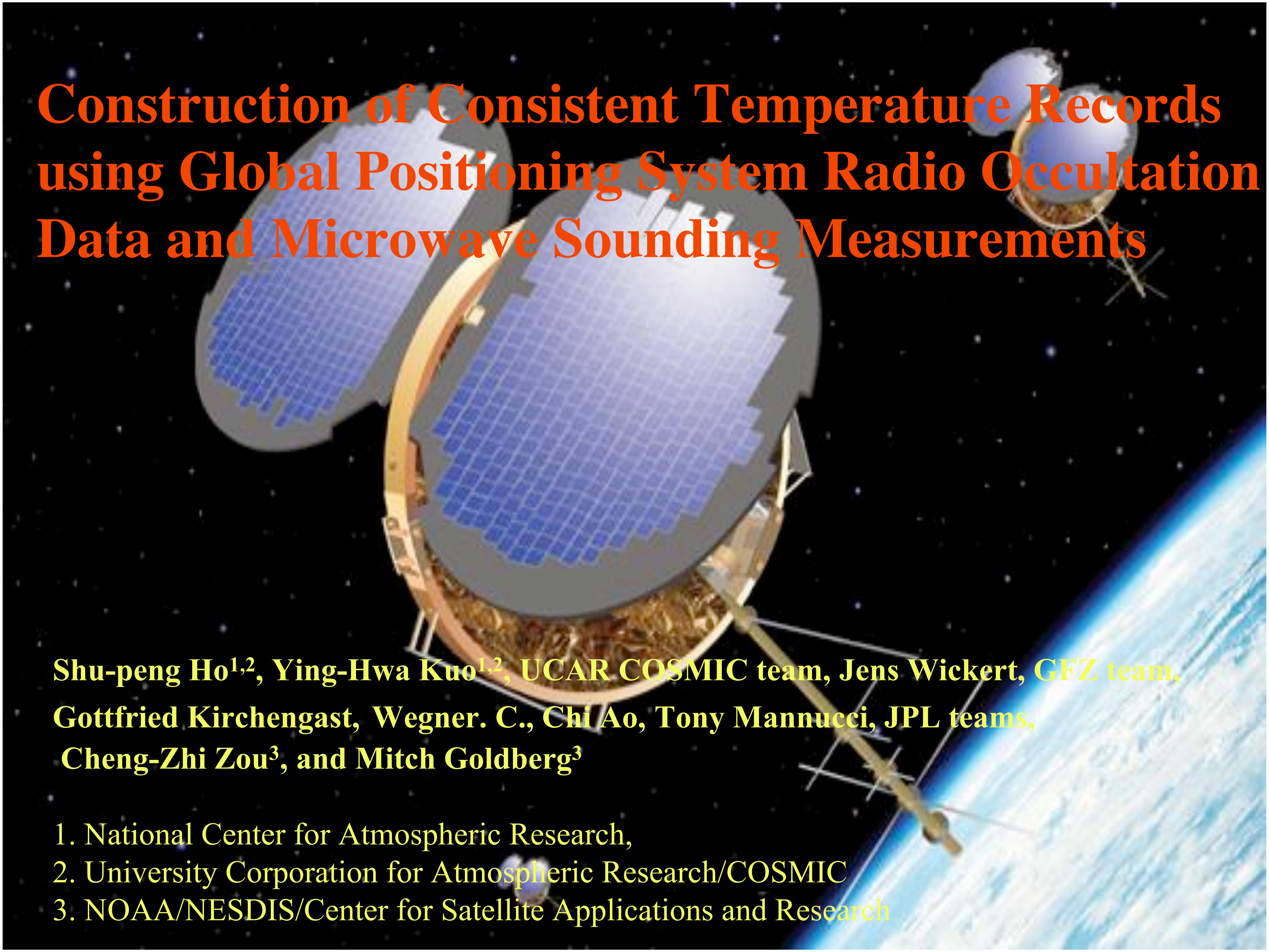
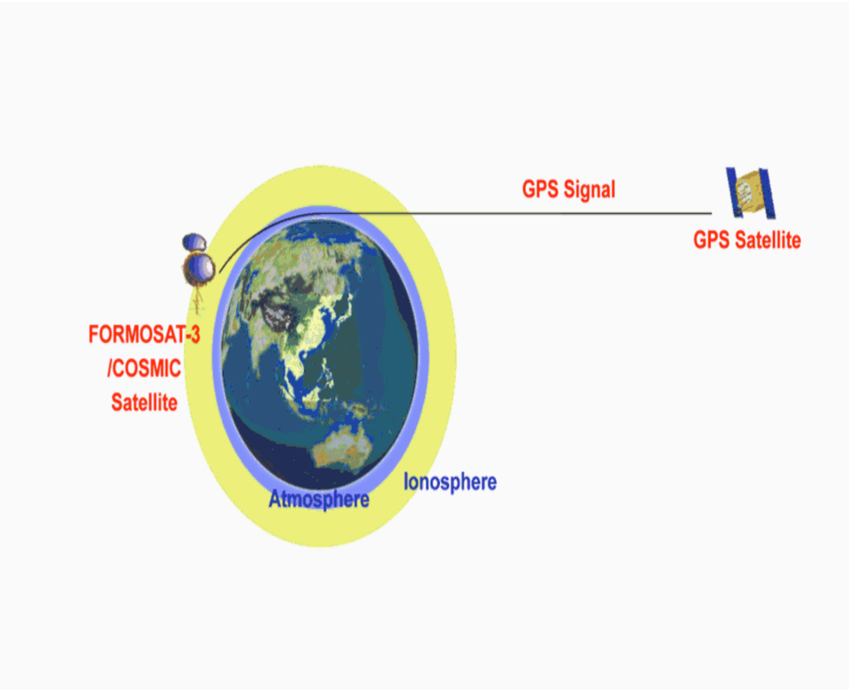


Construction of Consistent Temperature Records using Global Positioning System Radio Occultation Data and Microwave Sounding Measurements

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:
What are the uncertainties for using GPS RO data for climate monitoring ? Can we use GPS RO data to inter-calibrate other climate data ?



GPS RO data for climate monitoring:
no calibration issues, high vertical Resolution, insensitive to clouds and precipitation
a) Good temporal and spatial coverage,
b) High precision, c) Long term stability
d) Reasonable uncertainty among data processed from different centers ?

2. Outlines :

- Challenges to define/validate a global trend
- Long term stability of GPS RO data for climate monitoring
- Comparing refractivities generated from different centers
- Using RO data to identify location/local-time dependent biases
- Using the Calibrated AMSU data to calibrate other overlapped AMSU data

3. Conclusions and Future Work

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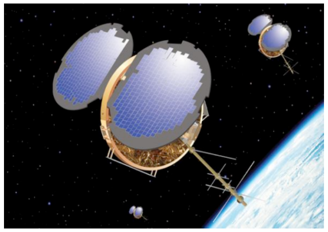
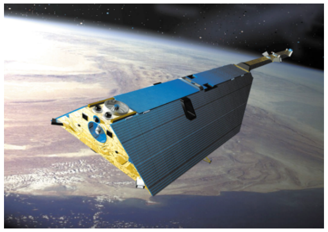


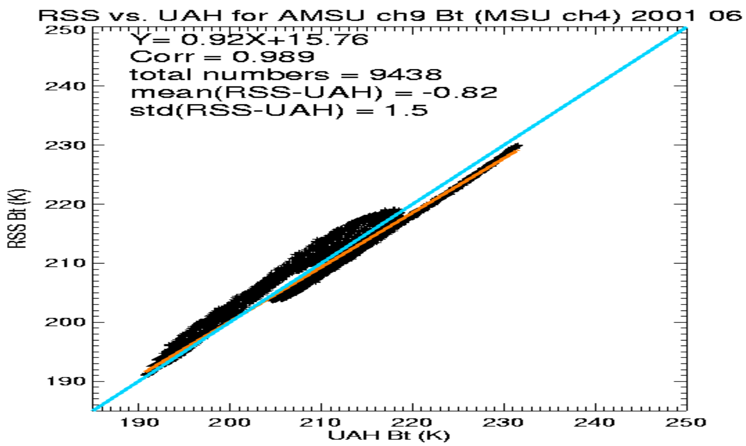
Challenges for defining the Global Temperature Trend

