Towards Improved Corrections for Radiation-induced Biases in Radiosonde Temperature Observations

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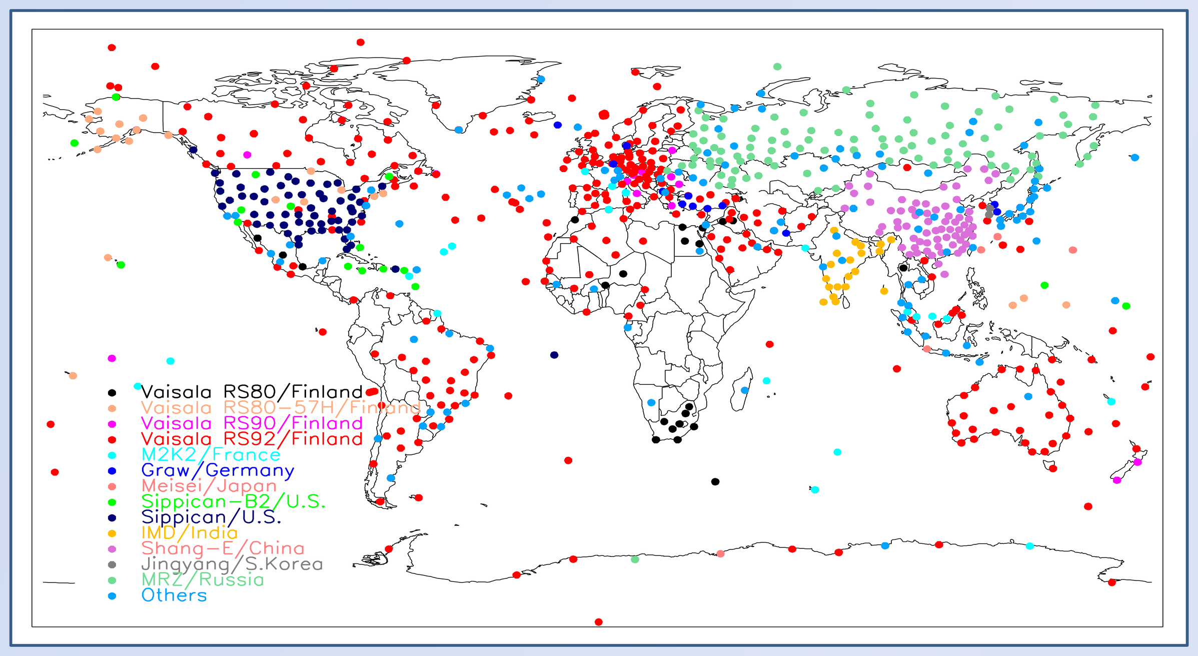
Problem and Solution

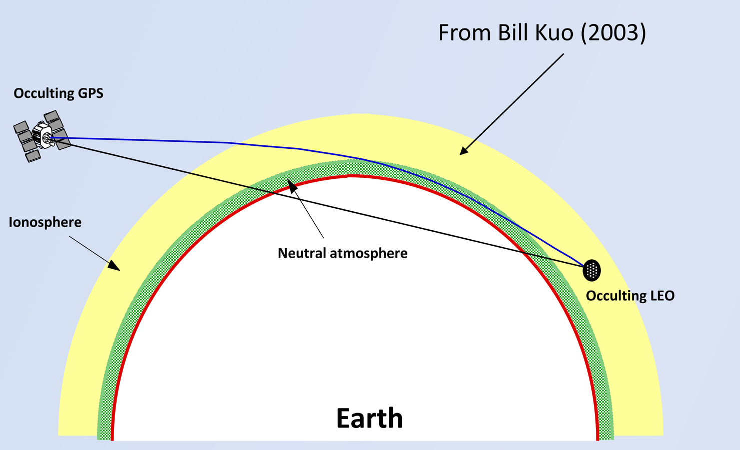
The largest error in radiosonde temperature measurements are daytime warm biases due to sunlight heating the sensor, and night cold biases as the sensor emits longwave radiation to space. Biases remain even in radiation "corrected" radiosonde temperature measurements because existing correction methods were derived using limited data and possibly non-optimal methods and because of the complexity of radiation errors.

