On the spatial variability of the alpine snow cover
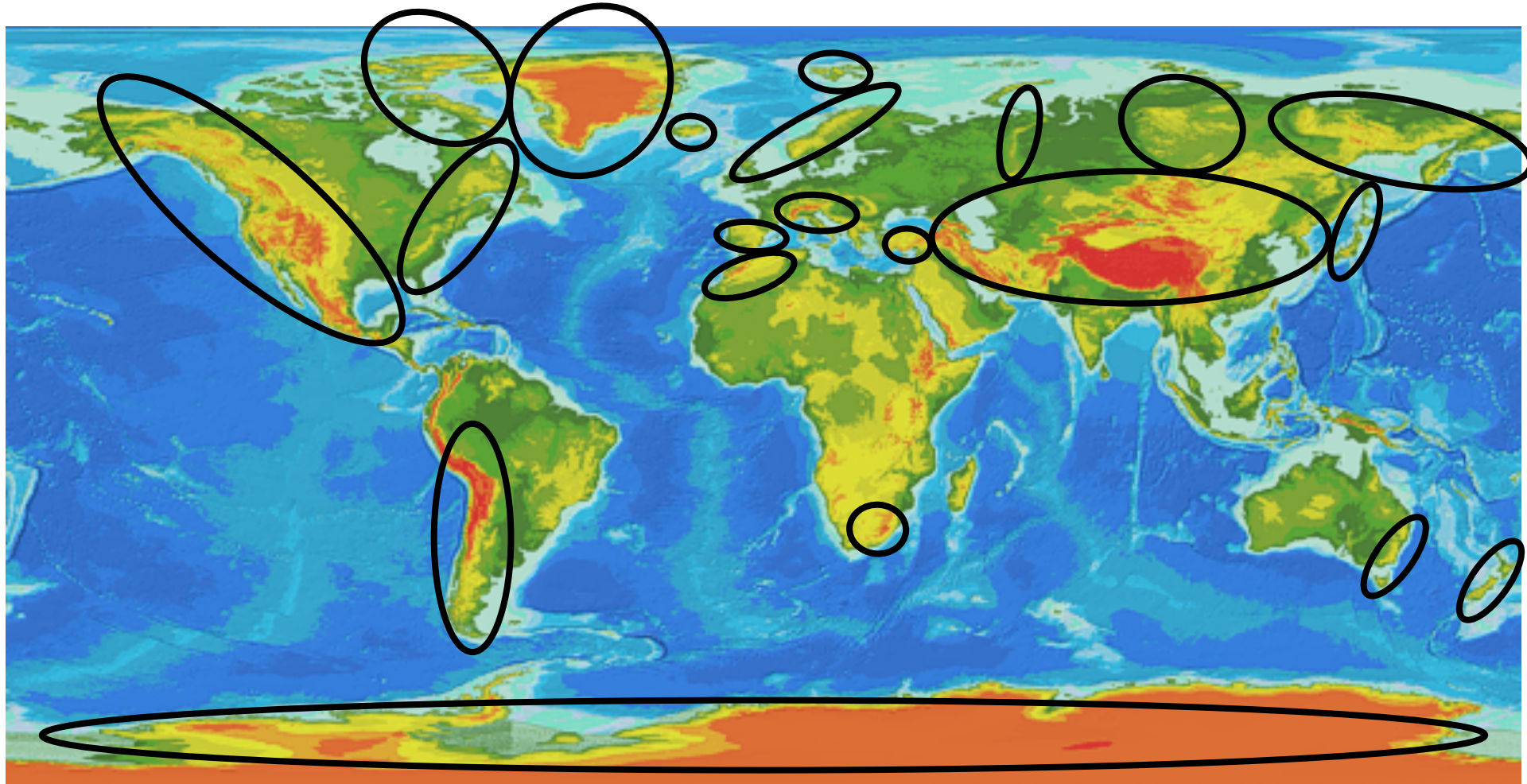
Yves Bühler

EARSeL Workshop on Land Ice and Snow

February 3rd – 6th 2014

Swiss Federal Institute for Forest, Snow and Landscape Research WSL
WSL Institute for Snow and Avalanche Research SLF

Snow in complex terrain: Mountain ranges in the world

- 20% of the terrestrial surface
- 20% of the human population

Source: UNEP – Global Assessment Report

2

Fundamental role for:

- Water supply

- Ecology

- Climate system

- Tourism

- Hydropower

- Hazard management

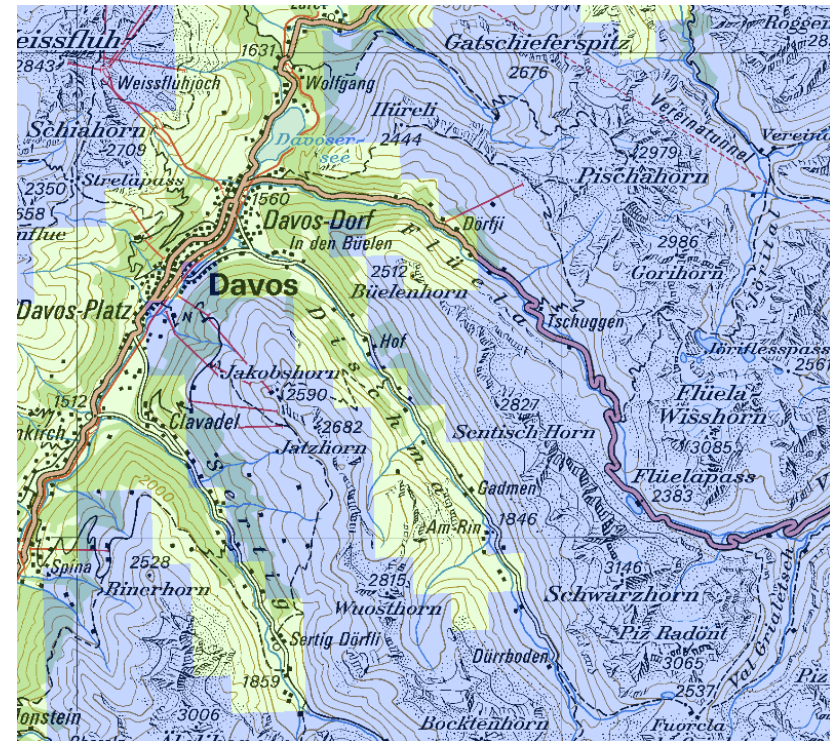➔ Large scale **coverage** needed

➔ **Spatially continuous** data needed

➔ But in which **spatial** and **temporal** resolution?

