

**Scientific evaluation of programme area 5  
Nature and Climate (2005-2013)  
at the Geological Survey of  
Denmark and Greenland  
(GEUS)**

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## Summary and overall observations and recommendations

The programme area 5 Nature and Climate was established several years ago based on strategic and organizational considerations by GEUS. The net appropriation/ core funding from GEUS has varied from 12.0 to 18.8 mill DKK annually during the 2005-2012 evaluation period, with the total revenue varying from 22.7 to 45.6 mill DKK/year. There has been a clear tendency for increasing income during the last 2 years of the evaluation period. The external funding has been higher than 50 % since 2008, varying from 55 to 65 % of the total income during the period 2008-2012. Between 2002 and 2012, 30 to 50 employees, financed by core and third party funding, have been assigned to the program.

Unfortunately the evaluation conditions were not perfect; see the part on Evaluation details for more information on this. However, the evaluation panel conducted detailed personal interviews and discussions with 20 staff members, including the main responsible for this programme area, deputy managing director Bjørn K. Jensen, two department heads, scientists, technical staff and a PhD student. In addition all research professors working in this programme area were interviewed. This evaluation is therefore based on observations made during the site visit to GEUS, and the written revised material that was received after the site visit.

The deputy managing director, who is in charge of programme area 5, identified for us, that this is a rather mixed area. This is also what the panel observed as the overall challenge for this programme area 5. It would be a clear advantage for GEUS to give more attention to developing this programme area Nature and Climate in a coherent way, by establishing strong and clear collaborations between projects that naturally contain scientific topics which go across the involved departments. This would demand much more coordination and cooperation between the different sub-groups, but it would also provide the basis for developing new interdisciplinary close collaborations, which can move science significantly forward. GEUS certainly has the potential to do so within programme area 5 with the generally high scientific level.

Below we provide our overall observations and overall recommendations for the programme area 5 Nature and Climate:

### **Overall observations**

- The research performed is of high quality.
- GEUS has very good research facilities incl. laboratories and offices.
- The scientists that were interviewed do not have any strong commitment towards programme area 5 Nature and Climate.
- The GEUS scientific staff is highly motivated to do basic research.
- There are a lot of high quality and diverse outreach activities in the two large sub-groups of programme area 5.
- The GEUS webpage is in need of improvement. The evaluation panel was informed that GEUS has been working on this for at least 3 years.

- There was no direct presentation or overview of research infrastructure provided during the evaluation.
- There is a significant pressure to provide external funding for research and other projects, which creates stress for the scientific staff.
- The Geocenter collaboration is very supportive for young scientists.
- The young scientists expressed interest in increasing and enhancing the international focus by belonging to international groups.
- There is a positive development in improving the gender balance both on individual scientist level and in the leadership.
- The allocation of core funding to basic research is not transparent.
- GEUS has generally a very good physical working environment.

### **Overall recommendations**

- If GEUS wants to continue operating programme area 5, a clear scientific strategy for this area is needed, and an implementation plan for how to reach the scientific goals must be developed. There is already a considerable amount of high quality research produced, but it appears to be not well coordinated.
- To establish good coordination it is necessary to promote scientific leadership for programme area 5.
- GEUS has a clear potential and can take a research leadership role in national coordination within the fields of glaciology, water and climate, sea bed mapping and potentially in other.
- GEUS research output would benefit from developing a fixed programme to encourage scientific publishing of results. It would be desirable with a model that guarantees allocation of one month science time per year for the scientific staff.
- GEUS should reconsider the 40% (basic funding) / 60% (external funding) funding structure, and potentially move back to the 50% / 50% it had before, to prevent losing scientific quality and capacity.
- GEUS should consider increasing its involvement in Nordic, European and international research programmes.
- GEUS should continue to support young researchers by improving the conditions for the talents.
- Make the PhD students that are working towards their degrees at GEUS, a visible part of the GEUS staff and scientific activities, by for example setting up an attractive PhD programme.
- The Geocenter is an asset and rather unique for GEUS. GEUS could take even more advantage of its collaboration and involvement in the Geocenter for scientific improvement. For example this could include combined recruitments, so that the GEUS Professors were formally associated with the Universities in Denmark, and then primarily with the other large partner in the Geocenter, the University of Copenhagen.
- GEUS should always keep an updated and quality checked database of its scientific and outreach activities within its programme areas. This is relevant not only for scientific evaluations but also for the running overall management of the research.

## Detailed recommendations

### Water resources and climate

- The panel recommends strengthening the current research on adaptation of water resources to climate and land use changes based on modelling approaches and process-based analysis of subsurface or surface water processes. On the short timescale (1-2 years), we suggest that the group should attract a further professor with a strong research background/experience to take on and develop this topic. This group should have two professors to develop and move forward the key research topics. It would be extremely beneficial if these professorships would be jointly affiliated with universities. The management should take the necessary measures to initiate such a process. The assignment of two professors within this group would put the group in a position to further grow and continue to attract high quality research projects. The group has already excellent conditions to grow in this direction due to their intensive cooperation with the University of Copenhagen, and the recommendation is to take this possibility further with determined actions.
- The group should take the leadership in establishing a centre on adaptation of water resources to climate change by integrating competences in the field of climate, agriculture, ecology but also socio-economic aspects and energy issues.
- The group should consider internationalising their field of research and not only address issues of water resources in Denmark. Their expertise is applicable to many urgent issues in Europe (e.g. Mediterranean area) and world-wide.
- The management should consider re-allocating the research activities towards the program area Water Resources. At present the research activities of the group that were presented during the evaluation are not clearly well-connected to the on-going activities in the program area Nature and Climate.

### Glaciology and Permafrost

- Maintaining and ensuring future funding for the PROMICE monitoring program should be given a high priority. In the recent years the program has proven successful in gathering very important data, as the basis for ensuring high quality research of the glaciology group.
- The newly appointed Research Professor in glaciology should aim to establish formal connections to the University of Copenhagen, both to attract glaciology PhD students to GEUS and to improve research relationships. There are a number of ways to do this; one possibility would be to establish an adjunct professorship at University of Copenhagen. GEUS could fund this, and this would then provide valuable input for the Geocenter collaboration.
- GEUS has the potential to strengthen its efforts in taking on a leading role in the coordination of national research collaboration about the Greenland ice sheet mass balance measurements and modelling. There are a number of national partners that have already established collaboration with the glaciology group, for example through the Polar Portal with DMI and DTU, but other institutes such as Niels Bohr Institute and Geological Museum at the University of Copenhagen could be included. A formal management ambition and associated decision would ensure the success of such national research coordination and collaboration.

