Sen3App snow products by FMI & SYKE
FSC and SWE data for NH & Pan-European domain

Kari Luojus, Ali Arslan, Jouni Pulliainen, Matias Takala,
Timo Ryyppö, Juval Cohen, Jaakko Ikonen, Tuomo Smolander
(Finnish Meteorological Institute)

Sari Metsämäki (Finnish Environment Institute)

18 April 2016 – ZAMG, Vienna, Austria, SEN3App workshop

Outline

- **SEN3App NH FSC product**

- **SEN3App DB Extended Baltic Sea FSC product**

- **SEN3App Pan-European High Resolution SWE**

  - Upgraded GS SWE retrieval approach

  - 5km resolution, Pan European domain

- **Combined 25km NH FSC/SWE product**
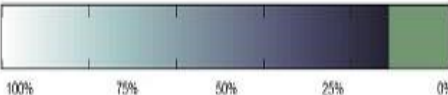
Sen3App NH FSC product

Based on GS Legacy 1km VIIRS product, preparation for S3 SLSTR in SEN3APP (production modified to 500m)

Sen3App Snow Extent Product

Daily Fractional Snow Cover (DFSC)

Version 1.0

- based on *Suomi NPP VIIRS* data -

Fractional Snow Cover (FSC) - Steps of 1% in product

100%   75%   50%   25%   0%

Layer-1 values when FSC is not retrieved

Water | Glacier | Not mapped in product time frame | Too low solar angle for snow retrieval | Missing or invalid satellite data | Cloud | Snow retrieval algorithm breakdown | No snow retrieval algorithm applicable

GlobSnow Snow Extent (SE) dataset

- 17 years SE data record has been produced using optical imagery from ESA ATSR-2 (1995-) and AATSR (2002-) on a hemispherical scale. NPP VIIRS from 2012-

- SYKE's *SCAmod* method for fractional snow cover mapping implemented for Northern hemisphere
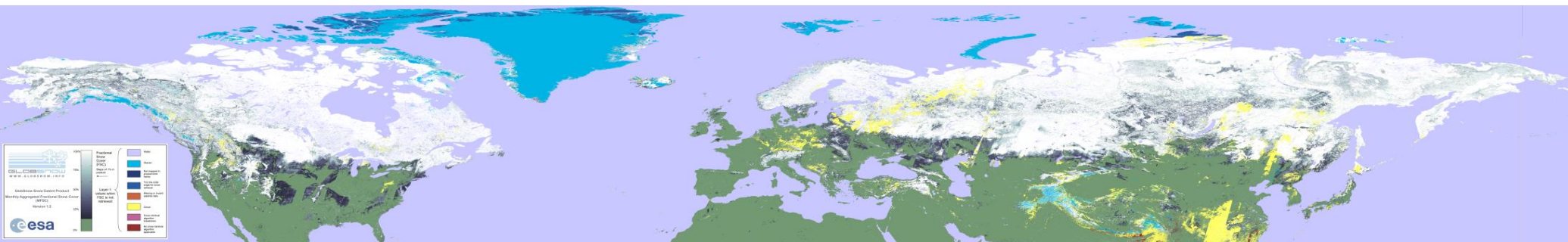
- Cloud detection algorithm developed by SYKE (+ contributed by ENVEO, FMI & NR)

- Methodology developed especially for forested regions – basically a tough challenge for optical SE retrieval

- Uncertainty estimate provided for each grid cell, data available as NetCDF CF

- Operational data production at the Finnish Meteorological Institute (FMI)

Metsämäki, S., Mattila, O.-P., Pulliainen, J., Niemi, K., Luojus, K., Böttcher, K. "An optical reflectance model-based method for fractional snow cover mapping applicable to continental scale", Remote Sensing of Environment, Vol. 123, August 2012, pp. 508-521, doi: 10.1016/j.rse.2012.04.010.

Daily, weekly and monthly products
Optical data ~ 1km spatial resolution

3 March 2010

1 March 2010

March 2010

SCAmod retrieval algorithm

- Based on reflectance model where forest canopy effect into the observed reflectance is compensated through pre-determined canopy *transmissivity*

- Designed to provide FSC in forested areas, and overall well applicable globally over any terrain

- A single band approach - Applicable to optical wavelengths and to a variety of sensors

Volume scattering   *Surface scattering*

$$\rho_{\lambda,obs}(FSC) = (1 - t_\lambda^2) * \rho_{\lambda,forest} + t_\lambda^2 * \left[FSC * \rho_{\lambda,snow} + (1 - FSC) * \rho_{\lambda,ground} \right]$$
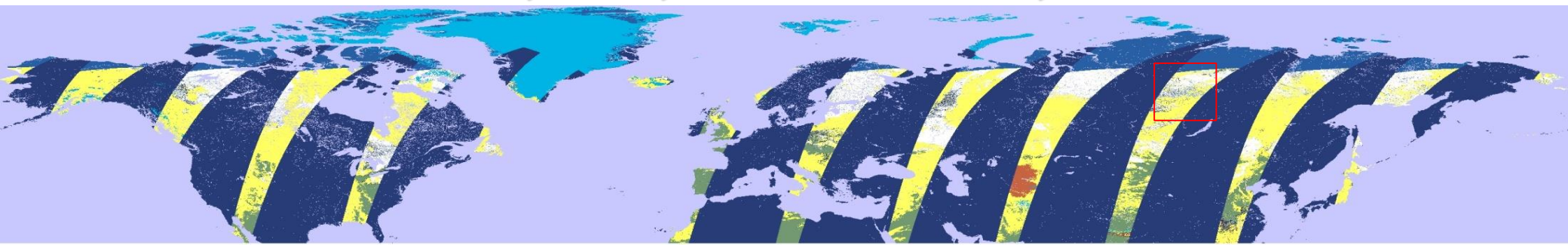
$$FSC = \frac{\dfrac{1}{t_\lambda^2} * \rho_{\lambda,obs}(FSC) + (1 - \dfrac{1}{t_\lambda^2}) * \rho_{\lambda,forest} - \rho_{\lambda,ground}}{\rho_{\lambda,snow} - \rho_{\lambda,ground}}$$
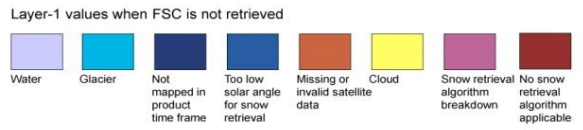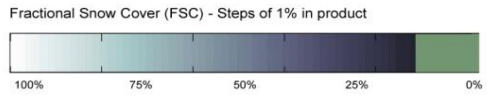
$\rho_{\lambda,obs}(FSC)$ observed reflectance from unit area
$\rho_{\lambda, snow}$ wet snow reflectance
$\rho_{\lambda,ground}$ snow-free ground reflectance
$\rho_{\lambda,forest}$ forest canopy reflectance
$\hat{t}$ forest canopy transmissivity for unit area
FSC fraction of snow covered area

March 09, 2010, full snow cover, dense forest

GlobSnow SE

NASA MOD10_L2

GlobSnow Snow Extent Product
Daily Fractional Snow Cover (DFSC)
Version 1.2

Fractional Snow Cover (FSC) - Steps of 1% in product

100%   75%   50%   25%   0%

Layer-1 values when FSC is not retrieved

Water | Glacier | Not mapped in product time frame | Too low solar angle for snow retrieval | Missing or invalid satellite data | Cloud | Snow retrieval algorithm breakdown | No snow retrieval algorithm applicable

W W W . G L O B S N O W . I N F O

esa
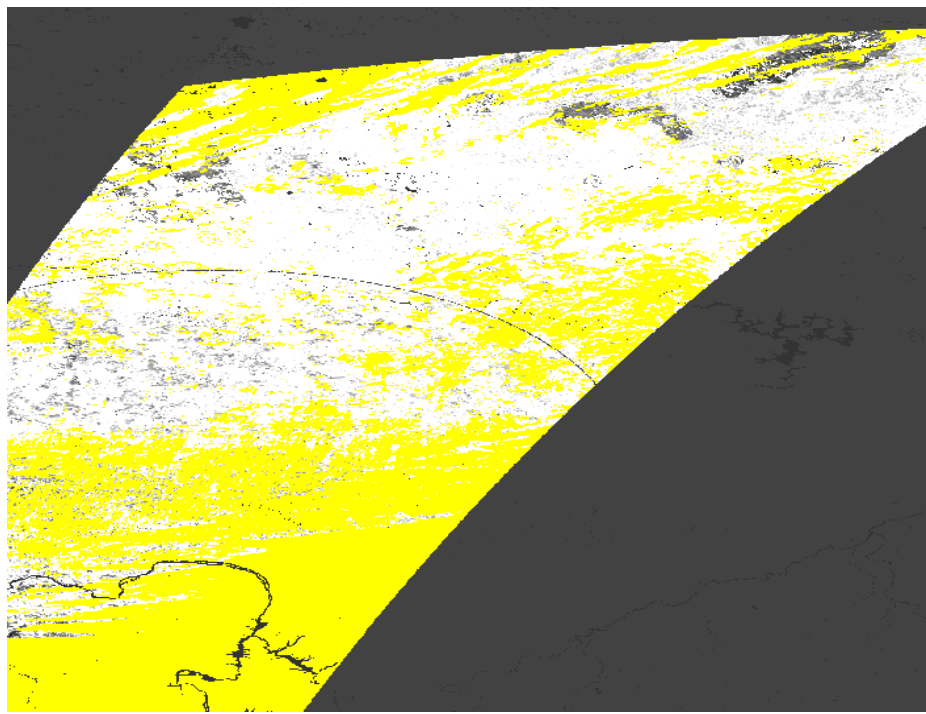
Mean Absolute FSC Difference
MOD10 versus GlobSnow - 1.3.-31.5.2010

$$(\Sigma | FSC_{MOD10} - FSC_{GlobSnow}|)/N$$

forest

	0
	10
	20
	30
	40
	50
	60
	70
	80
	90
	100

number of pixels (N)

