Recent AIRS/GEO Infrared Intercalibration Findings at UW-CIMSS

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University of Wisconsin-Madison

Cooperative Institute for Meteorological Satellite Studies (CIMSS)

3rd Meeting of GSICS Research Working Group (GRWG-III)

19-21 February 2008

NOAA Science Building

Camp Springs, MD

Winter in Madison,Wisconsin 2007/2008

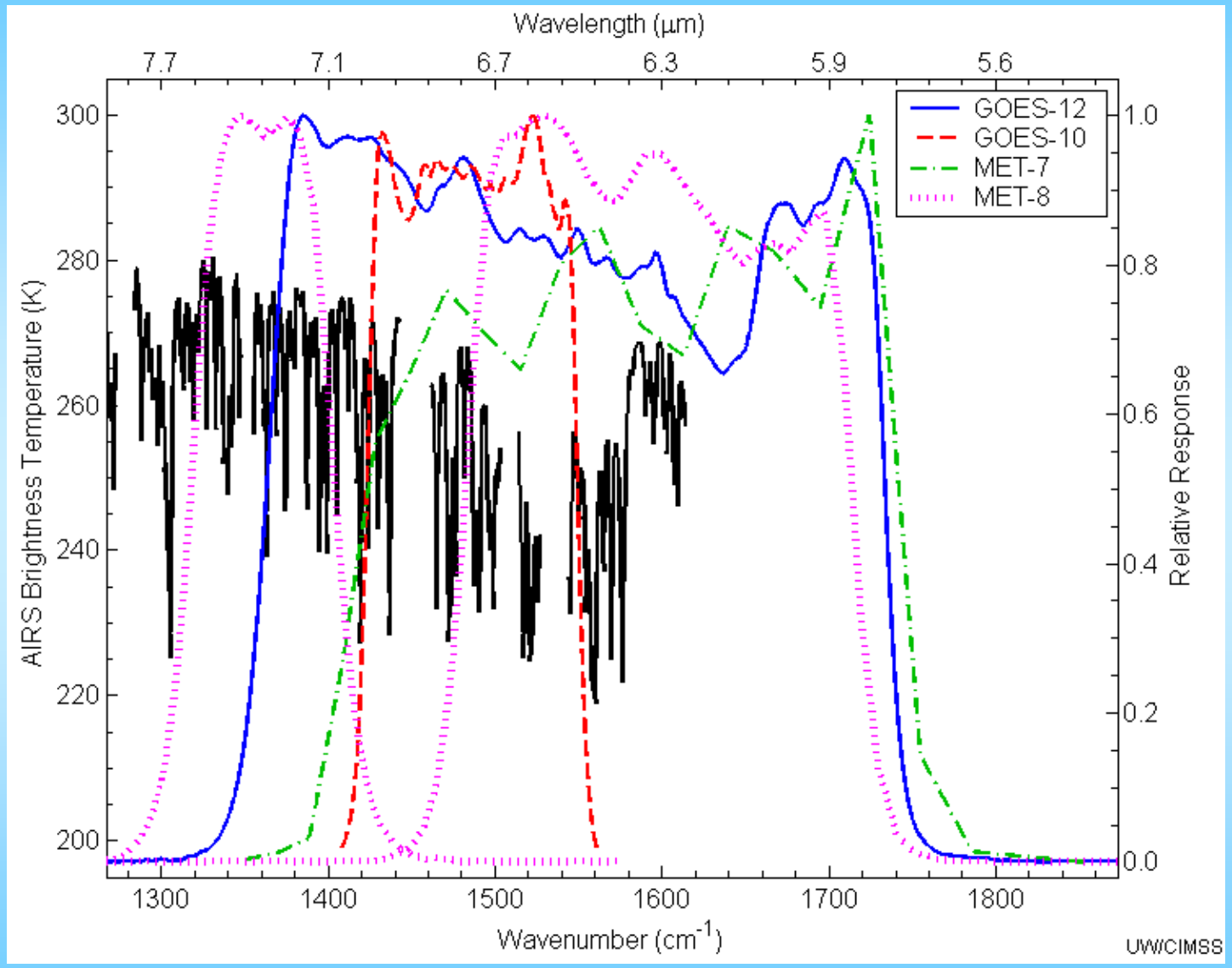
Normal winter snowfall: 36.2” (92cm) - This winter: 86.7” (220cm) - Former Record: 76.1” (193cm)

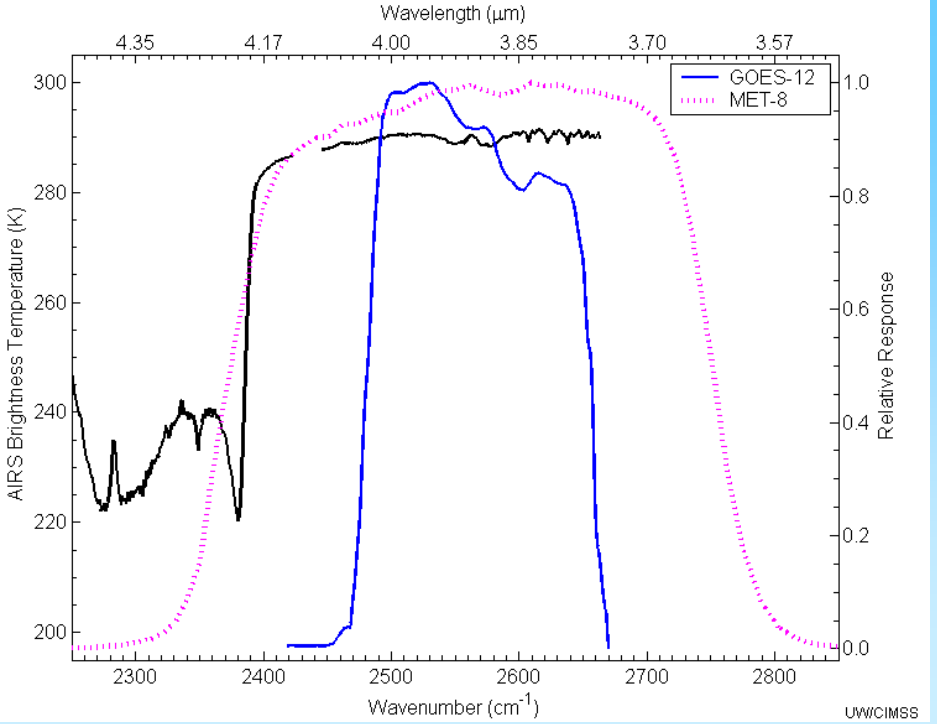
The disk drives (raid system) that have all of my intercalibration data died on 31 January!

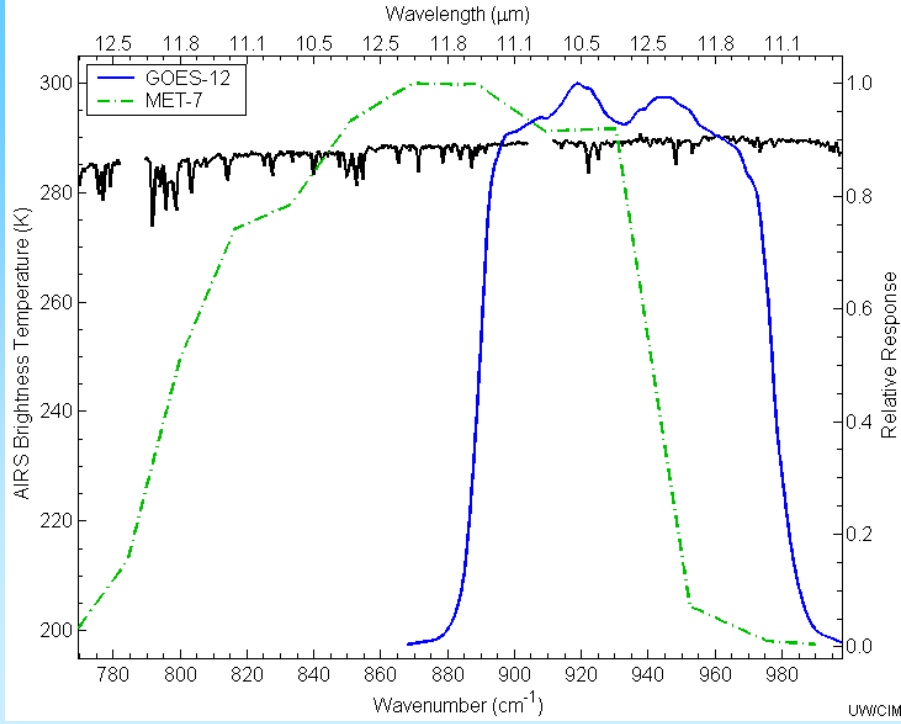
Overview

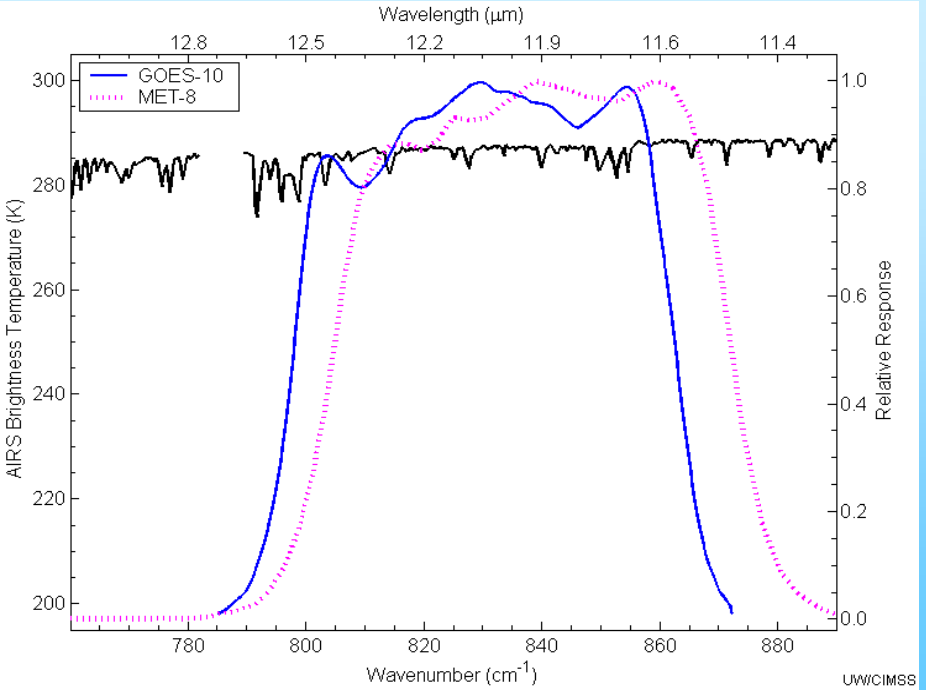
- Review of CIMSS AIRS/GEO infrared intercalibration procedures
- Results from January 2006 through October 2007 for GOES, METEOSAT, FY-2C, & MTSAT
- Time dependence
- GOES-12 Decontamination
- MET-8 Decontamination
- FY-2C “Stray Light”
- GOES-13 and GOES-O Post-launch Checkouts

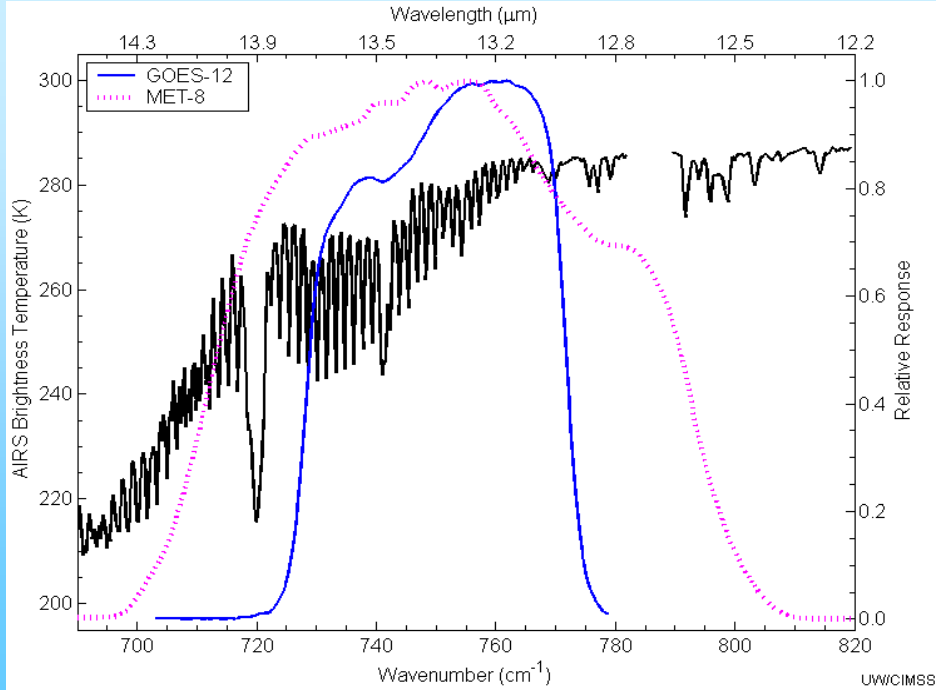
42 slides (12 hidden).


Wavelength (μm)
7.7
7.1
6.7
6.3
5.9
5.6
GOES-12
GOES-10
MET-7
MET-8
AIRS Brightness Temperature (K)
300
280
260
240
220
200
Relative Response
1.0
0.8
0.6
0.4
0.2
0.0
1300
1400
1500
1600
1700
1800
Wavenumber (cm-1)
UW/CIMSS


Wavelength (μm)
4.35
4.17
4.00
3.85
3.70
3.57
GOES-12
MET-8
AIRS Brightness Temperature (K)
Relative Response
Wavenumber (cm-1)
UW/CIMSS

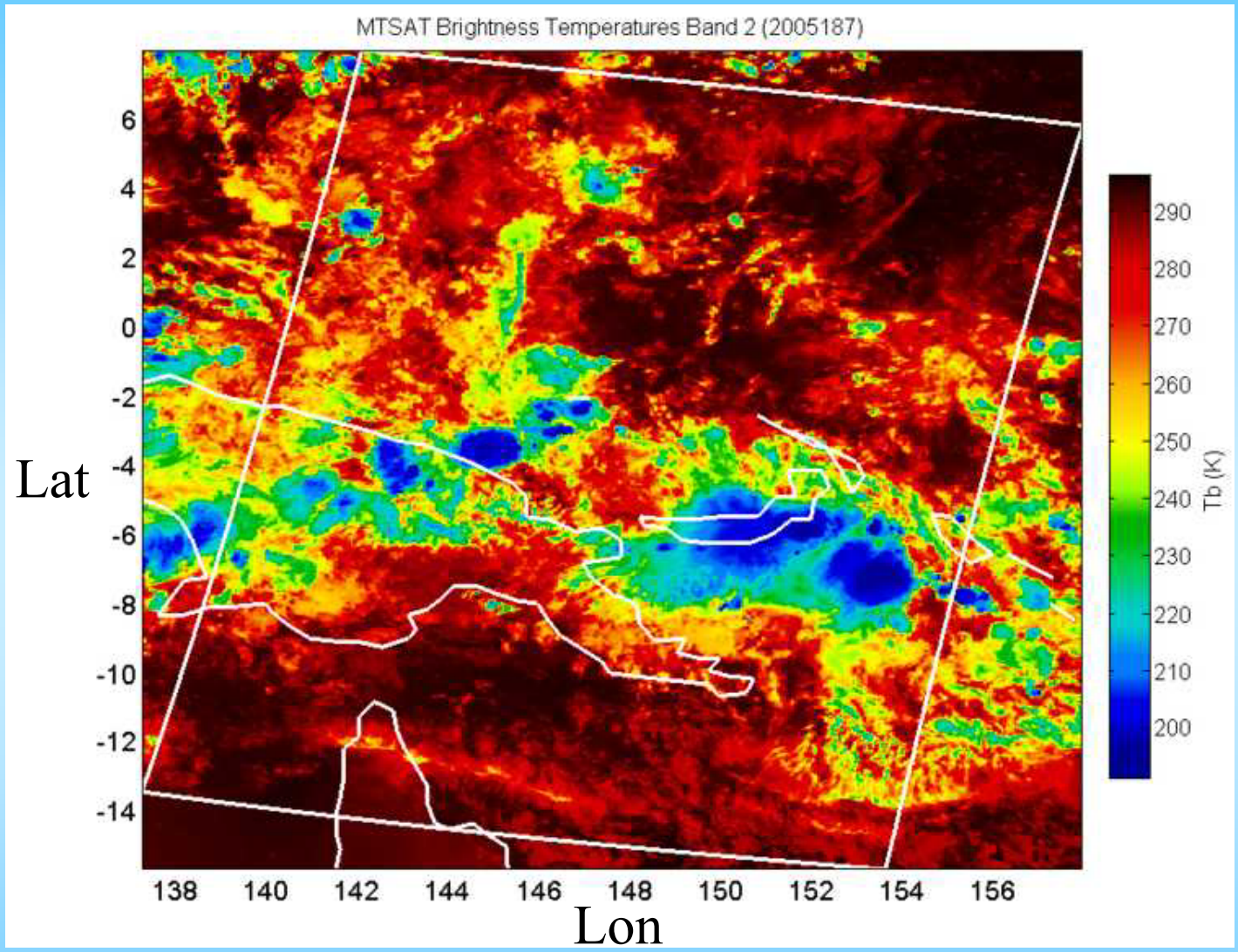

Wavelength (μm)
12.5
11.8
11.1
10.5
GOES-12
MET-7
AIRS Brightness Temperature (K)
Relative Response
Wavenumber (cm-1)
UW/CIM


