Retrieved Temperature and Humidity Profiles from the AERI During MC3E

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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 a n+1) using optimal estimation
  \[ X^{n+1} = X_n + \left( \lambda S_n + K_n S_n^T K_n^{-1} \right) ^{-1} K_n^T F(X^n) + K_n (X^n - X_n) \]
- State vector \( X \) profiles of T/Q, column amounts of CH₄ and N₂O, and 3 levels of CO₂
- Observation vector \( Y \), AERI-observed raiindsces 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 (\( X_n, S_n \)) computed from ARM SGP radiosondes
- Observational covariance (\( S_n \)) computed using unapodized spectra

Prior Information and the Gaussian Assumption

- Optimal estimation assumes that covariances (\( S_n, S_n \)) 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) H₂O mixing ratios, many use log(Q) instead of lin(Q)
- Working in log(Q) or li(Q) yield very different answers in both retrieved Q and T
- Gaussian assumption of log(Q) or li(Q), as well as T, is questionable and changes seasonally

Impact of Trace Gas Errors

- Assume constant CO₂ profile results in bias error in retrieved T
- Spectral overlap of H₂O, CH₄, N₂O 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 AERI's at Lamont and Garber X-band sites
- New ABB AERI at Central Facility
- Leased L-Ritch 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 if 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 H₂O 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

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