Construction of a Consistent Microwave Sensor Temperature Record in the Lower Stratosphere Using Global Positioning System Radio Occultation Data and Microwave Sounding Measurements

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1. **Motivation:**
   1) MSU/AMSU data from 1978 to 2010 are very valuable for temperature climate data records
   2) Using GPS RO data in the stratosphere and the identified radiosondes in the troposphere to validate MSU and AMSU measurements from RSS, UAH, and NESDIS
   3) Construction of a Consistent Microwave Sensor Temperature Record in the Lower Stratosphere Using Global Positioning System Radio Occultation Data and Microwave Sounding Measurements

2. **Outlines:**
   - Challenges to define/validate a global trend
   - Long term stability of GPS RO data for climate monitoring
   - Construction of a consistent Microwave Sensor Temperature Record in the lower stratosphere using GPS RO and microwave sounding measurements
   - Comparisons of RO-AMSU, RSS, UAH, and SNO

3. **Conclusions and Future Work**
Challenges for defining the Global Temperature Trend using MSU/AMSU data

Satellites: Comparability and Reproducibility?
1) Not designed for climate monitoring
2) Changing platforms and instruments
   (No Comparability)
   a. Satellite dependent bias, b. geo-location dependent bias, c. orbital drift dependent bias
3) Different processing/merging method lead to different trends (RSS vs. UAH).
   (No Reproducibility)

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.
Characteristics of GPS RO Data

- Measure of time delay (SI traceability): no calibration is needed
- Requires no first guess sounding
- Uniform spatial/temporal coverage
- High precision (<0.05K)
- Insensitive to clouds and precipitation
- No mission dependent bias
- Less sensitive to inversion algorithm (Ho et al., 2009b JGR)

Precision < 0.05 K
Using FM3-FM4 pairs in early mission
(Ho et al., TAO, 2009a)
(Anthes et al., BAMS, 2008)

COSMIC
Global COSMIC, CHAMP, SAC-C, GRACE-A, Metop/GRAS Comparison

Within 60 Mins, and 50 Km

- Comparison of measurements between old and new instrument
- CHAMP launched in 2001
- COSMIC launched 2006
- GRACE launched 2002

Don’t need to have stable calibration reference

(Ho et al., 2010 JGR in preparation)

CHAMP-COSMIC 2007-2008

GRACE-COSMIC 2006

Shu-peng Ben Ho, UCAR/COSMIC  http://www.cosmic.ucar.edu/~spho/
Approaches:

1. Data:
   COSMIC from 200606 to 200912
   CHAMP from 200106 to 200806
   RSS V3.2 200106-200912
   UAH V5.1 200106-200812
   SNO V2.0 200106-200912

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

3. 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 and generate consistent RO and MSU/AMSU TLS climate data records

Construction of a consistent RO and MSU/AMSU Temperature Climate Data Records
**Approaches:** Constructing RO-AMSU brightness temperature calibration coefficients for each month from 200106 to 200912

N15, N16 and N18 AMSU calibration against COSMIC

(Ho et al., 2009a TAO)
Approach: Use of RO Data to Identify the Location/local-time Dependent Brightness Temperature Biases for regional Climate Studies

(Ho et al. OPAC special issue, 2009c)
Comparisons of RO-calibrated AMSU with those from RSS, UAH, and SNO

200801 TLS
Comparisons of RO-calibrated AMSU with those from RSS, UAH, and SNO

200705 TLS
Comparisons over Lands and Oceans

Mean(SNO-RO_AMSU) = -0.56
Std (SNO-RO_AMSU) = 0.6

Mean(RSS-RO_AMSU) = -0.1
Std (RSS-RO_AMSU) = 1.3

Mean(UAH-RO_AMSU) = 0.03
Std (UAH-RO_AMSU) = 1.88

Mean(UAH-SNO) = -0.6
Std (UAH-SNO) = 1.4
Scattering plots of 10 x10 degree binned TLS from 200106 to 200812

Binning all into 10x10 grid
Monthly Mean for each month
Time series of TLS difference
Time series of TLS anomalies
The 2001-2008 trends of de-seasonalized lower stratospheric Tb anomalies (in K/5yrs) for RSS, UAH, RO-AMSU Tb, RSS-RO_AMSU and UAH-RO_AMSU for the global (82.5°N-82.5° S) and five latitudinal zones.

