Review of the manuscript egusphere-2025-766 titled *"Constraining CMIP6 sea ice simulations with ICESat-2"* by Petty et al.

This manuscript describes an evaluation of CMIP6 sea ice simulations using observations from NASA's ICESat-2, focusing on sea ice total freeboard and Arctic winter sea ice thickness—metrics not traditionally used in global climate model evaluation. The authors present a plausibility framework accounting for observational uncertainty and internal variability and explore its application in both hemispheres, ultimately suggesting the incorporation of altimetry data into model assessment pipelines and an increased focus on bulk sea ice density.

The manuscript clearly fits the journal's scope: it develops and evaluates Earth system models (here, sea ice representation in climate models), integrates observational constraints, and offers methodological innovations of interest to the modeling and remote sensing communities.

Even though I am not an expert in global climate models, I found the manuscript generally easy to read and well structured. However, I think it will benefit from minor changes, which I shall detail below, and a thorough proof-reading. I find the manuscript ready for publication after minor (albeit a rather lengthy list of) revisions.

We sincerely thank the reviewer for taking the time to provide this constructive feedback on our manuscript. Please see below for our responses (in blue).

General comments:

As is typical for a modelling study, and even more so for an intercomparison, there is an abundance of acronyms, abbreviations, and symbols. Perhaps a glossary or a table defining them could be helpful (in appendix)?

Yes, agreed. We will add a table in the revision.

As a non-expert, I think a conceptual flowchart early in the paper would guide (especially non-expert) readers through the multiple datasets, metrics, and model subsets used. I recommend adding such a figure.

Yes good idea, we will make this change.

Journal's guidelines are not completely followed, I will detail below those that caught my eye.

Thank you for catching these mistakes, and we will implement them in the revision.

Detailed comments:

Abstract: Per journal's guidelines, abbreviations need to be defined in the abstract and then

again at the first instance in the rest of the text. However, abbreviations CMIP6 and GCM are not used at all in the abstract. CMIP6 is perhaps necessary, as it appears in the title (although abbreviations should be avoided there), but there's no need for GCM. Furthermore, ICESat-2 is not explained in the abstract, but it is in the main text.

Yes, fair points. We will make these changes to the abstract.

L30ff: Throughout the manuscript, the reference to the very relevant paper Notz & SIMIP Community (2020) takes different forms (at least Community, 2020; Notz & SIMIP Community, 2020; Notz and SIMIP Community, 2020; Notz and Community, 2020). Furthermore, it appears wrong in the reference list under "Community, S" and not under Notz.

Yes, agreed. We will make references consistent throughout.

L44ff: please reword "improvements … have been suggested, suggesting improvements…"

Yes, good idea. We will make this change.

Fig. 1: I cannot find a single reference to this figure in the manuscript. Please increase the font size, it's insufficient. The only thing I can see from it are the (undefined) abbreviations in capital letters.

Yes, good point. This must have been dropped in the final edits. We will add a reference and make clear the abbreviations.

L78: This is the only occurrence of CO_2, better to spell it out as carbon dioxide.

We will make this change.

L96: Which spelling are you using, "(kilo)meter" or "(kilo)metre"?

We used kilometre which appears to be the correct (British/European) version for Copernicus journals.

L105 (and before): "their more limited temporal coverage", I would have expected a sentence or two about the reasons here in the introduction. Issues concerning summertime altimetry data are not mentioned before L228

Yes, this was omitted due to concerns about a lengthy introduction. We will add in an extra line in the revised manuscript to provide more detailed information.

L141: Per journal's guidelines, "data" is considered a countable noun --> CMIP6 data are

Yes, agreed. We will make that change.

L147: Typo? ESGF, not ESGP. Also, OPeNDAP is not defined.

Yes this was a typo. We will make that change and spell out OPeNDAP: Open-source Project for a Network Data Access Protocol

L185: Throughout the first half of the manuscript, the density units are formatted wrong. Per journal's guidelines, units of physical quantities must be formatted with negative exponents. Please check this also in all figures.