	0
	3
	6
	9
	12
	15
	18
	21
	24
	27
	30
	33

Thomas Nagler / ENVEO

Suomi NPP VIIRS product

~1km spatial resolution, improved (daily hemispherical) coverage
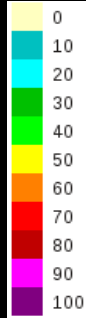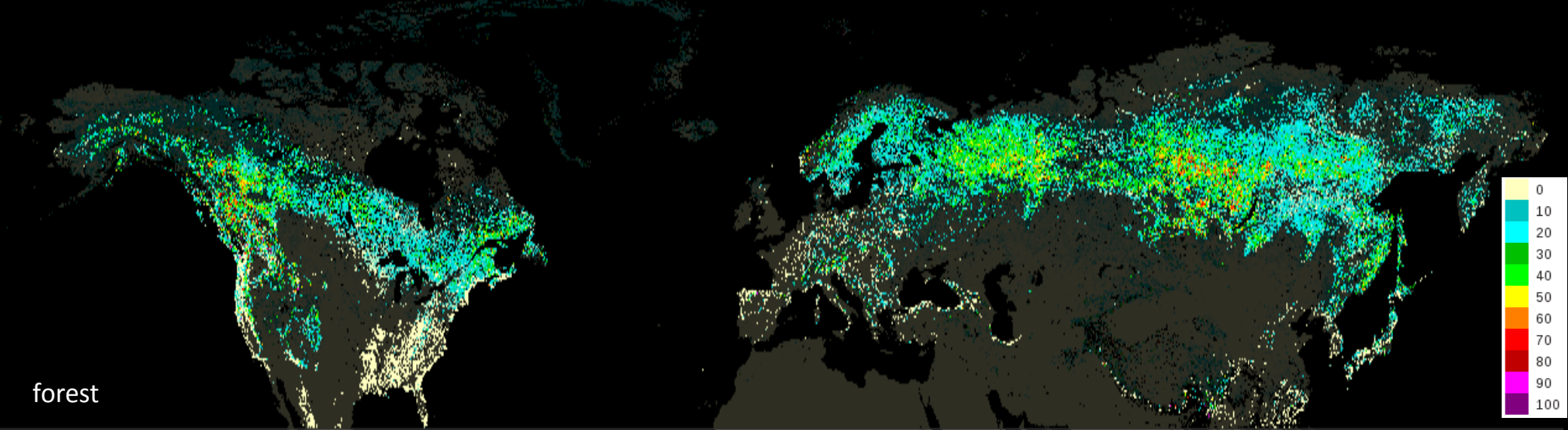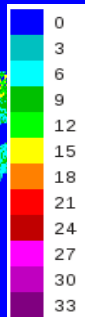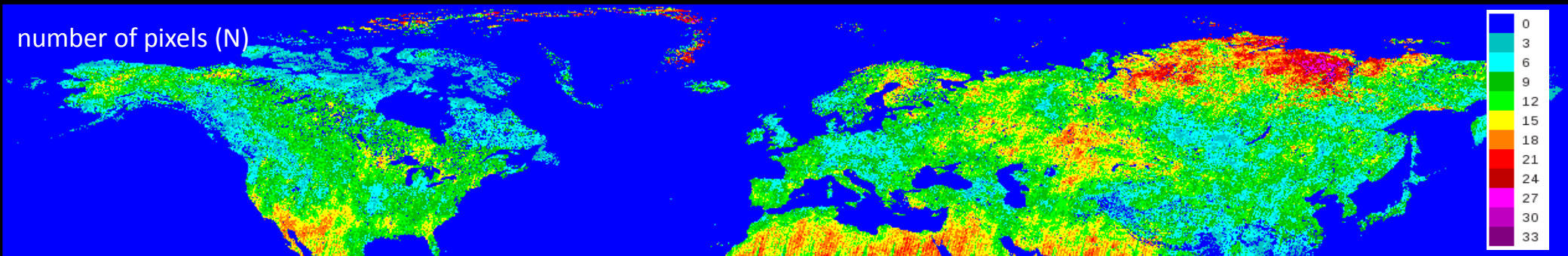## SEN3App development -> 500m resolution in preparation for S3 SLSTR

Sen3App Snow Extent Product
Daily Fractional Snow Cover (DFSC)
Version 1.0
- based on Suomi NPP VIIRS data -

Fractional Snow Cover (FSC) - Steps of 1% in product
100% 75% 50% 25% 0%

Layer-1 values when FSC is not retrieved
Water | Glacier | Not mapped in product time frame | Too low solar angle for snow retrieval | Missing or invalid satellite data | Cloud | Snow retrieval algorithm breakdown | No snow retrieval algorithm applicable

Sen3App DB Extended Baltic Sea FSC
(weekly aggregated product: 22-28 Feb. 2016)

Direct broadcast MODIS data from Sodankylä used to produce 500m resolution Pan-EU FSC product, 12h latency (due to DB)
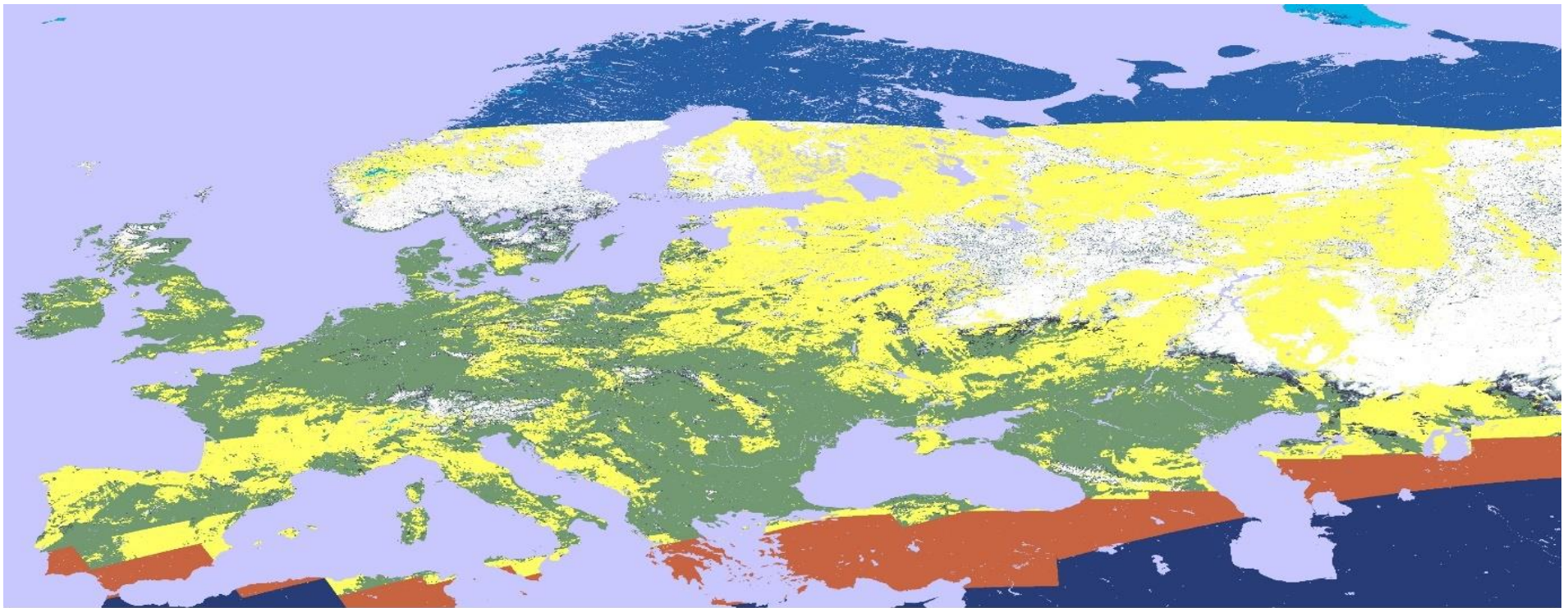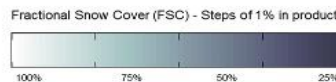
Pan-European High Resolution SWE

ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

esa

due
data user element
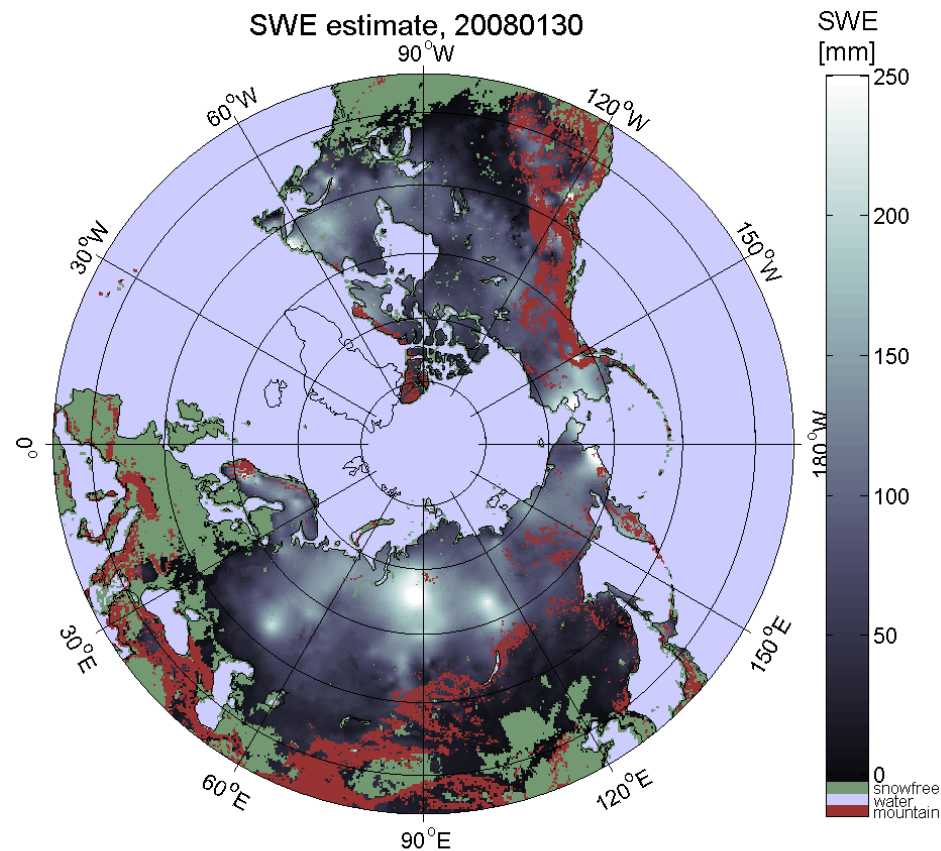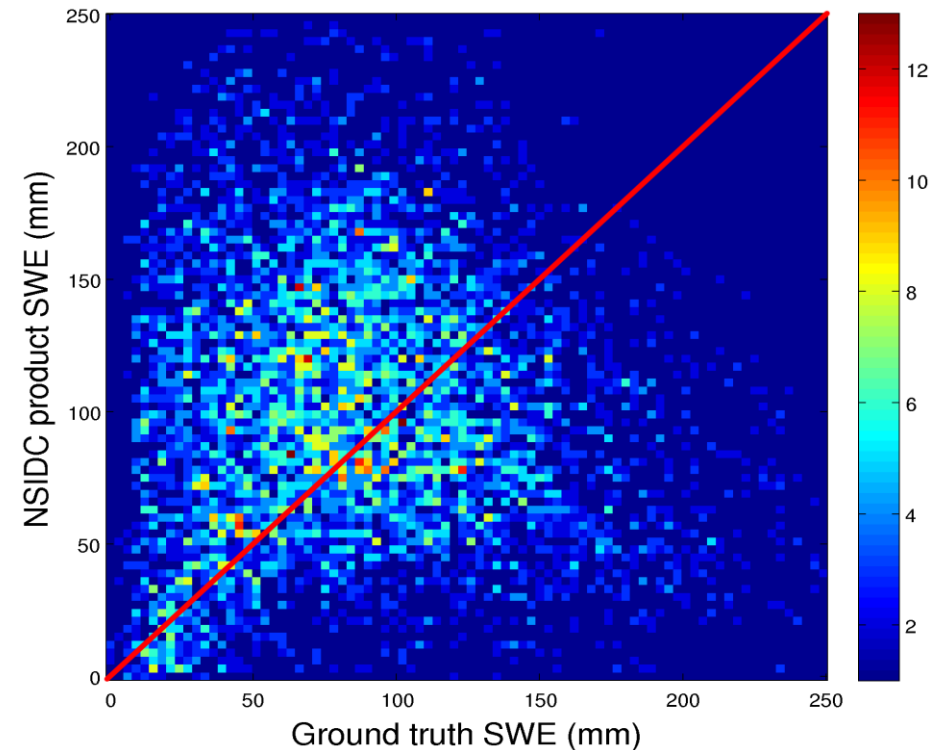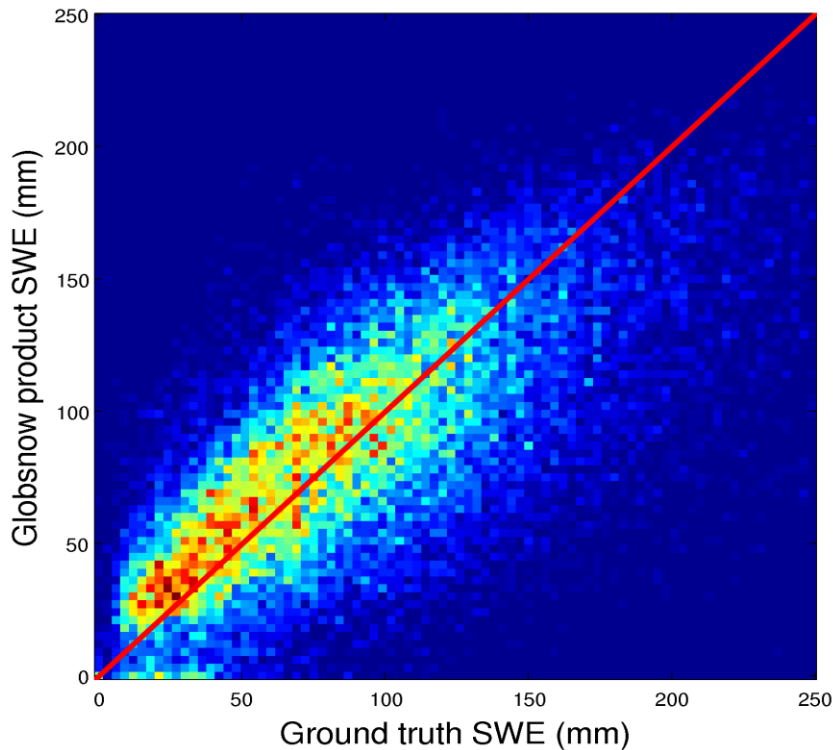
GLOBSNOW

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 1979-2015
- Passive microwave radiometer data combined with ground-based synoptic snow observations
    - Variational data-assimilation
- Available at open data archive (www.globsnow.info)

- **Daily NRT production** since 2010

SWE estimate, 20080130

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

SWE retrieval performance (benefit of data assimilation)

- Density scatterplot (assimilated vs. satellite only SWE)

- Russian INTAS SCCONE **SWE transect data** (distributed data) as reference

Super-SWE vs. GlobSnow CDR

- **Improved resolution by assimilating in a higher resolution grid (variation within footprint is dealt with simple convolution)**

- **Snow grain size and variance are interpolated using nearest neighbor interpolation with low pass filtering to reduce artefacts**

- **Auxiliary files are all overhauled (to the higher resolution grid), especially forest stem volume map (based on forest transmissivity map by Finnish Environment Institute SYKE)**

