Comparison of NASA AIRS and MODIS Land Surface Temperature and Infrared Emissivity Measurements from the EOS AQUA platform

Robert Knuteson,
Hank Revercomb, Dave Tobin

University of Wisconsin-Madison

16 Sept 2008

Imager/Sounder Synergy

- Imager – Contiguous spatial coverage.
- IR Sounder - Vertical profile at lower spatial res
- MW Sounder - “All weather” at lower spatial res.
- Ideally a single algorithm would combine these data “optimally”. But at a minimum, comparison of products from imager and sounder data should be used as a quality check on potential CDRs (climate data records). This presentation is a preliminary imager/sounder assessment using EOS MODIS and AIRS products as a prelude to the operational sensors on NPP/NPOESS.

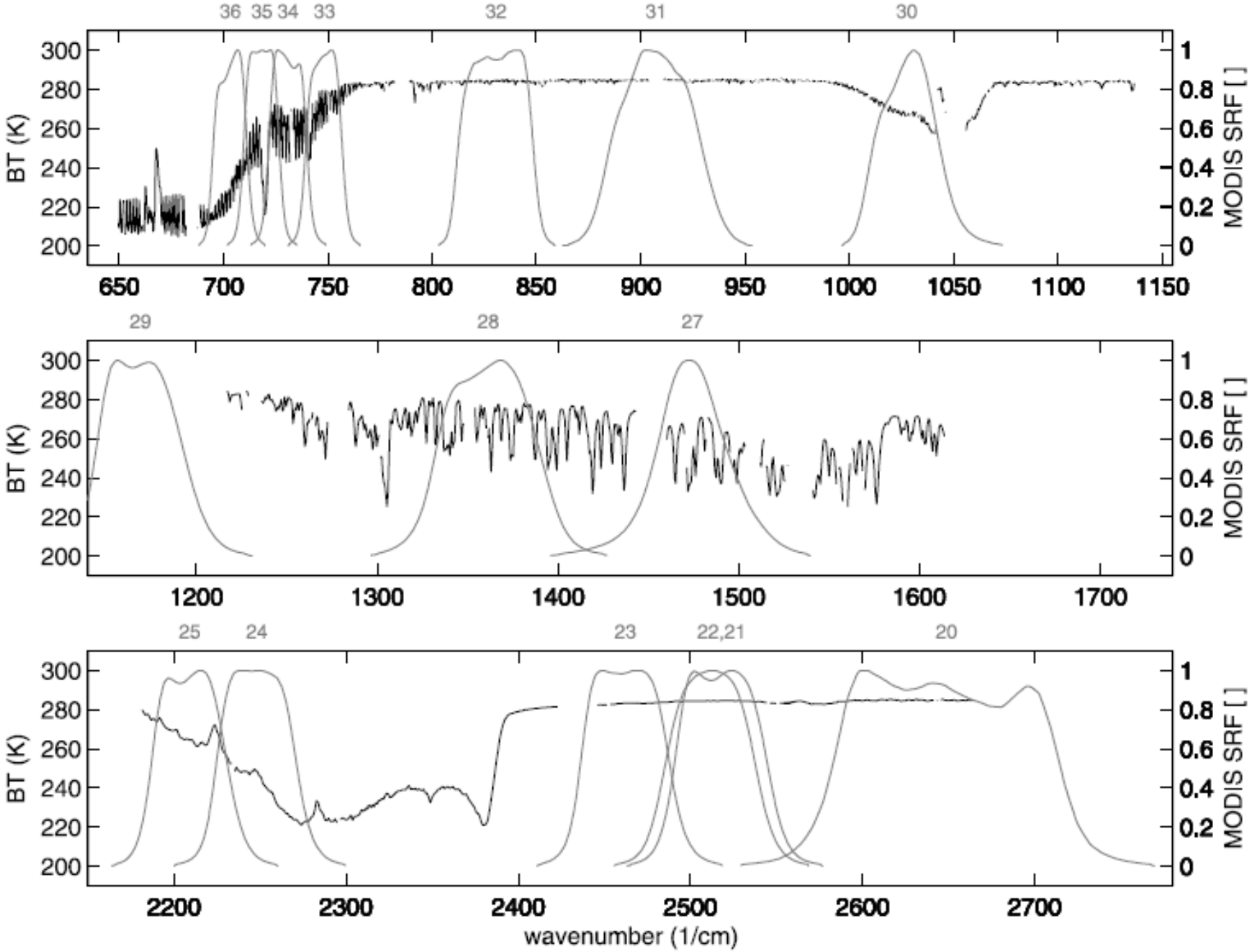
Goals

The goal of this effort is to evaluate the following:

• What are the natural spatial and temporal scales of the natural variability of the relevant quantities?

• To what degree can we identify BIASES in the LST product?

• When product algorithm changes are made (i.e. version changes), do we have a way of deciding if the intended improvements actually improve or degrade the product accuracy?


36 35 34 33
32
31
30
29
28
27
25 24
23
22,21
20
BT (K)
MODIS SRF [ ]
wavenumber (1/cm)

AIRS- MODIS Brightness Temperature Comparison (Tobin et al, 2006)

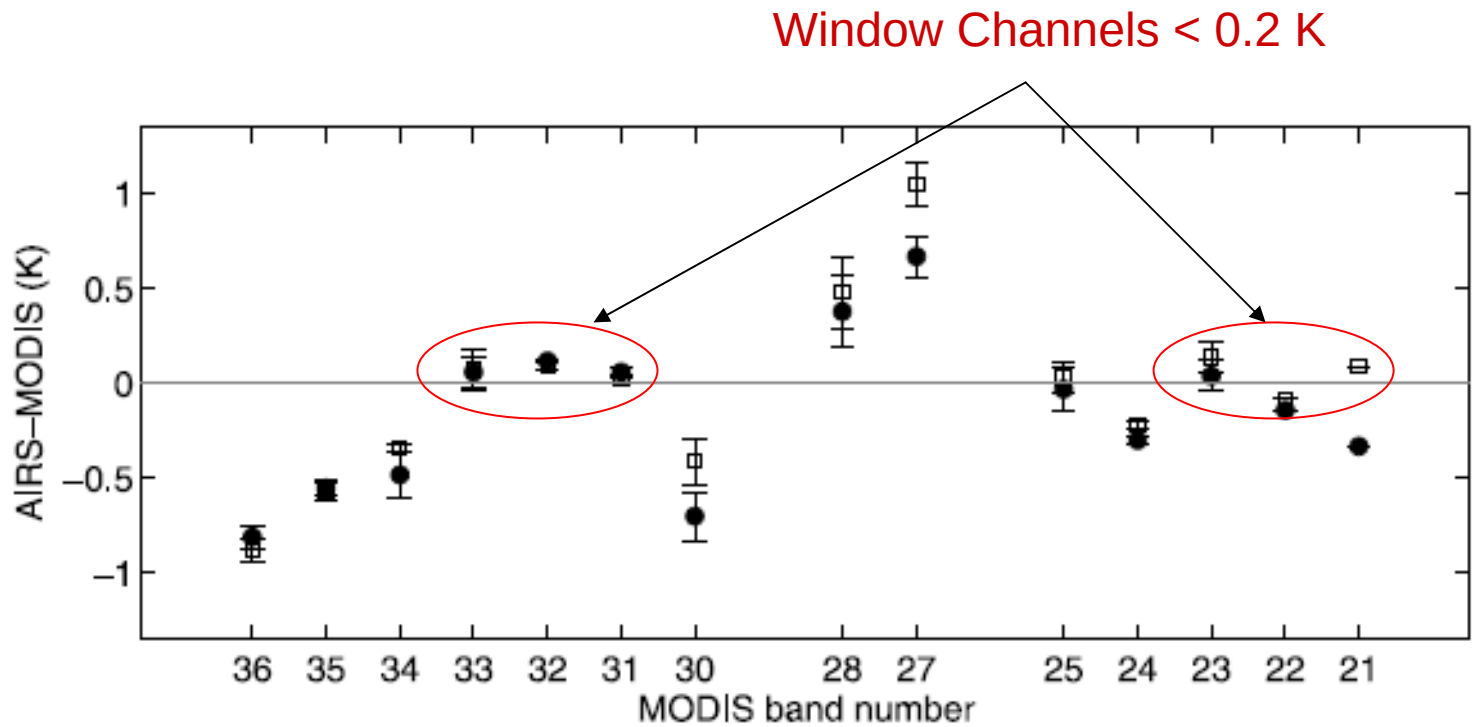


Figure 11. Mean AIRS minus MODIS brightness temperature differences and uncertainties for 6 September 2002 (open squares) and 18 February 2004 (solid circles).

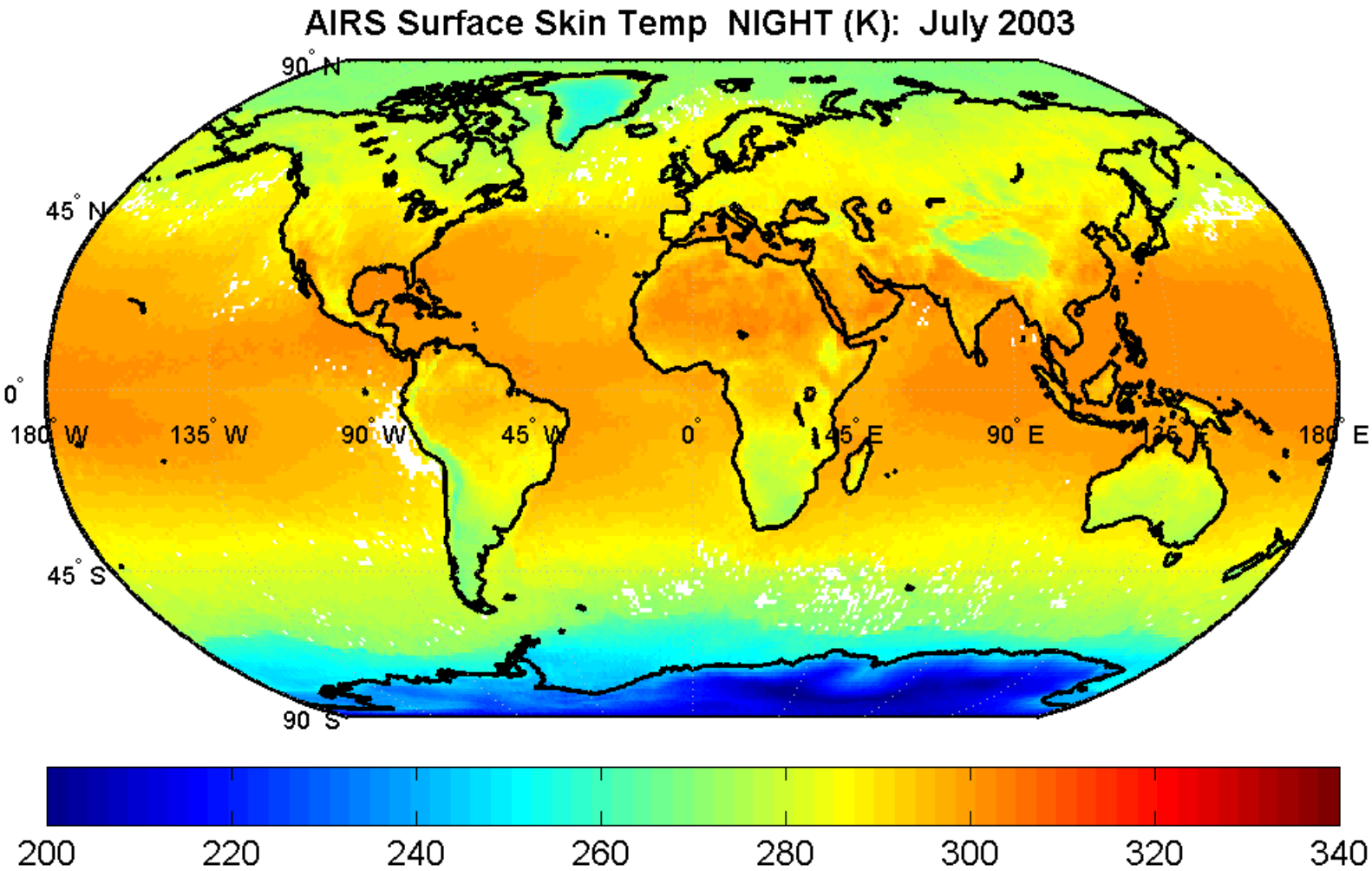
Tobin, D. C., H. E. Revercomb, C. C. Moeller, and T. S. Pagano (2006), Use of Atmospheric Infrared Sounder high–spectral resolution spectra to assess the calibration of Moderate resolution Imaging Spectroradiometer on EOS Aqua, J. Geophys. Res., 111, D09S05,

MODIS and AIRS LST Product Characteristics

	Aqua MODIS	Aqua AIRS
Sensor Calibration	< 0.2 K (windows)	< 0.2 K
Atmospheric Attenuation	Column Retrieved	Profile Retrieved
Cloud Contamination	Cloud Detection	Cloud Clearing
Surface Type	Multi-spectral (004) Land Cover Class (005)	Multi-spectral
Temporal Sampling and Resolution	Clear only; 1:30 AM, PM (0.333 msec per sample)	Partly Cloudy; 1:30 AM, PM (30 msec per sample)
Spatial Sampling and Resolution	1 km Clear Only Samples (1 km – 5 km –> 1 deg)	45 km CC (< 60% CF) (15 km – 45 km –> 1 deg)

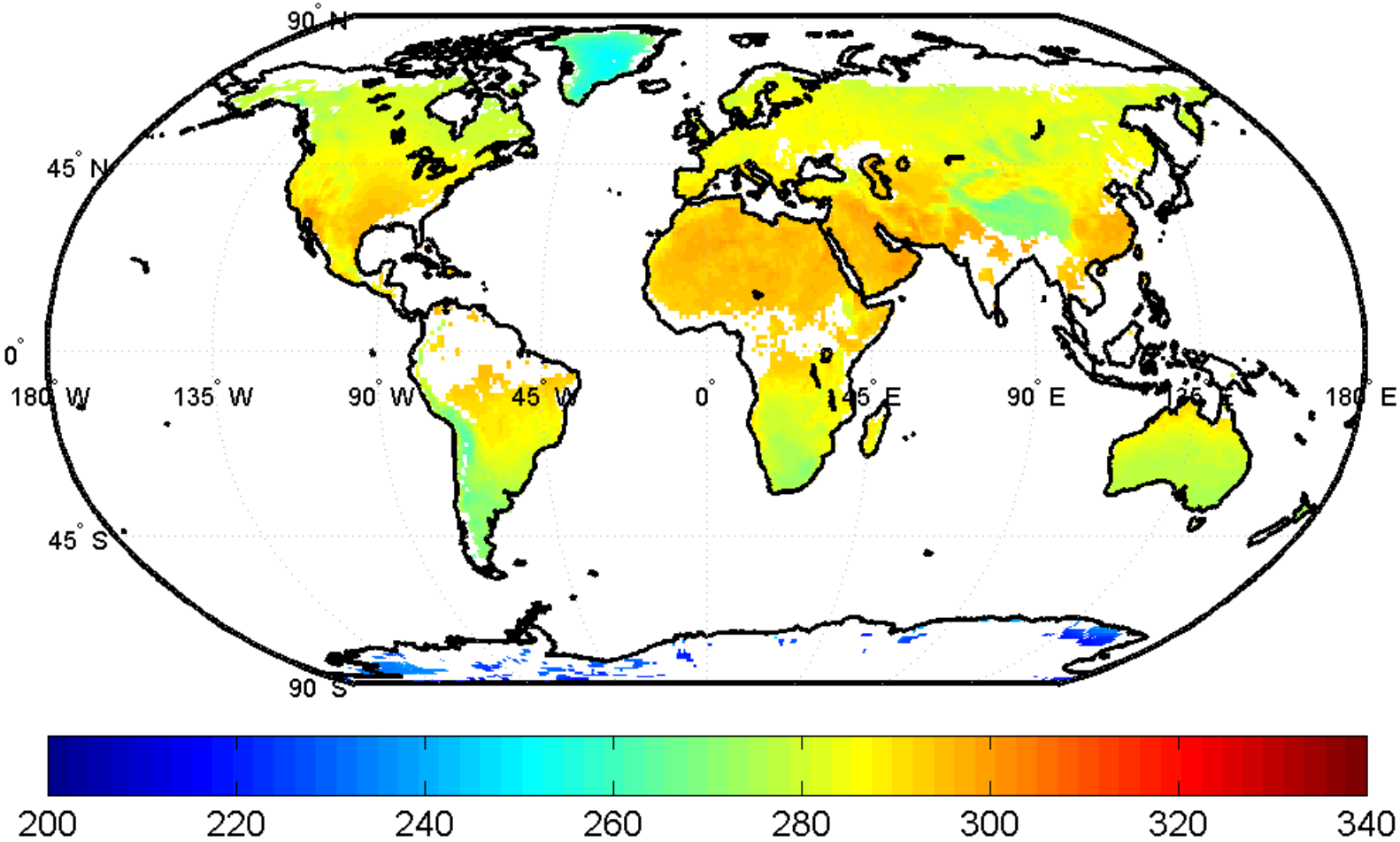
AIRS

Tskin
Night

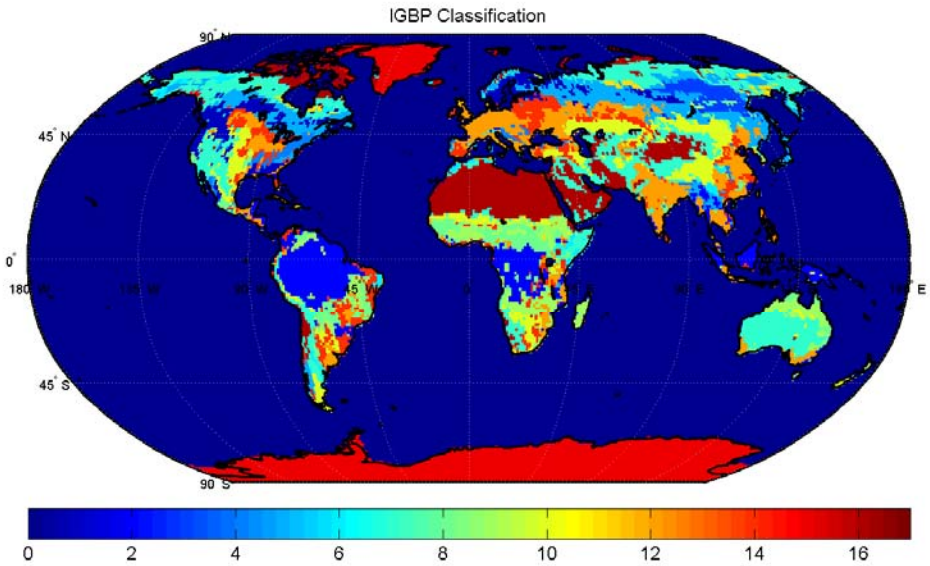


Mean 1 deg LST

MODIS NIGHT



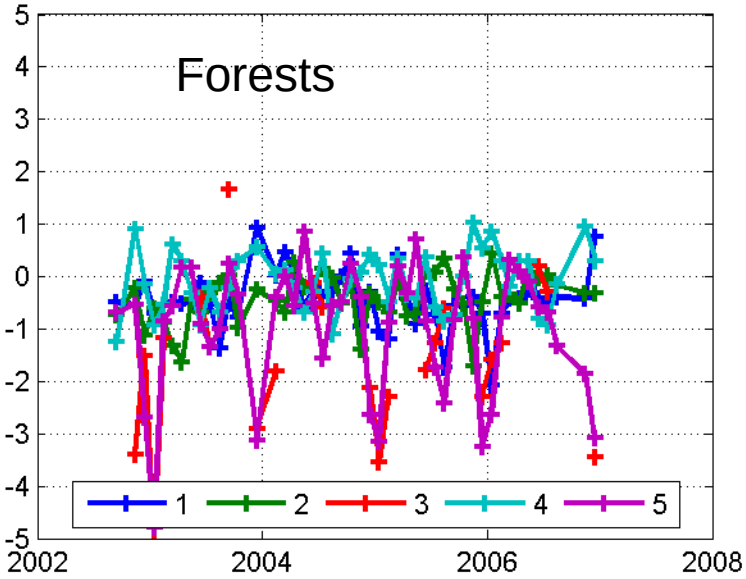
Use Land Classes (IGBP) to group the global data by land type for statistical analysis.



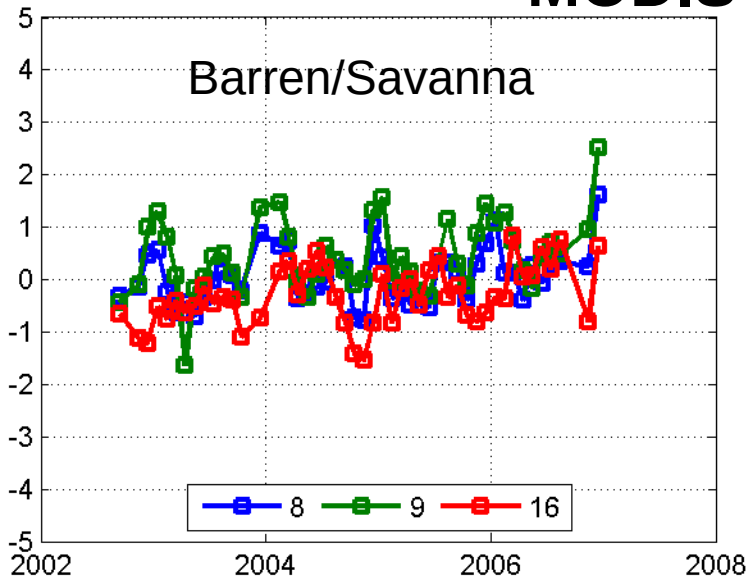
IGBP CLASS ID	IGBP CLASS Description
0	**Water Bodies**
1	**Evergreen Needleleaf Forest**
2	**Evergreen Broadleaf Forest**
3	**Deciduous Needleleaf Forest**
4	**Deciduous Broadleaf Forest**
5	**Mixed Forest**
6	**Closed Shrublands**
7	**Open Shrublands**
8	**Woody Savannas**
9	**Savannas**
10	**Grasslands**
11	**Permanent Wetlands**
12	**Croplands**
13	**Urban and Built-Up**
14	**Cropland/Natural Vegetation Mosaic**
15	**Snow and Ice**
16	**Barren or Sparsely Vegetated**
17	**Missing Data**

