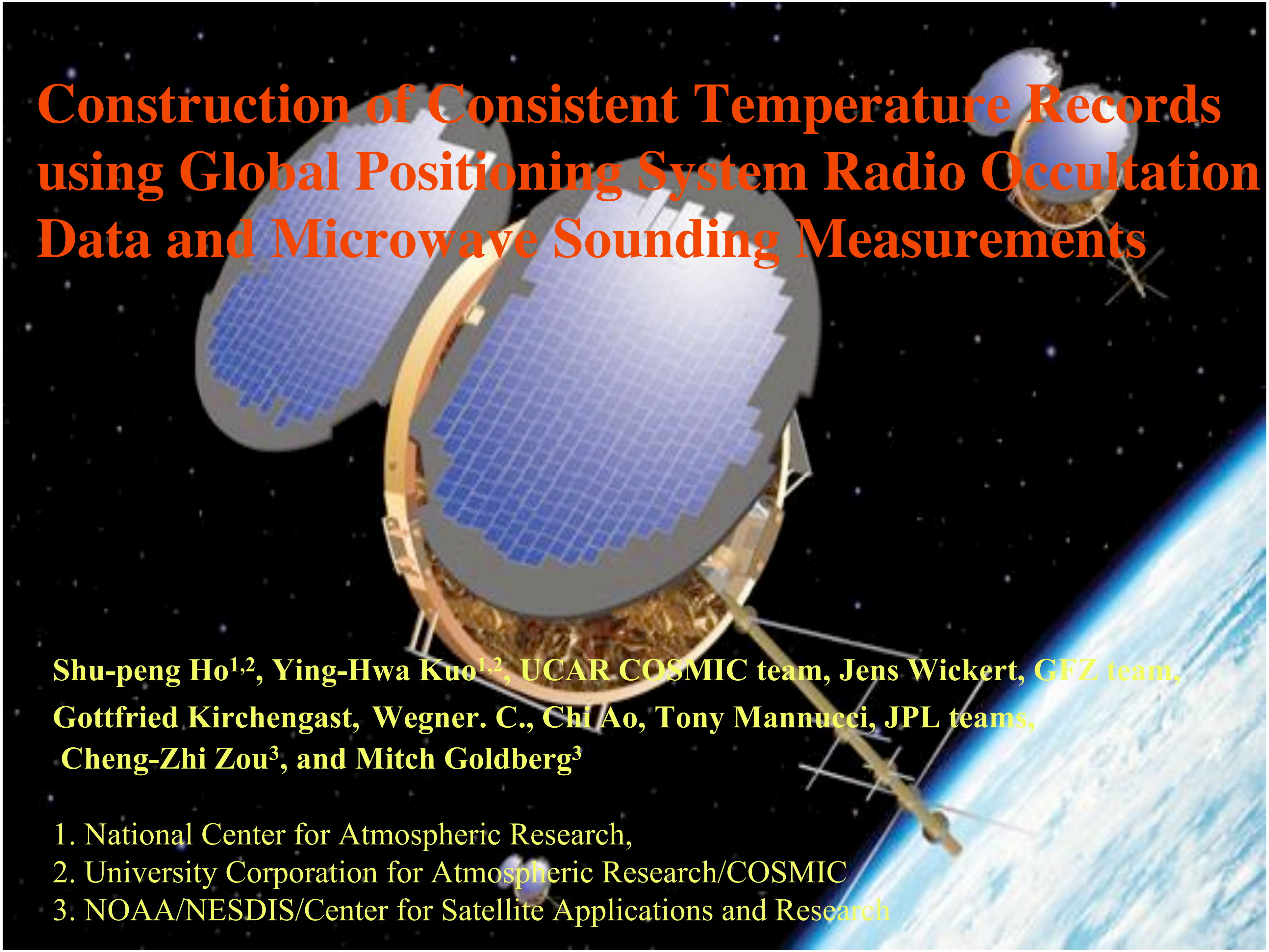


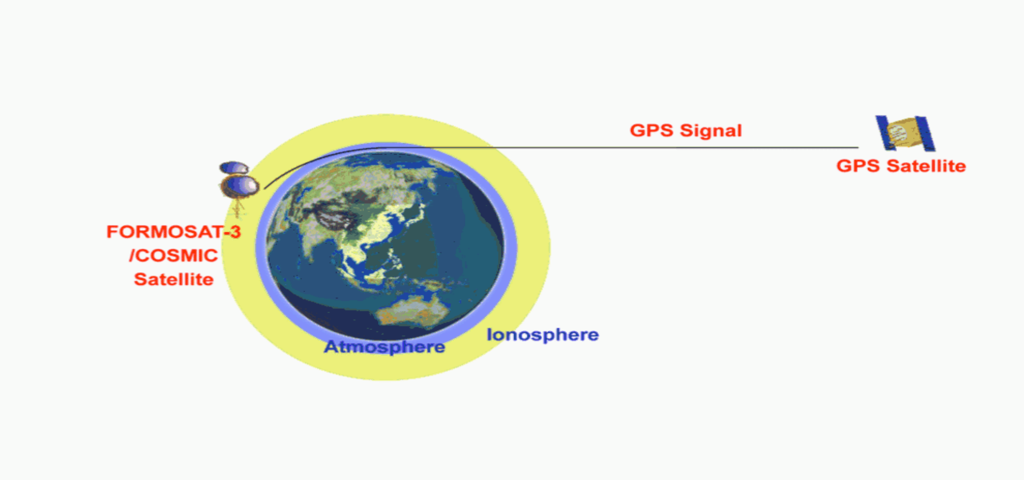
Construction of Consistent Temperature Records using Global Positioning System Radio Occultation Data and Microwave Sounding Measurements

Shu-peng Ho[1,2], Ying-Hwa Kuo[1,2], UCAR COSMIC team, Jens Wickert, GFZ team, Gottfried Kirchengast, Wegner. C., Chi Ao, Tony Mannucci, JPL teams, Cheng-Zhi Zou[3], and Mitch Goldberg[3]

1. National Center for Atmospheric Research,
2. University Corporation for Atmospheric Research/COSMIC
3. NOAA/NESDIS/Center for Satellite Applications and Research

1. Motivation : To demonstrate the usefulness of independent GPS RO data for climate monitoring. Can we use GPS RO data to calibrate AMSU/MSU data to generate consistent 30 years of climate temperature records ?

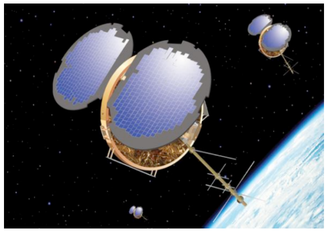
- high accuracy
- no calibration issues,
- high vertical resolution
- insensitive to clouds and precipitation



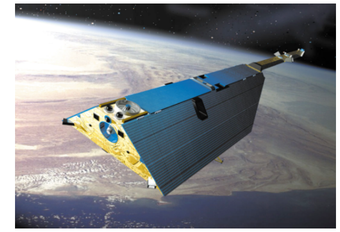
2. Outlines :

- Challenges to define/validate a global trend
- Characteristics of COSMIC GPS RO data : Can GPS RO data be used as a climate benchmark dataset ?
- Use GPS RO data as benchmark measurements to inter-calibrate other satellite data (NOAA AMSU) : Can we use GPS RO data as benchmark measurements to inter-calibrate measurements from other instruments?
- Can COSMIC 1D-Var water vapor be used for climate monitoring ?

3. Conclusions and Future Work

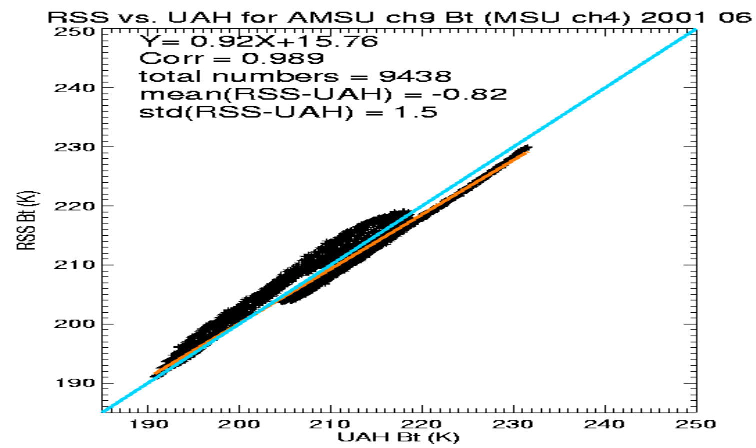


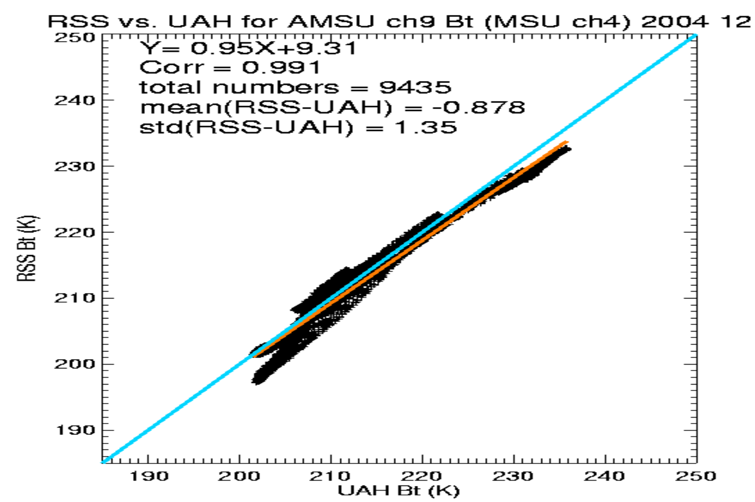
Challenges for defining the Global Temperature Trend



Satellites: changing platforms and instruments (diurnal cycle sampling, orbital decay); contribution of lower stratospheric to mid-tropospheric temperature estimates. Due to the differing methods used to account for errors before merging the time series of eleven AMSU/MSU satellites into a single, homogeneous time series, these derived trends are different from different groups (RSS vs. UAH).

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.

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Can GPS RO data be used as a climate benchmark dataset ? (measurement is time delay, no calibration issues, insensitive to clouds and precipitation, no on orbit measurement anomalies)

- Uniform spatial and temporal coverage

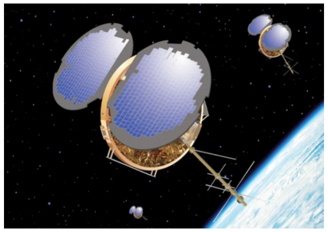
$$N = 77.6\frac{P}{T} + 3.73\times 10^{5}\frac{P_W}{T^2}$$

- Quantify the precision of GPS RO data

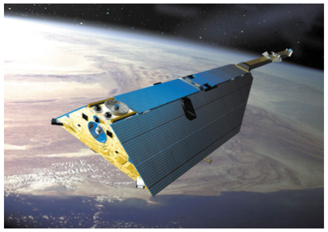
- Mission independent: Long term stability of GPS RO data for climate monitoring, no calibration issue, no on orbit anomalies

- Inversion algorithm independent: Comparing refractivities generated from different centers

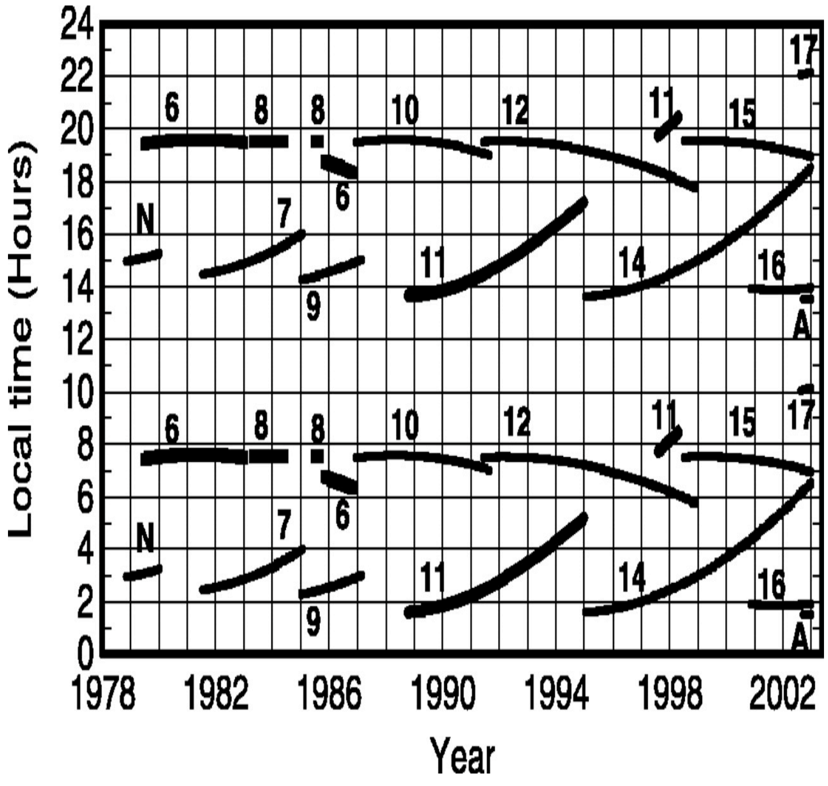
(Ho, et al., TAO, 2007)