<table>
<thead>
<tr>
<th></th>
<th>RSS</th>
<th>UAH</th>
<th>SNO</th>
<th>RO_AMSU</th>
<th>RSS-RO_AMSU</th>
<th>UAH-RO_AMSU</th>
<th>SNO-RO_AMSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>82.5°N-82.5° S</td>
<td>-0.59</td>
<td>-0.46</td>
<td>-0.48</td>
<td>-0.41</td>
<td>-0.18</td>
<td>-0.05</td>
<td>-0.07</td>
</tr>
<tr>
<td>60°N - 82.5° N</td>
<td>-1.04</td>
<td>-0.67</td>
<td>-0.74</td>
<td>-0.62</td>
<td>-0.42</td>
<td>-0.05</td>
<td>-0.12</td>
</tr>
<tr>
<td>20° N - 60° N</td>
<td>-0.60</td>
<td>-0.30</td>
<td>-0.31</td>
<td>-0.24</td>
<td>-0.42</td>
<td>-0.06</td>
<td>-0.07</td>
</tr>
<tr>
<td>20° N - 20° S</td>
<td>0.55</td>
<td>0.07</td>
<td>0.05</td>
<td>0.1</td>
<td>0.45</td>
<td>-0.03</td>
<td>-0.05</td>
</tr>
<tr>
<td>20° S - 60° S</td>
<td>-0.52</td>
<td>-0.38</td>
<td>-0.37</td>
<td>-0.29</td>
<td>-0.23</td>
<td>-0.09</td>
<td>-0.08</td>
</tr>
<tr>
<td>60°S - 82.5° S</td>
<td>-3.22</td>
<td>-1.70</td>
<td>-1.80</td>
<td>-1.70</td>
<td>-1.52</td>
<td>0.0</td>
<td>-0.1</td>
</tr>
</tbody>
</table>

Although the de-seasonalized TLS anomalies from UAH and SNO are, in general, agree well with that from RO-calibrated AMSU TLS in all latitudinal zones, small trend differences are found among SNO, UAH, and RO-calibrated AMSU.
Difference of TLS anomalies
Difference of TLS anomalies for UAH V5.1 vs. V5.2 RSS V2.1 vs. V3.2

(Ho et al., 2007)
Approach: Using Multi-year of RO data to assess the quality of radiosonde data

COSMIC from 2006 to 2009
CHAMP from 2001 to 2008
Radiosonde data DS351.0 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

<table>
<thead>
<tr>
<th>Region</th>
<th>Sonde Type</th>
<th>Matched Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>AVK-MRZ</td>
<td>2000 (20%)</td>
</tr>
<tr>
<td>China</td>
<td>Shang</td>
<td>650 (6.1%)</td>
</tr>
<tr>
<td>USA</td>
<td>VIZ-B2</td>
<td>600 (5.9%)</td>
</tr>
<tr>
<td>Others</td>
<td>Vaisala</td>
<td>3140 (30%)</td>
</tr>
</tbody>
</table>

Collocate COSMIC/CHAMP and radiosonde profiles
< 200 km
< 3 hrs  (He and Ho 2009 GRL)
Identify systematic radiosonde temperature biases using RO data

(He and Ho 2009 GRL)
Using RO data to Correct Diurnal variation of Radiosonde Temperature Anomalies

Solar absorptivity = 0.15
IR emissivity = 0.85
USA VIZ-B2 150hPa

Mean Bias = 0.217
Abs(Mean) Bias = 0.511
MeanSD = 1.441

Solar absorptivity = 0.15
IR emissivity = 0.02
Vaisala 150 hPa

Mean Bias = -0.053
Abs(Mean) Bias = 0.097
MeanSD = 1.563

(Ho et al., 2010 in preparation)
COSMIC vs. AMSR-E and GB-GPS total column water vapor

(Mears et al., 2010 BAMS)
Conclusions and Future Work

• The 0.02K-0.05 K precision of RO soundings are very useful to inter-calibrate AMSU/MSU data.

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

• The RO calibrated AMSU TLS matches better with SNO and RSS in terms of variations (higher correlation coefficient) and matches better with UAH and SNO in terms of mean.

• The de-seasonalized TLS anomalies from UAH and SNO are, in general, agree well with that from RO calibrated AMSU Tb in all latitudinal zones. Small trend differences are found among SNO, UAH, and RO-calibrated AMSU.

• In the future we will use RO calibrated AMSU/MSU to calibrate overlapped AMSU/MSU to construct temperature trend analysis using 30 years of MSU/AMSU data. GPS RO data is suitable for climate monitoring.