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Fred Daniëls, Subzone A, and the North American Arctic Transect

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Abstract. Prof. Fred Daniëls greatly influenced the current understanding of North American Arctic vegetation because of his important role in several key events, including the first and second international workshops on classification and mapping of Arctic vegetation, the Circumpolar Arctic Vegetation Map (CAVM), the 1999 CAVM Expedition to the Canadian Arctic, the 2005 Expedition to Isachsen, and the North American Arctic Transect (NAAT). The latter was established in 2002-2006 to study the biocomplexity of patterned-ground ecosystems across the full Arctic bioclimate gradient. In this festschrift for Fred Daniëls, we place special emphasis on Subzone A of the CAVM because this is an area of special interest to him and it is a rare and endangered Arctic bioclimate subzone. We also argue the need for a well-coordinated international effort to obtain a baseline of vegetation and environmental observations using the Braun-Blanquet approach along the full Arctic bioclimate gradient, and especially in Subzone A, so that future generations of Arctic scientists can document the consequences of ongoing rapid climate change in this sensitive region of the Arctic.

1 Introduction

One of Fred Daniëls' true loves is the Arctic – particularly Greenland. His early work with vegetation in the Angmagssalik region of southeast Greenland (DANIËLS 1968, 1969, 1975 & 1982, DANIËLS & DE MOLENAAR 1970) triggered a lifelong interest that eventually grew to encompass the entire circumpolar Arctic. Prof. Daniëls is among the small group of Arctic phytosociologists and geobotanists with training in the Braun-Blanquet approach to vegetation classification and a truly circumpolar perspective. He participated in twelve expeditions to Greenland, three to Arctic Canada, and five to areas bordering the Arctic including the Aleutian Islands, and East Siberia. He is a member of the Permanent Flora Group of the Conservation of Arctic Flora and Fauna (CAFF), the biodiversity group of the Arctic Council, the Circum-Arctic Terrestrial Biodiversity (CAT-B) group of the International Arctic Science Committee (IASC), and the International Union for the Conservation of Nature (IUCN) Arctic Plant Specialist Group. It was natural that he would play a leadership role in the first International Workshop on Classification of Arctic Vegetation held in Boulder, 5-9 March 1992 (WALKER et al. 1995).

At the Boulder workshop, Fred Daniëls was among the signers of the resolution to make a Circumpolar Arctic Vegetation Map (WALKER et al. 1994, WALKER 1995). The participants noted that the Arctic is increasingly recognized as a single geo-ecosystem with a common set of cultural, political, economic, and ecological issues. Previous vegetation maps of the circumpolar Arctic depicted a few broad arctic land-cover categories (PRENTICE et al. 1992, STEFFEN et al. 1996); however, it was noted that much more detail was needed for a variety of conservation studies, land-use planning, and education. In addition, changes associated with global warming and rapid land-use changes in the Arctic (NELLEMAN et al. 2001) added urgency to the creation of a new map.

In the ten years following the Boulder meeting, Fred Daniëls participated in all of the major workshops that led up to the final map including those at Lakta, Russia in 1994 (WALKER & MARKON 1996); Arendal, Norway in 1996; Anchorage, Alaska in 1997 (WALKER & LILLIE 1997); the Canadian Arctic Transect in 1999 (GONZALEZ et al. 2000); Moscow, Russia in 2001 (RAYNOLDS & MARKON 2001); and Tromsø, Norway in 2004 (DANIËLS et al. 2005). Prof. Daniëls led the effort to make the Greenland portion of the CAVM. This information was then synthesized, first with other information from North America then as one map for the whole Arctic (CAVM TEAM et al. 2003).

Prof. Daniëls edited the final CAVM volume published in *Phytocoenologia* that commemorated the completion of the map and the work of Dr. Boris Yurtsev with twelve papers that described the ongoing process to classify and map the vegetation of the Arctic (DANIËLS et al. 2005). Among the contributions to this volume were papers by KUCHEROV & DANIËLS (2005), TALBOT et al. (2005), and SIEG & DANIËLS (2005). The volume made a significant contribution to an enlarged syntaxonomical and synecological knowledge of arctic and related vegetation, but a coherent picture of circumpolar vegetation is still far away.

