



16th International Winds Working Workshop: Montreal, Canada May 8 -12 2023

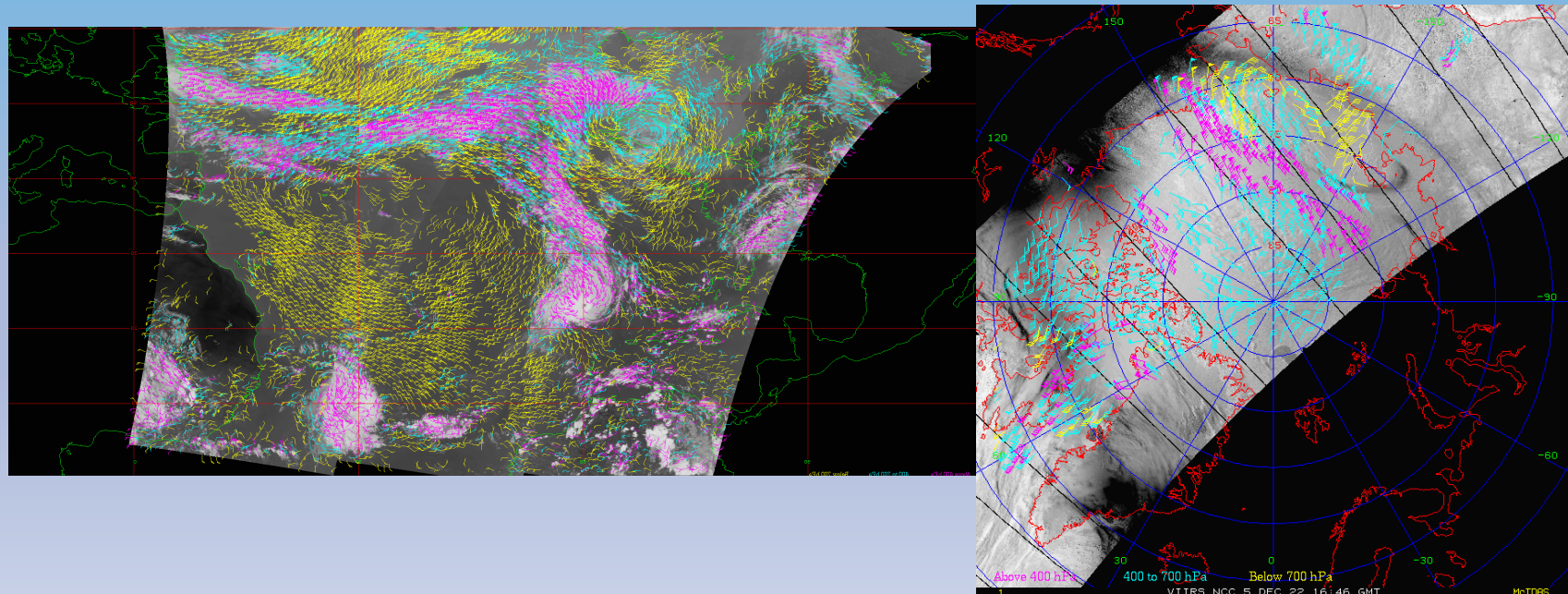
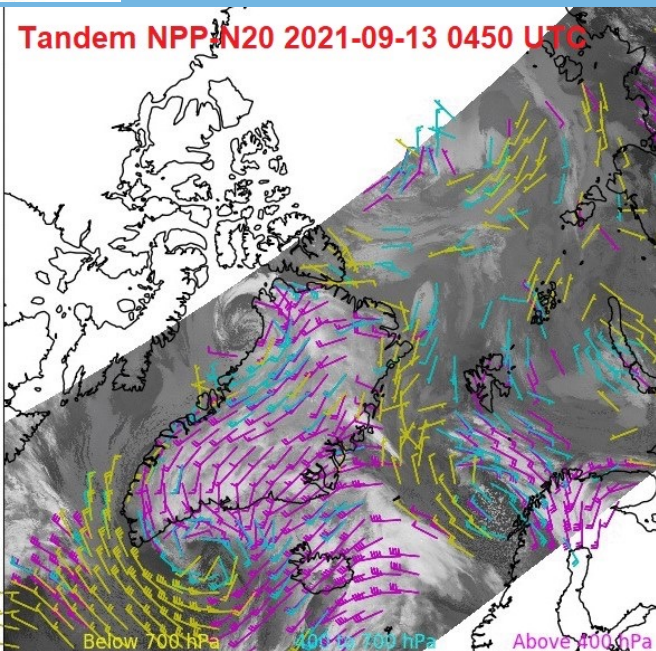


Experimental VIIRS AMV Products: Expanding Beyond the use of a Single Satellite

Richard Dworak^{1*}, Dave Santek^{*}, Jeff Key⁺ and Dave Stettner^{*}

^{*}University of Wisconsin, CIMSS

⁺NOAA/National Environmental Satellite Data and Information Services





Background and Introduction:

- **Currently, only single satellite S-NPP and NOAA-20 VIIRS instrument IR (SVM15, 11 μm) derived AMV observations are being used in operations.**
- NOAA-21 IR AMVs being validated at present with maturity review (Beta -> Provisional) expected later this year.
- UW-CIMSS provide single S-NPP and NOAA-20 IR AMVs being run from two direct broadcast sites from Fairbanks, Alaska and Sodankylä, Finland at 2 hour latency.
- Single VIIRS satellite AMVs have orbital period of 101 minutes.
- Using VIIRS satellites in **tandem cuts the time period in half** (51.5 min) for tracking cloud objects.
- This also increases the coverage of which cloud objects can be tracked.
- Locally at UW-CIMSS, we have alternating in **tandem S-NPP/NOAA-20 VIIRS IR AMVs** using the Enterprise algorithm. This tandem uses **3 overpasses (triplets)** JPSS product limited to **High latitude regions**, north (south) of 50°N (S) latitude.
- For **Global** coverage, only **2 overpasses (duplets)** can be used. Currently limited to one test period using Heritage algorithm.



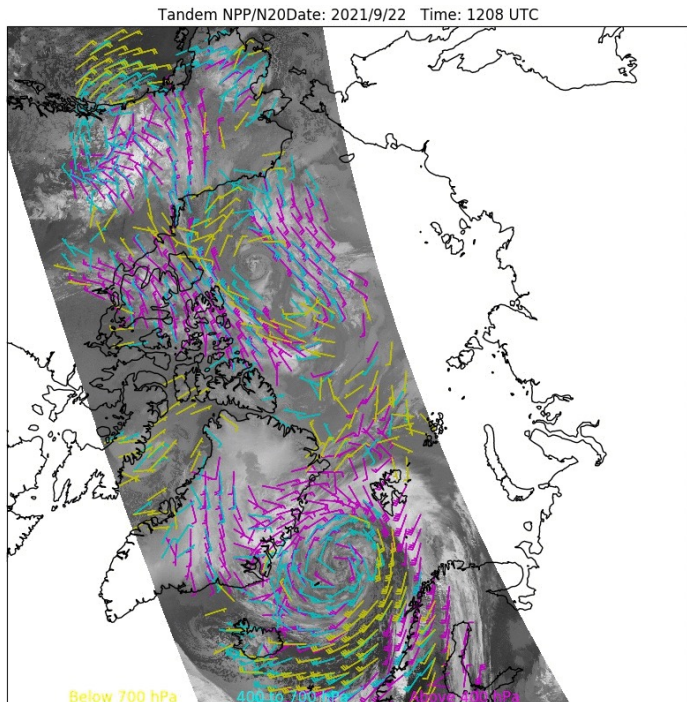
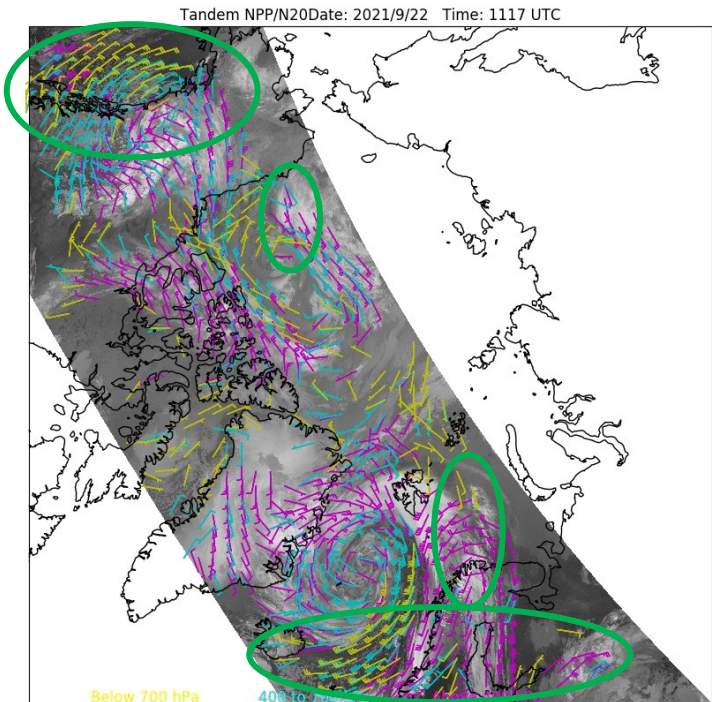
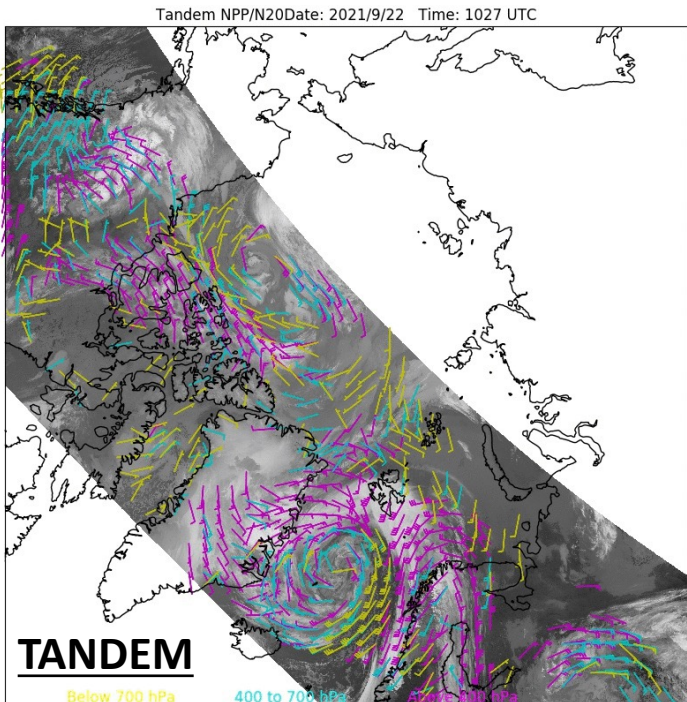
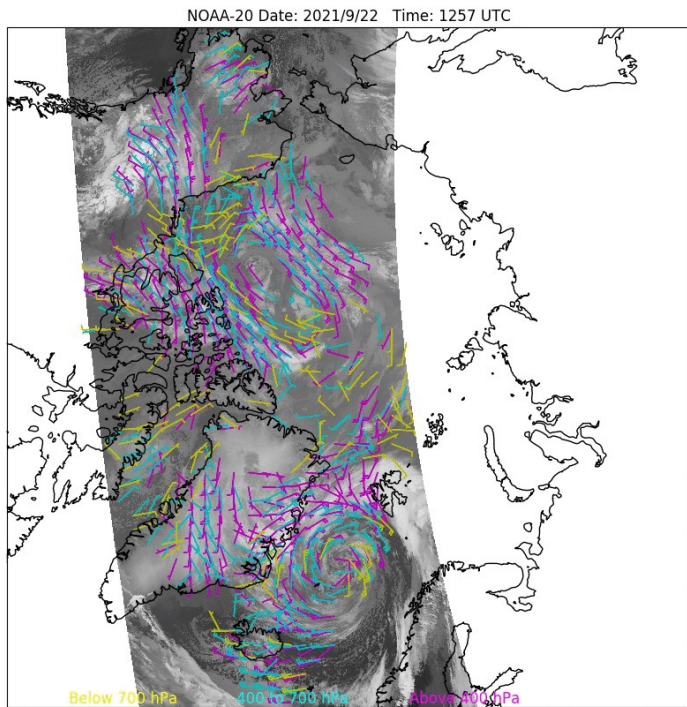
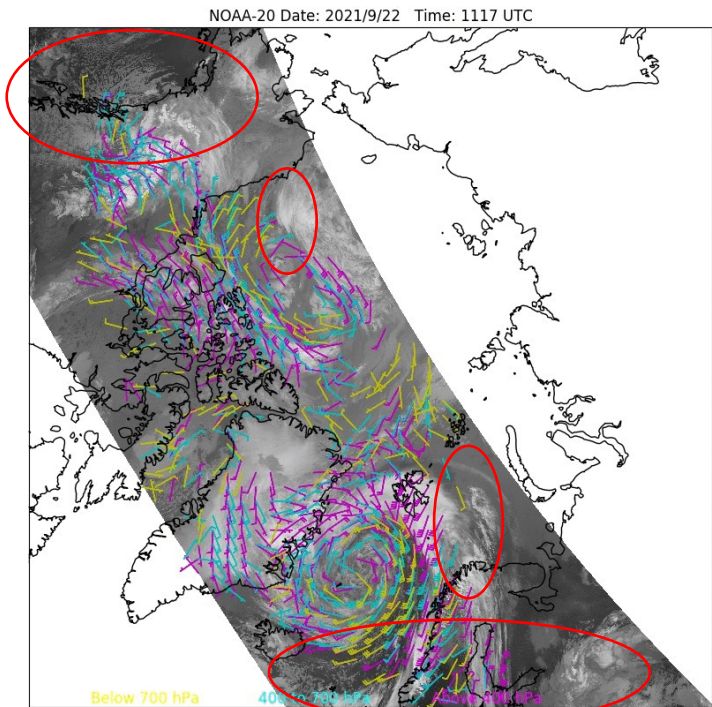
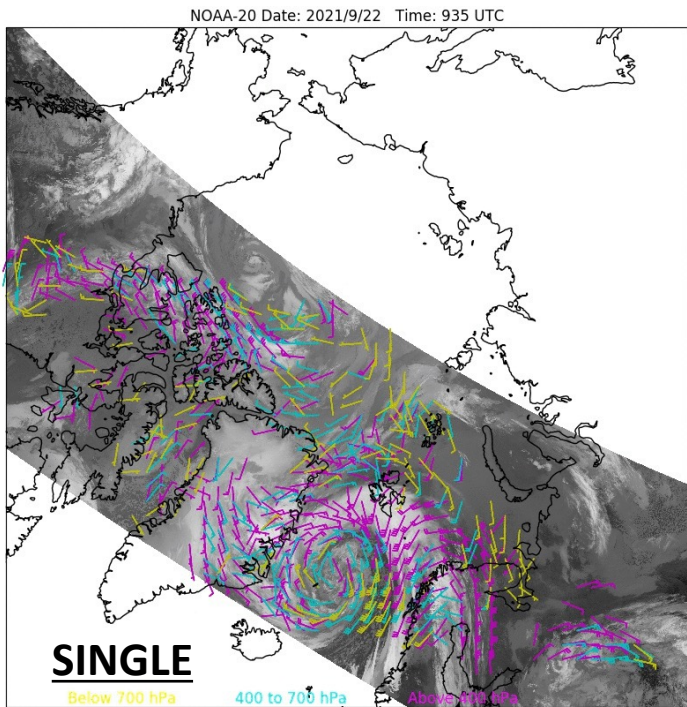
Background and Introduction (cont):