Wavelength (μm)
12.8
12.5
12.2
11.9
11.6
11.4
GOES-10
MET-8
AIRS Brightness Temperature (K)
Relative Response
Wavenumber (cm-1)
UW/CIMSS

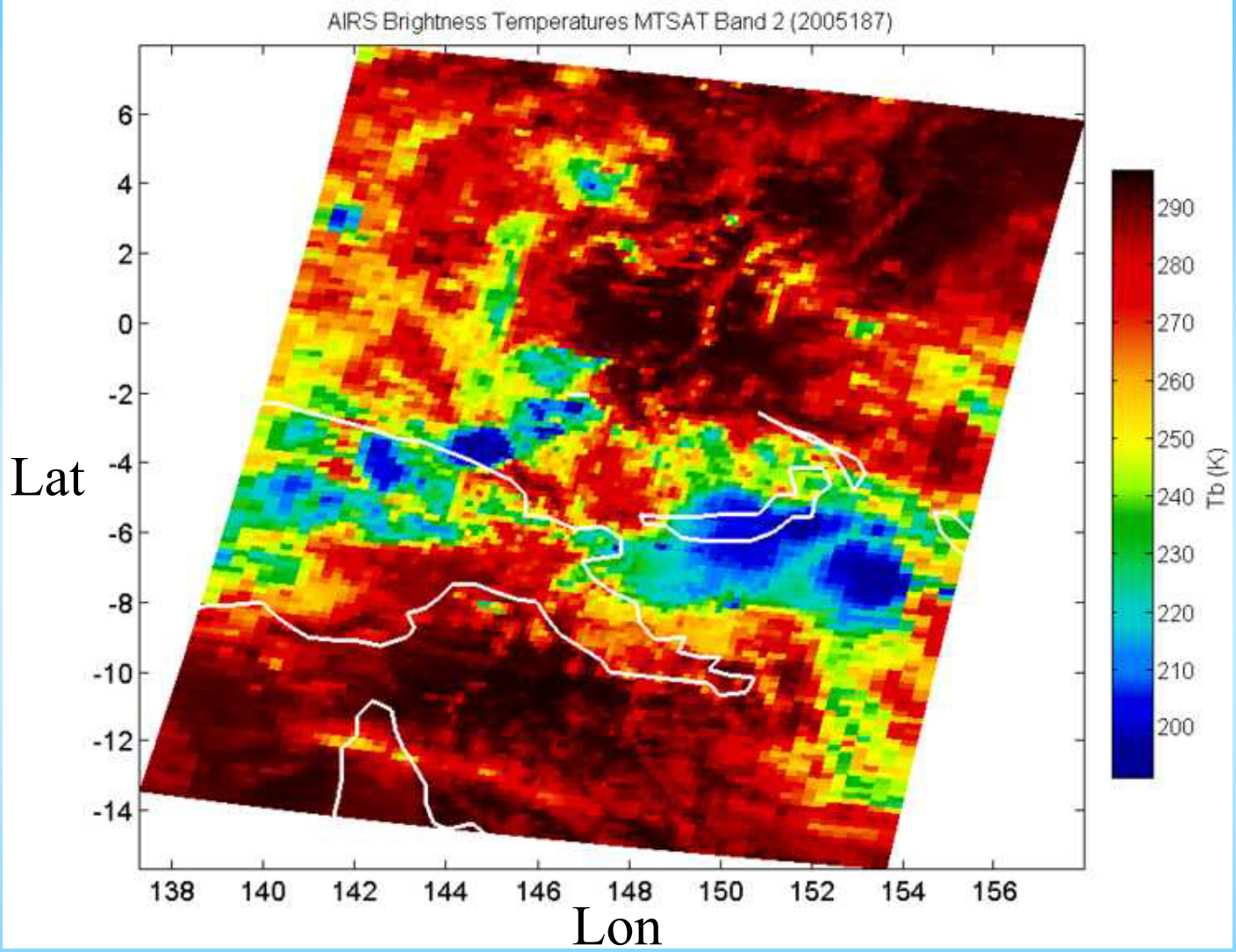

Wavelength (μm)
14.3
13.9
13.5
13.2
12.8
12.5
12.2
GOES-12
MET-8
AIRS Brightness Temperature (K)
Relative Response
Wavenumber (cm-1)
UW/CIMSS

CIMSS Methods

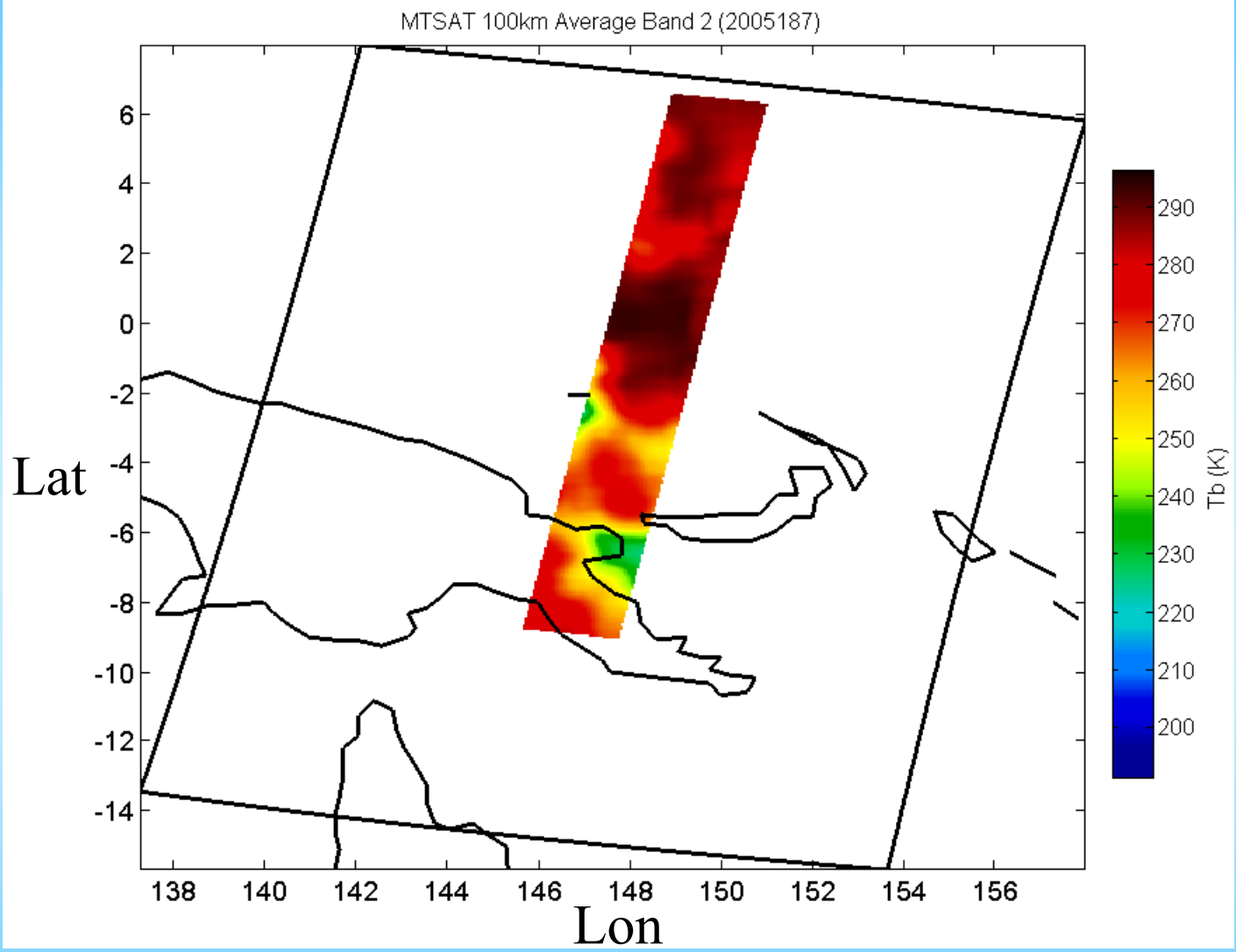
- Have not changed significantly in the last year.
- GSNO (Geostationary Simultaneous Nadir Observations)
- Area average (not pixel to pixel) – mean radiances converted to brightness temperature and differenced (GEO-AIRS).
- GEO and AIRS data averaged to 100KM effective FOV size
- AIRS spectral gaps are filled with the US Standard Atmosphere adjusted to fit the gap endpoints.
- No filtering is done for scene spatial uniformity.



