Climate Correction of Radiosonde Temperature Biases in the Lower Stratosphere using GPS RO data

Shu-peng Ben Ho, Xinjia Zhou

Nov. 11, 2019

1. **Characterization and Correction of radiosonde temperature biases in the upper troposphere and lower stratosphere using RO data: Assessment of Vaisala RS92, GRUAN RS92, and RS41**

2. **Re-construct of temperature profile in the lower stratosphere using data from re-processed RO data**

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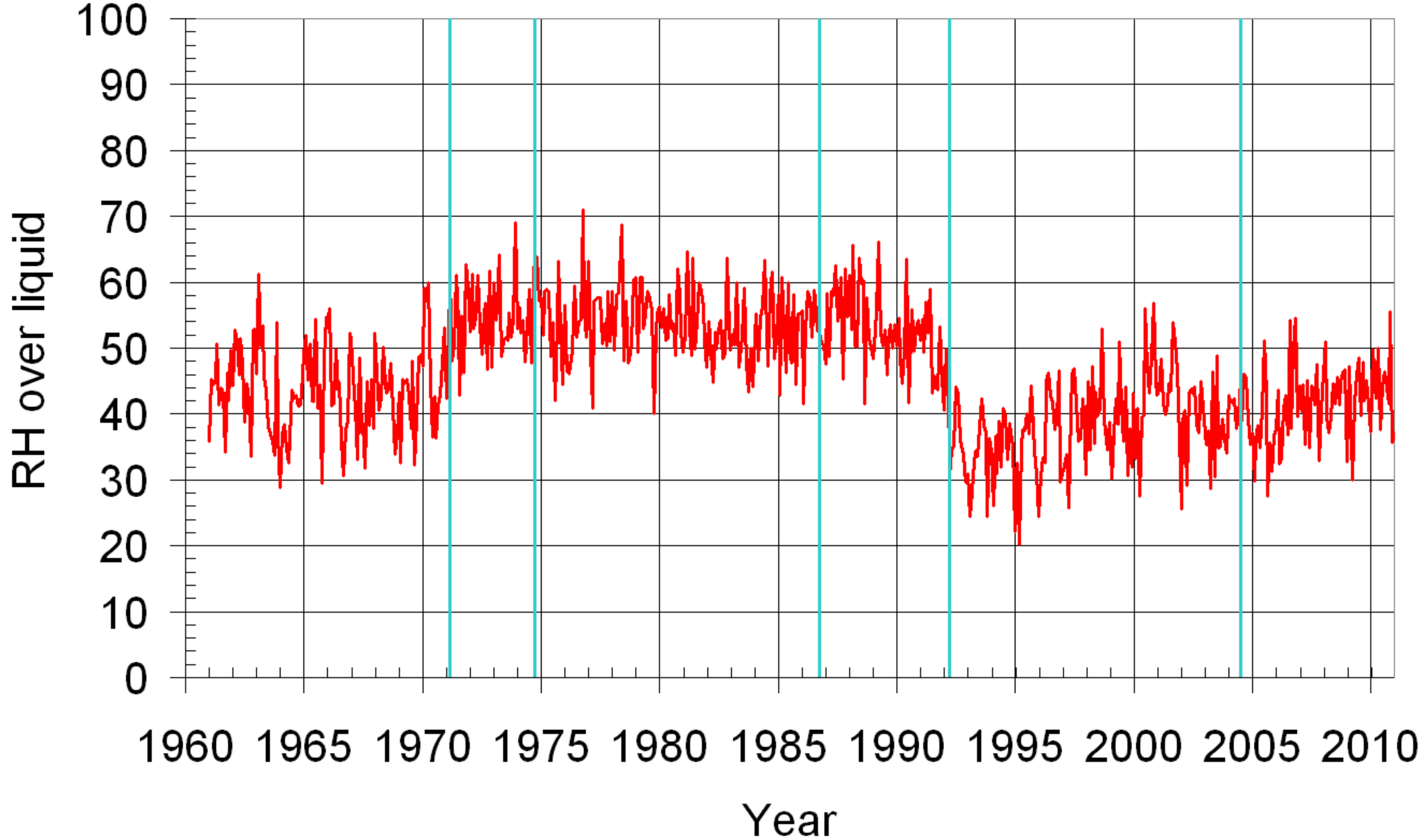
2. **Re-construct of temperature profile in the lower stratosphere using data from re-processed RO data**

Water vapor trends in the troposphere?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

e.g.: Lindenberg 8km (0:00 UT)



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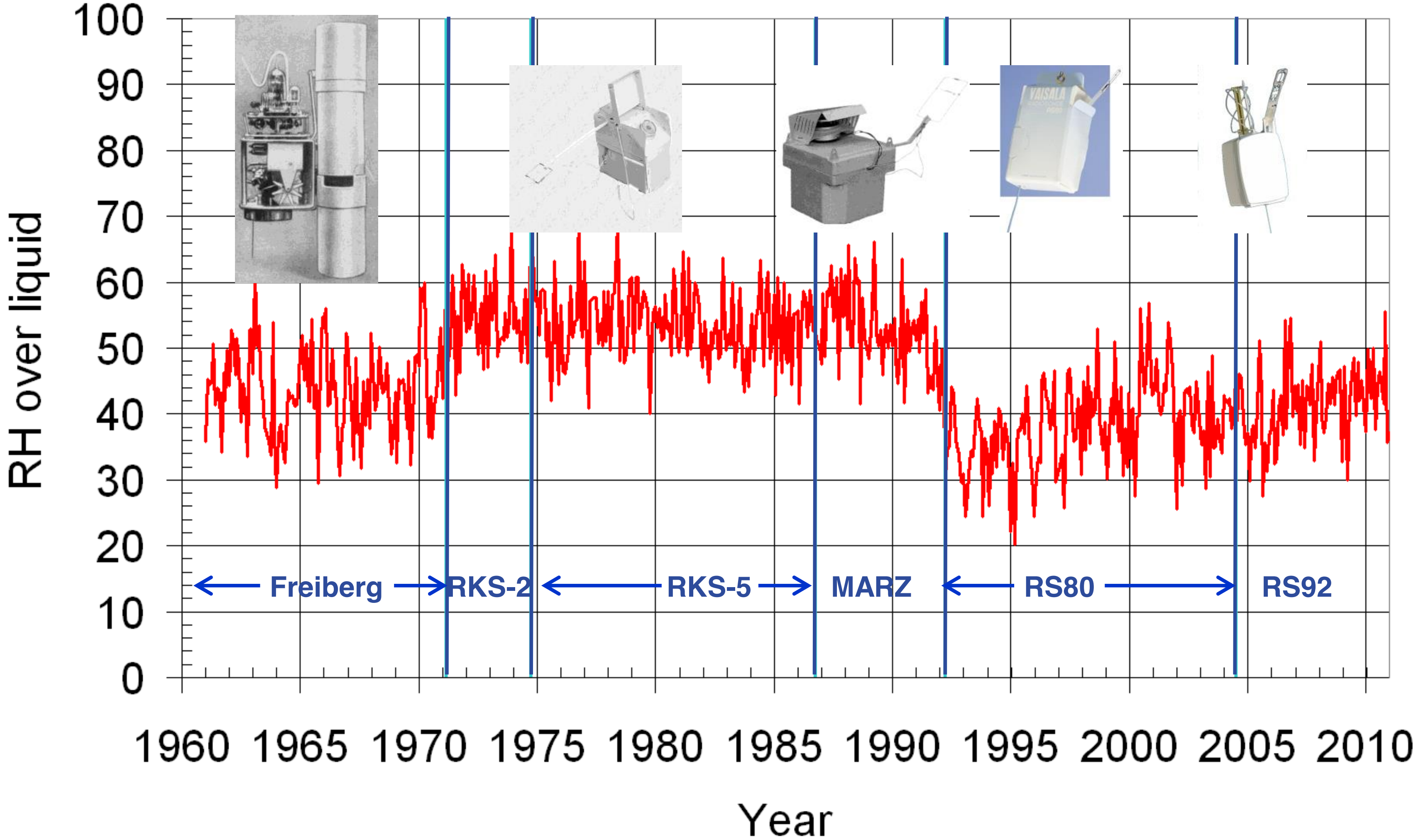


Outlines

a. Characterize global RAOB UTLS temperature biases from different sensor types using GPS RO temperature (Ho et al., ACP, 2017)

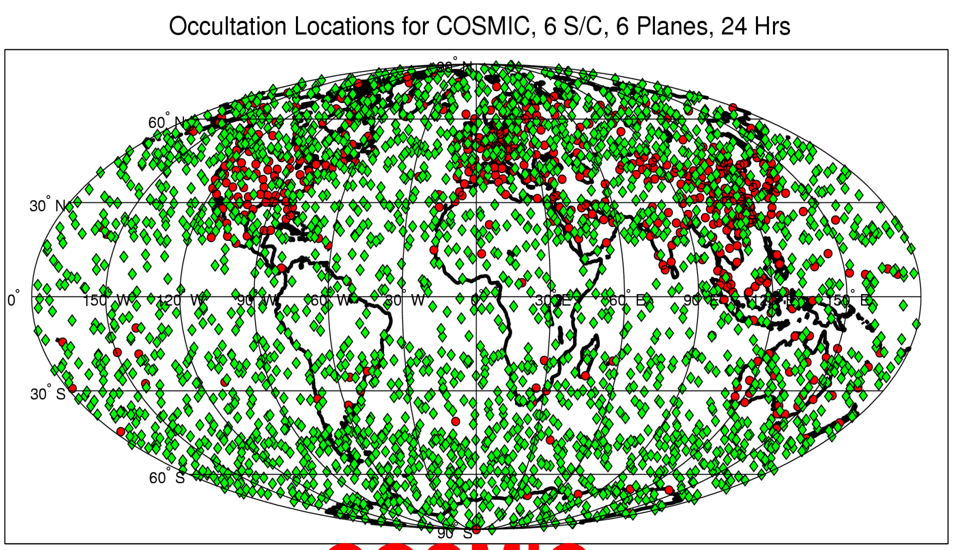
b. Correct global RAOB UTLS temperature biases from different sensor types

c. Characterize GRUAN RS92 and GRUAN RS41 RAOB temperature biases using RO data

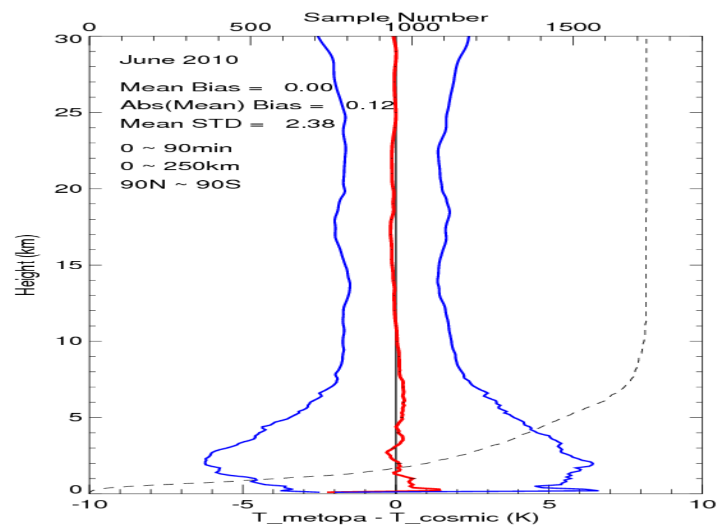
a. Identify global RAOB temperature biases in the UTLS using RO data

RO data for climate research

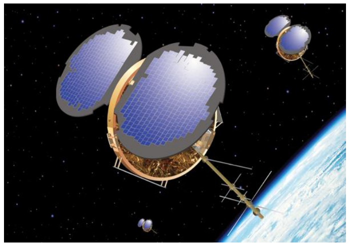
- **Measure of time delay: no calibration is needed**
- **Requires no first guess sounding**
- **Not affect by clouds**
- **Uniform spatial/temporal coverage**
- **High precision (<0.05K)** (Ho et al., TAO, 2009)
- **Insensitive to clouds and precipitation**
- **No mission dependent bias** (Ho et al., TAO, 2009)
- **Reasonable structural uncertainty among data processed from different centers (Ho et al., JGR, 2009, 2012, Steiner et al., ACP 2012)**
- **Short term RAOB vs. real time RO comparison (He et al., 2009; Sun et al., 2011, 2013)**
- **A 8-year of RAOB vs. re-processed RO comparison study (Ho et al., ACP, 2017)**



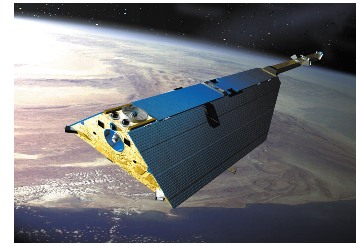
COSMIC

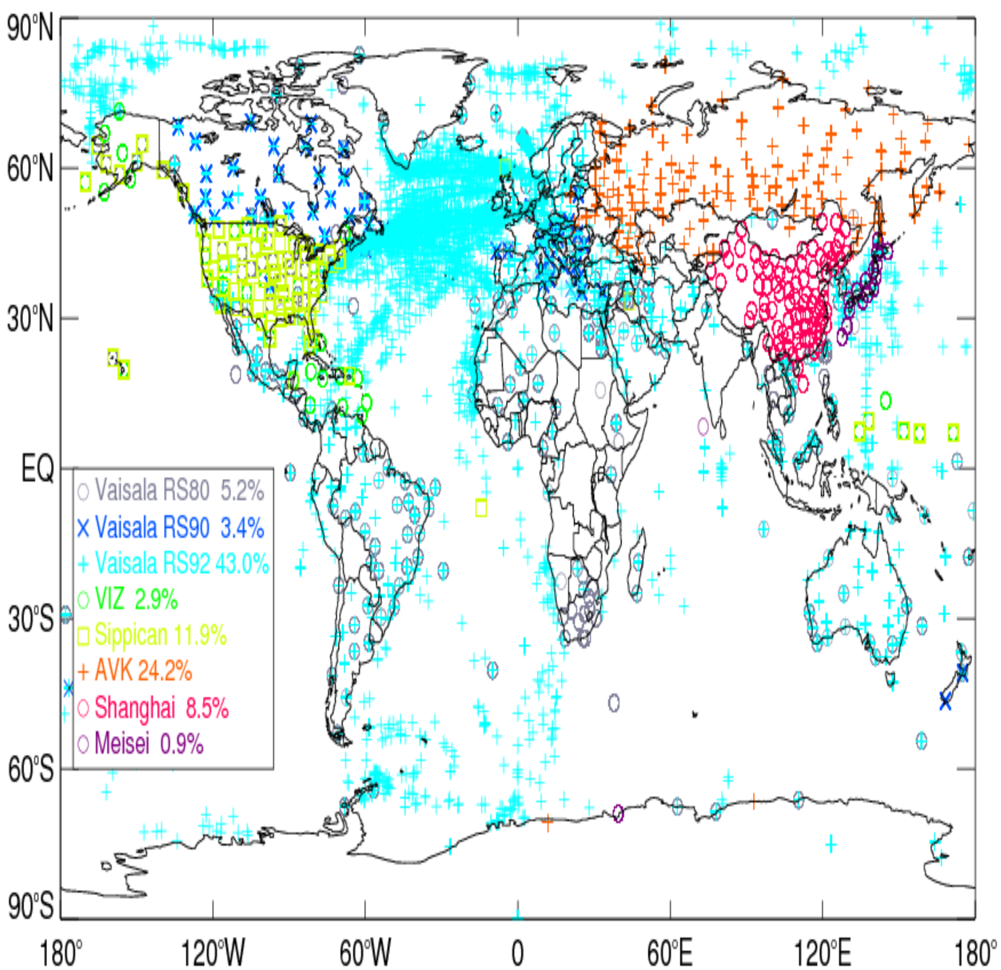


Metop-A – COSMIC



Approach: Using COSMIC and Metop-A/-B re-processed data from 2006 to 2015 to characterize the biases of radiosonde temperature over UTLS





Radiosodne data DS353.4 from NCAR
- originally acquired from NCEP.
- contains the original data values transmitted by stations
- no radiative or other corrections from NCEP are included in this dataset

He et al., (2009 GRL)

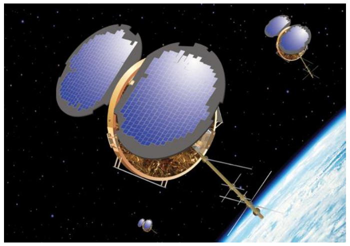
Collocate COSMIC/Metop-A/-B and radiosonde profiles from 2006-2015

< 200 km

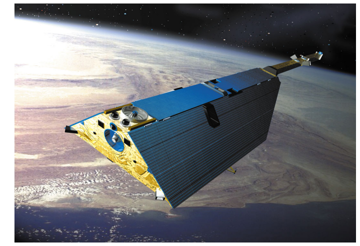
< 3 hrs

Separate all RAOB-RO pairs into two groups:

1) Testing subset: to define RAOB temperature biases using RO
2) Independent sub-set: Applying the bias correction and comparing to GPS RO



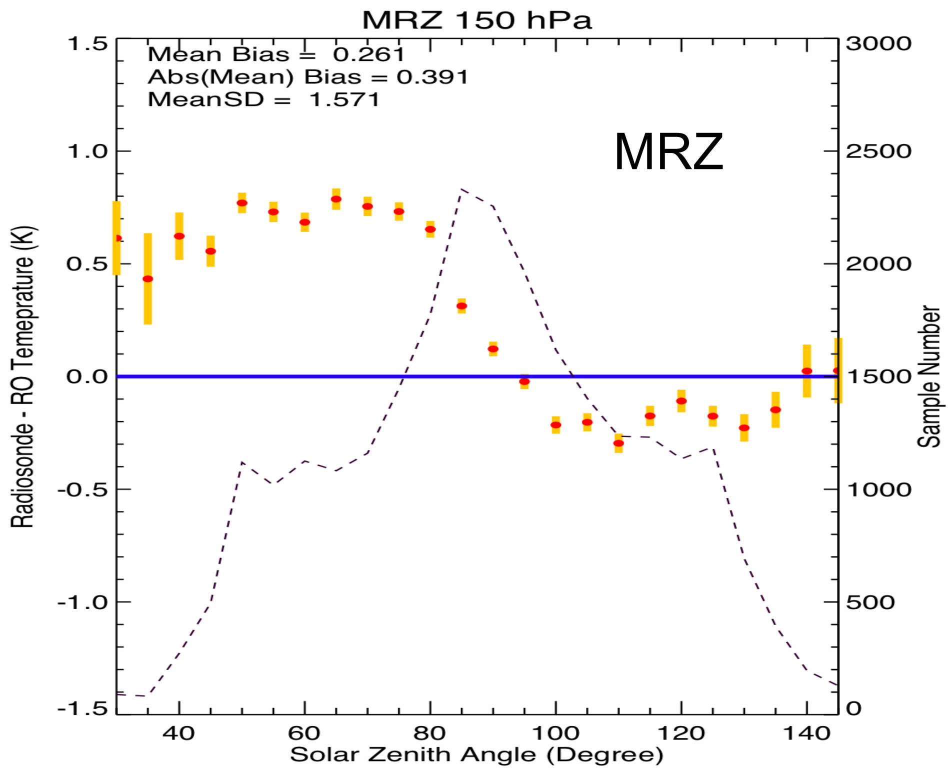
Using RO data to Identify Diurnal variation of Radiosonde Temperature Anomalies for i) different sensors, ii) different heights

