

## ***Interactive comment on “A record of Antarctic sea ice extent in the Southern Indian Ocean for the past 300 yr and its relationship with global mean temperature” by C. Xiao et al.***

**C. Xiao et al.**

doutf@ucas.ac.cn

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(1) The paper assumes that the relationship is straightforward between MS- and sea ice at this location. Given that the correlation coefficient is only 0.4, i.e., the variance in sea ice explains only 16% of the variance in MS-, a stronger argument can be made for the relationship if the authors examined and presented in detail the relationship between MS- and the wind field, SAM index, precipitation at the site, etc. If the dominant relationship remains with sea ice, it bolsters the case that long term variations in MS- reflect changes in sea ice in these sectors. Abram et al., (2010) methodically step through the various possibilities in their paper regarding ice extent in the Belling-

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shausen Sea, and I'd suggest a similar methodology here. Before publication, more detail in describing and establishing the link for MS- and sea ice at this particular ice core location is necessary.

Reply: We agree with this argument. The correlation coefficient, using a different SIE data set, as suggested by reviewer 4, is now 0.5 and explains 25% of variance. We investigated and strengthen this in three ways. (i) Identifying moisture sources by backward air mass trajectory analysis (Figure 2). This shows that, from an atmospheric circulation point of view, dominant mass sources come from high altitudes of SIO, lying in the sectors which the MS- and SIE correlation indicates; (ii) We also suggest that meridional circulation, especially southward wind from the same sector of SIO, favors deposition of MSA at LGB69 (Figure not shown); (iii) SAM can partly interpret SIE changes in the last decades, as indicated by Figure 6 and related text.

(2) I have strong reservations about sections 3 and 4. Section 3: Sea ice extent and global temperature. It is not clear why the authors seek a relationship with global surface temperature or with NH surface temperature. Let us assume that Antarctic sea ice extent should covary with global mean temperature, by the argument that global surface mean temperature is an indicator for surface radiative forcing. (We'll ignore the most recent decades where SIE does not covary with temperature.) One might expect that in general this relationship works for total circumpolar Antarctic sea ice extent. It is already mentioned in the manuscript that the regional sea ice extent variations is not coherent, primarily due to the variability in surface wind forcing around the continent. If in fact the sea ice extent reflects the global mean temperatures, it would be at least necessary to show first that the variability of sea ice extent in 70-100E is indicative of the circumpolar sea ice extent variability. Otherwise, there is no reason to expect that SIE in this region would have any particular relationship with temperature. Or that an observed relationship between SIE in this sector and global temperatures carries any meaning to understanding circumpolar ice conditions. It is not clear that the correlation with SAM at this point is helpful. Perhaps it should be investigated at the presentation

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of the record as one of the potential influences on the MS- record. See also comment below regarding correlation to SAM.

Reply: Thanks for this comment. There is no generally accepted (standard) SH temperature curve, only regional records. But we do now use an Antarctic record (by PAGES 2K group, from Antarctic ice cores) for investigating the SH relationship. We agree with you that we should show firstly that if the variability of SIE in 70-100E (now 62-92E when using the updated SIE data) is indicative of the circumpolar SIE variability. The correlation between the two is  $\sim 0.4$  and is now discussed in the paper (see added Figure 5). The correlation between the whole Indian Ocean sector and circum-polar SIE, it is 0.55. Therefore, changes of SIE over SIO do carry some signals of circum-polar changes, and we should investigate the relationship of MS- with global temperature.

(3) Section 4: Sea ice changes over the wider Indian Ocean. Though comparison of these two ice cores may be slightly useful, it is not clear that any relationship should exist between the sea ice extent in the two sectors. In Fig 2b, a comparison of the 70E sector to the sectors between 80E and 140E shows little correlation. Why then would one expect the long term reconstructions to resemble each other in any way?

