Assessment of Fusion-based VIIRS–CrIS IR Absorption Radiances through Comparisons with Aqua MODIS

Bryan A. Baum[1], Elisabeth Weisz[2], W. Paul Menzel[2] and Chris Moeller[2]

Special thanks to:
Geoff Cureton[2], Greg Quinn[2], Yue Li[2], and Andy Heidinger[3]

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[3]NOAA/NESDIS/STAR, Madison, Wisconsin

MODIS-VIIRS Science Team Meeting
November 20, 2019

Project Summary

Our product provides VIIRS M-band (750 m) IR absorption band radiances based on imager-sounder data fusion (VIIRS+CrIS), for both Suomi-NPP and NOAA-20

The IR absorption band radiances are constructed based on Aqua MODIS spectral response functions

Achieve an order of magnitude increase in spatial resolution from sounder to imager at the cost of an increase in noise compared to MODIS

Initial indications are that these fusion radiances are beneficial for cloud products (cloud mask/phase/height) when compared to results from IR window channels alone

Fusion Approach

Step 1: Based on a relationship (*k*-d tree) between split-window imager pixel radiances (single pixel and average of pixels within a sounder FOV), find *N* sounder FOVs that best match a given pixel

Step 2: For each of the *N* sounder FOVs assigned to a given pixel, apply a set of spectral response functions (SRFs) to the hyperspectral radiances and calculate narrowband radiances

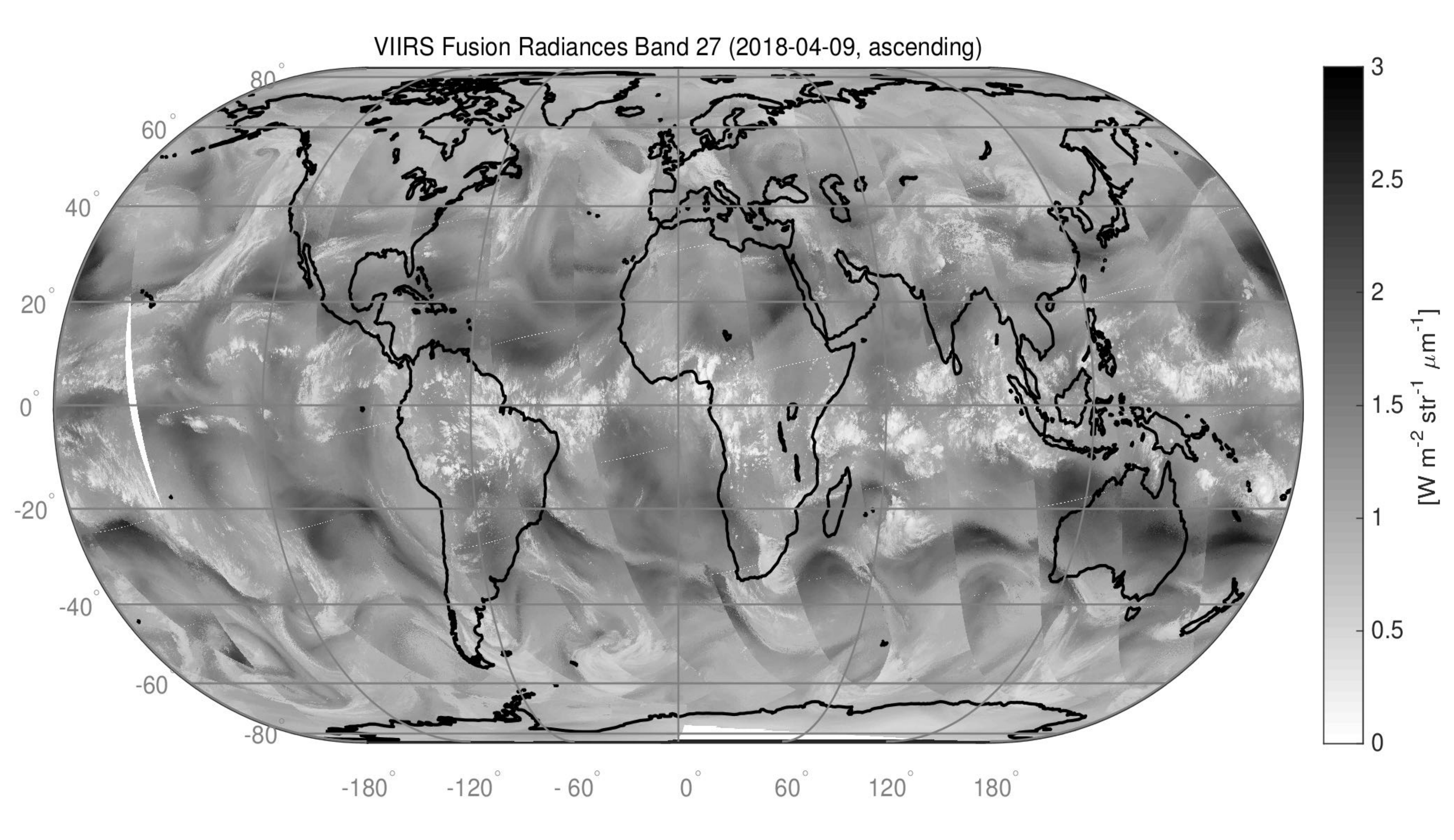
Step 3: Average the *N* narrowband radiances for each SRF and stamp on the pixel

Project: https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/viirs-cris-fusion/

Cross et al., 2013: Statistical estimation of a 13.3-μm Visible Infrared Imaging Radiometer Suite channel using multisensor data fusion. *J. Appl. Remote Sens*. **7** (1), 073473, doi: 10.1117/1.JRS.7.073473.

Weisz, E., B. A. Baum, and W. P. Menzel, 2017: Fusion of satellite-based imager and sounder data to construct supplementary high spatial resolution narrowband IR radiances. *J. Appl. Remote Sens*. **11** (3), 036022, doi: 10.1117/1.JRS.11.036022

VIIRS/CrIS Fusion Radiances for 6.7-μm Channel



Recent Transition to Operations

The relevant Aqua MODIS-like IR radiance channels (MODIS channels 23,24,25, 27,28,30,33,34,35,36) are provided in a VIIRS Level 2 granule (NetCDF4).

Additionally, VIIRS (measured – fusion) brightness temperature differences are included for VIIRS M15 and M16 so a user can assess fusion-based construction errors.

The VIIRS+CrIS Fusion product page (overview/documentation):

https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/viirs-cris-fusion

Direct access to the S-NPP VIIRS+CrIS fusion product archive:

https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5110/FSNRAD_L2_VIIRS_CRIS_SNPP

Direct access to the NOAA-20 VIIRS+CrIS fusion product archive:

https://ladsweb.modaps.eosdis.nasa.gov/archive/allData/5110/FSNRAD_L2_VIIRS_CRIS_NOAA20

Initial Production Stats

For Suomi-NPP: the failed/total ratio is 12,586/648,524 (1.96% failed)

For NOAA-20: the failed/total ratio is 131/150,967 (0.09% failed)

Observation: for Suomi-NPP, 12,020/12,586 granules failed because of a test involving the VIIRS L1B QC flags. The issue may not be so much with the L1B radiances themselves, but with how the L1B QC flags are handled. This is a topic of current consideration.

About the data fusion approach

Pros:

- No detector striping, out-of-band response, or other artifacts
- Spectral response functions are exactly the same as for Aqua-MODIS
- Sounder data are very well calibrated
- Can apply the same retrieval algorithms to any platform with minor changes

Cons:

- Radiance differences increase outside of sounder swath but this can be mitigated by accounting for increased water vapor/CO_2 absorption
- Increase in noise around edges of rapidly changing radiance fields
- *May have more noise than an algorithm requires for accuracy*

VIIRS Fusion and Aqua MODIS Monthly Matchups for Suomi-NPP

Chris Moeller and Greg Quinn (SSEC/UW-Madison)

Global matchups are available over entire records of Suomi-NPP and NOAA-20

Analysis limited to matchups where only one VIIRS measurement falls within the MODIS pixel.

Matchups are filtered using the MODIS cloud mask (99% confident clear only).

Matchups include day+night, all surfaces

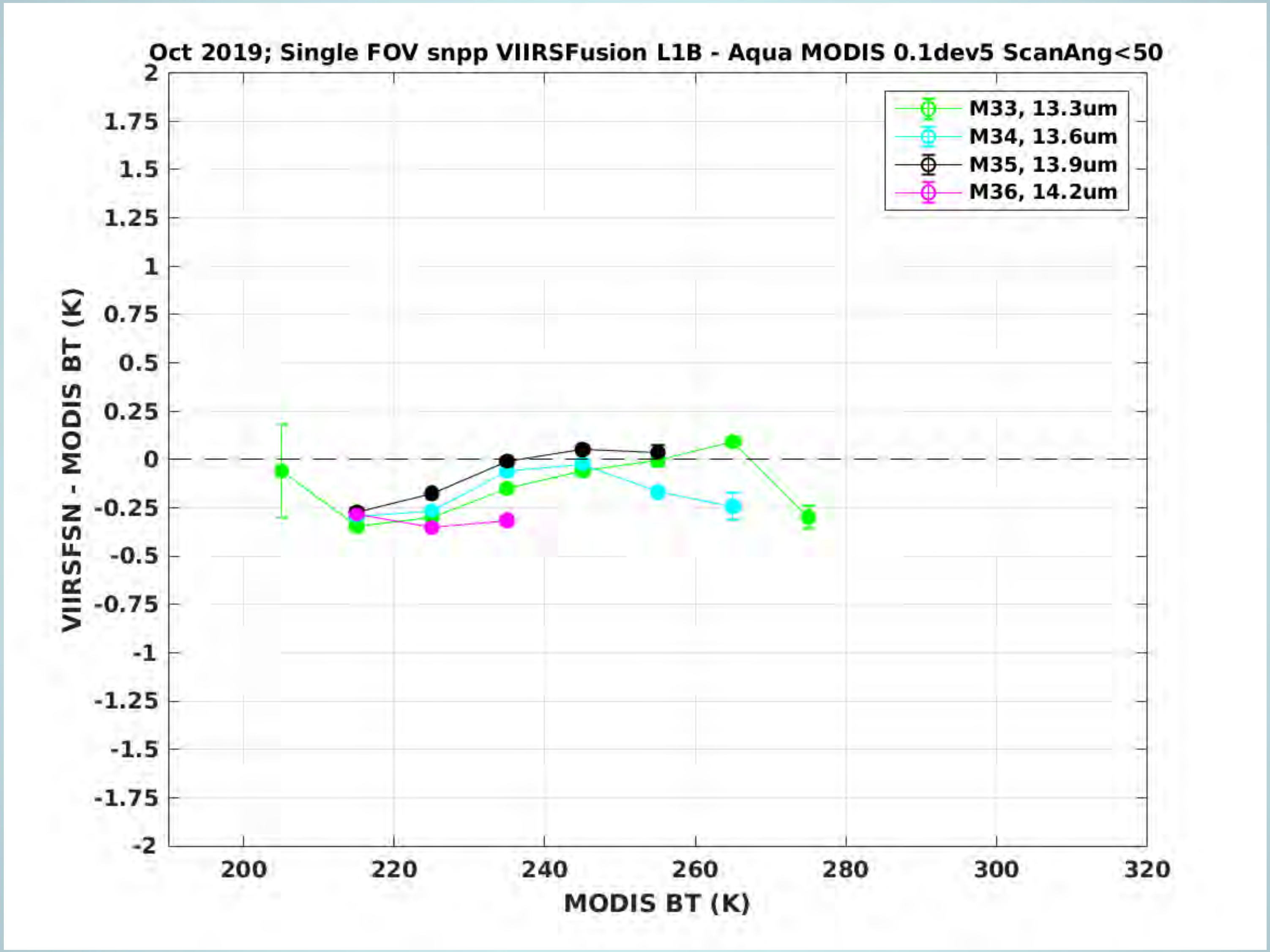
Each data point on the subsequent slides has at least 1,000 individual matchups, although most range between 10^5–10^6

