Request for
VIIRS Snow Cover EDR
(*Binary Snow Cover only*)
Validated Stage 1 Maturity

Validated Stage 1 Effectivity Date: 15 October 2012 (MX 6.4)

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8 January 2014

Outline

- VIIRS Snow Cover EDR: Specifications and Algorithms
- Binary Snow Cover
  - Maturity Evaluation
  - Maturity 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

Stage 1 EDR Maturity Definition

Using a **limited** set of samples, the algorithm output is shown to meet the threshold performance attributes identified in the **JPSS Level 1 Requirements Supplement with the exception of the S-NPP Performance Exclusions**. The list of required artifacts supporting each stage of Validated Maturity:

- Algorithm Assessment
  - Evaluation of algorithm performance to specification requirements
  - Evaluation of the effect of required algorithm inputs
  - Error Budget
  - Quality Flag analysis/validation
  - Input from key users
- Identification of the processing environment
  - IDPS Build Number and effectivity date
  - Version of LUT(s) used
  - Version of PCT(s) used
  - Description of environment used to achieve particular stage of Validated
- Documentation
  - Current or updated ATBD
  - Current or updated OAD (algorithm-related redline updates, if applicable)
  - README file for CLASS
  - Product User's Guide (Recommended)
- User Precautions
  - Identification of known issues
  - List of closed Discrepancy Reports between previous maturity milestone and current maturity milestone.
- Assessment of outstanding Discrepancy Reports

VIIRS Snow Cover EDR: Summary

- 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. **Snow fraction is <u>not</u> addressed in this review.**
- The Binary Snow Mask provides a mapping of snow covered areas as either containing or not having snow
- Binary Snow Mask is derived at the VIIRS imagery resolution under clear sky conditions using daytime observations.
- The performance of the product is largely dependent on the quality of the VIIRS cloud mask.

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

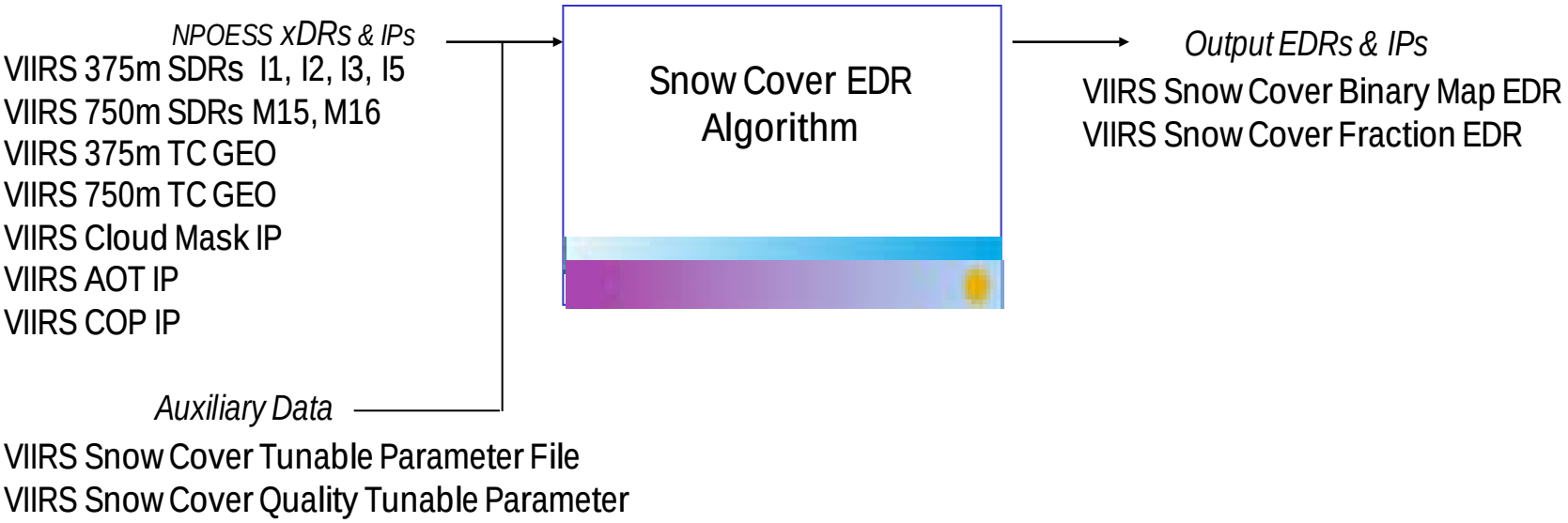
1. The probability of correct snow/no-snow detection applies only to climatologically snow-covered regions.
2. The accuracy of snow detection does not apply over forested/mountainous areas where snow may be hidden by vegetation or topographic shading.

[Joint Polar Satellite System (JPSS) Program Level 1 Requirements SUPPLEMENT – Final Version: 2.9 June 27, 2013]

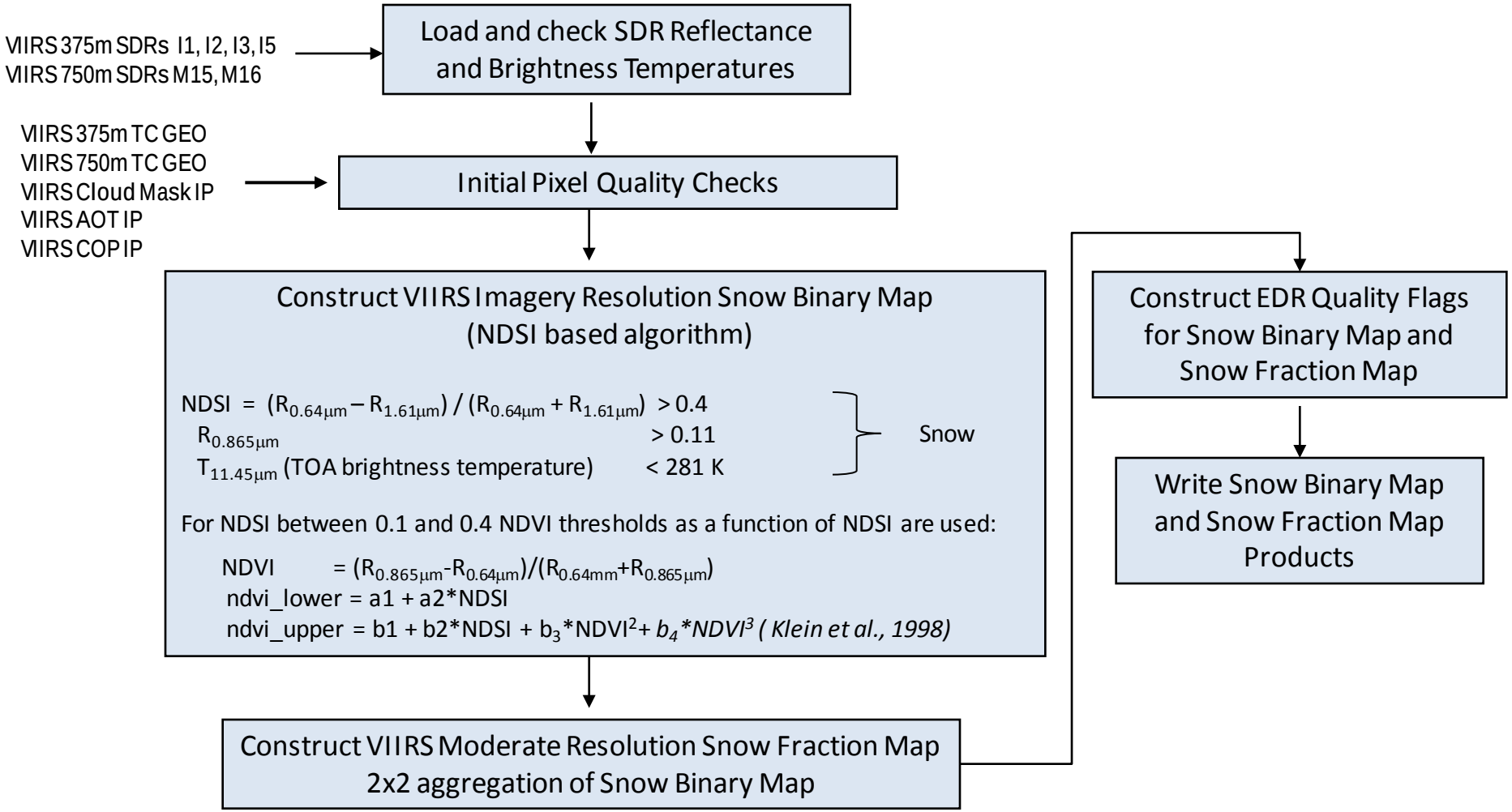
Snow Cover EDR Algorithm

- 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.