- **Snow covered area determined using IMS data for fall-winter season**

- **IMS+VIIRS used for the spring melt season**

Example of Sen3App high resolution (5km) SWE

Superresolution SWE estimate, 20130216
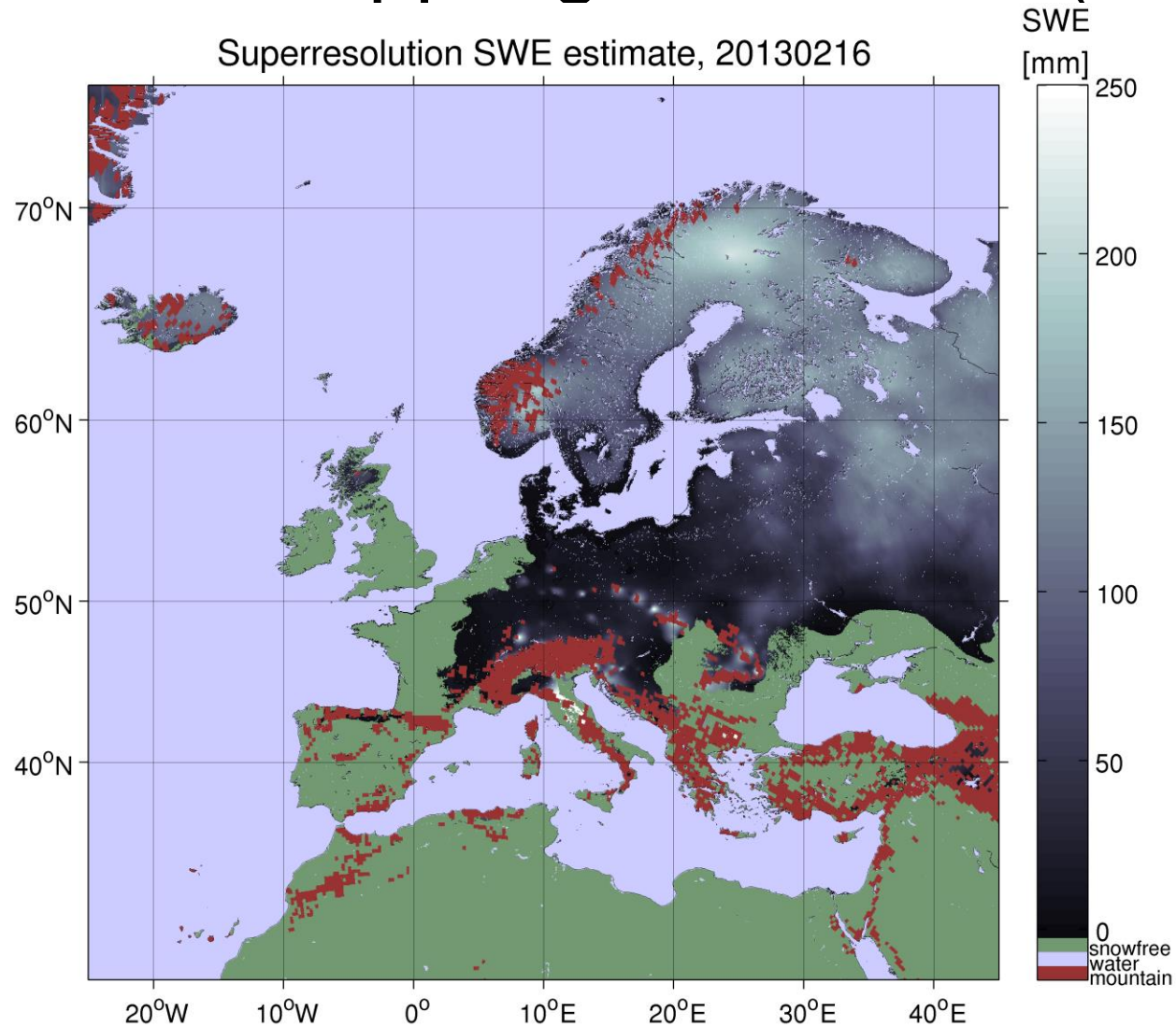
Super-SWE validation (winter 2012-2013)

- **Season 2012-2013 is validated in Finland using Finnish Environment Institute (SYKE) snow course data**

- **Validation data is independent of input SD data**

- **Super SWE: bias is 14.9 mm, RMSE 33.1 mm and RMSE with bias correction 29.6 mm**

- **H-SAF H13: bias 16.1 mm, RMSE 27.8 mm, and RMSE with bias correction 22.6 mm**

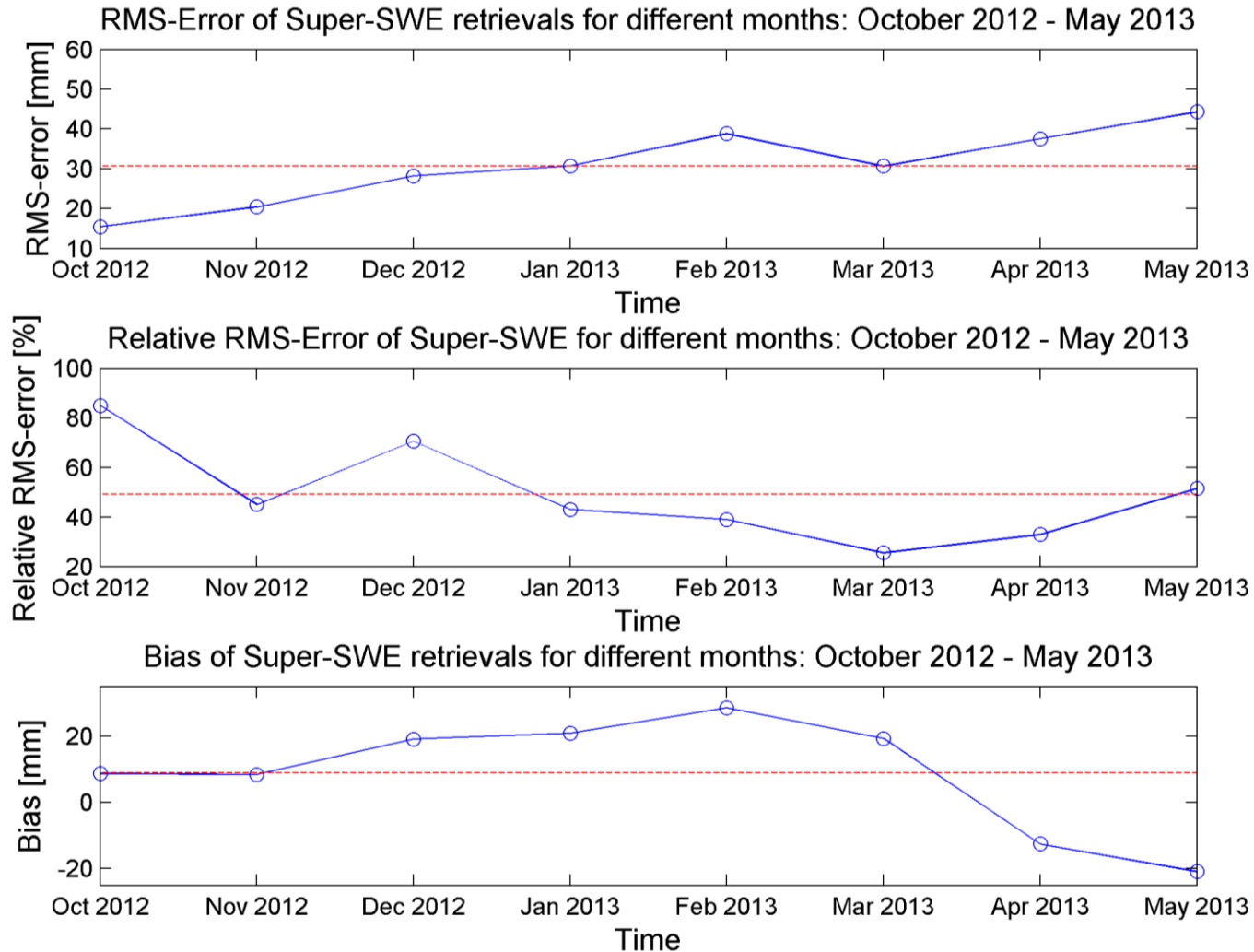# Super-SWE validation data scatterplot
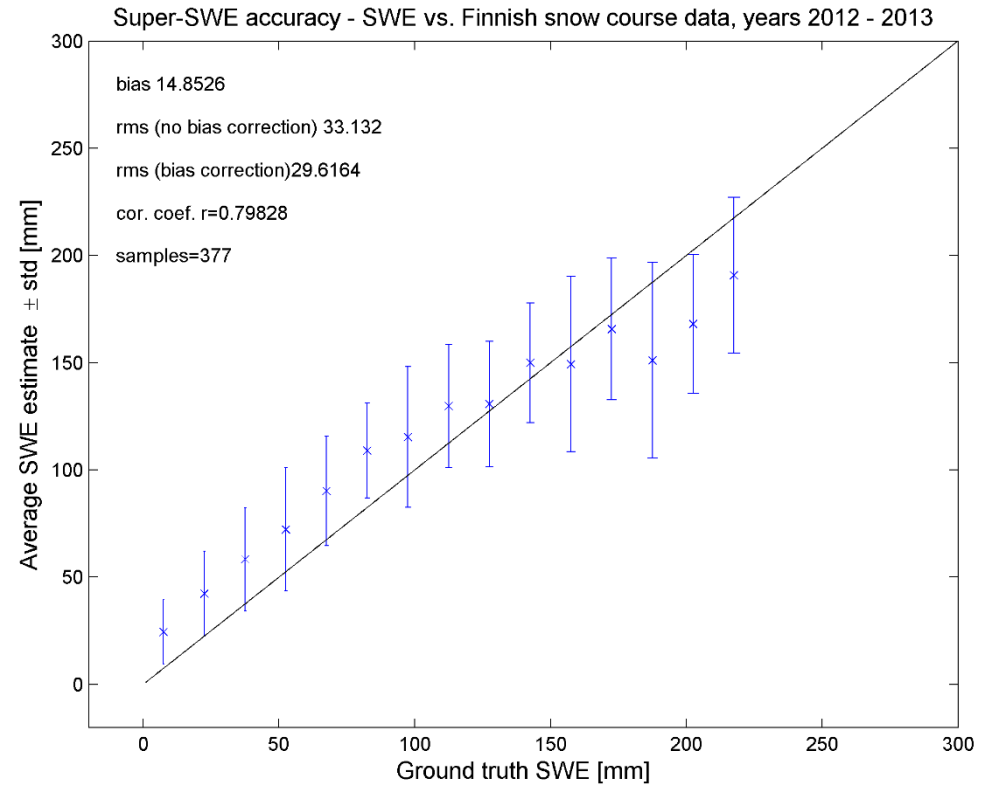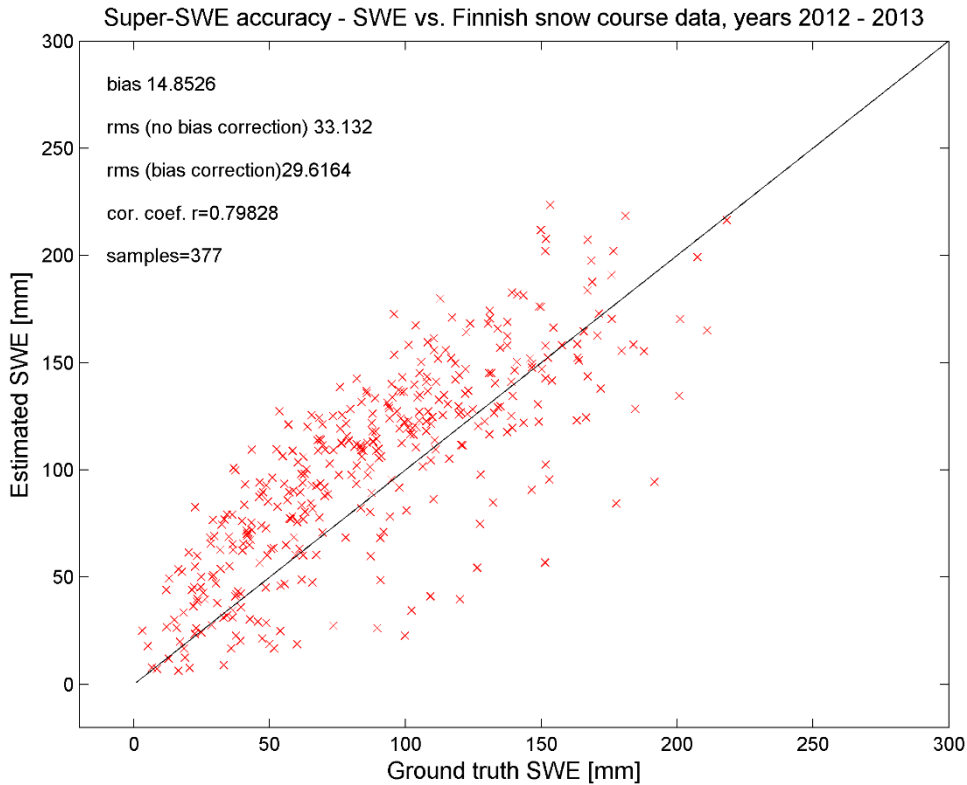
Interpretation of validation results

