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Global and Temporal Characteristics of hydroclimate/Vegetation Biophysical Process feedbacks

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Investigation of feedbacks within the climate system is crucial in understanding the current climate and climate changes. In this study, we present a global and seasonal assessment of biophysical feedbacks of vegetation biophysical process (VBP)/climate interaction on the hydrological cycle based on general circulation models of the atmosphere (AGCM) coupled to different land models, which are physically based models and include either comprehensive, or partial, or minimal VBP representations. The models have been extensively tested and comprehensively evaluated in climate studies and model comparison projects, such as PILPS and GLACE. Observed precipitation is applied to assess the VBP effect. The global and seasonal VBP effects are expressed by changes in simulated precipitation errors (bias and RMSE) by the coupled atmosphere/land models in reference to observations.

The AGCM results indicate that the vegetation/atmosphere interaction has substantial impact on global water cycle. In the AGCM simulation, VBP reduces the annual precipitation RMSE by about 40% and bias by about 60% over land, which equals to about 40% land precipitation. In the monsoon region VBP has strongest impact. VBP reduces the annual precipitation RMSE by about 50% and bias by about 70% over global monsoon regions, which equals to about 30% observed precipitation. This impact is about 10-20% higher than over other land regions. The partial VBP effect (excluding soil moisture and vegetation albedo) reduces annual precipitation bias over monsoon region that equals to about 13% of observed precipitation. Among monsoon regions, West Africa, South Asia, East Asia, and Amazon regions have largest impact while southeast Asian monsoon and North American monsoon have the least impact due to strong air/sea interactions and narrow land mass there. The temporal characteristics are also investigated. The impact mainly manifests in spring, summer, and fall with different regions having different primary seasons, depending on regional climate characteristics and geographic conditions. It is also found that the partial VBP plays a great dominant role within VBP in the high latitude region, which account for about 80% of the full VBP effect there. For the predominantly oceanic southern hemisphere, no significant Partial VBP effects were found over most areas. Studies using higher resolution atmospheric models and better validated biophysical models over these regions are needed to further explore these issues further in the Southern Hemisphere. One additional test has also conducted to assess the effect of photosynthesis process on the water cycle.

The major characteristics of VBP effects on surface energy and water balance as well as their interactions at different regions are also analyzed. The analysis of surface energy and water budgets showed that the change in evaporation induced by VBPs was the dominant factor in modulating the surface energy and water balance. The VBP/cloud interaction had great influence on the net radiation at the surface, which was dominated by the net longwave change in the VBP experiment. In the monsoon regions, the changes of surface evaporation and moisture flux convergence (MFC) were in phase, and both contributed to the atmospheric water cycle change. In mid and high latitudes, surface evaporation dominated the atmospheric water cycle. This study was restricted to VBP impacts at continental and seasonal scales. The conclusions may be different in other spatial and temporal scales.

This study uses comparisons of model simulations with observations to show quantitatively that VBP feedback is a major component of the global water cycle over land. Adequate representing this VBP feedback in global climate change and prediction studies is critically important.