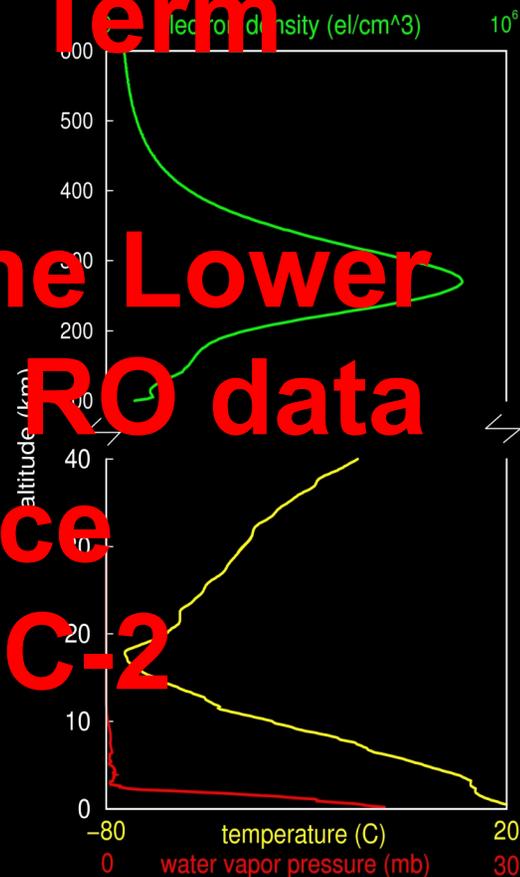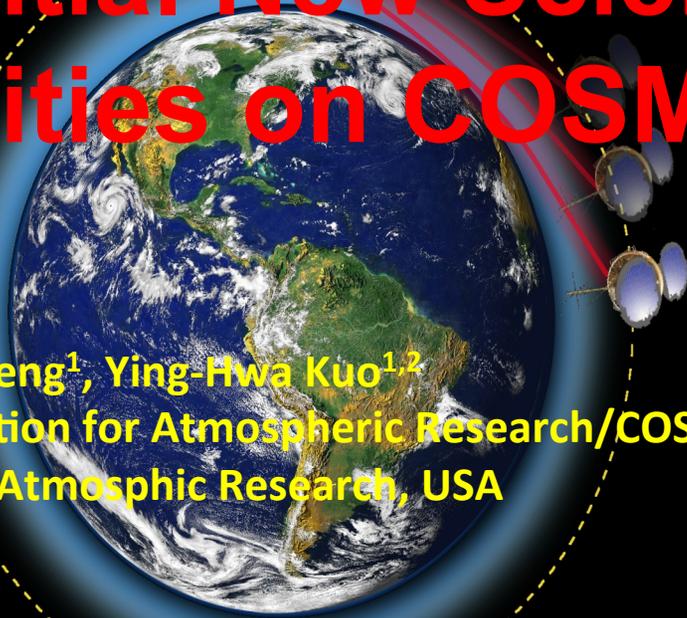# Assessment of the Long Term Variation of Radiosonde Temperature Biases in the Lower Stratosphere using GPS RO data and Potential New Science Opportunities on COSMIC-2

GPS

Shu-peng Ho[1],Liang Peng[1], Ying-Hwa Kuo[1,2]
1. University Corporation for Atmospheric Research/COSMIC, USA
2. National Center of Atmosphic Research, USA

electron density (el/cm^3)   10⁶

altitude (km)

temperature (C)
water vapor pressure (mb)
−80   20
0   30

Motivation:

Can we use RO data to identify
uncertainty of stratospheric temperature
trends from satellite data and radiosondes ?

Challenges
-Radiosonde sensor characteristics can be
affected by the changing environment, its
measurement accuracy varies considerably
in times and locations for different sensor
types
- Changes with instrument types
-Limited spatial coverage especially over
the oceans.
- Not traceable to SI units
- Temperature trends are subjective to the
choices of radiosonde subset

**It is important to assess systematic
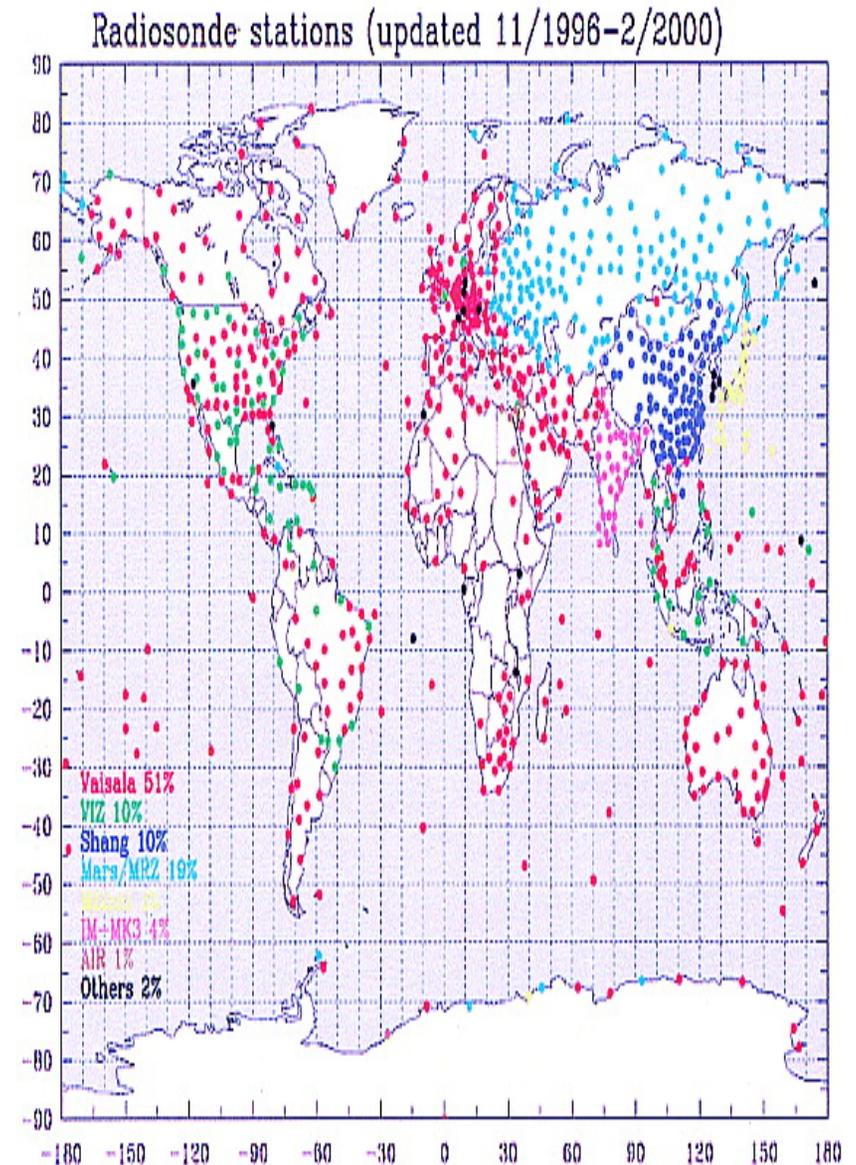biases of radiosonde temperature
measurements**

Shu-peng Ben Ho, UCAR/COSMIC
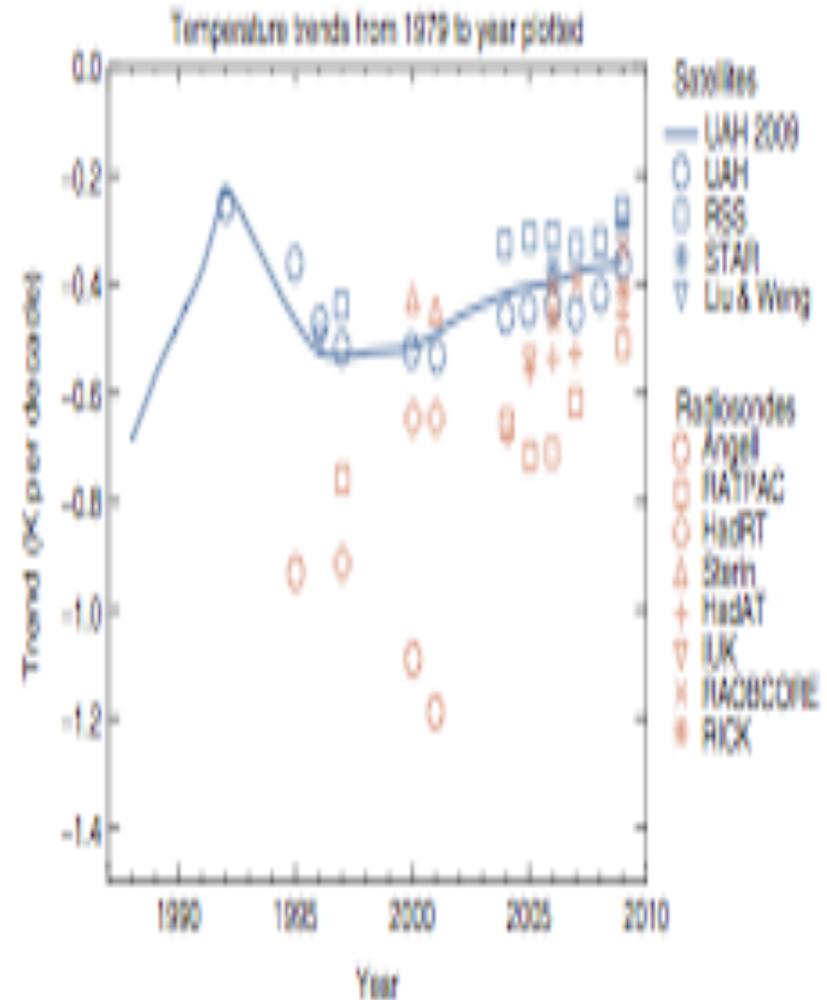
Dian J. Seidel et al., Stratospheric
temperature trends: our evolving
understanding, *WIREs: Clim Change*
2010.

Objectives :

1) **Using RO temperature profiles to identify temperature biases from radiosonde, where sensor characteristics vary considerably in times and locations for different sensor types**

2) **Using RO data to correct radiosonde systematic temperature biases**

Outlines :
- **Approaches**
- **Results, global, time series, trends**
- **Conclusions and Future Work**

Radiosonde stations (updated 11/1996-2/2000)

Vaisala 51%
VIZ 10%
Shang 10%
Mars/MRZ 19%
IM+MK3 4%
AIR 1%
Others 2%
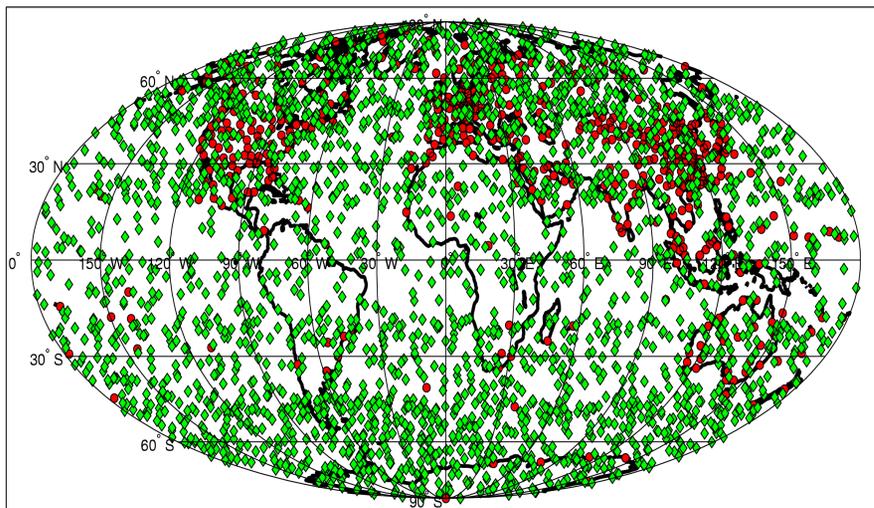
Shu-peng Ben Ho, UCAR/COSMIC
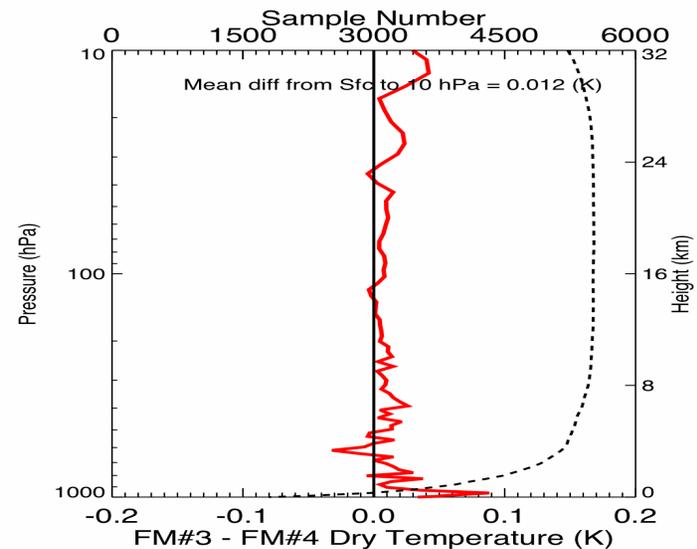
RO data for climate research

- **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)**
- **Short term RAOB vs. RO comparison (He et al., 2009; Sun et al., 2011, 2013)**
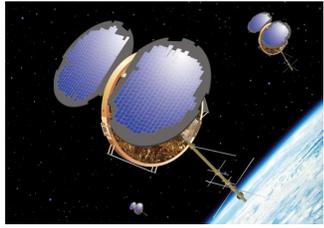
Using FM3-FM4 pairs in early mission

