South Dakota Diversity of Temperature: Pictures from Statistical Analysis

Shmagin, B. A. and D. P. Todey

Introduction.

Human activities and sustainability of ecological systems depend at first on the dynamics of climate events: daily, seasonal, and annual sequences of weather. The most used and representative characteristic of climate dynamics is air temperature. There is a huge literature of temperature regime analysis and the many ways to describe it [Ghil et. al., 2002]. The usual way to present a regional temperature is downscaling from global circulation models [Wu and North, 2003; Spak et. al., 2007]. Very few studies deal with real (empirical) temperature distribution for regions in space and time [Brunet, et. al., 2007]. Our goal in this article is the visual presentation of the temperature regime spatial diversity as a series of scientific pictures based on empirical data for the state of South Dakota, augmented by a few nearby stations in neighboring states.

The general approach of the research presented here is similar to other works of system analysis of climate which seek "… to reduce the numerous space-time degrees of freedom of the climate system to a minimum number of climatic modes that can explain a maximal part of its variability." [from Dima and Lohmann, 2004]. The mathematical models are developed for air flow in the atmosphere, and also coupling air flows with ocean flows [Lorenz, 1970]. But those are weather systems with timesteps of hours and days [Toth, 1995], whereas we are dealing with climate systems using monthly values of temperatures that depend more upon weather tracks than on individual weather events.

Methodology

In the case of regional research for an area such as SD, we initially have only a general description of the landscape's cyber model [Krcho, 1978; Krcho, 2003]. The knowledge about behavior of surface air temperature as a part of climate for SD is derived from the statistical structure describing dimensions and variability of analyzed processes. The primary statistical method used to obtain these dimensions from empirical data is factor analysis. Although our analysis is similar to the factor analysis of monthly air temperature for Spain by Brunet and colleagues (2007), the presented methodology is developed as a sequence of steps with statistical methods to describe at first, spatial diversity of SD surface air temperature and then, temporal behavior of the most variable time series.

Methodology for research included the following steps:

- System approach to the territory
- Task formulation for statistical analysis
- Performing the statistical analysis for individual tasks
- Interpretation of results for every task
- Discussion of results for South Dakota.

Average monthly surface air temperatures were regarded as characteristic of stages for the climate system of SD. A system model of the landscape [Krcho, 1978; Krcho, 2003] was employed for research task formulation. The system approach regards the region studied as a cyber system with initial degrees of freedom equal to the number of observation stations. Factor analysis is then used to obtain the model of structure and dimensions of SD from the initial empirical data.

This set of research tasks was first presented as an approach to analyze regional stream runoff [Shmagin, 1997] and then in a more general form for multilevel landscape water balance [Shmagin and Kanivetsky, 2006]. Table 1 presents seven directions of research and use of statistical analysis as groups of research tasks. Three of the seven were chosen for this research:

1. Identification and mapping of patterns of multi-year annual air temperature variability for a set of stations.

2. Description of annual variability (dimension for intra-annual process, the most variable months and links with annual values) for air temperature from meteorological stations chosen as typical for territory by results from Task #1.

4. Description and mapping of regional features of seasonal average values for air temperature.

We analyzed the regional diversity of monthly temperature based on long-term data obtained from the High Plains Regional Climate Center for SD. Maximum visualization was obtained with use of the sequence of 2- and 3-dimensional scatter-plot pictures depicting quantitative results. Statistical analysis was completed and scatter plots were obtained with use of software STATISTICA [StatSoft, 2004].

Task #1. Identification and mapping of patterns of multi-year annual air temperature variability for a set of stations.

Initial matrix: X_{t*p}, where are: rows: *t* – years, columns: *p*- time series of annual air temperature. Matrixes of results: $\{A_{p*k}\}$ – factor loadings, as dimensions of process (k) and grouping by types of regime (p => k); $\{F_{k*t}\}$ – factor scores, as components for types of regime.

Task #2. Description of annual variability (dimension for intra-annual process, the most variable months and links with annual values) for air temperature from meteorological stations.

Initial matrix: X_{t*p}, where rows: *t* – *y*ears; columns: *p* - time series of monthly and annual air temperature. Matrixes of results: $\{A_{p*k}\}$ – factor loadings, as dimensions of process and number of seasons (k), grouping months (p) by seasonal regimes; $\{F_{k*t}\}$ – factor scores, as components for seasonal regime. The station's time series for that group of tasks chosen for territory by results from Task #1. In the data every one obtained from groups of the existing station regime with highest factor loadings was regarded as typical and most variable for the group.

Task # 4. Description and mapping of regional features of seasonal average values for air temperature.

Initial matrix: X_{n*p}, where rows: *n* - stations of air temperature observation; columns: *p* – time series of average values of monthly and annual air temperatures. Matrixes of results: $\{A_{p*k}\}$ – factor loadings, as dimensional with the number of seasons and structure to relation of months in a season and seasons in a year; $\{F_{k*n}\}$ – factor scores, as distributions of stations by aggregation of average monthly air temperatures.

Empirical data of monthly temperatures for SD obtained in tasks 1 and 2 components were plotted with linear and polynomial (the 5^{th} power) trends. The use of named trends helps visualize the goal to present main differences in charts of the analyzed time series.

To analyze selected time series the model of simplified Fourier analysis [Shmagin, 1992] was applied like:

$$Y(t) = a + b*t + A_i * \cos(2t/T_i – F_i),$$

where a+b*t is a linear part of equation; A_i, T_i, F_i are amplitude, period and phase of i-cosinusoid. Parameters for this model were developed using special software was used [Shtengelov, 1994].

Data and Initial Matrixes

To proceed with these three research tasks, the search for a station with a data record that covered the mutual time interval most completely as possible was completed. Sets of initial matrices were created based on long-term data obtained from the High Plains Regional Climate Center [High Plains, Web). The first set of initial matrices of time series $\{X_{t*n}\}$, where t = number of years and n = number of meteorological stations, contains two matrixes: $X^1_{(67*29)}$ and $X^2_{(33*94)}$. In the second set with the general form of the matrix as: $\{X_{t*m}\}$, where t = number of years and m = number of months in a year, three real stations appear as result of analysis from first group of research tasks. The most variable stations are: Brookings, Camp Crook, and Highmore, - and the initial matrixes for them are: $X^3_{(113*12)}$, $X^4_{(110*12)}$, and $X^5_{(102*12)}$.

The third group of research tasks with general view of initial matrix - $\{X_{n*m}\}$, where n = number of meteorological stations and m = number of months in a year, contains two matrixes: $X^6_{(29*12)}$ and $X^7_{(94*12)}$. The first matrix has average values for the time interval 1932 – 1998 and the second one from 1963 – 1995.

For initial matrices from X^1 and X^6 locations of 29 stations and also location for 94 stations for matrixes X^2 to X^7 presented on Fig. 1 (Table 2).

The distribution of average temperature for two time intervals is shown in Figure 2 the most simple and elementary attempt of data analysis. The simplest way to present time spatial variance in temperatures is subtracting the average temperatures for the two time intervals (Fig. 2). Here the intervals each have different lengths and have equal intervals to compare the change in average temperatures. Figure 3 presents the difference between average temperatures for the time period 1932-1998 with a 23-year window: 1932-1954 (year in the middle of interval is 1943), 1954-1976 (1965) and 1976-1998 (1987). Results of simple arithmetic show that during the different time intervals, some parts of SD had increasing and decreasing temperatures.

Statistical results for research tasks

Task #1. Identification and mapping of patterns of multi-year annual air temperature variability for a set of stations.

For the matrix $X^{1}_{(67*29)}$ analysis allowed us to obtain a model with three factors reflecting 87% of initial data variability (Table 3). We see three groups of stations. The groups were denoted by stations with loading on one of the factors that were higher than 0.6 Note that on the last station, there are no high loadings with a single factor. We may place all of the 29 stations in planes of those three factors (Figure 4) and see the synchronization of the regime of temperatures. The factor scores present the main regime differences for the three stations groups (Figure 5). We may choose stations with high factor loadings in every group and those with the longest time series of observations, and then regard those as typical stations for a particular group (Fig. 6).

The same analysis for the matrix $X^{2}_{(33*94)}$ that has the most stations with long mutual time interval of observations allowed work with a model inclusive of four factors (Table 4). The model reflects 91% of initial data variability; has four groups related to factors stations, and 14 stations that do not strongly associate with groups. For four groups of stations, the charts of factor scores show the difference in regime for time interval 1963-95 (Fig. 7) and for each group of stations may be chosen the most variable time series for the period of observation 1963-95 (Tab. 4).

Task #2. Description of annual variability (dimension for intra-annual process, the most variable months and links with annual values) for air temperature from meteorological stations.

Three stations: Brookings ($X^{3}_{(113*12)}$), Highmore ($X^{4}_{(110*12)}$), and Camp Crook ($X^{5}_{(102*12)}$) - with longest periods of observation and high factor loadings in the factor model obtained for $X^{1}_{(67*29)}$ were chosen as typical for SD during the time interval of 67 years (1932-1998) (Fig. 8). For each of the initial matrixes: $X^{3}_{(113*12)}$, $X^{4}_{(110*12)}$, and $X^{5}_{(102*12)}$ factor model were obtained.

For Brookings ($X^{3}_{(113*12)}$), work with this station began first as it is the station with the longest period of record of the three named. The factor model has five factors and reflects 61% of the variability of the initial data (Fig. 9). The factor loadings for monthly and annual temperature together show the winter season (Factor 2 - January and February) as most connected to the annual temperature values (Fig. 9 – right part). Factor scores for each season allow comparison of annual and seasonal charts (Fig. 10). Looking at five seasonal charts (Fig. 10), we see that each appear with negative linear trend lines for the period of observations.

Time series analysis was used for annual and seasonal components of air temperature. The simplified Fourier analysis for annual air temperature gave a model that shows a wave approximation of empirical data (Figure 11) and the seasonal component of annual air temperature was not approximated well by the model (Fig. 12).

For the Highmore station, ($X^{4}_{(110*12)}$) the factor model reflects 61% of initial data variability and presents five seasons of annual temperature regime (Fig. 13). In comparison to the Brookings station's annual temperature observations, it correlated slightly more with the winter season (Factor Loading - 0.74). Five seasonal charts (Fig. 13) all demonstrate have different appearances of positive linear trends for the period of observation. The simplified Fourier analysis for annual air temperature gave a model that shows a wave approximation for the empirical data (Fig. 14).

For Camp Crook ($X^{5}_{(102*12)}$), the factor model reflects 60% of initial data variability and presents five seasons of annual temperature regime (Fig. 15). In comparison to Brookings and Highmore, the annual temperature correlated better with the winter season (Factor Loading - 0.81). From five seasonal charts (Fig. 15), three have the appearance of positive linear trends for the period of observation (the Factor 1, 2 and 4) and two (Factor 3 and 5) don't have a visible trend. The simplified Fourier analysis for annual air temperature gave a model that shows a wave approximation for the empirical data (Fig. 16).

Task # 4. Description and mapping of regional features of seasonal average values for air temperature.

The variability of monthly air temperature distribution over SD obtained as result of the factor analysis of two matrixes: $X^{6}_{(29*12)}$ and $X^{7}_{(94*12)}$. The first matrix $X^{6}_{(29*12)}$ has average values for the time interval 1932 – 1998 and just simple statistics from the initial matrix X^{6} allows us to see the mean, minimum, and maximum monthly air temperatures for entire territory (Fig. 17). Factor model obtained from this matrix allows significant steps toward understanding the temperature variability. Two groups of months reflect 98% of initial data variability (Fig. 17). The annual air temperature for SD takes place between those seasons in the table of factor loadings and on the scatter plot (Fig. 18). Actual data shown on the scatter plot are four groups of months.

The factor model obtained from matrix $X^{7}_{(94*12)}$ allows an understanding of the temperature variability for a shorter time interval but for a higher number of stations from the initial matrix X^{6}. The model has two groups of months reflecting 94% of the initial data variability (Fig. 19). The annual air temperature for the territory of SD takes place between those seasons in the table of factor loadings and on the scatter plot (Fig. 20). The scatter plot shows tree groups of months with the number of members from two to seven. The distribution of stations by factor scores posted in a plane of factors (Fig. 20) has few groups with different number of stations.

Conclusion and Discussion

The first of the factors that the models present are of a spatial temporal regime of annual average temperatures in SD for the time interval 1932-98 this regime reflects a three dimensional process that may be traced on the territory (Fig. 21). The second factor model from the first research task allowed not only the tracing of the temperature regime on a bigger set of stations (Fig. 22), but also comparison of two time intervals. In both cases, we have low dimensional processes with components of increasing and decreasing temperatures. The directions of these regimes for the time interval 1963-95 of increasing temperatures are located in two fuzzy areas in the north and west. Decreasing temperatures is also slightly different in two areas occupying southeast, third of SD.

Looking at the factor model results for two time intervals (1932-98 and 1963-95) of spatial time variability of SD annual air temperature (Figs 21 and 22) we recognize common patterns and differences. On both figures temperatures increase in the northern and western parts of the territory and decrease – in eastern and south central. For a longer time interval of mutual observations (1932-98), two factor scores show increase and decrease; for the shorter time interval (1963-95) the tendency is presented in two pairs of factor score charts and stations. To have two tendencies in regional surface air temperature distribution as observed here supports the idea of global distribution of temperature anomalies (Apguez, et. al., 2007). The picture such as the one published by NASA in December 2006 (Fig. 23) presents the details to fully understand the complexity of the surface air temperature's regime origin through interacting processes of global and regional continental levels.

To choose the typical time series for the SD air temperature regime it is better to use a model with a longer interval of observation. The three stations obtained from the model covering the years of 1932-98 for Brookings, Highmore, and Camp Crook help us not just see the difference in regime during the time interval but also see the two interval locations used for analysis on the longest existing time series (Fig. 24). The typical long interval observation station like Brookings may become intermediate in shorter intervals of comparison (Fig. 24).

Patterns of air temperature for all three stations are similar. In all cases, seasonality is weak (cumulative variability – 60 – 61%), reflecting just the main patterns of correlated monthly temperatures (Tab. 5). All three stations have five seasons and the first and second most variable seasons are the summer and winter months for all three stations.

Having five seasonal regime patterns to compare with the annual regime allows for more detailed pictures, which is better than just comparing annual regime over twelve months. For example, the Factor 3 chart model for Brooking has visually the most declining linear trend, after analysis of the trend during the months that create this seasonal pattern (October and November). We may assume that those month's regimes responsible for annual temperature decline for the period of observation.

Future research to complete the regime picture for the state of SD has to have goals to analyze seasonality of the most variable stations as we see from the model for 1963-1995: Watertown, Castlewood, Marion, and Harrison (Fig. 22).

Results of simplified Fourier analysis for all three time series (Figs 11, 14, and 16) show the significant oscillation components for annual values; and in case of the Brookings station, the completed analysis is not as clear as the seasonal components (Fig. 12).

Use of simplified Fourier analysis provides an equation for an oscillating curve reflecting the main components of the regime. This curve may be used to describe the regime and for forecast. Also, it may be used for finding a conceptual climate model responsible for the oscillations in the monthly surface air temperature regime. A more complex approach to analyze the hydrological or climatologic time series [Ghil et al. 2002; Golyandina and Zhigljavsky, 2001] doesn't provide so simple a visualization. To illustrate this point, we refer to two articles discussing the analysis and forecast of the same hydrologic time series [Pekarova P., and J. Pekar (2006); Shmagin, Trizna, 1992].

To discuss the obtained results from the oscillation curve for a typical time series for SD, we have to focus not on the period of represented by a cosin function but on the general character of a curve as a sum of those functions. This way we may say that the time series for Brookings is on an interval of existing data that is general declining and expect an increase in temperature during the period 2020-30. In case of Highmore and Camp Crook, we may expect decline of temperatures of those two stations during time interval of 2020-2030.

System analysis of the regime of annual and monthly air temperatures for of SD allows us to obtain spatial-temporal variability factor model with known and high (87 and 91%) representation of variability of initial data. Factor scores plotted on annual scatter plots allow visualization of the difference in the regime for groups of stations associated with certain factors. Factor loadings posted on the map demonstrate spatial differences in the regime, and allow selection of the typical station for each group of stations associated with a given factor. The typical station with empirical monthly observations provides the data for factor analysis of seasonality and time series analysis. The typical station also has one more function: to help visualize the big-picture of each individual time interval used for factor analysis (Fig. 24). All together, the factor model and results of analysis of a typical time series present the structure of spatial temporal variability of the monthly temperatures for SD.

The difference in monthly temperature from data of 29 stations is greater for the winter months (Fig. 17). In January, the gap between max and min temperature is 15.3 ^{o}F, for February – 13.3 ^{o}F and December – 11.6 ^{o}F; the smallest difference (5.8 ^{o}F) occurs August, and annual temperature has also difference - 5.8 ^{o}F.

For different and shorter time intervals from 1963-95 (Fig. 19), the min and max range for the state calculated on the average monthly temperatures is also associated with winter (January riches 25.7 ^{o}F), while April through September have two-digit difference. The smallest difference in the monthly temperature range occurred in November, at 8.6 ^{o}F. The range of annual temperature in the state of SD riches 8.3 ^{o}F.

The discussion of ranges of the difference in minimum and maximum monthly temperatures for SD just evokes the need for understanding this kind of variability. This analysis depicts differences in the average temperature for stations (Figs 2 and 3) and we can trace the difference each month trough the territory.

The factor model for the 29 stations over the 1932-98 time interval presents a distribution of monthly temperatures in four seasons (Fig. 18), but those seasons are not usual ones. Winter months create a second factor associating two months from the spring and fall: March and October. May and June have the highest loadings on the first factor - then with slightly lower loadings five remaining months form a separate group. The second model demonstrated similar grouping of months; except the first factor, formed a week group seven months from April to October.

Two factors from the model create a plane of scores in which the stations may be posted (Fig. 18), but those scores may be used for regression with the annual temperature (Fig. 25). The annual temperature has a coefficient of correlation with Factor 1 equal to 0.69 and with Factor 2 of 0.72; the values are statistically significant for both cases. Putting values of factor scores on a map of SD (Fig. 26) allows us to obtain a distribution not only of average annual temperature as it is traditionally done (Fig. 2) but also integrated seasonally; the station with highest factor scores have higher temperatures for months in the season, and opposite for negative values.

The range in monthly temperatures for the state of SD is higher for time the time interval 1963-95, but the factor model for this period is very much like that during 1932-98. There are slight differences in the first factor group of months: April - October, - seven months as a group, and a longer time interval in June and May have their own group, with five other months remaining. It is significant that the character of distribution of station by factor scores is pretty much the same for both time intervals. We have one main compact group of stations in the lower right part of scatter plot (Fig. 7c group in “a”) and then few groups (with one, two, and up to eleven stations) scattered in the rest of the factor plane (Fig. 27). The 3D scatter plot became more useful for the separation some of groups, such as case “a” and “b” (Fig. 27).

The pictures obtained for two of the factor score distributions of SD and obtained from the model for the time period of 1963-95 (Fig. 8c) are, at first, very similar from model of 1932-98 and, second, are a significant addition to understanding the spatial distribution that a much better recognizable picture with 94 station presents than to that of just 29. Those pictures (Fig. 26 and Fig. 28) have to be considered with two others (Fig. 25 and 27), and from comprising the way regression lines go through the scatter plot, we may surmise that the regression lines have to go through the groups and that the grouping has some underlying conditions in landscapes of SD for better regressions (Fig. 29).

The pictures from this statistical analysis open avenues to analyze the landscape property that underlies the spatial distribution of average monthly air temperatures.

The obtained result may have immediate application for:

- developing climatic monitoring network in SD ;
- establishing a plan for regional drought research in SD;
- understanding the bigger picture of scaling issues for average monthly and annual air temperature in SD with connection to global and continental temperatures.

The use of the results obtained and the methodology of system analysis of empirical data may be moving in further directions for performing analysis of spatial temporal variability for maximum and minimum monthly air temperature, monthly sum of precipitation, and total monthly snow accumulation. Results of all named characteristics will open a quantitative landscape regionalization for the SD. The straight one-step approach of cluster analysis for regionalization from station's 22 climatic characteristics [Bunkers, et. al. 1996] does not give diverse understanding and visualization of all components of regional climate process origin.

Acknowledgement

This study was partly supported by the Agricultural and Biosystems Engineering Department at South Dakota State University. Any opinions, findings, and conclusions are those of the authors and do not necessarily reflect the views of SDSU. Thanks to SDSU Prof. Carol Johnston for unconditional support and help. Jennifer Pickard did outstanding job in editing the paper. The authors would also like to thank Dr. Din Chen and special Prof. Nels Troelstrup for their detailed review and comments.

References

Apguez, A., A. M. Waple, and A. M. Sanchez-Lugostate (2007), State of the Climate in 2006. Executive Summary. BAMS, v. 88, p. 929-932.

Brunet, M., P. D. Jones, J. Sigry, O. Saladie, E. Aguilar, A. Moberg, P. M. Della-Marta, D. Lister, A. Walther, and D. Lypez (2007), Temporal and spatial temperature variability and change over Spain during 1850–2005, J. Geophys. Res., 112, D12117, doi:10.1029/2006JD008249.

Bunkers, M. J., J. R. Miller Jr., and A. T. DeGaetand (1996), Definition of Climate Regions in the Northern Plains Using an Objective Cluster Modification Technique Journal of Climate, v. 9, pp. 130–146

HPRCC (2007), High Plains Regional Climate Center (website): http://hprcc.unl.edu/
Last viewed 1 August 2007.

Dima M., and G. Lohmann (2004) Fundamental and derived modes of climate variability: concept and application to interannual time-scales Tellus A 56 (3), 229–249.

Dijkstra, H. A., and M. Ghil (2005), Low-frequency variability of the large-scale ocean circulation: A dynamical systems approach, Rev. Geophys., 43, RG3002, doi:10.1029/2002RG000122.

Ghil, M., M. R. Allen, M. D. Dettinger, K. Ide, D. Kondrashov, M. E. Mann, A. W. Robertson, A. Saunders, Y. Tian, F. Varadi, and P. Yiou (2002), Advanced spectral methods for climatic time series. Rev. Geophys., 40, p. 1-1–1-41

Golyandina, N., and A. A. Zhigljavsky (2001) Analysis of Time Series Structure: SSA and Related Techniques. Chapman & Hall/CRC. 320 p.

Krcho, J. (1978) The Spatial Organization of the Physical-Geographic Sphere as a Cybernetic System Expressed by Means of Measure of Entropy: Acta Facultatis Rerum Naturaium Universitatis Commenianae, Ceographica 16, p. 57-147.

Krcho, J. (2002) Landscape as a spatially organized system and the georelief as a subsystem of landscape - the influence of georelief on spatial differentiation of landscape processes. (Web posted 2002, address: http://www.mpsr.sk/slovak/dok/gn/book/45kap/45kap.htm?start)

Lorenz, E. N. (1970), Climatic Change as a Mathematical Problem. J. Appl. Meteor., v.9, pp. 325–329.

Pekarova P., and J. Pekar (2006) Long-term discharge prediction for the Turnu Severin station (the Danube) using a linear autoregressive model. Hydrol. Process. 20, pp. 1217-1228.

Shmagin, B.A. 1997. The use of a runoff hydrosphere system's structure model as a basis of monitoring water resources. Third USA/CIS Joint Conference on Environmental Hydrology and Hydrogeology – Water: Sustaining a Critical Resource. A selection of papers presented at the Conference held in Tashkent, Uzbekistan, September 22-27, 1996, (ed. J. D. Powell), pp. 107-111.

Shmagin, B.A., C.A. Johnston, H. Mooers. 1998. The systemic model of a hydrosphere of the earth and temporal-spatial variability of the river runoff in headwaters of the Mississippi. Pp. 484-489. In: A. Buccianti, A., G. Nardi, R. Potenza (eds.) Proceedings of IAMG'98, Fourth Annual Conference of the International Association for Mathematical Geology. Universita di Firenze, Italy.

Shmagin B. and R. Kanivetsky. 2006. Regional Hydrology: Tools vs. Ideas. In: “Coastal Hydrology and Processes”. Proceedings of the AIH 25th Anniversary Meeting & International Conference on "Challenges in Coastal Hydrology and Water Quality". Water Resources Publications, LLC. (Eds: Vijay P. Singh and Y. Jun Xu). Chapter 15, pp. 183-196.

Shmagin, B. and M. Trizna (1992) A Long-Term Prognosis of Average Annual Flows of Danube River in Orsova Station. Acta Faculitatis Rerum Naturalium Universitatis Comenianae. Geographica No 33, Bratislava, pp. 233-243.