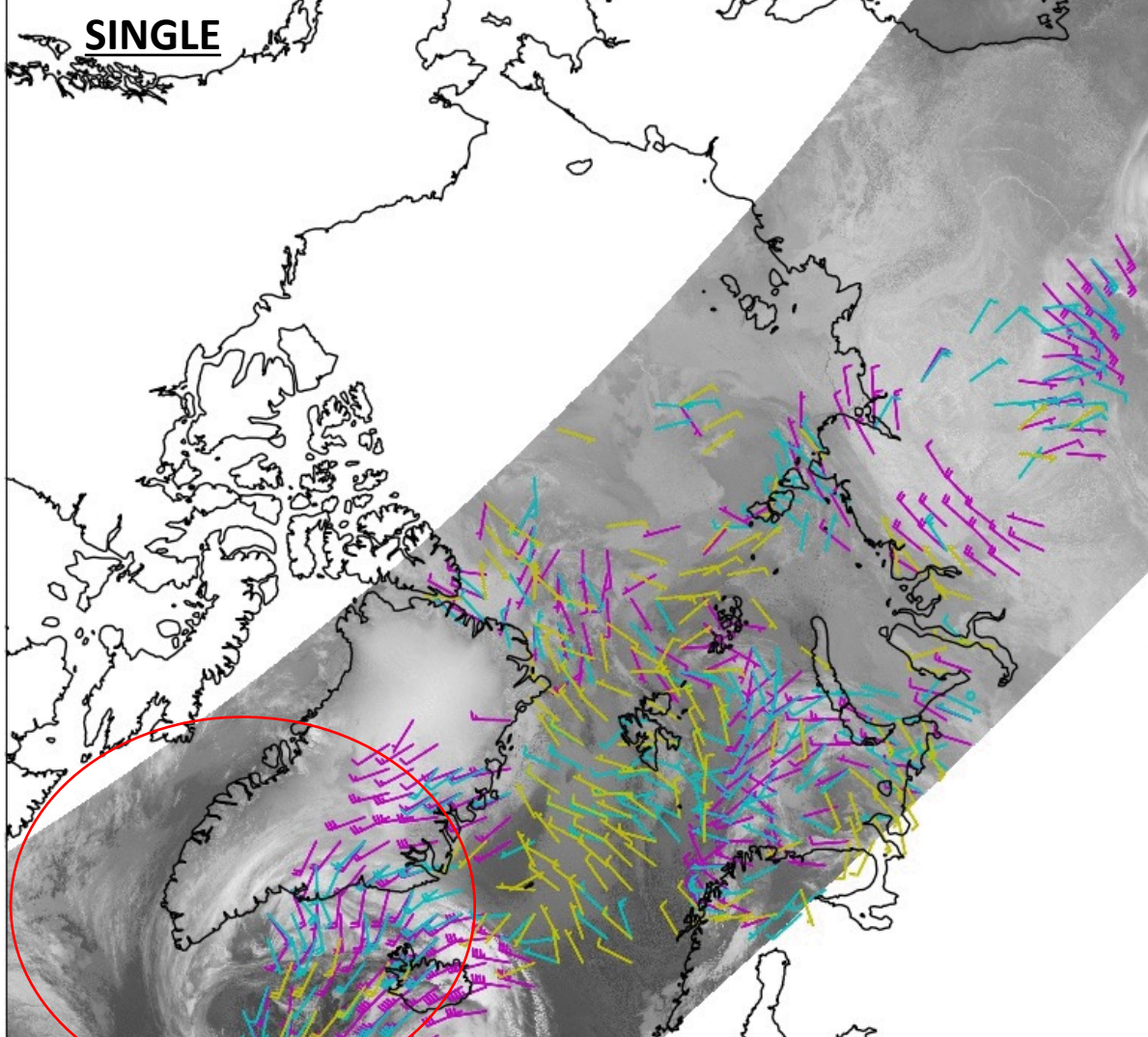
- **Shortwave-IR** (SWIR, M11 band, $\sim 2.25 \mu\text{m}$) and **Day-Night Band** ($0.5\text{-}0.9 \mu\text{m}$) provide unique sources for deriving AMVs. Has been shown that SWIR AMVs using MODIS.
- In the shortwave infrared (**SWIR**) portion of the spectrum, the scattering properties of liquid-phase clouds and snow/ice are significantly different. Clouds are much brighter than the underlying snow or ice surface and the **contrast between low clouds and the surface is larger** in SWIR bands ($1.6, 2.2, \text{ and } 3.7 \mu\text{m}$).
- More AMV coverage and better tracking of low-level cloud features.
- Currently routinely producing VIIRS SWIR AMVS using the heritage CIMSS algorithm (S-NPP only)
- The VIIRS day-night band (DNB) provides another unique source of spectral information: reflected radiation at night in the presence of moonlight.
- The DNB Near-Constant Contrast (NCC) product is utilized for AMV tracking.



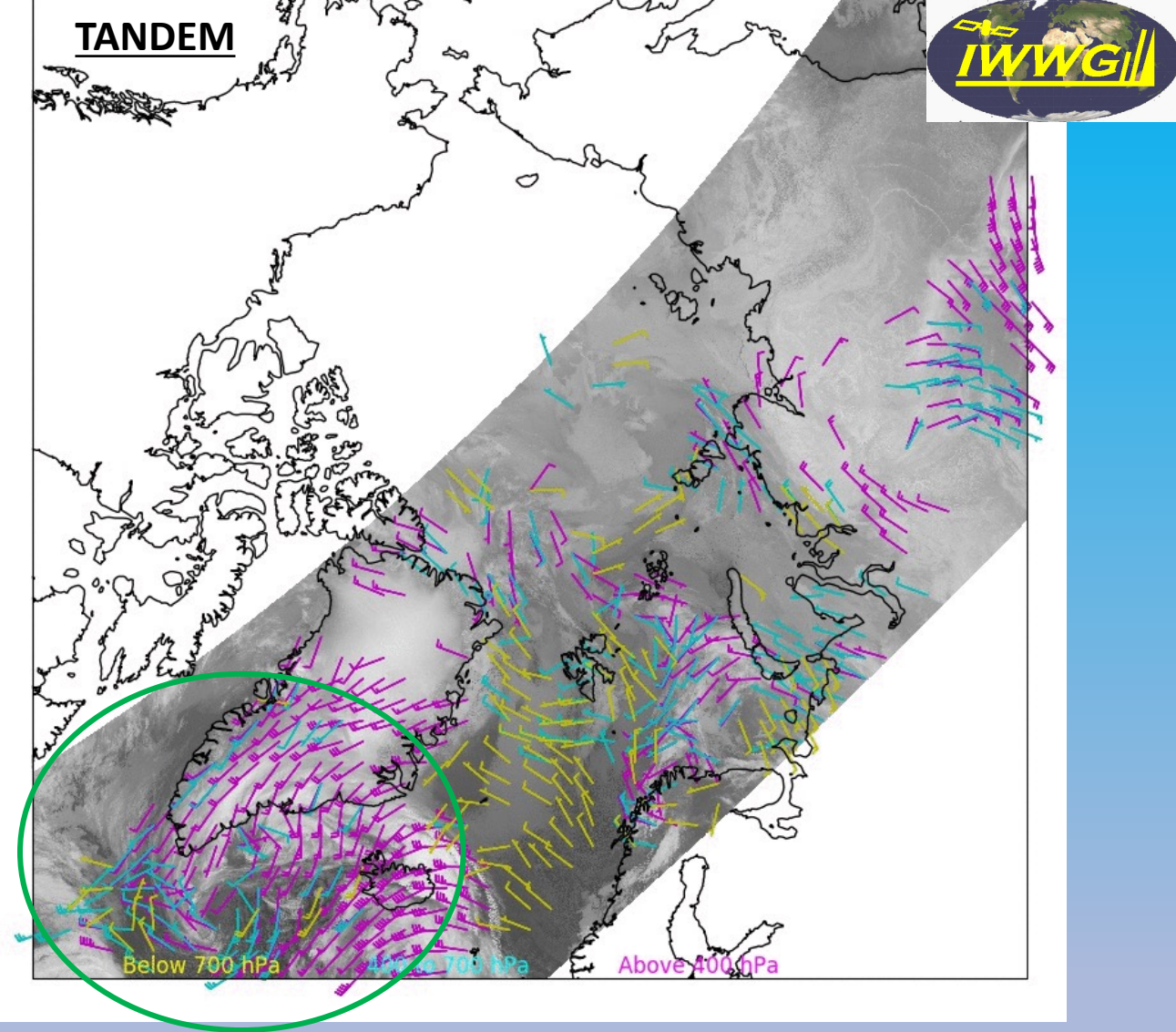
Increased area of overlap with tandem usage.

Increased AMV coverage, especially at lower high latitude regions (50-60°)



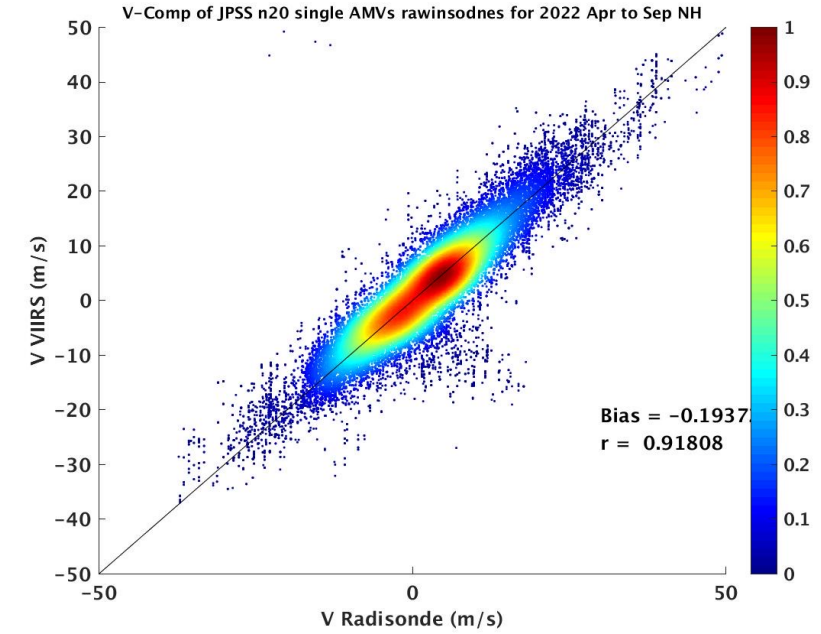
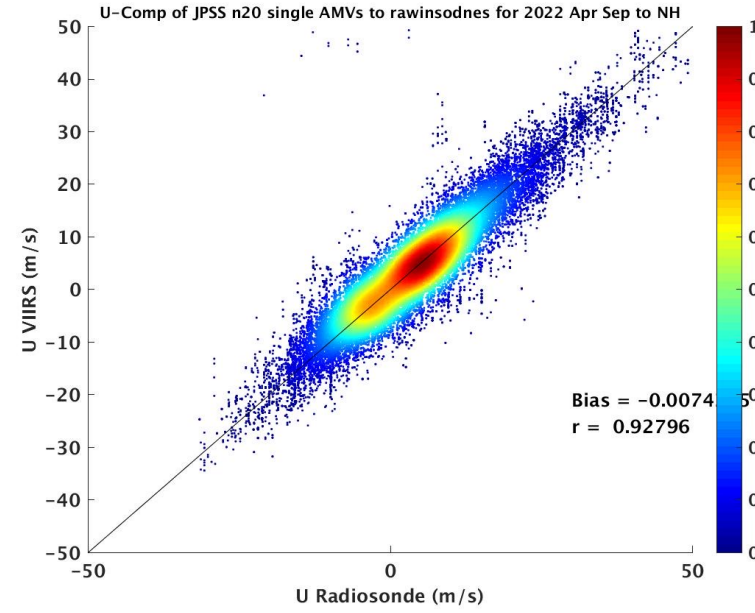
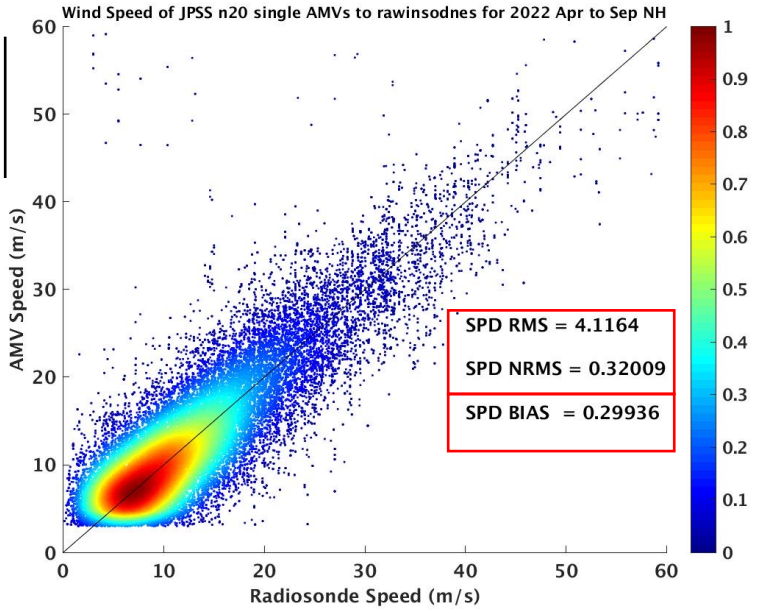


Atmospheric Motion Vectors (AMVs) for the same date and time on 2021 February 26 for 0430 UTC over the Arctic and North Atlantic from single NOAA-20 triplet of orbits.

