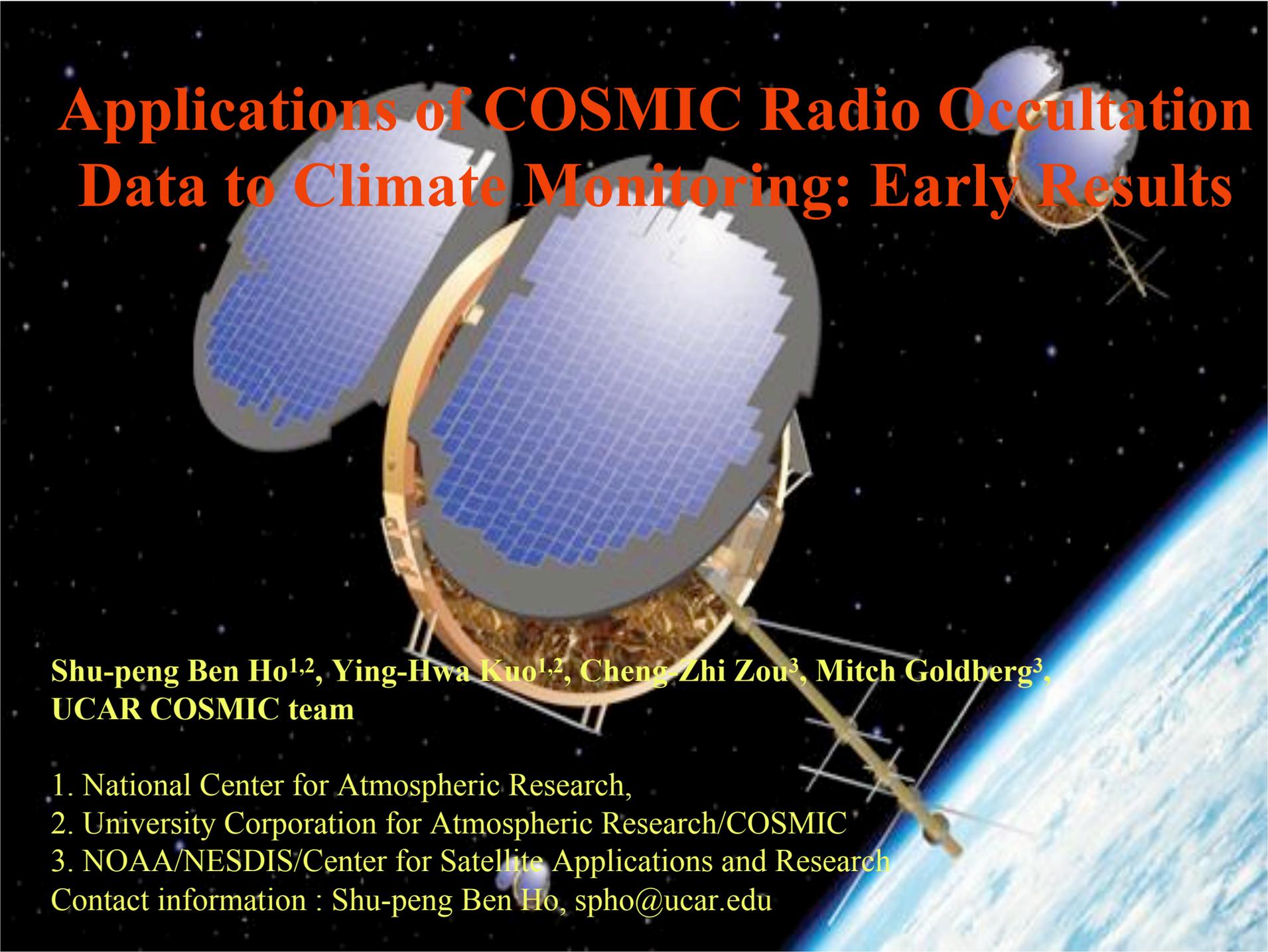# Applications of COSMIC Radio Occultation Data to Climate Monitoring: Early Results

Shu-peng Ben Ho[1,2], Ying-Hwa Kuo[1,2], Cheng-Zhi Zou[3], Mitch Goldberg[3], UCAR COSMIC team

1. National Center for Atmospheric Research,
2. University Corporation for Atmospheric Research/COSMIC
3. NOAA/NESDIS/Center for Satellite Applications and Research
Contact information : Shu-peng Ben Ho, spho@ucar.edu

1. Motivation: Can we use GPS RO data as benchmark measurements to inter-calibrate measurements from other instruments ?

To demonstrate the usefulness of independent GPS RO data for climate monitoring.

- high accuracy
- no calibration issues,
- high vertical resolution
- insensitive to clouds and precipitation
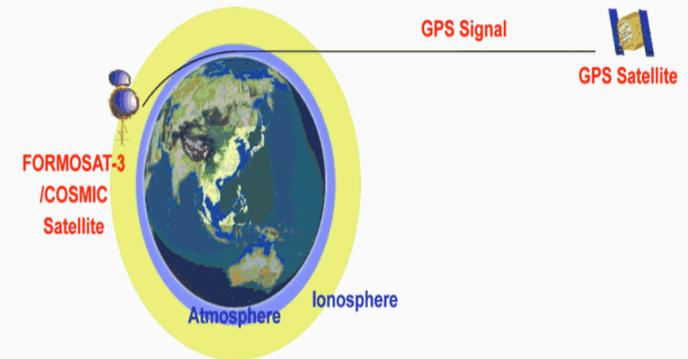
2. Outlines :

- Challenges to define/validate a global trend
- Characteristics of COSMIC GPS RO data
- Use GPS RO data as benchmark measurements to inter-calibrate other satellite data (NOAA AMSU)
- Compare refractivity generated from different centers
- Inter-compare GPS RO data with other existed climate datasets (RSS, UAH, NOAA SNO calibrated MSU Tbs, Radiosonde)
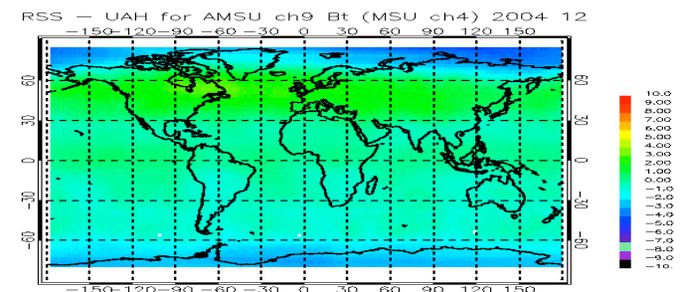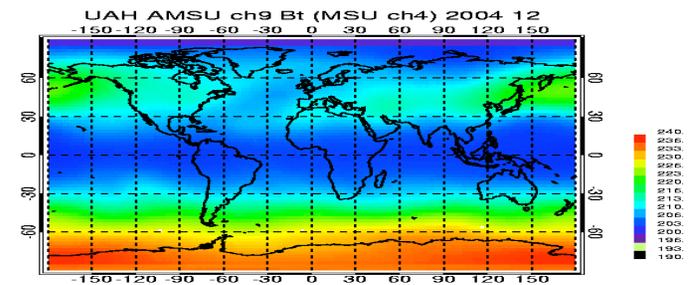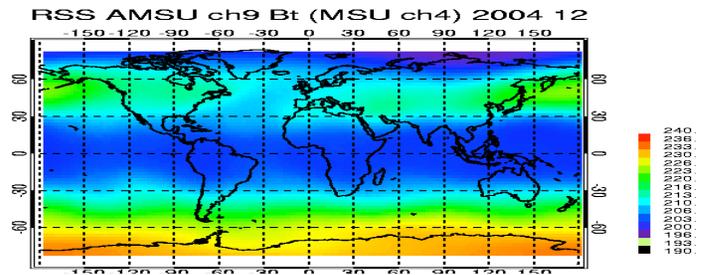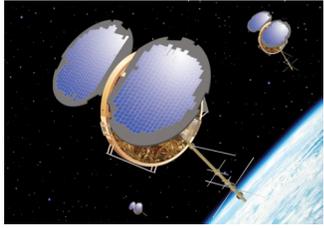
3. Conclusions and Future Work

Shu-peng Ben Ho, UCAR/COSMIC
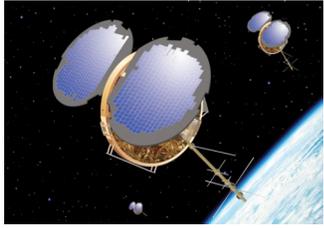
Challenges for defining the Global Temperature Trend