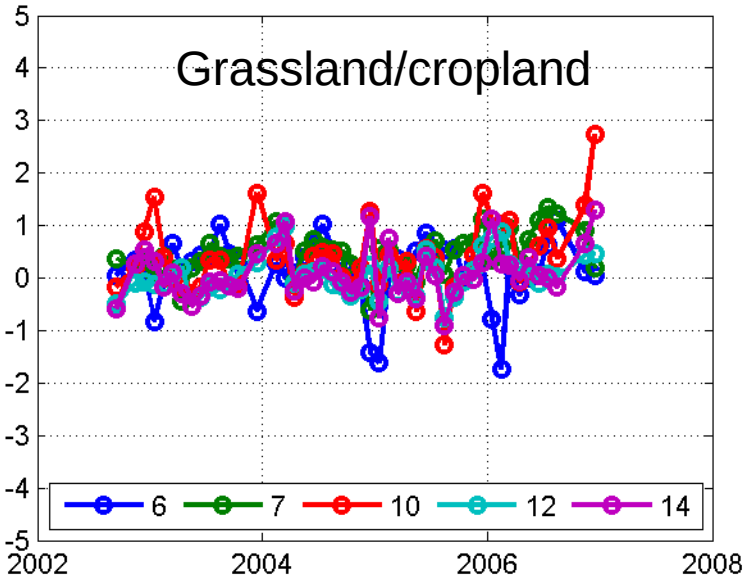
NIGHT

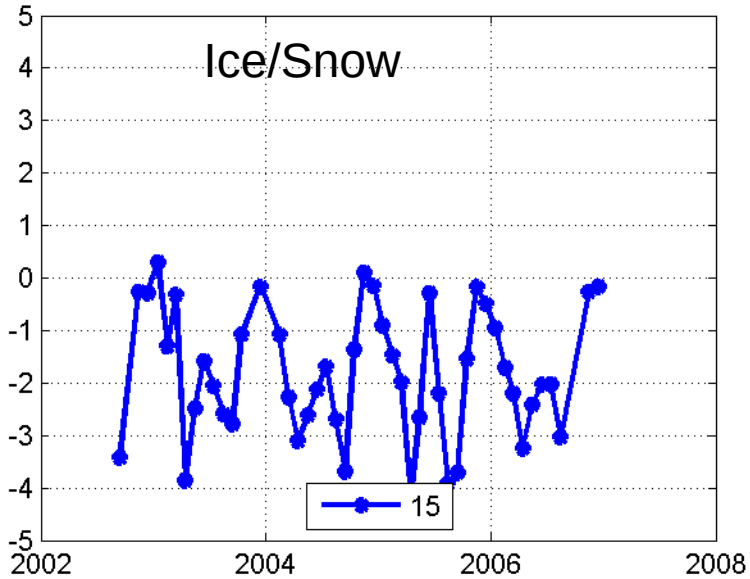
MODIS NIGHT minus AIRS(v5) NIGHT

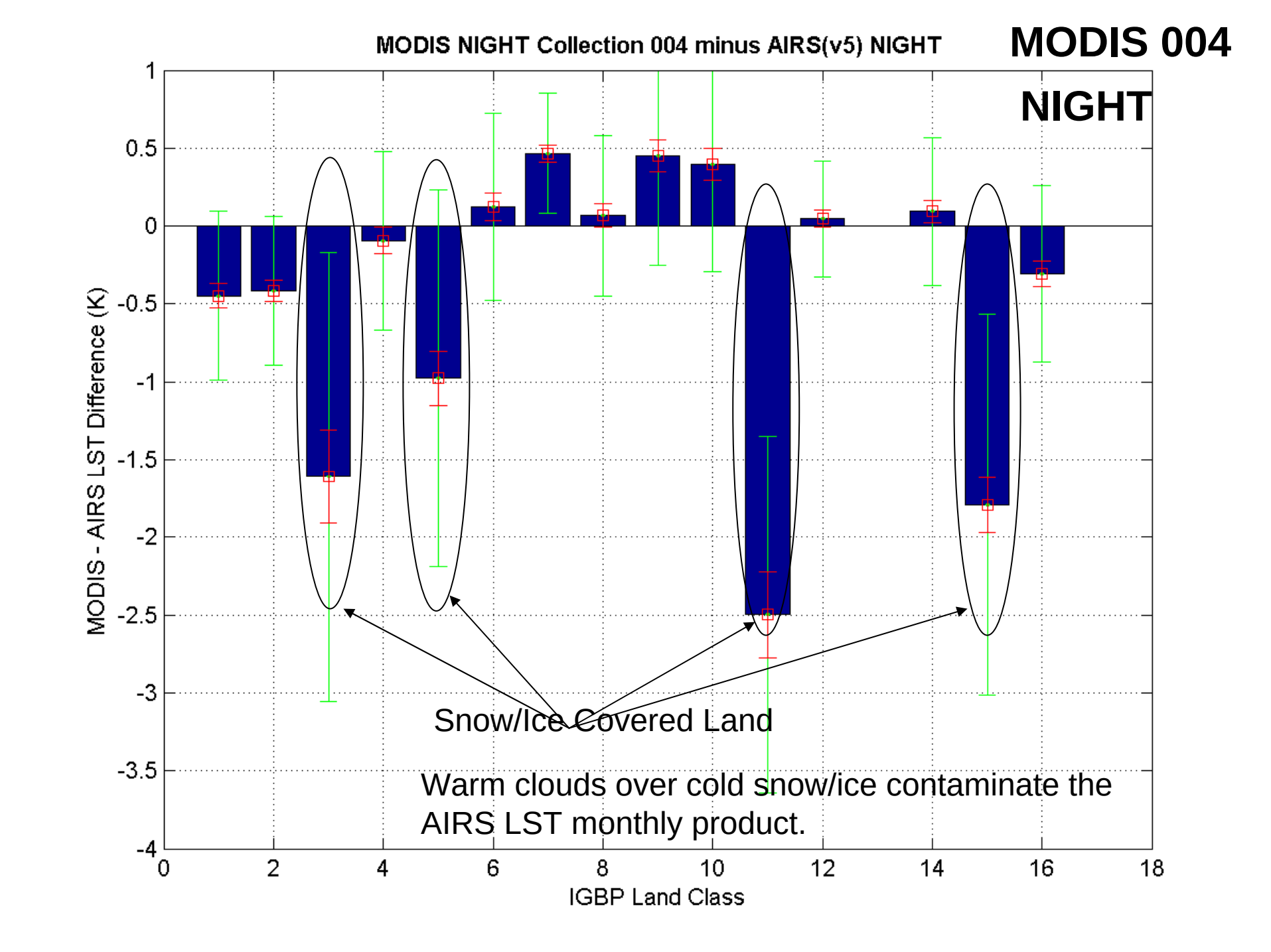


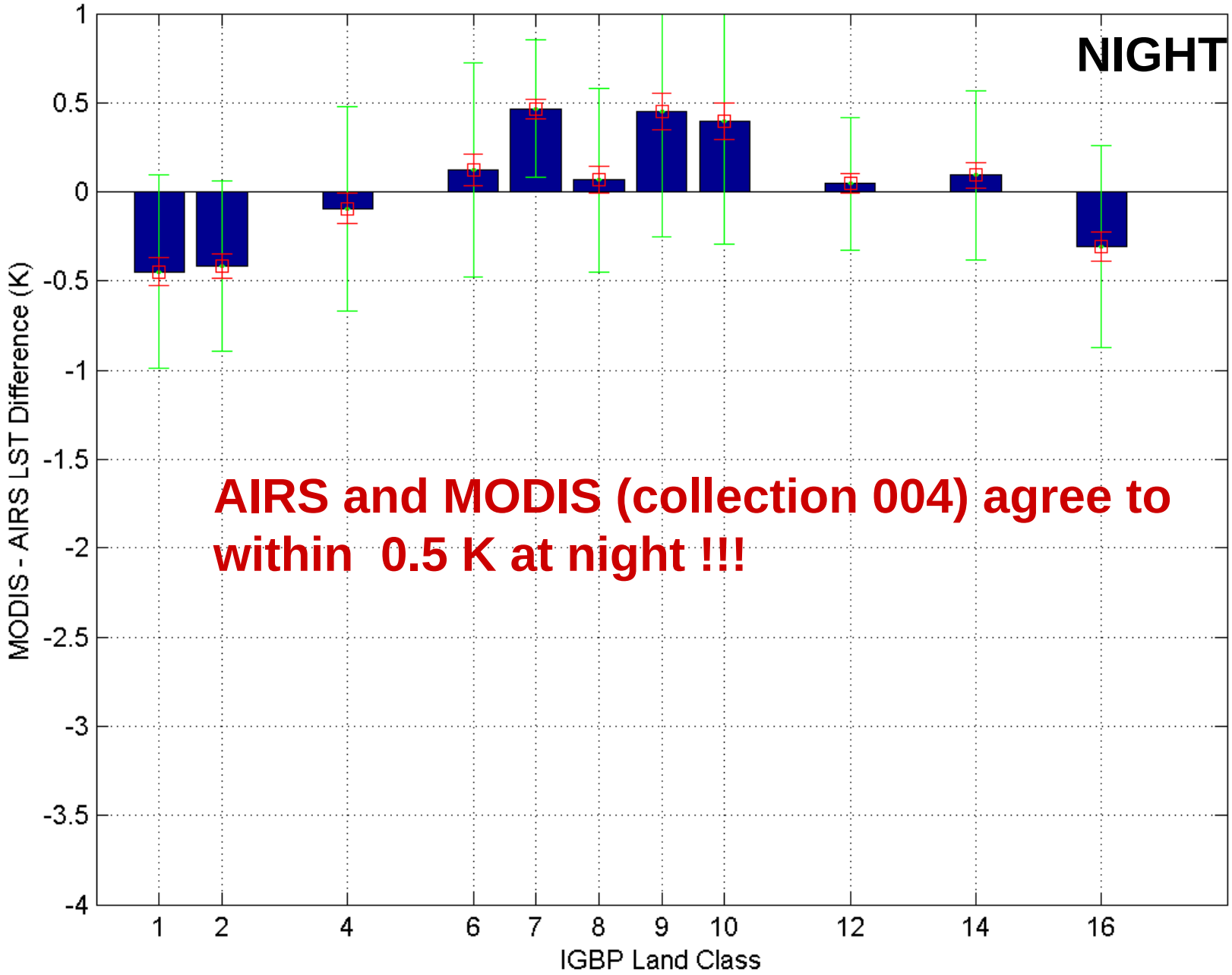
MODIS Collection 004 **MODIS 004**

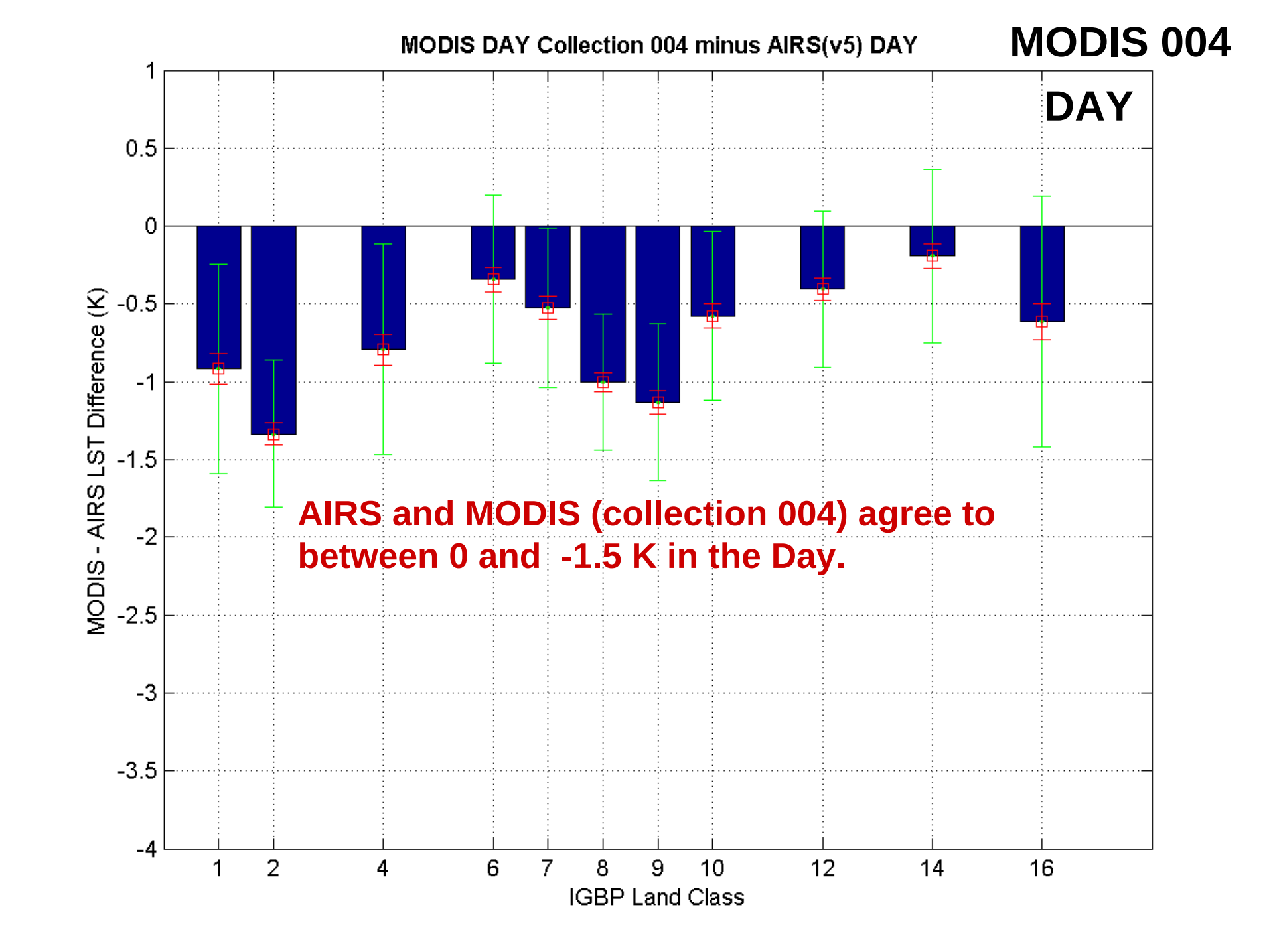


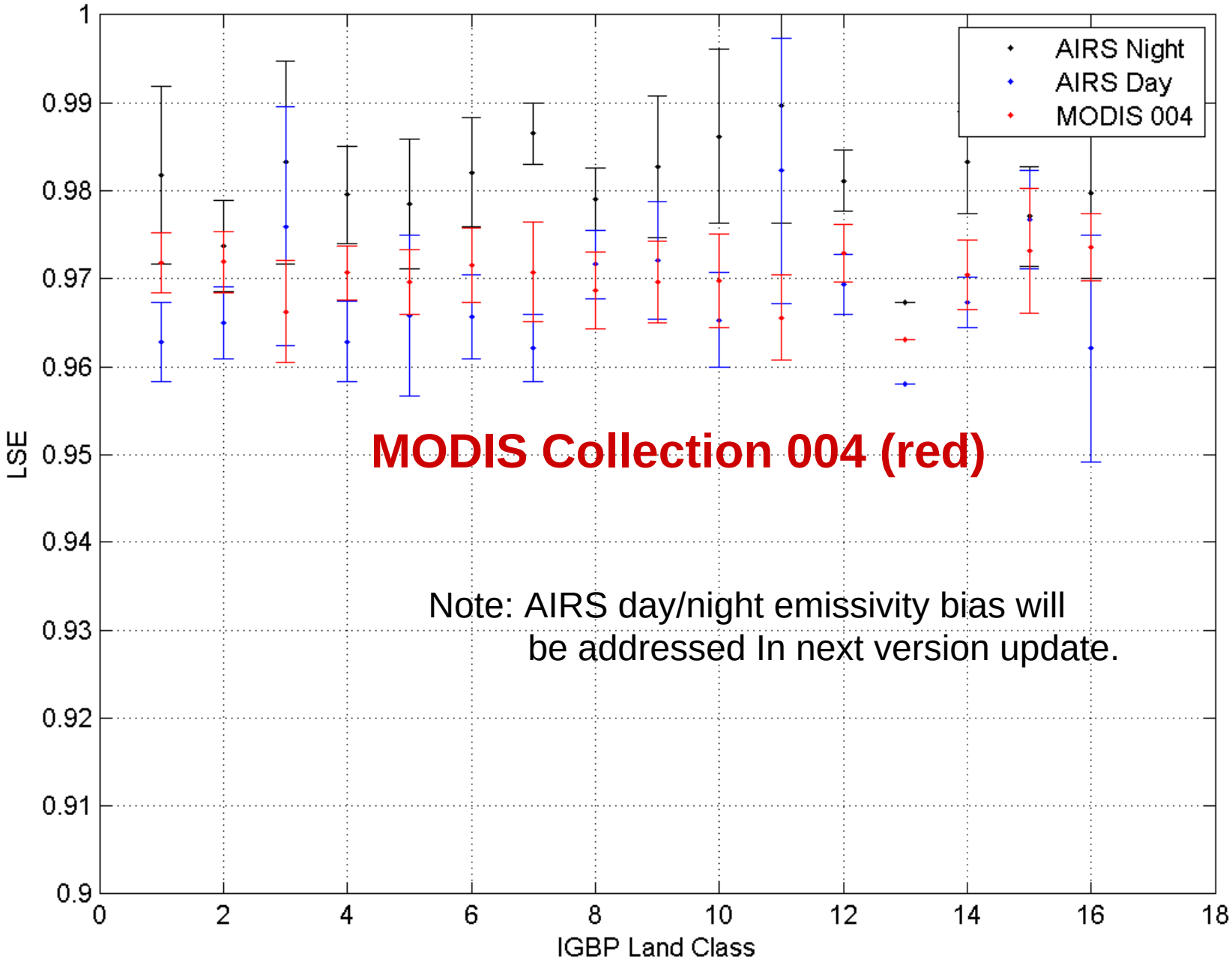





MODIS NIGHT Collection 004 minus AIRS(v5) NIGHT
MODIS 004
NIGHT
MODIS - AIRS LST Difference (K)
IGBP Land Class
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
0
2
4
6
8
10
12
14
16
18
Snow/Ice Covered Land
Warm clouds over cold snow/ice contaminate the AIRS LST monthly product.


MODIS NIGHT Collection 004 minus AIRS(v5) NIGHT
MODIS 004
NIGHT
MODIS - AIRS LST Difference (K)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
4
6
7
8
9
10
12
14
16
IGBP Land Class
AIRS and MODIS (collection 004) agree to within 0.5 K at night !!!


MODIS DAY Collection 004 minus AIRS(v5) DAY
MODIS 004
DAY
MODIS - AIRS LST Difference (K)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1
2
4
6
7
8
9
10
12
14
16
IGBP Land Class
AIRS and MODIS (collection 004) agree to between 0 and -1.5 K in the Day.

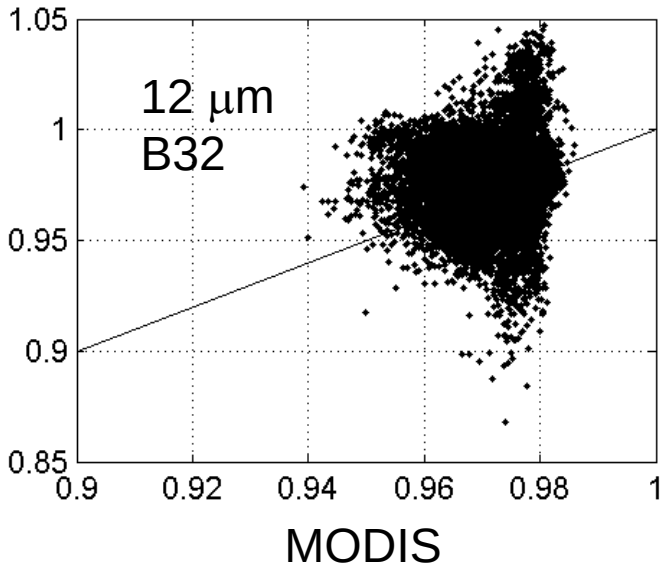

AIRS Night
AIRS Day
MODIS 004
MODIS Collection 004 (red)
Note: AIRS day/night emissivity bias will be addressed In next version update.
LSE
IGBP Land Class
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0
2
4
6
8
10
12
14
16
18

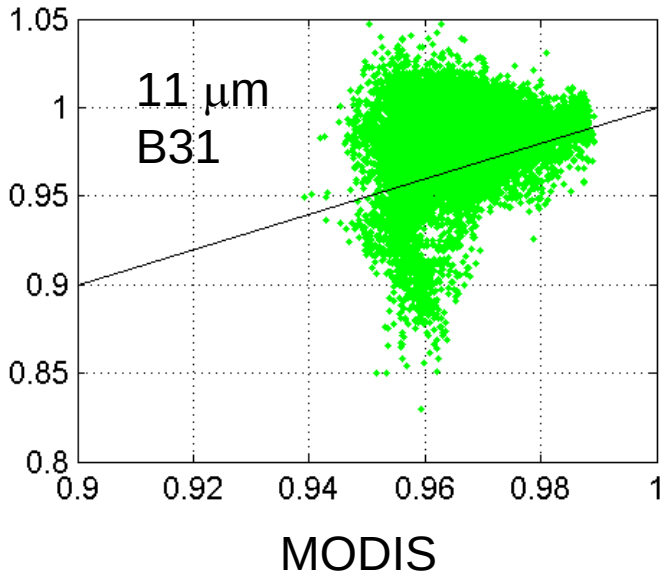
MODIS 004

NIGHT

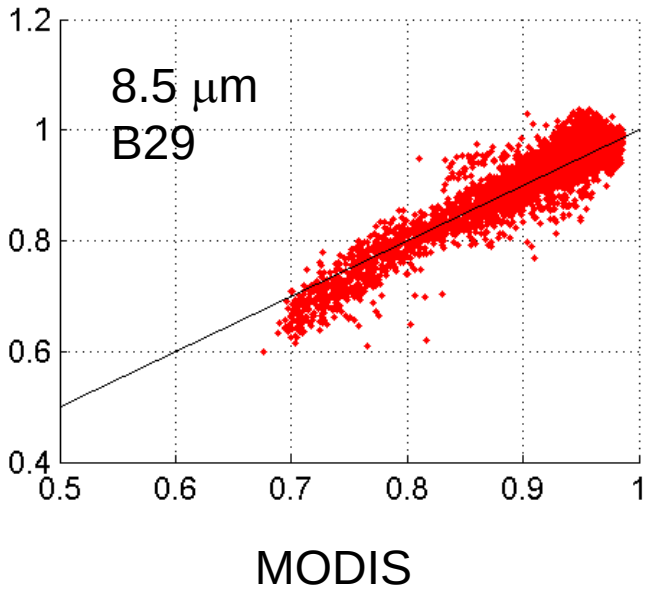
Single Month

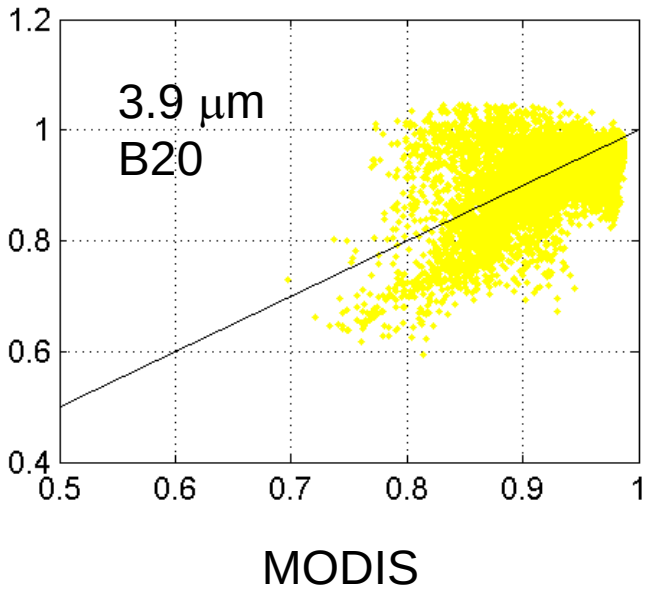
AIRS





AIRS





Summary: AIRS vs MODIS LST

1. Observed window brightness temperatures between AIRS and MODIS agree to < 0.2 K indicating good absolute calibration.

2. For Land Surface Skin Temperature the MODIS collection 004 Clear Day/Night algorithm and AIRS (version 5) cloud-cleared multi-channel regression retrieval agree to within 0.5 K at night (!!!) [excluding snow/ice covered land] and between 0 and -1.5 K during the day. I think is this is quite good agreement considering the difficulty of the problem although there are improvements that can be made.

3. The fact that biases can be assessed through a comparison of AIRS and MODIS suggests that a **continuous comparison of imager and sounder LST products** will be a useful quality check on future operational algorithms.

Validation of AIRS & IASI Total Precipitable Water Vapor at the ARM Southern Great Plains Site

Robert Knuteson,
Sarah Bedka, Hank Revercomb,
Dave Tobin, Dave Turner

University of Wisconsin-Madison

15 September 2008

Topics

- What are the current biases for AIRS and IASI L2 products?

