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Earth System Dynamics
Discussions

Interactive comment on "A multi-model analysis of teleconnected crop yield variability in a range of cropping systems" *by* Matias Heino et al.

Anonymous Referee #1

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The authors use a suite of historical global gridded crop simulations from the AgMIP ensemble to examine the influence of natural climate oscillations on correlated crop yield impacts. Consistent with observed yield analyses, they find that ENSO variability can simultaneously affect nearly 50% of harvested areas for certain crops, while other modes of variability affect smaller areas but still have significant impacts. The authors suggest that this could help forecast climate shocks on the food system. Using additional simulations, they show that irrigation reduces the sensitivity to such climate variability but fertilizer application doesn't have a significant influence on reducing the climate sensitivity on these crops.

The study is an extension of work that has already been done by the authors on observed yields. While these simulations are helpful to isolate the role of climate variabil-

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ity and test scenarios of irrigation and fertilizer application, they do not provide a mechanistic explanation of the impacts or comparisons with the magnitude and extent of observed impacts. Although, I think this is a worthwhile study since crop models present some important tools to study the impacts of climate variability and management decisions, I have some major concerns about the methods and design of the study, which will affect the main conclusions. Before considering the merit of this manuscript for publication, I believe these following concerns need to be addressed.

Major Concerns:

- The three indices used include ENSO, IOD and NAO. All 4 crops studied here have almost identical sensitivities to ENSO and IOD, with some differences likely due to slightly different time periods used. I have a strong suspicion that this is because the ENSO and IOD indices have strong co-variability. Positive IOD's tend to develop during the development of positive ENSO phases (e.g Zhang et al., 2015, Stuecker et al. 2017). IOD's in the Fall are often followed by the peak of El Nino events in the winter. Based on how the time periods of the analyses are defined, this analysis is likely capturing the effect of El Ninos NOT IOD's.

- Relatedly, there needs to be some mechanistic explanation for how the NAO and IOD events influence yields in remote areas where they do not have strong (if any) climate teleconnections (reference Figure 1). For example, what is driving the yield sensitivity of crops in North America during IODs or in southern Africa during NAO events? I would recommend showing the underlying temperature and precipitation variability in response to each ENSO, IOD and NAO phases to support these findings.

- (Page 6, Section 2.3) In defining the oscillation specific harvest years, the evolution of the oscillations and their teleconnections in not correctly accounted for. The harvest years, in some places, cover multiple growing seasons. For example, IOD climate teleconnections do not typically last beyond the Fall season in which the IOD's occur into the following year's growing season, so including those subsequent seasons will provide spurious relationships. Similarly, El Nino's affect certain areas of the tropics such as South Asia strongly during the developing phase (Kumar et al., 2006). By defining the harvest year as starting on 1 December, these important connections are missed. Further, by extending them to the following growing season, when the impacts don't occur or as is stated in the manuscript, phase changes might occur, these sensitivities are likely to be spurious. For ENSO, it might make sense to define the harvest year from the growing season of the year it starts to develop to the start of the following year's growing season. For IOD and NAO, which are shorter lived, it might be more suitable to restrict harvest years to seasons when their impacts are known.

- (Page 6, Section 2.2) Regarding the El Nino index used, I would recommend using more commonly used metrics such as the Nino 3.4 index or at least test the sensitivity of your results to the Nino 3.4 Index, which is typically used to identify climate teleconnections.

- I realize that the models used here have been evaluated in a different paper. However, it would be useful to include an evaluation of the models in the supplement for metrics relevant here. For instance, how does each model capture observed yield various across global harvested areas. While the authors state that no model is obviously superior, they do not state whether any of them are capable of simulating observed yields.

- (Page 7, Section 2.4) The authors have used a linear regression model here. As far as I can tell, each mode is tested separately. However, given that they are related, I would think it would be more appropriate to have a multiple regression framework to isolate their individual influences.

- I am a bit flabbergasted at the inclusion of 24 maps in one figure (!!!). I would strongly recommend either splitting this plot by index or phase or crop. 24 is too many and I imagine others, like me, might have difficulty processing the information in Figure 2. Instead of a separate figure for agreement, it would be helpful to show agreement on the maps in Figure 1 and 2, especially after splitting Figure 2. These changes will enhance the clarity of the figures and help decipher areas of model (dis)agreement more clearly.

- Page 14, Lines 15-20, It is a bit misleading to say that the sensitivity of crops to climate variability, increases with fertilizer application, given the discussion in these lines. If crop yields are improved during suitable climate conditions, that is a net positive, and it would be useful to have a metric to capture that improvement rather than suggest a negative effect of adding fertilizers.

- In Figure 4, the sensitivity of all crops is higher in the fully irrigated scenarios vs rainfed, based on Column 1. How does this suggest that irrigation reduces the sensitivity? This is likely just my confusion because of the way the information is presented in Figure 4. In Figure 4, is column 1, the difference in sensitivities of yield variability in the irrigation scenario – the rainfed scenario or vice versa? Does a positive difference suggest higher sensitivity in the irrigation scenario relative to the rainfed scenario?

- The conclusions will change if the analysis is changed to include the suggestions above. The discussion and conclusions sections will need to be edited accordingly.

Minor Comments:

I encourage the author to include a discussion of the existing literature on the covariability of IOD/NAO and EL Nino indices.

Page 2 Line 16, what is the reference for IOD events being forecast months in advance?

Page 5 Line 1, what are the default model assumptions?

Page 5, Line 3, how are literature-based values different from default assumptions?

Page 7, Line 14, Where does the sample size number N=216 – 297 come from? Is that 12 models * number of simulation years somehow?

Section 2.5, What is the sample size for the comparison of the strong phases of each climate mode?

Page 10, first para, it would be useful to define the regions referred to in the discussion. For instance, I do not see wheat yield increases in “eastern South Asia” in the Fig. 1 as is suggested here.

Page 14, The result that irrigation reduces sensitivity of different crops makes sense. It would be helpful to have a metric that captures the relative areas of “actual” irrigation to explain the differences in sensitivity of different crops.

Figure 4, Please edit this figure for clarity. I would recommend either including boxes around each panel or lines to separate them. Also, please provide complete panel titles for the right 3 columns. Is this “actual - fully irrigated” scenarios?

In section 3, please refer to the specific panels in figure 4 in the discussion. I don’t know which panel is being referred to the discussion, especially given the incomplete panel titles. I would also recommend doing this for other figures as much as possible.

References: Kumar, K. Krishna, B. Rajagopalan, M. Hoerling, G. Bates, M. Cane, 2006: Unraveling the Mystery of Indian Monsoon Failure During El Niño. Science, 314, 115-119.

Zhang, W., Wang, Y., Jin, F.âĂŘF., Stuecker, M. F., and Turner, A. G. (2015), Impact of different El Niño types on the El Niño/IOD relationship, Geophys. Res. Lett., 42, 8570–8576, doi:10.1002/2015GL065703.

Stuecker, M. F., Timmermann, A., Jin, F.âĂŘF., Chikamoto, Y., Zhang, W., Wittenberg, A. T., Widiasih, E., andZhao, S. (2017), Revisiting ENSO/Indian Ocean Dipole phase relationships, Geophys. Res. Lett., 44, 2481– 2492, doi:10.1002/2016GL072308.

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