- **Higher resolution SWE product is in par with other products such as H-SAF H-13 and GlobSnow SWE**

- **Bias and RMSE slightly improved, when compared with GlobSnow CDR SWE**

- **RMSE plotted as a function of month, the peak SWE month has the lowest relative RMSE**

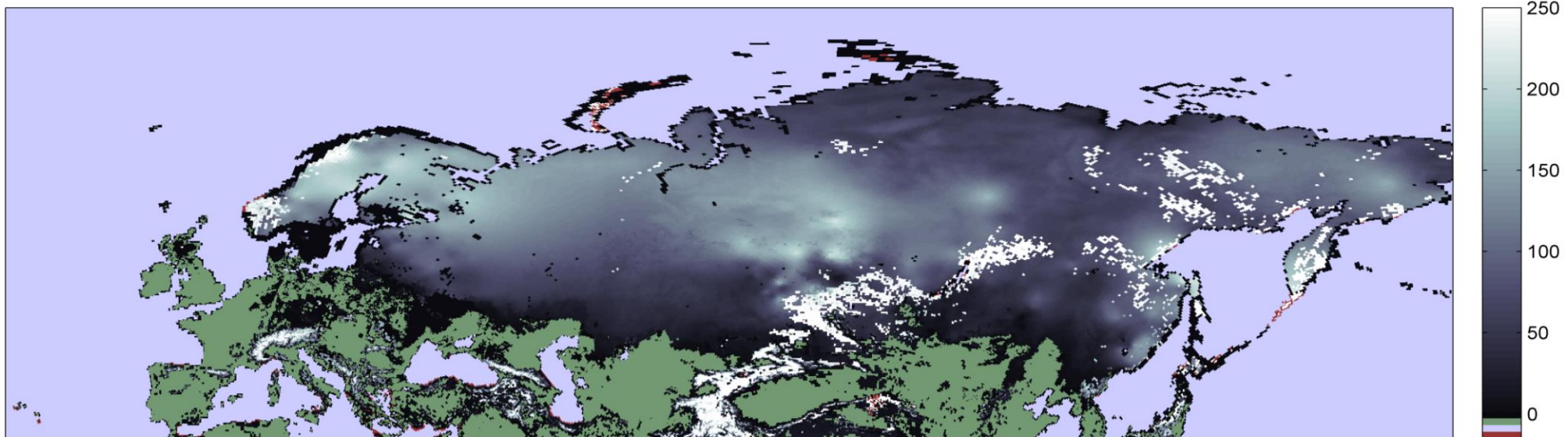# Monthly RMSE, relative RMSE & bias

SEN3App research product:
Combined 25km NH FSC/SWE product

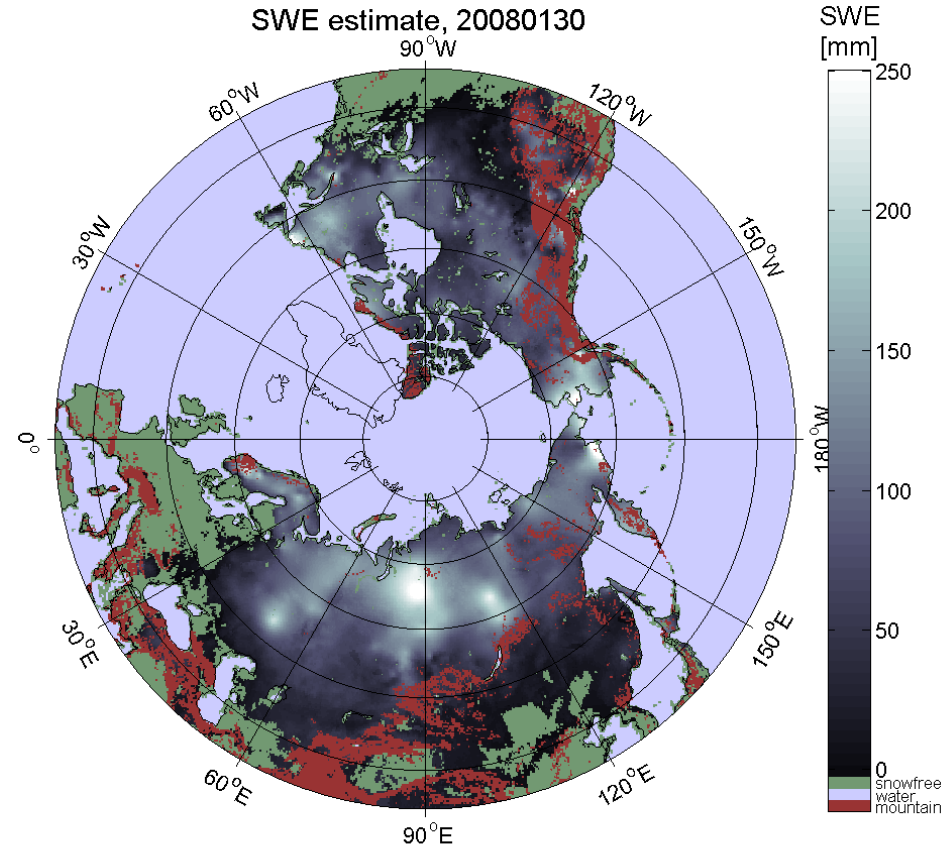# Sen3App 2-layer 25km NH combined FSC/SWE product