Reply: We disagree with the reviewers comment on this point. Fig 2b shows only that the LGB ice core MS does not give a good record of sector 80-140 SIE. It says nothing about how SIE in the two sectors may respond to a similar climate driver. One of our major conclusions is that MS- records from ice cores provide only a regional proxy of SIE, and that, hence, to reconstruct a circumpolar SIE record we need many (near-coastal) ice core records. We are addressing that with two high resolution ice cores over the Southern Indian Ocean. We expect there might be some similarity between the adjacent sectors of SIO, and readers might also be curious about the comparison. Many scientists (including reviewer-1 of this manuscript) also suggest the possibility of integrating a continent-scaled reconstruction of SIE history by combine proxies from different sectors of Antarctica.

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(4) Specific comments: P3613 L27 Please give the snow/SWE accumulation rate in the text. Reply: Accepted and done. P3615 L20 'The LGB69 MS...' In order to present the relationship between MS- and temperature as credible, one needs to quantify it. It's not clear just from comparing the two curves by eye.

Reply: As discussed in our response to reviewer-2 , NH temperature data is not evenly distributed thus not able to be used calculating their correlations quantitatively. P3615 L26 'We suggest that this paradox ...' Steig et al., (2009) have shown that Antarctic temperatures have been warming across the continent in recent decades, though the changes in E. Antarctica are smaller than on the Peninsula and W. Antarctica. Reply: There have been several controversial conclusions on this. For instance, an overview paper by Mayewski et al in Reviews of Geophysics (2009) suggest slight cooling in East Antarctica, which is more widely accepted. Most recently, IPCC AR5 gives no clear statement for Antarctic surface temperature change in the past decades because of inadequate evidences (Figure 2.22, IPCC WG1 AR5). . P3616 L8 'Both the summer SAM ...' The relationship with SAM could be tested with the SIE and MS- records for the calibration period to check to see whether the possible relationships between SAM and MS- or SAM and SIE exist. That would help remove some of the speculation about the reasons for the correlation in this paragraph. Also, it's not clear why a positive SAM favors transport of MS- to the continent. Reply: We investigate their relationships, and notice reasonably high correlation between MS- and SAM which is now discussed in the revised paper. We suggest more positive SAM may favor cooler and produce more sea ice, thus responsible for some portion of MS- .Please see details in the Linear correlation figure at the end of this file.

P3617 L10 'The proxy record...' This seems to be a bit of circular logic: The proxy is calibrated to satellite sea ice extent including the period since 1985, but then it is stated here that the proxy confirms that the sea ice extent increases during the same period. Reply: OK we change this sentence so to avoid circular logic. Fig 3a. Is the SIE curve smoothed? The SIE values in the yellow curve do not seem to match the values in the

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the inset scatter plot. Reply: No, we use annual SIE data both in curve and inset, they are the same data.

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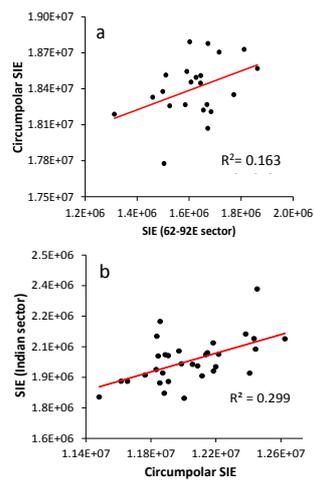


Figure 5. The linear correlation between SIE at (a) the sector highest-correlated with LG869 MS- (62°E-92°E), and (b) the whole Indian Ocean sector (30°E-105°E) with the total circumpolar SIE for August to October, 1979-2000 (unit: km<sup>2</sup>).

Fig. 1.

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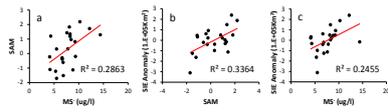


Figure (has not been included in the revised manuscript): Linear correlations between SAM and MS- (a), SIE and SAM (b), SIE and MS (c) for the period 1979-2000.

**Fig. 2.**

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