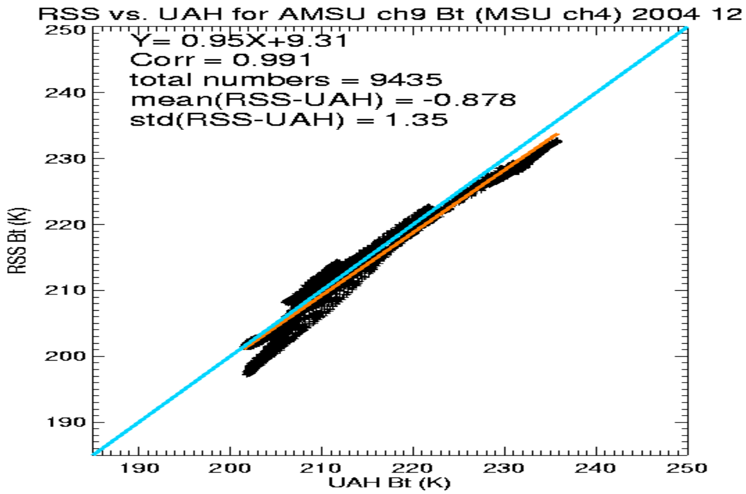


Satellites: changing platforms and instruments (diurnal cycle sampling, orbital decay); contribution of lower stratospheric to mid-tropospheric temperature estimates. Due to the differing methods used to account for errors before merging the time series of eleven AMSU/MSU satellites into a single, homogeneous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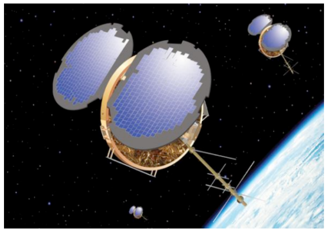
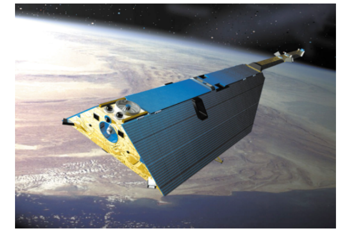
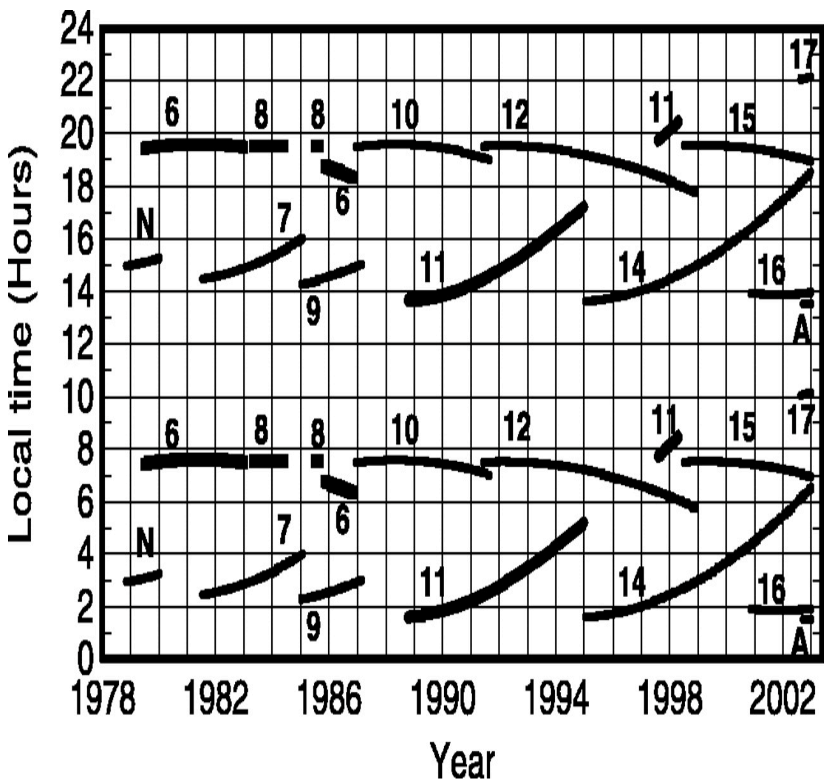


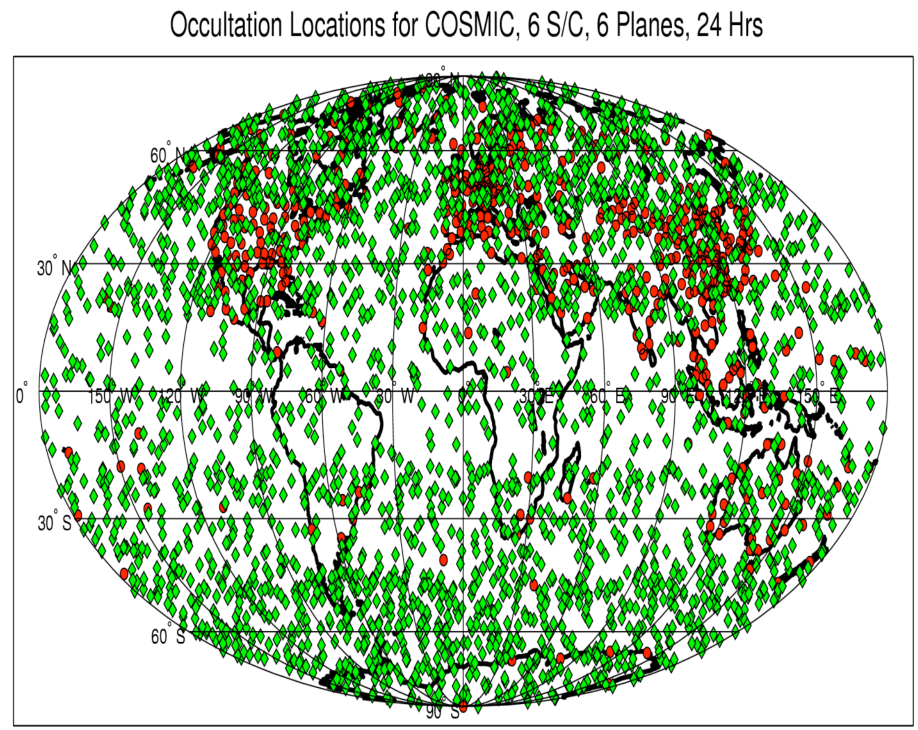
Difficulty I: to find observations with a good global and temporal coverage



AMSU/MSU local time



COSMIC has a more complete temporal and spatial global coverage



COSMIC

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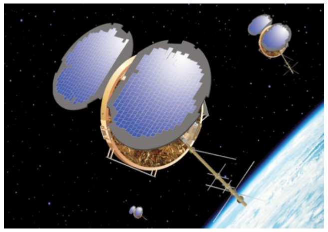
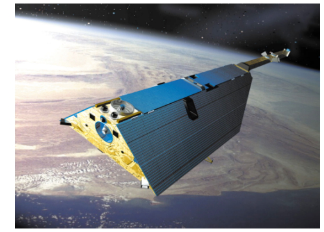
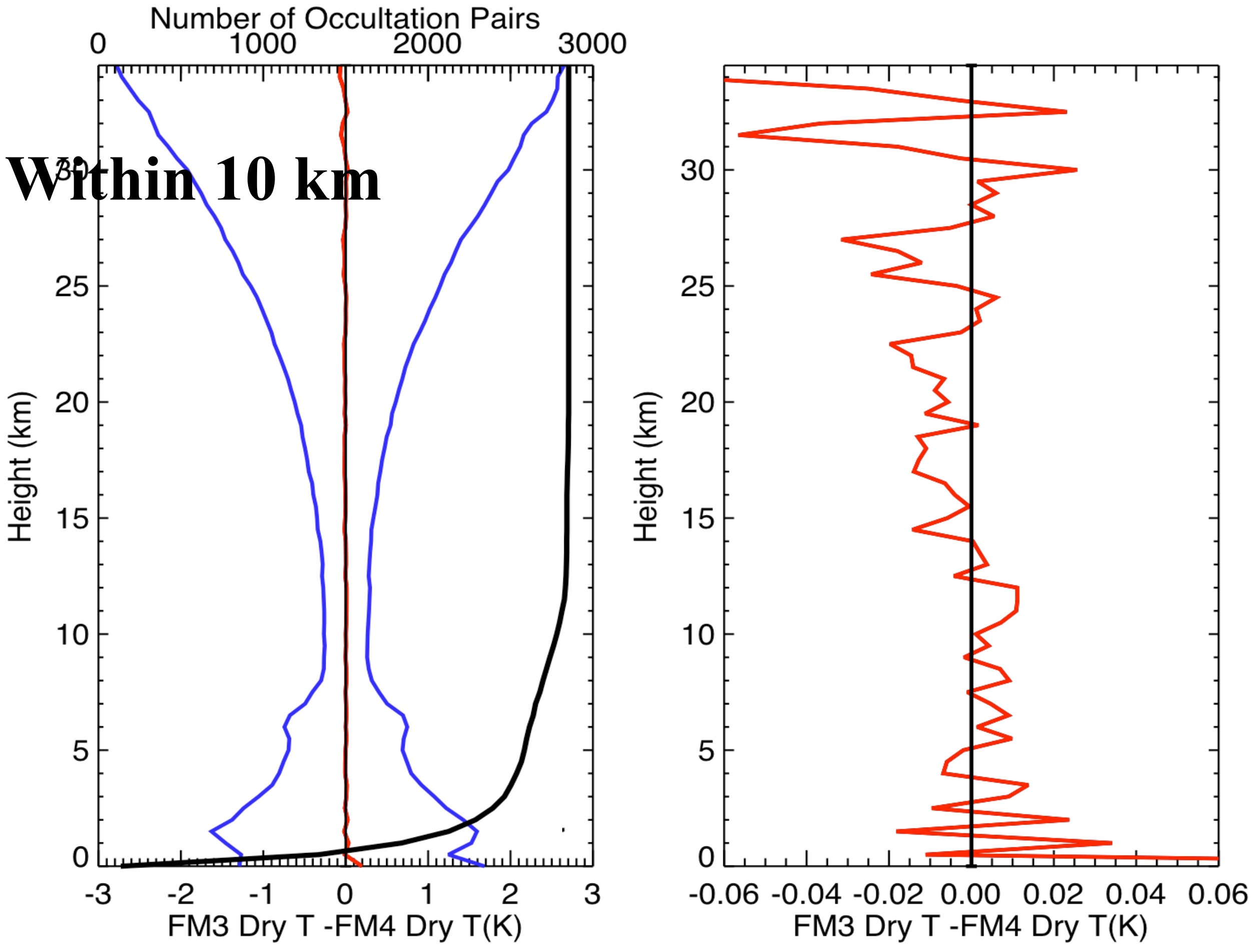


II: to find observations with very high precision





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

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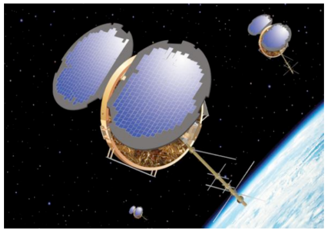
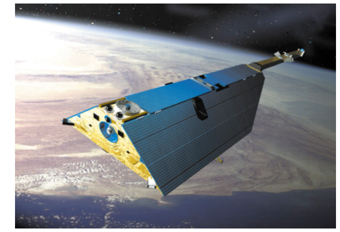
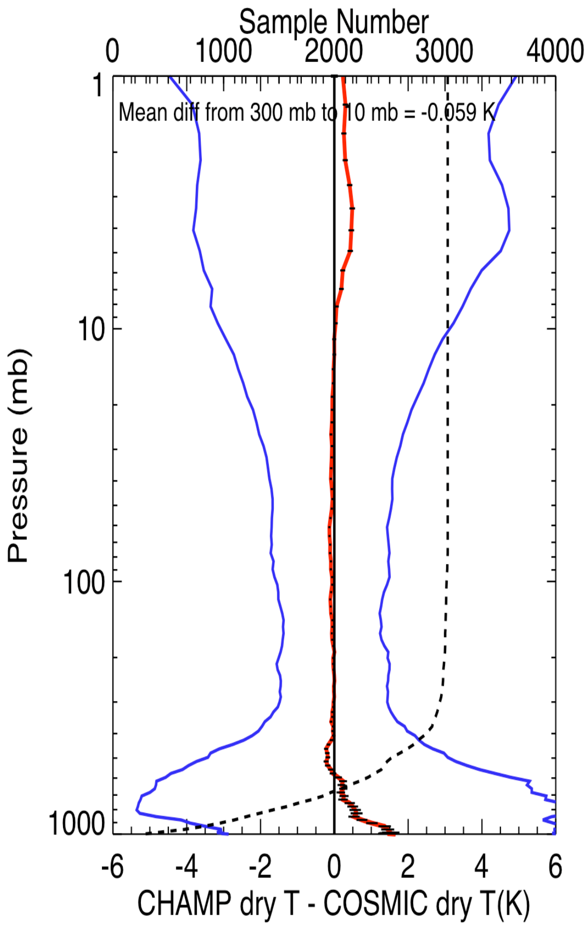