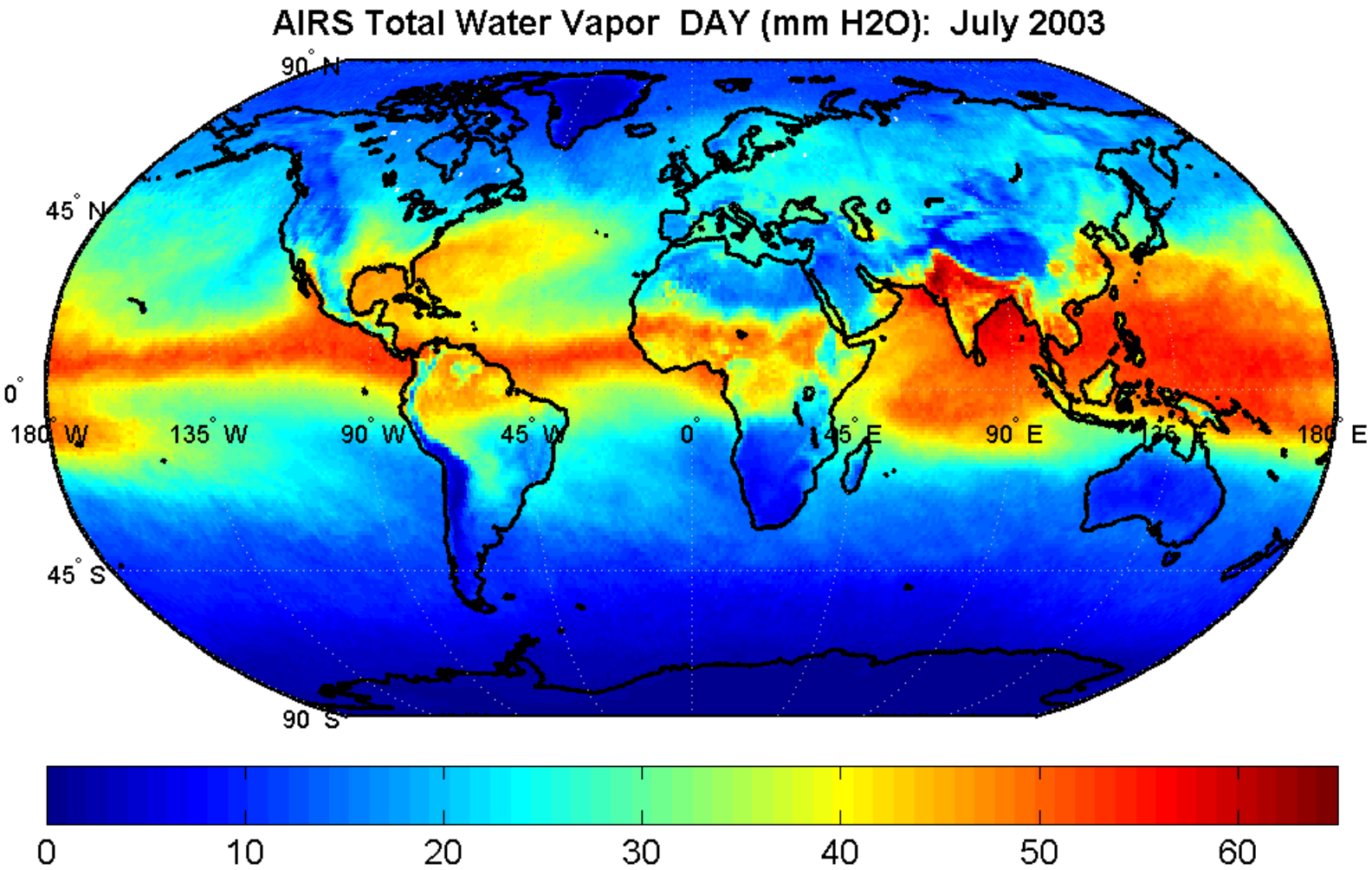
- Are AIRS and/or IASI L2 products of climate quality or do we need to do better? If so then how?

- Water vapor is the primary greenhouse gas, we look at the total column water vapor as a metric for the water vapor absolute accuracy.

AIRS

EOS AQUA Water Vapor

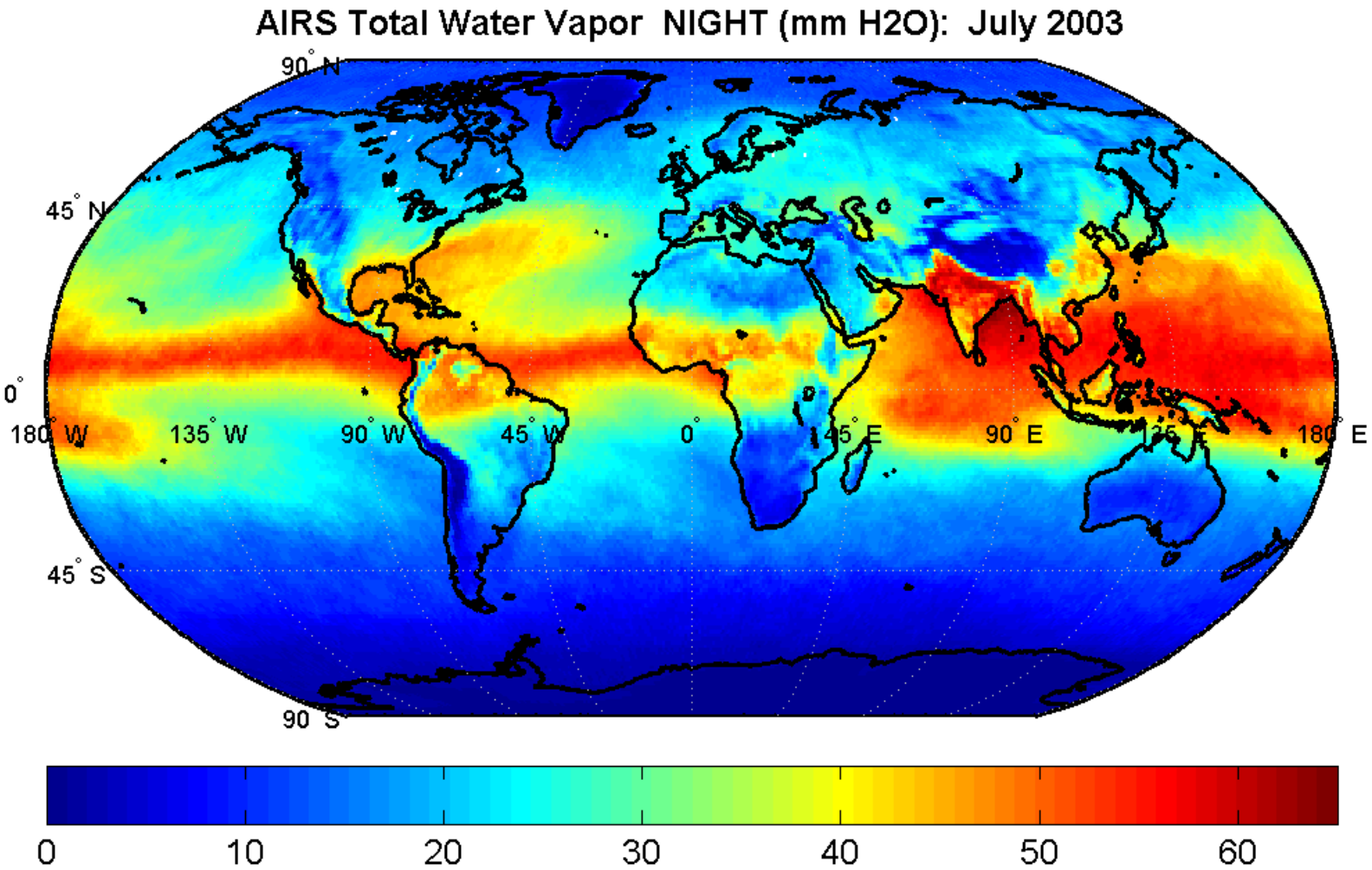
PWV Day



- This is monthly average but AIRS provides nearly complete daily coverage.

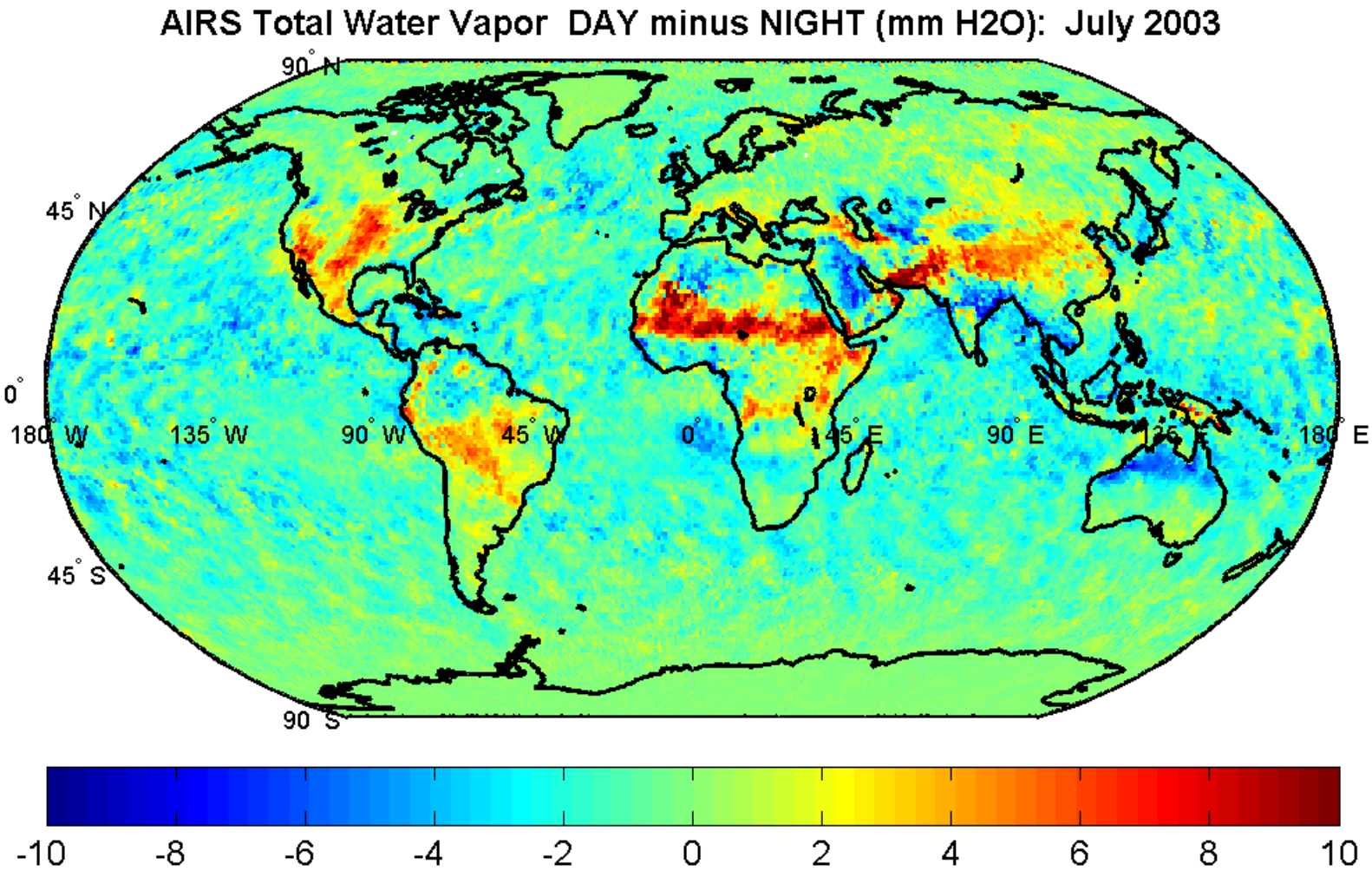
AIRS

PWV
Night



AIRS

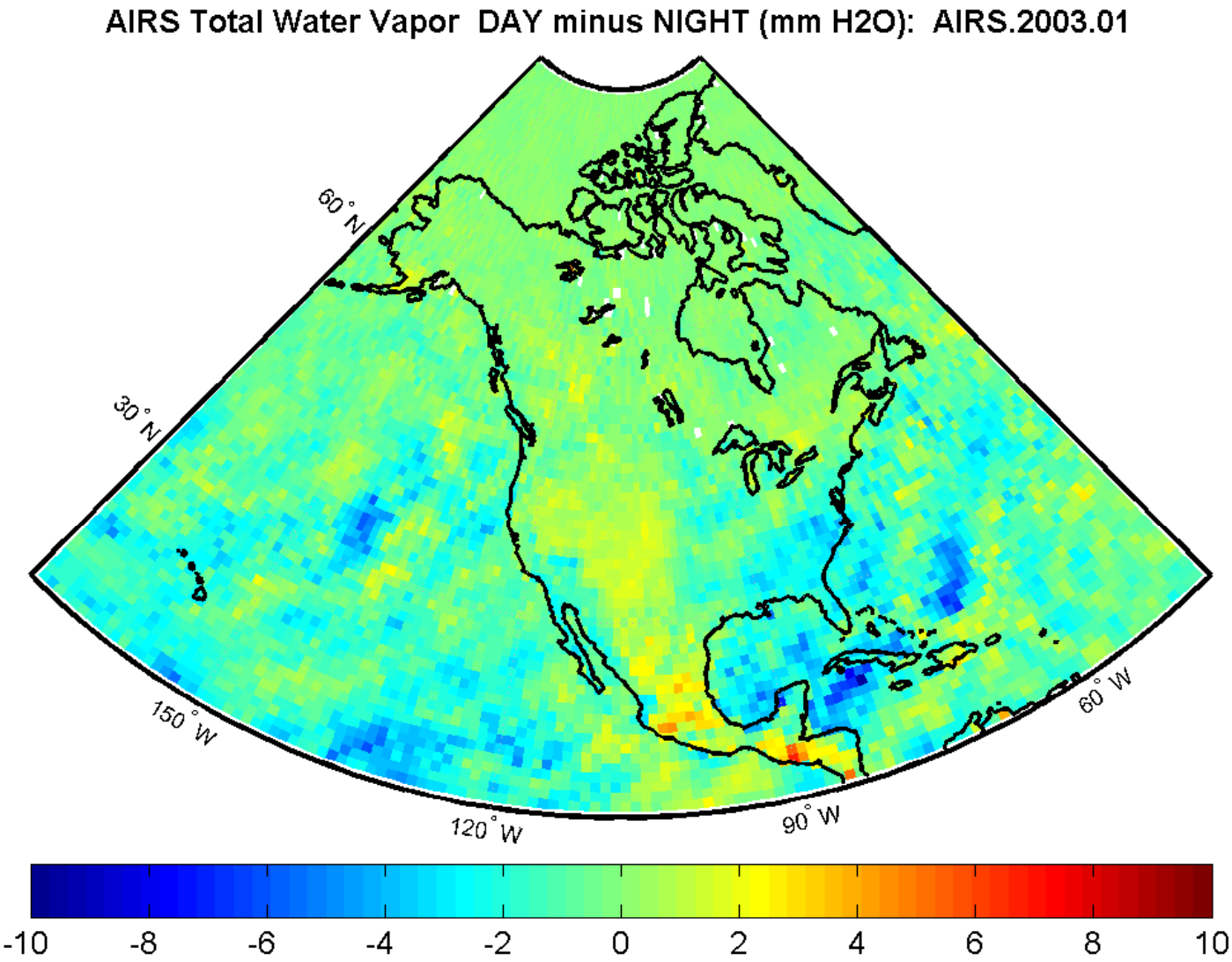
PWV
Day - Night



- Are Day/Night Total Water Vapor Retrievals impacted by surface?

