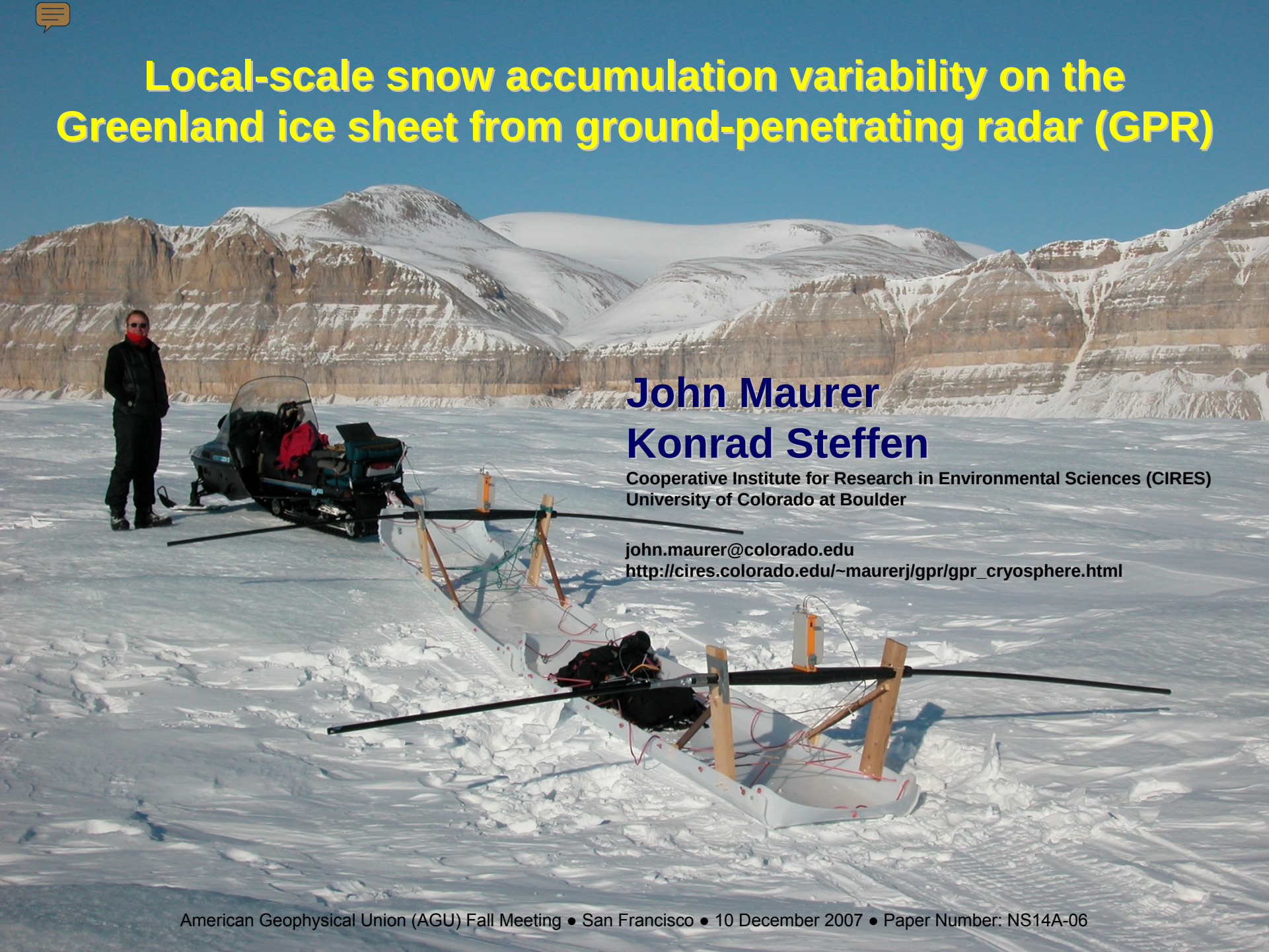
Local-scale snow accumulation variability on the Greenland ice sheet from ground-penetrating radar (GPR)