Difficulty I: to find observations with a good global and temporal coverage

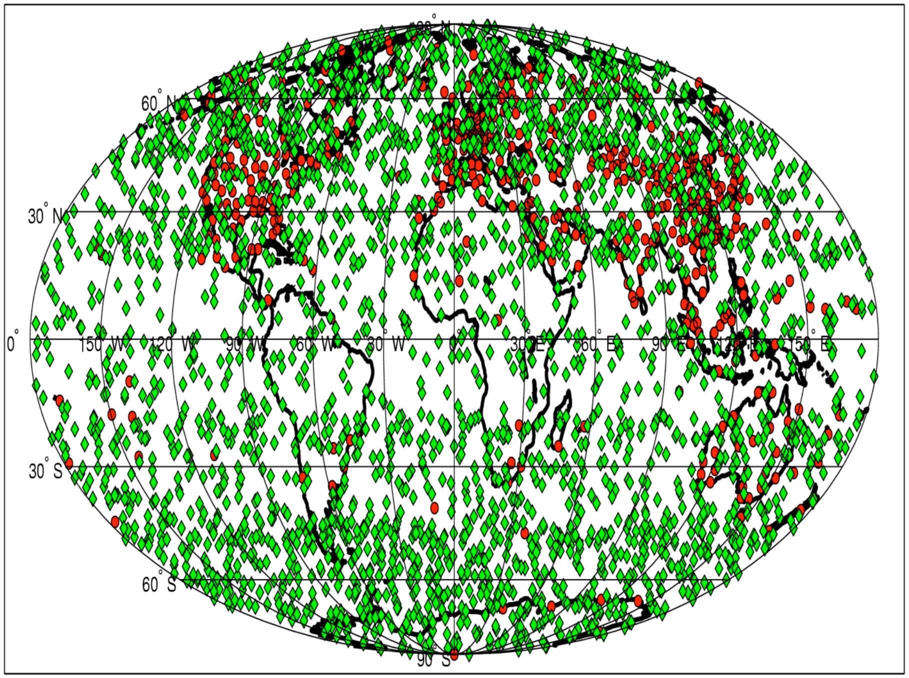


AMSU/MSU local time



COSMIC has a more complete temporal and spatial global coverage

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



COSMIC

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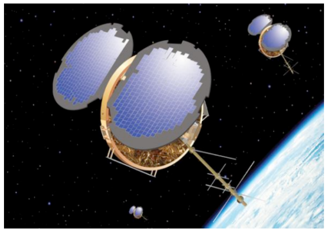
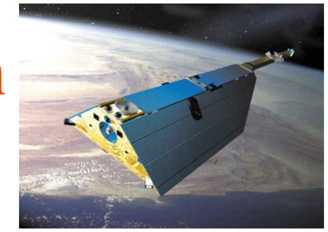
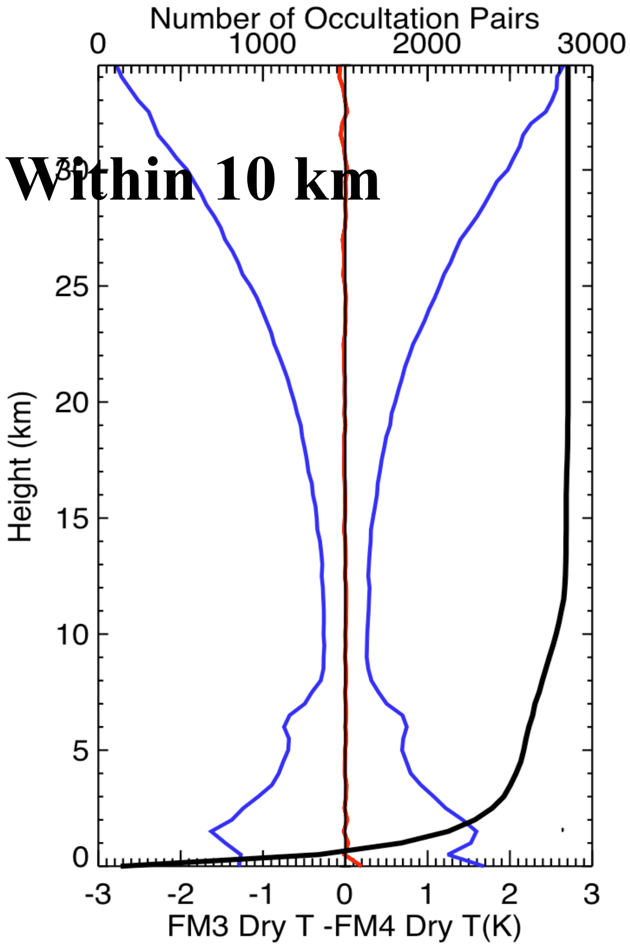
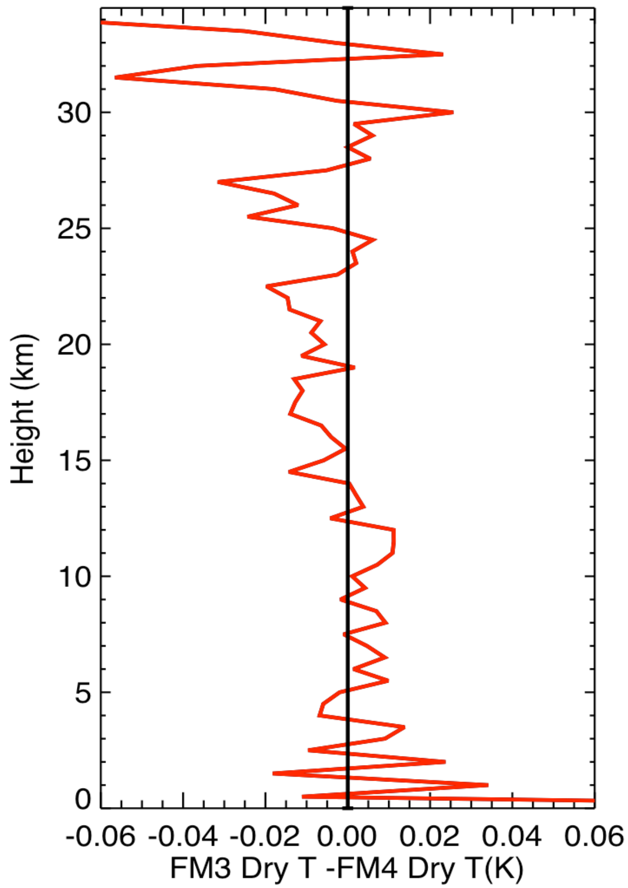


Difficulty II: to find observations with very high precision





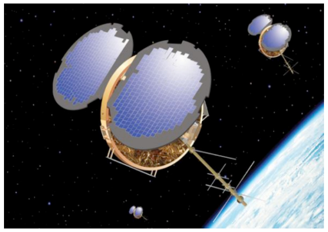


$$N = 77.6\frac{P}{T} + 3.73\times10^{5}\frac{P_W}{T^2}$$

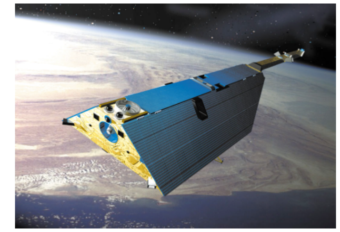
With 0.02-0.05 K of precision at all vertical levels, COSMIC data will be very useful to inter-calibrate measurements from other satellites

(Ho et al. TAO, 2007)

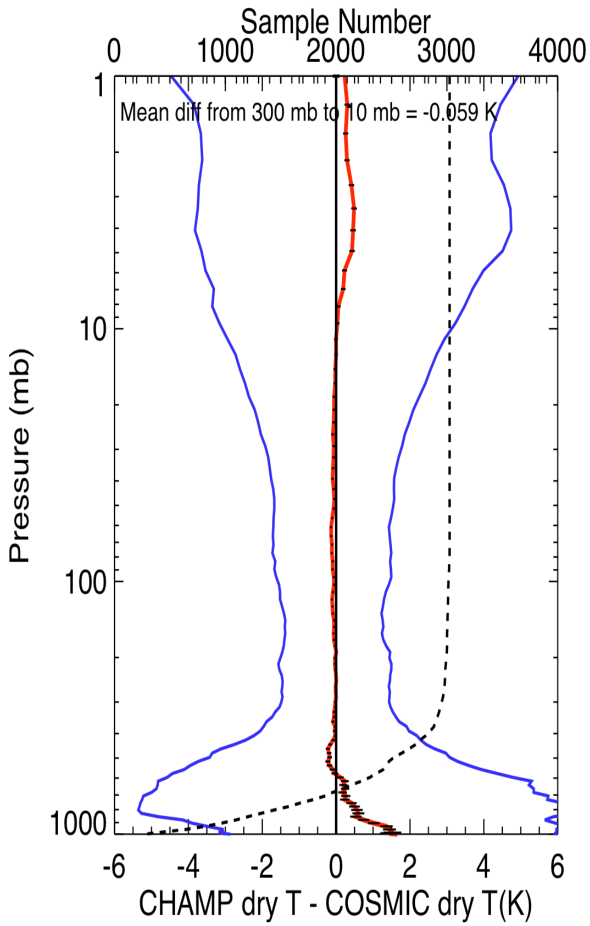
Dry temperature difference between FM3-FM4 receivers



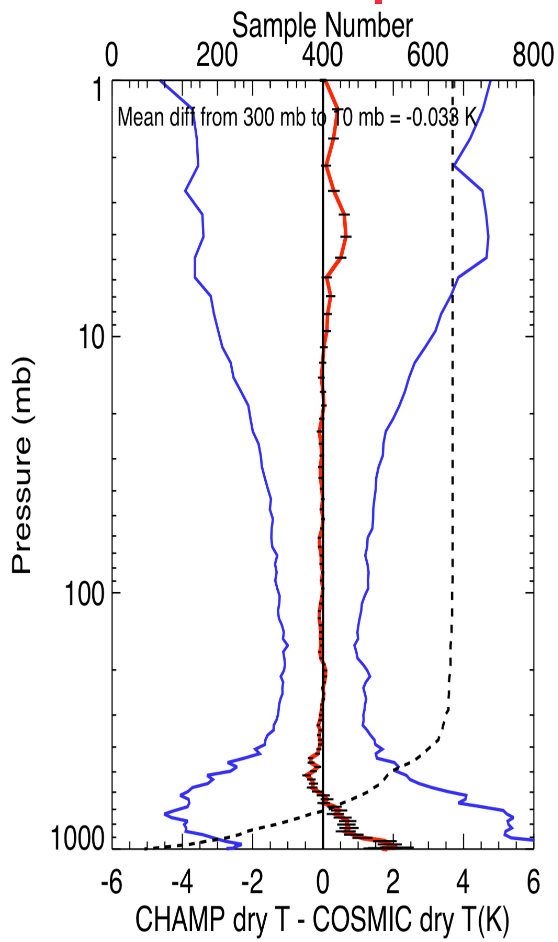
Difficulty III: to find measurements with long term stability, no on orbit drift, no calibration issue



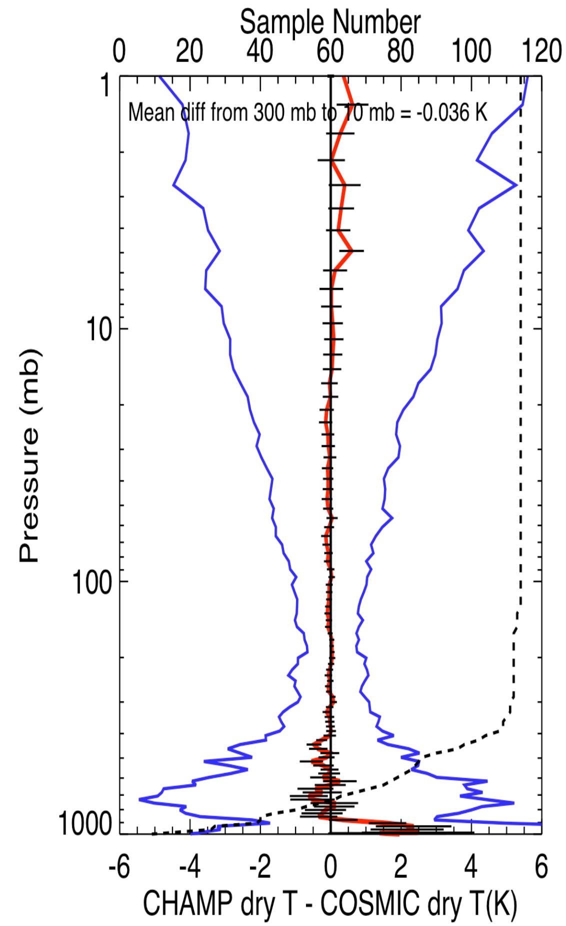
Global COSMIC-CHAMP Comparison from 200607-200707



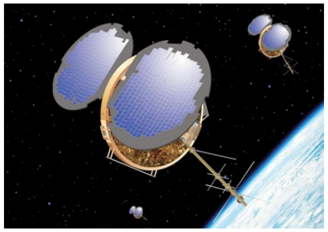
Within 90 Mins and 250 Km



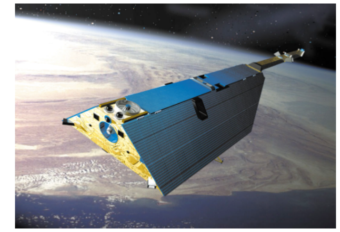
Within 90 Mins and 100 Km



Within 60 Mins and 50 Km



Difficulty IV: Independent Inversion Procedures (UCAR, JPL,GFZ, Weg C)



Raw measurements : phase and amplitude of RO signals

Knowledge of the precise position and velocities of the GPS and LEO satellites.

$$N = 77.6\frac{P}{T} + 3.73\times 10^5 \frac{P_W}{T^2}$$

⇒ Vertical distribution of bending angle

⇒ Vertical distribution of atmospheric refractivity

Assumption, simplification and approximations are used in the RO inversion procedures.