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

Validated Stage 1 Maturity Evaluation of the

Binary Snow Cover Map Product

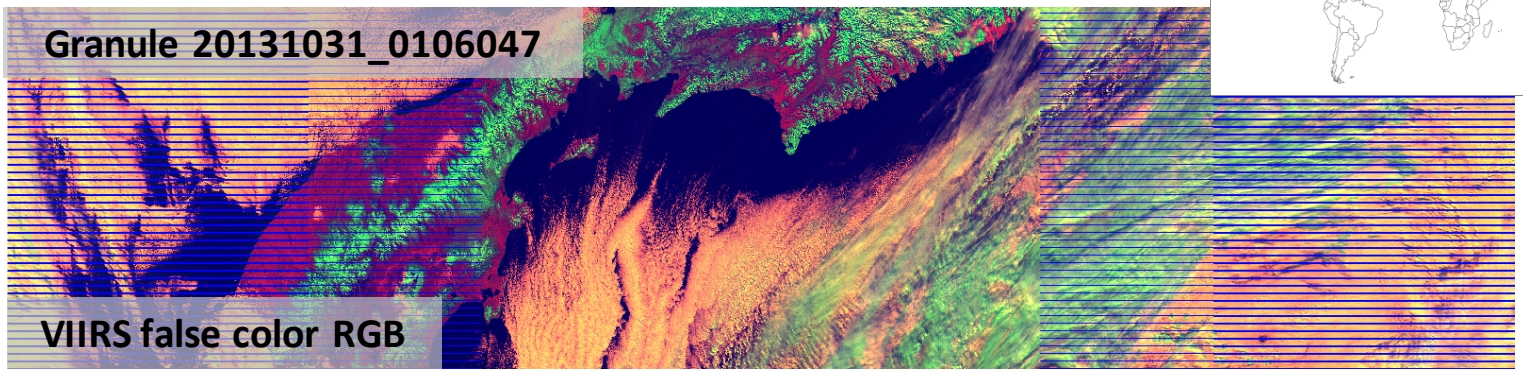
Evaluation Approach (1/2)

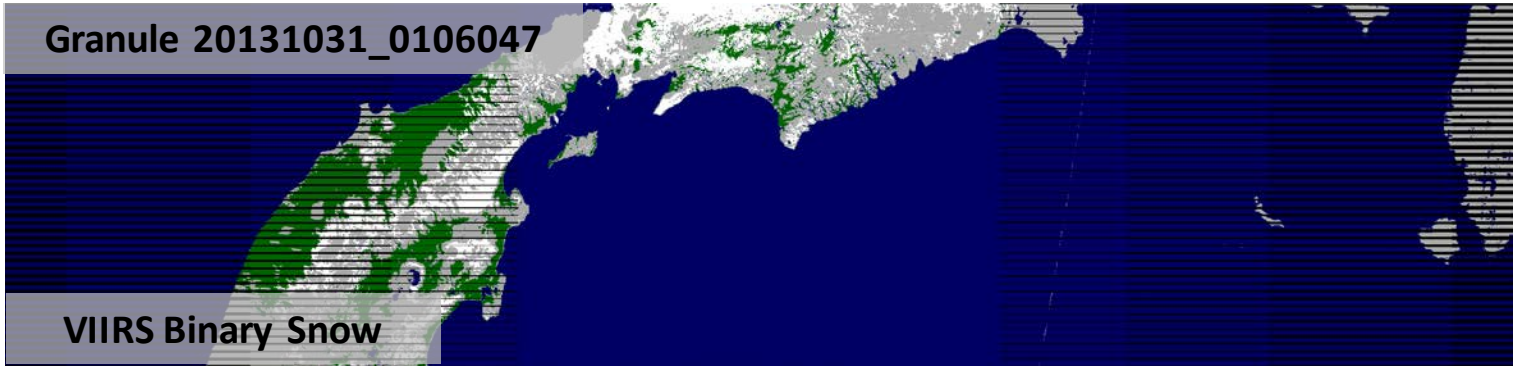
- Evaluation approach:
  - Qualitative visual analysis of the product, focus on
    - General consistency of mapped snow cover
    - Obvious failures of the algorithm/product
      - Missed snow in the regions which are known to be snow covered
      - Mapped snow in the regions which are known to be snow-free
      - Misclassification of clear-sky snow-covered or snow-free scenes as "cloudy"
  - Qualitative and 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)

Evaluation Approach (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 December 2013 (over 1 year)
      - No major changes to the VIIRS cloud mask (VCM)
    - VIIRS global snow cover data were acquired, processed and examined on every third day prior to October 2013 and daily afterwards. Over 160 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

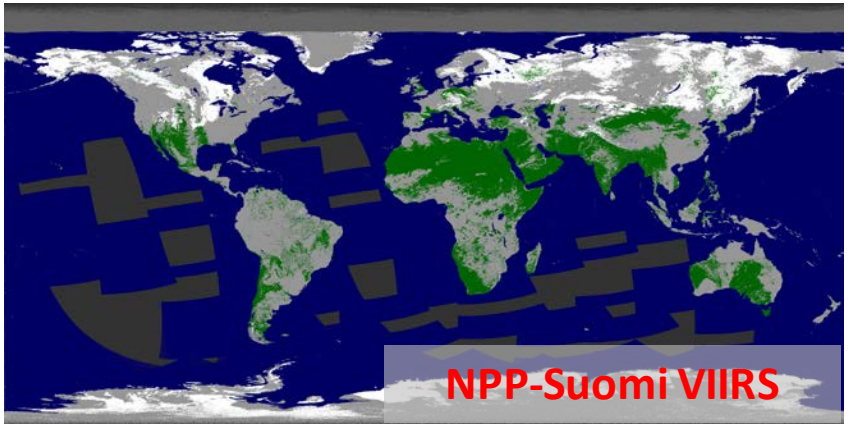
Stage 1 Maturity Evaluation – Granule Level



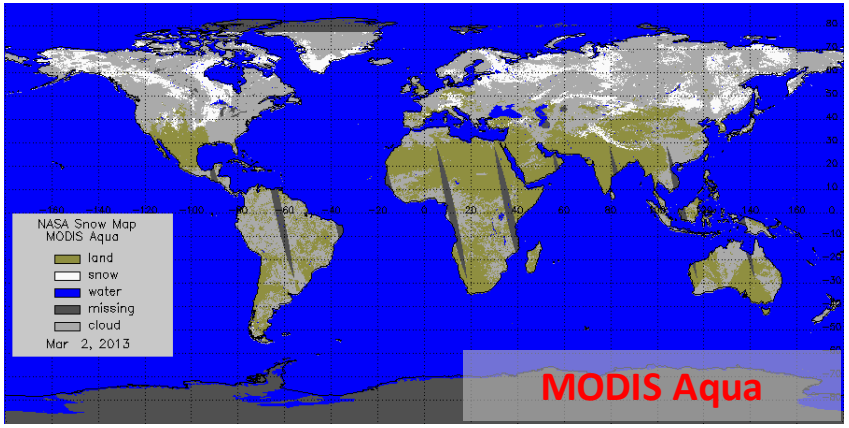


Overall, good qualitative agreement between the snow cover seen in VIIRS false color images and mapped in the VIIRS binary snow cover product.

Stage 1 Maturity Evaluation – VIIRS vs MODIS Snow Map



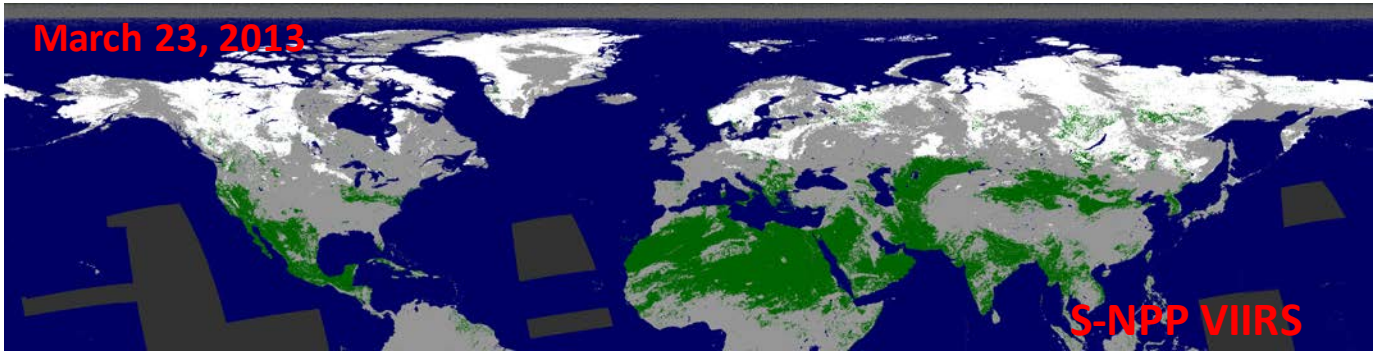
VIIRS binary snow maps compare well to MODIS Terra & Aqua snow maps. There are some differences in the cloud mask applied in the VIIRS and MODIS products.