a) Snow Covered Area SCA (FSC)

- Measured operationally by remote sensing instruments
- Rapid changes especially in spring (high temporal resolution needed)
- Influence of complex terrain (cast shadow, forests, rocks)?

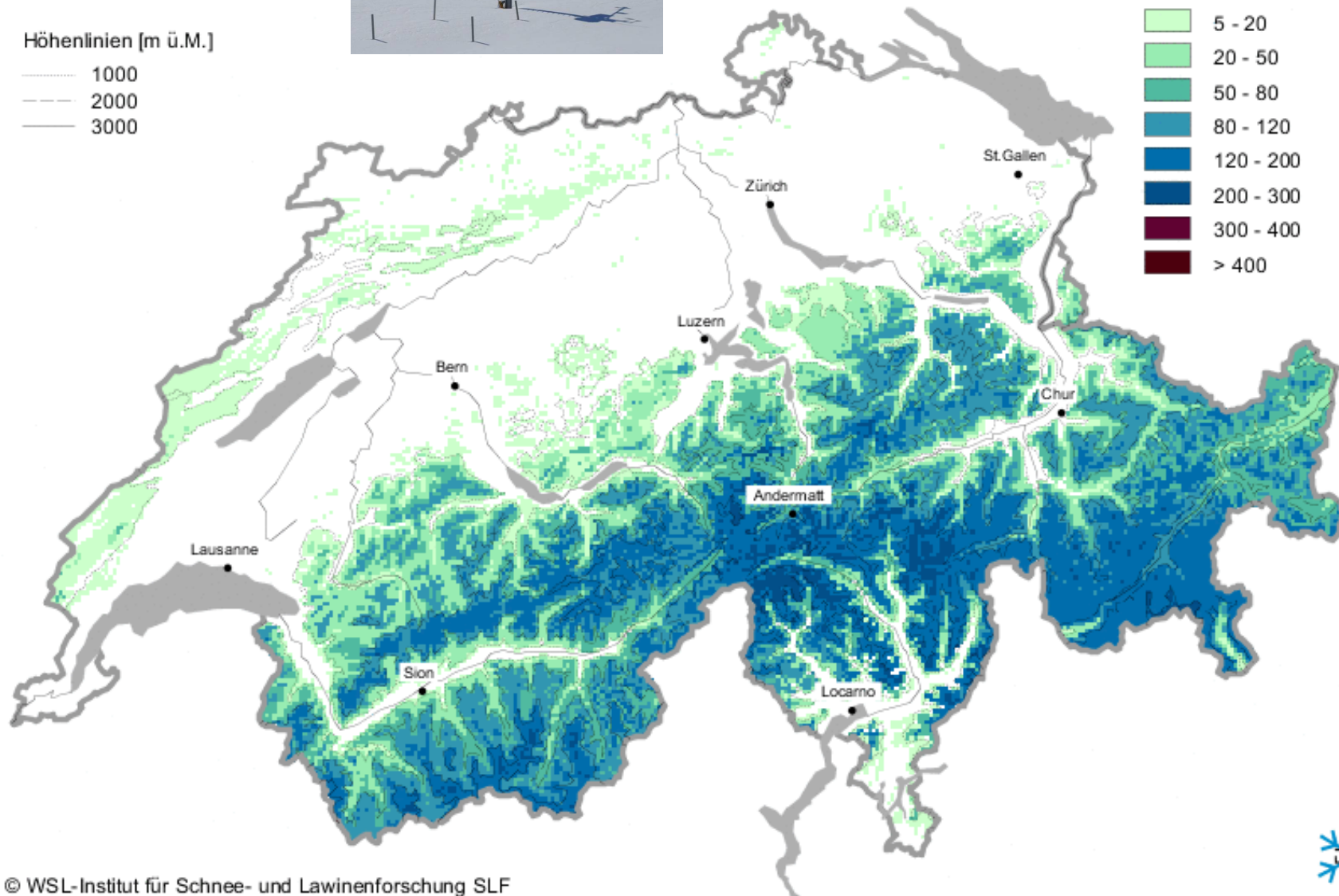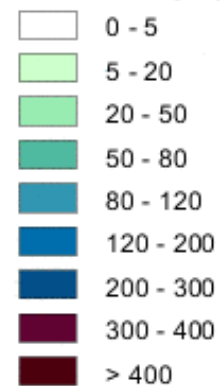AVHRR product GIUB, University of Bern

Schneehöhe
aktualisiert am 23.01.2014, 08:20

Höhenlinien [m ü.M.]
- 1000
- 2000
- 3000

Schneehöhe [cm]
- 0 - 5
- 5 - 20
- 20 - 50
- 50 - 80
- 80 - 120
- 120 - 200
- 200 - 300
- 300 - 400
- > 400

St.Gallen

Zürich

Luzern

Bern

Chur

Andermatt

Lausanne

Sion

Locarno

© WSL-Institut für Schnee- und Lawinenforschung SLF

SLF

b) Snow Depth / Snow Water Equivalent

- Global SWE products available with 25km resolution (passive microwave)

