Snow perspectives

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HIRLAM-ALADIN All Staff Workshop 2014
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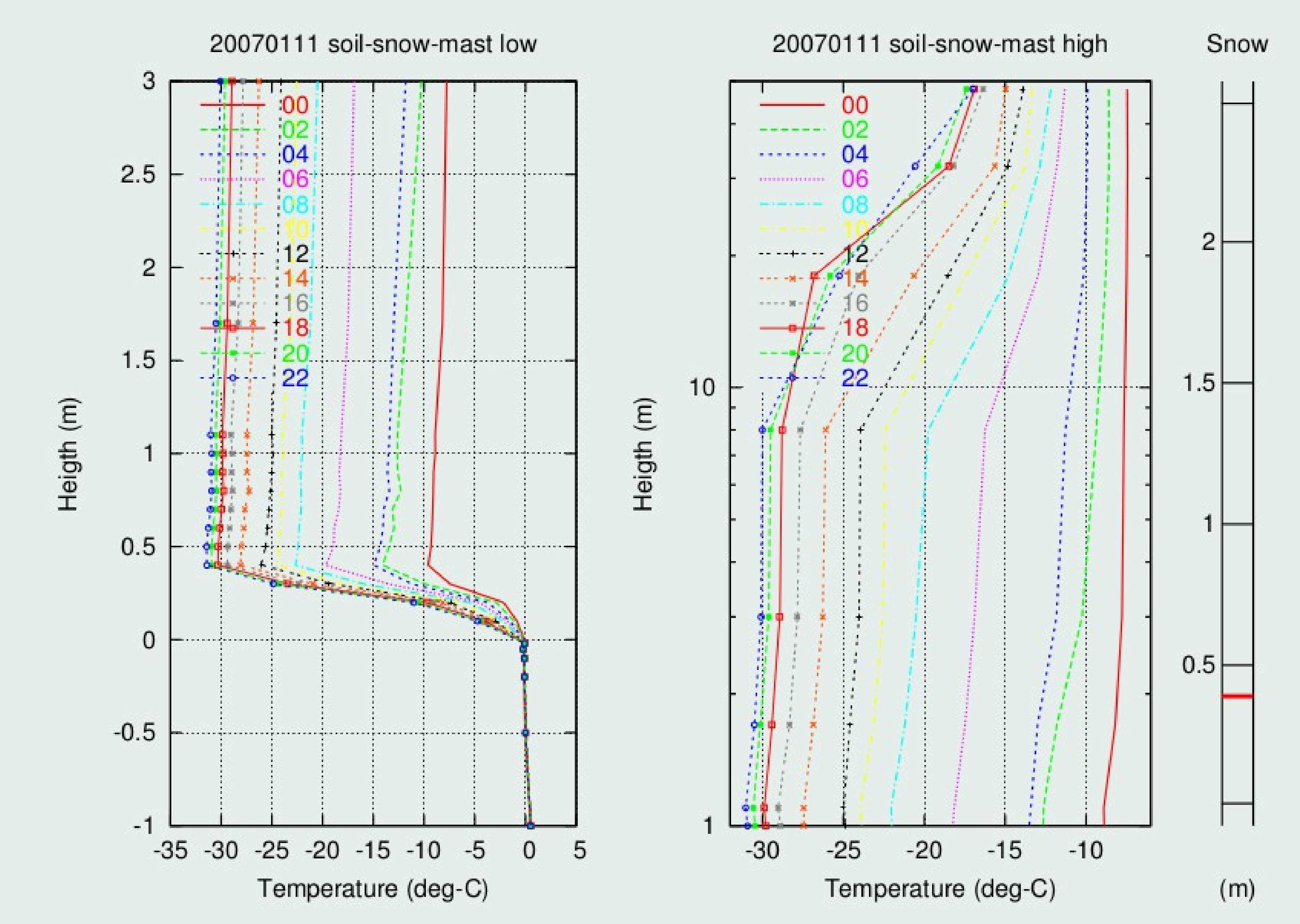
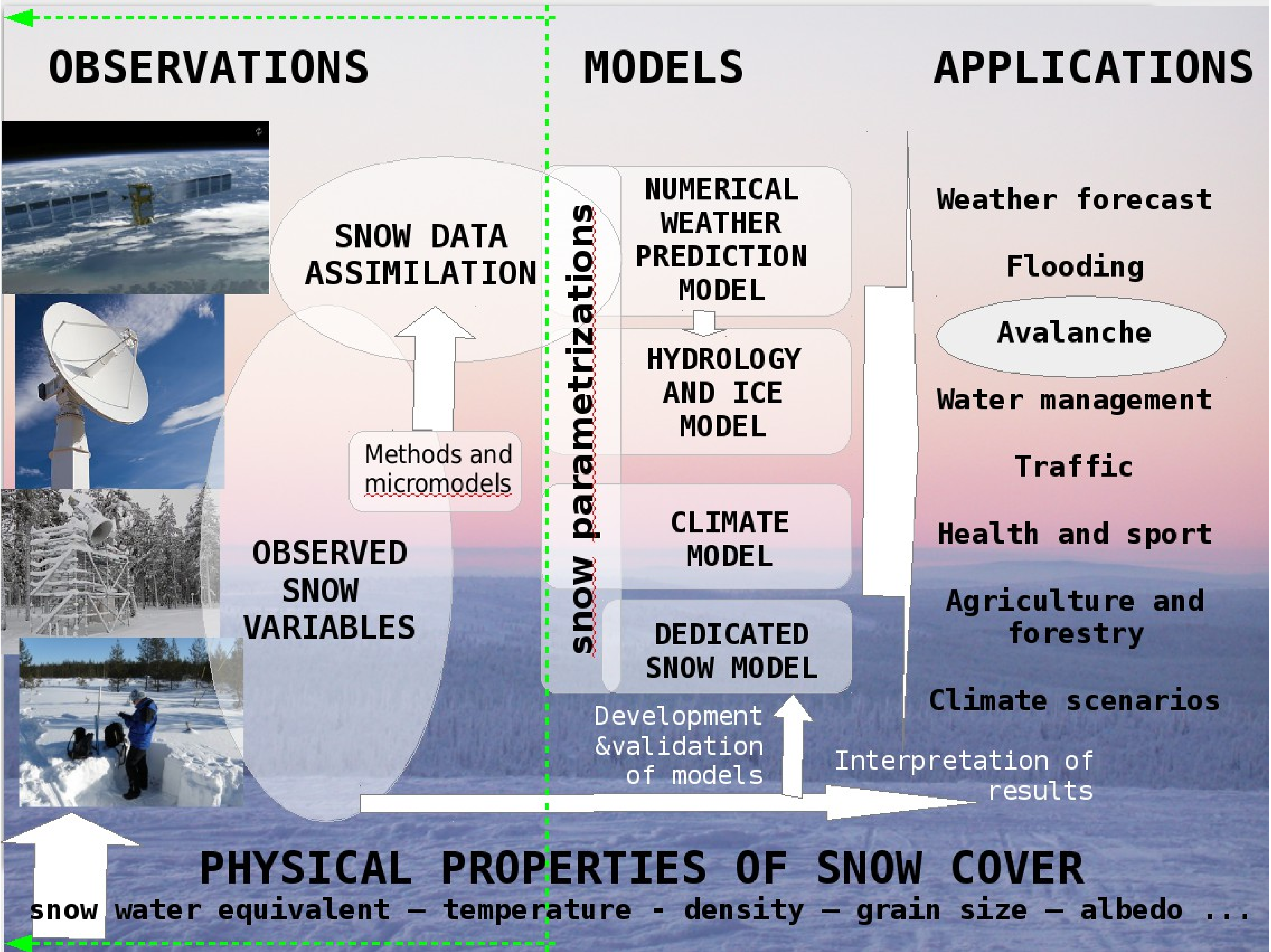
Contents

What does the snow cover mean for NWP?



Observed temperature profiles from the level of -1m (soil) to 50m (mast) when there was 0.4m snow on ground in Sodankylä and air cooled 20K during 24h


OBSERVATIONS
MODELS
APPLICATIONS
SNOW DATA ASSIMILATION
Methods and micromodels
OBSERVED SNOW VARIABLES
snow parametrizations
NUMERICAL WEATHER PREDICTION MODEL
HYDROLOGY AND ICE MODEL
CLIMATE MODEL
DEDICATED SNOW MODEL
Development &validation of models
Interpretation of results
Weather forecast
Flooding
Avalanche
Water management
Traffic
Health and sport
Agriculture and forestry
Climate scenarios
PHYSICAL PROPERTIES OF SNOW COVER
snow water equivalent – temperature - density – grain size – albedo ...

Contents

Local and remote sensing snow observations

SYNOP and climate stations:

Ultrasonic or manual snow depth measurements

- Represent local conditions

Satellite instruments:

