Validated Maturity Science Review For NOAA-20 VIIRS Polar Winds

Presented by Jeff Key and Jaime Daniels

Date: 2019/05/16

JPSS NOAA NASA

JPSS Data Products Maturity Definition

1. Beta

- Product is minimally validated, and may still contain significant identified and unidentified errors.
- Information/data from validation efforts can be used to make initial qualitative or very limited quantitative assessments regarding product fitness-for-purpose.
- Documentation of product performance and identified product performance anomalies, including recommended remediation strategies, exists.

2. Provisional

- Product performance has been demonstrated through analysis of a large, but still limited (i.e., not necessarily globally or seasonally representative) number of independent measurements obtained from selected locations, time periods, or field campaign efforts.
- Product analyses are sufficient for qualitative, and limited quantitative, determination of product fitness-for-purpose.
- Documentation of product performance, testing involving product fixes, identified product performance anomalies, including recommended remediation strategies, exists.
- Product is recommended for potential operational use (user decision) and in scientific publications after consulting product status documents.

3. Validated

- Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).
- Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.
- Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose.
- Product is ready for operational use based on documented validation findings and user feedback.
- Product validation, quality assurance, and algorithm stewardship continue through the lifetime of the instrument.

VALIDATED MATURITY REVIEW MATERIAL

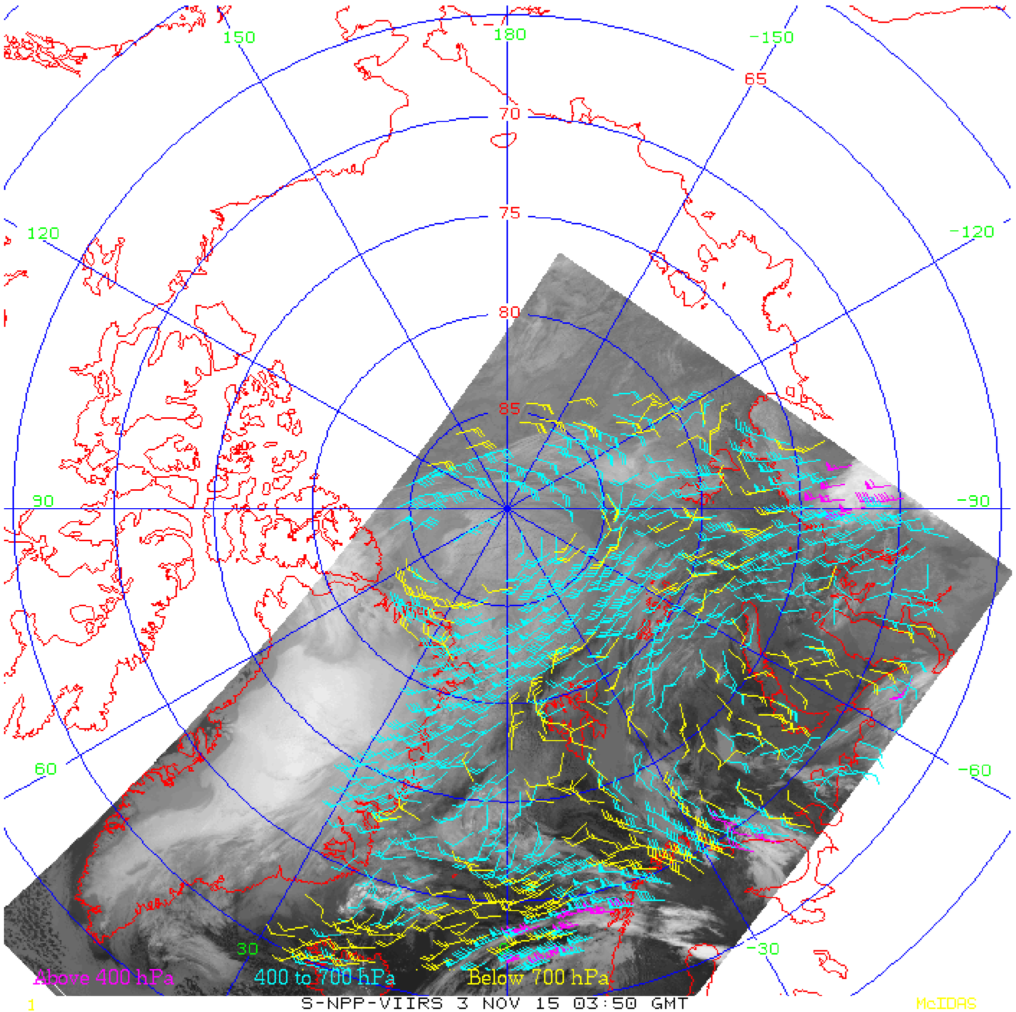
VIIRS Polar Winds Team

Name	Organization	Major Task
Jeff Key	STAR	Project management, DB winds
Jaime Daniels	STAR	Project management, algorithm development and testing
Wayne Bresky	IMSG	Algorithm development and testing
Andrew Bailey	IMSG	Algorithm development and testing
Rico Allegrino	IMSG	Validation
David Santek	CIMSS	Algorithm and product testing
Rich Dworak	CIMSS	Algorithm and analysis
Steve Wanzong	CIMSS	Algorithm and product testing
Hongming Qi	OSPO	Operations
Walter Wolf and others	STAR, AIT	Implementation

