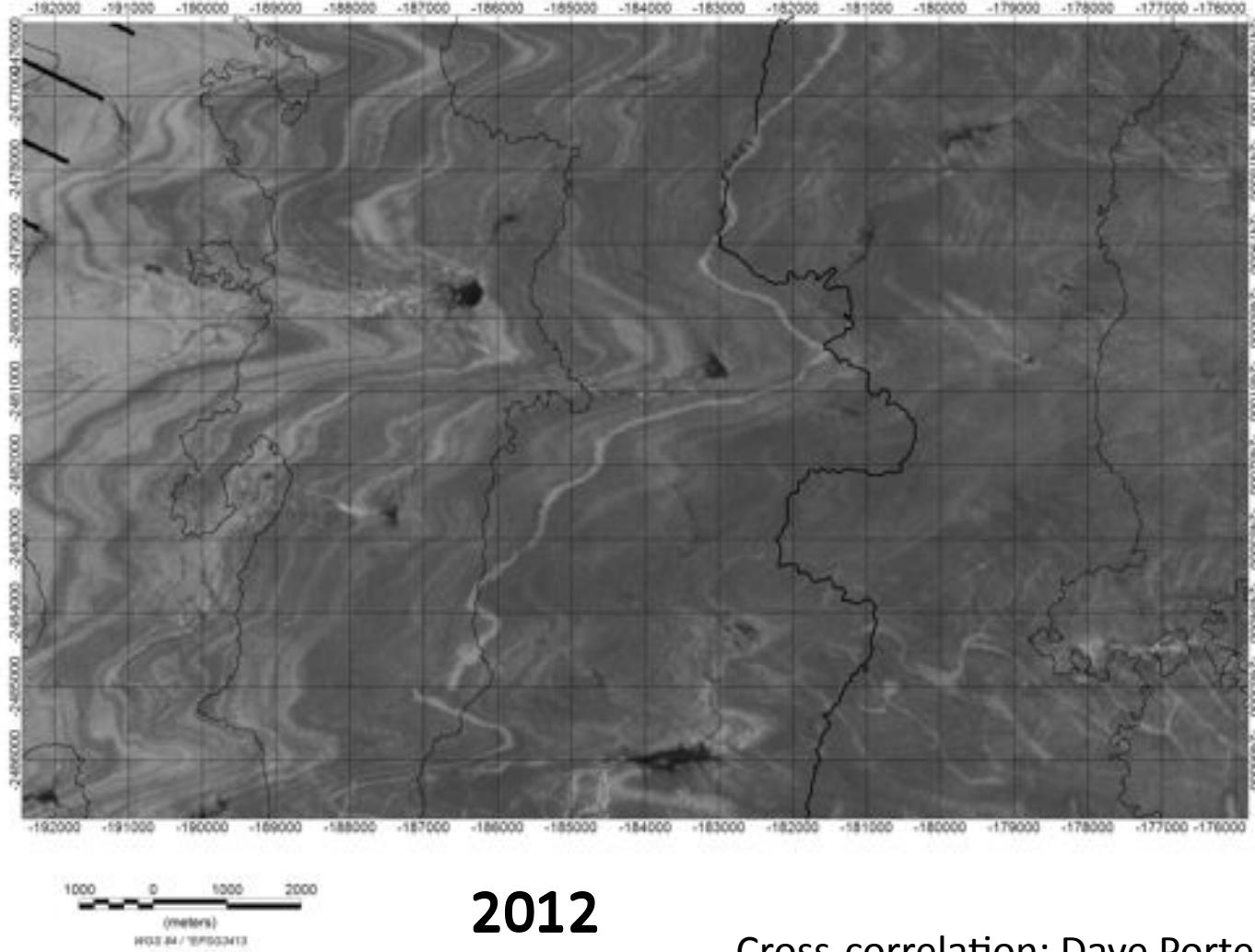


Cross correlation



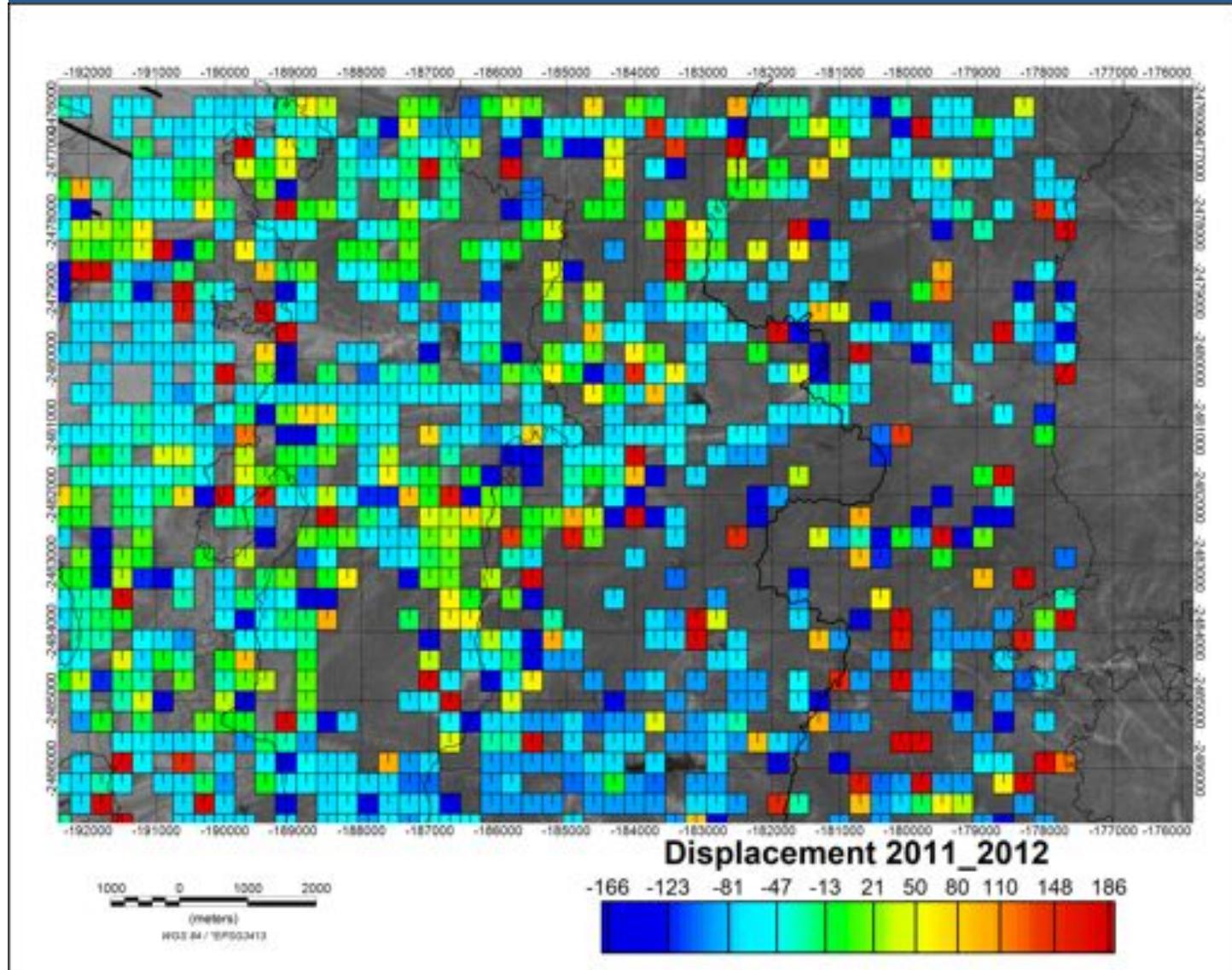
- 300 m cells
- 15 m pixels
(Landsat 7 panchromatic)
- search within neighbouring cells

Cross correlation



- 300 m cells
- 15 m pixels
(Landsat 7 panchromatic)
- search within neighbouring cells

