The Version 2 VIIRS+CrIS Fusion Radiance products

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**NASA Atmosphere-SIPS   **Retired*

Goal

- The VIIRS+CrIS Fusion Radiance (FSNRAD) products have been created to provide a path for continuity of products based on the Terra, Aqua, SNPP, and NOAA-20 platforms.

- *Why is this work important?* MODIS has three channels sensitive to CO_2 in the 4.5 µm CO_2 band, four channels in the broad 15 µm CO_2 band, 2 channels sensitive to H_2O near 6.7 µm, and an ozone channel near 9 µm. VIIRS has none of these IR absorption bands. The lack of the CO_2 and H_2O channels results in a degradation of the accuracy of the cloud mask especially at night in high latitudes, other cloud products (cloud top pressure/height and thermodynamic phase) and the moisture products (total precipitable water vapor, upper tropospheric humidity).

- We addressed this restriction by constructing similar Aqua MODIS IR band radiances for VIIRS based on a fusion method that uses collocated VIIRS and CrIS data.

Imager+Sounder Spatial Fusion Schematics

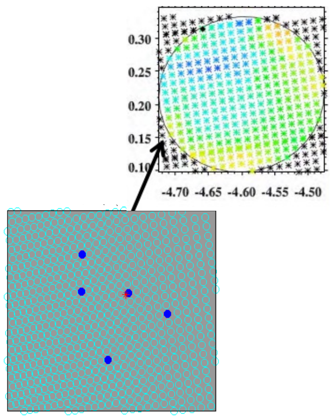
Step 1

Imager geolocation
HIRES Imager radiances
(imager bands X and Y)

Sounder geolocation

Collocation and Geographic Averaging

Sounder geolocation
LORES Imager radiances
(imager bands X and Y)



K-D Search Tree *(Bentley, 1975)*

N=5 Indices of N closest sounder FOVs
(for each imager pixel)

LORES/HIRES … low/high spatial resolution

Step 2

Radiance Fusion

LORES Sounder Radiance
Convolved to Band Z

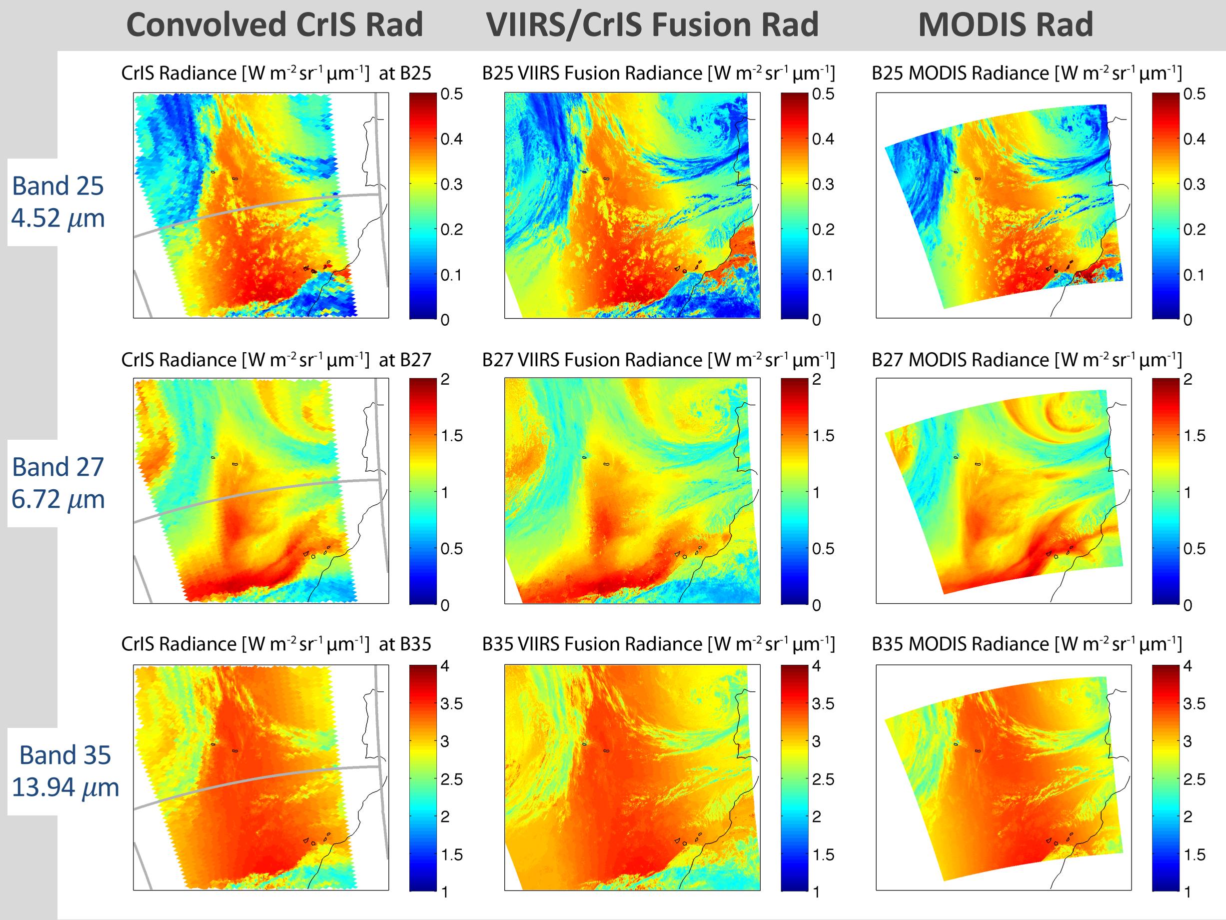
Average N Sounder FOVs
(for each imager pixel)

HIRES Fusion Radiance
At Imager Band Z

(Cross et al. 2013, Weisz et al. 2017)

Imager+Sounder Radiance Fusion Example

- Imager+sounder radiance fusion applied to VIIRS+CrIS to construct missing VIIRS CO_2 and H_2O absorption bands (i.e., MODIS-like bands).
- Can be applied to various instrument pairs (e.g., AVHRR+IASI, AVHRR+HIRS, VIIRS+TROPOMI, ABI+CrIS)



(Weisz et al. 2017)

VIIRS+CrIS FSNRAD Product (on full VIIRS spatial resolution)

