Applying A 2D Binning Method To The Simple Biosphere Model (SiB) For Improving The Representation Of Soil Moisture Heterogeneity

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Abstract

The exchange of energy, moisture, and momentum between the land surface and atmospheric boundary layer is controlled by non homogeneous variables at the land surface. Representing the spatial heterogeneity of these variables over length scales of General Circulation Model (GCM) grid areas is a continuing challenge. Using a finer GCM spatial resolution may never resolve the scaling problem, and other methods need to be used to represent the subgrid variability and surface dependent nonlinear processes. For this study, the methods of *Sellers et al.* (2007) are applied to lower atmospheric forcings used in the Simple Biosphere Model (SiB). Method I (area integrated) is the “ideal” method and is the most expensive, method II (area averaged) is the cheapest and is the method currently used with GCMs, and the expense of method III (binned) depends on the number of bins the modeler chooses to use. For a one month period, the results of method II and method III are compared to the performance of method I for an arbitrary grid area at the ARM site in north central Oklahoma. Preliminary findings show that with ten bins, the results of method III are close to those of method I, and allow SiB to deal more realistically with spatially variable lower atmospheric forcings, and improve the representation of non homogeneous surface variables and processes such as, soil moisture and canopy air space to boundary layer (CAS-BL) fluxes with little additional cost. As this research continues, we hope to find similar results when a statistical weather generator is applied to the grid area, and hope to improve the representation of soil moisture and CAS-BL fluxes by using method III and avoiding the high computational cost of method I and the erratic behavior of method II.

Methods

The Simple Biosphere Model (SiB) directly addresses the effect of vegetation on the interaction between the land surface and the atmosphere by modeling the physiological and biophysical processes influencing radiation, momentum, mass and heat transfer.

The Methods of *Sellers et al.* (2007) were used with SiB point by point (pbp) runs for a one month period (July) at the ARM site in north central Oklahoma. Method I (area integrated) was the “ideal” method and was the most expensive, method II (area averaged) was the cheapest (the method currently used with GCMs), and the expense of method III (binned) depended on the number of bins used. Sellers applied these methods to soil moisture values for a highly simplified toy model, but for this study, the methods were applied to all lower atmospheric forcings (temperature, relative humidity, wind, pressure, short wave radiation, long wave radiation, convective precipitation, and stratiform precipitation) for an arbitrary grid area. Seven complete driver sets of lower atmospheric forcings for the month of July were extracted from a seven year record (January 2001-December 2007) at the ARM site. The grid area was divided into seven different fractional areas and assigned a driver set to provide spatial variability in the lower atmospheric forcings. All of the driver sets were forced with the same amount of monthly precipitation that occurred at different times and at different rates for each set. The precipitation events were based on observations and artificial storms.

Method I (Area Integrated): An arbitrary grid area (normalized to a unit area (1.0)) was divided into 100 cells each defined by a SiB pbp run. The grid area was then divided into seven different fractional areas, and each fractional area was assigned a driver set. The individual cells within each fractional area used their assigned driver set to run SiB. For every time step (10 minute time step), a SiB pbp run occurred for every cell (100 individual runs) and output was area integrated to give a single grid area value. This method was expensive computationally and cost wise, and was taken as the standard for judging the other methods.

Method II (Area Averaged): The grid area was defined by a single SiB pbp run. For every time step, an area weighted average of the lower atmospheric forcings for the 100 driver sets used in method I was calculated, and only a single SiB pbp run occurred. The output from that single SiB run gave a value for the entire grid area. This method was the cheapest computationally and cost wise.

Method III (Binned): The grid area was divided into 5, 10, and 20 (bin size) individual SiB pbp runs. For every time step, precipitation was binned for the 100 driver sets used in method I, and all lower atmospheric forcings associated with each precipitation value were assigned to the same bin. SiB was run bin number of times, and the output from the runs was multiplied by the appropriate fractional area and summed to give a single grid area value. This method was not the cheapest computationally and cost wise, but gave results that were very close to those of method I.

These methods were used for two experimental precipitation events over the grid area for the preliminary results of this study. The first experiment used all convective precipitation and the second used all stratiform precipitation.

