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Interactive comment on "Using records from submarine, aircraft and satellite to evaluate climate model simulations of Arctic sea ice thickness" *by* J. Stroeve et al.

Anonymous Referee #2

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This study concerns the efficiency of climate models to simulate Arctic sea ice thickness. Assessment of a suite of CMIP5 numerical models is conducted via comparison with ice thickness observations collected from a variety of platforms. The authors find that although the mean thickness and volume for the Arctic Ocean appear to be well represented by many of the CMIP5 models, the spatial patterns of sea ice thickness are poorly represented. Indeed the range of spatial patterns, presented in Fig 4, is a useful contribution that delineates the current limitations of global climate models in representing Arctic sea ice state. The authors find that the model deficiencies in predicting the prevailing atmospheric circulation over the Arctic can partly explain the errors in the prediction of the geographical location of the thickest and thinnest sea ice

in the Arctic. The authors find that these deficiencies reduce confidence in the reliability of future projections based on the CMIP5 climate model suite.

A range of sea ice thickness observations spanning 1986-2013 are presented in this study and are used to assess the ability of a subset of CMIP5 models in reproducing both the mean sea ice thickness and the spatial gradient in ice thickness across the Arctic basin. There are a number of concerns with regard to the analysis of the model predictions using novel observational data. The treatment of the observational data sets used to validate the model simulations is unfortunately unsatisfactory since the uncertainties associated with each observational data set are neither discussed sufficiently (P2188 L27-L3) nor taken into account when comparing the observations to the model predictions.

For example, an assessment of the errors within and between the observational data sets has not been completed. The utility of the observational thickness datasets and associated data quality must be considered carefully, before these data are used to quantify the merits of other data or model predictions. The assessment is premature and impacted by biases across thickness estimates from different sensors. Many of the observational data utilized in this study have specific limitations that can result in ice thickness estimates with a range of uncertainties related to particular measurement conditions. Specific examples include uncertainty in the penetration of the snow pack by satellite radar altimeters and uncertainty in the snow depth and snow and ice densities used to convert altimeter measurements of sea ice freeboard to sea ice thickness. While these conditions and limitations are detailed in the publications (and/or documentation) associated with each dataset/technique, the authors of this manuscript make no reference to specific biases in the observational data or reference data filtering approaches that might be utilized to standardize the thickness estimates derived from the range of platforms used here. This is a serious limitation of this study that should either be addressed, or remedied by using e.g. one (or two?) specific datasets in the model assessment. The ULS data are likely the most convenient since these are likely to have the lowest associated uncertainty.

Further it is difficult to follow exactly how the observational data have been used in this study. First it appears that all observational data were treated equally (eg., P2182 L26 "aggregating all available data", P2183 L3 "combined thickness records", ...). Later it appears that some (or all?) datasets are compared to the models on an individual basis. Fig 3 compares each of the observational datasets to the CMIP5 model predictions. However the temporal sampling of the observational data is variable and does not match the time period of the CMIP5 model runs (1981-2010). The widespread decline in Arctic thickness and volume that occurred in the period between $\sim$ 2002 – 2008, as documented by many authors (e.g., Giles et al. 2008; Kwok and Rothrock 2009; Laxon et al., 2013) will give rise to a thickness bias due to the difference in temporal sampling of the particular observational data set vs the time period of the models were run (fig 3.). This also raises the question of the usefulness of assessing a mean field spanning 1981-2010, considering the rapid decline in mean thickness during the last decade.

The treatment of the observational data and the averaging approaches used should at least be clarified. The authors state on P2189 L10-11 that "the combined records show a decline through time in thickness" but this is not fully supported by the thickness maps in fig 2. For example the thin ice in the IceSat field is 0.5 – 1.0 m thinner than the sea ice in the same areas in the CryoSat field. The IceBridge data span a similar period to CryoSat but indicate the ice is 1-1.5 m thicker.

The section (P2186/2187, L22-L3) describing the technique used to derive sea ice thickness from altimeters is unclear. For example how is the sea surface height derived from gravity models? The authors mention that altimeters measure the height of snow and ice surfaces relative to the reference ellipsoid (L23) and then mention the heigh of these surfaces above the geoid (L25), but the geoid and reference ellipsoid are not the same. The authors could refer to the published literature on this technique in order to improve the description in this section of the paper.

Minor comments: Grammatical error in title - satellite should be pluralized since ice thickness fields from a number of satellite missions are discussed.

P2180 L1: "sea ice thickness distributions from models" - do the authors refer to the distribution of ice thickness across a range of thickness classes within CMIP5 models, or do they in fact refer to spatial mean / gradient across the Arctic?

P2181 L9: why only "in part"? If GCMs cannot reproduce realistic ice thicknesses then there can be little confidence in the projection of an ice free Arctic.

P2181 L27-29: statement should also address limitations in temporal coverage and latitudinal limit of IceSat's orbit.

P2182, L6; P2187 L6-9; P2188 L9: The ERS-1 mission ended on 10 March 2000 – can the authors provide further details and references for the mean field that spans to 2001?

P2812 L8-10: CryoSat was launched in 2010

P2182 L10: how do you define "sufficient coverage"?

P2182 L15: define meaning of "biases" in CMIP5 models. Potential for confusion with biases in the observations, which should be addressed.

P2182 L16-18: how is this evaluation accomplished?

P2182 L18-19. How does snow melt influence the radar measurements? IceBridge data are currently only available in March/April.

P2183, L20: What governed the choice of CMIP5 global model assessed? i.e. why was a subset of 27 models used in this study?

P2187 L8-10: What is the source of the ERS-1 single mean field ice thickness? Is it publicly available/reproducible?

P2187 L21 Thickness retrievals are not detailed in Kurtz and Farrell (2011) since their study concerns airborne snow depth retrievals from IceBridge

Table 1 how do the results presented for Icesat and CryoSat-2 compare to the results presented in Laxon et al 2013? The correlation between PIOMAS and CryoSat seems a lot lower in this study.

Fig 2: can the authors comment on the large scatter (3-4 m) in ice thickness in the scatterplots for IceSat and CryoSat, if the data were averaged to 100 km grid cells?

Interactive comment on The Cryosphere Discuss., 8, 2179, 2014.