DATA AND INFORMATION CENTRE

ESA SnowPEx project

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Finnish Environment Institute (SYKE)
Kari Luojus,
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+ several SnowPEx internal and external partners:

Enveo (T. Nagler), Environment Canada (C. Derksen, R. Brown),Canada Centre for Remote Sensing (R. Fernandes), NASA (D. Hall), NOAA (S. Helfrich), Rutgers University (D. Robinson), University of Waterloo (R. Kelly), Norwegian Computing Centre (R. Solberg) etc…

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ESA SnowPEx –The Satellite Snow Product Intercomparison and Evaluation Experiment

- Intercompare and evaluate global / hemispheric (pre)operational snow products derived from different EO sensors and generated by means of different algorithms, assessing the product quality by objective means.

- Evaluate and intercompare temporal trends of seasonal snow parameters from various EO based products in order to achieve well-founded uncertainty estimates for climate change monitoring.

- Both optical and (passive) microwave data-based snow products are investigated → Snow extent (SE), Snow Cover Fraction (SCF), Snow water Equivalent (SWE)

- In addition to in situ snow observations, also high-resolution data-derived snow infromation is employed to represent the 'truth'

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Motivation

- Several (tens of) different Earth observation-based products exist, relying on different algorithms and sensors
- It is known that these products provide different snow information
  - Where and under what conditions do they differ?
  - What is the reason for the differences
  - How can we know which product is the 'best'
- It is expected that none is 'the best' everywhere and throughout the time → need for spatial and temporal characterization of the differences and accuracies
- the current knowledge is that snow-related variables in the climate models are not always representative → reliable snow information enables the model improvement
- The existing accuracy assessment are more or less local or temporally limited→ need for hemispheric scale assessment
- Elaborate recommendations and needs for further improvements in monitoring seasonal snow parameters from EO data.

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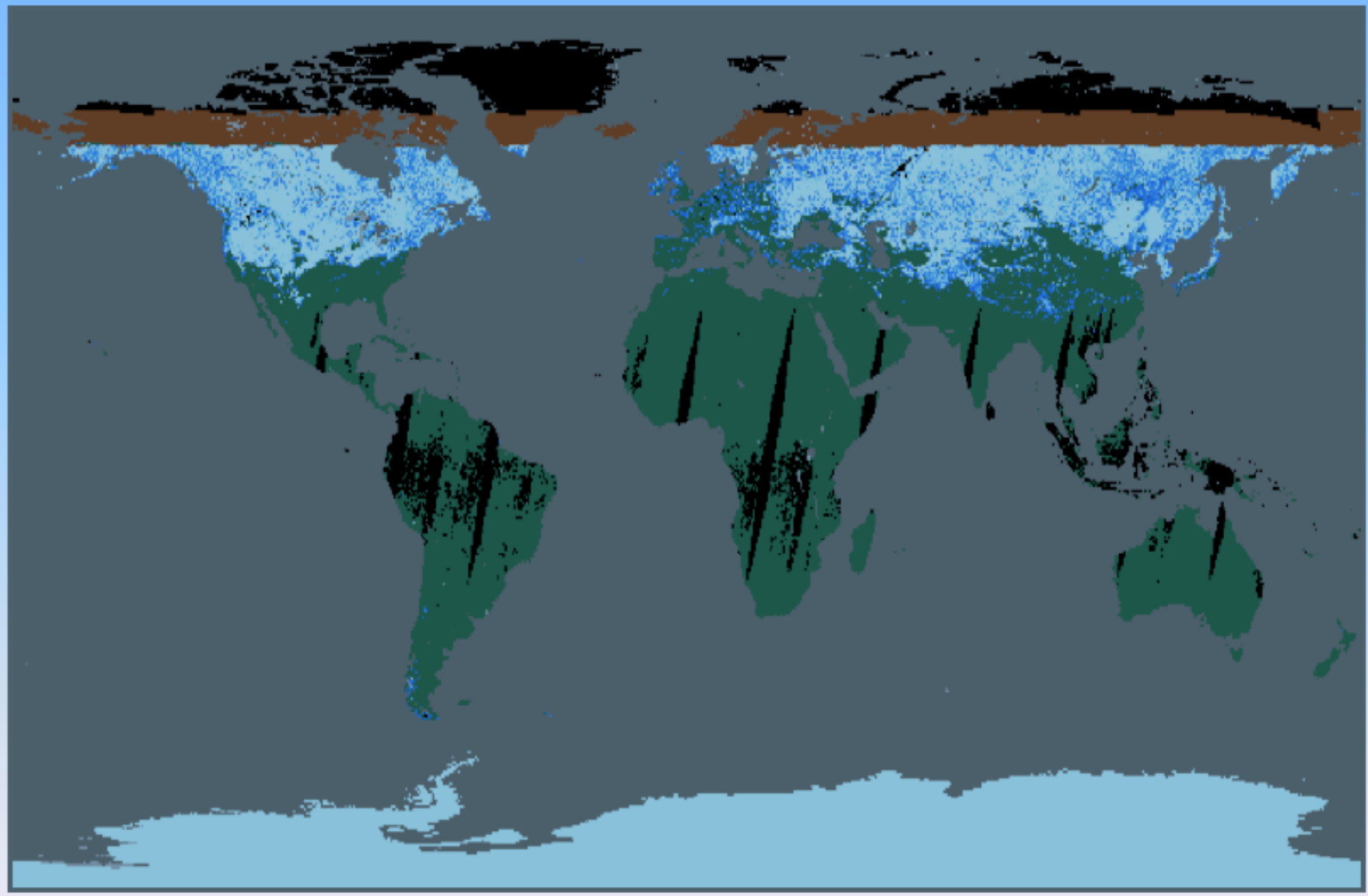
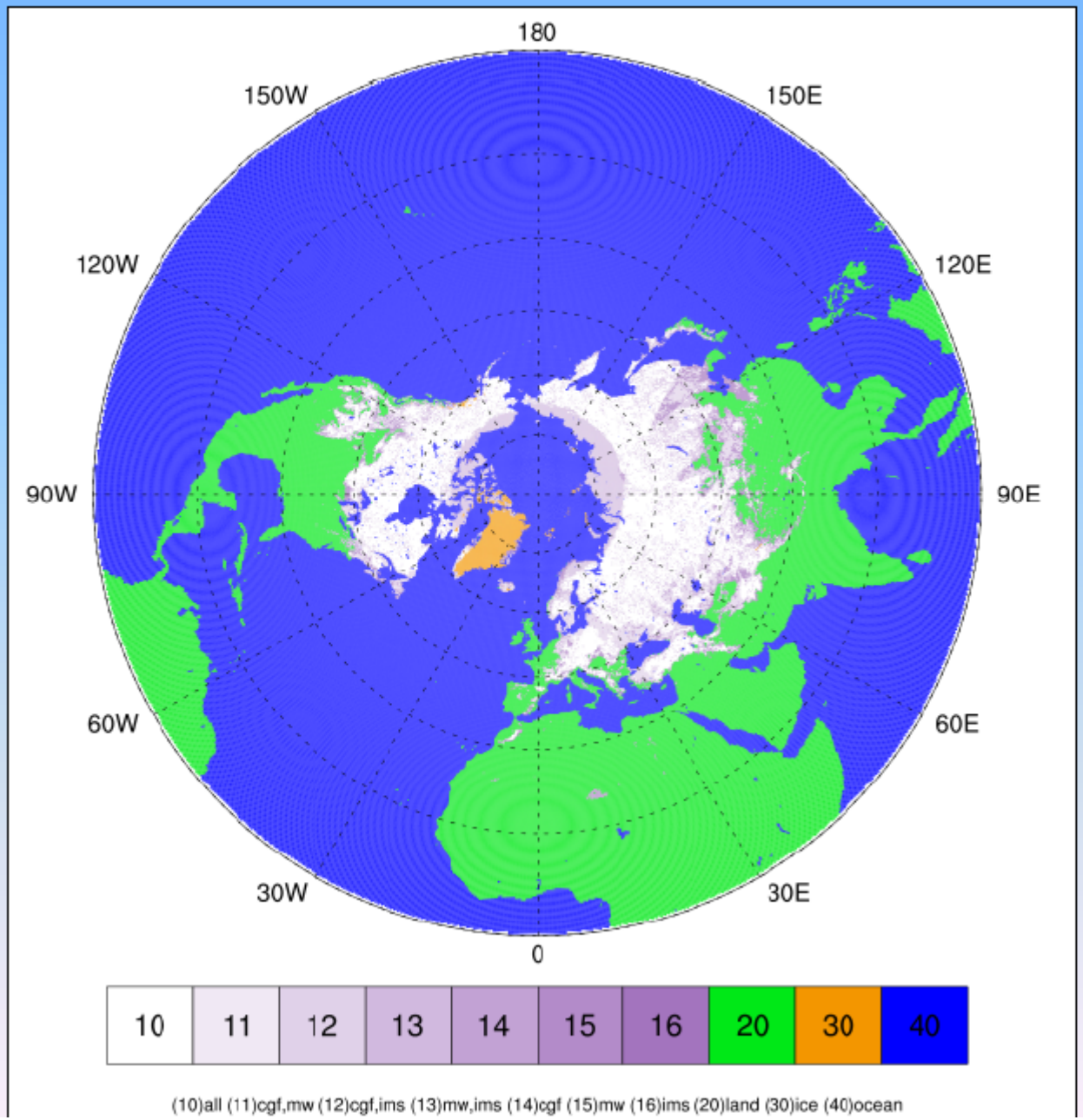
MODIS Fractional Snow Cover Level-3 daily global Climate Modeling Grid (CMG)



