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Regional and model-specific response types in a global gridded crop model ensemble

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Crop models are often employed to project crop yields under changing conditions such as global warming and associated management change for adaptation. Multi-model ensembles are promoted to enhance the robustness of projections, but questions remain on what causes often large differences between projections of individual models. Global Gridded Crop Models (GGCMs) are especially exposed to this question when applied for assessing climate change impacts, adaptation, environmental impacts of agricultural production, because their results are used in downstream analyses, such as in integrated assessment or economic modeling for projecting future land-use change. Even though global gridded crop models are often based on detailed field-scale models or have implemented similar modeling principles in other ecosystem models, global-scale models are subject to substantial uncertainties from both model structure and parametrization as well as from calibration and input data quality.

AgMIP's Global Gridded Crop Model Intercomparison (GGCMI) has thus set out to intercompare GGCMs in order to evaluate model performance, describe model uncertainties, identify inconsistencies within the ensemble and underlying reasons, and to ultimately improve models and modeling capacities. In phase 2 of the GGCMI activities, 12 modeling groups followed a modeling protocol that asked for up to 1404 31-year global simulations at 0.5 arc-degree spatial resolution to assess models' sensitivities to changes in carbon dioxide (C; 4 different levels) temperature (T; 7 different offset levels), water supply (W; 9 levels), and nitrogen (N; 3 levels), the so-called CTWN experiment (Franke et al. 2020; <http://dx.doi.org/10.5194/gmd-13-2315-2020>).

We here present analyses of model response types using impact response surfaces along the C, T, W, and N dimensions, respectively and collectively. Doing so, we can understand differences in simulated responses per driver rather than aggregated changes in yields. We find that models' sensitivities to the individual driver dimensions are substantially different and often more different across models than across regions. A cluster analysis finds regional and model-specific patterns. There is some agreement across models with respect to the spatial patterns of response types but strong differences in the distribution of response type clusters across models suggests that models need to undergo further scrutiny. We suggest establishing standards in model process evaluation not only against historical dynamics but also against dedicated experiments across the CTWN dimensions.