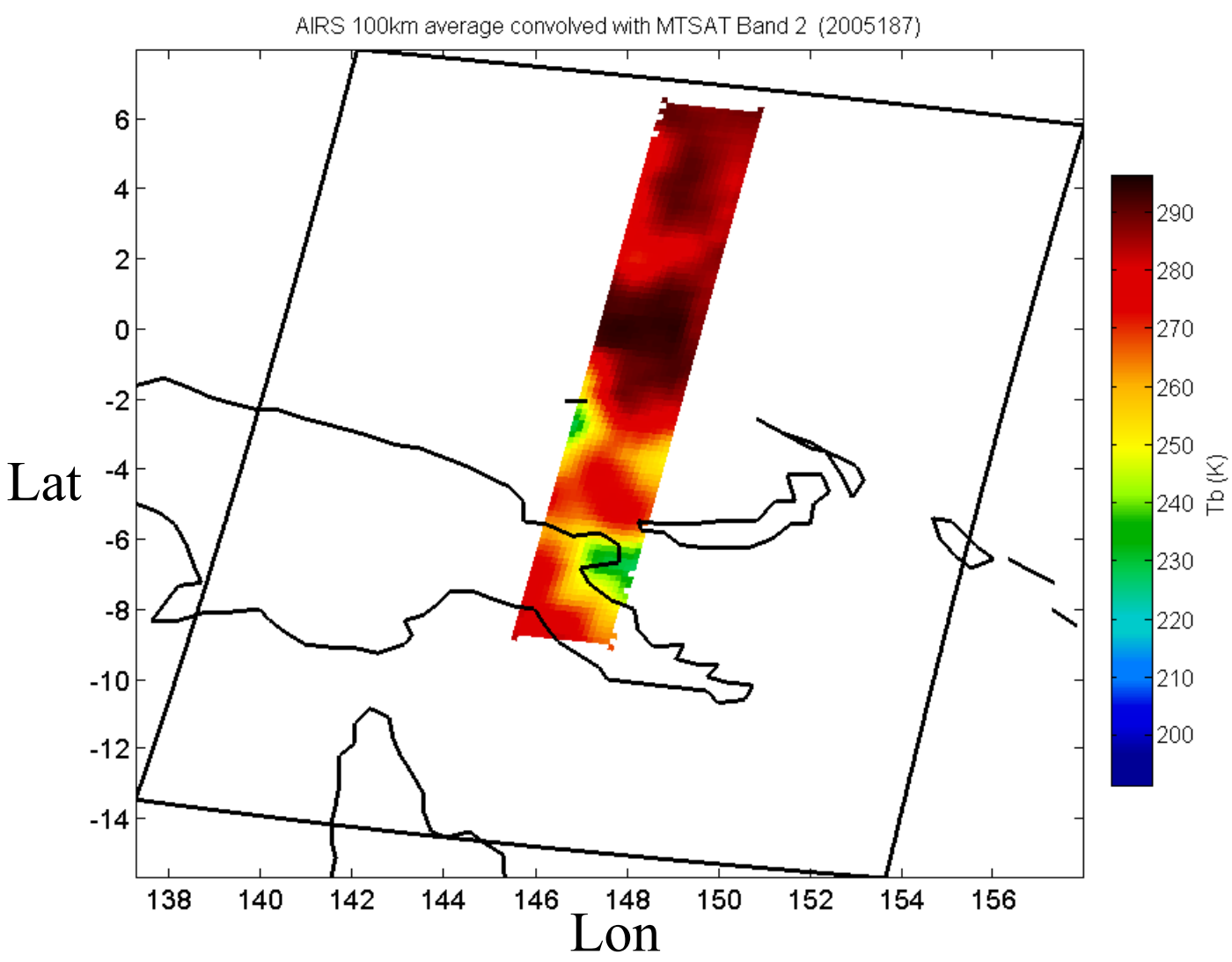
MTSAT 11μm 07 July 2005 at 15:33UTC



AIRS convolved with MTSAT 11μm 07 July 2005 at 15:36UTC

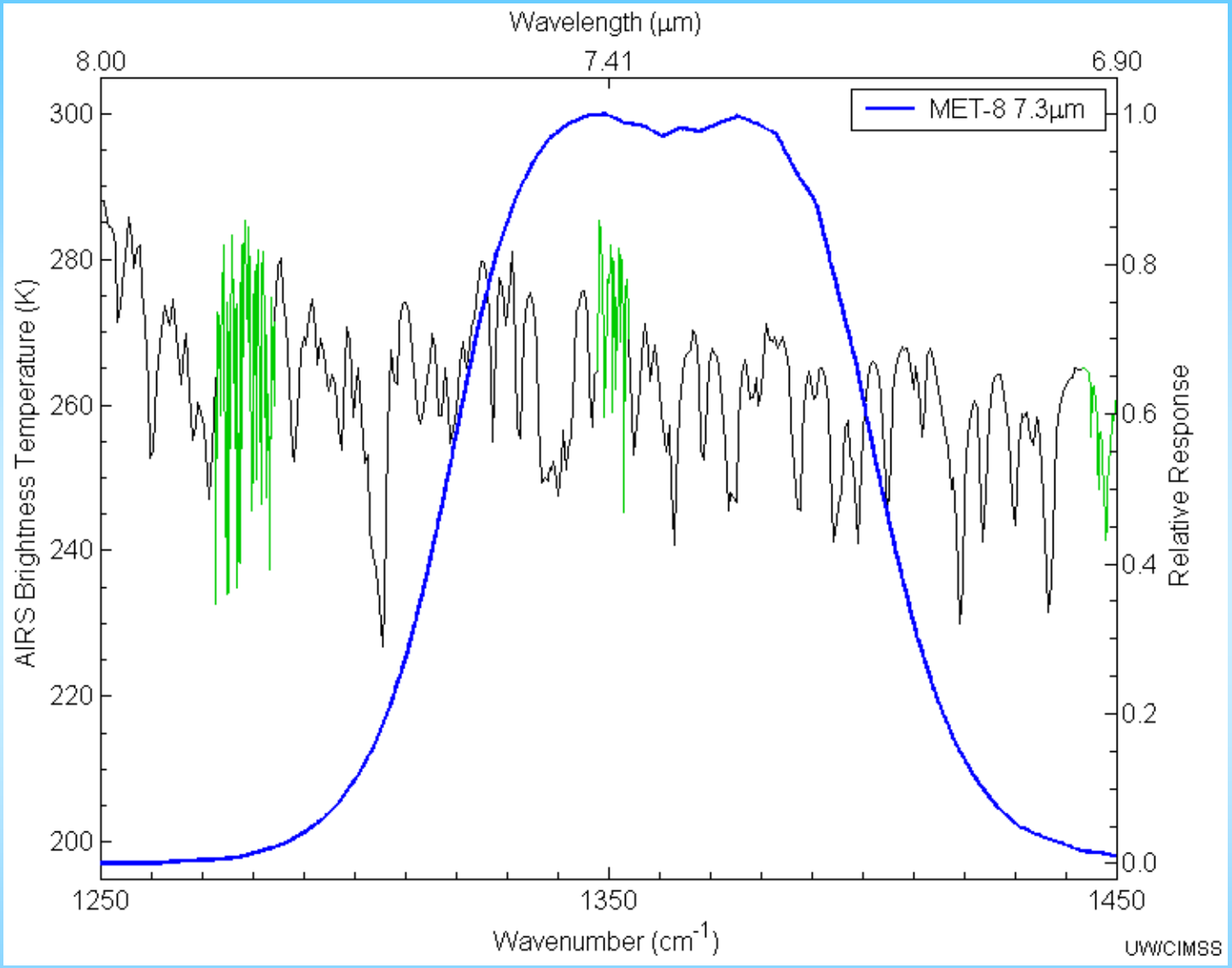


100km-smoothed MTSAT comparison area



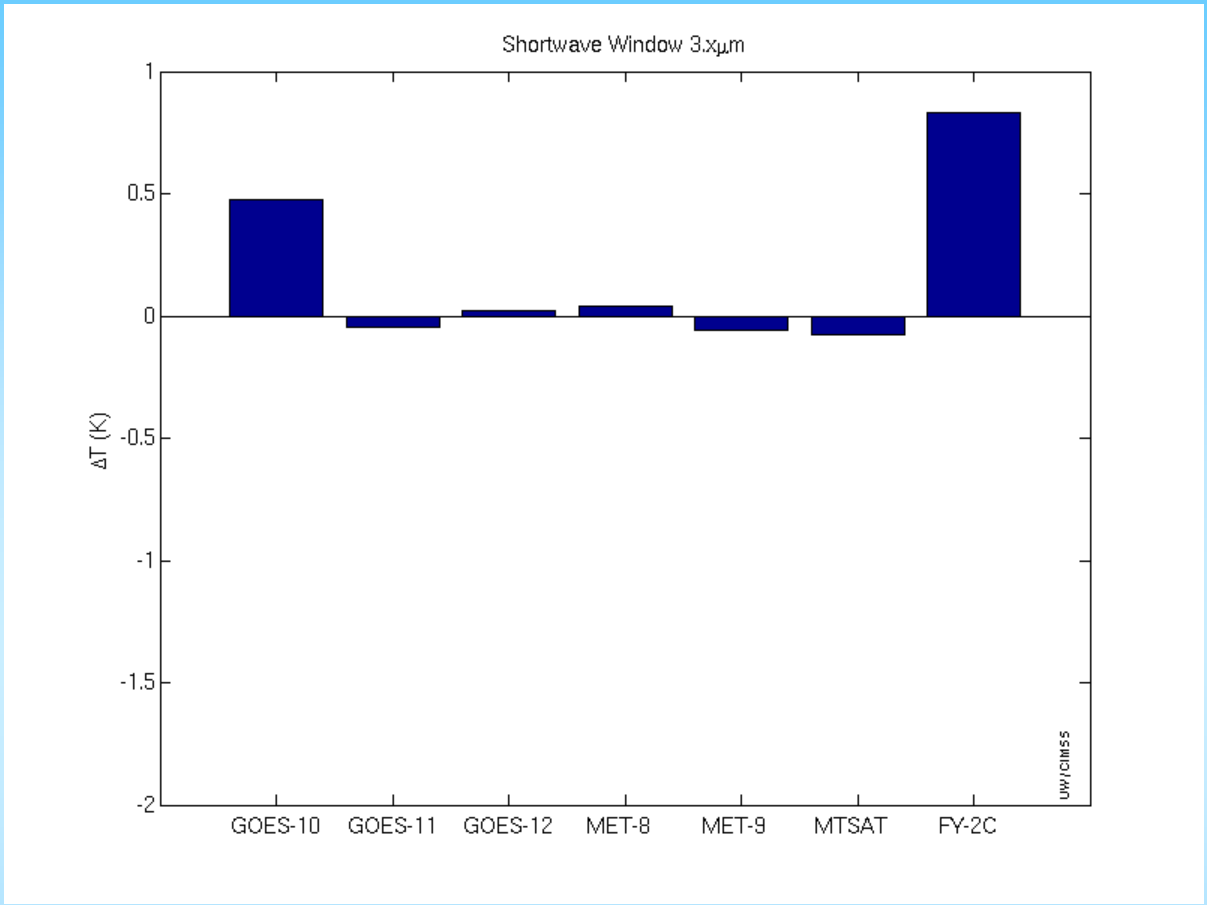
100km-smoothed AIRS convolved with MTSAT comparison area

(ΔTbb = -0.4 K)



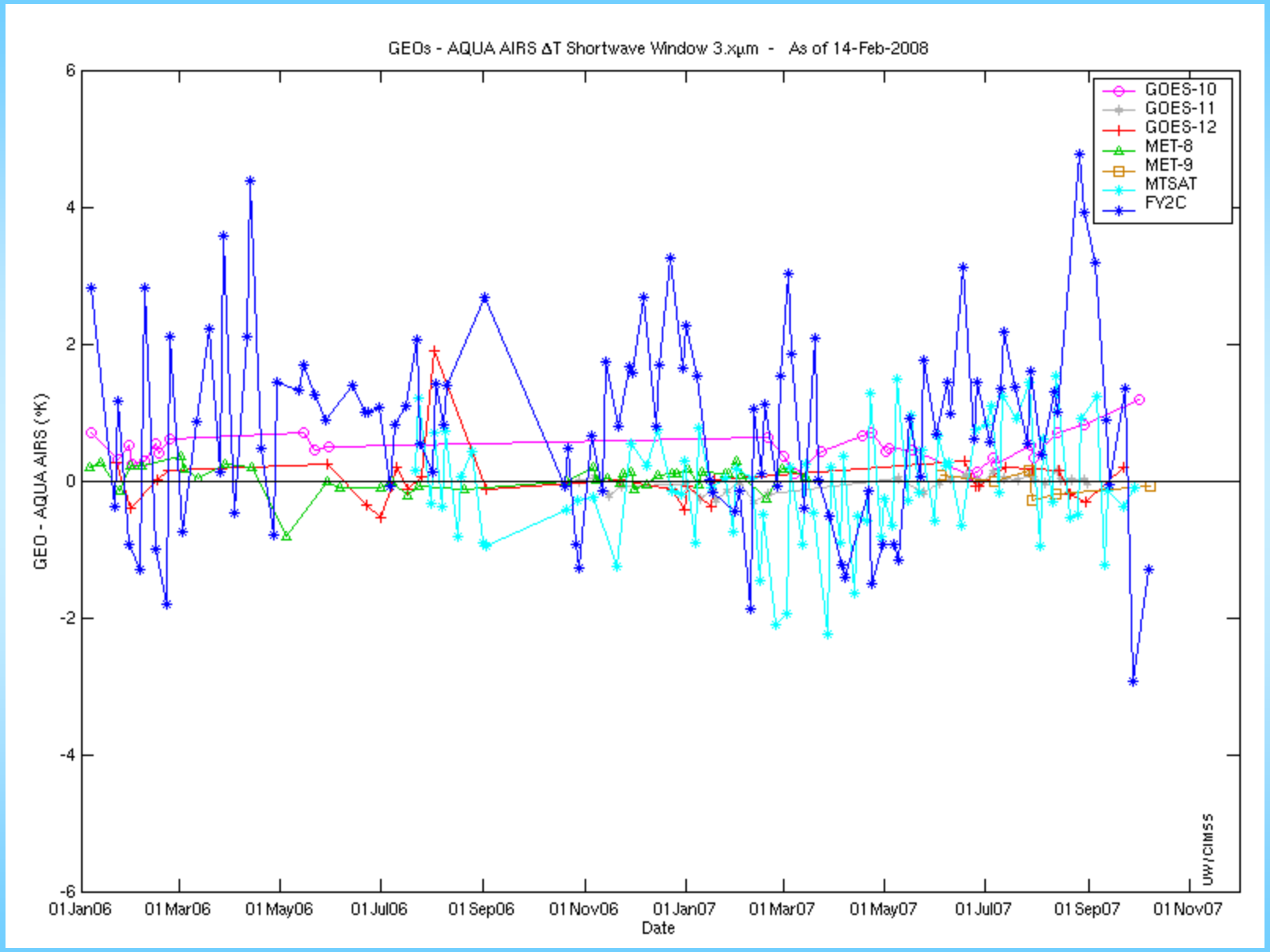
Meteosat-8 7.3µm Spectral Response (blue) with AIRS spectra (black). Gaps filled with adjusted US Standard Atmosphere spectra (green).

CIMSS Intercal Results Jan 2006 – Oct 2007

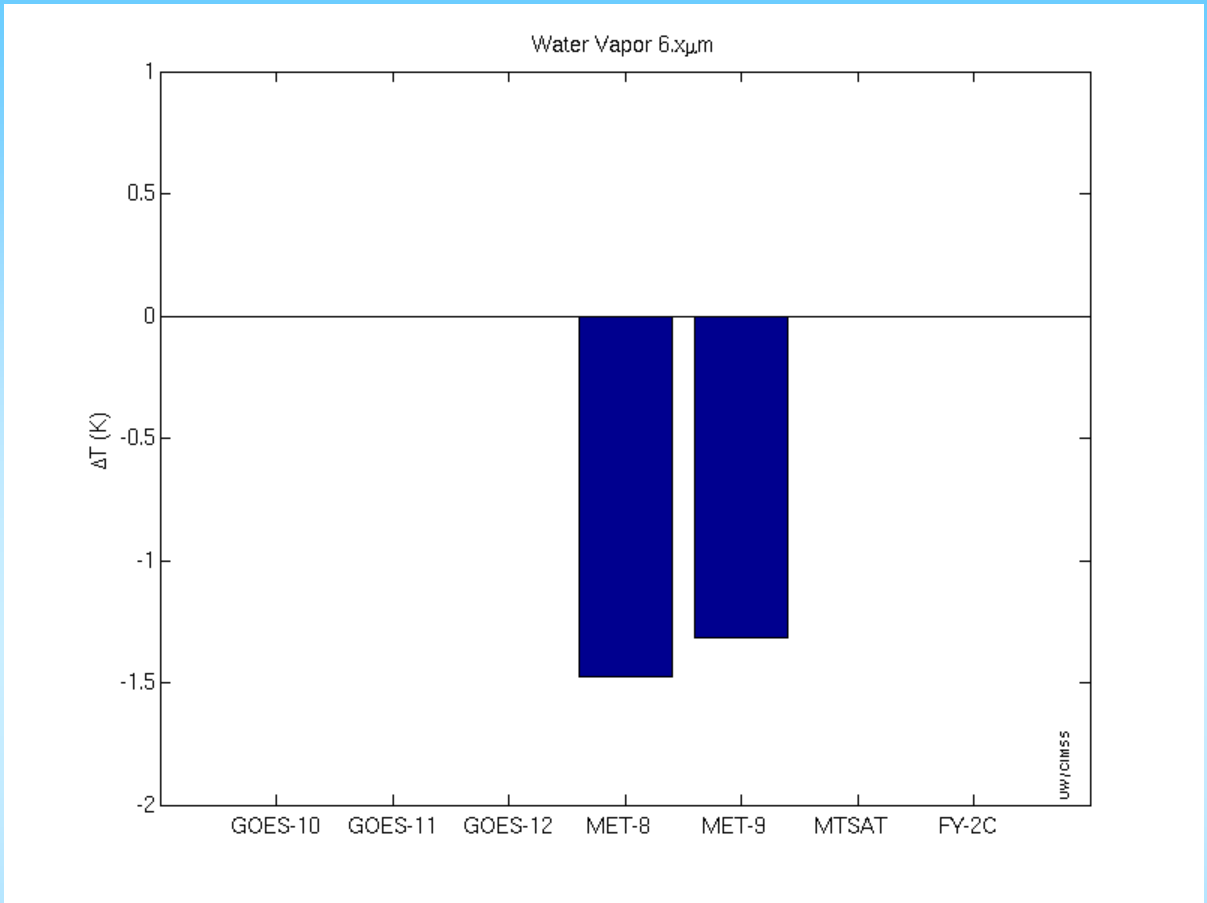


3.x um	G-10	G-11	G-12	M-8	M-9	MT1R	FY2C
Delta-T (K)	0.48	-0.05	0.02	0.04	-0.06	-0.08	0.83
STD (K)	0.24	0.12	0.43	0.2	0.16	0.85	1.41
N*	29	30	28	29	6	76	104

*Night Only

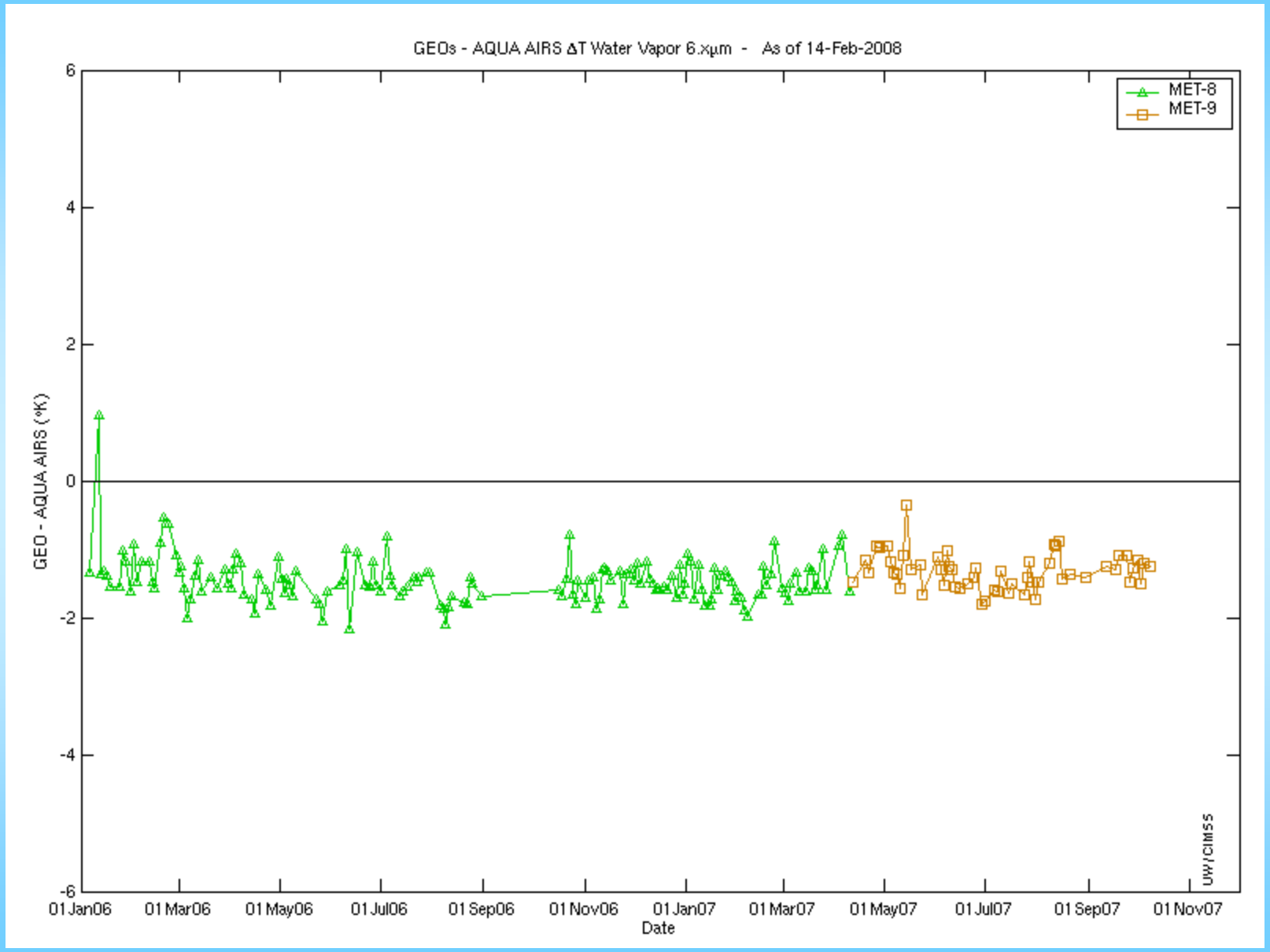

GEOs - AQUA AIRS ΔT Shortwave Window 3.xμm - As of 14-Feb-2008
GOES-10
GOES-11
GOES-12
MET-8
MET-9
MTSAT
FY2C
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