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.
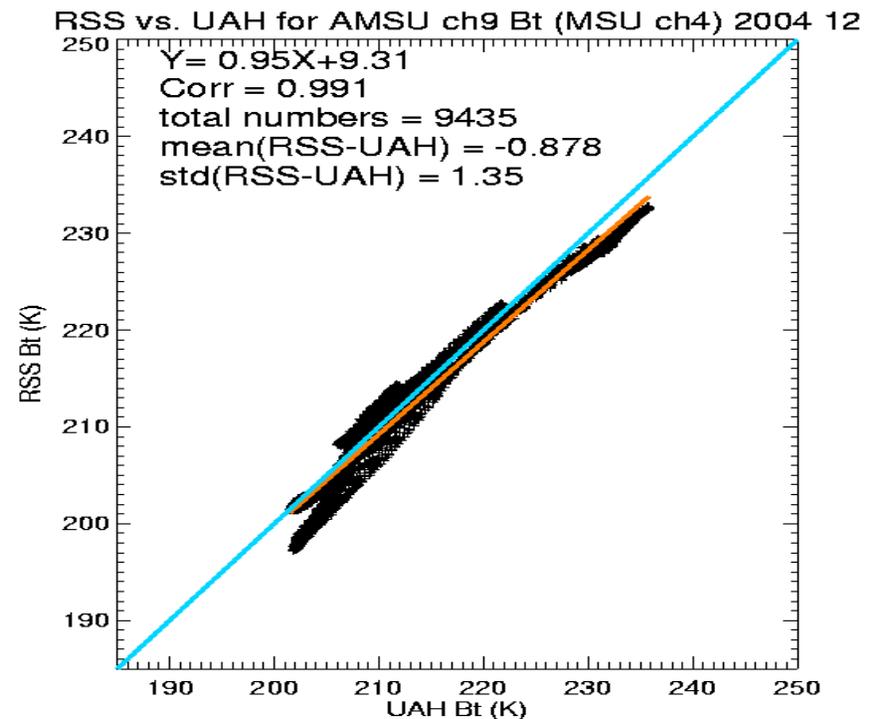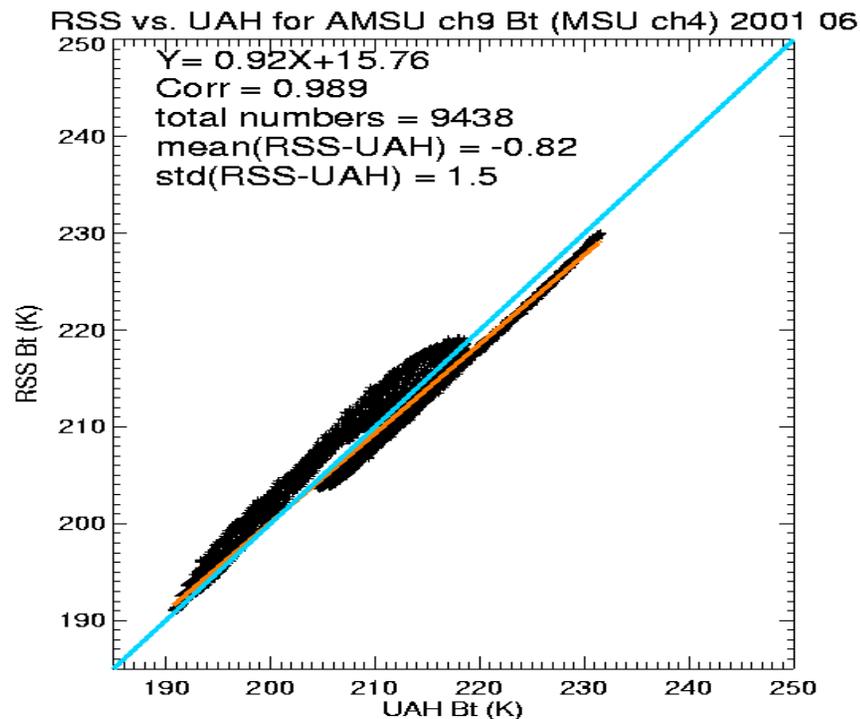

RSS AMSU ch9 Bt (MSU ch4) 2004 12

UAH AMSU ch9 Bt (MSU ch4) 2004 12

RSS — UAH for AMSU ch9 Bt (MSU ch4) 2004 12

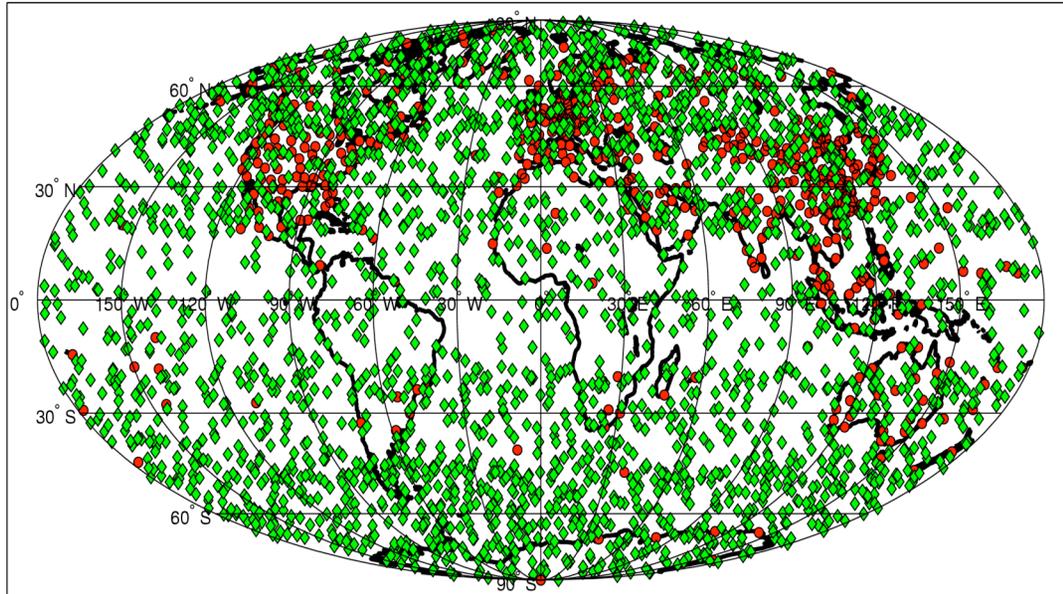Slide 3

Shu-peng Ben Ho, UCAR/COSMIC

Requirements for Climate Study

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

RSS vs. UAH for AMSU ch9 Bt (MSU ch4) 2001 06

Y= 0.92X+15.76
Corr = 0.989
total numbers = 9438
mean(RSS-UAH) = -0.82
std(RSS-UAH) = 1.5

RSS vs. UAH for AMSU ch9 Bt (MSU ch4) 2004 12

Y= 0.95X+9.31
Corr = 0.991
total numbers = 9435
mean(RSS-UAH) = -0.878
std(RSS-UAH) = 1.35

Slide 5

Shu-peng Ben Ho, UCAR/COSMIC
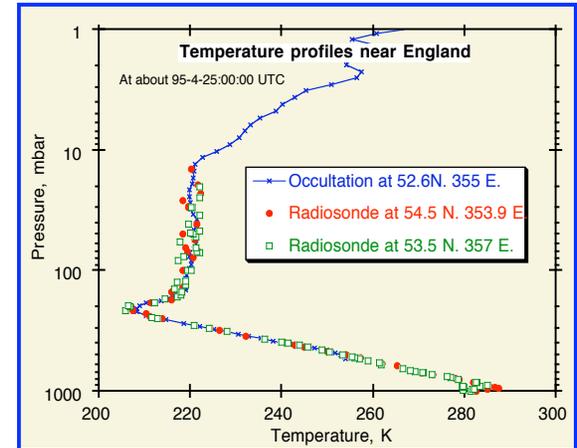
COSMIC

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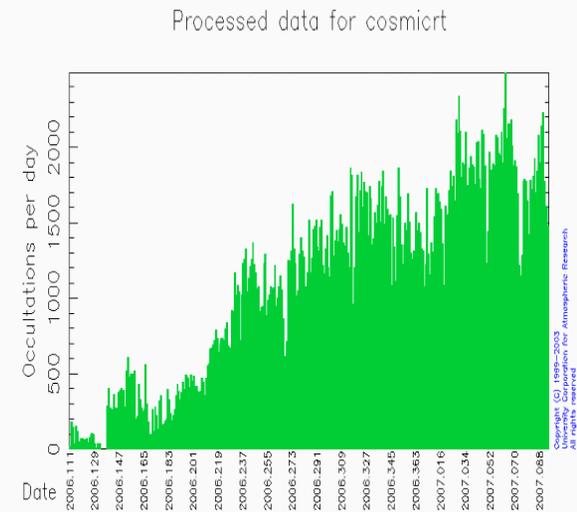

About 90,000 soundings / month
Or ~10 soundings / 2.5 x 2.5 pixel / month.

Can we use GPS RO data as benchmark measurements to inter-calibrate other instruments ?
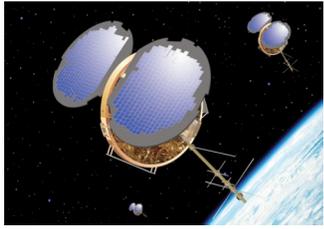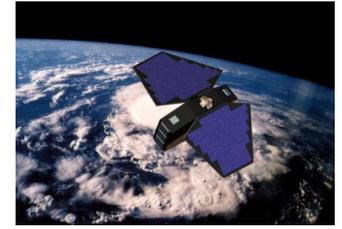
Slide 6   (Anthes et al. BAMS, 2007)