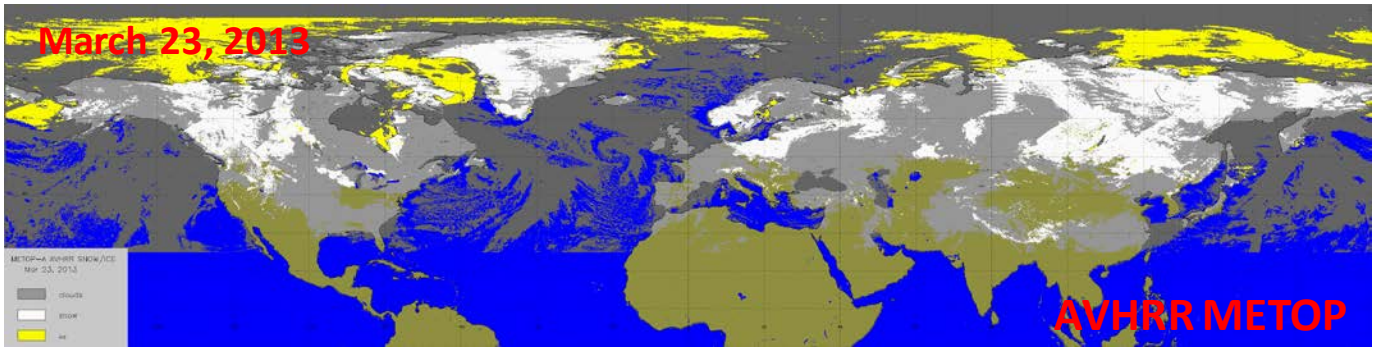
March 2, 2013 (day 2013061)

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

Stage 1 Maturity Evaluation – VIIRS vs AVHRR Snow Map

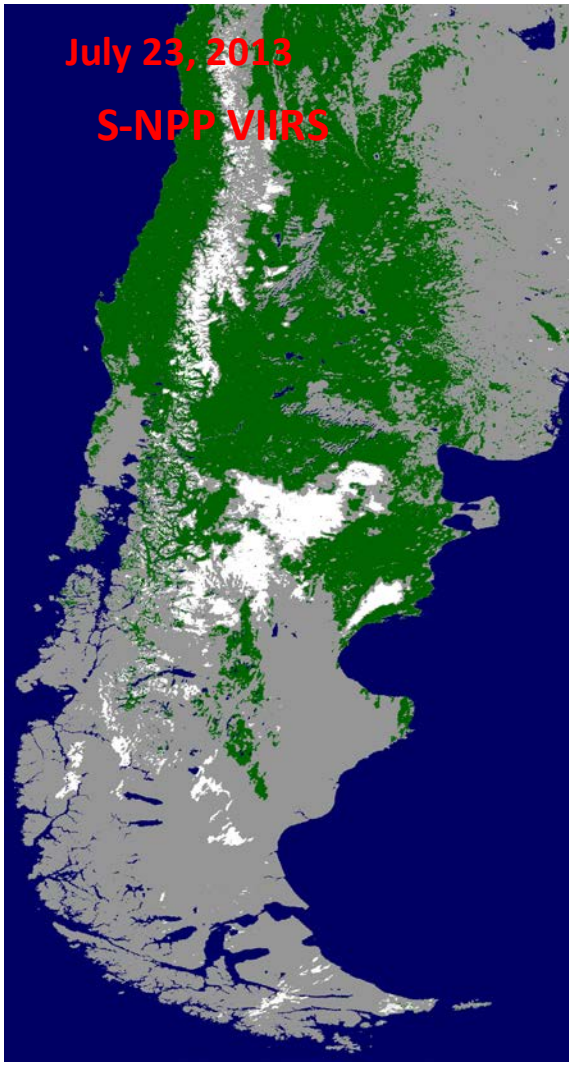


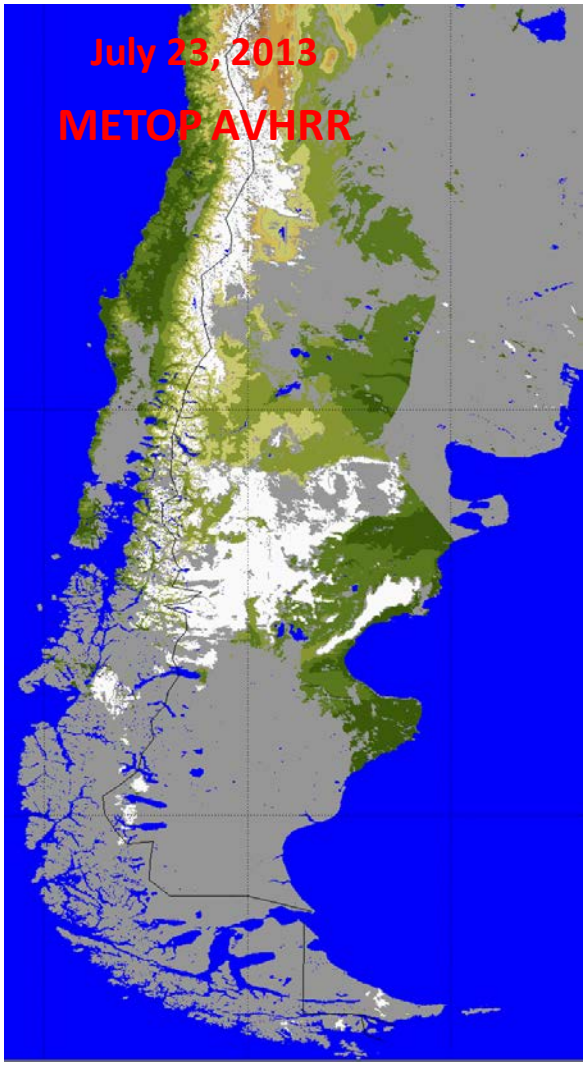
snow land cloud No data



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

Stage 1 Maturity Evaluation – VIIRS vs AVHRR Snow (South America)





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

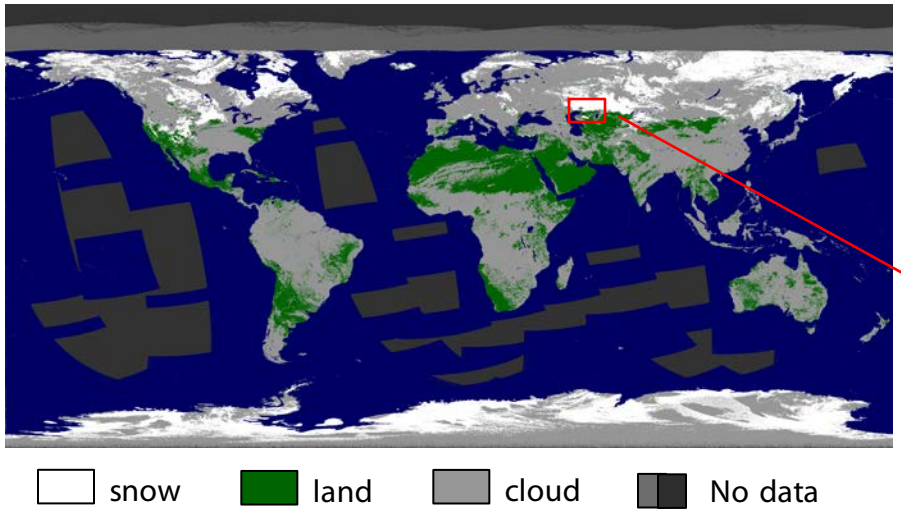
South America

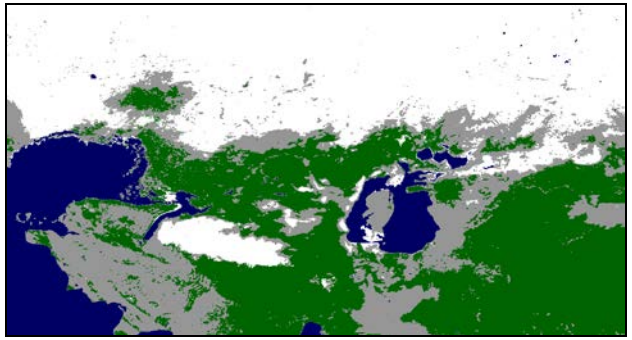
snow land cloud No data

Stage 1 Maturity Evaluation - VIIS vs NOAA IMS

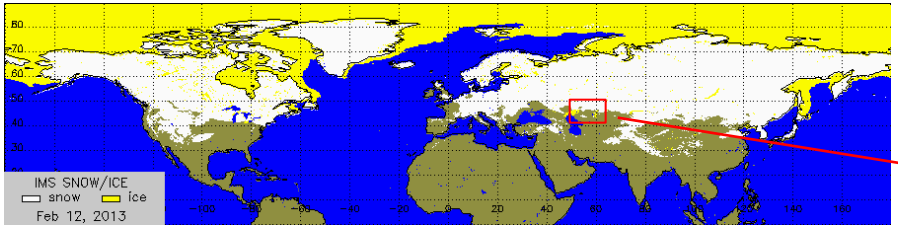
In clear sky portions of the image snow cover identified by VIIRS closely corresponds to the snow cover mapped interactively by IMS analysts.

