An Intercomparison of Tropospheric and Stratospheric Temperatures Measured by SABER and GPS

S.E. Palo¹, X. Zhang¹, J.M. Forbes¹, the TIMED SABER Team and the GPS Earth Observatory Team

The TIMED SABER Team
J.M. Russell², M. Mlynczak³ and C. Mertens²

The GPS Earth Observatory Team⁴
A. Mannucci, G. Hajj, C. Ao, B. Iijima, M. De La Torre Juarez, T. Meehan, D. Kuang and D. Dong

1 University of Colorado, Boulder CO
2. Hampton University, Hampton VA
3. NASA Langley Research Center, Langley VA
4. NASA Jet Propulsion Laboratory, Pasadena CA
Overview

• Instrument overview
  - GPS measurement technique

• Comparison overview

• Coincident statistics

• Representative temperature profiles

• Statistical temperature results

• Preliminary pressure results (selected)

• Summary
SABER Measurements

- Near to mid (1.27\(\mu\)m-17\(\mu\)m) infrared radiometer
- Limb viewing
- Both day and night measurements
- Absolute vertical registration using NCEP
- Temperature and pressure are determined from CO\(_2\) radiances at 14.9\(\mu\)m and 15.2\(\mu\)m
- Estimated accuracy 1.0K (prelaunch)
- Estimated precision 0.3K (prelaunch)
- Analysis using version 1.04 nLTE inversions
GPS Measurements

- Refraction of GPS signals (carrier phase)
  - $L_1 = 1575.42$ MHz
  - $L_2 = 1227.60$ MHz

- Radio occultation technique

- JPL Blackjack receiver

- Day and night measurements

- Basic measurement is ray bending

- Ionospheric contribution is removed via dual frequency measurements

- Hydrostatic integral used to determine temperature
  - Integral is seeded using NCEP

- Estimated accuracy 0.5K (individual profile)
The GPS occultation technique

Doppler Measurement

Bending vs Altitude

Abel transform

Refractivity vs Altitude

Ideal gas, hydrostatic equilibrium

\[ N = a_1 \frac{P}{T} + a_2 \frac{P_w}{T^2} + 40.3 \frac{n_e}{f_i^2} \]

\[ \frac{dP}{dh} = -\rho g \]

\[ \rho = \rho_{dry} + \rho_{water} = \frac{1}{RT} \left[ m_{dry} P + (m_{water} - m_{dry}) P_w \right] \]

\( T, P \) versus height
Comparison Overview

- GPS data from receivers on CHAMP and SAC-C
  - CHAMP (near circular, 87°, 454km)
  - SAC-C (circular, sun-sync 98.2°, 702km)
  - CHAMP & SAC-C provide 400 occultations per day

- Temperature and Pressure
  - April 2002 and August 2002

- Coincident Requirement
  - Solar local time difference < 1 hour
  - Angle between tangent points of each measurement measured to the center of the geoid < 2°, this corresponds to ~300km between tangent points.
Coincident Measurement Statistics
CHAMP/SABER coincidence statistics

Latitude Distribution of CHAMP/SABER Coincident Measurements

Distance Distribution of CHAMP/SABER Coincident Measurements

101 measurements
SAC-C/SABER coincidence statistics

Latitude Distribution of SAC-C/SABER Coincident Measurements

Distance Distribution of SAC-C/SABER Coincident Measurements

39 measurements
Representative Temperature Profiles
Temperature Comparison (April 2002)

GPS vs. SABER vs. NCEP

A typical profile

**SABER**

**NCEP**

**GPS**

Difference

**CHAMP_GPS - NCEP**

**SABER - CHAMP_GPS**

**SABER - NCEP**

<table>
<thead>
<tr>
<th>AVG GPS (NCEP)</th>
<th>AVG SABER</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAT -66.1°</td>
<td>-65.7°</td>
</tr>
<tr>
<td>LON 278.6°</td>
<td>275.7°</td>
</tr>
<tr>
<td>SLT 7.06</td>
<td>7.92 hour</td>
</tr>
<tr>
<td>UT 12.3</td>
<td>13.5 hour</td>
</tr>
<tr>
<td>DATE 4/1/2002</td>
<td></td>
</tr>
</tbody>
</table>
Good tropospheric agreement

Stratospheric gravity wave? ($\lambda_z = 5\text{km}$)

Shift in tropopause height
Tropospheric rollover
Temperature Comparison (April 2002)
GPS vs. SABER vs. NCEP

Noisy GPS Data

Low SNR?

CHAMP_GPS - NCEP
SABER - CHAMP_GPS
SABER - NCEP

AVG GPS(NCEP) AVG SABER
LAT -59.5° -59.5°
LTN 82.92° 80.45°
SLT 6.53 6.08 hour
UT 0.90 0.71 hour
DATE 4/11/2002
Statistical Temperature Comparison
CHAMP – April 2002 using all data
SAC-C – April 2002 using all data
CHAMP – April 2002 using $|\text{lat}| < 40$
CHAMP – April 2002 using |lat| > 40
Preliminary Pressure Profiles
Low pressure bias?

Pressure scaled by $\exp(z/H)$

$H=6.5\text{km}$
High pressure bias?
Summary

- Comparison for both CHAMP & SAC-C show a 1-2K warm bias for SABER compared with GPS
- Bias decreases above 25km
- Smallest variance occurs between 15km and 25km
- Bias does not show significant latitudinal differences
- Preliminary: SABER shows a low pressure bias at low latitudes and a high pressure bias at high latitudes
- Future work
  - Compare observations for August 2002
  - Compare refractivity profiles up to 50km
  - Compare upper tropospheric and lower stratospheric water vapor
  - Combine observations to estimate stratospheric nonmigrating tides