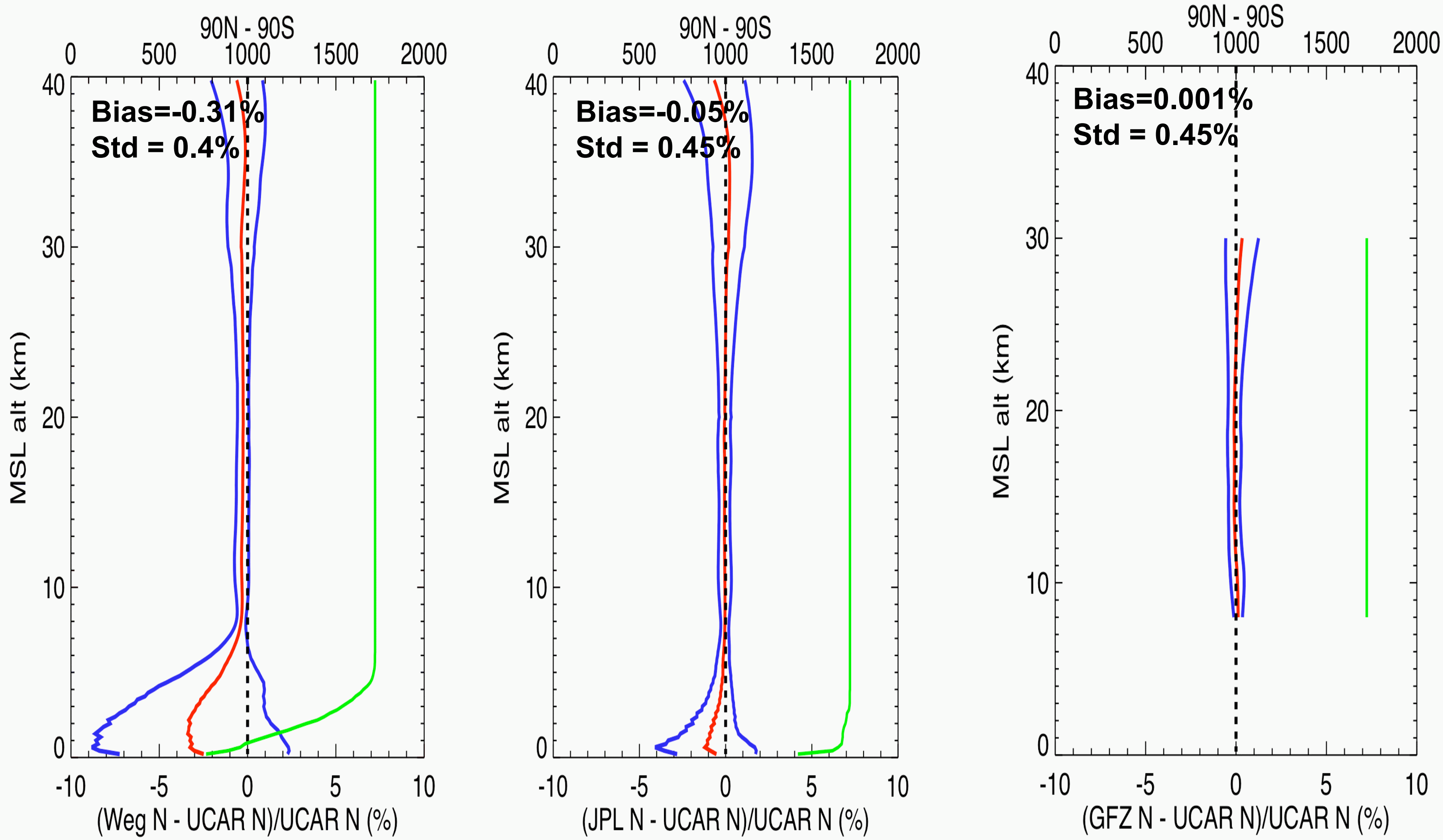
Refractivity uncertainty introduced by inversion procedures :

1. Method to calculate the bending angles
2. Ionospheric calibration calculation of refractivity from the bending angles
3. Uncertainty introduced by quality control procedures

Shu-peng Ben Ho, UCAR/COSMIC

Monthly , 5 deg-lat, 200-meter vertical resolution mean refractivity profiles from 200201-200512

UCAR, JPL, GFZ, WegC



Bias and std from 30km to 8 km

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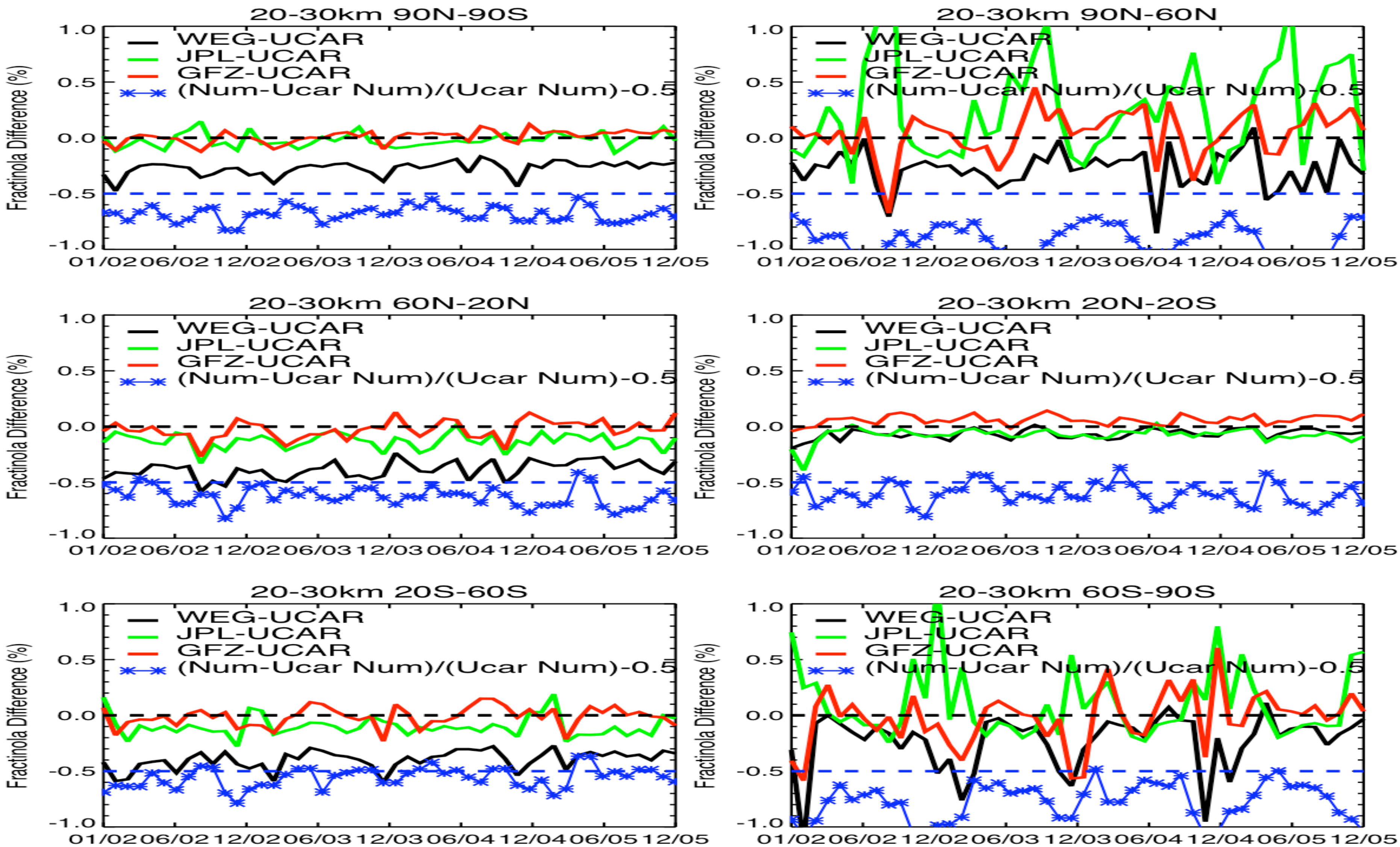
20-30 km

Systematic bias : Weg. C. (vs. GFZ)
Systematic seasonal differences : JPL



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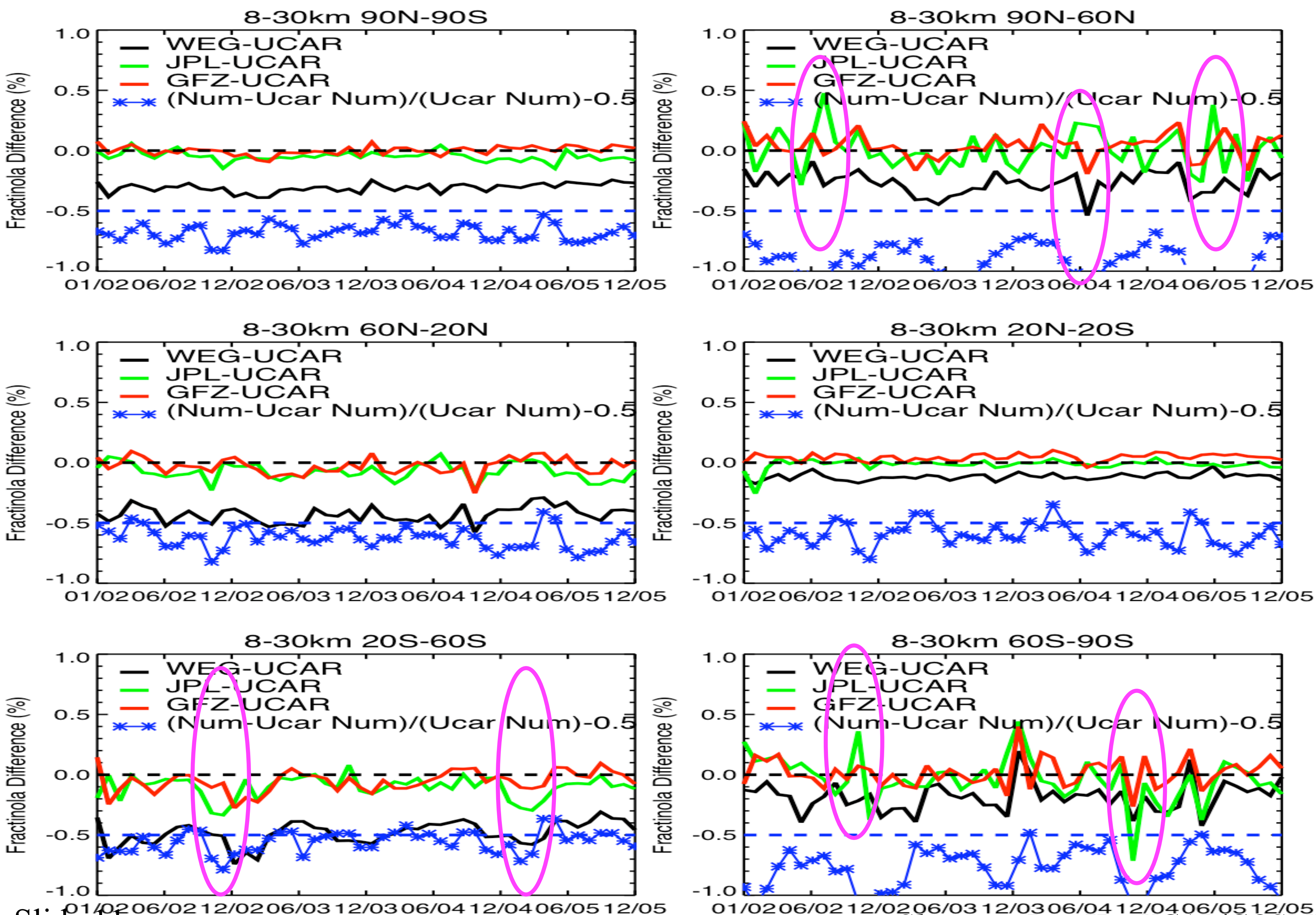
8-30 km The main reason for trend uncertainty is due to sampling errors



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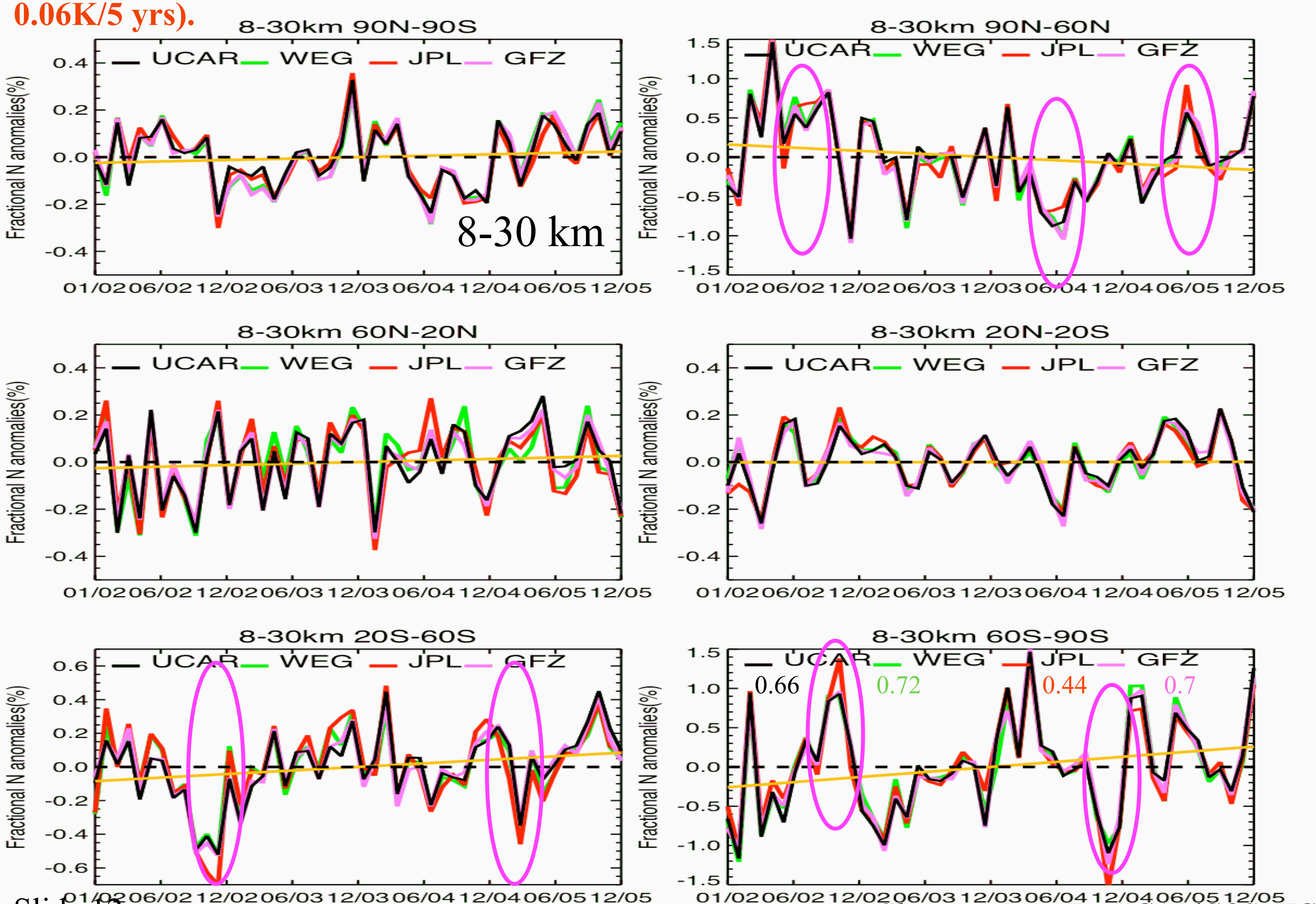
The uncertainty of the trend of fractional N anomalies is within +/-0.045 %/5yrs (+/-0.06K/5 yrs).



