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# INFERRING CONVECTIVELY-INDUCED ROLL STRUCTURES AND CONVERGENCE IN THE BOUNDARY LAYER USING PROFILING INSTRUMENTS: AN APPLICATION TO CONVECTIVE INITIATION DURING IHOP_2002

John R. Mecikalski[1‡], Kristopher M. Bedka[1], Ryan D. Torn[1], Wayne F. Feltz[1], and Tammy M. Weckwerth[2]

[1]Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin - Madison

[2]Atmospheric Technology Division
National Center for Atmospheric Research

## 1 MOTIVATION

The goals of this study are to develop new methods for inferring the patterns of three dimensional turbulent and water vapor structures within the convective boundary layer (CBL; e.g. convectively driven rolls, significant wind convergent-induced boundaries) from one-dimensional profiles of temperature, moisture and wind, as well as from hyperspectral aircraft-based instruments. Such turbulent structures, as formed in deepening CBLs under the influence of solar heating, provide the first clues to how deeper, precipitating convection may form. Obtaining three-dimensional information from profiling instruments has benefits when more elaborate radar measurements are not available. We hope to identify the critical case-specific factors that contribute to the first-time initiation of deep convection. These factors will be related to subtle variations in CBL moisture (Weckwerth 1996; Weckwerth 2000), and the mass and moisture convergences that support these moisture discontinuities which, in turn, support cumulus cloud growth. A better understanding of water vapor variability within the CBL will be an important outcome of this research. [‡]

An additional question that this study will address is the time scales and mechanisms of surface-based moisture and wind-convergent boundary formation and decay within the CBL wind field as related to roll evolution, cloud line formation and convective initiation. This will occur as observational analyses are combined with LES experiments generated by the University of Wisconsin Non-hydrostatic Modeling System or the Penn State/NCAR MM5 for selected days during IHOP_2002.

## 2 DATA

Several data sets will be utilized over the duration of this project. They constitute a variety of high-spectral, high-spatial resolution radiance information as collected by ground- and aircraft-based sensors. Other important data from the NCAR S-band polarmetric radar (S-Pol) deployed during IHOP_2002 in the Oklahoma panhandle and CRYSTAL-FACE in Florida during July 2002, and operational satellites (e.g., the GOES-11), will be heavily relied upon.

The high-resolution remote sensing instruments we will rely upon include the Atmospheric Emitted Radiance Interferometer (AERI), the Raman lidar, the National Polar-orbiting Operational Environmental Satellite System Airborne Sounder Testbed–Interferometer (NAST-I; see http://deluge.ssec.wisc.edu/∼nasti/ for more information), and the Snanning High-resolution Infrared Sounder (S-HIS; http://deluge.ssec.wisc.edu/∼shis/).

The AERI is designed to retrieve the moisture and temperature structure of the boundary layer from ground-based high-spectral resolution infrared measurements, and has been developed over a ten year period at the University of Wisconsin (Feltz et al. 1998). The AERI is a well-calibrated instrument that passively measures high-resolution (downwelling) emitted radiance from the atmosphere. AERI's vertical resolution ranges from from

[‡] *Corresponding author*: John R. Mecikalski, Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin - Madison, 1225 West Dayton Street, Madison, WI 53706-1695. email: *john.mecikalski@ssec.wisc.edu*

