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# Spatial variation of air temperature in the Arctic in 1951–1990

ABSTRACT: The paper presents a spatial distribution of changes of air temperature (*T*) in the Arctic. Estimates of their spatial relations in the study region were based on a correlation analysis. *T* in the Arctic is most strongly correlated spatially in winter and spring, and least in summer. The radius of extent of statistically significant correlation coefficients of changes of *T* at the stations Svalbard Lufthavn, Ostrov Kotelny and Resolute A is equal to 2000–2500 km in winter and 1500–2000 km in summer. An attempt was done to delimit the regions of consistent occurrence of the anomalies *T* with respect to the signs and magnitudes, as well as of the regions with the most coherent *T*. The Wrocław dendrite method was used to solve this problem. Relations of the mean areal *T* of the climatic regions and of the Arctic as a whole, with the northern hemisphere of temperature and selected climatic factors are presented.

Key words: Arctic, air temperature changes, spatial relations, correlation analysis.

## Introduction

Spatial distribution of changes of air temperature (*T*) in the Arctic is an aspect of climate variation, equally important as its time-dependent changes. Knowledge concerning rules of spatial distribution of these *T* changes could be extremely useful to their reconstruction and prediction, especially for areas devoid of meteorological stations. Such approach is possible, basing on data from the areas which are significantly correlated with a studied region. Information on spatial distribution of variation of *T* in the Arctic can be also helpful in revealing the global climatic changes. For example, if marked disturbances of these relations occur in long-term data, then the Arctic climate system will presumably undergo the important reorganization. With certain time lag, this can also result in a marked change of the global climatic system.

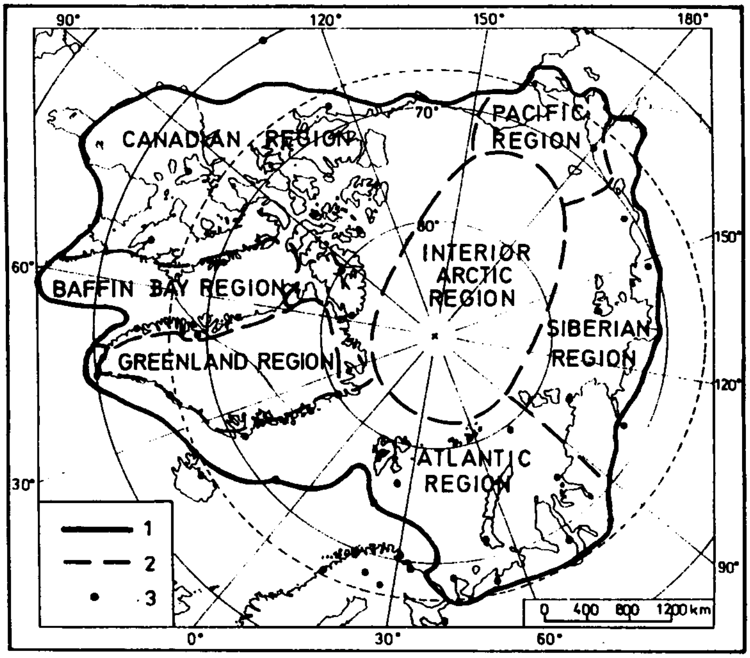


Fig. 1. Location of meteorological stations in the Arctic and Subarctic. Borders of: 1 – the Arctic, and 2 – climatic regions after Atlas Arktiki (1985); 3 – meteorological stations.

In the present paper, the border of the Arctic as well as the climatic regions are defined after Atlas Arktiki (1985; see also Fig. 1).

Mean seasonal and annual data from 35 arctic and 10 subarctic stations have been used in the analysis (Fig. 1). Most data come from the national meteorological institutes (Danish Meteorological Institute, Norwegian Meteorological Institute and Canadian Climate Centre) or from the other organisations (Arctic and Antarctic Research Institute at St. Petersburg, National Climatic Data Center at Asheville). Some data (mainly from subarctic stations) were also taken from the World Weather Records and the Monthly Climatic Data for the World. A quality control of the analysed series $T$ was performed and described by Przybylak (1996).

Estimates of the spatial relations of $T$ changes in the Arctic are mostly based on a correlation analysis (Eserkepova *et al.* 1982, Smirnova and Subbotin 1983, Subbotin 1983, Aleksandrov and Subbotin 1985, Alekseev and Svjaščennikov 1991). This method is also applied in the present work. The coefficient of linear correlation ($r$) was computed for each pair of stations. Mean seasonal and annual $T$ for the interval 1951–1990 were the input data. Results of these correlations are presented as a matrix of $r$ (Tables 1–3). Three different symbols were used to indicate statistically significant $r$ at the level of 0.1, 1 and 5%. Significance of $r$ was computed with a use of the Student's $t$ test (Gregory 1976):

$$t = \frac{\sqrt{n-2}}{\sqrt{1-r}},$$

where: $r$ is a coefficient of linear correlation and $n$ — a number of correlated years.

## Mean seasonal and annual air temperature

Correlation coefficients of the mean seasonal and annual *T* for 351 pairs of the Arctic stations are presented (Tables 1–3). Their analysis proves that *T* in the Arctic is most strongly spatially correlated in winter and spring, and least in summer. This conclusion is to be simply confirmed by the ratio of a number of statistically significant *r* to the all *r*. It was equal to 47.0 and 36.5% in winter and spring, respectively, and only 19.4% in summer. Similar results for the Arctic were presented by Alekseev and Svjaščennikov (1991), whereas for Europe *e.g.* by Gorczyński (1915, 1917), Kożuchowski and Marciniak (1986), and Marciniak *et al.* (1986). Good illustration which confirms these regularities, are distributions of *r* of the winter and summer *T* in the Arctic, in relation to *T* at the stations Svalbard Lufthavn (Fig. 2), Ostrov Kotelny (Fig. 3) and Resolute A (Fig. 4). These stations which represent the largest climatic regions in the Arctic (Fig. 1), are the reference points ("poles") for the isolines. Strong correlation of the winter *T* change in the Atlantic and the Baffin Bay regions seems to be caused by a very common vigorous cyclonic activity (Baranowski 1977, Przybylak 1992, Serreze *et al.* 1993). This circulation which carries warm and humid air masses from the lower latitudes, diminishes local and even regional features of climatic variations. Cyclones move most often along the Iceland — Kara Sea trough. As a result, the isocorrelates in the eastern Atlantic region have a north-eastern bend (Fig. 2). This bend is also present in isocorrelates of the annual *T* (Fig. 4). Correlation of winter *T* change in these regions is also undoubtedly caused by a lack of solar radiation over most of the area. In the other Arctic regions, a strong correlation of *T* change — besides the just mentioned reasons — is probably determined by predominance of anticyclonic circulation as well as by a high uniformity of the ground. In spring — almost in the whole Arctic — high *r* of *T* change are most probably connected with the highest simultaneous homogeneity of a ground (the largest part of the Arctic is covered by snow and sea ice) which, moreover, favours developing and upholding of anticyclones. Low correlation of the summer *T* change is probably caused by: *(i)* the greatest differentiation of the ground during this season, *(ii)* weak and evenly distributed cyclonic and anticyclonic circulation (Serreze *et al.* 1993), *(iii)* influence of local conditions which are remarkable during this season (the highest values of incoming solar radiation during a polar day).

Table 1

Matrix of correlation coefficients between the mean of spring (March–May, upper part of the table) and summer $T$ (June–August, lower part of the table) at the meteorological stations in 1951–1990 (hundreds of values of the correlation coefficient are given).