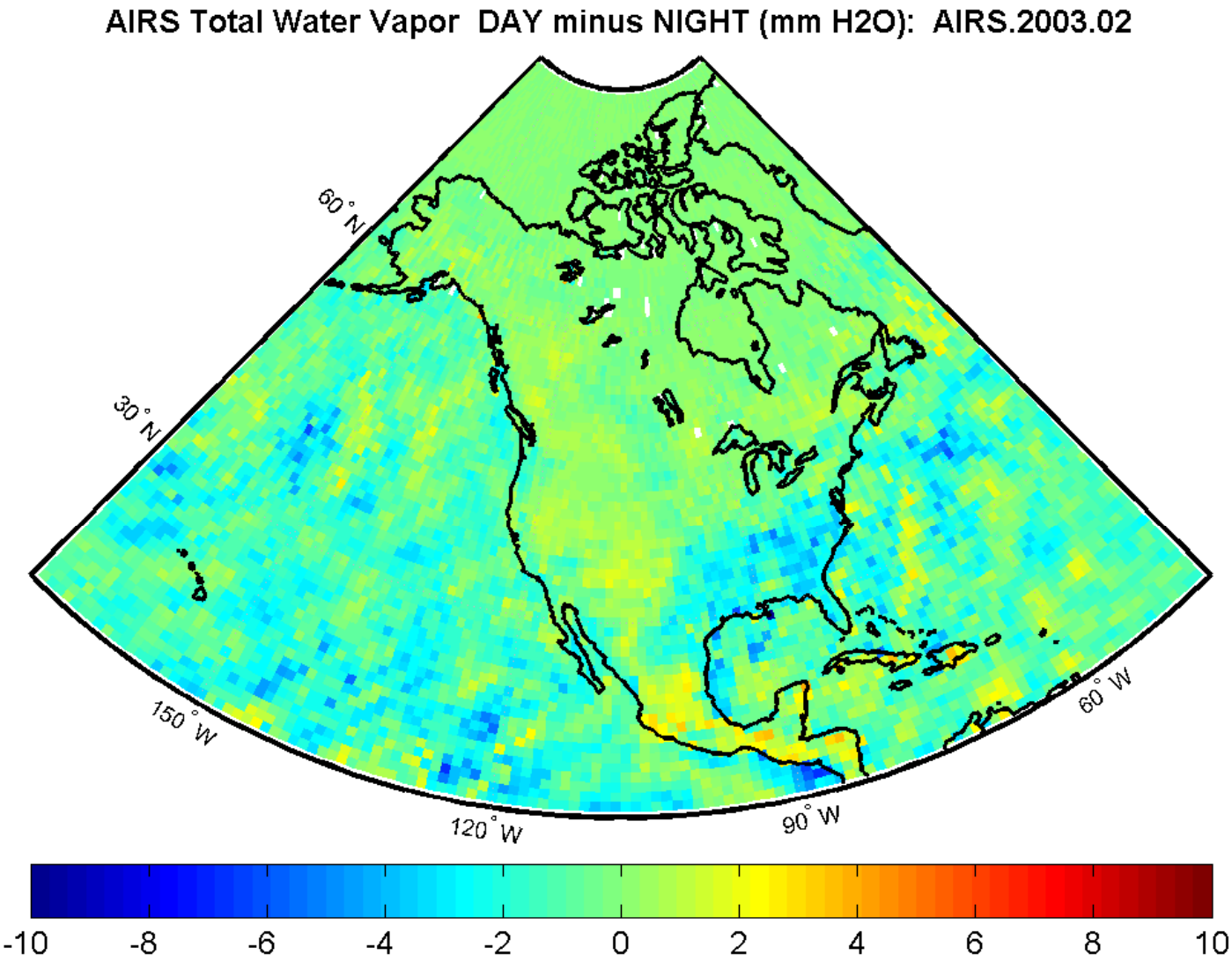
AIRS

PWV
Day - Night



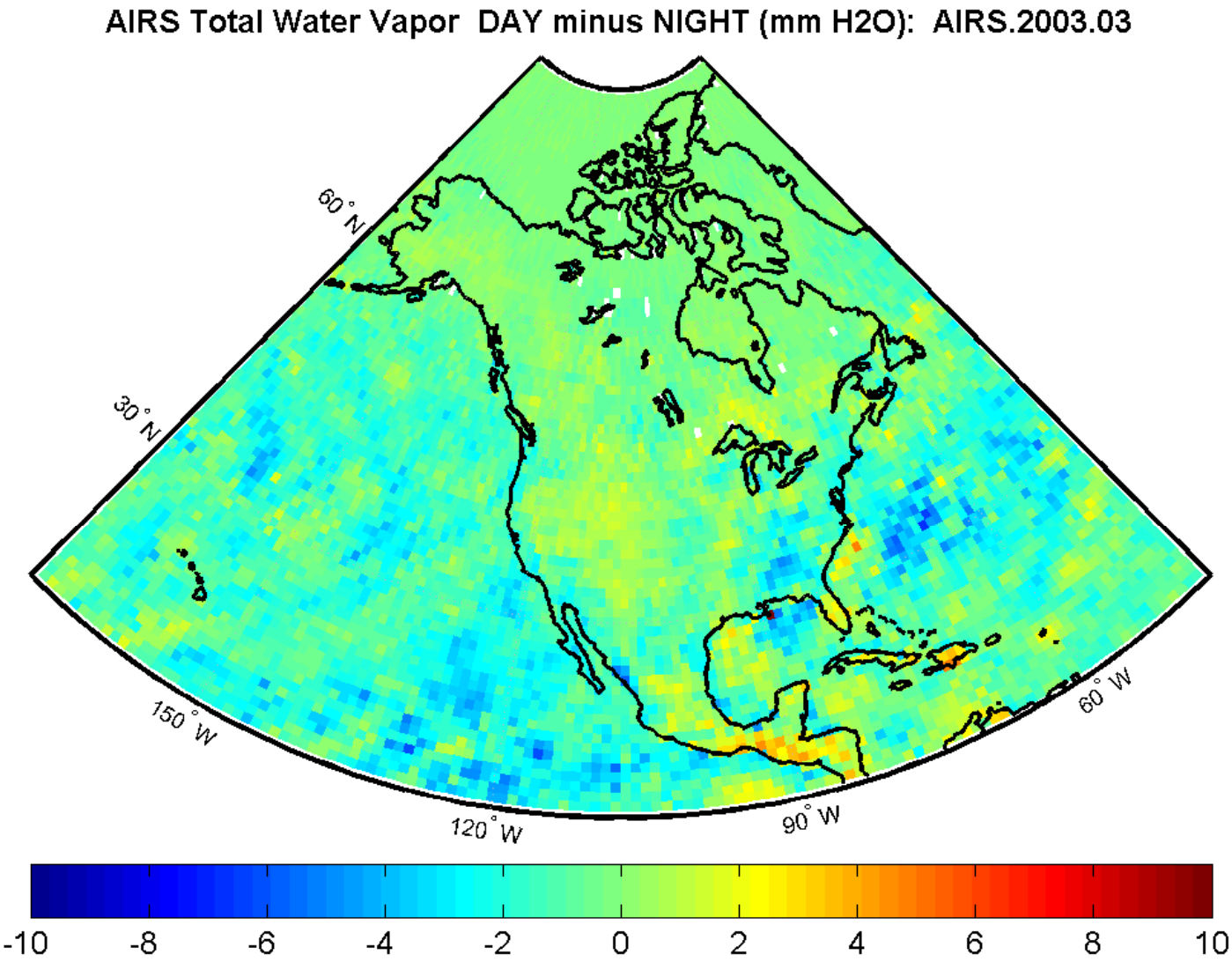
AIRS

PWV
Day - Night



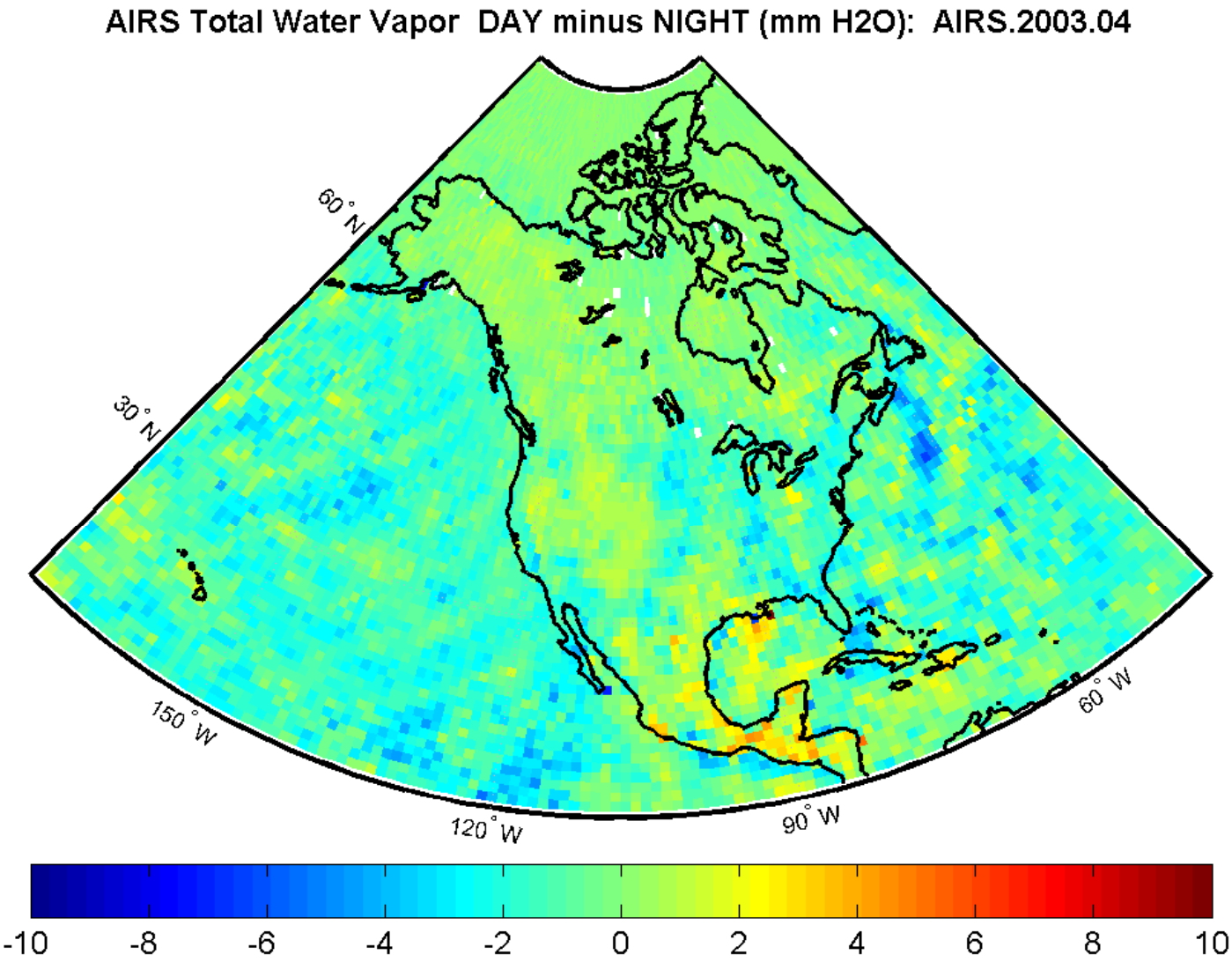
AIRS

PWV
Day - Night



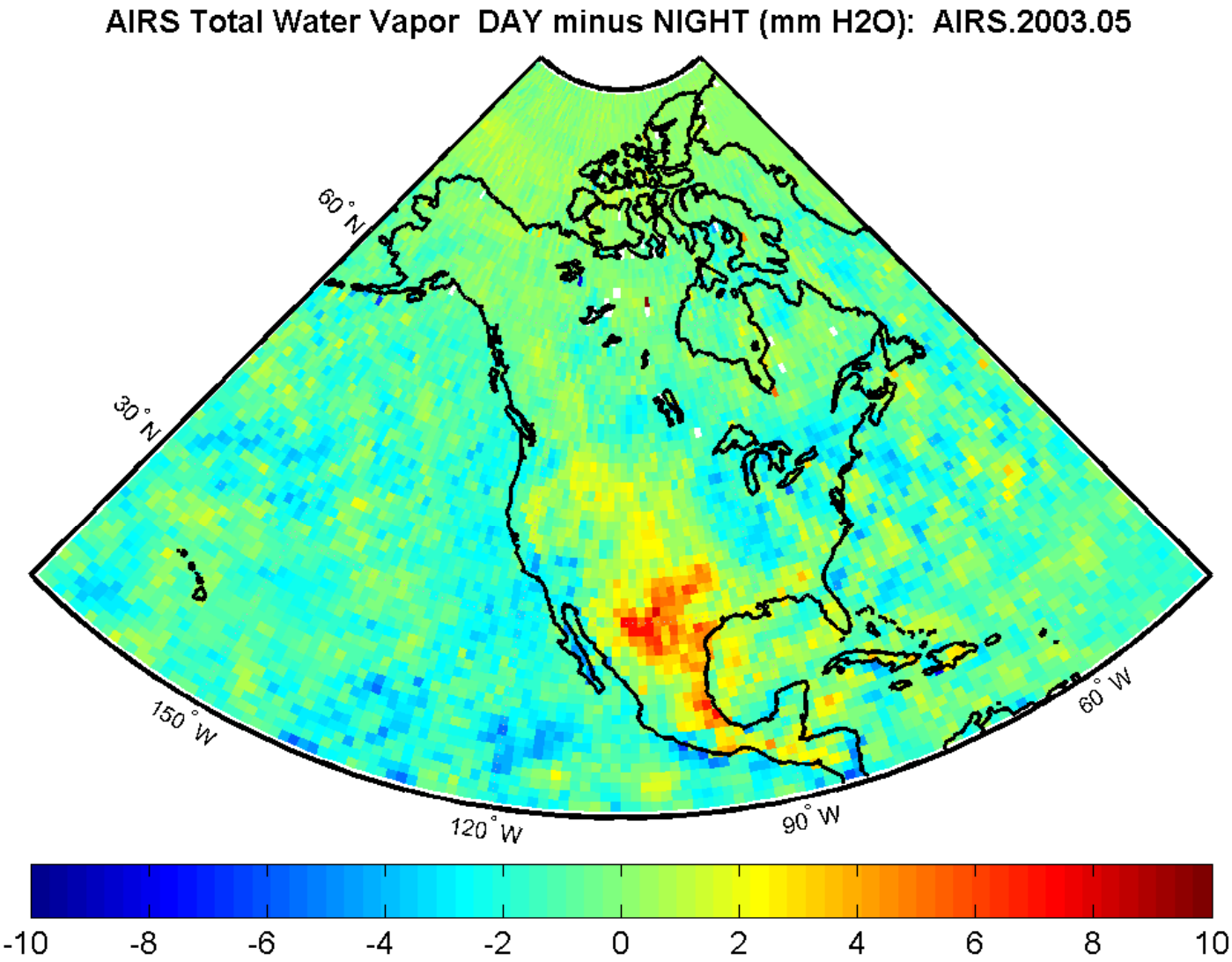
AIRS

PWV
Day - Night



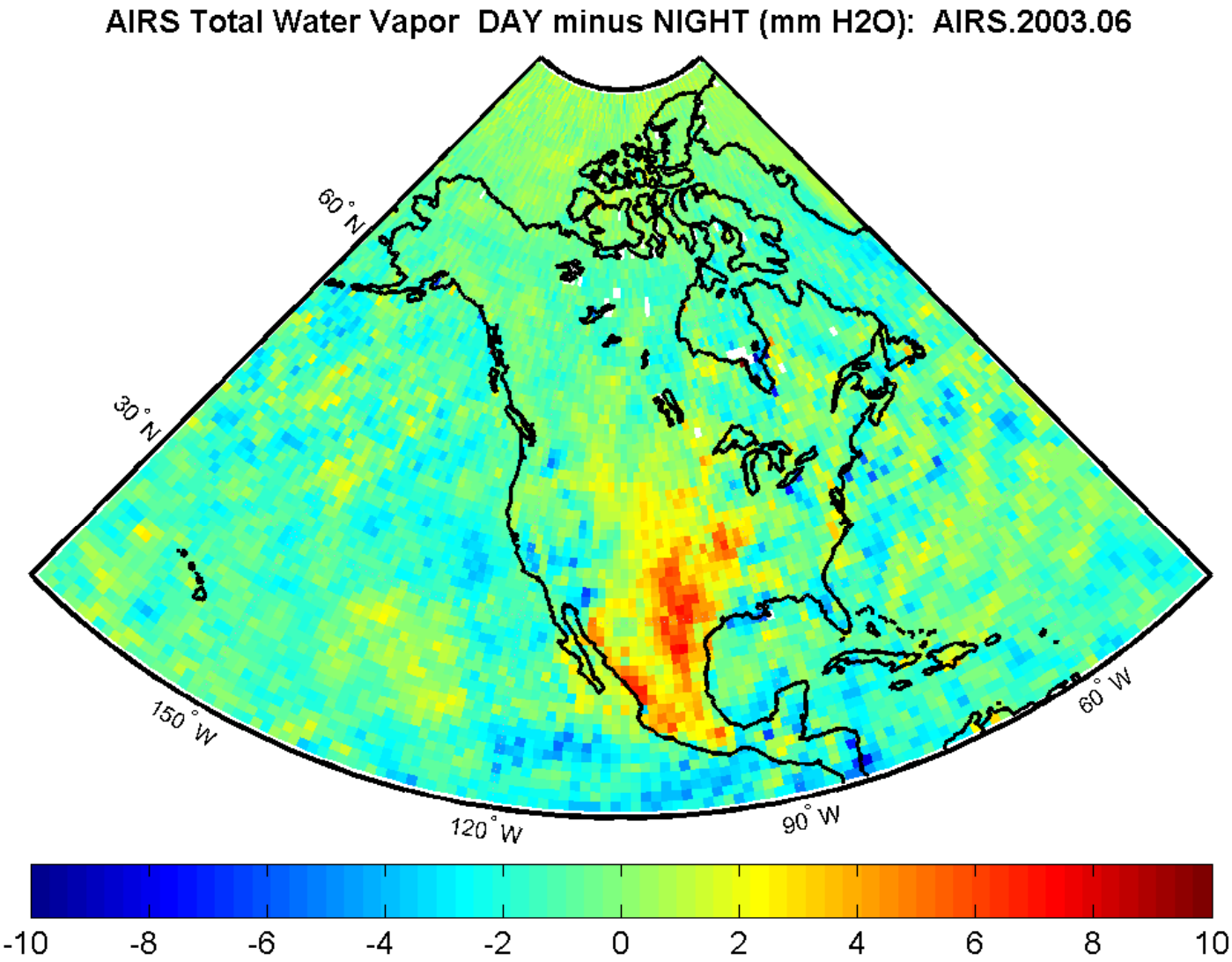
AIRS

PWV
Day - Night



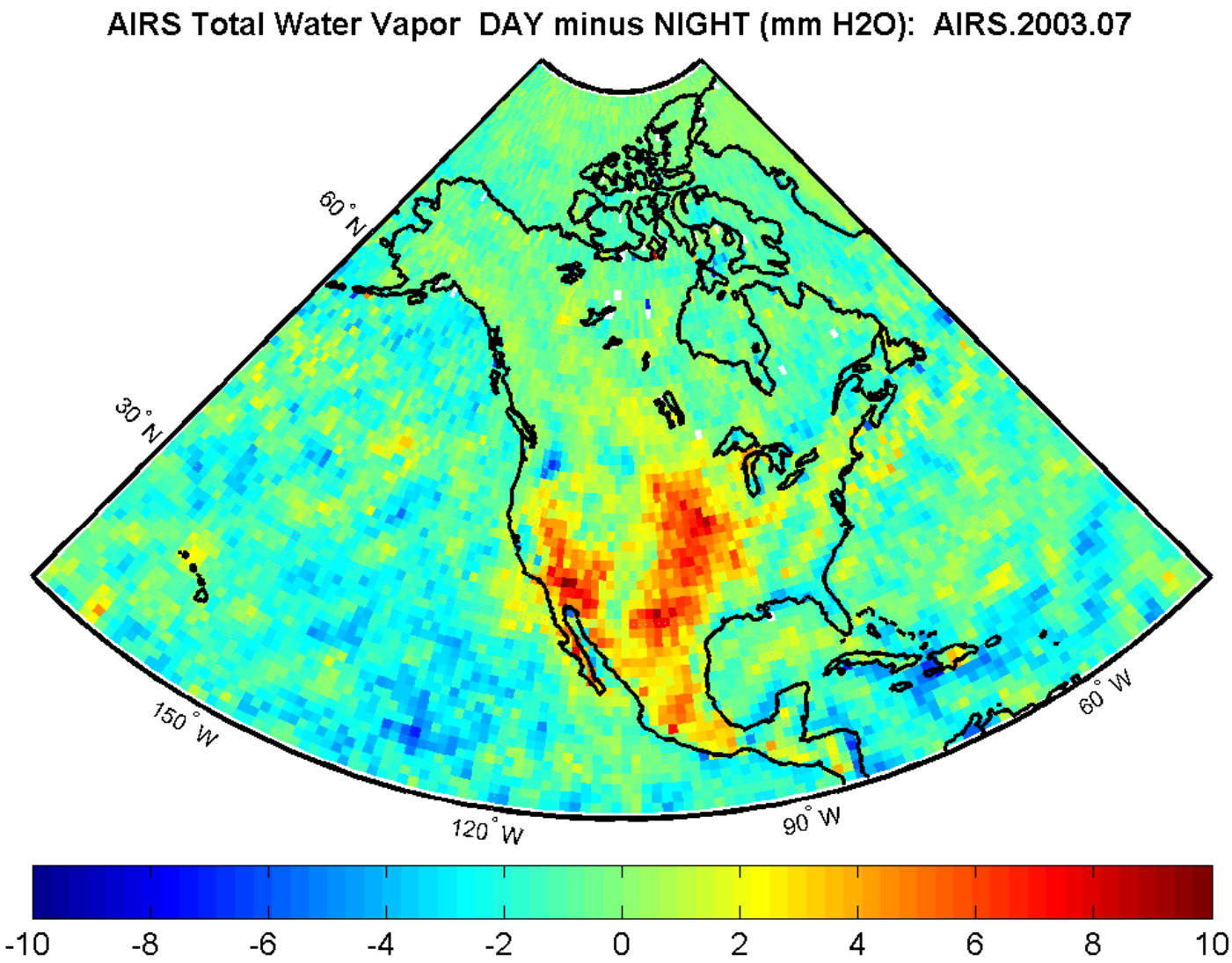
AIRS

PWV
Day - Night



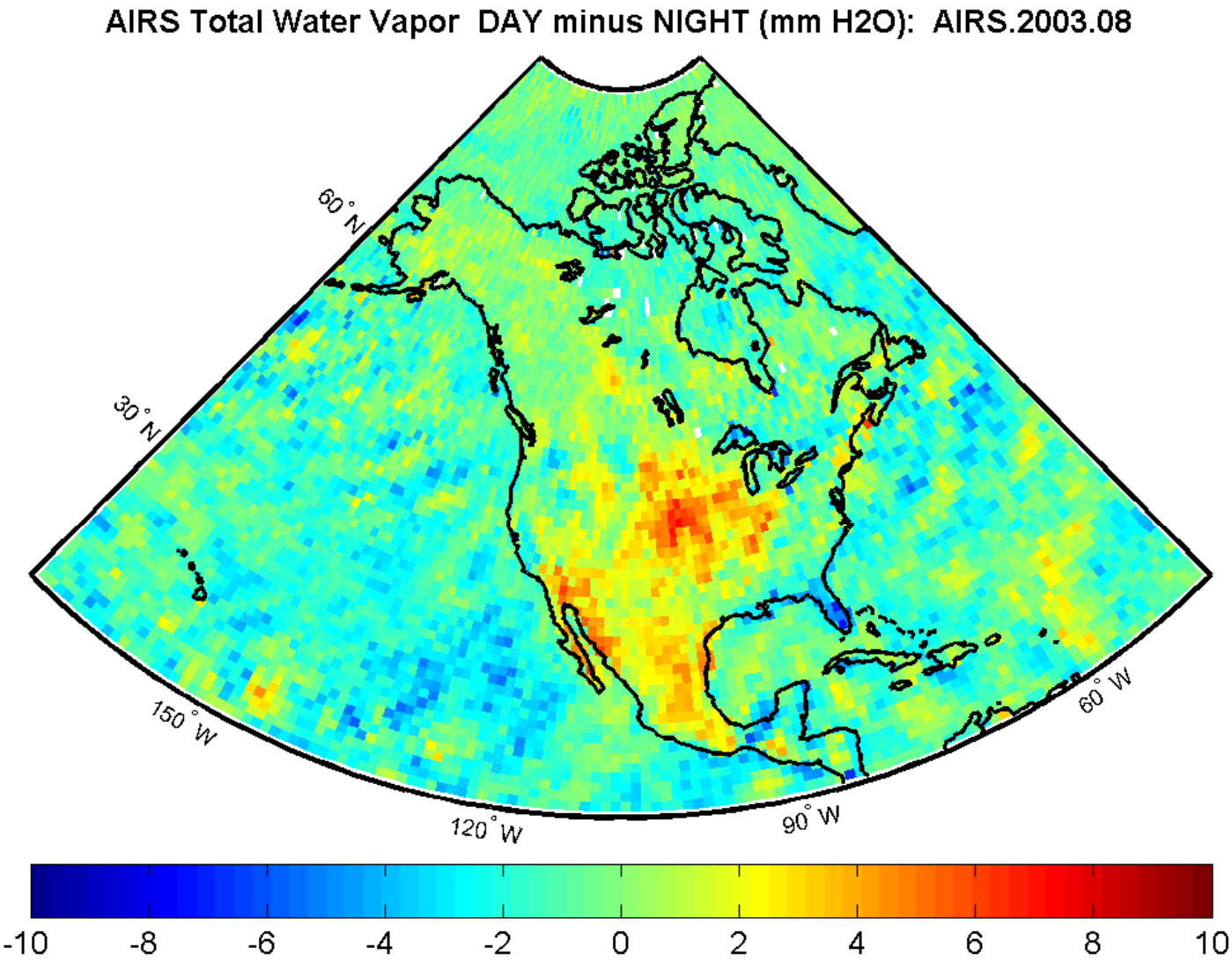
AIRS

PWV
Day - Night



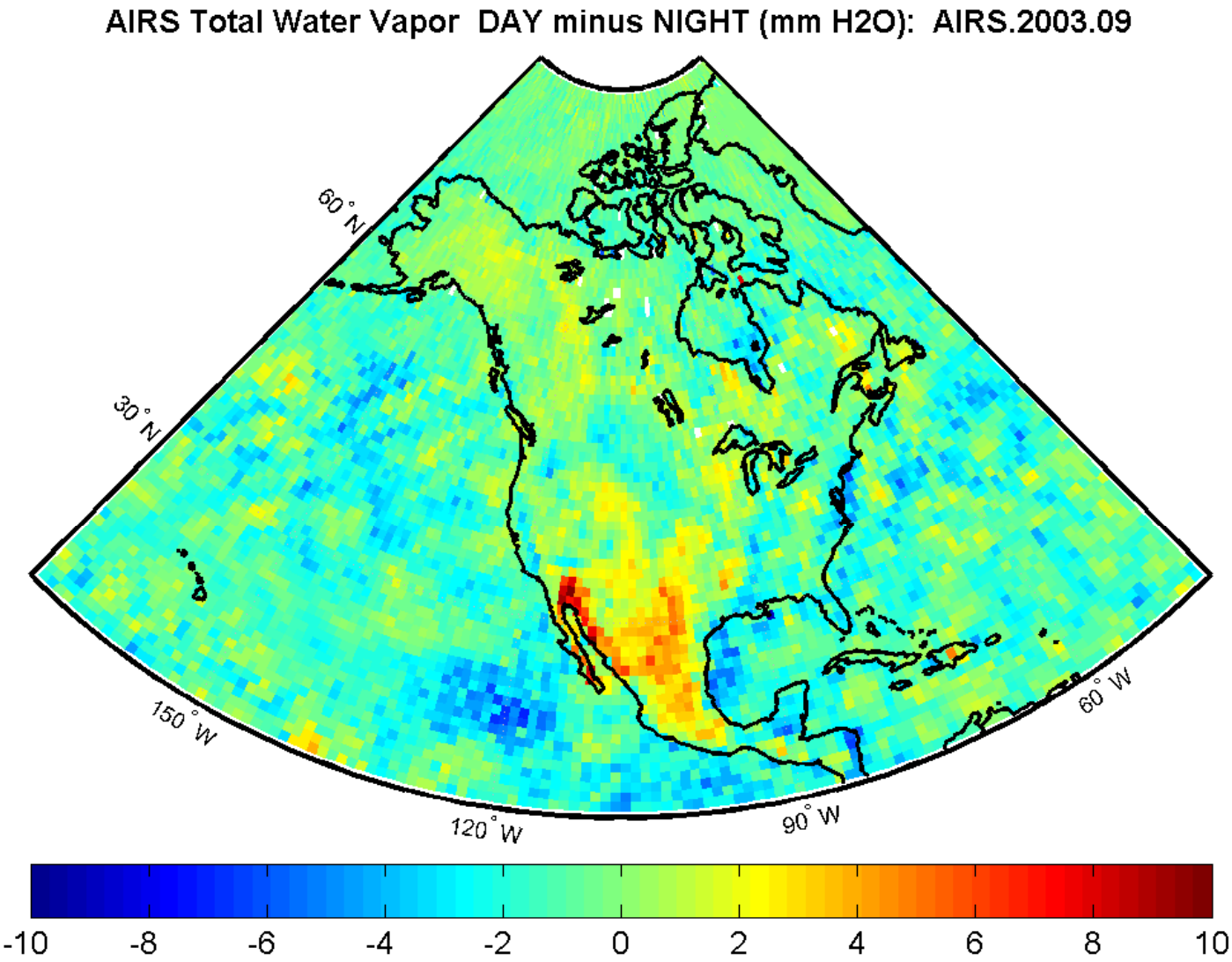
AIRS

PWV
Day - Night



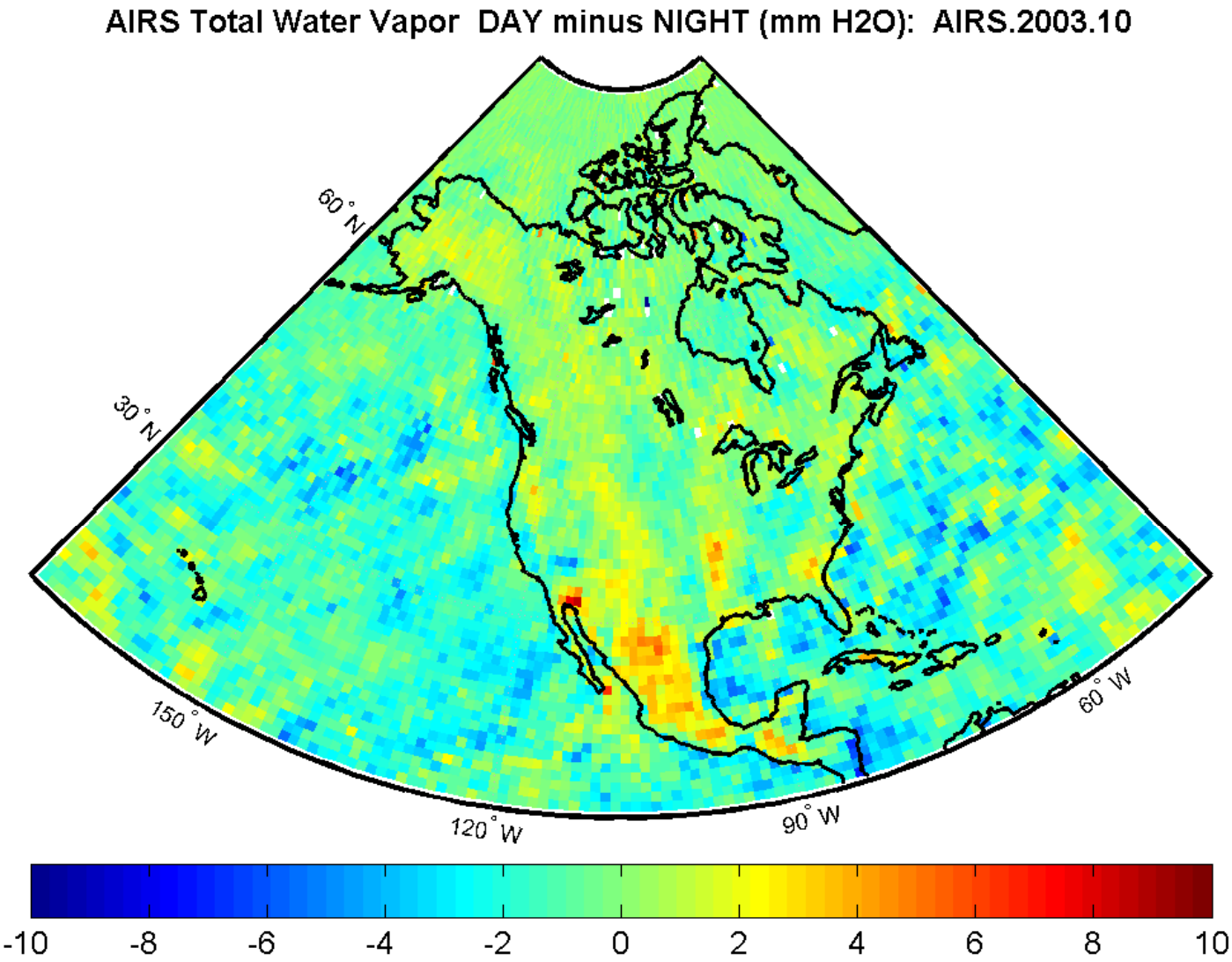
AIRS

PWV
Day - Night



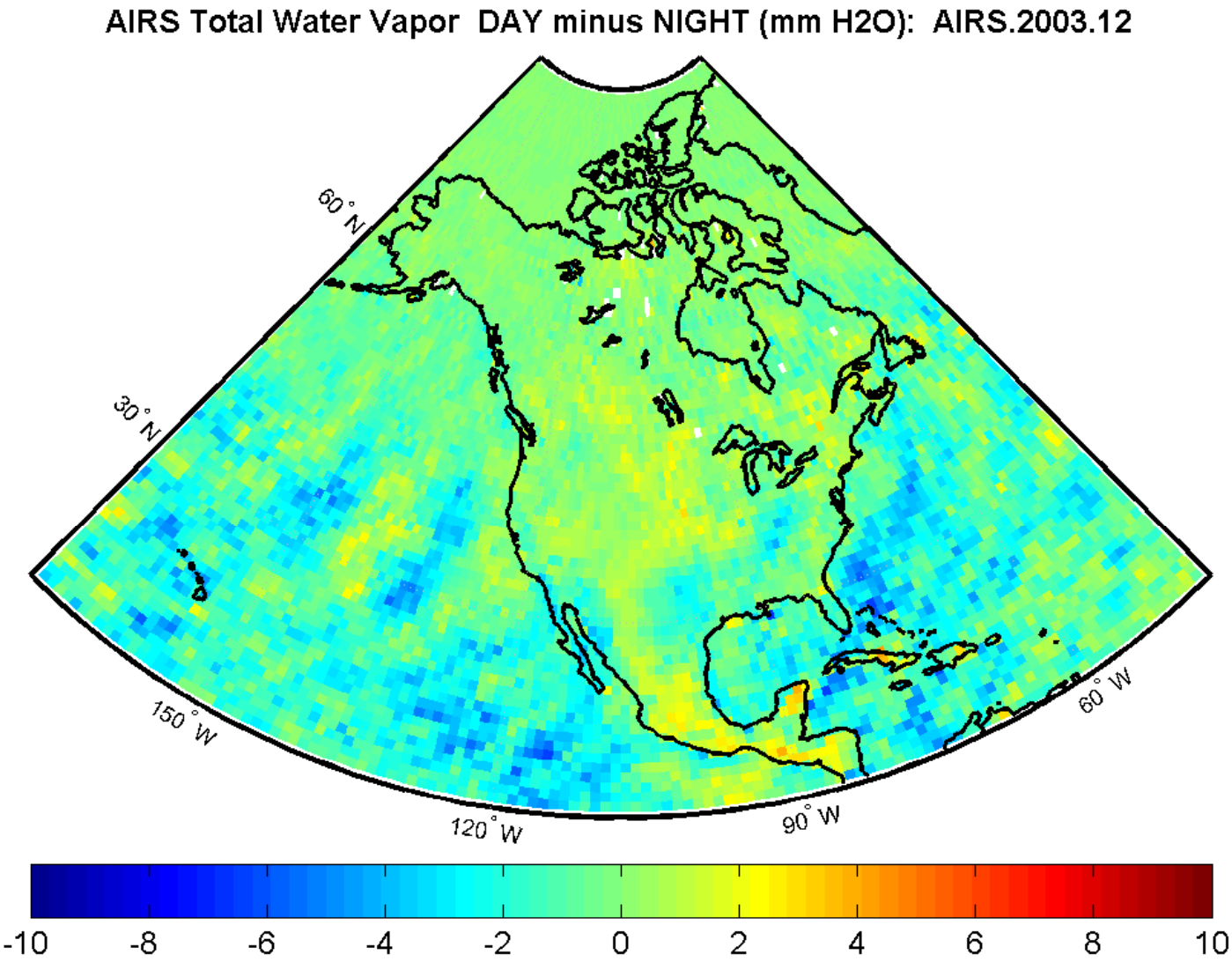
AIRS

PWV
