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SPATIAL AND TEMPORAL DISTRIBUTION OF AIR TEMPERATURE IN THE NORTHERN HEMISPHERE

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ABSTRACT
In the present study, the spatial and temporal surface air temperature variability for the Northern Hemisphere has been examined, for the period 1900-1996. Factor Analysis has been applied to 5^{o} Latitude x 10^{o} Longitude grid box data covering the area from almost the equator to 70^{o} N. These data are anomalies of the mean annual air temperature from the respective mean values of the period 1961-1990.
The analysis showed that, mainly 20 regions were determined in the Northern Hemisphere with significantly covariant air temperature time series. The comparison of the trends of the mean annual surface air temperature time series of these regions, revealed such common characteristics as the minimum of the first decade of the 20th century and the recent years warming. The results of this study are also compared to the respective results of a former study in which data for the last half of the century (1948-1996) have been analyzed. The findings extracted indicate the stability of climate distribution in Northern Hemisphere during the 20th century.

KEYWORDS: Factor Analysis, Air Temperature, Northern Hemisphere.

INTRODUCTION

During the last thirty years many studies relative to climatic changes and especially the surface air temperature anomalies for different time periods and regions, have been published. It is well known (Jones and Briffa, 1992; Jones, 1994; Jones et al, 1999; IPCC, 2001; Metaxas et al, 2000; Vinikov et al, 1990; WMO-No 856, 1996) that during the 20th century the mean air temperature on the earth's surface has been raised about 0.6 ± 0.2 °C. The temperature remains at low levels from about the end of 19th century or the beginning of the 20th century, which defines the end of the "little ice age", and after that shows a rapid increase till about 1940. Thereafter the temperature appears a low decrease until about the middle of the 70's when a rapid increase comes, which continues up to nowadays.

The goal of this paper is the study of the spatial distribution of the mean annual surface air temperature anomalies in Northern Hemisphere, for the period 1900-1996 (97 years) and in the process the comparison of these results with the respective ones derived from the study of Metaxas et al, (2000), where the used data refer to the period of the last fifty years (1948-1996). Finally, the temporal distribution of the air temperature anomalies of the grouped regions of Northern Hemisphere is examined.

DATA AND ANALYSIS

In this study, the used data of air temperature in the Northern Hemisphere, for the period 1900-1996, have been taken from the Climatic Research Unit of the University of East Anglia. They are anomalies of the mean annual air temperature from the respective mean values of the period 1961-1990. We defined 400 grid boxes of 5° Latitude x 10° Longitude. However, the regions over 70° N, the regions located in the South Mediterranean Sea in Sahara and in the Southern China have not been analyzed because of missing data. Also, we have not accessed the timeseries that cover the region from the Equatorial Pacific to the latitude of 25° N because these data, for the period 1900-1930, are not reliable. In the process the Factor Analysis (FA) was applied to the matrix ($n \times m$) of the mean annual air temperature anomalies, where n=97 the number of years of the period examined and m=387 the number of the available regions-variables. It is well known that, the main applications of FA are to reduce the number of variables and to detect structure in the relationships between variables, that is to classify variables. Therefore, FA is applied as a data reduction or structure detection method. The data should have a bivariate normal distribution for each pair of variables, and observations should be independent. Therefore each of the p initial variables $X_1, X_2, \dots, X_p$ can be expressed as a linear function of m (m<p) uncorrelated factors: $X_i = a_{i1}F_1 + a_{i2}F_2 + \dots + a_{im}F_m$ where $F_1, F_2, \dots, F_m$ are the factors and $a_{i1}, a_{i2}, \dots, a_{im}$ are the factor loadings which express the correlation between the factors and the initial variables. The values of each factor are called factor scores and they are presented in standardized form, having zero mean and unit variance (Jolliffe, 1986; Manly, 1986). The number m of the retained factors has to be decided, by using various rules (eigenvalue ≥ 1, screen plot) and considering the physical interpretation of the results (Bartzokas and Metaxas, 1993). Another important point of the analysis is the rotation of the axes, which maximizes some factor loadings and minimizes some others and in that way a better separation among the initial variables is succeeded. Varimax rotation is generally accepted as the most accurate orthogonal rotation, which maximizes the sum of the variances of the square factor loadings, keeping the factors uncorrelated (Rummel, 1970; Richman, 1986).