Establishing context for matchup results

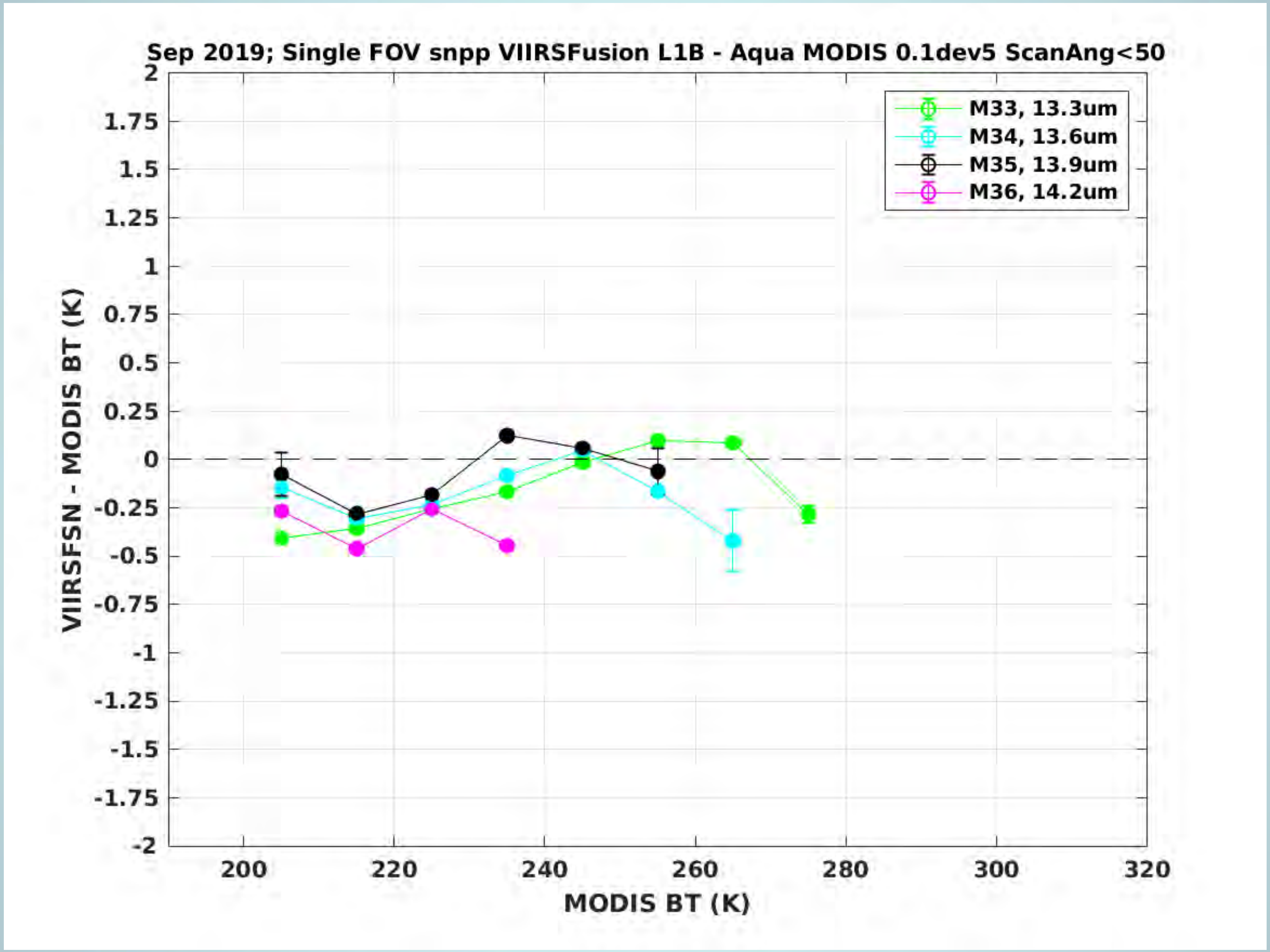
Primary Use	Band	Bandwidth[1]	Spectral Radiance[2]	Required NE[Δ]T(K)[4]
Surface/Cloud Temperature	20	3.660 - 3.840	0.45(300K)	0.05
	21	3.929 - 3.989	2.38(335K)	2.00
	22	3.929 - 3.989	0.67(300K)	0.07
	23	4.020 - 4.080	0.79(300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17(250K)	0.25
	25	4.482 - 4.549	0.59(275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00	150(SNR)
	27	6.535 - 6.895	1.16(240K)	0.25
	28	7.175 - 7.475	2.18(250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58(300K)	0.05
Ozone	30	9.580 - 9.880	3.69(250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55(300K)	0.05
	32	11.770 - 12.270	8.94(300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52(260K)	0.25
	34	13.485 - 13.785	3.76(250K)	0.25
	35	13.785 - 14.085	3.11(240K)	0.25
	36	14.085 - 14.385	2.08(220K)	0.35

S-NPP Results for 2019

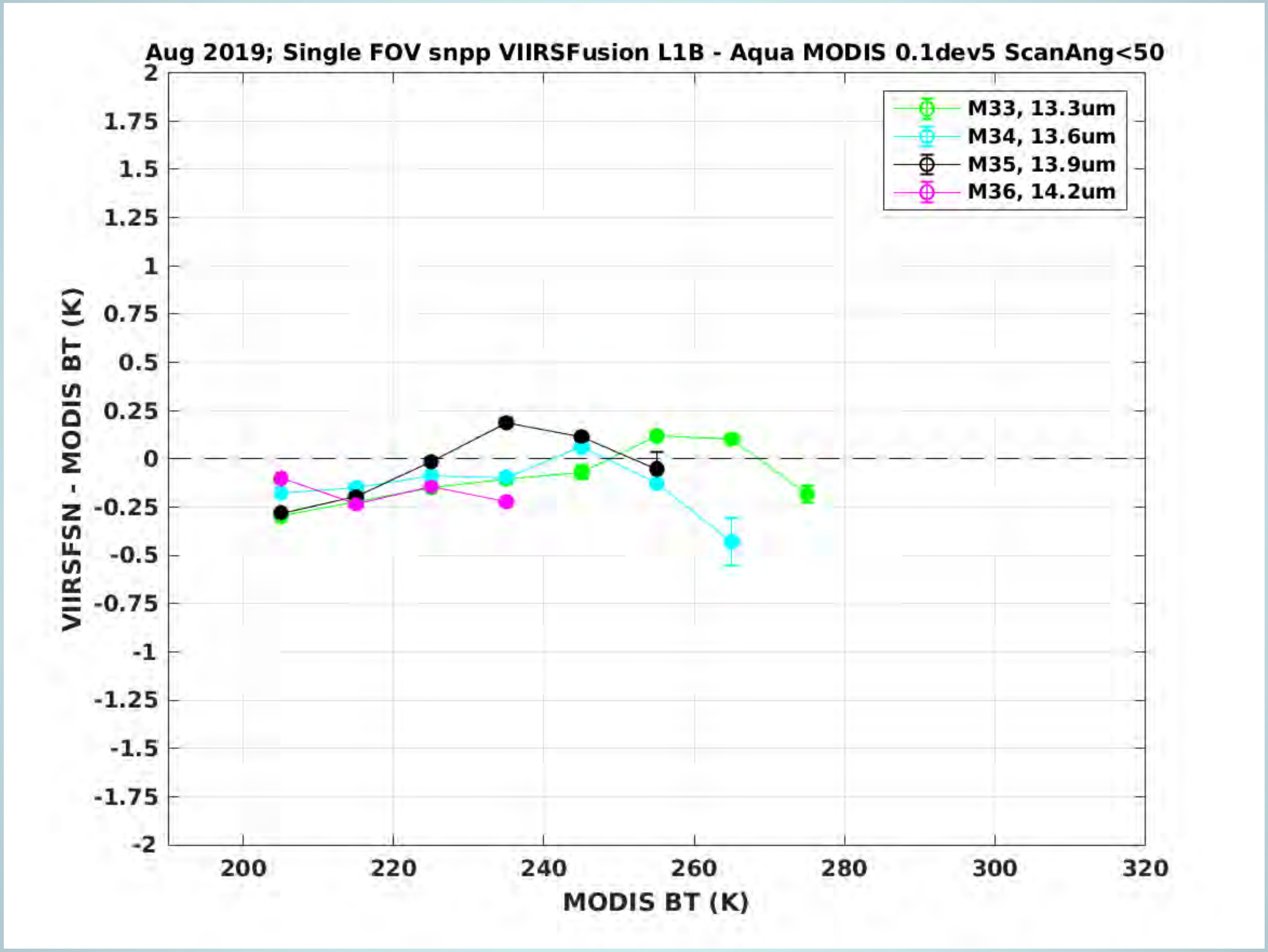
October 2019



September 2019



August 2019



Aug 2019; Single FOV snpp VIIRSFusion L1B - Aqua MODIS 0.1dev5 ScanAng<50
M33, 13.3um
M34, 13.6um
M35, 13.9um
M36, 14.2um
VIIRSFSN - MODIS BT (K)
MODIS BT (K)
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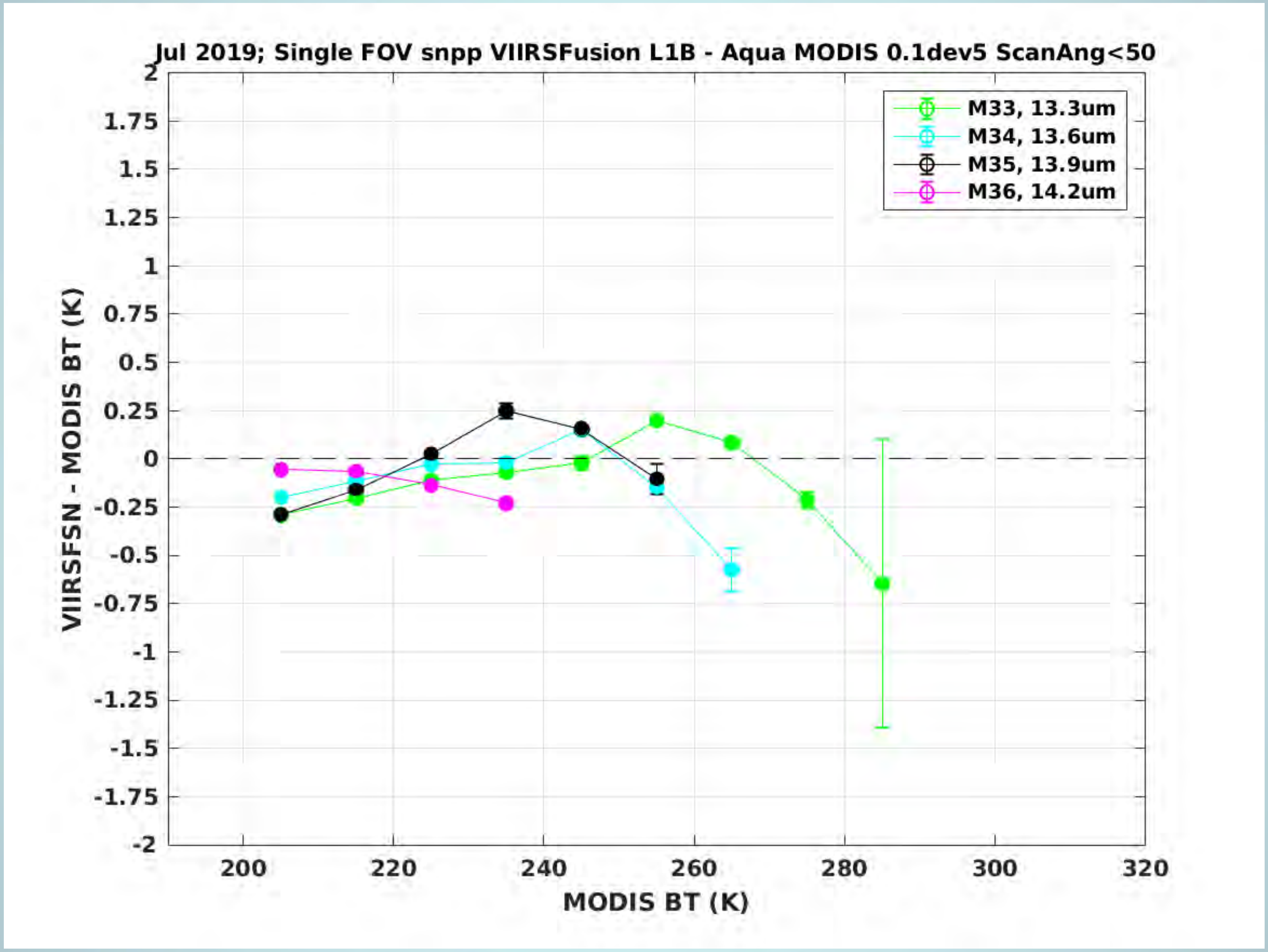
July 2019



