P2.3 THE IMPACT OF CLOUD MICROPHYSICS ON THE SURFACE SOLAR RADIATION

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1. INTRODUCTION

This paper will describe recent efforts at EMC to improve the solar radiation parameterization in the Eta model. A new solar radiation parameterization, which was originally developed by Chou (1990, 1992, 1999, and later updates), was implemented in the operational GFS model in 2002 (Hou et. al., 2002). The cloud optical properties are calculated to be internally consistent with the microphysical characteristics of cloud water and cloud ice (includes snow) assumed in the Eta's grid-scale microphysical scheme (Ferrier *et al*, 2002), while simplified optical properties of convective clouds are used. Preliminary results from 10-km/60-level High Resolution Window Eta model runs will be presented here along with verification statistics from a current 32-km Eta real-time parallel run, as well as 32-km retrospective runs from last summer.

2. DESCRIPTION OF THE SCHEME

Changes in the treatment of cloud optical properties were recently implemented in the operational Eta model on 8 July 2003, and they are described in more detail in Ferrier *et al*. (2003). The cloud amounts were set to zero over land in the lowest 100 hPa, and over water as well in the absence of a low-level inversion. Cloud amounts were also set to zero above 400 hPa. Both sets of changes removed legacy code that had been running in the Eta for several years. The grid-scale cloud cover follows the algorithm of Randall (1995) with modifications based on an assumed threshold relative humidity (RHgrd) for grid-scale saturation. The convective cloud cover is a modification of the parameterization of Slingo (1987), in which the cloud cover was increased by 20% for each rain rate interval and shallow, non-precipitating convection was ascribed a constant cloud fraction of 0.1. Maximum overlapping was used to treat the overlapped clouds. Although these changes led to some improvements, remaining high biases in incoming solar radiation required testing the new GFS solar radiation package.

Figure 1 shows depicts the set of cloud fields used as input to the new solar radiation driver (SWR95), which includes the following: 1) cloud cover of the grid-scale cloud (CSMID) and convective cloud (CCMID); 2) optical paths of cloud water (CWP) and cloud ice (CIP); and 3) effective radius of cloud water (REW) and cloud ice (REI). In the new solar radiation package, the effective radius for cloud water and cloud ice are needed to calculate the cloud optical properties. Fixed values for REW and REI are currently set to 10 μm and 75 μm, respectively, based on results from real-time parallel simulations. The liquid water and ice paths are calculated by integrating the cloud water and cloud ice contents from the cloud top to cloud bottom for both grid-scale and convective clouds.

Comparisons will also be made between the current operational control (CTL) and the old version of the operational Eta model prior to the 8 July 2003 implementation (OLD_OPS). It is expected that the modification of clouds in the new radiation code, which is currently being tested in the real-time 32-km parallel runs (EtaL), will further reduce the downward solar radiation compared to the current operational control (CTL). Both sets of changes in the form of the recent operational implementation (CTL) and the new radiation (EtaL parallel) substantially reduce the well-documented high bias in incoming surface solar radiation passing through clouds in the Eta model (e.g., Hinkelman and Ackerman, 1999).

3. RESULTS

The improvement associated with the recent 12-km Eta implementation can be seen in Figs. 2 and 3. Figure 2b shows the high bias in incoming solar radiation associated with the old operational Eta model prior to the 8 July 2003 implementation (labeled “OLD_OPS” in the figure caption). Solar radiation observations from SURFRAD sites are compared against 3-h operational Eta forecasts in the Eta Data Assimilation System (EDAS) for summer 2002 (Fig. 3a) and for summer 2003 (Fig. 3b). They show a

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reduction in the EDAS high bias in solar radiation. These changes are consistent with improved 2-m temperature forecasts over the Eastern US from summer 2002 (Fig. 3c) to summer 2003 (Fig. 3d), as well as over the Western US from summer 2002 (Fig. 3e) to summer 2003 (Fig. 3f), presumably due to the 8 July 2003 Eta implementation. An early morning cold bias remains over the Eastern US (Figs. 3c,d), while a warm bias persists out West.