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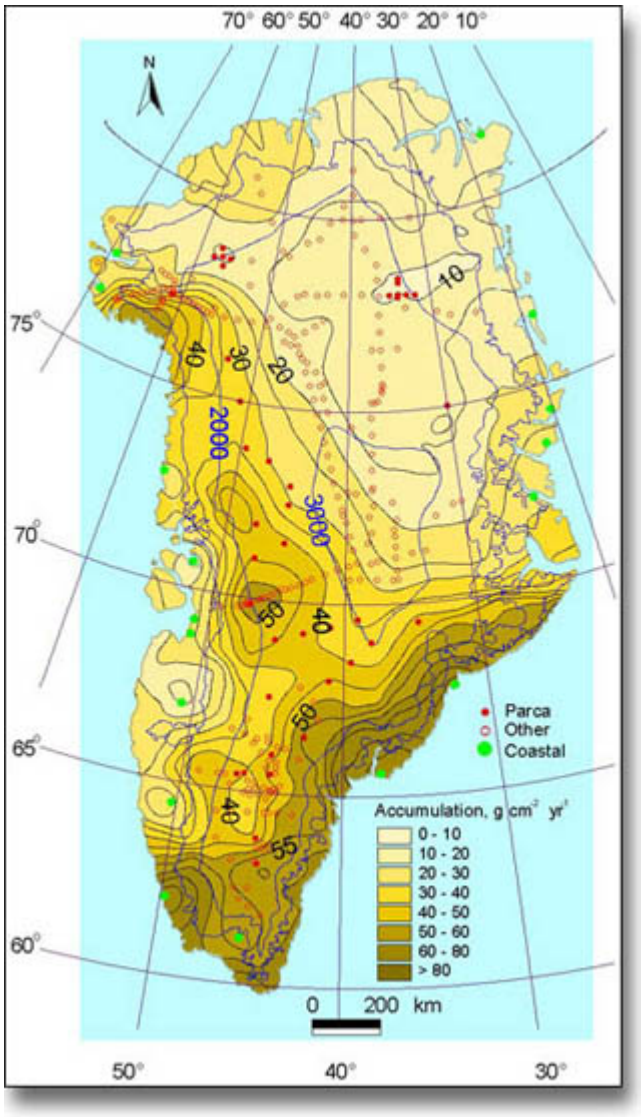
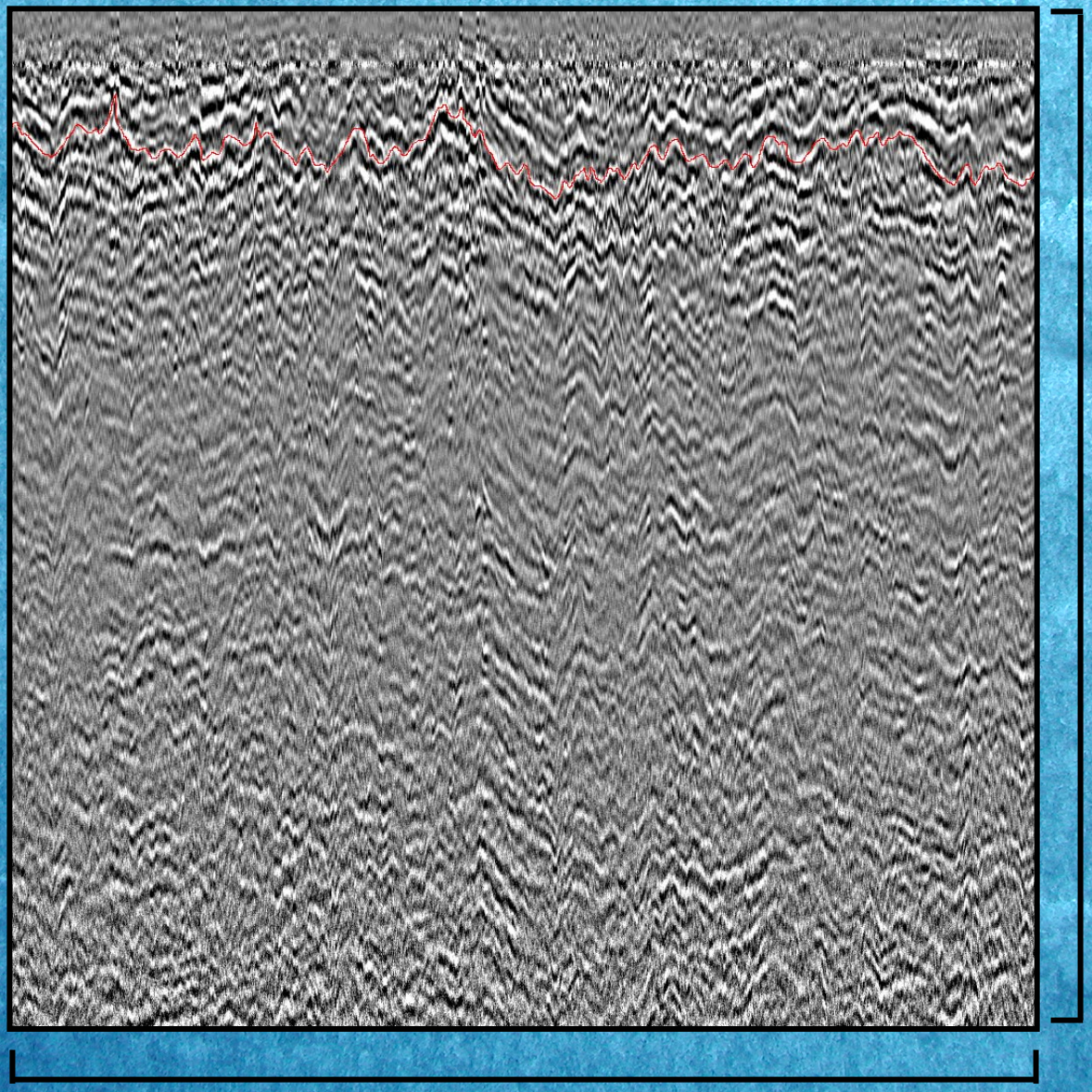
http://cires.colorado.edu/~maurerj/gpr/gpr_cryosphere.html

American Geophysical Union (AGU) Fall Meeting ● San Francisco ● 10 December 2007 ● Paper Number: NS14A-06