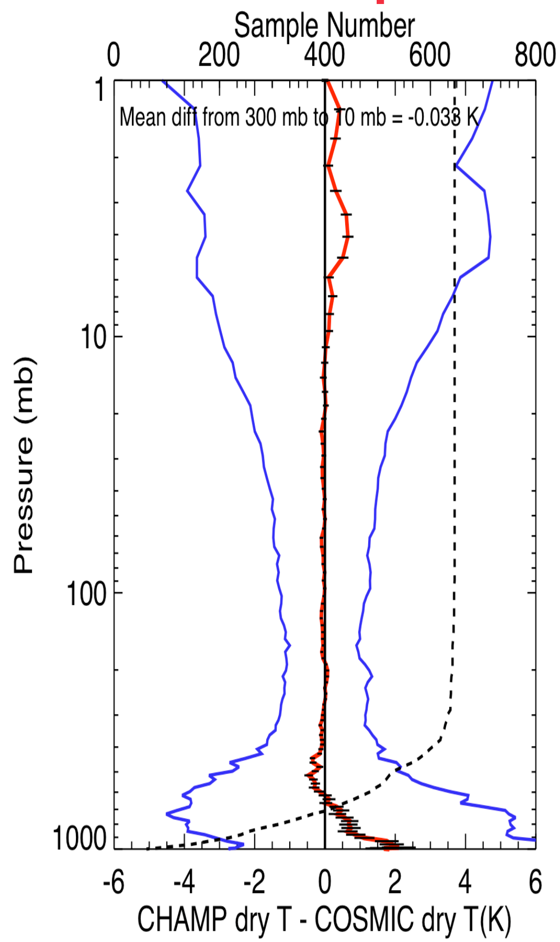
Difficulty III: to find measurements with long term stability



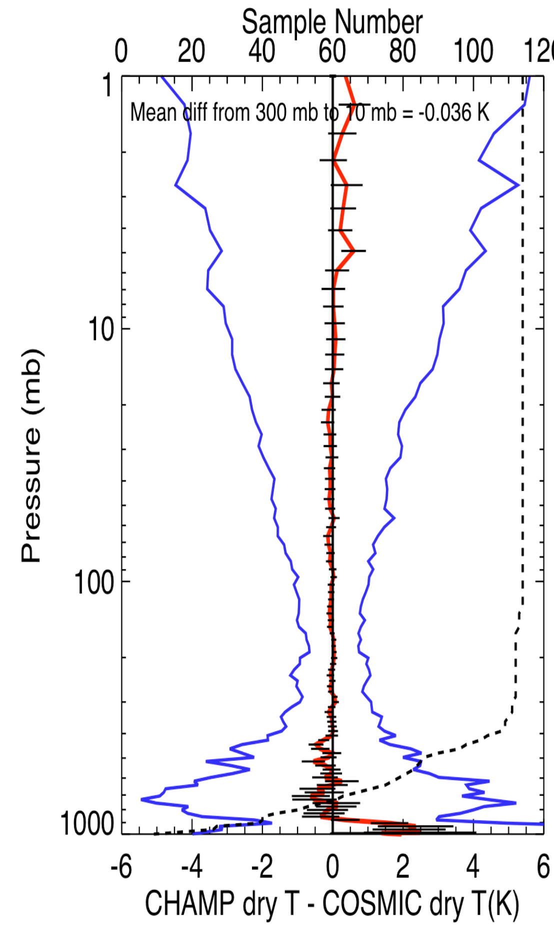
Global COSMIC-CHAMP Comparison from 200607-200707



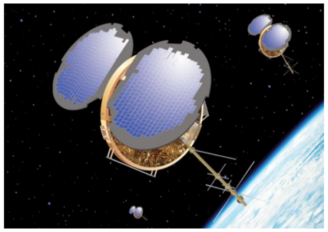
Within 90 Mins and 250 Km



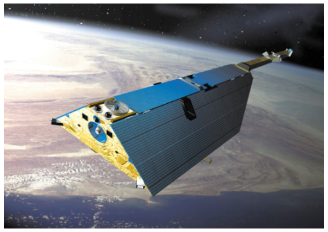
Within 90 Mins and 100 Km



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.

⇒ Vertical distribution of bending angle

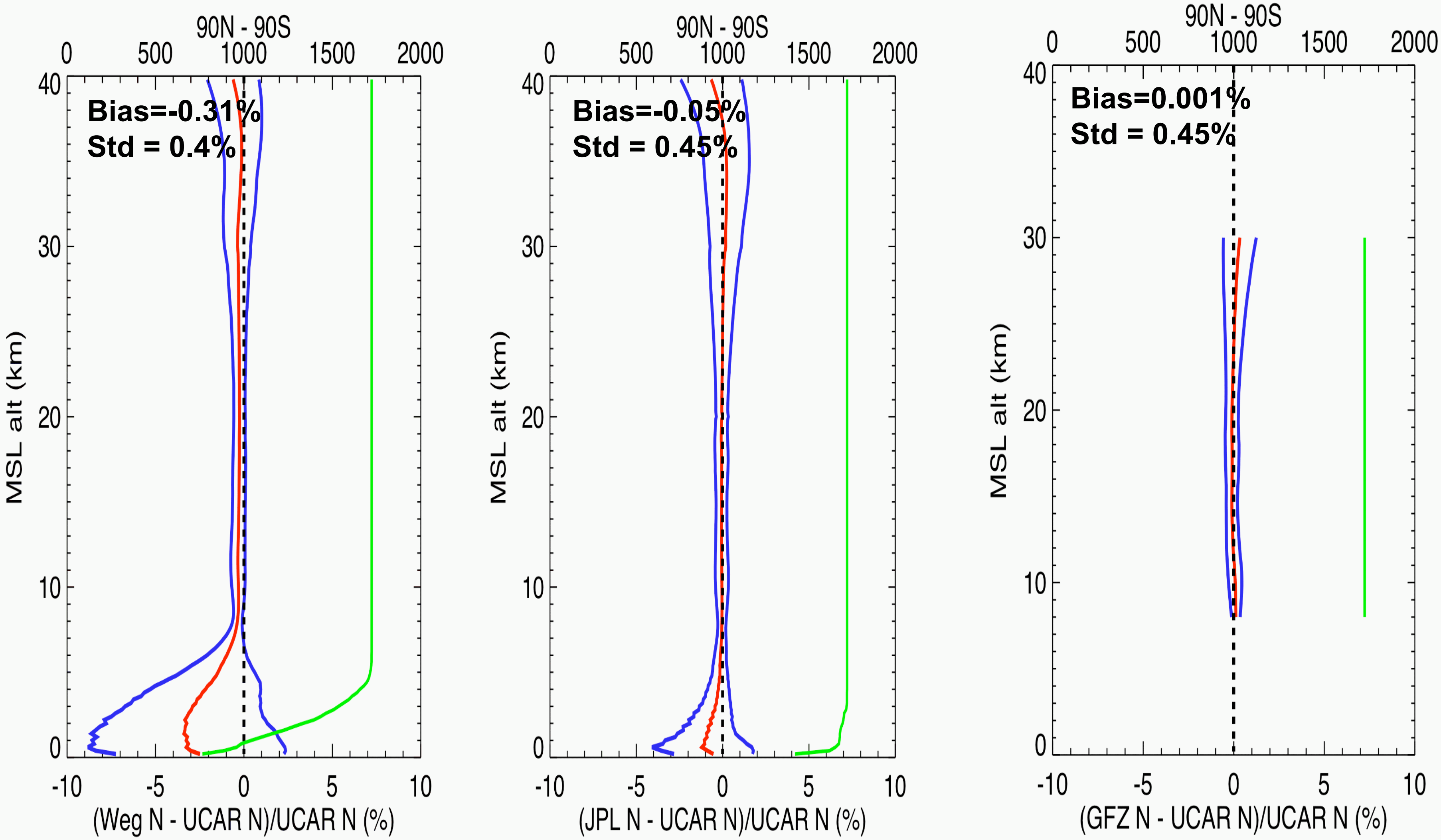
⇒ Vertical distribution of atmospheric refractivity

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

Refractivity uncertainty introduced by inversion procedures :

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

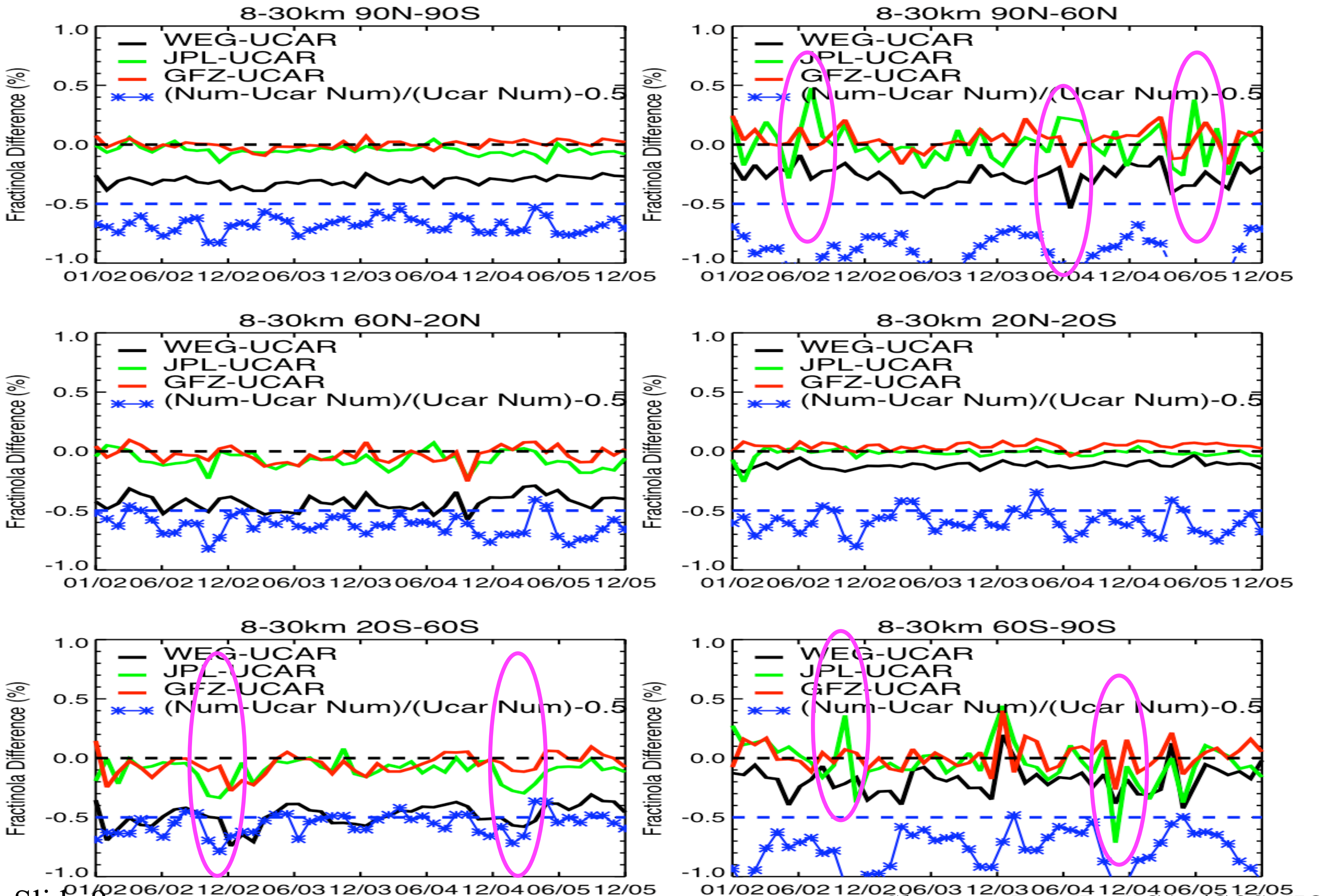
Monthly , 5 deg-lat, 200-meter mean refractivity profiles from 200201-200512