MODIS Infrared bands		VIIRS+CrIS Fusion Infrared bands		Primary Use
band	Central Wavelength [µm]	band	Central Wavelength [µm]	
23	4.05	M13	4.05	Atmospheric temperature
24	4.47	M24 Fusion	4.47	Atmospheric temperature
25	4.52	M25 Fusion	4.52	Atmospheric temperature
27	6.72	M27 Fusion*	6.72	Water vapor
28	7.33	M28 Fusion	7.33	Water vapor
29	8.55	M14	8.55	Surface and cloud properties
30	9.73	M30 Fusion	9.73	Ozone
31	11.03	M15 M15 Fusion**	10.76	Surface and cloud properties
32	12.02	M16 M16 Fusion**	12.01	Surface and cloud properties
33	13.34	M33 Fusion*	13.34	Cloud properties
34	13.64	M34 Fusion*	13.64	Cloud properties
35	13.94	M35 Fusion*	13.94	Cloud properties
36	14.23	M36 Fusion*	14.23	Cloud properties

*FSNRAD_SS subset for the CERES team – through Langley ASDC

**BT diff for M15 and M16 are also provided for uncertainty estimate

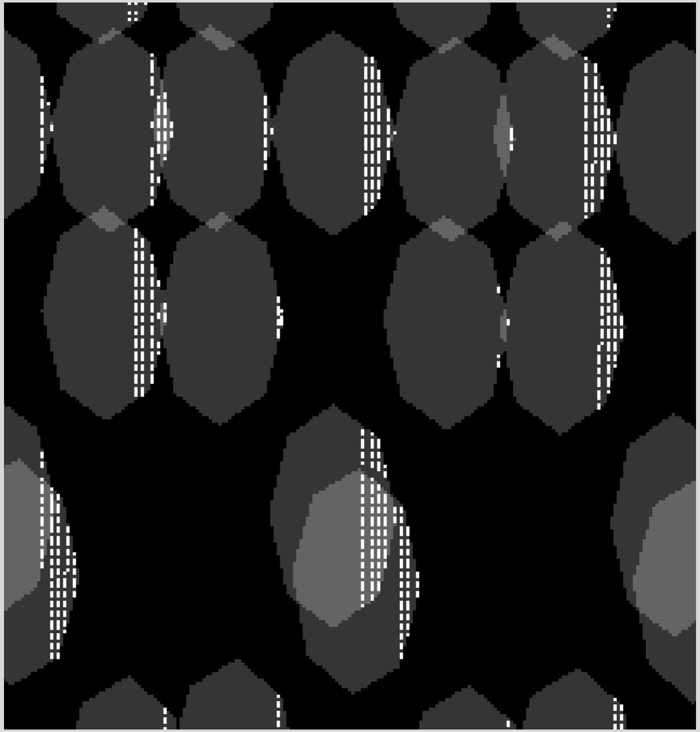
Status of the VIIRS+CrIS FSNRAD products

- **V1 released at NASA LAADS DAAC:** Fall 2019
- **V2 released at NASA LAADS DAAC**: March 8, 2022
    - DOI: 10.5067/VIIRS/FSNRAD_L2_VIIRS_CRIS_SNPP.002
- **Subsetter** products are available at A-SIPS:
    - https://sips.ssec.wisc.edu/#/products/availability;id=14372

Product Name	Description	Available at
FSNRAD_L2_VIIRS_CRIS_SNPP	S-NPP/VIIRS Fusion Radiances	LAADS DAAC
FSNRAD_L2_VIIRS_CRIS_NOAA20	NOAA20/VIIRS Fusion Radiances	LAADS DAAC
FSNRAD_L2_VIIRS_CRIS_SS_SNPP	S-NPP/VIIRS Subsetted Fusion Radiances	Atmosphere-SIPS
FSNRAD_L2_VIIRS_CRIS_SS_NOAA20	NOAA20/VIIRS Subsetted Fusion Radiances	Atmosphere-SIPS

- **Note for SNPP:** CrIS anomaly in LW data
    - May 21 –July 12, 2021: fill value for Band 30-36 (anomaly of CrIS LW channels)
    - July 14, 2021 - fill value for Band 27, 28, B30-36 restored (Side 1 -> Side 2)

Collocation and bug fixes



The old collocation code missed VIIRS pixels that should have been identified as residing within a CrIS FOV (false negative).

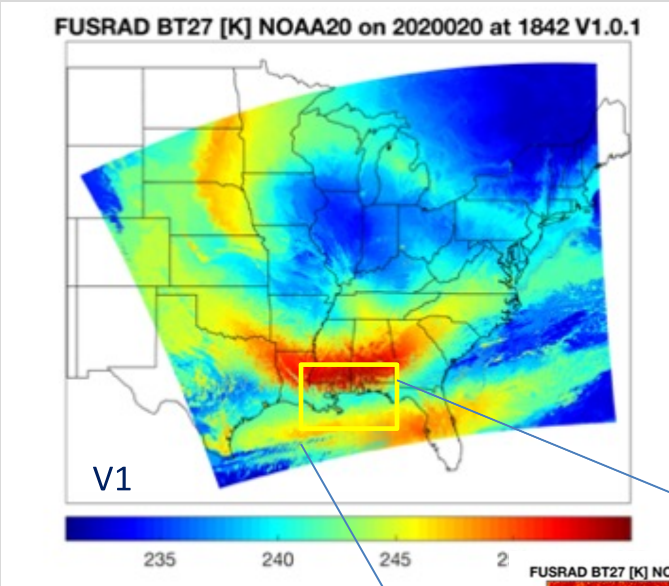
The image shows an area where the false negative problem was especially prominent. Each small white rectangle is a VIIRS pixel not identified before.

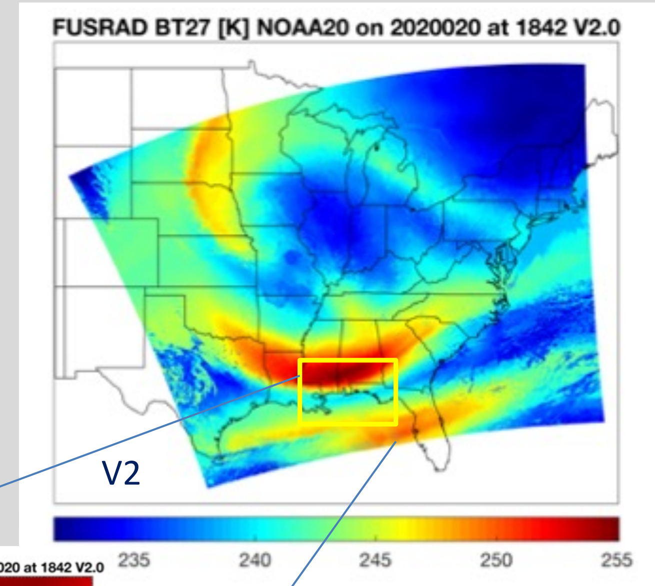
Overall, an average granule was missing under 1% of collocated VIIRS pixels (for a sense of scale, the new code has 189 false negatives for August 2020, while the old code had about 286 million).

