Chapter 13
A Composite Reconstruction of the Russian Arctic Climate Back to A.D. 1435

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During the last 100 years our planet apparently is passing through the fastest and the most significant warming in the history of civilization. Orthodox climatology and, in particular, that part of it, which prefers to base its conclusions on the data of numerical modeling, states that global warming is to increase significantly in the polar regions. In particular, one of the principal modern instruments for climate studying – general circulation models (GCMs) – states that the maximal temperature increase is to happen in autumn above water area of the Arctic Ocean (Kondratiev 2004; Pfeifer and Jacob 2005). However, basing on more than 100 year record of meteorological observations in high latitudes, one can state now that nowhere in the world the theory is so much far from the reality as it is in the Arctic (hereafter under this term we mean the Eurasian coast of Arctic Ocean between Norway and Chukotka). The Arctic is a real climatic paradox, as the most detailed data of observations taken within the last 50 years shows no significant warming until the beginning of the present century; and now, where it nevertheless happens, major temperature increase occurs in winter and spring, but not in autumn seasons (Przybylak 2000; Klimenko et al. 2001).

In this connection, data about Arctic climate fluctuations in the historical past, which may facilitate formation of more correct understanding of possible reasons and scales of changes in the past and in future, attracts high interest.

Due to considerations expressed the Global Energy Problems Laboratory (GEPL) of the Moscow Energy Institute (MEI) in collaboration with the Seminar of East European History of the Rhine University (Bonn, Germany) in 2002–2006 conducted a study of documentary evidence about climate condition in the basin of the Barents and Kara Seas as well as on the adjacent territory of the north-east of the European part of Russia and the western Siberia in the sixteenth to twentieth centuries. The map of the study region and neighbouring Arctic areas with the most

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important meteorological stations, each of which has at least 120 years of observational record, is given in Fig. 13.1. On the same figure the locations are indicated, for which detailed palaeoclimatic reconstructions are available, which are performed by dendroclimatic methods (Briffa et al. 1992; Earle et al. 1994; Mac Donald et al. 1998; Gervais and Mac Donald 2000; Kirchhefer 2001; Hantemirov and Shiyatov 2002; Naurzbaev et al. 2002). The box indicates region boundaries in the basin of the Barents and Kara Seas (BKS), for which in the present work a reconstruction of mean annual air temperatures (and hereafter the term "temperature" refers to the annual one if not stated otherwise) is developed.

In this work we tried to introduce in a scientific circulation either little-known, or unpublished before in Russian, or unpublished at all evidence of the European and Russian navigators, travellers and researchers, who have visited the basin of the Barents and Kara Seas. In total we gathered about 3,000 pieces of documentary evidence, containing this or that climatic and natural history information – a full collection of this evidence and origin sources are presented elsewhere (Klimenko and Astrina 2006; Astrina 2007). Unfortunately, we have to admit that the volume and density of the information received in the separate time intervals (especially it concerns the fifteenth and the first half of the seventeenth centuries) is not sufficient in order to perform a correct quantitative palaeoclimatic reconstruction on its basis. That's why for such a reconstruction a decision had been taken to combine historical-climatic research results with the data of numerical modelling of BKS region climate (region I in Fig. 13.1), recently undertaken in our work (Klimenko and Mikushina 2005).

Simulations were carried out with a regressive-analytical climate model, developed in the GEPL of the MEI (Klimenko et al. 1997; Klimenko and Mikushina 2005). This model gives an opportunity to calculate variations of annual average and seasonal average temperatures depending on changes of main climatic factors, information of which one can find in Table 13.1.

To investigate the relationship between regional temperatures and natural climate factors the multiple linear regression model was used. Its coefficients were calculated by the least square method from the smoothed instrumental data for the period 1863–2006. The estimation of the anthropogenic sensitivity of BKS region temperature to the forcing of greenhouse gases and aerosols was implemented in studies of climate variations through 1889–2004 (Klimenko and Mikushina 2005). The resulting temperature trend of the regressive-analytical climate model was determined by the joint influence of anthropogenic and natural factors with the significant role of the latter. The resulting trend is statistically significant on the 95% level, multiple determination coefficient is 0.51. It is completely consistent with the picture of the historical climate data, reconstructed on the basis of the documentary evidence of 1499–1911. Simulation results are shown in the Fig. 13.2 together with the data of instrumental observations. A final version of annual average temperatures reconstruction together with the data of instrumental observations and forecast until the end of this century are shown in Fig. 13.2. The produced reconstruction demonstrates that during the past six centuries climate of the studied Arctic sector experienced significant fluctuations which by both their scales and rate match those which were detected by the instrumental observations during the twentieth century. In particular, significant and

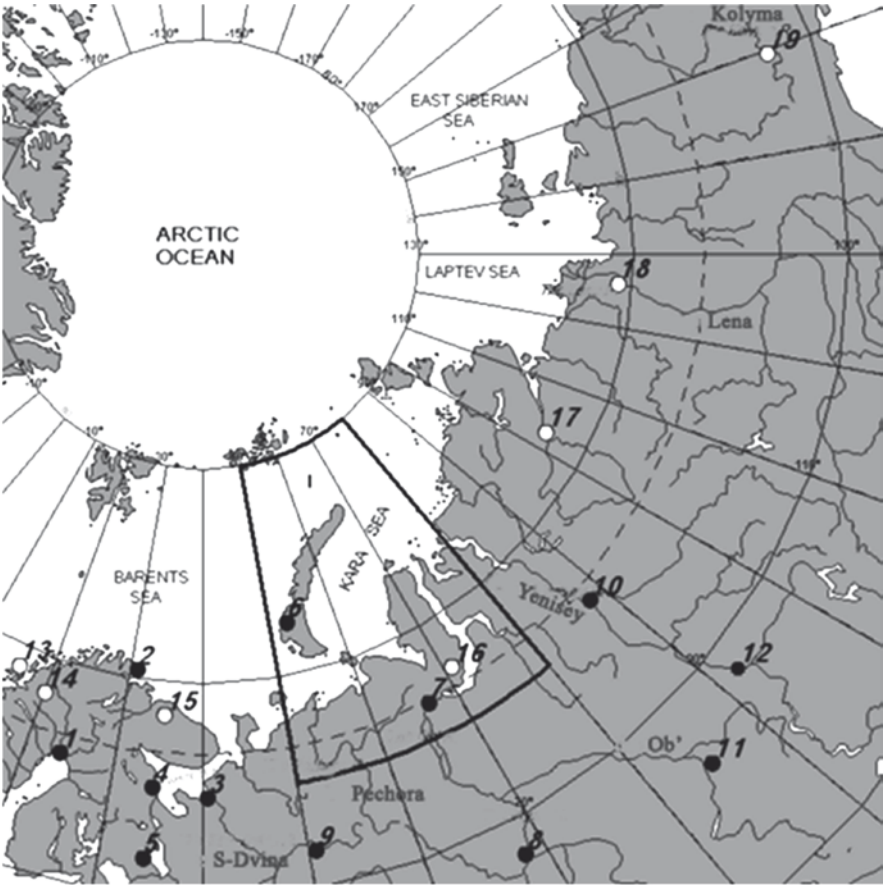

Fig. 13.1 The Russian Arctic and boundaries of a study area (I). Location of long-term meteorological stations: (1) Haparanda; (2) Vardø; (3) Arkhangelsk; (4) Kem; (5) Petrozavodsk; (6) Malye Karmakuly; (7) Salehard; (8) Tobolsk; (9) Syktyvkar; (10) Turuhansk; (11) Tomsk; (12) Yeniseysk. Location of tree-ring chronologies: (13) northern Norway; (14) Torneträsk Lake; (15) Kola Peninsula; (16) Southern Yamal; (17) eastern Taymyr; (18) the Lower Lena River; (19) the Upper Kolyma River

well-known Arctic warming, which took place in the 1920–1940s, apparently, was not unique – similar in scale warmings took place in the nineteenth century as well as in the late eighteenth century, and some weaker ones – at the beginning of the eighteenth and in seventeenth centuries, as well as in the first part of sixteenth century. The most significant cooling took place in the mid-fifteenth century, end of the sixteenth century, second half of the seventeenth century, early and late nineteenth century. All these prominent climatic events have quite a definite confirmation in our collection of a comprehensive documentary evidence. A greater part of this evidence has never been considered in a climatic context, that's why we think it's appropriate to demonstrate at least a part of it here.

Table 13.1 Major climatic factors, relevant variables and information

Climate forming factors	Variables, expressing climate forming factors influence	Source
Concentration of greenhouse gases of the atmosphere (carbon dioxide, methane, nitrous oxide, ozone, freons, etc.) and concentrations of troposphere aerosols (sulphate aerosols of anthropogenic origin mainly)	Total forcing of greenhouse gases and troposphere sulphate aerosol	Klimenko et al. (2000)
Volcanic activity (concentration of stratosphere, mainly sulphate, aerosol)	Acidity index $$ AI_c^N $$ for Northern hemisphere	Klimenko et al. (1997); Hammer et al. (1980)
Solar activity	Maximal Wolf numbers, i.e. maximal average annual values in each Schwabe cycle	Mikushina et al. (1997)
The Earth rotation velocity (Rot)	Average annual fluctuations of the Earth's day length from atomic day length ΔT	1790–present – Sidorenkov (2002); 1429–1790 – extrapolation by trigonometric trend with the principal period of 79 years
North Atlantic Oscillation winter index (NAOI)	Difference of normalized sea level pressures ΔP according to data from Lisbon station (Portugal) and Stykkisholmur station (Iceland)	1864–present Hurrell (1995); 1823–1863 Jones et al.(1997); 1429–1822 Glueck and Stockton (2001)

One hundred years before the first West European navigators arrival, the Russian North was a large deserted area, being under the formal control of Velikyi Novgorod. The main impulse, which caused people from Novgorod to come to the Far North, till the very shore of the "Cold Sea" (name of the Barents Sea up to the nineteenth century), was a search of goods for Novgorod market, furs in the first turn. People from Novgorod descended to the sea by rivers and portages and travelled by boats ("ushkuyas") along the sea shore, arranging temporary settlements, and were involved in plundering at convenient moments. At this, local population robbery was covered by the slogan of christening of "savage Lapps", "Karelia children" and "bloody Samoeds". To Belomorye and Murman, in Pechora and Yugra not only hunters came, but also soldiers for tributing or just plundering. Local population often resisted to this brigandage of Novgorod "boyar children and varmint people", and bloodshed resistance battles not always finished in favor of Russian violators. However, not just a persistent resistance of the local population, but also extremely hard natural conditions of the North facilitated those facts that until the collapse of Velikiy Novgorod