CIMSS Intercal Results Jan 2006 – Oct 2007

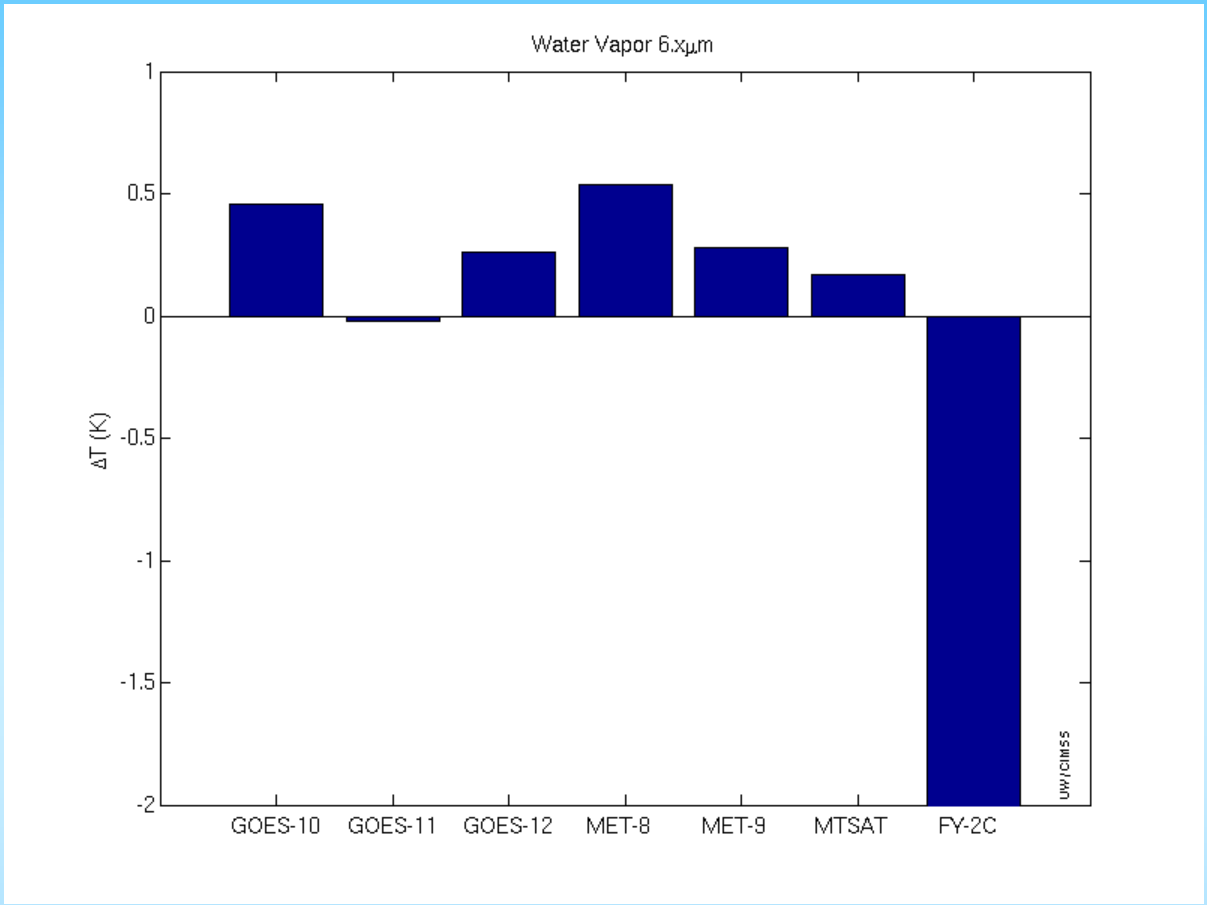


6.2um	M-8	M-9
Delta-T (K)	-1.48	-1.32
STD (K)	0.28	0.26
N	158	56

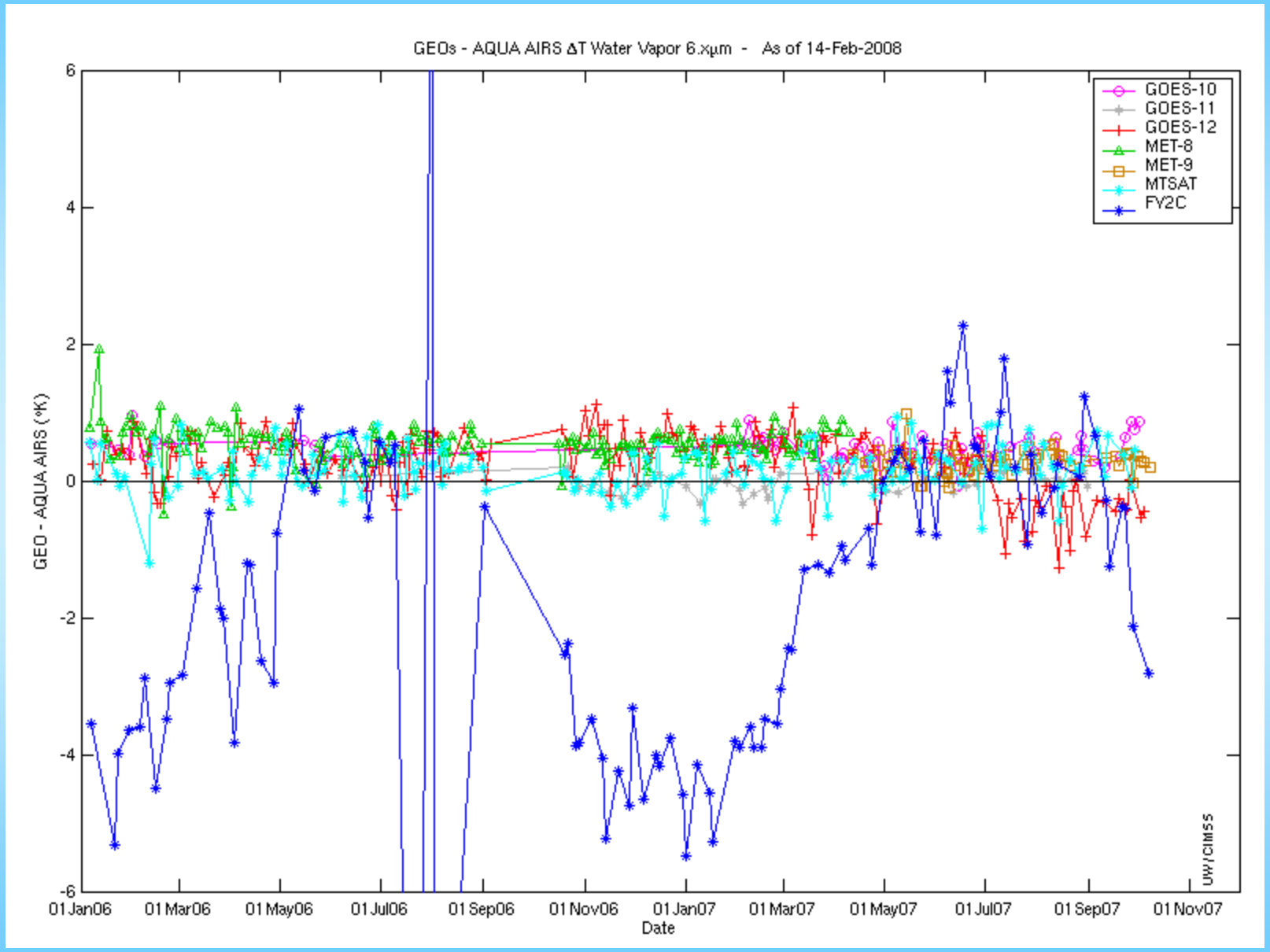
The gap-filling method is not adequate for this band!


GEOs - AQUA AIRS ΔT Water Vapor 6.xμm - As of 14-Feb-2008
MET-8
MET-9
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

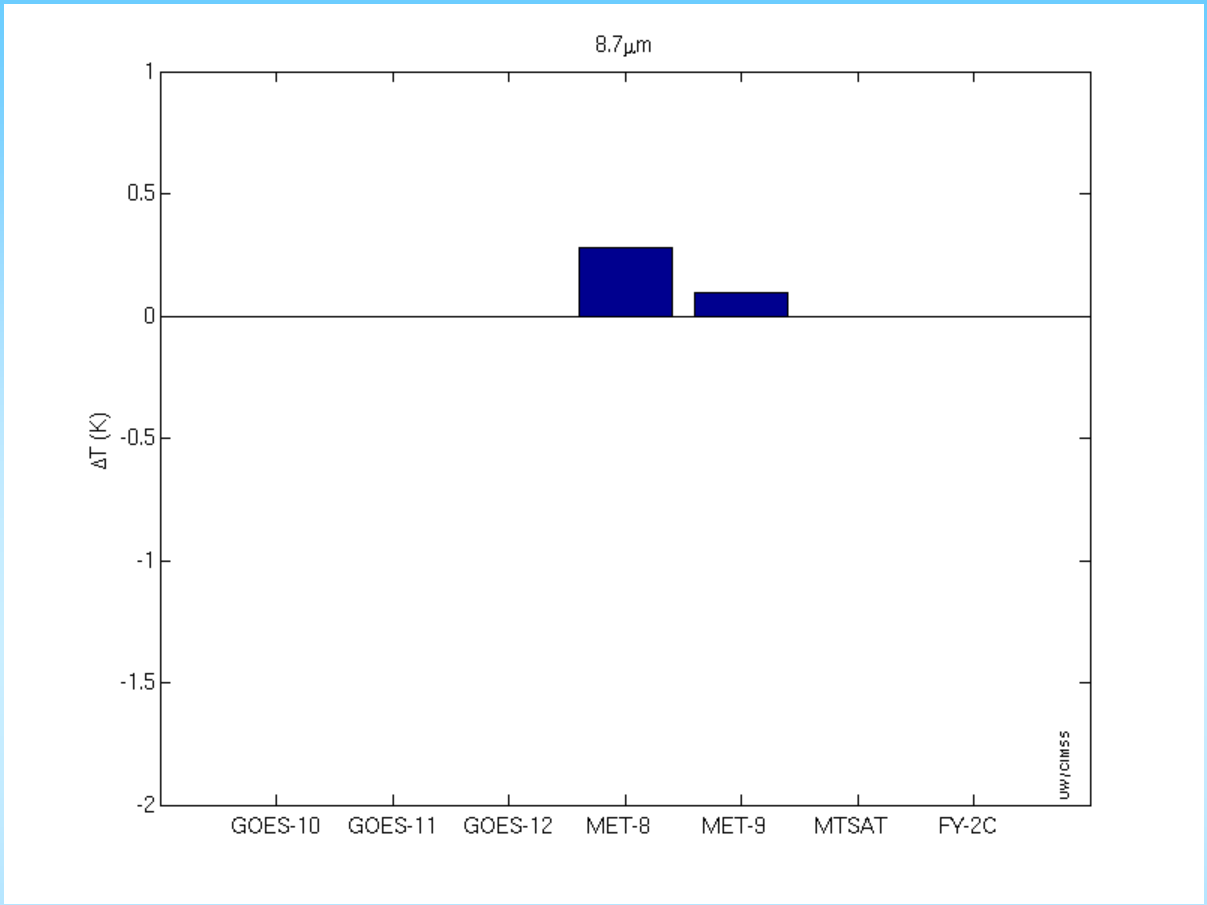
CIMSS Intercal Results Jan 2006 – Oct 2007



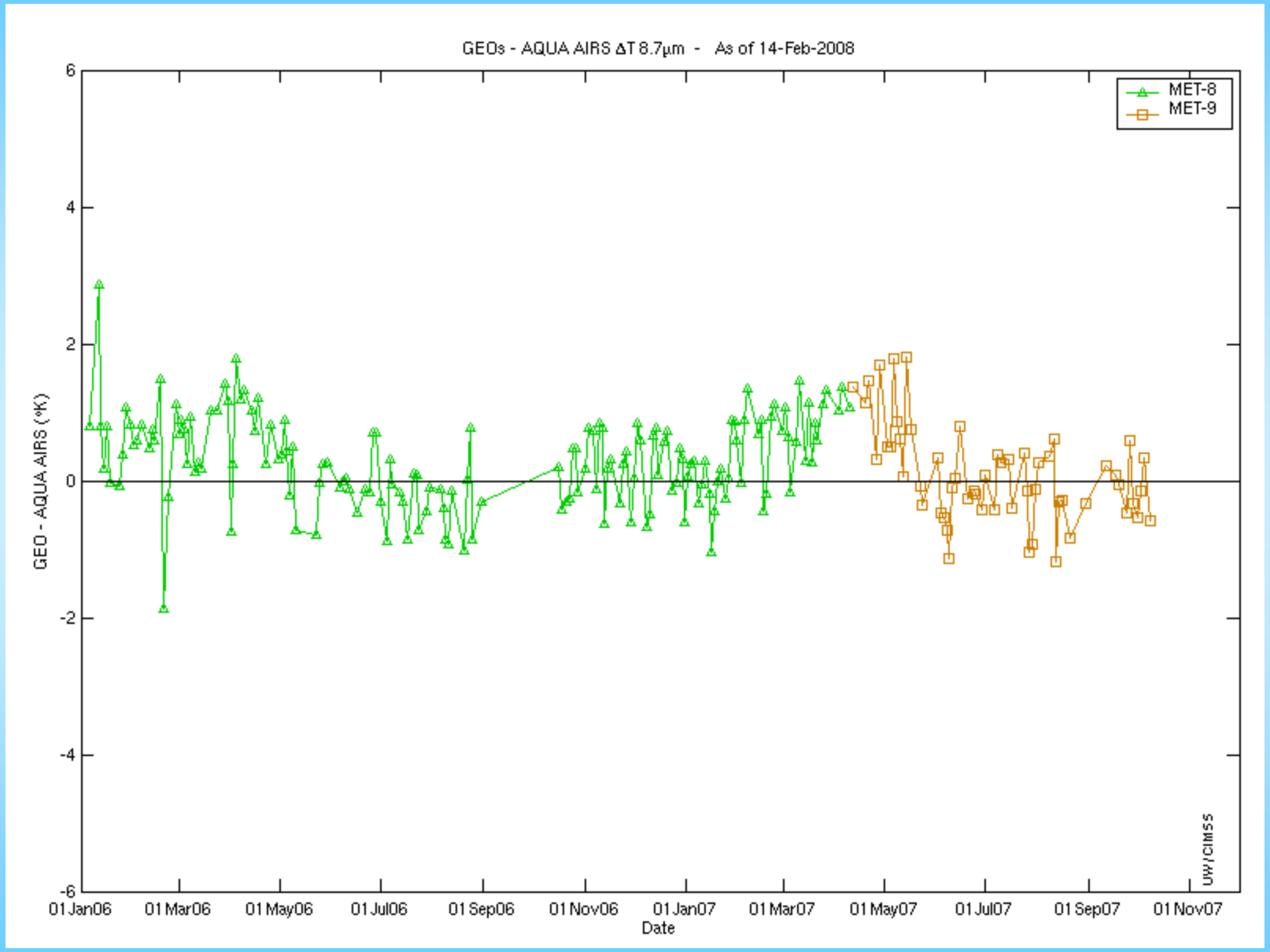
7um	G-10	G-11	G-12	M-8	M-9	MT1R	FY2C
Delta-T (K)	0.46	-0.02	0.26	0.53	0.28	0.17	-2.06
STD (K)	0.2	0.14	0.45	0.22	0.18	0.34	2.87
N	76	43	175	158	56	155	105


GEOs - AQUA AIRS ΔT Water Vapor 6.xμm - As of 14-Feb-2008
GOES-10
GOES-11
GOES-12
MET-8
MET-9
MTSAT
FY2C
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

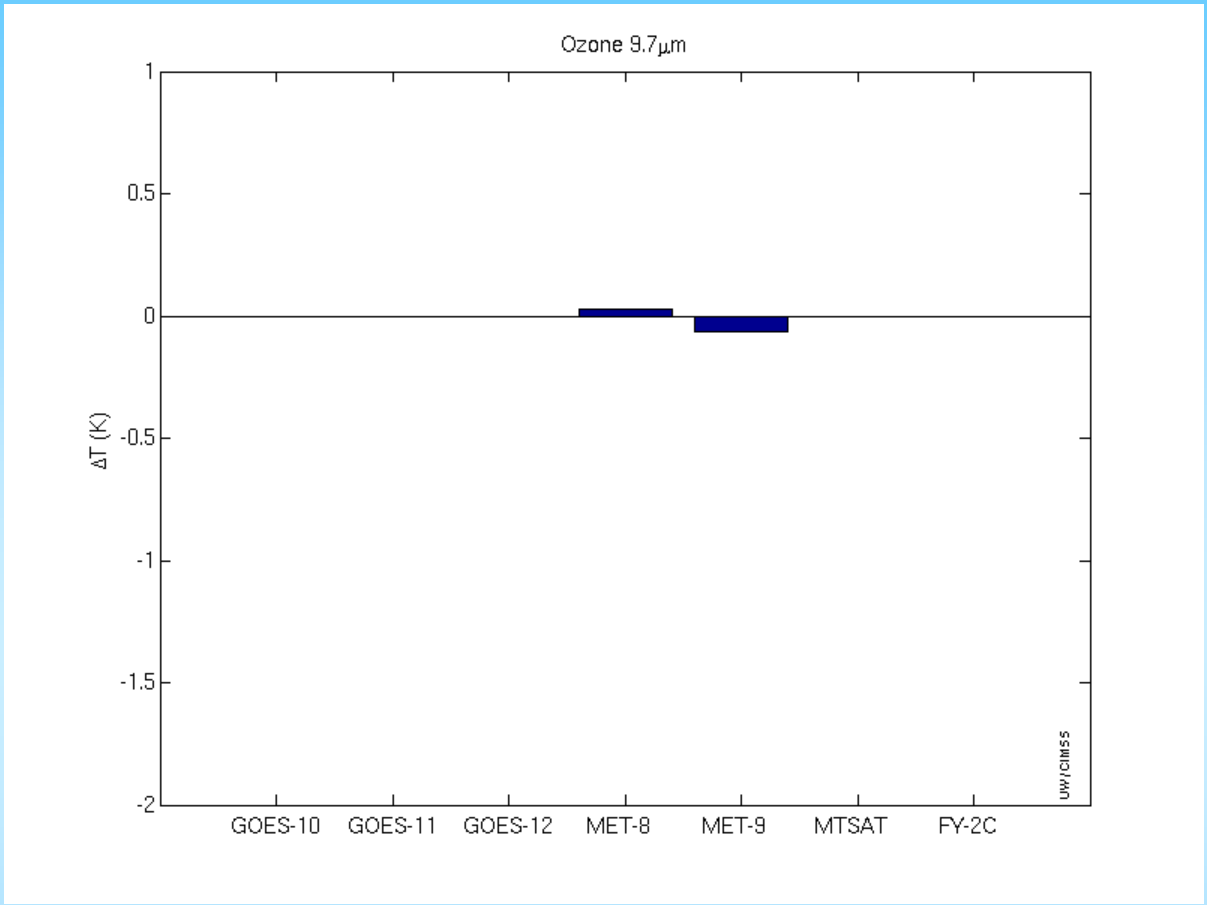
CIMSS Intercal Results Jan 2006 – Oct 2007