- Glaciology researchers should have time to publish their research and write peer reviewed papers, to excel in high quality research output. This would make the glaciology group at GEUS one of the most attractive international research partners for glaciology research in the Arctic. This could be done, like in other parts of GEUS, by allocating a fixed number of hours for paper writing.
- GEUS should develop permafrost research and management. As the national geological survey it seems most logical for GEUS to take on the national responsibility for managing key permafrost data. At present there is no official permafrost database structure in Greenland/Denmark. All permafrost data is solely collected and stored within individual research projects. GEUS should support the Global Terrestrial Network for Permafrost, GTN-P, by taking on the national correspondent role in this field, in a similar manner as done in glaciology.

## **Terrestrial and marine palaeoclimate, incl. sea bed mapping, sea currents and their temporal changes**

- The panel recommends more time and better administrative support to the researchers of this sub-group to perform basic research and to write research proposals. Concentrated and uninterrupted time for a month or more per year is recommended.
- GEUS is well equipped and holds a large database of high quality marine acoustic and sediment data. A closer collaboration between the sea-bed mapping group and the marine geology/palaeoclimate group would be beneficial to optimize the use of acoustic instruments for more goal oriented sediment coring, in particular on the Greenland continental margin and fjords, as well as in the waters surrounding Denmark.
- The panel recommends a closer collaboration between the glaciology group and the marine/palaeoceanography group. With the recent strengthening of the glaciology group, there is a particular opportunity to do this now, focused on research in Greenland. The past and present dynamics of the Greenland ice sheet is the focus for many international research groups as well as mass media attention, both with respect to basic glaciological/climatological research and to global warming issues. In this context GEUS has an (almost) unique opportunity to couple fjord and shelf sediment cores to the melting regime and dynamics of the Greenland ice sheet, to gain understanding of the interaction between atmospheric, marine and cryospheric processes; key components in the Arctic Earth System. Attempts to do this have partly been done already, but it could certainly be one major focus for GEUS research, a focus that would be internationally recognized.
- The panel recommends GEUS to consider one of two options to strengthen the leadership of this sub-group. One way is to employ a professor to be responsible for combining marine and terrestrial palaeoclimate studies. An alternative option is to move the terrestrial group into (or back to) the nature and landscape sub-group, and strengthen this with one professor, and strengthen the remaining marine/palaeoceanography/seabed mapping group with another professor.
- GEUS is recommended to involve more PhD students in the research projects in this sub-group at GEUS. A through-flow of PhD students vitalizes the general research environment. The panel in particular recommends to link supervision of these to the recently employed young researchers.
- Based on the expertise at GEUS and the relevance of the topic, it is recommended to start research on marine hypoxia/anoxia, especially in the Baltic Sea area.

## Nature and landscapes

- The panel's observation is that this group is a combination of topics not clearly scientifically connected. The scientific topics range from basic Quaternary and geomorphological mapping, over urban geology and climate adaptation to some geophysical permafrost studies. GEUS should establish a clear scientific leadership for this field to develop this research area as an entity.
- There is a lack of clear vision for the scientific goals of this group. The GEUS leadership should provide the coordination group of the programme with a clear mandate on what the future should be for this sub-group, if they see this sub-group as an important part of the programme area Nature and Climate.
- GEUS should consider whether the groundwater part of this sub-group would not be more naturally located directly together with the water resources and climate sub-group. It would make it possible to address the entire water cycle in one sub-group.
- GEUS should focus strongly on performing high quality Quaternary and geomorphological mapping of Denmark, and potentially also of at least parts of Greenland. This provides a very important basis for all kinds of scientific, educational and other uses of the landscape, and thus also for much of GEUS other activities. It should be ensured that all the mapping data are available in open access databases, allowing the best use of these public data.
- GEUS should consider to develop a sub-group or a scientific department focusing on Quaternary and geomorphological mapping and process dynamics in Denmark and Greenland. It could be called Landscape Dynamics. Scientifically this department should focus on Quaternary geology with stratigraphical and sedimentological studies. It should, however, also include glacial, periglacial and coastal geomorphology, with geohazards from rock slides to rill erosion. Permafrost studies could fit naturally into such a sub-group. Most geological surveys in areas with former and/or present glaciations have at least one such clearly identified research group, and in GEUS it would probably be most natural to have it as a scientific department considering the large influence on present and former cold climatic conditions in Denmark and Greenland.



## Evaluation process

### Objectives and tasks

According to the Danish Statutory Order from the Ministry of Climate and Energy of October 7, 2008 on Research Evaluation at the Geological Survey of Denmark and Greenland (GEUS), the GEUS Board has decided that the next research evaluation shall cover the Nature and Climate programme area. Below, we briefly present the terms of references of the evaluation presented in this report.

The evaluation panel shall undertake an evaluation of research and presentation activities to identify strengths, gaps and needs for amendments and improvements in relation to GEUS' strategy and mission within the GEUS programme area Nature and Climate. The evaluation concerns the period 2005-2013, constituted by the following main themes:

- Water resources and climate
- Glaciology and permafrost
- Terrestrial and marine palaeoclimate, incl. sea bed mapping, sea currents and their temporal changes
- Nature and landscapes

and will be based on a thorough examination of selected publications and reports produced by the survey in addition to a visit to GEUS in Copenhagen.

The tasks of the evaluation panel is to evaluate the research and the research outreach activities of GEUS on the basis of

- Publications, reports and other relevant material produced over the period 2005-2012, both included;
- Interviews with GEUS' management staff and scientists, and visits to laboratories and work facilities at GEUS.

In order to

- Identify areas of high quality research;
- Identify areas where the research of GEUS should be strengthened in order to meet GEUS strategy;
- Provide comments and proposals as to strategic changes, amendments, and improvements to GEUS' work within the, in order to improve GEUS' ability to fulfil its main mission within this programme area seen in the perspective of the survey's statutes and general mission.

The evaluation panel shall report their observations and conclusions in writing.

The evaluation panel visited GEUS for the evaluation 1-4 October, and started the preparation of the final draft report in October-November 2013.

The presentation of the findings in the final report will be presented to the GEUS Board in December 2013.

Based on the findings an implementation plan will be developed by the programme area staff and presented to the GEUS Board in spring 2014. The Board decisions are planned to be implemented from 2014.

