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The Cryosphere Discussions

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Interactive Comment

Interactive comment on "Model resolution influence on simulated sea ice decline" *by* J. O. Sewall

J. O. Sewall

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Identifying the level of significance of the differing ice input variables utilized in the various models is cruical. This can be done by a table of correlations. As is I am left wondering if the different handling of the ice variables is significantly influencing the correlation between resolution of the horizontal ocean heat flux and forecast sea ice extent.

Correlations between any single model variable (other than horizontal resolution) with the degree of Arctic sea ice loss at 4x CO2 are generally weak (˜0.2), see Table 2 below. In general (see Table 1 in the original manuscript) the models tend to fall into 2 or 3 groupings in terms of each model characteristic and within each of those groupings there will be models with very little ice loss, and models with significant ice loss. The only model characteristic that removes this spread in each category is horizontal resolution.

Model Characteristics	Correlation to FMA ice loss at 4x CO2
Ice Dynamics (Y/N)	0.23
Ice Rheology (None/VP/EVP/CF)	0.20
Ice layers (number)	0.22
Ice thickness categories (number)	0.14
Flux Corrections (Y/N/Extent)	-0.28

Table 2. Correlation of maximum ice season (February, March, and April averaged; FMA) Arctic sea ice concentration loss at 4x CO2 with model characteristics presented in Table 1. VP = Viscous Plastic, EVP = Elastic Viscous Plastic, CF = Cavitating Fluid.

761 8-9: This is true models have underestimated sea ice loss. Spend additional time on this as improving the model accuracies is key. You have looked to the future and compared forecasts with resolution. What about model errors in hindsignt? A figure or a table could illustrate the specific models and their under representation of sea ice loss to date. This can then be compared to your results of forecasting future loss. Are the same models that have the least sea ice loss in the past, also forecasting the least future sea ice loss.

Stroeve et al., 2007 do a thorough job of assessing model errors in hindsight and I see no reason to repeat their excellent analyses. Stroeve et al., start with 18 models from the [now] CMIP3 dataset and winnow those models based on how close the simulated mean Arctic ice cover is to observed mean ice cover. They continue analyses with those models where simulated mean ice cover is within 20% of the observed mean.

The 18 models analyzed by Stroeve et al., 2007 overlap with 12 of the 14 models in my analyses, with one of the 'missing' models being the GFDL CM2.1 (they include GFDL CM2.0, the two GFDL models plot in the same space in Figs 1 and 2 in my original manuscript).

Of the 14 models I analyze, 9 of the 12 overlap models have modeled ice extent within

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20% of observed extent for September in Stroeve et al. (2007) and those 9 models span low ice loss at 4x CO2 (CCCMA CGCM3.1) to extensive ice loss at 4x CO2 (NCAR CCSM3).

For the entire observed dataset (1953-2006) of Stroeve et al., (2007), no model matches the observed trend, though the model with the closest negative trend in Arctic sea ice cover is NCAR CCSM3 (one ensemble member), an extensive ice loss model at 4x CO2. For the satellite era, Stroeve et al. (2007) find that only 5 of 29 ensemble members from two models compare well with observations (NCAR CCSM3 [extensive ice loss in my analyses] and UKMO HadGEM1 [moderately extensive ice loss in my analyses]).

For March Arctic sea ice extent, all 12 of the 14 overlap models I analyzed have modeled mean ice extent within 20% of the observed mean in Stroeve et al. (2007). However, for the entire observed dataset (1953-2006) of Stroeve et al. (2007), only two models have trends in March ice extent that are within 20% of the observed trend (CCCMA CGCM3.1 [low ice loss in my analyses] and UKMO HadGEM1 [moderately extensive ice loss in my analyses]).