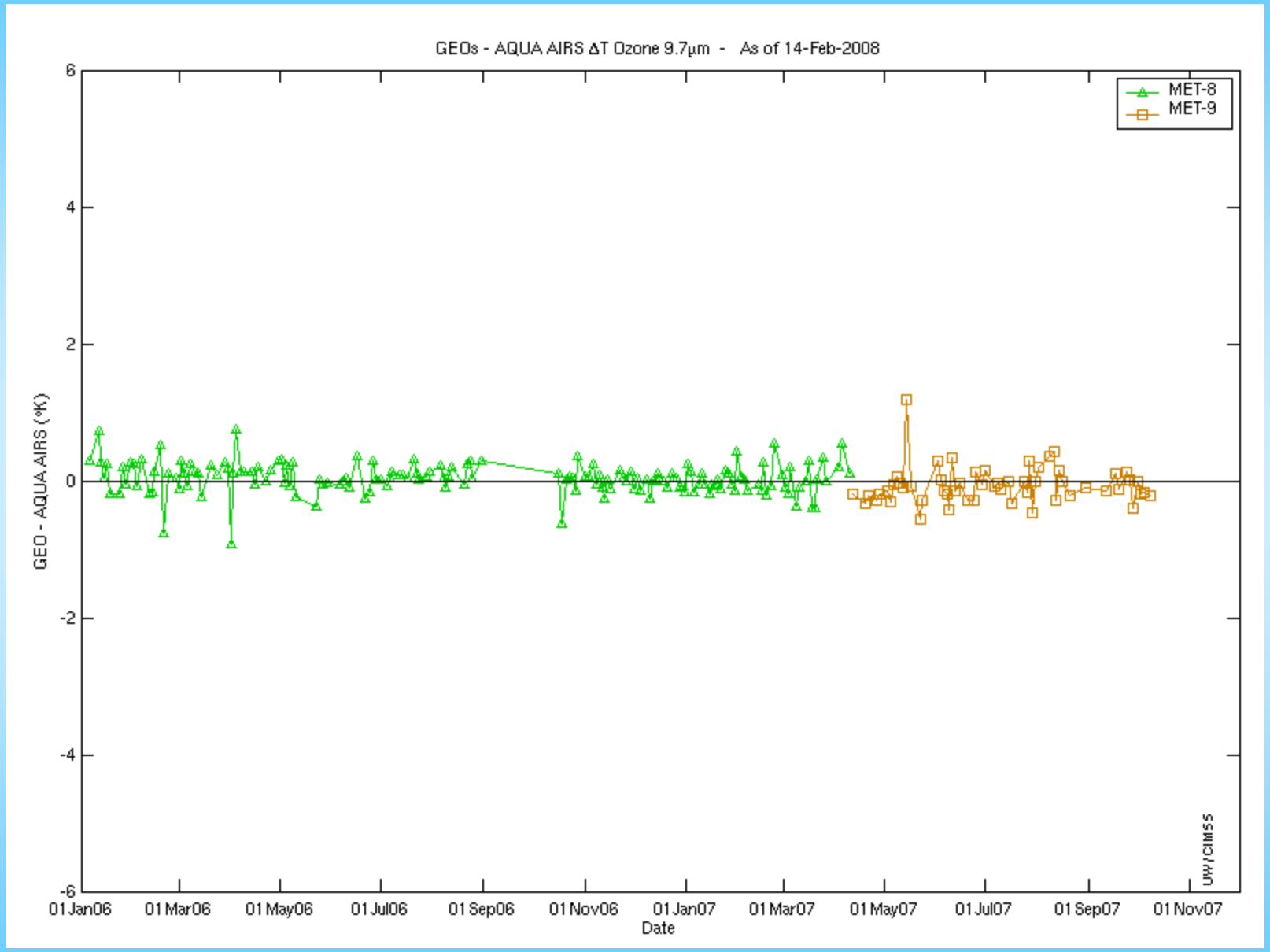
8.7um	M-8	M-9
Delta-T (K)	0.28	0.09
STD (K)	0.63	0.7
N	158	56


GEOs - AQUA AIRS ΔT 8.7μm - As of 14-Feb-2008
MET-8
MET-9
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

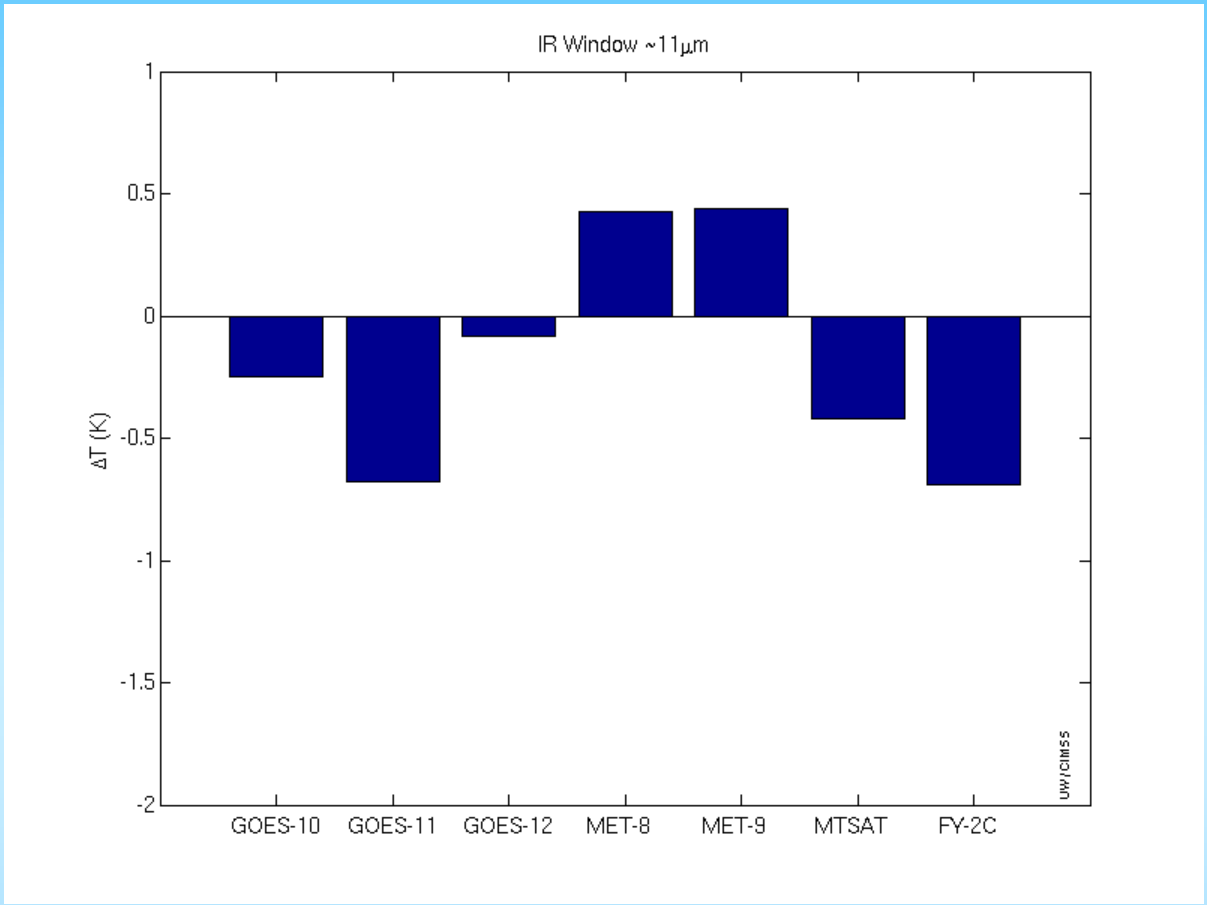
CIMSS Intercal Results Jan 2006 – Oct 2007



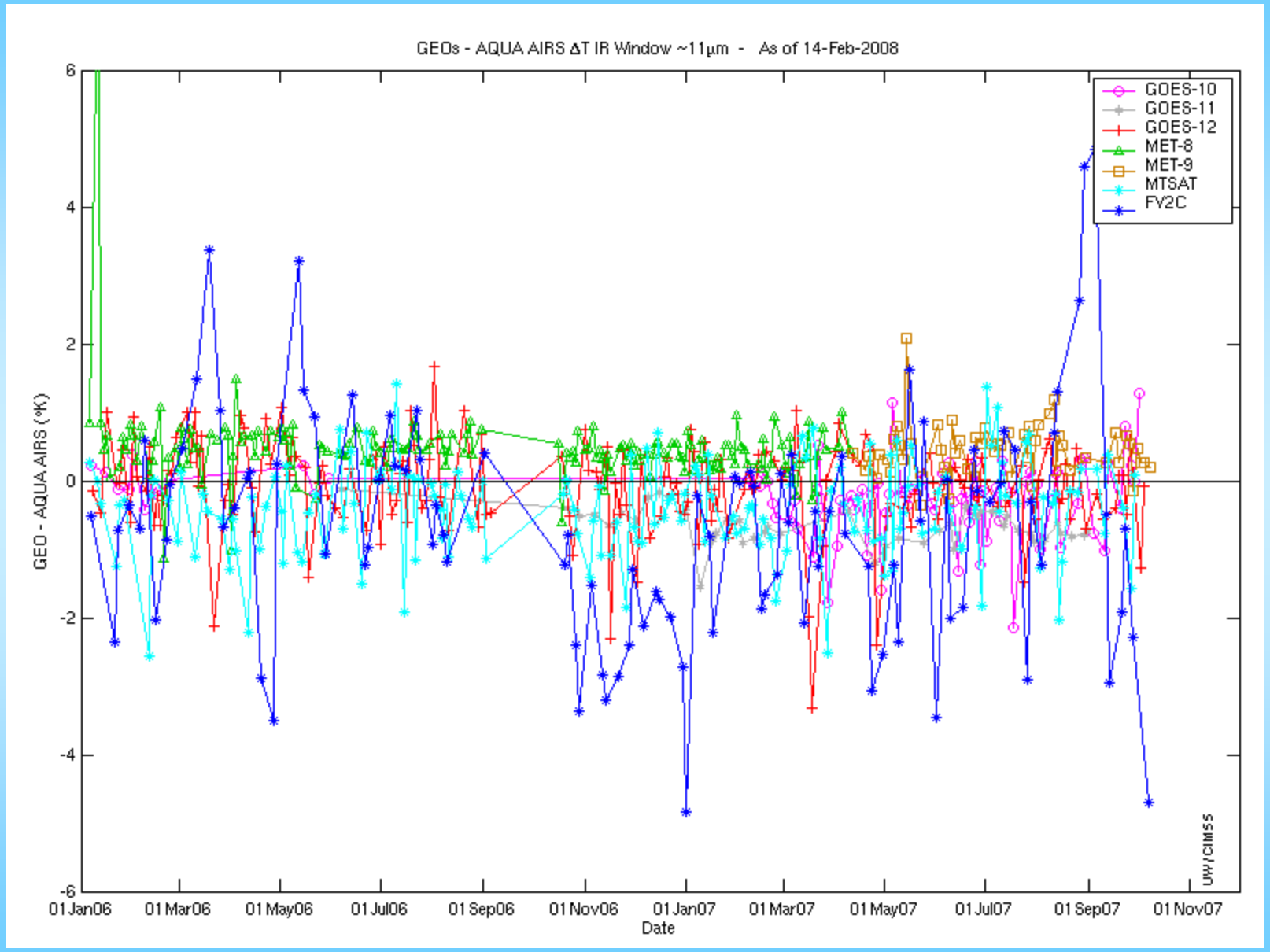
9.7um	M-8	M-9
Delta-T (K)	0.03	-0.07
STD (K)	0.22	0.27
N	158	56


GEOs - AQUA AIRS ΔT Ozone 9.7μm - As of 14-Feb-2008
MET-8
MET-9
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

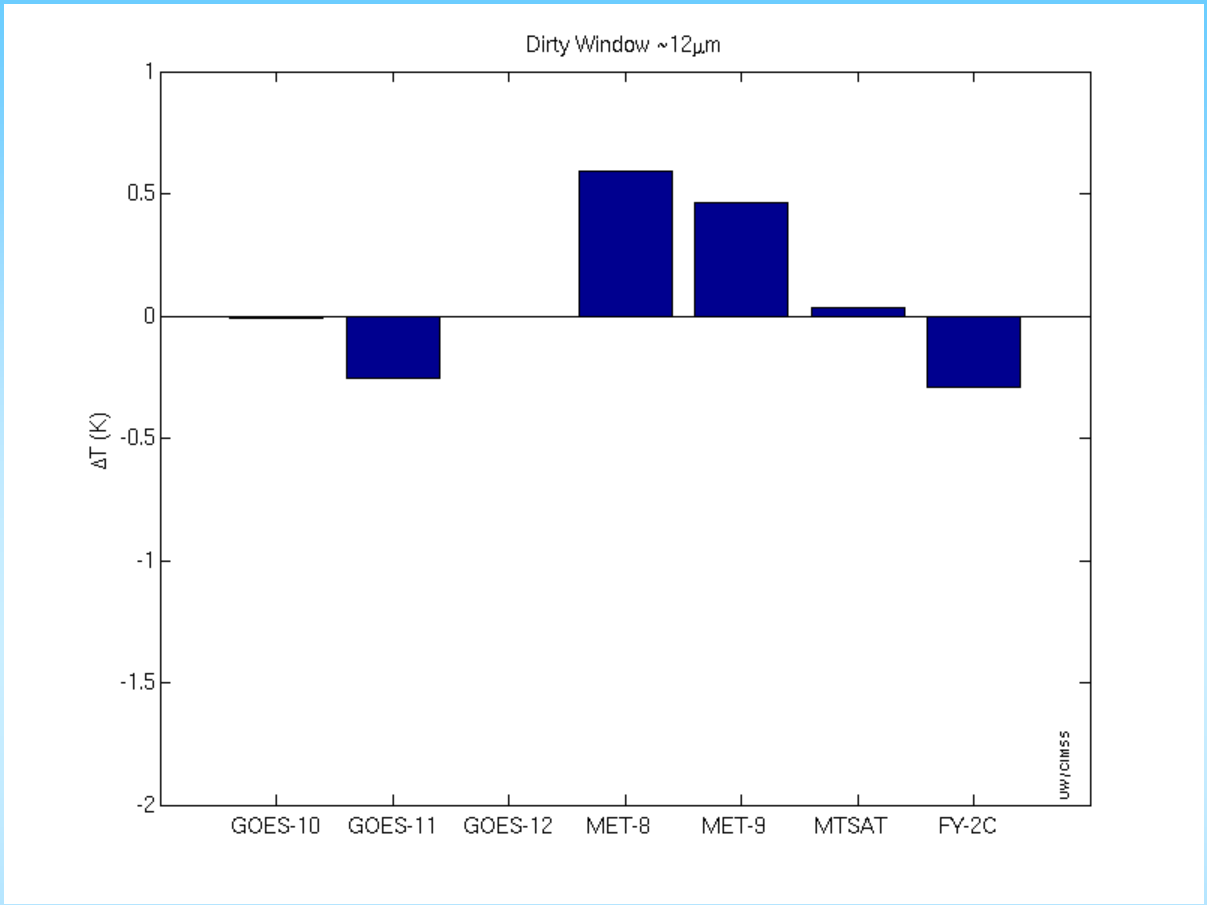
CIMSS Intercal Results Jan 2006 – Oct 2007



