



Activities in ground remote sensing at IGP

Alain Geiger, Ladina Steiner, Michael Meindl, Philippe Limpach

Institute of Geodesy and Photogrammetry

ETH Zürich

Switzerland

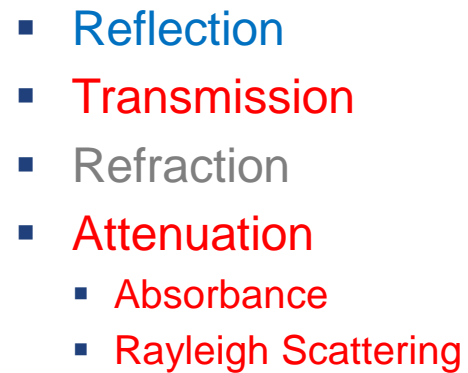
Topics

- Experimental water measurements
- Snow water equivalent
- Snow hight/depth
- Indirect soil moisture/temperature effect



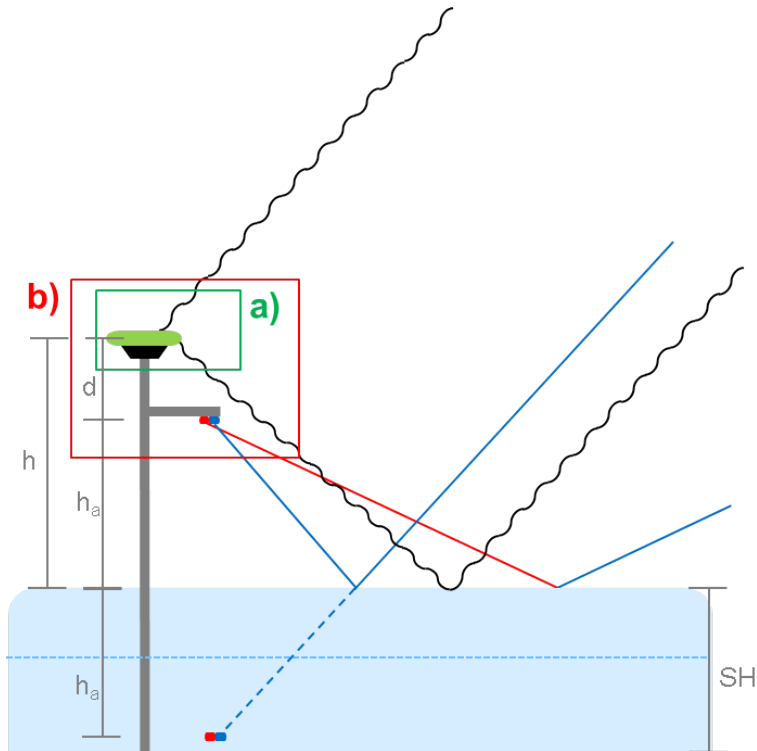
Switzerland





Snow Depth Estimation

GNSS-reflectometry (GNSS-R):



a) GNSS-R SNR method

b) GNSS-R phase method

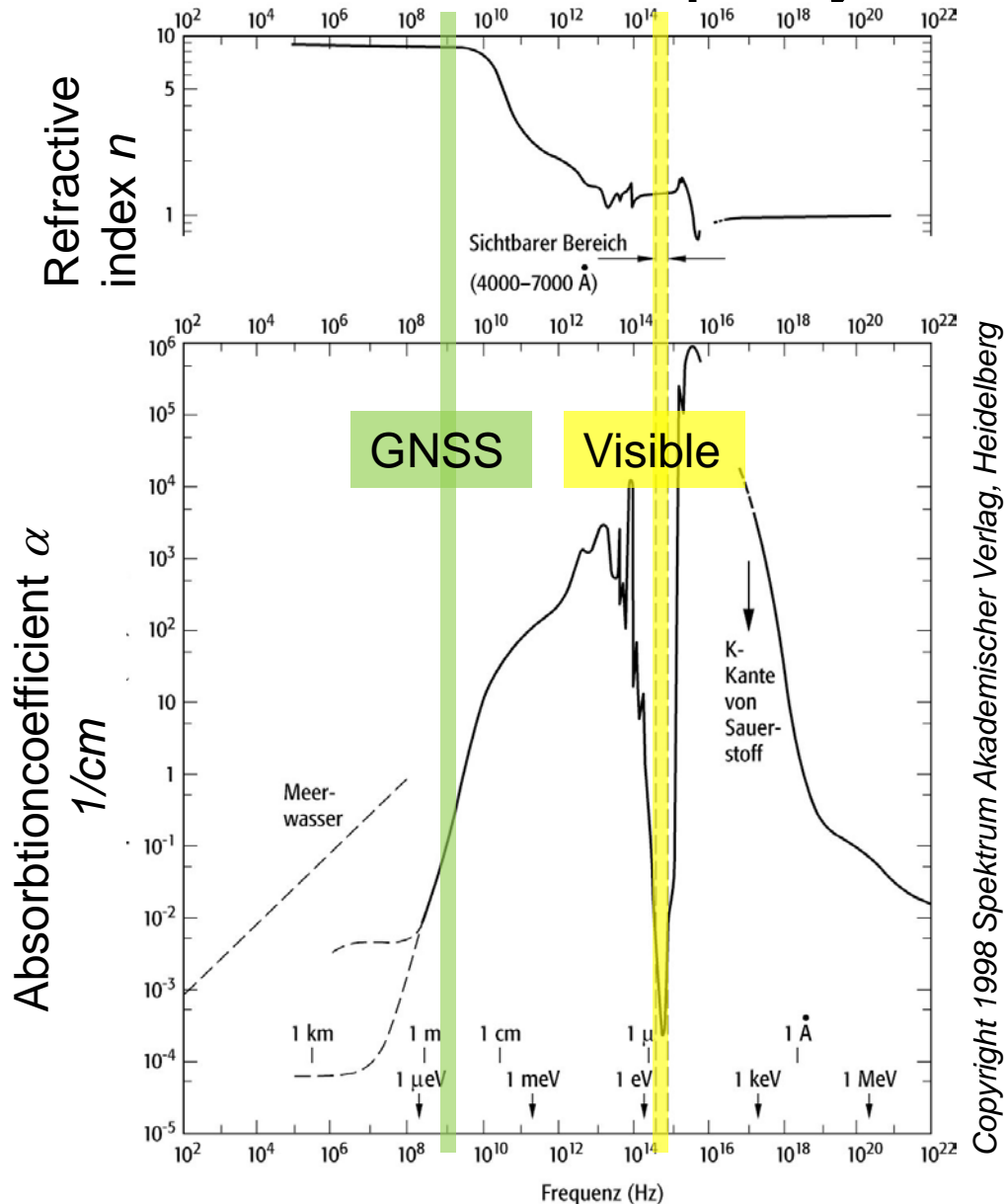
Refractive Index of Water

Table I. Refractive Index of Water at Temperatures of 20 and 0°C

Frequency (GHz)	Refractive index ($N = n' + in''$)	
	$T = 20^\circ\text{C}$	$T = 0^\circ\text{C}$
0.6	$8.96 + 0.1713i$	$9.374 + 0.3146i$
0.8	$8.956 + 0.2172i$	$9.363 + 0.4083i$
1.0	$8.952 + 0.2648i$	$9.348 + 0.5031i$
1.6	$8.933 + 0.4105i$	$9.283 + 0.7851i$
2.0	$8.915 + 0.5078i$	$9.225 + 0.9677i$
3.0	$8.858 + 0.7471i$	$9.035 + 1.394i$
4.0	$8.780 + 0.9771i$	$8.794 + 1.768i$
6.0	$8.574 + 1.399i$	$8.227 + 2.341i$
8	$8.319 + 1.761i$	$7.638 + 2.702i$
10	$8.033 + 2.058i$	$7.089 + 2.907i$
16	$7.148 + 2.614i$	$5.822 + 3.023i$
20	$6.614 + 2.780i$	$5.243 + 2.933i$
30	$5.581 + 2.848i$	$4.326 + 2.607i$
40	$4.886 + 2.725i$	$3.802 + 2.306i$
60	$4.052 + 2.393i$	$3.235 + 1.854i$
80	$3.581 + 2.100i$	$2.941 + 1.544i$
100	$3.282 + 1.864i$	$2.766 + 1.319i$
160	$2.82 + 1.382i$	$2.519 + 0.9088i$
200	$2.668 + 1.174i$	$2.448 + 0.7490i$
300	$2.481 + 0.8466i$	$2.368 + 0.5165i$

