Overview of revisions

We greatly appreciate the supportive reviews and the helpful comments by both reviewers. In the following, we address each point raised by the reviewers individually. We hope that added and modified text has served to further improve our manuscript. The most relevant modification to the originally submitted manuscript is an extended description and discussion of the choice and relevance of peatland model parameters. We also added information to Figure 6 (seasonal variations of inundated area for six regions). Model simulations have not been repeated and all results remain unchanged since the first submission. Below, quoted reviewer comments are indented and in blue font. New and/or modified text is in green font.

Response to Reviewer 2

> My only major suggestion is that the authors may want to consider a more systematic sensitivity analysis for certain parameters or values used, or at least provide further discussion about why the choices of these values would not significantly affect the results/conclusions. In particular, some parameters are not well constrained by observations, such as the minimum of fraction of 0.001%, and the relative areal change rate of 1% per year. I understand some parameter values were determined based on visual comparison of simulation results with available observations, and others by using coarse-resolution model due to computational costs. In any case, some additional justification/discussion on these and other parameters would strength the manuscript.

In our revised manuscript, we extended the discussion of model parameter choices. With regards to the minimum peatland area (seed) of 0.001% and the peatland expansion rate of 1% yr^{-1}, we also refer to our response to reviewer 1. Results presented here are only marginally affected by the choice of aforementioned parameter values. Here, we present simulations with a spinup to preindustrial quasi-equilibrium and the relatively small transient changes in climate and CO_2 throughout the 20th century imply small spatial shifts of peatlands, and hence small influence of processes affected by these parameters. We do not dwell on model predictions of spatial dynamics here. To investigate this aspect, we plan to run the model under transient and large climate shifts as suggested for the last Deglaciation (Last Glacial Maximum – Holocene) in a future study. This is mentioned in Section 7.2.1. Modified/extended text reads:

[...] This approach assumes that expansion is proportional to the peatland area and implies exponential areal growth where the potential peatland area fraction is attained on centennial to millennial time scales after initiation (pt_{crit} switched to TRUE). The choice of these parameter does not significantly affect the results presented here as shifts in the spatial peatland distribution are relatively minor throughout the 20th century. Simulated peatland C storage in gridcells not fulfilling establishment criteria (pt_{crit} =FALSE) is only 2.9 TgC (0.0005% of the global simulated peat C at 1900 (570 PgC)) and is therefore negligible for global C budgets. Further studies could be aimed at [...]

We also extended the discussion of other peatland model parameters. Added text in section 7.2.2 reads:

The mass balance criterium $\frac{dC^*_{peat}}{dt}$ determines whether conditions for long-term peat soil C accumulation are satisfied. This is relevant mostly for peatland initiation (at early stages, the criterium for C^*_{peat} is not satisfied). Additional transient long-term spinups showed that $\frac{dC^*_{\text{peat}}}{dt} = 20\ \text{gC m}^{-2}\ \text{yr}^{-1}$ would be too restrictive for North American peatlands to establish (not shown). Our choice of $\frac{dC^*_{\text{peat}}}{dt} = 10\ \text{gC m}^{-2}\ \text{yr}^{-1}$ is motivated by observational analyses that suggest that the vast majority of examined peats exhibit long-term C accumulation rates above this value (Charman et al., 2013). The C density criterium C^*_{peat} is not independent from $\frac{dC^*_{\text{peat}}}{dt}$ as it reflects a time-integration of the latter. I.e., after millennia of sustained peat C accumulation, soil properties are sufficiently altered and the land qualifies as a peatland even when $\frac{dC^*_{\text{peat}}}{dt}$ is too low. This is relevant when conditions become unfavourable for new establishment and introduces a hysteresis effect. The choice of $C^*_{\text{peat}} = 50\ \text{kgC m}^{-2}$ is chosen to reflect typically observed peatland soil C contents (Tarnocai et al., 2009). However, the variability is large. Again, the choice of this value is not critical for the results presented here where the vast majority of peatlands have soil C contents greater than 100 kgC m^{-2} and no large climate shifts are affecting the peatland distribution.

For a documentation of the parameter exploration of M and CTI_{min}, we now refer to Stocker (2013) in the manuscript .