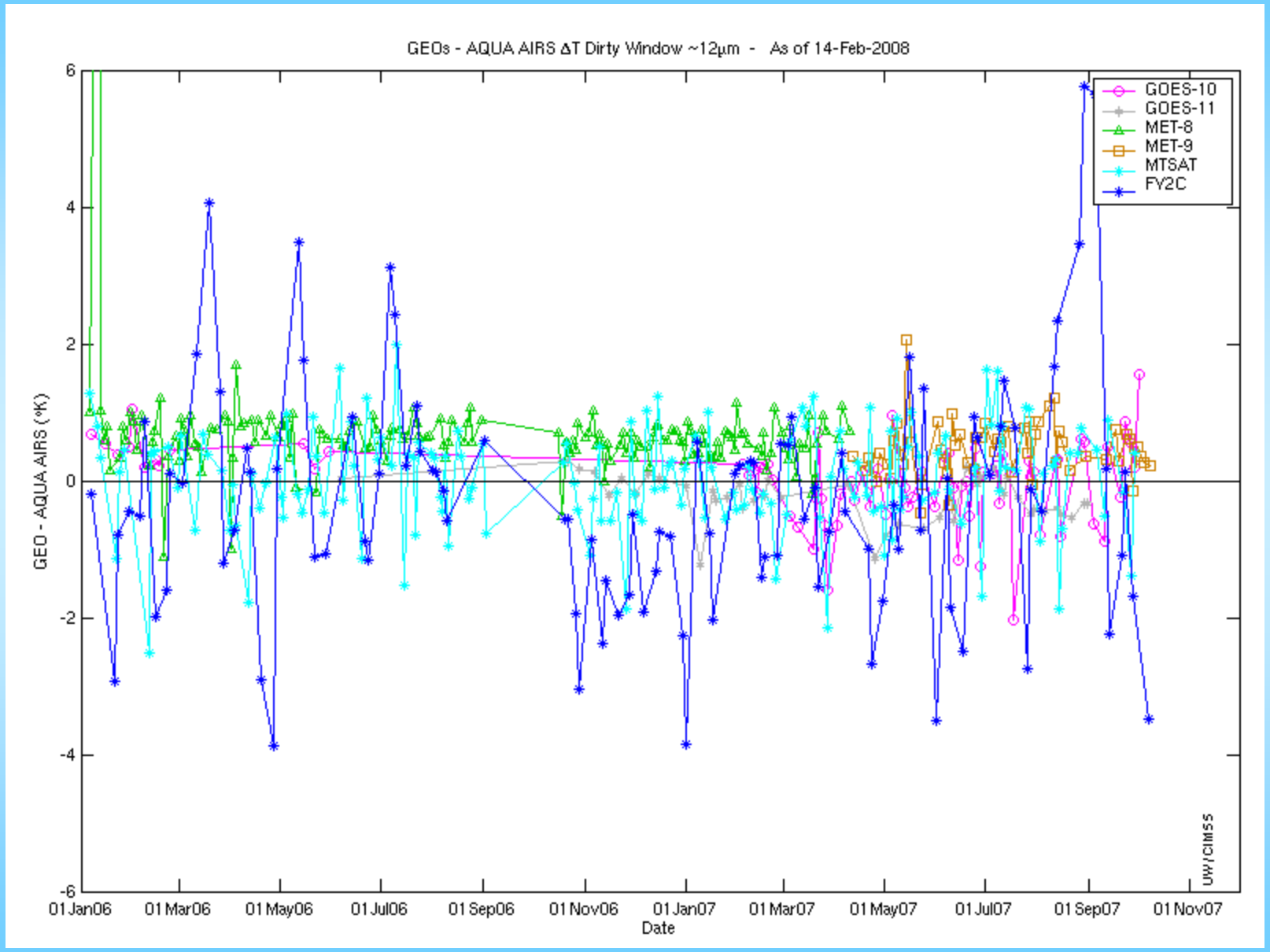
11um	G-10	G-11	G-12	M-8	M-9	MT1R	FY2C
Delta-T (K)	-0.25	-0.68	-0.08	0.42	0.44	-0.42	-0.69
STD (K)	0.54	0.26	0.68	0.32	0.38	0.7	1.69
N	87	43	174	158	56	154	105


GEOs - AQUA AIRS ΔT IR Window ~11μm - As of 14-Feb-2008
GOES-10
GOES-11
GOES-12
MET-8
MET-9
MTSAT
FY2C
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

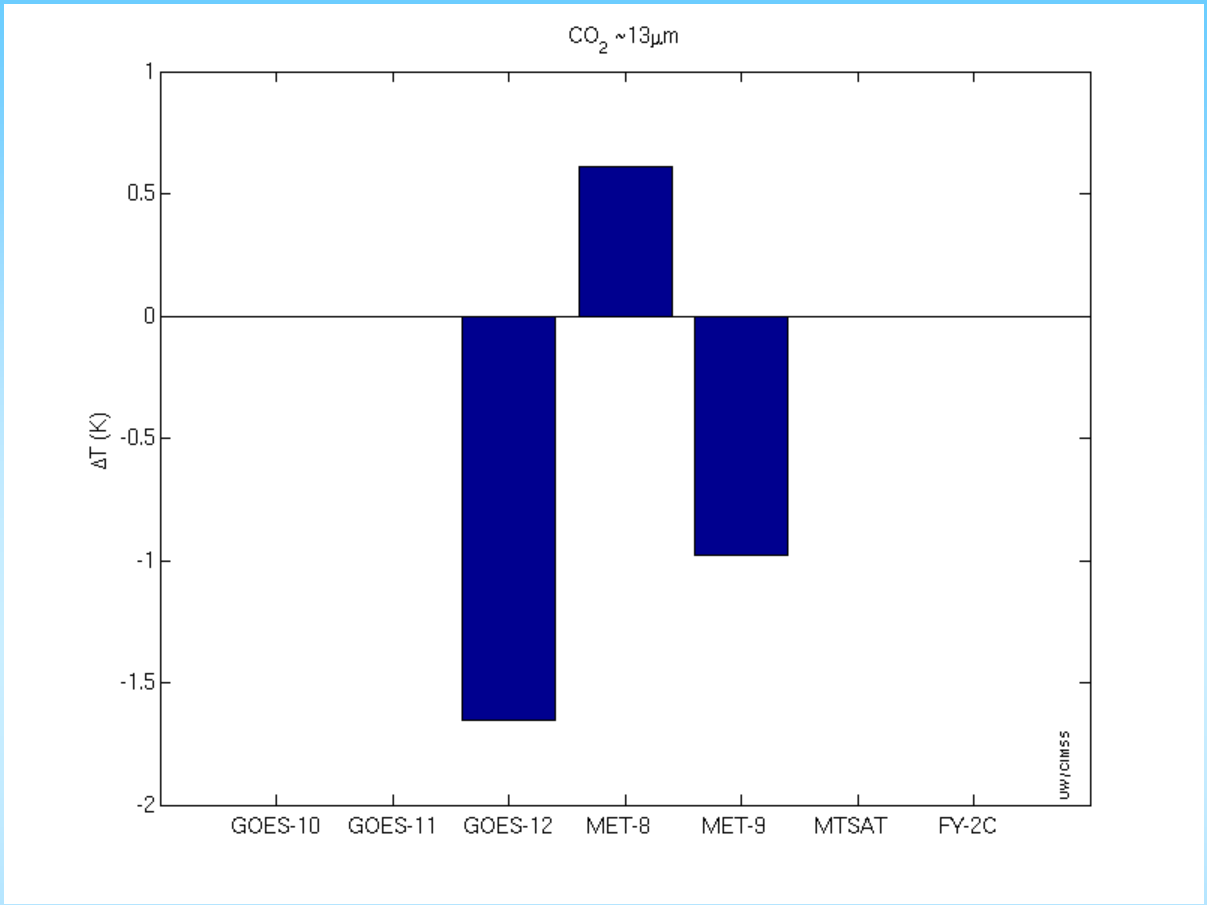
CIMSS Intercal Results Jan 2006 – Oct 2007



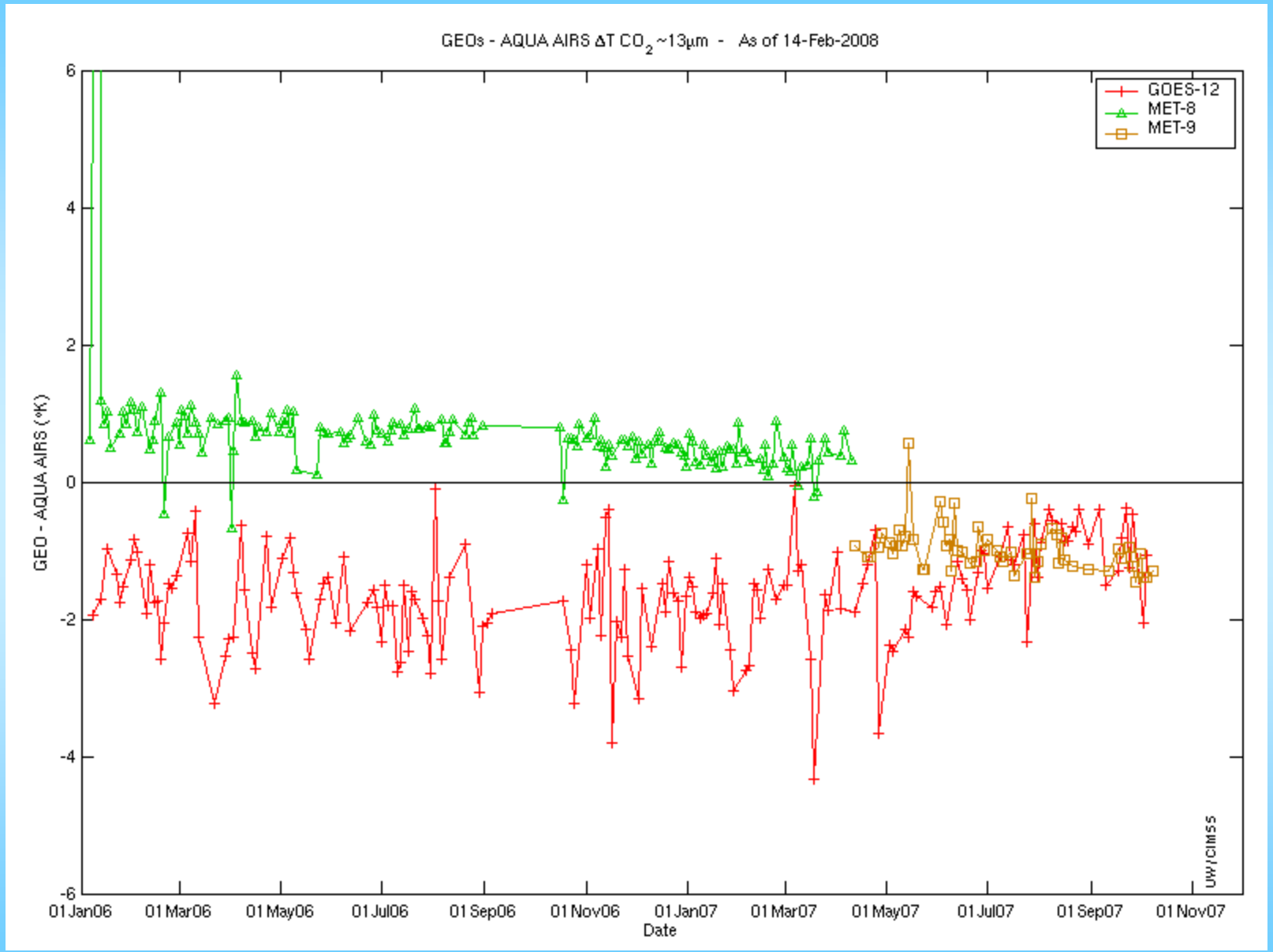
12um	G-10	G-11	M-8	M-9	MT1R	FY2C
Delta-T (K)	-0.01	-0.25	0.59	0.46	0.04	-0.29
STD (K)	0.58	0.34	0.34	0.4	0.77	1.76
N	79	43	158	56	155	105


GEOs - AQUA AIRS ΔT Dirty Window ~12μm - As of 14-Feb-2008
GEO - AQUA AIRS (°K)
Date
GOES-10
GOES-11
MET-8
MET-9
MTSAT
FY2C
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
UW/CIMSS

CIMSS Intercal Results Jan 2006 – Oct 2007



13um	G-12	M-8	M-9
Delta-T (K)	-1.66	0.61	-0.98
STD (K)	0.73	0.32	0.34
N	173	158	56

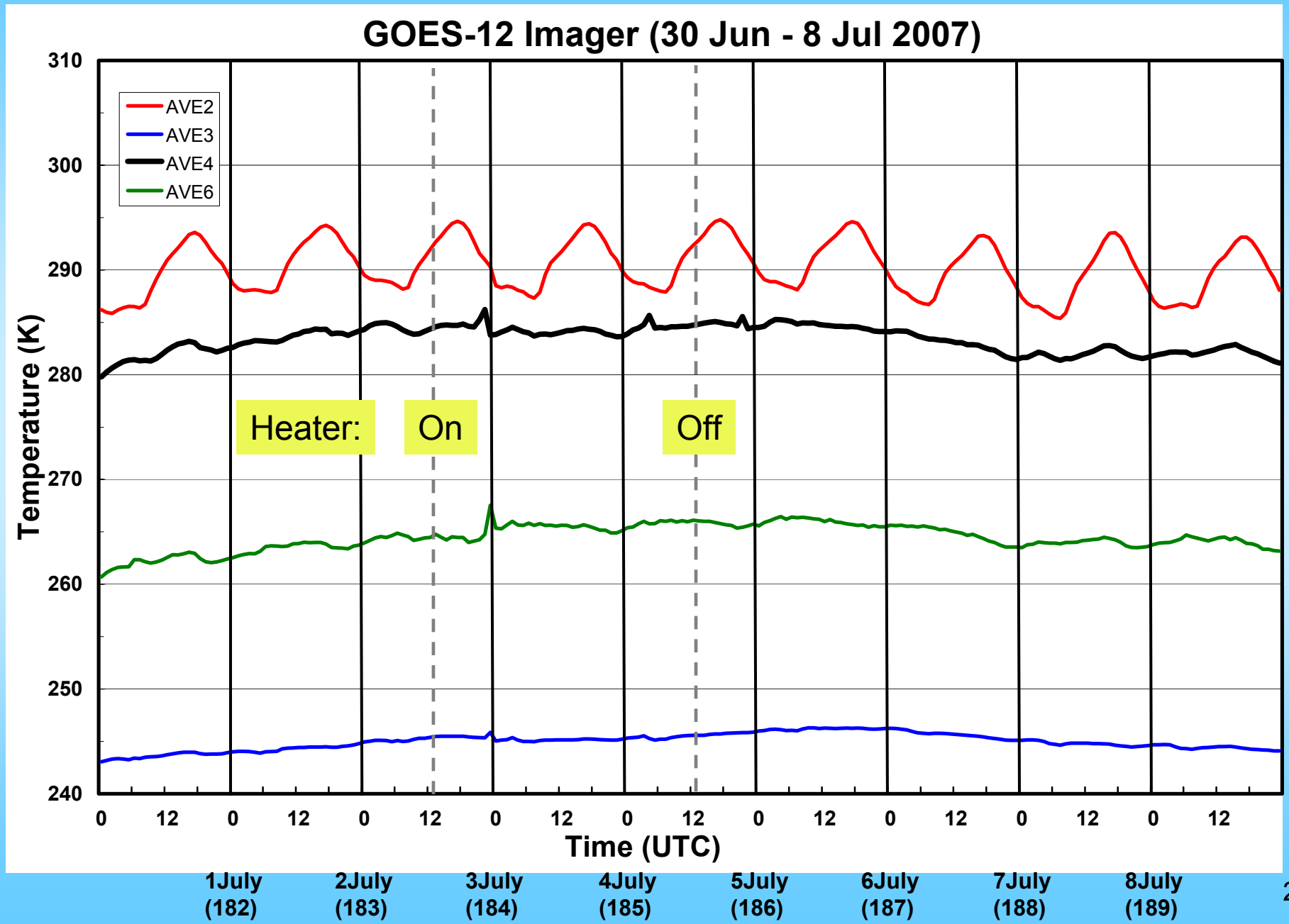

GEOs - AQUA AIRS ΔT CO2 ~13μm - As of 14-Feb-2008
GOES-12
MET-8
MET-9
GEO - AQUA AIRS (°K)
6
4
2
0
-2
-4
-6
01 Jan06
01 Mar06
01 May06
01 Jul06
01 Sep06
01 Nov06
01 Jan07
01 Mar07
01 May07
01 Jul07
01 Sep07
01 Nov07
Date
UW/CIMSS

