The Influence of Observation Geometry on the Quality of VIIRS Snow Products

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Introduction

The first Visible/Infrared Imager Radiometer Suite (VIIRS) onboard S-NPP platform was launched in October 2011. Along with a large number of other land surface, ocean, atmosphere and cryosphere products, VIIRS observations are used to routinely map and monitor the global distribution of snow cover.

Routine generation of the snow cover product with NPP VIIRS data started in January 2012. Daily snow cover maps are produced operationally at the finest spatial resolution of 375m. In this poster, the results of the analysis of the VIIRS snow cover product are presented and the performance of the algorithm is estimated. The algorithm performance is evaluated through a qualitative visual comparison of the derived maps with false color imagery data as well as through quantitative comparison at a pixel resolution.

VIIRS Instrument, Snow Cover Algorithm and Product

VIIRS is a 22-channel scanning radiometer which provides observations in the wavelength range from the visible to infrared. The nominal spatial resolution is 375 m for imagery resolution spectral bands and 750 m for moderate resolution spectral bands (see Table on the right).

Snow algorithm:
-Very similar to the one of MODIS
- Bands used: I1, I2, I3 and I5
- Threshold-based, decision tree technique
- Spectral features used: NDVI, NDSI, $I_{2,}$, I_5
- External cloud mask is applied

Snow Product accuracy requirement:
90% probability of correct typing

VIIRS binary snow map product is provided and validated as 5-min granules in the natural swath projection (along track / scan) at 375m resolution (see snow granule image examples in the section below) . About 500 daytime granules per day are generated.

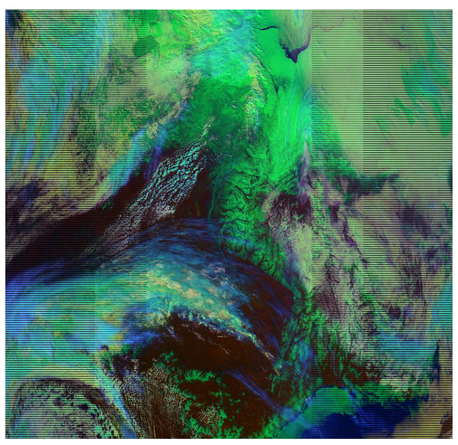
NPP VIIRS spectral bands

VIIRS Band	Spectral Range (μm)	Nadir HSR (m)
DNB	0.500 - 0.900	
M1	0.402 - 0.422	750
M2	0.436 - 0.454	750
M3	0.478 - 0.498	750
M4	0.545 - 0.565	750
I1	0.600 - 0.680	375
M5	0.662 - 0.682	750
M6	0.739 - 0.754	750
I2	0.846 - 0.885	375
M7	0.846 - 0.885	750
M8	1.230 - 1.250	750
M9	1.371 - 1.386	750
I3	1.580 - 1.640	375
M10	1.580 - 1.640	750
M11	2.225 - 2.275	750
I4	3.550 - 3.930	375
M12	3.660 - 3.840	750
M13	3.973 - 4.128	750
M14	8.400 - 8.700	750
M15	10.236 - 11.263	750
I5	10.500 - 12.400	375
M16	11.538 - 12.488	750

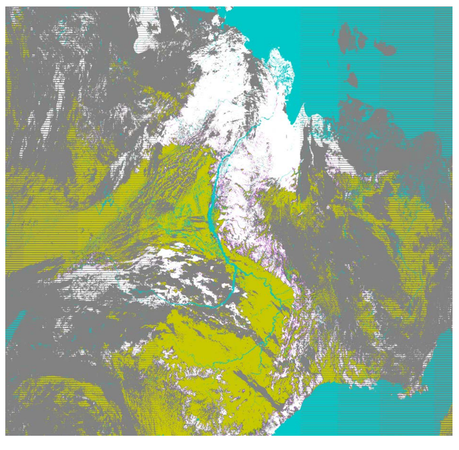
Spectral bands used in the snow mapping algorithm are shown in yellow