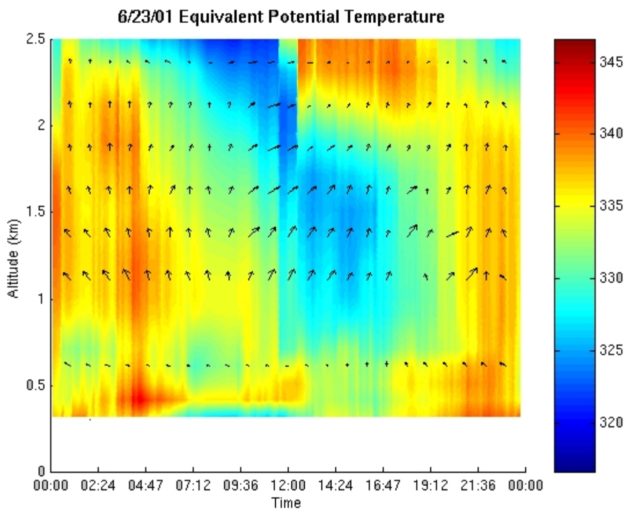


Figure 1: An AERI profile of $\theta_e$ from 0-2.5 km for the AERI located at the ARM "central facility" site near Lamont, Oklahoma. Data from the co-located 915 MHz wind profiler is added. Data are for 23 June 2001, and represent temperature and mixing ratio derived from AERI measurements.

100 m up to 1 km, 200 m to 2 km and 250 mat 3 km. AERI was deployed at the Homestead site within IHOP_2002 for the duration of the experiment, from 12 May to 25 June 2002, and operated for >98time. Currently, AERI data up to 3 km is joined with either GOES-derived soundings (of temperature and moisture) or model fields (e.g., from the RUC-2 model) above 3 km to ∼12 km to form a complete tropospheric sounding. This techniques capitalizes on the sounding strengths of both AERI and GOES when used. Figure 1 presents time series of AERI profiles of $\theta_e$ from 00:00–23:50 UTC on 23 June 2001 as collected as part of the ARM Program.

The Raman lidar is an active remote sensing systemn that functions as a robust measuring system for atmospheric water vapor mixing ratios, measures ratios of Raman-shifted nitrogen, oxygen and water vapor molecules. The procedure of Turner et al. (2000) describes how these ratios are converted into absolute water vapor mixing ratio information. The Raman lidar at the ARM central facility site measures water vapor to over 10 km altitude during nighttime clear conditions (restricted to 3-5 km during daytime due to low signal to noise ratios caused by solar contamination) at a temporally-averaged frequency of 10 minutes (1-mintue samples). The vertical resolution of this lidar is 39 m at night and 78 m during the day. Due to the strength of the Raman lidar for measuring water vapor (compared to AERI), and the ability of AERI for measuring temperatures very accurately, the *combination* of AERI temperature and Raman water vapor profiles is what this project will rely upon from these measuring systems.

Both the AERI, NAST-I and S-HIS instruments are supported by the University of Wisconsin–Madison (CIMSS) and make available to the researcher highly accurate retrieved temperature and moisture fields. For the AERI, temperature accuracies of 1 K are obtained (Feltz et al. 1998), while for Raman lidar, moisture accuracies of 0.5 $gkg^{-1}$ are obtained (Turner at al. 2000). Given these well-calibrated data, we feel justified and confident in using them to assess subtle variations in thermodynamic parameters (i.e., equivalent potential temperature, $\theta_e$) within the CBL.

The NAST-I and S-HIS instruments are scanning interferometers which measure emitted thermal radiation at high spectral resolution between 3.3 and 18 $\mu$m (specifications). The measured emitted radiance is used to obtain temperature and water vapor profiles of the Earth's atmosphere. Both NAST-I and S-HIS produce sounding data with 2 km resolution (at nadir) across a 40 km ground swath from a nominal altitude of 20 km when flow on the NASA ER-2 or PROTEUS aircrafts. S-HIS can also be placed on the NASA DC-8 aircaft to provide a 20 km ground swath from a nominal altitude of 10 km. Figure 2 shows data collected from the NAST-I on 19 March 2000 over Kansas.

The S-Pol reflectivity information used in this study provides a critical form of ground truth of CBL moisture and cloud patterns. In particular, the S-Pol's ability to detect tropospheric tracers (e.g., aerosols, insects), which can be used as proxies for the convergence of mass and moisture within the CBL, allow us to use this instrument's data to map the location of convectively-induced rolls and boundaries. Knowledge of the locations of such structures obtained from S-Pol will be used in conjunction with data from AERI, Raman lidar, NAST-I and S-HIS, as well as GOES 1 km imagery, to 1) evaluate how the individual profiling and scanning instruments measure CBL structures, 2) to help develop algorithms for use with data from these instruments, and 3) to corroborate our analysis by providing a form of validation.