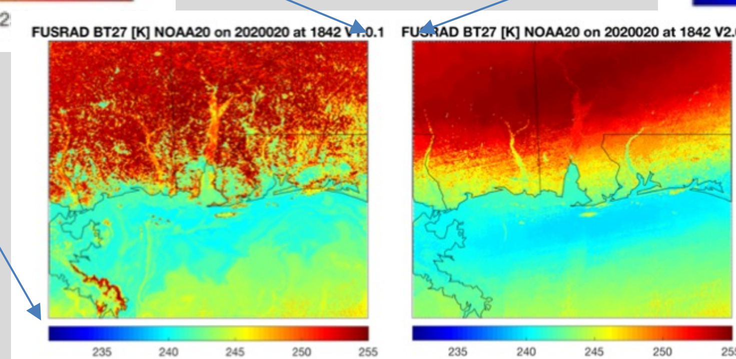
A *recent bug fix (Dec 2022*) related to the VIIRS M15&M16 band missing values also helped to fill up some missing granules.

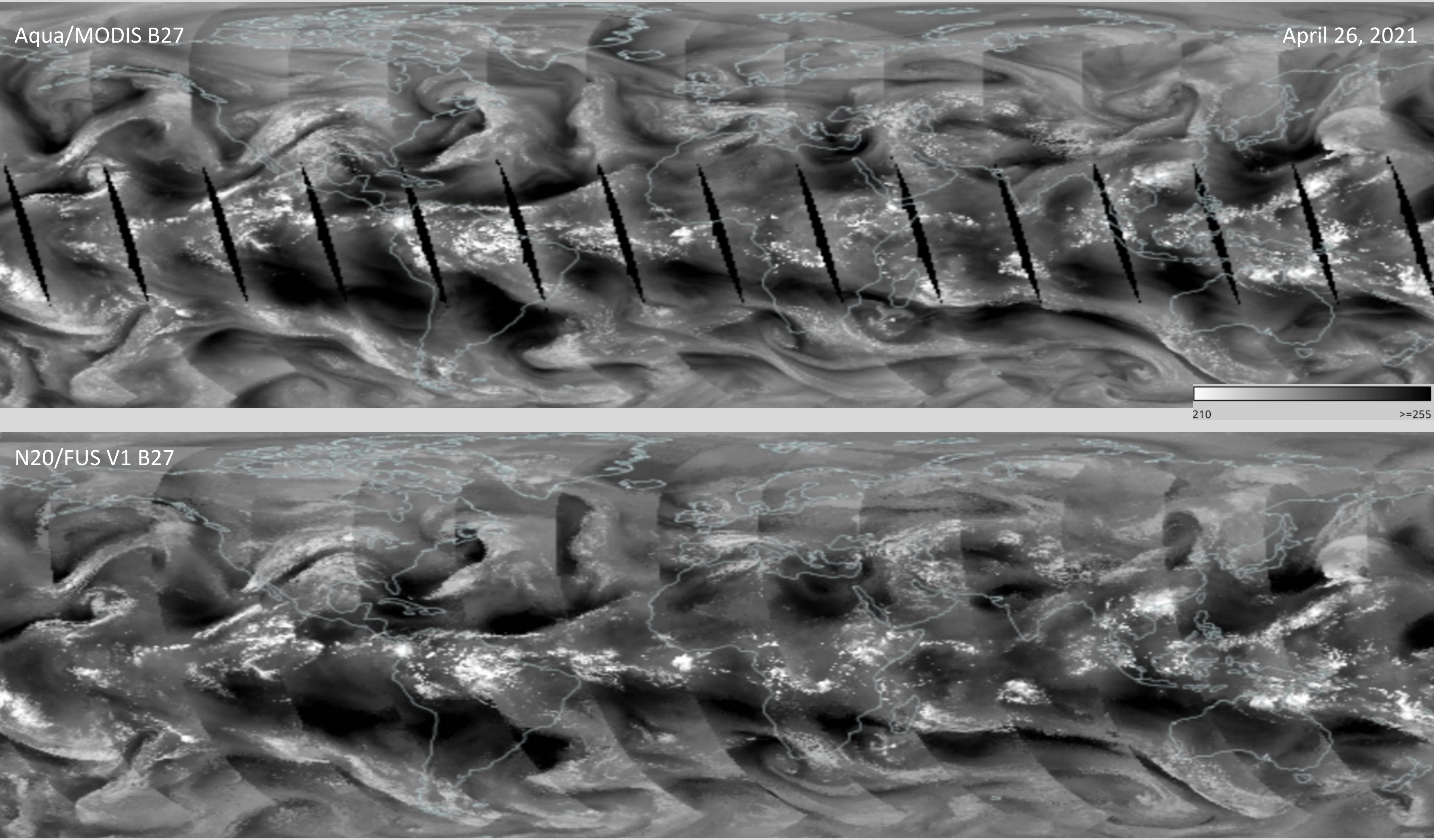
The yield for the fusion radiance product is now greater than 99.9% for NOAA20.