Preliminary Results

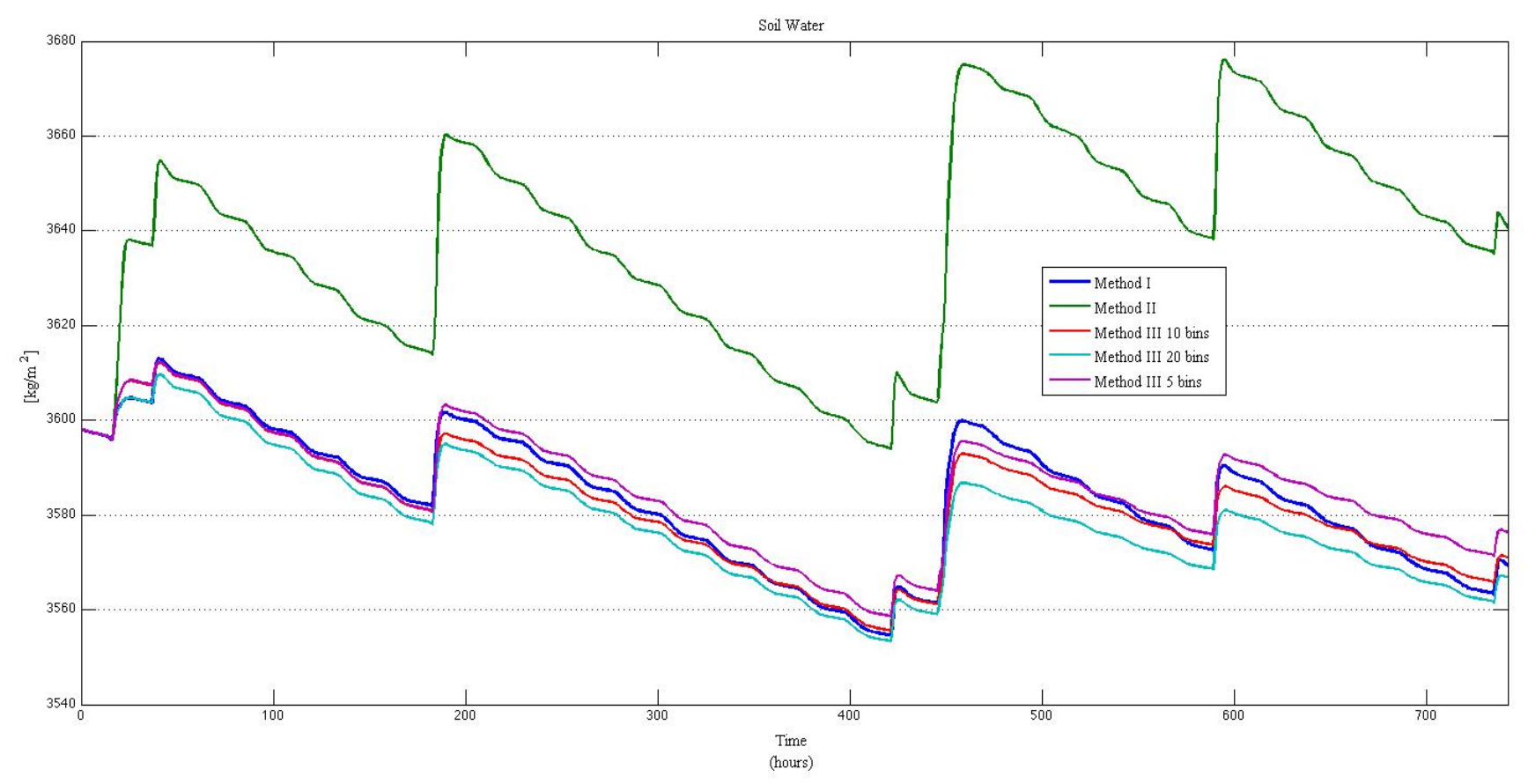

figure 1. Time series of integrated soil water as calculated by the different methods for the convective precipitation experiment. Simple area averaging (method II) greatly over estimates soil water when compared to method I because of SiB’s distribution of convective precipitation within the grid area (see summary). When all methods are compared to method I and absolute errors are calculated, method III performs the best.