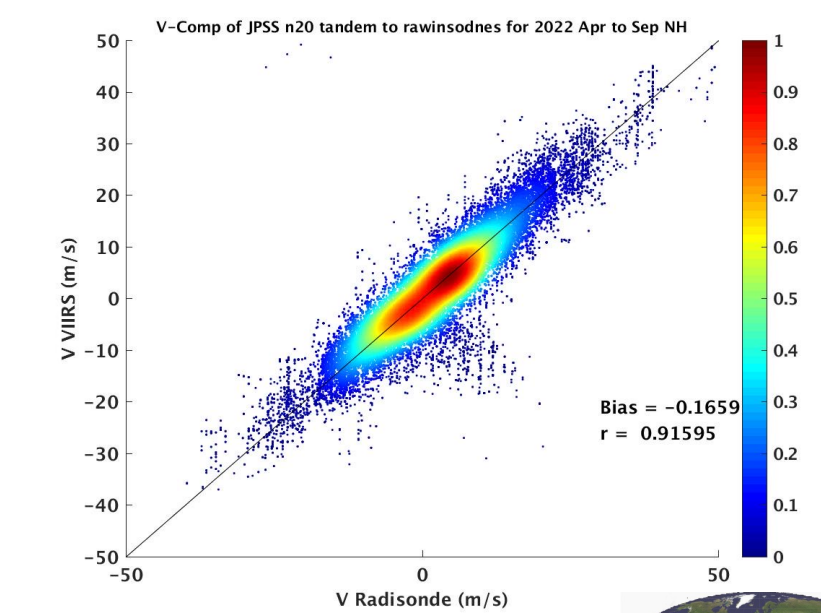
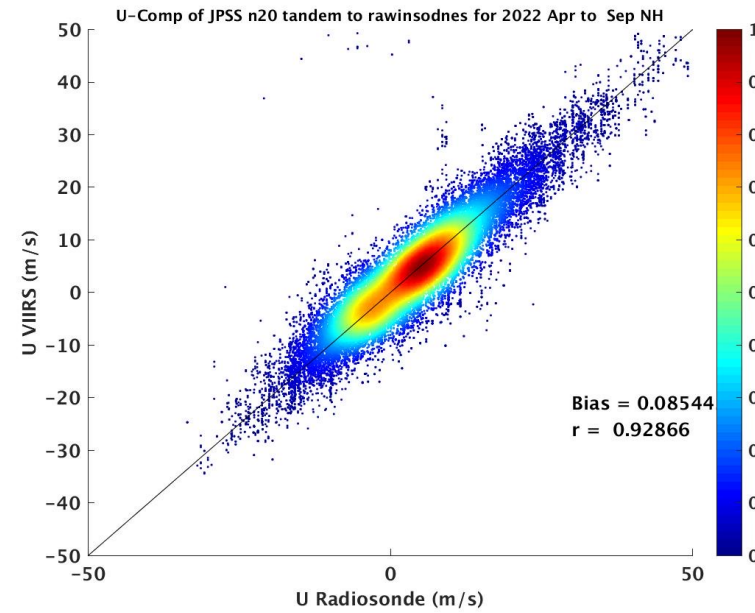
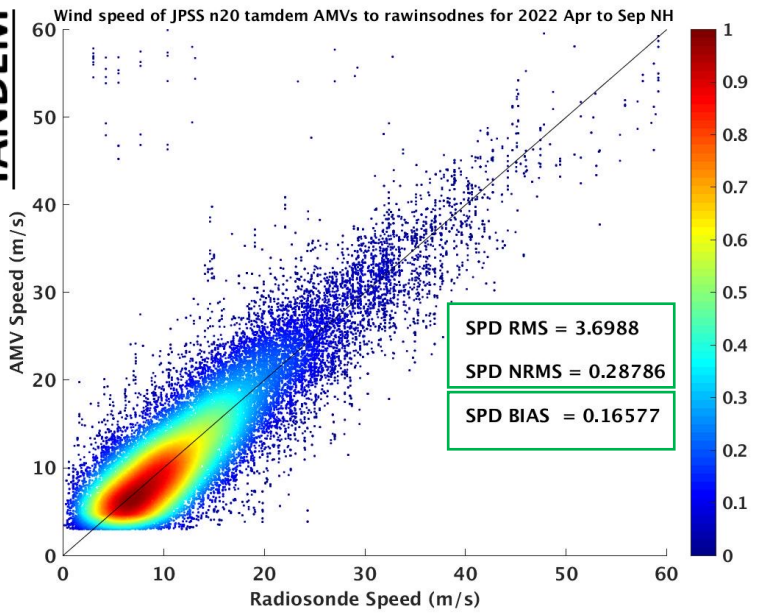


Atmospheric Motion Vectors (AMVs) for the same date and time on 2021 February 26 for 0430 UTC over the Arctic and North Atlantic from tandem S-NPP/NOAA-20/S-NPP triplet of orbits.

SINGLE



TANDEM

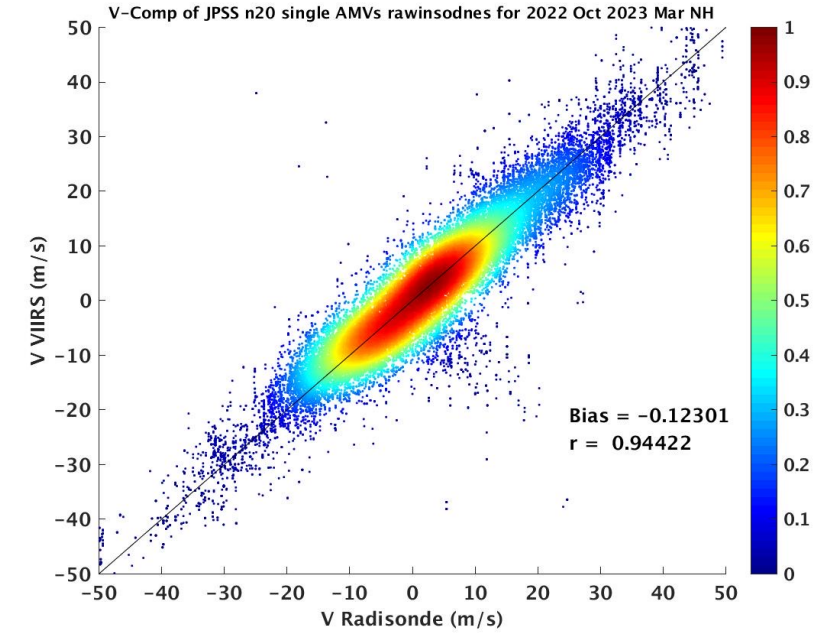
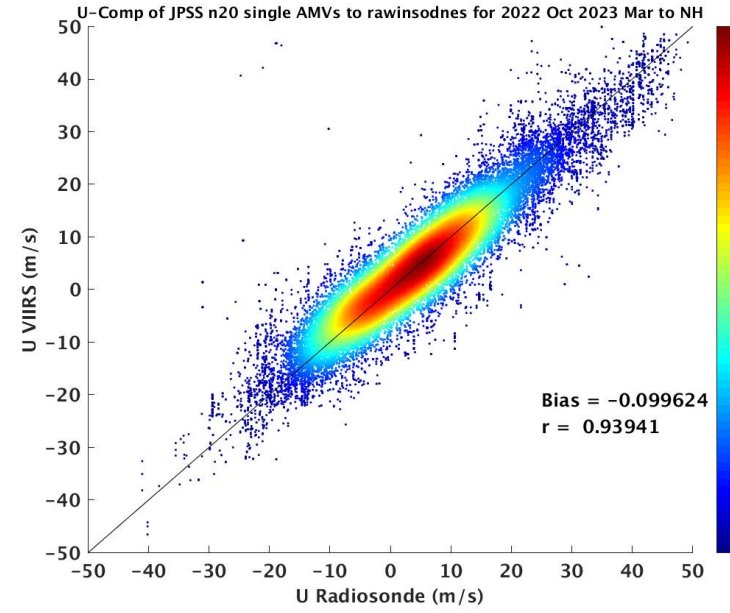
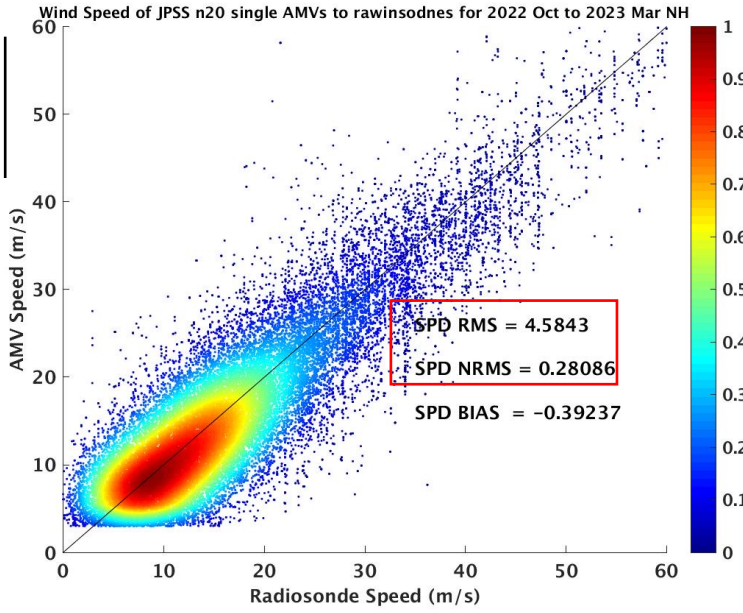


Samples: 62,280 ; Arctic 2022 April-September Tandem Triplets versus RAOBS

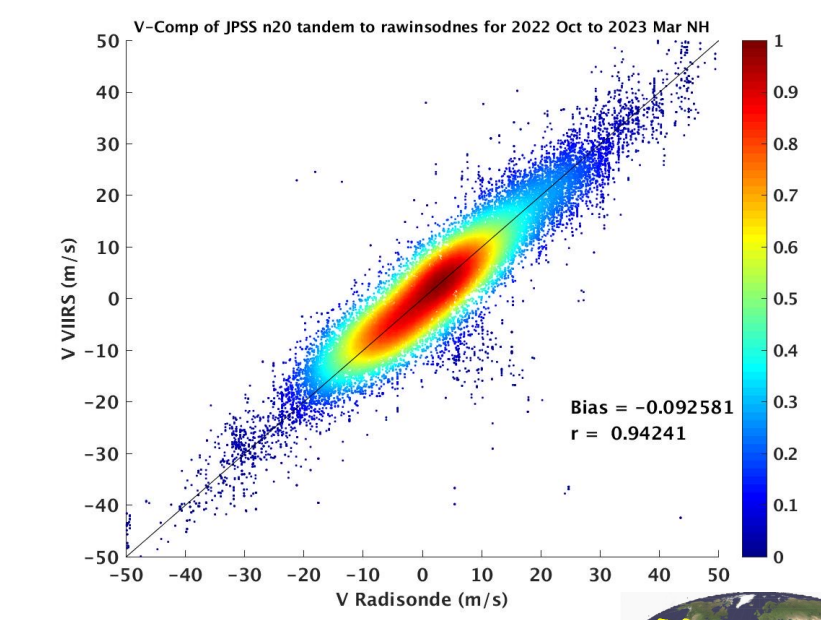
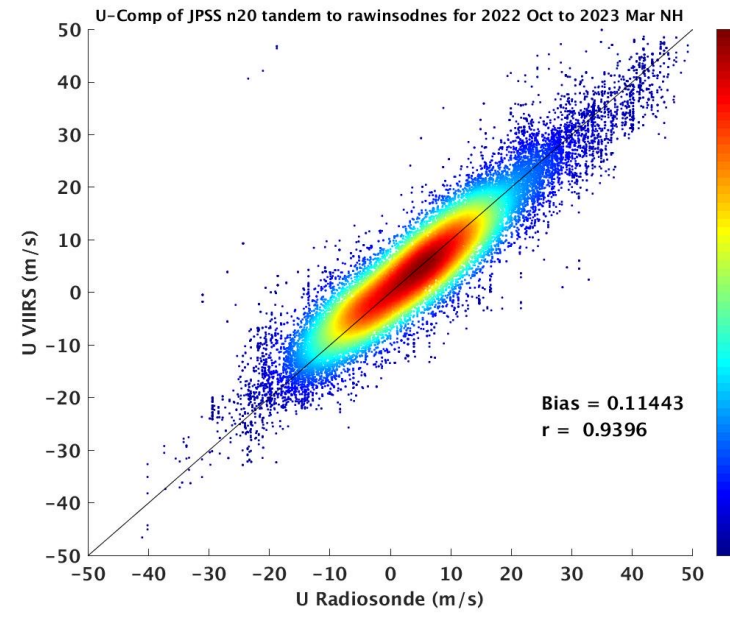
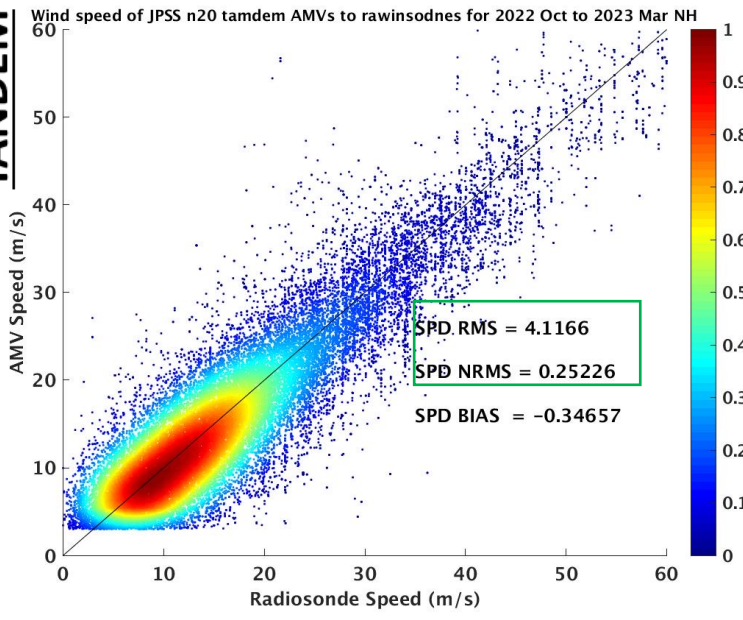
Vector RMSE: N20 6.3, Tandem 5.7; Vector NRMSE: N20 0.49, Tandem 0.44; Vector Precision N20 3.66, Tandem 3.58



SINGLE



TANDEM

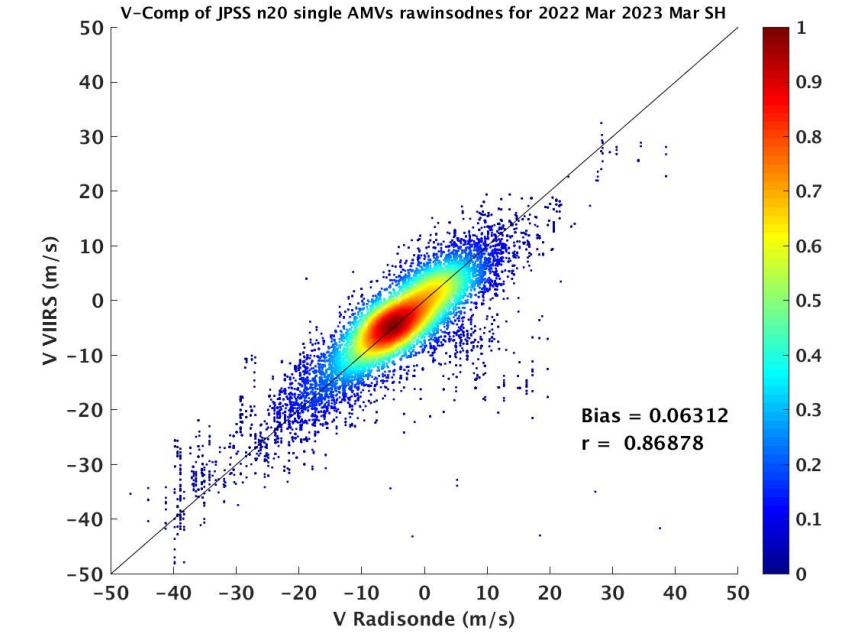
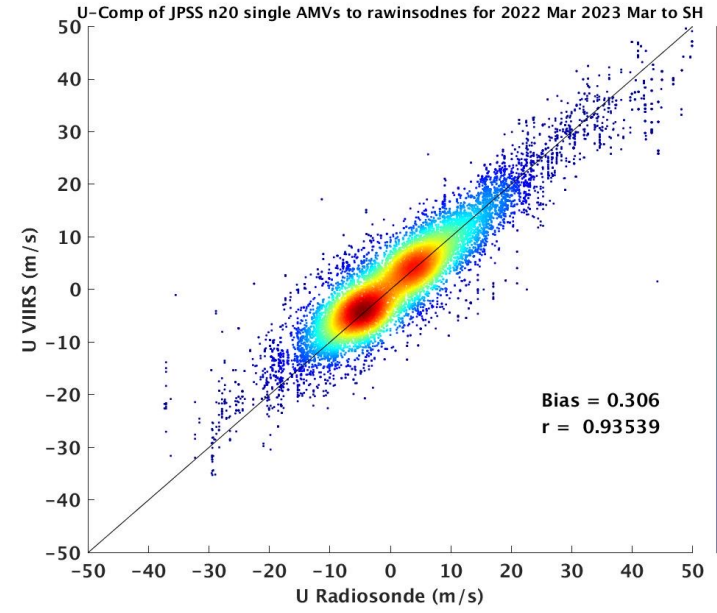
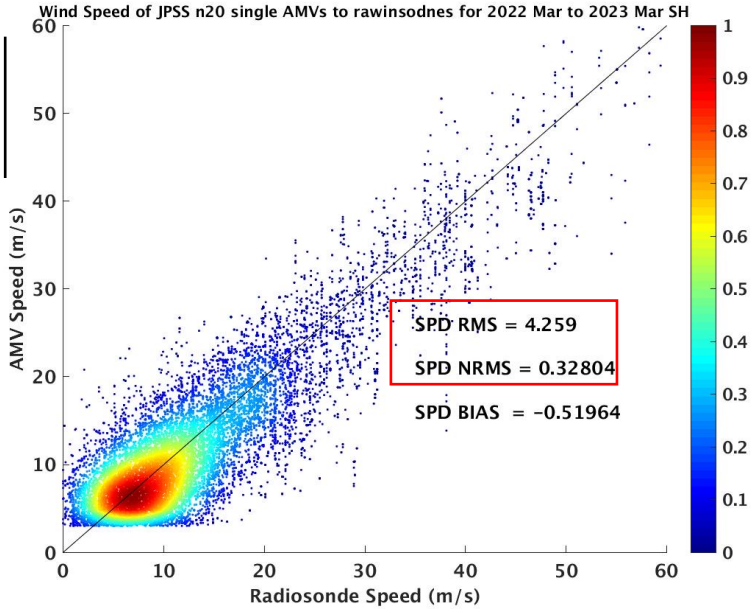