- Mountain regions excluded
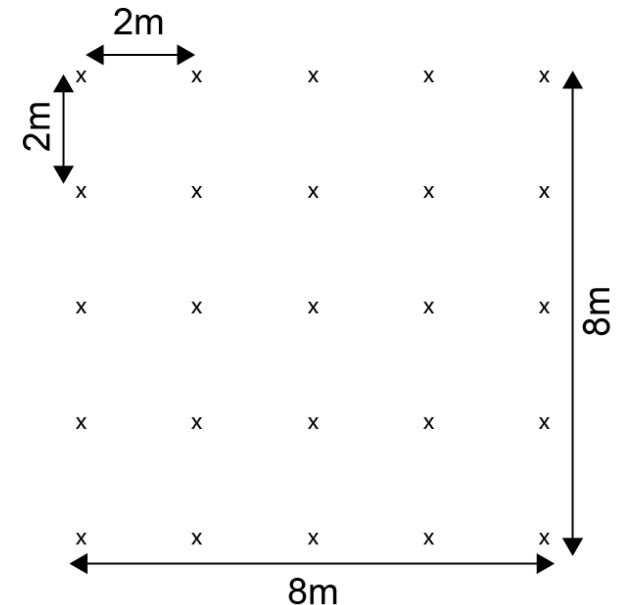
- Spatial resolution **insufficient** for alpine terrain
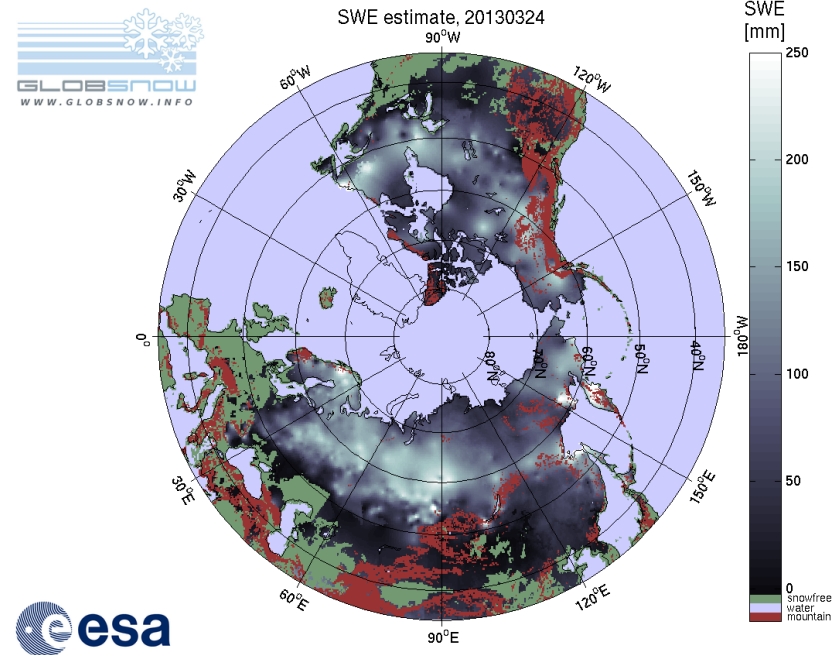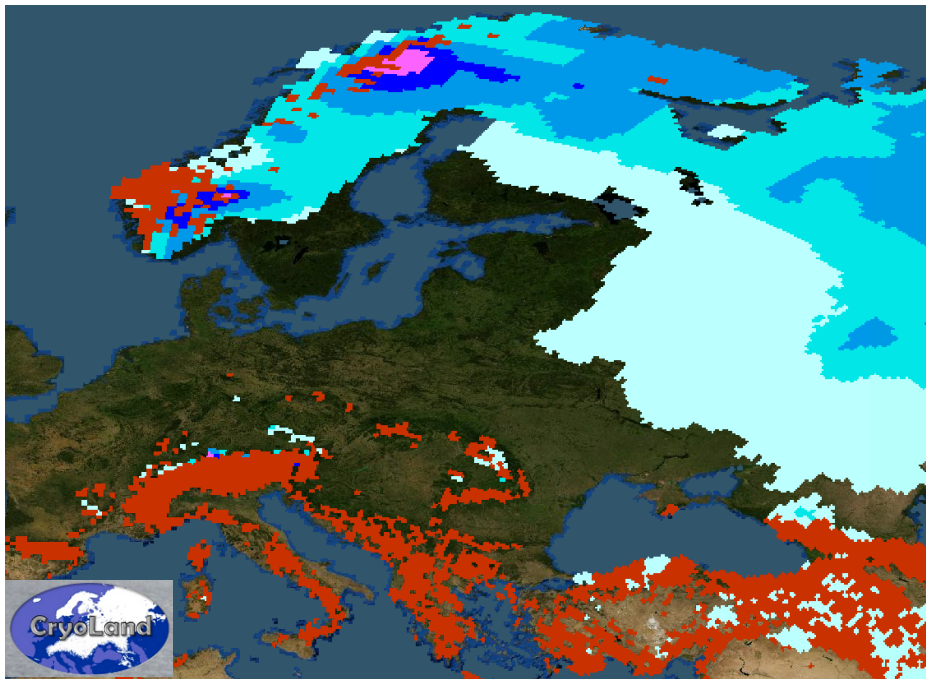
- Very high spatial variability due to:
  - Complex terrain
  - Wind
  - Avalanches
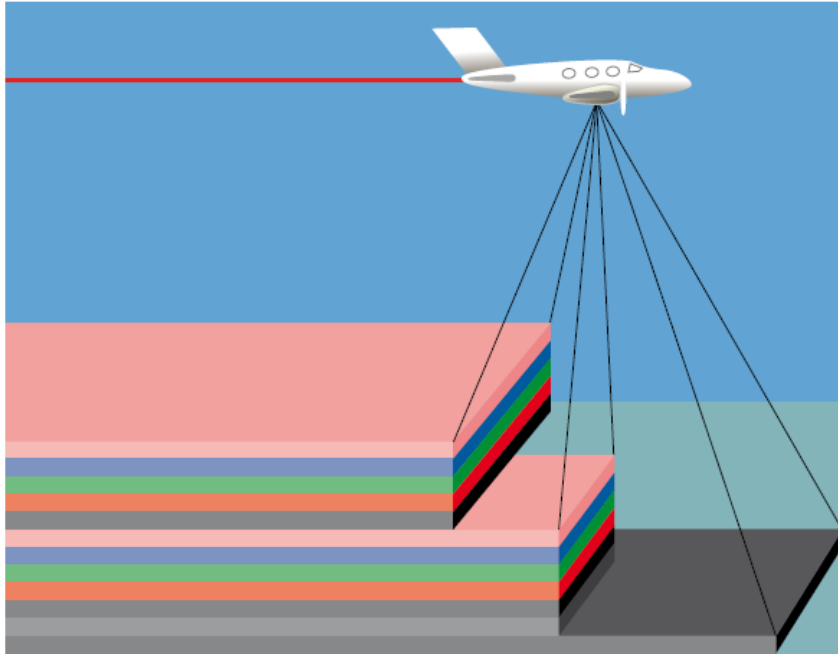- What is the **correct snow depth**?
- Very much **scale dependent**!

