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Interactive comment on "Influence of meltwater input on the skill of decadal forecast of sea ice in the Southern Ocean" *by* V. Zunz and H. Goosse

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The authors thank Anonymous Referee #1 for the careful reading and for the constructive and encouraging comments on the manuscript. We will take his/her remarks into account in the revised version of the manuscript as detailed below.

The referee's comments are in italic font and the author's response in upright font.

Response to Anonymous Referee #1's comments

The authors assess the impact of an unspecified additional freshwater flux on

the trend in simulated Southern Ocean sea ice extent and concentration using an 'ensemble' simulation with data assimilation for the period 1850–2009 as well as different hind- casts all initialized with assimilated data of 1980 and extending to 2009. For simulations with data assimilation and an additional freshwater flux the trend in sea ice extent and concentration from 1980 to 2009 improves the reconstruction. The hindcast simulations also have to be forced by an additional freshwater flux to avoid a model drift. Since the resulting trends in sea ice extent and concentration are in satisfying agreement with satellite observations, the authors are optimistic to have found an experimental design for sea ice predictions in the Southern Ocean. They also claim that the positive sea ice trend over the last 30 years is mainly determined by the ocean state in the late 1970's and does not need an increased meltwater flux from the Antarctic Ice Sheet as previously stated by others.

General comments:

The paper represents an interesting study especially with regard to recent claims relating the observed positive sea ice trend, although this has been questioned lately (Eisenman et al., 2014), to an increase in ice shelf basal melting. With this new view on the satellite measurements the authors might have to discuss their results from a slightly different perspective, i.e., the NODA and NOFWF simulations (Fig. 2) might be closer to reality than originally thought. However, their analysis provides additional evidence for the previous misinterpretation of the impact of ice shelf basal melting on the Southern Ocean sea ice extent.

Therefore, I urge the authors to consider this new finding thoroughly when analyzing the model results, but if done, I recommend publication in TC after consideration of the comments/corrections listed below.

Response: The recent work of *Eisenman et al.* (2014) indeed raises the issue whether the Antarctic sea ice extent has increased at a statistically significant rate during the last 30 years or not. The sea ice extent derived from the version 1 of the Bootstrap algorithm displays a trend of 6.3 $\times$ 10^6 km^2 yr^{-1} between 1979 and 2004 while the version 2 of the Bootstrap algorithm provides a trend of 14.8 $\times$ 10^6 km^2 yr^{-1} over the same period. Although it has not been demonstrated which version is closer to reality yet, we agree that it is important to discuss the results of our simulations with regard to the datasets derived from both versions of the Bootstrap algorithm in order to determine the influence of the related uncertainties on our conclusions. In the initial version of the manuscript, the observations of the sea ice extent correspond to the sea ice index (*Fetterer et al.*, 2002, updated daily) which is derived from sea ice concentration estimates from the NASA Team algorithm (http://nsidc.org/data/docs/noaa/g02135_seaice_index/). The trend in sea ice extent computed from the sea ice index is very close to the one computed from the version 2 of the Bootstrap algorithm. Our simulations NODA and DA_NOFWF provide trends in sea ice extent that are closer to the trend derived from version 1 than version 2 of the Bootstrap algorithm. Nevertheless, both simulations have more negative trends than the ones derived from observations. Among these two simulations, DA_NOFWF provides a trend in sea ice extent that is the closest to version 1 of the Bootstrap algorithm. Therefore, our conclusion that the data assimilation procedure used here improves the simulated trend in sea ice extent remains valid. Besides, the conclusion that including an additional freshwater flux in our simulation with data assimilation improves the agreement with data depends on the reconstruction selected and is thus not robust.

Action: In the revised version of the manuscript, we will replace the sea ice extent data from the sea ice index by the sea ice extent estimates based on the version 2 of the Bootstrap algorithm in order to be consistent with the observation dataset used for the sea ice concentration. In Sect. 1 Introduction, we will draw attention to the the different results of the two versions of the Bootstrap algorithm. In Sect. 2 Methodology,

we will specify that our results are, unless specified, compared to the observations of the sea ice concentration and extent derived from the version 2 of the Bootstrap algorithm, as done in many studies. In Sect. 3 Results, our results will be discussed with regard to the trends estimate derived from the two versions of the Bootstrap algorithm. In Sect. 4 Summary and conclusions, we will summarise the impact of the uncertainty of the observed trend on our conclusions.

Specific comments:

1. *The authors consider an unspecified additional freshwater flux which can but does not need to be related to ice shelf basal melting. Therefore, I recommend to modify the title to 'Influence of freshwater input....'*

   Response: We totally agree with this suggestion.

   Action: The title will be changed to “Influence of freshwater input on the skill of decadal forecast of sea ice in the Southern Ocean".

2. *The authors distribute the additional freshwater within the sector 0°to 170°W. Although I understand the rational behind, I question its applicability. The Filchner-Ronne and Ross ice shelves can be considered as 'low-melters', so why including the Weddell Sea and part of the Ross Sea? On the other hand, the coasts of East Antarctica are receiving most of today's precipitation, which will end up in marginal seas not included, and will be transported westward with the Antarctic Slope Current. The authors should show the difference with regard to sea ice extent for a circumpolar vs. sectoral distribution of the freshwater.*

   Response: Distributing the additional freshwater flux within different sectors indeed impacts the results of a simulation. Nevertheless, we want to keep the spatial distribution of the additional freshwater flux as simple as possible to limit the parameters associated with the additional freshwater flux. We have chosen a

simple spatial distribution that seems reasonable compared to the observations. Investigating in detail the influence of the spatial distribution of the freshwater flux would certainly provide insightful results and this issue should be tackled in future studies.

Action: In the revised version of the manuscript, we will point out that the choice of the sector over which the additional freshwater flux is distributed may impact the results of a simulation, in particular the spatial structure of the trend in sea ice concentration. We will also discuss the effects of different magnitudes and frequencies of variations of the freshwater flux in additional simulations, as suggested by Referee #2.

3. *Several figures, in particular Figs. 2, 4, 5, and 7, are too small to read labels, annotations, etc.*

   Action: We will pay particular attention to the size of these figures in the final printed version in order to ensure their readability.

Technical corrections:
P 3571/L10: ...flux from the estimate of the . . ...
P3572/L06: . . .,south of 70°S (area....
P3572/L18: ...inherit the value...
P3573/L16: ...consist of weighted averages.
P3574/L24: ...(Fig. 2a and 3b),...
P3575/L16: ...(green solid lines in Fig. 4a and b).
P3575/L20: ...(Fig. 4c).
P3576/L09: ...increase in the eastern Weddell Sea,..
P3577/L13: ...Bellingshausen and....
P3581/L27: If the decrease in the western part of the Southern Ocean is considered to be too large, it should also be mentioned that the increases in the Weddell and Ross seas are too low.

Action: The technical corrections listed above will be included in the revised version of the manuscript.

References

Comiso, J. (1999, updated daily), *Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I-SSMIS. Version 2, January 1980 to December 2009*, Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center.

Eisenman, I., W. N. Meier, and J. R. Norris (2014), A spurious jump in the satellite record: has antarctic sea ice expansion been overestimated?, *The Cryosphere*, *8*(4), 1289–1296, doi:10.5194/tc-8-1289-2014.

Fetterer, F., K. Knowles, W. Meier, and M. Savoie (2002, updated daily), *Sea Ice Index, January 1980 to December 2009*, Boulder, Colorado USA: National Snow and Ice Data Center, doi: http://dx.doi.org/10.7265/N5QJ7F7W.

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