Samples: 45,964 ; Arctic 2022 October- 2023 April Tandem Triplets versus RAOBS

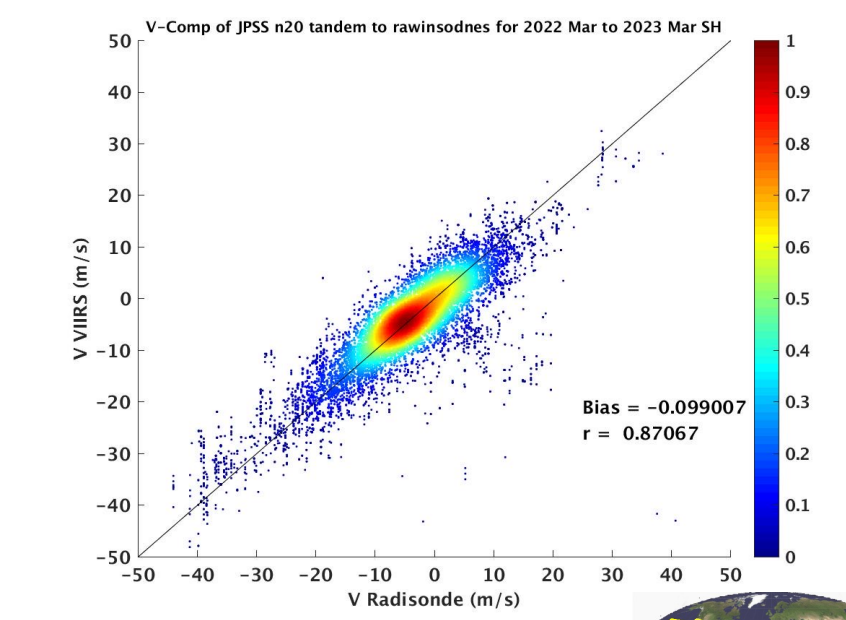
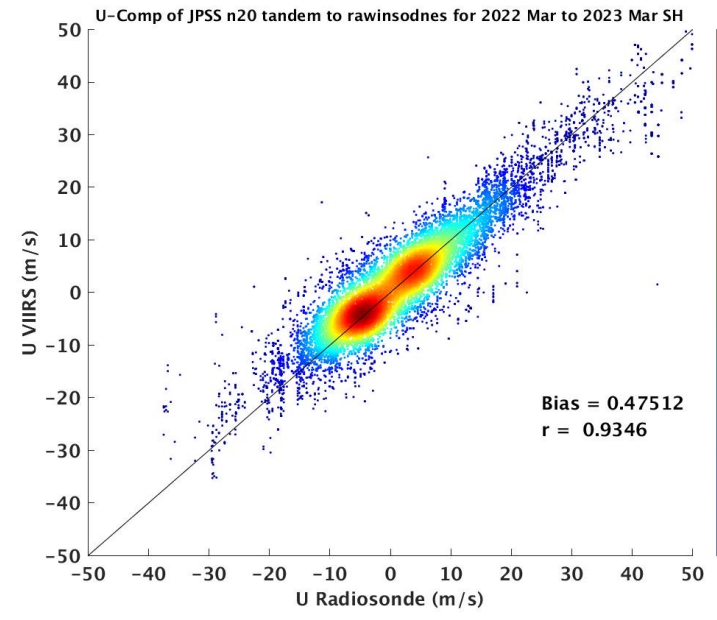
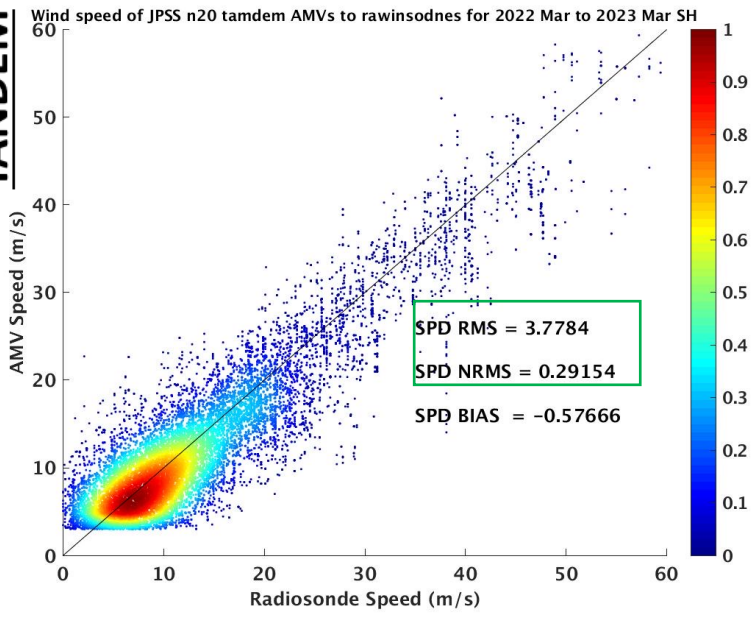
Vector RMSE: N20 6.9 Tandem 6.29; Vector NRMSE: N20 0.42, Tandem 0.39; Vector Precision N20 3.85, Tandem 3.84



SINGLE



TANDEM

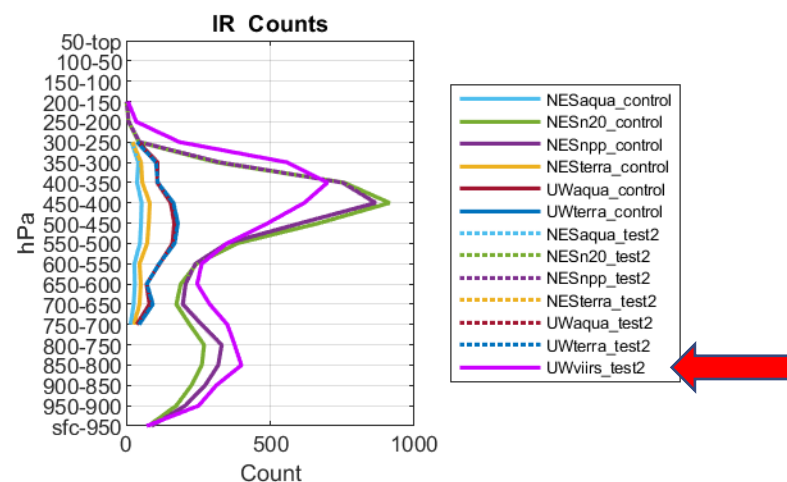
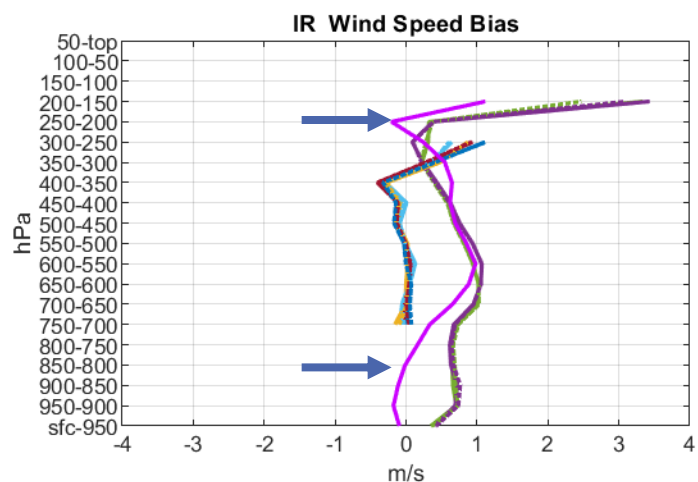
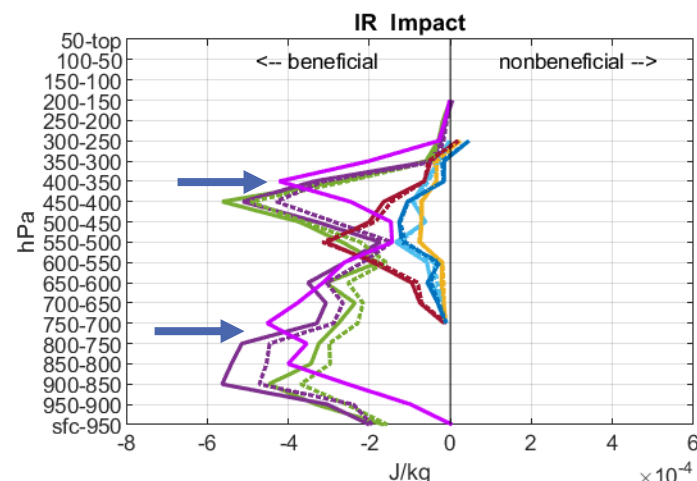
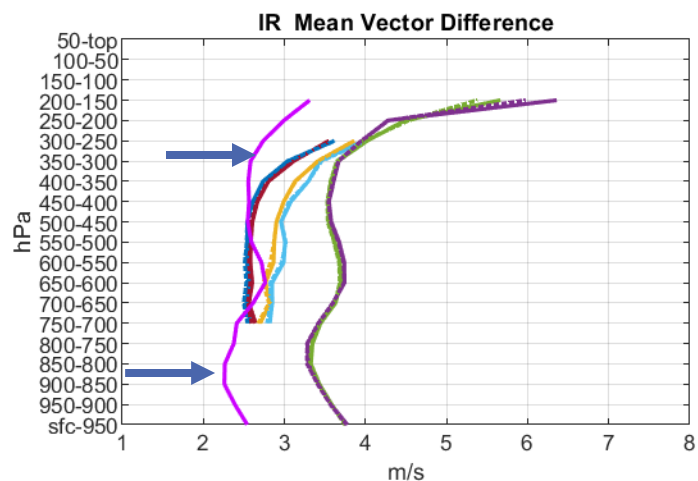


Samples: 22,130 ; **Antarctic 2022 March- 2023 March Tandem Triplets versus RAOBS**
 Vector RMSE: N20 6.94 Tandem 6.29; Vector NRMSE: N20 0.53, Tandem 0.49; Vector Precision N20 3.9, Tandem 3.8



Model Impact study of JPSS Tandem triplets: From Naval Research Laboratory (NAVGEM)

2021040106 - 2021043018

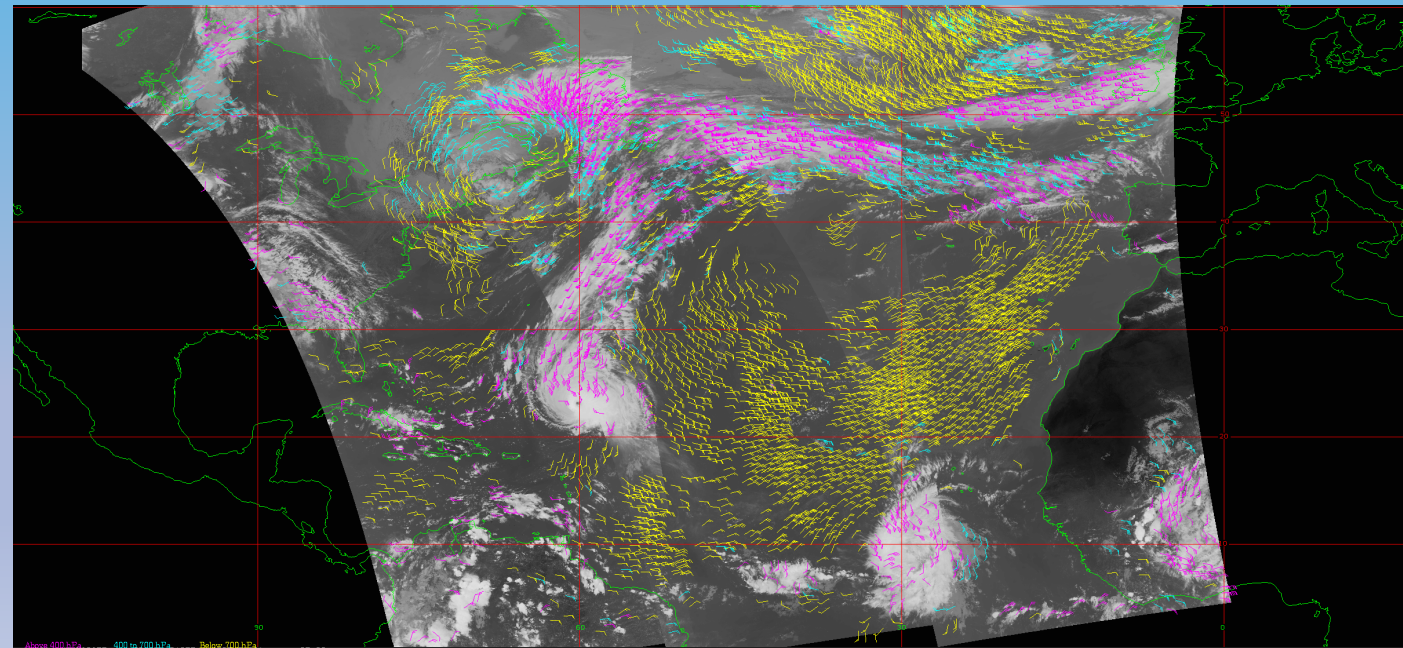
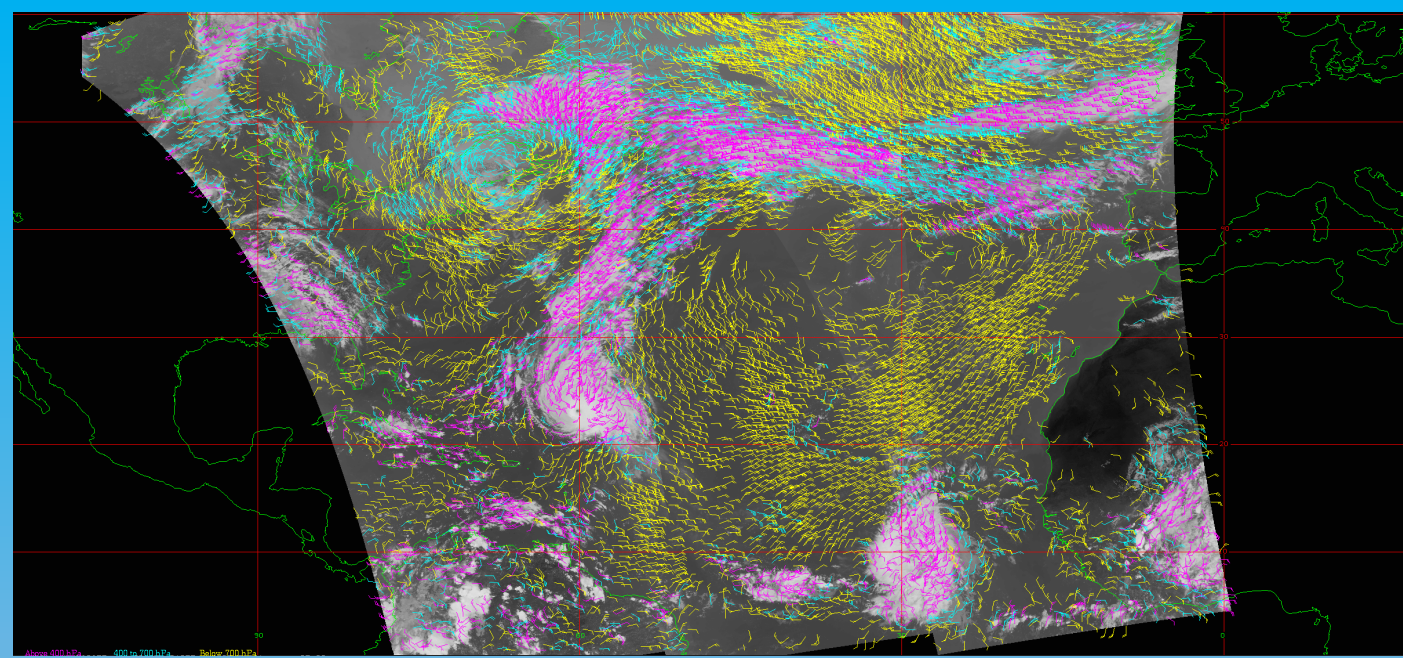