Passive microwave sensors - e.g SMSI

- Coarse resolution wide area snow water equivalent

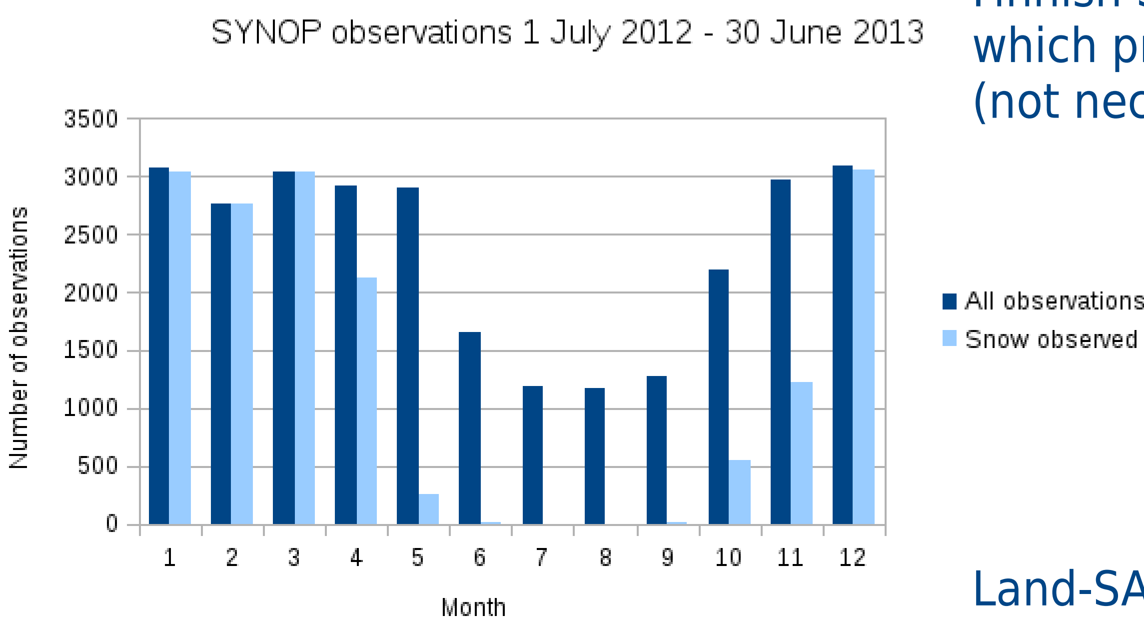
Optical/NIR – e.g.MODIS

- High resolution snow extent
- Limited by cloud and light problems

Active microwave – e.g. SAR from ESA's Sentinel-1

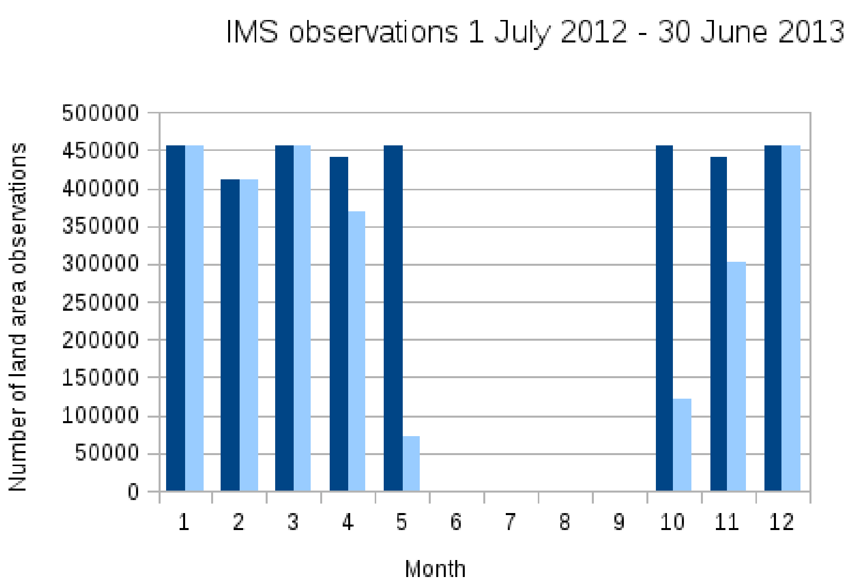
- Very high resolution indication of wet snow
- Narrow swath – infrequent data

Availability of various snow observations over Finland

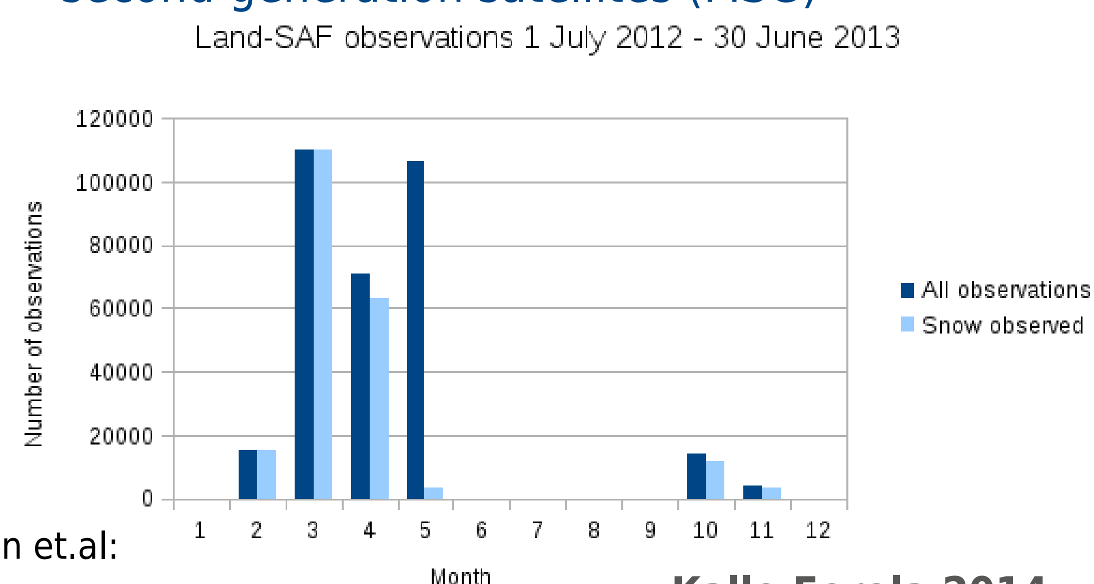


Finnish SYNOP snow depth observations which provide also no-snow information (not necessarily all transmitted via GTS)

Snow extent from the Interactive Multisensor Snow and Ice Mapping System (IMS*): multi-sourced datasets such as passive microwave, visible imagery, operational ice charts and other ancillary data



Land-SAF snow extent from EUMETSAT is based on visible imagery from geostationary Meteosat second generation satellites (MSG)



*National Snow and Ice Data Center (NSIDC), see Brown et.al: Remote Sensing of Environment 147 (2014) 65–78l,

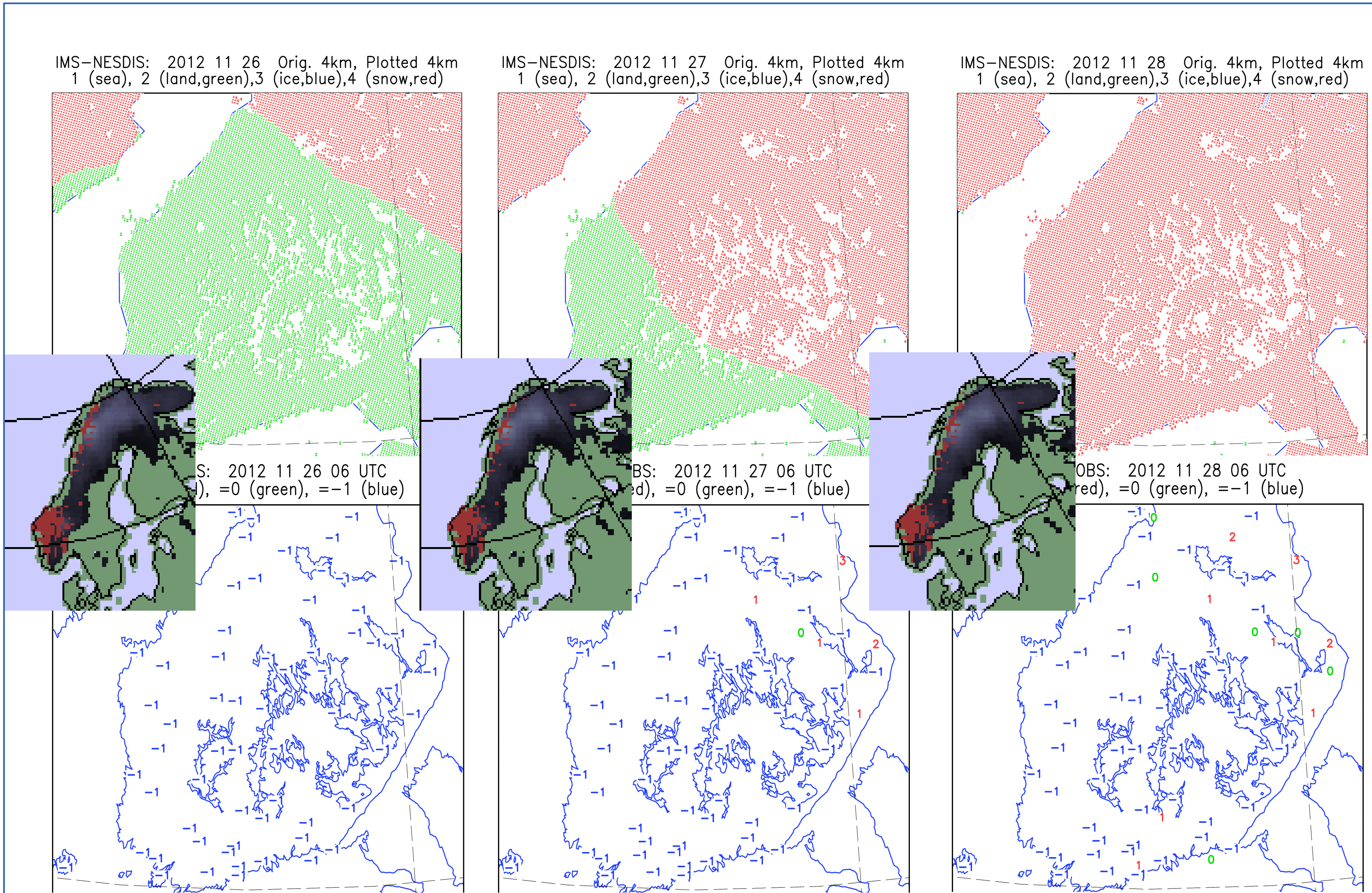
Kalle Eerola 2014

Example of the first snowfall in November 26-28 2012

IMS

Glob-snow SWE

SYNOP



(Land-SAF was not available those days)

What are the most valuable snow observations for NWP?

SYNOP + climate station snow observations, which provide also no-snow information

- Should be more widely available via GTS
- Should include the national group with no-snow information
- NWP models should read correctly the extended SYNOP code

Remote sensing observations

1) Snow water equivalent by passive microwave sensors
2) Snow extent seen by visible and derived from passive and active microwave signals
3) Snow wetness indicated by SAR instruments

Dilemma of using satellite data: ready-made products or spatialization + assimilation of the signals within surface DA of NWP models?

- Satellites with varying instrument specifications come and go – building long-lasting operational systems is difficult
- Products contain assumptions and rely on additional data sources different from those applied in NWP framework
- NWP model may provide up-to date background based on prognostic snow parametrizations – for quality control, for assimilation

e.g. IMS and Globsnow SWE are products, while SAR backscattering from the just launched Sentinel-1 would represent a raw signal

