Final Report

Evaluating Radiative Closure in the Middle-to-Upper Troposphere

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OBJECTIVES

This project had two general objectives. The first is the *characterization and improvement of the radiative transfer parameterization in strongly absorbing water vapor bands*, as these strongly absorbing bands dictate the clear sky radiative heating rate. The second is the *characterization and improvement of the radiative transfer in cirrus clouds, with emphasis on ensuring that the parameterization of the radiative transfer is consistent and accurate across the spectrum*. Both of these objectives are important for understanding the radiative processes in the mid-to-upper troposphere.

The research on this project primarily involved analysis of data from the First and Second Radiative Heating in Underexplored Bands Campaigns, RHUBC-I and II. This included a climate model sensitivity study using results from RHUBC-I. The RHUBC experiments are ARM-funded activities that directly address the objectives of this research project.

A secondary effort was also conducted that investigated the trends in the long-term (~14 year) dataset collected by the Atmospheric Emitted Radiance Interferometer (AERI) at the ARM Southern Great Plains site. This work, which was primarily done by a post-doc at the University of Wisconsin – Madison under Dr. Turner's direction, uses the only NIST-traceable instrument at the ARM site that has a well-documented calibration and uncertainty performance to investigate long-term trends in the downwelling longwave radiance above this site.

The Radiative Heating in Underexplored Bands Campaigns

Dr. Turner was the Principal Investigator, together with Dr. Eli Mlawer, of the ARM-sponsored Radiative Heating in Underexplored Bands Campaigns (RHUBC-I and RHUBC-II). The RHUBC experiments were designed to explicitly collect datasets needed to address the objectives of this project, namely to characterize the accuracy and improve the radiative transfer parameterizations in strongly absorbing water vapor band and characterize the radiative properties of cirrus, especially in the far-infrared (wavelengths longer than 15 μm). The first RHUBC campaign was held at the ARM North Slope of Alaska (NSA) site in February-March 2007; the second was conducted at an altitude of 5300 m in the Atacama Desert in Northern Chile in August-October 2009. A review article describing the scientific objectives, design of the campaigns, and major accomplishments was published in BAMS in 2010 (Turner and Mlawer 2010). Both of the RHUBC experiments were very successful, with numerous other resulting publications listed below.

Long-term trend analysis at the SGP site

One of the goals stated in the original ARM science plan is to collect a long-term dataset that could be used to analyze and test climate models. One observationally-based way to reach this goal is to analyze the long-term ARM datasets for significant trends, and if they exist, see if current climate model runs (such as from the AR4) show the same trends. However, it is important to understand both the calibration and sensitivity of the instrument that is providing the long-term dataset used in the trend analysis, as changes in either the calibration or sensitivity may induce a trend that does not really exist.

AERI instruments have been operating at the ARM Southern Great Plains (SGP) site since 1994; however, the current operational AERI-01 system was deployed in late 1995 and is still collecting data today. The AERI instrument has a NIST-traceable calibration, and due to its calibration strategy, both the calibration and the instrument sensitivity can be monitored routinely. Thus, the AERI is one of the few instruments at the SGP site that can be used with confidence for the detection of long-term trends. Dr. Jon Gero, a post-doctoral student at UW, has been associated with the NASA CLARREO mission, which is being designed to collect a NIST-traceable on orbit reference infrared and solar dataset for climate-trend analysis and is scheduled to be launched in the next decade. As the AERI is essentially a ground-based version of the infrared portion of a CLARREO satellite, Dr. Gero and Dr. Turner have begun analyzing a 14-year dataset collected by the AERI-01 in order to develop techniques to analyze the spectral infrared data, discover any trends that may exist, and attempt to connect any trends in the observed downwelling radiance to atmospheric phenomenon.

The initial analysis of the 11 μm brightness temperatures over this 14-yr period revealed a tri-modal distribution; this was naively assumed to be due to clear skies, thin clouds, and opaque

clouds. A neural-network based classification tool was built to identify clear vs. cloudy scenes from the AERI-observed radiance, as other sensors (e.g., micropulse lidar, cloud radar) cold not be used as a change in their sensitivity or calibration would influence the results of the AERI trend analysis. This tool demonstrated that our initial assumption of opaque clouds explaining the one warmest mode in the brightness temperature distribution was correct, but that the two colder modes were a convolution of clear sky, thin clouds, and seasonally dependent changes in precipitable water vapor.

