



EGUsphere, author comment AC2  
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## Reply on RC2

Alizée Chemison et al.

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Author comment on "Impact of an acceleration of ice sheet melting on monsoon systems" by Alizée Chemison et al., EGU sphere, <https://doi.org/10.5194/egusphere-2022-197-AC2>, 2022

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Chemison et al. investigate the impact of ice sheet melting in Greenland and Antarctic on global monsoon using IPSL-CM5A-LR with freshwater hosing experiments. They find that freshwater input to sea from Greenland and Antarctic has different impacts. The former may slowdown the Atlantic meridional overturning circulation, and result in a southward shift of rain belt and thus monsoon in American and Africa. However, the impact of freshwater input from Antarctic is moderate due to circumpolar current dilution. They also study the changes in some monsoon index to depict the details of monsoon changes.

I find this study is interesting because the climatic and hydrological impacts of ice melting and freshwater input are unclear and have large uncertainty. This study may improve our understanding of future monsoon change and the underlying mechanisms.

*Answer: We thank the reviewer for his/her constructive comments that helped improving the scientific quality of the manuscript.*

However, in some sections, such as the introduction and results, the authors present quite a large amount of details of all monsoon regions one by one which is hard to follow. The coherence should be improved. In addition, the methodology and novelty need to be clearly presented or highlighted before publication.

*Answer: We tried to simplify the introduction and avoid repetitions. We also underlined the novelty of this manuscript.*

### Major comments:

Freshwater input is added continuously between 2020 and 2070. What is the rate of release each year? Is it constant during the 50-yr period? More details on the process of release will aid the reader to fully understand the setup of the water hosing experiments and your analysis. I think something like Figure 3 is a good example.

*Answer: The annual rate of freshwater release is constant during the 50-yr period (2020-2070). The flow rate is 0.68 Sv for the GrIS3m and WAIS3m scenarios and 0.22 Sv for the GrIS1m scenario. 1 Sv corresponds to  $10^6 \text{ m}^3 \cdot \text{s}^{-1}$ . The annual volume of freshwater release is 21 444, 480  $\text{km}^3 \cdot \text{year}^{-1}$  for GrIS3m and WAIS3m and 6 937,920  $\text{km}^3 \cdot \text{year}^{-1}$  for GrIS1m (see details below).*

$0,68 \cdot 10^6 * 3600 * 24 * 365 = 21\,444\,480 \cdot 10^6 \text{ m}^3 \cdot \text{year}^{-1}$  and so  $21\,444\,480 \text{ km}^3 \cdot \text{year}^{-1}$

$0,22 \cdot 10^6 * 3600 * 24 * 365 = 6\,937\,920 \cdot 10^6 \text{ m}^3 \cdot \text{year}^{-1}$  and so  $6\,937\,920 \text{ km}^3 \cdot \text{year}^{-1}$

We added the following sentence [lines 173-174]: "The annual rate of freshwater release (0.68 Sv or 0.22 Sv depending on the simulation) is constant over 2020-2070."

Lines 112-115, and Lines 381-387: It seems that some previous studies have done similar work to yours. What's the difference and did you gain some new findings in this work? Your novelty and key results should be highlighted.

*Answer: The main novelty of our study relies on a detailed analysis of monsoons response to rapid ice-sheet melting at the ocean-atmosphere-cryosphere interface. Former work from our team focused on the African monsoon (Defrance et al., 2017) and the Köppen classification at global and regional scale, while omitting a detailed analysis of all monsoon systems and mechanisms at play (changes in large scale dynamics and relationship between rainfall and moist static energy).*

To underline the innovative aspect of our study we have added the following paragraphs:

In introduction:

*Lines: 133-138 "Previous studies have shown that freshwater release from melting ice sheets can have a major impact on climate (Defrance et al., 2017, Defrance et al.2020). However, the response of global and regional monsoons to such rapid ice melting has not been investigated in great details. The main objective of this study is to determine the impact of melting ice sheets on global monsoon but also on each regional monsoon using detailed analysis of mechanisms at play. In this study we highlight potential changes in rainfall seasonality and intensity using Hovmöller diagrams. We also investigate mechanisms at play at the ocean-atmosphere-cryosphere interface and assess the relationship between rainfall changes and moist static energy using the IPSL-CM5A-LR model."*

Line 380: The choice of scenarios and climate models has a strong impact on the robustness of the results. What is the impact of the two factors on your results?