VIIRS Polar Winds (VPW) in Brief

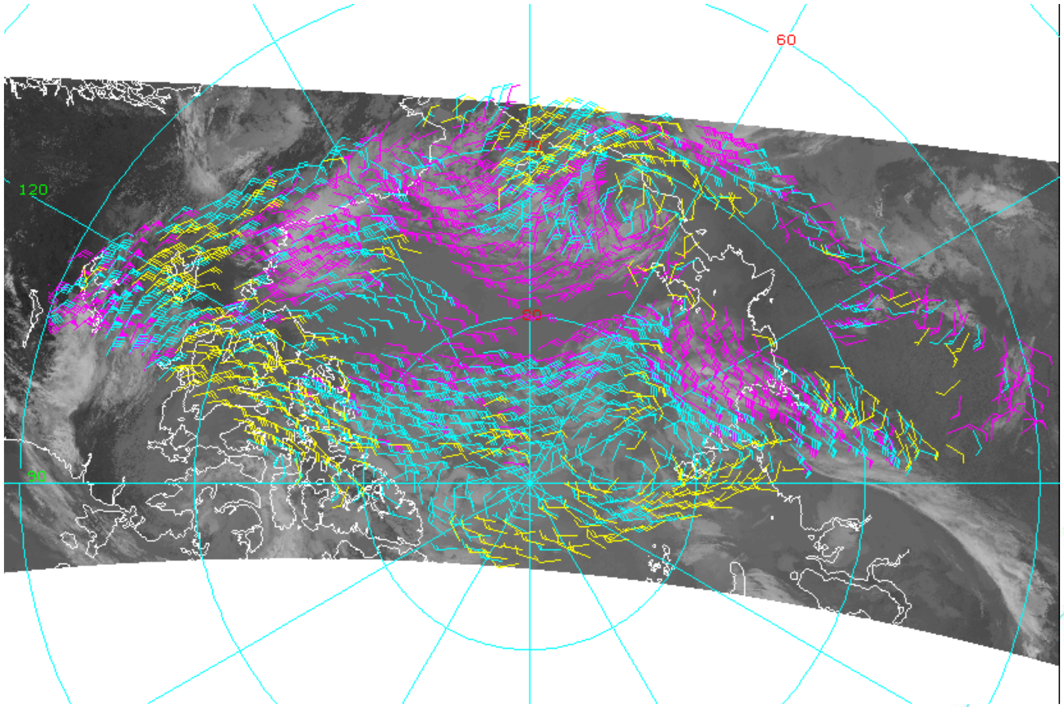
VIIRS Polar Winds are derived by tracking clouds features in the VIIRS longwave infrared channel

- Wind speed, direction, and height are determined throughout the troposphere, poleward of approximately 65 degrees latitude, in cloudy areas only
- Wind information is generated in both the Arctic and Antarctic regions
- The algorithm utilizes the Enterprise cloud height, phase, and mask

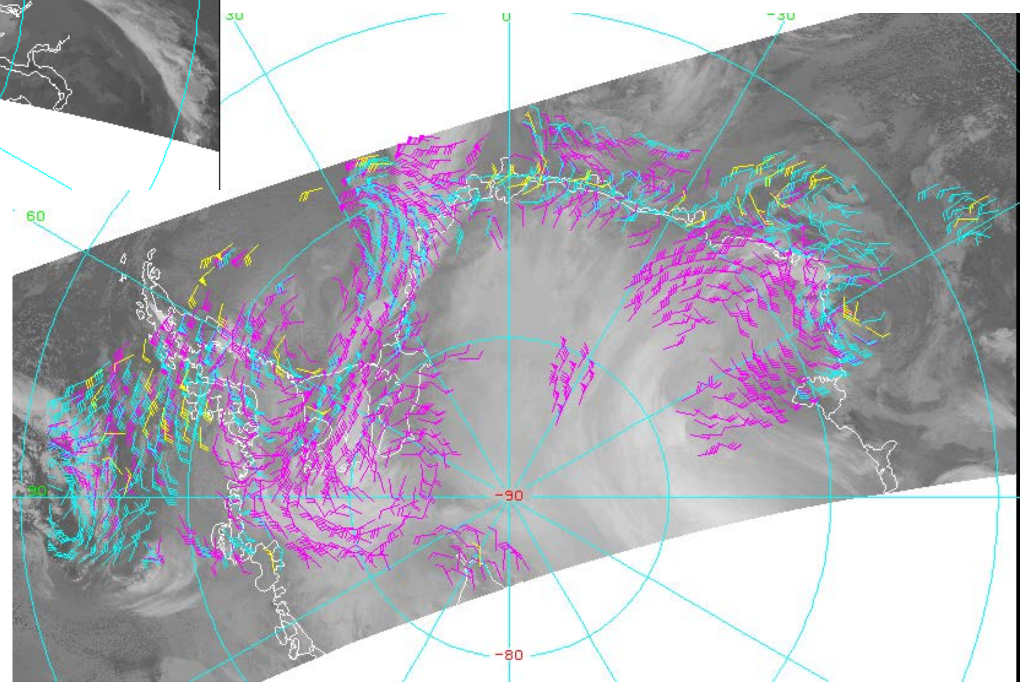


S-NPP VIIRS winds, Arctic

NOAA-20 VIIRS Winds Examples



Left: Arctic, 28 July 2018, 1942Z



Right: Antarctic, 28 July 2018, 2033Z

Requirements

JPSS L1RD supplement (threshold) requirements versus observed

Attribute	Threshold	Observed/validated
Geographic coverage	~70^o latitude to poles	~65^o to poles
Vertical Coverage	Surface to tropopause	same
Vertical Cell Size	At cloud tops	same
Horizontal Cell Size	10 km (should be ~19 km, CCR Aug 2015)	same
Mapping Uncertainty	0.4 km (nadir); 1.5km (edge of scan)	0.57 km
Measurement Range	Speed: 3 to 100 m s^{-1}; Direction: 0 to 360 degrees	same
Measurement Accuracy	Mean vector difference: 7.5 m/s	5.7-7.0 m/s (w/raobs)
Measurement Precision	Mean vector difference: 4.2 m/s (was 3.8 m/s)	2.7-3.8 m/s (w/raobs)
Measurement Uncertainty	Not specified	Not applicable

AMV Performance Metrics

AMVs (QI>60) are matched and compared against RAOBS or GFS model analysis winds. Accuracy is the mean vector difference (mean VD or MVD). Precision is standard deviation around the MVD.

$$Accuracy = \frac{1}{N}\sum_{i=1}^{N}(VD_i)$$

$$\Pr ecision = \sqrt{\frac{1}{N}\sum_{i=1}^{N}((VD_i) - (MVD))^2}$$

where:

$$(VD)_i = \sqrt{(U_i - U_r)^2 + (V_i - V_r)^2}$$

U_i and V_i ---> AMV

U_r and V_r ---> “Truth”

Processing Environment

- The NOAA-20 winds are in NDE, version 2.0.16 (April 2019).
- The operational NOAA-20 winds in NDE have been validated and are same as one in STAR/ASSISTT.
- NOAA-20 VIIRS winds evaluated here were produced by STAR/ASSISTT (v2r1).

Evaluation of algorithm performance

- The winds algorithm is described in the Algorithm Theoretical Basis Document (ATBD; see References).
- A Beta review was not performed. The S-NPP VIIRS winds were declared Validated Maturity in late 2016. There were no issues.
- The NOAA-20 VIIRS winds were declared Provisional Maturity in October 2018. There were no issues other than the limited data availability at that time.
- Improvements since Beta S-NPP Maturity Review (2016)
  - Algorithm Improvements: None
  - LUT / PCT updates: None
- Algorithm performance evaluation – See the following slides.

