Reviewer #2

This paper applies a recently developed hydrological forecasting and monitoring system (NHyFAS) to drought early-warning in Southern Africa. This forces a large-scale hydrological model whose parameters depend on global datasets, with 1) observation data and 2) a multi-ensemble forecast. These forcings input in the hydrological model provide monitoring and forecasting hydrological metrics that are then correlated with crop yields to assess their performance as early-warning signals of drought in Southern Africa. Rootzone soil moisture (RZSM) is used as the main hydrological variable for both monitoring and forecasting. With harvest starting in March, authors use monitoring variables available in early Dec, Jan, Feb, Mar (i.e. up to 3-4 months in advance) and monitoring in early Nov and Jan (i.e. up to 4-5 months in advance). Authors test the efficiency of these RZSM products, first on the 2015-16 drought event (with dramatic repercussions on the prices of staple foods) and then on the whole 1982-2018 period (36 years). They show that the proposed forecasting products could have forecast the food availability crisis in Southern Africa in 2015-16 up to 4-5 months before the next harvest starts. They then go on to show that if products are in the lower tercile, there is a high confidence that crop yields will be below average months in advance. Their conclusion is that the proposed products will improve early warning systems of low water-food availability. The paper's results are interesting, very relevant to this journal and timely, at a time when such early-warning systems for drought conditions are viewed as a priority in Africa (see Nature https://www.nature.com/articles/d41586-019-02760-9). Yet, the text is marred by unstated assumptions, the lack of comparison with existing early-warning systems, and the absence of rationale to explain the results' performance.

Response: Thank you very much for the review and your constructive comments. Thank you also for pointing us to the Nature article, which we have now cited in the manuscript. Please see our response to your comments below. We hope that these revisions made to respond to your comments would further clarify and substantiate the results. In addition, we have reviewed the method and results sections again to clarify further our methods as/when needed for improved comprehensibility of the manuscript.

Comment #1

In particular: 1) The work provides evidence that the proposed products correlate with crop yields, but as the authors know, correlation is not causation. Authors should discuss evidence in the literature of what key variables the forecasts pick up (ENSO maybe?), or alternatively, what supplementary work is needed to establish causation, and therefore, credibility for the products their propose.

Response: Thank you for this comment. It is indeed valid. In response to your comment and comment from the reviewer #1, we have now included an additional analysis in the manuscript, which focuses on predicting regional crop yield using ENSO and Rootzone soil moisture monitoring and forecasting product.

Please see the figure below which shows how well the DJF ENSO signal, February RZSM monitoring and forecasting products can forecast regional crop yield in Southern Africa. Crop yield forecasts were made using an AutoRegressive Integrated Moving Average (ARIMA) model. Detailed methodology is included in the manuscript.

