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

Cal/Val Team Members

Name	Organization	Roles and Responsibilities
Jeff Key	NOAA/NESDIS	Cryosphere Team Lead
Peter Romanov	CUNY/CREST	Snow Products Lead
Sean Helfrich	NOAA/NIC	User/Applications
Michael Ek	NOAA/NWS	User/Applications

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.

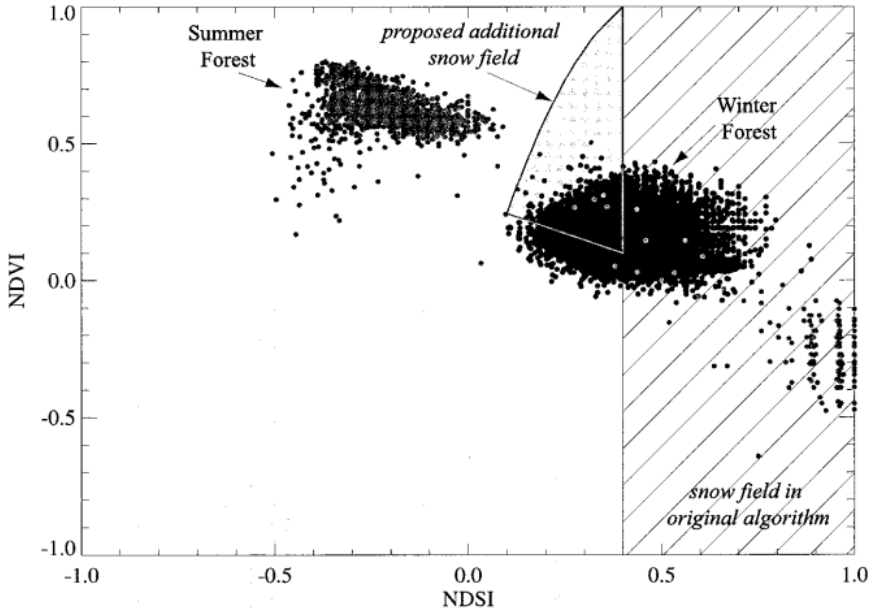
Binary Snow Cover

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)

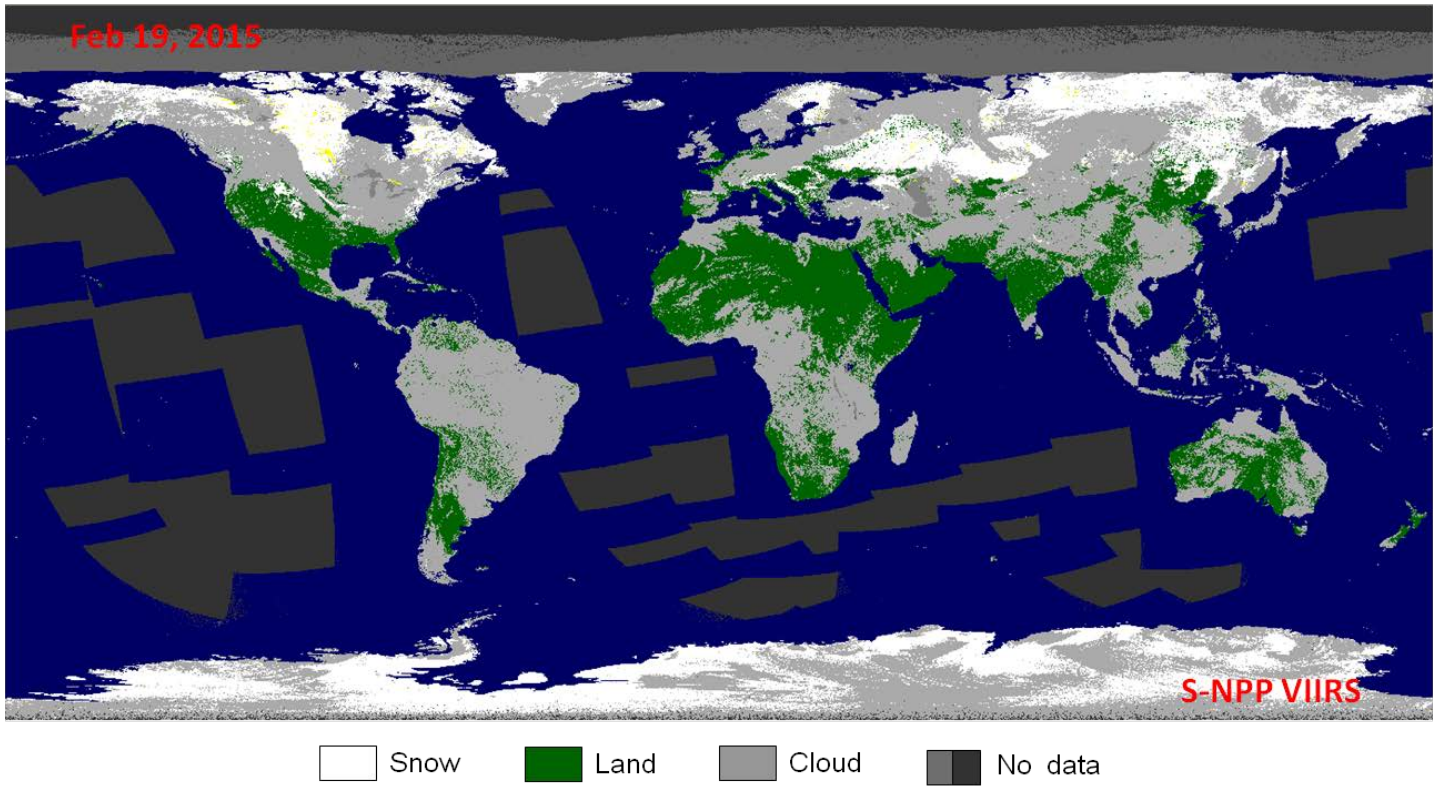
$$NDSI = (R_{0.6\mu m} - R_{1.6\mu m}) / (R_{0.6\mu m} + R_{1.6\mu m})$$

