VARANAL: Large-scale Forcing Data for SCM/CRM/LES from Constrained Variational Analysis

The large-scale forcing data (VARANAL) is derived based on the constrained variational analysis (CVA) approach developed by Zhang and Lin (1997) and Zhang et al. (2001). It calculates the large-scale vertical velocity and advective tendencies from sounding measurements of winds, temperature, and water vapor mixing ratio over a network of a small number of stations. Given the inevitable uncertainties in the original data, the basic idea in the CVA approach is to adjust these atmospheric state variables by the smallest possible amount to conserve column-integrated mass, moisture, static energy, and momentum. The current VARANAL data sets archived by ARM includes two major products: 1) Radiosonde- or NWP-based forcing data for short-term Intensive Operational Periods (IOPs) at different ARM fixed or mobile sites. Most of the IOP forcing is at 3-hr and 25-mb resolutions. 2) The NWP-based multi-year continuous forcing data constrained by surface and TOP observations at the ARM permanent sites (Xie et al. 2004). The continuous forcing is at 1-hr and 25-mb resolutions.

The VARANAL data has been used to drive Single-Column Models (SCMs), Cloud-Resolving Models (CRMs) and Large-Eddy Simulation Models (LESs) for different cloud and convective systems. Results from these model simulations are then used to improve cloud parameterizations in Global Climate Models (GCMs). It can also be applied to evaluate model results, as it includes diagnostic fields such as diabatic heating profiles, cloud fields, surface measurements, and large-scale conditions. Additionally, VARANAL is one of the critical datasets required for the ongoing routine ARM LES operation (LASSO).

The derivations of the VARANAL from field measurements are subject to uncertainties that can directly impact the simulated cloud and radiation fields by SCM/CRM/LES. These uncertainties originate from two sources. One is the instrument and measurement errors. The second is errors from scale aliasing, or sampling biases. Both error types depend on scales because horizontal derivatives are involved in the calculation of the horizontal fluxes. Generally speaking, the smaller the scale is, the larger the errors in the derivative fields. Ensemble forcing data by perturbing potential uncertainties in the constraints can help address this type of uncertainties in the forcing data. We recommend that users read the relevant technical report (Tang et al. 2019) for more information on this data product.

Reference:

Tang, S., C. Tao, S. Xie, and M. Zhang, 2019: Description of the ARM large-scale forcing data from the constrained variational analysis (VARANAL) – version 2. Available at: https://www.arm.gov/publications/tech_reports/doe-sc-arm-tr-222.pdf.

Xie, S., R. T. Cederwall, and M. Zhang, 2004: Developing long-term single-column model/cloud system resolving model forcing data using numerical weather prediction products constrained by surface and top of the atmosphere observations. *JGR-Atmospheres,* **109,** D01104.

Zhang, M., and J. Lin, 1997: Constrained variational analysis of sounding data based on column-integrated budgets of mass, heat, moisture, and momentum: Approach and application to ARM measurements, *Journal of the Atmospheric Sciences,* **54(11)**, 1503–1524.

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