Shu-peng Ben Ho, UCAR/COSMIC

Can we use GPS RO data as benchmark measurements to inter-calibrate other instruments ?

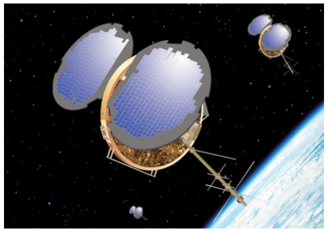
Objective :

This study is to demonstrate the usefulness for GPS RO data to inter-calibrate Microwave satellite data to improving Stratospheric Temperature Trend Analysis

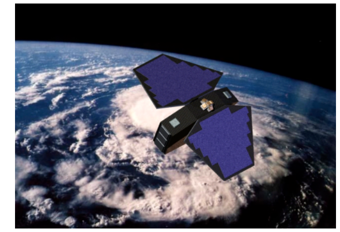
- **Using RO data to calibrate AMSU data from different missions**
- **Using RO data to identify temperature anomalies due to heating/cooling of satellite**
- **Using the Calibrated AMSU data to calibrate other overlapped AMSU data : consistency between GPS RO-AMSU and AMSU vs. ASMU**

(Ho et al. TAO, 2007, Ho et al. OPAC special issue, 2007, Ho et al. GRL, 2007)

  Shu-peng Ben Ho, UCAR/COSMIC



Approach



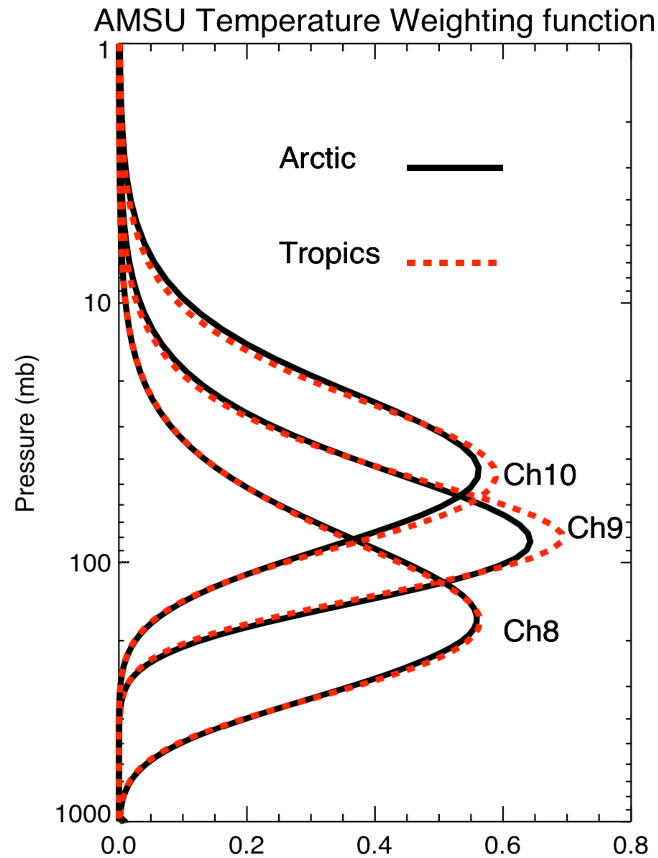
Approaches:

1. Apply CHAMP and COSMIC soundings to AMSU forward model to simulate AMSU TLS

2. Match simulated GPS RO TLS to NOAA AMSU TLS to find calibration coefficients for different NOAA satellites so that we can

a. use GPS RO data to inter-calibrate other NOAA satellite

b. use the NOAA satellite measurements calibrated by GPS RO data to calibrate multi-year AMSU/MSU data



-d(tau)/d(lnP)

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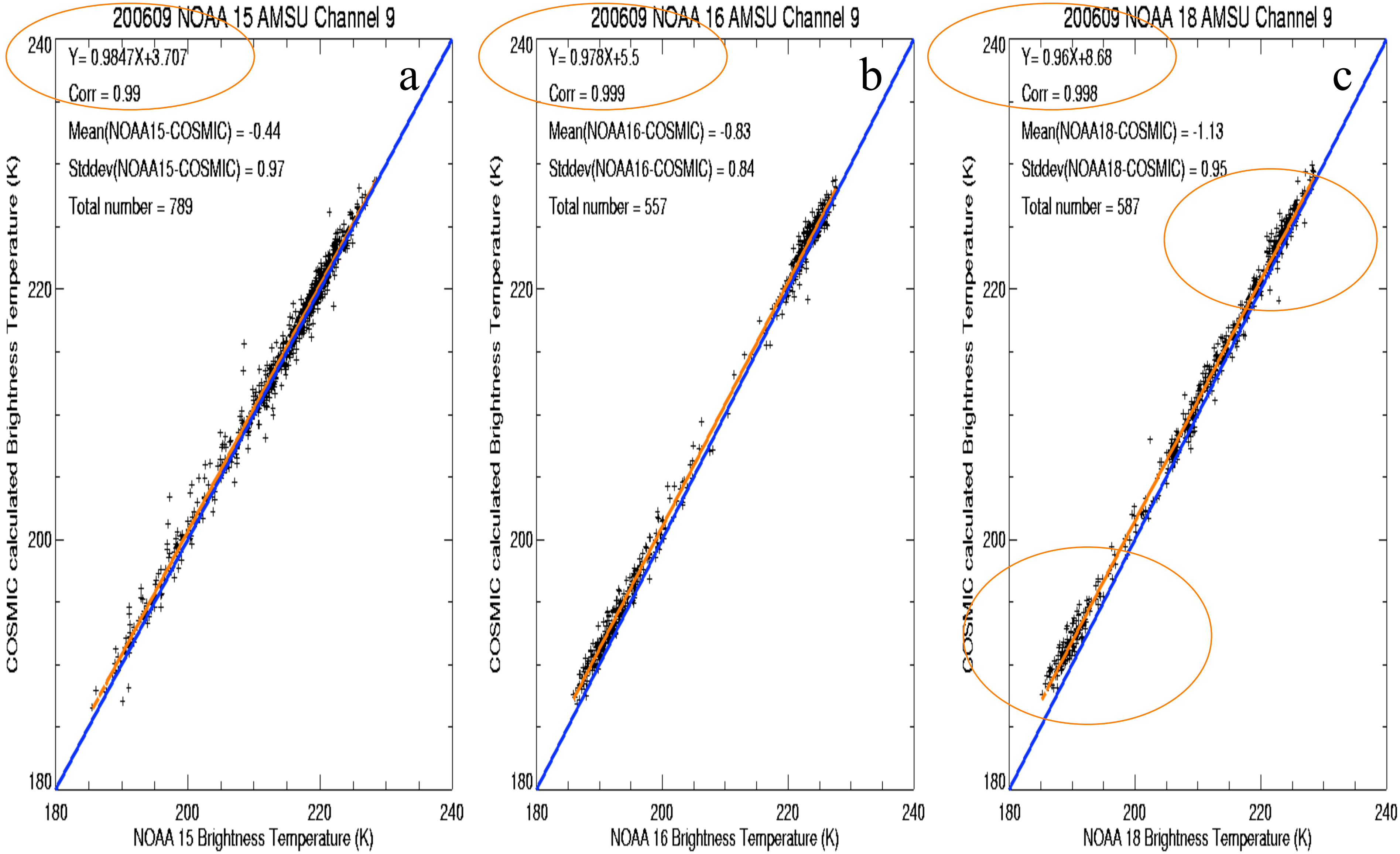
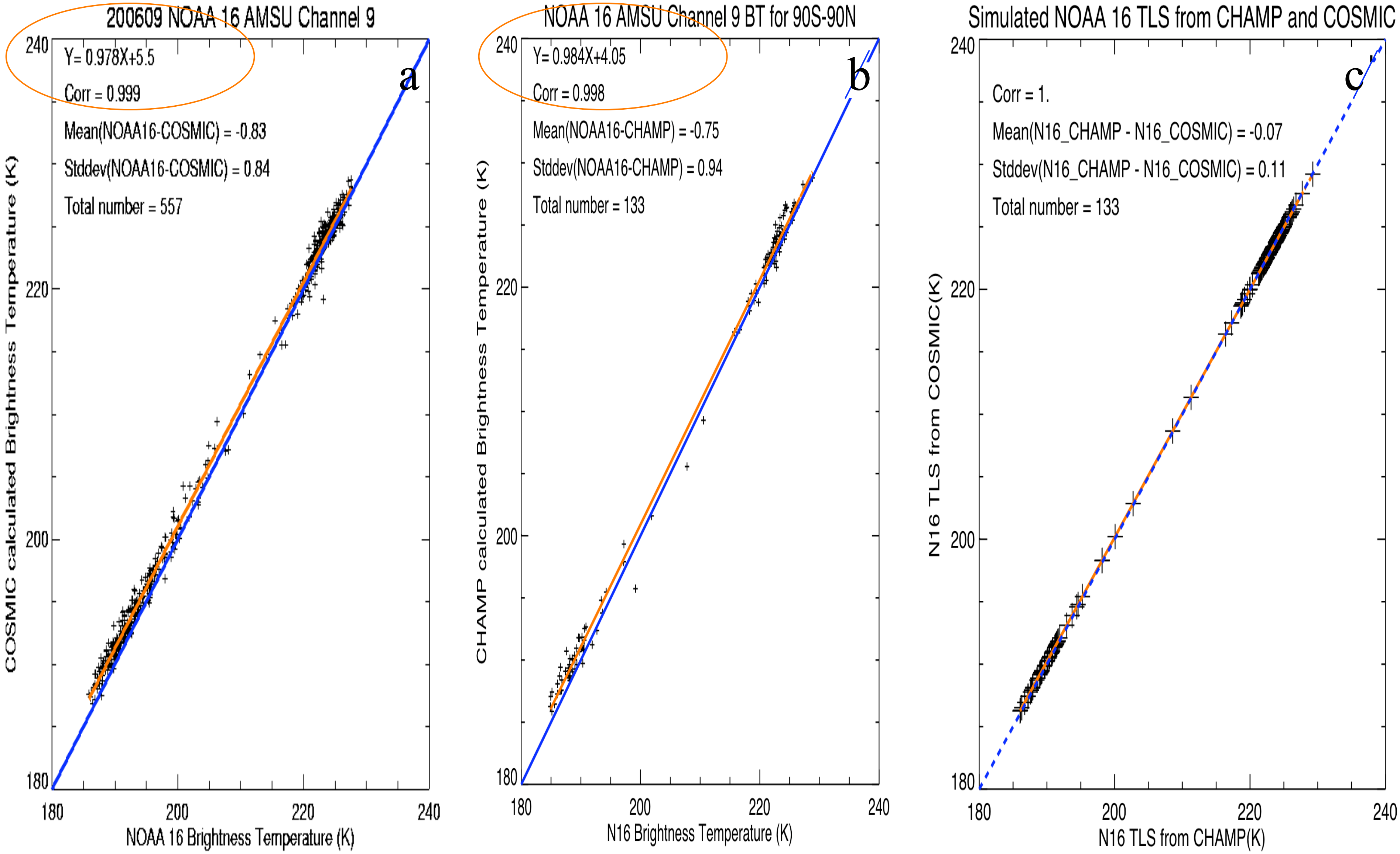
Can we use RO data to calibrate other instruments ?