| Meteorological station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. ALERT | 1. | -40* | 47% | -27 | 51# | 32* | 32* | 42% | 47% | 28 | 8 | 14 | 88# | 8 | -26 | 39* | -21 | 9 | 38* | -3 | 15 | 11 | 39* | 0 | 60# | -24 | -32* |
| 2. ANGMAGSSALIK | 24 | 1. | -35* | 37* | 1 | -26 | -2 | -18 | -25 | 10 | -16 | 29 | -39* | 40% | 37* | 0 | 52# | -7 | -23 | 7 | -9 | -19 | -11 | 12 | -29 | 33* | 46% |
| 3. BARROW | 1 | 8 | 1. | -5 | 14 | 18 | -1 | 49% | 29 | 22 | 21 | 6 | 41% | -9 | -5 | 3 | -21 | 26 | 35* | 11 | 15 | 25 | 63# | 7 | 27 | 7 | -26 |
| 4. BJÖRNÖYA | -8 | -18 | 9 | 1. | -42% | -20 | -28 | 8 | -1 | 27 | 0 | -45% | -44% | -43% | 90# | -47% | 59# | 24 | 13 | 39* | 22 | -11 | 14 | 28 | -56# | 87# | 45% |
| 5. CLYDE A | 45% | 24 | -3 | -10 | 1. | 46% | 75# | 2 | 10 | 19 | 15 | 59# | 57# | 60# | -38* | 82# | -29 | 4 | 4 | 4 | 11 | 19 | 4 | 6 | 81# | -39* | -20 |
| 6. COPPERMINE | 17 | -12 | 23 | 7 | 46% | 1. | 53# | 6 | 33* | 19 | 8 | -5 | 31 | 10 | -17 | 33* | -11 | 11 | 17 | 10 | 13 | 5 | 0 | -5 | 64# | -13 | -5 |
| 7. CORAL HARBOUR A | 26 | 4 | -11 | -5 | 73# | 58# | 1. | -8 | 8 | 6 | 14 | 34* | 40* | 57# | -26 | 88# | -14 | -4 | 12 | 3 | 17 | 2 | -19 | 17 | 73# | -30 | -9 |
| 8. OSTROV CHETYREKHSTOLBOVOY | 11 | 26 | 5 | 4 | 12 | 9 | 12 | 1. | 75# | 1 | 31 | -9 | 35* | -15 | 10 | -7 | -11 | 40% | 68# | 30 | 37* | 32* | 86# | 24 | 11 | 10 | -35* |
| 9. COKURDAH | 17 | 28 | -19 | 0 | 11 | 3 | 13 | 54# | 1. | 0 | 22 | -11 | 33* | -15 | 0 | -1 | -13 | 45% | 84# | 22 | 45% | 25 | 58# | 11 | 27 | -2 | -26 |
| 10. DANMARKSHAVN | 26 | 28 | 19 | 16 | 4 | 4 | -15 | 48% | 39* | 1. | 13 | -12 | 7 | -14 | 27 | 1 | 32* | 9 | 2 | 19 | 18 | 7 | 8 | 24 | 19 | 40* | 46% |
| 11. OSTROV DIKSON | 6 | 33* | 0 | -16 | 29 | -18 | 2 | -20 | -11 | -23 | 1. | 2 | 13 | -7 | 16 | 3 | -21 | 67# | 39* | 78# | 80# | 90# | 25 | 83# | 16 | 19 | -20 |
| 12. EGEDESMINDE | 19 | 57# | 1 | -27 | 34* | -20 | 17 | 19 | 45% | 30 | 19 | 1. | 23 | 79# | -46% | 61# | -16 | -19 | -7 | -24 | -6 | 6 | -4 | -4 | 39* | -53# | -17 |
| 13. EUREKA | 46% | 27 | 1 | -38* | 37* | 9 | 18 | 31 | 36* | 22 | 14 | 48% | 1. | 19 | -41% | 45% | -32* | 10 | 23 | 2 | 7 | 18 | 34* | -6 | 69# | -44% | -45% |
| 14. GODTHAB | 22 | 70# | -1 | -33* | 30 | -21 | 20 | 21 | 33* | 23 | 22 | 83# | 38* | 1. | -41% | 69# | -18 | -25 | -13 | -21 | -16 | -9 | -22 | -6 | 45% | -49% | -20 |
| 15. HOPEN | 3 | -4 | 12 | 88# | 2 | 17 | 3 | 16 | 7 | 29 | -12 | -9 | -20 | -11 | 1. | -44% | 52# | 31 | 11 | 52# | 30 | 6 | 14 | 43% | -50% | 89# | 41% |
| 16. IQALUIT A | 20 | 21 | -6 | -14 | 68# | 33* | 81# | 11 | 29 | -16 | 19 | 37* | 16 | 31* | -7 | 1. | -22 | -19 | -1 | -17 | -1 | -3 | -12 | 5 | 73# | -47% | -15 |
| 17. JAN MAYEN | 11 | 14 | -2 | 51# | 22 | 15 | 6 | 10 | 15 | 39* | 6 | 7 | -19 | 4 | 58# | 0 | 1. | -15 | -10 | 0 | 2 | -38* | -5 | 14 | -33* | 55# | 75# |
| 18. KANIN NOS | -4 | 3 | 23 | 40* | 23 | 27 | 21 | 10 | -2 | 10 | -10 | 1 | -3 | 4 | 47% | 18 | 8 | 1. | 51# | 81# | 64# | 72# | 47% | 50% | 2 | 31 | -15 |
| 19. OSTROV KOTELNY | 17 | 32* | -27 | -8 | -4 | -3 | 12 | 50# | 70# | 42% | -14 | 40* | 32* | 30 | 3 | 17 | 12 | -7 | 1. | 31 | 68# | 33* | 51# | 37* | 11 | 10 | -22 |
| 20. MALYE KARMAKULY | -5 | 13 | 33* | 36* | 28 | 18 | 10 | 5 | -5 | -1 | 30 | 11 | 15 | 11 | 45% | 16 | 22 | 68# | -8 | 1. | 70# | 73# | 31 | 75# | -2 | 51# | -9 |
| 21. GMO E.K. FEDOROVA | 1 | 25 | -20 | 4 | 15 | -24 | 6 | 3 | 6 | 1 | 64# | 19 | 25 | 20 | 7 | 20 | 14 | 0 | 29 | 31 | 1. | 67# | 25 | 82# | 9 | 31* | -4 |
| 22. MYS KAMENNY | 20 | 9 | 19 | 0 | 31* | 23 | 8 | 10 | 3 | -7 | 65# | 2 | 18 | 2 | 12 | 18 | 7 | 13 | -23 | 47% | 27 | 1. | 35* | 66# | 16 | 7 | -35* |
| 23. MYS SZMIDTA | 27 | 27 | 19 | 9 | 7 | 3 | -3 | 58# | 12 | 29 | -7 | 2 | 20 | 4 | 11 | -8 | 4 | 26 | 10 | 27 | -7 | 9 | 1. | 17 | 7 | 18 | -25 |
| 24. OSTROV VIZE | 12 | 36* | -1 | 8 | 48% | 15 | 35* | -15 | -12 | -15 | 48% | 21 | 15 | 27 | 9 | 38* | 24 | 20 | 11 | 50% | 59# | 16 | 1 | 1. | -3 | 45% | 5 |
| 25. RESOLUTE A | 40* | 24 | 16 | -29 | 52# | 27 | 38* | 27 | 27 | 28 | 7 | 48% | 78# | 45% | -11 | 27 | -5 | 0 | 24 | 0 | 14 | 4 | -1 | 20 | 1. | -47% | -25 |
| 26. SVALBARD LUFTHAVN | -3 | 7 | 16 | 55# | 5 | 6 | 7 | 1 | 9 | 26 | 8 | 2 | -24 | 6 | 66# | 9 | 57# | 41% | 12 | 51# | 15 | 13 | 13 | 24 | -22 | 1. | 52# |
| 27. KAP TOBIN | 17 | -18 | 21 | 10 | 14 | 22 | 5 | 14 | 9 | 34* | -17 | -3 | 6 | -22 | 24 | 6 | 37* | 1 | 10 | 14 | -2 | 12 | 2 | -16 | 2 | 38* | 1. |

#, %, * – denotes the correlation coefficients statistically significant at the levels of 0.1, 1 and 5%, respectively.

Table 2

Matrix of correlation coefficients between the mean of autumn (September-November, upper part of the table) and winter $T$ (December-February, lower part of the table) at the meteorological stations in 1951-1990 (hundreds of values of the correlation coefficient are given).

| Meteorological station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. ALERT | 1. | 0 | -1 | 8 | 38* | 14 | 34* | 2 | 19 | 37* | 10 | 16 | 72# | 2 | 12 | 30 | 14 | 34* | 22 | 28 | 3 | 17 | -13 | 9 | 54# | 15 | 11 |
| 2. ANGMAGSSALIK | -3 | 1. | -6 | 30 | 2 | -18 | -6 | 22 | -5 | 22 | -19 | 52# | 20 | 51# | 26 | -1 | 72# | -3 | 4 | 8 | -3 | -26 | 17 | 6 | -1 | 27 | 49% |
| 3. BARROW | 7 | -7 | 1. | -1 | -12 | 19 | -15 | -19 | -19 | 1 | 3 | 14 | -12 | 15 | 4 | -5 | -3 | -16 | -4 | 4 | 0 | 11 | 3 | 11 | 7 | 4 | -13 |
| 4. BJÖRNÖYA | -31* | 42% | -42% | 1. | -36* | -19 | -41% | 19 | 0 | 62# | 11 | -15 | -22 | -14 | 96# | -37* | 64# | 37* | -10 | 41% | 23 | -5 | 9 | 44% | -31 | 95# | 67# |
| 5. CLYDE A | 36* | -7 | 3 | -36* | 1. | 31* | 74# | -8 | -9 | -6 | -29 | 64# | 63# | 55# | -34* | 85# | -21 | -20 | -6 | -22 | -30 | -15 | 7 | -28 | 74# | -33* | -22 |
| 6. COPPERMINE | 30 | 3 | 46% | -37* | 20 | 1. | 54# | -39* | -36* | -23 | 15 | 4 | 19 | 5 | -16 | 30 | -34* | 3 | -12 | 11 | -6 | 32* | -22 | -3 | 52# | -16 | -36* |
| 7. CORAL HARBOUR A | 34* | -20 | -2 | -42% | 73# | 35* | 1. | -6 | -8 | -28 | -11 | 38* | 58# | 38* | -43% | 86# | -27 | -3 | 4 | -7 | -25 | 7 | 3 | -30 | 80# | -41% | -40* |
| 8. OSTROV CHETYREKHSTOLBOVOY | 20 | -3 | 22 | -12 | 12 | 16 | 25 | 1. | 67# | 16 | -12 | 9 | 10 | 1 | 19 | -3 | 31* | 11 | 56# | 7 | 11 | -20 | 74# | -2 | -13 | 18 | 27 |
| 9. COKURDAH | 24 | 9 | -14 | 5 | 1 | 19 | 21 | 68# | 1. | 16 | 27 | 3 | 18 | -10 | 6 | -1 | 7 | 23 | 80# | 26 | 49% | 11 | 42% | 30 | -5 | 6 | 18 |
| 10. DANMARKSHAVN | 13 | 34* | -27 | 62# | -30 | -30 | -38* | 8 | 18 | 1. | 0 | 7 | 3 | -3 | 67# | -17 | 45% | 19 | -2 | 16 | 11 | -14 | -4 | 34* | -19 | 69# | 78# |
| 11. OSTROV DIKSON | -16 | -11 | -3 | 18 | -41% | -1 | -32* | 12 | 48% | -3 | 1. | -24 | -6 | -32* | 13 | -23 | -15 | 59# | 27 | 76# | 71# | 86# | -22 | 66# | -11 | 13 | -6 |
| 12. EGEDESMINDE | 32* | 26 | 9 | -28 | 78# | 12 | 51# | 4 | -8 | -27 | -57# | 1. | 51# | 87# | -16 | 61# | 17 | -14 | 7 | -11 | -17 | -19 | 18 | -18 | 44% | -17 | 12 |
| 13. EUREKA | 65# | -3 | 1 | -36* | 65# | 18 | 59# | 22 | 15 | -23 | -16 | 55# | 1. | 38* | -21 | 54# | 8 | 14 | 27 | 2 | -13 | 8 | -2 | -15 | 69# | -16 | -7 |
| 14. GODTHAB | 31* | 21 | 8 | -34* | 79# | 17 | 61# | 7 | -5 | -24 | -59# | 91# | 57# | 1. | -15 | 63# | 11 | -21 | 0 | -20 | -22 | -25 | 15 | -23 | 36* | -17 | 2 |
| 15. HOPEN | -28 | 35* | -43% | 95# | -38* | -41% | -44% | -15 | 7 | 65# | 24 | -35* | -34* | -38* | 1. | -38* | 56# | 29 | -2 | 38* | 30 | -5 | 11 | 52# | -27 | 97# | 68# |
| 16. IQALUIT A | 45% | -8 | -10 | -35* | 86# | 14 | 87# | 20 | 11 | -19 | -45% | 70# | 70# | 81# | -35* | 1. | -23 | -12 | 3 | -14 | -29 | -8 | 13 | -32* | 70# | -38* | -31* |
| 17. JAN MAYEN | -15 | 58# | -34* | 70# | -44% | -24 | -43% | -1 | 15 | 60# | 23 | -30 | -20 | -36* | 68# | -36* | 1. | 12 | 0 | 15 | -2 | -31 | 23 | 15 | -14 | 61# | 71# |
| 18. KANIN NOS | -26 | -3 | -11 | 23 | -51# | -10 | -46% | -5 | 11 | -2 | 58# | -48% | -25 | -57# | 24 | -59# | 37* | 1. | 18 | 74# | 31 | 66# | -20 | 24 | -12 | 30 | 7 |
| 19. OSTROV KOTELNY | 20 | -7 | -10 | 7 | -8 | 15 | 22 | 47% | 78# | 12 | 56# | -35* | 11 | -27 | 7 | 3 | 16 | 28 | 1. | 22 | 62# | 14 | 44% | 28 | 7 | -3 | 0 |
| 20. MALYE KARMAKULY | -41% | -5 | -23 | 43% | -44% | -10 | -38* | -12 | 16 | 5 | 71# | -61# | -28 | -63# | 49% | -52# | 34* | 75# | 35* | 1. | 56# | 76# | -5 | 57# | -3 | 35* | 18 |
| 21. GMO E.K. FEDOROVA | -10 | -2 | -10 | 30 | -34* | -2 | -26 | 5 | 48% | 18 | 81# | -54# | -23 | -52# | 37* | -36* | 20 | 44% | 63# | 68# | 1. | 42% | 15 | 82# | -14 | 28 | 10 |
| 22. MYS KAMENNY | -16 | -15 | 6 | 6 | -39* | -2 | -35* | 12 | 33* | -7 | 90# | -52# | -7 | -58# | 11 | -44% | 22 | 67# | 42% | 71# | 66# | 1. | -28 | 36* | 5 | -4 | -25 |
| 23. MYS SZMIDTA | 10 | -17 | 50# | -17 | -2 | 20 | -3 | 59# | 26 | 8 | 7 | -14 | 2 | -16 | -24 | -9 | -10 | 6 | 31* | 3 | 4 | 17 | 1. | 1 | -1 | 7 | 10 |
| 24. OSTROV VIZE | -23 | 10 | -31* | 56# | -40* | -18 | -30 | 1 | 34* | 39* | 67# | -57# | -31 | -51# | 67# | -35* | 39* | 36* | 42% | 76# | 80# | 48% | -6 | 1. | -10 | 53# | 30 |
| 25. RESOLUTE A | 53# | 5 | 10 | -37* | 76# | 55# | 76# | 26 | 22 | -28 | -28 | 62# | 68# | 62# | -43% | 73# | -28 | -31 | 17 | -31 | -28 | -25 | 11 | -33* | 1. | -24 | -29 |
| 26. SVALBARD LUFTHAVN | -32* | 33* | -40* | 91# | -47% | -38* | -46% | -15 | 4 | 71# | 24 | -45% | -39* | -45% | 95# | -40* | 73# | 24 | 9 | 45% | 34* | 11 | -20 | 63# | -47% | 1. | 67# |
| 27. KAP TOBIN | -14 | 59# | -31 | 67# | -38* | -28 | -43% | 4 | 14 | 75# | 7 | -25 | -33* | -29 | 62# | -32* | 77# | 8 | 10 | 14 | 20 | 0 | -6 | 34* | -33* | 68# | 1. |

Key as in Table 1.