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



MODIS SnowMap
snow acceptance region

VIIRS IDPS Daily Snow Map



- 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/smcd/emb/snow/viirs/viirs-snow-fraction.html
  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

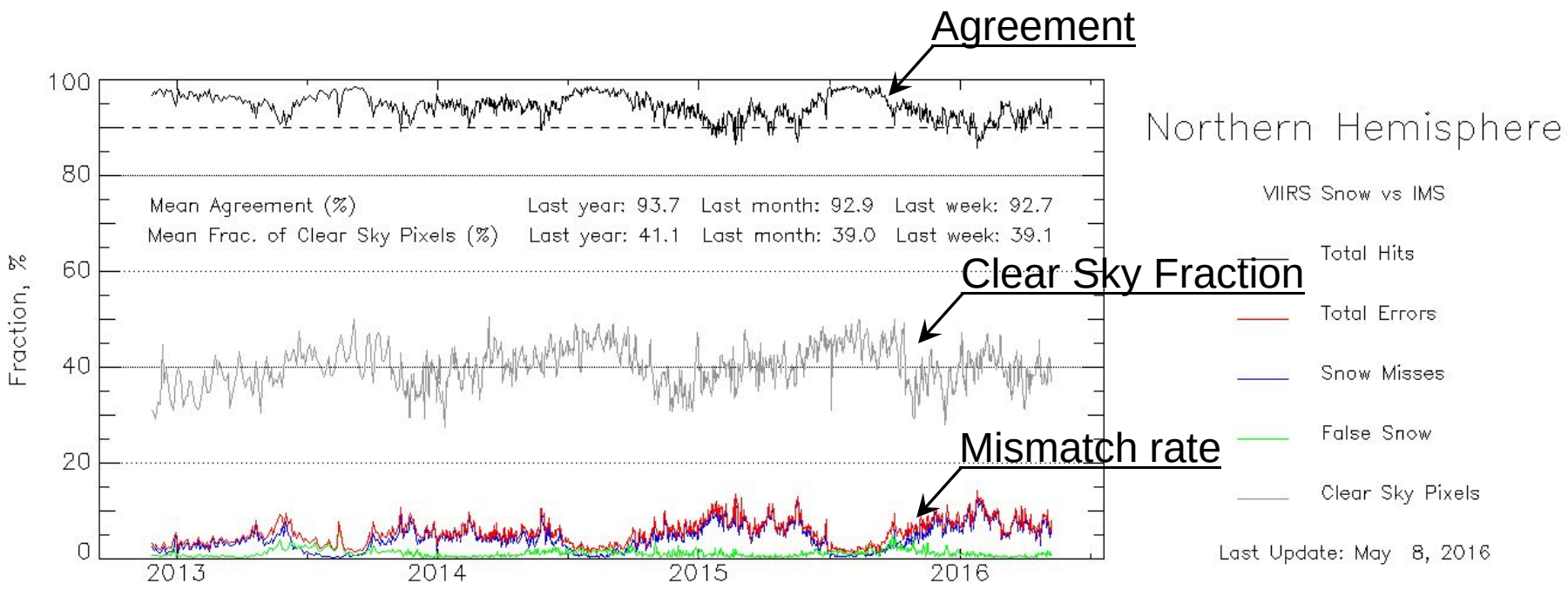
- To Interactive Snow Product (IMS)
  - Yearly mean: 94%, range: 88-98% (NH, over “snow possible” areas)
- To in situ reports
  - Mean: 92%, range: 85-96% (CONUS, November-April)

Product	L1RDS APU Thresholds	Performance
Binary Snow	90% Correct Typing	Mean Daily: 92-94% Range: 85-98%

Product generally satisfies current requirements

VIIRS Snow vs IMS

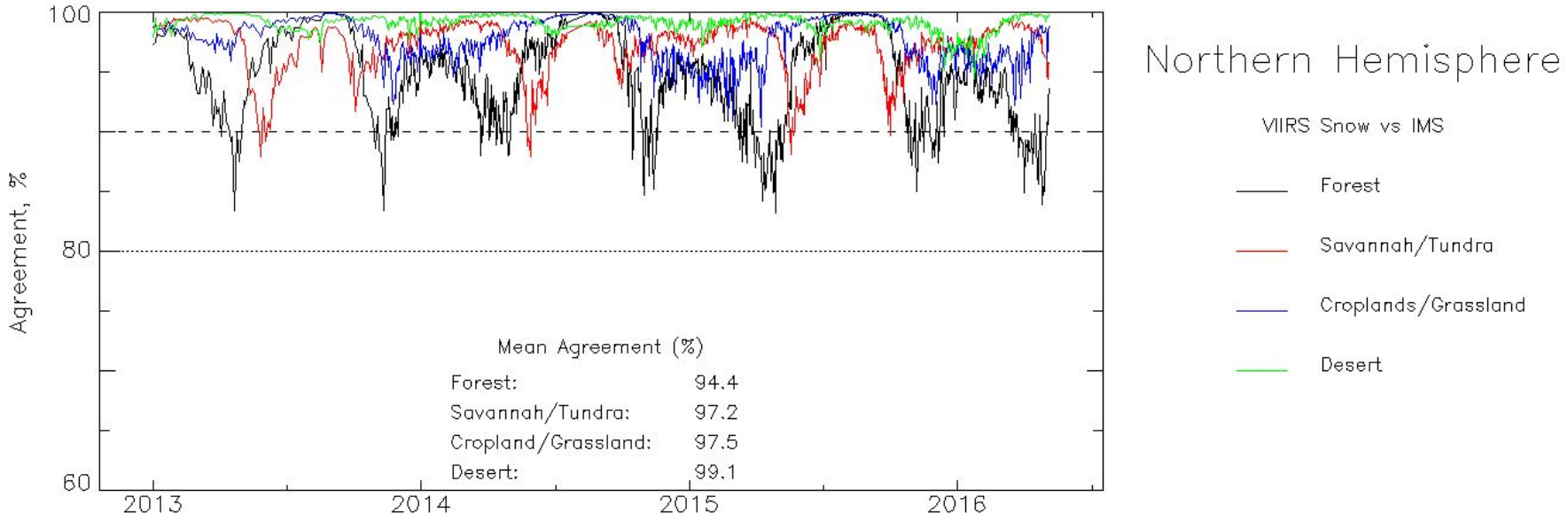
VIIRS binary snow map : Daily agreement to IMS



