モデル–観測連携 GTMIP の成果と将来に向けて

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Outcomes of and outlook from the Modeling-Field Collaboration GTMIP

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As part of the terrestrial branch of the Arctic Climate Change Research Project (GRENE-TEA), which aims to clarify the role and function of the terrestrial Arctic in the climate system and assess the influence of its changes on a global scale, this model intercomparison project (GTMIP) is designed to a) enhance communication and understanding between the modeling and field scientists (cf. Fig 1), and b) assess the uncertainty and variations stemming from variability in model implementation/design and in model outputs using climatic and historical conditions in the Arctic terrestrial regions (Miyazaki et al. 2015). GTMIP consists of two stages. The stage 1 is site simulations for the last 3 decades driven by statistically fitted data created through model–field collaborations with use of the observation data for four GRENE-TEA sites of different eco-climate background (i.e., Fairbanks, Kevo, Tiksi, and Yakutsk) (Sueyoshi et al. 2016). The stage 2 is 0.5°x0.5° circum-Arctic simulations for 1850 to 2100 driven by outputs of the MIROC-ESM simulations for IPCC AR5 (historical and RCP8.5 scenarios), with bias-corrected by Reanalysis data. The target metrics for the model evaluation cover key processes in both physics and biogeochemistry, including energy and water budget, snow, permafrost, phenology, and carbon budget.

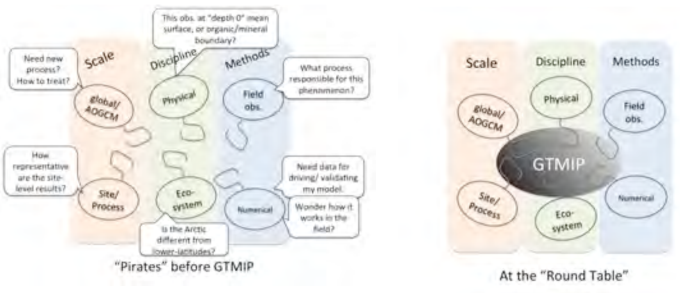

Figure 1. Collaborative schematic before and after the GTMIP.

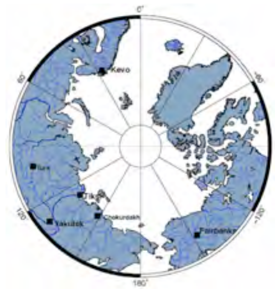

Figure 2. Sites for stage 1.

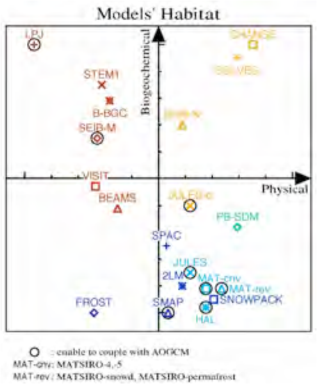

Figure 3. Participating models.

19 models of different complexity and disciplinal characteristics, ranging from detailed processes physical models to GCM-compatible land surface models to versatile physical-biogeochemical models, submitted the simulated results for the stage 1 (fig 3), and 5 models (namely, Biome-BGC, SEIB-Noah, MATSIRO-permafrost, MATSIRO-ssnowd and VISIT) for the stage 2, as of early January, 2016. Energy and water budget analysis for the stage 1 showed that latent heat flux (Qle) had smaller inter-model differences than other energy fluxes—e.g., sensible (Qh), and net radiation (Rn)—did (fig 4 shows an example for Fairbanks). Storage of water within the top 1-m soil was almost in balance, with slight increase (wetting) for Fairbanks, Kevo, and Tiksi, while small decrease (drying) for Yakutsuk.

Reproducibility of snow depth largely correlates with the complexity of the physics and numbers of snow layers implemented, although no model succeeded in reproducing wind crust in Tiksi. With respect to subsurface thermal regime, importance of the snow insulation process, which was found strongly associated with realistic snow density dynamics (and hence, snow compaction processes), was demonstrated. Carbon budget was larger for the taiga sites while they are limited for the tundra site. Relative inter-model variations in the carbon budget components—especially those for exchanges between the atmosphere, i.e., gross primary production (GPP), and auto- and heterotrophic respirations (RA and RH, respectively) —were smallest for the Yakutsk site, primarily owing to at the site (fig 5). Since all of the participating ecosystem models assign only one plant function type that is dominant at a site, this is speculated to owe to the site's characteristics that one vegetation type (larch in this case) dominates the budget. Net ecosystem production (NEP) largely showed positive values (sink for CO_2), but individual values varied even for the sign.