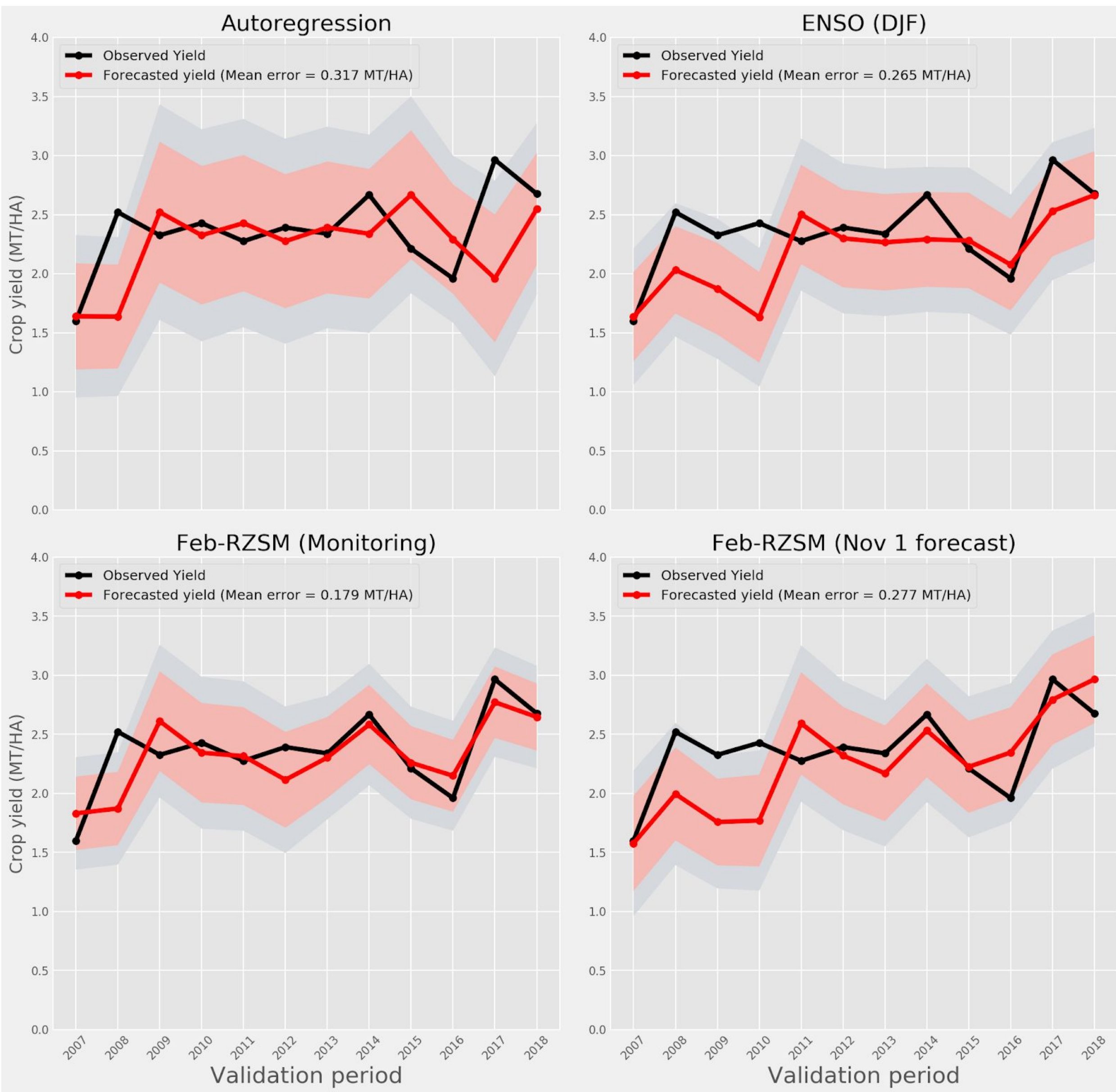


Figure: Comparison of observed crop yield with forecasted crop yield estimates made using (from top left corner to the bottom right corner) Autoregression alone, Autoregression and DJF ENSO, Autoregression and Feb RZSM Monitoring product, Autoregression and Feb RZSM forecasting product. Gray shading indicates 95% confidence interval and pink shading indicates 80% confidence interval.

The results indicate that mean error of forecasted yield over 2007-2018 is smallest (0.179 MT/HA) when Feb RZSM (monitoring) product is used as a predictor. When DJF ENSO is used as a predictor the mean error increases to 0.265 MT/HA. Finally when Feb RZSM forecasts, made on Nov 1, are used as a predictor the error level is comparable to DJF ENSO (0.277 MT/HA) but of worth noting is that RZSM forecast based estimates of crop yield are made available 4 months before the crop yield estimates based on DJF ENSO or RZSM (monitoring product). The results also show that adding environmental predictor (RZSM or ENSO) does improve the skill of crop yield forecasts beyond what an autoregressive model alone can provide.

These results highlight the potential value of using RZSM forecasts as well as RZSM monitoring product for predicting regional crop yield in Southern Africa.

Comment #2 and #3:
Other forecasting systems for the area are evoked (Sheffield et al 2014, the African Flood and Drought Monitor (lines 103-104)), why not compare results with those obtained with other products? A justification should be provided in the introduction. If forecasting systems are unavailable, authors link food security crises with El Niño. So that’s a simple, well-established indicator (the ENSO index) whose predictive power could easily be compared with that of the RZSM-based products.