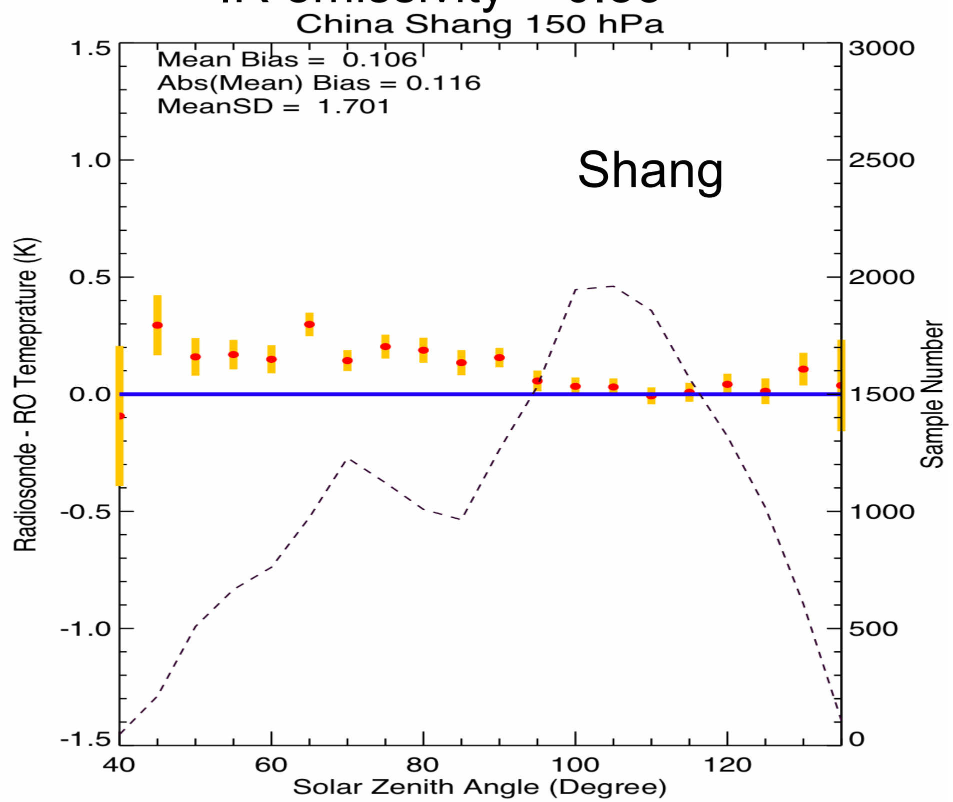


Solar absorptivity = 0.2
IR emissivity = 0.04

150 hPa

Solar absorptivity = 0.15
IR emissivity = 0.85



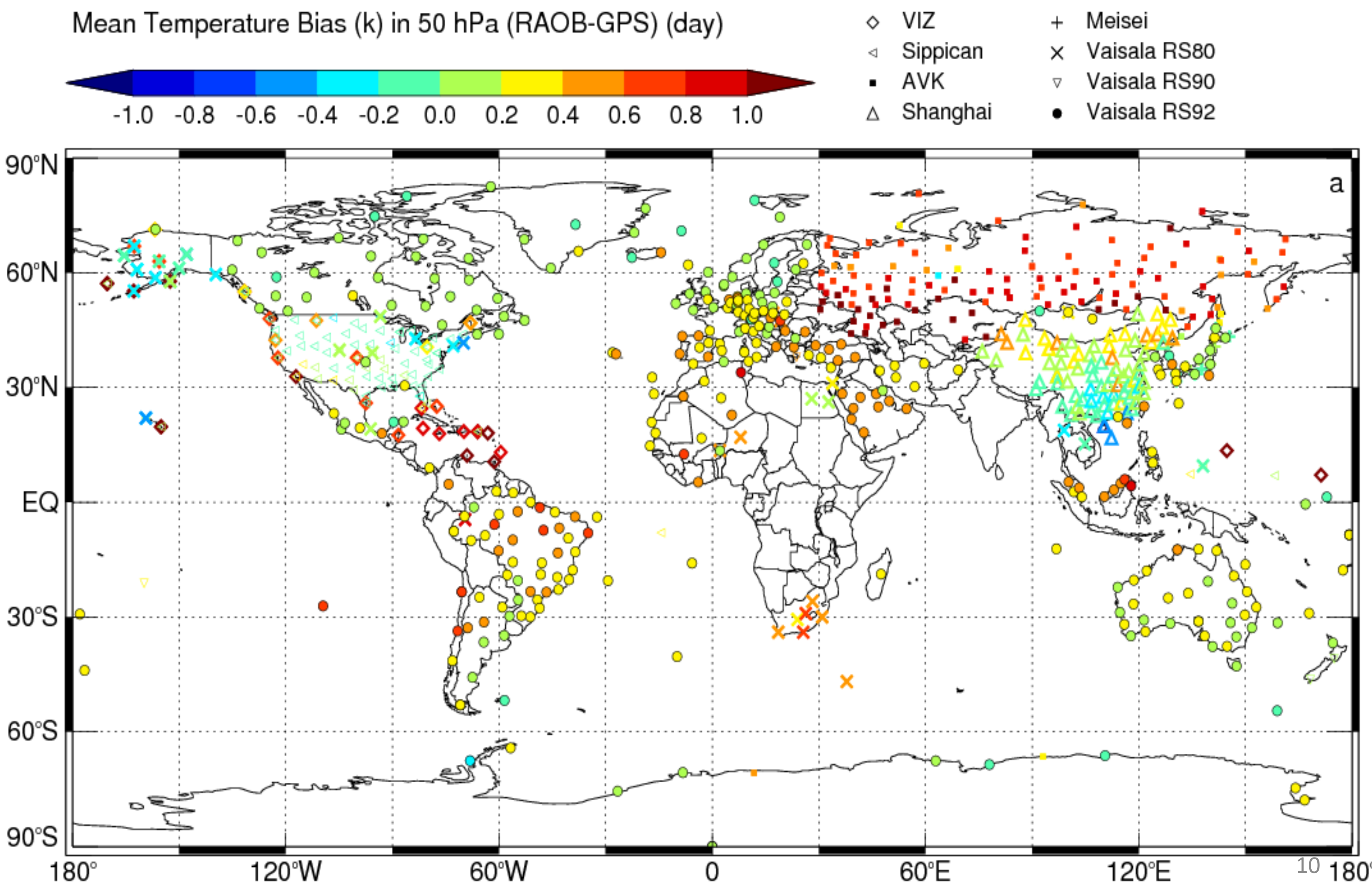


Ho, S. -P., L. Peng, and H. Voemel, 2017: Characterization of the long-term radiosonde temperature biases in the upper troposphere and lower stratosphere using COSMIC and Metop-A/GRAS data from 2006 to 2014. *Atmospheric Chemistry and Physics*, 17, 4493-4511, doi:10.5194/acp-17-4493-2017.

b. Correction of global RAOB temperature biases in the UTLS using RO data

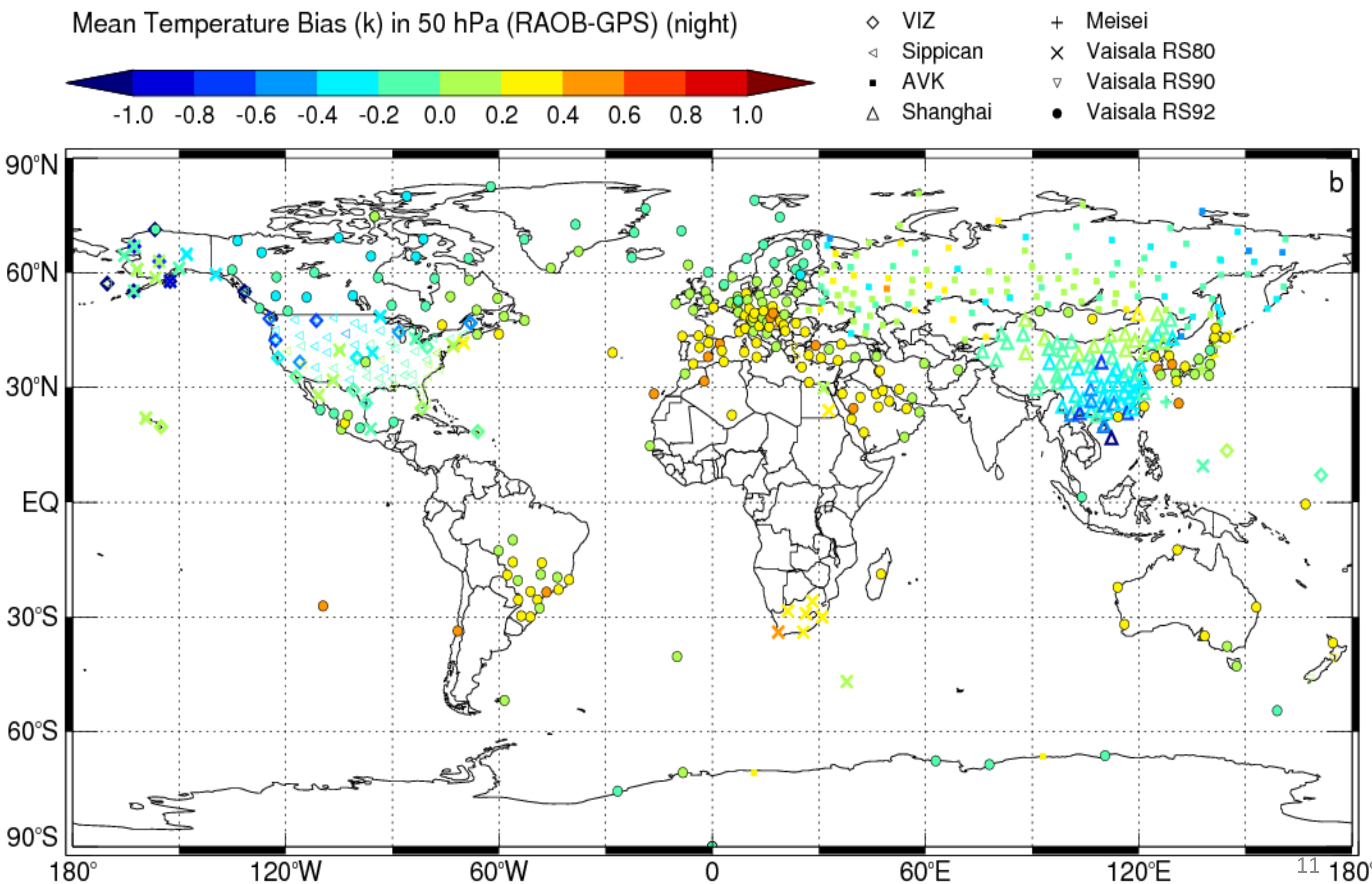
i). Global map

50 hPa Day time



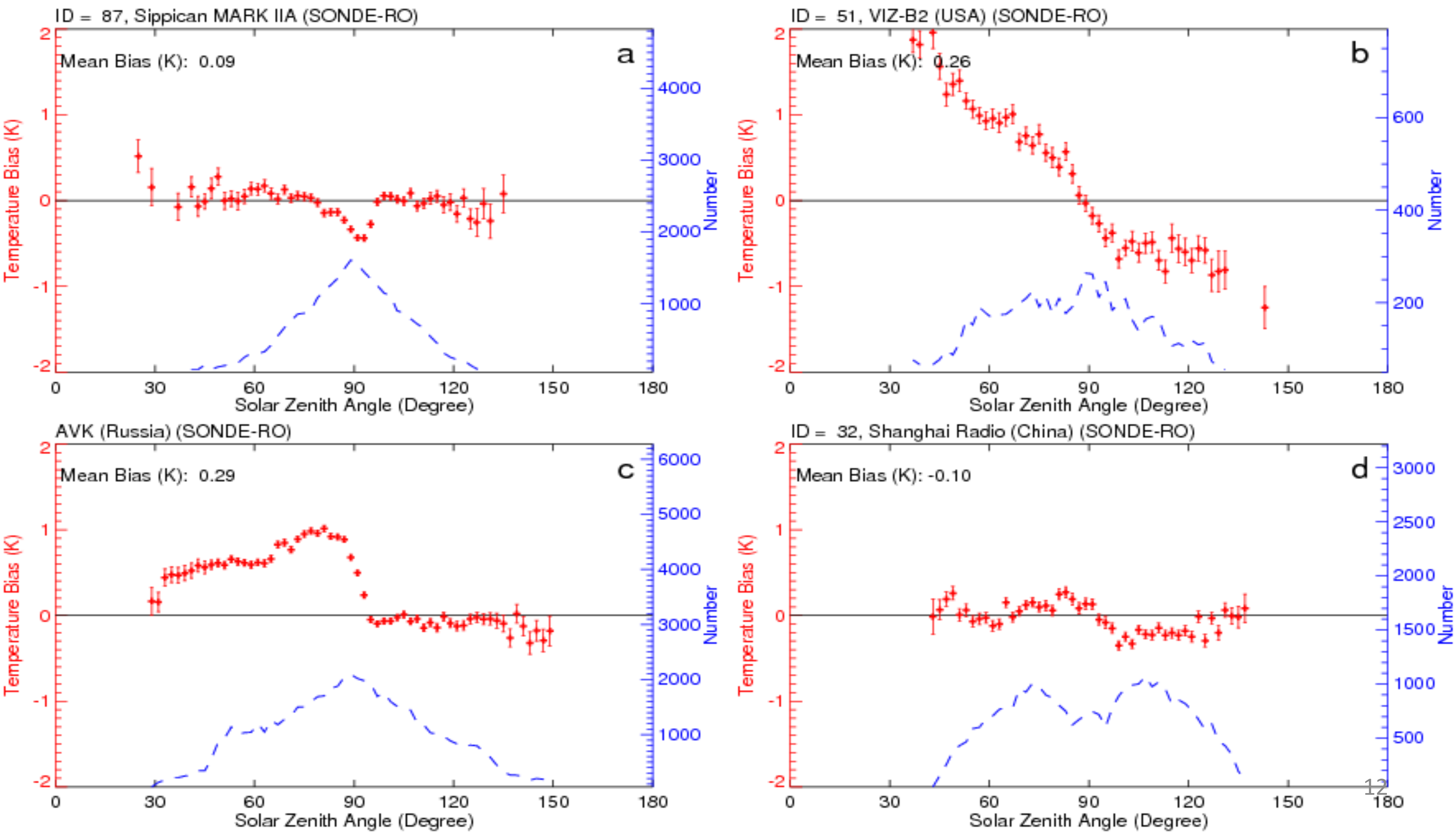
i). Global map

50 hPa Night time



ii). Correction RAOB temperature for different solar zenith angle

Before correction



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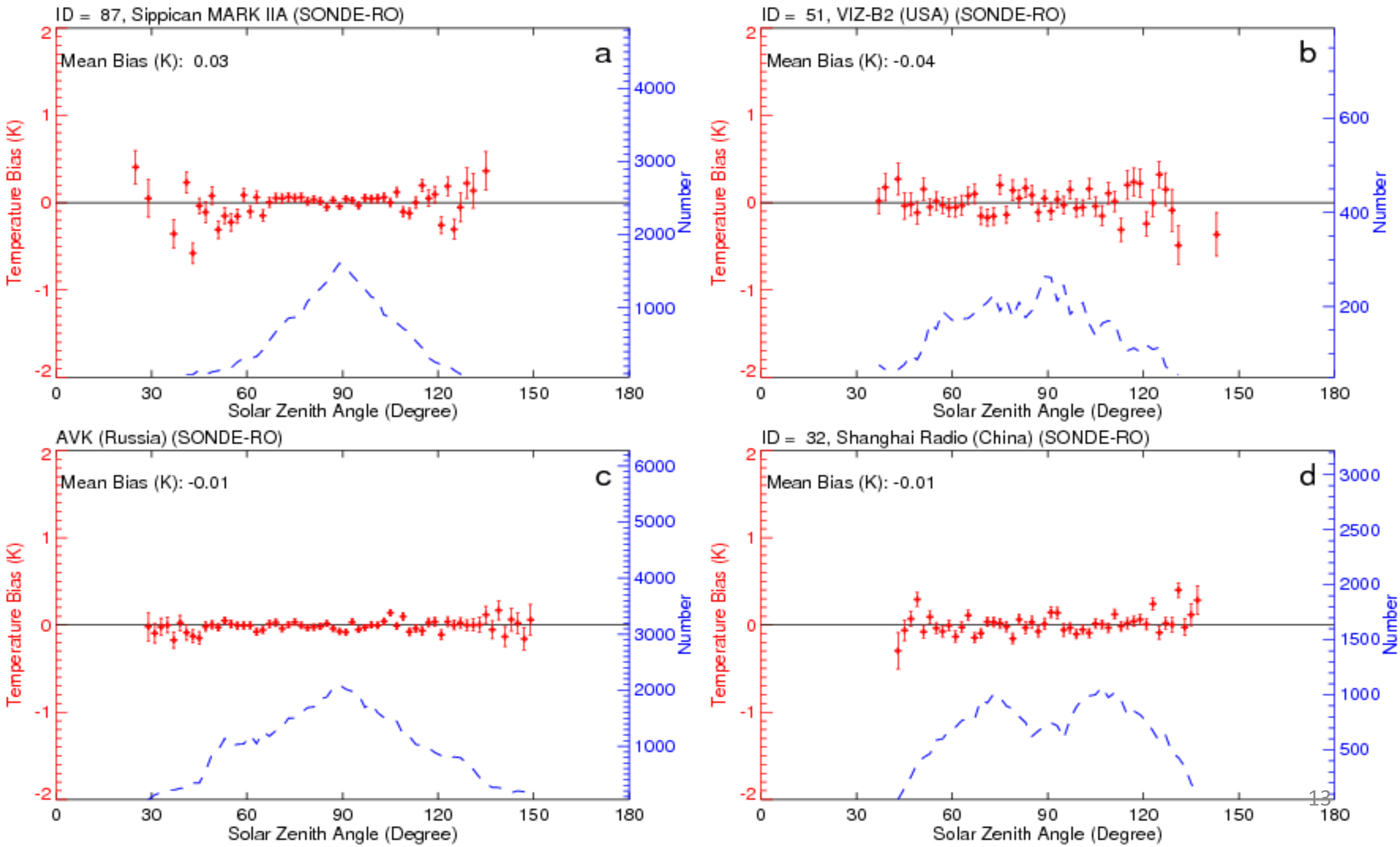
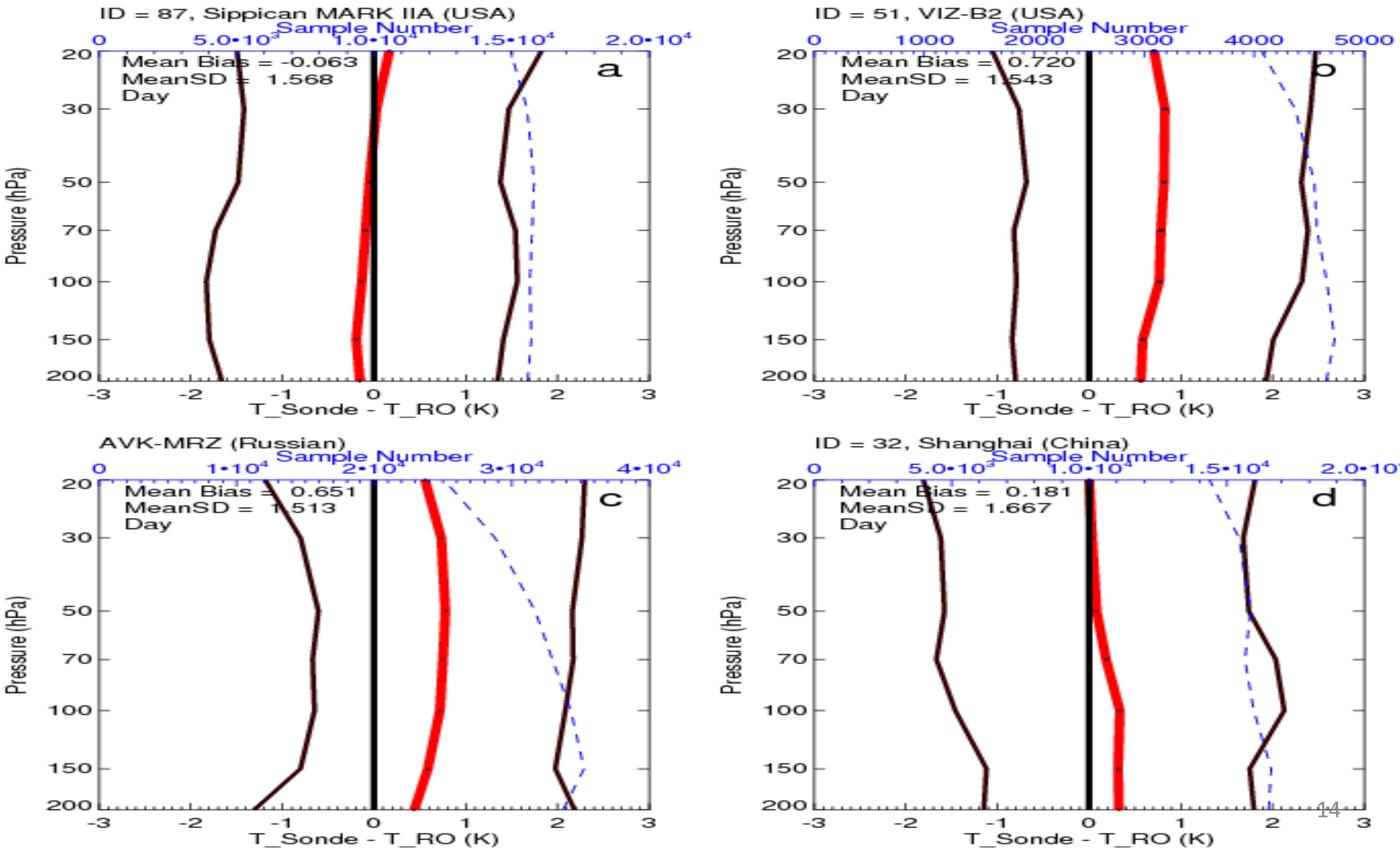
After correction