The map took over 11 years from the initial Boulder resolution until its final publication (CAVM TEAM et al. 2003). During that period, several of us in North America benefited greatly from our association with Prof. Daniëls. He helped introduce the methods of the Braun-Blanquet approach to vegetation classification in the North American Arctic and provided numerous insights regarding the geobotanical relationships of Arctic vegetation, particularly the mosses and lichens.

One of the most interesting aspects of making the CAVM was the focus on Arctic bioclimate zonation and different approaches to zonation that had developed in Eurasia and North America. These differences had to be resolved in order to produce a consistent map legend for the whole Arctic. Nowhere were the differences greater than in the northernmost part of the Arctic, the region that was called ‘polar desert’ in Russia and what became to be known as ‘Subzone A’ on the CAVM. This area was relatively poorly known in North America, and it became an area of intense interest by all the members of the CAVM and later projects working in the North American Arctic. One of the justifications for making the CAVM was the rapid land-use and climate-related changes that were occurring in the Arctic. This concern has only increased with the astonishingly rapid reduction of the extent of perennial Arctic sea ice (NGHIEM et al. 2007, COMISO et al. 2008). Subzone A has become of special concern because for the first time it is clear that the very conditions that created the northernmost bioclimate subzone, i.e., the presence of multi-year sea ice, would likely no longer exist within the lifetime of the present generation of Arctic geobotanists. The second chapter of this article provides a brief overview of the characteristics of Subzone A and the debate regarding how it should be named, as well as its special sensitivity to climate change.

In the years after the CAVM was completed, several of us in North America were interested in using the zonation approach of the CAVM as a framework for studying tundra ecological processes along the complete Arctic bioclimate gradient. Towards this end we established the North American Arctic Transect (NAAT) to study cryo-ecological processes involved in patterned-ground formation (Fig. 1). The third chapter of this article provides a description of the NAAT with a summary of Fred Daniëls' role in several key events associated with the transect, including a 1999 expedition to the Canadian Arctic, the Biocomplexity of Patterned-Ground project, and the 2005 expedition to Isachsen.

2 The unique character of Subzone A, the 'polar desert' of Russian geobotanists

One dream of Fred Daniëls during the construction of the CAVM was to visit Subzone A. This coldest subzone covers only about 2 % of the Arctic and is confined to areas where the mean July temperature is less than 2-3°C. Subzone A is especially poorly known in North America. Very few American geobotanists have visited this subzone or recognized its unique character. Before the elaboration of the CAVM, the approaches used to subdivide the Arctic were quite different in North America and Eurasia. Russian geobotanists typically divided the Arctic into many more subzones or regions than their North American counterparts. For example ALEKSANDROVA (1980) recognized eight subdivisions; whereas in North America, the most widely cited approaches recognized only two or three (POLUNIN 1951, BLISS 1997). Most of the Russian approaches recognized the region with temperatures less than 2-3°C as a truly unique part of the Arctic that they call the 'polar desert' (GORODKOV 1935, ALEKSANDROVA 1980, MATVEYEVA 2006). Important characteristics of this zone include a complete lack of woody species, sedges, and *Sphagna,* absence of peat in wetlands, and a predominance of bryophytes, crustose lichens, and blue-green algae with a mixture of scattered cushion-forming herbaceous species. The total species number of vascular plants in local floras within this subzone is generally less than 60, and the total summer warmth index (sum of mean monthly temperatures greater than 0°C) is less than 6°C (YOUNG 1971). It has also faunal uniqueness that has been studied most extensively in Russia (CHERNOV 1995, CHERNOV & MATVEYEVA 1997).

In North America the term 'polar desert' has a different connotation than that used in Russia, and this has led to considerable confusion regarding Arctic zonation terminology. In North America the works of J. Tedrow and L. Bliss were most influential. Tedrow, an American soil scientist, provides a thorough review of the Russian geobotanical and pedologic zonation schemes in his book *Soils of the Polar Landscapes* (TEDROW 1977), but he arrives at an endpoint that is quite different than any of the current Russian approaches. He defined 'polar desert', 'subpolar desert', and 'tundra' pedologic zones. These more or less followed POLUNIN's (1951) High-, Middle-, and Low-Arctic boundaries. Even though he used the terms 'polar desert' and 'tundra' to describe his zones, neither term was equivalent to the present-day Russian usage. His polar desert was defined on the basis of desert soil processes, which operate in extremely cold and dry climates. TEDROW (1977) also defined specific polar desert soils, which are characteristically very well drained, often with gravelly desert pavements, little organic matter, and salt encrustations. Polar-desert soils predominated in his 'polar desert zone'. This included all of Ellesmere, Axel Heiberg, Devon, Cornwallis, and Bathhurst Islands, an area much larger than Aleksandrova's polar desert region. Mean July temperatures in many areas of Tedrow's 'polar desert' can be much warmer than 2-3°C, which is the temperature often used as the southern limit of the Russian polar desert.