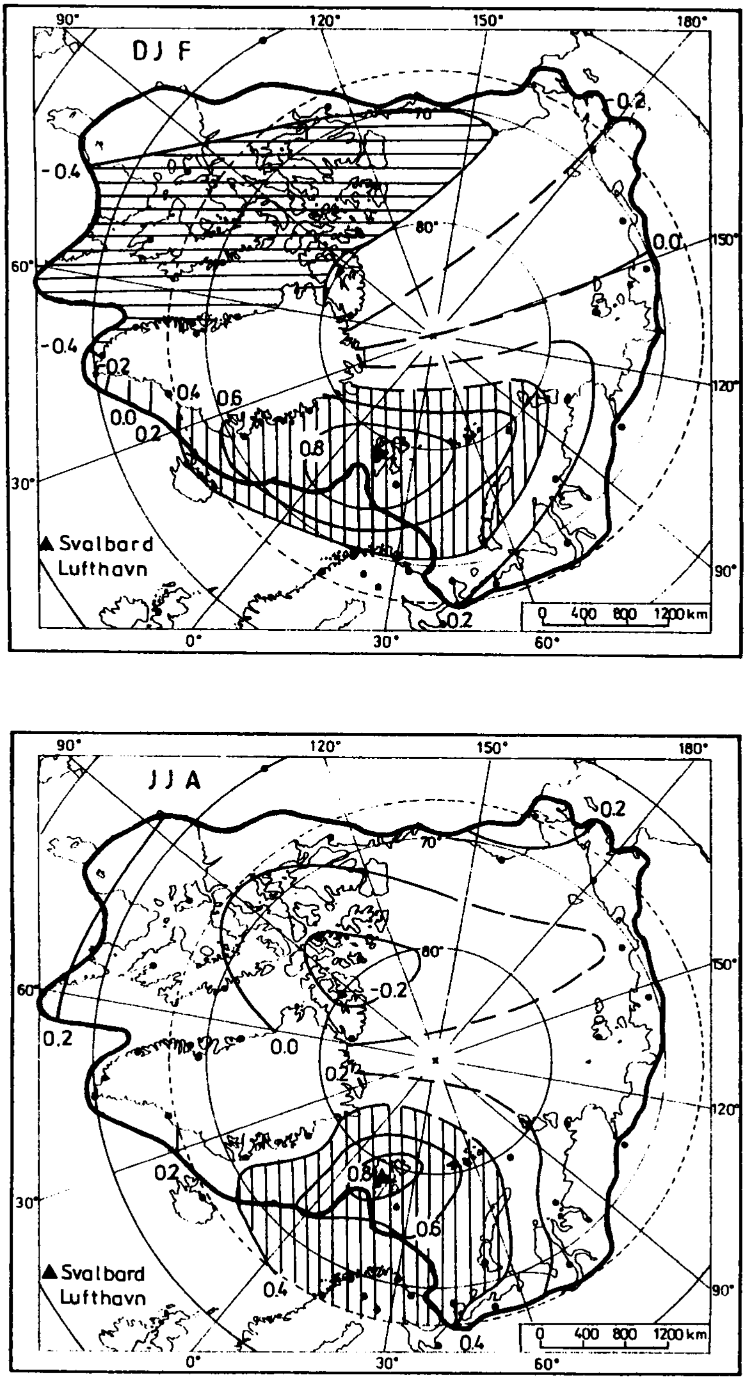


Fig. 2. Isocorrelates of winter (DJF) and summer (JJA) mean *T* in the Arctic in relation to the Svalbard Lufthavn and Ostrov Kotelny stations, in 1951–1990. For explanations see Fig. 4.

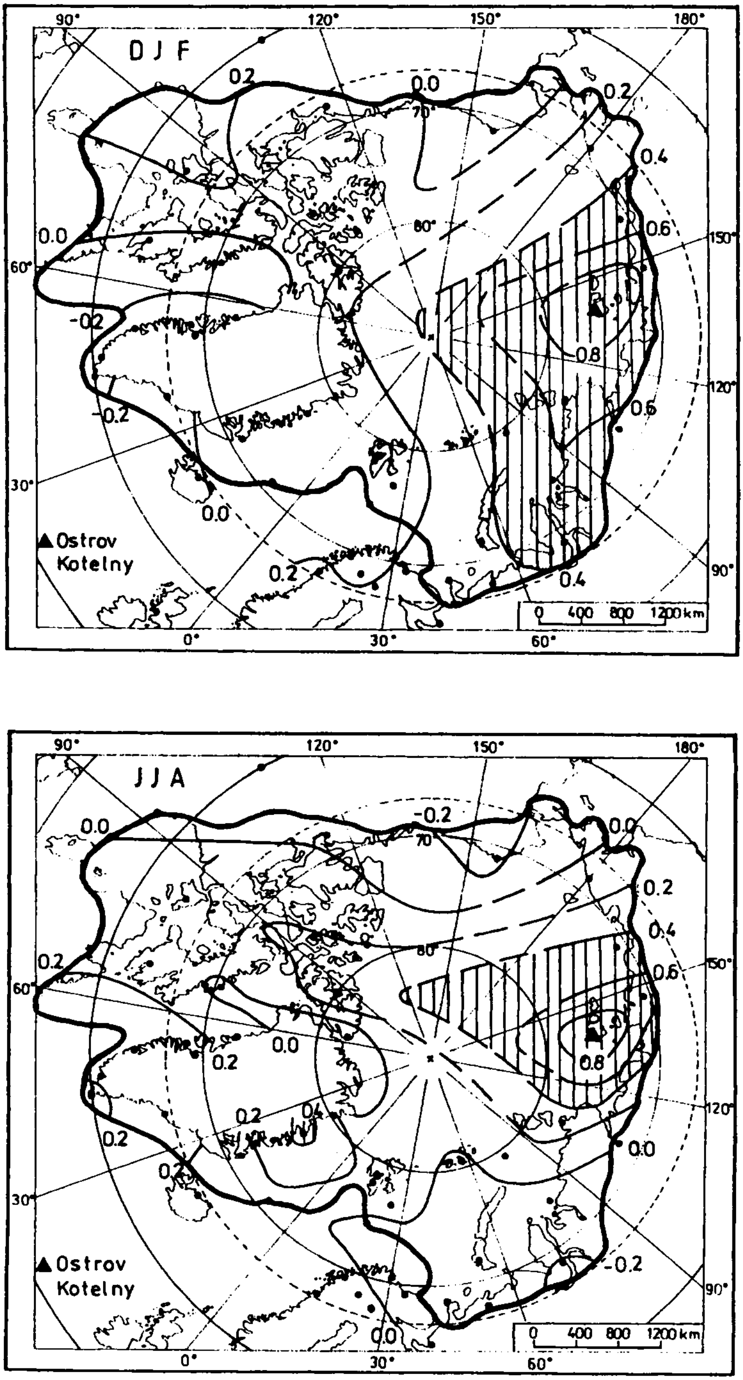
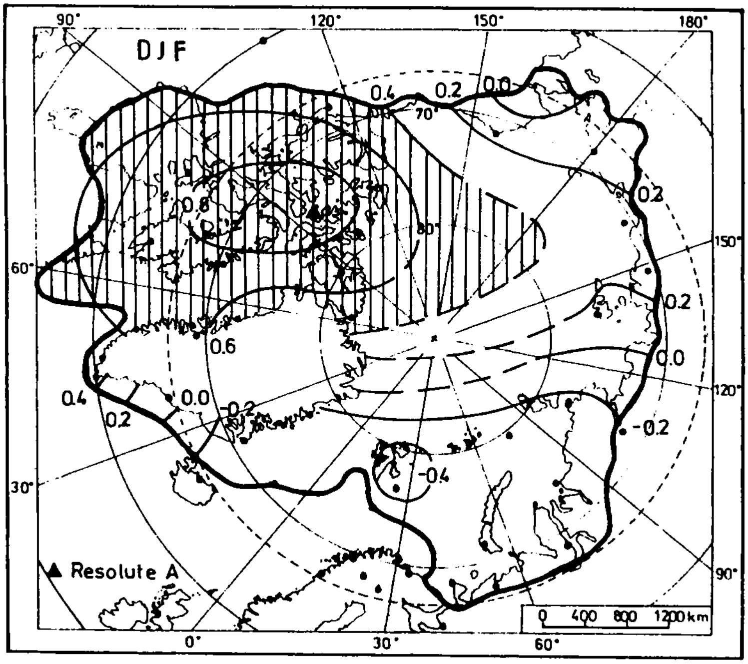


Fig. 2. (*continued*)



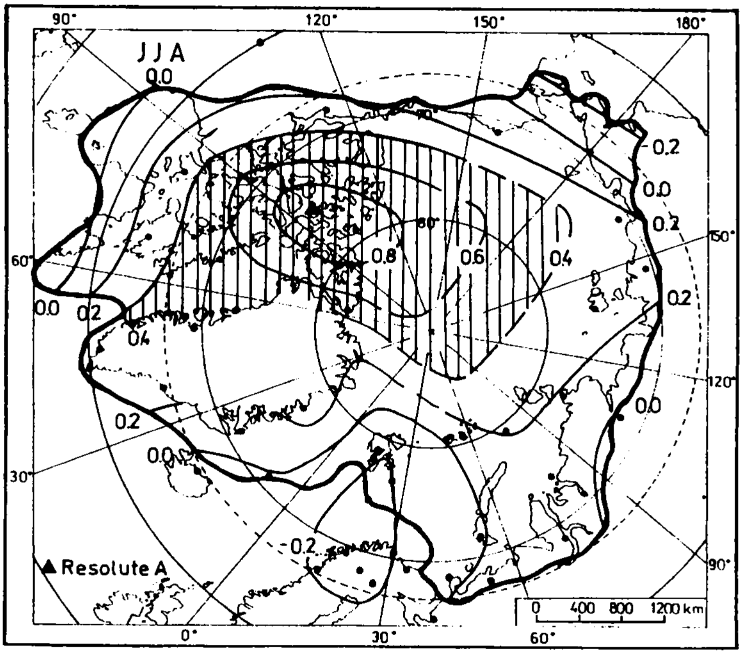


Fig. 3. Isocorrelates of winter (DJF) and summer (JJA) mean *T* in the Arctic in relation to the Resolute A station, 1951–1990. For explanations see Fig. 4.