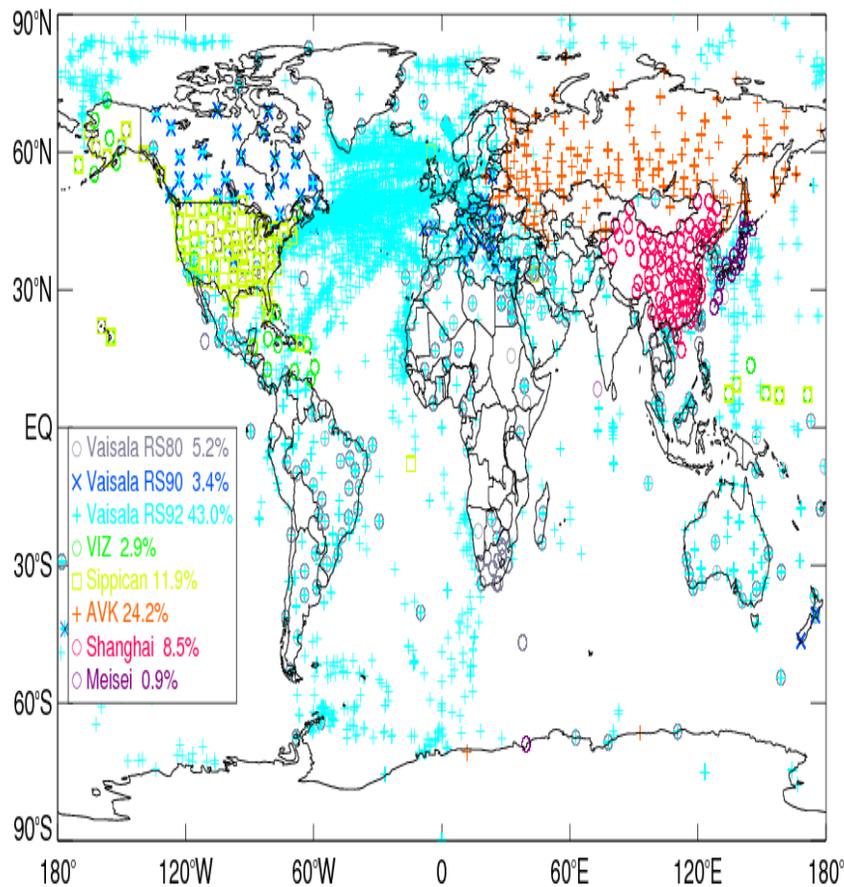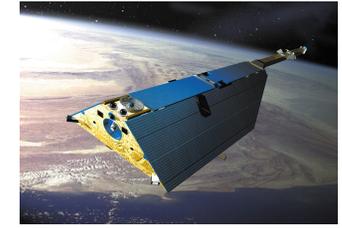Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs

COSMIC

Sample Number

Mean diff from Sfc to 10 hPa = 0.012 (K)

Pressure (hPa)

Height (km)

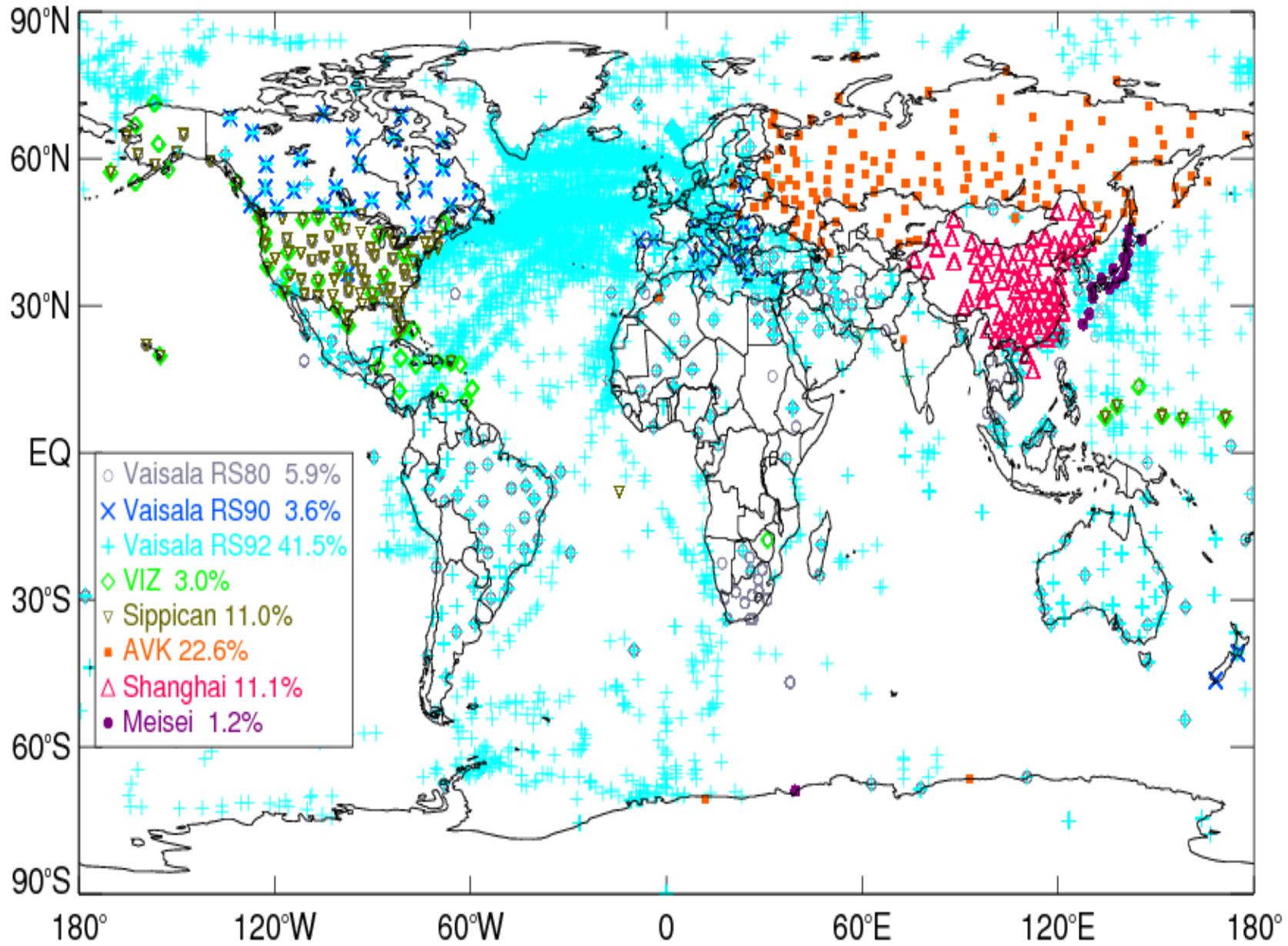FM#3 - FM#4 Dry Temperature (K)

4

Approach: Using COSMIC, CHAMP, and GRACE data from 2006 to 2013 to assess the quality of radiosonde data
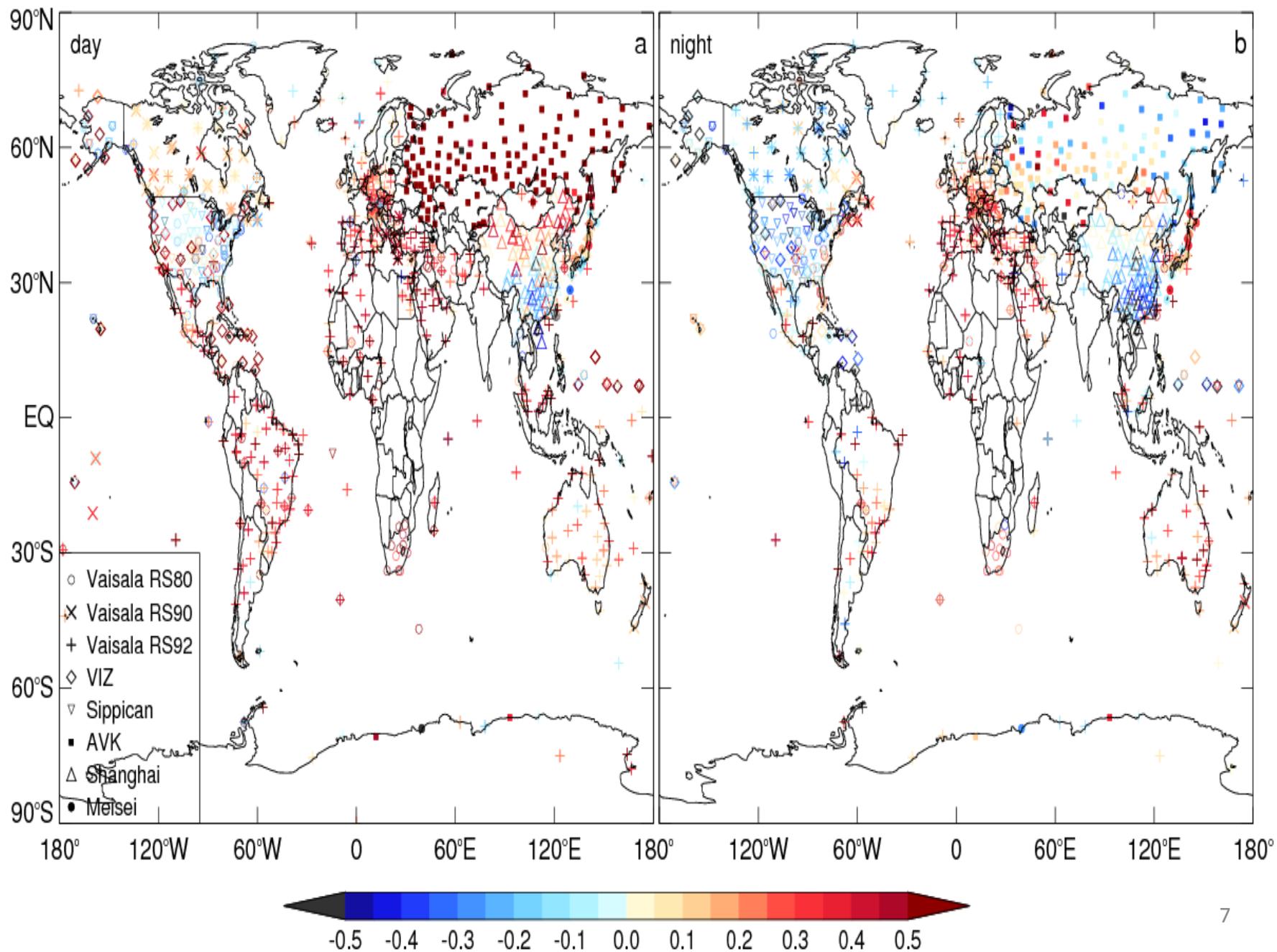

Radiosodne data DS353.4 from NCAR
- originally acquired from NCEP.
- contains the original data values transmitted by stations
- no radiative or other corrections from NCEP are included in this dataset
He et al., (2009 GRL)

Region	Sonde Type	Matched Sample
Russia	AVK-MRZ	2000 (20%)
China	Shang	650 (6.1%)
USA	VIZ-B2	600 (5.9%)
Others	Vaisala	3140 (30%)

Collocate COSMIC/CHAMP/GRACE and radiosonde profiles
< 200 km
< 3 hrs

5

Legend:
- ○ Vaisala RS80 5.9%
- × Vaisala RS90 3.6%
- + Vaisala RS92 41.5%
- ◇ VIZ 3.0%
- ▽ Sippican 11.0%
- ■ AVK 22.6%
- △ Shanghai 11.1%
- ● Meisei 1.2%

