Improving Boundary Layer Profiling by Augmenting Space-Based Measurements with Ground-Based Interferometers

David M. Loveless[1], Timothy J. Wagner[2], Robert O. Knuteson[2], and S. A. Ackerman [1,2]
[1]Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison
[2]Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin-Madison
WISCONSIN UNIVERSITY OF WISCONSIN–MADISON
Contact: **dloveless@wisc.edu**

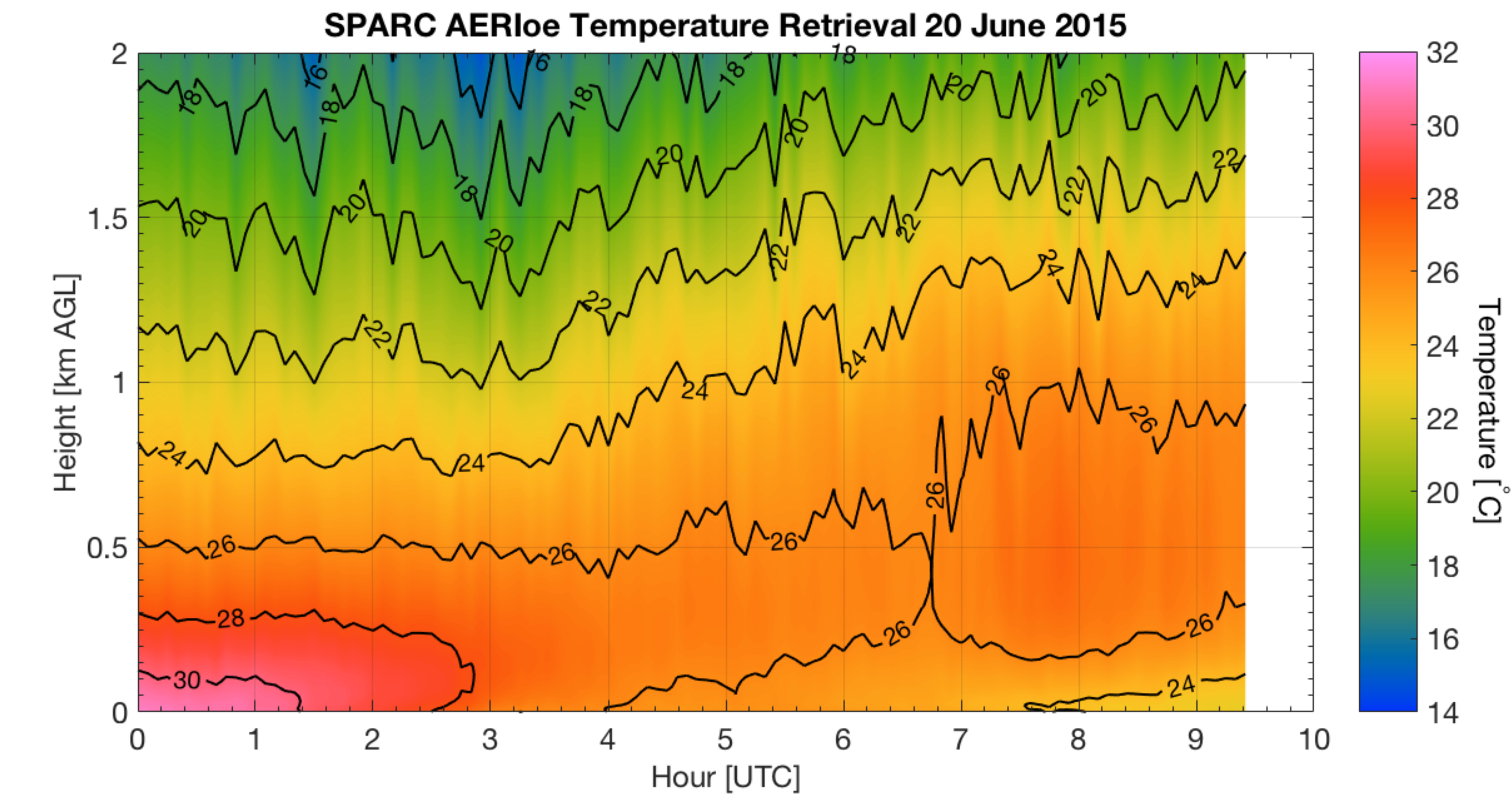
Introduction

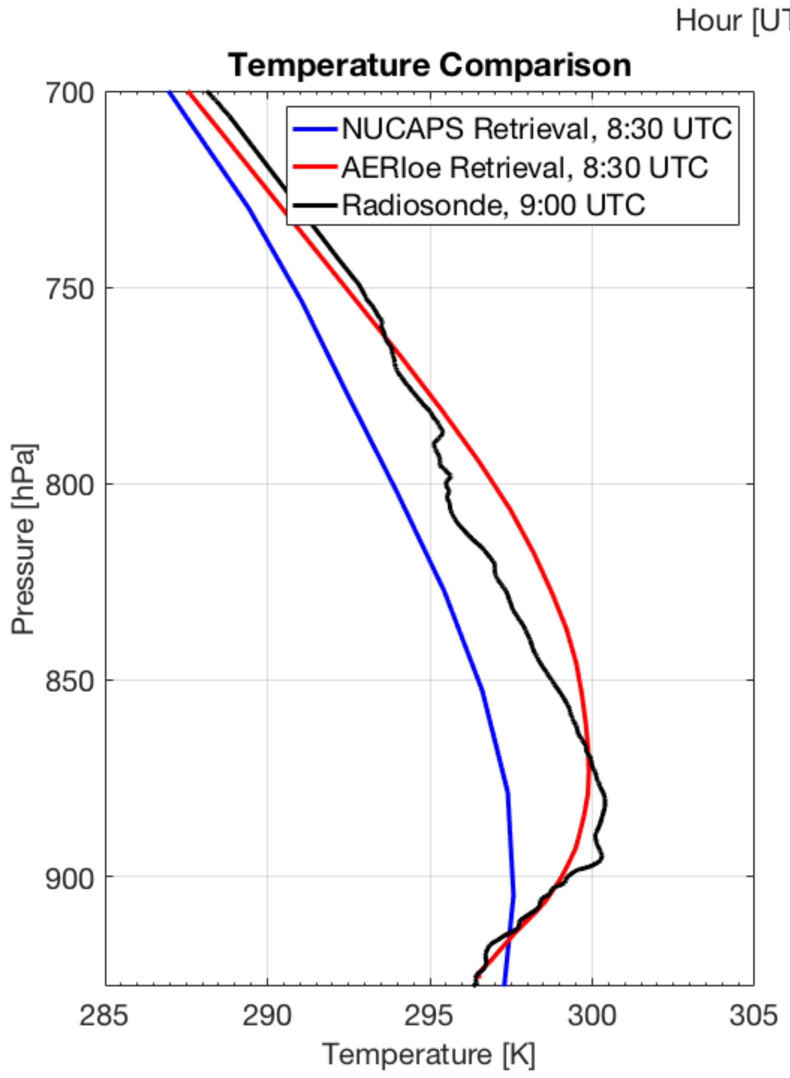
Motivation: Improving observations of the boundary layer was identified as a priority by the 2017 Decadal Survey.