In this analysis, radiation biases in global operational radiosonde temperature data are examined by using spatially and temporally collocated Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) data as estimate of the truth, with the intention to facilitate the improvements in correction techniques and thus make better use of radiosonde data in NWP assimilation and forecasting, upper air climate change research and satellite data calibration/validation.



Global distribution of radiosonde stations and ship reports collocated within 6 hr and 250 km of COSMIC soundings for May 2008 to August 2010 collected at the NOAA satellite Products Validation System (NPROVS, http://www.star.nesdis.noaa.gov/smcd/opdb/poes/NPROVS.php). Temperature measurements for most of the sonde types already experienced radiation corrections at the field sites using schemes provided by vendors, etc. but biases remain in "corrected" data.

COSMIC Data Characteristics

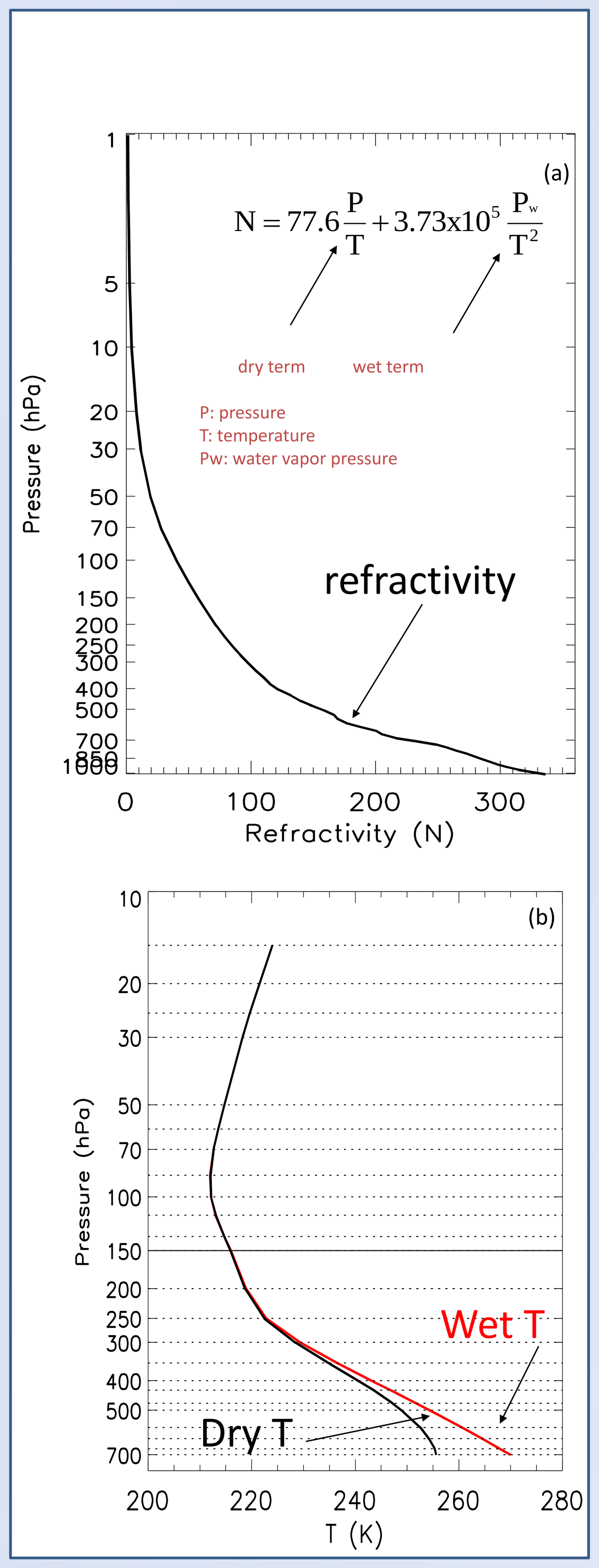


By measuring the phase delay of radio waves transmitted by GPS satellites as they pass through the Earth's atmosphere, vertical profiles of the atmosphere are derived.

COSMIC Radio Occultation (RO) data from the University Corporation for Atmospheric Research (UCAR) COSMIC Data Analysis and Archive Center (CDAAC) near-real-time (nrt) processing are used in the analysis as Reference.