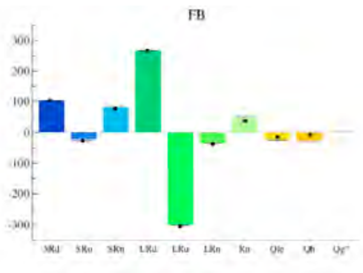

Figure 4. Energy budget (Fairbanks; W/m^2). *SR* and *LR* are Short- and longwave radiation, and suffices *d* and *u* denote down- and upward. Qg* is heat flux to the ground obtained as residual.

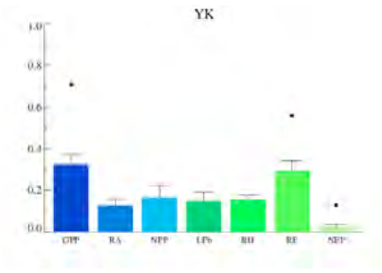

Figure 5. Carbon budget (Yakutsk; KgC/m^2/year). NPP, LFb, RE are net primary production, litter fall, total respiration, total respiration.

Despite a simple seesaw pattern in temperature and precipitation increase projected under the RCP8.5 scenario between the Atlantic and Pacific sectors in the circum-Arctic (fig 6a-b), the terrestrial hydrological response, revealed by evapotranspiration and soil water storage, showed more complex spatial patterns influenced by regional to local geography and topography; drier in the continental interiors while wetter along the coastal (fig 6c-d).

a) b) c) d)

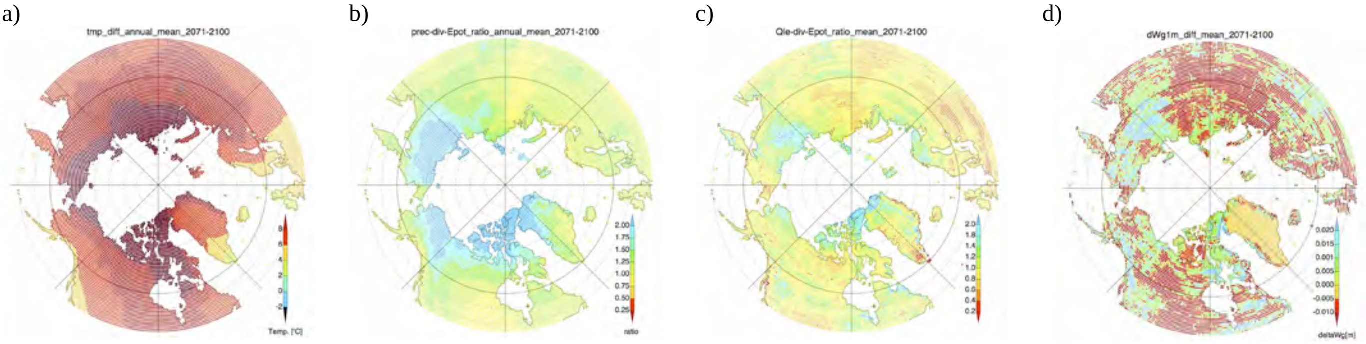

Figure 6. Projected changes in a) temperature, b) wetness index, defined as precipitation divided by the potential evaporation, c) evapotranspiration efficiency, defined by latent heat flux divided by the potential evaporation, and d) soil water storage in the upper 1-m layer for 2071-2100. Changes are shown in terms of difference from the baseline (the 1981-2010 average) for a) and d), while shown in terms of ratio to the baseline for b) and c).

Other than the scientific outcomes mentioned above, the GTMIP brought qualitative and transformative progresses on the following five aspects; i) establishment of communications and a common community between domestic modeling and field scientists working on the terrestrial Arctic, ii) deepening mutual understanding among modeling scientists, bridging different disciplines (physics, biogeochemistry, and ecosystem) and scales (plot/local to regional to global) of interest, iii) conduct of collaborations between the above two communities as a team, iv) creation of observation-fitted, quality-controlled, open-access common forcing data through the collaboration, and v) creation of standardized, ready-to-use validation data sets compiled from different sources that had followed different protocol and conventions among sites, research groups and disciplines.

It is an apparent trend in the international Arctic research that groups and projects consisting of the modeling and field science communities of different domains (e.g., disciplines or geographical locations) collaborate together to produce substantial outcomes. This GTMIP activity has been one of the forerunners in the area of terrestrial research with distinct scope in target and unique range of participants. This momentum is being inherited to the currently conducted and/or planned activities, not limited to the Arctic.

References

Miyazaki et al. 2015: The GRENE-TEA Model Intercomparison Project (GTMIP): overview and experiment protocol for Stage 1. Geosci. Model Dev., 8, 1–16, doi:10.5194/gmd-8-1-2015.

Sueyoshi et al. 2016: The GRENE-TEA Model Intercomparison Project (GTMIP) stage 1 forcing dataset. accepted, ESSD.