Overview of Cryosphere EDRs

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Algorithm Cal/Val Team Members

EDR	Name	Organization
Lead; ice and winds	Jeff Key	NESDIS/STAR
Co-Lead; ice and snow	Pablo Clemente-Colón	NESDIS/STAR and NIC
Wisconsin:		
Ice conc., temp.	Yinghui Liu	CIMSS/U. Wisconsin
Ice thickness	Xuanji Wang	CIMSS/U. Wisconsin
Ice	Rich Dworak	CIMSS/U. Wisconsin
Maryland:		
Snow cover, fraction	Peter Romanov	CREST/CCNY
Snow fraction	Igor Appel	IMSG
Colorado:		
Ice temp., conc.	Mark Tschudi	U. Colorado
Ice temp., conc.	Dan Baldwin	U. Colorado
Other:		
All	Paul Meade	DPE

Products

1. Sea ice characterization (IDPS and NDE)
   - Age category: no ice, new/young ice, other ice (IDPS); thickness (NDE)
2. Sea Ice concentration IP (IDPS and NDE)
   - Fractional coverage of ice in each pixel
3. Ice surface temperature (IST) (IDPS and NDE)
   - Radiating temperature of the surface (ice with or without snow)
4. Snow cover (IDPS and NDE)

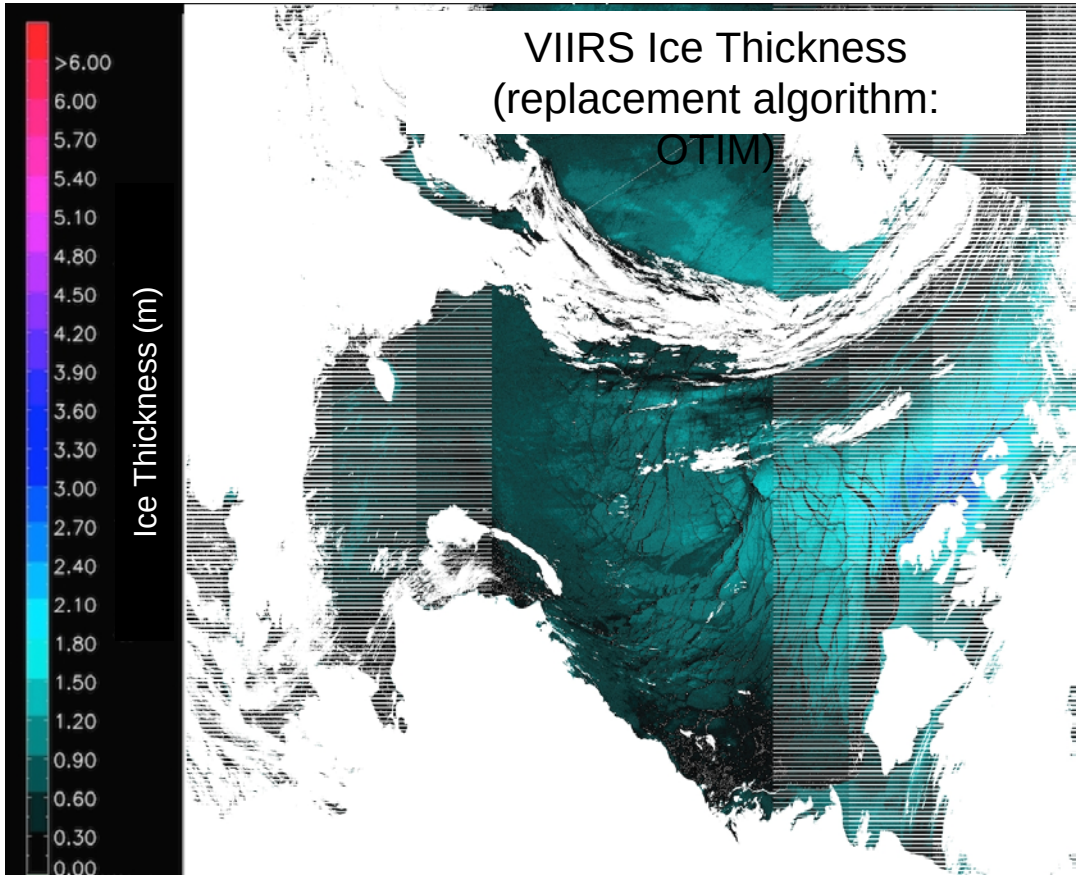
   4a. Binary snow cover

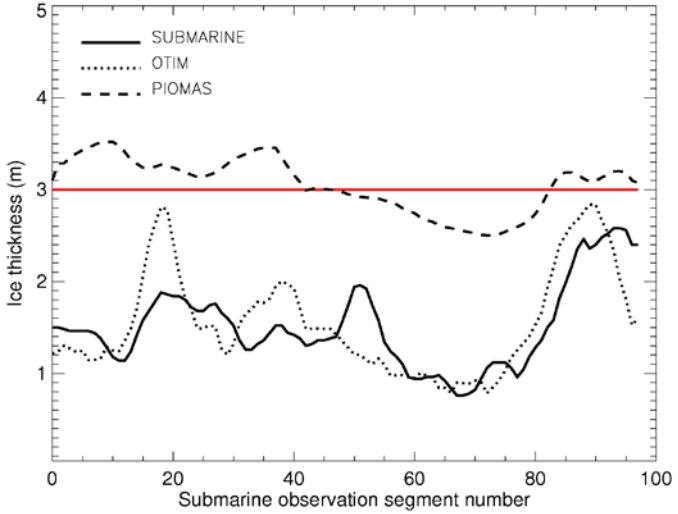
   4b. Fractional snow cover (currently 2x2 averages of binary mask)
5. Polar winds (NDE; *historically funded by PSDI*)
   - Tropospheric winds at various levels

- NOTE: AMSR2 on GCOM-W1 will have other snow and ice products that will be operational in 2016: Ice Characterization, Snow Cover, Snow Depth, Snow Water Equivalent (SWE)

Sea Ice Thickness

The IDPS Sea Ice Characterization EDR is a 3-category product: new/young ice (< 30 cm thick), “other ice”, and ice-free. The IDPS product does not meet requirements. The new product for JPSS-1 will provide a continuous ice thickness range from 0 ~ 2.5 m.