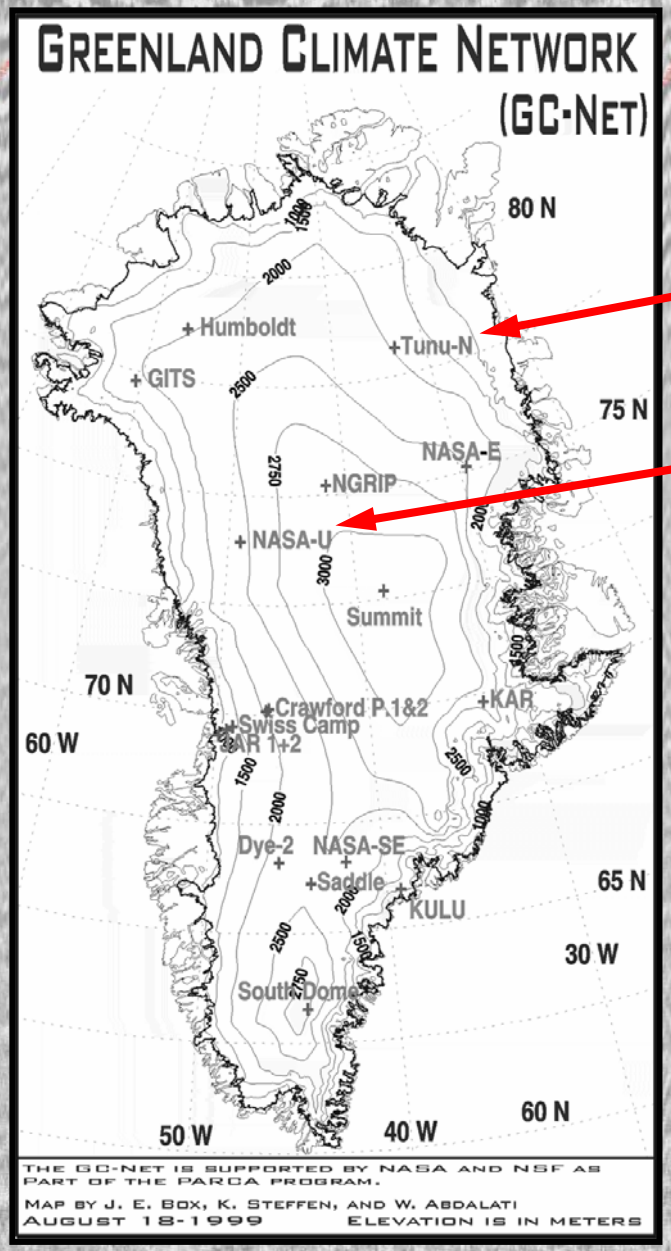


Bales et al., *JGR*, 2001

- **256 snow pits and ice cores**
- **collected 1913-1999**
- **158 pre-1981, 98 post-1981**
- **17 coastal met stations**