Validation Strategy

- Derive winds over both poles using overlapping S-NPP or NOAA-20 VIIRS orbits

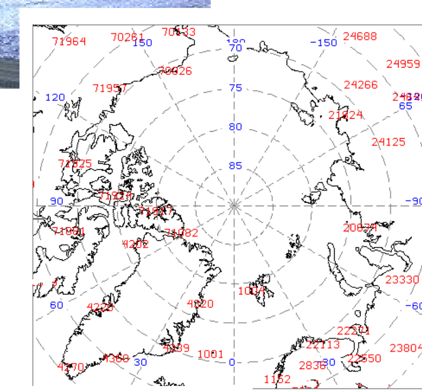
- Derive winds with full product precedence in place
  - Enterprise cloud mask (ECM) product is used
  - Cloud Products (cloud-top temp, pressure, phase, type) are generated as part of the product precedence chain

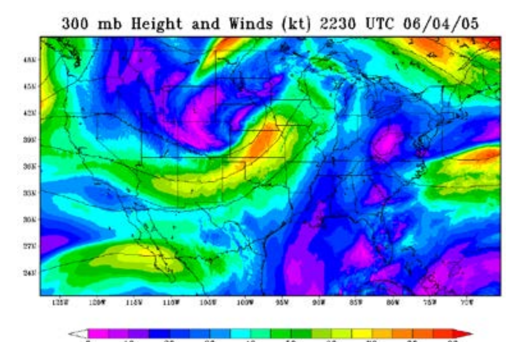
- Collocate (in space and time) derived satellite winds with reference ("truth") winds
  - Radiosonde wind observations (Land)
  - Aircraft wind observations (Land & Ocean)
  - GFS analysis winds (Ocean)

- Generate comparative statistics (satellite winds minus reference winds)
  - Accuracy
  - Precision

Derived Motion Winds Test Plan – Offline Validation: Truth Data

- Radiosonde wind observations serve as a key validation data source for derived motion wind products
  - Used by all operational satellite processing centers that generate satellite derived motion winds
- Aircraft wind observations
- GFS Model Analysis Wind Fields





Validation Statistics: Northern Hemisphere Winter

NOAA-20 VIIRS Winds vs. Radiosondes, December 2018 – March 2019

Northern Hemisphere	**All levels**	**Low (>700 hPa)**	**Middle (700-400 hPa)**	**High (<400 hPa)**
Accuracy	**5.92**	**5.89**	**5.82**	**6.12**
Precision	**4.22**	**4.08**	**4.03**	**4.58**
Speed bias	-0.09	0.10	-0.22	0.04
Speed RMSE	4.64	4.58	4.61	4.72
Mean AMV speed	18.71	11.44	16.62	25.32
Mean raob speed	18.80	11.35	16.85	25.28
Count	13,972	1,954	7,511	4,507

Requirements:
Accuracy: 7.5 m/s
Precision: 4.2 m/s

All values except counts are m/s.
NOAA-20 VIIRS winds used in the analysis were generated at STAR.

Validation Statistics: Southern Hemisphere Summer

NOAA-20 VIIRS Winds vs. Radiosondes, December 2018 – March 2019

Southern Hemisphere	**All levels**	**Low (>700 hPa)**	**Middle (700-400 hPa)**	**High (<400 hPa)**
Accuracy	**5.42**	**4.84**	**5.26**	**6.33**
Precision	**3.52**	**2.76**	**3.32**	**4.35**
Speed bias	-0.03	0.02	0.27	-0.87
Speed RMSE	4.15	3.89	3.96	4.80
Mean AMV speed	12.37	8.73	11.52	17.67
Mean raob speed	12.40	8.71	11.25	18.54
Count	4,088	751	2,430	907

Requirements:
Accuracy: 7.5 m/s
Precision: 4.2 m/s

All values except counts are m/s.
NOAA-20 VIIRS winds used in the analysis were generated at STAR.

Validation Statistics: NH (summer) and SH (winter)

NPP VIIRS Winds vs. Radiosondes July 5-29, 2018

100_1000mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
Accuracy	5.79	5.79	0.00	0.00
Precision	3.58	3.58	0.00	0.00
Speed Bias	1.03	1.03	0.00	0.00
Speed	20.44	20.44	0.00	0.00
Sample	4668	4668	0	0
101_400mb	**90S – 90N**	**25N – 90N**	**25S – 25N**	**25S – 90S**
Accuracy	6.39	6.39	0.00	0.00
Precision	3.76	[illegible]	[illegible]	[illegible]
Speed Bias	1.33	[illegible]	[illegible]	[illegible]
Speed	23.85	2[illegible]	[illegible]	[illegible]
Sample	2085	[illegible]	[illegible]	[illegible]
401_700mb	**90S – 90N**	**25N**	[illegible]	[illegible]
Accuracy	5.42	[illegible]	[illegible]	[illegible]
Precision	3.40	[illegible]	[illegible]	[illegible]
Speed Bias	0.81	[illegible]	[illegible]	[illegible]
Speed	18.95	1[illegible]	[illegible]	[illegible]
Sample	2071	[illegible]	[illegible]	[illegible]
701_1000mb	**90S – 90N**	**25N**	[illegible]	[illegible]
Accuracy	4.81	[illegible]	[illegible]	[illegible]
Precision	3.13	[illegible]	[illegible]	[illegible]
Speed Bias	0.66	[illegible]	[illegible]	[illegible]
Speed	12.56	12.56	0.00	0.00
Sample	512	512	0	0