Such a concept does have precedent in the Russian literature. B. N. Gorodkov, whom many consider the father of the polar desert concept, distinguished three subzones within his 'arctic desert'. The southernmost included abundant prostrate dwarf shrubs (*Salix arctica, S. polaris, Dryas punctata*). In other words, Gorodkov's original concept (GORODKOV 1935) was closer to the polar desert of Tedrow and Bliss. V. Aleksandrova later restricted the polar desert concept to the northernmost of Gorodkov's subzones, an herb-moss arctic desert with an extremely poor angiosperm flora. The present-day Russian concept of polar desert is based largely on 12 criteria used by ALEKSANDROVA (1980, p. 145-150). She stressed that this region corresponds almost completely with Young's floristic Zone 1 (YOUNG 1971). She thus places primary emphasis on the floristic differences between the polar desert and warmer parts of the Arctic.

Bliss further departed from the Russian concepts by applying the term 'polar desert' broadly to barren arctic landscapes throughout the Canadian High Arctic islands (BLISS & SVOBODA 1984, BLISS et al. 1984, BLISS 1997). He considers the concept of zonation inappropriate in the Canadian Arctic because of the numerous islands and highly dissected landscapes and does not use 'polar desert' in a zonal sense at all, but more as a landscape descriptor. Bliss has only two 'zones', the High Arctic and the Low Arctic. The High Arctic is the region of primarily mineral soils and discontinuous vegetation, whereas the Low Arctic is the area with primarily peaty tundras and mostly continuous vegetation cover. The boundary between the High and Low Arctic roughly follows the boundary between the 'Arctic tundra' and 'sub-Arctic tundra' of ALEKSANDROVA (1980) and the 'Arctic tundra' and 'hypo-Arctic tundra' of YURTSEV (1994). Within the High Arctic there are mires, polar semideserts, and polar deserts. These are further divided into vegetation types based on dominant plant growth forms. As such, Bliss's polar desert describes huge poorly vegetated areas of the Canadian Arctic. These areas often have water deficits, and there is less importance placed on their floristic aspects than on the overall landscape physiognomy. His polar deserts include areas with coarse-grained sediments at high elevations such as the Devon Plateau. This is unlike the Russian concept of polar deserts. In the Russian concept, the term was based on the zonal vegetation, which occurs on fine-grained sediments at or near sea level. In summary, Bliss's concept of polar desert was much broader than the Russian concept. It was based to a large extent on Tedrow's ideas of polar desert soils and their strong correspondence with sparsely vegetated landscapes. The concept was primarily a physiognomic one that was used to describe landscapes at high and low elevations on zonal and nonzonal sites. It extended into much warmer areas than the Russian concept, and was only weakly tied to floristic criteria. This is in contrast to the Russian concept, which, through the influence of Aleksandrova, Young, Yurtsev and others, developed strong floristic criteria for polar desert delimitation. However, there was one exception to this view in North America. S. Edlund during extensive work in the Canadian Archipelago in the 1980's defined subzones that were surprisingly close to those in Russia (EDLUND 1983, 1987, 1990 & 1996, EDLUND & ALT 1989). She recognized a 'herb zone' that corresponds to the polar desert subzone of the Russians.

