Variance-Based Sensitivity Analysis of BIOME-BGC for Gross and Net Primary Production

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Anthropogenic activities have affected adversely the global climate by increasing CO_2 concentration in the atmosphere. Forest ecosystem plays an important role in mitigating CO_2 from the atmosphere and therefore serves as a low cost option for carbon sequestration. The interactions of environment and the forest site conditions must be identified properly to estimate the carbon budget and sink capacity of forest ecosystem. Atmospheric CO_2 levels are strongly controlled by forest gross and net primary productivity (GPP and NPP). Therefore, these are important variables in global carbon cycle and a key process in land surface atmosphere interactions.

Process-based models can evaluate ecosystem activity by simulating different physiological forest processes under different climatic conditions, atmospheric properties and stand structures to explore the forest primary productivity. These models require many input parameters which distinguish the vegetation types by their physiological and morphological characteristics. A major problem with the use of process-based models is incomplete knowledge of input parameters for species of interest, which are often taken from the literature. This causes uncertainty in the simulated productivity. Model calibration should be performed in order to reduce it. Calibration of all input parameters is not always required as the output variable of interest is not always dependent on all input parameters. Therefore parameterization, including sensitivity analysis, is an important step before running these models for specific vegetation/species type.

BIOME-BGC is a widely employed model to simulate carbon, water and nitrogen fluxes. BIOME-BGC requires 39 ecophysiological parameters having varying degree of influence on the simulated productivity. Previously the sensitivity analysis experiment was performed on BIOME-BGC to explore the sensitivity of GPP and NPP to the variation in input ecophysiological parameters (White et al. 2000, Tatarinov et al. 2006 and Ma et al. 2011). These all experiments were based on one-at-a-time (OAT) sensitivity analysis techniques. The input ecophysiological parameters were varied from mean or reference value. The sensitivity of input parameters is based on the ratio of change in output to change in input parameter. This approach has limitation when the model input is uncertain and when the model is of unknown linearity. OAT is only informative at the base point where they are computed and do not provide for an exploration of the rest of the space of the model input. This is important because process-based model, such as BIOME-BGC, exhibit non-linear dependence between simulated fluxes (such as GPP) and parameters (Wang et al. 2001). Furthermore, parameters often interact. Global variance-based sensitivity analysis (VBSA) is another technique that is suitable for non-linear models and samples over the whole input space. It quantifies the contribution of each model input to the variance in the model output variable of interest. This method is independent of model structure and therefore can be applied to process-based model regardless of whether they are linear.

The objective of this research is the demonstration of VBSA using BIOME-BGC model. The sensitivity of simulated GPP and NPP to the variation in ecophysiological parameters will be assessed.

We parameterized BIOME-BGC for *Pseudotsuga menziesii* (Douglas fir) stand in the Speulderbos site, The Netherlands. This species belongs to evergreen-needle leaf forest. The range of each ecophysiological parameter has taken from White et al. (2000) and Hessl et al. (2004). If the range of some parameters were not available, we used either the range belonging to evergreen needle-leaf forest or those belonging to biome. We conducted VBSA in SIMLAB software by running BIOME-BGC for four year (2007-2010).First order (S_f) and total effect (S_t) sensitivity indices were calculated for yearly average value of both GPP and NPP. Initially, we screened 20 parameters by OAT sensitivity analysis. We then used Soboli method to generate samples of screened parameters by making two assumptions: (1) uniform distribution of each parameter; (2) no correlation between parameters. For any year, both GPP and NPP were found highly sensitive to two parameters: (1) specific leaf area (SLA), S_f iY 0.4 for GPP and, S_f IY 0.30 for NPP; (2) fraction of leaf nitrogen in Rubisco enzyme (LNr), S_f IY 0.20 for GPP and, S_f IY 0.10 for NPP. Nearly the same values of S_t was also observed for these parameters. Therefore, these two parameters influence GPP and NPP directly and through interaction with other parameters within the model. The S_f of LNr showed increase (from 0.1 to 0.33 for NPP and from 0.20 to 0.33 for GPP) from 2009 to 2010. It leads us to investigate the sensitivity of weather condition to simulated GPP and NPP.

None of the other parameters showed substantial sensitivity. Results also indicated that leaf carbon to nitrogen ratio shows limited sensitivity (S_f <0.03) for both GPP and NPP, which was found sensitive in previous research. These can be due to the initial assumption of uniform distribution with no correlation. We will extend this work by incorporating realistic distribution of each parameter and correlation between them for VBSA.

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