> **Specific comments:**
> Title: Change "spatio-temporal" to "spatiotemporal"?

Both spellings are used. E.g. the Oxford Dictionary suggests "spatio-temporal" (`http://www.oxforddictionaries.com/definition/english/spatio-temporal`). We left it unchanged.

> Page 4876, line 11: Delete "Here" or change to other wordings, as you use "Here" earlier in the abstract already.

Done. We simply dropped the word "here" on l.11.

> P4877, l15: change to "40-50 Tg CH4" if that is the case, as the later part of sentence refers to C

Done. In fact, it's Tg CH_4-C (only the weight of the element C is counted).

> P4878, l11: change "area specific fluxes" to "flux rate per unit area" or "flux intensity"?

Done.

> P4879, l7: define f here in its first use (="inundation area fraction") to increase readability.

To clarify this, we reformulated this sentence to "the area at maximum soil water content is used as a surrogate for the inundated area fraction, thereafter referred to as f."

> L9-11: rephrase this 2 sentences, such as "Here we present an implementation of TOPMODEL by ... We term our module/implementation ... DYPTOP." The readability can be improved with rephrasing.

To improve redability, we write the meaning behind the acronym (DYPTOP) in italics: "Here, we present the *DYnamical Peatland model based on TOPmodel* (short DYPTOP)."

> P4881, l20: change "sphagnum" to "Sphagnum" (also italic). L25: do you mean "deciduous" by "raingreen"?

Done. Yes, this refers to "deciduous".

> P4885, l2: change to "...in R (R Code Team, 2012)" (similar typo in Figure 1 caption) L24: change "Sect." to "Subsection"? Distinguishing Sections and Subsections in the text may help increase the clarity.

It is actually correct to refer to "R Core Team" (see function `citation()` in R).

> P4885, L24: change "Sect." to "Subsection"? Distinguishing Sections and Subsections in the text may help increase the clarity.

Copernicus requires references to sections and subsections to be referred to as "Sect.".

> P4888, l15: minimum fraction of peat at 0.001%: How sensitive would it be if using different value other than 0.001%? What is the impact on the global C balance using different values? Is it the smallest fraction to make "peatland seeding" effective? Some discussion on how this prescribed values would affect results/conclusions may be useful.

See above and response to reviewer 1.

> P4889, l10-15: Again, it would be useful if additional sensitivity analysis is done to make sure that the selection of specific values for these parameters, such as 10 gC/m2/yr, 50 kg/m2, or 31 years, would not affect the results/conclusions. I don't think we have empirical observations on the limits for peatland persistence, so sensitivity analysis or additional discussion would increase the readers' confidence and strengthen the manuscript.

We added text to justify and discuss our parameter value choices for C^*_{peat} and $\frac{\mathrm{d}C^*_{\text{peat}}}{\mathrm{d}t}$ (see above). The choice of the averaging period being 31 years is twofold: First, 30 years (1961-1990) is the common time period over which meteorological variables are averaged to derive mean modern climatologies (`http://www.wmo.int/datastat/wmodata_en.html`). Second, during spinup, the climate is held constant (but including stationary inter-annual variability) at preindustrial levels whereby 31 years are recycled. These 31 years correspond to 1901-1931 in the CRU TS 3.21 data set, see section 5.2. By averaging over this period (also relevant during the spinup, see Section 5.1), we eliminate inter-annual climate variability and largely eliminate variations in pt_{crit} within individual gridcells during the spinup. This is now made clearer by added/modified text:

[...] by averaging the simulated C balance variables and POAET over the preceeding 31 years. This is to reduce interannual variability in pt_{crit}, which is driven by interannual variability in climate (a 31-years time series is repeatedly prescribed during the spinup, see Sect. 5.2).

> P4890, l17-18: change to "...allocated to f_{oldpeat}, and re-expanding peatlands first expand into f_{oldpeat}." (add a "," between two phrases separated by "and").

Done.

> P4896, l7: change "but are biased low..." to "but are underestimated..."

Done.

> P4897, l119-26: Good point about human modification on rice paddies. The authors may want to point out more explicitly that some rice paddies fields were constructed on the mountain slopes as terraces, so certainly topographic analysis (as modeled here) would not consider these slopes (some times quite steep) as wetlands, but satellites as in inundation dataset can still see.