Matthew N. O. Sadiku
APPLIED OPTICS/Vol.24,No.4/15 February 1985

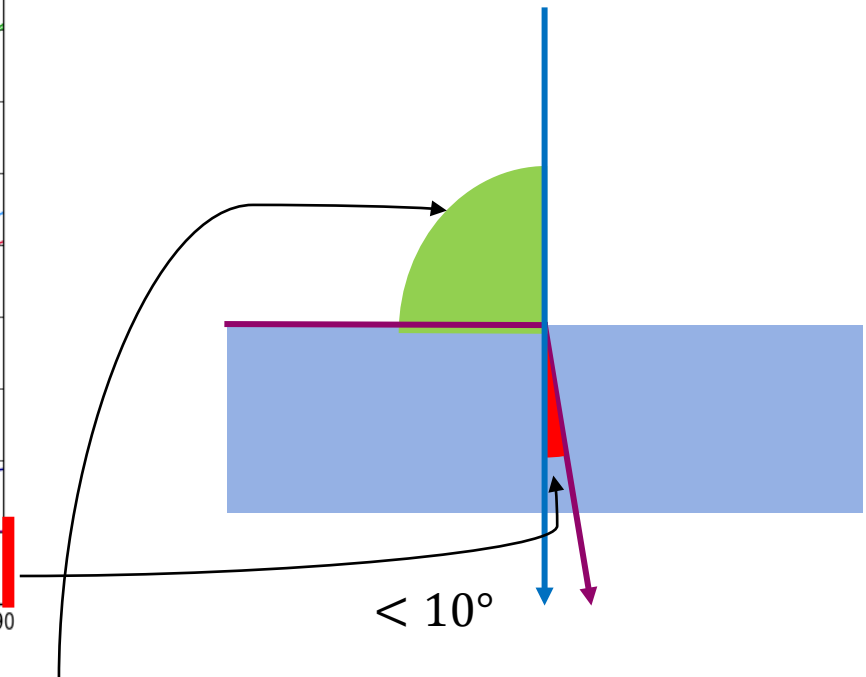
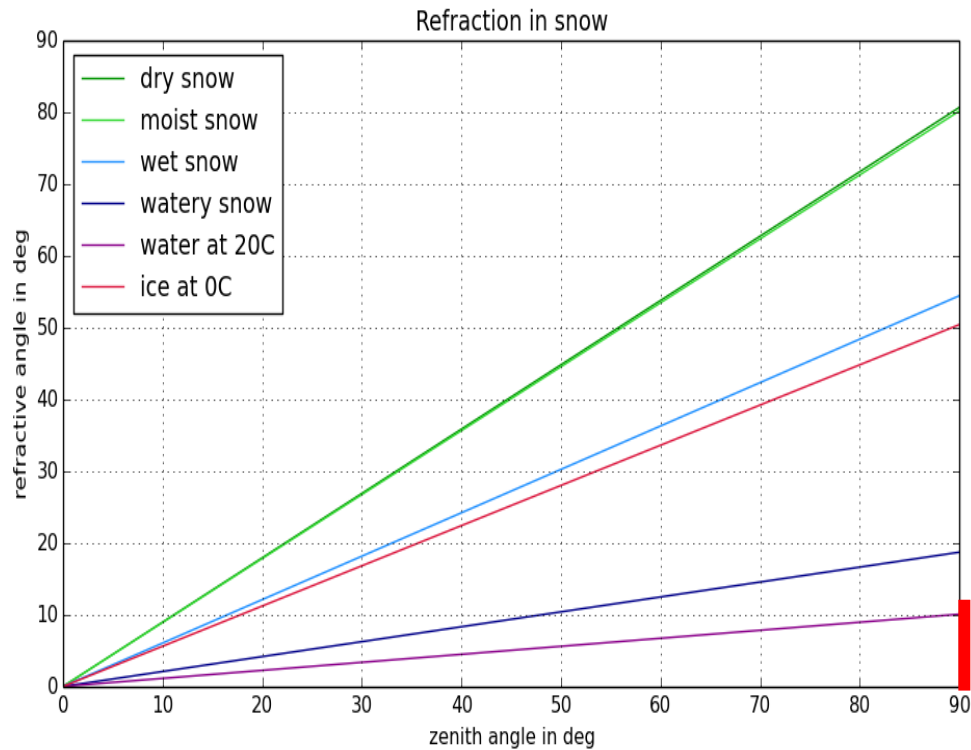
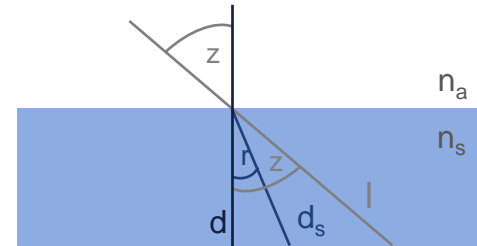
Refractive index of Water vs. Frequency



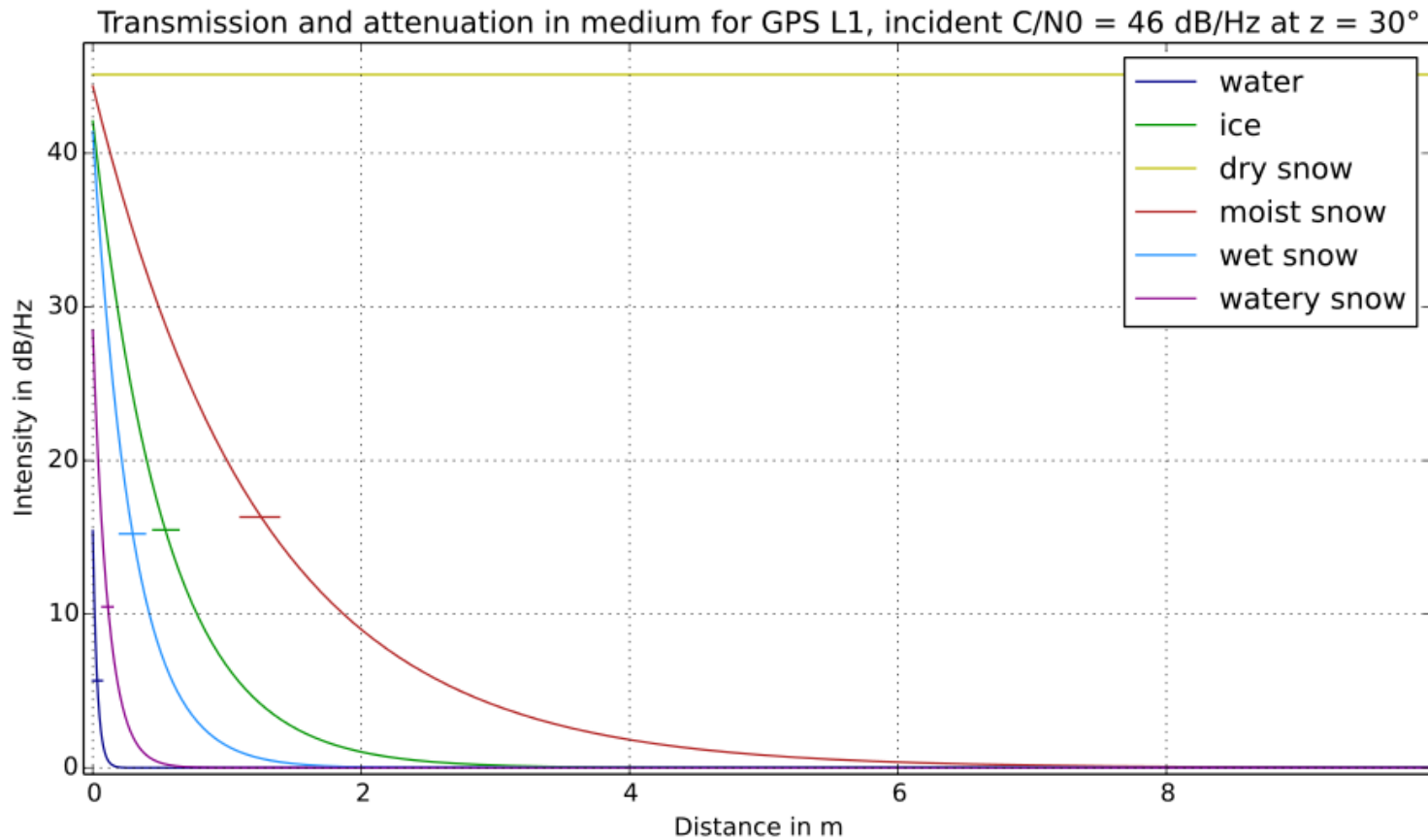
Copyright 1998 Spektrum Akademischer Verlag, Heidelberg

