Monitoring the Dynamics of Glaciers with Low-Cost GNSS receivers

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Intention

- The former BEK (Bavarian Commission for International Geodesy) has been joined with Commission for Glaciology
- Glaciology is the main focus of the entire group
- Geodesy as a new component in Glaciology

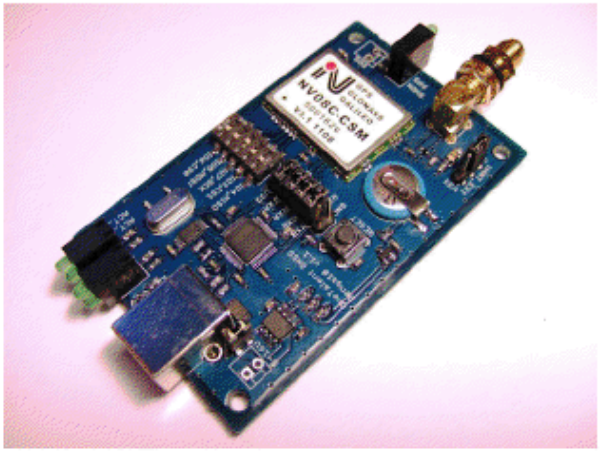
New Aspects for Glaciology:

- Typically observations are carried out during the field season in the summer
- Perform continuous observation of the processes on the glacier
- Increase the accuracy of the positions
- Development of a LOW-COST-GNSS System

USB-GNSS Receiver (GG, L_1)

Denga10

Multi-constellation L1 receiver



Main components
- FTDI FT2232D USB-DUART IC
- NVS NV08C-CSM GNSS receiver
- Regular SMA Female RF connector
- Rechargeable backup battery

~200 €

GPS specifications
- Tracking sensitivity -160dBm
- Power consumption <250mW
- RAW measurements up to 10Hz
- Timepulse accuracy 50ns RMS

NVS-Chip: ~ 40 €

Features
- No specific drivers needed
- Easy evaluation with free software
- Glonass and QZSS enabled already
- Galileo ready

Custom designs welcome!

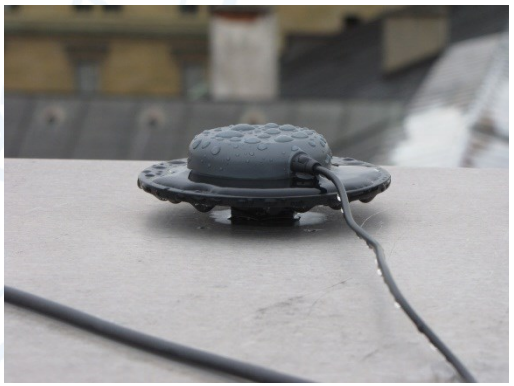
Connected to RaspberryPi for control and data storage

Tallysman TW32-2410 (~ 100 €)

Setup	Antennae	Samples	BADW (b=0.65m)				0256 (b=681)			
			East	North	Up	Outl.	East	North	Up	Outl.
60 min	GPS	96	1.8	2.2	4.0	0	**2.1**	**2.8**	**6.1**	0
	GPS+GLONASS	96	1.4	1.8	3.2	0	**1.7**	**2.1**	**5.9**	0
30 min	GPS	192	2.5	3.7	6.3	0	2.7	3.7	7.6	3
	GPS+GLONASS	192	1.8	2.6	4.4	0	2.4	2.8	6.5	1
15 min	GPS	384	3.0	4.5	7.4	20	3.1	4.3	8.6	28
	GPS+GLONASS	384	2.3	3.1	5.3	2	2.7	3.3	7.7	14

(Units in mm)

Outlier: 4 Sigma!



Low-Cost GNSS Sensors on Glaciers

- Operation of instruments in danger zone
- Limited accessibility (location and season)
- Electrical Power not available
- Internet connection is missing
- Currently Real-Time-Analysis is not intended

Design:

- Timer controlled
- Battery powered, recharged by solar cells
- Observation time 2h/day , 15 sec rate
- Mounted on top of poles

Experiments on Vernagtferner (August 13)