2.30	1.78	1.35	0.95	0.65
2.25	1.60	0.90	0.65	**0.55**
1.90	1.35	0.85	0.70	0.75
1.40	1.00	0.90	1.50	1.85
1.35	1.25	1.20	2.10	**2.35**

$\sigma = 0.56\text{m}$
$x = 1.34\text{m}$

ADS80 (100) opt-electronic scanner

Field of View:	64°
Pixel:	6 µm
CCD Zeile:	12'000 (20'000)
Räumliche Auflösung:	~ 0.25 m
Radiometrische Auflösung:	12-bit
Spektrale Auflösung:	4 Kanäle
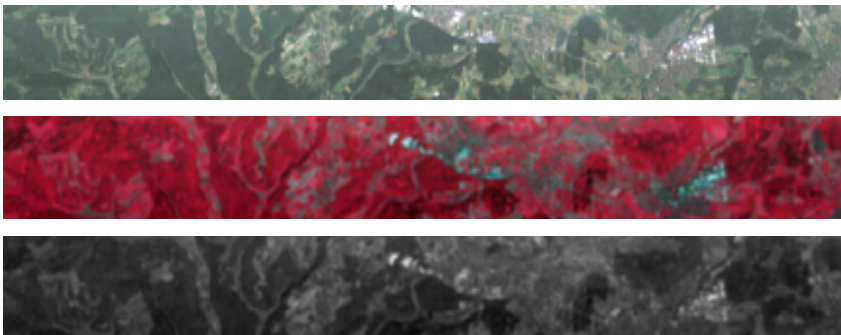
pan:	465 – 680 nm	-16/0/27°
blue:	428 – 492 nm	-16/0°
green:	533 – 587 nm	-16/0°
red:	608 – 662 nm	-16/0°
nir:	833 – 887 nm	-16/0°

