The Simulated Surface Radiation Budget over North America in a Suite of Regional Climate Models

Marko Markovic[1], Colin Jones[1], Paul Vaillancourt[2], Dominique Paquin[3]
[1]University of Quebec at Montreal, [2]Environment Canada, [3]Consortium Ouranos
markovic@sca.uqam.ca

Downward longwave radiation (DLR) and shortwave radiation (ISR) are important parameters in climate models, being the main terms in the surface energy balance controlling the evolution of surface temperature and soil moisture. Systematic biases in the representation of surface radiation can lead to errors in a number of key near surface climate variables (e.g. soil moisture, snow cover and sea-ice). In this report we evaluate the DLR and ISR simulated by 3 Regional Climate Models (RCMs) over North America. The RCMs used are: The Canadian Regional Climate Model (CRCM, version 4.0.2) (Caya and Laprise 1999), GEM-LAM, the regional version of the Global Environmental Multiscale Model (Côté et al 1998) and the Swedish Rossby Centre Regional Climate Model, RCA3, (Jones et al. 2004). Observations are derived from six measurement sites within the NOAA-SURFRAD (Surface Radiation Budget) network, representing a cross-section of various climate types over North America. 3-hourly, grid point DLR and ISR values, collocated with the 6 SURFRAD sites, were extracted from the respective RCM simulations and form the basis for an evaluation of the simulated surface radiation.

Figure 1 presents a normalized frequency distribution (FD) of surface ISR and DLR separately for summer (JJA) and winter (DJF) from the 3 models and surface observations. The FDs are averaged over the 6 observation sites. Cloud free conditions are defined as a given 3-hour period having a cloud cover less than 10% in both observations and model, while cloudy conditions are when each data set has a cloud cover value greater than 90%. All sky is the total surface radiation for all cloud cover conditions.

The DJF distribution of all-sky DLR (Fig. 1d) shows all models biased towards low values. For RCA3 and GEM-LAM this is due to a negative bias in the clear-sky DLR frequency distribution (Fig. 1e), cloudy-sky DJF DLR (Fig. 1f) being well simulated by these 2 models. A negative bias in simulated clear sky DLR in cold, dry winter conditions was also seen by Wild et al. (2000). This problem is often due to inaccuracies in either the representation of the water vapor continuum in dry conditions or deficiencies in including the contribution of trace gases and aerosols to the total DLR. CRCM has the same DLR clear-sky error (Fig. 1e) but also a negative bias in DJF DLR under cloudy skies (Fig. 1f). GEM-LAM and CRCM represent the distribution of all-sky DJF ISR well (Fig. 1a). Clear sky ISR DJF (Fig. 1b) is accurate in both models, while GEM shows the best result in cloudy conditions (Fig. 1c). The cloudy-sky DJF ISR is biased low in CRCM, suggesting winter clouds are optically too thick with respect to solar radiation. This is in contrast to the DJF DLR cloudy-sky errors in CRCM, biased towards low values, which is consistent with too low cloud emissivity. Cloud water appears to be treated in an inconsistent manner between the 2 radiation streams in CRCM. The negative bias in CRCM DJF cloudy-sky ISR (Fig. 1c) is balanced by an overestimate of the occurrence of clear-sky conditions (underestimated cloud cover, *not shown*). RCA3 DJF all sky ISR (Fig. 1a) has too few occurrences of low ISR (< $200 Wm^{-2}$) and too many occurrences in the range 200-$600 Wm^{-2}$. RCA3 simulated clouds in DJF appear to contain too little water or have a systematic underestimate in the effective radius leading to winter clouds that have too low albedo. Clear sky DJF ISR (Fig. 1b) is quite accurate in RCA3.

In JJA CRCM has a bias towards low values of all-sky DLR (Fig.1j), due to an underestimate of cloudy-sky DLR (Fig. 1l), also consistent with an underestimate of cloud emissivity. The negative bias in cloudy-sky DLR in CRCM during JJA is partially balanced by a positive bias in clear-sky DLR. This arises either from the CRCM atmosphere being too warm, and/or clear-sky conditions in CRCM, at high water vapor concentrations, being frequently simulated as cloud-free while the same moisture conditions produce a cloud in observations (CRCM systematically underestimates JJA cloud cover, *not shown*). GEM-LAM has a similar bias to CRCM in clear sky JJA DLR (Fig. 1k), probably for similar reasons.