## **Evaluation procedure**

The evaluation panel consisted of five members. It elected as the chair:

*Hanne Hvidtfeldt Christiansen, Professor, Dr., Head of Department, Geology Department, The University Centre in Svalbard, UNIS, Longyearbyen, Norway.*

The other evaluation panel members were:

*Guðfinna Aðalgeirsdóttir, Associate Professor, Dr., Institute of Earth Sciences, University of Iceland.*

*Svante Björck, Professor, Dr., Head of Department, Quaternary Sciences, Department of Geology, Lund University, Sweden.*

*Morten Hald, Professor, Dr., Dean, Faculty of Science and Technology, The Arctic University of Norway, Tromsø, Norway.*

*Harry Vereecken, Professor, Dr., Director, Institut für Bio- und Geowissenschaften, IBG-3: Agrosphäre, Forschungszentrum Jülich GmbH, Germany.*

The evaluation panel carried out their work according to the original planning and the detailed programme shown below:

## **Evaluation time schedule for the site visit to GEUS**

Programme for the Research Evaluation of Nature and Climate 1 – 4 October 2013

### **Ole Winther meeting room**

#### ***Tuesday, 1 October 2013***

- 9.00 Welcome coffee/the. Introduction to GEUS and the Evaluation Project. Presentation of results contracts, the involved departments and the sub-programme areas by Bjørn Kaare Jensen – deputy managing director.
- 10.00 Discussion on the role of the evaluation panel members, on the mission programme, the outcome of the mission, and the timescale for the evaluation. (Selection of researchers to be interviewed by the panel may be done running during the presentations.)
- 11.00 Overview presentation of the programme area 5 by Karen Edelvang and Heidi Christiansen Barlebo.
- 11.30 Bibliometric analyses by Jason Box.
- 11.50 Nature and landscaper by Peter Roll Jakobsen and Knud Erik Strøyberg Klint.
- 12.20 Lunch at GEUS (Panel and selected GEUS staff and researchers).
- 13.10 Terrestrial and estuarine environmental history by Jens Peter Rasmussen and Peter Friis Møller.

- 13.40 Seabed geology: Sediment and habitat mapping by Jørn Bo Jensen and Zyad Al-Hamdani.
- 14.10 North Atlantic Climate and Ocean Circulation Variability by Antoon Kuijpers and Kaarina Weckström.
- 14.40 Glaciology and permafrost by Jason Eric Box and Andreas Peter Ahlstrøm.
- 15.10 Break.
- 15.40 Cryo-microbiology and global change by Carsten Suhr Jacobsen.
- 16.00 Past influence of climate on the Greenland ice sheet – elucidating the marine geological archive by Camilla Snowman Andresen and Niels Nørgaard-Pedersen.
- 16.30 Water resources and climate by Jens Christian Refsgaard and Klaus Hinsby.
- 17.00 Review of the day.
- 19.00 Dinner in town for the panel, Karen Edelvang, Bjørn K. Jensen and Jens Stockmarr.

***Wednesday, 2 October 2013***

- 9.00 Coffee/the
- 9.15 Laboratory visit: Molecular biological laboratory presented by Carsten Suhr Jacobsen, Sedimentary laboratory presented by Ingelise Nørgaard, Geobotanical laboratory presented by Karen Dybkjær, and geological well sample laboratory (Henrik Granat).
- 10.30 Presentation and discussion with Head of Information, Henrik H. Thomsen.
- 11.15 Develop the interview programme and discuss the overall content of the evaluation.
- 12.00 Lunch at Statens Museum for Kunst Café for the panel, Karen Edelvang and Jens Stockmarr.
- 13.00 Interview with Heidi C. Barlebo.
- 13.30 Interview with Karen Edelvang.
- Two parallel interview groups. Group 1: Guðfinna, Hanne and Harry. Group 2; Morten and Svante.
- 15.30 Group 1 interview with Jason Box
- 15.30 Group 2 interview with Peter F. Møller.
- 16.00-17.00 Panel discussed the structure of the interview and the evaluation report.
- 19.00 Most of the panel had dinner in town.

***Thursday, 3 October 2013***

- 9.15 Group 1 interview Knud E. Klint
- 9.15 Group 2 interview Ole Bennike.
- 9.45 Group 1 interview Stig S. Pedersen
- 9.45 Group 2 interview Peter Rasmussen
- 10.15 Group 2 interview Jørn B. Jensen
- 10.45 Break
- 11.00 Group 1 interview Andreas Ahlstrøm
- 11.00 Group 2 interview Kaarina Weckström
- 11.30 Group 1 interview Signe B. Andersen
- 11.30 Group 2 interview Camilla S. Andresen
- 12.00 Lunch in the Geocenter Canteen for the panel, Jens Stockmarr and Karen Edelvang.

- 13.00 Group 1 interview Carsten S. Jacobsen
- 13.00 Group 2 interview Niels Nørgaard-Pedersen
- 13.30 Group 1 without Hanne interview Jens C. Refsgård
- 13.30 Group 2 with Hanne interview Jens M. Hansen
- 14.30 Group 1 without Hanne interview Hans J. Henriksen
- 15.00 Group 1 without Hanne interview Ida B. Karlsson.
- 15.30-17.45 Panel working on updating the interviews, and developing the overall observations and recommendations.
- 19.00 Dinner in town for the panel, Heidi C. Barlebo, Karen Edelvang, Bjørn K. Jensen and Jens Stockmarr.

### ***Friday, 4 October 2013***

- 9.00 Panel discussed the oral presentation of the overall evaluation.
- 9.30 All panel interview with Bjørn K. Jensen.
- 10.30 Break
- 10.45 Oral presentation of the overall evaluation with the panel, Bjørn K. Jensen, Heidi C. Barlebo, Karen Edelvang, Flemming Larsen and Jens Stockmarr.
- 12.00 Lunch in the meeting room at GEUS for the panel, Heidi C. Barlebo, Karen Edelvang and Jens Stockmarr.
- 13.00-14.00 Panel discussion on detailed evaluation and overall time planning of the reporting.

## **Evaluation conditions**

The programme area 5 Nature and Climate is run by a coordination board consisting of one of the deputy managing directors, the four heads of the scientific departments involved in this programme area, and the professors from these departments. The four scientific departments involved are ranked in order of number of staff involved in this area from largest to smallest: Marine Geology and Glaciology, Groundwater and Quaternary Mapping, Hydrology and Geochemistry.

The structure of the programme area is not defined by law. The Nature and Climate programme area 5 is mainly perceived by the GEUS staff as being useful for administrative purposes only and to some degree for coordinating activities. The staff articulated that they see the programme area not being relevant for their daily research activities or cooperation between the staff and research groups (“nothing depends on them”). This is a drawback as it could and should be used for inspiration for multi-disciplinary nature and climate research projects, as an overall forum for the GEUS PhD students, and potentially for cooperation within the Geocenter on the various topics in this area.