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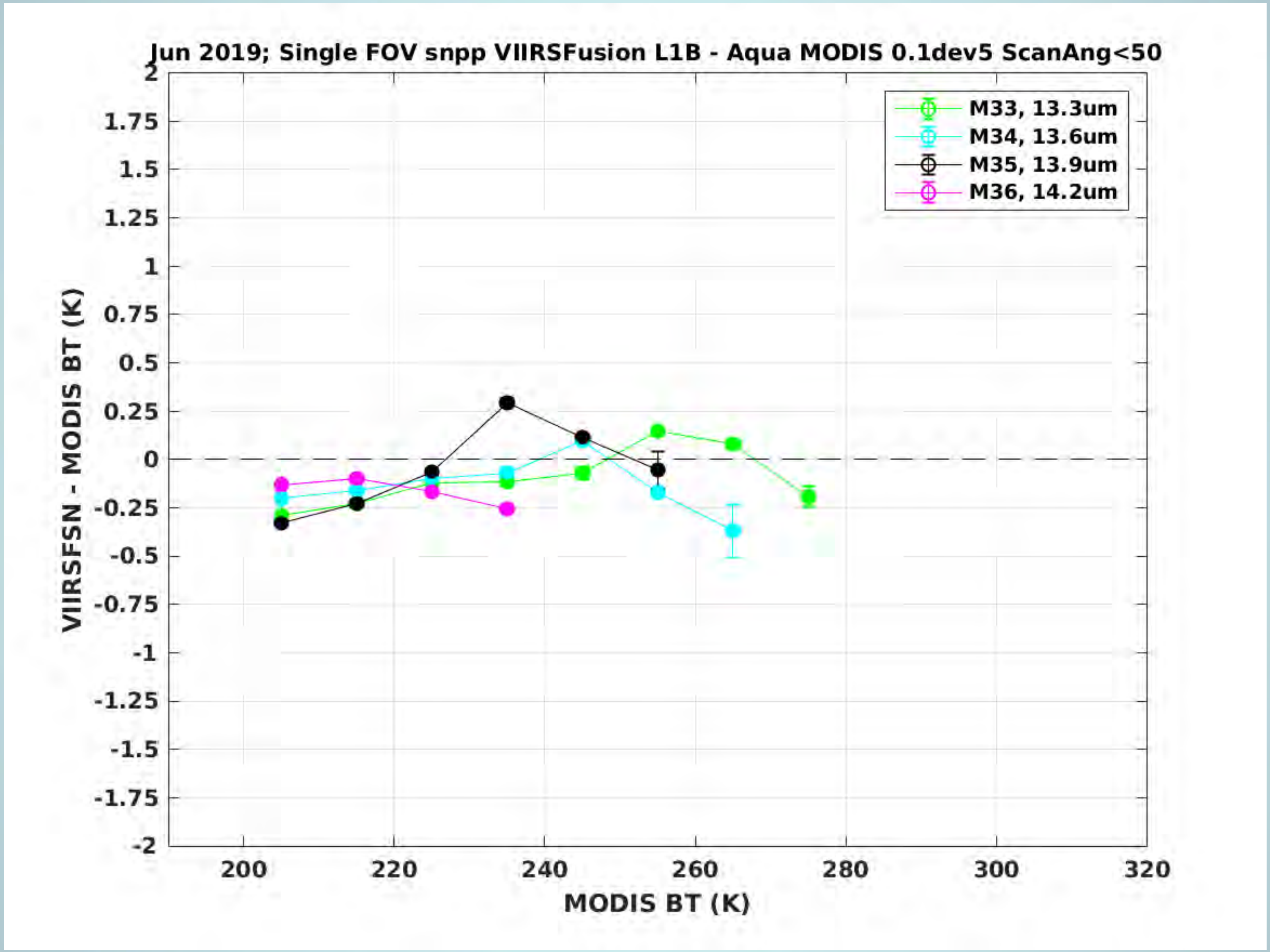
June 2019



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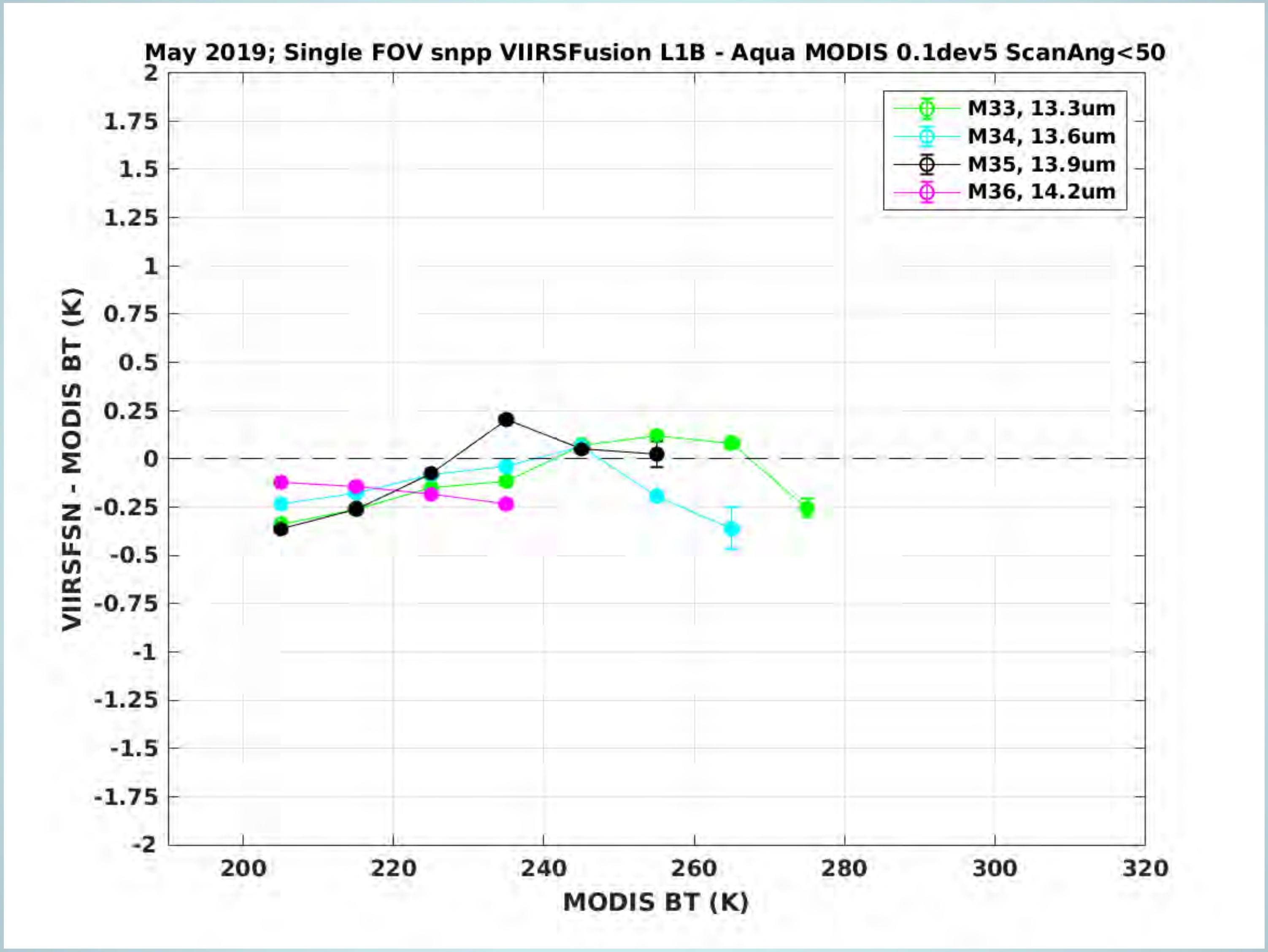
May 2019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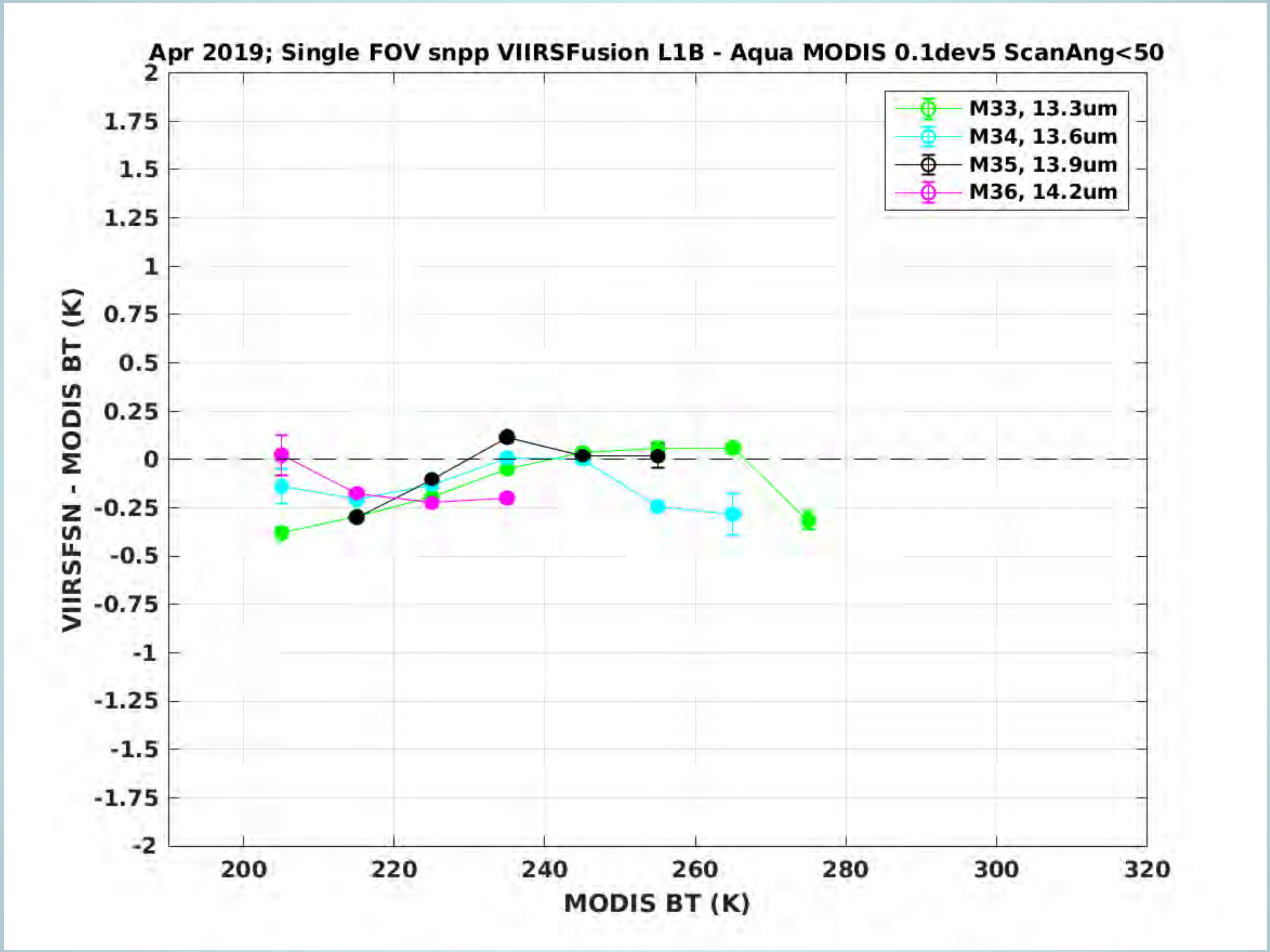
April 2019



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MODIS BT (K)