The application of FA determined 22 factors-regions within the air temperature covariates, in the Northern Hemisphere.

SPATIAL DISTRIBUTION OF THE AIR TEMPERATURE

Table 1 presents the results of FA applied to the annual air temperature timeseries, and the regions with respect to factors extracted. Comparing the results of Table 1 to the respective ones in the study of Metaxas et al, (2000) the following are derived (Figure 1, 2):

- Factor 1 explains 20.6% of the total variance and represents the region from the coasts of East Africa to the Sea of Indochina (Figure 1) and is similar to factor 3 of the prolonged study (Figure 2).
- Factor 2 explains 10.2% of the total variance and covers the region of the Tropical Atlantic Ocean (Figure 1), while corresponds to factor 5 in Metaxas et al, (2000) study (Figure 2).
- Factor 3 explains 7.2% of the total variance and includes the region of North Europe and Scandinavia (Figure 1) and corresponds to factor 4 of the previous study (Figure 2). It is remarkable that in both distributions a negative teleconnection (-0.5) with Iraq region is also appeared.
- Factor 4 (Figure 1) corresponds to factor 12 (Figure 2) and factor 5, which covers the Siberia (Figure 1), corresponds to factor 1 (Figure 2) of the mentioned study.
- There is a general sense of concern that, the spatial distribution of the 387 annual air temperature timeseries in Northern Hemisphere during 1900-1996 (Figure 1) is similar to the respective one of the Metaxas et al. (2000) study in which data of about 600 timeseries of the period 1948-1996 were used (Figure 2). It is well known that, during the last time period almost the whole region of the Northern Hemisphere is covered by meteorological observations.

Figure 1. Spatial distribution of the regions in the Northern Hemisphere within the air temperature covariates. Period 1900-1996

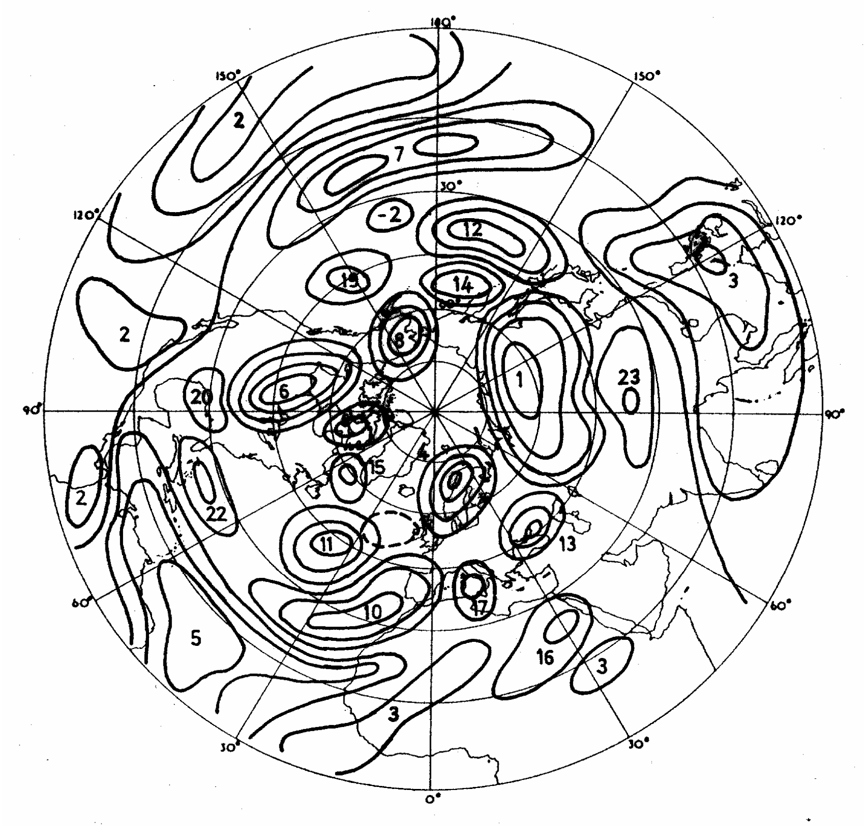

Figure 2. Spatial distribution of the regions in the Northern Hemisphere within the air temperature covariates. Period 1948-1996 (Metaxas et al, 2000)

Table 1. Factor Analysis results and regions within the Northern Hemisphere air temperature covariates

