Supplementing Space-based Sounding with the Ground-based Atmospheric Emitted Radiance Interferometer (AERI) to Improve Thermodynamic Sounding of the Planetary Boundary Layer

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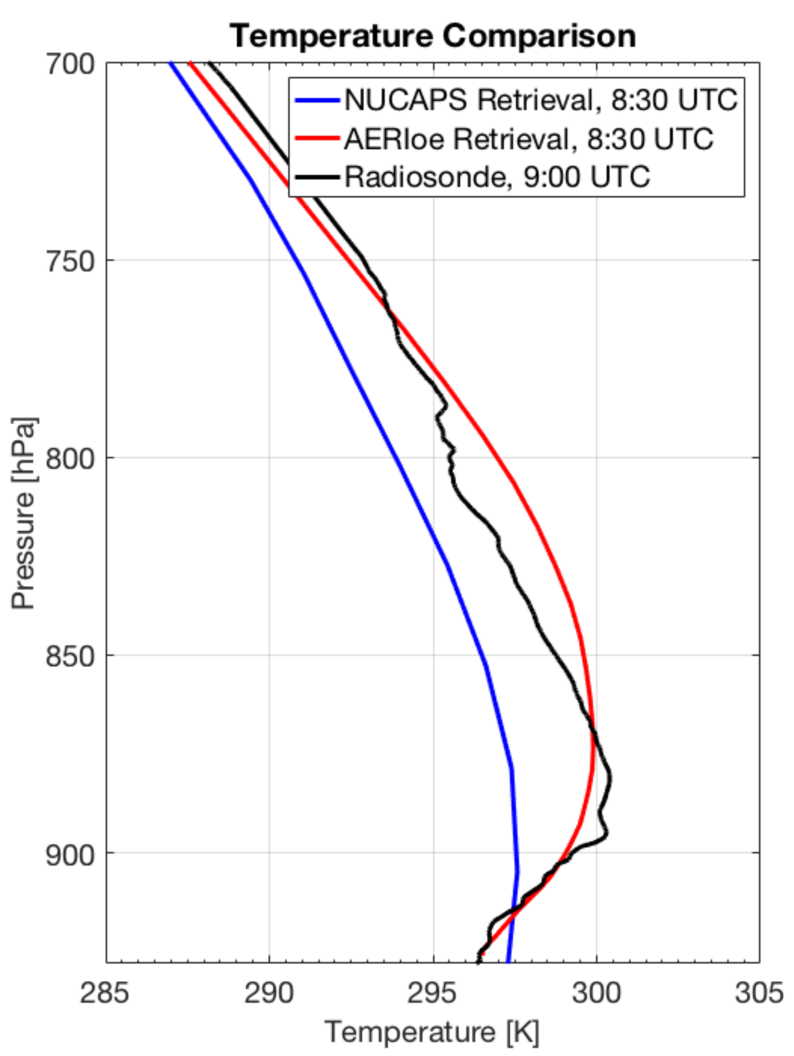
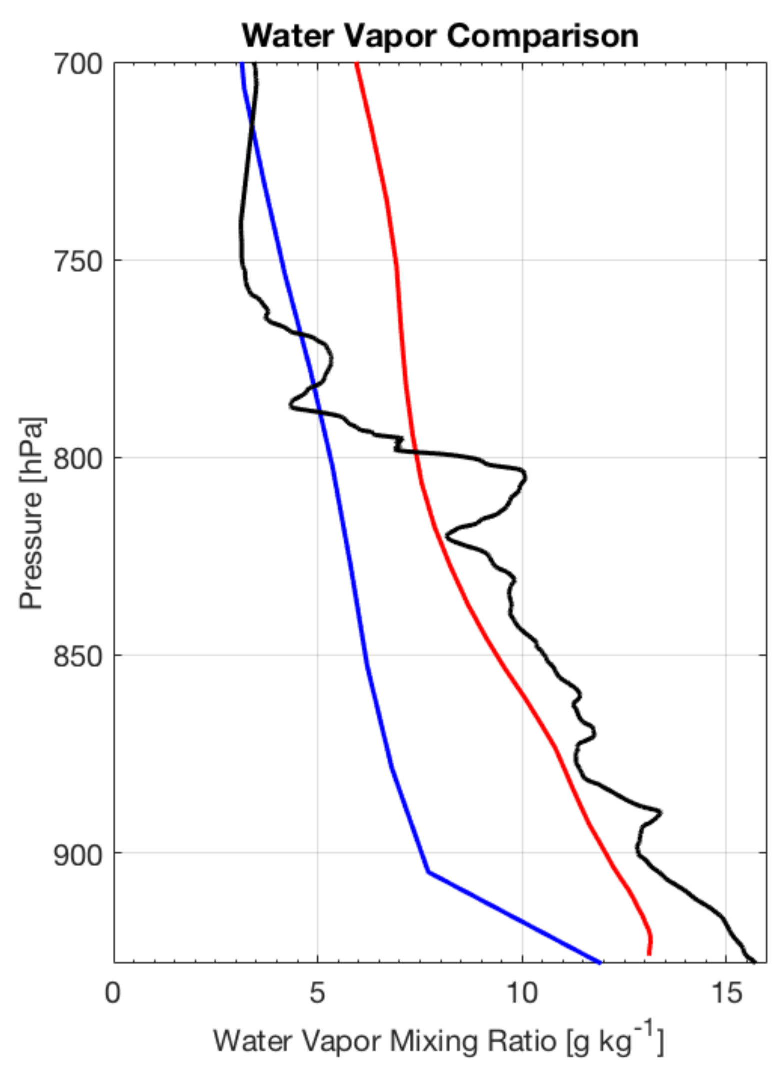
Introduction