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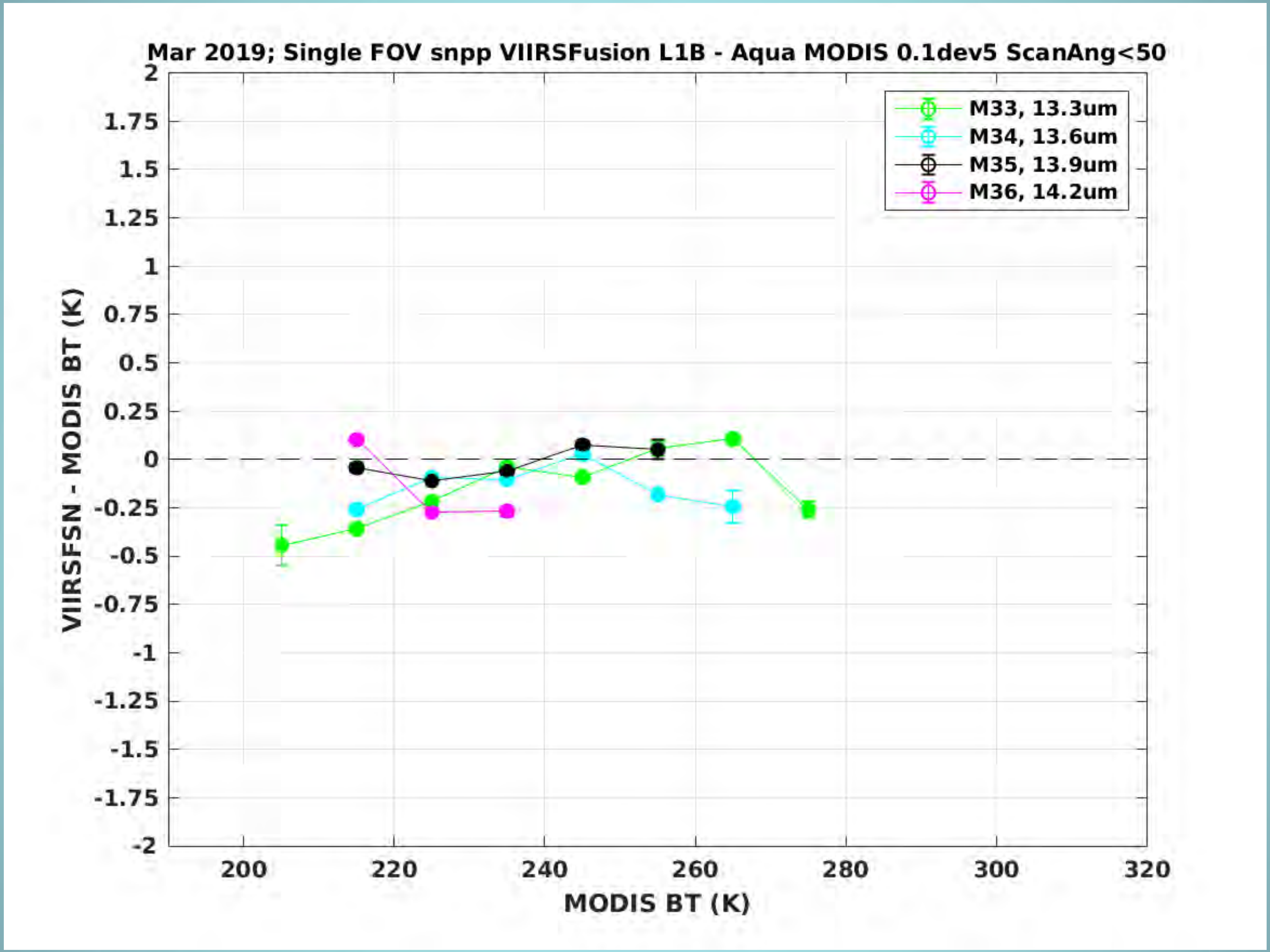

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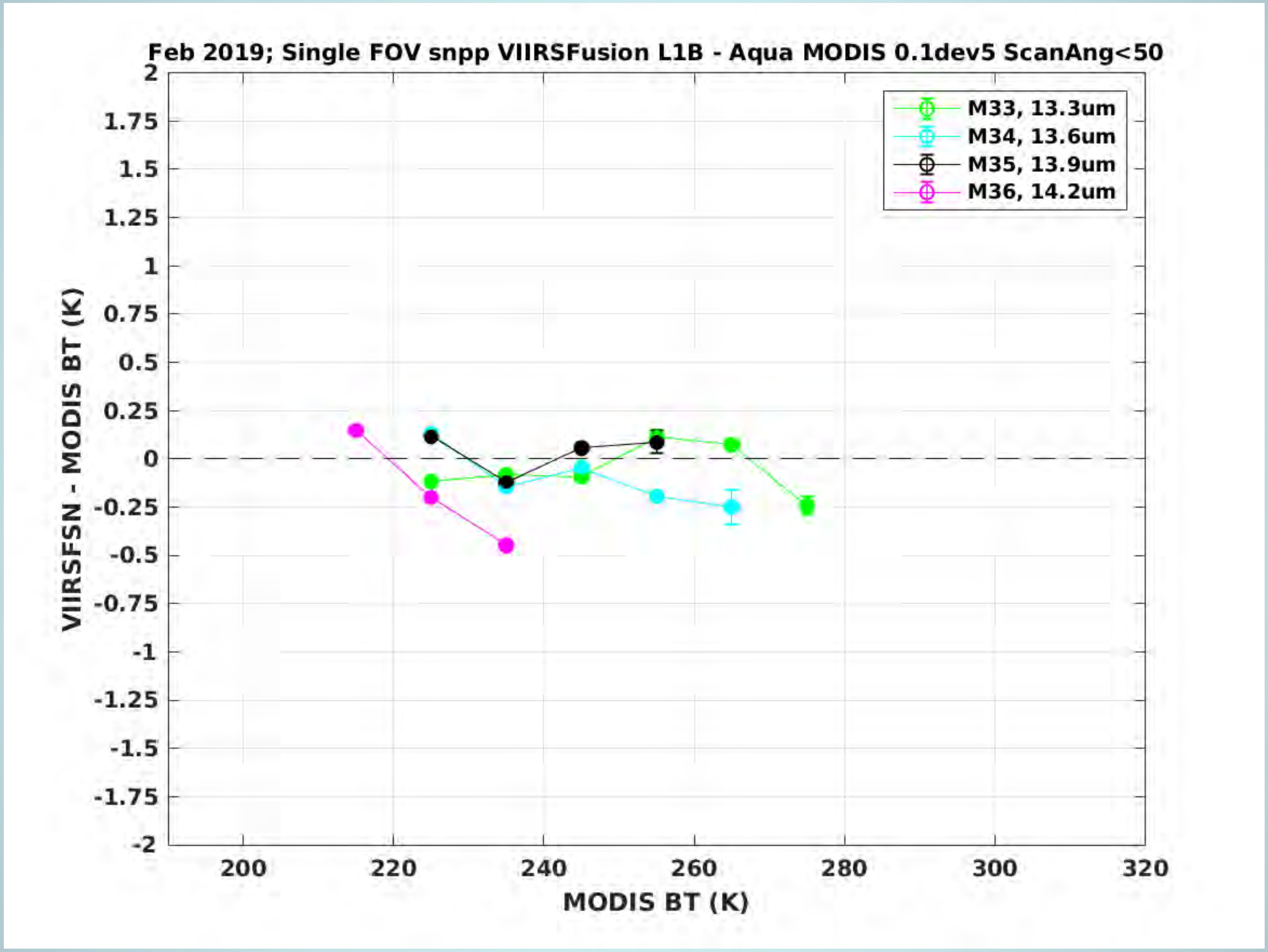
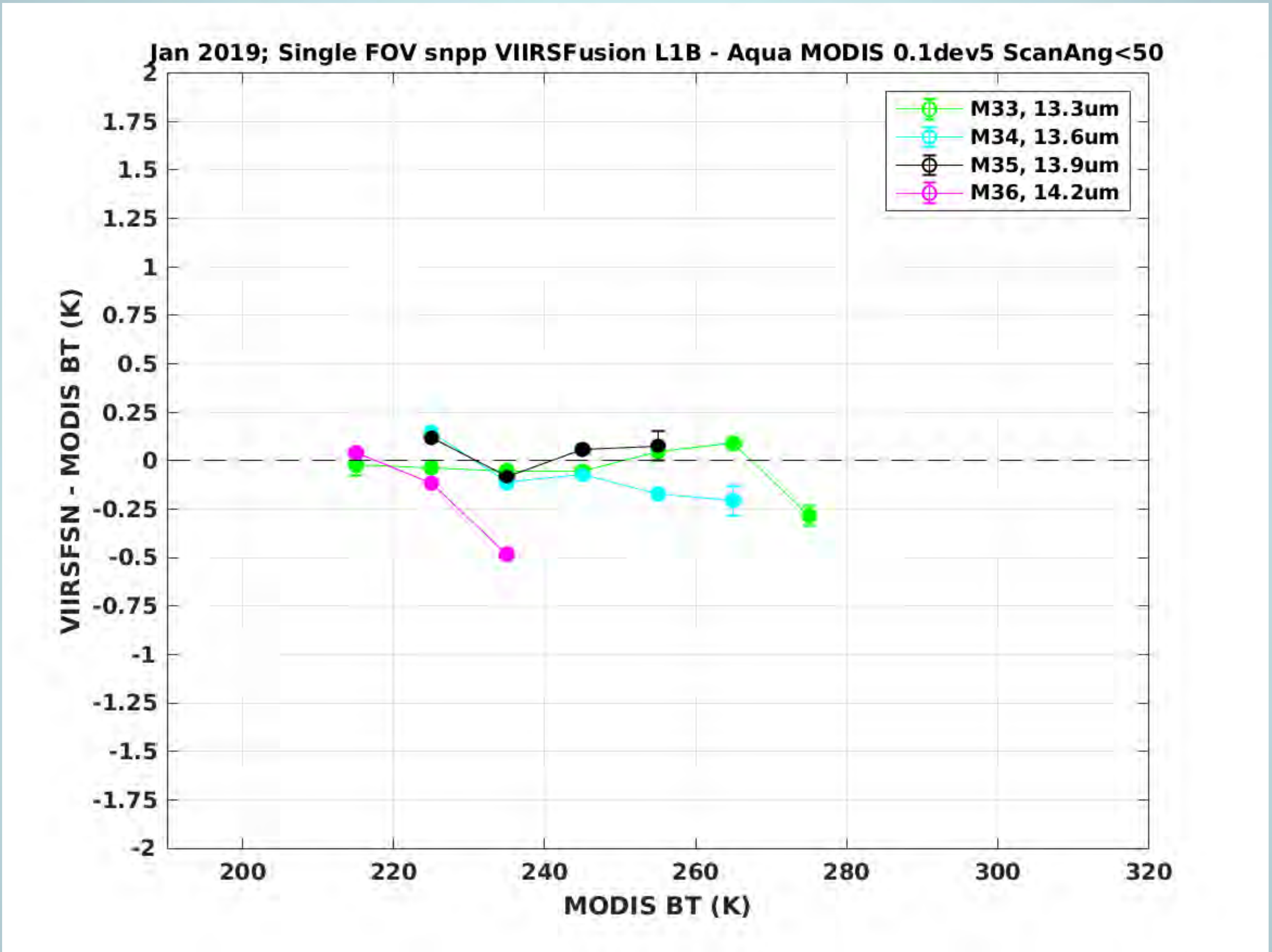
February 2019