Retrospective tests of the new solar radiation from the GFS were made using the 10-km High Resolution Window Eta runs. Three-hour forecasts of incoming surface solar radiation from the new GFS solar radiation (labeled EtaL in the figure caption), the operational control (labeled CTL in the caption), and the difference between the runs (EtaL-CTL) on 11 May 2002 are shown in Figs. 4a-4c, respectively. These figures show considerably less incident radiation in the new solar radiation package (EtaL) compared to the current operational Eta (CTL). Figures 4d-4f show the cloud-base pressure (hPa) associated with types of cloud (total; Fig. 4d), grid-scale cloudiness (Fig. 4e), and convective cloudiness (Fig. 4f). From the differences in radiation (Fig. 4c), the major reduction of incident solar radiation occurs in regions where cloud bases are low and cloud water exists, especially in the convective cloud region (Fig 4f).

This new solar radiation is currently being evaluated in real-time 32-km parallel runs. Preliminary results comparing observed and forecast 2-m temperatures from the operational code against the new solar are shown in Fig. 5. The new radiation has resulted in improved 2-m temperature forecasts over the Western US (Fig. 5a), both in terms of the afternoon maxima and early-morning minima. Over the East (Fig. 5b), the new radiation has improved daytime maximum temperature forecasts, but unfortunately has exacerbated the early-morning cold bias. There are several hypotheses for this early-morning cold bias that are currently being investigated.

4. REFERENCES

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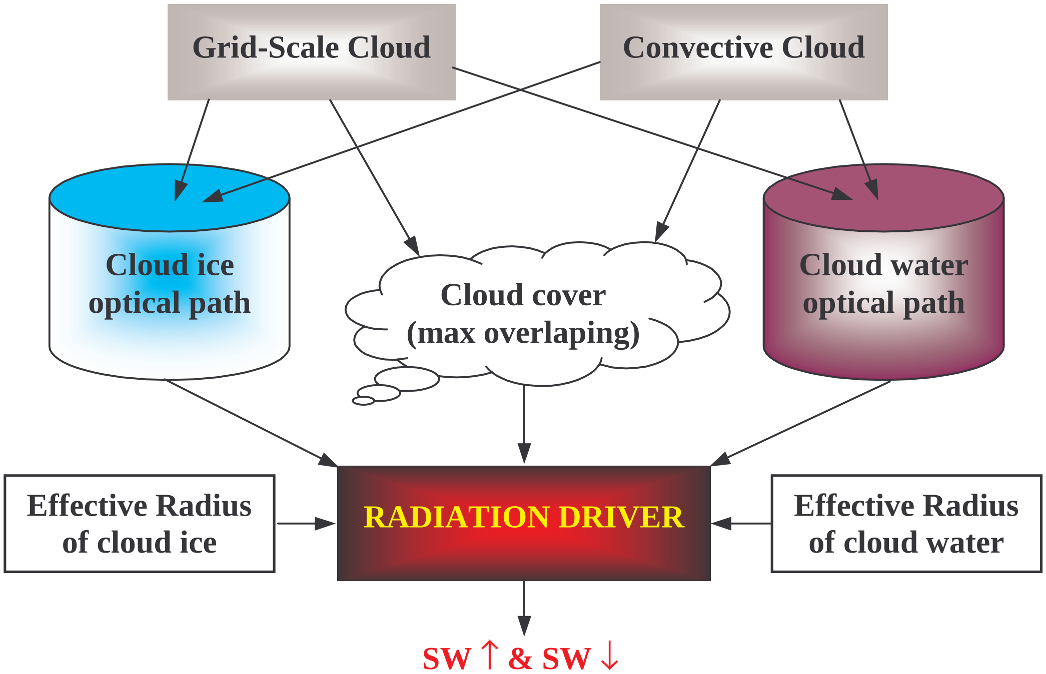


Fig. 1 Input cloud optical properties into the new solar radiation driver (SWR95)

a. b.