Impact of the VIIRS Tandem in an April 2021 test case at NRL. The magenta "UWviirs_test2" line shows the beneficial impact of the new VIIRS Tandem winds (Courtesy of Rebecca Stone SAIC/NRL).



JPSS Tandem Duplet (2 orbits) AMVs provide Global coverage!

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). The top panel is all derived winds; the lower panel is parallax-corrected, quality-controlled winds.



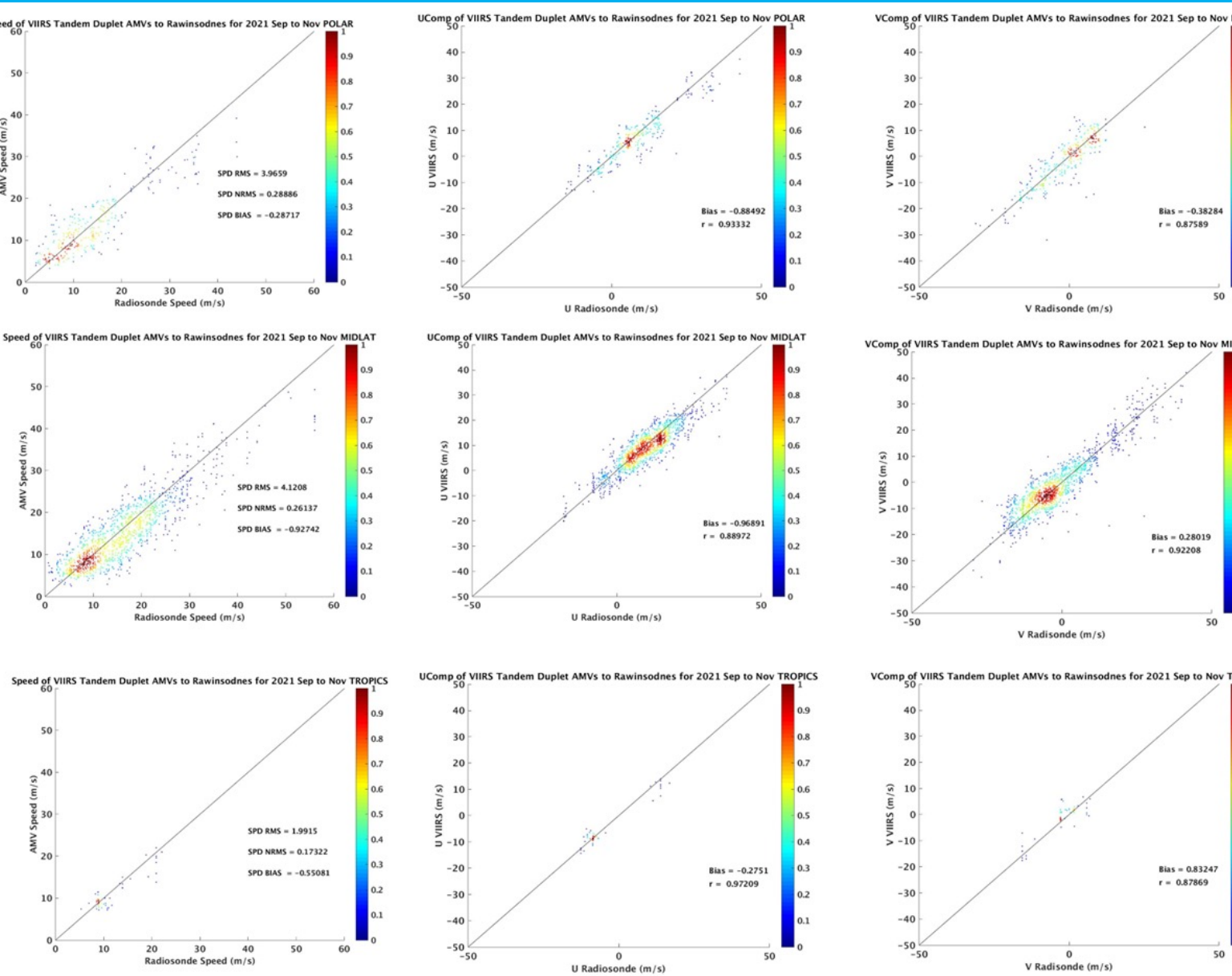
Comparisons to RAOBs

Separated into four latitude bands.

Poles: ≥ 60 deg

Mid-Latitudes: >30 to <60 deg

Tropics: ≤ 30 deg



	Vector Accuracy (ms^{-1})	Vector Precision (ms^{-1})	Vector NRMS (ms^{-1})	Mean AMV (ms^{-1})	Mean Raob (ms^{-1})	Sample Size
Poles	6.06	3.55	0.44	13.44	13.73	318
Mid-Lat	6.21	3.31	0.39	14.84	15.77	1394
Tropics	3.91	2.36	0.34	10.95	11.50	56

Tandem Duplets -Positive results

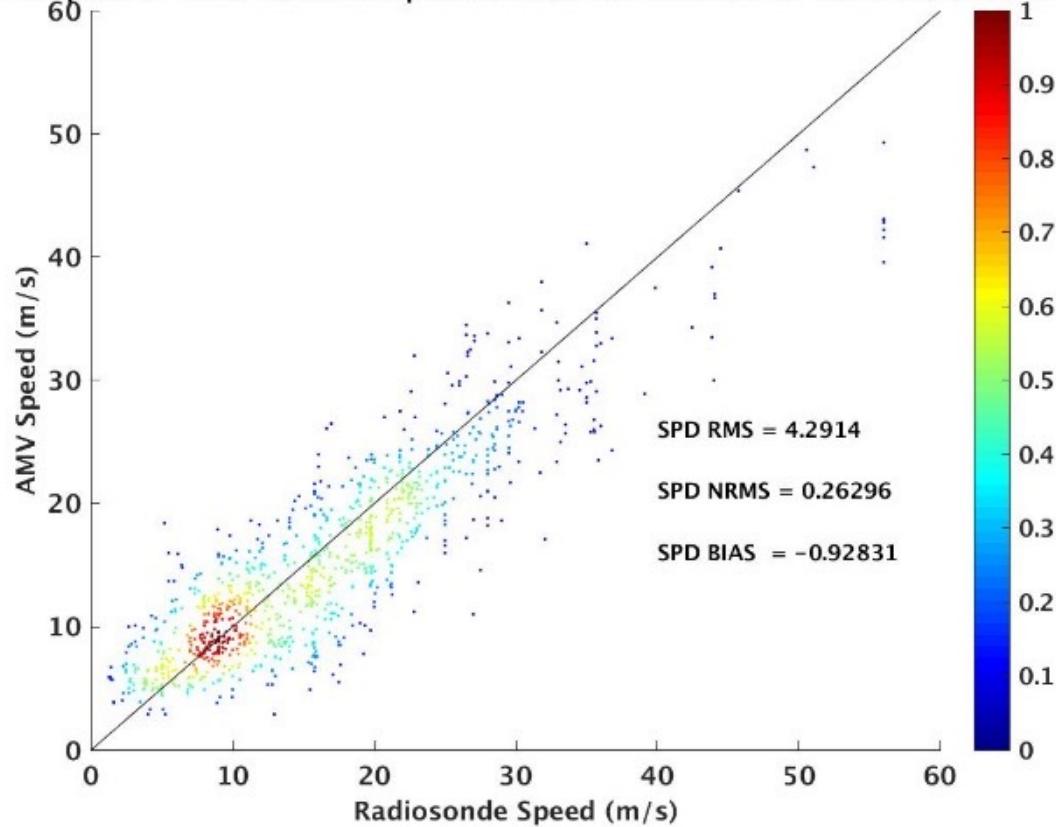


Importance of Quality Control

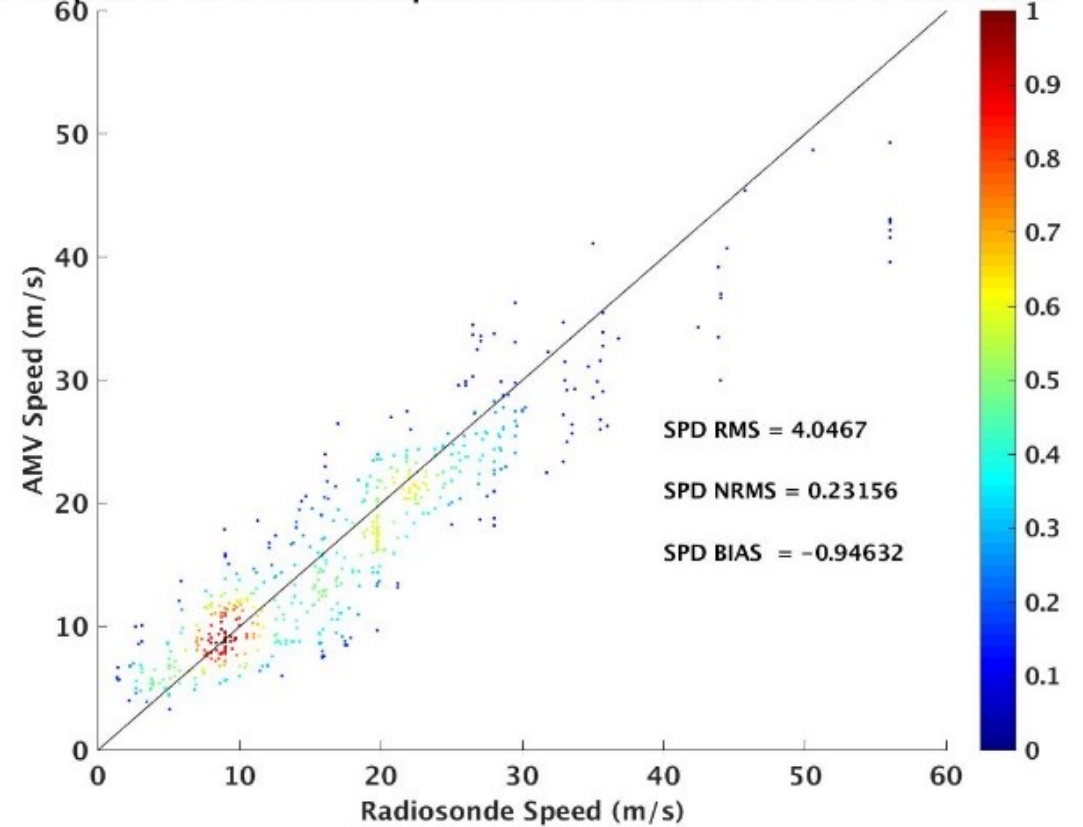
QI \geq 60

QI \geq 80

Wind Speed of VIIRS Tandem Duplet AMVs to Rawinsodnes for 2021 Oct GLOBAL



Wind Speed of VIIRS Tandem Duplet AMVs to Rawinsodnes for 2021 Oct GLOBAL

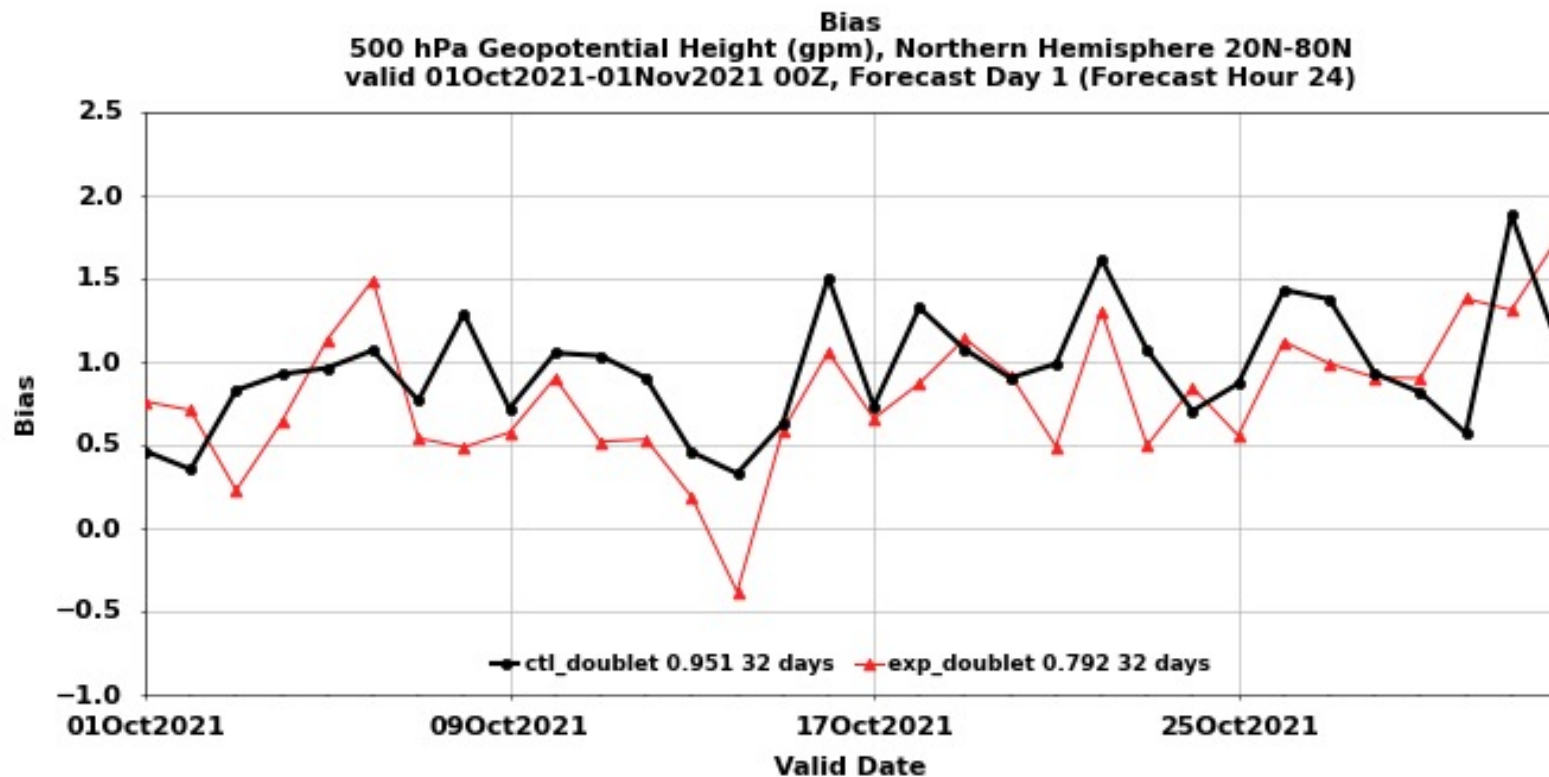


QI	Vector Accuracy		Vector Precision		Sample sizes	
	≥ 60	≥ 80	≥ 60	≥ 80	≥ 60	≥ 80
All	5.29	4.67	3.49	2.98	1036	568