5 m
100 m

Data: 2003

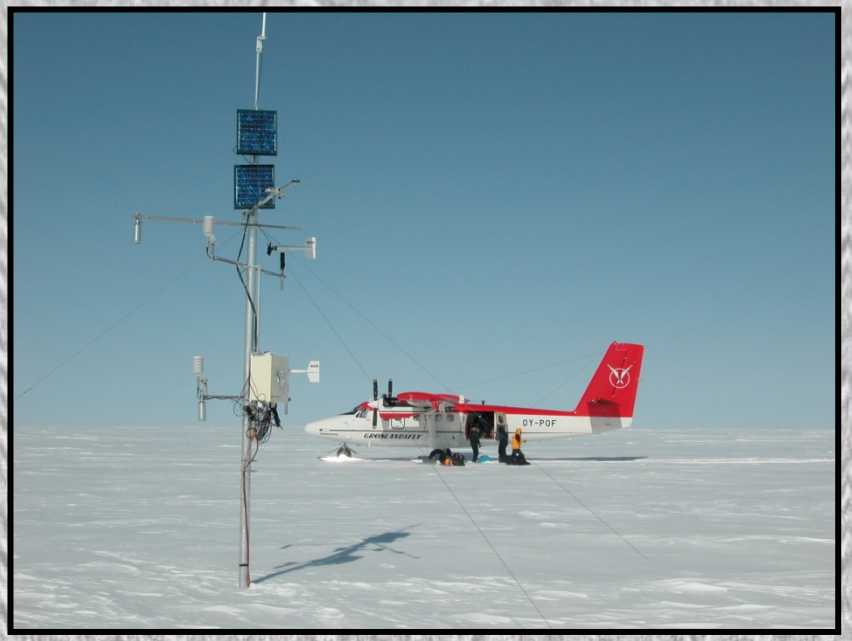


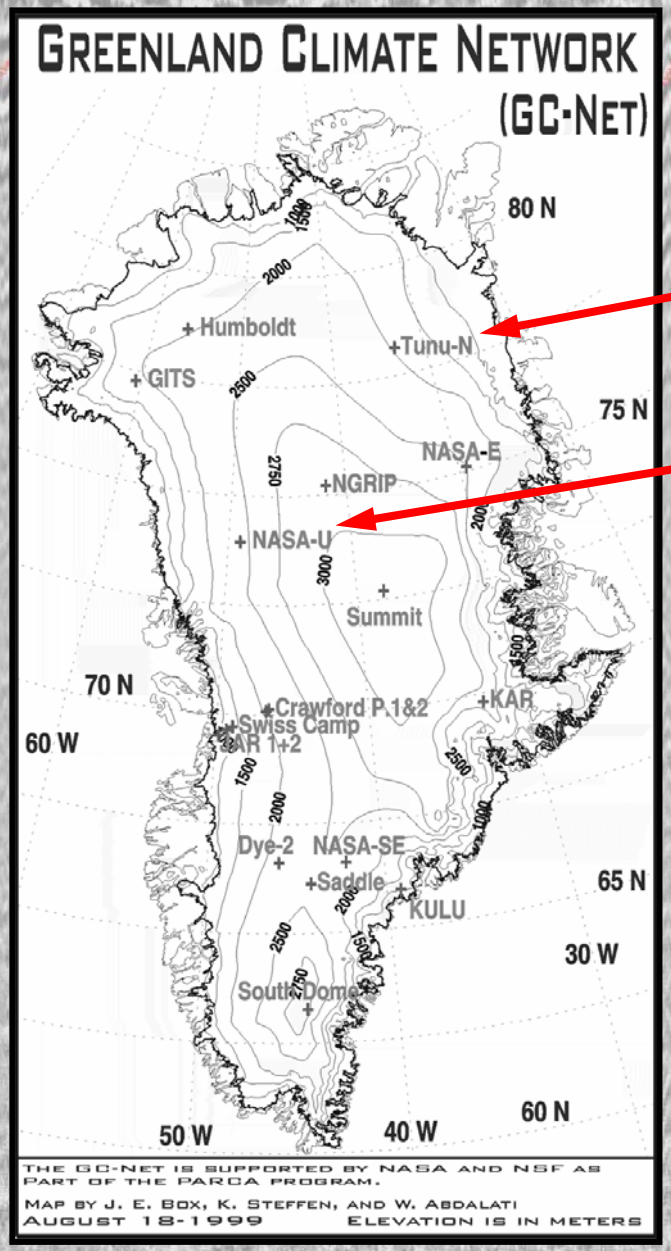
1. Tunu-N

100-150 mm·yr^{-1} SWE, ~40 cm snow depth

2. NASA-U

200-300 mm·yr^{-1} SWE, ~75 cm snow depth





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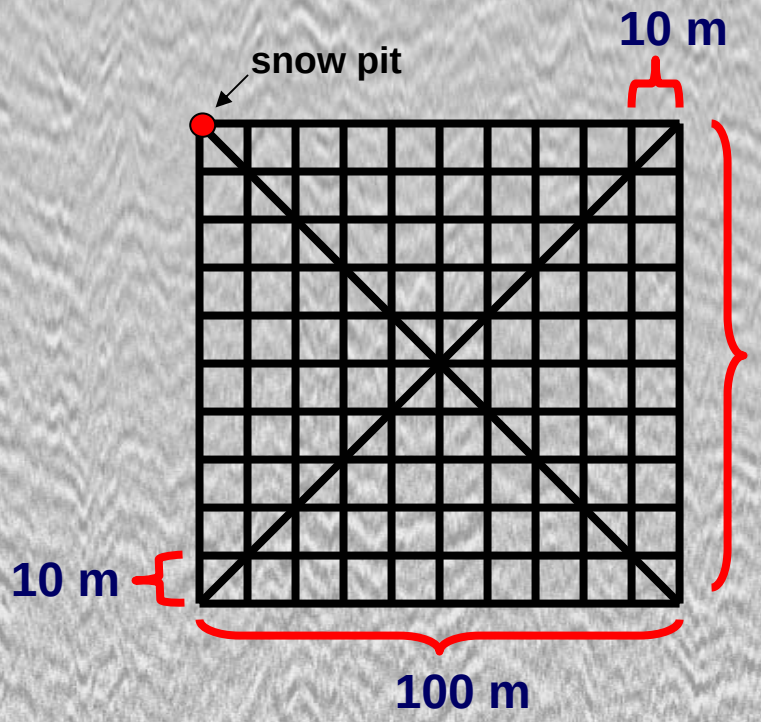
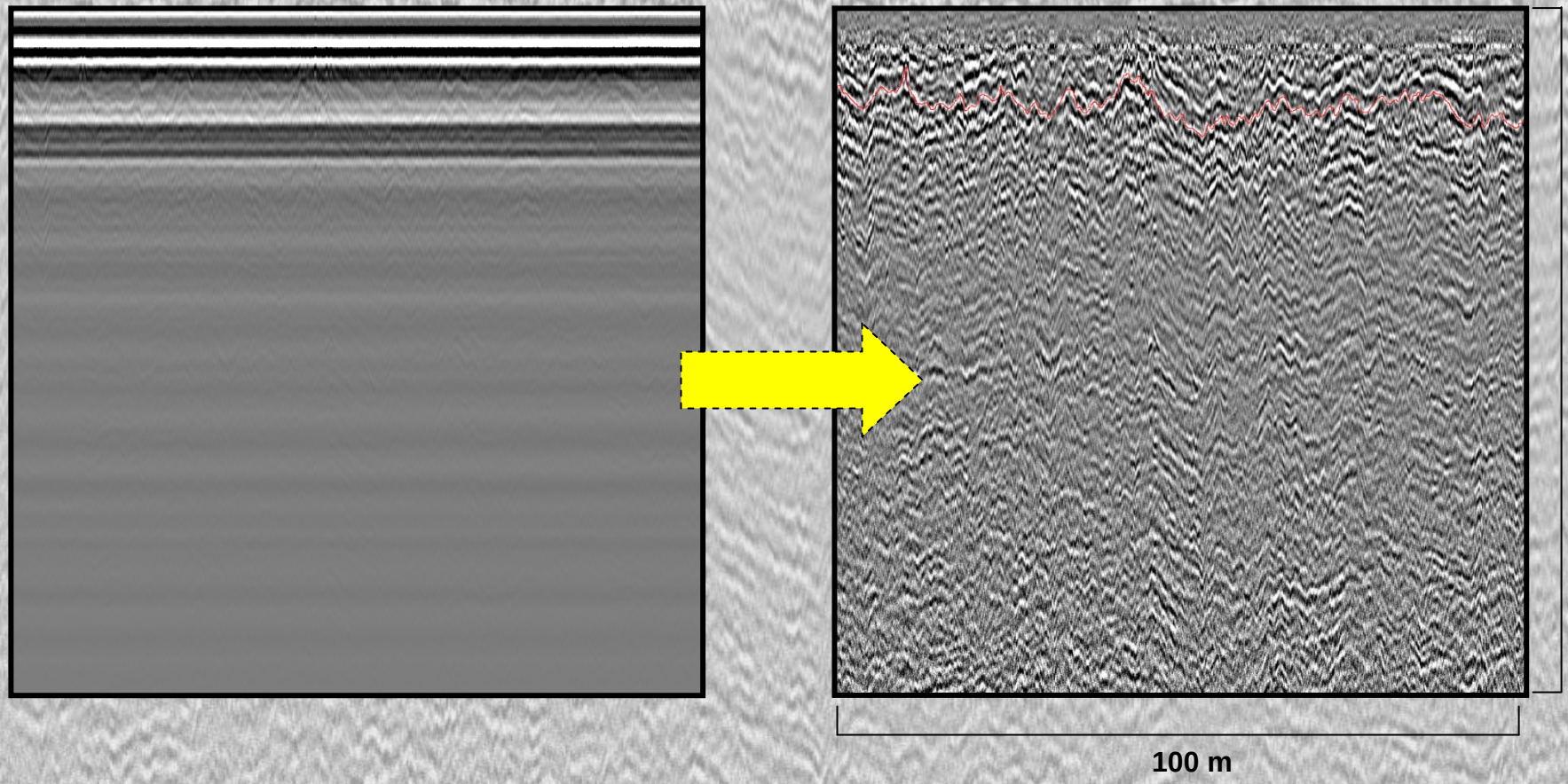
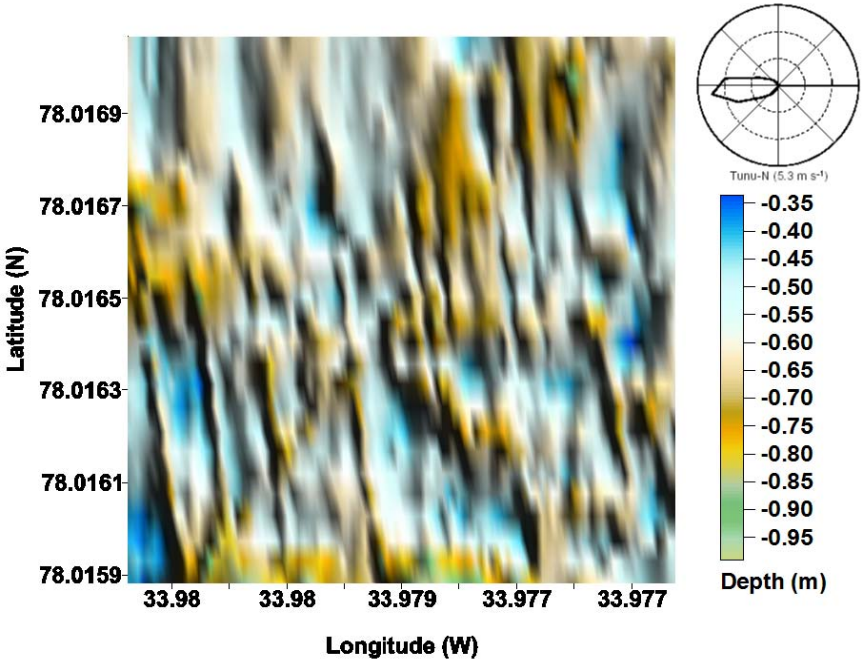


