Classifying simulated wheat yield responses to changes in temperature and precipitation across a european transect

S. Fronzek[1*] – *N. Pirttioja*[1] – *T. R. Carter*[1] – *M. Bindi*[2] – *H. Hoffmann*[2] – *T. Palosuo*[2] – *M. Ruiz-Ramos*[2] – *F. Tao*[2] – *M. Trnka*[2] – *M. Acutis*[2] – *S. Asseng*[2] – *P. Baranowski*[2] – *B. Basso*[2] – *P. Bodin*[2] – *S. Buis*[2] – *D. Cammarano*[2] – *P. Deligios*[2] – *M.-F. Destain*[2] – *B. Dumont*[2] – *F. Ewert*[2] – *R. Ferrise*[2] – *L. François*[2] – *T. Gaiser*[2] – *P. Hlavinka*[2] – *I. Jacquemin*[2] – *K. C. Kersebaum*[2] – *C. Kollas*[2] – *J. Krzyszczak*[2] – *I. J. Lorite*[2] – *J. Minet*[2] – *M. I. Minguez*[2] – *M. Montesino*[2] – *M. Moriondo*[2] – *C. Müller*[2] – *C. Nendel*[2] – *I. Öztürk*[2] – *A. Perego*[2] – *A. Rodríguez*[2] – *A. C. Ruane*[2] – *F. Ruget*[2] – *M. Sanna*[2] – *M. A. Semenov*[2] – *C. Slawinski*[2] – *P. Stratonovitch*[2] – *I. Supit*[2] – *K. Waha*[2] – *E. Wang*[2] – *L. Wu*[2] – *Z. Zhao*[2] – *R. P. Rötter*[2]

[1] Finnish Environment Institute (SYKE), 00251 Helsinki, Finland; * Corresponding author
[2] Affiliations of co-authors as in Pirttioja et al., (2015)

Introduction

A wide variety of dynamic crop growth simulation models have been developed over the past few decades that can differ greatly in their treatment of key processes and hence in their response to environmental conditions. Here, multi-model ensemble approaches have been adopted to quantify aspects of uncertainty in simulating yield responses to climate change (e.g. Asseng et al., 2013). We use a large ensemble of wheat models applied at sites across a European transect to compare their sensitivity to changes in climate by plotting them as impact response surfaces (IRSs; Fronzek et al., 2010). A previous paper using the same simulated yield dataset (Pirttioja et al., 2015) presented ensemble medians and inter-quartile ranges, focusing on long-term averages. This paper extends that work by classifying the responses of individual models and attempting to interpret differences in response between groups of models by examining results from selected extreme years in addition to the long-term average.

Materials and Methods

An ensemble of 26 process-based crop models was used to simulate yields of winter and spring wheat at three sites: in Finland (mainly temperature-limited), Germany (close to optimal conditions) and Spain (precipitation limited). The sensitivity of simulated yield to systematic increments of changes in temperature (−2 to +9°C) and precipitation (−50 to +50 %) was tested by modifying values of baseline (1981 to 2010) daily weather. The results were plotted as IRSs that show the changes in yields relative to the baseline. IRSs of 30-year averages and selected extreme years were classified using a hierarchical clustering method and a second approach based on the location of the maximum yield and strength of the model response. IRSs were classified and compared to aspects of model performance, structure and genealogy (indicating the development history and relationships among some of the models).

Results and Discussion

Ensemble median responses showed declining yields with higher temperatures and decreased precipitation and yield increases with higher precipitation. However, individual models departed considerably from the average. An illustration of how responses are classified is given in Fig. 1, which distinguishes three patterns of winter wheat response across all three sites: (1) maximum yield at temperatures lower than the baseline, (2) stronger sensitivity to precipitation than temperature changes, and (3) large yield decreases with cooling and for strong warming. While some models were grouped into the same classes of response patterns for the different locations and crop varieties, a single factor could not be identified to explain common model responses. IRSs for anomalous weather-years showed larger model differences than for 30-year averages (e.g. in a cool year some models simulated crop failure over large parts of the IRS and others only small reductions relative to the baseline).

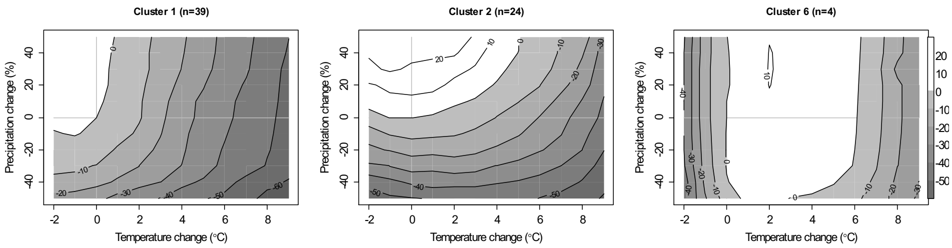

Figure 1. Ensemble mean changes in winter wheat grain yield (%) relative to the 1981-2010 baseline for the three dominant patterns of response identified using a hierarchical clustering approach across all study sites

Conclusions

At the time of writing, analysis of the modelled patterns of response were still ongoing. Preliminary results indicate that the study site is an important determinant of the positioning of the response pattern for a given crop with respect to baseline climate. Differences in the shape and strength of the response pattern, especially under high-end changes and in anomalous weather-years, appear to be related to the model representation of processes such as heat stress, moisture stress and vernalisation. Differences in calibration methods may also contribute to inter-model discrepancies.

Acknowledgements

This work is part of the FACCE-JPI Knowledge Hub MACSUR. For funding sources see Pirttioja et al., (2015).

References

Asseng, S., F. Ewert, C. Rosenzweig et al., (2013). Nature Climate Change 3 (9): 827–32.
Fronzek, S., T.R. Carter, J. Räisänen et al., (2010). Climatic Change 99 (3): 515–534.
Pirttioja, N., T.R. Carter, S. Fronzek et al., (2015). Climate Research, 65: 87–105.