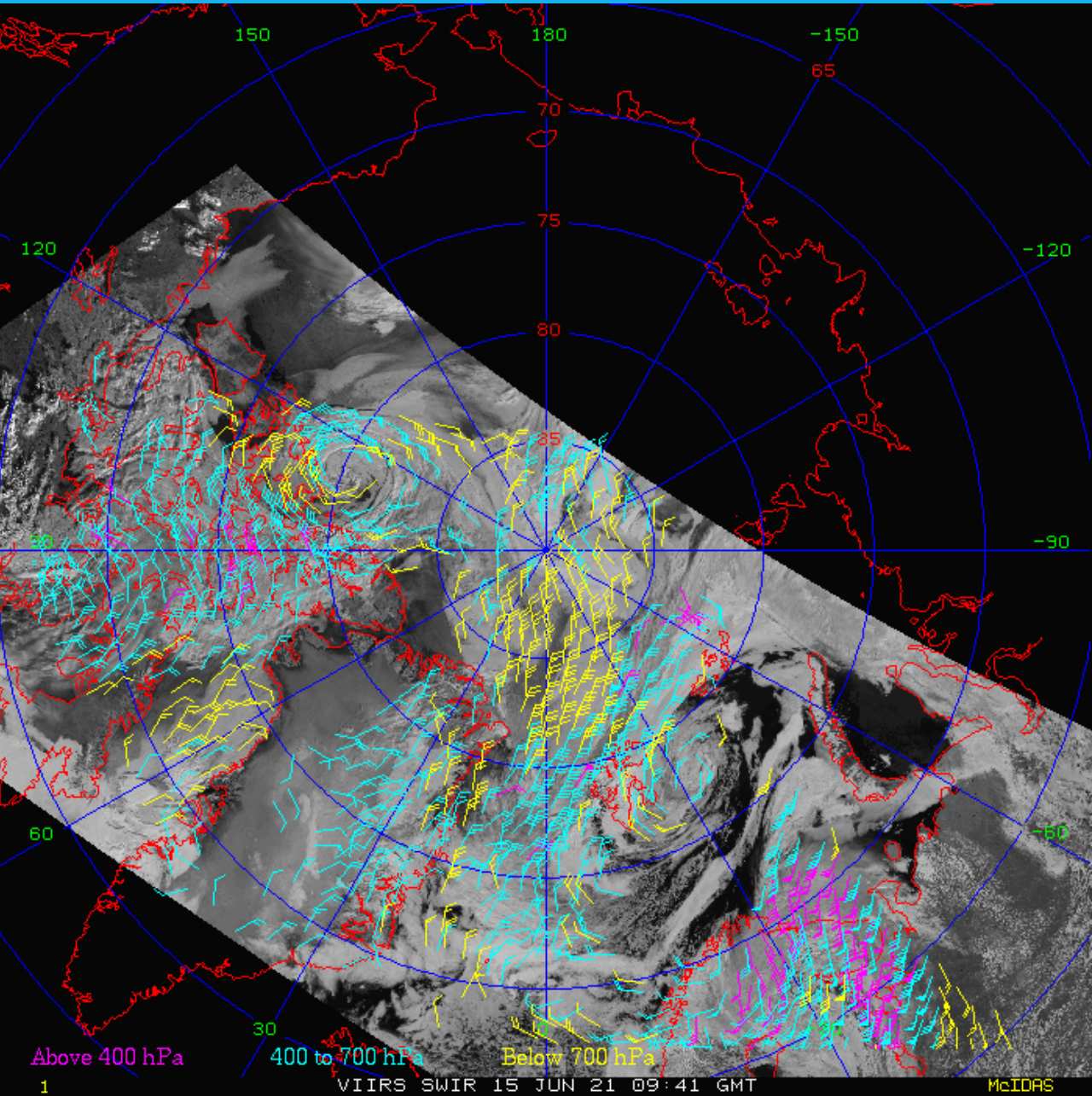


Model Impact study of JPSS Tandem duplets: GFS



A significant improvement was evident in the Northern Hemisphere geopotential height bias throughout the troposphere at the 24-hr forecast. At the 500 hPa level (above), the red curve (experiment) is generally nearer the 0.0 bias line compared to the control (black). The reduction of the bias from 0.95 (control) to 0.79 (experiment) is statistically significant at the 95% level.

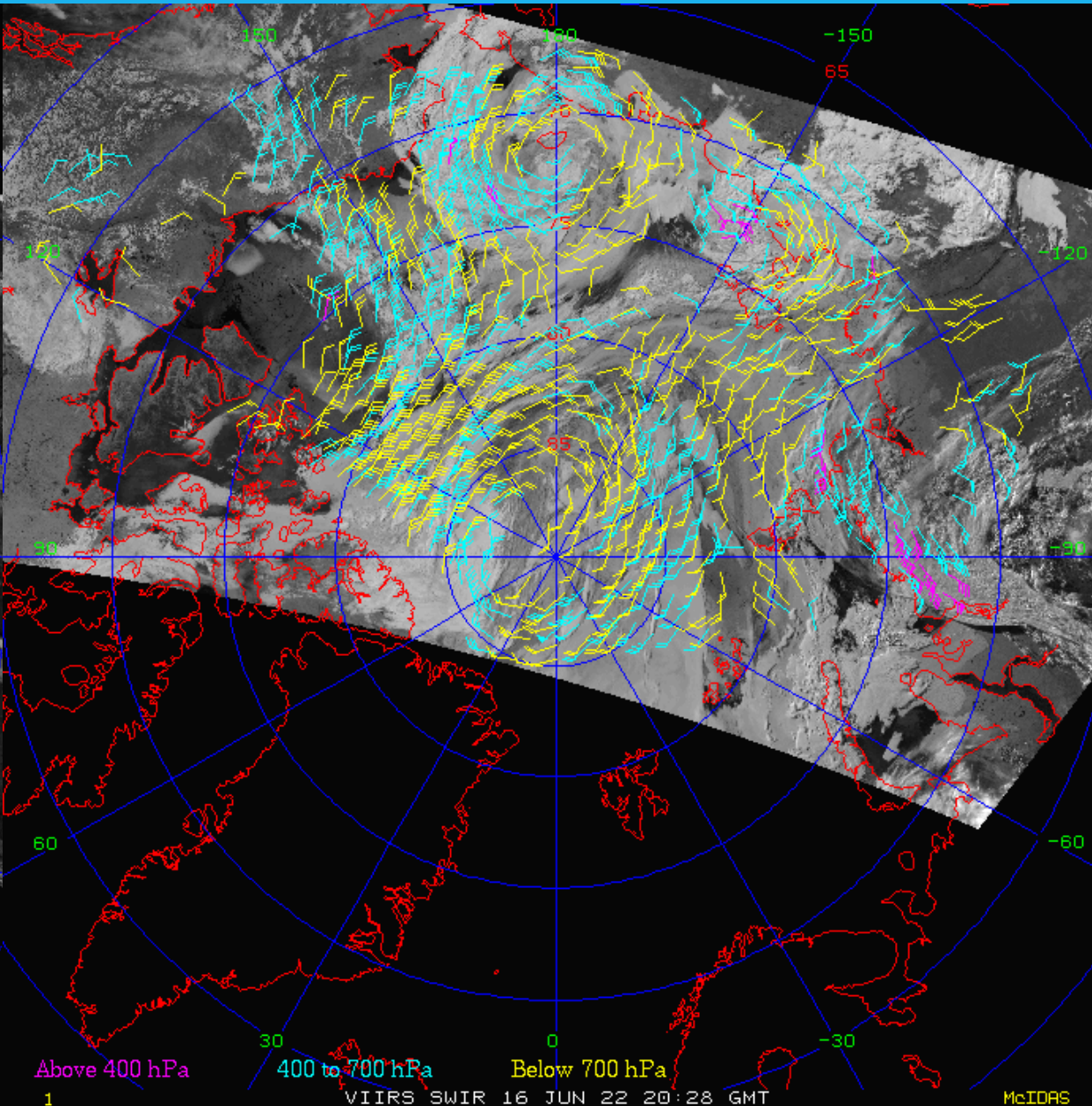
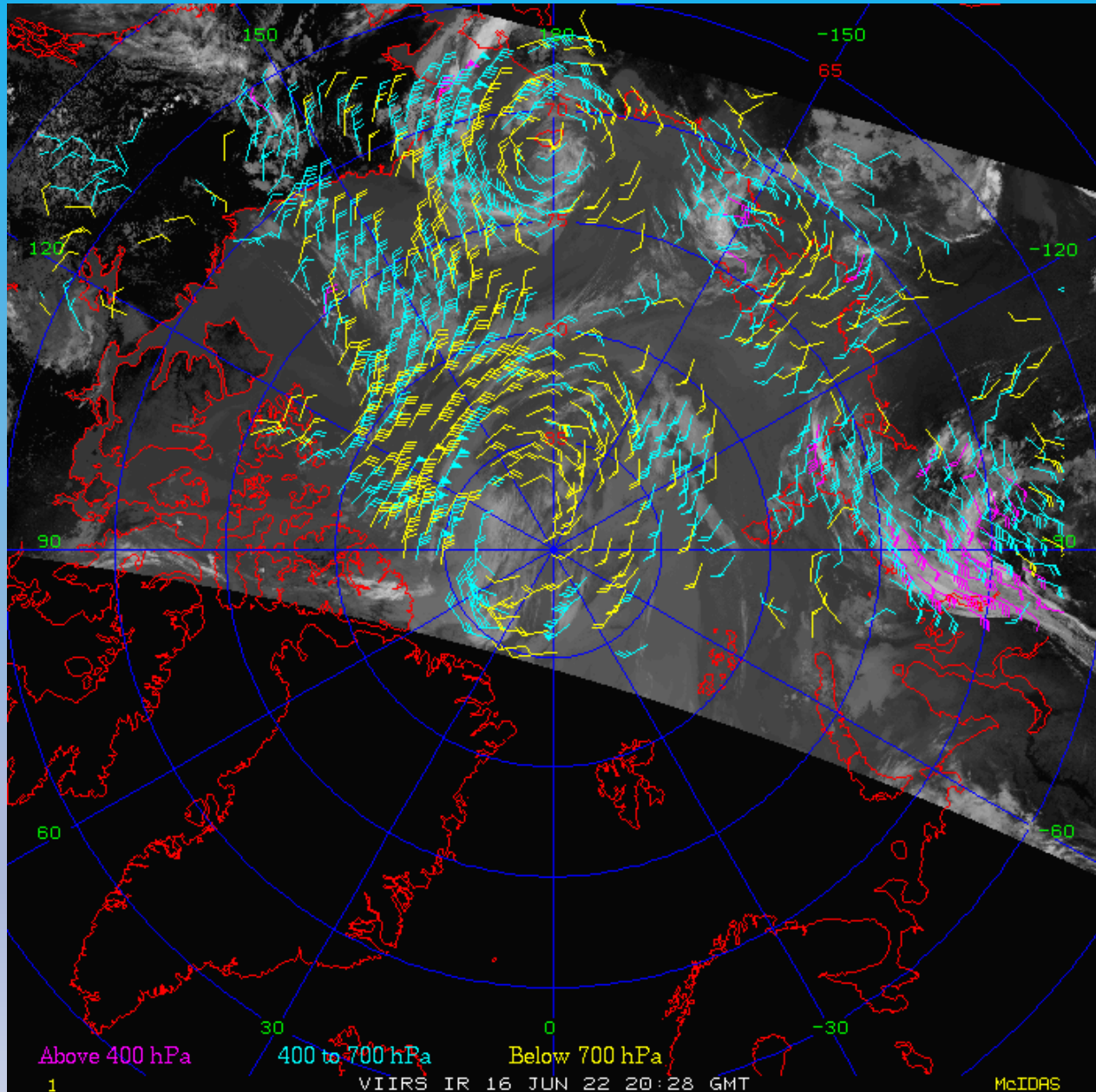
SWIR AMVs