200609



Slide 15 N15, N16 and N18 AMSU calibration against COSMIC

The precision of using GPS RO data to inter-calibrate other satellite is about 0.07 K



(Ho et al. TAO, 2007)

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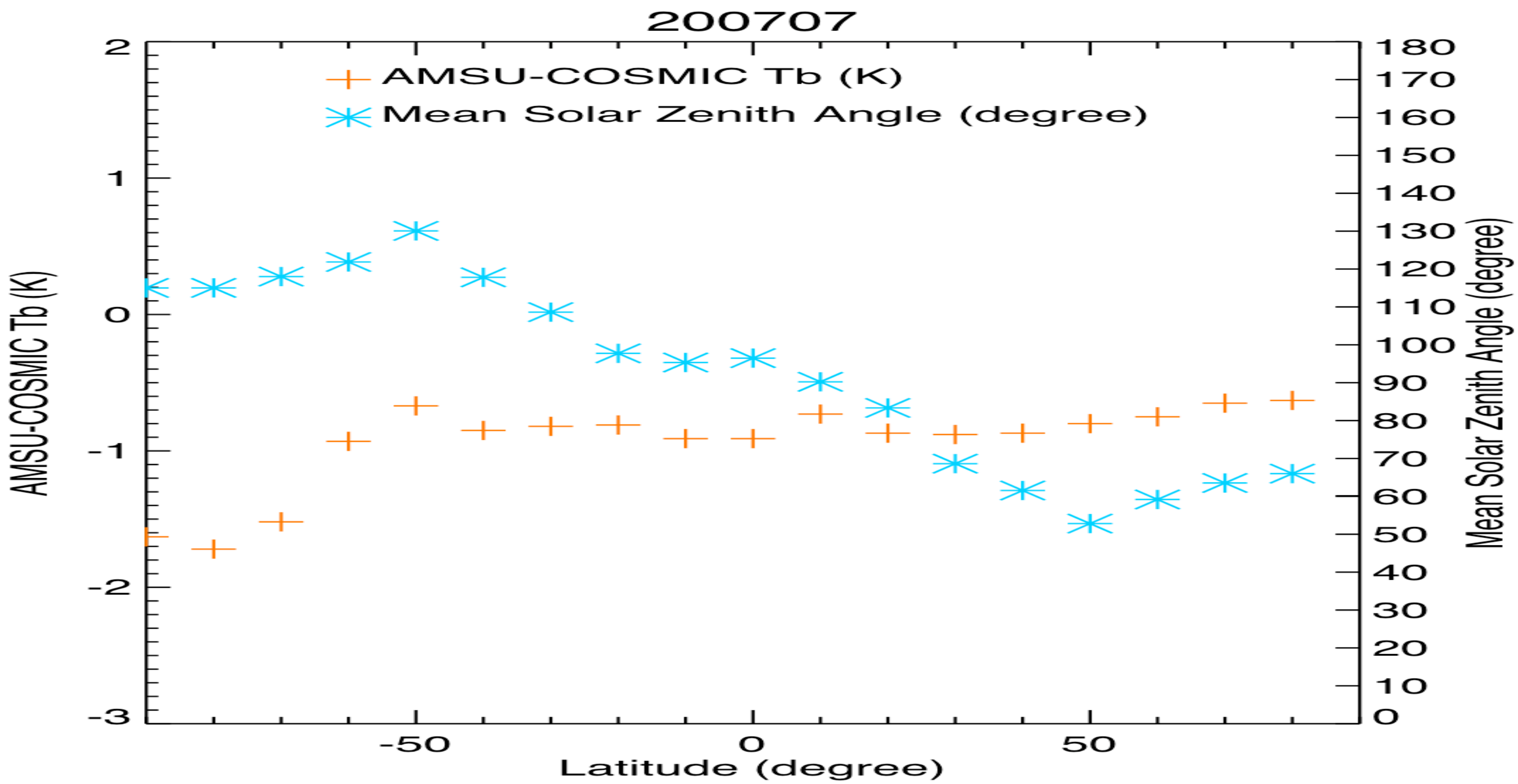
Use of RO Data to Identify the Location/local-time Dependent Brightness Temperature Biases for regional Climate Studies

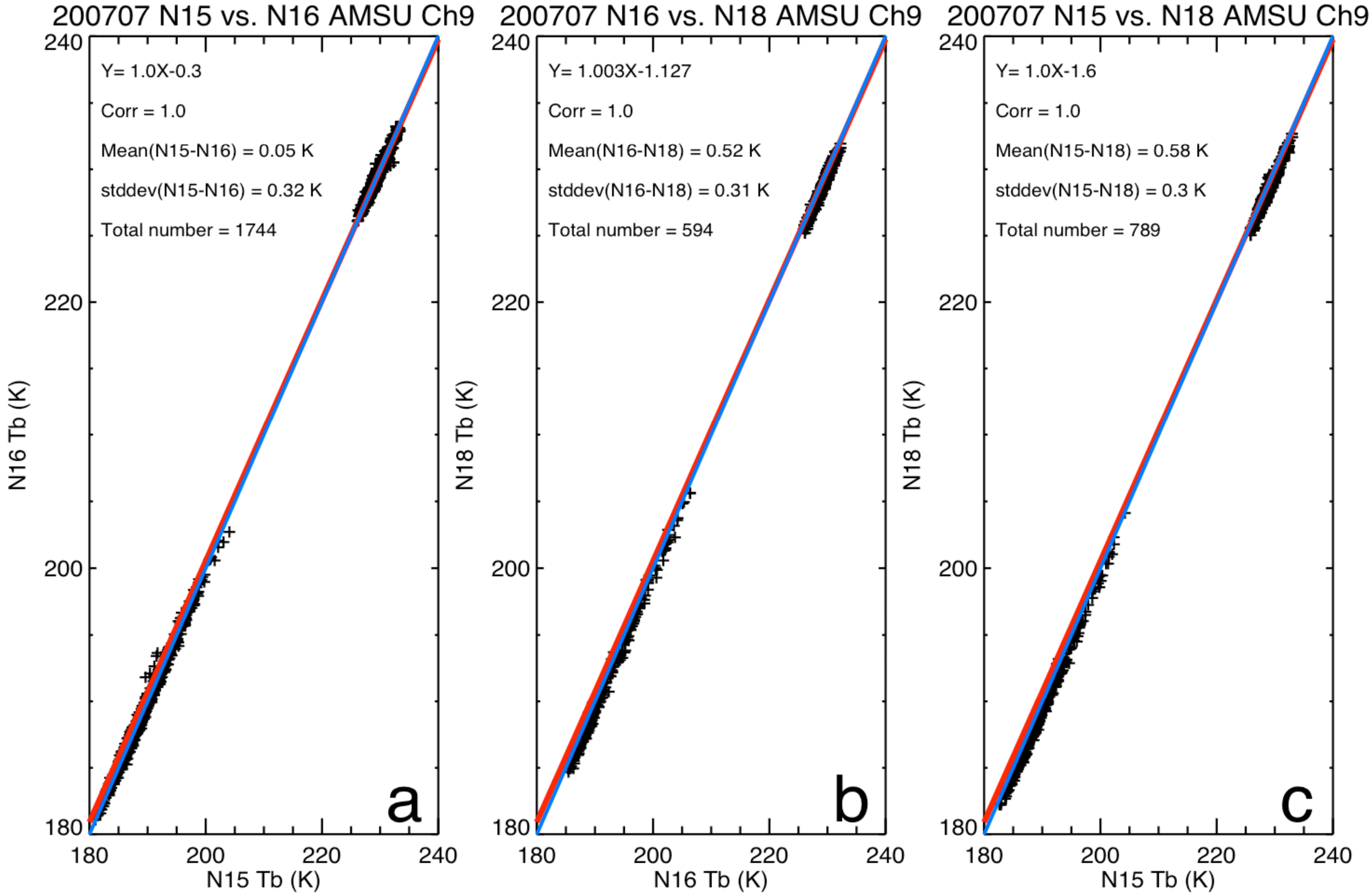
Radiative heating/cooling of satellite component
Important for NWP and regional climate researches



(Ho et al. OPAC special issue, 2007)

  Shu-peng Ben Ho, UCAR/COSMIC

Can we use the Calibrated AMSU data to calibrate other overlapped AMSU data ?



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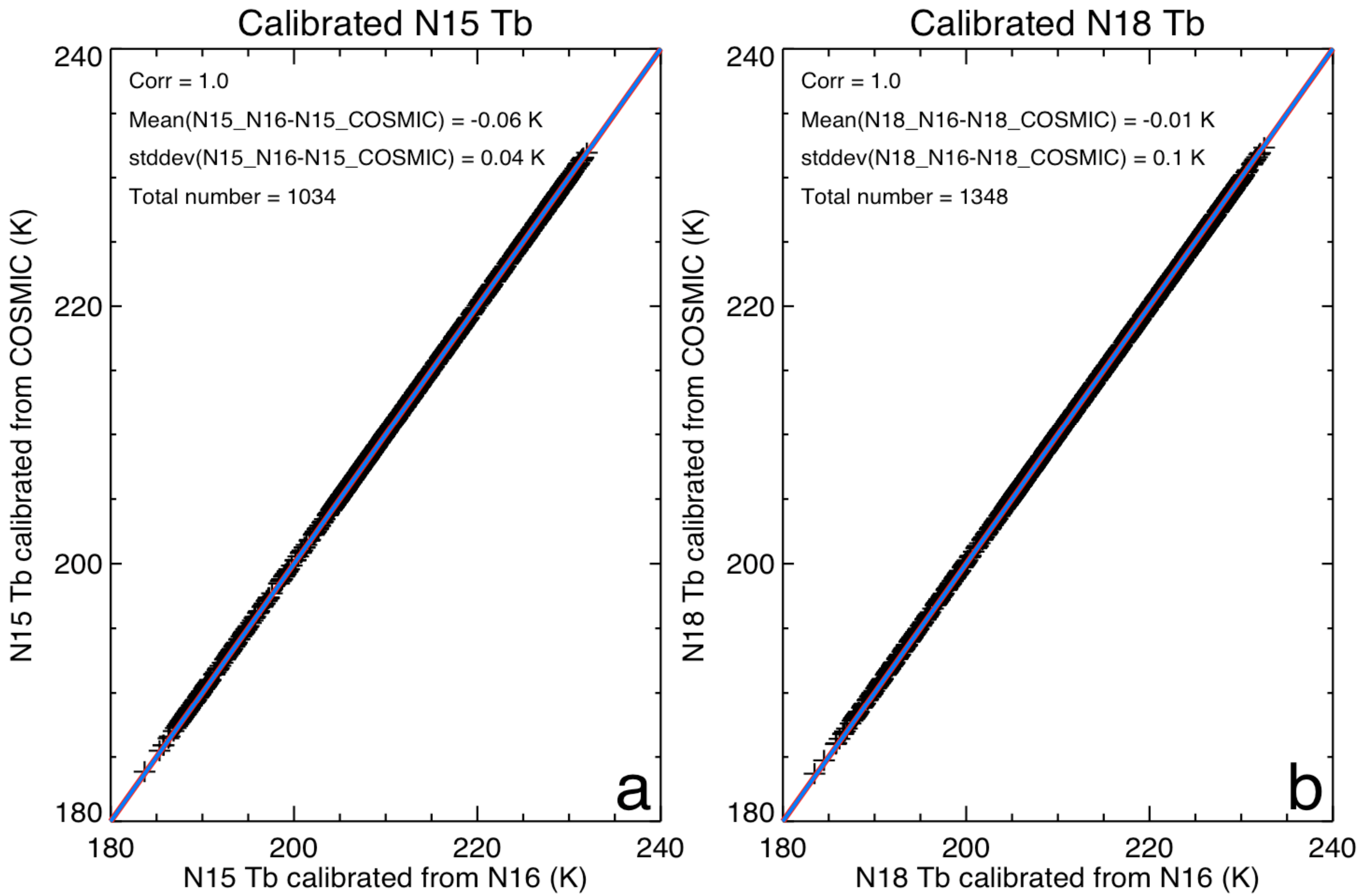
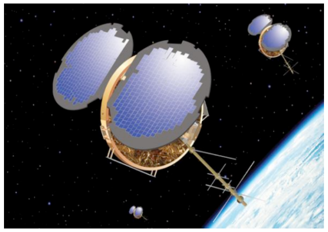
Using the Calibrated AMSU data to calibrate other overlapped AMSU data

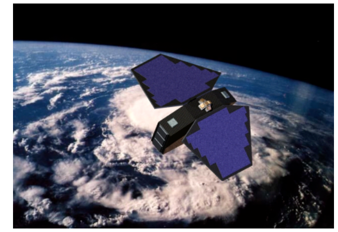


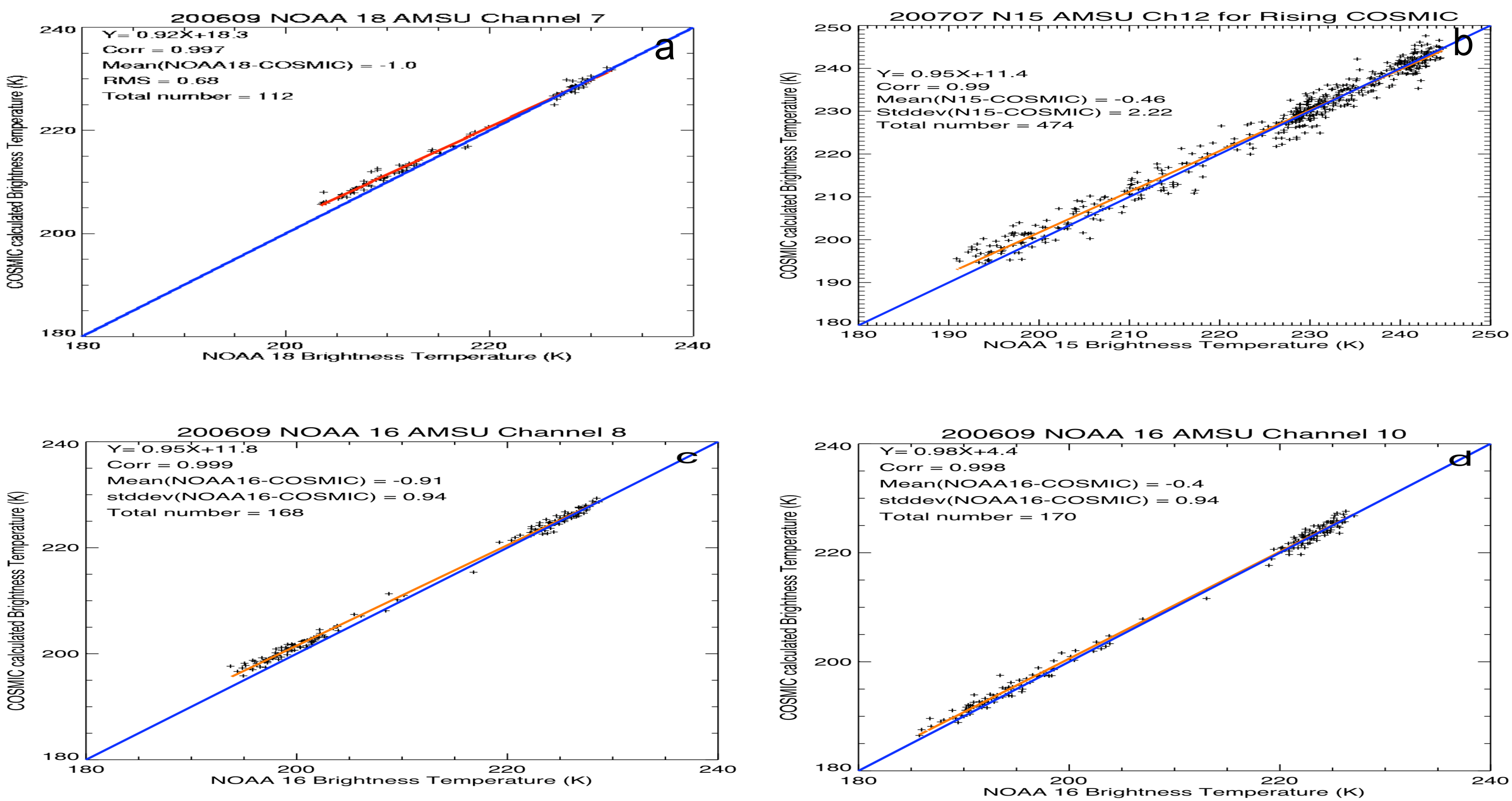
(Ho et al. OPAC special issue, 2007)

Shu-peng Ben Ho, UCAR/COSMIC



AMSU Ch8 and 12 vs. COSMIC synthetic Bt





Shu-peng Ben Ho, UCAR/COSMIC

Can GPS RO 1D-var water vapor be used for climate research ?

