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

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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**
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

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

COSMIC

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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 satellites (Ho et al. TAO, 2007)

Dry temperature difference between FM3-FM4 receivers
Difficulty III: to find measurements with long term stability

Global COSMIC-CHAMP Comparison from 200607-200707
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

Slide 8

Bias and std from 30km to 8 km

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8-30 km

Slide 9

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8-30 km
The uncertainty of the trend of fractional N anomalies is within +/-0.045 %/5 yrs (+/-0.06K/5 yrs).

<table>
<thead>
<tr>
<th>Fractional Anomalies (%)</th>
<th>WEG-C</th>
<th>UCAR</th>
<th>JPL</th>
<th>GFZ</th>
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<tr>
<td>90°N-90°S</td>
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<tr>
<td>8-30 Km</td>
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<tr>
<td>8-12km</td>
<td>0.12 (0.06)</td>
<td>0.06</td>
<td>0.018 (-0.04)</td>
<td>0.1 (0.04)</td>
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<tr>
<td>12-20km</td>
<td>0.28 (0.06)</td>
<td>0.22</td>
<td>0.15 (-0.07)</td>
<td>0.24 (0.02)</td>
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<tr>
<td>20-30km</td>
<td>0.08 (0.05)</td>
<td>0.03</td>
<td>-0.013 (-0.043)</td>
<td>0.07 (0.04)</td>
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<td>-0.32 (0.1)</td>
<td>-0.42</td>
<td>-0.39 (0.03)</td>
<td>-0.3 (0.12)</td>
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<tr>
<td>60°N - 90° N</td>
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<tr>
<td>8-30 Km</td>
<td>-0.44 (-0.03)</td>
<td>-0.4</td>
<td>-0.47 (0.06)</td>
<td>-0.41 (-0.01)</td>
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<td>8-12 Km</td>
<td>0.11 (-0.04)</td>
<td>0.15</td>
<td>0.03 (-0.12)</td>
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<td>12-20km</td>
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<td>-0.41</td>
<td>-0.47 (-0.06)</td>
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<td>20-30km</td>
<td>-2.6 (0.0)</td>
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<td>-2.5 (0.01)</td>
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<td>8-30 Km</td>
<td>0.14 (0.04)</td>
<td>0.07</td>
<td>0.04 (0.02)</td>
<td>0.09 (0.02)</td>
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<td>8-12 Km</td>
<td>0.13 (0.07)</td>
<td>0.06</td>
<td>0.069 (0.009)</td>
<td>0.073 (0.013)</td>
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<td>12-20km</td>
<td>0.03 (0.05)</td>
<td>-0.02</td>
<td>-0.09 (-0.07)</td>
<td>-0.007 (0.01)</td>
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<td>20-30km</td>
<td>0.5 (0.14)</td>
<td>0.36</td>
<td>0.38 (0.02)</td>
<td>0.49 (0.13)</td>
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<tr>
<td>20° N - 20° S</td>
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<tr>
<td>8-30 Km</td>
<td>0.048 (0.045)</td>
<td>0.003</td>
<td>0.022 (0.02)</td>
<td>0.033 (0.03)</td>
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<td>-0.02 (0.01)</td>
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<td>20° S - 60° S</td>
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<tr>
<td>8-30 Km</td>
<td>0.35 (0.13)</td>
<td>0.22</td>
<td>0.2 (0.0)</td>
<td>0.3 (0.1)</td>
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<tr>
<td>8-12 Km</td>
<td>0.42 (0.16)</td>
<td>0.28</td>
<td>0.25 (-0.03)</td>
<td>0.36 (0.08)</td>
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<td>0.21 (0.01)</td>
<td>0.33 (0.11)</td>
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<td>20-30km</td>
<td>0.1 (0.14)</td>
<td>-0.04</td>
<td>-0.03 (0.01)</td>
<td>0.02 (0.06)</td>
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<td>60°S - 90° S</td>
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<tr>
<td>8-30 Km</td>
<td>0.72 (0.06)</td>
<td>0.66</td>
<td>0.44 (-0.22)</td>
<td>0.7 (0.04)</td>
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<tr>
<td>8-12 Km</td>
<td>1.23 (0.18)</td>
<td>1.05</td>
<td>0.77 (-0.28)</td>
<td>1.07 (0.02)</td>
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<td>12-20km</td>
<td>0.63 (0.0)</td>
<td>0.63</td>
<td>0.4 (-0.23)</td>
<td>0.63 (0.0)</td>
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<td>20-30km</td>
<td>-0.51 (0.17)</td>
<td>-0.68</td>
<td>-0.7 (-0.02)</td>
<td>-0.43 (0.25)</td>
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Can we use RO data to calibrate other instruments?

200609

N15, N16 and N18 AMSU calibration against COSMIC

Slide 12
The precision of using GPS RO data to inter-calibrate other satellite is about 0.07 K

(Ho et al. TAO, 2007)
Can we use GPS RO data to identify AMSU location/local-time dependent biases?

Slide 14
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

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

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

Slide 15
Use of RO Data to Identify the Location/local-time Dependent Brightness Temperature Biases for regional Climate Studies

(Ho et al. OPAC special issue, 2007)
The 2001-2005 global mean RSS, UAH and CHAMP TLS

- Comparing to $\text{RSS}_{\text{TLS}}$, $\text{UAH}_{\text{TLS}}$ 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 $\text{RSS}_{\text{TLS}}$ and $\text{UAH}_{\text{TLS}}$ when comparing to $\text{CHAMP}_{\text{TLS}}$.

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(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.

(Ho et al. GRL, 2007)
Can we use the Calibrated AMSU data to calibrate other overlapped AMSU data?
Can we use the Calibrated AMSU data to calibrate other overlapped AMSU data?
Using the Calibrated AMSU data to calibrate other overlapped AMSU data

Calibrated N15 Tb

Corr = 1.0
Mean(N15_N16-N15_COSMIC) = -0.06 K
stddev(N15_N16-N15_COSMIC) = 0.04 K
Total number = 1034

Calibrated N18 Tb

Corr = 1.0
Mean(N18_N16-N18_COSMIC) = -0.01 K
stddev(N18_N16-N18_COSMIC) = 0.1 K
Total number = 1348

Slide 22 (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/