Terrestrial Snow 25km EASE-Grid 2.0 merged product, 1 February 2006



Sources:

1) Interactive Multisensor Snow and Ice Mapping System (IMS)

2) MODIS Cloud Gap Filled imagery (CGF)

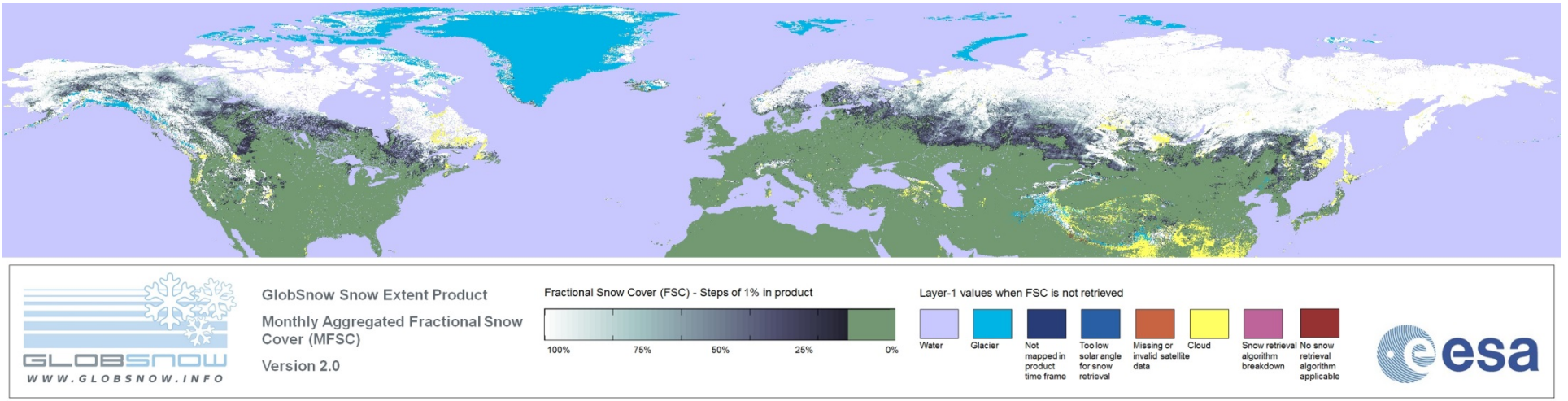
3) Passive Microwave snow extent (PM) from SSM/I

User community:

- Weather and hydrologic forecasting modelers;
- Climate scientists;
- Planning and Monitoring officials (i.e., commerce, engineering, agriculture, etc

GlobSnow SE-product

- SE (fractional snow cover, FSC) based on *SCAmod* , applied to ERS-2/ATSR-2 and Envisat/AATSR
- NRT GlobSnow processing system and data archives at FMI-Sodankylä Facility
- Time series for 1995-2011



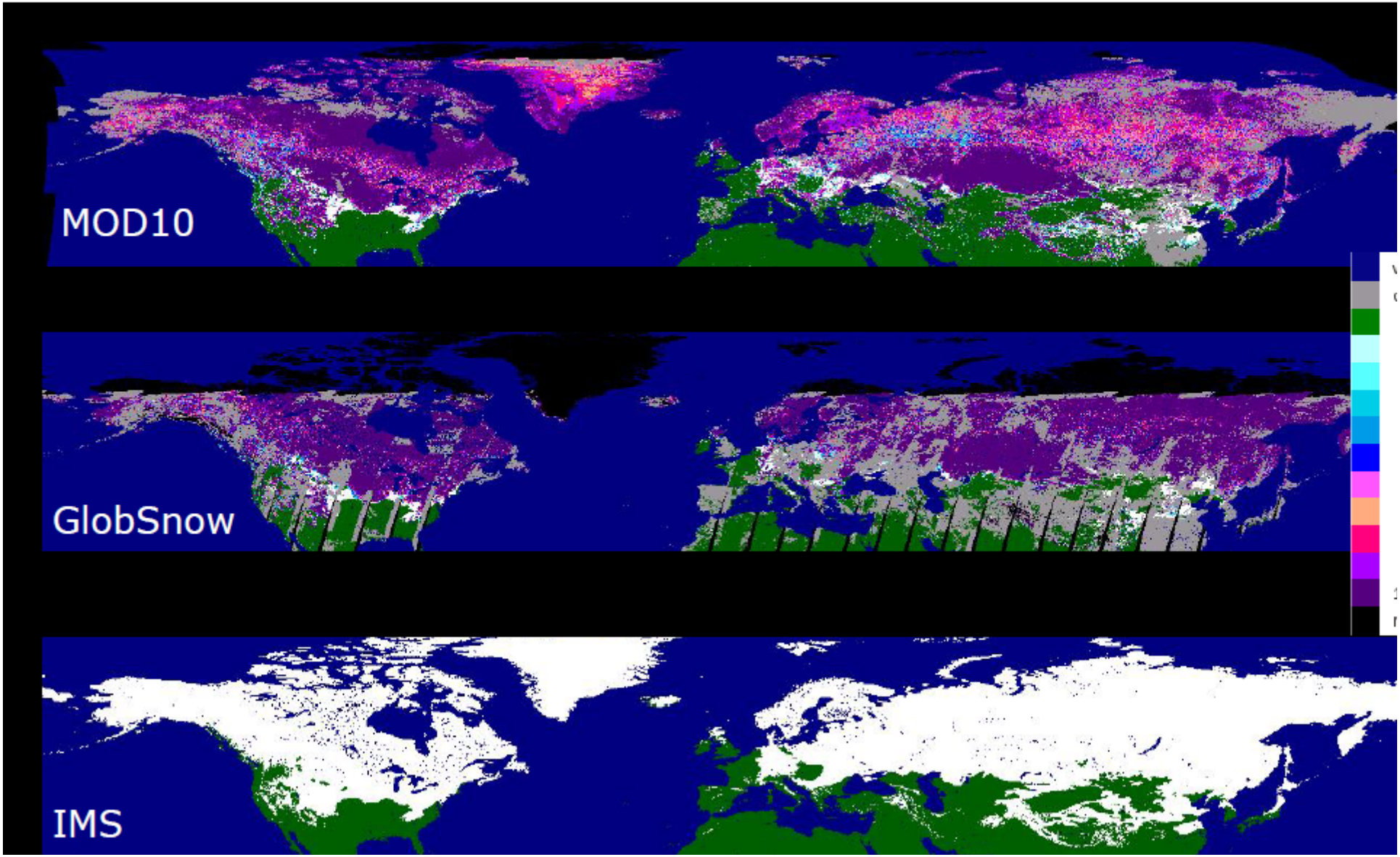
Metsämäki, S., Anttila, S., Huttunen, M., & Vepsäläinen, J. (2005). A feasible method for fractional snow cover mapping in boreal zone based on a reflectance model. *Remote Sensing of Environment*, *95, 77-95.*

Metsämäki, S., Mattila, O.-P., Pulliainen, J., Niemi, K., Luojus, K., Böttcher, K. (2012). An optical reflectance model-based method for fractional snow cover mapping applicable to continental scale. *Remote Sensing of Environment, 123, 508-521.*

Salminen, M., Pulliainen, J., Metsämäki, S., Böttcher, K. and Heinilä, K. (2013). MODIS-derived snow-free ground reflectance statistics of selected Eurasian non-forested land cover types for the application of estimating fractional snow cover. *Remote Sensing of Environment, 138,* 51-64.

Metsämäki, S., Pulliainen, J., Salminen, M., Luojus, K., Wiesmann, A., Solberg, R., Böttcher, K., Hiltunen, M., Ripper, E. (2014) Introduction to Globsnow Snow Extent products with considerations for accuracy assessment . *Remote Sensing of Environment*, ,Vol. 156, January 2015, pp. 96-108, doi: 10.1016/j.rse.2014.09.018.