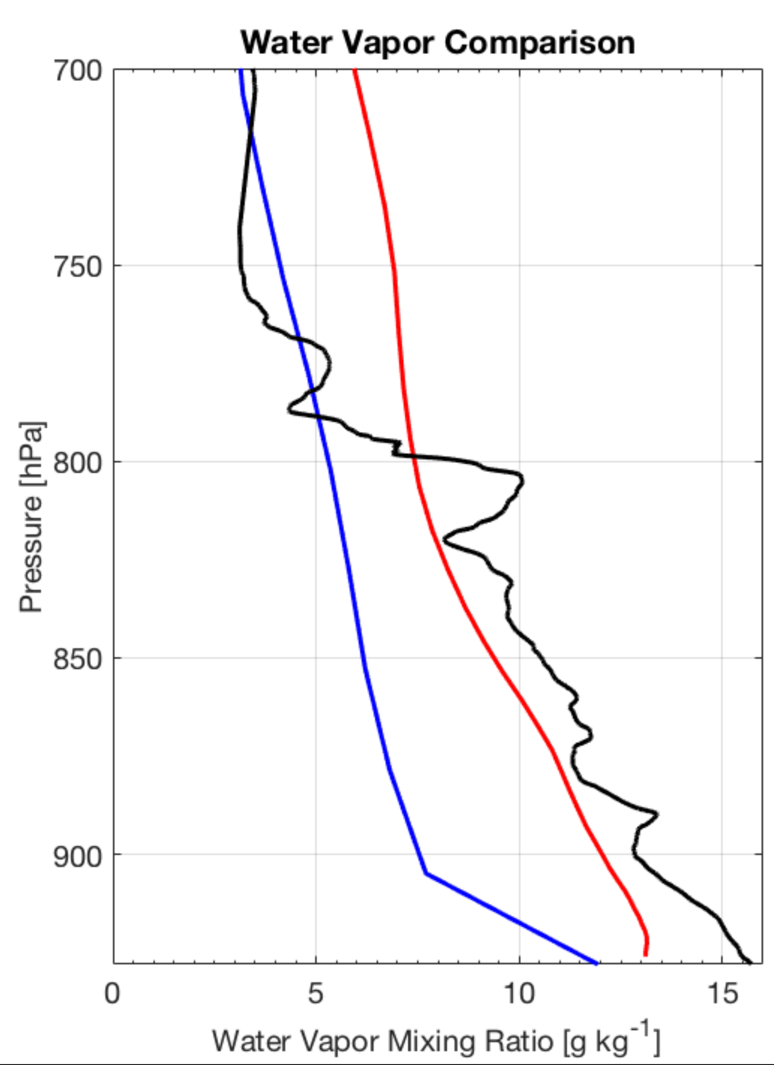
Method: Supplement the space-based Cross-track Infrared Sounder (CrIS) with the ground-based Atmospheric Emitted Radiance Interferometer (AERI) to improve the representation of the boundary layer.

AERI Overview:

AERI is a ground-based interferometer that measures downwelling radiance at 1 cm^{-1} resolution from 520 to 3000 cm^{-1} (19.2 to 3.3 μm). Its high-temporal resolution makes it ideal for observing changes to the boundary layer, such as the development of a low-level inversion in this 20 June 2015 example. It also compares favorably to radiosondes in the boundary layer when compared to a CrIS-based retrieval, NUCAPS. NUCAPS appears to have a more accurate water vapor retrieval above the capping inversion.



