Ziaja W., 2011. Four dimensions of the Spitsbergen landscape. The Problems of Landscape Ecology. Vol. XXX. 333-338.

Four dimensions of the Spitsbergen landscape

Wiesław Ziaja

Jagiellonian University, Institute of Geography and Spatial Management, Gronostajowa 7, 30-387 Kraków, Poland
e-mail: wieslaw.ziaja@uj.edu.pl, tel. 48 12 6645284, fax 48 12 6645385

Abstract: Spatial differentiation of the Spitsbergen landscape is not determined by its geographical latitude and longitude due to the island's location and influence of the sea-currents around the island. There is a clear landscape contrast between the eastern and western Spitsbergen coast. Horizontal and vertical landscape differentiation and its temporal development are outlined. There are three landscape vertical zones in Spitsbergen (glacial-nival, sub-nival, and the continuous Arctic tundra), apart from its eastern coast where there are only two of them (without the continuous tundra). However, the continuous tundra zone, absent in the east until today, may develop due to contemporary climate warming and its environmental implications there.

Key words: Spitsbergen, landscape differentiation, landscape vertical zones, landscape development

Introduction

The Spitsbergen landscape has (of course) four dimensions: two horizontal, i.e. length and width (which can be measured using the geographical longitude and latitude), one vertical, i.e. height or thickness (which can be measured using the altitude above the sea level), and time (of development). The first three of the mentioned dimensions cause landscape to be a solid figure. Its shape and volume may be different: from a flattened one (easy to show in a map) to a vertically expanded (best to show in a so-called 3-dimensional model). This figure is also changeable in the course of time. Each dimension is more or less visible in the landscape differentiation of particular parts of the island. The importance of particular dimensions in the landscape differentiation may vary in different areas, in respect of not only their location but also their size, according to a scale.
The main objective of the paper is to show the four dimensions (longitude, latitude, altitude, and time) in the whole Spitsbergen landscape, which enables to outline the Spitsbergen landscape general differentiation.

Materials and method

A systematic description of the contemporary Spitsbergen landscape dimensions does not exist. There is no full study of the landscape (i.e. physico-geographical, or geoecological, or climate-and-vegetation) zonal differentiation, either horizontal or vertical, in Spitsbergen. However, there are very good descriptions of some particular zones, first of all of the latitudinal tundra zone (Elvebakk 1997) or boundaries between zones, first of all of the equilibrium (in mass balance) line altitude on glaciers (Hagen et al. 1993, Lefauconnier, Hagen 1991), which is connected with the snow and firn lines. However, these data on the equilibrium line altitude are not up-to-date due to a significant climate warming and intensive glacial recession for the past several dozen years. A lot of authors described a polar (Arctic) desert zone as a contradiction of the tundra zone (e.g. Hisdal 1985), or a periglacial zone in a contrast to the glacial zone (e.g. Jahn 1975, Różycki 1957). The best synthetic pictures of the Spitsbergen landscape components' differentiation are contained in the thematic maps of the Svalbard

archipelago: glaciological (Krintiansen, Sollid 1986), geomorphological (Klemsdal 1989), of superficial materials (Krintiansen, Sollid 1987), of soils (Låg 1993), of vegetation (Elvebakk 2005), of animal life (Fjeld, Mehlum 1988), and others. Landscape structure of some areas in the southern, southeastern and middle-western parts of Spitsbergen was described as a result of a detailed field landscape mapping carried out by the author during 12 summer seasons between 1982 and 2008 (e.g. Ziaja 1991, 1992, Ziaja et al. 2007, 2009).
An analysis of the aforementioned papers and maps together with the results of the author's field observations carried out in different parts of Spitsbergen (apart from its northern part) was the main method leading to the shortest outline of the Spitsbergen landscape dimensions, presented below.