Refraction

$$r = \arcsin\left(\frac{n_a * \sin(z)}{n_s}\right)$$



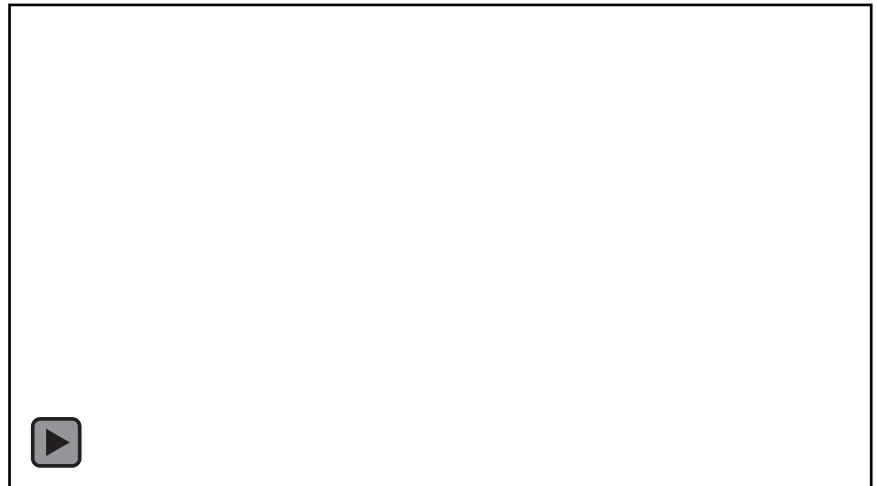
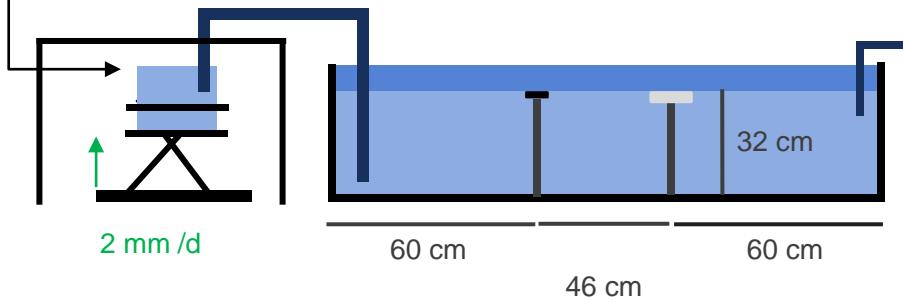
Theoretical Conclusion



Experimental Setup

Field Regions		Leica AS10	ublox
Antenna dimension		16 cm	6 cm
1. Reactive Nearfield	$R_1 < 0.62 (D^3/\lambda)^{1/2}$	9.1 cm	2.1 cm
2. Radiative Nearfield	$R_2 < 2D^2/\lambda$	26.9 cm	3.8 cm
3. Farfield	$R_3 > R_2 + \lambda$	45.9 cm	22.8 cm

Level of reference



Self regulating water level by communicating vessels

Further Impressions



SLF Test Site



More snow

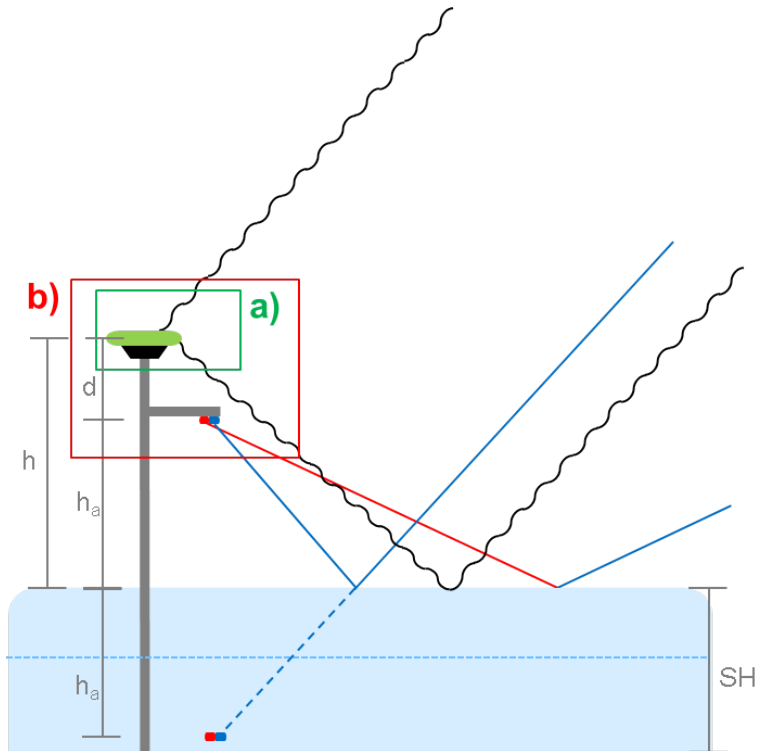


Less snow

Fotos: Ph. Limpach

Snow Depth Estimation at Test Site

GNSS-reflectometry (GNSS-R):

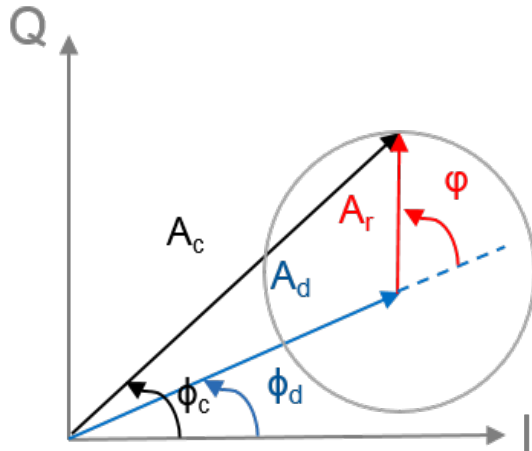


a) GNSS-R SNR method

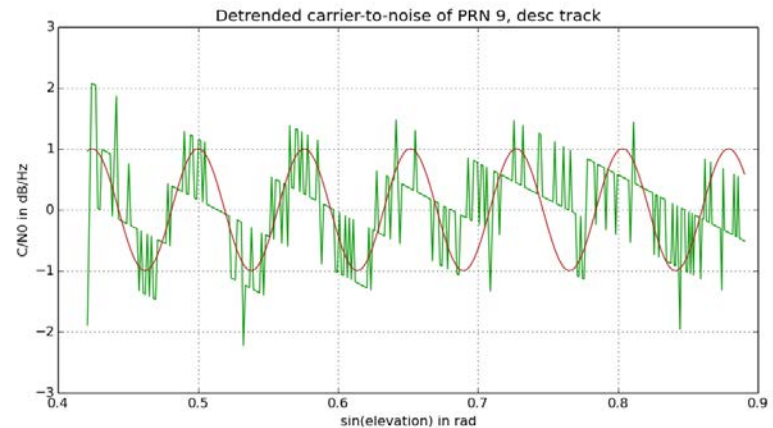
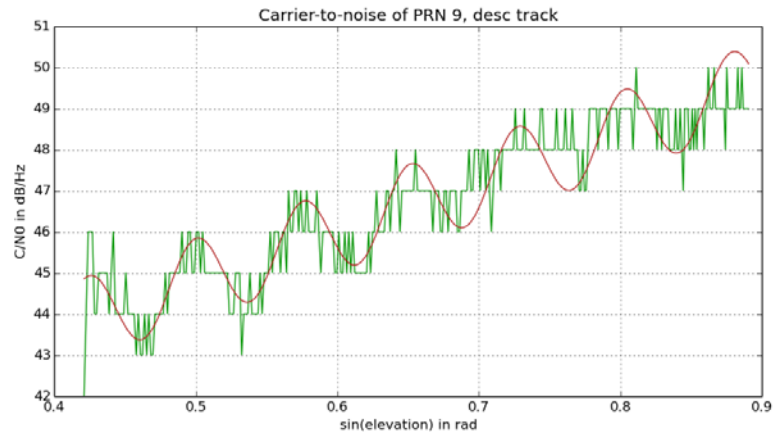
b) GNSS-R phase method