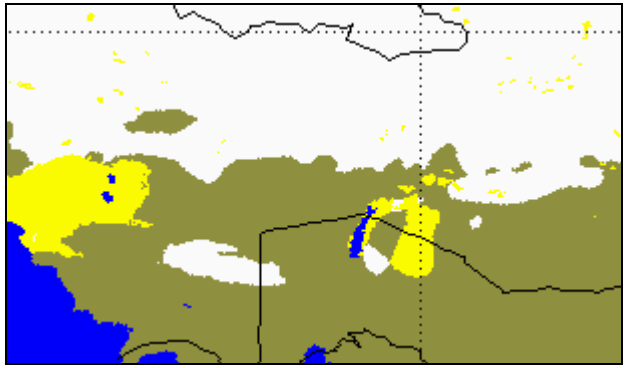
VIIRS snow map





IMS Snow and Ice Chart

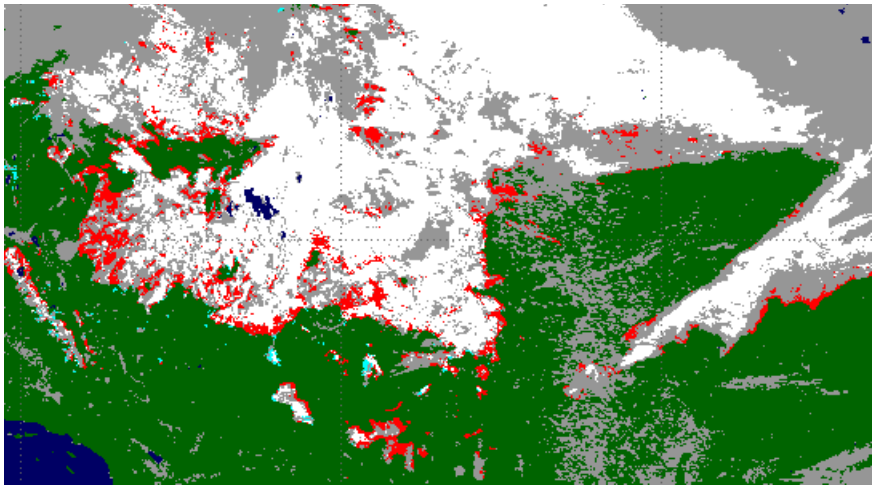




February 12, 2013

Stage 1 Maturity Evaluation – VIIRS vs NOAA IMS: Overlay

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

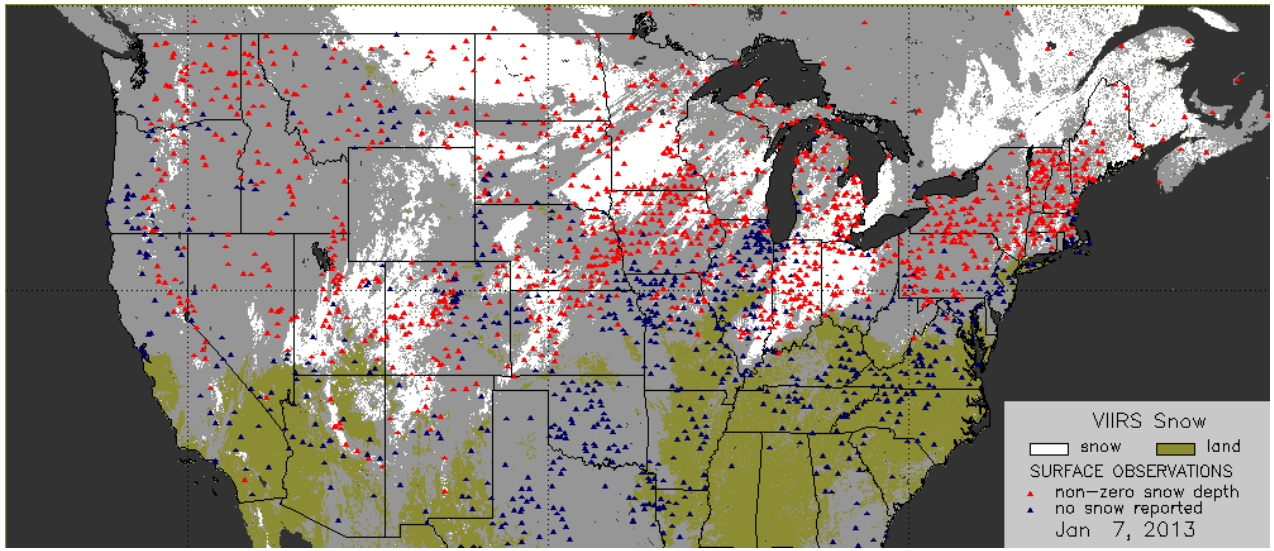


White: VIIRS & IMS snow, Light Gray: VIIRS clouds, Green: VIIRS & IMS snow-free land, Dark gray: no data

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.

Stage 1 Maturity Evaluation – VIIRS Snow Map vs In Situ Observations



VIIRS snow map with station observation data on snow overlaid

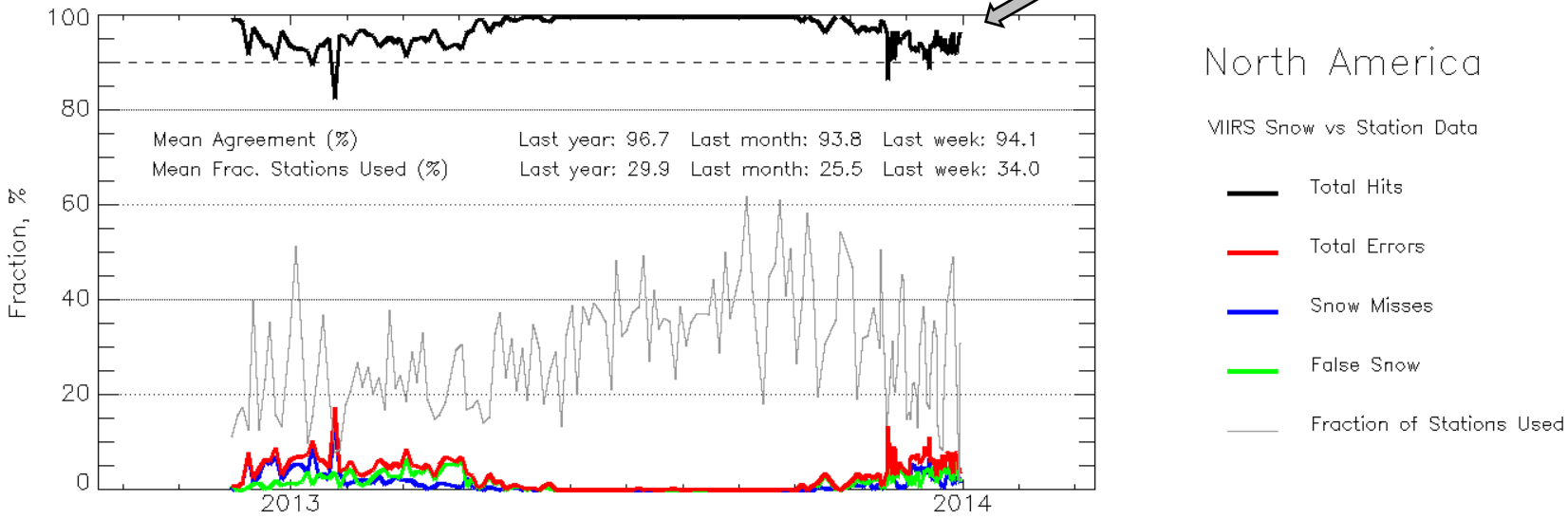
Observations from WMO and US Cooperative network stations over Conterminous US and Southern Canada have been used for qualitative and quantitative validation of VIIRS Snow Maps

The number of daily VIIRS-in situ match ups ranged from 150 to 1030

Stage 1 Maturity Evaluation – VIIRS vs Station Data: Daily Statistics

Daily statistics of correspondence between VIIRS snow and in situ data

Percent agreement between VIIRS and in situ data

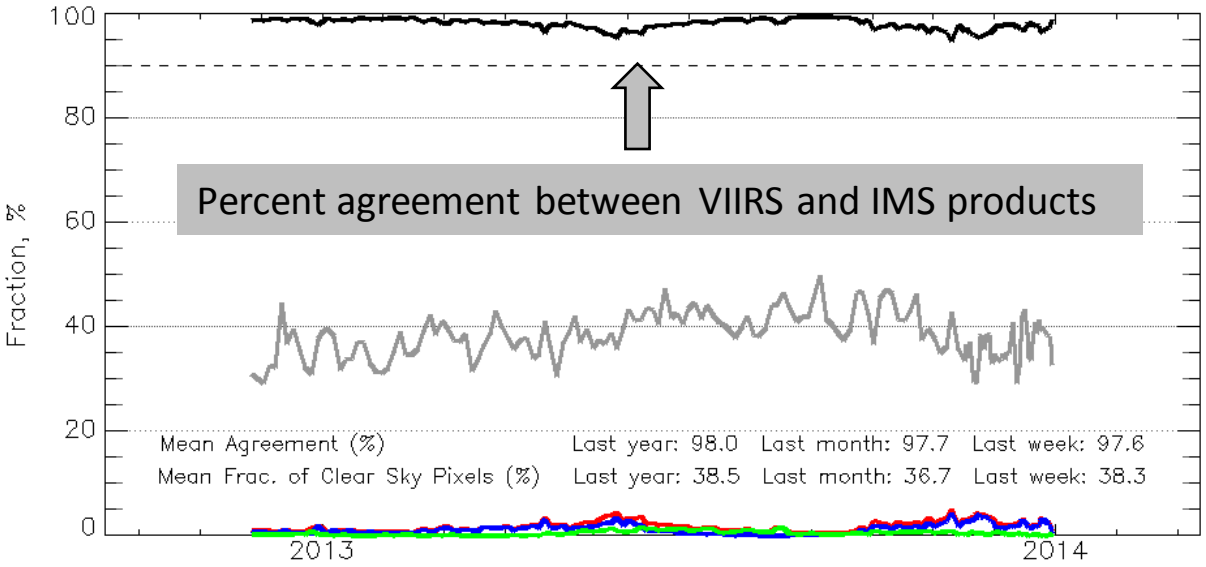


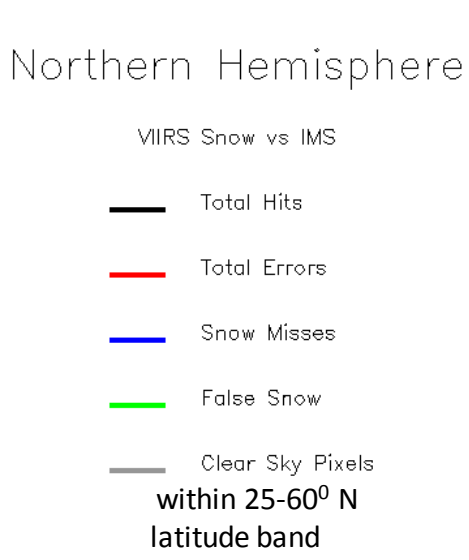
Daily agreement between VIIRS daily snow retrievals and ground station data over CONUS area remains above 90% most of the time. The mean agreement in winter months is close to 94%.