Observed
Accuracy: 5.79-5.99 m/s
Precision: 3.58-3.64 m/s

Requirements:
Accuracy: 7.5 m/s
Precision: 4.2 m/s

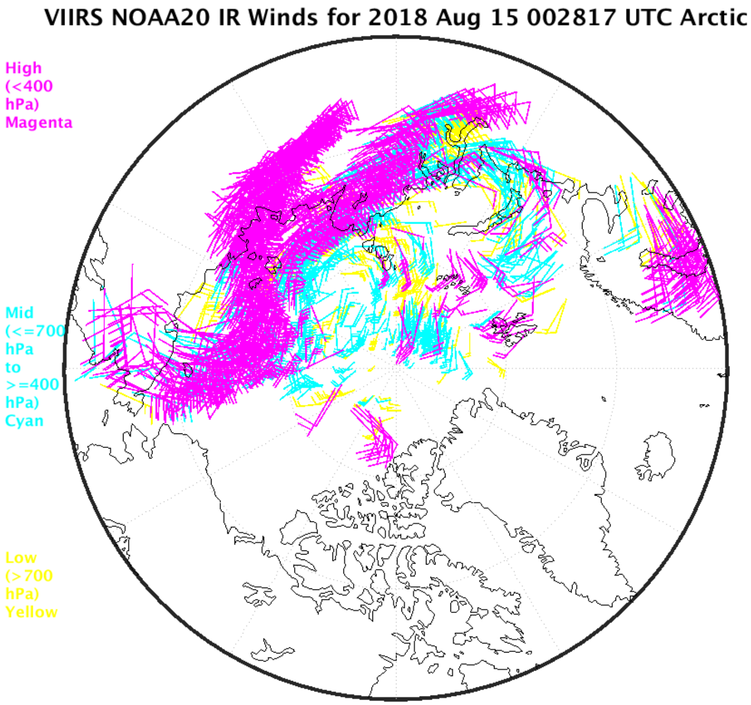
NOAA-20 VIIRS Winds vs. Radiosondes July 5-29, 2018

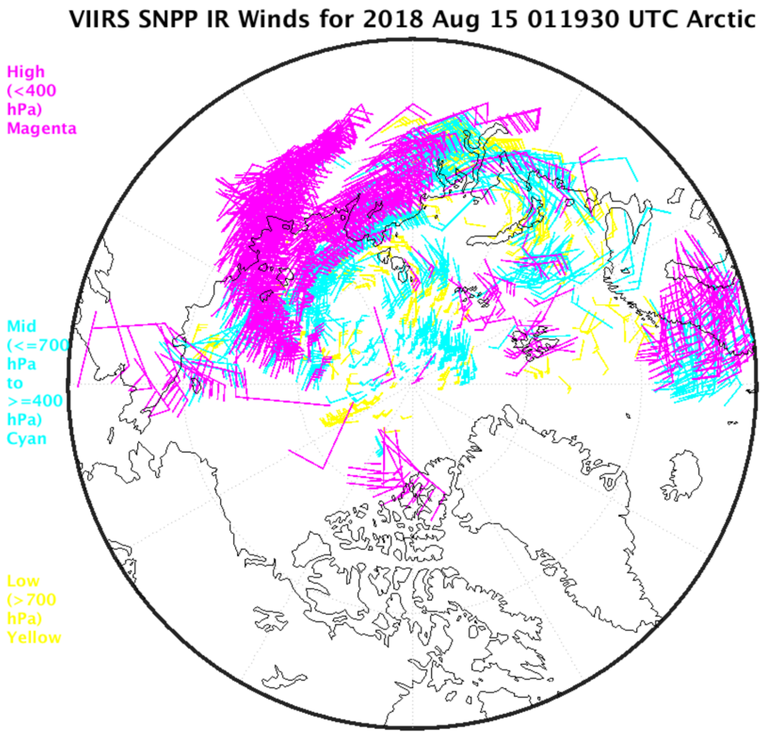
100_1000mb	90S – 90N	25N – 90N	25S – 25N	25S – 90S
Accuracy	5.99	5.99	0.00	0.00
Precision	3.64	3.64	0.00	0.00
Speed Bias	1.02	1.02	0.00	0.00
Speed	20.19	20.19	0.00	0.00
Sample	3860	3860	0	0
101_400mb	**90S – 90N**	**25N – 90N**	**25S – 25N**	**25S – 90S**
Accuracy	6.36	6.36	0.00	0.00
sion	3.82	3.82	0.00	0.00
Bias	1.23	1.23	0.00	0.00
[illegible]	23.71	23.71	0.00	0.00
e	2073	2073	0	0
700mb	**90S – 90N**	**25N – 90N**	**25S – 25N**	**25S – 90S**
acy	5.79	5.79	0.00	0.00
sion	3.47	3.47	0.00	0.00
Bias	0.53	0.53	0.00	0.00
[illegible]	17.93	17.93	0.00	0.00
e	1190	1190	0	0
1000mb	**90S – 90N**	**25N – 90N**	**25S – 25N**	**25S – 90S**
acy	5.10	5.10	0.00	0.00
sion	3.16	3.16	0.00	0.00
Speed Bias	1.28	1.28	0.00	0.00
Speed	12.47	12.47	0.00	0.00
Sample	597	597	0	0

S-NPP VIIRS winds generated at OSPO

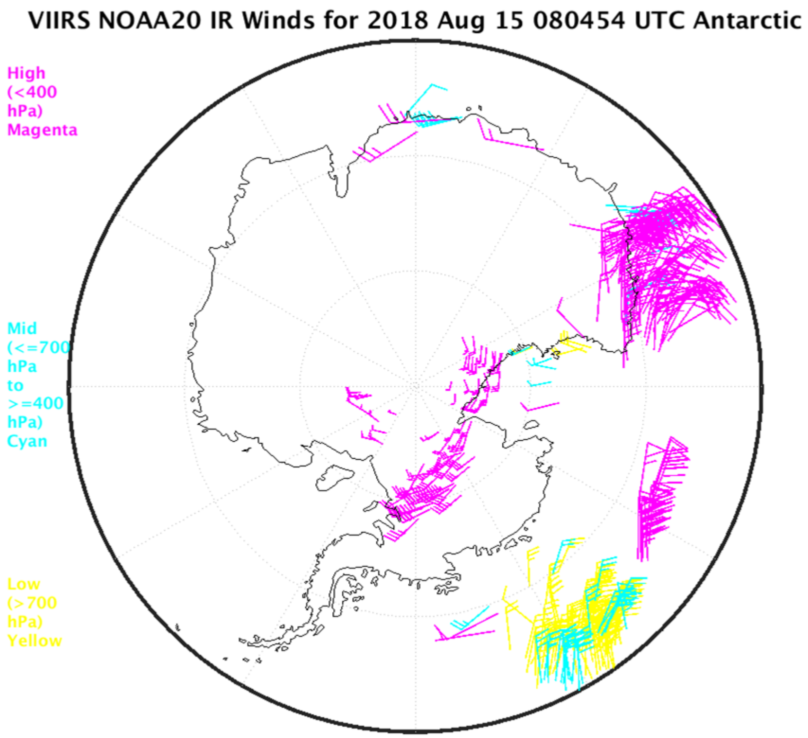
NOAA-20 VIIRS winds generated at STAR. Statistics include only VIIRS winds at 12Z. NOAA-20 VIIRS Winds/Raob co-location files being reprocessed for the month of July to include 00Z matchups

