Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2020-324-RC1, 2020

Geoscientific Model Development Discussions

Interactive comment on "Cutting out the middleman: Calibrating and validating a dynamic vegetation model (ED2-PROSPECT5) using remotely sensed surface reflectance" *by* Alexey N. Shiklomanov et al.

Anonymous Referee #1

Received and published: 6 November 2020

General Comments (overall quality): This manuscript uses remotely-sensed surface reflectance observations to calibrate/constrain a series of ecosystem parameters from the ED2-PROSPECT (EDR) model characterizing the land surface at 54 forested sites related to leaf biochemistry, canopy radiative transfer, and soil characteristics. An important innovation is the introduction of the radiative transfer model PROSPECT to the biosphere model ED2 to provide an improved spectrally resolved simulation of surface reflectance. This is done, in part, to bring the observed surface reflectance closer to what the model actually predicts, helping to reduce the impact of observational uncer-

tainty as well as more effectively constraining multiple components of the model. The authors find that through the assimilation of surface reflectance EDR can provide better simulations of the surface reflectance spectra and leaf area. The findings suggest that this approach could be used to better constrain surface energy balance as well as overall ecosystem functioning. Given many other ecosystem models include a two-stream radiative approach they contend their results should be widely applicable.

Scientific Questions/Issues: The authors bring up the issue of equifinality in the introduction, which presents a challenge for this application in that the surface reflectance can be a function of leaf biochemical properties, leaf structure, and canopy and soil radiative transfer characteristics. To some degree, equifinality was reduced in that the prior parameter distributions for biochemical leaf properties were tightly restricted, and limited to the extent the surface reflectance observations could influence them. In contrast the canopy radiative transfer parameters and LAI (through SLA) were simultaneously being adjusted by the optimization. Was hoping the authors could comment more about how equifinality of the surface reflectance influenced their results.

As a follow up question to the equifinality question above – ED2 is a dynamic vegetation model with the ability to simulate competition amongst cohorts thus providing a simulation of co-existing dominant PFTs. It wasn't clear how well the simulation of cohort competition influenced the final distribution of PFTs and to what extent this matched the site level observed vegetation state. Given that the parameter optimization was PFT specific, the precise vegetation PFT distribution could have a large impact. Was the PFT distribution prescribed?

Was there any attempt to withhold some site reflectance data and apply the calibrated model parameters at those sites? It seems the optimized surface reflectance simulations were performed at sites that were already calibrated. The fact that the authors performed an across-site joint assimilation may in part account for this, but was interested how the calibrated parameters would perform at sites outside the calibration sites.

It is known that radiative transfer models are challenged in simulating evergreen species in part because of the irregular and open space canopy structure. Many of the figures in the supplement demonstrate stronger biases in simulated surface reflectance exist for evergreen sites as compared to deciduous. Was hoping the authors could comment on this, and recommendations for getting around this.

Whereas leaf level biochemistry related parameters were well constrained by the priors, many of the radiative transfer posterior parameters seemed to be edge hitting parameters. To what extent do the authors believe this behavior was caused from structural error in canopy radiation transfer and/or mismatch caused in part from radiation directionality differences between the simulated and observed canopy reflectance? The authors devote a considerable amount of general discussion regarding this topic, but don't directly address how this might have effected their own results.

The manuscript begins by justifying the inclusion of the PROSPECT model in to ED2 to bring the model closer to the observations, to, in part help reduce the uncertainty of the observation that are assimilated into EDR. More explanation on how the surface reflectance observational uncertainty was quantified here, and what it represents, and to what extent overconfidence in uncertainty may have led to the posterior edge hitting parameters.

Detailed Comments:

Abstract and manuscript in general: Need more discussion on what we hope to gain by this. We don't really care about surface reflectance (although energy balance is important), but we do care about how LAI, chlorophyll, pigments and water status influence ecosystem functioning through carbon and water exchange. I think this needs to be emphasized more, and provide evidence that this sort of setup can accomplish this.

Line 1: Remove 'derived'. The fact that they are 'data products' and not 'observations' gets across the point.

Line 5: 'compared against airborne and satellite data' Technically, this is still data and not observations in that even reflectance data requires RTM models, I believe. But it is more direct relationship

Line 23: add 'to' calibrate or constrain

Line 25: I know exactly what you mean by 'constrain', but could you use 'calibrate' or 'inform' in this context?

Line 32: "More sophisticated approaches for estimating vegetation properties based on physically-based radiative transfer models face issues of equifinality, whereby many different combinations of vegetation and soil properties can ultimately produce the same modeled surface reflectance (Combal et al., 2003; Lewis and 35 Disney, 2007)." This is important I think – and raises a key point for this analysis – is there not equifinality when trying to constrain leaf structure vs. leaf status? I would think equifinality could be a problem here, and I think you need to acknowledge this and how you might address this – Strong priors? Demonstration that surface reflectance can tease apart these two things. . ...

Line 52: Awkward topic sentence. Simplify "Some land surface models already include there own . . .. that allowd for a more direct comparison to remotely sensed surface reflectance."

Line 57:"Canopy radiative transfer plays a particularly important role in the current generation of demographically-enabled dynamic vegetation models, where differences in canopy radiative transfer representations and parametrizations have major impacts on predicted community composition and biogeochemistry (Loew et al., 2014; Fisher et al., 2018; Viskari et al., 2019)."

Seems weird to word it this way. Isn't it the other way around, community composition and biogeochemistry impact the RTM?