- High spatial resolution data gets available
  - Airborne laserscanning LiDAR (accurate)
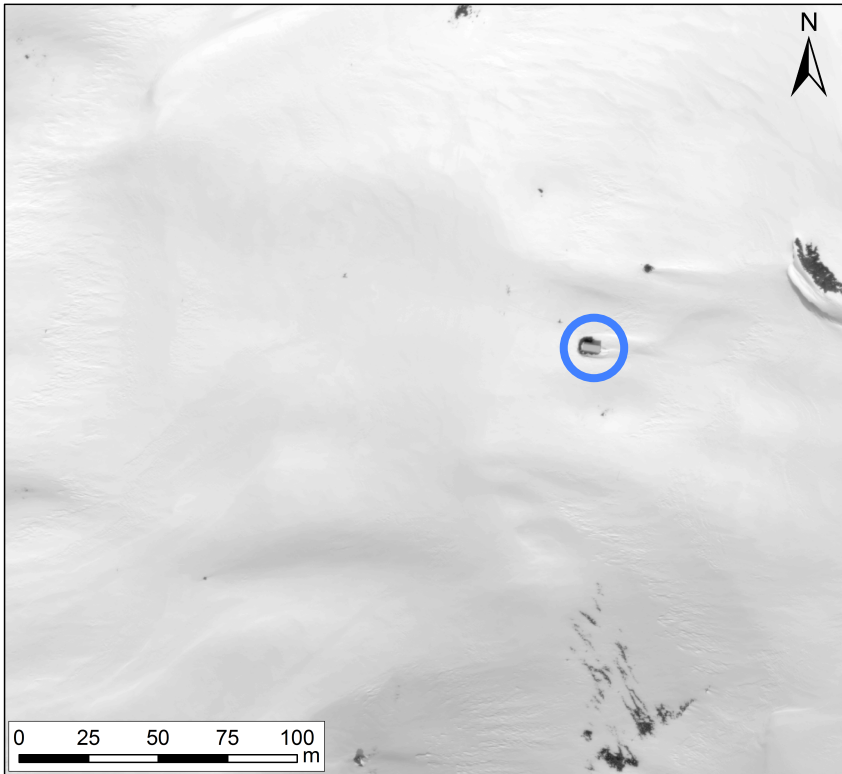 - Digital photogrammetry (more economic)
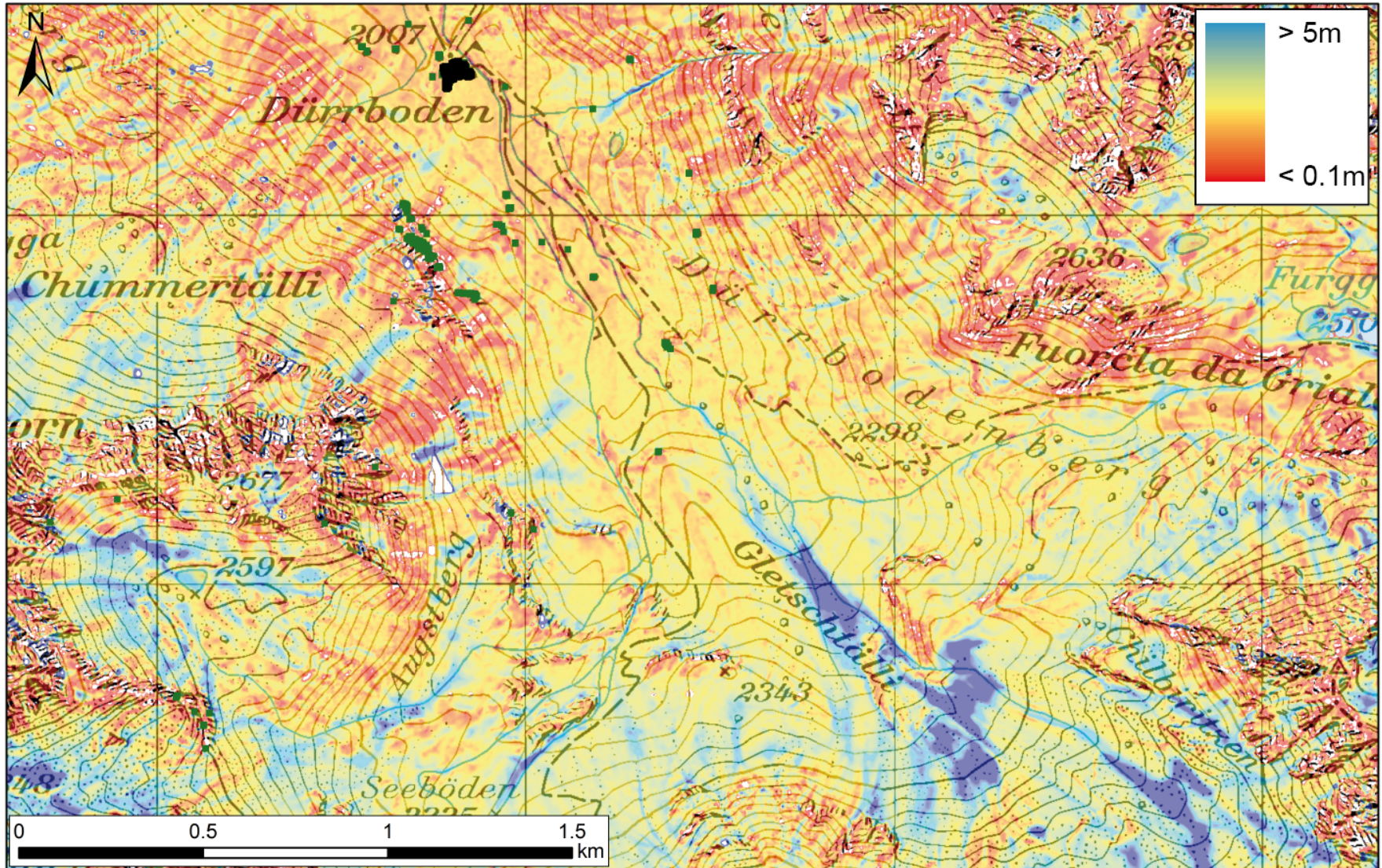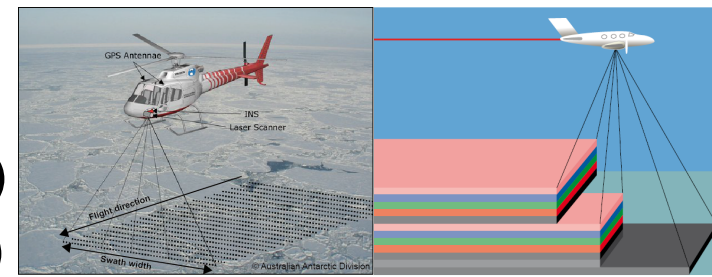
Comparison TLS vs. digital photogrammetry

R = 0.92

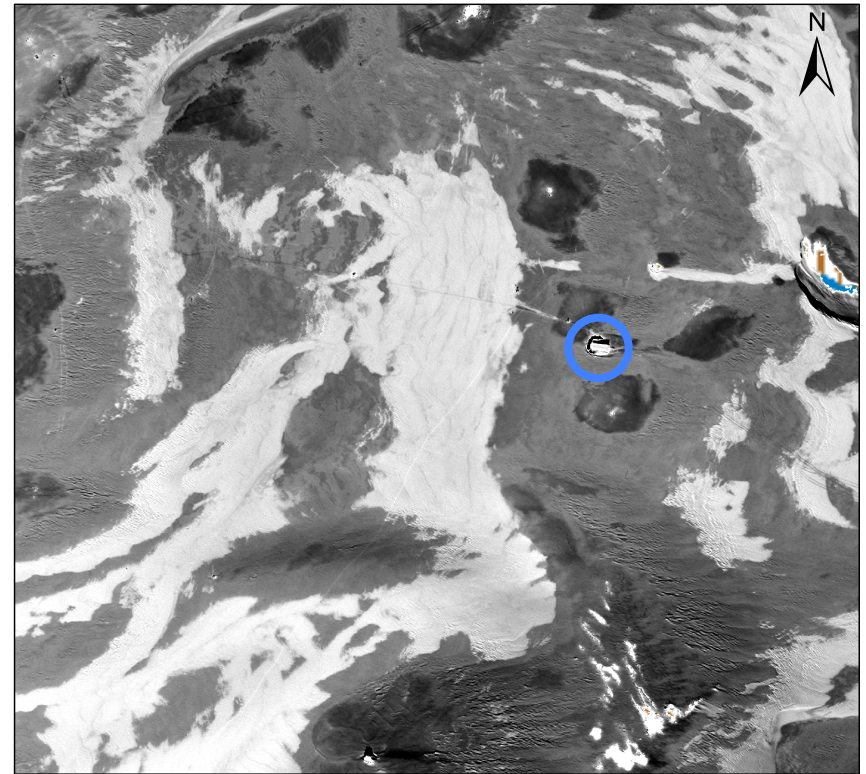Snow depth ADS [m]

