Request for VIIRS Snow Cover EDR Provisional Maturity

Provisional Effectivity Date: 16 October 2012 (MX 6.4)

Cryosphere Products Validation Team
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14 November 2013

Outline

- VIIRS Snow Cover EDR: Specifications and Algorithms
- Binary Snow Cover
  - Provisional Maturity Evaluation
  - Provisional Justification Summary
- Fractional Snow Cover
  - Provisional Maturity Evaluation
  - Provisional Justification Summary
- Planned Algorithm Improvements and Modifications

VIIRS Snow Cover Product Users

- U.S. Users
  - NSIDC - National Snow Ice Data Center
  - NIC - National/Naval Ice Center
  - OSPO - Office of Satellite and Product Operations
  - NOHRSC - National Operational Hydrological Remote Sensing Center
  - STAR- Center for Satellite Applications and Research
  - CLASS - Comprehensive Large Array-data Stewardship System

- User Community
  - Agriculture
  - Hydrology
  - Numerical Weather Prediction
  - Transportation
  - Emergency Management
  - DOD

Provisional EDR Maturity Definition

- Product quality may not be optimal
- Incremental product improvements are still occurring
- Version control is in affect
- General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing
- Users are urged to consult the EDR product status document prior to use of the data in publications
- Ready for operational evaluation

VIIRS Snow Cover EDR

- The VIIRS Snow Cover/Depth Environmental Data Record (EDR) product consist of two products
  - Snow/no snow binary map
  - Snow fraction in a horizontal cell
- The objective of the VIIRS retrieval is to achieve the performance specifications designed to meet the requirements stated in the NPOESS System Specification.
- The specifications apply under clear-sky, daytime conditions only. Surface properties cannot be observed through cloud cover by a Visible/Infrared (VIS/IR) sensor.
- The specification for the NPOESS Snow Cover/Depth EDR places requirements on the VIIRS binary map product and the VIIRS snow fraction product.

Specification of the VIIRS Binary Map

Parameter	Specification Value
a. Binary Horizontal Cell Size,	
1. Clear – daytime (Worst case)	0.8 km
2. Clear – daytime (At nadir)	0.4 km
3. Cloudy and/or nighttime	N/A
b. Horizontal Reporting Interval	Horizontal Cell Size
c. Snow Depth Range	> 0 cm (Any Thickness)
d. Horizontal Coverage	Land
e. Vertical Coverage	> 0 cm
f. Measurement Range	Snow / No snow
g. Probability of Correct Typing	90%
h. Mapping Uncertainty	1.5 km

Specification of the VIIRS Snow Fraction

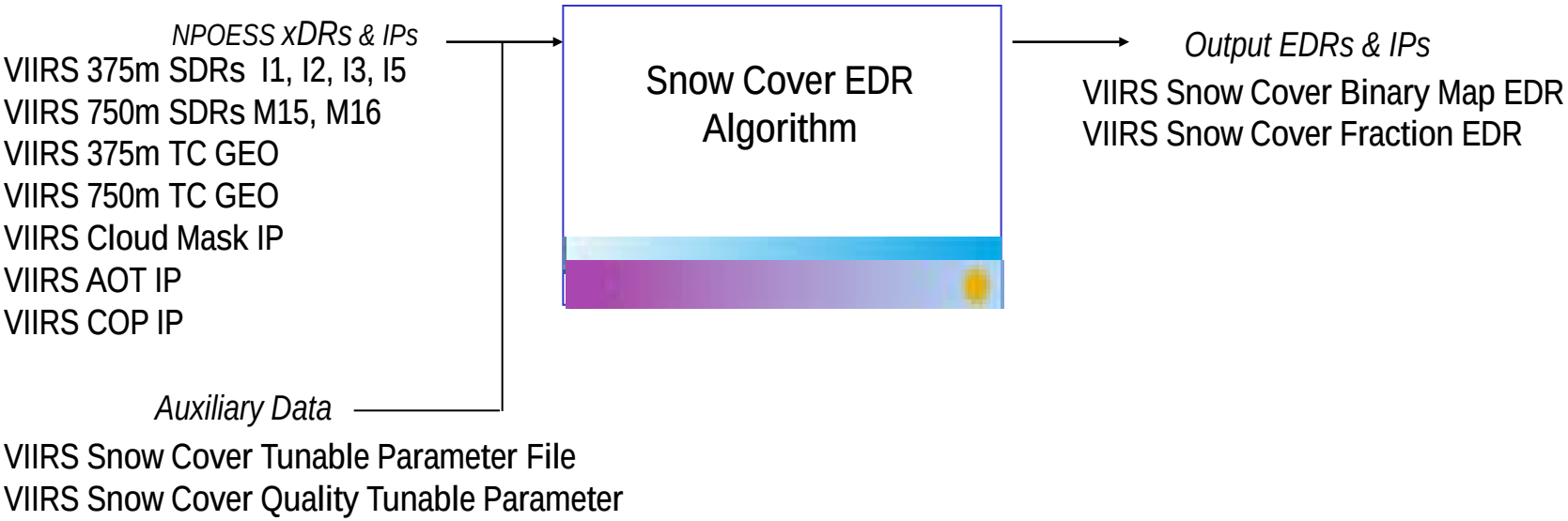
Parameter	Specification Value
a. Horizontal Cell Size,	
1. Clear – daytime (Worst case)	1.6 km
2. Clear – daytime (At nadir)	0.8 km
3. Cloudy and/or nighttime	N/A
b. Horizontal Reporting Interval	Horizontal Cell Size
c. Snow Depth Ranges	> 0 cm (Any Thickness)
d. Horizontal Coverage	Land
e. Vertical Coverage	> 0 cm
f. Measurement Range	0 – 100% of HCS
g. Measurement Uncertainty	10% of HCS (Snow/No Snow)
h. Mapping Uncertainty	1.5 km

Snow Cover EDR Algorithms

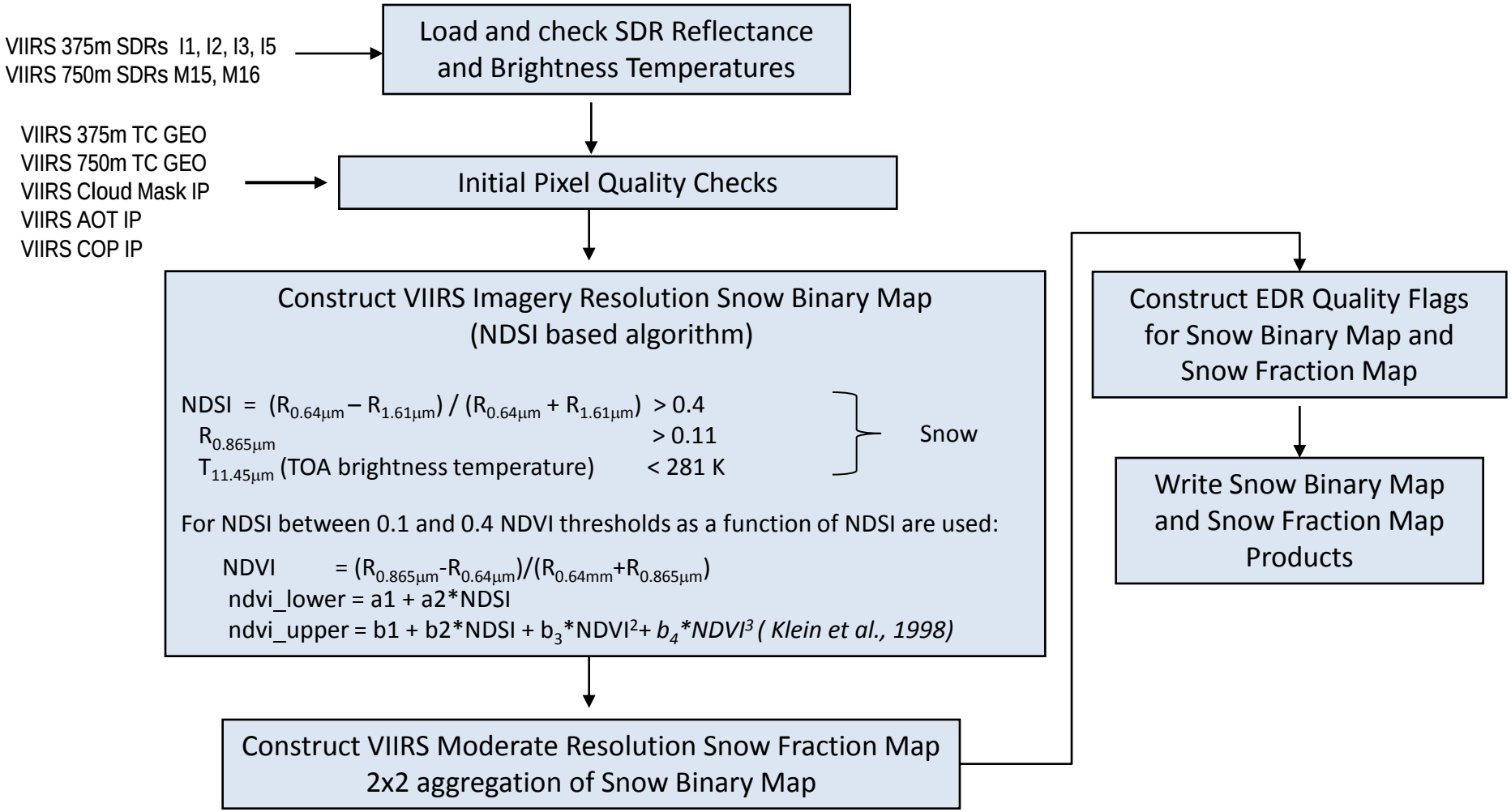
- The VIIRS Binary Snow Cover EDR algorithm is an adaptation of the heritage MODIS SnowMap algorithm (Hall et.al 2001) that classifies snow based upon the Normalized Difference Snow Index (NDSI) and additional reflectance, thermal and NDVI thresholds. Binary Snow Map is derived at 375 m spatial resolution at nadir.

- The VIIRS Snow Cover Fraction EDR is derived from the VIIRS Binary Snow Map as an aggregated snow fraction within 2x2 pixel blocks. The spatial resolution of the product is 750 m at nadir.

Summary of the Snow Cover EDR Algorithm Inputs



Snow Cover EDR Processing Flow



Status of Upstream Products

Snow Cover EDR performance depends on VIIRS SDR, VIIRS Cloud Mask IP and Aerosol Optical Thickness IP

- VIIRS SDR Cal and Geo products reached provisional maturity in March, 2013.
- VIIRS Cloud Mask IP reached provisional maturity in February, 2013
- VIIRS Aerosol Optical Thickness reached beta maturity in September 2012 and provisional in March 2013

Provisional Maturity Evaluation of the

Binary Snow Cover Map Product

Provisional Maturity Evaluation Approach, Binary Snow Cover (1/2)

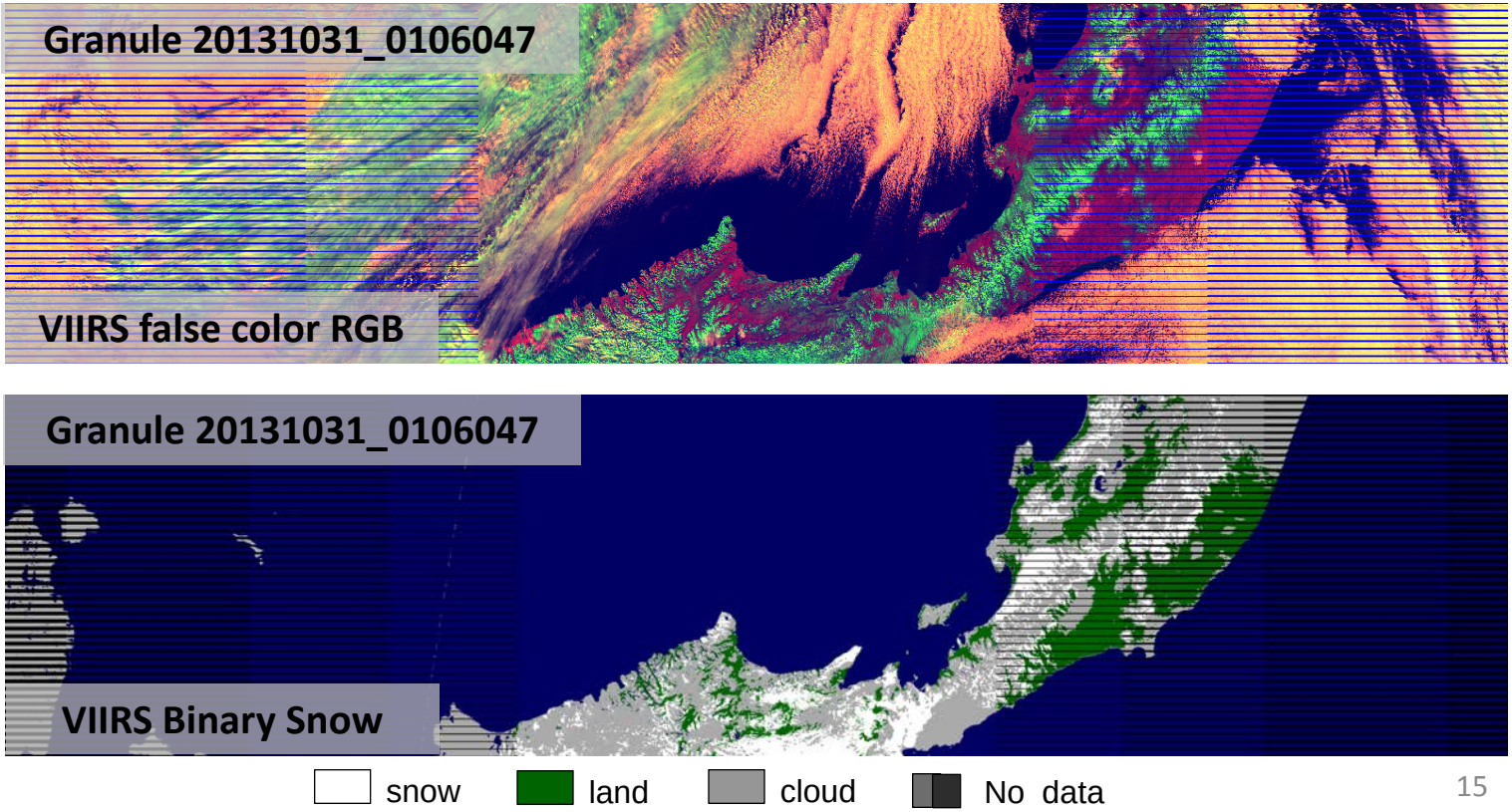
- Evaluation approach:
  - Qualitative visual analysis of the product, focus on
    - General consistency of snow cover maps
    - Obvious failures of the algorithm/product
      - Missed snow in the regions which are known to be snow covered
      - Mapped snow in the regions which are known to be snow-free
      - Misclassification of snow-covered scenes as “cloudy”
  - Quantitative comparison of VIIRS maps with in situ data and other remote sensing-based snow cover products
    - In situ snow cover observations
    - NOAA IMS interactive snow cover analysis
    - Automated snow cover products (MODIS, AVHRR)

