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Biogeosciences Discussions

Interactive comment on "Future challenges of representing land-processes in studies on land-atmosphere interactions" *by* A. Arneth et al.

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We have received the two sets of reviewer comments and appreciate their careful reading of our manuscript, and the constructive suggestions for improving it.

In the following we detail our response to the more major comments; all minor technical corrections have been dealt with, thanks for spotting these.

Refereee #2: —Add a paragraph on plant migration: The reviewer highlights an important point, and we thank her/him for the list of insightful papers. In a sense, the migration comment fits very closely also to the comment of reviewer #3 regarding species diversity. In both cases, the history and general principle of DGVMs isn't well suited to include these processes, even though they are undoubtedly important from some

aspects. We add to the revised version with that in mind, and refer the reader to some important work in that area (see list of added references in response to both referees' comments). However, in order to not dilute the focus of the paper too much we prefer to keep the textual-additions relatively short:

"...Moreover, ecosystem responses to environmental changes might well be more resilient than expected when allowed to adjust flexibly. This includes stability through adjustment in species composition (see Kühn et al., 2008; Isbell et al. 2011; and references therein). Modelling species distributions on global scale clearly is not feasible, and DGVMs that represent vegetation by a limited number of plant functional types have not been designed to test ecosystem function in response to adjustment of species richness. What is more, DGVMs typically do not include process-based description of migration patterns of individual species. While the models have been shown to successfully reproduce past changes in larger vegetation units that can be inferred from pollen records (Miller et al., 2008; Kleinen et al., 2011) the assumption of mutually immediate distribution shifts in response to rapid future climate change remains unproven, with potentially large implications for transient simulations of terrestrial carbon and nitrogen balances (Solomon and Kirilenko, 1997; van Minnen et al., 2000; Higgins, 2009).

Still, resolving canopy structural processes and individual establishment and mortality is feasible with some of today's state-of-the art models, and it has been shown that including such features aids analysis of diverse processes such habitat diversity (Hickler et al., 2012), emissions of BVOC, and structural stability (Higgins and Scheiter,2012)..."

Refereee #3:

– Abstract: Revised as ".. accounting for ecological process understanding.."

— Abstract: the reviewer is correct in that there is an active research community regarding interactions of environmental and economic models. However, our manuscript

deals specifically with terrestrial models that are used either as off-line models, or coupled to GCMs; and in the climate-land modelling community, the representation of land management processes is indeed still rather limited. (Systematic intercomparison studies of land use change effects on climate have only been initiated in the last 2-3 years, with the LUCID experiment; currently, only three models used to assess terrestrial C-cycle-climate responses for the IPCC-AR5 account for human land cover changes, and in these, crop areas are represented by the "grass" plant functional types. We do not wish to include all this detail in the paper, but have revised the abstract to remove any ambiguity in that respect:

"...representation of human response-prcesses in ecosystem models that are coupled to climate models.." to emphasise that in our manuscript we do not focus on environmental-economic assessments.

Figure: 1: The reviewer has made some v. good suggestions: we have removed subscripts (1) and (2) from the delta-F, as the forcings in any case are denoted separately for GHG and short-lived substances. We had originally chosen "c" to be in line with the letters used by Raes et al, from whom we have redrawn the figure. But using the letter "c" is indeed confusing. Changed now to "L" and revised in the Figure caption accordingly.

The reviewer correctly highlights the work by Roger Pielke as an author who has worked a lot with land-atmosphere interactions: but this work was mostly on biophysical exchange processes, and on regional scale. In contrast, our focus here lies more with biogeochemical exchange processes and the global scale. We have revised the sentence for clarification: "... but also land use and land cover change when studying land-atmosphere interactions, especially those related to biogeochemical cycles on global scale.".

Booth et al., 2012: The paper is now published, and the reference updated in the ms. This makes the comment by the reviewer also to some degree immaterial, however,

we have still added a comment on the parameter correlation: " In the analysis, parameters were sampled using a latin hypercube design, which seeks to explicitly minimise correlations between parameters. Yet with 6 parameters and 17 simulations (Figure 2) some degree of correlation is inevitable, and as discussed in more detail (Booth et al., 2001), it was thus only possible to tie model responses to parameters where only one or two parameters dominate."

Reviewer comment on P3351, l 1-5, and (further below) on p 3552, l27-29 (version BGD website): it is true that the DGVM in HadCM3 has relatively few PFTs. DGVMs in general were historically not developed to work as biodiversity models, but to represent broad patterns of biome biogeography and terrestrial C and water cycles. A limited number of DGVMs that operate on global scale include explicit representation of canopy structural processes (establishment, mortality, growth done on an individual or cohort-level), and these can be applied to questions of large-scale shifts in habitat. We have revised the text accordingly (see added paragraph also in response to rev. #2).

Figure 3, colour scale: The colour scale was changed, according to the suggestion by the reviewer. More explanation regarding the white areas is added to the Figure 3 caption.

p. 3552, also in non-tropical regions: true, "tropical" is deleted & revised as (page 5): "Preliminary results showed an increase in simulated annual gross primary productivity by up to 25% in the year 2100..."

Figure 4: To avoid confusion, we have added: "Dotted lines do not represent modelled trajectories between present-day and late 21st century."

P2557 l.2: We have added: "Recent fire models have attempted to include ignition or extinction effects (Pechony and Shindell, 2009; Thonicke et al., 2010) " (page 8)

P 3561, l1-2/CO2 effects: We have revised the text to reflect the reviewer's concerns:

"Incidentally, studies that seek to assess the interactions of climate change, yields and terrestrial biogeochemical cycles, with other important facets like increasing CO2 so far are rare and/or concentrate on regional rather than global scales (Mueller et al., 2010; Huang et al., 2009). Enhanced CO2 should at least be somewhat beneficial to C3 crops even though experimental evidence is conflicting (see Jaggard et al., (2010) and references therein). No published work to our knowledge has assessed these crop yield and biogeochemical cycling response on global scale to increasing ozone levels despite ozone's known deleterious effects (Ashmore, 2005)."

P 3561, l13-14: added farming systems to the list of examples.

P 356, l17-24: We partially agree with the reviewer, even though there may have been also a misunderstanding w.r.t. what is meant by mechanistically-based representation of human processes. Revised as: "Quantification of feedbacks between socio-economic and biophysical/biogeochemical dynamics remains a challenge while even the interactions between important environmental drivers and crop yields are poorly represented in terrestrial models (Rotter et al., 2011). Still, a more integrated perspective is necessary and should become an active area of research that bridges the socio-economic and biophysical communities (Hulme, 2011) to facilitate robust analysis of how people affect the global environment and to test for global effects of climate change mitigation and adaptation strategies (Rounsevell and Arneth, 2011)."

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