Snow depth TLS [m]
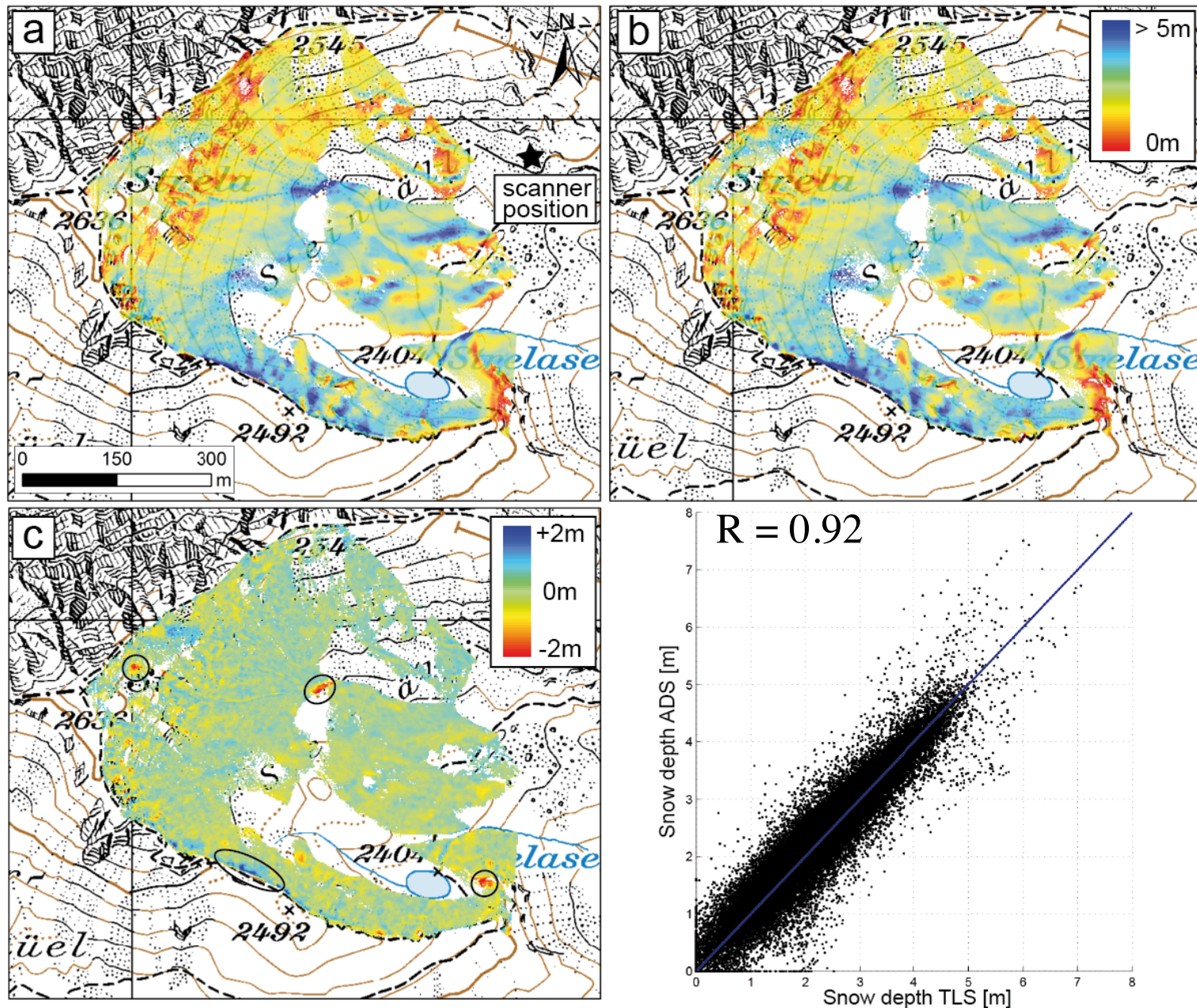
c) Surface snow type / grain size

- Near infrared bands are sensitive to optical equivalent grain size (Warren 1982)