Provisional Maturity Evaluation Approach, Binary Snow Cover (2/2)

- Details of Evaluation Approach
  - Different spatial scales
    - On a per-granule basis (qualitative analysis)
    - Over Conterminous US (CONUS) when comparing to station data
    - Over Northern Hemisphere when comparing with IMS
    - Globally when comparing with MODIS and AVHRR products
  - Time period covered
    - Routine evaluation: since the beginning product generation
    - Maturity assessment basis: November 2012 to September 2013 (10 months)
      - No major changes to the VIIRS cloud mask (VCM)
    - VIIRS global snow cover data were acquired, processed and examined on every third day. Over 100 global images were used for product evaluation.
  - VIIRS IDPS EDR products were acquired from
    - NESDIS/STAR Central Data Repository (SCDR)
    - NASA Land Product Evaluation and Analysis Tool (PEATE) Element

Provisional Maturity Evaluation – Qualitative Assessment (1/5)

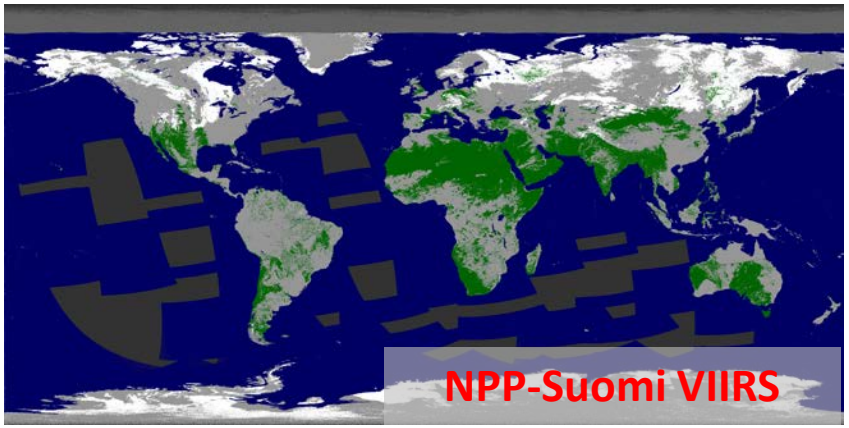
VIIRS Binary Snow Map: Granule Level



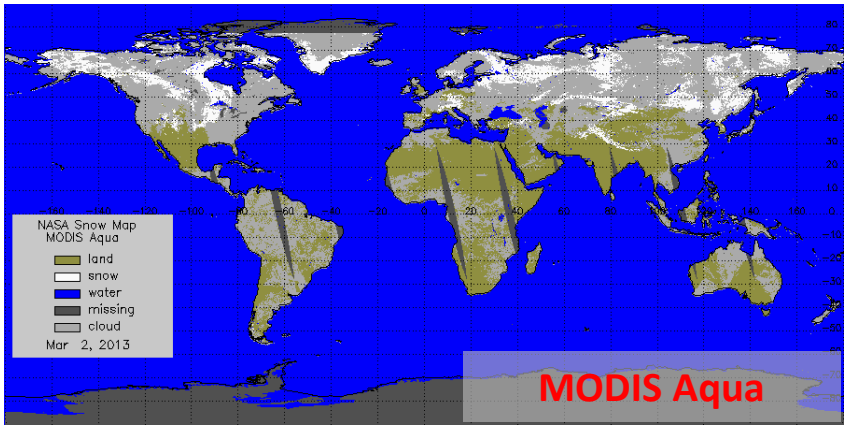
Overall, good qualitative agreement between the snow cover seen in VIIRS false color images and mapped in the VIIRS binary snow cover product.

Provisional Maturity Evaluation – Qualitative Assessment (2/5)

VIIRS vs MODIS Binary Snow Map



VIIRS binary snow maps compare well to MODIS Aqua snow maps. There are some differences in the cloud mask applied in the two products.

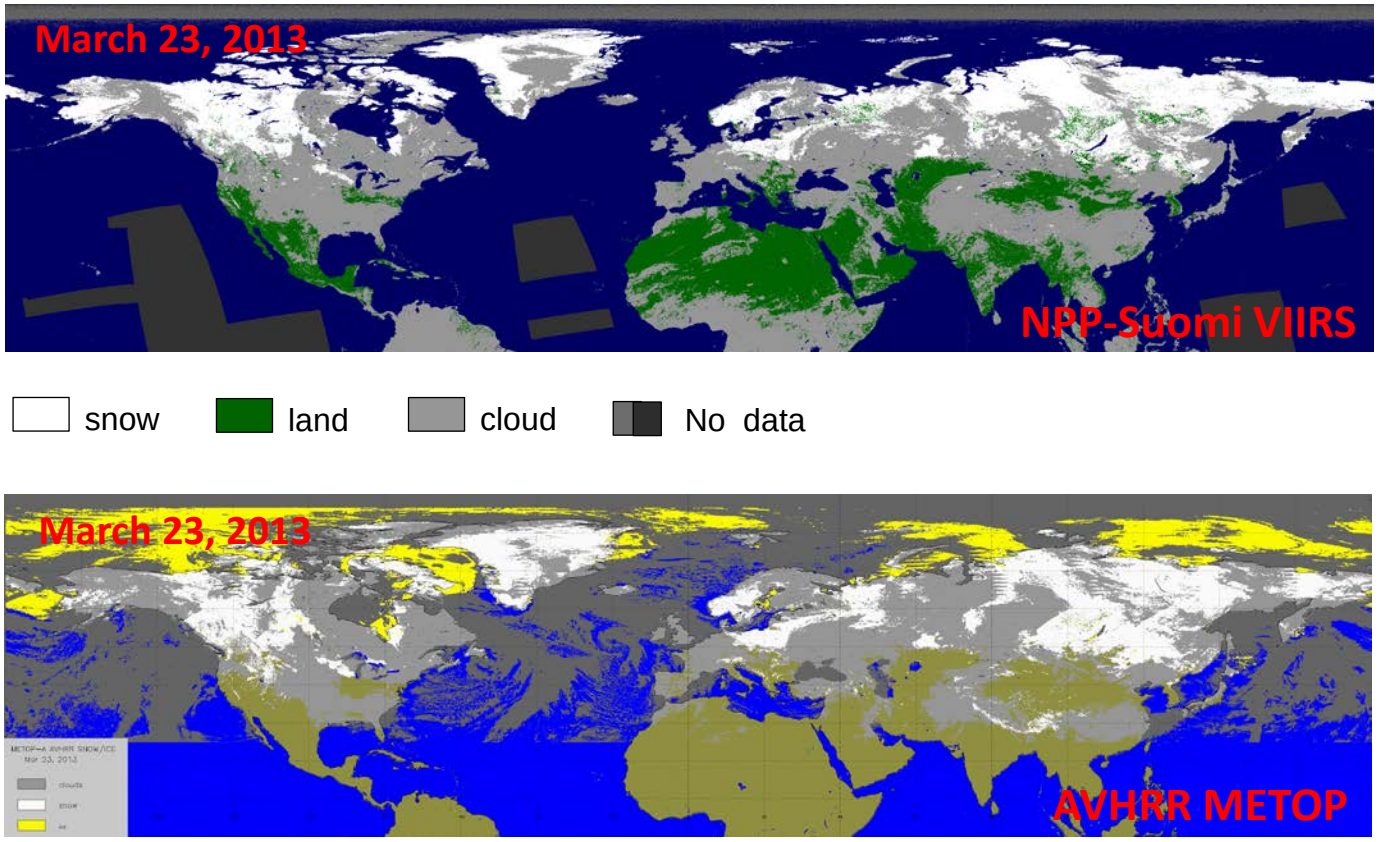


Due to a wider swath VIIRS daily global snow map has no gaps between adjacent swaths inherent to the MODIS global snow product.

March 2, 2013 (day 2013061)

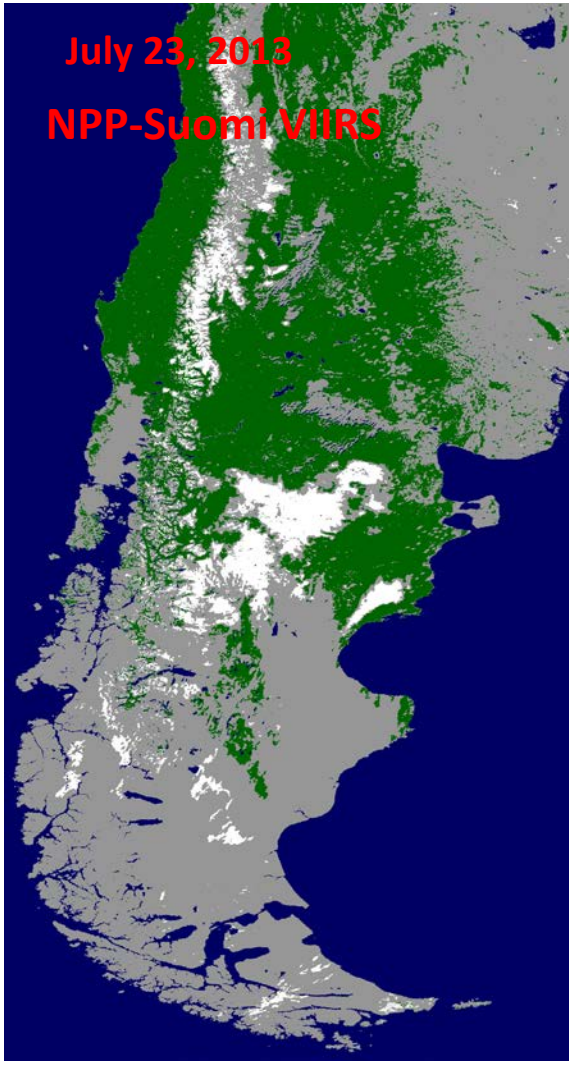
Provisional Maturity Evaluation – Qualitative Assessment (3/5)

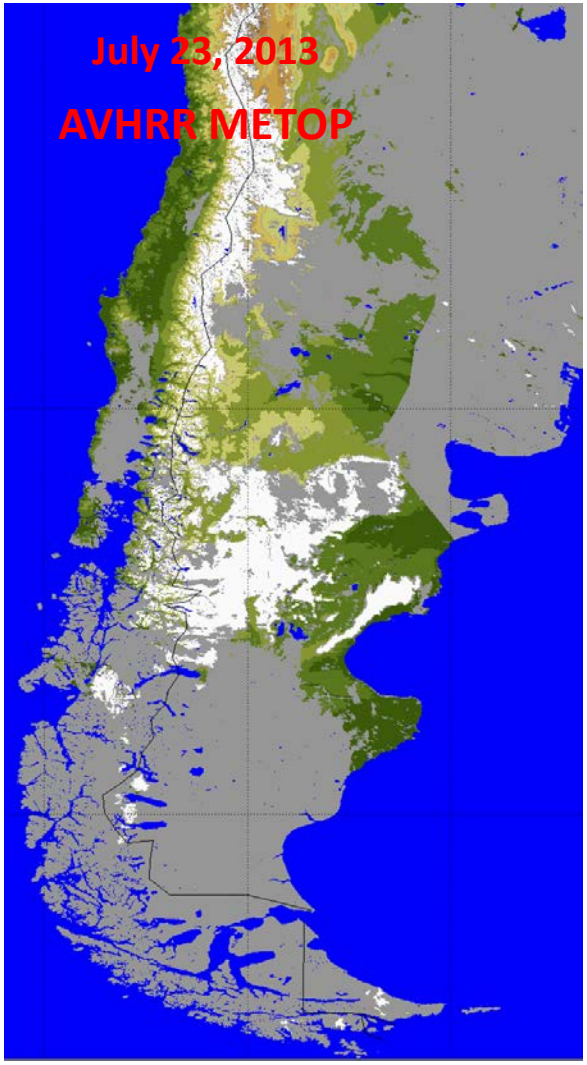
VIIRS vs AVHRR Binary Snow Map



VIIRS Binary Snow Maps agree well to NESDIS AVHRR METOP snow/ice maps
VIIRS Cloud Mask maps more clouds in midlatitudes than the AVHRR cloud mask.

Provisional Maturity Evaluation – Qualitative Assessment (4/5)





Part of the difference in the mapped cloud cover in AVHRR and VIIRS snow products is due to 4 hours difference in the satellite overpass time

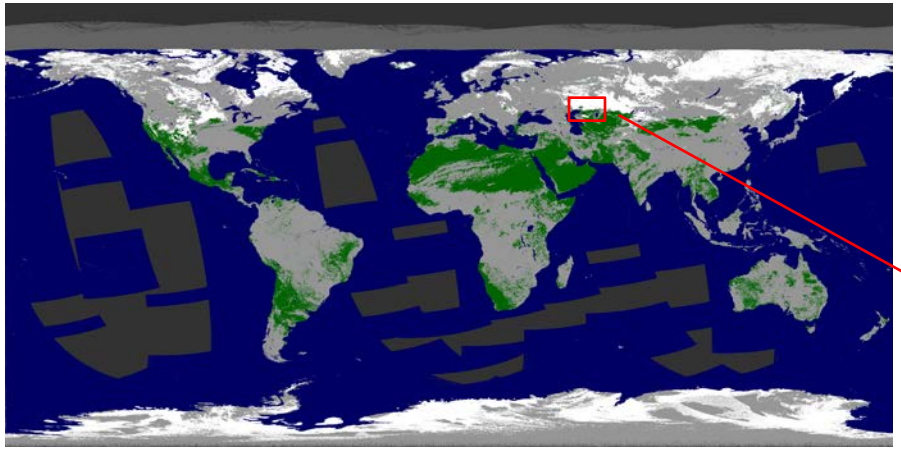
South America

snow land cloud No data

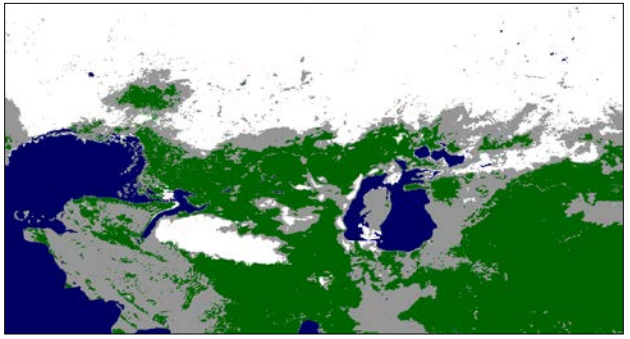
Provisional Maturity Evaluation - Qualitative Assessment (5/5)

VIIRS vs NOAA IMS

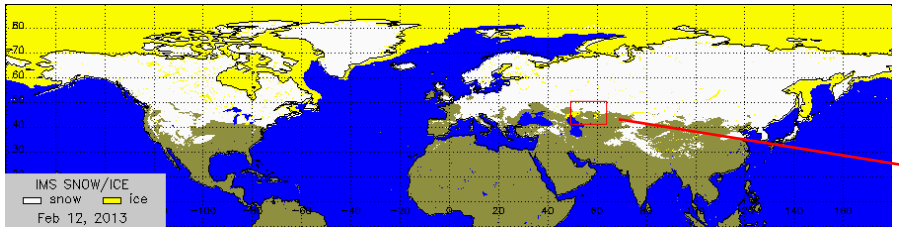
VIIRS snow map

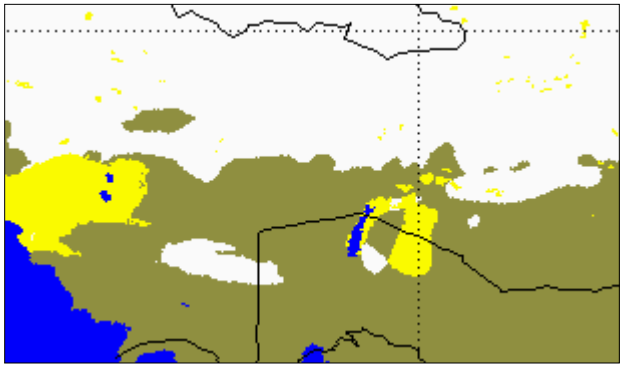


In clear sky portions of the image snow mapped by VIIRS closely corresponds to the snow cover identified interactively by IMS analysts.