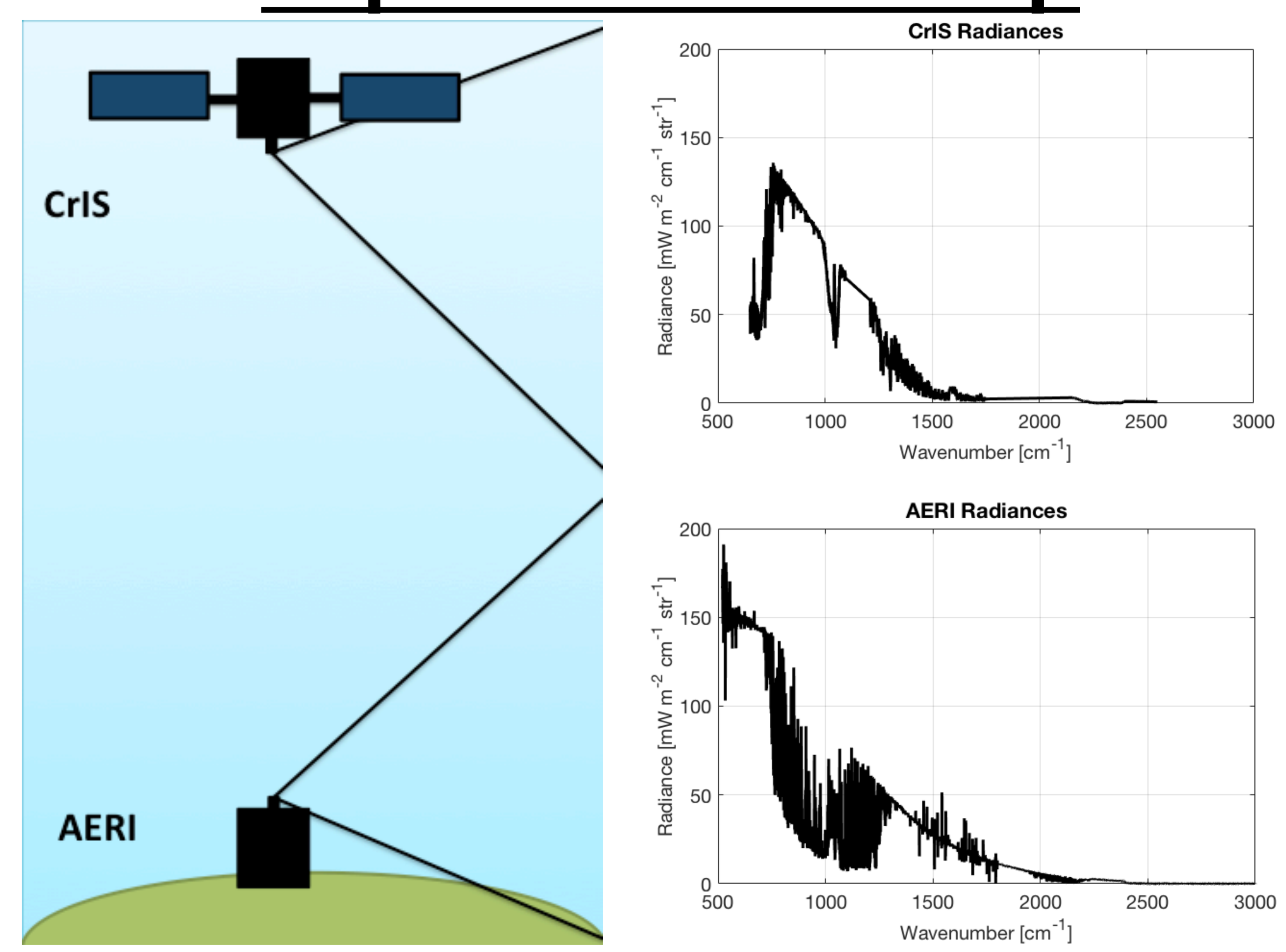




Objective

Objective: Assess the potential gains from a synergy between the space-based CrIS and the ground-based AERI by quantifying information content, using degrees of freedom (DOF).