Contents

Prognostic snow schemes available in SURFEX

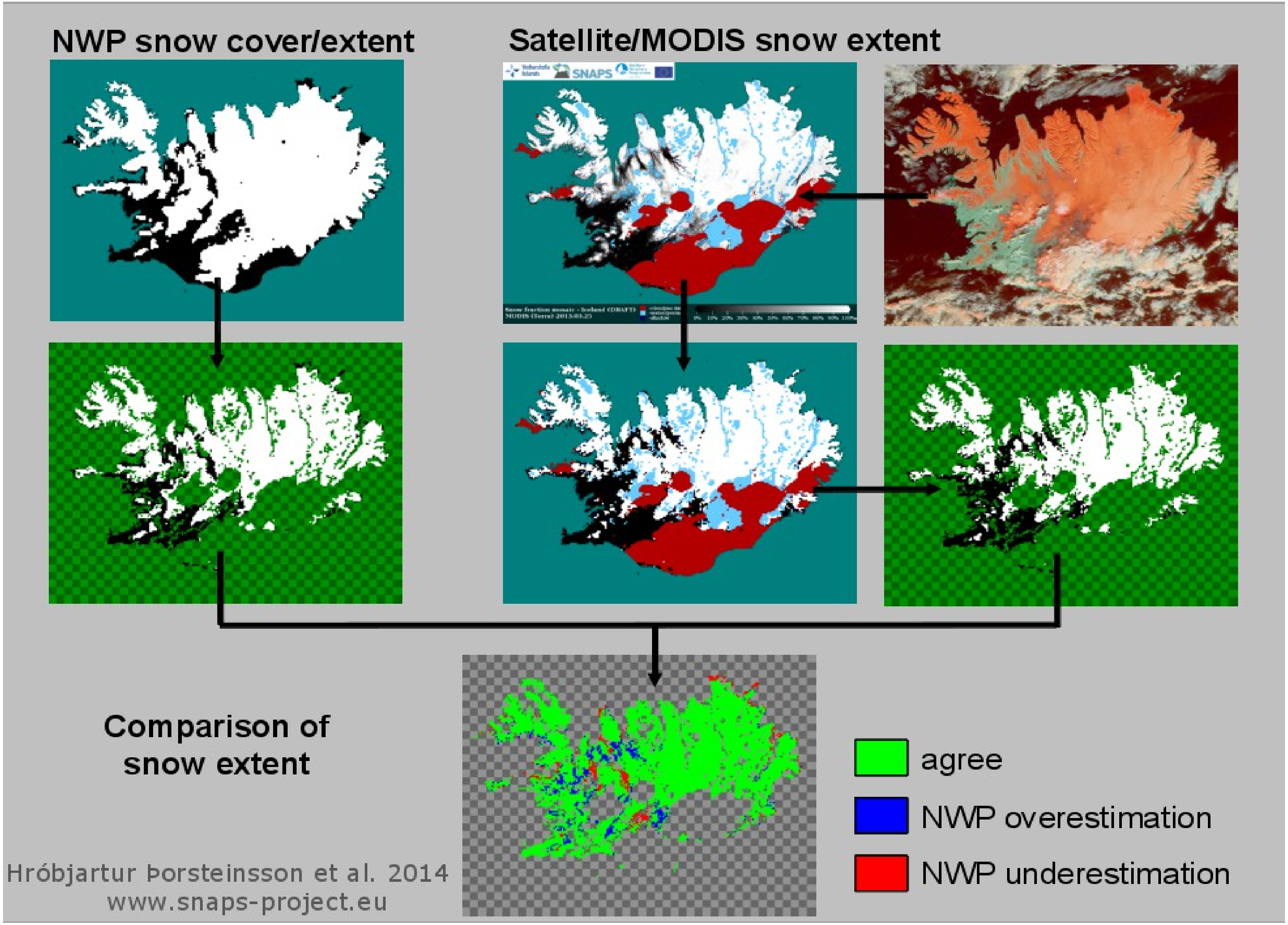
Single-layer	D95	Douville *et al.* (1995a,1995b)
Multi-layer	Explicit-Snow (ES)	Boone (2000); Boone and Etchevers (2001)
Multi-layer	Crocus	Brun *et al.* (1989,1992); Vionnet *et al.* (2012)

Table 4.1: Summary of the snowpack schemes available in ISBA*

ISBA + D95
Operational in HARMONIE-SURFEX

Layers in snowpack: One
Prognostic variables: SWE, snow density, snow albedo
but no separate snow temperature/liquid water content
Data assimilation: SWE updated with optimally interpolated snow depth

* SURFEX SciDoc v.2



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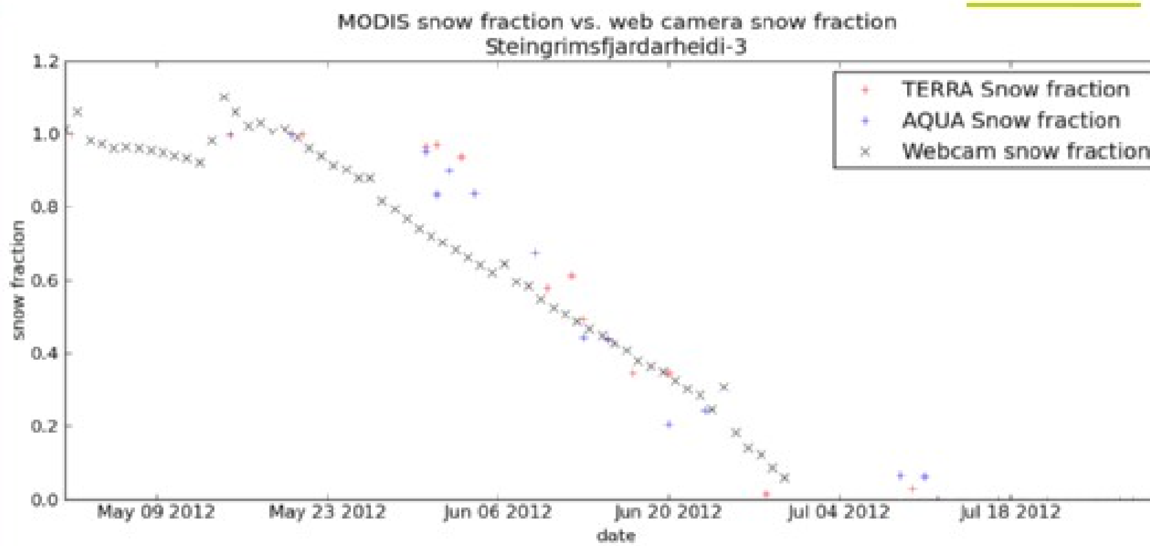
Verification of MODIS snow cover maps with web cameras



Road authority web camera was used to evaluate remote-sensing fractional snow cover

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Hróbjartur Þorsteinsson et al. 2014

Icelandic Met Office

Prognostic snow schemes available in SURFEX

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Multi-layer	Explicit-Snow (ES)	Boone (2000); Boone and Etchevers (2001)
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Table 4.1: Summary of the snowpack schemes available in ISBA*

ISBA + ES

Next operational in HARMONIE-SURFEX?

Layers in snowpack: ca. 3

Prognostic variables: heat content > temperature and liquid water, layer thicknesses and densities

Data assimilation: None yet

Other features: Possibly to couple MEB

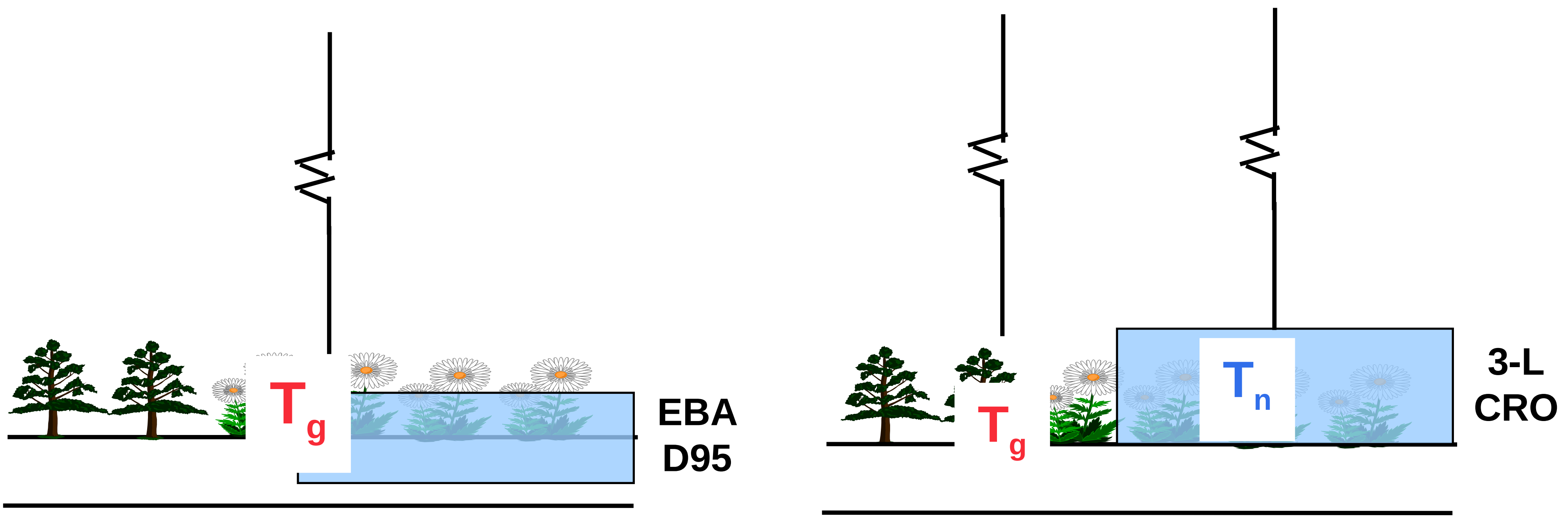
* SURFEX SciDoc v.2

SMHI

Surface-processes development in HIRLAM and in SURFEX

Patrick Samuelsson, SMHI
Aaron Boone, Meteo France
Stefan Gollvik, SMHI

Current SURFEX ISBA



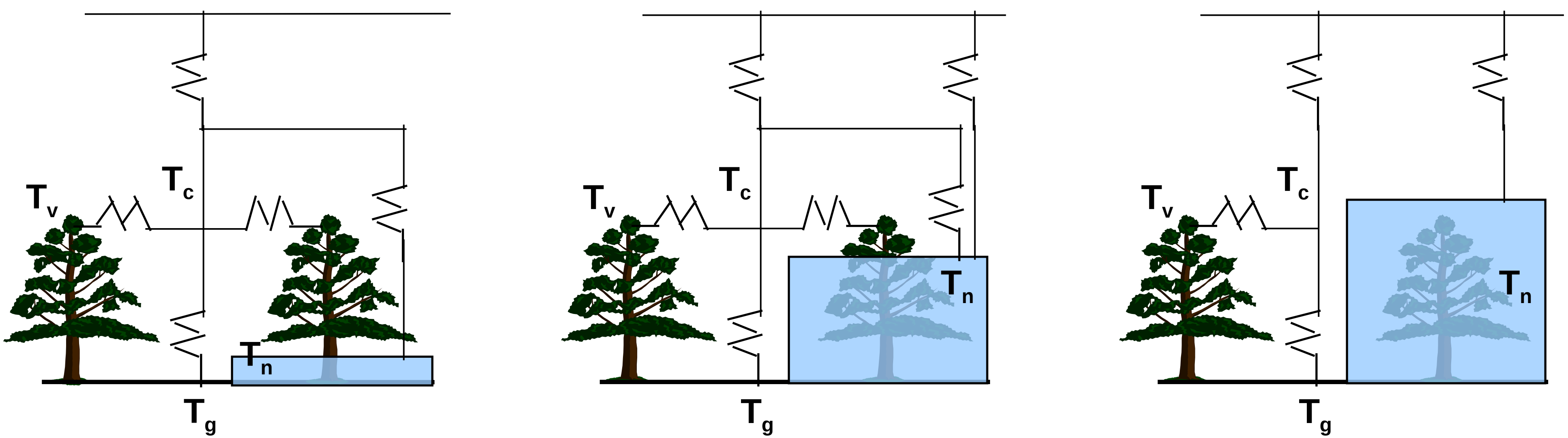
No explicit canopy vegetation energy balance (temperature)!
(and even no explicit snow temperature with EBA-D95 option)

Multi-Energy Balance (MEB)