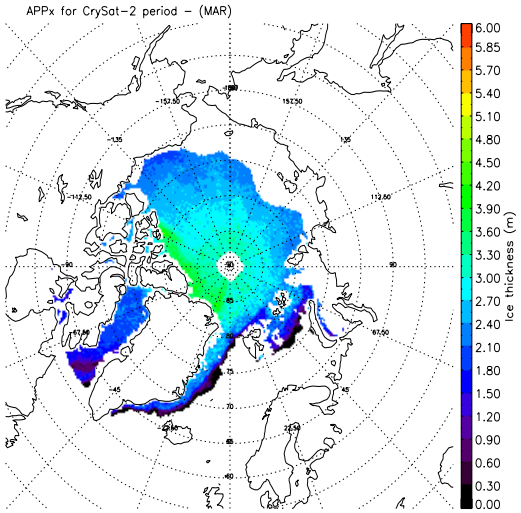




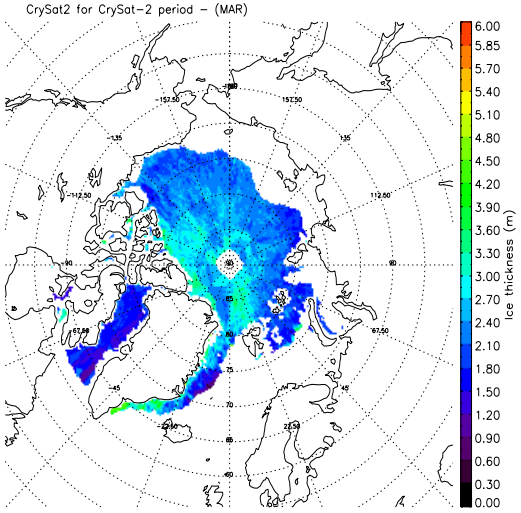
Validation with submarine sonar and modeled ice thicknesses.

Ice Thickness Intercomparison

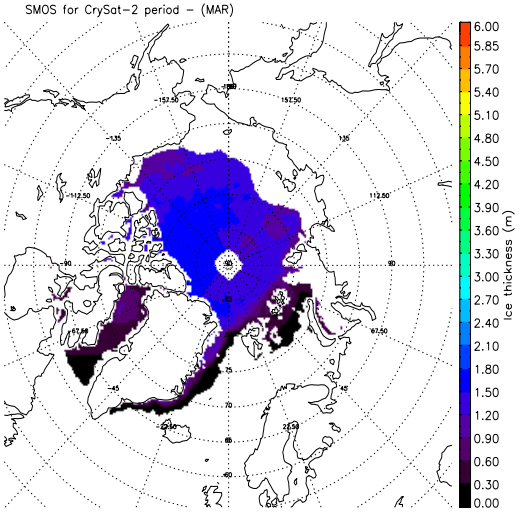
APP-x (VIIRS algorithm)



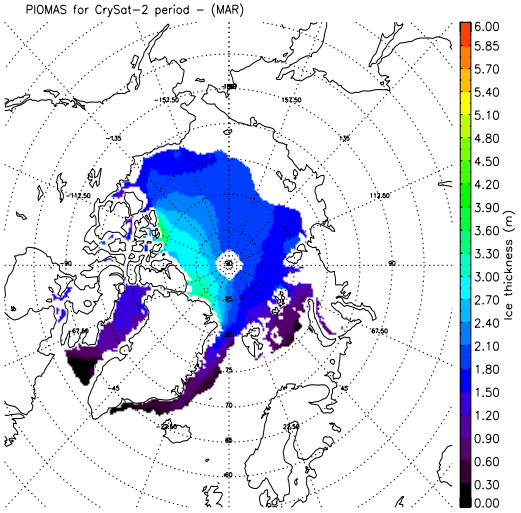
CryoSat-2



SMOS



PIOMAS



Period: 01/2011 – 03/2013, March

APP-x - PIOMAS: Bias=0.51 m
CryoSat-2 – PIOMAS: Bias=0.57 m
SMOS – PIOMAS: Bias=-0.43m

