PREFACE: THE INTERNATIONAL POLAR YEAR PROJECT 'KINNVIKA' – ARCTIC WARMING AND IMPACT RESEARCH AT 80° N

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Background

The international polar year 2007–8 was a large international effort to extend exploration of the polar systems. Furthermore, the significant role of the Arctic and Antarctic in climate change allowed for even greater opportunity to focus scientific and medial attention to the processes active in the Polar Regions. This Polar Year was the fourth to occur, and approximately 50 000 persons played an active role. IPY-KINNVIKA was one of the 228 registered and endorsed IPY4 projects, containing 69 persons, from 10 nations active in the 11 work packages of KINNVIKA from 2007 to 2009 (Fig. 1). The overarching aim with IPY-KINNVIKA was to initiate a cross-disciplinary study of change and variability within Arctic systems, particularly focused on the northernmost terrain of the European Arctic: Nordaustlandet, Svalbard. This was apt since the early years of the twenty-first century showed signs of record warmth in Svalbard, in accordance with predictions made by the climate modeling society. Our intention was to monitor these changes and to study their impact on ecosystems and landscapes. This Special Issue of *Geografiska Annaler: Series A, Physical Geography* is a collection of primary (in the sense of first) publications from many of the contributing projects – with many more anticipated over coming years – and as such a legacy of IPY4.

The background of IPY-KINNVIKA is rooted in the expeditions to Nordaustlandet led by A.F. Nordenskiöld and H.W. Ahlmann during the early years of polar exploring (c.f. Ahlmann 1932; Liljequist 1993). A large station was erected at Kinnvika in Murchison Bay as a part of the International Geophysical Year, or IPY3 (Liljequist 1993) by Swedish-Finnish-Swiss expeditions. The station

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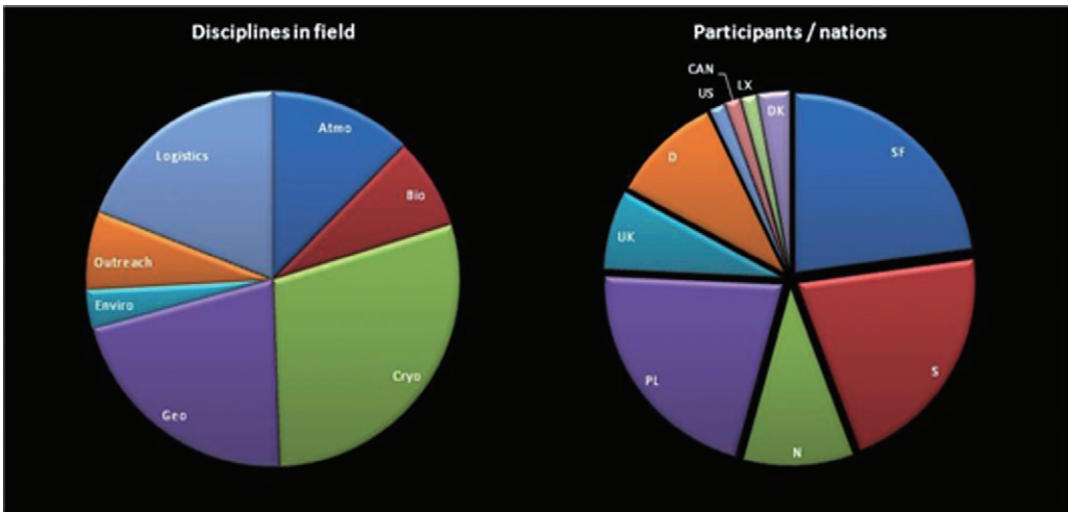

Fig. 1. Pie charts of the distribution of the 69 participating persons in respect of a) disciplines and function, and b) nations where the person was employed. The disciplines are: Cryosphere, Geosphere, Atmosphere, Biosphere, Environmental sciences, Logistics and Outreach. The nations are: Finland, Poland Sweden, Norway, Germany, United Kingdom, Denmark, Canada, Luxemburg and United States of America.