IMS Snow and Ice Chart

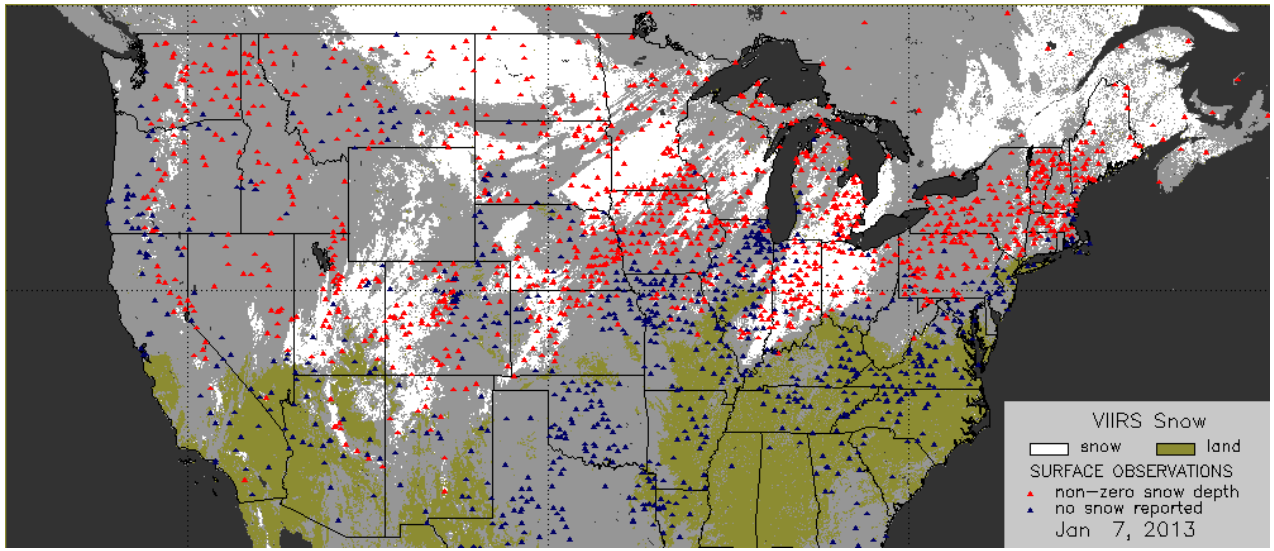




February 12, 2013

Provisional Maturity Evaluation – Quantitative Assessment (1/5)

VIIRS vs In Situ Observations

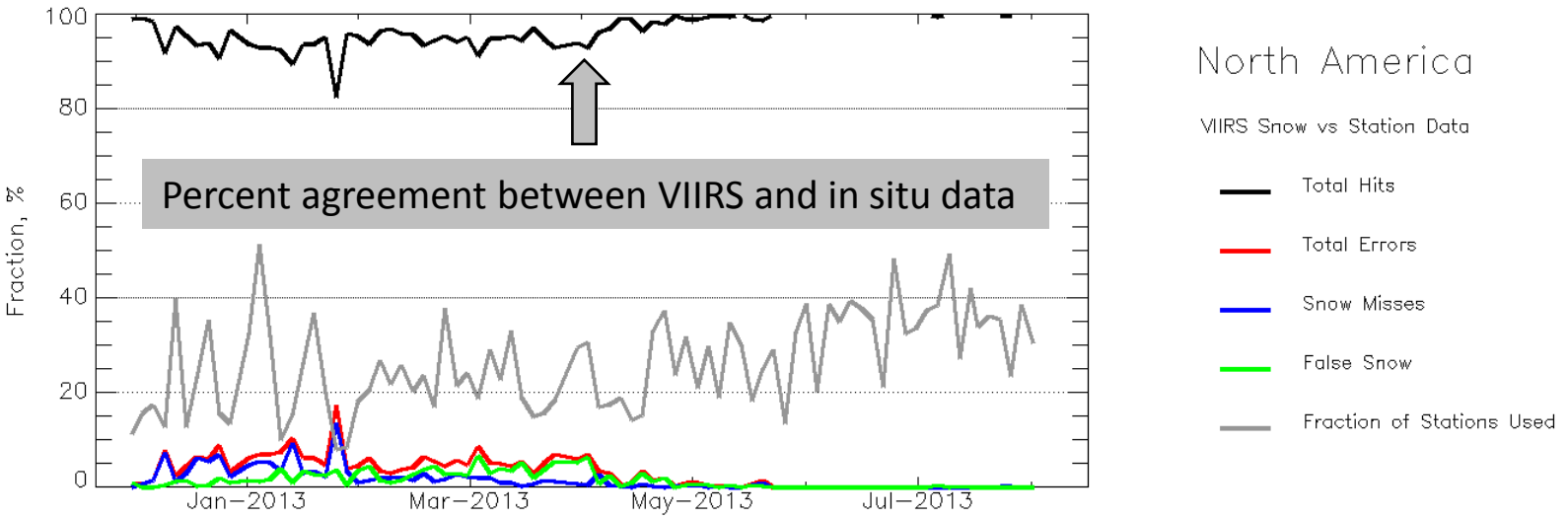


Observations from WMO and US Cooperative network stations over Conterminous US and Southern Canada have been used for validation. The number of daily VIIRS-in situ match ups ranged from 150 to 1030.

Provisional Maturity Evaluation – Quantitative Assessment (2/5)

VIIRS vs In Situ Observations

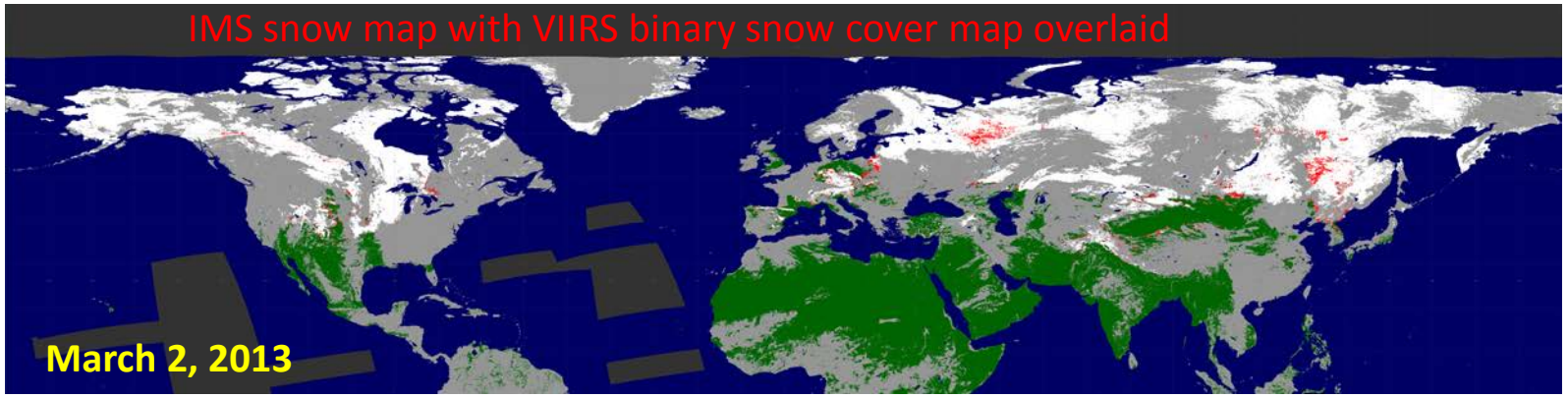
Daily statistics of correspondence between VIIRS snow and in situ data



Except of two days in January 2013 the overall agreement between VIIRS daily snow retrievals and in situ data over CONUS area never dropped below 90%.

Provisional Maturity Evaluation – Quantitative Assessment (3/5)

VIIRS vs NOAA IMS



VIIRS snow map errors: Omission (snow miss) Commission (false snow)

White: VIIRS & IMS snow, Light Gray: VIIRS clouds, Green: VIIRS & IMS snow-free land, Dark gray: no data

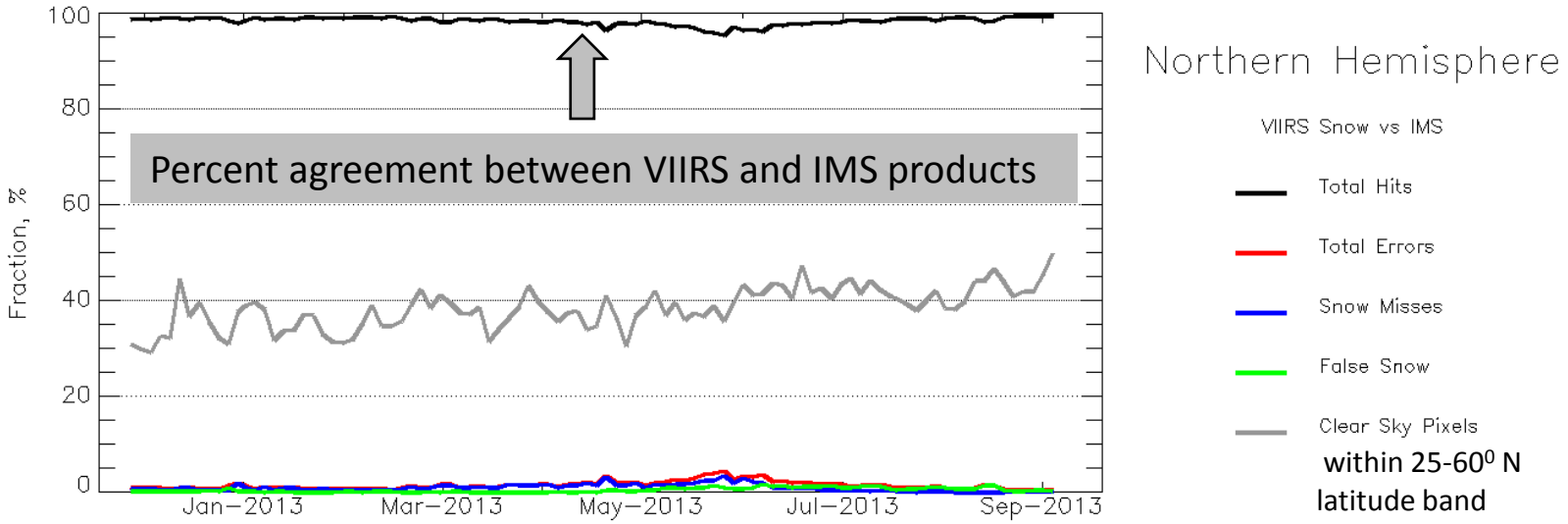
VIIRS-IMS overlaid images have been generated routinely and used to quantitatively assess the accuracy of VIIRS Binary Snow Maps.

Snow omissions in the VIIRS map occur mostly over densely forested areas and along the snow cover boundary. Commission errors occur mostly in cloudy areas.

Provisional Maturity Evaluation – Quantitative Assessment (4/5)

VIIRS vs NOAA IMS

Daily comparison statistics for VIIRS clear-sky data

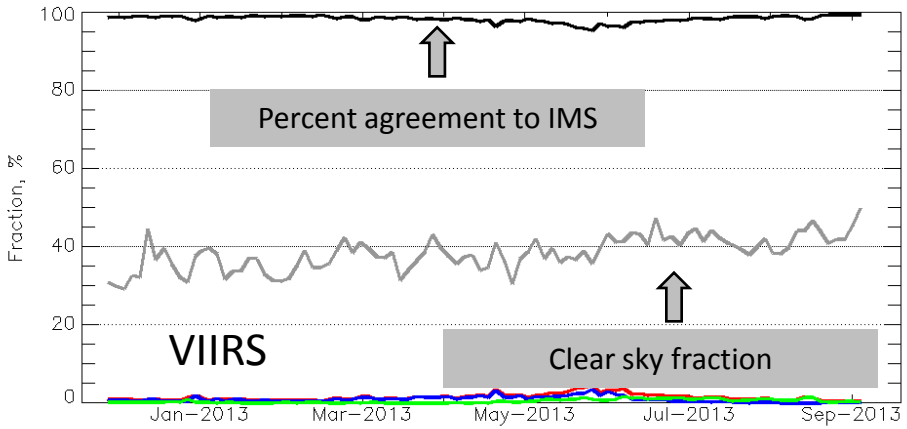


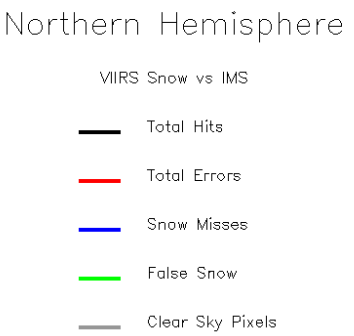
Since the end of 2012 over Northern Hemisphere

- The mean daily agreement between VIIRS and IMS remained above 97%.
- The daily rate of agreement never fell below 93%
- As compared to IMS, VIIRS more often mapped less snow than more snow
- No substantial accuracy differences between North America and Eurasia

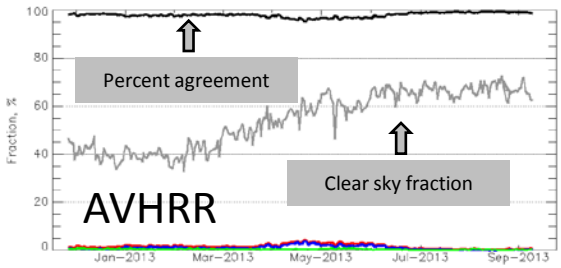
Provisional Maturity Evaluation – Quantitative Assessment (5/5)

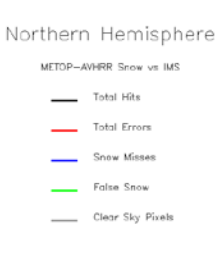
VIIRS, MODIS & AVHRR vs NOAA IMS

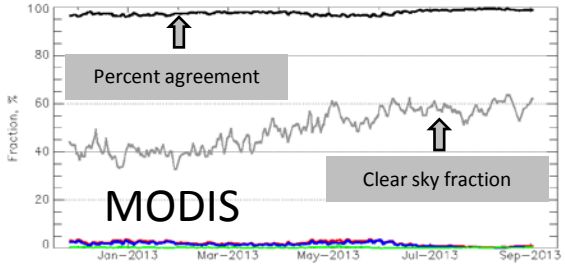


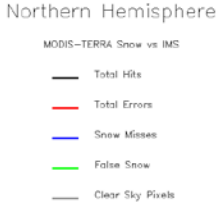


within 25-60^0 N latitude band









The VIIRS agreement to IMS is 2-3% better than of MODIS and AVHRR automated snow maps. This difference however is mostly due to the use of a much more conservative cloud mask in the VIIRS snow product which labels many clear sky snow-covered scenes as cloudy.