- Cloud fraction over land in the VIIRS IDPS snow product is about 60%
- This is more than in similar MODIS and AVHRR products

VIIRS Snow vs IMS

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

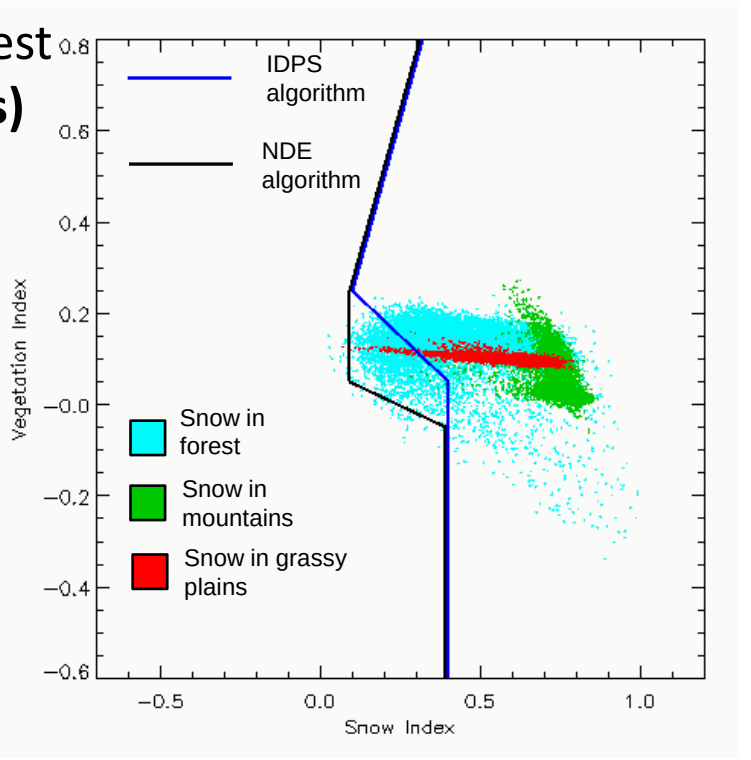
2. Consistency tests (applied to "snow" pixels)

- Eliminate spurious snow

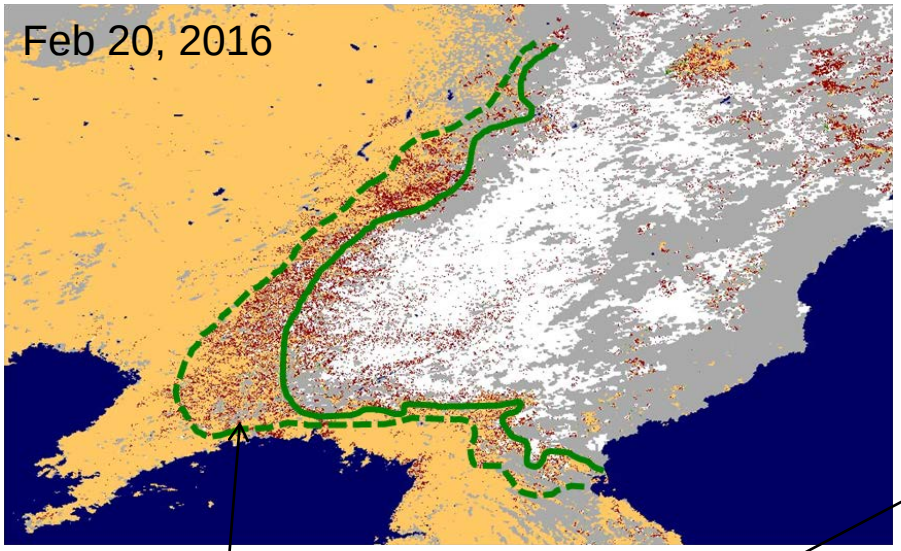
Consistency tests:

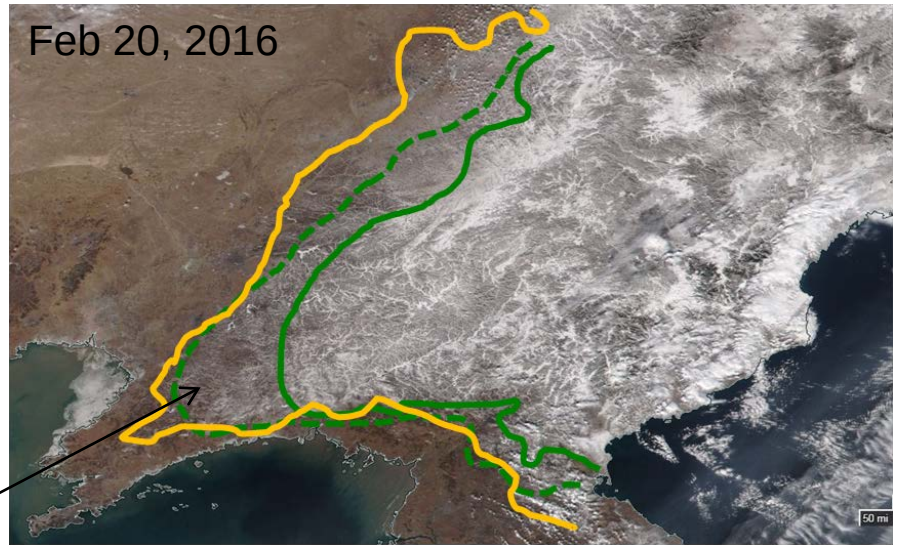
- Snow climatology
- Surface temperature climatology
- Spatial consistency
- Temperature spatial uniformity

