Regional (Subgrid) Scale Variability and Sensitivity of Longwave Radiative Heating[a]

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Introduction

Following on the work of Ellingson et al. (1991), we noted (Baer et al. 1996) a strong impact on the thermal field in the global scales of climate prediction due to longwave radiation. This observation was based on sensitivity studies with longwave radiation column models (LWRM) currently used in atmospheric global climate models (AGCMs). Because these effects may also occur at the regional scale, we have investigated this over the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site, which corresponds roughly to an AGCM grid box, and we have used the same LWRMs that we employed in our global study. We have evaluated the heating rates (HRs) from seven LWRM algorithms at the central SGP site and four surrounding sites. The algorithms used are identified in Table 1, and the five SGP sites may be seen at *http://www.arm.gov/docs/sites/sgp/images/sgp_site.gif*. For subsequent site identification, C1 is the central site (Lamont) and the others are B1 (Hillsboro), B4 (Vici), B5 (Haskell), and B6 (Purcell). We have used data profiles needed by these algorithms and taken them from several days of observations at the five sites, including both clear and cloudy sky conditions.

Effects of Algorithms and Site Location (Clear Skies)

Figure 1 is an example of heating rates derived from clear-sky data taken on October 9, 1996; results for six algorithms and all five sites, including site means are included. Significant differences can be seen among the heating rate profiles determined by the various algorithms for identical data (at one site), which are comparable to our previous results. However, note that the spatial gradients of heating rates over the site domain are also pronounced, and this for the same algorithm. We determined that this was due primarily to the variation over the domain of the moisture pattern, and we corroborated our assessment by control calculations involving changes in both moisture and/or temperature.

From Figure 1, we can also compare the profiles of the site mean heating rates to the profiles at C1. It is evident from the data presented that C1 is not representative of the grid box through averaging. Nevertheless, such values must be used in a GCM calculation.

Table 1. The set of 7 models intercompared.

Model ID	Organization	Participant
BLA	Canadian Climate Center, Canada	J.-P. Blanchet
CCM	National Center for Atmospheric Research, USA	D. L. Williamson
CSU	Colorado State University, USA	D. Randall
ELL	University of Maryland, USA	R. Ellingson
GAR	Recherche en Prevision Numerique, Canada	L. Garand
MOR	European Center for Medium Range Weather Forecasts, United Kingdom	J.-J. Morcrette
NMC	National Meteorological Center, USA	K. Campana

(a) A complete version may be found on the web at the following address: *http://metosrv2.umd.edu/~baer/ARMpost_98./*.