Results

Horizontal landscape dimensions

The geographical latitude of Spitsbergen (fig. 1) determines the following basic common features of the island's natural environment and landscape: (1) small delivery of the sun energy, (2) long polar night and day, (3) permanent glaciation in the form of permafrost and glaciers, (4) short stature and species scantiness of the tundra vegetation, even in optimal habitats, with a lack of tundra on the majority of the island's territory.
However, the latitude does not determine the internal variety of Spitsbergen landscape because its climate differentiation depends much more on the sea-currents around the island than on the island's north–south extension. The spatial arrangement of the currents results from the continents' distribution around the oceans and the location and shape of the island.
The island's eastern coast is being cooled by the cold East Spitsbergen Current which flows from the Arctic interior to the south, whereas the western coast is affected by the warm West Spitsbergen Current from the south. The cold current's water goes round the southern cape of Spitsbergen and is often pushed between the warm current's water and the western coast (Klungsøyr et al. 1995), under the pressure of the southern and southeastern winds. Presence or absence and intensity of this phenomenon depend on the power and duration of the mentioned winds. The longer distance along the western coast to the north, the more seldom and in a shorter time this coast is affected by this cold water. Hence, the southwestern part of Spitsbergen coast is colder than the northwestern part and especially the middle-western one (the more colder climate the bigger glaciation in the same altitude, and the smaller density and biodiversity of the terrestrial vegetation).

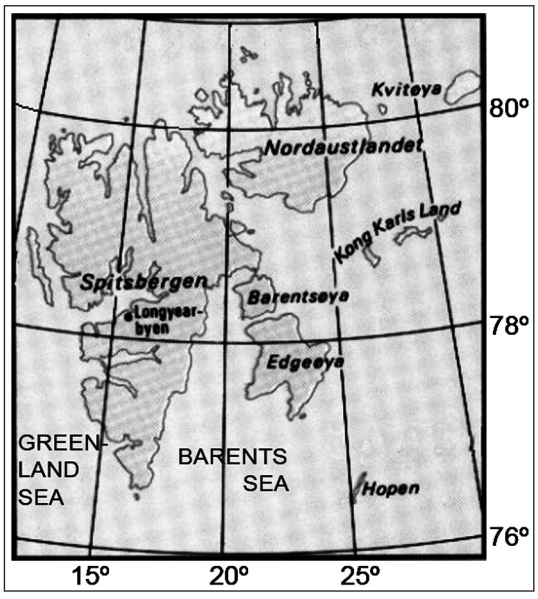

Fig. 1. Location of Spitsbergen in the Svalbard archipelago

The geographical longitude (fig. 1) – the coordinate whose essence is to be perpendicular to the latitude, with a conventional choice of the 0° meridian – does not influence neither features of the Spitsbergen landscape and environment nor their differentiation.
The aforementioned climatic differentiation overlaps a geological-structural variety which has its reflection in terrain relief (landforms).
Old tectonic structures, which consist of very resistant, more or less methamorphic, Proterozoic and Lower Paleozoic rocks, predominate at the western edge of the island (Dallmann 1999). Mountain ranges built of them (with sharp peaks which gave the island's name: Spitsbergen means "the pointed mountains") are separated from the Greenland See by lowlands, mostly several km wide, which form a belt (so-called strandflat) interrupted by huge fjords. These fjords cut the island from the west to the east up to two thirds of its width. The lowlands consists of marine terraces which have been raised up to several dozen m above

the sea level during the Quaternary and mostly preserved due to a high resistance of their bedrock. The terraces have been mostly free of glaciers since the end of the Weichselian (Salvigsen, Elgersma 1993) due to the aforementioned warm current.

The eastern Spitsbergen is built of low-resistant Mesozoic and Tertiary sedimentary rocks (Dallmann 1999). Thus the mountains are lower and their culminations are more flat there. However, they are mostly glaciated under the impact of the aforementioned cold current. Their slopes fall steeply to the Barents Sea. In many places, they are being cut at their base directly by the sea. There is no belt of coastal lowlands there, and low (up to a few dozen m high) and narrow (below 1 km wide) plains occur only in places, often newly abandoned by glaciers which have recessed since the beginning of the 20th century. The eastern coast is much less developed than the western one, with a few short fjords which have appeared recently (since the end of the 20th century).

The co-existence of the warmer climate (limiting glaciation) and extensive flat areas (with a stable bedrock enabling plants to root) had resulted in the appearance of the continuous (though low and scanty in species) Arctic tundra (fig. 2) in the Holocene before the Little Ice Age.