Snow Depth Estimation at Test Site

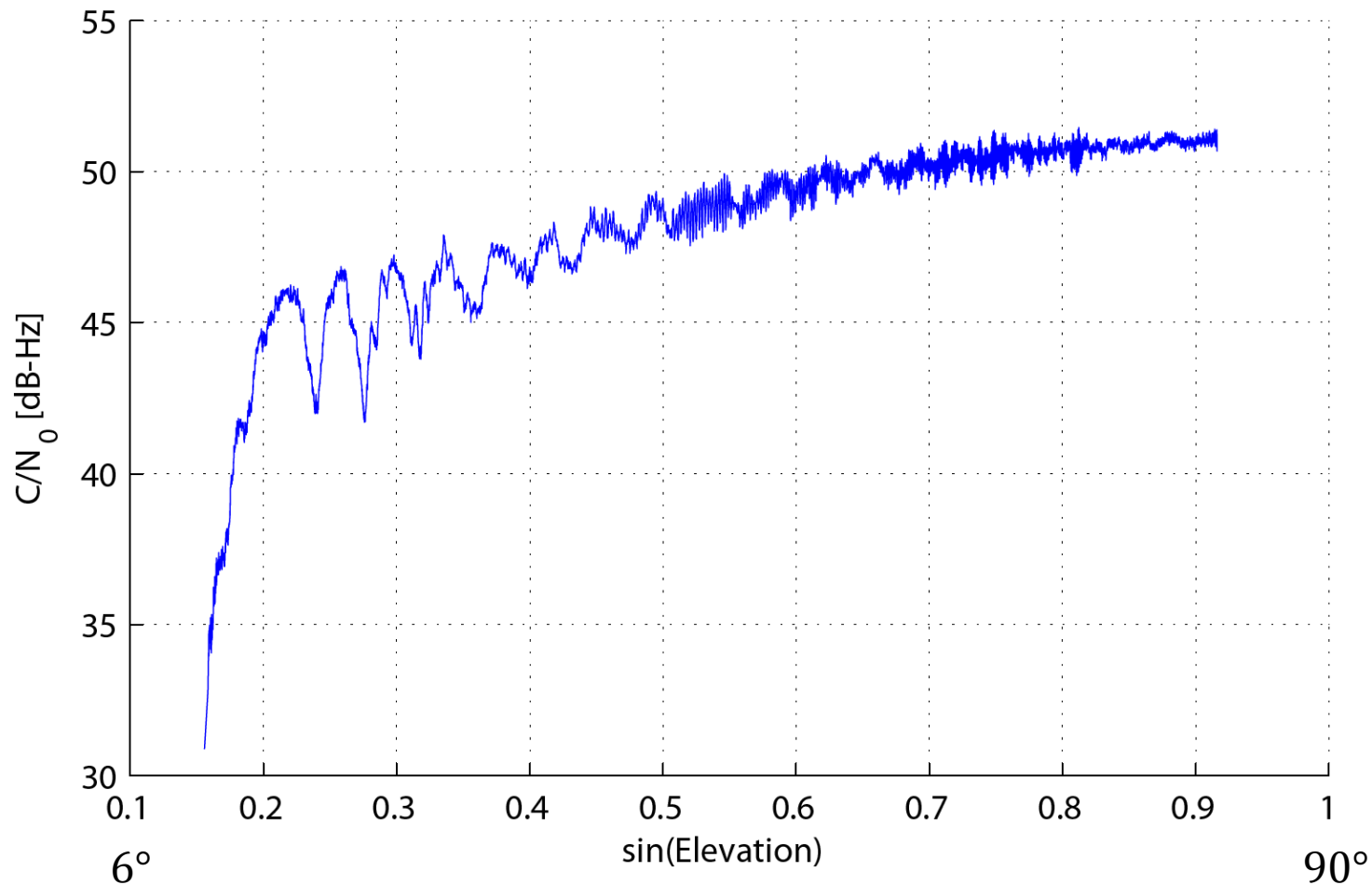
GNSS-R SNR method



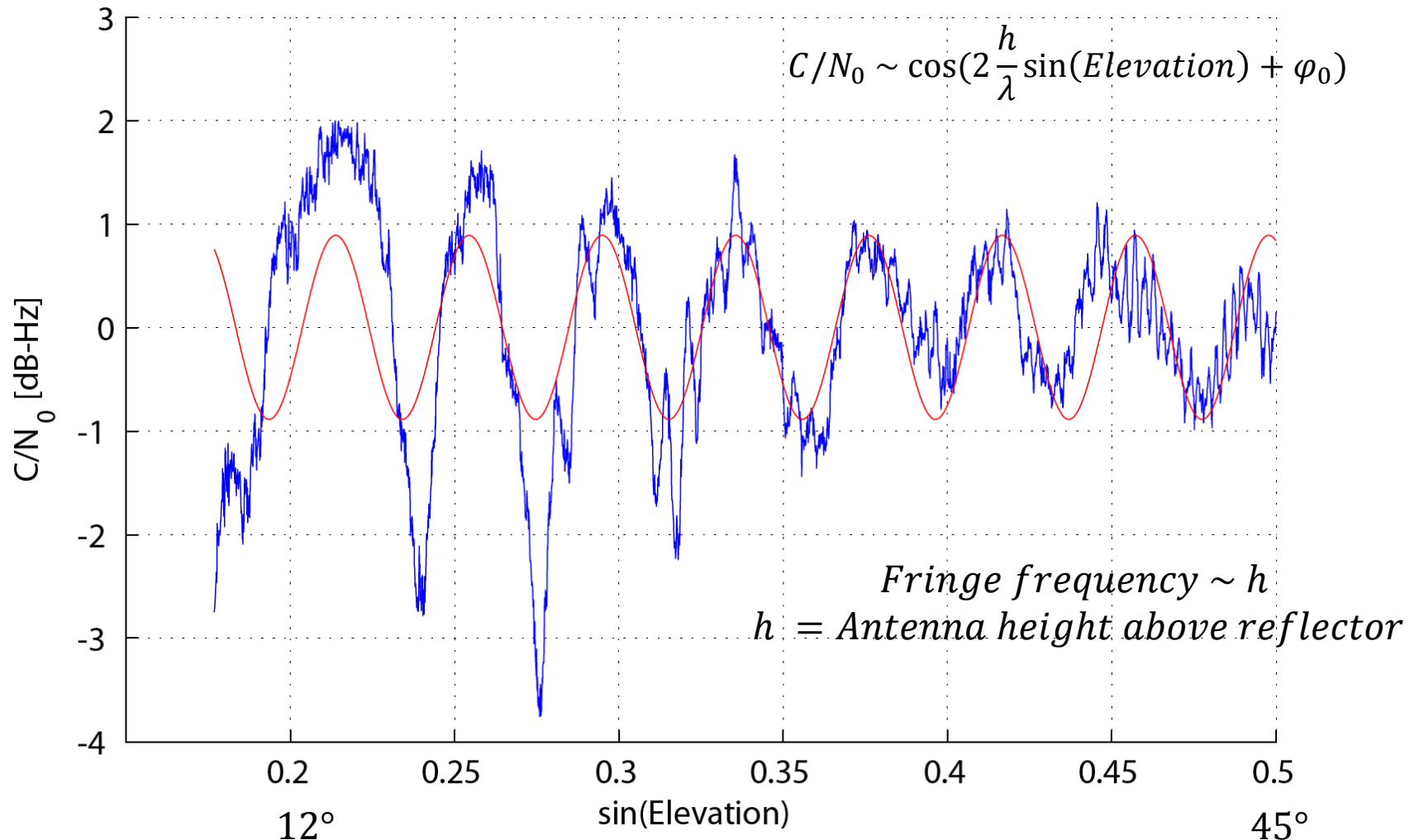
$$C/N_0 \sim \cos\left(2 \frac{h}{\lambda} \sin(Elevation) + \varphi_0\right)$$



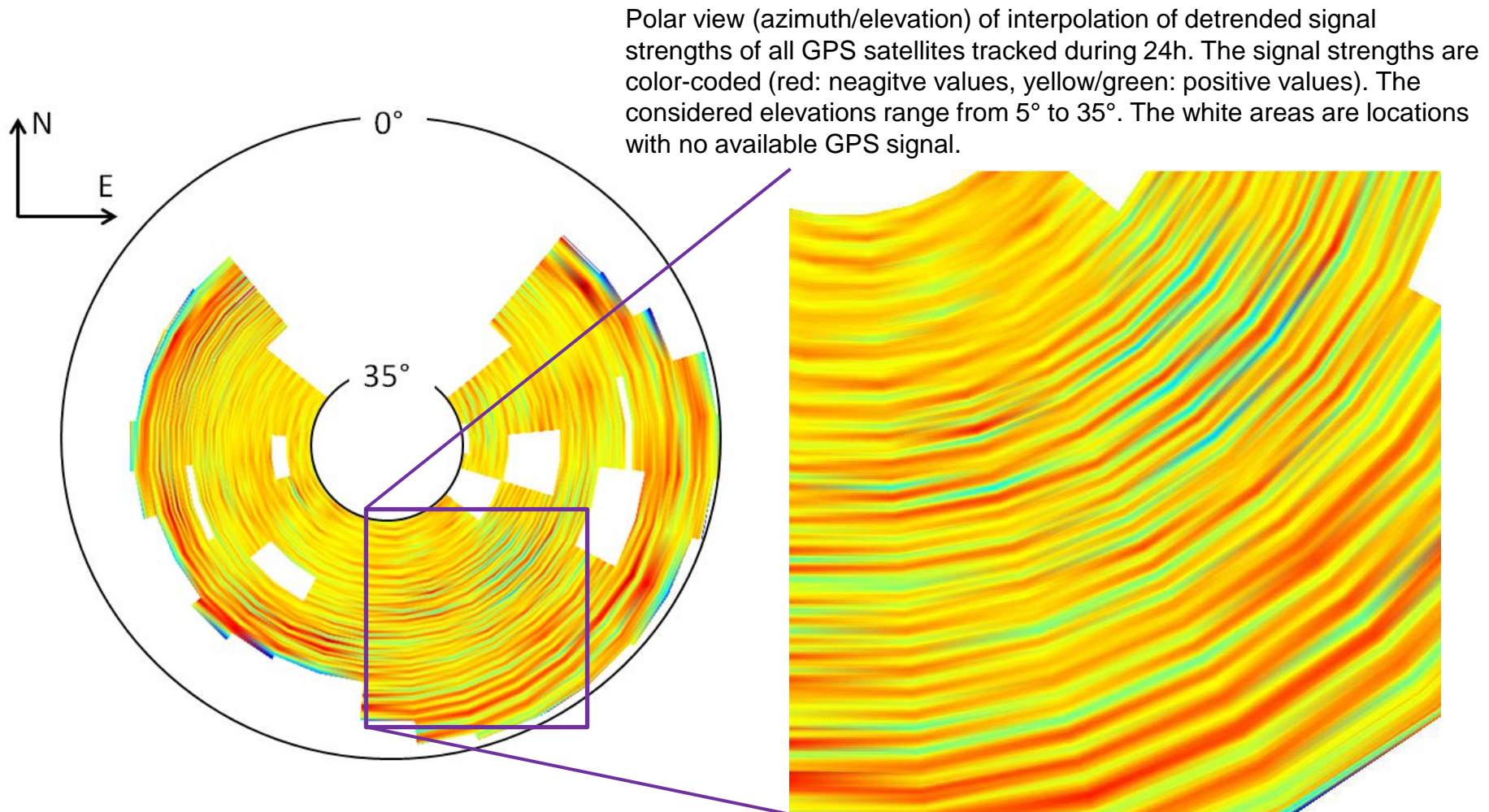
Carrier to Noise (one satellite) vs. sin(elevation)



