Response to Interactive comment on "Modeling photosynthesis of discontinuous plant canopies by linking Geometric Optical Radiative Transfer model with biochemical process" by Q. Xin et al.

We thank the reviewer for the constructive comments. We studied the comments and revised the draft accordingly. Our responses to the comments follow below.

General comments: This ms provided a useful study to model GPP of discontinuous plant canopies using GORT model. The analytical solutions are good and quite informative. The most interesting thing I think is that authors tries to separate the canopy into sunlit and shaded parts and integrated into GORT models. This is evidently an advance to current research and would be quite useful for future GPP modeling. I think the ms needs some moderate revision before final publication.

1. It is not clear that why authors selected two deciduous sites. The reason I have is that GPP of deciduous sites are much "easier" to simulate than evergreen forests. Also, the GORT for evergreen sites might be quite different from deciduous ones. Second, even for these two sites, there are more data available in the flux database. Why only part of them was used? For example, for Harvard site, the data could be from 1994 - 2010. If the analytical solutions are the same, then I would guess the validation should be easy to implement.

Reply: thank you for your advice. One reason that we chose to validate our model with two deciduous sites is that one of us (Q.X.) conducted fieldworks on both forest sites in the summer of 2009. In the fieldwork, we measured tree parameters and performed ground-based Lidar scans. We considered that tree crowns in both sites could be approximated by ellipsoidal shapes appropriately. It is true that the current model may have difficulties to model GPP for evergreen forest stands. Tree crown shapes in boreal areas are mostly conical rather than ellipsoidal. Needle clumping within shoot clumping may also need to be considered. We would like to further develop and validate models when data from evergreen sites become available. To address your concerns, we revised our manuscript, and it reads as "Fourth, we use ellipsoids to describe tree crown shapes for deciduous broadleaf forests. Because many evergreen needleleaf forests have conical crowns, future applications to areas with conifer forests may require different treatment on crown shapes in the models."

There are indeed more data available for these sites. For the Bartlett site, Level 4 data are available from 2004 to 2006 and Level 2 data are available from 2004 to 2011. However, GPP estimates are missed in Level 2 products; we therefore only performed analysis using Level 4 data for the years from 2004 to 2006. For the Harvard site, Level 4 data are available from 1992 to 2006 and Level 2 data are available from 1991 to 2011. To model GPP on a yearly basis, we also have to know leaf area index (LAI) as obtained from MODIS data. Based on your suggestions, we now performed model simulations for the Harvard Forest site from 2001 to 2011, and summarized the results in a table. These results now read as follows:

Table 4 lists major statistical results for our model performance, as evaluated using all available hourly data at both sites. The model performance is consistent through time and is comparable to the simulation of 8-day data (Figure 7), despite the fact that satellite-derived LAI instead of field measurements were used for yearly simulation.

Table 4. The model performance at two study sites as evaluated using hourly data. Units for root mean square error (RMSE) and mean bias error (Bias) are in μmol CO_2 m^{-2} s^{-1}.

Year	US-Bar			US-Ha1		
	R^2	RMSE	Bias	R^2	RMSE	Bias
2001				0.804	5.44	2.00
2002				0.729	6.75	3.09
2003				0.781	5.62	2.85
2004	0.784	4.28	1.01	0.737	6.39	1.85
2005	0.795	4.11	0.47	0.736	6.83	1.18
2006	0.801	4.31	1.06	0.777	6.49	2.28
2007				0.768	6.21	2.50
2008				0.689	7.34	3.10
2009				0.662	7.62	3.68
2010				0.752	6.55	0.35
2011				0.715	6.96	1.34

2. The GORT model is suggested to be more accurate than empirical models in GPP simulation. Also, separating the whole canopy into sunlit and shaded parts is to improve the underestimation of GPP at upper ends. In figure 11, we still see clearly that the underestimation is not solved. I think authors may give some discussion on this issue.

Reply: thank you for your insights. Separating the whole canopy into sunlit and shaded parts is to improve the biased GPP estimates. It is worth noting that sunlit leaves receive full illumination while shaded leaves only receive scattered illumination. Because there are light saturation on leaf photosynthesis, we consider the biases, if uncorrected, should be overestimates rather than underestimates at upper ends, as compared to measured GPP values. In our study, we have corrected this effect well, but it seems that there are some over-corrections. One possible reason is that we only employed empirical functions here for the correction. To understand the details, further tests on the photosynthesis – conductance model should be implemented. Another possible reason is that we only used Muneer's method to estimate diffuse radiation components for the US-Ha1 site, which were missing in flux tower measurements. Note that there were no apparent biases for the US-Bar site in our simulations.

To address your concerns, we revised related sentences in our draft and now it reads, "There were slight GPP underestimates when measured GPP values are high at the US-Ha1 site, possibly due to empirical functions that we used in modeling diffuse radiation and leaf photosynthesis."

3. Figure 10 showing the daily GPP simulation, and I like to see how it works at hourly time scale as shown for Harvard site.

Reply: we added a subplot in Figure 11 that shows hourly GPP simulation for the Bartlett site, and modified the related texts. It reads as follows,

For the US-Bar site, the R^2 value is 0.801 and the RMSE value is 4.31 μmol CO_2 m^{-2} s^{-1}. For the US-Ha1 site, the correlation between modeled and measured GPP is strong with an R^2 value of 0.777 and an RMSE value of 6.49 μmol CO_2 m^{-2} s^{-1}.

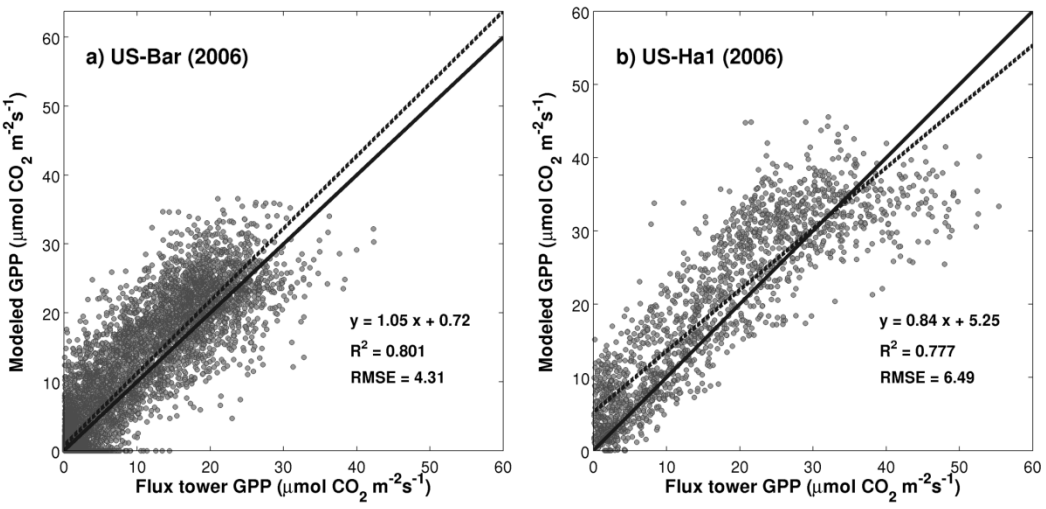

Figure 11: Regressions between modeled and measured GPP for all available hourly data at the sites of a) US-Bar and b) US-Ha1 in 2006. Only data from the photosynthetically active period are included in the regression. The solid line denotes the 1 : 1 line, and the dashed line denotes the regression line.

Thank you again for your help!