Shtengelov. R. S. (1994) Hydrogeodynamic calculation using computer. Textbook. Moscow University. 335 p. (In Russian - Gidrogeodinamicheskie raschety na EVM).

Spak, S., T. Holloway, B. Lynn, and R. Goldberg (2007), A comparison of statistical and dynamical downscaling for surface temperature in North America, J. Geophys. Res., 112, D08101, doi:10.1029/2005JD006712.

StatSoft, Inc. (2004). STATISTICA (data analysis software system), version 7. www.statsoft.com.

Toth, Z. (1995), Degrees of freedom in Northern Hemisphere circulation data. Tellus A, Vol. 47, issue 4, p.457

Wu, Q., and G. R. North (2003), Statistics of calendar month averages of surface temperature: A possible relationship to climate sensitivity, J. Geophys. Res., 108(D2), 4071

Table 1. Groups of research tasks and statistical methods for multilevel system analysis of climate characteristics of landscape

Group of tasks	Research level	Initial matrix $X_{(t,n)*p}$		Statistical method	Matrices of results	Final graphics and equations
		Rows ***t, n***	Columns ***p***			
1. Identification and mapping of patterns of multi-year annual regime variability (stream runoff, air temperature, precipitation) for set of watersheds or stations	Global Regional Basin	Years	Time series (TS) of discharge $\{Q_{j*i}\}$ temp. $\{T_{j*n}\}$ and $\{W_{j*n}\}$ – precip.	Factor, Time serries and Cluster analyses	A_{p*k} – dimensions of process, grouping by types of regime F_{k*t} – components for types of regime Ed - distances for watersheds and observation years.	Map of multi-year variability patterns. Component curves for patterns and smoothed component curves. Dendrograms of observation years. Tables for time series parameters
2. Description of annual variability (dimension for intra-annual process, the most variable months and links with annual values) for runoff from watershed, ground water level (GWL) in wells and data from meteorological stations, trend analysis	Planet Global Regional Basin Station	Years	TS of discharge $\{Q_{j*12,13}\}$, level $\{H_{j*12,13}\}$, temperature $\{T_{j*12,13}\}$ and $\{W_{j*12,13}\}$ - precipitation	Factor, Time serries and Cluster analyses	A_{p*k} – dimensions of process, grouping by seasons regime F_{k*t} – components for seasons. Ed - distances for months and observation years	Scatterplots (2D and 3D) of connections in the planes of factors Component curves for annual and seasonal runoff and smoothed component curves, Tables for time series parameters Dendrograms of seasons and observation years
3. Establishment of association between multi-year runoff parameters and other state indices or attributes of landscape	Planet Global Regional Basin	Years	TS of discharge $\{Q_{j*i}\}$, and state indices $\{H_{j*i}\}$	Factor analyses and Step by step regression	A_{p*k} – structure of relations $Y=a_0+\sum_{i=1}^{m} a_i x_i + e$, - regression equation	Scatterplots (2D and 3D) of connections in the planes of factors. Regression equation with other state indices or attributes of landscape.
4. Description and mapping of regional features of seasonal average values for runoff, GWL and meteorological data	Global Regional Basin	Watersheds. Stations or well of observation.	Average values of runoff TS $\{Q_{j*i}\}$, $\{Q'_{j*i}\}$ and meteodata TS $\{T_{j*i}\}$, $W_{j*i}\}$	Factor analyses	A_{p*k} – dimensions as number of seasons and structure of relations of months in a season in a year F_{k*n} – location of watershed, well or station in each season	Scatterplots (2D and 3D) of unification months in seasons and in year in the planes of factors. Map of distribution watersheds, wells or stations with different seasonal pattern
5. Identification of relationship between surface and GW runoff parameters, min and max temperatures	Regional Basin	Watersheds	Runoff parameters $\{q_{j*i}, k_{j*i}\}$	Factor analyses	A_{p*k} – dimensions of process and structure of relations F_{k*n} – grouping of watersheds by generalized characteristics	Scatterplots (2D and 3D) of connection of runoff characteristics in the planes of factors Diagrams of distribution of watersheds by runoff characteristics in the planes of factors
6. Establishment of relationship between runoff parameters distribution and attributes of atmosphere and lithosphere components for watersheds	Regional Basin	Watersheds	Parameters of runoff and attributes of atmosphere and lithosphere conditions $\{q_{j*i}, k_{j*i}, T_{j*i}, W_{j*i}, H_{j*i}\}$	Factor analyses and Step by step regression	A_{p*k} – object dimensions and structure of relations of runoff with conditions of formation F_{k*n} – grouping of watersheds by generalized characteristics of runoff and conditions $Y=a_0+\sum_{i=1}^{m} a_i x_i + e$, - regression equation	Scatterplots (2D and 3D) of relations of runoff with conditions of formation in the planes of factors Scatterplots (2D and 3D) of distribution of watersheds by runoff and conditions of formation in the planes of factors Regression equation for characteristics of runoff from characteristics of conditions
7. Reevaluation and mapping of units with quazi-uniform landscape conditions (elements of regionalization), reevaluation of the influence on river runoff components (ground water and surface)	Regional Basin	Watersheds	Parameters of runoff and attributes of atmosphere and lithosphere conditions by elements of regionalization $\{q^h, k^h, H^h\}$	Factor analyses, Step by step regression, Student, Fisher and Nonparametric tests	A_{p*k} - structure or runoff parameters relations by elements of regionalization $Y=a_0+\sum_{i=1}^{m} a_i x_i + e$, - regression equation Table: Statistical criteria estimates of divisions by elements of regionalization	Scatterplots (2D and 3D) of relations of runoff with conditions of formation by elements of regionalization in the planes of factors Regression equation for parameters of runoff from attributes of conditions by elements of regionalization Maps of rivers and ground water runoff

Table 2 (beginning). List of station with mutual time interval 1963-95 (94 stations – $N^o{}_1$) and 1932-98 (29 – $N^o{}_2$), YMMD – years with missing monthly data, % - percent of YMMD to years in the time interval

$N^o{}_1$	$N^o{}_2$	Name	Longitude	Latitude	Elev [m]	YMMD	%
1	1	ABERDEEN WSO AP	-98.43	45.45	395		
2	2	ACADEMY 2 NE	-99.07	43.50	512		
3	3	ALEXANDRIA	-97.78	43.65	411		
4		ARDMORE 2 N	-103.65	43.05	1082		
5	4	ARMOUR	-98.35	43.32	461	5	15
6		BELLE FOURCHE	-103.85	44.67	920	5	15
7		BISON	-102.47	45.52	847	7	21
8		BONESTEEL	-98.95	43.08	605	2	6
9	5	BOWMAN COURT HOUSE, ND	-103.38	46.18	902		
10		BRIDGEWATER	-97.50	43.55	433	9	27
11	6	BRITTON	-97.75	45.78	408		
12	7	BROOKINGS 2 NE	-96.77	44.32	500		
13	8	CAMP CROOK	-103.98	45.55	951		
14		CANTON 4 WNW	-96.67	43.30	410	1	3
15		CASTLEWOOD	-97.03	44.72	514	3	9
16	9	CENTERVILLE 6 SE	-96.90	43.05	384		
17	10	CLARK	-97.73	44.88	543		
18		CLEAR LAKE	-96.68	44.75	549	2	6
19	11	COLONY	-104.20	44.93	1088		
20		COLUMBIA 8 N	-98.30	45.73	396	2	6
21	12	COTTONWOOD 2 E	-101.87	43.97	736		
22		DE SMET	-97.55	44.38	524	1	3
23		DEADWOOD	-103.70	44.38	1406	4	12
24	14	DUPREE	-101.60	45.05	724		
25	15	EKALAKA, MT	-101.45	45.88	640		
26	16	EUREKA	-99.63	45.78	570		
27	17	FAITH	-102.03	45.03	790		
28	18	FAULKTON	-99.13	45.03	478		
29		FLANDREAU	-96.60	44.05	475	1	3
30	19	FORESTBURG 3 NE	-98.07	44.03	375		
31		FORT MEADE	-103.47	44.40	1006		
32	20	GANN VALLEY 4 NW	-99.07	44.07	524		
33		GETTYSBURG	-99.95	45.02	631	4	12
34		GLAD VALLEY 2 W	-101.82	45.40	887	6	18
35	21	GORDON 6 N, NE	-102.20	42.88	1128		
36	22	GREGORY	-99.43	43.23	658		
37	23	HARRISON, NE	-101.27	43.17	908		
38		HAWARDEN, IA	-96.48	43.00	363	3	9
39	24	HETTINGER EXPERIMENT	-102.65	45.98	817		
40	25	HIGHMORE 1 W	-99.47	44.52	576		
42	26	HOT SPRINGS	-103.47	43.43	1085		
43		HOWARD	-97.52	44.02	475		
44		HURON WSO AIRPORT	-98.22	44.38	390	2	6
45		IPSWICH	-99.03	45.45	466		
46		KENNEBEC	-99.87	43.92	518	1	3
47		LEAD	-103.77	44.35	1631	1	3

Table 2 (end). List of station with mutual time interval 1963-95 (94 stations – N^o$_1$) and 1932-98 (29 – N^o$_2$), YMMD – years with missing monthly data, % - percent of YMMD to years in the time interval.

N^o$_1$	N^o$_2$	Name	Longitude	Latitude	Elev [m]	YMMD	%
48		LEMMON	-102.17	45.93	782	2	6
49		LEOLA	-98.93	45.72	482	3	9
50		LUDLOW 3 SSE	-103.37	45.78	911		
51		MADISON 2 E	-97.07	44.00	521	1	3
52		MARION	-97.25	43.42	442	7	21
53		MCINTOSH 6 SE	-101.30	45.88	663	7	21
54	27	MELLETTE	-98.50	45.15	393		
55		MENNO	-97.58	43.23	404	3	9
56		MERRIMAN	-101.70	42.90	991	6	18
57		MILBANK 2 SSW	-96.63	45.20	354	8	24
58		MILESVILLE 8 NE	-101.57	44.53	677		
59		MILLER	-98.98	44.52	485		
60	28	MITCHELL 2 N	-98.02	43.73	381		
61		MOBRIDGE 2 NNW	-100.45	45.57	517	2	6
62	29	MURDO	-100.70	43.88	707		
63	30	Newcacle WY	-104.22	43.85	1315		
64		NEWELL	-103.42	44.72	872	1	3
65		OAHE DAM	-100.42	44.45	506		
66		OELRICHS	-103.23	43.18	1018	2	6
67		ONIDA 4 NW	-100.15	44.73	564	5	15
68		PACTOLA DAM	-103.48	44.07	1439	3	9
69		PICKSTOWN	-98.53	43.07	454	1	3
70		PIERRE FAA AIRPORT	-100.28	44.38	526		
71		POLLOCK	-100.28	45.90	498	5	15
72		RALPH 1 N	-103.07	45.78	850	3	9
73		RAPID CITY	-103.28	44.12	1052	6	18
74		RAPID CITY WSO	-103.07	44.05	965		
75		REDFIELD 2 NE	-98.50	44.90	393	4	12
76		REDIG 11 NE	-103.38	45.38	936	2	6
77		SELBY	-100.03	45.50	570		
78		SIOUX FALLS WSFO	-96.73	43.57	432		
79		SISSETON	-97.05	45.67	372	2	6
80		SPEARFISH	-103.87	44.50	1109	8	24
81		SUMMIT 1 W	-97.07	45.30	594	3	9
82		TIMBER LAKE	-101.07	45.43	655		
83		TYNDALL	-97.87	43.00	433	2	6
84		VALENTINE WSO AP	-100.55	42.87	789		
85		VERMILLION 2 SE	-96.92	42.75	363	4	12
86		WAGNER	-98.30	43.08	436		
87		WASTA	-102.43	44.07	707		
88		WATERTOWN FAA AP	-97.15	44.92	533		
89		WAUBAY NATL WILDLIFE	-97.33	45.43	558	2	6
90		WEBSTER	-97.53	45.33	565	4	12
91		WENTWORTH 2 WNW	-97.00	44.02	515	2	6
92		WESSINGTON SPRINGS	-98.57	44.08	499	1	3
93		WHITE LAKE	-98.72	43.73	497		
94		WINNER	-99.87	43.38	613	2	6
95		YANKTON 2 E	-97.35	42.88	360		

Table 3. Factor Loadings for 29 stations for mutual period of observations 1932-98 (shown values > 0.25)

Coop Station	Factor 1	Factor 2	Factor 3
HIGHMORE 1 W, SD	**0.82**	0.28	0.38
FAULKTON 1 NW, SD	**0.80**	0.38	0.38
CLARK, SD	**0.80**	0.41	0.30
BRITTON, SD	**0.79**	0.26	0.46
ABERDEEN WSO AP, SD	**0.79**	0.34	0.36
FORESTBURG 3 NE, SD	**0.78**	0.37	0.43
ALEXANDRIA,	**0.75**	0.37	0.49
EUREKA, SD	**0.73**	0.40	***0.50***
ACADEMY 2 NE, SD	**0.72**	***0.56***	
DUPREE 5 NNE, SD	**0.70**	0.36	***0.56***
GANN VALLEY 4 NW, SD	**0.67**	***0.58***	
ARMOUR, SD	***0.63***	0.47	***0.52***
BOWMAN COURT HOUSE, ND	***0.60***	0.38	***0.57***
CENTERVILLE 6 SE, SD	0.25	**0.83**	
BROOKINGS 2 NE, SD	0.42	**0.77**	0.30
MELLETTE, SD	***0.56***	**0.71**	0.30
MITCHELL, SD	***0.55***	**0.70**	0.35
HARRISON, NE		***0.68***	***0.61***
COTTONWOOD 3 E, SD	***0.51***	***0.63***	0.40
MURDO, SD	***0.55***	***0.63***	0.40
GORDON 6 N, NE		***0.62***	***0.59***
NEWCACLE, WY	0.27	0.34	**0.83**
COLONY, WY	***0.52***		**0.77**
EKALAKA, MT	***0.54***	0.25	**0.75**
HOT SPRINGS, SD	0.37	0.44	**0.72**
CAMP CROOK, SD	***0.59***		**0.71**
FAITH, SD	0.45	0.46	***0.61***
HETTINGER EXP FA, ND	0.47	***0.54***	***0.60***
GREGORY, SD	***0.57***	***0.50***	0.49
Explained Variability	10.50	7.31	7.65
Proportion of Total	0.36	0.25	0.26

Table 4 (beginning). Factor Loadings (left – sorted by number, right – presented by groups) for 94 stations for mutual period of observations 1963-95

No	Station	Factor 1	Factor 2	Factor 3	Factor 4		Station	Factor 1	Factor 2	Factor 3	Factor 4
1	ABERDEEN WSO AP, SD	0.74	0.44	0.32	0.26	88	**WATERTOWN FAA AP, SD**	**0.76**	0.27	0.38	0.37
2	ACADEMY 2 NE, SD	0.09	0.83	0.41	0.28		LEMMON, SD	**0.76**		0.26	***0.58***
3	ALEXANDRIA,	0.59	0.43	0.51	0.42		ABERDEEN WSO AP, SD	**0.74**	0.44	0.32	0.26
4	ARDMORE 4 NNE, SD	0.36	0.34	0.40	0.71		BRITTON, SD	**0.74**	0.47	0.28	0.32
5	ARMOUR, SD	0.61	0.30	0.55	0.45		RALPH 3 NW, SD	**0.73**	0.30		***0.57***
6	BELLE FOURCHE, SD	0.43	0.45	0.25	0.53		VERMILLION 2 SE, SD	**0.72**	0.30	0.35	0.40
7	BISON, SD	0.64	0.09	0.39	0.59		LEOLA, SD	**0.72**	0.40	0.36	0.39
8	BONESTEEL, SD	0.24	0.80	0.23	0.21		YANKTON 2 E, SD	**0.71**	0.29	0.36	0.45
9	BOWMAN COURT HOUSE, ND	0.58	0.38	0.42	0.55		POLLOCK, SD	**0.71**	0.40	0.37	0.38
10	BRIDGEWATER, SD	0.32	0.59	0.60	0.17		KENNEBEC, SD	**0.71**	0.45		0.45
11	BRITTON, SD	0.74	0.47	0.28	0.32		MOBRIDGE 2 NNW, SD	***0.69***	0.39	0.36	0.46
12	BROOKINGS 2 NE, SD	0.60	0.42	0.51	0.36		SIOUX FALLS WSFO, SD	***0.69***	0.33	0.43	0.42
13	CAMP CROOK, SD	0.55	0.34	0.31	0.67		WESSINGTON SPRINGS, SD	***0.68***		0.44	0.45
14	CANTON 4 WNW, SD	0.49	0.33	0.56	0.43		HURON WB AIRPORT, SD	***0.68***	0.41	0.37	0.37
15	CASTLEWOOD, SD	0.35	0.84	0.35	0.14		TIMBER LAKE, SD	***0.68***	0.48	0.26	0.47
16	CENTERVILLE 6 SE, SD	0.24	0.29	0.82	0.35		WAUBAY NATL WILDLIFE RE, SD	***0.67***	0.32	***0.53***	0.35
17	CLARK, SD	0.46	0.77	0.30	0.26		MC INTOSH 6 SE, SD	***0.67***	0.30	0.39	0.48
18	CLEAR LAKE, SD	0.66	0.45	0.47	0.32		EUREKA, SD	***0.66***	0.41	0.45	0.41
19	COLONY, WY	0.55	0.30	0.24	0.71		CLEAR LAKE, SD	***0.66***	0.45	0.47	0.32
20	COLUMBIA 8 N, SD	0.41	0.66	0.50	0.25		PIERRE FAA AIRPORT, SD	***0.65***	0.50		0.48
21	COTTONWOOD 3 E, SD	0.17	0.58	0.51	0.49		BISON, SD	***0.64***	0.09	0.39	***0.59***
22	DEADWOOD, SD	0.40	0.23	0.27	0.74		OAHE DAM, SD	***0.62***	0.38	0.40	0.51
23	DE SMET, SD	0.49	0.60	0.49	0.27		SUMMIT 1 W, SD	***0.62***	0.42	***0.53***	0.30
24	DUPREE 5 NNE, SD	0.58	0.54	0.21	0.53		WENTWORTH 2 WNW, SD	***0.62***	0.49	0.49	0.34
25	EKALAKA, MT	0.55	0.27	0.25	0.65		ARMOUR, SD	***0.61***	0.30	***0.55***	0.45
26	EUREKA, SD	0.66	0.41	0.45	0.41		WEBSTER WATER DEPT, SD	***0.61***	0.48	0.44	0.35
27	FAITH, SD	0.59	0.35	0.30	0.61		SISSETON 1 E, SD	***0.61***	***0.52***	0.49	0.25
28	FAULKTON 1 NW, SD	0.52	0.68	0.32	0.34		BROOKINGS 2 NE, SD	***0.60***	0.42	***0.51***	0.36
29	FLANDREAU, SD	0.41	0.44	0.61	0.37		LUDLOW, SD	***0.60***		0.46	***0.56***

Table 4 (continued). Factor Loadings (left – sorted by number, right – presented by groups) for 94 stations for mutual period of observations 1963-95

No	Station	Factor 1	Factor 2	Factor 3	Factor 4		Station	Factor 1	Factor 2	Factor 3	Factor 4
30	FORESTBURG 3 NE, SD	0.58	0.48	0.50	0.38	15	**CASTLEWOOD, SD**	0.35	**0.84**	0.35	0.14
31	FORT MEADE, SD	0.46	0.33	0.41	0.68		ACADEMY 2 NE, SD		**0.83**	0.41	0.28
32	GANN VALLEY 4 NW, SD	0.33	0.82	0.29	0.27		GANN VALLEY 4 NW, SD	0.33	**0.82**	0.29	0.27
33	GETTYSBURG, SD	0.35	0.35	0.67	0.45		BONESTEEL, SD		**0.80**		
34	GORDON 6 N, NE	0.17	0.20	0.18	0.75		CLARK, SD	0.46	**0.77**	0.30	0.26
35	GLAD VALLEY 2 W, SD	0.47	0.43	0.36	0.53		HOWARD, SD	0.41	**0.74**	0.43	
36	GREGORY, SD	0.47	0.22	0.55	0.56		MILLER, SD	0.45	**0.70**	0.40	0.32
37	HARRISON, NE	0.33	0.23	0.29	0.80		RAPID CITY, SD		***0.69***	0.36	0.47
38	HAWARDEN, IA	0.42	0.55	0.57	0.28		FAULKTON 1 NW, SD	***0.52***	***0.68***	0.32	0.34
39	HETTINGER EXP FA, ND	0.48	0.44	0.44	0.56		COLUMBIA 8 N, SD	0.41	***0.66***	***0.50***	0.25
40	HIGHMORE 1 W, SD	0.57	0.56	0.34	0.29		Murdo SD	0.43	***0.62***	0.35	0.45
42	HOT SPRINGS, SD	0.45	0.17	0.37	0.74		DE SMET, SD	0.49	***0.60***	0.49	0.27
43	HOWARD, SD	0.41	0.74	0.43	0.24	52	**MARION, SD**		0.31	**0.83**	0.28
44	HURON WB AIRPORT, SD	0.68	0.41	0.37	0.37		CENTERVILLE 6 SE, SD		0.29	**0.82**	0.35
45	IPSWICH, SD	0.54	0.38	0.60	0.38		MILBANK, SD	0.34	0.35	**0.76**	
46	KENNEBEC, SD	0.71	0.45	0.21	0.45		Mitchell SD	0.27	0.42	**0.73**	0.36
47	LEAD, SD	0.36	0.43	0.22	0.77		MADISON 2 E, SD	0.32	0.38	**0.73**	0.28
48	LEMMON, SD	0.76	0.06	0.26	0.58		Mellette SD	0.38	0.40	**0.70**	0.35
49	LEOLA, SD	0.72	0.40	0.36	0.39		TYNDALL, SD	0.43	0.33	***0.69***	0.38
50	LUDLOW, SD	0.60	0.24	0.46	0.56		REDFIELD 2 NE, SD	0.36	0.47	***0.68***	0.31
51	MADISON 2 E, SD	0.32	0.38	0.73	0.28		SELBY, SD	0.32	0.38	***0.68***	0.46
52	MARION, SD	0.21	0.31	0.83	0.28		GETTYSBURG, SD	0.35	0.35	***0.67***	0.45
53	MC INTOSH 6 SE, SD	0.67	0.30	0.39	0.48		MENNO, SD	0.49	0.39	***0.66***	0.34
54	Mellette SD	0.38	0.40	0.70	0.35		WHITE LAKE, SD	***0.55***		***0.63***	0.37
55	MENNO, SD	0.49	0.39	0.66	0.34		FLANDREAU, SD	0.41	0.44	***0.61***	0.37
56	MERRIMAN, NE	0.20	0.40	0.58	0.55		BRIDGEWATER, SD	0.32	0.59	***0.60***	
57	MILBANK, SD	0.34	0.35	0.76	0.16		IPSWICH, SD	***0.54***	0.38	***0.60***	0.38
58	MILESVILLE 8 NE, SD	0.57	0.52	0.19	0.56		MERRIMAN, NE		0.40	***0.58***	0.55
59	MILLER, SD	0.45	0.70	0.40	0.32		PICKSTOWN, SD	***0.50***	0.33	***0.58***	0.52
60	Mitchell SD	0.27	0.42	0.73	0.36		HAWARDEN, IA	0.42	***0.55***	***0.57***	0.28
61	MOBRIDGE 2 NNW, SD	0.69	0.39	0.36	0.46		CANTON 4 WNW, SD	0.49	0.33	***0.56***	0.43

Table 4 (continued). Factor Loadings (left – sorted by number, right – presented by groups) for 94 stations for mutual period of observations 1963-95

