Response to anonymous referee #2

We thank the referee for their constructive comments, which will certainly help to shape this manuscript into an improved paper. We provide here our responses to each comment and/or question made and how we will modify the manuscript as a result. The referee's comments are in blue, and our response in normal text.

Summary: this paper describes the climatic controls on the surface mass balance (SMB) of the North and South Patagonian Icefields (NPI, SPI). This is achieved by estimating the annual and seasonal SMB with a simple snow, firn and ice accumulation and ablation model, subsequently regressing the SMB-anomalies time series to a suite of local, regional and climate indices. Results indicate that winter precipitation and summer temperature anomalies are the main drivers of SMB interannual variability. Also, the authors find that a pressure anomaly over the Drake's passage (the Drake low) is the dominant feature related to SMB departures, seemingly driving increased westerly winds and cooler conditions off the coast of Patagonia. No significant correlation was found between the SMB and major climate indices such as ENSO, which confirms previous work published in the area.

General comments: this is a well written paper, and is a nice contribution to the understanding of the NPI and SPI present-day behavior. The authors have taken preemptive actions to prevent the inevitable modeling uncertainties from affecting their conclusions, by focusing on correlations/anomalies only and by ensuring that potential biases in the meteorological forcings of the SMB model don't result in major changes in the year-to-year variability, measured through correlation and standard deviation of the time series. The organization of the manuscript is very intuitive and the use of English language is appropriate but for a few minor issues. Because the analysis rests so strongly on the simulated mass balance, the manuscript should devote a bit more space to discussing the calibration of the four main parameters of the model, namely the threshold at which precipitation falls as snow (here set as 2°C), and the ablation parameters (albedo, c_0 and c_1). The sensitivity of the model to these parameters should in turn influence the interplay between precipitation and temperature during the accumulation season, and the relative influence of radiation and temperature during the ablation season. It may be that the main conclusions don't change with respect to what is shown in the current version, but so far the paper seems to gloss over this topic in a manner too succinct.

We thank the referee for these valuable comments. We realize the importance of devoting more space to discussing the calibration of the main parameters of the model. In a revised version of the manuscript, we will perform sensitivity analyses for each one of the calibration parameters, varying their values within appropriate intervals and assessing the temporal variability of the SMB associated with each outcome. We will show the results in separate Taylor diagrams. These figures will be included in the supplementary material and they will be discussed in the manuscript.

Specific comments:

L132: It is not clear to me what the verification of RegCMv4 against CR2MET intends to achieve. There are clear biases shown in Fig2, which could result from several factors. Because you have threshold term in accumulation that depends on T, this bias in temperature could have compounded effects on the simulated SMB correlations. Do you do anything after verifying the two products against each other?

We compare the RegCMv4 against the CR2MET in order to verify the interannual variability of the main variables and to get an estimation of the possible biases in temperature and precipitation. With these estimates we performed a sensitivity analysis in order to ensure that the interannual variability of the SMB would not change even if there were biases in temperature and precipitation as large as those indicated in Fig. 2c. In this manner, the verification of the RegCMv4 against the CR2MET let us guarantee that the temporal variability of the SMB is maintained even after considering the compound effects of biases in the main meteorological variables.

L201: snow, firn and ice should not be called “soil”. Please use something like “land cover”.

We thank the referee for pointing this out. We will use “type of surface” instead of “soil” when referring to snow, firn and ice.

L210: in modeling parlance, “true” has a very specific meaning. Please revise.

We thank the referee for pointing this out. We will reformulate the paragraph accordingly.

L218: See general comments regarding the detail that is needed about the SMB model calibration process. Also, why do you compare the 2000-15 simulation with the 2000-19 Minowa estimates? Is it not possible to compare a common period?

Please see our response to the general comments. Regarding the periods of comparison, Minowa et al. estimates were informed only for the full 2000-19 period. Consequently, we are only capable of comparing our results against that period.

L229: These biases could also result from inadequacies in the CR2MET product. In particular, if it is station-based, previous research has shown that meteorological station data in Patagonia is unreliable, particularly precipitation.