6

Mean temperature bias (k) in 50 hPa (RAOB-GPS)

day   a
night   b

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

7

Check the accuracy of the RO temperature

RS 92 vs. COSMIC derived temperature profiles in 2007
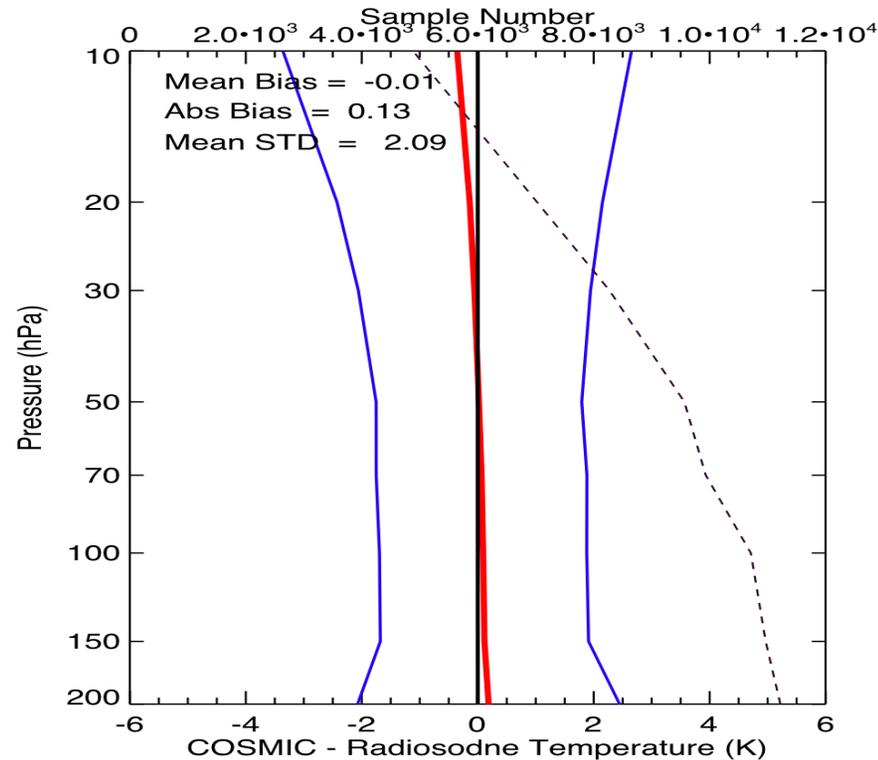
Ho, S.-P., Ying-Hwa Kuo, William Schreiner, Xinjia Zhou (2010),
Using SI-traceable Global Positioning System Radio Occultation Measurements for
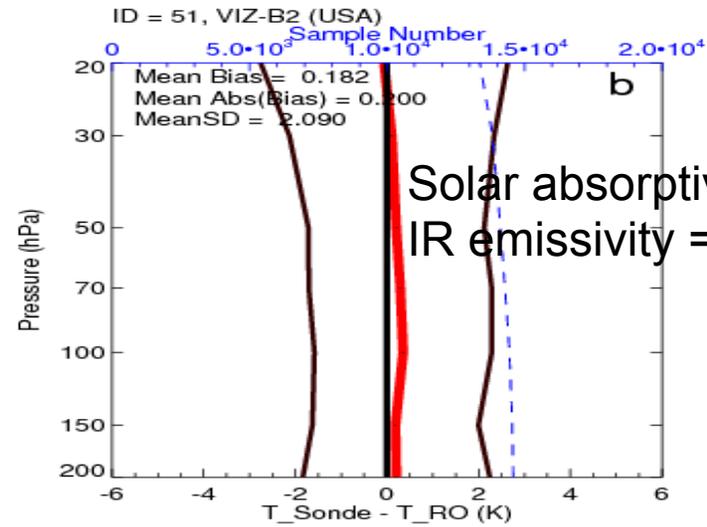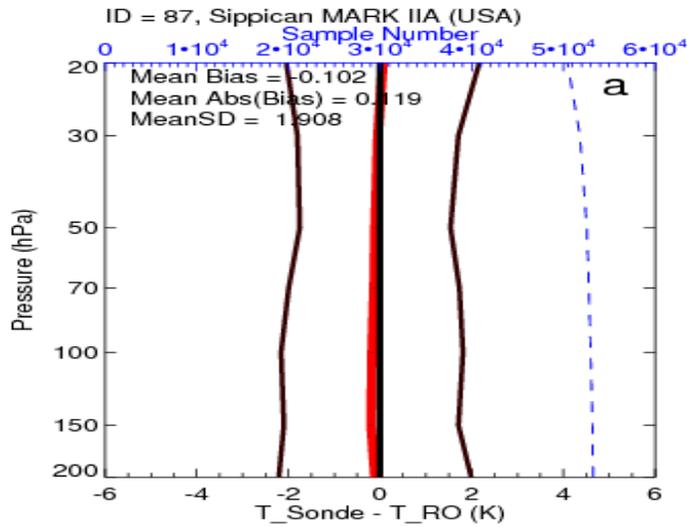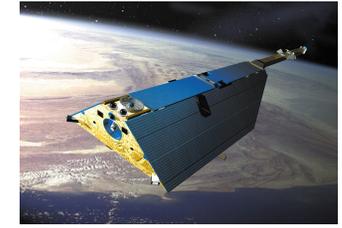Climate Monitoring [In "States of the Climate in 2009]. *Bul. Amer. Meteor. Sci.*, **91** (7).
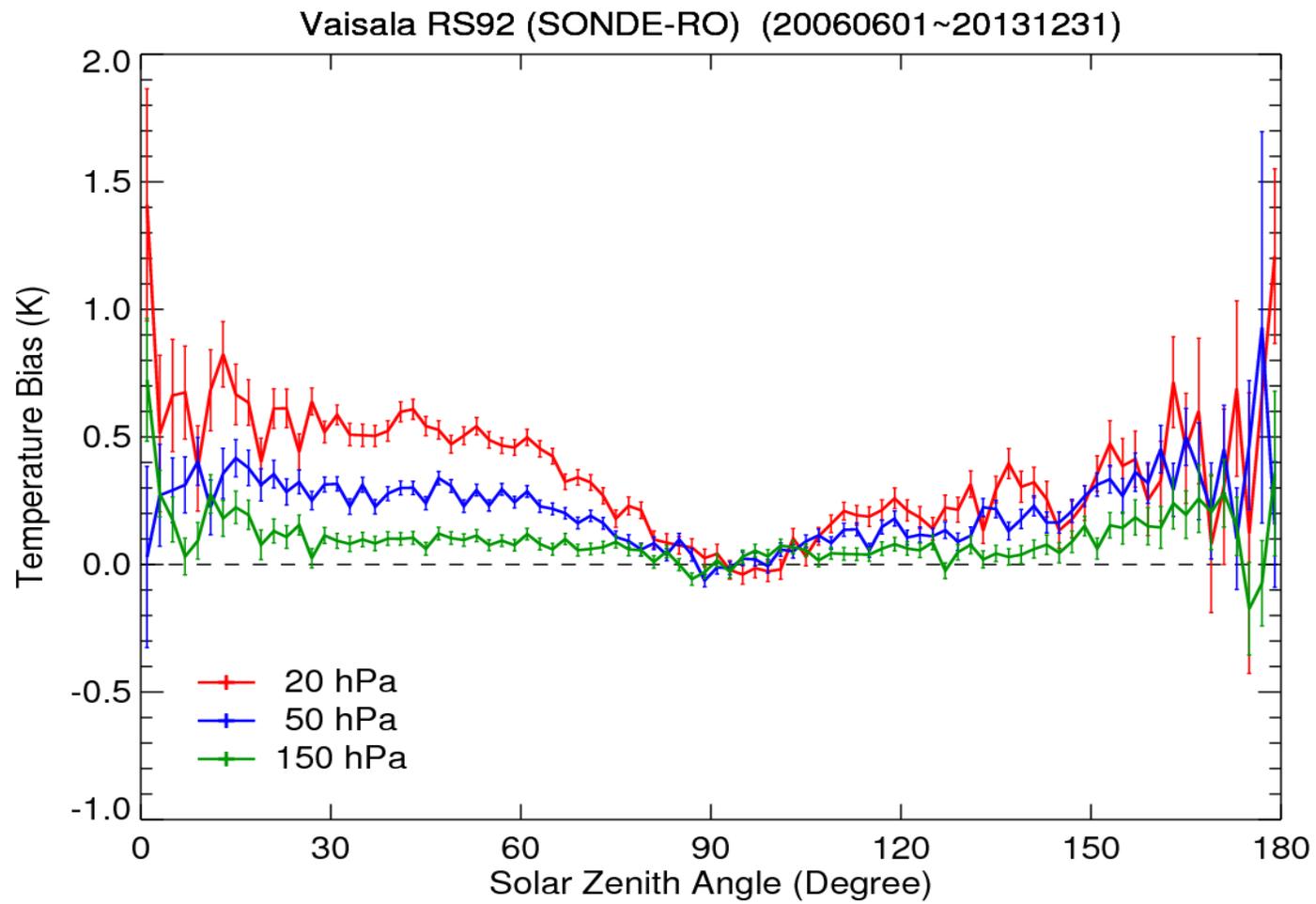
Fig. 5
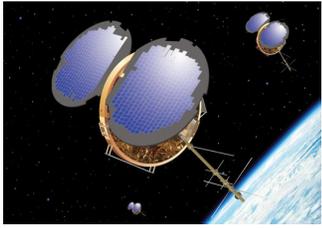
Detection the Changing of Instrument Type
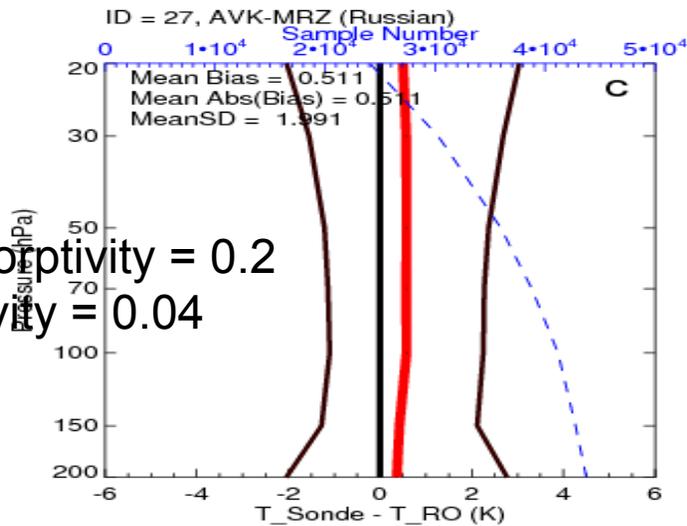
Panel a: ID = 87, Sippican MARK IIA (USA)
Mean Bias = 0.102
Mean Abs(Bias) = 0.119
MeanSD = 1.908

Panel b: ID = 51, VIZ-B2 (USA)
Mean Bias = 0.182
Mean Abs(Bias) = 0.200
MeanSD = 2.090

Solar absorptivity = 0.15
IR emissivity = 0.85

Panel c: ID = 27, AVK-MRZ (Russian)
Mean Bias = 0.511
Mean Abs(Bias) = 0.511
MeanSD = 1.991

Solar absorptivity = 0.2
IR emissivity = 0.04

Panel d: ID = 32, Shanghai (China)
Mean Bias = 0.148
Mean Abs(Bias) = 0.148
MeanSD = 2.073

Solar absorptivity = 0.15
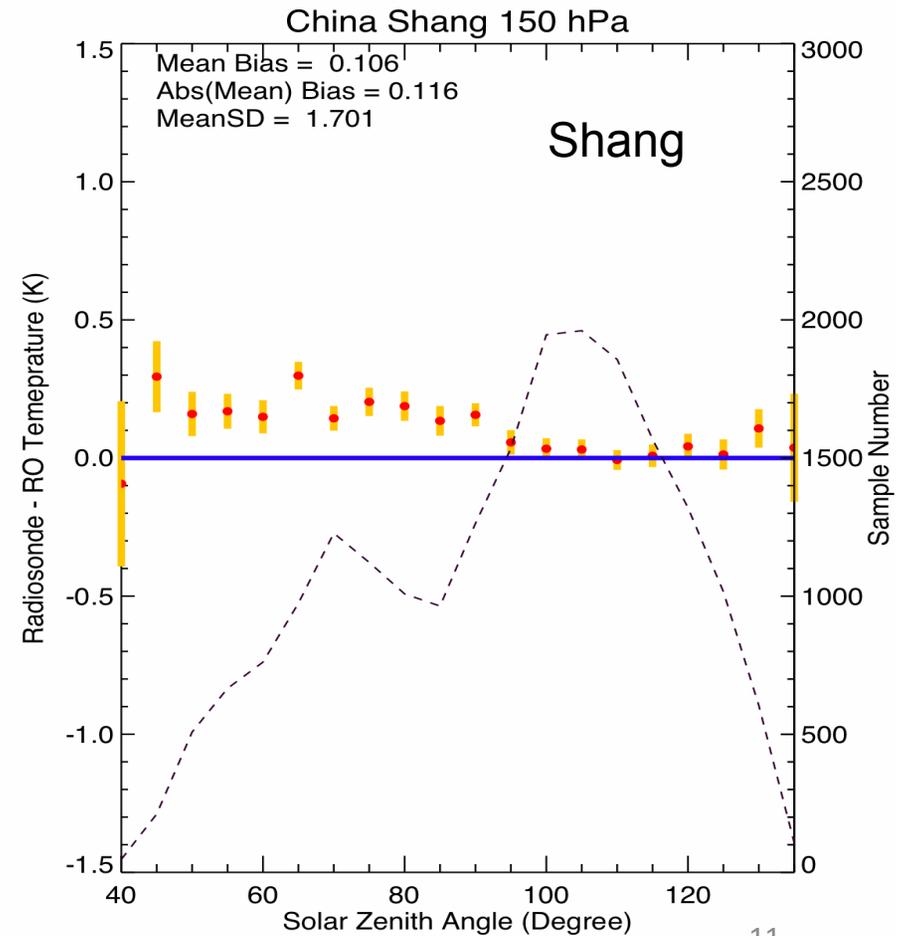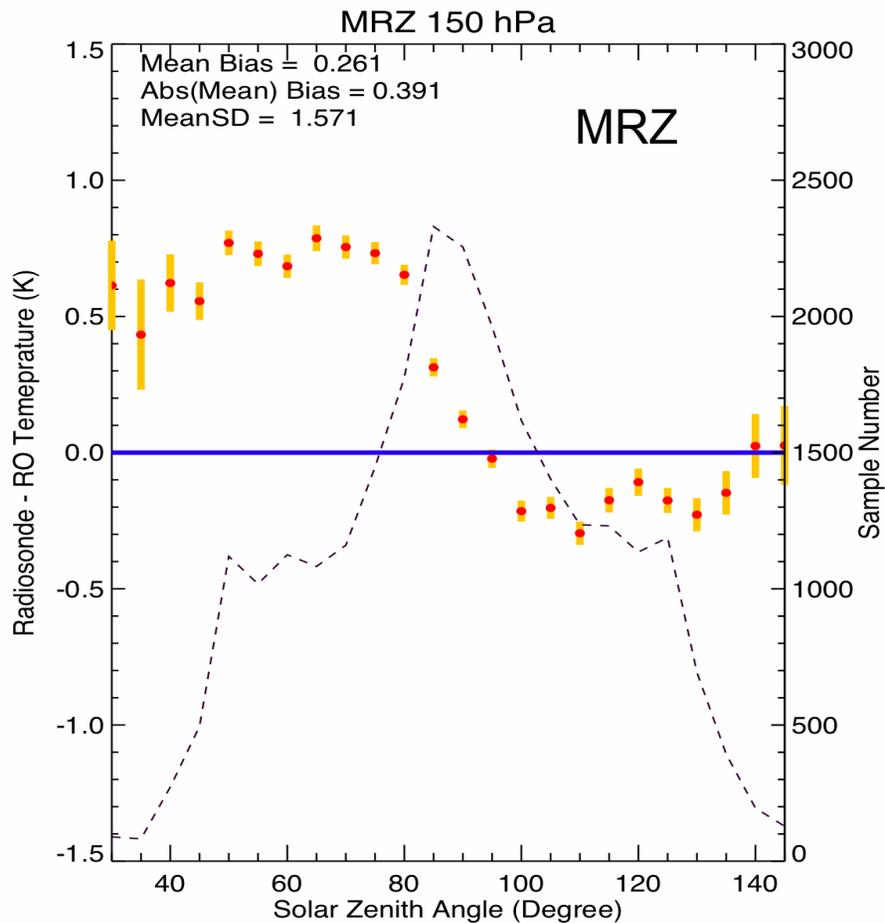IR emissivity = 0.85