Sea Ice Characterization Requirements

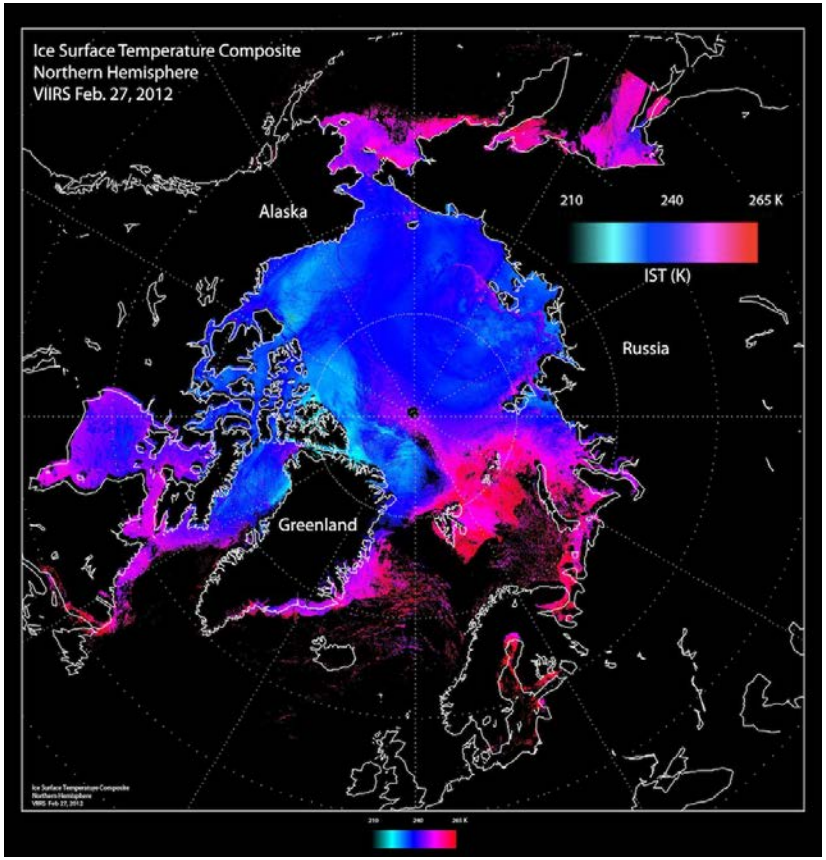
Sea Ice Characterization Requirements from L1RD version 2.4

EDR Attribute	Threshold	Objective
a. Vertical Coverage	Ice Surface	Ice Surface
b. Horizontal Cell Size **1. Clear** **2. All weather**	 1.0 km No capability	 0.5 km 1 km
c. Mapping Uncertainty, 3 sigma **1. Clear** **2. Cloudy**	 5 km No capability	 0.5 km 1 km
d. Measure Range **1. Ice Age** **2. Ice Concentration**	 Ice Free, New Young, all other ice 0/10 to 10/10	 Ice free, Nilas, Gray White Grey, White, First Year Medium, First Year Thick, Second Year, Multiyear, Smooth and Deformed Ice 0/10 to 10/10
e. Measurement Uncertainty **1. Probability of Correct Typing (Ice Age)** **2. Ice Concentration**	 70% Note 1	 90% 5%
f. Refresh	At least 90% coverage of the global every 24 hours (monthly average)	6 hrs
g. Geographic coverage	All Ice-covered regions of the global ocean	All Ice-covered regions of the global ocean

Notes:
1. VIIRS produces a sea ice concentration IP in clear sky conditions, which is provided as an input to the ice surface temperature calculation

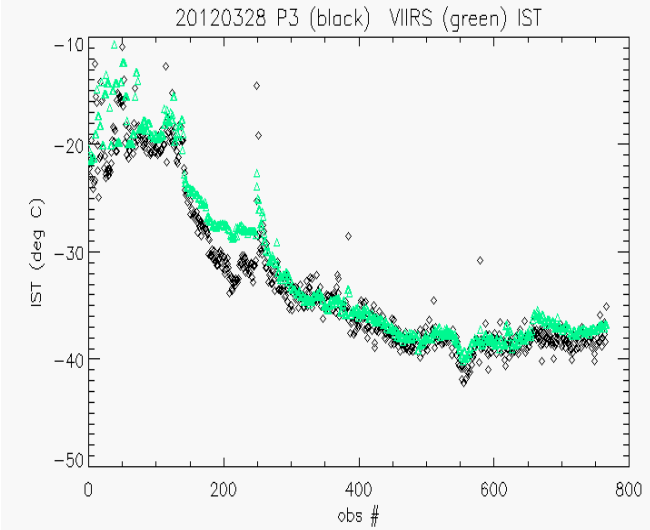
Ice Surface Temperature

The Ice Surface Temperature (IST) is the surface skin, or radiating, temperature of sea ice. Validation has been done primarily with IceBridge aircraft data.



Composite of VIIRS Ice Surface Temperature on 27 Feb 2012.

IceBridge KT19 vs VIIRS IST, 2012



DATE	BIAS	RMS
3/14	0.56	0.08
3/15	-0.84	0.63
3/16	1.01	0.71
3/21	-0.55	0.41
3/22	-0.21	0.14
3/27	0.12	0.21
3/28	1.12	0.53
3/29	0.46	0.10
4/02	0.66	0.19

BIAS = VIIRS - KT19

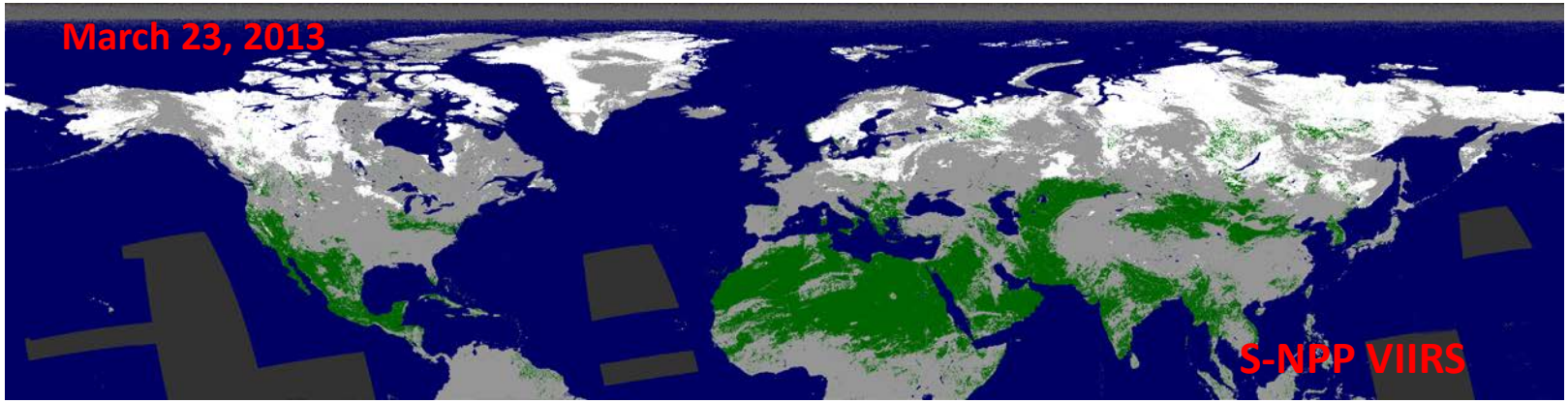
Ice Surface Temperature Requirements

Ice Surface Temperature (IST) Requirements from L1RD Supplement. V2.9 (27 June 2013)