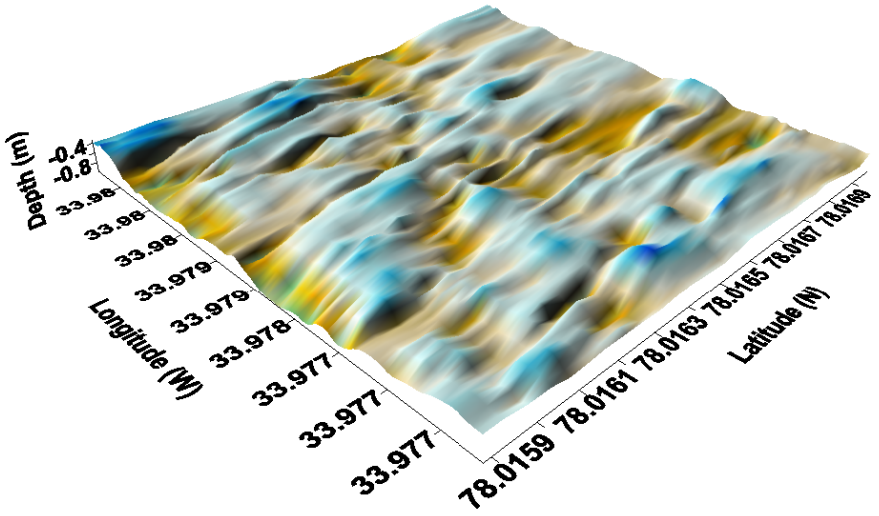
software developed for data processing



Issues: **(1) antenna ringing, (2) spreading loss, (3) layer tracing, (4) depth calculation, (5) 3-D surface rendering**