No	Station	Factor 1	Factor 2	Factor 3	Factor 4		Station	Factor 1	Factor 2	Factor 3	Factor 4
62	Murdo SD	0.43	0.62	0.35	0.45	37	**HARRISON, NE**	0.33	0.23	0.29	**0.80**
63	Newcacle WI	0.45	0.03	0.44	0.69		LEAD, SD	0.36	0.43		**0.77**
64	NEWELL, SD	0.57	0.32	0.27	0.68		GORDON 6 N, NE			0.18	**0.75**
65	OAHE DAM, SD	0.62	0.38	0.40	0.51		DEADWOOD, SD	0.40		0.27	**0.74**
66	OELRICHS, SD	0.27	0.53	0.38	0.61		HOT SPRINGS, SD	0.45		0.37	**0.74**
67	ONIDA 4 NW, SD	0.54	0.58	0.31	0.35		RAPID CITY WSO, SD	0.49	0.29	0.30	**0.73**
68	PACTOLA RANGER STN, SD	0.16	0.44	0.29	0.69		ARDMORE 4 NNE, SD	0.36	0.34	0.40	**0.71**
69	PICKSTOWN, SD	0.50	0.33	0.58	0.52		COLONY, WY	***0.55***	0.30		**0.71**
70	PIERRE FAA AIRPORT, SD	0.65	0.50	0.16	0.48		SPEARFISH, SD	0.36		0.45	**0.70**
71	POLLOCK, SD	0.71	0.40	0.37	0.38		PACTOLA RANGER STN, SD		0.44	0.29	***0.69***
72	RALPH 3 NW, SD	0.73	0.30	0.17	0.57		Newcacle WI	0.45		0.44	***0.69***
73	RAPID CITY WSO, SD	0.49	0.29	0.30	0.73		FORT MEADE, SD	0.46	0.33	0.41	***0.68***
74	RAPID CITY, SD	0.10	0.69	0.36	0.47		NEWELL, SD	***0.57***	0.32	0.27	***0.68***
75	REDFIELD 2 NE, SD	0.36	0.47	0.68	0.31		CAMP CROOK, SD	***0.55***	0.34	0.31	***0.67***
76	REDIG 9 NE, SD	0.57	0.31	0.35	0.64		WASTA, SD	0.39	***0.51***	0.32	***0.67***
77	SELBY, SD	0.32	0.38	0.68	0.46		EKALAKA, MT	***0.55***	0.27	0.25	***0.65***
78	SIOUX FALLS WSFO, SD	0.69	0.33	0.43	0.42		REDIG 9 NE, SD	***0.57***	0.31	0.35	***0.64***
79	SISSETON 1 E, SD	0.61	0.52	0.49	0.25		OELRICHS, SD	0.27	***0.53***	0.38	***0.61***
80	SPEARFISH, SD	0.36	0.20	0.45	0.70		FAITH, SD	***0.59***	0.35	0.30	***0.61***
81	SUMMIT 1 W, SD	0.62	0.42	0.53	0.30		GREGORY, SD	0.47		***0.55***	0.56
82	TIMBER LAKE, SD	0.68	0.48	0.26	0.47		COTTONWOOD 3 E, SD		***0.58***	***0.51***	0.49
83	TYNDALL, SD	0.43	0.33	0.69	0.38		ALEXANDRIA,	***0.59***	0.43	***0.51***	0.42
84	VALENTINE WSO AP, NE	0.48	0.30	0.47	0.58		FORESTBURG 3 NE, SD	***0.58***	0.48	***0.50***	0.38
85	VERMILLION 2 SE, SD	0.72	0.30	0.35	0.40		VALENTINE WSO AP, NE	0.48	0.30	0.47	***0.58***
86	WAGNER, SD	0.57	0.53	0.41	0.39		HETTINGER EXP FA, ND	0.48	0.44	0.44	***0.56***
87	WASTA, SD	0.39	0.51	0.32	0.67		MILESVILLE 8 NE, SD	***0.57***	***0.52***		***0.56***
88	WATERTOWN FAA AP, SD	0.76	0.27	0.38	0.37		BOWMAN COURT HOUSE, ND	***0.58***	0.38	0.42	***0.55***
89	WAUBAY NATL WILDLIFE RE, SD	0.67	0.32	0.53	0.35		DUPREE 5 NNE, SD	***0.58***	***0.54***		***0.53***
90	WEBSTER WATER DEPT, SD	0.61	0.48	0.44	0.35		BELLE FOURCHE, SD	0.43	0.45	0.25	***0.53***
91	WENTWORTH 2 WNW, SD	0.62	0.49	0.49	0.34		GLAD VALLEY 2 W, SD	0.47	0.43	0.36	***0.53***
92	WESSINGTON SPRINGS, SD	0.68	0.22	0.44	0.45		WINNER, SD	***0.53***	0.42	0.40	***0.50***

Table 4 (end). Factor Loadings (left – sorted by number, right – presented by groups) for 94 stations for mutual period of observations 1963-95

No	Station	Factor 1	Factor 2	Factor 3	Factor 4		Station	Factor 1	Factor 2	Factor 3	Factor 4
93	WHITE LAKE, SD	0.55	0.22	0.63	0.37		WAGNER, SD	***0.57***	***0.53***	0.41	0.39
94	WINNER, SD	0.53	0.42	0.40	0.50		ONIDA 4 NW, SD	***0.54***	***0.58***	0.31	0.35
95	YANKTON 2 E, SD	0.71	0.29	0.36	0.45		HIGHMORE 1 W, SD	***0.57***	***0.56***	0.34	0.29
	Explained Variability	25.61	18.93	19.39	21.91		Explained Variability	25.61	18.93	19.39	21.91
	Proportion of Total	0.27	0.20	0.21	0.23		Proportion of Total	0.27	0.20	0.21	0.23

Table 5. Factor Loadings (shown > 0.25) for Brookings, Highmore and Camp Crook seasonal temperatures.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5		Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		**0.78**	-0.27				JAN		**0.77**	0.26		
FEB		**0.74**					FEB		**0.76**			
MAR					**0.82**		MAR					**0.82**
APR		0.48		0.36	0.28		APR		0.45		0.32	0.27
MAY	0.56				-0.31		MAY	***0.56***				-0.31
JUN	0.52			0.35	0.31		JUN	***0.51***			0.34	0.31
JUL	**0.79**						JUL	***0.80***				
AUG	**0.71**		-0.36				AUG	***0.71***		0.36		
SEP	0.33		-0.40	0.29	0.45		SEP	0.34		0.38	0.26	0.45
OCT			**-0.77**				OCT			**0.78**		
NOV			***-0.56***	***0.52***			NOV			***0.56***	***0.52***	
DEC				**0.82**			DEC				**0.84**	
Expl.Var	1.89	1.50	1.32	1.34	1.24		Brookings	0.46	***0.64***	0.33	0.40	0.31
Prp.Totl	0.16	0.13	0.11	0.11	0.10		Expl.Var	2.10	1.92	1.42	1.49	1.33
							Prp.Totl	0.16	0.15	0.11	0.11	0.10

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		**0.79**					JAN		**0.80**			
FEB		***0.69***		0.26			FEB		**0.72**			
MAR				**0.80**			MAR					**0.78**
APR		***0.57***	0.34		0.29		APR		***0.52***	0.25	-0.44	
MAY	0.34		***0.50***				MAY	0.36		0.42		
JUN	***0.56***		0.41	0.35			JUN	***0.60***		0.34		0.32
JUL	***0.69***		0.29				JUL	**0.72**				
AUG	**0.72**						AUG	**0.71**				
SEP	***0.63***			-0.26			SEP	***0.61***				-0.30
OCT					**-0.92**		OCT				**0.87**	
NOV			0.47	***-0.50***			NOV		0.27	***0.51***		***-0.53***
DEC			**0.77**				DEC			**0.82**		
Expl.Var	1.90	1.58	1.51	1.20	1.09		Highmore	0.43	**0.74**	0.45		
Prp.Totl	0.16	0.13	0.13	0.10	0.09		Expl.Var	2.13	2.13	1.63	1.14	1.21
							Prp.Totl	0.16	0.16	0.13	0.09	0.09

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5			Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		***0.61***	0.25				JAN	***0.64***				
FEB		**0.80**		-0.28			FEB	**0.76**		-0.31	-0.30	
MAR		***0.58***		0.46			MAR	***0.58***			0.43	
APR			***0.64***	-0.42			APR			***0.60***	-0.46	
MAY			**0.83**				MAY			**0.84**		
JUN	***0.57***	0.25	0.37				JUN	0.26	***0.54***	0.37		
JUL	**0.72**						JUL		**0.72**			
AUG	***0.63***						AUG		***0.65***			
SEP	***0.56***				0.30		SEP		***0.56***			0.30
OCT				**0.83**			OCT				**0.82**	
NOV					**0.89**		NOV					**0.88**
DEC					0.37		DEC	0.28				0.37
Expl.Var	1.65	1.47	1.50	1.27	1.18		Camp Cr.	**0.81**	0.33	0.32		0.34
Prp.Totl	0.14	0.12	0.13	0.11	0.10		Expl.Var	2.19	1.73	1.59	1.27	1.27
							Prp.Totl	0.17	0.13	0.12	0.10	0.10

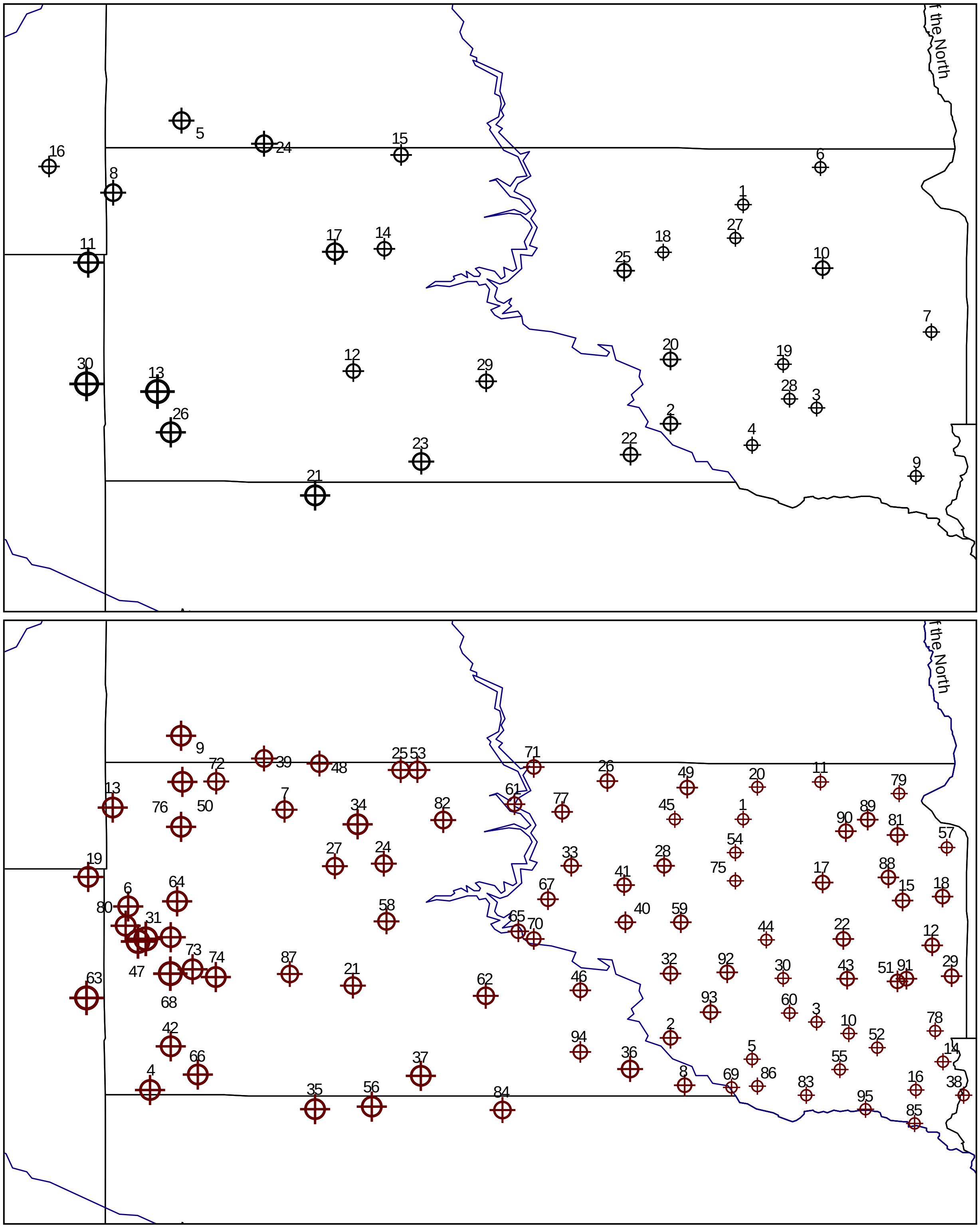


Figure 1. Coop meteorological stations from HP Web site with numbers of rows in initial matrixes for: 1932-98 time interval and 29 stations (upper); 1963-1995 (94) – (lover). Size of sign follows grades in elevation [m]: 354, 466, 631, 850, 1128 & 1631.

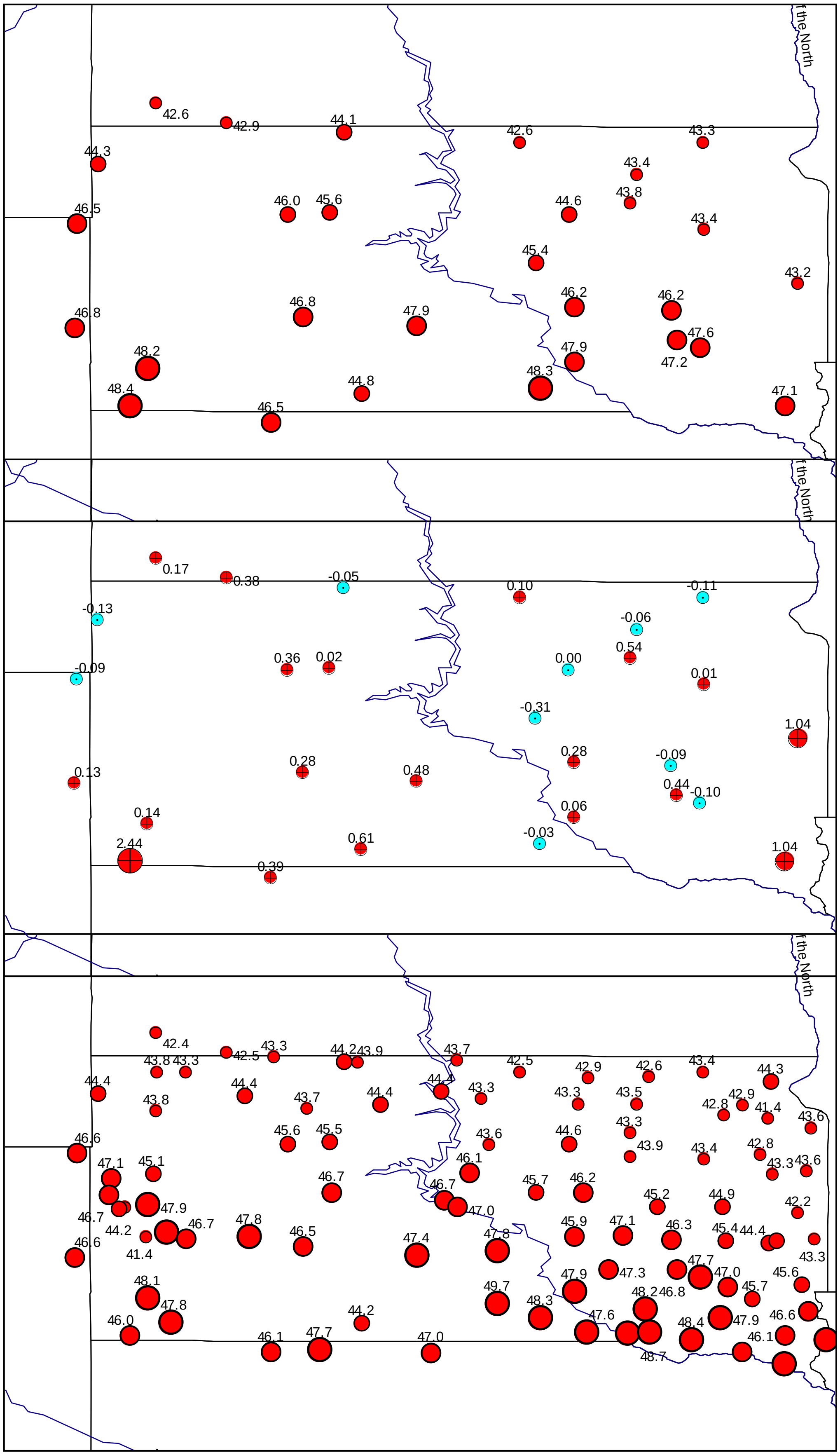


Figure 2. Annual average air temperature for: 1938-98 (29 stations) - top; 1963-1995 (94) - bottom; the difference in temperature for 29 station (middle). Size of sign follows grades in temperature [F] for top: 42, 44, 46, 48 and 49.9; for bottom: 41.4, 43.9, 45.7, 47.3 and 49.7 and for the middle: -0.31, 0, 1, 2, and 2.44.

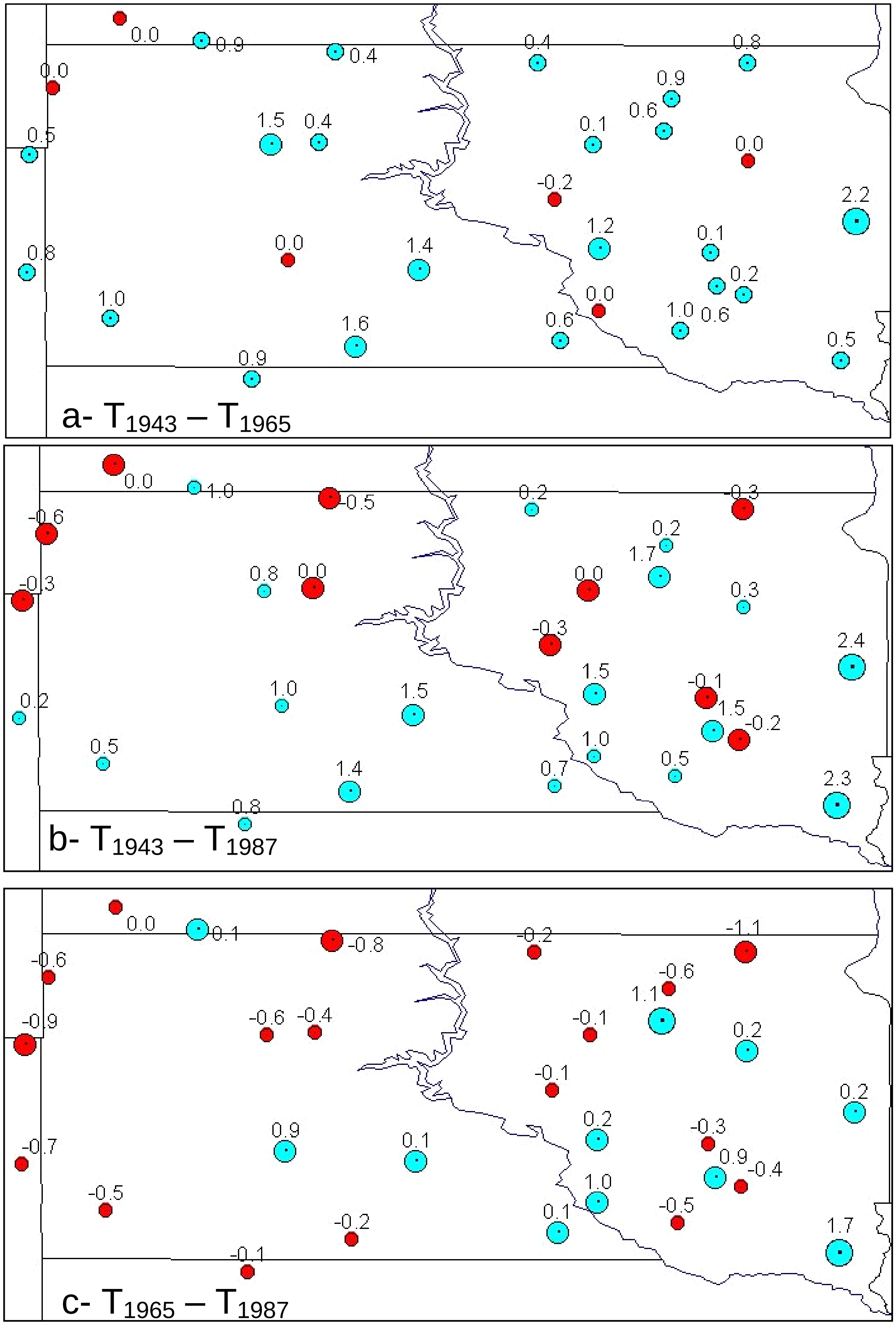
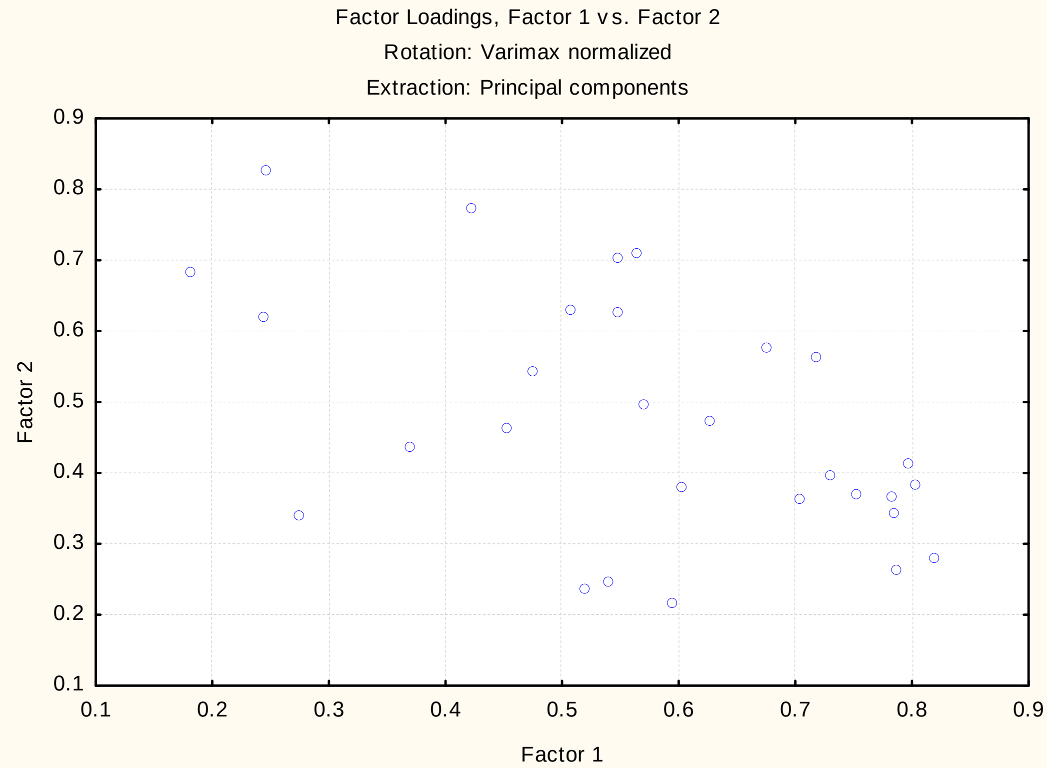
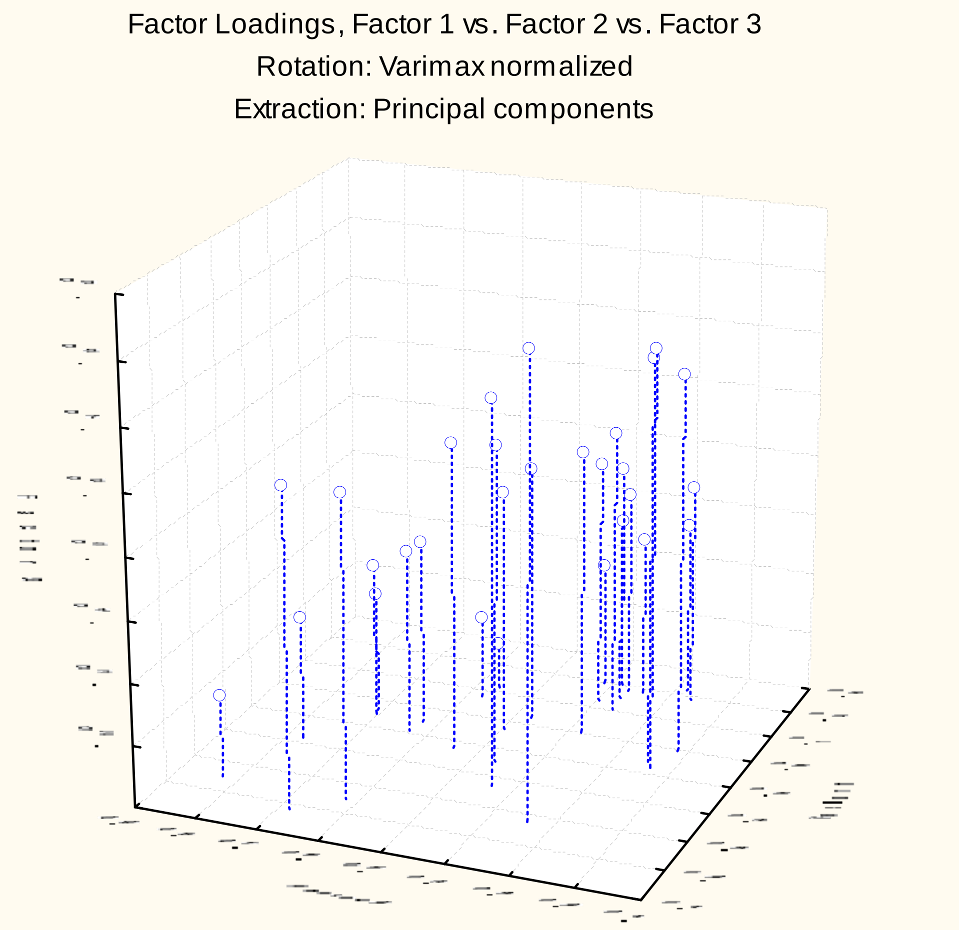


Figure 3. Difference in average annual air temperatures [^oF] for period 1932-98 with window 23 years: 1932-1954 (year in the middle of interval is 1943), 1954-1976 (1965) and 1976-1998 (1987). Size of sign follows grades in temperature [^oF]: 0.0 – 1.0; 1.0- 2.0 and > 2.0. The red color of sign shows increase and blue – decrease in temperature for interval: a- 1943-65; b- 1943-87 and c- 1965-87.





