



A statistical analysis of three ensembles of crop model responses to temperature and CO₂ concentration

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ARTICLE INFO

Article history:

Received 6 March 2015

Received in revised form 29 July 2015

Accepted 20 September 2015

Keywords:

Climate change

Crop model

Emulator

Meta-model

Statistical model

Yield

ABSTRACT

Ensembles of process-based crop models are increasingly used to simulate crop growth for scenarios of temperature and/or precipitation changes corresponding to different projections of atmospheric CO₂ concentrations. This approach generates large datasets with thousands of simulated crop yield data. Such datasets potentially provide new information but it is difficult to summarize them in a useful way due to their structural complexities. An associated issue is that it is not straightforward to compare crops and to interpolate the results to alternative climate scenarios not initially included in the simulation protocols. Here we demonstrate that statistical models based on random-coefficient regressions are able to emulate ensembles of process-based crop models. An important advantage of the proposed statistical models is that they can interpolate between temperature levels and between CO₂ concentration levels, and can thus be used to calculate temperature and [CO₂] thresholds leading to yield loss or yield gain, without re-running the original complex crop models. Our approach is illustrated with three yield datasets simulated by 19 maize models, 26 wheat models, and 13 rice models. Several statistical models are fitted to these datasets, and are then used to analyze the variability of the yield response to [CO₂] and temperature. Based on our results, we show that, for wheat, a [CO₂] increase is likely to outweigh the negative effect of a temperature increase of +2 °C in the considered sites. Compared to wheat, required levels of [CO₂] increase are much higher for maize, and intermediate for rice. For all crops, uncertainties in simulating climate change impacts increase more with temperature than with elevated [CO₂].

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