- Important for avalanche danger assessment

- Wetness / free water content, density

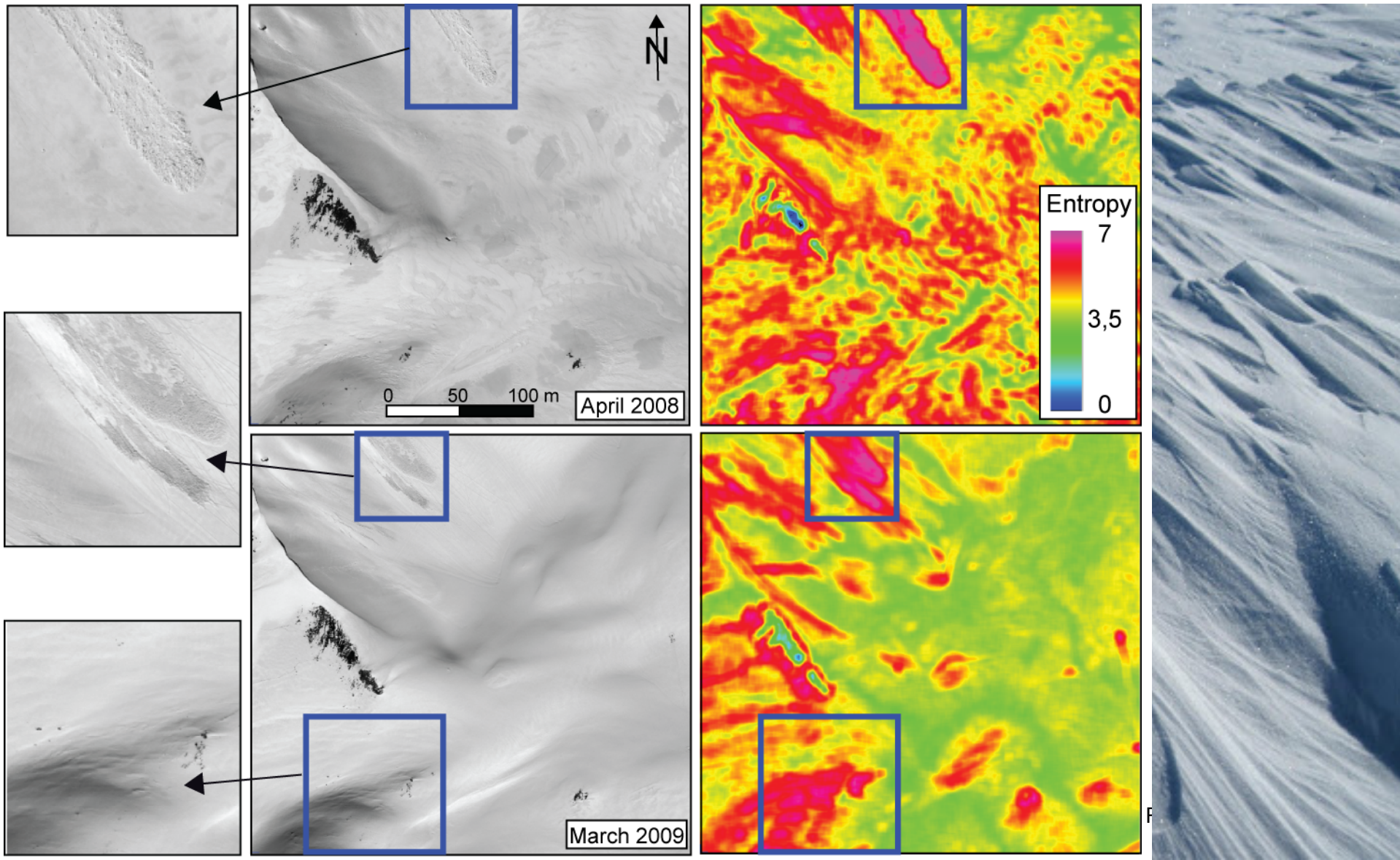ADS blue band

Normalized difference index
NDI (nir + blue / nir - blue)

d) Surface roughness

April 2008

March 2009

0 50 100 m

N

Entropy
7

3,5

0

e) Snowpack layering

50 cm

100 cm

150 cm

Source: http://lima.nasa.gov/antarctica/

Measurement techniques

- Computer tomography (CT):
  - Reconstruction of 3D microstructure
  - Resolution ~ 0.02 mm

- SnowMicroPen (SMP):
  - High resolution stratigraphy
  - Resolution ~ 1 mm
  - Portable and fast –> spatial variability