was manned from 1957 to 1959, and monitored meteorological and upper atmospheric physical parameters with an aim to improve knowledge of the Arctic atmosphere. An extensive glaciological campaign was also undertaken during IPY3 (Schytt 1964). The station was built to the highest modern standards at that time with electrical power and warm water radiators, and comprised eight separate wooden buildings and laboratories. This meant that an overwintering party of 13 persons lived in relative comfort during the first year of operations of the Kinnvika station. During the 1960s and the 1980s Swedish glaciological and geological expeditions used the station as a platform for spring and summer campaigns around Murchison Bay and the ice cap Vestfonna (Liljequist 1993). Occasional small groups have temporarily used its facilities, but the station remains remote and logistically challenging even today and has been dormant and in decay, despite the Governor of Svalbard's aim to preserve the station.

Little did we know what kind of pool we dove into when in autumn 2003 we decided to form an international IPY4 project dedicated to research around the old abandoned station in Kinnvika (Fig. 2), and if had we known at that stage all the administrational, financial and political issues emerging along the road, we are not sure we would have persevered with our mission. However now we see the project, if not in perspective, then at least with the benefit of hindsight. We are naturally full of joy our colleagues performed such useful and productive science, and we have a good measure of satisfaction with our efforts to aid their work.

The preparatory phase of IPY-KINNVIKA started with writing up an itinerary for a science plan, identifying work packages where individual scientists or groups of scientists could contribute according to their interests. Via an open call, we managed to solicit about 100 scientists interested in the project. With this foundation of ideas we filed an expression of intent to the IPY-joint commission, and submitted a proposal to the Nordic Council of Ministers for financial aid to cover logistical scouting of the Kinnvika station, and its environment. Both proposals were granted in 2004, with the support of the Finnish and the Swedish Arctic Council representatives. In 2005 we negotiated the Environmental Office of the Governor of Svalbard to visit Kinnvika, and to use the station from 2007 to 2010. The Governor was very supportive of our plans, and offered assistance to refurbish any parts of the station. In September 2005 we sailed up for an inspection, and found that the station buildings were still proudly standing but their interiors were in worse shape than expected, and our plan was revised to make more modest usage of the houses. Later that year our second and more elaborate expression of intent was approved by the IPY-committee, and so we were an official IPY project. With this seal, and