COSMIC dry temperature (T) is computed from the equation of refractivity, neglecting the water vapor term, and is considered accurate in the upper troposphere and stratosphere where water vapor is negligible. Wet T is retrieved using 1DVar initialized with NCEP GFS 12-hr forecast.

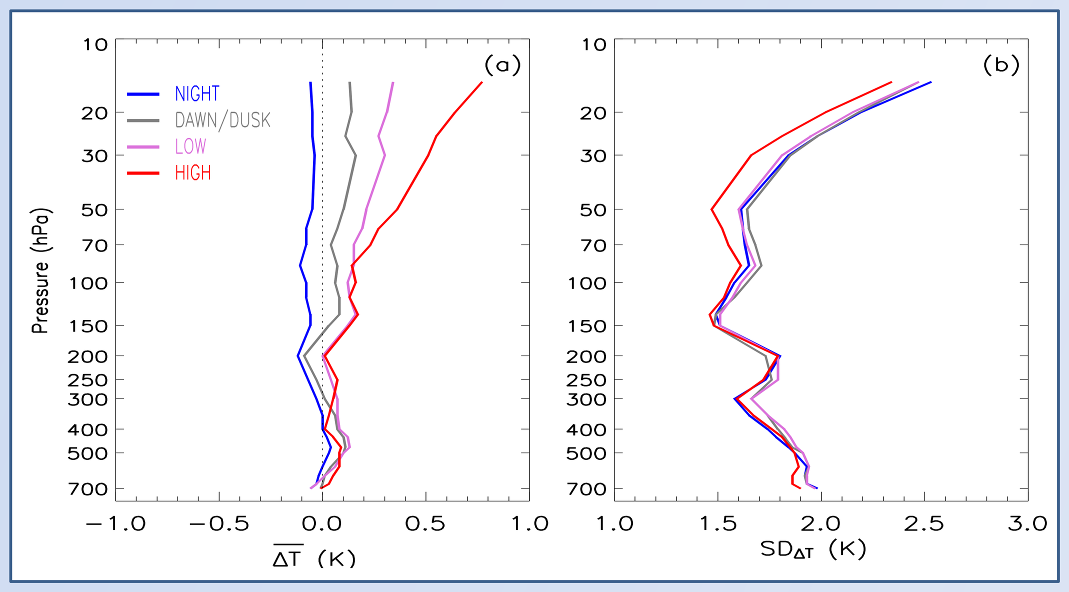
For this study, dry T at altitudes between 150 and 15 hPa and wet T between 700 and 150 hPa to form COSMIC T profiles at 24 fixed pressure levels for evaluating biases in radiosonde profiles.



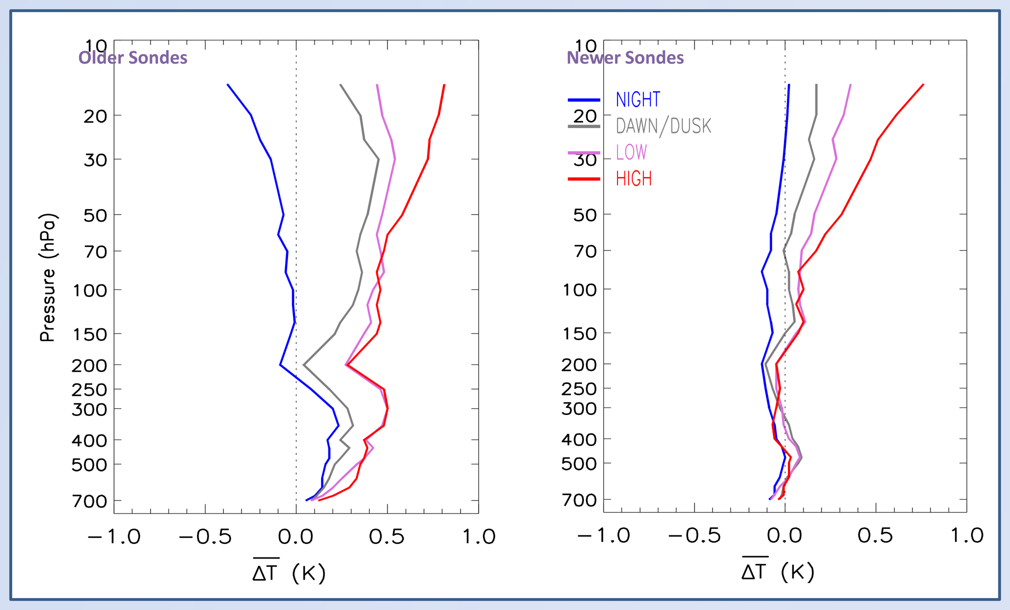
COSMIC mean refractivity (a) and temperature (b) profiles for May 2008 to August 2011.