Tunu-N

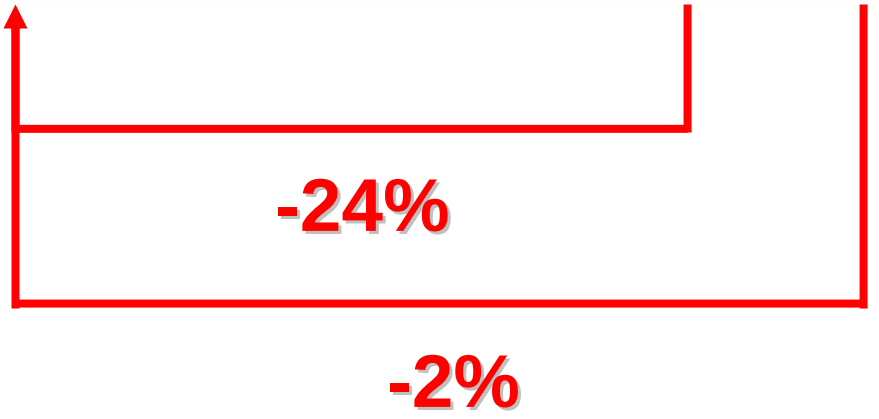




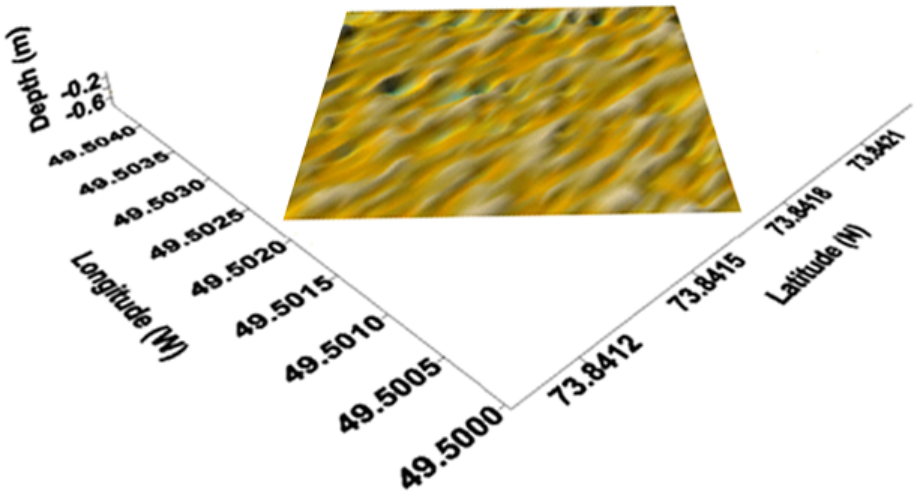
Mean depth: 66 cm
Standard deviation: 12.2 cm
Minimum depth: 34 cm
Maximum depth: 105 cm

TABLE 1. Depth comparison of stratigraphic layers identified within the GPR data compared to their corresponding depths identified in a snow pit and by a nearby AWS sonic surface-height sensor, where possible.

Site	*Layer*	*Date*	*N*	*Mean Depth (cm ±1 S.D.)*	*Depth Range (cm)*	*Snow Pit (cm)*	*AWS (cm)*
Tunu-N	1	summer 2001	42554	65.6 (± 12.2)	33.8 – 105.5	50	64

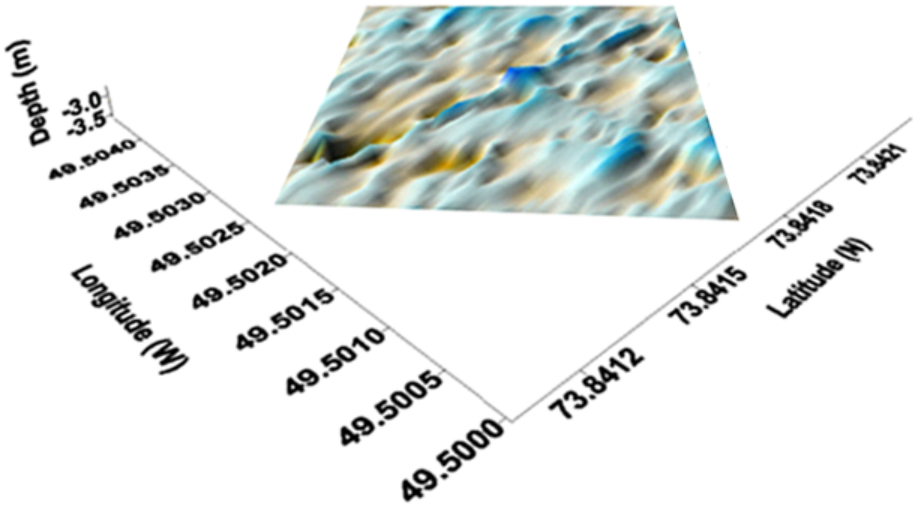


NASA-U layer #1



Mean depth: 50 cm
Standard deviation: 7.4 cm
Minimum depth: 35 cm
Maximum depth: 89 cm

NASA-U layer #2



Mean depth: 302 cm
Standard deviation: 11.3 cm
Minimum depth: 270 cm
Maximum depth: 356 cm

TABLE 1. Depth comparison of stratigraphic layers identified within the GPR data compared to their corresponding depths identified in a snow pit and by a nearby AWS sonic surface-height sensor, where possible.

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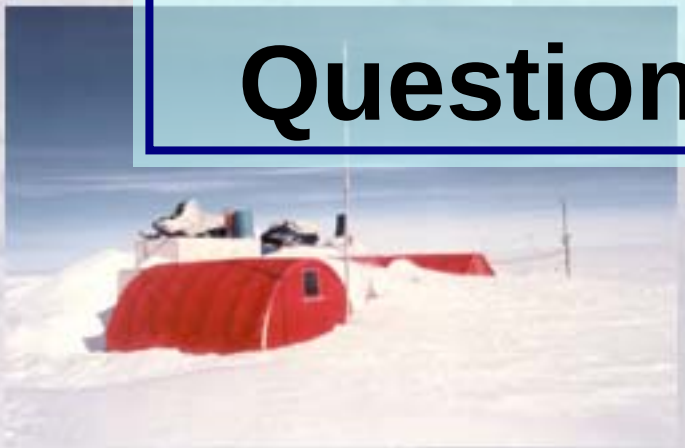
Tunu-N	1	summer 2001	42554	65.6 (± 12.2)	33.8 – 105.5	50	64
NASA-U	1	wind crust 2002	29291	49.9 (± 7.4)	35.2 – 88.5	54	n/a
NASA-U	2	ice layer 2000	31010	302.2 (± 11.3)	270.0 – 356.1	n/a	n/a

Average standard deviation: ±10 cm
Average range: ±35 cm

Conclusions

- Spatial variability is important, even at local-scale (100 m x 100 m)
- GPR is an improvement over point measurements
- Aid in interpretation of ice cores & remote sensing
- Shallow penetration depth: cannot assess temporal variability
- High resolution: greatest strength & greatest weakness
- Complex stratigraphy can make interpretation difficult; need other *in situ* observations for validation
- Need more studies

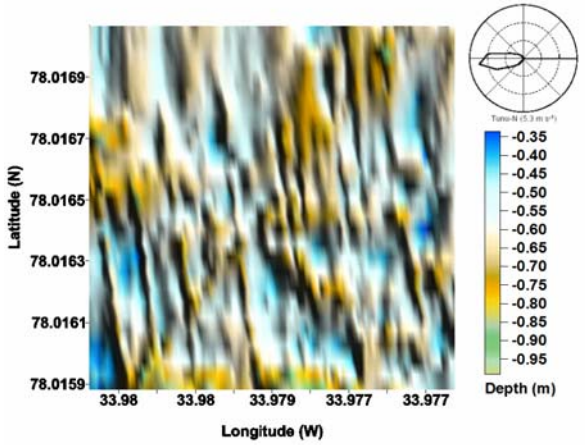
Questions?, Comments?