More data in the lower troposphere
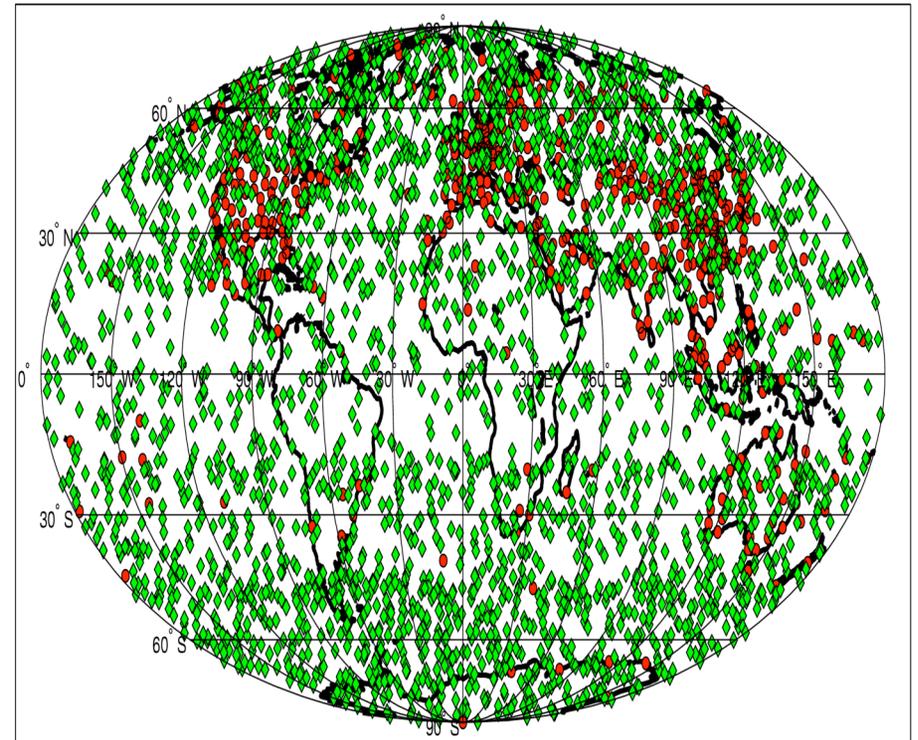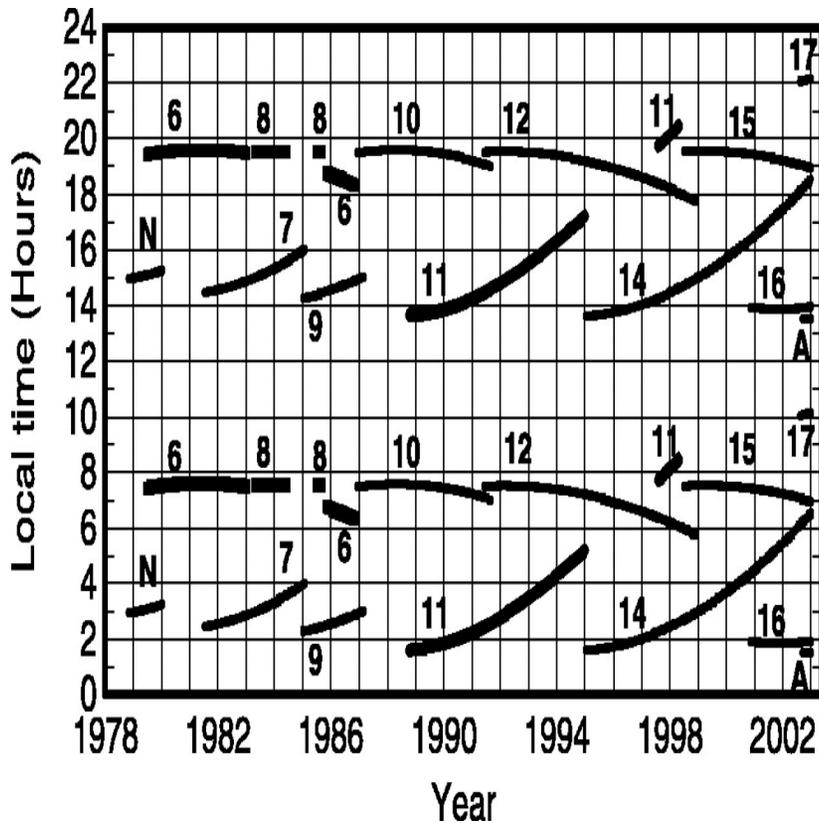

Shu-peng Ben Ho, UCAR/COSMIC

Difficulty I: to find observations with a good global and temporal coverage
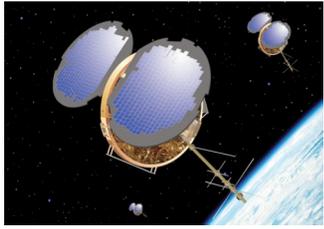
AMSU/MSU local time

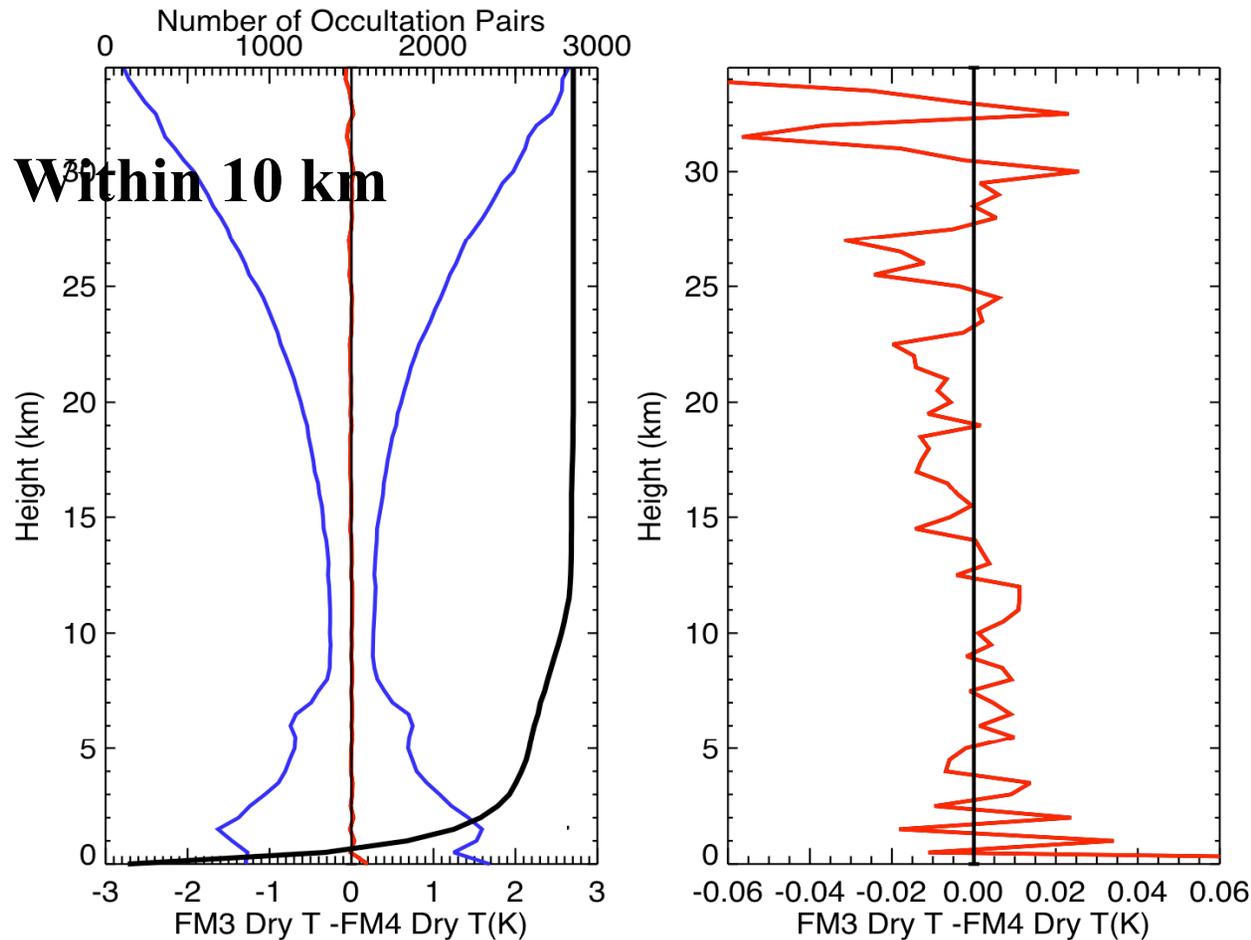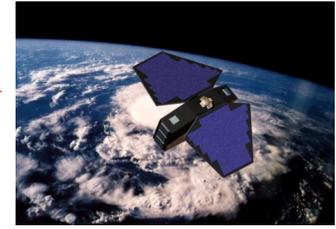## COSMIC has more complete temporal and spatial global coverage

Occultation Locations for COSMIC, 6 S/C, 6 Planes, 24 Hrs
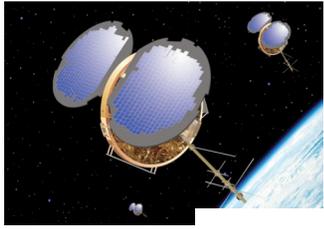
Shu-peng Ben Ho, UCAR/COSMIC

Difficulty II: to find observations with very high precision
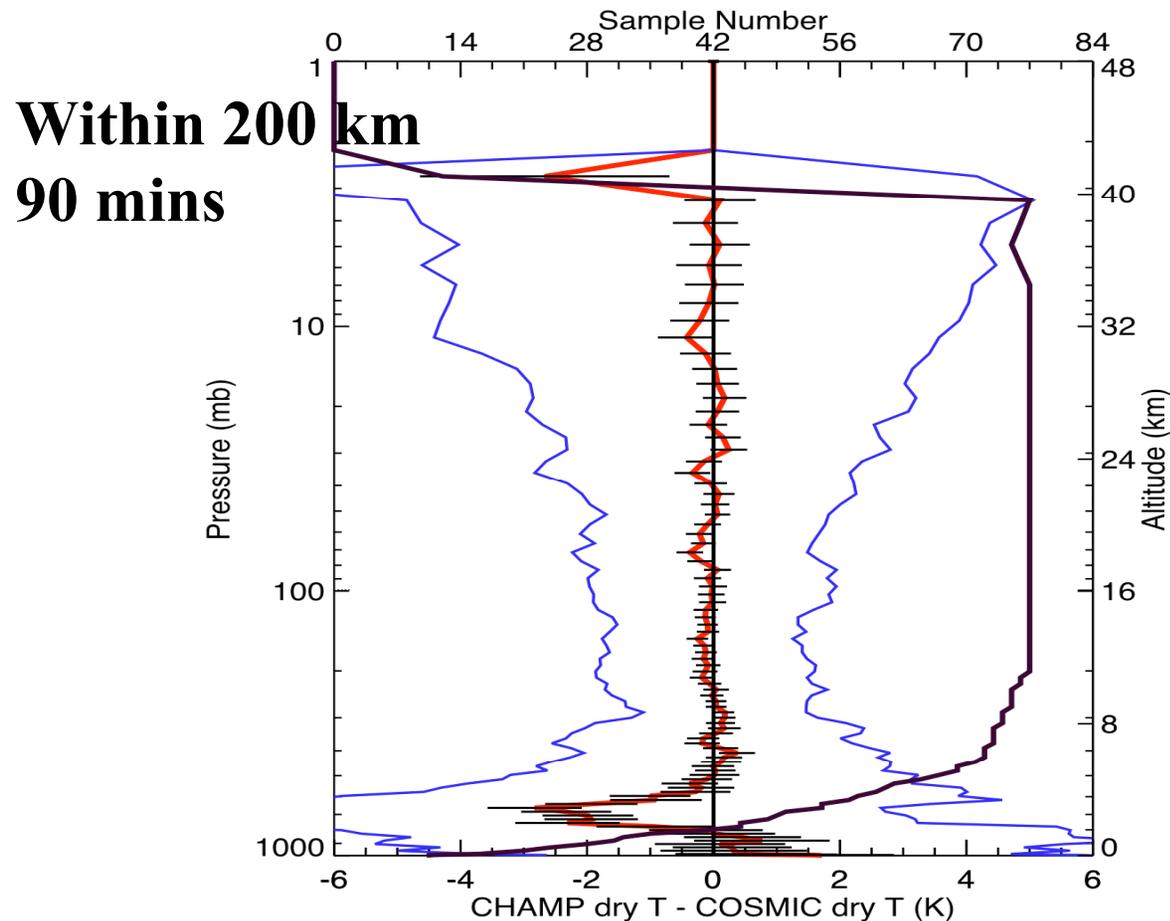

