

Dear Editor Leslie Almberg, dear Reviewers

Thank you very much for your constructive review. We trust we have addressed all your comments and are happy to submit an improved revised version of the manuscript. Our response is detailed below, highlighted in red. In addition, we provide a tracked changes version of the manuscript and a clean version of the manuscript.

All the best,

Kim Senger (on behalf of the authors)

Comments from Reviewer 1 – Aleksandra Smyrak-Sikora

Arctic Tectonics and Volcanism: a multi-scale, multidisciplinary educational approach

Kim Senger, Grace Shephard, Fenna Ammerlaan, Owen Anfinson, Pascal Audet, Bernard Coakley, Victoria Ershova, Jan Inge Faleide, Sten-Andreas Grundvåg, Rafael Kenji Horota, Karthik Iyer, Julian Janocha, Morgan Jones, Alexander Minakov, Margaret Odlum, Anna M. R. Sartell, Andrew Schaeffer, Daniel Stockli, Marie A. Vander Kloet, and Carmen Gaina

Status: open (until 30 May 2024)

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- **RC1:** [Comment on gc-2024-3](#), Aleksandra Smyrak-Sikora, 03 May 2024 [reply](#)

Comments to the authors

Dear authors,

I was invited by the GC editorial support team, Copernicus Publications to review the manuscript, and I found it highly relevant for publication. However, there are some minor corrections that could enhance the reader's overall experience with the manuscript. Please consider my comments and suggestions in the attached PDF file. I am happy to discuss any unclear aspects or misunderstandings.

With kind regards,

Aleksandra Smyrak-Sikora

Comments to the manuscript:

1. Does the paper address relevant scientific questions within the scope of GC?

The manuscript by Senger et al. presents the content of the course titled "Arctic Tectonics and Volcanism," organized as part of the NOR-R-AM project ("Changes at the Top of the World through Volcanism and Plate Tectonics"). It provides information about the course objectives, activities, and learning outcomes. Additionally, the manuscript offers references to the data package used for the learning activities and provides an overview of topics used for individual term projects. Furthermore, it informs about the project itself and additional scientific initiatives. Moreover, the paper includes feedback from students in the form of a questionnaire, along with reflections from four students involved in the project activities. This approach clearly fulfills the purpose of GC, which is to help share knowledge in the main subject areas of geoscience education with its pedagogical approach and promote open geoscience through data sharing.

2. Does the paper present novel concepts, ideas, tools, or data?

The paper introduces a novel international approach to teaching Arctic Geology, encompassing various perspectives on the topic. This includes a comprehensive examination from the Earth's mantle to surface geological architecture, as well as the integration of geology and geophysics methods into a single MSc/PhD-level course.

3. Are the scientific methods and assumptions valid and clearly outlined?

The course content is systematically presented, detailing all course modules, introduced methods, and the data package utilized for certain activities. Additionally, the manuscript includes overall reflections from students. While it provides listed results from the student questionnaire and reflections from those involved in the NOR-R-AM project, offering valid perspectives and feedback on the course content, there seems to be a lack of a clear outline of the course structure. Therefore, I suggest incorporating a flow diagram outlining all modules and activities into the manuscript during the revision process.

4. Are the results sufficient to support the interpretations and conclusions?

The students' reflections serve as documentation of the pedagogical efforts of the course. Sufficient documentation of the course activities, methods, and data used is provided within the manuscript

5. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

The references throughout the manuscript are adequate and, in my opinion, appropriately credit both the current state of the art in geological research in the Arctic and the educational approach to teaching about Arctic geology. The selected students who have provided personal reflections on the course are included in the list of authors.

6. Does the title clearly reflect the contents of the paper?

yes

7. Does the abstract provide a concise and complete summary?

The abstract could be moderately modified to include more information about the course objectives, motivation, and the mission of UNIS as an institution, while reducing the focus on introducing the challenges of the modern Arctic. This aspect, in my opinion, should be expanded upon in the Introduction section.

