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Towards metrics for using process-based and statistical models to project regional-scale crop responses to climate.

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One of the key 21st century science challenges is understanding the impacts of climate change on global food security. Analyzing regional-scale (> 100km) crop responses to climatic drivers is a critical component of efforts to project future crop production. While there is considerable experimental knowledge of the field scale response of crops to changes in mean and extremes of temperature, our inability to perform controlled regional-scale experiments results in a much more limited understanding of regionally-relevant biophysical processes, and a greater reliance on modeling studies. Two of the primary crop modeling approaches at the regional scale are statistical models and process-based models. Statistical models can help us identify regional scale interactions between climate and crop production from historical observations, but assume a level of stationarity in these relationships which may not hold for future climate scenarios. Process-based crop models explicitly simulate biophysical relationships, making them suitable for modeling the effects of a wide variety of unobserved climates. However, our limited experimental understanding of regionally-relevant processes means that the biophysical relationships assumed to be relevant are derived from field scale experiments. Consequently, the impact of errors in weather data and climate models on the skill of statistical and process-based models at the regional scale is not well understood. In this study we analyze the particular strengths and weaknesses of these two modeling approaches by comparing the crop-weather interactions extracted by a statistical hindcast model, and the processes abstracted by the GLAM process-based crop model. Both models are run in hindcast mode using the E-OBS weather dataset, and are assessed according to the impact of systematic errors introduced to the precipitation and temperature observations. Two types of errors, shuffling of existing values and biases, are simulated at subseasonal, seasonal and climatological timescales. This allows us to measure which characteristics of precipitation and temperature are relevant to each respective model. The skill of predictive models of temperature and precipitation can vary significantly with the temporal scale of interest. For example, global climate models are known to poorly capture daily precipitation patterns and temperature extremes, but have significantly better performance for seasonal means. Also, parsimonious use of models helps minimize uncertainties and assumptions. Thus these results provide metrics for assessing whether a data source, such as a climate model or weather generator, is fit for purpose in a given impacts study. By comparing the strengths and weaknesses of statistical and process-based crop models at the regional scale, this work offers a methodology for the assessment and combined use of these disparate model types for regional-scale crop yield projections.