Maximum Snow Extent: 1-7 March 2010



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SnowPEx PRODID_VXX	SnowPEx PRODID_VXX	Product Name	Thematic Parameter	Pixel Sp.	Frequency	Period	Contact Organisation
M10C06	V01	MOD10_C6	Fractional Global	0.5 km	daily	2000 (Terra)	dorothy.k.hall@nasa.gov NASA
SCAG	V01	SCAG	Fractional NH	0.5 km	daily	2000 - 2013	thomas.painter@jpl.nasa.gov karl.rittger@nsidc.org JPL, NSIDC
GLSSE	V01	GlobSnow v2.1	Fractional NH	1 km	daily - monthly	1996 - 2012	jari.metsamaki@ymparisto.fi SYKE
ASNOW	V01	Autosnow	Fractional NH	4 km	daily	2006 - present	peter.romanov@noaa.gov NESDIS
IMS01	V01	IMS	NH	1 km	daily	2014 ->	sean.helfrich@noaa.gov NOAA
IMS04	V01	NOAA IMS	Binary NH	4 km	daily	2004 - present	sean.helfrich@noaa.gov NOAA
IMS24	V01	NOAA IMS	Binary NH	24 km	daily	1997 - 2004	sean.helfrich@noaa.gov NOAA
CRCLIM	V01	CryoClim	Binary Global	5km	daily	1982 - present	rune.solberg@nr.no NR,METNO
JXM10	V01	JASMES MDS10C	Binary NH	5 km	Daily weekly half-monthly	2000 – 2013	hori.masahiro@jaxa.jp JAXA
JXAM5	V01	JASMES GHRM5C	Binary NH	5 km	Daily weekly half-monthly	1979 – 2013	hori.masahiro@jaxa.jp JAXA

Subset of Snow Extent products to be analyzed – there's more…

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Metrics for intercomparison/ validation

- Root Mean Squared Error (RMSE)
- Bias
- Bias-corrected RMSE (precision), relative RMSE
- Correlation coefficient
- Similarity (Kolmororov Smirnov Distance between two distributions of SCF over a spatial and temporal partition)
- For binary snow/no-snow classifications:
  - Probability of detection, hit-rate, false alarm rate etc.

➢ All these determined separately for different land covers, climate zones etc.

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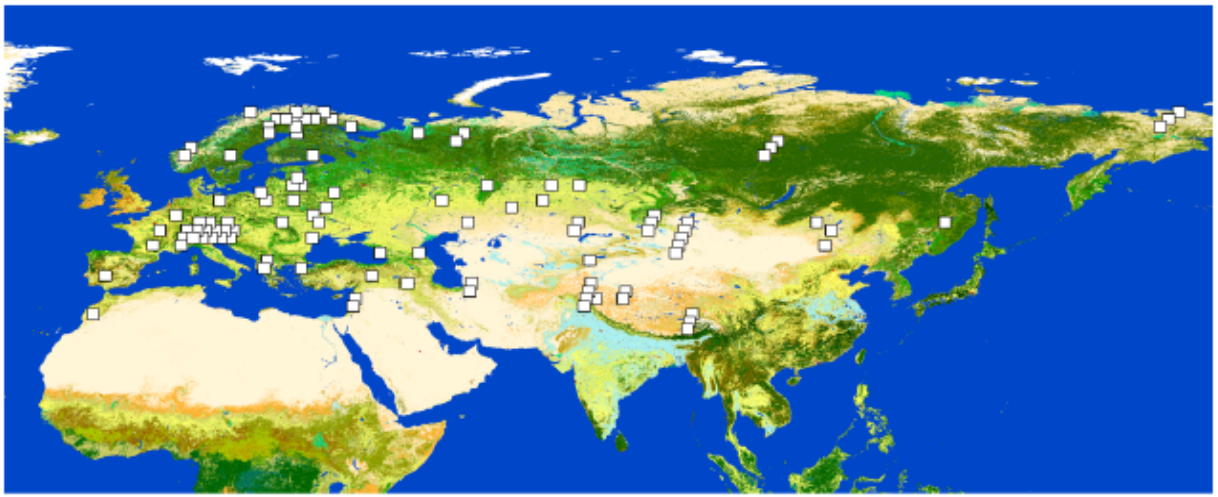
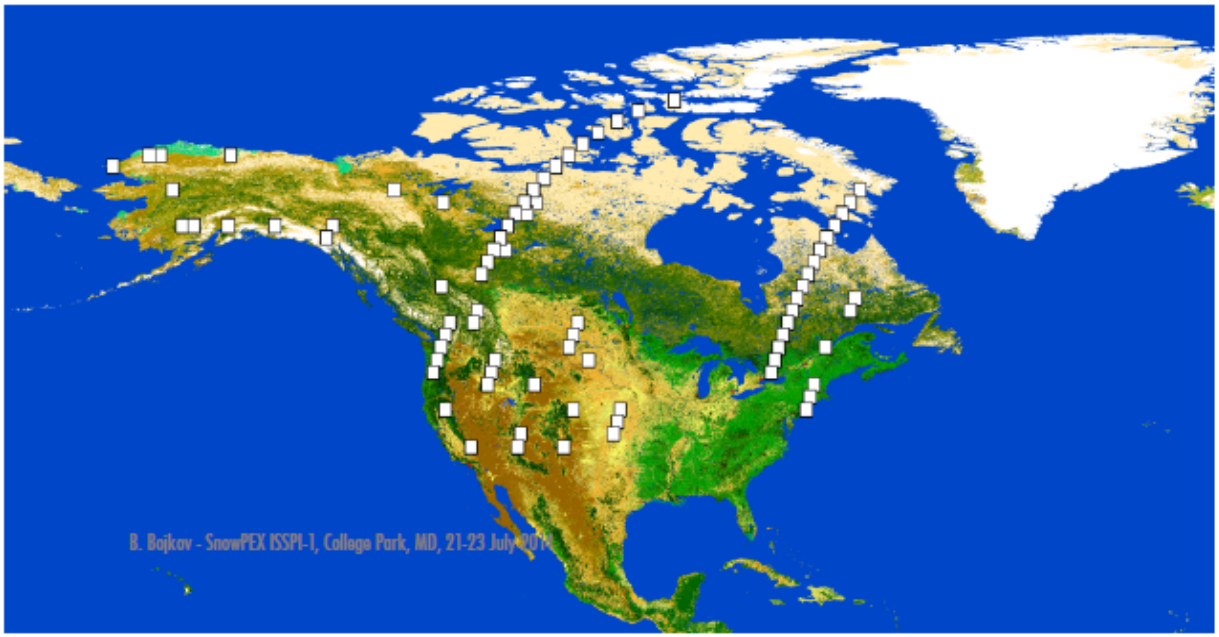
Identified Landsat data (2000–2014) for SE Evaluation in SnowPEX



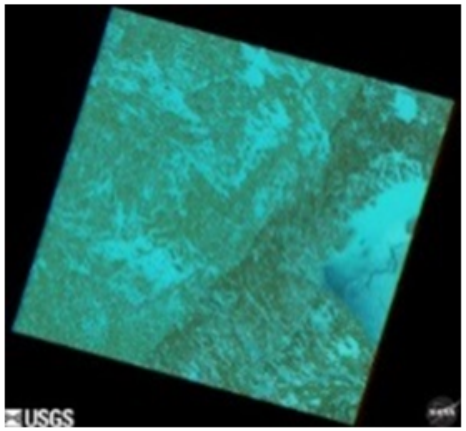


About 400 Landsat scenes were so far identified for SE evaluation (data are available at ENVEO, SYKE and Rutgers University):

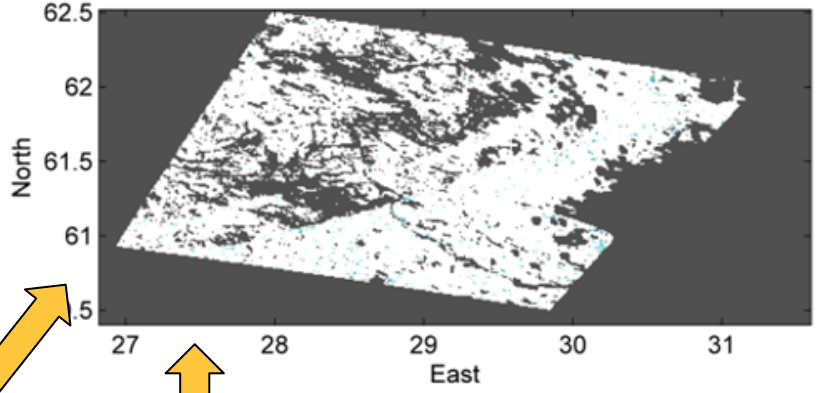
- For many locations only 1 clear sky scene with snowy conditions is available for that period
- Only for a few regions (e.g. Alps, northern Scandinavia) a well spatial and temporal coverage of reference data could be identified
- Additional reference data is needed for the U.S. and Asia *– some images were shown yesterday that would be great additions for the SnowPEX inter-comparisons*

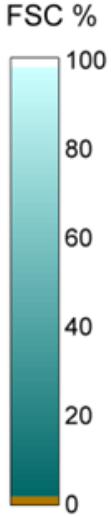
Evaluation is difficult due to the lack or representative high-resolution reference data