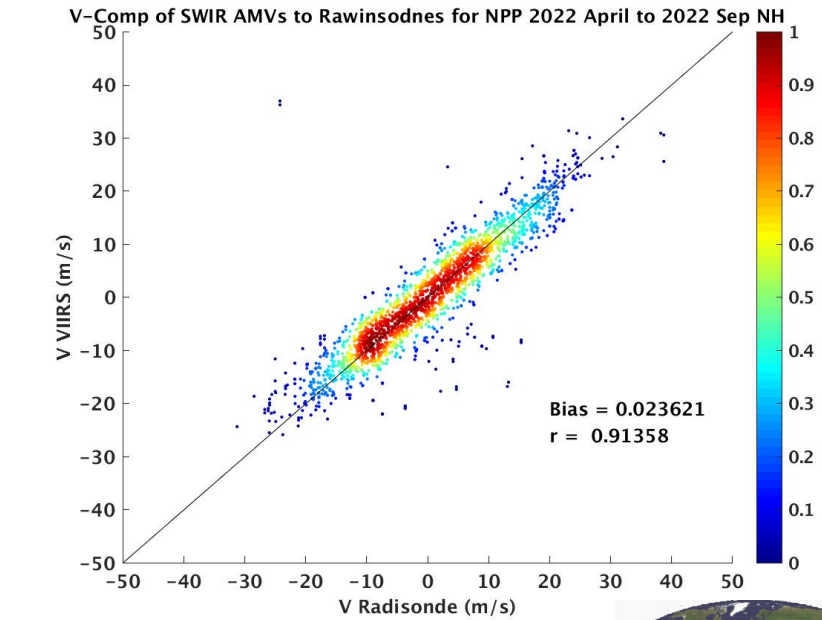
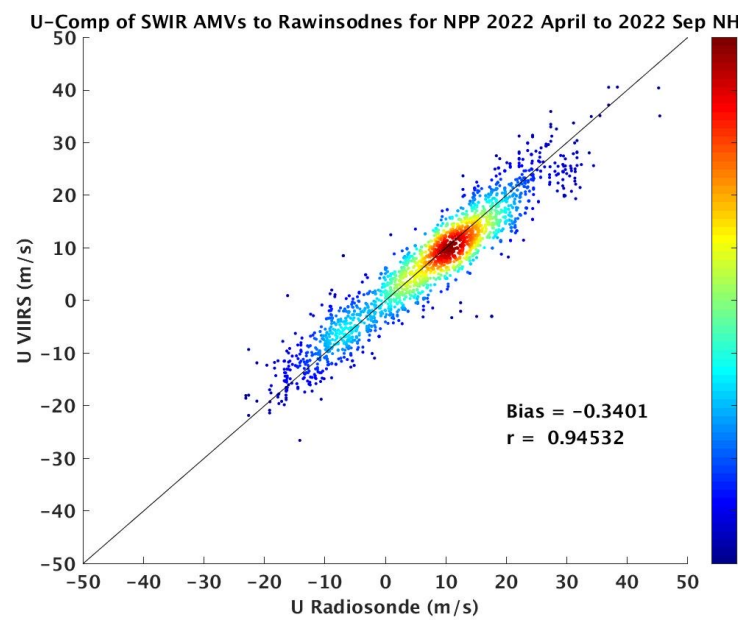
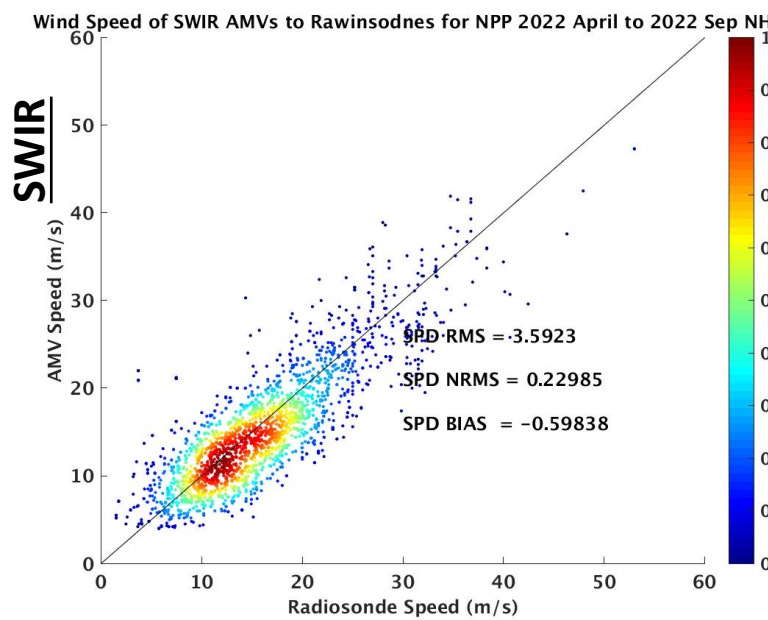
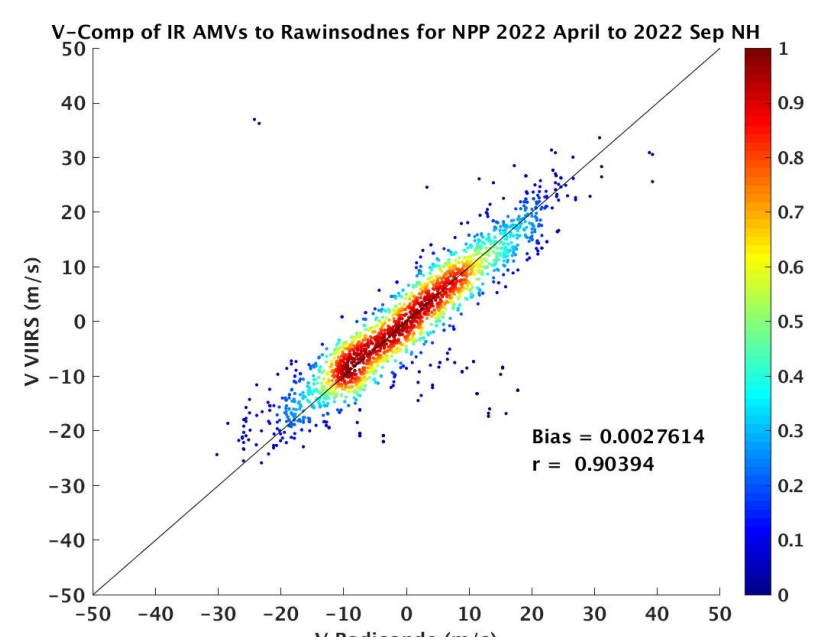
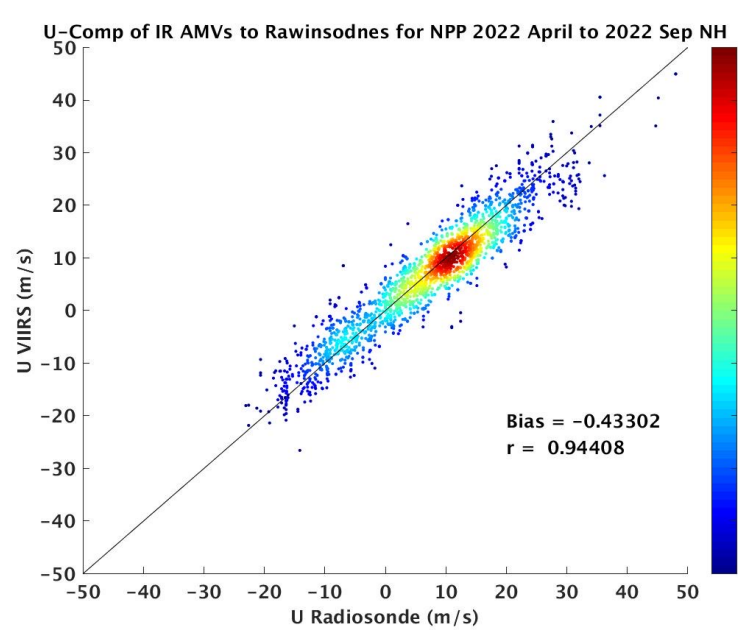
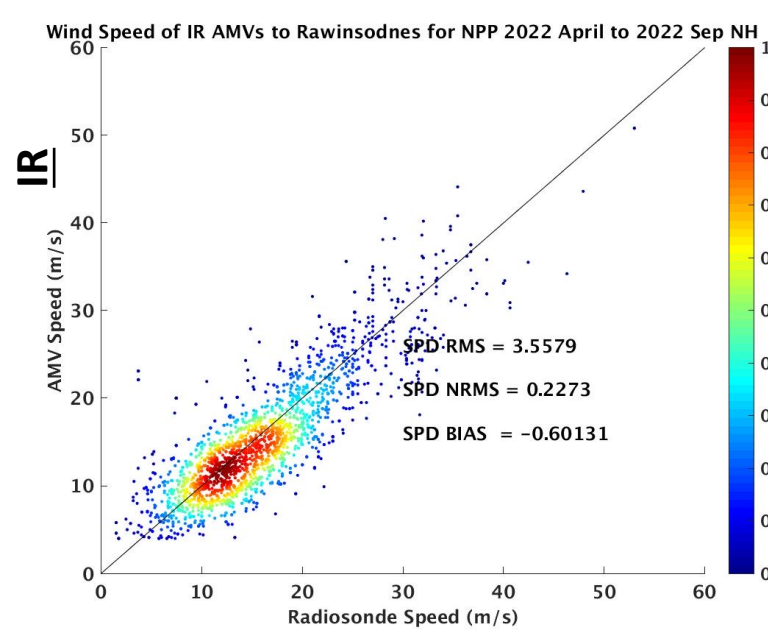


- Routine production began in early 2021 of S-NPP VIIRS SWIR M11 (2.2 μm) band winds over both poles using the heritage (UW-CIMSS) winds algorithm.
- UW-CIMSS continues to produce SWIR AMVs for MODIS.
- Work on-going to get into operations.
- Better at tracking water (mainly low-level) cloud features due to greater scattering liquid water \gg ice at 2.2 μm channel.
- This creates better contrast and therefore more accurate tracking.
- More Low-level winds and at better quality compared to IR.
- IR lower contrast due to surface BT and low-level liquid cloud top can have similar temperatures (ubiquitous inversions in cryosphere environments).

IR

SWIR





Samples: 2,577;

Arctic 2022 April-September SWIR versus RAOBS

Vector RMSE: IR 5.72, SWIR 5.66; Vector NRMSE: IR 0.37, SWIR 0.36; Vector Precision IR 3.61, SWIR 3.48

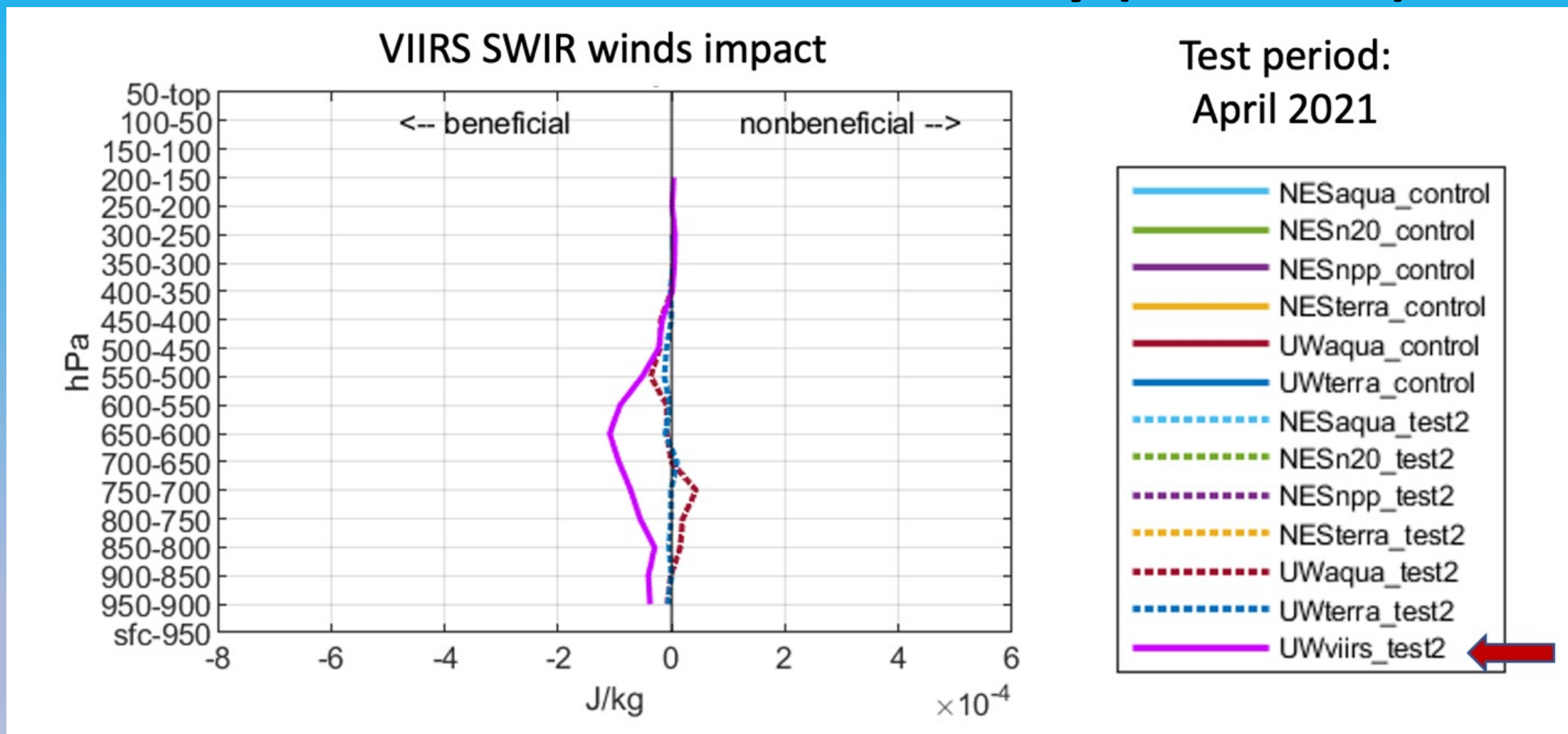




IR	Sample	Accuracy	Precision	NRMSVD	U-bias	V-bias	Speed RMS
<400 hPa	319	5.77	5.29	0.36	0.44	1.00	4.19
400to<700 hPa	1876	4.15	2.98	0.33	-0.59	-0.10	3.24
>=700 hPa	382	4.67	4.37	0.54	-0.41	-0.33	4.36
Total	2577	4.43	3.61	0.37	-0.43	0.00	3.56
SWIR	Sample	Accuracy	Precision	NRMSVD	U-bias	V-bias	Speed RMS
<400 hPa	346	5.55	5.33	0.35	0.46	0.91	4.17
400to<700 hPa	1953	4.25	2.93	0.34	-0.42	-0.06	3.29
>=700 hPa	384	4.58	3.83	0.50	-0.59	-0.30	4.40
Total	2577	4.46	3.48	0.36	-0.34	0.02	3.59

