Poster: 247

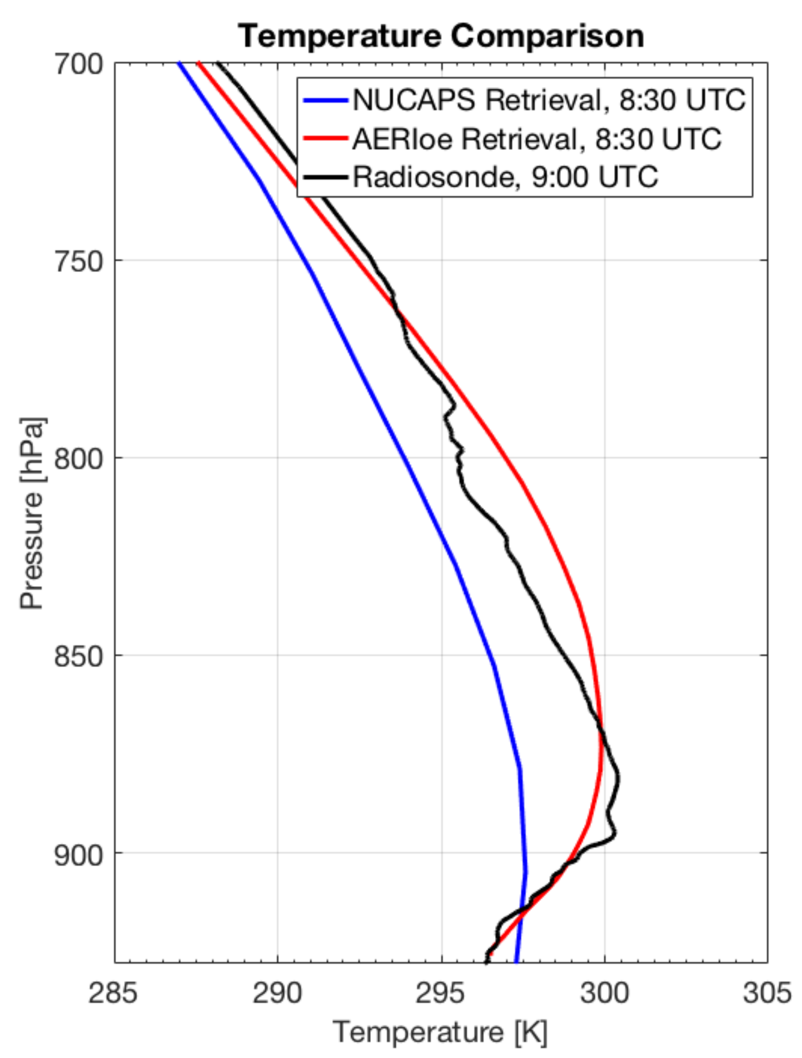
Ground-based Sounders as a Solution to Infrared Sounding in Cloudy Environments

