Internal structure and development of snow cover on Svalbard glaciers (Hansbreen and Vestfonna) derived from high frequency GPR and classical methods

Mariusz **Grabiec**[1], Dariusz **Puczko**[2], Tomasz **Budzik**[1]

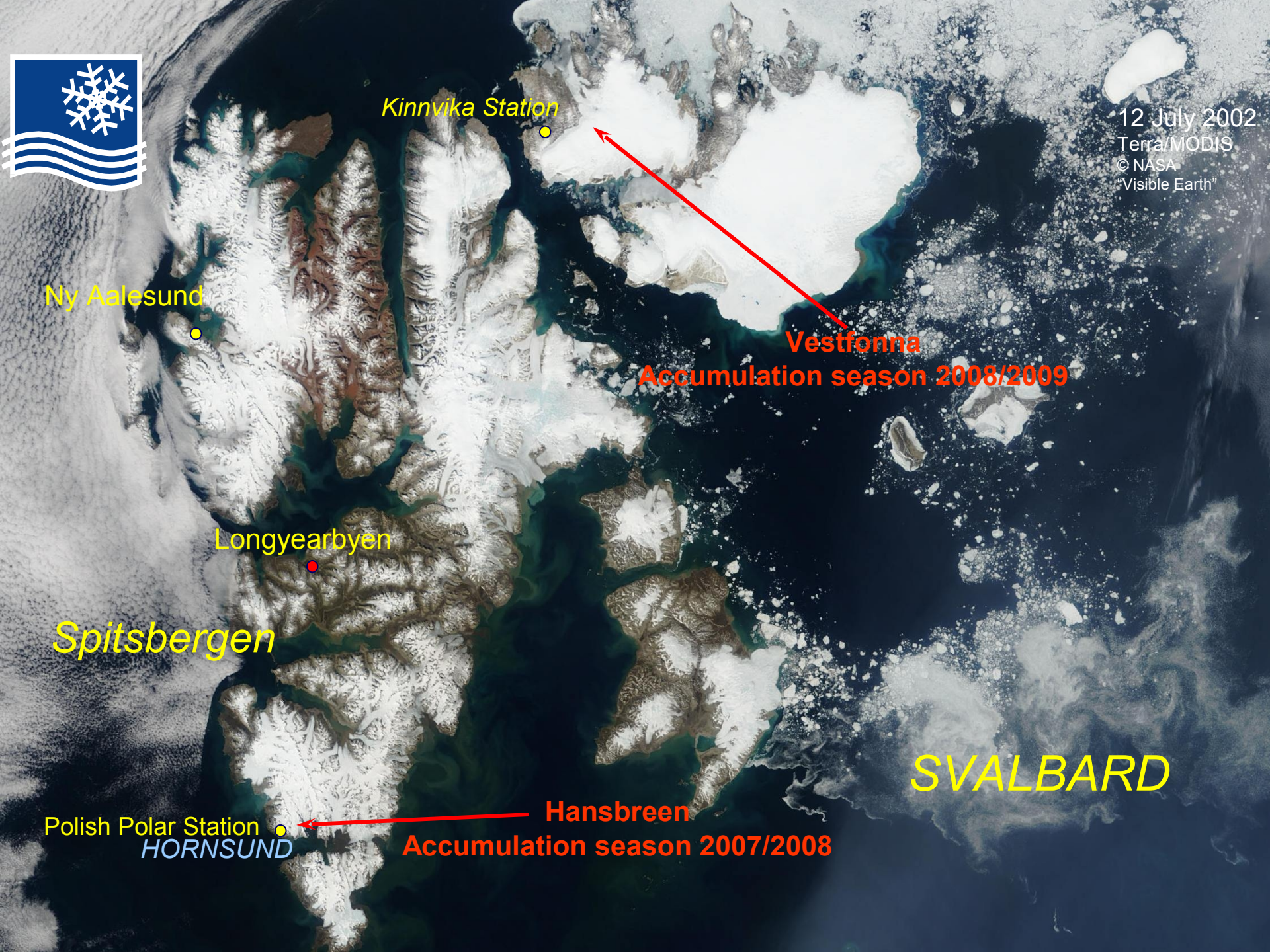
[1] Faculty of Earth Sciences, University of Silesia, Sosnowiec, Poland
[2] Institute of Geophysics, Polish Academy of Sciences, Warszawa, Poland

Gdynia
8-10 October 2010

Objectives

- Estimation of snow dynamics and phases of formation on selected Svalbard glaciers in accumulation seasons by analysis of snow depth changes, internal structure of snow cover and available meteorological data

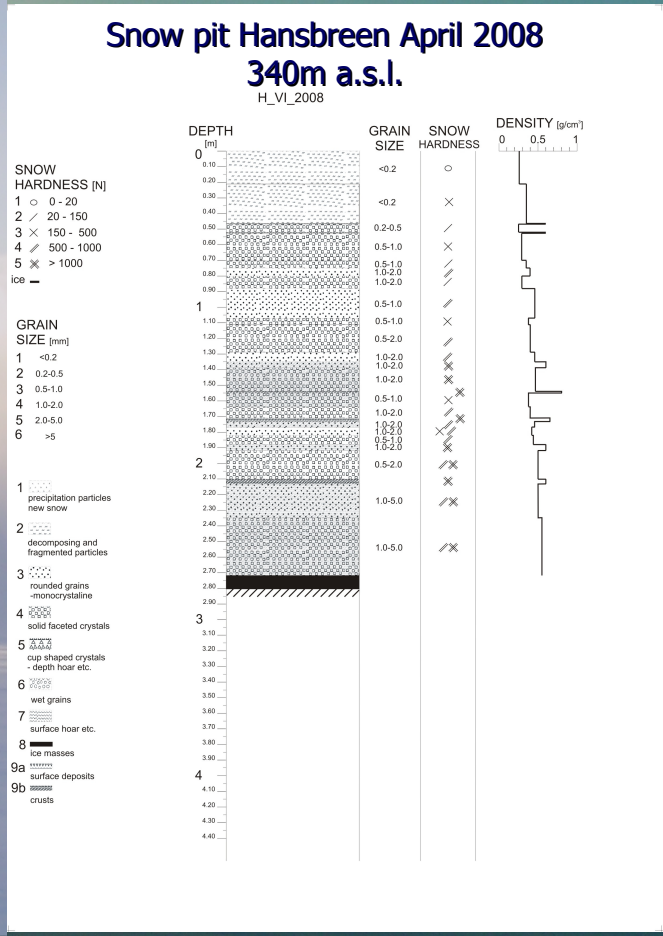
- Analysis of snow dynamics and internal structure of snow cover in remote polar areas basing on minimum input data


Kinnvika Station
12 July 2002
Terra/MODIS
© NASA
"Visible Earth"
Ny Aalesund
Vestfonna
Accumulation season 2008/2009
Longyearbyen
Spitsbergen
SVALBARD
Polish Polar Station
HORNSUND
Hansbreen
Accumulation season 2007/2008

Previous work on snow and accumulation

Hansbreen:

- permanent stakes monitoring and snow pits analysis since 1988
- ultrasonic snow depth sounding since 2006
- dense snow probing with classical method 1989, 2003, 2005 (Grabiec 2006)
- studies on snow cover formation (Leszkiewicz & Pulina 1999)



Vestfonna:

- Snow stratification studies (Ahlmann 1933, Glen 1939, Schytt 1964, Palosuo 1987) and accumulation distribution (Schytt 1964)
- snow chemistry studies related to Kinnvika IPY projects (Beaudon & Moore 2009, Mantila, Luks)

