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Global SWE Mapping by Combining Passive and Active Microwave Data: The GlobSnow Approach and CoReH$_2$O

April 28, 2010

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Background

- Investigations are connected to two ongoing ESA-projects:
  - Synergy of CoReH_2O SAR and microwave radiometry data to retrieve snow and ice parameters
  - Data User Element (DUE) project GlobSnow
- This presentation focuses to activities currently ongoing at FMI
  - Possibilities to improve the accuracy and usability of global passive microwave cryosphere products by supplementing active microwave data

Applications of passive data and potential of supplementary SAR-observations

- Present and near-future space-borne microwave radiometers are able to provide information related to snow cover and soil frost on a global scale:
  - AMSR-E, SSM/I and SMMR for historical data:
    - Snow water equivalent (SWE), snow depth (SD) and (dry) snow extent
    - Snow melt (on-set and snow clearance)
  - SMOS
    - Soil moisture, soil frost and soil thawing
- Restrictions
  - Poor spatial resolution =>
    - Mixed pixels
    - Need of downsclaling for NWP and hydrological forecasting
- **Potential benefits of accompanying SAR-data:**
  - Consideration of varying land cover and lakes
  - Spatial improvement of SWE mapping (especially X- and Ku-bands, but even C-band may have some feasibility)

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Synergy Project: An Overview

esa

- **Synergy of CoReH$_2$O SAR and microwave radiometry to retrieve snow and ice parameters**
  - Can radiometer observations benefit from CoReH$_2$O and *vice versa*
    - Combined use including the downscaling of passive data
    - Parameter initialization
  - Consortium led by the Finnish Meteorological Institute (FMI) with sub-contractors: ENVEO IT (Austria), IFAC (Italy), University of Waterloo (Canada) and Environment Canada; additionally co-operation with Meteo-France.

IFAC

Environment Canada

enveo

UNIVERSITY OF Waterloo

METEO FRANCE
Toujours un temps d'avance

GlobSnow: An Overview

❖ ESA DUE GlobSnow

- Global products on Snow Water Equivalent (SWE) and Snow Extent (SE) for climate research
  - Fundamental Climate Data Record (FCDR) aiming for ECV-record
- Team including Finnish, Austrian, Swiss, Norwegian and Canadian partners

ESA GlobSnow (2008 – 2011)

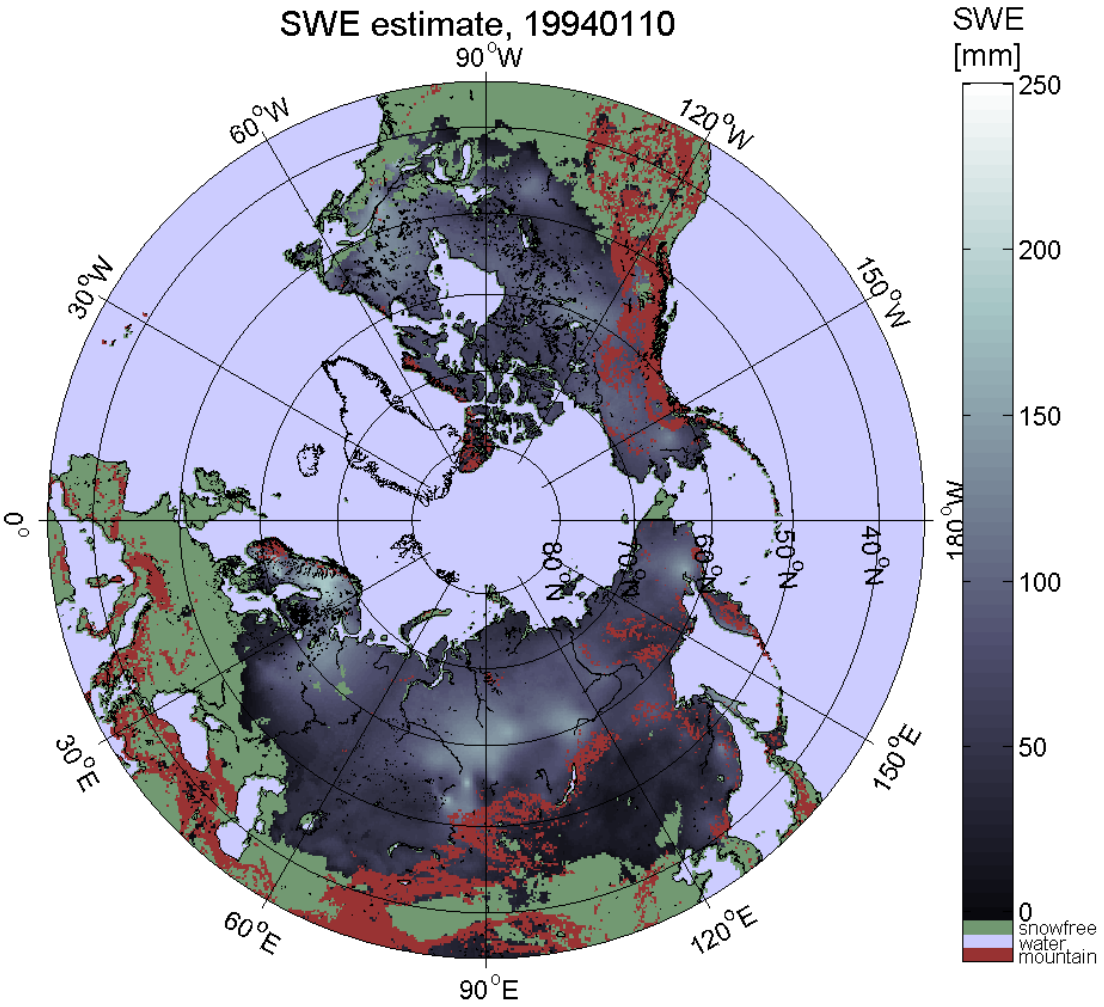
- Production of new global snow extent (SE) and snow water equivalent (SWE) climate data records, with a demonstration of a near-real-time processing capability.