RCA3 gives an accurate JJA ISR all-sky distribution (Fig. 1g) while both GEM-LAM and CRCM overestimate the occurrence of high ISR values. RCA3 is biased towards too many occurrences of very low ISR (<200Wm^{-2}) in JJA cloudy conditions (Fig. 1i), consistent with summer clouds that are frequently optically too thick. This also helps explains the positive bias in the frequency of very high value cloudy-sky DLR (>440Wm^{-2}) in RCA3 in JJA(Fig. 1l). All 3 models underestimate cloud fraction in the JJA, we therefore conclude that the accurate total sky ISR (Fig. 1g) in RCA3 results from an overestimate of clear-sky radiation, due to an overestimate of clear-sky occurrence, balanced by clouds that are too reflective when present. GEM-LAM has numerous occurrences of very high cloudy-sky ISR in JJA (>800Wm^{-2}) (Fig. 1i). These cloudy-sky ISR values only occur for optically thin cirrus, suggesting an overestimate of these cloud types in GEM-LAM. The JJA ISR bias in CRCM seems mainly due to clear sky errors (e.g. the clear sky is too transmissive).

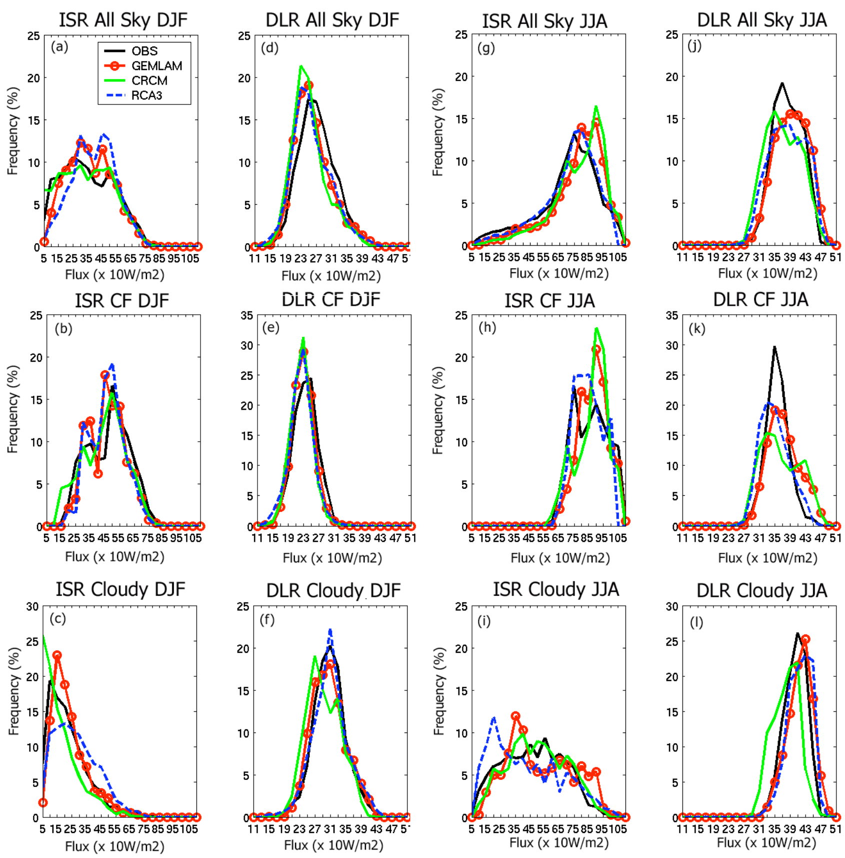

Figure 1: Distribution of ISR and DLR 3-hourly radiation fluxes from RCMs and observations. The period 15-21 UTC is analysed due to cloud observations only being available during sunlight: a) winter ISR all sky, b) winter ISR cloud free, c) winter ISR cloudy, d) winter DLR all sky, e) winter DLR cloud free, f) winter DLR cloudy, g) summer ISR all sky, h) summer ISR cloud free, i) summer ISR cloudy, j) summer DLR all sky, k) summer DLR cloud free, l) summer DLR cloudy.

References:

Caya D and Laprise R. 1999: A Semi-Implicit Semi-Lagrangian Regional Climate Model: The Canadian RCM. *Monthly Weather Review*, 127: 341-362.

Jones, C. G., Willén, U., Ullerstig, A. and Hansson, U 2004: The Rossby Centre Regional Atmospheric Climate Model Part I: Model Climatology and Performance for the Present Climate over Europe. *Ambio 33:4-5,* 199-210., 2004

Cote, J., S. Gravel, A.Methot, A. Patoine, M. Roch, and A. Staniforth 1998: The operational CMC-MRB global environmental multiscale (GEM) model. Part I: Design considerations and formulation. Mon. Wea. Rev, 126, 1373-1395.

Wild et al. Evaluation of Downward Longwave Radiation in General Circulation Models, Journal of Climate, 2000