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Triggering abrupt climate change by freshwater perturbations of the LGM surface ocean: a systematic study of the sensitivity to different release locations

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Numerous studies have aimed at studying the impact of imposed freshwater perturbation to the surface ocean in different climate models. Most studies have directed the perturbation to the North Atlantic Ocean, where the addition of freshwater tends to modify the deep water formation and slows down the THC.Recently however some additional studies have analysed the effect of freshwater perturbation in the Southern Ocean and most recently, a study has demonstrated that forcing the Arctic Ocean with freshwater leads to comparable results as forcing the North Atlantic.

Up to date, however, no study has provided a comprehensive and systematic picture of the effect of freshwater forcing added in an ensemble of precisely defined geographical zones within the same model, and hence discussed the relative importance of the different climatic feedbacks at work. This is of crucial importance if one aims at simulating correctly the climate evolution at times when there is a strong meltwater flux from decaying ice-sheets directed to the ocean, as was the case during the last deglaciation and might be the case in the future. Indeed, the most recent climate period in which freshwater forcing is thought to have played a dominant role is the last deglaciation (21 kyr B.P. to 8 kyr B.P.) when the shrinking ice-sheets were delivering huge amounts of freshwater to the ocean.

We therefore present here the first comparative and systematic study of the sensitivity of spatially localised and well-defined regions to freshwater forcing under Last Glacial Maximum (LGM) climate conditions. We first define a series of regions representative of those receiving most of the melting of decaying ice-sheet during the deglaciation. Then, we test the effect of several given freshwater fluxes applied separately in each of these regions on regional and global climate. The climate response is analysed both for the atmosphere and oceans. In a second part, we also test whether a preconditioning of each zone by a small freshwater flux, preceding the main pulse, has an impact on the robustness of the climate response obtained. We find that amongst the regions defined, the areas close to the main deep water formation zone in the North Atlantic are most sensitive to freshwater pulses, as is expected. We, however, found some important differences between the effects of freshwater forcing in the Arctic Ocean and Nordic Seas, the former having a longer-term response linked to sea-ice formation and advection, whereas the latter exhibits more direct influence of direct freshening of the deep water formation sites. Some more regional features associated with local forcing are also discussed.