Experiment Set-Up



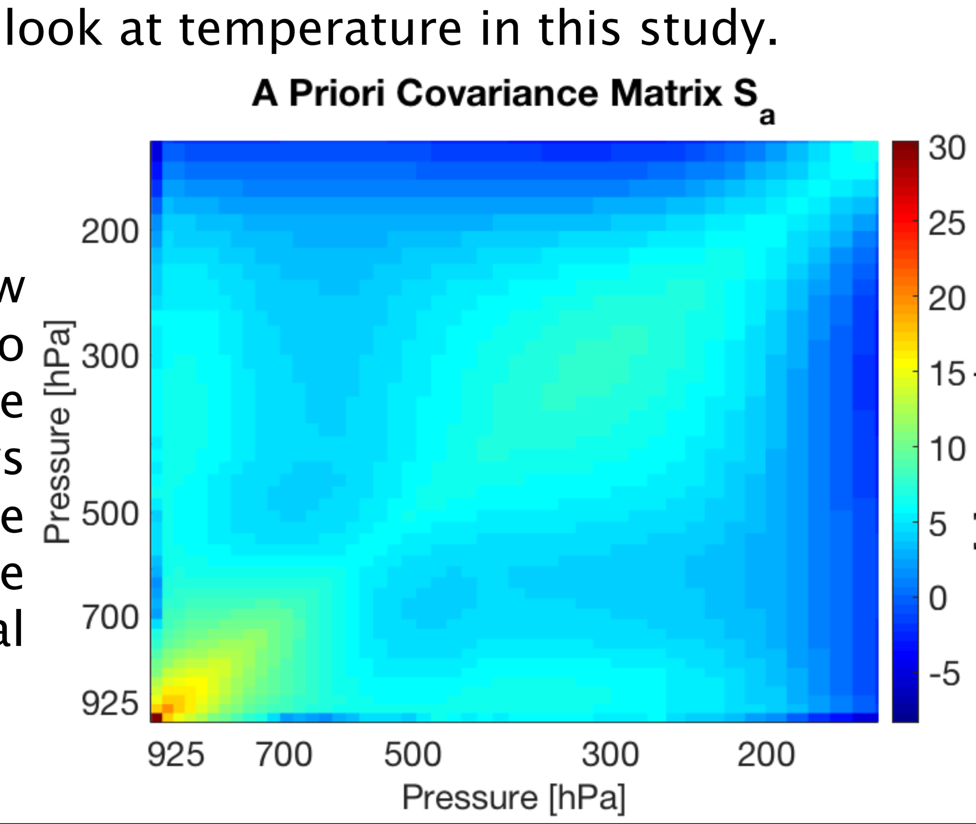
CrIS and AERI observe the same atmospheric state, but from different perspectives. Combining the two sets of measurements should result in an improved estimate of the observed state. Calculating degrees of freedom (DOF) is one way to assess the information content of a retrieval, and assess this improvement. 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, $\mathbf{S}_e$ is the measurement error covariance matrix, which is set to be 0.2 mW m^{-2} str^{-1} cm^{-1} K^{-1} for each channel (we assume no model error for simplicity). $\mathbf{S}_a$ is the a priori covariance matrix. $\mathbf{S}_a$ is calculated from 4,014 summertime radiosondes in clear sky conditions from the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains (SGP) site in Lamont, OK. We will only look at temperature in this study.

