Reviewer #1

To my understanding, this paper connects dynamical forecasts of soil moisture with regional crop yields over southern Africa statistically, and the results are encouraging since the soil moisture forecast correlates with crop yield quite well with a lead time of a few months. This study is novel and has a solid basis on climate-hydrology forecasting, where NASA Hydrological Forecasting and Analysis System that incorporates seasonal climate prediction and land surface hydrological simulation is implemented over southern Africa, and is evaluated for a number of extreme drought cases including the 2015/16 drought during the super El Nino. Utilizing dynamical hydrological forecasts in agricultural and water resources management sectors is not trivial, and this study push it a step further by smartly combining dynamical and statistical approaches, which provides implications for applications over other regions around the world. The paper is well written and the results are convincing, so I could not comment more while listing only a few minor suggestions below.

Response: Thank you so much for your review and encouraging feedback. Your summary of the study is indeed accurate. Below we have responded to each of your comments. We believe that the revisions made in response to your comments will improve the manuscript.

Comment #1:

The abstract could be condensed and reconstructed by placing this southern Africa study in a wider context, where I believe the system has potential to be implemented Globally.

Response: Great suggestion. We have revised the abstract to provide a wider context.

Comment #2:

Two references regarding the African ensemble drought forecasting (Yuan et al., 2013) and southern Africa 2015/16 severe drought attribution (Yuan et al., 2018) might be relevant. The latter focus on rapid evolving soil moisture drought (i.e., flash drought) over southern Africa, where the anthropogenic climate change intensified southern Africa flash drought, especially during 2016/16 El Nino in the midst of heat waves. So, an effective early warning system is essential for drought mitigation over the region.

References:

Yuan, X., L. Wang, and E. F. Wood, 2018: Anthropogenic intensification of southern African flash droughts as exemplified by the 2015/16 season. Bulletin of the American Meteorological Society, 99, S86-S90, doi:10.1175/BAMS-D-17-007.1

Yuan, X., E. F. Wood, N. W. Chaney, J. Sheffield, J. Kam, M. Liang, and K. Guan, 2013: Probabilistic Seasonal Forecasting of African Drought by Dynamical Models. Journal of Hydrometeorology, 14, 1706-1720, doi:10.1175/JHM-D-13-054.1 **Response:** Thank you for suggesting these articles. Both of them have been cited now.

Comment #3:

L208-209. The authors mentioned that existing systems like FEWS NET and SADC failed to forecast rainfall during 2015/16. I am wondering whether they can compare the latest GEOS5 rainfall prediction, which is a central component in the forecast system proposed in this study, with those predictions from existing systems. This might highlight the advantage of the new system/method.

Response:

Regarding the first sentence, please allow us to clarify that we did not imply that FEWS NET and SADC had failed to forecast rainfall during 2015/16. Please see the corresponding text from the manuscript:

"By this time in the season, both FEWS NET and SADC had provided early warning of poor rainfall performance in the region (Magadzire et al. 2017). The NHyFAS RZSM forecasts would have provided further evidence of a looming unprecedented drought in the region"

FEWS NET and SADC were indicating below normal rainfall in the region during the start of this season, as it was accompanied by one of the strongest El Nino events ever recorded. We argue that RZSM forecasts available on November 1, 2015, (if this system was live back then) would have further substantiated their assessments and actually would have further supported their concerns, as the Nov 1 RZSM forecasts indicated that the RSA, which is one of the main producers in the region, was going to experience the strongest level of drought severity.

The reviewer's point about comparing FEWS NET's and SADC's forecasts with the forecasts from the NHyFAS is fair suggestion. However a direct comparison between NHyFAS forecasts and FEWS NET and SADC forecasts is either not feasible or out of the scope of this study due to the following reasons.

(1) FEWS NET's official forecast is an outlook of food insecurity conditions (see: <u>https://fews.net/</u>) which is based on not just on agroclimatology (i.e., agriculture and climate conditions) but Market conditions, Nutrition and Livelihood conditions. The NHyFAS forecasts which are now being used by FEWS NET would fall into the category of agroclimatological conditions. In fact the goal of the evaluation of the NHyFAS forecasts is to establish if NHyFAS forecasts can be suitable agroclimatological forecast input for FEWS NET to guide the development of food insecurity outlook assessments. Also, FEWS NET Food Insecurity Outlook is based on subjective assessments (in some ways similar to the US drought monitor or US Seasonal Drought Outlook) in addition to quantitative assessments such as agroclimatological forecasts. Finally, FEWS NET's archive of Food Insecurity Outlooks currently spans back to mid-2011 only.

(2) SADC CSC forecasts -- which are typically probabilistic seasonal scale rainfall forecasts, are also based on multiple models (both statistical and dynamical models) as well as expert assessments (hence not entirely based on quantitative inputs). For example, see the text describing the SADC CSC's forecasts methodology behind their latest forecasts below. (Source:

http://csc.sadc.int/en/news-and-events/265-climate-outlook-oct-2019-to-mar-2020)

" METHODOLOGY

Using statistical analysis, other climate prediction schemes and expert interpretation, the climate scientists determined likelihoods of above-normal, normal and below-normal rainfall for each area (Figures 1 to 4) for overlapping three-monthly periods i.e. October-November-December (OND), November-December-January (NDJ); December-January-February (DJF); and January- February-March (JFM). Above-normal rainfall is defined as rainfall lying within the wettest third of recorded (30 years, that is, 1971 -2000 mean) rainfall amounts; below-normal is defined as within the driest third of rainfall amounts and normal is the middle third, centred on the climatological median. Figure 5 (a), 5(b), 5(c) and 5(d) show the Long-term (1971-2000) mean rainfall October-November-December, November-December-January, December-January-February and January-February-March season over SADC countries.

The climate scientists took into account oceanic and atmospheric factors that influence our climate over the SADC region, including the El Niño-Southern Oscillation (ENSO), which is currently in its neutral phase. The ENSO is projected to continue in the neutral phase during the entire forecast period. Additional inputs were considered from other global climate prediction centres namely: the European Centre for Medium Range Weather Forecast (ECMWF), National Oceanic and Atmospheric Administration (NOAA), Beijing Climate Centre (BCC), Météo-France, Australian Bureau of Meteorology (BoM), Famine Early Warning Systems Network (FEWSNET), International Research Institute for Climate and Society (IRI), Korea Meteorological Agency, Japan Meteorological Agency (JMA), National Centre for Atmospheric Research (NCAR) and UK Met Office"

Additionally the archive of the purely quantitative forecasts from SADC CSC only goes back to 2017, as can be seen here: <u>http://csc.sadc.int/en/long-range-forecasts</u>

Comment #4:

Although Figure 4 shows a good relationship between crop yield and predicted soil moisture, it might be useful to use some statistical techniques to convert soil moisture prediction into crop yield prediction. Perhaps the authors could comment on that in the discussion section, if they believe it would be useful for their future development of the

forecast system.

Response: Great point. In response to this comment as well as comments by the Reviewer #2, we have now included an additional analysis in the manuscript, which focuses on predicting regional crop yield using ENSO and RZSM 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.