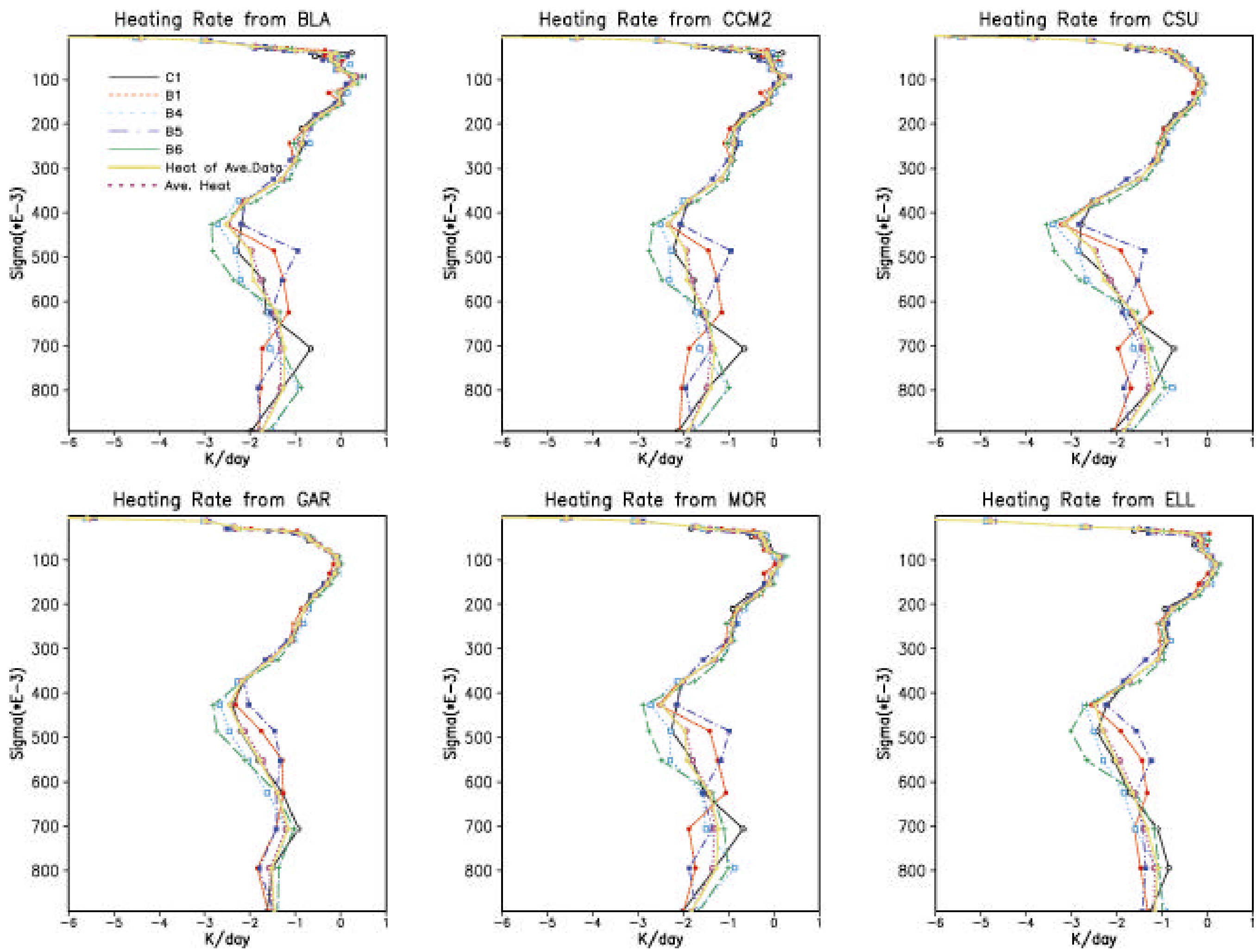

Figure 1. The 30-level LW heating rate for different sites from six models—clear sky, October 9, 1996, 17:30z. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/baer-98.pdf*.)

Effects of Algorithms and Site Location (Cloudy Skies)

We noted from our previous studies that the different algorithms produced strongly differing heating profiles under cloudy sky conditions. This observation was corroborated by this study and is documented in Figures 2 and 3. The figures show the site heating rate profiles and their means for the various algorithms and for a case of low (Figure 2) and a case of high (Figure 3) clouds. Note here the disparate effect of clouds at the different sites. Those differences are particularly pronounced in the case of low clouds. Again, we see that C1 does not represent the mean of the grid box well.

Impact on AGCMs

To test the GCM output of heating rates over a grid box, we introduced global data into the Version 3 of the NCAR (National Center for Atmospheric Research) Community Climate Model (CCM3) (available from NCAR) at a time near the observations taken at the ARM SGP site on January 9, 1997. The model was then integrated to the observation time, and the heating rates it produced were interpolated to the five sites. Concurrently, the observation data was processed directly by the CCM3 and MOR algorithms and the heating rate profiles were created. The GCM produced no clouds in the area and therefore the