There is also a good argument against using the term 'polar desert' for this coldest bioclimatic subzone – namely because it is often climatically less desert-like than the adjoining subzone. Numerous studies have shown that this subzone is primarily due to oceanic phenomena. Recent reevaluations of the 'polar desert' areas in northern Greenland and the Taimyr Peninsula have confined the subzone to the coastal fringes (BAY 1997, RAZZHIVIN 1999). Similarly, during the 1999 Canadian CAVM transect, we saw that the interior areas of the larger Canadian islands were drier and more desert-like than the cold coastal margins. The colder temperatures at the coast (due to fog and the ice covered seas) cause a later snowmelt and lower evapotranspiration, promoting a moister situation. Many areas on fine-grained sediments in the coldest regions of the Canadian Arctic are well vegetated, whereas the warmer, more continental inland areas are more desert like. YURTSEV (1994) commented on tundra-like conditions within the coastal fringe in northern Ellesmere Island. On Amund Ringnes Island we encountered large areas of meadow-like vegetation growing on mesic fine-grained sediments in the vicinity of Stratigrapher Creek. Pictures from the 'polar desert' islands in Russia show similar vegetation. The cold moist conditions near the coast keep the soils on zonal sites in a continuously moist condition. ALEKSANDROVA (1980) commented on the "oceanic, cryo-humid climate" in the vicinity of the Barents Sea, and the resulting abundant cryptogam cover. BAY (1997) noted that the coastal fringe of northeast Greenland, where the so-called 'polar desert' occurs, is foggy and considerably moister than the inland area. About 200 mm of moisture occur at the coast compared to ca. 25 mm inland. Although arid saline conditions can be locally found on the drier portions of toposequences, 'placor' areas on fine-grained soils are moister and often more meadow-like than the term 'desert' implies. The interior areas of the larger islands in the Canadian Archipelago, Greenland and elsewhere are sunnier, warmer and more desert-like but also have the woody plants and floras typical of the more southern subzones. Pictures of continental inland areas of Peary Land, Ellesmere, Cornwallis, Melville, Bathurst, and Devon Islands depict extremely arid desert landscapes, but these areas are not within the Russian concept of the 'polar desert'.

The northernmost subzone probably covers much less than the 4.6% of the Arctic depicted on YURTSEV'S (1994) map because it is primarily a coastal phenomenon. Despite its small size there are several good reasons for portraying this subzone on global maps: (1) The subzone represents the endpoint along the Arctic bioclimatic gradient. The low temperatures, not aridity control the extremely low stature of the vegetation. (2) The area of the subzone is large enough to portray on global maps. (3) Similar 'oropolar desert' landscapes occur at higher elevations in all arctic subzones due to adiabatic cooling. These create complex mosaics of 'polar desert' landscapes that may cover larger areas than their low-elevation zonal counterparts (BLISS & MATVEYEVA 1992). (4) There is a great deal of research that has shown this subzone to have distinctive ecosystem properties (BLISS et al. 1984, ALEKSANDROVA 1988, CHERNOV & MATVEYEVA 1997). (5) This subzone could have special significance for global change because even small changes in temperature at this extreme will result in major biological changes.

Many climate and vegetation-change modelers today use maps depicting 'tundra' and 'polar desert' (HOLDRIDGE 1947, WALTER 1979, OLSON et al. 1983, CRAMER 1997), but the polar desert regions on all of these maps are closer to the concept of Tedrow and Bliss. They depict broad regions of northern Canada as desert (including Bliss's 'polar desert' and 'polar semidesert') rather than a narrow coastal strip and the few islands in the northwestern Canadian Archipelago as delimited on Russian zonal maps. At this point, it appears unlikely that the Eurasians will accept a broad delimitation of the polar desert, nor is it likely that Americans will accept an extreme restriction of the concept to the coastal strips and a few islands in the coldest part of the Artic. Thus, the CAVM authors agreed to the compromise of subdividing the Arctic into five subzones along the lines of YURTSEV'S (1994) subdivisions, but using alphabetic labels A to E. The mean July temperatures in each subzone are roughly as follows: A: <3˚C; B: 3-5˚C; C: 5-7˚C; D: 7-9˚C; and E: 9-12˚C.

In summary, although there is good reason to recognize the existence of this northernmost subzone, there is also good reason not to use the term 'polar desert' to describe it. There are major conflicts in the meaning of the term in Eurasia and North America. To limit 'polar deserts' to the extreme coldest bioclimatic region in North America would cause confusion and would be inappropriate and inaccurate – despite the long use of the term in this context in Eurasia.

3 The North American Arctic Transect (NAAT)

The NAAT was designed to examine zonal ecosystems along the full Arctic bioclimate gradient in North America. Here we describe the transect, its history, and how it might be utilized as part of a network of circumpolar Arctic observatories. We also outline the special role that Fred Daniëls played in the NAAT.