10
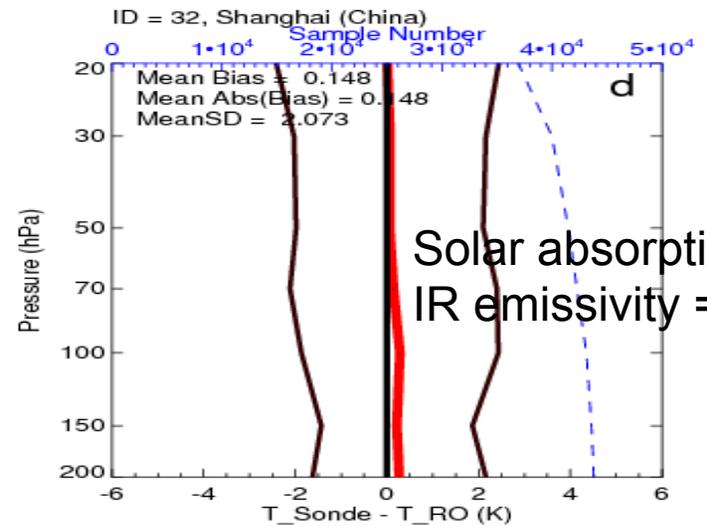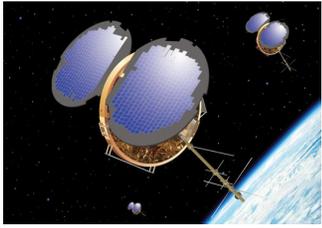
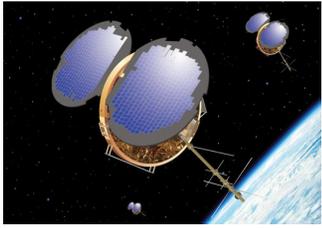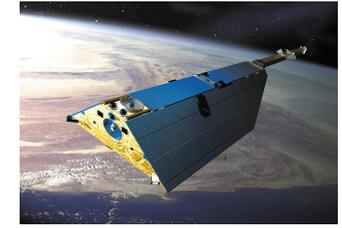# Using RO data to Identify Diurnal variation of Radiosonde Temperature Anomalies
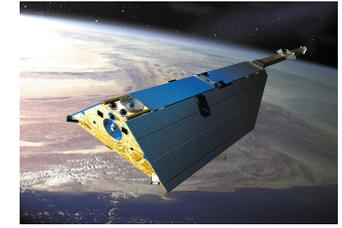
Solar absorptivity = 0.2
IR emissivity = 0.04

150 hPa

Solar absorptivity = 0.15
IR emissivity = 0.85

MRZ 150 hPa

Mean Bias = 0.261
Abs(Mean) Bias = 0.391
MeanSD = 1.571

MRZ

China Shang 150 hPa

Mean Bias = 0.106
Abs(Mean) Bias = 0.116
MeanSD = 1.701

Shang

Slide 9

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Using RO data to Identify Diurnal variation of Radiosonde Temperature Anomalies

Solar absorptivity = 0.15
IR emissivity = 0.85
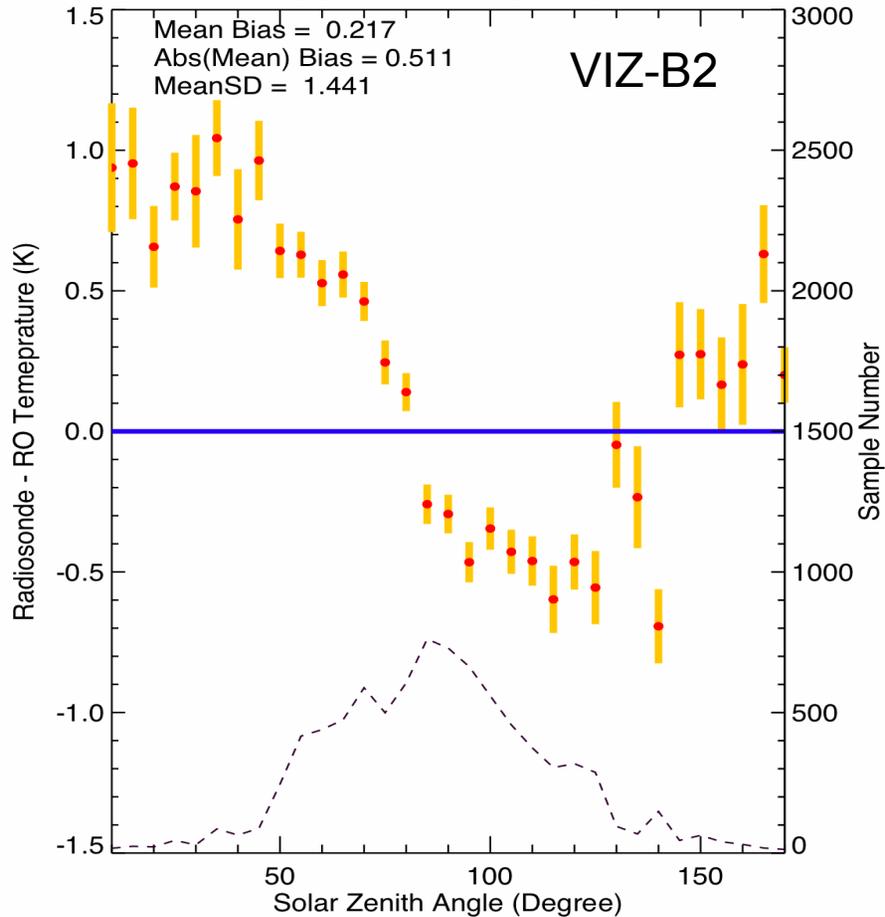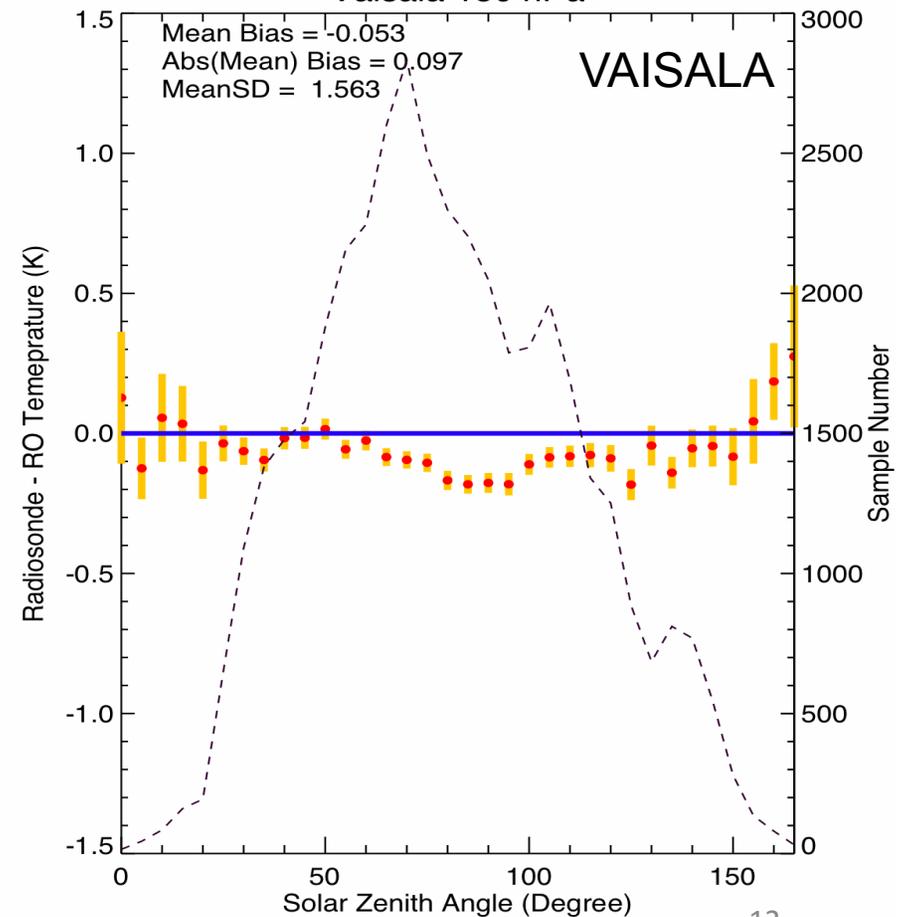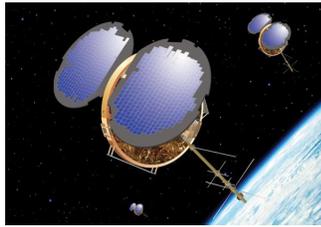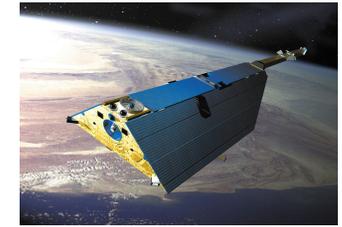
150 hPa

Solar absorptivity = 0.15
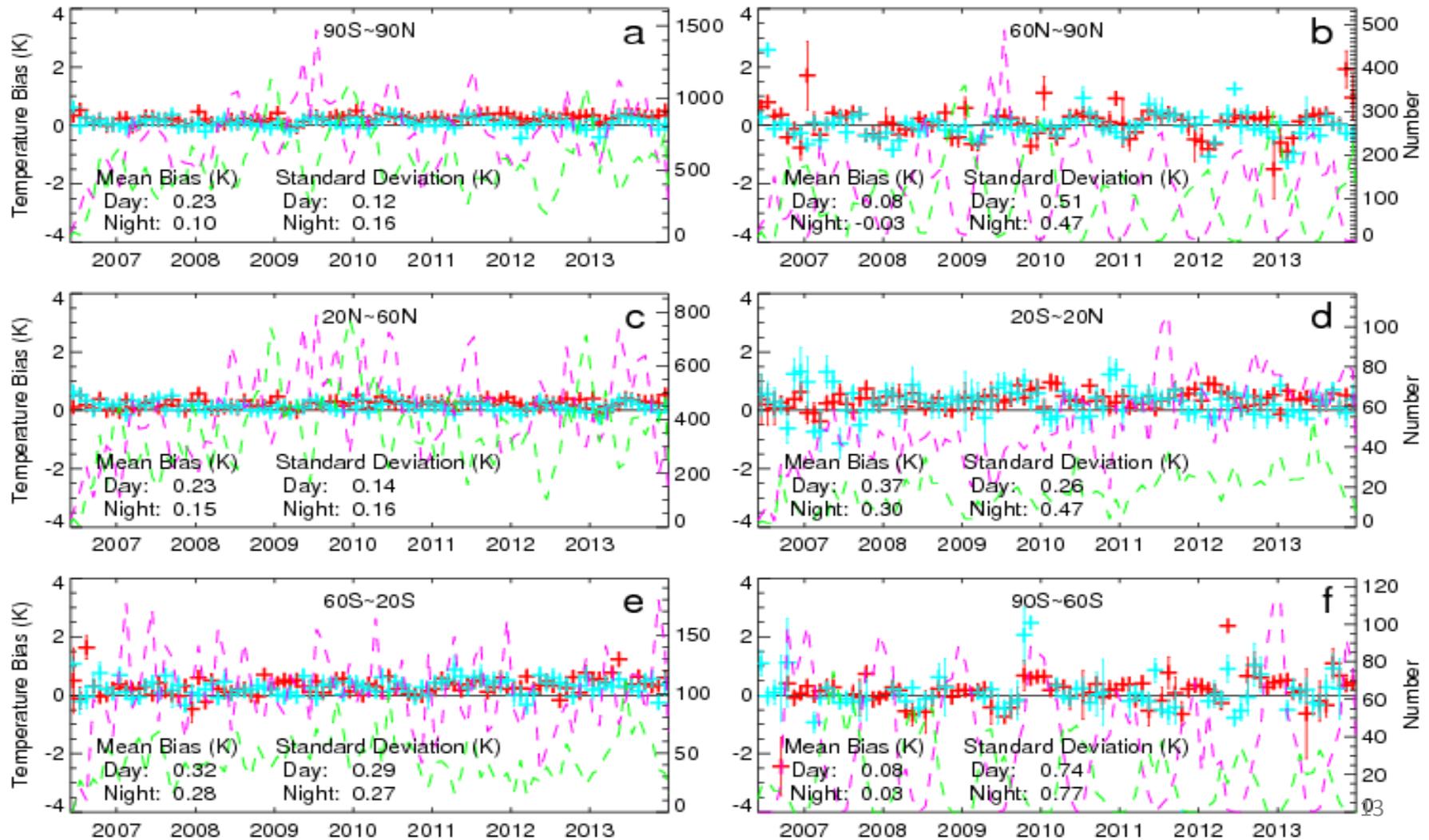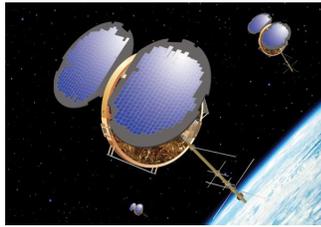IR emissivity = 0.02