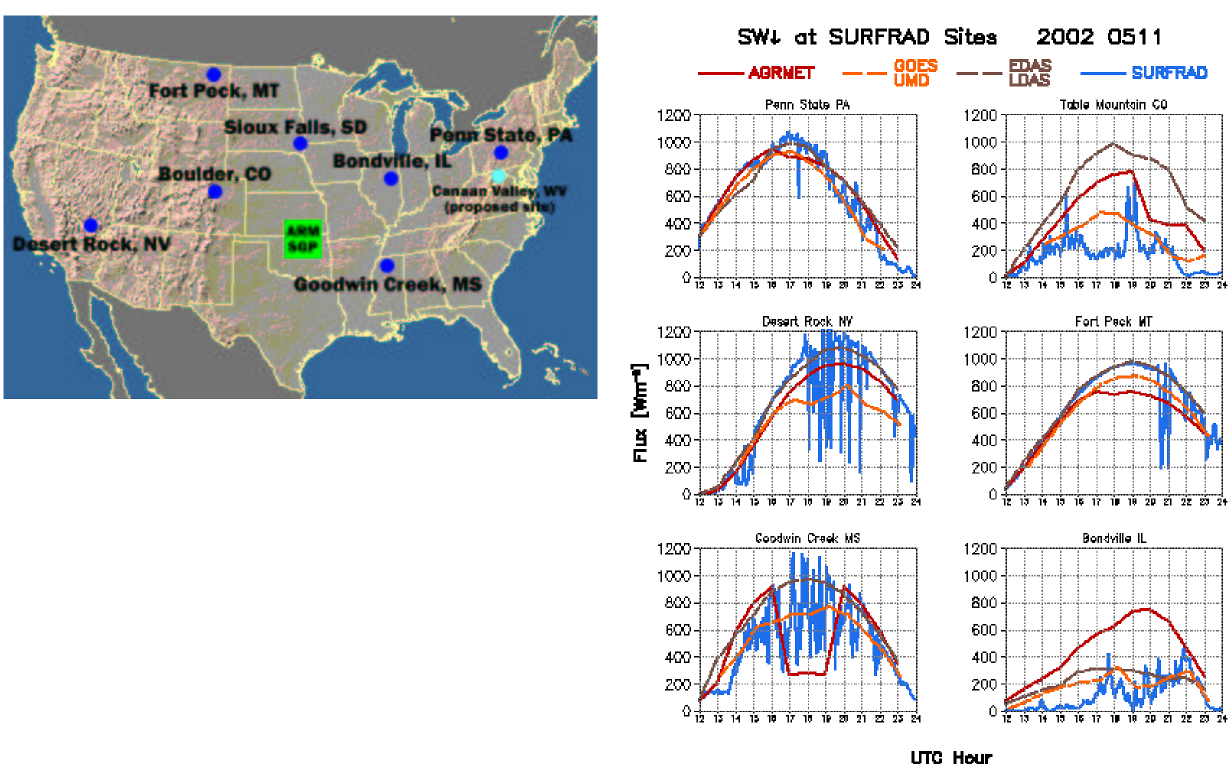


Fig. 2 Surface downward shortwave radiation from the observation of SURFRAD sites. (a) observation sites (b) comparison between observation and model output. The brown line (EDAS) used the OLD_OPS