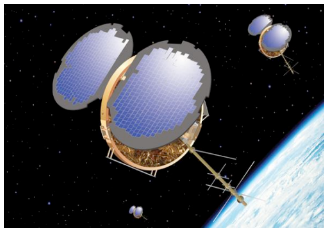
$$N = 77.6\frac{P}{T} + 3.73 \times 10^5 \frac{P_W}{T^2}$$

Objective :

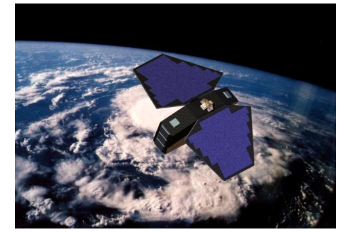
This study is to demonstrate the independence of COSMIC RO 1d-Var water vapor to initial T and W so that they shall be suitable for detecting moisture trends

- **What is the relative Sensitivity of Refractivity to T vs. that of W?**
- **Does 1D-var WV results depend on initial WV ?**
- **How the uncertainty of initial T and retrieved T will affect 1D-var Water vapor ?**

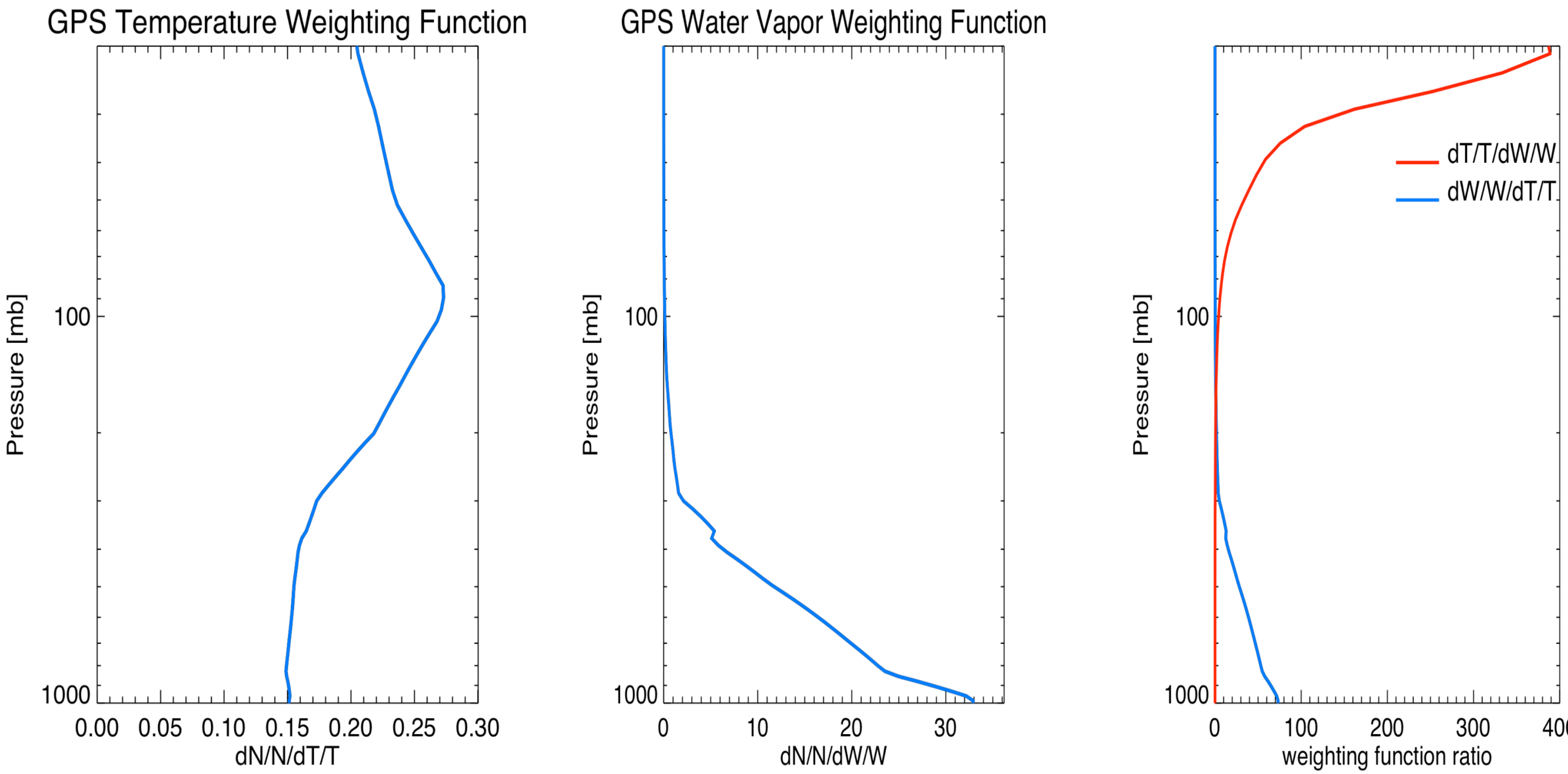
Shu-peng Ben Ho, Bill Kuo, T-K Wee, NOAA Boulder team



Sensitivity of Refractivity to T and W



$$N = 77.6\frac{P}{T} + 3.73\times10^{5}\frac{P_W}{T^2}$$



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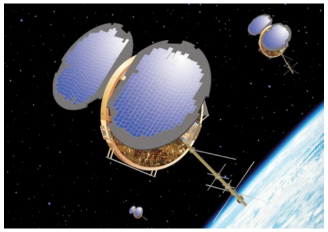
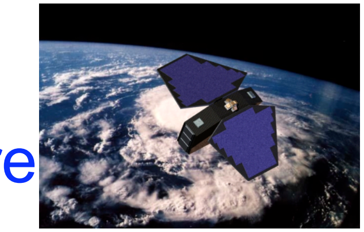
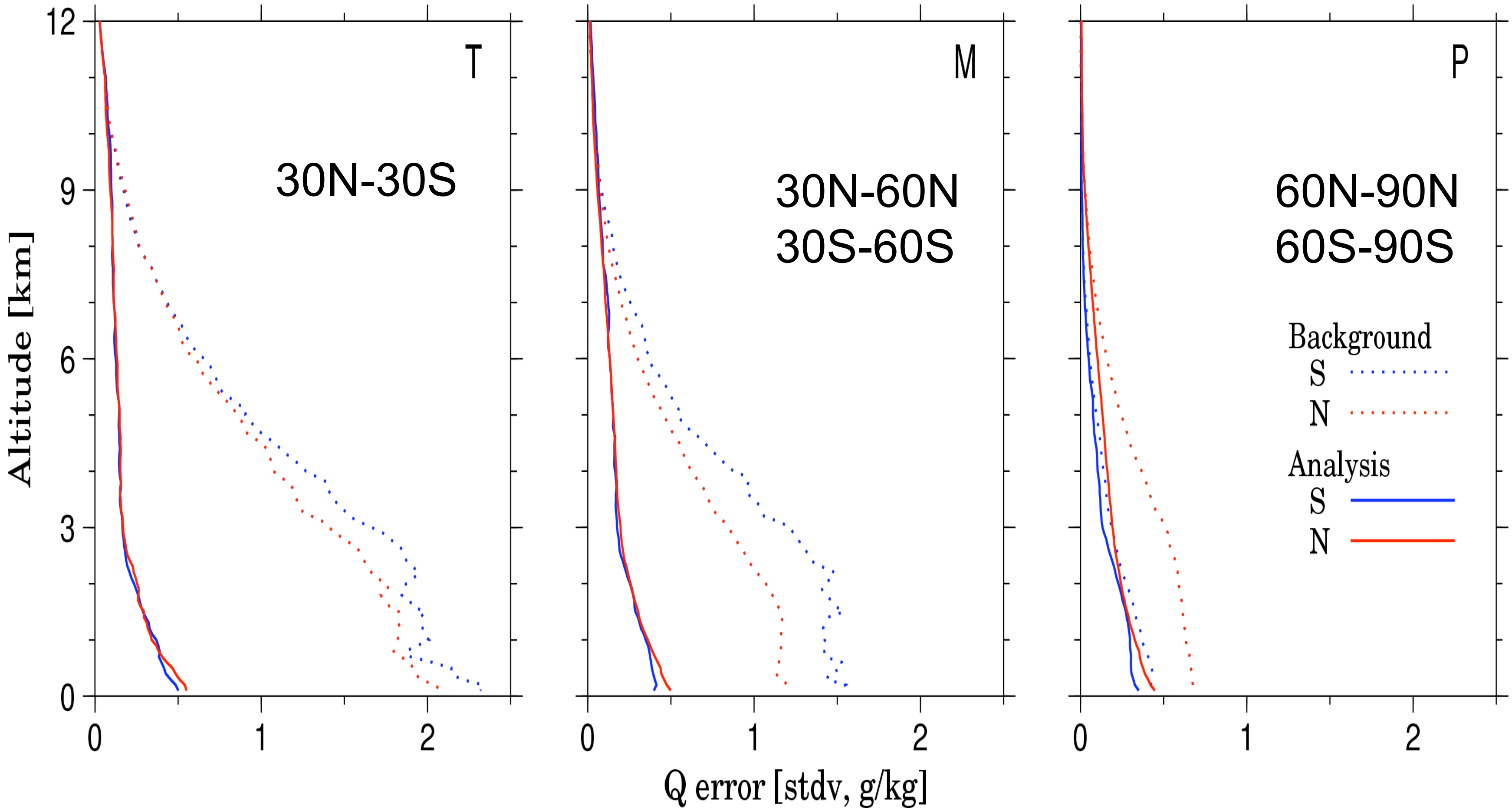


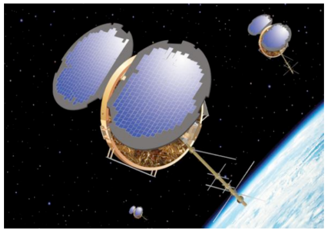
RO Refractivity is very sensitive to water vapor in the mid-/low- troposphere



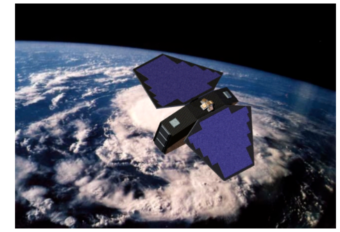
Simulation results, using radiosonde T, W, P + noise to generate N



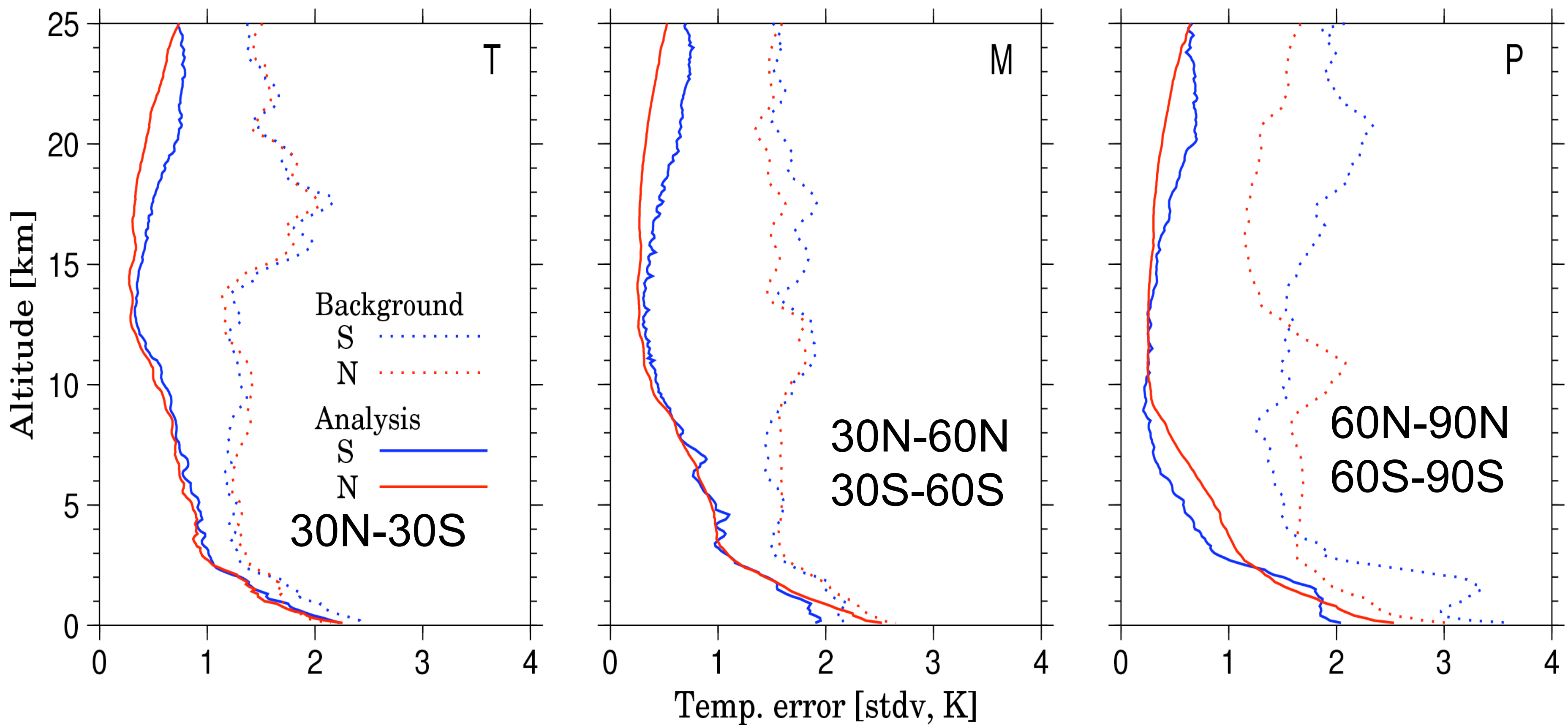
Standard Deviation of 1D- Var WV - Radiosonde WV