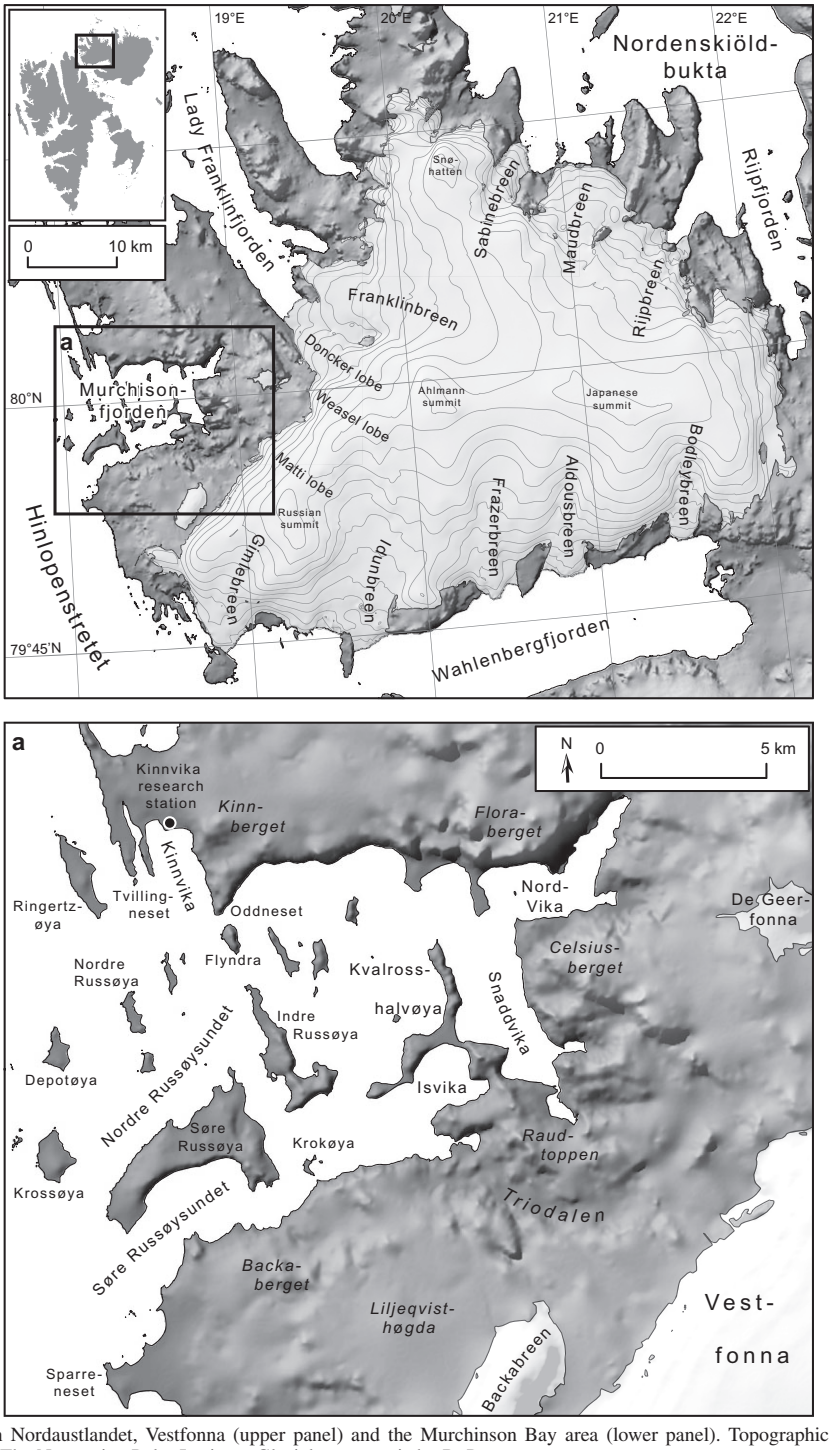

Fig. 2. Western Nordaustlandet, Vestfonna (upper panel) and the Murchinson Bay area (lower panel). Topographic data is from TopoSvalbard, The Norwegian Polar Institute. Glacial coverage is by R. Pettersson.

with the goodwill of the Governor of Svalbard to pursue expeditions to the environmentally restricted natural reserve of Nordaustlandet, we were ready to contact our colleagues and give the green light for submitting grant proposals to their respective research councils. We filed a second proposal to the Nordic Council of Ministers to cover expenditure for the coming expeditions. We also got a positive and enthusiastic response from the Swedish Polar Research Secreteriate (SPRS) who allocated technical personnel and equipment for our expeditions, as well as the administrational and political support SPRS harbours. Further, a private company, Metsä-Tissue Serla OY/AB/AS, gave us a financial support for our expeditions. With the logistical support from SPRS and the support in for cruises up to Kinnvika with the Polish research vessel *RV Horyzont II*, managed by our Polish colleges at the Polish Polar Station in Hornsund, IPY-KINNVIKA became afloat.

Physical setting of western Nordaustlandet

Nordaustlandet is the northernmost sizeable terrestrial platform in the European sector of the Arctic, and is a part of the Svalbard Archipelago (Fig 2). Nordaustlandet is 90% ice-covered, mainly by the large ice caps Austfonna (8450 m^2) and Vestfonna (2400 m^2). Polar desert and semi-desert ecosystems, underlain by continuous permafrost dominate the unglaciated terrain. Bedrock is formed by Proterozoic igneous rocks and Neoproterozoic to Mesozoic volcanic and sedimentary rocks (e.g., Stouge *et al*. 2011). Glaciogene strata is frequent from the Quaternary, but they also form Neoproterozoic tillites. Nordaustlandet is climatically more influenced by Arctic air masses, rather than westerlies and therefore experiences a high arctic climate; colder especially in summer than the other parts of Svalbard.