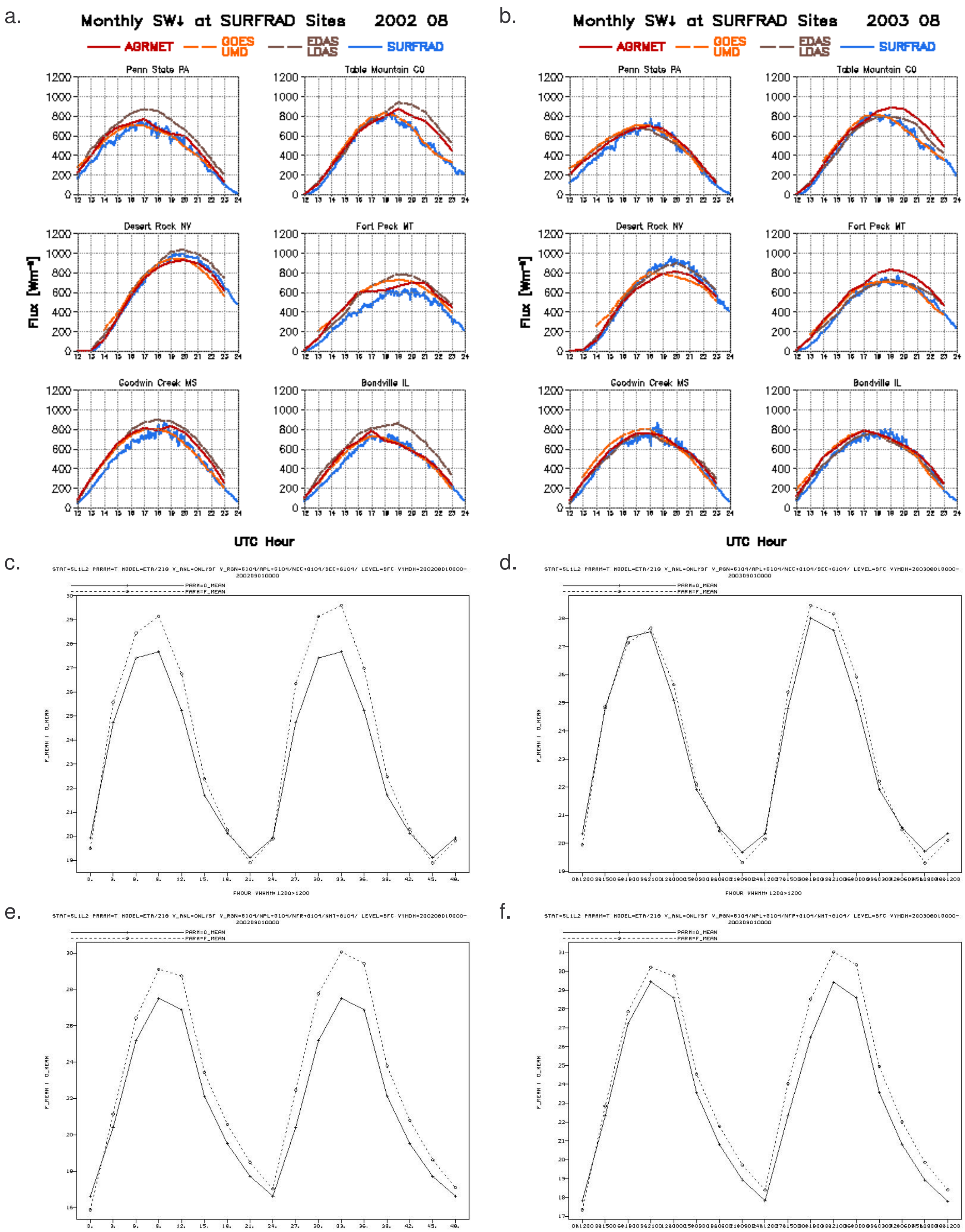


Fig. 3 Comparison of surface downward shortwave radiation and 2-m temperature between OLD_OPS (2002) and CTL (2003) with respect to observation for the month of August. The brown lines in (a) (b) are EDAS model output. From (c) to (f), the solid lines are observations and dashed lines are CTL model output. SURFRAD site surface downward shortwave radiation are (a) 2002 (b) 2003; 2-m temperature are (c) 2002 US East (d) 2003 US East (e) 2002 US West (f) 2003 US West.