Fringe Frequency (one satellite)

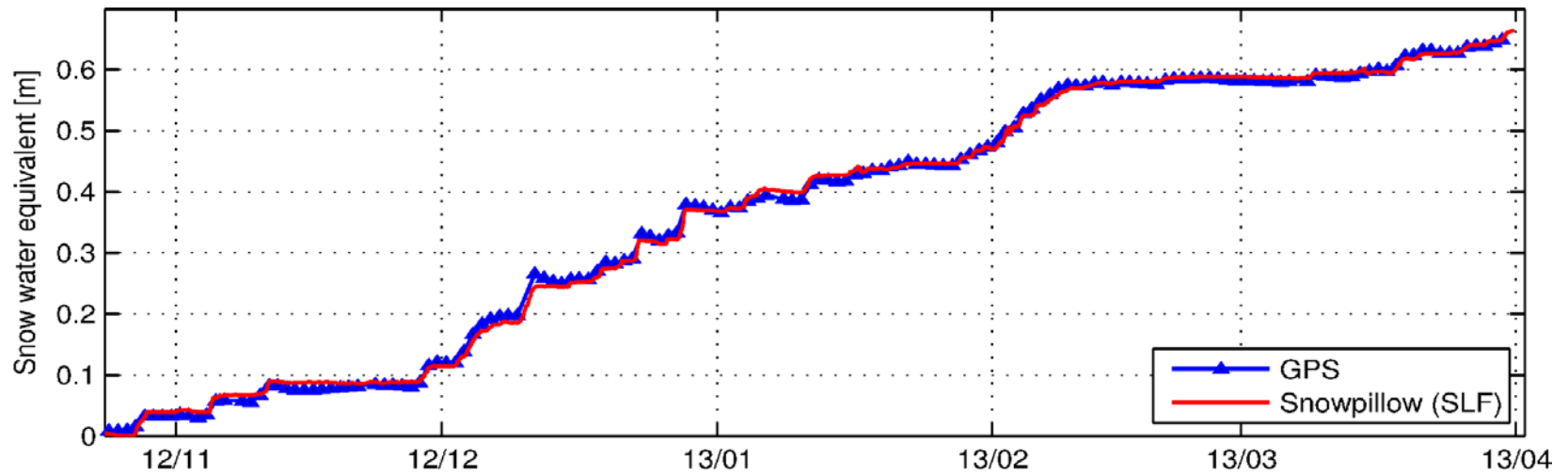


Fringes of all Satellites as Polar Plot

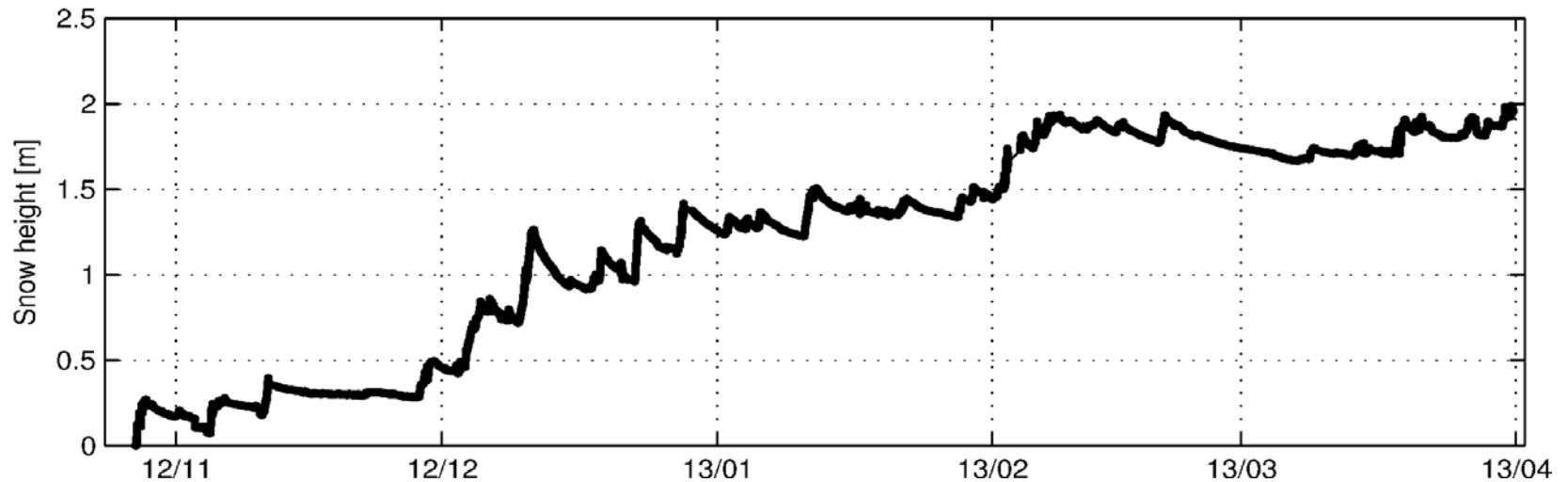


From Masterthesis, Gschwend

First Results SWE and SH

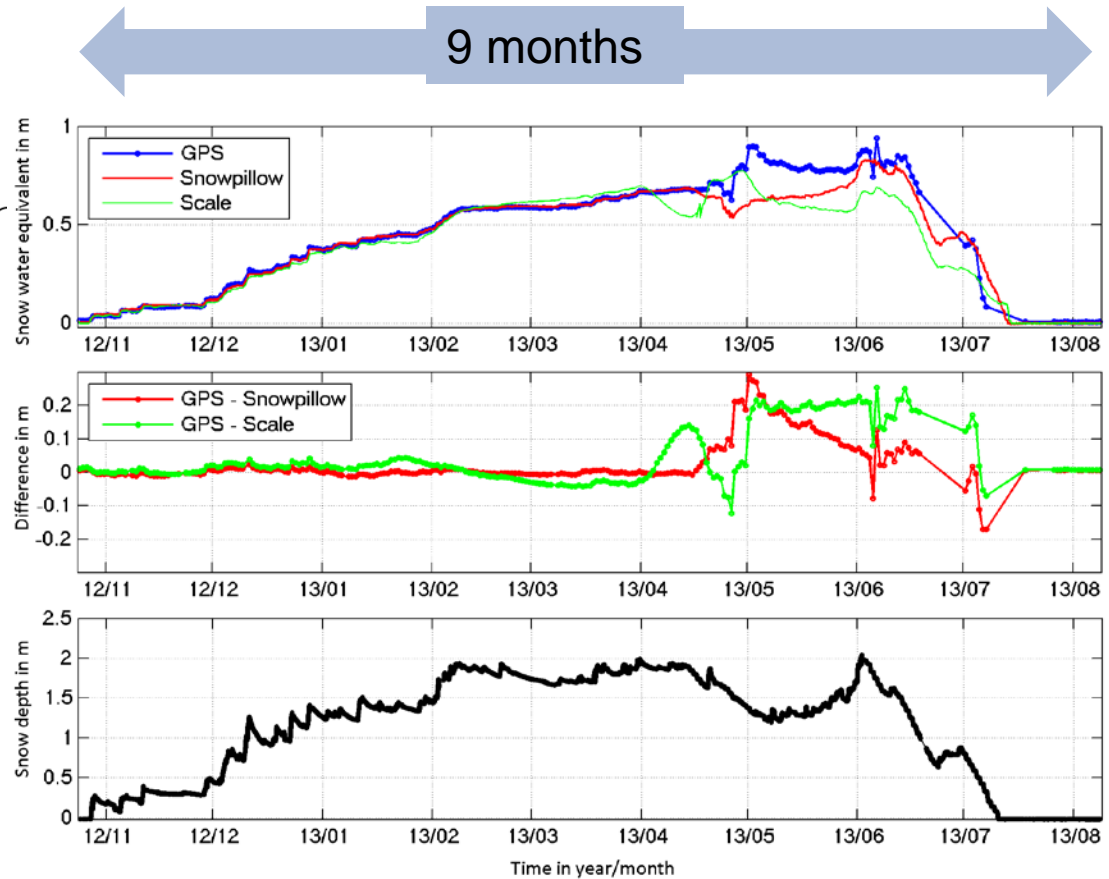
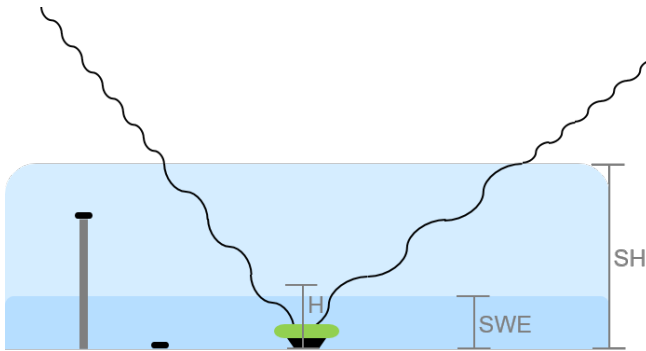