Algorithm implemented as part of NDE system



NDE vs IDPS Binary Snow Product





IMS snow

IDPS snow

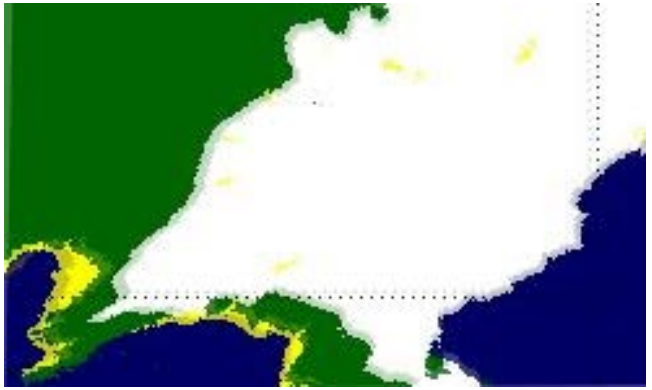
NDE snow

Snow mapped by NDE <u>but not IDPS</u>

Snow mapped by both NDE and IDPS

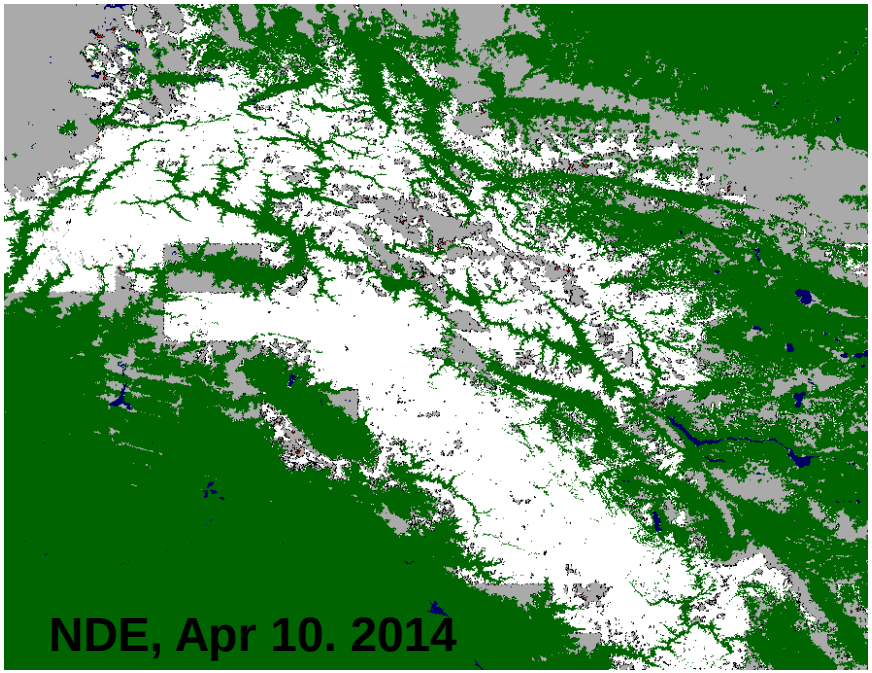
Clouds

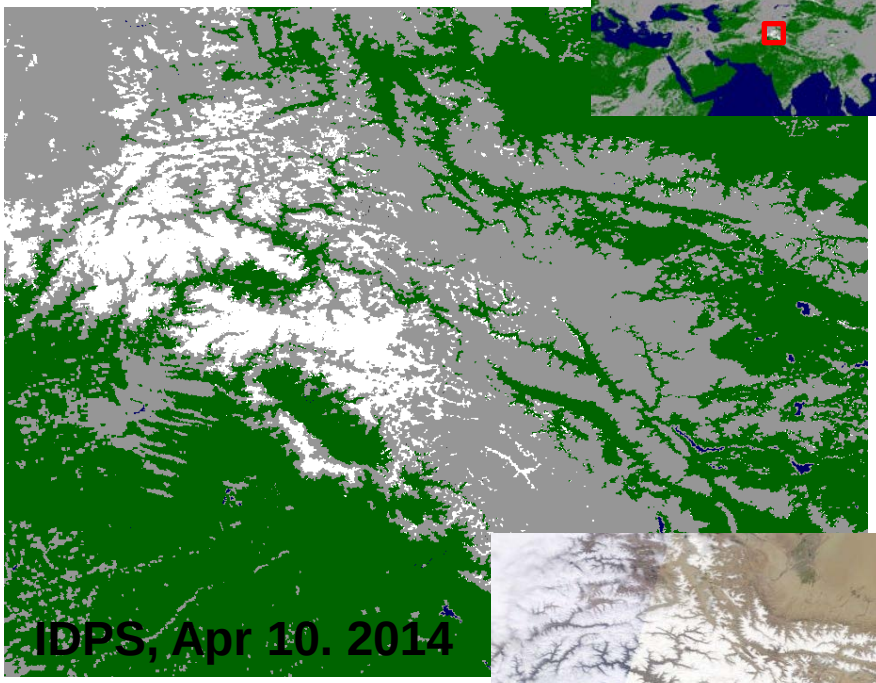
IMS snow

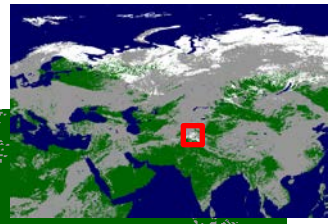


NDE vs IDPS Binary Snow Product

NDE: Better delineation of the snow cover boundary due to less conservative cloud masking







snow land cloud No data

NDE vs IDPS Accuracy

Mean daily agreement to IMS and mean cloud cover extent over Northern Hemisphere

Date	Agreement to IMS, %			Cloud Fraction, %	
	IDPS	NDE		IDPS	NDE
Jan 01, 2015	96.9	96.5		58	52
Apr 10, 2014	97.5	96.9		52	47
Jul 10, 2014	98.4	99.0		55	44
Oct 10, 2014	97.4	96.6		65	55

