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Evidence for carbon dioxide and moisture interactions from the leaf cell up to global scales: Perspective on human-caused climate change

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Abstract

It is of utmost interest to further understand the mechanisms behind the potential interactions or synergies between the greenhouse gases (GHG) forcing(s), particularly as represented by CO_2, and water processes and through different climatic scales down to the leaf scale. Toward this goal, the factor separation methodology introduced by Stein and Alpert [Stein U. and Alpert, P. 1993. Factor separation in numerical simulations, J. Atmos. Sci., 50, 2107–2115.] that allows an explicit separation of atmospheric synergies among different factors, is employed. Three independent experiments carried out recently by the present authors, are reported here, all strongly suggest the existence of a significant CO_2–water synergy in all the involved scales. The experiments employed a very wide range of up-to-date atmospheric models that complement the physics currently introduced in most Global Circulation Models (GCMs) for global climate change prediction.

Three modeling experiments that go from the small/micro scale (leaf scale and soil moisture) to mesoscale (land-use change and CO_2 effects) and to global scale (greenhouse gases and cloudiness) all show that synergies between water and CO_2 are essential in predicting carbon assimilation, minimum daily temperature and the global Earth temperature, respectively. The study also highlights the importance of including the physics associated with carbon–water synergy which is mostly unresolved in global climate models suggesting that significant carbon–water interactions are not incorporated or at least well parameterized in current climate models. Hence, there is a need for integrative climate models. As shown in earlier studies, the climate involves physical, chemical and biological processes. To only include a subset of these processes limits the skill of local, regional and global models to simulate the real climate system.

In addition, our results provide explicit determination of the direct and the interactive effect of the CO_2 response on the terrestrial biosphere response. There is also an implicit scale interactive effect that can be deduced from the multiscale effects discussed in the three examples. Processes at each scale-leaf, regional and global will all synergistically contribute to increase the feedbacks — which can decrease or increase the overall system's uncertainty depending on specific case/setup and needs to be examined in future coupled, multiscale studies.

Keywords: factor separation; biosphere atmospheric interactions; scale interactions; carbon-dioxide assimilation; land-use changes; coupled carbon–water processes; elevated CO_2

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