Comparison of Selected In-Situ and Remote Sensing Technologies for Atmospheric Humidity Measurement

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95th AMS Annual Meeting
19th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)
# Radiosonde Humidity Measurement

**RS92 vs. RS41**

<table>
<thead>
<tr>
<th>Radiosonde</th>
<th>RS92-SGPD</th>
<th>RS41-SG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor type</td>
<td>Thin-film capacitor, heated twin sensor</td>
<td>Thin-film capacitor, integrated T sensor, heating functionality</td>
</tr>
<tr>
<td>Uncertainty in sounding</td>
<td>5 %RH</td>
<td>4 %RH</td>
</tr>
<tr>
<td>Response time (63 %)</td>
<td>&lt; 20 s (T=-40 ºC)</td>
<td>&lt; 10 s (T=-40 ºC)</td>
</tr>
<tr>
<td>Ground check</td>
<td>Corrected against 0%RH humidity generated by desiccants</td>
<td>Corrected with RS41 in-built Physical Zero Humidity Check</td>
</tr>
</tbody>
</table>
NASA Jet Propulsion Laboratory Table Mountain Facility in California, USA

34.40°N, 117.70 °W
2285 m above mean sea level

Sounding campaign:
- 2014-05-29 - 2014-10-30
- 19 dual launches RS41-RS92
- Night-time soundings
Instruments in the Table Mountain Campaign

Raman Lidar
- Nd:YAG 355 nm, 650mJ/pulse
- Detection range 1–20 km
- Calibration to RS92 3–6 km
- MR uncertainty 5–15 % (1-13 km)

GPS, NOAA Forecast Systems Lab
- Seth Gutman, Kirk Holub
- IPW uncertainty 1.5 mm + 1%

MWR, Naval Research Lab
- Gerald Nedoluha
- IPW uncertainty 3%
Examples of Relative Humidity Profiles

Flight 12. LIDAR_40 RS41 RS92

Humidity

2014-10-17

Flight 2. LIDAR120 RS41 RS92

Humidity

2014-07-02
Relative Humidity – Summary of 17 Flights

Difference to RS41

Std. Dev. of Difference

RS41 (ref.)
RS92
Lidar 40 min
Lidar 120 min
A Water Vapor Volume Mixing Ratio Profile

Sounding 11, 2014-10-14

Height [km] vs. Mixing Ratio [ppmv]

- RS41
- RS92
- Lidar 40
- Lidar120
Water Vapor Volume Mixing Ratio
- Means of 17 Flights

[Graph showing water vapor volume mixing ratio with height and mixing ratio in ppmv, with lines for RS41, RS92, Lidar 40, and Lidar120.]
Water Vapor Volume Mixing Ratio
- Means of 17 Flights

Lidar 40 min vs. RS41
Relative ppmv differences typically
< 10% up to 14 km
< 20% up to 16 km
Above 16 km larger differences
(still under 3% in RH)
Water Vapor Volume Mixing Ratio
- Means of 17 Flights

- Lidar 40 min vs. RS41
  Relative ppmv differences typically
  < 10% up to 14 km
  < 20% up to 16 km
  Above 16 km larger differences
  (still under 3% in RH)

- RS92 vs. RS41
  Relative ppmv differences typically
  < 5% up to 17 km
  < 20% above 17 km
Integrated Precipitable Water Column

Sample sizes
GPS: 18
RS41: 18
RS92: 18
MWR: 16

\[
y = 0.98x - 0.10 \\
R^2 = 0.98
\]

\[
y = 0.94x + 0.24 \\
R^2 = 0.96
\]

\[
y = 0.87x + 0.28 \\
R^2 = 0.94
\]
Integrated Precipitable Water Column

GPS, MWR, RS92, RS41
Agreement in IPW typically better than 1 mm

Sample sizes
GPS: 18
RS41: 18
RS92: 18
MWR: 16

$y = 0.98x - 0.10$
$R^2 = 0.98$

$y = 0.94x + 0.24$
$R^2 = 0.96$

$y = 0.87x + 0.28$
$R^2 = 0.94$
Arctic Research Center of Finnish Meteorological Institute in Sodankylä

67.368 °N, 26.633 °E
179 m above mean sea level
6 launches: CFH - RS41 - RS92
2014-02-07 - 2014-11-19

2015-01-08
19th Conference on Integrated Observing and Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS)
# Cryogenic Frostpoint Hygrometer (CFH)

<table>
<thead>
<tr>
<th>Measured Parameters</th>
<th>Ambient Frost Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derived Parameters</td>
<td>Relative Humidity, Mixing Ration</td>
</tr>
<tr>
<td>Technique</td>
<td>Temperature-controlled chilled mirror</td>
</tr>
<tr>
<td></td>
<td>&lt; 4% in tropical lower troposphere</td>
</tr>
<tr>
<td>Uncertainty Measurement</td>
<td>&lt; 10% in middle stratosphere</td>
</tr>
<tr>
<td></td>
<td>&lt; 9% in tropopause</td>
</tr>
<tr>
<td>Altitude Range</td>
<td>0 - 25 km (all climates)</td>
</tr>
<tr>
<td>Weight</td>
<td>&lt; 400 g (without coolant)</td>
</tr>
<tr>
<td>Instrument Dimensions</td>
<td>7.6 cm x 7.6 cm x 13.3 cm</td>
</tr>
<tr>
<td>Dimensions (in Flight Box)</td>
<td>~12&quot; W x 12&quot; D x 12&quot; H (~39cm x 39cm x 39cm)</td>
</tr>
</tbody>
</table>
Examples of Relative Humidity Profiles

Flight 4. RS92 RS41 CFH

Flight 6. RS41 CFH

2014-07-25

2014-11-19
Examples of Relative Humidity Profiles

2014-07-25

T = -45.6°C at 25 km → RH = 0.1% (MR at 5 ppmv level)

2014-11-19

T = -85.4°C at 25 km → RH = 18% (MR at 5 ppmv level)
Relative Humidity – Summary of 6 Flights

Difference to CFH

Std. Dev. of Difference

CFH (ref.)
RS41 (6 flights)
RS92 (5 flights)
Example of Water Vapour Mixing Ratio Profile

Sounding 5, 2014-10-03

Max deviation seen at 28 km corresponds 0.8% in RH
Water Vapor Volume Mixing Ratio
- Means of 6 Flights
Water Vapor Volume Mixing Ratio
- Means of 6 Flights

RS41 vs. CFH
Relative ppmv difference
< 2% up to 12 km
<10% up to 15 km
Above 15 km larger differences (still under 1% in RH)
Water Vapor Volume Mixing Ratio
- Means of 6 Flights

**RS41 vs. CFH**
Relative ppmv difference
< 2% up to 12 km
<10% up to 15 km
Above 15 km larger differences (still under 1% in RH)

**RS92 vs. CFH**
Relative ppmv differences typically < 2% up to 10 km
Above 10 km larger differences
Table Mountain Campaign

<table>
<thead>
<tr>
<th>Altitude, km</th>
<th>Raman Lidar MR [ppmv]</th>
<th>GPS IPW [mm]</th>
<th>MWR IPW [mm]</th>
<th>RS92 RH [%]</th>
<th>RS41 RH [%]</th>
<th>CFH Tfp [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Raman Lidar MR [ppmv]</td>
<td>GPS IPW [mm]</td>
<td>MWR IPW [mm]</td>
<td>RS92 RH [%]</td>
<td>RS41 RH [%]</td>
<td>CFH Tfp [°C]</td>
</tr>
</tbody>
</table>

Sodankylä Campaign
Thank you