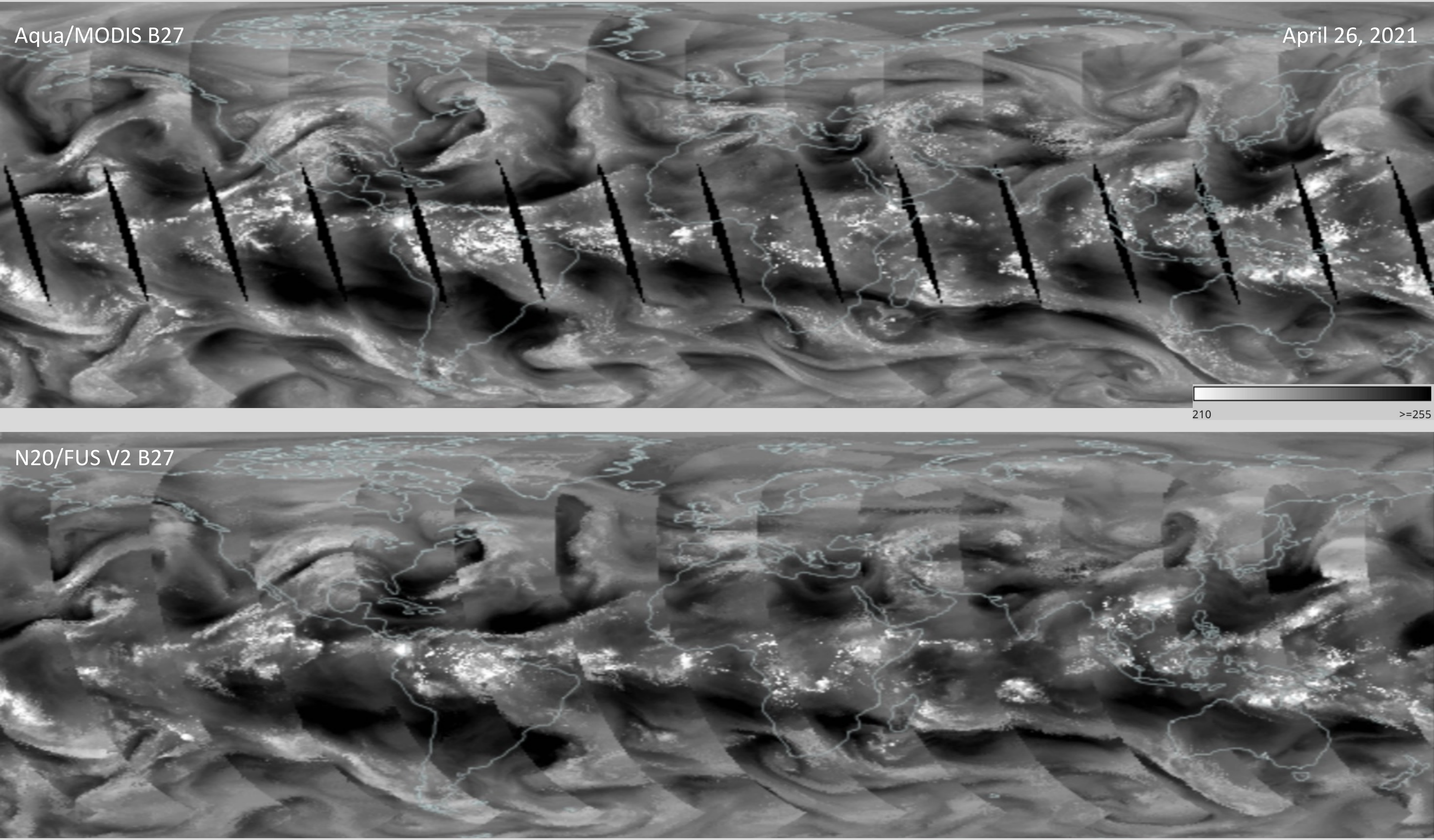
V2 update: Decreasing surface effect in WV bands








Aqua/MODIS B27
April 26, 2021
210
>=255
N20/FUS V1 B27


Aqua/MODIS B27
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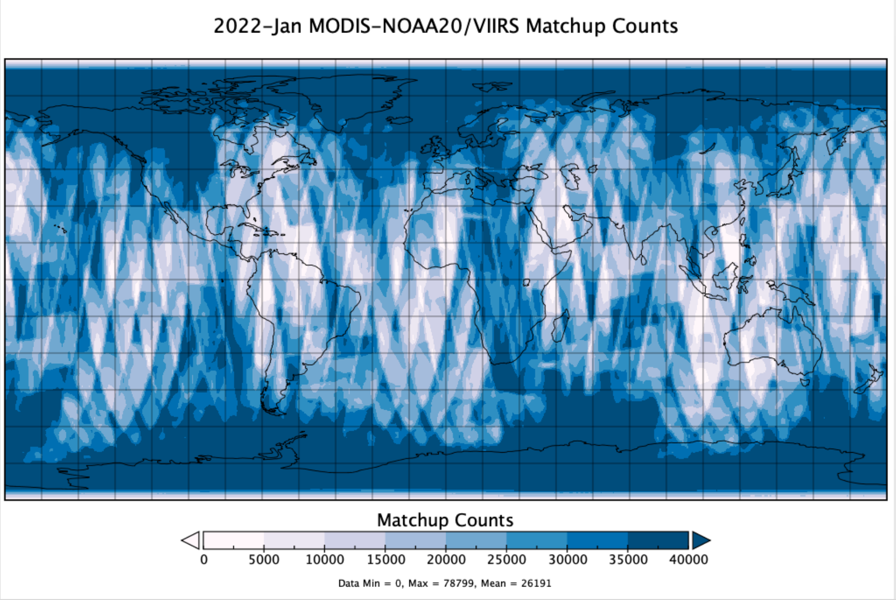
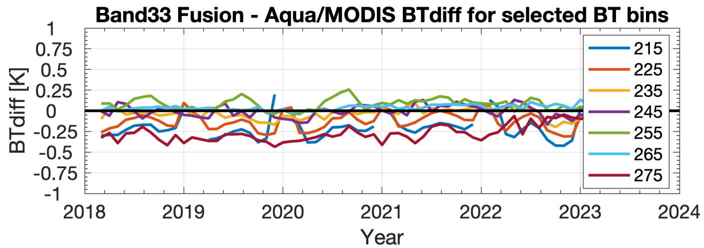
>=255
N20/FUS V2 B27

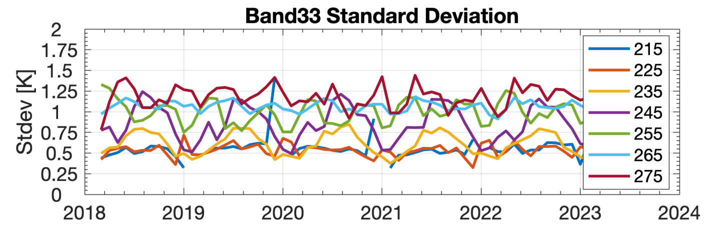
Assessment of Product Quality

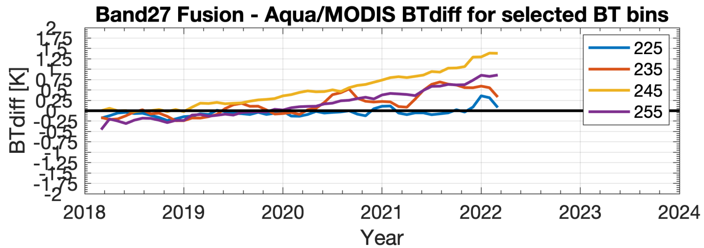
SNPP and NOAA20 fusion radiance products are compared directly with Aqua/MODIS measured radiances operationally.