We included this suggestion. Modified/added text in Sect. 6.1 reads

[...] This has to be interpreted with regard to the fact that anthropogenic modifications of the land surface in areas of wet rice cultivation increase the flooded area beyond naturally inundated regions (e.g., rice paddies constructed on slopes). This anthropogenic extension of flooded areas is most relevant in the wet season, while in the dry season, rice paddies are commonly drained, resulting in an amplification of the seasonal amplitude. Additionally accounting for information on rice cultivation areas improves the agreement between modelled and observed inundation areas in region IC (dashed line in Figure 6).

> P4899, l6-10: maybe reword the sentence(s) here to use either phrases or full sentences, rather than a mixture of both for items (i), (ii) and (iii). Something like: "the following three criteria/steps: (i). . .."

We re-formulated this sentence. Modified text reads:

As outlined in Sect. 4, the distribution of the peatland area fraction f_{peat} is simulated as the combination of (i) the suitability of climate and peatland vegetation growth conditions for long-term C accumulation in soils, (ii) the flooding persistency, and (iii) the effect of peatland presence on the regional-scale hydrology by imposing a positive feedback on the extent of peatlands.

> P4903, l7: change to "Ringeval et al. (2012)" (misplaced "(") L13: change to "Note, however, that M. . ." (add a "," before "however")

Done.

> P4904, l10: change "E.g., " to "For example,". Similar change can be applied in several other places in the text, such as page 4907, line 14.

Done, we changed some of these "e.g."s.

> P4909, l10-11: any reference to the values used (for example, 1% per year)? Or further comments on the sensitivity of the simulation results/conclusions to the specific value used. See comments above on sensitivity analysis.

See discussions above.

> P4910, l17-18: maybe indicate here which three additional PFTs to represent peatland beyond boreal regions. Also, it would be useful to readers if the authors also briefly state the PFTs used for boreal peatlands in Spahni et al. (2013).

This is described in Sect. 2: "Peatland vegetation is represented by *Sphagnum* (moss) and *Graminoids* (sedges). [...] In contrast to earlier studies of Spahni et al. (2011, 2013), we include three additional PFTs on peatlands. These inherit properties of the tropical evergreen and tropical deciduous tree PFTs and the C4 grass PFT (see Sitch et al., 2003), but are adapted for flood tolerance (Ringeval et al., 2014). Additionally, we removed the upper temperature limitation of the other peatland-specific PFTs, already used in previous studies (*Graminoids, Sphagnum*) to permit their growth outside the boreal region."

> Comments on figures: Figure 1. -Figure caption about Step 3 is a little unclear. If "$(v, k, q, f^{\max})$ are prescribed to LPX-Bern" (used as input as indicated on page 4885 line 9), then would it be useful to add a line/arrow in the flowchart to link "fit parameters" box with "LPX" diamond? -in figure caption, state what the brown double-lined arrow stands for "feedback of peat growth on water table". The authors mention this in the text, but not here in figure caption.

We added a reference (number 7) to the red (brown) arrow that represents the peatland-water table position feedback. With regards to the additional arrow to the "LPX" diamond: We decided to illustrate all steps related to the TOPMODEL implementation separate from LPX because no direct feedbacks (except via f_{peat}) exist between f and any state variable within LPX. f is simply calculated as a function of Γ and fit parameters $(v, k, q, f^{\max})$. Figure 1 also visualises that the TOPMODEL implementation presented here may be treated as a diagnostic that can also be applied offline to the outputs of LPX or any other model that predicts Γ (after the simulation is completed) – with no difference to the results so long as peatlands are not included in model simulations (see Sect. 7.1.5). The fact that the read-in of $(v, k, q, f^{\max})$ and the calculation of f is actually implemented within the LPX framework is only a technical aspect. Conceptually, we think it's better to represent this as is and we decided not to change the figure.

> Figure 2 -caption: change "industrial period" to "instrumental period"? -is that also for the 31-year period (1982-2012)? If so, indicate so.

We modified this sentence for clarification: "Vertical blue lines illustrate Γ for each month as simulated by LPX for the period 1901–2012 (see Sect. 5.2)."

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