Response to Anonymous Referee #2, received and published: 24 March 2020

27 March 2020

Please see our responses in blue color in the reviewers text.

Thank you for this careful review and the constructive comments below, which have been used to revise the paper.

Anonymous Referee #2
The paper presents an introduction and major update to the anticipated satellite mission, Copernicus Polar Ice and Snow Topography Altimeter (CRISTAL). The key observables of the mission are sea-ice thickness and elevation measurements of ice sheets and glaciers. The motivation for these observables are described. The content of the paper is useful for the scientific and broader communities, and warrants publication. However, there are major issues in the clarity, organization, and redundancy of the text that require attention. These issues prevent the main points of the paper from being communicated.

Thank you for your suggestions and comments. We have re-organised the paper to take into account the reviewers comments by changing the title, the abstract, shortened section 2 considerable and interchanged sections 4 and 5. These structural changes help to reduce repetition.

My major recommendations are to: consolidate Section 5 with the mission objectives listed in Section 3 since much of the content is repetitive; break up numerous run-on sentences and rewrite for clarity; carefully proof the manuscript and correct the many typos and grammatical errors within.

Thank you. A re-organisation of the text has been done to account for this.

L24. Here and throughout the paper, it is not clear what is meant by "evolution." Please describe.
The term ‘evolution’ is now explained within abstract text, see line 30.

L28. "properties of snow cover on ice" I recommend changing this to snow depth since its retrieval has been demonstrated with Ku- and Ka-band data, whereas the other suggested property retrievals have not yet been fully demonstrated.
Ok, changed.

- Polar Regions, Polar Oceans, and Total Column Water Vapour should not be capitalized.
Ok, all capitalisations corrected.

L29. "foreseen" does not seem like the correct word here since it is not a prediction. "Planned" may be a better word.
Ok, changed to ‘planned’.

L43-46. Here and throughout the paper, there are run-on sentences with mixed messages. Please rewrite these for clarity.
The sentence has been changed and shortened.

L50-51. I’d suggest changing this to stakeholders for inclusivity. Derived products may be useful for indigenous communities.
Ok, changed to stakeholders.

L51. While I understand this is a European effort, the listed motivations in this paragraph also apply to other countries. I'd suggest broadening this or adding a statement to be more inclusive of the international community, as it would strengthen the motivation and utility of such a mission.
Ok, understood and changed to be more inclusive.

L53. "It also has..." what does "it" refer to here?

Sentence removed. It referred to 'Europe'.

L57. These potential impacts are not limited to European weather. They may affect global weather patterns.
Ok, changed and 'European' removed.

L61-63. The following section is more about the history of the Copernicus programme, rather than an overview of the missions under development. I'd suggest editing either this sentence or the section to be consistent with one another. Depending on who the target audience is, the mission overviews may be more useful for the broader community than the history of the Copernicus programme.
Ok, the sentence was changed.

L70-82. Who is the target audience of this paper? Do they need to know the history of the Copernicus programme?
Ok, agreed. We have shortened the first two paragraphs in this section and merged them. We need some introductory sentences since otherwise we cannot introduce the concept of the HPCMs.

L84. This is vague. Potential for what?
Ok, shortened and changed to 'The intense use of Copernicus'.

L85. For future what? This is vague.
Ok, removed.

L103. What "so-called Long-Term Scenario" is this sentence referring to? It is unclear.
OK, it is now explained.

L105. "EC" and "RMC" elsewhere. Use acronyms consistently.
Ok, changed use of EC and RMC consistently.

L105-106. What does "integrated end-to-end system approach" mean? Here and throughout, such buzzwords are not informative.
The paragraph was removed.

L133. UNFCC. This and other acronyms are defined and used only once. I recommend deleting unnecessary acronyms such as this one for easier reading.
Ok, acronym UNFCC and several others removed from the list.

L150. OSTST in-text definition missing.
Ok, added in the text.

L155+ I suggest using bold font or italics for the first lines of each bullet point for easier reading.
OK, used 'bold font' to better highlight these lines.

L202-203. "is added for snow depth measurements to distinguish between snow and ice layers" needs rewriting for clarity.

Ok, sentence re-written.

L216-217. Is a parenthesis missing?
Ok, corrected.