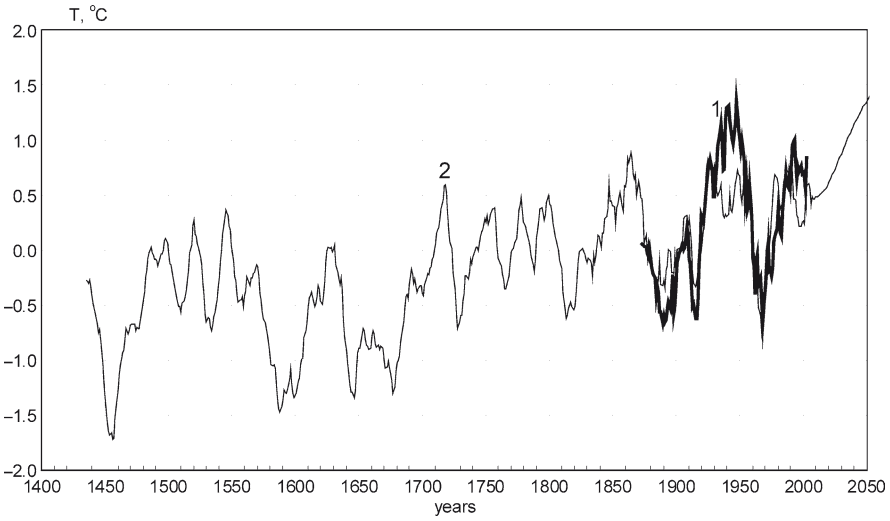

Fig. 13.2 Mean-annual temperature record (smoothed 10-year values) in the Barents and the Kara Seas basin since A.D. 1435. (1) Instrumental observations; (2) Reconstructed temperature (with reference to the period 1951–1980)

(1478) actual colonization of the seashores by Russians didn't start. In the mid-fifteenth century, except several small settlements in the lower reaches of the Severnaya Dvina, Onega and Varzuga rivers, the only permanent settlement, situated directly at the seashore, was Solovetskiy Monastery, founded in 1435.

Together with Novgorod collapse the way to Yugra (the lower Ob' River) fell completely into Moscow's hands, but only in 1499 in the mouth of Pechora River near Pustoe Lake, a famous Pustozersky fortification was built ("stockaded town was built in the tundra place, cold and forestless"). It was the first step made by Russians to the Arctic Ocean shores. We think it wasn't accidentally that Pustozersk was founded at the time of a short Arctic warming, when its climate suddenly became warmer and approached the modern one (hereafter the "modern climate" refers to the average temperatures observed in 1951–1980) by its characteristics (see Fig. 13.2). Having reached the Arctic Ocean shore, Russians, naturally, couldn't resist navigation – for trading aims as well as for fishing and whaling. Possibly at this very time some unknown Russian navigators discovered Novaya Zemlya – an exact date of this event is still unknown, however there is a very important evidence, pointing exactly the boundary between the fifteenth and sixteenth centuries. Italian writer Mauro Urbino in his book, published in 1610, writes the following: "Russians, sailing in the northern sea, discovered about 107 years ago an unknown island, inhabited by Slavs and subjected to eternal cold. It is bigger than Cyprus island and on the maps it is indicated as Novaya Zemlya" (Vise 1934).

Colonization of Kola Peninsula by Russians began undoubtedly later, and its first visible sign also coincided with a new phase of warming in the Arctic, which lasted this time for more than 30 years, since the middle of the 1530s to the early 1570s.

(Fig. 13.2). At this time on Murman at the Kola River bank a permanent settlement, although small, arises – according to the evidence of Dutchmen, who were permanent visitors to Murman, except church there were only three houses. In the 1530s at the western Murman, in Pechenga, the northernmost monastery in the world was founded. About people, who carried out a civilizing mission in this remote region, we can find evidence in extracts of a diary of the Dutch Simon van Salingen, who met personally with the monastery founder, Tryphon by name. Before becoming a monk, Tryphon, as he said, had been a drunkard, "robbed and beggared a lot of people and shed a lot of blood" (Kharusin 1890). In the sixteenth century the Pechenga monastery had an extensive economy, based mainly on fish and salt, and also sea ships were constructed there. The monastery became richer not only for the account of trade, but also for the account of vivid exploitation of local population– Lapps (Saami). A famous researcher of Russian Lapps N. Kharusin wrote that Pechenga monastery "till the certain extent, was a disaster for Lapps" (Kharusin 1890). About everyday life of the monastery monks the following extracts from an inquiry which took place when the monks became too much out-Herod: "Monk Illya is always drunk and steals monastery property, and the reason of his becoming a monk was a penalty which he would have had for robbery". And about other monks: "He is always drunk, spends all his time in a kabak (pub)", "he is a groggy person", "he has a lot of lush", etc., later a rigid order had been given to the monks from this monastery "not to let women into cells under any reason" (Vise 1934).

A flood of Russians to the Far North increased especially in the middle of the sixteenth century – it is usually considered to take place because of political oppression of Moscow which became harsher during Ivan the Terrible rule. According to the same van Salingen, people "because of the tyranny predominated at that time in Russia, escaped and went to live in Lapland". However, we think that significantly improved climatic conditions had also played a positive role in this movement of people to the North. In this connection, it's necessary to give some additional comments that average decadal annual temperatures in the middle of the sixteenth century exceeded the temperatures in the coldest decades of the fifteenth and sixteenth centuries by more than 2ºC (Fig. 13.2). In the North of the European territory of Russia such increase of temperatures is equivalent to moving southwards at the distance up to 550–600 km. Thus, at the warmest times inhabitants of Belomorye could enjoy the climate, which was representative rather for Vologda or Yaroslav regions and didn't experience some stress after leaving the historical center of the country. Implicitly, in favor of this judgment that fact attests that in the late sixteenth century under conditions of a new cold wave, nobody wanted to escape not only to Murman, but even to more benign Belomorye, and Moscow had to undertake serious forced actions to inhabit the lower reaches of the Severnaya Dvina River, where in 1584 Arkhangelsk town was founded, which had been initially called as Novokholmogorsk town. Upon Arkhangelsk foundation, Moscow, because of political considerations closed the Murman "shelters" (ports) in Kola, Varzuga and Kevrola, and confined a foreign trade to the mouth of the Severnaya Dvina River. However, some time later Englishmen and Dutchmen continued using Murman "shelters".

In the middle of the sixteenth century in England a serious public concern arose, resulted from the sea monopoly for the eastern trade of Spain and Portugal established by that time. These countries completely controlled the southern sea routes around Africa and America, but why not to try reaching China and India from the North, moreover, if the most prominent geographers of that time (Schöner, Mercator, Ortelius) accepted such a possibility? The first large English expedition which sailed to find a new alternative northern sea passage to the East was headed by a noble Hugo Willoughby, who wasn't however too experienced navigator (it was a usual practice in Europe at those times). This expedition was organized by the Company Merchant Adventurers for the Discovery of Regions, Dominions, Islands and Places Unknown, later called Muscovy Company. A squadron consisting of three ships left England on 20 (30) May 1553. During a hard storm near North Cape the ship *Edward Bonaventure* under the command of Richard Chancellor was separated from the other ships. Willoughby pressed to sail eastwards and on 14(24) August saw a land, the greater part of researchers thinks it was Kolguyev Island. After this the expedition moved northward, but met with ice and turned to the south-west, where, on 28 September (8 October) anchored in the mouth of the Varsina River on the eastern Murman. Here Willoughby decided to spend winter; the first in the history wintering in the Far North ended with tragedy – all 63 participants died apparently from cold and scurvy. Next spring Russian hunters found the expedition's wintering place, where they also found both ships with crew members' bodies. Also Willoughby's log was found which had the last notice made in January 1554.

The third ship of the expedition under the Chancellor command was luckier: Chancellor reached the mouth of the Severnaya Dvina River, where he established trading relations with Russians. Pretending to be an English ambassador, Chancellor was invited by Ivan the Terrible to Moscow, which, by the way, he describes as follows: "I think Moscow is more spacious then London and its suburbs, but this city is ugly and built without any order". In 1554 Chancellor came back to England, as a result of his traveling diplomatic and trading relations between Moscow and England had been established.

Having established trading relations with Moscow, Muscovy Company didn't leave its main objective – to search for the north-eastern passage to China and India. In 1556 a new expedition left England on the small ship *Searchthrift* under the command of Steven Barrow, who served as a pilot on Chancellor's ship before. On 14 (24) July Barrow was near Kanin Nos, on 24 July (3 August) – at the Pechora River mouth, and on 4 (14) August he reached the south-eastern coast of Novaya Zemlya. Thus, Barrow became the first foreigner who saw this arctic isle. At the Novaya Zemlya coast he met some Russian hunting ships; a helmsman of one of them called Loshak gave him an information he was interested in about sailing to the Ob' River mouth. From this we can make a conclusion that Russians were quite familiar with a sea route to the Ob' River in the mid-sixteenth century – according to our climate reconstruction (Fig. 13.2), we think that this route might be passed for the first time in the 1480s–1490s. On the last days of August Barrow sailed near Vaygach Isle trying to reach the Kara Sea through Yugorsky Shar. However, on 3 September he

had to give up his attempts and turn back as persistent northern winds were blowing and caused "terrible bulk of ice which he saw by his own eyes". On 21 September (1 October) Barrow came to Kholmogory where he arranged wintering. The ice situation during the pioneering voyages of Englishmen was not so much hard and corresponded to the present one, what confirms our simulation data (Fig. 13.2).

After Barrow's expedition Holland joined the race of searching for the north-eastern sea passage. In the 1560s Dutchmen had active trade with Russians not only on Murman coast and in Belomorie, but also in Pechora region. In 1565 Dutchmen founded a trading post in Kola. Oliver Brunell from Brussels played a great part in developing trading relations with Moscow. This person's biography is very unusual – in about 1570 he worked as a steward for the Stroganovs family who were famous merchants and established steady trade with Ostyaks (Hanty) and Nentsys in the lower reaches of the Ob' River, they exchanged cheap "German" goods for valuable furs. Before this Brunell lived in Kholmogory where he studied Russian language. Naturally soon he was taken as a spy and was put into Yaroslav prison from where the Stroganovs begged him off. Between 1577 and 1580 Brunell by order of the Stroganovs travelled twice to the lower reaches of the Ob' River, the second one was done by sea from the Pechora River mouth. Thus, it was Brunell who was the first foreigner to have passed the northern sea route to the Ob' River mouth. In about 1584 Brunell fit out a ship for his own expedition in order to sail to China, but this time ice didn't let him pass further than Vaygach. At that time annual average temperatures in the Barents Sea region were close to their historical minimum (Fig. 13.2) and there is no wonder that Brunell's expedition even led by an experienced Russian pilot, couldn't reach its goal.

In summer of 1580 Englishmen Arthur Pete (he also served on Chancellor's ship) and Charles Jackman became, it seems, the first west Europeans who by their own brought their ships to the Kara Sea. This is what they saw on their way from Vardhus (modern port of Vardø in Norway) to Yugorsky Shar: "Winds between NO and SO kept them there (near Vardhus – author's note) till 1 (11) July. As they continued their way to the East they met a lot of ice and on 7 (17) July saw at the 70°5′N latitude a land, surrounded by ice which they took for Novaya Zemlya. They stayed near that place till 14 (24) [July], and sailed then to SO and came on 18 (28) [July] at Vaygach, where they filled their stocks of fresh water and wood. Then they entered the Kara Sea and found there so impassable ice that they stuck there for 16–18 days surrounded by thick fog. With great difficulties they went back to Yugorsky Shar on 12 August and decided to return home, so, on 22 [August] (1 September) their ships were separated from each other" (quoted in Litke 1835).