Over the period May 2007 to May 2009 our automatic weather station on the western flank on Vestfonna at 335 m a.s.l. measured an average air temperature of –10.4°C and an average wind speed of 6.1 m s^{-1}. During the IPY3 the average air temperature of –6.8°C and the average wind speed of 5.6 m s^{-1} were measured over the station in Kinnvika at 15 m a.s.l. (August 1957–August 1959) (Liljequist 1993). These two sets of measurements were done at different locations, and at different altitudes, but if we use an adiabatic lapse rate of 0.005°C m^{-1} (Liljequist 1993) we find that the 2007–2009 temperatures at sea level is in the order of –8.8°C. Monthly averaged temperatures are shown in Fig 3. Lateral gradients probably exist between the ice cap and the non-glaciated terrain close to Murchinson Bay so it is not certain that IPY4 was colder than IPY3, but at least it seems from our data that the weather during IPY4 was not much different from the weather recorded during

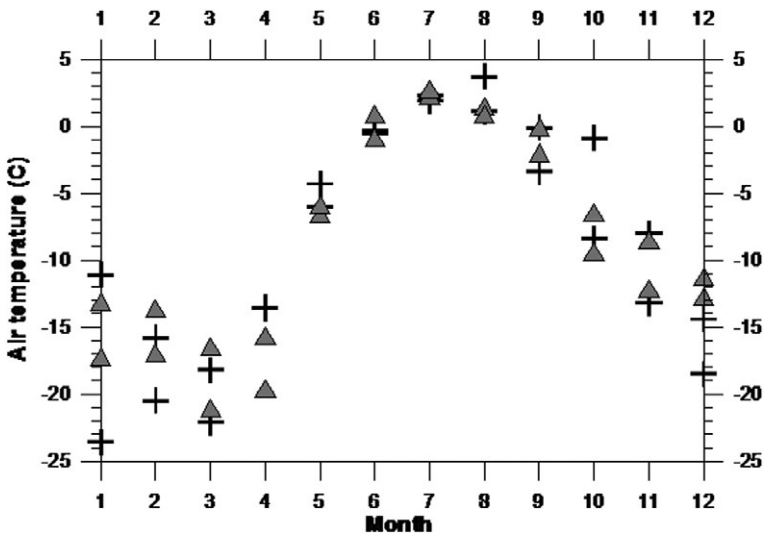

Fig. 3. Monthly average air temperatures for Kinnvika during IPY3 and IPY4. The black crosses are the Kinnvika monthly temperatures at 15 m a.s.l. during 1957–1959. The grey triangles are monthly temperatures calculated to 15 m a.s.l. using a lapse rate of 0.5°C (100 m)$^{-1}$ from temperatures from the western rim of Vestfonna 335 m a.s.l. 2007–2009.

IPY3. On the other hand, during IPY3 the 10 m ice temperatures at 315 m a.s.l. of Vestfonna was found to be –8°C (Palosuo 1987), while the ice temperatures we measured at the same depth at 335 m a.s.l. gave –7.0°C, one degree warmer. The temperature at 10 m depth in ice is usually referred to as the annual average ice temperature. From these simple data, and the results from Braun *et al*. (2011) showing a continuous retreat of most outlet glacier terminus from Vestfonna, we get a hint of the complexity and subtlety of the environmental changes that have occurred over the 50 years between IPY3 and 4. The wind speeds between the different localities and the time periods are comparable with each other, proving the Murchinson Bay area to be a windy region.