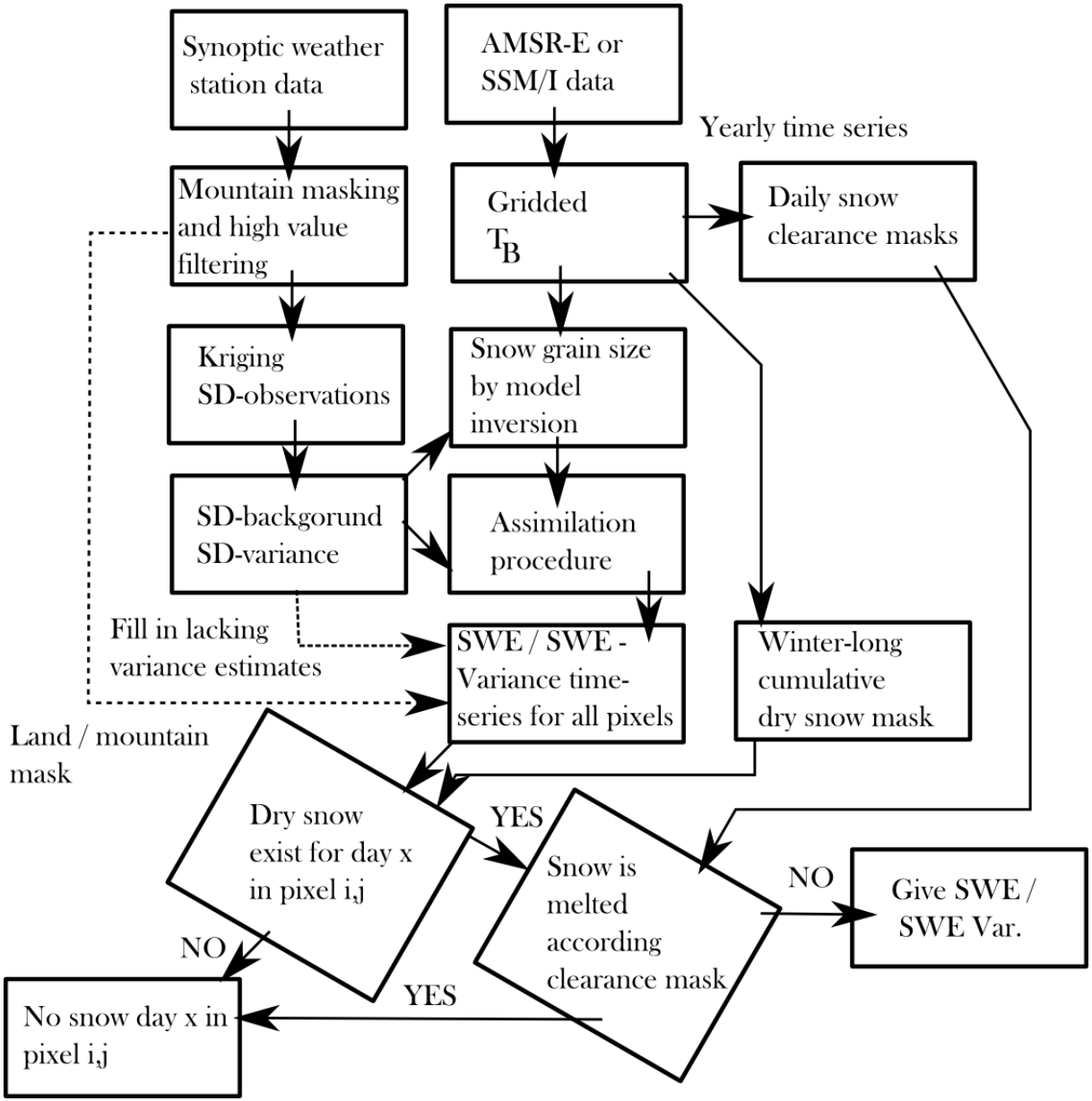
- Consortium led by the Finnish Meteorological Institute (FMI) with collaborators: ENVEO IT (Austria), GAMMA Remote Sensing (Switzerland), Norwegian Computing Center (NR), Finnish Environment Institute (SYKE), Environment Canada and Norut (Norway).

- Project details including technical reports and newsletters available at globsnow.fmi.fi. (**new and present users can obtain data sets by web-interface**)

Version 0.92 SWE Product

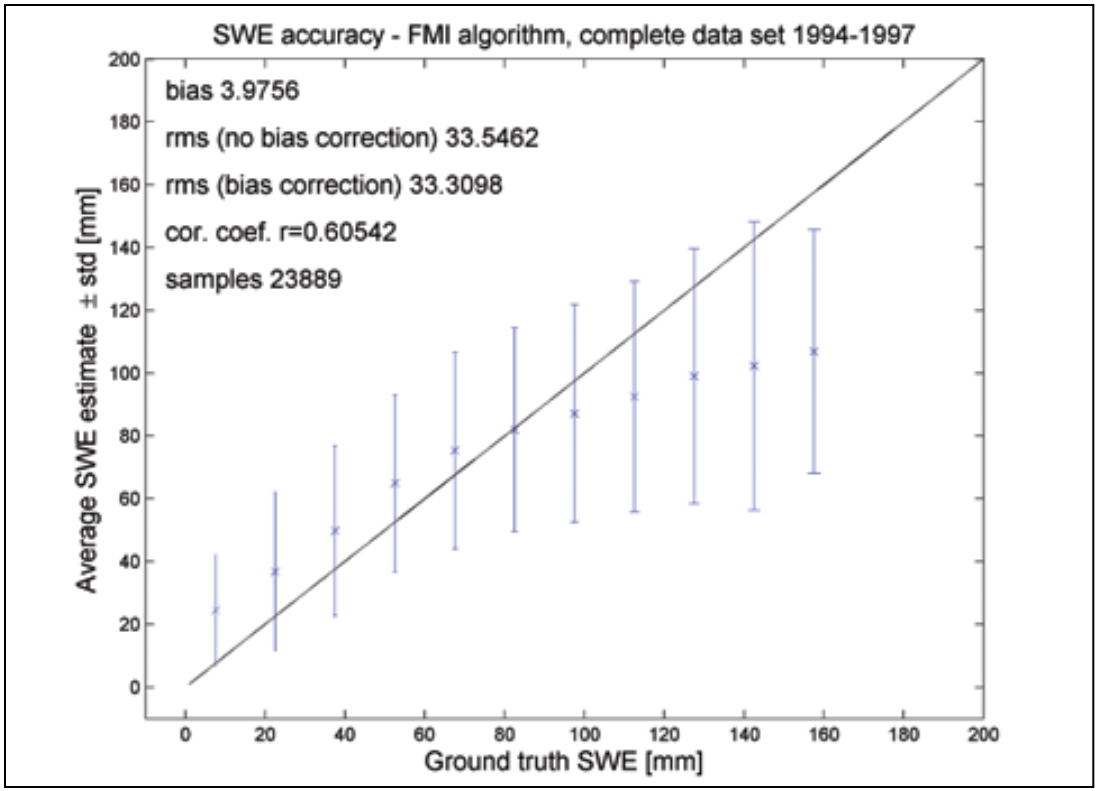
- Daily maps of hemispherical snow cover:
  - Total snow area
    - Permanent sesonal snow cover
  - SWE for the snow area
- Regions with high topograpical variability are masked off
  - Alpine regions
  - Glaciers will be also masked
- NRT production of SWE will be demonstrated in 2010-2011

