VIIRS SNOW COVER PRODUCTS: CURRENT STATUS AND PLANS

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Outline

• VIIRS Binary Snow Cover and Fractional Snow Cover
  – Definition, requirements
  – IDPS product performance
  – Improvements in the Enterprise system (NDE)
  – JPSS-1 readiness, post-launch plans
  – NOAA vs NASA approach
  – Further algorithm enhancements
<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Roles and Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeff Key</td>
<td>NOAA/NESDIS</td>
<td>Cryosphere Team Lead</td>
</tr>
<tr>
<td>Peter Romanov</td>
<td>CUNY/CREST</td>
<td>Snow Products Lead</td>
</tr>
<tr>
<td>Sean Helfrich</td>
<td>NOAA/NIC</td>
<td>User/Applications</td>
</tr>
<tr>
<td>Michael Ek</td>
<td>NOAA/NWS</td>
<td>User/Applications</td>
</tr>
</tbody>
</table>
VIIRS Snow Cover Products

- Binary snow map:
  - Snow/no snow discrimination
  - 375m resolution
  - 90% probability of correct typing
    - Over climatologically snow-affected areas
    - Excludes forested areas

- Snow fraction:
  - “Viewable” snow fraction
  - 750m resolution (IDPS), 375m for JPSS-1
  - 10% accuracy

- Both products are clear-sky daytime-only land products
- Both products depend on the accuracy of VIIRS cloud mask.
Binary Snow Cover
IDPS Binary Snow Cover Algorithm

- Analogous to MODIS SnowMap algorithm (Hall et.al 2002)
- Decision-tree threshold-based classification approach
- Uses NDSI, NDVI, reflectance, temperature (VIIRS bands I1, I2, I3, I5)

\[
NDSI = \frac{R_{0.6\mu m} - R_{1.6\mu m}}{R_{0.6\mu m} + R_{1.6\mu m}}
\]

- Output: Binary snow/no-snow map at 375 m resolution

MODIS SnowMap
snow acceptance region
- Daily global gridded snow maps at 1 km resolution produced since 2013
- Granules with no land pixels are not processed (shown in dark gray)
- On the Web:
  http://www.star.nesdis.noaa.gov/jpss/EDRs/products_snow.php
IDPS Binary Snow: Accuracy

Daily rate of agreement of VIIRS IDPS binary snow maps

- To Interactive Snow Product (IMS)
  - Yearly mean: 94%, range: 88-98% (NH, over “snow possible” areas)
- To in situ reports
  - Mean: 92%, range: 85-96% (CONUS, November-April)

<table>
<thead>
<tr>
<th>Product</th>
<th>L1RDS APU Thresholds</th>
<th>Performance</th>
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<tbody>
<tr>
<td>Binary Snow</td>
<td>90% Correct Typing</td>
<td>Mean Daily: 92-94% Range: 85-98%</td>
</tr>
</tbody>
</table>

Product generally satisfies current requirements
VIIRS binary snow map: Daily agreement to IMS

- Cloud fraction over land in the VIIRS IDPS snow product is about 60%
- This is more than in similar MODIS and AVHRR products
VIIRS binary snow map: Agreement to IMS by surface type

Agreement decreases
- In forests
- During transition seasons (Fall/Spring)
Enterprise Snow Algorithm

Modifications focus at
- More efficient snow detection in forests
- Elimination of spurious snow retrievals (e.g. due to missed clouds)

Two-stage algorithm:
1. Spectral tests
   - Improved snow identification in the forest
2. Consistency tests (applied to “snow” pixels)
   - Eliminate spurious snow

Consistency tests:
- Snow climatology
- Surface temperature climatology
- Spatial consistency
- Temperature spatial uniformity

Algorithm implemented as part of NDE system
NDE vs IDPS Binary Snow Product

Feb 20, 2016

IMS snow
IDPS snow
NDE snow
Snow mapped by NDE but not IDPS
Snow mapped by both NDE and IDPS
Clouds

Feb 20, 2016
NDE vs IDPS Binary Snow Product

NDE: Better delineation of the snow cover boundary due to less conservative cloud masking
Mean daily agreement to IMS and mean cloud cover extent over Northern Hemisphere