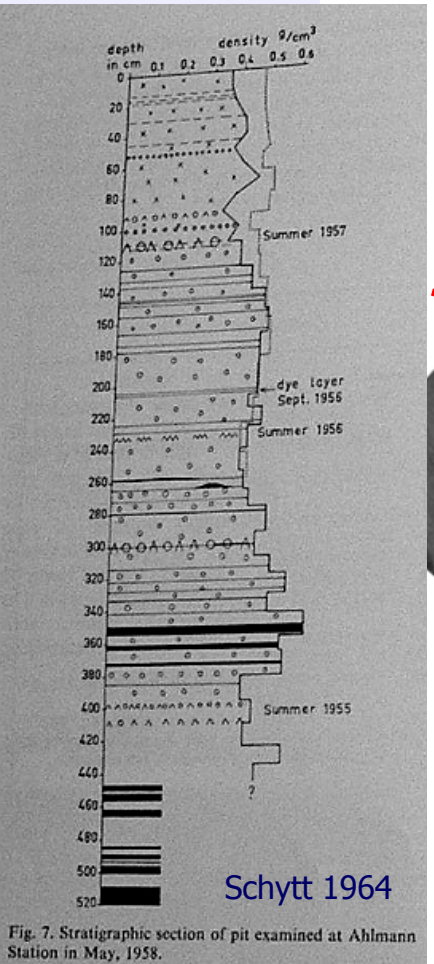
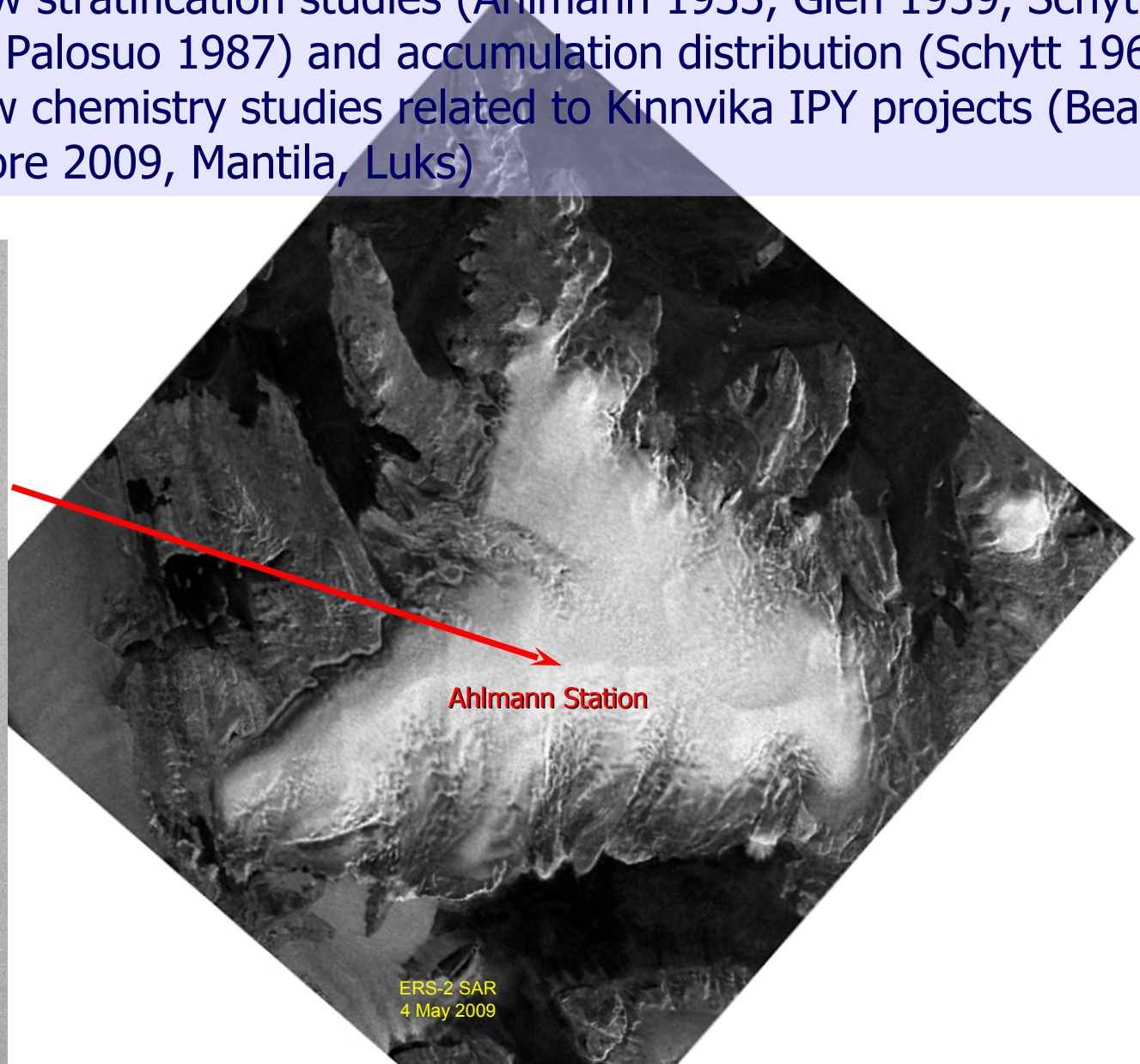


Fig. 7. Stratigraphic section of pit examined at Ahlmann Station in May, 1958.



Methods:

- Classical stake readings and snow probe monitoring
- Automatic snow depth records (sonic ranger)
- Snow pits for physical snow properties and internal structure analysis
- High frequency radio echo-sounding for snow depth, SWE and internal structure
- On-site meteorological data and meteorological re-analysis
- Simple snow dynamics model

Model of snow cover changes (scc model)

Snow accumulation (B)

$$B = \sum P; T < 0^{\circ} C$$

P - precipitation
T – air temperature

Prognostic snow density

(Douville et al. 1995; Verseghy 1991; White 2002)

$$\rho_s^{t+1} = \left(\rho^*_s - \rho_{max}\right) \exp\left(-\tau_f \frac{\Delta t}{\tau_1}\right) + \rho_{max}$$

ρ_s^{t+1} – next step snow density
ρ^*_s – current snow density
ρ_{max} – maximum snow density
τ_f - coefficient for exponential decrease of snow density
τ_f - length of day

Drift index (DI)

(Liston & Sturm 1998; Lehninf & Fiertz 2008)

$$DI = \frac{Q_s}{s_l}$$

Q_s – snow flux in way of saltation
s_l – coefficient of slope length

$$Q_s = 0.68 \frac{\rho_a u_{*th}}{g u_*} \left(u_*^2 - u_{*th}^2\right)$$

ρ_a – density of air
g – acceleration due to gravity
u_* - friction velocity
u_{*th} – threshold friction velocity

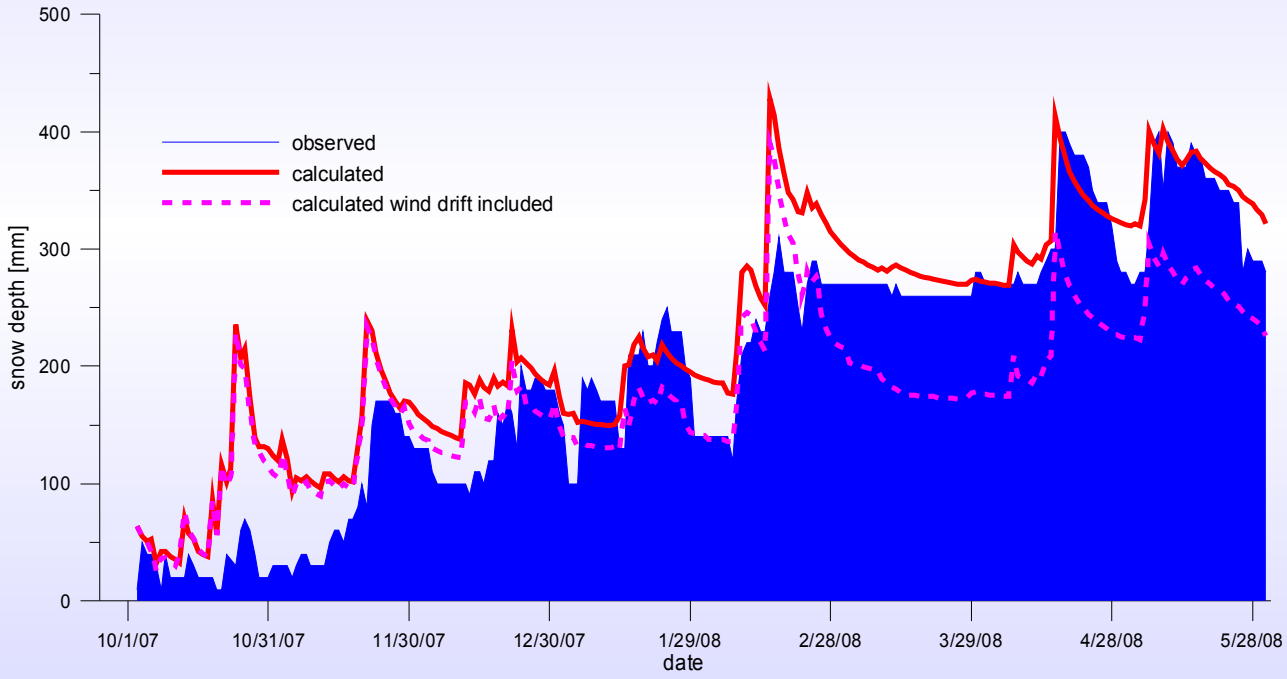
Surface melting (M)