RO Refractivity is very sensitive to temperature in the mid-troposphere and above

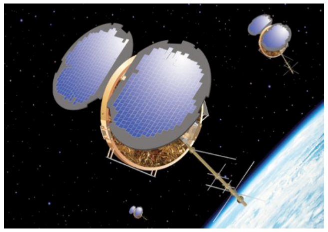


Simulation results, using radiosonde T, W, P + noise to generate N

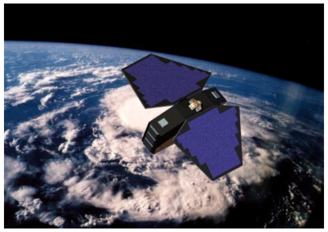


Standard Deviation of 1D- Var Temperature - Radiosonde Temperature

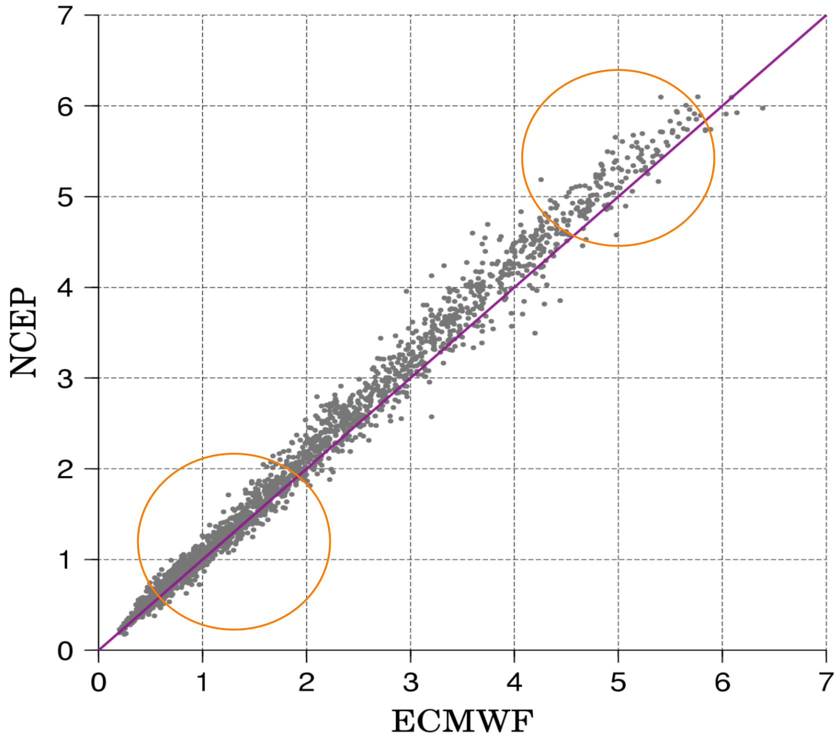
Shu-peng Ben Ho, UCAR/COSMIC



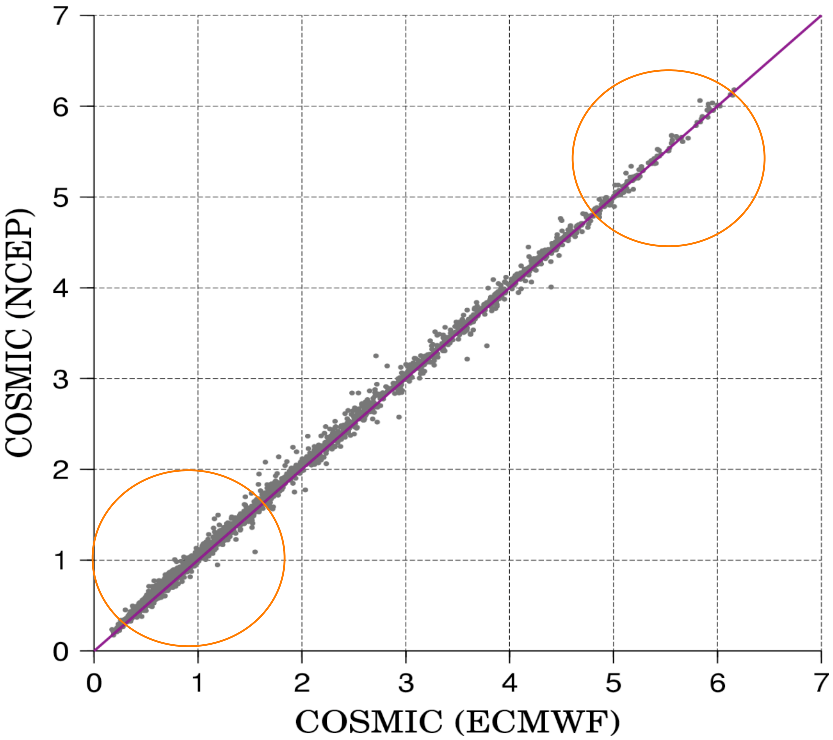
Q. Does 1D-var WV results depend on initial WV ?



PW derived from NCEP or ECMWF analyses

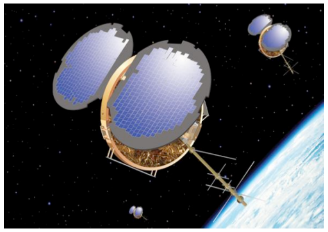


PW retrieved from COSMIC GPS RO data using NCEP or ECMWF analysis as first guess

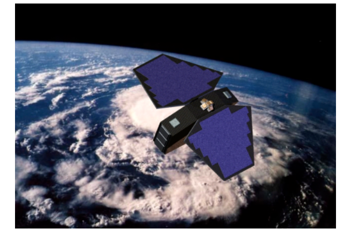


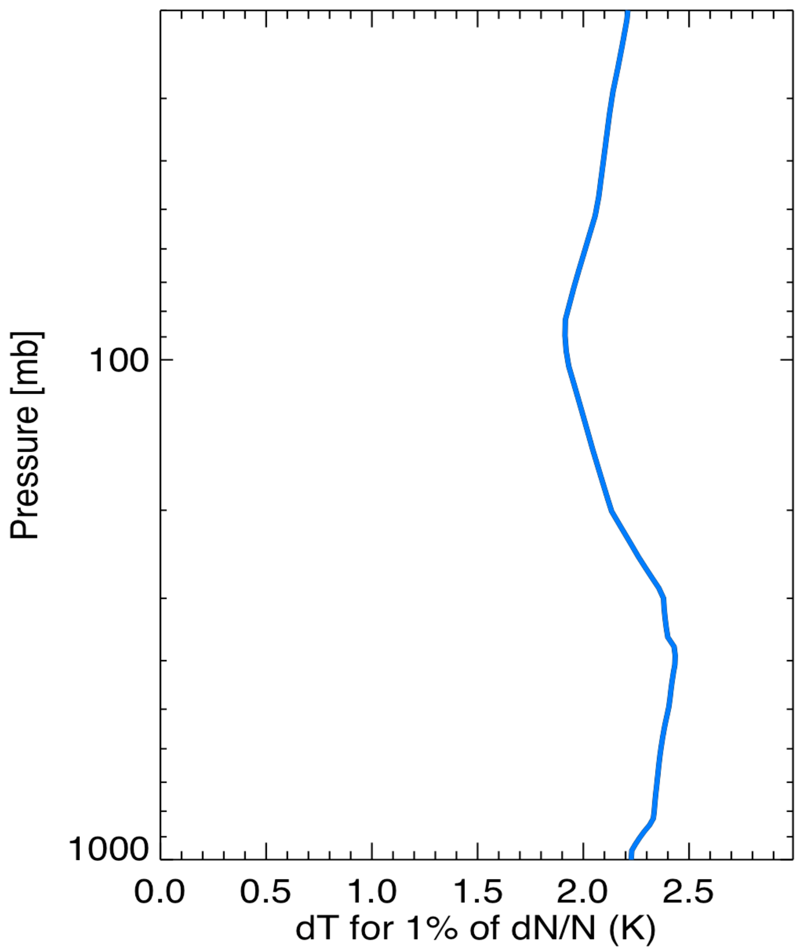
From: Wee and Kuo (2007)

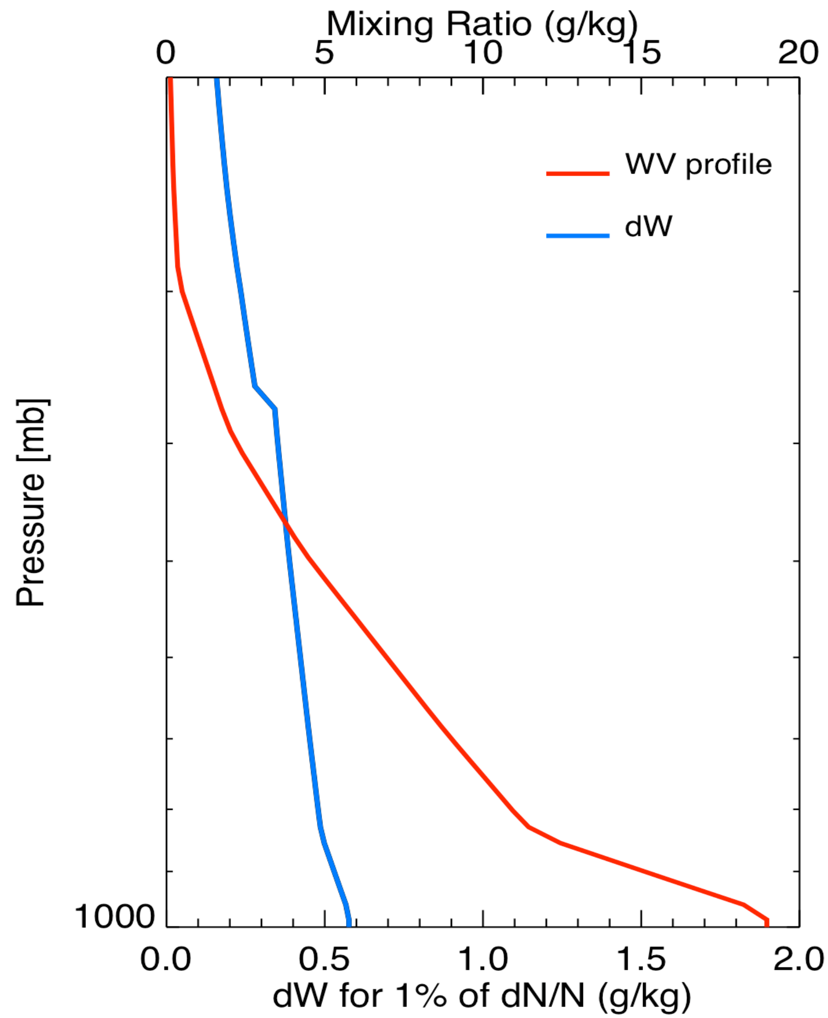
Comparison of PW data from COSMIC and global analyses