Cross correlation 2011-2012

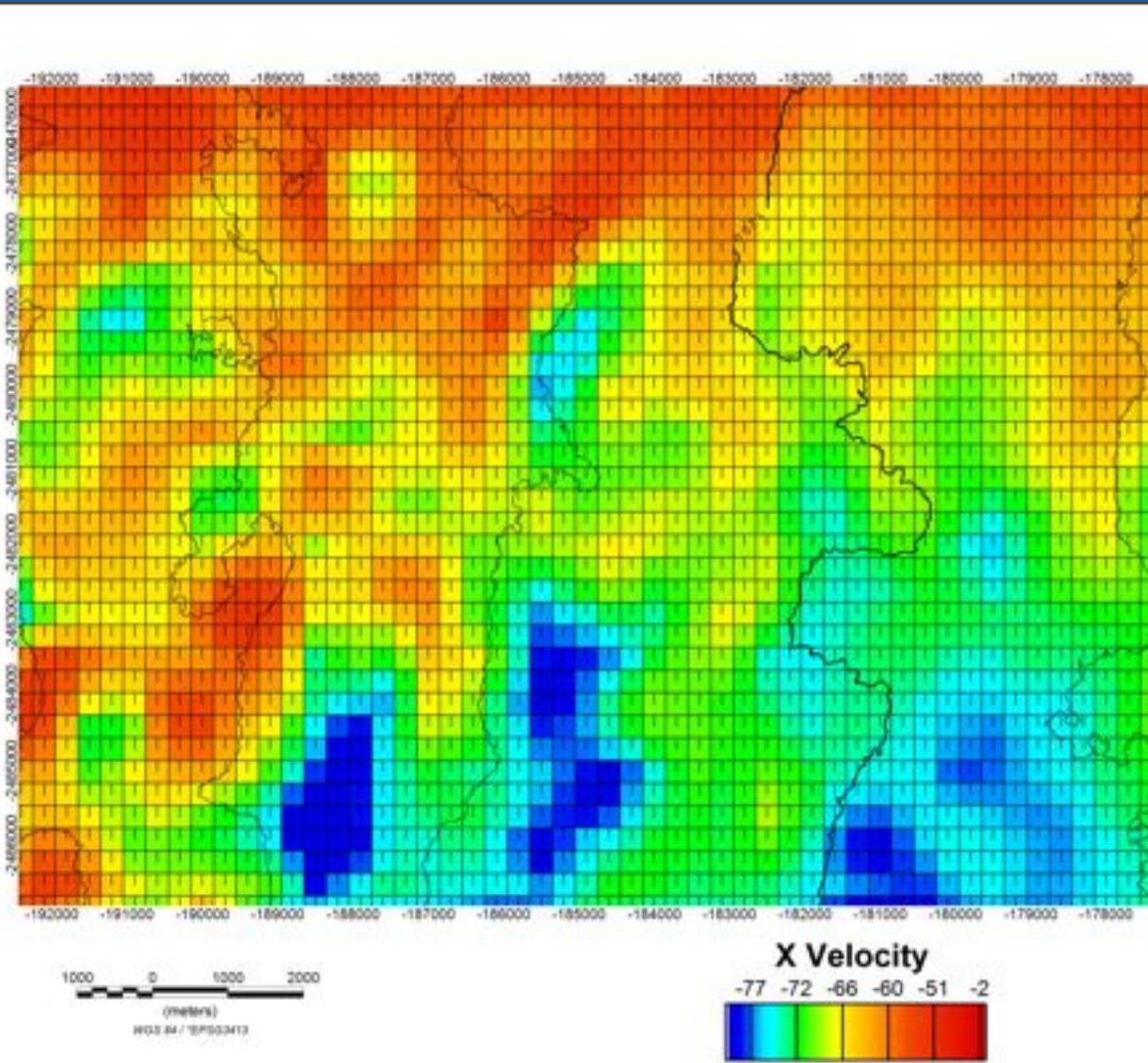


-ve X

←

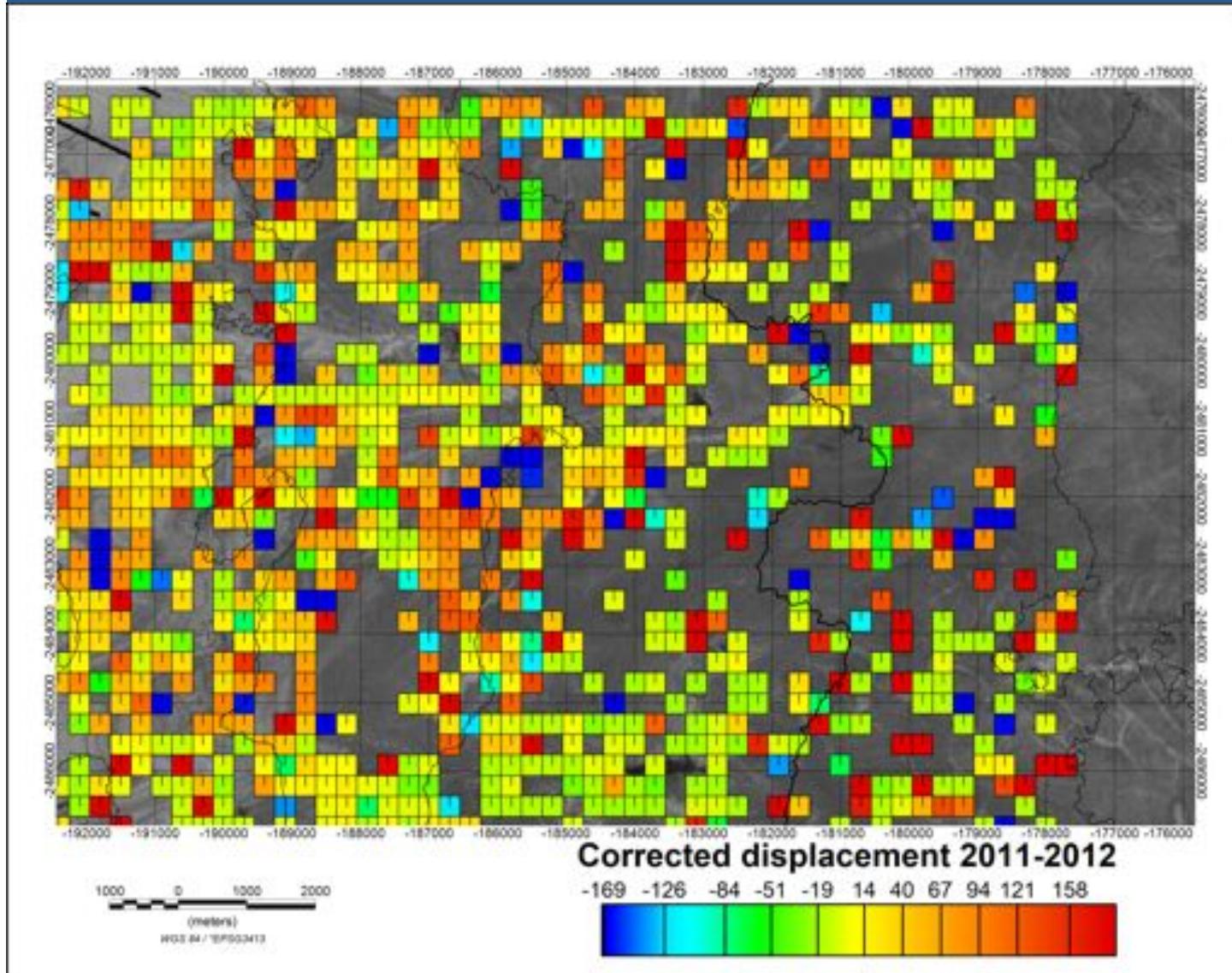