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

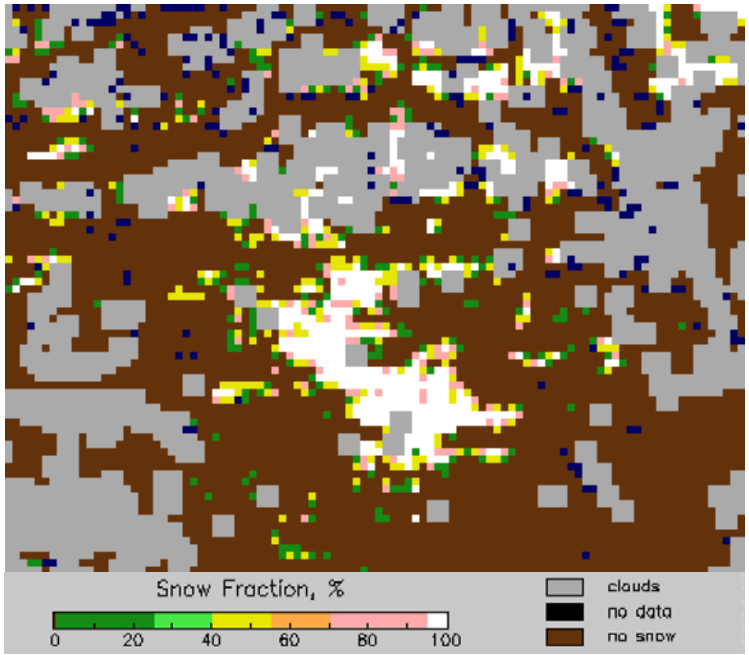
Snow Fraction

IDPS Snow Fraction

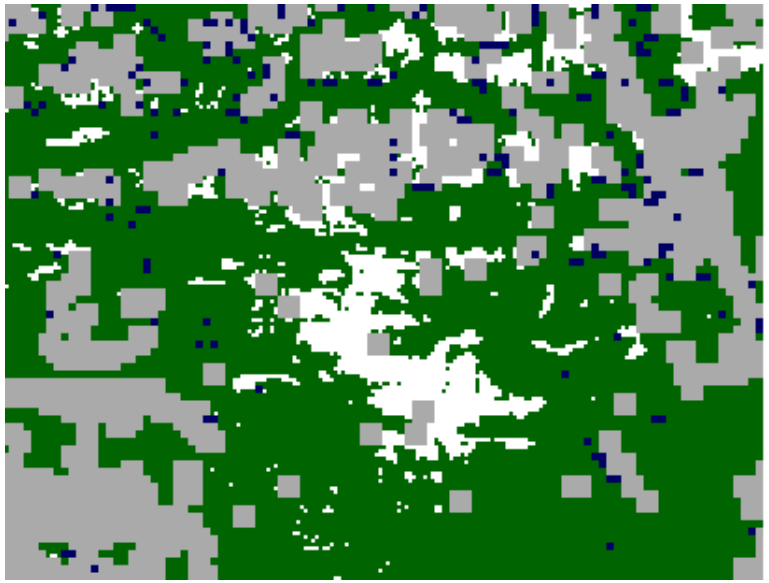
IDPS: Based on aggregated 2x2 binary snow retrievals

- 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

$$\textbf{SnowFraction} = -0.01 + 1.45 * \textbf{NDSI}$$

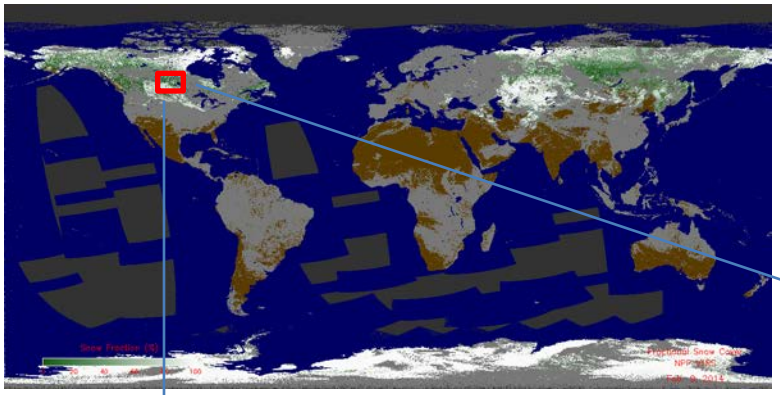
- **NDSI** = $(R_{0.6} - R_{1.6}) / (R_{0.6} + R_{1.6})$
- MODIS heritage algorithm, used up to Collection 5 (not in Collection 6)