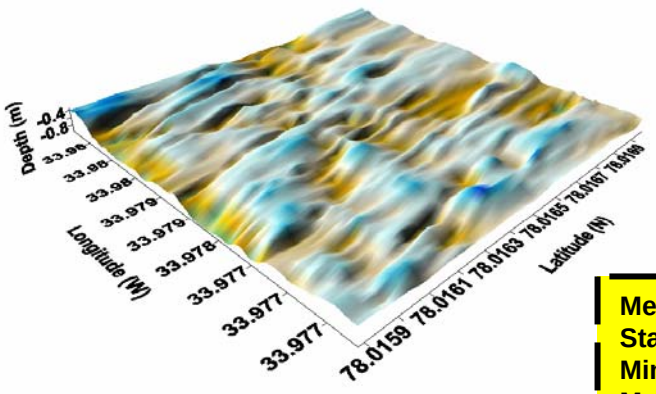


Thank you!

For further information:
http://cires.colorado.edu/~maurerj/gpr/gpr_cryosphere.html
john.maurer@colorado.edu

Tunu-N





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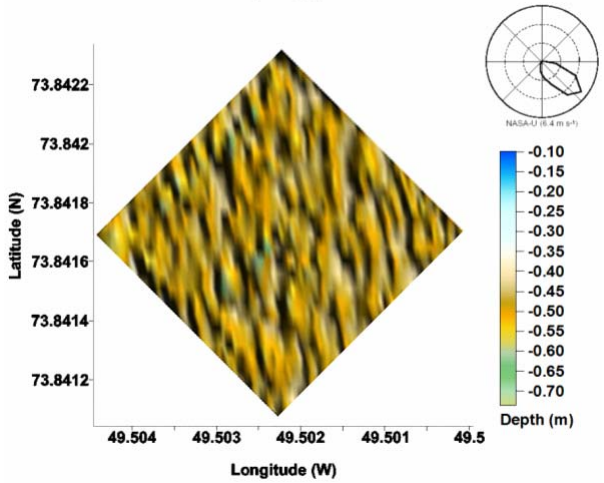

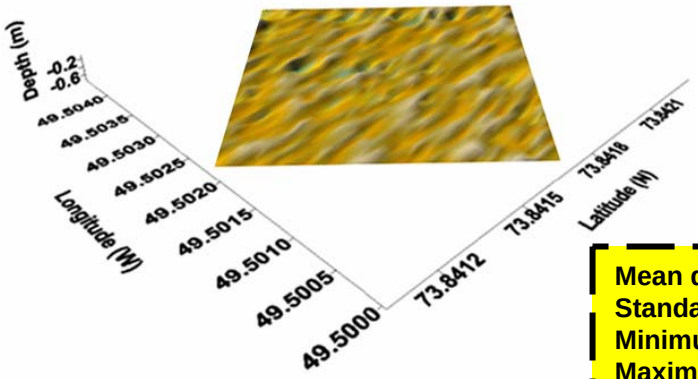

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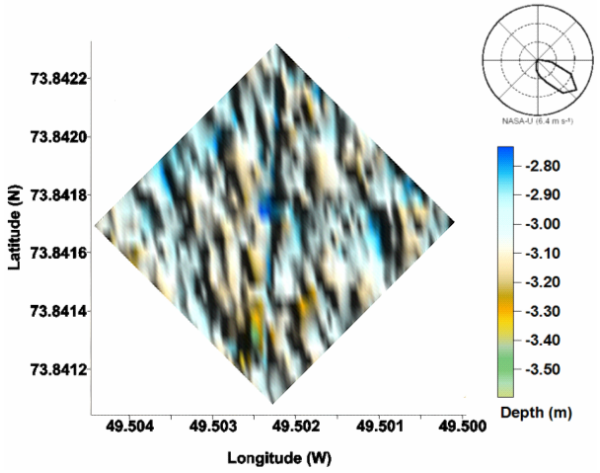

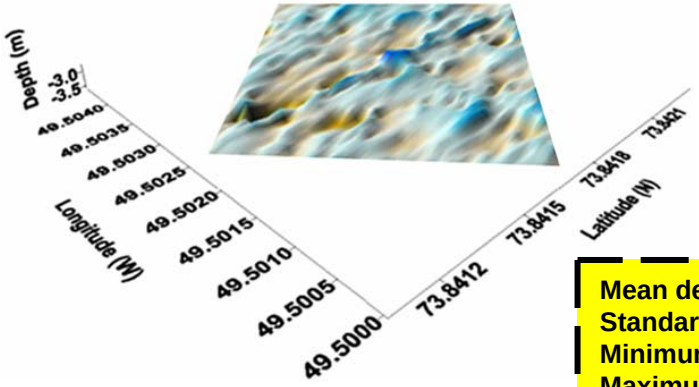

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A Wideband Radar for High-Resolution Mapping of Near-Surface Internal Layers in Glacial Ice

Pannirselvam Kanagaratnam, *Member, IEEE*, Siva Prasad Gogineni, *Fellow, IEEE*, Vijay Ramasami, *Student Member, IEEE*, and David Braaten

***Abstract*—Snow accumulation rate is an important parameter** in determining the mass balance of polar ice sheets. Accumulation rate is currently determined by analyzing ice cores and snow pits. Inadequate sampling of the spatial variations in the ice sheet accumulation has resulted in [illegible] large as 24%. We designed ar borne radar system for high-re face internal layers for estimat ice sheets. Our radar system can poral coverage by mapping a co layers in the ice sheet. During t we successfully mapped the nea in the dry-snow zone, 120 m in the melt zone. We determined rate at the NASA-U_1 site to be 1992. This is in close agreement lation rate of 34.6 cm/year for t