Bias and std from 30km to 8 km

Shu-peng Ben Ho, UCAR/COSMIC

8-30 km



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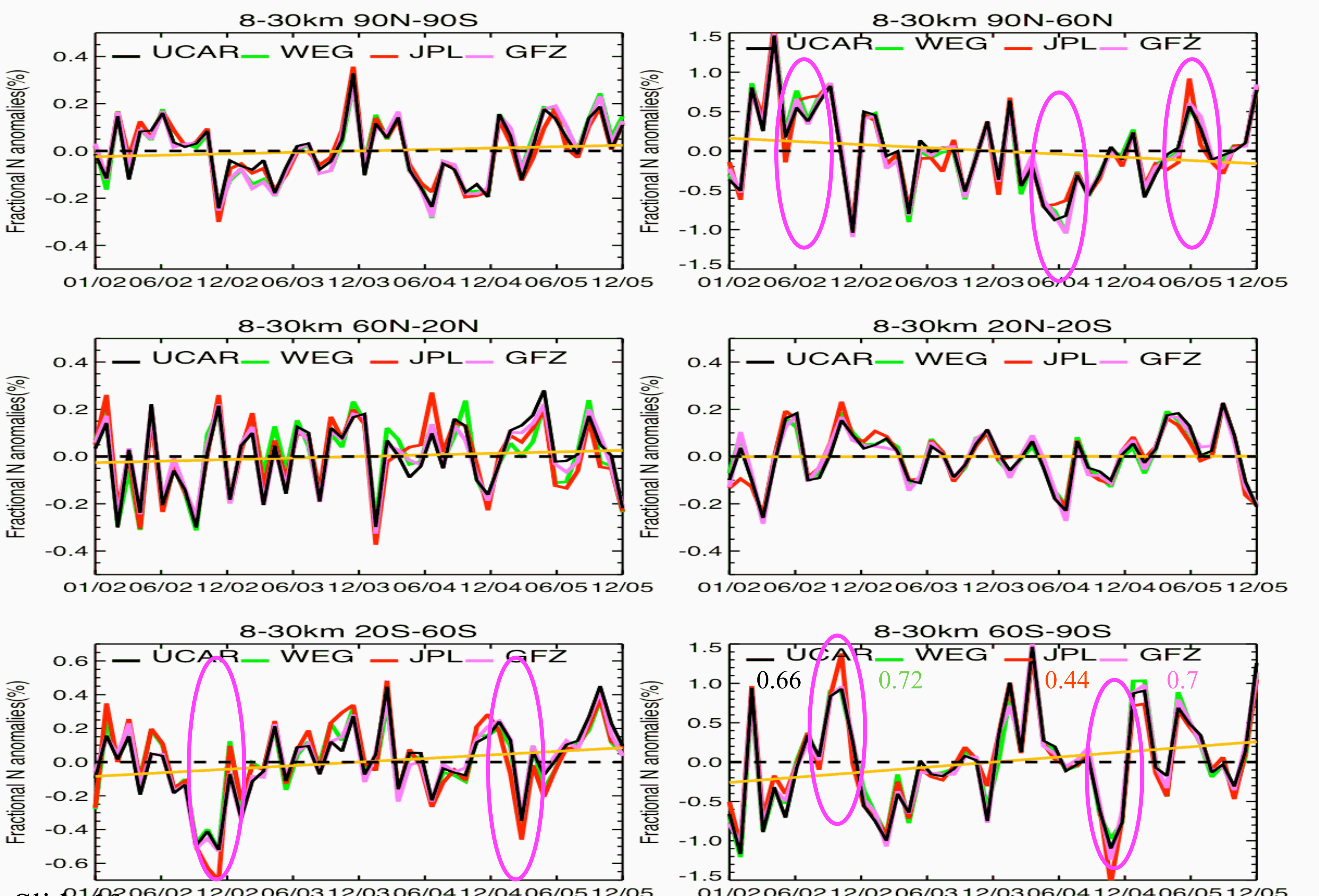
8-30 km



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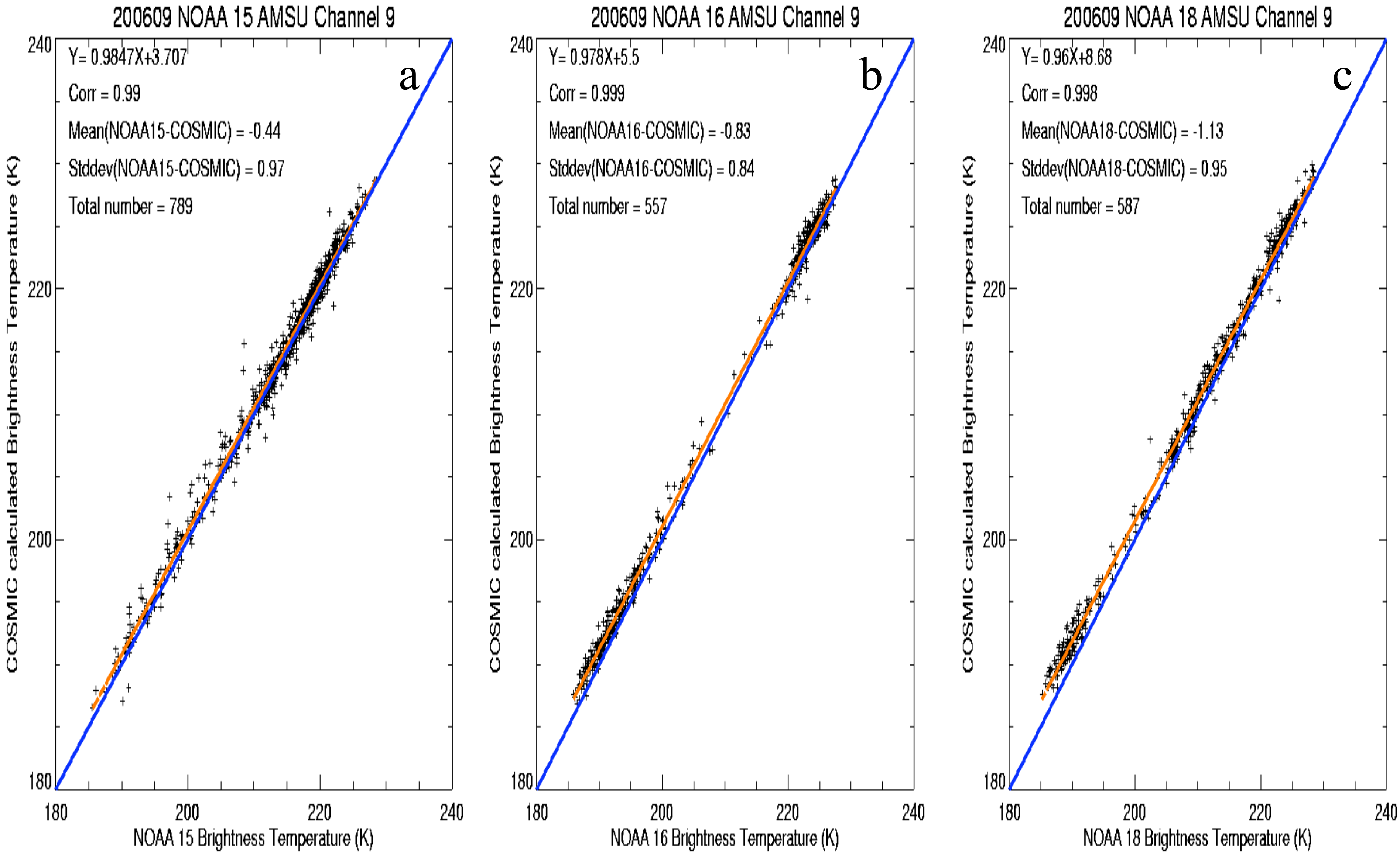
The uncertainty of the trend of fractional N anomalies is within +/-0.045 %/5 yrs (+/-0.06K/5 yrs).