Response: Typically the forecast outputs from seasonal forecasting systems are only available in the form of images through web-portals and more importantly historical forecasts are not available for a sufficiently long enough period. For example (as accessed on November 22nd, 2019). the Africa Flood and Drought monitor only provides access to seasonal forecasts from April 2018 to September 2018.

It is also worth noting that the NHyFAS is the only seasonal hydrologic forecasting system for Africa that is based on the The Climate Hazards Infrared Precipitation with Stations (CHIRPS) (https://www.nature.com/articles/sdata201566) which benefits from the satellite era precipitation estimates as well as greater access to stations based precipitation measurements, hence over Africa, is of higher quality. Several past studies have indicated that too. Reliance on high quality precipitation dataset allows for an improved climatology of simulated hydrologic variables (such as RZSM) and improvement in hydrologic initial conditions (which are a substantial source of skill in any seasonal scale hydrologic forecasting system).

We have now added the above discussion in the manuscript. We have also addressed your comment on comparison with ENSO by including a new analysis. Please see our response to comment #1.

Comment #4
This journal is an interdisciplinary forum around natural hazards such as droughts and not a hydroclimatology outlet, so authors should make their methods more accessible. A figure of the workflow could help, and so could extra explanations along some of the acronyms.

Response: Makes sense. Initially we had not provided details on the setup of the NHyFAS as it is described in Arsenault et al. (in review), which is the key paper on this system. However, now we have added the following flow chart in the manuscript. This flow chart provides an overview of the process to get gridded RZSM percentile and also defines the hydrologic forecast-related acronyms.

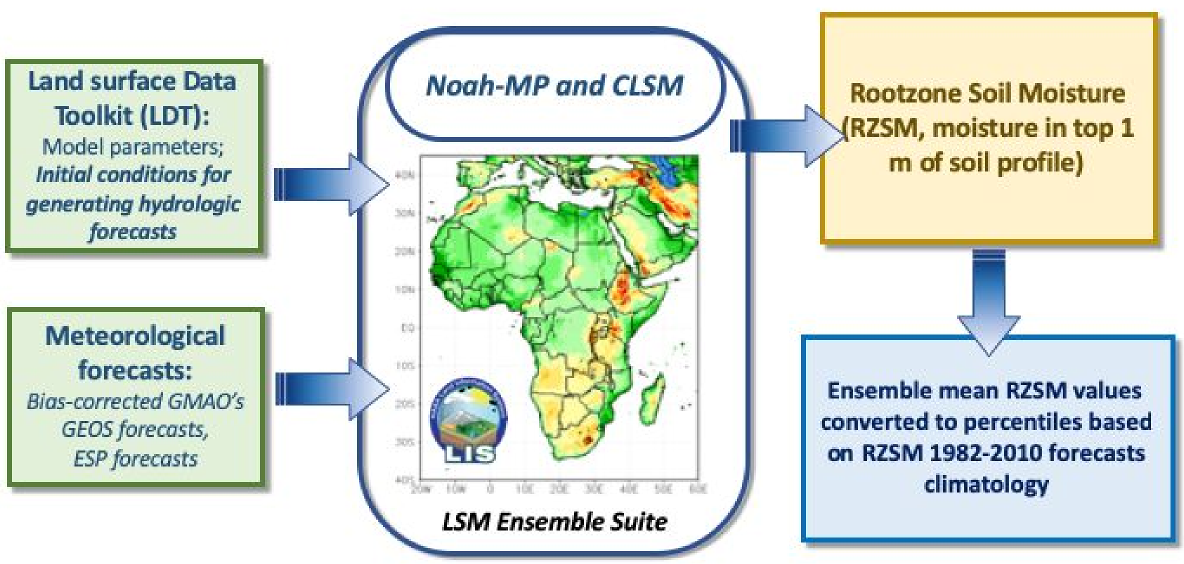


Figure: Flow diagram of the process and inputs to generate RZSM forecast percentiles