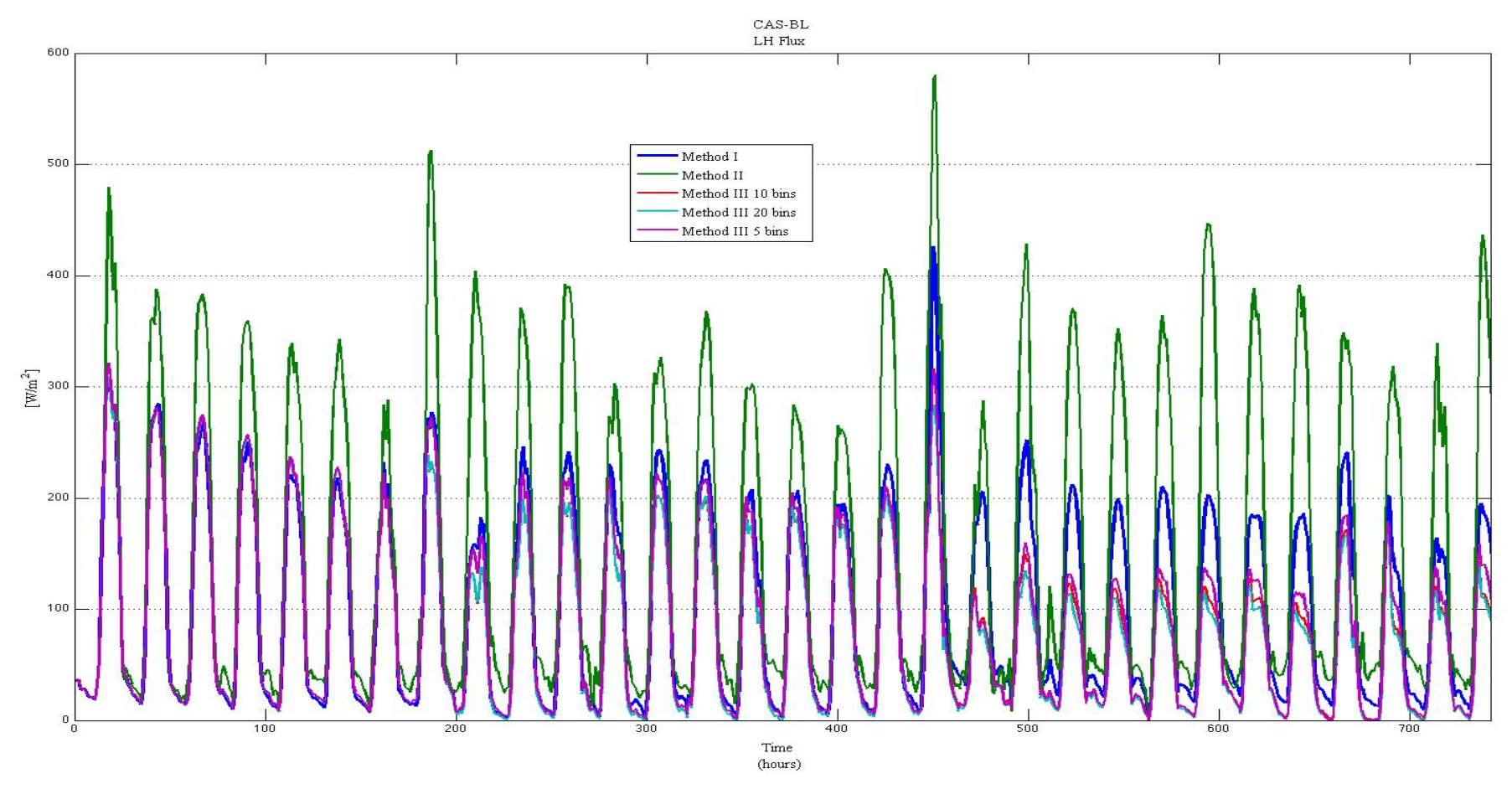

figure 2. Time series of the CAS-BL LH flux as calculated by the different methods for the convective precipitation experiment. Simple area averaging (method II) greatly over estimates LH fluxes when compared to method I because of SiB’s distribution of convective precipitation within the grid area (see summary). When all methods are compared to method I and absolute errors are calculated, method III performs the best.