The Nature and Climate programme area 5 was identified to us as containing activities from three of the nine strategic topics of GEUS listed in the GEUS Strategy 2012: 1) Water resources under pressure, 2) Geology across land and sea, and 3) Past and future climate. However, we also think it contributes to two more strategic topics: Dissemination of digital data and knowledge, and Geology in the public arena.

Unfortunately, the materials we were given to base the evaluation on during the opening of the evaluation process were not adequately prepared. The impression that the panel got was that the material was the result of not well-coordinated efforts by the GEUS leadership and leading scientists. The scientific activities, objectives and challenges within the sub-groups were equally not well prepared for the purpose. This is not the best condition for performing a high quality evaluation. This deficiency was pointed out during the oral presentation of the overall evaluation with the panel towards the end of the site visit, but no further information or feedback on this issue have been received.

Discrepancies between the listed publications in the different sub-groups and the actual staff members of these sub-groups were discovered during the site visit. Therefore the evaluation panel asked for updated publication and outreach information on Friday 4 October. GEUS provided a new set of tables and texts regarding publication and outreach information by mid-October. However, there are still inconsistencies between these documents. These are pointed out in the detailed evaluations of the sub-groups below. In particular the number of peer-reviewed publications is different between the files 'Peer reviewed publications in topic groups 10.10.2013.pdf', 'Employee 2005-2013 publ.s and outreach in topic groups.pdf' and 'Summary Table - Peer reviewed publ. in topic groups 11-10-2013-2.pdf'. We feel that not being able to provide a set of consistent, quality checked data on the key numbers of publication and outreach activities for a scientific evaluation is a major weakness at the organizational level of the programme area. Keeping track of such numbers in a robust and thorough way would seem a natural part of the strategy for operating a good programme area. When inquired, the deputy managing director did not know who was responsible for quality checking the evaluation material that the panel received during the initiation of the site visit.



## Detailed evaluation of the main themes of Nature and Climate programme area

### **Water resources and climate**

#### **Observations**

The panel was very impressed by the research activities in the field of water resources and climate. This sub-group is a key asset for the research activities at GEUS and essential for designing and formulating adaptation and mitigation strategies for the sustainable use of water resources. The research in the group focusses on the uncertainty analysis in hydro-climate research and the coupled modelling of climate and hydrology with a specific focus on water resources. Particularly, the research activities deal with quantifying hydrological fluxes, analysing irrigation requirements, the assessment of seawater intrusion in coastal areas, water quantity and quality in subsurface hydrosystems as well as their ecological status. One of the key expertises in the group is the combination and integration of field work based knowledge and modelling approaches from both climate research and hydrology. We used the information material provided by the program, the presentations given by the scientists as well as interviews with the scientific and technical staff as a basis for the evaluation and recommendations.

#### **Evaluation**

The scientific research conducted by this group is excellent, and it has a unique position in the field of hydrological research. The group should continue its scientific efforts in the above mentioned fields. The knowledge gaps addressed by the group and their approach to tackle these are excellent. The direction chosen is a natural continuation of on-going activities including the uncertainty of climate change on water resources, improved projections of changes in the hydrosystem and reduced uncertainty in hydrosystems modelling by improved modelling approaches.

The group has a strong expertise in modelling hydrological processes and in the integrated analysis of the hydrosystem. The panel feels that addressing more process-based studies in the field of soil-groundwater-surface water systems will strengthen the research portfolio of the group and bring in new elements that are essential when addressing adaptation of the hydrosystem to climate and land use change.

The group is ideally positioned to take leadership on the integrated analysis of adaptation of water resources to climate and land use change. This would extend their present work from impact analysis to the design of adaptation measures. This needs to be done in collaboration with other institutions in Denmark with expertise in the field of agroecology, climate, soils, terrestrial and aquatic ecology as well as socio-economic considerations.

The scientists in the group are internationally visible, and the scientific leader of the group has an outstanding reputation in his science community. The publication track record has greatly

improved after a slow start between 2007 and 2010. This period was mainly used to build up the group, which grew from one PhD student to a group consisting of 9 full time staff members and 10 PhD students. In the last three years, the average publication rate was about 2.4 (2011-2013), which is very good. The group should strive to stabilize its scientific output and at the same time try to get scientific results published in even more highly ranked journals.

The number of publications has strongly increased in the last years, and publications appear in internationally highly ranked journals. The group has taken flight in the last two to three years and much more is to be expected. It has been very active in acquiring third party funding amounting up to more than 30 Million DKK for the period between 2005 and 2012 indicating that the group is highly competitive in its field.

The group has an excellent collaboration with universities and this should be further strengthened. Since 2006 10 PhD students have been working in the group, of which 8 have worked on their PhD projects in close cooperation with the University of Copenhagen. Especially the interaction with HOBE, the hydrological observatory in Denmark is excellent and should be further continued. It could be the basis for the establishment of a Danish centre for water resources and climate adaptation. HOBE benefits from the interaction with the scientists from GEUS especially through modelling expertise and the support of PhD students and post docs.

The group is strongly scientifically driven, which is excellent, but it should consider improving on communicating its research to the broader audience. The establishment of the above mentioned centre could provide a good opportunity to address this topic.

The activities are not well connected with the other activities in the programme area 5. However, this is also the case for the other sub-groups in this programme area. The lack of a clear strategy for the program area will be also addressed in the more general part of this evaluation. It is worthwhile to consider the possibility that this group might better fit in the program area on water resources, with which they naturally have the largest cooperation with within GEUS.

## **Recommendations**

- The panel recommends strengthening the current research on adaptation of water resources to climate and land use changes based on modelling approaches and process-based analysis of subsurface or surface water processes. On the short timescale (1-2 years), we suggest that the group should attract a further professor with a strong research background/experience to take on and develop this topic. This group should have two professors to develop and move forward the key research topics. It would be extremely beneficial if these professorships would be jointly affiliated with universities. The management should take the necessary measures to initiate such a process. The assignment of two professors within this group would put the group in a position to further grow and continue to attract high quality research projects. The group has already excellent conditions to grow in this direction due to their intensive cooperation with the University of Copenhagen, and the recommendation is to take this possibility further with determined actions.