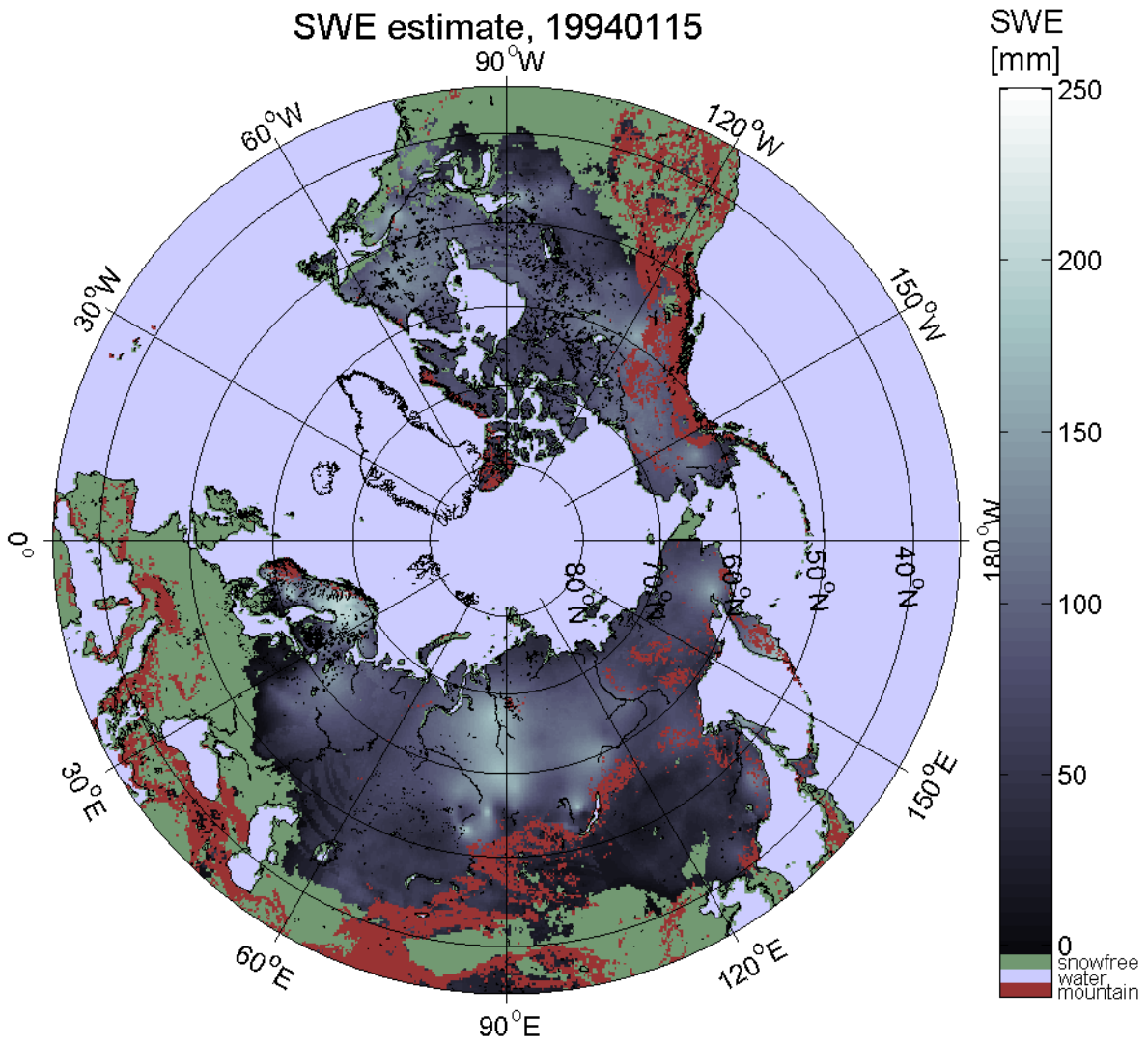


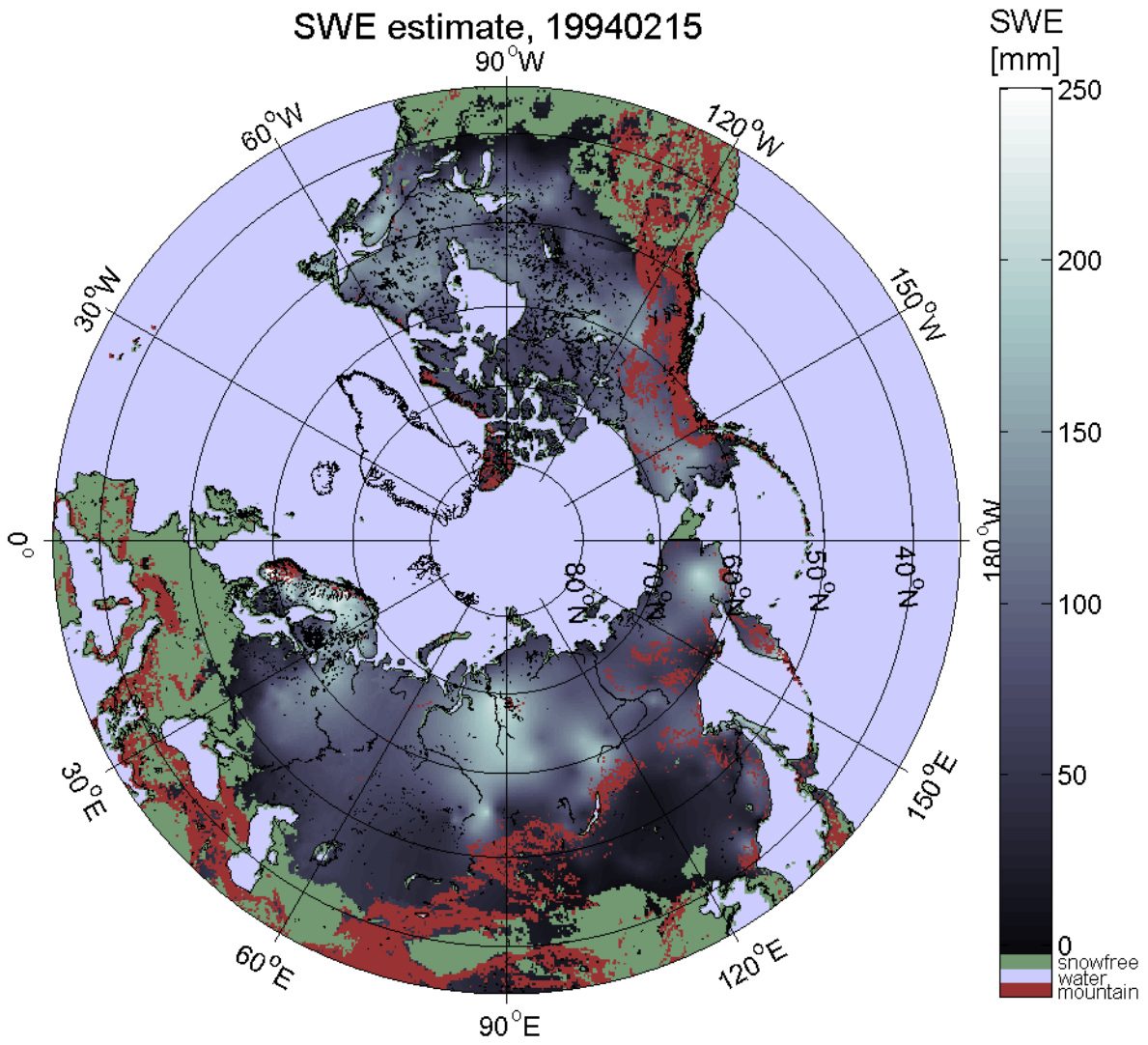

Synoptic weather station data
AMSR-E or SSM/I data
Yearly time series
Mountain masking and high value filtering
Gridded T_B
Daily snow clearance masks
Kriging SD-observations
Snow grain size by model inversion
SD-backgorund SD-variance
Assimilation procedure
Fill in lacking variance estimates
SWE / SWE - Variance time-series for all pixels
Winter-long cumulative dry snow mask
Land / mountain mask
Dry snow exist for day x in pixel i,j
YES
Snow is melted according clearance mask
NO
Give SWE / SWE Var.
NO
YES
No snow day x in pixel i,j