Global Bias Pattern

The mean raob-minus-COSMIC temperature difference and its standard deviation are used to quantify raob bias statistics. They are computed for **four Solar Elevation Angle (SEA) classes: NIGHT (SEA < -7.5°); DUSK/DAWN (SEA -7.5° ~ 7.5°); LOW (SEA 7.5° ~ 22.5°); HIGH (SEA > 22.5°).**

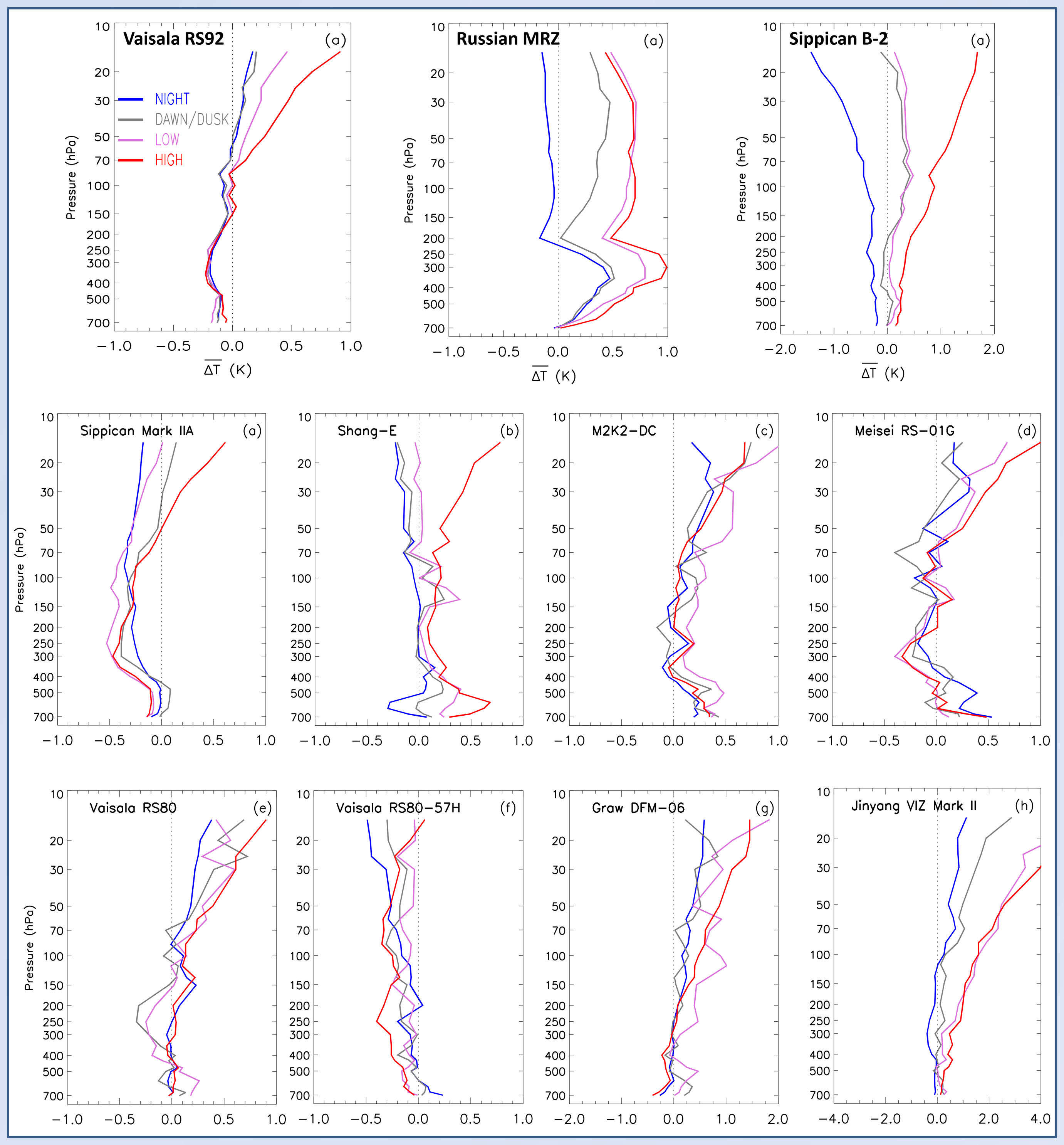


Raob-minus-COSMIC (a) mean temperature difference and (b) its standard deviation based on global collocation data for May 2008 to August 2011. Curves in different colors show results segregated by solar elevation angle classes. **Warm bias increases with height and solar elevation angle.**



Raob-minus-COSMIC mean temperature difference for older (left plot) and newer (right plot) sonde types based on global collocation data for May 2008 to August 2011. "Older" sondes are those that already flown prior to 2000 and are still in use, and "newer" sondes are those started being flown after 2000. **Biases are smaller in newer sondes.**

Biases of Sonde Types



Raob-minus-COSMIC mean temperature difference for major sonde types. **Temperature biases vary among sonde types but most show radiation error signal.**

