The Cryosphere Discuss.,
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The Cryosphere Discussions

Interactive comment on "Impact of assimilating sea ice concentration, sea ice thickness and snow depth in a coupled ocean-sea ice modeling system" *by* Sindre Fritzner et al.

Anonymous Referee #2

Received and published: 4 December 2018

General Comments

In this paper, the authors perform 5 experiments with a 20 km coupled ROMS-CICE model forced with ERA-Interim forcing for 3 full years for the period of 2011-2013. The five experiments are 1) assimilation of OSISAF sea ice concentration (SIC) only, 2) assimilation of OSISAF SIC and CryoSat-2 sea ice thickness (SIT), 3) assimilation of OSISAF SIC and SMOS SIT, 4) assimilation of OSISAF SIC and AMSR-E/2 snow depth observations, and 5) control run without any data assimilation. The Ensemble Kalman Filter (EnKF) is the data assimilation technique used in this study. Ocean boundary conditions are provided by the FOAM ocean model. Two sets of experiments

are performed: 1) assimilation experiments with 20 ensemble members with a 7-day assimilation time step, 2) seasonal forecasts with 20 ensemble members for the five-month period beginning in April/May to examine the skill in predicting the September sea ice minimum extent.

The authors computed the annual RMSE of the ensemble mean SIC over the three-year period and found that from January – August, the SIT experiments performed similarly and outperformed the SIC-only run during that period when using the weighted AMSR-E/2 data. From September – November, the SIC experiment had the lowest error. This could be related to no IT data during the summer months. The authors speculate the model has difficulty in transitioning from the melt to growing season. When comparing against the OSISAF ice concentration (which was assimilated into the model), the SIT experiment using SMOS showed the lowest RMSE from January – July. The snow depth experiment showed a lower RMSE than the SIC-only experiment for the period of January – June.

The authors examined "hit rates" to determine which experiment led to the most accurate number of grid cells classified as open water (concentration < 10%), low (<50%) or high concentration (>50%) and found that the experiments with the assimilation of ice thickness performed best. Total ice volume is examined for all 5 experiments and they find that except for the control run, the volume steadily decreases from year to year. The authors need to better address why this is happening, and propose future studies to investigate this further.

Comparisons are performed with the annual mean ice thickness and snow depth from all 5 experiments versus data from NASA Operation IceBridge. Since IceBridge data is only available for typically 10 transects for March/April each year; this is not a very compelling analysis. While Arctic snow depth data is difficult to obtain, it is recommended that the authors examine additional sources of ice thickness data, such as ice mass balance data (see comment below) which has much better temporal and spatial resolution.

Seasonal forecasts are evaluated by performing 5-month experiments for all five cases beginning in April of 2011, 2012 and 2013 to examine the SIC RMSE. When averaged for all three years, the SIT experiments perform best. Through mid-June, the snow depth experiment is very similar to the CryoSat-2 (SITI), but afterward the error increased significant and mirrors the control runs high error from August through September.

With the exception to the Lisæter (2007) reference, throughout the paper you should consistently refer to CryoSat as CryoSat-2.

Why aren't ice mass balance buoys used in your study? Look at available data at: http://imb-crrel-dartmouth.org/results/. During the period of your study, there is drifting buoy data available.

Are melt ponds used in your CICE simulations? If yes, state that in Section 4.3.

Why didn't you evaluate model ice drift errors using the International Arctic Buoy Programme buoy data? See http://iabp.apl.washington.edu/

This is a very well written paper with clear tables and complementary graphics. I recommend publication after my comments are addressed.

Specific Comments

Page 2 lines 15-25: Suggest you add the following reference to this section when discussing operational system assimilating SIC:

Posey, P. G., Metzger, E.J., Wallcraft, A.J., Hebert, D.A., Allard, R.A., Smedstad, O.M., Phelps, M.W, Fetterer, F., Stewart, J.S., Meier, W.N., Helfrich, S.R., 2015. Assimilating high horizontal resolution sea ice concentration data into the US Navy's ice forecast systems: Arctic Cap Nowcast/Forecast System (ACNFS) and the Global Ocean Forecast System (GOFS 3.1). The Cryosphere 9 2339-2365. doi: 10.5194/tcd-9-2339-2015.

Page 3 first paragraph: Consider adding the following recent references when discussing the use of CryoSat-2 data:

Allard, R. A., Farrell, S. L., Hebert, D. H., Johnston, W. F., Li, L., Kurtz, N. T., Phelps, M. W., Posey, P. G., Tilling, R., Ridout, A., and Wallcraft, A. L.: Utilizing CryoSat-2 sea ice thickness to initialize a coupled ice-ocean modeling system, Advances in Space Research, 62, doi:10.1016/j.asr.2017.12.030, 2018.

Blockley, E. W. and K. A. Peterson: Improving Met Office seasonal predictions of Arctic sea ice using assimilation of CryoSat-2 thickness, Cryosphere, 12, 3419–3438, doi:10.5194/tc-12-3419-2018.

Xie, J., F. Countillon, and L. Bertino: Impact of assimilating a merged sea-ice thickness from CryoSat-2 and SMOS in the Arctic reanalysis, Cryosphere, 12, 3671-3691, doi:10.5194/tc-12-3671-2018.

Page 4 line 12: Please state the horizontal resolution of the ERA-Interim dataset

Page 4 lines 13-14: You use FOAM for prescribed ocean boundary conditions. What do you use for the CICE boundary conditions?

Page 6 last paragraph: What is the accuracy of the AMSR-E/2 snow depth data?

Page 8: You state the coupled modeling system is run for 1 year as an initial state. Was it spun-up from rest? How was ice initialized? Uniform everywhere from a particular thickness?

Page 8 last paragraph: Why didn't you include another experiment which included a blended CryoSat-2/SMOS ice thickness?

Page 13 Figure 4b: Please explain your views on why the ice volume (except for control run) steadily decreases. I suggest in your conclusions section to include to some possible follow-on studies to better investigate this issue.

Page 14 lines 20-24: Please include figures and discussion on comparison for April

2012 and 2013?

Page 14 last paragraph: Have you looked at Dartmouth (formerly CRREL) IMB data for an additional source of ice thickness data? These data sets have much more temporal coverage than just Mar/Apr from NASA IceBridge.

Page 16 last paragraph: Table 3 shows yearly averaged RMSE values of ensemble average of snow depth compared to NASA IceBridge. Explain how you can do this when NASA IceBridge is only available for Mar/Apr each year.

Page 18 lines 15-16: You state five-month forecasts, but experiments are performed April – September What are the actual dates? Apr 30 – Sept 30 would be 5 months; April 1 – Sept 30 would be 6 months.

Technical Corrections:

Page 1 line 7: replace “asses” to “assess”

Page 1 line 12: should be CryoSat-2 (and throughout the paper)

Page 1 line 16: replace “lead” to “led”

Page 2 line 14: add comma after “later”

Page 8 line 30: reword “Five assimilation experiments” to “Five experiments”

Page 12: Fig 3 caption: first line should read “low concentration ice <50%” (not >50)

Page 13 line 8: replace “to much ice” to “too much ice”

Page 26 line 24: Provide more complete info for Sakov EnKF-C user guide (2015) reference

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