Based on comparisons between the results of Stroeve et al. (2007) and my analyses, it is difficult to draw any robust conclusion regarding the correlation between model performance in hindcast and model predictions. While the majority of the models I analyzed are within 20% of the observed mean, very few capture observed ice loss trends of the past half-century. There is potentially some argument to be made based on September where those models closest to the observed trends are in the high end of ice loss at 4x CO2. However, that comparison is less convincing in the March comparison where my analyses show similar correlations in all seasons, but the hindcast comparisons of Stroeve et al. (2007) show the best comparisons to observed trends from one low ice loss model and one higher ice loss model from my analyses. In addition, Stroeve et al. (2007) include in their analyses the MPI ECHAM5 model, and, while it is the model with the highest ice loss in my analyses, it is not one of the models that more accurately captures observed ice loss trends.

761 13: Save the conclusion for later in the paper.

I see nothing wrong with providing a reader with a partial conclusion at this point to, hopefully, provide incentive to continue reading yet another multi-model intercomparison paper.

Section 2.1 How do you address the various atmospheric resolutions and their potential impact or does that matter?

Atmospheric resolution differences are not directly controlled for. Not surprisingly, models with higher horizontal resolution in the ocean and ice components, frequently have higher resolution in the atmospheric component (correlation coefficient is 0.70).

There is, obviously, also a positive correlation between increasing atmospheric resolution and Arctic sea ice loss (0.58 for February, March, and April average, 0.46 for August, September, and October average, 0.63 for Annual average).

The atmosphere, and, in particular trends in Arctic winter sea level pressure (i.e. the Arctic Oscillation [AO]), has been implicated in recent Arctic sea ice decline (e.g. Stroeve et al., 2007, Deser and Teng, 2008). However, factors other than wind forcing due to a strong positive AO, e.g. ocean heat transport, ice albedo feedback, are also prominent in observed ice reductions and account for persistent ice loss in recent years even as the AO has taken a negative trend. (Deser and Teng, 2008). Under either forcing regime, current models underestimate ice loss (Stroeve et al., 2007). While model inability to accurately capture trends in Arctic winter sea level pressure (e.g. Gillet, 2005) could certainly account for some of the mismatch between observed and simulated Arctic sea ice cover decline (e.g. Stroeve et al., 2007), inadequacies in other components doubtless contribute as well; I will note in particular the strong correlations between Arctic ice loss and poleward ocean heat flux (Figure 4b in my original manuscript) and increased poleward ocean heat flux and increased ocean model resolution (Fig 4a in my original manuscript).

With a spread of 69% in predicted future ice loss at 4x CO2 and the limited capture of observed ice loss (Stroeve et al., 2007), it is unlikely that any single component accounts for the entire mismatch/uncertainty. The data I present suggests that poleward ocean heat flux, as influenced by horizontal ocean model resolution, plays a significant, but not exclusive, role in that mismatch.

Section 2.2 Should lead to a separate figure comparing results just of the resolution change. For the two models. The figure would be added later in the paper.

Figure 3 (original manuscript) compares the ice thickness and concentration differences for the two different ice-only simulations.

763 2-4: Very important sentence. Prove this point to us with a table of correlations for specific ice vairables used by the various models and identified in Table 1.

See response and Table in initial comment/response above.

763 14: Does this indicate ocean modelling was left at the same resolution when the ice modelling resolution changed or is it constant?

These were ice-only simulations so there was no interactive, dynamic ocean component present. Instead the ice model interfaces with an internal thermodynamic slab ocean that calculates changes in sea surface temperatures and freeze/melt potential based on atmospheric and ice heat fluxes.

763 24: Reference or data to support this argument.

See Figure 3 (original manuscript). If ice resolution changes were resulting in different answers in coupled simulations, then ice-only simulations at different resolution would be expected to show different answers. They do not.

Conclusion: Does your analysis suggest that the inadequate ocean horizontal

heat flux resolution is part of the reason for sea ice models underestimating sea ice loss to date?

See second comment/reply above re. historical changes in ice cover as well as comment/reply re. atmospheric resolution influence. Comparisons of historical mismatch and predicted uncertainty provide little basis for adding this conclusion. While ocean heat transport is part of observed ice reduction in the Arctic (e.g. Deser and Teng, 2008) I suspect that accurately modeling changes in heat fluxes may be more important under higher CO2 concentrations than it has been for the more limited temperature forcing of recent decades.

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Interactive comment on The Cryosphere Discuss., 2, 759, 2008.