Table 3

Matrix of correlation coefficients between the mean annual $T$ (the hundreds of values of the correlation coefficient are given, lower part of the table) and matrix of the least geometrical distances between the 40-years' series of the mean annual $T$ (°C, upper part of the table) at the meteorological stations in 1951–1990.

| Meteorological station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. ALERT | X | 106 | 37 | 102 | 37 | 43 | 42 | 29 | 26 | 38 | 40 | 85 | 11 | 107 | 78 | 56 | 108 | 109 | 20 | 82 | 20 | 57 | 40 | 27 | 11 | 75 | 67 |
| 2. ANGMAGSSALIK | -13 | X | 70 | 9 | 70 | 64 | 65 | 78 | 81 | 68 | 67 | 23 | 116 | 7 | 31 | 52 | 5 | 10 | 87 | 26 | 88 | 51 | 66 | 82 | 96 | 33 | 40 |
| 3. BARROW | 28 | -34* | X | 66 | 10 | 10 | 12 | 12 | 15 | 10 | 12 | 49 | 48 | 71 | 43 | 22 | 72 | 73 | 20 | 47 | 22 | 22 | 9 | 18 | 28 | 40 | 32 |
| 4. BJÖRNÖYA | -14 | 42% | -37* | X | 67 | 60 | 62 | 74 | 77 | 64 | 63 | 22 | 112 | 14 | 25 | 49 | 8 | 12 | 83 | 22 | 83 | 46 | 62 | 77 | 92 | 27 | 36 |
| 5. CLYDE A | 26 | 0 | -1 | -39* | X | 9 | 8 | 11 | 14 | 9 | 11 | 49 | 47 | 71 | 43 | 20 | 72 | 74 | 18 | 47 | 20 | 23 | 10 | 16 | 27 | 41 | 32 |
| 6. COPPERMINE | 39* | -36* | 22 | -30 | 41% | X | 7 | 16 | 18 | 10 | 9 | 44 | 53 | 65 | 37 | 15 | 66 | 67 | 24 | 41 | 25 | 17 | 9 | 21 | 33 | 35 | 26 |
| 7. CORAL HARBOUR A | 15 | -7 | -13 | -29 | 68# | 55# | X | 16 | 18 | 11 | 11 | 44 | 52 | 66 | 38 | 14 | 67 | 68 | 23 | 42 | 25 | 19 | 11 | 20 | 32 | 36 | 28 |
| 8. OSTROV CHETY-REKHSTOLBOVOY | 31* | 8 | 5 | 16 | 6 | 14 | 13 | X | 6 | 12 | 15 | 57 | 39 | 79 | 50 | 28 | 79 | 81 | 10 | 54 | 13 | 30 | 12 | 11 | 20 | 47 | 39 |
| 9. COKURDAH | 39* | -18 | -4 | 7 | 8 | 35* | 27 | 65# | X | 15 | 16 | 60 | 36 | 82 | 53 | 31 | 83 | 84 | 7 | 57 | 9 | 32 | 16 | 9 | 16 | 50 | 42 |
| 10. DANMARKSHAVN | 22 | 48% | -10 | 59# | -11 | -8 | -24 | 16 | 2 | X | 10 | 48 | 48 | 70 | 40 | 20 | 70 | 72 | 20 | 45 | 21 | 21 | 8 | 15 | 29 | 37 | 29 |
| 11. OSTROV DIKSON | 23 | -4 | -13 | 21 | -8 | 17 | 4 | 9 | 37* | 16 | X | 47 | 51 | 68 | 39 | 20 | 68 | 70 | 22 | 43 | 22 | 18 | 10 | 17 | 31 | 36 | 29 |
| 12. EGEDESMINDE | 16 | 31 | 27 | -38* | 61# | 9 | 36* | -10 | -13 | -15 | -23 | X | 95 | 22 | 18 | 31 | 25 | 27 | 66 | 14 | 67 | 31 | 46 | 61 | 75 | 18 | 22 |
| 13. EUREKA | 82# | -1 | 24 | -31 | 52# | 33* | 38* | 28 | 34* | 0 | 8 | 43% | X | 117 | 88 | 66 | 118 | 119 | 30 | 92 | 30 | 67 | 51 | 37 | 20 | 86 | 77 |
| 14. GODTHAB | 10 | 46% | 8 | -31 | 63# | 4 | 52# | -4 | -10 | -6 | -31* | 87# | 41% | X | 34 | 52 | 10 | 12 | 88 | 28 | 89 | 52 | 68 | 83 | 97 | 35 | 42 |
| 15. HOPEN | -7 | 46% | -36* | 96# | -33* | -27 | -25 | 15 | 11 | 65# | 24 | -36* | -24 | -25 | X | 27 | 32 | 34 | 58 | 11 | 59 | 24 | 39 | 52 | 68 | 4 | 13 |
| 16. IQALUIT A | 19 | 5 | 0 | -37* | 80# | 39* | 90# | 7 | 11 | -21 | -13 | 59# | 47% | 74# | -31 | X | 54 | 55 | 37 | 30 | 38 | 12 | 19 | 33 | 45 | 24 | 17 |
| 17. JAN MAYEN | 2 | 65# | -30 | 70# | -33* | -29 | -24 | 16 | -3 | 67# | 12 | -17 | -12 | -8 | 73# | -26 | X | 9 | 88 | 27 | 89 | 52 | 68 | 83 | 98 | 34 | 41 |
| 18. KANIN NOS | 11 | 11 | -10 | 39* | -20 | -4 | -23 | 37* | 30 | 23 | 49% | -25 | 2 | -32* | 37* | -35* | 35* | X | 90 | 28 | 90 | 53 | 69 | 84 | 99 | 36 | 43 |
| 19. OSTROV KOTELNY | 40* | -18 | -24 | 11 | 16 | 28 | 39* | 51# | 82# | 2 | 43% | -20 | 38* | -13 | 15 | 18 | -4 | 30 | X | 63 | 5 | 38 | 22 | 10 | 11 | 56 | 48 |
| 20. MALYE KARMAKULY | 12 | 15 | -11 | 53# | -20 | 5 | -9 | 34* | 40* | 34* | 72# | -36* | 3 | -36* | 54# | -26 | 37* | 77# | 44% | X | 63 | 26 | 43 | 57 | 72 | 11 | 18 |
| 21. GMO E.K. FEDOROVA | 18 | -1 | -33* | 41% | -7 | 10 | 6 | 18 | 54# | 22 | 81# | -38* | 7 | -36* | 46% | -15 | 13 | 43% | 69# | 75# | X | 39 | 23 | 8 | 12 | 56 | 49 |
| 22. MYS KAMENNY | 34* | -16 | 8 | 4 | -4 | 27 | -3 | 15 | 30 | 5 | 89# | -14 | 18 | -30 | 5 | -14 | -1 | 58# | 29 | 65# | 57# | X | 19 | 33 | 47 | 22 | 15 |
| 23. MYS SZMIDTA | 13 | -1 | 21 | 3 | -7 | 0 | -21 | 76# | 44% | -1 | 7 | -14 | 11 | -20 | 2 | -18 | 3 | 38* | 28 | 29 | 11 | 20 | X | 18 | 84 | 36 | 28 |
| 24. OSTROV VIZE | 1 | 26 | -31* | 56# | -13 | -9 | 7 | 8 | 28 | 36* | 67# | -29 | -6 | -18 | 62# | -7 | 37* | 26 | 42% | 68# | 82# | 32* | -2 | X | 18 | 50 | 37 |
| 25. RESOLUTE A | 56# | -7 | 21 | -38* | 68# | 63# | 76# | 20 | 37* | -6 | 11 | 51# | 75# | 51# | -32* | 73# | -19 | -9 | 39* | -3 | 4 | 12 | -8 | -3 | X | 66 | 57 |
| 26. SVALBARD LUFTHAVN | -8 | 47% | -34* | 93# | -40* | -31 | -29 | 17 | 11 | 68# | 28 | -43% | -26 | -31 | 97# | -36* | 79# | 39* | 15 | 56# | 46% | 8 | 6 | 63# | -33* | X | 10 |
| 27. KAP TOBIN | 1 | 49% | -27 | 72# | -35* | -30 | -30 | 4 | -8 | 72# | -1 | -26 | -19 | -22 | 73# | -28 | 81# | 22 | -8 | 28 | 11 | -13 | -5 | 25 | -27 | 77# | X |

Key as in Table 1; X — denotes 1.0 or 0.0 in the case of correlation coefficients and geometrical distances, respectively.

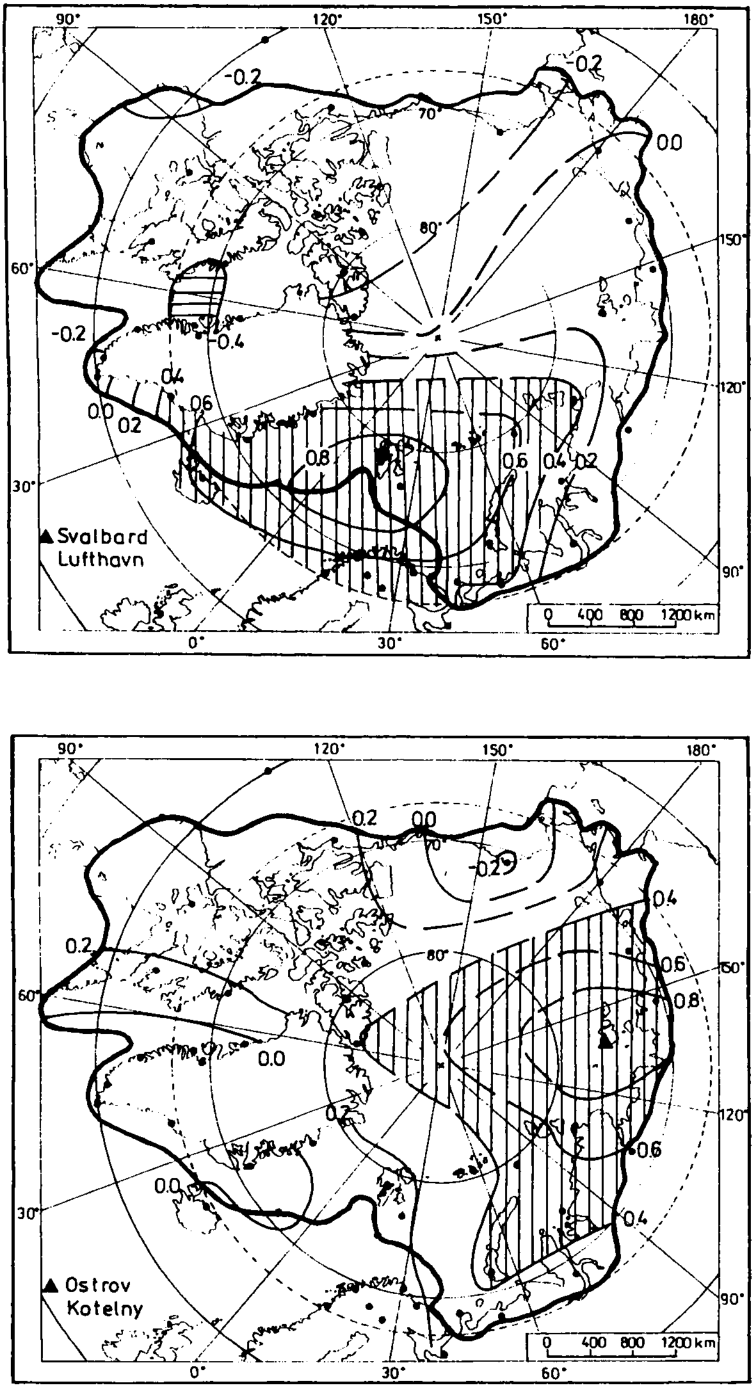

90°
120°
150°
180°
60°
30°
0°
30°
60°
90°
120°
150°
70°
80°
-0.2
0.0
-0.4
0.4
0.6
0.2
0.8
Svalbard Lufthavn
0 400 800 1200 km
0.2
0.0
-0.2
0.4
0.6
0.8
Ostrov Kotelny

Fig. 4.

