Effects of GPS/RO refractivities on IR/MW retrievals

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Outline

• Motivation
• Characteristics of the two types of systems
• Simulation approach
• Results of simulation studies
• Preliminary results with real data
• Summary, Future plans
Temperature
NOAA17
NCEP Model minus ATOVS
IAPP retrieval
Jul 01 to Oct 20 2003
## Characteristics of the two types of systems

<table>
<thead>
<tr>
<th></th>
<th>GPS/RO</th>
<th>IR and MW (ATOVS)</th>
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<tbody>
<tr>
<td></td>
<td>good absolute accuracy</td>
<td>high horizontal resolution, poor vertical resolution</td>
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<tr>
<td></td>
<td>very high vertical resolution, poor horizontal resolution</td>
<td>information from the total atmospheric column</td>
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<td>information in upper troposphere and stratosphere</td>
<td>more information on lower tropospheric temperature</td>
</tr>
<tr>
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<td>high accuracy around tropopause</td>
<td>little information around the tropopause</td>
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<td>“all weather” instrument</td>
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Geometry of radio occultation

\[ N = 77.6 \frac{P}{T} + 3.73 \times 10^5 \frac{P_w}{T^2} + 4.03 \times 10^7 \frac{n_e}{f^2} + 1.4W \]
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Statistical regression retrieval method

NOAA88 data set (training 90 %)  
(Forward Models)  
Simulated Brightness Temperatures, Refractivities, SFC  
(BT, N, T_{sfc}, W_{sfc}, BT^2, N^2, T_{sfc}^2, W_{sfc}^2)  
Regression Coefficients  
Temp and Humidity Retrievals (NOAA88 – test 10 %)
Simulation of data

ATOVS/CrIS brightness temperatures:

- model called **PFAAST** (pressure layer fast algorithm for atmospheric transmittances)
- 42 pressure level from 0.1 to 1050 hPa
- **Noise**: NedT + 0.2 K forward model noise
- 39 ATOVS channels, 393 selected CrIS channels

GPS/RO refractivity profiles:

- 1 km vertical resolution between 6 and 28 km (23 levels)

\[ N(z) = c_1 \frac{P(z)}{T(z)} + c_2 \frac{P_w(z)}{T^2(z)} \]

- Vertically correlated measurements errors
  (Healy & Eyre, 2000; Kursinski et al., 1997)

Surface temperature:

\[ T_{sfc} = T_{\text{lowest}} + \text{noise}(0.5K) \] (Kelvin)

Surface mixing ration:

\[ w_{sfc} = w_{\text{lowest}} + \text{noise}(10\%) \] (g/g)
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  - Impact of different sources of information
  - Impact of GPS noise
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Impact of different sources of information

Retrievals from different combinations of satellite data (IR, MW, and GPS/RO) are compared to radiosonde profiles

- RTVL(IR)
- RTVL(GPS)
- RVL(IR + SFC)
- RTVL(IR +GPS)
- RTVL(IR +AMSU + SFC) ……

Better agreement with radiosondes assumed to indicate improved retrievals

Statistics of bias and rms differences calculated

- 1 km layers of temperature profiles
- 2 km layers of mixing ratio profiles up to 300 hPa

\[
BIAS = \frac{1}{n} \sum \frac{w_{true} - w_{retr}}{w_{true}} \\
RMS = \sqrt{\frac{1}{n} \sum \left(\frac{w_{true} - w_{retr}}{w_{true}}\right)^2}
\]
RMS/bias diff of simulated temp retrievals from diff systems

wo SFC data

w SFC data

- GPS
- ATOVS
- CrIS+AMSU
- ATOVS+GPS
- CrIS+AMSU+GPS
RMS/bias diff of simulated moist retrievals from diff systems

wo SFC data

w SFC data

-40 -20 0 20 40 60 80
RMS/bias of moist retrievals (%)

-40 -20 0 20 40 60 80
RMS/bias of moist retrievals (%)