- The group should take the leadership in establishing a centre on adaptation of water resources to climate change by integrating competences in the field of climate, agriculture, ecology but also socio-economic aspects and energy issues.
- The group should consider internationalizing their field of research and not only address issues of water resources in Denmark. Their expertise is applicable to many urgent issues in Europe (e.g. Mediterranean area) and world-wide.
- The management should consider re-allocating the research activities towards the program area water resources. At present the research activities of the group that were presented during the evaluation are not clearly well-connected to the on-going activities in the program area Nature and Climate.

## **Glaciology and Permafrost**

### **Observations**

The glaciology group has grown rapidly during the evaluation period, from having only a few employees in 2005 to a sizeable group of one Research Professor, one Emeritus scientist, 6 scientists (4 senior scientists), 1 postdoc, 4 students (2 PhD students, 2 MSc), one engineer and one technician. This group has successfully established and maintained a monitoring programme of the Greenland ice sheet, PROMICE, since 2007. The group is diverse with a high level of competences, and extensive experience has been gathered from developing and running the instruments of the Automatic Weather Stations in the ablation zone of the Greenland ice sheet. The data collected at these stations are extremely important both nationally and internationally. In addition to the weather station data, observations from satellites and on-ice GPS instruments are gathered to assess changes in ice dynamics, elevation and length changes of outlet glaciers, to obtain a full picture of the mass balance of the Greenland ice sheet. The group does well in making these data world-wide available for collaborating scientists. To some extent the group will be able to base its future research as well as national and international collaborations on these basic data. In the group presentation during the site visit emphasis was put on three activities, monitoring, consultancy and research with additional emphasis on outreach activities.

In addition to the basic glaciology work there is an interesting new research development combining microbiology with glaciology in the EMERALD project, where the albedo of the Greenland ice sheet is studied in relation to microbial growth. This work is done by researchers from the geochemistry department that is working on the theme arctic microbiology within the Nature and Climate programme area.

The research performed by this group has been project driven, with a large focus on extracting external funding for maintaining the size of the group and the level of activity high. They participate in a number of international research projects; EU FP7 project ice2sea (2009-2013), the Nordic Top-Level Research Initiative (TRI) where the Nordic Centre of Excellence SVALI is funded (2010-2015), the earlier Nordic Energy research projects (Climate and Energy Systems (2007-2010) and its predecessors, Climate, Water and Energy (CWE) and Climate and Energy (CE)) and a number of other smaller national and international projects. The group is well presented internationally and participates in IASC (International Arctic

Science Committee) activities, the International Glaciology Society national correspondent is in the group, and they are contributing to AGU Cryosphere Focus Group.

The outreach strategy is excellent, with the use of diverse outlets integrating all members of the group. They have created “Isskolen I and II” (<http://www.isskolen.dk/>) for 4-6 grade and 7-10 grade school students, a national web based educational programme. They present news on Twitter and Facebook, and recently in 2013 the PolarPortal.org, a new arctic monitoring web-site, was established in collaboration with the Danish Meteorological Institute, DMI and DTU Space. The interest in the topic of glaciology, and the melting of the Greenland ice sheet in particular, is currently high, as can be seen on the level of response to the news history from 08/04/2011. This story was covered all over Denmark in the local newspapers and other media.

It is clear that the glaciology research group within the Nature and Climate programme area is doing very well. Strategic decisions have been made, culminating in appointing a new research professor to the group in 2013, to ensure and expand the success.

The panel was asked to also evaluate permafrost, but we did not find any specific activity within this topic, despite the overall oral presentation of this theme was called glaciology and permafrost. We were informed that GEUS is not yet working on permafrost, but that this might be a possibility in the future. This could happen in close collaboration within the Geocenter, where there is Centre for Permafrost, CENPERM, a 10 year basic research centre that GEUS is already a partner in. Likewise the Arctic Technology group, Artek at DTU has some permafrost engineering activities which GEUS is considering to start collaborating with.

## **Evaluation**

In the past years the glaciology group successfully established a very important monitoring network on the periphery of the Greenland ice sheet for observing the ablation and meteorology, which is of high relevance for current glaciological and climate research. The presented research focus is clear and builds on the expertise and the knowledge that has been gathered within the group through the establishment of the monitoring programme PROMICE. It would be scientifically beneficial to expand the present work from monitoring melt and collecting vital associated data, to more focused research on melt water retention and refreezing on the Greenland ice sheet, as the key glaciological processes.

The focus of the glaciology workload group has been on operating and maintaining the stations. It will, however, in the near future be very important to identify and address key scientific questions based on the available data, and thus assist with filling gaps in the knowledge about the Greenland ice sheet dynamics, as the key scientific focus of this group.

The group has excelled in attracting external funding with little core funding from GEUS. Funding has been gathered for both national monitoring and international research projects. The Danish funding for the largest monitoring project, PROMICE, provides some stability for the group. Only the newly appointed research professor in glaciology is fully GEUS funded during the first year, whereas other staff members have to attract funding for their salaries from project activities. The next few years will be very important for the continued success

and further development of the group. It is therefore essential to provide the scientists in the group with the possibility to use the data from their great monitoring efforts for scientific publications. This might be challenging when there is a continued pressure to attract external funding for their activities. Earlier this year GEUS hired a research professor to the group, whose role will be to lead the development of the glaciology group. He has a good international research profile, including extensive collaborations with key national and international glaciology partners. There is a clear potential for bringing the research of the glaciology group to a high scientific level, by ensuring that the members of the group have the time and possibility to write research publications.

The glaciology group at GEUS is in a good position to lead national collaboration on this topic and draw together expertise from other institutes in Denmark, such as climate modelling and model development at DMI, remote sensing at DTU and Quaternary geology at University of Copenhagen Geological Museum. In addition, increased collaboration with the glaciology group at the University of Copenhagen, Niels Bohr Institute, is strongly suggested. This could strengthen the research profile of the group, and it is important at this time to bring new elements into the research agenda.

The number of peer reviewed publications for the whole evaluation period 2005-2013 is 69, with a rapid increase in numbers during the years 2012 and 2013, before 2012 the numbers were 3-6 per year, but increased to 24 and 17 in 2012 and 2013, respectively (from table Peer reviewed scientific papers 2005-2013 in topic groups). Another table (Employee with peer reviewed publications in 4 topic groups – but the name of file is confusing: Employee 2005-2013 publ.s and outreach in topic groups.pdf – is the table giving numbers of peer reviewed publications or outreach?) indicates a total of 115 papers distributed on 19 employees, which amounts to an average of 6.05 papers for the whole period, and less than 1 (0.67) per employee per year.