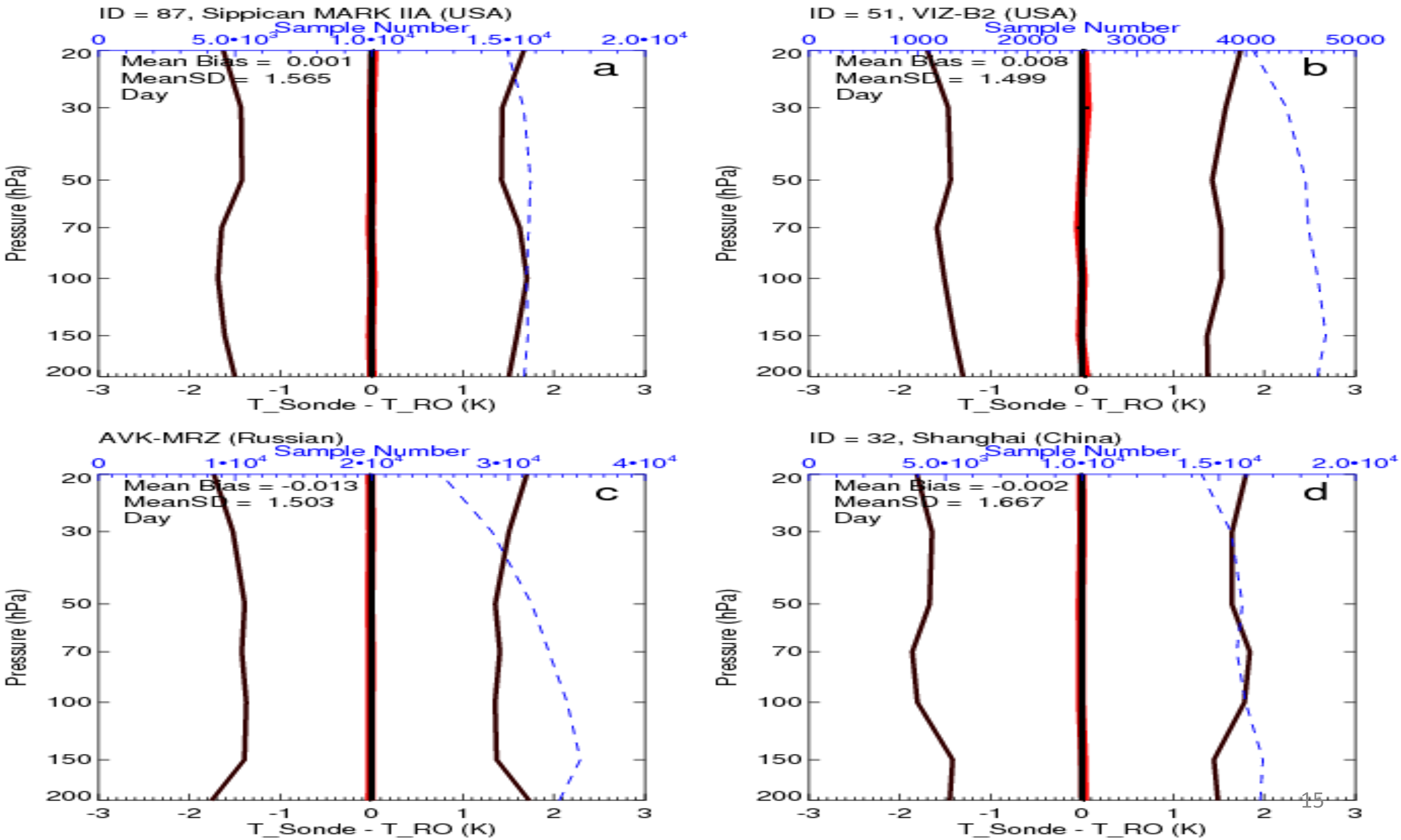
iii). Correction RAOB temperature for different solar zenith angle at different heights

Before correction



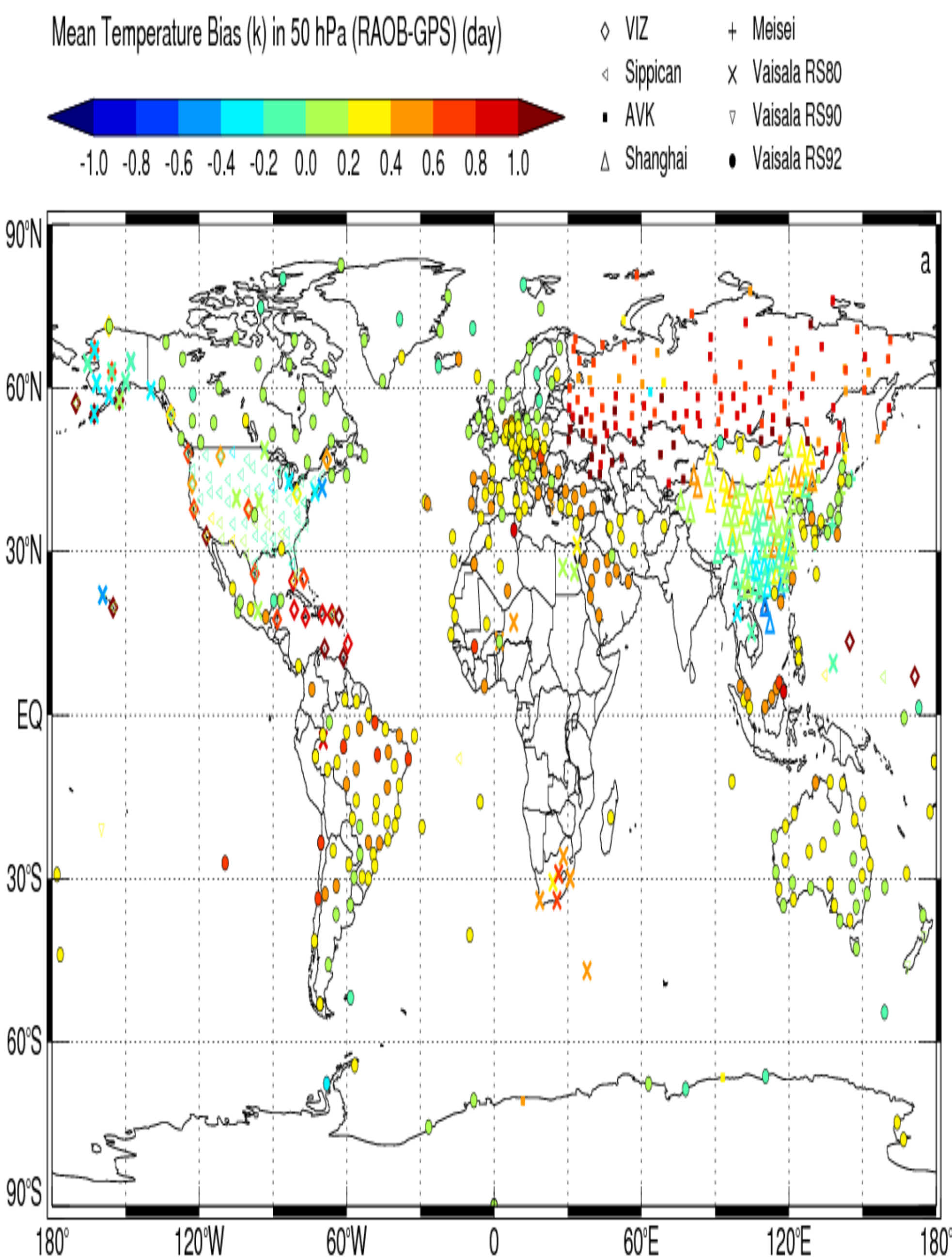
iii). Correction RAOB temperature for different solar zenith angle at different heights