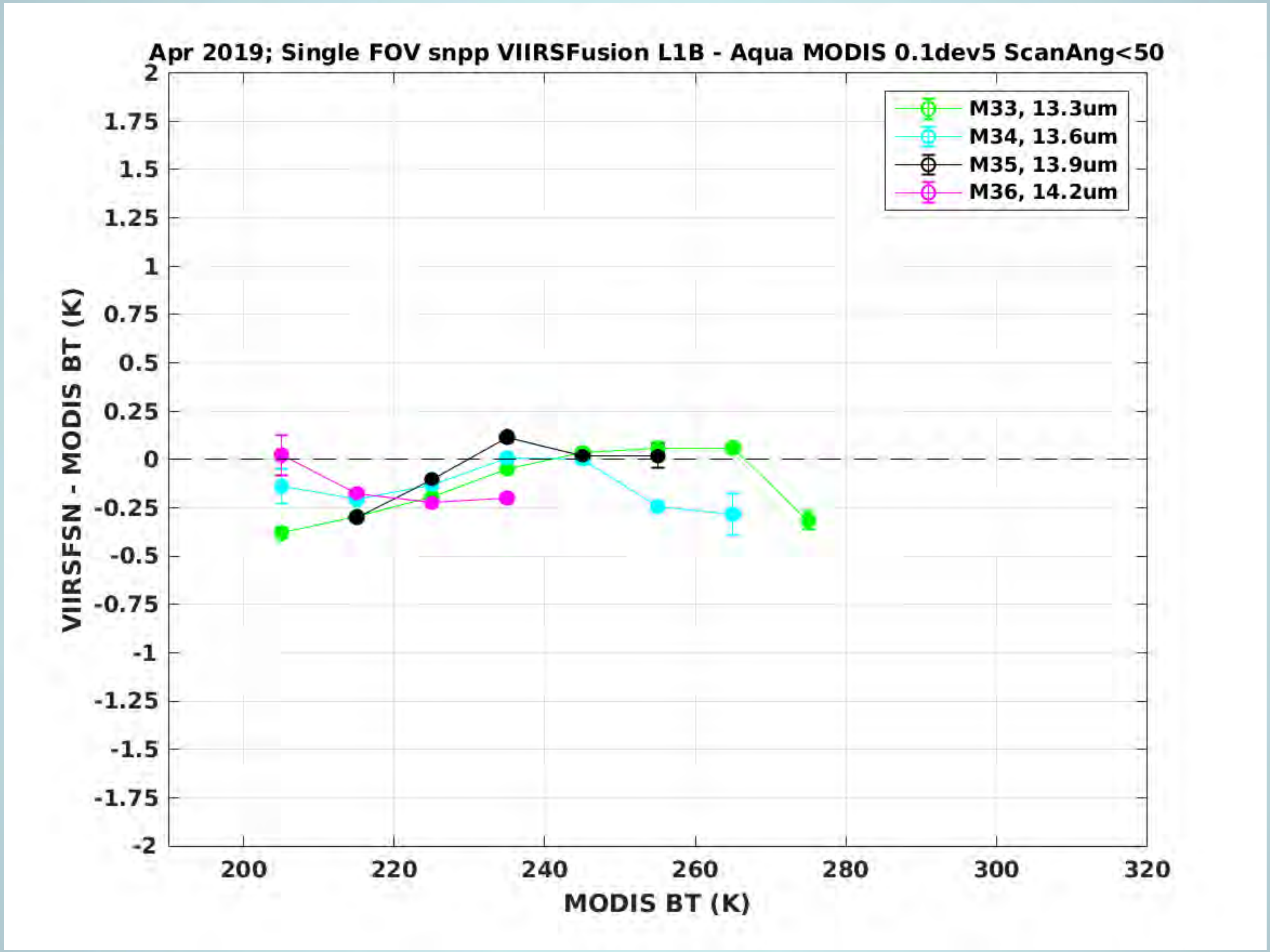


January 2019



S-NPP Monthly Results for April Between 2012 and 2019

April 2019



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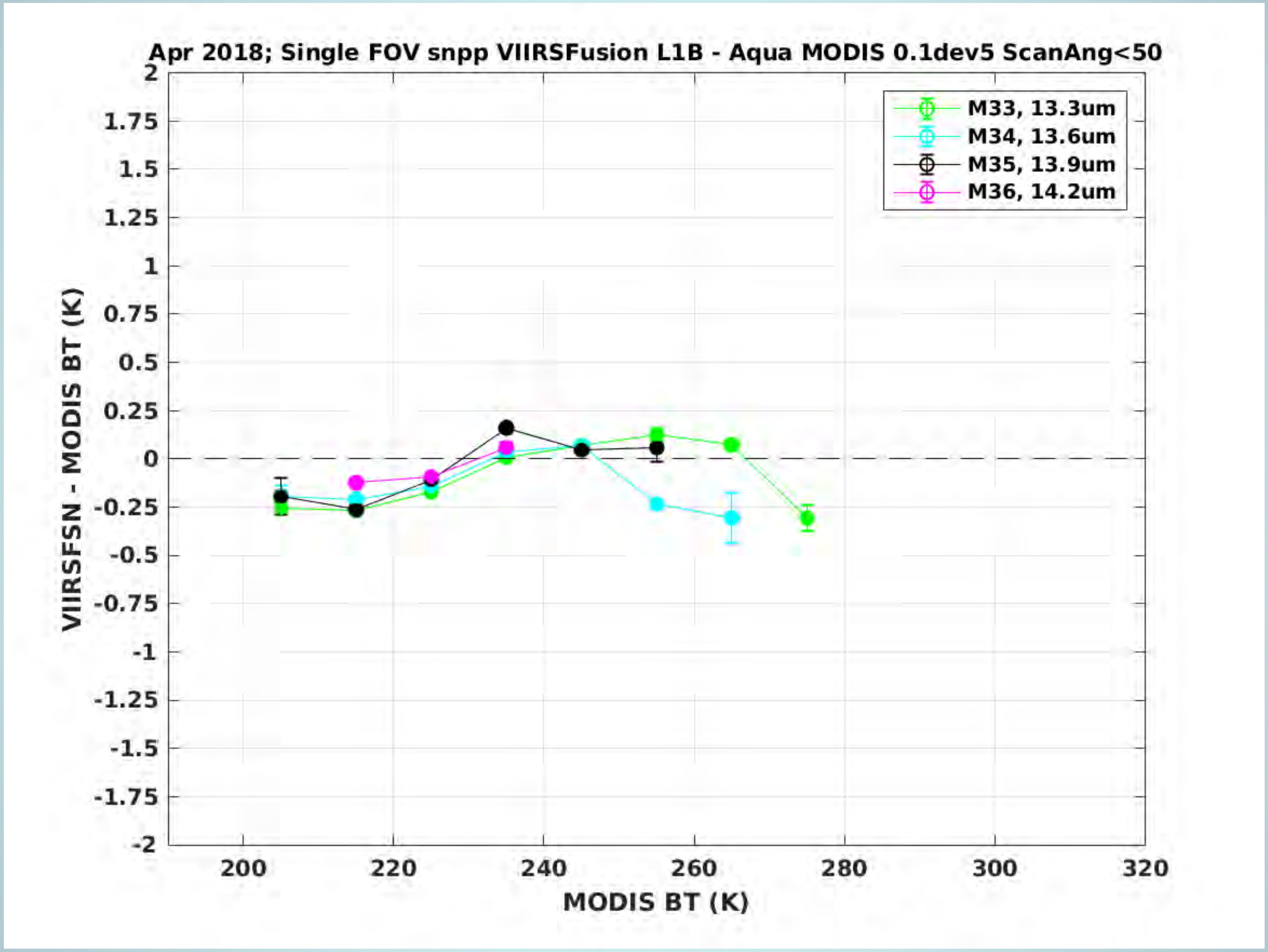
April 2018



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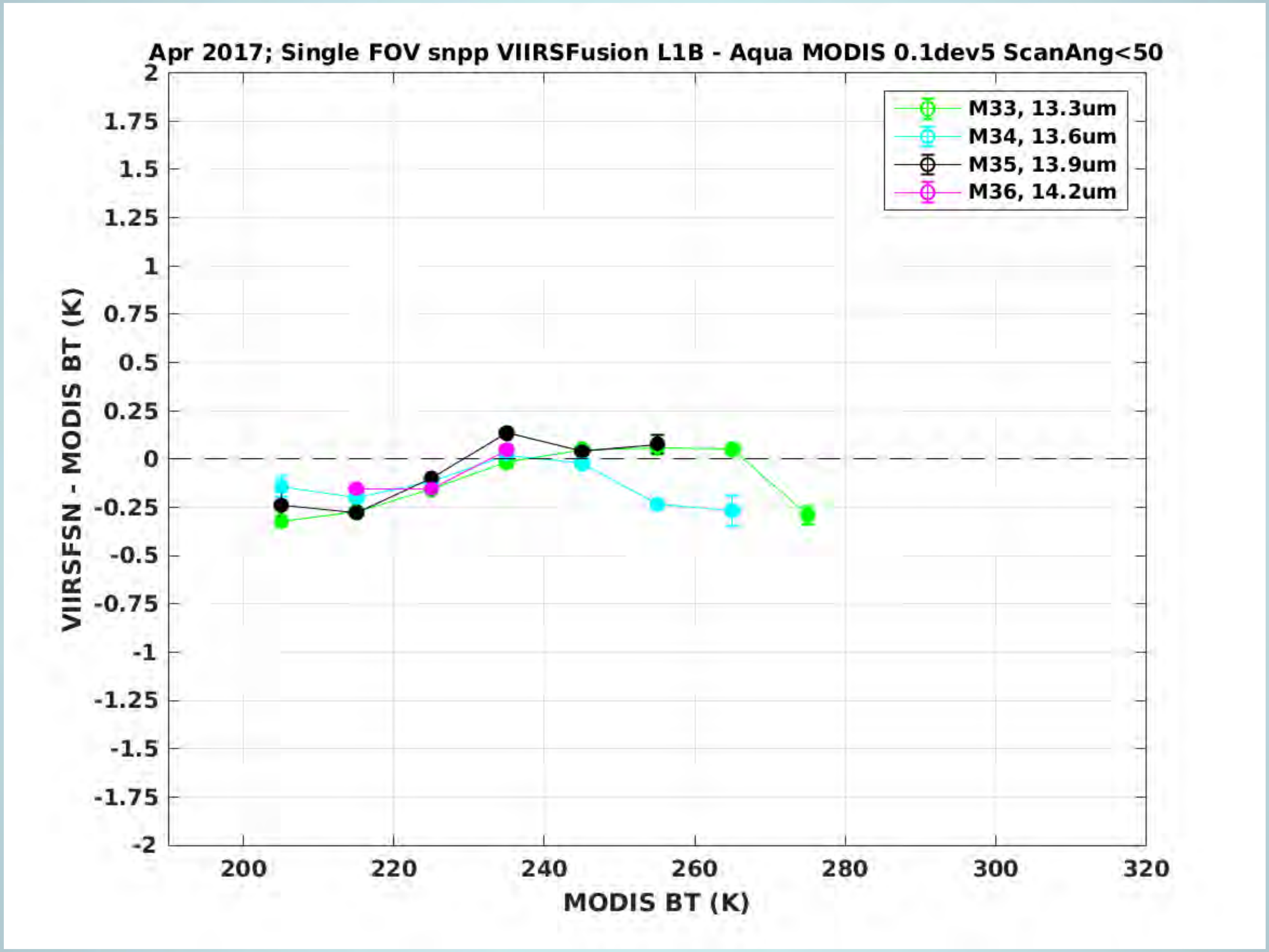
April 2017