- Near Infrared Photography (NIP):
  - 2D SSA profiles
  - Resolution ~ 1 mm

(Source: M. Schneebeli, SLF)
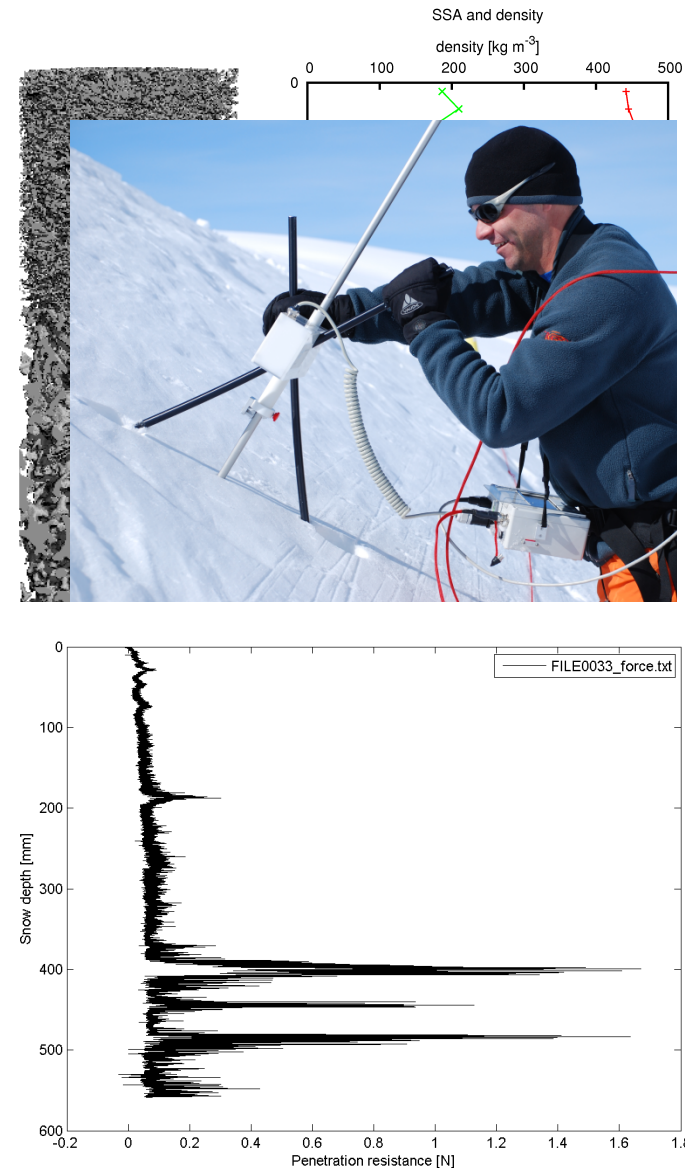
SMP measured Density at Kohnen Station Antartica (cross-section), measurement every 40cm
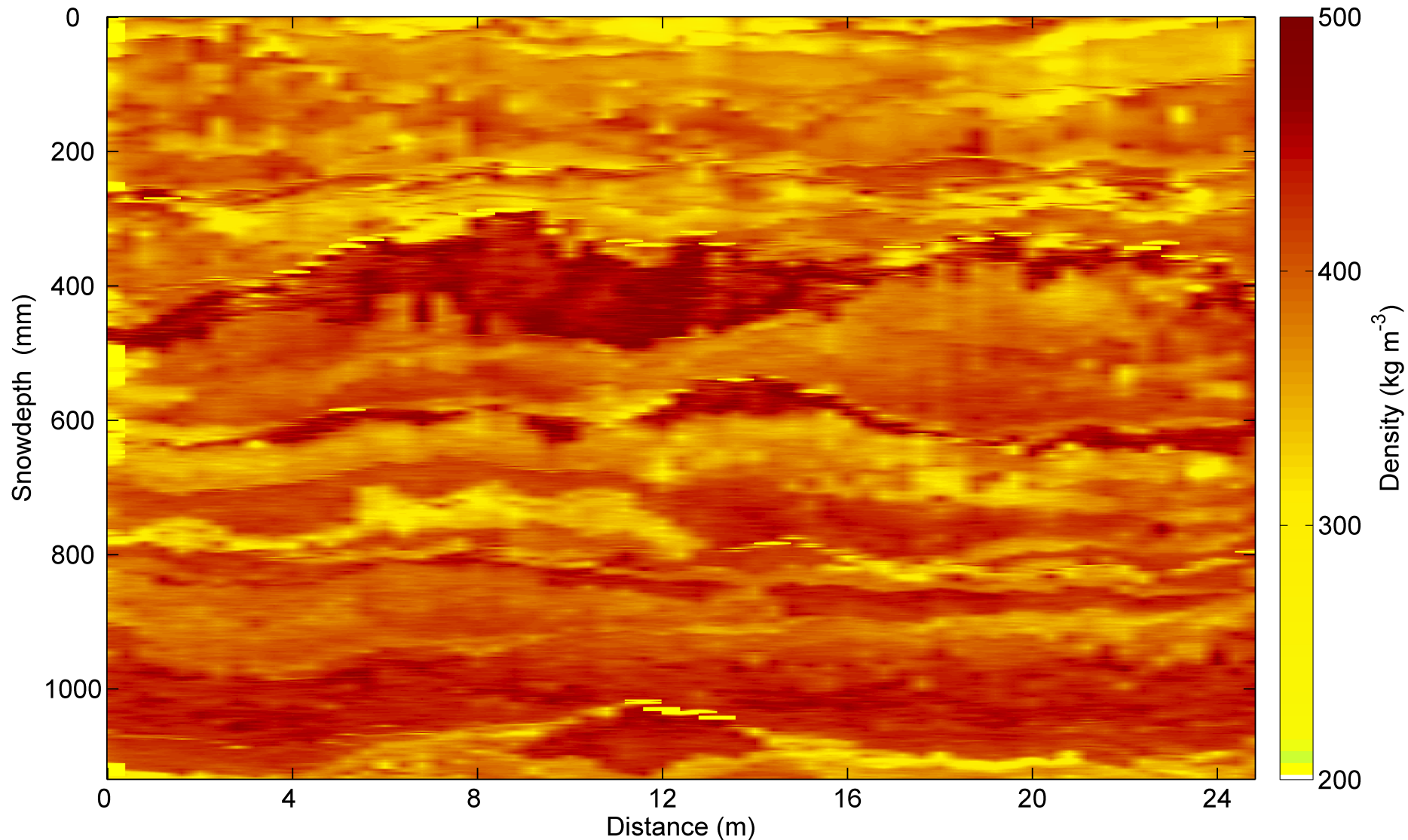
Conclusions

- **Snow in complex terrain** is **important** for numerous applications

- Remote sensing can provide **spatially continuous** data

- The **spatial variability is very high** for all parameters

➔ **high spatial** resolution is requested

- Temporal variability can be high

➔ **high temporal** resolution is requested

- Today's operational remote sensing products **might not be able** to capture the **spatial variability in alpine terrain**

- **Extensive validation** using **high spatial resolution** data

- **Further development** RS of products using high resolution data

EAS IAP Project
Improved Alpine Avalanche Forecast service

- How can we use satellite technology (earth observation, GNSS & satcom) to improve avalanche warning?

- Consortium: SLF/ NGI / ENVEO / GAMMA

- Key users:

  - European avalanche warning services

  - Regional/local users (e.g. road administration, ski resorts, authorities)

  - The general public

Thank you

Hanuman Tibba, 5928m a.s.l.
Manail, Himachal Pradesh, India