Review for JAMES 2017MS001253

General:

This manuscript represents a major effort to improve and develop a dynamic land ecosystem model (DLEM-AG2.0) for both crop growth and yield assessments, while also explicitly considering linkages to the land surface and key biogeophysical and biogeochemical impacts. The authors improve upon a previous version of DLEM-AG2.0, to incorporate new formulations and parameter sets for phenology, photosynthesis and respiration, allocation and growth, and biomass partitioning, all of which are based upon a host of previous work and accepted methodologies. The authors then run DLEM-AG2.0 for maize, wheat, and rice, and validate against a variety of experimental datasets. They show generally good improvements and consistency with field data for important growth attributes like LAI, above ground biomass and yield, demonstrating the utility of the model for regional (China) agroecosystem assessments related to crop growth. Additionally, this improved model allows for a more comprehensive spatial/regional assessment of how multiple co-occurring environmental factors – ranging from meteorological events to ozone concentrations, and the dynamic fluctuations and time evolution of these things – can impact regional crop growth (as opposed to more site-based assessments).

This manuscript represents a great deal of work to comprehensively incorporate crop development and agricultural management into an Earth system modeling framework, and I believe thereby advances efforts to better understand land-atmosphere feedbacks, specifically and particularly as they impact cropping systems at larger scales. Additionally, it provides a framework for improved understanding of the many ways in which humans modify the land surface, not just in land cover change, but through intensive crop management, which will be a dominant driver of local and regional land changes into the future.

However, my main general concern with the work surrounds the way it's presented and couched as an advance for earth system models to evaluate the role of agriculture in climate, as opposed to providing more regional perspective on crop growth as a result of environmental/climate forcings. Indeed, the authors do address the latter point, particularly in the Results and Discussion sections, and as part of their abstract. As a large-scale approach to assessing distributed environmental/climate impacts on agriculture, this is a needed and strong contribution.

However, a good portion of the Introduction and Section 4.2 discusses agriculture in ESMs. The issue with this is less with the model development per se and more that it is highly data intensive, which (as the authors note) has been an outstanding limitation of incorporating agriculture into ESMs. Global gridded crop models (Mueller et al and Elliott et al), for example, have faced huge challenges developing both cultivation masks and prescribing management regimes on a global grid. I'm

not sure how the authors' model development addresses these concerns, as they instead opt for a more data intensive representation that can only be sustained through dedicated and comprehensive data collection.
When evaluating the "role of agriculture in the climate system", as the authors state explicitly, I would be concerned that their methods a) introduce some of the large uncertainties by running at a global scale, and b) that several processes may be represented in this method that are both expensive and not additive or skillful to regional climate simulation. These comments reflect the outstanding tension as to whether this would be considered a major advance/development for Earth system modeling versus large-scale agricultural modeling.

That being said, I do think that this model can be leveraged for regional (China specific at the moment) Earth system modeling in a way that is additive, novel, and it would be interesting to see how this impacts baseline climate simulations. Additionally, I think this model provides newfound ability to regionally simulate crop yields in response to dynamic changes in environmental conditions – an evolution in crop modeling that the field is rapidly working towards. In this sense, this manuscript is very valuable.

I think many of my above comments could be addressed with some slight re-framing of the manuscript and some clarifications within the text. The methods for incorporating all the new crop growth formulations I find to be sound and well-implemented.

As such, I would highly recommend this manuscript for publication after some of my following (mostly minor) concerns are addressed, and the authors perhaps re-focus on the current major utility of their improved model.

Page and Line Specific Comments:

Line 73: There are more updated references for irrigation and global effects that should be included (e.g. Cook et al 2014; Guimberteau et al.).

Page 3: This is an enormous paragraph that's hard to follow. Please break this up.

Lines 80-87: To help with the above, they authors may want to consider trimming these sentences on point-based crop models, as these typically serve a different purposes. For example, one could skip to Line 87, the sentence starting with "However. . ." to make the point.

Line 111: In reference to my general comments, what evidence is there to show that crop organ development is a key uncertainty or important process for climate simulation and considerations? This can be argued by studies that consider the influence of LAI (experiments with both Had-GLAM and the CLM run with a coupled atmosphere do suggest this – references below). I think a few words here referencing this work would be needed, if improved climate simulation is one of the authors goals.

Line 159-160: When CLM-Crop was first tested (Levis et al), it was run coupled to see if seasonal precipitation responded to the explicit crop growth. It does not appear that the authors have yet coupled their improved model to see what the atmosphere feedbacks and impacts might be. This might be a step ahead, and is OK, but then another reason to reframe the paper a bit. If this could be done, however, that would be great to see.

Line 226: As many process-based crop models, DLEM-Ag2.0 runs on a daily time step. It occurs to me that if the ultimate intent is to couple with the atmosphere, it would need to a more highly resolved time step. As such, it occurs to me that it could be useful – even if it was not yet coupled – to have a section that briefly discusses how DLEM-AG2.0 would be coupled to an atmosphere model, or what would need to be done to couple would be useful to a wider audience.

Section 2 – 2.1: Apologies if I just am missing this, but what is the spatial resolution?