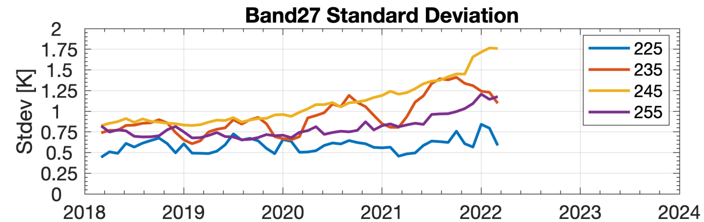


Band33



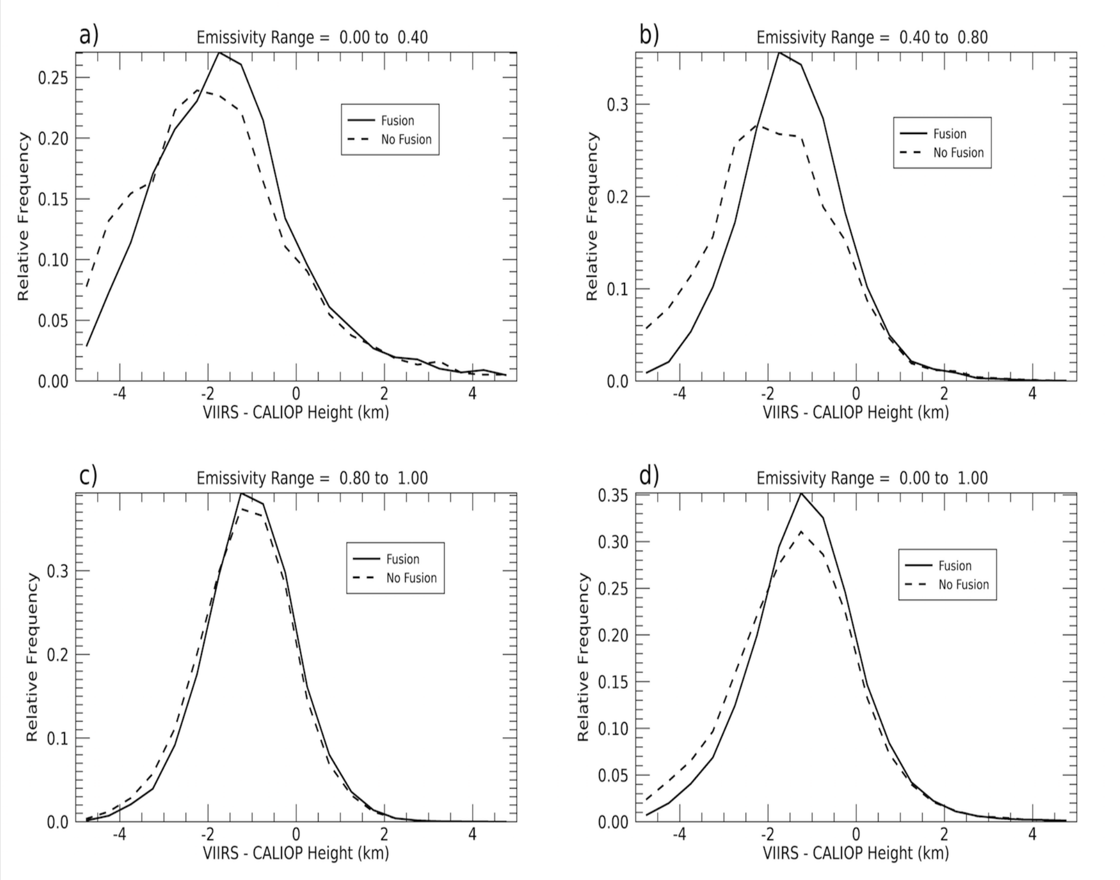


Band27



Cloud Application

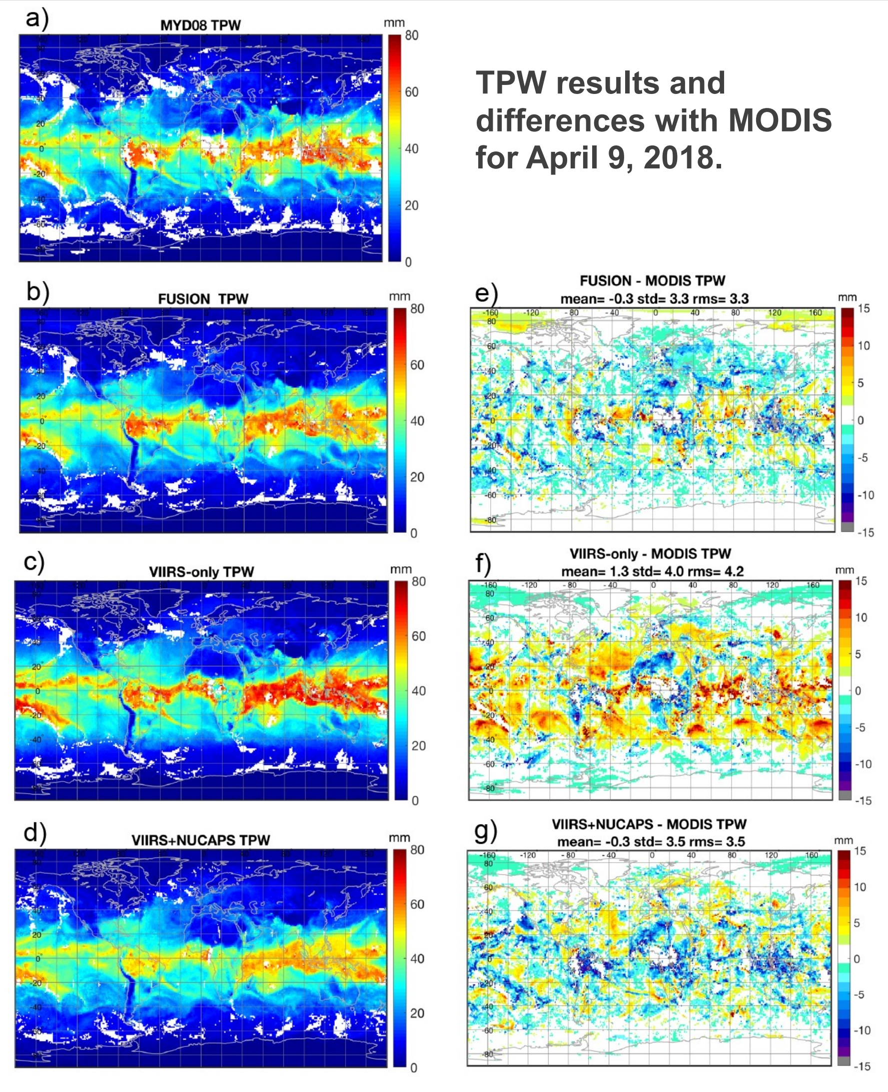
(Li et al. 2020) used the 6.7 and 13.3 μm CrIS+VIIRS fusion bands in CLAVR-X, the NOAA operational cloud processing package. They demonstrated that the fusion radiancies improved cloud parameters, *like cloud mask (polar regions), type/phase, and cloud height for all latitudes.*



Bias distribution of cloud top height of ice phase clouds between S-NPP VIIRS and CALIPSO/CALIOP for emissivity range a) 0 to 0.4; b) 0.4 to 0.8; c) 0.8 to 1.0; and d) 0 to 1.0. Solid and dashed lines indicate data with/without fusion channels.

