Characteristics of Conventional RAOBS and their Use in Satellite Sounding Product Validation

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Goal

Conventional radiosonde observations (RAOBs) have historically been used as a commonly accepted reference dataset in satellite measurement and derived product validation, but they are not perfect. In this work, we provide an overview on RAOBs, with the focus on:

- Accuracy of their temperature and water vapor measurements.
- Meteorological peculiarities, including temperature inversion and water vapor abrupt change.
- How those characteristics are reflected in the satellite performance evaluation and what attention we need to pay to in the validation.

Finally, we demonstrate the overall usefulness of operational RAOBs in satellite product validation.

Approach

Uncertainty in radiosonde temperature and humidity measurements were quantified using GPSRO COSMIC – RAOB collocation data (2008 – 2011) collected at the NOAA Product Validation System (NPROVS).

NOAA IASI sounding retrieval product is used as the example of satellite product being validated. Three years (2010-2012) of NOAA IASI- RAOB collocations, extracted from NPROVS collocation data, are used to quantify

- Impact of RAOB measurement uncertainty and meteorological peculiarities (ie, temperature inversion and water vapor abrupt change) on the IASI validation.

The IASI-RAOB collocation dataset is then employed to demonstrate the usefulness of conventional RAOBs in validating and understanding the relationship between clouds, temperature and humidity in the NOAA IASI retrievals.

Mean bias and root-mean-square (RMS) difference from RAOB are used to measure the IASI retrieval performance. The statistics displayed in the profile are ~ 1 km layer values for temperature and ~ 2 km layer values for water vapor. For water vapor, the statistics are in percent difference weighted by radiosonde water vapor amount for each layer.

NOAA Products Validation System
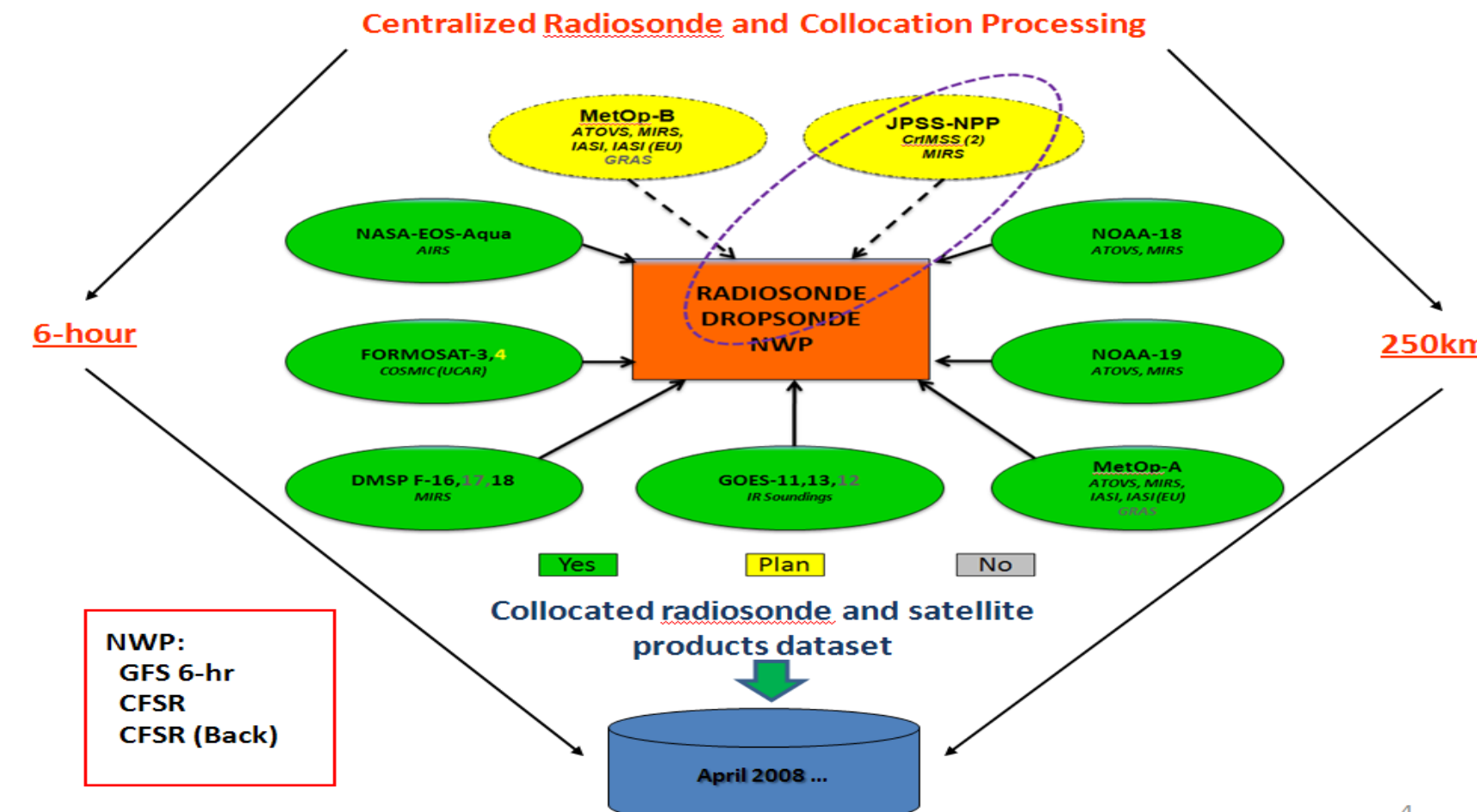
NPROVS provides daily compilation of conventional RAOBs collocated with derived satellite soundings from multiple satellites and product systems. The collocation strategy is consistent for all satellites, including 6 hr & 250 km window, and "single, closest" satellite profile to a given sonde from each satellite product.
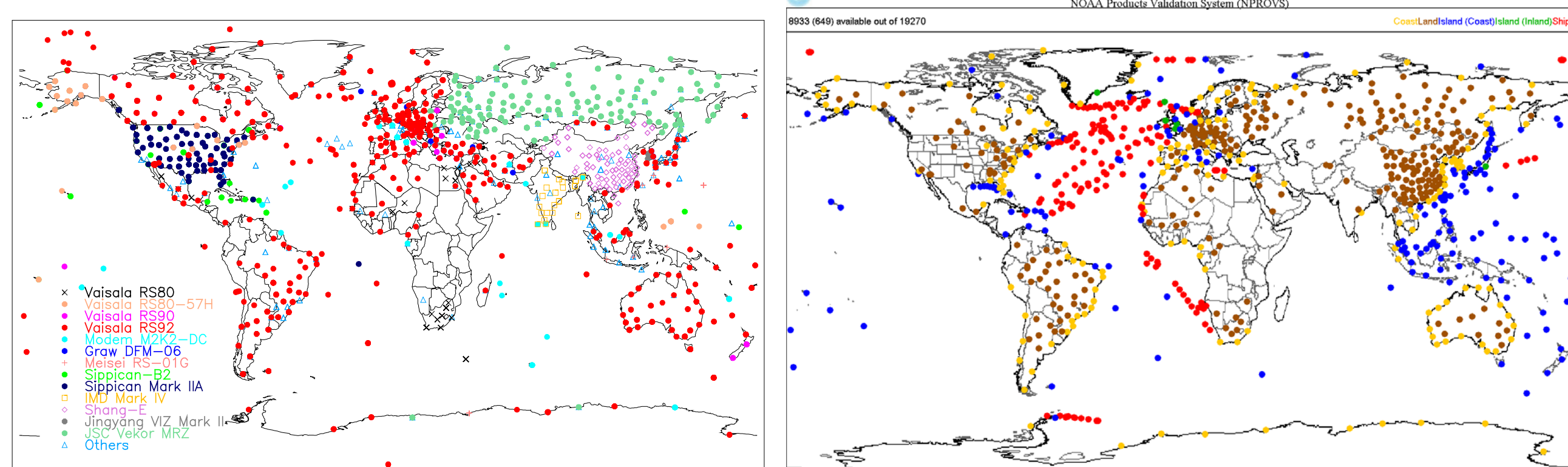
Global operational RAOB sites (2008-2011. Sun et al. 2013). Different colors for different sonde types.