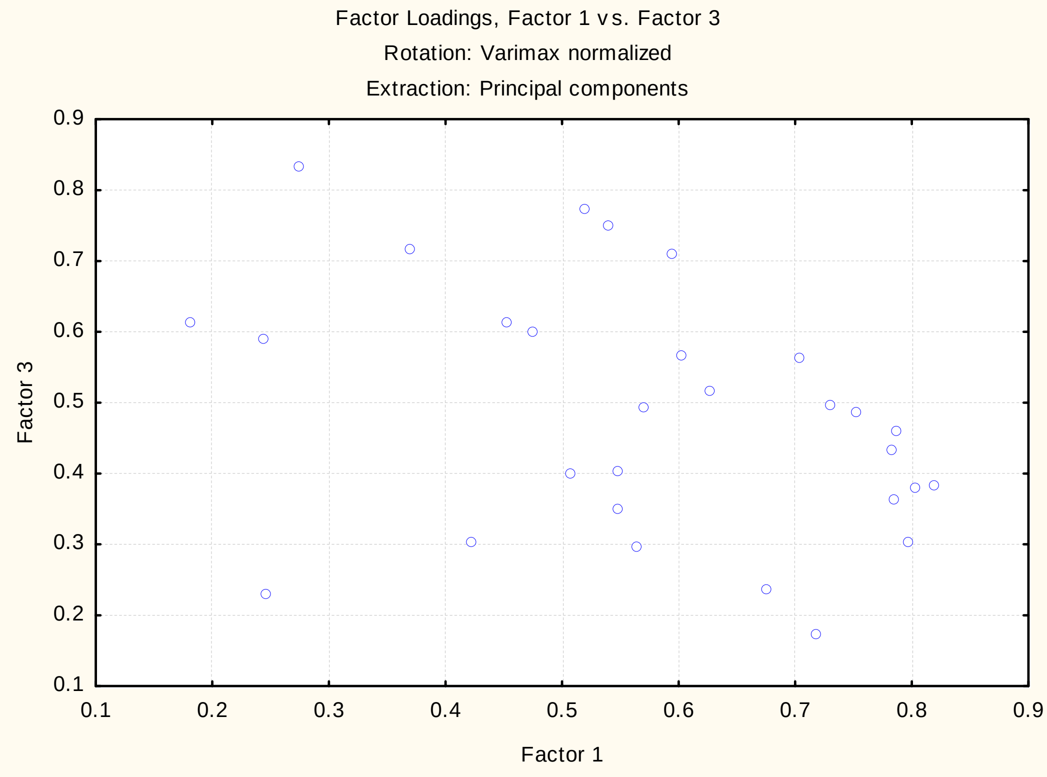


Figure 4. Scatter plots with factors as an axis of the 29 stations during the mutual period of observation 1932 – 1998.

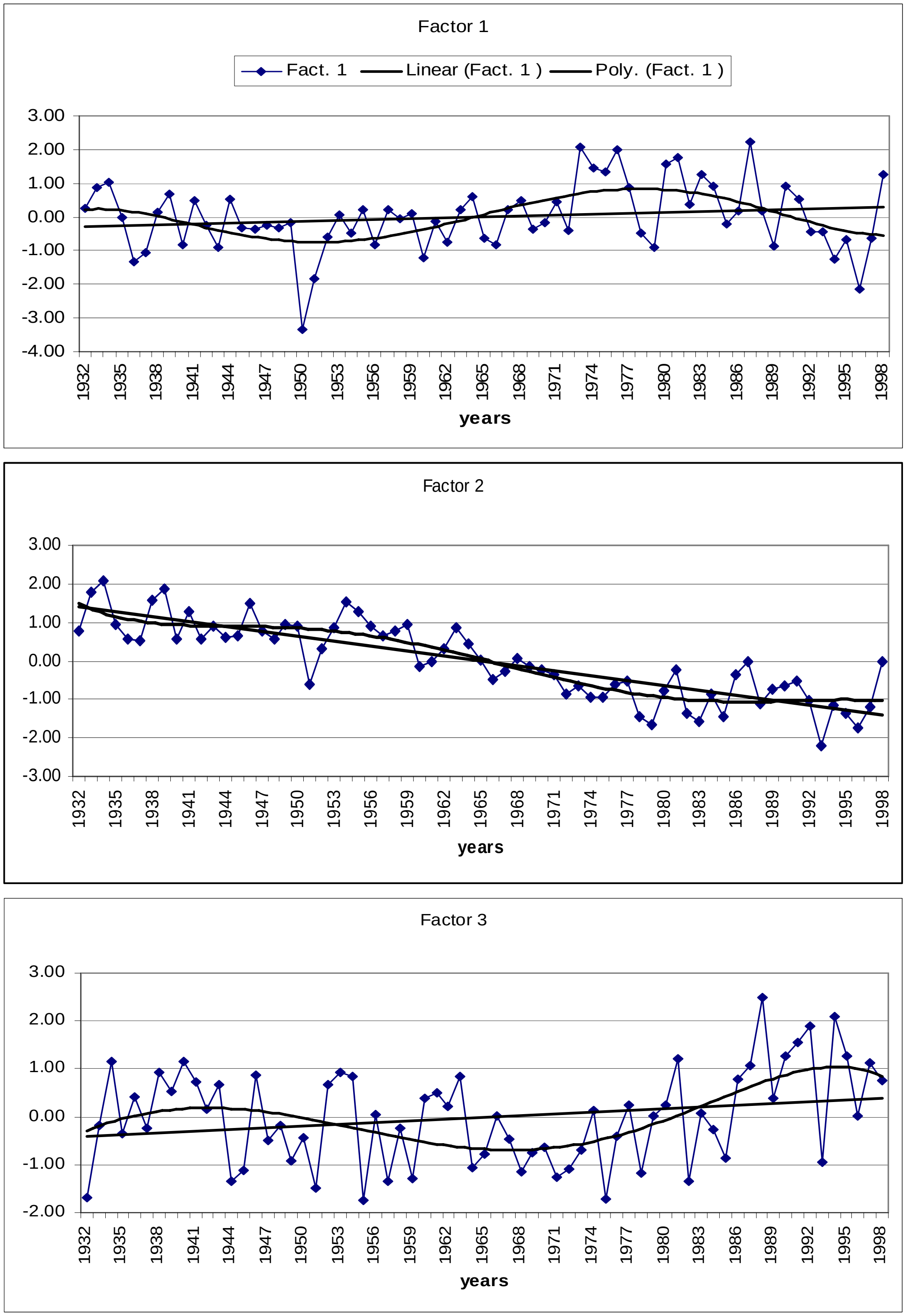
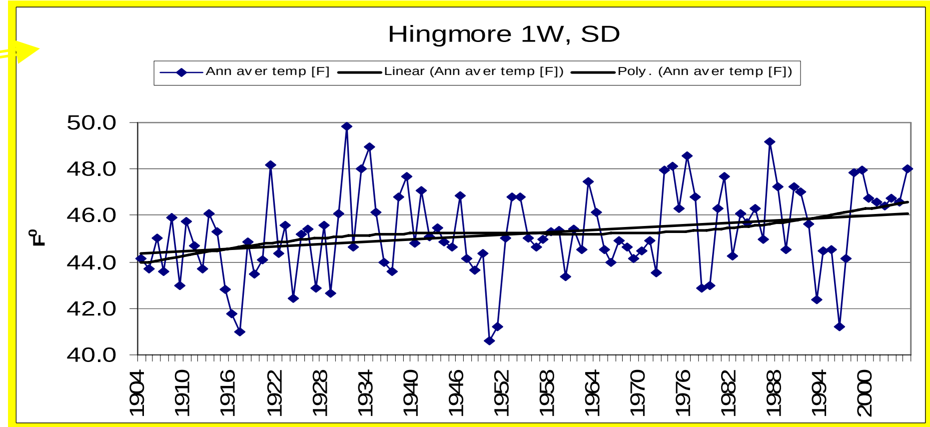
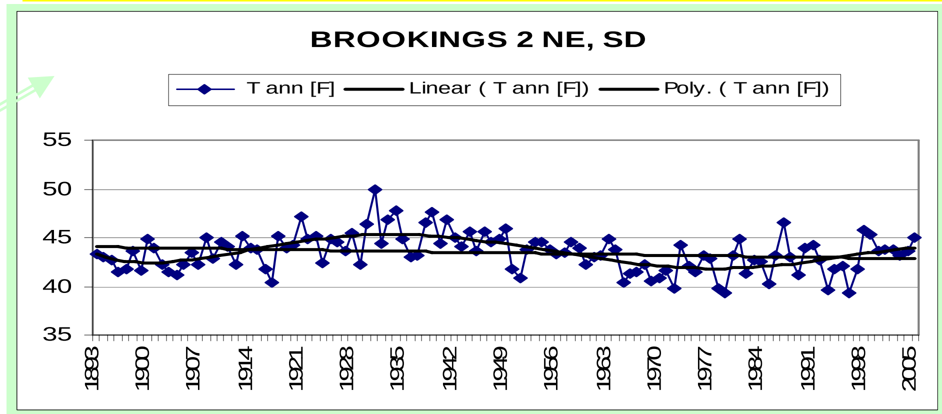


Figure 5. Charts of Factor Scores from the 29 station model for 1932 – 1998.

Coop Station	Factor 1	Factor 2	Factor 3
HIGHMORE 1 W, SD	**0.82**	0.28	0.38
FAULKTON 1 NW, SD	**0.80**	0.38	0.38
CLARK, SD	**0.80**	0.41	0.30
BRITTON, SD	**0.79**	0.26	0.46
ABERDEEN WSO AP, SD	**0.79**	0.34	0.36
FORESTBURG 3 NE, SD	**0.78**	0.37	0.43
ALEXANDRIA,	**0.75**	0.37	0.49
EUREKA, SD	**0.73**	0.40	***0.50***
ACADEMY 2 NE, SD	**0.72**	***0.56***	
DUPREE 5 NNE, SD	**0.70**	0.36	***0.56***
GANN VALLEY 4 NW, SD	**0.67**	***0.58***	
ARMOUR, SD	***0.63***	0.47	***0.52***
BOWMAN COURT HOUSE, ND	***0.60***	0.38	***0.57***
CENTERVILLE 6 SE, SD	0.25	**0.83**	
BROOKINGS 2 NE, SD	0.42	**0.77**	0.30
MELLETTE, SD	***0.56***	**0.71**	0.30
Mitchell SD	***0.55***	**0.70**	0.35
HARRISON, NE		***0.68***	***0.61***
COTTONWOOD 3 E, SD	***0.51***	***0.63***	0.40
MURDO, SD	***0.55***	***0.63***	0.40
GORDON 6 N, NE		***0.62***	***0.59***
NEWCACLE, WY	0.27	0.34	**0.83**
COLONY, WY	***0.52***		**0.77**
EKALAKA, MT	***0.54***	0.25	**0.75**
HOT SPRINGS, SD	0.37	0.44	**0.72**
CAMP CROOK, SD	***0.59***		**0.71**
FAITH, SD	0.45	0.46	***0.61***
HETTINGER EXP FA, ND	0.47	***0.54***	***0.60***
GREGORY, SD	***0.57***	***0.50***	0.49
Expl.Var	10.50	7.31	7.65
Prp.Totl	0.36	0.25	0.26





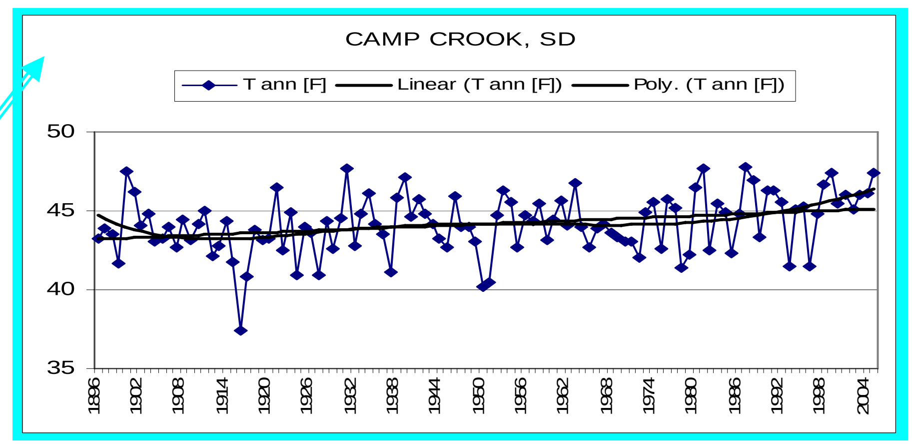


Figure 6. Table 3 of Factor Loadings for 29 stations for mutual period of observations 1932-98, and charts of annual average temperature for three stations chosen as typical for South Dakota.

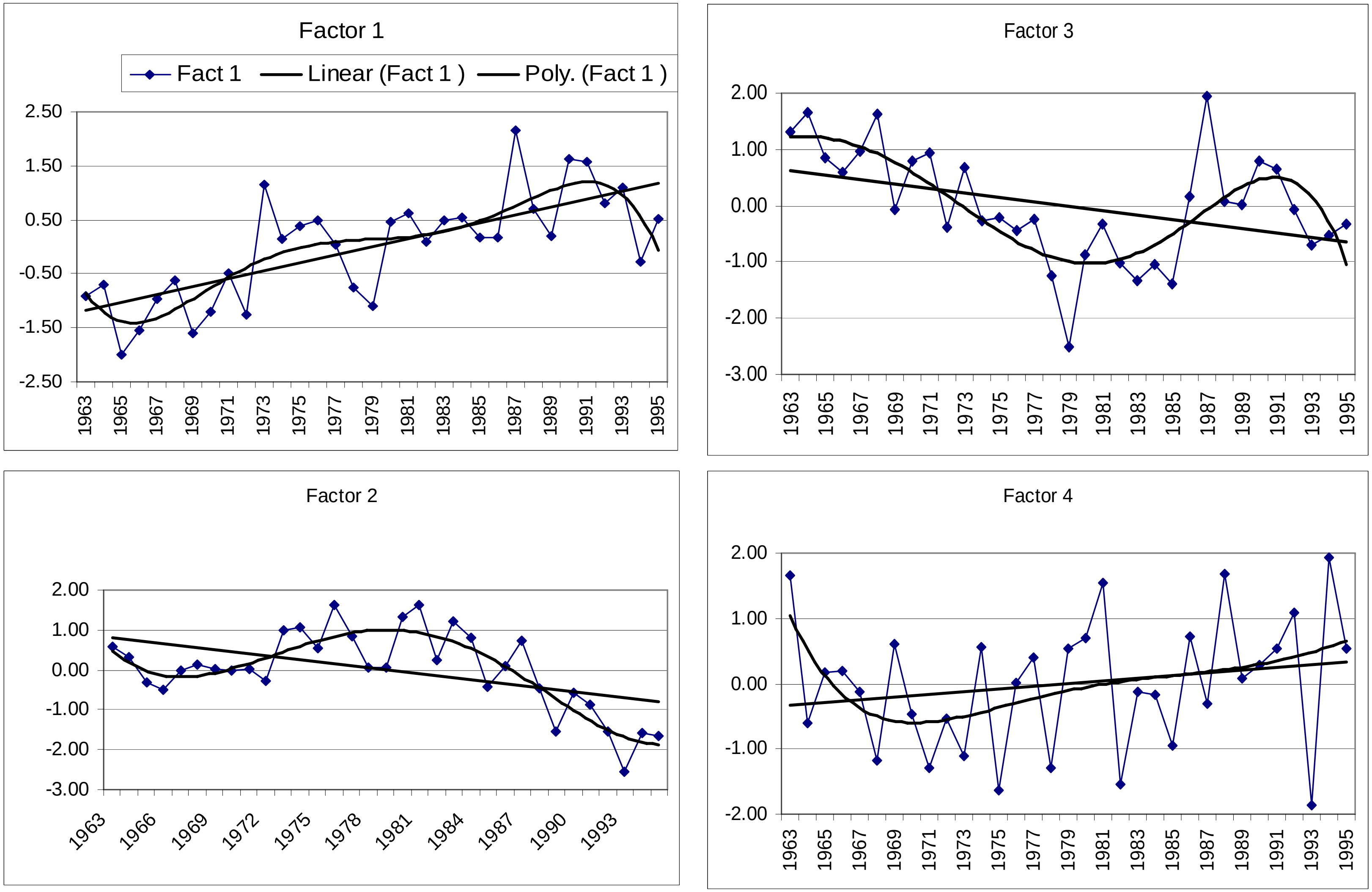


Figure 7. Charts of Factor Scores from model of 94 stations for 1963 – 1995.

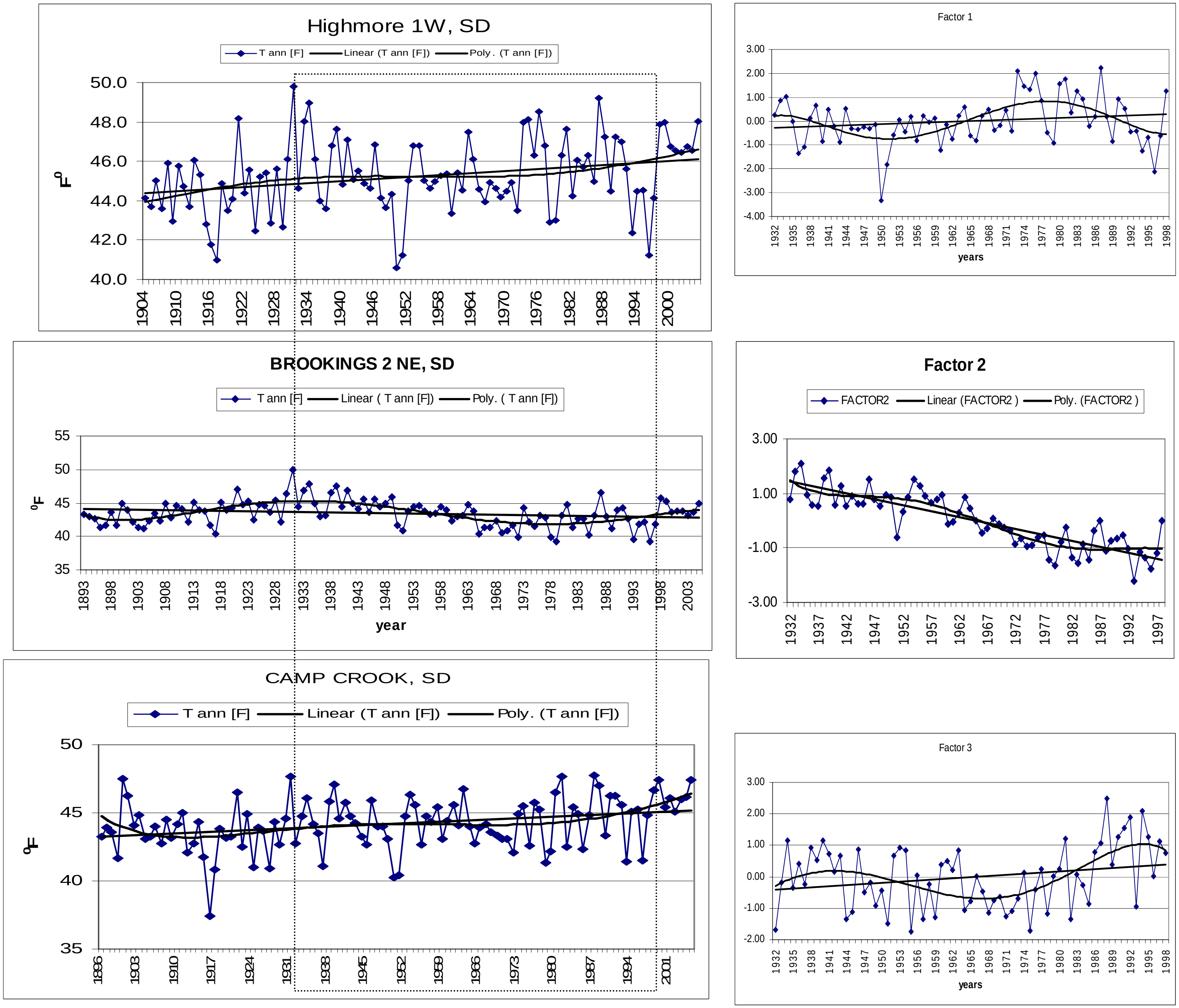
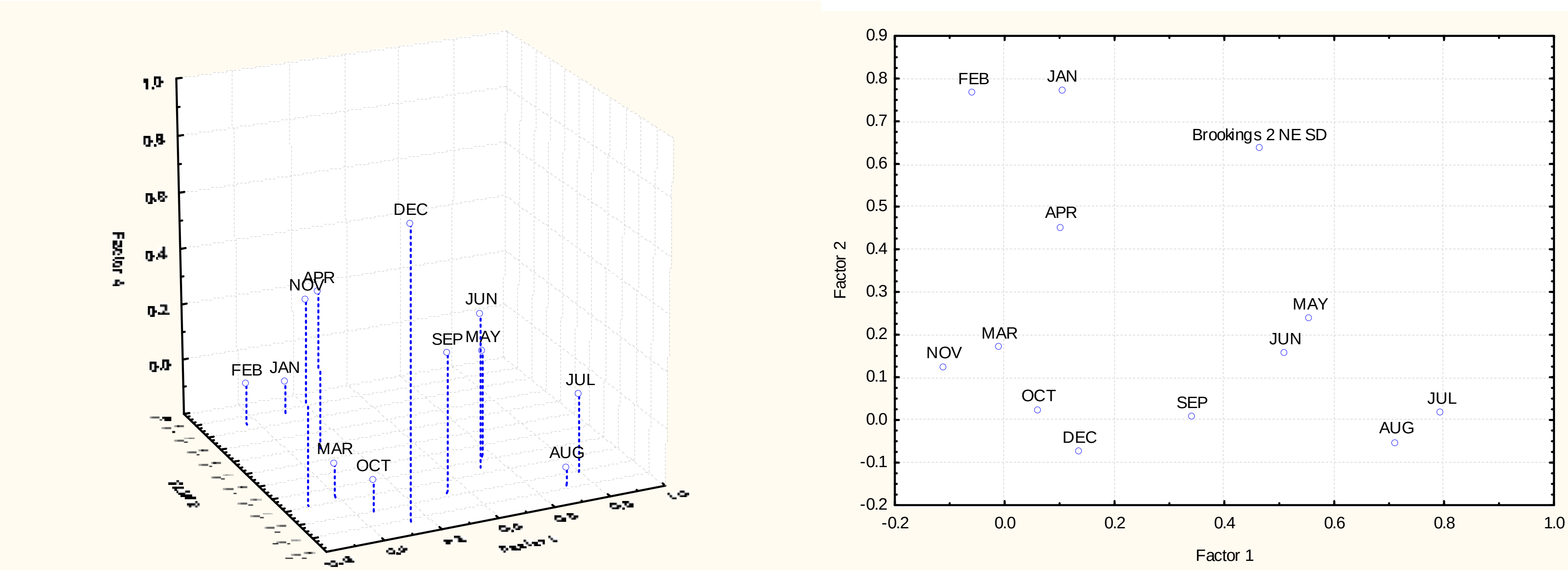


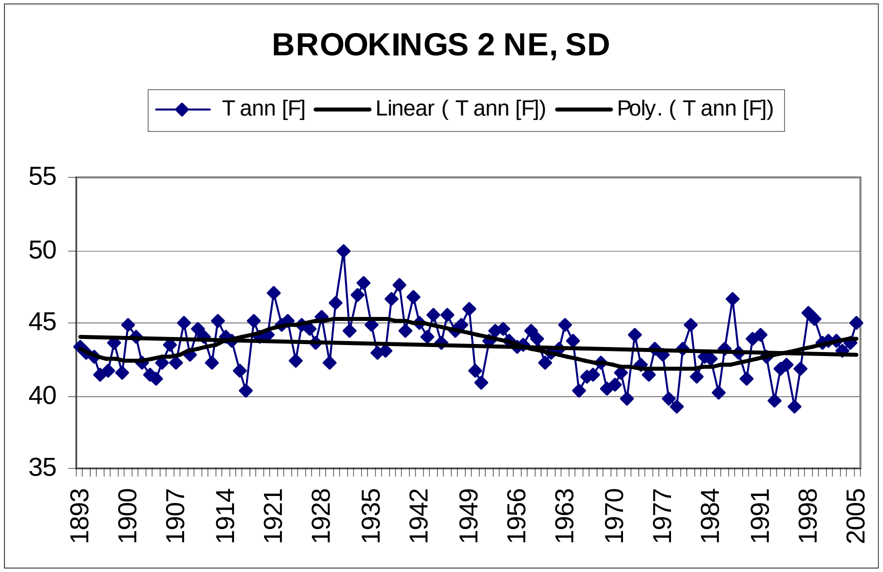
Figure 8. Time series charts for typical stations (Highmore, Brookings and Camp Crook – box shows the time interval of data in 1932-98 factor model) and Factor Scores.



Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		**0.78**	-0.27		
FEB		**0.74**			
MAR					**0.82**
APR		0.48		0.36	0.28
MAY	0.56				-0.31
JUN	0.52			0.35	0.31
JUL	**0.79**				
AUG	**0.71**		-0.36		
SEP	0.33		-0.40	0.29	0.45
OCT			**-0.77**		
NOV			***-0.56***	***0.52***	
DEC				**0.82**	
Expl.Var	1.89	1.50	1.32	1.34	1.24
Prp.Totl	0.16	0.13	0.11	0.11	0.10
Cumulative Eigenvalue	2.44	3.90	5.10	6.27	7.29
Cumulative %	20.30	32.46	42.46	52.24	60.77

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		0.77	0.26		
FEB		0.76			
MAR					0.82
APR		0.45		0.32	0.27
MAY	0.56				-0.31
JUN	0.51			0.34	0.31
JUL	0.80				
AUG	0.71		0.36		
SEP	0.34		0.38	0.26	0.45
OCT			0.78		
NOV			0.56	0.52	
DEC				0.84	
Brookings	0.46	0.64	0.33	0.40	0.31
Expl.Var	2.10	1.92	1.42	1.49	1.33
Prp.Totl	0.16	0.15	0.11	0.11	0.10

Figure 9. Tables and scatter plots of Factor Loadings (in Tables shown > 0.25) for Brookings seasonal temperature.



	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		**0.78**	-0.27		
FEB		**0.74**			
MAR		0.13			**0.82**
APR		0.48		0.36	0.28
MAY	***0.56***				-0.31
JUN	***0.52***			0.35	0.31
JUL	**0.79**				
AUG	**0.71**		-0.36		
SEP	0.33		-0.40	0.29	0.45
OCT			**-0.77**		
NOV			***-0.56***	***0.52***	
DEC				**0.82**	
Expl.Var	1.89	1.50	1.32	1.34	1.24
Prp.Totl	0.16	0.13	0.11	0.11	0.10
Cumulative Eigenvalue	2.44	3.90	5.10	6.27	7.29
Cumulative %	20.30	32.46	42.46	52.24	60.77

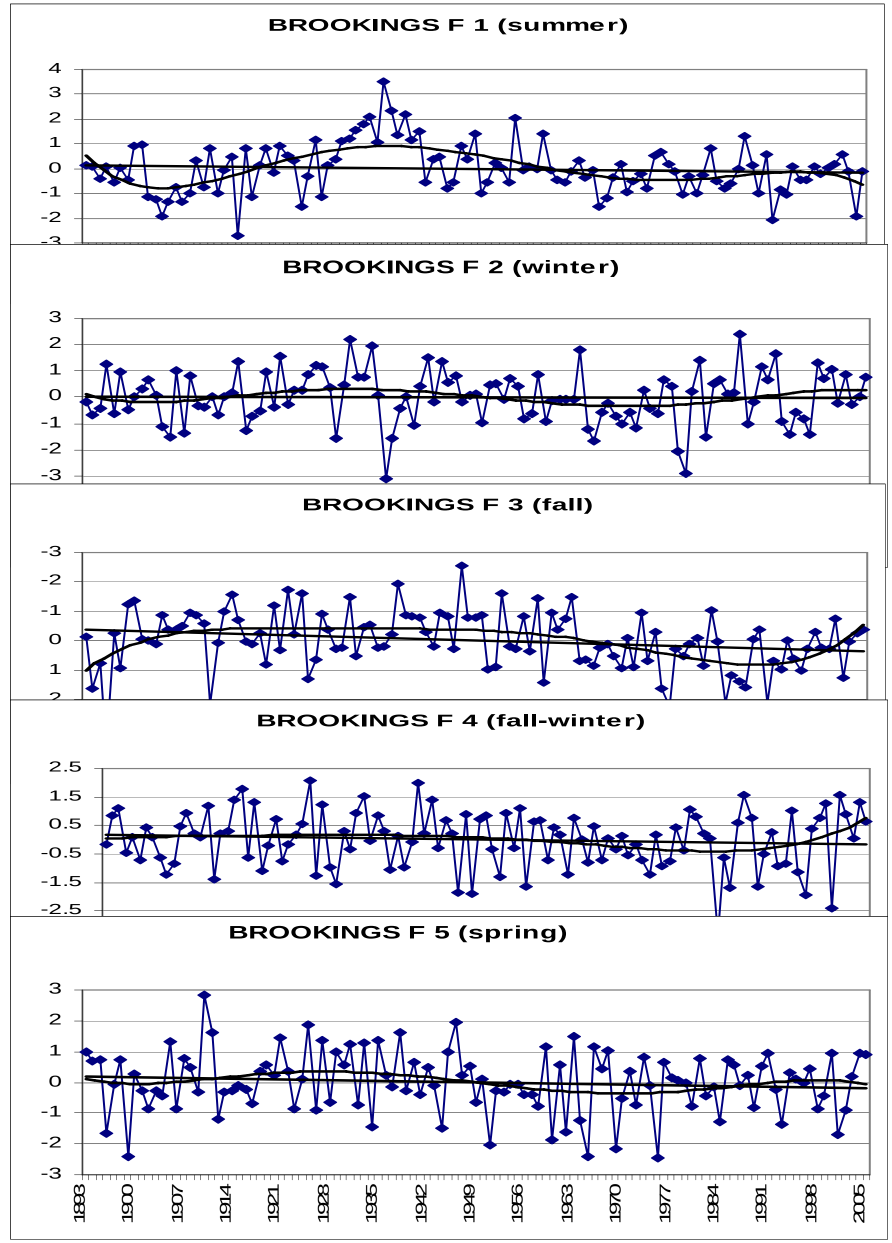
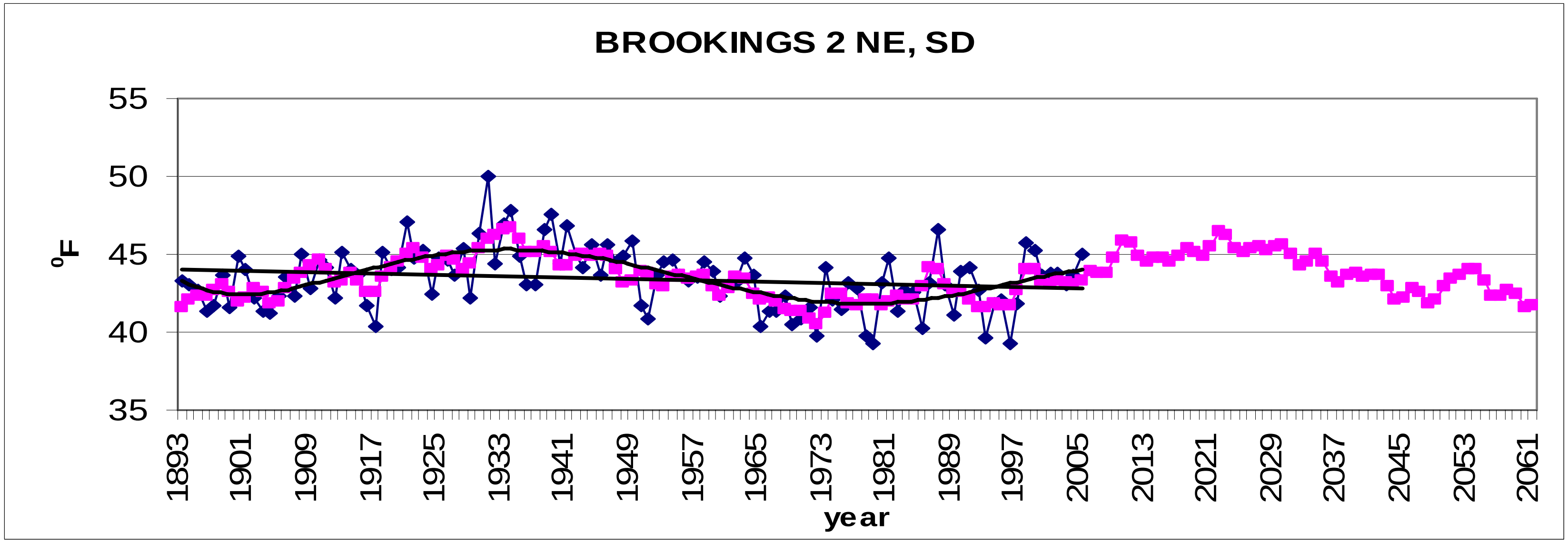
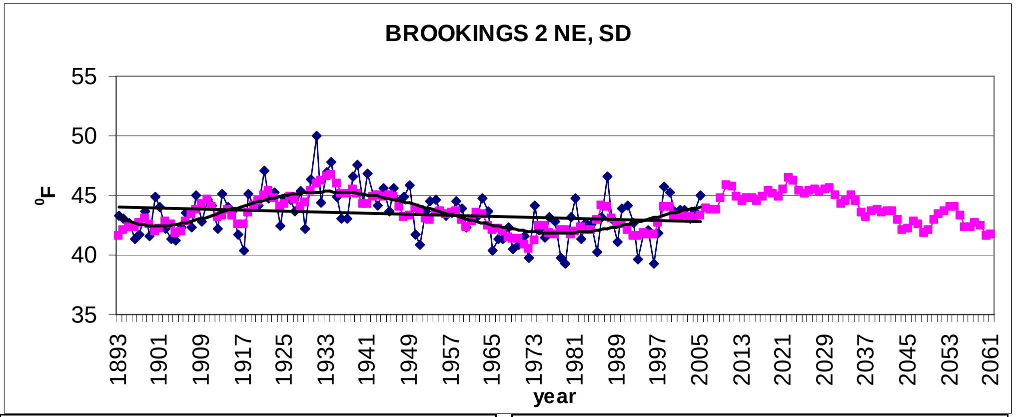


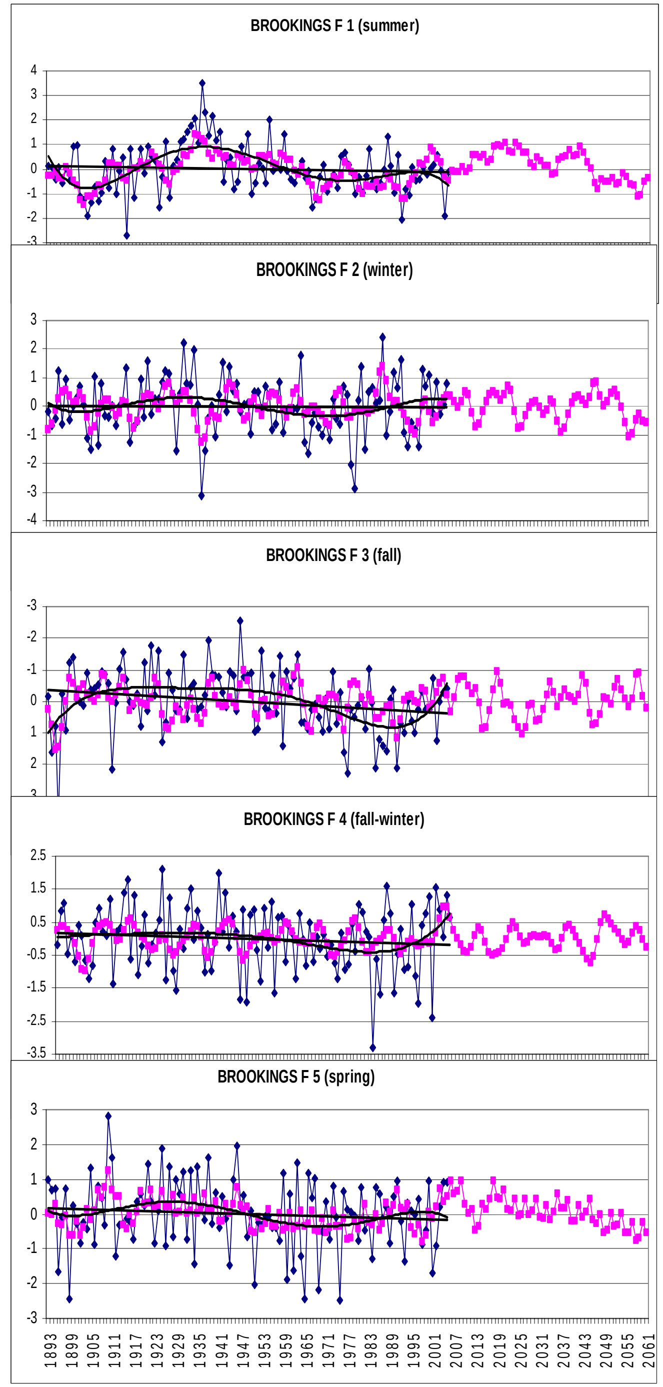
Figure 10. Seasonal structure of annual temperature for Brookings (from Table 5) and charts of annual and seasonal regime.



Annual air temperature			
No	Period [years]	Amplitude	Phase
1	3	1.93833	-1.0583
2	8	2.56663	-0.8274
3	10	1.4472	1.76535
4	13	1.15988	-0.4971
5	16	1.31838	-0.23414
6	21	2.54391	4.27391
7	39	1.02108	4.22381

Figure11. Annual air temperature for Brookings (1893-2005) and results from simplified Fourier analysis (Table). Blue line - annual temperature, black lines are linear and polynomial trends, pink line is model composed from cosins with parameters from Table.





Factor 1			
No	Period [years]	Amplitude	Phase
1	3	0.16029	0.22646
2	6	0.20223	1.31858
3	11	0.18769	4.37053
4	13	0.2621	2.11484
5	21	0.37494	0.74761
6	84	0.63212	3.58725

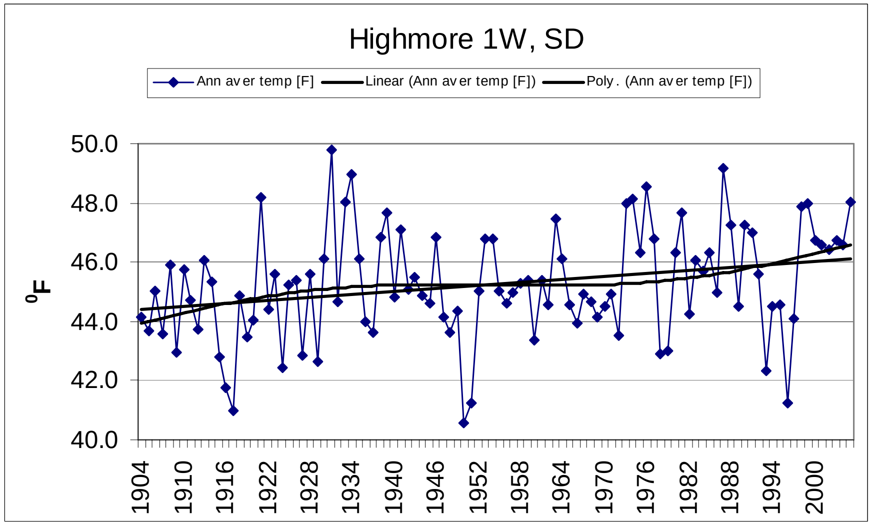
Factor 2			
1	4	0.13171	4.19911
2	6	0.3638	-1.47416
3	11	0.28613	4.05137
4	15	0.28474	2.82017
5	20	0.24016	4.35592
6	31	0.2427	0.36591

Factor 3			
1	3	0.13222	-0.15226
2	5	0.35029	-1.22183
3	8	0.30021	2.5803
4	10	0.19668	2.29238
5	12	0.22555	1.20264
6	15	0.14255	1.48139
7	19	0.20982	0.95253
8	25	0.07796	1.57209
9	32	0.17842	0.70497
10	49	0.21089	-0.93434

Factor 4			
1	5	0.12379	1.5169
2	9	0.33543	2.90933
3	12	0.20554	1.08064
4	16	0.10345	0.46563
5	18	0.05545	0.47558
6	23	0.17821	-0.69769
7	30	0.07695	4.0957
8	47	0.07571	2.58715

Factor 5			
1	3	0.28606	-0.13383
2	7	0.08153	-1.48537
3	9	0.1595	0.27919
4	12	0.13547	2.82676
5	14	0.156	0.70709
6	16	0.16188	0.59013
7	20	0.15396	-0.99627
8	25	0.07865	-1.15649
9	32	0.05096	4.28308
10	93	0.31392	2.14487

Figure 12. Charts of annual temperature and seasonal components for empirical data and models from simplified Fourier analysis (Tables). Blue line - annual temperature and seasonal components, black lines are linear and polynomial trends, pink line is model composed from cosinuses with parameters from the Table.



	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		**0.79**			
FEB		***0.69***		0.26	
MAR				**0.80**	
APR		***0.57***	0.34		0.29
MAY	0.34		***0.50***		
JUN	***0.56***		0.41	0.35	
JUL	***0.69***		0.29		
AUG	**0.72**				
SEP	***0.63***			-0.26	
OCT					**-0.92**
NOV			0.47	***-0.50***	
DEC			**0.77**		
Expl.Var	1.90	1.58	1.51	1.20	1.09
Prp.Totl	0.16	0.13	0.13	0.10	0.09

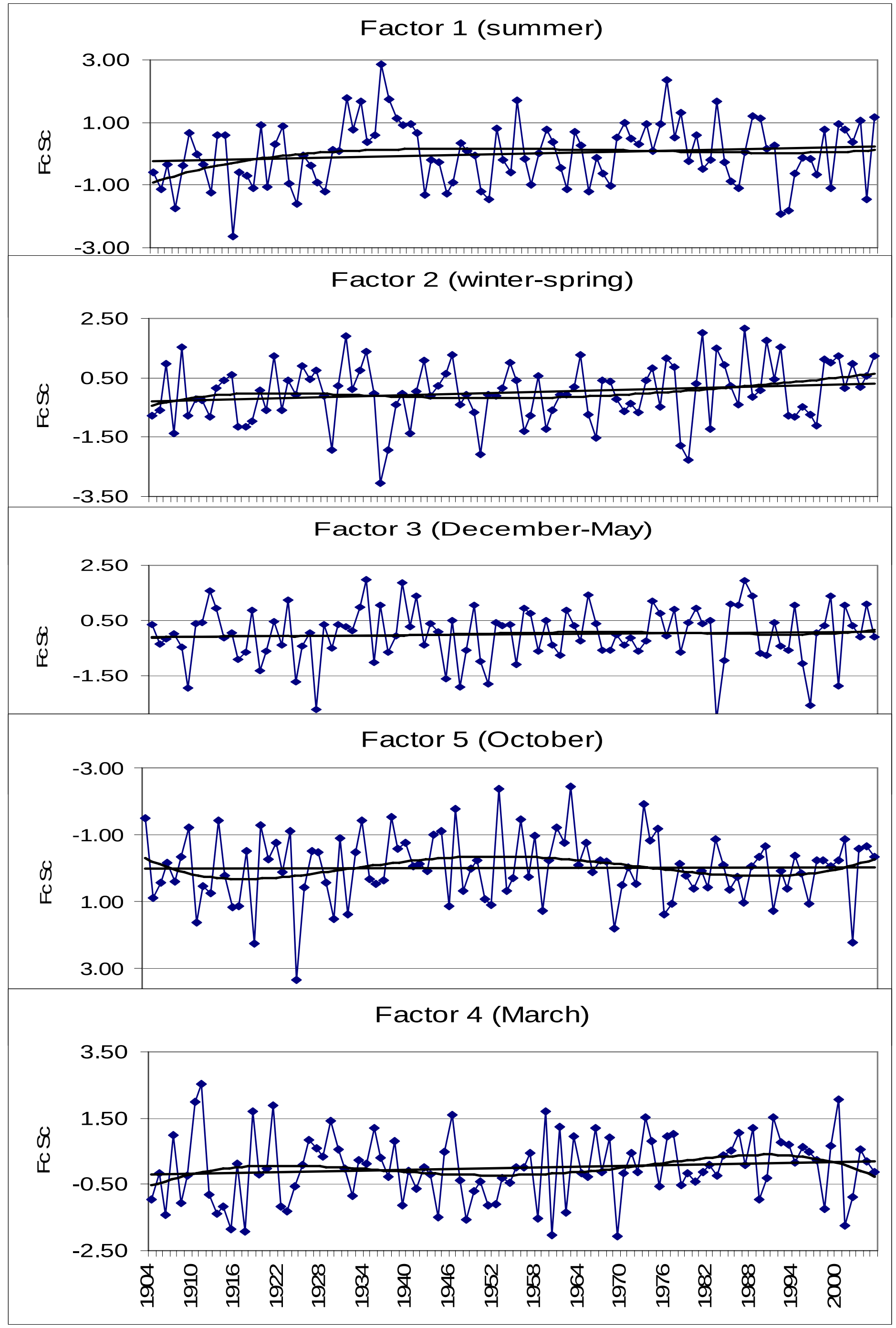
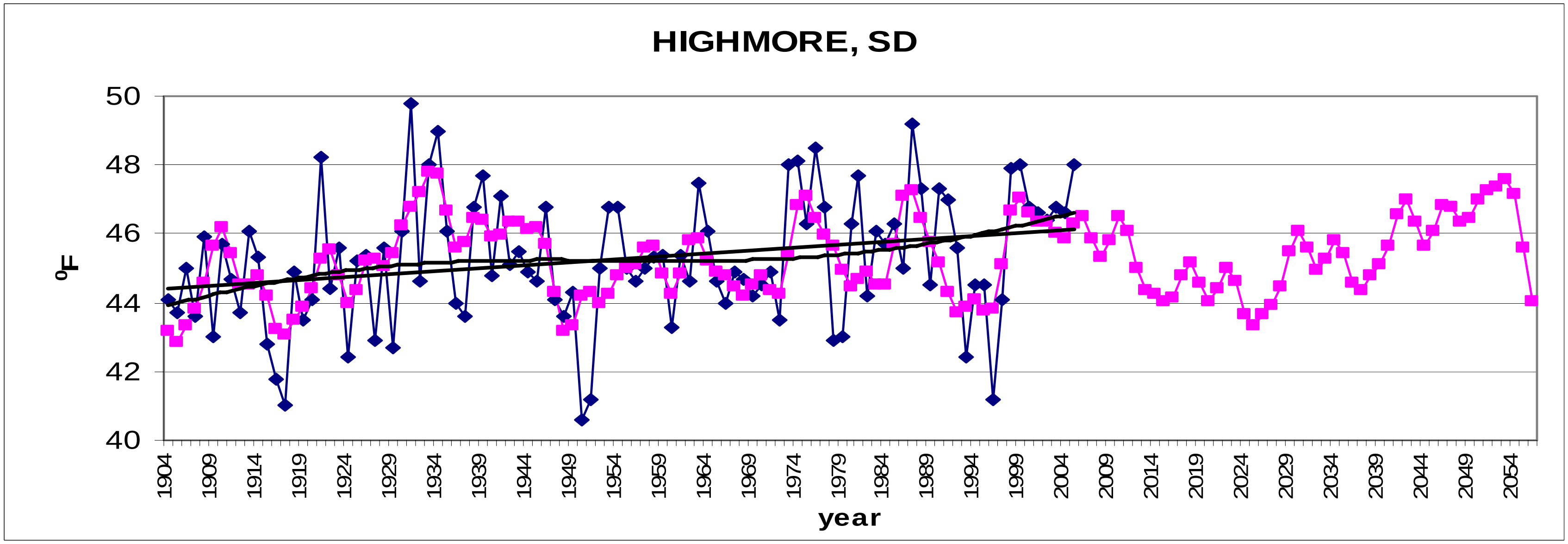
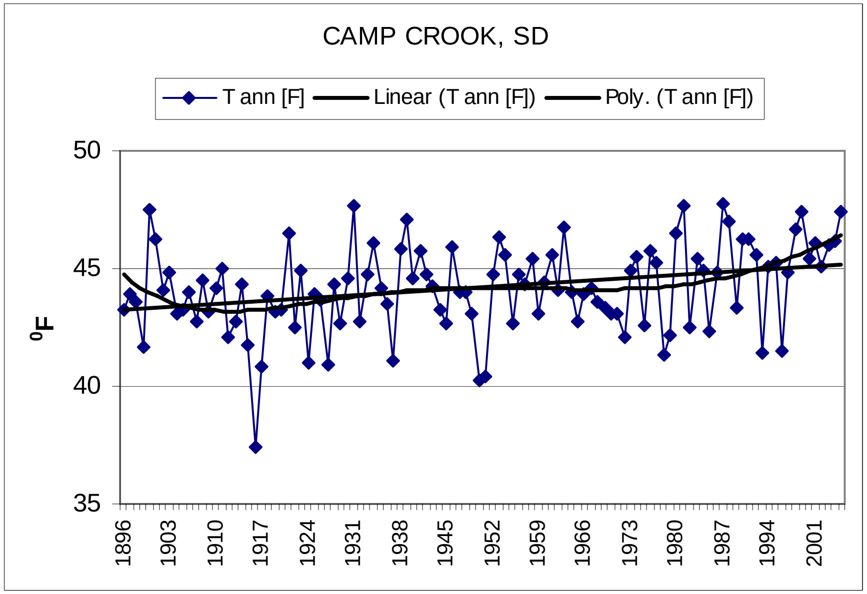


Figure 13. Seasonal structure of annual air temperature for Highmore (from Table 5) and charts of annual and seasonal



Annual air temperature			
No	Period [years]	Amplitude	Phase
1	4	0.34944	-1.3951
2	6	0.46465	-0.03954
3	11	0.74039	4.14611
4	13	0.36575	3.02404
5	15	0.48759	4.23392
6	23	0.50429	2.72906
7	38	0.73824	-1.39315
8	52	0.63713	4.46382

Figure14. Annual air temperature for Highmore (1904-2005) and results from simplified Fourier analysis (Table). Blue line - annual temperature, black lines are linear and polynomial trends, pink line is model composed from cosinuses with parameters from the Table.