On the other hand, in the east, vegetation is very dispersed, in a form of single individuals or small patches, due to both the more severe climate and the lack of wider flat areas free of glaciers before, what was a barrier for the development of a denser vegetation (fig. 2).

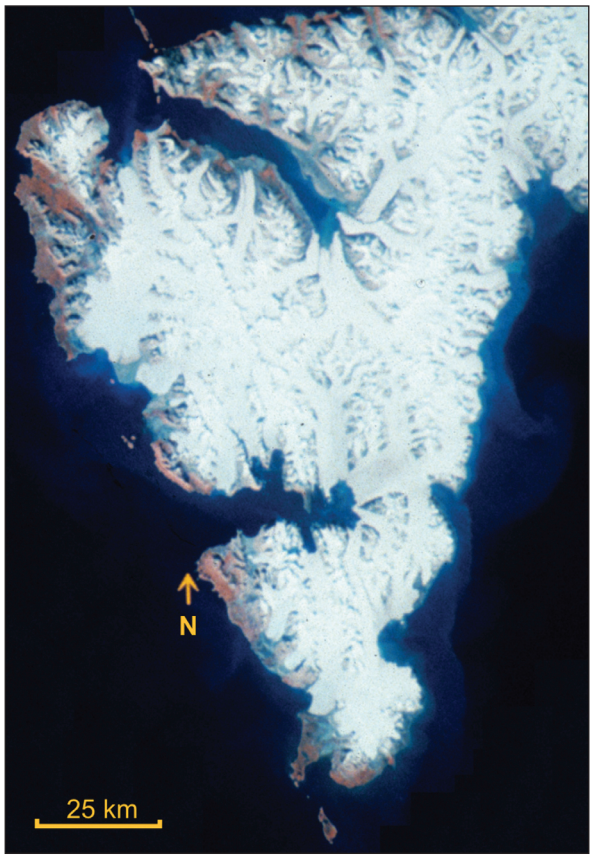

Fig. 2. Satellite image of south Spitsbergen (south of Van Mijenfjorden) from August 20th, 1985: Landsat 5, MSS-421 (elaborated by the author in Norsk Polarinstitutt), shows the contrast between the eastern and western coasts. Color scheme: white – glaciers; red or reddish – continuous vegetation cover; beige and blue-grey – unglaciated areas without vegetation cover; black – seawater; blue-and-black – glacial water mixed with seawater

This contrast in vegetation between the western and eastern Spitsbergen coast was ignored by Wüthrich (1991).

There is a similar contrast between the western and eastern Spitsbergen in the animal life. The lack of continuous tundra determines a virtual absence of herbivores in the eastern coast (both mammals, like reindeer, as well as birds, like gees). In addition, there is a much smaller number of birds feeding in the sea there, probably because of a longer sea-ice season and colder sea-water.

The eastern coast and the western coast are divided by the mountainous island's interior which is almost completely glaciated until today, apart from the middle mountainous part of Spitsbergen (Nordenskiöld Land) which is mostly ice-free.

A short southern coast (ca. 20 km long), with the strandflat a few km wide, overgrown with a continuous tundra, is a connection between the long (about 500 km without bays) eastern and western coasts. The landscape of this coast is similar to the western coastal landscape.

Vertical landscape dimensions

All the interrelations between the aforementioned features of the geological structure, climate, glaciation and terrain relief have led to a bigger vertical (determined by the altitude above the sea level) landscape differentiation in the west coast than in the east coast (fig. 3).

In the west (and south) Spitsbergen coast, there are three following landscape vertical zones (from top to bottom):
1) glacial-nival, with glaciers and perennial snow-patches,
2) sub-nival, with numerous snow patches disappearing shortly before the end of summer,
3) the Arctic tundra (more or less continuous vegetation).
Only the two upper vertical zones (glacial-nival and sub-nival) are visible in the east Spitsbergen coastal landscape (fig. 3).