Identified Problems in the

VIIRS Binary Snow Cover Map Product

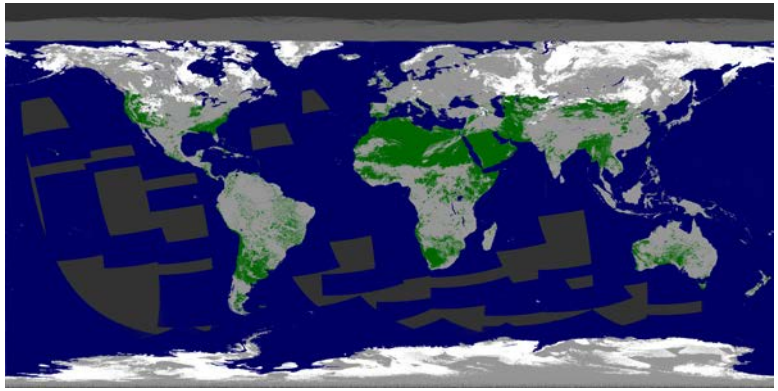
VIIRS Binary Snow Cover: Cloud Mask Ambiguity (1/2)

Information on clouds in the VIIRS Binary Snow Cover product is provided as a 4-category cloud confidence flag. This may confuse the users since none of the product documents explicitly indicate what particular cloud mask should be used to generate the snow map.

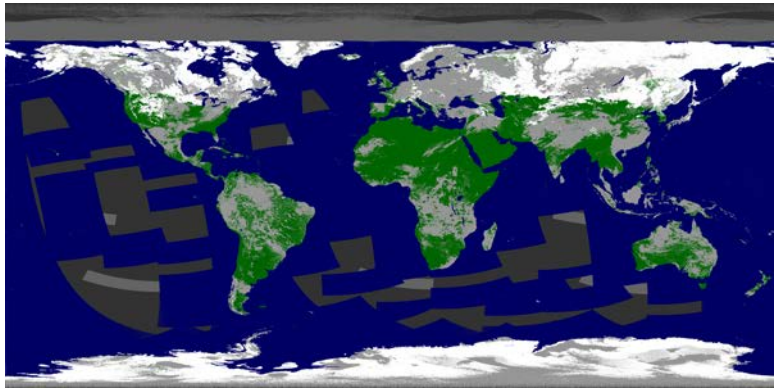
We compared snow cover maps generated with two different cloud masks:

- "**Conservative**": Only "confidently clear" pixels were assumed cloud-clear
- "**Relaxed**" : "Confidently clear" and "probably clear" pixels were assumed cloud-clear

"Conservative" cloud mask used



"Relaxed" cloud mask used



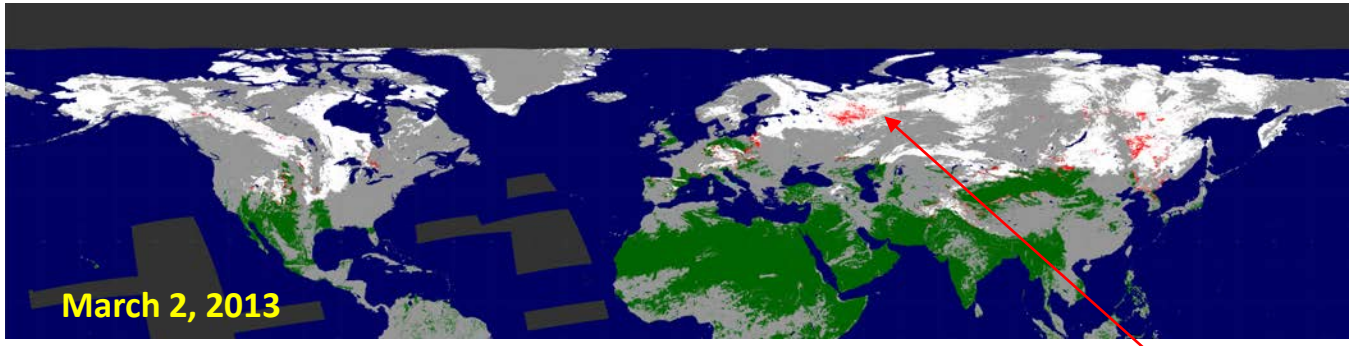
White: snow
Light Gray: clouds

Green: snow-free land
Dark Gray: not processed or no data

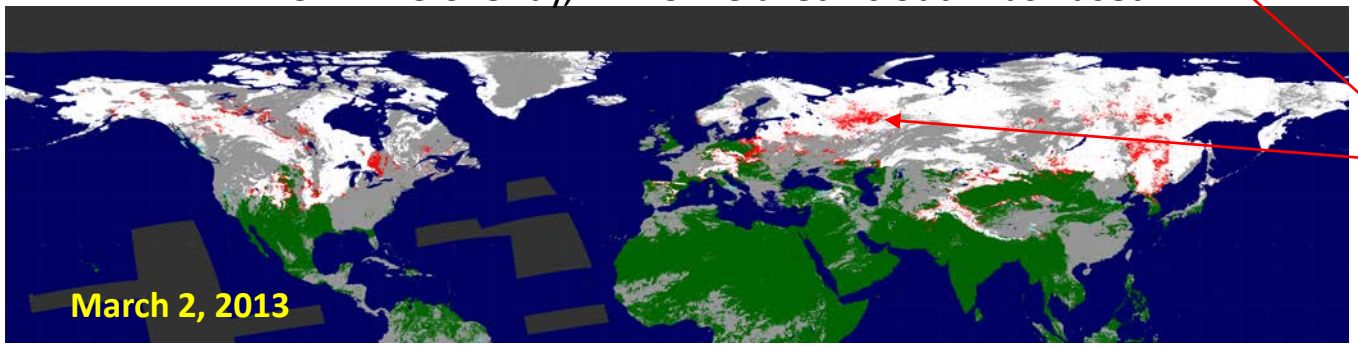
VIIRS Binary Snow Cover: Cloud Mask Ambiguity(2/2)

As compared to IMS, the VIIRS snow map with a “conservative” cloud mask tends to miss less snow than the snow map with the “relaxed” cloud mask. Therefore it is recommended to use the “conservative” cloud mask with the VIIRS snow product.

IMS - VIIRS overlay, VIIRS “conservative” cloud mask used



IMS - VIIRS overlay, VIIRS “relaxed” cloud mask used



White: VIIRS & IMS snow
Light Gray: VIIRS clouds
Green: VIIRS & IMS snow-free land
Dark gray: not processed, or no data

VIIRS snow map errors:

Omission (snow miss)

Commission (false snow)

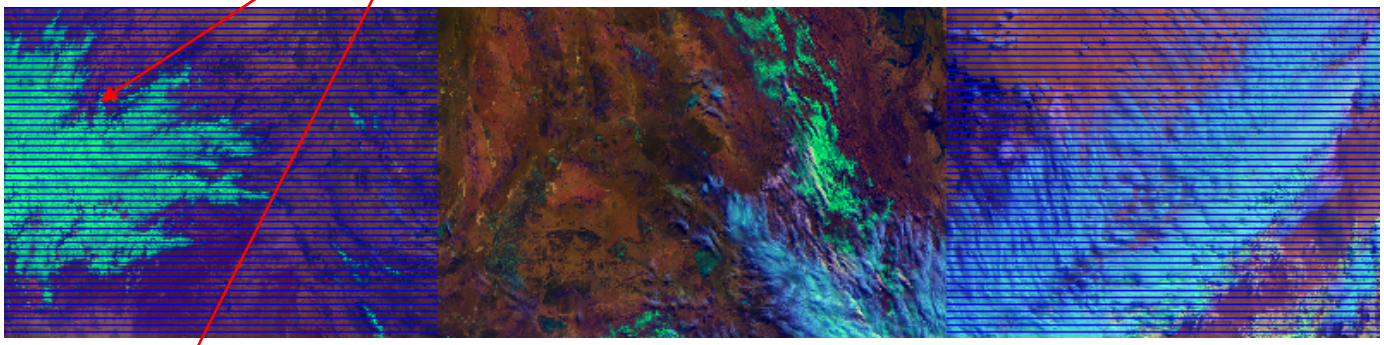
More “omission” errors with “relaxed” cloud mask

VIIRS Binary Snow Cover: Overestimated cloud extent

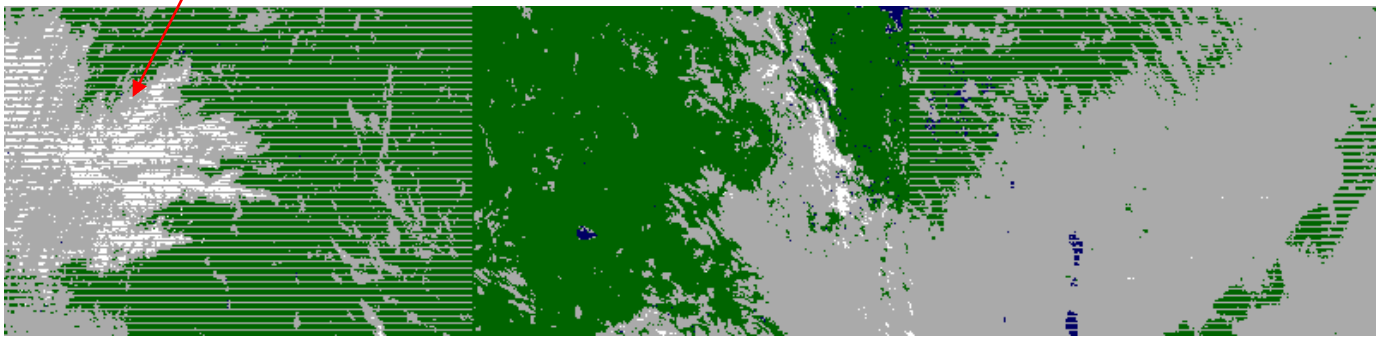
Cloud clear snow-covered pixels are often be labeled as cloudy. Most often this occurs along the snow cover boundary and in the mountains.

No clouds seen in false color imagery

Clouds are mapped in the VIIRS snow product



VIIRS RGB granule image



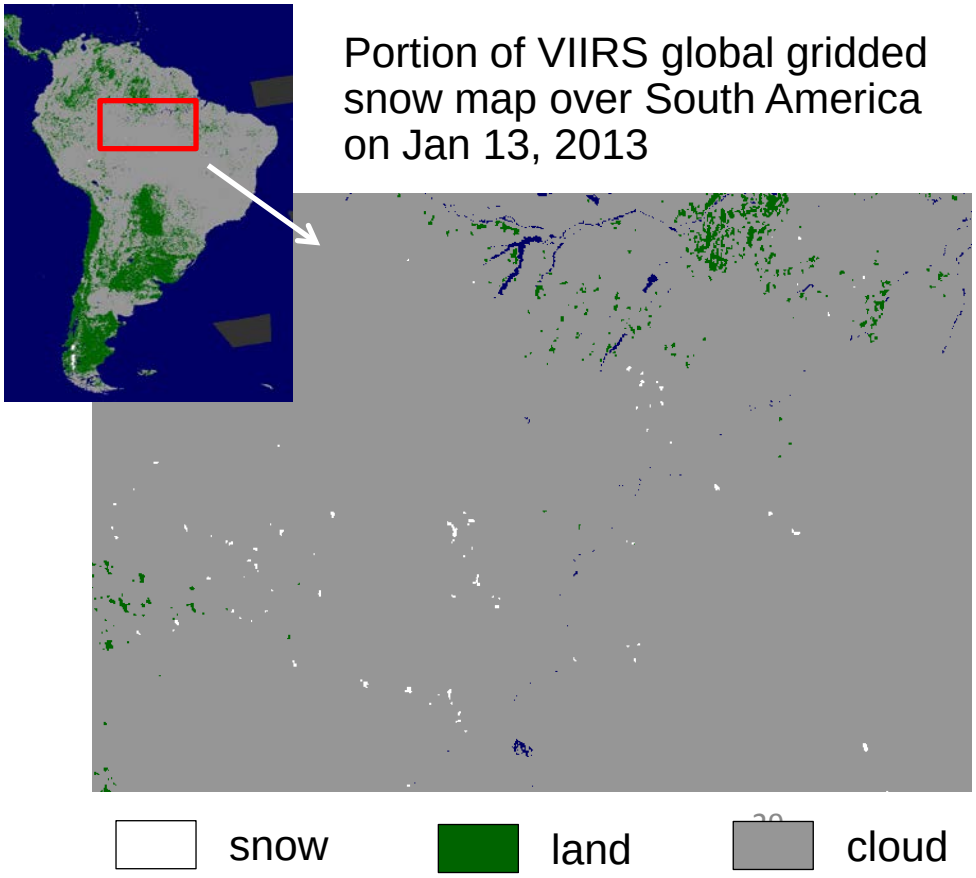
VIIRS granule snow product

snow land cloud No data / not processed

VIIRS Binary Snow Cover: False Snow

Some clouds are missed by the VIIRS cloud mask (VCM). Missed clouds are more often interpreted as snow and thus may appear in the snow product as spurious snow.

On the global scale the extent of spurious snow cover is small, 1-2%, compared to the extent of correctly identified snow.