The NAAT was established during a project funded by the National Science Foundation entitled 'Biocomplexity of Patterned-Ground Ecosystems' (WALKER et al. 2008, in press). The transect is approximately 1800 km long. The purpose of the transect was to observe tundra processes on zonal sites in all five bioclimate subzones of the Circumpolar Arctic Vegetation Map (CAVM TEAM et al. 2003) (Fig. 1). The transect includes ten locations: six are along the Dalton Highway in northern Alaska (Happy Valley, Sagwon, Franklin Bluffs, Deadhorse, West Dock, and Howe Island) and four are in Canada (Inuvik, Green Cabin, Mould Bay, and Isachsen). The locations were selected using the following criteria: (1) They have representative zonal vegetation on fine grained soils (to avoid rocky soils for active layer measurements or sandy leached situations) and are mostly unglaciated during the last glacial maximum so that zonal vegetation and soils have had time to develop; (2) they have small patterned-ground features that are representative of the subzone; (3) they have long-term climate records; and (4) they have good air strips that permit year-round access. Most of the subzones have at least two study locations, but there is only one location in subzones A and B (Isachsen and Mould Bay respectively). These were the only sites in these subzones within North America that satisfied the other criteria.

At each location, a suite of baseline climate, permafrost, soil, vegetation, and other site observations were collected. During the project, it was clear that these data would be most useful if they were collected using standardized protocols that could be applied at many sites around the circumpolar Arctic and which could be repeated in future years. Such protocols existed for describing the vegetation and soils (DIERSCHKE 1994, SOIL SURVEY STAFF 1993); however, for variables such as species diversity and plant biomass, no internationally accepted standards existed.

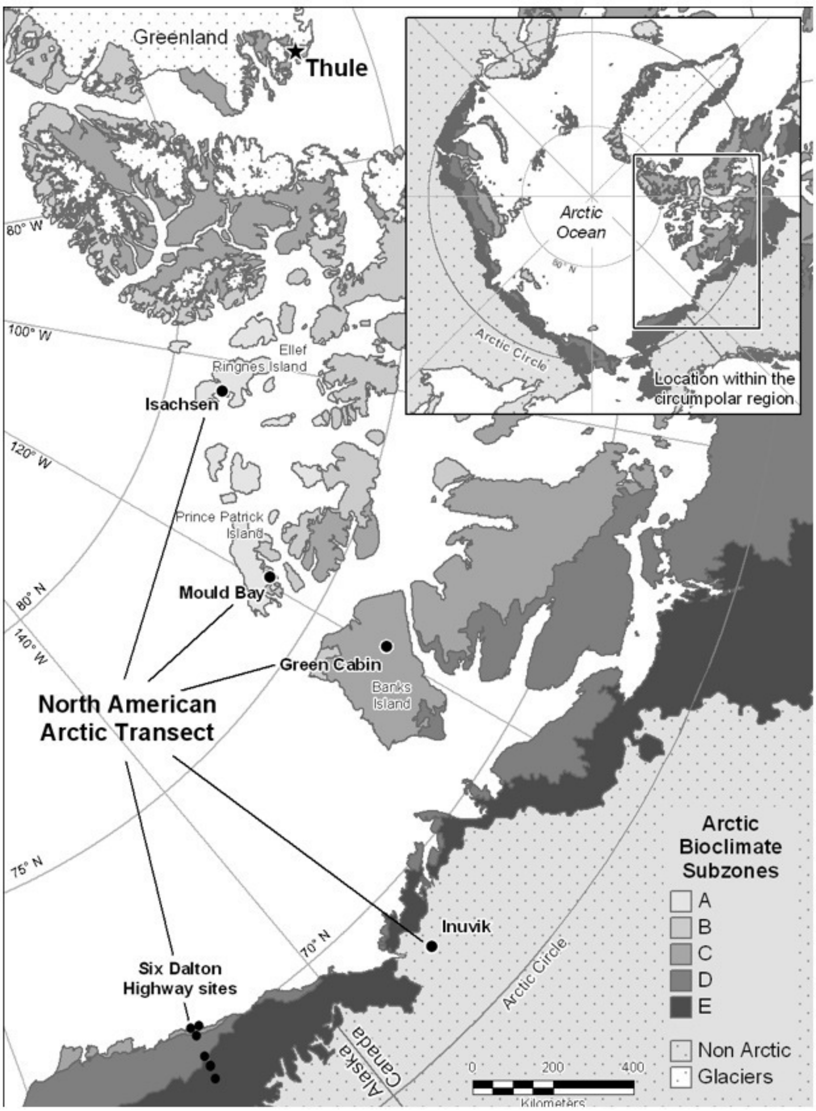

Fig. 1: Locations of the study sites for the Biocomplexity of Patterned-Ground Project (NAAT). The Arctic tundra bioclimate subzones are from the Circumpolar Arctic Vegetation Map (CAVM et al. 2003). The inset map shows the circumpolar distribution of the Arctic tundra biome.