Slide 10

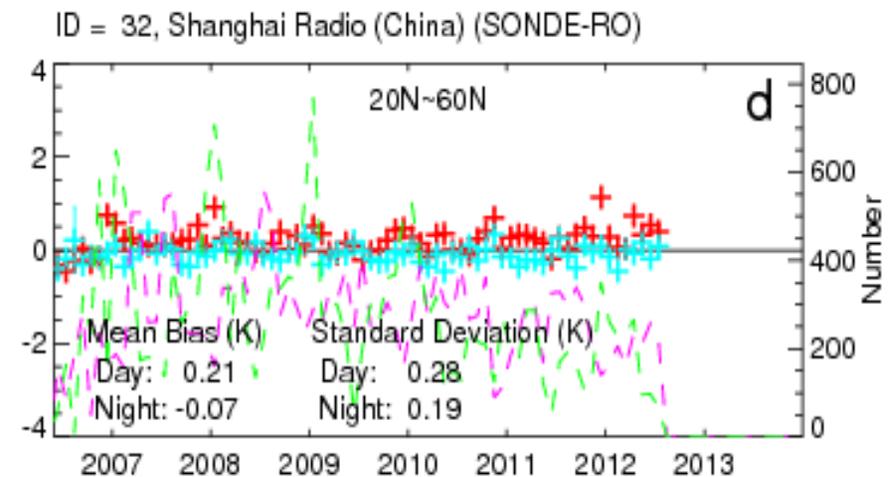# Using RO data to identify/Correct Inter-seasonal Temperature Biases Vailsala RS92

ID = 80, Vaisala RS92/Digicora III (Finland) (SONDE-RO)

ID = 87, Sippican MARK IIA (USA) (SONDE-RO)

20N~60N

a

Mean Bias (K)
Day: -0.15
Night: -0.24

Standard Deviation (K)
Day: 0.31
Night: 0.25

ID = 51, VIZ-B2 (USA) (SONDE-RO)

20N~60N

b

Mean Bias (K)
Day: 0.84
Night: -0.78

Standard Deviation (K)
Day: 0.85
Night: 0.50

ID = 27, AVK-MRZ (Russian Federation) (SONDE-RO)

20N~60N

c

Mean Bias (K)
Day: 1.21
Night: 0.11

Standard Deviation (K)
Day: 0.42
Night: 0.32

ID = 32, Shanghai Radio (China) (SONDE-RO)

20N~60N

d

Mean Bias (K)
Day: 0.21
Night: -0.07

Standard Deviation (K)
Day: 0.28
Night: 0.19

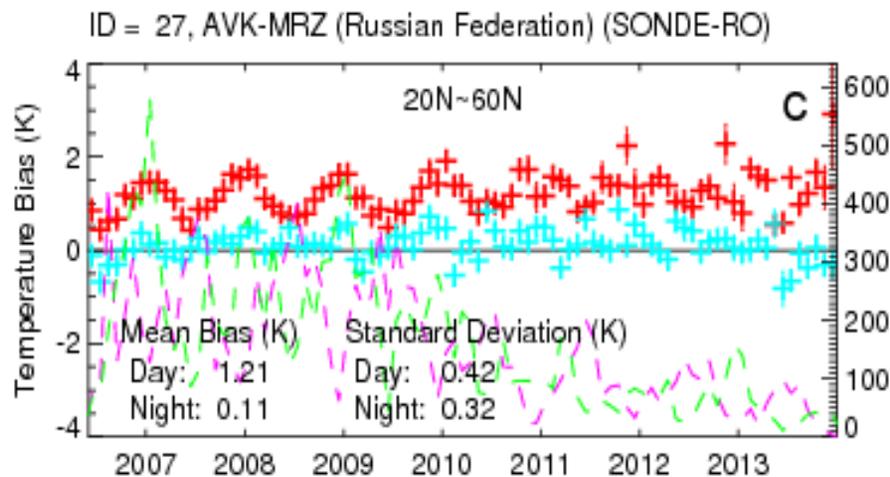**Removing the seasonal cycle**
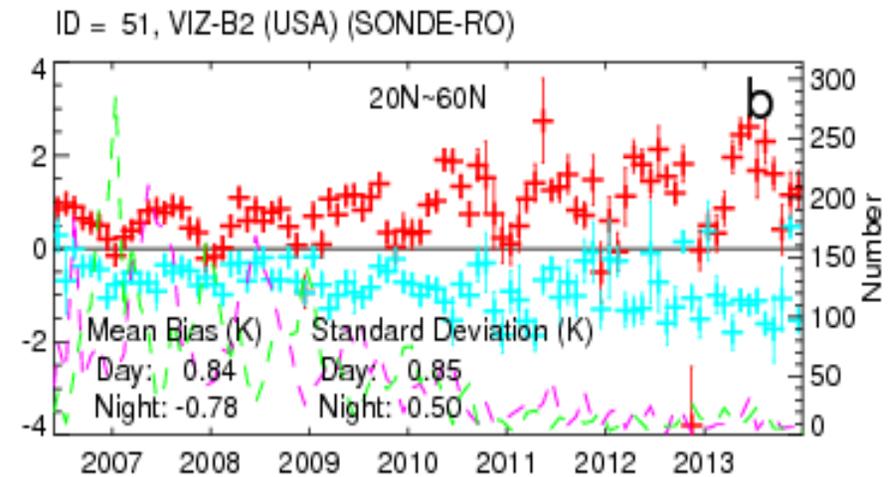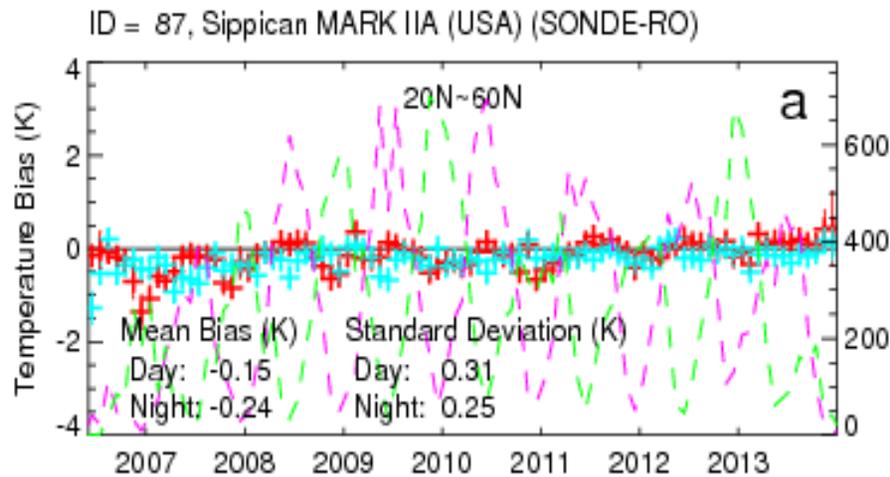**Detection of the drifting of ROAB – RO temperature bias**

ID = 80, Vaisala RS92/Digicora III (Finland) (SONDE-RO) in 20N~60N

a

Mean Bias (K)   Standard Deviation (K)   Trend of Anomaly (K/year)
Day: 0.23   Day: 0.14   Day: 0.014
Night: 0.15   Night: 0.16   Night: -0.014

ID = 81, Vaisala RS92/Autosonde (Finland) (SONDE-RO) in 20N~60N

b

Mean Bias (K)   Standard Deviation (K)   Trend of Anomaly (K/year)
Day: 0.21   Day: 0.26   Day: 0.028
Night: 0.17   Night: 0.24   Night: -0.010
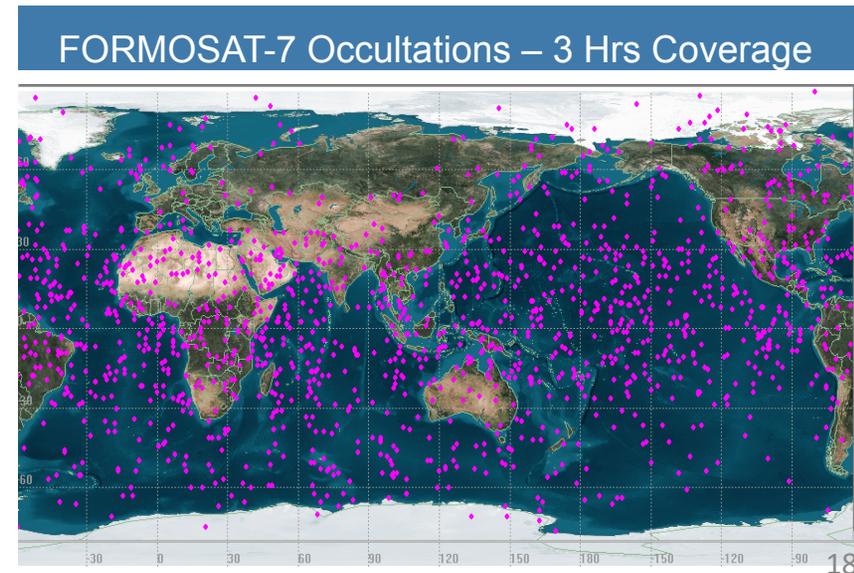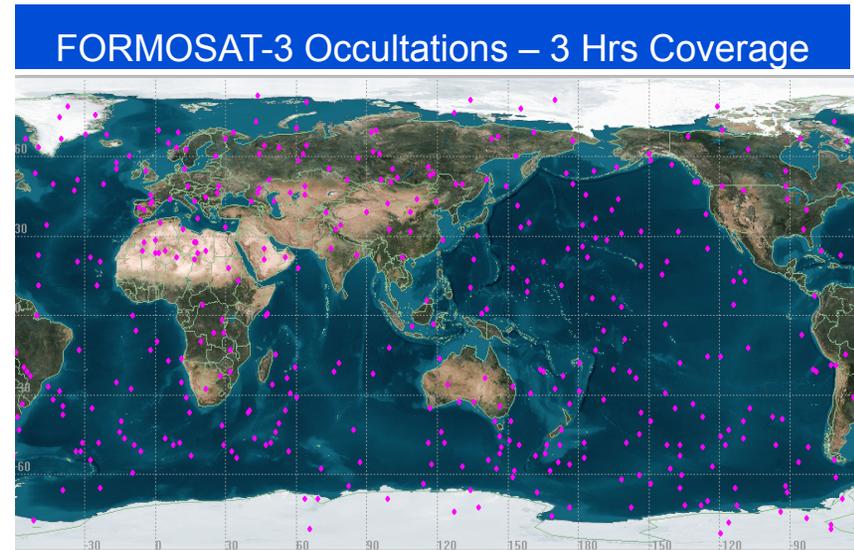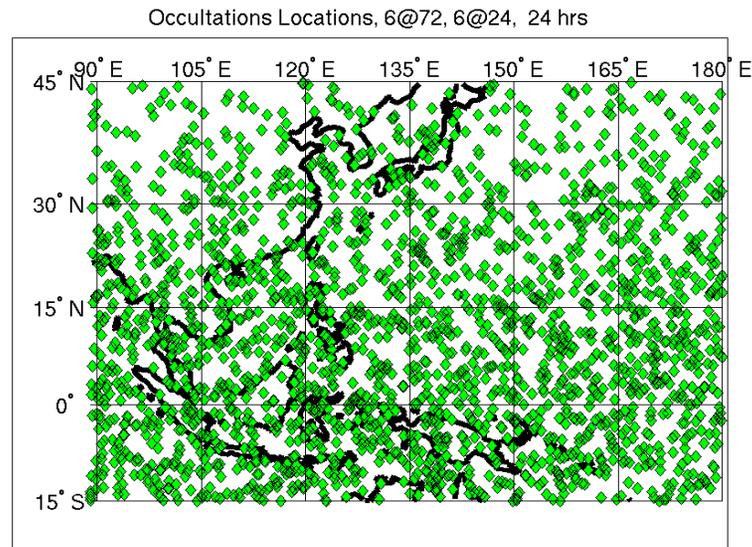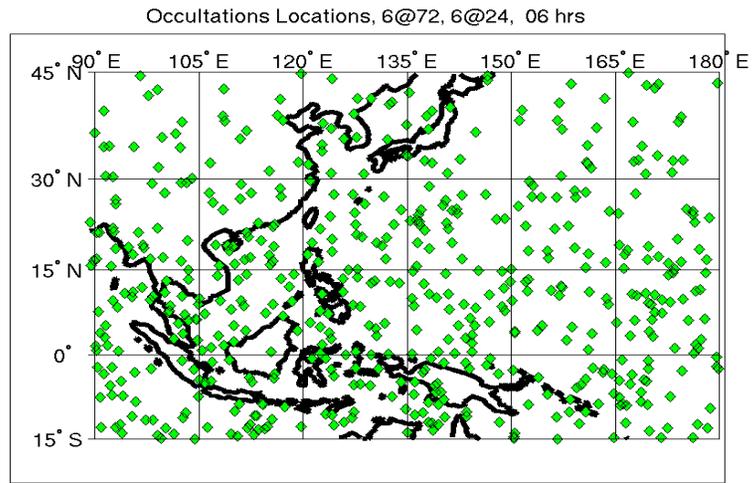
Removing the seasonal cycle
## Detection of the drifting of ROAB – RO temperature bias