Motivation:

The 2017 Decadal Survey highlighted the need to improve observations of the planetary boundary layer. However, space-based sounding lacks the necessary accuracy in the boundary layer. The National Research Council (2009) suggested the development of a nationwide network of ground-based profilers to supplement the space-based observing system in order to improve observations of the planetary boundary layer.





Objective: Develop synthetic information content studies in clear sky and cloudy sky environments to quantify the improvements offered by a synergy of space-based and ground-based IR sounders.

Quantifying Information Content – Degrees of Freedom:

Degrees of freedom (DOF) is a measure of the independent pieces of information able to be determined by the measurements. DOF is the trace of the averaging kernel **A**:

$$\mathbf{A} = (\mathbf{K}^T \mathbf{S}_e^{-1} \mathbf{K} + \mathbf{S}_a^{-1})^{-1} \bullet (\mathbf{K}^T \mathbf{S}_e^{-1} \mathbf{K})$$

Where **K** is the jacobian and $\mathbf{S}_e$ is the error covariance matrix. Given the difficulties computing model error, we utilize instrument noise for the error covariance matrix $\mathbf{S}_e$. $\mathbf{S}_a$ is the a priori covariance matrix:

$$\mathbf{S}_a^{i,j} = \mathrm{CORR}(\mathbf{x}_i, \mathbf{x}_j)\, \boldsymbol{\sigma}_{\mathbf{x}_i} \boldsymbol{\sigma}_{\mathbf{x}_j}$$

$\mathbf{S}_a$ is a radiosonde climatology.