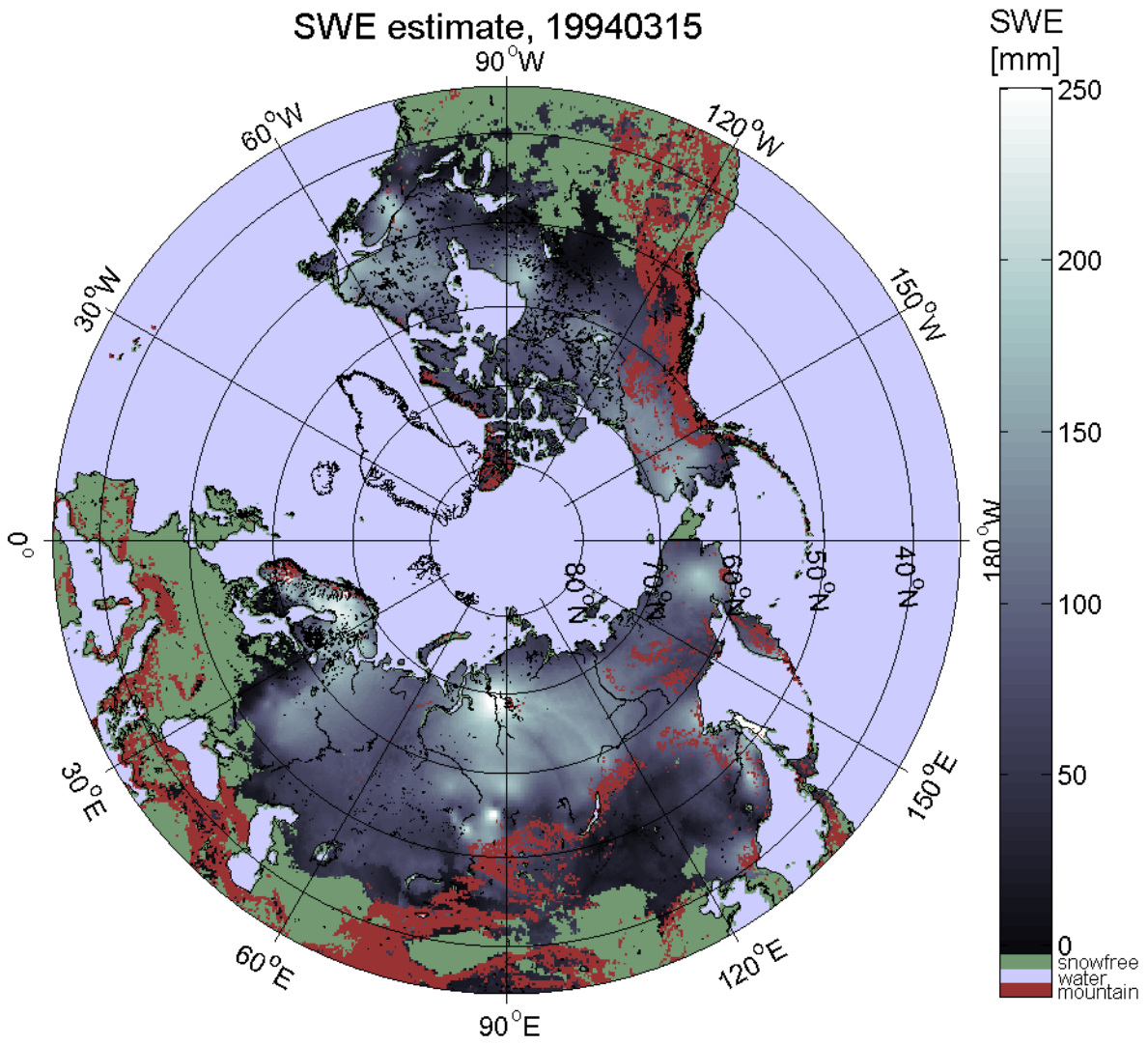
GlobSnow SWE Product

- Approach: Assimilation of satellite data with *in situ* observations-derived bckground field on snow depth.
  - Sufficient accuracy level on a global scale can be obtained
- Statistical error estimate produced for each grid cell.
- SWE retrievals for all terrestrial snow regions of northern hemisphere excluding alpine regions and glaciers.
- Time-series currently under processing extending from 1978 to present
- Operational near-real-time service will be demonstrated during 2010/2011.

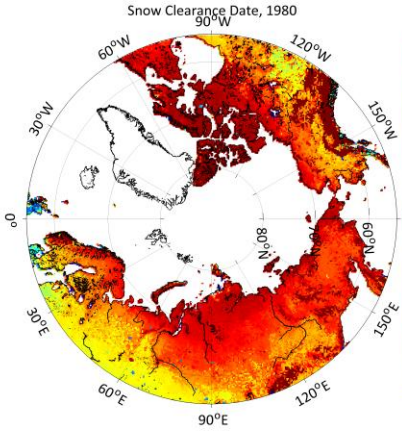



SWE estimate, 19940115
90°W
60°W
120°W
30°W
150°W
0°
180°W
30°E
150°E
60°E
120°E
90°E
80°N
70°N
60°N
50°N
40°N
SWE
[mm]
250
200
150
100
50
0
snowfree
water
mountain

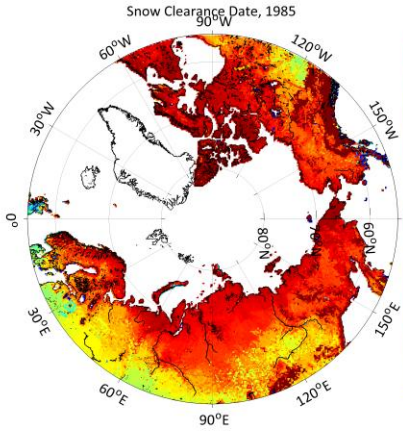

SWE estimate, 19940215
90°W
60°W
120°W
30°W
150°W
0°
180°W
30°E
150°E
60°E
120°E
90°E
80°N
70°N
60°N
50°N
40°N
SWE
[mm]
250
200
150
100
50
0
snowfree
water
mountain


SWE estimate, 19940315
90°W
60°W
120°W
30°W
150°W
0°
180°W
30°E
150°E
60°E
120°E
90°E
80°N
70°N
60°N
50°N
40°N
SWE
[mm]
250
200
150
100
50
0
snowfree
water
mountain

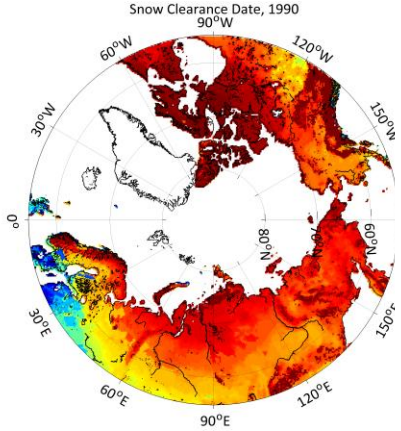
Day of snow clearance derived from GlobSnow–product (Julian day from the beginning of the year)