Fractional Anomalies (%)		WEG-C	UCAR	JPL	GFZ
90°N-90° S	8-30 Km 8-12km 12-20Km 20-30km	**0.12 (0.06)** 0.28(0.06) 0.08(0.05) -0.32(0.1)	**0.06** 0.22 0.03 -0.42	**0.018 (-0.04)** 0.15(-0.07) -0.013(-0.043) -0.39(0.03)	**0.1(0.04)** 0.24(0.02) 0.07(0.04) -0.3(0.12)
60°N - 90° N	8-30 Km 8-12 Km 12-20Km 20-30km	-0.44(-0.03) 0.11(-0.04) -0.46(-0.05) -2.6 (0.0)	-0.4 0.15 -0.41 -2.6	-0.47(0.06) 0.03(-0.12) -0.47(-0.06) -2.5(0.01)	-0.41(-0.01) 0.1(-0.05) -0.44(-0.03) -2.4(0.02)
20° N - 60° N	8-30 Km 8-12 Km 12-20Km 20-30km	0.14(0.04) 0.13(0.07) 0.03(0.05) 0.5(0.14)	0.07 0.06 -0.02 0.36	0.04(0.02) 0.069(0.009) -0.09(-0.07) 0.38(0.02)	0.09(0.02) 0.073(0.013) -0.007(0.01) 0.49(0.13)
20° N - 20° S	8-30 Km 8-12 Km 12-20Km 20-30km	0.048(0.045) -0.02(0.01) 0.09(0.07) 0.14(0.07)	0.003 -0.03 0.022 0.07	0.022(0.02) -0.06(-0.03) 0.086(0.06) 0.097(0.03)	0.033(0.03) -0.04(-0.01) 0.095(0.07) 0.094(0.02)
20° S - 60° S	8-30 Km 8-12 Km 12-20Km 20-30km	0.35(0.13) 0.42(0.16) 0.34(0.12) 0.1(0.14)	0.22 0.28 0.22 -0.04	0.2(0.0) 0.25(-0.03) 0.21(0.01) -0.03(0.01)	0.3(0.1) 0.36(0.08) 0.33(0.11) 0.02(0.06)
60°S - 90° S	8-30 Km 8-12 Km 12-20Km 20-30km	0.72(0.06) 1.23(0.18) 0.63(0.0) -0.51(0.17)	0.66 1.05 0.63 -0.68	0.44(-0.22) 0.77(-0.28) 0.4(-0.23) -0.7(-0.02)	0.7(0.04) 1.07(0.02) 0.63(0.0) -0.43(0.25)

Ho, S.-P., Gottfried Kirchengast, Stephen Leory, Chris Rocken, Ying-Hwa Kuo, Jens Wickert, Tony Mannucci, Sergey Sokolvskiy, William Schreiner, Doug Hunt, Andrea Steiner, Ulrich Foelsche, and Chi Ao, 2008: Estimates of the Uncertainty for using Global Positioning System Radio Occultation Data for Climate Monitoring: Inter-comparisons of Refractivity Derived from Different Data Centers, *J.* of Climate (to be submitted).

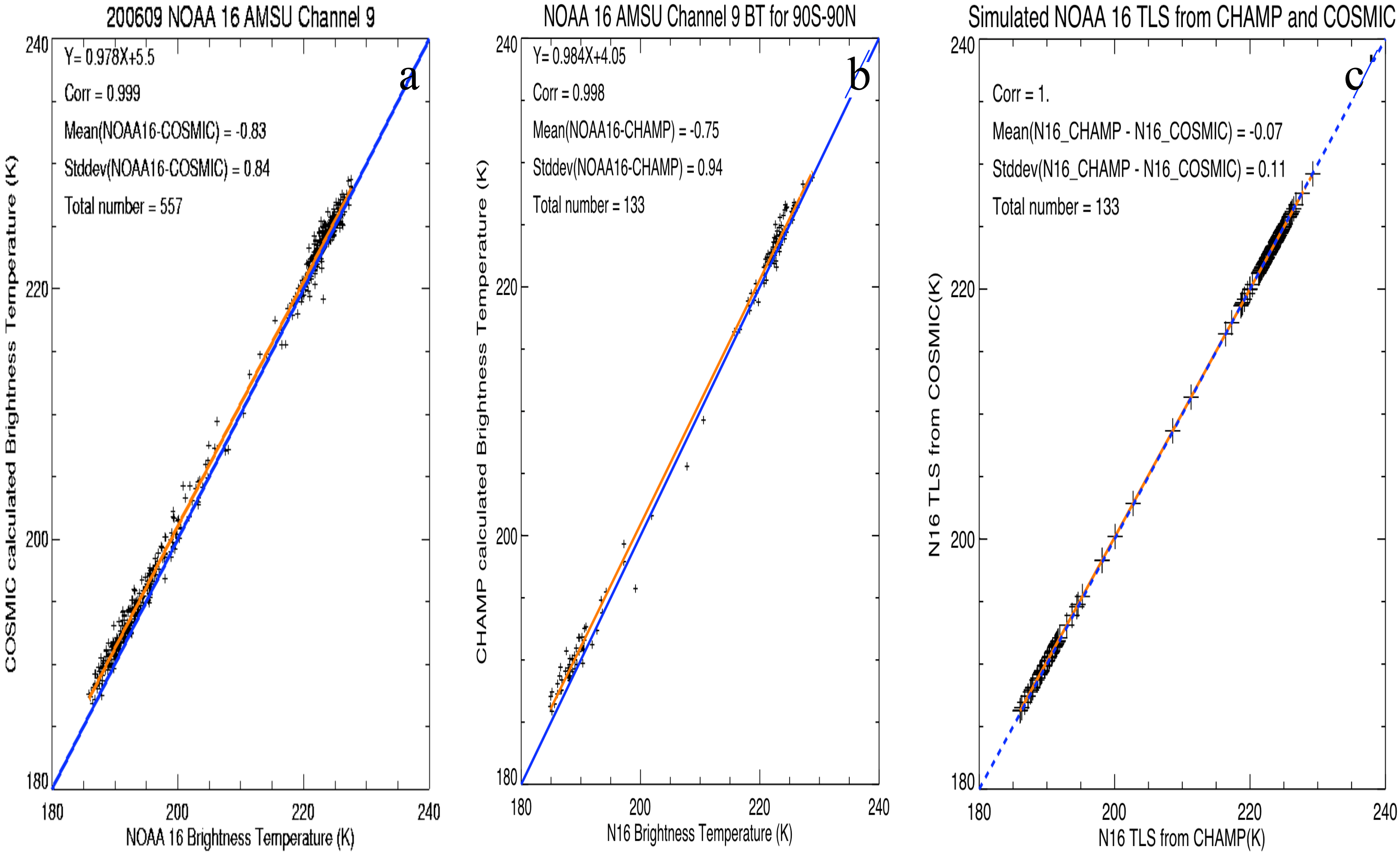
Can we use RO data to calibrate other instruments ?

200609



Slide 12 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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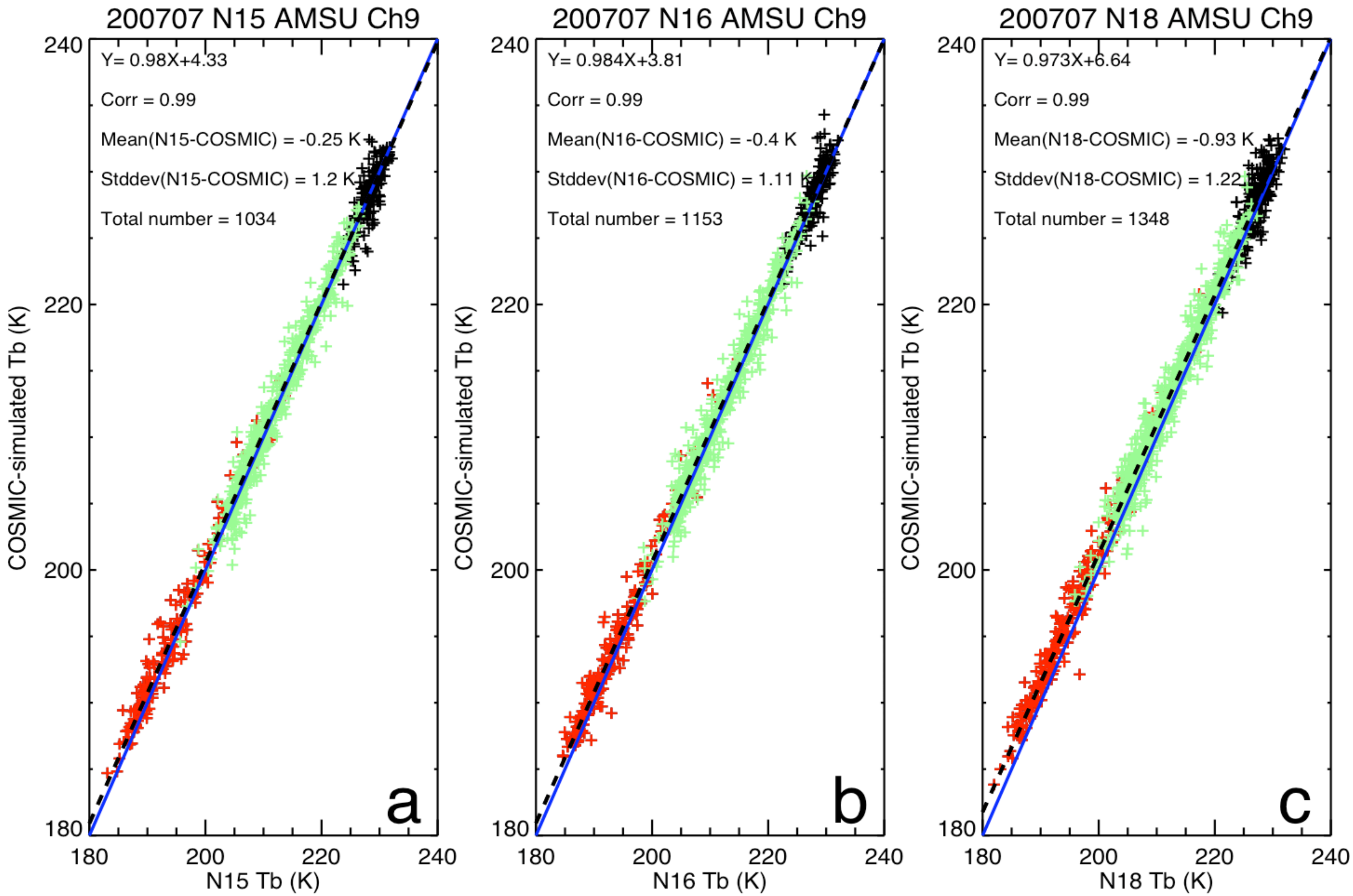
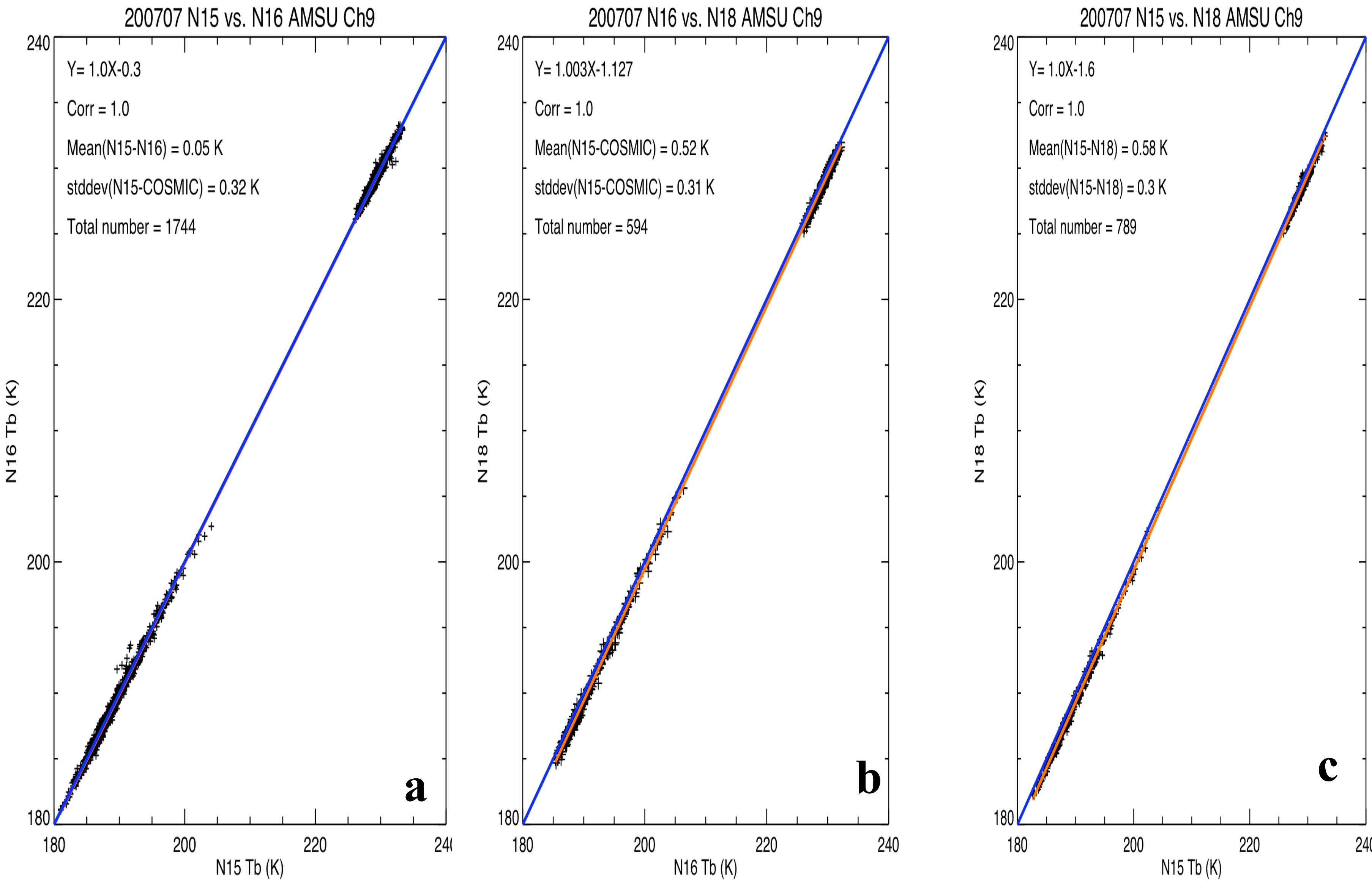
Can we use GPS RO data to identify AMSU location/local-time dependent biases ?

