The GlobSnow Snow Water Equivalent Product

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ESA DUE GlobSnow

• ESA DUE GlobSnow project: Production of novel hemispherical snow extent (SE) and snow water equivalent (SWE) climate data records.

• Generation of long time-series employing FMI supercomputing facilities at Helsinki (daily, weekly and monthly maps of SE and SWE for northern hemisphere) + NRT processing

• Consortium members: Finnish Meteorological Institute (FMI) with ENVEO IT GmbH (Austria), GAMMA Remote Sensing (Switzerland), Norwegian Computing Center, Finnish Environment Institute (SYKE), and Environment Canada (EC). + Univ. Bern, MeteoSwiss, ZAMG & Norut

• GlobSnow-1 (3.5 years): 11/2008 – 11/2011 (36 months)
• GlobSnow-2 (2 years): 05/2012 – 09/2014 (24 months)

• Details and products available at www.globsnow.info
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

GlobSnow SWE time series (FCDR)

- Northern Hemisphere
  - 1979 to 1987 (SMMR)
  - 1988 to 2013 (SSM/I, SSMIS)
  - FPS v1.0 2003 to 2011 (AMSR-E)
- Daily, weekly, monthly products
- Includes error estimates (statistical std of the SWE estimate in mm)
- Data format HDF4 & NetCDF CF
- EASE-Grid projection (~25km resolution)
- Snow grain data available as well
- Glaciers, mountains & Ice Sheets masked out
- Versions: 1.0; 1.3 and 2.0 (current)
(1) Satellite observation

(2) Weather station obs. (SD)

(3) Kriged grain size background & gs variance map

(4) Kriged SD map & SD variance map

(5) Vegetation background map

HUT emission model applied

SD/SWE estimate
SWE Retrieval ‘Saturation’ (PMW signal)

“what if we would not apply the synop data?”

Chang et al.

EC

GlobSnow
Impact of Radiometer Derived Information

Difference between final assimilated SWE and background SWE from interpolated synoptic weather station data.
Validation of coarse resolution PWM data

• Point-wise data not feasible (625 km² grid cells) due to data representativeness

For GlobSnow, “extensive” evaluations have been carried out:

• Multiple snow seasons
  • Russia: 1979 - 2009
  • Finland: 2005 - 2011
  • Canada: 2005 - 2008

• Different geographical regions

• Several algorithms were assessed (3 years data) in GlobSnow-1
Canadian data: single grid cell SWE retrieval vs. Multiple sub-grid measurements
- point measurements show a large spread within a single 25x25 grid cell
-> reference data has to be distributed (e.g. snow transect data)

SWE PDF’s from intensive tundra field campaigns near Daring Lake, NT
Validation: Northern Eurasia
Snow Survey data (from the 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
• http://meteo.ru/english/climate/snow1.php

GlobSnow SWE FPS (Full Product Set) v.2.0 weekly aggregated SWE product assessed with INTAS SSCONE snow survey data from the former Soviet Union and Russia:
• 1978 through 2009, 1264 unique snow survey locations
• 146k samples (SWE<150mm) & 163k samples (all SWE values)

Bias +9.8 mm, RMS-error: 32.5 mm  
Bias +2.3 mm, RMS-error: 43.5 mm
Eurasia: SWE evaluation (density scatterplot)

- Russian INTAS SCCONE SWE transect data as reference
Comparisons for:

GlobSnow-1 v1.3 SWE (black)  vs  GlobSnow-2 “variable density“ (blue) algorithm

GlobSnow-1 SWE v 1.3  
Bias +1.5mm, RMS-error: 29.1mm

GS-2 SWE var. dens. dev. v1.8
Bias +10.3mm, RMS-error: 35.6mm
Comparisons for:

GlobSnow-1 v1.3 SWE (black)  
vs  
GlobSnow-2 “variable density“ (blue) algorithm

GlobSnow-1 SWE v 1.3  
Bias +6.3mm, RMS-error: 38.8mm

GS-2 SWE var. dens. dev. v1.8  
Bias +11.3mm, RMS-error: 41.6mm
Canadian Reference Datasets

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>Reference Dataset</th>
<th>Year</th>
<th>n</th>
<th>Mean SWE (mm)</th>
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<tr>
<td>Tundra</td>
<td>Intensive Sites; SnowSTAR 2007</td>
<td>2006-2008</td>
<td>28</td>
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<tr>
<td>Northern Boreal</td>
<td>EC Snow Surveys</td>
<td>2006-2007</td>
<td>105</td>
<td>135</td>
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<td></td>
<td>SWE &lt;150 mm</td>
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<td>Prairie</td>
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Evaluation with Canadian Reference Datasets