From the point of view what is known to us about the Arctic (Arctic Atlas 1985); a described situation with ice in this period can be characterized as moderately hard – such conditions could be met in colder periods of the twentieth century – this is confirmed by results of our simulation (Fig. 13.2). But by the end of the sixteenth century, when Willem Barents in 1594–1597 made three voyages to the eastern part of the Cold Sea which is called now after him, he had no chance to reach his goal. During the last of these voyages on 21 (31) August 1596 his ship was captured in Icy Harbor (Ijshafen), and the crew had to spend winter on the north-eastern coast of

Novaya Zemlya; several seamen, including Barents himself, couldn't stand that winter burden and died. We know exactly that Barents was aware of Pete's and Jackman's voyage – a handwritten description of this voyage together with other valuable artefacts were found in their wintering place in Novaya Zemlya by a Norwegian whaler Elling Karlsen in 1871. You will never know if that knowledge had a fatal role in the fate of the last Barents' expedition. As before that time when the ship had been captured forever, Dutchmen during the last days of August did their best to pass by the Kara Sea to the south-west, the same as English did shortly before. But could they imagine that unstable arctic climate would suddenly become so cold (Fig. 13.2) and cut their way for rescue? In fact, notes of Dutch expedition participants (Gerrit de Veer and Jan Huyghen van Linschoten) depicted that hard situation with ice even in summer, which was almost the same as it could be during certain hardest years in the early or second part of the twentieth century. Following are the extracts of those notes:

1594	
Guba Krestovaya Gorbovy Isles	"On 13 (23) July they met so much of ice, that round-top horizon (mainmast basket) was completely covered by it, then they were casting about between this ice and Novaya Zemlya coast and on 26 (5 August) came to Cape of Uteshenya"
Muchnoy Nos Cape (Cherniy Cape now)	" … ice traverse was almost impossible"
Sakhanin Isles	On 12 (22) August "They met there a large quantity of ice and they had to sail southwards"
	"Large bulks of ice which was — like today — drifted from Karskie Vorota Straight restricted his (Barents) advance into this area. That's why he couldn't reach the southernmost point of Novaya Zemlya and had to stick to Matveev and Dolgiy Isles"
Cheshskaya Guba	"On 5 (15) July they met a lot of ice and several times took fog for a land. The latitude was according to astronomic observations 71°20′N. On 7 (17) July they saw Kaninsky coast. During the next two days they met a lot of ice again, which was drifted out of a bay situated between Kanin and Svyatoy Nos (Cheshskaya Guba), and which stopped and stayed near Kolguev Isle, on the shallow […], they found there that ice in a form of high hills"
Pechorskaya Guba	"On 18 (28) (July) they came to the Pechora. […] Stormy weather from the East". "Eastern current which brought a lot of ice"
1595	"On 7 (17) August they sailed round North Cape and on 17 (27) met piles of immovable ice. They calculated its latitude which was 70°5′N. And their distance from Novaya Zemlya which was 12–13 miles. Having overcome great difficulties they passed through new ice bulks and sailed next day to Dolgy Isle, and on 19 (29) in Yugorskiy Shar, fully surrounded by drifting ice […]. On 25 (4 September) Dutchmen tried to move further eastwards, but met such great quantity of ice, that they had to hurry back to their previous place of anchorage. On 2 (12) of September ice moved away a bit and they again started their voyage and at last entered the Novoe Severnoe (the Kara Sea — author's note). But there they met new huge ice bulks from which they hardly could escape near Myasnoy Isle (12 miles eastwards from Yugorskiy Shar entrance — author's note), where they were surrounded by ice completely". (quoted from Litke 1835)

Thus, quoted extracts from observations definitely show that in the late sixteenth century hard ice conditions ruled in the study region – suffice it to say that at present starting from the late July and until the early September all western coast of Novaya Zemlya and south-eastern part of the Barents Sea are normally free from drifting ice. Consequently, at the time of Barents' voyages mean annual temperatures were significantly lower than modern, what fully corresponds to the modeling results (Fig. 13.2). One more extremely interesting circumstance, connected with the destiny of the famous Dutch expedition. The original map of Novaya Zemlya, drawn by Barents himself survived and it is shown in Fig. 13.3. This figure shows that at Barents' times the northernmost extremity of Novaya Zemlya was not Karlsen Cape, situated at 77°01′N and 67°30′E, but Bol'shoy Ledyanoy Mys (Yshoeck), situated several miles eastwards from it. At the end of the sixteenth century a technique of geographic latitudes determination was high leveled enough and it was impossible even to expect that such an experienced navigator as Barents was unable to determine a correct location of the isle extreme northern point. Conseguently, one may assume that 400 years ago Bol'shoy Ledyanoy Mys really stretched much further northwards and probably was a tidewater part of an inland ice sheet. Now, at the epoch of a warmer climate there is no sign of Bol'shoy Ledyanoy Mys any more and this name now bears a usual foreland, vicinage of which keeps one of the greatest mystery of the Arctic – Barents's tomb mystery. Thanks to widely known Gerrit de Veer's notes (de Veer 1936) eyewitness of those events, the circumstances of the last days of Barents' life are well-known. On 14 (24) June 1597 15 men who survived wintering in Ice Harbor started the way back by two oar boats, made from the debris of the destroyed vessel. On 20 June near Bol'shoy Ledyanoy Mys at the same time on these two boats, sailing in a thick fog, two persons died – Commander Willem Barents and his servant Klaas Andris Gautejk. As Gerrit de Veer stated both were buried in an "ice tomb". So, it could

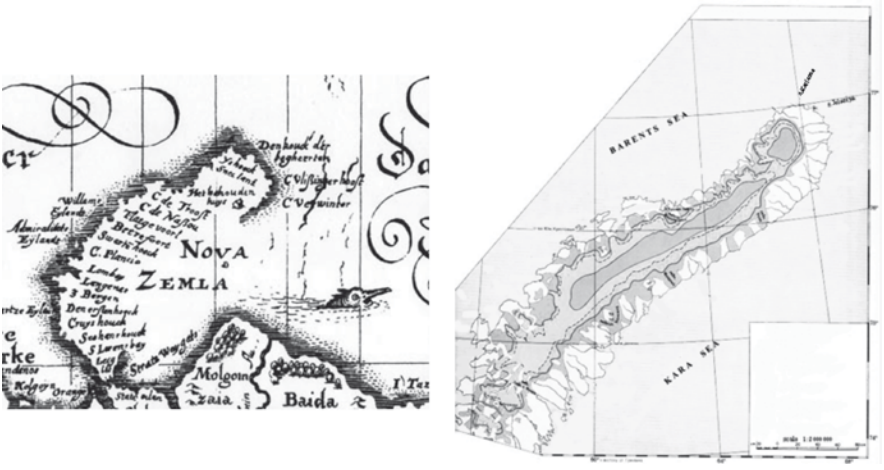

Fig. 13.3 Map of the Novaya Zemlya northern coast: *left* – Willem Barents' manuscript; *right* – modern (both from Arctic Atlas 1985)

be implied that this place was the ice anchored to the coast or a tidewater glacier. This glacier later melted and disappeared without a trace as well as the bodies kept by it. No wonder that regardless of all possible efforts of Dutch and Russian expeditions – the latest of them were dedicated to the year of Barents' memory (1997) – to find any signs of this tomb failed. We think that the glacier of Bol'shoy Ledyanoy Mys could disintegrate as far back as in the first half of the seventeenth century,[1] when the climate of this part of the Arctic became much warmer and navigation in the Artic seas developed greatly.

At this time a number of English (Hudson) and Dutch (Van Hoorn, Boosman, Cornellison) expeditions reached a coast of Novaya Zemlya and even penetrated the Kara Sea. In 1607 a famous English explorer Henry Hudson (in Russia he is better known under the name of Gudson, after whom bay and strait in Canada and river on which New York City stands were named) reaching 80º23′N near Spitsbergen, set the astonishing world record. This record was broken only 200 years later by an English whaler Skoresby, who managed to reach 81º30′N in 1806. Our temperature reconstruction shows that both record voyages were made during epochs when the climate of this part of the Arctic had been significantly warmer than usual (see Fig. 13.2). Not less amazing events took place near the southern coast of the Barents and Kara seas: in 1601 at the distance of 180 km from the Taz River mouth and more than 2000 km from Arkhangelsk a prosperous trading town of Mangazeya came into being, with the population of two thousand inhabitants at its best years. The name "Mangazeya" derives from "mongomzi" – the name of Nenets tribe which used to live there. In legend "about people unknown on the eastern side and about languages different" (the late fifteenth century) it says: "On the eastern side behind the Yugor' land, above the sea, Samoyed' people live, called malgonzei". In Mangazeya not only merchants and state officials lived, "different people" came there, escaped from "state taxes, and some of them from robbery and from their clans, from different debts" (Vise 1934). During the first decades of the seventeenth century up to 16–17 ships per year came to Mangazeya, famous for fur fairs and "fish tooth" trade (walrus ivory) – in comparison with the next eighteenth century each voyage like that would have been a great exploit. But even in the seventeenth century a sea route to Mangazeya was considered to be hard, because it passes through "impassable evil places of great ice", where it was necessary to suffer from "different needs". And, nevertheless, "Mangazeya town, being deep into 'cold tundra', almost under the Polar circle, among bellicose tribes of 'bloody Samoyad' and other 'hostile' indigenous people, cut off from Russia and even from other parts of Siberia by Mangazeya Sea storms, notwithstanding all disadvantages of its location, had been during 50 years of the seventeenth century one of the most important centers of Russian trade in Siberia" (Bakhrushin 1929). Continuing the series of successful voyages of the early seventeenth century, in 1610 a ship under the command of Kondratiy Kurochkin sailed down the Yenisey River from Turukhansk and, without any obstacles, passed the Kara Sea

[1]Modern observation of glaciers of Novaya Zemlya northern isle (Zeeberg and Forman 2001) show that glaciers which were in the tidal zone were able to retreat with a great speed, exceeding 300 m per year.

for two days and came to the Pyasina River mouth. No later than in 1618 unknown Russian seafarers sailed round the northernmost Eurasia point – Chelyuskin Cape – and therefore overcame the most difficult part of the northern sea route. The rests of wintering of this unique expedition were found only in autumn 1940 on the coast of Faddey Bay 130 km south-east from Chelyuskin Cape. Wreck of the ship and rigging were also found – it leaves no doubts that travellers came there by sea (Okladnikov 1957).