- NRT north-hemisphere daily snow monitoring product combining 25km NH SWE and 1km FSC products (based on SSMI-S and VIIRS+Sentinel-3)

- SE information from VIIRS & NOAA IMS applied for (NRT) SWE production

GlobSnow, 25km Northern Hemisphere SWE

- 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 1979-2015

- Passive microwave radiometer data combined with ground-based synoptic snow observations

  - Variational data-assimilation

- Available at open data archive (www.globsnow.info)
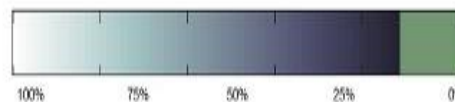
- **Daily NRT production** since 2010

SWE estimate, 20080130

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

Sen3App NH FSC product (1km)
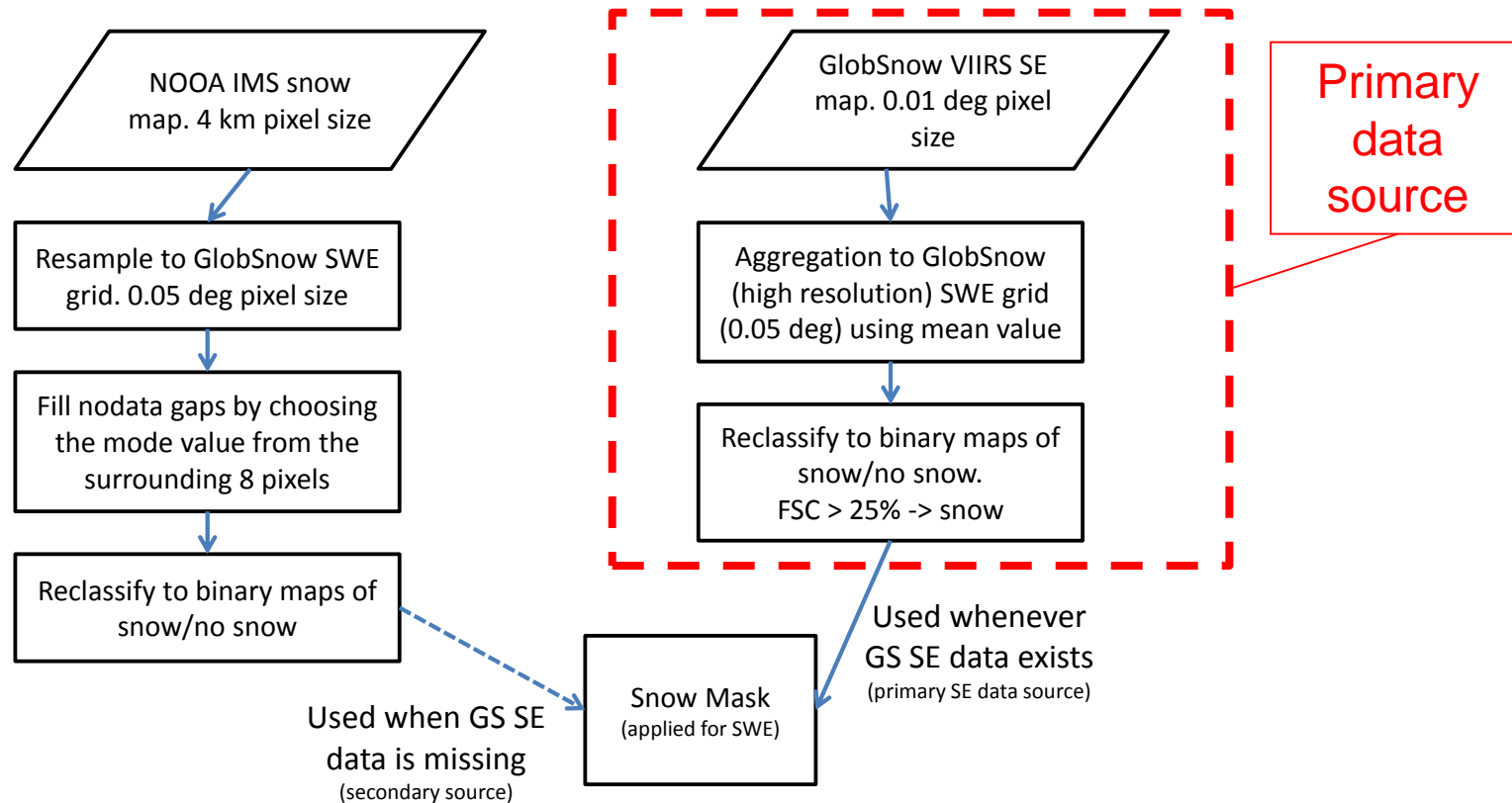
NOAA/NESDIS IMS Snow/Ice

- **Daily 1km / 4km SE product based on multisensor data and human analyst interpretation**