GOES-12 Time Dependence

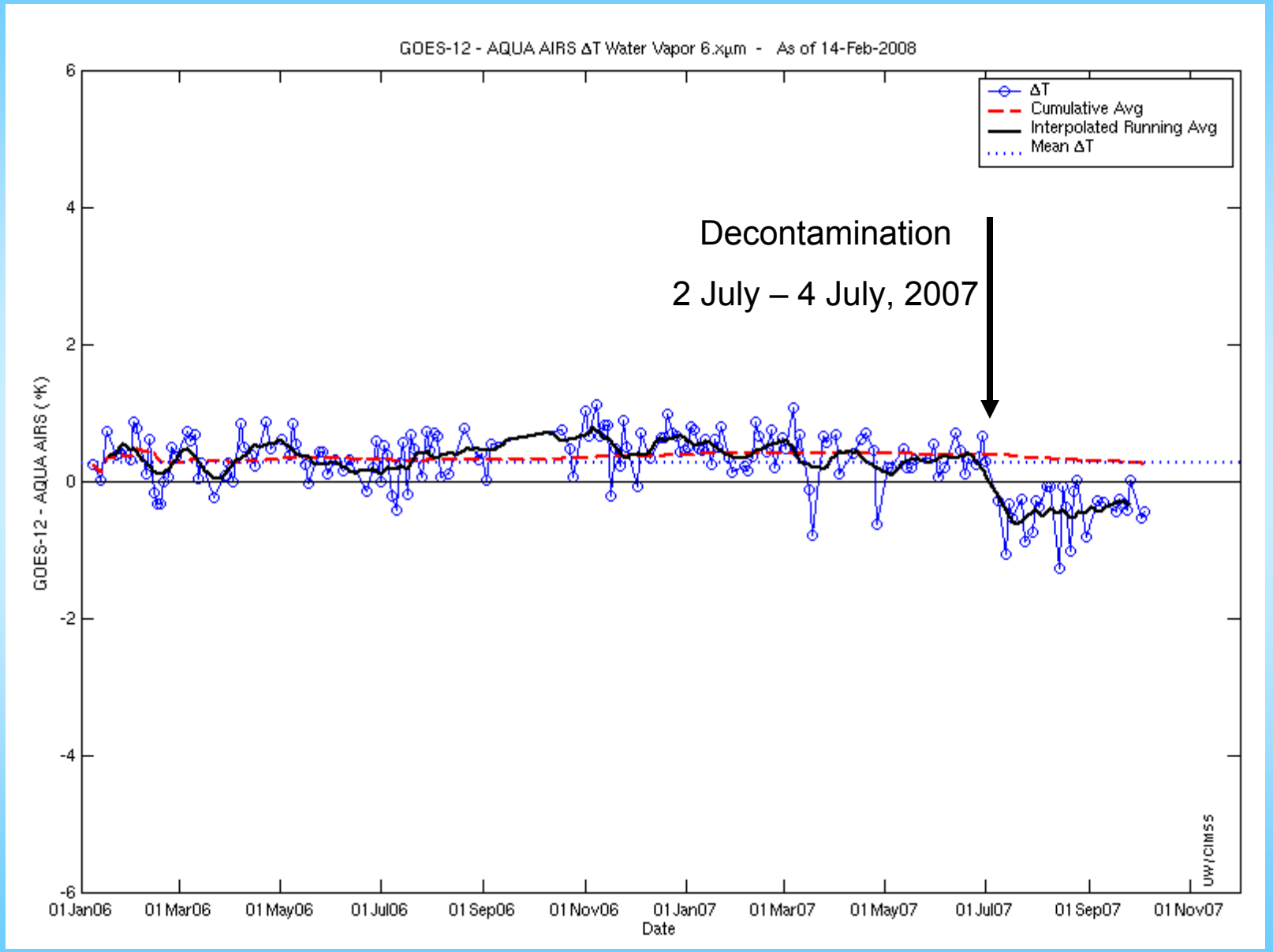
		3.9 μm	6.7 μm	11.2 μm	13.3 μm
Unadjusted	ΔT	-0.71 K	0.26 K	-0.08 K	-1.66 K
	STD	0.78 K	0.45 K	0.68 K	0.73 K
	N	151	175	174	173
5 Minute Limit	ΔT	0.02 K	0.21 K	0.02 K	-1.54 K
	STD	0.23 K	0.53 K	0.35 K	0.55 K
	N	40	46	46	46

- The standard deviation improves with a 5 minute time limit in most bands.
- The mean temperature difference moved closer to 0 with a 5 minute time limit in all bands.
- Other time limits were tried but 5 minutes gave the best results. Fewer than 5 minutes reduces N drastically without a noticeable return. Greater than 5 minutes increases the mean difference and standard deviation.

GOES-12 Decontamination



GOES-12 Decontamination



GOES-12 Decontamination

		3.9 μm	6.7 μm	11.2 μm	13.3 μm
Unadjusted	ΔT	-0.71 K	0.26 K	-0.07 K	-1.68 K
	STD	0.78 K	0.45 K	0.70 K	0.81 K
	N	151	175	175	174
Prior to Decontamination	ΔT	-0.72 K	0.39 K	-0.04 K	-1.82 K
	STD	0.80 K	0.33 K	0.73 K	0.78 K
	N	125	148	148	147
Post Decontamination	ΔT	-0.64 K	-0.43 K	-0.21 K	-0.94 K
	STD	0.68 K	0.34 K	0.50 K	0.49 K
	N	26	27	27	27

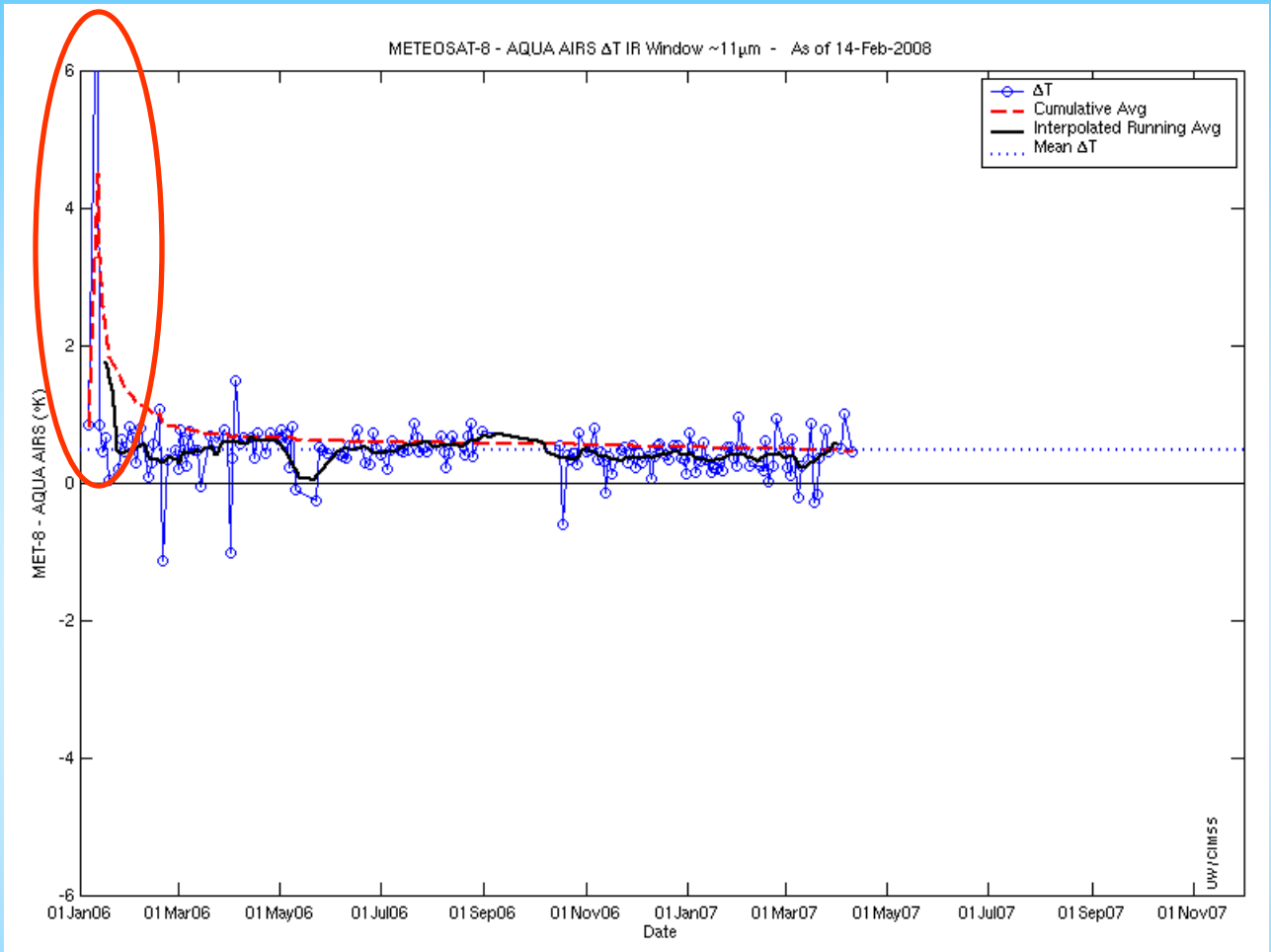
- After decontamination standard deviations tend to get better and mean differences are affected as well (not always closer to 0 K).
- The water vapor band mean temperature difference is the same magnitude, opposite sign, after decontamination.
- The 13.3 micrometer band mean temperature difference was improved by nearly 1K.

GOES-12 Decontamination and Time Dependence

		3.9 μm	6.7 μm	11.2 μm	13.3 μm
5 Minute Limit	ΔT	0.02 K	0.21 K	0.02 K	-1.54 K
	STD	0.23 K	0.53 K	0.35 K	0.55 K
	N	40	46	46	46
Pre Decon, 5 min Limit	ΔT	-0.91 K	0.35 K	0.13 K	-1.62 K
	STD	0.81 K	0.34 K	0.66 K	0.66 K
	N	31	37	37	37
Post Decon, 5 min Limit	ΔT	-0.72 K	0.20 K	-0.31 K	-1.76 K
	STD	0.82 K	0.20 K	0.54 K	0.45 K
	N	9	9	9	9

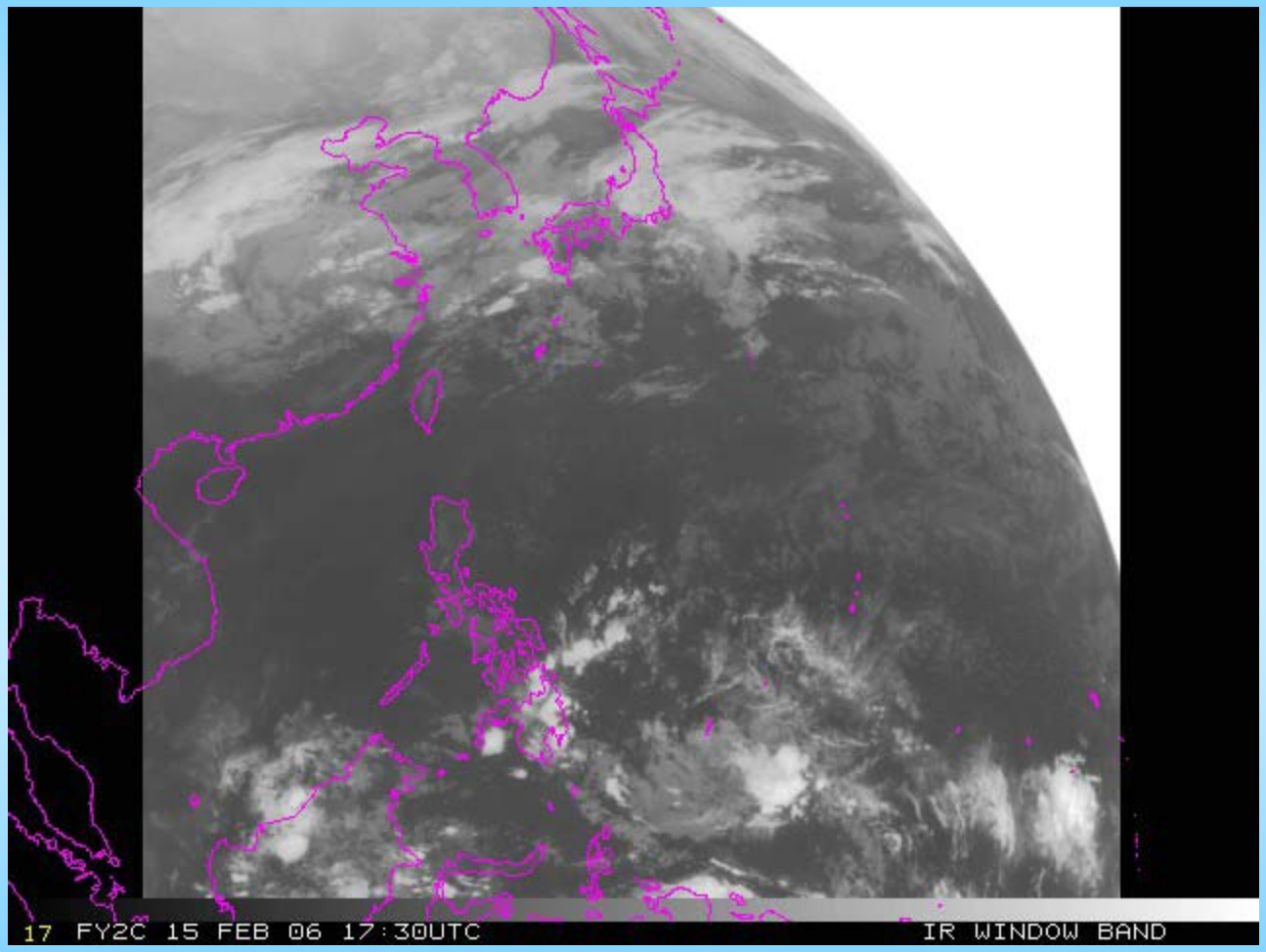
- After decontamination standard deviations tend to get better and mean differences are affected as well (not always closer to 0 K). But the effects are less dramatic in the 5-minute limit subsample.
- N may be too small for these to be meaningful.
- The water vapor band mean temperature difference is still the opposite sign, but farther from 0 K after decontamination.
- The 13.3 micrometer band mean temperature difference was not improved.

METEOSAT-8 11 micrometer time series…



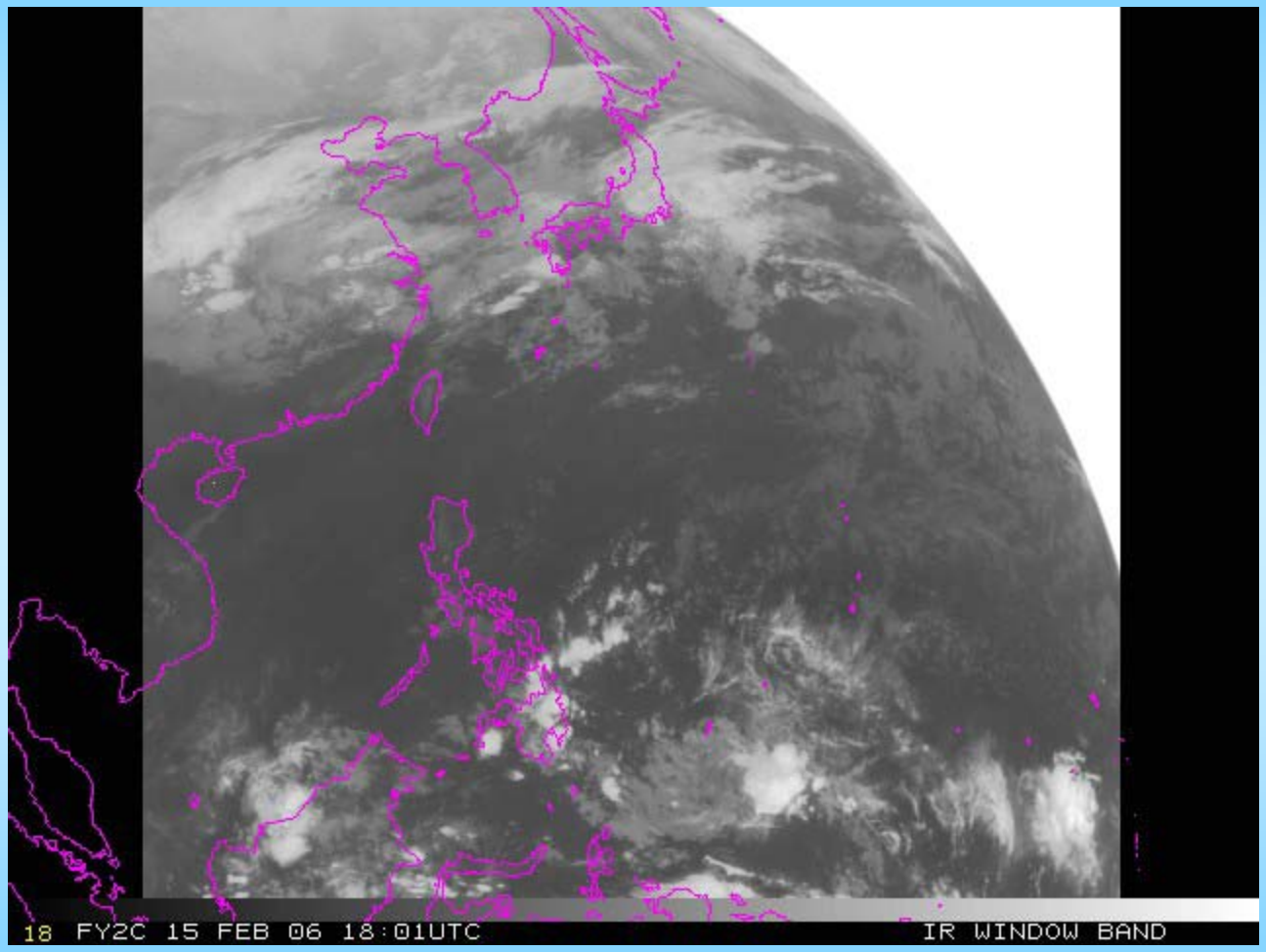
(MSG/Meteosat-8 note: Due to ongoing decontamination of the SEVIRI instrument, several infrared channels will not be available until after 1400 UTC on 1/13/06. Only SEVIRI visible channel images (HRV, VIS0.6, VIS0.8, and NIR1.6) are available.) – **Do satellite operators need to do more to protect users?**

FY-2C “Stray Light”