COSMIC-2

- COSMIC-1: 2800 registered users, 130 papers, 3915 citations

- Partnership project is on schedule
  - Taiwan to provide: 12 spacecraft and integration of payloads onto spacecraft, command and control
  - US to provide: RO and Space Weather payloads, launches, ground systems, data processing
    - USAF provides payloads and launch
    - NOAA provides ground stations and processing
  - 6 satellites launched into 24 degree inclination (1st launch) plus 6 satellites at 72 degree inclination (optional)
    - Launches in 2016 and 2018
  - System will provide 10,000+ worldwide atmospheric and 10-12,000 ionospheric soundings per day

COSMIC and COSMIC-2

Occultations Locations, 6@72, 6@24, 06 hrs

FORMOSAT-3 Occultations – 3 Hrs Coverage

Occultations Locations, 6@72, 6@24, 24 hrs

FORMOSAT-7 Occultations – 3 Hrs Coverage

The potentially new climate applications that can be explored using COSMIC-2 data

- With increase data density and quality, COSMIC-2 will provide significant data set to support science and operations

- Continue climate benchmark observations without gap

- Study of hydrological processes over the tropics

- Evaluation of climate prediction models – Assess their ability to capture climate processes

- Calibration of other satellites measurements – to build long-term climate records

- Improve accuracy and quality of global re-analyses
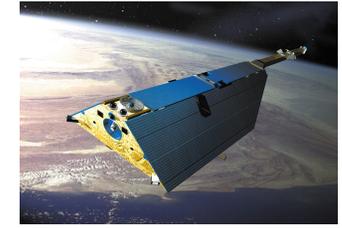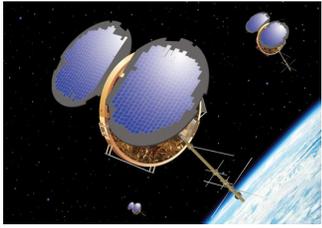
- Science for Weather and Climate Applications
  - **what happens within, below, and outside clouds**
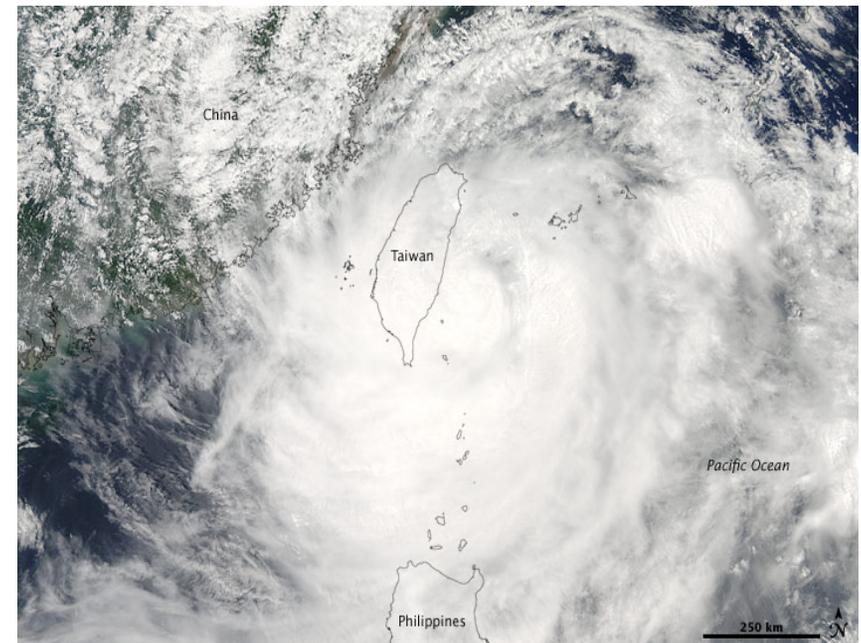
Tropical cyclone cloud-top height and vertical temperature structure detection using GPS radio occultation measurements

Riccardo Biondi, Shu-Peng (Ben) Ho, William Randel, Stig Syndergaard, and Torsten Neubert
(ACP, JGR, 2013, 2014)
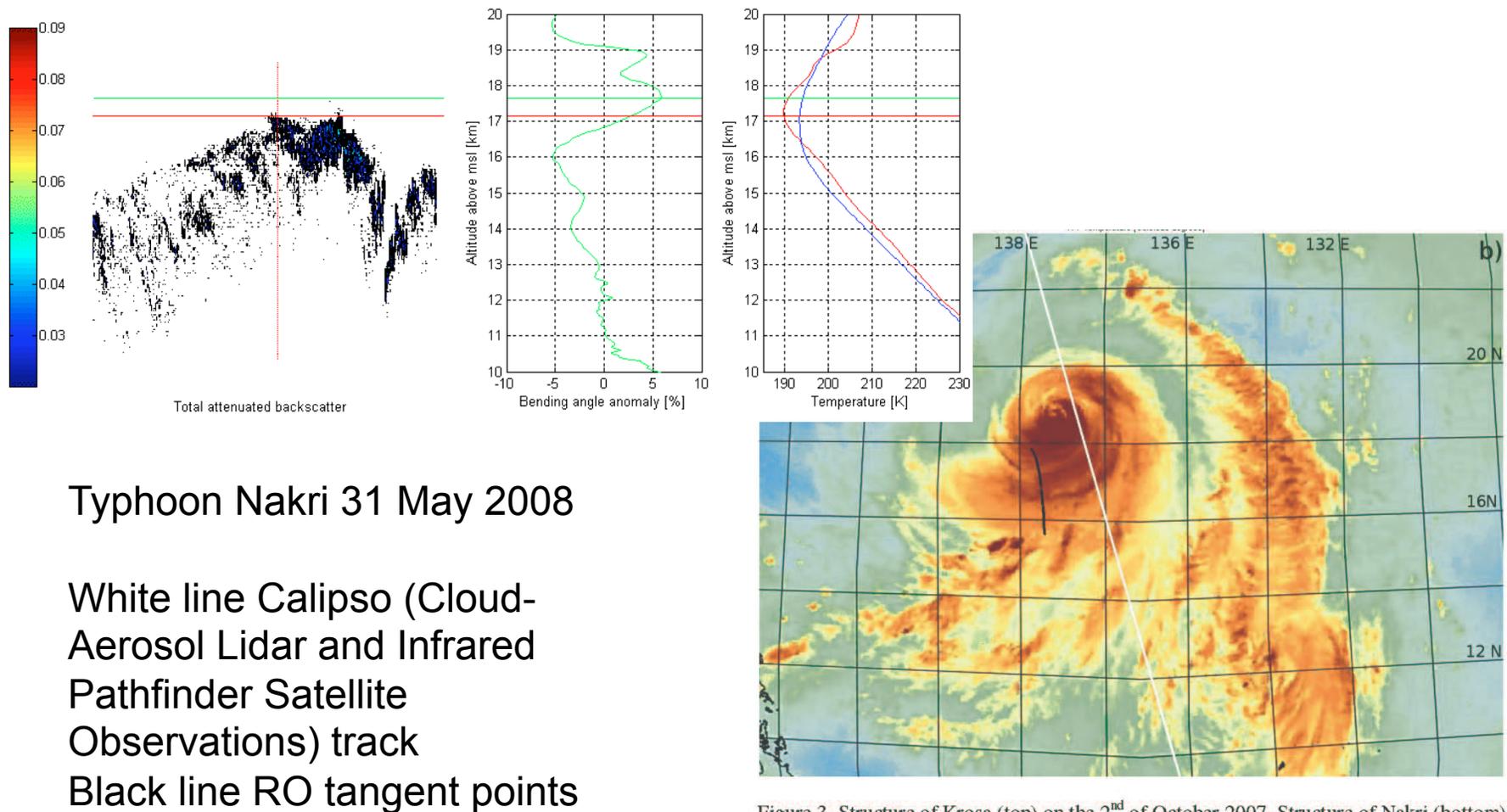
Typhoon Nakri 31 May 2008

White line Calipso (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) track
Black line RO tangent points

Figure 3. Structure of Krosa (top) on the 2nd of October 2007. Structure of Nakri (bottom) on the 31st of May 2008. Colors denote GMS brightness temperature (° Celsius) in the
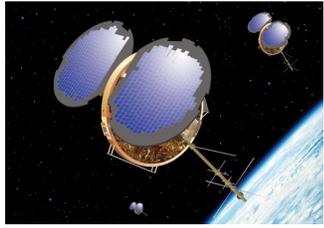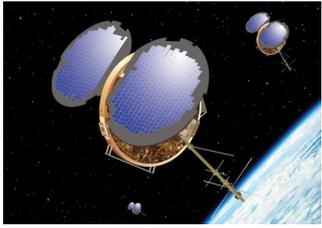
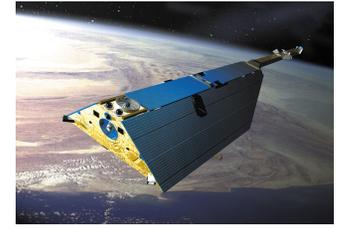# Collocation of CALIOP and COSMIC data to detect thermal structure of MBL clouds
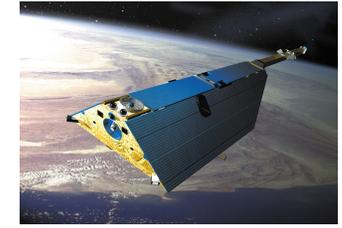
The ensembles of CALIOP-detected MBLH within 2 hours and 200 km for individual COSMIC profiles from September 2007 to March 2010 are collected.

