Characteristics of Radiosonde Observations and their Impact in Satellite Sounding Product Validation

Bomin Sun\textsuperscript{1,2}, Tony Reale\textsuperscript{2}, Frank Tilley\textsuperscript{1,2}, and Mike Pettney\textsuperscript{1,2}

\textsuperscript{1} I. M. Systems Group, Inc., Rockville, Maryland
\textsuperscript{2} NOAA/NESDIS/STAR, College Park, Maryland
Goals

1. What are the RAOB error characteristics & how they are reflected in satellite retrieval validation
   - Temperature
   - Humidity
   Coarse-layer averaging statistics:
   ~1 km for AVTP and ~2 km for AVMP

2. To what extent that satellite retrieval can detect atmospheric structures shown in RAOBs
   - Atmospheric boundary layer
     - Surface-based inversion
     - Unstable boundary layer
   - Tropopause

100-lvl retrieval profiles are utilized.
Data

- MetOp-A IASI L2 sounding product developed by NOAA NESDIS.

- Three-yr (2010-2012) RAOB-IASI collocations collected via NPROVS.

- qc-accepted IR+MW IASI retrieval profiles.

Collocations within 6-hr & 50-km
- Sample: 550,500 (939 sites)

Collocations within 3-hr & 50-km
- Sample: 313,500 (837 sites)

Collocations within 1-hr & 50-km
- Sample: 99,000 (541 sites)
NOAA Products Validation System (NPROVS)

Centralized RAOB and Satellite Product Collocation

- Conv RAOB
- DropSonde
- NWP

NASA-EOS-Aqua
AIRS v.6

FORMOSAT-3
COSMIC
(UCAR)

DMSP F-16,18,19
MIRS

S-NPP
NUCAPS
MIRS

MetOp-B
ATOVS, MIRS,
IASI, IASI (EU)
GRAS

MetOp-A
ATOVS, MIRS,
IASI, IASI (EU)
GRAS

NOAA-18, 19
ATOVS, (19)
MIRS (18,19)

GOES
IR Soundings

6-hour
150km

NWP:
- GFS
- CFSR
- ECMWF

Every Day since April 2008... over 2 million stored

Collocation DataSet

“single closest”

https://www.star.nesdis.noaa.gov/smcd/opdb/nprovs

Poster 4p.02
Simplified flow diagram of the NOAA IASI retrieval algorithm

- Climatological First Guess
- Microwave Physical for $T(p)$, $q(p)$, LIQ(p), $\varepsilon(f)$
- $R_{\text{warm}}$ Regression for $T_s$, $T(p)$, $q(p)$
- Initial Cloud Clearing, $\eta_j$, $R_{\text{ccr}}$
- $R_{\text{ccr}}$ Regression for $T_s$, $\varepsilon(v)$, $T(p)$, $q(p)$
- IR Physical $T_s$, $\varepsilon(v)$, $\rho(v)$
- Improved Cloud Clearing, $\eta_j$, $R_{\text{ccr}}$
- IR Physical $T(p)$
- IR Physical $q(p)$
- IR Physical $O_3(p)$
- Final Cloud Clearing, $\eta_j$, $R_{\text{ccr}}$
- IR Physical $T_s$, $\varepsilon(v)$, $\rho(v)$
- IR Physical $T(p)$
- IR Physical $CO(p)$
- IR Physical $HNO_3(p)$
- IR Physical $CH_4(p)$
- IR Physical $CO_2(p)$
- IR Physical $N_2O(p)$

Courtesy of C. Barnet
RAOB Accuracy Impact in Validation

- RAOB measurement accuracy characteristics and impact on satellite validation
  - Temperature
  - Humidity
Errors in RAOB T and Impact in Validation

Radiosonde T error

IASI-minus-RAOB T diff.

Solar Elevation Categories
- NIGHT (<−7.5 deg)
- DAWN/DUSK (−7.5 − 7.5 deg)
- LOW (7.5 − 22.5 deg)
- HIGH (>22.5 deg)

Radiosonde temperature radiation-induced errors (Sun et al., 2013, JGR).