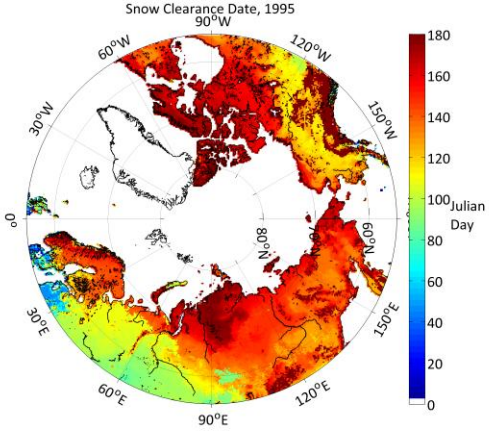
1980



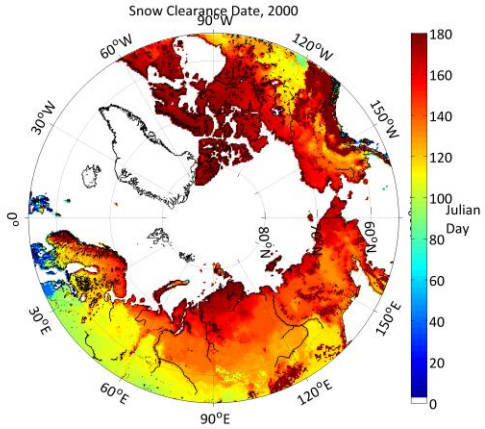
1985



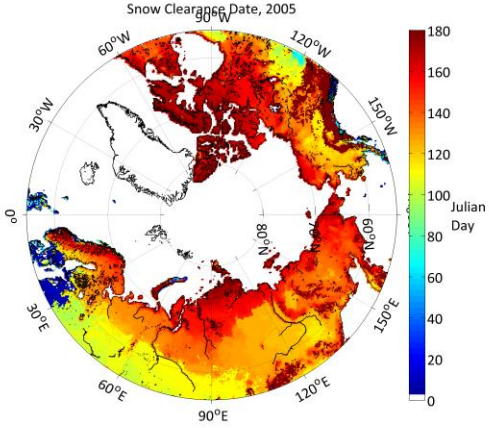
1990



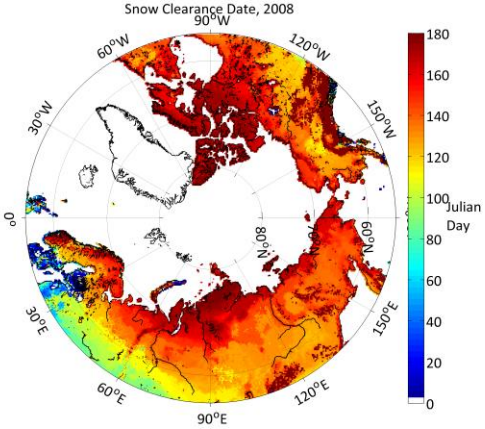
1995



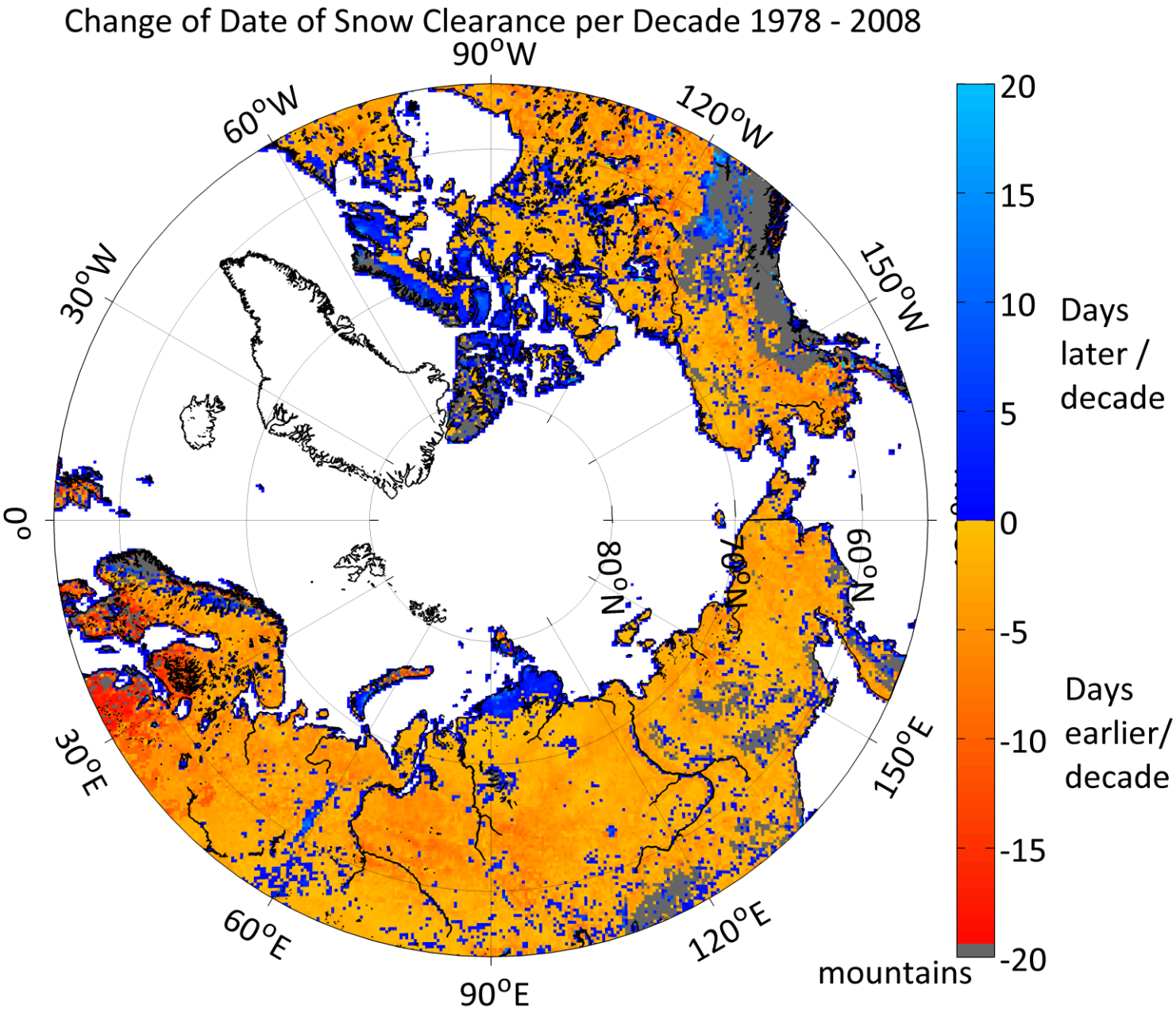
2000



2005

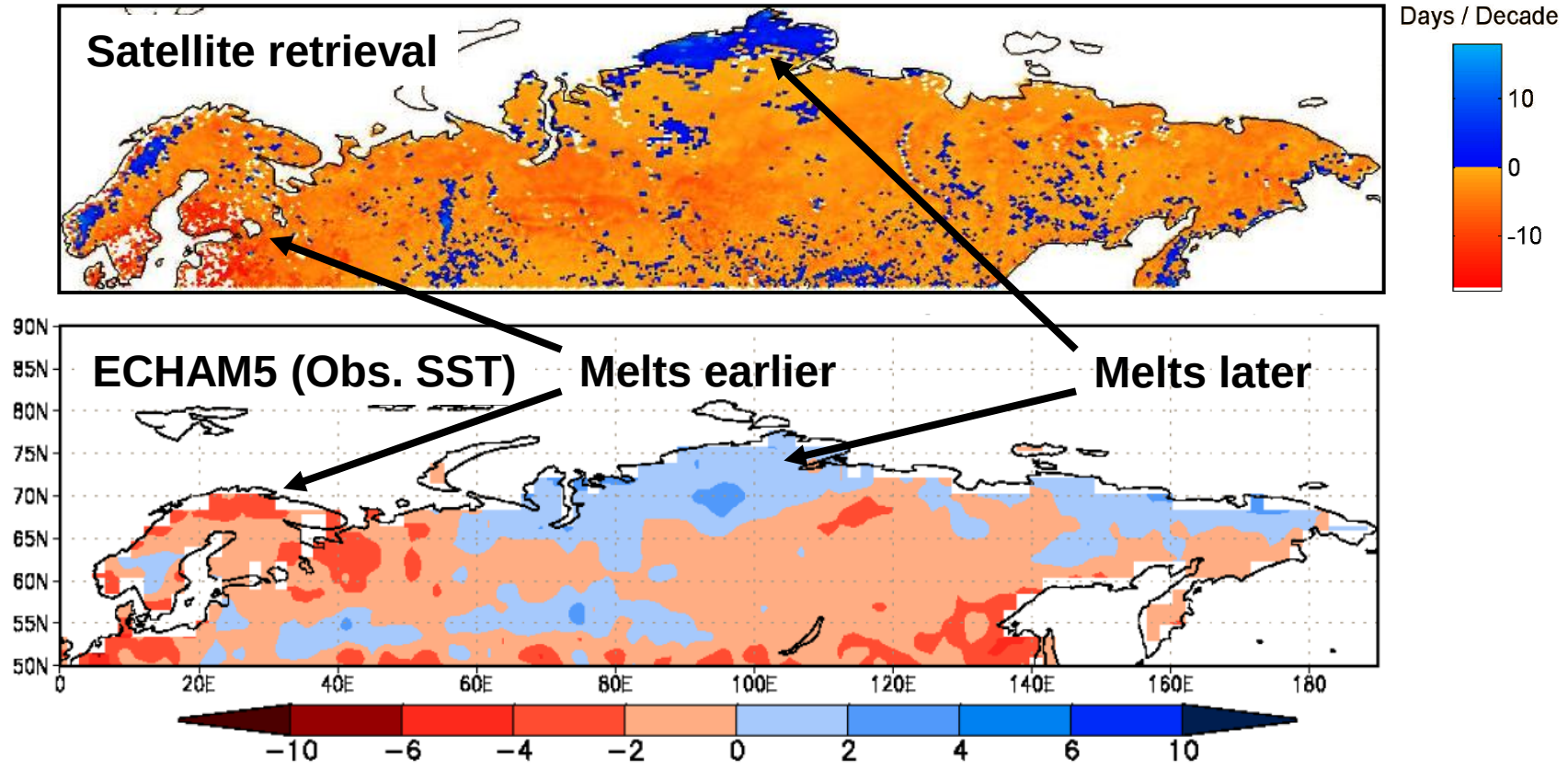


2008


Change of Date of Snow Clearance per Decade 1978 - 2008
90°W
60°W
120°W
30°W
150°W
0°
30°E
60°E
120°E
150°E
90°E
80°N
70°N
60°N
20
15
10
5
0
-5
-10
-15
-20
Days later / decade
Days earlier/ decade
mountains

Example on Trend Analysis

Change in snow clearance date in days/decade



Possibilities to improve passive retrievals (I)

- Improved consideration of mixed pixels
  - Especially lake ice covered by snow has a major effect on microwave radiometer observations
  - SAR data used as forcing to a simple lake ice model may significantly improve the modeling of brightness temperature, and thus SWE retrieval for land areas

Effect of lake ice on passive satellite scenery

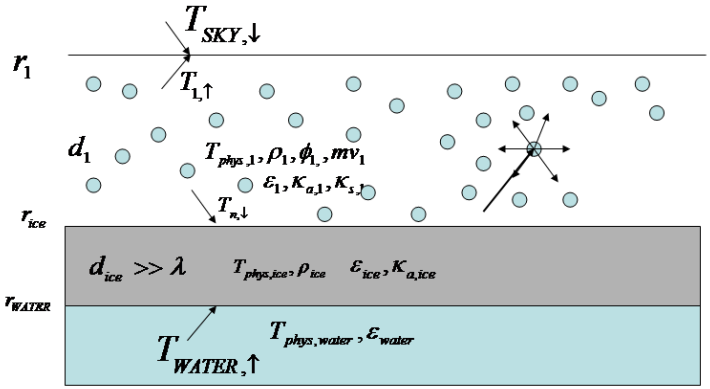
Water bodies affect observed Tb:

- Differing background emission
- Differing snow cover properties

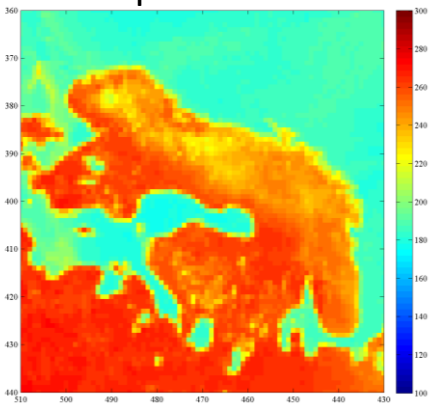
Land and lake ice snow cover simulated based on in situ obs

Lakes simulated separately as multiple layer structure (water-ice-snow)

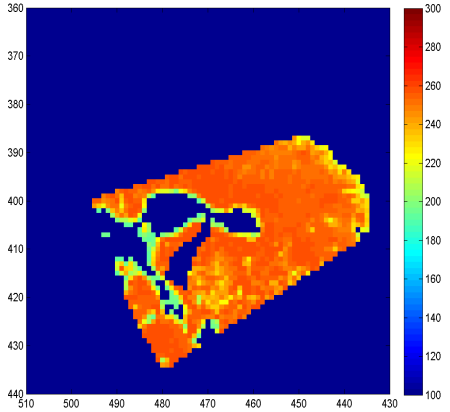
Fractional lake cover accounted for in each pixel



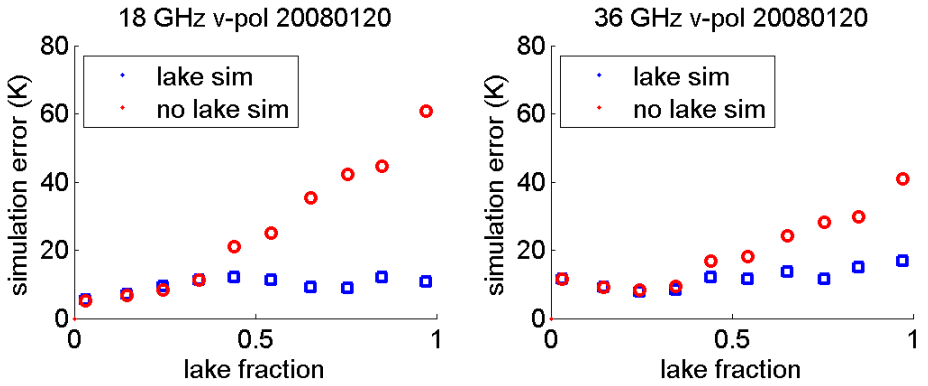
Observed AMSR-E 18 GHz V pol



Simulated 18 GHz V pol, multilayer HUT model



Simulation error correlation with lake fraction



Possibilities to improve passive retrievals (II)

- Resolution improvement (downscaling) by combining active and passive data
  - Current GlobSnow product does only yields coarse resolution estimates on SWE (scale of 25 km)
    - Fusion of higher resolution SAR data e.g. by iterative optimization algorithms

$$F = \sum_{i=1}^{N} \left\{ \sum_{j=1}^{M} \frac{1}{2\sigma_i^2} \left[\Phi_i(SWE_j, x_1, \ldots x_q) - Z_{i,j} \right]^2 \right\} + \sum_{k=1}^{P} \frac{1}{2\lambda_k^2} \left[\Psi_k(SWE, y_1, \ldots y_w) - T_k \right]^2$$