Snow well below the canopy

Snow partly buries the canopy

Snow buries the canopy



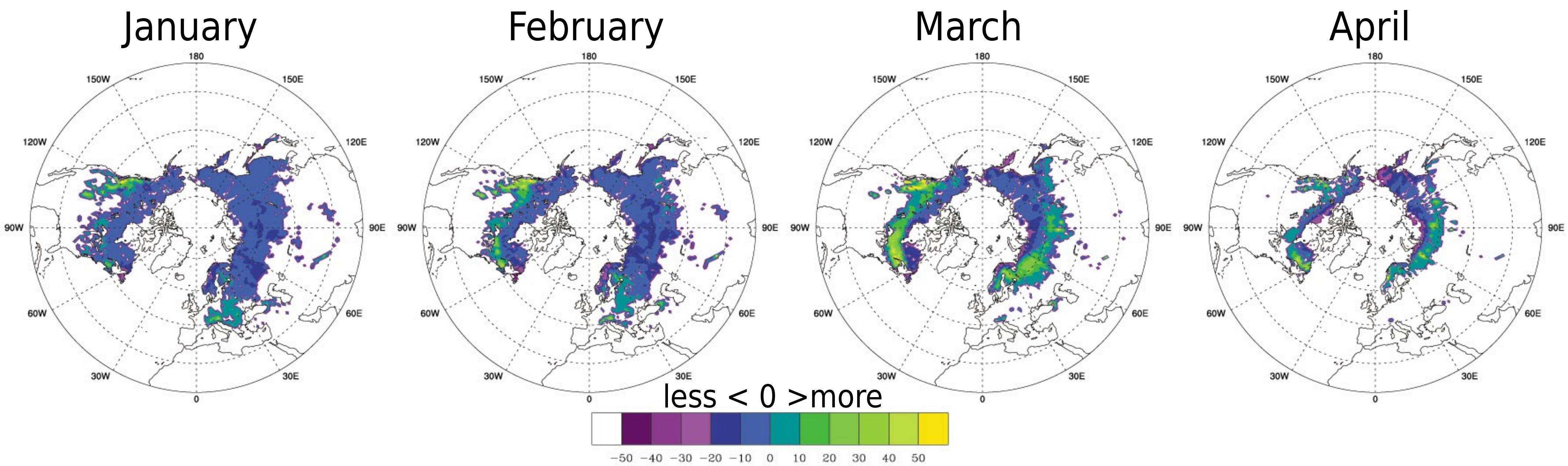
MEB is designed to work with

- snow schemes ES (3-L) and CRO (requires separate snow energy balance)
- soil scheme ISBA-DIF (diffusion) with patches (separate forest/grass/bare land)

2D offline experiment – Snow Water Equivalent

With MEB:

- Less snow in forested areas in mid winter (10-20 kg m^{-2}) due to snow interception
- More snow in forested areas late in winter (20-50 kg m^{-2}) due to a combination of radiation and turbulence effects
- The melting is delayed



Difference SWE ISBA-MEB – ISBA
Average over 1978-2008 in kg m^{-2}

Status of SURFEX-MEB April 2014

Technical status and tests

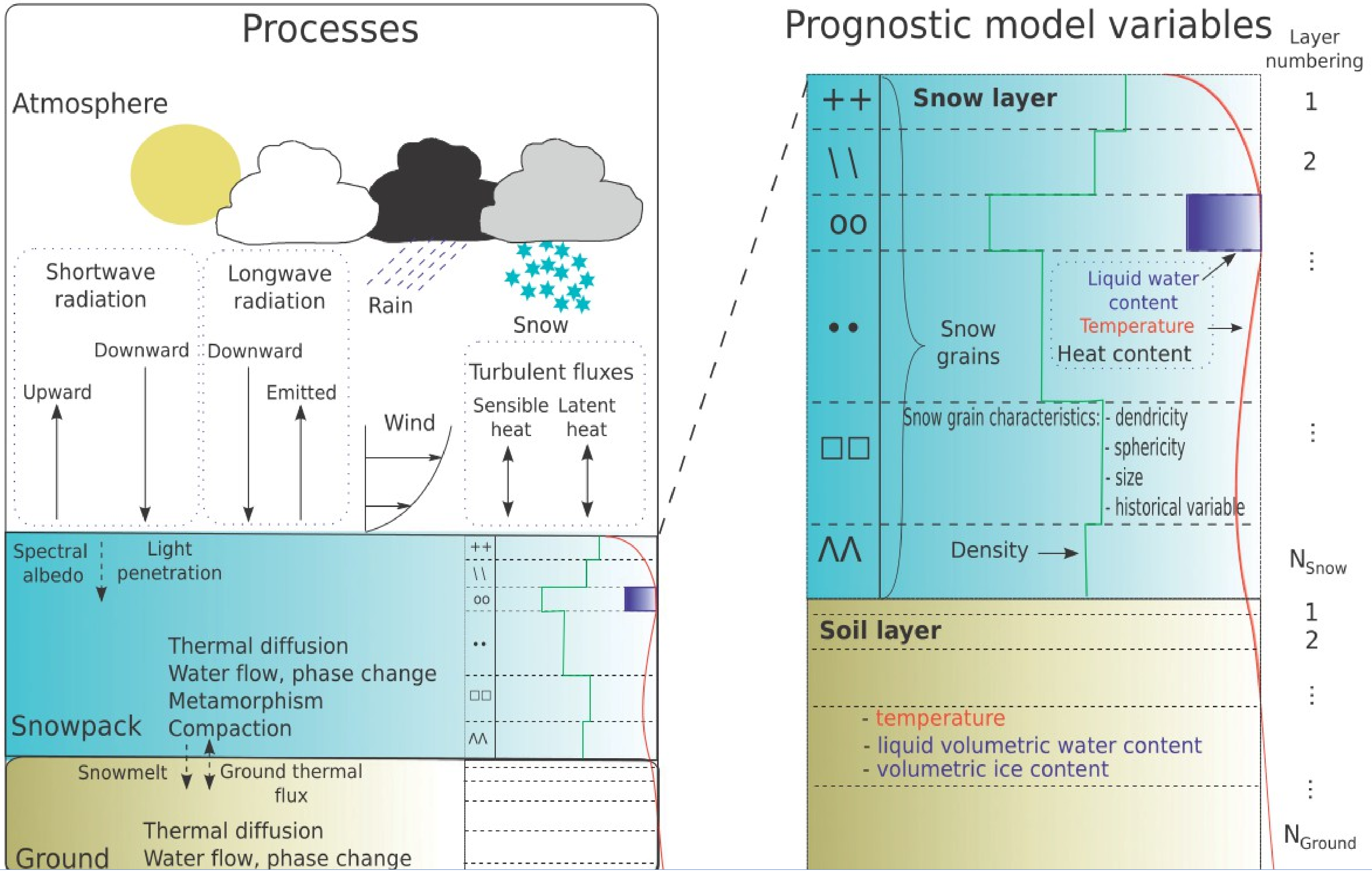
- Since January 2014 MEB is running in SURFEX7.3 development environment in offline 1D and 2D multi-year setups.
- MEB will be part of the SURFEX v8 release later this year.
- Later this year MEB will be tested in coupled mode for AROME/ALARO climate simulations.

Scientific status and tests

- Multi-year 2D offline test simulations have been performed over an European domain (100x100 grid boxes) forced by lowest model level from a hindcast climate simulation. All variables look realistic and MEB T2m climate agrees well with ISBA T2m climate.
- Tests using meteorological tower based forcing are ongoing for various sites. Evaluation is done against available observations (turbulent fluxes, snow, soil temperature and moisture, …).
- Scientific evaluation including parameter tuning will continue for the rest of the year as well as preparation of per-reviewed publications.

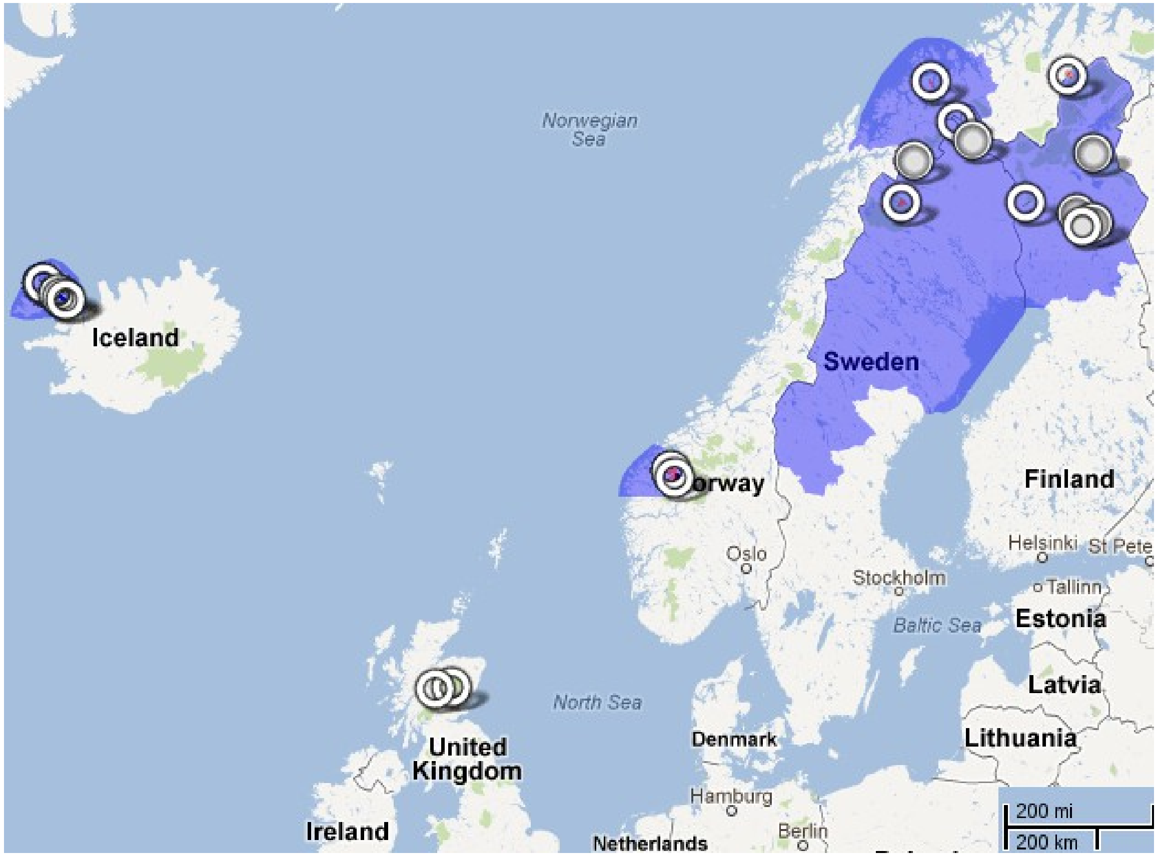
MEB scientific documentation is ongoing (to be part of SURFEX v8 scientific documentation).

Explicit snow and Crocus snowpack model



Brun, E., V. Vionnet, A. Boone, B. Decharme, Y. Peings, R. Valette, F. Karbou and S. Morin, Simulation of northern Eurasian local snow depth, mass and density using a detailed snowpack model and meteorological reanalyses, J. Hydrometeor., 14, 203–219, doi: 10.1175/JHM-D-12-012.1, 2013.

How to use stand-alone Crocus driven by NWP output?*



Data picked from HIRLAM and HARMONIE

Lowest model level variables to be used as atmospheric forcing for SURFEX/CROCUS, wind drift

Snow-related variables for comparison/validation against observations

* See also the Norwegian poster!