Towards coast

X-velocity component

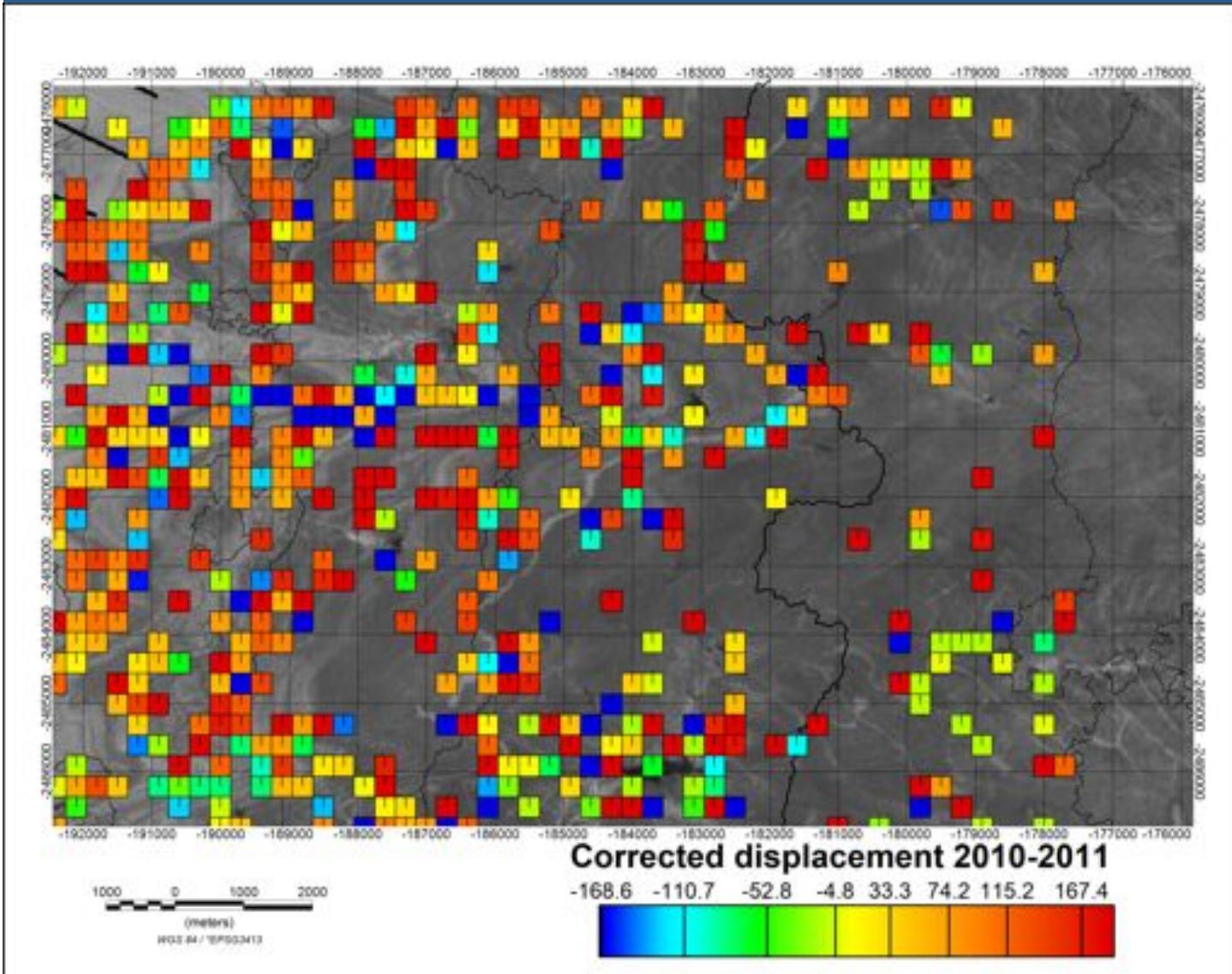


Joughin, I., B. Smith, I. Howat,
and T. Scambos.. 2010.
*MEaSUREs Greenland Ice
Sheet Velocity Map from InSAR
Data.*