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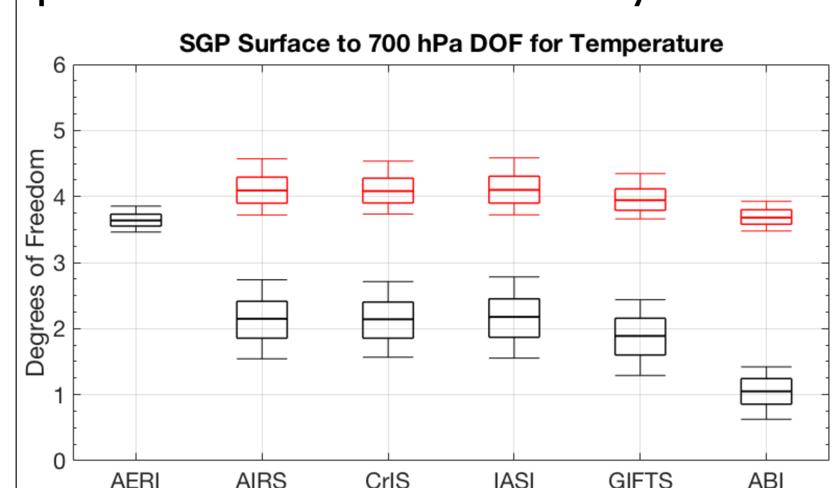
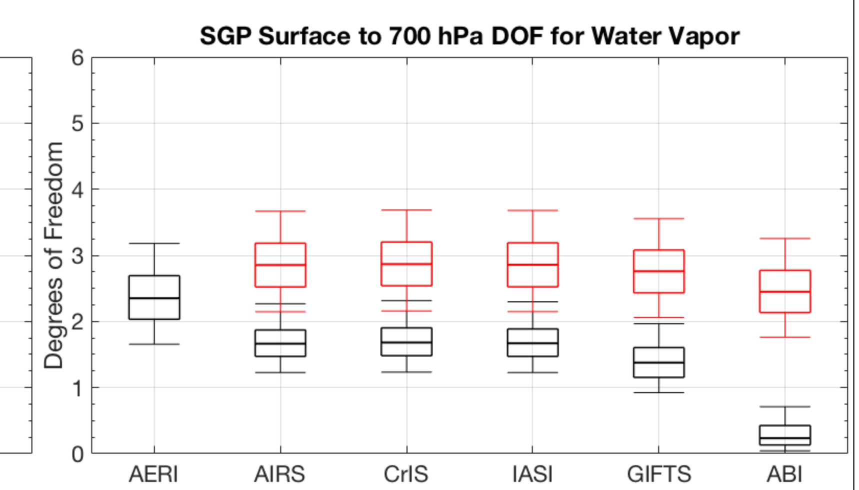
Key Point: A synergy of ground-based and space-based sensors provides more information content and better vertical resolution than any sensor operating individually.

Clear Sky Study

Clear sky radiosondes profiles from ARM-SGP between October 2013 and September 2019 are used to provide input thermodynamic profiles for radiative transfer simulation. 3765 profiles meet our clear sky criteria (relative humidity less than 90%).