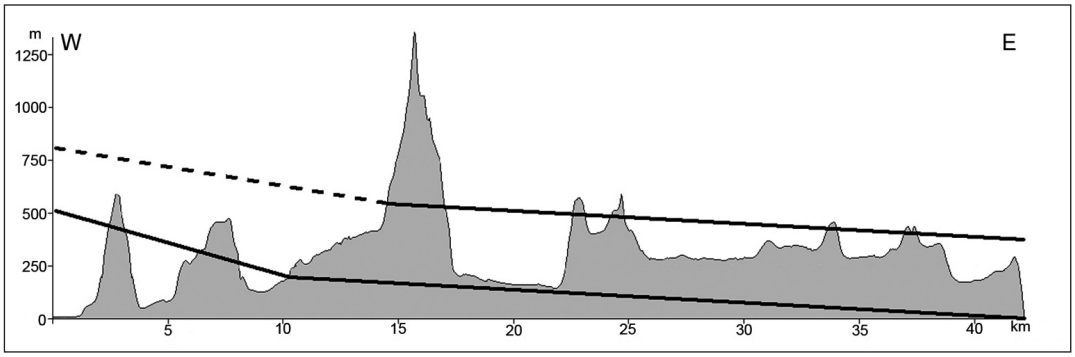

Fig. 3. Vertical landscape zones in the southern Spitsbergen lower their altitude above sea level from the west to the east: a typical example from the northern Sørkapp Land. That results in the lack of the continuous Arctic tundra in the eastern coast. The glacial-nival vertical zone, with accumulation parts of glaciers and perennial snow patches, is located near the snow line (or equilibrium line of the mass balance on glaciers) and above these lines. The sub-nival vertical zone, with glacier tongues and numerous snow patches which disappear shortly before the end of the summer season, and sparse plants in places, is located above the upper extent of continuous vegetation and below the aforementioned lines. The Arctic tundra vertical zone includes areas with more or less continuous vegetation

Hence, contrary to Wüthrich (1991), vegetation of the lowest landscape zone is not the same in the western and eastern Spitsbergen open coast.
The continuous Arctic tundra does not exist even just above the sea level in the east. It can not be excluded – after the period of contemporary climate warming since the beginning of the 20th century, and especially the current climate warming for the past 30 years – that climatic conditions for the development of the tundra have recently appeared. However, such a development demands (centuries of) time, the more so as the non-climatic environmental conditions are rather poor.

Time dimension: temporal landscape development

No landscape remains unaffected by the passage of time. Landscape development (evolution) is obviously permanent. However, it accelerates or slows down from time to time. Nowadays, it is the time of its acceleration. The acceleration of landscape development in Spitsbergen has occurred due to the climate warming after the end of the Little Ice Age, i.e. since the beginning of the 20th century. That was observed earlier in the western Spitsbergen (since the middle of the 20th century) and later in the eastern Spitsbergen (for the past 30 years).

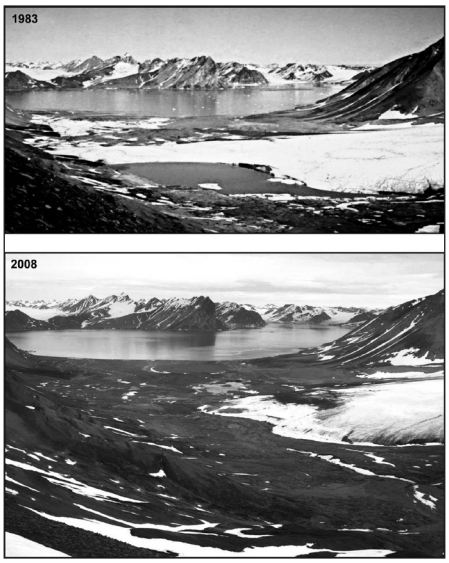

Fig. 4. A typical Spitsbergen landscape change: in the Gåshamna area, the Goësvatnet glacial-dammed lake (which still existed in 2000) disappeared before 2005 because of the glacier's recession. The Gåsbreen glacier is much shorter now and does not dam up the valley. View from the south. Upper photo: W. Ziaja. Lower photo: J. Niedźwiecki

