Project: **1236**
Project title: **Q-ARCTIC**
Principal investigator: **Victor Brovkin**
Report period: **2021-11-01 to 2022-10-31**

Summary

The Q-Arctic related model development tasks during the last year were focused on the general improvement of soil hydrology (thereby contributing also to the CoolRuby Project) and on the development of an ICON-L tile structure that allows for the explicit representation of topographical differences within grid cells and the resulting lateral water flows above and within the soil.

General improvements in soil hydrology

The soil hydrology scheme has seen improvements in its parametrization that

- allow for surface water infiltration during winter while limiting drainage and percolation in the presence of soil ice,
- account for the effect of pore water on the soil thermal properties, which reduces the overestimation of ground heat capacity and conductivity in arid regions, and
- consider the effect of organic matter on soil thermal and hydrological properties.

This changes improve the soil ice distribution for North America and Eurasia and reduce the warm bias during boreal summer over continental areas (see Figure 1).

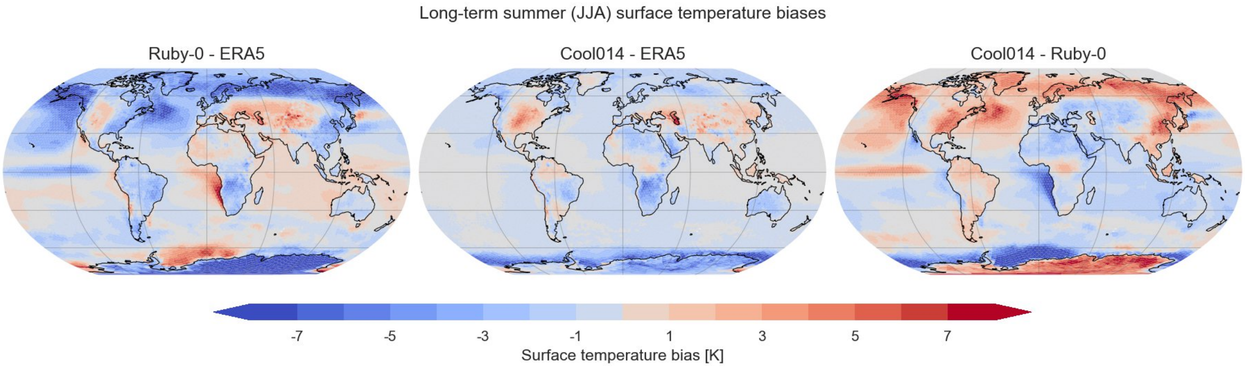

Figure 1 Surface temperature bias during summer for the reference model (Ruby-0) and the improved soil hydrology model (CoolRuby014) compared with ERA5.

Furthermore, the numerics of the vertical soil water transport were improved, allowing to simultaneously solve all soil hydrology fluxes – infiltration, evapotranspiration, percolation and diffusion – in one matrix instead of sequentially iterating through the soil layers. While this does not effect the overall climate on short time scales, it leads to a much more realistic representation of the individual runoff components (see Figure 2)

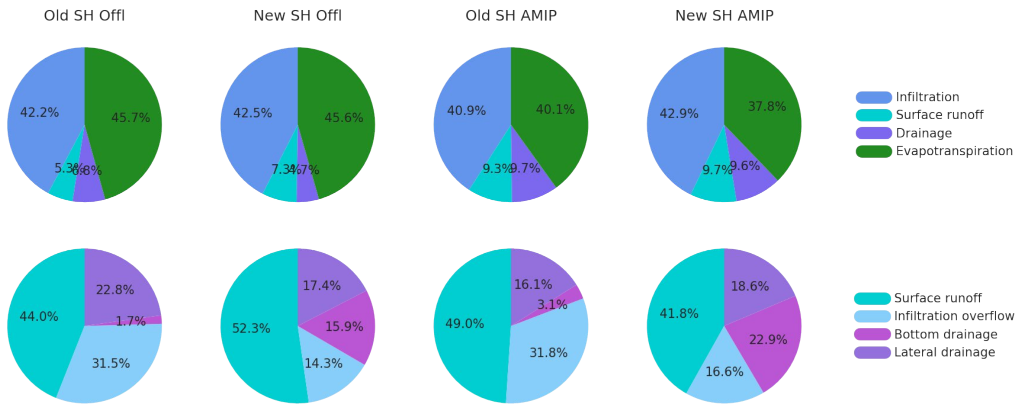

Figure 2 Soil hydrology (upper panel) water fluxes and runoff components (lower panel) for JSB4 (Offl) and AMIP simulations using the old soil hydrology scheme (Old SH) or the new (New SH).

Hillslope hydrology

Representing areas with different topography within one grid cell, requires the addition of dedicated tiles within the JSB4 infrastructure. We created an *use case* (Figure 3) that introduces tiles representing the macro- (upland and lowland) and micro-topography (ridges and depression within a macrotopography) and allows to define processes that act depending on the tile type.