5 months

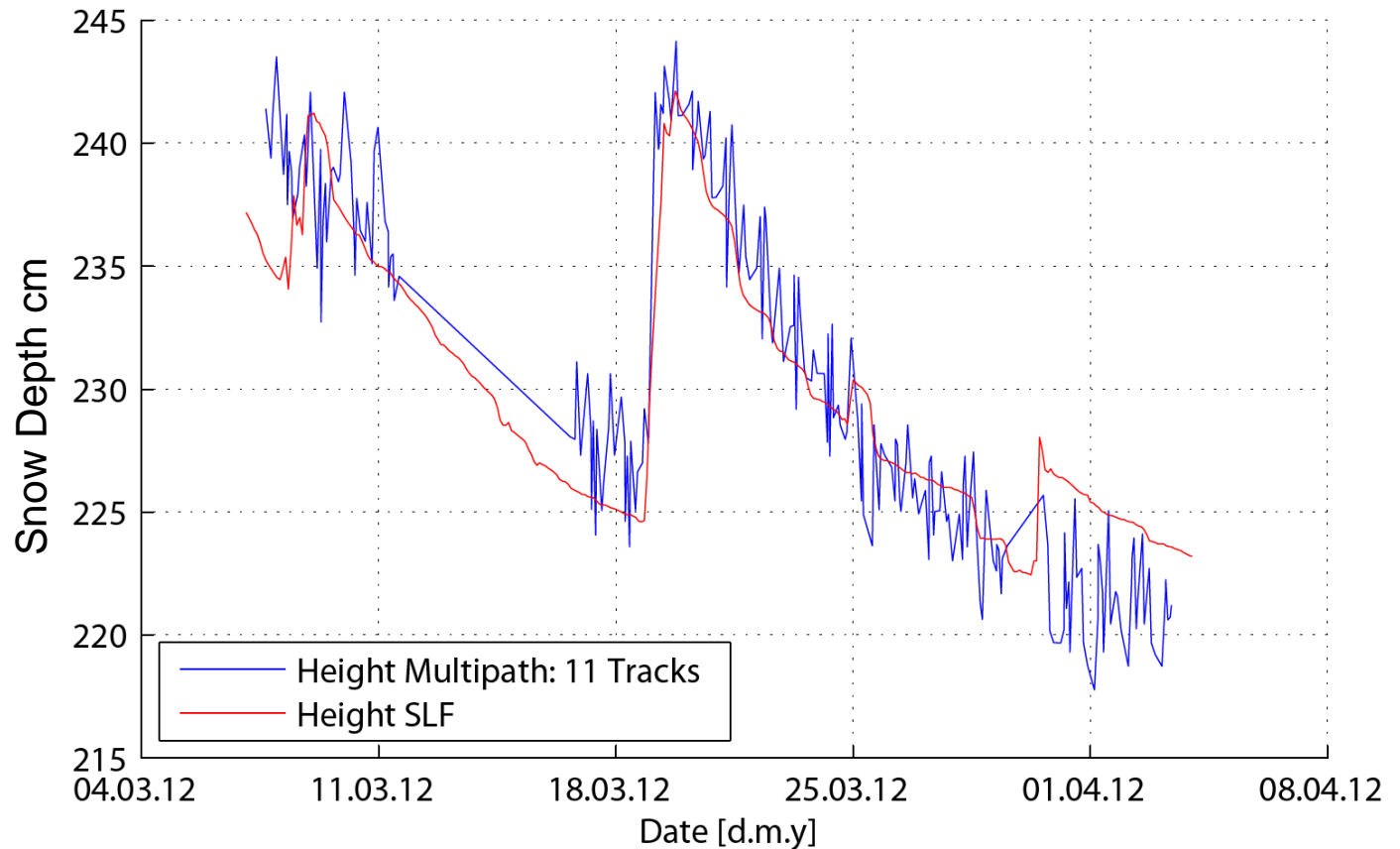


Snow Water Equivalent (SWE) Estimation at Test Site

GNSS sub-surface refraction method:



Snow Depth Determination

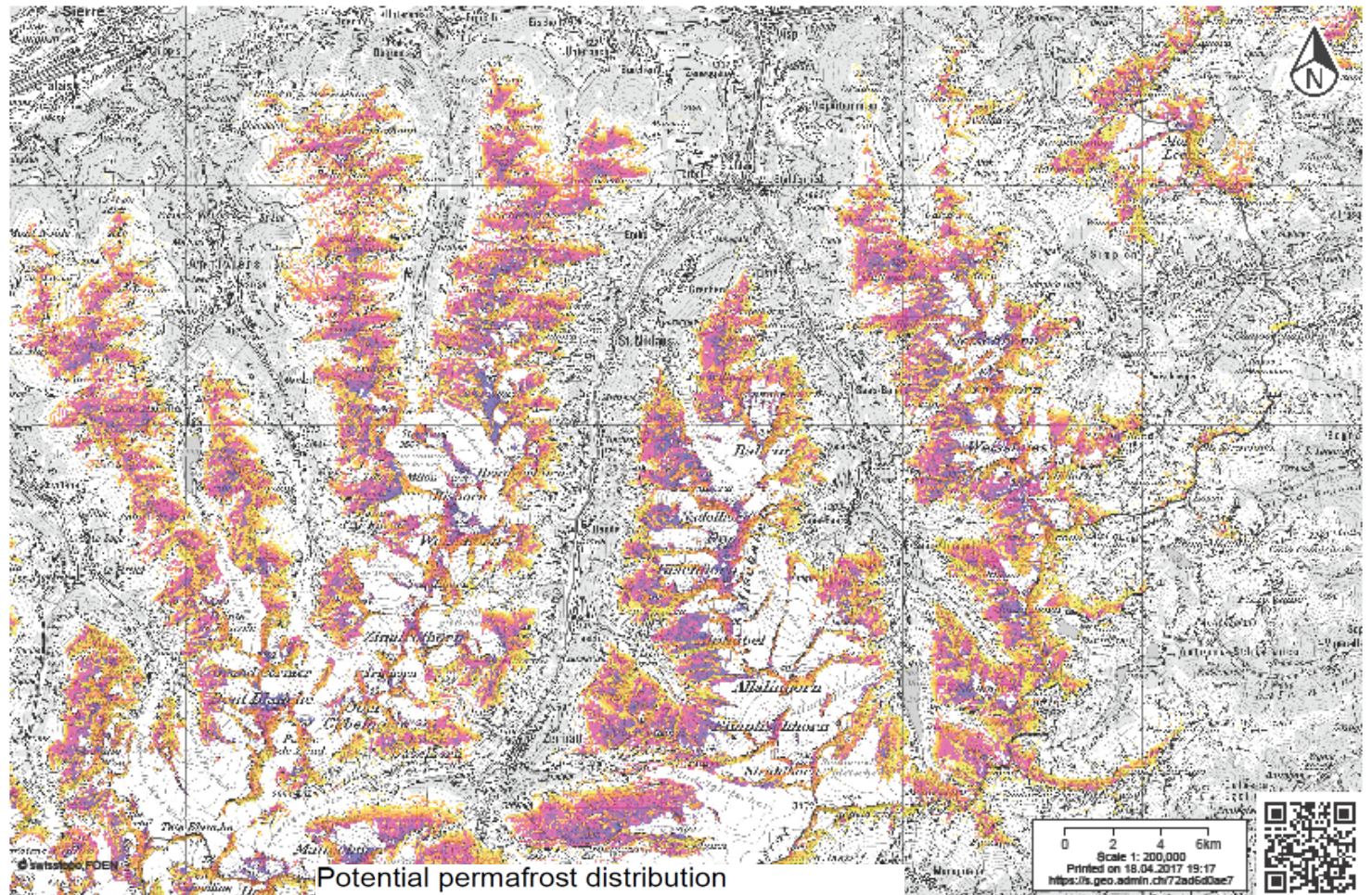


Snow heights computed from GPS signal strengths (blue line) and snow surface observed with a laser distance sensor (red line). The GPS snow heights are a superposition of the results from 11 satellite tracks.