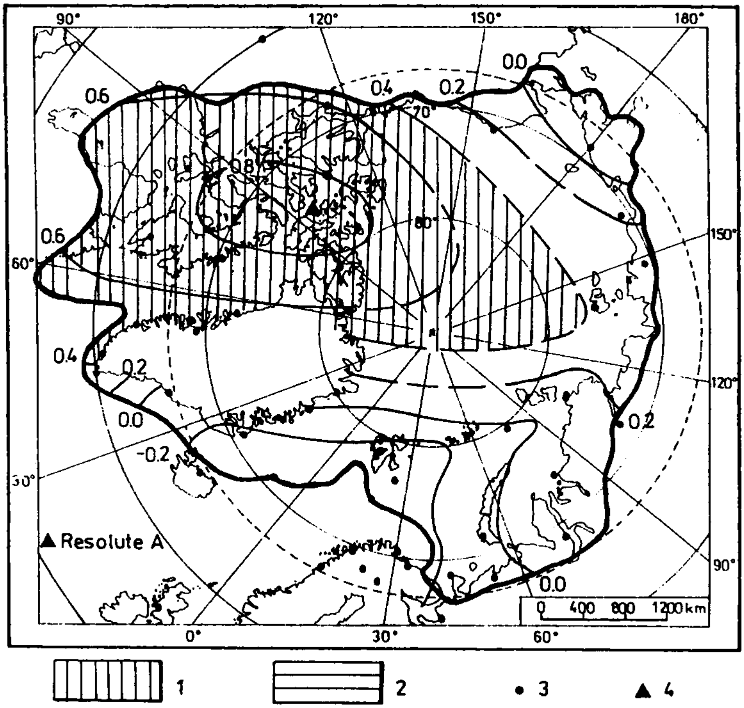


Fig. 4. Isocorrelates of mean annual *T* in the Arctic in relation to the Svalbard Lufthavn, Ostrov Kotelny and Resolute A stations, 1951–1990. 1 – positive correlations statistically significant at the level 0.05, 2 – negative correlations statistically significant at the level 0.05, 3 – meteorological stations, 4 – station, in relation to which the correlation coefficients of *T* were computed.

Magnitude and number of statistically significant *r* between the mean annual *T* in the analysed Arctic stations is lower, in comparison with similar computations made for winter *T* only (Table 1). Isocorrelates drafted in reference to the previously mentioned meteorological stations confirm this conclusion too (Fig. 4). The enclosed figures (Figs 2–4) are based on data from the all available stations, while the tables (Tables 1–3) present *r* for only 27 Arctic stations which supplied with full data for the period 1951–1990.

The radius of extent of statistically significant *r* of changes of *T* around the stations Svalbard Lufthavn, Ostrov Kotelny and Resolute A is equal to 2500–3000 km for annual values, 2000–2500 km for a winter and 1500–2000 km for a summer (Figs 2–4). Similar results were also obtained *e.g.* by Eserkepova *et al.* (1982), Smirnova and Subbotin (1983), Subbotin (1983), Aleksandrov and Subbotin (1985). Among the three analysed climatic regions, the highest correlation of *T* occurred in the Canadian region, probably due to the highest stability of atmospheric circulation, especially in the winter and spring (Serreze *et al.* 1988). The highest variation of the radius of the statistically significant *r* of *T* change between a summer and a winter was noted at the Ostrov Kotelny station. The results (Figs 2–4) confirm the known regularity, according to which the correlation of *T* between the two stations is not always a simple function of a distance between them. In the Arctic, such disturbances are most often caused by a variable atmospheric circulation which can seriously change the value of *T*.

## Atlantic region

*T* of most of this region — except its western and especially eastern parts — is significantly correlated with *T* at the Svalbard Lufthavn. The results obtained (Tables 1–3, Figs 2 and 4) generally confirm a presence of this climatic region, distinguished in the Atlas Arktiki (1985). However, affiliation of the Kara Sea and the neighbouring areas seems doubtful, because their thermic conditions are more similar to the ones in the Siberian region. Such situation is probably mainly due to presence of Novaya Zemlya which is certainly a very important climatic

Table 4

Matrix of correlation coefficients between mean values for spring (March-May, upper part of the table) and summer (June-August, lower part of the table) of air and sea temperatures, and selected climatic factors in 1951–1990 (hundreds of values of the correlation coefficient are given).

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. *T* Atlantic region | 1. | 35* | 18 | -26 | -30 | 64# | 56# | -18 | -8 | 56# | 13 | 28 | -9 | -73# | -57% |
| 2. *T* Siberian region | 15 | 1. | 57# | 24 | -6 | 70# | 71# | 15 | 46% | 37* | 25 | 28 | 4 | -32* | -8 |
| 3. *T* Pacific region | 34* | 0 | 1. | 19 | -2 | 52# | 48% | -9 | 33* | 20 | 18 | 13 | -10 | -8 | 4 |
| 4. *T* Canadian region | 18 | 28 | 9 | 1. | 61# | 50% | 48% | 18 | 31 | 5 | -11 | 0 | 16 | -3 | 0 |
| 5. *T* Baffin Bay region | 26 | 35* | 2 | 59# | 1. | 27 | 31 | 18 | -9 | -10 | -18 | -29 | 35* | 11 | 32 |
| 6. *T* Arctic1 | 75# | 55# | 37* | 67# | 67# | 1. | 93# | 2 | 24 | 53# | 9 | 22 | 8 | -60# | -43* |
| 7. *T* Arctic2## | 40* | 11 | 23 | 41* | 6 | 44% | 1. | 19 | 18 | 44% | 2 | 25 | 23 | -52% | -28 |
| 8. TNH (land) | 19 | 9 | -3 | 38* | 29 | 30 | 39* | 1. | 41% | -7 | 6 | 18 | 28 | 10 | 9 |
| 9. TNH (land+sea) | 39* | 12 | 28 | 36* | 26 | 45% | 9 | 55# | 1. | 2 | 31 | 21 | -33* | 10 | -19 |
| 10. Tw Barents Sea | 50% | 6 | 25 | 35* | 16 | 52# | 28 | 1 | 13 | 1. | -8 | 28 | -2 | -83# | -25 |
| 11. Zonal index | 8 | -32 | -16 | -8 | -25 | -14 | 2 | 5 | -6 | 21 | 1. | -2 | -23 | -1 | -23 |
| 12. Geom. index aa | 17 | 7 | 24 | -4 | 16 | 17 | 9 | 20 | 19 | 14 | -12 | 1. | 36* | -28 | -30 |
| 13. Geom. index Ap | 1 | 15 | -2 | -12 | 30 | 6 | -25 | 24 | -9 | -9 | -16 | 30 | 1. | 1 | 45* |
| 14. Ice cov. B. Sea | -65# | -21 | -3 | -28 | -27 | -59# | -34* | -8 | 4 | -65# | -11 | 2 | 2 | 1. | 44* |
| 15. Ice cov. G. Sea** | -36* | 24 | 4 | -6 | -23 | -18 | -16 | -21 | -10 | -16 | -6 | -28 | -2 | 44% | 1. |

1–5 – means of T for 5 Arctic regions computed by author; 6 – means of Arctic *T* computed from 27 stations; 7 – means of *T* for 65-85°N zone (after Alekseev and Svjaščennikov 1991); 8 – anomalies of the northern hemisphere *T* (data only from land) in relation to 1950-1979 reference period (after Jones 1994); 9 – as in 8 but for combine data from land and sea; 10 - means of water temperature in the layer 0–200 m in the section across the Barents Sea (source: Zubakin 1992, *personal commun.*); 11 – zonal circulation index; 12 – means of *aa* index of geomagnetic activity; 13 – means of *Ap* index of geomagnetic activity; 14 – mean ice coverage of the Barents Sea in mln km$^2$ (source: Zubakin 1992, *personal commun.*); 15 – mean ice coverage of the Greenland Sea in mln km$^2$ (source: Zubakin 1992, *personal commun.*) #,%,* denotes the correlation coefficients statistically significant at the levels of 0.1, 1 and 5%, respectively; ## - 1951-1986; ** – 1967–1990 (only for spring).

barrier, significantly isolating the Kara Sea from the cyclones that form near Iceland. Circulation is therefore significantly different than in the remaining part of Atlantic region.

Table 5

Matrix of correlation coefficients between mean values for autumn (September-November, upper part of the table) and winter (December–February, lower part of the table) of air and sea temperatures and selected climatic factors in 1951–1990 (hundreds of values of the correlation coefficient are given).

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. *T* Atlantic region | 1. | 36# | 1 | -23 | -29 | 76# | 71# | 8 | 6 | 21 | -1 | 5 | 8 | -57# | -33 |
| 2. *T* Siberian region | 47% | 1. | 22 | -9 | -14 | 57# | 62# | -1 | -7 | 3 | -13 | 19 | 6 | -14 | 14 |
| 3. *T* Pacific region | -37* | 5 | 1. | -5 | 9 | 25 | 24 | 2 | 5 | -28 | -6 | -6 | 16 | 9 | 4 |
| 4. *T* Canadian region | -57# | 7 | 14 | 1. | 69# | 33* | 23 | 29 | 22 | 9 | -40* | -3 | 12 | 3 | 37 |
| 5. *T* Baffin Bay region | -68# | -35* | 4 | 76# | 1. | 21 | -2 | -1 | -4 | -4 | -55# | 6 | 32* | 13 | 31 |
| 6. *T* Arctic1 | 57# | 72# | -8 | 28 | -1 | 1. | 87# | 18 | 12 | 17 | -33* | 9 | 21 | -45% | 2 |
| 7. *T* Arctic2## | 45% | 68# | 19 | 14 | -17 | 76# | 1. | 29 | 40* | 14 | -13 | 2 | 10 | -44% | 8 |
| 8. TNH (land) | 4 | 0 | -5 | 17 | 4 | 16 | 37* | 1. | 47% | 0 | 24 | 13 | 33* | -8 | 2 |
| 9. TNH (land+sea) | -16 | 7 | 24 | 26 | 0 | 5 | 46% | 63# | 1. | 4 | 20 | 15 | -14 | 13 | -10 |
| 10. Tw Barents Sea | 58# | 30 | -40% | -43% | -39* | 21 | 27 | 12 | 0 | 1. | -3 | 19 | -14 | -25 | -10 |
| 11. Zonal index | 11 | -7 | 7 | -40* | -48% | -31 | 13 | 19 | 43% | 12 | 1. | -14 | -25 | 8 | -21 |
| 12. Geom. index aa | 14 | 15 | 17 | -15 | -36* | -3 | 11 | 25 | 30 | 1 | 43% | 1. | 32* | 4 | -25 |
| 13. Geom. index Ap | 8 | -27 | -34* | -3 | 18 | -3 | -12 | 28 | -25 | 11 | -13 | 7 | 1. | -1 | 43* |
| 14. Ice cov. B. Sea | -77# | -39 | 52# | 36* | 42% | -47% | -28 | -1 | 27 | -63# | 8 | 1 | -23 | 1. | 53% |
| 15. Ice cov. G. Sea** | -53% | 2 | 43* | 21 | 35 | -17 | -27 | -21 | -26 | -12 | -33 | -23 | 33 | 36 | 1. |

Key as in Table 4. ## – 1951–1986; ** – 1967–1990.