Stage 1 Maturity Evaluation – VIIRS vs NOAA IMS: Daily Statistics

Statistics of daily comparison of VIIRS and IMS

All land area included (no account for snow cover climatology)





Since the end of 2012 over Northern Hemisphere

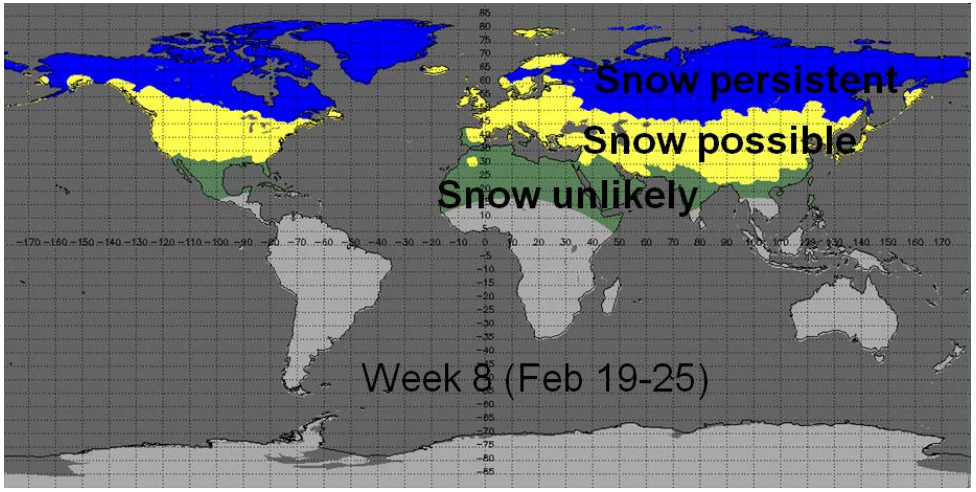
- The yearly mean agreement between daily VIIRS and IMS products was 98%.

- 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

Stage 1 Maturity Evaluation – Considering Snow Cover Climatology



Weekly snow occurrence probability based on IMS snow charts since 1972

Proper approach to validation of the snow product should account for the snow cover climatology

Most important is the performance of the product in the region where the snow cover may or may not be present at the given time of the year ("snow possible")

Mean agreement (%) of daily VIIRS snow to IMS in 2013

	Northern Hemisphere	North America	Eurasia
All Land Area	98.0	97.8	98.0
"Snow Possible"	95.1	95.7	94.9

Agreement between the two products drops 2-3 % in the "Snow Possible" region as compared to "All Land"

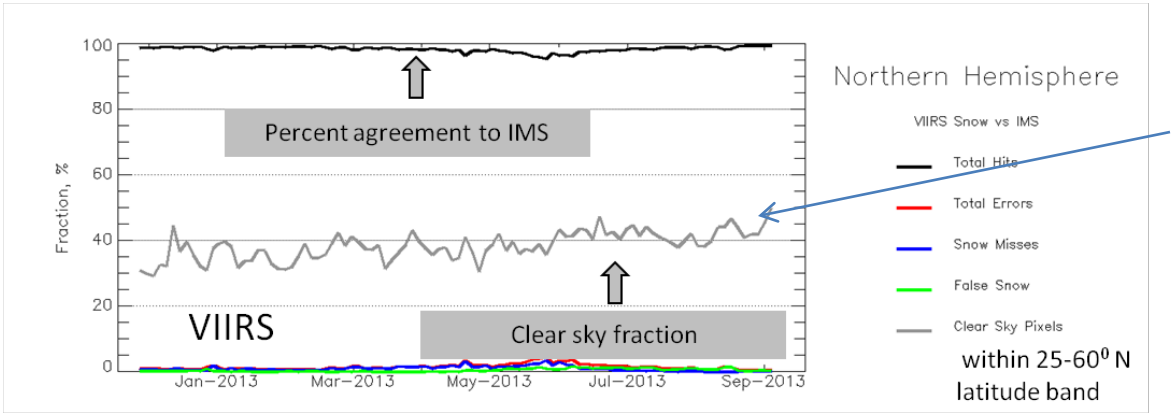
Stage 1 Maturity Evaluation – Product Accuracy Change 2013 vs 2012

VIIRS snow vs IMS in November-December: Comparison Statistics (%)

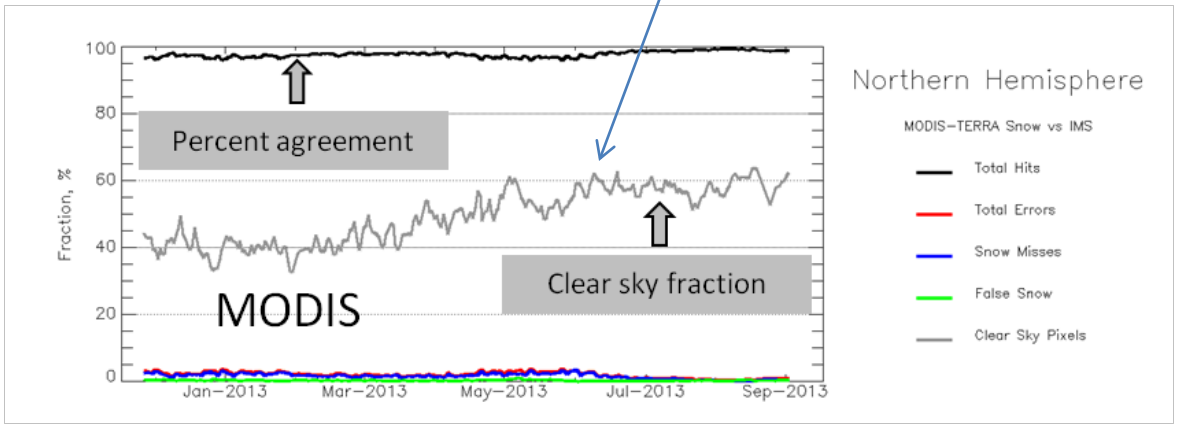
	2012	2013
Northern Hemisphere		
Total Agreement	98.2	97.2
False snow	0.53	0.42
Snow Miss	1.21	2.40
Cloud clear	34.2	42.9

Changes in the product accuracy and error budget from 2012 to 2013 are minor and may be caused partially by different snow cover properties/distribution in the two years and partially by changes introduced to the VCM.

Stage 1 Maturity Evaluation – VIIRS vs MODIS Snow: Different Clear-Sky Fraction



Clear sky fraction in VIIRS and MODIS snow products is noticeably different



In mid latitudes VIIRS VCM identifies considerably more clouds than MODIS. The difference is the largest in late spring and summer. More clouds means smaller effective (clear sky) area coverage of the VIIRS snow cover product.

Stage 1 Maturity Evaluation – VIIRS, AVHRR, MODIS Snow vs IMS

Mean agreement to IMS and cloud-clear fraction of daily automated snow products in 2013 Northern Hemisphere

	Agreement to IMS (%)	*Cloud-clear(%)**
VIIRS	98.0	38.6
MODIS (T)	97.3	49.1
MODIS(A)	97.1	48.3
AVHRR	97.9	55.0

*Cloud-clear fraction is estimated in 25-60^{0}N latitude band

VIIRS agreement to IMS is ~1% better than that of MODIS and AVHRR snow maps, however VIIRS identifies ~10-15% less cloud-clear scenes than MODIS and AVHRR.

Better accuracy of VIIRS snow maps is attained (at least partially) at the expense of reduced effective clear-sky coverage

Identified Problems in the

VIIRS Binary Snow Cover Map Product

Cloud Mask Ambiguity

Neither ATBD nor OAD tells the user how to get the most optimal cloud mask for the product using the 4-category cloud confidence flag. This may cause confusion and incompatibility of snow maps generated from the same VIIRS snow product

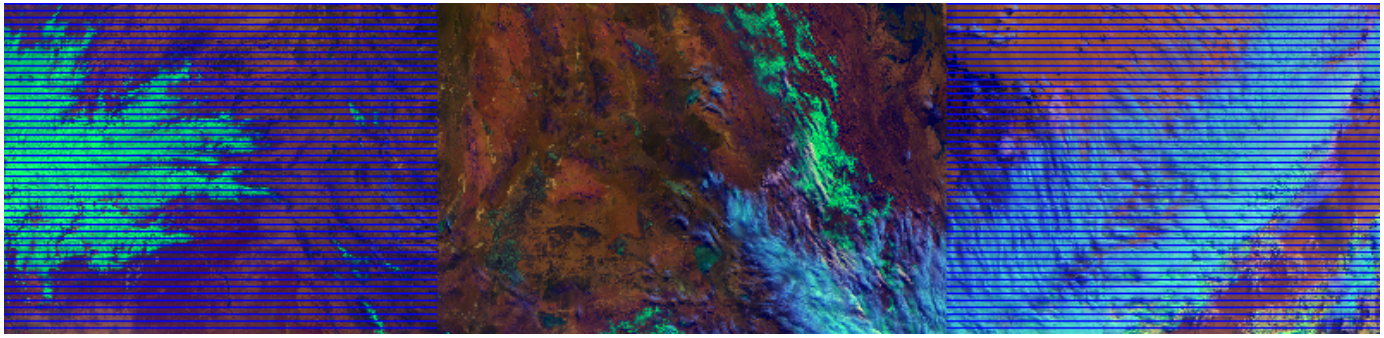
We recommend applying the most conservative cloud mask where only "confidently clear" pixels are assumed cloud-clear.