Significant improvement is found for all ice cloud emissivities but especially for semi-transparent ice clouds, when the spectral information is used what the FUSION products provide.

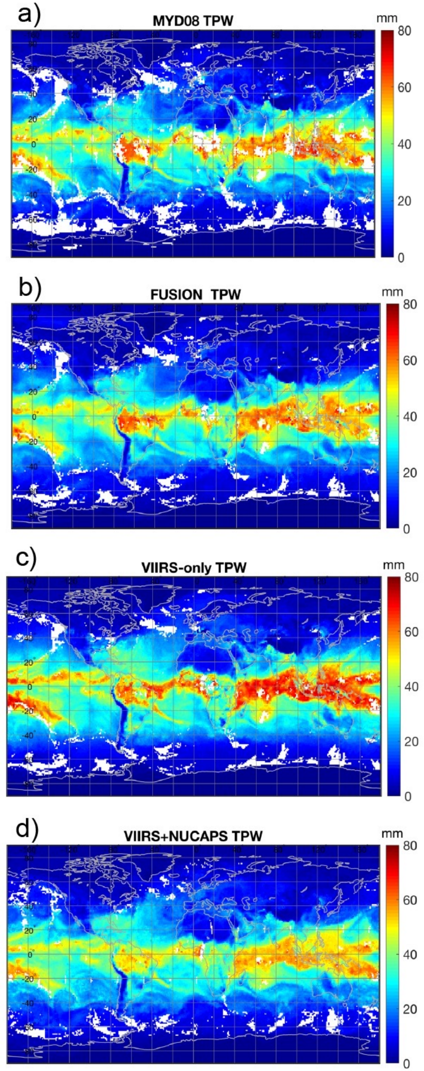
MOD07 TPW Application

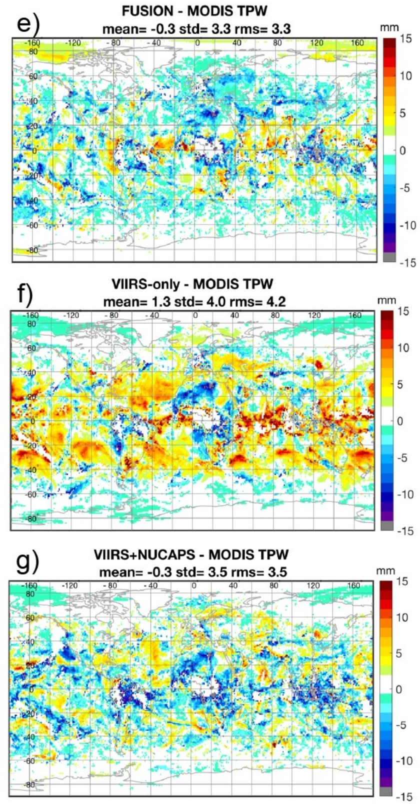


TPW results and differences with MODIS for April 9, 2018.

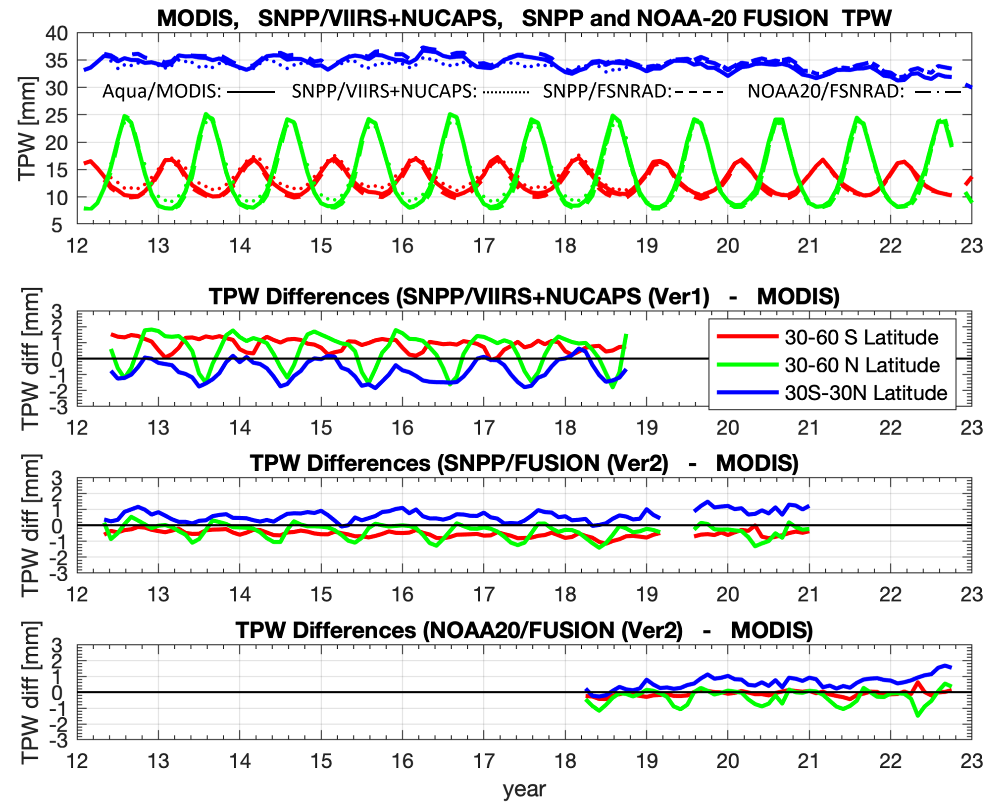
(Borbas et al., 2021)