Collaborating with NCEP to improve their radiosonde “RADCOR” in DA.
RAOB Temperature error impact in validation

For 10-150 hPa

RAOB temperature error: 0.27 K
IASI-minus-RAOB difference: -0.32 K

“Cold bias” in IASI-minus-RAOB at UTLS is largely due to warm bias in RAOB
Radiosonde type relative humidity (RH) bias

Most sonde types have a dry bias at upper levels particularly during daytime.

Russian sonde is one of the few exceptions, showing a wet bias.

RS92

MRZ

Calculated RAOB BT -minus-satellite observed BT for 183+/− 1 GHz

Sun et al. (2010, JGR)
RAOB humidity error impact in validation

RAOB humidity tends to have a dry bias particularly at the upper level during daytime.

This bias largely leads to a “wet bias” in satellite data validated.

Recommend: use nighttime data
However, conventional RAOBs are useful in satellite product validation

**An example:** as the independent data source verifying the consistency among cloud, temperature and humidity in the IASI retrieval system

![Graph showing relative humidity vs. cloud fraction. The graph includes two lines, one solid and one dotted. The solid line represents IASI data for 220hPa - 425hPa and 650hPa - surface, while the dotted line represents RAOB data. The graph is based on 3-yr data.](attachment:graph.png)
RAOB vs. IASI atmospheric structure

- Atmospheric structure features in RAOB vs. IASI retrieval profiles
  - Surface inversion
  - Unstable boundary layer (surface-based inversion cases excluded)
  - Tropopause
Surface-based temperature inversion statistics in RAOBs

Based on 3-yr global data (445,000 profiles)

Inversion strength (K)

Box-and-Whisky:
- 90th
- 75th
- 50th
- 25th
- 10th

Inversion depth (km)

Surface inversion layer
- Depth: 876 m
- Strength: 6.2 K
Surface-based inversion statistics: RAOB vs. IASI

Based on 3-yr RAOB-IASI collocations within 1-hr window

RAOB Inversion | IASI Inversion
---|---
YES (100) | YES (51)
NO (100) | NO (88)

54% of IASI are within 0.75 K of RAOB

42% of IASI are within 150 m of RAOBs
Detection of convective/unstable boundary layer

RAOB profile

Unstable boundary layer

Capped inversion layer

Boundary layer height
RAOB vs. IASI unstable boundary layer height
(with surface inversion cases excluded)

58% of IASI are within 150 m of RAOBs

Sample 2905  4018  5199  3710
### RAOB and IASI Time Difference Matters in boundary layer detection comparison

<table>
<thead>
<tr>
<th>RAOB and IASI within 3-hr diff.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RAOB Inversion</td>
<td>IASI Inversion</td>
</tr>
<tr>
<td>YES (33829)</td>
<td>YES 42%</td>
</tr>
</tbody>
</table>

Unstable boundary layer height
RAOB median height is 1241 m, higher than IASI by 239 m.

<table>
<thead>
<tr>
<th>RAOB and IASI within 1-hr</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RAOB Inversion</td>
<td>IASI Inversion</td>
</tr>
<tr>
<td>YES (11455)</td>
<td>YES 51%</td>
</tr>
</tbody>
</table>

Unstable boundary layer height
RAOB median height: 1203 m, higher than IASI by 80 m.

<table>
<thead>
<tr>
<th>RAOB and IASI within 0.5-hr or less?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RAOB Inversion</td>
<td>IASI Inversion</td>
</tr>
<tr>
<td>YES (2160)</td>
<td>YES 55%</td>
</tr>
</tbody>
</table>
RAOB vs. IASI tropopause pressure based on 3-yr collocation data

Based on 3-yr data, tropopause in IASI is 6.1 (±42.9) hPa higher than in RAOB.
Summary

- Conventional RAOBs are useful in retrieval product evaluation on individual variables and the physical consistency of different variables as well.

- RAOB accuracy issues include T warm bias at UTLS and humidity dry bias in cold & dry environment.

- IASI retrievals can basically capture the climatological characteristics of atmospheric structures (i.e., surface inversion, boundary layer height, and tropopause) shown in radiosonde profiles, but

- Challenge is there for the structure detection on individual profile basis.
Final retrieval and its first-guess vs. radiosonde

AIRS overpass 18 minutes after RS92 launch at Beltsville
IASI retrieval vs. its first-guess

Retrieval accuracy vs. cloud fraction

Solid: retrieval
Dotted: first-guess

Cloud fraction (%)