Russian government's reaction to the suddenly appeared possibility of northern navigation was firm and peculiar – in 1619 Tsar Mikhail Romanov under the threat of death penalty prohibited to use "Mangazeya sea route" due to the reason that this route may be used by foreigners and "Germans will be able to come to Mangazeya from their lands bypassing Arkhangelsk". Moreover, the government wanted to counteract the trade of Russian merchants with foreigners on the North, as there they could escape taxation ("they will begin to trade with Germans, hiding behind Yugorskiy Shar, on Kolguev, on Kanin Nos and the state treasury will loose this taxation"). Of course, people there at first protested against such a destructive innovation, but they had to surrender when under the petition of local voivode Prince Kurakin "hard order" came from Moscow, disobeyed were threatened by "being executed cruelly and their houses are being destroyed completely". In result, "that route, under the tsar's order, under the threat of death penalty, from great ocean sea (the Barents sea) into Mangazeya Sea (the Kara Sea) as well as from Mangazeya Sea into the Great Ocean is prohibited for anybody". To observe the order fulfillment a permanent outpost had been established in Yugorskiy Shar. Thus, the destiny of Mangazeya had been predetermined, but the town had been dying for several decades more and was finally abandoned only in 1672, when new sharp cooling (Fig. 13.2) made human's living there impossible. Mangazeya hadn't reborn. The place where prosperous polar town stood was forgotten and found by accident only in 1900. Until 1927 no scientific expedition visited this site.

It goes without saying that at the time of warming in the seventeenth century (possible, that partially also during the previous one, in the middle of the sixteenth century) unknown Russian seafarers made great geographical discoveries in the Russian Arctic. These discoveries were almost unknown during a long period of time. The point is that in 1609 a Dutch trade agent in Moscow, Isaac Massa, copied the map of "North Russia", and he published it in 1612 in Holland, together with the following notes: "I had a friend in Muscovy, his brother had been on the North of Russia and he made a big map of those countries. He visited personally Vaigachskiy Strait and knew all locations till the Ob' River, but about countries which situated further he only heard … All, what I know, I collected with great difficulties and I owe this to my friendship with several Moscow courtiers, who gave me this data after numerous refuses to do so. They could pay with their lives for this, as Russian people are really distrustful and can't stand to disclose secrets of their country" (Pasetsky 2000). Amazing on Massa's map (see Fig. 13.4) is that not only Matochkin Shar strait, dividing Novaya Zemlya into two parts, had been indicated, but also the whole north of Russia from

Fig. 13.4 Map of the North Russia by Isaac Massa (A.D. 1609) (Atlas of geographical discoveries … 1964)

Norway boundaries to western reaches of Taymyr, including Beliy Isle, Oleniy, and Sibiriakov isles, the Ob', Yenisey and Pyasina Rivers, i.e. many lands, officially discovered only 150 years later.

Cooling came to the Arctic, apparently, about the mid-seventeenth century – beginning from that time we have a significant number of evidence about aggravation of ice conditions, bad weather conditions in summer, crop failures, famine years, severe winters, etc. Thus, starting in summer 1652 from Arkhangelsk, the governmental expedition under the command of Ivan (according to the other data – Roman) Nepluev, run into ice near Kanin Nos already, where nowadays the sea is sometimes ice free even in winter. Because of the ice the expedition couldn't approach the south coast of Novaya Zemlya; however during the previous decades it caused no troubles at all (Borisenkov and Pasetsky 2003). This time the expedition managed to reach "Burlov coast", situated near Dolgiy and Matveev Isles. Here they had to stay for really difficult wintering during which the greater part of the crew died. The least part of survivors came back to Pustozersk, the center of Yugor region at that time, situated in the lower reaches of the Pechora River. The same tragedy stroke the next expedition of Ivan Nekludov, sent in 1672 in order to search for silver on Novaya Zemlya (legends about rich silver mines on Novaya Zemlya existed for a long time among people from Novgorod, but no precious metals had been found on the isle). Nekludov, just like his predecessor, died without having reached the goal he had to attain (Pasetsky 1980).

English expedition of Captain Wood (1676) started out for search of north-eastern passage between Spitsbergen and Novaya Zemlya. His ships met ice at the end of June 1676 (according to the Julian Calendar): "On 22 June, when they were at 75°53′N of latitude and 39°48′E of longitude to the east from Greenwich, low and connected with each other ices appeared, stretching from west-north-west to east-south-east" (Litke 1835). Attempts to overcome this "rather solid and impassable wall" failed: near Novaya Zemlya, where ice "connected with the coast", Wood suffered shipwreck and had to land where he and his crew were found in several days by the escorting ship *Prosperous*. Being shocked by his failure, Wood stated that to

find north-eastern passage was impossible as Spitsbergen and Novaya Zemlya are connected with each other by impassable ice masses.[2] This point of view didn't change even after 1688, when the last attempt of the western Europe to find the north-eastern passage to Asia had been taken. Dutchman Flaming, having been sailed to Novaya Zemlya in 1664 already and having been encouraged by the results of the previous sailing, when he reached the middle of the Kara Sea under 74°N, decided to start the second expedition. And this time he managed to reach Zhelaniya Cape (77°00′N, 68°31′E) – extreme north-eastern point of Novaya Zemlya, but it was impossible to move eastwards any more. Flaming's expedition was the last from 150-year epic of persistent but unsuccessful attempts to find north-eastern passage to Asia. During extremely cold decades of the second half of the seventeenth century (see Fig. 13.2) these attempts were sentenced to fail – as a result the idea to find the sea route to China passing the northern Asia had been postponed for almost 200 years. In general, by the late seventeenth century under the influence of described above events there was an opinion that Novaya Zemlya was a part of a landmass which stretched through the Cold Sea eastwards and possibly connected there with Eurasia or America. Nobody in the Western Europe or on the Russian North knew that Novaya Zemlya was an island! Until the middle of the eighteenth century the Kara Sea had often been displayed on maps as a great bay landlocked from its three sides. This point of view had been clearly expressed in the text and in the title of the most important document of that epoch – "Description why it is impossible to reach Chinese state from Arkhangelsk town and then to Eastern India", which was compiled under the order of Tsar Aleksey Mikhailovich.

The destiny of arctic sailings could be different as in the late seventeenth century the climate of high latitudes again became significantly warmer (see Fig. 13.2). It can be proved by various sources, evidence of which this time belong to inland regions only: Solikamsk Chronographer, notes of journeys of different authors – Bell, Unkovsky, Chirikov, Messerschmidt and others. The main source of climate information is evidence on break-up and freezing of rivers, as it was rivers which had the main transport function then, not only in summer but in winter also. This is a summary of some observations:

1719	Solikamsk Chronographer registers the date of the Kama River freezing: "on 13 (24) day of October the Kama and other rivers froze over, in 3 days after this it became warm and rain started and ice melted. Rivers froze over again at Phillip's Lent" (Berkh 1841) (i.e. after 28 November (9 December) — Authors' note)
1719–1720	Bell passed Western Siberia on his way to "Asian lands" and in winter 1719–20 suffered from "severe cold", noticing that frosts in Solikamsk were harder then in other journey points being closer to the North. It's known from his diary that for example in 1720 it was possible to sail to the Ob' River by boat even at the end of September, snow at Irtysh fell out on 4 October, and the Irtysh itself froze over on 13 October, the day before it began to be covered with sludge (Bell 1776)

[2]At present this famous ice wall exists also, but usually it is destroyed in August-September and in the warmest years it doesn't even exist from April through November.

1724	Unkovsky — an envoy to Djungar Taichjy-Khan — noted in his diary on 6 April 1724, that sleigh way at the Irtysh River began to be destroyed, on 16 April of the same year the ice broke up at the Tura River. (Unkovsky moved through usual at that time route down on Irtysh to Tobol'sk and then up on the Tobol and Tura rivers to Tumen' and then to Solikamsk.) (Embassy to Tsevan Rabtan ..., 1887)
1725	A famous German scientist and explorer of Siberia Daniel Gottlieb Messerschmidt noted that in October of 1725 on the Ob' River near the Vakh River mouth a really high snow had been, and on 12 October floating ice appeared. About Surgut he wrote "that there are no cereals. The land thaws out not earlier than in June and in August there are frosts again. Cabbage grows but doesn't form heads; carrot, and onion as well as horse-radish grow and ripe well here". On 20 October of the same year the Ob' River in the region of the Irtysh mouth in the middle was still free of ice; however there was a lot of it near the banks already. On the next day, 21 October, Messerschmidt's boat had been frozen into the ice in Kuriya Bay, on 27 October the river froze over completely (Nachricht von Daniel Gottlieb … 1782). According to Lieutenant Alexei Chirikov's data, on 10 October 1725 the Ilim River froze over (right tributary of the Angara), however "there was almost no snow on the land" (Vakhtin 1890).
	In the diary of Petr Chaplin (as well as A. Chirikov, he was a participant of the First Kamchatka expedition) we can find a note about the Irtysh break-up on 4 May 1725. "On the Irtysh River ice broke up and in three days after this [river] was ice-free" (ibidem).

Comparison of this and other data with modern ones shows that in the early eighteenth century the duration of ice occurrence on the upper Kama and western rivers of Siberia was shorter than nowadays or nearly the same, thus, it indicates the fact of short-term warming in the Arctic. Of course we don't have and can't have any direct evidence about changed navigation conditions in the arctic seas,[3] as at that time Europeans accepted the fact that it was impossible to sail that way, and Russia was in a war with Sweden. It's interesting that, during the Great Northern War, in 1713 Fyodor Saltykov made a report to Peter I with a proposal "About a search of a sea route" round the northern coasts of Asia to China, but then this proposal, of course, couldn't be accepted. It was decided to come back to the idea of exploration of the Arctic Ocean coasts in 20 years only. The Great Northern Expedition (1733–1743) faced incredible difficulties, as it took place during the next new period of cold in the Arctic (Fig. 13.2).

So, a famous scientist Johann Georg Gmelin, a participant of the academic group of the expedition, made the following interesting observations about the severe winter of 1735 in Eniseysk: "5 January. Crows and sparrows fell down to the ground as dead and they could become alive again only if taken into a warm

[3] It's just known that till the end of this warm period, i.e. until the late 1720s Dutch whalers regularly came to Novaya Zemlya – pits dug by them on the western coast for whales' fat melting out were encountered till the late 18th century. However in the second quarter of the 18th century when the ice situation aggravated landing to Novaya Zemlya became more dangerous and foreign whalers abandoned the waters of Novaya Zemlya for a very long time – until the middle of the next nineteenth century.

room. Residents tell, such occasions happen not often. I learned that in the forests there were a lot of animals died from the frost and a lot of people caught on their way by frost had their blood frozen in their veins".