After correction

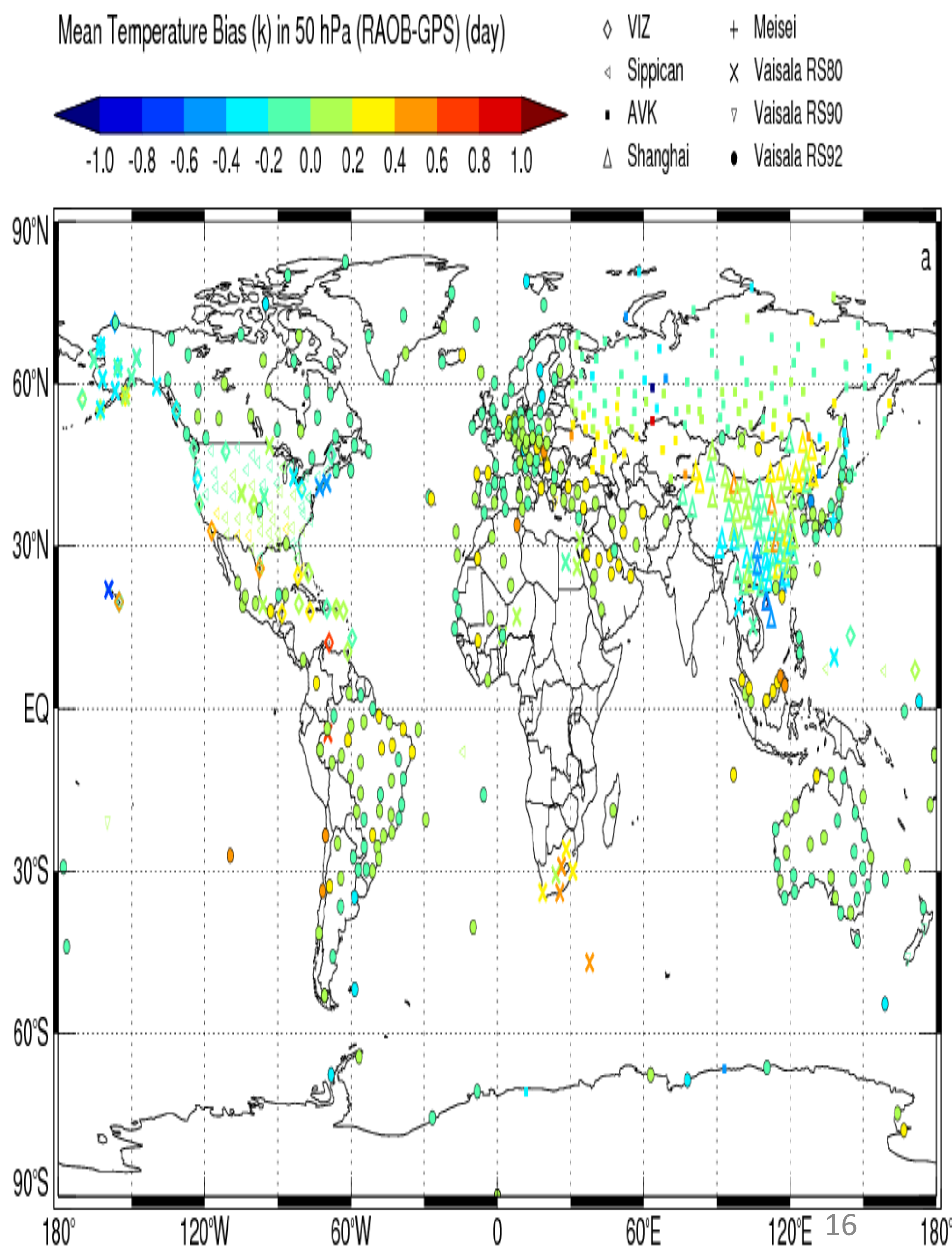


iv). Day-night difference

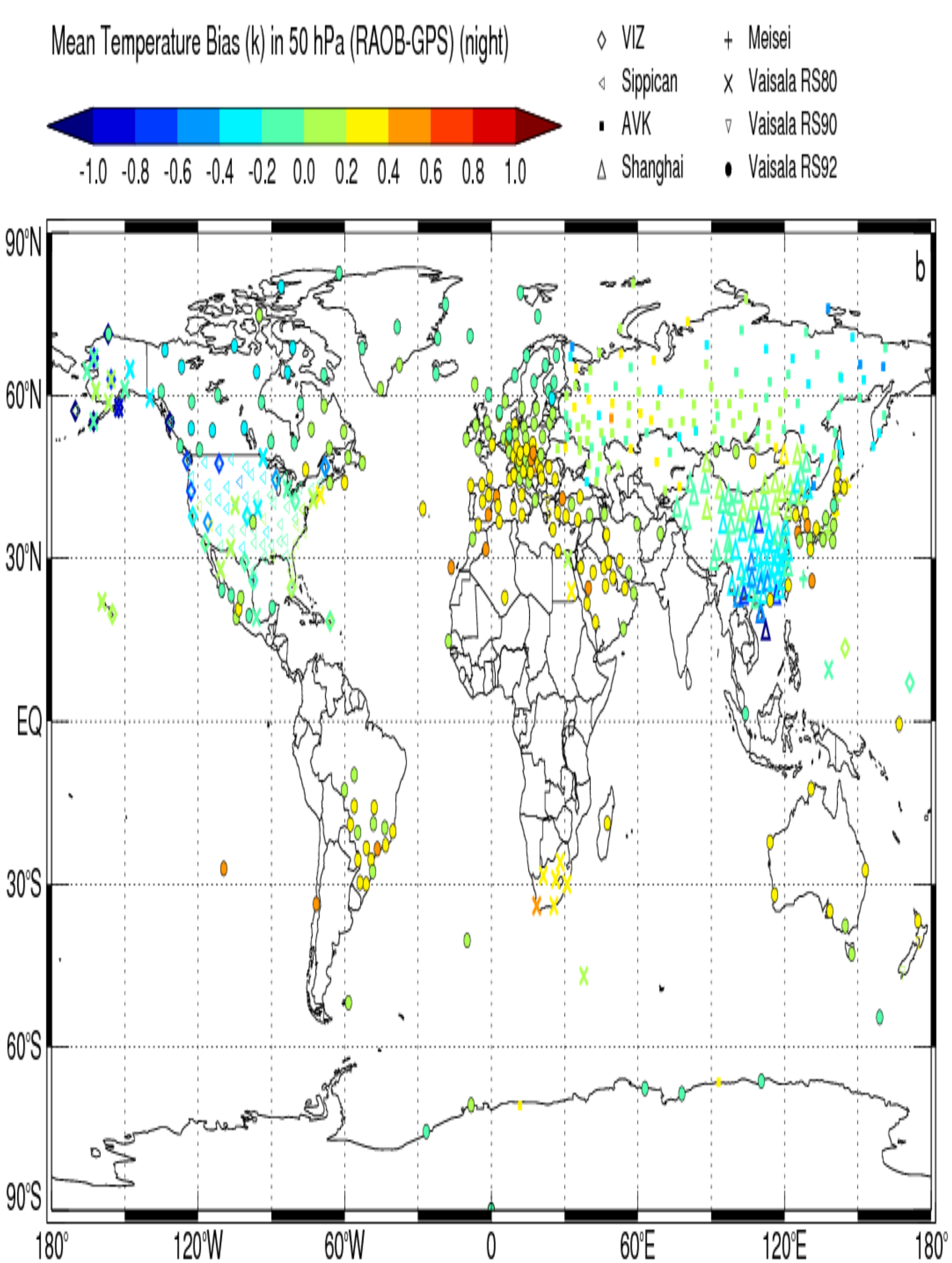
RAOB – RO at 50 hPa Day



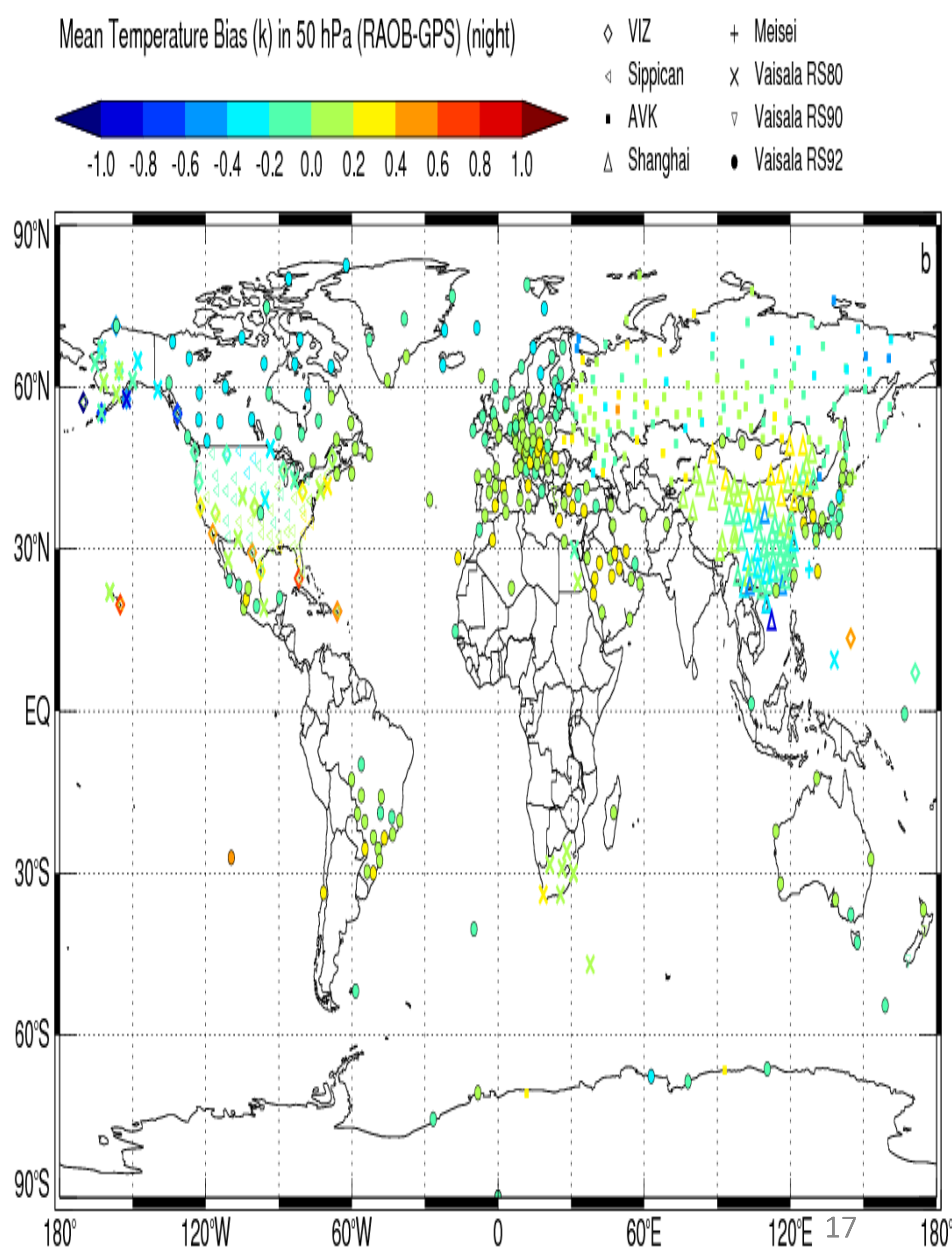
Corrected RAOB – RO at 50 hPa Day



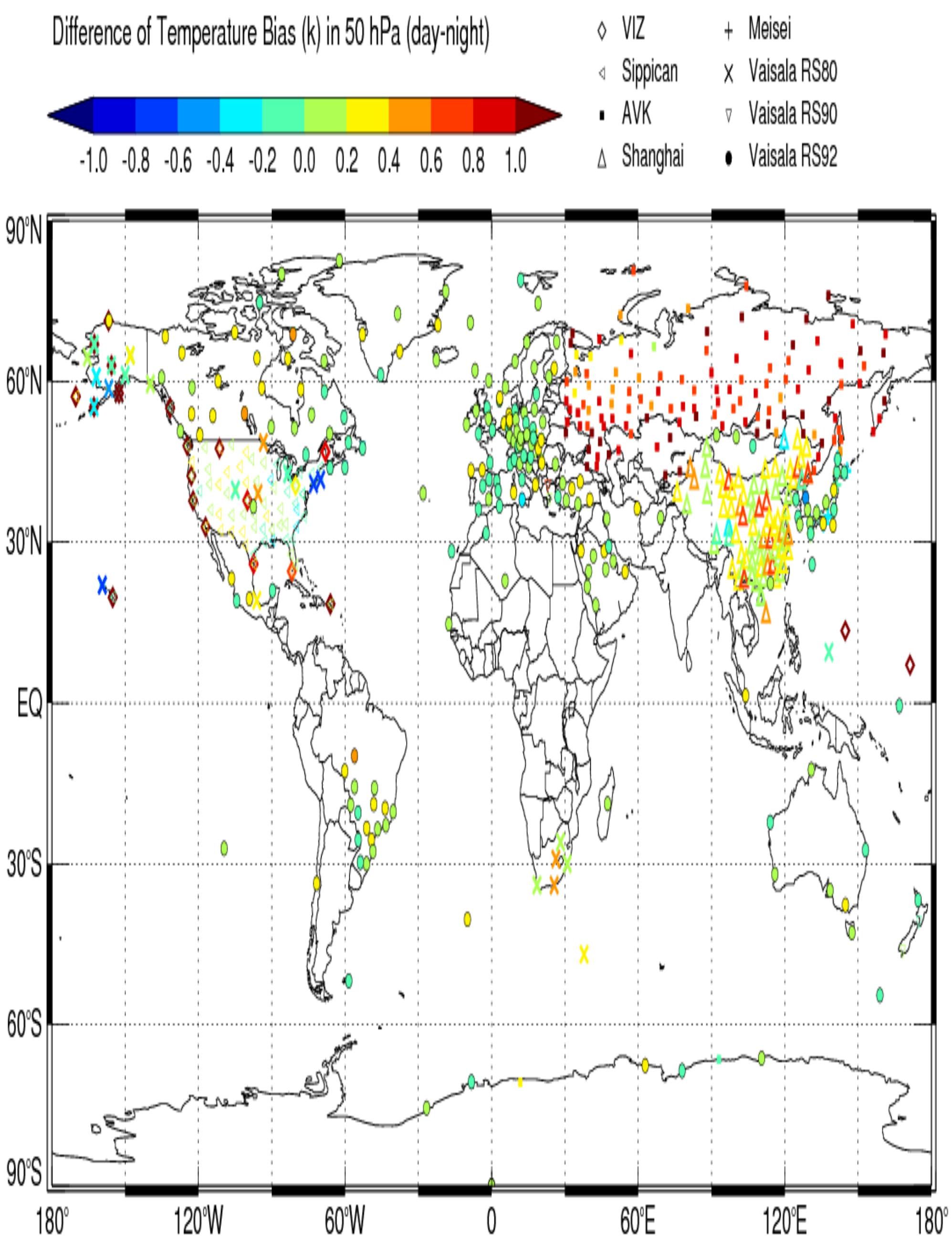
RAOB – RO at 50 hPa Night



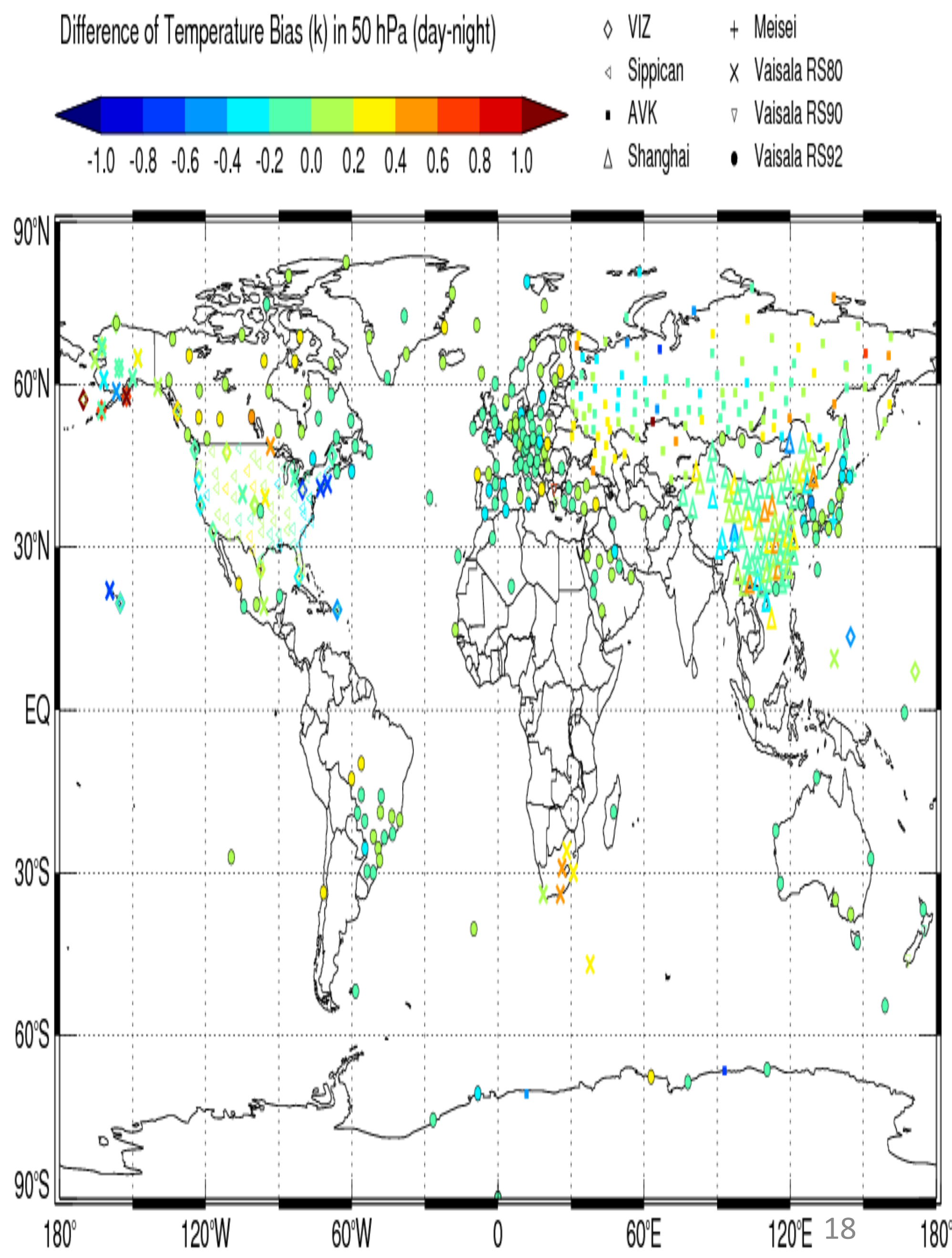
Corrected RAOB – RO at 50 hPa Night



RAOB – RO at 50 hPa Day - Night

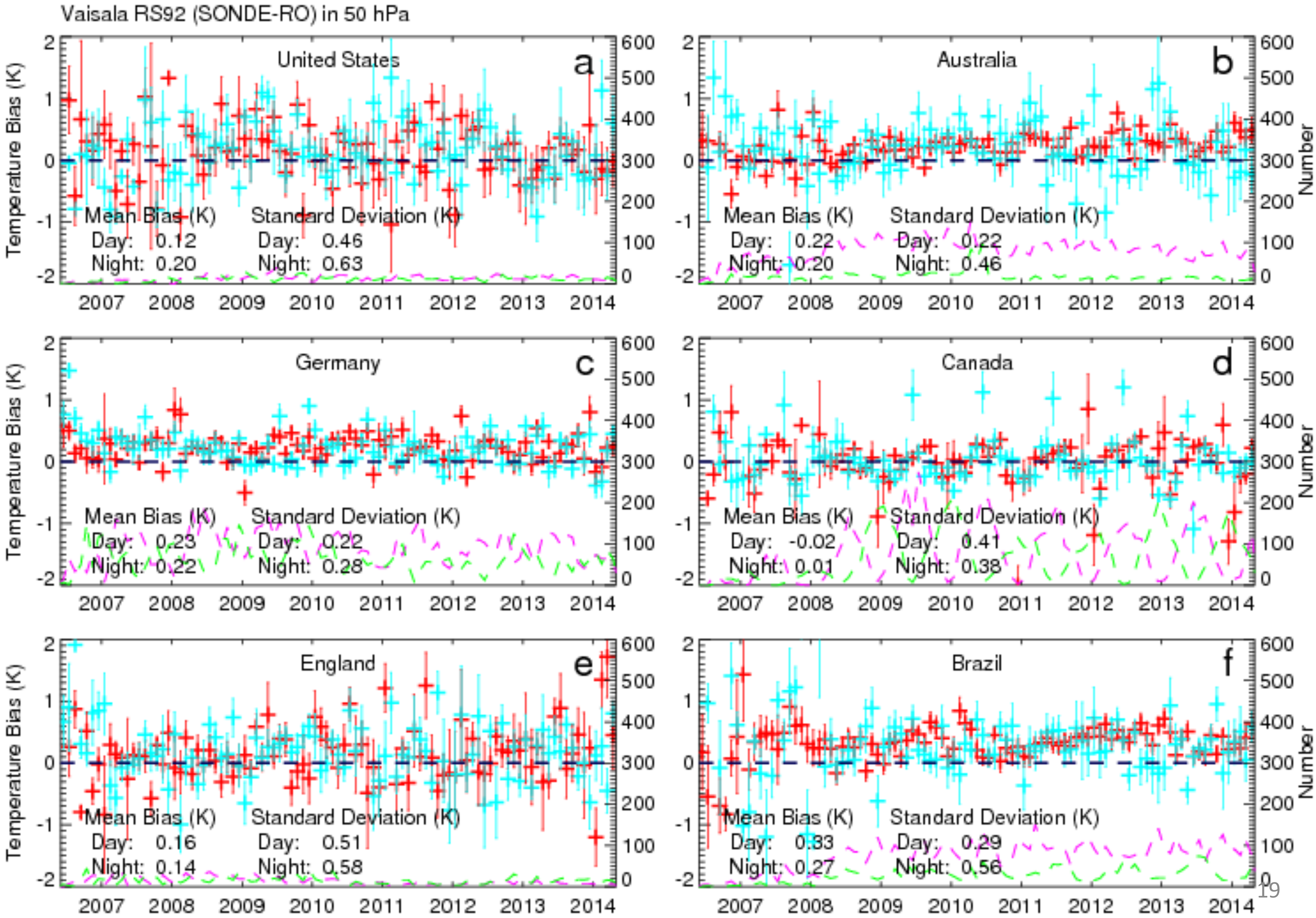


Corrected RAOB – RO at 50 hPa Day - Night

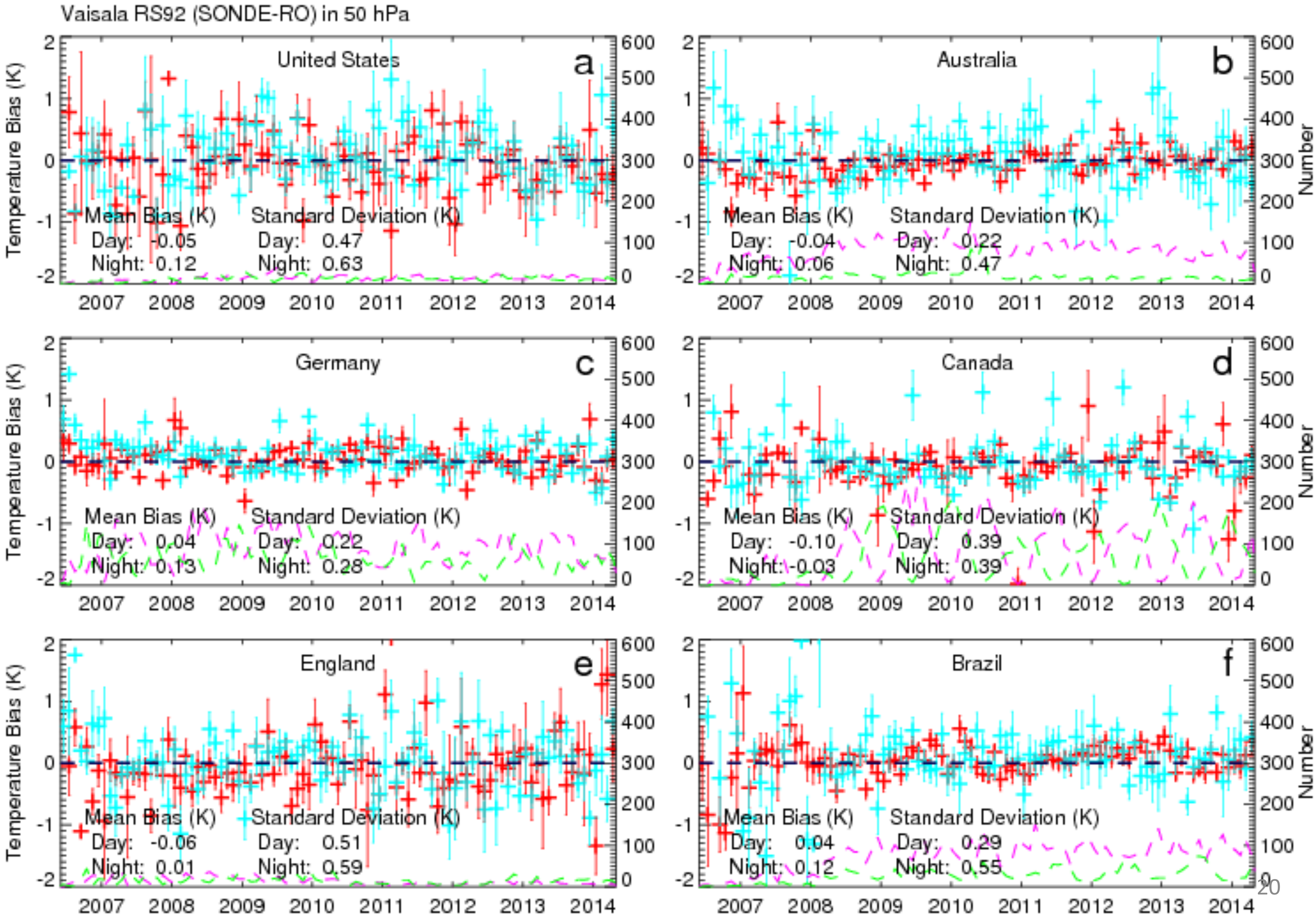


v). Time series biases

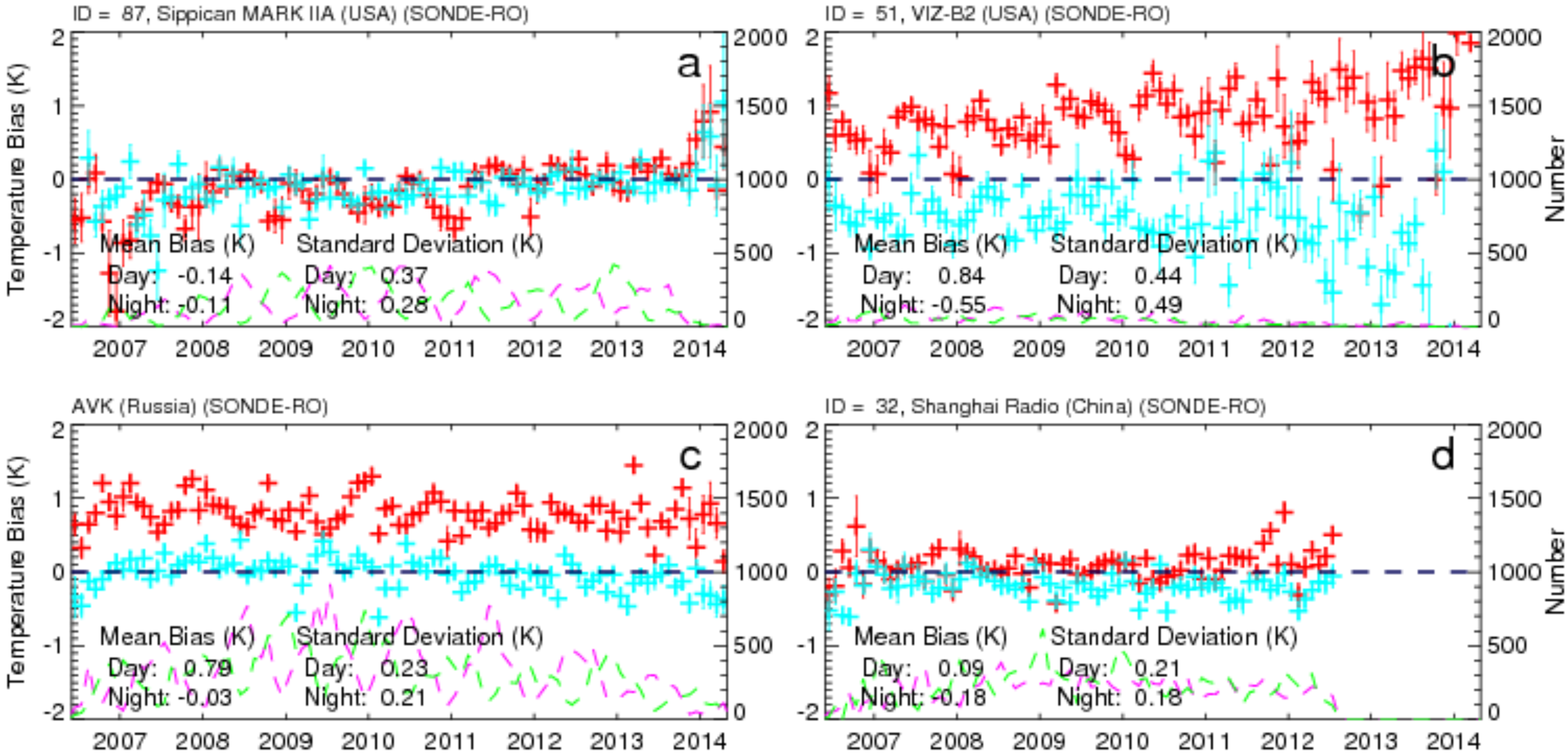
Before correction