Using more "relaxed" cloud masks increased the effective area coverage but also results in a substantial increase of snow mapping errors.

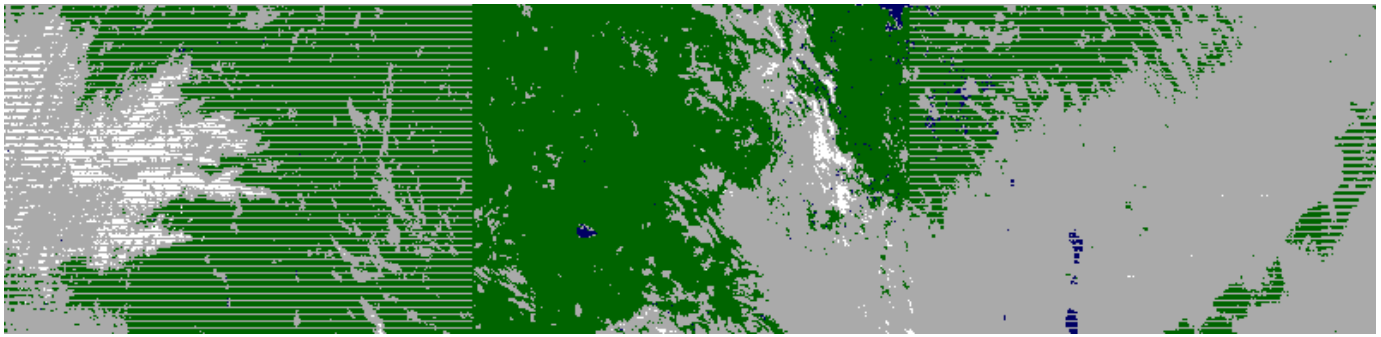
Overestimated cloud extent

Clear snow-covered pixels are often labeled as cloudy.

Most often this occurs along the snow cover boundary and in the mountains.



VIIRS RGB granule image



VIIRS granule snow product

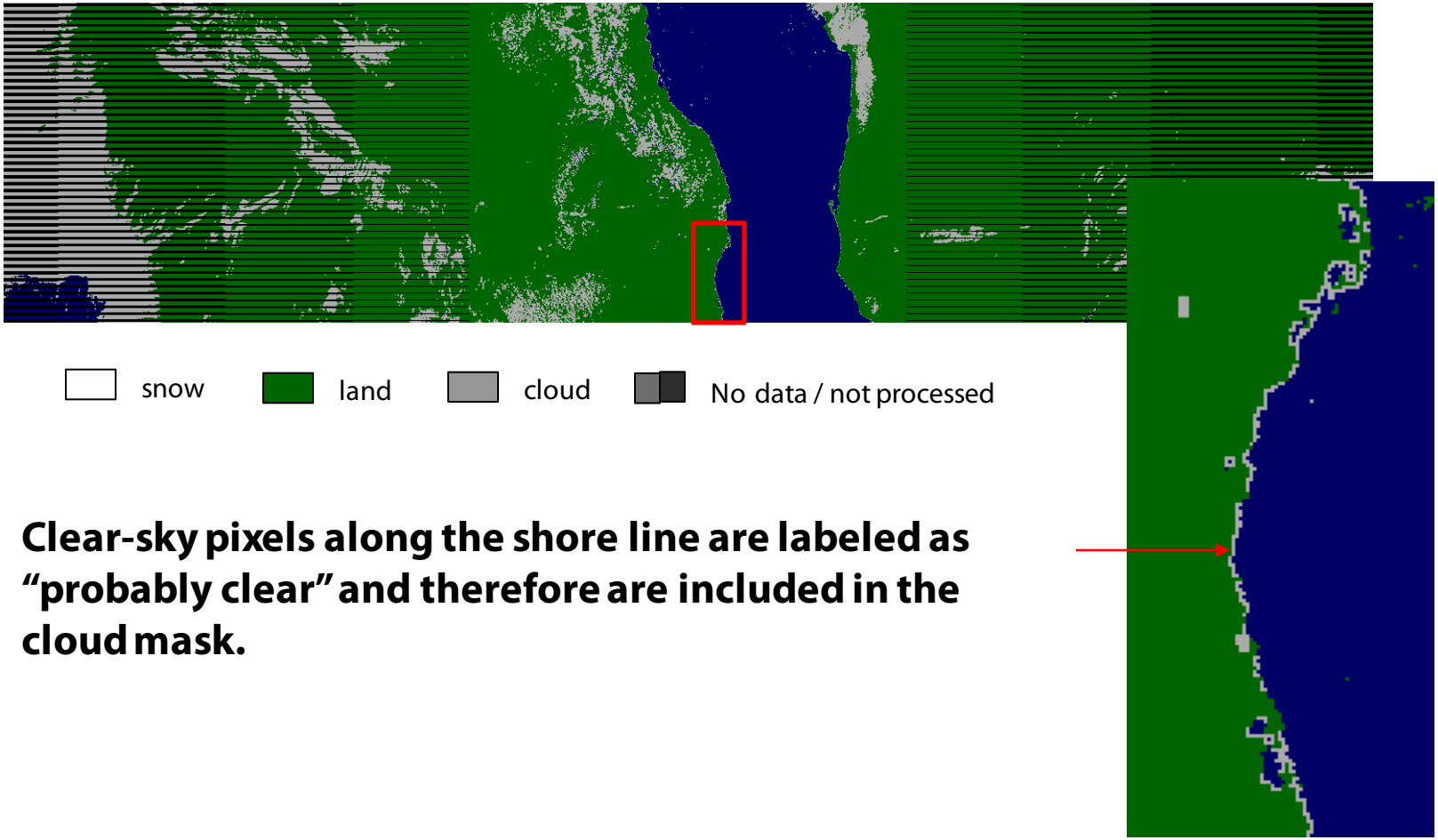
snow land cloud No data / not processed

Covered in VCM presentation

Overestimated cloud extent

Clear snow-covered pixels are often labeled as cloudy.

Most often this occurs along the snow cover boundary and in the mountains.



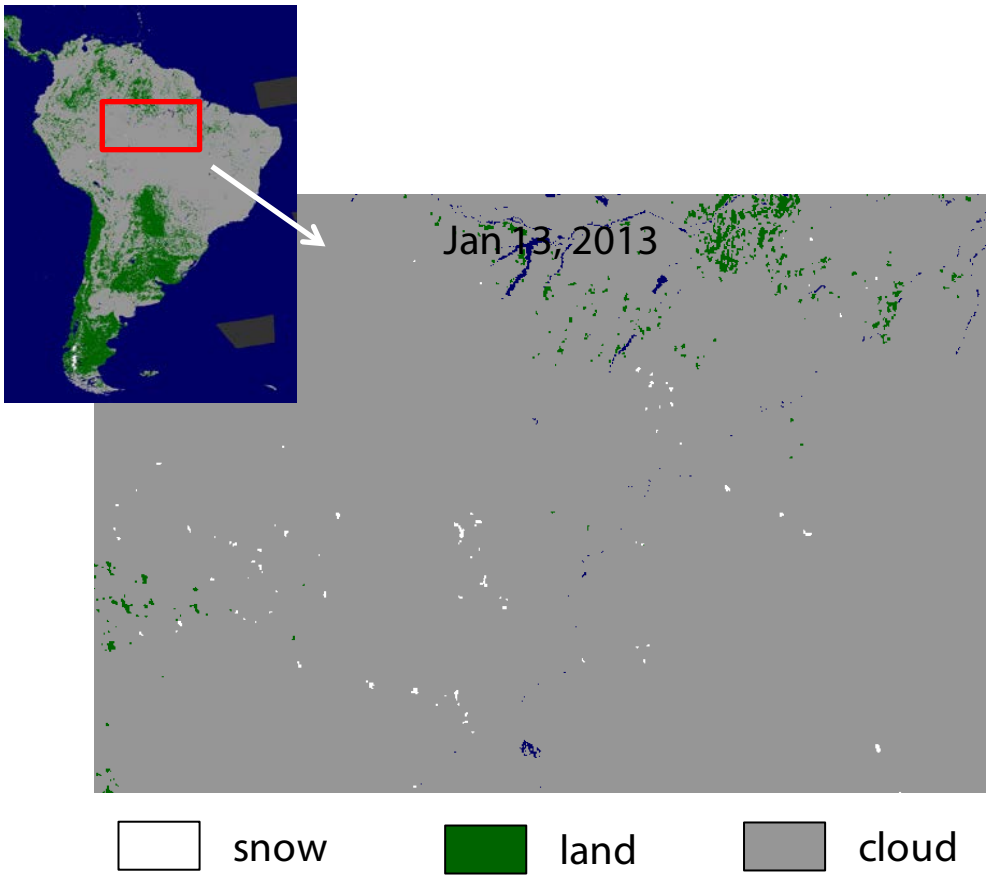
Clear-sky pixels along the shore line are labeled as "probably clear" and therefore are included in the cloud mask.