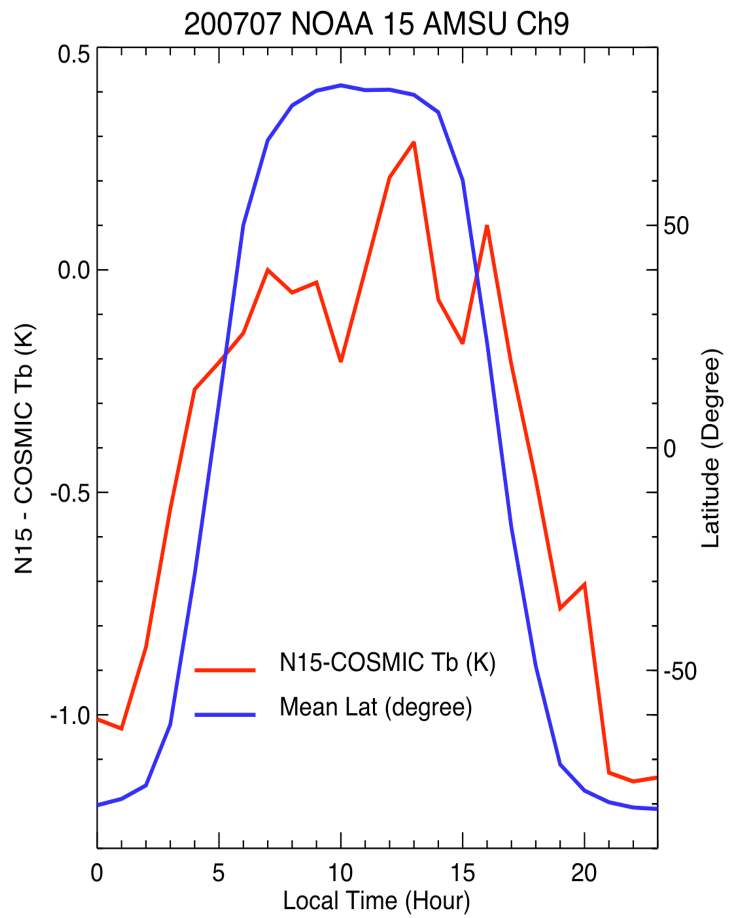


200707



200707 N15 vs. N16 AMSU Ch9
Y= 1.0X-0.3
Corr = 1.0
Mean(N15-N16) = 0.05 K
stddev(N15-COSMIC) = 0.32 K
Total number = 1744
N16 Tb (K)
N15 Tb (K)
a
200707 N16 vs. N18 AMSU Ch9
Y= 1.003X-1.127
Corr = 1.0
Mean(N15-COSMIC) = 0.52 K
stddev(N15-COSMIC) = 0.31 K
Total number = 594
N18 Tb (K)
N16 Tb (K)
b
200707 N15 vs. N18 AMSU Ch9
Y= 1.0X-1.6
Corr = 1.0
Mean(N15-N18) = 0.58 K
stddev(N15-N18) = 0.3 K
Total number = 789
N18 Tb (K)
N15 Tb (K)
c

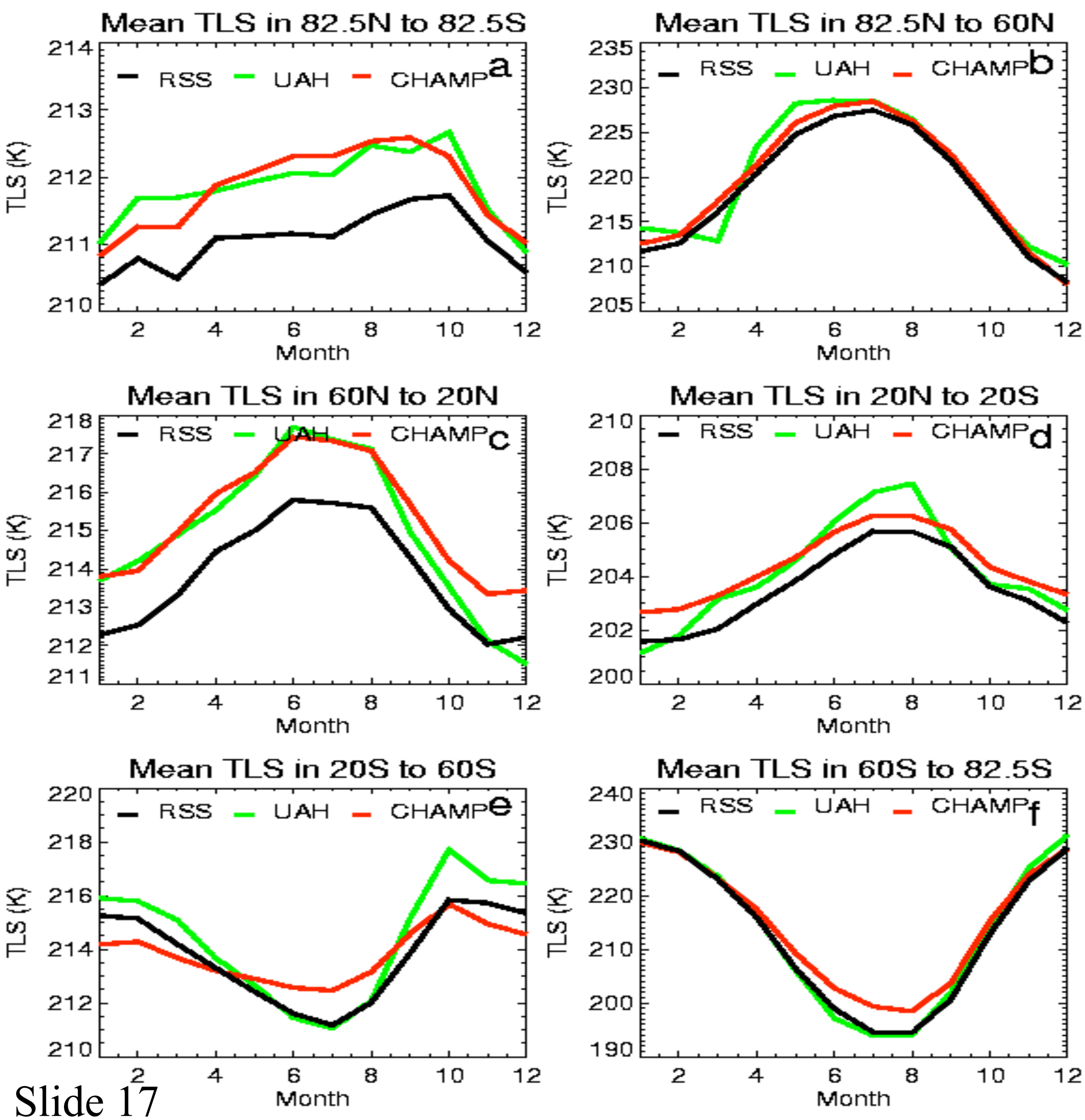
Use of RO Data to Identify the Location/local-time Dependent Brightness Temperature Biases for regional Climate Studies



	60°N-90°N	60°S-90°S
N15-COSMIC	-0.05K	-0.73K
N16-COSMIC	-0.22K	-0.83K
N18-COSMIC	-0.55K	-1.50 K
N15-N16	0.03 K	0.09 K
N16-N18	0.47 K	0.57 K
N15-N18	0.5 K	0.69 K

(Ho et al. OPAC special issue, 2007)

The 2001-2005 global mean RSS, UAH and CHAMP TLS



- Comparing to RSS_{TLS}, UAH_{TLS} has more obvious seasonal biases to that of CHAMP.
- A systematic 2-4 K cold bias at the latitudinal zone of 60°S to 82.5°S during the Southern Hemisphere winter was found for both RSS_{TLS} and UAH_{TLS} when comparing to $CHAMP_{TLS}$.