We have revised the abstract considerably, and moved parts of the challenges of operating in the modern Arctic to the Introduction.

8. Is the overall presentation well structured and clear?

The overall structure is good; however, the narrative appears segmented, and minor grammar/language corrections of some parts of the manuscript would be beneficial

I am missing, however a geological context. The reader comes back several times to the diverse geological events, that are not listed chronologically but rather to follow the individual course modules.

NEW FIGURE 1 A) It would be a great help if reader could be anchored with a figure/table/timeline listing all major geological events (tectonic, volcanic but also mass extinctions) in chronological order, ideally listing all major events for the Arctic, and clearly indicating which of them manifest in Svalbard. B) Map of the Arctic showing compilation of some of the geological events, with the position of the orogenic belts and position of diverse LIPs mentioned in the text would be also beneficial (similar to fig 5A, but expanded). This would illustrate why Svalbard is considered a window to the arctic and highlight the Svalbard-Arctic link as well as illustrate the relevance of Svalbard for running the described course.

We have added a few figure with the key tectono-thermal units affecting Svalbard (new Figure 2).

The issue with manuscript segmentation could be fixed by better introduction- paragraph (before the section 4.2.), informing that the following part of the manuscript describes the course modules.

This is added now

I am missing also a NEW FIGURE 2 illustrating an outline of the course. Several modules are mentioned but the reader is left with a bit non-systematic structure of the course. An overview flow diagram listing the major modules (and activities performed as a part of the modules), including fieldwork and assessment would be beneficial.

Original Figure 2 (now Figure 3) is now updated and illustrates the course modules

I would therefore suggest replacing the figure 9 with a more general flow diagram mapping main course activities and modules, including type of assessment. This figure would be placed before section 4.2. Figure 9 in this context appears not very informative and not contributing to better understanding of all project activities.

We have re-vamped Figure 2 (now Fig 3) to be the course module overview figure now.

Regarding Figure 9 (now Fig 10), we disagree and would – unless there are strong limitations on number of figures, article length etc. from the editors – like to include it. The main reason is that it is a good, relatable, student-led figure that brings value to this type of paper and provides a clear student perspective on the NOR-R-AM project as it is. In addition, the figure links nicely to the text sections 6.2.1 to 6.2.4

Finally, I can see that the fieldwork is important part of the course, but there is very little information about field locations. Some names mentioned in the text are not well introduced. I would like to see A NEW FIGURE 3 with a map showing the location and maybe the gps track of summer/ spring fieldwork with a geological map as a background and additional information which geological event was considered an objective for the excursion: e.g. HALIP, WSFTB, CSB, ect..

Figure 7 is now updated with maps and main themes of the visited locations

9. Is the language fluent and precise?

Overall, the language throughout the manuscript is clear, precise, and easy to understand. However, some small sections require language corrections to ensure they match the high standards set by the rest of the manuscript.

We have carefully proof-read the entire manuscript and refined the language where required.

10. Are the number and quality of references appropriate?

In my opinion, the references appear appropriate, but I haven't had the chance to check them all.

Comments from Reviewer 2 – Anonymous

Dear Reviewer,

Thank you very much for your constructive review. We here provide a response to your comments, highlighted in red.

Reviewer 2 comments:

The authors outline the main features of a master's and PhD level teaching course called Arctic Tectonics and Volcanism, which has been taught over a number of years at UNIS in Svalbard. The manuscript serves as a good reflection of the style of courses on offer at UNIS, which incorporates fieldwork, groupwork, research questions and teaching. Feedback from the students is used to highlight the longer-term impact such courses have on students, of which I am in agreement, as I also took a UNIS course during my PhD (a different course, prior to the start of the Tectonics and Volcanism course). There are also many good examples of open data and open science within the manuscript. At times, the manuscript is overly long, with too much detail on the specifics of the topic. There are also many figures which do not relate to the manuscript, but rather serve as a showing of available data. The readers would be better served with more analysis of the educational approach and impact of such courses, or a better insight into the multidisciplinary aspect, for those who are not experts in geology.

