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The Cryosphere
Discussions

Interactive comment on “Mechanisms causing reduced Arctic sea ice loss in a coupled climate model” *by* A. E. West et al.

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Replies to comments by Referee #2

> Could not see temporary ice loss slowdown in Wang and Overland paper.

This is because they show only one ensemble member (ANT 1), in which the slowing is less severe than in four other members. In addition, the same approximate change in gradient naturally looks less striking in one ensemble member than it would in many plotted on the same graph.

Will add the following clarification after the sentence ending page 2657, line 15. ’; this is not apparent in Wang and Overland 2009 because they show only one ensemble member (ANT 1) in which the slowing is less severe than in many other members.’

> In Wang and Overland (2012) the HadGEM2 models do not show any halts in September ice loss. There are however decadal signals in other models, and also in the Massonnet et al paper.

True, there is no similar signal in the HadGEM2 models, which tend to lose ice much faster than the HadGEM1 runs. It is interesting reading the Massonnet paper, which shows ’phase-space’ plots of ice extent versus rate of change of ice extent; virtually all models follow a U-shaped curve, with initially slow loss, then speeding up, then slowing down again as zero ice is approached. When a similar phase-space diagram is plotted for the HadGEM1 runs in question (Figure 1), an asymmetric ’double-dip’ pattern appears; there is a smaller U corresponding to the fast ice loss in the 1990s and the subsequent slowdown, then a larger U after 2030 as the remaining ice is lost. According to the Massonnet Figure 4, no CMIP5 model shows a similar trajectory, and HadGEM1 would therefore appear to be fairly unique in this regard. Which reinforces the suggestion that its behaviour will not be closely matched in reality.

> I suspect however in the real world in future decades as the warming trend accelerates (rather than the 90s than the authors talk about in the discussion) that the flushing of multiyear ice from the Arctic will only have multi-annual rather than decadal effects on slowing the ice covers rate of retreat.

Yes, this is probably one reason why the behaviour is not seen more widely in models. In HadGEM1 the ’flushing’ is possibly able to have effect over a slightly longer timescale because it is strongly concentrated at a particular place and time. But the ocean changes will nevertheless be crucial in causing the interdecadal changes.

> It might be more useful to include the actual time series you used for Figure 3 so that the reader can match the variability with the time of the ice variability.

Yes. As the two panels of Figure 3 are fairly similar it might be better to replace the first panel with timeseries of global and Arctic temperature, to allow the cross-referencing mentioned by the reviewer. The second panel would then show the scatter plot between global temperature and September sea ice extent; it would be remarked that the relationship between Arctic temperature and SSIE is similar, but with a smaller spread.

> Line 23, p2659; suggest reword time mean control the same as in figure caption.

Good idea.

> As an aside did you look at the decadal variability in the control, whilst there may not be as much a trigger from increased northward heat transport as in the historical-recent period, did any of the other mechanisms seen in this study show up, for example the impact of the flushing of the ice from the Arctic basin.

We have just had a brief look at a 90-year period of the control run, and indeed there is an intriguing rapid ice loss event in the Western Arctic region which is followed, 5 years later, by a considerable increase in total Arctic ice volume. This occurs about a decade earlier than the similar events in the ALL runs (and about 20 years earlier than those in the ANT runs), suggesting that the timing in the latter is caused at least partly by the forcing. Will attempt to investigate to see if the mechanisms are similar to those in the perturbation experiments.

> In line 11 p2660 and line 3 p2261 you talk about sharp drop and sharp decrease. As these are both negative and your sign convention is positive northwards I would rephrase them as change in outflow of the ice transport it reads more logically.

True, but be aware that positive northwards ice heat transport is equivalent to positive southwards ice export; ice volume is equivalent to negative heat energy, so the sign changes. As the mean rate of ice export from the Arctic Ocean is indeed positive southwards, discussing 'sharp drops' in this quantity should not be misleading. Figure 5 may be misleading in this regard; the ice heat transport quantities appear negative here because the control time mean has been subtracted, and control ice export is always greater than that in the perturbation experiments.

> I found line 21 page 2661 confusing, though I think it is right to clarify suggest you

say 'ALL IHT drop occurs a decade earlier than that seen in the ALL IHU'.

Will reword as suggested.

> Illustrate periods of increased heat convergence in the Western Arctic region with a figure.

Yes, it would probably be appropriate to illustrate the differing mechanisms of the WA rapid ice loss generally. It would be necessary to add another figure for this - between 7 and 8, and reference at the end of section 3.3. Will aim to include in the final revised paper.

> Fig 6 caption you define WA Western Arctic in Figure 4 not section 4.

Will amend.

> Also you make no reference to the effect of the freshening of the Arctic Ocean/ Greenland Sea system from the ice melt which could also contribute to a reduction in ice-ocean flux and reduce ice melt though I would expect that to occur more on an annual than decadal time scale.

