Objective Comparison of High Resolution FIR and MIR Spectral Observations for Atmospheric Retrievals

Aronne Merrelli[1,2] and David D. Turner[1,2]

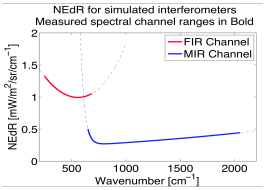
1. Cooperative Institute for Meteorological Satellite Studies, 2. Dept. of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison

Approach

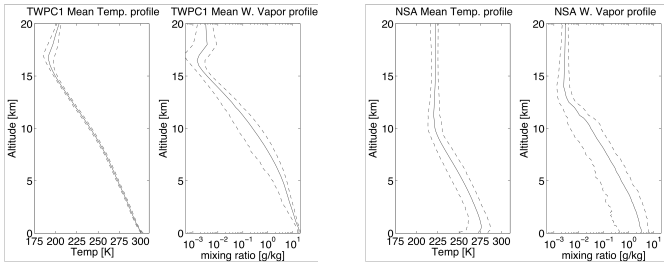
1) Simulate upwelling infrared spectra from clear – sky atmospheres as observed by two satellite interferometers, one with Far Infrared (FIR) and one with Mid Infrared (MIR) spectral coverage
2) Use optimal estimation (OE) to retrieve atmospheric profiles
3) Objectively compare information content in the two spectral ranges by comparing "degrees of freedom" for signal

Methods and Data

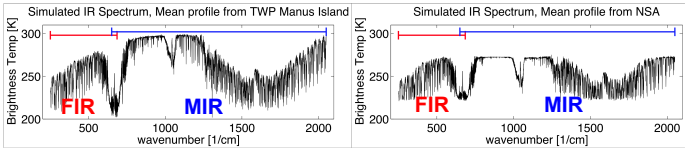
Sensor Noise Characteristics (S_ε): The sensor is assumed to have a diagonal noise covariance. The NEdR curves show the assumed sensor noise levels.



A Priori Climatology (S_a): The temperature and water vapor climatology was developed from radiosonde data collected at the ARM ground sites: North Slope Alaska (NSA) and Tropical West Pacific, Manus Island (TWP C1).
The mean profiles are displayed below, with a dashed line envelope showing the central 90% of the distribution.



Forward Model (y, K): We used the LBLRTM line-by-line radiative transfer code to simulate radiance spectra and compute analytic Jacobians. The bottom plot shows the upwelling radiance spectra for the two mean profiles.



Retrieval Algorithm

The nonlinear retrieval computes an estimate of the atmospheric state ($\boldsymbol{x}$) from the observed spectral radiance ($\boldsymbol{y}$) as a perturbation from the climatological mean.

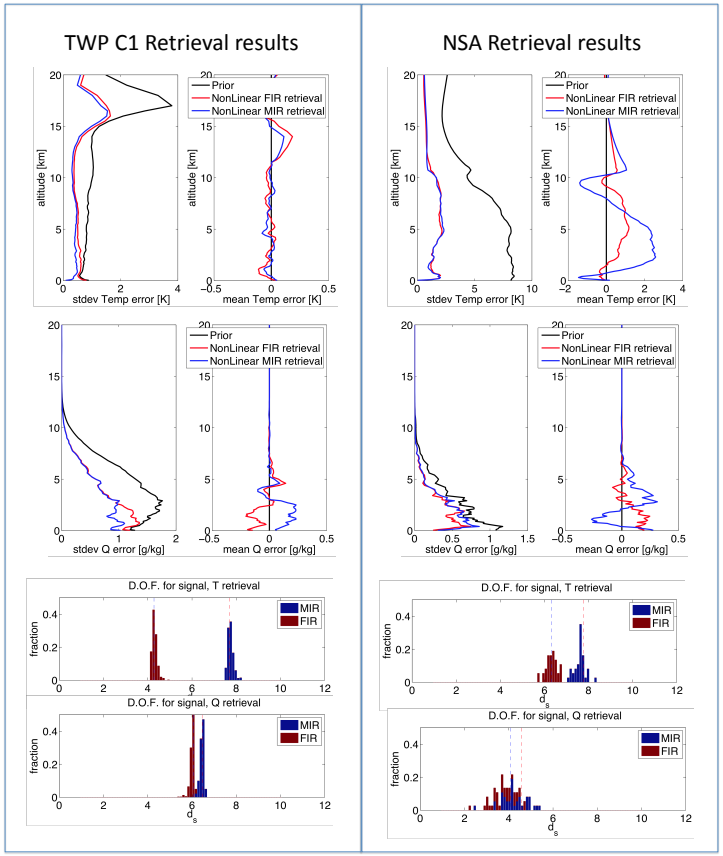
The state consists of the surface temperature, and the air temperature and water vapor mixing ratio at each level.

$$\hat{x} - x_a = \left[K^T S_\varepsilon^{-1} K + S_a^{-1}\right]^{-1} K^T S_\varepsilon^{-1}\left(y - y_a\right) = G\left(y - y_a\right)$$

The Jacobian ($\boldsymbol{K}$) is recomputed at updated state estimate, and the iteration continues until the state vector changes less than the estimate's uncertainty.

The degrees of freedom for the atmospheric signal is the trace of the matrix product $\boldsymbol{G}\,\boldsymbol{K}$, and it can be considered the number of independent "levels" in the retrieval.

Results



We obtained roughly 400 cloud free retrievals for TWP, and 40 for NSA.

RMSE and Mean Error Profiles (left) are computed from the differences between the retrieved profiles and the "truth" radiosonde profiles.

Degrees of Freedom histograms (lower left) highlight differences in the information content.

The FIR contains similar water vapor information as the MIR, surprisingly even in the tropical profiles.

The FIR temperature information is significantly lower, possibly due to overlap between the water vapor rotational band and the longwave side of the carbon dioxide absorption band at 660 cm^{-1}.

Corresponding author address:
Aronne Merrelli (merrelli@wisc.edu)
Dept. of Atmospheric and Oceanic Sciences
1225 W Dayton St., Madison, WI 53706