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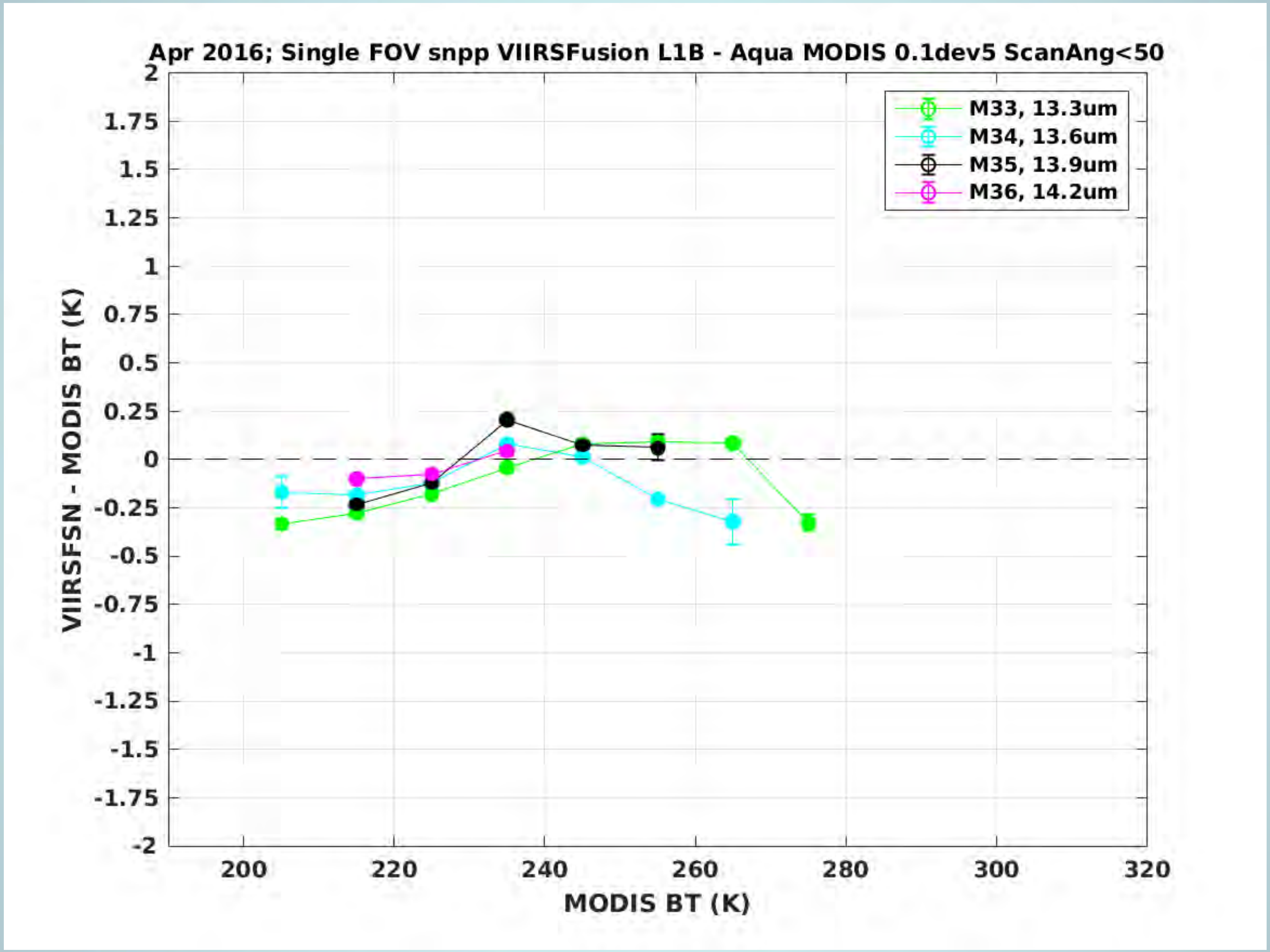
April 2016



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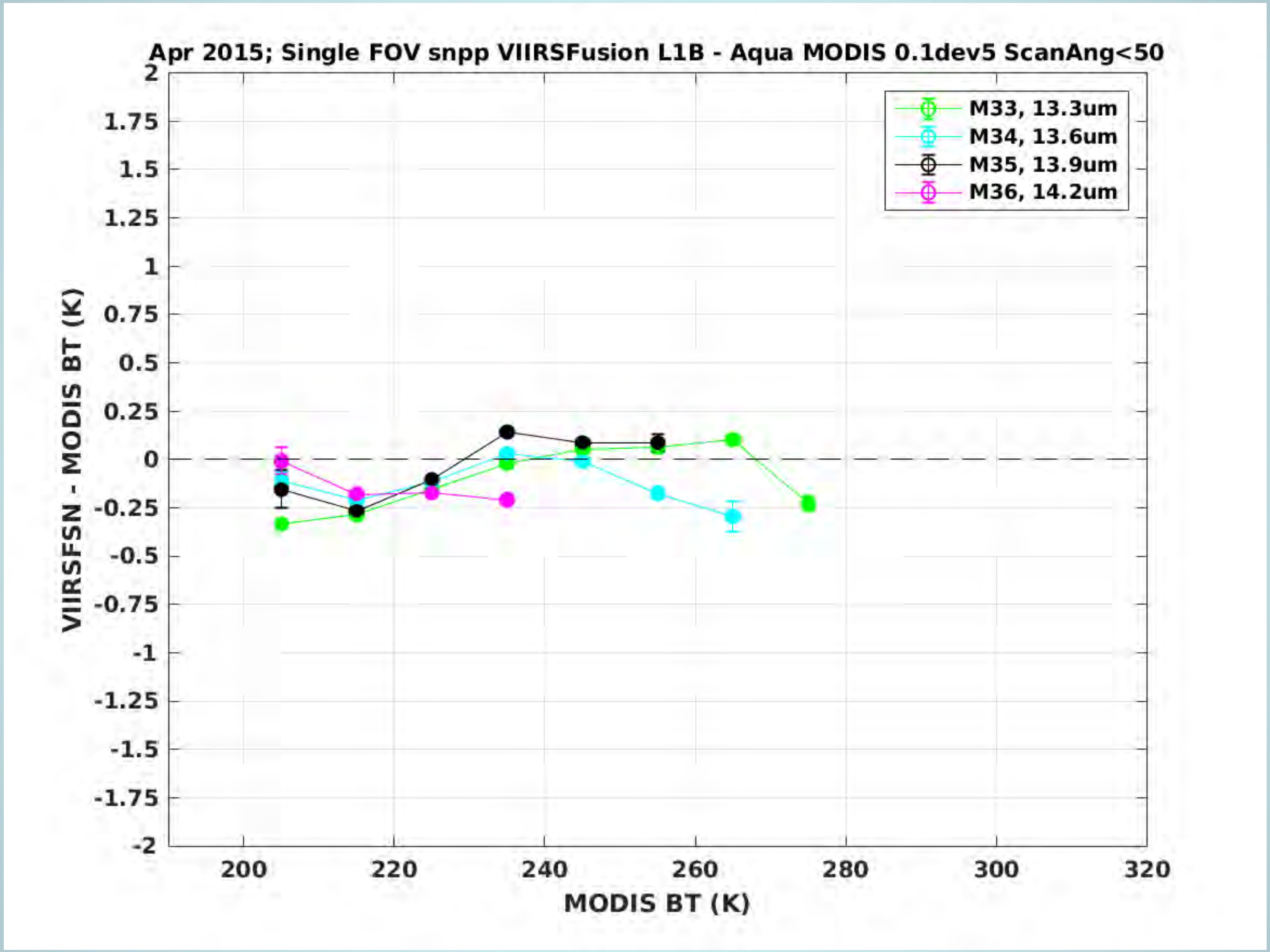
April 2015



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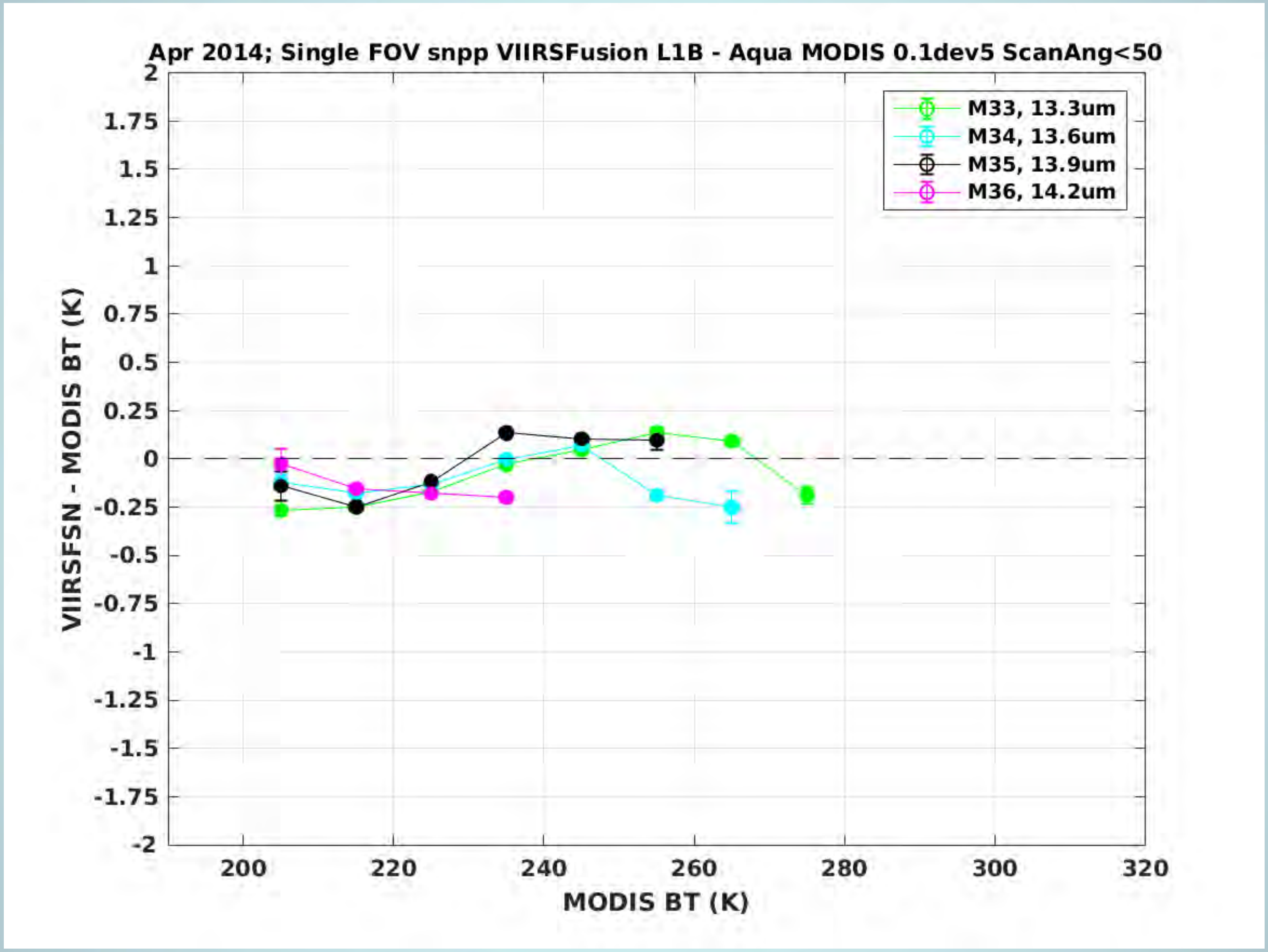
April 2014



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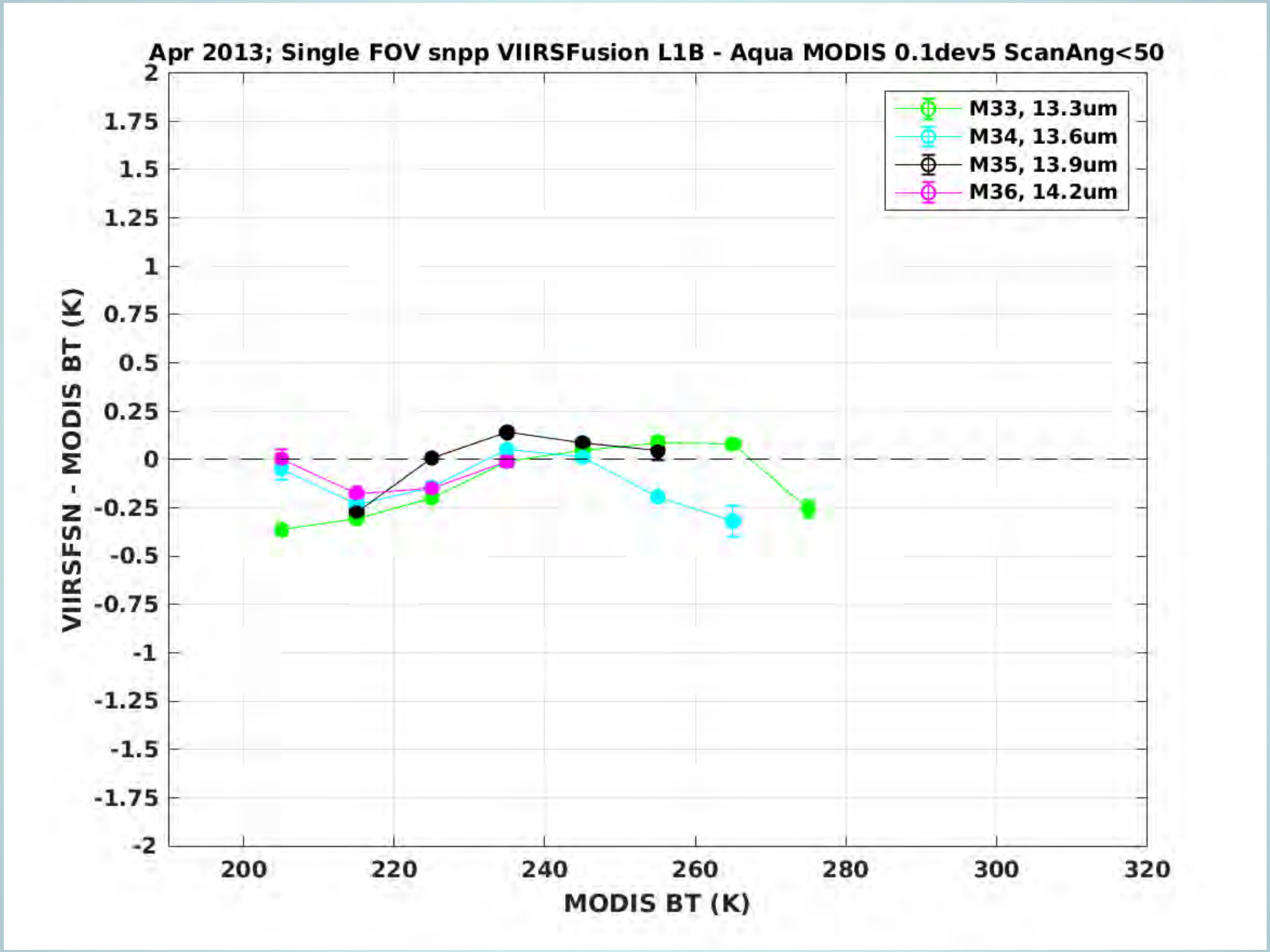