2. Visible reflectance-based

$$\textbf{SnowFraction} = (R - R_{land}) / (R_{snow} - R_{land})$$

- 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

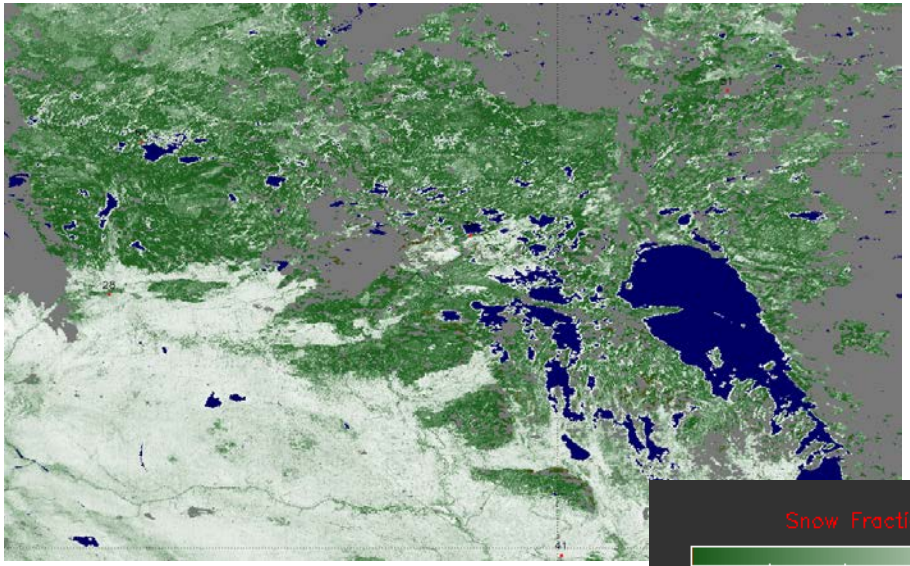


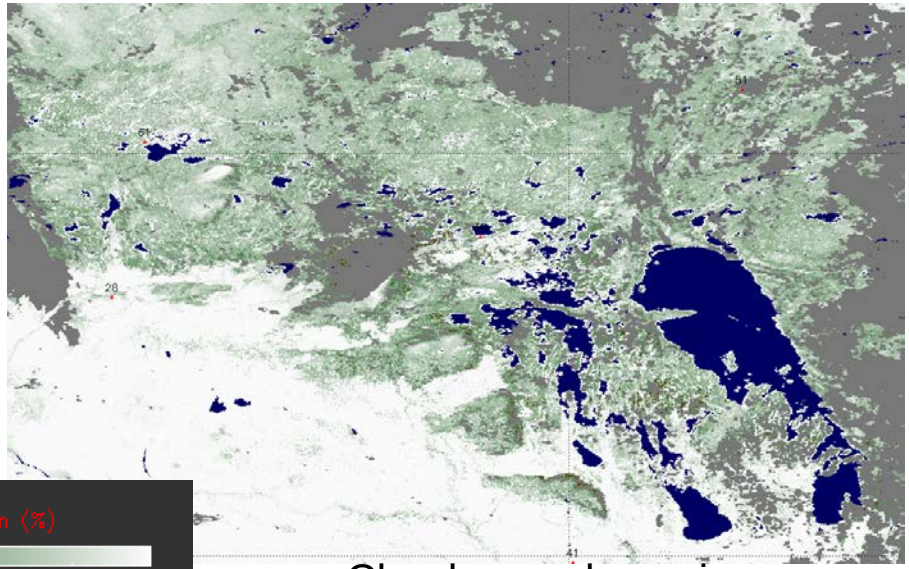
Reflectance-based Snow Fraction vs NDSI-based snow fraction

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

Reflectance-based snow fraction

NDSI-based snow fraction





Clouds are shown in gray

Snow Fraction Evaluation Approach

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

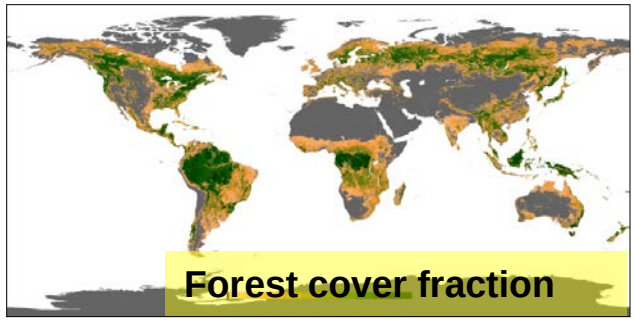
Higher spatial resolution retrievals are not independent. Limited applicability

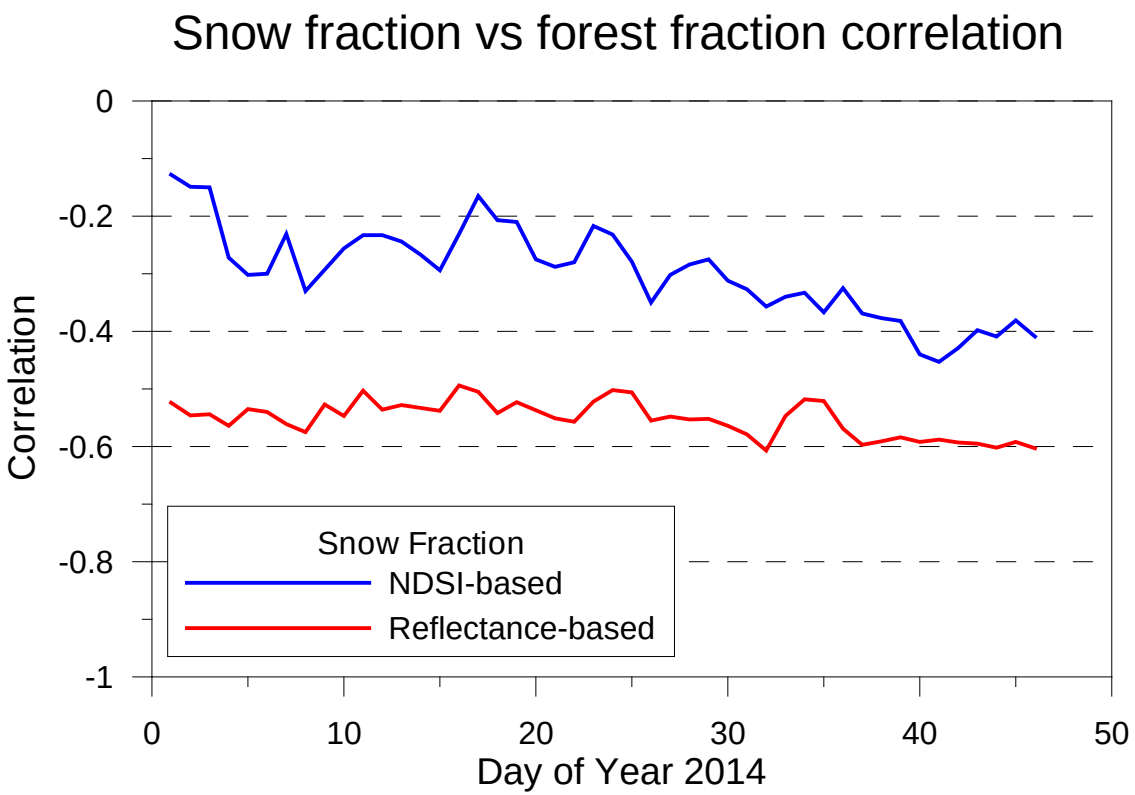
Theoretically estimated accuracy is within 10-20%