Forest area with 100% snow cover

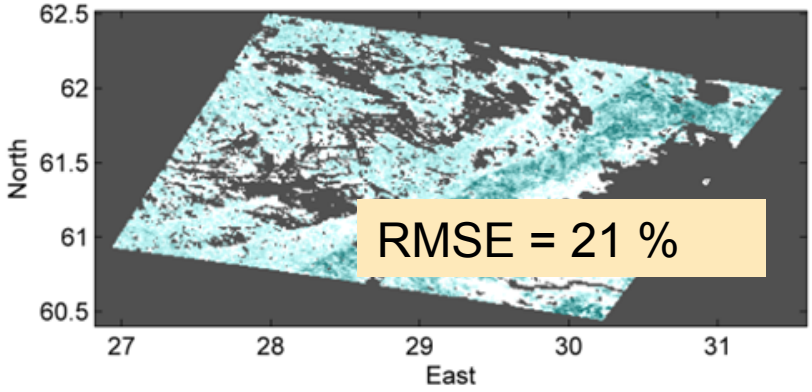


GlobSnow DFSC

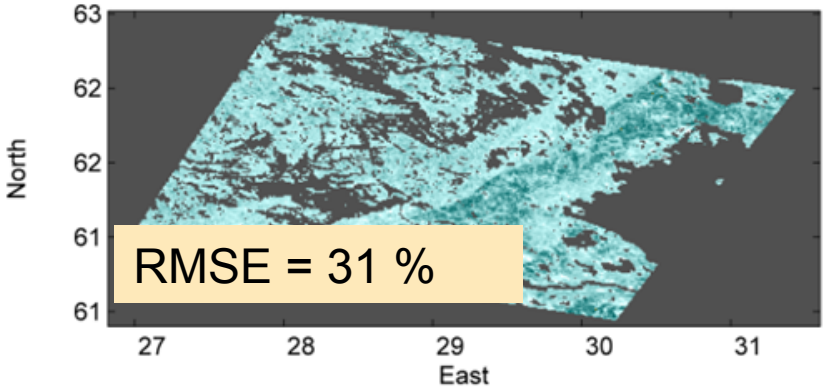




c) LE71860172003074SGS00 FSCklein



d) LE71860172003074SGS00 FSCsalapp



→ This is not a 'validation'

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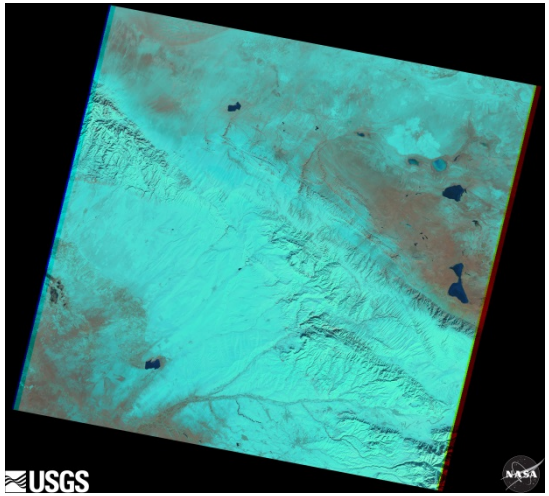
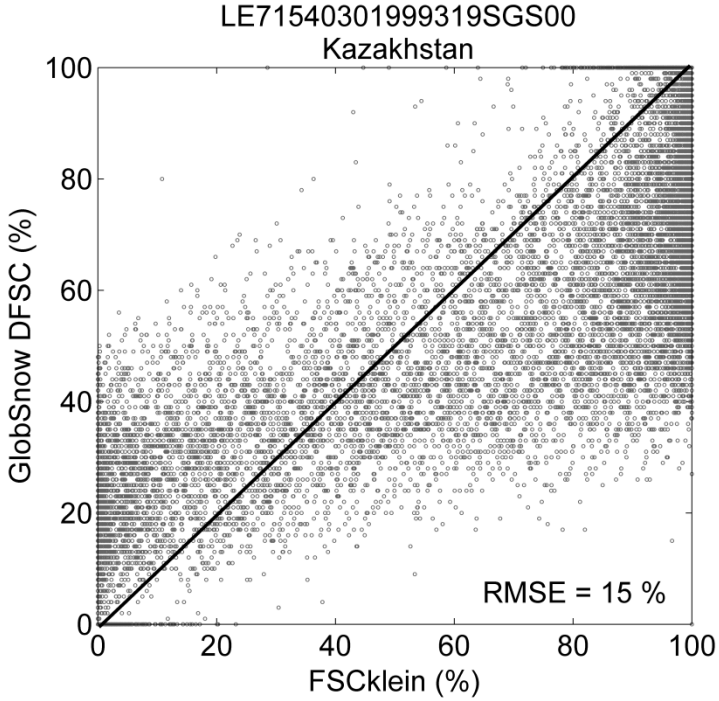
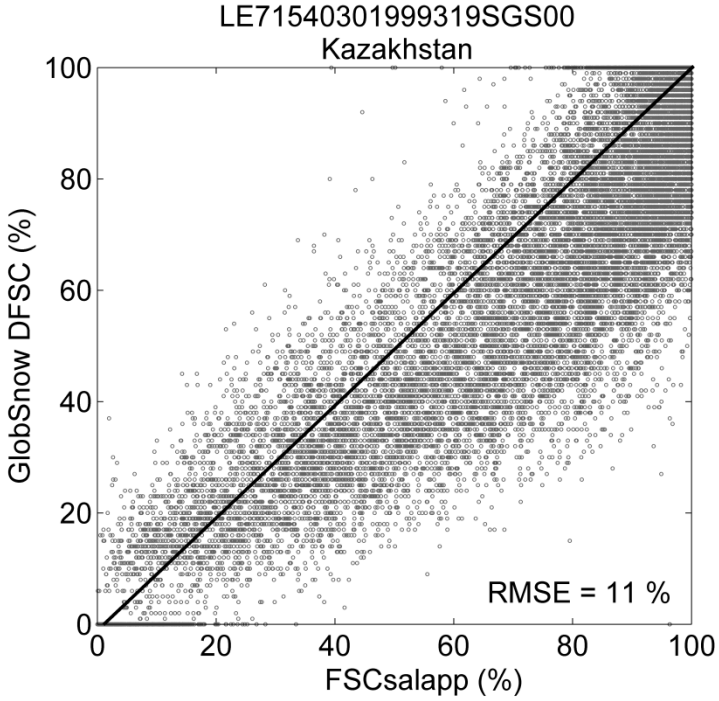
Evaluation is difficult due to the lack or representative high-resolution reference data







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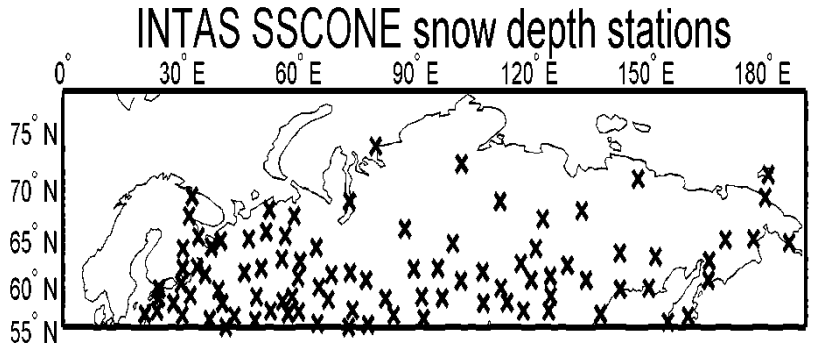
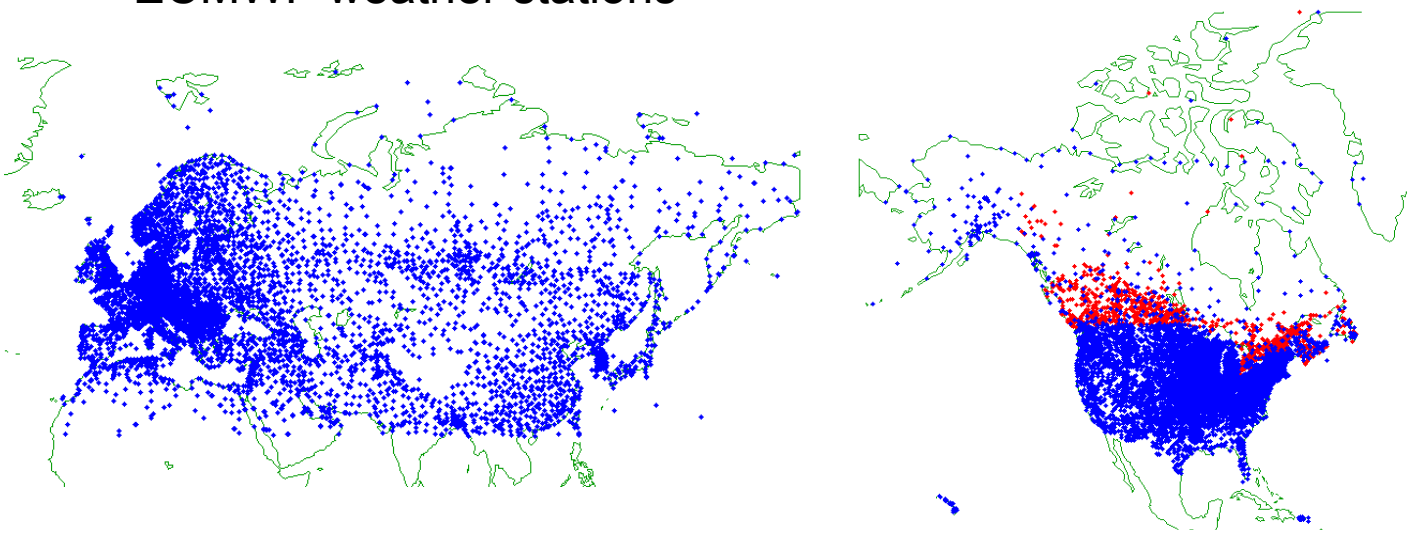
- Usually Snow Depth is measured, not Snow Cover Fraction
- Need for conversion SD → SCF