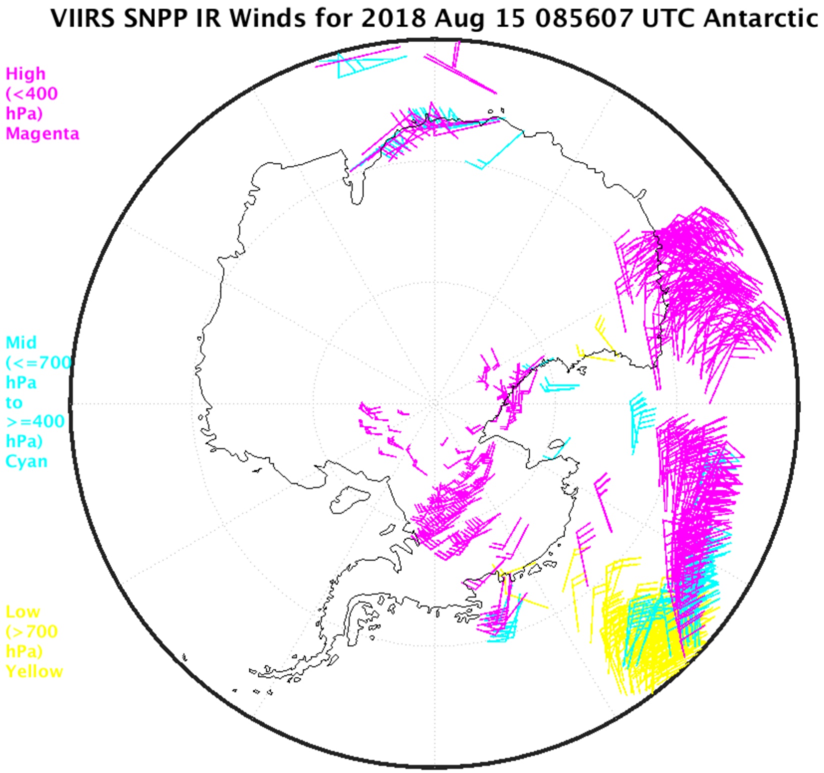
NOAA-20 and S-NPP Comparison, Arctic



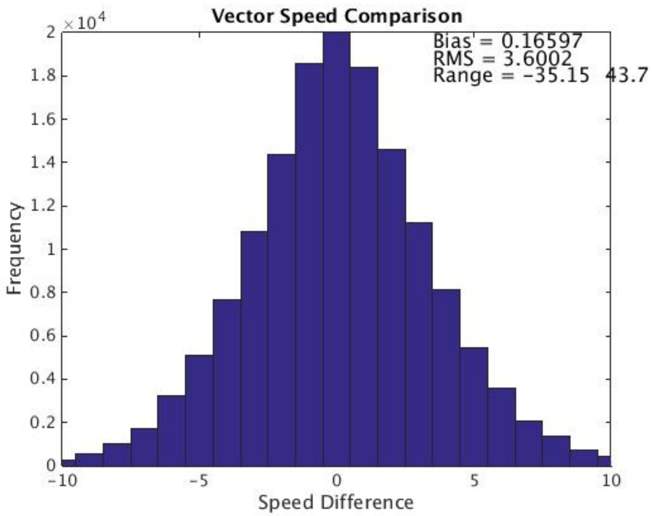


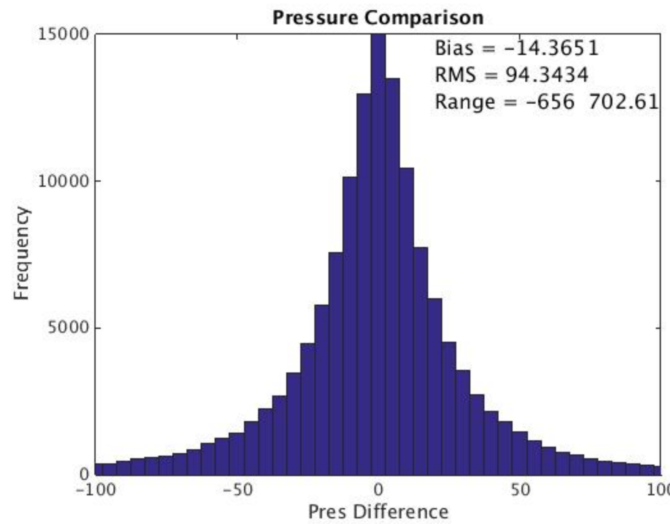
NOAA-20 and S-NPP Comparison, Antarctic

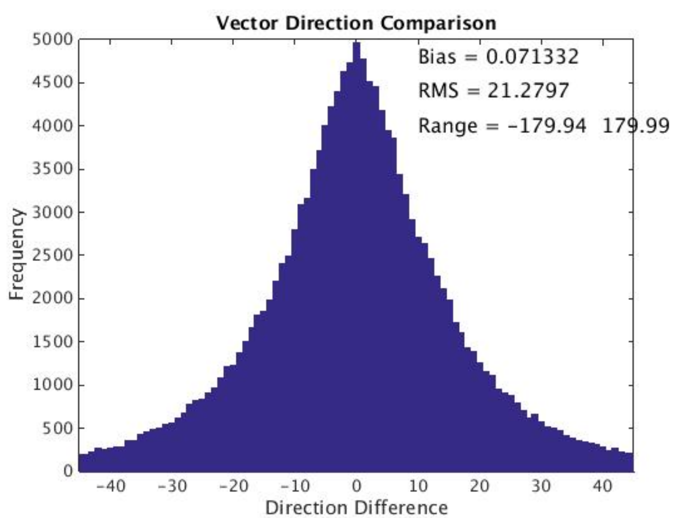




NOAA-20 and S-NPP Comparison



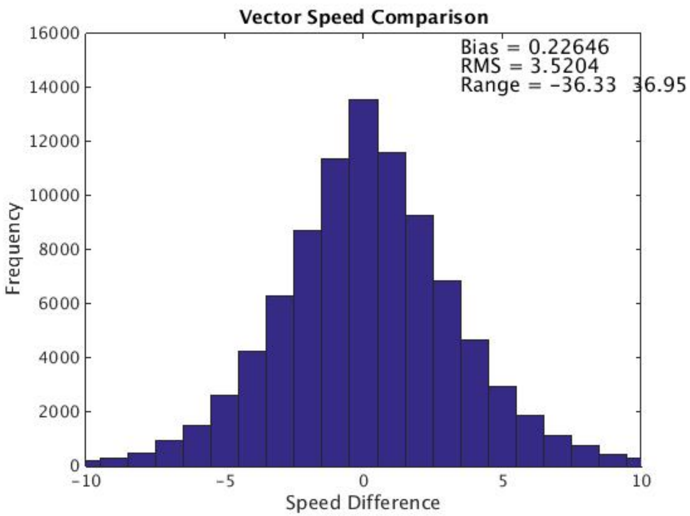


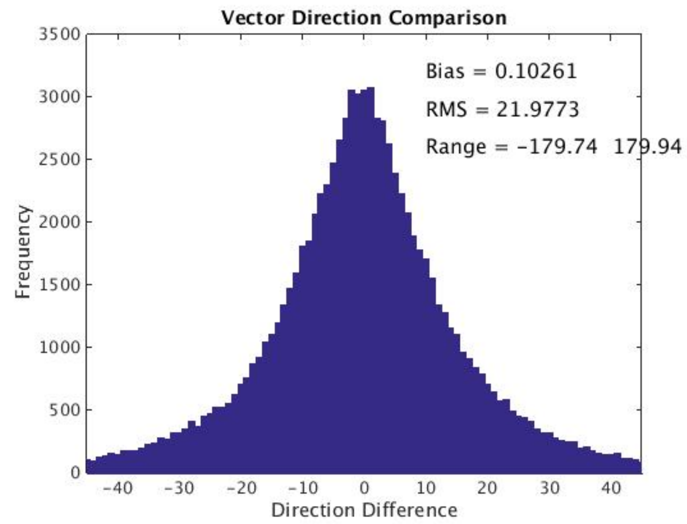


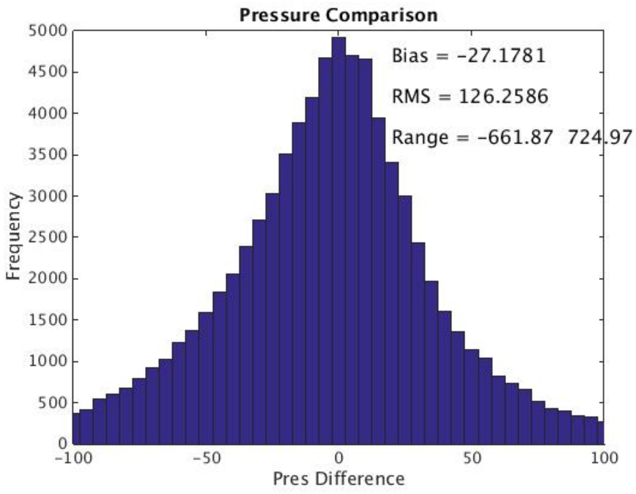
Winds are from STAR. Matchups are within 10 km and 50 min. Dates: 2018/08/15, 09/18-21, 10/05-08, 10/24-11/01, 11/14, 11/16, 11/22-24, and 11/26

Statistics:
count = 152129
Spd rms = 3.6
Dir rms = 21.3
Press rms = 94.3
Mean pres diff = -14.365
Mean spd diff = 0.166
Mean dir diff = 0.071

NOAA-20 and MODIS Comparison







Winds are from STAR. Matchups are within 10 km and 50 min. Dates: 2018/08/15, 09/18-21, 10/05-08, 10/24-11/01, 11/14, and 11/16

Statistics:
count = 91300
Spd rms = 3.5
Dir rms = 21.98
Press rms = 126.26
Mean pres diff = -27.18
Mean spd diff = 0.227
Mean dir diff = 0.103

Evaluation of the effect of required algorithm inputs

- Required Algorithm Inputs
  - VIIRS SDR granule files containing science data (radiances) for 16 Moderate Resolution Bands over north and south polar region. Each polar pass has 14~18 granules.
  - VIIRS granule files containing geolocation data.
  - VIIRS granule files containing cloud data over polar region.
  - The 0.25 degree global AVHRR only Daily OISST.
  - GFS 6-hour global forecast data at 0.5 degree in GRIB2 format from NCEP (Vertical profiles of NWP temperature, wind, and pressure; NWP level for the surface and tropopause)
- Upstream algorithms: Cloud detection (ECM) and properties (cloud phase/type and top pressure)
- Evaluation of the effect of required algorithm inputs: Sensitivity to input cloud products.

Quality Indicators

- All derived winds are subject to the following quality assurance checks and are flagged if test thresholds are exceeded
  - Correlation check (threshold = 0.60)