$$M = aT_i; T_i > 0^{\circ} C$$

M – surface melting
T_i – average daily temperature
a – melting factor

Snow depth at Hornsund station OCT 2007 – MAY 2008

Observed data and results of scc model

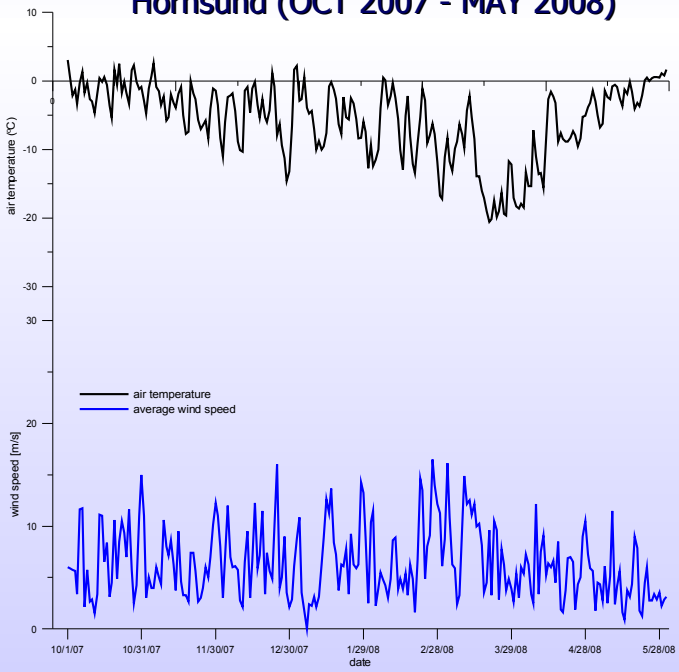


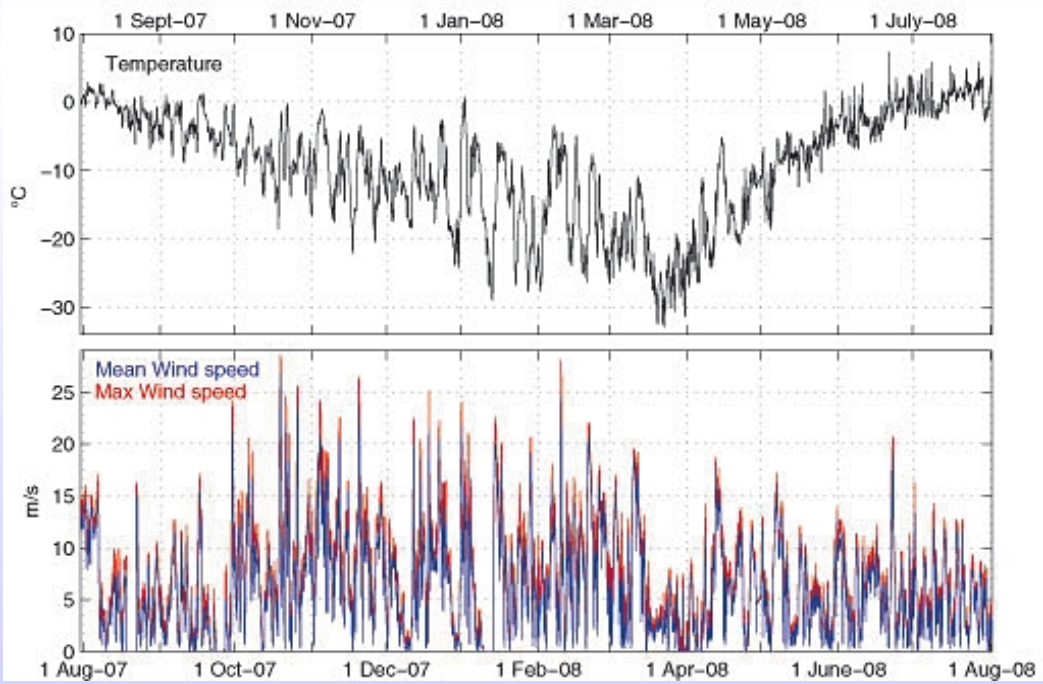
Meteorological conditions Hornsund and Vestfonna



Vestfonna (AUG 2007 - JUL 2008)

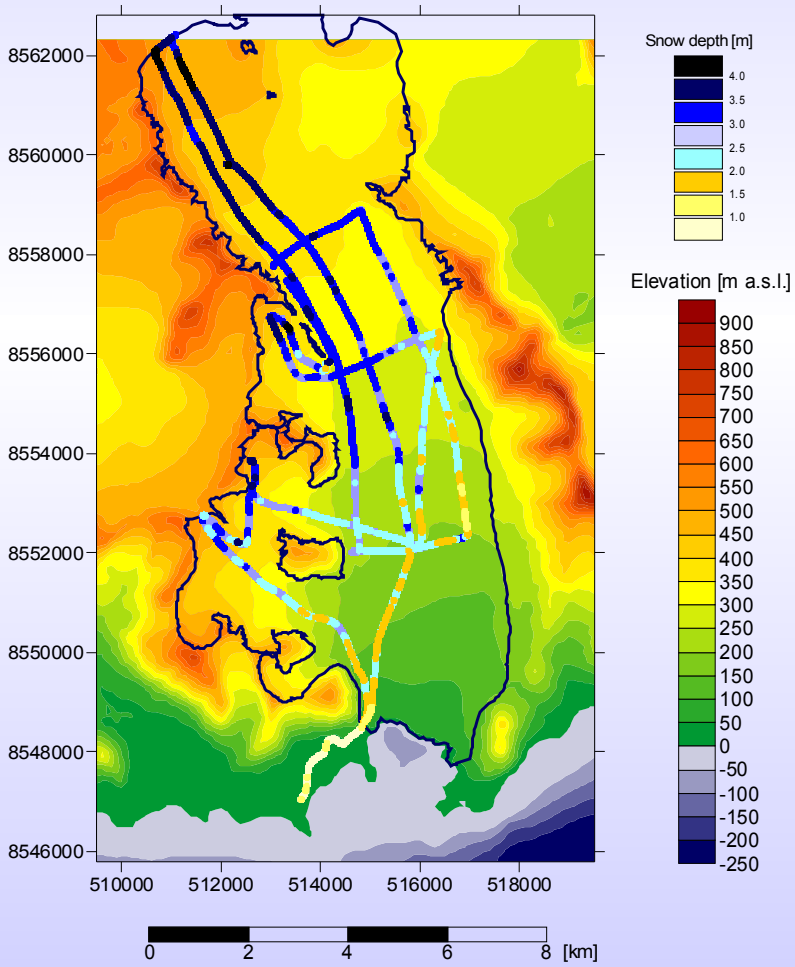
Hornsund (OCT 2007 - MAY 2008)

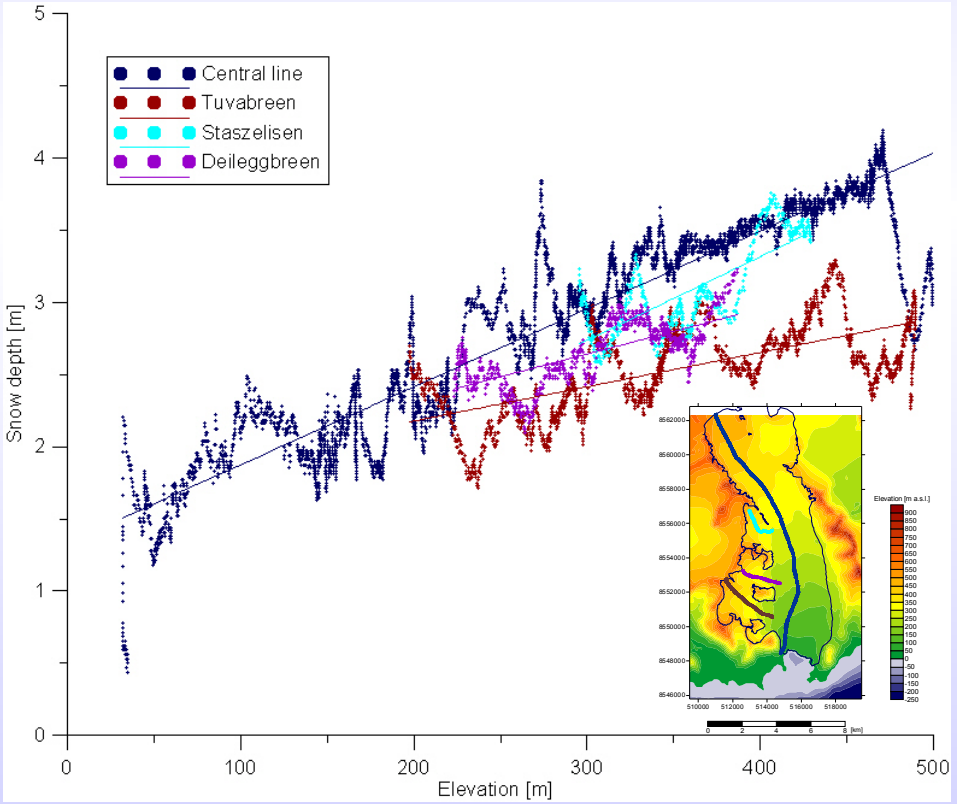




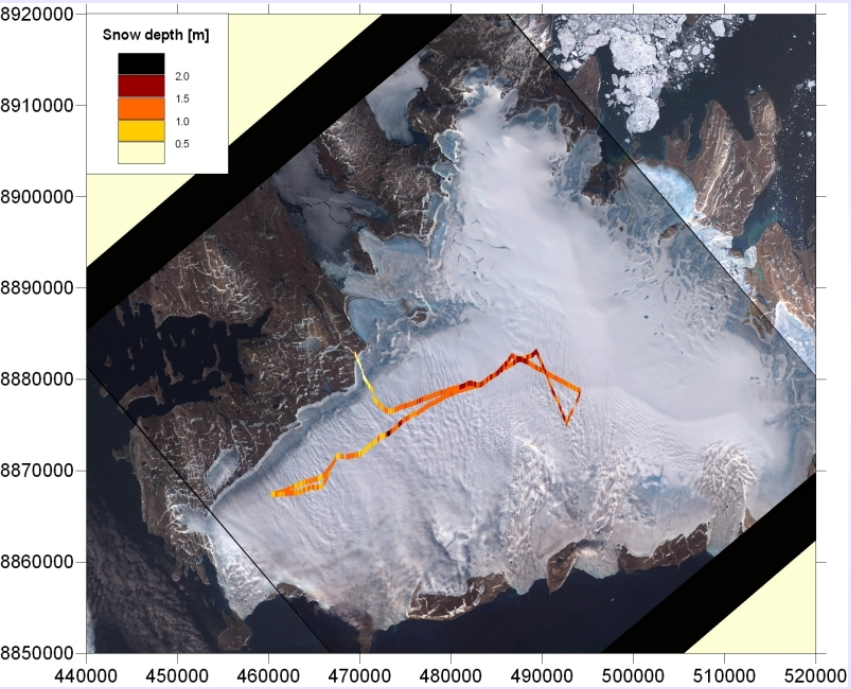
Spatial distribution of snow cover
Hansbreen 2008