Reference: Arsenault, K.R., Shukla, S., Hazra, A., Getirana, A., McNally, A., Kumar, S.V., Koster, R.D., Peters-Lidard, C.D., Zaitchik, B.F., Badr, H., Jung, H.C., Narapusetty, B., Navari, M., Wang, S., Mocko, D., Funk, C., Harrison, L., Husak, G.J., Adoum, A., Galu, G., Magadzire, T., Roningen, J., Shaw, M., Eylander, J., Bergaoui, K., McDonnell, R.A., and Verdin, J.P., 2019, The NASA hydrological forecast system for food and water security applications. Bulletin of the American Meteorological Society, In review.water security applications. Bulletin of the American Meteorological Society (in review)

Comment #5
Likewise, justifications for the selection of the key variable (RZSM) or of the forecast ensemble, among others, should be provided to help the paper to be understandable by a larger audience.

Response: Good point. We have now added the following text in the manuscript.

Rootzone SM (RZSM) is the main hydrologic variable used in this analysis. RZSM indicates the soil moisture in the top one meter of the soil profile. Typically the length of the root of crops such as maize (main crop in the region of SA) close to one meter, hence the choice of RZSM as the key forecast variables. Moreover the entire depth of the soil profile is different for the two models used in this analysis, typically about 2 m for Noah-MP and about 4 m for CLSM, hence RZSM also allows for a consistent way to merge soil moisture products from both models.

Comment #6
I would advise a careful, rigorous revision accounting for the remarks above and where at the minimum, the products' performance should be compared with that of ENSO. If the products work mainly because the forecast ensemble picks up the state of the ENSO index, is there added value to that work.

Response: Please see our response to your comment #2 and #3, which addresses this comment as well.

Comment #7
There is no mention of model/ code / processed data availability for this study: all data sources are the raw data that was used into NHyFAS.

Response: Good point. We have mentioned in the manuscript where the models source code and input 'observed' forcings data can be found. The maps of output seasonal forecasts are also available for public access. Bias-corrected seasonal forecasts and hydrologic forecasts (e.g., RZSM) data are currently not available for public access. We anticipate though that those forecasts will eventually be available for public access from NASA web-services, similar to other NASA and FEWS NET supported land data assimilation (FLDAS) outputs.

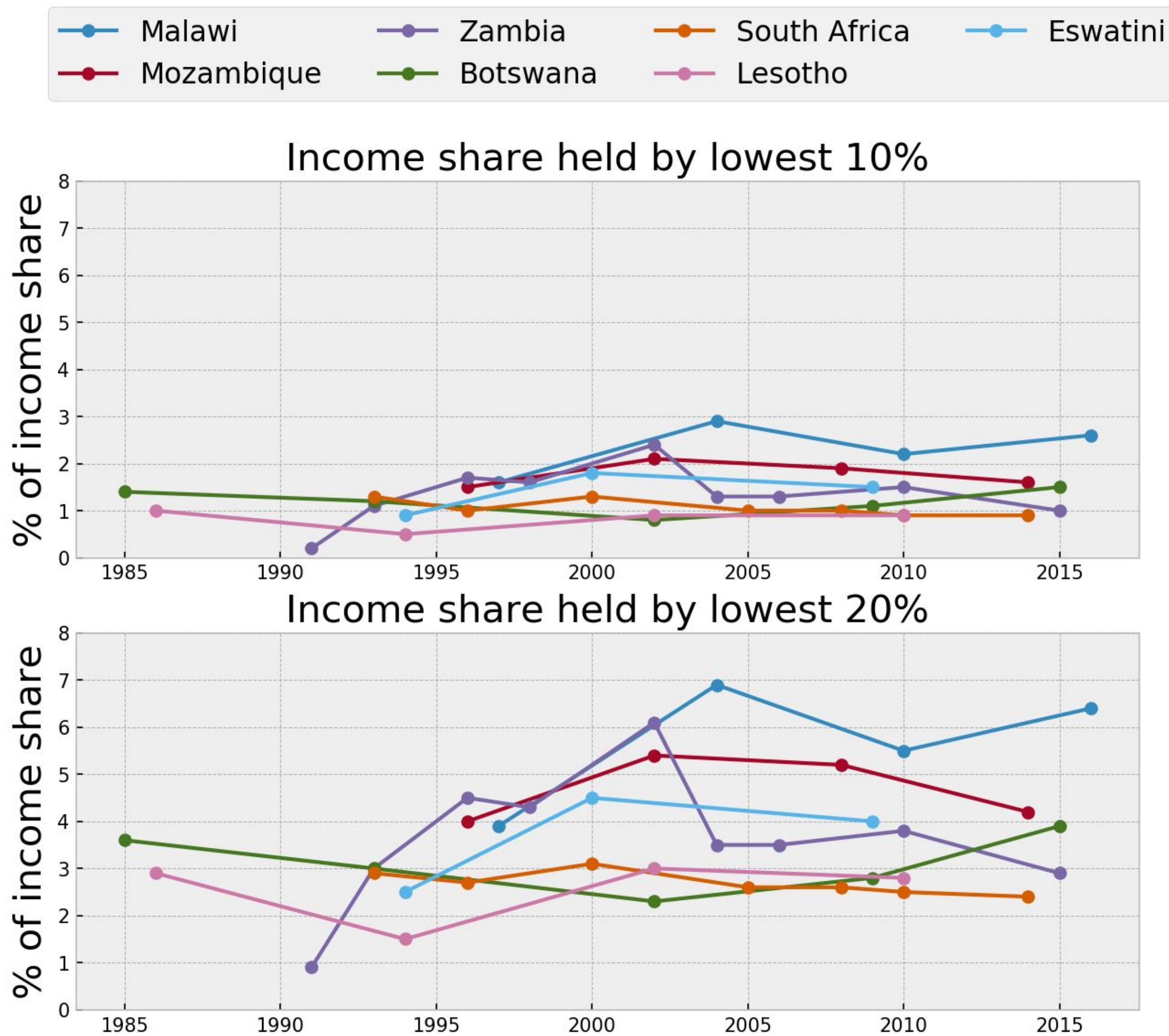
Some detailed comments:

Comment #8
Abstract: it should be made clear in there that the RZSM products are derived from the new NHyFAS. It reads like that they are not.

Response: Done.

Comment #9
lines 39-43: authors aren't obligated to show a graph (also that is helpful) but they should cite references.

Response: We have added the following figure showing that the percentage of income held by the bottom 10% and 20% of the population has not changed much in the region.



Comment #10
Line 137: the choice of RZSM as a hydrologic variable of interest makes sense but a rationale should be provided for it being the main (or indeed only) variable of interest in this study. What justifies not using other variables.

Response: Please see our response to your comment #5.

Comment #11
Figure 3, and commentary lines 230-250: this seems needlessly confusing. My understanding is that Fig 3 shows the correlation of crop yield with three monitoring-based products whereas the text touts the superiority of the forecasting-based product on all three as early as November. The latter, as well as one of the three monitoring products, includes RZSM, and the distinction is not always clear on first read.

Besides, back-and-forth with Figure 4 doesn't make the reading easy either. Could it be a good idea to 1) include the forecasting-based product on Figure 3 to provide a striking visual of why the proposed product is better, and 2) separate comment on Figure 3 from that of Figure 4.

Response: Sorry about the confusion. We have now revised the texts discussing the results of Figure 3 and 4. We now discuss each of those figures in distinct sub-sections. The goal of the Figure 3 (that shows the correlation between monitoring products such as RZSM, seasonal precipitation and Air temperature with crop yield) is to:

(1) Examine how the correlation changes as the season progresses.
(2) Which variable and when has the strongest correlation occurs with crop yield.

Based on our Figure 3, we identify February RZSM to be the variable with the strongest correlation with the crop yield. Once that is established, Figure 4 then focuses on examining how well the forecast of Feb RZSM made on November 1 and January 1 correlates with crop yield.

Comment #12
Line 266: why the lower tercile? Please justify

Response: Southern Africa is a mostly rainfed region, hence the crop yield is generally below normal during drought years as evident by several drought years in the recent past (2014-15, 2015-16, 2018-19). Thus in order to evaluate the performance of NHyFAS monitoring and forecasting products in identifying below normal crop yield, we focused on the years when the RZSM monitoring and forecasting products were in the lowest tercile (bottom 12 out of 36 values) as those events represent drought years. We have now added this text in the manuscript as well.