Seven out of the 19 employees have higher publication numbers than the average for the sub-group (one has 20 publications), and 4 have 0 publications. In the period there were two completed PhD projects, and 3 PhD projects started in 2012 indicating an increase in the number of PhD projects.

From the number of conference contributions, popular scientific articles, popular oral presentations, newspaper articles and interviews listed in the Publication Catalogue, it is clear that the exposure of the glaciology group is large, and the importance of the topic for society very high. There is continuous high number of interviews given by the employees of the group, in 2005 13 interviews, 2007 18 interviews, in 2009 12 interviews and in 2011 one interview from the Experimentarium Online was picked up and discussed 40 times on 08/04 2011 or the days after in local newspapers and other media in Denmark.

Greenland is one of few Arctic nations, which does neither have a systematic national permafrost data structure nor a long-term strategy for even simple permafrost thermal observations. This is despite the fact that most of the land areas without glacier coverage in Greenland have permafrost, and the settlements are located in landscapes with permafrost. The land areas without glacier coverage in the continent Greenland contains all the types of

permafrost from continuous to sporadic, and even some areas are without any permafrost. This and the highly climatically sensitive location in the North Atlantic region makes permafrost research a climatically important research topic. The basic research Center for Permafrost, CENPERM, which GEUS is partner in, has a focus on green-house gases released from the permafrost. GEUS is the natural national institution to be responsible for permafrost monitoring and data management, in a similar manner as GEUS is for glacier monitoring in Greenland.

## **Recommendations**

- Maintaining and ensuring future funding for the PROMICE monitoring program should be given a high priority. In the recent years the program has proven successful in gathering very important data, as the basis for ensuring high quality research of the glaciology group.
- The newly appointed research professor in glaciology should aim to establish formal connections to the University of Copenhagen, both to attract glaciology PhD students to GEUS and to improve research relationships. There are a number of ways to do this; one possibility would be to establish an adjunct professorship at University of Copenhagen. GEUS could fund this, and this would then provide valuable input for the Geocenter collaboration.
- GEUS has the potential to strengthen its efforts in taking on a leading role in the coordination of national research collaboration about the Greenland ice sheet mass balance measurements and modelling. There are a number of national partners that have already established collaboration with the glaciology group, for example through the Polar Portal with DMI and DTU, but other institutes such as Niels Bohr Institute and Geological Museum at the University of Copenhagen could be included. A formal management ambition and associated decision would ensure the success of such national research coordination and collaboration.
- Glaciology researchers should have time to publish their research and write peer reviewed papers, to excel in high quality research output. This would make the glaciology group at GEUS one of the most attractive international research partners for glaciology research in the Arctic. This could be done, like in other parts of GEUS, by allocating a fixed number of hours for paper writing.
- GEUS should develop permafrost research and management. As the national geological survey it seems most logical for GEUS to take on the national responsibility for managing key permafrost data. At present there is no official permafrost database structure in Greenland/Denmark. All permafrost data is solely collected and stored within individual research projects. GEUS should support the Global Terrestrial Network for Permafrost, GTN-P, by taking on the national correspondent role in this field, in a similar manner as done in glaciology.

## **Terrestrial and marine palaeoclimate, incl. sea bed mapping, sea currents and their temporal changes**

### **Observations**

This very wide sub-group of GEUS activity partly covers what one could call a university Quaternary geology/sciences research group, but with, e.g. glacial geology lacking, but found in another sub-group. In many other ways it is also similar to a university department: a wide and skilled research profile, a mix of young and older researchers, a significant flow-through of researchers, with fairly many PhD students engaged in the research activities, and a good international network. This is also obvious from the bibliographic analysis, where it stands out as being twice as productive (mean number of peer reviewed publications/person) as the other groups during the last 9 years. However, although they have maintained a high publication profile, their share of the total publications of Program Area 5 has decreased significantly during the last 4-5 years due to the increasing support to and success of other groups. In 2005-2008 it produced 83% of the publications within programme area 5, which decreased to 53% during the following 4½-year period, with a similar citation trend. This change is the result of increased activity of and support to other sub-groups, such as the Glaciology sub-group. The number of publications for the sub-group has, however, been rather stable with a mean publication rate of 23 publications/year (from table “Peer reviewed scientific papers 2005-2013 in topic groups”). The group is large (35 listed persons), varied and with researchers coming and leaving. Sixteen persons have belonged to the group for the whole period. Two of those researchers have produced more than 50 papers, i.e. ca. 6 papers/year, and eight researchers have published between 10 and 26 publications (from the file “Employee with peer reviewed publications in 4 topic groups”). Considering the fact that these 35 persons have published 333 peer reviewed publications in total, and with a mean GEUS employment time of 5.3 years for this sub-group over the 2005-2013 period, amounting to 185 person-years, it results in a mean publication rate of 1.8 publications/researcher/year. In the light of the fact that five of the researchers employed during the whole period have only produced 2 publications, we think the general publication (and citation) record is very good. Although most members of this GEUS sub-group seem aware of and are realistic about their situation, some of them feel that there is too little “concentrated” time for conducting basic research. This is not surprising, since most of them have a research education and enjoy doing research. The leadership of the sub-group seems aware of this problem, and it is also clear that most of the individual researchers confide in the leadership.

The research of the marine geology/palaeoclimate group mainly focuses on palaeoceanography, deep and surface ocean circulation, palaeoclimate and glacial history in the northern North Atlantic region during the Holocene and the last glacial –interglacial cycle. This includes research in the fjords and continental margin around Greenland, the open northern North Atlantic and the Arctic Ocean. In addition, some projects are oriented on the waters surrounding Denmark, including the Baltic Sea and the North Sea. The group includes very active senior researchers, and in addition two recently employed younger female researchers,

who are also very active. The group has expertise within marine sedimentation and (palaeo)oceanographic issues, in deep-sea and shelf environments, microfossils and geochemistry. The group has been active in international research and project collaboration as well as outreach activities e.g. during the International Polar Year.

The sea bed mapping part of this sub-group contains a very qualified group of researchers. Their sediment and habitat mapping of Danish waters stand out as being of high quality. They are involved in many national and international applied research projects, but seem to be hampered in their efforts to do more basic research, by the high potential to bring in external funding for these types of activities. The group obviously possesses a wealth of interesting and new information that can be used for a wide array of research projects, within marine geology, biology and archaeology. However, the direct scientific output from this database/source, in terms of international peer-reviewed publications, is rather sparse. A large part of Denmark is surrounded by shallow water. Much would be gained, both for applied and basic research, by exploring this still fairly unknown landscape further with targeted research projects. The potential for high quality research is high for this group, but it is vital to maintain the high quality of their mapping activities by supporting research within the field. We noted with some surprise that no research on hypoxia/anoxia is carried out, in spite of the international efforts on this key research issue.