### RMSE

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<tr>
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<td>N. Boreal (All)</td>
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<tr>
<td>N. Boreal (SWE&lt;150 mm)</td>
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### Bias

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### Correlation

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### Change Relative to FPS1.3

<table>
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<tr>
<th></th>
<th>RMSE</th>
<th>Bias</th>
<th>Correlation</th>
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<tbody>
<tr>
<td>Tundra</td>
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<tr>
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<td>-8</td>
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<tr>
<td>S. Boreal</td>
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<tr>
<td>BERMS</td>
<td>1</td>
<td>0</td>
<td>-0.02</td>
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<tr>
<td>Prairie</td>
<td>0</td>
<td>5</td>
<td>0.46</td>
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</table>

Improvement of v2.0 relative to v1.3 at tundra and prairie sites.
Evaluation with Canadian Reference Datasets

150 mm is the critical threshold…
Validation data: Finland

Finnish Snow survey data

- Monthly/bi-monthly measurements for SYKE during winter season
- National network of +100 snow courses
- 2 - 4 km
- 40 - 80 snow depth measurements points
- 8 snow density measurements points
- Distinction into five land cover classes
- Historical data available from early 1900’s
- Digital archive from 1990’s; individual snow courses from 1970’s

Example: snow course in Tähtelä, Sodankylä
GS-1 SWE v1.0 evaluation – Finland 2005-2008

GlobSnow v1.0 algorithm validated using Finnish (4 km) snow course data

- Grid resolution 0.125 deg
- RMS-error 34.4 mm, very low bias: 1.7 mm, high correlation, >1500 samples

SWE accuracy - complete dataset (Finland) 2005-2008

bias = 1.7
rms (no bias correction) = 34.4
rms (bias correction) = 34.4
r = 0.785
samples = 1523
GS-2 evaluation, Finland: 2006-2011 (SWE v1.3 vs. 2.0)

Comparison for:

GlobSnow-1 v1.3 SWE (black)  
vs  
GlobSnow-2 v2.0 SWE (blue)

Bias increased slightly, the RMS-error and corr.coeff improved

GS-1 SWE v1.3  
Bias +7.4 mm, RMS-error: 37.8 mm

GS-2 SWE v2.0  
Bias +9.8 mm, RMS-error: 37.0 mm
Consistency of SWE retrieval 1980 - 2009

- RMS error and retrieval bias calculated independently for each year
- Russian INTAS SCCONE SWE transect data as reference

RMS-Error of SWE retrievals for the evaluated years: 1980 - 2009

Bias of SWE retrievals for the evaluated years: 1980 - 2009

SWE<150 mm
GlobSnow-1 evaluation: multiple SWE algorithms
Eurasia 09/1994 – 12/1997- 450 INTAS snow transect sites

<table>
<thead>
<tr>
<th>Name</th>
<th>RMSE</th>
<th>bias</th>
<th>Corr.coeff</th>
<th>Unbiased RMSE</th>
<th>Samples</th>
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<tbody>
<tr>
<td>GlobSnow algorithm</td>
<td>43.2 mm</td>
<td>-3.1 mm</td>
<td>0.611</td>
<td>43.1 mm</td>
<td>26063</td>
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<td>EC algorithm</td>
<td>67.6 mm</td>
<td>-28.2 mm</td>
<td>0.210</td>
<td>61.5 mm</td>
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<tr>
<td>Chang et al. 1987 (desc node)</td>
<td>70.7 mm</td>
<td>1.6 mm</td>
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<tr>
<td>SPD algorithm (desc node)</td>
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<td>-3.1 mm</td>
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<td>63.9 mm</td>
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<tr>
<td>Armstrong et al. 2001 (desc node)</td>
<td>73.7 mm</td>
<td>-42.9 mm</td>
<td>0.029</td>
<td>59.9 mm</td>
<td>24791</td>
</tr>
</tbody>
</table>
ESA GlobSnow-1/2 summary

- GlobSnow-1: SE & SWE from regional to hemispherical scale
- GlobSnow-2: Further work for improving retrieval methodologies
- SWE CDR v2.0 processed & released 12/2013, data access: http://www.globsnow.info/swe/
- Extensive evaluation activities have been carried out using distributed (dense network measurement) data
- The near-real-time GlobSnow processing system is still online
- Data & additional info: www.globsnow.info