EDR Attribute	Threshold	Objective
IST Applicable Conditions **1. Clear, only**		
a. Sensing Depth	Ice Surface	Ice Surface
b. Horizontal Cell Size **1. Nadir** **2. Worst Case**	 1 km 1.6 km	 0.1 km 0.1 km
c. Mapping Uncertainty, 3 sigma **1. Nadir** **2. Worst Case**	 1 km 1.6 km	 0.1 km 0.1 km
d. Measure Range	213-275 K	213-293 K (2 m above ice)
e. Measurement Uncertainty	1 K	
f. Refresh	At least 90% coverage of the global every 24 hours (monthly average)	12 hrs
g. Geographic Coverage	Ice-covered oceans	All ice-covered waters

Binary Snow Cover

Snow Cover is the horizontal and vertical extent of snow cover. The binary product gives a snow/no-snow flag.



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

Binary Snow Cover Requirements

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.

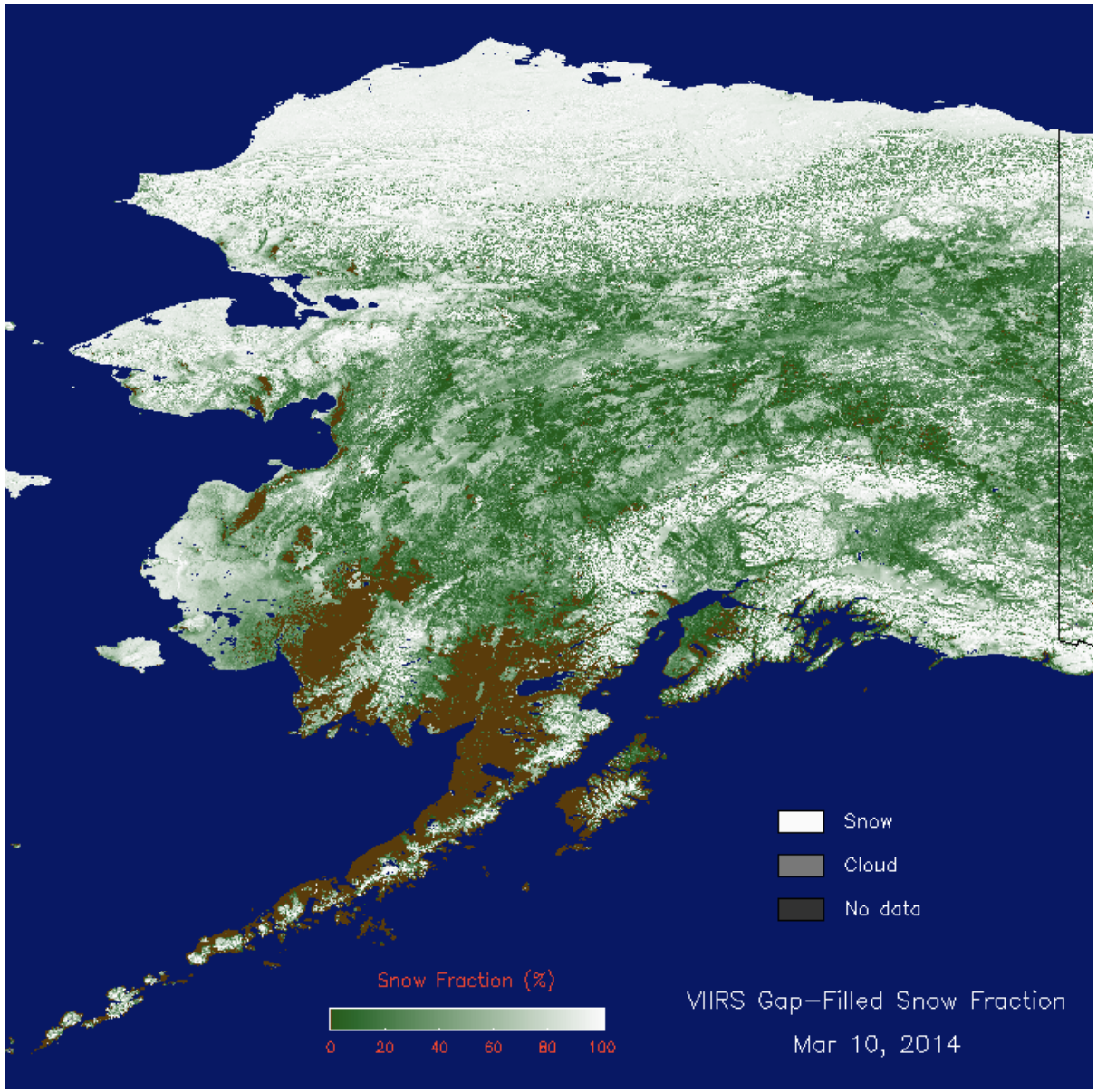
[Joint Polar Satellite System (JPSS) Program Level 1 Requirements SUPPLEMENT – Final Version: 2.9 June 27, 2013]

Snow Fraction

The IDPS snow fraction product is not useful, given that it is a 2x2 pixel binary snow mask average.