## 3 PROCESSING APPROACH

As we seek to characterize conditions within the CBL prior to convective initiation, the plan for an-

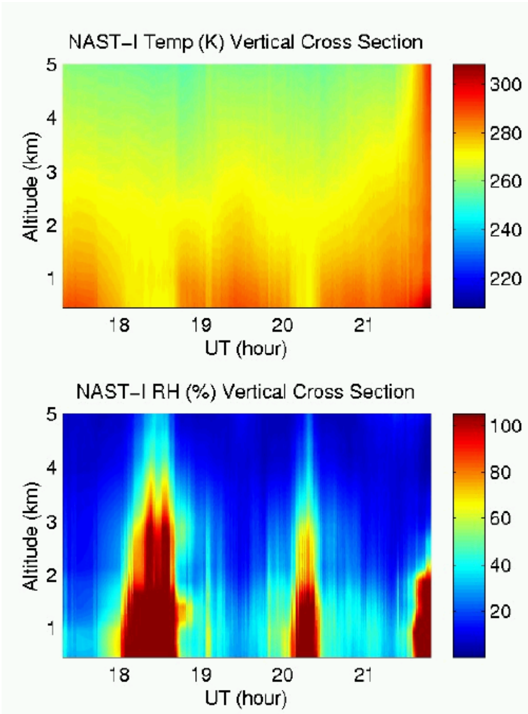


Figure 2: An example of NAST-I profiles of temperature and relative humidity perpendicular to the flight path of the ER-2 on 19 March 2000 over a region in Kansas.

alyzing the above data sets will be to first, assess how well an individual scanning or profiling instrument measures observed turbuent structures within the CBL, and second, evaluate how well CBL patterns can be measured by the combined processing of the above data sets.

Two approaches are taken toward evaluating how one-dimensional profiles measure three-dimensional convective features:

1. Use time series analysis to relate the statistics of one-dimensional profile measurements to the anticipated statistics of three-dimensional structures. Specifically, we quantify the subtle variations in heat and moisture associated with rolls as they move over a stationary profiling instruments to assess the period, size and orientation of CBL rolls. This statistical analysis is then compared to rolls as they appear in radar or satellite data. Subsequent analysis of quantities such as the Richardson number (based on the stability and shear within a CBL) allow us to evaluate how CBL turbulence should organize and evolve in a given set of meteorological conditions.

2. Directly compare how observed turbulent structures (measured by profiling instrument) statistically compare to modeled structures using LES experiments, and S-Pol radar - observed roll and boundary features as measured by high-resolution satellite imagery. This analysis again helps infer what CBL properties profiling and scanning instruments are measuring.

Beyond this, work will involve using co-located AERI and lidar analyses, NAST-I and S-HIS, and finally S-Pol and GOES 1 km imagery, as we attempt to correlate profile-derived CBL patterns with spatial patterns of (hyperspectrally-measured) moisture variability. Again, the end-scientific of this work is to better understand the CI process, yet addressing this goal through the processing of state-of-the-art remote-sensing data sets is a very important component as well.

## 4 PRELIMINARY RESULTS

Preliminary results using 10-minute AERI retrievals (on 23 June 2001) of temperature and moisture within a simple autocorrelation analysis highlight that for single levels through AERI profiles, there appears to be a relatively high correlation between temperature/moisture patterns every 50-70 minutes. This autocorrelations (with lags of ~50 minutes) are evident from the mid-morning hours through 00 UTC. New work will involve 40-second AERI retrievals during the CRYSTAL-FACE field experiment in Florida during June-July 2002.

The poster presentation accompanying this abstract will describe our progress to date, in particular, with regards to the co-analysis of S-Pol, GOES, AERI, Raman lidar, and NAST-I data for selected convective initiation events (during IHOP_2002 and CRYSTAL-FACE).

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