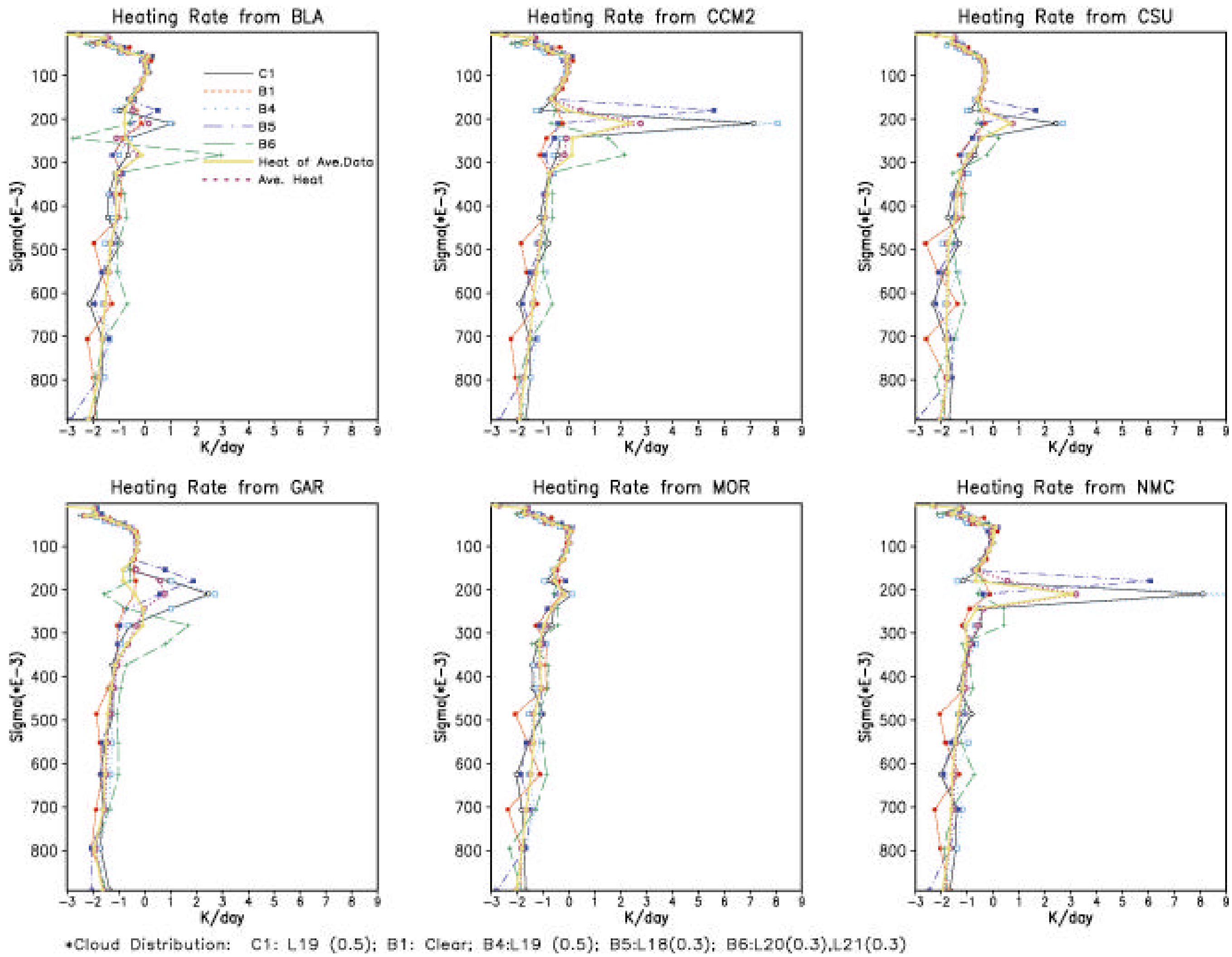

Figure 2. The 30-level LW heating rate for different sites from six models with high cloud 1997.03.11 17:30. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/baer-98.pdf*.)

algorithms were given no clouds. The resulting heating rate profiles are presented in Figure 4. From the figure, it is evident that at all sites, the GCM output is distinctly different from the algorithm output despite only small interpolations, which were required by the GCM. Even without clouds, such differences could lead to substantially different climate outcomes. The importance of clouds is highlighted when they are included in the calculations. If the clouds produced by the CCM3 are also used by the algorithm when calculating with the observed data, the heating rates produced are significantly more similar from one calculation to another. This comes about because the clouds used in the separate calculations (GCM and algorithm) are identical.

Conclusions

For clear and cloudy sky conditions, LWRM algorithms again show significant differences in the heating rates they produce given the same input data. Heating rates produced at the ARM SGP sites surrounding C1 show pronounced differences from one another when using the same algorithm. For the clear-sky conditions, this seems to be primarily dependent on the moisture distribution. For cloudy sky conditions, large differences are also noted but based on the cloud distributions observed.