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

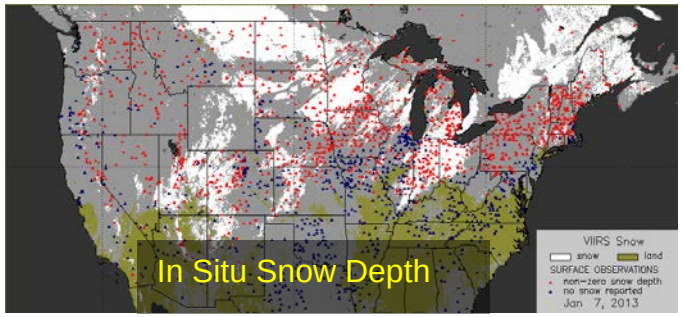




- Stronger correlation (-0.5 ÷-0.6), indicates better consistency of Reflectance-based snow fraction with forest cover properties

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

Date	Snow Depth Range, cm	Number of match-ups	Reflectance-based		NDSI-based	
			Mean SnFrac	Correlation	Mean SnFrac	Correlation
01/14/15	2 - 27	66	0.57	0.31	0.83	0.29
01/16/15	2 - 25	90	0.41	0.11	0.71	0.07
01/17/15	2 - 25	47	0.43	0.52	0.79	0.49
01/18/15	2 - 15	42	0.25	0.40	0.57	0.47
01/19/15	2 - 12	15	0.27	0.34	0.64	0.61
Mean			0.39	**0.34**	0.71	**0.38**

Comparison with Landsat Data

Approach

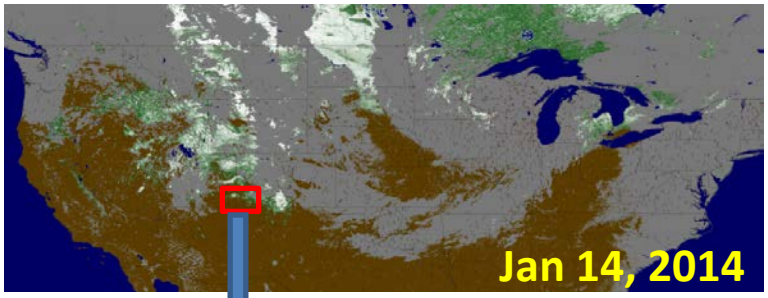
(1) Generate binary snow mask for a Landsat scene at 30 m resolution

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

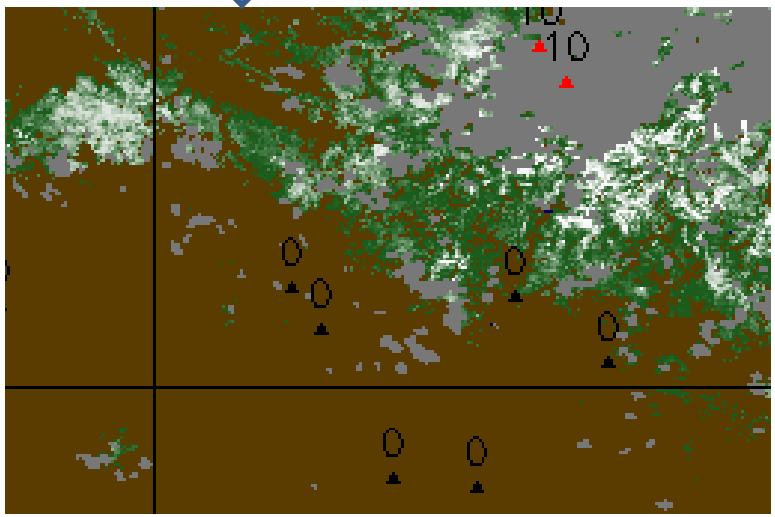
(3) Compare with VIIRS sub-pixel snow fraction estimate