MOD07 TPW Application





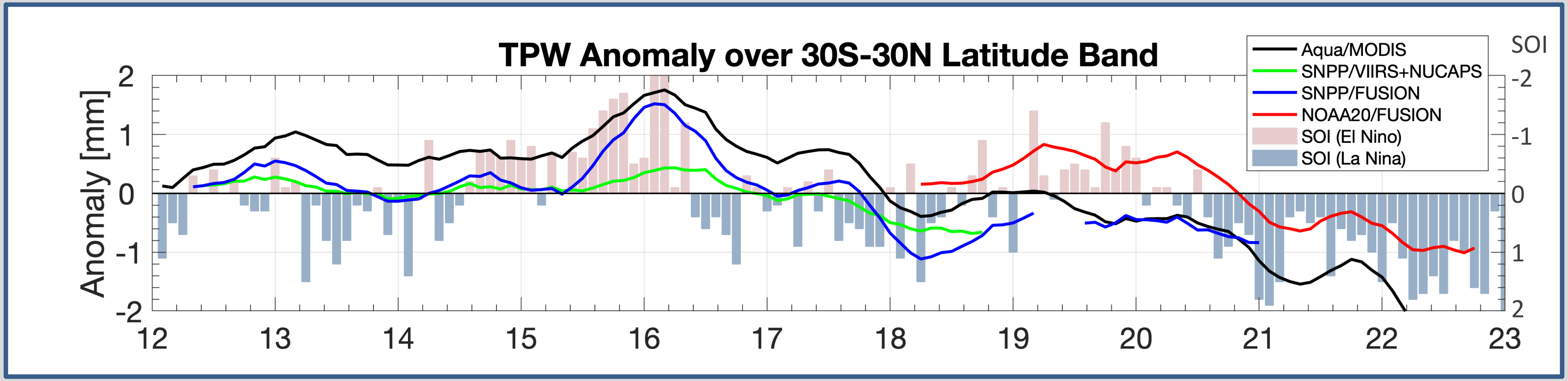
TPW results and differences with MODIS for April 9, 2018.



VIIRS+CrIS fusion TPW and MODIS TPW remain within 1mm for all three latitude bands (mid-latitudes north, tropics and mid-latitudes south).

(Borbas et al., 2021)

MOD07 TPW Application (cont.)

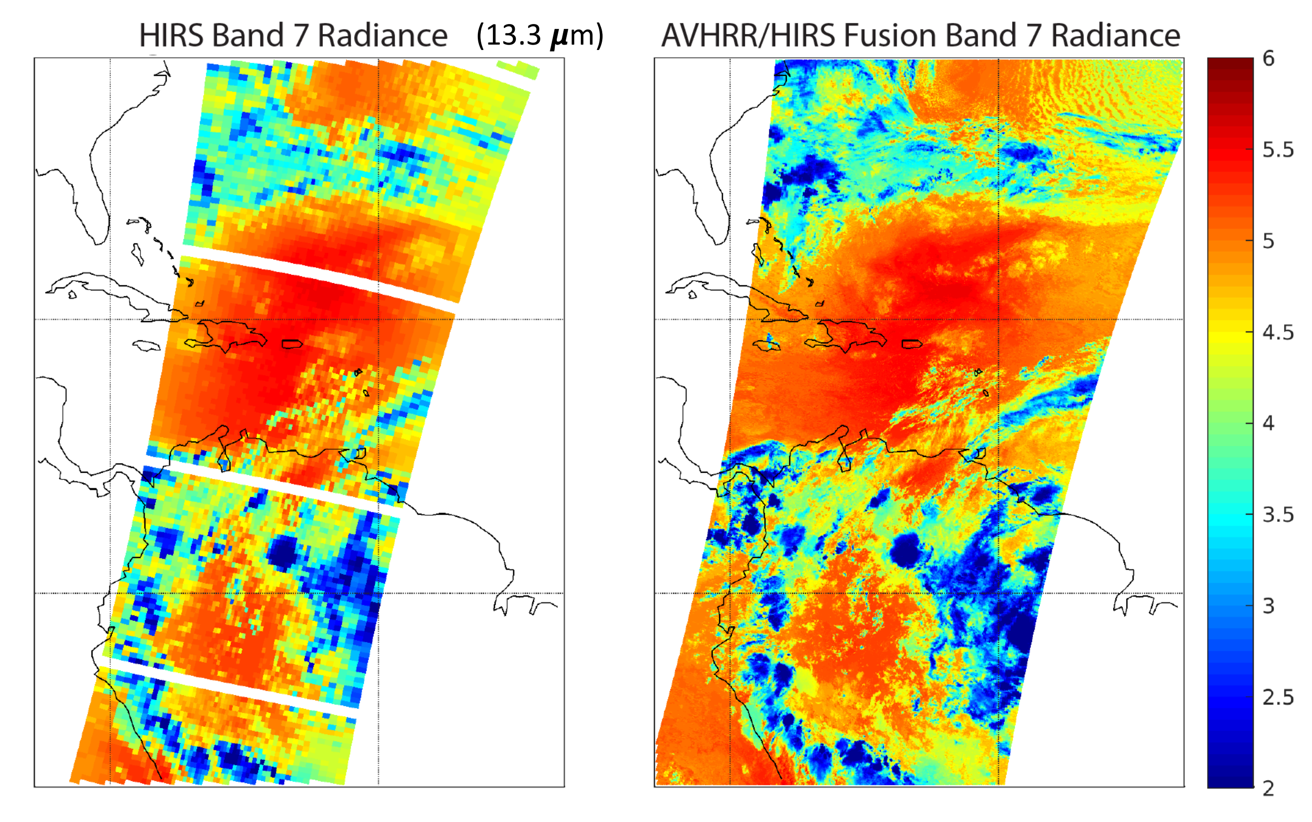


Borbas et al. (2021) show the advantage of using the VIIRS+CrIS fusion radiances for IR absorption bands at 4.5, 6.7, 7.3, 13.3, 13.6, 13.9, and 14.2 µm to determine TPW and demonstrate the potential for continuity of the Terra/Aqua MODIS infrared water vapor products. This study established the feasibility of extending the MODIS IR TPW and UTH into the future. The VIIRS+CrIS fusion TPW product, supplemented with the missing IR bands, was implemented using the same approach as the MODIS TPW product. Note that the fusion-based TPW product is in excellent agreement with MODIS.

(Borbas et al., 2021)

PATMOS-X Application

PATMOS-X V6 now includes the AVHRR+HIRS radiance fusion for the multidecadal NOAA POES and EUMETSAT METOP satellite record.