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.

Update: The problem of missed clouds and subsequent false snow identification in the Amazon and in other tropical areas has been mostly fixed

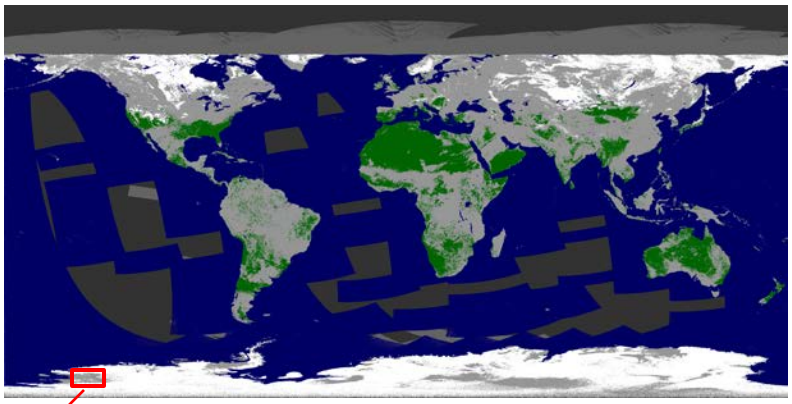


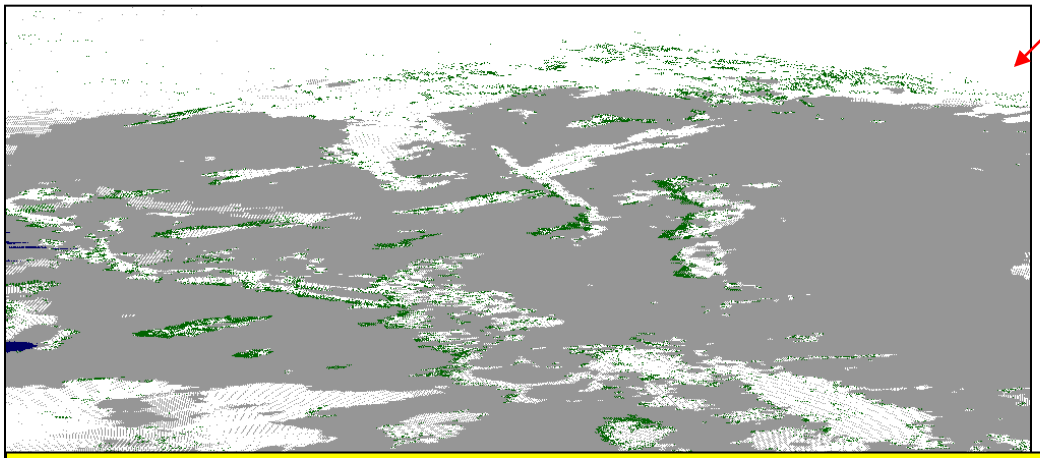
Covered in VCM presentation

Missed Snow due to Cloud Shadows

Occasional failures to detect snow shadowed by clouds.

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





snow

land

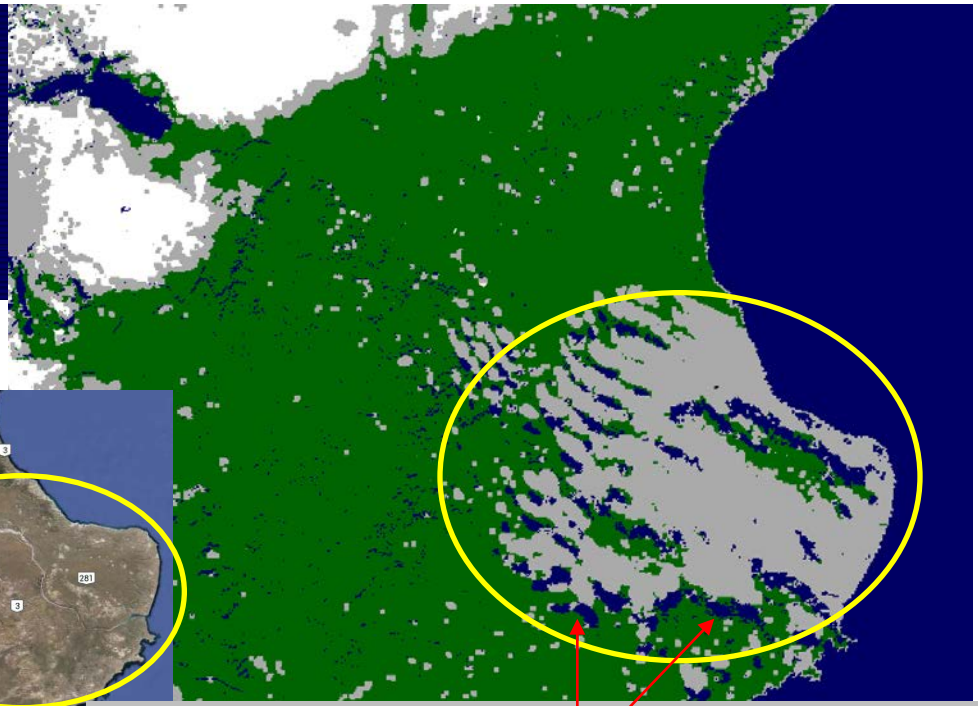
cloud

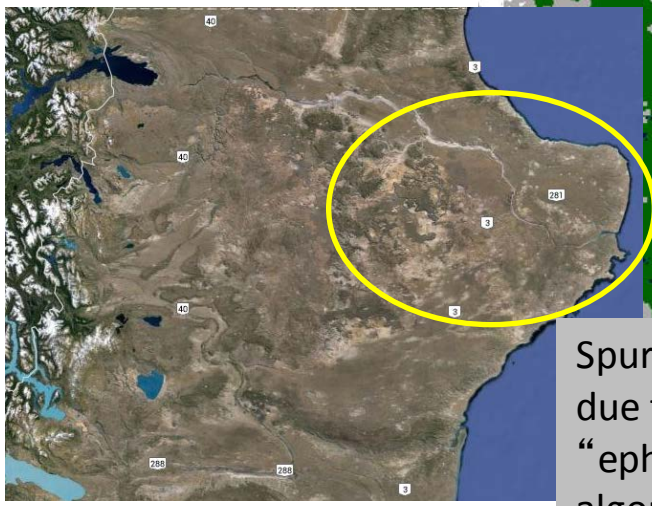
Covered in VCM presentation

Corrupted Land/Water Mask

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.