During the Great Northern Expedition rather detailed instrumental meteorological observations were made for the first time, often daily, however, the quality of such observations, unfortunately, was rather low. At that time in Russia a temperature scale and thermometers of Delisle were used for scientific research, which weren't precise and reproducible (it should be mentioned that in this 150° scale the boiling point was at 0°, and freezing point was at 150°). So, in the sailing logs of boat "Ob'-postman" under the command of Pilot F. Minin it's written: "9/20 June 1738: 19°C (121° Delisle). 10/21.6 at 13.00 17°C (124°D), at 21.00 18°C (123°D), at 12.00 19° (121°D); 11/22.6 at 12.00 8°C (138°D); 12/23.6 air is cold, at 17.00 7°C (139°D), at 12.00 19°C (122°D); 14/25.6 at 12.00 18°C (123°D); 15/26.6 at 12.00 17°C (125°D); 16/27.6 at 21.00 23°C (115°D); 17/28.6 at 21.00 17°C (125°D); 19/30.6 at 13.00 23°C (115°D); 21.6/2.7 at 14.00 20°C (120°D), at 20.00 20°C (120°D); 22.6/3.7 at 12.00 13°C (130°D); 23.6/4.7 at 19.00 13°C (131°D), at 12.00 11°C (133°D); 24.6/5.7 13°C (130°D); 25.6/6.7 at 12.00 3°C (145°D), at 21.00 3°C (146°D)" (Log-book of the boat Ob'-postman ..., D. 30).

Obviously, it's hard to imagine, that in June of 1738 in Yenisey Bay, where boat was situated at that time, such high temperatures (up to 20–23°C) could really take place – because in such case it's impossible to understand why during this voyage Minin couldn't advance further than the North-Eastern Cape (73°32′N 80°33′E), where nowadays the sea is absolutely free from ice at maximum temperatures usually not exceeding 14–15°C. In confirmation of above stated, Table 13.2 presents data of instrumental meteorological observations at Dickson's station (73°32′N 80°15′E) from which it follows that within the last 70 years maximum June temperatures were only three times higher than 19°C, but according to the sailing log of Minin it happened five times only in June 1738!

In winter of 1738/39 Minin's expedition anchored at Isakovo wintering place, situated in the southern part of Yenisey Bay under 70°37′N. Here in spring of 1739

Table 13.2 June days with the highest daily average (T_{ave}) and maximum (T_{max}) temperatures recorded at Dickson meteorological station (observation years 1936–2005)

Year	Month	Day	T_{min}	T_{ave}	T_{max}
1943	6	21	10.6	16.1	22.2
1943	6	20	10	16	21.3
1984	6	30	11.8	16.1	20.7
1984	6	29	3.1	10	18.9
1957	6	26	5.6	13.4	18.7
1941	6	24	6	10.4	18.3
1943	6	19	5.6	12.1	17.7
1943	6	22	7.9	10.6	17.5
1982	6	30	1.9	6.2	16.8
1943	6	18	6.9	10.2	16.8

the following observations were made: “20/31.5 at 12.00 0°C (150°D); 23.5/3.6 light snowing; 24.5/4.6 light snowing and then snowstorm, at 9.00 –2°C (153°D); 25.5/5.6 at 9.00 –3°C (154°D); 26.5/6.6 at 12.00 average wind, cloudy weather, light snowing, warm air; 27.5/7.6 light snowing, at 9.00 great snowstorm; 28.5/8.6 south-south-east (wind), cloudy, great snowstorm, heavy wet snowing; 29.5/9.6 wet snowing, at 9.00 south-east (wind) –6°C (159°D); 30.5/10.6 snow, storm, at 9.00 1°C (149°D); 31.5/11.6 wet snow, at 9.00 1°C (148°D); 1/12.6 at 1.00 1°C (149°D), fog; 2/13.6 wet snow; 3/14.6 at 9.00 –1°C (152°D); 4/15.6 heavy snow; 5/16.6 snow, cold air; 7/18.6 snowstorm at 9.00 –5°C (158°D); 8/19.6 ice broke up; 9/20.6 snow and fog, snowstorm; 10/21.6 fog and snow, snowstorm; 12/23.6 at 9.00 2°C (147°D); 14/25.6 at 9.00 2°C (147°D); 15/26.6 at 9.00 2°C (147°D); 16/27.6 at 9.00 2°C (147°D), drifting ice on Yenisey; 17/28.6 at 9.00 1°C (149°D)” (Log-book of the boat Ob’-postman ..., D. 42). These temperature changes are closer to the real situation and, in particular, show rather cold summer and late break-up on Yenisey that year. May be due to this reason sailing in 1739 was rather unsuccessful, but next year of 1740 Minin at last managed to reach 75°15′N (Sterlegov Cape nowadays), where on 21 August he entered “impassable and motionless ice, […] behind that ice it was impossible to advance northwards due to the severe frosts” (Lieutenant Ovtsyn’s voyage, D. 4081).

In September 1740 the boat sailed up the Yenisey River and anchored for wintering in the mouth of the Dudina River (at the place of the modern city of Dudinka), where it, ice-bound, had to stay until July 1741. In spring and summer of 1741 the following observations were made on board: “21 April –48°C (222°D), sun shining; 22.4/3.5 –48°C; 23.4/4.5 snowstorm,–48°C; 24.4/5.5 wet snow, –48°C; 25.4/6.5 cloudy, –48°C, snow; 26.4/7.5 snowstorm,–52°C; 27.4/8.5 –52°C, snow, snowstorm; 28.4/9.5 –51°C, cloudy, snowstorm; 29.4/10.5 snowstorm, –48°C; 30.4/11.5 cloudy, snow, storm, –60°C; 1.5 snow, –51°C; 2.5 –51°C, fog; 3.5 cloudy, snowing; 5.5 –54°C, cloudy, heavy snowstorm; 6.5 clear, –52°C; 7.5 –51°C, clear; 8.5 clear, –49°C; 16.5 clear, –23°C; 17.5 clear, –21°C; 18.5 cloudy, –12°C, snowing; 19.5 cloudy, snowstorm, –25°C; 20.5 at 13.00 –16°C, at 9.00 –23°C; 21.5 heavy snowstorm, –23°C; 22.5 clear, –17°C; 23.5 snowing, –19°C; 24.5 snowing, –15°C; 15.6/26.6 snowing, ice motion on the Yenisey; 16.6 clear, –23°C; 17.6 clear, –17°C; 18.6 clear, –19°C; 19.6 clear, –7°C; 20.6 clear, –8°C; 21.6/2.7 there is still ice on the Dudina River, –3°C; 24.6/5.7 clear, there is a lot of ice still on the Yenisey, 11°C; 25.6/6.7 cloudy, there is no ice already on the Yenisey, –8°C” (Log-book of the boat Ob’-postman ..., D. 53). Of course, it’s hardly possible that in May–June 1741 air temperatures could be so low (for comparison, absolute minimum according to the data of meteorological station in Turukhansk for the last 100 years was recorded in May at –26,6°C, and in June –8,2°C – see Table 13.3), but nevertheless we again have obvious evidence of a very late drifting of ice in the lowest reaches of the Yenisey River and its tributaries as well as extremely cold spring and summer of 1741.

Apart from rather contradictory data of instrumental observations we have a significant number of other evidence from the Great Northern Expedition participants at our disposal, showing the picture of extremely hard ice conditions. Thus, ships started from Arkhangelsk in 1734 under the command of S. Muravyov and

Table 13.3 Days in May–June with the lowest daily average (T_{ave}) and minimal (T_{min}) temperatures recorded at Turukhansk meteorological station (observation years 1936–2005)

Year	Month	Day	T_{min}	T_{ave}	T_{max}
1986	5	2	–26.6	–16.1	–7.8
1999	5	1	–26.1	–13.1	–1
1986	5	1	–25.7	–18.2	–12.1
1970	5	11	–23.1	–14.8	–8.2
1964	5	3	–21.7	–16.8	–4
1986	5	5	–21	–12.4	–6.6
1986	5	6	–20.5	–9.2	–0.8
1991	5	2	–20.4	–13.2	–4.9
1964	5	4	–20.3	–11.4	–2.7
1970	5	2	–20.2	–11.1	–2.9
1962	6	1	–8.2	1	6.7
1992	6	1	–7.7	–4.8	–1.8
1968	6	5	–7.2	–3	0.8
1967	6	1	–7	–2.4	3.2
1987	6	4	–5.8	–3.5	–1.3
1987	6	3	–5.7	–3.8	–0.1
1968	6	4	–4.8	–2.7	–0.2
1968	6	6	–4.8	0	5.7
1987	6	5	–4.7	–2.5	1.1
1964	6	5	–4.5	–2.8	1.5

M. Pavlov, for two consecutive years had been trying to round Yamal Peninsula from the north, but failed. In 1736 Stepan Malygin, an experienced seaman, was appointed as a head of the western detachment, but even he at the beginning couldn't achieve a success – ships of his expedition had to winter on the Kara River, and only in summer of 1737 Malygin and Skuratov during their fourth attempt managed to round Yamal and reach the Ob' mouth. Malygin, the commander of expedition, after whom the strait in the Kara Sea is named and, as well as a street in Moscow, was rude and cruel person. According to the words of his crew, he abused his men badly, "broke heads till blood" and severely beat them up. With local population Malygin had a lively trade, changed polar foxes' fur for spirits, and also "oppressed differently". Generally, it should be said, that later all commanders of the western and the Ob'-Yenisey detachments were prosecuted due to the reason of constant quarrels with each other or abuses and outrages. Success and virtue rarely accompany each other.

Events in the Ob'-Yenisey detachment of the expedition developed synchronically. Beginning with the summer of 1734 Lieutenant Dmitry Ovtsyn on the boat *Tobol* made three unsuccessful attempts to leave Obskaya Guba into the Kara Sea, but every time ice stopped him: in June 1735 under 68°40' N, in August 1736 – under 72°40' N, almost at the entrance to the ocean. Only in summer of 1737 Ovtsyn managed at last to enter the Arctic Ocean and in late August he reached the Yenisey mouth. The early seventeenth century comes into one's mind at once, when

this route of the Great Northern Expedition had been yearly passed by about 15 ships making the whole route from Arkhangelsk and back during the same navigation. My own observations may be added to this, as I repeatedly sailed in the Kara Sea between 68 and 74°N during 1980s, but I have never seen floating ice there.

Full of staggering tragedy the Great North Expedition took lives of a lot of people, commanders and sailors, and as a result it brought the greatest geographical discoveries, but at the same time its initial geopolitical plans failed as it was shown that it was impossible to sail in Arctic seas safely. Russian government had to accept this fact, but the idea of discovering the northern route to Asia had been so much attracting that it was returned to it again and again. One of the most active and influential adherent of this idea was M.V. Lomonosov, who expressed this idea in his widely-known poem:

> Severe nature hides
> from us the entrance vainly.
> From the evening coast
> I see eastwards with my clever eyes:
> Russian Columbus amidst the ice
> is in hurry despising doom.