	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
JAN		***0.61***	0.25		
FEB		**0.80**		-0.28	
MAR		0.58		0.46	
APR			***0.64***	-0.42	
MAY			**0.83**		
JUN	***0.57***	0.25	0.37		
JUL	**0.72**				
AUG	***0.63***				
SEP	***0.56***				0.30
OCT				**0.83**	
NOV					**0.89**
DEC					0.37
Expl. Var	1.65	1.47	1.50	1.27	1.18
Prp.Totl	0.14	0.12	0.13	0.11	0.10

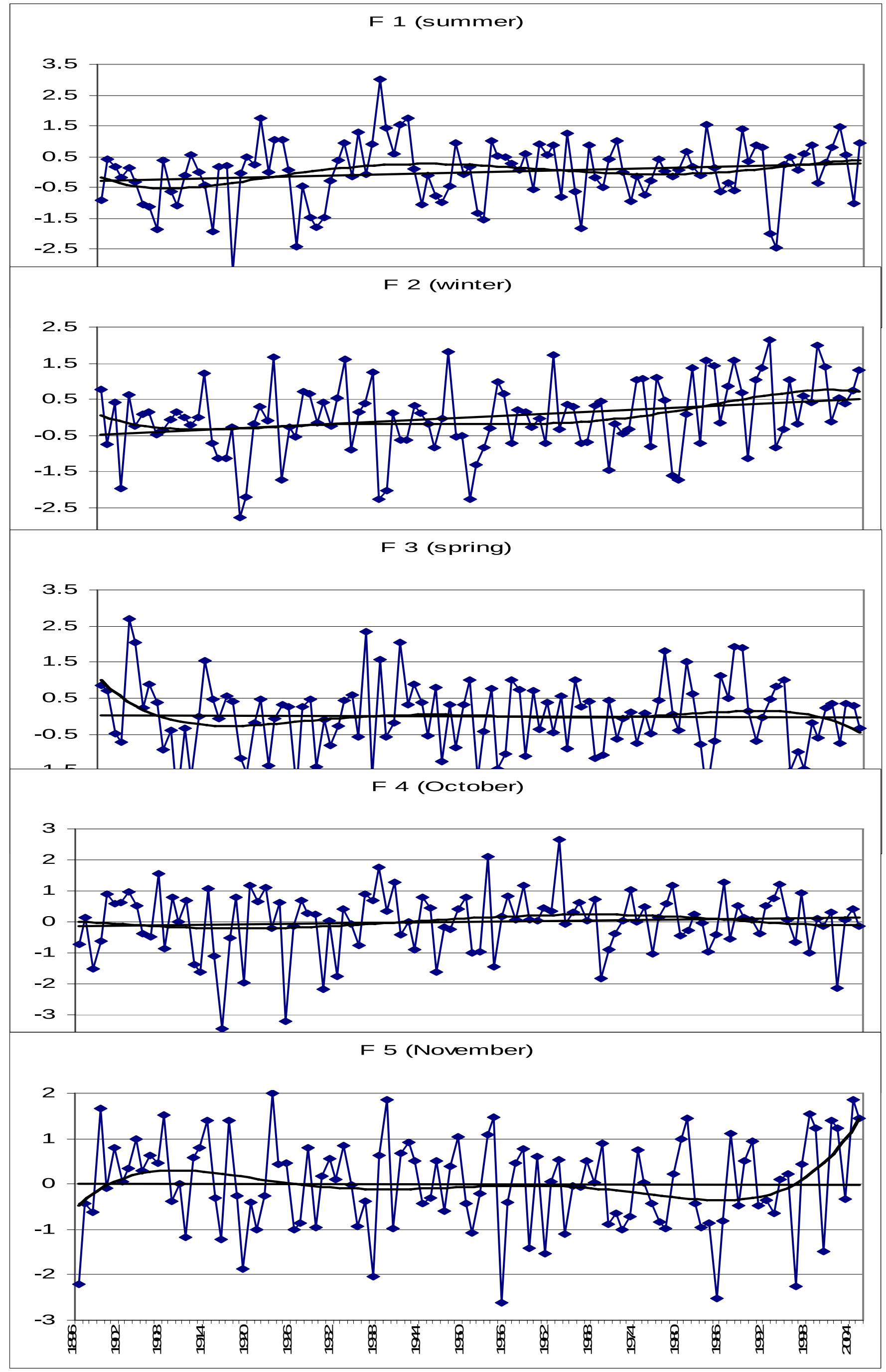
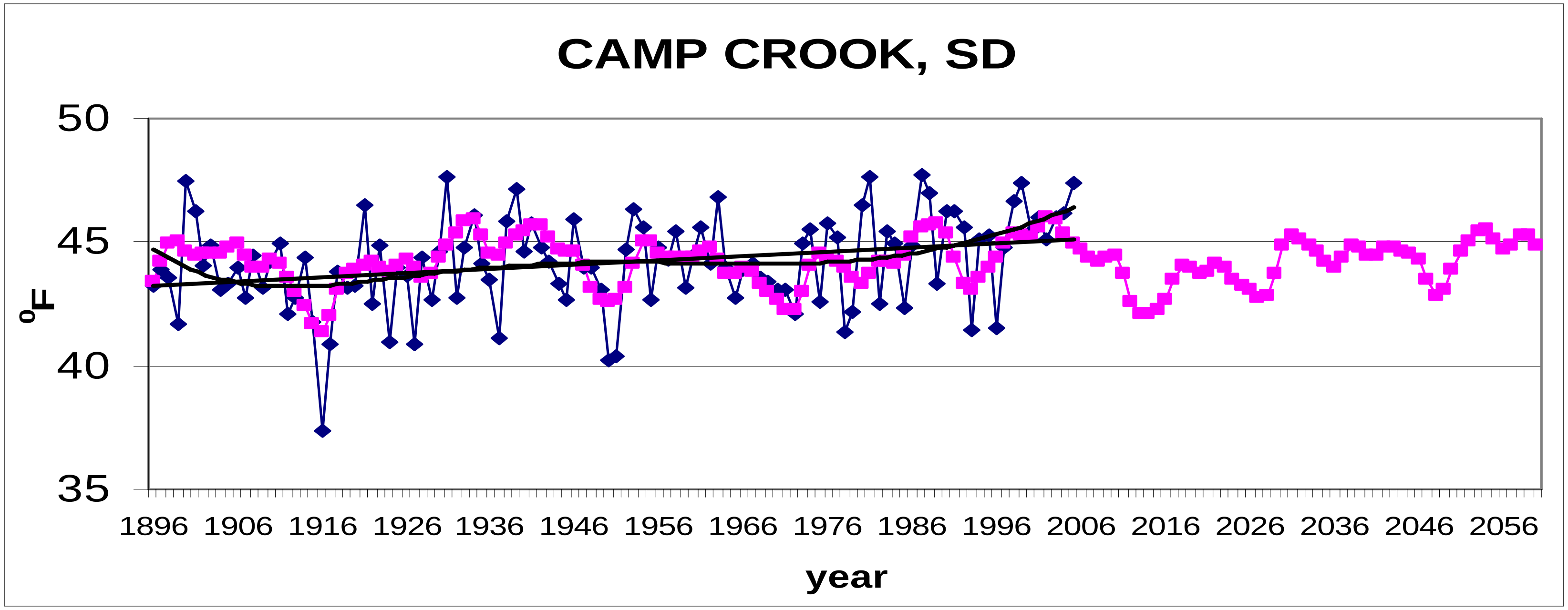
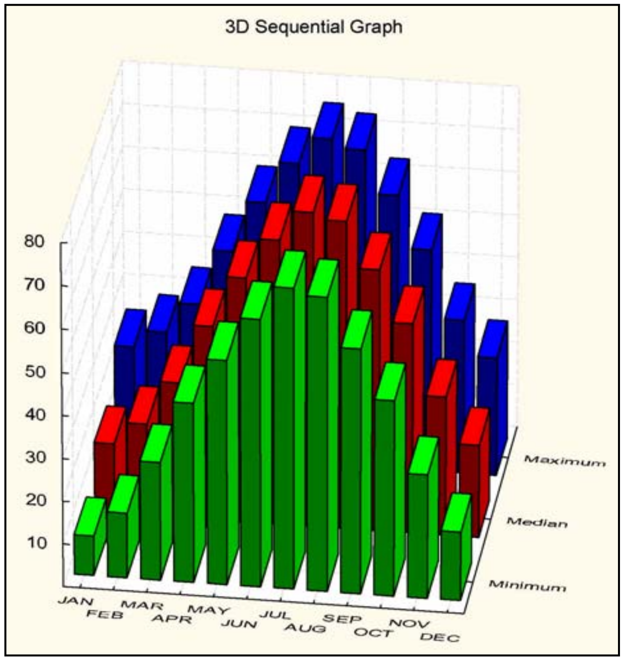


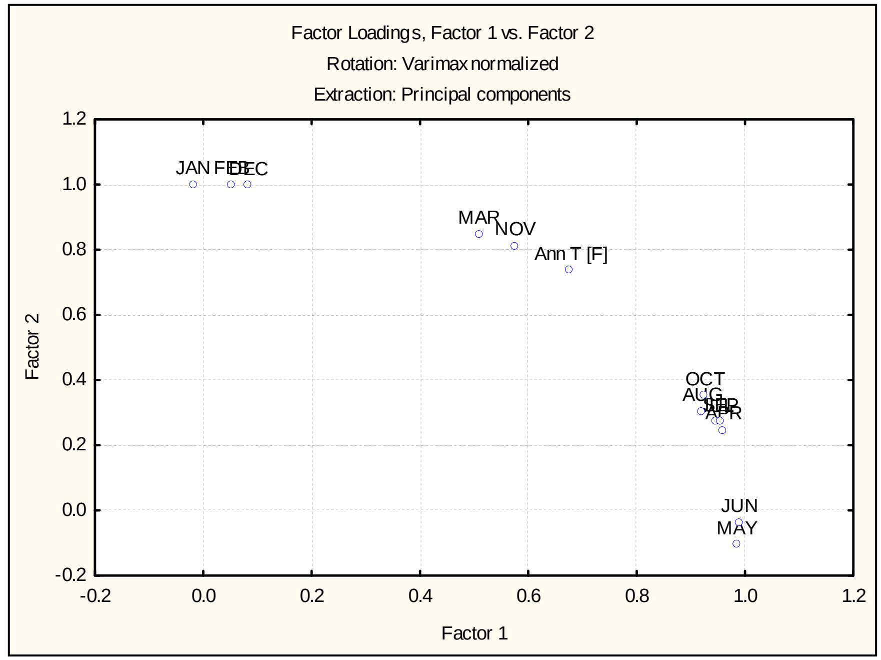
Figure 15. Seasonal structure of annual air temperature for Camp Crook (from Table 5) and charts of annual and seasonal regimes.



Annual air temperature			
No	Period [years]	Amplitude	Phase
1	4	0.19544	-1.3093
2	7	0.42165	2.79188
3	11	0.5968	2.59445
4	14	0.24524	4.38533
5	16	0.3803	-1.06161
6	20	0.44461	2.11095
7	25	0.43526	3.22506
8	32	0.39537	1.36274
9	54	0.70476	-0.97402

Figure 16. Annual air temperature for Camp Crook (1896-2005) and results from simplified Fourier analysis (Table). Blue line - annual temperature, black lines are linear and polynomial trends, pink line is model composed from cosins with parameters from the Table.



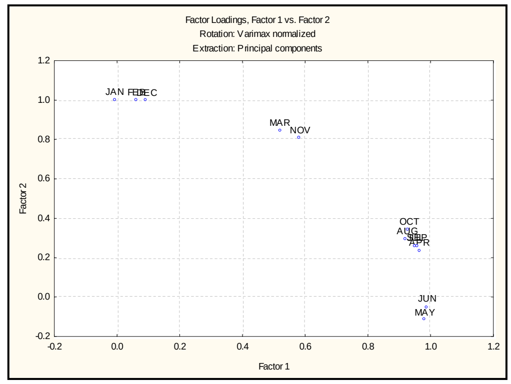


Variable	Mean	Minimum	Maximum
JAN	16.3	9.3	24.6
FEB	21.3	15.2	28.5
MAR	31.4	27.6	35.6
APR	45.4	42.0	48.6
MAY	57.0	52.4	60.4
JUN	66.5	62.3	70.1
JUL	73.3	70.1	76.3
AUG	71.6	68.5	74.3
SEP	61.1	57.2	64.2
OCT	49.0	45.7	51.9
NOV	32.5	29.0	35.9
DEC	21.4	16.1	27.8
Ann T [F]	45.6	42.6	48.4

	Factor 1	**Factor 2**			**Factor 1**	**Factor 2**
JAN		**1.00**		JAN		**1.00**
FEB		**1.00**		FEB		**1.00**
MAR	***0.51***	**0.85**		MAR	***0.52***	**0.84**
APR	**0.96**			APR	**0.96**	
MAY	**0.98**			MAY	**0.98**	
JUN	**0.99**			JUN	**0.99**	
JUL	**0.95**	0.27		JUL	**0.95**	0.26
AUG	**0.92**	0.30		AUG	**0.93**	0.29
SEP	**0.95**	0.27		SEP	**0.96**	0.26
OCT	**0.93**	0.35		OCT	**0.93**	0.34
NOV	***0.58***	**0.81**		NOV	***0.58***	**0.80**
DEC		**1.00**		DEC		**0.99**
Ann T [F]	***0.68***	**0.73**		Expl.Var	7.04	4.74
Expl.Var	7.45	5.33		Prp.Totl	0.59	0.39
Prp.Totl	0.57	0.41				

Figure 17. Statistics and factor model of monthly air temperature for the state of South Dakota: left – graph and table from 29 stations during 1932-98; right – scatter plot and table for Factor Loading; the values of Factor Loading equal 1.0 are result of formatting numbers in the Table.

	Factor 1	Factor 2			Factor 1	Factor 2
JAN		**1.00**		JAN		**1.00**
FEB		**1.00**		FEB		**1.00**
MAR	***0.51***	**0.85**		MAR	***0.52***	**0.84**
APR	**0.96**			APR	**0.96**	
MAY	**0.98**			MAY	**0.98**	
JUN	**0.99**			JUN	**0.99**	
JUL	**0.95**	0.27		JUL	**0.95**	0.26
AUG	**0.92**	0.30		AUG	**0.93**	0.29
SEP	**0.95**	0.27		SEP	**0.96**	0.26
OCT	**0.93**	0.35		OCT	**0.93**	0.34
NOV	***0.58***	**0.81**		NOV	***0.58***	**0.80**
DEC		**1.00**		DEC		**0.99**
Ann T [F]	***0.68***	**0.73**		Expl. Var	7.04	4.74
Expl.Var	7.45	5.33		Prp.Totl.	0.59	0.39
Prp.Totl	0.57	0.41				



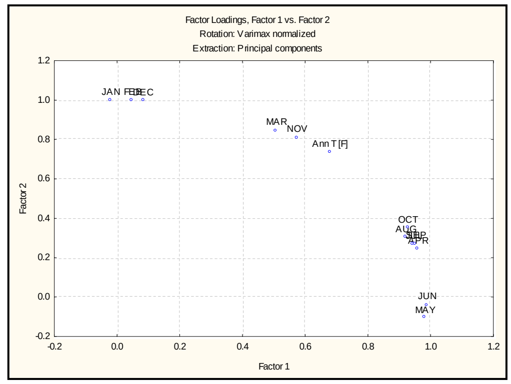
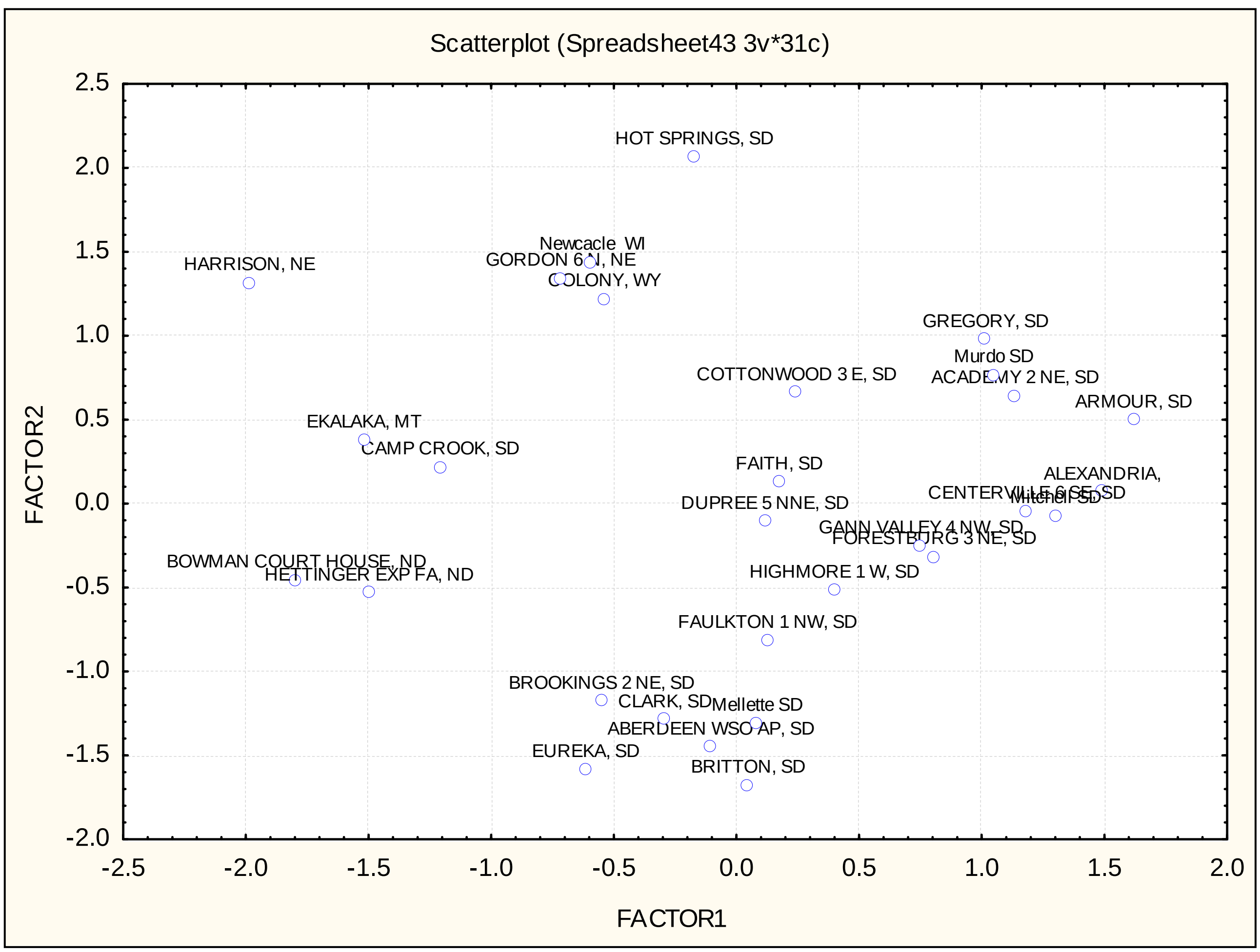
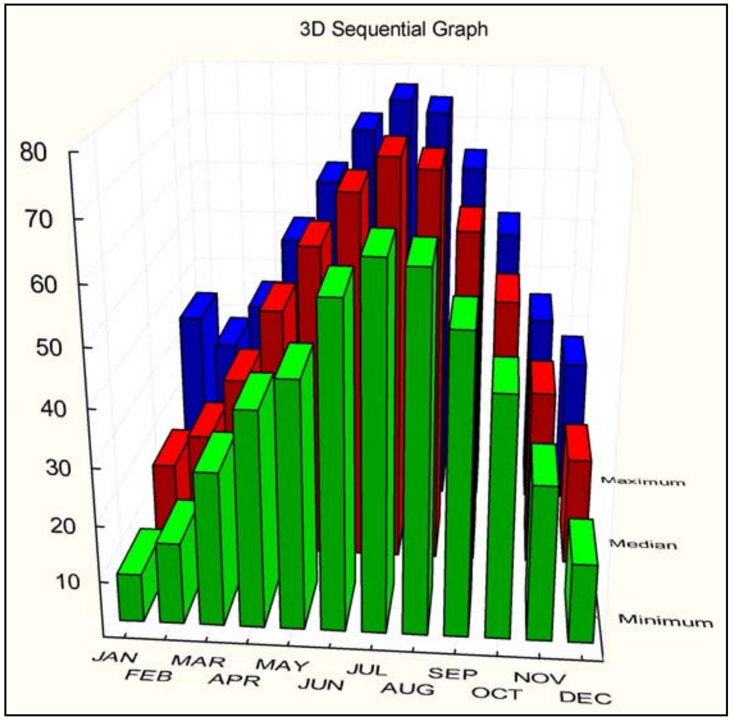
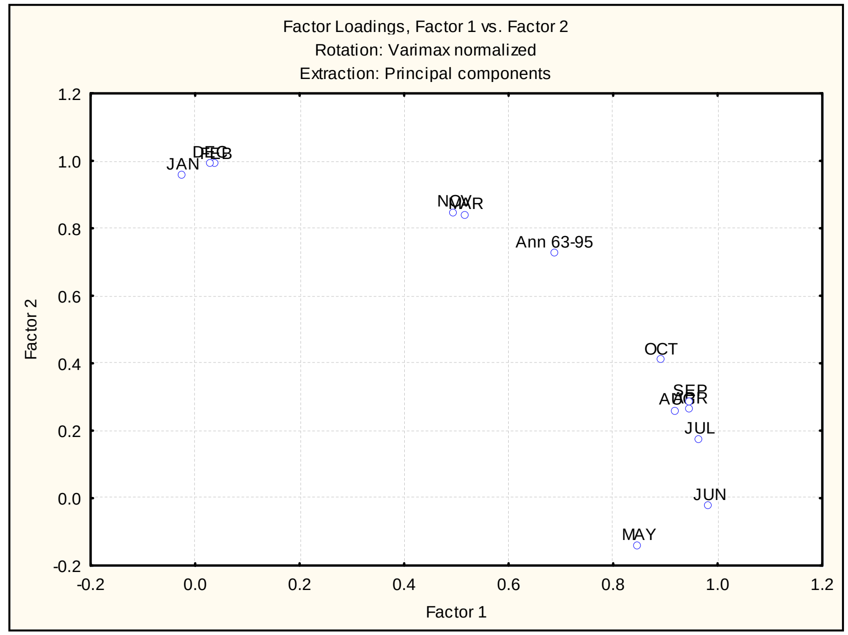


Figure 18. Table of Factor Loading and scatter plots for monthly air temperature for territory of South Dakota (upper part); scatter plot for Factor Scores from 29 stations for 1932-98 (down).