ECMWF weather stations



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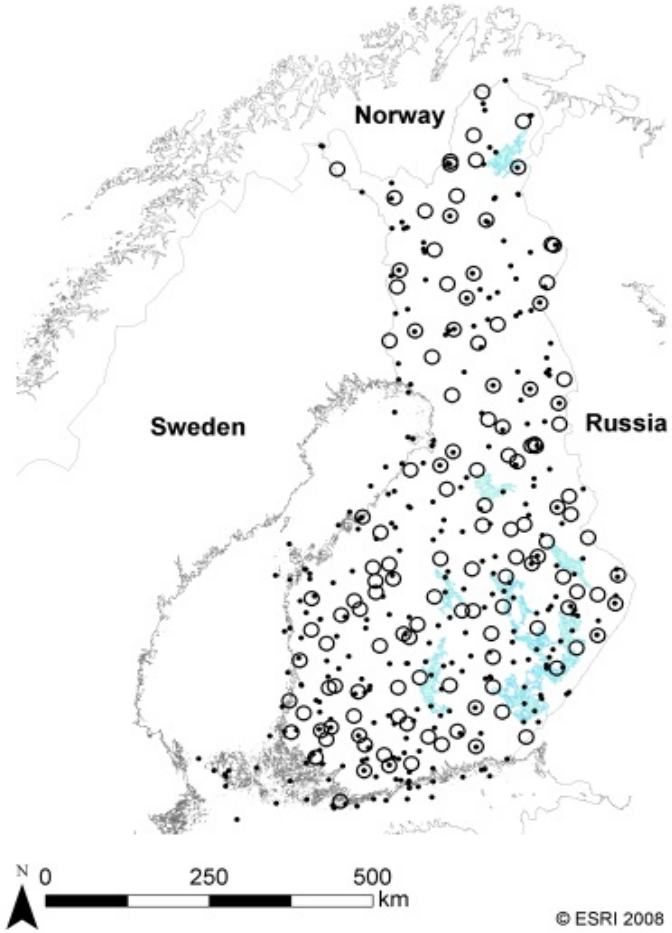
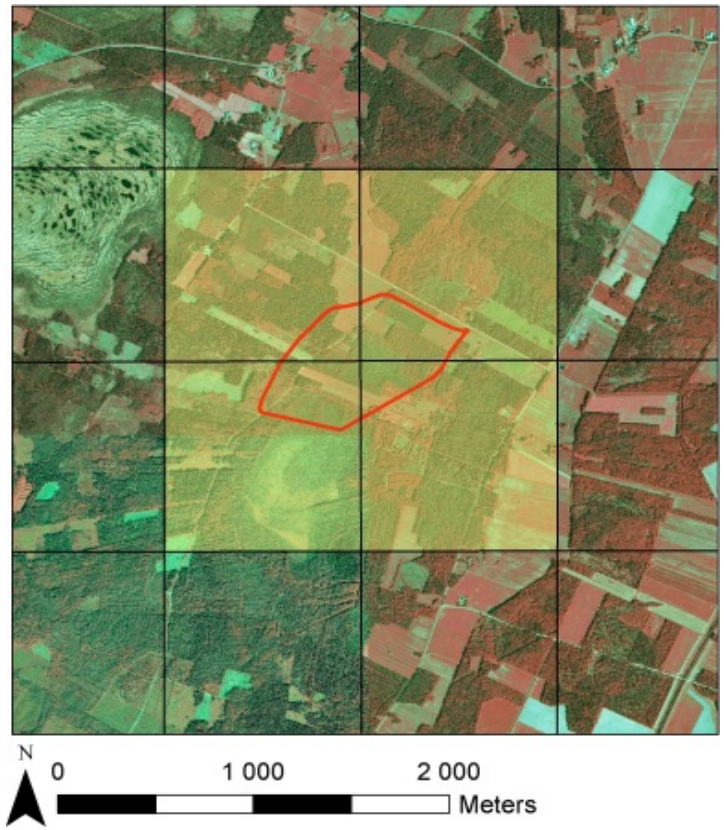
At Finnish Snow courses, SCF is measured (and Snow depth)





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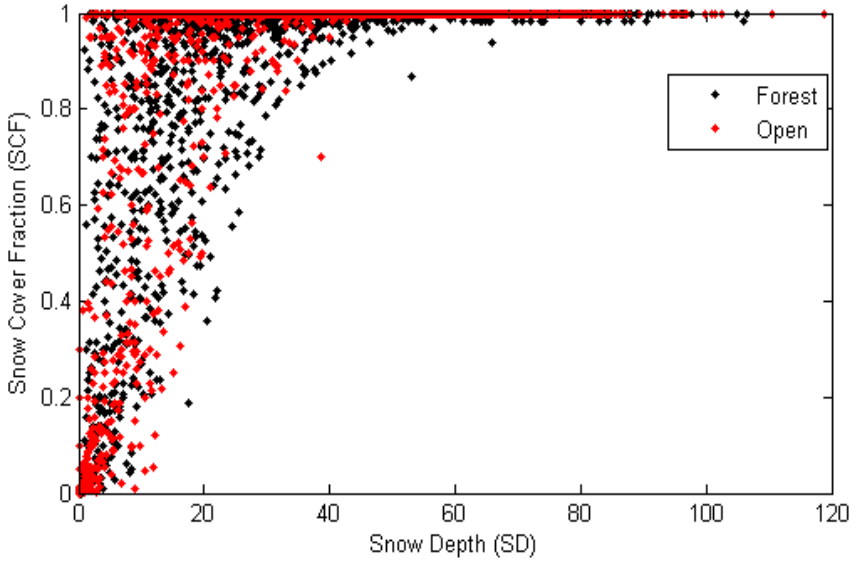
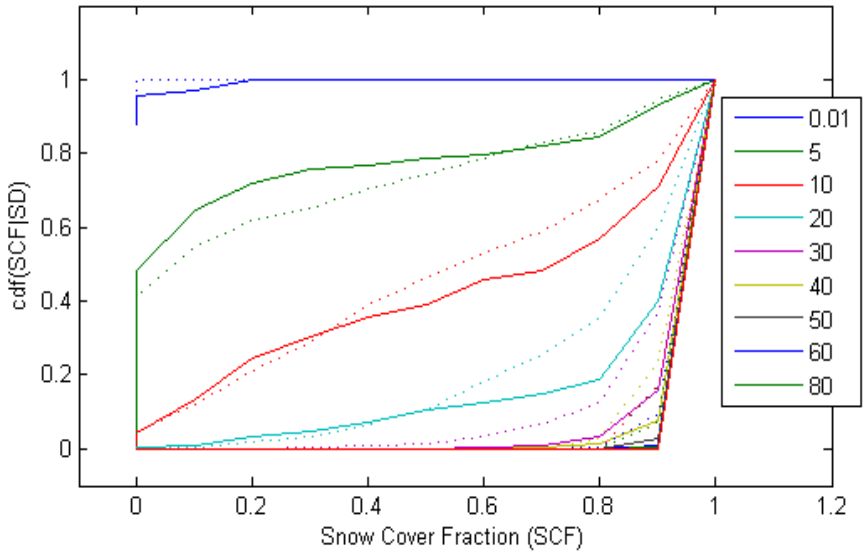
Relationship between SD and SCF from Finnish snow courses

→ Statistical approach for validation: we are not comparing pixel-to-pixel SCF, but probabilites of SCF





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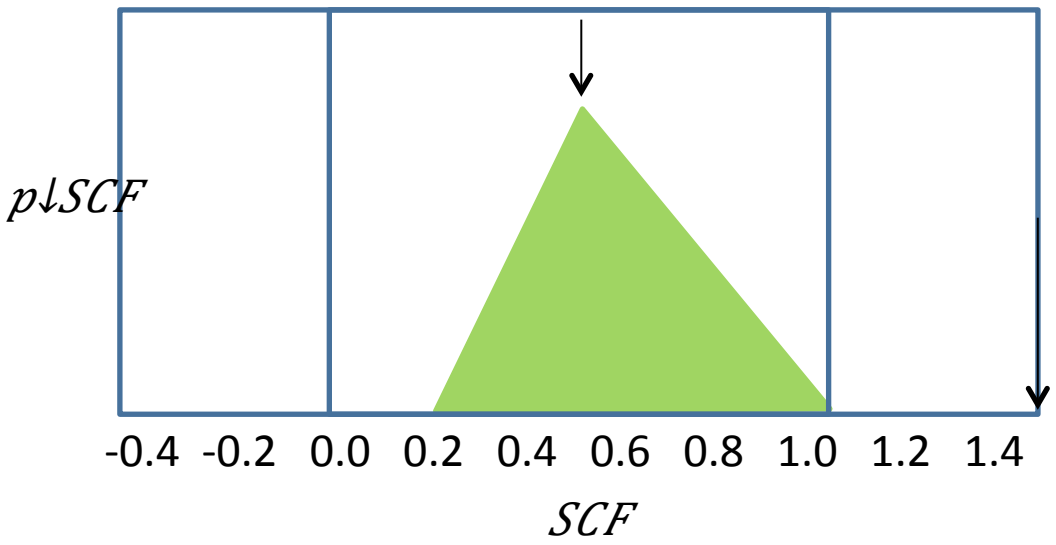
- Mainly point-wise measurements available → scale problem: EO snow product ground resolution typically varies from 500m to 25 km

→ is it reasonable to compare coarse resolution snow estimate with point?