  - Correlation match occurs on the boundary of the search scene
  - u- and v-component acceleration checks (threshold = 10 m/s)
  - Minimum speed check (threshold >= 3 m/s)
  - Directional (threshold = 50 deg) and speed checks (threshold = 8 m/s) against forecast
- Quality indicators are computed and appended to each derived wind vector
  - Quality Indicator (QI)
  - Expected Error (EE)

Quality Indicators, cont.

- QI Component Tests:
  - AMV Direction Consistency Check
  - AMV Speed Consistency Check
  - Vector Consistency Check
  - Spatial Consistency Check
    - Test of the spatial wind consistency of the AMV with its closest neighbor.
  - Forecast Check (Optional)
    - Comparison of AMV against NWP wind interpolated to AMV location and time.
- Expected Error (EE)
  - Originally developed at the Australian Bureau of Meteorology (LeMarshall et al., 2004) as an alternative to the QI.
  - Based on a linear regression of collocated AMV – RAOB vector differences using predictors that include the QI consistency tests and other vector and NWP information
  - Regression produces an error estimate in m/s rather than a normalized score.

Quality Indicators, cont.

- Both the QI and EE have their strengths. The EE estimated vector reliability values have a closer 1-to-1 relationship with actual RMS errors measured against raobs. The QI tends to rank more vectors as reliable, especially fast AMVs.
- Both methods are used as AMV quality flags. Users can selectively employ the flags in their local quality control.
- AMVs that pass both EE and QI thresholds are kept.

Exception Handling

- The algorithm checks whether the time interval is valid and that the temporal data has been loaded properly.
- The algorithm checks that the search region is larger than the target scene.
- The algorithm checks the sensor data flags to see if channel data is valid.
- If the AMV retrieval is not performed, the retrieved parameters are set to a missing value and the quality flags are set to the lowest quality value.