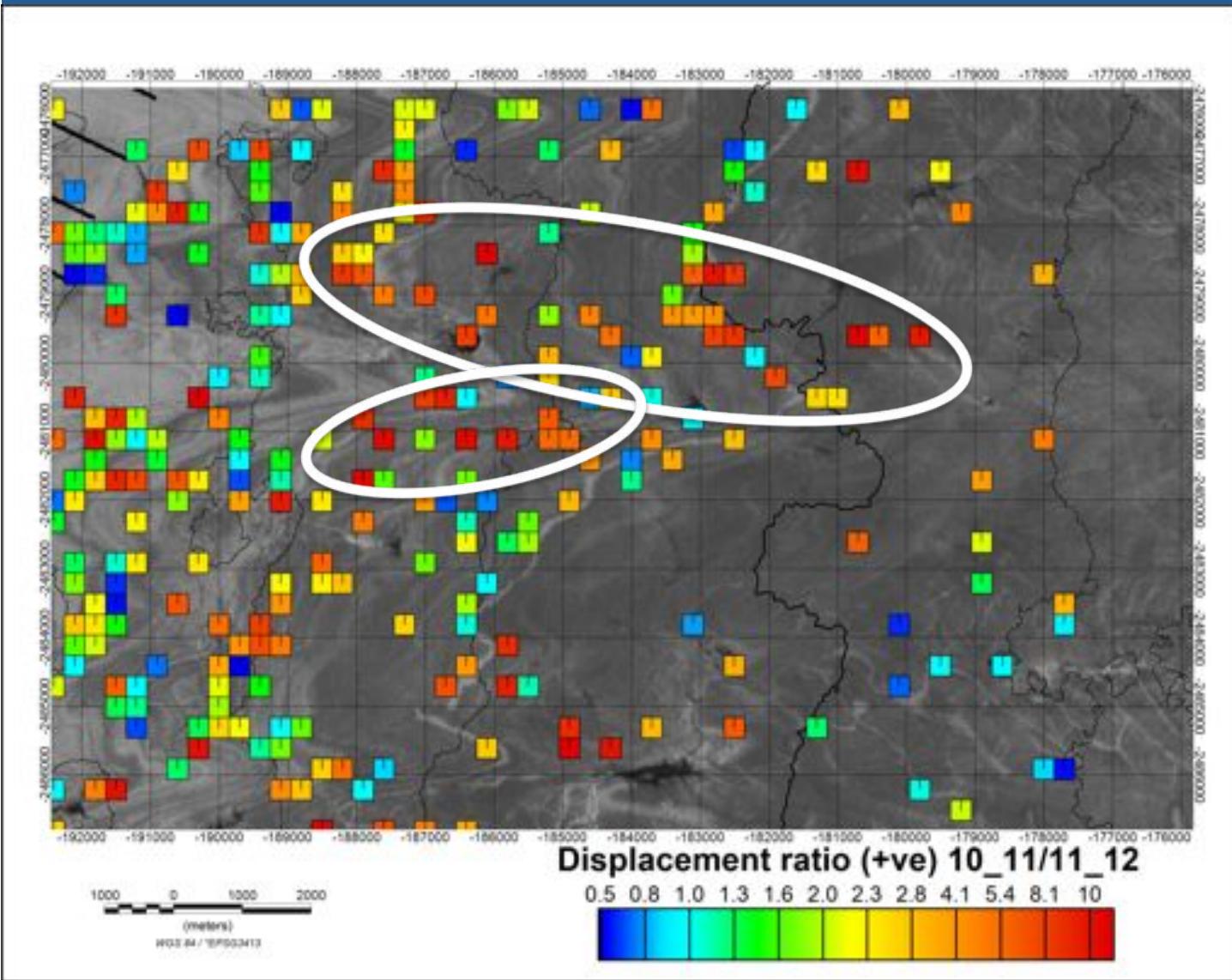
Cross correlation – minus horizontal flow



Cross correlation – 2010-2011



Cross correlation – variable melt??



2010-2011
2011-2012

Average 3x more lowering 2010-2011 than 2011-2012

Assume constant geometry

Conclusions

- Displacement of exposed strata in western Greenland gives a regional record of surface melt
 - Depends on
 - Local velocity
 - Local dip of strata
 - Local surface slope
- Can identify known surface mass balance anomalies
- Reveals regional variations in melt