L242. Add "over sea ice" after snow depth.
Ok, corrected.

L254. What does "on a best effort basis" mean?
It will be systematically observed if data volume /downlink capabilities allow so. “On a best effort basis” removed.
L272. "its presence limits human access" I suggest considering a different perspective of sea ice. It’s a platform enabling subsistence hunting and travel for indigenous coastal communities.
Ok, sentence changed.

L274. ice-infested. Why use a word with such negative connotations?
Ok, removed.

L280-281. "to safeguard both climate and operational data services" Safeguard does not seem like the right word. "extending" or "advancing" may be better.
Ok, we changed it to ‘extending’.

L282-289. Confusing, run-on sentences.
Ok, sentences shortened and changed.

L288. Essential Climate Variable sounds important, but what does that really mean?
It is a term used by GCOS. We will not change it in the text.

L308. Please clarify that this information relates to Copernicus sea ice thickness products.
Rewritten to ‘Most sea ice thickness products …’

L310. Please state which satellite this uncertainty pertains to.
CryoSat-2 data. Added to the text.

L319-322. Run-on, confusing sentence.
Shortened and corrected.

L320. This uncertainty value is not consistent with the one given in the preceding paragraph. Please provide more detail on why these are different values.
Paragraph was updated and more details provided.

L330-333. References are needed. The uncertainty in snow depth data from the historical period is as good as it can possibly get, on the order of 1 cm and less. The uncertainty is not halved over first year sea ice. Several studies have shown snow to be thinner over first year sea ice in areas where Operation IceBridge surveys were conducted. In other regions of the Arctic, deep snow can exist on first year sea ice.
Another reference added and the text was shortened to make it more readable.

L333 Giles et al. 2007 seems like a more appropriate reference here since it was the first study to demonstrate the propagating uncertainties associated with snow depth and other geophysical parameters.
Ok, the reference was added and the sentence shortened.

L338-341. Please rewrite for grammar.
Ok, sentences updated and changed.

L354-355. Computing mass balance and identifying mass imbalance seem like the same thing here.
Sentence updated and changed.

L360. The continuous record provides.... a long-term record. This is circular.
Ok, sentence changed.

L365-366. Are commas missing? Please rewrite for grammar.
Commas added. Sentences shortened.

L375. "agility of tracking" It's not clear what is meant by this. How is the satellite going to be agile?
Sentence changed.
L378. Grammar.
Changed.
L382-383. I suggest adding a little more detail here for clarity, e.g. retrieval accuracy of what exactly?
Ok, changed.

L386. "allow" seems like the wrong word here. "Have" may be better.
Ok, changed.

L389. It would be relevant to state the anticipated spatial resolutions here since leads come in all sizes.
Ok, added.

L399-401. This is unclear. Please rewrite.
L403. Reference needed for main causes...
Reference added. Shepherd, A., Fricker, H.A. & Farrell, S.L. Trends and connections across the Antarctic cryosphere. Nature 558, 223–232 (2018). https://doi.org/10.1038/s41586-018-0171-6
L404. Reference needed for largest uncertainty in the current prediction.
Reference added. Edwards, T.L., Brandon, M.A., Durand, G. et al. Revisiting Antarctic ice loss due to marine ice-cliff instability. Nature 566, 58–64 (2019). https://doi.org/10.1038/s41586-019-0901-4.
L414. Please rewrite for clarity.
Ok, sentence changed.
L427-428. These sentences are vague. Please be more direct. Is snow depth retrieval not possible over land with CRISTAL frequencies?
Text modified.
L432-433. What is meant by status?
ok
L434-435. Is it the spatial resolution that limits the wide use of altimetry data for snow and permafrost research or the frequencies used?
Text modified.

L460+ Wouldn't it be important to mention the relevance for monitoring the Antarctic cryosphere?
Antarctica also added to the text in a sentence.

L467. Is this true? ICESat-2 reaches 88-deg latitude.
Sentence changed.

L471. It'd be helpful to restate the along-track resolution here since it is a key element

for the mission.
Ok, added to the paper.

We would like to change the reviewer for providing such a thorough list of technical changes and suggestions. We have incorporated all of these changes in the revised version of the manuscript.