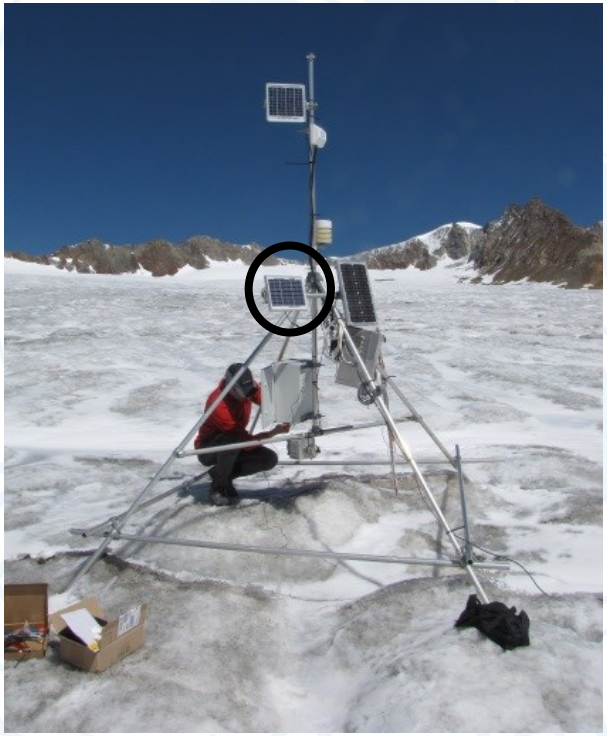
Pyramid

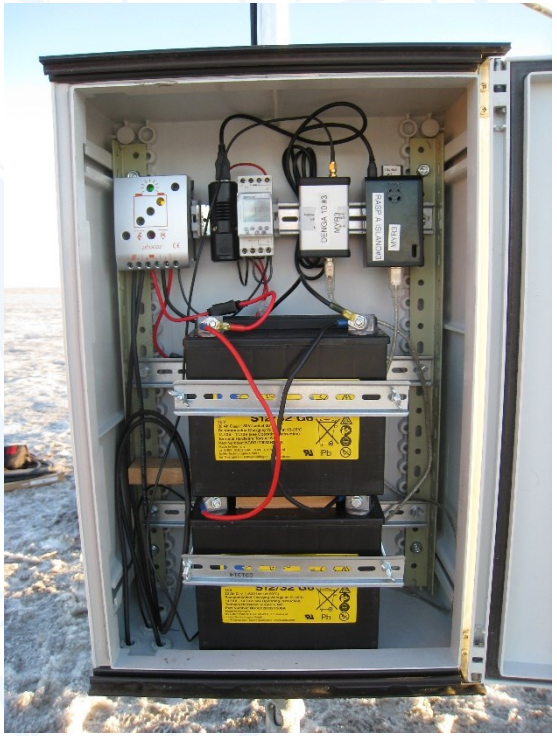
with four legs on the ice

Instruments

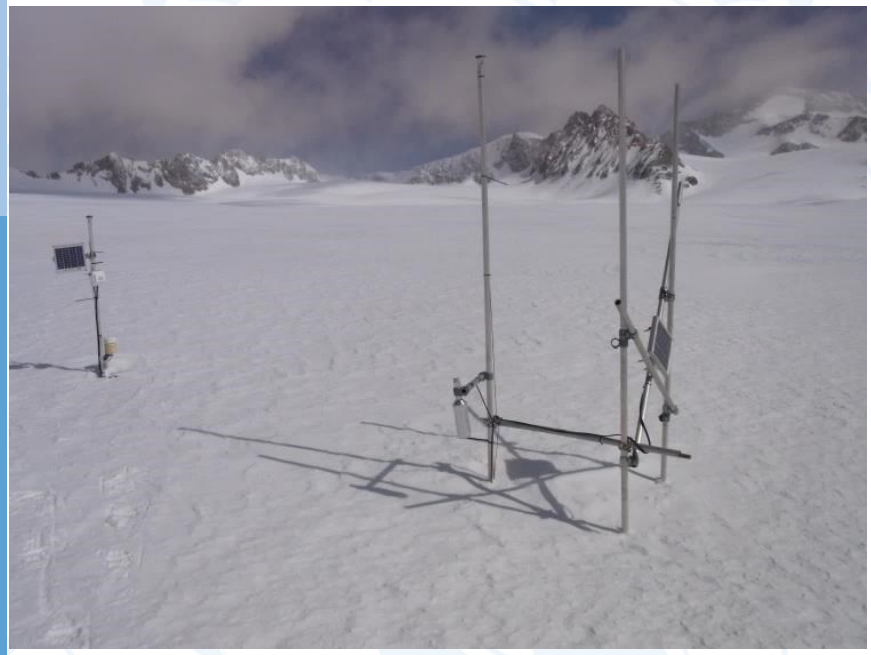