Comparison with Landsat Data

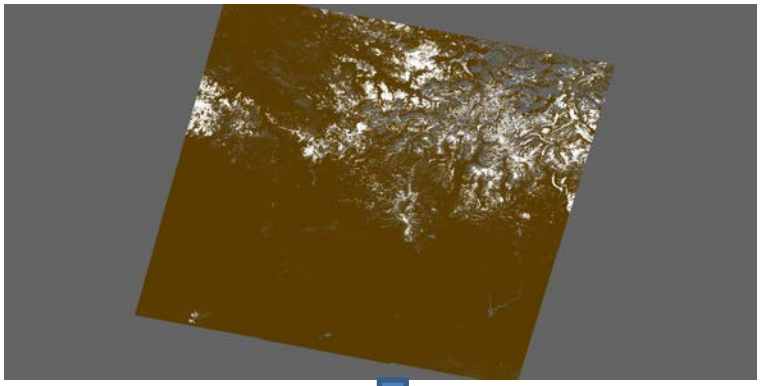
VIIRS Snow Fraction



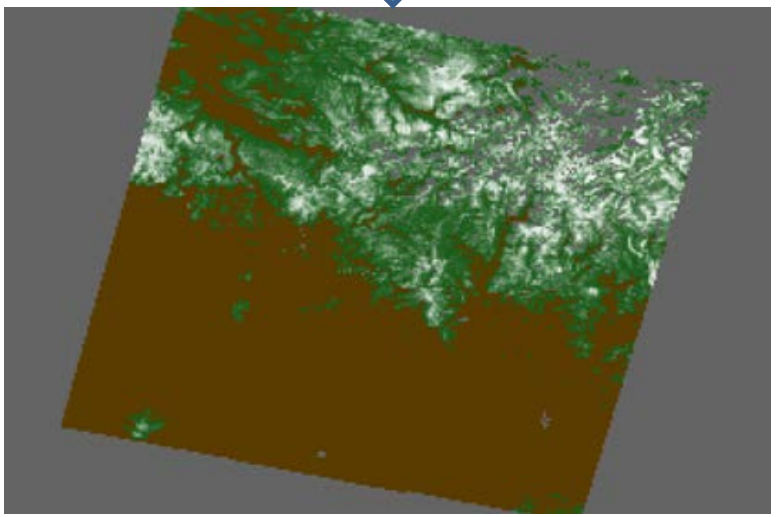
VIIRS Snow Fraction, 0.01 deg

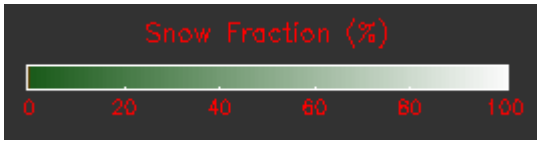


Landsat Binary Snow



Landsat Snow Fraction, 0.01 deg





Comparison with Landsat Data

VIIRS reflectance-based snow fraction vs Landsat

Date	Place	Path	Row	Aggregation: 1 km			Aggregation: 5 km		
				Corr	Bias	RMSE	Corr	Bias	RMSE
01/01/15	Mongolia	140	28	0.78	-0.054	0.247	0.85	-0.076	0.162
01/13/15	Germany	192	26	0.78	-0.004	0.04	0.93	-0.006	0.021
01/13/15	Austria	192	27	0.67	0.064	0.208	0.87	0.077	0.144
01/14/15	Iran	167	35	0.88	-0.031	0.122	0.94	-0.039	0.096
01/14/15	Iran	167	36	0.82	-0.018	0.085	0.91	-0.027	0.072
01/15/15	Caucasus	174	28	0.95	-0.035	0.150	0.98	-0.037	0.082
01/15/15	Caucasus	174	29	0.93	-0.025	0.174	0.98	-0.026	0.079
01/15/15	Turkey	174	32	0.76	-0.025	0.263	0.94	-0.037	0.089
01/16/15	Kazakhstan	165	27	0.92	-0.025	0.197	0.95	-0.019	0.163
01/22/15	Rocky Mnts	38	30	0.80	-0.095	0.210	0.89	-0.105	0.134
04/10/14	Himalaya	150	36	0.95	0.001	0.099	0.93	0.002	0.106
04/10/14	Himalaya	150	35	0.89	-0.013	0.193	0.87	0.001	0.112
07/14/14	Greenland	6	13	0.93	-0.040	0.181	0.84	-0.046	0.156
07/14/14	Greenland	6	14	0.86	-0.070	0.154	0.95	-0.07	0.128
07/14/14	Greenland	6	15	0.93	-0.045	0.150	0.95	-0.051	0.114
Mean				**0.84**	**-0.036**	**0.174**	**0.89**	**-0.054**	**0.127**

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)

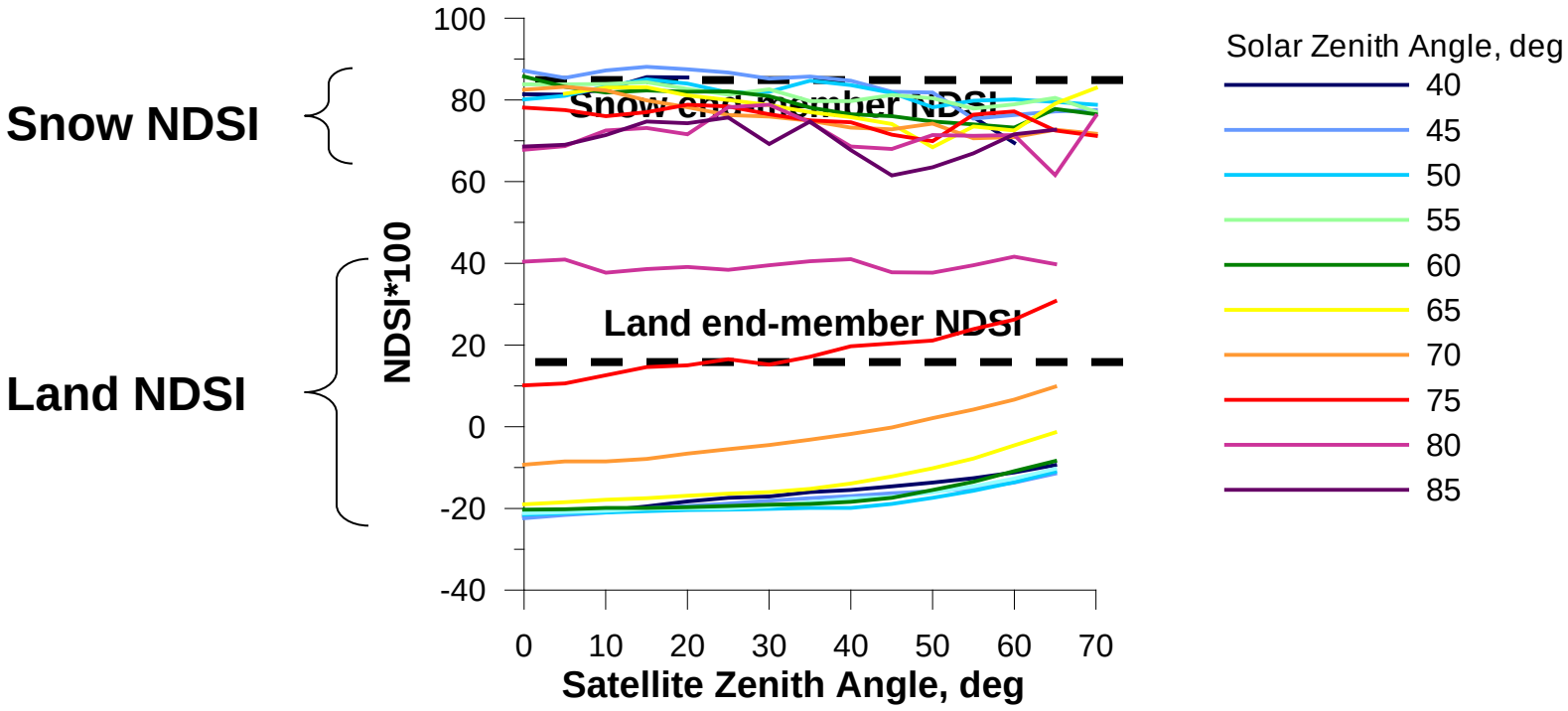
Requirements (10%) may be too strict

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)

Summary

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