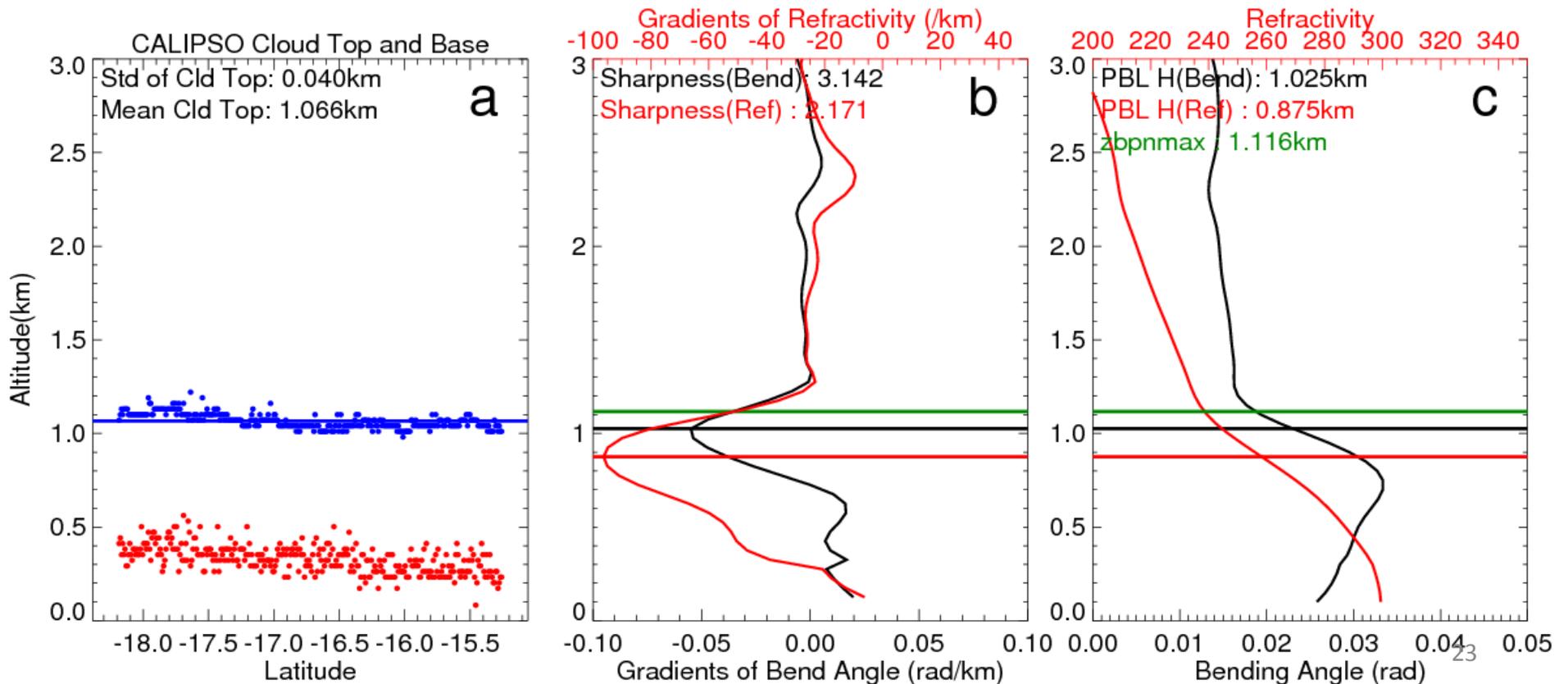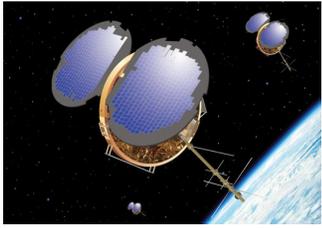GOES 12 Channel 4 10.7(micron)   October 09 2009 07:45
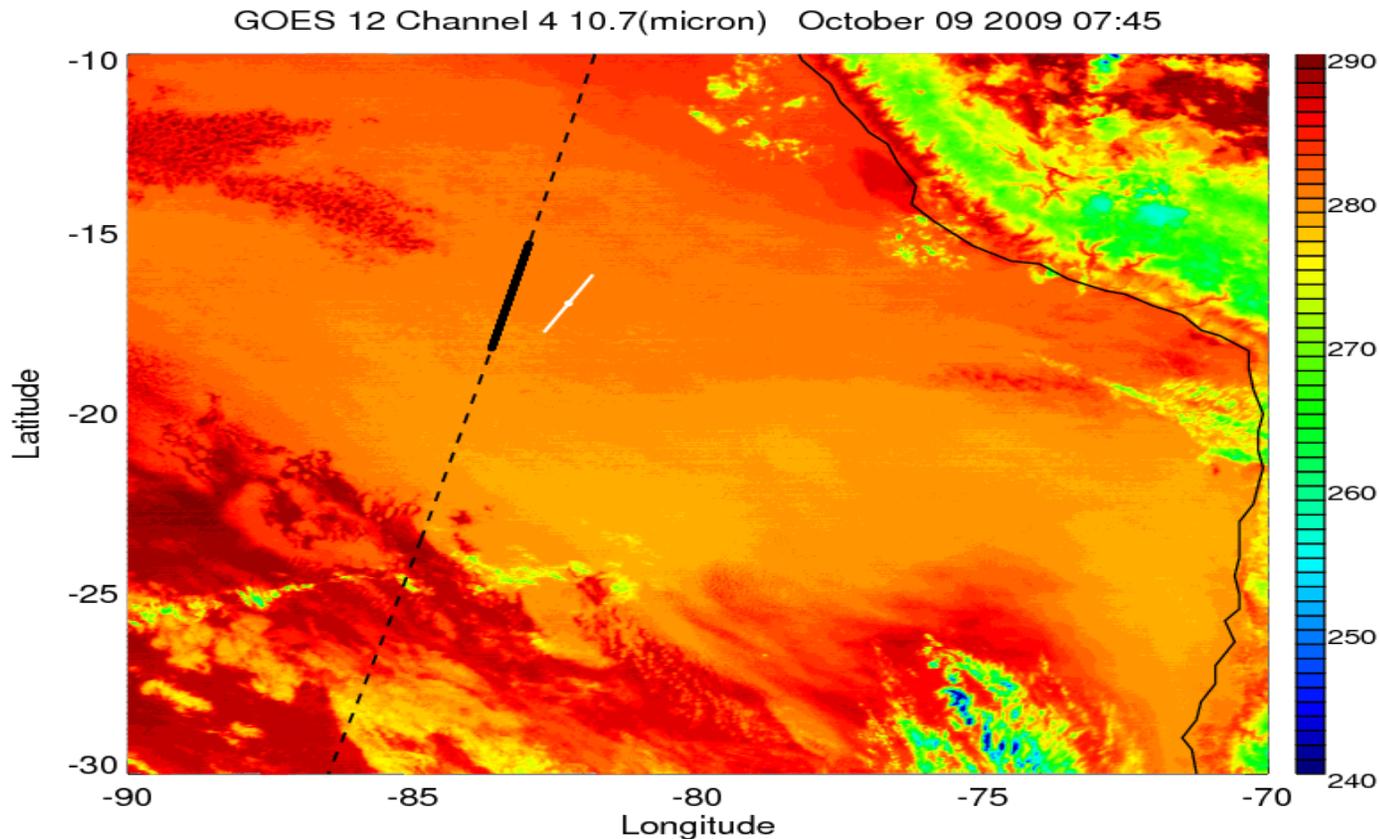
Using GPS RO data to explore the thermal structure of Stratocumulus clouds
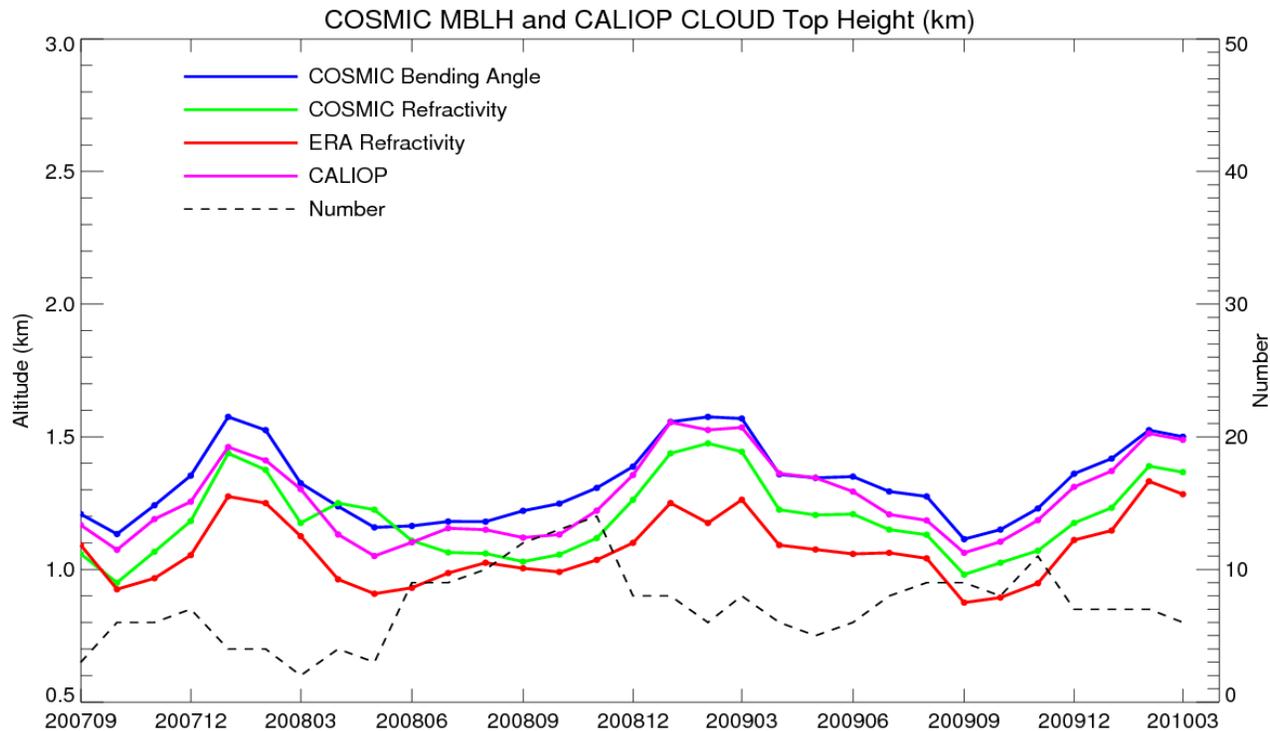

1) within the 200-km and 2-hour window,
2) more than 150 CALIOP pixels,
3) CALIOP ensemble relative to its mean is less than 0.1 km are used.
This is to reduce the possible cloud heterogeneity (i.e., broken clouds) for RO-CALIOP pairs.
A total of 77 CALIOP-RO pairs are identified.

Seasonal MBLH variations

COSMIC MBLH and CALIOP CLOUD Top Height (km)

Legend:
- COSMIC Bending Angle
- COSMIC Refractivity
- ERA Refractivity
- CALIOP
- Number
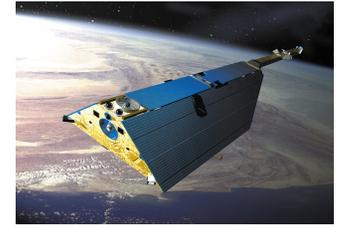
The RO bending angle PBL height, the MBLH from the ERA-Interim refractivity profiles, and cloud top height detected by CALIOP in the VOCALS region from September 2007 to March 2010. (Ho et al., 2014, J. of Climate)

Conclusions and Future Work

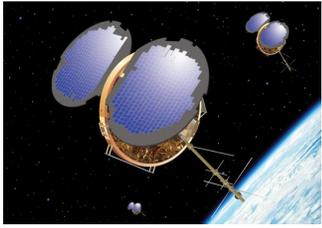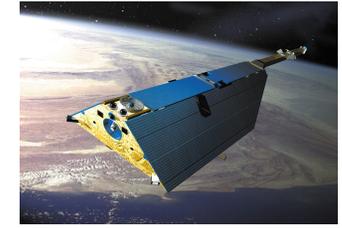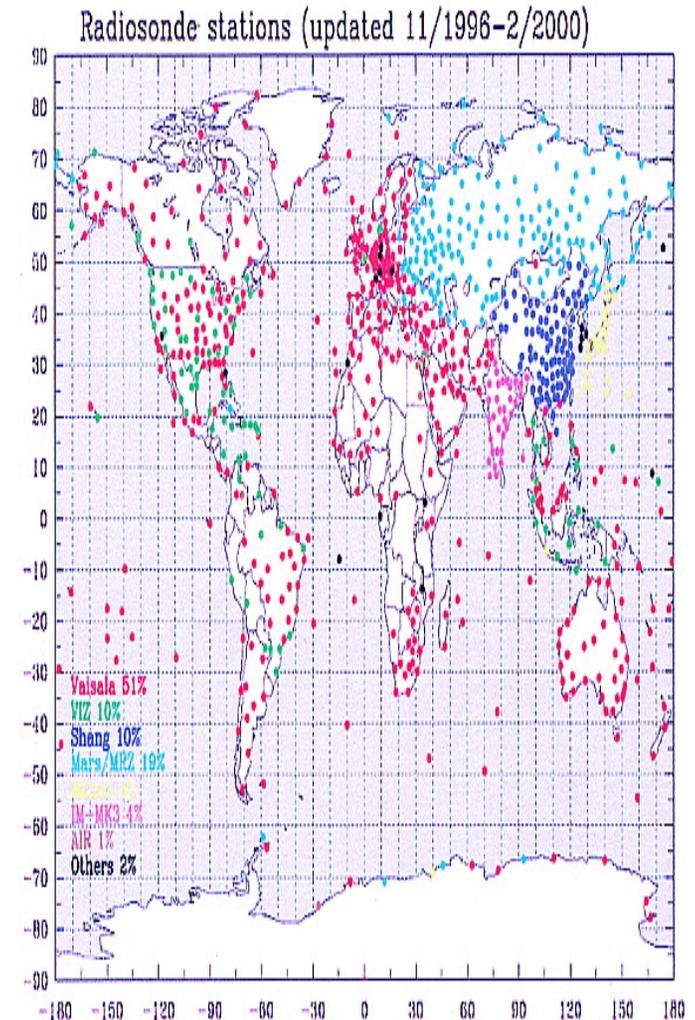- **Geo-location independent COSMIC RO data are useful to assess the quality of radiosonde temperature in the higher troposphere and lower stratosphere**
- **These results suggest that COSMIC temperature observations are extremely useful as benchmark observations for differentiating radiosonde temperature errors resulting from instrument characteristics and identifying the variation of inter-seasonal biases.**
- **MRZ (RUSSIA) contains warm temperature bias during the day but seems consistent with RO temperature during the night**
- **COSMIC-2 is coming**

Radiosonde stations (updated 11/1996-2/2000)

Vaisala 51%
VIZ 10%
Shang 10%
Mars/MRZ 19%

IM-MK3 4%
AIR 1%
Others 2%

Shu-peng Ben Ho, UCAR/COSMIC

The mystery of recent statospheric temperature trends (David Thompson Nature, 2012)
SPARC meeting in Reading to resolve this mystery

SSU Ch1 06/10/2005~06/14/2005

Tropics (-20 ~ 20)
North (20 ~ 90)
South (-90 ~ -20)

corr.= 0.992
N = 563
Mean = -1.921
Stdev = 1.614

RO simulated SSU BT (K)