Within 10 km

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

(Ho et al. TAO, 2007)

Ref/dry temperature difference between FM3-FM4 receivers

Shu-peng Ben Ho, UCAR/COSMIC

Difficulty III: to find measurements with long term stability

Within 200 km 90 mins
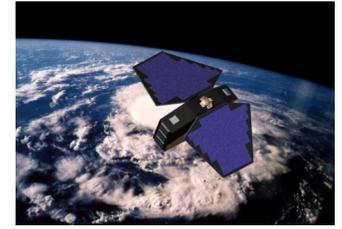
Mean bias CHAMP-COSMIC temp from 500mb to 5 mb =-0.021K

(Ho et al. TAO, 2007)

COSMIC (launched in 2006) vs. CHAMP (launched in 2000) atm tmp

Shu-peng Ben Ho, UCAR/COSMIC
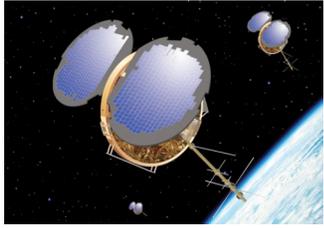
Approach

Approaches:

1. Apply CHAMP and COSMIC soundings to AMSU forward model to simulate AMSU TLS
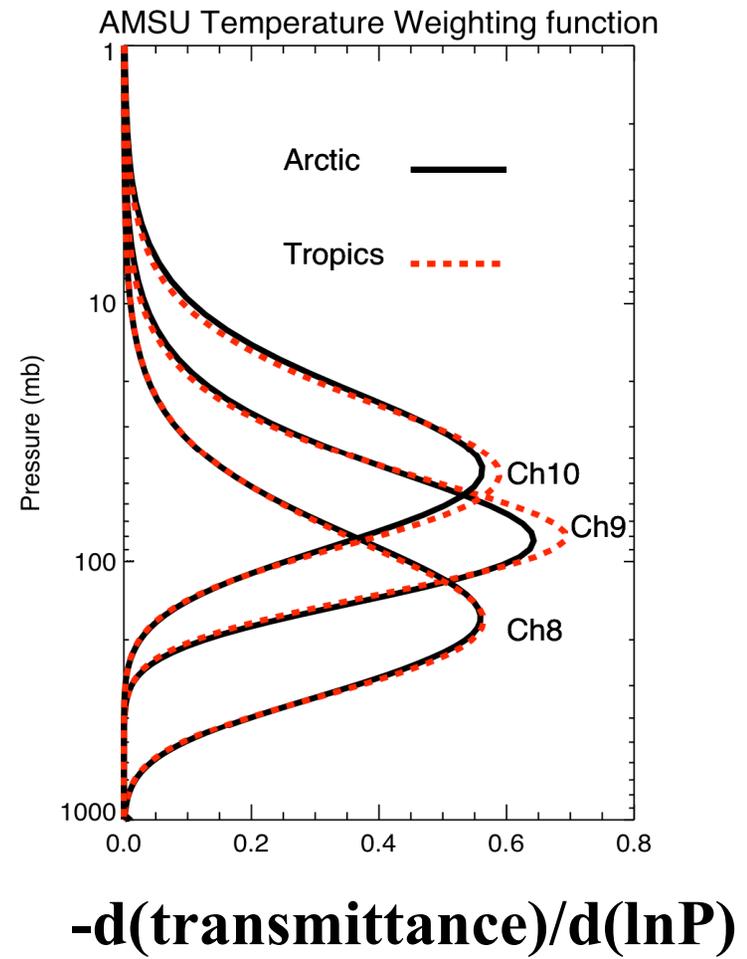
2. Match simulated GPS RO TLS to NOAA AMSU TLS within 30 minutes and 0.5 degree to find calibration coefficients for different NOAA satellites so that we can

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

AMSU Temperature Weighting function

Arctic ——————

Tropics ┄┄┄┄┄

Ch10

Ch9

Ch8

Pressure (mb)

-d(transmittance)/d(lnP)

Shu-peng Ben Ho, UCAR/COSMIC

Can we use GPS RO data to calibrate other instruments ?
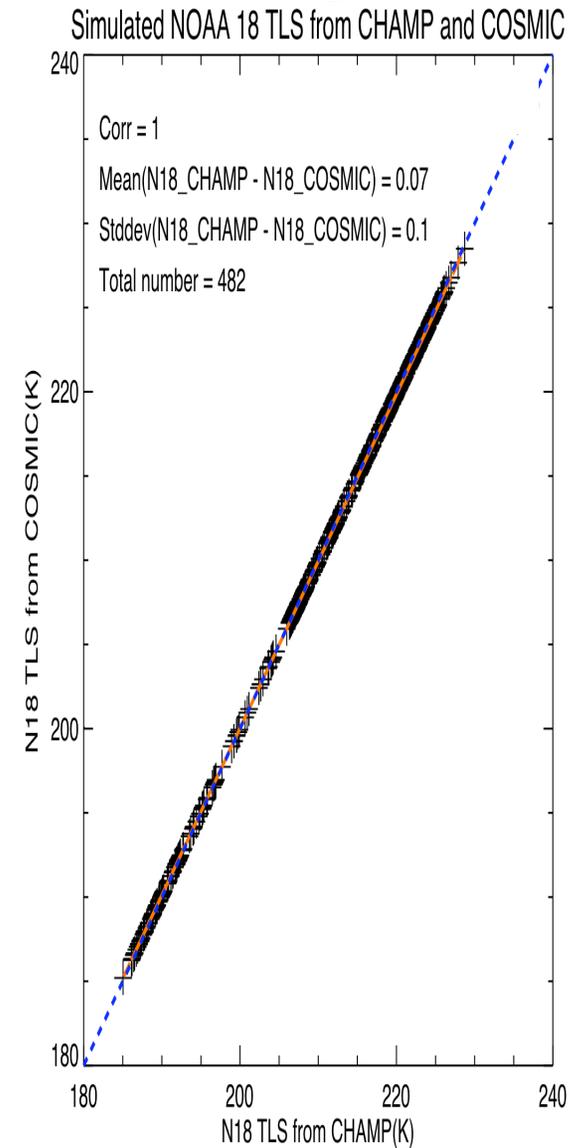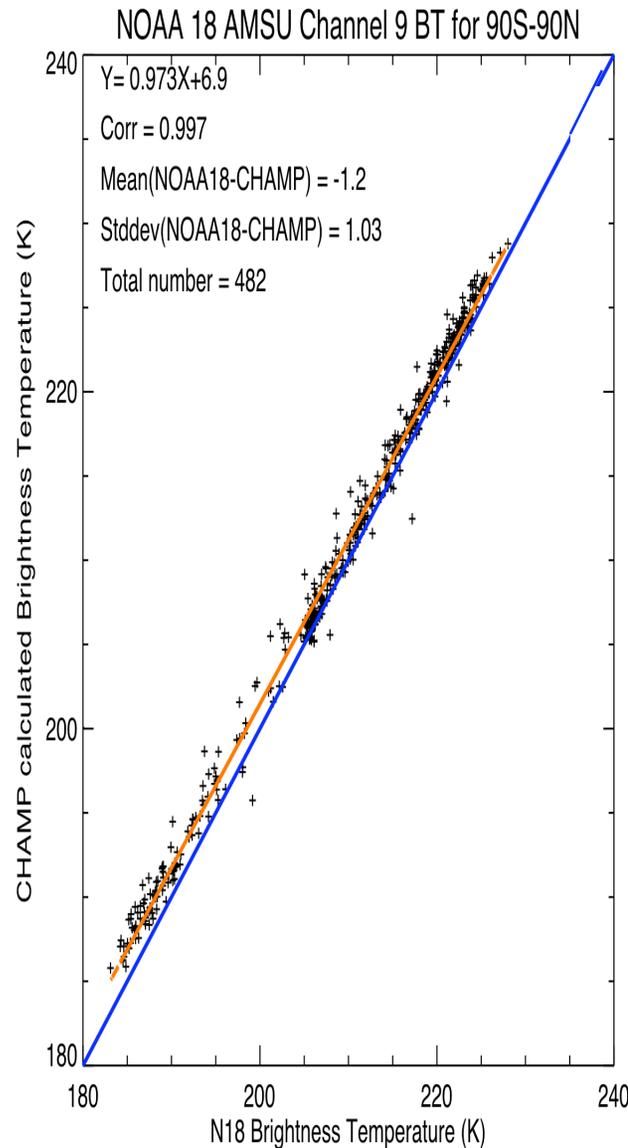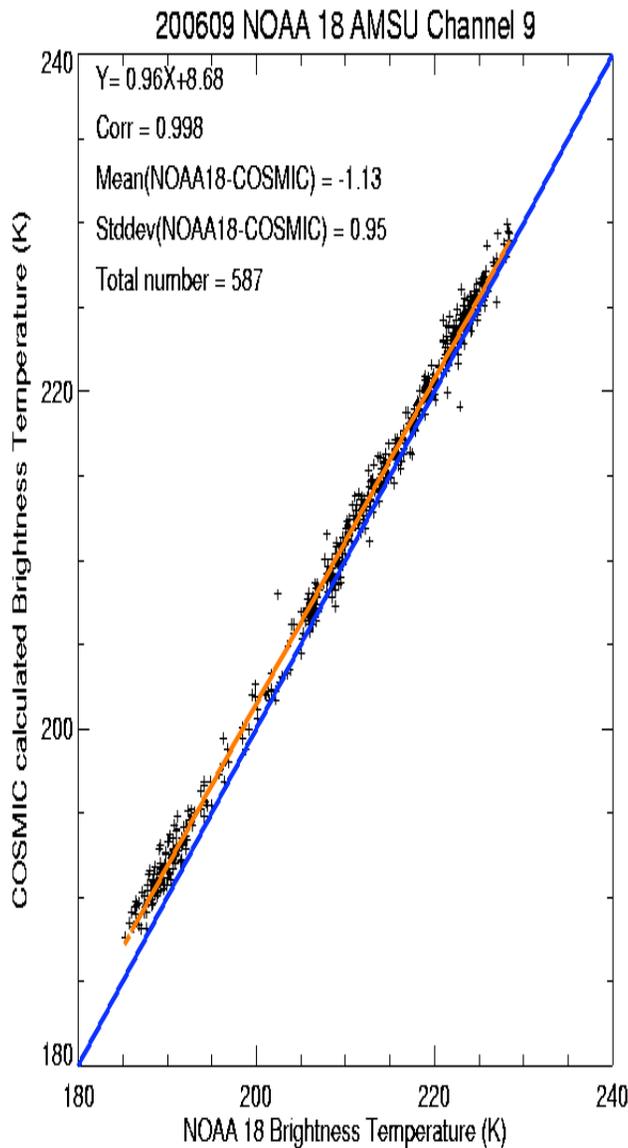## N15, N16 and N18 AMSU calibration against COSMIC