→ Solution: use probability density function instead of one value. PDF is provided for each SCF estimate

- This applies to the direct SCF (~uncertainty) and Binary SE (expected SCF for snow and no-snow cases)



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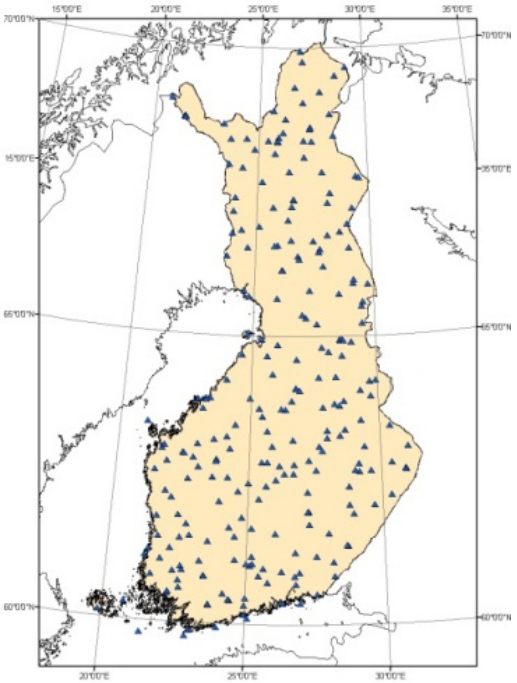
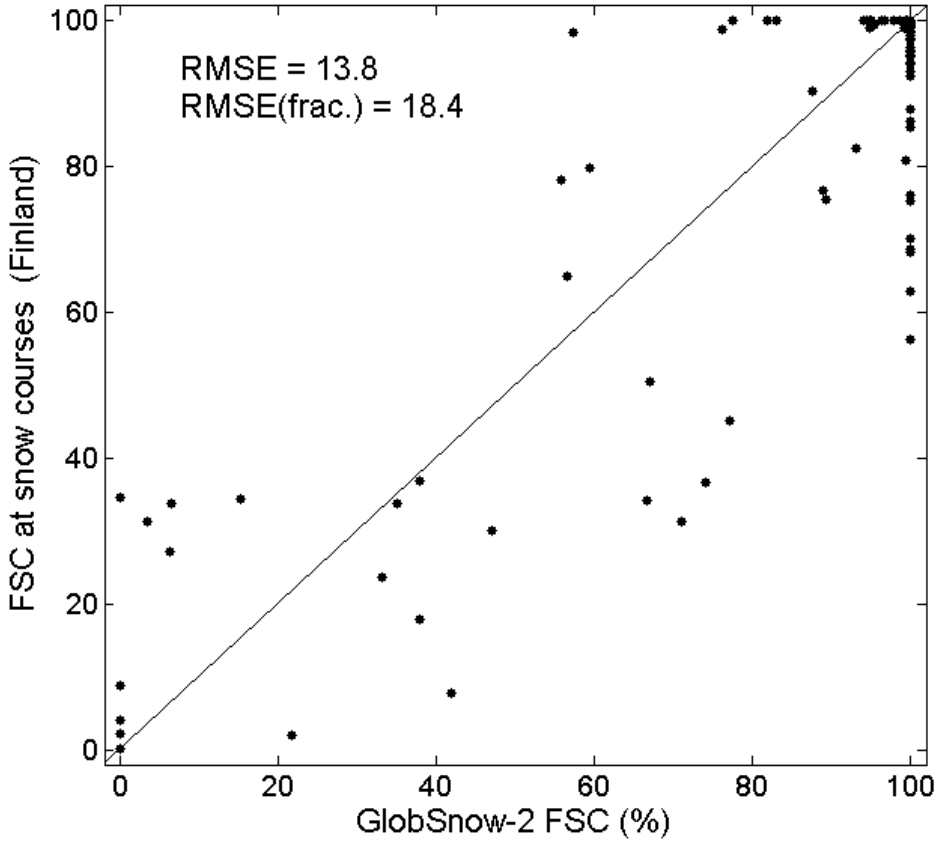
GlobSnow validation with In-situ Data

- 137 comparison pairs for 1999-2010 were found; 64 fractional cases
- Possible false cloud omissions were not considered
- i.e. comparison uses all available FSC-estimates

  → some of the overestimations may originate from the presence of clouds





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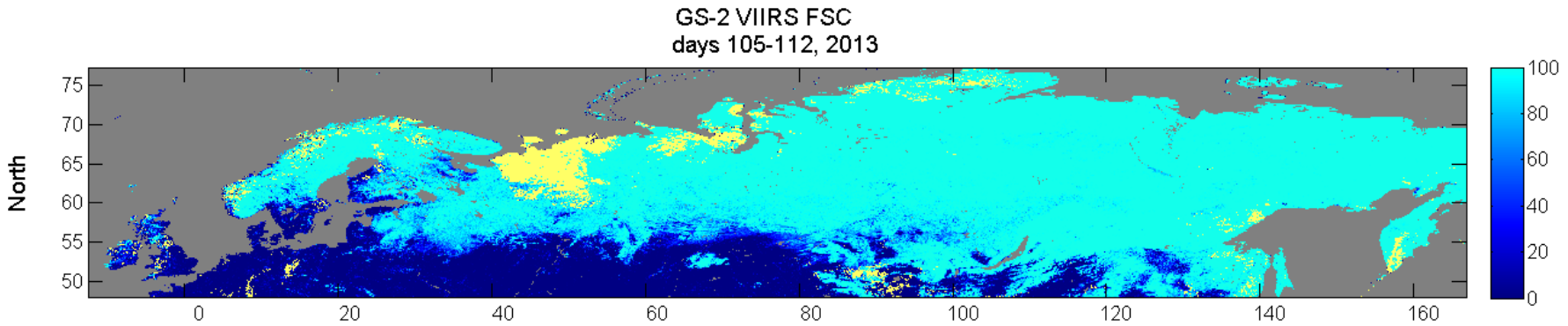
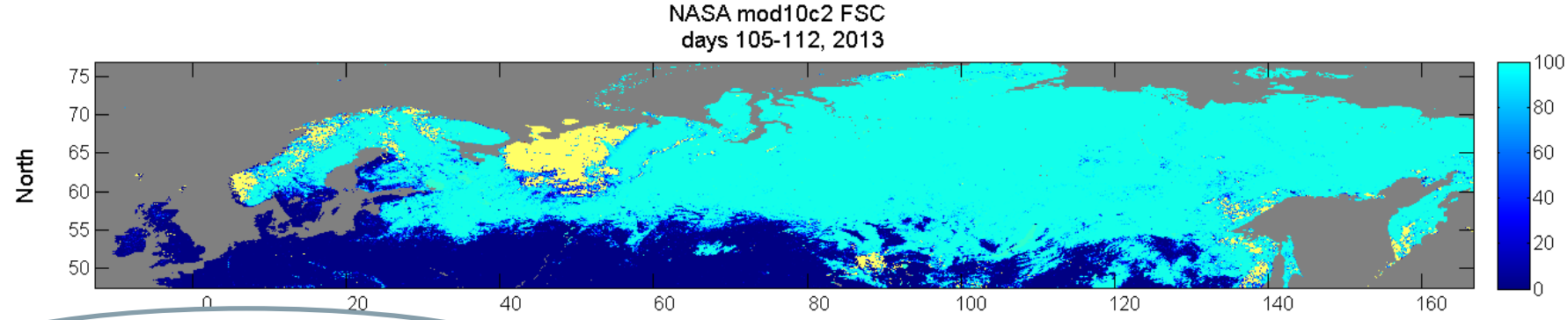
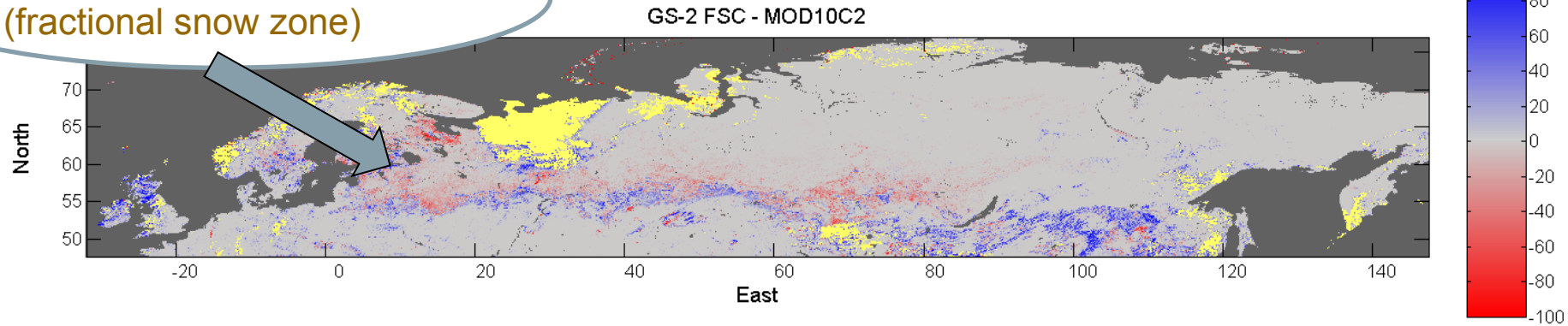
Direct FSC retrieval compared to that of binary -> fractional approach