In this part of the paper, we used the CR2MET in order to estimate the magnitude of the possible biases in temperature and precipitation. We agree with the referee in that these biases could result also from inadequacies in the CR2MET product, but in this step we were motivated in deriving optimal intervals for performing the sensitivity analysis rather than determining the origin of the biases.

L231: a similar analysis could be performed by perturbing some of the model parameters (see general comments).

Please see our reply to general comments.

L260: If I understand correctly, AAO was calculated only for the 1979-2000 period? But SMB is available until 2015? Maybe it’d be useful to have a summary table with all datasets used, indicating time window, time-step, and citation.

We used the AAO data computed for every day from 1980-01-01 to 2015-12-31. The daily value of the AAO can be calculated for any date, projecting the daily height anomalies at 700 hPa poleward 20º S onto a particular atmospheric pattern. To derive that pattern (the leading mode of EOF analysis of monthly mean 700 hPa height) it is considered only the data between 1979 and 2000. In a revised version of the manuscript, we will include a summary table with all datasets used as suggested.

L272: please reword to remind the reader that all these numerical quantities are estimates from your model. Also, the fact that annual SMB is positive means that for the ice fields to be in equilibrium (or decreasing in mass, as the literature suggests) then calving should account for the excess mass. Is that right? Also: there appears to be a slight increasing trend in the simulated SMB? Could you comment on this?

We thank the referee for this comment. 1. We will reformulate the paragraph as suggested. 2. Yes, calving accounts for the excess of mass. We will mention this in a revised version of the manuscript. 3. Precisely, there is a slight increasing trend in the simulated SMB, associated with a positive trend in the simulated precipitation. Nonetheless, in this investigation, we decided not to focus on the trend of the variables in order to maintain the purpose of the investigation delimited.

L298: How do you interpret the fact that although insolation shows the second-highest correlation with annual SMB (line 287), then the local-scale control indicates exactly the opposite? Maybe I'm missing something, but these two results seem inconsistent. Please clarify. Is this result sensitive to assumptions regarding the seasonal evolution of snow, firn and ice albedo? Nevertheless, it is expected that, unlike glaciers in mediterranean regions, solar radiation should have a minor role compared to temperature in Patagonia. High relative humidity and high very persistent cloud cover are coherent with this result.

On the one hand, the fact that insolation shows the second-highest correlation with annual SMB (r=-0.44*) does not necessarily imply that annual variations of insolation exert an effective control over the annual variation in SMB. We interpret the correlation between insolation and SMB as a mere consequence of the correlation between insolation and precipitation (r=-0.53*) due to the presence of clouds and the diminishing of solar radiation when precipitating. As precipitation shows the best correlation with SMB (r=0.69*), this covariance necessarily will be reflected in the insolation.

On the other hand, the local-scale analysis shows a negligible dependence of the annual SMB on insolation. To give a more detailed interpretation of this result, please consider again the eq. 5 and assume snow as the type of surface. To compute the effect on the surface energy flux of an insolation anomaly we have to multiply the anomaly by a factor 0.15, while in the case of temperature this factor increases to 9.5. For instance, a temperature anomaly of one standard deviation (0.37 ºC if we use the std. dev. of the annual time series to estimate the magnitude of typical deviations) implies an addition of 3.5 W/m^2 to the surface energy flux while an insolation anomaly of one standard deviation (4 W/m^2) adds only 0.6 W/m^2. Thus, temperature anomalies have a greater influence on the ablation field than insolation anomalies (with an approximate ratio of 7:1). This does not contradict the previous result about correlations because the local-scale analysis assesses the causes of the year-to-year variations of the SMB, while the correlation analysis does not assess causality.

L406: a small detail: probably "good" is not an appropriate adjective for describing correlation.

We thank the referee for pointing this out. We will change this word to a more appropriate adjective in a revised version of the manuscript.

L446: suggest replacing "maintains" with "remains".

We thank the referee for this suggestion. We will change this word accordingly.