The new enterprise product provides the sub-pixel snow fraction. It is based on the normalized difference snow index (NDSI), also used by NASA for MODIS.

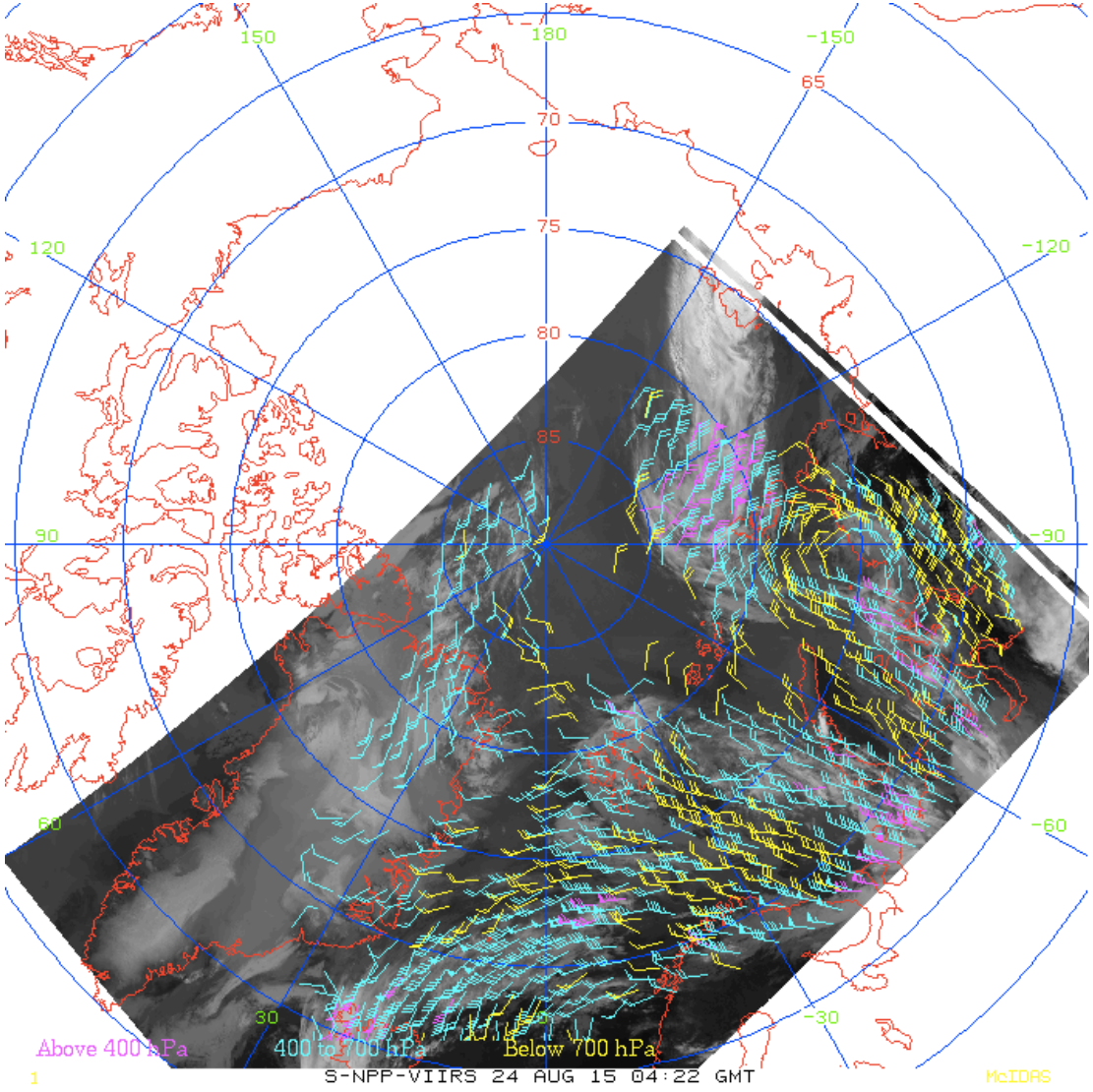
A reflectance-based product will also be generated.



Snow Fraction Requirements

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

VIIRS Polar Winds



VIIRS polar winds are derived by tracking clouds in infrared imagery. Wind speed, direction, and height are estimated throughout the troposphere, poleward of approximately 70 degrees latitude.

Left: VIIRS winds from Sodankylä, Finland on 24 August 2015

Polar Winds Requirements

Table 5.2.12 - Polar Winds (VIIRS)		
EDR Attribute	**Threshold**	**Objective**
a. Vertical Coverage	Surface to Tropopause	Surface to 20 km
b. Horizontal Resolution	10 km	10 km
c. Vertical Reporting Interval	At cloud tops	0.1 km
d. Mapping Uncertainty, 3 sigma	5 km	5 km
e. Measurement Range	Speed: 3 to 100 m/sec (1) Direction: 0 to 360 degrees	Speed: 0 to 100 m/sec Direction: 0 to 360 degrees
f. Measurement Precision	Mean vector difference: 3.8 m/sec	0.5 m/s
g. Measurement Accuracy	Mean vector difference: 7.5 m/sec	± 1 m/s
h. Refresh	100 min	1 hour
		v2.4, 12/10/12

Notes:
1. Changed from "0 - 100 m/s" to "3 - 100 m/s" as wind vectors below 3 m/s are usually removed.

Unique VIIRS Characteristics for Winds

- The Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (S-NPP) satellite was launched 28 October 2011.
- VIIRS will be on the JPSS series of satellites, replacing AVHRR as NOAA's operational polar-orbiting imager.