Day - Night



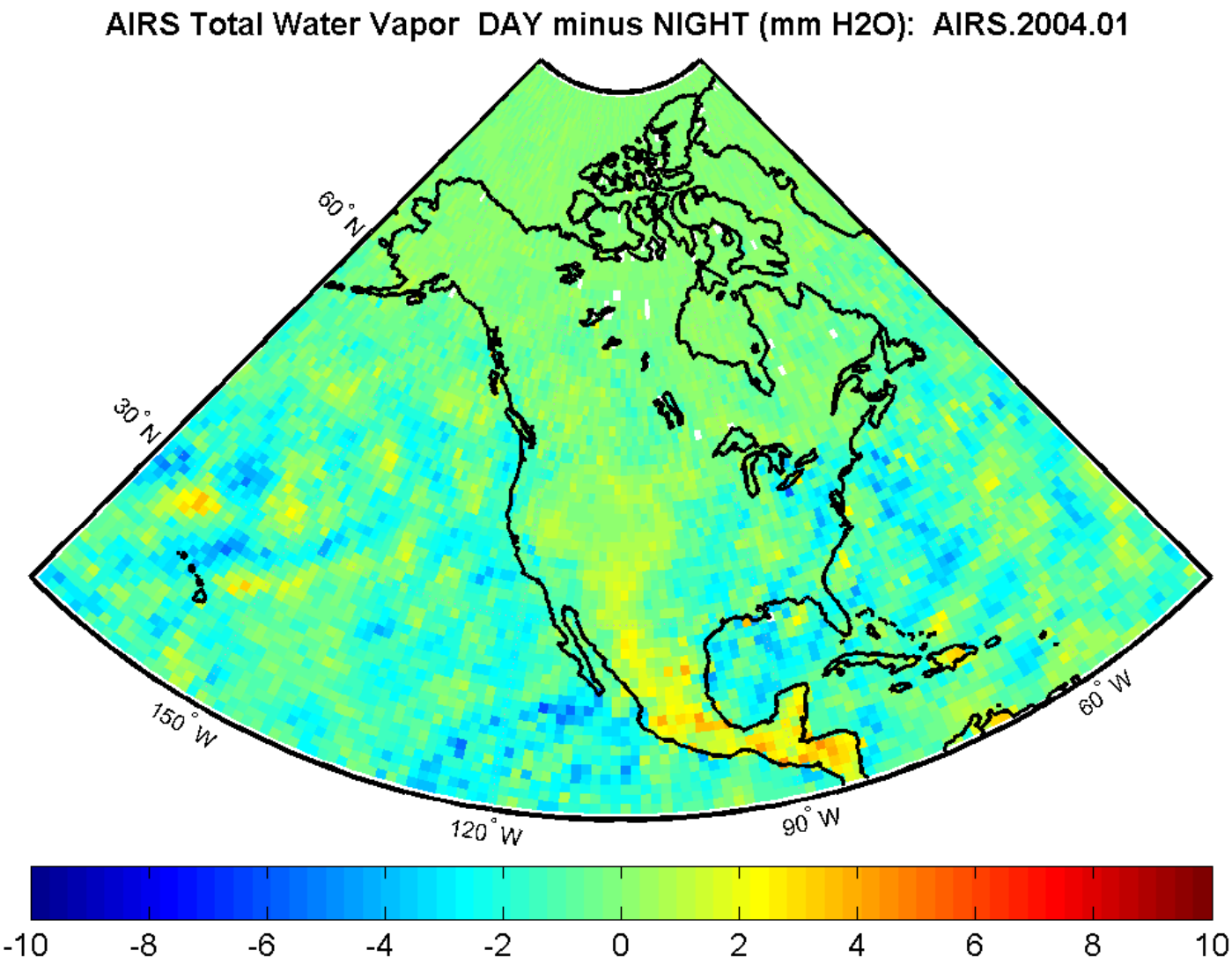
AIRS

PWV
Day - Night



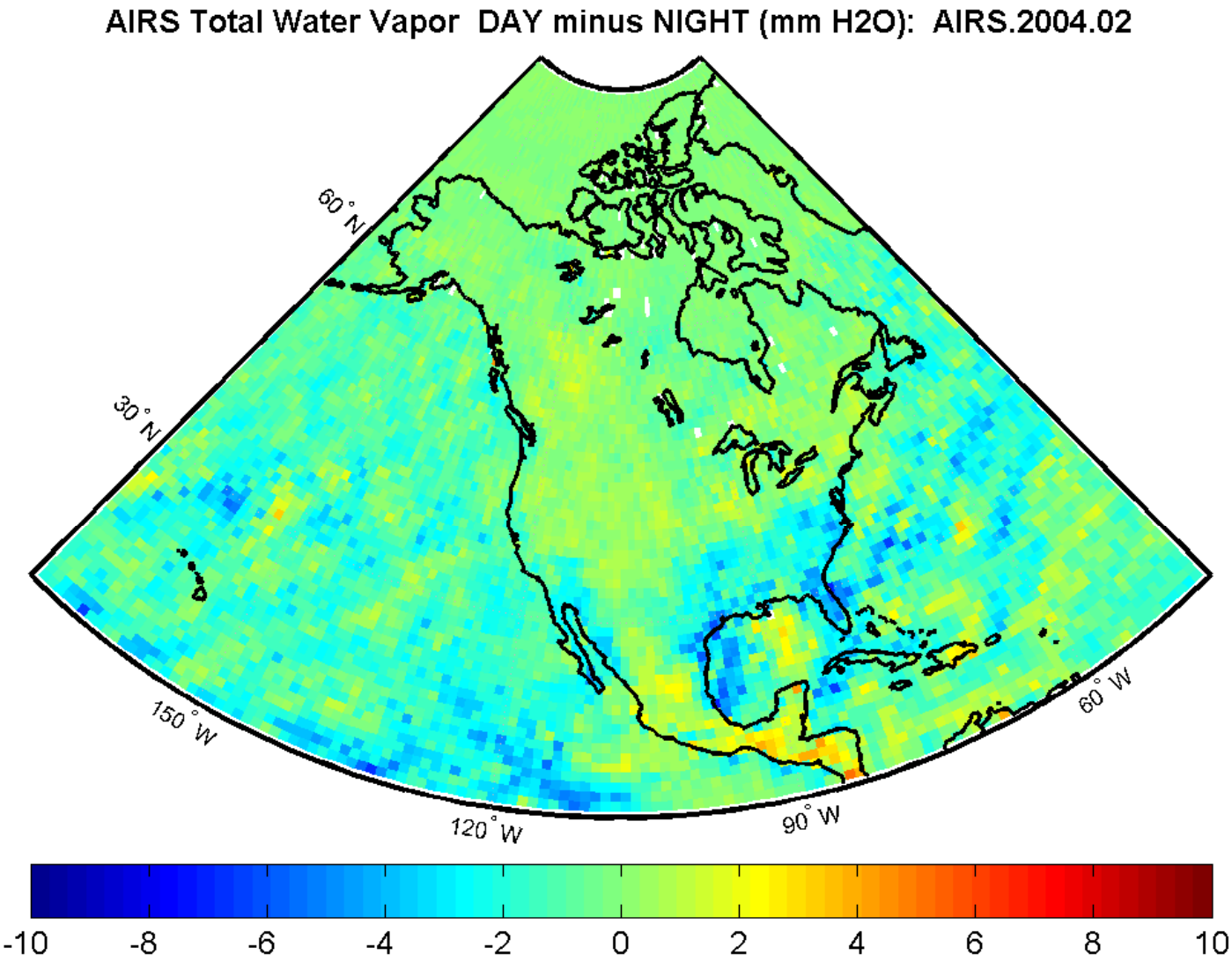
AIRS

PWV
Day - Night



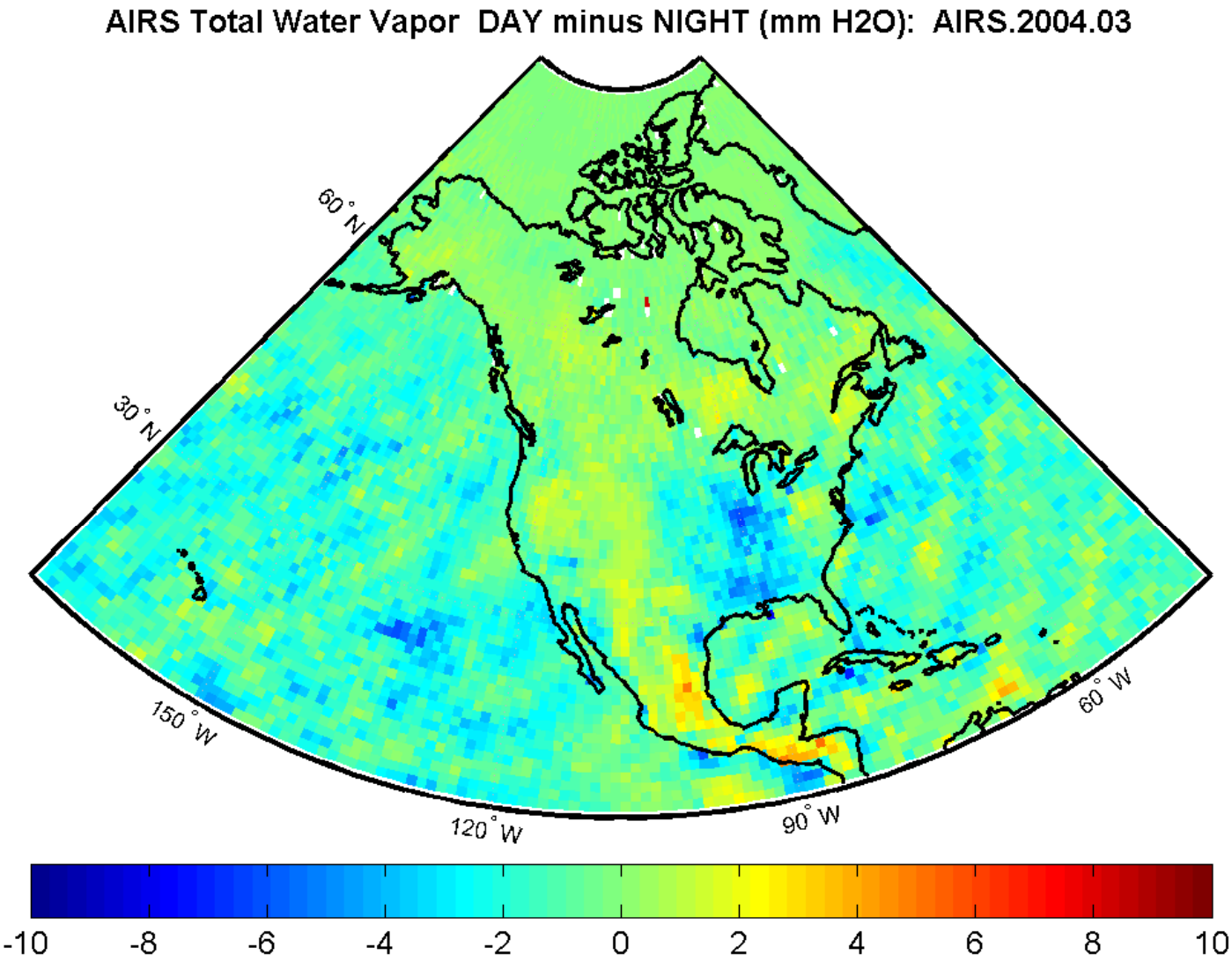
AIRS

PWV
Day - Night



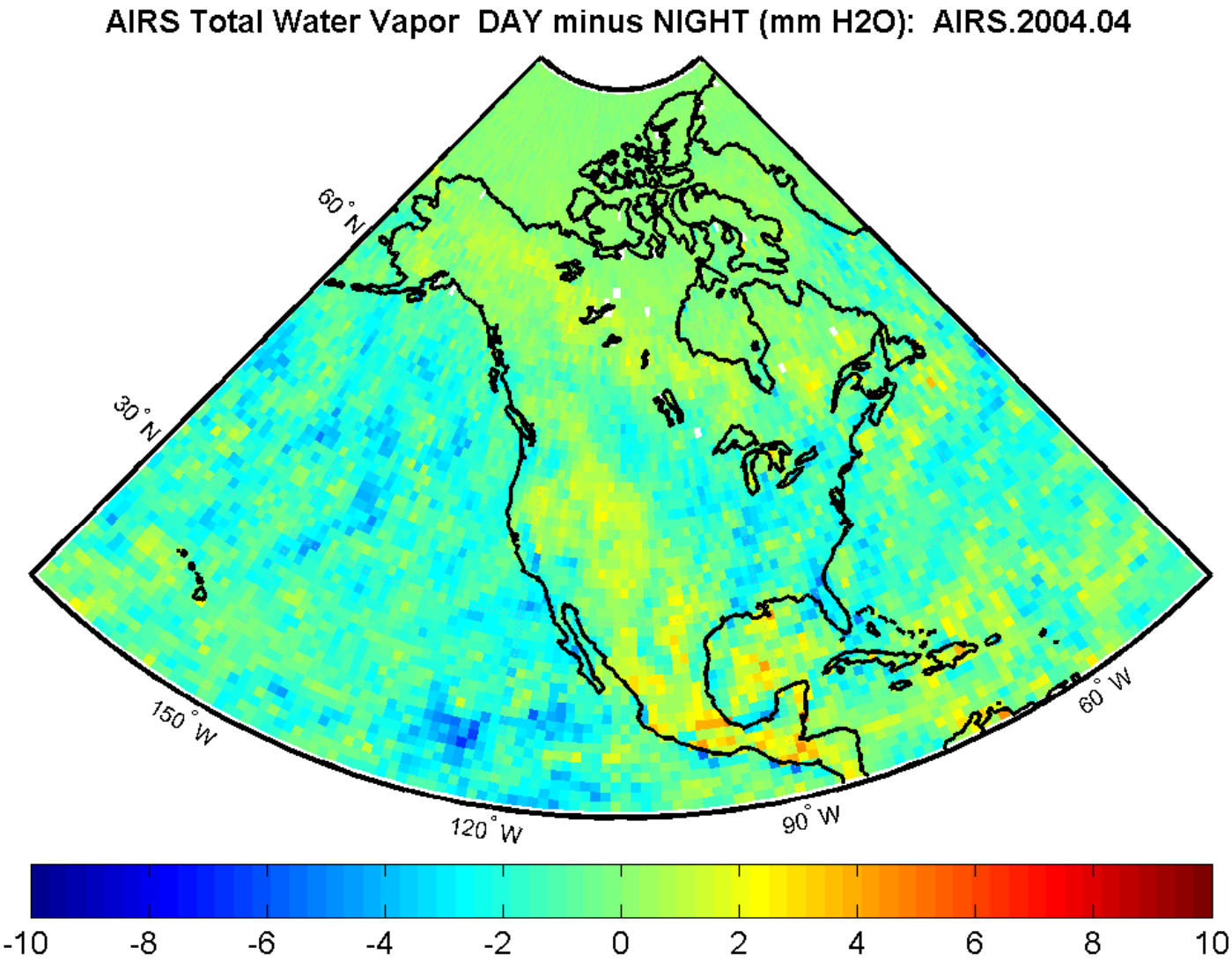
AIRS

PWV
Day - Night



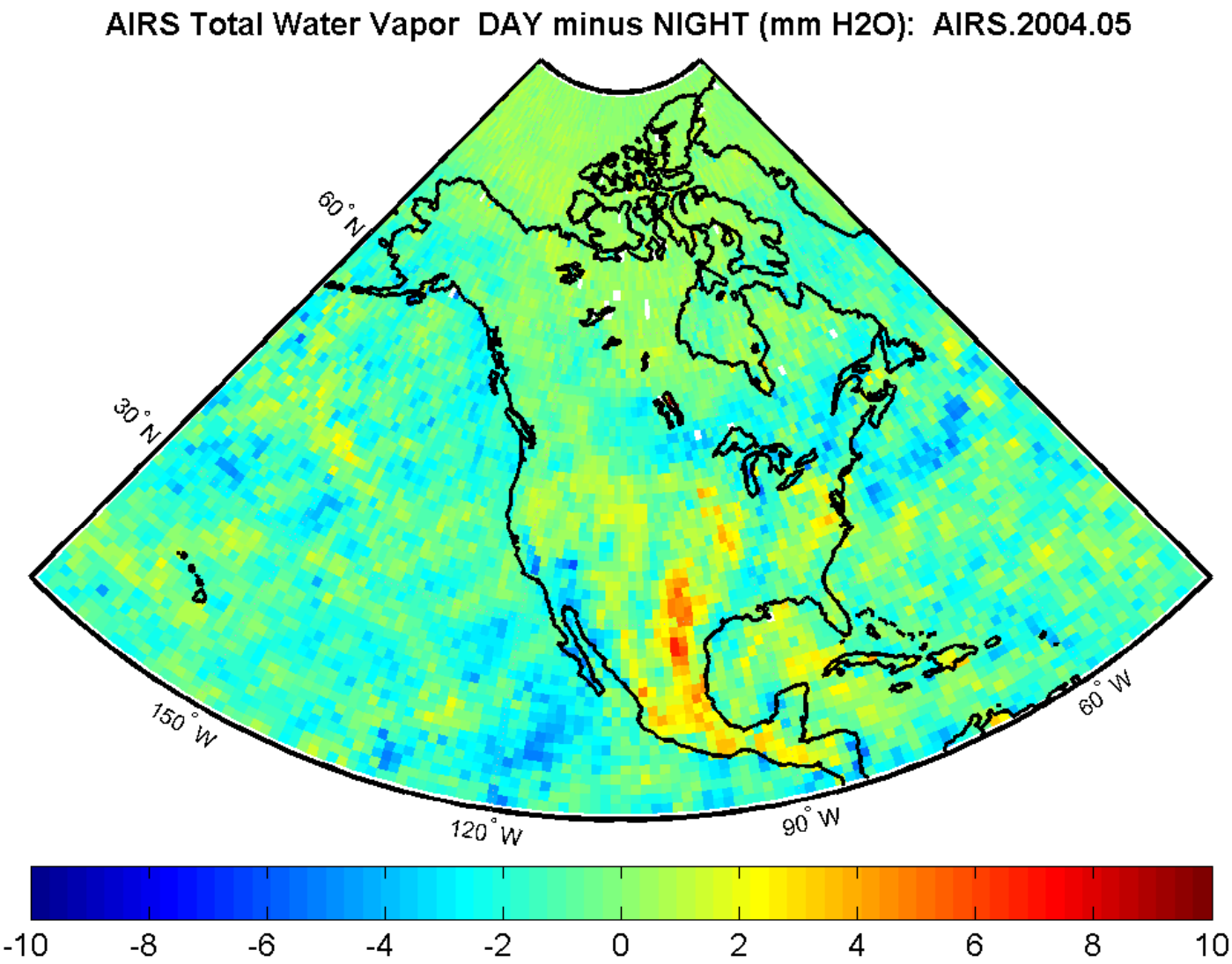
AIRS

PWV
Day - Night



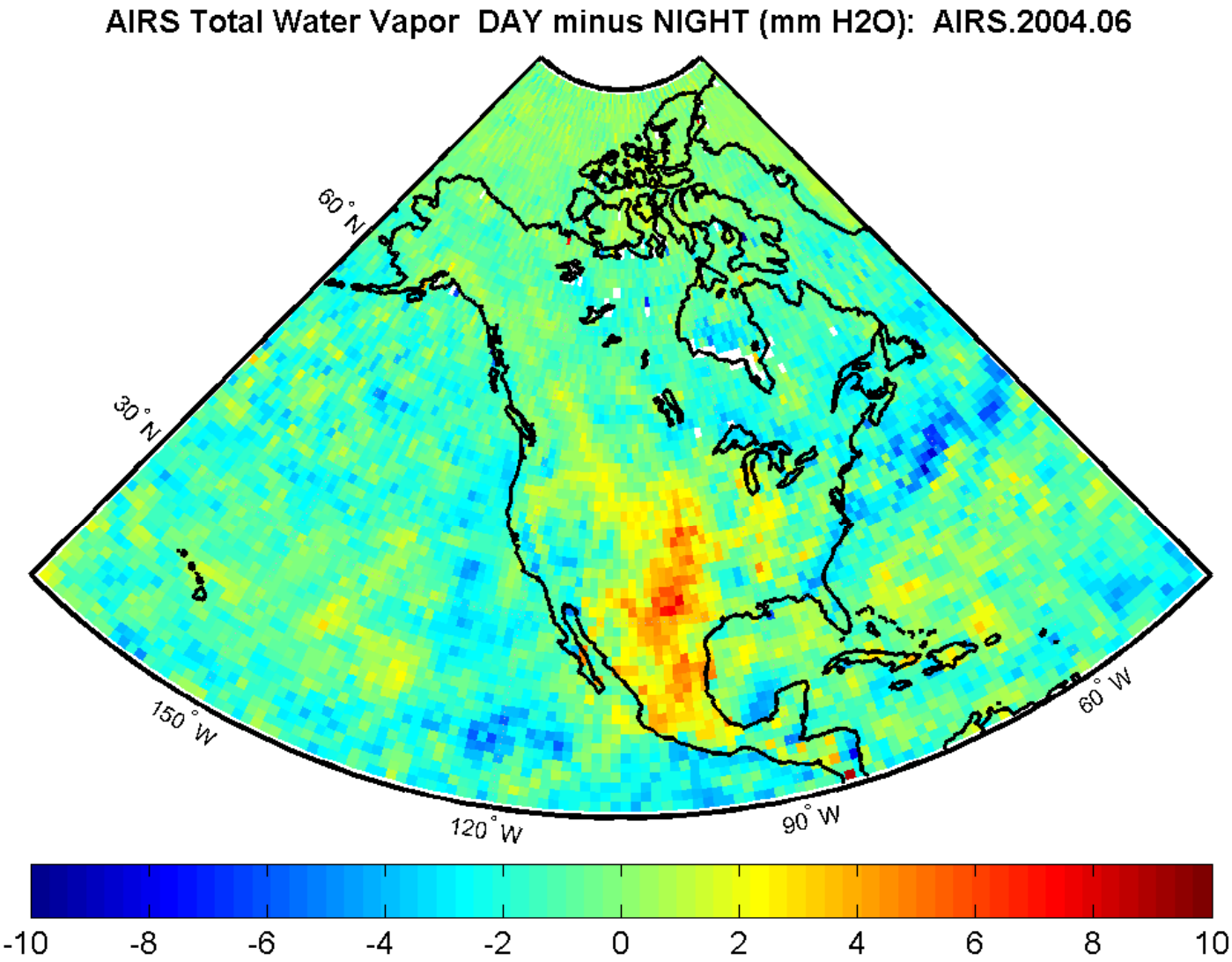
AIRS

PWV
Day - Night



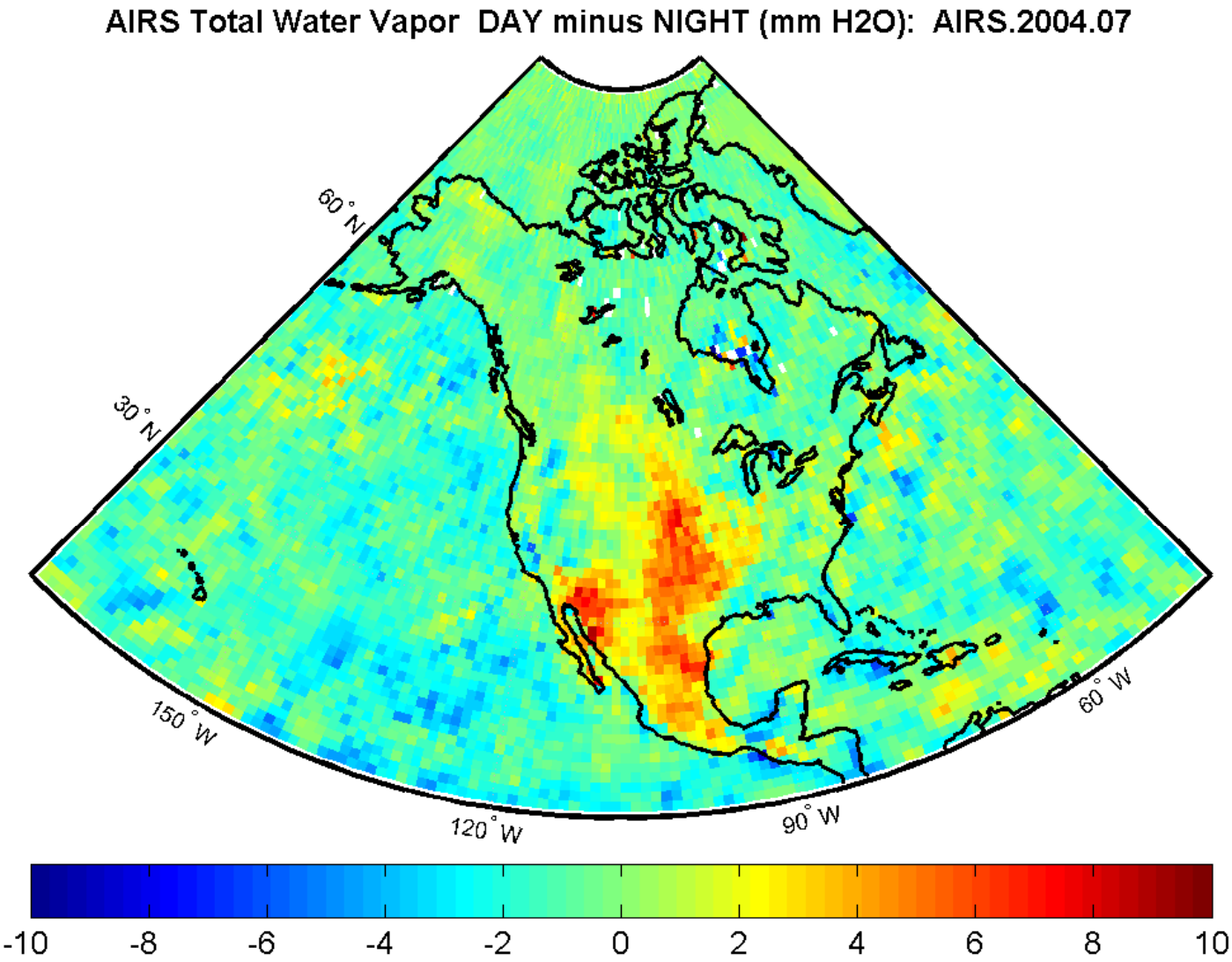
AIRS

PWV
Day - Night



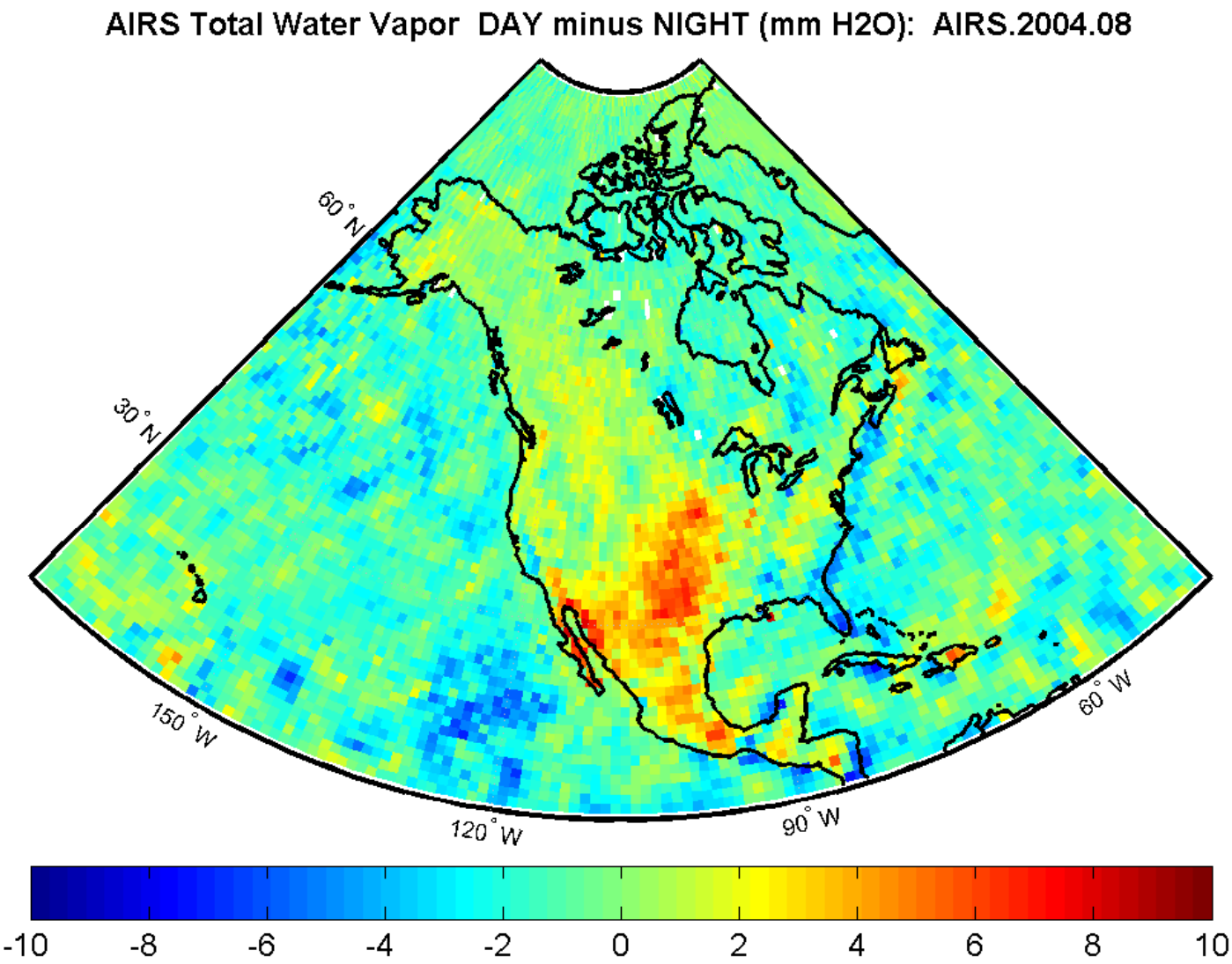
AIRS

PWV
Day - Night



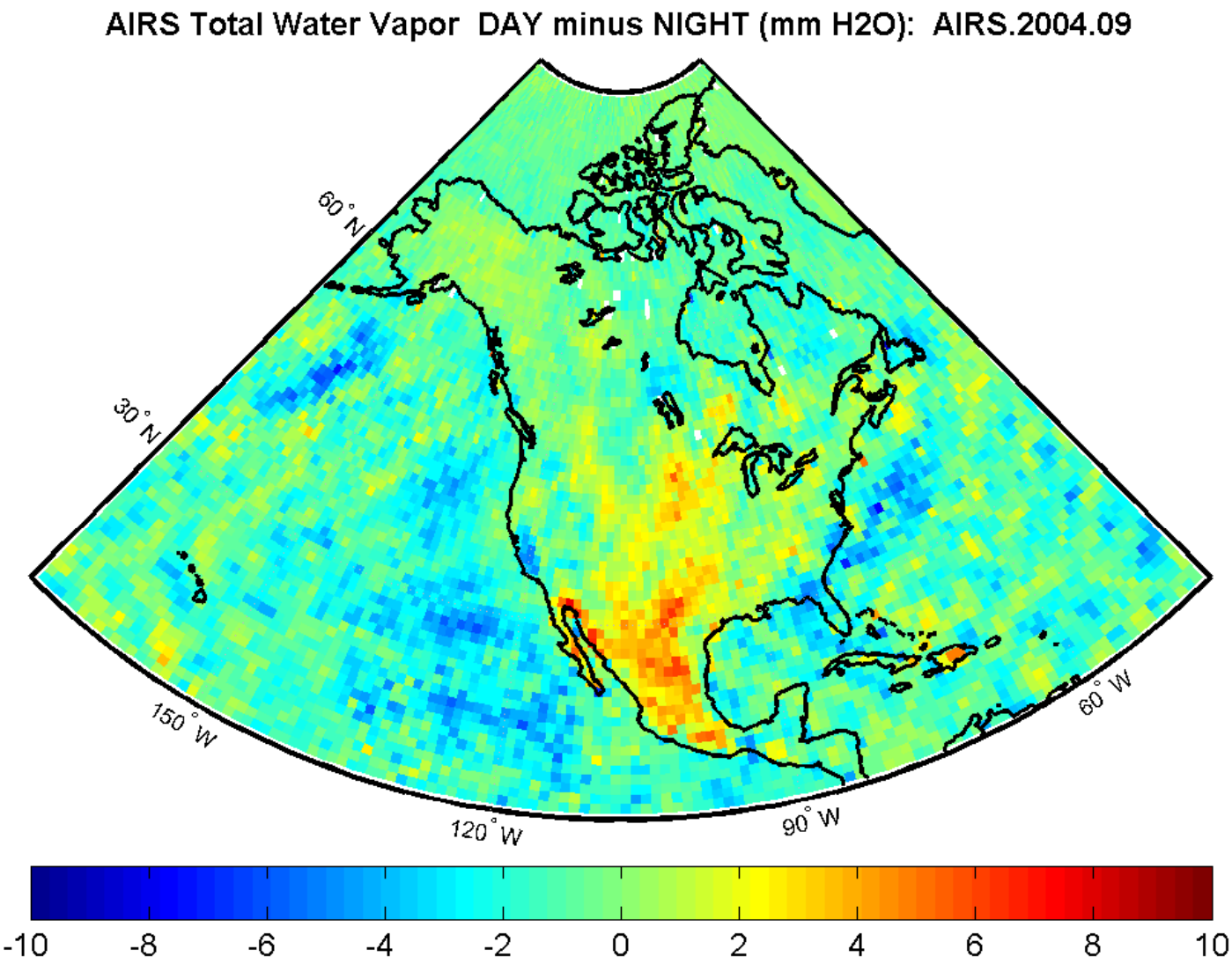
AIRS

PWV
Day - Night



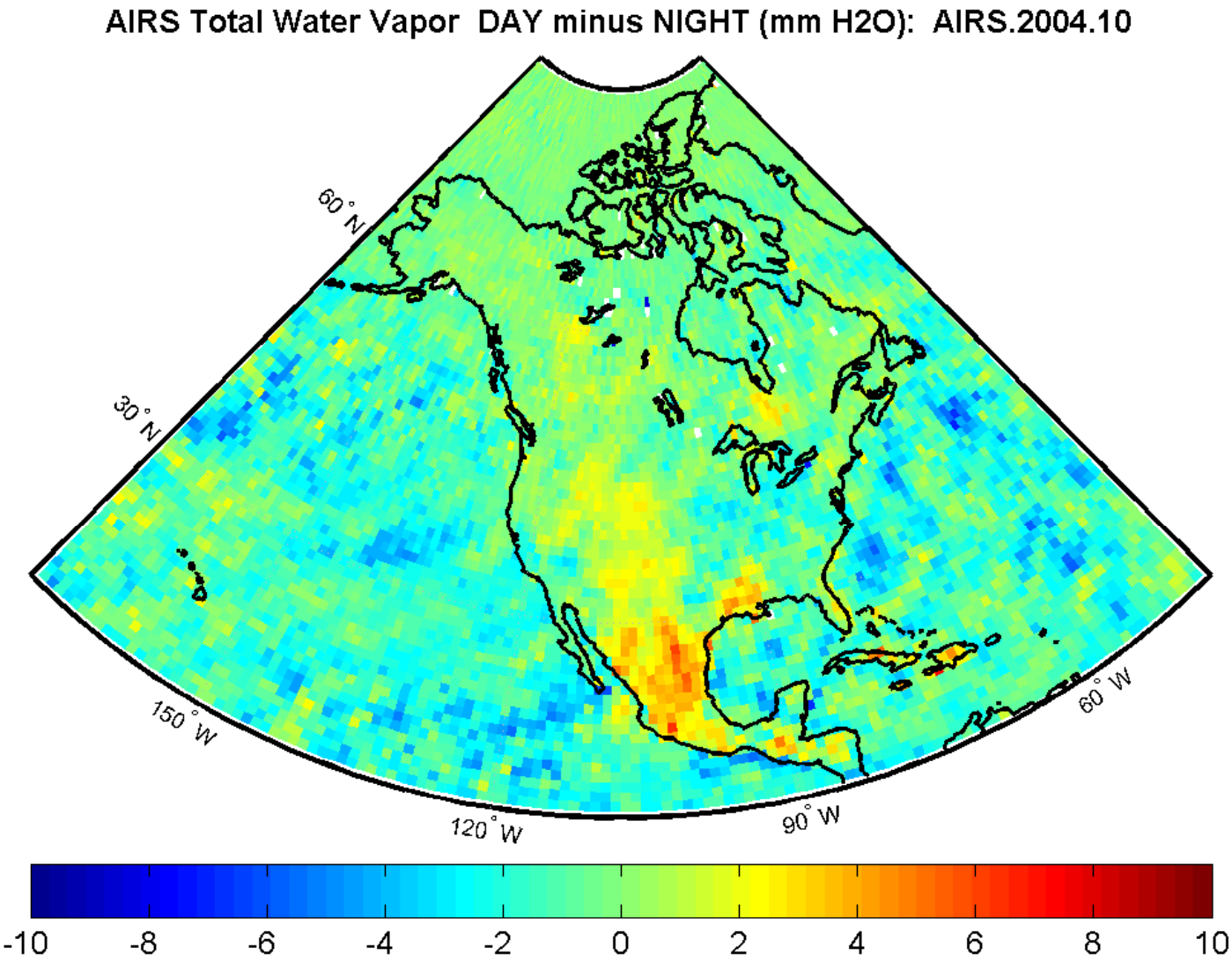
AIRS

PWV