A plan developed by Lomonosov had been accepted by Catherine II who had just been enthroned, and in summer of 1765 a small squadron left Arkhangelsk under the command of Vassiliy Chichagov, which had a secret mission to pass through the Arctic Ocean to American coasts and further westwards, through Bering Strait to Kamchatka. This enterprise was kept "in secret, even from Senate till time to disclose it comes". In early summer of 1765 Chichagov faced ice in such a place where there is normally no ice nowadays even in winter – near Bear Island: "26.5 cloudy and foggy, L 74°10'L 40°24', icing at midnight; 27.5 Berren-Island (Bear Island): snowing, thick fog, ice on NNW" (Description of expedition of Chichagov, Popov and Babaev …, D. 92). Nevertheless, the sailors continued their voyage but on the north-west of Spitsbergen at latitude 80°26' N they met heavy ice and had to return to Arkhangelsk. Chichagov's failure (a plan of that expedition from the point of view of the modern knowledge about the Arctic was absurdly and that's why it was impossible to expect any success) caused an extreme discontent in the Board of Admiralty, and the commander of the expedition had been accused in "seamen thought about the returning too early and their great fear made them come back". Nevertheless, Lomonosov's authority and his cabinet plan were so much strong that the Admiralty ordered "to repeat the voyage", and next 1,766 year Chichagov was sent to Spitsbergen again. But unfavorable ice conditions accompanied his voyage this year too: "7.6 Berren Island: ice between north and west. Cold, cloudy, isle is foggy; 10.6 L 77°09'L 25°29' scattered snow, other ships are invisible under the thick snow, thick ice on south-south-west, later from north through east to south; 13.6 at night a bit of snow fell out, L 77°17'L 26°32'; 18.6 air is warmer then before, ice, large seal herds, snow, L 77°50'L 22°36'; 23.6 rigging is covered with hoar, fog, ice, snow, L 77°48'L 19°54'; 27.6 cloudy, cold, fog, rigging and sails are covered with hoar, L 78°03'L 19°46'; 3.7 1\4 of sea is covered by thick ice, L 77°06'; 15.7 snow, L 76°55'; 19.7 cloudy and cold, a lot of ice, L 77°48'L

18°53'; 24.7 foggy and snowy, rigging is covered completely with hoar, seals and sea hares, L 78°58'L 24°50'; 18.8 Spitsbergen: there is a lot of ice in the bay" (ibidem). This time the expedition failed to proceed further than 80°30′N – nowadays in this region the boundary of pack ice is situated 70–100 km northwards.

In 1768 a ship under the command of Fyodor Rozmyslov came to Novaya Zemlya, the aim of it was again the search for silver and also "description and observation of what is found… through the Novaya Zemlya strait". There are the following notes in the ship's log: "20.7 scattered clouds, sun shining. Since midnight the wind is weak and changeable, cloudy, in the morning scattered clouds, sun shining. On 22 July calm, Ninth Camp, cloudy. On 27 July, same place, since midnight the wind is calm, scattered rain". Since 15 August there are more notes about cold air: "On 22 August in Britvinsky Strait it's cloudy since midnight, scattered snow. At 5 o'clock it's cloudy and cold, at 9 scattered clouds, sun shining. On 26 August Matochkin Shar, cloudy weather, rain, storm at night, at 9 am sometimes sun shining, storm. 14.9 storm since the evening, cloudy weather. 15.9 Matochkin Shar, snowing at night, light frost in the morning. 16.9 cloudy and snowing. 19.9 frost in the morning. 20.9 frost with snow at night" (Log-book of the merchant A. Barmin's vessel ..., D. 137). Rozmyslov and his team had to winter on Novaya Zemlya; during wintering they continued their weather observations: On 1 October a notice is left about "Matochkin Shar is covered with ice. On the 25th a team wintering on Derevyannyi Mys came to Rozmyslov and report that the Kara Sea was covered with ice to the horizon also. This month there were prevailing weak eastern winds at cloudy weather, and it was snowing almost every day" (Litke 1835). Since the end of April 1769 more detailed notices appeared, as the team, apparently, started to prepare for the departure and followed the changes in the air and in the sea more carefully. "7.5.1769 frost and sun shining. 14.05 frost and sun shining. 15.5 cloudy and snow broth. Heavy mountain air like a smoke …" (Log-book of the merchant A. Barmin's vessel ..., D. 137). On 27 June 1769 "ice in the strait reached thickness of two arsheens (about 1.5 m – author's note). On the 30th it was seen that rain and water coming down from mountains significantly reduced the thickness of snow coverage" (Litke 1835). From the same text we learn that that year "Matochkin Shar became free of ice only on 2 August".

The data given leaves no doubts that low temperatures prevailed in the European part of the Arctic until the late 1760s, and it corresponds to the results of our calculations (Fig. 13.2). Under these circumstances Russian Government abandoned further efforts to reach high latitudes – ironically it happened just before a new and the most significant for 350 years warming of the Arctic took place (Fig. 13.2). But again, just like in the early eighteenth century, nobody used the advantages of such circumstances, and the next cohort of explorers came to the Arctic only in half a century. For 50 long years after Rozmyslov's voyage a single expedition had been sent to Novaya Zemlya shores. This expedition, headed by a mining engineer Vassiliy Ludlov, had been equipped at the own expense of State Chancellor Count N. P. Rumiantsev and had an aim to explore minerals and map coastlines of the island. The small ship *Pchela* (35 tons) under the command of pilot Grigoriy Pospelov left Kola on 11 (23) July 1807 and, having met no (!) ice, on 29 July (10 August) entered Kostin Shar strait off the south-western coast of Novaya Zemlya. The expe-

dition made several landings on the island and by the end of summer successfully came back to it's base. Participants of the expedition made meteorological observations, from which it follows that the summer of 1807 in the region was unusually warm. Apparently it was the last signal of the passing away warming as in just a few years the situation in the Arctic has drastically changed.

It became clear when after the end of Napoleonic wars the Russian Government again turned it is attention northwards and took a decision to make a detailed charting of the Barents and Kara seas coasts. With this aim in June 1819 the old, confiscated from the English ship *Novaya Zemlya* left Arkhangelsk under the command of Aleksey Lazarev, a brother of the outstanding seafarer Michael Lazarev, who at that very time was sailing to the coasts of undiscovered yet Antarctica. The northern team failed completely, having reached none of the aims – they could neither enter the Kara Sea, nor even reach the southern coast of Novaya Zemlya! The commander of the expedition stated that according to the evidence, received from hunters and Pomors, nobody from Pomor people, who sailed for hunting into those waters, had ever "found coasts" of that island due to the reason that they had always been surrounded by pack and floating ice. The same idea Lazarev expressed in his report for the Minister of the Navy I. I. Traverse and in his letter to I. F. Krusenstern. Any attempt to send an expedition on a ship he considered as being a victim, useless for science, sea navigation and trade (Pasetsky, 1980). The commander of the expedition noted "extreme ice conditions of the sea and really bad weather conditions", and also that "the whole south coast up to Britvin Cape had been surrounded by impassable ice barrier". It is obvious, that Lazarev's voyage happened in a really cold year, possibly one of the last in the phase of the next cold period in the Arctic. Along with this, an astonishing expedition failure and a total scepsis of its commander had to be accompanied with really unique circumstances. And such circumstances did exist – the point is that on 5 April 1815 the largest over a few last 1,000 years eruption of Tambora volcano occured, causing a significant (by 0.5–0.7 C) temperature drop in the northern hemisphere, which had been the most pronounced in the high latitudes during 3–4 years after the eruption. It is absolutely clear that Lazarev's expedition was preceded by not a single, but rather several severe winters and cold summers, such as in 1816 which entered the history as "a year without summer" (Stothers 1984) – there could have been no more unfortunate time for an arctic voyage at all. Of course at that time nobody even thought to take into account such exotic circumstances as an eruption of a tropical volcano, and Lieutenant Lazarev had to stand disgrace and humiliations in full – almost everybody accused him in cowardice and mismanagement! Neither Litke, nor Nordenskiöld who later sailed the same region but under the much more advantageous circumstances had a word of mercy to him – the latter wrote that "expedition under the command of such a man had to fail". However, several years passed and the situation changed completely.

Lieutenant Friedrich Litke's voyages to Novaya Zemlya in 1821–1824 were more successful – for the first time in the whole history of this archipelago exploration it was possible to sail along its whole western coast for four straight years and to describe it in details. In logbooks of the *Novaya Zemlya* brig, constructed purposely

for this expedition, weather conditions had been fixed in details as well as ice conditions, wind direction and clouds – it helps to make a conclusion that in the early 1820s a significant warming had been observed in this sector of the Arctic and this perfectly corresponds to the data of our calculations (Fig. 13.2). Here is a summary of the most interesting observations: the Severnaya Dvina River near Arkhangelsk in 1821 broke up in the middle of May: "at last, on 30 April (12.5) the ice on the Dvina broke up, but the river got free of it completely only in five days", and in the next 1822 it broke up on 23 April, Litke himself noticed that for "more than 50 years there hadn't been such an early drifting of ice" (ibidem). Winter of 1822 was extremely mild. In March 1822 Litke noticed "unusually early beginning of spring […] Approximately till the middle of the way to Arkhangelsk the snow melted almost completely". Litke also gave this evidence of a local population: "Lapps told that the last winter there was unusually warm; there was little ice, and that's why in many regions in spring sea seal hunting almost failed". Finally, according to Litke's own observations, it was "unusually warm and stormy winter. Kol'skiy Bay, which is usually for 20 or 25 miles from Kola covered with ice, this year wasn't almost frozen even near the town. On the coast of the White Sea fishery had been very unsuccessful, as there was lack of ice, on which Pomors use to hunt sea animals, so called serky and others" (ibidem). Winter of 1823 was, apparently quite usual, and in spring of 1823 drifting of ice on the Dvina occured in time, usual for the present time too: "On 27 April (9.5) ice broke up, on 6 (18) May it disappeared".

The author of this article dedicated several papers to the influence of climate on the world historical process (see e.g. Klimenko 2003). This influence for sure is applicable for personal destinies as well and may be nowhere so distinct as in the history of the Arctic. Lieutenant Lazarev started his voyage in a wrong time – and he died in disgrace and obscurity. Another Lieutenant – Litke – weighed his anchor only a few years later, and ice suddenly let him pass. He made a brilliant career, was one of the founders of the Russian Geographical Society, became an Admiral and the Head of the Academy of Sciences, a world-renowned scientist and of course he never thought that he wouldn't have had all that if there hadn't been a small peak in the temperature in the early 1820s. Despite a relative success of his mission, Litke for the rest of his life had kept a feeling of continuous danger which accompanied his voyage in the Arctic – being Admiral already and Deputy Head of the Russian Geographical Society he continued to argue that "the sea link with Siberia is a kind of impossible things". This statement was fully supported by another famous explorer – Academician Karl Ernst von Baer, who headed a complex scientific expedition to Novaya Zemlya in autumn 1837. Due to his authority during the next decades there was an opinion that Novaya Zemlya was a gloomy and dead desert, and the Kara Sea was "an ice cellar" and it contributed to the opinion about inaccessibility of this sea. Both scientists at the end of their lives were hardly assaulted, especially when in the late 1860s a new era in an arctic navigation history began, and all previous opinions about impossibility to sail in high latitudes at once collapsed. Baer was accused in "geographical deception", and a prominent German geographer Oscar Peschel wrote: "All what had been told us about Novaya Zemlya and the Kara Sea is a rude and shameful mystification.

