Comparison of Cloud Microphysics between GEM and ARM-SGP Observations

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Introduction

Microphysical processes play a key role in controlling the liquid and ice water content of simulated clouds and, as a result, are important controls on precipitation and on the interaction of clouds with both solar and terrestrial radiation. Due to their extreme complexity most microphysical processes are highly parameterized in present-day climate models. In this article, we evaluate the microphysical parameterizations in the new Canadian Regional Climate Model, based on the limited area version of GEM (Global Environmental Multiscale Model, [1]). We compare simulated frequency distributions of Liquid Water Path (LWP) and precipitation rate, with observed distributions.

Model and Observations

Observations comes from the ARM Southern Great Plains (SGP) site, at the central facility (CF-1). Data streams used for this model evaluation are the "improved MicroWave Radiometer RETrivals of cloud liquid water (LWP) and precipitable water vapor (PWV)" (MWRRET, www.arm.gov/data/pi_products.stm) with LWP and PWV retrieved from the 2-channel microwave radiometer, the "Surface Meteorological Observation Station" (SMOS) which gives precipitation as a 1min average and the "ShortWave Flux Analysis on SIRS data by the LONG algorithm" (SWFANAL, [2]) which provides observed surface shortwave radiation and cloud cover at a 15min time resolution.

GEM uses a prognostic total cloud water variable, with a Sundqvist-type, bulk-microphysics scheme. GEM-LAM was integrated for the period 1998-2004 over a domain centred on the ARM-SGP site CF-1 (37°N, 97 °W). The integration used ECMWF reanalysis as lateral boundary conditions, prescribed SSTs and employed a horizontal resolution of ~42km.

Both observations and model are averaged (for LWP) or accumulated (for precipitation) over 3h periods for the entire 7 years. The MWR cannot operate when its teflon window is wet. For this reason, all precipitation events greater than 0.25mm/3h are removed from the dataset of LWP for both observations and model. The uncertainty of observations is estimated to be around $\pm 15 g/m^2$ for LWP and ±0.25mm under normal conditions (without strong winds) for precipitation.

Results

In this section, we present results from one season, the winter (DJF), to focus on particularities of the winter cloud and synoptic regimes. We present normalized frequency distributions of LWP or precipitation for observations, in blue, and model, in red. The frequency of occurence of each bin represent a percentage of the observed or modelled total occurence separately. The first bin is divided by 10 due to its disproportionate size. Values on the x-axis represent a centred value for that bin.

Figure A shows the normalized PDF of LWP for observations and model. Relative to observations, GEM underestimates the occurence of LWP (for LWP$\geq 30 g/m^2$) and overestimates the occurence of LWP between 0 and $15 g/m^2$. This underestimate can arise from a number of sources such as: an overestimate of cloud-free occurences, precipitation too frequently triggered at too low LWP in the simulated clouds, or from an incorrect separation of cloud water into liquid and ice. If precipitation is triggered at too low LWP, there are two consequences: (i) the LWP value is removed from the model results and (ii) the simulated LWP is reduced due to precipitation removal.

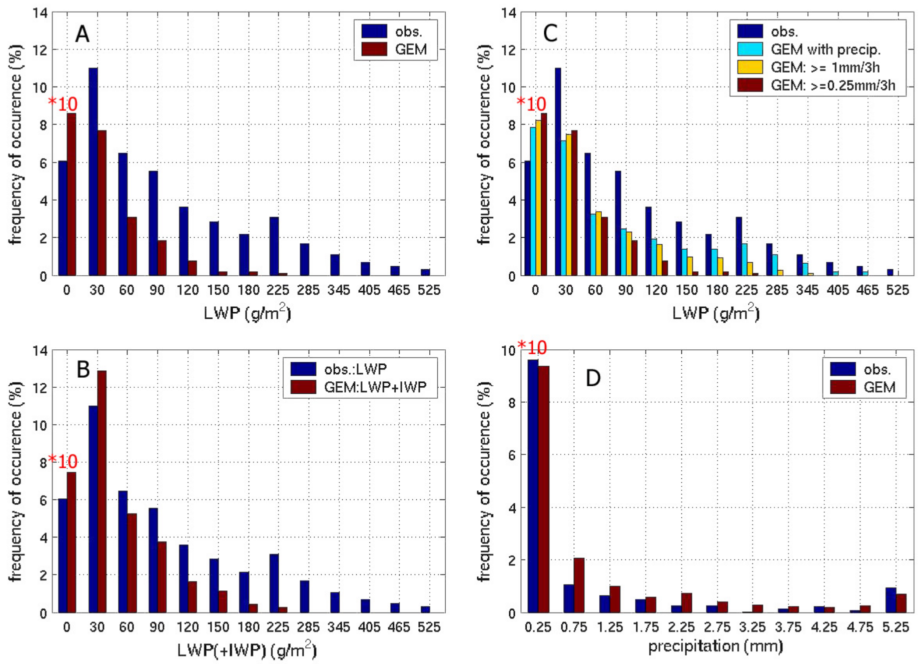

Figure B shows the same observations as in A, but, for the GEM results, the ice water path (IWP) is combined with LWP to determine whether some of the model LWP underestimate arises from the model classifying liquid as ice to frequently. Even with the inclusion of IWP, GEM still underestimate the occurence of high amounts of LWP ($\geq$90g/m^2). This underestimation occurs at a LWP range where cloud albedo varies greatly with LWP whereas the cloud emissivity is already at saturation.

Figure C shows the same observations (dark blue) and model (red) data as for A. The orange data set is the simulated LWP with a different threshold for removing precipitation: 1mm/3h instead of 0.25mm/3h. The light blue data set is the simulated LWP for all conditions (precipitation events not removed). Simulated LWP, even when all LWP events, irrespective of precipitation occurences, are included is still underestimated for all LWP bins $\geq$30g/m^2. One can also see that filtering of precipitation with the threshold of 0.25mm/3h in GEM has a large impact on LWP classes $\geq$120g/m^2 suggesting precipitation removal of cloud liquid water begins to occur efficiently at too low LWP in the GEM microphysics.

Finally, figure D shows the overestimation of the frequency of precipitation in GEM relative to observations for the range [0.75:3.25]mm/3h confirming the general overestimate of light precipitation in GEM. This problem of overestimation of light precipitation and underestimation of LWP exists for all seasons, with winter being the worst example and summer closest to observed values.

Conclusions

From these initial results, we conclude that the underestimate of LWP in GEM has two main causes. First, GEM too frequently simulates clear-sky conditions, reducing the occurence of higher LWP values. Second, even when GEM simulates clouds with higher LWP, when occurences of precipitation are removed, the majority of these LWP events are also removed, thus GEM has too many occurences of light precipitation and as a direct consequence of this, systematically too low LWP values. This underestimate of LWP can have a large impact on the simulated surface radiation budget.

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