Average snow depth: 2,84m
Snow depth gradient: 0,45 m/100 m of elevation

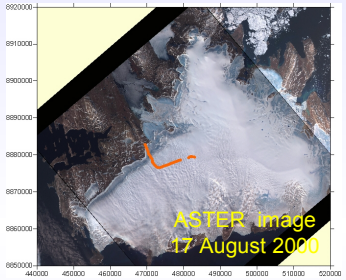


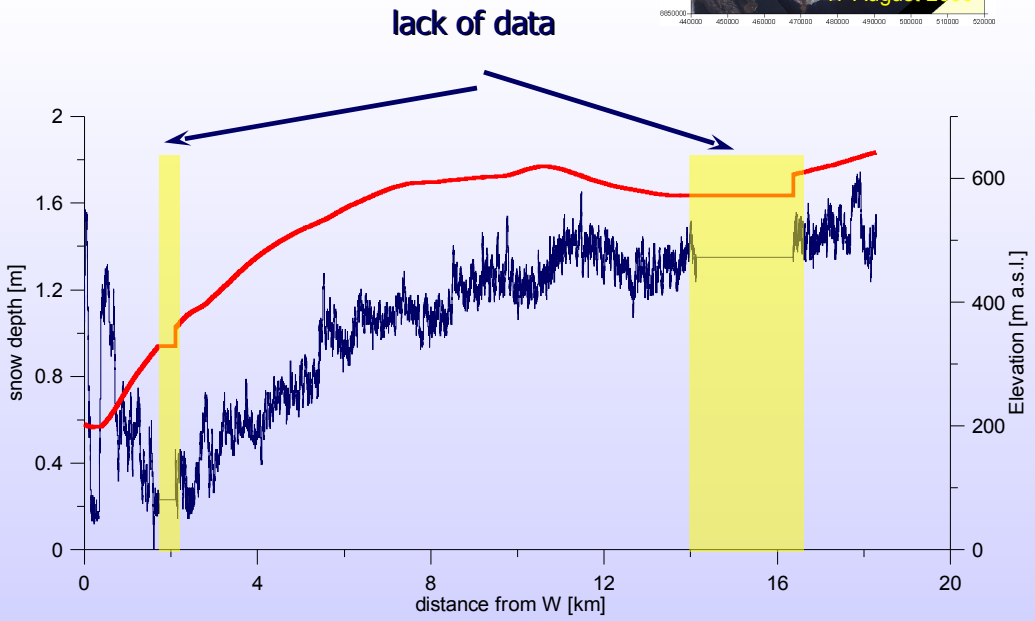


Spatial distribution of snow cover
Vestfonna 2009



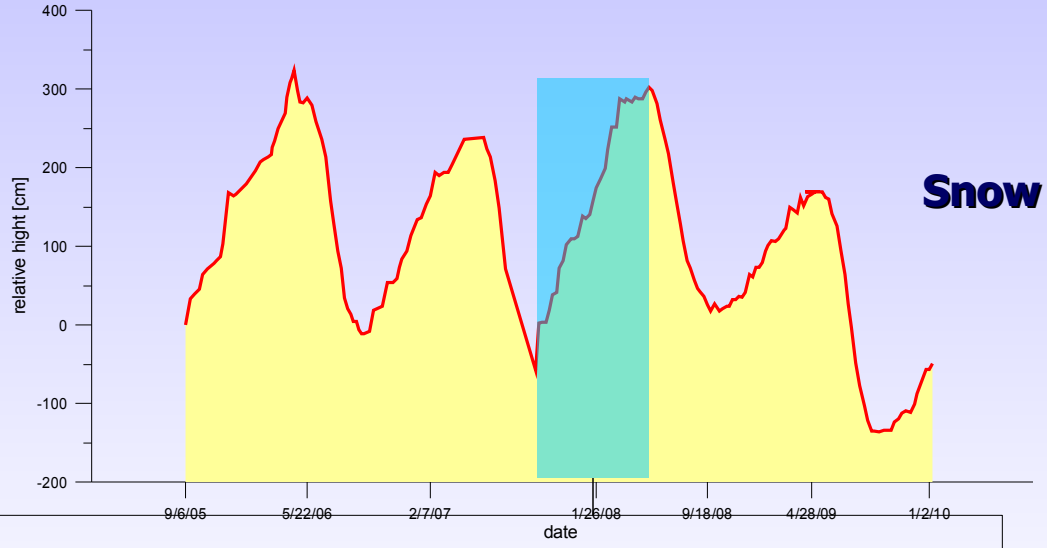
Average snow depth: 1,2m
Snow depth gradient: 0,23 m/100 m of elevation

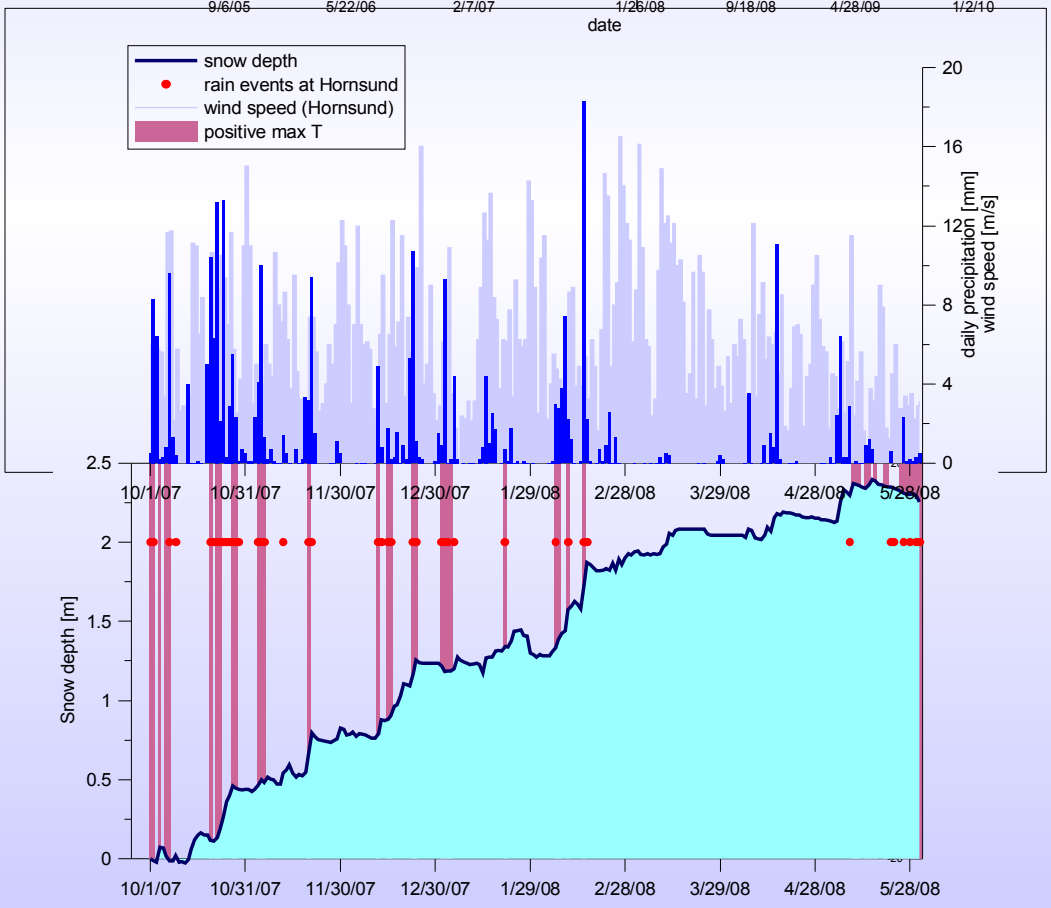


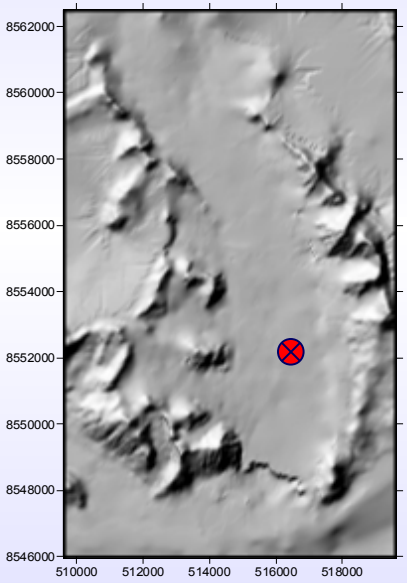


Snow cover development on Hansbreen

184 m a.s.l.

