Enhanced 30+ year global snow and ice dataset and climatology

Peter Romanov\textsuperscript{1,2}

\textsuperscript{1} NOAA-CREST, City University of New York, New York, NY
\textsuperscript{2} Center for Satellite Applications and Research (STAR), NOAA/NESDIS, College Park, MD
Outline

Motivation
Approach
Source datasets
Accuracy assessment
Application
Summary

- Focus on the snow cover component
NOAA Interactive Snow Mapping

- Based on visual analysis of satellite imagery
- Deliver snow and ice extent over NH
- Operationally generated since early 1970s
- Used in most NOAA operational NWP models

Operational map spatial resolution and update time period

Year: 1972

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>200 km</td>
<td>24 km</td>
<td>4 km</td>
<td>1 km</td>
</tr>
</tbody>
</table>

IMS: Interactive Multisensor Snow and Ice Mapping System

- IMS 24 km
-IMS 4 km
-IMS 1 km
NOAA Snow
Climate Data Records (CDR)

- Operational to Snow CDR conversion at Rutgers University

Operational Snow Maps

<table>
<thead>
<tr>
<th>Year</th>
<th>Resolution</th>
<th>Time Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>200 km</td>
<td>weekly</td>
</tr>
<tr>
<td>1998</td>
<td>24 km</td>
<td>daily</td>
</tr>
<tr>
<td>2004</td>
<td>4 km</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>1 km</td>
<td></td>
</tr>
</tbody>
</table>

No change in the spatial resolution and time step.

Aggregated to 200 km grid. Day-3 map of each week is used.

Snow CDR

<table>
<thead>
<tr>
<th>Year</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>200 km</td>
</tr>
<tr>
<td>1998</td>
<td>200 km</td>
</tr>
<tr>
<td>2004</td>
<td>200 km</td>
</tr>
<tr>
<td>2014</td>
<td>200 km</td>
</tr>
</tbody>
</table>

weekly

NOAA Snow CDR: 200 km spatial resolution at weekly time step
NOAA Snow CDR: Weaknesses and Concerns

- Coarse spatial (200 km) and temporal (weekly) resolution
- Inconsistency/inhomogeneity due to changes in the source maps
- Limited area coverage
  - Northern Hemisphere only
Global Multisensor Automated Snow and Ice Mapping System (GMASI)

- Fully automated
- Combines optical (AVHRR) and PMW (SSMI/SSMIS) satellite data
- Output: Global daily maps of snow and ice cover at 4 km resolution
- Operational at NESDIS since 2006

Objective of this work:
- Apply GMASI to consistently process historical satellite observations since 1987
- Develop 30+ year enhanced daily snow and ice cover dataset and climatology
- Compare with the exiting coarse resolution snow cover climatology
Source Satellite Data

- All data are processed from Level 1B
- Corrected calibration is applied to all sensor data
NOAA Snow CDR vs GMASI

NOAA Snow CDR (weekly, 200 km, NH)  
GMASI dataset (daily, 4km, global)
**CDR, GMASI, IMS vs in situ data**

**GMASI Snow Mapping Accuracy:** better than CDR, close to 4 km IMS

Winter season of 2014-2015

- Daily Estimates

- Winter-Season Mean

**Graphs:**
- Comparing GMASI, CDR, IMS 4km, IMS 24km agreement rates over time.
Mean Snow Cover Duration 1988-2017

- Local-scale features are resolved in the new dataset
Yearly Mean Snow Extent 1988-2018

- Close agreement on year-to-year changes between datasets
- Coarser resolution products map more snow
- GMASI fits best IMS 4 km snow extent
### Snow extent trends (% per year)
#### 1988-2018