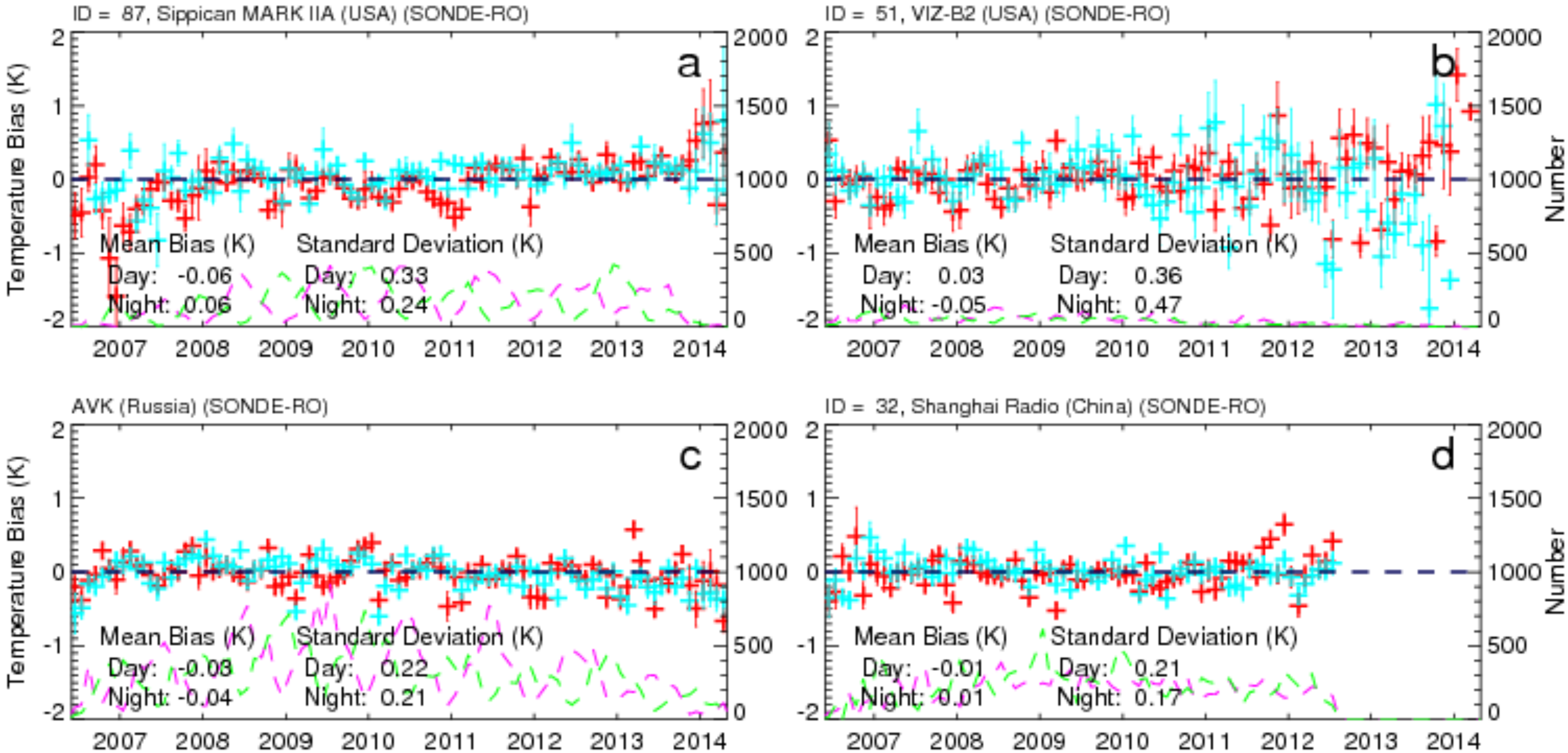
After correction



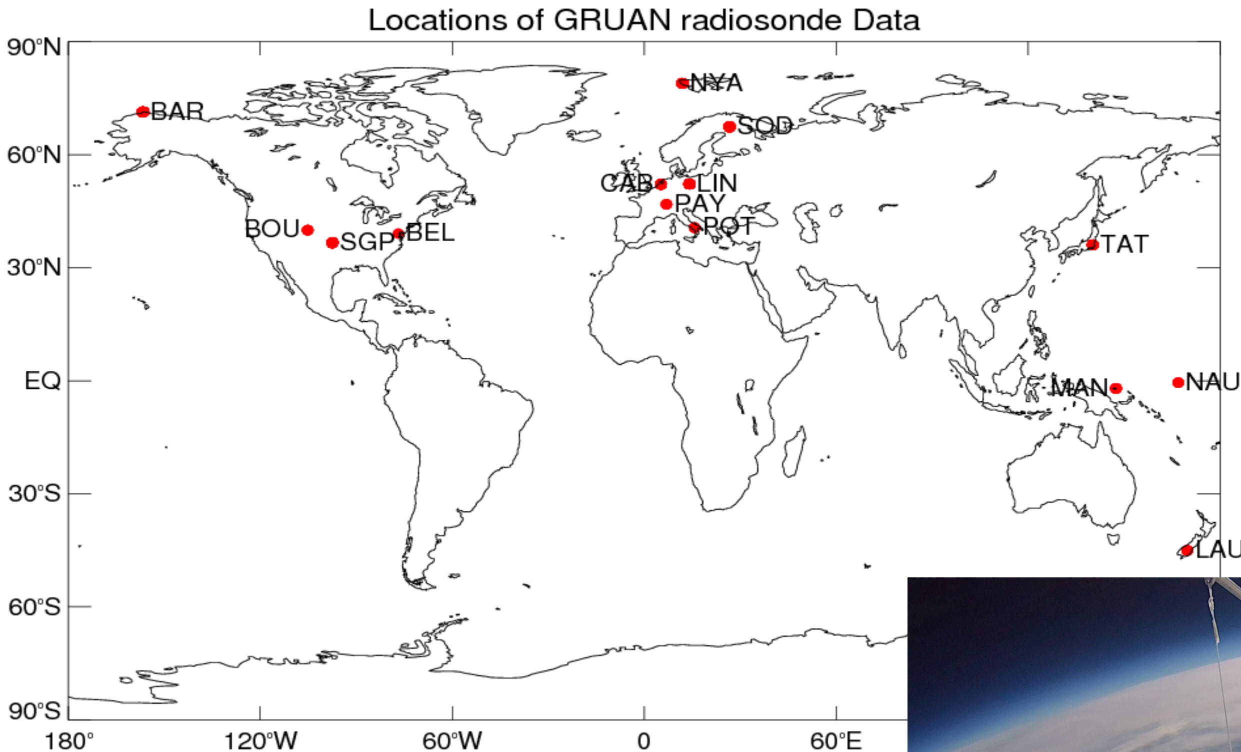
Before correction



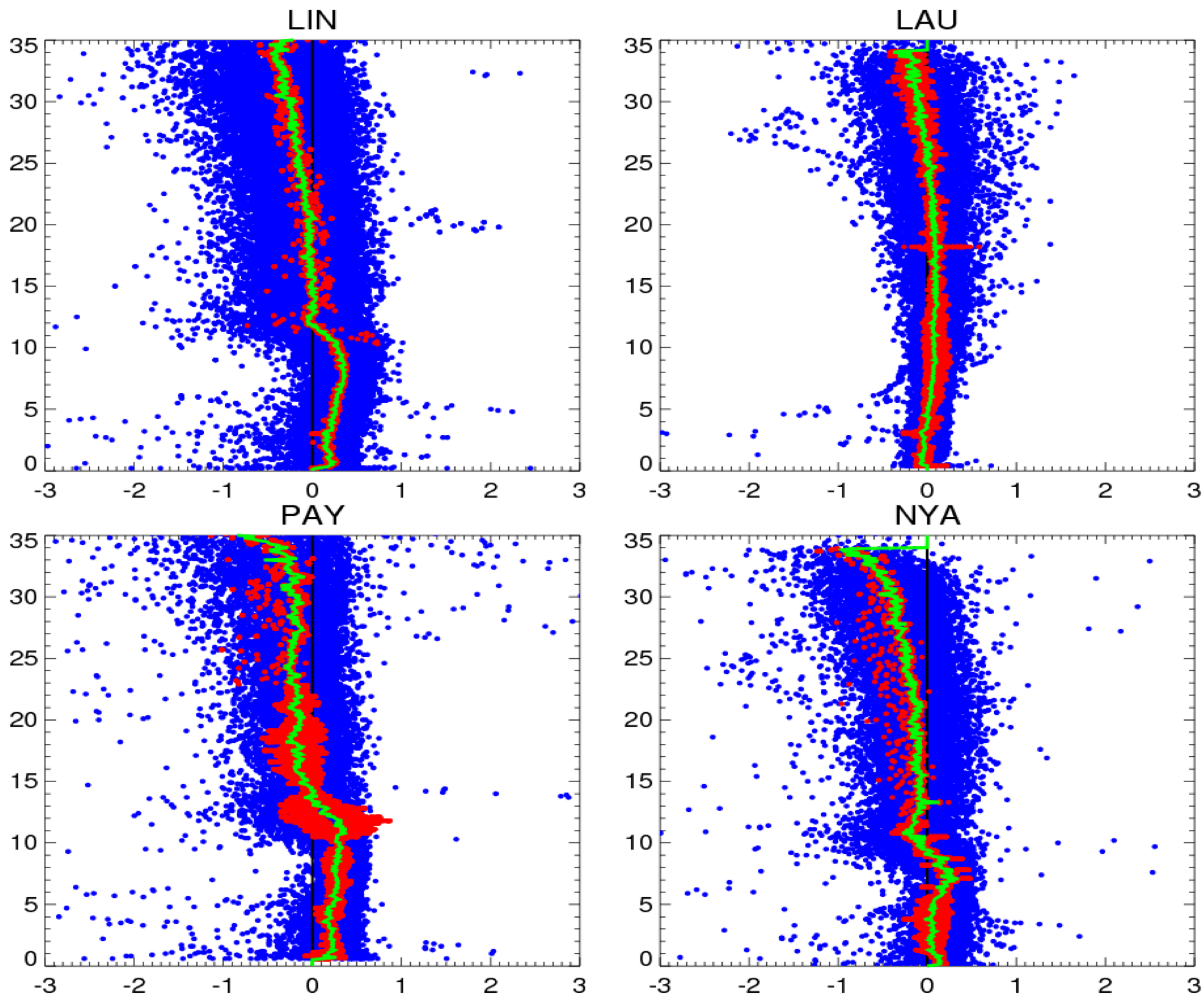
After correction

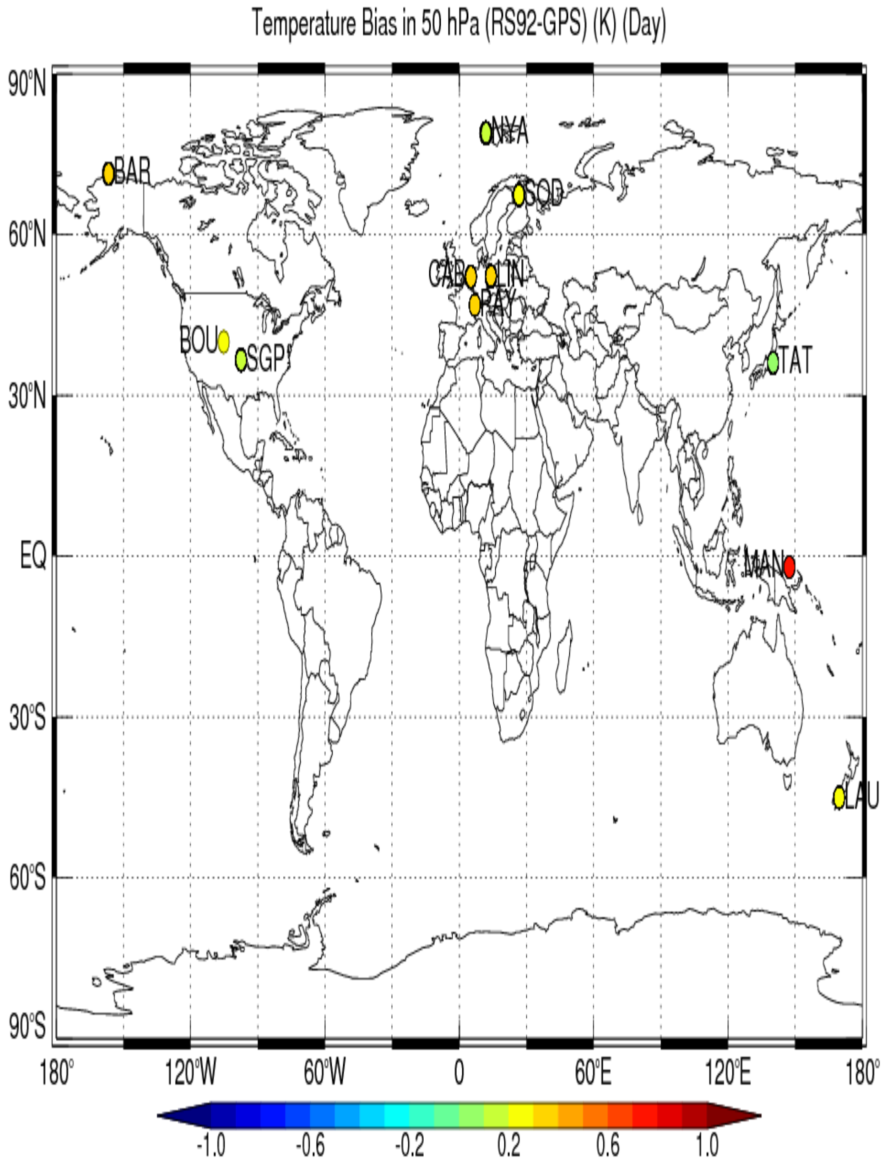


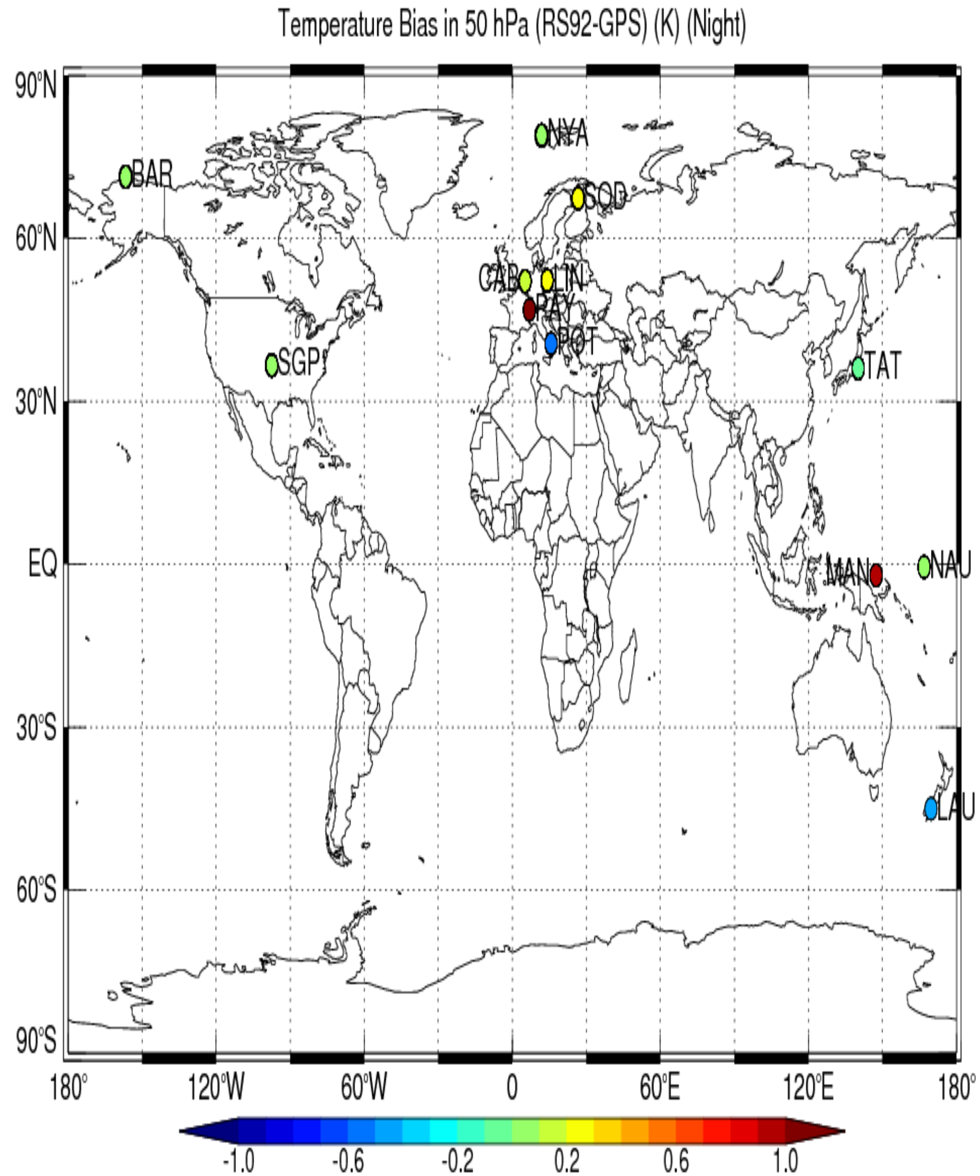
c. Characterize GRUAN RS92 and GRUAN RS41 RAOB temperature biases using RO data



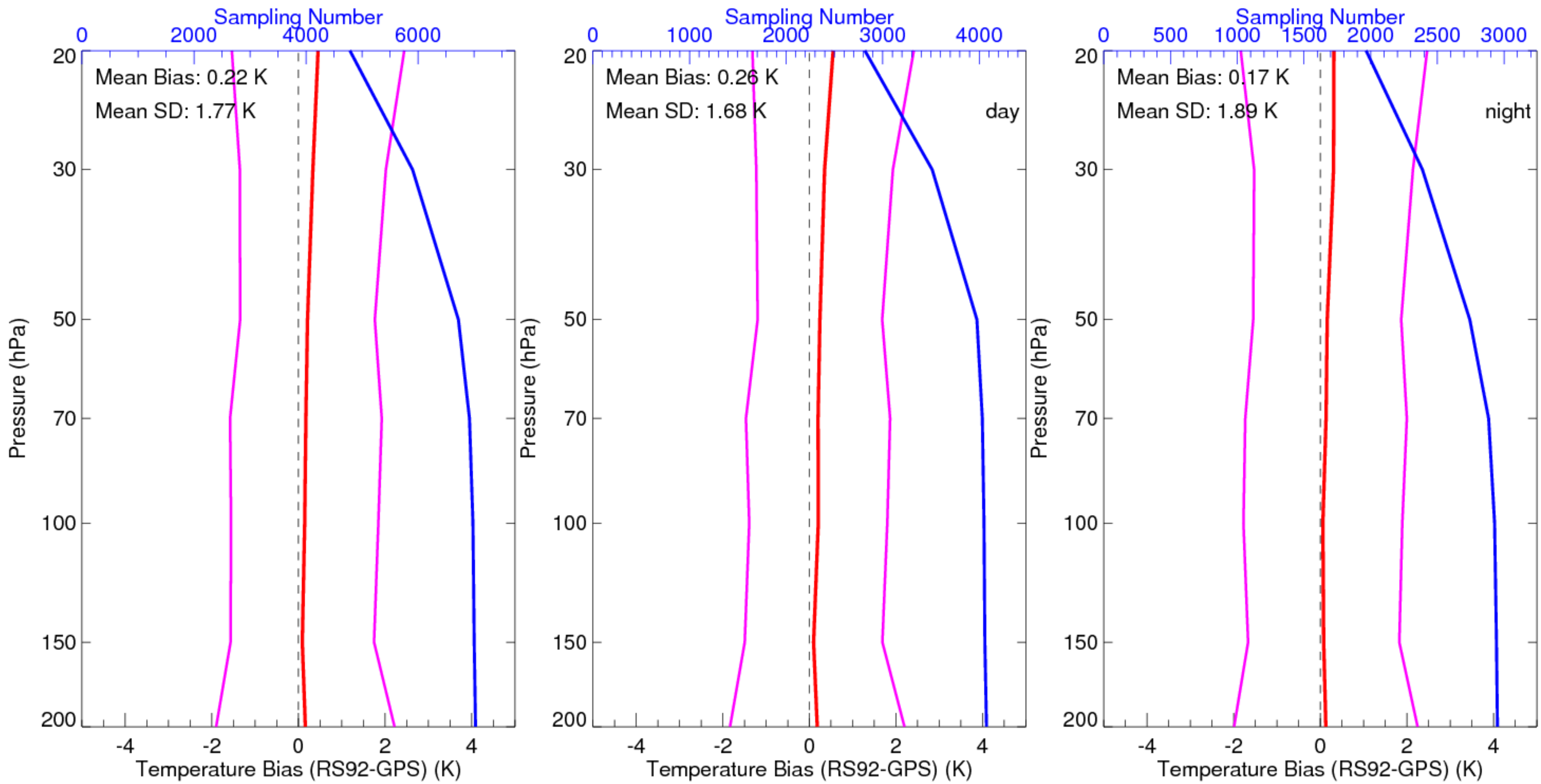
GRUAN RS41 – RS92



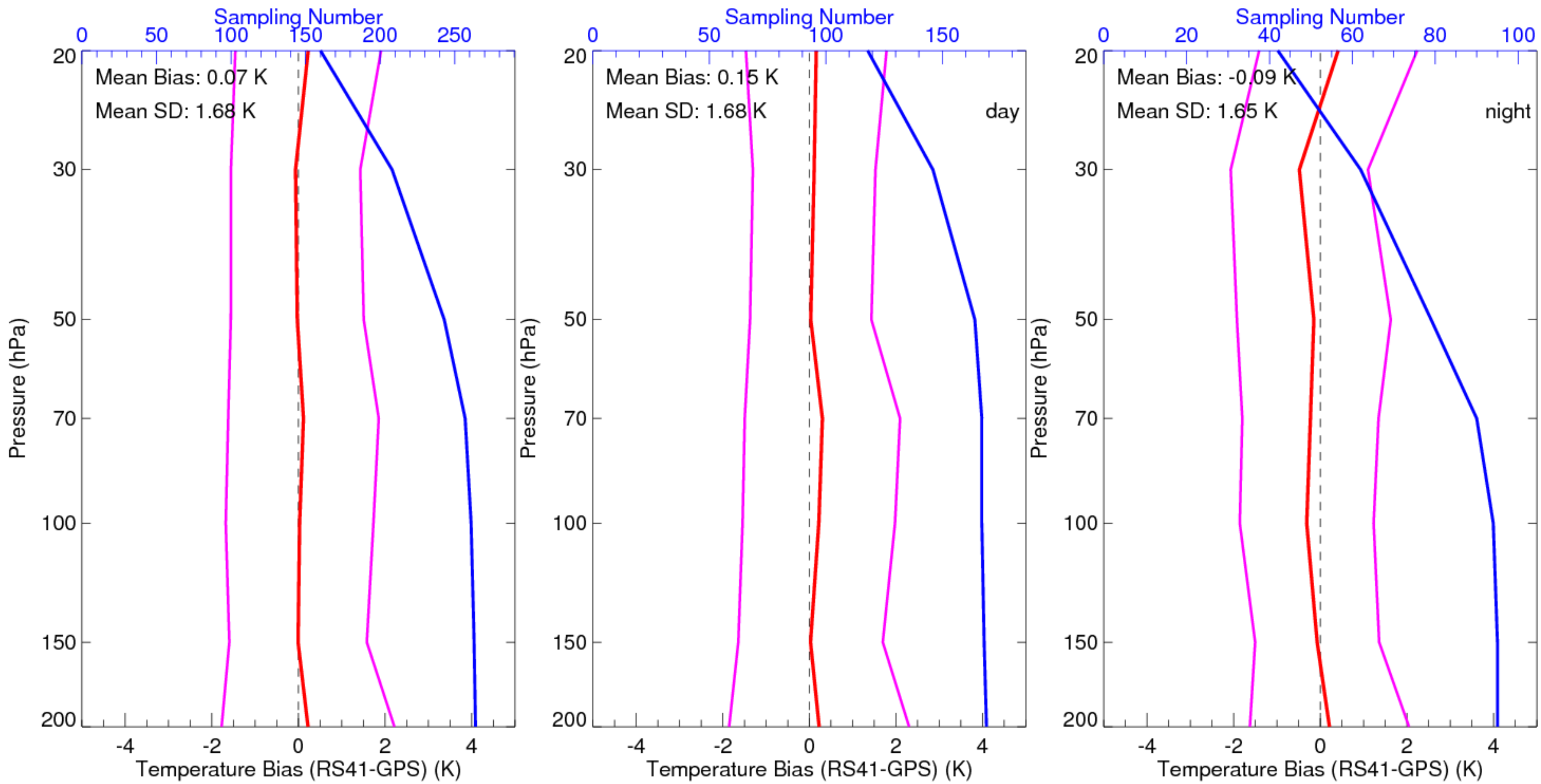

Temperature Bias in 50 hPa (RS92-GPS) (K) (Day)
90°N
60°N
30°N
EQ
30°S
60°S
90°S
180°
120°W
60°W
0
60°E
120°E
180°
BAR
NYA
SOD
CAB
LIN
PAY
BOU
SGP
TAT
MAN
LAU
-1.0
-0.6
-0.2
0.2
0.6
1.0