Error Budget

Attribute Analyzed	L1RD Threshold	On-orbit Performance	Meet Requirement?	Additional Comments
Accuracy	7.5 m/s	4.8-6.3 m/s	Yes	Raob, aircraft
Precision	4.2 m/s	2.8-4.3 m/s	Yes overall	Raob, aircraft
Horizontal cell size	10 km	19 km (inherent to the algorithm)	Yes	
Mapping uncertainty	0.4 km nadir; 1.5 km EOS	0.57 km	Yes	MS2GT and McIDAS[1]

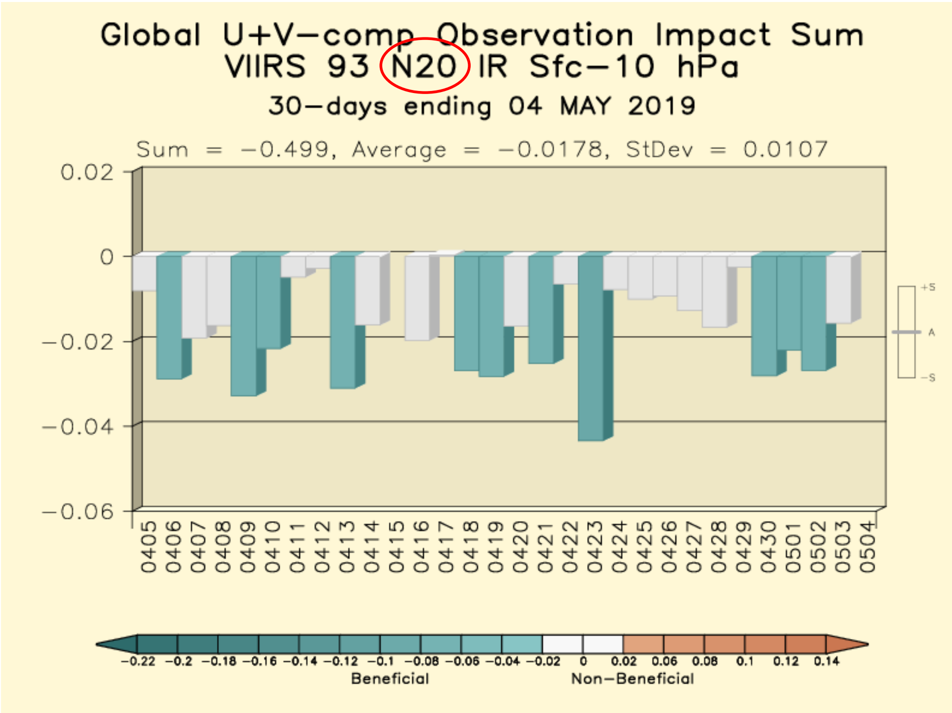
[1]Details on mapping uncertainty were given in the 18 October 2016 maturity review.

Users

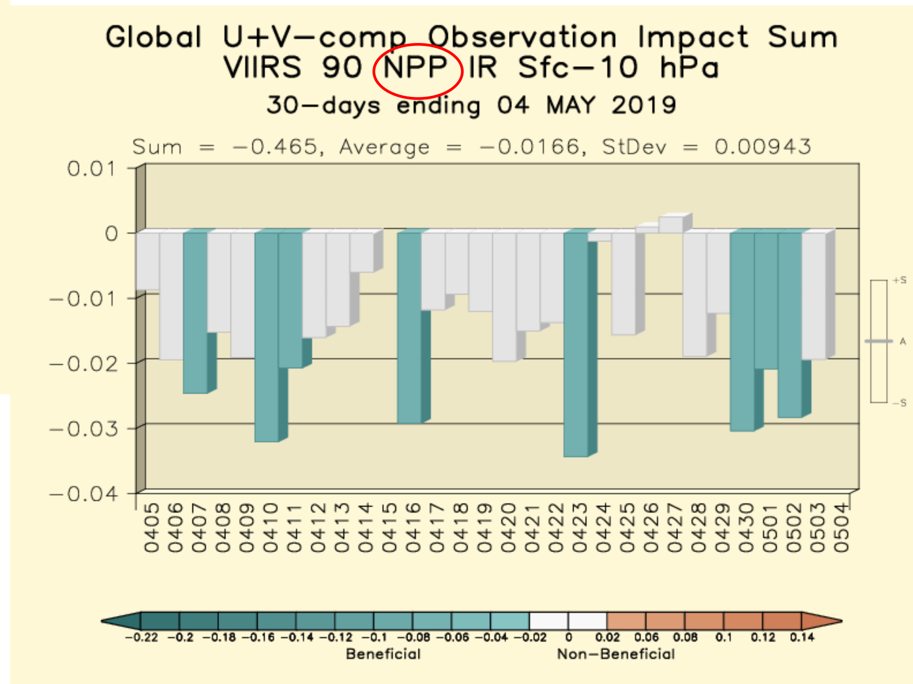
13 NWP centers in 9 countries use polar winds, some using VIIRS winds operationally:

- U.S. Users:
  - NCEP (TBD)
  - NRL/FNMOC (Randy Pauley)
  - GMAO/JCSDA
- Foreign Users:
  - UK Met Office (Mary Forsythe)
  - JMA (Masahiro Kazumori)
  - ECMWF (Jean-Noel Thepaut)
  - DWD (Alexandar Cress)
  - Meteo-France (Bruno Lacroix)
  - CMC (Real Sarrazin)
  - BOM (John LeMarshall)
  - EUMETSAT (Simon Elliott)
  - Russian Hydrometcenter (Mikhail Tsyrulnikov)
  - CMA (China)

Forecast Impact, NRL



Forecast impacts from NOAA-20 (left) and S-NPP (below) VPW for the 30-day period ending 4 May 2019. **Negative means positive impact.**



Courtesy of Naval Research Lab

Regarding the addition of NOAA-20 VPW to the system that already assimilated S-NPP VPW, there was no decrease in the NPP FSOI (forecast sensitivity observation impact) with the introduction of NOAA-20, so if they are borrowing impacts, it appears to be from other data types rather than each other.

User Feedback

- Over the last decade, model impact studies have demonstrated that model forecasts for the extratropics are improved when the polar winds are assimilated. Forecasts can be extended 2-6 hrs, depending on the location.
- NWP users have reported positive results for the VIIRS Polar Winds at the International Winds Workshops (2016, 2018). From NRL: "*The VIIRS ob impact is noteworthy—20% of the polar wind ob impact from 11% of the polar wind obs.*"

Organization	Use VPW operationally	Currently monitoring	Plan to use?
NCEP	Yes (SNPP)	Yes	Yes (2019 for N20)
DWD	Yes		
Navy	Yes		
ECMWF	Yes		
Met Office		Yes	Yes
CMC	Yes		
MeteoFrance		Yes	Yes

Awaiting information from the other NWP centers.