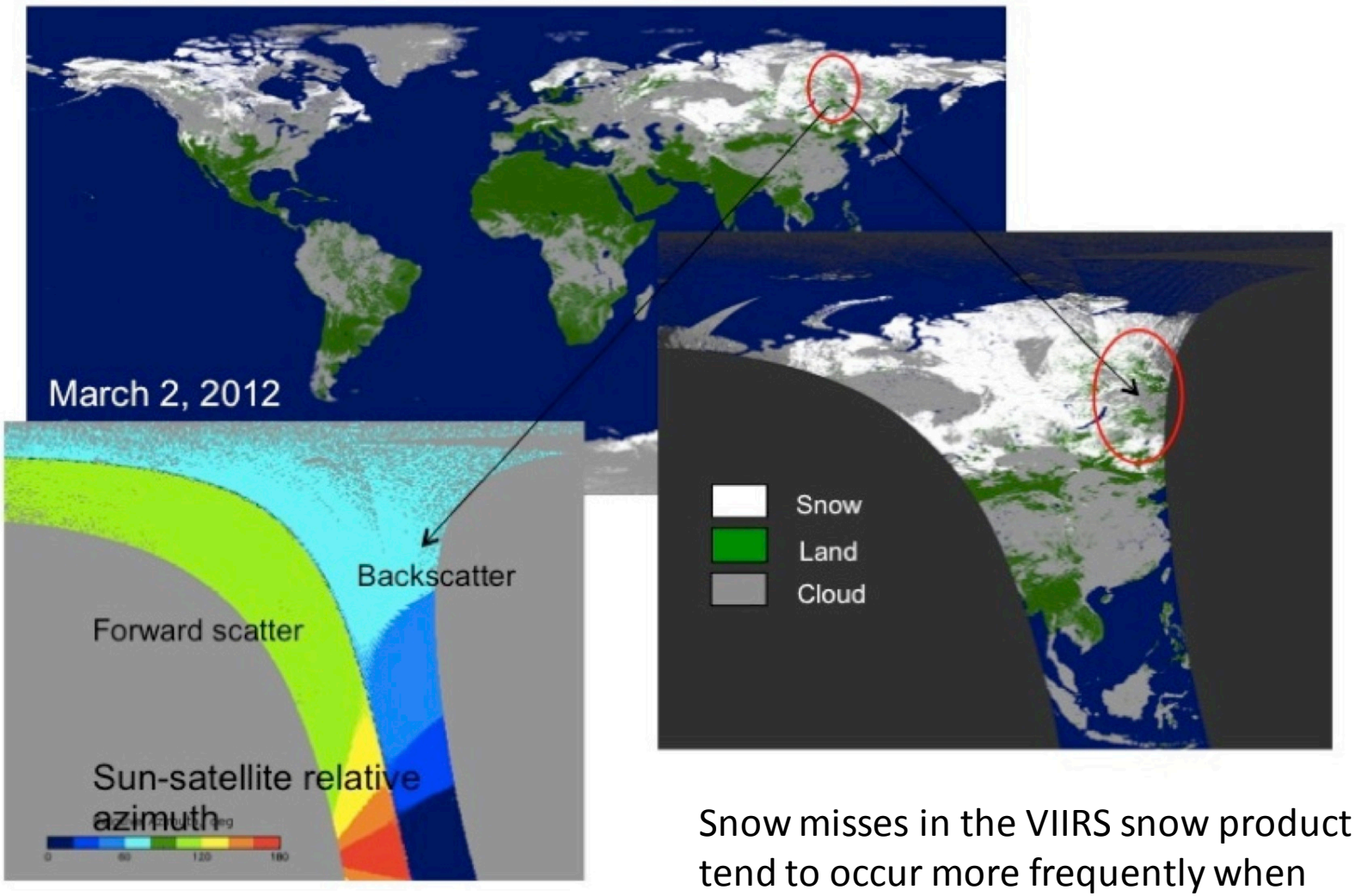
Date&time :20130718_t1838355





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

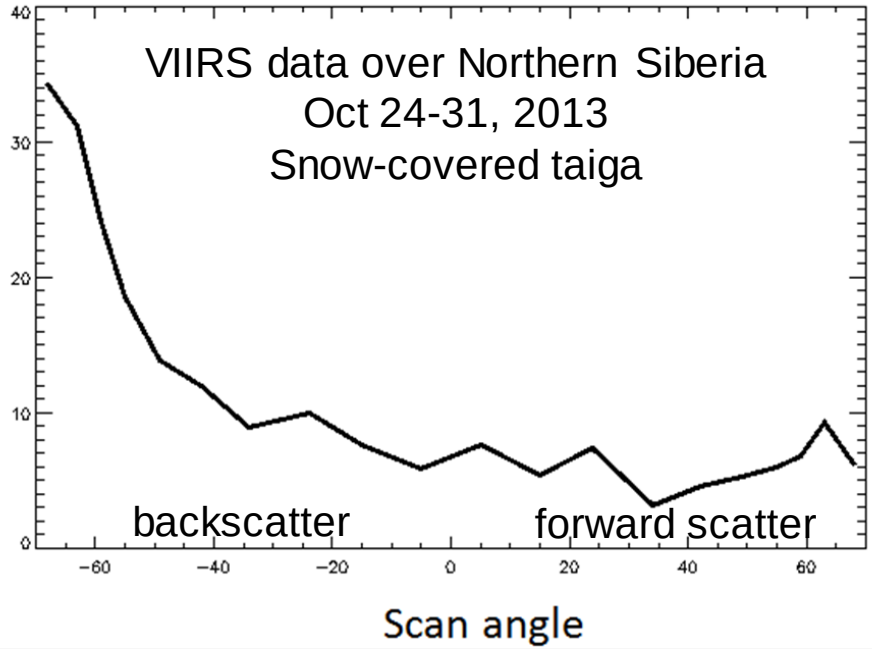
Observation Geometry Effects (1/2)

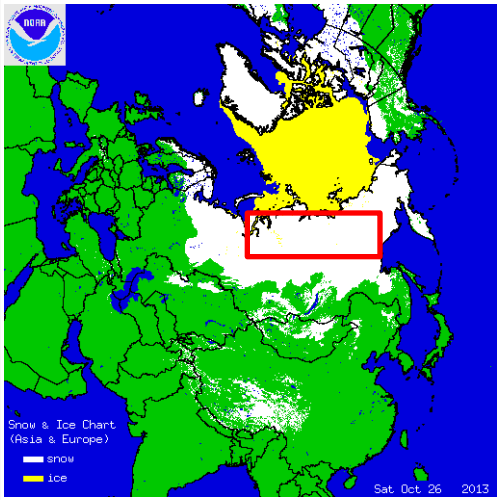


Snow misses in the VIIRS snow product tend to occur more frequently when observations are made in the backscatter

Observation Geometry Effects (2/2)

Probability of snow omission





Efficiency of snow identification decreases at scan edges, most noticeably in the backscatter and over densely forested regions. This is partially due to the fact that the snow detection algorithm does not account for changing surface reflectance with view geometry.

Quality Flags

- Overall: 16 quality flags
  - Related to SRDs, clouds, aerosol, observation geometry, land/water, surface type, results of spectral threshold test applied
  - Some flags are not obviously relevant (e.g., cloud phase, fire, snow fraction exclusion)

- Most Important flags have been checked
  - Cloud Confidence
  - Land/Water
  - Input SDR quality
  - Solar zenith angle exclusion

Discrepancy Reports (DRs)

Date	Update/DR#	Reason	Status
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	Completed Updated VIIRS-SCD-SNOW-COVER-LUT Revision Date: 2/11/2011 Source Version: ISTN_VIIRS_NGST_3.3.5 Source Files:snow_cover_btmax281K.lut Provenance Version ID: 1-D-NPP-2
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	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 VIIRS-SCD-SNOW-COVER-QUAL-LUT Revision Date: 08/23/2012 Source: CCR-12-480 Provenace Version ID: 1-0-CCR-12-480-JPSS-DPA-003; Build Identifier: Mx7
04-12-2013	Request for Beta Maturity Status for VIIRS Cryospheres EDRs and Ips/DR7132	Approval requested for the Snow Cover EDR .	Completed

Justification Summary (1/2)

Algorithm/Product Assessment

- Performance: The product meets accuracy requirements under most conditions. Evaluation is based on an over 1-year long time period of analysis from October 2012 to December 2013 and involves VIIRS global snow cover retrievals. The product can be offered for evaluation by the community, however the users has to be warned that product has flaws.
- Impact of algorithm inputs: Non-optimal performance of VCM results in occasional "false snow" identifications and frequent labeling of partially snow covered scenes as "cloudy".
- Error Budget: Daily agreement with IMS is generally within 94-98% depending on whether the snow cover climatology is accounted for or not. The rate of agreement to the station data is 3-4% less. In both cases the accuracy of he product is within the required 90% probability of correct typing.
- Quality flag analysis: Land/water flag provided with the product may be set incorrectly. Cloud shadows and topographical shadows are frequently interpreted by the VCM as "ephemeral water" and the land water mask is modified accordingly. No problems in setting of other flags have been found.
- Input from users: The primary user is the National Ice Center. A NIC presentation was given at the Snow Cover EDR Provisional Maturity Review.

Justification Summary (2/2)

Processing Environment

- IDPS build and effectivity date: MX 6.4, 15 October 2012
- Version of LUT(s): VIIRS-SCD-SNOW-COVER-LUT_npp_20020101010000Z_20020101010000Z_ee000000000000Z_PS-1-D-NPP-2-PE-_devl_dev_all-_all (2010 NPP prelaunch)
- Version of PCT(s): VIIRS-SCD-SNOW-COVER-QUAL-LUT_npp_20120501000000Z_20120501000000Z_ee000000000000Z_PS-1-0-CCR-12-480-JPSS-DPA-003 (Updated by DR4787; implemented on IDPS operational system 11/30/2012)

Documentation

- ATBD: ATBD is accurate, up-to-date and consistent with the current product
- OAD: Operational Algorithm Description is accurate, up-to-date and consistent with the current product
- README file for CLASS: Will be produced (based on the Report)
- Product User Guide: Deemed unnecessary given the abundance of other documentation on algorithms, data formats, and cautionary notes

User Precautions

- Identification of known issues: Known issues are identified in the current presentation and in the corresponding in the Report. They will also be included in the README file to CLASS
- Discrepancy Reports: Issues are being addressed

Future Plans

- 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
- Detailed characterization of the product performance
  - Comprehensive evaluation of the product stratified by the season of the year, climatic/geographic zone, surface cover type, observation geometry
  - More detailed analysis of the algorithm and product performance at local scales
- Continued evaluation of the product quality flags
- Some changes/modifications to the Binary Snow Map algorithm are currently considered
  - Replace fixed snow detection threshold values with variable values that depend on the observation geometry.

Conclusions

- The **VIIRS Binary Snow Cover Product** (which is part of the VIIRS Snow Cover EDR) has reached the Validated Stage 1 maturity level based on the definitions and the evidence shown

- Issues have been uncovered during validation of **the VIIRS Binary Snow Cover Product** and solutions are being evaluated.
  - Improvements in the Snow Cover EDR performance are expected with improved performance of the VCM

- The Validated Stage 1 effectivity date is October 16, 2012 (MX 6.4), as validation datasets produced after this time formed the basis of our evaluation.

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

  https://groups.ssec.wisc.edu/groups/jpss/cryosphere/reports

- TIM Meetings and Presentations

  Cal/Val Team Meeting, April 2012

  TIM on snow/ice rolling tiles, June 2012

  TIM on snow/ice rolling tiles, July 2012

  DRAT on gridding, September 2012

  TIM on automated snow/ice map use in Rolling Tiles, February 2013

  TIM on gridding, April 2013

  TIM on snow cover fraction, May 2013

  Meeting with Surface Type EDR group, July 2013

- Publications and Presentations

Key R.J., R. Mahoney, Y. Liu, P. Romanov, M. Tschudi, I. Appel, J. Maslanik, D. Baldwin, X. Wang, and P. Meade (2013) Snow and Ice Products from Suomi NPP VIIRS. *Accepted in JGR.*

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

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. (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.

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

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

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