Temperature Bias in 50 hPa (RS92-GPS) (K) (Night)
90°N
60°N
30°N
EQ
30°S
60°S
90°S
180°
120°W
60°W
0
60°E
120°E
180°
BAR
NYA
SOD
CAB
LIN
PAY
POT
SGP
TAT
MAN
NAU
LAU
-1.0
-0.6
-0.2
0.2
0.6
1.0

Comparison between GRUAN RS92 and GPS RO



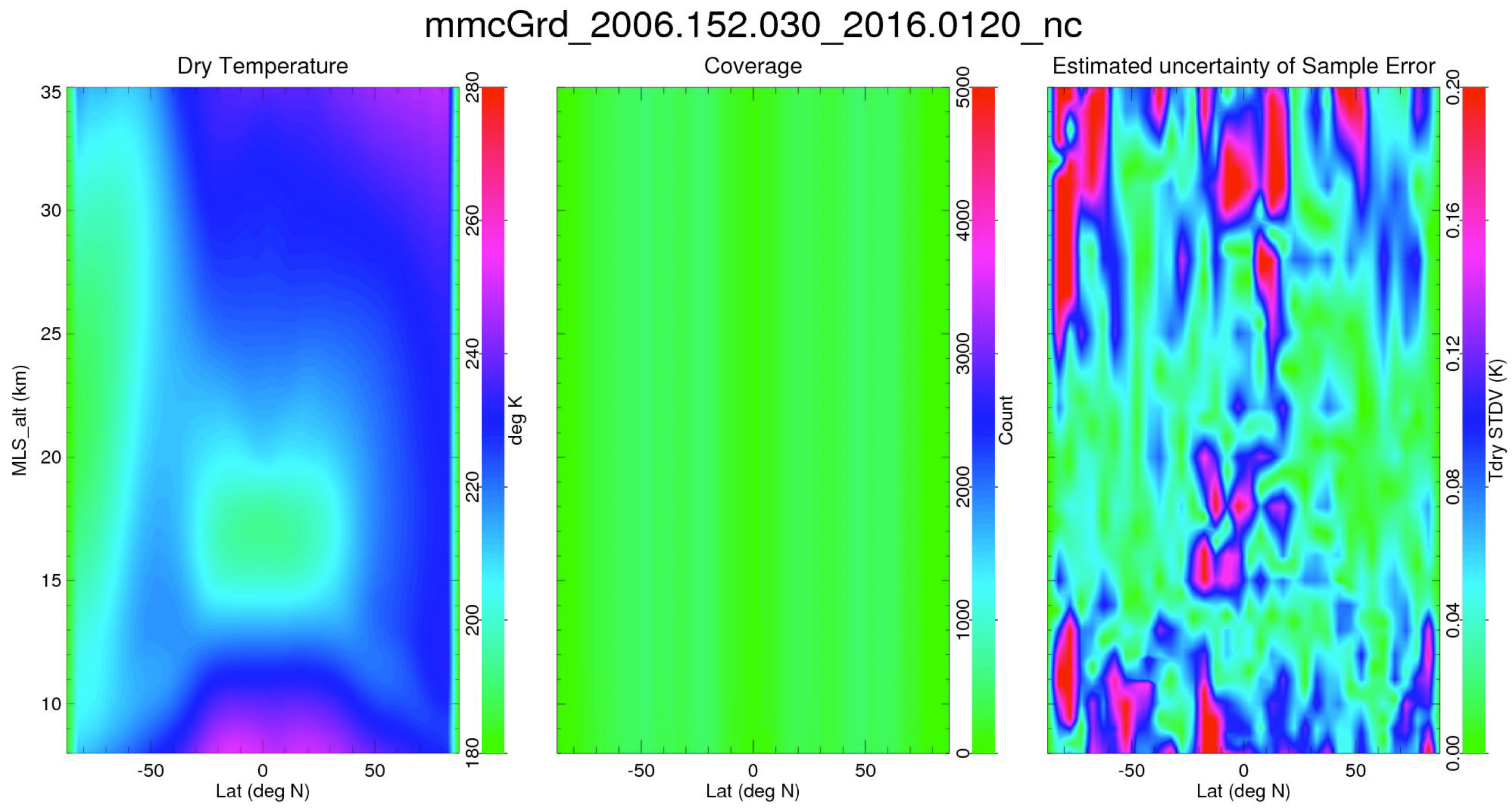
Comparison between GRUAN RS41 and GPS RO

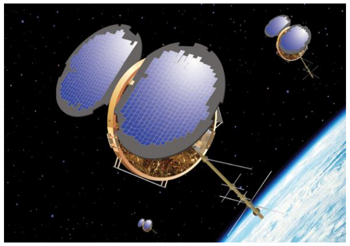


1. **Characterization and Correction of radiosonde temperature biases in the upper troposphere and lower stratosphere using RO data: Assessment of Vaisala RS92, GRUAN RS92, and RS41**

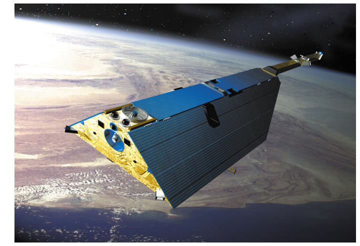
2. **Re-construct of temperature profile in the lower stratosphere using data from re-processed RO data**

Temperature MMC re-constructed using re-processed COSMIC, Metop-A, -B





Conclusions and Future Work

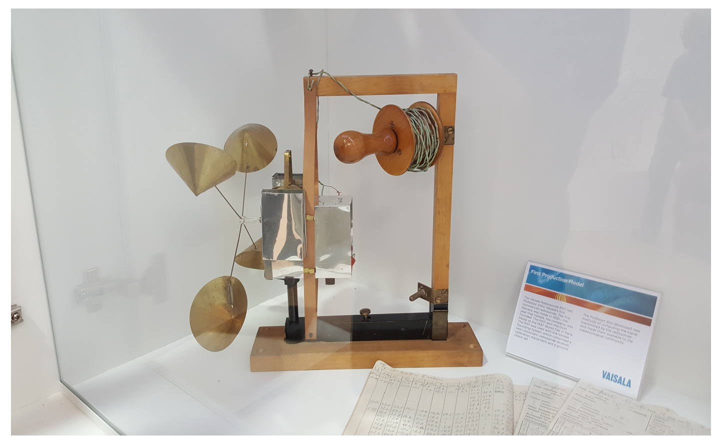


• Geo-location independent COSMIC RO data are useful to identify and correct of radiosonde temperature in the higher troposphere and lower stratosphere

• These results suggest that COSMIC temperature observations are extremely useful as benchmark observations for differentiating radiosonde temperature errors resulting from instrument characteristics and identifying the variation of inter-seasonal biases.

• Here we present the RAOB temperature SZA dependent biases, b. sensor type dependent biases, c. height dependent biases d. Long term stability of RAOB temperature Measurements

- Using RO data to identify GRUAN RS92 and RS41 temperature biases
- Temperature MMC re-constructed using re-processed COSMIC, Metop-A, -B



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Introduction: Challenges for Climate Applications using Infrared and Microwave sounders

Satellites: Comparability and Reproducibility ?

1) Not designed for climate monitoring

2) Changing platforms and instruments

(No Comparability)

a. **Satellite dependent bias, b. geo-location dependent bias, c. orbital drift dependent bias**

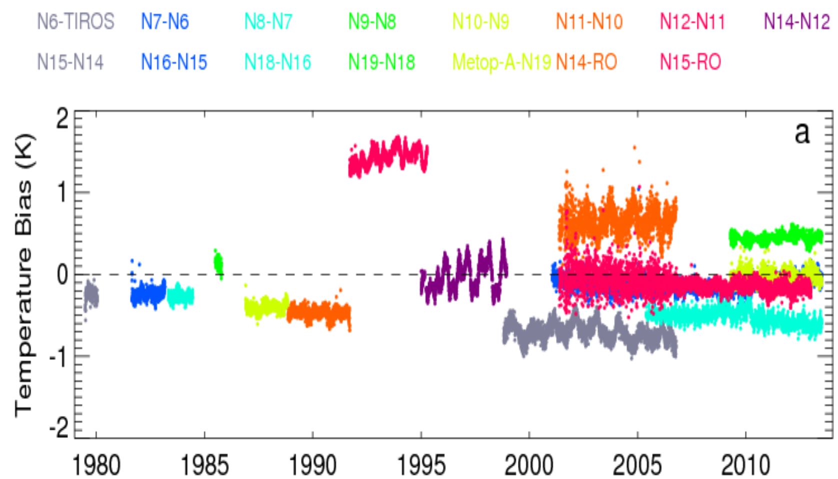
3) Different processing/merging method lead to different trends (RSS vs. UAH).

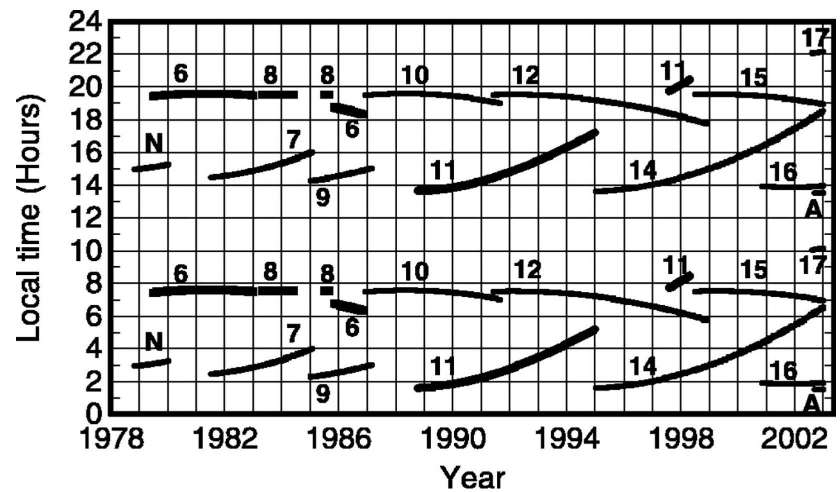
(No Reproducibility)

Radiosondes: changing instruments and observation practices; limited spatial coverage especially over the oceans.

We need measurements with high precision, high accuracy, long term stability, reasonably good temporal and spatial coverage as climate benchmark observations.

Inter-satellite brightness temperature biases for MSU/AMSU instruments





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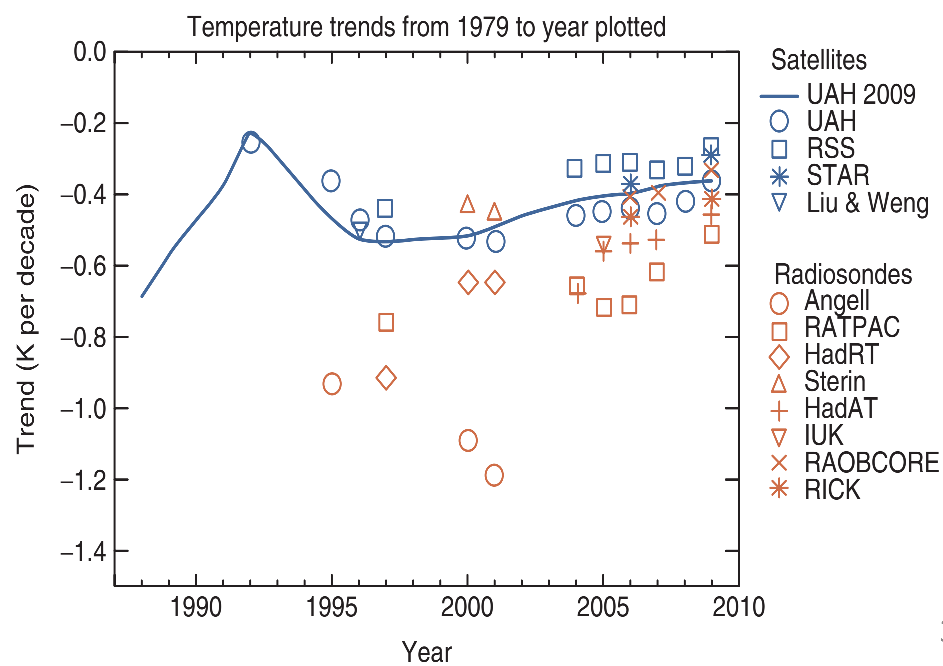
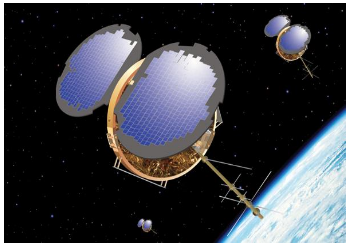
key uncertainties identified in IPCC AR5

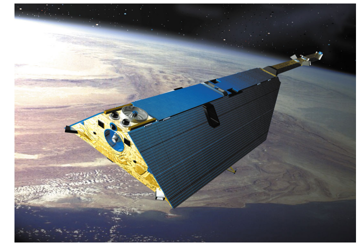
- “There is only medium to low confidence in the rate of change of tropospheric warming and its vertical structure
- ... and low confidence in the rate and vertical structure of the stratospheric cooling”

Dian J. Seidel et al., Stratospheric temperature trends: our evolving understanding, *WIREs: Clim Change* 2010.





Proposed Tasks



1) Performing reanalysis of all available data from multiple RO missions, and an extensive validation to quantify RO climate data quality in terms of precision, accuracy, consistency, and homogeneity.

1) Using reanalysis data including ERA-Interim, MERRA, and NCEP to estimate the uncertainty of sampling errors among multiple RO missions. The estimated sample errors in each individual months from June 2001 to June 2016

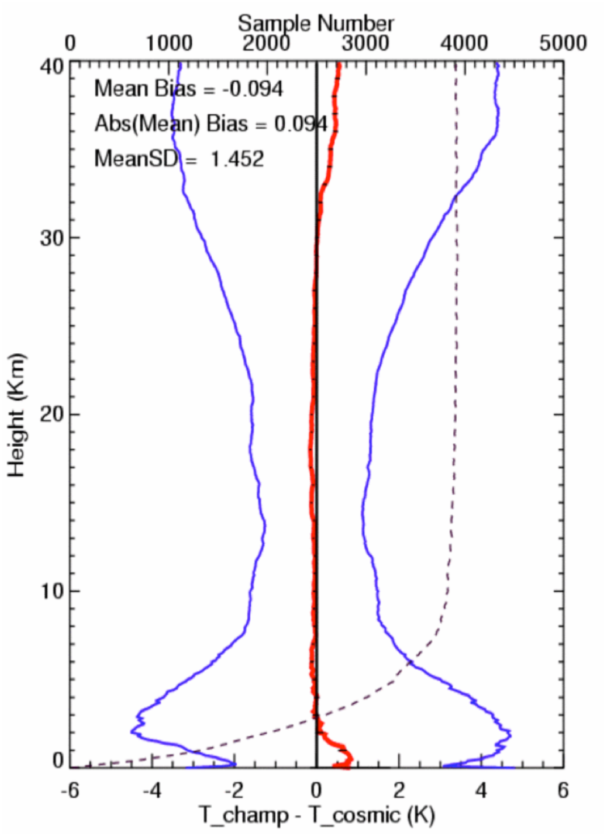
1) Using RO data from multiple RO centers to estimate temperature structure uncertainty for different RO missions and document the results.

1) Using GPS RO data to monitor and correct radiosonde temperature biases and satellite temperature biases

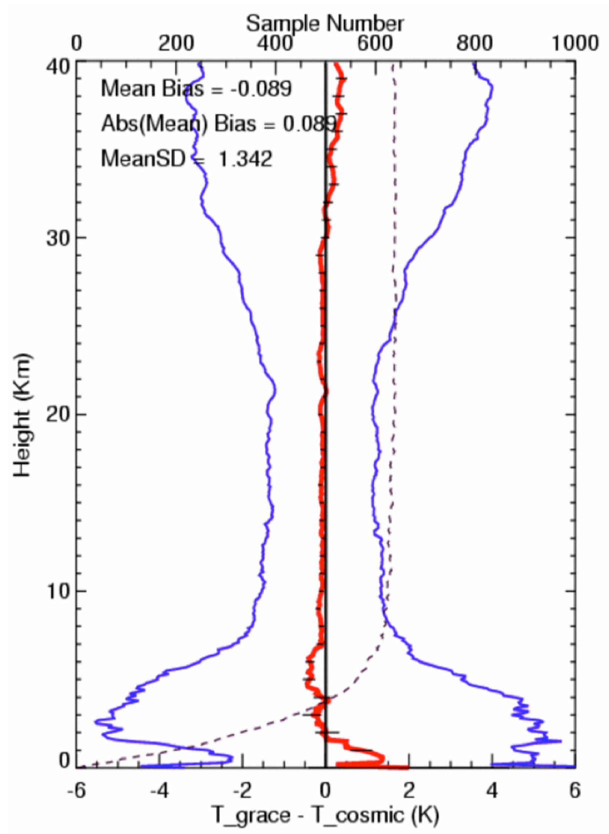
1) Monitoring Long-term Stability, precision, and consistency among UCAR RO missions

Global COSMIC, CHAMP, SAC-C, GRACE-A, Metop/GRAS Comparison

Within 60 Mins, and 50 Km



CHAMP-COSMIC
2007-2008



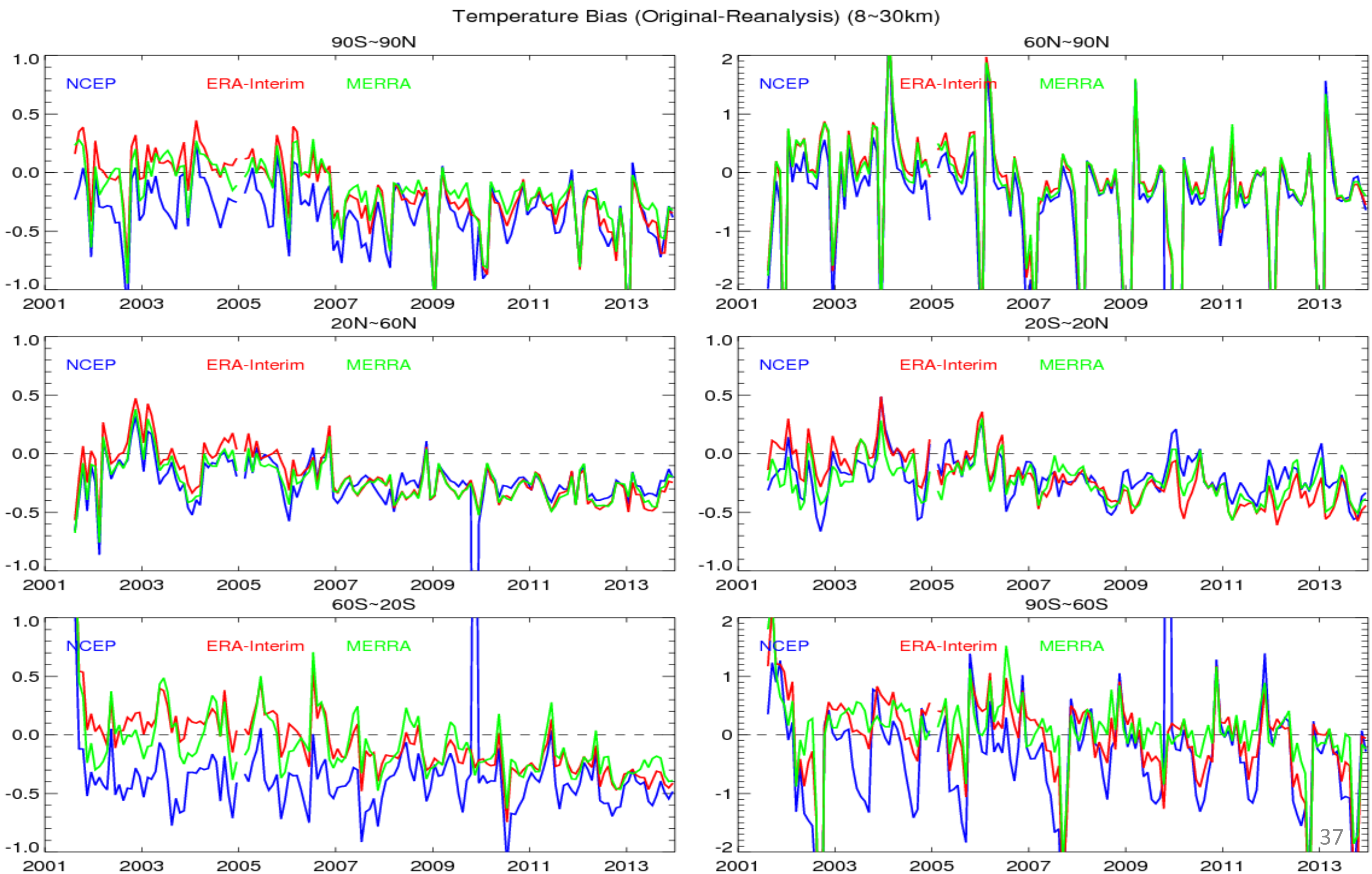
GRACE-COSMIC
2006

- Comparison of measurements between old and new instrument
- CHAMP launched in 2001
- COSMIC launched 2006
- GRACE launched 2002