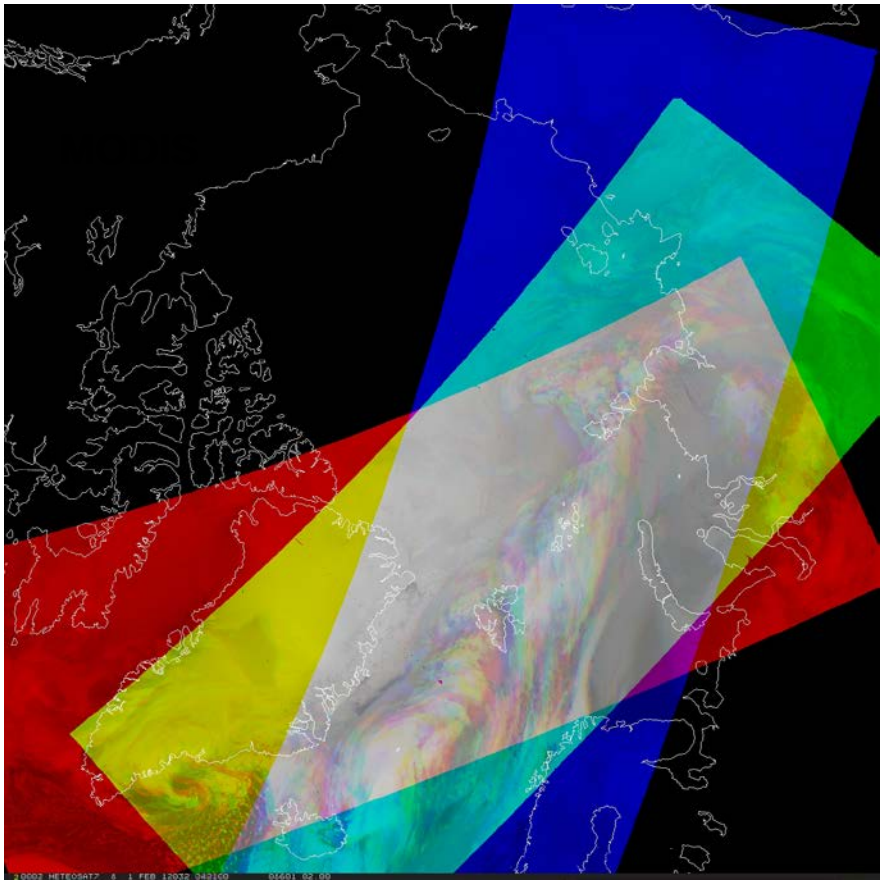
- VIIRS' unique characteristics relevant to a polar winds product include:

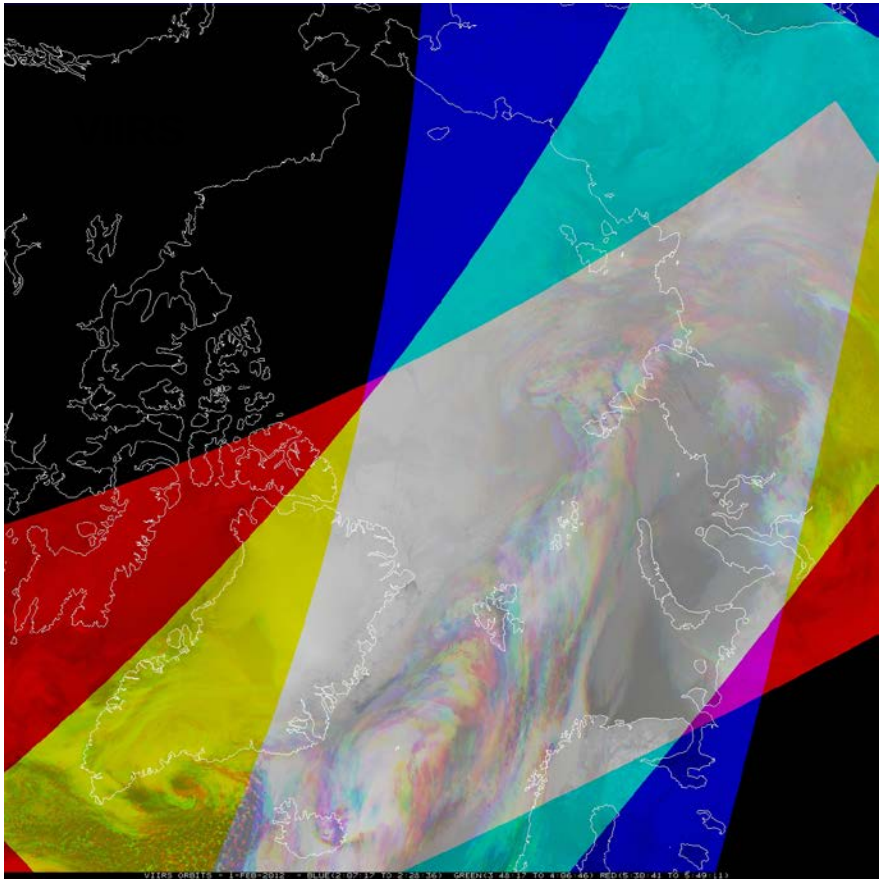
  - **Higher spatial resolution (750 m for most bands; 375 m for some)**
  - **Wider swath than MODIS**
  - **Constrained pixel growth: better resolution at edge of swath**
  - **Day-night band (DNB)**
  - Disadvantage: No thermal water vapor band so no clear-sky WV winds

- The VIIRS polar winds processing **utilizes the GOES-R AMV algorithm**.

VIIRS Coverage: Wider Swath

VIIRS has a wider swath (3000 km) than MODIS (2320 km), so the coverage will be better and will extend further south.