Qualitative estimate of VIIRS Snow Map Binary Product

Near snow line

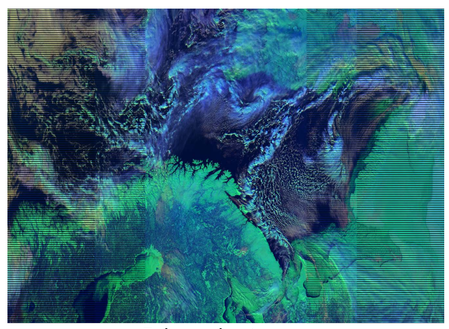


False color image

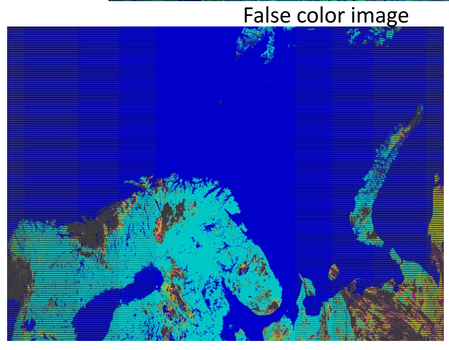


Snow cover retrieval

Within snow-covered areas



False color image



VIIRS cloud mask confidence



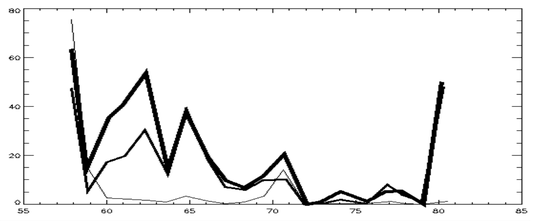
Snow cover retrieval

Approach to Quantitative Estimate of VIIRS Snow Product

Proper validation is a critically important means to improve snow cover retrieval. The careful detailed validation of VIIRS snow data on the basis of comparison with the ground truth for a variety of conditions provides valuable information on the reasons of retrieval errors and helps identify the directions to improve the snow products.
The geometry of VIIRS observations is included in the stratified analysis of the VIIRS snow algorithm performance. As a first approximation, the illumination and viewing geometry of observation are parameterized by latitude and a scam angle.

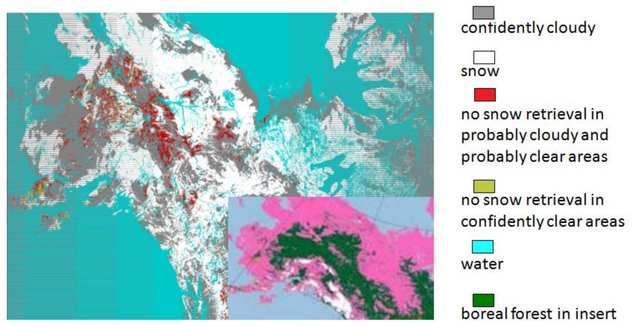
Influence of Solar Zenith Angle and Surface Type

The analysis shows that the probability of omission errors typically decreases toward North and South which indicates a secondary role of the solar zenith angle.



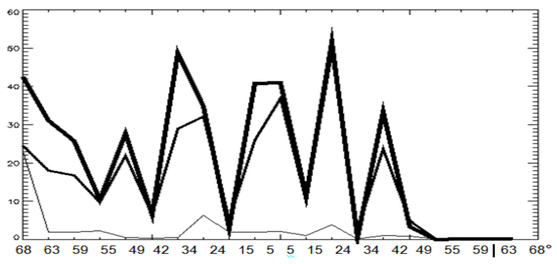
The probability of omission errors as a function of latitude for probably cloudy (thick), probably clear (medium) and confidently clear (thin) conditions

In many cases, increased percentage of missing snow is observed in the regions of the boreal forest. Missing snow (red and yellow) is not necessarily related to clouds.



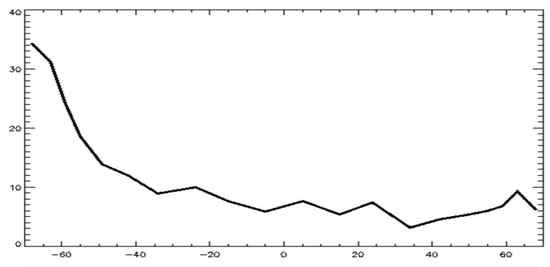
Influence of Scan Angles on Omission Errors

On the whole, the omission errors for probably clear and probably cloudy areas change across the scan in similar manner, while the shape of the changes for confidently clear regions is quite different.



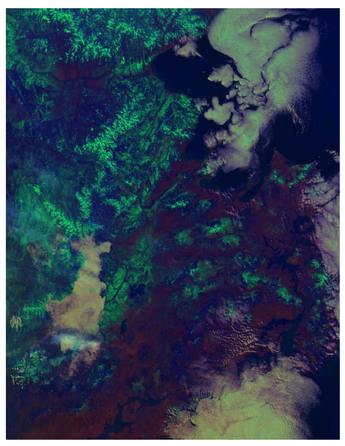
The probability of omission errors as a function of a scan angle for probably cloudy (thick), probably clear (medium) and confidently clear (thin) conditions

The influence of the scan angle on omission errors is better revealed for confidently clear areas having weaker dependence on cloudiness and surface type. In typical cases, the probability of omission errors rises significantly toward the ends of scans.