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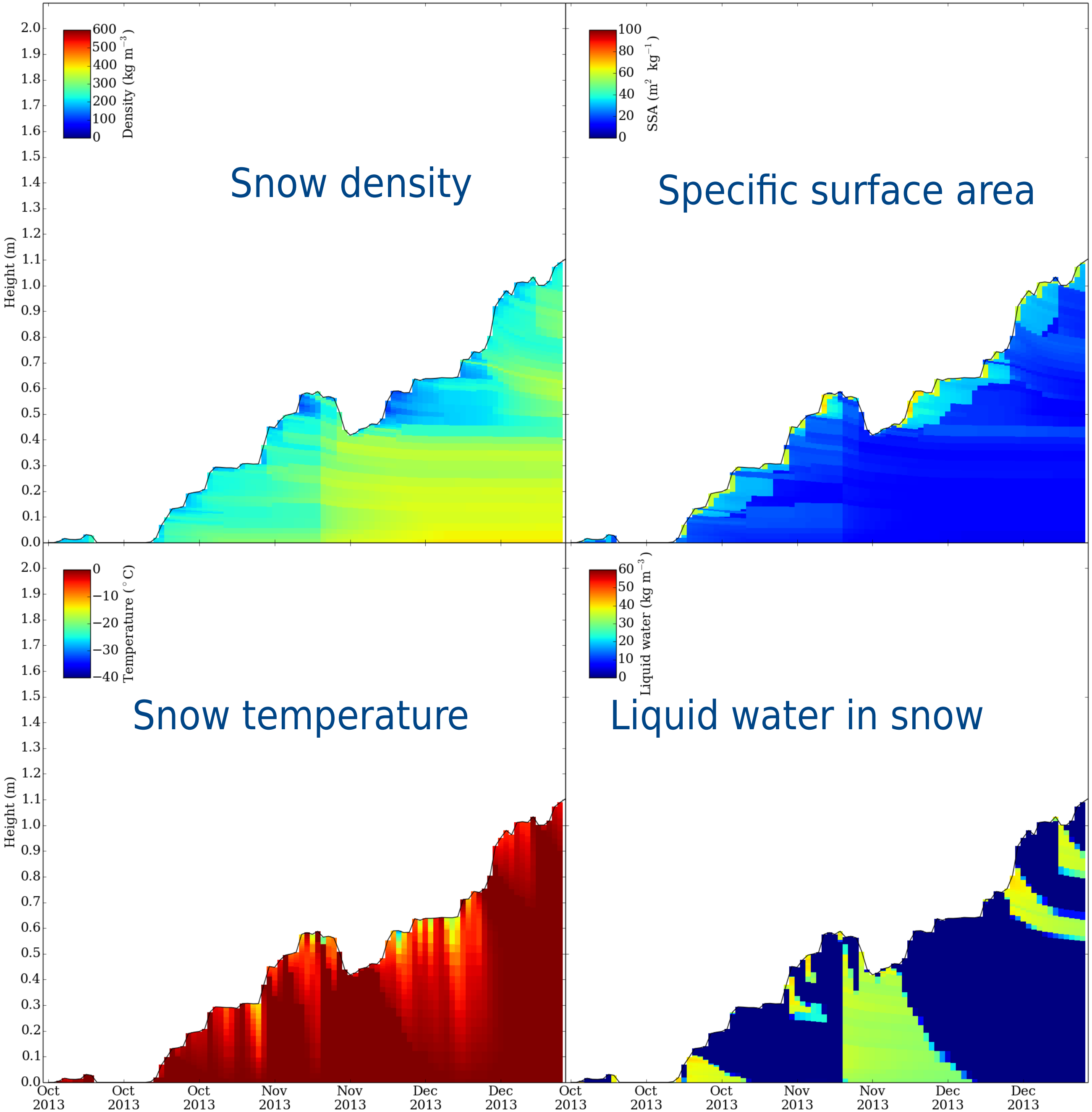
CROCUS on Kistufell (23.257W 66.074N)



HIRLAM forecast (resolution 7 km/65L) temperature, humidity, wind, downward SW and LW radiation and (snow) precipitation were applied to drive CROCUS for the autumn 2013 at Kistufell target point

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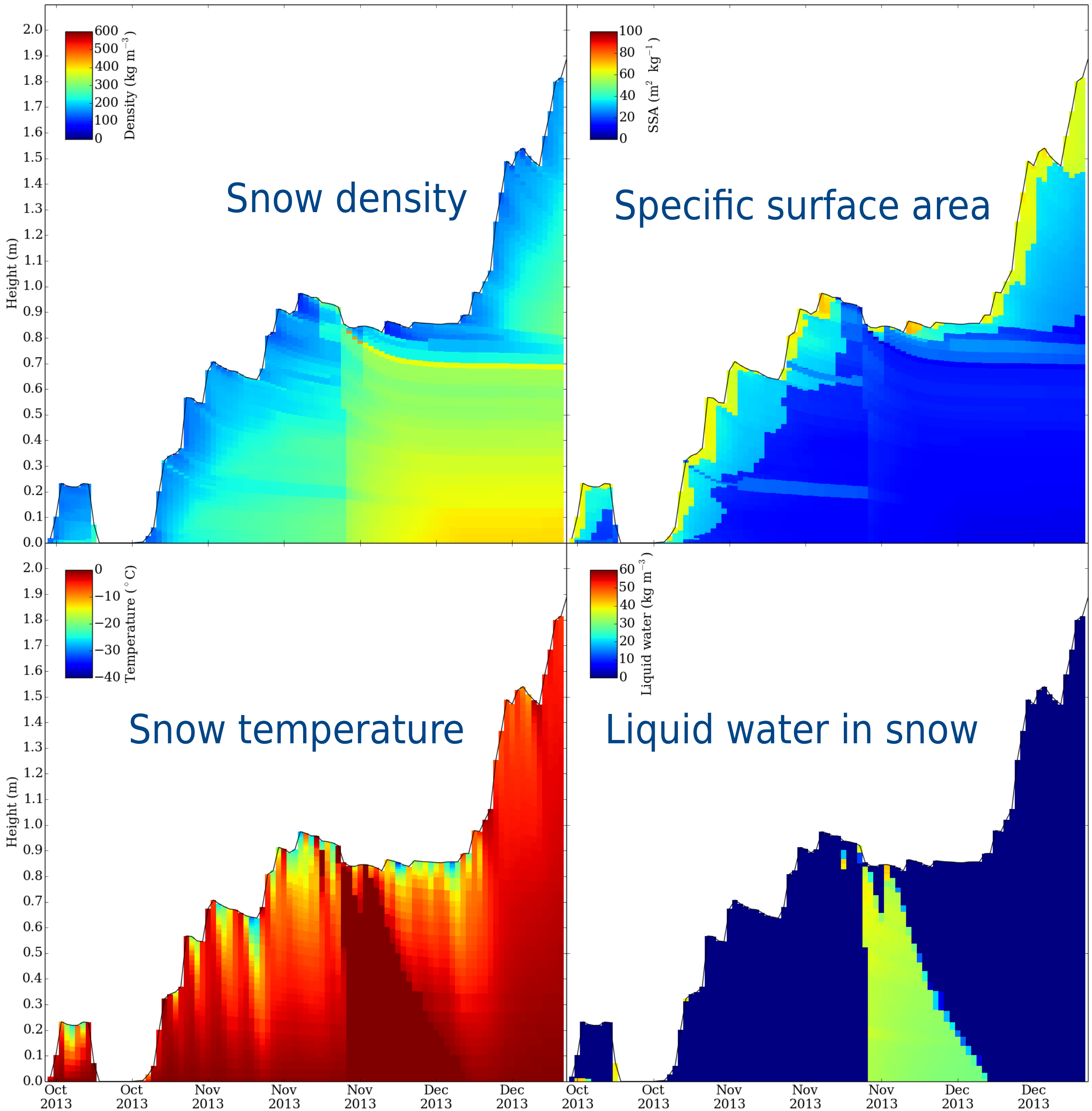
CROCUS on Kistufell (23.257W 66.074N)



HARMONIE/AROME forecast (1km/65L) temperature, humidity, wind, downward SW and LW radiation and (snow) precipitation were applied to drive CROCUS for the autumn 2013 at Kistufell target point

