What is the GCOS Reference Upper Air Network (GRUAN) and How Can It be Useful to Reanalysis Efforts?

Dian J. Seidel
NOAA Air Resources Laboratory, Silver Spring, Maryland, USA

Greg Bodeker
Bodeker Scientific, Alexandra, Central Otago, New Zealand

Peter Thorne
CICS-NC, NCSU / NOAA's National Climatic Data Center, Asheville, North Carolina, USA

Holger Vömel
GRUAN Lead Center, Deutscher Wetterdienst, Lindenberg, Germany

This presentation seeks to encourage dialogue between the reanalysis community and the community engaged developing a reference upper-air network for climate studies. We hope (1) to explain the need for and potential value of reference observations and (2) to engage reanalysis experts in both productively using reference observations in reanalyses and helping set future directions for the reference upper-air network.

Why do we need reference upper-air observations?

Measurements of upper atmosphere variables (temperature, pressure, humidity, and wind) have long been made to support weather forecasting. They are among the key input to numerical weather prediction models and are a primary observational source for meteorological reanalyses. Over time, changes in instrumentation, data processing methods, retrieval techniques, and calibration affect the balloon-borne, ground-based and satellite-based systems. These changes can lead to time-varying observational biases and are generally poorly documented. Removing their effects from the data record is a difficult and rarely-attempted undertaking. As a result, detection and attribution of upper-air climate change is compromised by uncertainties that are difficult to characterize and remove.

In the early days of meteorological reanalyses, some investigators hoped that the process of assimilating observations into a fixed, state-of-the-art model would largely remove space and time-varying observational biases. Some optimistically predicted that reanalyses would yield homogeneous climate records more useful for the detection of past climate change than the observational records themselves. With time, however, it became apparent both that reanalysis cannot (at least yet) identify and remove all biases and that the changing mix of assimilated data can introduce additional inhomogeneity in reanalysis products.

Not only do reanalyses not fully fix problems with observational climate records, but, for the most part, they cannot take advantage of independently made adjustments to those records. For upper-air data from radiosondes, most adjustments have focused only on temperature records (not humidity, wind, pressure or geopotential height), only on monthly anomaly data (not individual soundings), and only on observations at mandatory reporting levels. For satellite records, adjustments have generally been made to retrieved layer-mean temperature estimates, not to the observed brightness temperatures. In neither case are the resulting homogenized records ideal for assimilation. Thus both the climate monitoring and reanalysis communities are hampered by a lack of reliable long-term upper-air climate records.

What is GRUAN?

To address this specific observational deficiency, the World Meteorological Organization and the Global Climate Observing System (GCOS) supported the establishment of a new state-of-the-art global network of high quality measurements of essential climate variables in the upper atmosphere. Development of this GCOS Reference Upper Air Network (GRUAN) began in 2005. Fifteen sites participating in the implementation phase of GRUAN now or will soon provide reference-quality measurements adhering to GCOS climate monitoring principles and GRUAN protocols.

Each of the initial sites has a rich remote-sensing and in-situ sounding heritage. The GRUAN Lead Centre, hosted by Deutscher Wetterdienst at Lindenberg Meteorological Observatory, oversees day-to-day management. Overall guidance is provided by a Working Group on Atmospheric Reference Observations, under the GCOS Atmospheric Observations Panel for Climate, with international membership representing climate science, instrumentation, statistics, metrology, site operations, and the reanalysis community.

The cornerstone of GRUAN is reference measurements, which must be traceable to absolute or relative standards at every step of the observational and data processing chain. Errors that can be eliminated should be. Other uncertainties must be accounted for to produce defensible, quantitative uncertainty estimates. We will outline the GRUAN uncertainty estimate procedure, including an example application to Vaisala RS-92 radiosonde observations. This processing cannot be completed in real-time, although raw soundings, without GRUAN processing, can be made available. Thus fully processed GRUAN data will not likely play a role in real-time weather forecasting but could be used in reanalyses. Processed GRUAN data have been available since summer of 2011 through NOAA's National Climatic Data Center. The other key GRUAN requirement is redundant measurement of the same geophysical parameter by different instruments. This is essential for ongoing verification of GRUAN uncertainty estimates.

Initially GRUAN is focused upon temperature, humidity and pressure measurements but aims eventually to cover all GCOS Essential Climate Variables. The network will be truly international, and sites will have multiple sponsors with different priorities. Therefore GRUAN will not consist of identical sites. Rather, sites will be intercomparable based on consistency of measurement technique and protocols.

How does, or might, GRUAN relate to reanalyses?

Discussions within the GRUAN community have identified several potential areas of interaction with reanalyses, none of which has yet been actively pursued. One is the use of GRUAN uncertainty budgets in the assimilation of GRUAN data. A second is the use of GRUAN observations to better constrain uncertainties in conventional upper-air observations. A third is to evaluate the temporal homogeneity of reanalysis products using GRUAN time series as a reference, once a sufficiently long record has been acquired. GRUAN also sees the use of its data in reanalyses as a means of quality assurance of GRUAN data products because reanalysis systems can flag input data that fall outside of the range of expected values and natural variability, thus providing feedback to test and validate GRUAN measurements.

How can the reanalysis community engage with GRUAN?

The network is currently in the development phase. We would like to take the opportunity of this conference to invite participation in GRUAN and to solicit views on several specific issues to ensure the data are of maximum benefit to the reanalysis community. A few questions are:

1. What is the primary value of GRUAN observations in reanalysis efforts? As part of the overall ingest of observational data or as independent validation?
2. As GRUAN expands its station network, what locations or regions would be most beneficial to reanalysis activities and why?
3. What upper-air variables beyond temperature, humidity and pressure would be of greatest utility to the reanalysis community?
4. Can uncertainties in reanalyses be sufficiently well characterized to allow validating reference observations?

We seek feedback from participants on all aspects of GRUAN and look forward to growing interactions between the GRUAN and reanalysis communities.

Corresponding Author:

Name: Dian J. Seidel
Organization: NOAA Air Resources Laboratory
Address: NOAA Air Resources Laboratory (R/ARL)
1315 East West Highway

Silver Spring, MD 20910
USA