

## Response to Anonymous Referee #3, received and published: 26 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

Overview: This paper presents the justification for and early design candidate for the CRISTAL mission. The paper also presents on the individual science applications that will be serviced by such a mission.

Summary: Firstly, apologies for my tardy review, I could would like to blame it on the new situation the world finds itself in with COVID-19 but I procrastinated well before that became a factor. A thorough presentation of the need for, and technical capabilities of, the CRISTAL mission is a welcomed contribution to the community. The mission is very exciting and will provide invaluable data necessary to advance polar sciences in the coming decades.

Overall, I found this manuscript very difficult to review. I tried to review the manuscript multiple times but the first 4 sections were such a slog that it was unmotivating. The first 4 sections read like a cut and paste of multiple science agency white papers while the final section, section 5, provides a nice science justification for the mission but is completely decoupled from the first 4 sections. In my opinion the paper requires significant restructuring and more consideration as to what is included and why. I would start with a section (1) that provides the motivation for the mission: that is the science justification (essentially section 5) with a dedicated subsection that summarizes the EU Arctic Policy and primary user requirements that motivate the mission. (2) I would then summarize the geophysical observables that are needed to satisfy the science and application needs (maybe as a table). There is a table for radar specification but not for the geophysical observation requirements that are more relevant to an overview paper. This could be followed by a section (3) that describes the CRISTAL mission capabilities showing that it meets the needs presented in the prior section. The current section 2 could be reduced to 1 or 2 paragraphs that get included in the new section (3), no need to review the full Copernicus program. I think nearly all of the material is in the document, it just needs to be reworked into a coherent justification and description of the mission.

[Thank you for this important comment. We have restructured the paper to address this comment. It should be noted, however, that addressing Copernicus services requirements \(operational\) in the context of the High-Priority Candidate Missions remain the predominant justification for the mission. The science needs are undoubtedly important.](#)

[To take into account the reviewers comment, we have re-organised the paper by changing the title, the abstract, shortened section 2 \(into 3 paragraphs\) and interchanged sections 4 and 5 after modifying them to reduce repetition.](#)

I have many small comments on grammar and wording but I don't think the manuscript is at the point yet where those details would be all that useful. For that reason, I only list my major comments here:

- There is a reasonable amount of redundant text between section 5 and the rest of the manuscript. This is mostly a result of organization and can be fixed by structuring and being more selective on what's included

We have restructured the paper to remove repeating sentences and redundant text as much as possible.

- Sections 1-4 lack references supporting statements (I believe there is only 1 reference supporting the idea that the combination of ka- and ku- band altimeter will substantially improve measurements of snow on sea ice.

More references have been added. It is true that more experimental data is required further study the combination of Ka-band and Ku-band and its impact.

-Also several citations are outdated (e.g. Chen 2013), DeCanto and Pollard, 2016 is highly controversial and is not a representative citation for a current best estimate of future ice sheet change.

This has been changed and replaced with more representative citations.

- There is virtually no justification for including a microwave radiometer and no supporting literature, this should be shored up with a clear justification as to the applications (with list of geophysical observables) and science it will support with appropriate citations

Agreed. A justification is now added to the paper. There are perhaps two points to mention:

- Over sea ice, the active/passive synergy enables to classify the sea ice type
- Over open ocean, the radiometer is required to meet the range accuracy requirement.

- Observing mode “Land-ice and Glacier” doesn’t make a lot of sense since glaciers are Land-ice. I would suggest renaming this mode to “Land-ice” -or- glaciers and permafrost (GP) –or glaciers, ice sheets and permafrost (GISP)

Understood. However, the names for the observing modes have now been used throughout the mission preparation phase, with different study partners and industry. We would prefer to keep these names in order not to confuse partners involved. Acronyms have been removed for better clarity.

- It is not clear how CRYSTAL will handle range ambiguities over complex glacier and permafrost terrain as advertised.

The purpose of the interferometric mode is to allow the across-track angle offset of the echoing point to be determined directly (using interferometric phase information). Phase-wrapping can occur when the across track offset is great enough and this can have the effect of the echo appearing to come from the other side of the ground track. This restricts the method to areas with an average cross-track slope of  $\sim 0.5$  to  $\sim 2^\circ$ . Normally, this is flagged by use of an ambiguity Digital Elevation Model.

A sentence is added.

- The colors for Figure 3 are difficult to distinguish (particularly magenta and purple). The figure should also include a colorbar and pole hole data gap.

Figure 3 shows the required masks for operation, which is the reason why the polar gap is not relevant here. The figure caption was updated and improved.