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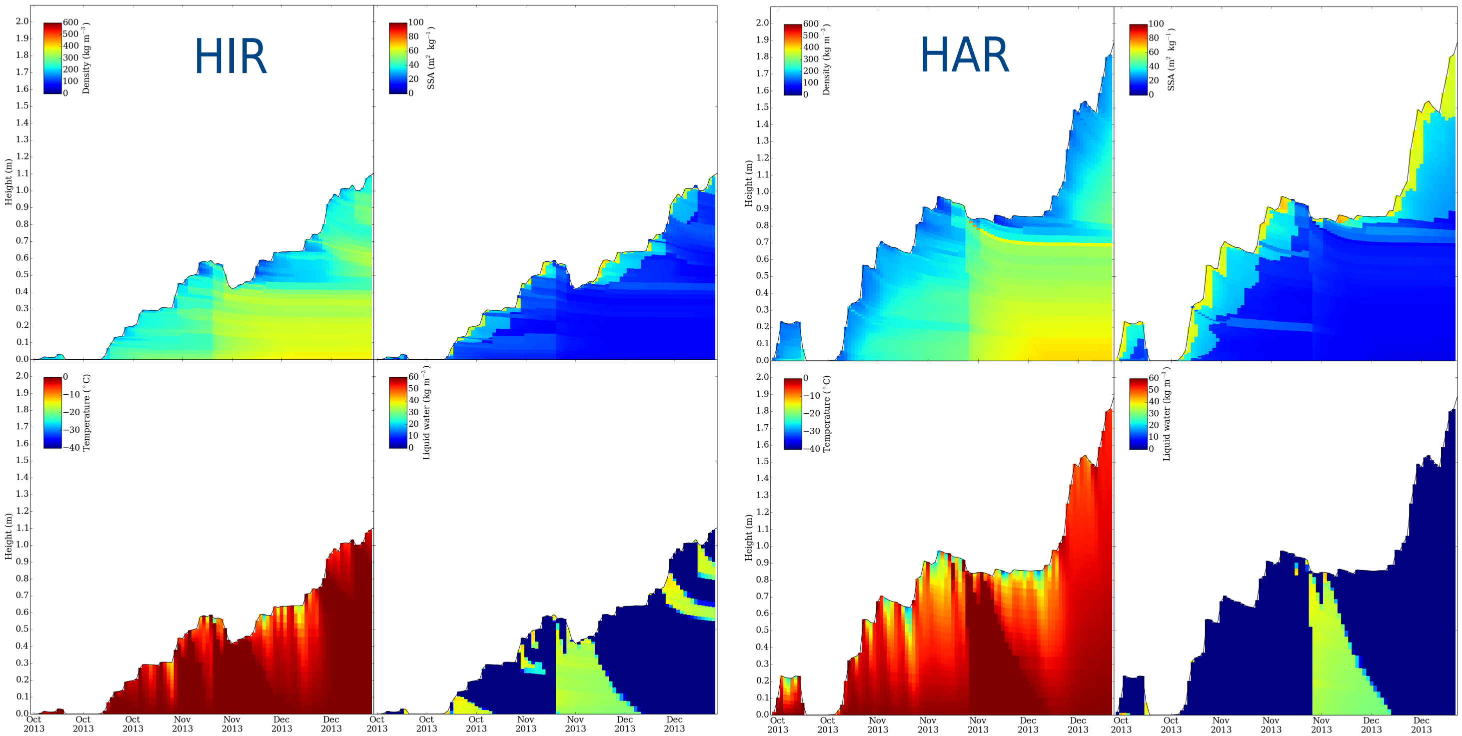
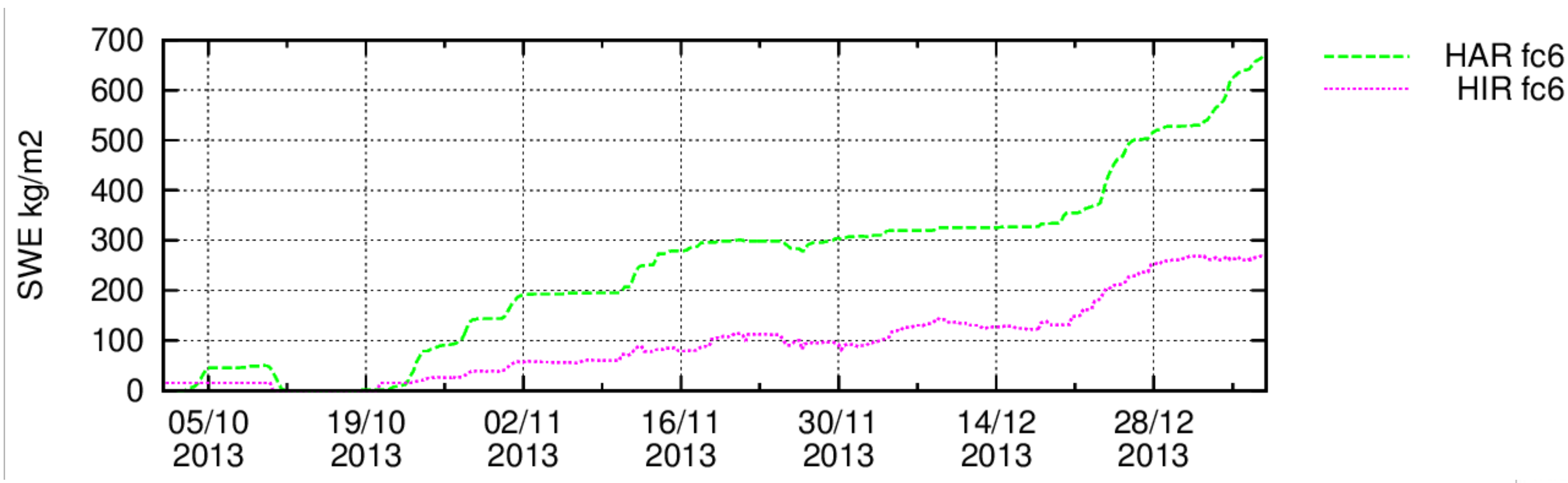
CROCUS on Kistufell (23.257W 66.074N)



The result is different because of the different atmospheric forcing by two weather models

CROCUS could also be driven by observations, but they are seldom sufficiently available



Contents

Introduction

Snow observations

Snow forecast

Snow data assimilation

Perspectives

Operational snow analyses

Model	Observations	Assimilation	Operational
CMC	SYNOP	OI	1999
ECMWF	SYNOP	Cressman	1987
	IMS	Cressman	2004
		OI	2010
HARMONIE	SYNOP	OI	2010
HIRLAM	SYNOP	Cressman	1995
	SYNOP	OI	2004
	Globsnow	OI	Experimental
Met Office	IMS	Update	2009

Richard Essery
http://www.ecmwf.int/newsevents/meetings/workshops/2013/Polar_prediction/Presentations/Essery.pdf

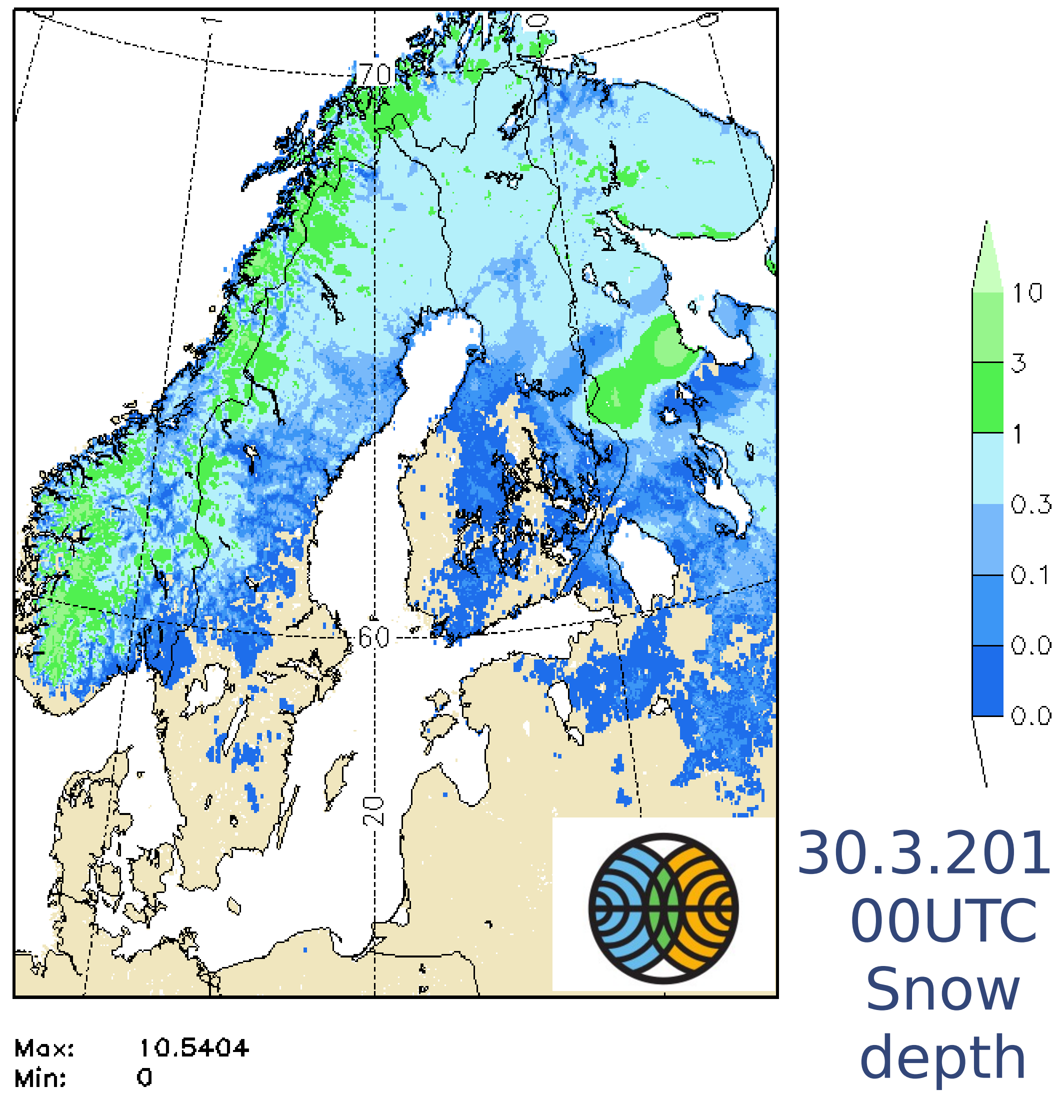
Operational CANARI snow analysis

spreading snow observations to model grid in horizontal

Optimal interpolation of snow depth of SYNOP station observations

Snow depth > SWE using assumed snow density

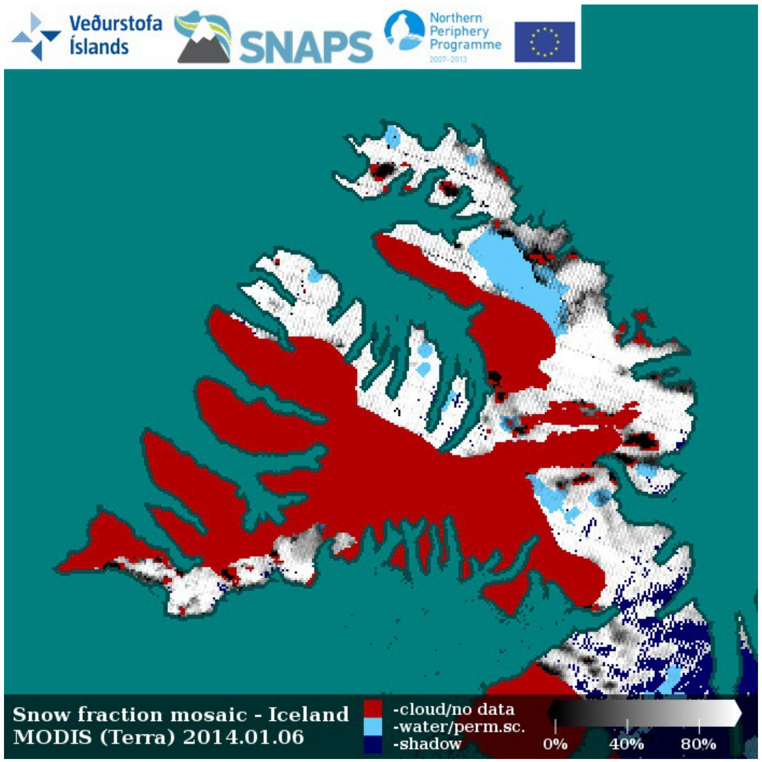
Background error correlations include horizontal and vertical terms*