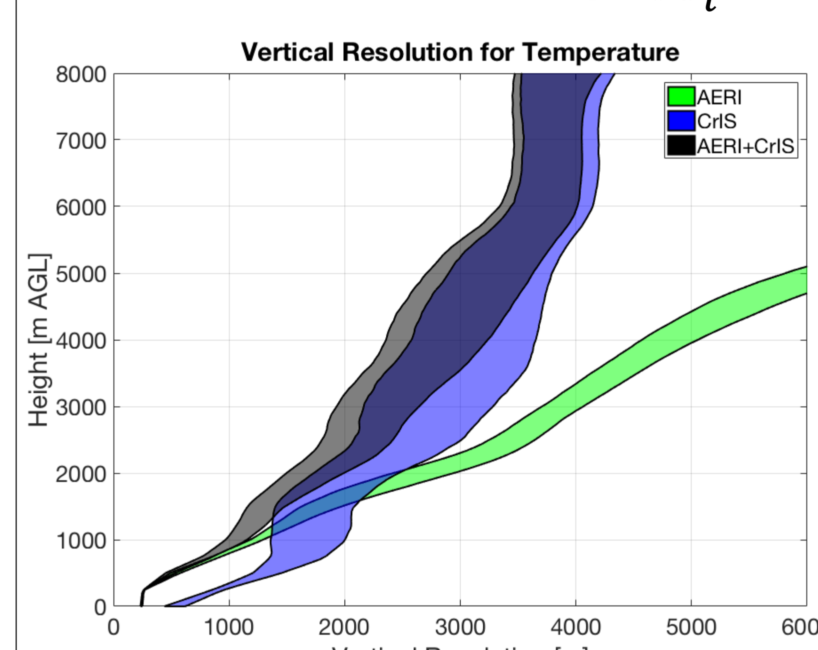


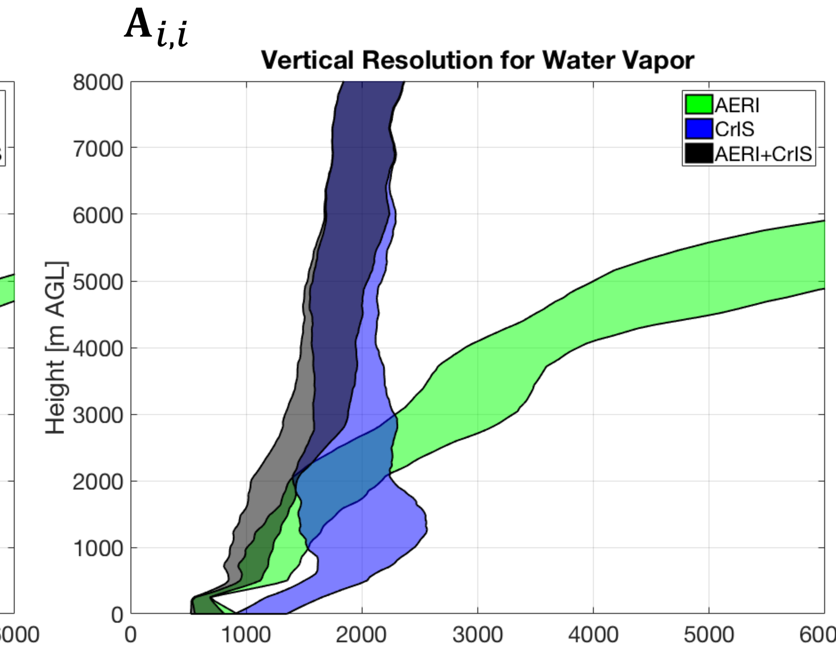


- AIRS, CrIS, and IASI have almost the exact same information content as one another
- AERI has greater information near the surface than any of the space-based sensors.
- The synergy of AERI with any of the space-based sensors produces more information than either sensor individually

Vertical resolution of the retrieval may be calculated from **A** (Hewison 2007):