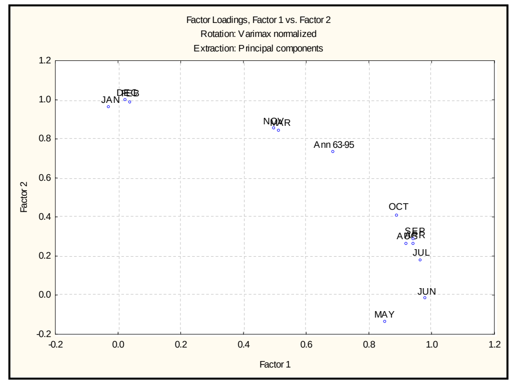
Variable	Mean	Minimum	Maximum
JAN	16.1	8.6	34.3
FEB	21.7	14.5	29.2
MAR	32.6	27.5	37.1
APR	45.7	38.5	50.5
MAY	57.1	43.9	61.8
JUN	66.8	57.3	71.6
JUL	72.8	63.8	77.2
AUG	70.9	62.5	74.9
SEP	60.5	52.8	64.8
OCT	48.4	42.7	52.5
NOV	32.2	27.5	36.1
DEC	20.1	14.0	27.4
Ann T [F]	45.4	41.4	49.7

	Factor 1	Factor 2			Factor 1	Factor 2
JAN		**0.96**		JAN		**0.96**
FEB		**0.99**		FEB		**0.99**
MAR	0.47	**0.87**		MAR	***0.53***	**0.83**
APR	**0.93**	0.31		APR	**0.95**	0.25
MAY	**0.86**			MAY	**0.85**	
JUN	**0.98**			JUN	**0.98**	
JUL	**0.95**			JUL	**0.97**	
AUG	**0.91**	0.31		AUG	**0.92**	0.25
SEP	**0.93**	0.34		SEP	**0.95**	0.27
OCT	**0.87**	0.46		OCT	**0.90**	0.40
NOV	0.45	**0.87**		NOV	***0.51***	**0.84**
DEC		**0.99**		DEC		**0.99**
Ann T [F]	***0.65***	**0.76**		Expl.Var	6.63	4.68
Expl.Var	6.77	4.65		Prp.Totl	0.55	0.39
Prp.Totl	0.56	0.39				

Figure 19. Statistics and factor model for monthly air temperature for the state of South Dakota: left – graph and table from 94 stations for 1963-95; right – scatter plot and table for Factor Loading.

	Factor 1	Factor 2
JAN		**0.96**
FEB		**0.99**
MAR	0.47	**0.87**
APR	**0.93**	0.31
MAY	**0.86**	
JUN	**0.98**	
JUL	**0.95**	
AUG	**0.91**	0.31
SEP	**0.93**	0.34
OCT	**0.87**	0.46
NOV	0.45	**0.87**
DEC		**0.99**
Ann T [F]	***0.65***	**0.76**
Expl.Var	6.77	4.65
Prp.Totl	0.56	0.39

	Factor 1	Factor 2
JAN		**0.96**
FEB		**0.99**
MAR	***0.53***	**0.83**
APR	**0.95**	0.25
MAY	**0.85**	
JUN	**0.98**	
JUL	**0.97**	
AUG	**0.92**	0.25
SEP	**0.95**	0.27
OCT	**0.90**	0.40
NOV	***0.51***	**0.84**
DEC		**0.99**
Expl.Var	6.63	4.68
Prp.Totl	0.55	0.39



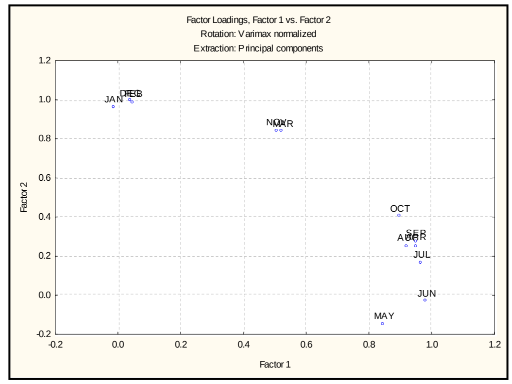
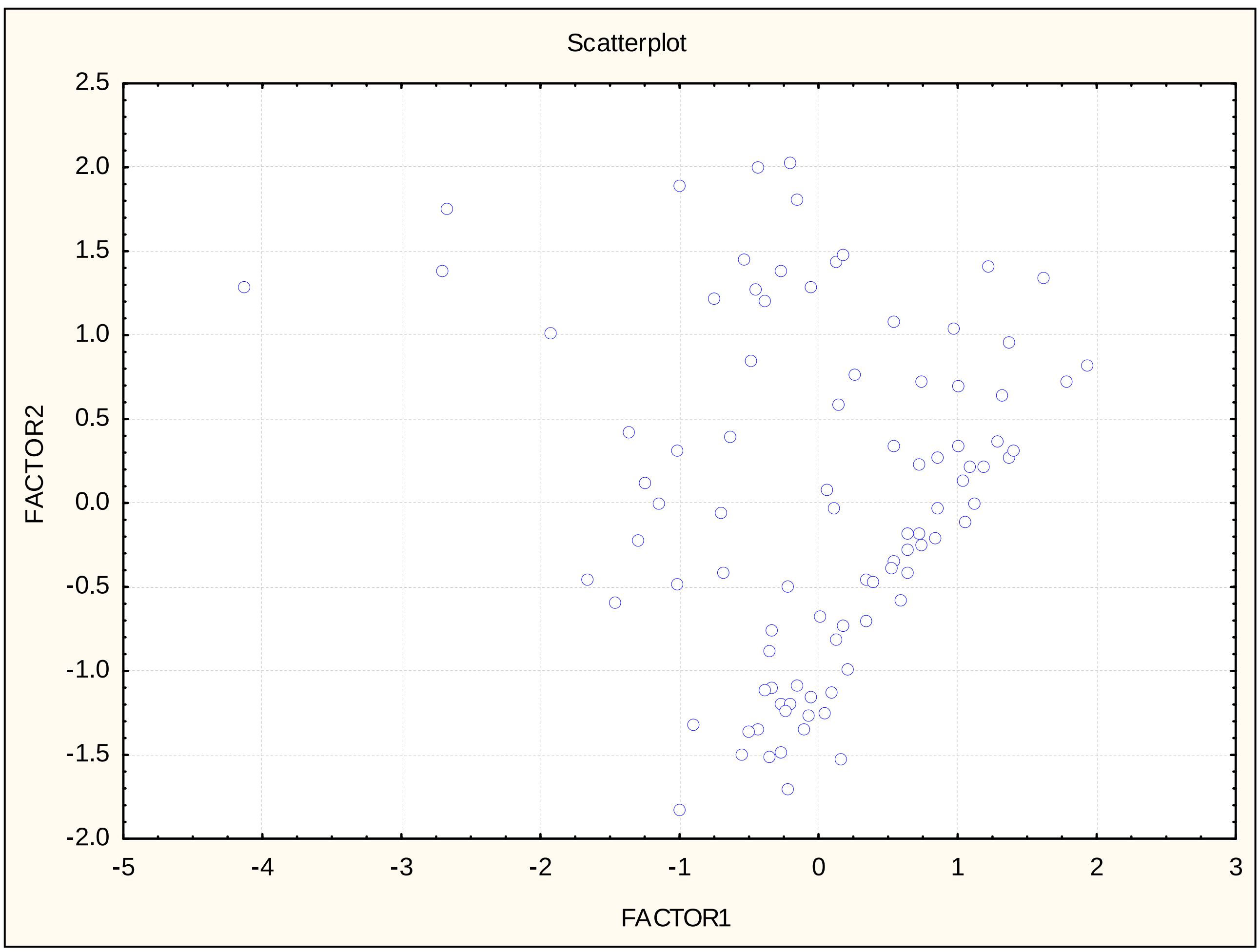


Figure 20. Table of Factor Loading and scatter plots for monthly air temperature for territory of South Dakota (upper part); scatter plot for Factor Scores from 94 stations for 1963-95 (down).



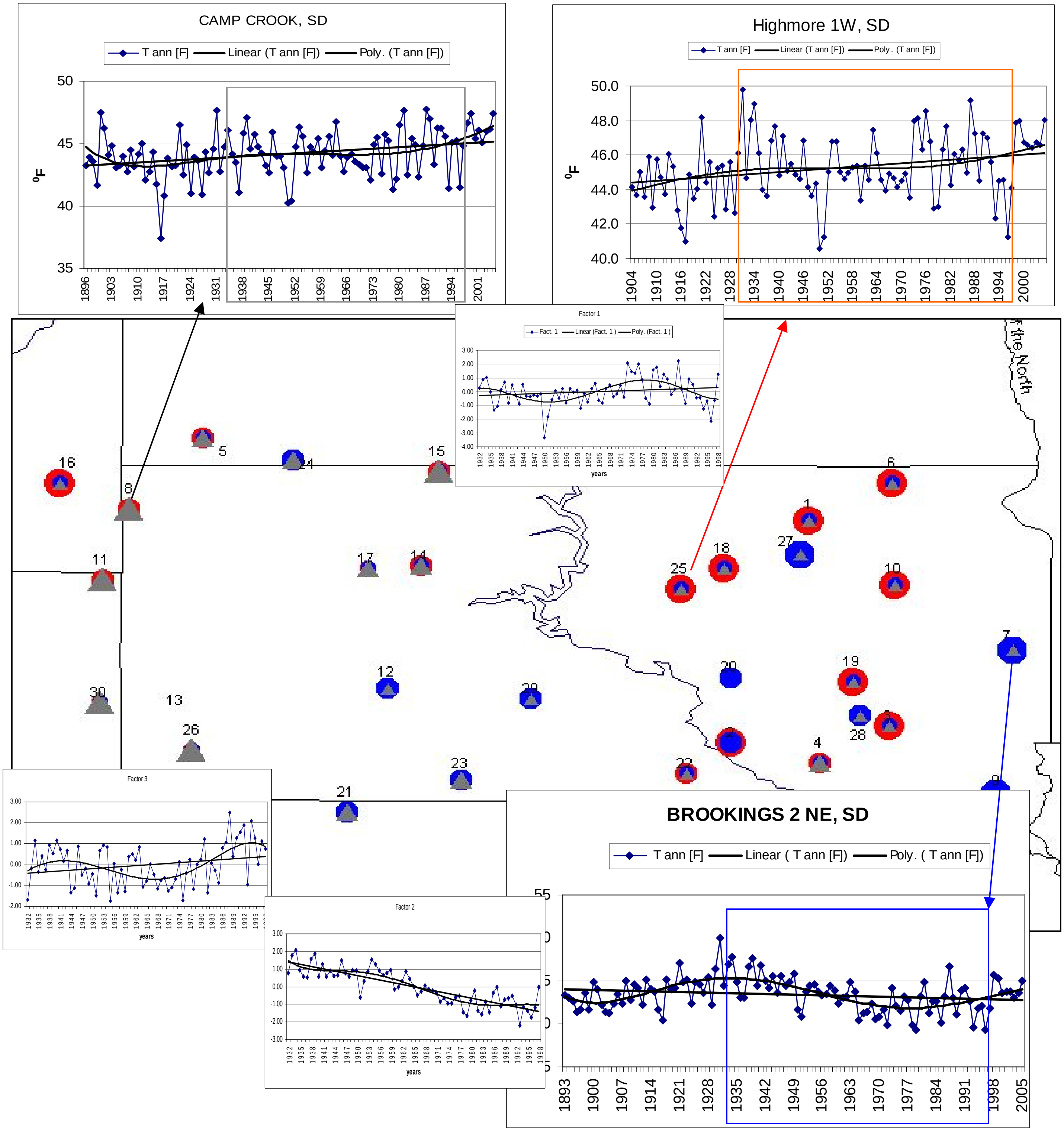


Figure 21. Distribution of Factor Loadings for period of observation 1932 – 1998; size of sign follows grades in factor loadings: 0.25 – 0.5; 0.5-0.7; 0.7- 0.99, charts of annual temperature regime (^{o}F) for three the most typical for every group of stations; the box shows the mutual interval; charts of factor scores.

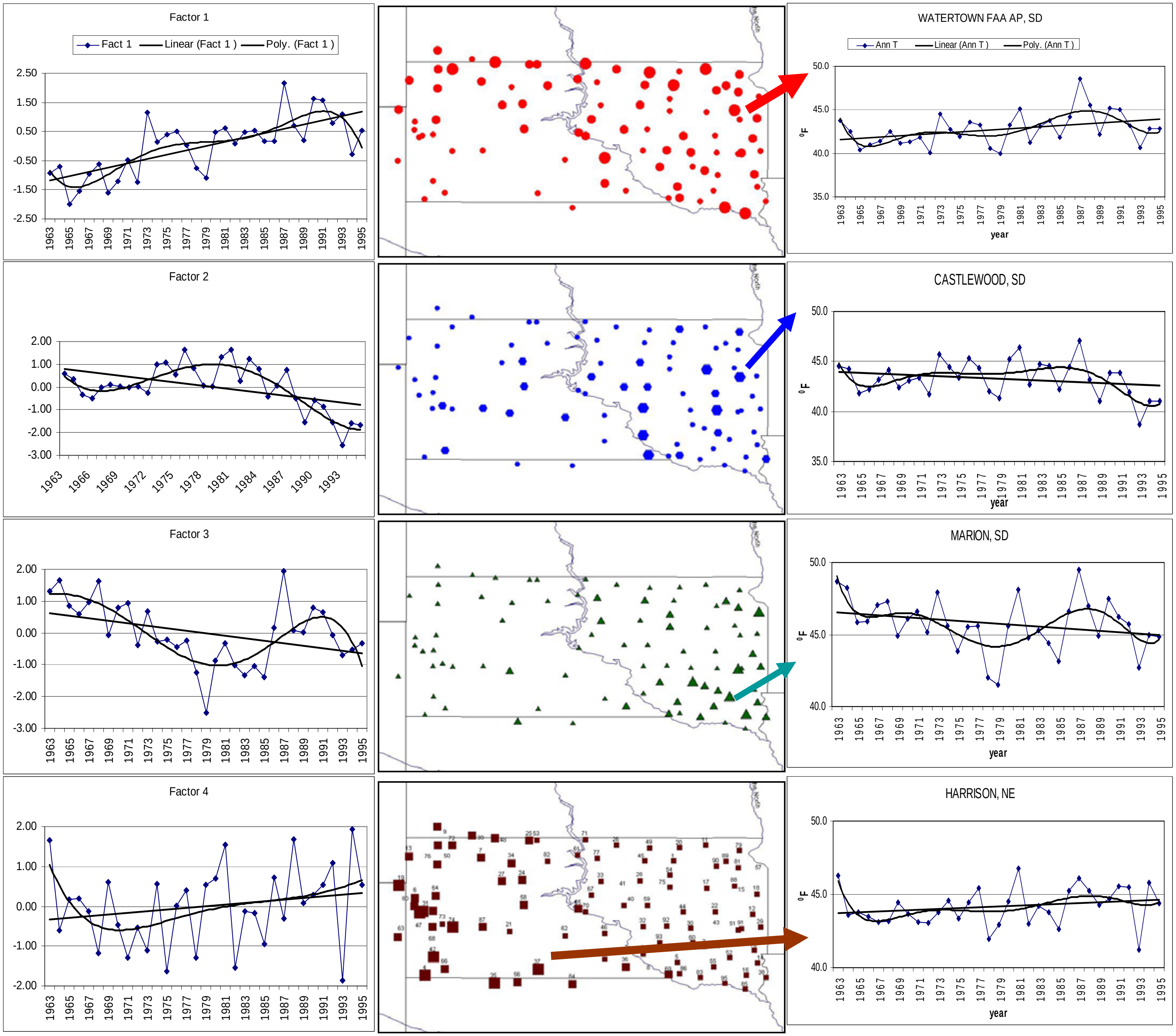


Figure 22. Distribution of Factor Loadings (middle) for period of observation 1963 – 1995; size of sign follows grades in factor loadings: 0.25 – 0.5; 0.5-0.7; 0.7- 0.99 and charts of factors scores (left) and of annual temperature regimes (^{o}F) for four of the most typical group of stations (right): Watertown, Castlewood, Marion and Harrison.

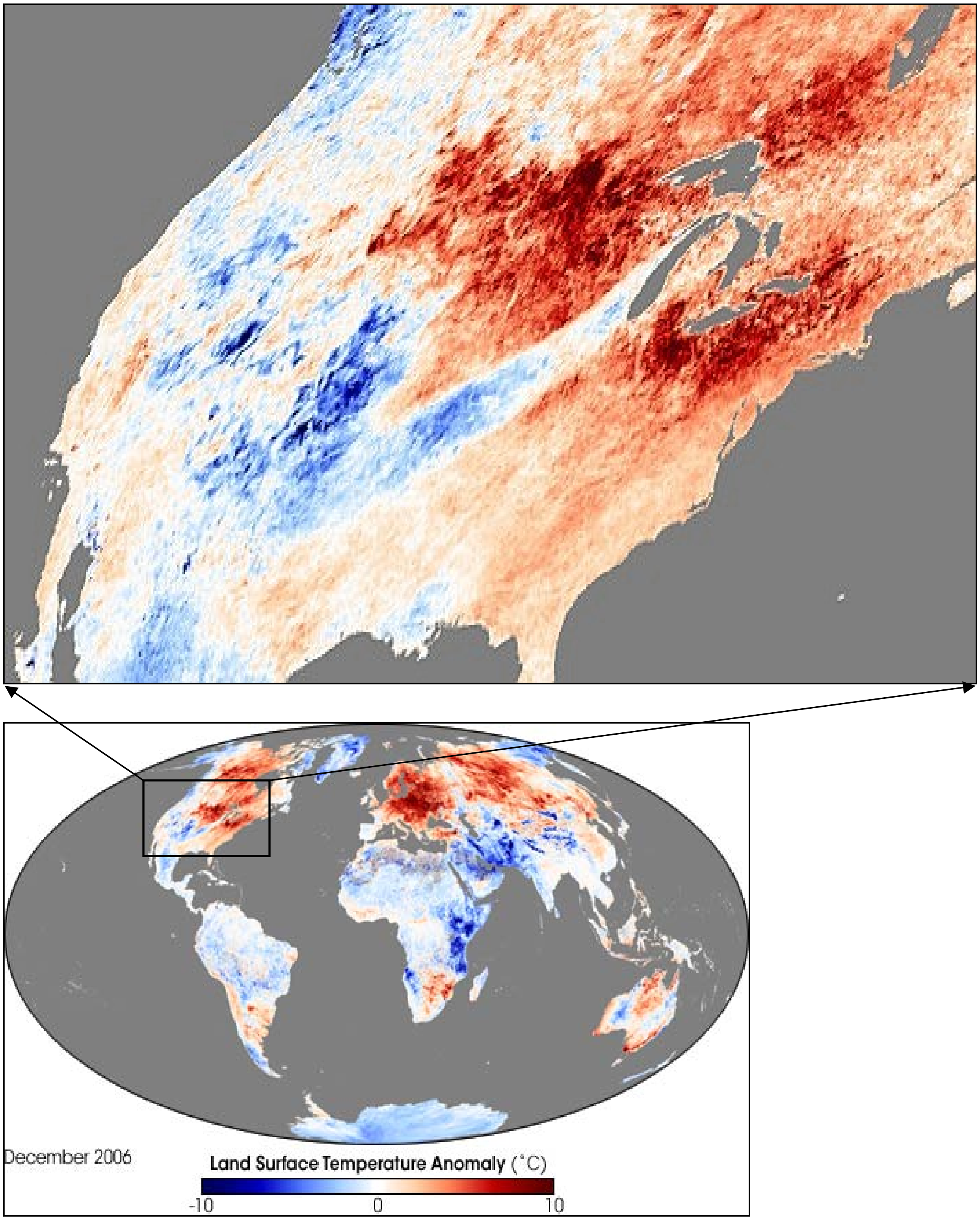
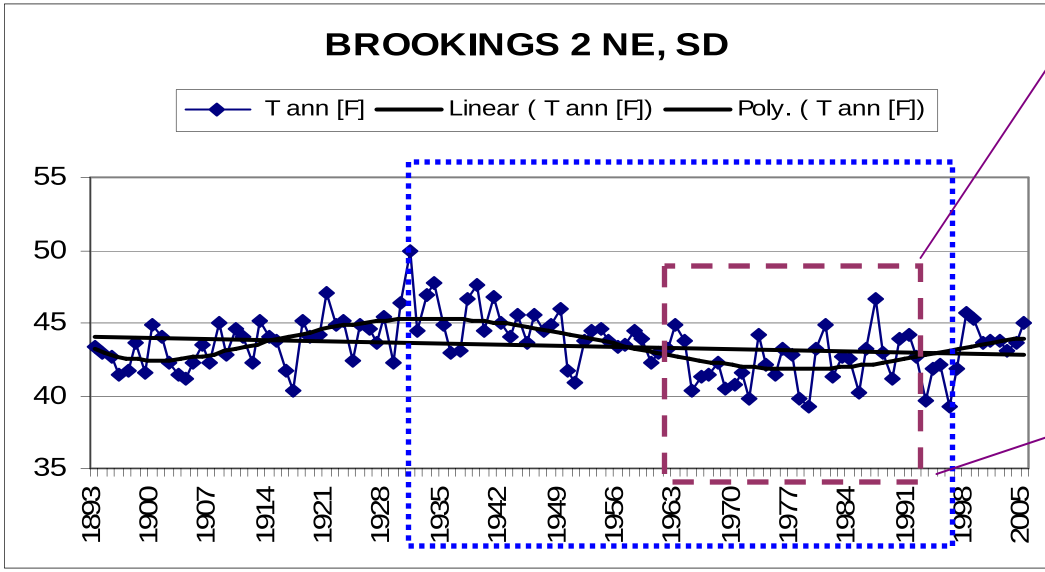
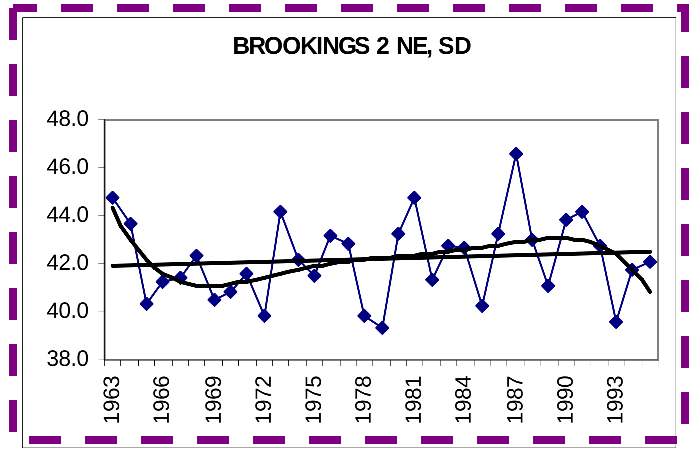
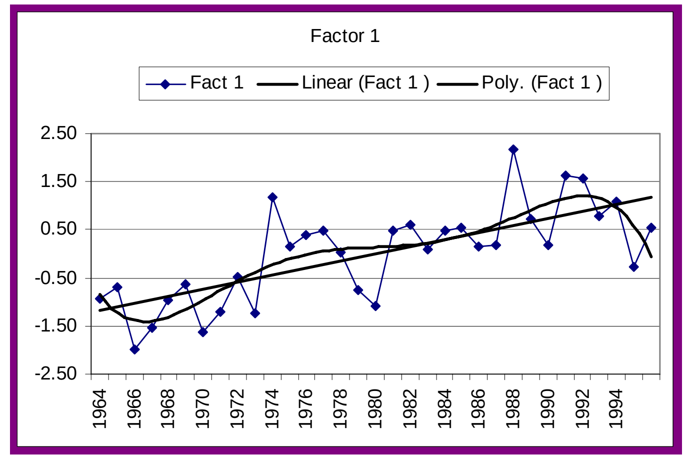
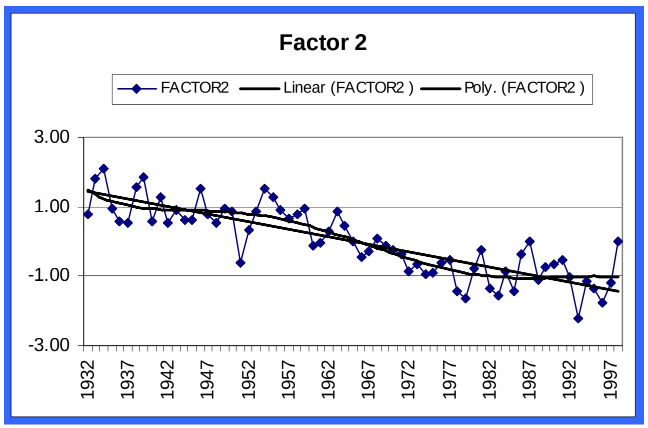


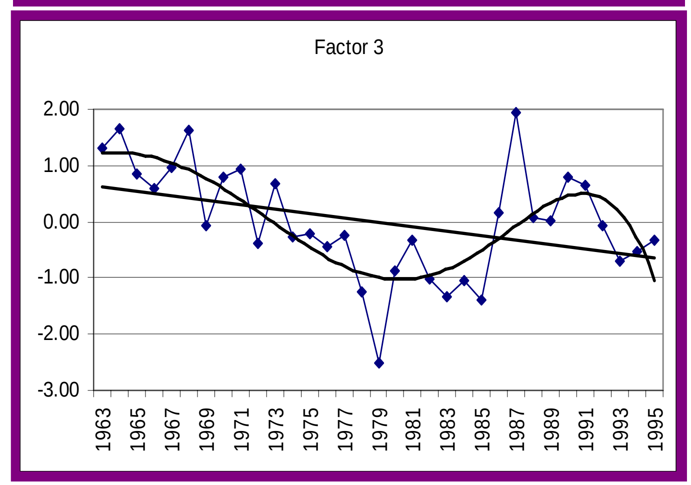
Figure 23. Distributions of Temperatures in December 2006 temperature anomalies on a global scale and an enlarged part of the contiguous US. From NOOA Web site Earth Observatory: http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/globallsta_tmo_200612.jpg











Station (from Table 2)	Factor 1	Factor 2	Factor 3	
BROOKINGS 2 NE, SD	0.42	**0.77**	0.30	
Station (from Table 3).	Factor 1	Factor 2	Factor 3	Factor 4
BROOKINGS 2 NE, SD	***0.60***	0.42	***0.51***	0.36

Figure 24. Time series of annual temperature for Brookings; boxes show the intervals used for different factor models: 1932-98 and 1963-95; exemptions of Factor Loadings from Tables 2 and 3 for Brookings and charts of Factor Scores from those models of Brookings having high values.