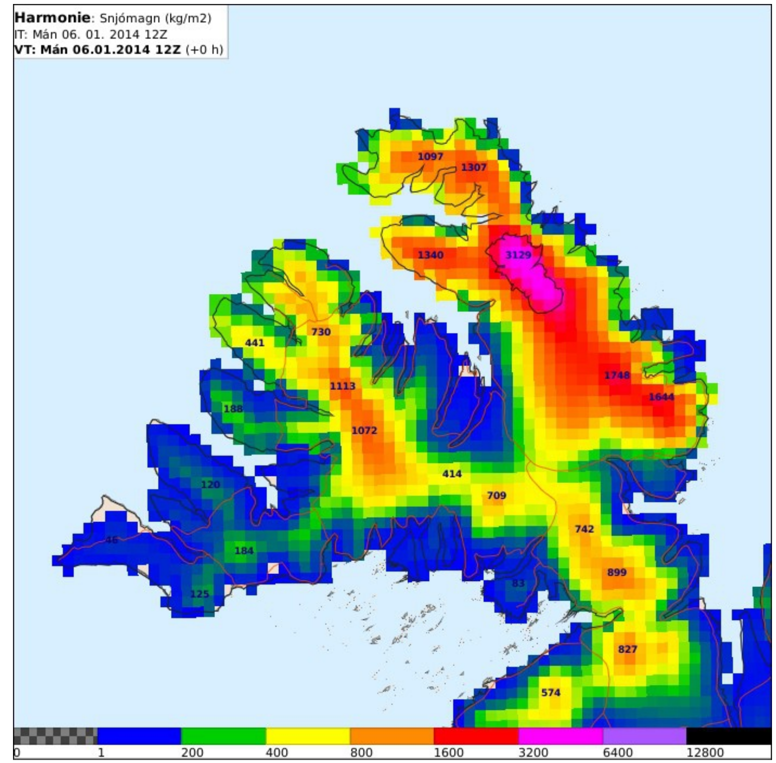
30.3.2014 00UTC Snow depth

* presentation by Mariken Homleid, ASW13

Snow in Westfjords 6 Jan 2014



MODIS satellite
snow cover



HARMONIE Vedurstofa AROME
Forecast snow water equivalent

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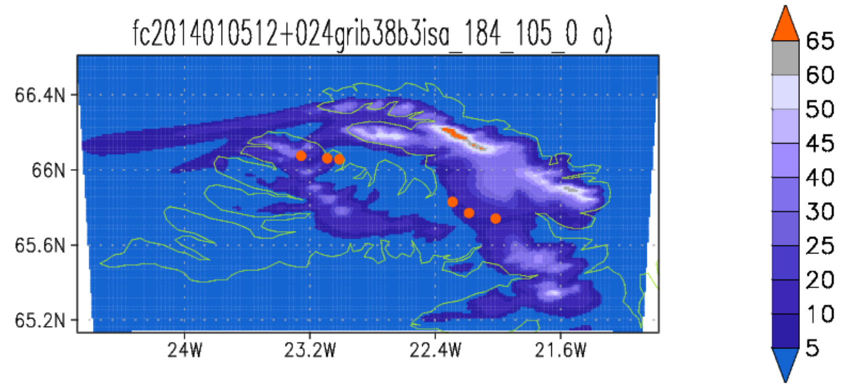
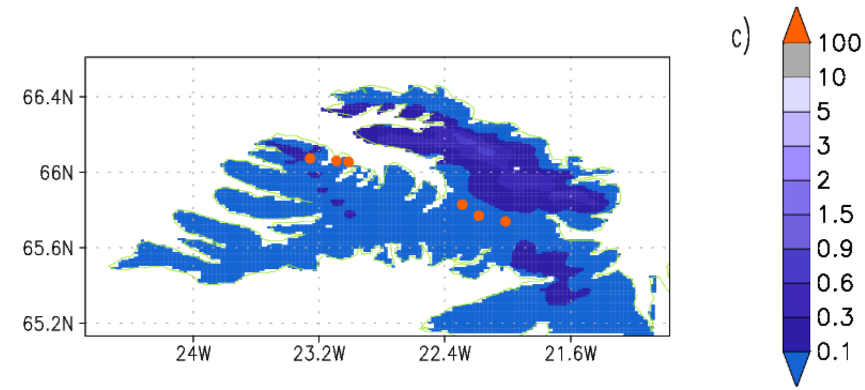
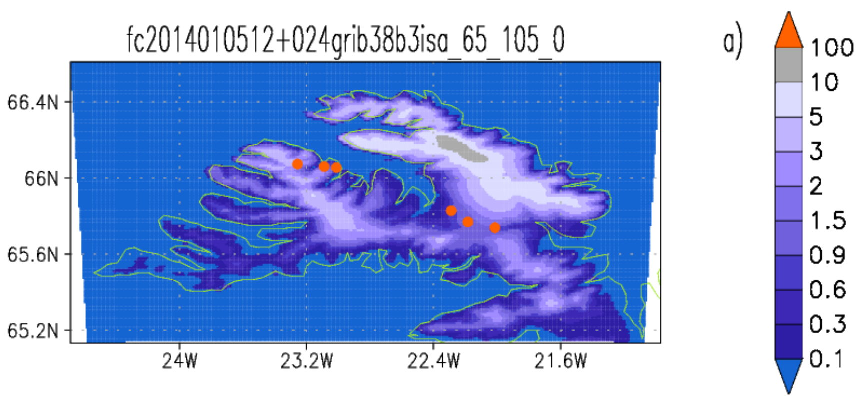
HARMONIE 1km-resolution experiment



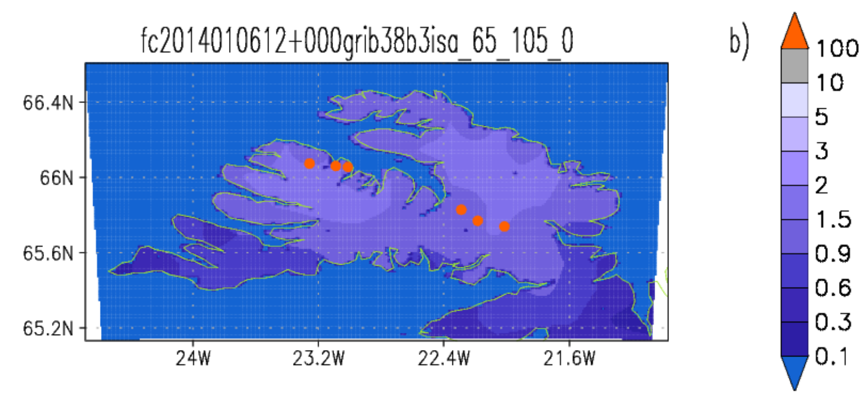
predicted snowfall (mm SWE)



predicted increase of snow depth (m*)



predicted snow depth (m*)



analysed snow depth (m*)
based on very few observations?

* assumed snow density 250 kg/m3

● target points, not observations for analysis

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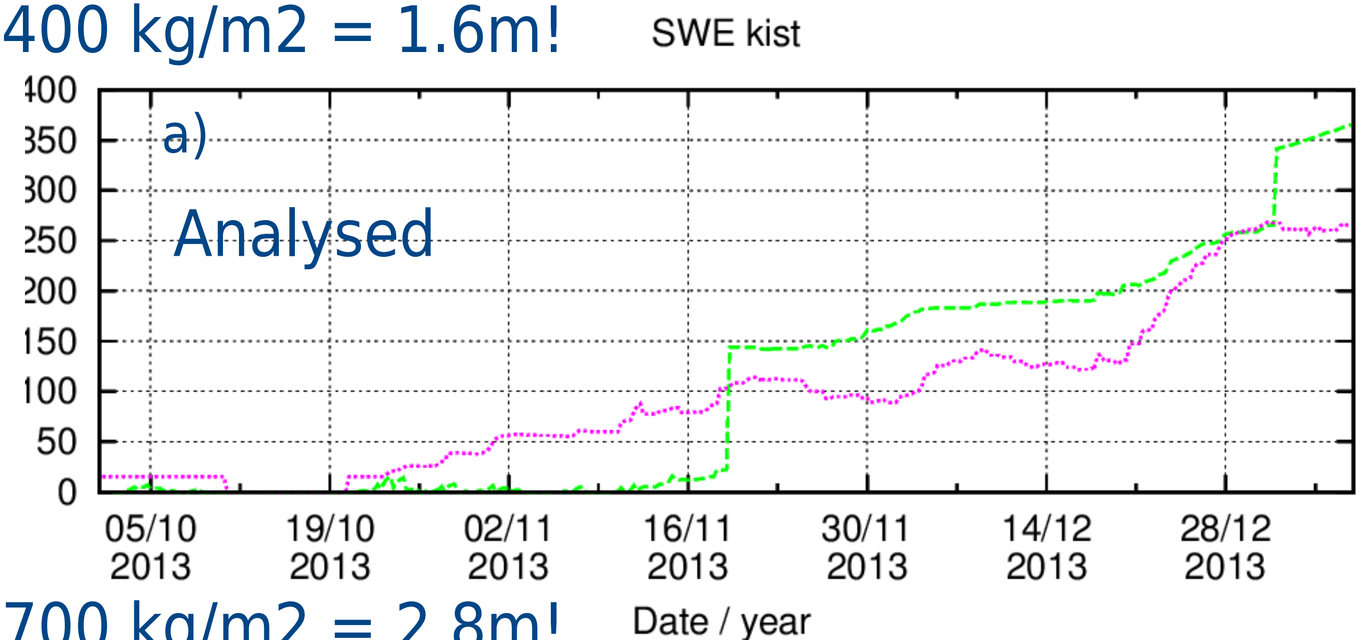
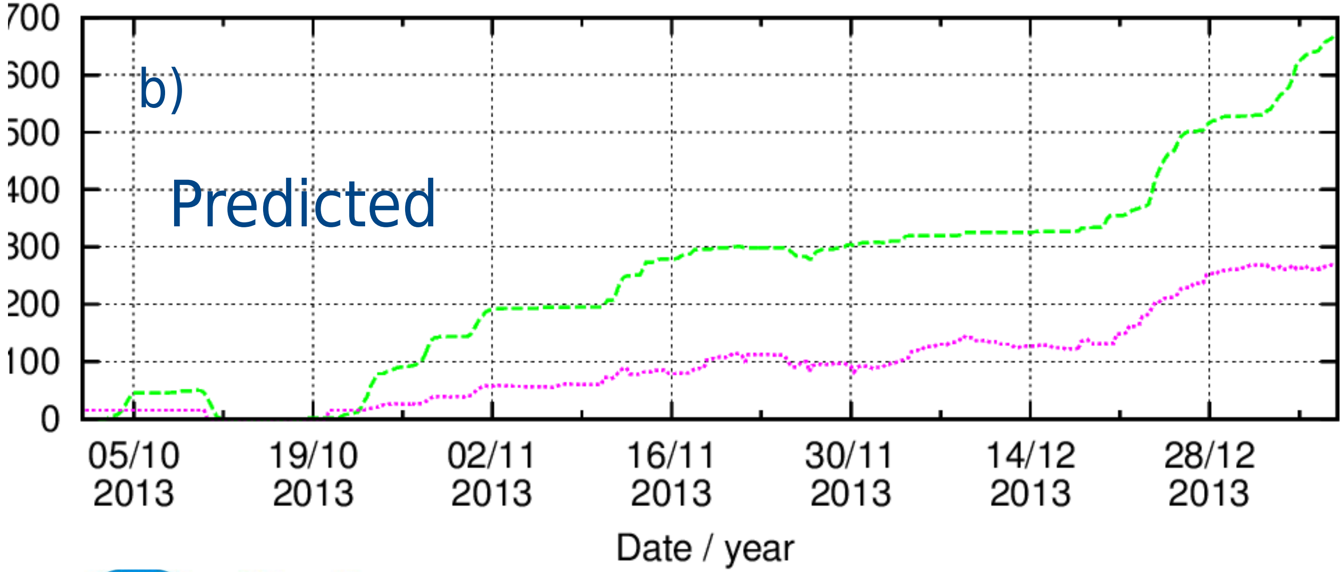
400 kg/m2 = 1.6m!



