Future projection of global climate, water, food, bio-energy, and land investigated with MIROC-INTEG: a global bio-geophysical land surface model with human components

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Future climate changes possibly affect water resources, food production, energy supply, and ecosystem services. It is critical to better understand the interactions between the changes in these complicated factors. While earth system models and integrated assessment models are applicable to explore this topic, parts of their natural and/or human processes tend to be simplified depending on their scope. As such, it still remains a challenge to realistically model the human-natural interface. In this context, the MIROC integrated terrestrial model (MIROC-INTEG) was developed. One of the features of MIROC-INTEG is that the natural ecosystem and human activity models are coupled to a global land surface model MATSIRO (Nitta et al. 2014, Journal of Climate), which is a component of a state-of-the-art global climate model, MIROC (Watanabe et al. 2010, Journal of Climate). As a natural ecosystem model, we use a global vegetation model, VISIT (Ito and Inatomi 2012, Biogeosciences). As human activity models, we use a global land-surface model with anthropogenic water regulation modules, HiGW-MAT (Pokhrel et al, 2012, Journal of Hydrometeorology), and a global crop model, PRYSBI2 (Sakurai et al, 2014, Scientific Reports). In HiGW-MAT, models of human water regulations such as water withdrawal from river, dam operation, and irrigation (Hanasaki et al. 2008, Hydrol. Earth Syst. Sci.) are incorporated to the above-mentioned global land surface model, MATSIRO. In PRYSBI2, the growth and yield of four crops (wheat, maize, soybean, rice) are calculated. In addition to these models, a global land use model (Terrestrial Land-use Model, TeLMO) is newly developed in the present study. TeLMO calculate the grid ratio of cropland (food and bio-energy crops), pasture, forest (managed and un-managed), as well as their transition. Output variables of each sub-model are passed to other sub-models during the time integration.
We will present an analysis of historical and future simulations with a focus on the interactions between water, food, energy, and land. In the historical simulations, we validated the model output such as irrigated water, crop yield, ecosystem productions, and cropland area by comparing to the observed or reanalysis data. In the future simulations, we investigated the role of uncertainties in climate (Representative Concentration Pathways) and socio-economic (Shared Socio-economic Pathways) scenarios. We also investigate the role of uncertainties in model parameters, and found that an uncertainty in the fertilization effect of crop growth model PRYSBI2 strongly affect uncertainty in future projection of crop yield and land use change in TeLMO. We found that future changes in precipitation and/or temperature possibly cause decrease in soil moisture, leading to decreases in crop yield (especially in high emission scenario such as RCP8.5). Decrease in crop yield bring about increase in crop land area, which also causes the increase in irrigation demands. Interaction between water, crop yield, and land use, as well as possible impacts on ecosystem service will be discussed in the presentation.

Keywords: Global Climate Model, Earth System Model, Human activity