The terrestrial part of this sub-group partly originates from an internationally very well-known and active palaeoecological scientific department, which was in part dismantled a decade or so ago. In spite of this, the sub-group has maintained a high publication profile, and is possibly one of the most productive units - in terms of basic research – within GEUS.

The research of this group has been, and still is very wide and spans an extensive range of classic Quaternary geology topics, such as sea level changes/shore displacement studies, palaeoecology (terrestrial and marine), including forest-cultural landscape history, palaeolimnology, and even marine palaeoecology. An important scope of the palaeoecologic research is to understand the development, dynamics and human impacts on the Danish nature, including acidification and pollution. This is partly a successful continuation of a long DGU/GEUS research tradition, where, e.g. the long record from the Draved forest is scientifically a treasure. However, members of the group have also been part of very diverse palaeoenvironmental-palaeoclimatic projects that have carried out significant and important research outside Denmark, e.g. in the Baltic Sea and other parts of Scandinavia, on the Faroe Islands and the Azores, in N Ireland, Uganda, Canada, USA, Russia, Romania, Antarctica, and not least in many different parts of Greenland as well as in more regional-continental scale syntheses. The international network of this group is essential for their rather impressive publication rate, but we find it very noteworthy that the most publishing researcher within this group is not even employed as a researcher.

10 PhD students have been linked to this sub-group during the time period 2006-2012. In 2012 the sub-group is reported to have 5 PhD students, however, none of them employed by or located at GEUS.

## Evaluation

The research produced by this GEUS sub-group is excellent, internationally visible and at the international research front. The scientific publication record of the group, and in particular some of its seniors, has been steadily high over the evaluation period (2005-2013). It is the most productive group within programme area 5 Nature and Climate, and it is possibly one of the most productive groups within whole GEUS. The papers are published in international high quality scientific journals with an international review system, with a number of publications in several high impact journals, both as lead authors and as co-authors. The research is internationally orientated, and the papers document international collaboration with many universities and research institutions. The evaluation panel is impressed by the variety of research documented by the publications. Examples are many, but e.g. linking marine sediments along the Greenland coast with Greenland ice sheet response is a very creative approach. The group has taken advantage of the high resolution sediment archives in the fjords and shelf of Greenland, and produced some interesting and original papers dealing with e.g. rapid response of glaciers in Greenland to climate variability over the past century and/or during the Holocene. Other innovative approaches include the use of classic (terrestrial) palaeoecologic methods for shallow marine sediments, detecting regime shifts in lakes by using a wide set of proxies, how to use a long “instrumental” forest record, in combination with soil proxies, to elucidate recent anthropogenic impact, and how to use a wide spectrum of marine mapping techniques to carry out sea floor habitats. Many of the papers deal mainly with palaeoenvironmental reconstructions, while others discuss principal climate forcing factors, such as tracking the Atlantic Multidecadal Oscillation through the last 8,000 years, and others develop methods, e.g., possibilities to use IP25 and diatoms to map present and past sea ice extent - an important climate forcing factor that has previously been difficult to find a good proxy for. It is thus a generally good mix of research topics and directions generated by a multifold spectrum of creative ideas.

By linking expertise and infrastructure to the sea-bed mapping group, even more goal oriented research on high resolution sediment records can be achieved. This again will strengthen the research within this whole GEUS sub-group. Restrictions in time to perform basic research may pose a threat to keeping up the high publication rate. In particular the young researchers in the group have a large potential, and thus should be given the possibility to develop into internationally well-recognized researchers in the field, and should be encouraged to enter international research programmes/projects.

The whole sub-group has a large potential for a steady and high out-reach activity in various media, since many of the topics they deal with are of large general interest. They have already shown great activity in this respect, and should continue to do so to inform the public and politicians. Because this may often be a time-consuming task it is important that this activity has the largest possible support from GEUS, which is certainly possible following GEUS communication strategy. After all, most of the activities of this sub-group connects today’s world with a longer, and still very valid, perspective on many current topics. The research is potentially important, both within international research, for the public and for decision makers/politicians.

This sub-group of GEUS has no clear scientific leadership. However, it is probably difficult to find one person with a scientific expertise that could fill such a role, given the fact that this is a scientifically very wide sub-group. One way to over-come this could be to identify one leader covering the marine science both palaeoceanography and sea bed mapping, and one leader within the field of terrestrial palaeoclimate.

## **Recommendations**

- The panel recommends more time and better administrative support to the researchers of this sub-group to perform basic research and to write research proposals. Concentrated and uninterrupted time for a month or more per year is recommended.
- GEUS is well equipped and holds a large database of high quality marine acoustic and sediment data. A closer collaboration between the sea-bed mapping group and the marine geology/palaeoclimate group would be beneficial to optimize the use of acoustic instruments for more goal oriented sediment coring, in particular on the Greenland continental margin and fjords, as well as in the waters surrounding Denmark.
- The panel recommends a closer collaboration between the glaciology group and the marine/palaeoceanography group. With the recent strengthening of the glaciology group, there is a particular opportunity to do this now, focused on research in Greenland. The past and present dynamics of the Greenland ice sheet (GIS) is the focus for many international research groups as well as mass media attention, both with respect to basic glaciological/climatological research and to Global Warming issues. In this context GEUS has an (almost) unique opportunity to couple fjord and shelf sediment cores to the melting regime and dynamics of the GIS, to gain understanding of the interaction between atmospheric, marine and cryospheric processes; key components in the Arctic Earth System. Attempts to do this have partly been done already, but it could certainly be one major focus for GEUS research, a focus that would be internationally recognized.
- The panel recommends GEUS to consider one of two options to strengthen the leadership of this sub-group. One way is to employ a professor to be responsible for combining marine and terrestrial palaeoclimate studies. An alternative option is to move the terrestrial group into (or back to) the Nature and Landscape sub-group, and strengthen this with one professor, and strengthen the remaining marine/palaeoceanography /seabed mapping group with another professor.
- GEUS is recommended to involve more PhD students in the research projects in this sub-group at GEUS. A through-flow of PhD students vitalizes the general research environment. The panel in particular recommends to link supervision of these to the recently employed young researchers.
- Based on the expertise at GEUS and the relevance of the topic, it is recommended to start research on marine hypoxia/anoxia, especially in the Baltic Sea area.