$$\mathbf{Vres}_i = \frac{z_{(i-1)} - z_{(i+1)}}{\mathbf{A}_{i,i}}$$





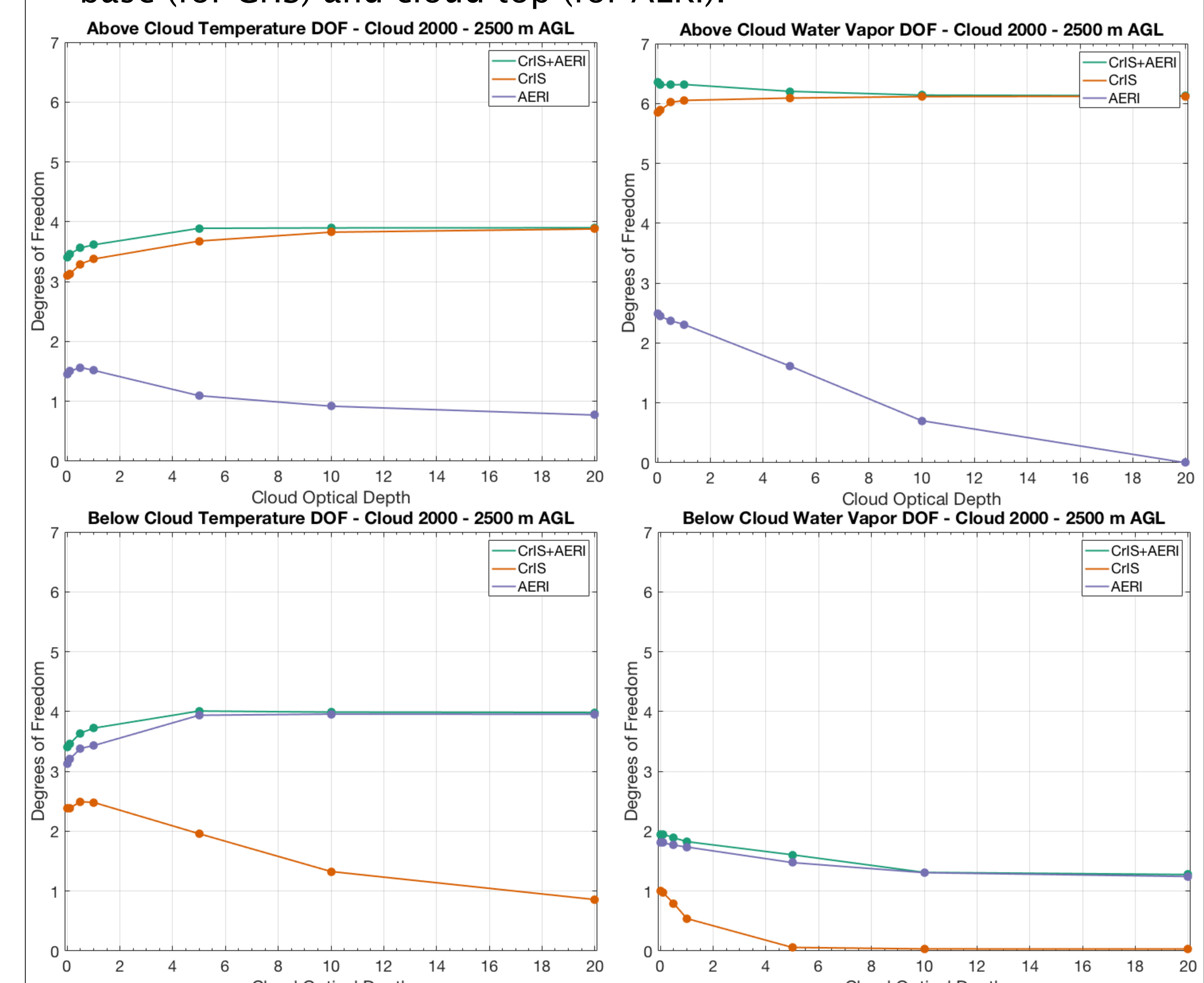
- Choice of the vertical grid for calculations underestimates AERI's vertical resolution in lowest 500 m AGL
- A synergy of AERI+CrIS has better vertical resolution than AERI or CrIS individually from 500 m to 5000 m AGL
- A synergy of AERI+CrIS provides significant improvements to vertical resolution compared to CrIS alone from the surface to 5000 m AGL.

Cloudy Sky Study

Adding a ground-based sensor, such as AERI, would provide information below the cloud layer, providing a potential solution to IR sounding in cloudy environments. We apply the same information content analysis to a cloudy sky profile, using LBLDIS (Turner et al. 2003, Turner 2005) to compute radiances for the cloudy sky scene.

Hypothesis: DOF for CrIS below the cloud and DOF for AERI above the cloud should both approach zero with higher cloud optical depths.

- This hypothesis is largely validated, however the below cloud DOF of CrIS and above cloud DOF of AERI do not go fully to zero all the time. This is primarily due to information coming from the cloud base (for CrIS) and cloud top (for AERI).



- At high optical depths, AERI provides all the information for the synergy below the cloud while CrIS provides all the information for the synergy above the cloud.
- Thicker clouds result in a decrease of water vapor DOF, it results in an increase of temperature DOF. The optically thick cloud provides a boundary condition that sharpens the temperature weighting functions relative to the cloud-free atmosphere.

References:

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