Retrieved Temperature and Humidity Profiles from the AERI During MC3E

David Turner, NOAA National Severe Storms Laboratory, Norman OK, dave.turner@noaa.gov
Ulrich Löhnert, Institute for Geophysics and Meteorology, University of Cologne, Germany

Background

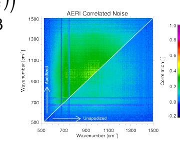
- Mid-latitude Continental Convective Cloud Experiment (MC3E) objective: to provide a complete observational characterization of convective storms using unique suite of ARM instruments
- Temperature and water vapor (T/Q) variability in vertical and horizontal dimensions influences many processes (e.g., including convective initiation, cloud and storm development, etc)
- Network of Atmospheric Emitted Radiance Interferometers (AERIs) deployed in the "Inner Domain" to provide high temporal resolution T/Q profiles
- Retrievals of T/Q profiles from AERI-observed downwelling infrared spectra has many challenges

Retrieval Methodology

- Physical-iterative retrieval ($n \rightarrow n$+1) using optimal estimation

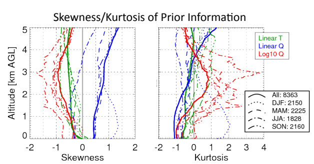
$$X^{n+1} = X_a + \left(\lambda S_a^{-1} + K_n^T S_e^{-1} K_n\right)^{-1} K_n^T S_e^{-1}\left(Y - F\left(X^n\right) + K_n\left(X^n - X_a\right)\right)$$

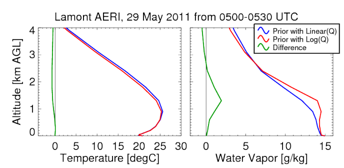
- State vector ***X***: profiles of T/Q, column amounts of CH_4 and N_2O, and 3 levels of CO_2
- Observation vector ***Y***: AERI-observed radiances in 538-713 cm^{-1} and 1140-1350 cm^{-1} spectral regions
- Forward model (***F***) is LBLRTM
- Jacobian (***K***) computed using finite differences (expensive)
- Prior (X_a, S_a) computed from ARM SGP radiosondes
- Observational covariance (S_e) computed using unapodized spectra



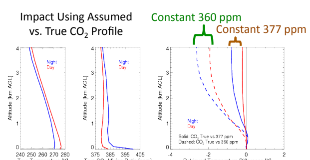
Prior Information and the Gaussian Assumption

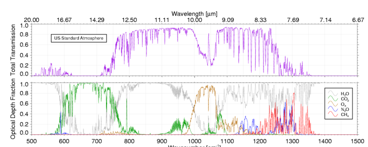
- Optimal estimation assumes that covariances (S_a, S_e) are from Gaussian distributions
- Prior data on the vertical level-to-level correlation in the T/Q profiles required to help constrain the ill-posed retrieval
- To avoid unphysical (i.e., negative) H_2O mixing ratios, many use log(Q) instead of lin(Q)
- Working in log(Q) or lin(Q) yield very different answers in both retrieved Q and T
- Gaussian assumption of log(Q) or lin(Q), as well as T, is questionable and changes seasonally

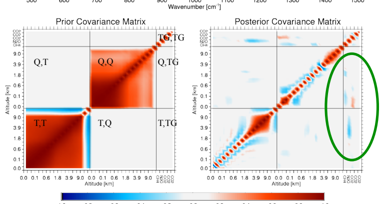




Impact of Trace Gas Errors



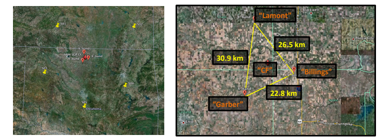


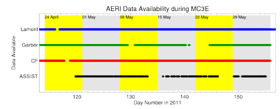


- Assume constant CO_2 profile results in bias error in retrieved T
- Spectral overlap of H_2O, CH_4, N_2O bands in 1250-1350 cm^{-1}
- Overlapping trace gases results in bias Q profile and correlated errors in T and Q

Deployment and Uptime

- Two original ARM AERIs at Lamont and Garber X-band sites
- New ABB AERI at Central Facility
- Leased LRtech ASSIST at the Billings X-band site

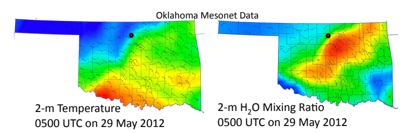


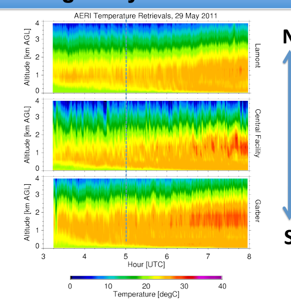


- Enclosures constructed for Lamont/Garber sites
- Uptimes less-than-ideal for MC3E
- ASSIST data still being calibrated

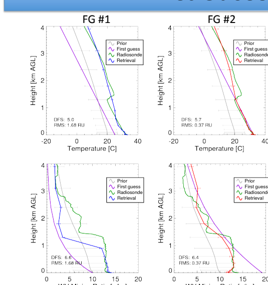
Case Study: Horizontal Inhomogeneity

- Stationary front over SGP domain on 29 May 2011
- Oklahoma Mesonet data show strong gradients in surface T/Q, and strong change in winds, at boundary
- Different vertical temperature structure (deeper & warmer) in S (Garber) in AERI retrievals relative to N (Lamont)
- "Funny" temporal noise in the new CF AERI system





First Guess Sensitivity and Example Profiles



- Physical-iterative retrievals need an initial first guess (FG)
- AERI retrieval of T/Q very sensitive to FG; often won't converge is FG is poor
- Adjusting λ in retrieval from large value (~1000) to 1 during retrieval improves stability & convergence at additional computational expense (i.e., more iterations)
- Critical when cloud properties (LWP, R_{eff}) are added to ***X*** (current work)

- Two FGs give similar, not identical, answers (both valid)
- Number of independent levels (degrees freedom of signal) is 5-7 for both T and Q profiles
- Most information in the BL; unable to resolve elevated features

Clouds – Huge IR Contribution

- Clouds are very efficient IR emitters (i.e., have large optical depths)
- T/Q retrievals must account for cloud emission
- Cannot treat the cloud as a purely emissive cloud; must include scattering
- Not including scattering results in bias in spectral region used for H_2O profiling (approx 1200 cm^{-1})
- Attempting to develop model that accounts for scattering in 1st order sense, as full scattering treatment is too computationally expensive