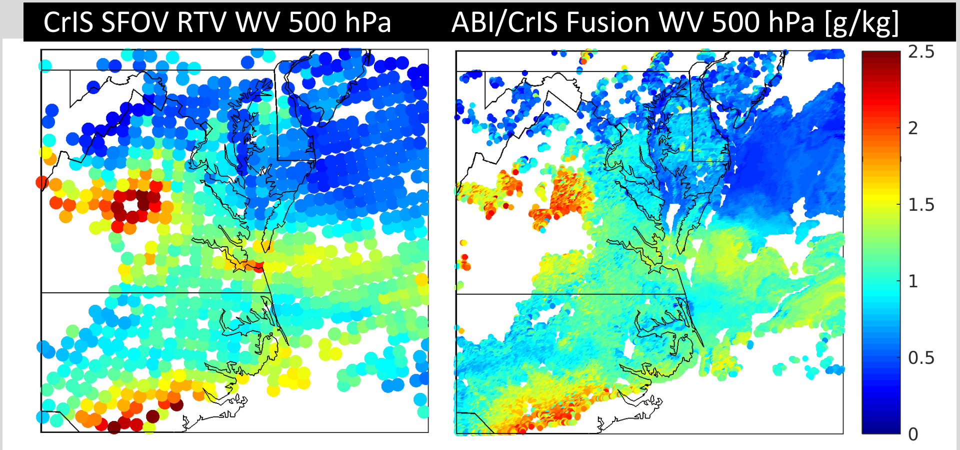
(Foster et al., 2023)

Other Applications

- **GEO/LEO Application**: *spatial and temporal fusion (*between imager radiances from subsequent time steps) - (***Weisz et al., 2020) (Anheuser et al., 2020)***
  - ABI/CrIS fusion captures the rapidly evolving atmospheric changes during thunderstorm & tornado development (when CrIS overpass is timely) (***Smith et al, 2020***)
  - Volcanic SO_2 detection at nighttime is demonstrated with ABI/CrIS fusion (***Weisz and Menzel, 2022***)

- "**Product fusion**" is used to transfer retrieval products at low spatial resolution (LORES) to high spatial resolution (HIRES)
  - Imager / sounder product fusion has been demonstrated for VIIRS, ABI, AHI / CrIS, TROPOMI

Product Fusion Example



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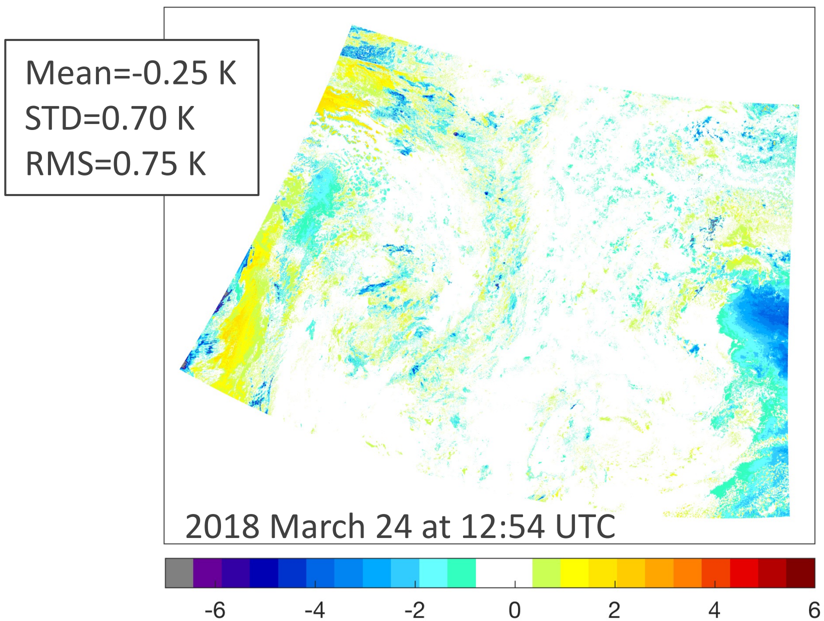
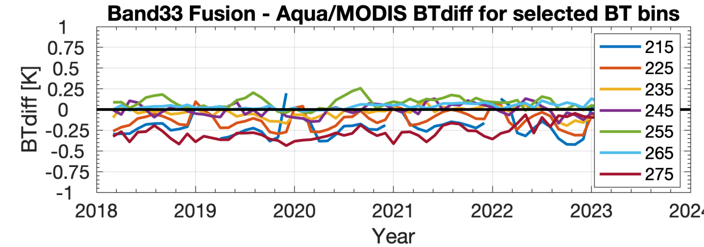
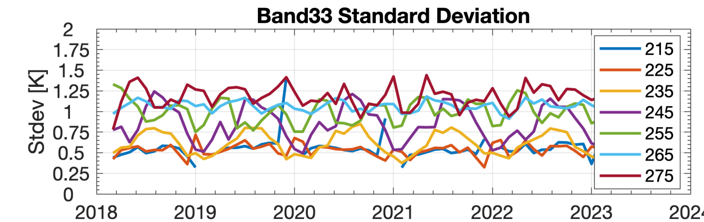
Next: Providing uncertainty estimate for all the bands based on the 11 and 12 μm BT differences between VIIRS and FSNRAD and the monthly mean SNOs time series.

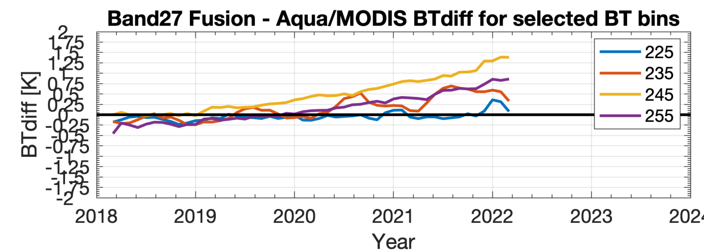
VIIRS/CrIS Fusion – VIIRS BT differences for 12 μm



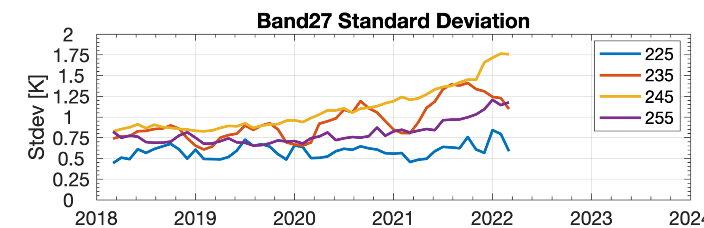


Band33





Band27




Aqua/MODIS B33
April 26, 2021
210
>=280
Thank you!
NOAA-20/FSNRAD V2 B33