Table 1: Are there references for these parameter values, and the authors may want to put these into the table so the reader can dig a bit deeper as to how these were obtained.

Lines 262-264: The authors mentioned several references used to derive the different ATT targets (which could help answer the above). I imagine these datasets are at different resolutions, so how were these scaled and used? This doesn't have to be onerous, but should be briefly addressed. Other studies have pointed to the aggregation of parameters being a major issue (Iizumi et al).

Line 265: Good that the authors had access to such an extensive climate dataset, but I wonder if the presence of any long-term trends might complicate using the climatology at all to determine the timing between crop growth stages? Or is this inconsequential? Also, was there provisioning to simulate CO2 fertilization effects?

Line 429-470: The authors have a section on uncertainties in their Discussion. However, given the number of datasets detailed here, from soil properties, to land cover data, to plant/harvest dates, to management, I wonder if some of the uncertainties associated with the individual datasets could be mentioned here. This could help with interpreting or understanding the limitations of the results.

Also, for the planting and harvest dates – the authors state that these were obtained from met stations. Can a bit more be said on how these were derived and/or what rules were developed/used?

Again, this section (and the genetic coefficients required in section 2.3) also highlights the level of data needed to run these experiments in a representative way.

Many of the data used, while available at the global scale, still come with a significant amount of uncertainty.

Line 592-601: As an aside, it appears that the LAI declines discussed by the authors – and the limitation on incorporating more dynamic SLA variation – can be an issue for climate simulation. Other experiments have revealed that steep reductions in LAI or weak vegetation/crop growth can have substantially atmospheric feedbacks, and in some cases misrepresent spatial patterns of drought. It would seem that this may be an important thing to rectify for climate experiments. This is also true given that this seemed to also drive the underestimates in biomass, etc. in DLEM-AG2.0.

Lines 679-683: I think these sentences really highlight the utility of DLEM-AG2.0 ("However. . ."), while conveying the limitations for ESM/climate applications ("Therefore. . ."). The model seems to be a much needed development to assess the spatial patterns of environmental impacts on crops (and therefore has a wide array of ag applications), but currently does not represent the spatial heterogeneity that might be needed for finer scale climate assessments, or at least the distributions are uncertain. That said, that is still probably better than more generic crop representations.

Lines 710-711: Even for yield assessments and given the large amount of data availability in this domain, there were under-predictions based on fertilizer/data uncertainty and limitations. Advances in modeling in many ways are contingent upon data availability, and so this is an important point.

Figure 15: A legend would be helpful here.

Lines 752-757: Ozone impacts are mentioned many times throughout, but I'm wondering if this was explicitly looked at or if there is a comparison plot here to show how incorporating ozone either compared with observed yields (particularly during years where ozone impacts were high)? Or is the fairly good simulation of yields implicitly indicative ozone impacts? It could be useful to demonstrate some utility here with respect to ozone impacts/applications, given that it's mentioned.

Section 4.2: I feel like much of Section 4.2 would be better suited to motivate your introduction!

Section 4.3: It would be good to say in the Methods that natural veg and crops can be co-simulated, as this is a bit more novel and good to have from an Earth systems standpoint. Are the soil columns separated for agricultural vegetation and natural vegetation?

Section 4.3 and 5: If this is intended for coupling to ESMs to help improve climate simulation as well, future work should also focus on what of the crop growth features and management were important to climate. This could very much help highlight what is needed for ESM development, versus a more agricultural application.

References:
[*Cook et al.*, 2014]
[*Guimberteau et al.*, 2012]
[*Osborne et al.*, 2009]
[*Levis et al.*, 2012]
[*Iizumi et al.*, 2014]

Cook, B. I., S. P. Shukla, M. J. Puma, and L. S. Nazarenko (2014), Irrigation as an historical climate forcing, *Clim. Dyn.*, doi:10.1007/s00382-014-2204-7.

Guimberteau, M., K. Laval, A. Perrier, and J. Polcher (2012), Global effect of irrigation and its impact on the onset of the Indian summer monsoon, *Clim. Dyn.*, *39*(6), 1329–1348, doi:10.1007/s00382-011-1252-5.

Iizumi, T., Y. Tanaka, G. Sakurai, Y. Ishigooka, and M. Yokozawa (2014), Dependency of parameter values of a crop model on the spatial scale of simulation, *J. Adv. Model. Earth Syst.*, *6*(3), 527–540, doi:10.1002/2014MS000311.

Levis, S., B. B. Gordon, Erik Kluzek, P. E. Thornton, A. Jones, W. J. Sacks, and C. J. Kucharik (2012), Interactive Crop Management in the Community Earth System Model (CESM1): Seasonal influences on land-atmosphere fluxes, *J. Clim.*, *25*(14), 4839–4859, doi:10.1175/JCLI-D-11-00446.1.

Osborne, T., J. Slingo, D. Lawrence, and T. Wheeler (2009), Examining the interaction of growing crops with local climate using a coupled crop-climate model, *J. Clim.*, *22*(6), 1393–1411, doi:10.1175/2008JCLI2494.1.