## **Nature and landscapes**

### **Observations**

This is by far the most undefined sub-group within the Nature and Climate programme area. There is no leadership of this group, which consists of a mixture of many topics. During the evaluation visit to GEUS we did not meet the head of the Groundwater and Quaternary Mapping Department, where most of the staff members in this sub-group work. The panel was told that this department head is located in GEUS in Århus as are most of the staff members in this department. However, we find it rather unusual for a department head to not be involved in a scientific evaluation involving large numbers of his/hers staff. During the interviews, when asked about the definition of this nature and landscape sub-group the response was that the staff is not happy with it, but that they have the flexibility to work on the projects they are interested in so the poorly defined structure is not hindering their research.

The researchers that were interviewed from this sub-group clearly said that the Nature and Climate programme area is only providing an administrative structure without leadership, practical to have for locating their projects. And that they do not see any need for this structure. This is parallel to what other sub-group scientists said, except that the other sub-groups have got some scientific leadership. This sub-group has been directly characterized to us as a bucket of leftovers within the programme area 5.

In the overview presentation during the introduction to the evaluation this theme was mixed with the terrestrial environmental history group, showing that the identity of this sub-group is far from clear for GEUS staff. The oral presentation of the nature and landscape sub-group did not contain any information about the structure or the scientific focus of this group. It was rather a list of the methods used, status of mapping and examples of projects in progress.

Scientifically this theme contains a mixture of traditional geological mapping, geomorphological mapping including both coastal, glacial and periglacial environments in Denmark, urban geology and climate, and geological repository studies for nuclear fuel in Greenland including geophysical studies of permafrost. Due to reasons that include not being able to interview the head of the department from which most staff in this sub-group comes, lack of identified research leadership, and no further written material on the overall strategy of this sub-group, the panel cannot assess whether there is any scientific strategy for this sub-group. This is a rather sad situation, in particular because this sub-group provides the key products of a geological survey; the geological maps.

### **Evaluation**

Geological mapping has a long history in Denmark, and is one of the oldest disciplines of GEUS originating in 1888, when the Danish Geological Survey, DGU was established. Impressively, all parts of Denmark are now mapped in the scale 1:50,000 both with respect to the Quaternary sediments and the geology of the pre-Quaternary surface. Digital geological

maps are available in the scale 1:25,000 for a very large part of the country. Until recently a separate Quaternary Geology Department existed at GEUS, but this department was closed during restructuring of GEUS. The associated technical unit, which is the key for producing maps, was then relocated to the geology data centre. The scientists of this sub-group now belong to the Groundwater and Quaternary Mapping Department.

The methods used are of high technical quality, an example is the use of satellite radar scanning for improved high resolution topographical data, which is useful primarily for geological mapping, but also for various research projects.

The panel considers it a great pity that this sub-group appears to be without clear scientific leadership, which results in all kinds of projects to simply develop in undefined directions, without any overall clear research strategy.

According to the updated material received mid-October 2013, this sub-group has 50 peer-reviewed publications during the evaluation period (file: Summary table - Peer reviewed publ. in topic groups 11-10-2013-2), and 27 peer-reviewed publications in the file Employee 2005-2013 publ.s and outreach in topic groups.pdf, whereas the publication overview shows only 19 publications for this sub-group (file: Peer reviewed publications in topic groups - 10.10.2013), counted according to sub-group color coding. Using the last source, in which GEUS provides the information on which sub-group the staff members belong the number of peer-reviewed papers have been rather consistent throughout the period varying from 0 to 4 annually. This sub-group published 2 publications/year on average in the period 2005-2012. This gives a rather low number of 0.3 publications per employee per year for this sub-group during the evaluation period 2005-2012.

According to the bibliometric analyses provided by GEUS as a part of the background material, and presented to the panel orally during the site visit (updated and sent to us again by mid-October), the nature and landscape sub-group published 6 % of all the publications of the entire Nature and Climate programme area in the period 2005-2008, and 5 % from 2009-2013. Citations varied from 2% in 2005-2008 to 3 % in 2009-2013. However, it is not possible to assess which set of basic data these numbers are calculated from.

No PhD students have been associated with this sub-group during the evaluation period according to the updated material provided by GEUS. However, staff members mentioned collaboration with PhD students as important for publishing during the interviews

This group has low outreach activity. During the evaluation period 9 popular science papers, 18 conference contributions, no newspaper articles, 7 oral popular presentations and 2 contributions to workshops, exhibitions or seminars were made. This is a low contribution compared to the other sub-groups. Only the rather new water resources and climate sub-group has less outreach activity.

This group does not work on mapping in Greenland, which happens in other departments as part of mineral resource mapping. It would, however, be scientifically logical for this sub-group to focus on Quaternary and geomorphological mapping in Greenland. At present GEUS

does not work on this, but it might be appropriate to start this activity, at least close to the settlements, where the different use of the landscape would benefit from such mapping.

## **Recommendations**

- The panel's observation is that this group is a combination of topics not clearly scientifically connected. The scientific topics range from basic Quaternary and geomorphological mapping, over urban geology and climate adaptation to some geophysical permafrost studies. GEUS should establish a clear scientific leadership for this field to develop this research area as an entity.
- There is a lack of clear vision for the scientific goals of this sub-group. The GEUS leadership should provide the coordination group of the programme with a clear mandate on what the future should be for this sub-group, if they see this sub-group as an important part of the programme area Nature and Climate.
- GEUS should consider whether the groundwater part of this sub-group would not be more naturally located directly together with the water resources and climate sub-group. It would make it possible to address the entire water cycle in one sub-group.
- GEUS should focus strongly on performing high quality Quaternary and geomorphological mapping of Denmark, and potentially also of at least parts of Greenland. This provides a very important basis for all kinds of scientific, educational and other uses of the landscape, and thus also for much of GEUS other activities. It should be ensured that all the mapping data are available in open access databases, allowing the best use of these public data.
- GEUS should consider to develop a sub-group or a scientific department focusing on Quaternary and geomorphological mapping and process dynamics in Denmark and Greenland. It could be called Landscape Dynamics. Scientifically this department should focus on Quaternary geology with stratigraphical and sedimentological studies. It should, however, also include glacial, periglacial and coastal geomorphology, with geohazards from rock slides to rill erosion. Permafrost studies could fit naturally into such a sub-group. Most geological surveys in areas with former and/or present glaciations have at least one such clearly identified research group, and in GEUS it would probably be most natural to have it as a scientific department considering the large influence on present and former cold climatic conditions in Denmark and Greenland.