Isachsen on Ellef Ringnes Island is a particularly important location on the transect. It has the coldest summer climate of any weather station in Arctic North America. Summer air temperatures are held close to 0˚C all summer. It is cold because Ellef Ringnes Island is in the region of perennial sea ice with strong summer winds that blow off the ice-pack. Isachsen is in Subzone A of the CAVM. There is no other terrestrial research site in the North American Arctic in this subzone except for Alert, which is on a rocky non-zonal site and has difficult access issues for terrestrial research. The corner of the Arctic along the northwestern part of the Canadian Archipelago may become the last refuge for perennial sea-ice in the Arctic, and it is important that we obtain baseline observations in this area before the sea-ice is eliminated and Subzone A vanishes.

3.1 The 1999 expedition to the Canadian Arctic

One of the key steps in making the CAVM and an important basis for the NAAT was unification of the North American and Eurasian concepts of Arctic zonation into a circumpolar perspective. In 1999, key scientists participating in the CAVM project and students from five countries combined research and education in an investigation of bioclimatic zonation along a Canadian Arctic transect, from Amund Ringnes Island and Ellesmere Island in the north to the Daring Lake research camp at the southern edge of the tundra in Nunavut (GOULD et al. 2003). The major goal of the expedition was to determine if the Russian approach of zonation could be applied to North America in order to resolve the terminology conflicts that prevented unification of the Russian and North American approaches to classifying vegetation. The expedition visited all five subzones in North America as they were defined by Boris Yurtsev's latitudinal phytogeographic subdivision of the Arctic (YURTSEV 1994). General agreement was reached that the subzone boundaries can be defined primarily on the basis of the northern limits of several species of woody plants with distinct upright or prostrate growth forms, and ultimately with the northern limit of woody plant species. The five subzones, A-E, from north to south, are characterized by dominant growth forms: (A) cushion forb, (B) prostrate dwarf shrub, (C) hemiprostrate dwarf shrub, (D) erect dwarf shrub, and (E) low shrub.

One of the many highligths of the expedition was the trip to Subzone A, which is difficult to access even from the camp at Eureka at 80˚N on Ellesmere Island. A helicopter took a subgroup of the expedition to Stratigrapher Creek on Amund Ringnes Island. Unfortunately the helicopter could only hold five people including the pilot. Skip Walker, and Bill Gould, organizers of the expedition, along with Nadya Matveyeva, who had come specifically from Russia to see Subzone A in North America, joined the flight. Arve Elvebakk from Norway and Fred Daniëls drew straws for the remaining seat, and Arve won. Although disappointed, Fred accepted the situation with his usual grace and good nature.

Fig. 2: Members of the 1999 CAVM Expedition to Canada. Standing from left to right: Christine and Howard Hill (students, USA), Boris Yurtsev (Russia), Fred Daniëls (Germany), Sylvia Edlund (Canada), Arve Elvebakk (Norway), April Desjarlais (student, USA), Diana Alsup (student, USA). Seated, from left to right: D. A. (Skip) Walker (USA), Nadya Matveyeva (Russia), Bill Gould (USA), Chris Schadt (student, USA).

3.2 The Biocomplexity of Patterned-Ground Project and the NAAT

Patterned-ground features, such as non-sorted circles, small non-sorted polygons, and hummocks are common in nearly all Arctic landscapes. The goal of this project was to understand the complex linkages between patterned-ground processes, climate, biogeochemical cycles, vegetation, soils, permafrost, and disturbance across the full temperature gradient in the Arctic, in order to better predict arctic ecosystem responses to changing climate (WALKER et al. 2008, in press). A standard set of environmental information was collected at each location along the NAAT and is available in four data reports (MUNGER 2004 & 2005, BARREDA et al. 2006, VONLANTHEN et al. 2006). Two papers describe the plant communities along the transect (KADE 2005, VONLANTHEN 2008, in press). Fred Daniëls is a co-author on the second paper and played a key role in both by providing guidance, advice and editorial comments regarding the application of the Braun-Blanquet methods to these studies. A synthesis of the project is presented in nine papers of a special section of the *Journal of Geophysical Research - Biogeosciences* that describe the key observations and models from the project (WALKER et al. 2008, in press).