IASI-RAOB collocations within 3 hr and 50 km are used in the study. Different colors represent different RAOB terrain types.

References

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Sun, B., A. Reale, E. Maddy, A. Gambacorta, and C. Barnet, 2013: **Relationship between clouds, temperature and humidity in NOAA IASI retrievals**. *Ninth Annual Symposium on Future Operational Environmental Satellite System, 93rd AMS annual meeting*, Austin, TX, 5-10 January 2013.

Reale, A., B. Sun, F. Tilley, and M. Pettey, 2012: **The NOAA Products Validation System (NPROVS)**. *J. Atmos. Oceanic Tech.*, 29, DOI:10.1175/JTECH-D-11-00072.1.

Seidel, D. J., B. Sun, M. Pettey, and A. Reale, 2011: **Radiosonde balloon drift statistics**. *J. Geophys. Res.*, 116, D07102, doi:10.1029JD014891.

Sun, B., A. Reale, D. J. Seidel, and D. C. Hunt, 2010: **Comparing radiosonde and COSMIC atmospheric profile data to quantify differences among radiosonde types and the effects of imperfect collocation on comparison statistics**. *J. Geophys. Res.*, 115, D23104, doi: 10.1029/2010JD014457.

## RAOB Accuracy and Issue in Product Validation

Temperature
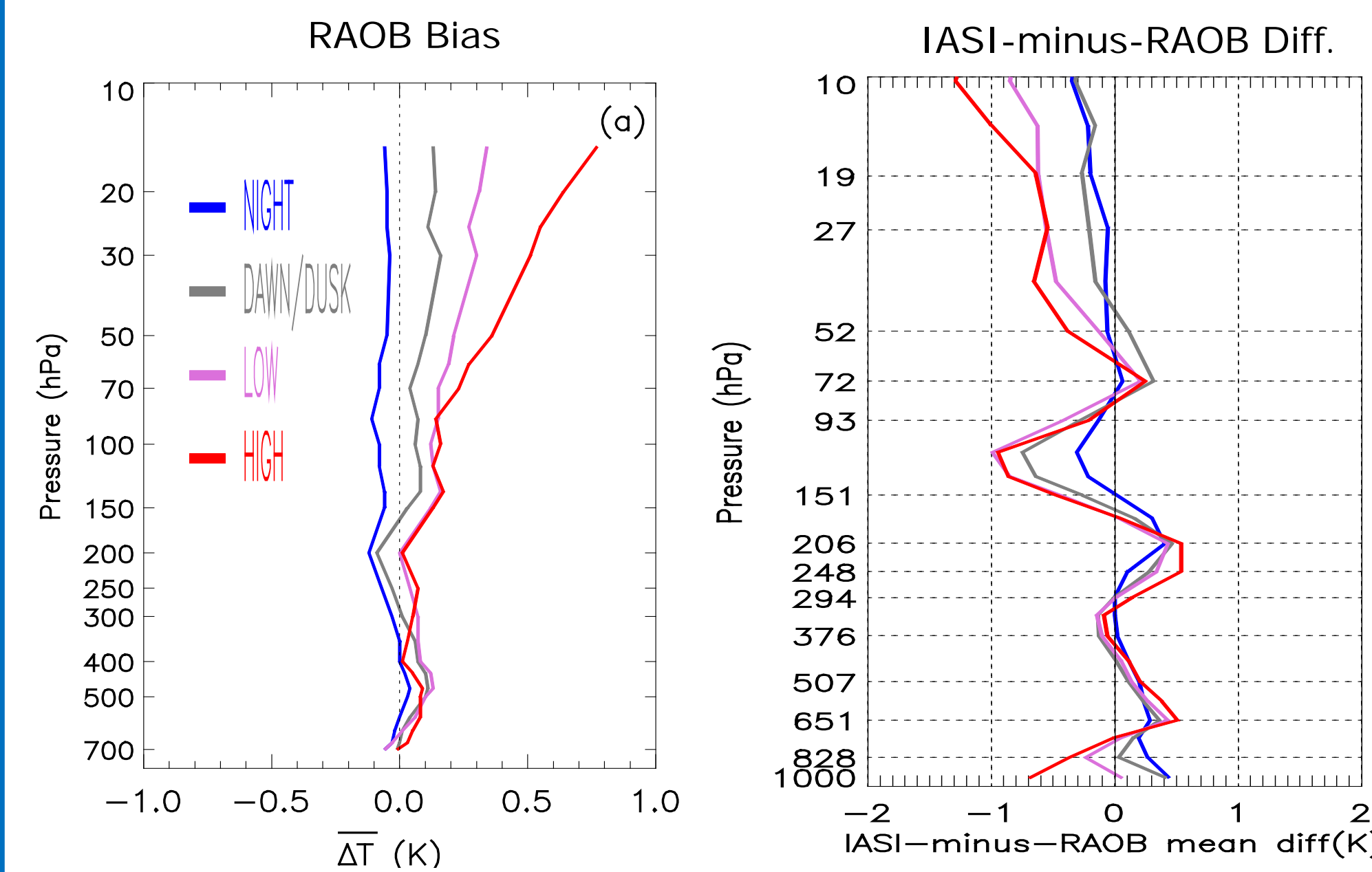
RAOB-minus-COSMIC temperature difference for different solar angles averaged from global data of May 2008 to August 2011 (Sun et al. 2013). A radiation-induced bias appears to be shown in RAOB in the upper troposphere and lower stratosphere.

IASI-minus-RAOB temperature difference averaged from global data of January 2010 to December 2012. IASI-RAOB collocations within 3 hr and 100 km are used.

The daytime "cold bias" in the IASI data in the upper troposphere and lower stratosphere (right) could primarily reflect the "warm bias" in RAOB (left).

Nighttime RAOB temperatures are recommended for the validation use.