Unavailability of the Kara Sea is a pure fiction; it can serve for fishing and not just as ice cellar". But all this will happen later, when a unique warming period comes to the Arctic (see Fig. 13.2), but at the beginning of the century warming wasn't so much significant but pretty short and soon changed to a colder period soon, which prevailed with some interruptions in the North until the late 1850s. A piece of the most significant evidence characteristic of that cold period and which hadn't been published before in the special literature is the following.

In the journal "Otechestvenniye zapiski" in 1849 "Notes on the way from Petersburg to Barnaul" were published, written by an unknown author. In these notes, in particular, some exact dates of freezing-over and breaking-up of Western Siberia rivers are given, indicating longer periods of freeze-up in comparison with modern ones: "Breaking up of the Irtysh (in Tobolsk) may be: the earliest on 30 April (12 May) (1832) and the latest on 15 (27) May (1833)… In Tomsk the river breaks up between 13/25 (1839 and 1840) and 29 (11 May) April (1833 and 1841), and freezes over on 8/20 October (1840) and 5/17 November (1834)" (Notes on the way from Petersburg to Barnaul 1849). From the same source we learn about returning of frosts in Tomsk Province in 1847: "twofold spring last time was in 1847", and about a severe winter in 1848/49 in Yekaterinburg: "winter is the most severe, in December there are constant frosts, often up to –35° Reaumur (–44°C), what never happened here before".

In 1858 traveller Russel-Killough made quite precise observations of temperature regime and weather conditions, as he was traveling through the western Siberia to India. He had a thermometer with him and made a number of observations, belonging to late November-early January, most of which were recorded in Tomsk, where Russel-Killough stayed for almost a month. In Nizhniy Novgorod on 15 (27) November the lowest temperature observed was –30°R (–37,5°C), and in Kazan' on 30 November (12 December) –28°R (–35°C). When crossing the Irtysh on 3 (16) December 1858 he wrote down the following: "then below –35°R (–44°C) (beyond thermometer limit), and the same for another two days, sometimes thermometer showed for several minutes–40°C. Sheepskin coat, pillow, clothes were dead frozen, toes were frostbitten for the rest of the life, horse is covered with a layer of ice etc., I heard that frost reached up to –42,5°C". In Tomsk on 18–20 December (30 December–1 January) temperature dropped at strong wind down to –47…–48°C (Russell-Killough, 1871).

Some extracts of already known texts are consistent with these notes, for example, 1834: "very frosty winter on the north-east of European part of Russia. Frosts reach more than up to 40°R (50°C). And in Vologda, Prezovets, Velikiy Ustug and near Vitebsk mercury in thermometers was frozen".

1834	Vologda province	"On 5 July and on 12 August frosts damaged crops"
1835	Northern Russia	"In 1835 since early November and up to 20 December frosts reached up to 40 Reaumur degrees (lower than –50°C). Severe winter of 1835–36 in Olonets Province. Frosts reached up to 32°R (40°C)"
1841	Vologda Province	"On 10 July in Yarensk there was an early frost, damaging winter and spring crops"

1841–1842		"In Vyatka on 31 May (12 June) snow fell out, ½ arsheen deep; the same happened along Siberian highway for 300 verst; local news said (but it's quite hard to believe), that there on 2 (14) June people were sleighing. In Belozersk region on 25 August (6 September) spring crops were damaged by frost".
	Arkhangelsk, Petersburg Provinces	"Long winter with heavy snow, especially in March, lasted till the middle of May"
1852	Northern Russia	"Frosts were in June in Arkhangelsk Province. On the 14th hoar was seen on the grass. 'Such coldness … at that time nobody from old people would remember. In order not to catch cold, it was necessary to heat stoves in houses and to wear warm underwear'. Cold and rainy weather in Vologda Province, in a number of regions there a fever appeared"
		"In Arkhangelsk guberniya, Kholmogory and Shenkursk Province in the first half of August there were frosts at night which damaged crops"
1857		"In July in Vologda Province frosts were observed (–5°C)"
1860		"March of 1860 is likely to become the coldest of the century in the whole Siberia and the European part of Russia till the Moscow meridian"
		(Extracts from the texts according to Borisenkov and Pasetsky 2003)

During the same years polar seas became again inaccessible. Here is one example – for almost 20 years (from 1844 through 1862) one more mariner from a famous family, Pavel Krusenstern (a grandson of the first Russian circumnavigator) unsuccessfully tried to sail from the White Sea to Siberia; during his fourth voyage in 1862 his vessel the *Ermak* was crushed by ice off the western coast of Yamal. This fatal voyage was sponsored by a famous "North devotee" Mikhail Sidorov, who earlier established a high reward of 14,000 rubles to the one who will pass from Europe to the Yenisey mouth. This prize had never been awarded.

At last, in the 1860–1870s new warming came to the Arctic again, maybe, one of the most significant for the last 500 years (Fig. 13.2). After centuries of endless failures the intensity of navigation in the Barents and Kara Seas grows, and this was connected with such names of enthusiasts like Mikhail Sidorov, Alexander Sibiryakov, Oscar Dickson, Ludwig Knoop etc. They managed to realize a number of successful commercial voyages from European ports to the Ob' and Yenisey mouths, between 1875 and 1884 23 out of 43 ships which started their voyages having successfully completed their mission (Dahlmann 2001). In the 1870s numerous Norwegian ships of sea animals hunters appeared near Novaya Zemlya, who came there to look for seals, walrus and other sea animals. Only in 1870 about 80 –90 Norwegian ships, as well as eight Russian ships hunted in this region which was so dangerous and almost inaccessible not so long ago. In September 1871 a captain of one of such ships named Elling Karlsen, found on the north-western coast of Novaya Zemlya a wintering camp of Barents and his companions, which nobody saw before for almost 300 years. During these exceptionally warm years

(1878–79) a Swedish explorer Adolf Erik Nordenskiöld on the ship *Vega* managed to round Eurasia from the north and reached the Pacific for the first time in the history. I think that an unprecedented success of the Arctic navigation in these years was significantly conditioned by drastically improved ice condition, which in its turn, was a result of a sudden warming in the high latitudes of Eurasia. In fact, beginning from 1869 till 1881 ships' log-books had been fixing unprecedented number of extremely favorable seasons concerning the ice condition, when the Kara Sea almost freely had been passed by a great number of ships in all directions. Absolutely unique was a navigation in 1878, when Nordenskiöld on the *Vega* passed through the whole Kara Sea up to Chelyuskin Cape, without having met any drifting ice on his way. Only on 29 September the ship came to anchor near Pitekay settlement on the coast of Chukotka Peninsula which is only 220 km away from the entrance to Bering Strait. Thus, within a single navigation on an ordinary trading ship a route had been passed which all previous seafarers couldn't manage for 400 years! The same year Norwegian sea hunter Edvard Johannesen on the schooner *Nordland* reached far to the north-east of the Kara Sea, to the waters where nobody has ever been before, and under 78º N discovered an island, named by him the Island of Uyedineniya (Seclusion), the last big island on the Earth found without a help of an icebreaker. Amazingly but according to Johannesen's description "*the island was completely free* (italics are mine – author's note) from snow …", and this points to unusually warm summer of 1878. After him nobody had seen the Island of Uyedineniya for the next 40 years, till the expedition on the *Eclipse* in 1915. It's obvious, that the new cold period began in the Arctic in the early 1880s, which brought about nearly a total termination of navigation in the high latitudes: breakages and accidents of the ships followed one after another, and the both largest ship-owners, Ludwig Knoop and Alexander Sibiryakov, had to interrupt a regular connection with European ports. At the end of his life Sibiryakov couldn't hide his disappointment: "Navigation in the Kara Sea hides a lot of difficulties, with which it's necessary to fight and that's why it is not suitable for commercial aims" (ibidem). If just during 4 years (1876–1879) 13 successful voyages from Europe to the Western Siberian rivers mouths were completed, then during the next 10 years (1880–1889) there were only 7. The epoch of a commercial navigation in the Kara Sea renewed only after 1911 and this time it was connected not only with warming which was just in it's initial stage (Fig. 13.2), but also with a development of a network of hydrometerological radio stations which significantly increased the safety of navigation.

A reconstruction of annual average temperatures (Fig. 13.2) is the first, produced for this Arctic region on the basis of documentary evidence and model simulations. Along with this, during the last 20 years both in Europe and the Russian Arctic a great number of dendroclimatic studies had been taken which resulted in reconstruction of summer temperatures back several centuries or even (millennia). On Fig. 13.5 a comparison of this work's data with the results of dendroclimatic reconstructions, covering nearly the whole area of the northern Eurasia from the coastal line of the northern Norway to the western Beringia, are given. Taking into account a significant geographical remoteness of the study

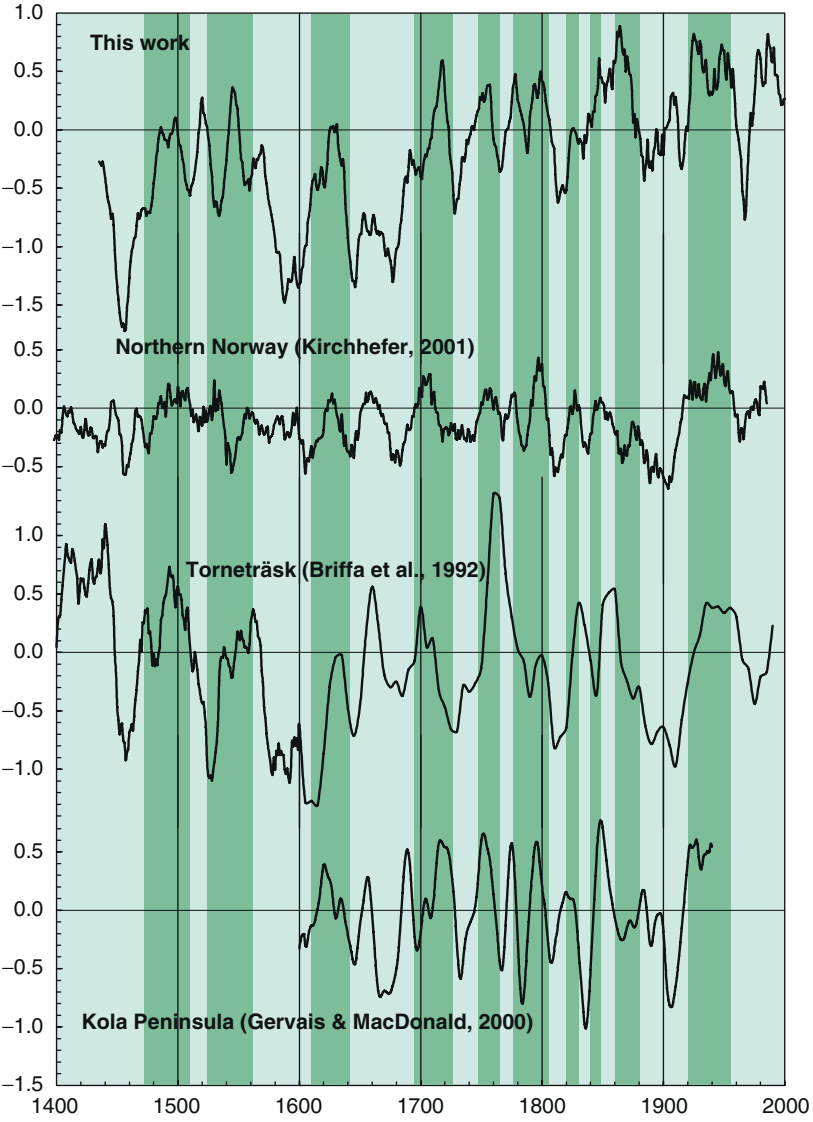

Fig. 13.5 This work's data as compared with the data of tree-ring reconstructions of summer temperatures for North Eurasia (smoothed with the 10-years moving average filter)

regions and principal differences in reconstruction methods, a correspondence of various data sets should be regarded as remarkable. In fact, almost all significant warm episodes (1470–1510, 1520–1555, 1610–1640, 1695–1725, 1775–1805,