Scientific goals

At the preparatory phase of IPY4 it became evident that the Arctic was experiencing a warming, and with this a rapid change of the biosphere and the cryosphere was at hand. Our aim was to expand the monitoring net of various global change parameters, especially towards the High Arctic since this area naturally has a sparse coverage. Our focus became Nordaustlandet, due to its extreme position. In contrast to a variety of extensive research and monitoring activities in southern and western Svalbard, very little research has focused on the northeastern part of Svalbard during the last decades. This is probably due to difficult access and logistics. Since IPY-KINNVIKA obtained permission to use the old Kinnvika Station as a platform, and we could work in combination with *RV Horyzont II*, we saw the potential to launch a broad monitoring and mapping programme to temporarily fill in the white space in this part of the High Arctic. Our initiative was meant to provide a broad scientific and logistic platform around which a number of research and monitoring activities could be centred in a truly interdisciplinary manner. With the promising response to call for interest in our project, we managed to form 25 different work packages (www.kinnvika.net). Out of these 25 work packages in the planning stage, 11 became operative, and are represented by the papers of this special issue of *Geografiska Annaler: Series A, Physical Geography*. Some packages fell by the wayside due to the stochastic nature of domestic research funding. In that respect IPY4 differed considerably from the top-down structure of IPY3. Nevertheless we received about 4 million Euro in funding and resulting in the 1305 person-days spent working at Kinnvika. In this issue we present this collection of papers representing the initial publications of the findings of our expeditions. The multi-disciplinary work in merging the different scientific disciplines into each other has just begun, although the seeds started to grow during the joint field work.

The expeditions

In short we managed six summer and spring expeditions between 2007 and 2010. The expeditions are described in detail at www.kinnvika.net. In spring 2010 we removed the last installations used for IPY-KINNVIKA. Some of the instruments we used were transformed into operations within the ESF-PolarClimate project 'SvalGlac' and will remain monitoring until spring 2012. Due to weather and sea ice, planning and executing these expeditions was a challenge and a good field work school. Last minute changes of operations, ubiquitous polar bears and a 'plan B' mind-set was the order of the day. Without the skilled manoeuvres of the hands governing our transportation platforms such as ships, smaller boats, helicopters and snow mobiles, we would have gone nowhere. For many of us this experience was a story of the life-time, and a large part of the media coverage on us centred on these adventures. Still, it was just another day in the High-Arctic. As supplemental information we add the description from the captain of *RV Horyzont II*, Tadeusz Pastusiak, of how a large ship can navigate through uncharted waters, without excessive risks of shoaling using proper instrumentation and precautions.

Outreach

This international polar year had much more media coverage then earlier ones, and the media had a key role in making the expeditions of IPY a widely experienced venture. The aim posted by the IPY4 central committee was that schools and the general public should be integrated as much as possible with cutting-edge science during the expeditions. Accordingly we paid special attention to outreach and communication in this project and succeeded in making the expeditions visible in TV, newspapers, radio, exhibitions, schools, brochures and websites. Metsä-Tissue Serla OY/AB/AS, a private company that supported our expeditions even mentioned the Kinnvika project in a TV commercial. A colourfully illustrated popular science book on the project is in preparation, and should be available in

2012. Furthermore, a 70 minutes documentary film (Kinnvika – The Last Border by Petteri Saario) was released September 2011, focusing on the work of one of the IPY-KINNVIKA teams.

The Kinnvika-project inspired pupils of four Finnish high schools to travel to Svalbard for a week in summer 2007. They published a diary of their activities in blogs at Kinnvika-netschool website, and also asked questions directly to scientists from the field. Furthermore, in summer 2008, the schooner *SY Helena* sailed from Finland to Svalbard with high-school pupils together with scientists, receiving environmental education during the trip. A photo exhibition about the Kinnvika-expedition from 1957 was prepared by Forum Marinum, Åbo Akademi and was set up at the Arctic Centre Arktikum-house in 2007–2008. The Polarmuseum at Gränna, Sweden held an exhibition on Polar Years, with focus on the Kinnvika expeditions. The Kinnvika-project is also visible as an IPY legacy in the permanent science centre exhibition of the Arctic Centre (Finland) through photos, video and an interactive field station. The Swedish Polar Research Secretariat continuously updated their home page, and their press-releases, where our expedition routinely was mentioned. The website www.kinnvika.net provided information about the project both for the general public as well as the scientists, and is planned to be available on the net as a legacy of our expeditions and IPY4. All this outreach effort resulted in large media attention of both local small-scale activities, as well as national events in major Finnish newspapers and in Finnish and Swedish TV. Swedish TV4 broadcasted a series of 5 minute reports from our expeditions, as well as having a set of discussions in morning-sofa TV.