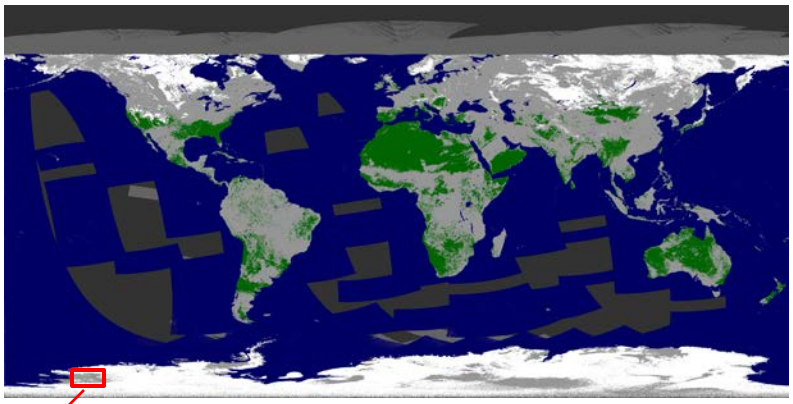


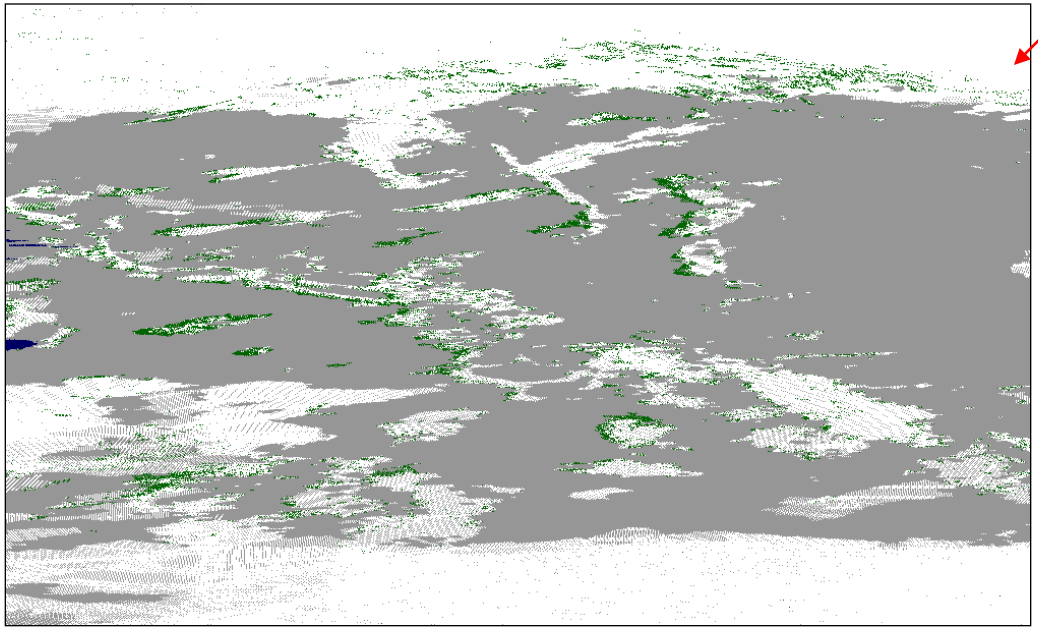
Portion of VIIRS global gridded snow map over South America on Jan 13, 2013

VIIRS Binary Snow Cover: Missed Snow due to Cloud Shadows

Occasional failures to detect snow shadowed by clouds were noticed in the VIIRS snow product

VIIRS snow cover, January 31, 2013 (day 2013031)





snow

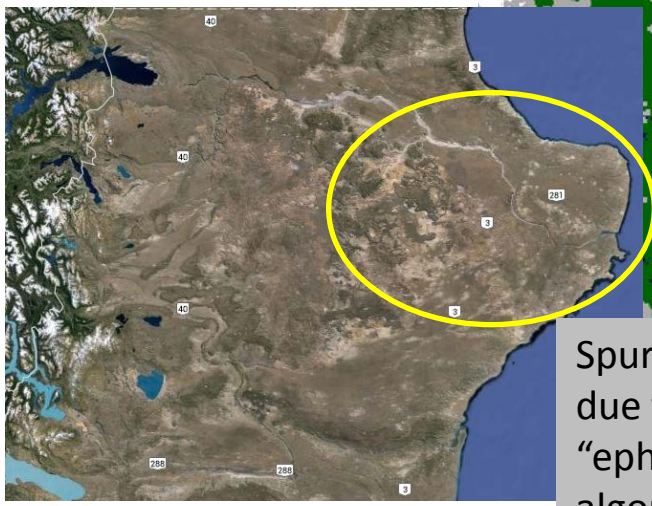
land

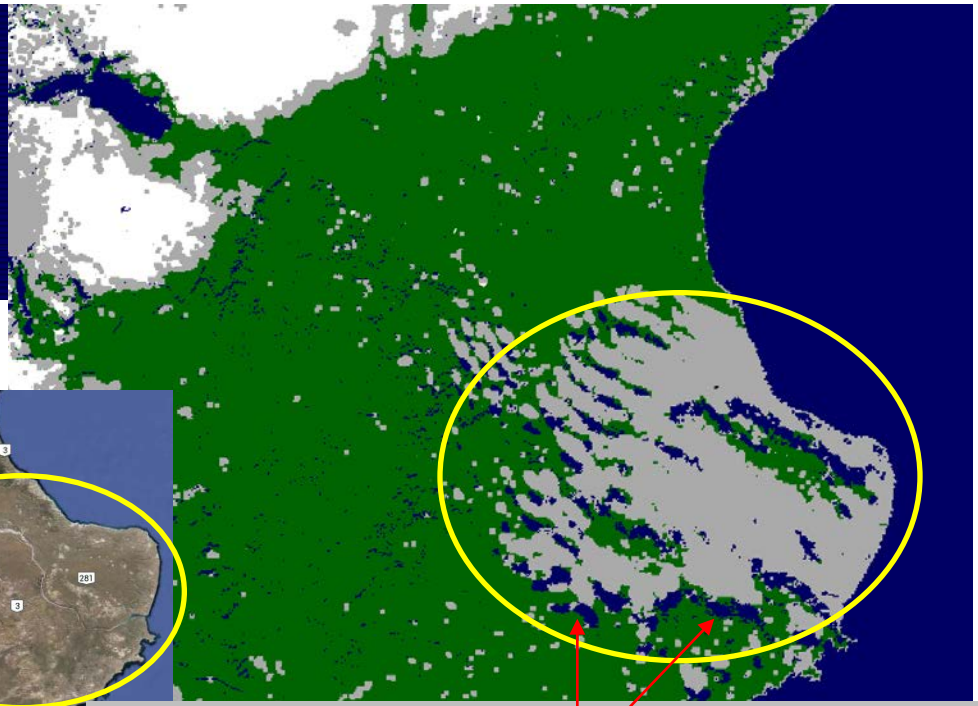
cloud

VIIRS Binary Snow Cover: Corrupted Land/Water Mask (1/3)

Problem: VCM interprets pixels with NDVI < 0.01 as “ephemeral water” and modifies the land/water mask accordingly by assigning an “inland water” flag to these pixels. However a large (if not the largest) portion of pixels with low NDVI actually represent cloud shadows and topographical shadows . As a result, the land/water mask in the snow product gets corrupted.

Date&time :20130718_t1838355

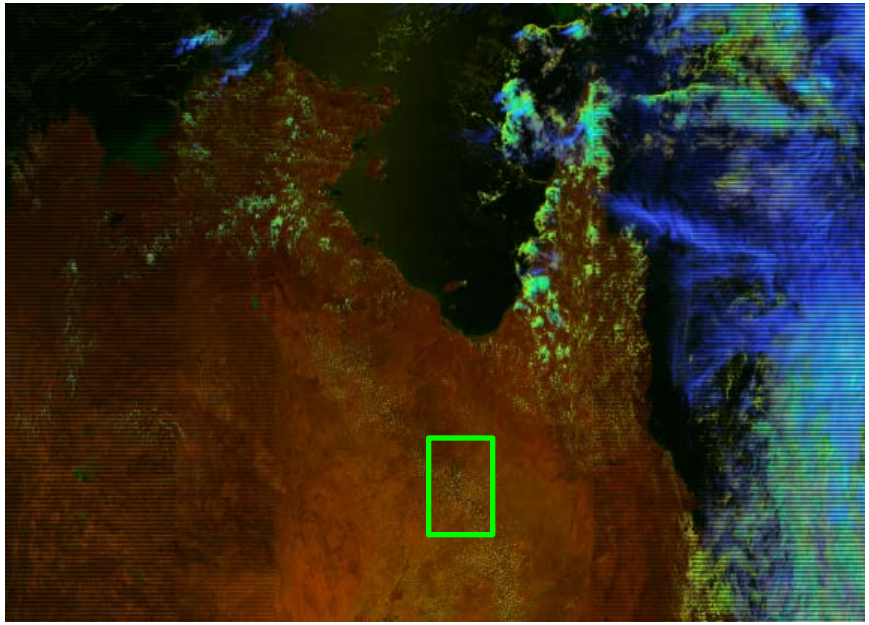


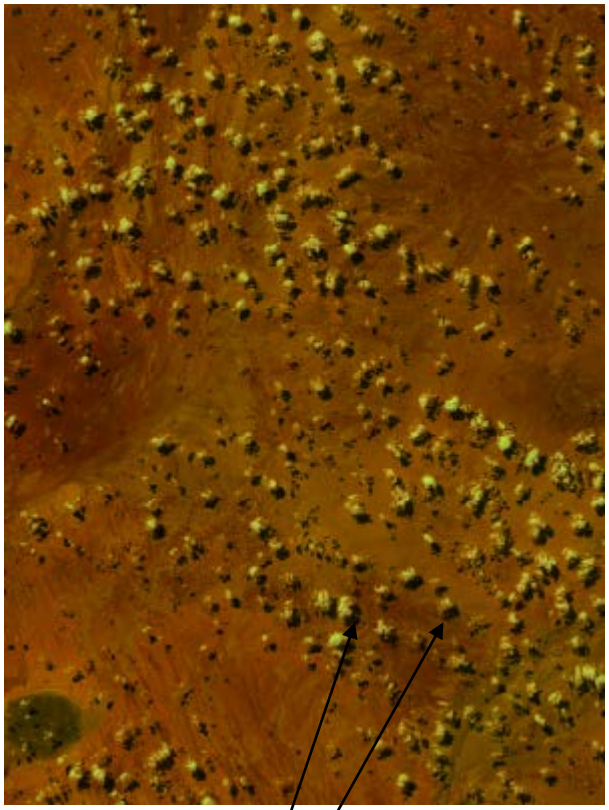


Spurious water bodies in the VIIRS snow product due to misinterpretation of cloud shadows as “ephemeral water” by the VIIRS cloud mask algorithm

VIIRS Binary Snow Cover: Corrupted Land/Water Mask (2/3)

Australia on March 15, 2013 at 04:15

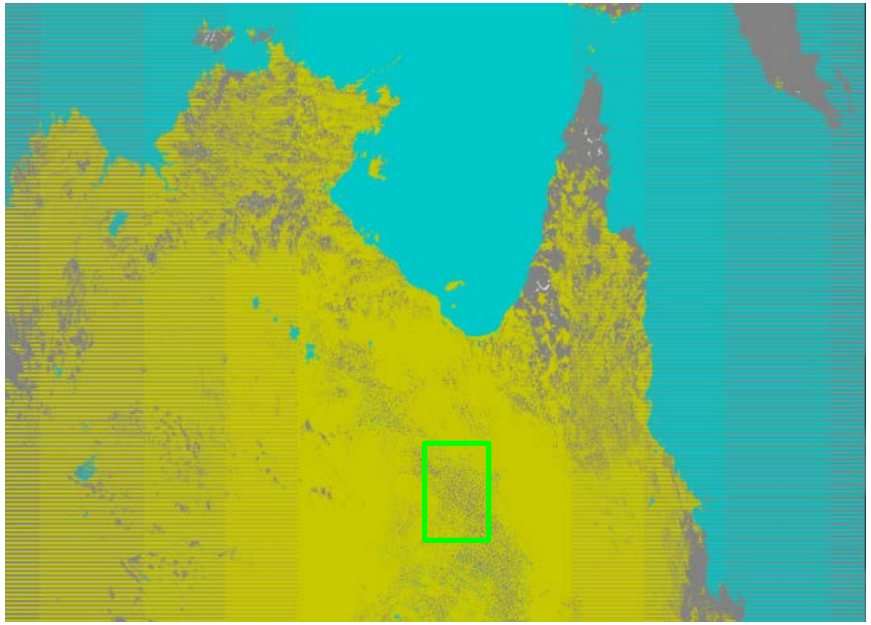


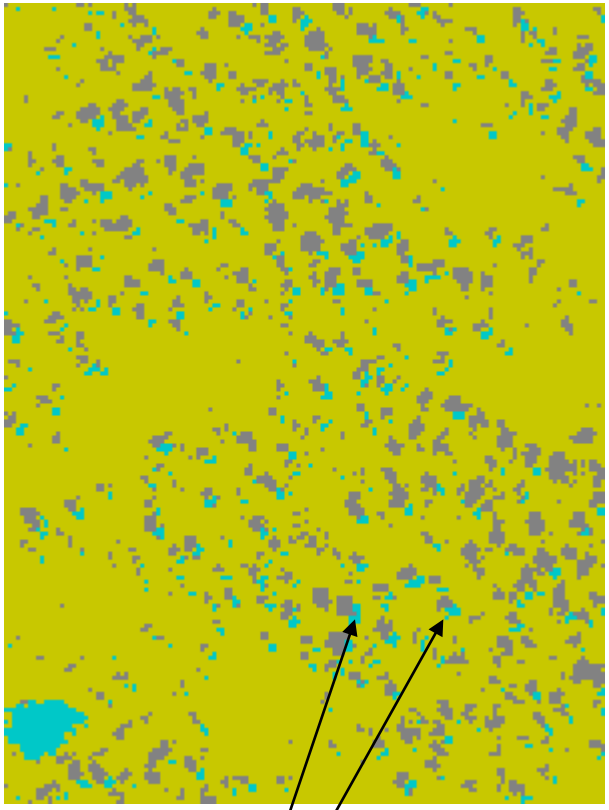


VIIRS Binary Snow Cover: Corrupted Land/Water Mask (3/3)

Spurious water bodies mapped in place of cloud and topographical shadows can be found practically in every land granule in the middle and high latitudes.
This problem apparently affects all other land products that use VCM

