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Geoscientific Model Development Discussions

Interactive comment on "Simulating migration in dynamic vegetation models efficiently with LPJ-GM" *by* Veiko Lehsten et al.

Anonymous Referee #2

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The paper presents two methods for simulating tree species migration, newly implemented in the dynamic global vegetation model LPJ-Guess. I find the paper mostly well written and generally an interesting scientific contribution.

What I, based on the presented material, cannot consent to is the reoccurring statement that the model can be used for continental simulations of multiple interacting species, nor that it is suitable for DGVMs beyond special cases (i.e. species simulations in Europe). Most DGVMs use plant functional types with mixed dispersal/reproduction traits, particularly when used for large spatial applications. The example application deals with only two species, and only the dominant late successional tree species Fagus Sylvatica is tracked, which has a quite narrow dispersal kernel. Furthermore, the application deals with a homogenous landscape. From what the authors show and

write I am not convinced that/how a continental simulation with multiple interacting and dispersing species would/can be possible. From the paper I understood that using FFTM with widely spread transects would not be appropriate in heterogonous areas. SMSM with terrain, on the other hand, would not save enough computation time to be applicable on continental area. Is the plan to use FFTM with transects in homogeneous areas and SMSM in heterogeneous areas? But if so, how would these algorithms then communicate with each other in a continental simulation?

Given that the paper, the presented ideas and the LPJ-GM implementation are already a substantial contribution, I recommend reconsidering the (over?) statements regarding continental applications and DGVMs e.g. in the last sentence of the abstract and particularly the first sentence in the discussion and talk about DVMs with species and spatial extents exceeding applications of a few ha, which is a good and sound contribution. Another way could be closing the explanatory gaps, i.e. (1) discussing issues with DGVMs and how DGVMs, which usually use plant functional types (PFTs) for large scale applications, could be parameterised for the algorithms, (2) discuss the costs/difficulties of an application with a realistic number of interacting species, with differing dispersal traits and (3) explaining how a realistic continental simulation could be assembled with the FFTM and/or the SMSM simulation, given spatial fragmentation and spatial heterogeneity.

General comments

1. In many places in the text the authors state that transect simulations lead to similar/only slightly reduced migration speed. However, from the figures/table it seems to be quite a significant underestimation, and the less transects the worse the underestimation of the migration speed (>20%; i.e. in the 3000y application >600y delay). I recommend stating this clearly and to discuss the consequences.

2. The authors claim that they fulfil the stochastic requirements because they have 200 or so 1km2 grid-cells when comparing to the usual 0.5°x0.5° grid cell. However,

this only holds if the spatial heterogeneity caused by the stochastic disturbances and stochastic mortality does not affect tree species migration. In the example application the authors choose Fagus Sylvatica, a dominant late successional tree species, and I can imagine that for this species the stochasticity might indeed play a minor role. However, what in case of e.g. pioneer, less dominant/more specialised species? These might depend on disturbed areas for establishment – is the transect approach valid for such species? I would find it very helpful to see how the stochasticity and the few available transect cells might affect the spread of such species.

3. It is correct that if applied globally DGVMs usually use 0.5° grid-cells, however when applied as DVMs on continents or regionally the resolution is usually much smaller. See e.g. the dispersal experiments by Snell (2014), and the simulation of European potential natural vegetation with LPJ-Guess (Hickler et al. 2012).

4. I would recommend referring a bit more to relevant literature in some parts of the text, since several of the ideas/methods have already been discussed/used elsewhere. (I mentioned some references in the specific comments list below).

5. What I miss in the current introduction is a bit more on why migration is missing in DGVMs. The authors state that one reason is the '1D' property, i.e. that cells are not interacting and thus the computation costs of making them interacting. But what should also be mentioned is the problem of parameterisation: DGVMs usually use PFTs, often compiled of species with various different traits with respect to migration (dispersal vectors, competitiveness, generation times, ...) (e.g. Snell et al., 2014). Furthermore, if I understood it correctly, the example simulation is for 3000y and the tracked species migrates ∼100km in that time. Several of the criticized studies with DGVMs (e.g. "land use change on vegetation and ecosystem properties") would use well below 3000y; mostly around 100/200y – given the comparable cheapness of 1D simulations and the mentioned constraints due to parameterisation: wouldn't a 'no dispersal' simulation be sufficient for many simulations with large spatial extent and coarse resolution?