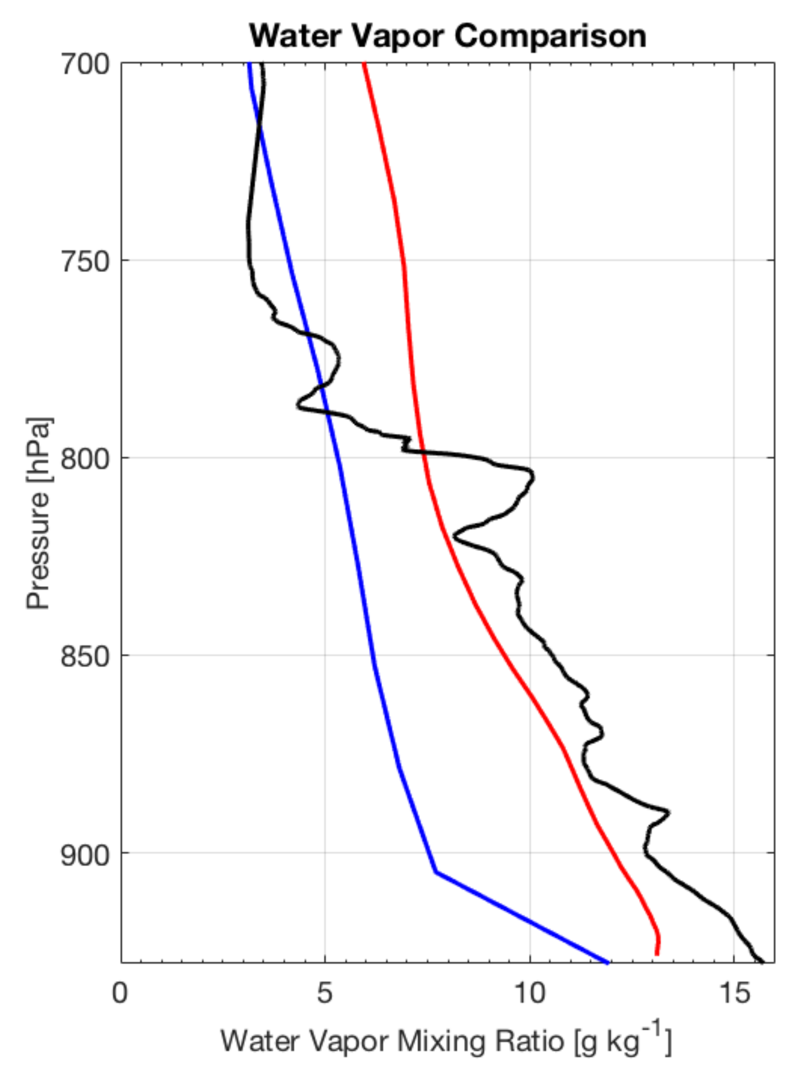
David M. Loveless[1,2], Timothy J. Wagner[2], David D. Turner[3], and Steven A. Ackerman [1,2]
[1]Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison
[2]Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin-Madison
[3]National Oceanic and Atmospheric Administration Earth System Research Lboratory, Global Systems Division
Contact: dloveless@wisc.edu

Introduction

Motivation:

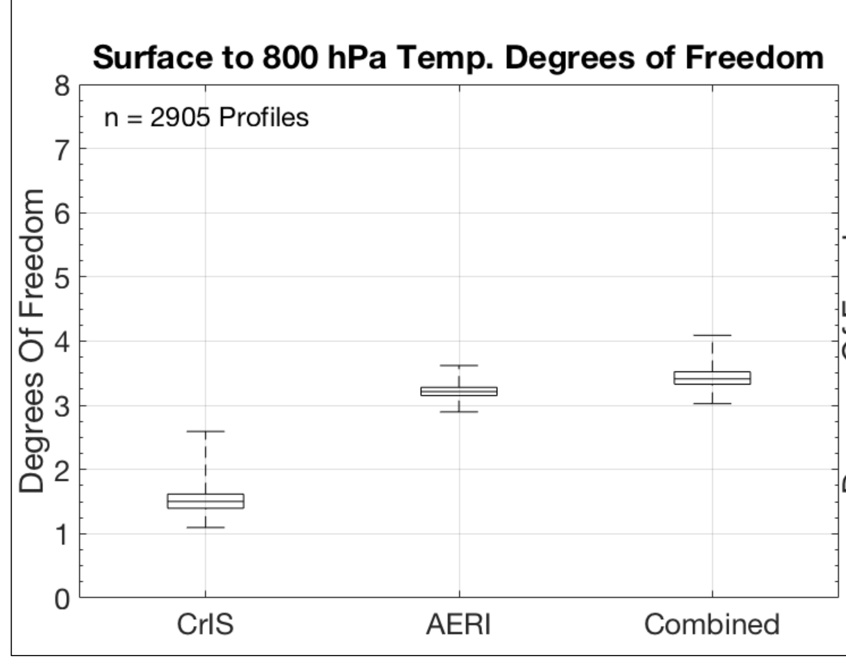
The 2017 Decadal Survey highlighted the need to improve observations of the planetary boundary layer. However, space-based sounding lacks the necessary accuracy in the boundary layer. Additionally, infrared (IR) sounding is frequently limited to the upper levels of the troposphere due to the presence of clouds. Microwave sensors are able to profile below the cloud layer, but lack the desired vertical resolution.