Area of Investigation



Areas Prone to Permafrost (Valais, CH)



- Local permafrost possible, patchy, discontinuous
- Local permafrost possible, frequent patchy distribution
- Local permafrost possible, patchy to extensive
- Extensive permafrost likely
- Extensive permafrost likely, increasing thickness
- Extensive permafrost likely, very thick in places, to over 100m

Rockglacier 08.2009 to 04.2011 (Grabengufer, Wallis, Switzerland)

25.07.2009



Credits: R.Delaloye, Uni Fribourg

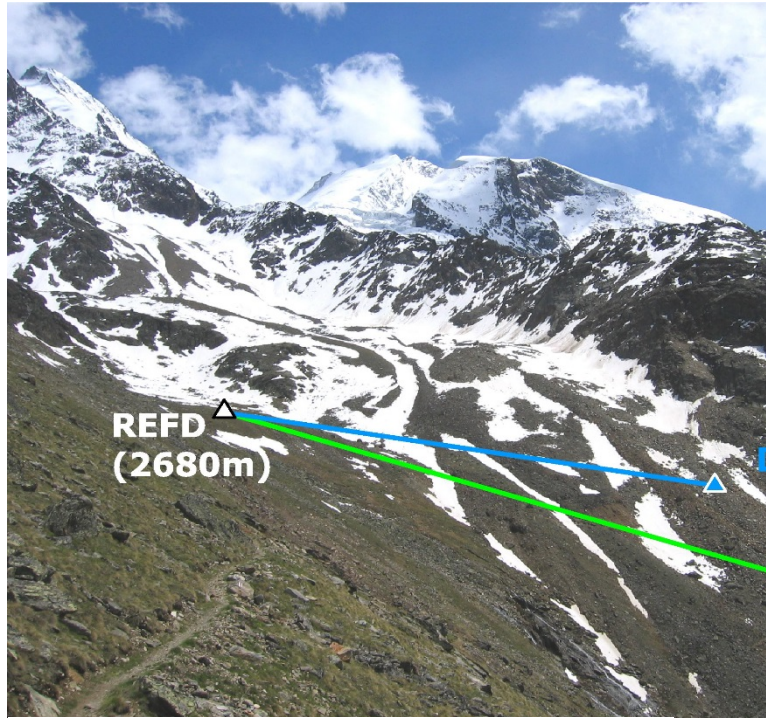
Permafrost: local, year to rapid

Image Analysis



Automatically analyzed sequence of single camera frames (pictures: R. Delaloye, Uni Fribourg). White points: stable areas, also used for picture calibration. White arrows: deforming area, difference over 15 days. Grabengufer rock glacier.

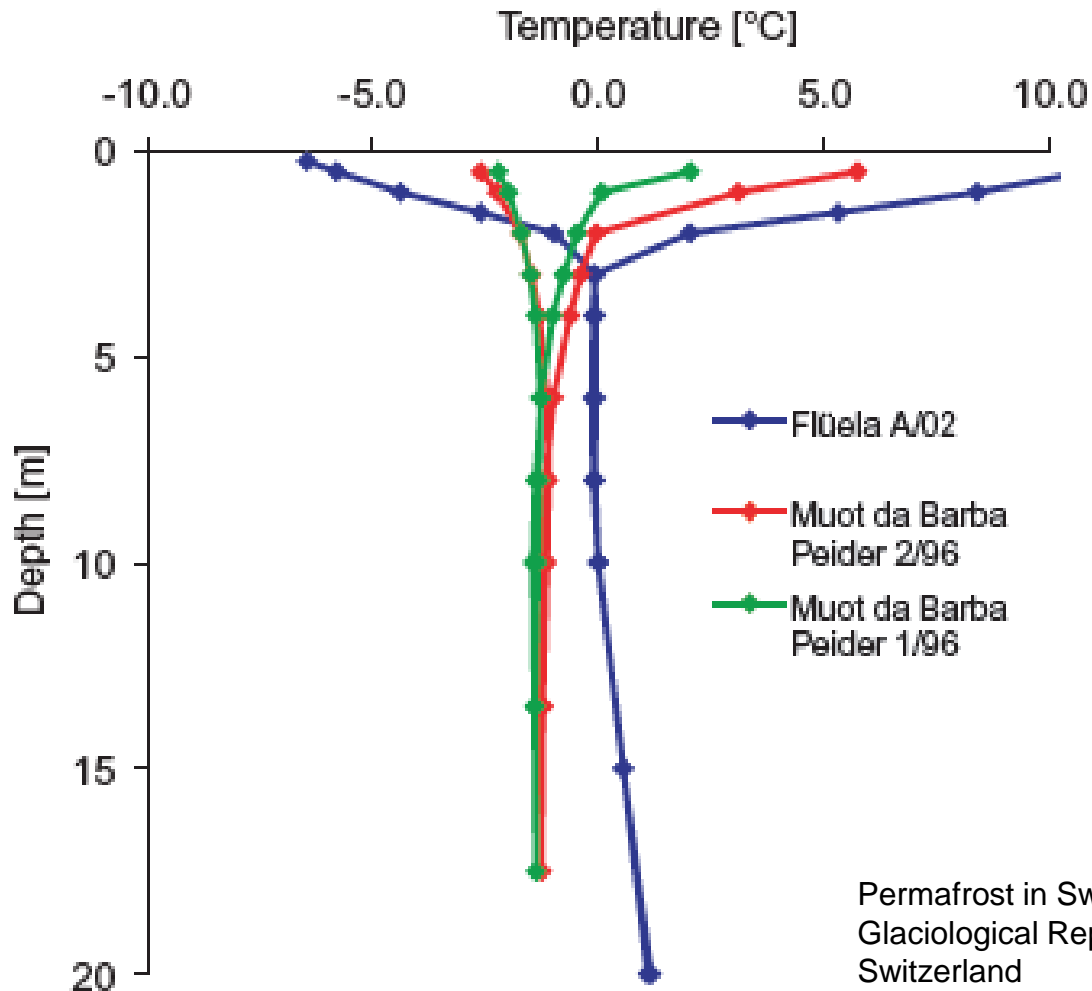
GPS Installation



Box incl.
-GPS receiver
-data logger
-battery

Distance	REFD-DIR2	REFD-DIR3
horizontal	360m	285m
vertical	130m	50m

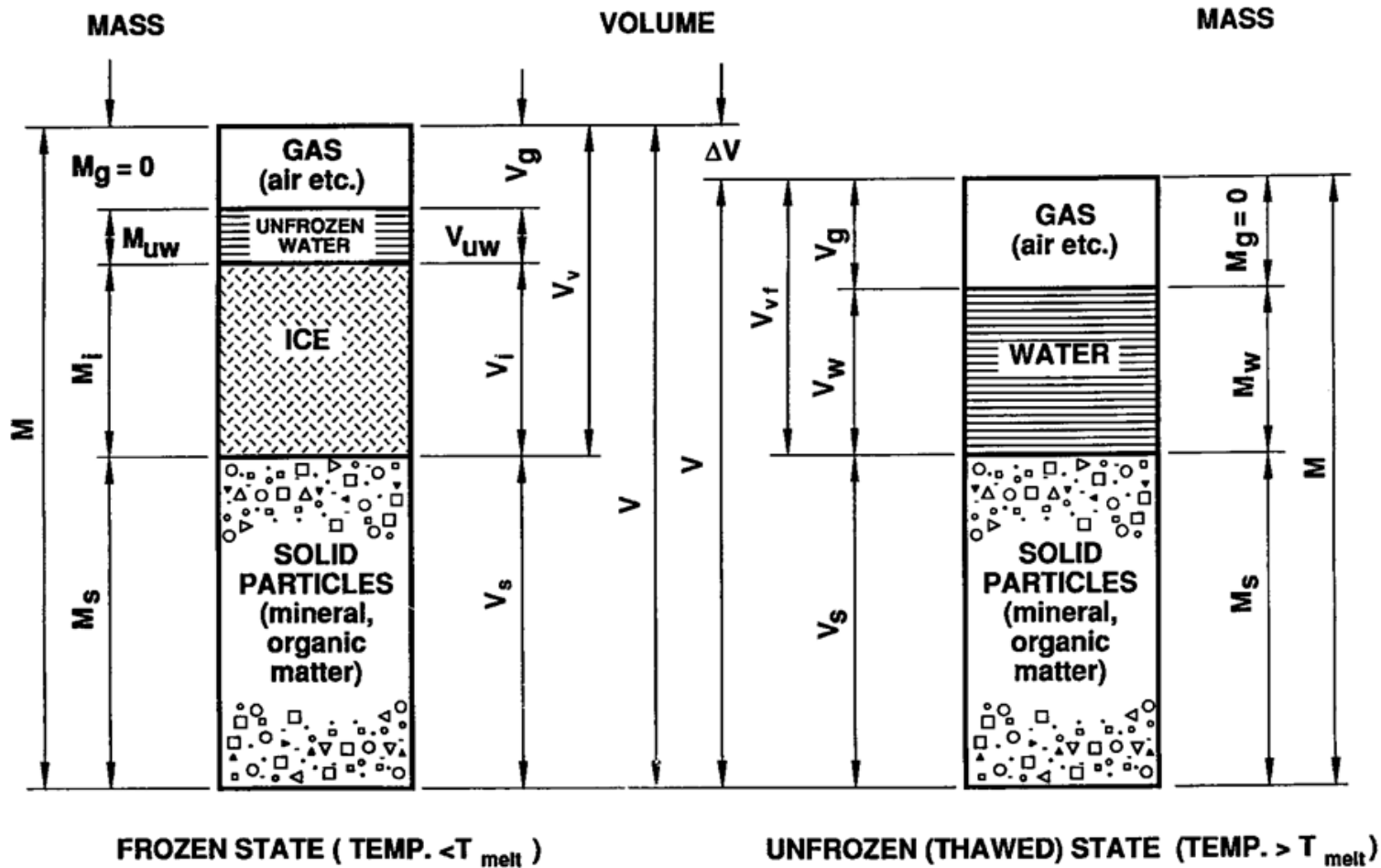
Temperature in Ground



Permafrost-temperature distribution with depth at three PERMOS drill sites. The T-z profiles are plotted for February and August 2003 for Muot da Barba Peider, and for March and August 2003 for Flüela, respectively.