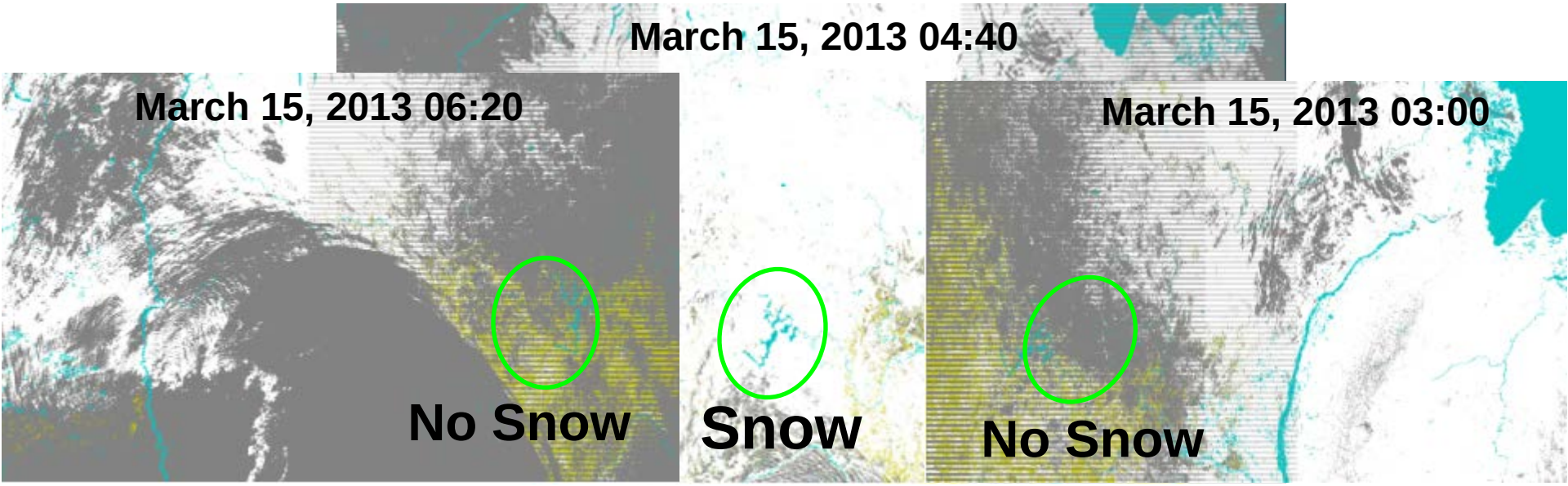
Australia on March 15, 2013 at 04:15



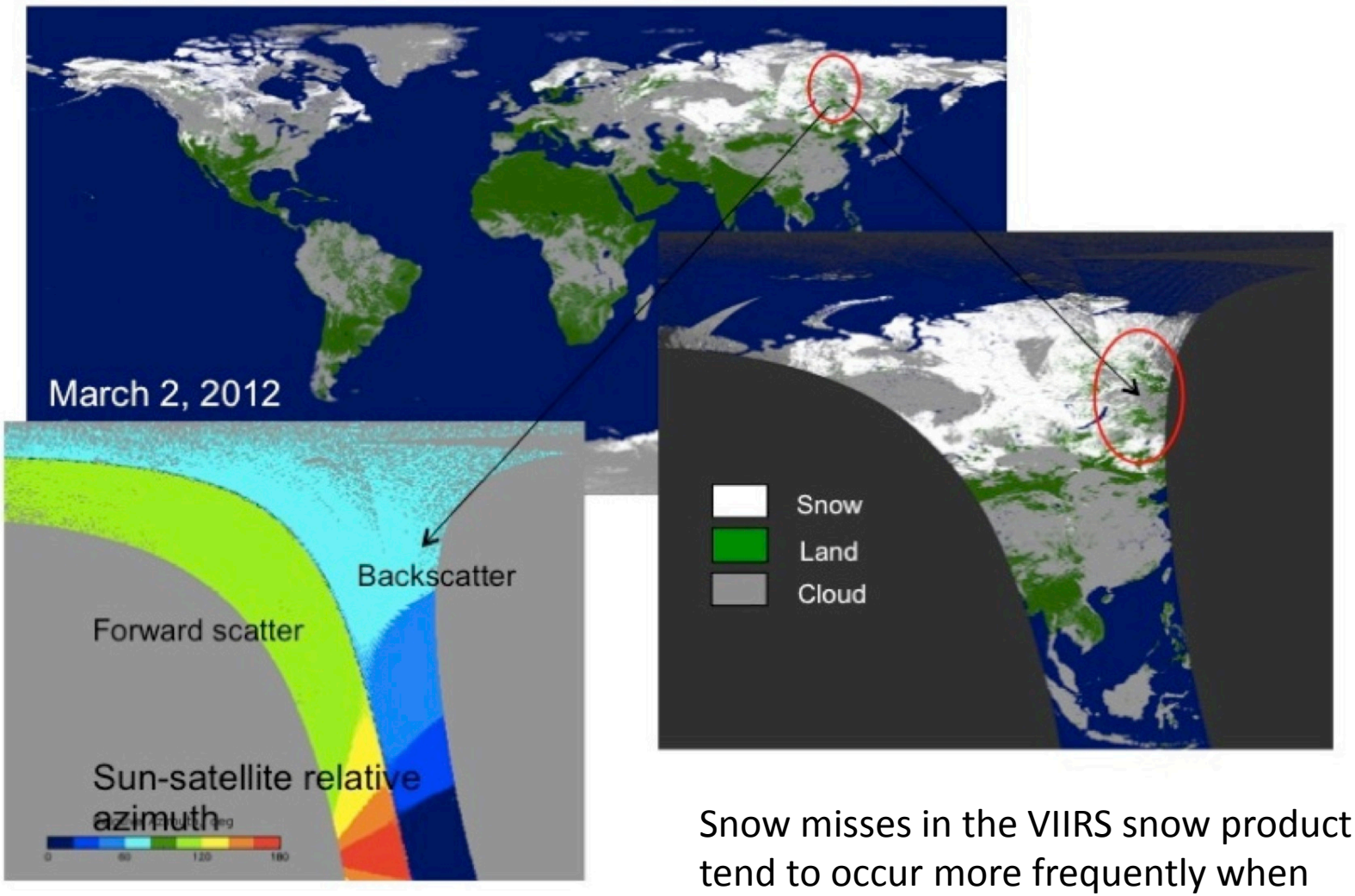


VIIRS Binary Snow Cover: Scan Edge Effect (1/2)

Efficiency of snow identification drops at scan edges. This is due to the fact that the algorithm does not account for changing view geometry.



VIIRS Binary Snow Cover: Scan Edge Effect (2/2)



Snow misses in the VIIRS snow product tend to occur more frequently when observations are made in the backscatter

History of Algorithm changes/updates (1/2)

Date	Update/DR#	Reason	Completed
12-20-2010	VIIRS Snow Cover EDR Look-up/DR4138	Updated false snow thermal screening threshold. Previous threshold value was based on MODIS data. New threshold values has been derived from VIIRS F1 test program results	No indication that the work has been completed
03-31-2011	Snow algorithm inconsistent with new requirements/DR4246	Operational approach for snow fraction retrieval is inadequate	Not Completed
04-10-2013 (last update)	Snow EDR has fixed limit setting on solar zenith angle (SZA)/DR4895	Need to remove the fixed limits on solar zenith angle and make the limits tunable	Not Completed
04-25-2012	Alternative snow/ice grid needed to support algorithms/DR4700	Need to modify the Snow/Ice GranToGrid algorithm to make use of the NOAA Global Multisensor Automated Snow/Ice Map	Not Completed

History of Algorithm changes/updates (2/2)

Date	Update/DR#	Reason	Completed
06-18-2012	VIIRS-SNOW-COVER-QUAL LUT SZA Thresholds/DR4787	Updates needed to solar zenith angle thresholds in the VIIRS-SNOW-COVER-QUAL LUT and to the seed data for the GridIP-VIIRS-Snow-Ice-Cover-Rolling-Tile dataset	Completed
04-12-2013	Request for Beta Maturity Status for VIIRS Cryospheres EDRs and Ips/DR7132	Approval requested for the Snow Cover EDR .	Completed

Provisional Justification Summary: Binary Snow Cover (1 of 3)

Product quality may not be optimal

- The product meets accuracy requirements under most, but not all, conditions.
- Evaluation is based on a limited, 10 months-long time period of analysis from October 2012 to August 2013
- The overall quality of the product is sufficient to justify its evaluation and use by a broader community, however the users has to be warned that product has flaws

<u>The known issues are as follows</u>

- Occasional “false snow” identifications occur due to the failure of the VIIRS cloud mask algorithm to properly identify clouds
- Occasional snow misses occur due to inability of the algorithm to identify snow in densely forested areas
- Clear sky partially snow-covered scenes are often mapped as cloudy. This hampers locating the snow cover boundary.
- Land/water mask in the snow product is corrupted. External land-water mask should be used.

Provisional Justification Summary: Binary Snow Cover (2 of 3)

Incremental product improvements are still occurring

- The accuracy of the snow cover product is critically dependent on the accuracy of the VIIRS cloud mask (VCM) product. Further changes in the VCM may affect the quality of the VIIRS Binary Snow Map Product both favorably and adversely .

- Once the VCM is finalized tuning of the VIIRS binary snow algorithm may be needed. Introducing additional test filtering clouds missed by VCM may improve the product quality.

- The land/water mask in the VIIRS snow product is corrupted by the current VCM algorithm. The usability of the snow product will improve when this problem is fixed.

Provisional Justification Summary: Binary Snow Cover (3 of 3)

ATBD is accurate, up-to-date and consistent with the product running

General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing

Users are urged to consult the EDR product status document prior to use of the data in publications

Ready for operational evaluation

- Key NOAA and non-NOAA end users have been identified and feedback has been requested. (User presentation follows)

Future Plans and Issues: Binary Snow Cover Product (1/3)

- Some changes/modifications to the Binary Snow Map algorithm are currently considered
  - Make the threshold values variable depending on the view geometry
- Detailed performance characterization requires
  - Comprehensive evaluation of the product stratified by the season of the year, climatic/geographic zone and surface cover type
  - A more detailed analysis of the algorithm and product performance at local scales
- Routine monitoring of the quality of VIIRS Binary Snow Map product will be conducted to assess its possible changes due to changes in the VIIRS cloud mask

Conclusion: Binary Snow Cover Product

- The **VIIRS Binary Snow Cover Product** (which is part of the VIIRS Snow Cover EDR) has reached the provisional maturity stage based on the definitions and the evidence shown
  - It exceeds the definition of provisional maturity in most cases
  - The product performance is close to meeting requirements at this time.

- Issues have been uncovered during validation of **the VIIRS Binary Snow Cover Product** and solutions are being evaluated.
  - Identified problems are mostly related to failures of the VIIRS cloud mask algorithm and product
  - If the accuracy of the cloud mask does not change as the result of latest improvements, modifications to the VIIRS Binary Snow Map algorithm should be introduced to at least partially compensate for the cloud mask errors

- The provisional effectivity date is October 16, 2012 (MX 6.4), as validation datasets produced after this time formed the basis of our evaluation.

Provisional Maturity Evaluation of the

Fractional Snow Cover Product

VIIRS Snow Fraction: Facts

- VIIRS Snow Fraction is derived through aggregation of the VIIRS Binary Snow Map data within 2x2 pixel blocks.
- The current algorithm is a substitute for a more advanced multiple end-member linear mixture algorithm (MESMA)
- VIIRS Snow Fraction is reported in 25% and 33% increments.
- Because of the rough quantization reaching the required accuracy of 10% is not feasible.
- Performance of the VIIRS Snow Fraction product is completely determined by the accuracy of the VIIRS Binary Snow Cover map.

Provisional Maturity Evaluation Approach

Snow fraction is not measured in situ. None of the existing satellite-based snow fraction products have been validated and evaluated on the global scale, therefore direct quantitative validation of VIIRS snow fraction retrievals requires significant efforts.

The current quality assessment of the product was based on

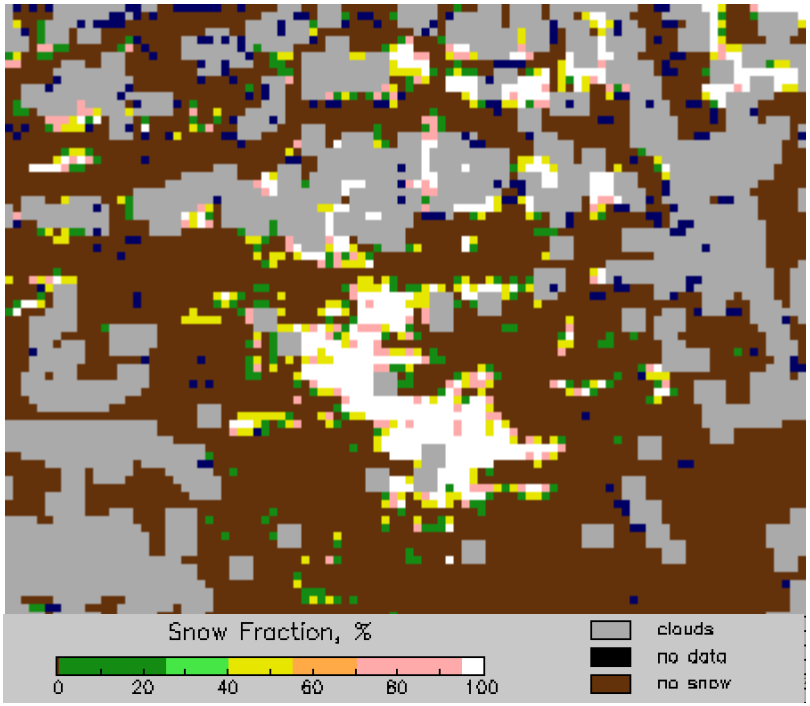
- Visual analysis of snow fraction retrievals
- Qualitative comparison with false-color imagery
- Qualitative comparison with MODIS snow fraction product
- Temporal and spatial consistency checks

In the analysis we have used

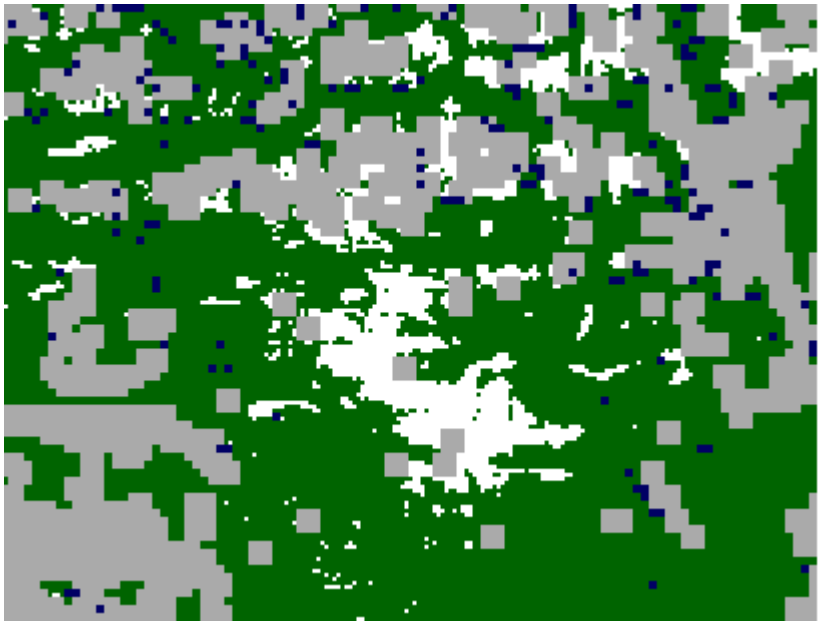
- Individual granules of VIIRS Snow Fraction product
- Daily global gridded composited maps of VIIRS-based snow fraction