$$\text{and } SWE = \frac{1}{M} \sum_{j=1}^{M} SWE_j$$

  - Can be used to improve the spatial accuracy of the GlobSnow SWE product

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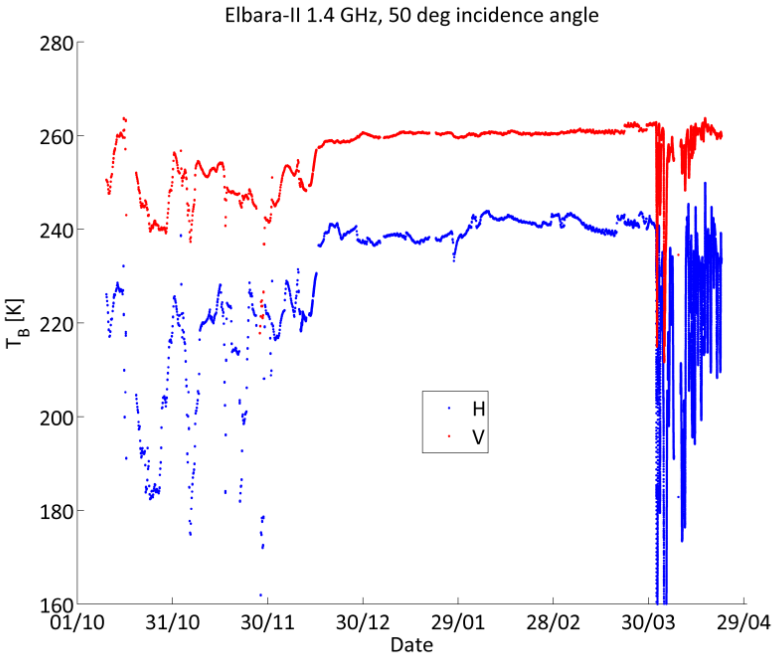
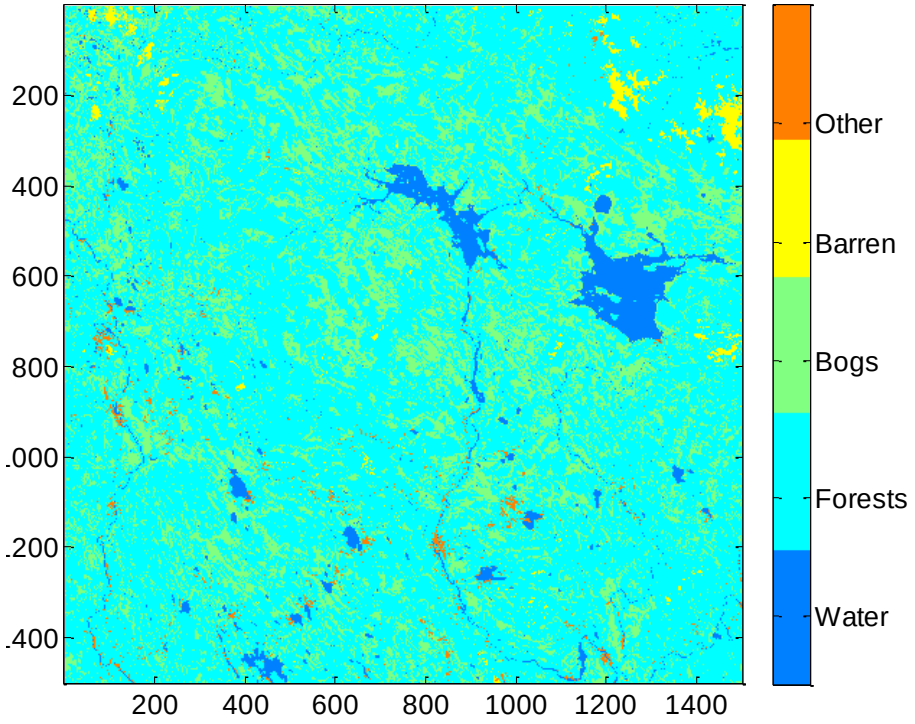
Testing of downscaling for the Sodankylä site, northern Finland

- Land cover and forest information processed to the resolution of 100 m
- Using both simulated and real data
- Accompanied with NoSREx campaign data





Possibilities to improve passive retrievals (III)

- Snow-line and fractional snow cover during the melting period
  - SAR data applicable to produce this information independent of cloud conditions
    - Calibration and validation of global passive algorithms
  - Idea can be demonstrated using optical ENVISAT AATSR data-based GlobSnow product as reference to microwave data retrieved snow-line

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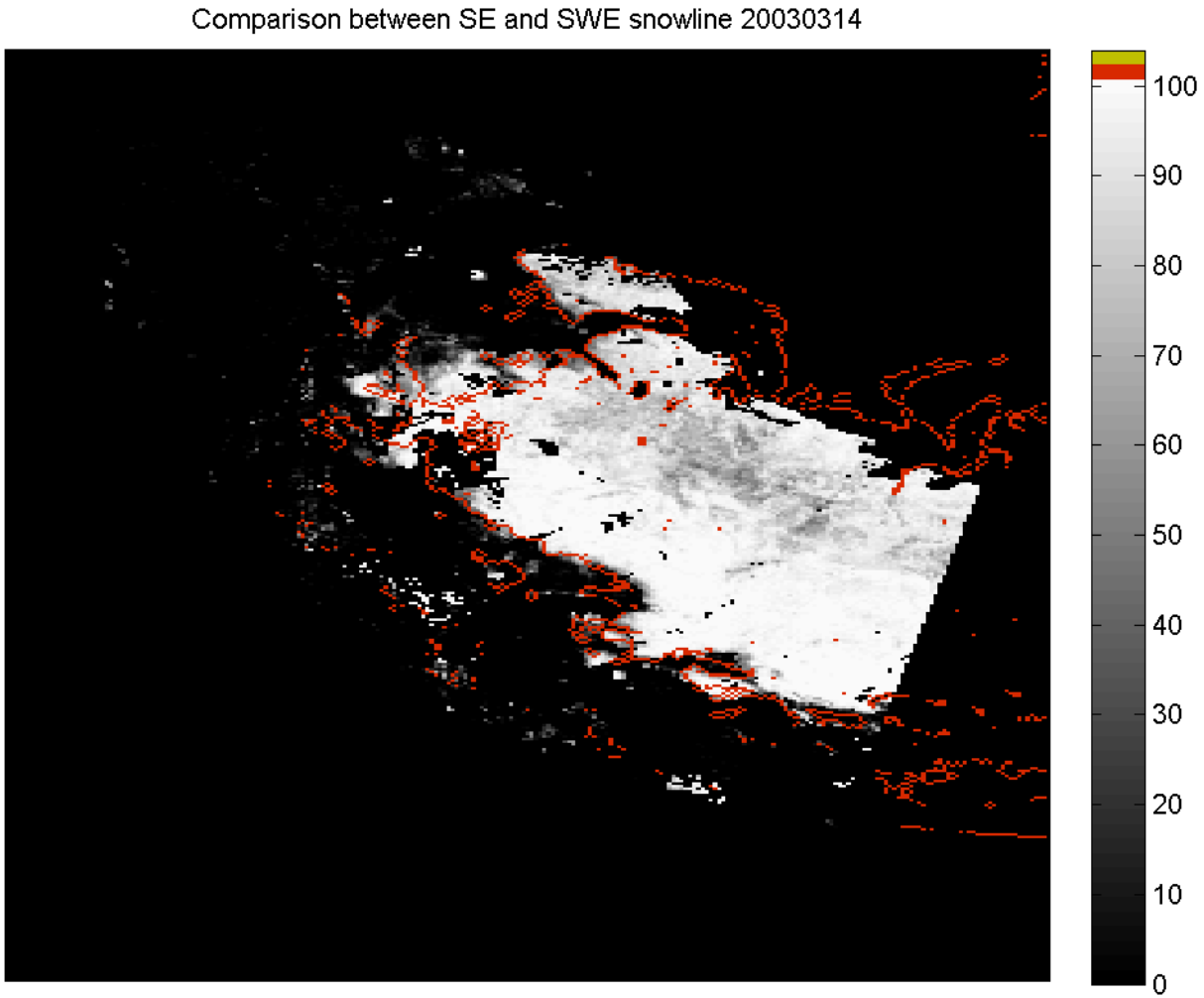
SWE product-derived snow-line compared with GlobSnow