6. I would appreciate a more detailed description of the SMSM method. Maybe an illustration? Would this method work with a species with a more pronounced long distance dispersal tail than Fagus Sylvatica? What would this mean regarding computation costs? How to parameterise the SMSM? Could a setting like Fig 5 be simulated with transect at all? Looking at the supplementary figure it seems that the matrix shift method with a terrain has a very small computational gain?

7. I would appreciate more discussion of the limitations and a clearer directive how to apply the algorithms for a continental simulation, if possible. When reading the text I got the feeling that the remedy for the FFTM limitations (heterogeneity/fragmentation, wind directions) is to use the SMSM, but that this method, particularly if used with terrain, is not performant enough for continental applications. Some more buzzwords for the limitation section: parameterisation of SMSM; species parameterisation; fragmentation when using the FFTM; what about ecosystems with many species (i.e.. tropics). Reduction of migration speed by >20%, i.e. in the 3000y simulation > 600y delay.

8. The editor provided me with the model code. Unfortunately I was not able to understand how the simulations were done. There are no hints on how the simulations were conducted, nor was I able to identify the configuration file (instruction script (ins)?) used for the simulations or to find out how/where the transects were defined. I know that it is cumbersome but in the spirit of "good scientific practice" it might be nice to provide and mark the configurations files?

Specific comments:

l.1: Maybe consider to adapt the title, since LPJ-GM does not necessarily lead to a more efficient simulation of migration in dynamic vegetation models per se – e.g.: "Simulating migration in dynamic vegetation models efficiently on the example of LPJ-GM" or maybe better "Simulating migration efficiently in the dynamic vegetation model LPJ-GM"

l.21: Most DGVMs do not use species but plant functional types (PFTs)

l.31: From the last Figure in the supplementary, SMSM with terrain seems to be much slower than FFTM?

l.40: “Furthermore, with the transect method both methods. . .”?

l.49: DGVMs assume that some instance (i.e. species) of the PFT can establish

l.51: Something seems not correct with the embedded sentence – maybe that instead of the?

l.53 & 63: Anyway DGVMs usually do not simulate species but only PFTs

l.60: When considering ecosystem properties in the future hardly any study would make projections »100y, maybe 200y, but the example in this study uses 3000y. Wouldn’t – based on what is shown in this paper – a “no migration between large grid-cells (0.5°) assumption” be appropriate for studies with ∼100-200y?

l.76: Another example of a model even accounting for wind speed and direction: LAVESI-WIND (Kruse et al. 2018)

l.82: What does the spatial heterogeneity refers to in this context – soil and climate? If I understood the set-up right LPJ-GM also does not account for such heterogeneities within the grid cell, only to such with regards to species interactions and stochasticity?

l.88-90: e.g. Fisher et al. (2010) call these one-dimensional DVMs

l.94: why every time-step? LPJ-GM only does it once per year?

l.100: If I understood it correctly the presented simulations only simulate two species

l.101: What would a simulation with several species look like, does each need one FFT/SMSM? What are the resulting costs?

l.110-111: Please list a few key references describing LPJ-GUESS 4.0

l.119: Above and below this node is called master

l.123: “no seed dispersal”-> “no seed limitation”?

l.130: There are species producing seeds throughout the year (see e.g. Owens 1994, Brokaw, 1998)

l.140: Here or generally in LPJ-Guess?

l.153-157: How is this similar to Lischke et al., 2006? Lischke et al. (2006) do not mention LAI but state: "The number of seeds S produced per year by each tree depends on its height, species and mast seeding period."?

l.175: For Fagus Sylvatica?!

l.181-182: But wouldn’t the implementation of wind direction lead to anisotropy and therefore make the FFTM not applicable anymore (E.g. Neupane (2015))?

l. 185: maybe use θ and add the θ = 1 in the text below?

l.186: long term -> long distance?

l.197: but how is the number of seeds defined in this case, since in the next para it is stated that the establishment of seedlings depends on the number of available seeds?