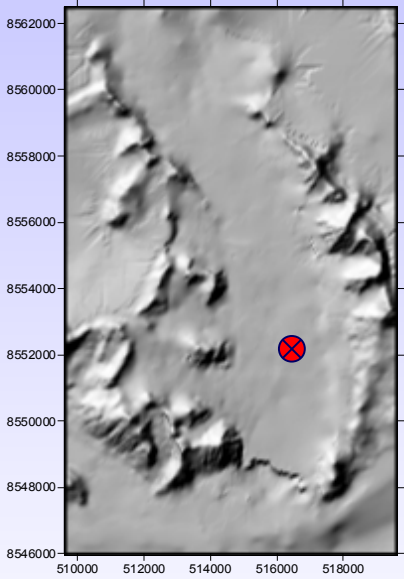


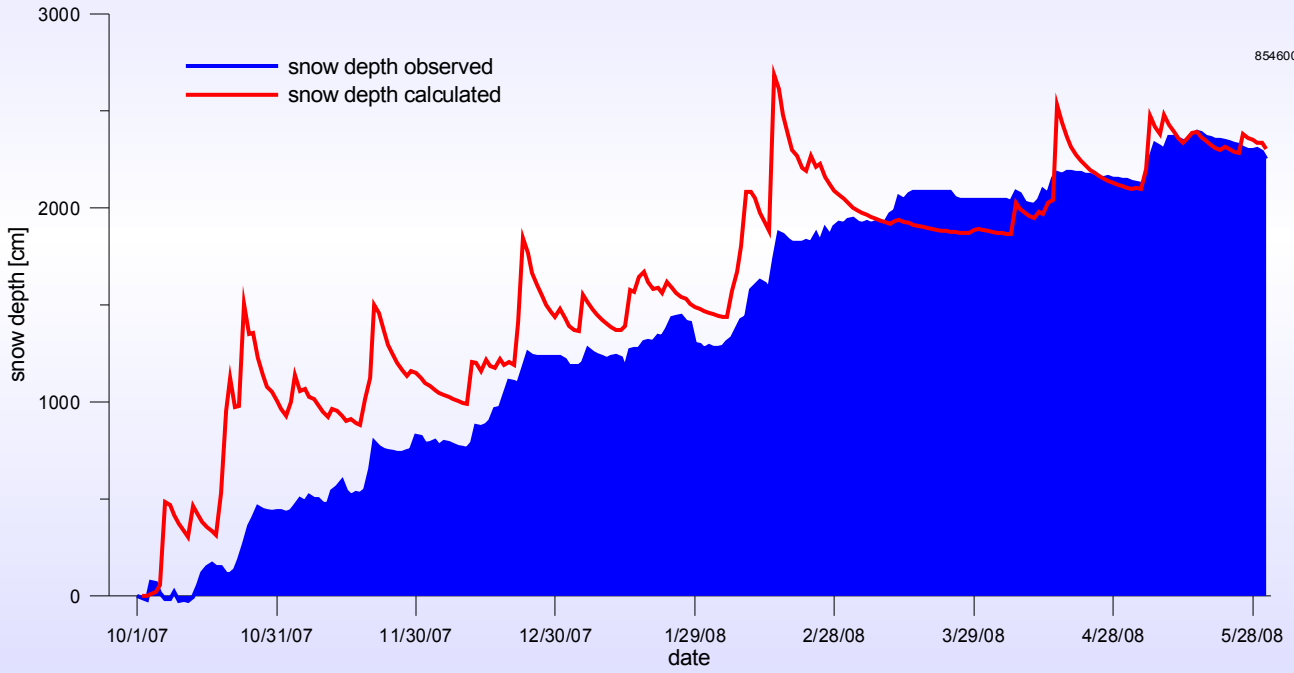




Snow cover developement observations and modelling

Hansbreen (OCT 2007 - MAY 2008)



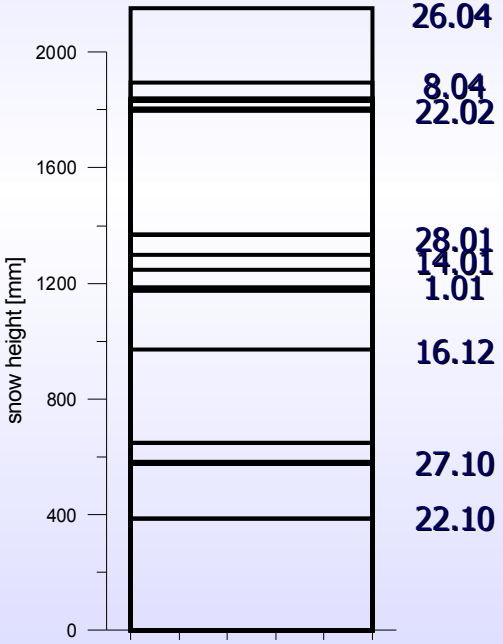


Snow pit analysis v. results of snow devlopement model

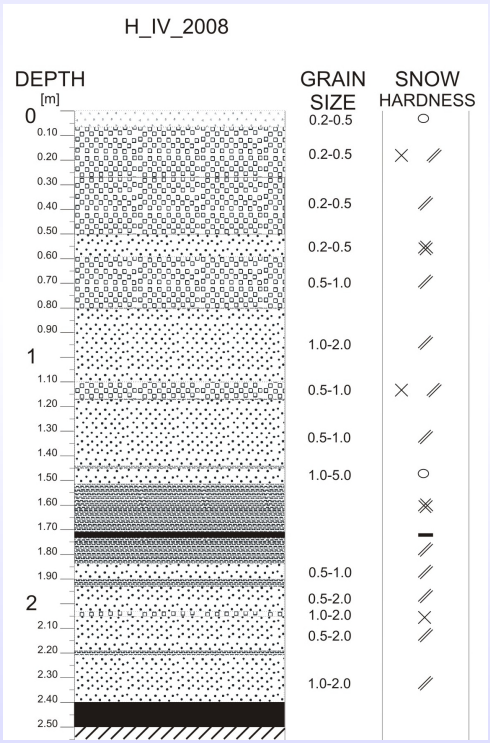
Hansbreen (OCT 2007 - MAY 2008) 186 m a.s.l.