Differences near snow line (fractional snow zone)



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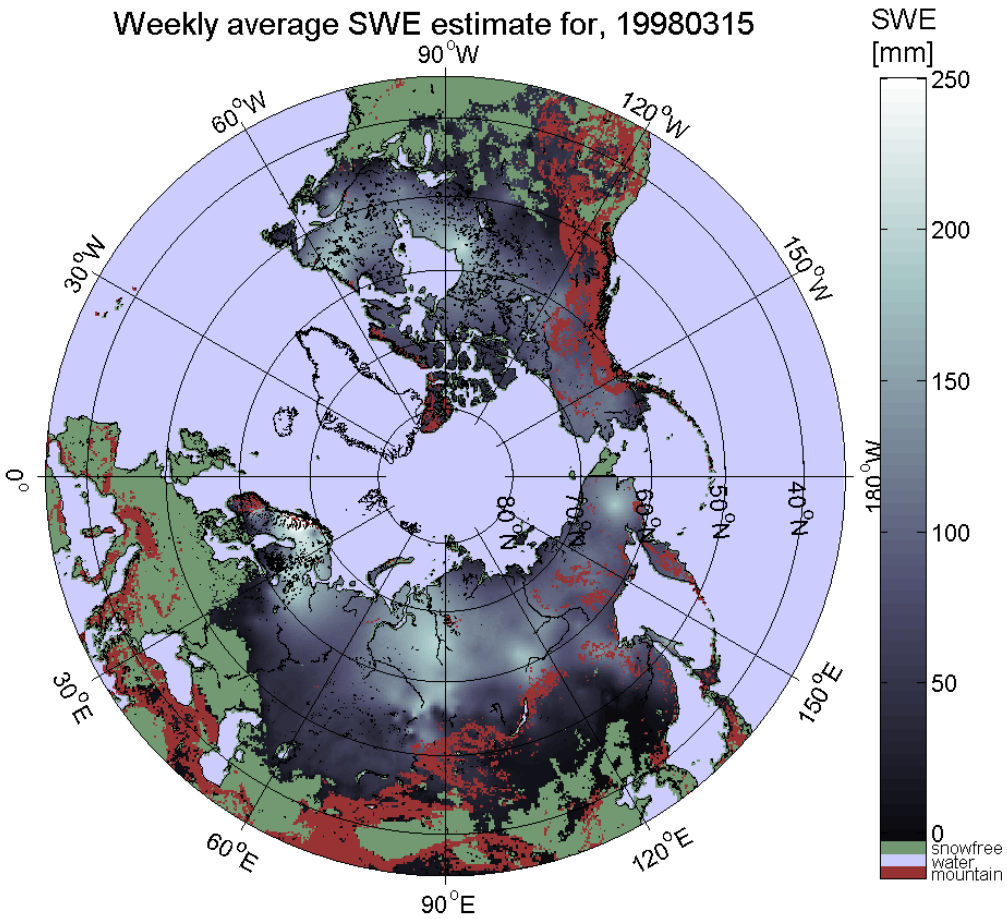
esa due data user element GLOBSNOW

35 year-long CDR time-series on snow conditions of Northern Hemisphere

- First time reliable daily spatial information on SWE (snow cover):
  - Snow Water Equivalent (SWE)
  - Snow Extent and melt (+grain size)
  - 25 km resolution (EASE-grid)
  - Time-series for 1979-2014
- Passive microwave radiometer data combined with ground-based synoptic snow observations
  - Variational data-assimilation
- Available at open data archive (www.globsnow.info)
- Demonstration of NRT processing since October 2010
- Greenland, glaciers & mountains masked out



Takala, M., Luojus, K., Pulliainen, J., Derksen, C., Lemmetyinen, J., Kärnä, J.-P, Koskinen, J., Bojkov, B., "Estimating northern hemisphere snow water equivalent for climate research through assimilation of spaceborne radiometer data and ground-based measurements", Remote Sensing of Environment, Vol. 115, Issue 12, 15 December 2011, doi: 10.1016/j.rse.2011.08.014

SnowPEx SWE Datasets

Dataset	***Method***	***Contact***	***Reference***
ESA GlobSnow	Microwave + ground stations	K. Luojus	Takala et al., 2011
NASA AMSR-E (standard)	Standalone microwave	R. Kelly; M. Tedesco	Kelly 2009
NASA AMSR-E (prototype)	Microwave + ground station climatology	M. Tedesco	TBD
JAXA AMSR-E/2	Standalone microwave	R. Kelly	Kelly 2009 (to be updated)
CMA AMSR-E/FY-3	Semi-empirical, regression based	Shengli Wu	TBD

Spatial coverage	Northern Hemisphere (masking of sub-regions is permitted)
Time period	Minimum 2002 onwards (covers AMRE-E period); complete through 2010 As long as possible for trend analysis
Temporal resolution	Daily
Grid	EASE-Grid 25 km northern

Do the candidate time series meet these requirements?

Candidate in situ Reference Data

Dataset	*Region*	*Snow Class*	*Method*	*Time Period*	*Temporal Resolution*	*Contact*
Boreal Ecosystem Research and Monitoring Sites	Saskatchewan	Taiga	Sonic snow depth	1997-2014	Daily	H Wheater, U. Saskatchewan
Environment Canada – Bratt's Lake	Saskatchewan	Prairie	Sonic snow depth; manual surveys	2011-	Daily	C Smith, Environment Canada
FMI – Sodankyla	Finland	Taiga	Sonic snow depth; cosmic	19xx-2014	Daily	J. Pulliainen, FMI
EC – Olympics 2010	Southern coast mountains	Alpine	Sonic snow depth	2008-2010	Daily	C. Derksen, EC
Trail Valley Creek	Northwest Territories	Tundra	Sonic snow depth	2002-2014	Daily (may be gaps in mid-winter)	P. Marsh, WLU
Fraser	Colorado	Alpine	TBD	19xx-2014	Daily	K. Elder, USFS
Finnish Environment Institute Snow Surveys	Finland	Taiga	Manual snow course	19xx-2014	Monthly	S. Metsämaäki, SYKE
RusHydroMet Snow Surveys	Russia	Taiga; Tundra	Manual snow course	1966-2014	Bi-weekly	O. Bulygina, RIHMI-WDC)
Hydro-Quebec Snow Survey Network	Quebec	Taiga	Kriged snow course	1970-2012	SWEmax	D. Tapsoba (IREQ)

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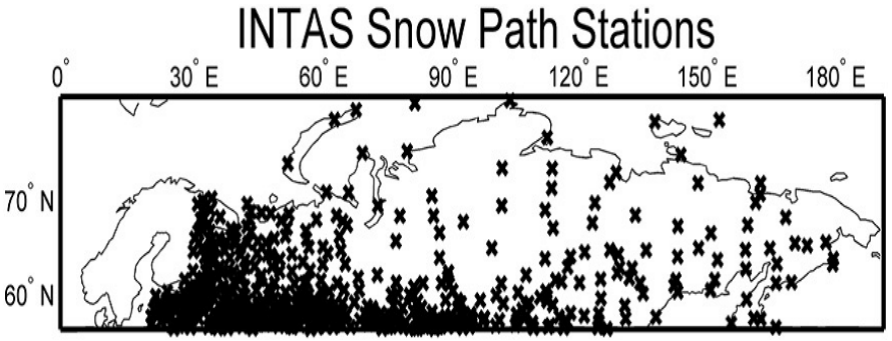
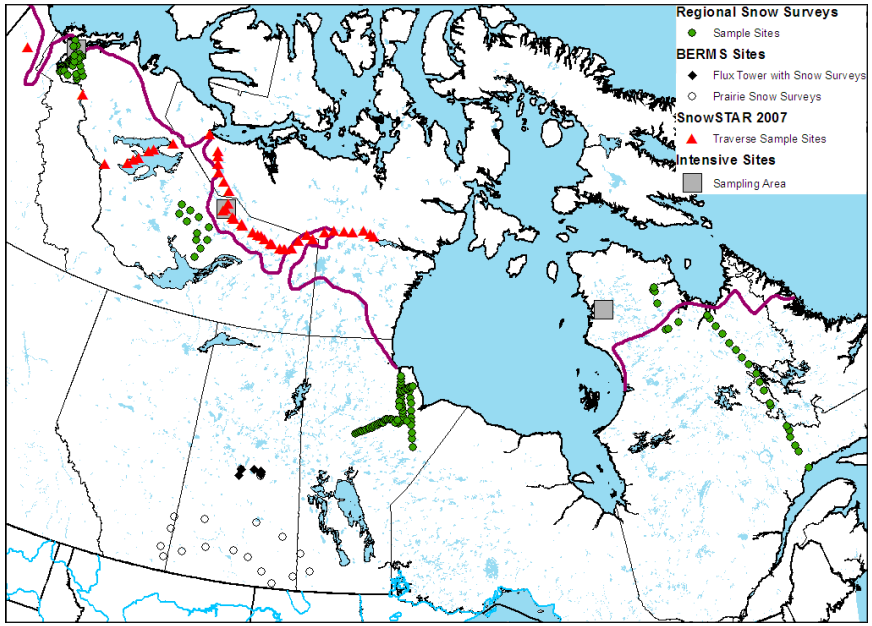
Validation using distributed data: Northern Eurasia & Canada