(Ho et al. TAO, 2007)
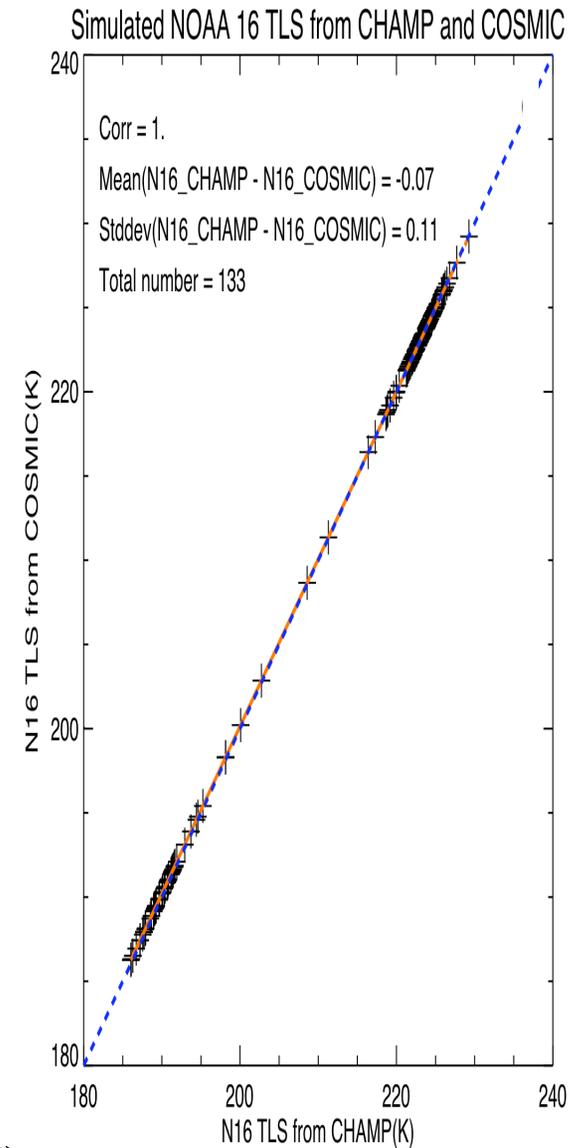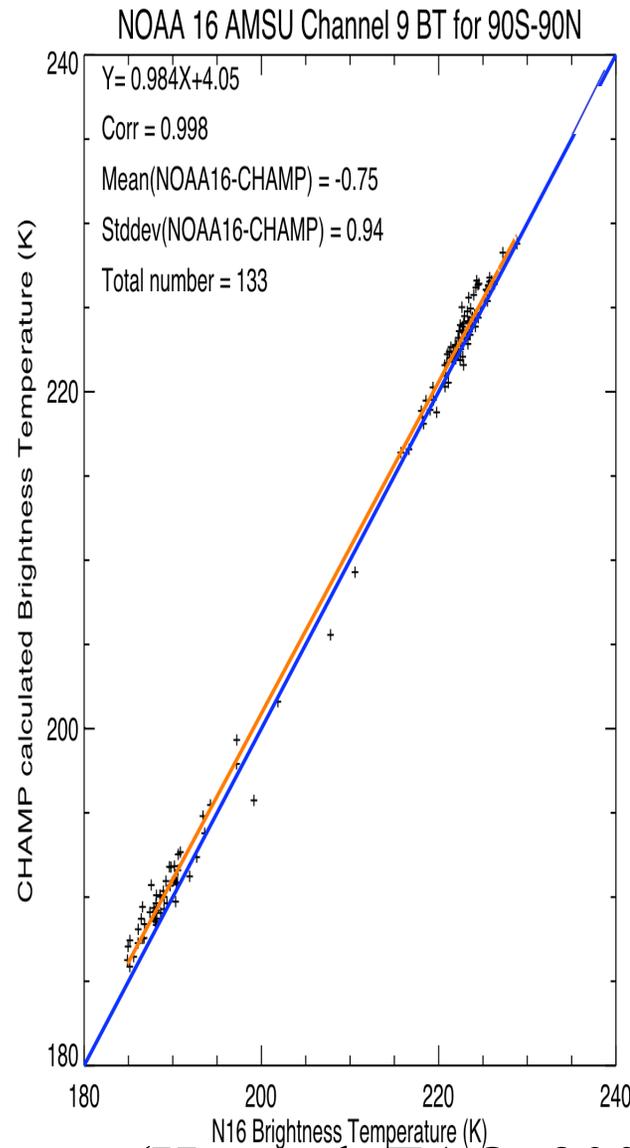
Shu-peng Ben Ho, UCAR/COSMIC
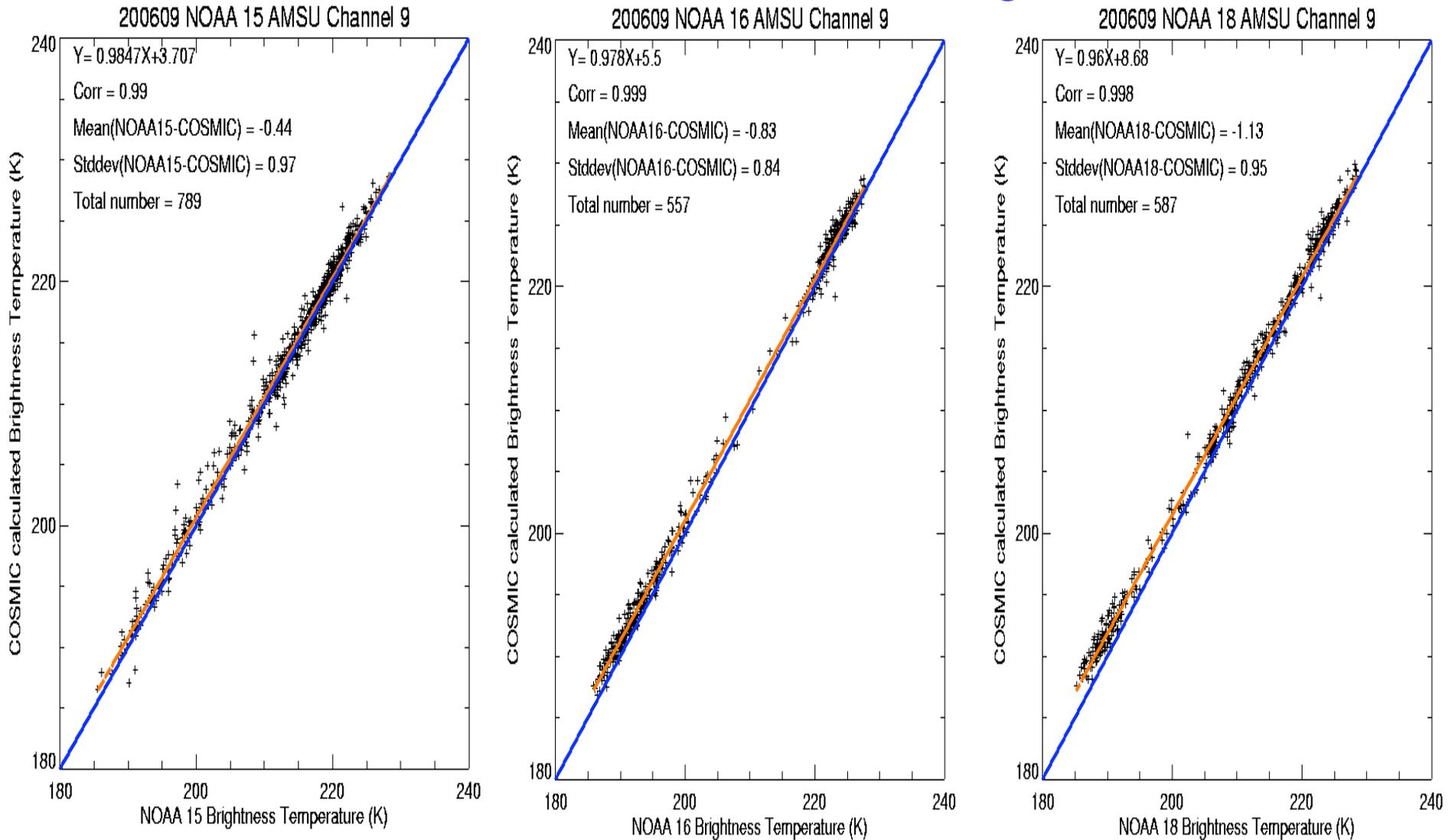
The precision between CHAMP and COSMIC synthetic Tb is around +/- 0.07 K
NOAA 18 AMSU Ch9 Brightness Temperature

