Model improvements reduce the uncertainty of wheat crop model ensembles under heat stress

Andrea Maiorano, Pierre Martre, S. Asseng, F. Ewert, C. Müller, R. P. Rotter, A. C. Ruane, M. A. Semenov, Daniel D. Wallach, E. Wang, et al.

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A. Maiorano [1] – P. Martre [1] – S. Asseng [2] – F. Ewert [3] – C. Müller [4] – R. P. Rötter [5] – A. C. Ruane [6] – M. A. Semenov [7] – D. Wallach [8] – E. Wang [9] – P.D. Alderman [10] – B. T. Kassie [2] – C. Biernath [11] – B. Basso [12] – D. Cammarano [13] – A. J. Challinor [14,15] – J. Doltra [16] – B. Dumont [12] – S. Gayler [24] – K. C. Kersebaum [17] – B.A. Kimball [18] – A. K. Koehler [14] – B. Liu [19] – G. J. O'Leary [20] – J. E. Olesen [21] – M. J. Ottman [22] – E. Priesack [11] – M. P. Reynolds [23] – E. Eyshi Rezaei [3] – P. Stratonovitch [7] – T. Streck [24] – P. J. Thorburn [25] – K. Waha [25] – G. W. Wall [18] – J. W. White [18] – Z. Zhao [9] – Y .Zhu [19]

[1] INRA INRA, UMR759 LEPSE, 2 Place Viala, F-34 060 Montpellier, France, e-mail: pierre.martre@supagro.inra.fr
[2] Agricultural and Biological Engineering Department, University of Florida, Gainesville, FL, USA
[3] Institute of Crop Science and Resource Conservation (INRES), University of Bonn, Bonn, Germany
[4] Potsdam Institute for Climate Impact Research, Potsdam, Germany
[5] Environmental Impacts Group, Natural Resources Institute Finland (Luke), Vantaa, Finland
[6] NASA Goddard Institute for Space Studies, New York, NY, USA
[7] Computational and Systems Biology Department, Rothamsted Research, Harpenden, UK
[8] INRA, UMR1248 AGIR, Castanet-Tolosan, France
[9] CSIRO Agriculture Flagship, Black Mountain, Australia
[10] Oklahoma State University, Dep. of Plant and Soil Sciences, 371 Agricultural Hall, Stillwater, OK, USA
[11] Institute of Biochemical Plant Pathology, Helmholtz Zentrum München, German Research Center for Environ Health, Neuherberg, Germany
[12] Department of Geological Sciences and W.K. Kellogg Biological Station, Michigan State University, MI, USA
[13] James Hutton Institute, Invergowrie, Dundee, DD2 5DA, Scotland, UK.
[14] ICAS, School of Earth and Environment, University of Leeds, Leeds, UK
[15] CGIAR-ESSP Program on Climate Change, Agriculture and Food Security, CIAT, Cali, Colombia
[16] Cantabrian Agricultural Research and Training Centre (CIFA), Muriedas, Spain
[17] Institute of Landscape Systems Analysis, Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany
[18] USDA-ARS, US Arid-Land Agricultural Research Center, Maricopa, AZ, USA
[19] College of Agriculture, Nanjing Agricultural University, Nanjing, Jiangsu, China
[20] Grains Innovation Park, Department of Economic Development Jobs, Transport and Resources, Horsham, Australia
[21] Department of Agroecology, Aarhus University, Tjele, Denmark
[22] The School of Plant Sciences, University of Arizona, Tucson, AZ, USA
[23] CIMMYT, D.F. Mexico, Mexico
[24] Institute of Soil Science and Land Evaluation, University of Hohenheim, Stuttgart, Germany
[25] CSIRO Agriculture Flagship, Queensland, Australia

Introduction

Wheat crop multi-model ensembles (MME) have been suggested as an effective measure to increase reliability of impact estimates (Martre et al., 2015), but they are costly to execute. Therefore, model improvements have been suggested to reduce uncertainty of climate impact assessments and reduce the number of models required for an acceptable level of simulation uncertainty (Challinor et al., 2014; Rötter et al., 2011). In this study we improved 15 wheat crop models in simulating heat stress impacts and investigated the effect on MME performances and predictive skills.

Materials and Methods

Fifteen models from the AgMIP-Wheat model ensemble (Asseng et al., 2015) were improved through re-parameterization or incorporating or modifying heat stress effects on phenology, leaf growth and senescence, biomass growth, and grain number and size. Quality-assessed data from the USDA 'Hot Serial Cereal' (HSC) experiment were used to calibrate the improved models. The CIMMYT 'International Heat Stress Genotype Experiment' (IHSGE) global experiment was used to independently evaluate the improvements. Performances and predictive skills, using a new uncertainty estimation framework (Wallach et al., unpublished), of the population of 15 unimproved and improved models were evaluated through mean squared error and its decomposition in squared bias and variance. Model improvement effects on MME and the number of models required in an ensemble were analyzed through bootstrap calculation with 1 to 15 models MME.

Results and Discussion

Improvements decreased the variation (10th to 90th ensemble percentile range) of simulated grain yields on average by 26 % in the independent evaluation dataset for crops grown in mean seasonal temperatures > 24°C. Model population grain yield mean squared error decreased by 37 % in particular for the consistent improvement of the worst skilled models. Model population prediction skills increased by 47 % due to a reduction in the model population uncertainty range by 26 %. The latter improvement was mostly due to a decrease in model variance. Considering 13.5 % coefficient of variation as a benchmark (Taylor, 2001), the number of required models for MME impact assessments was halved, from 15 to 8, with improved models.

Conclusions

We demonstrated that crop model improvements using experimental data sets can increase the simulation and predictive skills of MME and can reduce the number of models required for reliable impact assessments. Improving crop models is therefore important reducing the size of MME for practical impact assessments.

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