VIIRS Binary and Snow Fraction Map

Granule date: 20130915 time: 0355267



Snow fraction map (granule fragment)
750 m spatial resolution

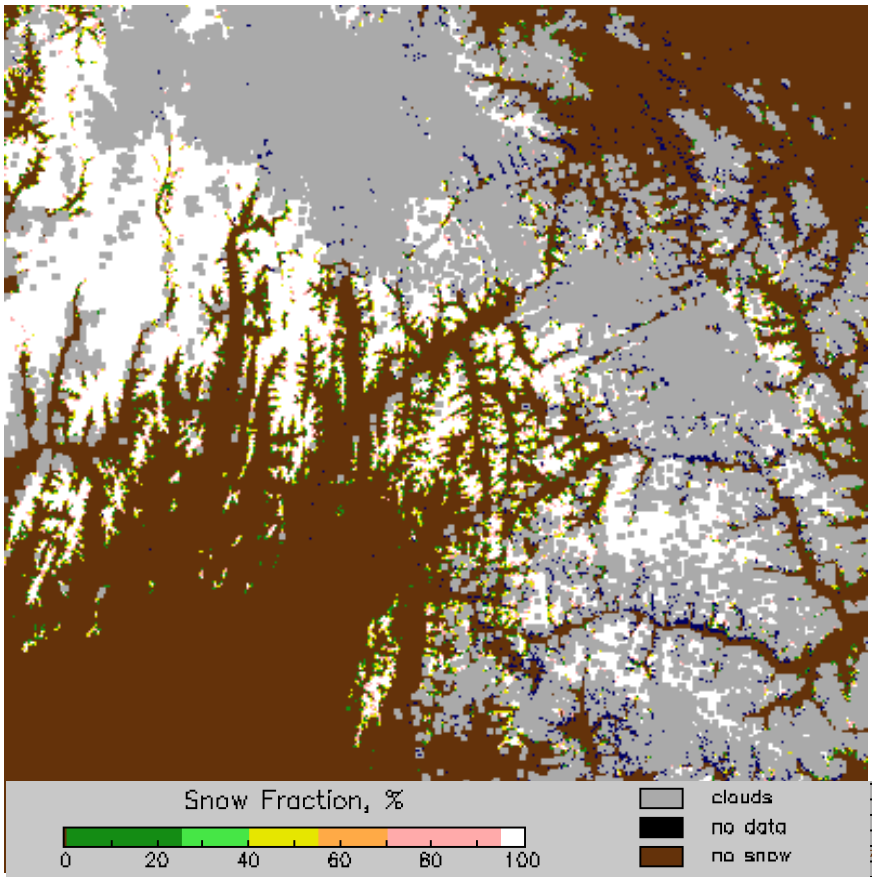


Binary snow map (granule fragment)
375 m spatial resolution

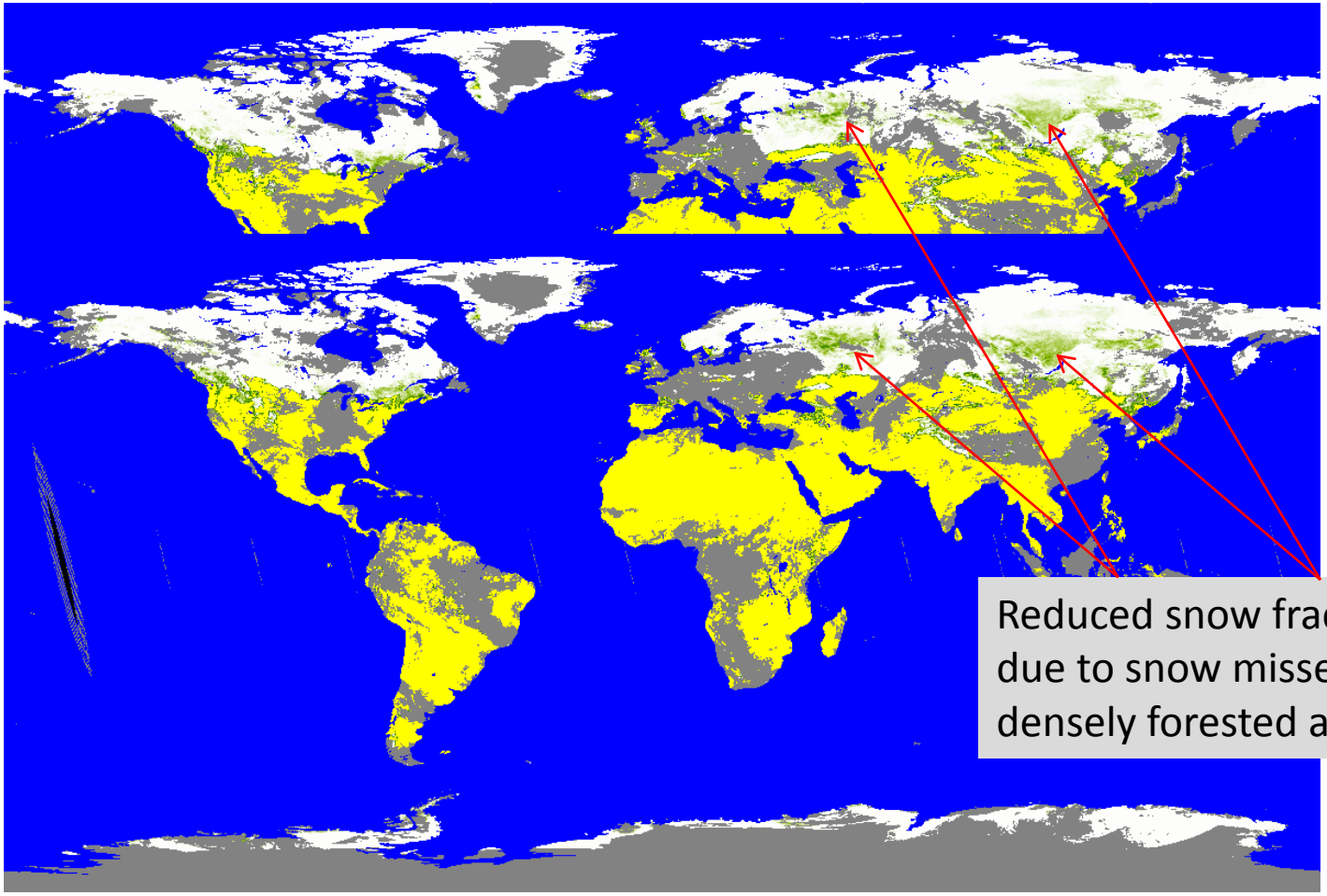
VIIRS Snow Fraction Algorithm correctly converts binary snow cover map data into coarser resolution snow fraction.

VIIRS Snow Fraction Map and RGB image

The VIIRS Snow Fraction Map adequately reproduces the spatial distribution of the snow cover in clear sky conditions.



Temporal consistency of VIIRS Fractional Snow Cover Product



Mar 29 , 2013

Mar 30, 2013

Reduced snow fraction due to snow misses in densely forested areas

Snow fraction retrievals are consistent in time

Non-zero snow fraction is shown in shades of green to white

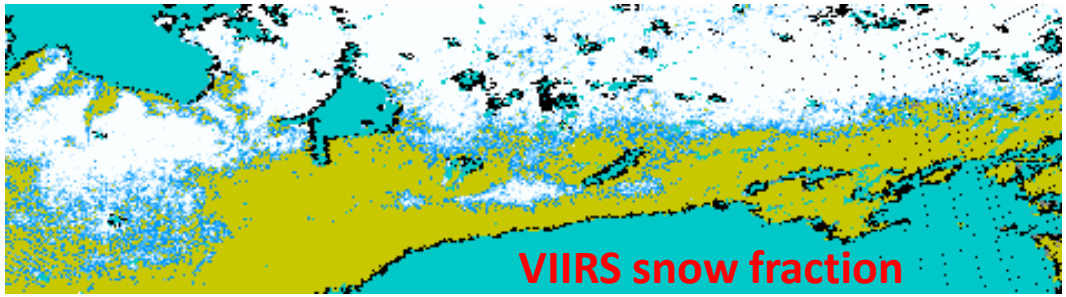
VIIRS vs MODIS Snow Fraction

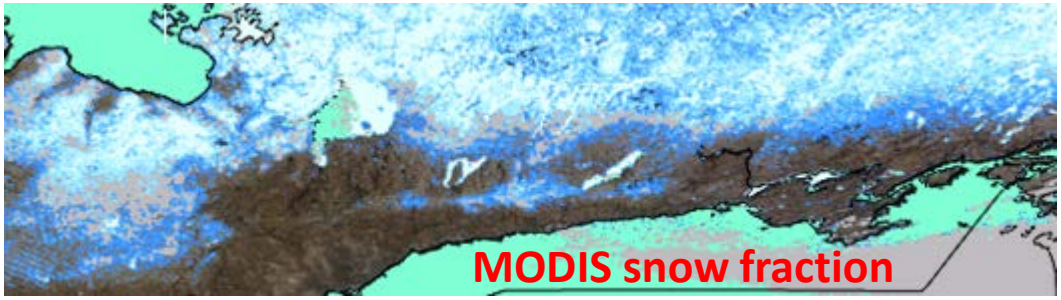
Direct comparison of VIIRS and MODIS snow fraction is not legitimate since the two products are physically different.

VIIRS: 2x2 aggregation of binary snow cover, characterizes snow cover patchiness

MODIS: sub-pixel snow cover, characterizes patchiness and masking of snow cover by vegetation

MODIS snow fraction is generally smaller than the VIIRS snow fraction.





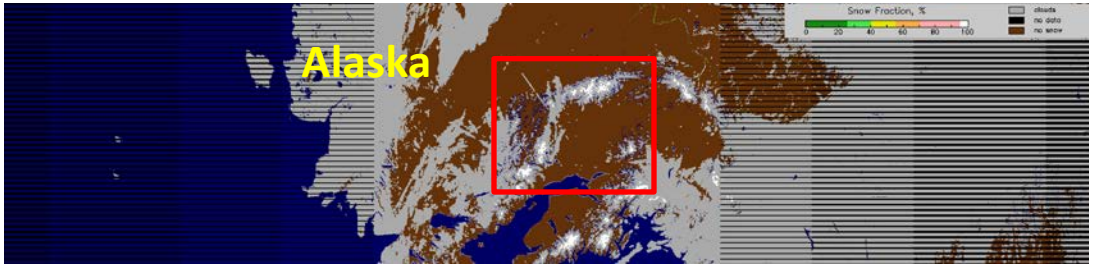
History of Algorithm changes/updates

No changes/modifications specific to the Snow Fraction algorithm have been requested/introduced.

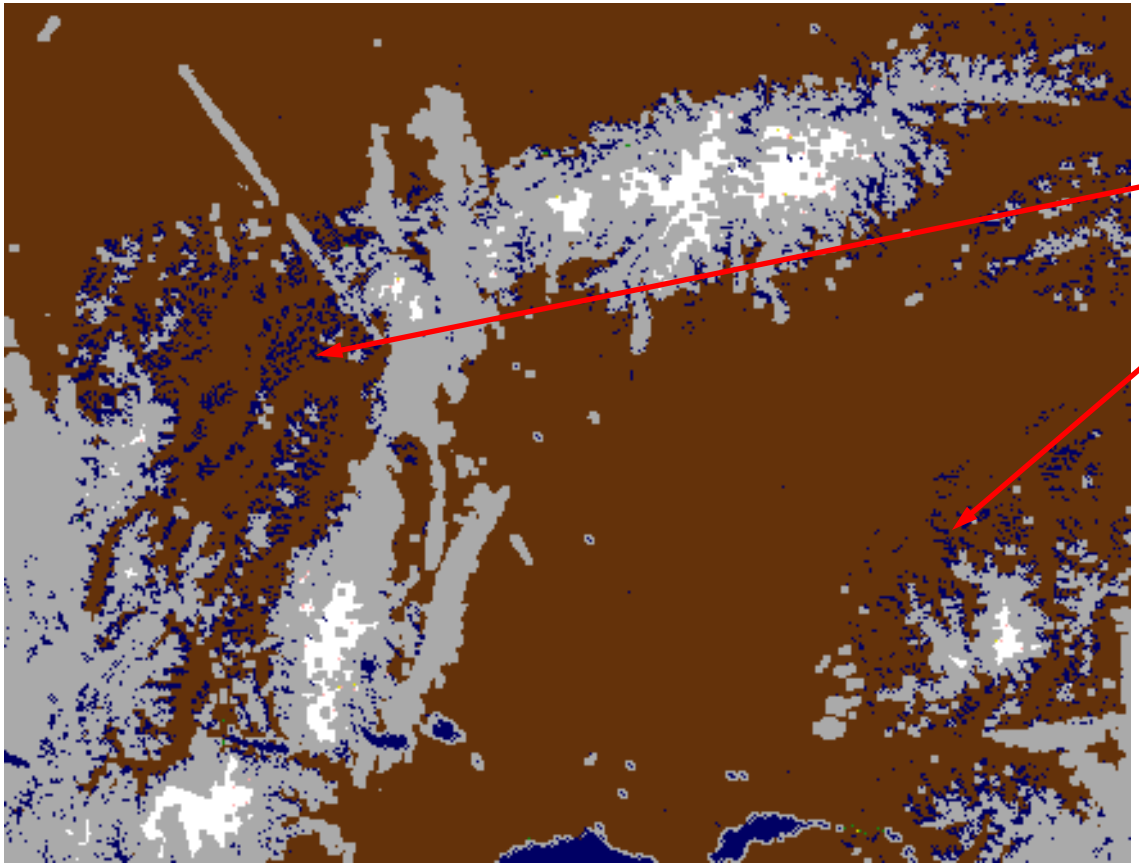
Identified Problems in the

VIIRS Fractional Snow Cover Map Product

Corrupted Land/Water Mask in the Snow Fraction Product



Day: 20130915 Time: 2227506

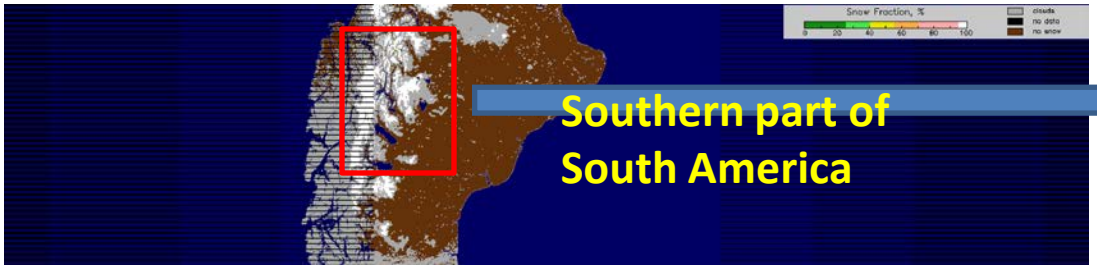


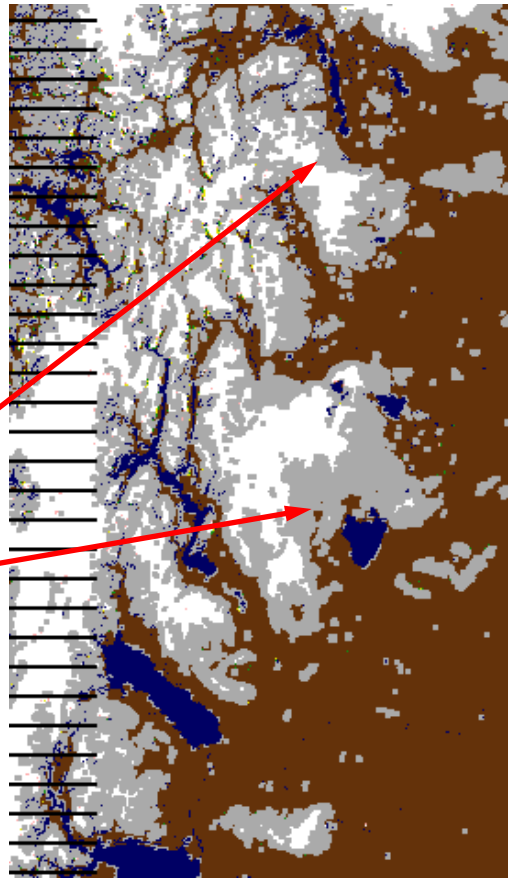
"False water" (blue) due to misinterpretation of topographical shadows as "ephemeral water" by the VIIRS Cloud Mask

Overestimated Cloud Extent Issue

- Clear sky scenes along the snow cover boundary (where partial snow cover is most likely to occur) are typically misinterpreted by the VIIRS cloud mask as “cloud covered”. As a result the vast majority of cloud-clear grid cells in the snow fraction product is labeled either as “snow free” or “100% snow covered”
.