The scientific results (so far)

Scientific production in the form of peer-reviewed papers usually has a substantial time-lag from the data collection phase of a project. The intention of this special issue of *Geografiska Annaler: Series A, Physical Geography* is to collect in a convenient location the key observations we made and give a context for the primary (in the sense of first) results of IPY-KINNVIKA. Previously published results are also available on Triassic microbialites of Northeastern Svalbard (Krajewski 2011), the Quaternary sedimentary and environmental evolution of Murchinson Bay by Kaakinen *et al*. (2009), Kubischta *et al*. (2010), Ojala *et al*. (2010) and Nevalainen *et al*. (2011), the snow chemistry of and formation of frost flowers by Beaudon and Moore (2009), and a reconstruction of the mass balance of Vestfonna during the previous decade by Möller *et al*. (2011b). Terrestrial mapping of western Nordaustlandet was published by Kolondra (2007), and bathymetric mapping of parts of Murchinson Bay by Moskalik and Bialik (2011) and how to navigate in uncharted waters (Pastusiak 2011). A vast part of the data collected during the IPY-KINNVIKA expeditions was weather data from automatic weather stations. The stations are presented in Möller *et al*. (2011a), but the full range of this data is not yet published.

The papers in this special issue can be generally be grouped into: geological and environmental history (Kubischta *et al*. 2011; Luoto *et al*. 2011; Stouge *et al*. 2011); contemporary ecological situation of arthropods and plants (Cooper 2011; Coulson *et al*. 2011); contemporary climatological state of western Nordaustlandet (Beaudon *et al*. 2011; Käsmacher and Schneider 2011; Möller *et al*. 2011a) and the ice dynamical situation of Vestfonna (Braun *et al*. 2011; Pettersson *et al*. 2011; Pohjola *et al*. 2011).

We will now give a short summary of the findings reported in the papers in this special issue. Mapping the stratigraphic sequences on the northern flank of the Hinlopen strait Stouge *et al*. (2011) suggest that the lower Paleoozoic sequences matches the stratigraphy of Ny Friesland on the opposite side of Hinlopen. This finding aids the understanding of the evolution of the Iapteus Ocean 600–400 m years ago. The sediment cores taken in Murchinson Bay and in fresh water lakes by Kubischta *et al*. (2011) and Luoto *et al*. (2011) reveal the ecological and environmental evolution of the area after the deglaciation of the area, with the result that the most ecologically dynamic period was the pioneering phase in the early Holocene. A large change is suggested in sea surface temperature not only to be due to the increase in insolation, but also the opening of new pathways for ocean currents.

The contemporary mapping of plants (Cooper 2011) and of mites, spiders and springtails (Coulson *et al*. 2011) resulted in relatively large numbers of specimens, despite the harsh environment of Nordaustlandet. Many of the specimens were found in the more lush areas beneath bird cliffs, but surprisingly many specimens dwell in the sparse vegetative pockets of the mostly rocky pavement. These vegetation oases presented relatively rich seedbanks, suggesting airborne transport, but the plant speci-

mens were dominated by species that also use asexual vegetative reproduction (lateral migration of the root system).