Good spot. We will make that change across the manuscript and figures.

L195: Earlier at L168 seawater density was 1024 kg m^{-3}, now 1026 kg m^{-3}. A bit confusing for the reader. Was the value 1024 kg m^{-3} used anywhere in the study? What is the effect of this change?

Good spot. 1026 should have been 1024, so we will make that correction.

Table 1: Caption should be situated above the table, please correct also for the other tables. Variables simass and sivol are not explained like the others are.

We will make that change across table captions and define those variables.

L211: Here and elsewhere, are embedded URLs necessary in the text, especially when they are followed by a citation with a DOI/permalink? This is a bit more personal preference, but I think they interrupt the flow of reading.

We will revise to include these in the data section.

Fig. 2+: Per journal's guidelines, "only the first word is capitalized in headers (in addition to proper nouns)." Please check throughout the manuscript.

Good spot. We will fix the capitalization across the headers.

L261-264: Per journal's guidelines, common Latin phrases are not italicized nor hyphenated: in situ.

Good spot. We will make that change across the manuscript.

L267: The abbreviation EM is not defined nor used elsewhere. Furthermore, the sentence fails to acknowledge all instruments used in the derivation. I suggest "derived from coincident laser scanning, snow radar, and electromagnetic induction sounding data".

Good spot. We will add in that suggestion.

Fig. 3 caption: Per journal's guidelines, Figure --> Fig. when it's not starting a sentence. Please check throughout the manuscript.

Good spot. We will make that change across the manuscript.

L280: Not EASE 2.0 like before? Also, this abbreviation should have been explained earlier (L208).

Good spot. This will be revised to EASE 2.0.

L290: Rewording needed "large-scale basin-scale"?

Agreed. Will change.

L294: NASA Team data has --> have

Agreed. Will change.

L300: Roach et al. (2020)

Agreed. Will change.

L321: No need for capitalization: upward looking sonar

Agreed. Will change.

L323: an --> the AWI CS2/SMOS product, or do they have several?

Will change to add 'the'. Yes, they also have a non SMOS version.

L344: Typo? 2014 --> 2024

Yes, this was a typo. Will change.

L361: Abbreviation IS-2 not introduced. If you use such an abbreviation, do it consistently throughout the manuscript. Moreover, what is the Bessel correction?

We will make this consistent across the revised manuscript. The Bessel correction is used to account for the fact we are calculating the variance from a sample and not the entire population. We will clarify in the manuscript.

L364: Typo? SSP-2.45 --> SSP2-4.5

Yes, this was a typo. Will change.

L366: Typo? increasingly --> increasing

Yes, this was a typo. Will change.

L379ff: The sentence starting “We then…” is too complex. Please rephrase.

Agreed. Will change.

L391: Per journal’s guidelines, Section --> Sect. (like you have written on the next line) when it’s not starting a sentence. Please check throughout the manuscript.

Agreed. Will change throughout as suggested.

L392ff: I suggest Method 1) and Method 2) to avoid subsequent colons within a single sentence.

Yes, agreed. Will use that approach!

L395: The figure numbering in the Supplementary Information is broken, you have S4 twice. Thus, all the subsequent figure numbers are off. Please correct.

Good spot. Will update the numbering

L409: Do you mean CNRM-CM6-1-HR? In Fig. 4 that model doesn’t have the black triangle marker.

Yes, this refers to CNRM-CM6-1-HR. We will update that.

Fig. 4: SI prefix for kilo is a lower case k, not K. Also in Fig. 10 and in the caption of Fig. 5.

Agreed. Will change.

L441: Fig. 5 has 16 models, as mentioned in its caption, too.

Good spot. Will change.

