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Dynamics of ice sheet and sea ice under changing climate in the geological past and future

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Ice sheets and sea ice are key players in "Our Interconnected Earth" for understanding the climate changes. Abrupt climate changes and tipping points of centennial to millennial time scales in the past under different climate and cryosphere conditions are implied by past climate change data from ice core, ocean sediment and various kinds of proxy. Paleoclimate modelling using GCMs (General Circulation Models) combined with earth system components has become a powerful tool for interpreting past climate data (proxy) and understanding how the long-term climate system responds to external forcings such as Milankovitch forcing and greenhouse gases. Whether the small changes in astronomical forcing (eccentricity, precession and obliquity) are enough to induce ice age climates and glacial-interglacial cycles has been a theme of climate science for more than a century. The very first climate model experiments were performed to simulate the contrast between LGM (Last Glacial Maximum) and present-day climate to validate the model, which is still the case for CMIP (Coupled Model Intercomparison Project) and PMIP (Paleoclimate Modelling Intercomparison Project). With the aid of supercomputers and advances in climate model development, it is now possible to perform a much larger number of "snapshot" experiments than before with fixed forcings or even "transient" experiments with evolving forcings. This talk will show model results using a climate model, MIROC and an ice sheet model, IcIES, that simulate the Northern Hemisphere ice sheet change, ocean circulation (AMOC, Atlantic Meridional Ocean Circulation) and climate in the past. We show the current status of modelling the glacial-interglacial climates and millennial scale climate changes and discuss the “tipping points”, which induce unexpected large (and relatively abrupt) changes despite a small change in given external forcings. We discuss the role of cryosphere in the climate system and the internal climate feedback and the implications for our understanding of long term future climate.