Humidity
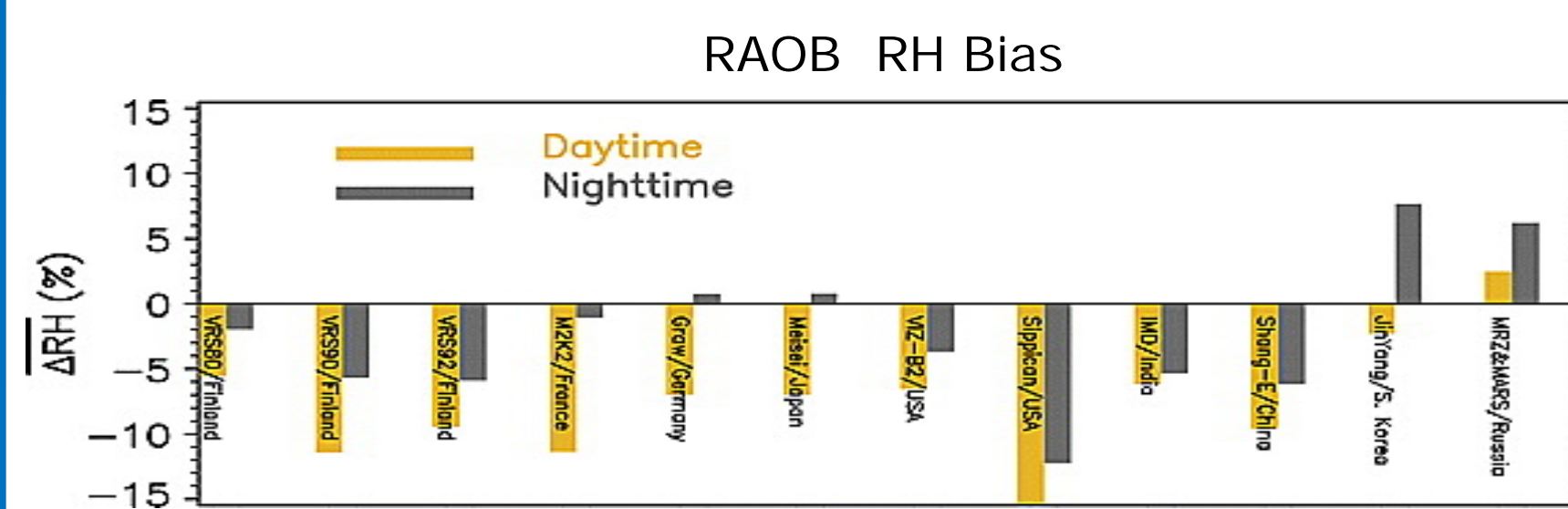
RAOB-minus-COSMIC 300 hPa relative humidity differences for different radiosonde types for daytime and nighttime (Sun et al. 2010). Most of the sondes show a dry bias particularly during daytime. Russian sonde is one of a few exceptions which have a wet bias.
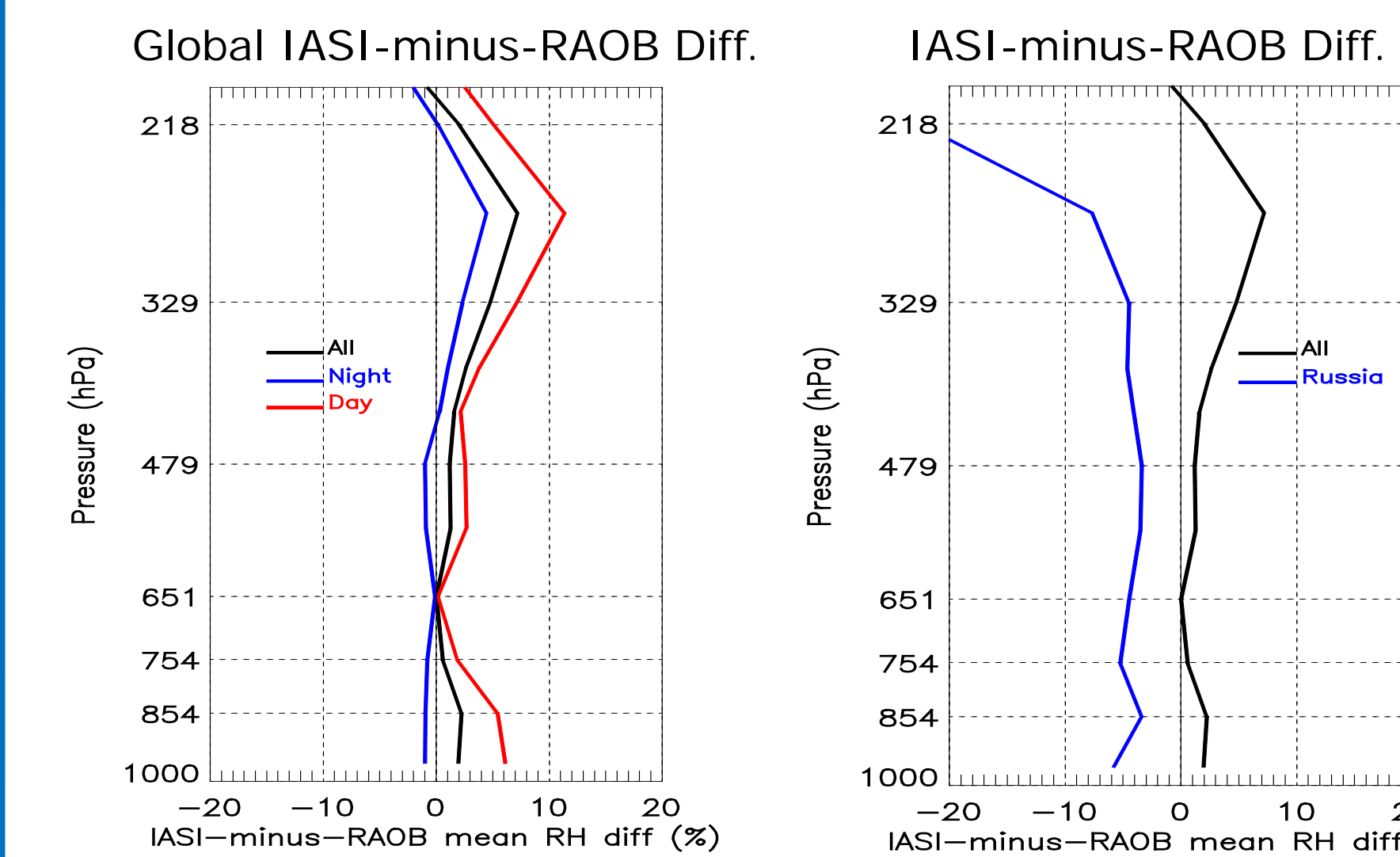
IASI-minus-RAOB relative humidity difference for daytime, nighttime and the whole day averaged from global data of January 2010 to December 2012.