The clear sky / thin cloud / opaque cloud classification was used to segregate the dataset for the analysis. Several robust trends were identified. As an example, this dataset shows a statistically significant decrease in the downwelling radiance at 11 μm in clear sky during the winter over this 14-year period; this can only be explained by a decrease in the precipitable water vapor in the wintertime over this period. The methodology, results, and hypotheses that explain the results were published in Turner and Gero, 2010 and Gero and Turner, 2010.

ARM / ASR Program Leadership

Dr. Turner has been extremely active in leadership activities in the ASR program. He is the co-chair of the Cloud-Aerosol-Precipitation Interactions (CAPI) working group, which is one of the three science working groups within ASR, and serves on the Science and Infrastructure Steering Committee (SISC) for ARM / ASR. In these roles, Dr. Turner helps to organize both the fall working group meetings and the annual science team meeting in the spring, participates on regular conference calls to prioritize research and activities of the program, and coordinates activities within CAPI.

Dr. Turner also continues to serve as the chair of the ARM Climate Research Facility (ACRF) Science Board, which reviews all proposals submitted to ACRF for field experiments and campaigns and makes recommendations to DOE about the scientific merit and feasibility of these proposals.

Collaborations

- A workshop on Far-Infrared Remote Sensing was held and focused on the scientific and observing challenges of characterizing the Earth's spectral radiance properties in the 15 to 100 μm region. Topics discussed included instrumentation, radiative transfer model development and validation, thermodynamic profiling, cloud property remote sensing, and climate studies. The workshop presenters were from research groups worldwide involved in far-infrared remote sensing. The workshop took place November 8-9, 2011, in the Pyle Center on the University of Wisconsin-Madison campus. http://www.ssec.wisc.edu/farir_workshop/2011/
- Dr. Turner is the Principal Investigator of the RHUBC experiments with Dr. Eli Mlawer from Atmospheric and Environmental Research (AER). In this experiment, Dr. Turner is collaborating with Dr. Jennifer Delamere (AER), Dr. Scott Paine (Smithsonian Astrophysical Observatory), Drs. Marty Mlynzcak and Dave Johnson (NASA Langley Research Center), and Drs. Luca Palchetti and Giovanni Bianchini (Institute of Applied Physics, Florence Italy).

- Dr. Turner is working closely with Drs. Susanne Crewell, Ulrich Löhnert, and their students at the University of Cologne (Germany) to improve the ability to retrieve the atmospheric temperature and humidity profiles simultaneously with cloud properties from ground-based remote sensing measurements. This collaboration has already yielded numerous papers. This capability will be important for the new ASR program's scientific objectives.
- Dr. Turner continues to work closely with Dr. Maria Cadeddu (Argonne National Laboratory) on ARM microwave radiometer issues and analyses.
- Dr. Turner is the co-chair of the ASR Cloud-Aerosol-Precipitation Interactions (CAPI) working group, and thus a member of the ARM Science and Infrastructure Steering Committee (SISC).
- Dr. Turner is a member of the International Scientific Steering Committee (ISSC) for the Convective and Orographic Precipitation Study (COPS), which is being conducted in the Black Forest region of Southwestern Germany. The ARM Mobile Facility was deployed as part of the COPS campaign. Dr. Turner is one of the primary contacts between the international COPS principal investigators and the ARM program. In this role, Dr. Turner interacts regularly with Dr. Volker Wulfmeyer (University of Hohenheim, Stuttgart, Germany), who is the principal investigator of COPS.
- Dr. Turner is the PI of the Inner Domain Thermodynamic Profiling (IDTP) experiment, which was held at the ARM SGP site in the spring of 2011 as part of the Mid-Continental Convective Cloud Experiment (MC3E). The IDTP experiment deployed 3 AERI instruments at the X-band radar locations that surround the SGP site. Profiles of temperature and humidity will be retrieved from these radiance observations and used to investigate the small-scale horizontal inhomogeneities in these fields during MC3E/IDTP.
- Dr. Turner is the co-PI of the Humidity Experiment (HUMEX). During HUMEX, three small compact microwave radiometers (CMRs) were deployed by the HUMEX co-PI Dr. Steve Reising (Colorado State University) between the IDTP AERIs. The CMRs were operated in a variety of 3-D scanning modes. The CMR datasets, along with the AERI data, will be used to investigate if tomographic retrievals of water vapor can be performed.
- Dr. Turner is an external member of Subhashree Mishra's Ph.D. committee at the University of Nevada – Reno. Mishra is analyzing in-situ data collected during the ARM-sponsored campaign SPARTICUS to develop improved methods to quantify ice particle fall velocity as a function of size, IWC, and habit. Her research also is providing a new way to look at ice nucleation, and in particular the relative importance of homogeneous vs. heterogeneous nucleation, as a function of temperature.

ARM Related Publications

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