Line 72: ". . .. . .will significantly constrain model parameters related to canopy structure." So the goal all along was to constrain canopy structure with surface reflectance, not necessarily foliar biochemistry? Maybe talk a bit more about the differences in sensitivity of surface reflectance to canopy structure vs foliar biochemistry.

Section 2.3: Can you provide a sense of scale? For example for the 54 sites, what spatial range was the inventory data taken, and what spatial resolution did AVIRIS cover? Trying to get a feel for spatial mismatch, etc. Were sites chosen because they were rather homogeneous for certain PFTs?

Figure 1: Was a little surprised to see many sites so close to Lake Superior. No issues with interference from nearby water reflectance ? Line 200: Could you provide a bit more explanation of what including the EDR predicted LAI term within your probability function accomplishes? EDR response becomes saturated to LAI so is this an artificial way to account for increased reflectance ?

Line 227: So, to evaluate the model you compared the EDR-spectra against the AVIRIS observations at sites that were used to calibrate the model? Was there any attempt to withhold some site data and apply the calibrated model at those sites?

Line 232: Can you quantify what 'informative' means

Line 233: I cannot see in figure where PROSPECT N parameter is ?

Section 3 Results: Although Figure 2 was very informative, I found the Results section in general, relatively vague, perhaps some sense of % reductions in 95% credible interval.

Figure 2: Hopefully, the authors comment on some of the apparent edge-hitting parameters specifically related to canopy RTM parameters such as leaf orientation, canopy clumping and water. I worry that the information from the relatively strong and defensible leaf biochemistry prior parameters leading to relatively self contained and PFT-differentiated posteriors for the leaf biochemistry parameters is lost or made irrelevant due to biases between model simulated and observed surface reflectance that are

corrected by 'fitting' the RTM parameters.

The context of this manuscript doesn't indicate how sensitive the surface reflectance is for the suite of parameters calibrated here... perhaps included in one of cited manuscripts.

Figure 3: A map would be helpful with site codes provided. Perhaps a zoomed in map that demonstrates where these sites are spatially? Also is the stem diameter plot on the right simulated or observed? In fact, doesn't that have a large impact on the assimilation, the PFT distribution and stem diameter distribution?— has it been demonstrated that ED2 can properly simulate the competition of PFTs at the site providing the correct vegetation state, such that the parameter optimization reflects the observed vegetation state ?? Or has the vegetation state been prescribed in this case?

Figure 5: "The observed vs. predicted line had a slope of 0.37 and an intercept of 2.80, indicating that EDR calibration underpredicted LAI on average but overexagerrated across-site LAI variability." What do you attribute this clear structure in residuals between observed-simulated LAI? Line 258-270: I like the overview explanation of bringing observations closer to models or alternatively bring models closers to the observations. In the end, it's a bit of semantics, especially for using information from satellites we will always need some sort of transfer function or forward operator to convert from what a satellite observes and what a model predicts. I don't think one way or the other should take precident. The advantage in your approach, however, is the potential for the observed surface reflectance to constrain multiple model components, whether that be leaf structure or biochemistry or water status. I think that is potentially extremely valuable although I am not sure it has been demonstrated, yet, that this is the case. I feel more could be 'learned' about what information surface reflectance could provide if you could prescribe the LAI and PFT-distribution in ED2, then you could really get a grasp on what it can inform, leaf biochemistry? Within-canopy RTM parameters? Etc.

But, as you brought up in the introduction, this brings up equifinality issues. Not so much in this case for your leaf biochemistry parameters because of strong priors, but it does seem to be the case for canopy RTM parameters and predicted LAI (SLA). I think you need to caveat or address this concern.

Lines 286-310: It seems like you are pointing out sources of structural error within the radiative transfer of EDR or, to the extent, mismatch between what EDR simulates vs. what AVIRIS-Classic observes. Could this help explain why the calibration caused some posterior RTM parameters to be edge-hitting against the bounds of the priors? Also, this work was in part motivated by being better able to quantify the uncertainty in the surface reflection observations, but I am not sure I saw a clear explanation of the uncertainty that was used or provided for the AVIRIS and how was this quantified. It seems parameters have the potential to be overfit, if the observation uncertainty is not realistically quantified. May have missed this.

Line 320: Really it's the power to upscale that remote sensing products provide. However, this comes at a cost, they 'observe' reflected radiation from the land surface which indirectly characterizes things that we care about like, like leaf biochemistry, albedo etc.

Line 326: 'accurately reproduce surface reflectance and leaf area index' I think this is a bit of an overstatement, especially because the figures demonstrate systematic mismatch between the optimized surface reflectance and observed reflectance (figure 3), and strong residual error structure in LAI (Figure 5). Perhaps this approach provided 'improved' reflectance and LAI is better wording.

Line 330: I think you also need to say where this work can lead — this is of interest for those that are concerned with ecosystem functioning and that this could provide improved estimates of both biomass and land-atmosphere carbon and water exchange. Also some discussion of the differences between evergreen and deciduous forests would be helpful. Generally RTM's have more difficulty with more open canopy evergreen species and not really discussed in this manuscript.

Appendix:

Figure A2: What would be really helpful is to use the same color-coding in Figure A1 to show deciduous vs evergreen sites. Also this brings about the question – why did you choose the sites that you did to put in the manuscript itself?

Figure A3: This sort of gets at the hardwood vs conifer performance as well. I think it would be helpful to comment on this distinction in performance within the results/discussion.

Figure A13: This is also a very compelling figure that gets at the increased bias in spectra for conifer. Worth discussing in main manuscript.

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-324, 2020.