*T* at Svalbard Lufthavn and in the Canadian region are negatively correlated. It is clear especially in winter (Fig. 2) when the whole area of the Canadian Archipelago is statistically significantly correlated with *T* at this station. In the case of the annual values, only a small part of the western coast of Greenland and the Baffin Bay have significant negative *r* with the Svalbard Lufthavn station (Fig. 4). Pacific region has a weak negative and Siberian region (without the eastern part in winter) — a small positive correlation.

To estimate more reliably the average correlation of *T* between the analysed climatic regions, their mean areal values were used. Results of *r* between the mean seasonal and annual *T* of each region are presented (Tables 4–6). Mean annual *T* of the Atlantic region is significantly positively correlated with *T* of the Siberian region (r = 0.42). The other regions indicate negative correlations (Table 6) and their magnitude is getting greater, as we go further to the east. In fact, the mean annual *T* of the Atlantic region has the strongest significant connections with *T* of the Baffin Bay region (r = -0.35). Clearly, the strongest correlation concerns the winter *T* (Table 5). The Atlantic region is statistically significantly correlated during this season with the all climatic regions. The winter determines also (see Tables 5 and 6) a character and magnitude of ties of the annual *T*. Beyond doubt, this high correlation of the winter *T* is caused by

Table 6

Matrix of correlation coefficients between the mean annual values of air and sea temperatures and selected climatic factors in 1951–1990 (hundreds of values of the correlation coefficient are given).

| Variable | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. *T* Atlantic region | 1. | 42% | -16 | -23 | -35* | 74# | 61# | -6 | -11 | 53# | 10 | 23 | 5 | -74# | -71# |
| 2. *T* Siberian region | | 1. | 12 | 31 | -16 | 70# | 73# | 10 | 20 | 34* | 15 | 29 | 4 | -39* | 0 |
| 3. *T* Pacific region | | | 1. | 5 | 1 | 6 | 17 | -2 | 40* | -12 | 21 | 16 | -11 | 31 | 16 |
| 4. *T* Canadian region | | | | 1. | 63# | 43% | 41* | 45% | 39* | -15 | -28 | -11 | 18 | 11 | 24 |
| 5. *T* Baffin Bay region | | | | | 1. | 15 | -1 | 22 | -1 | -30 | -46% | -32* | 42% | 26 | 36 |
| 6. *T* Arctic1 | | | | | | 1. | 86# | 18 | 18 | 40* | -5 | 16 | 18 | -56# | -39 |
| 7. *T* Arctic2## | | | | | | | 1. | 38* | 39* | 32 | 14 | 24 | 12 | -44% | -35 |
| 8. TNH (land) | | | | | | | | 1. | 37* | -5 | 0 | 22 | 34* | 5 | -5 |
| 9. TNH (land+sea) | | | | | | | | | 1. | 1 | 39* | 23 | -28 | 25 | -19 |
| 10. Tw Barents Sea | | | | | | | | | | 1. | 23 | 26 | -6 | -67# | -23 |
| 11. Zonal index | | | | | | | | | | | 1. | 27 | -33* | -4 | -25 |
| 12. Geom. index aa | | | | | | | | | | | | 1. | 17 | -9 | -38 |
| 13. Geom. index Ap | | | | | | | | | | | | | 1. | -4 | 45* |
| 14. Ice cov. B. Sea | | | | | | | | | | | | | | 1. | 56% |
| 15. Ice cov. G. Sea** | | | | | | | | | | | | | | | 1. |

Key as in Table 4. ## – 1951–1986; ** – 1967–1990.

the atmospheric circulation. Warm air masses entering the Atlantic and Siberian regions from the North Atlantic result in common flowing down of cold air masses from the central Arctic towards the North America.

In summer, the correlation of *T* is the weakest (Table 4), but everywhere it is positive. The Atlantic region is statistically significantly correlated with the Pacific region ($r = 0.34$).

## Siberian region

The characteristic feature of this region, which is represented by the Ostrov Kotelny station, is a lack of correlation of its *T* with *T* of the neighbouring regions, *i.e.* the Atlantic and Pacific regions (Figs 2 and 4). Coefficients of correlation are low and mainly oscillate between 0.0 and -0.2. A slightly better correlation exists between a seasonal *T* of the analysed and the Canadian region. On the contrary, the mean annual *T* at the Ostrov Kotelny is statistically significantly correlated at the level of 5% with *T* of the northern and central parts of the Canadian Arctic. A lack of stronger correlation between the mean winter *T* of these regions could be explained by cyclones which start in the North Atlantic, the Barents Sea, northern part of the Pacific and the Baffin Bay, and meet near the North Pole (see Serreze and Barry, 1988). Cyclones bringing warm and humid air masses from the lower latitudes, can significantly disturb the field of *T* in this region, in its surroundings and in the overpassed areas when reaching the North Pole. As a result (Fig. 2), the region near the Ostrov Kotelny station is more strongly correlated with *T* in the southern than in the northern part of the Canadian region.

The mean annual $T$ of the Siberian region is positively correlated with $T$ of the Atlantic, Pacific and Canadian regions, but significant connections have been noticed only for the Atlantic region. Close correspondence of $T$ changes in the Siberian and Atlantic regions is present also for seasonal values, except summer. In summer and winter, there is also a significant interrelation between $T$ of the Siberian and Baffin Bay regions. Summer has positive ($r$ = 0.35) and winter negative ($r$ = -0.35) correlation. The spring $T$ of the Siberian region is strongly positively correlated (except for the Atlantic region) also with $T$ of the Pacific region ($r$ = 0.57). This analysis indicates that coefficients of correlation, using a mean regional $T$, are very different from these in figures 2 and 4. It means that $T$ at the Ostrov Kotelny station rather badly represents the thermic conditions in the whole Siberian region.

## Pacific region

$T$ in this region is not statistically significantly correlated with any of the three analysed $T$ series, representing the greatest climatic regions in the Arctic (Figs 2–4). It is well seen, both in the case of the seasonal and the annual $T$. Therefore, inter-annual changes of $T$ in the Pacific region seem possible to be the most peculiar among the analysed regions. This conclusion confirms also the computations of $r$ between the mean seasonal and annual $T$ of the Pacific region, and $T$ of other regions, which are the lowest (see Tables 4–6). It is probably due to a sole influence of this region by the Pacific Ocean. Its annual and autumn $T$ do not indicate any statistically significant correlation. In winter, the Pacific region is significantly negatively correlated with the Atlantic region only. Such opposite behaviour of $T$ in these two regions cause also a very clear opposite trend of the magnitude of the area covered by a sea ice (Wendler and Nagashima 1987). Moreover, significant connections have been noted between the spring and summer $T$ of this region, and the respective $T$ of the Siberian ($r$ = 0.57) and Atlantic ($r$ = 0.34) regions.

## Canadian region

$T$ of this region, which is represented by the Resolute A station, is negatively correlated with $T$ of a greater part of the Atlantic region and southern part of the Pacific region. Coefficients of correlation are not, however, statistically significant, except for the area of Spitsbergen in the case of the winter $T$. On the contrary, the Canadian region is particularly strongly positively correlated with the Baffin Bay region. Similar is the case of the Pacific region, but the strength of connection is much lower. Nevertheless, the mean annual $T$, especially in its coastal part, has the statistically significant $r$ at the level of 5% (Figs 2 and 4).

Analysis of $r$, computed between the mean seasonal and the annual $T$ of the analysed regions (Tables 4–6), almost completely confirms the previous conclusions (*cf.* Figs 3–4). It means that $T$ at the Resolute A station is a good representative of $T$ for the whole Canadian region.

### Baffin Bay region

Seasonal and annual $T$ of the Baffin Bay region are markedly positively correlated with $T$ at the Resolute A station and (only central part of Baffin Bay region) negatively correlated with the winter and annual $T$ at the Svalbard Lufthavn (Tables 4–6, Figs 2–4). Seasonal (spring and autumn included) and annual $T$ of the Baffin Bay region are strongly positively correlated with $T$ of the Canadian region. The annual $T$ of this region indicates also a significant negative correlation with $T$ of the Atlantic region ($r = -0.35$). In winter, the Baffin Bay region has no significant connections with $T$ of the Pacific region only. On the other hand, a strong negative correlation was computed for the Atlantic ($r = -0.68$) and Siberian ($r = -0.35$) regions (Table 5). The summer $T$ of the Baffin Bay region is also highly correlated (except for the earlier mentioned Canadian region) with the Siberian region ($r = 0.35$).

## Regions of correlated changes and coherent air temperatures in the Arctic

This analysis clearly indicates that $T$ in most of the Arctic is statistically significantly correlated. There are also some regularities in spatial distribution of changes of this element. Subsequently, the regions of consistent occurrence of the $T$ anomalies were delimited with respect to signs and magnitudes, as well as of the regions with the most coherent $T$. The Wrocław dendrite method was used to solve this problem (Parysek and Wojtasiewicz 1979). This method was applied for climatic investigations *e.g.* by Woś (1977), Kożuchowski (1985, 1988), Kożuchowski and Marciniak (1986), who presented a detailed description.

As a measure of taxonomical distance of a pair of stations *ab* in the present work, the following definition was adopted:

— magnitude $1\text{-}r_{ab}$ (after Kożuchowski 1985), where $r_{ab}$ is a coefficient of correlation of the mean annual $T$ at stations $a$ and $b$. The matrix of $r_{ab}$ was converted into a matrix of the values $1\text{-}r_{ab}$, which were used to construct the dendrite.