Day - Night



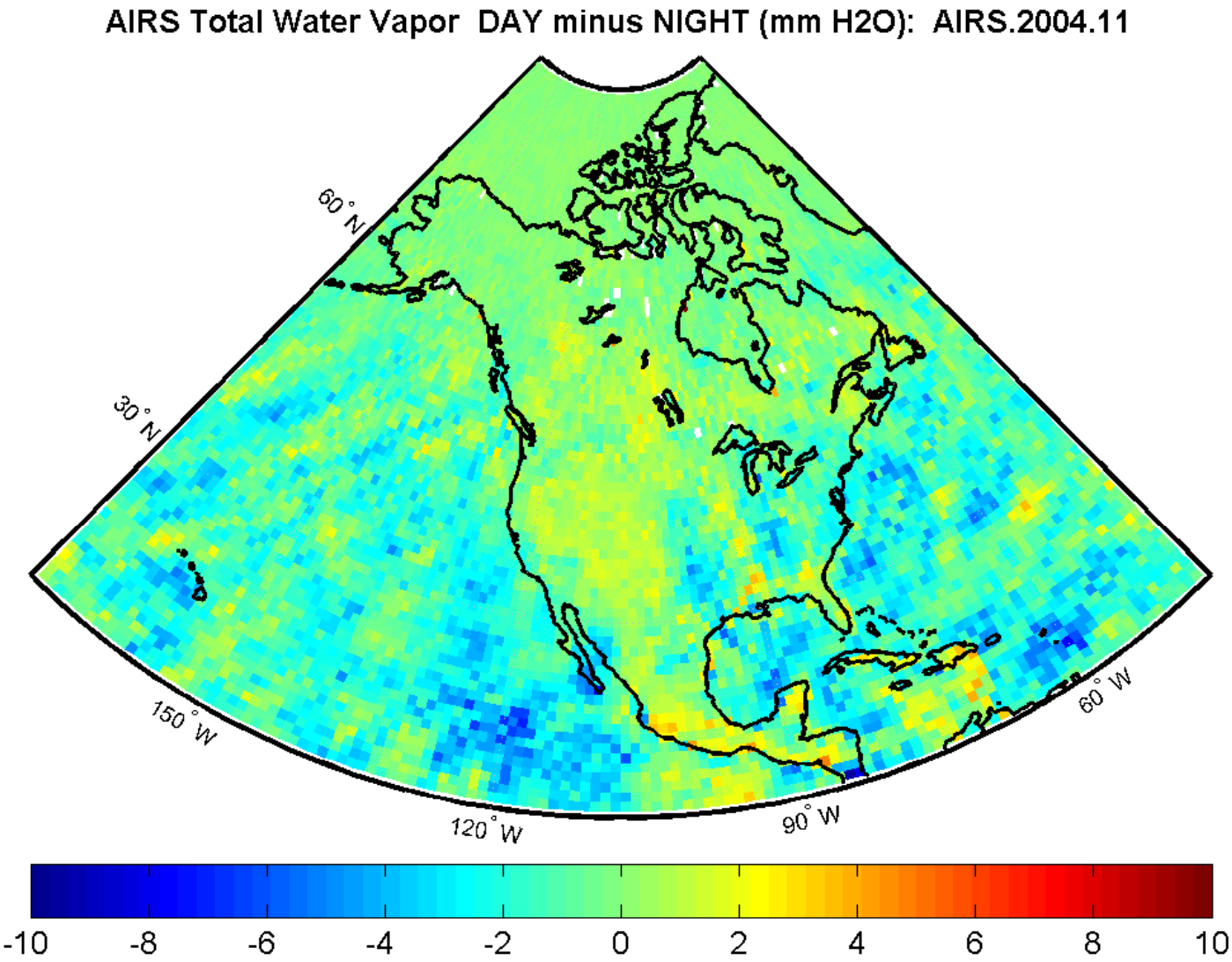
AIRS

PWV
Day - Night



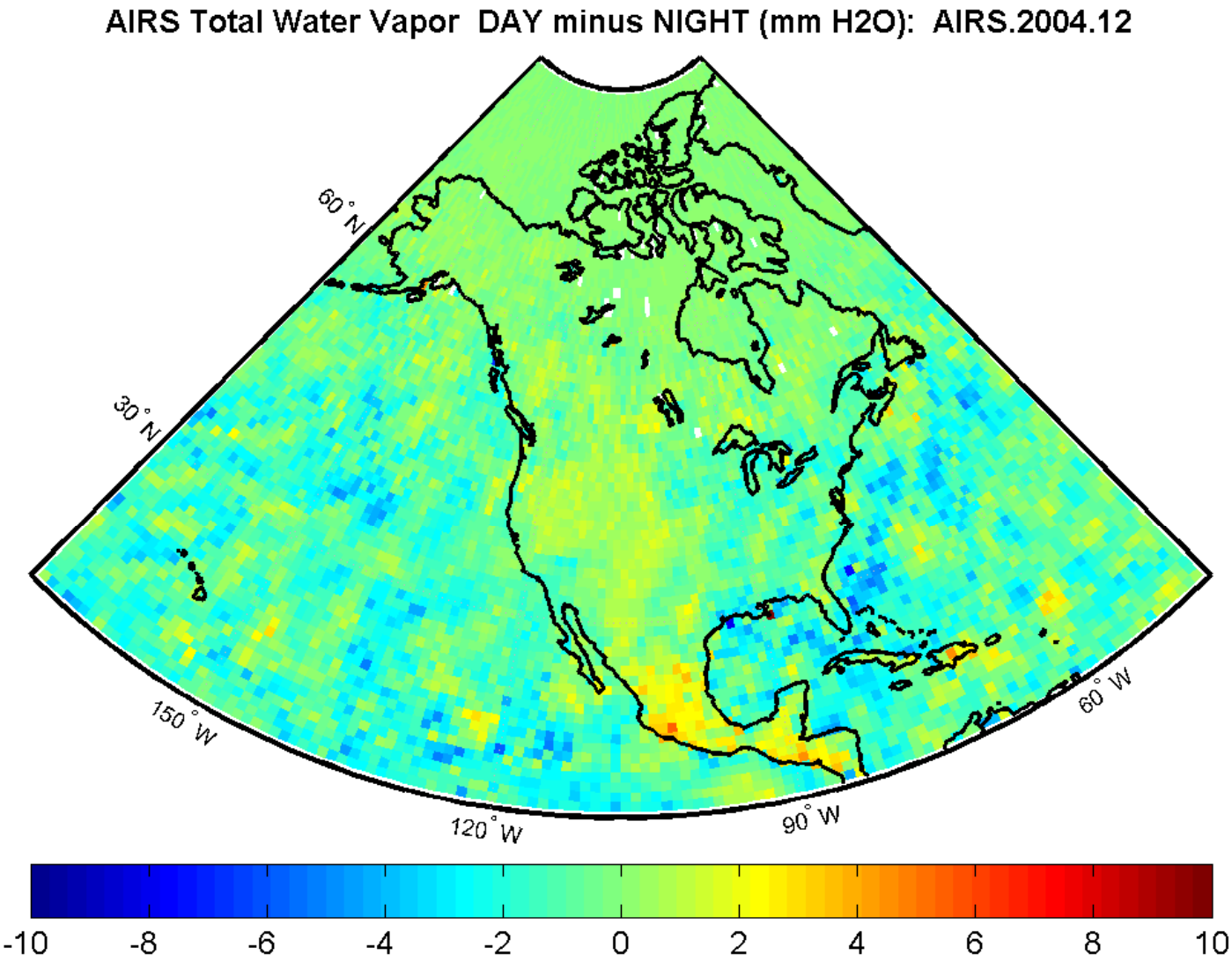
AIRS

PWV
Day - Night



AIRS

PWV
Day - Night

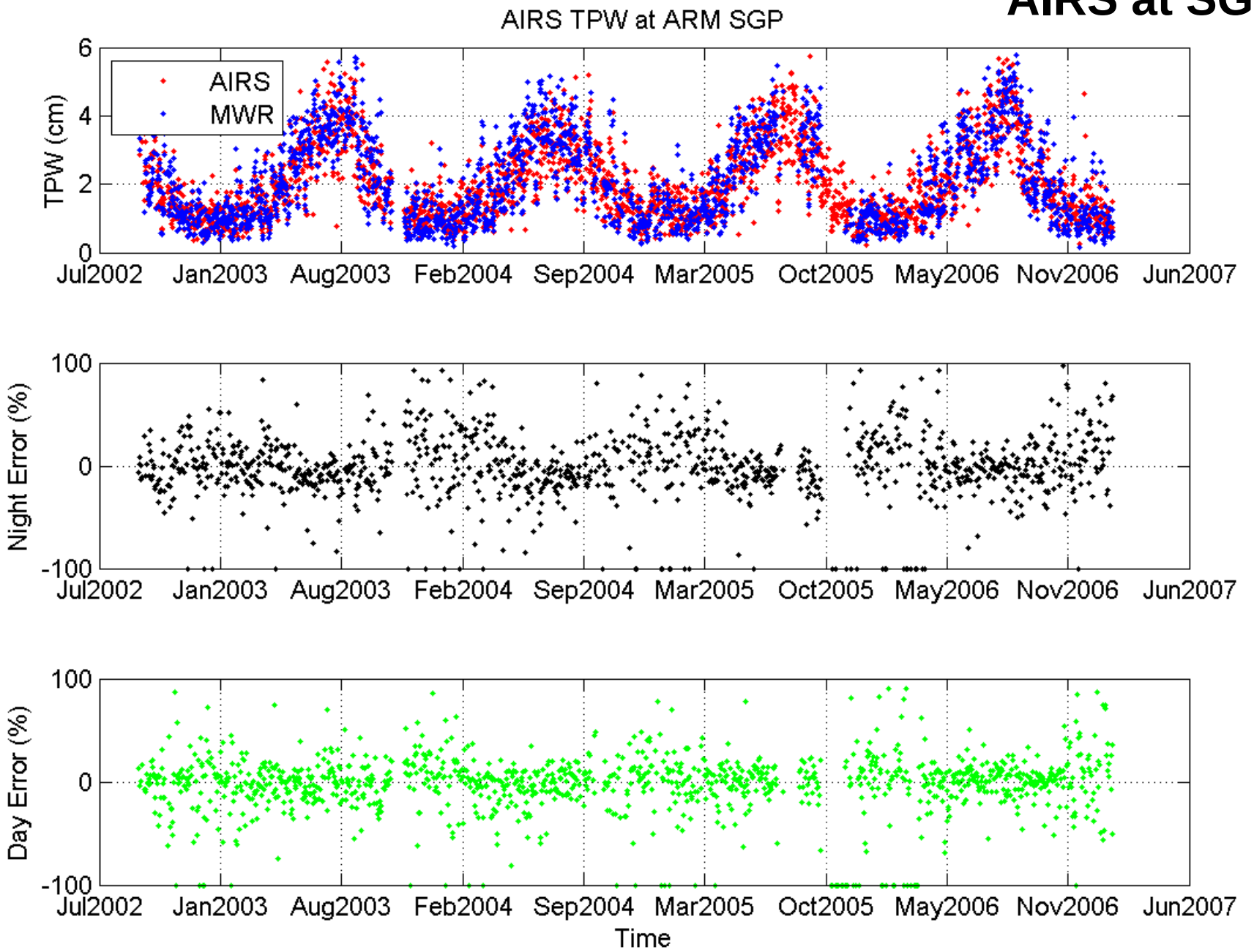


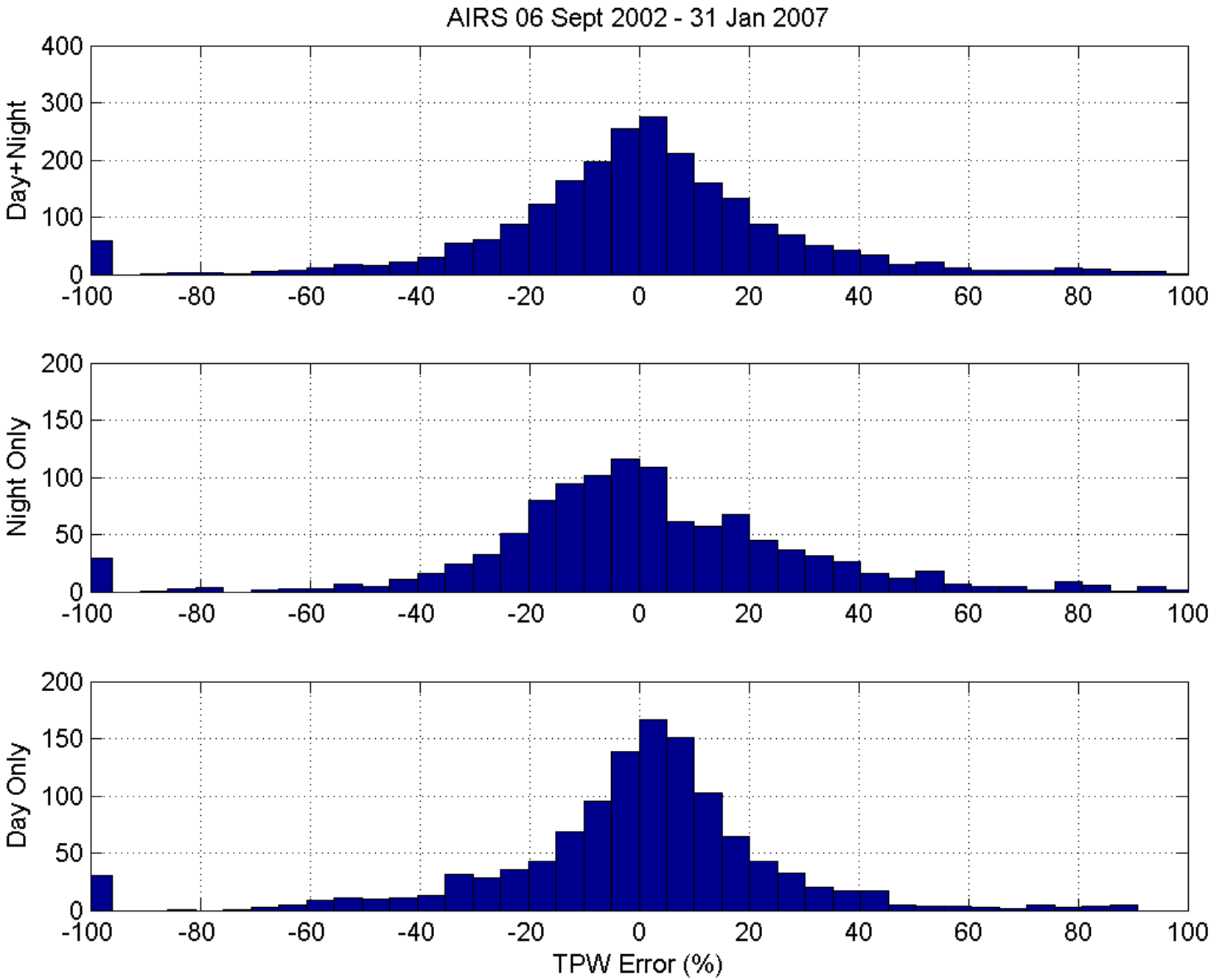
22 GHz MWR Retrieval of TPW (built by Radiometrics, Inc.)

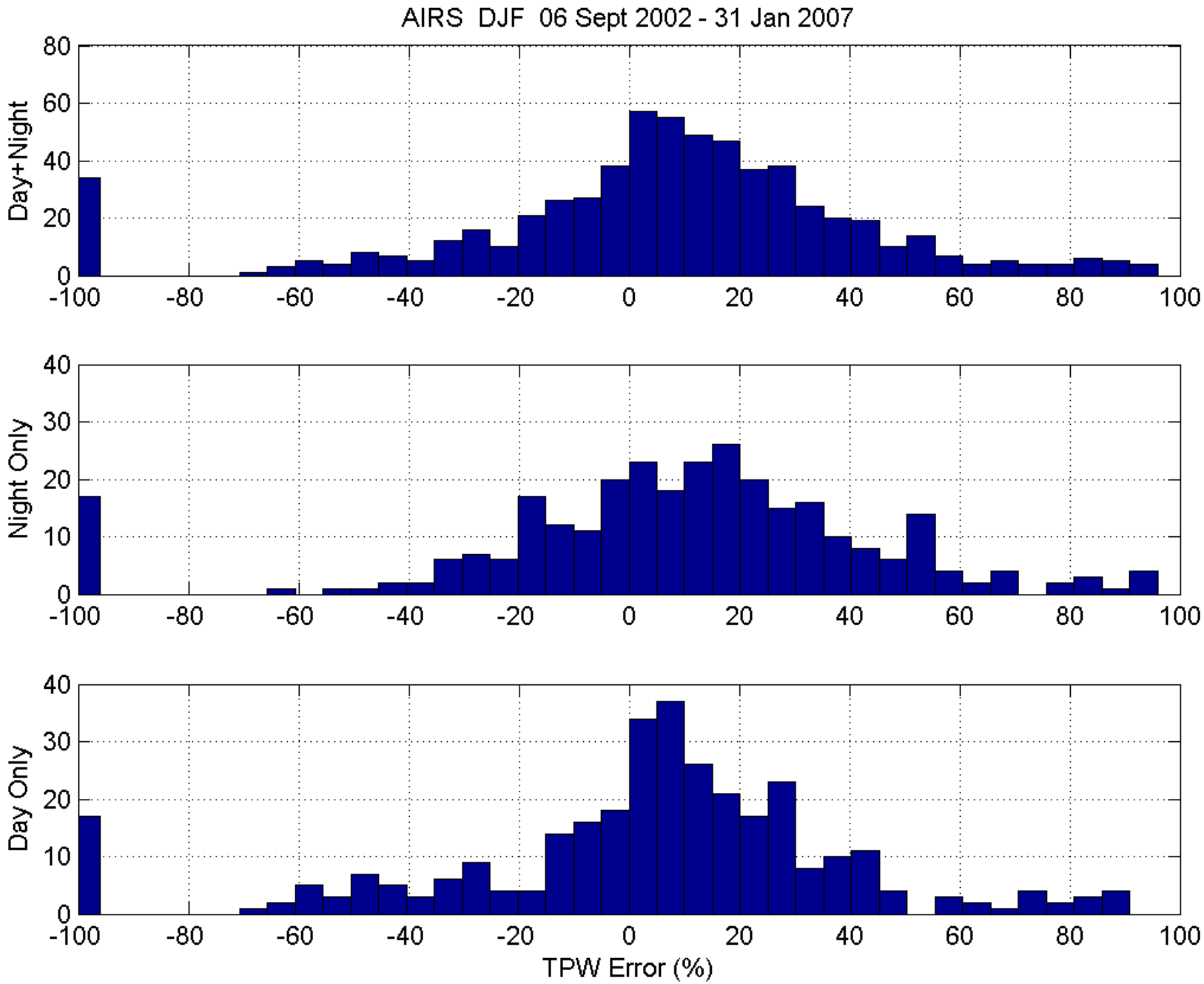
- 22 GHz spectroscopy known to better than 1% (Clough et al.,1973 Stark Effect paper)
- Radiometrics, Inc MWR stated calibration accuracy about 1%.
- TPW “best estimate” retrieval method used to analyze ARM time series by Dave Turner (Turner et al., 2007)