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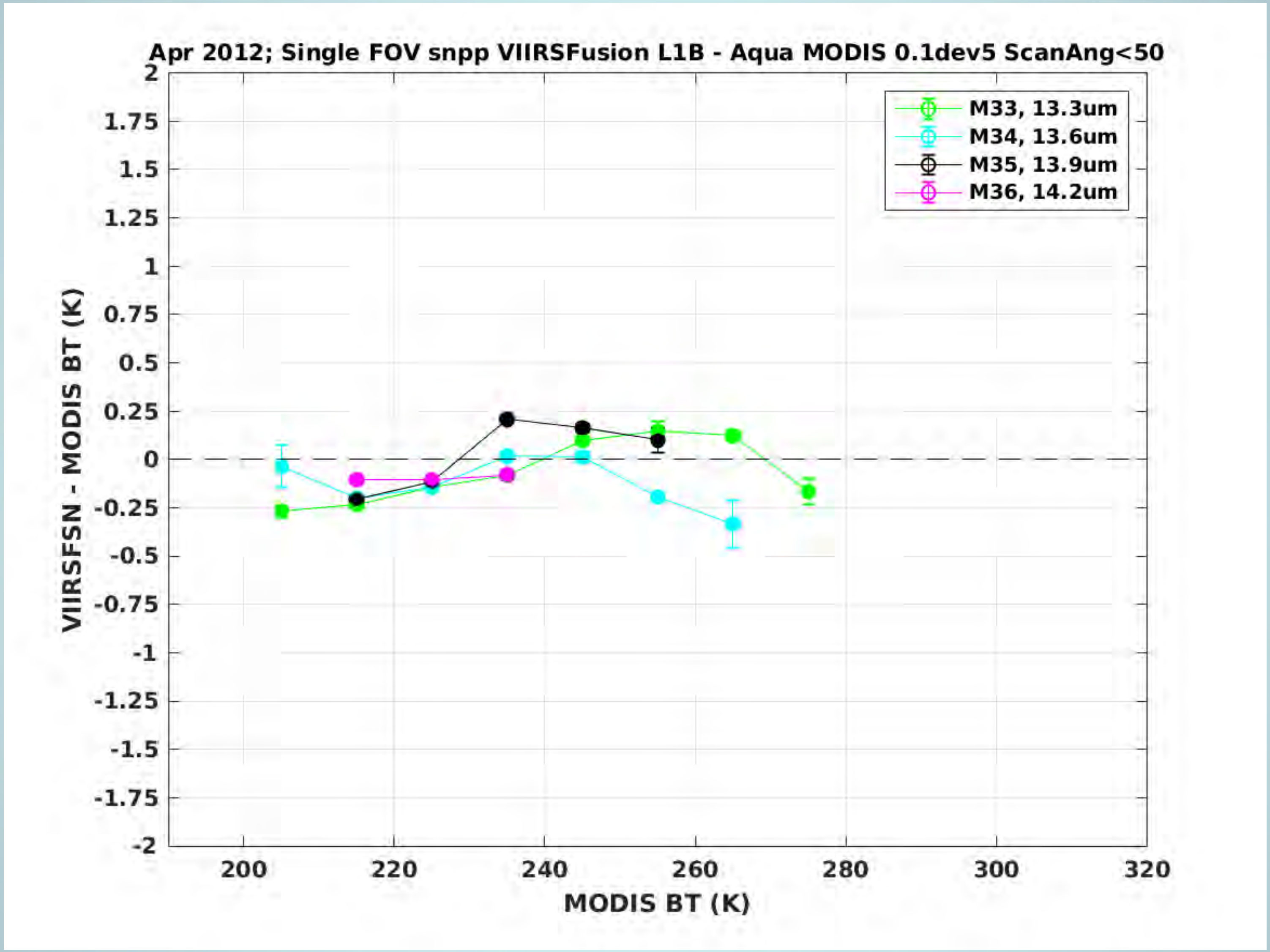
April 2012



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Impact on cloud property retrievals: Comparison with CALIPSO

Yue Li (SSEC/UW-Madison) and Andy Heidinger (NOAA)

Study underway using CLAVR-x/ACHA (AWG Cloud Height Algorithm; AWG refers to the NOAA Algorithm Working Group)

ACHA adopts an optimal estimation approach

S-NPP analysis limited to one week of data in April 2018 and one week of data in October 2018

Collocations between VIIRS and CALIPSO assume time difference < 15 minutes and lat/lon difference < 4°

CALIOP cloud height adopted as the truth

Each CLAVR-x run produces different cloud mask, phase/type and cloud height products.

Cloud Mask Results

No fusion: 0.41, 0.65, 0.87, 1.61, 2.25, 3.7, 8.5, 11, 12 μm channels

With fusion: 0.41, 0.65, 0.87, 1.61, 2.25, 3.7, **6.7**, 8.5, 11, 12 μm channels

S-NPP cloud mask–CALIPSO comparisons

	Sample Size		Correct Detection	Missed Cloud	False Detection
Global	5,873,247	With fusion	83.3	12.5	4.2
		No fusion	82.5	12.8	4.7
60˚N to 60˚S	4,207,459	With fusion	85.8	10.7	3.5
		No fusion	85.6	10.8	3.6
Arctic	836,0389	With fusion	76.9	15.4	7.6
		No fusion	74.7	16.8	8.4
Antarctic	829,750	With fusion	77.2	18.5	4.3
		No fusion	74.7	19.1	6.2

Correct detection: both VIIRS and CALIOP indicate cloudy
Missed cloud: VIIRS reports clear and CALIOP indicates cloudy
False detection: VIIRS reports cloud and CALIOP indicates clear

Cloud Phase Results

No fusion: 1.6, 3.7, 8.5, 11, 12 μm channels

With fusion: 1.6, 3.7, **6.7**, 8.5, 11, 12, **13.3** μm channels

Cloud Phase Results

			CALIPSO/CALIOP		Percentage Agreement
			Ice	Liquid Water	
Suomi-NPP	With fusion	Ice	39.4	4.5	76.2
		Liquid Water	19.3	36.8	
	No fusion	Ice	36.0	3.6	74.2
		Liquid Water	22.2	38.2	