<table>
<thead>
<tr>
<th>Date</th>
<th>Agreement to IMS, %</th>
<th>Cloud Fraction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IDPS</td>
<td>NDE</td>
</tr>
<tr>
<td>Jan 01, 2015</td>
<td>96.9</td>
<td>96.5</td>
</tr>
<tr>
<td>Apr 10, 2014</td>
<td>97.5</td>
<td>96.9</td>
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<tr>
<td>Jul 10, 2014</td>
<td>98.4</td>
<td>99.0</td>
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<tr>
<td>Oct 10, 2014</td>
<td>97.4</td>
<td>96.6</td>
</tr>
</tbody>
</table>

IDPS vs NDE:
- Similar accuracy as compared to IMS
- More clear sky retrievals (less clouds) in the NDE product
NOAA vs NASA Approach

NASA:
- IDPS algorithm with minor modifications
- Will remove IR temperature screen allowing pixels at all temperatures be classified as snow (same as MODIS Collection 6)

NOAA:
- New 2-stage algorithm
- Spectral thresholds + consistency testing
Snow Fraction
IDPS: Based on aggregated 2x2 binary snow retrievals
- No added value as compared to Binary Snow
- Can be easily generated by users
- Accuracy is defined by the binary snow product accuracy

Granule date: 20130915 time: 0355267

Snow fraction map (granule fragment)
750 m spatial resolution

Binary snow map (granule fragment)
375 m spatial resolution, white: snow, gray: clouds, green: land
Enterprise (NDE) Snow Fraction

**NDE**: Two algorithms implemented

1. **NDSI-based**

   \[
   \text{SnowFraction} = -0.01 + 1.45 \times \text{NDSI}
   \]

   - \(\text{NDSI} = \frac{R_{0.6} - R_{1.6}}{R_{0.6} + R_{1.6}}\)
   - MODIS heritage algorithm, used up to Collection 5 (not in Collection 6)

2. **Visible reflectance-based**

   \[
   \text{SnowFraction} = \frac{R - R_{\text{land}}}{R_{\text{snow}} - R_{\text{land}}}
   \]

   - Uses VIIRS band I1 (0.6 μm) reflectance (\(R\))
   - Algorithm used with GOES Imager and AVHRR; Approach similar to GOES-R
Snow Fraction: Two Algorithms

Reflectance-based Snow Fraction vs NDSI-based snow fraction

There is some similarity in the snow fraction patterns in the two products on the regional scale. NDSI-based snow fraction is much larger in the forest.

Clouds are shown in gray.
Snow Fraction Evaluation Approach

Snow fraction: No in situ data. Quantitative validation is not feasible

Higher spatial resolution retrievals are not independent. Limited applicability

Theoretically estimated accuracy is within 10-20%

Verification of retrievals is possible through consistency testing

Self-consistency
  Lack of abnormal spatial patterns
  Day-to-day repeatability of spatial patterns
  Consistency with the forest cover distribution
  Consistency with in situ snow depth data over open flat areas.
Consistency with Forest Fraction

Snow fraction vs forest fraction correlation

- Stronger correlation (-0.5 \(\div\) -0.6), indicates better consistency of Reflectance-based snow fraction with forest cover properties
Consistency with Snow Depth

- VIIRS Snow Fraction vs matched In situ Snow Depth
- Correlation calculated over Great Plains
- Correlation is positive meaning that estimated snow fraction is consistent with the snow depth data

**Snow Fraction vs Snow Depth Statistics**

<table>
<thead>
<tr>
<th>Date</th>
<th>Snow Depth Range, cm</th>
<th>Number of match-ups</th>
<th>Reflectance-based</th>
<th>NDSI-based</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td>Mean SnFrac</td>
<td>Correlation</td>
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<tr>
<td>01/14/15</td>
<td>2 - 27</td>
<td>66</td>
<td>0.57</td>
<td>0.31</td>
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<tr>
<td>01/16/15</td>
<td>2 - 25</td>
<td>90</td>
<td>0.41</td>
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<tr>
<td>01/17/15</td>
<td>2 - 25</td>
<td>47</td>
<td>0.43</td>
<td>0.52</td>
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<tr>
<td>01/18/15</td>
<td>2 - 15</td>
<td>42</td>
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<tr>
<td>01/19/15</td>
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<td>0.27</td>
<td>0.34</td>
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<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>0.39</td>
<td><strong>0.34</strong></td>
</tr>
</tbody>
</table>
Comparison with Landsat Data