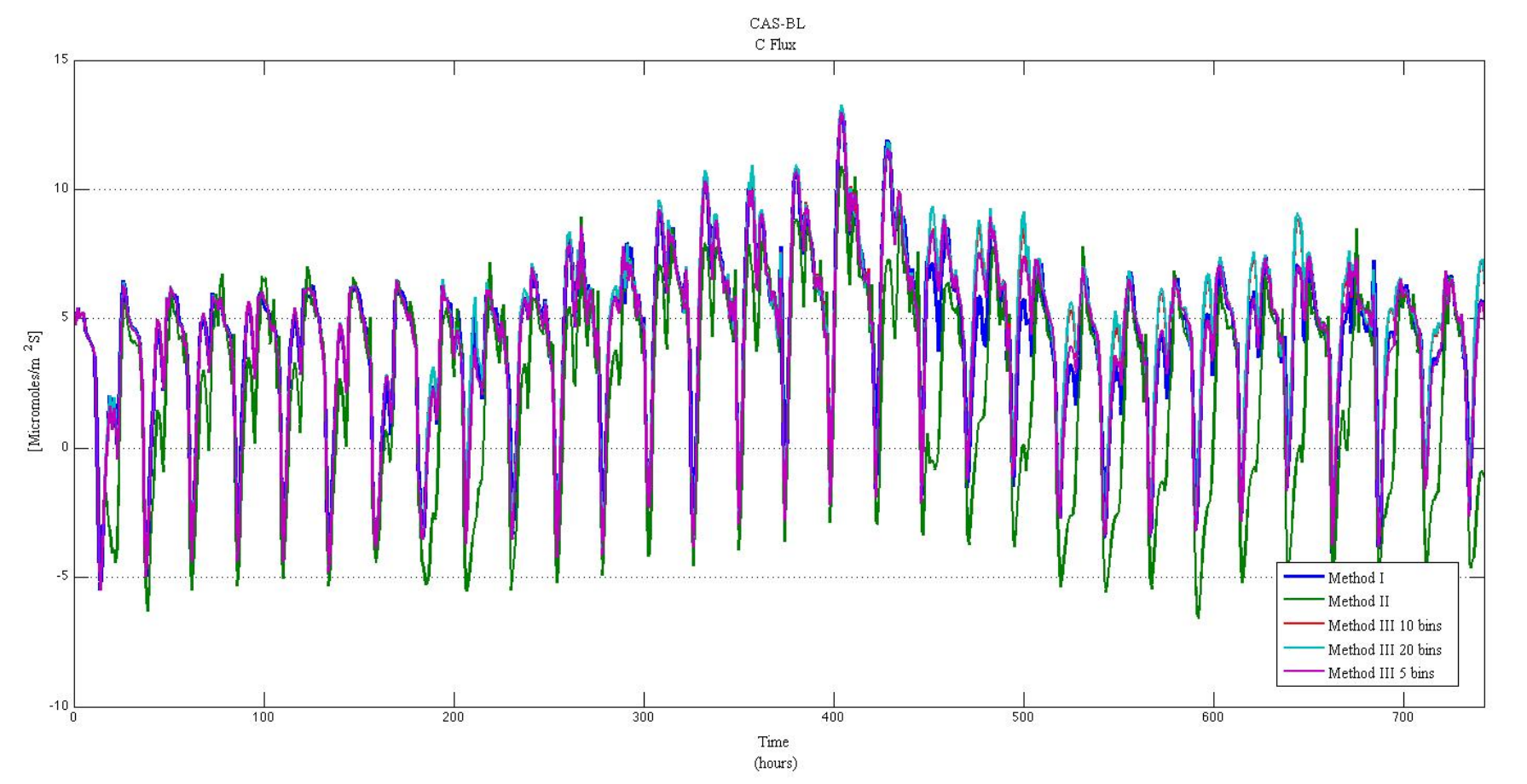

figure 3. Time series of the CAS-BL carbon flux as calculated by the different methods for the convective precipitation experiment. When all methods are compared to method I and absolute errors are calculated, method III performs the best.