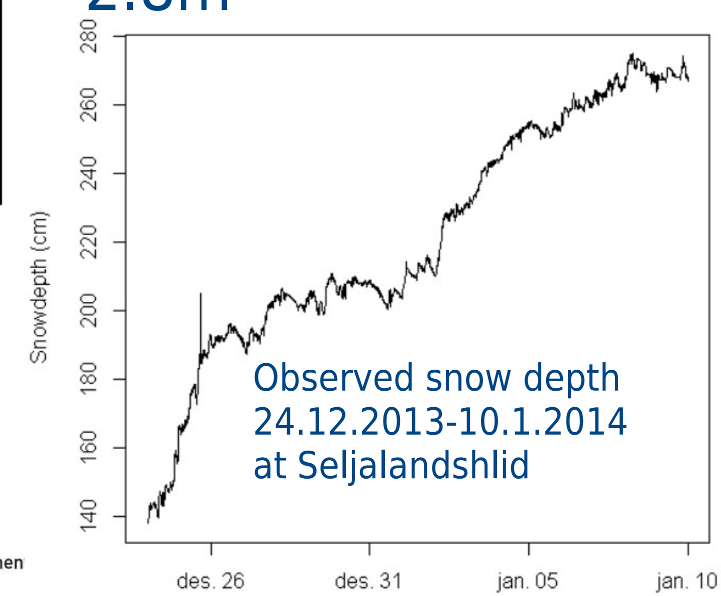
Analysed (a) and predicted (b) snow water equivalent at Kistufell till 6th Jan 2014.

700 kg/m2 = 2.8m!



HARmonie 1km,
HIRlam 7km
fc0=analysis,
fc6=6h forecast

2.8m



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Snow in Westfjords – first conclusions?

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Would the snow data assimilation of a NWP model provide up-to date observation-based snow maps sufficient not only for the NWP itself but also for the SNAPS purposes?
- i.e., to replace the satellite snow maps?

Problems:

- Satellite snow maps by optical sensors suffer from cloudiness
- HARMONIE snow forecast looks qualitatively good as snow map but needs more validation
- HARMONIE snow data assimilation may not work properly

→ No, we are not yet there:
both NWP forecast and satellite maps are needed for snow mapping

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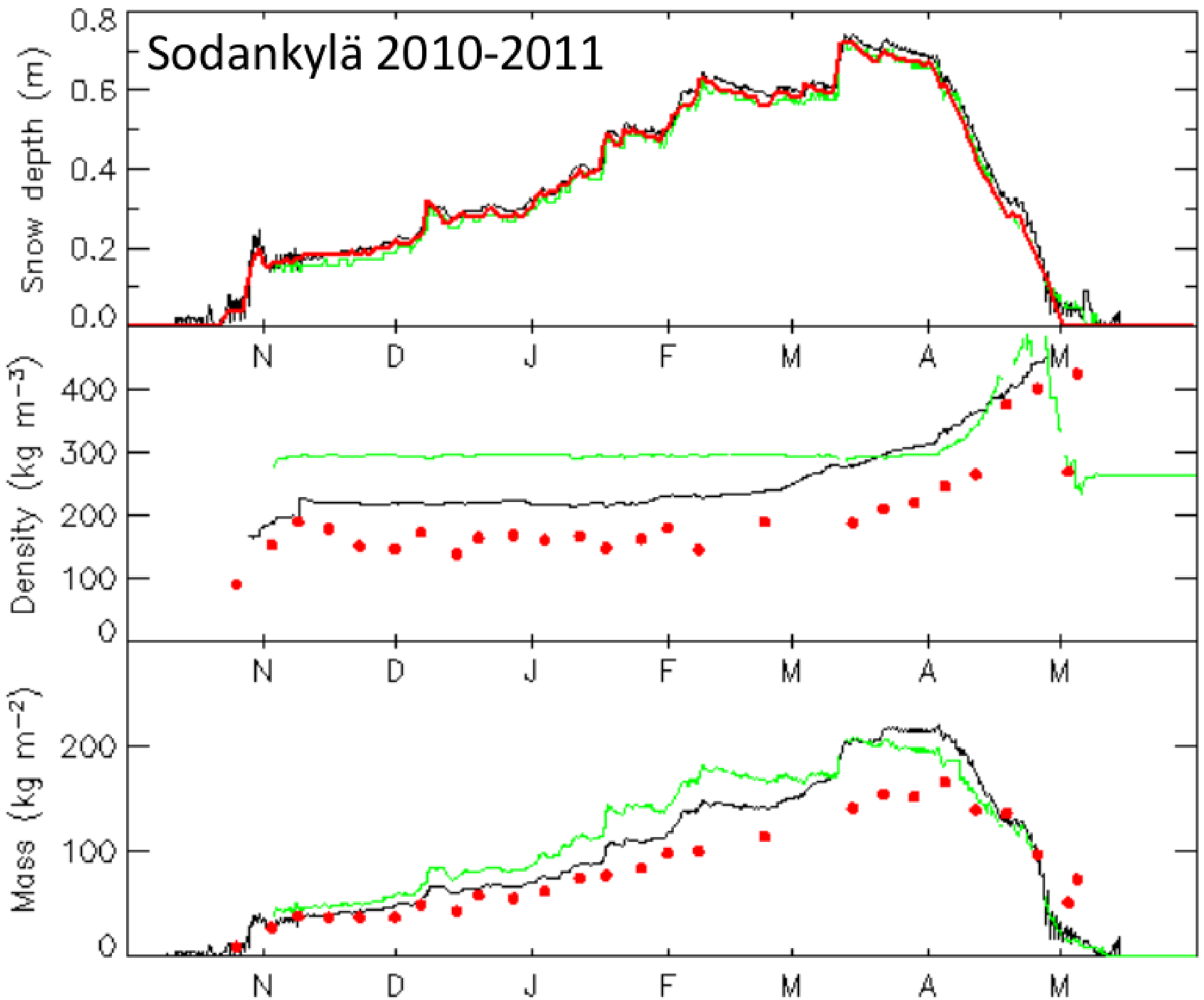
Operational snow analyses



SYNOP snow depths and FMI snow pits (from Timo Ryyppö)

Hirlam snow analyses (from Laura Rontu)

ECMWF snow analyses (from Patricia de Rosnay)

Richard Essery

http://www.ecmwf.int/newsevents/meetings/workshops/2013/Polar_prediction/Presentations/Essery.pdf

Development of snow data assimilation methods

Assimilation of ground-based snow data requires:

- good background estimate of snow density
- good estimates of observation and model errors (underestimation of model / observation error ratio is worse than overestimation)
- may not require advanced data assimilation techniques

The use of a Kalman Filter will still be beneficial if information can be propagated to unobserved state variables through off-diagonal elements in the gain matrix, either due to <u>correlation between state variables in the model</u> or the use of a <u>complex observation operator</u> such as a <u>microwave emission model</u> or <u>assimilation of radiance data</u>.

Richard Essery
http://www.ecmwf.int/newsevents/meetings/workshops/2013/Polar_prediction/Presentations/Essery.pdf

Contents

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Near future snow work in HARMONIE

Acquire more and use fully SYNOP/climate station snow depth observations

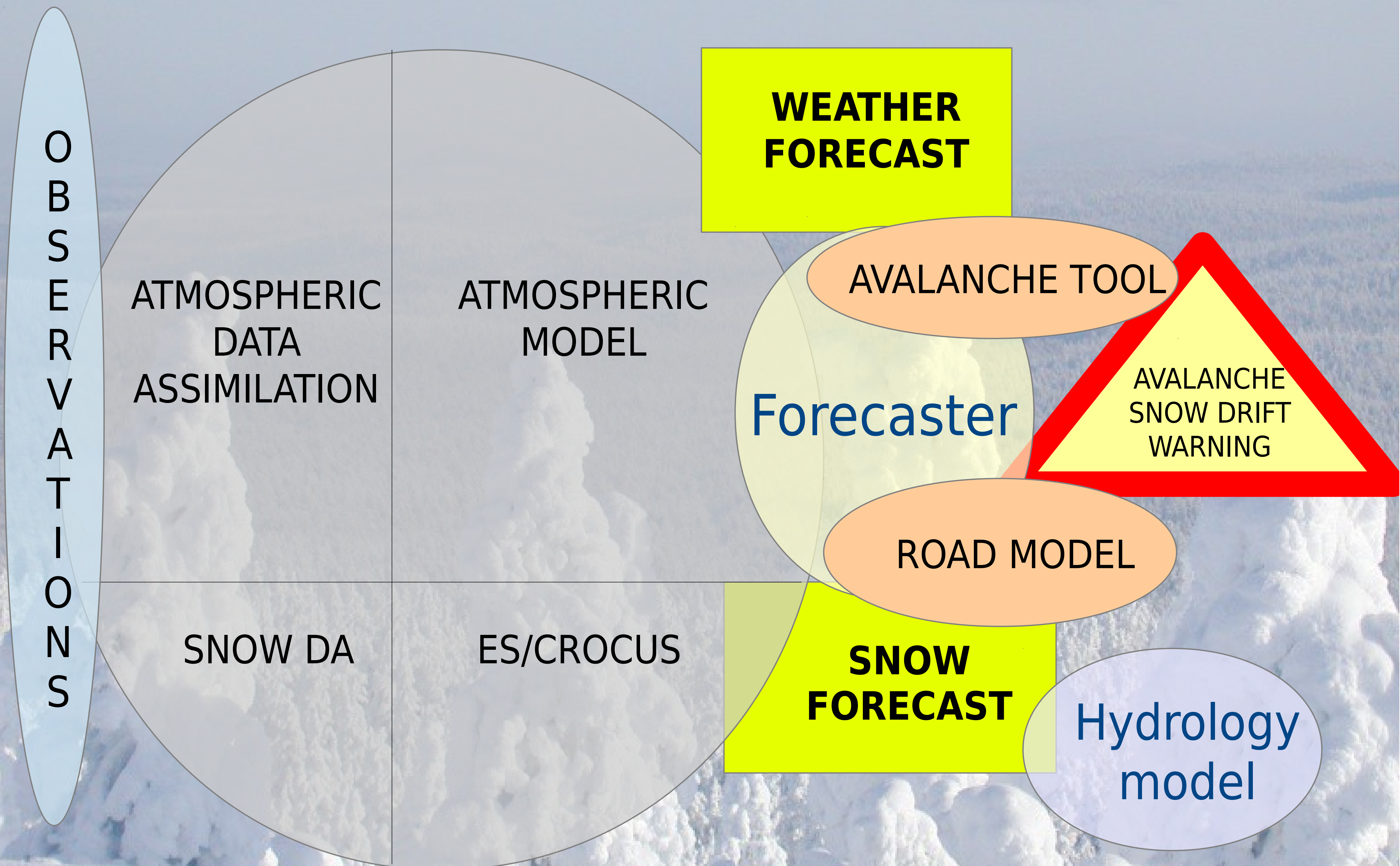
Implement ES snow parametrizations with MEB and ISBA-DIF (using also patches) into 3D HARMONIE

Combine ES-MEB with optimally interpolated snow depth observations

Introduce passive microwave SWE observations (Globsnow via Hydro-SAF) into the CANARI snow analysis

Researh task: Develop advanced data assimilation methods to combine multilayer prognostic snow to various types of remote-sensing observations

Future NWP model for dedicated applications?




THANK YOU!