Same as the left panel but for IASI-minus-RAOB relative humidity difference for Global and Russian territory.
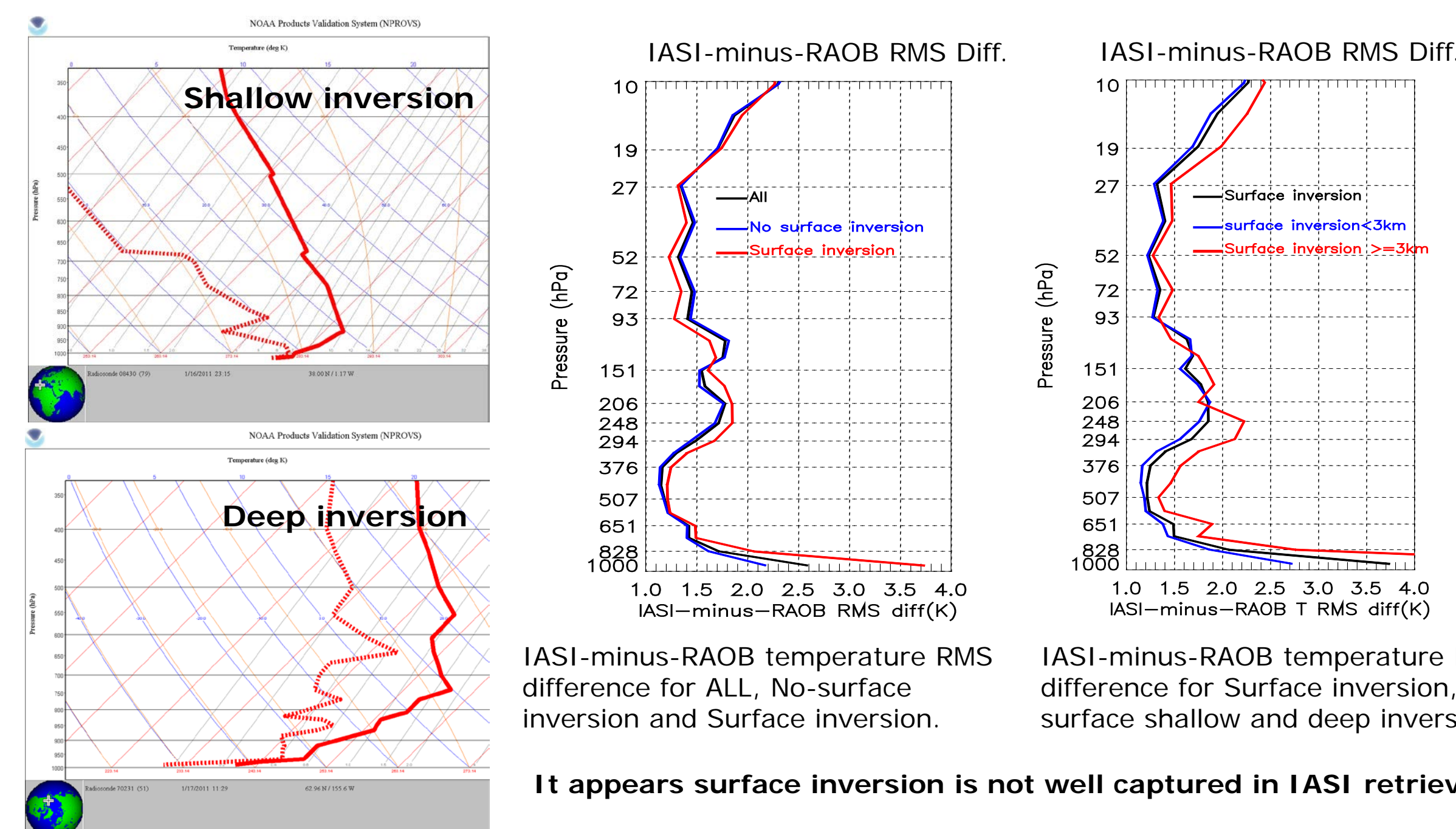
The "wet bias" in the IASI data particularly during daytime in the upper troposphere (left) could primarily reflect the "dry bias" in RAOB (upper).

The IASI "dry bias" over Russia (right) primarily reflects the wet problem in Russian sondes (upper).

Nighttime RAOB humidity data which have a smaller bias are recommended for the validation use. Russian sondes show a wet bias and caution is needed for regional validation.

RAOB Meteorology Peculiarity and Challenge for Satellite Retrieval

Surface Temperature Inversion

Shallow inversion

Deep inversion

IASI-minus-RAOB temperature RMS difference for ALL, No-surface inversion and Surface inversion.

IASI-minus-RAOB temperature RMS difference for Surface inversion, surface shallow and deep inversion.

It appears surface inversion is not well captured in IASI retrieval.