- **Satellite + ground-based + modelled data**

- **Combines optical, PMW and SAR data**

- **Cloud filling**

- **Binary product**

- **89km / 24km / 4km / 1km**

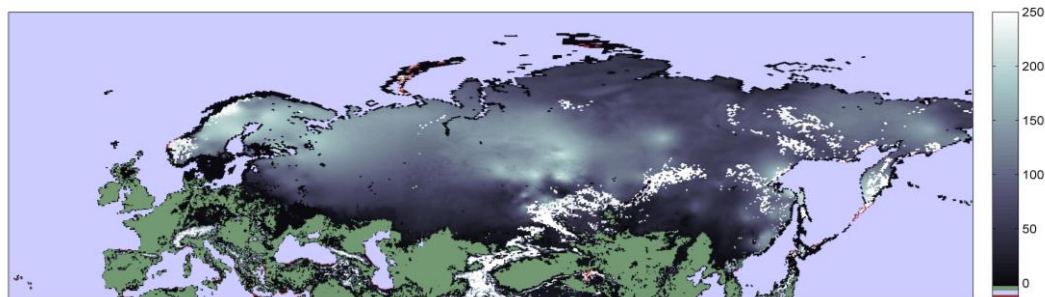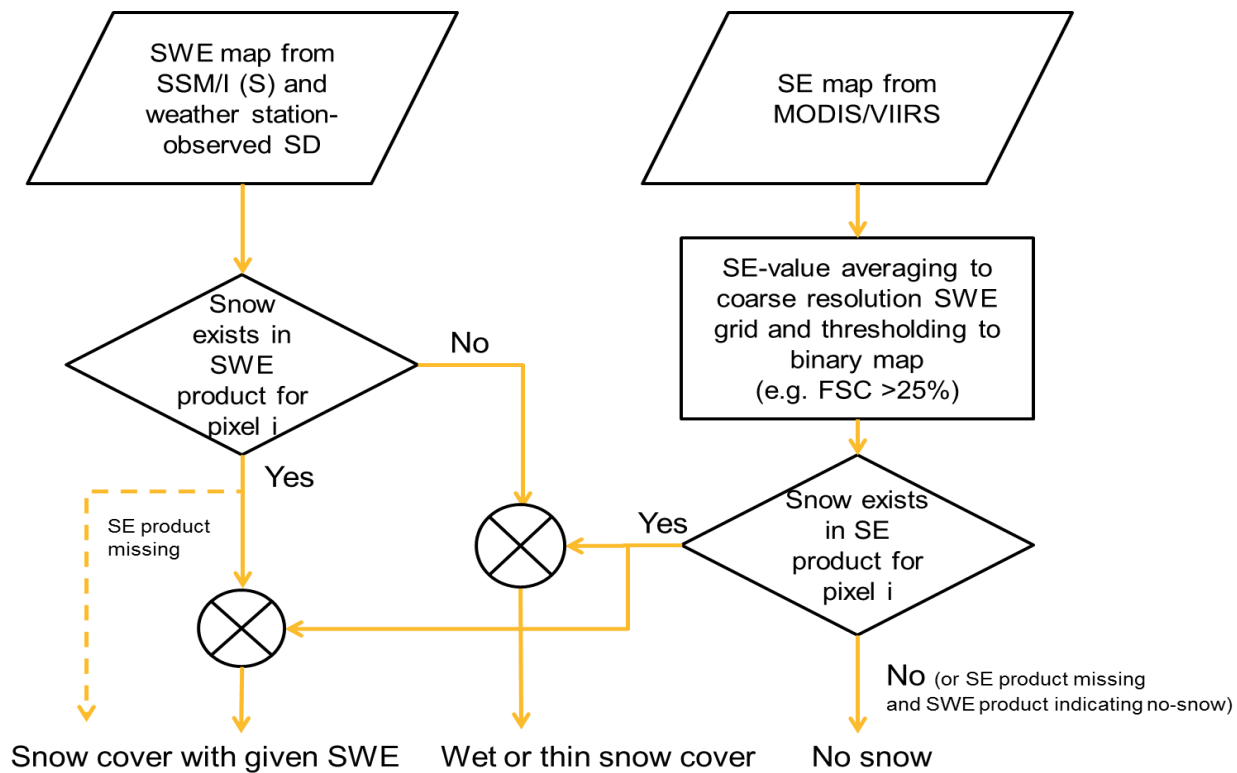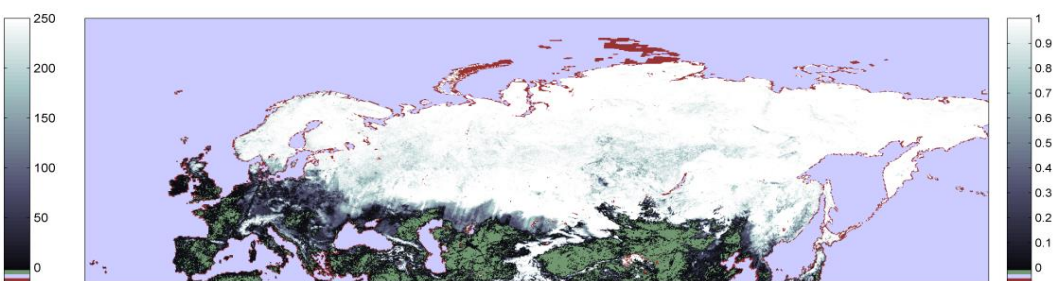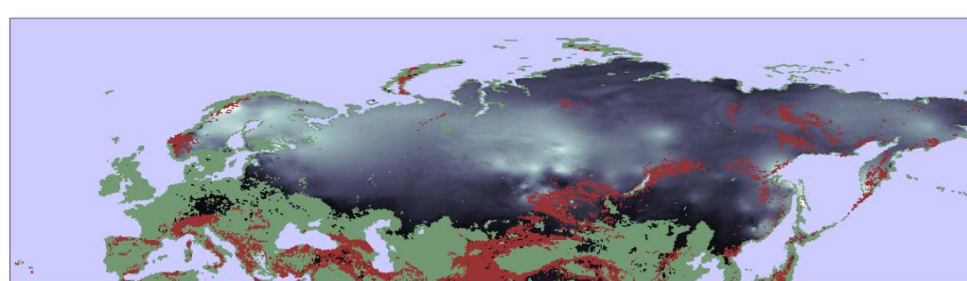- **Operational focus, numerous methodology improvements since 1966**
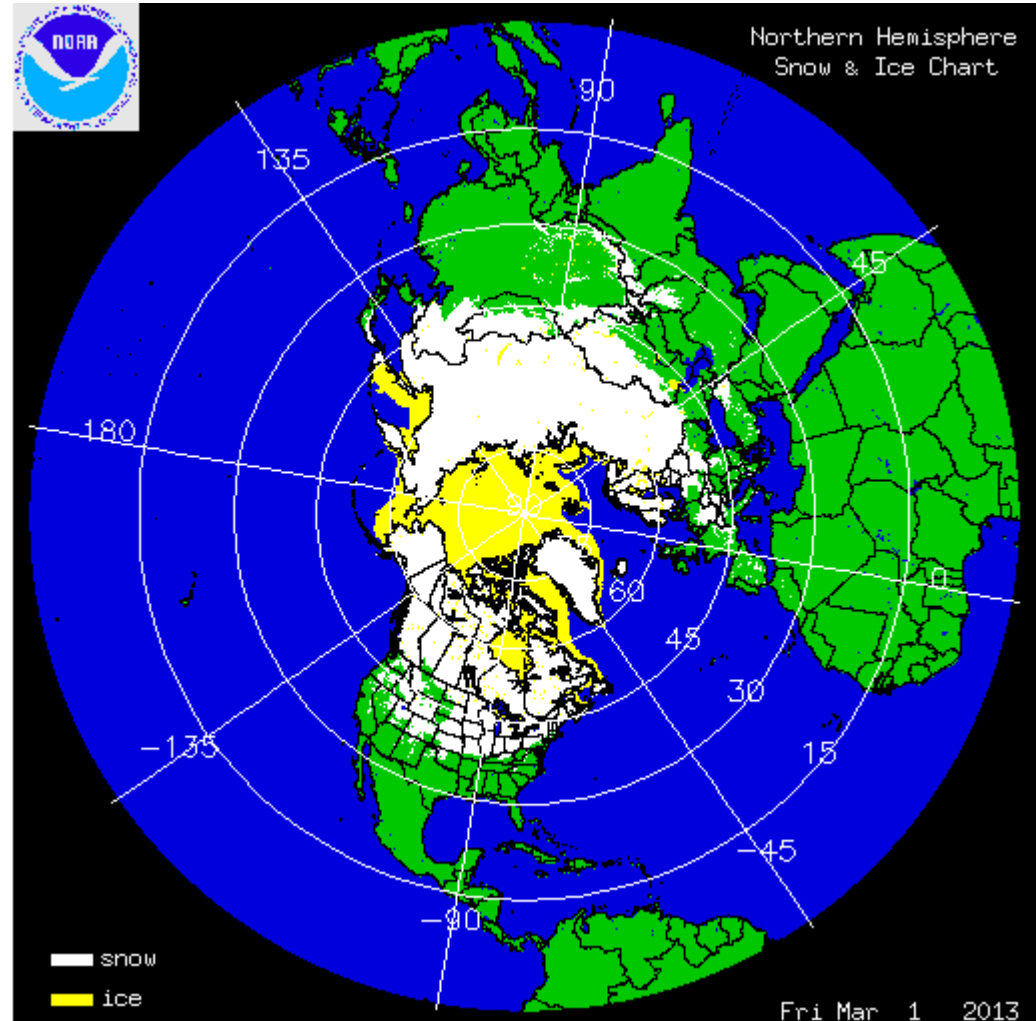
Combination of SE & SWE products
for the generation of concise snow cover information

Combined snow mask from GS VIIRS SE and NOAA IMS

NOOA IMS snow map. 4 km pixel size

GlobSnow VIIRS SE map. 0.01 deg pixel size

Primary data source

Resample to GlobSnow SWE grid. 0.05 deg pixel size

Aggregation to GlobSnow (high resolution) SWE grid (0.05 deg) using mean value

Fill nodata gaps by choosing the mode value from the surrounding 8 pixels

Reclassify to binary maps of snow/no snow.
FSC > 25% -> snow

Reclassify to binary maps of snow/no snow

Snow Mask
(applied for SWE)

Used whenever GS SE data exists
(primary SE data source)

Used when GS SE data is missing
(secondary source)

SWE map from SSM/I (S) and weather station-observed SD

SE map from MODIS/VIIRS

SE-value averaging to coarse resolution SWE grid and thresholding to binary map (e.g. FSC >25%)

Snow exists in SWE product for pixel i

No

Yes

SE product missing

Snow exists in SE product for pixel i

Yes

No (or SE product missing and SWE product indicating no-snow)

