An Assessment of the Surface Radiation Budget over North America in the GEM-LAM Regional Climatemodel, Reanalysis Datasets and Satellite Based Products

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In this report we evaluate the components of the surface radiation budget (SRB) from 2 sets of reanalysis data (ERA40, Uppala et al. 2005 and the NCEP-NARR, Mesinger et al., 2004) against a suite of surface observations (SO) across North America. We further use the direct surface radiation observations to evaluate the SRB derived from the ISCCP satellite dataset (Rossow and Schiffer, 1991) The surface radiation measurements consist of downwelling longwave (DLR) and solar (ISR) radiation at 6 sites across North America, coordinated by the NOAA US-SURFRAD Network (http://www.srrb.noaa.gov/surfrad/). The most accurate gridded surrogate SRB data set (reanalysis or satellite product) is subsequently used to evaluate the SRB components simulated by GEM-LAM for the recent past (1996-2002), when run at 0.5° resolution for a domain covering the entire North American continent forced by ECMWF analysed lateral and surface boundary data.

Figure 1 presents the mean annual cycle of monthly mean ISR (Fig. 1a) and DLR (Fig. 1b), averaged across all 6-measurement sites for: SO, ERA40, NARR and ISCCP along with their respective biases (Figs. 1c and 1d). NARR overestimates ISR by ~30-50 Wm^{-2} in summer and winter. These errors are considerably larger than the uncertainty of SO and are primarily due to a significant underestimate of cloud fraction in NARR which reaches as large as a 25% in the summer season (not shown). In winter, the average ISR error in ERA40 is less than 10 Wm^{-2} and in summer ~7 Wm^{-2}. The ERA40 ISR therefore appears very accurate at the 6 locations we are able to evaluate it over North America. ISCCP ISR in winter also agrees very well with SO, while in summer an overestimate of ~7 Wm^{-2} is present. The ISCCP ISR errors are therefore also close to the range of observational uncertainty. For DLR, monthly mean DJF and JJA biases are less then 5 Wm^{-2} (Figs.1b and d) in ERA40, while larger winter season biases are found in NARR (~10 Wm^{-2} underestimate) and in ISCCP (~10 Wm^{-2} overestimate). The ISCCP DLR winter errors are likely associated with the known difficulties in detecting clouds during the winter season, when the frequent presence of atmospheric inversions over a highly reflective snow surface makes satellite detection of clouds extremely difficult (Schweiger and Key, 1992). A similar comparison performed separately for the 6 SURFRAD stations revealed that the accurate ISR ISCCP values resulted, in part from the cancellation of opposite signed biases spatially across the 6 station locations (not shown), confirming ERA40 to be the most accurate surrogate SRB product over North America and an appropriate validation data set for RCM simulated SRB.

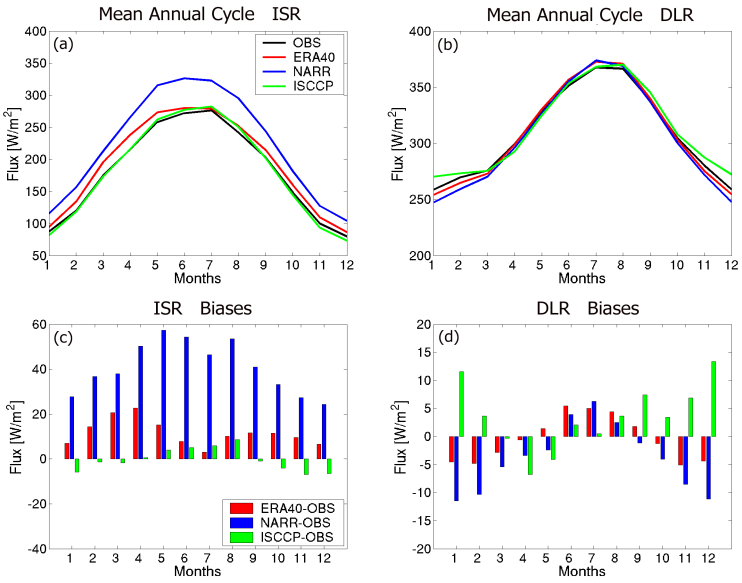

Figure 1: Mean annual cycle of: (a) ISR, (b) DLR, (c) ISR biases, (d) DLR biases. Observations are given in black, ERA40 in red, NARR in blue and ISCCP in green color.