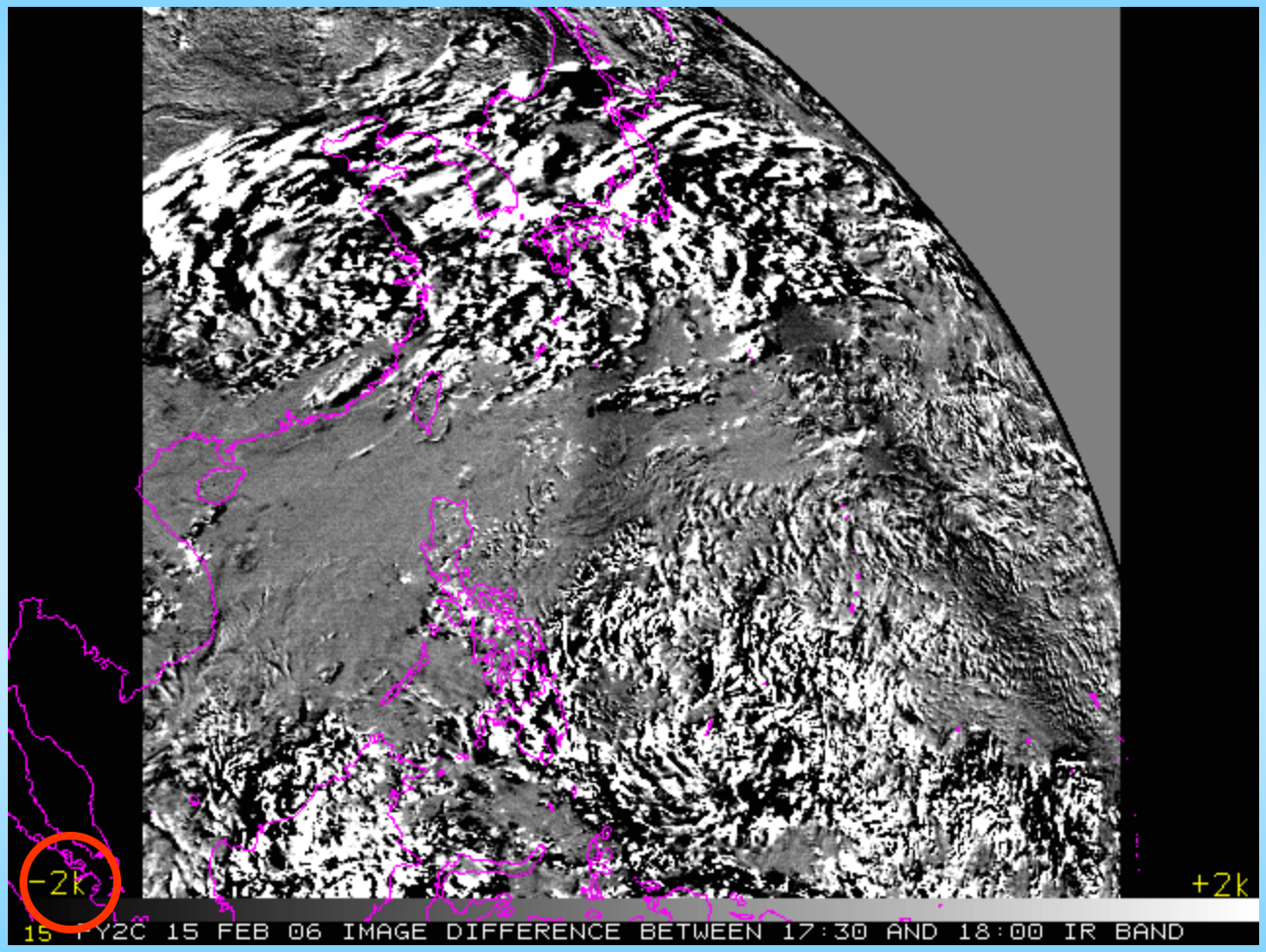
Around 18 UTC (near satellite midnight), there is light reflected from a telescope mounting. It affects all bands, though is most obvious in the shortwave.

FY-2C “Stray Light”



It is hard to see there is a “stray light” problem here…

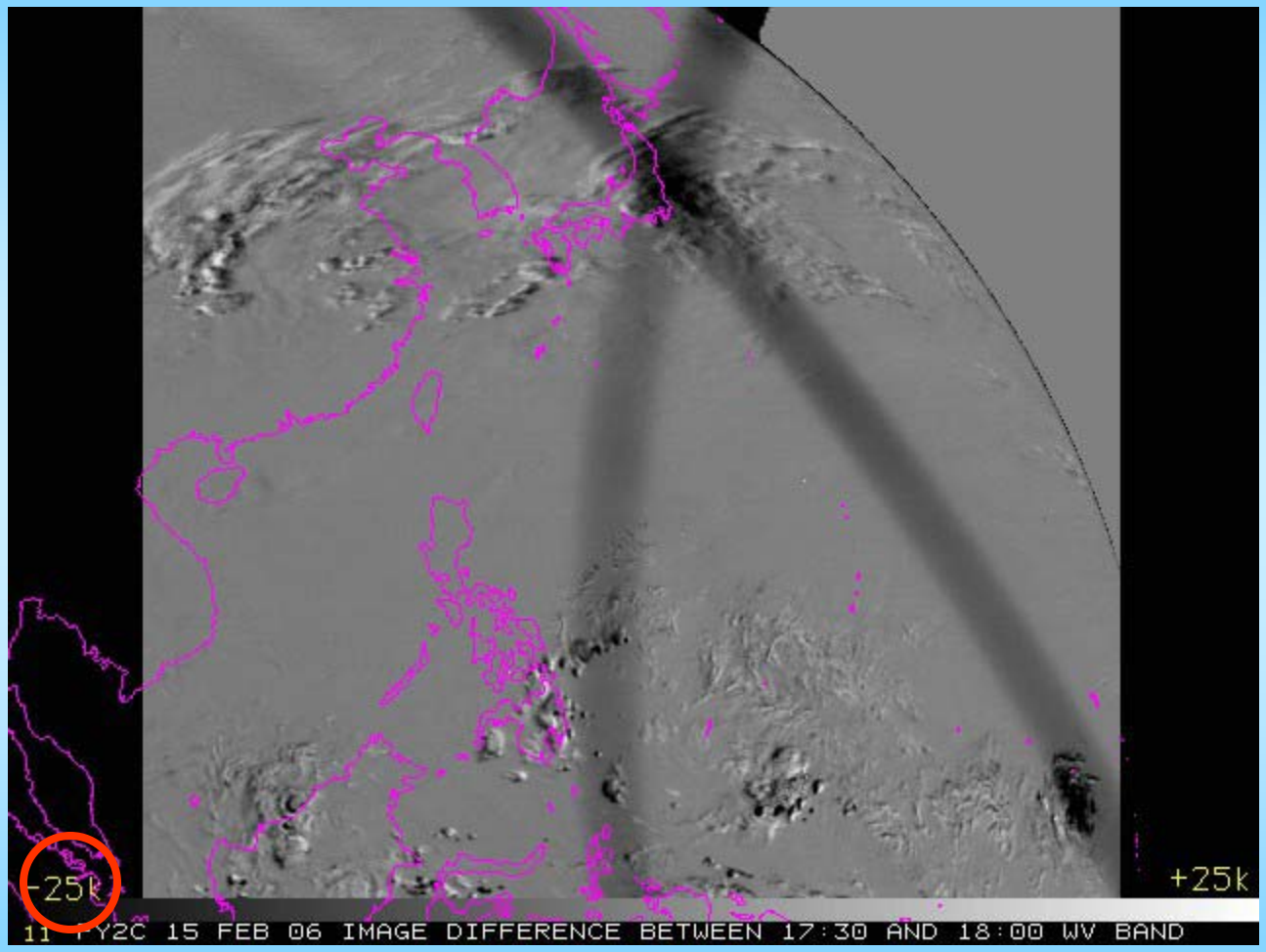
FY-2C “Stray Light”



Differences on the order of 2K in the IR Window.

… Until you see the difference between the two time steps (17:30 and 18:00 UTC).

FY-2C “Stray Light”



Differences on the order of 25K in the water vapor band!

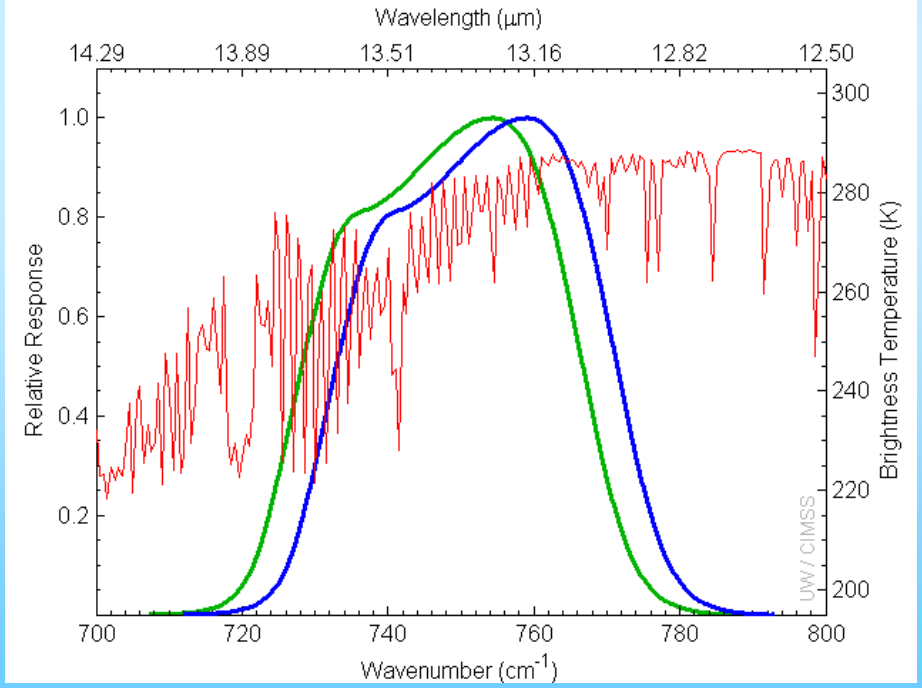
In China they do not use these data to produce operational products. However, the data are still available.

GOES-13 Science Check Out

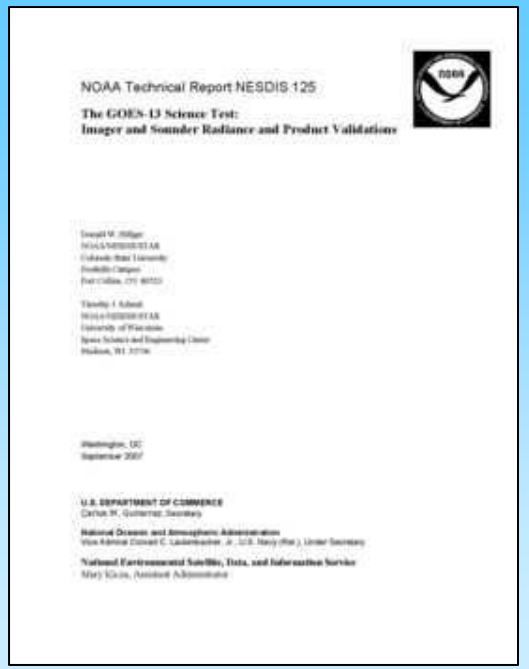
Imager Band	Bias (K)	Standard Deviation of Differences (K)
2 (3.9 μm)	0.2	0.6
3 (6.5 μm)	-0.4	0.3
4 (10.7 μm)	-0.1	0.4
6 (13.3 μm)	**-2.4**	0.6

N=19

GOES-13 Imager band 6 (13.3 um) spectral response function (blue) and the shifted spectral response function (green) shifted **-4.7 cm^{-1}** (approximately 13.4 um). By shifting the spectral response this amount, the bias, or mean brightness temperature difference for all 19 cases, becomes **0.01K** with a standard deviation of **0.7K**.



NOAA Tech Memos


NOAA Technical Report NESDIS 125

The GOES-13 Science Test:
Imager and Sounder Radiance and Product Validations

U.S. DEPARTMENT OF COMMERCE

National Environmental Satellite, Data, and Information Service

- GOES-11 (#103)
- GOES-12 (#115)
  - *http://rammb.cira.colostate.edu/research/calibration/goes_12_science_test_report.asp*
- GOES-13 (#125)
  - http://rammb.cira.colostate.edu/projects/goes_n/

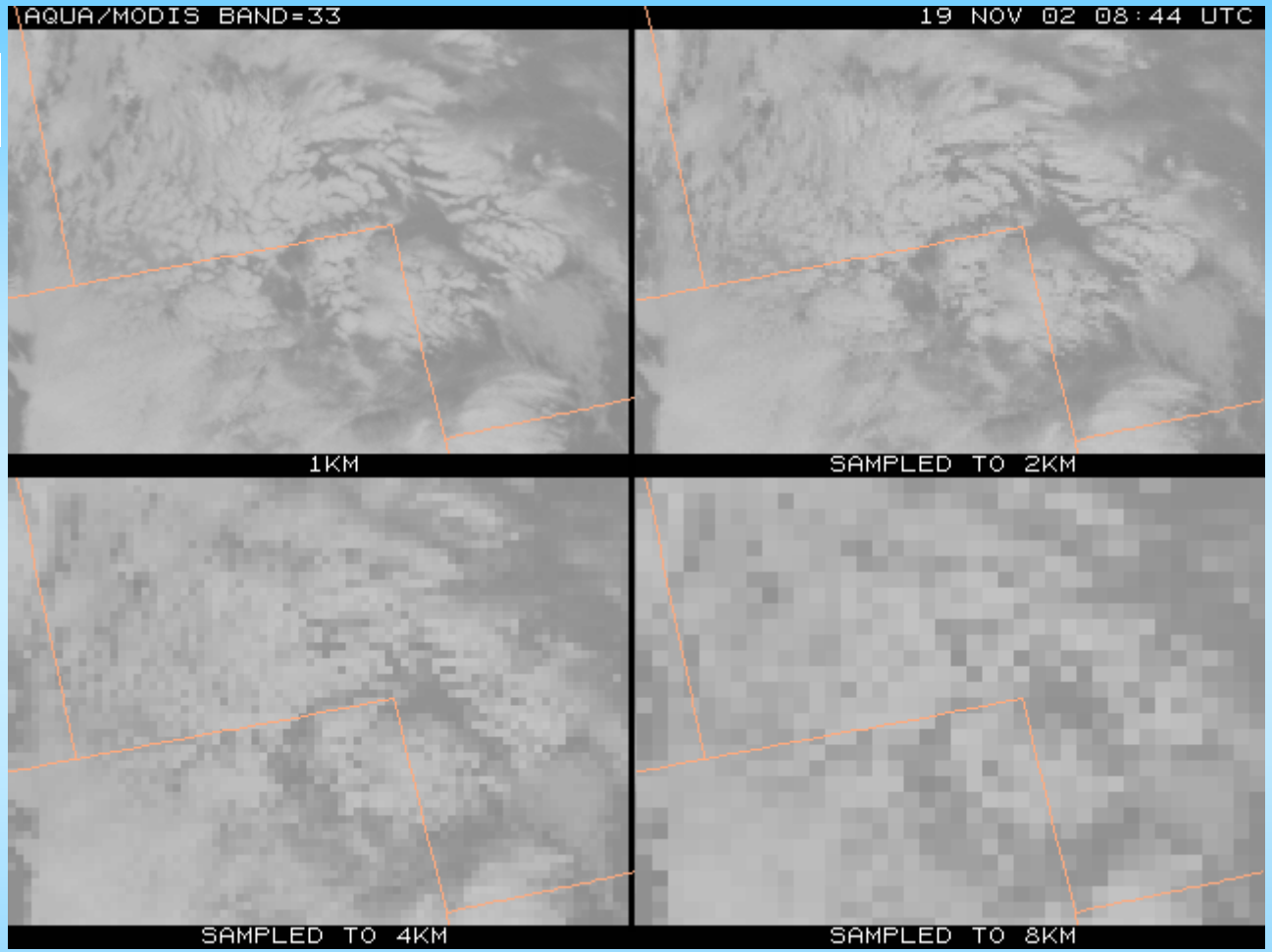
GOES-O

- GVAR Change (to support the 4km 13.3 um band)
- To become GOES-14
- Launch date *may* be August of 2008
- Followed by a post-launch check-out and on-orbit storage.
- Should GSICS investigate pre-operational satellites? Non-operational data are not archived by NOAA's CLASS.

GOES-O – improved spatial resolution of the 13.3 µm band.

1 km

2 km



4 km

8 km

GOES-O

GOES-12 & GOES-13

Conclusions

• Most of the world's IR geostationary satellite bands are "adequately" calibrated.

• Limiting comparisons to an actual 5 minute time difference is preferable to CIMSS current method.

• Decontamination affects GOES-12 results in all bands.

• More should be done to protect users from data we know are poorly calibrated or have quality issues, especially internationally.

• The most important time for Intercalibration is following launch, in the pre-operational phase after the engineering check-out phase.