Q. How the uncertainty of initial T and retrieved T will affect 1D-var Water vapor ?







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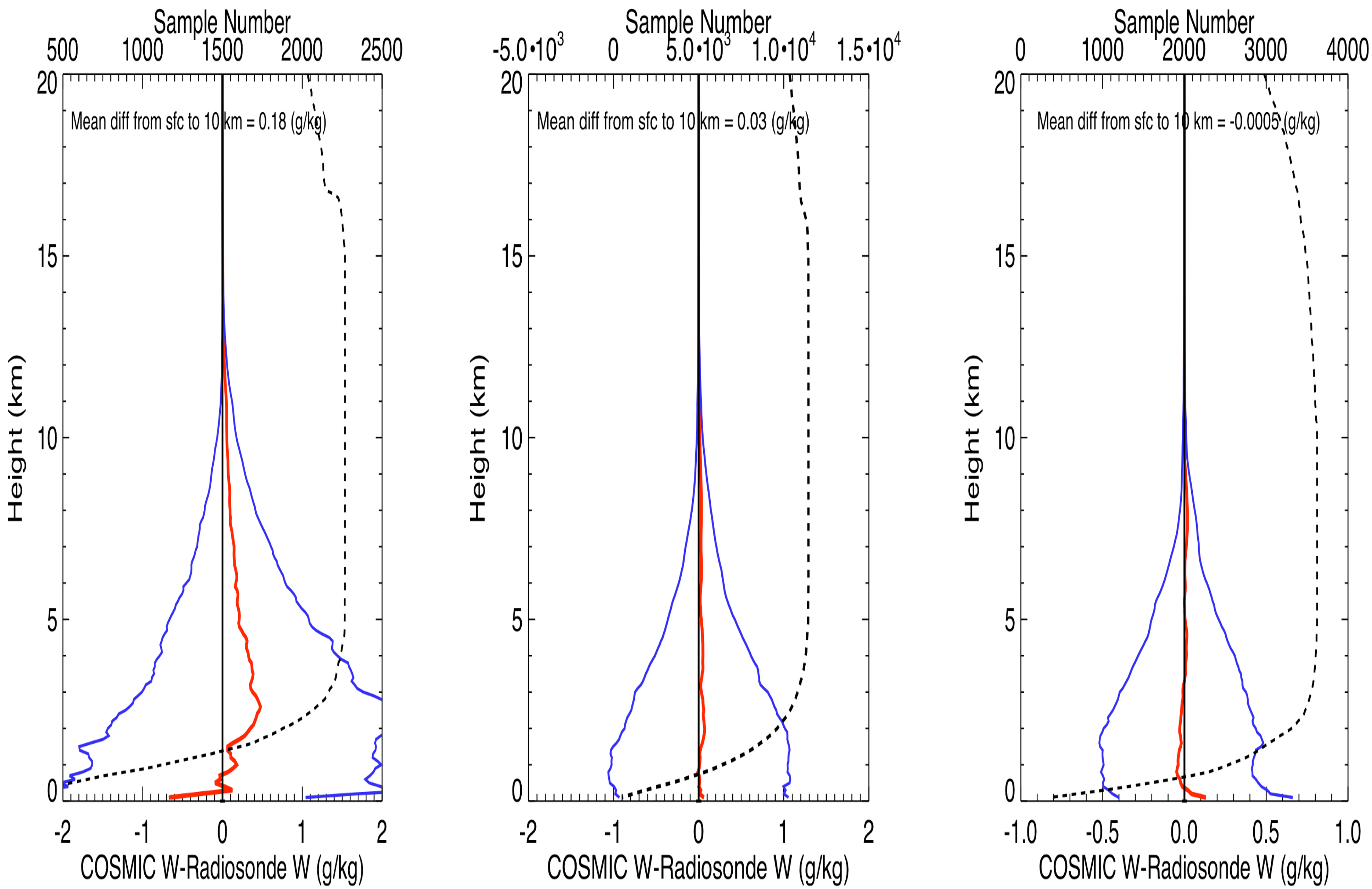
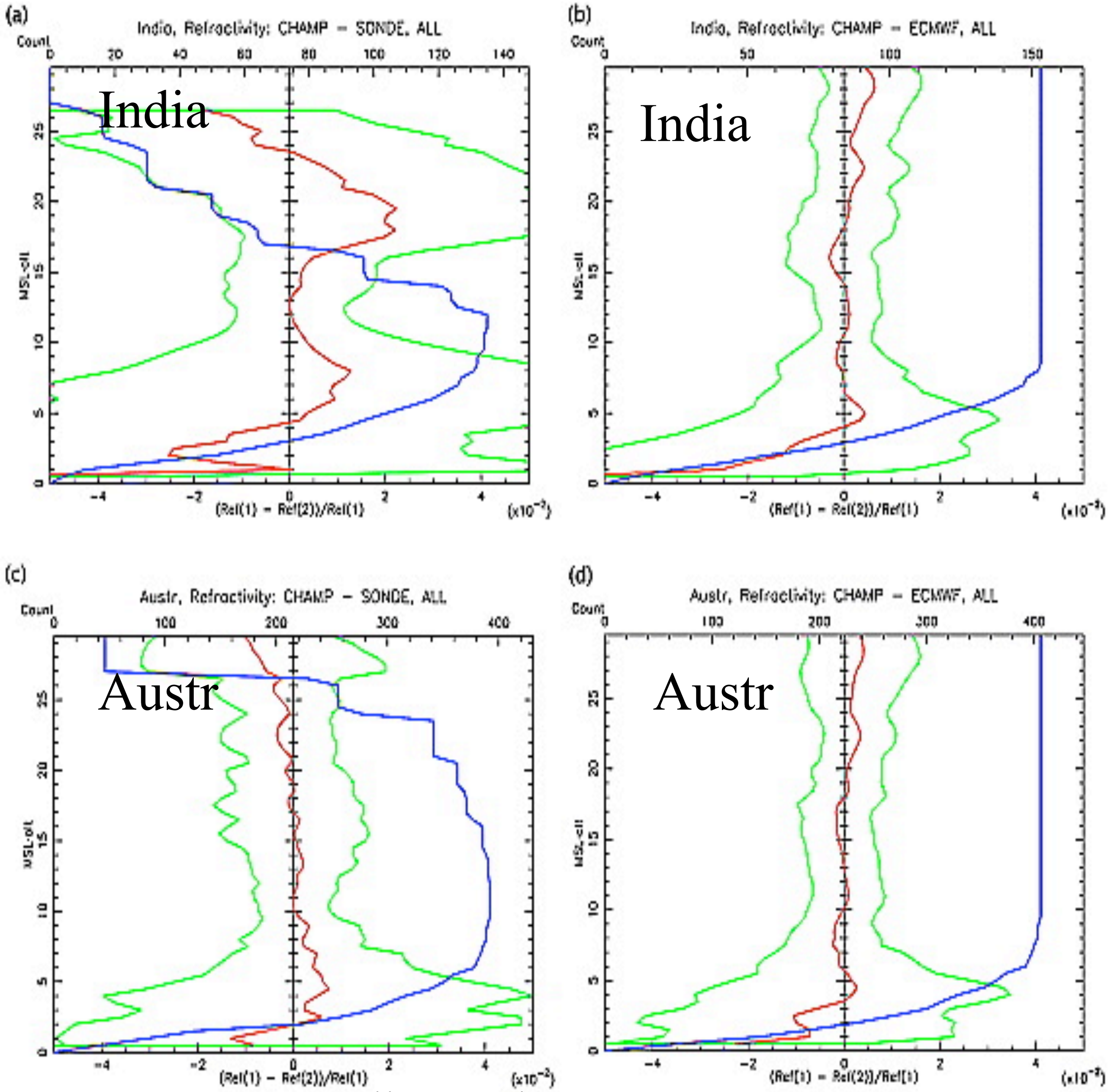
1D Var WV - Radiosonde WV (g/kg)



30N-30S

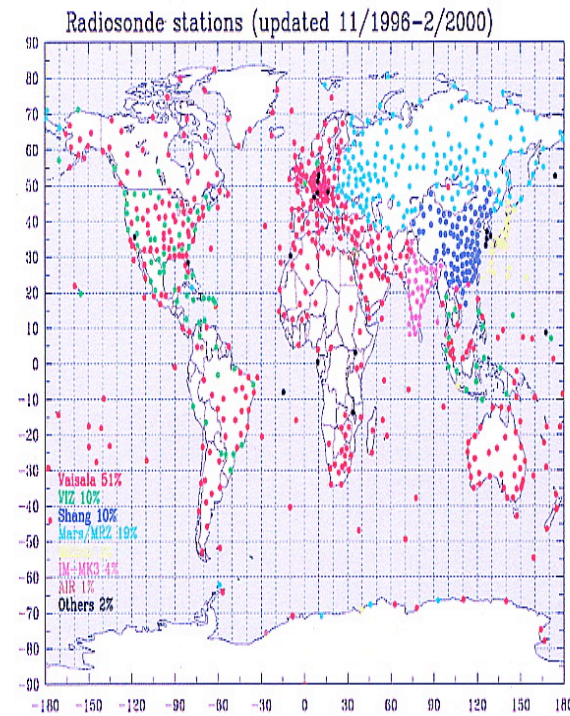
30N-60N
30S-60S

60N-90N
60S-90S



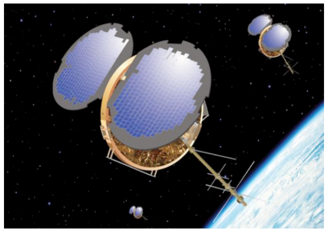
CHAMP-Radiosonde

CHAMP-ECMWF

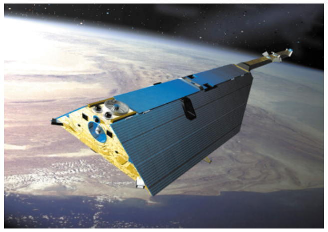


(Kuo et al., GRL, 2005)

Shu-peng Ben Ho, UCAR/COSMIC



Conclusions and Future Work



- It is a great challenge to use current available datasets to construct reliable climate records.

- The 0.02K-0.05 K precision of COSMIC will be very useful to inter-calibrate AMSU/MSU data.

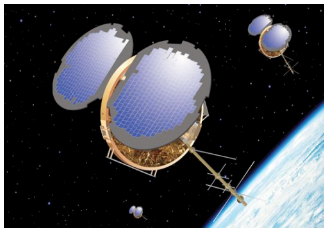
- The long term stability of GPS RO data is very useful for climate monitoring.

- Although different centers using different inversion procedures and initial conditions to derive refractivity, and using the different quality control criteria to bin the datasets, the mean bias for JPL-UCAR pairs is -0.05%, for GFZ-UCAR pairs is 0.001%, and for WEG-UCAR pairs is -0.3%.

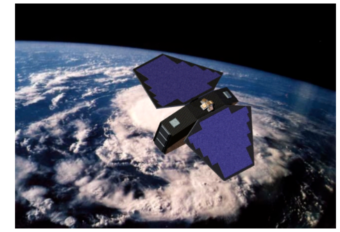
- The uncertainty of the trend of the fractional N anomalies is within +/-0.045 N-unit/5 yrs (+/-0.06 K/5 yrs). And the major causes of uncertainties between these trends are from sample profiles used by different centers.

- GPS RO temperature is very useful to calibrate measurements from other satellites.

- GPS RO derived water vapor profiles shall be suitable for climate researches.



Future Work



• Work with NOAA to use GPS RO data to calibrate MSU on board NOAA 12-14 and AMSU on board NOAA 15-18

• Work with NOAA to use GPS RO data to validate the new NOAA MSU L1B data

• Using GPS RO data over polar region to calibrate MSU/AMSU temperature over middle atmosphere

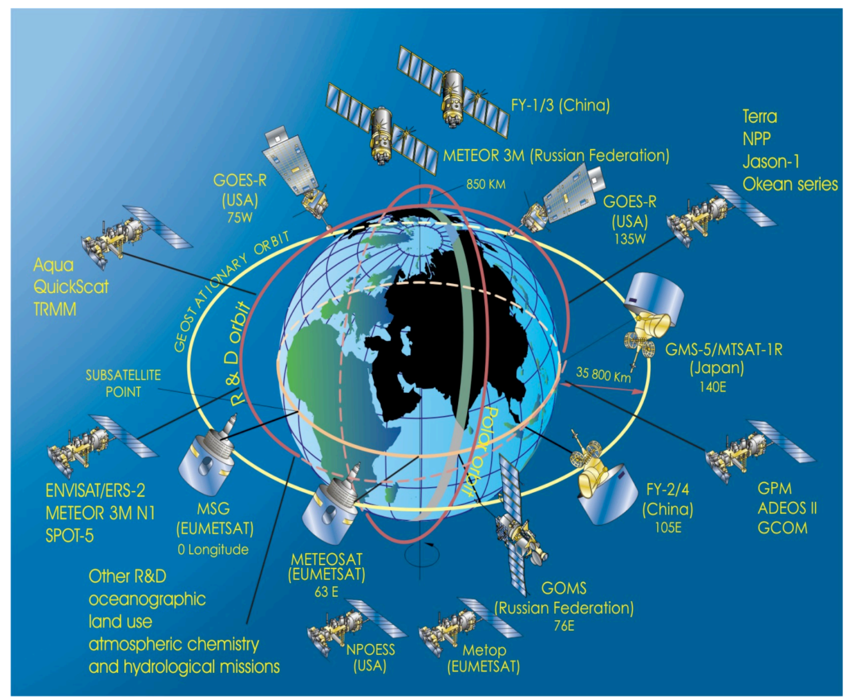
• Work with NOAA to generate consistent GPS RO and AMSU/MSU temperature records
Work with RSS and UAH to quantify the uncertainty/bias and causes of difference among RSS, UAH, NOAA and UCAR temperature records

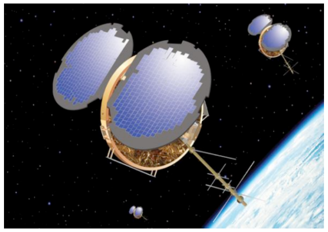
• Work with NOAA to calibrate long term temperature data from infrared measurements

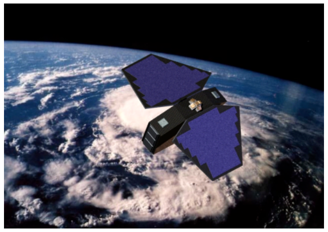
• Working with GFZ, Weg-C, and JPL to examine the consistency of GPS RO dry temperature, bending angle derived from different centers

• GPS RO vs. Radiosonde

• Work with NOAA and ECMWF to inter-compare COSMIC 1D-var WV to WV retrieved from other instruments and using different algorithms







1. What need to be done to establish GPS RO soundings as robust climate reference data set?
2. How GPS RO soundings can be used to help establish a robust climate record from satellite radiance measurements?
3. How GPS RO soundings can help us understand the hydrological processes over the tropics that are intimately related to climate change?
4. How to use GPS RO data for climate model validation, testing, and improvement ?
5. How to use GPS RO data for climate process studies (e.g., external/internal forcings, feedback mechanisms);
6. How to use GPS RO data for anthropogenic climate change detection and attribution?
7. How to transform GPS RO data into climate data products (e.g., retrieval schemes, sensor inter-calibration, data assimilation systems).
8. What more we can do to work with NOAA/NASA and institutions by using COSMIC data for climate research ?
9. COSMIC II ?

Referred papers and this presentation can be downloaded from

http://www.cosmic.ucar.edu/~spho/