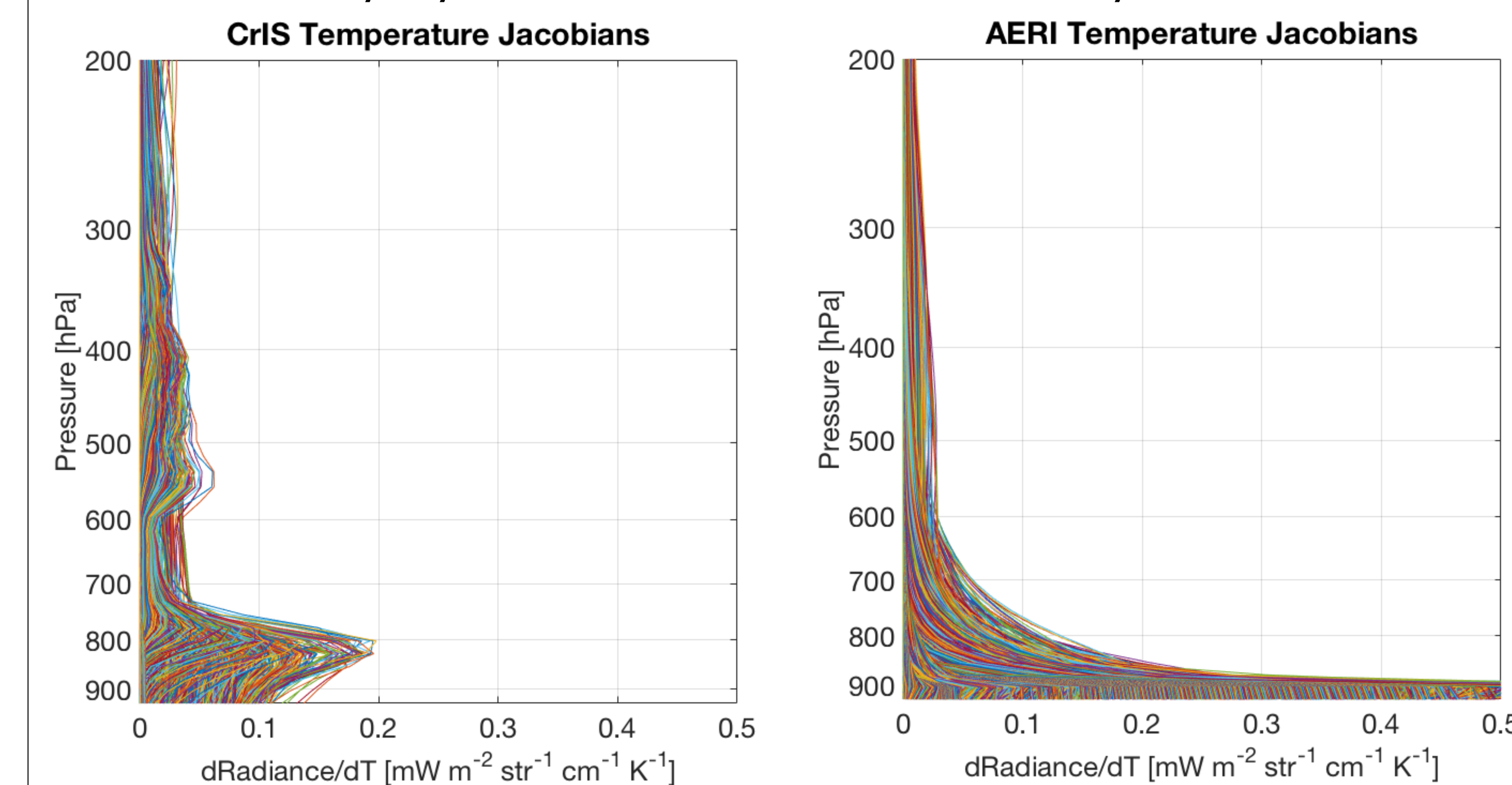
$$\mathbf{S}_a^{i,j} = \mathrm{CORR}(\mathbf{x}_i, \mathbf{x}_j)\, \boldsymbol{\sigma}_{xi}\, \boldsymbol{\sigma}_{xj}$$

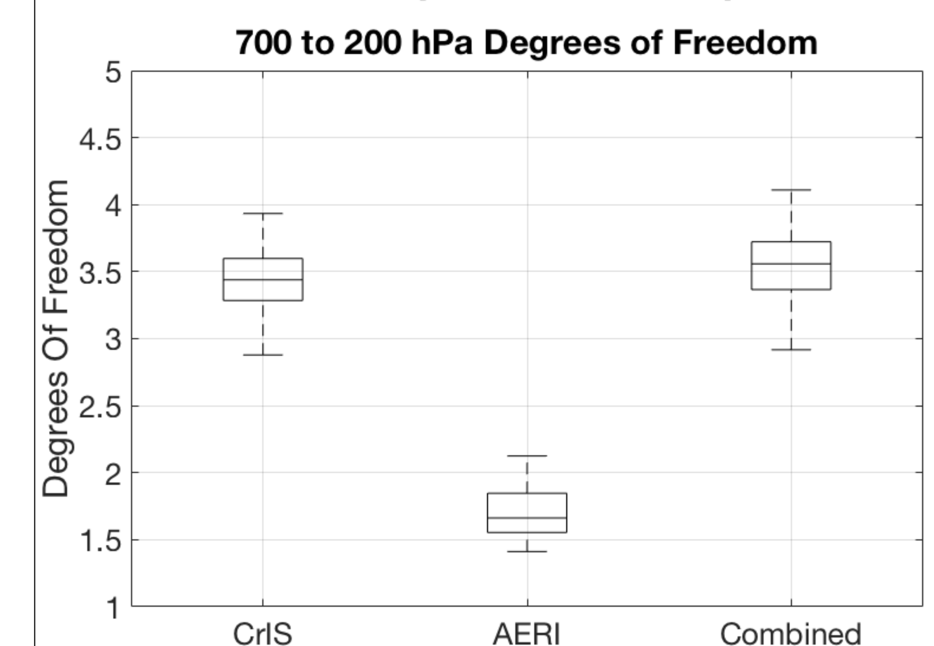
$\mathbf{S}_a$ is a measure of how each layer is correlated to another layer of the atmosphere. It allows knowledge about one layer to improve the estimate the retrieval makes for another layer.