Ablatometer

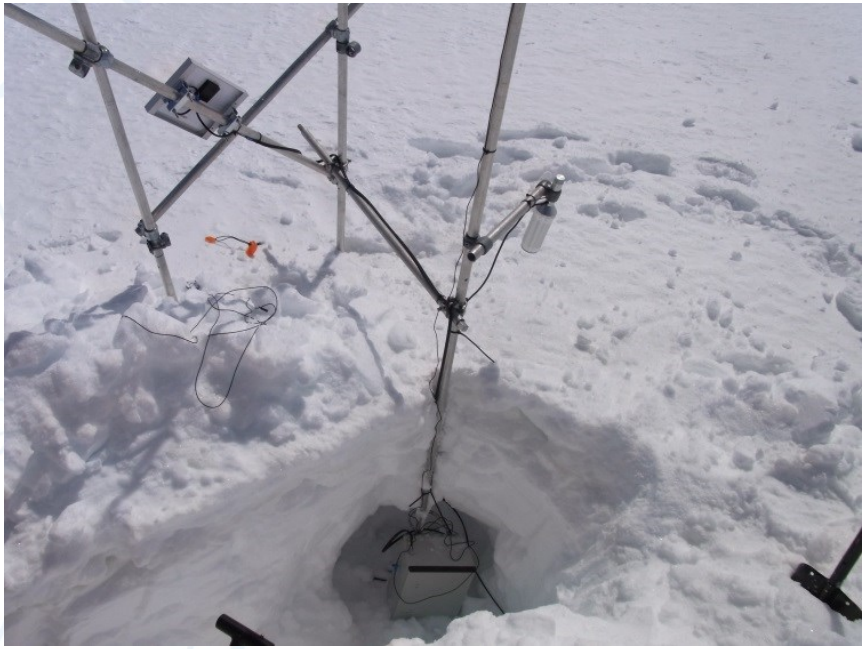
three poles drilled into the glacier





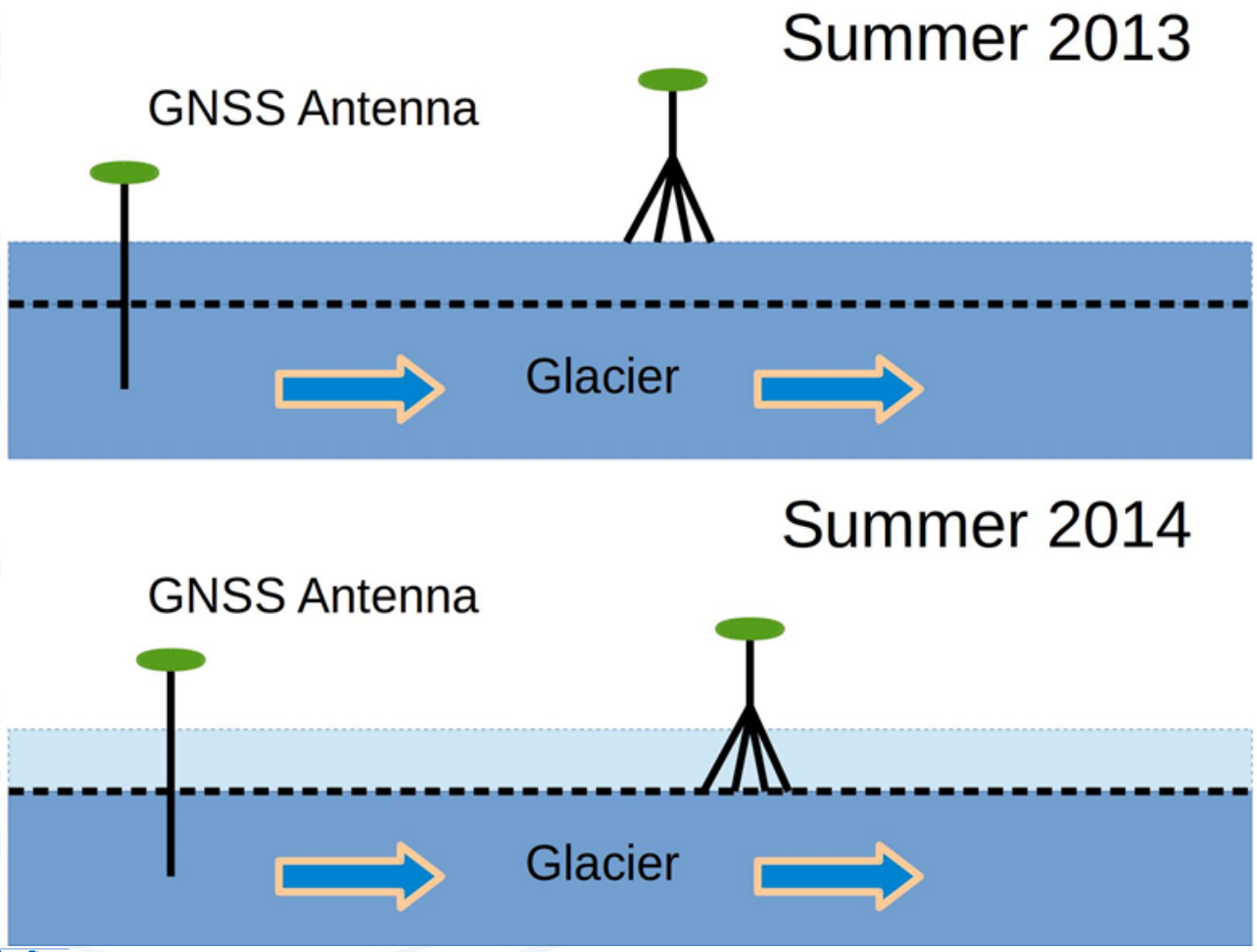
Revisiting the site in Winter (April 2014)