## Water Vapor Vertical Change

RAOB Water Vapor Abrupt Change Score
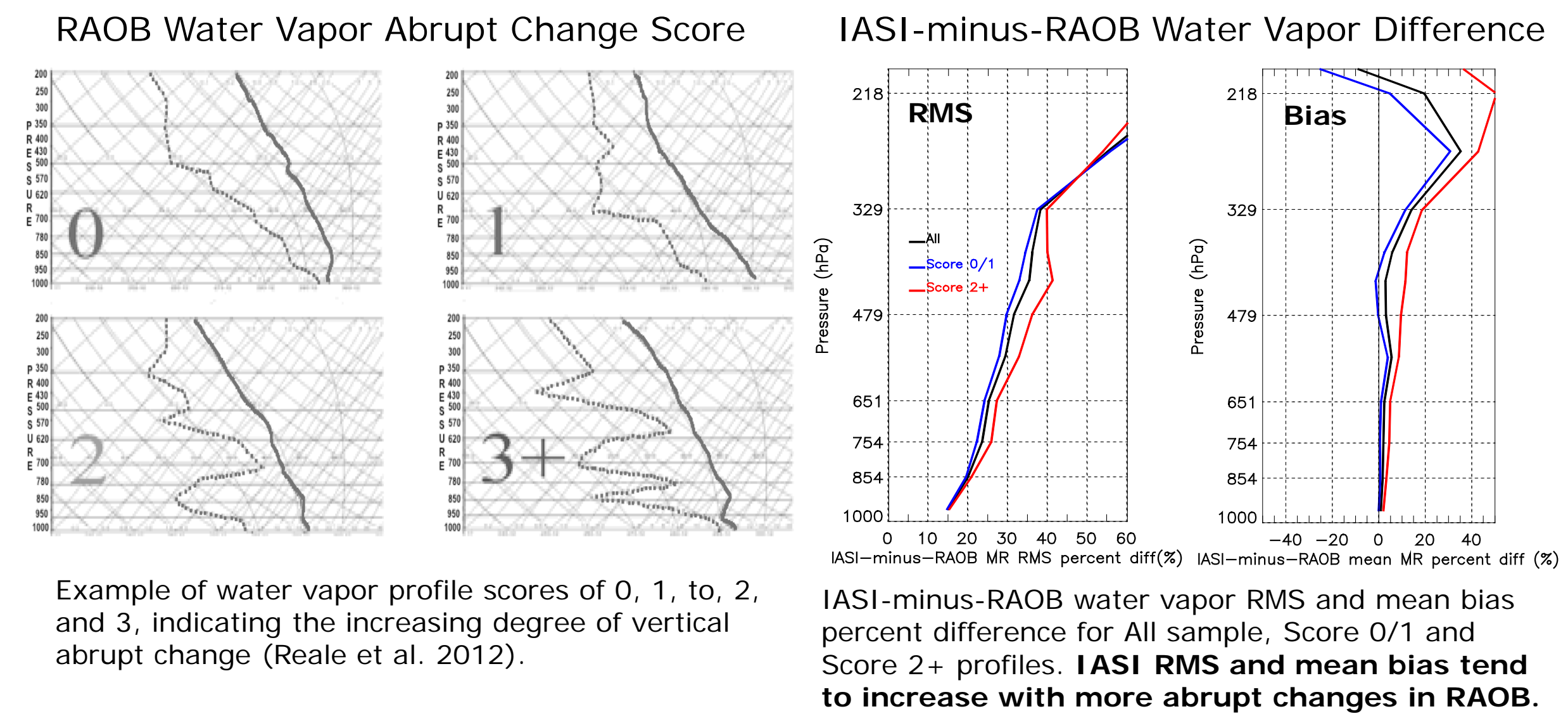
Example of water vapor profile scores of 0, 1, to 2, and 3, indicating the increasing degree of vertical abrupt change (Reale et al. 2012).

IASI-minus-RAOB Water Vapor Difference

IASI-minus-RAOB water vapor RMS and mean bias percent difference for All sample, Score 0/1 and Score 2+ profiles. **IASI RMS and mean bias tend to increase with more abrupt changes in RAOB.**

RAOB Usefulness for Validation

Validating the Relationship between Clouds, Temperature, and Humidity in IASI Retrievals
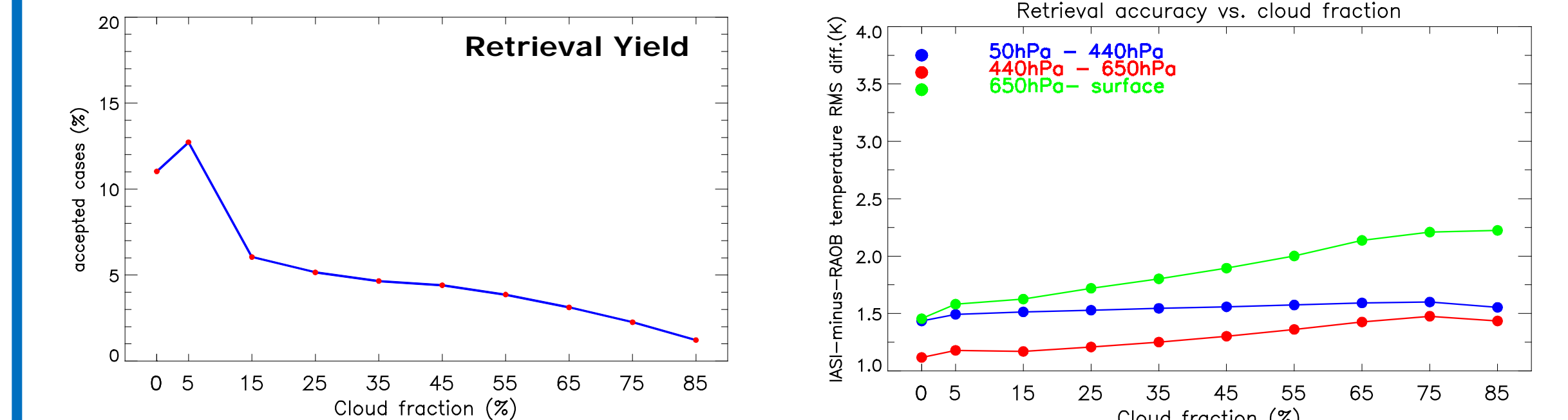
IASI retrieval yield for different bins of effective cloud amount. IASI-RAOB collocation data of January 2010 – December 2012 are used.