- Water Vapor Intensive Periods connected Chilled Mirror (better than 1%) to MWR column using Raman Lidar (Revercomb et al., 2003)

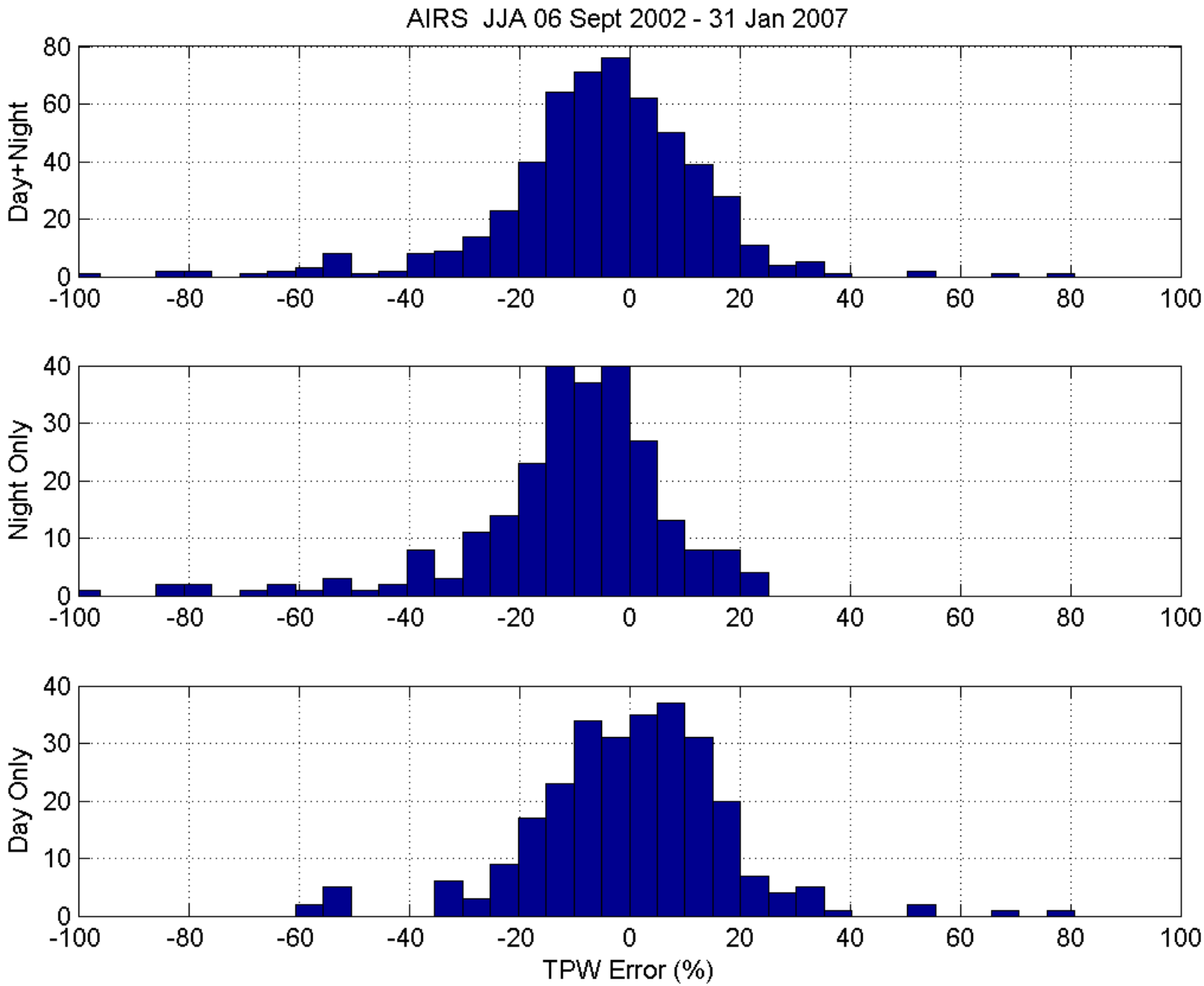
Conclusion is that DOE ARM MWR TPW has absolute accuracy of 1% - 3%

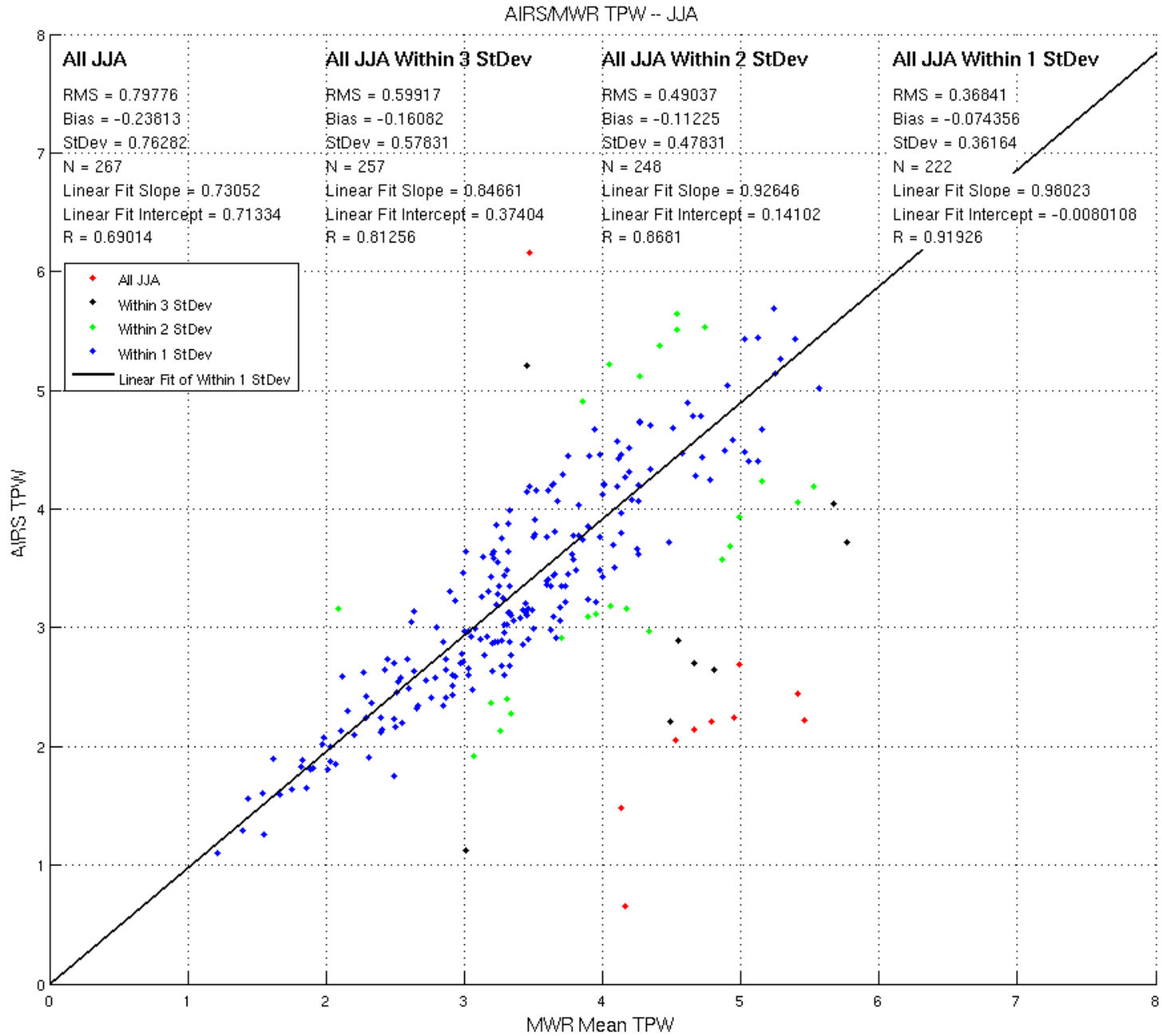
AIRS at SGP

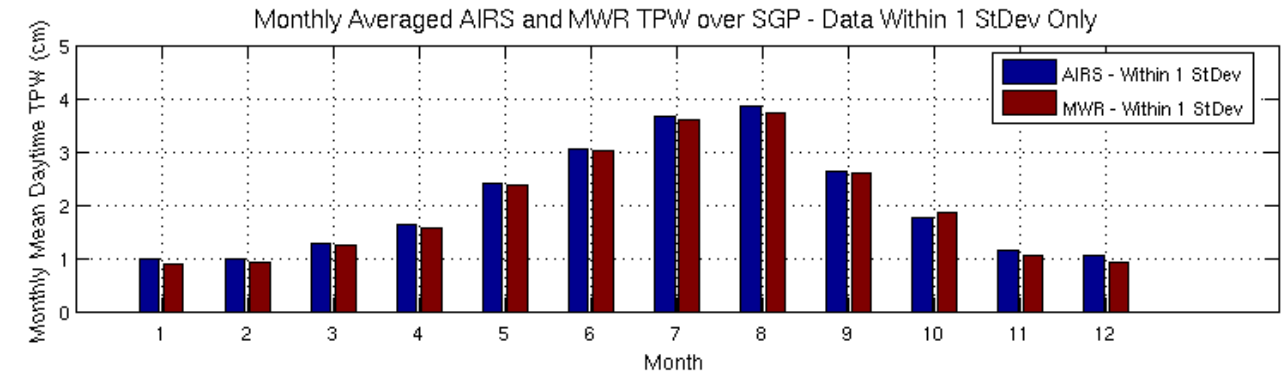

AIRS TPW at ARM SGP
AIRS
MWR
TPW (cm)
6
4
2
0
Jul2002
Jan2003
Aug2003
Feb2004
Sep2004
Mar2005
Oct2005
May2006
Nov2006
Jun2007
Night Error (%)
100
0
-100
Day Error (%)
Time

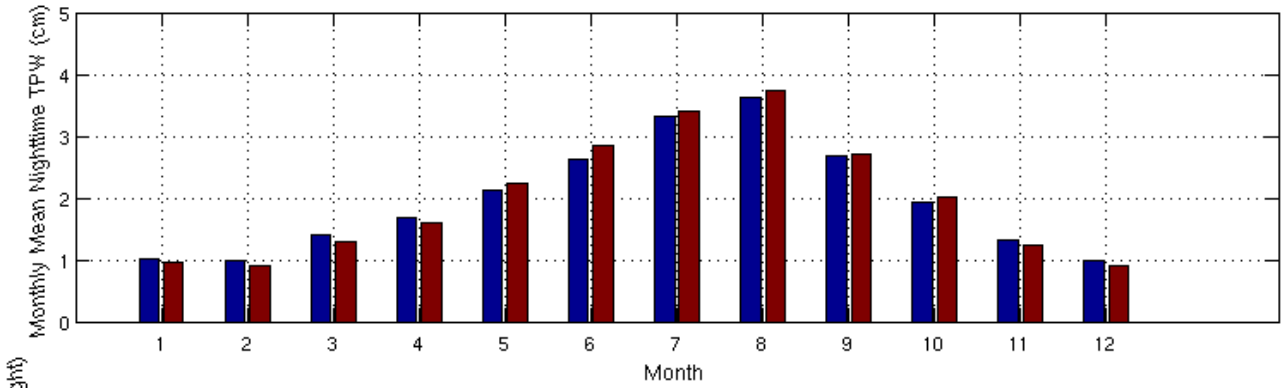

AIRS 06 Sept 2002 - 31 Jan 2007
Day+Night
Night Only
Day Only
TPW Error (%)
400
300
200
150
100
50
0
-100
-80
-60
-40
-20
0
20
40
60
80
100