The work by Käsmacher and Schneider (2011) uses reanalysed weather prediction model data to draw a conclusion of the classes of synoptic pressure fields over Svalbard, and offer an improved way to understand the climate and climate variability of Svalbard. The snow pit and ice core studies by Möller *et al*. (2011a) and Beaudon *et al*. (2011) show a large spatial and temporal variability in accumulation rates over Vestfonna. Their results are in the same range as the findings by the IPY3 expeditions (Schytt 1964; Palosuo 1987) suggesting that no large change in accumulation of snow is detected during these two windows. The results by Braun *et al*. (2011) on the other hand find retreat of almost all of the outlet glacial margins of Vestfonna, except Franklinbreen, that is suspected to be in a surge phase. This strongly suggests a decrease in accumulated mass, either due to negative surface mass balance, or to dynamical controls at the tide water margins of the outlets, probably in concert with the past decades of warming of the Arctic. Pettersson *et al*. (2011) present an updated ice thickness map of Vestfonna, and from the radio-echo soundings they further show that large parts of the outlet glaciers are wet based, while the interior of the ice cap and the terrestrial margin is frozen to the base. The velocity map of Vestfonna by Pohjola *et al*. (2011) show that the fast flow mode of these outlets are probably controlled by the wet based bedrock beneath the glaciers. Pohjola *et al*. (2011) further suggest that the ice dynamical situation of Vestfonna has been stable for the last 15 years, except for the surging glacier Franklinbreen, corroborating the results by Braun *et al*. (2011).

All the science presented above has been focused on the primary data, and specific to the location of western Nordaustlandet. However, all the participating groups are now active in the integration of their results into the wider contexts of their fields. We look forward with pleasure and anticipate taking part in this endeavour over the coming years.

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References

Ahlmann, H.W., 1932. Den svensk-norska expeditionen till Nordostlandet och farvatten däromkring sommaren 1931 [The Swedish-Norwegian expedition to Nordostlandet and the surrounding waters in summer 1931]. *Ymer*, 1932, 1–31. [In Swedish].

Beaudon, E., Arppe, L., Jonsel, U., Martma, T., Möller, M., Pohjola, V.A., Scherer, D. and Moore, J.C., 2011. Spatial and temporal variability of net accumulation from shallow cores from Vestfonna ice cap (Nordaustlandet, Svalbard). *Geografiska Annaler: Series A, Physical Geography*, 93, 287–299.

Beaudon, E. and Moore, J., 2009. Frost flower chemical signature in winter snow on Vestfonna ice cap (Nordaustlandet, Svalbard). *The Cryosphere*, 3(2), 147–154.

Braun, M., Pohjola, V.A., Pettersson, R., Möller, M., Finkelnburg, R., Falk, U., Scherer, D. and Schneider, C., 2011. Changes of glacier frontal positions of Vestfonna (Nordaustlandet, Svalbard). *Geografiska Annaler: Series A, Physical Geography*, 93, 301–310.

Cooper, E.J., 2011. Polar desert vegetation and plant recruitment in Murchisonfjord, Nordaustlandet, Svalbard. *Geografiska Annaler: Series A, Physical Geography*, 93, 243–252.

Coulson, S.J., Fjellberg, A., Snazell, R., Gwiazdowicz, D.J. and Ávila-Jiménez, M.L., 2011. On the Collembola, Araneae and Gamasida from the Kinnvika region of Nordaustlandet, Svalbard. *Geografiska Annaler: Series A, Physical Geography*, 93, 253–257.

Kaakinen, A., Salonen, V.-P., Kubischta, F., Eskola, K.O. and Oinonen, M., 2009. Weichselian glacial stage in Murchisonfjorden, Nordaustlandet, Svalbard. *Boreas*, 38(4), 718–729.

Käsmacher, O. and Schneider, C., 2011. An objective circulation pattern classification for the region of Svalbard. *Geografiska Annaler: Series A, Physical Geography*, 93, 259–271.

Kolondra, L., 2007. Murchinsonfjorden, a satellite orthofoto map of western Nordaustlandet 1:50.000, University of Silesia, Poland.

Krajewski, K.P., 2011. Phosphatic microbialites in the Triassic phosphogenic facies of Svalbard. In *Stromatolites: Interaction of Microbes with Sediments*, Springer Science+Business Media B.V. 187–222. doi:10.1007/978-94-007-0397-1.

Kubischta, F., Knudsen, K.L., Kaakinen, A. and Salonen, V-.P., 2010. Late Quaternary foraminiferal record in Murchisonfjorden, Nordaustlandet, Svalbard. *Polar Research*, 29, 283–297.

