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Innovative Atmospheric Motion Vector Products from VIIRS:
Expanding Beyond the Use of a Single Channel and Satellite

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Introduction

In current polar Atmospheric Motion Vector (AMV) operations, the VIIRS IR channel data from a single satellite is utilized. To maximize the usefulness of VIIRS winds at improving weather forecasts, both NOAA-20 and S-NPP can be used in tandem to develop IR AMVs that have increased spatial coverage, as both satellites follow similar orbital paths. Furthermore, this cuts in half the time to track targets (50.5 versus 101 minutes), providing more timely wind information. Validation results compared to rawinsondes will show this, and a model impact study confirms the improvement in forecasts. The focus of this poster is the use of a triplet of VIIRS orbits over the polar regions, where coverage does not change as much between successive overpasses. To expand coverage more equatorward, where a triplet of orbits cannot be used, a test period of tandem VIIRS IR AMVs were created using a novel method of Quality Control (QC) that expands coverage into mid- and low-latitudes with the use of only two orbits (duplet). Initial results from this test period will be shown. In addition, two other products will be discussed that expand the usage of VIIRS AMVs beyond the IR channel: the Short-Wave IR (SWIR) and Day-Night-Band (DNB) AMV products. Examples will be presented with initial validation results compared to rawinsondes.

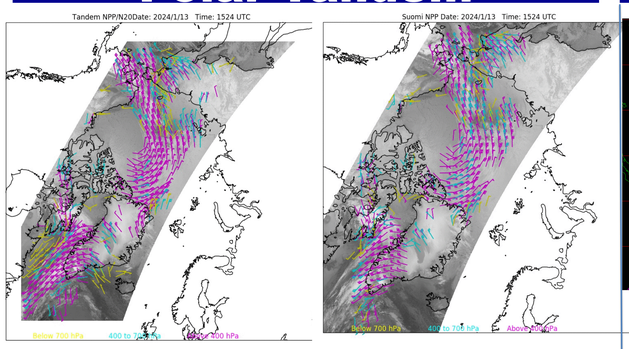
In summary, it is vital to maximize the VIIRS data for AMV production beyond single satellite and one channel. To maximize the impact of VIIRS winds, we need to be innovative. This includes using multiple satellites that use the same instrument (VIIRS) and follow a similar orbit and utilizing more channels that can offset limitations in the VIIRS IR wind product.

Discussion

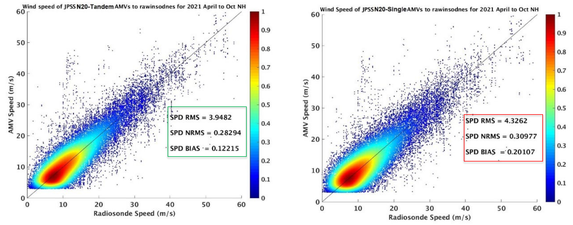
VIIRS experimental AMVs shown below have been validated against rawinsondes, model analysis and tested for model impact. Model impact studies by Naval Research Laboratory (NRL) show positive impact of the polar tandem (triplet of orbits) and SWIR products in the NAVGEM model. The global tandem (2-orbits) product has a positive impact on the 24-hour geopotential height forecast with overall neutral impact on the GFS model beyond 72-hours. The polar tandem AMV product (https://stratus.ssec.wisc.edu/products/rtpolarwinds/rtpolarwinds.html) has been shown to increase spatial coverage and improve statistics over single satellite compared to rawinsondes. Most notable is the 0.4 ms^{-1} reduction of speed Root Mean Squared (RMS) error for tandem over single. The global tandem product has a speed RMS of around 4 ms^{-1} which is about 0.1 ms^{-1} higher than the polar tandem. SWIR AMVs have been shown to have better accuracy, precision, Normalized RMS Vector Difference (NRMSVD) than IR AMVs at low levels (>= 700 hPa). DNB AMVs have been shown to have slightly higher speed RMS than IR overall; however, accuracy, standard deviation, speed rms, and NRMSVD is observed to be better than IR at low levels, with the overall u and v components having slightly higher correlation coefficients. A model study of the DNB winds by Naval Research laboratory is expected later this year. These products are routinely generated daily and archived with data provided by request for scientific purposes.