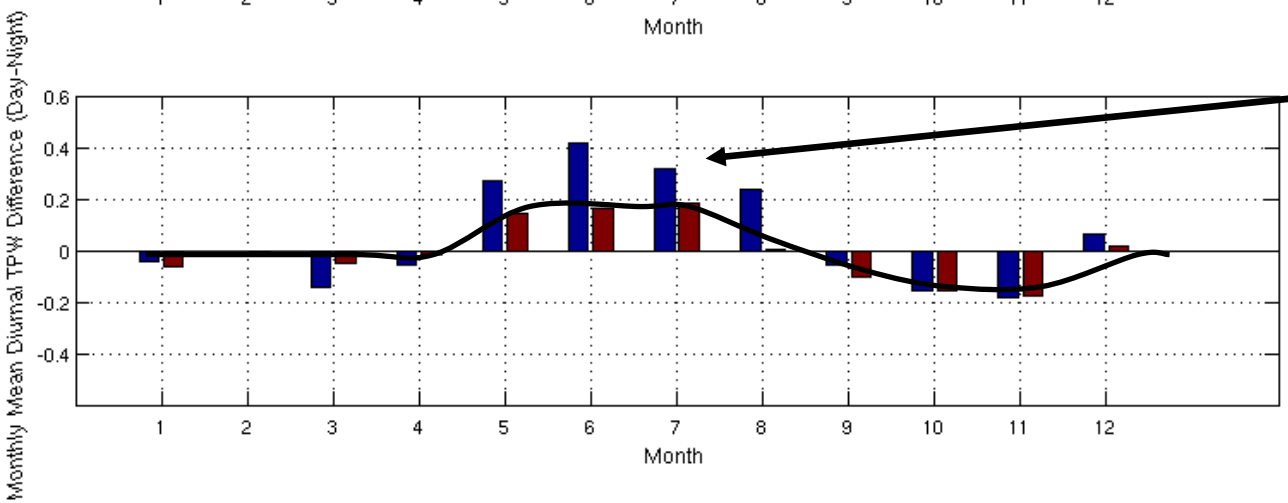

AIRS DJF 06 Sept 2002 - 31 Jan 2007
Day+Night
Night Only
Day Only
TPW Error (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100


AIRS JJA 06 Sept 2002 - 31 Jan 2007
Day+Night
Night Only
Day Only
TPW Error (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100


AIRS/MWR TPW -- JJA
All JJA
RMS = 0.79776
Bias = -0.23813
StDev = 0.76282
N = 267
Linear Fit Slope = 0.73052
Linear Fit Intercept = 0.71334
R = 0.69014
All JJA Within 3 StDev
RMS = 0.59917
Bias = -0.16082
StDev = 0.57831
N = 257
Linear Fit Slope = 0.84661
Linear Fit Intercept = 0.37404
R = 0.81256
All JJA Within 2 StDev
RMS = 0.49037
Bias = -0.11225
StDev = 0.47831
N = 248
Linear Fit Slope = 0.92646
Linear Fit Intercept = 0.14102
R = 0.8681
All JJA Within 1 StDev
RMS = 0.36841
Bias = -0.074356
StDev = 0.36164
N = 222
Linear Fit Slope = 0.98023
Linear Fit Intercept = -0.0080108
R = 0.91926
All JJA
Within 3 StDev
Within 2 StDev
Within 1 StDev
Linear Fit of Within 1 StDev
AIRS TPW
MWR Mean TPW
0
1
2
3
4
5
6
7
8

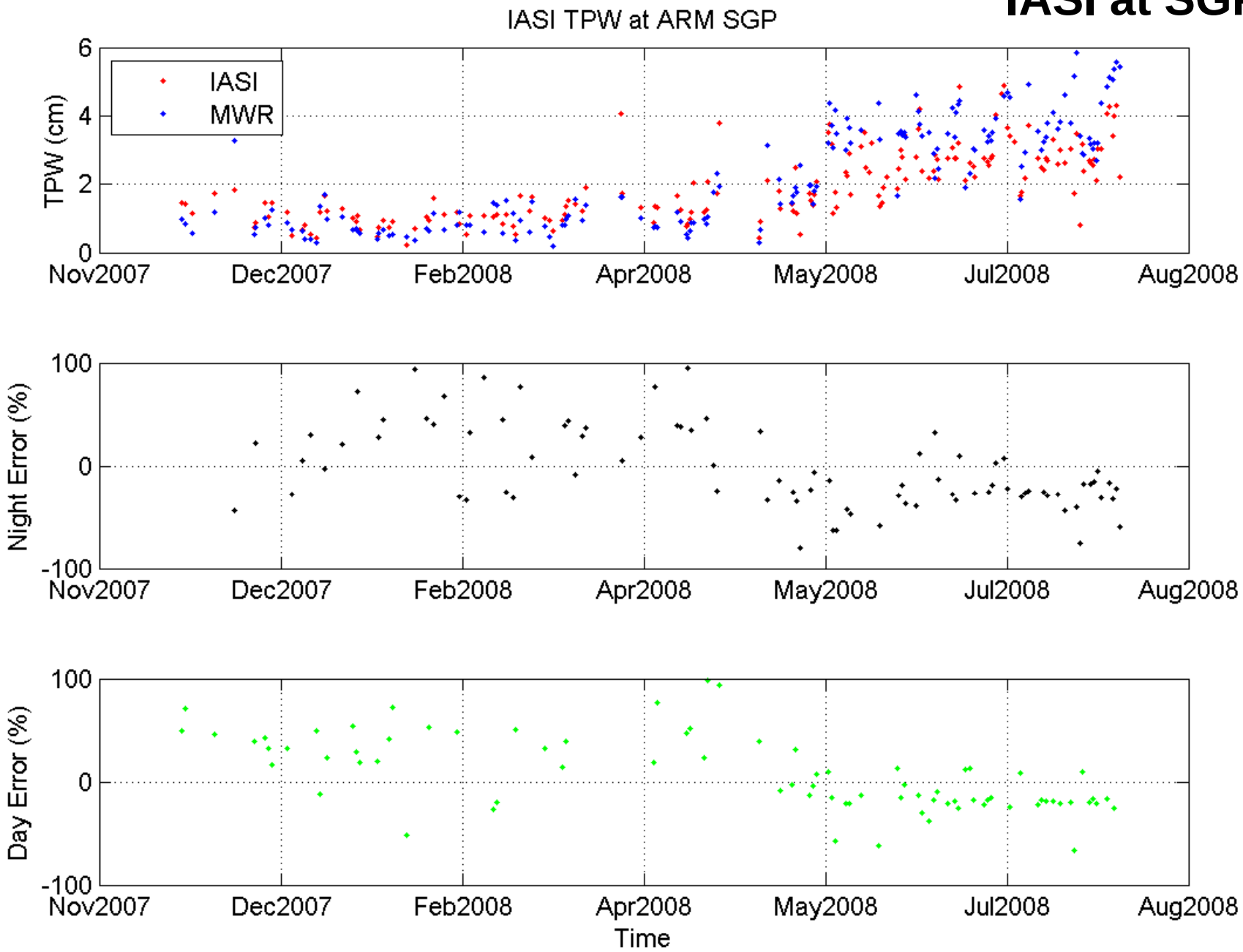


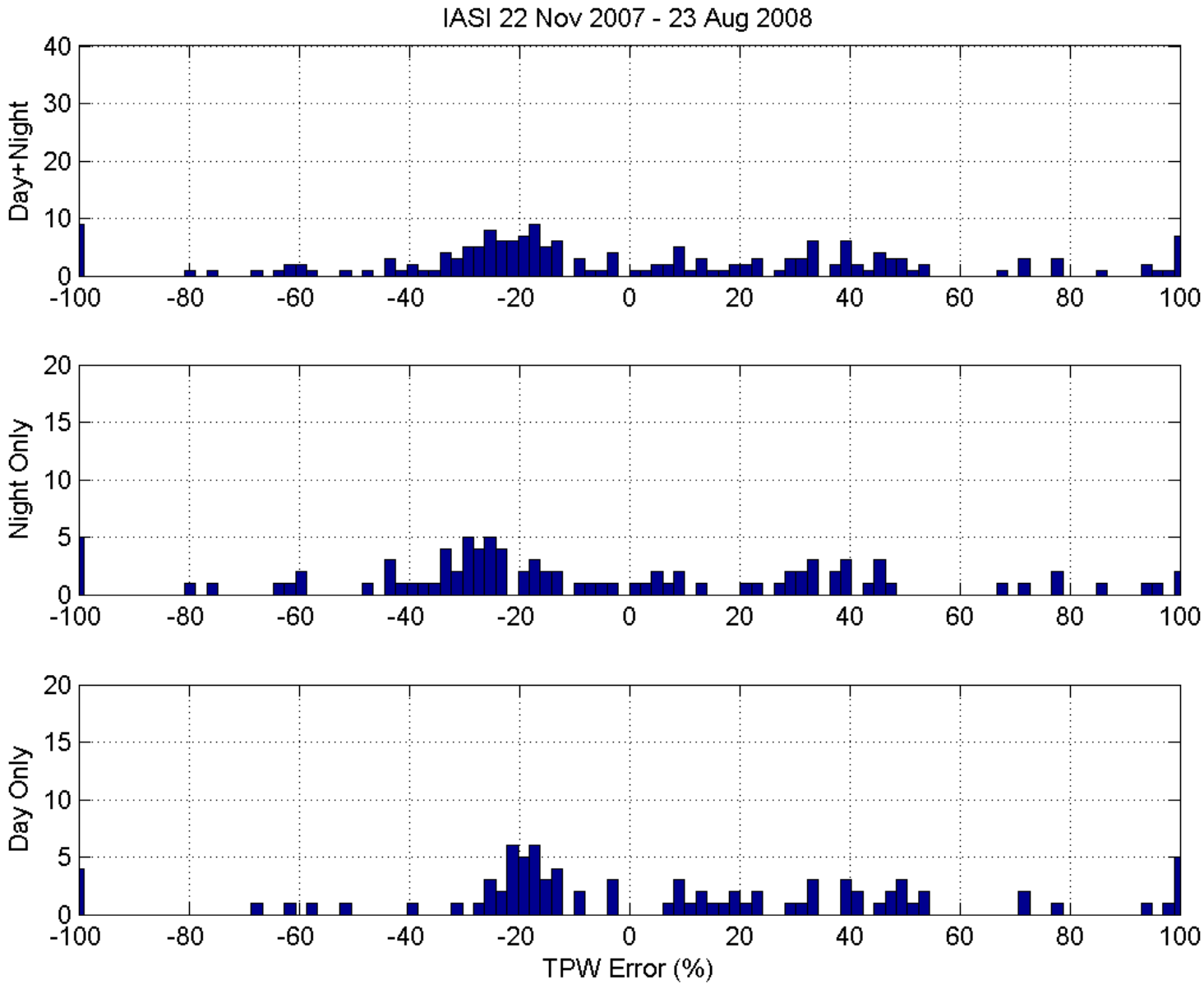


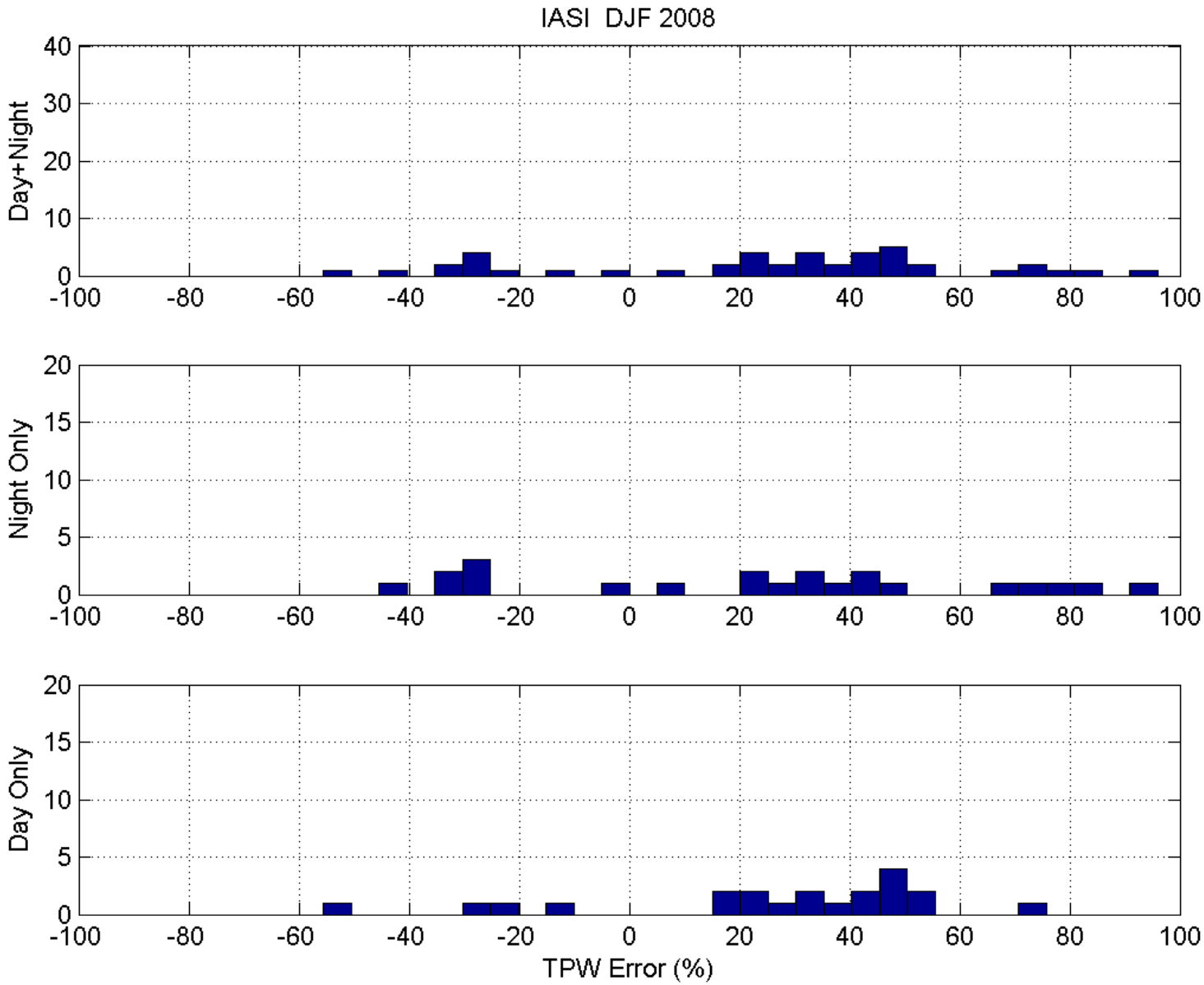


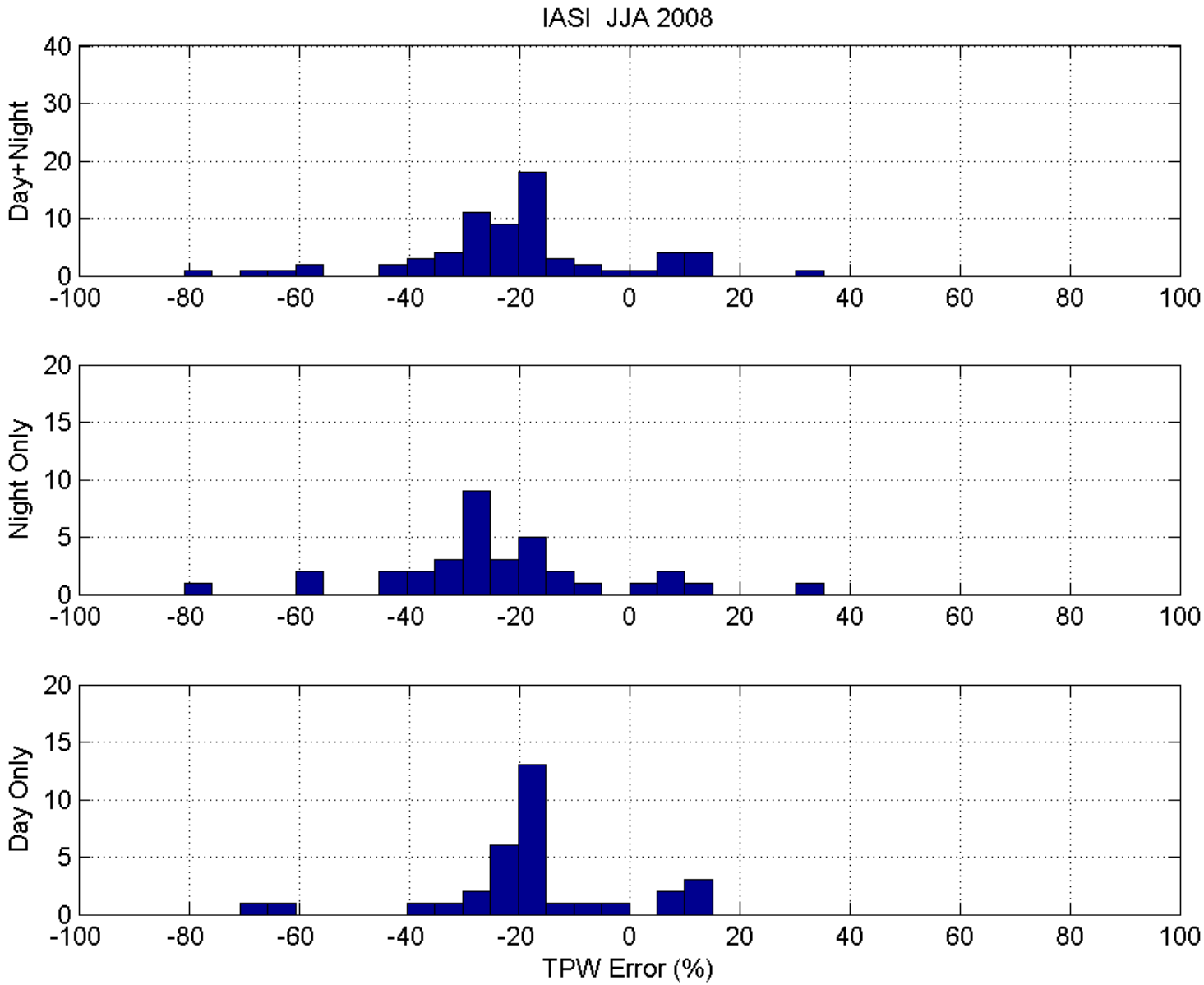
AIRS Over-Estimates Diurnal TPW Signal

IASI at SGP


IASI TPW at ARM SGP
IASI
MWR
TPW (cm)
6
4
2
0
Nov2007
Dec2007
Feb2008
Apr2008
May2008
Jul2008
Aug2008
Night Error (%)
100
0
-100
Day Error (%)
Time


IASI 22 Nov 2007 - 23 Aug 2008
Day+Night
Night Only
Day Only
TPW Error (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100


IASI DJF 2008
Day+Night
Night Only
Day Only
TPW Error (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100


IASI JJA 2008
Day+Night
Night Only
Day Only
TPW Error (%)
-100
-80
-60
-40
-20
0
20
40
60
80
100

Summary: AIRS & IASI TPW at SGP

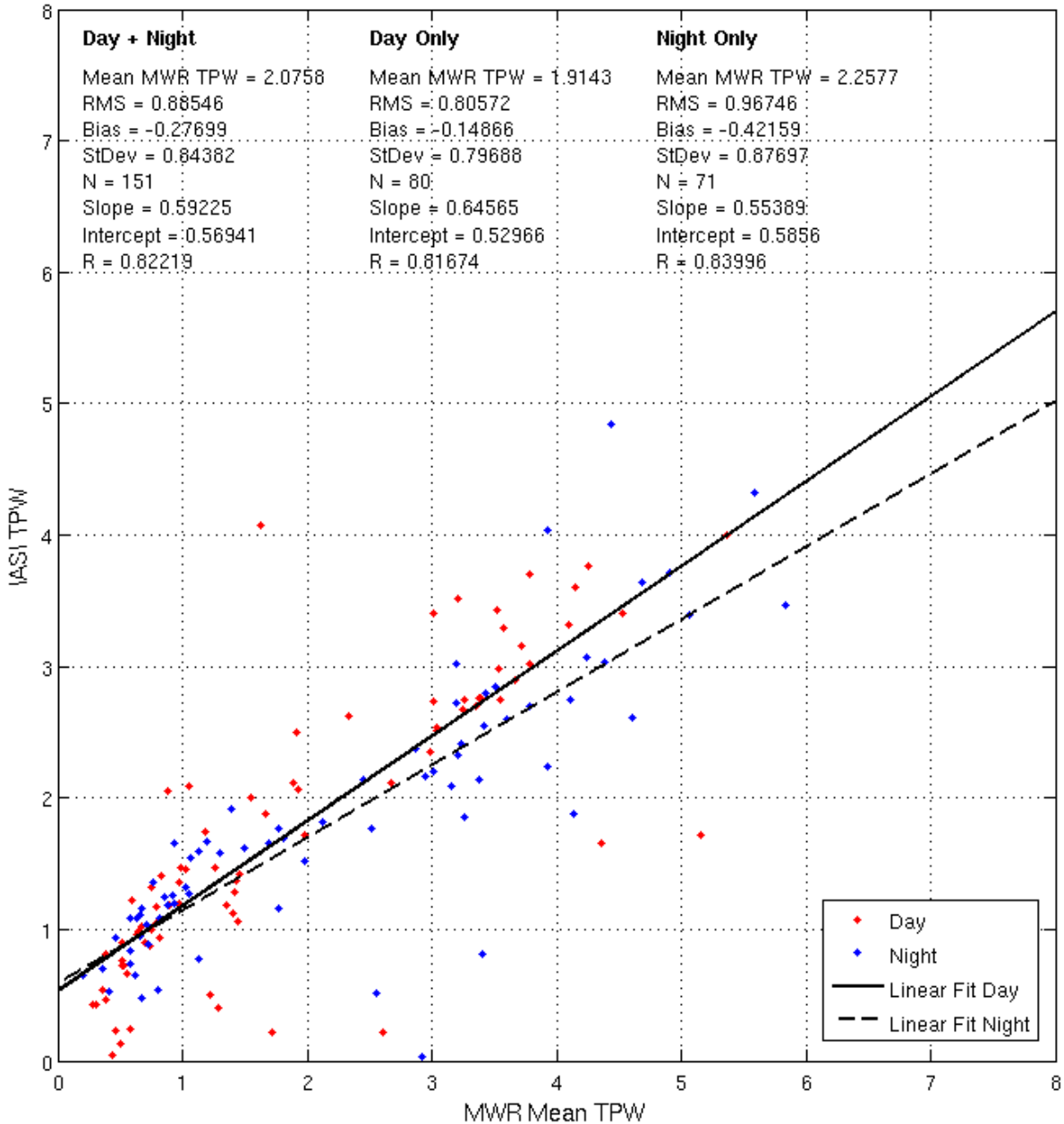
1. AIRS Daytime TPW agrees with MWR ground truth to within 1%.
2. AIRS Nighttime TPW is 5-10 % too dry at night in summer (high humidity). About 5-10% too wet in winter (low humidity)
3. AIRS Day minus Night diurnal signal is real but larger in summer than MWR would indicate.
4. Preliminary IASI L2 comparison to MWR at SGP site suggests IASI is about 50% too wet in winter (low humidity) but without much skill (wide variance). IASI L2 is consistently 20% too dry in summer (high humidity) but with better skill (narrower distribution).

Conclusions:

- AIRS water vapor biases are small but should be improved

In order to use the data for climate studies.

- Peter Schussel indicated that an IASI L2 error has been corrected. This change should be re-evaluated against ARM SGP MWR data.


Day + Night
Mean MWR TPW = 2.0758
RMS = 0.88546
Bias = -0.27699
StDev = 0.84382
N = 151
Slope = 0.59225
Intercept = 0.56941
R = 0.82219
Day Only
Mean MWR TPW = 1.9143
RMS = 0.80572
Bias = -0.14866
StDev = 0.79688
N = 80
Slope = 0.64565
Intercept = 0.52966
R = 0.81674
Night Only
Mean MWR TPW = 2.2577
RMS = 0.96746
Bias = -0.42159
StDev = 0.87697
N = 71
Slope = 0.55389
Intercept = 0.5856
R = 0.83996
IASI TPW
MWR Mean TPW
Day
Night
Linear Fit Day
Linear Fit Night
0
1
2
3
4
5
6
7
8