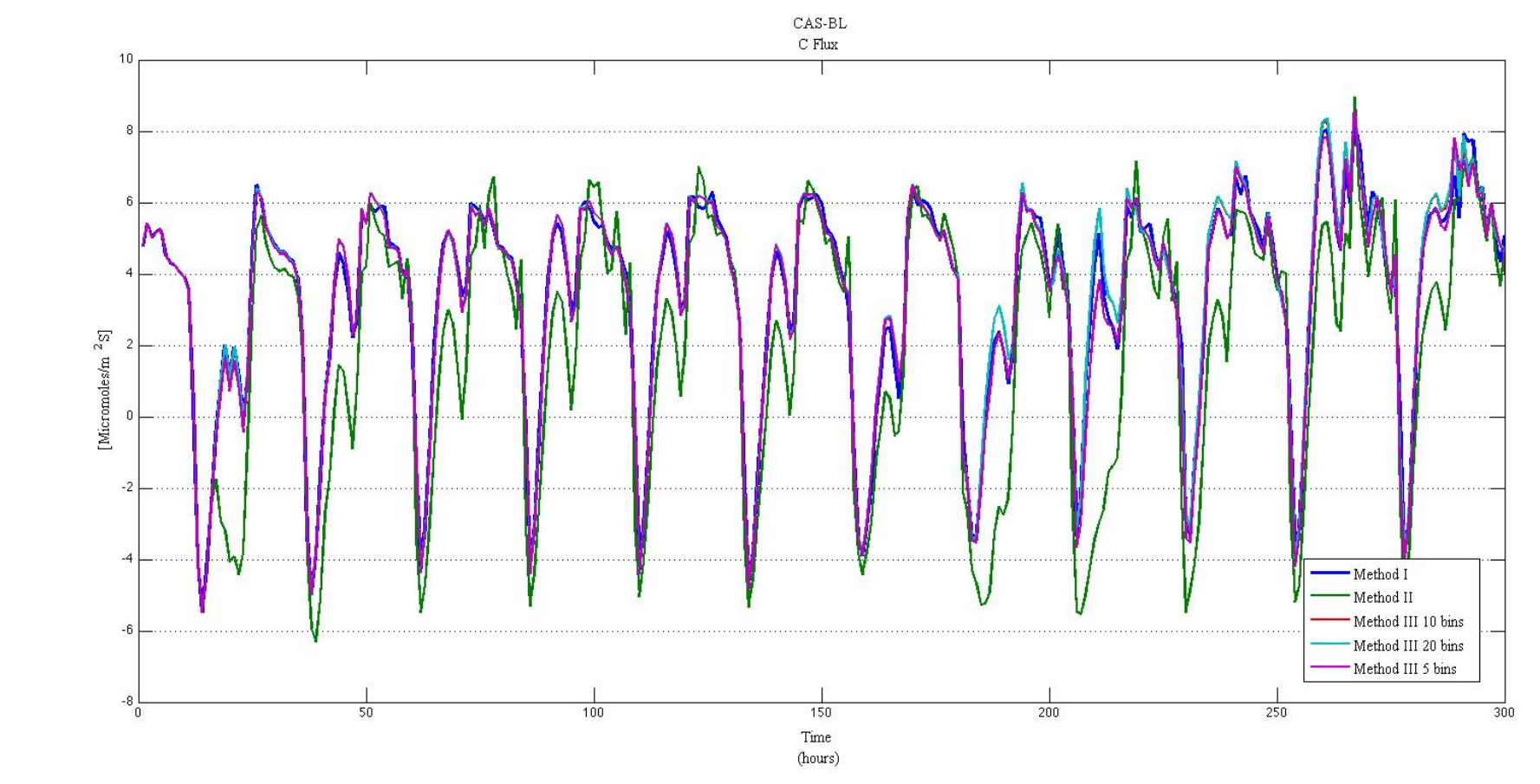

figure 4. Time series (first 300 hours) of the CAS-BL carbon flux as calculated by the different methods for the convective precipitation experiment. When all methods are compared to method I and absolute errors are calculated, method III performs the best.

Preliminary Results

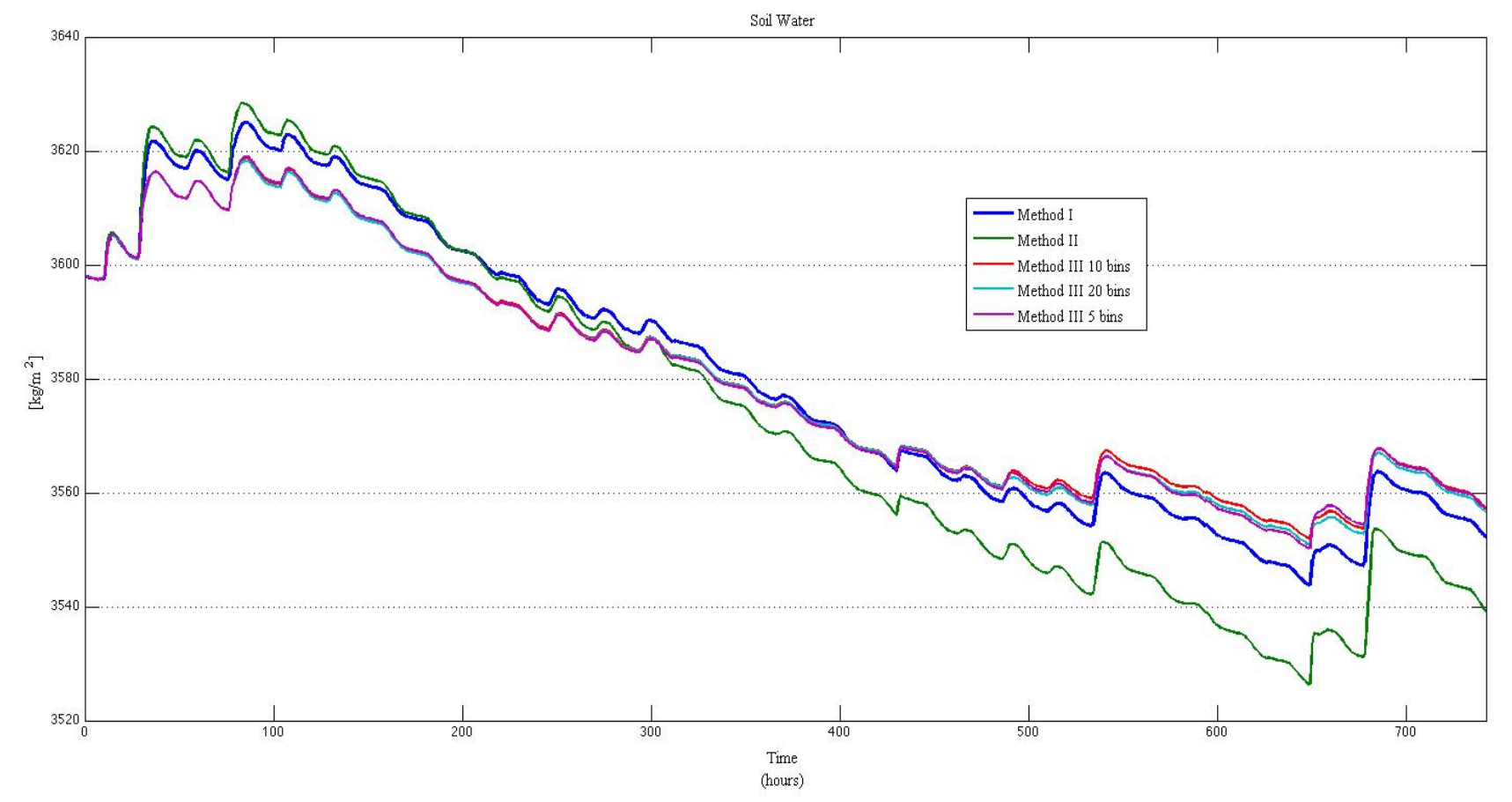

figure 1b. Time series of integrated soil water as calculated by the different methods for the stratiform precipitation experiment. Simple area averaging (method II) is not as problematic as with the first experiment (see summary), and when all methods are compared to method I and absolute errors are calculated, method III performs the best.