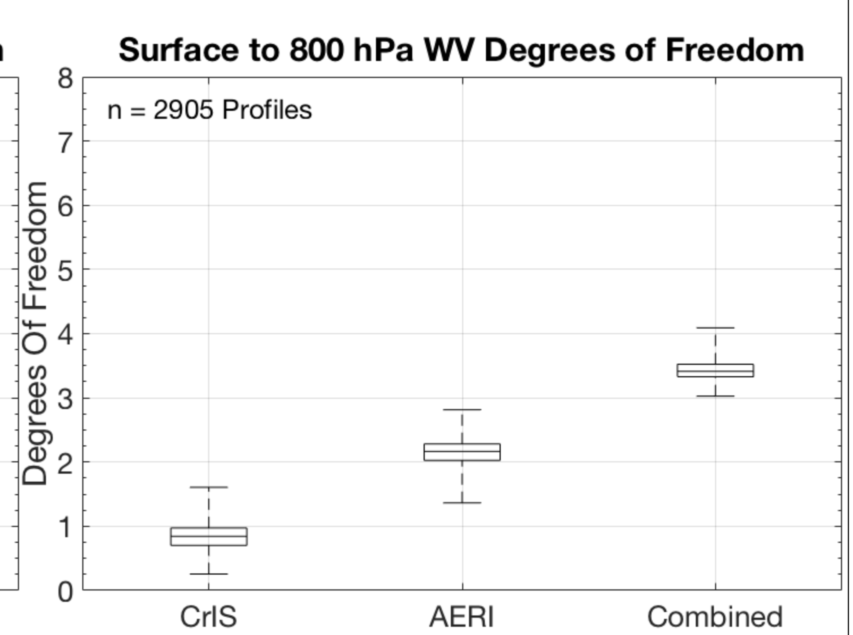




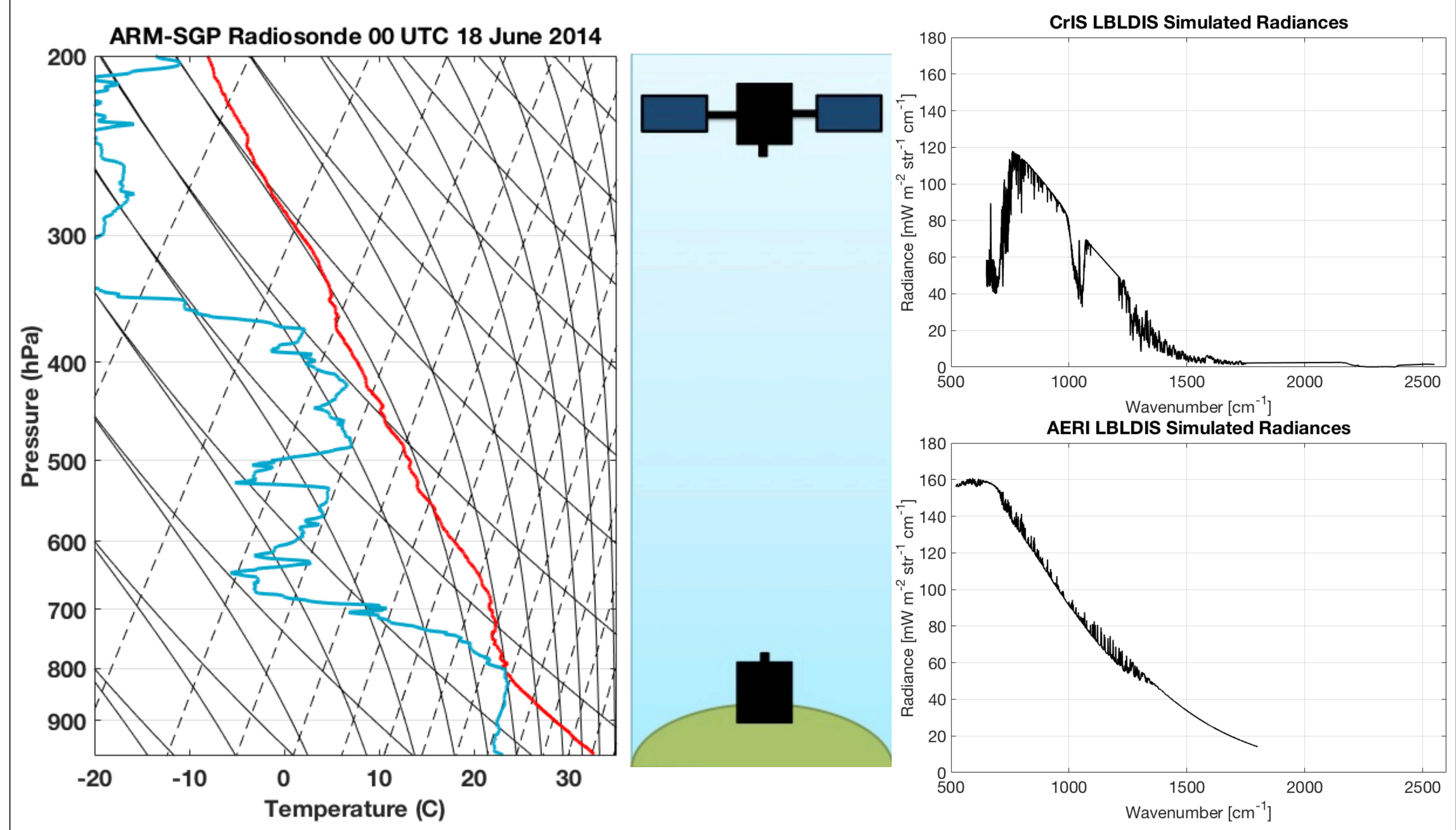
AERI as a Ground-based Solution:

The National Research Council has previously suggested the development of a network of ground-based thermodynamic profilers to supplement the space-based sounders in order to improve observations of the boundary layer. The Atmospheric Emitted Radiance Interferometer (AERI, Knuteson et al. 2004a,b) is one instrument that could be used for such a network. A clear sky information content study using radiosonde profiles from the Atmospheric Radiation Measurement Program (ARM) Southern Great Plains (SGP) site displays the benefits of a synergy between the AERI and space-based Cross-track Infrared Sounder (CrIS):





Experiment Set-Up



Objective: Calculate information content (degrees of freedom) in a cloudy environment in order to quantify the improvement provided by the AERI.

We simulate radiances for the cloudy sky scene (displayed above) for AERI and CrIS using LBLDIS (Turner et al. 2003, Turner 2005). We use a cloud base of 2 km (780mb) , effective radius of 7.5 um, and an optical depth of 10 across the entire spectrum. We use 1 K and 10% water vapor mixing ratio perturbations in order to calculate temperature and water vapor jacobians for the AERI and CrIS.