⊗

⊗

Snow cover with given SWE
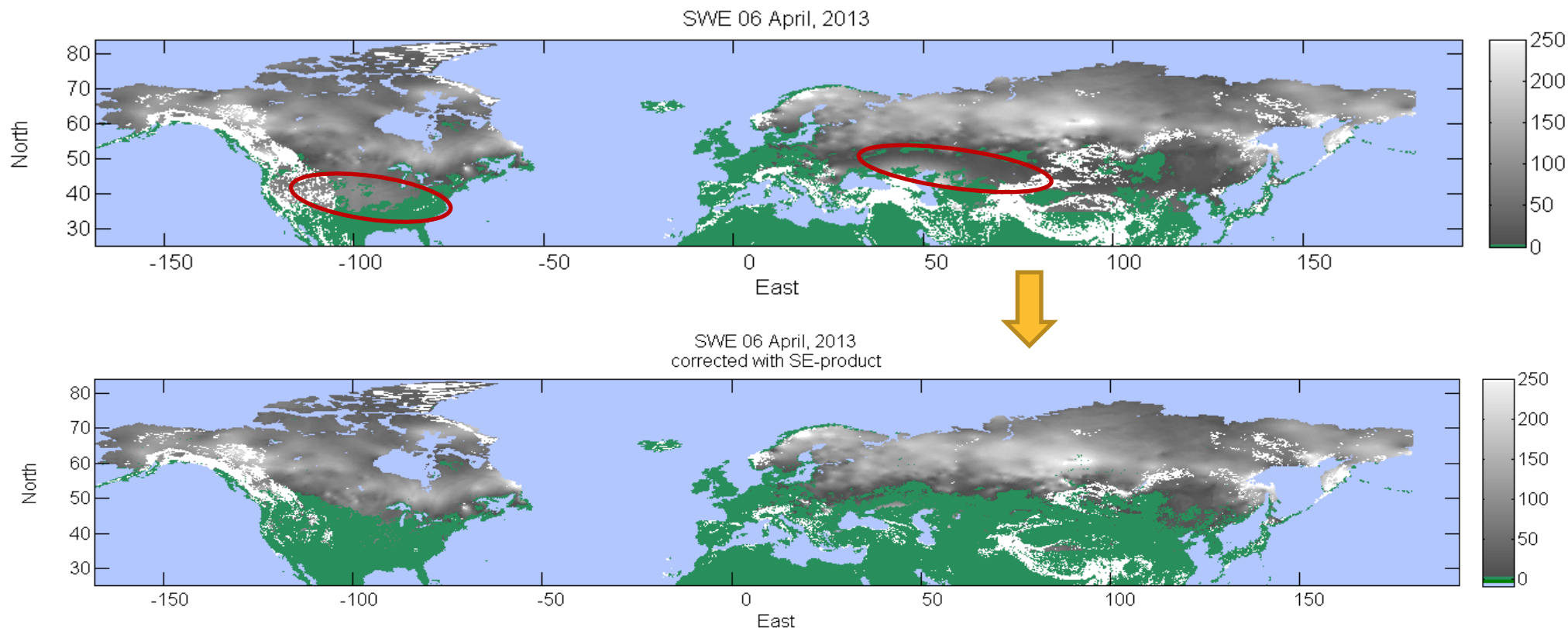
Wet or thin snow cover

No snow

Fusion of SE and SWE products on NH scale

GlobSnow SWE NRT-product has difficulties in detecting snow line during spring melt season -> snow line identification from SE-product
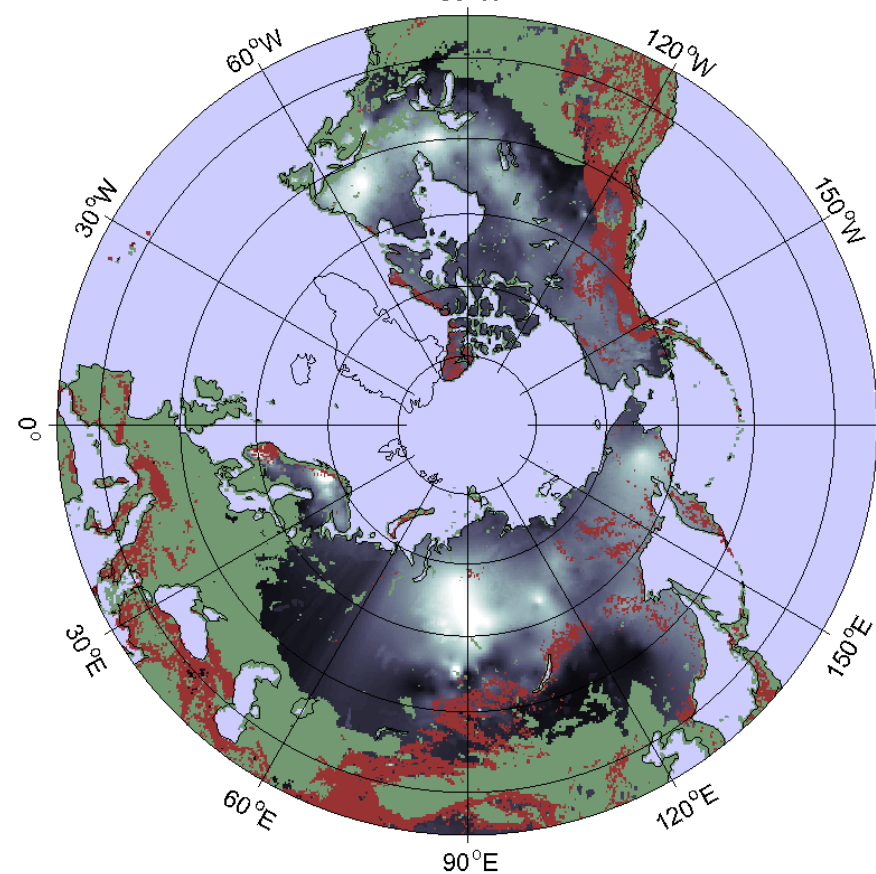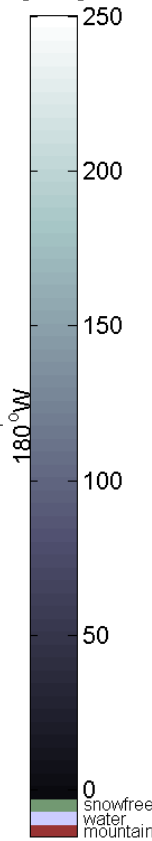

SWE 06 April, 2013

SWE 06 April, 2013
corrected with SE-product

Example for spring season 2013

Example of fusion during spring season (2014)

Legacy GS
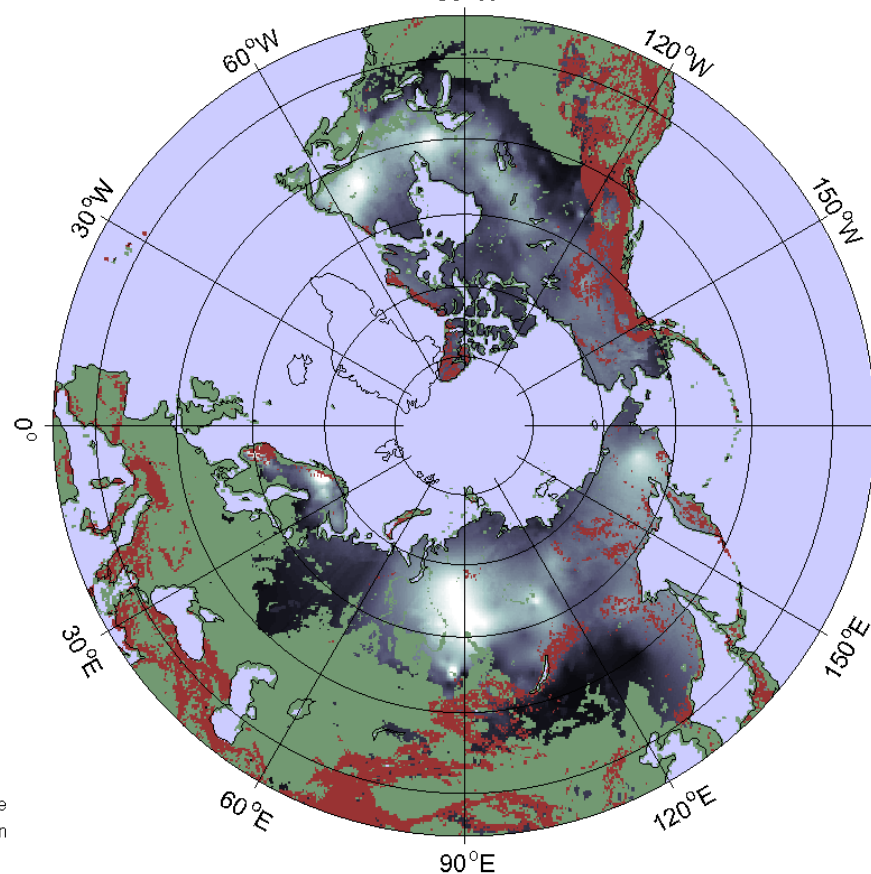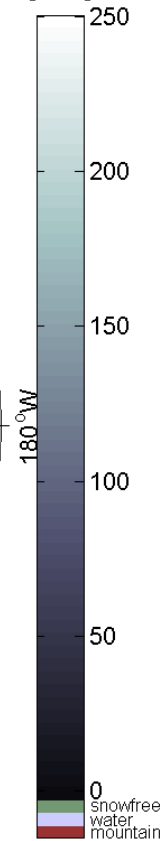
IMS + VIIRS masked

Conclusions

Production & demonstration for SEN3APP project:

- NH VIIRS (S3 SLSTR preparatory) FSC product
- Pan-EU DB VIIRS FSC product
- High-resolution Pan-European SWE product
  - Data assimilation can be used to estimate SWE in a finer resolution despite the radiometer instrument footprint

Combination of SE & SWE data for a single "fused" product

- SWE and SE fused into a single layer 25km NH product (research product, can be delivered upon user request)