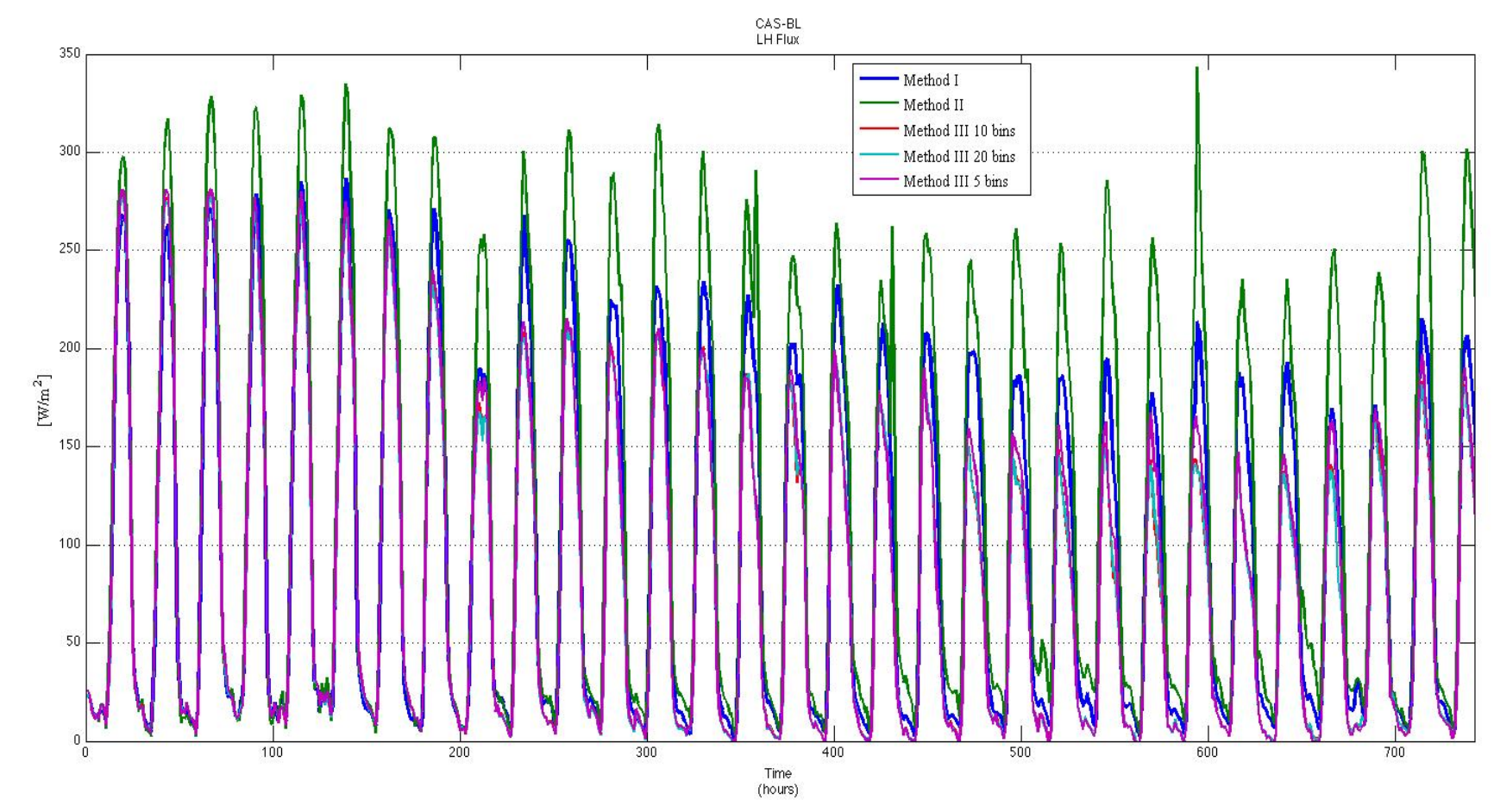

figure 2b. Time series of the CAS-BL LH flux as calculated by the different methods for the stratiform precipitation experiment. Simple area averaging (method II) is not as problematic as with the first experiment (see summary), and when all methods are compared to method I and absolute errors are calculated, method III performs the best.