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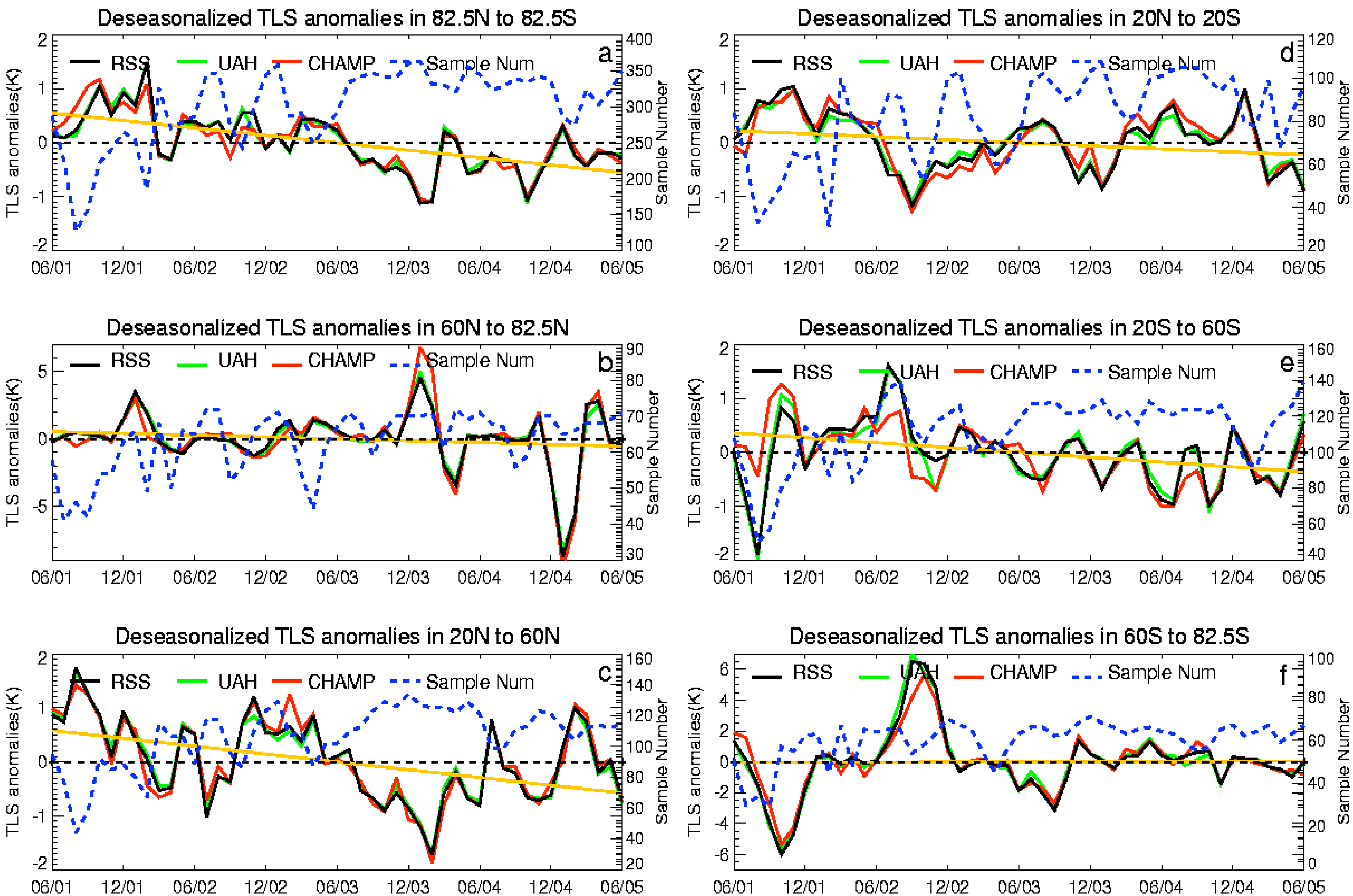

(Ho et al. GRL, 2007)

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	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

(Ho et al. GRL, 2007)

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.

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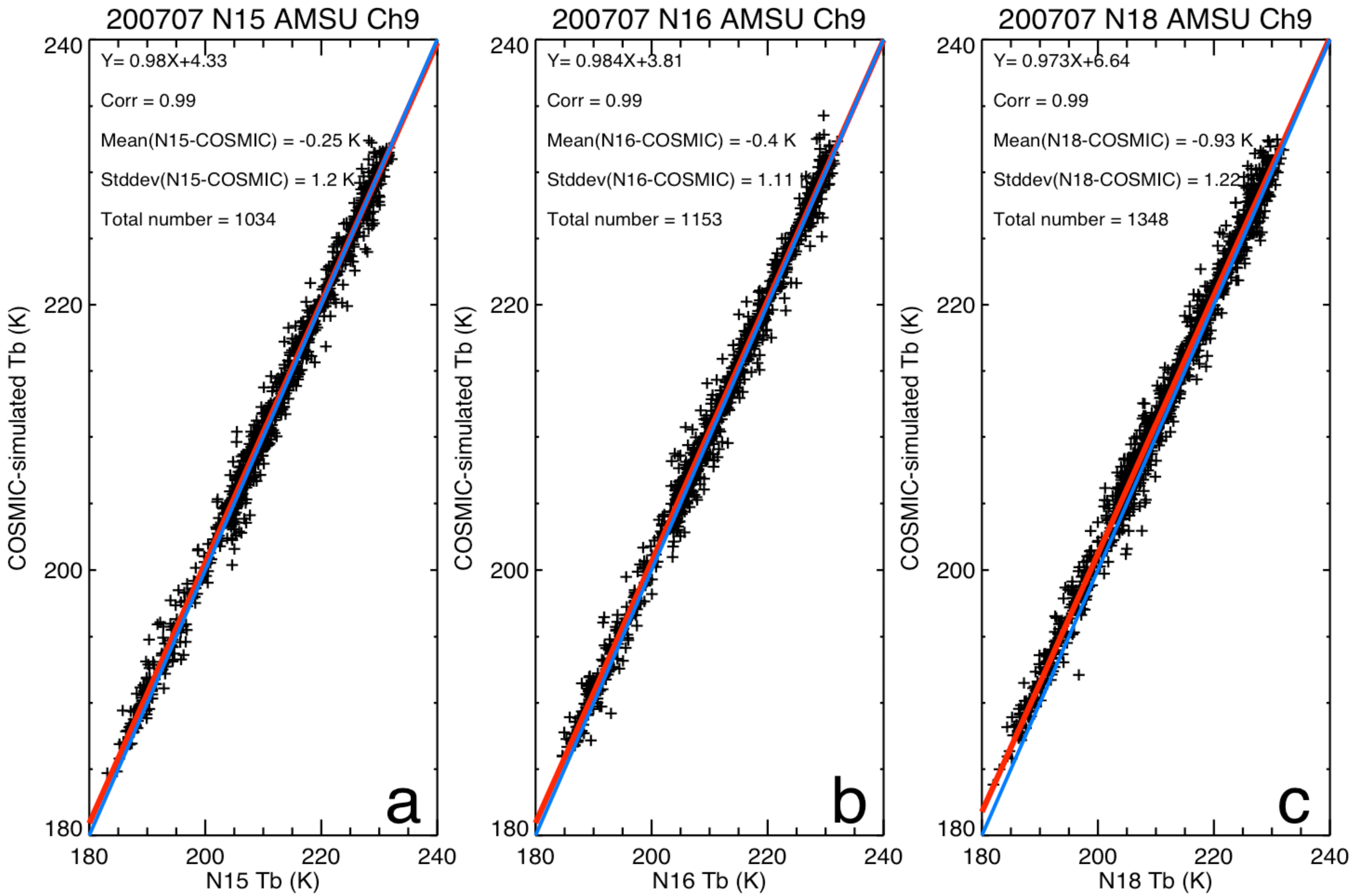
Can we use the Calibrated AMSU data to calibrate other overlapped AMSU data ?