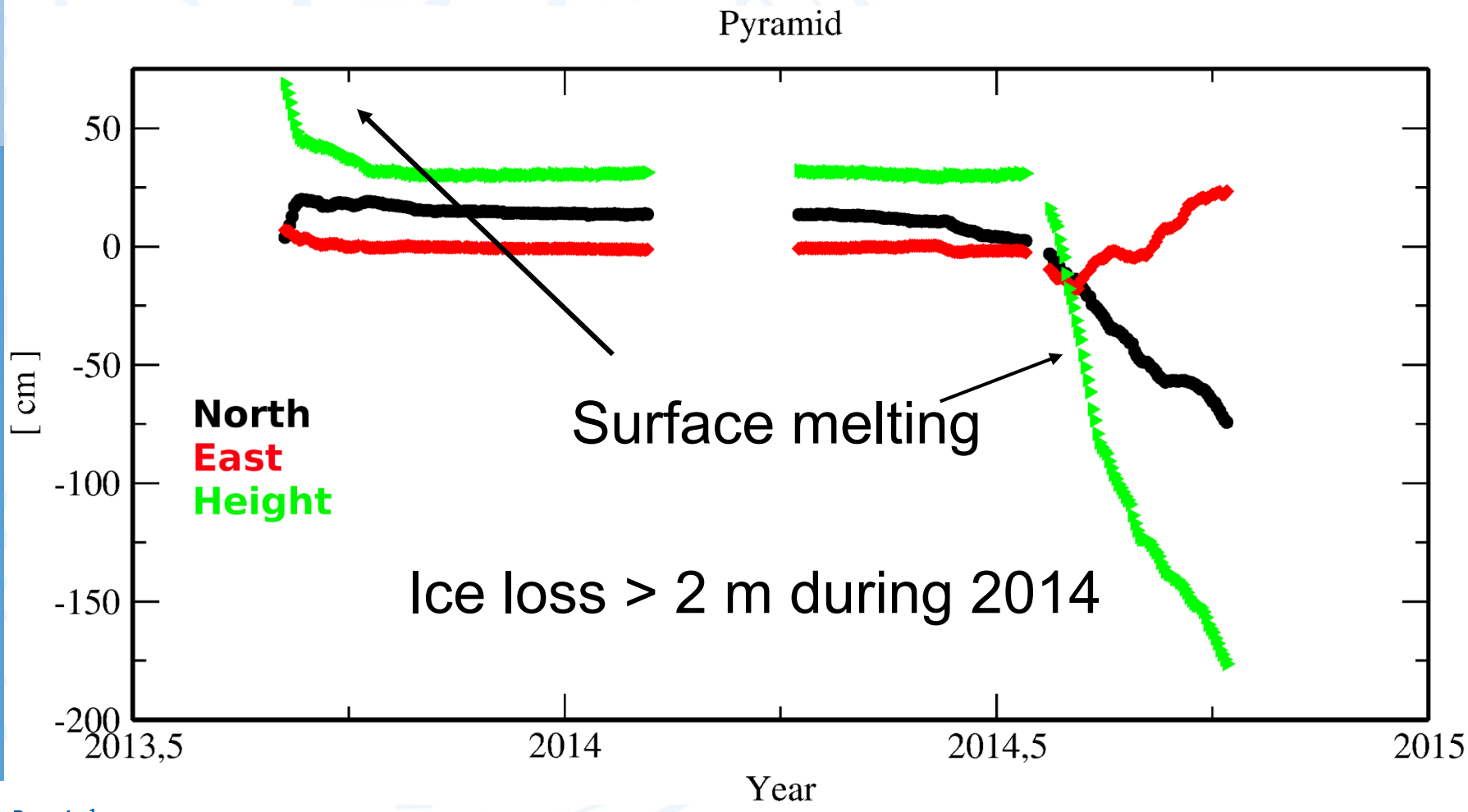


- Accumulation of snow covered the solar cell!
- Instruments had to be excavated in order to retrieve data.

