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A fully integrated Earth System Model: focus on dynamical coupling of climatic and cryospheric model sub-systems

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Earth system models (ESMs) have been widely used in the recent years for complex studies of the climate system of the planet in the context of interactions between the atmosphere, oceans, ice sheets and the biosphere. Incorporation of the Earth syb-systems with very different spatial and temporal scales and response times into one model is really a challenging task. In particular, coupling of an AO GCM and ice sheet models of Greenland and Antarctic ice sheets (GrIS and AIS) requires application of special downscaling procedures. Within the frameworks of our research study, we implemented several coupling strategies. The choice of a strategy is dictated mostly by two factors – by the purpose of the research and by spatial resolution of an AO GCM. Several versions of the latter (called INMCM) were developed in the Institute of Numerical Mathematics (Moscow, Russia). For instance, the version aimed primarily for the relatively long numerical experiments (for e.g. palaeostudies) has spatial resolution of $5^\circ \times 4^\circ$, 21 vertical layers in the atmospheric block, $2.5^\circ \times 2^\circ$, 33 vertical layers in the oceanic block. To provide proper data exchange between the INMCM and GrIS and AIS models (spatial resolution 20×20 km), we employ rather simple buffer (sub-) models, describing regional heat and moisture diffusion. Applying buffer models enables to avoid systematic shifts in INMCM-generated precipitation fields and to much more realistically describe influence orographically driven precipitation (in Greenland) and elevation-temperature dependence. Novel versions of the INMCM with the spatial resolution of $2{,}5^\circ \times 2^\circ$ and higher generate much more realistic climatic fields, therefore the coupling procedure can be simplified to just averaging, resampling and remapping data from the AO GCM global domain to regional domains enclosing ice sheets. Increase in spatial resolution inevitably causes additional computational cost and reduces the area of the ESM application to comparatively short numerical experiments, primarily aimed at simulation of present day and nearest future climates.