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Assessing the variability of soil temperatures in Land Surface Models using outputs from the Soil Parameter Model Intercomparison Project (SP-MIP)

Anne Verhoef[1], Yijian Zeng[2], Matthias Cuntz[3], Lukas Gudmundsson[4], Stephan Thober[5], Patrick C. McGuire[6], Hannah Bergner[5], Aaron Boone[7], Agnès Ducharne[8], Rich Ellis[9], Hyungjun Kim[10], Sujan Koirala[11], Dave Lawrence[12], Keith Oleson[12], Sean Swenson[12], Salma Tafasca[8], Philipp de Vrese[13], Sonia Seneviratne[4], Dani Or[4], and Harry Vereecken[14]
[1]Geography and Environmental Science, The University of Reading, Reading, United Kingdom of Great Britain – England, Scotland, Wales (a.verhoef@reading.ac.uk)
[2]Department of Water Resources, Faculty of Geo-Information Science and Earth Observation, The University of Twente, Enschede, the Netherlands (y.zeng@utwente.nl)
[3]Université de Lorraine, AgroParisTech, INRAE, UMR Silva, 54000 Nancy, France (matthias.cuntz@inrae.fr)
[4]ETH Zürich, Zürich, Switzerland
[5]Helmholtz Center for Environmental Research - UFZ, Leipzig, Germany (stephan.thober@ufz.de)
[6]Department of Meteorology & National Centre for Atmospheric Science, University of Reading, Reading, UK (p.mcguire@reading.ac.uk)
[7]CNRM - Université de Toulouse, Météo-France/CNRS, Toulouse, France (aaron.a.boone@gmail.com)
[8]METIS (Milieux Environnementaux, Transferts et Interactions dans les Hydrosystèmes et les Sols), Institut Pierre Simon Laplace (IPSL), Sorbonne Université, CNRS, EPHE, Paris, France (Agnes.Ducharne@upmc.fr)
[9]UK Centre for Ecology & Hydrology, Wallingford, UK (rjel@ceh.ac.uk)
[10]Moon Soul Graduate School of Future Strategy, Korea Advanced Institute of Science and Technology, Daejeon, Korea (hyungjun.kim@kaist.ac.kr)
[11]Max Planck Institute for Biogeochemistry, Jena, Germany (skoirala@bgc-jena.mpg.de)
[12]National Center for Atmospheric Research, Boulder, Co, USA
[13]Max Planck Institute for Meteorology, The Land in the Earth System, Hamburg, Germany (philipp.de-vrese@mpimet.mpg.de)
[14]Agrosphere Institute (IBG-3), Institute of Bio- and Geosciences, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Results: Soil temperature is a crucial variable in Land Surface Models (LSMs) because it affects the fractions of frozen and unfrozen water content in the soil. For example, getting the coupling between below-ground heat- and water transfer correct in LSMs is very important in permafrost regions because these are particularly sensitive to climate change. Poor predictions of the energy- and water balance in these regions will lead to large uncertainties in predicted carbon fluxes, and related land-atmosphere feedbacks. Also, simulated near-surface soil temperatures can be used to diagnose and explain model differences in skin temperatures and soil heat fluxes, both of which are pivotal in the prediction of the surface energy balance.

Soil temperature is generally under-researched as part of LSM intercomparisons. Here we present

an analysis of the spatial distribution (including the vertical distribution along the soil profile) and seasonal evolution of soil temperature simulated by eight LSMs as part of the Soil Parameter Model Intercomparison Project (SP-MIP). We found large inter-model differences in key metrics of the annual soil temperature wave, including the amplitude, phase shift and damping depth, which were partly attributed to diversity in hydraulic as well as thermal soil properties. Soil layer discretisation also played a role.

Methods: Via manipulation of model soil hydraulic properties, and the soil texture inputs required to calculate these properties, controlled multi-model experiments have been conducted as part of SP-MIP, this MIP was originally proposed at the GEWEX-SoilWat workshop held in Leipzig (June 2016).

The model experiments closely followed the LS3MIP protocol (van den Hurk et al. 2016). Eight land models (CLM5, ISBA, JSBACH, JULES, MATSIRO, MATSIRO-GW, NOAH-MP and ORCHIDEE) were run globally on 0.5° with GSWP3 forcing, from 1980-2010, for vertically homogeneous soil columns. There were 4 model experiments, leading to 7 model runs: *Experiment 1.* Global soil hydraulic parameter maps provided by SP-MIP; *Experiment 2*. Soil-hydraulic parameters derived from common soil textural properties, provided by SP-MIP, using model-specific pedotransfer functions (PTFs); *Experiment 3*. Reference run with all models applying their default soil hydraulic settings (including their own soil maps to derive the parameters); *Experiment 4*: four runs using spatially uniform soil hydraulic parameters for the whole globe (loamy sand, loam, clay and silt) provided by SP-MIP.

Differences between the model experiments will allow the assessment of the inter-model variability that is introduced by the different stages of preparing model parameters. Soil parameters for Experiments 1 and soil textures for Experiment 2 at 0.5° resolution were prepared from dominant soil classes of the 0-5 cm layer of SoilGrids (Hengl *et al.* 2014) at 5 km resolution. Brooks and Corey hydraulic parameters come from Table 2 of Clapp and Hornberger (1978), Mualem-Van Genuchten hydraulic parameters are ROSETTA class average hydraulic parameters (Schaap *et al.* 2001), and soil textures are from Table 2 of Cosby *et al.* (1984). Experiments 4 a-d use the USDA soil classes, using the same PTFs for Brooks and Corey and Mualem-van Genuchten parameters as in Experiment 1.