Internal snow structure

Scc model

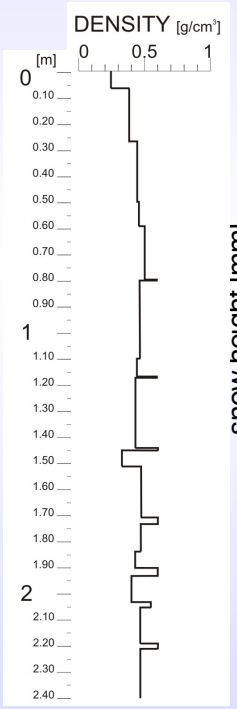


Snow pit

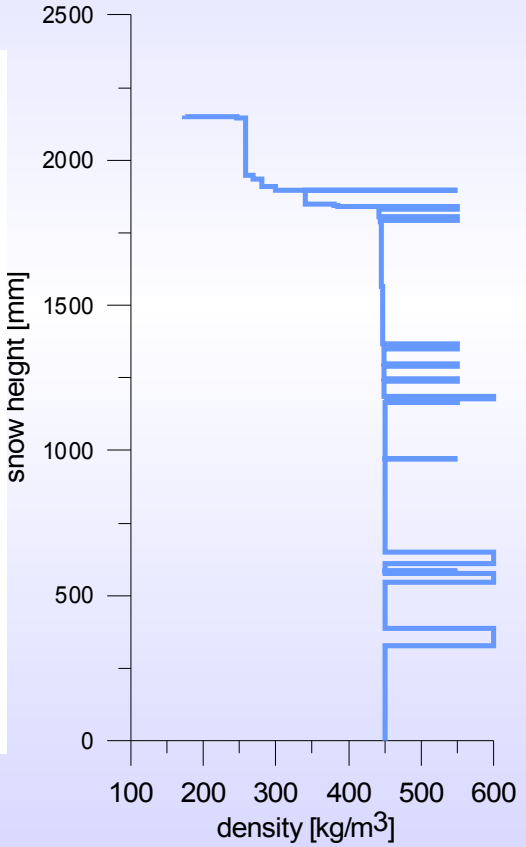


Snow density

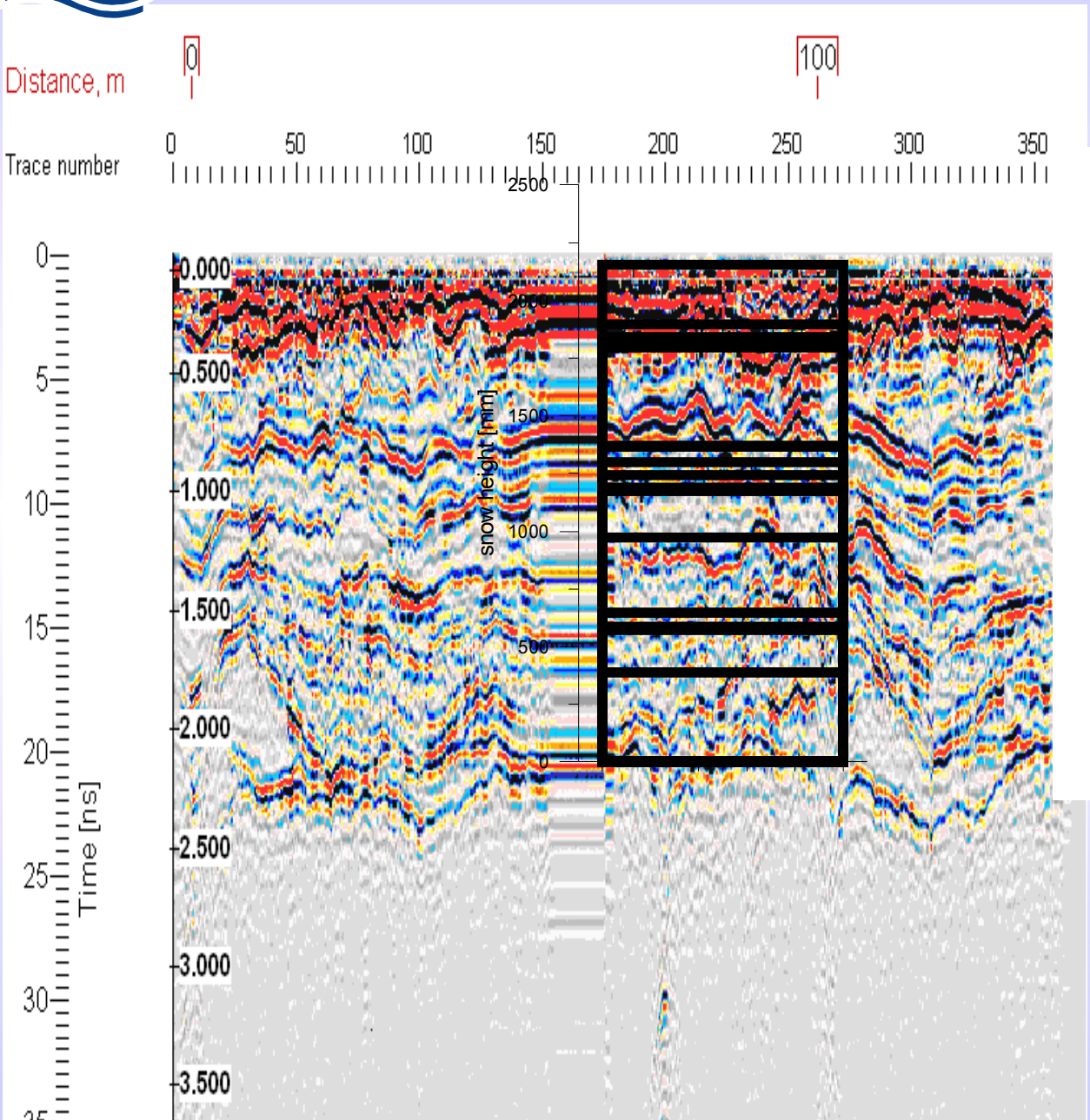
Snow pit

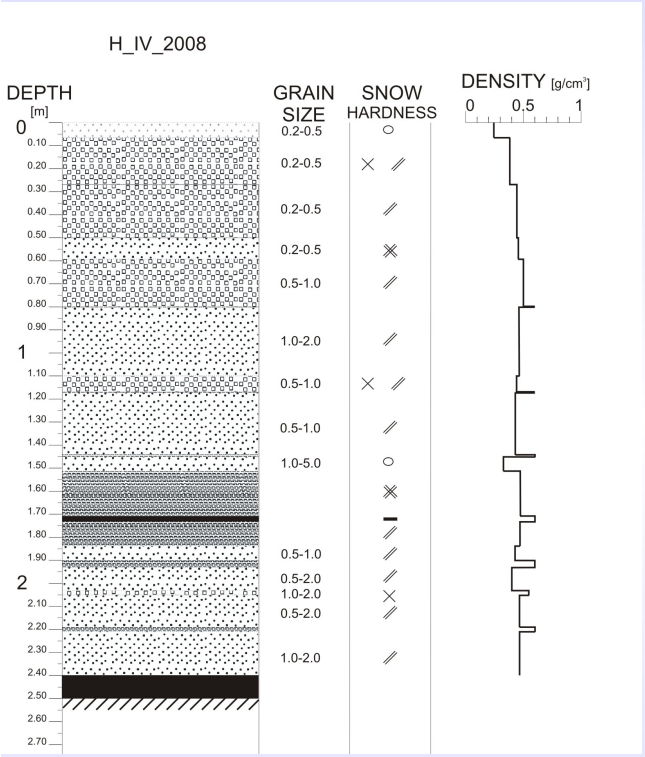


Scc model



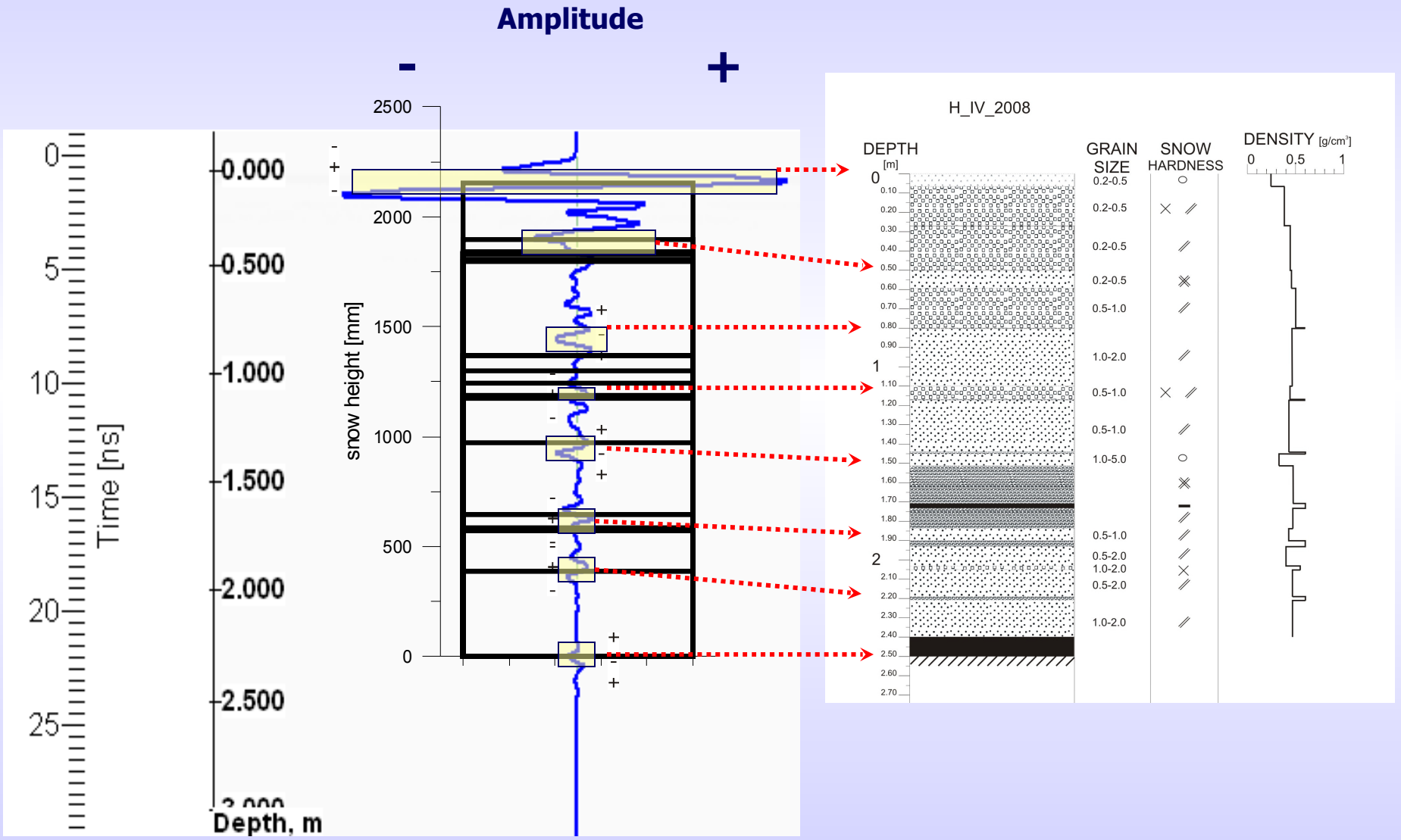
Snow cover internal structure





Hansbreen T04 April 2008

Snow cover internal structure
Wavelet analysis