200609 NOAA 18 AMSU Channel 9

Y= 0.96X+8.68

Corr = 0.998

Mean(NOAA18-COSMIC) = -1.13

Stddev(NOAA18-COSMIC) = 0.95

Total number = 587

COSMIC calculated Brightness Temperature (K) vs *NOAA 18 Brightness Temperature (K)*

NOAA 18 AMSU Channel 9 BT for 90S-90N

Y= 0.973X+6.9

Corr = 0.997

Mean(NOAA18-CHAMP) = -1.2

Stddev(NOAA18-CHAMP) = 1.03

Total number = 482

CHAMP calculated Brightness Temperature (K) vs *N18 Brightness Temperature (K)*

Simulated NOAA 18 TLS from CHAMP and COSMIC

Corr = 1

Mean(N18_CHAMP - N18_COSMIC) = 0.07

Stddev(N18_CHAMP - N18_COSMIC) = 0.1

Total number = 482

N18 TLS from COSMIC(K) vs *N18 TLS from CHAMP(K)*

(Ho et al. TAO, 2007)

Slide 10

Shu-peng Ben Ho, UCAR/COSMIC

The precision between CHAMP and COSMIC synthetic Tb is around +/- 0.07 K

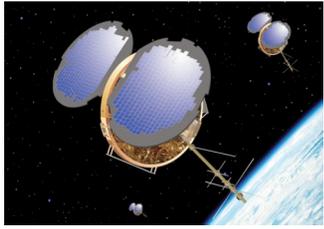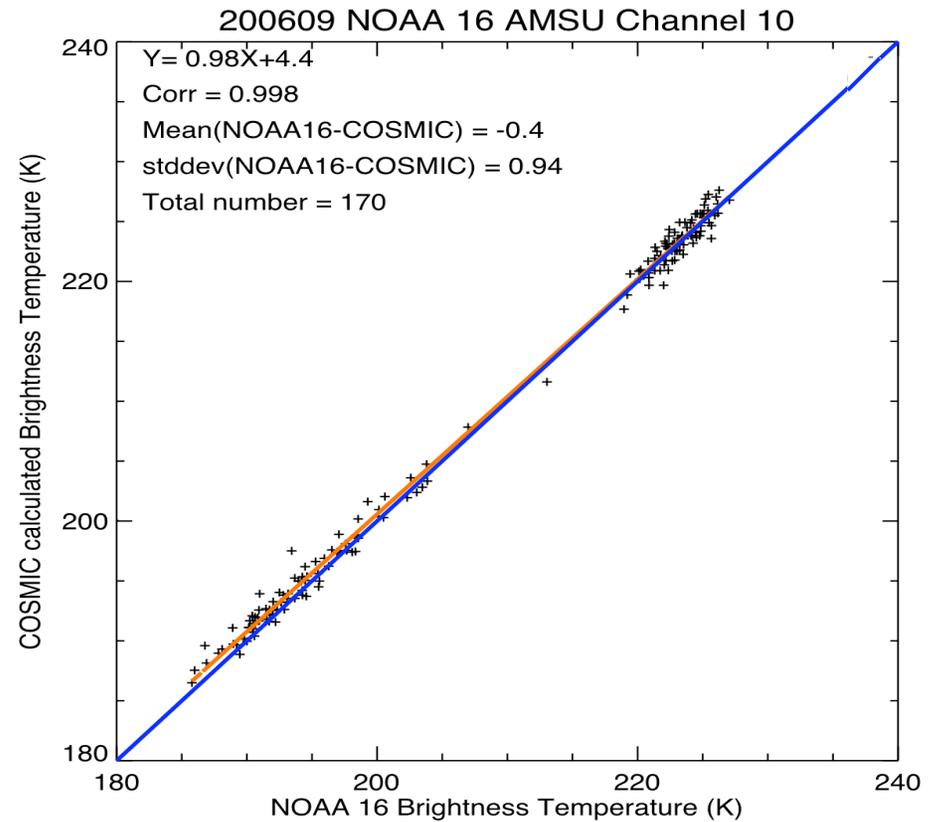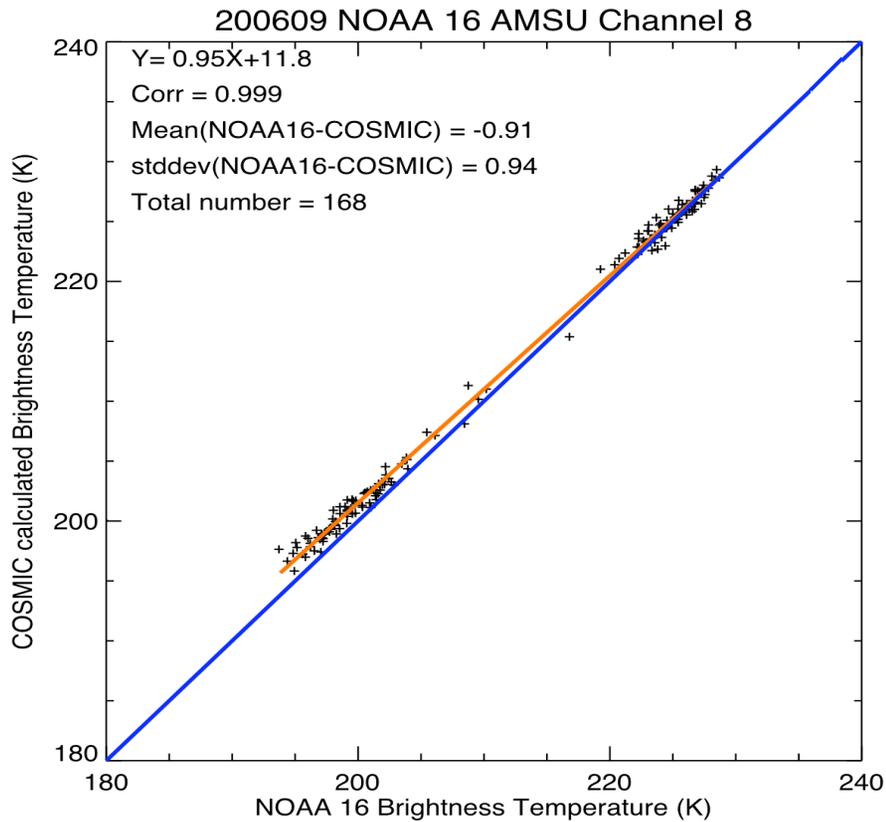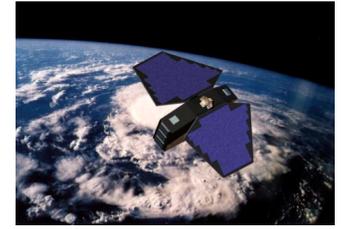(Ho et al. TAO, 2007)

Slide 11   *Shu-peng Ben Ho, UCAR/COSMIC*

200609 NOAA 16 AMSU Channel 8

Y= 0.95X+11.8
Corr = 0.999
Mean(NOAA16-COSMIC) = -0.91
stddev(NOAA16-COSMIC) = 0.94
Total number = 168

COSMIC calculated Brightness Temperature (K)

NOAA 16 Brightness Temperature (K)

200609 NOAA 16 AMSU Channel 10

Y= 0.98X+4.4
Corr = 0.998
Mean(NOAA16-COSMIC) = -0.4
stddev(NOAA16-COSMIC) = 0.94
Total number = 170

COSMIC calculated Brightness Temperature (K)

NOAA 16 Brightness Temperature (K)