Of course, the east Spitsbergen coastal landscape changed slowly until the 1980s, but the intensive current warming since the 1980s (Ziaja 2012) was necessary to speed up this landscape development.
Dramatic landscape changes have occurred in Spitsbergen during the past century due to the climate warming and recession of glaciers, including the development of completely new landscape in areas abandoned by glaciers (e.g. wide marginal zones with different types of moraines as well was other accumulation and erosion landforms), or a sea transgression on areas in which the basement of recessing glaciers was situated below the sea level. Due to the latter, a lot of new gulfs, including fjords, and sounds appeared, and some peninsulas or headlands were transformed into islands or islets. Less dramatic but clearly visible changes which affected the environment functioning have occurred almost everywhere (fig. 4), maybe apart from some highest parts of the island's interior. Some of these changes in the middle-western and southeastern Spitsbergen were described by the author (Ziaja 2001, 2004, 2010, 2012; Ziaja, Pipała 2007; Ziaja et al. 2007, 2009).

General remarks and conclusions

The differentiation of the Spitsbergen landscape depends mainly on the geological structure, distribution of peninsulas and fjords (shoreline course), and sea currents' system. Three landscape vertical zones: glacial-nival, sub-nival, and the Arctic tundra, occur on the west Spitsbergen coast (with a relatively wide belt of lowlands, cut by long fjords, under the warm West-Spitsbergen Current), which can be distinguished after field observations and according to hitherto referred research results. Their boundaries rise up from both the north and south to the warmest middle of the island. These three zones occur also on a very short south coast. Only the two upper vertical zones (glacial-nival and sub-nival) are visible in the east Spitsbergen coastal landscape (without any lowland belt, with a much shorter shoreline, under the cold East-Spitsbergen Current) because plants are absent or very dispersed there. However, plant succession may result in the appearance of the tundra there in future. According to the aforementioned thematic maps and explorers' reports (e.g. Schramm 1996), the author (who has not visited the north Spitsbergen coast) supposes that the number of vertical zones in the north is in places the same as in the west and in places the same as in the east.

References

Dallmann, W.K. (ed.) 1999. Lithostratigraphic Lexicon of Svalbard. Upper Palaeozoic to Quaternary bedrock. Review and recommendations for nomenclature use. Norsk Polarinstitutt, Tromsø, 318 p.

Elvebakk, A. 1997. Tundra diversity and ecological characteristics of Svalbard. In: Polar and alpine tundra. Ecosystems of the World, 3. Wielgolaski, F.E. (ed.). Elsevier, Amsterdam, p. 347–359.

Elvebakk, A. 2005. A vegetation map of Svalbard on the scale 1:3,5 mill. Phytocoenologia 35(4), p. 951–967.

Fjeld, P.E., and Mehlum, F. 1988. Dyreliv Svalbard og Jan Mayen (Animal life Svalbard and Jan Mayen), 1: 1 000 000. Norsk Polarinstitutt Temakart, 7 (map). (in Norwegian and English)

Hagen, J.O., Liestøl, O., Roland, E. and Jørgensen, T. 1993. Glacier Atlas of Svalbard and Jan Mayen. Norsk Polarinstitutt Meddelelser 129, 141 p.

Hisdal, V. 1985. Geography of Svalbard. Polarhåndbook, 2, Norsk Polarinstitutt, Oslo, 81 p.

Jahn, A. 1975. Problems of the Periglacial Zone. PWN, Warszawa, 223 p. + 116 photos.

Klemsdal, T. 1989. Landformer – Svalbard og Jan Mayen (Landforms – Svalbard and Jan Mayen), 1: 1 000 000. Nasjonalatlas for Norge, kartblad 2.1.3, Statens kartverk (map). (in Norwegian and English)

Klungsøyr, J., Sœtre, R., Føyn, L. and Loeng H. 1995. Man's Impact on the Barents Sea. Arctic 48(3), p. 279-296, Fig. 2.