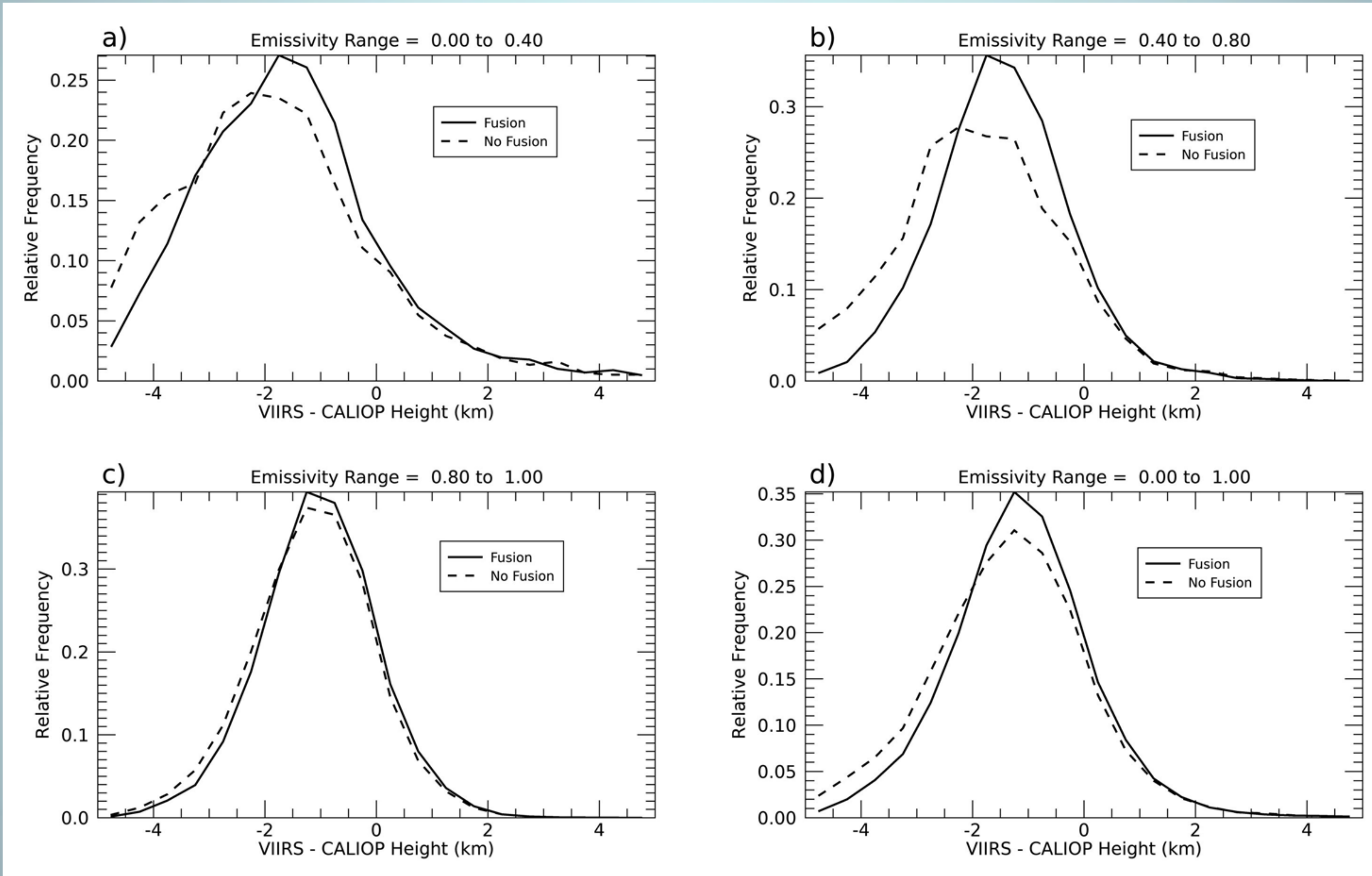
Ice Cloud Height Results

No fusion: 8.5, 11, 12 μm channels

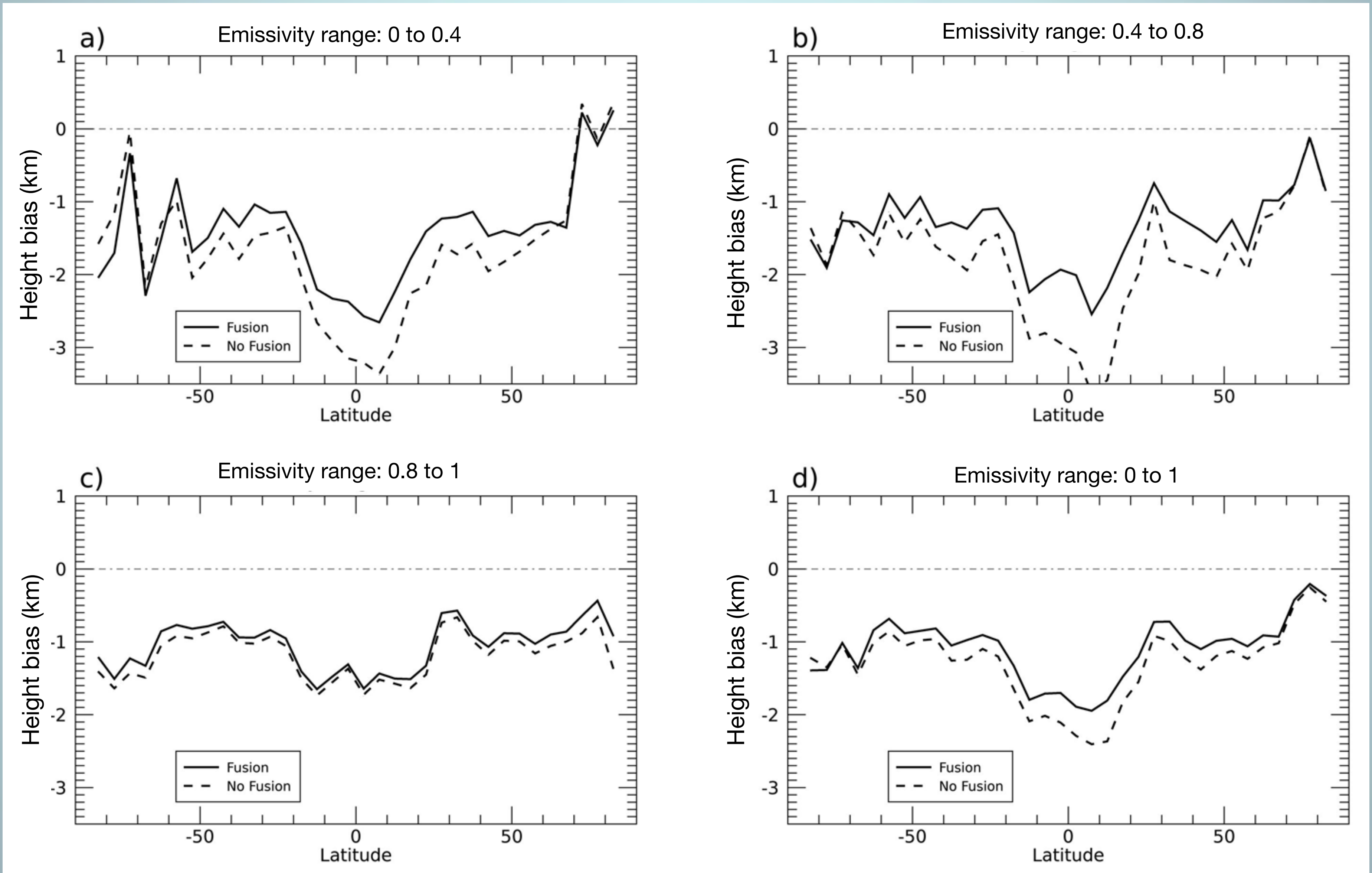
1st case with fusion: 8.5, 11, 12, **13.3** μm channels

2nd case with fusion: **6.7**, 8.5, 11, 12, **13.3** μm channels

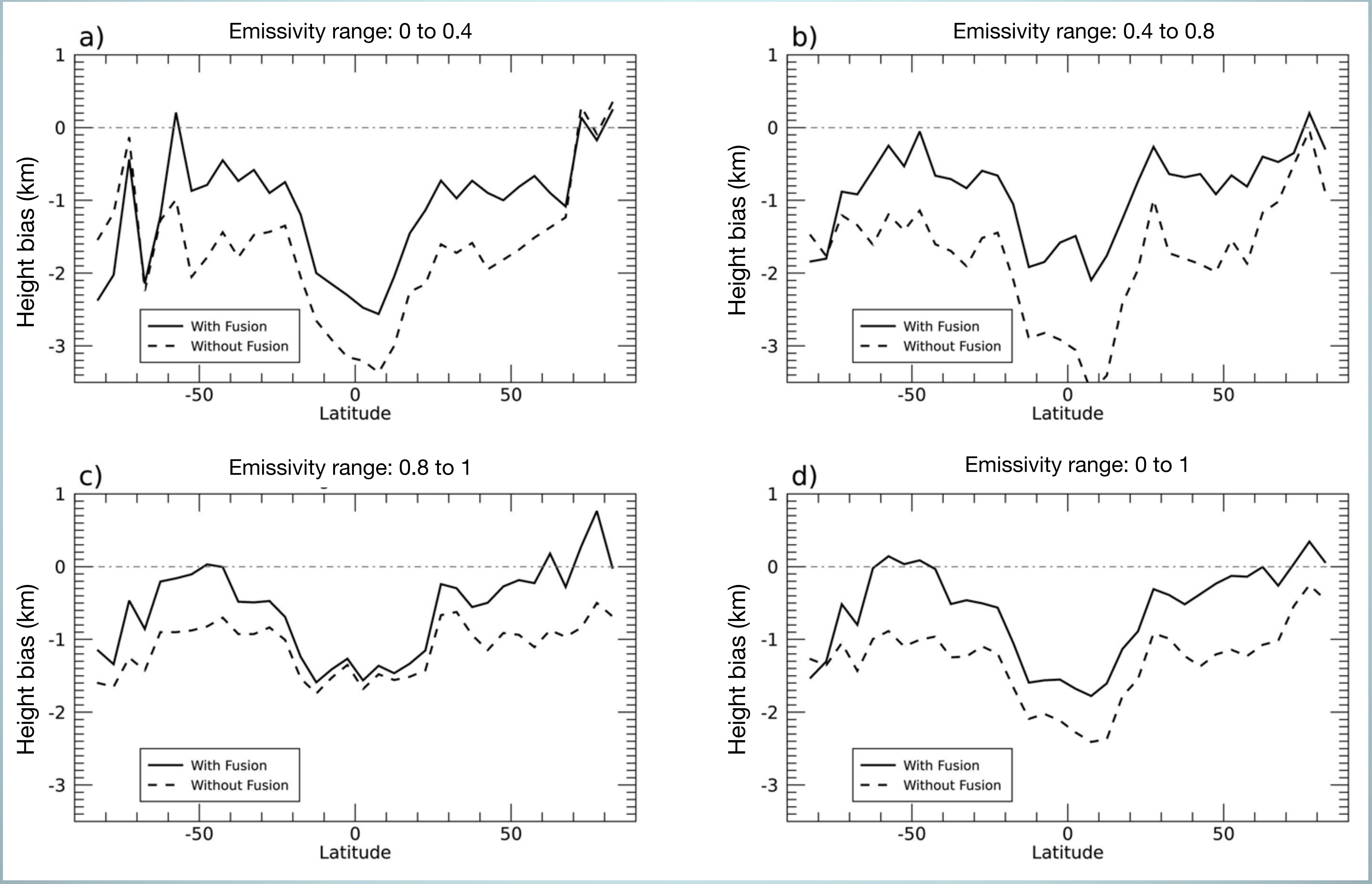
Suomi-NPP ACHA – CALIPSO comparisons for ice clouds
1st case: 8.5, 11, 12, **13.3** μm



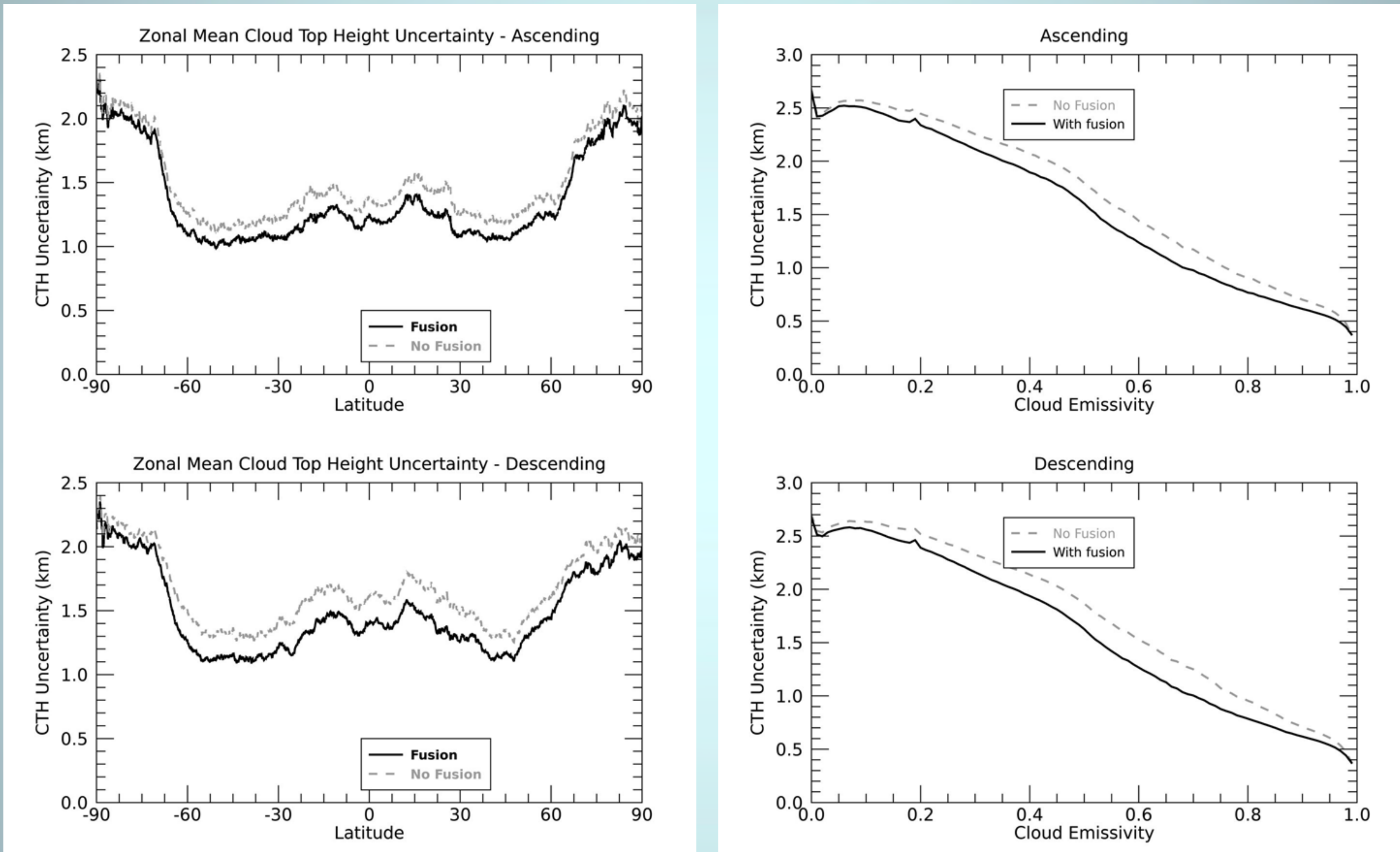
Zonal averages of S-NPP CTH differences (VIIRS-CALIOP) for ice clouds: 1st case: 8.5, 11, 12, **13.3** μm channels



2^{nd} case with fusion: **6.7**, 8.5, 11, 12, **13.3** μm channels



Ice Cloud Height Uncertainties Decrease



1st case: 8.5, 11, 12, **13.3** μm channels

Summary

The full records of the fusion product S-NPP and NOAA-20 are now available at the NASA LAADS DAAC:
https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/science-domain/viirs-cris-fusion/

The relevant Aqua MODIS-like IR radiance channels (MODIS channels 23-25, 27, 28, 30–36) are provided in a VIIRS Level 2 granule (NetCDF4).

Also provide brightness temperature differences (VIIRS – VIIRS fusion) for M-bands 15 and 16 (split window); useful for uncertainty estimates

The VIIRS L2 granule is 6 minutes; very similar format to Level-1B

We would appreciate gaining community feedback on this product so that we can improve it!

Remote Sensing Special Issue

Title: Analysis of Decadal-Scale Continuous Data Products from Weather Satellite Platforms

Goals:

- clearly document, at a minimum, Terra/Aqua/S-NPP+ continuity products
- provide information for upcoming Senior Review
- summarize key findings, algorithms, uncertainties, etc.

Guest editors: Bryan Baum; Ping Yang; Hartwig Deneke

Relevant details:

- New papers accepted until April 30, 2020
- No page limit
- Papers will be published as soon as they complete the review process
- Review process moves very quickly; be prepared for this
- Cost is 1800 Swiss francs (about $1850 USD)

https://www.mdpi.com/journal/remotesensing/special_issues/weather_satellite