Change of IASI-minus-RAOB temperature RMS difference with effective cloud amount for different deep atmospheric layers. Quality "accepted" IASI and collocated RAOB are used (upper right).
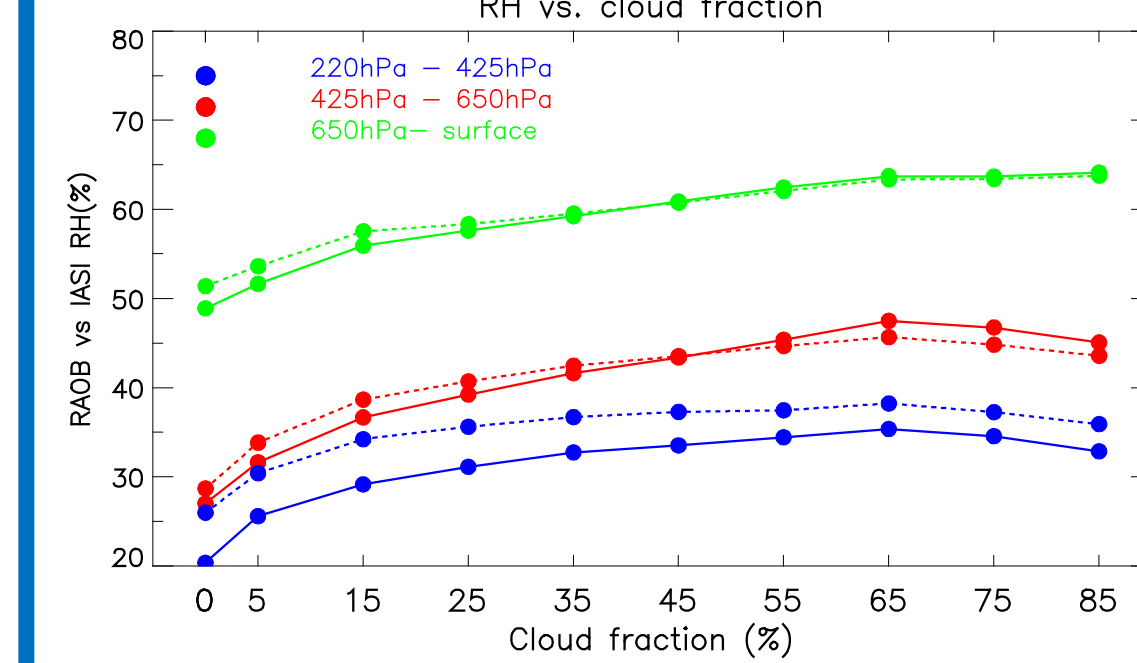
Change of IASI (dotted) and RAOB (solid) relative humidity with effective cloud amount for different deep atmospheric layers (left). Quality "accepted" IASI and collocated RAOB are used (left)

IASI retrieval errors degrade slightly with increasing cloud amount particularly in the mid-troposphere; relative humidity and cloud amount within the IASI retrievals are basically truly consistent tot each other (Sun et al. 2012).

Ongoing Validation Effort
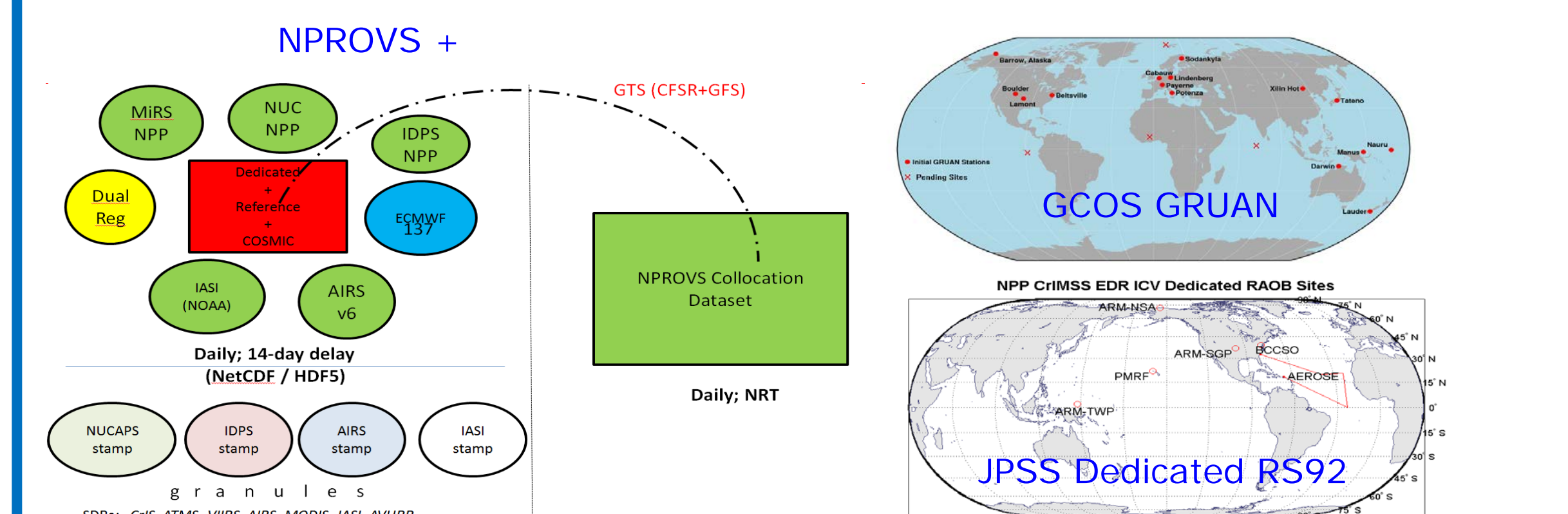
NPROVS + leverages from NPROVS and provides daily compilation of collocated **Reference** and **Dedicated** RAOBs (with measurement uncertainty included) with satellite sounding and sensor data. It constitutes the resource for robust sounding product validation and retrieval algorithm development.