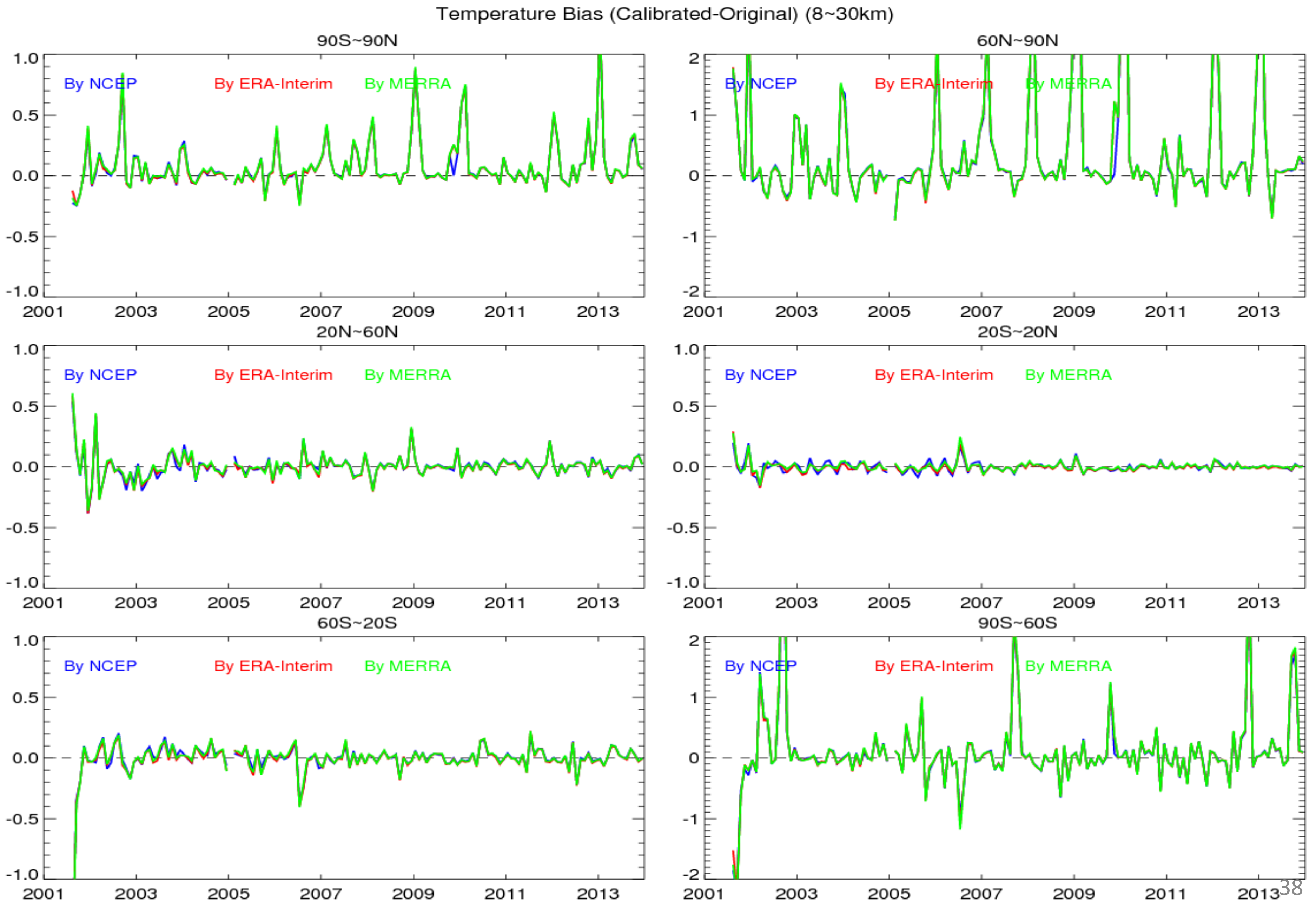
Don't need to have stable calibration reference

(Ho et al., 2010 JGR)
Structural uncertainty of RO data (Ho et al., 2009, 2013)

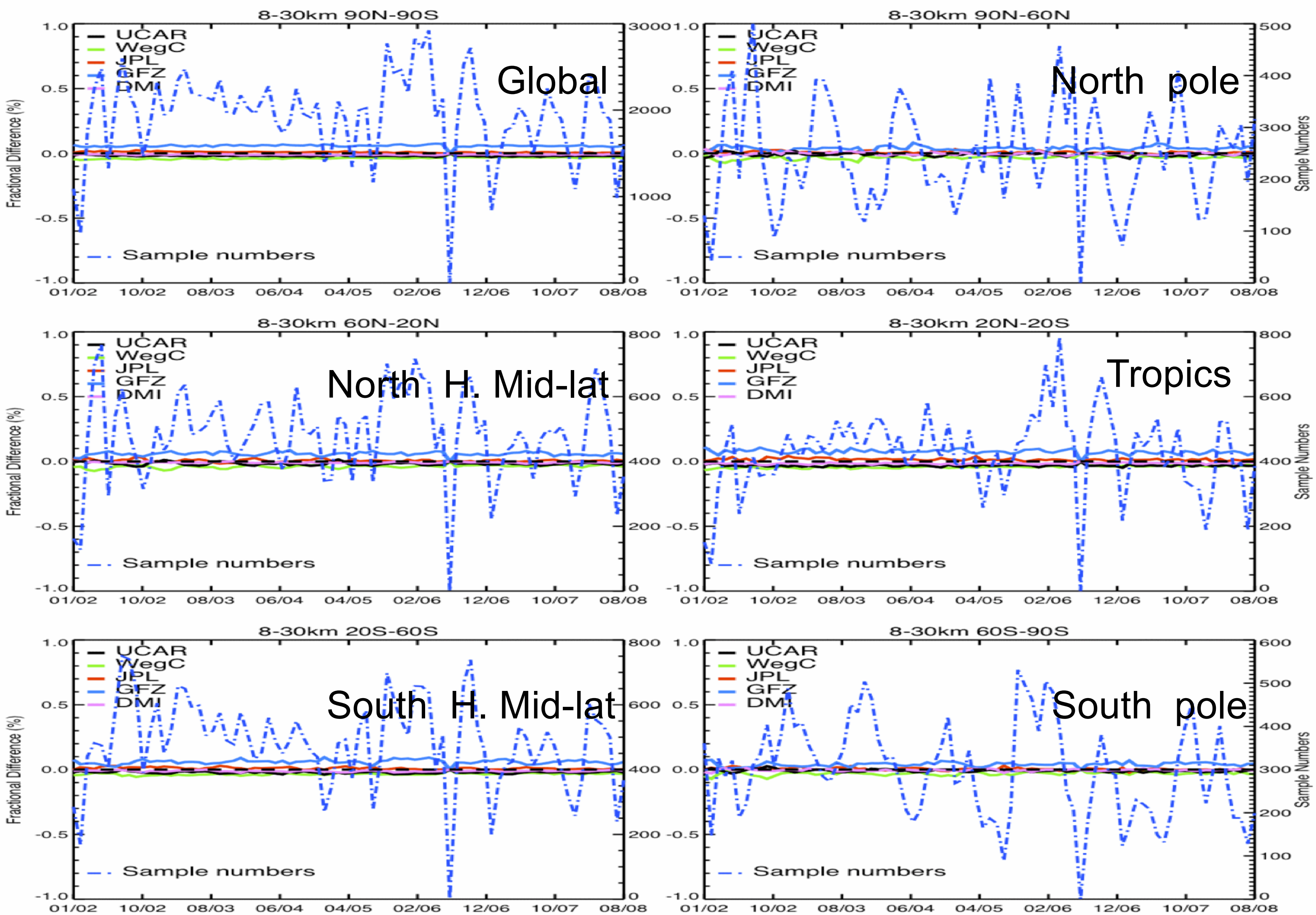
2) Monitoring homogeneity of UCAR RO data: removing the sampling errors



Comparisons of sampling errors removed temperatures



3) Using RO data from multiple RO centers to estimate among different RO missions and document the results



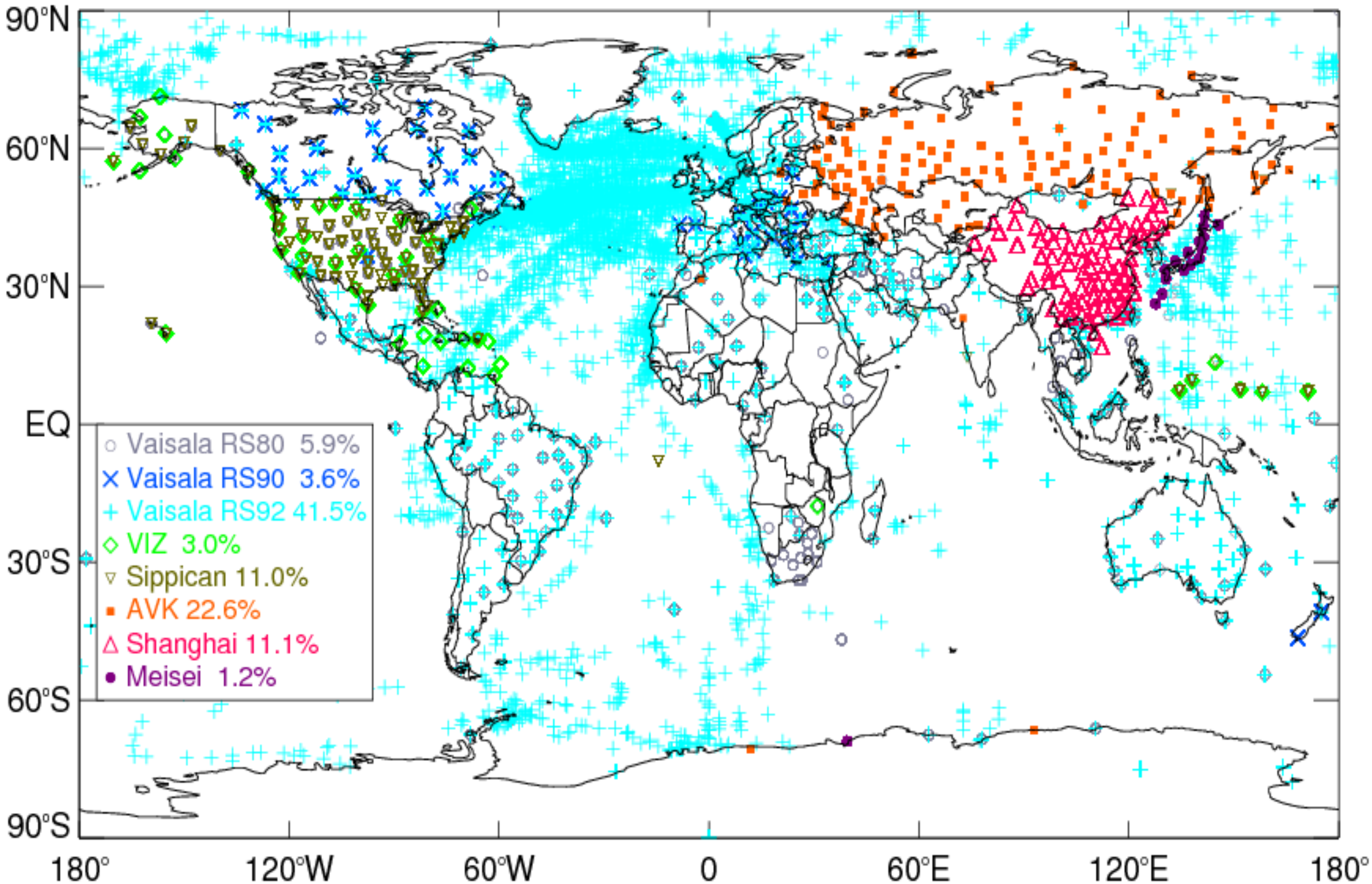
8-30 km

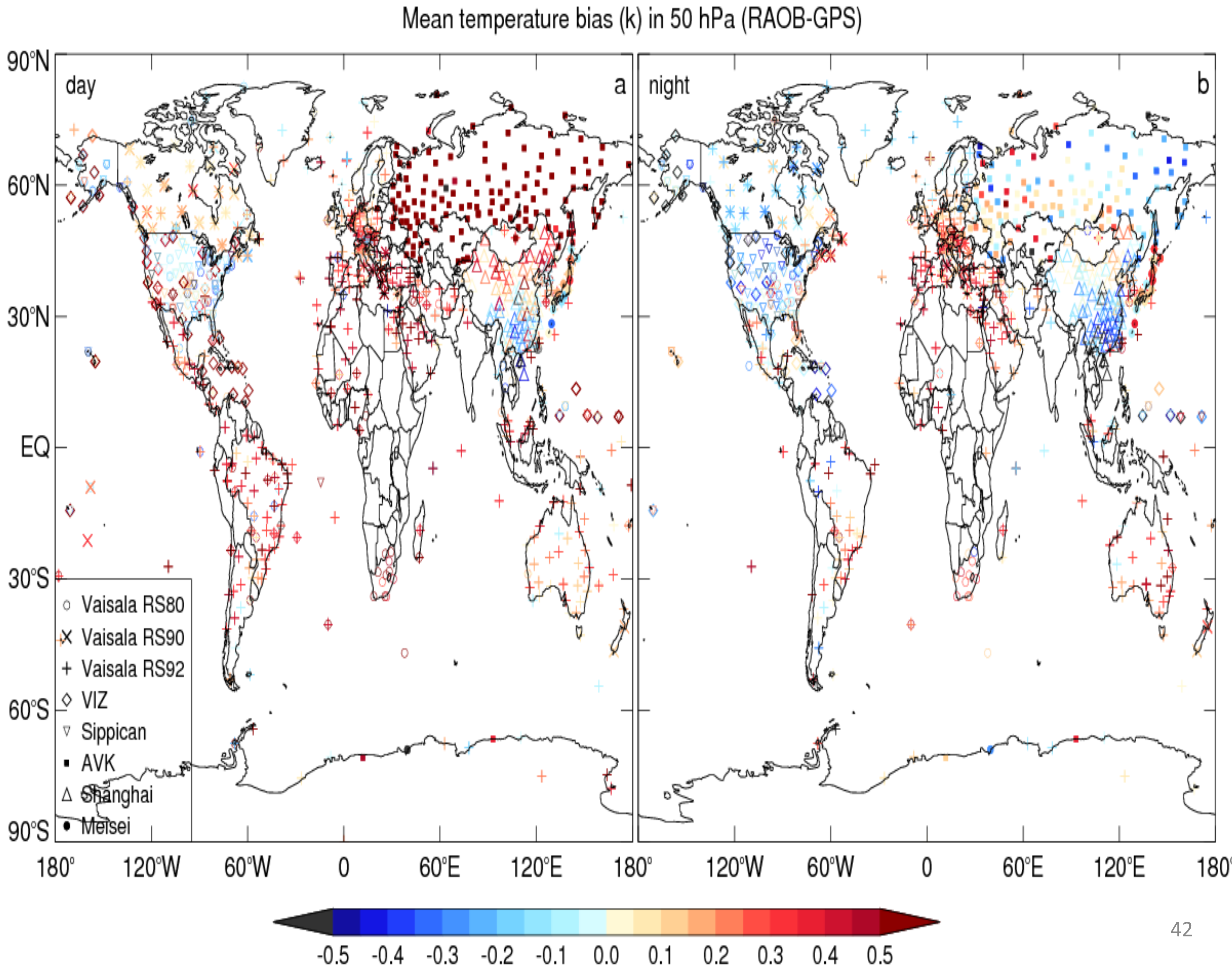
(Ho et al., 2009, 2012 JGR)

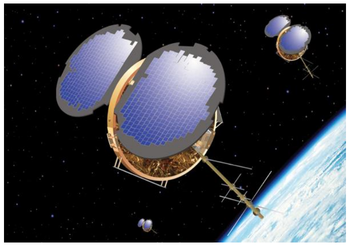
Current CDAAC post-processed and re-processed data

MISSION	Re-processed	Post-processed
CHAMP	**Version: 2014.0140** 2001.138 - 2008.279	**Version: 2009.2650** 2001.139 - 2008.274
CNOFS	No data available	**Version: 2010.2640** 2010.060 - 2011.365
COSMIC	**Version: 2013.3520** 2006.112 - 2014.120	**Version: 2010.2640** 2006.111 - 2014.030 **Version: 2014.2860** 2014.121 - 2015.180
GPSMET	No data available	**Version: 2007.3200** 1995.111 - 1997.047
GPSMETAS	No data available	**Version: 2007.3200** 1995.237 - 1997.016
GRACE	No data available	**Version: 2010.2640** 2007.059 – 2014.089 **Version: 2010.2640** 2014.090 - 2015.089
METOPA	**Version: 2011.2980** 2007.273 - 2011.364	**Version: 2011.2980** 2012.001 - 2015.059
METOPB	No data available	**Version: 2010.2640** 2013.032 - 2015.059
SACC	No data available	**Version: 2010.2640** 2006.068 - 2011.215
TSX (TerraSAR-X)	No data available	**Version: 2010.2640** 2008.041 – 2013.120 **Version: 2014.2760** 2015.058

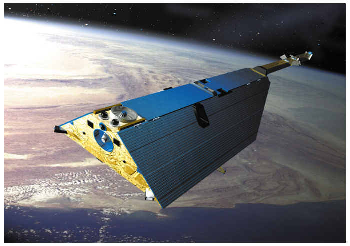
4). Using RO data to monitor and correct satellite and radiosonde systematic temperature biases




Mean temperature bias (k) in 50 hPa (RAOB-GPS)
day
a
night
b
90°N
60°N
30°N
EQ
30°S
60°S
90°S
180°
120°W
60°W
0
60°E
120°E
180°
Vaisala RS80
Vaisala RS90
Vaisala RS92
VIZ
Sippican
AVK
Shanghai
Meisei
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5