— Euclides' geometrical distance computed according to the formula:

$$d_{ab} = \sqrt{\sum_{i=1}^{n} (T_{ia} - T_{ib})^2}\ ,$$

where $d_{ab}$ is a geometrical distance for air temperature series at stations $a$ and $b$, $T_{ia}$ is the mean $T$ for station $a$ and year $i$, $T_{ib}$ is the mean $T$ for station $b$ and

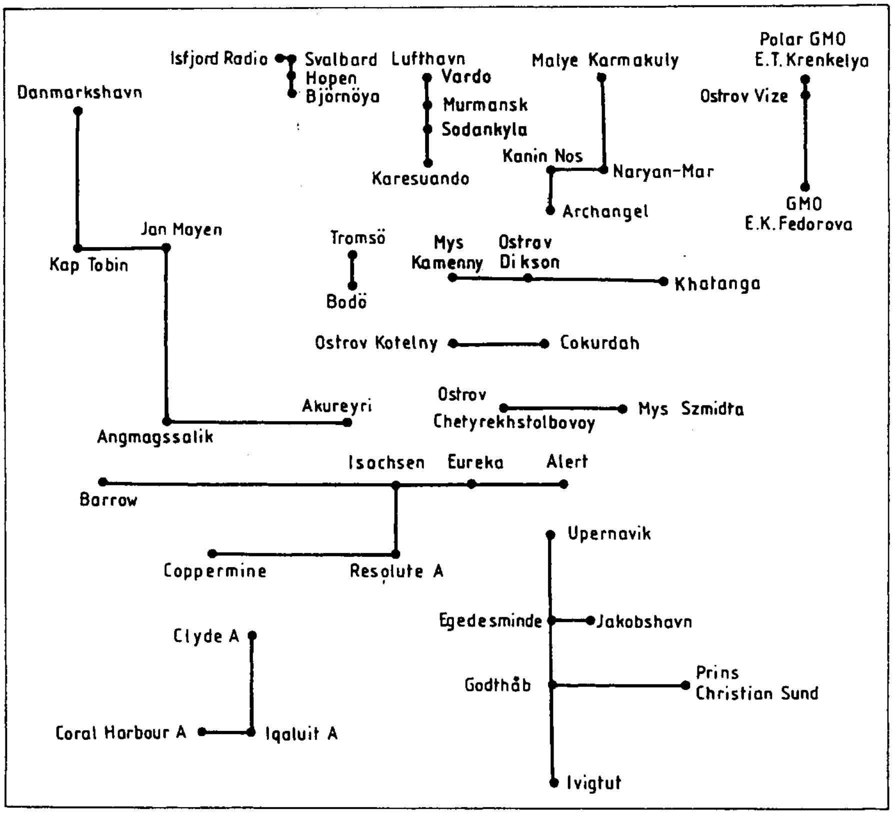


Fig. 5. Arrangement of meteorological stations according to the correlation coefficients of mean annual $T$ (1951–1990) by the dendrite method.

year $i$, $n$ is a number of years. The "raw" and standardized values were used to computations. Geometrical distances, similarly as $r$, were calculated for 741 pairs of meteorological stations and the mean annual $T$ for the period 1951–1990 (Table 3 presents data for 27 stations, *i.e.* for 351 pairs of stations).

The Wrocław dendrite allows to delimit homological groups of stations, with assumption that their location results only from the least taxonomical distances. Using the matrix of values $1\text{-}r_{ab}$, the dendrite consisting of 12 graphs was obtained: 10 of them include arctic and 2 subarctic stations (Fig. 5). Each group delimits the region with the correlated mean annual anomalies of $T$. Schematic distribution of these regions in the Arctic is presented (Fig. 6), with two additional regions *i.e.* Greenland and Interior Arctic after Atlas Arktiki (1985), for which however no data are available. Number of the delimited regions, their shape and magnitude are relevant and strongly dependent on density of meteorological stations and assumptions of the dendrite method. Comparison of this regionalisation with the one in Atlas Arktiki (1985), reveals some similarities.

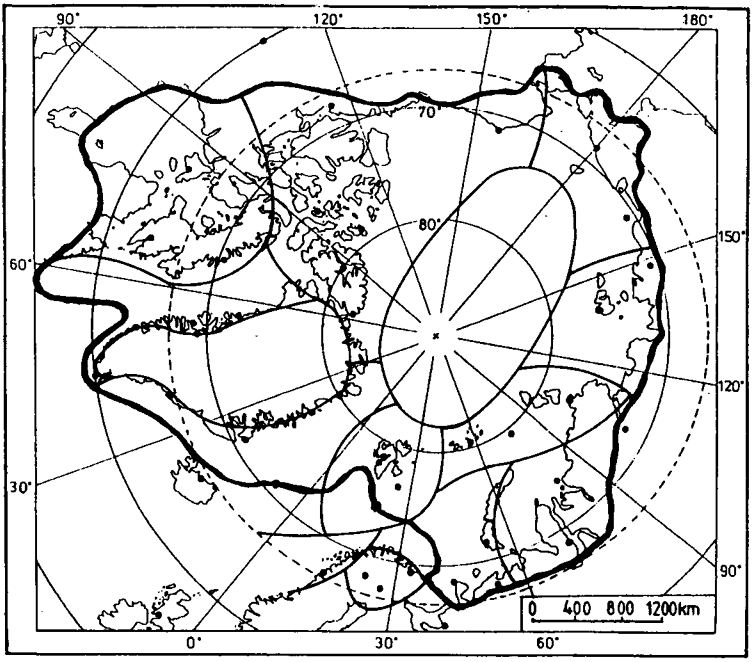


Fig. 6. Regions of correlated anomalies of annual *T* in the Arctic, in 1951–1990. The lines are the borders of the regions.

High correspondence exists, especially in the case of the Canadian Arctic. In the rest of the Arctic, a degree of similarity is much smaller.

Matrix of the least geometrical distances calculated from non-standardized values (Table 3) and the dendrite method were used to delimite 10 groups of stations, with the most similar (coherent) mean annual *T* during the study period. Schematic distribution of these regions (8 of them are located in the Arctic and 2 in the Subarctic) are presented (Fig. 7). Comparison of regionalisations (see Figs 6–7) indicates significant differences: groups of stations with the similar mean annual *T* do not have to be simultaneously represented by consistent anomalies of *T* (with respect to their sign and magnitude) and *vice versa.* Thus, in the analysed division most regions consist of two isolated areas. For example, the southeastern part of the Canadian Arctic has similar annual *T* as the area of the southwestern Kara Sea and its surroundings in the Atlantic region, and the Pacific region as the northeastern part of Greenland (Fig. 7).

Regionalisation based on the dendrite method, but using the least geometrical distances computed from the standardized values of *T*, gives the same results as the regionalisation based on values $1\text{-}r_{ab}$. Such agreement of results was obtained when calculations were conducted for the stations, which provided data for the study period. If dealing with stations with different length of data series

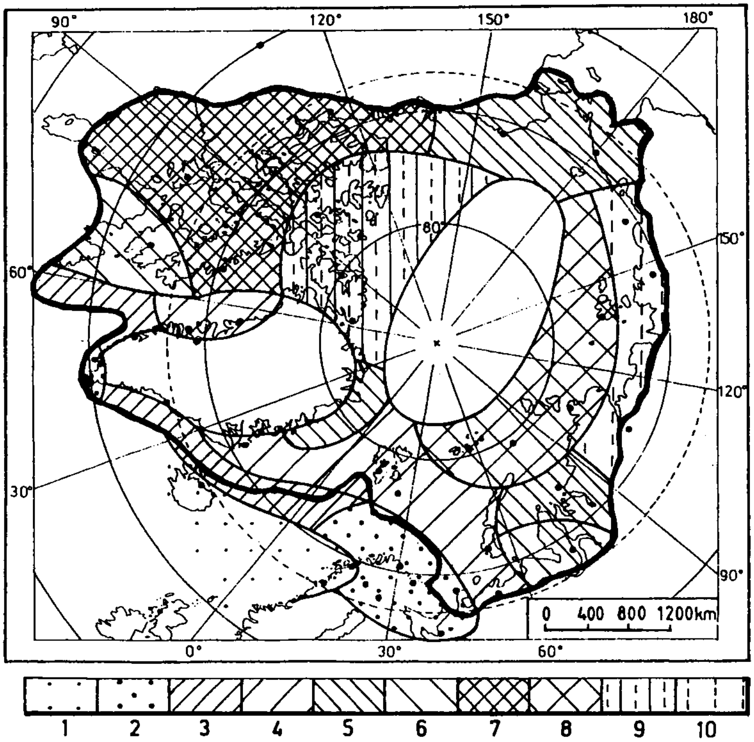


Fig. 7. Regions of coherent annual *T* in the Arctic according to non-standardized values in 1951–1990. Isolated areas with the same hachure have a similar (coherent) annual *T*.

(as in our case), it seems better to use the method of Kożuchowski (1985). This method allows to comprise all or almost all the stations in the analysis if differences between *r* for a short period and the full studied period are insignificant. This advantage is especially important for the Arctic and other areas with sparse network of meteorological stations. Therefore, this method was used in the present study and allowed to obtain a more reliable regionalisation.

## Relations of temperatures and selected climatic factors in the Arctic and the northern hemisphere

Global climate variations are asynchronic in different geographic regions. It is especially evident in short time scales, but can be observed also in secular changes. A good example of these relations gives Jones and Kelly (1983), who computed correlations between *T* at each grid point ($5°\phi \times 10°\lambda$) and the mean northern hemisphere *T* ($T_{NH}$). Coefficients of correlation indicate large spatial differentiation and they are not high, rarely exceeding 0.5; they oscillate between

0.1 and 0.3 for Europe, and are slightly higher for the North America. Kożuchowski and Marciniak (1989) obtained also similar results, comparing changes of the mean annual $T$ at Warsaw and in the northern hemisphere. The computed coefficients of correlation are equal to 0.298 for the raw data and 0.571 for the data smoothed by a binomial 5-year filter. Moreover, it is worth-noting that correlations determined in this way are inconstant in time.

Nevertheless, majority of $T$ series generally indicates similar changes. The average $T_{NH}$ is rising in the present century, except for the period 1940–1965 (IPCC 1992).

This part of the paper examines relations between the average Arctic $T$ ($T_A$) and $T_{NH}$, as well as determines influence of selected climatic factors on $T_A$. Computations were based on the areal mean $T$ in *i)* the all climatic regions, *ii)* the Arctic, *iii)* the northern hemisphere, and *iv)* a few series of data of climatic factors (see Tables 4–6 for description).

The $r$ between the above mentioned series of data were computed for seasonal and annual values for the period 1951–1990 (Tables 4–6). They prove that relations between both the seasonal and annual $T_A$ and $T_{NH}$ are not strong. $T_A$ computed from 27 stations is statistically insignificantly positively correlated (for annual values $r = 0.18$). Among 5 series of the mean annual regional $T$, the highest correspondence with $T_{NH}$ (both series) has $T$ of the Canadian region. $T$ of the Pacific region has also a high correlation, but only for $T_{NH}$ computed from the land stations (series 8 in Table 6). Such relations are typical for almost all the seasons (Tables 4–5). The examined series of $T$ is strongly correlated in spring, and still stronger in summer. For the last season, the statistically significant correlations were computed between $T_{NH}$ and $T$ of the Atlantic and Canadian regions (Table 4).

A more significant relation, although also not very high, exists between $T$ of 65–85°N ($T_{A2}$) band and $T_{NH}$. For the annual values, $r$ is equal to 0.38 (for $T_{NH}$ land only) and 0.39 (for $T_{NH}$ land+sea). An increase of strength of the relation between these two series is likely connected with the fact that for computations of $T_{A2}$, data from continental stations in the Subarctic were applied. As follows from Chapman and Walsh (1993), these areas indicate the largest warming in the recent decades, thus their inclusion rises the correlation.