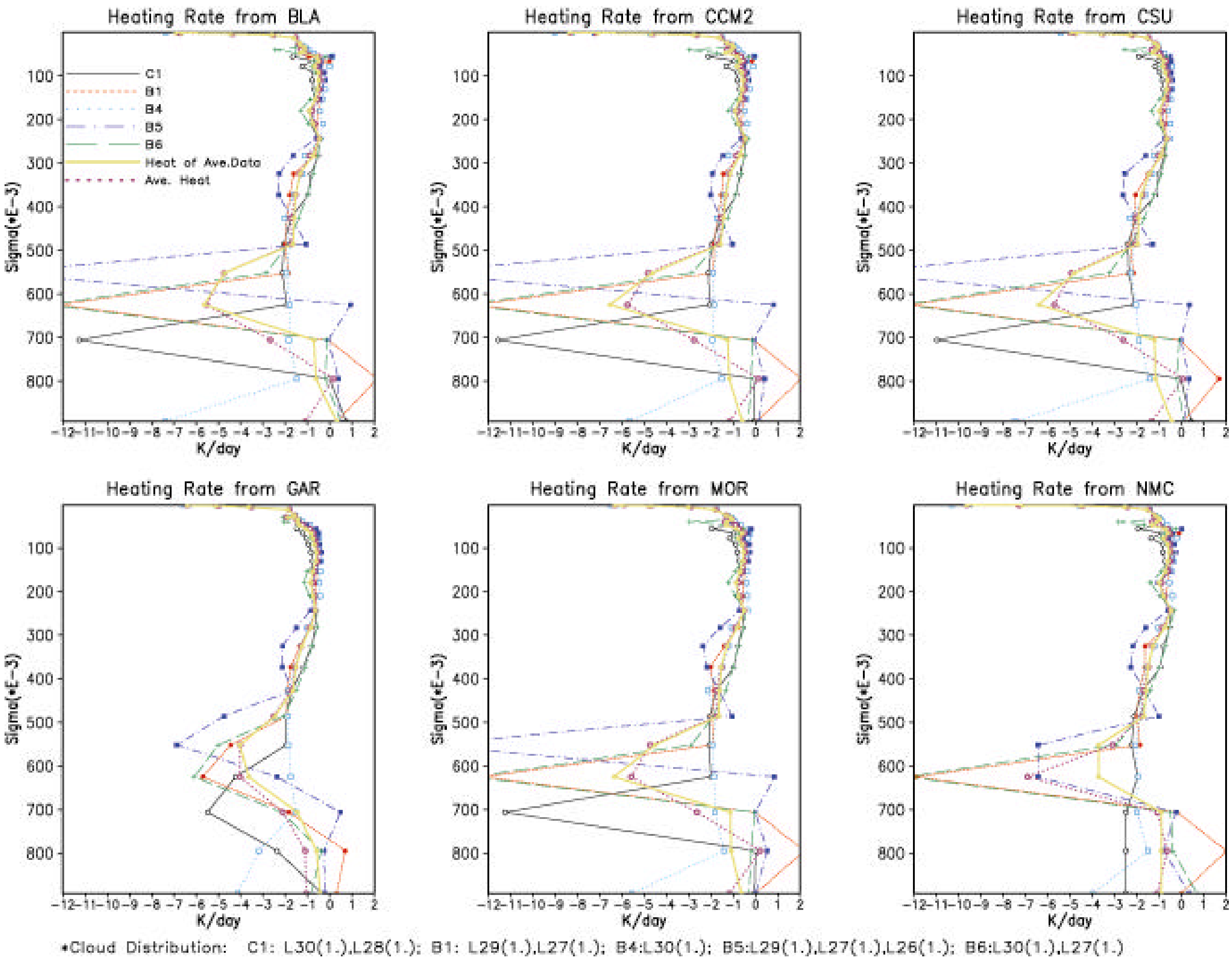

Figure 3. The 30-level LW heating rate for different sites from six models with low cloud 1997.03.08 17:30. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/baer-98.pdf*.)

The mean heating rates determined from the sites comprising the grid-box differ significantly from the values determined at the central site. This is true for both clear and cloudy sky conditions.

A GCM does not produce the same heating rates as its algorithm does when given observational data, despite close similarities in the input conditions. Moreover, the GCM-produced heating rates are strongly dependent on clouds, which are not accurately predicted by it.