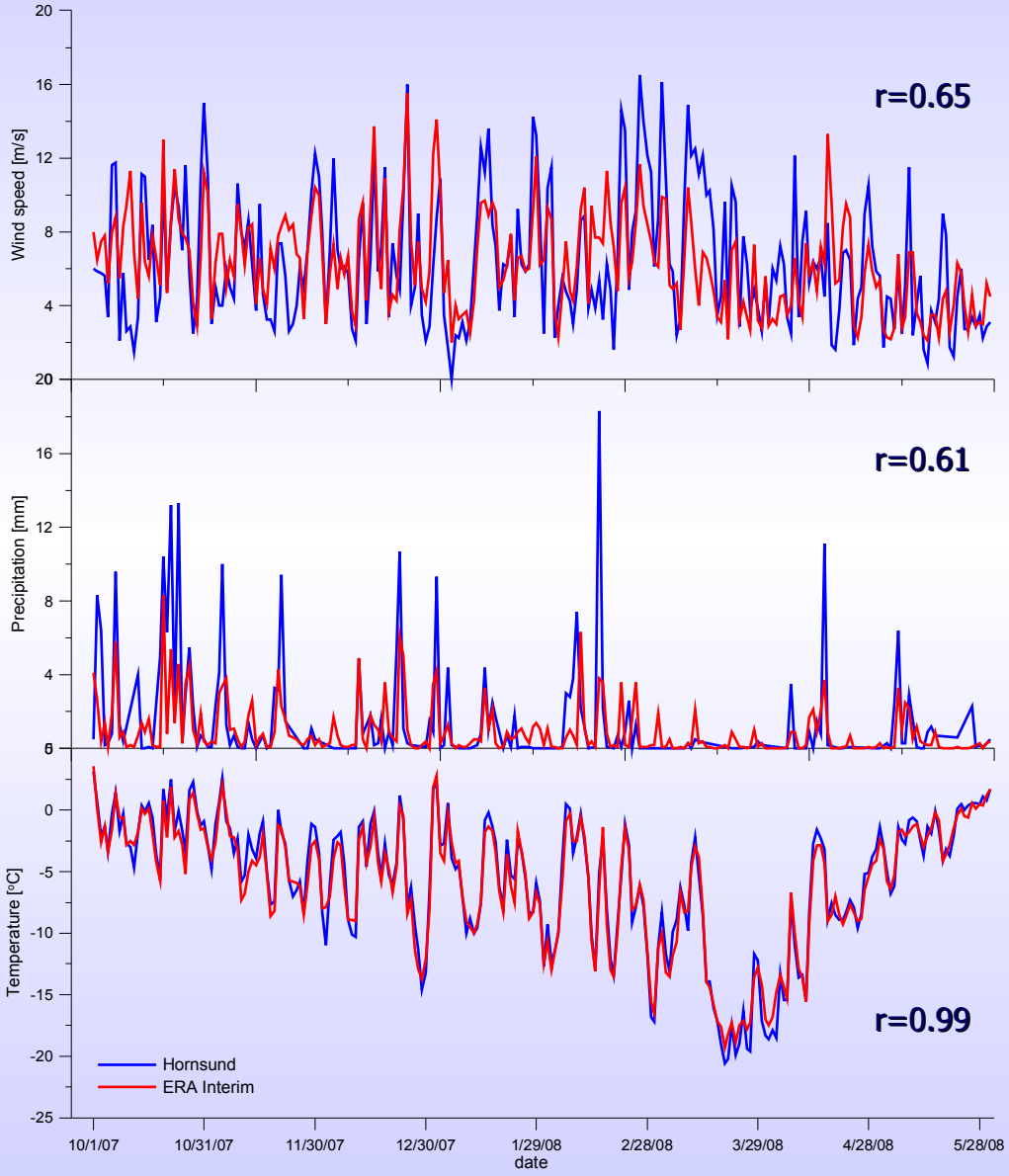
Hansbreen T04 April 2008

Hornsund meteorological data and ERA Interim re-analysis

(OCT 2007 - MAY 2008)

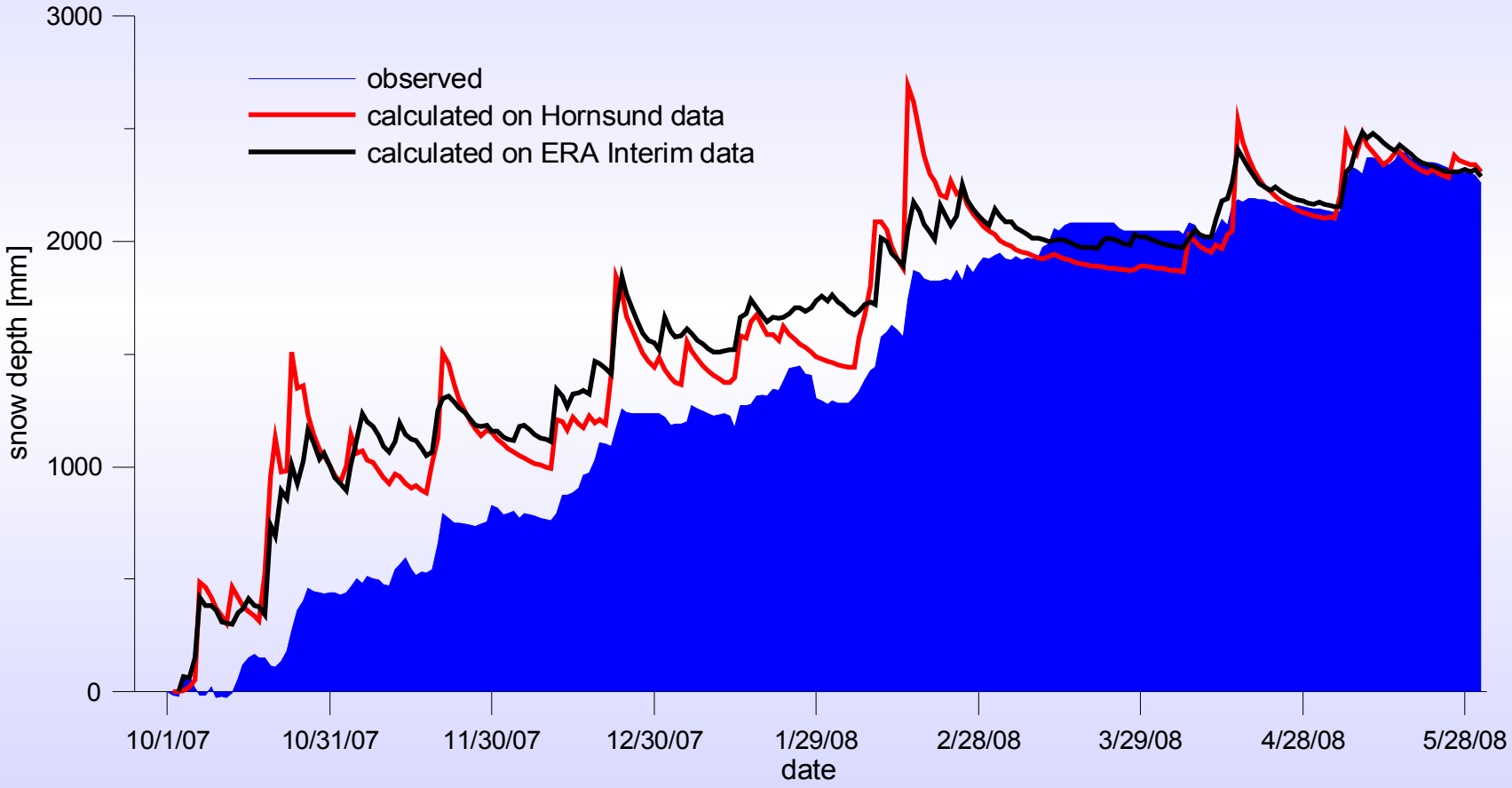


ERA Interim grids



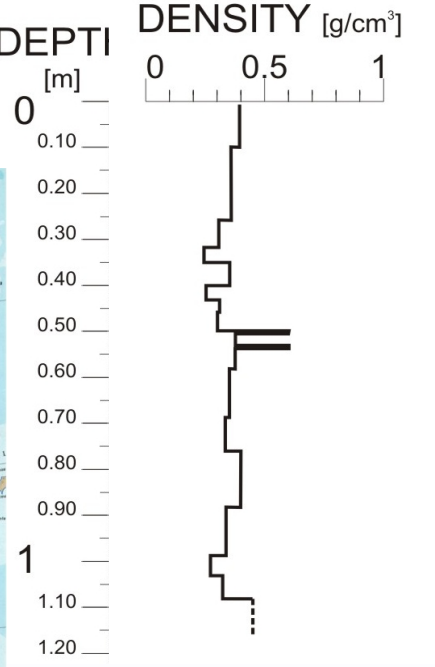
Reconstruction of snow cover developement on Hornsund meteorological data and ERA Inteim re-analysis

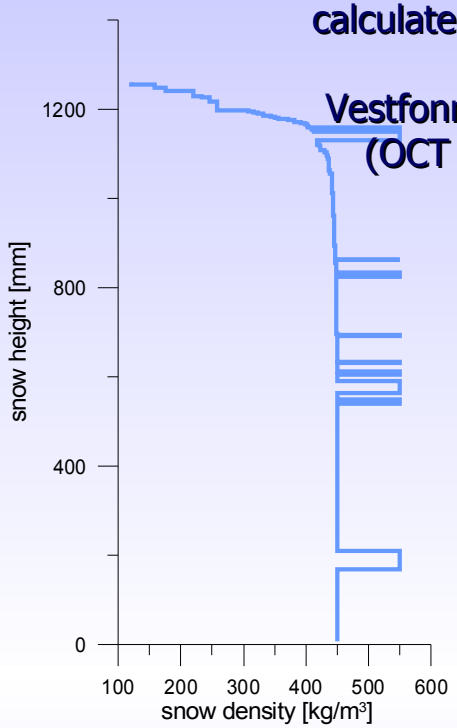
Hansbreen (OCT 2007 - MAY 2008) 186 m a.s.l.