AMV Products

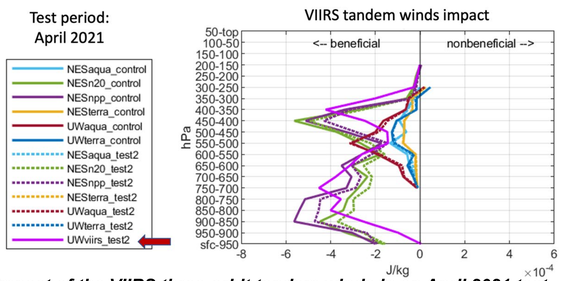
Polar Tandem



IR AMVs from S-NPP VIIRS (right) and tandem (NOAA-20+NPP, left) over the Arctic on January 13, 2024. This was a negative Arctic Oscillation pattern with strong poleward flow converging over north Greenland. Notice the increase coverage with Tandem product south and west of Greenland and SW Alaska.

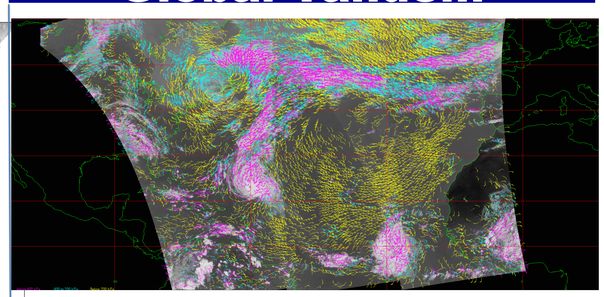


April through October Arctic VIIRS AMV comparisons to rawinsondes, for single-satellite NOAA-20 (right) and tandem (left; Scatter difference plots with density distribution (right color bar), for wind speed with AMV on y-axis and rawinsonde on x-axis.

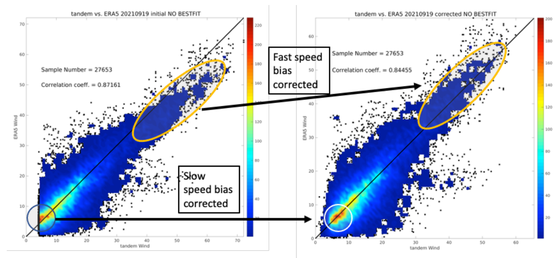


Impact of the VIIRS three-orbit tandem winds in an April 2021 test case at NRL. The magenta "UWviirs_test2" line shows the impact of the new VIIRS triplet tandem winds (Courtesy of Rebecca Stone SAIC/NRL).

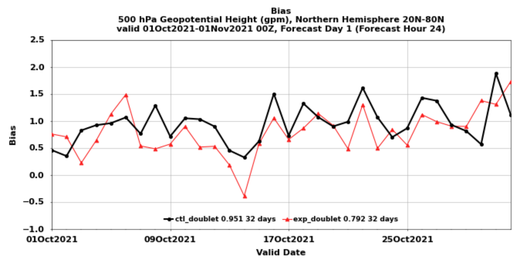
Global Tandem



An example of VIIRS IR winds coverage using several orbits of alternating passes from S-NPP and NOAA-20, color-coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).

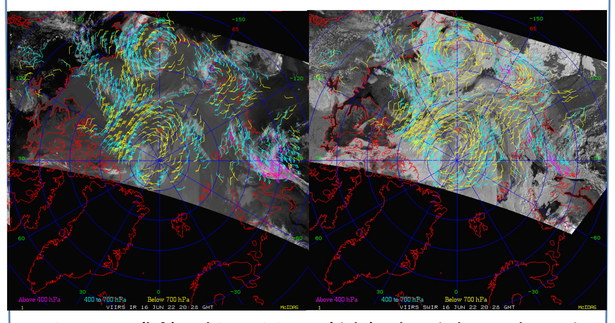


ERA5 vs tandem doublet wind speed density plot for the raw winds (left) and parallax corrected (right). Circles in the lower left of each panel show the correction of a slow speed bias; ellipses in the upper right denote the correction of a fast speed bias.



The 24-hour forecast of GFS 500 hPa geopotential height bias over the northern hemisphere from 01 October to 01 November 2021. Control (black), experiment (red).