Kubischta, F., Knudsen, K.L., Ojala, A.E.K. and Salonen, V.-P., 2011. Holocene benthic foraminiferal record from a high-arctic fjord, Nordaustlandet, Svalbard. *Geografiska Annaler, Series A, Physical Geography*, 93, 227–242.

Liljequist, G. 1993. *High Latitudes*. The Swedish Polar Research Secretariat/Streiffert. 607 pp.

Luoto, T.P., Nevalainen, L., Kubischta, F., Kultti, S., Knudsen, K.L. and Salonen, V.-P., 2011. Late Quaternary ecological turnover in High Arctic Lake Einstaken, Nordaustlandet, Svalbard (80° N). *Geografiska Annaler: Series A, Physical Geography*, doi: 10.1111/j.1468-0459.2011.00435.x.

Möller, M., Möller, R., Beaudon, E., Mattila, O.-P., Finkelnburg, R., Braun, M., Grabiec, M., Jonsell, U. and Luks, B., 2011a. Snowpack characteristics of Vestfonna and De Geerfonna (Nordaustlandet, Svalbard) – A spatiotemporal analysis based on multiyear snow-pit data. *Geografiska Annaler: Series A, Physical Geography*. 93, 273–285.

Möller, M. Finkelnburg, R. Braun, M. Hock, R. Jonsell, U., Pohjola, V.A. Scherer, D. and Schneider, C., 2011b. Climatic mass balance of the ice cap Vestfonna, Svalbard – a spatially distributed assessment using ERA-Interim and MODIS data. *Journal of Geophysical Research*, 116(F03009), doi:10.1029/2010JF001905.

Moskalik, M. and Bialik, R.J., 2011. Statistical analysis of topography of Isvika Bay, Murchisonfjorden, Svalbard. *Experimental Methods in Hydraulic Research*, 1, 225–233.

Nevalainen, L., Van Damme, K., Luoto, T.P. and Salonen, V.-P. 2011 Fossil remains of an unknown *Alona* species (Chydoridae, Aloninae) from a High Arctic lake in Nordaustlandet, Svalbard, and its relation to glaciation and Holocene environmental history. *Polar Biology*, 34. Doi:10.1007/s00300-011-1077-z.

Ojala, A.E.K., Kubischta, F., Kaakinen, A. and Salonen, V.-P., 2010. Characterization of diamictons on the basis of their mineral magnetic properties in Murchisonfjorden, Nordaustlandet, Svalbard. *Sedimentary Geology*, 233, 150–158.

Palosuo, E., 1987. A study of snow and ice temperatures on Vestfonna, Svalbard, 1956, 1957 and 1958. *Geografiska Annaler: Series A, Physical Geography*, 69, 431–437.

Pastusiak T., 2011. Ship's navigational safety in the Arctic unsurveyed regions. In *Miscellaneous Problems in Maritime Navigation, Transport and Shipping*, CRC Press, London. 59–64.

Pettersson, R., Christoffersen, P., Dowdeswell, J.A., Pohjola, V., Hubbard, A. and Strozzi, T., 2011. Ice thickness and basal conditions of Vestfonna ice cap, eastern Svalbard. *Geografiska Annaler: Series A, Physical Geography*, 93, 311–322.

Pohjola, V.A., Christoffersen, P., Kolondra, L., Moore, J.C., Pettersson, R., Schäfer, M., Strozzi, T. and Reijmer, C.H., 2011. Spatial distribution and change in the surface ice-velocity field of Vestfonna ice cap, Nordaustlandet, Svalbard, 1995–2010 using geodetic and satellite interferometry data. *Geografiska Annaler:, Series A, Physical Geography*, 93, 323–335.

Schytt, V., 1964. Scientific results of the Swedish glaciological expedition to Nordaustlandet, Spitsbergen, 1957 and 1958. *Geografiska Annaler*, 46(3), 442–481.

Stouge, S., Christiansen, J.L. and Holmner, L.E., 2011. Lower Paleozoic stratigraphy of Murchisonfjorden and Sparreneset, Nordaustlandet, Svalbard. *Geografiska Annaler: Series A, Physical Geography*, 93, 209–226.

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