***Index Terms*—Airborne rada** lated continuous wave, snow.

Accumulation rate is a key variable in interpreting surface elevation measurements and in determining the mass input [5]–[7]. It is currently determined from ice cores and pits [8], and there are large errors in the estimated accumulation rate for

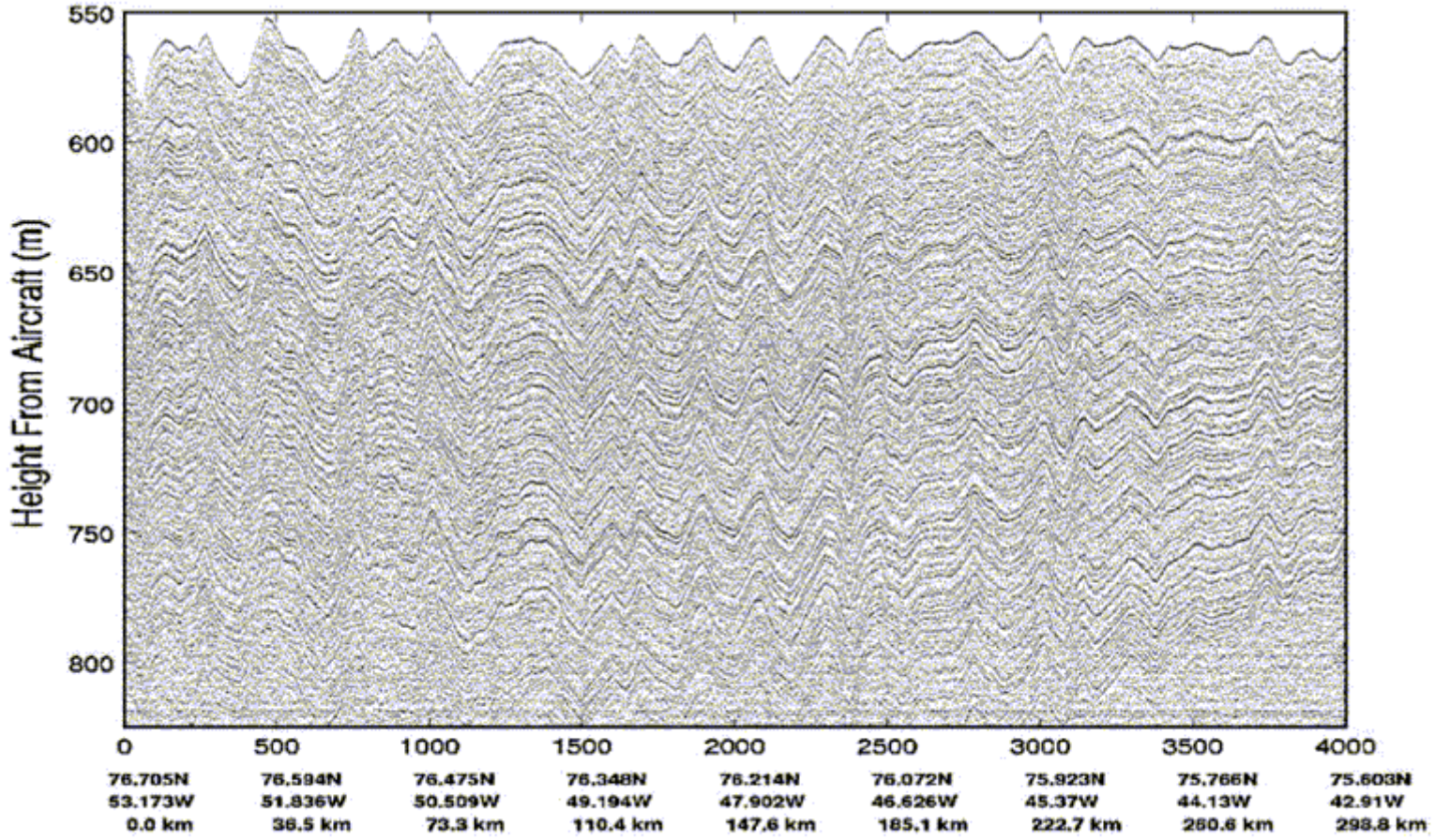


Fig. 4. (a) Internal layers observed over a 300-km traverse over the Greenland ice sheet.

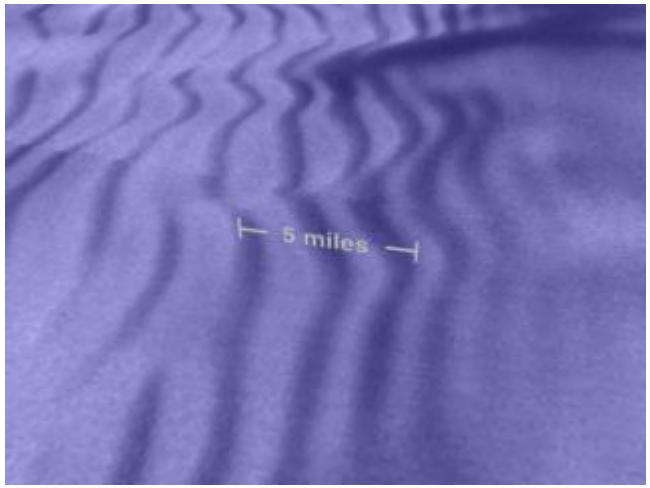
Kanagaratnam et al. 2004
IEEE Trans. Geosci. & Rem. Sens. 42(3)

sastrugi

Form parallel to predominant wind direction.

Antarctica. Source: Wikipedia

megadunes



Form perpendicular to predominant wind direction (like sand dunes).

Antarctica. Source: Ted Scambos, NSIDC