Validation of MM5 with AERI observations over the Southern Great Plains ARM site

Derek J. Posselt*[1], Wayne F. Feltz[1], and David D. Turner[1,2]

[1]Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin–Madison
[2]Pacific Northwest National Laboratory, Richland, Washington

1. INTRODUCTION

During the International H_20 Project (IHOP, 13 May–25 June 2002), the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin–Madison is running MM5 over the Southern Great Plains (SGP) Atmospheric Radiation Measurement (ARM) site. Daily MM5 runs are compared with observations and retrievals from the Atmospheric Emitted Radiance Interferometer (AERI) at six different locations. Two validation methods are developed, which take advantage of the AERI's high temporal and spectral resolution observations of the boundary layer.

2. DESCRIPTION OF AERI INSTRUMENT

The AERI is an upward-looking passive instrument that measures downwelling infrared radiation in wavelengths between 3 and 25 micrometers at less than one cm^{-1} wavenumber spectral resolution and ten-minute temporal resolution. The AERI has been extensively calibrated using explicit line-by-line radiative transfer codes (Clough et al. 1995), and has been field-tested continuously since March 1993 in an ongoing field campaign funded by the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) program.

High spectral-resolution radiances collected by the AERI are converted to vertical temperature and water vapor profiles in the lowest 3 km of the earth's atmosphere through inversion of the infrared radiative transfer equation (Smith et al. 1998). Statistical comparison between AERI retrievals and radiosonde observations for 221 cases has revealed average rms differences of 0.6-1.35 K and 0.8-1.4 g/kg for temperature and water vapor respectively (Feltz et al. 1998). Temperature and water vapor profiles retrieved from the five AERI locations at the Southern Great Plains (SGP) ARM site have been automated since 1998, and have been used to track the passage and evolution of mesoscale meteorological features including boundary-layer destabilization, cold-frontal passages, and warm-air advection events (Feltz et al. 1998).

*Corresponding author address: Derek J. Posselt, SSEC/CIMSS Univ. of Wisconsin–Madison, 1225 W. Dayton Street, Madison WI 53706-1695. email: dposselt@ssec.wisc.edu, phone: (608) 263-1116, fax: (608) 262-5974

3. MM5 CONFIGURATION

MM5 version 3.5 is run once each day over the SGP ARM site on a 2-way interactive nest at 60 km and 20 km horizontal resolution (Figure 1) with 38 vertical sigma levels. Simulations are initialized from 1 degree 0000 UTC AVN model output and run out to 48-hours. The model employs the Reisner mixed-phase microphysics scheme, MRF boundary layer scheme, Kain-Fritsch cumulus parameterization, and RRTM radiation scheme.

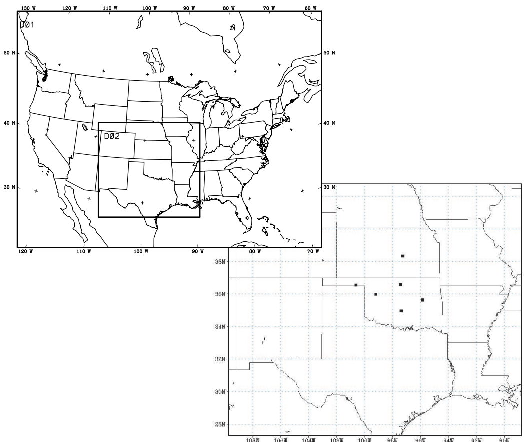

Figure 1. MM5 domain configuration

4. VALIDATION PROCEDURE

In the first validation method, AERI time-height cross-sections are produced for each of the six AERI locations at the SGP ARM site (marked with filled squares in Figure 1), as well as for an additional mobile field site specific to the 2002 IHOP field experiment. Temperatures and mixing ratios retrieved from the AERI update continuously to a web page (http://barrage.ssec.wisc.edu/~dposselt/ihop/), and are plotted alongside forecast MM5 time-height cross-sections. Sample time-height cross-sections from AERI and MM5 on 16 May 2002 are depicted in figures 2a and 2b respectively. These plots, obtained from the AERI site located near Vici, Oklahoma, exhibit good agreement between the observations and model throughout the time period depicted. Note, however, that the gradients of temperature and mixing ratio are much sharper in the AERI observations than in the model. Comparison of time-height plots of model output fields with AERI retrievals allows an approximate assessment of the performance of the