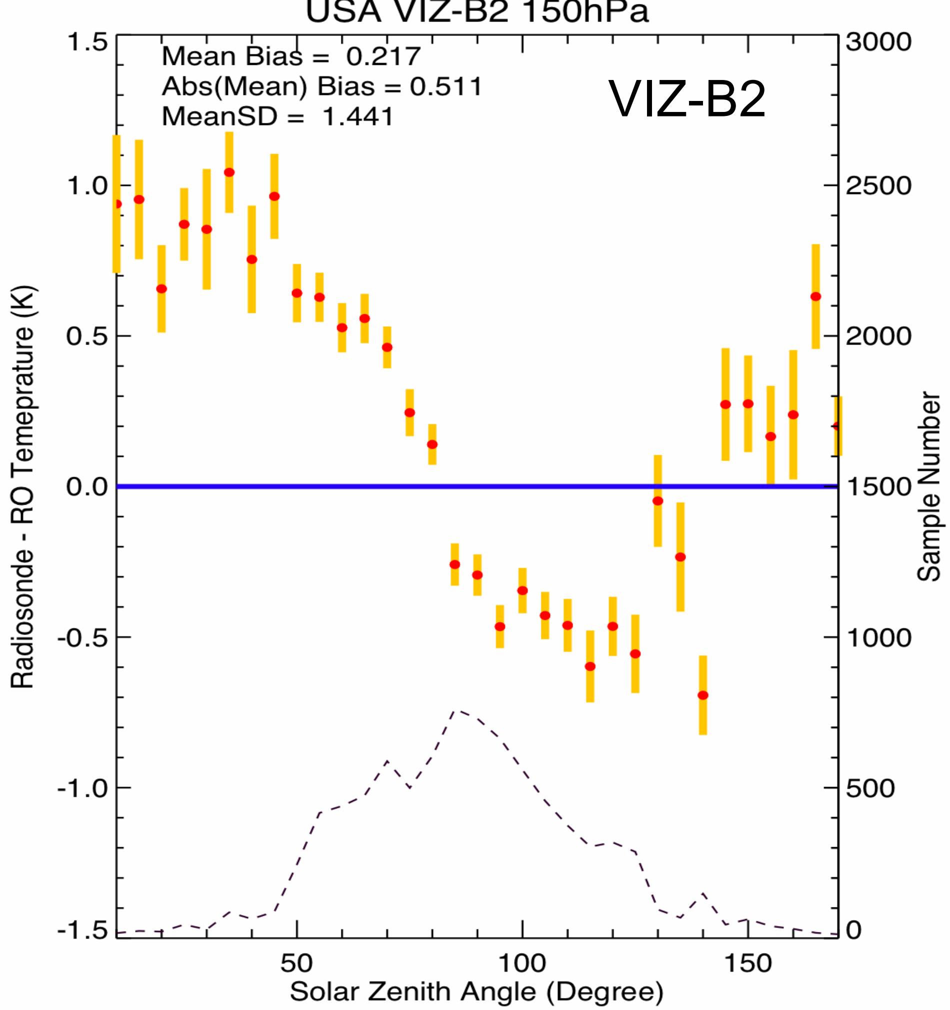


Using RO data to Identify Diurnal variation of Radiosonde Temperature Anomalies

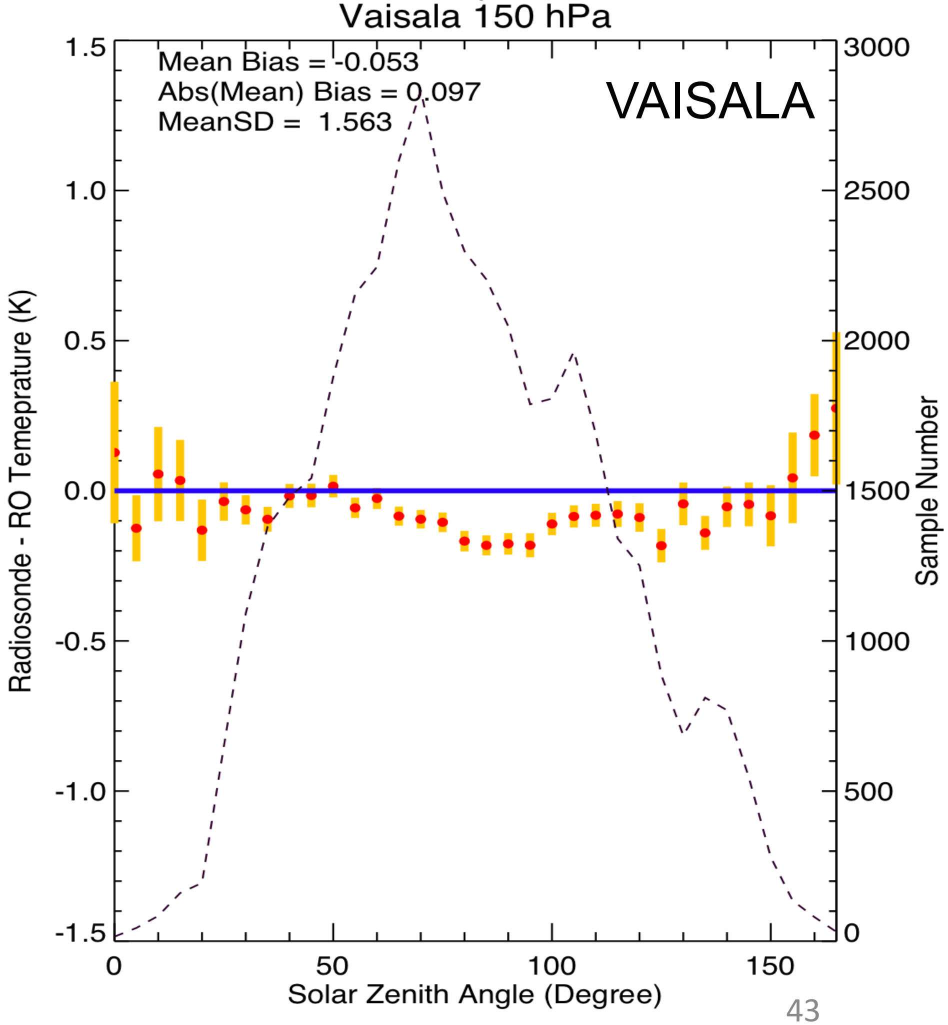


150 hPa

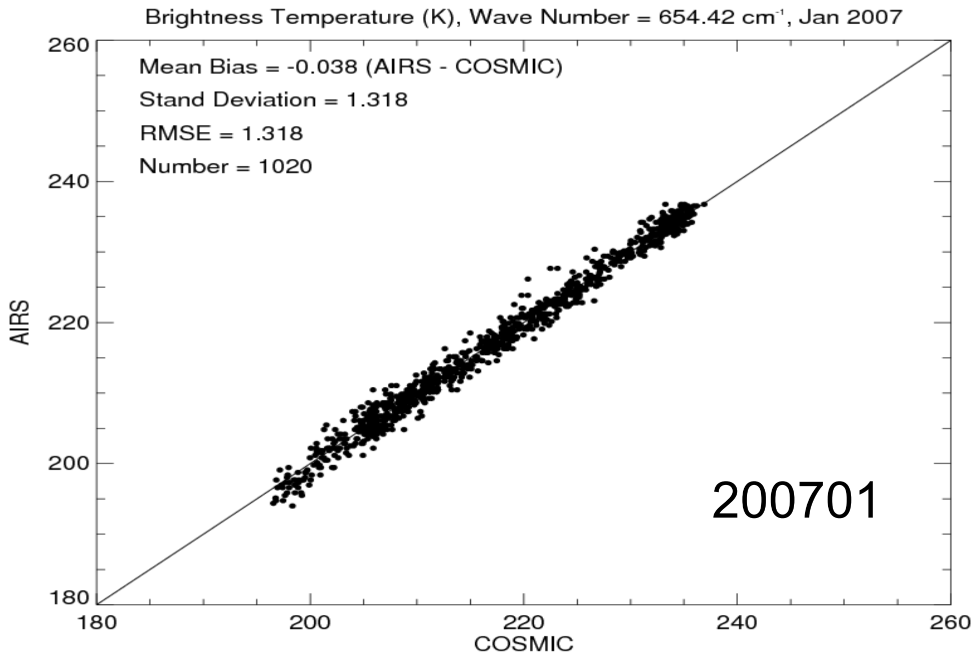
Solar absorptivity = 0.15
IR emissivity = 0.85

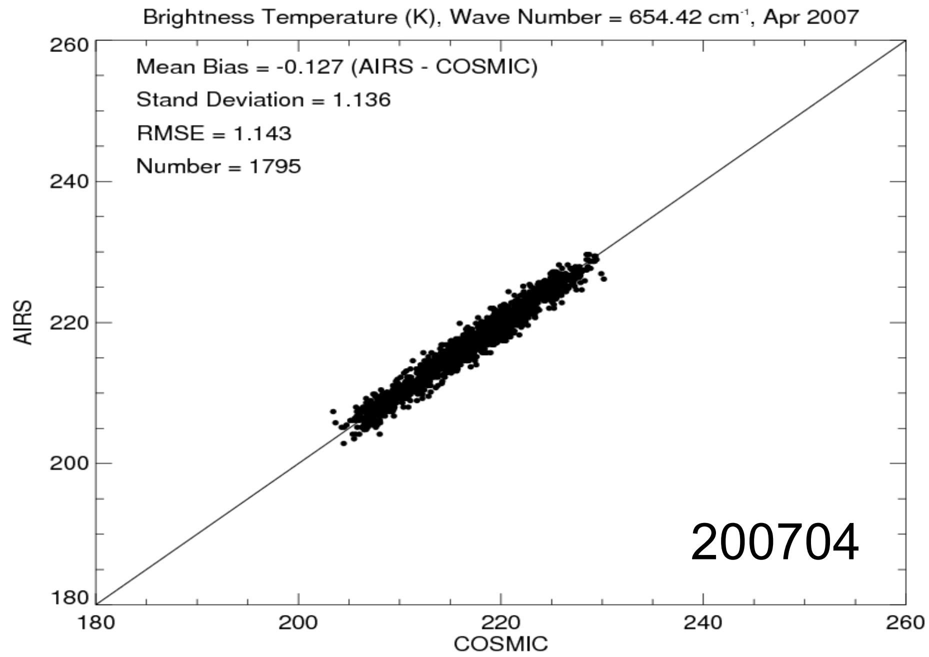


Solar absorptivity = 0.15
IR emissivity = 0.02

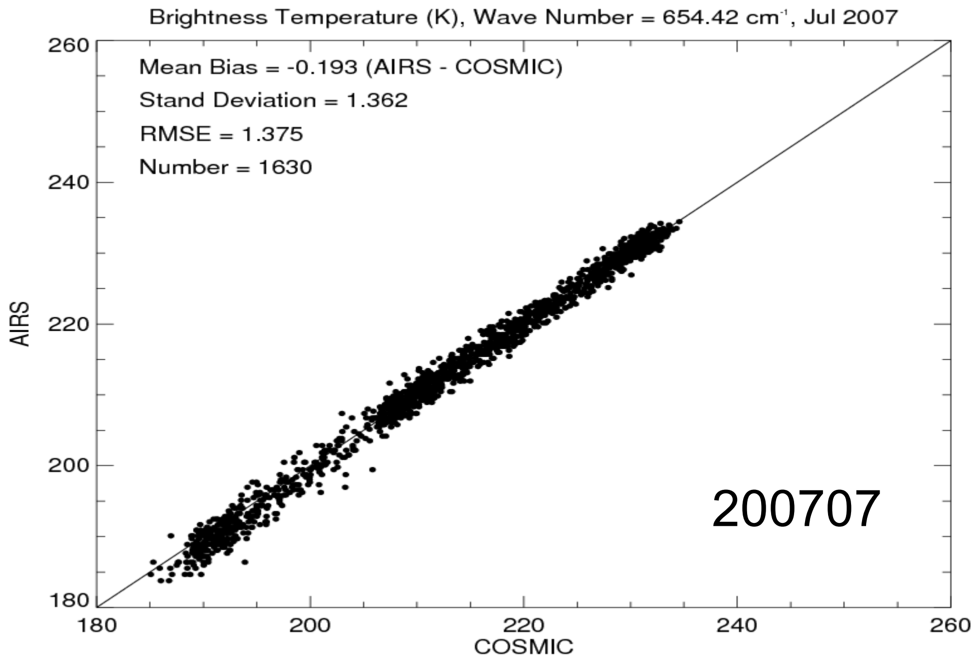


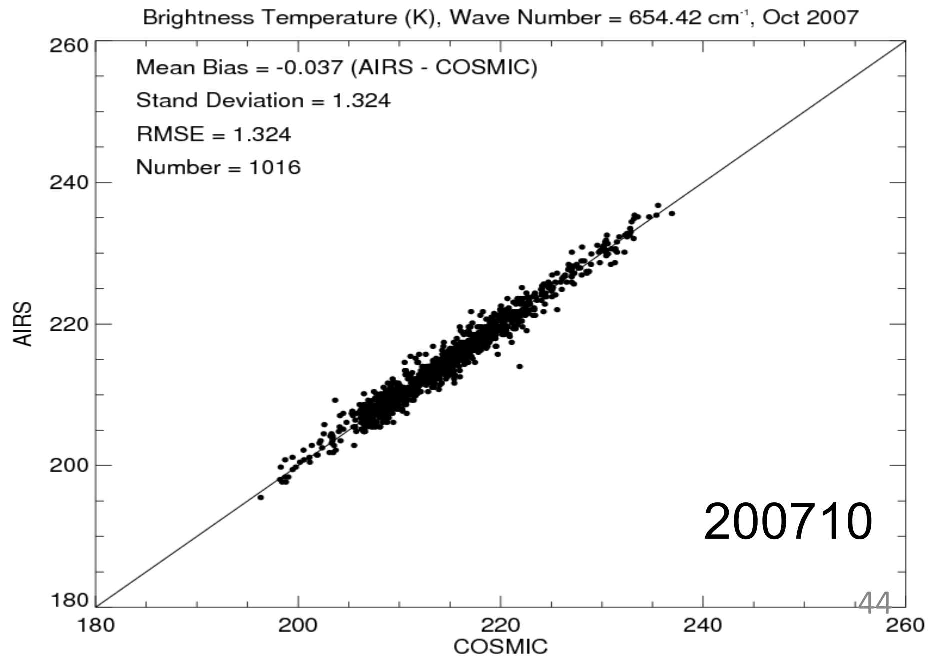
Using RO data to monitoring quality of AIRS Measurements



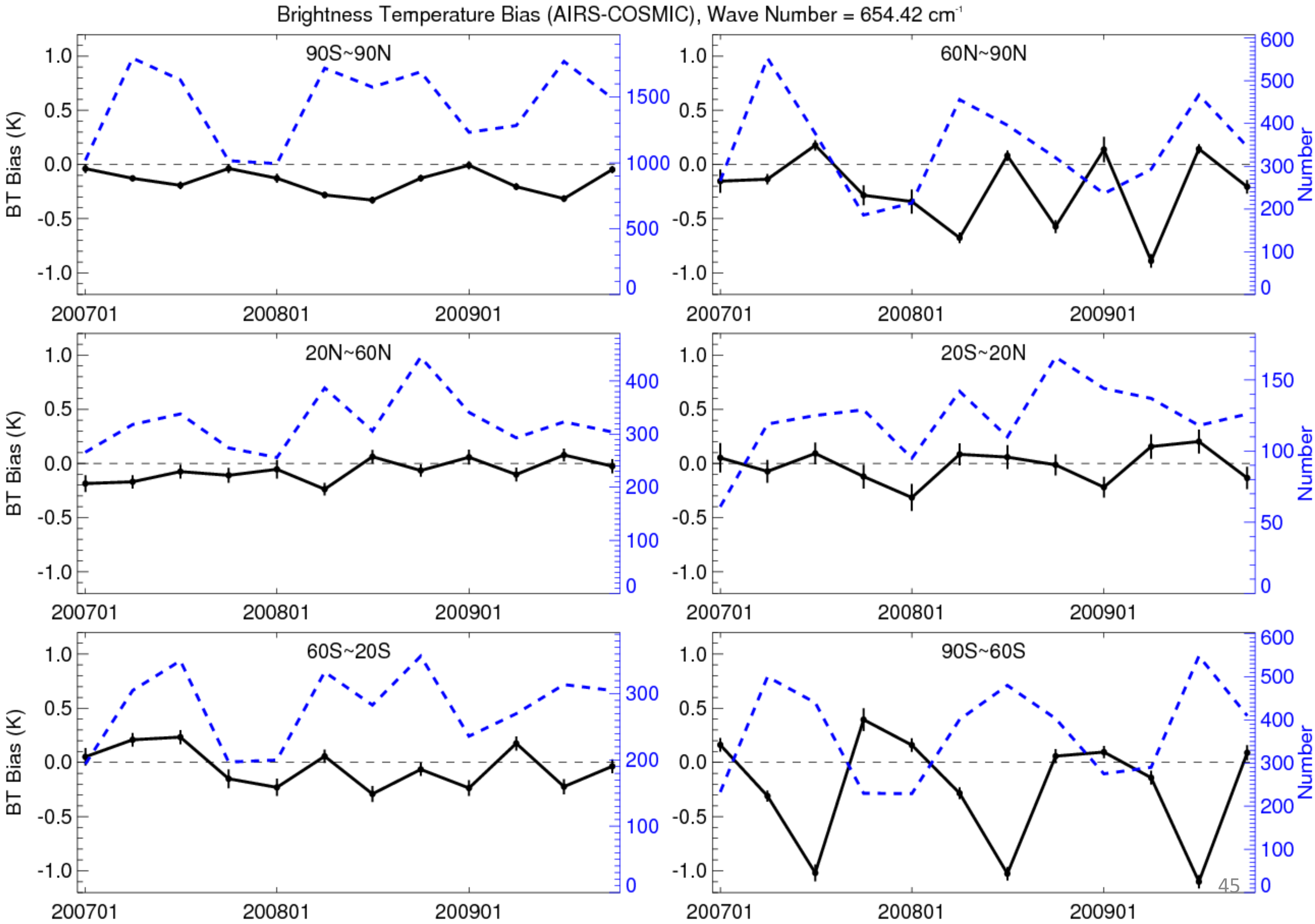


Distance difference = 100km, Time Difference = 30 minutes

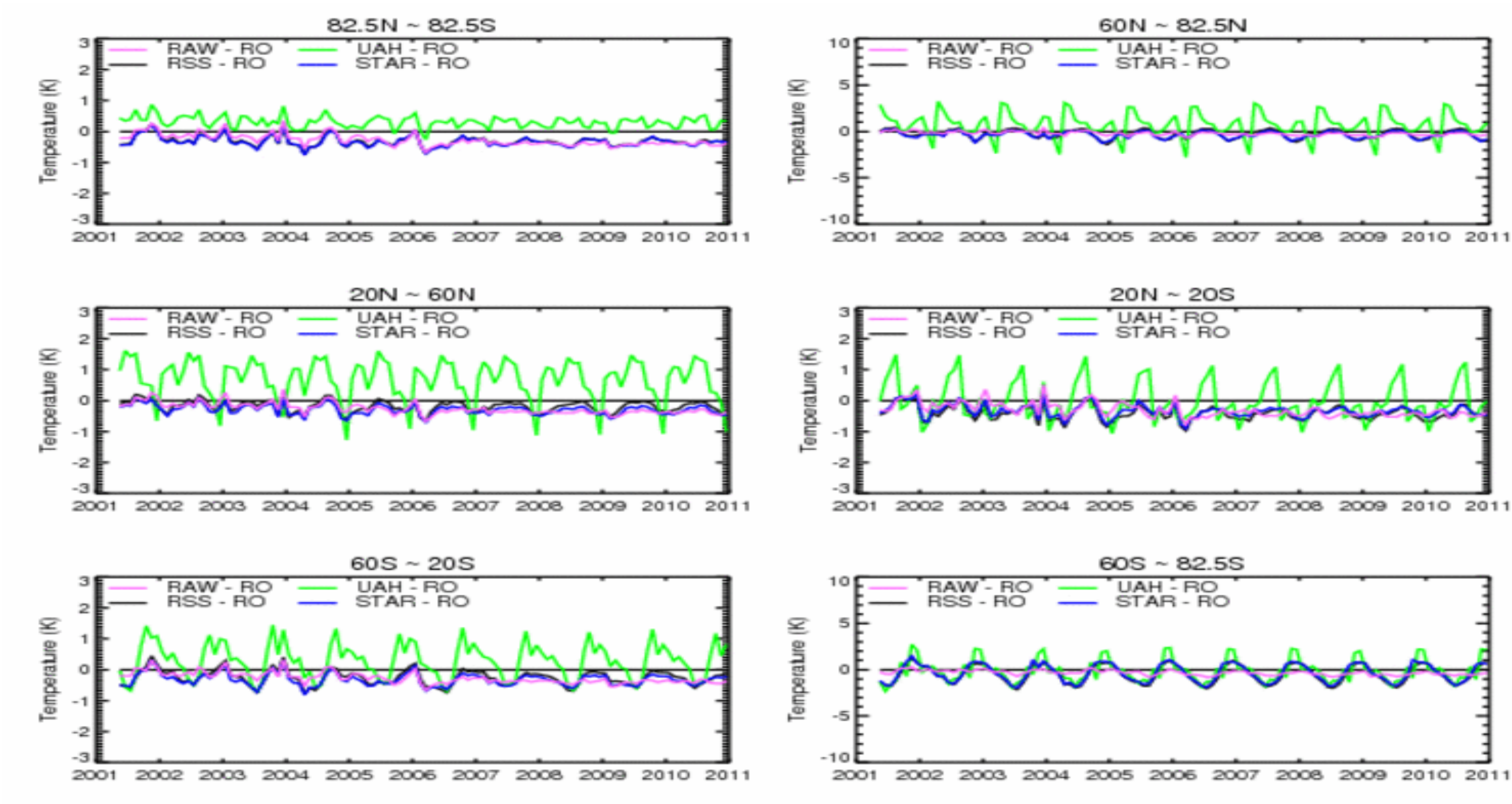




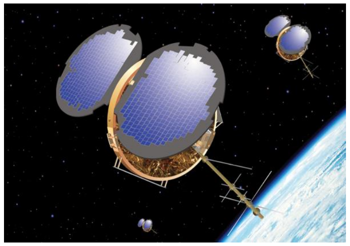
2.a Using RO data to monitoring quality of AIRS Measurements



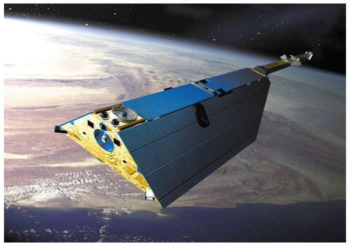
Time Series of RSS, UAH, STAR relative to RO_AMSU TLS



The time series of the TLS difference for RSS-RO_AMSU, UAH-RO_AMSU, and SNO-RO_AMSU for the entire globe (82.5ºN-82.5ºS, the left upper panel), the 82.5ºN-60ºN zone (the upper right panel), the 60ºN-20ºN zone (the middle left panel), the 20ºN-20ºS zone (the middle right panel), the 20ºS-60ºS zone (the bottom left panel), and the 60ºS-82.5ºS zone (the bottom right panel).



Proposed Tasks



1) Performing reanalysis of all available data from multiple RO missions, and an extensive validation to quantify RO climate data quality in terms of precision, accuracy, consistency, and homogeneity.

2) Using reanalysis data including ERA-Interim, MERRA, and NCEP to estimate the uncertainty of sampling errors among multiple RO missions. The estimated sample errors in each individual months from June 2001 to June 2016

3) Using RO data from multiple RO centers to estimate temperature structure uncertainty for different RO missions and document the results.

4) Using GPS RO data to identify and correct radiosonde temperature biases and construct homogenized radiosonde temperature climate data records