Quantifying Information Content - Degrees of Freedom:

Calculating degrees of freedom (DOF) is one way to quantify the information content of a retrieval. 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**:

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

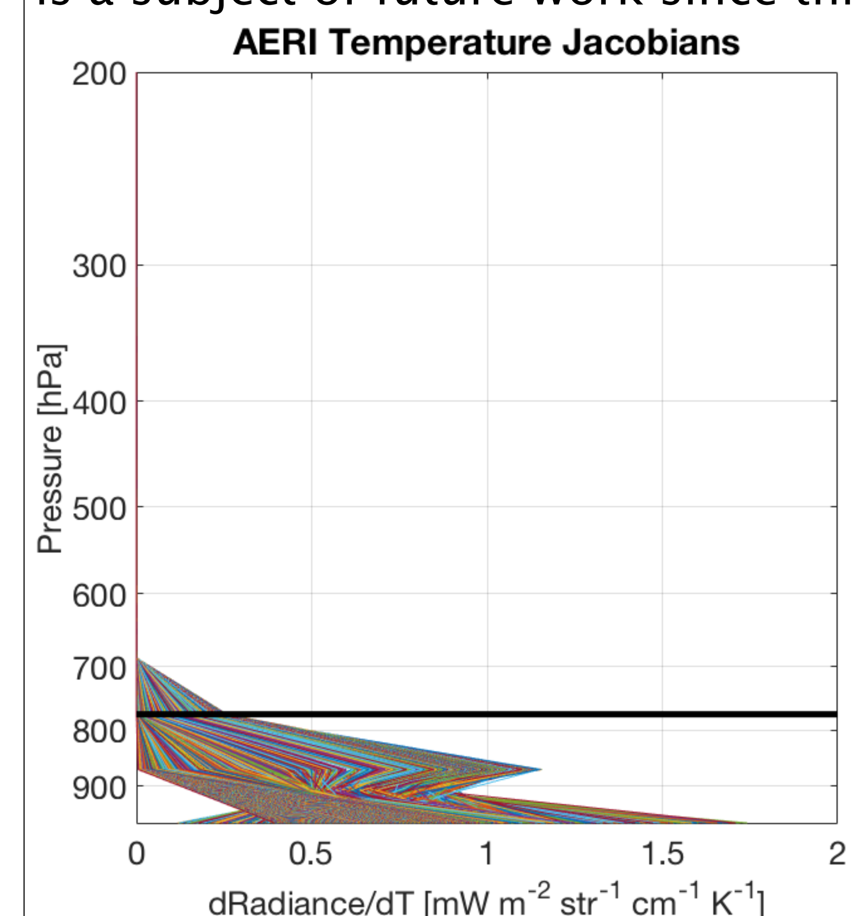
Where **K** is the jacobian, $\mathbf{S}_e$ is the measurement error covariance matrix, which is set to be 0.2 mW m^{-2} str^{-1} cm^{-1} K^{-1} for each channel (we assume no model error for simplicity). $\mathbf{S}_a$ is the a priori covariance matrix:

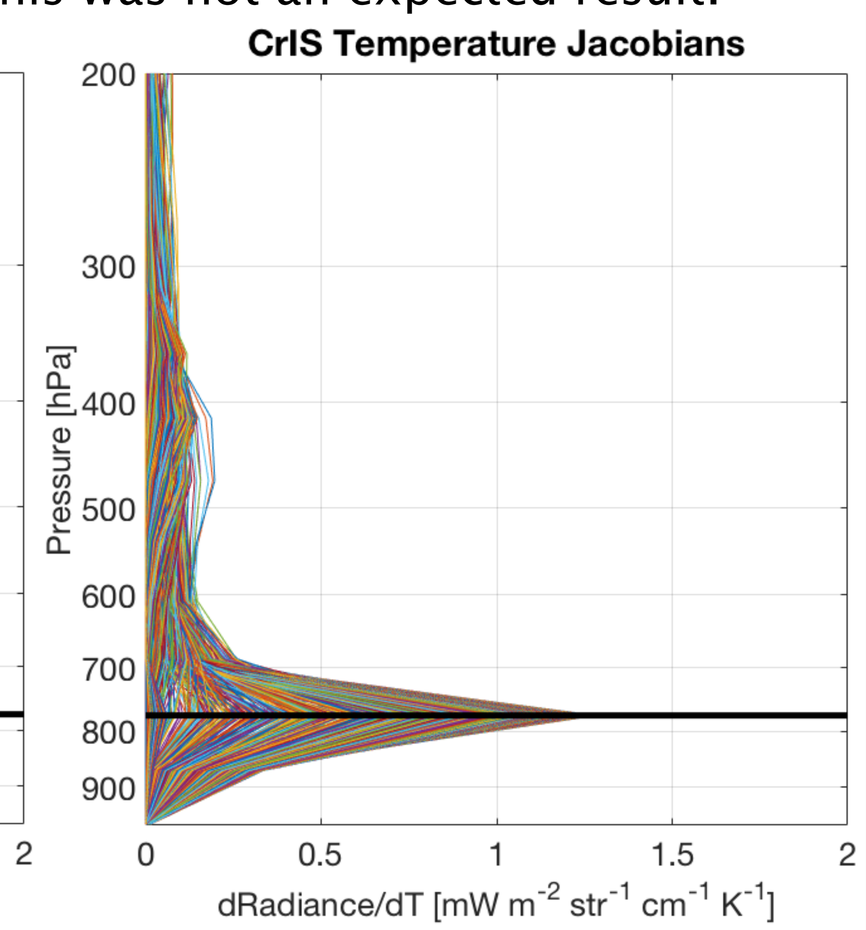
$$\mathbf{S}_a^{i,j} = \mathrm{CORR}(\mathbf{x}_i, \mathbf{x}_j)\, \boldsymbol{\sigma}_{\mathbf{x}_i} \boldsymbol{\sigma}_{\mathbf{x}_j}$$