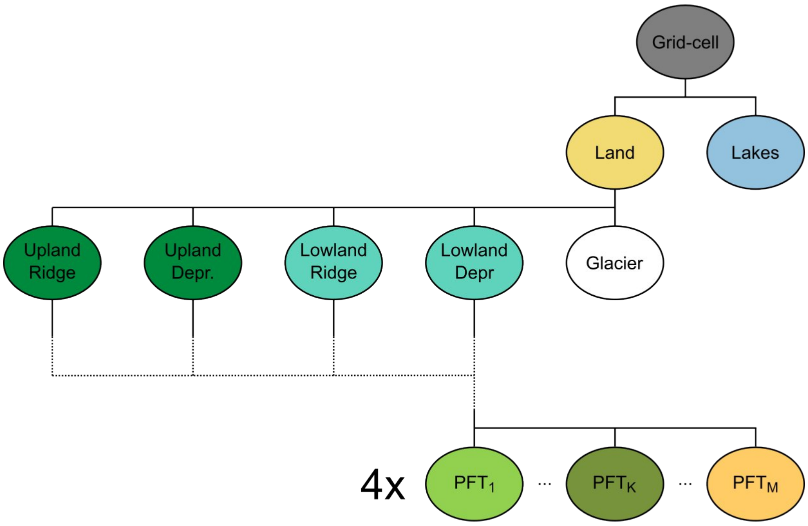

Figure 3 Q-Arctic use case with additional tiles representing macro- and microtopography. These tile replace the standard veg tile and run not only the HYDRO and SSE processes but also the new MIX process which allows for inter-tile exchange of water. Each of these tile feature the full set of PFTs.

The new MIX (multi-scale inter-tile exchange) process prescribes the lateral transport of surface runoff and lateral drainage along predefined flow paths (e.g. upland ridge → upland depression) while lateral diffusion is only allowed between micro-topography tiles. As a result, water is redistributed between the tiles as shown in Figure 4. This redistribution constitutes an important prerequisite to realistically simulation e.g. methane emission from water-logged soils in boreal regions.

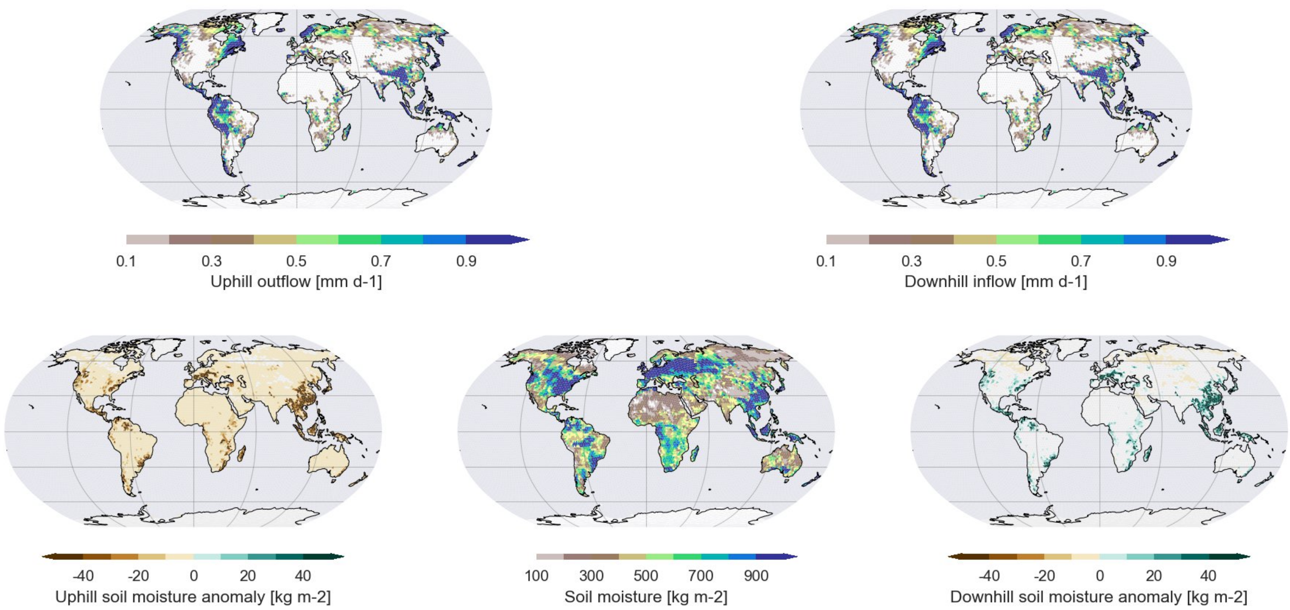

Figure 4 Water flows from uphill to downhill tiles (upper panels) and the resulting differences in soil moisture (lower panels) compared to the average soil moisture of the grid cell.