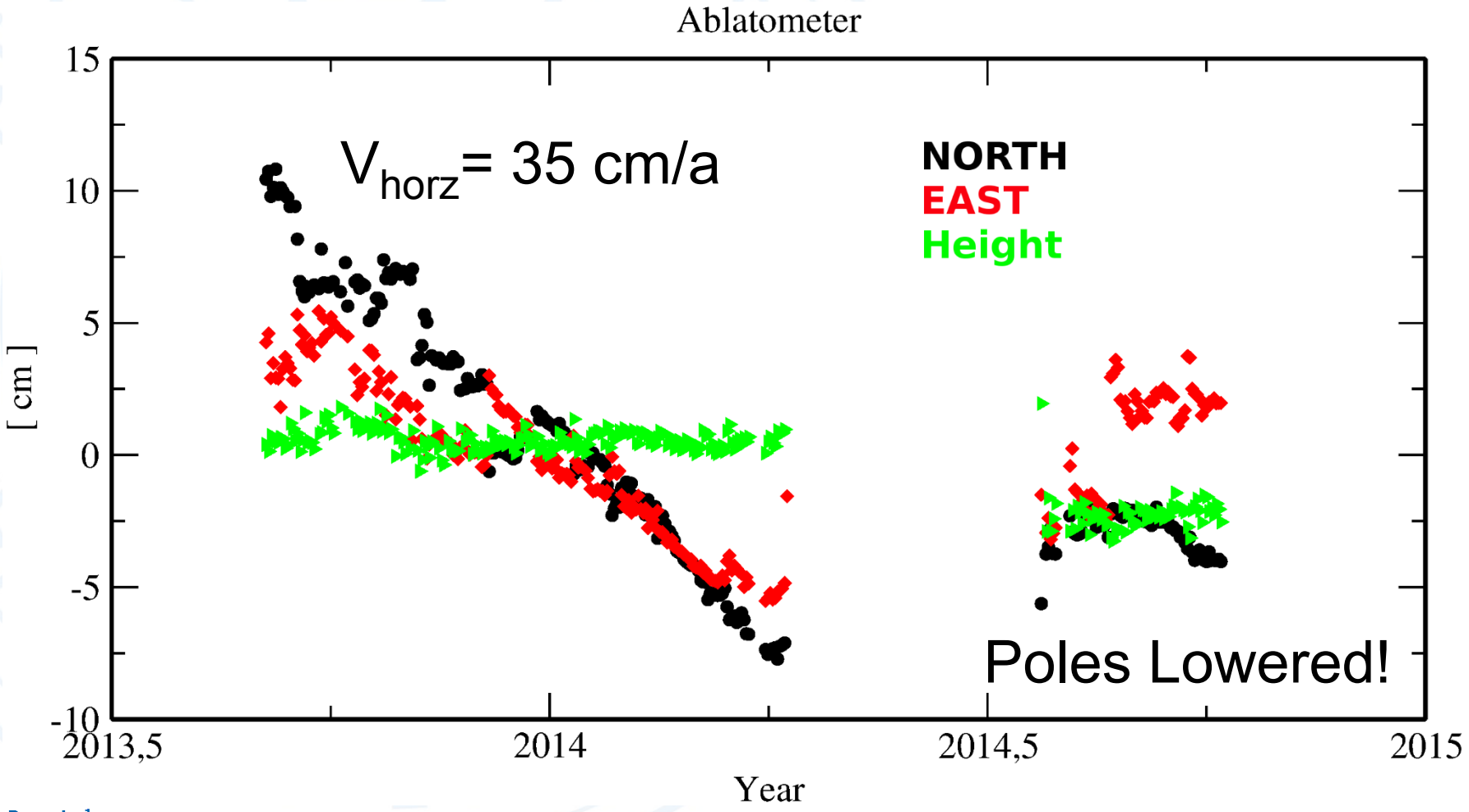
Principle Motion of the two Monuments



Change of Position at site "*Pyramid*"



Change of Position at site "*Ablatometer*"



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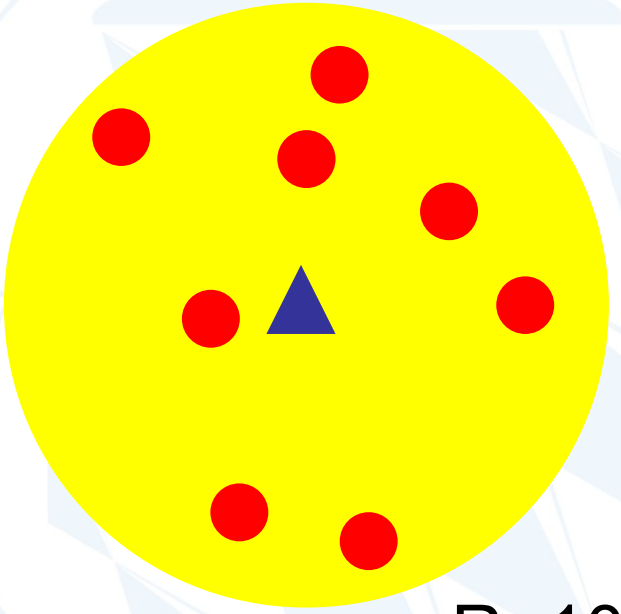
Concepts for GNSS Data Processing

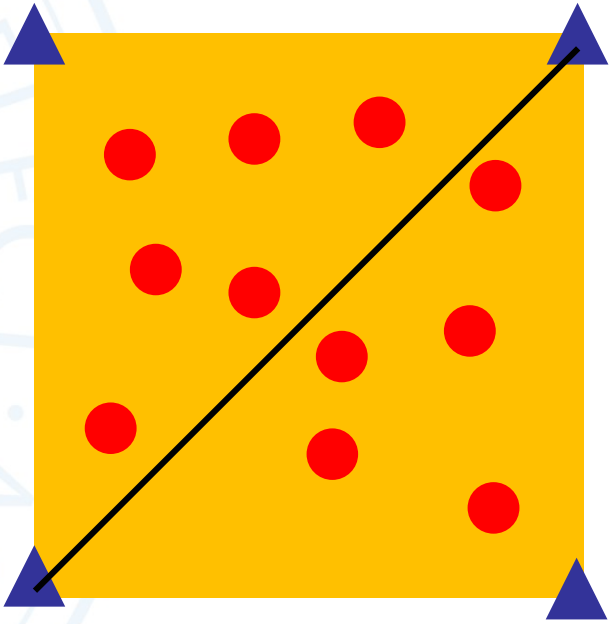
Double Difference (DD)