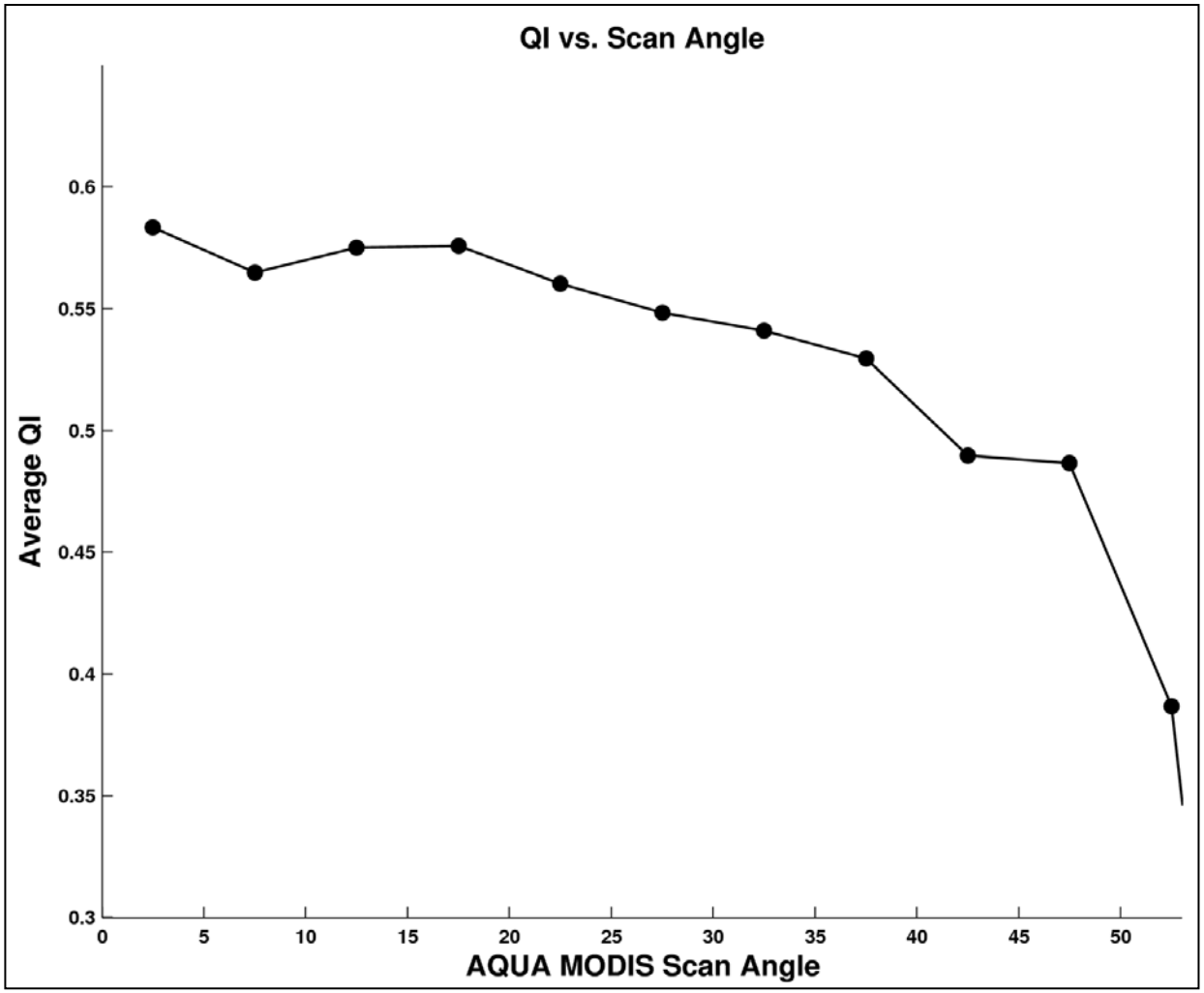




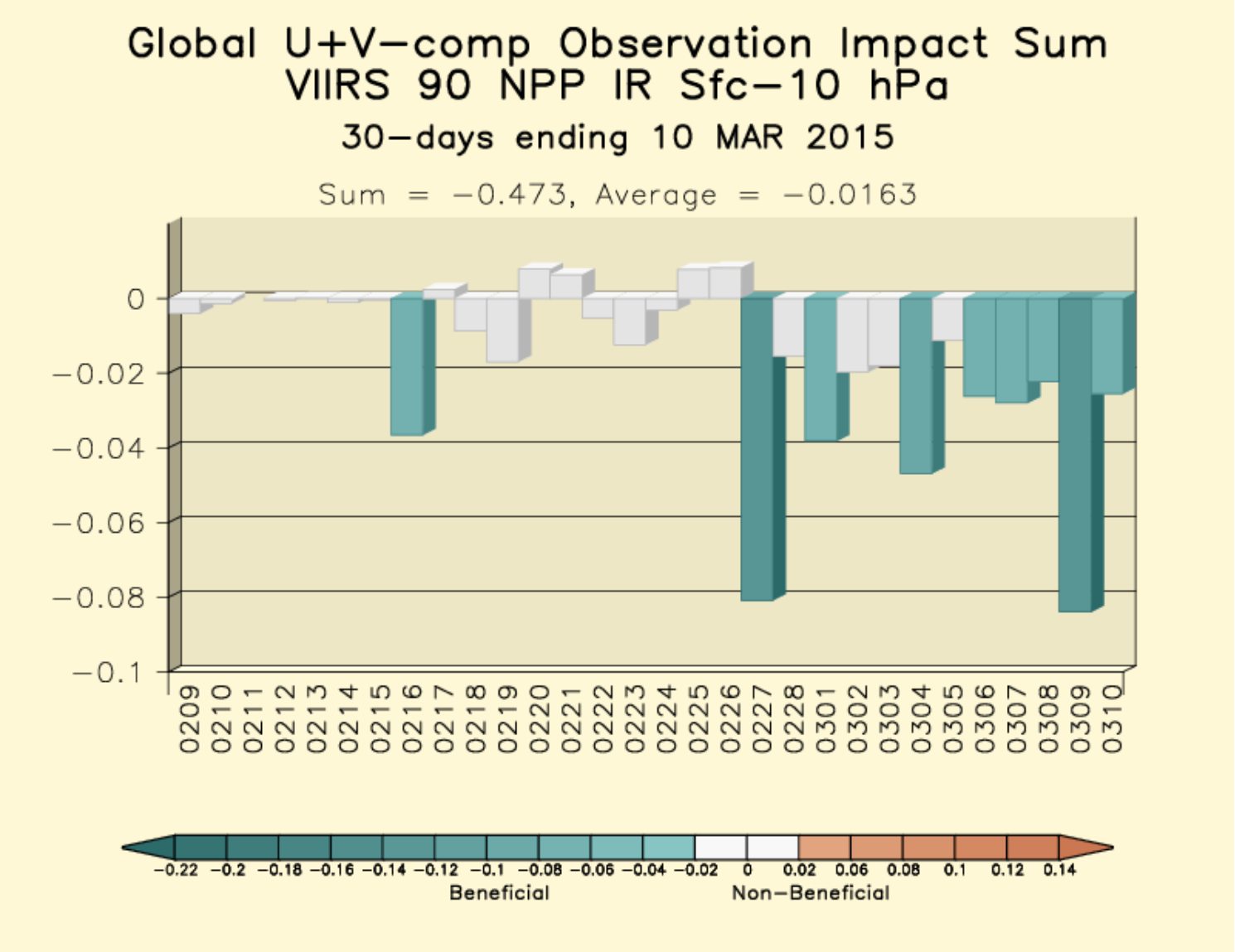
A wider swath means more winds with each orbit.