We sincerely appreciate your feedback. However, we are reluctant to broaden the perspective of this manuscript to other UNIS courses at the expense of the circum-Arctic geology approach. In essence we strive to describe a very special course in the UNIS portfolio (special largely because it has been externally financed through NORRAM until 2023 and includes a truly circum-Arctic approach, and integrating many disciplines within the geosciences to tackle large issues) to motivate the geoscientific community to establish similar courses elsewhere (and if desired, use the data packages provided by us).

We have revised the motivation to make this objective clearer in the text. We agree with you that there is a strong focus on the geoscience-focussed modules in the manuscript, but as the focus of the manuscript is to facilitate re-creating this course elsewhere we find it difficult to significantly cut it.

Regarding the impact of this multidisciplinary course, we believe that Figure 8 and Table 3 provide a good sample from the anonymous answers received from the course students. Understanding the Arctic region in a regional and global context, now and in the geological past is something that most students seem to have appreciated. We believe that this is the main result of the course multidisciplinary.

Whilst the paper in its current form is just within scope of the GC journal, as it highlights practical, pedagogical research and geoscience curricula development for higher education, it does not go as far as to analyse the course in detail. The feedback from students has not been used to evaluate and amend the course, and there is little reflection from the authors on what limitations the course has. Additionally, it is not a completely novel method – this is typically the 'UNIS' model of teaching (guest lecturers, fieldwork and fieldwork safety, research question focused group work). However, this doesn't detract from the need for the publication – the increased geopolitical tension in the Arctic coupled with the decreasing numbers of students taking geoscience education at higher levels highlights the immediate need for more cross-border collaboration and continued science diplomacy in the region. This publication highlights that out-of-classroom education and networking can lead to further career development and increased interest in taking geology at PhD level.

We have taken student input into consideration when optimising the course over the years – but you are completely right that this section is not reflected in the manuscript. We have expanded section 3 “The AG-x51 course: motivation, establishment and incremental optimization” → 3 The AG-x51 course: motivation, establishment, and incremental optimization and limitations.

New text: “The course is intentionally scientifically and geographically broad, but is limited by the 6-week period applicable for 10 ECTS intensive courses. Financially, the biggest budget posts are field activities and travel/salary costs for the significantly higher number of guest lecturers compared to other UNIS courses. From a pedagogical perspective, students attending the AGx51 course (and other UNIS courses too) typically have a varied background reflecting diverse home universities and study programmes. On the one hand, this requires careful consideration for the teaching staff on balancing the academic content. On the other hand, we consider this heterogeneous background as beneficial in the context of “experts in a team”, as students are placed in groups reflecting their complementary expertise and encouraged to also teach each other.”

With some minor corrections, I believe this manuscript should be published in GC.

Minor comments:

The abstract a bit too long – some of it reads like introduction. The list of what the course entails is too much information for the abstract. It could be shortened in the second paragraph to mention the main components (field safety, Arctic geology theory, group exercises, digital visualization tools, course assessment) but not go into detail.

We have shortened the abstract.

The motivation for the publication could be stronger – I am left wondering if this should serve as a template for others who wish to teach this course. If you are to include some limitations of the course (content, pedagogical style, location) or reflection on how to improve, then I believe it could also serve as a foundation for others to build similar courses and/or a best practice assessment. Do you aim to have some longterm impact on the number of students in geosciences or increased careers in geology after education? As I do see this in the student feedback and discussion, but there is not a mention of this in the introduction, which could strengthen the motivation. At the moment, the motivation is very tectonics/volcanology specific, but it should be widened to fit the broader geoscience scope of the journal.

We have now strengthened the motivation to make it clear we want this manuscript to serve as a blueprint for running similar courses elsewhere.