GPS
ATOVS
CrIS+AMSU
ATOVS+GPS
CrIS+AMSU+GPS
RMS difference of simulated temperature retrievals (K)

IR=HIRS
IR=CrIS

IR + AMSU

GPS/RO improvement

SFC improvement

AMSU improvement

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)
RMS difference of simulated moisture retrievals (%)

IR=HIRS
IR=CrIS

IR + AMSU
Impact of GPS/RO noise
Summary of simulation studies

GPS/RO improves:

HIRS (GOES) temp retrievals
- from the tropopause by 1.8 K down to 450 hPa by 0.5 K. (Wu et al., 1998)
- between 10 hPa and the tropopause by about 0.8 K

ATOVS (AMSU plus HIRS) temp retrievals
- around the tropopause level by 0.8 K.
- between 30 hPa and the tropopause by about 0.5 K.

CrIS+AMSU temp retrievals
- between 10 hPa and the tropopause by about 0.4 K (Collard and Healy, 2003)

HIRS (GOES) moist retrievals
- at 250 hPa by 5 % and at 700 hPa by about 2 %.

ATOVS moist retrievals
- from 250 to 780 hPa by about 2.5 %.

Tripling GPS/RO N noise lowers the ATOVS temperature improvement
- by 0.5 K from 85 to 350 hPa

real studies !!!!
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## Data

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<th>GPS/RO data</th>
<th>CHAMP and SACC (from GFZ &amp; JPL)</th>
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<tbody>
<tr>
<td></td>
<td>May 2001 to July 2002</td>
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<tr>
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<td>1 km vertical resolution between 8 and 30 km (~350 to 10 hPa)</td>
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<td>excluding polar regions</td>
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<tr>
<td>IR/MW data:</td>
<td>NOAA-16 ATOVS BT (processed by IAPP at CIMSS)</td>
</tr>
<tr>
<td></td>
<td>16 HIRS + 12 AMSU-A + 4 AMSU-B</td>
</tr>
<tr>
<td></td>
<td>3X3 HIRS FOVs</td>
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<td>mean of the clear sky FOVs / all 9 cloudy FOVs</td>
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<tr>
<td>RAOB NWP</td>
<td>AVN / NCEP analyses (00, 06, 12, 18 UTC)</td>
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<tr>
<td>Collocations:</td>
<td>interpolation to GPS/RO measurements (11 km altitude)</td>
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<tr>
<td></td>
<td>vertical interpolation to ATOVS pressure levels</td>
</tr>
<tr>
<td></td>
<td>within 3 hour, 300 km</td>
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<tr>
<td></td>
<td>for multiple ATOVS FOVs choose clearest and closest in time</td>
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</tbody>
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Regression retrieval

- Statistical regression (similar as simulation studies)
- Two sets: with and without GPS/RO data
- Training data: AVN/NCEP analyses
- Validation data: RAOB collocations (excluded from training data)
- Four months (representative of four seasons)
- Classify by clear/cloudy & sea/land
- In cloudy conditions only MW channels are used
- QC: if deviation from RAOB >10 %, then temperature retrieval is rejected
RAOBD validation of CHAMP/SACC refractivities for April 2002

- North midlat
- Subpolar
- Polar
- South midlat
- Tropic
- All

Nb: 76, 164, 27, 33, 24, 324

CHAMP
SACC
GPS/RO (CHAMP) data improves the radiometric (ATOVS) temp retrievals around the tropopause by 0.5 K (larger impact over the cloudy skies)
Summary

• Simulation studies showed GPS/RO improve radiometric temperature retrievals

• Refractivity data are most different in the tropics and most alike in the sub polar region; refractivity data are most different above 100 hPa

• Quality of SAC-C and CHAMP refractivity data within 1% overall

• GPS/RO refractivity data improves the radiometric (ATOV5) temp retrievals around the tropopause by 0.5 K (larger impact over the cloudy skies)
Future plans

- Conduct similar studies with a high resolution IR data (AIRS)