Permafrost in Switzerland, 2002/2003 and 2003/2004,
Glaciological Report (Permafrost) No. 4/5, Permafrost Monitoring
Switzerland

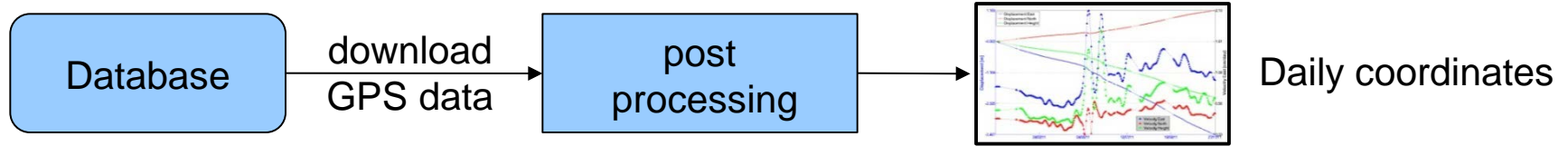
Frozen and Unfrozen Ground



Mass-volume model for frozen and unfrozen ground (Andersland and Ladanyi, 1994)

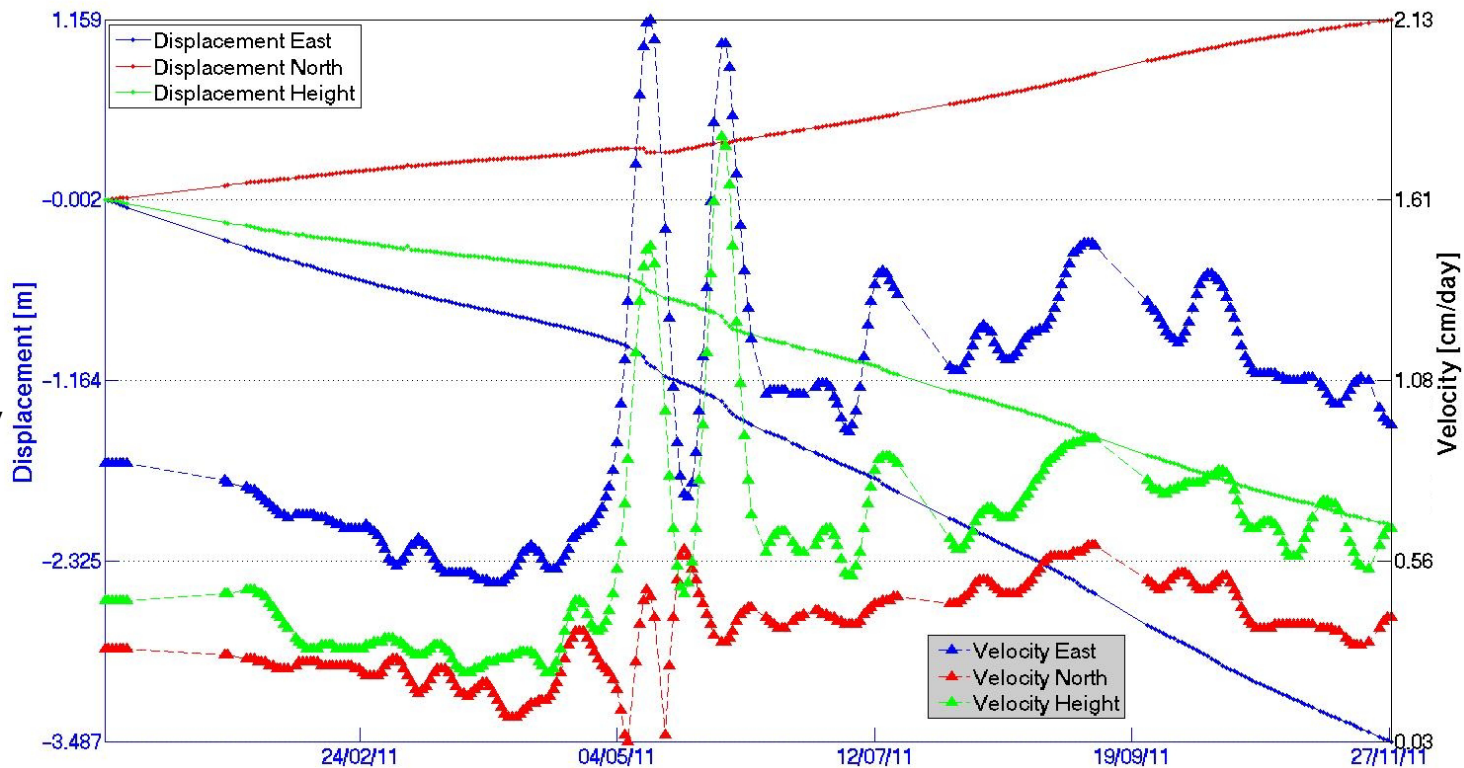
Displacements measured by GPS receivers:

Daily solutions

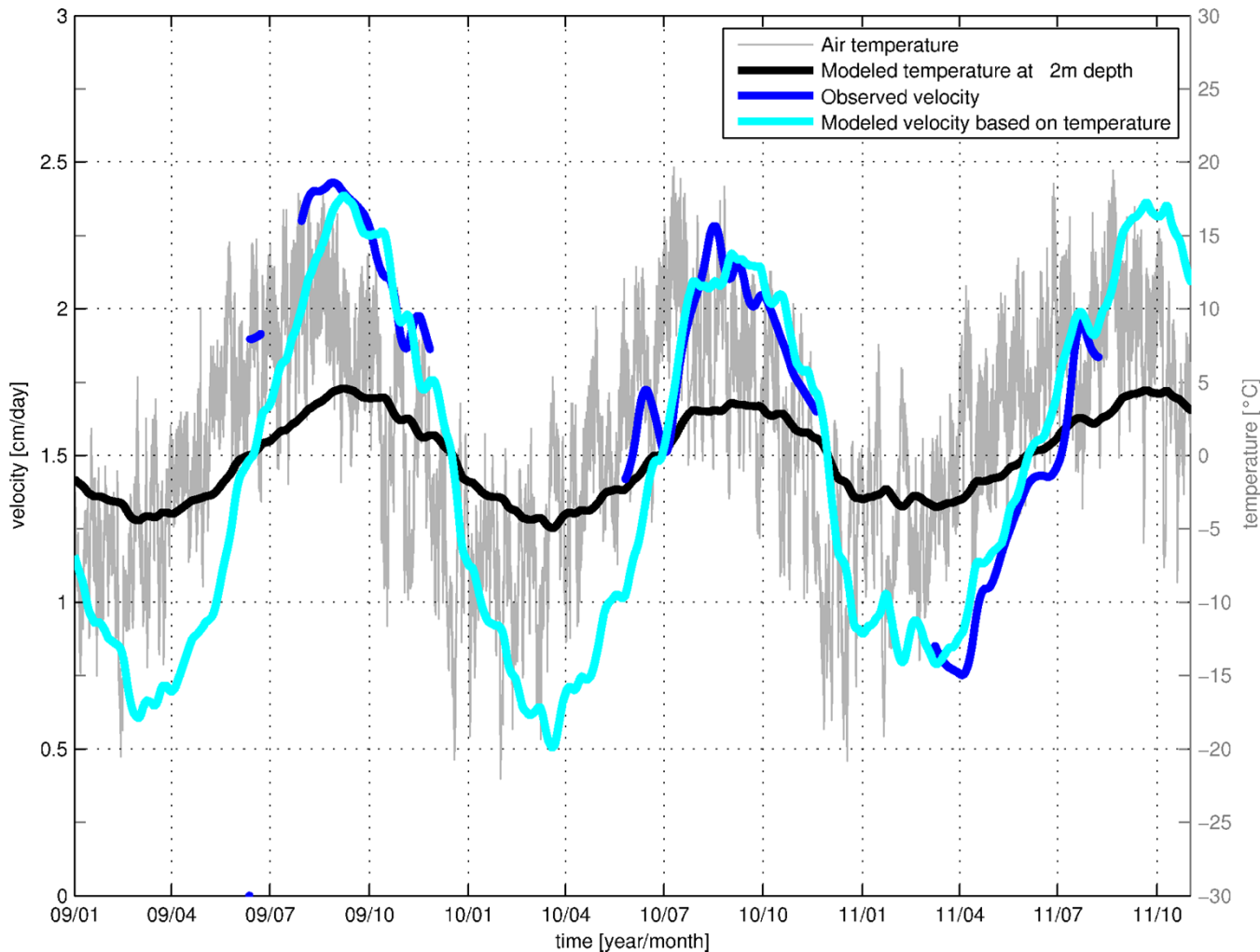


■ Low temporal resolution
(one position per day)

■ High accuracy
(2~3 mm)



Correlation of Movement, Temperature, Depth, and ...?



What's about
soil moisture?



Thank you for your interest