We have no concrete plans or ongoing long-term pedagogical projects on the influence of the course on career choices, largely because UNIS only offers single courses and the background of the students is so varied. We included a comment that research that connects students' experiences in courses with their pursuit of careers in geosciences warrants further investigation - are good experiences enough or do geoscience educators need to more proactively mentor, advise and encourage pursuing geoscience careers. The theme will be tectonics/volcanology (see also point 1 above about our dilemma of being thematically constrained vs UNIS constrained).

A number of limitations of our course were mentioned throughout the manuscript, and specifically listed in Section 3.

There is no reflection from the authors on the limitations of the course. There is a 'lessons learned' section, but doesn't really give any learnings. Whilst the education is free, travelling to Svalbard is not – and this therefore provides a very real financial barrier to many students (especially masters students who often do not have project funding with a travel budget). Additionally, living in Svalbard for 6 weeks is costly, especially for those who are not already living in Norway. Whilst fieldwork in Svalbard is relatively safe (limited concerns for people who identify as women or within the LGBTQ community for instance), travelling to a remote destination is still a limitation for some with visa issues for example (Svalbard is outside of Schengen).

We have clarified this and added a section on the limitations of the course (see answer above). The NORRAM project actually fully funded all its affiliated students to participate in the course. This is now specified in the manuscript

Were there any questions in the survey/evaluation which asked the students for constructive feedback on how the course could be improved? Whilst we can't go back in time, I do think it is a shame that the evaluation came after so many years, which could make it difficult for those who joined earlier to remember their feedback. It would be useful going forward for you to evaluate the course each year and make changes based on that feedback. If this sort of critical feedback isn't available, perhaps the authors could reflect amongst themselves on ways the course should be improved. Do you also have any other demographic information besides country? Gender for instance?

We have this kind of feedback internally at UNIS, but this was not part of the pedagogical aspects of this present manuscript. We have added the following in section 6 now:

“In addition to the pedagogical questionnaire designed for this contribution, UNIS conducts standardised course evaluations for every course. These provide useful information for the course responsible to optimize the course from year to year. The recurring theme of these questionnaires for AG-x51 from 2019 to 2023 was that the field component was the highlight of the course.”

There's a lot of information in section 4 which I do not think is needed. The subsections describing the course modules should be significantly shortened, or perhaps (as reviewer 1 suggested) the information could be displayed visually. Similarly, many of the figures seem redundant to the manuscript's focus. Figure 3/4/5 are geological maps and are a focus on the topic of the lectures given in the course, but are not related to the course pedagogy or the educational approach. These figures can be removed and the results/conclusions would still be the same. The paper really is too long, so I hope the authors can see the benefit of shortening it to focus on the key aspects that the paper should convey.

Here we disagree, as we want to provide adequate information for the specific modules so that the course can be reproduced elsewhere. Clearly the fieldwork component would need to be either fully digital or visit other relevant Arctic locations (none of which are as accessible as Svalbard). We have clarified the motivation.

We have added a figure with the course modules (new Figure 3) as Reviewer 1 requested, and also a temporal figure illustrating the main tectono-thermal events affecting Svalbard.

Specific Comments

Line 70: could we provide a statistic here? Perhaps take this for some inspiration:

<https://nordregio.org/maps/indigenous-population-in-the-arctic/>. Whilst the density of Indigenous peoples varies and is relatively low in the European Arctic, there are also many millions of people who live there who are not Indigenous, and who require sustainable development and better education opportunities too.

Ok, this is incorporated now. “The Arctic is home to approximately one million indigenous peoples that represent ca. 9% of its total population (Nordregio 2019) “

Line 78-80: A reference or two could strengthen this section regarding the Arctic being in the spotlight of media and policies. Take a read of this and the relevant references therein:

<https://arcticyearbook.com/arctic-yearbook/2020/2020-briefing-notes/367-an-arctic-boom-of-policies-strategies-56-and-counting>

Ok, two relevant references were added now

Line 100-105: does this differ in non-Arctic nations? I could imagine that at least undergraduate education is carried out in country of origin for the vast majority of places/countries. I could be wrong though, I have not looked into it. In the case of the Arctic though, there is evidence of a southward migration of students (university level) and skilled workers to the south, due to the position of the capital cities outside of the north/arctic circle. It is complex, but there's a breakdown of countries here (Arctic+Scotland):

https://www.pure.fo/files/24328830/Arctic_Connections_Final_Report_Rural_Youth_Out_Migration.pdf

We have rephrased this.