Given the significance small changes in heating rates may have on climate evolution, a more accurate process must be found for selecting input values to an LWRM representing a grid-box.

References

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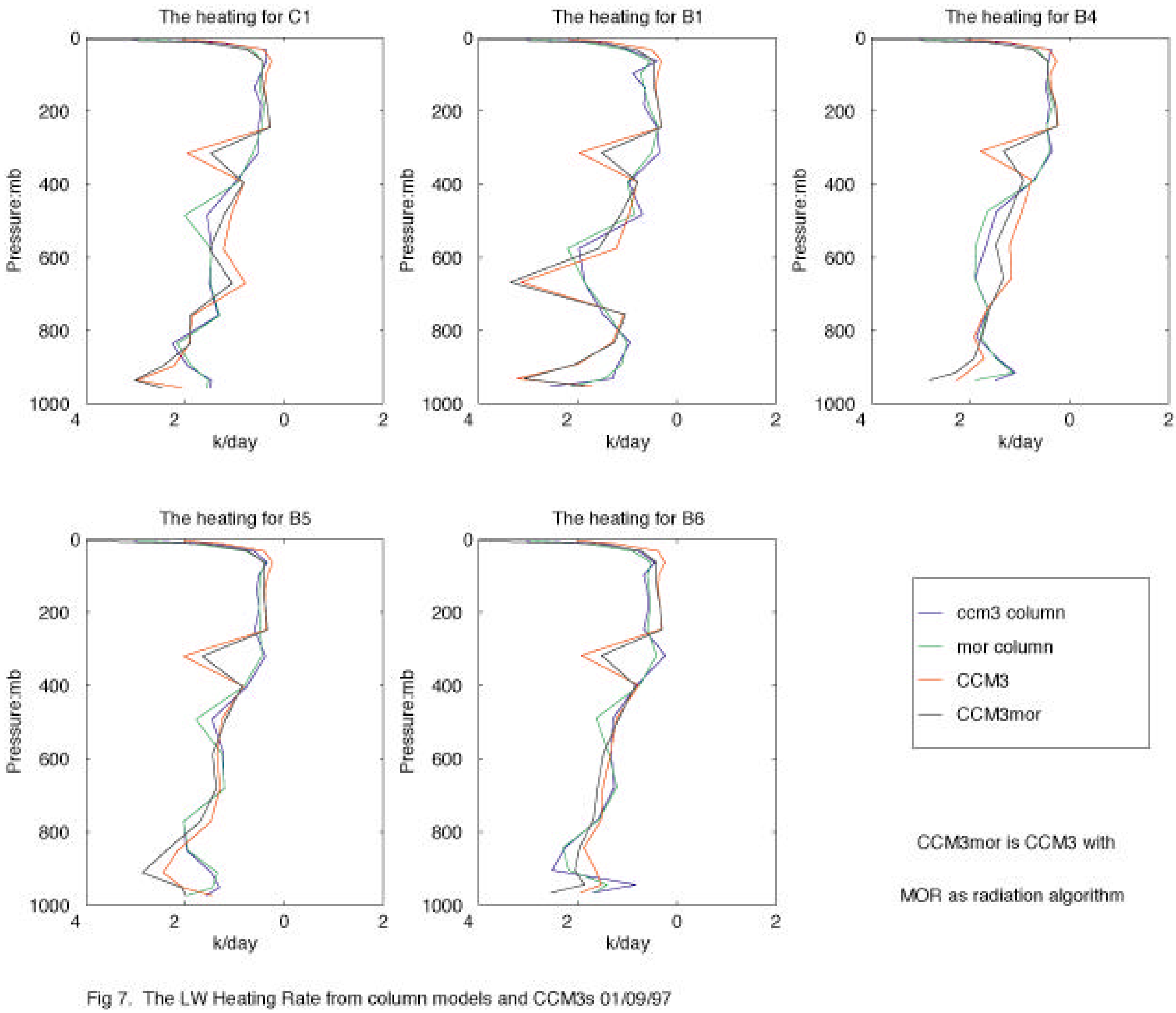

Figure 4. The LW heating rate from column models and CCM3s, January 9, 1997. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/baer-98.pdf*.)