l.202: “depending stochastically depending”

l.206: “seed bank per and the germination” remove the per?

l.216: The authors should definitely mention that the method has also already been broadly applied in simulating dispersal. E.g. have a look at Powel (2001) + shortly googling I e.g. found Pueyo et al. (2008) and Prasad et al. (2013) and I assume there are more.

l.235: “different wind distributions” -> only if they are valid for the whole simulated area, or?

l.242: How is this proportion determined?

l.242: 1km2 cell?

l.249: How often is this done/ needs to be done to account for long distance dispersal? What happens with the seeds at the boundary of a simulation area?

l.255: Figure 2 is not cited in the main text (only in Fig. 5).

l. 266: Wouldn't the heterogeneous landscape be much more crucial to test the applicability of the methods?

l.274-275: And? But?

l.276: Out of interest: how many CPUs were used/ what computing environment? Would it be possible to add a 'no dispersal and no communication' (i.e. a 1D) simulation for comparison?

l.303: 1km2 grid cells

l.306: somewhat? >20%!

l.309: Maybe add the numbers for the variability

l.312: Which probably also explains the patterns in the migration front?!

l.314: When FFT when FFTM?

l.318-319: How do the simulations compare to a simulation without communication between grid cells, i.e. 1D simulations?

l.323: How to specify this parameter when not having a FFTM simulation at hand? How for SMSM with terrain, does this require a simulation without terrain before? What are the cost reductions then?

l.335-337: I would find it valuable to have the simulation times for the terrain simulation in the table, too!

l.341: This would probably not work with transects?!

l.358: K is the number of iterations?!

l.361: "a very similar migration pattern" I would delete the "very"

l.362: it is slower by 20%!

l.362-363: in l. 310-312 the authors state that its slower because of the migration path? How do these two different explanations contribute?

l.364: how to parameterise "explicit considerations of wind directions"

l.376: Something is missing in this sentence

l.379: Maybe in a DVM? But not in ecology and not to simulate dispersal; the authors should mention some applications - as mentioned above: have a look at Powell (2001) + other references such as Pueyo et al. 2008; Prasad et al. 2013 + I imagine there are much more.

l.384: "DGVMSs"

l.410-412: 63-85% instead if 85%? I would maybe remove this quantitative comparison. In my understanding the size of the reduction will be dependent on the model and the set-up of the simulations, i.e. on a variety of factors, such as the number of simulated and dispersing species, the resolution, settings of the applied algorithms, etc., and since its two different models and probably very different simulation set-ups, it seems to me to be comparing apples and oranges?

l.413: more pronounced than what or where?

l.416: maybe 0.5 and 1.0?

l.449: From the last Figure in the supplementary it seems that SMSM simulations with terrain are comparably much slower. Is it possible to speed them up with transects?

l.462: I would not call 20% slightly

l.457: "FTTM" -> "FFTM"

l.465: unfortunate – I think this would be really interesting, especially when simulating fragmented landscape or non-dominant species

l.481: missing ")"

l.486: What was the tested set-up? I assume FFTM? I.e. no 'terrain'? Transects with 50km distance? How many competing/migrating species? All grid cells homogeneous? How many years?

l.488: "considerable computation costs" – what were they in the tests (e.g. CPU h per simulated y)? Are continental applications possible, or are they not possible?

l.488: plural and singular mix: "a high ... amounts" + what does "of the FFT as the local simulations" mean?

l.498: what do you mean with "truly mechanistic"? I recommend deleting this statement

l.503: "related estimates the Conclusion section"?

l.613: Again "10" + something with the formatting

l.627: Please provide a legend – even if the figure is only schematic

l.635: When looking at the Figure and reading 2.4 I wondered where the 5*10-7 came from and how this parameter is determined? – Finally I found some information in 3.3 Fig.3 and 4: I would appreciate if the y-axis of the distance plots on the right would have similar scales, this would really help for comparison

l.647-648: difficult sentence – maybe: "only taken into account for grid cells ..."?

l.661: Comparing the dark blue spots in Fig . 2 and the white ones in Fig. 5 the Figures seem to be mirrored along the diagonal?

l.664: cpu*h = CPU h?

l.671: FFTM with 10: shouldn't this be 64% instead of 67%?

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