Direct and indirect feedbacks of simultaneous soil moisture and atmospheric CO_2 changes on simulated terrestrial ecosystem response

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We tested the hypothesis that the effect of the role of CO_2 change and soil moisture availability on terrestrial net primary productivity (NPP) is interactively linked for all the GCM based vegetation types globally. Two set of studies are performed. One is a process study with a 1D atmospheric model dynamically coupled with a prognostic soil moisture / soil temperature scheme with a photosynthesis based vegetation / stomatal resistance submodel, for a month long simulation corresponding to wet and dry condition. The second is an offline analysis using a photosynthesis based biospheric model over the Amazon region The objective was to analyze the effects of CO2 doubling, under high as well as limiting soil moisture conditions, over different terrestrial biomes. Results for all the nine global biomes, as defined through the SiB2 land cover classification, were analyzed for responses such as evaporation /transpiration, NPP or net carbon assimilation, stomatal resistance, and air temperature.
Results confirm the observations that CO_2 and soil moisture related effects are critical for both the C3 and C4 plants. In particular the study highlights the role of soil moisture and CO2 interactions as a key component of the terrestrial ecosystem. Our results also indicate that (a) explicit resolution of the direct and interactive effects associated with the input variable changes are useful measures for assessing the effects due to CO_2 changes; (b) resolving the interactions explicitly, both C3 and C4 vegetation will be significantly affected by the CO_2 changes; and not support a conclusion that C4 may not be significantly affected; (c) studies linking CO_2 effects in a sensitivity - type analysis both in observational as well as numerical experiments should explicitly resolve the interactions. Thus, impacts associated with CO_2 doubling cannot be assessed without considering the soil moisture status. As that, each vegetation type has a different strategy to account for CO_2 changes with regard to soil moisture availability. Events such as drought or high soil moisture availability can enhance, or completely balance, or even reverse the effects associated with CO_2 doubling by itself, and needs to be considered in any comprehensive future assessment. Often, despite dramatic leaf level impacts due to climate changes, the natural ecosystem tends to buffer and does not show a dramatic response. Our analysis suggests that the interactions between the biotic and abiotic changes tend to have a compensatory / antagonistic response. This reduces the effect of the variable change on the overall system response.
Our results indicate that the effect of soil moisture availability (and drought) is an important modulator of the terrestrial carbon cycle, and its impact for both present day as well as climatological feedback (under doubling of CO_2 or ENSO like events) needs to be investigated.

Table 1 Model simulations performed for each of the nine SiB2 vegetation types to study the interactive effect of CO_2 and soil moisture change.

Simulation Set	CO_2 concentration	Soil Moisture State
I	Present day (34 Pa)	Limiting (0.23 m3 m-3)
II	Doubling (68 Pa)	Limiting (0.23 m3 m-3)
III	Present day (34 Pa)	High (0.3 m3 m-3)
IV	Doubling (68 Pa)	High (0.3 m3 m-3)

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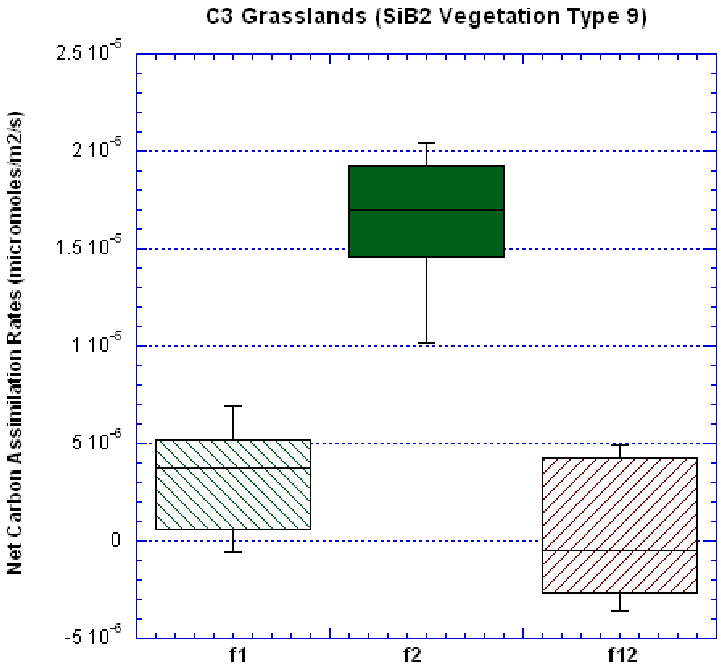

Fig.1 Effect of the direct change in soil moisture (f1) and the CO_2 loading (f2) the indirect or interactive effect of soil moisture and CO_2 changes on NPP or net photosynthesis rates for a C3 grassland.

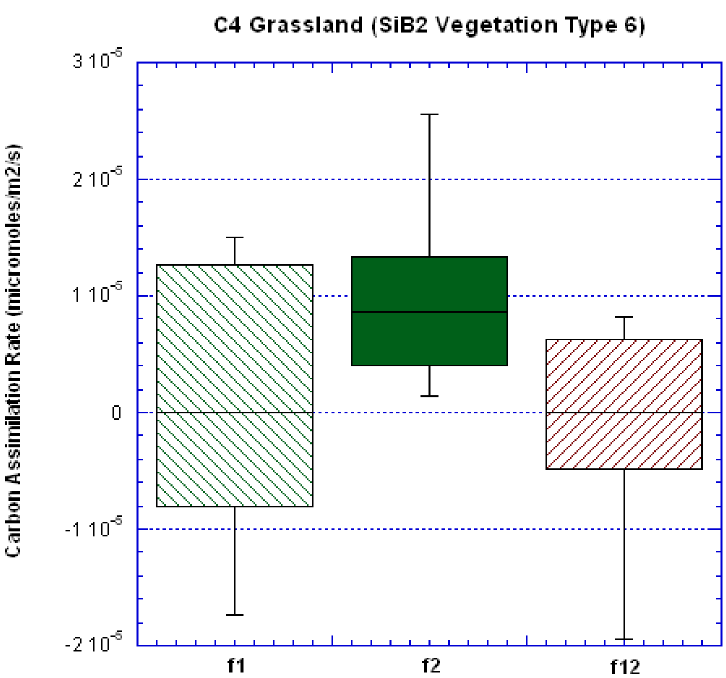

Fig.2 Same as Fig. 1 except for C4 grassland. Note that the direct effect of CO_2 are much dominant as well.