     Shu-peng Ben Ho, UCAR/COSMIC

Difficulty IV: Independent Inversion Procedures
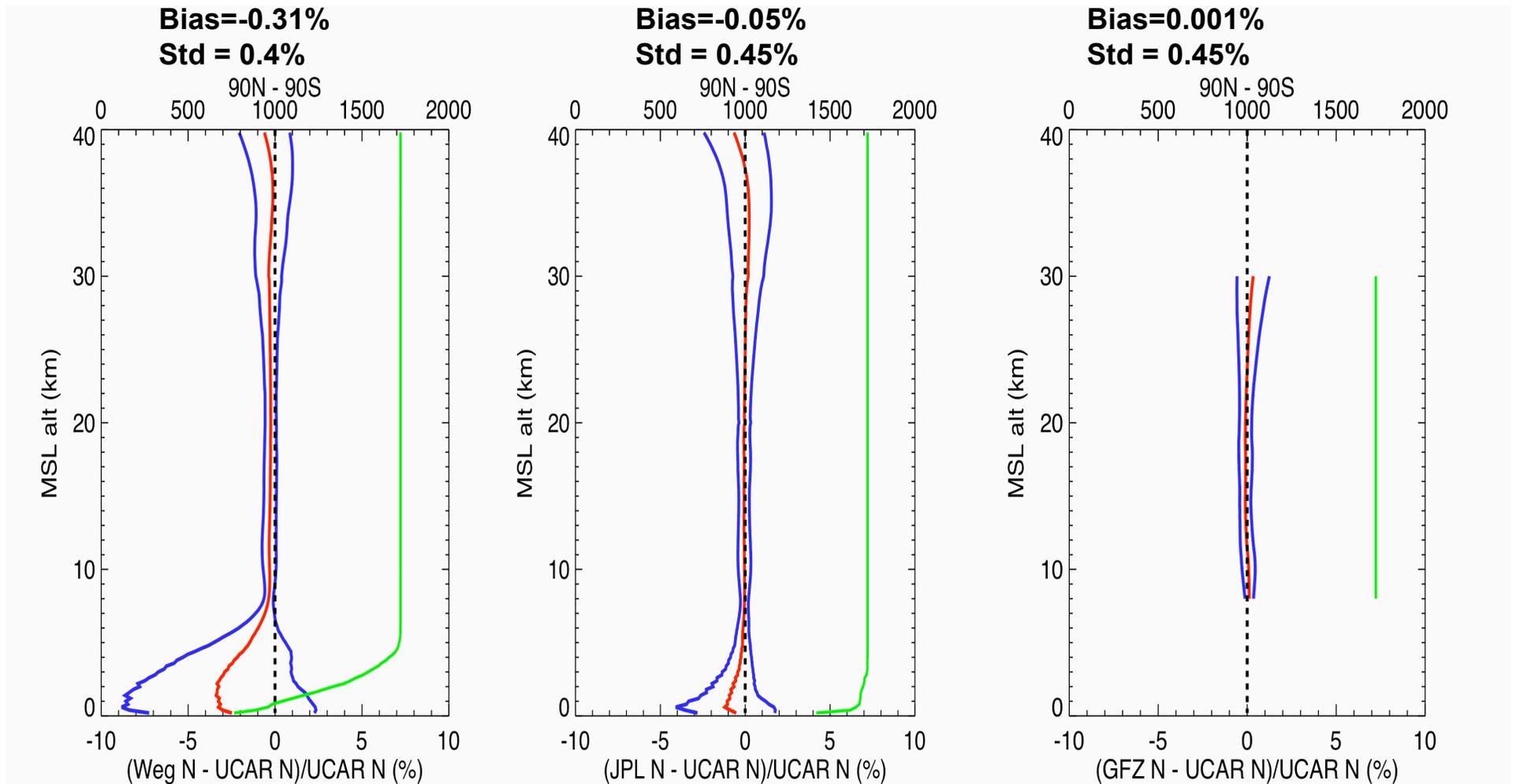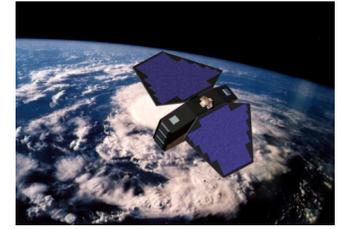
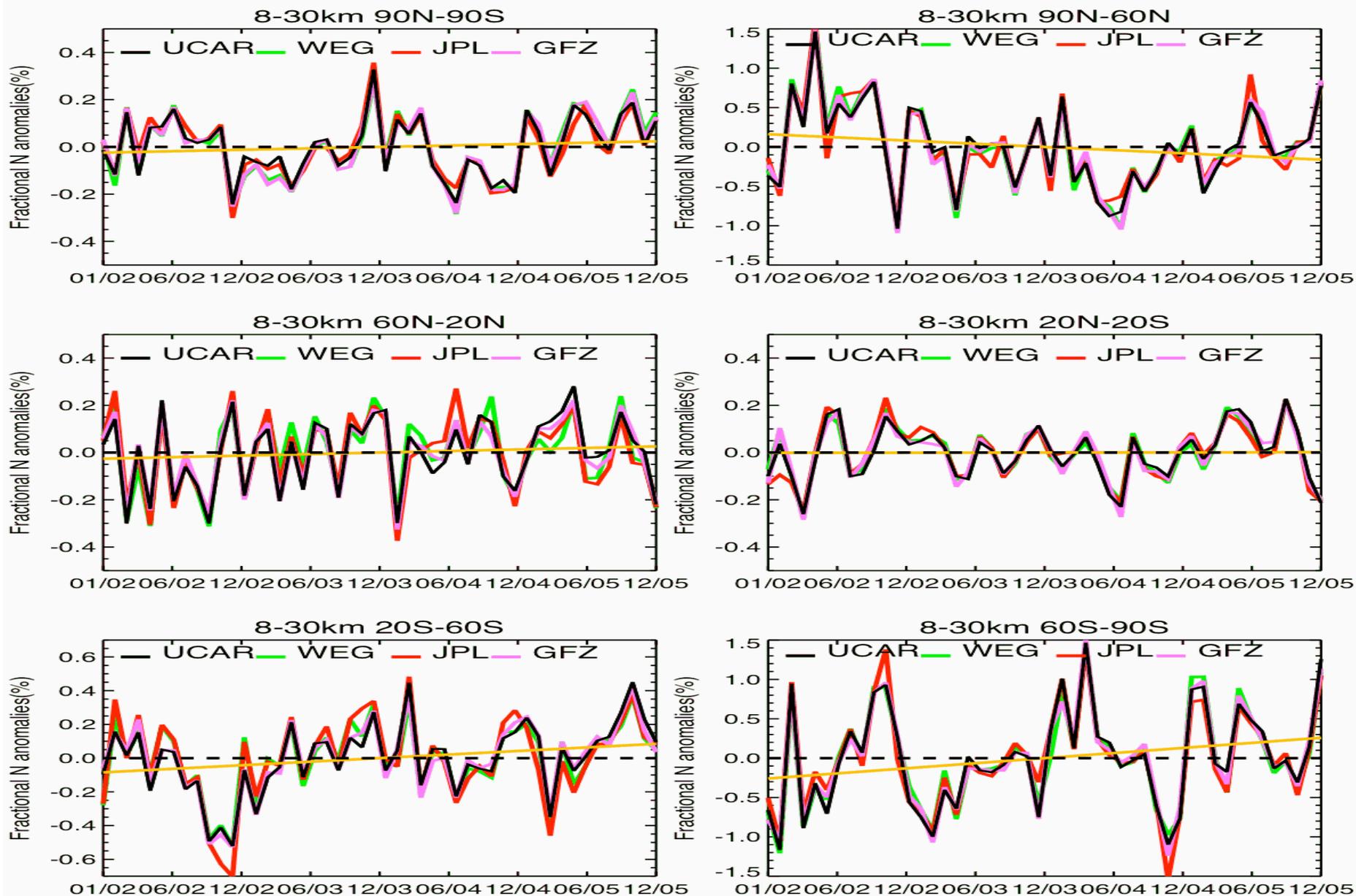Bias and std from 30km to 8 km

Shu-peng Ben Ho, UCAR/COSMIC

De-seasonalized N anomalies

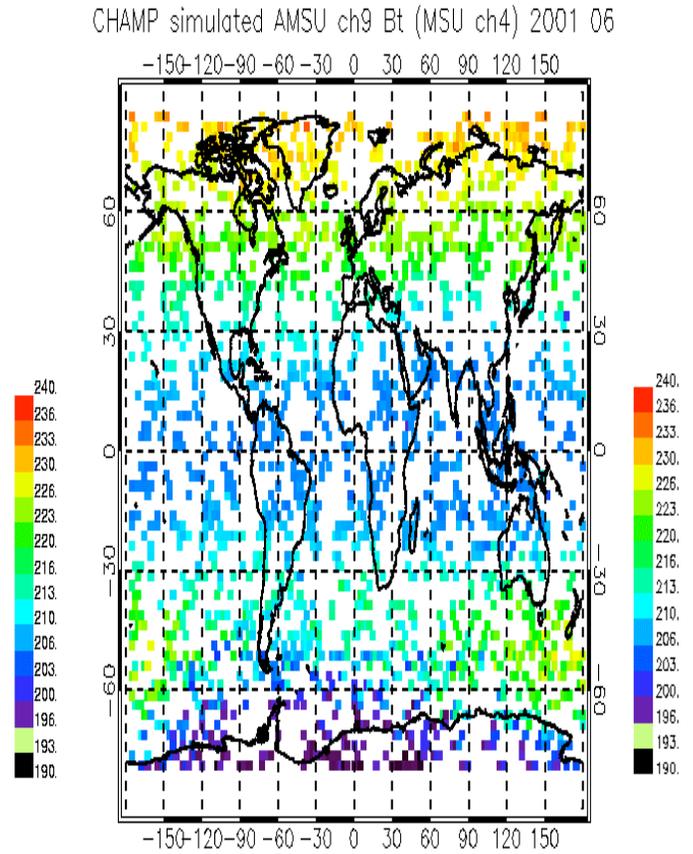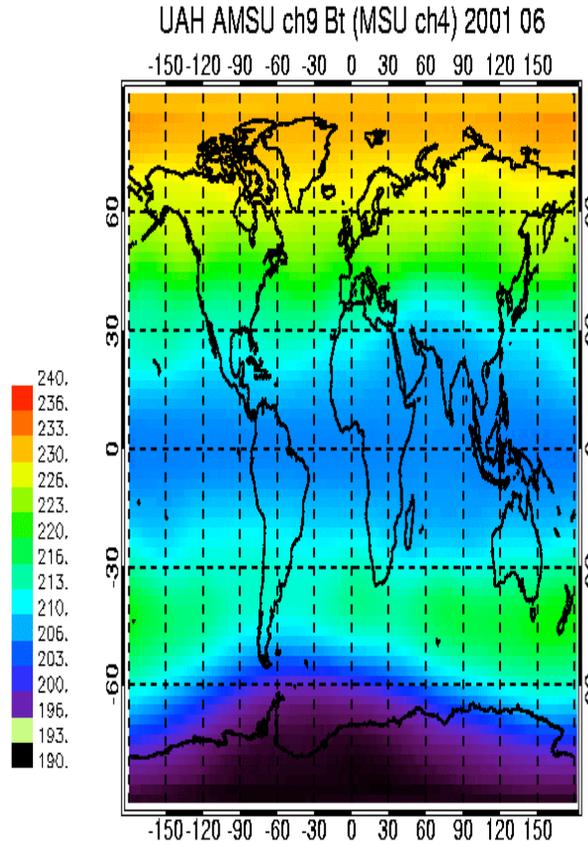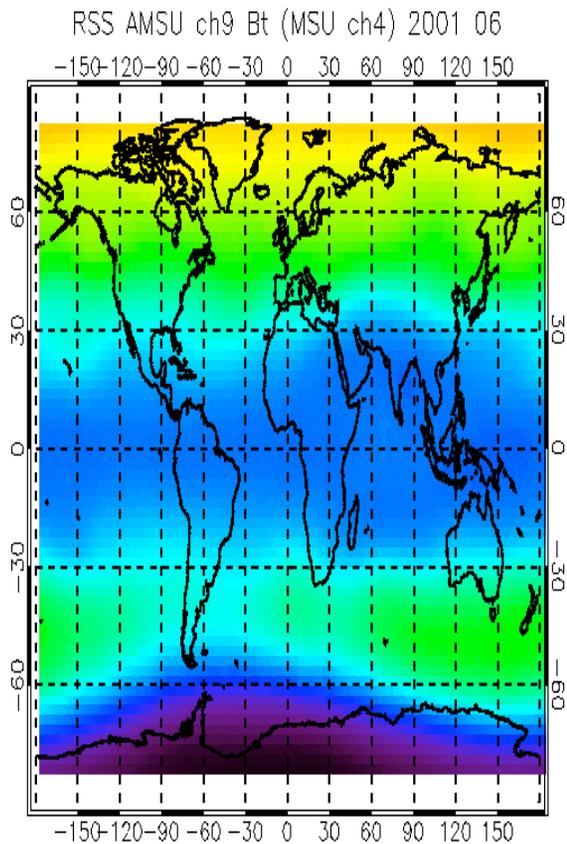