<table>
<thead>
<tr>
<th></th>
<th>N. Hemisphere</th>
<th></th>
<th>Eurasia</th>
<th></th>
<th>North America</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GMASI</td>
<td>CDR</td>
<td>GMASI</td>
<td>CDR</td>
<td>GMASI</td>
<td>CDR</td>
</tr>
<tr>
<td>Jan</td>
<td>0.09</td>
<td>0.19</td>
<td>0.07</td>
<td>0.24</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td>Feb</td>
<td>0.10</td>
<td>0.19</td>
<td>0.06</td>
<td>0.20</td>
<td>0.17</td>
<td>0.16</td>
</tr>
<tr>
<td>Mar</td>
<td>-0.00</td>
<td>0.07</td>
<td>-0.12</td>
<td>-0.05</td>
<td>0.18</td>
<td>0.09</td>
</tr>
<tr>
<td>Apr</td>
<td>0.01</td>
<td>-0.01</td>
<td>-0.12</td>
<td>-0.07</td>
<td>0.18</td>
<td>0.07</td>
</tr>
<tr>
<td>May</td>
<td>-0.17</td>
<td>-0.37</td>
<td>-0.30</td>
<td>-0.48</td>
<td>-0.05</td>
<td>-0.26</td>
</tr>
<tr>
<td>Jun</td>
<td>-0.38</td>
<td>-1.46</td>
<td>-0.65</td>
<td>-2.40</td>
<td>-0.23</td>
<td>-0.94</td>
</tr>
<tr>
<td>Jul</td>
<td>-0.32</td>
<td>-1.17</td>
<td>-0.66</td>
<td>-5.54</td>
<td>-0.25</td>
<td>-0.29</td>
</tr>
<tr>
<td>Aug</td>
<td>-0.28</td>
<td>-0.24</td>
<td>-1.05</td>
<td>-4.11</td>
<td>-0.19</td>
<td>0.23</td>
</tr>
<tr>
<td>Sep</td>
<td>-0.43</td>
<td>0.38</td>
<td>-0.67</td>
<td>0.32</td>
<td>-0.33</td>
<td>0.41</td>
</tr>
<tr>
<td>Oct</td>
<td>0.13</td>
<td>1.11</td>
<td>0.30</td>
<td>1.62</td>
<td>-0.08</td>
<td>0.48</td>
</tr>
<tr>
<td>Nov</td>
<td>-0.00</td>
<td>0.27</td>
<td>0.00</td>
<td>0.38</td>
<td>-0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>Dec</td>
<td>0.11</td>
<td>0.10</td>
<td>0.08</td>
<td>0.07</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>Yearly</td>
<td>0.04</td>
<td>0.11</td>
<td>0.02</td>
<td>0.14</td>
<td>0.06</td>
<td>0.07</td>
</tr>
</tbody>
</table>

- **GMASI:**
  - Smaller decreasing trends in the warm season of the year
  - Longer period of the year associated with general snow loss
  - Similar to CDR small increase in the yearly mean snow extent
Snow Cover Duration: Beltsville, MD

Mean increase of snow cover duration: 2-3 days per decade
Summary

GMASI snow dataset
- Improves characterization of historical changes of NH snow cover over CDR
- Allows for a wider range of applications (local climate, alpine snow)
- Can be used for establishing climate normals (over 30-years duration)

GMASI dataset provides more consistent snow data vs CDR
- Better consistency implies more accurate trend estimates

GMASI snow extent trends
- Agree to CDR on the sign of seasonal changes
- Indicate much slower loss of snow in summer

The GMASI dataset may be extended back to 1982 (but can not match 47 years of CDR). Ice cover component needs detailed evaluation.
Links

Dataset is available for download from

NOAA-CREST Data Repository
https://datadb.noaacrest.org/public/snow-ice-cover

NOAA-STAR ftp

The project has been partially funded by NOAA grant NA14NES4320003

THANK YOU!
Backup Slides
Snow cover duration trends 1988-2018

Trends statistically significant
Snow cover duration in “hot spots”

1. Alaska South
   \[ y = -0.74x + 1686, \quad R^2 = 0.190 \]

2. US North East
   \[ y = 0.84x - 1618, \quad R^2 = 0.178 \]

3. Northern Europe
   \[ y = 0.49x - 953, \quad R^2 = 0.056 \]

4. Tibet
   \[ y = -0.68x + 1418, \quad R^2 = 0.254 \]

5. Siberia Arctic
   \[ y = -0.69x + 1660, \quad R^2 = 0.277 \]

6. Eastern China
   \[ y = 1.31x - 2531, \quad R^2 = 0.354 \]