ERA40 is therefore used to evaluate the simulated SRB in GEM-LAM for the period 1996-2002. The

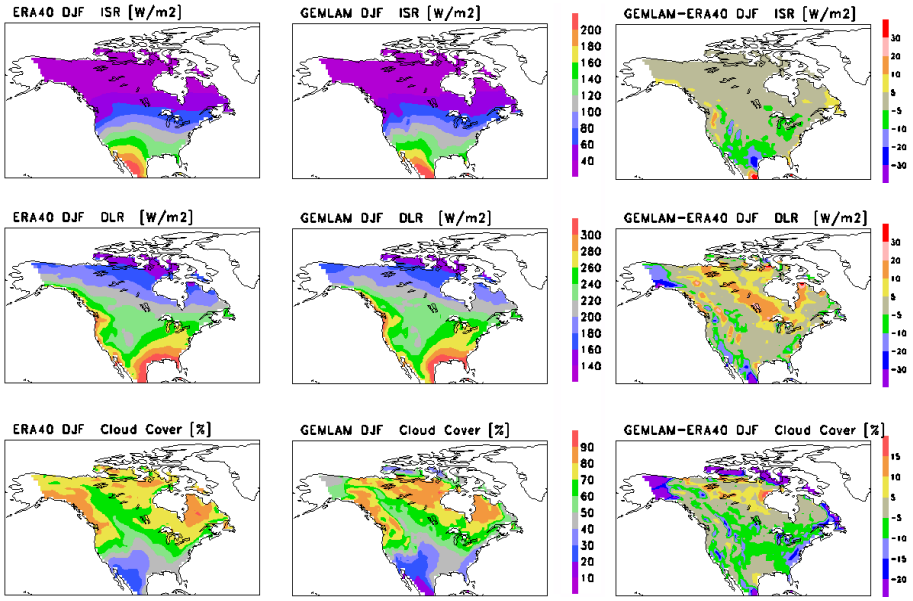

Figure: 2. Comparison of ISR, DLR and cloud cover for ERA40, GEM-LAM and their bias, winter season.

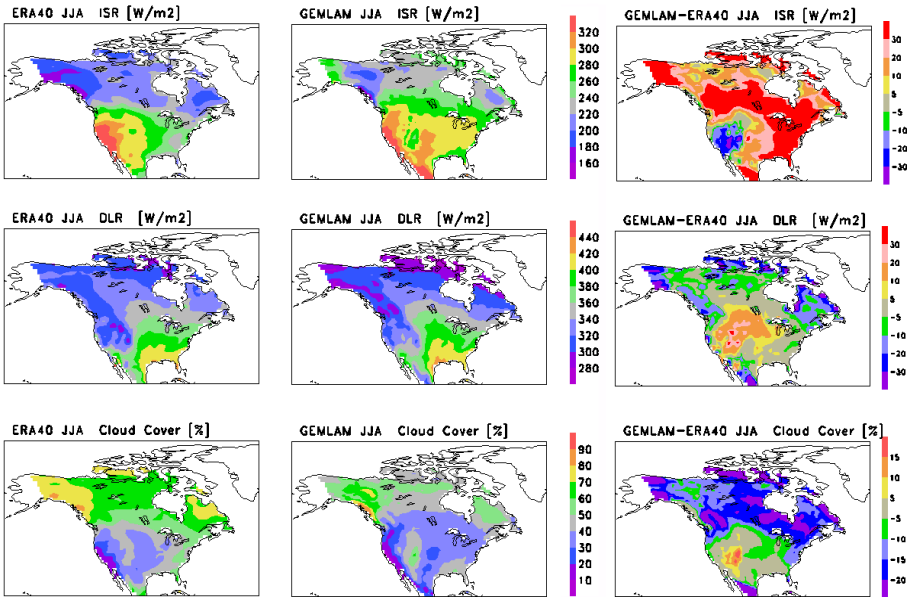

Figure: 3. Comparison of ISR, DLR and cloud cover for ERA40, GEM-LAM and their bias, summer season.

simulated DJF ISR in GEM-LAM (Fig. 2 top row) follows quite closely the ERA40 values both in terms of magnitude and spatial pattern. In the high and mid-latitudes GEM-LAM has very accurate DJF ISR while further south negative biases of ~5-10 Wm^{-2} are evident. DJF DLR in GEM-LAM also shows a similar distribution to ERA40 (Fig. 2 middle row), with biases generally in the range ±10 Wm^{-2} mostly located in the north. The bottom row in Figure 2 shows the comparison of simulated cloud cover (ERA40 and GEM-LAM). Biases may exist in the ERA40 cloud cover, hence simulated errors in the model cloud amounts should be treated with caution. Consistency between errors in cloud cover and those in surface radiation are clearly evident over Northern Canada where GEM-LAM overestimates cloud amounts, collocated with a positive bias in DJF DLR. Figure 3 shows absolute values of ERA40 and GEM-LAM ISR, DLR and cloud cover for JJA season. GEM-LAM has a positive bias in ISR (> 30 Wm^{-2}) over much of North America, which is spatially coherent with a negative bias (0 to -20 Wm^{-2}) in DLR. Both of these errors appear consistent with an underestimate of JJA cloud cover.

References: Mesinger et al., 2004: North American Regional Reanalysis. *AMS Bulletin* submitted.
Rossow and Schiffer, 1991: ISCCP cloud data products, *Bull. Am. Mel. Soc.*, **72**.
Schweiger and Key., 1992: Arctic Cloudiness: Comparison of ISCCP-C2 and Nimbus-7 Satellite derived Cloud Products with a Surface-based Cloud Climatology. *J. of Clim*: Vol. **5**,
Uppala et al., 2005: The ERA 40 re-analysis. *Q. J. R. Met. Soc*. **131**.