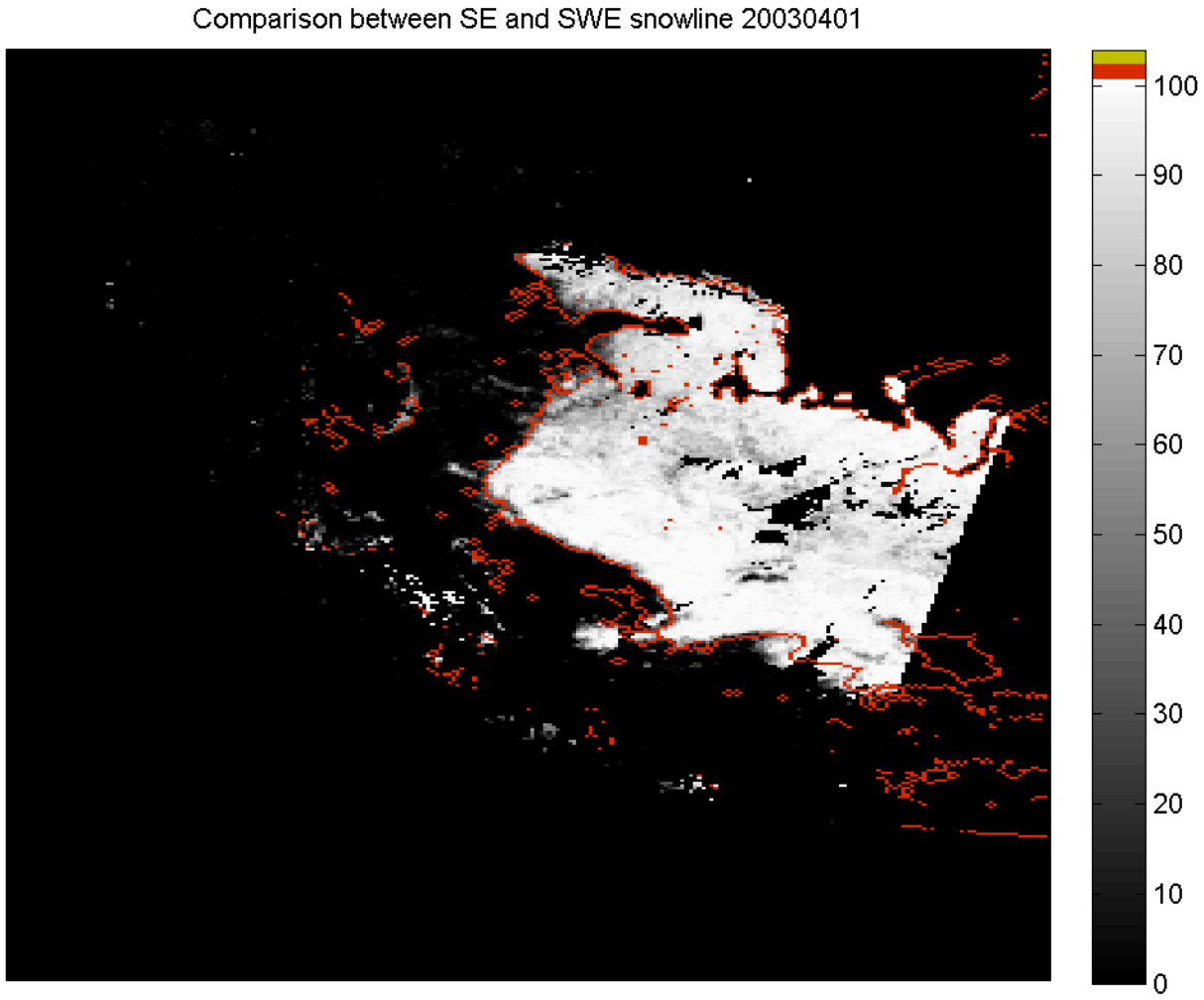
AATSR SE 10-days composite (14 March 2003)

CoReH2O can provide similar information as AATSR for snow-line and fractional snow cover area

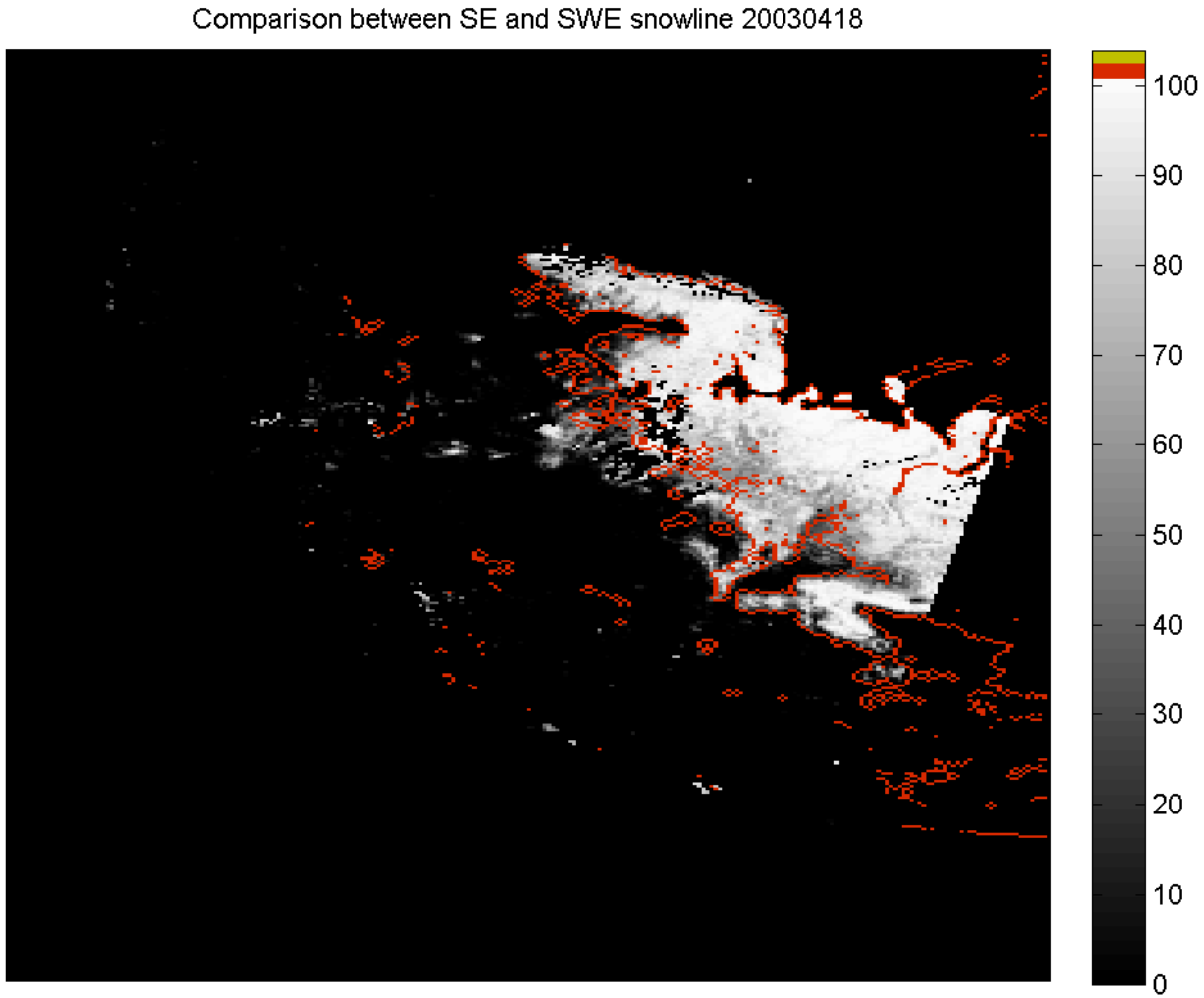
- Combined use
- Calibration of passive products



SWE-product derived snow-line compared with SE 10-days composite (1 April 2003)



SWE product-derived snow-line compared with SE 10-days composite (18 April 2003)



Thank You for Your Attention!