Conclusion

Relative to COSMIC data,

- **Overall, the global radiosonde network has a nighttime cold bias and daytime warm bias with daytime bias increasing with altitude and solar elevation angle.**
- **Newer sondes (introduced after 2000) have smaller biases than older sondes.**
- **Temperature biases vary among sonde types, but most show the radiation error signal.**

Caveats

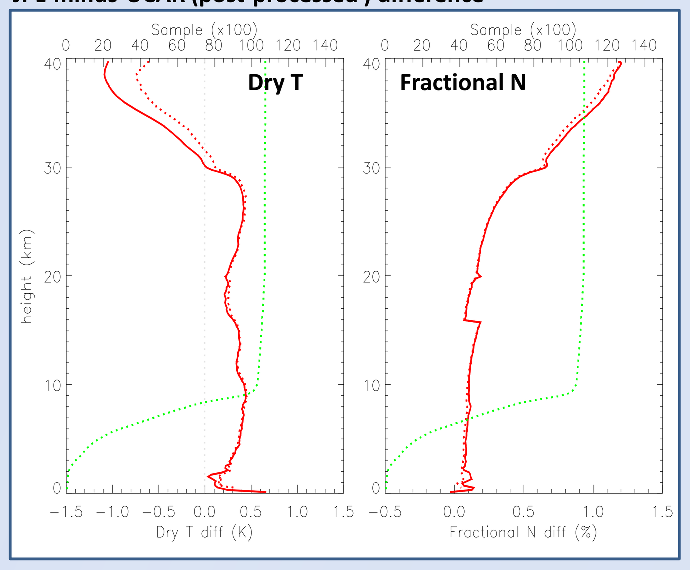
Questions exist about the validity of COSMIC RO as Reference data:

- **Is there any significant difference in dry T between different RO products?**
- **Is the RO accuracy dependent on space and time?**

Right plot: Difference between JPL and UCAR post-processed COSMIC products for dry T (left) and fractional N (right) based on 2-week global data. Red solid and dotted curves denote arithmetic average and median JPL-minus-UCAR differences and green dotted curves represent sample sizes.

For the 8-25 km layer, JPL-minus-UCAR difference is 0.14% for fractional N and 0.32 K for dry T, a magnitude similar to raob temperature bias. Are these differences true? Which product is more accurate?