Kristiansen, K.J. and Sollid, J.L. 1986. Svalbard glasialgeologi og geomorfologi (Glacial geology and geomorphology), 1: 1 000 000. Nasjonalatlas for Norge, kartblad 2.3.5, Geografisk institutt, Universitetet i Oslo (map). (in Norwegian and English)

Kristiansen, K.J. and Sollid, J.L. 1987. Svalbard jordartskart (Map of surficial materials), 1: 1 000 000. Nasjonalatlas for Norge, kartblad 2.3.6, Geografisk institutt, Universitetet i Oslo. (in Norwegian and English)

Lefauconnier, B. and Hagen, J.O., 1991. Surging and calving glaciers in eastern Svalbard. Norsk Polarinstitutt Meddelelser 116, 130 p.

Låg, J. 1993. Jordbunn Svalbard (Soils of Svalbard), 1: 1 mill. Nasjonalatlas for Norge, kartblad 2.3.10, Statens kartverk (map). (in Norwegian and English)

Różycki, S.Z. 1957. Strefowość rzeźby i zjawiska peryglacjalne na Ziemi Torella (Spitsbergen) [Geomorphic zones and periglacial phenomena in Torell Land (Spitsbergen)]. Biuletyn Peryglacjany 5, p. 51–87. (in Polish, French summary)

Salvigsen, O. and Elgersma, A. 1993. Radiocarbon dating of deglaciation and raised beaches in north-western Sørkapp Land. Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Geograficzne 94, p. 39–48.

Schramm, R.W. 1996. Dwa długie dni. Dzień pierwszy (Two long days. The first day). Publisher: R.W. Schramm, Poznań, 380 p. (in Polish)

Wüthrich, C. 1991. Landschaftsökologische Umweltforschung: Beiträge zu den Wechselwirkungen zwischen biotischen und abiotischen Faktoren im hocharktischen Ökosystem (Spitzbergen) [Landscape-ecological investigations in the High Arctic (Spitsbergen): Contributions concerning the relations between the biological and physical environments]. Die Erde 122, p. 335–352. (in German, English summary)

Ziaja, W. 1991. Fizycznogeograficzne zróżnicowanie górskiej części północno-zachodniego Sörkapplandu (Spitsbergen). Część I: Uroczyska [Physicogeographical differentiation of the mountainous part of the north-western Sörkappland (Spitsbergen). Part I. „Uroczysko" units], Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Geograficzne 83, p. 31–54. (in Polish, English summary)

Ziaja, W. 1992. Fizycznogeograficzne zróżnicowanie górskiej części północno-zachodniego Sörkapplandu (Spitsbergen). Część II: Tereny. Zeszyty Naukowe Uniwersytetu Jagiellońskiego [Physicogeographical differentiation of the mountainous part of the north-western Sörkappland (Spitsbergen). Part II: Terrains], Prace Geograficzne 88, p. 25–38. (in Polish, English summary)

Ziaja, W. 2001. Glacial Recession in Sørkappland and Central Nordenskiöldland, Spitsbergen, Svalbard, during the 20th Century. Arctic, Antarctic, and Alpine Research 33(1), p. 36–41.

Ziaja, W. 2004. Spitsbergen Landscape under 20th Century Climate Change: Sørkapp Land. Ambio 33(6): 295–299.

Ziaja, W. 2010. Spitsbergen landscape development under the current global warming. In: Landscape ecology – methods, applications and interdisciplinary approach. Barancokova, M., Krajci, J., Kollar, J. and Belcakova, I. (eds.). Institute of Landscape Ecology, Slovak Acadaemy of Sciences, Bratislava, p. 495–503.

Ziaja, W. (ed.) 2012. Transformation of the natural environment in Western Sørkapp Land (Spitsbergen). Jagiellonian University Press, Kraków, p. 93 + 6 maps.

Ziaja, W., Maciejowski, W. and Ostafin, K. 2007. Northeastern Sørkappland landscape dynamics (Spitsbergen, Svalbard). Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków, p. 93.

Ziaja, W., Maciejowski, W. and Ostafin, K. 2009. Coastal Landscape Dynamics in NE Sørkapp Land (SE Spitsbergen), 1900–2005. Ambio 38(4), p. 201–208.

Ziaja, W. and Pipała, R. 2007. Glacial recession 2001–2006 and its landscape effects in the Lindströmfjellet-Håbergnuten mountain ridge, Nordenskiöld Land, Spitsbergen. Polish Polar research 28(4), p. 237–247.