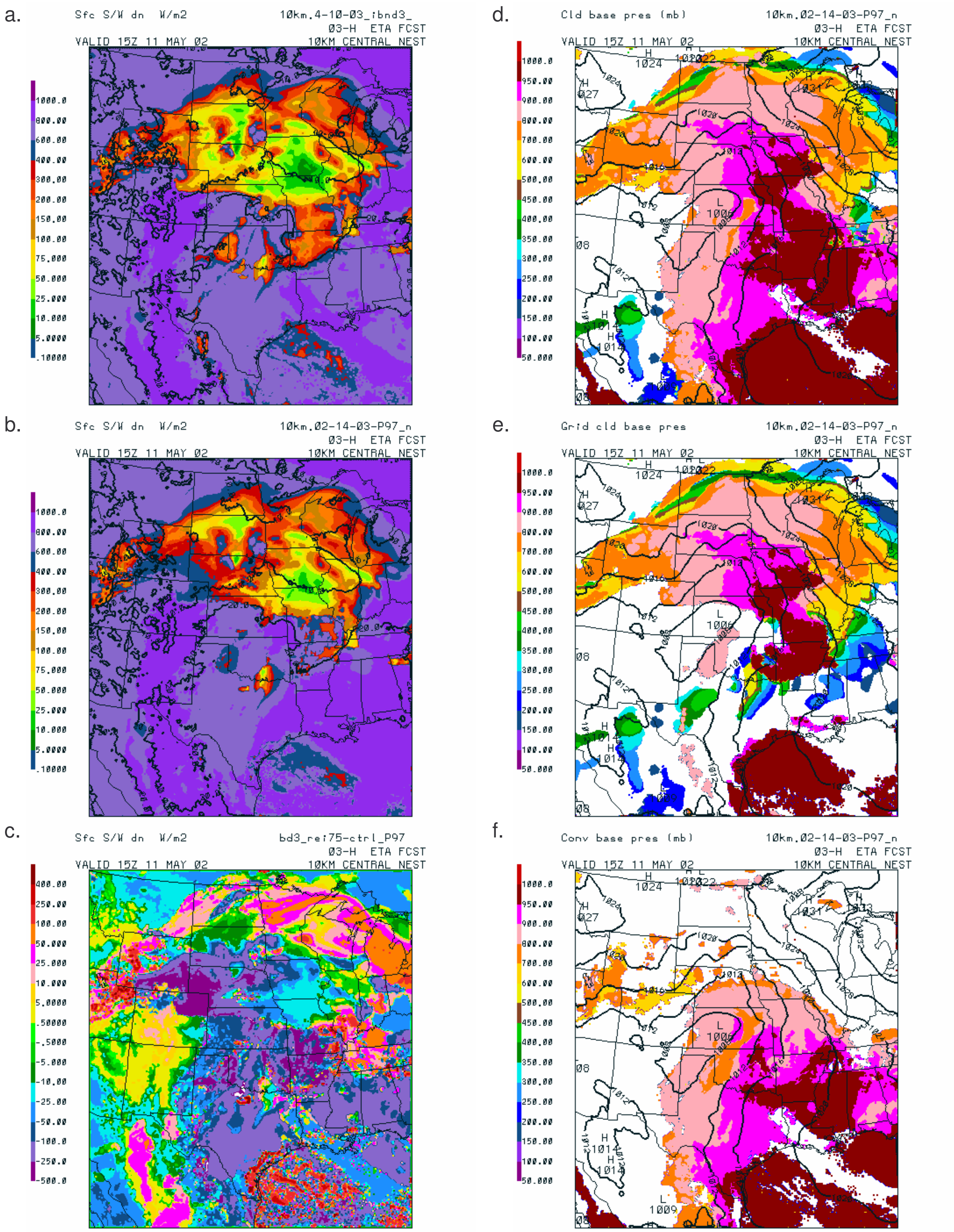
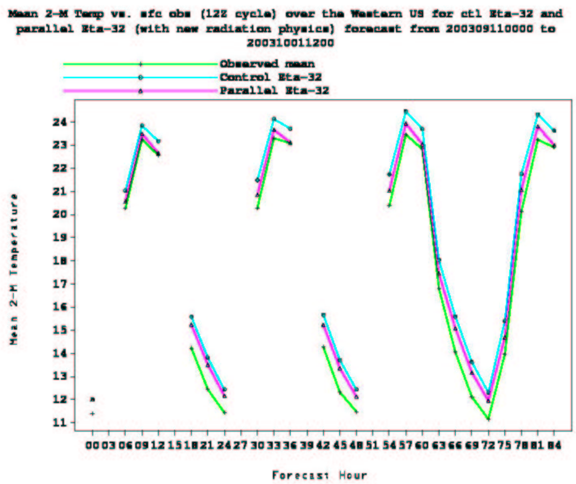


Fig. 4 Surface downward shortwave radiation (SWDN) and the cloud base pressure (mb) (a) EtaL SWDN, (b) CTL SWDN, (c) SWDN difference, EtaL-CTL, (d) Total cloud, (e) Grid-scale cloud, and (f) convective cloud.

a.



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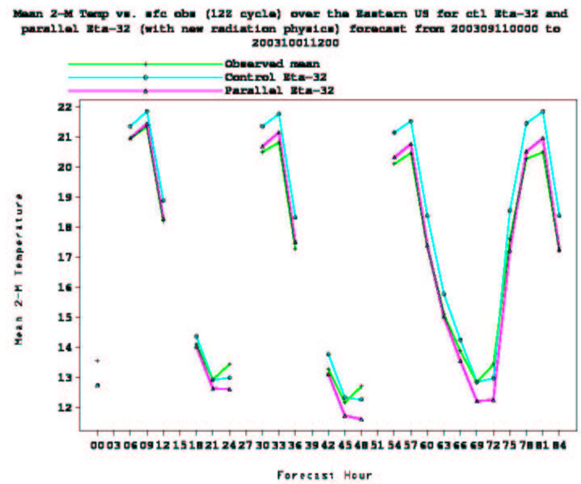

Fig. 5 Verification statistics of the 2-m temperature of the 32-km parallel run. The green line is the observed diurnal cycle, blue line is for CTL, and pink line is for EtaL for (a) Western US and (b) Eastern US.