R=10km

Virtuell Reference Station (VRS)

FKP

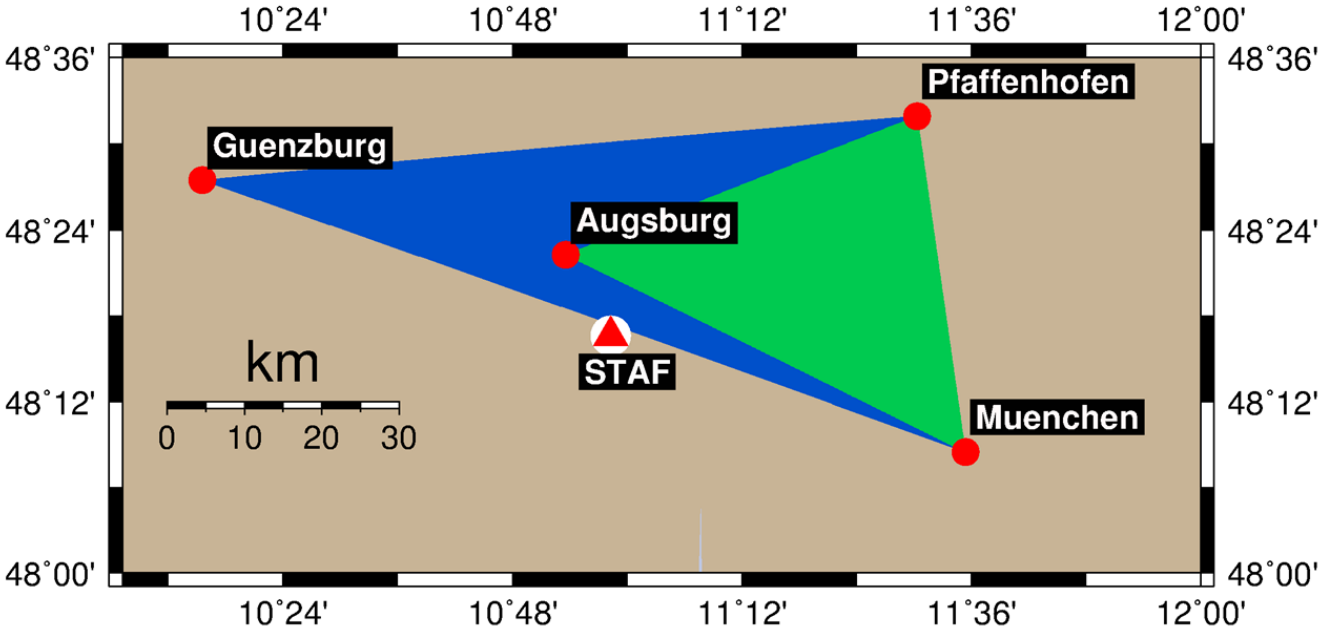


a=30-100 km

Single Frequency

GNSS CORS Site (2-Frequency)

Position Estimation by VRS (WaSoft)



Observation 1h

Mode	REF	S_{East}	S_{North} [mm]	S_h
DD	AUG (b=15km)	4.5	5.1	11.6
DD	MUC (b=45km)	10.5	5.9	23.8
VRS	AUG-MUC-PFA	2.8	2.9	4.3
VRS	GUZ-MUC-PFA	3.1	3.8	9.8