Snow Survey data (from former USSR and Russia)

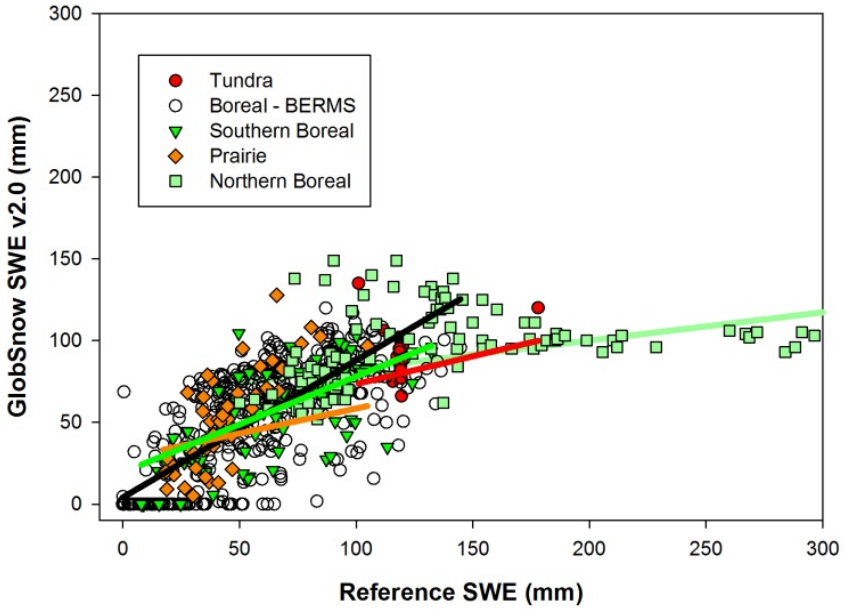
- There are 517 snow path stations with data for (1979 – 2009)
- Manual ground-based measurements on snow depth/SWE
- 1 - 2km snow transects, measurements every 100m - 200m

Land Cover	Reference Dataset	Year	n	Mean SWE (mm)
Tundra	Intensive Sites; SnowSTAR 2007	2006-2008	28	120
Northern Boreal	EC Snow Surveys	2006-2007	105	135
Northern Boreal	EC Snow S. (SWE < 150mm)	2006-2007	73	134
Southern Boreal	EC Snow Surveys	2005-2007	57	75
Southern Boreal	BERMS Towers	2005-2008	468	70
Prairie	EC Snow Surveys	2005-2007	41	44





Validation Examples



- Comparison of areally weighted point measurements from Canada with GlobSnow v2.0 SWE retrievals

- Statistical distribution of in situ SWE measurements and GlobSnow v2.0 SWE retrievals (blue column) for a grid cell (tundra) near Daring Lake, Canada

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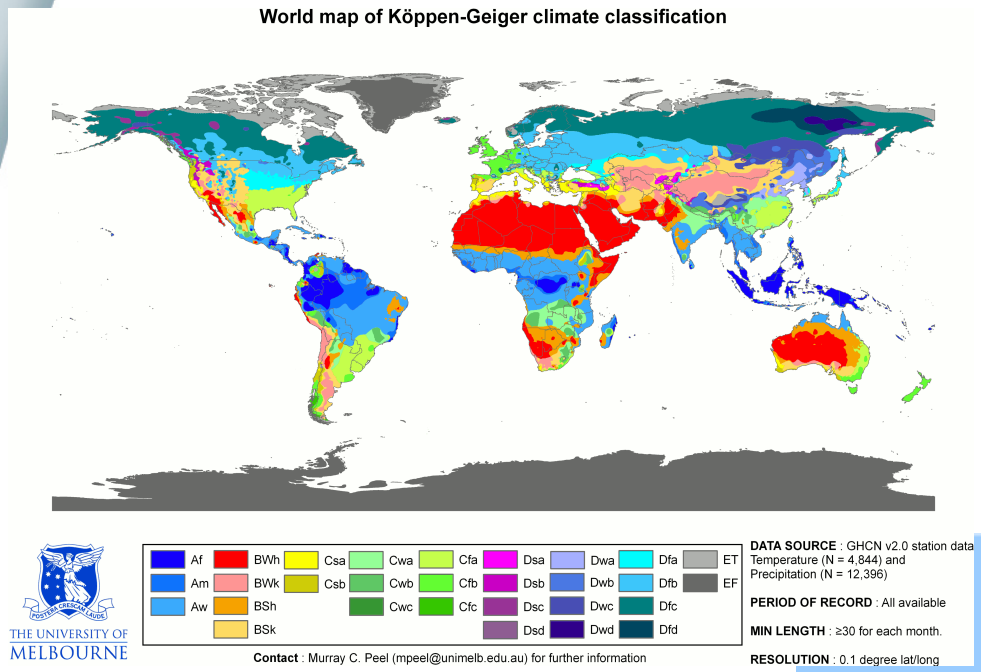
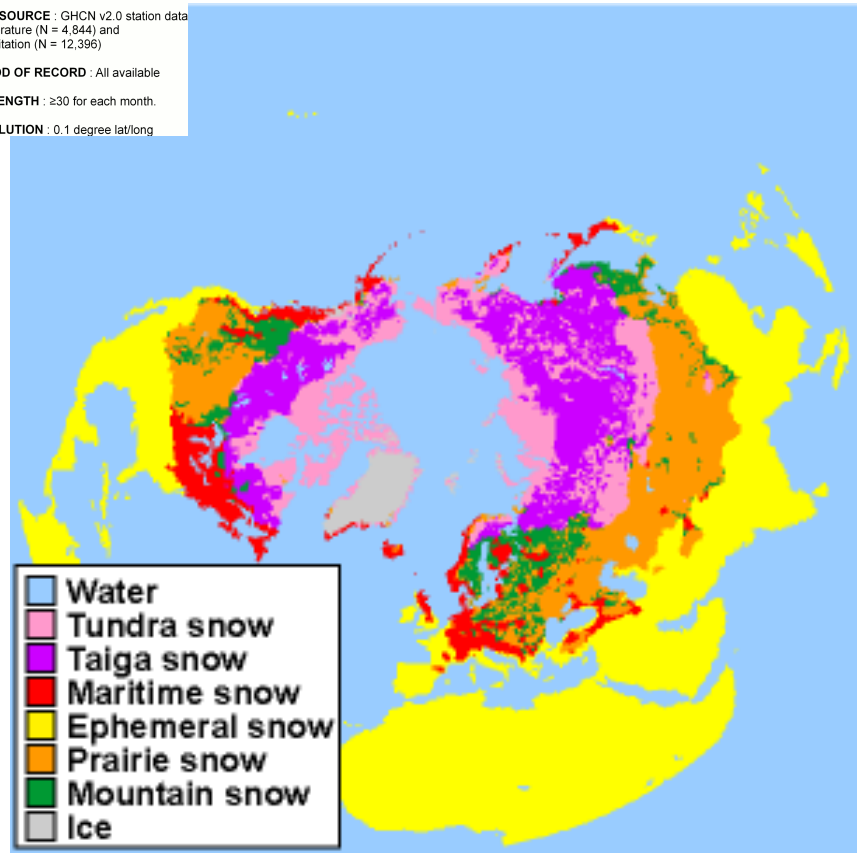


SE products and reference data should be globally representative for climate regimes, snow types, land cover conditions, seasonal stages etc.



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Organizing the work

- The SnowPEx partners have prepared the protocol for validation and intercomparison
- The SnowPEx partners also provide the guidelines for data formats and metadata
- The external participating organizations have committed to provide their EO datasets according to the SnowPEx specifications
- The SnowPex partners take care of the further processing of the data (e.g. reprojection)
- The external partners grant the access to (at least) part of their *in situ* data

- The current status: collection of snow dataset and conversion to SnowPEx format in progress. Validation and intercompairson will start in Q1/2015

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Thank you for your attention!