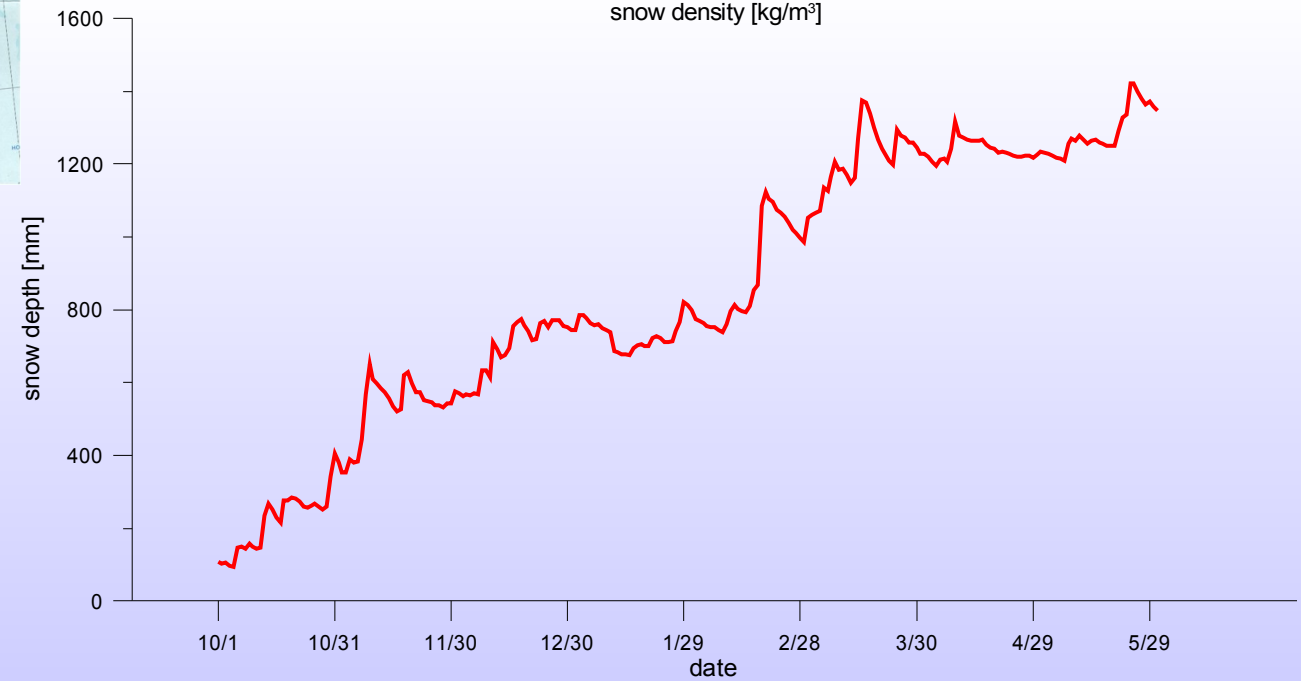


Snow cover developement and density calculated on ERA Interim data

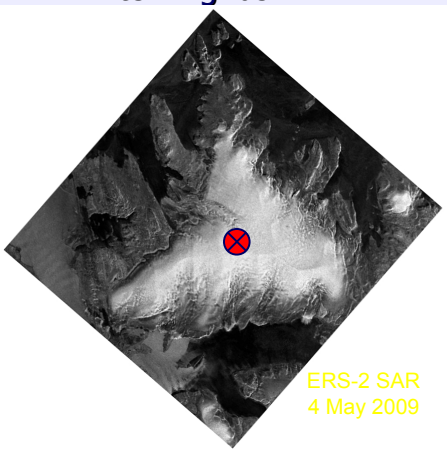




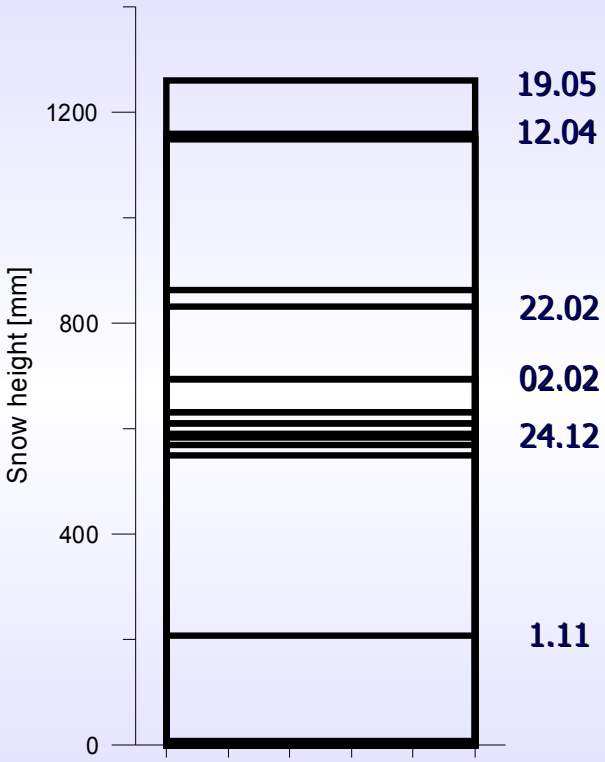




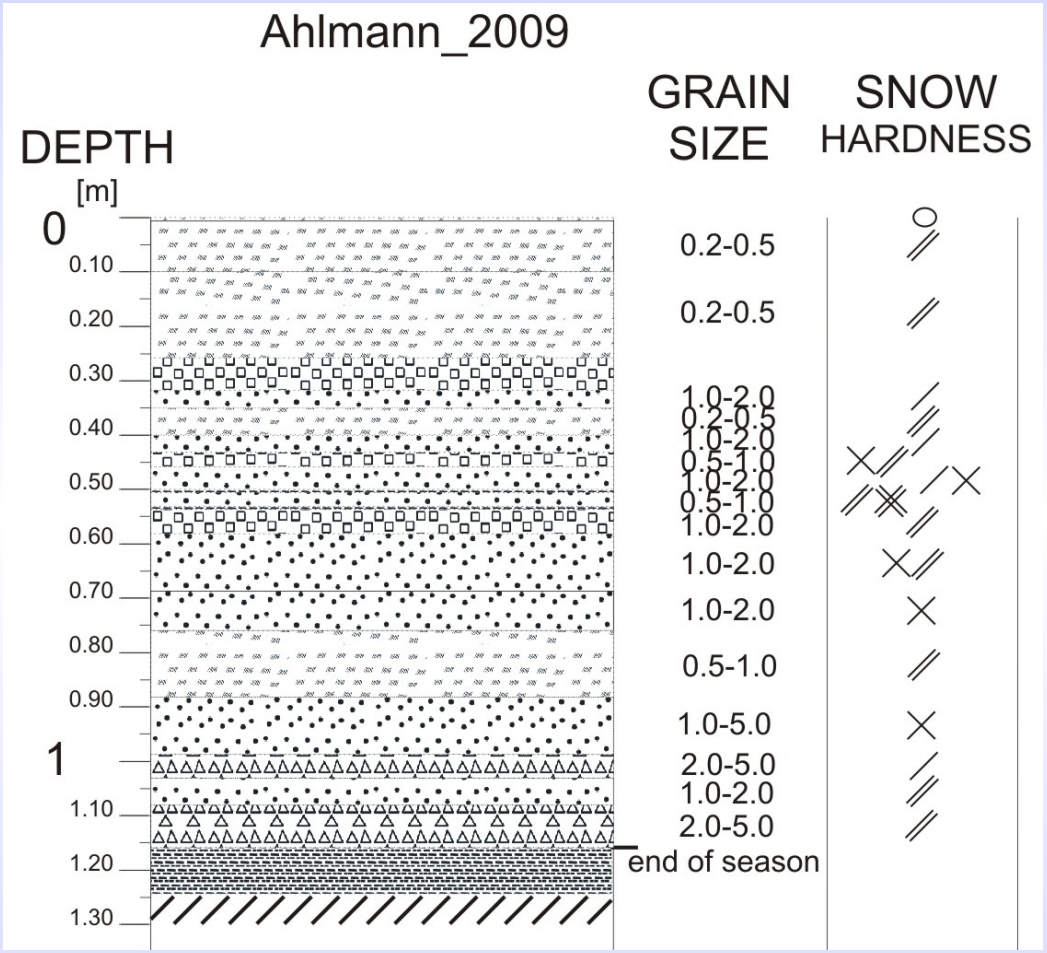
ERA Interim grids



Internal structure of snow cover on Vestfonna (Ahlmann Summit)



scc model



Snow pit

Conclusions

The snow cover development on Svalbard glaciers can be recreate relatively easy by analysis of meteorological data and physical processes within snow cover.

Simple one-dimensional model of snow cover changes (scc) was developed. The model satisfactorily reconstructs snow cover development on glaciers (Hansbreen as an example). SCC model approximates also variability of snow density in vertical profile and separates basic internal boundaries as an effect of short term warming and redeposition period.

Climatic re-analysis data were successfully applied for analysis of snow cover development in remote Arctic areas. ERA Interim re-analysis data were used to run scc model for snow cover study of Hansbreen and Vestfonna.

Thank you !



Acknowledgements

Authors would like to thank the Institute of Geophysics of the Polish Academy of Sciences and the European Centre for Medium-Range Weather Forecasts
for granting access to meteorological data and re-analysis. We also would like to express our thanks to Dr. Andrzej Araźny for making AWS data available and Hornsund/Kinnvika crew for field support. This research has been supported from finance for scientific research in 2007 - 2010 provided in research grants from the Polish Ministry of Science and Higher Education (IPY/269/2006 and IPY/279/2006) and continued within the confines of the ESF Project – SvalGlac (NCBiR/PolarCLIMATE–2009/2-1/2010) financed by the National Centre of Research and Development