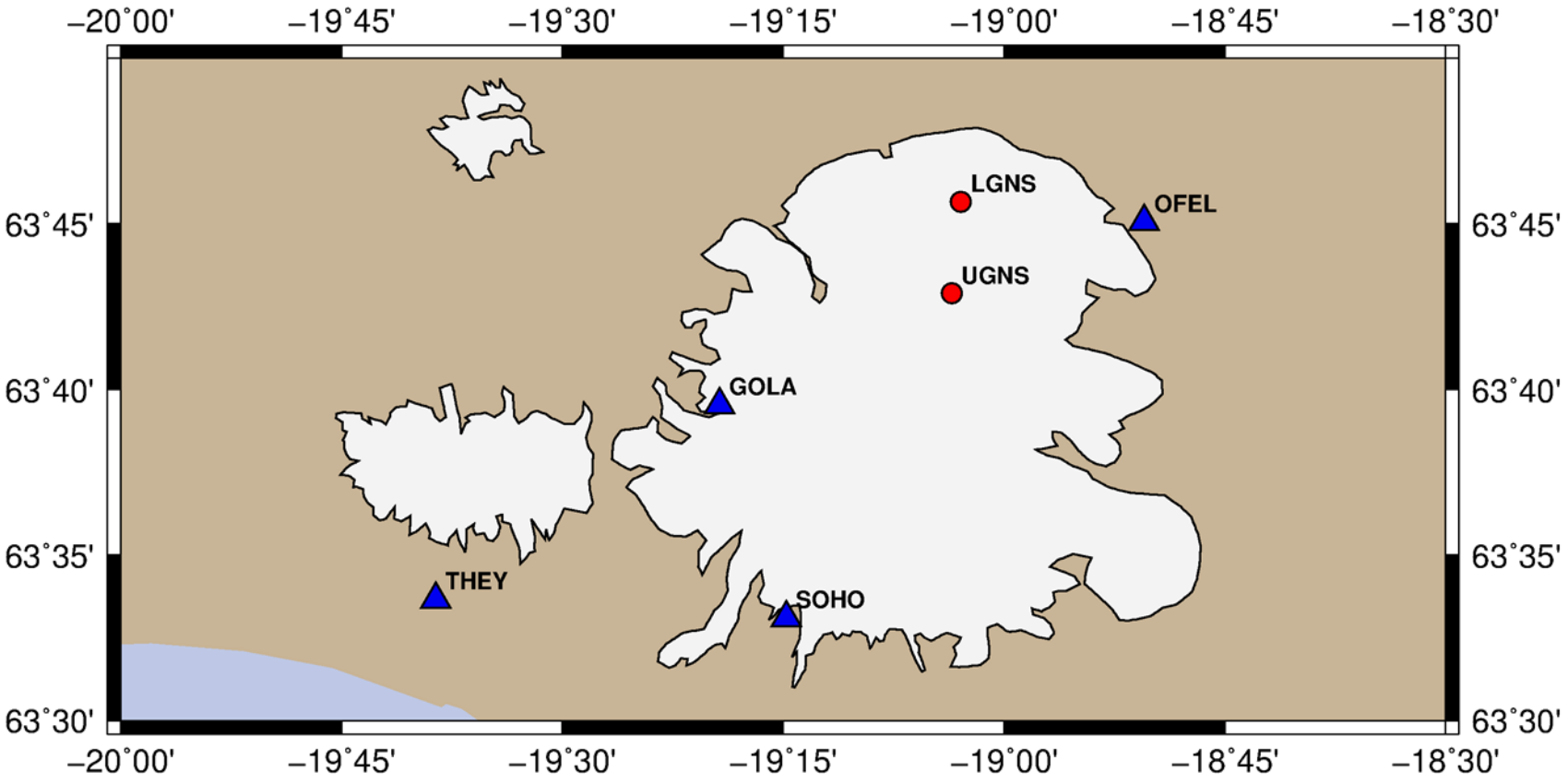
The IsViews Project

- Estimate the mass balance of Mýrdalsjökull Glacier
    - TerraSAR X, TanDEM-X and Rapid Eye
- Test the application as an early warning system
- Ground truth required through field campaigns
- Campaign style GNSS measurements for seasonal position estimation

Additional:

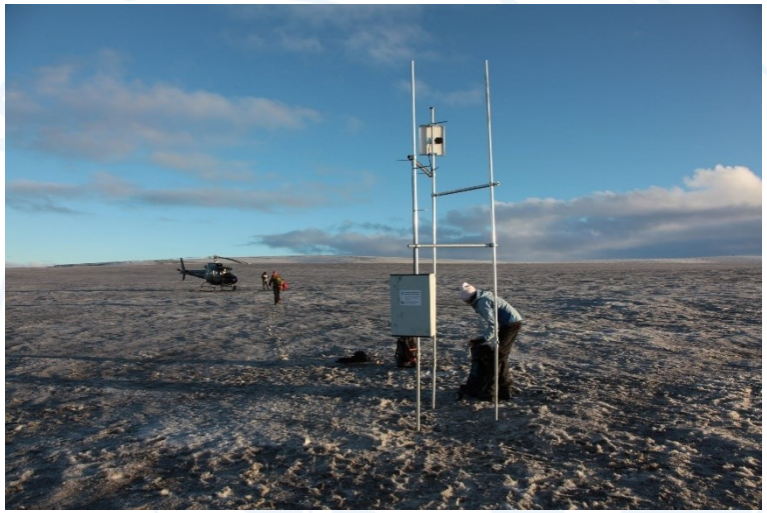
- Add continuous Low-Cost GNSS system
- Establish two new sites and test their performance

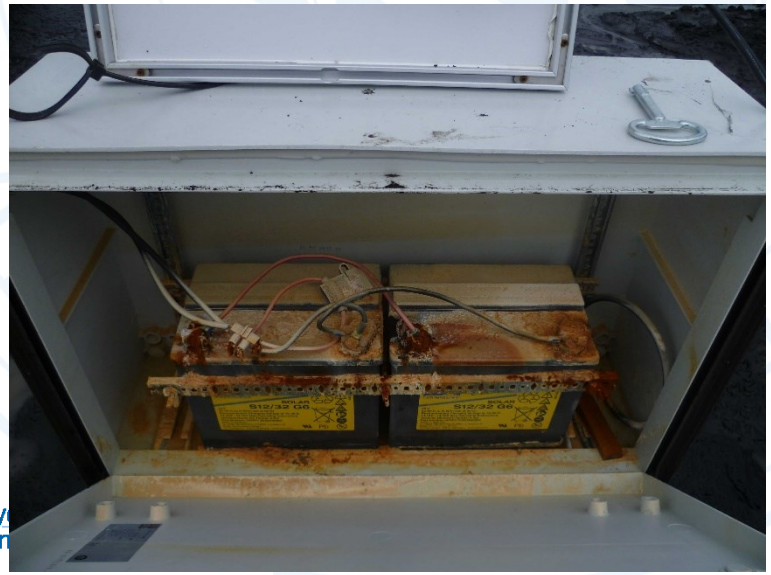
Low-Cost Sensors on Mýrdalsjökull (IS)