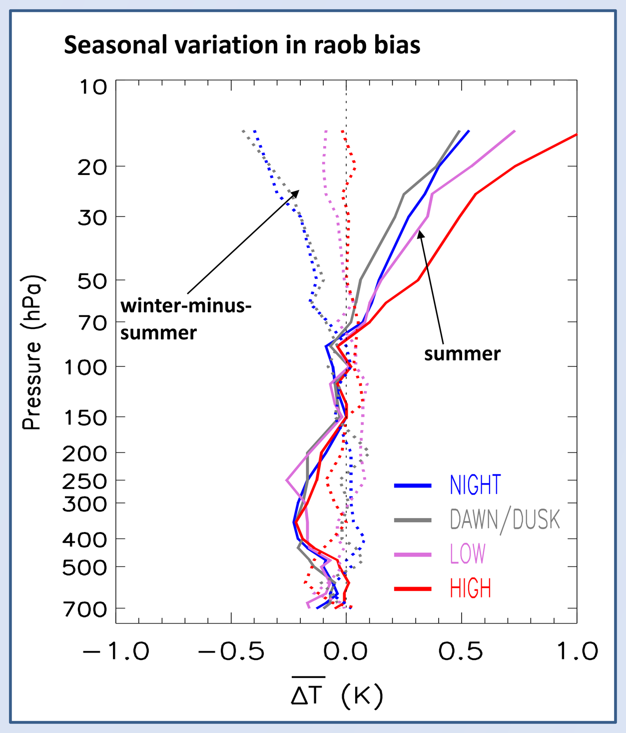
JPL-minus-UCAR (post-processed) difference



Right plot: Vaisala RS92 raob-minus-COSMIC mean temperature differences for Northern Hemisphere summer (solid curves), and winter-minus-summer differences (dotted curves) for different solar elevation angle classes.

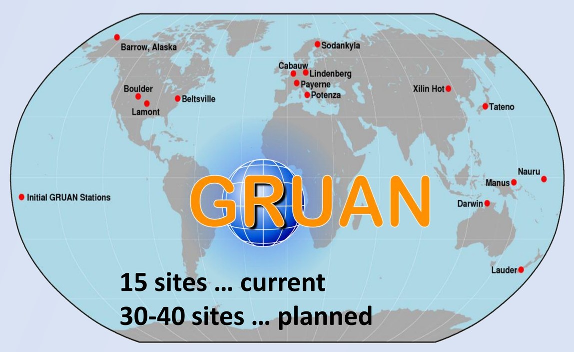
The plot and other analyses (not shown) tend to indicate nighttime raob-minus-COSMIC temperature biases show greater seasonal and latitudinal variations than daytime.

Vaisala RS92 temperature sensor is supposed to be "immune" to IR effect and time-lag error due to its small size of the sensor and its low emissivity of the aluminum coating. So why are there such variations in raob-minus-COSMIC biases?



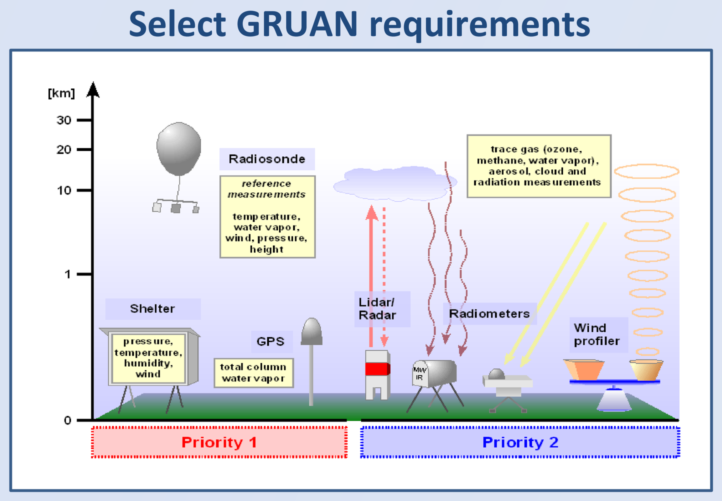
In a summary, COSMIC data shows a great potential in improving radiosonde radiation correction schemes, but more need to be understood about the RO accuracy characteristics.

GCOS Reference Upper Air Network (GRUAN)



http://www.gruan.org

Select GRUAN requirements



Activity is underway at NOAA/NESDIS/STAR to routinely integrate observations from the evolving Global Climate Observing System (GCOS) Reference Upper Air Network into NPROVS. Currently 15 sites are contributing with up to forty proposed by 2016. Each site would provide traceable sets of measurements of priority 1 and priority 2 climate variables (Fig 2); also visit the web site. The underlying objective is to replace the concept of providing a "***true value***" and "***error***" for a given measurement with that of a "***range of values***" and "***uncertainty***". Their integration and utility to further clarify the results presented in this poster will be a focus of future work.

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