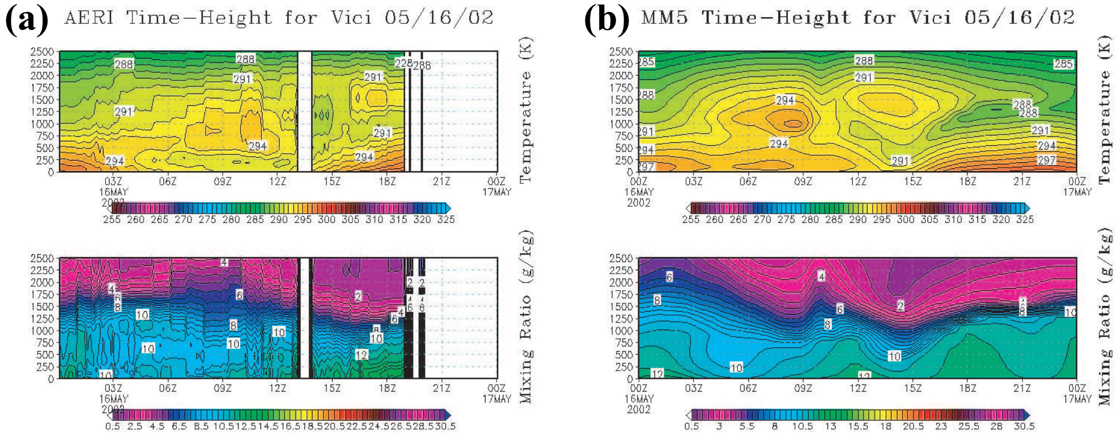

Figure 2: Comparison of time-height cross-sections of temperature in degrees K (top) and mixing ratio in g/kg (bottom) from (a) AERI and (b) MM5.

MM5 forecast as compared with AERI observations, especially with respect to the timing accuracy of mesoscale features within the boundary layer.

In the second comparison, we use the fact that RRTM long-wave radiative parameterization computes radiances over a spectral region that includes the full AERI spectral range. MM5 is modified to carry 16 new two-dimensional prognostic variables, which correspond to radiances in each of the 16 discrete RRTM wavenumber bands (Table 1).

RRTM Band	Wavenumber (cm^{-1})
1	10-250
2	250-500
3	500-630
4	630-700
5	700-820
6	820-980
7	980-1080
8	1080-1180
9	1180-1390
10	1390-1480
11	1480-1800
12	1800-2080
13	2080-2250
14	2250-2380
15	2380-2600
16	2600-3000

Table 1. RRTM bands and associated wavenumbers

Radiances observed with the AERI are then summed within RRTM bands 4-11, and compared with output from the MM5's RRTM radiation scheme. This method of comparison allows a more direct evaluation of the performance of MM5 compared with AERI, as the AERI observations have not been affected by any statistical retrieval procedure. In figures 3a and 3b, radiance spectra from AERI and MM5 are plotted for 0230 and 1800 UTC 24 January 2001. The full AERI spectrum is represented in the thin solid lines while the heavy solid and heavy dashed horizontal lines correspond to averages over each of the RRTM bands for MM5 and AERI respectively. At 0230 UTC there was cloud cover over the AERI instrument, while at 1800 UTC, the sky was clear. Note the close correspondance between the AERI spectrum and the MM5's RRTM output at both times. A detailed inspection reveals the largest differences between MM5 and AERI to lie in the vicinity of 1000 cm^{-1} wavenumber (RRTM band 7), a region sensitive to ozone concentration. Errors in this spectral region may result from improper specification of ozone in the MM5 RRTM parameterization, where a climatological profile is used, or from temperature errors in layers where ozone is concentrated most strongly in the model.

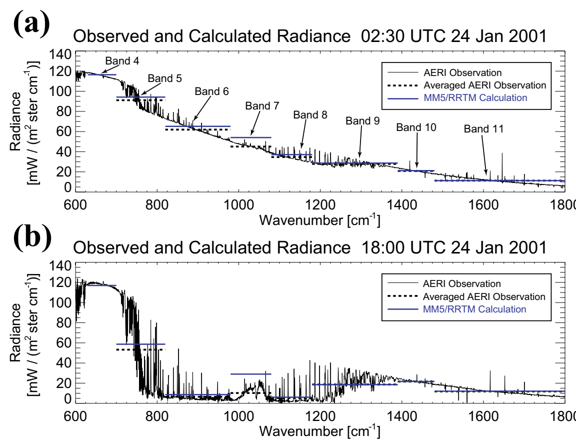

Figure 3: Radiance spectra from MM5 and AERI at (a) 0230 UTC and (b) 1800 UTC 24 January 2001.