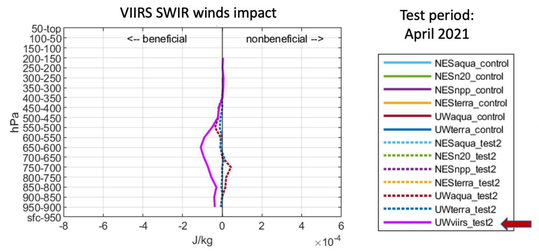
SWIR



VIIRS IR 11 μm (left) and SWIR 2.25 μm (right) polar winds over the Arctic from Suomi NPP on 16 June 2022 at 20:28 UTM pole crossing, color-coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).

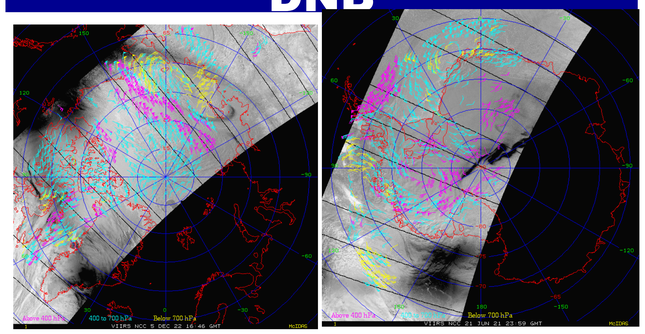
SWIR	Sample	Accuracy	Precision	NRMSVD	U-bias	V-bias	Speed RMS
<400 hPa	346	5.53	5.20	0.34	0.48	0.73	4.28
400to<700 hPa	1953	4.26	2.94	0.34	-0.39	-0.08	3.32
>=700 hPa	396	4.58	3.79	0.51	-0.63	-0.07	4.38
Total	2695	4.47	3.47	0.36	-0.31	-0.01	3.63

Comparison to Radiosondes over the Arctic. Statistics of SWIR VIIRS AMVs over 2022 April through September Green indicates where SWIR had lower value versus IR. Note that NRMSVD is Vector RMS divided by AVG RAOB wind speed.



Impact of the VIIRS SWIR in an April 2021 test case at NRL. The magenta "UWviirs_test2" line shows the beneficial impact of the new VIIRS SWIR winds (Courtesy of Rebecca Stone SAIC/NRL).

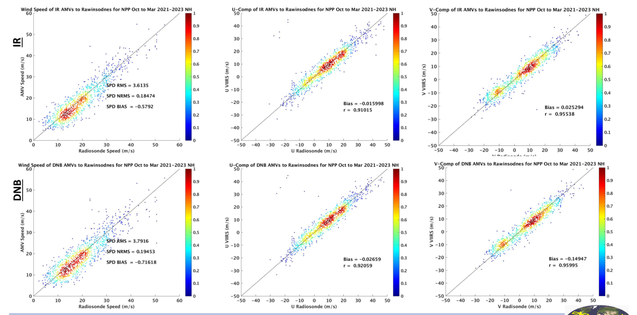
DNB



S-NPP VIIRS NCC image over the Arctic (left) on 05 December 2022 at 16:46 UTC and over Antarctic (right) 21 June 2021 at 23:59 UTC. The derived winds are color-coded by height: Yellow (below 700 hPa), cyan (400 to 700 hPa), magenta (above 400 hPa).

	Vector Acc.		Vector Prec.		Speed RMS		NRMSVD		Samples	
	DNB	IR	DNB	IR	DNB	IR	DNB	IR	DNB	IR
High ≤400 hPa	5.43	5.31	5.97	5.62	4.40	3.92	0.27	0.25	268	256
Mid 700 to <400 hPa	4.70	4.65	3.93	4.20	3.59	3.50	0.35	0.35	802	816
Low >700 hPa	4.45	4.55	2.86	3.33	3.65	3.69	0.40	0.43	139	137

Statistical comparisons of DNB and IR VIIRS CMV pairs compared to RAOBs over the Arctic (≥ 60° N) from April 2021 through March 2023 . The statistics are Vector Accuracy, Precision, Speed RMS, Vector Normalized RMS and sample size. Results are separated into three layers: High ≤400 hPa, Mid 700-400 hPa and below 700 hPa. Scatter density plots of absolute speed, u and v components are given below.



Samples: *1,209* ; Vector RMSE: IR 6.54, DNB 6.52; Vector NRMSE: IR 0.33, DNB 0.33; Vector Precision IR 4.46, DNB 4.38

A model impact study of DNB AMVs is expected in 2024.

Validation

Model Impact