STAR SSU BT (K)
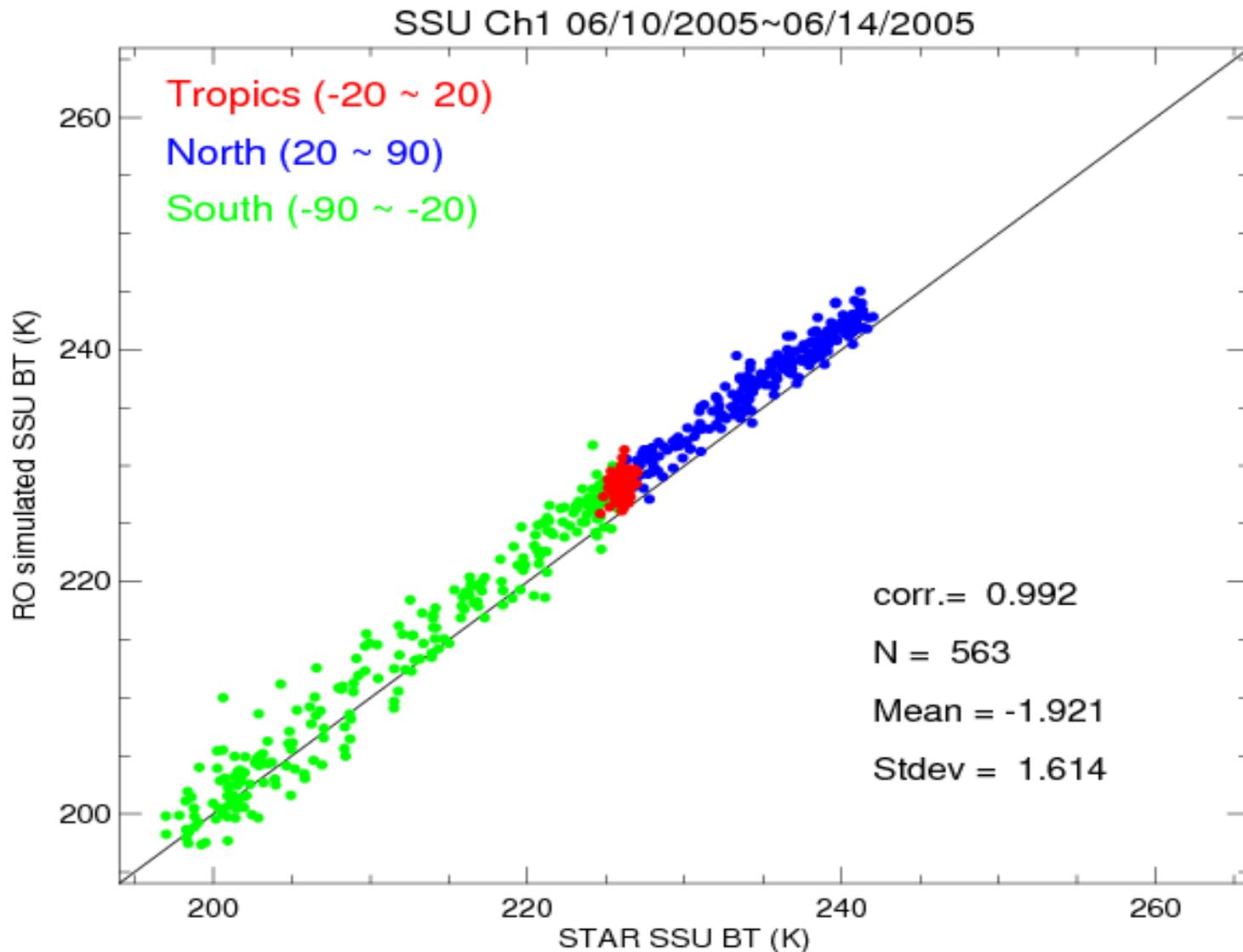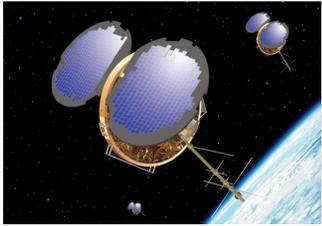
ECMWF-RO Time Series
Over locations of Vailsala RS92
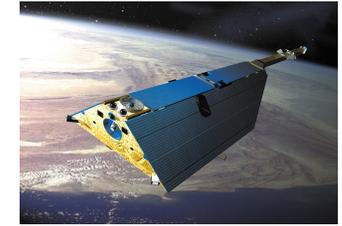
ID = 80, Vaisala RS92/Digicora III (Finland) (ECMWF-RO)

Slide 12

COSMIC-2: Equatorial Boundary Layer

Number of measurements per 500x500 km area per 24 hours
Tropics (±30 degrees latitude)

9X Factor Improvement vs COSMIC-1 (assumes 2x penetration yield from TriG/TGRS)

- Better resolving dynamical scales (gravity waves etc)
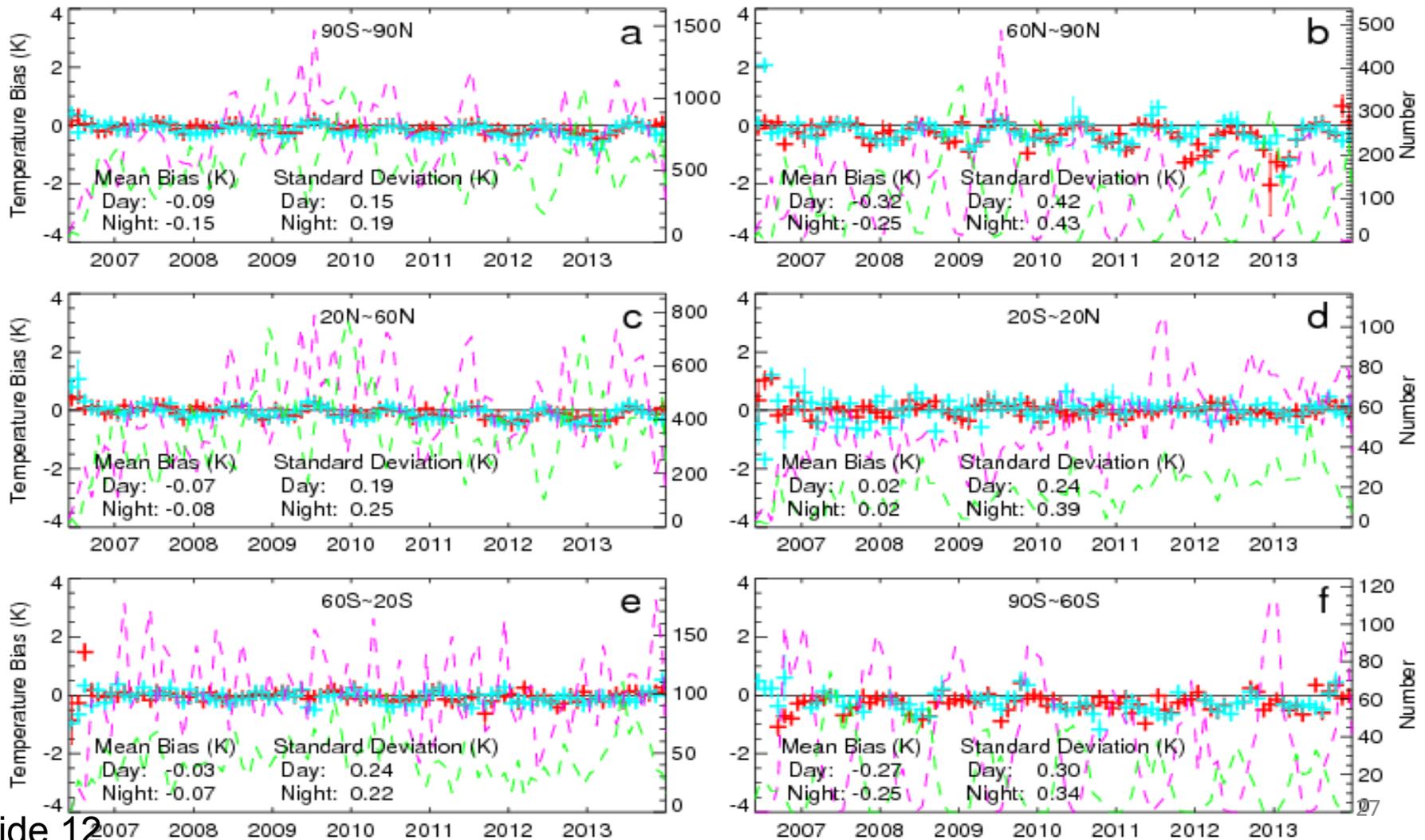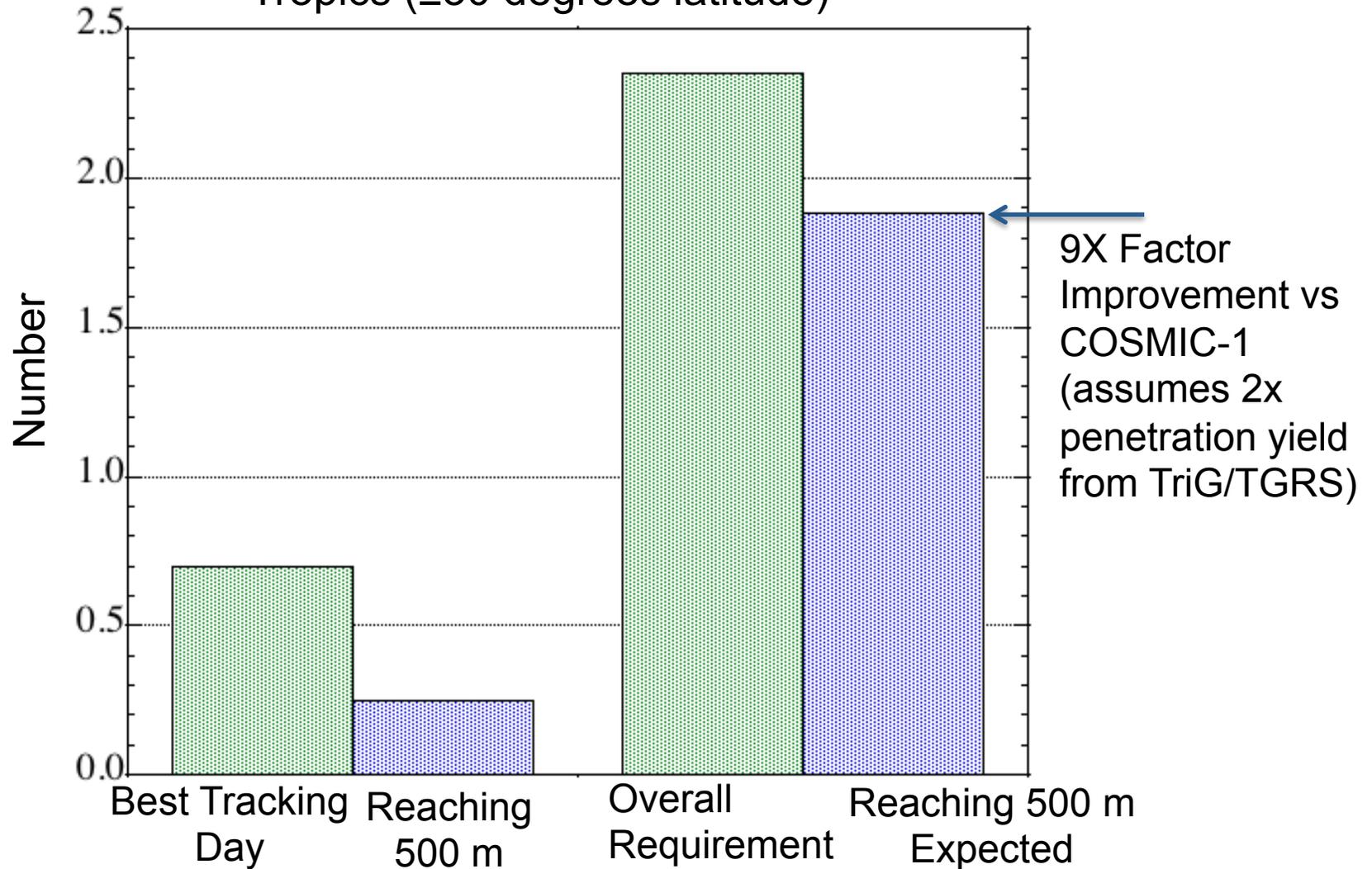- Modes of variability
  - ENSO - enhanced density from COSMIC2, towards more of a gridded product with better time resolution
  - MJO
  - Equatorial Waves
  - QBO
- Structure of tropic storms
- (Marine) PBL: height, structure, seasonal and diurnal behavior
- Tropical expansion, change of circulation due to global warming
- Combine with other datasets: TRMM, CloudSat, AIRS to study moisture, stability, cloud and precipitation
- Be part of a longer data record for defining the climate state and monitoring its changes

Stratocumulus Clouds

Sc Cloud Cover Fraction

Stratocumulus cloud cover [annual mean]

Insufficient data

0 5 10 15 20 25 30 35 40 45 50 55

60%
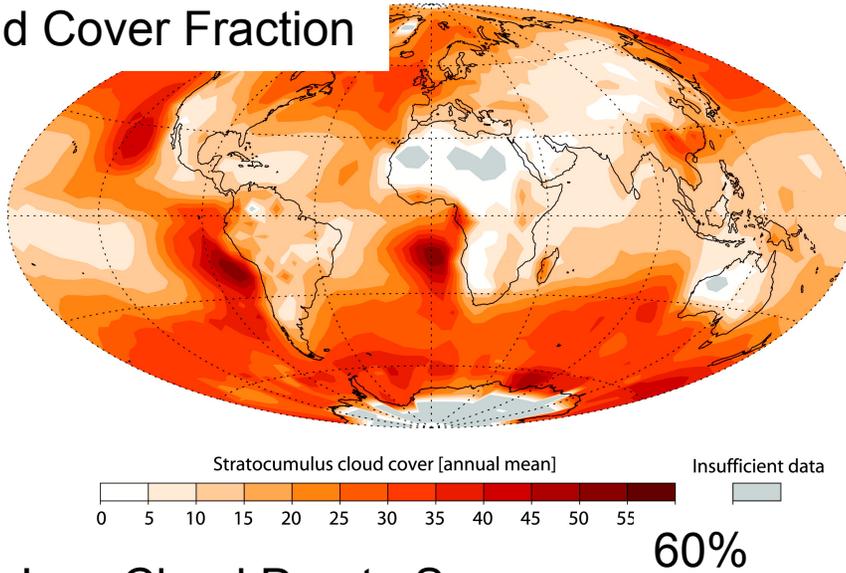
Fraction Low Cloud Due to Sc

Fraction of low cloud cover due to stratocumulus [annual mean]

Insufficient data

0 10 20 30 40 50 60 70 80

90%

Wood, "Stratocumuls Clouds", MWR 2012

Significant diurnal variability

(a)

Low cloud amount (%)

(b)

Frequency (%)

Cumulus - $C_L 1$ plus $C_L 2$

Stratocumulus - $C_L 5$

Cumulus and Stratocumulus - $C_L 8$

Local hour