

Interactive comment on “Model constraints on the anthropogenic carbon budget of the Arctic Ocean” by Jens Terhaar et al.

Anonymous Referee #1

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1 Overview

Terhaar et al. ask: what effect does model resolution have on simulated Arctic Ocean anthropogenic CO₂ storage and acidification? The answer: increased model resolution shows higher regional storage by up to 25%, moving the inventory closer to data-based estimates, and increased acidification with faster shoaling of the aragonite saturation horizon.

This is an interesting and useful question, and the study has been well-designed to answer it. The results and their interpretation seem sensible, although as mentioned below, a robust uncertainty analysis is critically lacking.

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The manuscript is interesting and easy to read. The Introduction is very well-written and Methods are clear. Results and Discussion are succinct, but in places the Discussion in particular could be developed further to provide more insight. Many of the questions below are really prompts in this direction.

2 Scientific questions

The highest-resolution model is “still not eddy resolving” (3-28 i.e. page 3, line 28). Does that mean that you would expect further changes still with yet higher resolution? Would you expect the anthropogenic CO₂ inventory to increase even more?

The monthly averaging process introduces an error of 27% for the lowest-resolution model (7-20). This is a similar magnitude to the difference in anthropogenic CO₂ inventory between the different resolutions, which is your most important result. Does this error being the same size as the ‘signal’ not significantly reduce your confidence in the results (i.e. differences between resolutions)?

Following from the previous point, what is the uncertainty in the differences between your inventories at different resolutions? Without a robust estimate of this we cannot trust that they are meaningfully different. This would also aid comparisons with data-based estimates (e.g. in Section 4.3). Section 2.6: the recent decline in atmospheric CFC-12 is problematic for applications of the TTD approach after the concentration peak. Other still-increasing tracers such as SF₆ may be more suitable for this recent period. Could this adversely influence your results, and if so are alternative tracer data available for comparison? Might this be linked to why your simulated CFC-12 underestimates the observations in the upper water column (Section 4.1)?

You note that overestimation of sea-ice cover should reduce air-sea CO₂ exchange (9-14). There are a number of observational studies that attempt to quantify this effect. Can these be used to quantify your statement?

Section 3.4: my impression was that the primary reason to expect model resolution to influence the anthropogenic CO₂ inventory was because of better representation of circulation features. Therefore the increase in lateral flux, being a function of circulation, is expected – but the simultaneous increase in the air-sea flux does not seem so intuitive. Indeed if additional anthropogenic CO₂ is being transported into the region from elsewhere we might expect this to increase total dissolved inorganic carbon and thus reduce net air-to-sea CO₂ flux. Do you have a conceptual explanation for what is driving the air-sea flux increase with resolution?

In order to declare that two things are ‘not statistically different’ (14-12) you must also provide the statistical information that were used to demonstrate this.

Does the increase in resolution alter lateral anthropogenic CO₂ fluxes primarily because of the representation of circulation (1) inside the Arctic Ocean, (2) at its boundaries/interfaces, (3) in the non-Arctic global ocean, or (4) everywhere? You note that for computational reasons we cannot routinely run these models globally at high resolution, but if only one region of the model needed to be at high resolution to achieve your results, would it be possible to strike a balance with a hybrid resolution model?

Some of the notes about possible future work on CFC-12 and the TTD parameters in the Conclusions would probably be more suited to the Discussion.

No other studies have been mentioned that have attempted to answer this same question for the Arctic Ocean, but there have been other investigations of the effect of increased model resolution in various contexts. Do these provide any insights that would be useful in interpreting your results?

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3 Figures

Use of red vs green (e.g. Fig. 3) with no difference in line style can render these lines indistinguishable to colorblind readers.

The blue-green-yellow-red color scale used on transect plots (e.g. Fig. 4) is not perceptually uniform, leading to visual artifacts such as false boundaries.

Depth should be positive going down into the ocean (Figs. 4 and 6).

4 Technical/grammatical notes

There is inconsistency in usage of past and present tenses in the Methods.

The contexts in which the word 'though' is used are highly colloquial and, to me, not suited for scientific writing (2-12, 14-29, 15-8).

Suggested corrections:

- 1-6 eddy-admitting
- 2-3 consequences for
- 4-30 following Moore et al.
- 10-24 (Fig. 6) ?
- 11-21 Arctic Ocean basins
- 15-33 reword this sentence to indicate the direction of the effect

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