1820–1830, 1840–1850, 1920–1950) happened with a remarkable synchronism in all study regions. Moreover, not only the sign, but also a scale of temperature anomalies appeared to be similar in the most of cases – thus, in all study regions the temperature in 1470–1510, 1695–1725 and 1775–1805 sometimes exceeded the modern level. A significant and absolutely clear warming of the 1820s (it had been recorded by early instrumental observations on subarctic stations of Arkhangelsk, Syktyvkar and Haparanda) wasn't observed on the eastern Taymyr and in the low reaches of the Lena River, but was clearly pronounced on the Kolyma. Warming of 1840s, which is also confirmed by early instrumental observations of not only European but Western Siberian (Tobolsk) stations also, left clear signs in the western part of Eurasia, but was hardly seen in the region to the east of the Ob' River. On the contrary, warming of the 1860s and 1870s, having a prominent place in our reconstruction, was accompanied by a period of cold in the western region (northern Norway, northern Fennoscandia and on Kola Peninsula), at least, in the warm season of the year. At the same time this warming was quite strong on Yamal, Taymyr, and in the low reaches of the Lena River and, in particular, on the Kolyma, where it had been the most significant during the nineteenth century.

The general picture of cold periods is also very much the same for all reconstructions under consideration and indicates the most significant cold periods between 1450–1465, 1590–1610, 1645–1690, 1725–1750, 1805–1820 and 1880–1920. It's interesting that in western regions the peak of coldness came to the mid-fifteenth and the turn of the sixteenth–seventeenth centuries while in the eastern regions (Taymyr, the Lena and Kolyma Rivers) the coldest period was indicated in the early nineteenth century.

A striking synchronism of climate fluctuations on the whole territory of the northern Eurasia confirms the existence of a common mechanism, regulating those processes. Our climate model gives an opportunity to indicate the main reasons of climate changes in the Arctic, among which there are natural factors, namely – the Earth's rotation velocity, atmosphere circulation pattern, sun and volcanic activity – which played the dominant role up to the middle of the twentieth century. As to the anthropogenic influence, it became noticeable only in the last 50–60 years, and it is likely to increase in the nearest future.

Simulations with a climate model clearly show that attempts of monocausal explanation of arctic climate fluctuations are predetermined to be a failure – in fact, it is impossible to explain a very complicated and as though unsystematic character of these fluctuations by a single factor influence. Thus, periods of abnormally low and high temperatures corresponded to the epochs of the lowest for the last 600 years solar activity, so called Spörer (A.D. 1420–1530) and Maunder minimums (A.D. 1645–1715) (Fig. 13.2). More often warm episodes were accompanied by periods of a high rotation velocity of the Earth, but strong cold periods happened too, for example, in the early nineteenth century. Thus, each significant climatic event during the last six centuries has been determined by a unique combination of the main climatic factors. Thus, a famous warming of the Arctic in the 1920–40s has been conditioned by a favourable combination of a rather high rotation velocity, zonal character of the atmospheric circulation (high NAO index), elevated solar

activity and a complete absence of significant volcanic eruptions. Moreover, an outstanding role of natural factors explains the well-known climatic paradox of the last 20 years period, when with increasing to the absolute high average global temperatures, larger parts of the Arctic still remain significantly colder than in the second quarter of the twentieth century. Moreover, in the Arctic study area the temperature trend during the last 20 years is altogether negative (Fig. 13.2).

We have a limited possibility to make an additional check-up of our palaeoclimatic reconstruction with the help of the data of earlier instrumental observations, made in the adjacent parts of arctic and subarctic regions. Immediately in the BKS region (sector I in Fig. 13.1) only two meteostations are situated, each having an observational record longer than 120 years – Malye Karmakuly (since 1876) and Salehard (since 1886). In the immediate proximity from the study area there are several more stations, some of which are having an observational record since the early or mid-nineteenth century. The main information about these stations is given in Table 13.4.

Thanks to the recent work (Klingbjer and Moberg 2003) a record of Haparanda station in the northern Sweden is the longest continuous instrumental record in the Arctic, with more than 200-year period of observation. Haparanda station data confirms the existence of a series of warm summers during the initial period of observations up to 1808, in particular during the record Skoresby's voyage (1806) and successful Pospelov's expedition (1807), when temperatures of each summer month were higher than modern. A subsequent cold period of the 1810s was rather pronounced and was the strongest for the whole 200-year record of observations. Also a sequence of very cold years has been recorded at that time on stations of Arkhangelsk, Petrozavodsk and Syktyvkar what confirms completely our hypothesis about a strong cooling, preceded the tragic voyage of A. P. Lazarev.

On the contrary, the 1820s appeared to be extremely warm – thus, in separate years (1821, 1822, 1825, 1826) mean annual temperature on the stations mentioned above exceeded modern values by 2–2.5°C, and in Arkhangelsk the absolute temperature maximum for the whole period of observations was recorded (1826). At the end of

Table 13.4 Arctic and subarctic stations at which lengthy monthly data records are available

No.	Station	Latitude °N	Longitude °E	Time span of observations	Percent of missing monthly data
1	Haparanda	65.8	24.1	1802–2006	0.5
2	Vardø	70.4	31.1	1829–2006	5.1
3	Petrozavodsk	61.8	34.3	1816–2006	14.4
4	Kem	65.0	34.8	1862–2006	0.9
5	Arkhangelsk	64.6	40.5	1813–2008	1.0
6	Syktyvkar	61.7	50.8	1817–2008	11.8
7	Malye Karmakuly	72.4	52.7	1876–2006	20.9
8	Salehard	66.5	66.5	1886–2008	3.4
9	Tobolsk	58.2	68.2	1832–2008	12.9
10	Tomsk	56.4	86.0	1837–2008	14.2
11	Yeniseysk	58.5	92.2	1853–2008	11.1

the 1820s a sharp coldness came which lasted for more than 10 years – during this period in Petrozavodsk (1829) and on the both stations in western Siberia, Tobolsk (1839) and Tomsk (1840) absolute temperature minimums for the last 180 years were recorded. Similarly all stations represented in Table 13.4 reconstruct a picture of the rather warm 1840s and cold 1850s. Extremely cold year A.D. 1862 indicates, apparently, the upper boundary of the latter cold period. As it follows from this discussion, data of earlier instrumental observations during the first 60 years of the nineteenth century shape rather consistent picture with our reconstruction data. However our reconstructed warming of the 1860–70s doesn't have an adequate counterpart in the instrumental data and this aspect deserves a separate discussion. The point is, that unfortunately, all Russian stations, listed in Table 13.4, except only Arkhangelsk and Petrozavodsk, have a significant percentage of missing data during these particular years, nevertheless, some of them (Syktyvkar, Petrozavodsk, Yeniseysk) do give high temperatures anomalies in separate years: (1863, 1864, 1869, 1872, 1874), close to absolute maximums over the entire record of observations.

Along with this, as it has been mentioned above, implicit observations, including the ones on South Yamal, situated immediately in the BKS region (Fig. 13.5), confirm the fact of a pronounced warming of the Arctic in those years. However, as to the scale of this warming on the average through the region, it has formed, apparently, as a result of an occasional coincidence of several favourable circumstances. To confirm this is the fact that arctic climate fluctuations are amazingly synchronous, but almost never coincide in magnitude (Fig. 13.5). It means that temperature anomaly in the BKS region could well reach values corresponding to our reconstruction. I feel, it's worth to cite here an evidence of an authoritative contemporary of the events described, Prince Peter Kropotkin, who served then as Scientific Secretary of the Russian Geographical Society. I suppose, this evidence shows that in the scientific society of that time there were no doubts that some really unusual events were taking place in the Arctic. "In A.D. 1869–1871 brave Norwegian whalers absolutely unexpectedly proved that the navigation in the Kara Sea was possible. To our great astonishment, we learned that into 'a cellar always full of ice', as we routinely called the Kara Sea, small Norwegian schooners entered and ploughed it in all possible directions. Inventive Norwegians visited even the place of wintering of the famous Dutch Barents, which, as we thought, had been hidden from humans by ice fields, more than 100 years old. Our marine scientists decided that such an unexpected success of Norwegians could be explained exclusively by the warm summer and by exclusive state of ice" (Kropotkin 1988).

Thus, we have all grounds to assume that in the Arctic study area the indicated significant warming really took place. There is no other good reason, except a significant warming, which could explain the unprecedented success in navigation and outstanding geographical discoveries, accomplished in these years.

Thus, the analysis of the climate fluctuations, following from historical evidence, is fully consistent with model simulations and early instrumental observations data. The developed reconstruction is based on the results of instrumental meteorological observations of the last century and is well correlated with other

temperature reconstructions, elaborated by dendroclimatic methods. It allows to argue that forecast of climate changes in the Russian Arctic sector may be quite reliable. Extrapolation of values of the major climatic factors has been made on the basis of considerations, presented elsewhere (Klimenko et al. 2000; Klimenko and Mikushina 2005). Results of the corresponding model calculations, shown in Fig. 13.2, allow to conclude that as a result of a restraining influence of natural factors maximal temperature marks, recorded between A.D. 1930–1950, will not be exceeded in the first part of the current century. Only after 2050 a very strong and long-term warming will come to the Russian Arctic, the scale and duration of it will become unprecedented in the context of the last 600 years as well as in the context of a few last millennia (Klimenko 2001). Unlike all previous, this warming will be generally conditioned by anthropogenic factors, and namely by continuing accumulation of greenhouse gases in the atmosphere and gradual atmosphere's release from troposphere sulphate aerosol.

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