“The same could be said for the tertiary educational systems, where students often study in their country or continent of origin. Arctic indigenous students often move from their homes to study outside the Arctic, as most higher education institutes are located south of the Arctic Circle. Svalbard, however, has no indigenous population and all UNIS students have to migrate north to undertake studies there.”

Line 113: first mention of motivation – but a lot of relevant information above with which to strengthen the motivation further. Line 150 is the next motivation point – but could be stronger.

Our motivation part was changed as suggested, see our earlier response. The motivation is now clarified in the last paragraph of the introduction

Line 131: I'm not sure this is true – there are regular field courses run by the geosciences department at UiT in Lyngen and other northern regions of Arctic Norway. Additionally, UiT and other universities use the Abisko research station in Sweden too.

Yes, but still most mainland universities in Norway (who are also represented on the UNIS board) send their students to UNIS for field geology training.

Rephrased section now. UNIS courses need a field based component in Svalbard, else they are not approved by the mainland universities.

Line 232: occurred since 'the' beginning

Ok, this is fixed

Line 246: 'one lecture' – how long is this lecture?

Ok, this is fixed

Line 556: There is no table 12, perhaps 2? However this table only showcases European and North American countries – where are the other students from?

Yes, this is table 2. All countries are listed, there were no students from outside Europe or North America (based on institution they study at, not based on passports.) We have also added the guest lecturers into Table 2

Line 563: Can you split up the number of answers into the years? Did more people from the 2023 course respond than those from many years prior? Were you able to get in touch with those from 2018 with email and affiliation changes over time?

We have specified this now. When institutional emails bounced we did actively try to find other contact details through the other students. The large percentage of replies from the 2022 course probably reflects the students sharing the questionnaire link in their internal Whatsapp group

New text: “The questionnaire was sent to all course participants from 2018-2023 for completion in February 2024. 27 of the 57 invitees (47%) responded (5/15 from 2018, 4/13 from 2019, 11/15 from 2022 and 7/14 from 2023).”

Line 579: This lines up with my comment above: It is interesting that many respondents are still involved in Arctic research, but does this reflect that the majority of respondents were from 2022 or 2023 perhaps? In which case, they may still be doing their studies/PhD? Or are there also cases of longevity in the career choices? Which could be interesting to highlight if so, as this could be a further motivation of the course.

We have tried this and investigated the responses per year and incorporated this information in Figure 9. However, we feel the size of the groups per year (ranging from 4 to 11) are too limited to provide robust conclusions or trends – but at the least we identify that students are either heavily involved in Arctic research or not at all.

Following up course alumni for a longer time is of course interesting and could contribute to designing better, or different teaching and learning methods, but our group do not have the means to do that. However, if there are groups or individuals who would like to pursue that task, the authors could be contacted for further discussions and possible collaborations.

Figure 8: Two of the pie charts have the same title.

Ok, fixed

Line 684: extra r in the sentence after 'necessary'.

Ok, fixed

Line 685: What are the nationalities/affiliations of the lecturers and guest lecturers? Does this course bring together not only students from diverse places but also the lecturers? One can look at the author list of course, but I assume these are not all the guest lecturers from over time.

Ok, added to Table 2 now

Line 773 – 793: I personally don't see the need for including this section – Table 5 is enough.

Ok, we have removed this section.

Conclusions: Perhaps bolster again the motivation of your paper – just to outline a project is not enough in the scope of the journal.

Ok, we will incorporate this, to clarify that we provide adequate material to reproduce the course elsewhere and highlight our experiences with this.