*Answer: This sentence in the text was not very clear. We discuss the differences between our scenarios extensively in the text, but we only used one climate model (a multi-model risk assessment would require more funding and partners involved). This statement is based on a study by Stouffer et al, 2006, which is a multi-model analysis of the impact of different freshwater release simulations. We have added details to this paragraph to improve clarity:*

*Lines: 420-433 "The choice of scenarios and climate models has a strong impact on the robustness of the results as demonstrated by Stouffer et al. (2006). Stouffer et al. (2006) conducted a multi-model analysis in pre-industrial climatic conditions using freshwater inputs of 0.1 Sv and 1 Sv (to compare to 0.22 Sv and 0.68 Sv in our simulations). All climate models simulate a temperature decrease over the Northern Atlantic and Greenland, consistently with our findings, but the responses between climate models vary significantly over other regions of the Northern Hemisphere. A southward shift of the ITCZ is also simulated by other climate models and this change was robust with the addition of +1 Sv. Pressure gradients change, resulting in a north-south pressure force that pushes the rain belt southward, this phenomenon is also confirmed by the proxy studies carried out by Mulitza et al. (2008); Marzin et al. (2013b) and Liu et al. (2020). The addition of fresh water into a hemisphere leads to cooling of that hemisphere and a southward shift of the ITCZ is simulated in response to fresh water inputs in the North Atlantic, regardless of*

*the selected climate model. Regarding the choice of scenario, the northern or southern location of freshwater input plays a crucial role in the see-saw effect. The amount of added water also impacts the intensity of changes. For example, the spatial and temporal trends between the GrIS1m and GrIS3m scenarios are similar, but much more pronounced with the latter for which a larger amount of freshwater is released. For the WAIS3m scenario, the freshwater disturbance tends to be diluted by circumpolar currents in our simulations."*

The authors study the monsoon changes at both global and regional scales. However, global monsoon includes land and sea areas while regional monsoon is only limited to land area. This should be clearly noted in the methodology, subtitle or caption. Please add "land monsoon" or something similar to avoid misunderstanding.

*Answer: This is an important point indeed. For the sake of clarity, we have modified the methodology section as follows:*

*Lines: 206-209 "Monsoon areas consist of any land grid point corresponding, in at least one of the simulations, to the aforementioned criterion (Lee and Wang, 2014). Thus, the selected monsoon areas include monsoon regions for historical and scenario simulations (RCP8.5, GrIS1m, GrIS3m, WAIS3m). All land grid points per monsoon region were retained to derive spatial averages, except for the AUSMC box for which one outlier (southernmost point) was removed. Only Land data was considered."*

*Lines: 229-232 "Six indices, defined by the Expert Team on Climate Change Detection and Indices (ETCCDI), were used to determine changes in daily rainfall extremes and statistics per land monsoon region (Sillmann et al., 2013): the average precipitation ( $P_{av}$ ), the number of rainy days ( $R_{1mm}$ ), simple precipitation daily intensity index ( $SDII$ ), seasonal maximum 5 days precipitation total ( $RX5day$ ), seasonal maximum consecutive dry days ( $CDD$ ) and seasonal maximum consecutive wet days ( $CWD$ )."*

*Accordingly, we also updated the following captions:*

*"Table 2. Definition and description of land monsoon indices, during monsoon period, used in this study."*

*"Figure 10. Comparison of the interannual variability of each land monsoon index for the period 2041-2070 with the average of the historical period (1976-2005) for a) NAMS, b) SAMS, c) NAF, d) SAF, e) SAS and for each simulation. RCP8.5 is shown in red, GrIS1m in green, GrIS3m in blue and WAIS3m in purple."*

### **Minor comments:**

Line 16: tropical regions with perennial rain regime are not belong to monsoon regions.