3 The 2005 expedition to Isachsen

One of Fred Daniëls' dreams during the construction of the CAVM was to visit Subzone A, and in 2005 he joined the Biocomplexity expedition to Isachsen (Fig. 3). He participated in the expedition by sampling the wetland and snowbed vegetation at the site and is a co-author on the paper describing the zonal vegetation at Isachsen (VONLANTHEN et al. 2008, in press). Most importantly, Fred Daniëls, along with Russian participants Nadya Matveyeva and Olga Makarova, helped us realize the unique nature of this location and encouraged further investigations that could not be achieved during the brief 16 days that we spent there in 2005.

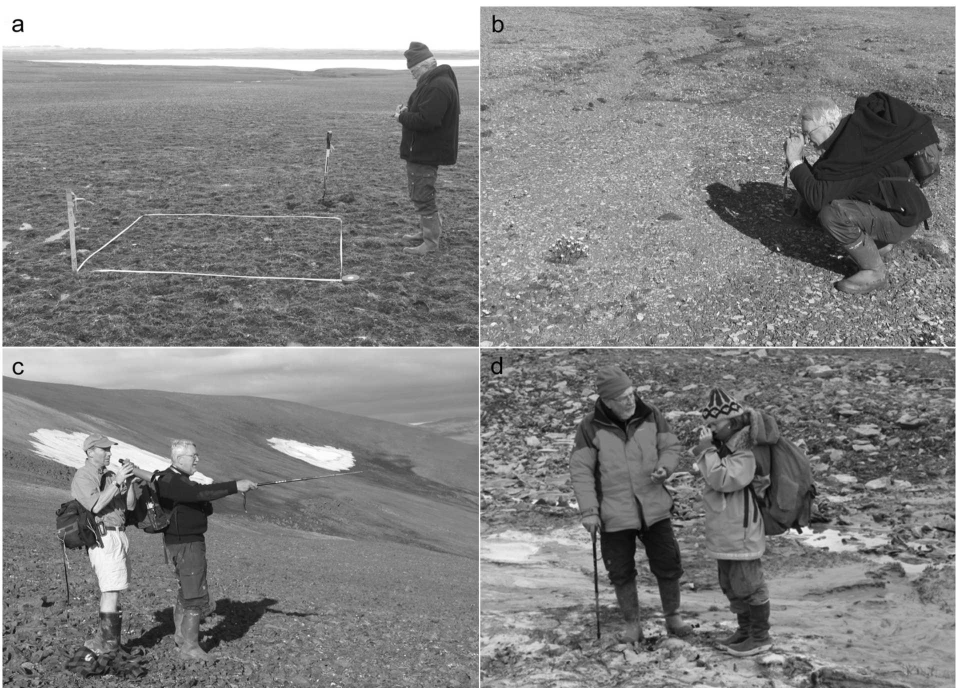

Fig. 3: Fred Daniëls at Isachsen and Mould Bay. (a) Collecting relevé data in an Isachsen wetland, (b) photographing *Papaver polare* at Isachsen, (c) during a walk to a nearby mountain with Bill Gould, (d) collecting mosses with Martha Raynolds at Mould Bay.

4 Summary

Fred Daniëls played a very important role at every stage in planning and documenting the existing vegetation information along the North American Arctic Transect using the Braun-Blanquet method, including conducting vegetation studies at the northernmost site at Isachsen. The NAAT is an important network of sites that could potentially be of long-term value as part of the developing network of Arctic observatories. It would be a fitting tribute to Fred Daniëls if the vegetation along the gradient, and especially at Isachsen, could be fully documented using the Braun-Blanquet approach. Such documentation is needed now because this site is in a rare and endangered bioclimate subzone with unique vegetation properties that is likely to change dramatically if the perennial sea ice is eliminated.

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