Effects of Scan Angle on Winds

Does the improved resolution away from nadir matter for wind retrieval?



VIIRS Winds Model Impact at NRL



FY14-15 Top Accomplishments

Accomplishment #1: Developed a new VIIRS sea ice thickness product. Provides a reasonable estimate of actual ice thickness, not just ice in two categories. The IDPS EDR is problematic.

Accomplishment #2: Developed a new VIIRS snow fraction product. The snow fraction product in the IDPS Snow Cover EDR is of limited value (2 x 2 pixel average of binary snow cover) so a new algorithm was implemented outside of IDPS. The new algorithm provides MODIS heritage. A second algorithm with GOES heritage was also implemented.

Accomplishment #3: VIIRS polar winds became operational through NDE in May 2014. Direct broadcast VIIRS winds are now generated at Fairbanks, Alaska, and Sodankylä, Finland. Users report positive impact as good or better than MODIS winds.

Accomplishment #4: Some of these algorithms are being applied to Himarwari-8 AHI data. They were developed for GOES-R.

Uses and Users

- Numerical Weather Prediction (NWP centers)
  - Snow and ice cover are commonly used (though not from VIIRS yet)
  - Ice thickness is not yet utilized; should be used universally!
  - Polar winds (13 NWP centers in 9 countries use the various polar winds products)
- Navigation and Transportation (National Ice Center, Alaska Ice Desk, Navy, USCG, local services)
  - Ice concentration (currently evaluating)
  - Ice thickness (near future)
  - Snow cover/fraction (currently evaluating)
- Hydrologic Modeling (NOHRSC, local services)
  - Snow fraction

FY16 Milestones/Deliverables

Task Category	Task/Description	Start	Finish	Deliverable
Development (D)	NSDI-based snow fraction algorithm; sea ice thickness algorithm	9/2014	12/2015	NDE snow fraction product; sea ice thickness product
Integration & Testing (I)	Snow fraction algorithm; sea ice thickness algorithm	6/2015	3/2016	same
Calibration & Validation (C)	Revise cal/val plans; Implement cal/val plan tasks (see plans for details);	6/2015	Ongoing	Product error assessments
Maintenance	Algorithm maintenance and minor improvements	10/2014	Ongoing	Product improvements
LTM & Anomaly Resolution (L)	Develop LTM website	10/2015	9/2016	LTM website for cryosphere products

Path Forward (FY17 thru FY20)
High Priority Tasks/Milestones

	S-NPP	JPSS-1	JPSS-2
FY17	Operational generation of new snow fraction and sea ice thickness products in enterprise environment.	• Begin transitioning to JPSS • Redefine products if needed • Generate LUTs for J1 VIIRS sensor	
FY18	Algorithm maintenance and minor improvements; long-term validation of VIIRS snow and ice products; product reprocessing	• Evaluate use of dual S-NPP/JPSS-1 pairing for polar winds • Algorithm maintenance and minor improvements	Define validation plan
FY19	Long-term validation of VIIRS snow and ice products	• Blended VIIRS/CryoSat/ICESat ice thickness? • Long-term validation of JPSS-1 VIIRS snow and ice products	• Hold algorithm preliminary and critical design reviews, as necessary • Begin transitioning to JPSS • Redefine products if needed • Generate LUTs for J2 VIIRS sensor
FY20	Long-term validation of VIIRS snow and ice products	Long-term validation of JPSS-1 VIIRS snow and ice products	

Summary

Robust validation has been performed for all snow and ice products. Validation data include aircraft radiometer and laser measurements, in situ observations, and other satellite products.

Significant deficiencies were found in the operational Sea Ice Characterization EDR and the snow fraction portion of the Snow Cover EDR.

Two new VIIRS products have been developed and are being implemented in the enterprise system:

- Sea ice thickness
- Snow fraction

The other operational snow and ice products – ice surface temperature, ice concentration (currently an IP), and binary snow cover – perform reasonably well. Nevertheless, enterprise versions of these products are also being implemented.

VIIRS polar winds are seeing increased use by NWP centers and positive impact.