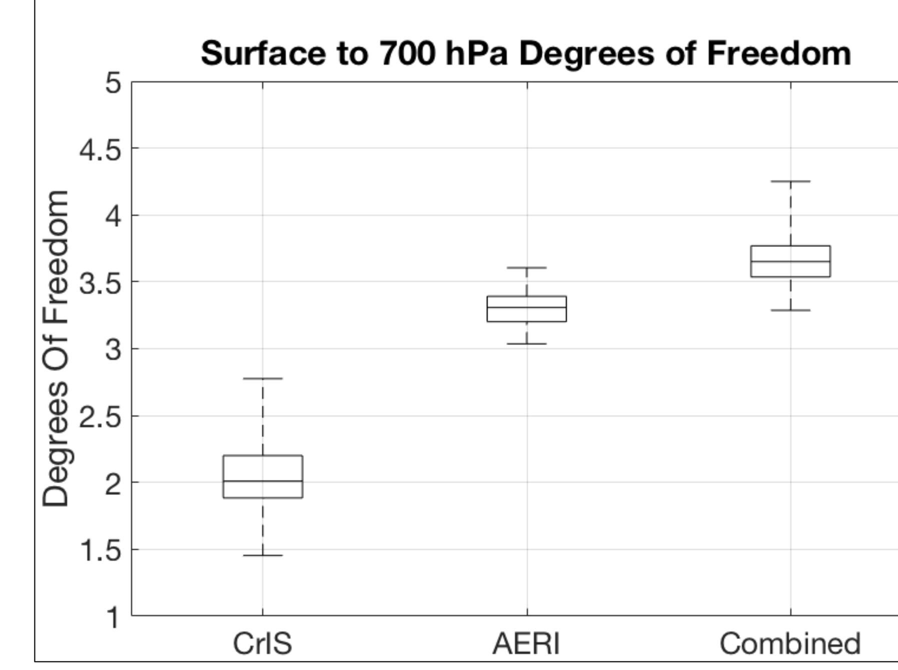
Results

Temperature jacobians suggest that CrIS is most sensitive to the middle troposphere and upper boundary layer. AERI is very sensitive to the boundary layer but has almost no sensitivity above 750 hPa.





We simulate 100 summer profiles, taken from the database used to calculate the a priori, using upwelling and downwelling versions of OSS, a line-by-line model created by Atmospheric and Environmental Research (AER) Inc. We calculate **A** for each profile and calculate the DOF.



- CrIS has greater information in the 700 hPa to 200 hPa layer (proxy for the free troposphere).
- AERI has greater information in the surface to 700 hPa layer (proxy for the boundary layer).
- ***The combined information in each layer is greater than using a single instrument!***

Future Work

- Repeat this analysis for water vapor mixing ratio in order to understand improvements from this synergy for the entire thermodynamic state.
- Overall goal is to develop an optimal estimation retrieval using the two instruments.

Potential Benefits

- We hypothesize that a combined retrieval will improve the representation of the capping inversion and thus improve monitoring of convective initiation.
- Potential operational benefits depend on the development of a ground-based thermodynamic profiling network and infrared hyperspectral sounding from geostationary orbit.

Acknowledgements

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