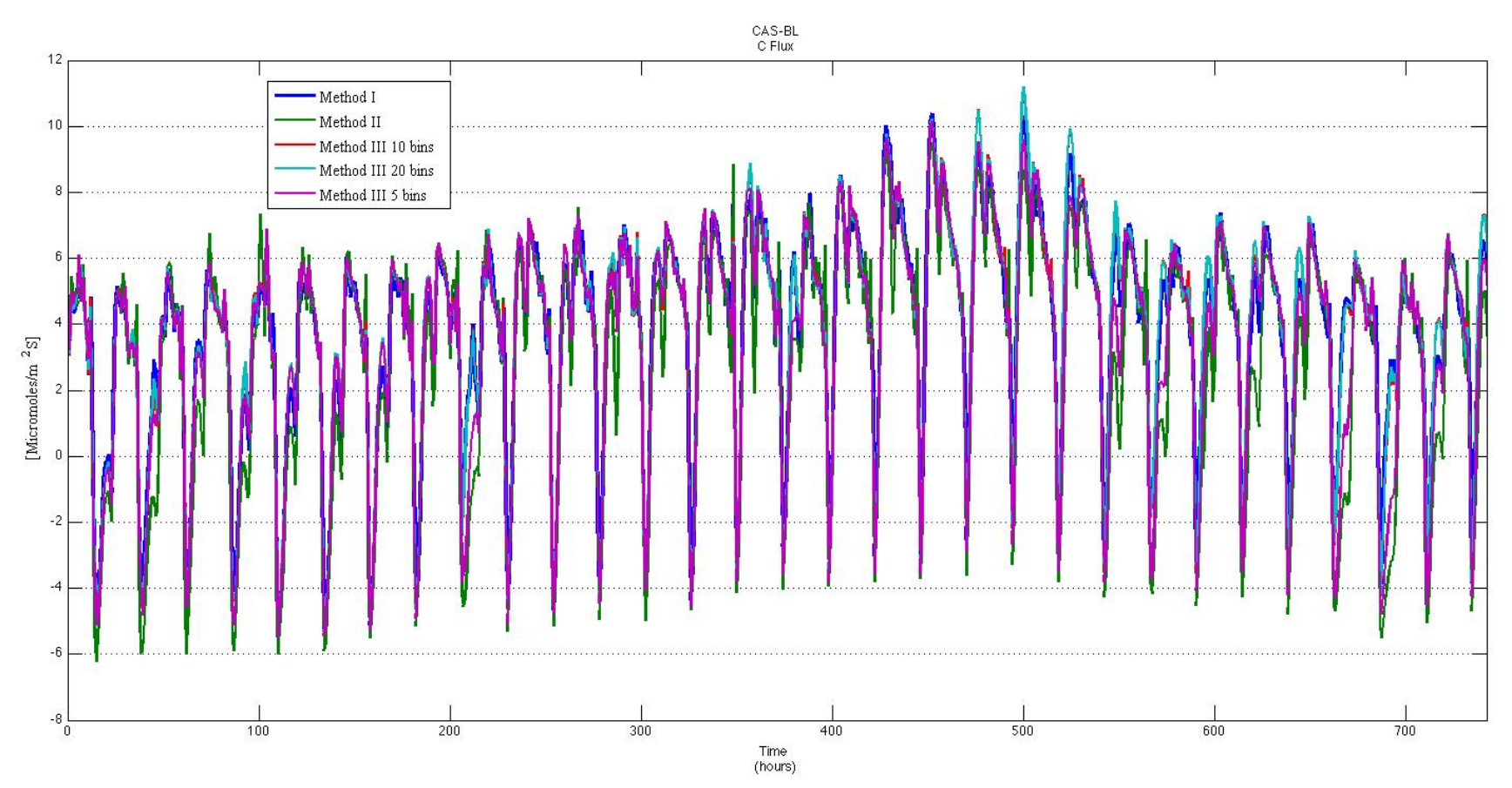

figure 3b. Time series of the CAS-BL carbon flux as calculated by the different methods for the stratiform precipitation experiment. When all methods are compared to method I and absolute errors are calculated, method III performs the best.