Factors	EIGENVALUE	(%)	Region
1	79.0	20.6	Indochina's Sea
2	38.9	10.2	Tropical Atlantic Ocean
3	27.4	7.2	North Europe and Scandinavia
4	20.4	5.3	Northwest Pacific Ocean
5	16.7	4.4	Siberia
6	16.1	4.2	Greenland
7	11.2	2.9	Northeast Black Sea and Caspian
8	10.1	2.6	Northwest USA and Canada
9	9. 5	2.5	North Atlantic Ocean
10	9. 0	2.4	East Equatorial Pacific
11	8.0	2.1	East USA
12	7.8	2.0	Northeast Pacific Ocean
13	7.0	1.8	Alaska
14	6.2	1.6	Central Mediterranean Sea
15	6.0	1.6	East Pacific Ocean
16	5.3	1.4	Southeast Canada
17	4.9	1.3	Central Pacific Ocean
18	4.7	1.2	West USA
19	4.6	1.2	North Pacific Ocean
20	4.3	1.1	Cara Sea (Arctic Ocean)
21	4.0	1.0	Tropical Atlantic Ocean
22	3.9	1.0	England-Ireland

TEMPORAL DISTRIBUTION OF AIR TEMPERATURE

The fluctuations in time of the mean annual air temperature anomalies in the Northern Hemisphere are exhibited in Figure 3, where the graphs included present the averaged grid boxes timeseries with loadings greater or equal to 0.6, for each factor. It is obvious from Figure 3 that, a temperature minimum appears in the beginnings of 1910's, for the regions of Indochina's Sea (factor 1), Tropical Atlantic Ocean (factor 2), Siberia (factor 3), Caspian Sea (factor 7) and Central Mediterranean Sea (factor 14).

On the contrary, the minimum of air temperature timeseries for the regions located westerly and northly, that is Scandinavia (factor 3), Greenland (factor 6) and North America (factors 8, 11, 13, 18) is appeared in 1920, a decade later. The following maximum is appeared in about the middle of 1930's for the regions of Scandinavia and Greenland, while in the area of North America, Tropical Atlantic Ocean and Indochina's Sea comes about in 1940, and a decade later, about 1950, in Siberia. Also, the air temperature timeseries, which correspond to continental region of Northern Hemisphere (Siberia, Scandinavia and north America), appear a minimum at the end of 1960's and thereafter a continuous increasing trend is crystal clear up to nowadays. This trend is more remarkable in Siberia, in which rises up to 1.5 °C, for the examined period, while the regions in North America appear an increase of about 1.0 °C for the same period. The minimum, at the regions in Tropical Atlantic Ocean (factor 2), North Atlantic Ocean (factor 9), Pacific Ocean (factors 4 and 12), Central Mediterranean Sea (factor 14) and Western Europe (factor 22), is appeared a little bit later, that is, in the middle of 1970's. The increasing trend that follows is about 0.5 °C, quite less than the respective one, the continental regions appear. Finally, it would be mentioned that the air temperature timeseries of the continental regions appear a greater variability than the timeseries corresponding to oceanic regions.

CONCLUSIONS

The application of the FA to the Northern Hemisphere mean annual air temperature anomalies, for the period 1900-1996, shows that the Northern Hemisphere is divided in about