The values of $r$ were computed for certain climatic factors (sea water temperature, sea ice area, atmospheric circulation and geomagnetic activity) and $T_A$ (Tables 4–6). Statistically strong significant correlation was found between $T_A$ and water temperature in the Barents Sea and its covering by sea ice. Higher $r$ for the annual values (Table 6) have been computed for $T_{A1}$ (0.40 and -0.56 for temperature and ice coverage, respectively) than for $T_{A2}$ (0.32 and -0.44). Changing sea ice area in the Greenland Sea has poorer correlation with $T_A$ than in the Barents Sea (Tables 4–6). Influence of atmospheric cicrulation on $T_A$ was examined in mean latitudes, using values of a zonal index (difference of mean sea level air pressure between 35° and 65°N). Atmospheric circulation plays a very important role in shaping the climate of the Arctic, especially during the cool half-year when the incoming solar radiation is very small or completely absent during a polar night. Therefore, in this time the relations between atmospheric circulation and $T_A$ should be well pronounced and this is really the case (Tables 4–6). Increasing frequency of a zonal circulation leads to a statistically significant drop of $T_{AI}$ ($r$ equal to -0.33 and -0.31 in autumn and winter, respectively). This is connected with a smaller heat influx to the Arctic from the lower latitudes. Presented results are in good agreement with results of the other authors (*e.g.* Vinogradov *et al.* 1991).

Indices of geomagnetic activity indicate a small positive correlation with $T_A$ (Table 6). A statistically significant $r$ was computed with $T$ of the Baffin Bay region only. For the annual values, $r$ was equal to -0.32 (for *aa* index) and 0.42 (for *Ap* index). These results are in agreement with investigations by Bucha (see *e.g.* Bucha 1979), who found the strongest relation between geomagnetic activity and $T$ in Canada and to the north of Siberia. *Ap* index proves significant correlation with $T_{NH}$ (0.34 for a land) and with a zonal index (-0.33). Therefore, a geomagnetic activity influences weather and climate in the Arctic through the atmospheric circulation. This view is widely supported in many papers by Bucha (*e.g.* 1983, 1988, 1991).

## References

ALEKSANDROV E.I. and SUBBOTIN W.W. 1985. Dinamika termičeskogo režima severnoj polarnoj oblasti v poslednije desatiletija. — *In:* Materialy u Vsesojužnogo soveščanija po primeneniju statističeskich metodov v meteorologii. Kazan, 37 pp.

ALEKSEEV G.V. and SVJAŠČENNIKOV P.N. 1991. Estestvennaja izmenčivost' charakteristik klimata severnoj polarnoj oblasti i severnogo polušarija. — Gidrometeoizdat, Leningrad, 159 pp.

ATLAS ARKTIKI 1985. Glavnoje Upravlenije Geodezii i Kartografii pri Sovete Ministrov SSSR, Moskva, 204 pp.

BARANOWSKI S. 1977. Subpolarne lodowce Spitsbergenu na tle klimatu tego regionu. — Acta Univ. Wratisl., 393: 157 pp.

BUCHA V. 1979. Connections between geophysical and meteorological processes. — Studia Geophys. et Geod., 23: 55–67.

BUCHA V. 1983. Direct relations between solar activity and atmospheric circulation, its effect on changes of weather and climate. — Studia Geophys. et Geod., 27: 19–45.

BUCHA V. 1988. Influence of solar activity on atmospheric circulation types. — Ann. Geophys., 6: 513–524.

BUCHA V. 1991. Solar and geomagnetic variability of weather and climate. — J. Atm., Terrestr. Physics, 53: 1161–1172.

ESERKEPOVA I.B., LUGINA K.M., SPERANSKAJA I.A., KAGAN P.D., SMIRNOVA I.P. and SUBBOTIN V.V. 1982. Ispolzovanije novych metodov v monitoringe termičeskogo režima Arktiki. — *In:* Issledovanija Arktiki, Antarktiki i Mirovogo okeana. Gidrometeoizdat, Leningrad: 56–64.

GORCZYŃSKI W. 1915. Badania współzależności przebiegów temperatury metodą korelacyjną. — Spraw. Tow. Nauk. Warsz., Wydz. III, 8 (8).

GORCZYŃSKI W. 1917. Linie jednakowej korelacji ciśnienia i temperatury powietrza w stosunku do Warszawy. — Spraw. Tow. Nauk. Warsz., Wydz. III, 10 (2).

GREGORY S. 1976. Metody statystyki w geografii. — PWN, Warszawa, 300 pp.

IPCC, Supplement 1992. Climate Change 1992, The Supplement Report to the IPCC Scientific Assessment. — *In:* J.T. Houghton, B.A. Callander, S.K. Varney (eds), Cambridge Univ. Press, 200 pp.

JONES P.D. 1994. Hemispheric surface air temperature variations: a reanalysis and an update to 1993. — J. Climate, 7: 1794–1802.

JONES P.D. and KELLY P. M. 1983. The spatial and temporal characteristics of Northern Hemisphere surface air temperature variations. — J. Climatol., 3: 243–252.

KOŻUCHOWSKI K. 1985. Zmienność opadów atmosferycznych w Polsce w stuleciu 1881-1980. — Acta Geogr. Lodz., 48: 158 pp.

KOŻUCHOWSKI K. 1988. Przestrzenna struktura zmienności opadów w Polsce. — Bad. Fizjogr. n. Polską Zach., A, 39: 51-65.

KOŻUCHOWSKI K. and MARCINIAK K. 1986. Fluktuacje i tendencje zmian temperatury powietrza w Europie w latach 1881-1970. — AUNC, Geografia, 19: 69-88.

KOŻUCHOWSKI K. and MARCINIAK K. 1989. Temperatura powietrza w Warszawie na tle średniej temperatury na półkuli północnej w okresie 1841-1985. — Przegl. Geogr., 3: 295-303.

MARCINIAK K., KOŻUCHOWSKI K. and MISIEWICZ-ŚNIESZKO Ł. 1986. Zagadnienie zróżnicowania przestrzennego anomalii termicznych w Europie. — Acta Univ. Lodz., Folia Geogr., 7: 3–24.

PARYSEK J. and WOJTASIEWICZ L. 1979. Metody analizy regionalnej i metody planowania regionalnego. — Kom. Przestrz. Zagosp. PAN, Studia 59, 195 pp.

PRZYBYLAK R. 1992. Stosunki termiczno-wilgotnościowe na tle warunków cyrkulacyjnych w Hornsundzie (Spitsbergen) w okresie 1978-1983. — Dokument. Geogr., 2, 105 pp.

PRZYBYLAK R. 1996. Zmienność temperatury powietrza i opadów atmosferycznych w okresie obserwacji instrumentalnych w Arktyce. — UMK, Toruń, 280 pp.

SERREZE M.C. and BARRY R.G. 1988. Synoptic activity in the Arctic Basin, 1979–85. — J. Climate, 1: 1276–1295.

SERREZE M. C., BOX R. G., BARRY R. G. and WALSH J. E. 1993. Characteristics of Arctic synoptic activity, 1952–1989. — Meteorol. and Atmosph. Physics, 51: 147–164.

SMIRNOVA I.P. and SUBBOTIN V.V. 1983. Prostranstvenno-vremiennaja struktura termičeskich polej Arktiki. — *In:* Obektivnaja otsenka meteorologičeskich informacii pri obespečenii poletov vozdušnych sudov. OŁAGA, Leningrad: 106–117.

SUBBOTIN V.V. 1983. Ispol'zovanije regresionnogo analiza dla polučenija nepreryvnych rjadov meteorologičeskich elementov po nabljudenijam drejfujuščich stancij. — Trudy AANII, 381: 111-121.

VINOGRADOV N.D., DMITREV A.A., BOLOTINSKA M.S., BELJAZO B.A. and SLEPCOV-SEVLEVIČ B.A. 1991. Vlijanije izmenenija cirkuljacii atmosfery na klimat. — *In:* B.A. Krutskich (ed.), Klimatičeskij režim Arktiki na rubeže XX i XXI vv. Gidrometeoizdat, Sankt-Petersburg: 62–94.

WENDLER G. and NAGASHIMA Y. 1987. Inter-relations between the Arctic sea ice and the general circulation of the atmosphere. — J. Glaciol., 33): 173–176.

WOŚ A. 1977. Zarys struktury sezonowej klimatu Niziny Wielkopolskiej i Pojezierza Pomorskiego. — Geogr. UAM, 15: 88 pp.

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## Streszczenie

W artykule przedstawiono związki przestrzenne temperatury powietrza (*T*) w Arktyce w okresie 1951–1990. Południową granicę Arktyki, jak również podział Arktyki na regiony klimatyczne przyjęto wg Atlasu Arktiki (1985). Do analizy wzięto średnie sezonowe i roczne *T* z 35 stacji arktycznych i 10 subarktycznych (fig. 1). Większość danych uzyskano bezpośrednio z instytutów meteorologicznych poszczególnych państw arktycznych (Danii, Kanady i Norwegii) oraz innych instytucji (Instytutu Naukowo-Badawczego Arktyki i Antarktyki w Sankt-Petersburgu i Narodowego Centrum Danych Klimatycznych w Asheville). Tylko dla niewielu stacji (głównie subarktycznych) dane wzięto z World Weather Records i Monthly Climatic Data for the World. Kontrola jakości analizowanych serii *T* została przeprowadzona przez Przybylaka (1996).

Do oceny związków przestrzennych zmian *T* w Arktyce wykorzystano, najpowszechniej stosowaną w tym celu metodę, tj. analizę korelacyjną. Obliczono współczynniki korelacji liniowej (*r*) dla każdej pary stacji, a ich wyniki — dla 27 stacji posiadających komplet danych z okresu 1951–1990 — zestawiono w postaci macierzy (tab. 1–3). Istotność *r* na poziomach 0,1, 1 i 5% oceniono korzystając z testu *t* Studenta (Gregory 1976).

*T* w Arktyce jest najsilniej przestrzennie skorelowana w zimie i na wiosnę, a najsłabiej latem. Wymowną ilustacją potwierdzającą te prawidłowości są rozkłady *T* w Svalbard Lufthavn i Ostrov Kotelnyj (fig. 2) oraz Resolute A (fig. 3). Powyższe 3 stacje, reprezentujące największe regiony klimatyczne w Arktyce (fig. 1) stanowią tu tzw. ośrodki (bieguny) odniesienia do których nawiązują izolinie. Promień zasięgu skorelowanych w sposób statystycznie istotny zmian *T* wokół tych stacji dochodzi maksymalnie do ok. 2500–3000 km dla wartości rocznych, 2000–2500 km dla zimy i 1500–2000 km dla lata (fig. 2–4).

Korzystając z wrocławskiej metody dendrytu wydzielono na obszarze Arktyki (poza regionem grenlandzkim i M. Arktycznego, dla których jest brak danych długookresowych) 10 regionów występowania zgodnych pod względem znaku i wielkości anomalii *T* (fig. 5–6) i 8 regionów o największym podobieństwie *T* (fig. 7).

Przedstawiono wyniki badań dotyczących związków *T* Arktyki i jej poszczególnych regionów klimatycznych z *T* półkuli północnej i wybranymi czynnikami klimatycznymi. Obliczenia *r* między poszczególnymi seriami danych przeprowadzono dla wartości sezonowych i rocznych z okresu 1951–1990 (tab. 4–6). Ich przegląd dowodzi, że związek zarówno sezonowych, jak i rocznych *T* Arktyki i półkuli północnej jest niezbyt silny. Ścisłą statystycznie istotną zależność stwierdzono między *T* Arktyki a temperaturą wody w Morzu Barentsa i stopniem jego zlodzenia. Ujemną istotną korelację obliczono między *T* Arktyki i indeksem strefowym, a słabą pozytywną korelację ze wskaźnikami aktywności geomagnetycznej.