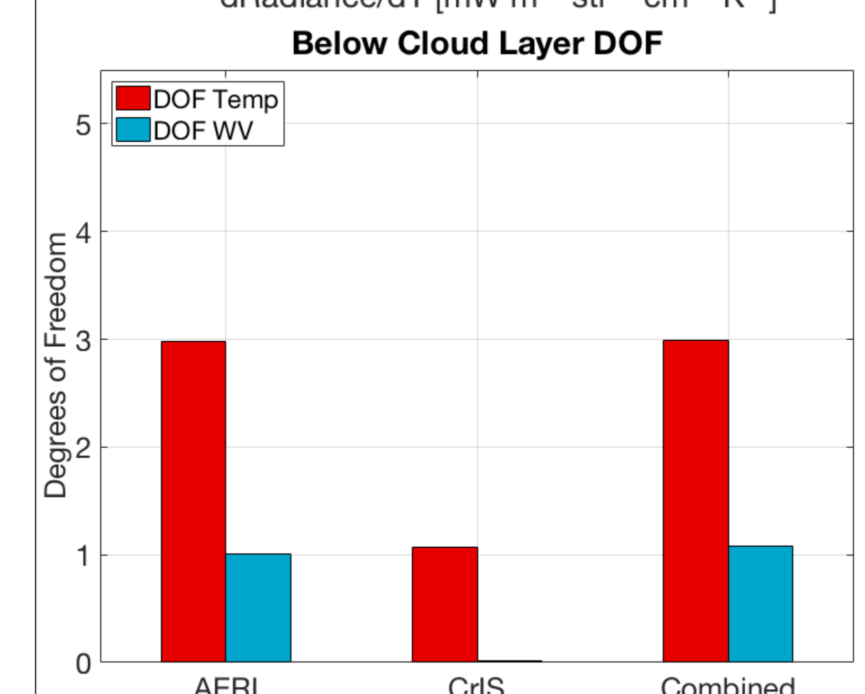
$\mathbf{S}_a$ is calculated from 2,905 summertime radiosondes in clear sky conditions from the ARM-SGP site.