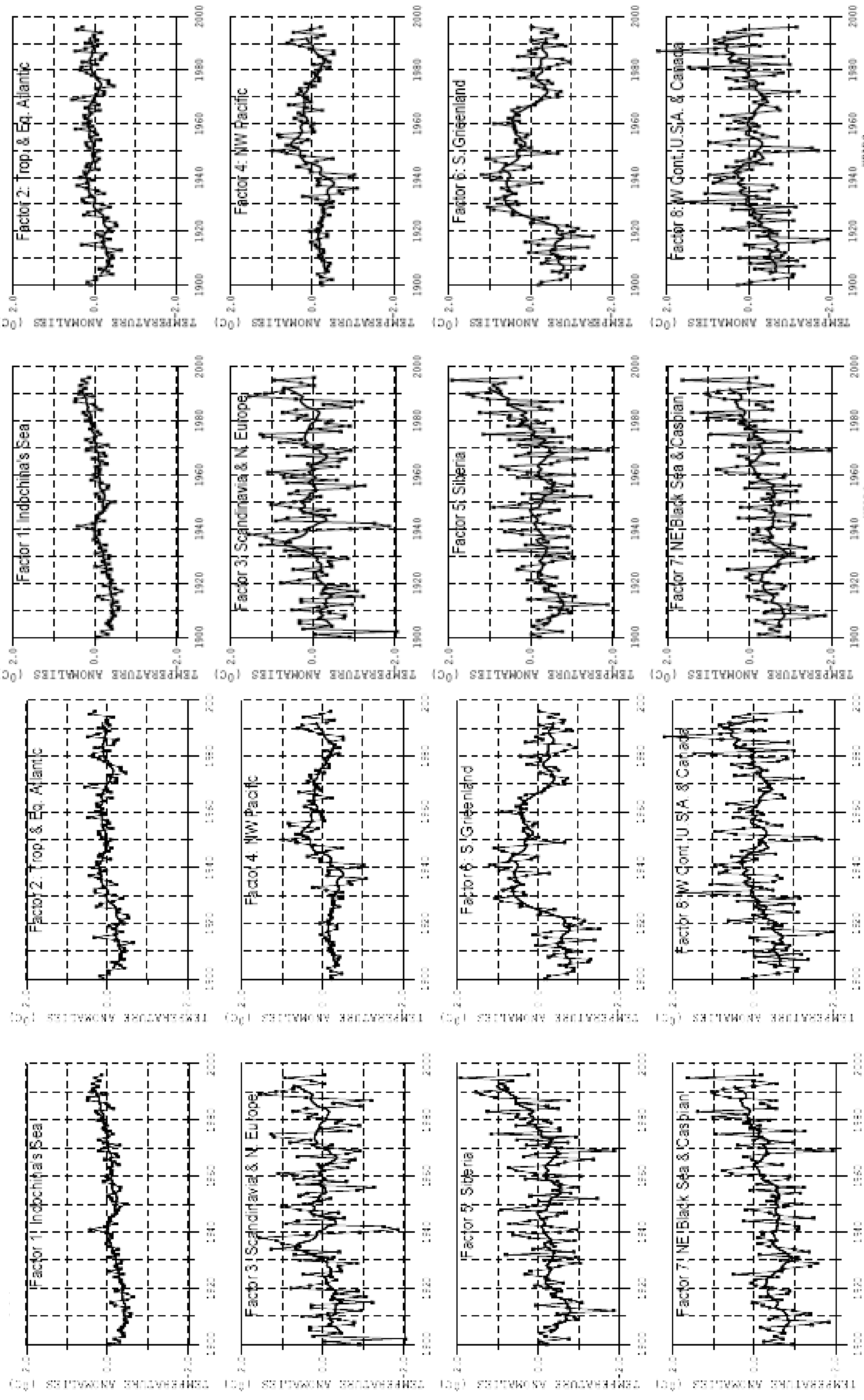

Figure 3. Variations of the mean annual air temperature anomalies with respect to the period 1961-1990, in the regions within the air temperature covariates (thin line) along with 9 year moving average (dash line)

twenty regions (factors), within the air temperature covariates. The greater percentage of the total variance is explained by the factor 1, which covers the region from the coasts of East Africa to the Sea of Indochina and by the factor 2, that corresponds to the region of Tropical Atlantic Ocean. Comparing these results to them derived from Metaxas et al (2000) study, it is obvious that the spatial distribution approved in this paper is almost similar to the respective one for the period 1948-1996, in which the Northern Hemisphere is covered completely with meteorological data. These findings are an indicator for the stability of climate distribution in Northern Hemisphere during the last century.

The air temperature minimum appears in about 1910 at regions such as Indochina's Sea (factor 1), Siberia (factor 5), Caspian sea (factor 7), Central Mediterranean Sea (factor 14) and Tropical Atlantic Ocean (factor 2), while it appears a decade later in north-western regions (Scandinavia, Greenland, North America).

The air temperature maximum is remarked in about 1930 in Greenland and Scandinavia and a decade later in North America and Siberia. The air temperature timeseries of the continental regions (Siberia, America, Scandinavia) appear great variability and a crystal clear heating trend since the beginnings of 1960's up to nowadays. Meanwhile, the air temperature timeseries of the oceanic regions (Indochina's Sea, Tropical Atlantic Ocean, Mediterranean Sea) appear less variability and heating trend, compared to continental regions.

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