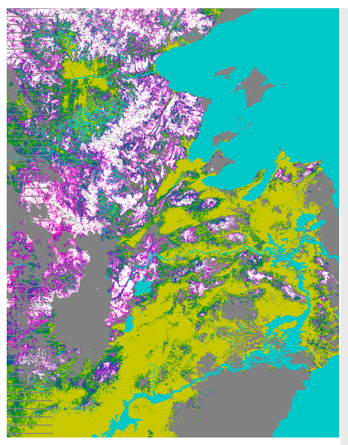


The probability of omission errors averaged over all observations in Siberia during the period of October 24-31, 2013 as a function of a scan angle

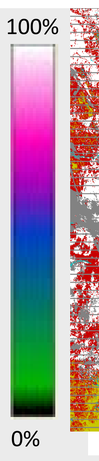
Fractional Snow Diminishes Omission Errors and Enhances Information



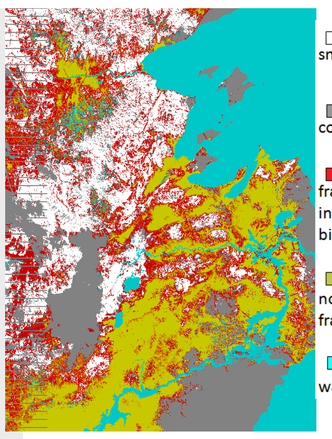
False color image



Snow fraction retrieval



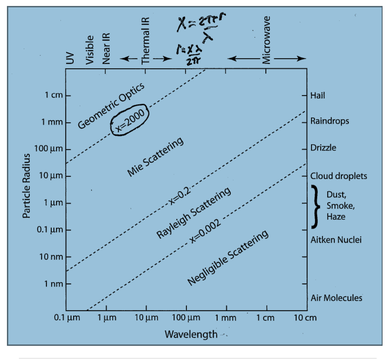
Palette



Fractional product increases snow extent

Analytical Asymptotic Description of Radiative Transfer in Snow

It has been demonstrated that the means of geometric optics could describe angular dependencies related to bidirectional snow reflectance, and a simple asymptotic analytical model could be used to calculate theoretically bidirectional reflectance.



Scattering regimes

Resulting Equation for Reflectance

$$R(\mu,\nu,\varphi) = R_0(\mu,\nu,\varphi) - \lambda K_0(\mu) K_0(\eta)$$

$R_0 = F(P(\theta))$

$P(\theta)$ – phase function (very important)

Where K_0 – the escape function approximated as

$$K_0(\xi) = (3/7)(1 + 2\cos(\xi))$$

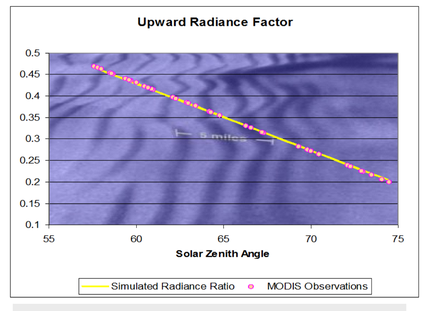
And fraction of absorbed energy (λ)

$$\lambda = 4\sqrt{(1-w)/3(1-g)}$$

Reflectance = Φ (ω, g, $P(\theta)$)

Analytical solution of radiative transfer

Reflection Ratio



Highly accurate analytical solution

Summary

Current VIIRS snow maps provide generally realistic characterization of the global snow extent on a daily basis. Problems are mostly associated with snow misses in dense forests and near edges of scans. False snow identifications in suppressed to a large degree after recent modifications of the VIIRS cloud mask.

TA number of enhancements to the algorithm is foreseen to improve the accuracy of snow retrievals. Enhancements concern additional filtration of clouds that look similar to snow, implementation of observations geometry-dependent threshold values for use in snow identification tests.

The optimal approach to improve moderate resolution remote sensing information on snow cover will combine allowing for the variability of snow and non-snow properties with snow fraction retrieval within a scene-specific snow algorithm to create unbiased and consistent information on snow cover distribution required for global studies, regional and local scale hydrological applications.