The comments of Mikhail Verbitsky are reproduced below in black. Our responses are in blue.

The authors endeavor to study the limitations of some quantitative methods of assessing future economic damages using "an ad absurdum example of a hypothetical cooling of climate at speed and magnitude equivalent to what the business-as-usual scenario of the IPCC announces."

Though ad absurdum examples are always entertaining and occasionally useful, the "degree" of absurdity should be constrained by the laws of physics. From this standpoint, fast cooling of the planet toward the end of this century, though hard to imagine, is not precluded by physics. The real absurdity, which is not supported by physics and therefore invalidates the study, appears elsewhere. The authors suggest that "…the regions covered by ice at the LGM would in our scenario be buried under several meters of snow at the end of the century…The impacted regions would be: Canada, Alaska and the Great Lakes region of the United States, the states north of 40N on the East coast, the Scandinavian countries, the northern part of Ireland and of the British islands, half of Denmark, the northern parts of Poland and the north-east territories of Germany, all of the Baltic countries as well as the north-eastern part of Russia, Switzerland and half of Austria". It appears that the authors think that an ice age begins immediately and simultaneously on 50 mln square kilometers when the winter snow is not completely melted during the summer and over time becomes what we know as Laurentide and Scandinavian ice sheets. This is not how ice-age physics works. The timing of the ice ages is defined by the speed of the moving horizontal boundary of the spreading viscous ice media, not by the snow growth from the ground.To spread all over the areas mentioned above, would take about 100,000 years, not 1,000 years as the authors suggest. Therefore, though the authors call this vast permanent snow coverage the "most obvious consequences for human societies", it is in fact far from obvious and all of these regions may be permanent-snow-free for a very long period of time.

Even the emergence of smaller, nucleus, glaciers (that do grow from the ground) is not granted because the cooling may reduce snow precipitation rates in polar regions instead of increasing them. In short, the climate system is non-linear; the ice ages begin when the global temperature is high and end when it is low.

Thank you for your comment; we agree that ice sheets do not grow only because of static snow accumulation and the role of the viscous spreading should indeed be mentioned in the text. We also perfectly acknowledge that reaching the last glacial maximum northern ice sheets geometry would not be possible within 100 years, as stated L. 214 of our paper. By "millennia" we meant "thousands of years", the text should be modified for greater clarity. L.214 would then be modified as follows (in italics): "Of course, the growing and *spreading* of large ice sheets actually requires *thousands of years*, not a century."

We also agree that ice sheets do not build quickly as soon as snow accumulates on the ground. However, according to the Milankovitch theory, ice ages are triggered by the reduction of summer insolation at high latitudes, which allows winter snow to persist in summer and then eventually, because of various positive feedbacks (e.g. Khodri et al., 2001; Calov et al., 2005), to the ice-sheet build-up and full glaciation. Snow accumulation is not sufficient to build an ice sheet, but it is necessary.
Indeed, the last ice age was drier than present-day climate (e.g. Kageyama et al., 2020) and precipitation decrease could prevent snow accumulation on the areas listed in our paper.

However the LGM simulations of Calov et al. (2005) show that the area of positive annual mass balance correspond to the area of the ice sheets (except on the edges of the Fennoscandian ice sheet). In another context, Robock et al. (2009) also simulated the persistence of snow in the midlatitudes of the North hemisphere in response to a massive volcanic eruption, because of very low temperatures. Therefore, our assumption does not seem utterly unreasonable, even if it is of course a rough first-order estimate.

Moreover, the direct comparison between the timing of the last glacial cycle and our thought experiment is not possible since the slow ice-sheet build-up during the last glacial period was triggered by the slow evolution of the orbital forcing. Their evolution was far from linear during the ~100 ky between the last interglacial and the LGM: proxy data show a fast growth of the ice sheets between 120-110 ky, with a 30-60 m of sea level drop. Simulations of the glacial inception by Calov et al. (2005) show that "*Between 118 and 117 kyr BP the land area covered by ice increases by more than 4.10^6 km^2 in just a few hundred years, reaching approximately 30% of the area of LGM ice sheets in North America".* The temperature decrease during the LGM compared to present-day would be a much stronger driver than the orbital forcing at the last glacial inception, and the ice-sheet growing and spreading could then be much faster than what was observed for the last glacial inception. However, to our knowledge, no modelling study is currently available in the literature to test this hypothesis. The closest comparison could be with the strong cooling induced by a massive volcanic eruption (Robock et al., 2009) or a nuclear war (Robock et al., 2007), but in such cases the pattern of temperature and precipitation changes is different from the LGM and lasts only a few years.