Day: 20130915 Time: 1833077





Clear sky scenes with intermittent snow cover along the snow cover boundary are typically misinterpreted as “cloudy”

Provisional Maturity Justification Summary for

VIIRS Fractional Snow Cover Map Product

Provisional Justification Summary: Fractional Snow Cover (1 of 4)

Product quality may not be optimal

- Proper quantitative validation of the product is not made
- Based on the qualitative evaluation of the product, the product reasonably reproduces the large scale snow cover distribution in general and intermittent (patchy) snow cover in the snow transient zone.
- Evaluation is based on a limited, 10 months-long time period of analysis from October 2012 to August 2013
- The overall quality of the product is sufficient to justify its evaluation and use by a broader community, however the users has to be warned that product has flaws

<u>The main issues are the same as in the Binary Snow Product</u>

- Occasional “false snow” identifications occur due missed clouds
- Occasional snow misses in densely forested areas
- Overestimation of the cloud coverage particularly over partially snow-covered scenes. The location of the snow cover boundary often can not be precisely established
- Land/water mask in the Fractional Snow product is corrupted. External land-water mask should be used.

Provisional Justification Summary: Binary Snow Cover (2 of 4)

Incremental product improvements are still occurring

- The accuracy of the snow cover product is critically dependent on the accuracy of the VIIRS Binary Snow Map and VIIRS Cloud Mask (VCM) products. Further changes in both product may affect the quality of the VIIRS Fractional Snow Map Product both favorably and adversely .

- The land/water mask in the VIIRS snow product is corrupted by the current VCM algorithm. The usability of the snow product will improve when this problem is fixed.

Provisional Justification Summary: Binary Snow Cover (3 of 4)

However

Within the technique used the product can not achieve the required 10% accuracy.

The current Fractional Snow Cover product does not fully answer the needs of the community and therefore has limited application due to

- Rough quantization
- Lack of account of snow masking by trees

The current algorithm has to be replaced with a more sophisticated algorithm deriving the snow cover fraction at a sub-pixel level

Provisional Justification Summary: Binary Snow Cover (4 of 4)

ATBD is accurate, up-to-date and consistent with the product running

General research community is encouraged to participate in the QA and validation of the product, but need to be aware that product validation and QA are ongoing

Users are urged to consult the EDR product status document prior to use of the data in publications

Towards Improved

VIIRS Fractional Snow Cover Map Product

Current VIIRS Snow Fraction Product: Need for Improvement

Current VIIRS Snow Fraction presents a direct derivative of the VIIRS Binary Snow Mask and therefore has little added value. The product can be viewed as a reduced resolution substitute of the Binary Snow Map product. It may be useful for applications where having snow cover data at VIIRS full spatial resolution is not critical.

Land models need a different snow fraction which accounts both for patchiness of the snow cover on the ground and for masking of snow cover by trees. This latter snow fraction is typically derived at a sub-pixel level and is based on the spectral analysis of the scene reflectance.

To derive the subpixel snow fraction the current VIIRS snow fraction algorithm should be replaced with a proper, more advanced algorithm

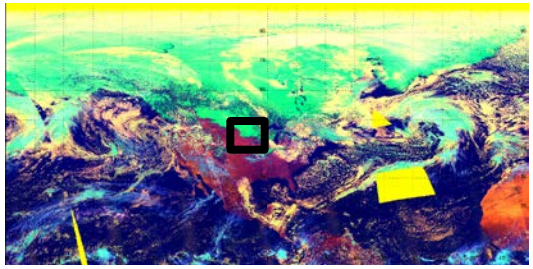
Existing algorithms for sub-pixel snow fraction retrieval

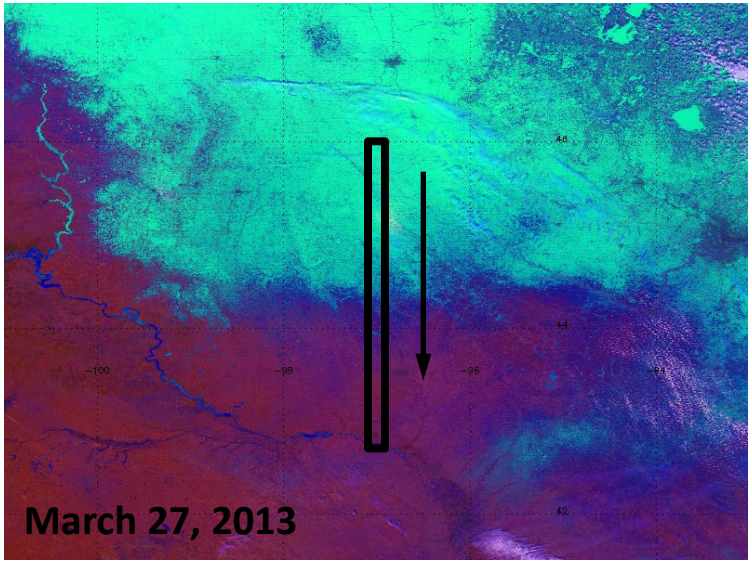
A number of different snow fraction algorithms is avaialble:

- NDSI-based (Solomonson/Appel, Hall/Riggs)
  - Linearly relates snow fraction to NDSI (Normalized Difference Snow Index)
  - Easy to implement, routinely applied to MODIS
- Visible reflectance –based (Romanov/Tarpley)
  - 2-endmember linear mixture model, uses observations in one (visible) band
  - Routinely applied to GOES Imager data since 2002
- Multiple endmember multispectral approach (Painter)
  - Uses reflectance data in several spectral bands in the visible and near infrared
  - The most theoretically solid approach
  - Needs accurate definition of snow endmember spectral properties
  - Has not been routinely tested on a global scale
  - A similar algorithm, MESMA, was implemented but not activated within the VIIRS processing system

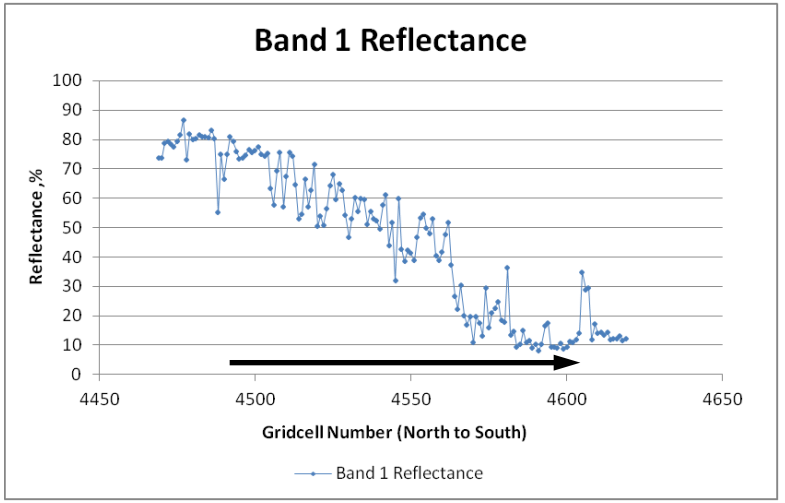
Next two slides illustrate the difference between NDSI-based and reflectance-based approach to snow fraction definition and retrieval

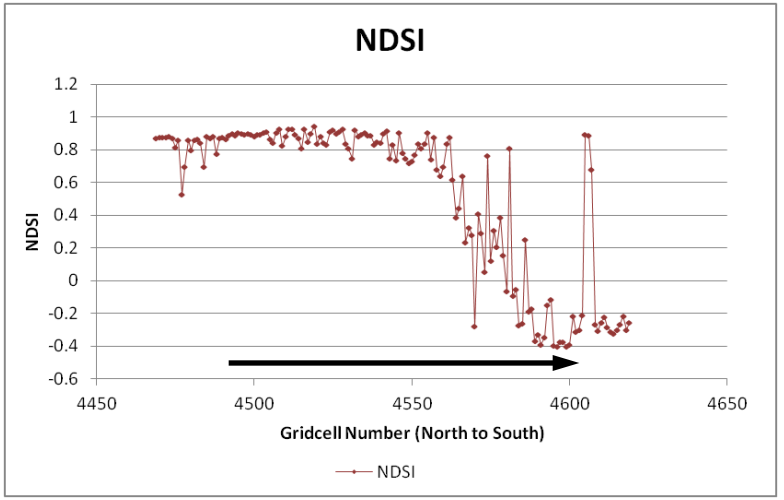
Snow Fraction: NDSI vs Reflectance-Based Estimation (1)





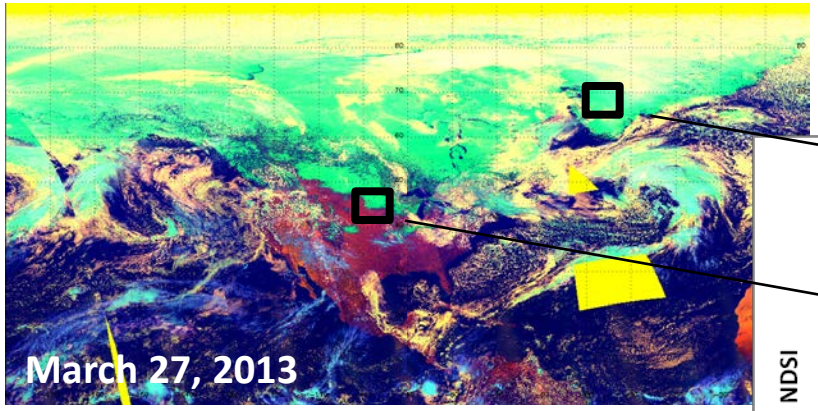
VIIRS Band 1 reflectance and NDVI along the north-to-south transect line crossing the snow boundary



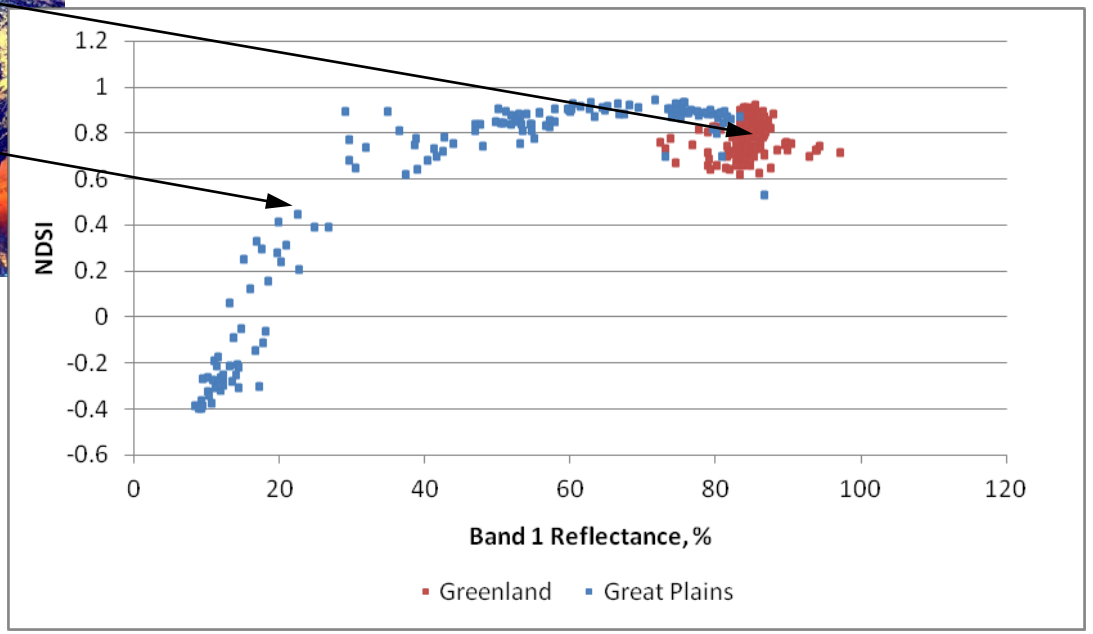


VIIRS Band 1 reflectance appears to be more sensitive to changing snow fraction than NDSI, particularly at large snow fractions. Although it is not demonstrated what approach is more accurate.

Snow Fraction: NDSI vs Reflectance-Based Estimation (2)



VIIRS Band 1 reflectance vs NDVI
Great Plains and in Greenland



- NDSI “saturates” at large snow fractions (as follows from Great Plains data)
- “Pure snow” cluster is more compact (has less scatter) in Band 1 Reflectance metric than in NDSI (as follows from Greenland data)

Conclusion: Fractional Snow Cover Product (1)

- The **VIIRS Fractional Snow Cover Product** (which is part of the VIIRS Snow Cover EDR) has reached the provisional maturity stage based on the definitions and the evidence shown
  - It satisfies the definition of provisional maturity in most cases
  - The product performance is robust but it can not meet the requirements since the requirements have been formulated assuming a different physical meaning of the snow fraction.

- Most issues uncovered during evaluation of **the VIIRS Fractional Snow Cover Product** originate from the VIIRS Binary Snow Cover product and other products contributing to the Binary Snow Map.

- The provisional effectivity date is October 16, 2012 (MX 6.4), as validation datasets produced after this time formed the basis of our evaluation.

Conclusion: Fractional Snow Cover Product (2)

- To meet the product accuracy requirements the current **VIIRS Fractional Snow Cover Algorithm** has to be replaced by a more advanced algorithm estimating the sub-pixel snow cover fraction

- Near-term plan: implement the NDSI-based algorithm

- Longer-range plan: improve, test and implement the spectral unmixing algorithm, either single-band or multiple-band.

Additional Supporting Documentation

- List reports

  Weekly, monthly, quarterly Progress Reports are posted at

  ftp://ftp.star.nesdis.noaa.gov/pub/smcd/emb/promanov/VIIRS_SNOW

- Publications and Presentations

  Jeffrey R. Key, Robert Mahoney, Yinghui Liu, Peter Romanov, Mark Tschudi, Igor Appel, James Maslanik, Dan Baldwin, Xuanji Wang, and Paul Meade (2013) *Snow and Ice Products from Suomi NPP VIIRS.*

  Romanov P., Appel I. (2012) Mapping Snow Cover with Suomi NPP VIIRS, EUMETSAT Conference, Gdansk, Poland, September 2012.

  Romanov P., Appel I. (2012) Snow cover products from Suomi NPP VIIRS: Current status and potential improvements, IGARSS, Munich, Germany, July 2012.

  Romanov P., Appel I. (2012) Mapping Snow Cover with Suomi NPP VIIRS, NOAA 2012 Satellite Science Week. Meeting. Summary Report. April 30 – May 4, 2012. Kansas City, Missouri.

Additional Supporting Documentation

- Publications and Presentations (cont'd)

Appel. I. (2012) Improved VIIRS Snow Cover Information for Terrestrial Water Cycle Applications. AGU Chapman Conference on Remote Sensing of Terrestrial Water Cycle, Kona, Hawaii, February 2012.

Appel. I. (2012) Validation and Potential Improvements of the NPP Fractional Snow Cover Product Using High Resolution Satellite Observations. 32nd EARSeL Symposium and 36th General Assembly, Mykonos, Greece, May 2012.

Appel I. (2013) Remote Sensing Information for Snow Monitoring. Third International Symposium on the Arctic Research, Tokyo, Japan, January 2013.