Arctic 2022 April-September SWIR versus RAOBS

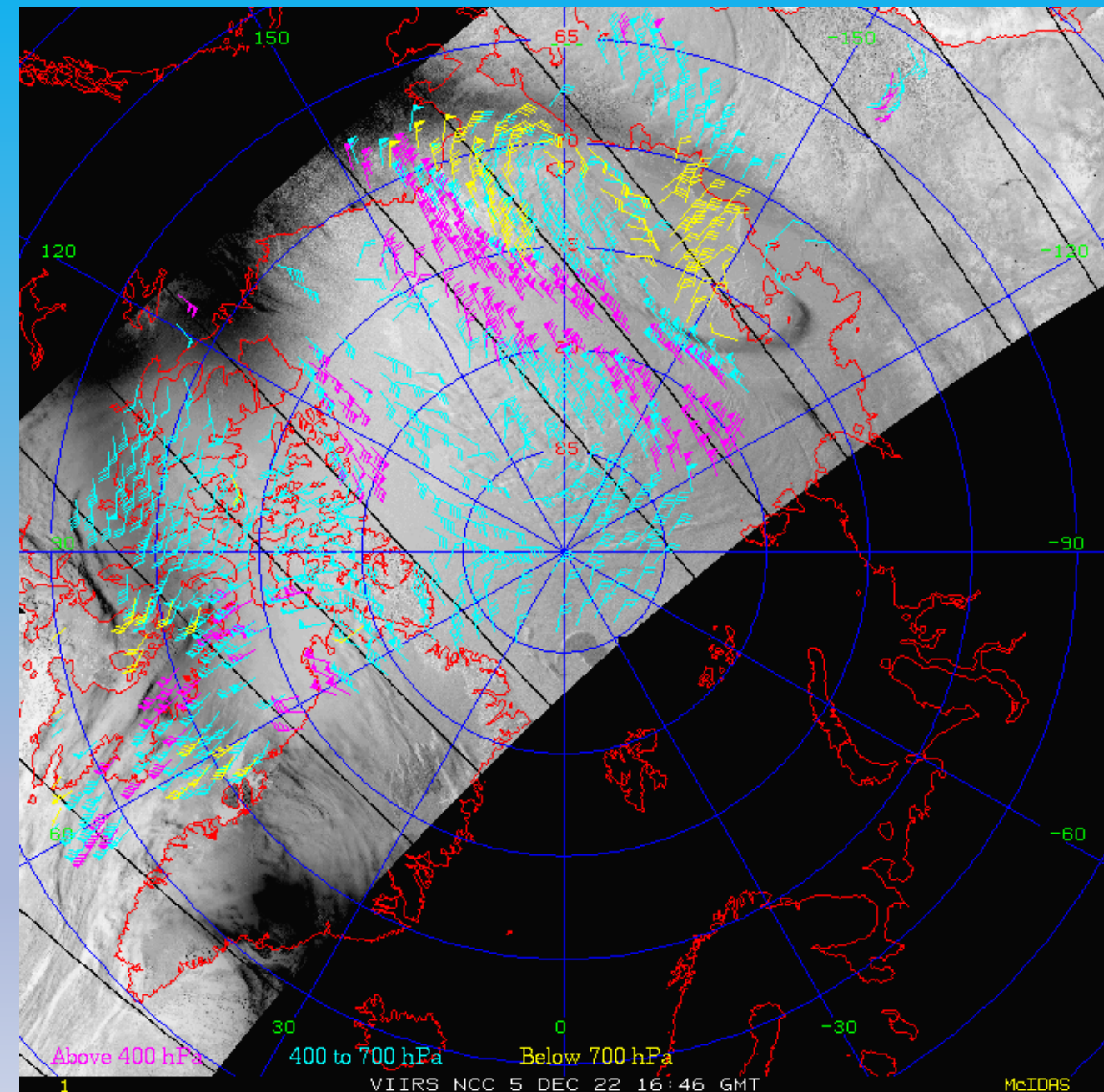
Model Impact study of JPSS Tandem triplets: From Naval Research Laboratory (NAVGEM)

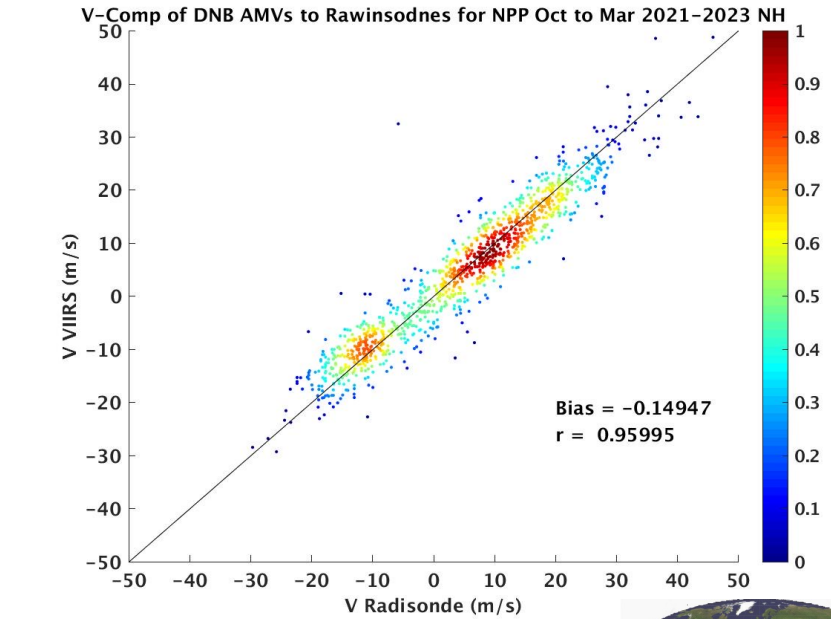
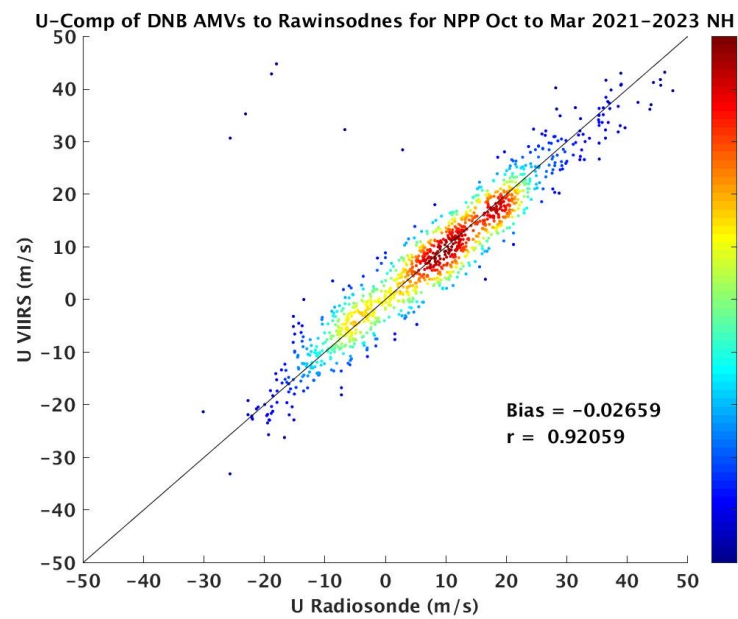
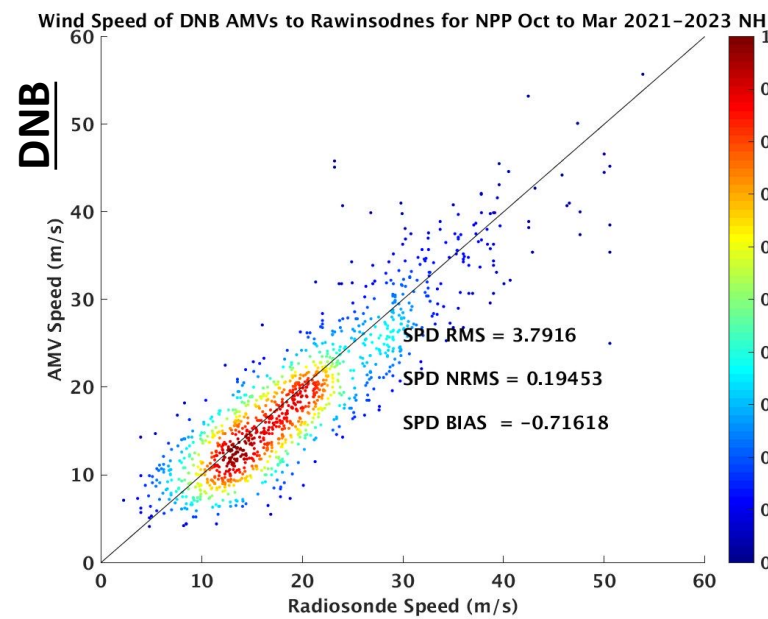
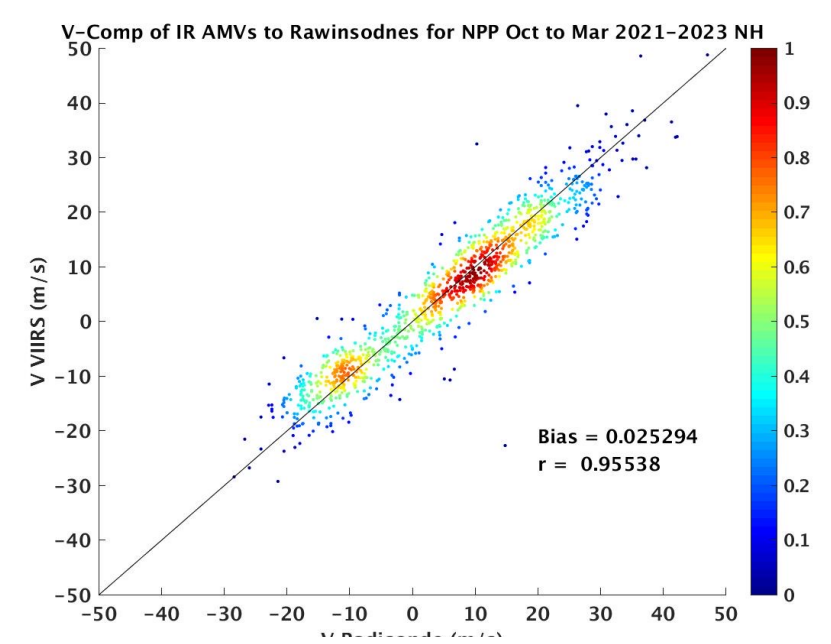
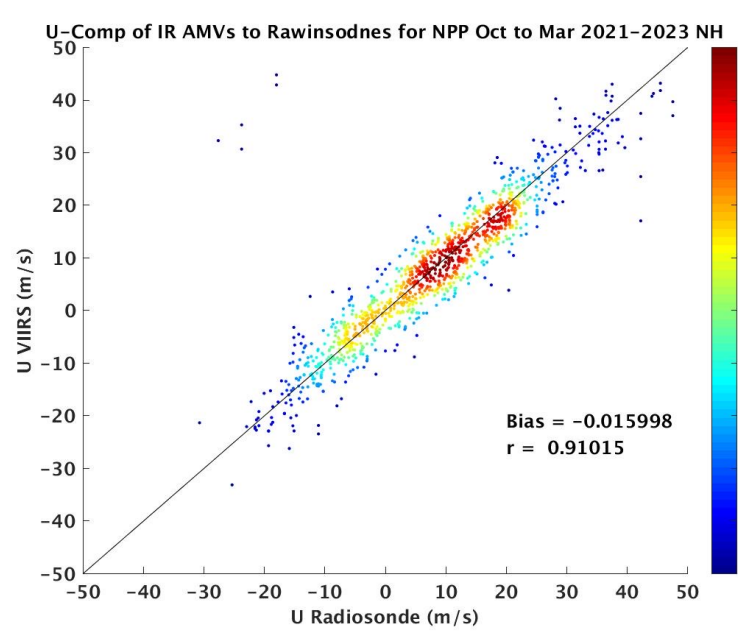
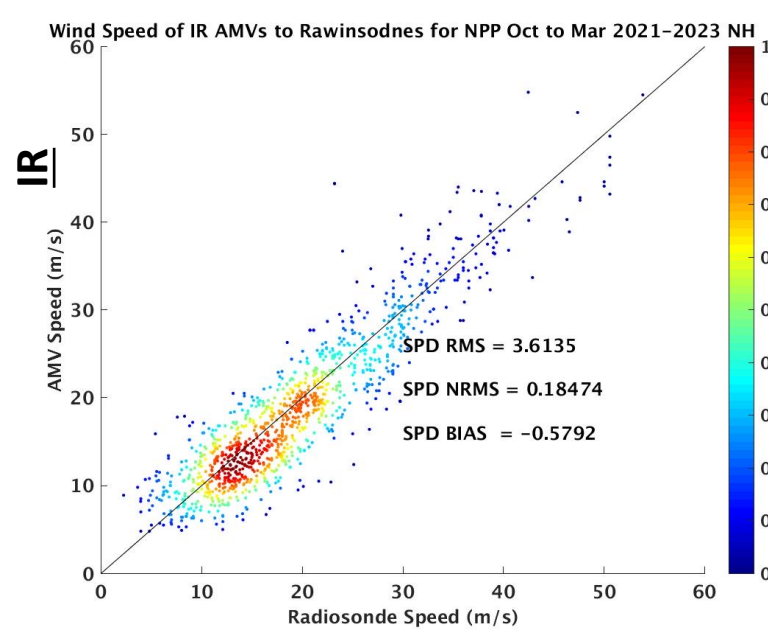


Impact of the VIIRS SWIR in an April 2021 test case at NRL. The magenta "UWviirs_test2" line shows the beneficial impact of the new VIIRS SWIR winds (Courtesy of Rebecca Stone SAIC/NRL).

DNB AMVs

- Routine production began in spring 2021 from S-NPP VIIRS Near-Constant Contrast (NCC) product over both poles using the heritage winds algorithm.
- NCC converts DNB radiance into reflectance-like values that are useful for tracking.
- Begin to transition into enterprise framework soon.





Samples: 1,209 ;

Arctic 2021 October - 2023 March DNB versus RAOBS

Vector RMSE: IR 6.54, DNB 6.52; Vector NRMSE: IR 0.33, DNB 0.33; Vector Precision IR 4.46, DNB 4.38



IR	Sample	Accuracy	Precision	NRMSVD	U-bias	V-bias	Speed RMS
<400 hPa	256	5.31	5.62	0.27	0.18	0.09	3.92
400to<700 hPa	816	4.65	4.20	0.35	0.01	-0.15	3.50
>=700 hPa	137	4.55	3.33	0.43	-0.53	0.92	3.69
Total	1209	4.78	4.46	0.33	-0.02	0.03	3.61
DNB	Sample	Accuracy	Precision	NRMSVD	U-bias	V-bias	Speed RMS
<400 hPa	268	5.43	5.97	0.29	-0.36	-0.06	4.40
400to<700 hPa	802	4.70	3.93	0.35	0.20	-0.39	3.59
>=700 hPa	139	4.45	2.86	0.40	-0.67	1.07	3.65
Total	1209	4.83	4.38	0.33	-0.03	-0.15	3.68

Arctic 2021 October – 2023 March DNB versus RAOBS



Summary, Conclusions and Future Work:



- Using NOAA-20 and S-NPP in ***tandem*** with three overpasses (***triplets***) improves coverage and quality of JPSS AMV product available at ***high latitudes***.
- Reduce error when compared to RAOBs. Reduction of Speed RMS (0.5 m/s), Vector RMS (0.6 m/s) and Normalized RMS (3-5%).
- Positive impact on NAVGEM model forecast.

<https://stratus.ssec.wisc.edu/products/rtpolarwinds/rtpolarwinds.html>

- 1-month test period of the ***tandem duplets*** (two-overpasses) shows ***global*** coverage.
- Positive results when compared to RAOB. For example, NRMS 0.34 over Tropics indicating working parallax correction.
- Positive results when assimilated into GFS. Improved N. Hemi 500 hPa geopotential height bias.

To do list

- Include NOAA-21 into tandem products. Reduce Δ time by 25 minutes.
- Start migrating tandem AMV code over to Enterprise framework (operations).

Summary, Conclusions and Future Work:



- Other **experimental** JPSS AMV products also include **exploring** other channels such as **M11** solar reflective component at $2.2\ \mu\text{m}$ (**SWIR/Day**) and Near-Constant Contrast product at $0.7\text{-}0.9\ \mu\text{m}$ (**DNB/Night**)
- **SWIR** AMVs produce **greater coverage** at **low to mid levels**.
- Comparison to RAOBs show **improvement at low-levels**. NRMS difference reduced by 4% with SWIR compared to IR.
- Positive results when assimilated into NAVGEM with beneficial information provided by low and mid level SWIR AMVs.
- **DNB** AMV RAOB comparisons show **similar results to IR**, with 3% (NRMS) improvement at low-levels.

To do list

- Still need to do model impact study of DNB.
- Adjust code for SWIR and DNB bands in the Enterprise framework environment (operations).
- Get SWIR and DNB AMVs working with tandem JPSS satellites.

Thank You!

Extratropical storm Larry