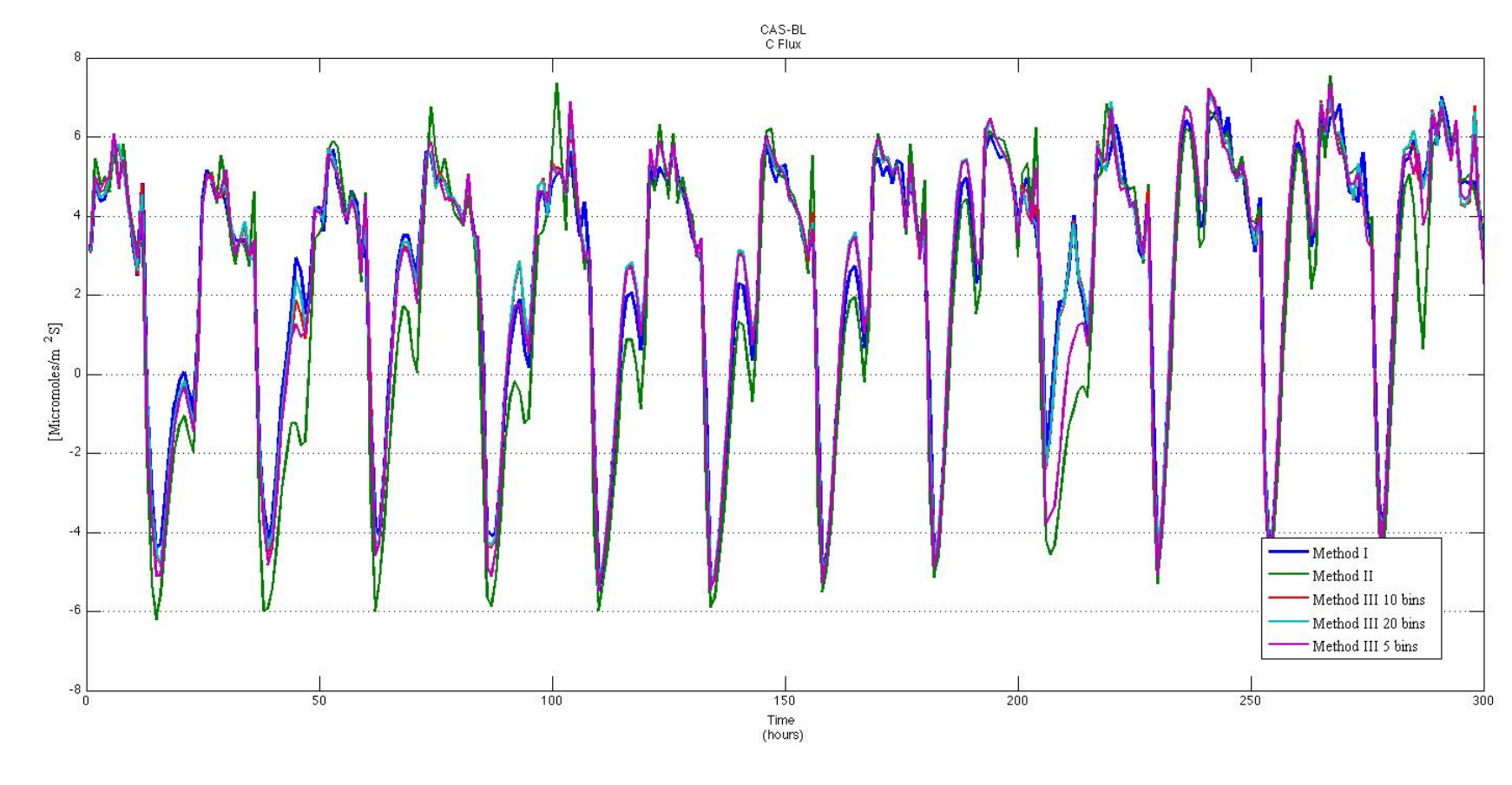

figure 4. Time series (first 300 hours) of the CAS-BL carbon flux as calculated by the different methods for the stratiform precipitation experiment. When all methods are compared to method I and absolute errors are calculated, method III performs the best.

Summary/Continuing Work

Preliminary results indicate that simple area averaging, as used with GCMs (method II), of lower atmospheric forcings is more problematic when convective precipitation occurs. When compared to methods I and III, the grid area for method II is much wetter and CAS-BL fluxes are overestimated for the evaporative flux and underestimated for the carbon flux. The exponential distribution of convective precipitation used in SiB is partly to blame for these findings. When convective precipitation occurs, only a fraction of the grid area receives precipitation, and once the precipitation reaches the subsurface, it is evenly distributed. Therefore, when a single SiB pbp defines the grid area, a larger fraction of the grid receives convective precipitation (relative to the individual cells defining the grid area in methods I and III), and when the water is evenly distributed, the grid area is wetter and evaporative fluxes are much higher. After comparing all methods to method I and calculating absolute errors, method III is better at estimating soil water and CAS-BL fluxes.

The results for the stratiform precipitation experiment indicate that simple area averaging (method II) is not as problematic. SiB evenly distributes stratiform precipitation over the grid area and this distribution does not respond erratically to area averaging as the convective distribution does. When a fraction of the cells (as in methods I and III) receive stratiform precipitation, the even distribution within those cells allows for a contribution to SiB output that is similar to the even distribution of the area averaged (method II) stratiform precipitation. Compared to methods I and III, method II fluxes are still either overestimated (evaporative) or underestimated (carbon flux), but the differences are not as large as those found when convective precipitation occurs. After comparing all methods to method I and calculating absolute errors, method III is better at estimating soil water and CAS-BL fluxes.

As this research continues, we hope to find similar results when a statistical weather generator is applied to the grid area. The weather generator will supply time series of lower atmospheric forcings that will be different for every SiB pbp defining the grid area (100 pbp’s). This will allow for great variability both in the lower atmosphere and land surface. With this research we hope to improve the representation of soil moisture and CAS-BL fluxes by using method III and avoiding the high computational cost of method I and erratic behavior of method II.

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