In any case, the estimated -4°C of global cooling during the LGM corresponds to a climate more or less at equilibrium, where all feedbacks had enough time to act (snow and ice albedo , decrease of greenhouse gases, vegetation changes, elevation of the ice sheets…etc). In our work, we chose to assume equilibrium as a simplification for the sake of the demonstration and to have a known period to estimate the plausibility of econometrics projections. The only exception to this assumption are the ice sheets and associated sea level drop, as the timing is obviously too short. The LGM ice-sheet extension is used as a rough constraint for the location of the areas where snow accumulation would occur, not taking into account the role of ice dynamics during the LGM, which should be mentioned in the text for more clarity. But we cannot constrain the hypothetical rate of snow accumulation, (taking into account a drier climate) without ad hoc experiments with a climate model, which is beyond the scope of the paper. In any case, even if some of the regions listed in our paper would remain snow-free for a long time, the cold would anyway be a strong constraint to economic activities, even if not as dramatic as with a thick permanent snow cover. By comparison, currently most of the high northern latitudes have a very low population density (see also the recent work by Xu et al. 2020 on human ecological niche).

We suggest adding at L.227 the following sentence (in italics): "We presume that the regions covered by ice at the LGM would in our scenario be buried under several meters of snow at the end of the century. *This is a rough first-order estimate, not taking into account the role of ice dynamics in the spreading of the ice-sheets over the north hemisphere during the last glacial period*".

Anthropogenic global warming, if extended, may preclude next ice age; it doesn't necessarily mean that anthropogenic global cooling would "instantaneously" generate one.
I understand that this paper is not about ice-age physics, and the authors want to make a (probably valid) point about the inconsistency of some economic models, but their choice of the thought experiment is very unfortunate. As economists, they want to ": : :conclude that temperature only is a very bad proxy to estimate damages of a major climate change at a country scale or at the global scale and should not be used for that

purpose" but, as climatologists, they make exactly the same mistake, assuming that temperature only (-4°C) would bring our climate exactly where it was 20,000 years ago.

We do not assume that such a cooling would be of anthropogenic origin. Actually, we do not propose any physical mechanism. We make the hypothesis of a return to the LGM, even if physically implausible, and merely have a look at what the consequences would be according to econometrics. Our main focus is on highlighting the unrealistic results obtained with statistical damage functions for a climatic change symmetrical to the RCP8.5 (when looking only at the mean temperature), not to discuss the physical mechanisms that could trigger such a change. Although not fully comparable, our approach is inspired from Nolan et al. (2018), who use the ecosystem changes during the last glacial-to-interglacial transition as a proxy to assess the risk of future major ecosystem transformations worldwide in the case of unabated greenhouse gas emissions.

However, our working hypothesis probably needs to be clarified in the introduction. We do not assume that temperature change would trigger a return to a glacial climate. Rather, we assume a return to the last glacial maximum, with all its consequences (including precipitation and ecosystem changes for instance), and use it as a benchmark to test econometric models based on mean annual temperature, to illustrate that looking at temperature changes only leads to unrealistic impacts on GDP. Therefore, we did not consider only temperature changes to quantitatively estimate the impacts, but also precipitation, vegetation, permafrost or desert area changes, since lower temperatures and large ice sheets are not the only features of the last ice age. This could be clarified in the text by modifying L.37 as follows: "*Therefore, we can try them for a hypothetical return to the LGM, corresponding to a cooling of 4°C in 2100*". In the conclusion, L.353 could also be modified as follows: "*In order to strengthen this point, we have used an ad absurdum example of a hypothetical return to the climatic and environmental conditions of the last glacial maximum, corresponding to a global cooling at speed and magnitude equivalent to what the business-as-usual scenario of the IPCC announces*".

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