Risks, Actions, and Mitigations

There were no risks identified at the S-NPP Validated Maturity Review in late 2016 or the NOAA-20 Provisional Review in October 2018.

Identified Risk	Description	Impact	Action/Mitigation and Schedule
None			

Documentation

Science Maturity Check List	Yes ?
ReadMe for Data Product Users	Yes
Algorithm Theoretical Basis Document (ATBD)	Yes
Algorithm Calibration/Validation Plan	Yes
(External/Internal) Users Manual	Yes
System Maintenance Manual (for ESPC products)	Yes
Peer Reviewed Publications (Demonstrates algorithm is independently reviewed)	Yes
Regular Validation Reports (at least annually) (Demonstrates long-term performance of the algorithm)	Yes

Check List - Validated Maturity

Validated Maturity End State	Assessment
Product performance has been demonstrated over a large and wide range of representative conditions (i.e., global, seasonal).	All requirements have been met
Product analyses are sufficient for full qualitative and quantitative determination of product fitness-for-purpose	Yes
Comprehensive documentation of product performance exists that includes all known product anomalies and their recommended remediation strategies for a full range of retrieval conditions and severity level.	Yes
Product is ready for operational use based on documented validation findings and user feedback.	Yes

Conclusion

- Cal/Val results summary:
  - Team recommends algorithm Validated Maturity. Validated Maturity declaration should not be a problem after more data are available.
  - Caveats: None

Path Forward

- Lessons learned for N20 cal/val:
  - No issues
- Planned improvements:
  - Work toward *Objective* requirements.
  - Algorithm plans: Parallax correction
  - Research: Day-night band; S-NPP/NOAA-20 dual ("tandem") winds (PGRR project)
- Future Cal/Val activities / milestones:
  - See cal/val plan

References

ATBD

Daniels, J., W. Bresky, J. Key, S. Wanzong, and A. Bailey, 2018, Algorithm Theoretical Basis Document for VIIRS Polar Winds, Version 1.1, NOAA/NESDIS Center for Satellite Applications and Research, 77 pp.

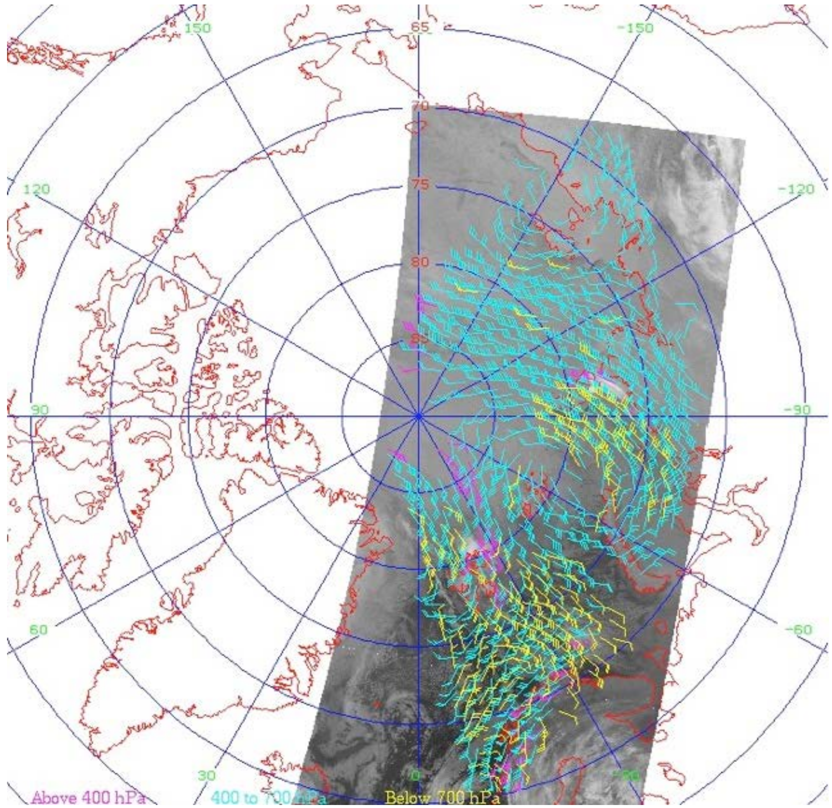
Journal Papers

Bresky, W., J. Daniels, A. Bailey, and S. Wanzong, 2012: New Methods Towards Minimizing the Slow Speed Bias Associated With Atmospheric Motion Vectors (AMVs). J. Appl. Meteor. Climatol., 51, 2137-2151.

Daniels, J. and W. Bresky, 2010: A New Nested Tracking Approach for Reducing the Slow Speed Bias Associated With Atmospheric Motion Vectors (AMVS). Proceedings of the 10th International Winds Workshop, Tokyo, Japan.

Heidinger, A., 2010: GOES-R Advanced Baseline Imager (ABI) algorithm theoretical basis document for cloud height. GOES-R Program Office, 77 pp. [Available online at http://www.goes-r. gov/products/ATBDs/baseline/Cloud_CldHeight_v2.0_no_color.pdf.]

Key, J., D. Santek, C.S. Velden, N. Bormann, J.-N. Thepaut, L.P. Riishojgaard, Y. Zhu, and W.P. Menzel, 2003, Cloud-drift and Water Vapor Winds in the Polar Regions from MODIS, IEEE Trans. Geosci. Remote Sensing, 41(2), 482-492.



Thank you!

Extra Slides

Requirement Check List – VIIRS Polar Winds

JERD		
JERD-2139	The algorithm shall produce a polar winds product that has vertical coverage from the surface to the tropopause	
JERD-2140	The algorithm shall produce a polar winds product that has a horizontal resolution of 10 km	
JERD-2141	The algorithm shall produce a polar winds product that has a vertical reporting interval at cloud tops	
JERD-2142	The algorithm shall produce a polar winds product that has a mapping uncertainty (3 sigma) of 5 km	
JERD-2143	The algorithm shall produce a polar winds product that has a measurement range of: 3 to 100 m/sec for speed and 0 to 360 degrees for direction	
JERD-2144	The algorithm shall produce a polar winds product that has a measurement precision mean vector difference of 3.8 m/sec	
JERD-2145	The algorithm shall produce a polar winds product that has a measurement accuracy mean vector difference of 7.5 m/sec	

Additional References

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