In addition to an examination of wavenumber spectra at discrete times, time-series of brightness temperatures from discrete RRTM bands can be computed from MM5 and AERI and compared over the length of the forecast. Time-brightness temperature cross-sections from RRTM bands 4 and 6 are depicted in figures 4a and 4b respectively. RRTM band 4 lies in the atmospheric window region, and thus, brightness temperatures in this wavenumber range are related to temperatures near the surface. As RRTM band 6 lies in a spectral region opaque to clouds, brightness temperatures calculated from this band are related to cloud-base temperature. Specifically, higher brightness temperatures generally correspond to a lower cloud-base, while lower brightness temperatures indicate a higher or non-existent cloud. A close examination of this plot reveals a timing error that existed in the MM5 simulation of this case. A band of low cloud and fog passed over the AERI site between 0900 and 1200 UTC, and can be seen in the higher brightness temperatures during this time. A similar cloud and fog feature can be seen in the MM5 brightness temperatures between 1100 and 1500 UTC, an indication that this feature was late in MM5 as compared to reality.

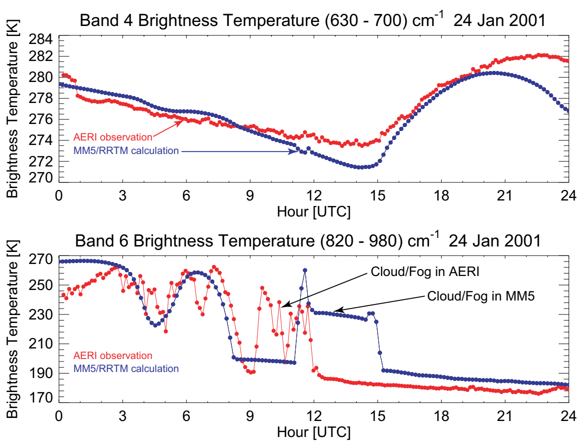

Figure 4: Time series comparison of MM5 with AERI brightness temperatures for RRTM bands (a) 4 and (b) 6 between 0000 UTC 24 January and 0000 UTC 25 January 2001.

5. SUMMARY

Two methods of validating MM5 with AERI observations have been developed for use during the 2002 IHOP field experiment. The first method, an approximate comparison between time-height cross-sections of temperature and mixing ratio from MM5 output and AERI retrievals, lends insight into the timing and variability of mesoscale features in the boundary layer. The second method, a direct comparison between radiances measured by the AERI and calculated by RRTM in MM5, allows the user to evaluate the performance of RRTM, as well as the timing of cloud features in the model.

ACKNOWLEDGEMENTS

This research is funded by the DOE ARM program through grants to SSEC/CIMSS at the University of Wisconsin–Madison.

REFERENCES

Clough, S.A., P.D. Brown, N.E. Miller, J.C. Liljegren, and T.R. Shippert. 1995: Residual analysis of surface spectral radiances between instrument observations and line-by-line calculations. *Proceedings of the Fourth Atmospheric Radiation Measurement (ARM) Science Team Meeting*, pp 101-109. CONF-940277, U.S. Department of Energy, Washington, D.C.

Feltz, W. F., W. L. Smith, R. O. Knuteson, H. R. Revercomb, H. B. Howell, Harold H. Woolf, 1998: Meteorological Applications of Temperature and Water Vapor Retrievals from the Ground-Based Atmospheric Emitted Radiance Interferometer (AERI). *Jour. Appl. Meteor.*, **37**, 857-875.

Smith, W. L., W. F. Feltz, R. O. Knuteson, H. R. Revercomb, H. B. Howell, Harold H. Woolf, 1998: The Retrieval of Planetary Boundary Layer Structure Using Ground Based Infrared Spectral Radiance Measurements. *Journal of Atmospheric and Oceanic Technology*, **16**, 323-333.