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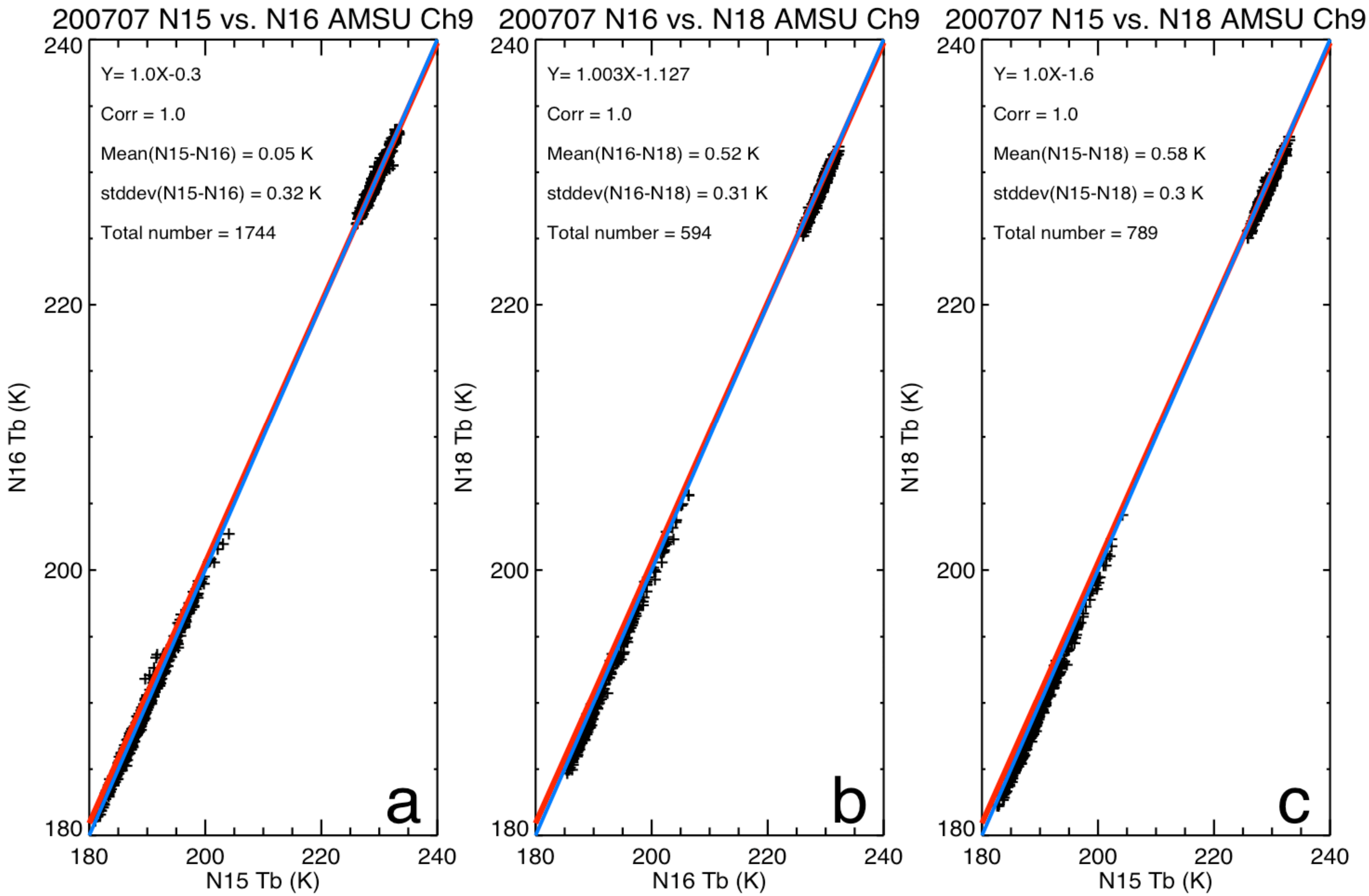
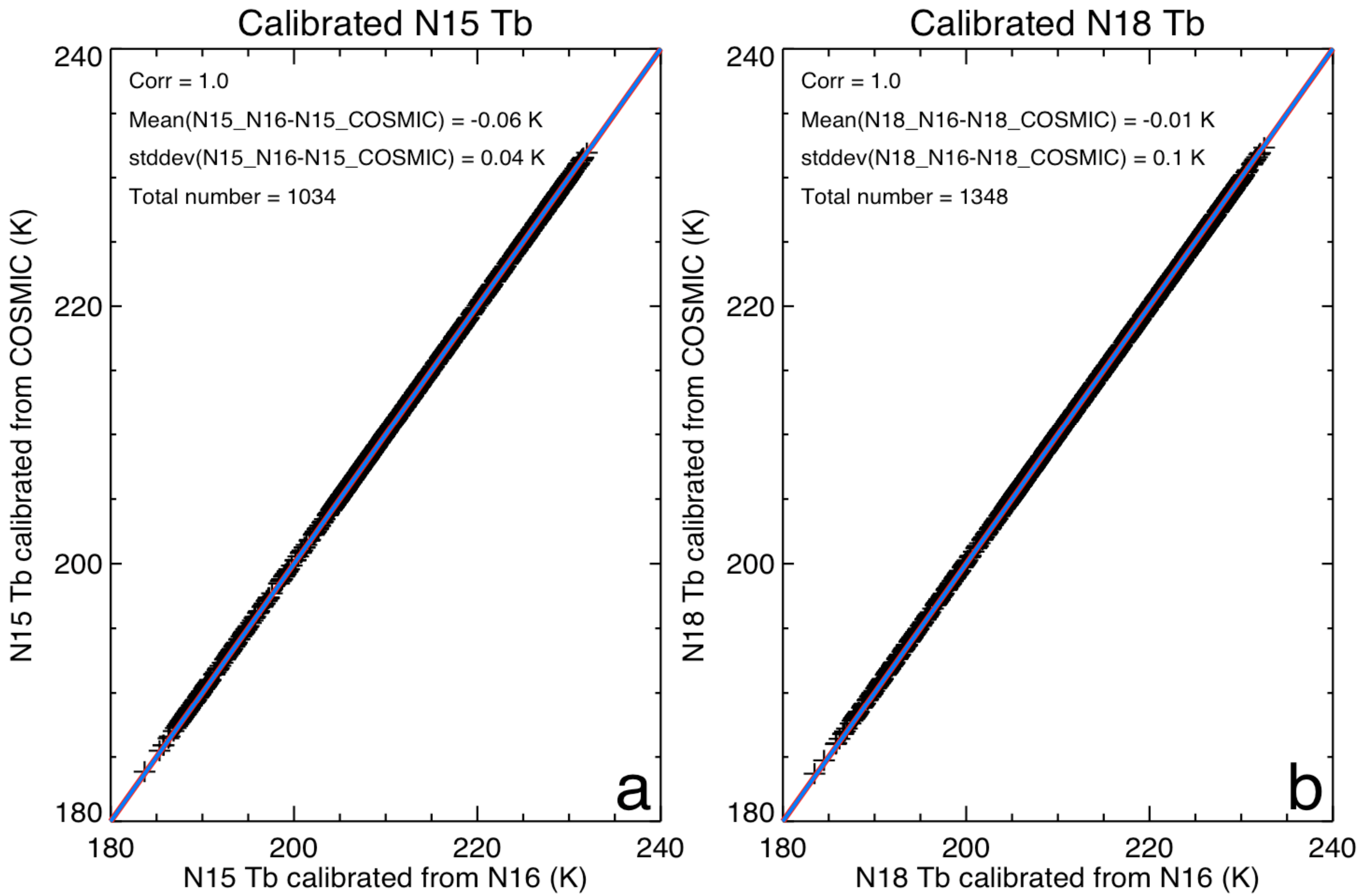
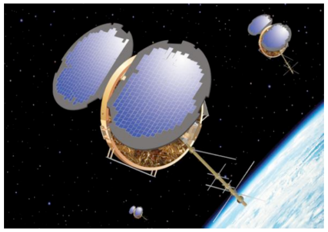


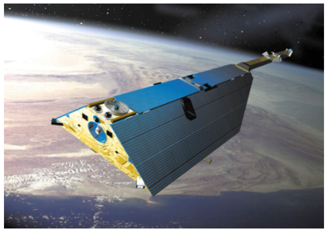
Using the Calibrated AMSU data to calibrate other overlapped AMSU data



(Ho et al. OPAC special issue, 2007)



Conclusions and Future Work



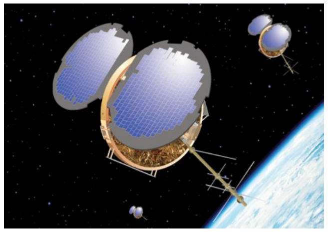
•The 0.02K-0.05 K precision of COSMIC will be very useful to inter-calibrate AMSU/MSU data.

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

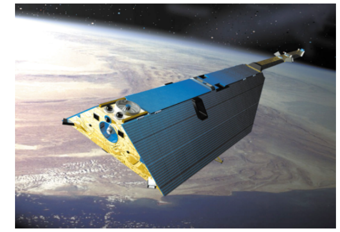
• Although different centers using different inversion procedures and initial conditions to derive refractivity, and using the different quality control criteria to bin the datasets, the mean bias for JPL-UCAR pairs is -0.05%, for GFZ-UCAR pairs is 0.001%, and for WEG-UCAR pairs is -0.3%.

• 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.

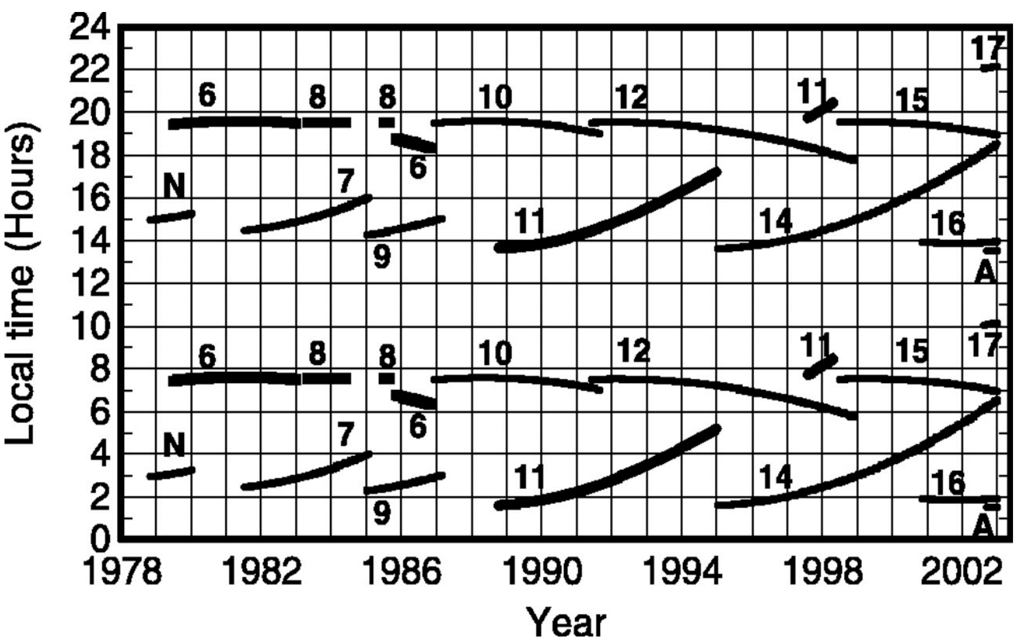
• This study demonstrates that even with different inversion procedures used by different centers, the refractivity uncertainties from GPS RO provided by different centers are reasonably consistent. GPS RO data is suitable for climate monitoring.

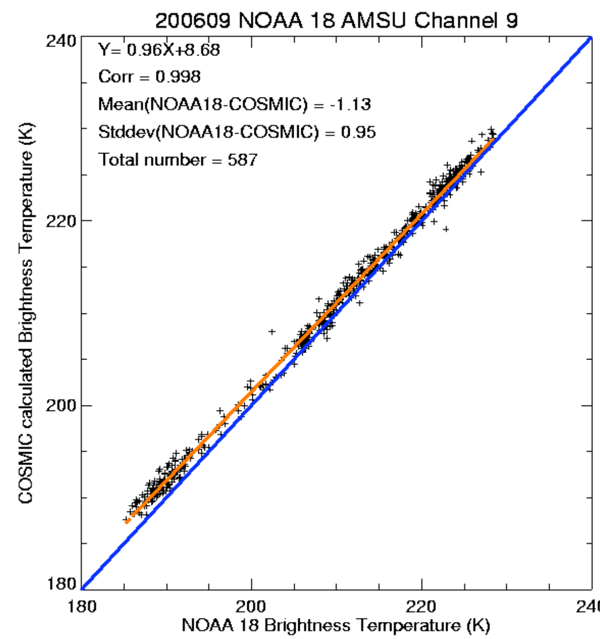


Conclusions and Future Work



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





(Ho et al. GRL, 2007) **http://www.cosmic.ucar.edu/~spho/**

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