Yes - one natural explanation for the slowdown in ice loss would be that the rapid ice melt of the 1990s is freshening the mixed layer and reducing the amount of ocean heat reaching the ice. (We originally actually considered the possibility that low salinity anomalies from the ice melt were escaping into the North Atlantic and helping to cause the drop in the MOC around 2008. As regards this, there were no signs of consistent salinity anomalies moving southwards in the 1990s and 2000s.)

However, the salinity of the top 50 metres of the Arctic Ocean, when examined for ALL 4 (the run with the most severe slowing of ice loss), shows a more or less continuous decrease from 1980-2030 (Figure 2), which is to be expected. The decrease is slowed markedly in the 1990s, and reaches a maximum gradient in the 2010s. This suggests that, along with the changes in ocean heat convergence, decreasing salinity is helping to cause the temporary drop in ocean-to-ice heat flux. However, whether the salinity changes are reacting to rates of ice loss ~15 years in the past is uncertain; it could equally reflect changes in river runoff or ocean currents. It is possible that the weakening of the SPG in ALL 4 commented upon in section 3.4 is linked to this.

The correlation of salinity change with ocean-to-ice flux change will be examined more fully in the revised paper, and an effort will be made to identify a mechanism for the ALL 4 changes in particular.

Interactive comment on The Cryosphere Discuss., 6, 2653, 2012.

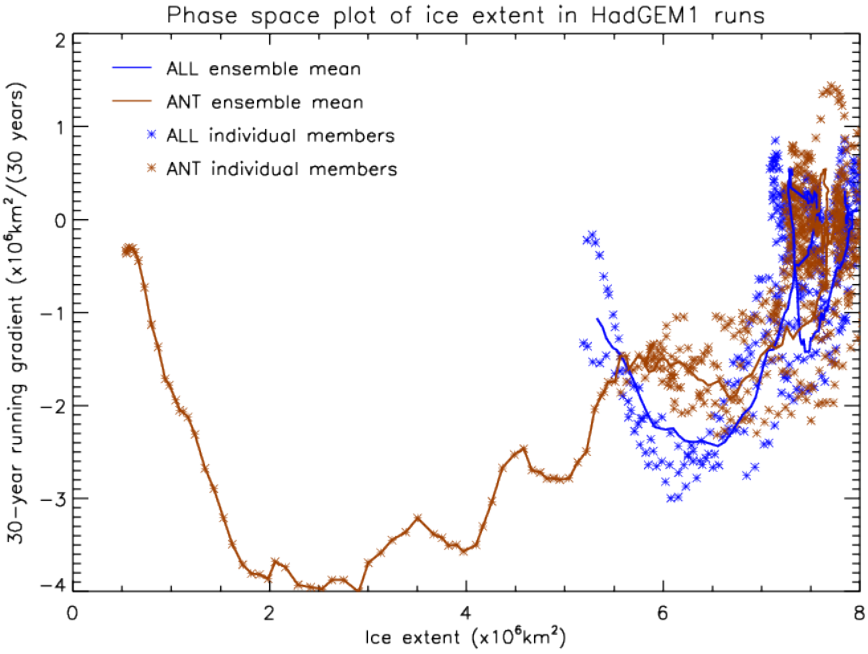

Fig. 1.

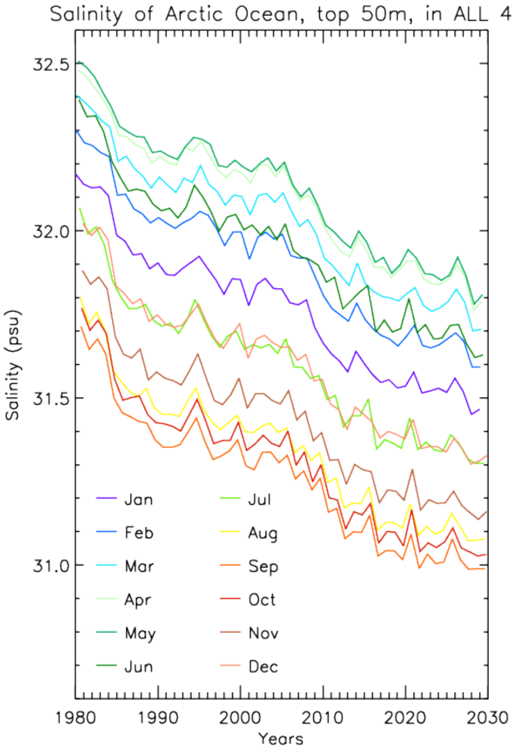
Salinity of Arctic Ocean, top 50m, in ALL 4
Salinity (psu)
32.5
32.0
31.5
31.0
1980
1990
2000
2010
2020
2030
Years
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Fig. 2.