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Towards explicit representation of the mountain cryosphere in earth system models: Case study from the "Third Pole" and the tropics

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Representing mountain glaciers in climate models has always been complicated by the scale mismatch between the size of glaciers and the grid size in atmospheric models. Thus, approaches that quantified their multi-scale relationship usually relied on extensive statistical scale corrections. With the increasing computational power and numerical set-ups adopted from dynamic meteorology, we are showing explicit solutions to quantifying the glacier-climate linkage in the framework of an atmospheric model. Depending on the size of the mountain cryosphere considered, the simulation can be treated as two-way interaction or - in the case of very small glaciers (which provide hardly any feedback to atmospheric circulation) - as offline and subgrid one-way interaction. In both cases, statistical downscaling is completely avoided, so the multi-scale system is modeled by the governing physical principles. We demonstrate the success of these strategies by case studies from the High Asian Mountains, also known as the "third pole", and from the tropics. Despite shrinkage, the mountain cryosphere will in general continue to contribute to sea-level rise in the 21st century. However, its representation in earth system models is even more important for paleoclimate simulations of past glacial cycles, when mountain glaciation was more extensive and possessed increased potential for strong feedback to large-scale circulations in the climate system.