L446: Why is “Annual” capitalized? It appears so multiple times in the manuscript, but not always. Please check thoroughly. Furthermore, in Fig. 5 the multi-model mean freeboard looks more like 22 cm, not 25 cm. Is the figure correct (version)?

Yes, we will change to ‘annual’ throughout. This was updated in final analysis revisions, so we will update the text accordingly.

L448: But ACCESS-CM2 is shown in Fig. 5?

Yes we decided to show the version with ACCESS instead. We will update the text accordingly.

L480: Typo? inter-modal --> inter-model

Yes, this is a typo. Will correct.

Table 3: Does the upper case M for sea ice area stand for the SI prefix mega, i.e. 10_6? If so, please use the scientific exponent notation, because area in “mega kilometers squared” does not read well with two prefixes.

Yes. Will update.

L539ff: Why do you want to highlight the models and metrics that are implausible? To me that’s thinking backwards, wouldn’t you want to highlight those that are plausible (/good/usable)? Think positive!

This is an understandable suggestion. However, we tested this and generated a figure that highlights plausible values instead,, but this made the plot much harder to interpret in our view. We think it best to keep this as is.

L542: highest --> best? Very high (and low) values are implausible, correct?

Yes, that was poor word choice. We will change the wording to ‘best’, as suggested.

Fig. 9: The colorbar should extend at both min and max ends, as values beyond ~7 exist, please add arrows/triangles at the ends indicating that (like in Fig. 11). Additionally, abbreviations should be explained (SIA/SIT/TFB/NH/SH/IA).

Good spot. We will extend the color scale and explain abbreviations.

L587ff: Again, does the upper case M for sea ice area stand for the SI prefix mega, i.e. 10_6? If so, please use the scientific exponent notation, because area in “mega kilometers squared” does not read well with two prefixes. Furthermore, looking at Fig. 10, the volume changes are 10_3, not 10_6. Which one is correct?

Godo spot. We will use the exponent notation throughout to avoid confusion! That should have been 10^3.

L610: Typo? Grid-scale

Yes. Will change.

L611: uncertainties … was --> were

Agreed. Will change.

L614: Fig. --> Figure as it starts a sentence

Agreed. Will change.

L622: remove second “with”?

Agreed. Will change.

L642: Fig. --> Figure as it starts a sentence

Agreed. Will change.

L694ff/Discussion: I would recommend adding subsections to improve and clarify the structure. The subsections can be short, e.g. on sea ice bulk density, uncertainty quantification, altimetry datasets, etc. L691 could be removed completely.

This is an interesting suggestion. We prefer to use bold subtitles, which will be incorporated in the revised manuscript.

L722: split infinitive, to better consider --> to consider better

Yes agreed thanks, will change.

L724: split infinitive, the ability of models to accurately capture regional internal variability --> the ability of models to capture regional internal variability accurately

Agreed. Will change.

L784ff: split infinitive, … to better constrain current and future variability in sea ice and their associated climate impacts. --> … to constrain current and future variability in sea ice and their associated climate impacts better.

Agreed. Will change.

L832ff: Is the citation correct, particularly the indicated time period?

Good spot. Will change.

L837: Wrong author

Good spot. Will change.

L933ff: No longer in press, please add DOI

Good spot. Will change.

L976ff: Accepted and published, please update

Good spot. Will change.

L981ff: Accepted and published, please update

Good spot. Will change.

L987ff: Page range or article number missing

Good spot. Will change.

L992: Incomplete citation, add journal, pages/article number, DOI

Good spot. Will change.

L994ff: Update article number

Good spot. Will change.

L1013ff: Accepted and published, please update

Good spot. Will change.

L1021ff: Update article number

Good spot. Will change.

L1025: Incomplete citation, add journal, pages/article number, DOI

Good spot. Will change.

L1027ff: This preprint was not accepted, but resubmitted as https://doi.org/10.5194/egusphere-2024-2821

Thanks very much for pointing that out! Will change.