*Answer: Corrected*

*Lines: 17-19 "Monsoons influence tropical regions without perennial rain regime, providing the vast majority of rainfall in one season (Wang and Ding, 2006). Consequently, monsoons have a significant impact on two thirds of the world's population (Wang and Ding, 2006; Moon and Ha, 2020)."*

Line 19: add some early seminal refs on land-sea temperature contrast in addition to Zhou and Zou, 2010, such as Li et al., 1996.

*Answer: We have added the reference to Li et al., 1996, as well as two references (Sutton et al., 2007 & Fasullo, 2012) about changes in ocean-land temperature contrasts in the context of climate change.*

*Lines: 20-24 "Monsoons are related to atmospheric moisture content, land-sea temperature contrast (Li and Yanai, 1996; Sutton et al., 2007; Zhou and Zou, 2010; Fasullo, 2012), thermodynamic and dynamic features (Kitoh et al., 2013; Endo and Kitoh, 2014), land cover and use (Timbal and Arblaster, 2006), atmospheric aerosol loadings (Lau et al., 2008) and vegetation physiological effect of rising atmospheric CO2 (Cui et al., 2020)."*

Lines 19-20: monsoon is also impacted by other possible drivers such as thermodynamic and dynamic (Kitoh et al. 2013; Endo et al., 2014), vegetation physiological effect of rising atmospheric CO2 (Cui et al. 2020).

*Answer: Agreed, see former paragraph.*

Line 21: the order of first and last names of the authors is not correct. Please check.

*Answer: Thank you we have carefully checked but we have not found the error. Only the last names are listed in the core text and we did not find an error in the bibliography at the end of the paper.*

Line 31: important?

*Answer: Yes, we think this is an important precision. This is a well-known bias in the literature and for ethical purposes it is an important uncertainty to mention. Moreover, it justifies our choice to study a long time period (30 years) in the medium term (2040-2070).*

Lines 33-34: total precipitation is projected to decrease in the North American monsoon regions by CMIP5/6, e.g. Wang et al., 2021.

*Answer: We have added the reference to Wang et al., 2021 to mention differences across GCMs.*

*Lines: 58-59 "For the NAMS, a decrease in precipitation is simulated over the 21st century, although significant differences are shown across GCMs (Wang et al., 2021)."*

Lines 43-66: the authors only list previous studies by monsoon regions and some of them are common knowledge. Shortening these sections may improve the coherence and legibility.

*Answer: We did our best to reduce this section, but another reviewer asked to include more references so we have tried to simplify this paragraph while adding extra references. We hope that this part now reads better but it is still detailed.*

Figure 4f ,h: the precipitation shows contrasting change in north and south Equator at very short distance in tropical America and Atlantic. What's the reason for this strange phenomenon?

*Answer: The release of fresh water into the North Atlantic modifies the wind and pressure patterns (Figure 4f-h). An increase in pressure is shown where a significant decrease in rainfall is also shown in Northern Hemisphere particularly visible between 60°West and 120°West and between 0 and 30°North. In the southern hemisphere, in the Atlantic near the equator, decrease in atmospheric pressure is associated with a rainfall increase. This is a dynamical shift, pressure changes push the rain band southward. In addition, changes in Moist Static Energy (MSE) are consistent with simulated rainfall changes in the Tropics (the MSE analysis was required by another reviewer).*

Line 278: how did you infer double ITCZ from Figure 6?

*Answer: The double ITCZ is shown on Figure 6 with the presence of two distinct rain bands over the Pacific Ocean, which is a standard bias in coupled GCMs. We have added this precision:*

*Lines: 307-308 "All model experiments tend to simulate a double Intertropical Convergence Zone (ITCZ), highlighted by the presence of two distinct rain bands over the Pacific Ocean, a classical drawback in state-of-the-art GCMs (Fig. 6)"*

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