     Shu-peng Ben Ho, UCAR/COSMIC

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

Fractional Anomalies (%)		WEG-C	UCAR	JPL	GFZ
90°N-90° S	8-30 Km	0.12 (0.06)	0.06	0.018 (-0.04)	0.1(0.04)
60°N - 90° N	8-30 Km	-0.44(-0.04)	-0.4	-0.47(-0.07)	-0.41(-0.01)
20° N - 60° N	8-30 Km	0.14(0.07)	0.07	0.04(-0.03)	0.09(0.02)
20° N - 20° S	8-30 Km	0.048(0.018)	0.03	0.022(-0.08)	0.033(0.003)
20° S - 60° S	8-30 Km	0.35(0.12)	0.22	0.2(-0.02)	0.3(0.1)
60°S - 90° S	8-30 Km	0.72(0.06)	0.66	0.44(-0.22)	0.7(0.04)

Fractional anomalies; fractional anomalies from different centers- fractional anomalies from UCAR are in parenthesis. **(N unit/5 yrs)**

Slide 15

Shu-peng Ben Ho, UCAR/COSMIC
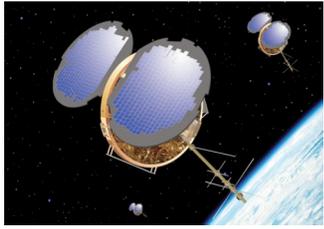
Using GPS RO data to inter-compare to UAH and RSS TLS

2.5x2.5 grid

(Ho et al., GRL, 2007)

Shu-peng Ben Ho, UCAR/COSMIC

26036 pair of pixels are included

Matched pairs of CHAMP, RSS and UAH for each 10x10 grid for all 49 months

     Shu-peng Ben Ho, UCAR/COSMIC

Deseasonalized TLS anomalies in 82.5N to 82.5S (a)

Deseasonalized TLS anomalies in 20N to 20S (d)

Deseasonalized TLS anomalies in 60N to 82.5N (b)

Deseasonalized TLS anomalies in 20S to 60S (e)

Deseasonalized TLS anomalies in 20N to 60N (c)

Deseasonalized TLS anomalies in 60S to 82.5S (f)

Slide 18   Copy right © UCAR, all rights reserved

Shu-peng Ben Ho, UCAR/COSMIC

	RSS	UAH	CHAMP	RSS-CHAMP	UAH-CHAMP
82.5°N-82.5° S	-1.239	-1.227	-1.32	0.08	0.09
60°N - 82.5° N	-1.7	-1.689	-1.3	-0.394	-0.385
20° N - 60° N	-1.43	-1.5	-1.39	-0.03	-0.118
20° N - 20° S	-0.74	-0.63	-0.54	-0.2	-0.092
20° S - 60° S	-0.33	-0.24	-0.865	0.53	0.62
60°S - 82.5° S	0.55	0.33	0.13	0.41	0.2

Although the de-seasonalized TLS anomalies from UAH and RSS are, in general, agree well with that from CHAMP in all latitudinal zones, statistically significant trend differences are found between RSS to CHAMP and UAH to CHAMP.

The 2001-2005 trends of de-seasonalized lower stratospheric Tb anomalies (in K/5yrs) for RSS, UAH, CHAMP, RSS-CHAMP and UAH-CHAMP for the global (82.5°N-82.5° S) and five latitudinal zones.
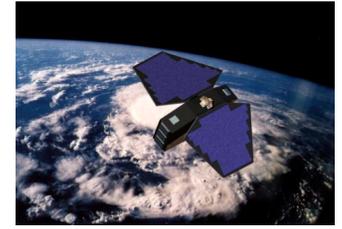
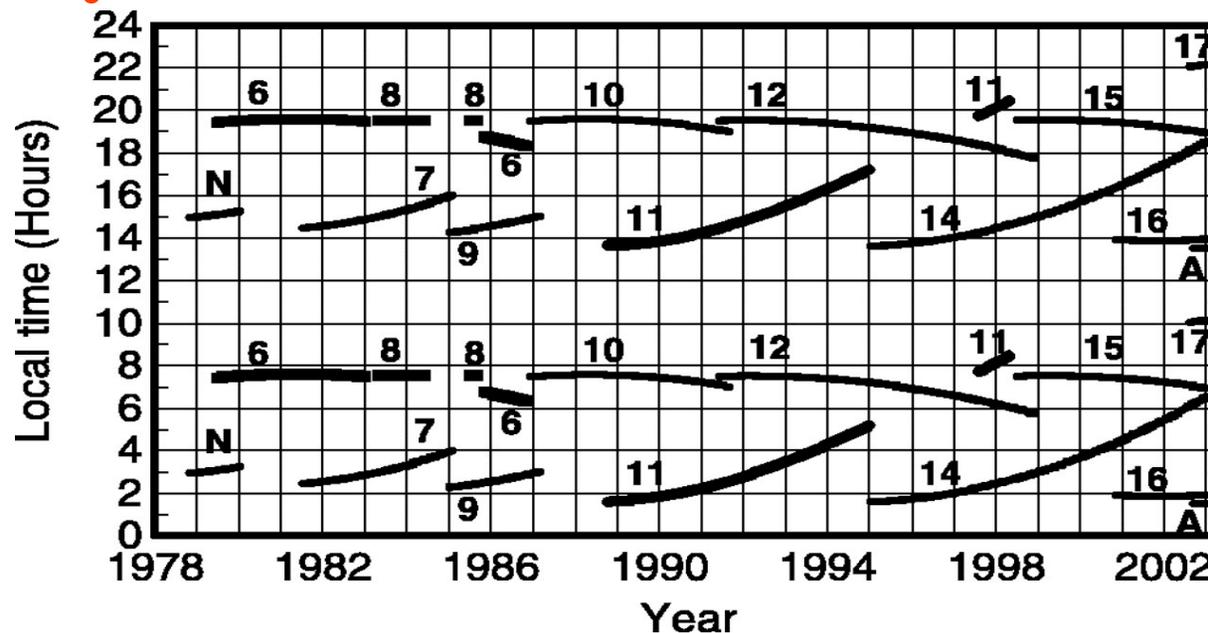   *Shu-peng Ben Ho, UCAR/COSMIC*
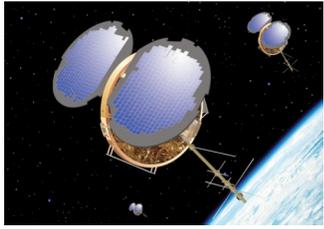
Conclusions and Future Work
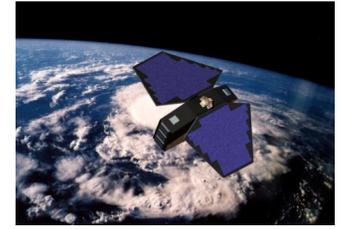
•The 0.02K-0.05 K precision of COSMIC will be very useful to inter-calibrate AMSU/MSU data.

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

•In this study, GPS RO sounding from COSMIC and CHAMP are used to collocate with AMSU/MSU measurements from various NOAA soundings to find the optimal spatial and temporal matches. Different AMSU and MSU data can be calibrated using consistent COMSIC/CHAMP GPS RO sounding.

• Although different centers using different inversion procedures and initial conditions to derive refractivity, the uncertainty of the trend of the fractional N anomalies is within +/-0.06 N-unit/5 yrs (+/-0.06 K/5 yrs).

•Due to different calibration methods, RSS and UAH produces different TLS values, which also give different TLS trend. Globally RSS TLS is 0.79K biased lower than that of UAH. There exists seasonal and latitudinal differences between RSS and UAH TLS.

•Although the de-seasonalized TLS anomalies from UAH and RSS are, in general, agree well with that from CHAMP in all latitudinal zones, statistically significant trend differences are found between RSS to CHAMP and UAH to CHAMP.

                       Shu-peng Ben Ho, UCAR/COSMIC
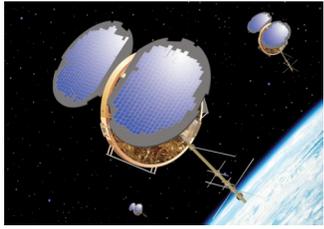
Conclusions and Future Work

Can we use the NOAA satellite measurements calibrated by GPS RO data to calibrate multi-year AMSU/MSU data ?

Contact information : Shu-peng Ben Ho, spho@ucar.edu

    Shu-peng Ben Ho, UCAR/COSMIC