Approach

(1) Generate binary snow mask for a Landsat scene at 30 m resolution

(2) Aggregate Landsat binary snow identifications to estimate snow fraction at VIIRS spatial resolution

(3) Compare with VIIRS sub-pixel snow fraction estimate
Comparison with Landsat Data

VIIRS Snow Fraction

Landsat Binary Snow

Landsat Snow Fraction, 0.01 deg

F. Snow Fraction (%)

0 20 40 60 80 100

VIIRS Snow Fraction, 0.01 deg

Jan 14, 2014
Comparison with Landsat Data

VIIRS reflectance-based snow fraction vs Landsat

<table>
<thead>
<tr>
<th>Date</th>
<th>Place</th>
<th>Path</th>
<th>Row</th>
<th>Aggregation: 1 km</th>
<th>Aggregation: 5 km</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Corr</td>
<td>Bias</td>
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<tr>
<td>01/01/15</td>
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<tr>
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<td>Germany</td>
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<tr>
<td>01/13/15</td>
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<tr>
<td>01/14/15</td>
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<tr>
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<td>01/15/15</td>
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<td>04/10/14</td>
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<td>150</td>
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<td>0.95</td>
<td>0.001</td>
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<tr>
<td>04/10/14</td>
<td>Himalaya</td>
<td>150</td>
<td>35</td>
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<tr>
<td>07/14/14</td>
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<td>6</td>
<td>13</td>
<td>0.93</td>
<td>-0.040</td>
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<tr>
<td>07/14/14</td>
<td>Greenland</td>
<td>6</td>
<td>14</td>
<td>0.86</td>
<td>-0.070</td>
</tr>
<tr>
<td>07/14/14</td>
<td>Greenland</td>
<td>6</td>
<td>15</td>
<td>0.93</td>
<td>-0.045</td>
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<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>0.84</td>
<td>-0.036</td>
</tr>
</tbody>
</table>

Each Landsat-VIIRS matched scene includes from about 400 to several thousand matched snow fraction estimates.

The RMSE between VIIRS and Landsat snow fraction estimates is 17.4% for 1 km grid cells and 12.7% for 5 km aggregation.
NOAA vs NASA Approach

NASA:
- Dropped snow fraction retrieval
- Will provide NDSI values only (same as MODIS Collection 6)

NOAA:
- Two snow fraction products
  - May follow NASA and drop NDSI snow fraction, provide NDSI value only
JPSS-1 Readiness

- Enterprise algorithms will be used
  - Minor modifications are expected (coefficients, thresholds)

- Algorithms have been implemented within NDE

- Accuracy, Binary Snow: Requirements will be met

- Accuracy, Fractional Snow: Direct validation is not feasible
  Indirect estimates: 10-20% (below requirements)

  Requirements (10%) may be too strict

  GOES-R: 15% accuracy, 30% precision
Further Enhancements: Binary Snow

- Develop and implement an improved snow cover climatology
- Account for angular anisotropy of NDSI, NDVI, Reflectance

Important: NDSI of snow-free land surface exhibits a substantial angular anisotropy. This should be accounted for to improve snow detection.
Further Enhancements: Fraction

- Incorporate shadows as class, multi-endmember retrievals

- True (not “viewable”) snow fraction
  - Need to account for snow masking by forests
JPSS-1: Post-Launch Plans

- Testing (FY17) and implementation (FY18) of improved algorithms

- Routine next-day accuracy assessments (FY17)

- Involve additional validation datasets (FY17)
  - CoCoRAHS (ground-based network) added to SYNOP and COOP data
  - Sentinel-2 added to Landsat

- Upgrade VIIRS snow validation web page (FY17-18)
IDPS algorithm performance:
- Binary Snow: adequate, within requirements, robust performance
- Fractional snow: Product has little value, not needed

Enterprise Algorithms are ready for use with JPSS-1
- Binary snow:
  - Better performance over forest, better area coverage
  - Meets requirements
- Fractional snow:
  - “Viewable” snow fraction
  - Two products to satisfy most potential users
  - No direct validation
  - Further work needed to meet accuracy requirements

Further improvements of both algorithms are planned