GRUAN reference Measurement principles: Two observations on different platforms are consistent if

$$|m_1 - m_2| < k\sqrt{\sigma^2 + u_1^2 + u_2^2}$$

Where (σ) is the atmospheric variability from time/space, and u is the uncertainty of variable m.
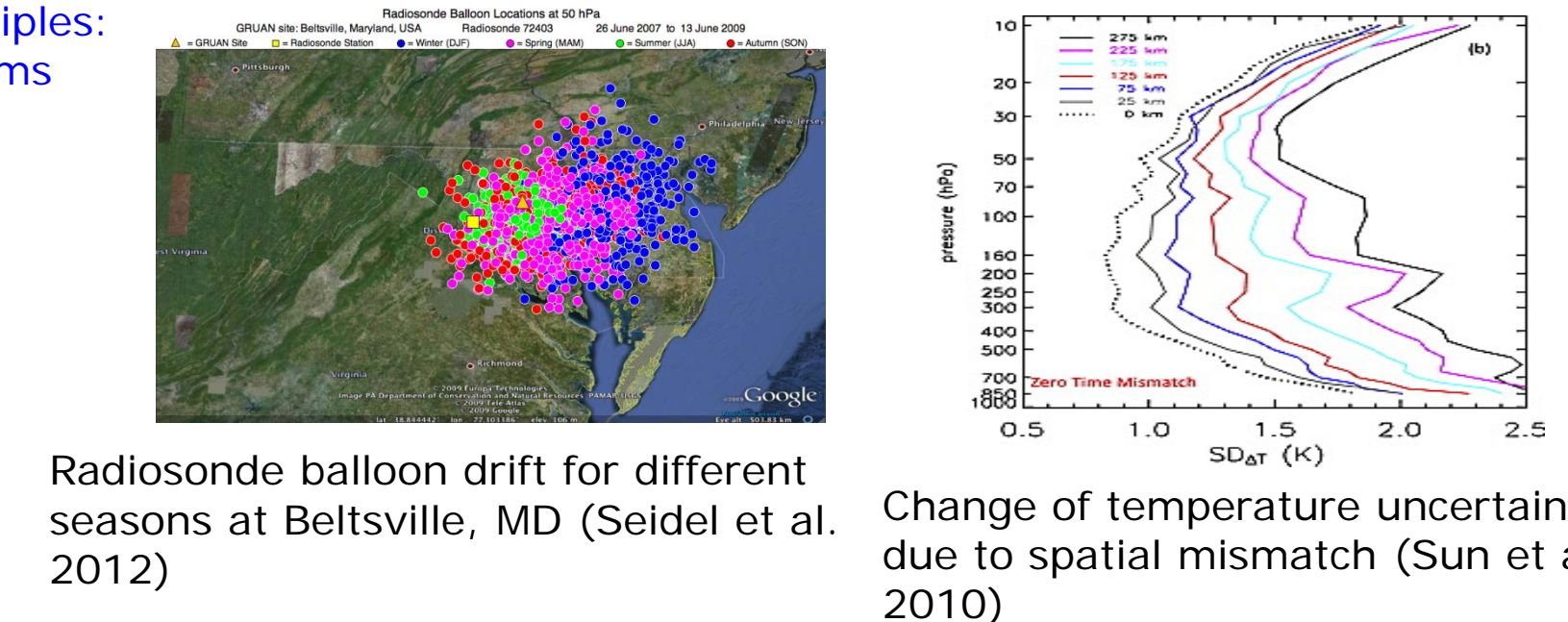
Radiosonde balloon drift for different seasons at Beltsville, MD (Seidel et al. 2012)

Change of temperature uncertainty due to spatial mismatch (Sun et al. 2010)

Conclusions

- Conventional RAOBs generally suffer radiation-induced temperature bias in the UT/LS, and humidity bias in the UT that shows regional variability.
- Atmospheric conditions including temperature inversion and humidity multiple abrupt change sampled by radiosonde profiles pose a challenge for satellite retrieval.
- Despite those, conventional RAOBs are shown to be a very useful source for validating satellite data and understanding the retrieval performance.

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