**Problem**

How should we combine multiple instrument uncertainties and collocation uncertainty to obtain overall uncertainty in atmospheric profiles?

- The cornerstone of GRUAN is complete characterization of uncertainty in atmospheric profile measurement (Immler et al. 2010).
- No one instrument provides best-quality observations through the troposphere and stratosphere.
- Overall uncertainty estimates must account for the uncertainties in each measurement system.
- Observations from different sensors do not sample identical air parcels, which complicates the estimation of overall uncertainty.

There is no well-established methodology for combining uncertainties of imperfectly collocated observations.

GRUAN sites have redundant measurements of a given parameter by different instruments, with different uncertainties, and with imperfectly matched spatial and temporal sampling. (Figure from Seidel et al., Bull. Amer. Meteorol. Soc., 2008)

**Approach**

The GRUAN Analysis Team for Network Design and Operations Research (GATNORD) has undertaken a series of studies, with the ultimate goal of developing a tool for estimating overall uncertainty in GRUAN observations.

1. Quantify uncertainty in temperature and humidity observations from radiosondes, using profiles from Global Navigation Satellite System Radio Occultation (GNSS/RO) as a reference. (Sun et al. 2010)
2. Develop statistics of uncertainties associated with space and time collocation differences. (Sun et al. 2010)
3. Develop radiosonde balloon drift statistics for estimating collocation mismatches. (Seidel et al. 2011)
4. Develop a tool to obtain overall uncertainty by combining radiosonde and other instrumental uncertainties with collocation uncertainty. (In progress)

**References**


**Uncertainties in Radiosonde Observations Derived via Comparison with GNSS/RO Profiles**

- Plots compare radiosonde and COSMIC temperature profiles, by radiosonde type (colored curves) and the average for global radiosonde network average (heavy black curves).
- Radiocarbon observations from COSMIC served as a reference for this analysis. Similar methods could be applied to GRUAN observations. [Figure 1](#)

**Uncertainties Associated with Collocation Mismatch**

- The standard deviation of radiosonde-COSMIC temperature difference ($\Delta T$) is a measure of uncertainty associated with the mismatch in the collocation of the two observations.
- Dependence of 300 hPa $\Delta T$ on time and distance collocation mismatch shows that collocation uncertainty increases as mismatch time or distance increases, due to atmospheric variability. Dotted curves show the number of collocations used to compute $SD_{\Delta T}$.

**Global Radiosonde Balloon Drift Statistics**

- Radiosondes launched at GRUAN sites will drift with prevailing winds, which impacts:
  1. Retrieval of reference sonde observations
  2. Comparison of radiosonde observations with those from other observing systems, and
  3. Merging observations from nearby sub-sites.

- For these applications, we have developed a global climatology of balloon drift, including its variability with height, season, and latitude.

**Next Steps**

- Develop methodology for characterizing total uncertainty of imperfectly collocated observations.
- Model uncertainty as the distribution of measurements differences, with two main components:
  1. A stochastic model of spatial and temporal correlations
  2. Smooth component defining the true environmental trend
- Both components may involve several terms, require some assumptions, and be based on historical data.