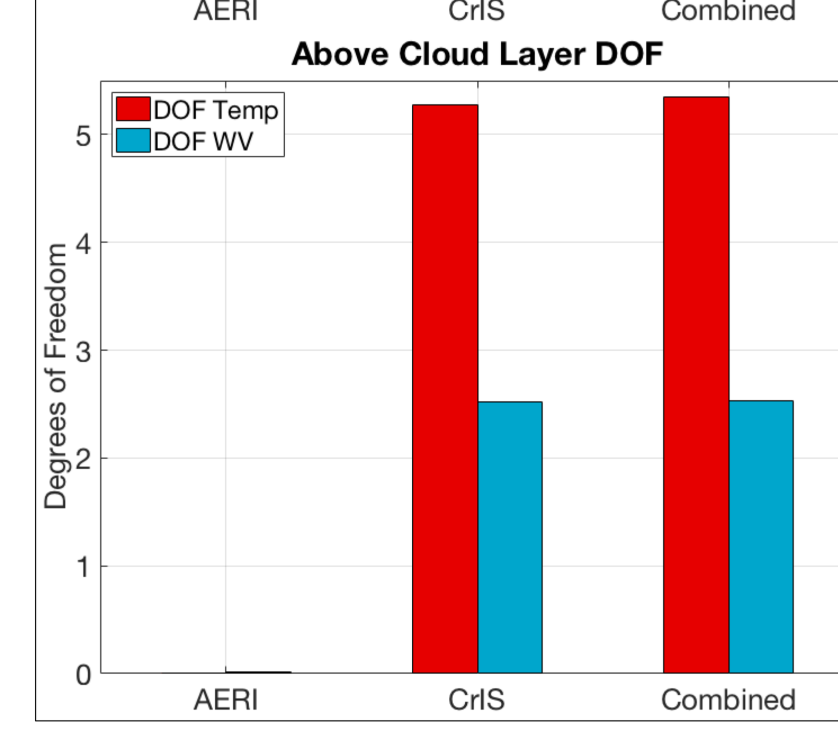
Results

Temperature jacobians display that AERI is only sensitive below the cloud layer, while CrIS is most sensitive above the cloud layer. Surprisingly the CrIS sensitivity is not zero below the cloud layer - this is a subject of future work since this was not an expected result.









Below Cloud Layer:

- AERI has 3 DOF for temperature and 1 DOF for water vapor. This is lower but comparable to clear sky results from the surface to 800 mb (likely a result of the lower vertical resolution used in LBLDIS simulations).
- CrIS has 1 DOF for temperature, but nearly zero for moisture.

Above Cloud Layer (to 200 hPa):

- AERI has no information above the cloud layer
- CrIS has more than 5 DOF for temperature and about 2.5 for water vapor.
- ***AERI and CrIS combined would provide more than 8 DOF for temperature and 3.5 DOF for water vapor across the troposphere - more than either instrument alone.***

Future Work

- Calculate DOF for the Advanced Technology Microwave Sounder (ATMS) in order to quantify the improvement with the AERI compared to a microwave sounder, which is able to profile below the cloud layer.
- Repeat this study for partly cloudy scenes in order to understand how CrIS (AERI) becomes sensitive to the boundary layer (free troposphere) as cloud cover in a field of view decreases.

References:

Knuteson, R. O. and Coauthors, 2004a: Atmospheric Emitted Radiance Interferometer. Part I: Instrument design. *J. Atmos. Oceanic Technol.*, **21**, 1763-1776.
Knuteson, R. O. and Coauthors, 2004b: Atmospheric Emitted Radiance Interferometer. Part II: Instrument performance. *J. Atmos. Oceanic Technol.*, **21**, 1777-1789.
Turner, D. D., S. A. Ackerman, B. A. Baum, H. E. Revercomb, and P. Yang, 2003: Cloud phase determination using ground-based AERI observations at SHEBA. *J. Appl. Meteor.*, **42**, 701-715.
Turner, D. D., 2005: Arctic mixed-phase cloud properties from AERI-lidar observations: Algorithm and results from SHEBA. *J. Appl. Meteor.*, **44**, 427-444.

Acknowledgements:

This research is supported by National Aeronautics and Space Administration (NASA) prime award number NNX15AQ03A "Educational Opportunities in NASA STEM (EONS)".