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

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Background

• Investigations are connected to two ongoing ESA-projects:
  - Synergy of CoReH$_2$O 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 downsclalng 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)
Synergy Project: An Overview

- Synergy of CoReH₂O SAR and microwave radiometry to retrieve snow and ice parameters
  - Can radiometer observations benefit from CoReH₂O 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.
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 seasonal snow cover
  - SWE for the snow area
- Regions with high topographical variability are masked off
  - Alpine regions
  - Glaciers will be also masked
- NRT production of SWE will be demonstrated in 2010-2011
GlobSnow SWE Product

- Approach: Assimilation of satellite data with \textit{in situ} observations-derived background 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.
Day of snow clearance derived from GlobSnow–product (Julian day from the beginning of the year)
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

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

and \( SWE = \frac{1}{M} \sum_{j=1}^{M} SWE_j \)

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