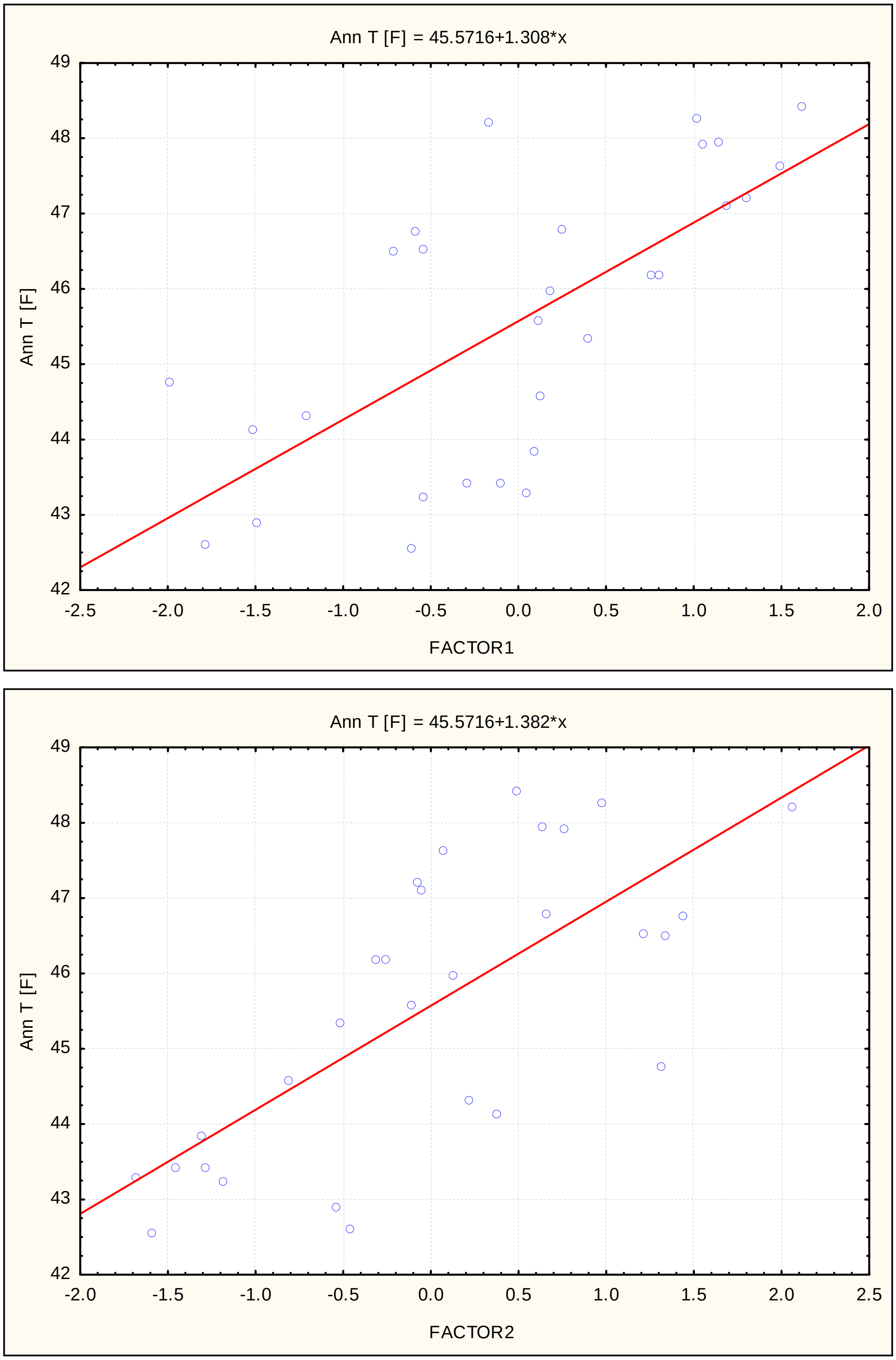
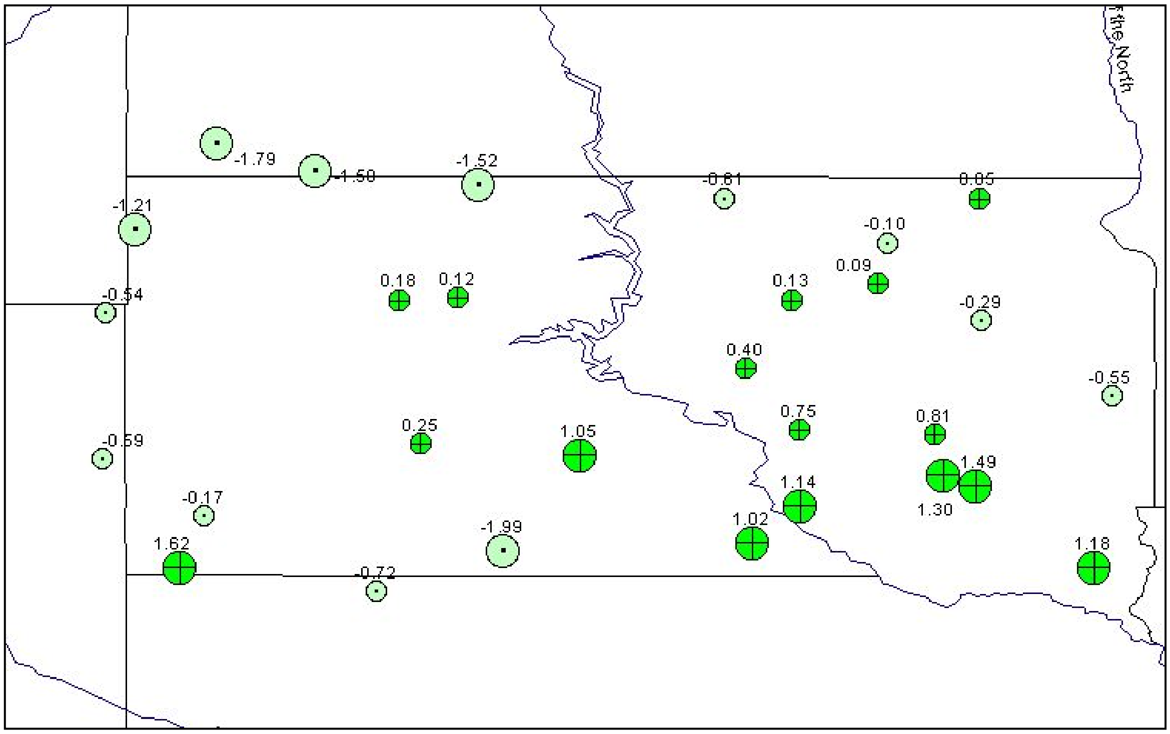


Figure 25. Regression of annual temperatures from Factor Scores for 29 stations during 1932-1998.



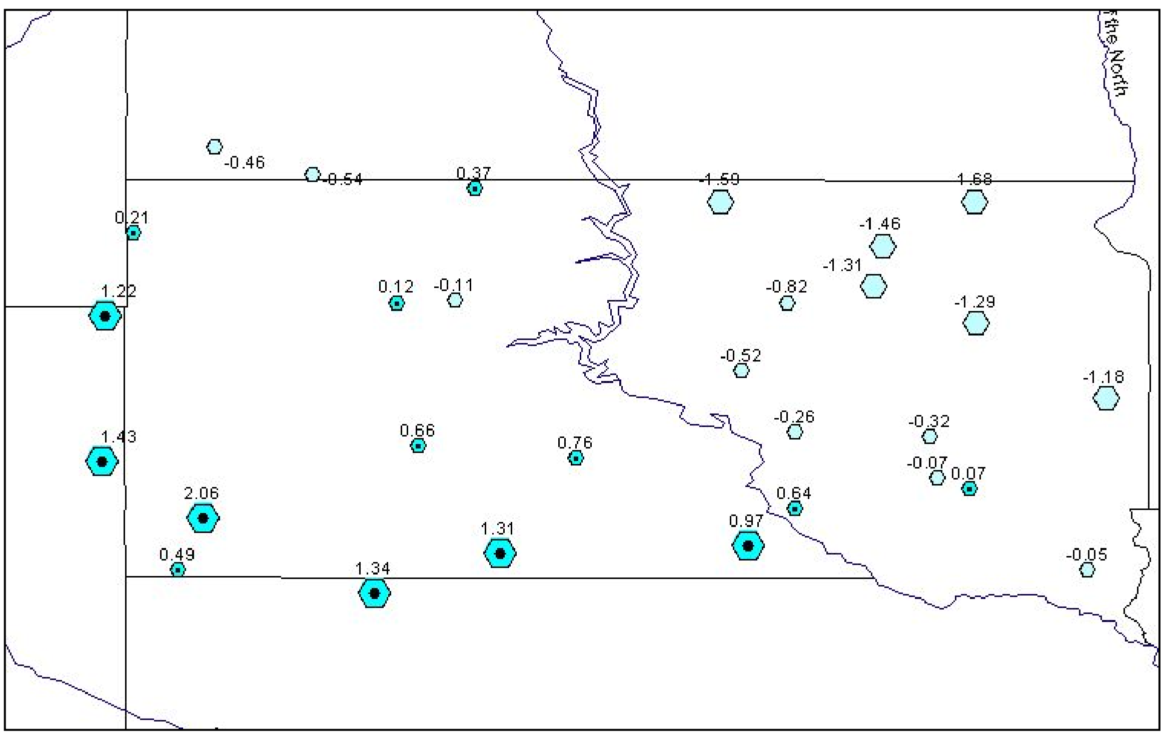


Figure 26. Distribution of Factor Scores for stations during the observation period of 1932 – 1998; size of signs follows grades of negative and positive Factor Scores values: < -1.0; -1.0 – 0.0; 0.0 – 1.0; > 1.0.

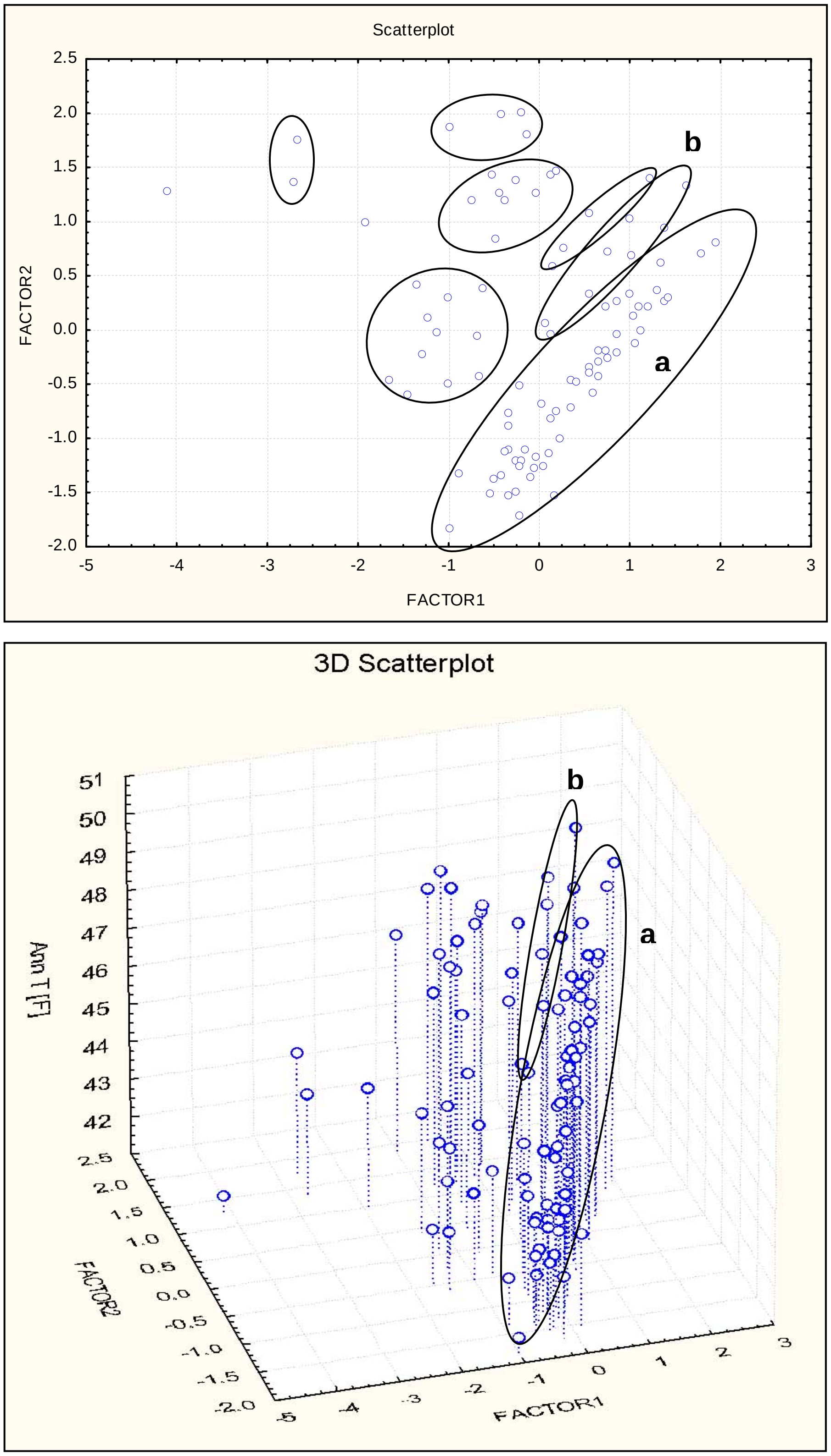


Figure 27. Distribution of stations in planes of Factors 1 & 2 for 1963-95 (upper); the same with additional axis of annual temperature. Ovals on both scatter plots show possible groupings of stations.

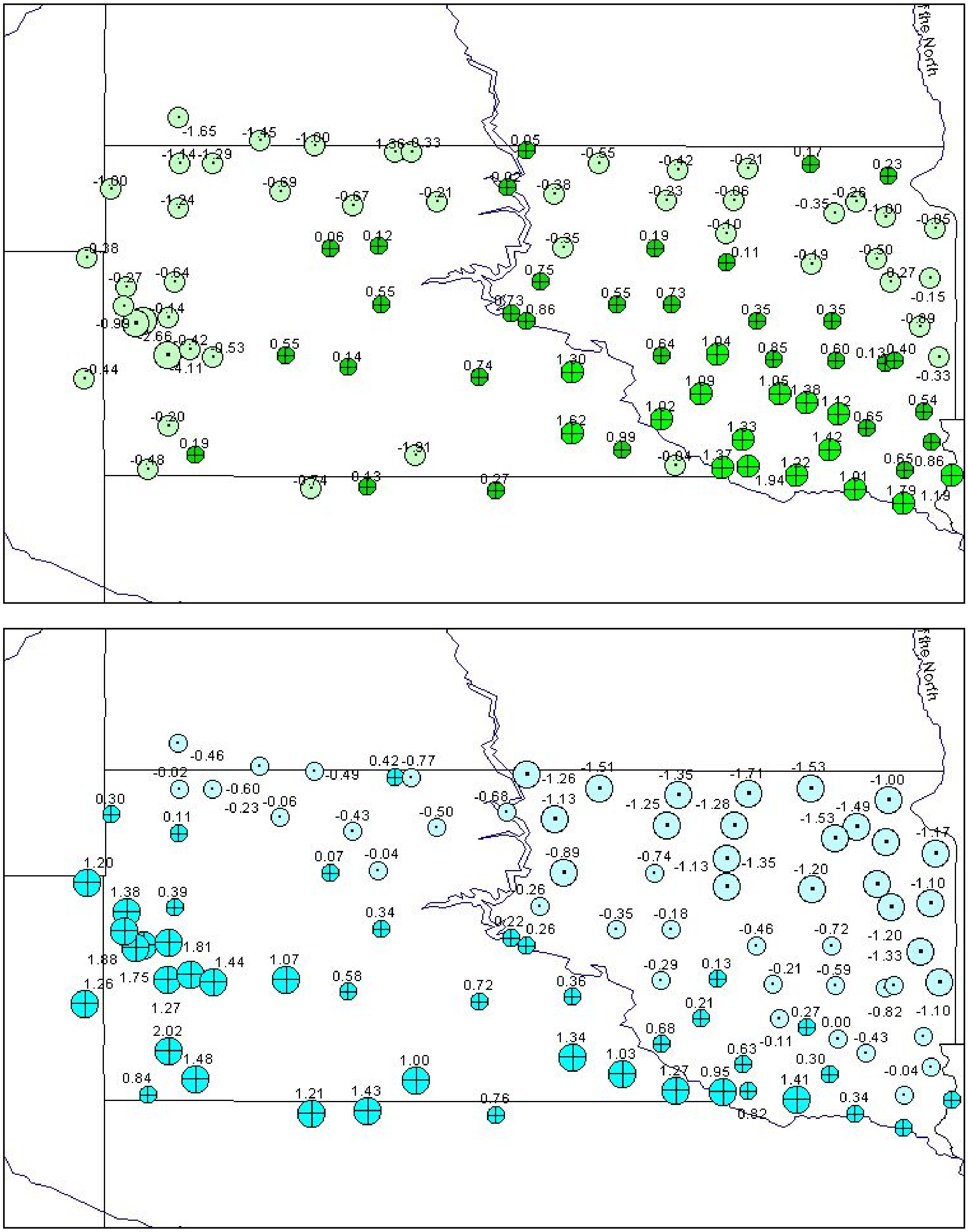


Figure 28. Distribution of Factor Scores for stations during the observation period of
1963 – 1995; size of signs follows grades of negative and positive Factor Scores values:
< -1.0; -1.0 – 0.0; 0.0 – 1.0; > 1.0.

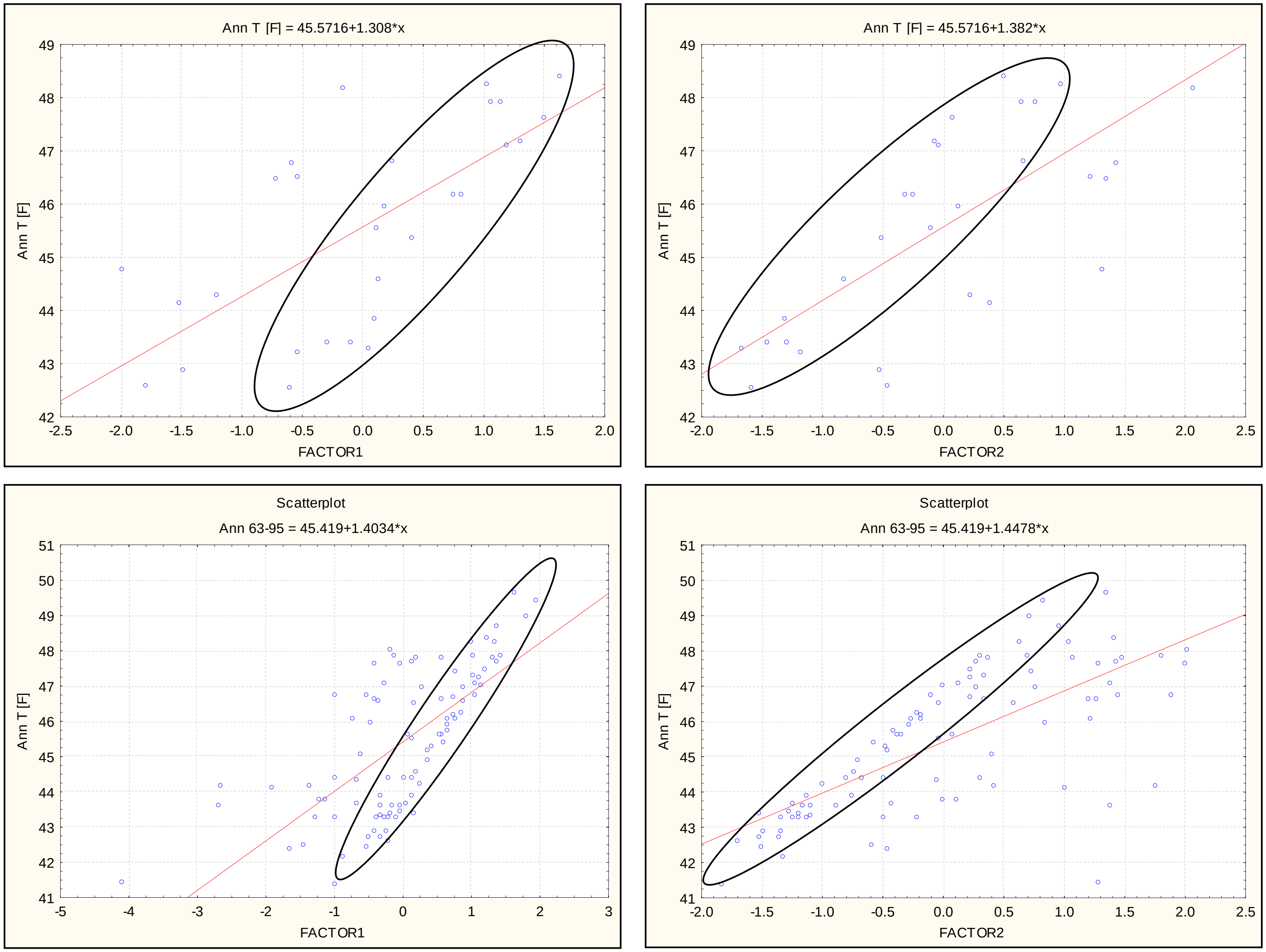


Figure 29. Regression of annual temperature from Factor Scores for stations for 1932-98 (upper) and 1963-95 (lower). The regression lines inside the ovals (as the long axis) have to provide a higher coefficient of correlation.