Setup on Mýrdalsjökull

UGNS

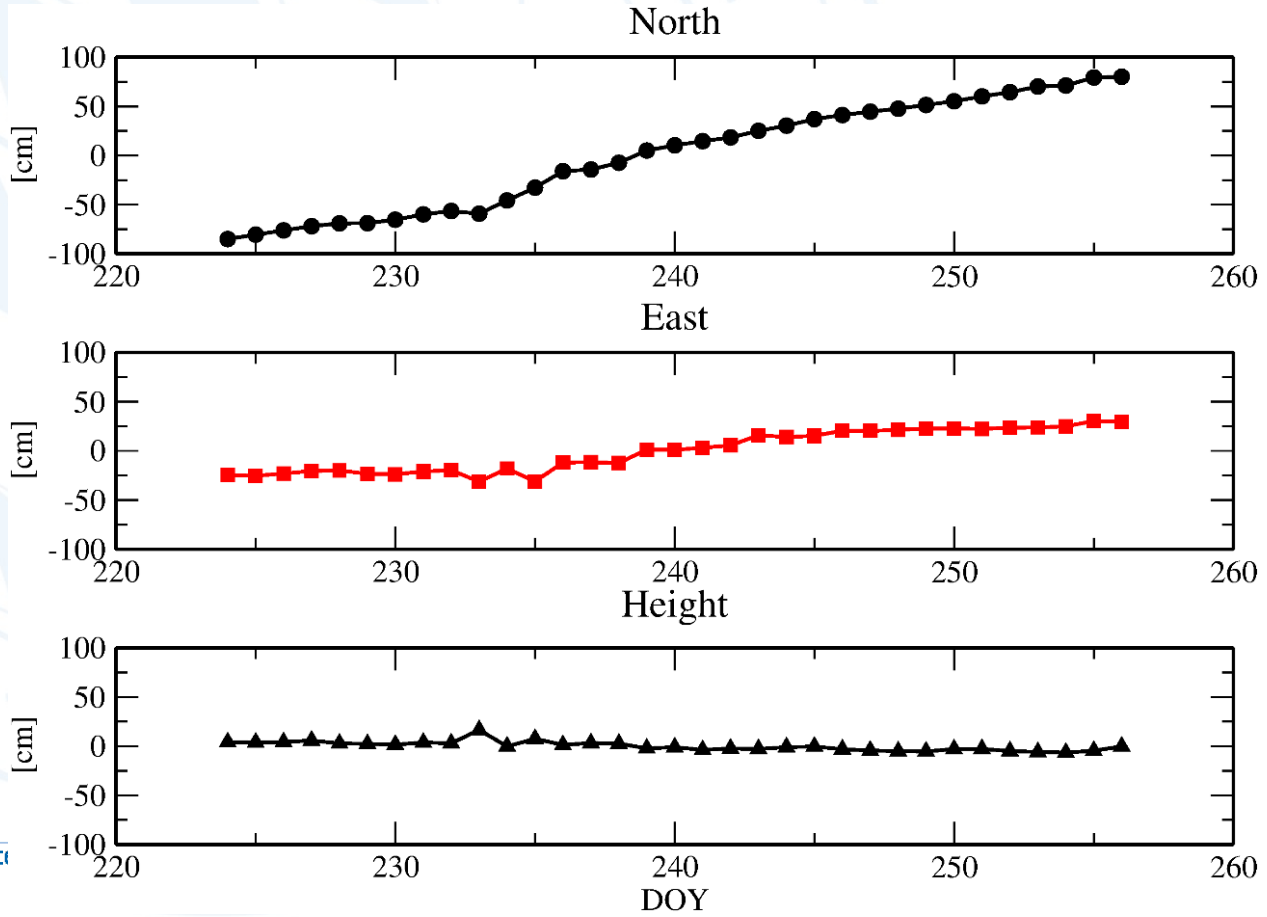




LGNS

Positions at Site LGNS

	Horizontal	Azimuth	Vertical
Continuous	21,7 m/a	19,4°	-1,2 m/a
Two Epochs (2014-2013)	13,4 m/a	13.2°	-1,5 m/a



Outlook

- Semi-continuous observations show that the motion of a glacier is variable
- Complete system costs are 500-600 €, but the need to improve reliability
- The precision is remarkable (~ 1-1.5 cm 3D)
- Currently installations on Fedchenko (Pamir), Mýrdalsjökull (Iceland) and Vernagtferner (Austria)
- Real-time is possible (RTKLIB) but data transmission is the limiting factor