The spatial differentiation of correlation coefficient between the tropospheric thermobaric field and air temperature in Europe - preliminary results

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Abstract. The aim of this study is to determine the spatial differentiation of the relationship between the thermobaric field of the lower troposphere and the air temperature at the Earth's surface in Europe in the period 1961–2010 expressed by a simple, yet effective measure, i.e. correlation coefficient. The source material consisted of the daily data (12 UTC), from the NCEP–NCAR Reanalysis. The analysis carried out confirmed the above relationship, demonstrating its considerable spatial diversification, variable throughout the year. At the same time the results obtained indicate the existence of other relevant factors, not related to a combination of the temperature and pressure fields in the free atmosphere, diversifying the examined relationship over the area of Europe.

Key words

Thermobaric field, geopotential height, air teperature, NCEP–NCAR Reanalysis.

Introduction

Atmospheric circulation is considered to be one of the most important factors responsible for current weather conditions as well as climate variability. The temperature at the Earth's surface is formed under the influence of advection of air masses with specific physical properties. Among these properties, the most significant in the context of the impact on the thermal conditions at the Earth's surface can be described as the thermobaric field.It is a combination of the pressure and temperature fields in the free atmosphere. As cold air is characterized by higher density, the pressure decrease along with the higher altitude is faster in a cold air mass than in warm one. Therefore the consecutive isobaric levels hights allow to deduce the mean temperature of the layers between. The higher the relative height, the higher the temperature of the air between the respective isobaric surfaces. The image of such layer thickness is called a relative topography map, most frequently presenting the surface of 500 hPa over the surface of 1000 hPa (*Słownik*... 2003). This gives us a very clear insight into the thermal conditions of the troposphere, and to a significant extent also into its temperature. A careful examination of these relationships will enable us to assess the impact of the troposphere (and its thickness) on the thermal conditions at the surface of the Earth, which will be the subject of a further study by the authors.

The properties of the free atmosphere discussed are of substantial use in synoptic meteorology. The knowledge about the relationships between the troposphere temperature (described by the thickness of particulatr layers) and air temperature by the surface in different spatial and temporal scale may improve the weather (especially temperature conditions) forecast. Therefore maps of baric topography are used by the most serious meteorological services for the study and forecasting of thermal and baric conditions. It is an excellent example proving the importance of the thermobaric field in forming air temperature at the surface of the Earth. Moreover, the analysis of specific relationships between atmosphere properties and weather or climate conditions (especially air temperaturę) seems to be essential while considering the occurence of contemporary weather extremes and climate anomalies.

The fields of pressure and temperature in the free atmosphere were already studied by climatologists in the past. Fleming et al. (1988) worked out monthly average values of air temperature, wind parameters, geopotential height and atmospheric pressure for the whole atmosphere in a global scale. Long-term variability of the thermobaric field across the globe was also examined (Mordvinov et al. 2004) indicating differences in the trends of changes in different regions of the world and identifying their causes in such phenomena as, for example, El Niño, having particular significance for tropical regions. A more thorough study of the time variability in the Northern Hemisphere can be found, in turn, in the work of Wallace and Zhang (1993). Bąkowski (2007) carried out a direct examination of the impact of air advection from the level of 850 hPa on the temperature at the Earth's surface in Kraków (Poland). He found a clear effect of thermal advection in the free atmosphere on the changes in the air temperature at the Earth's surface, particularly evident in the spring and summer and weaker in the autumn and winter, which was affected by the predominance of anticyclonic systems in these seasons of the year in Kraków.

The aim of this study is to determine the spatial differentiation of the correlation coefficient between the thermobaric field and the air temperature at the Earth's surface in Europe in the period 1961–2010.

This paper is a contribution to the further research deepening the understanding of these relationships, and the role of the thermobaric field in forming the air temperature at the surface of the Earth.

Material and methods

For the purpose of this study, the daily data (12 UTC) for the period 1961–2010, obtained from the NCEP–NCAR Reanalysis (Kalnay et al. 1996), i.e. the geopotential height of the main isobaric surfaces: 1000, 850, 700 and 500 hPa and the air temperature from the σ=0.995 level (i.e. conventionally the level of the Earth's surface) were used. Within the study area (Europe) of the meridional extent of 65° (25°W–40°E) and the latitudinal extent of 40° (35°N–75°N) there are 459 grid points (the so-called grids). On the basis of preliminary studies, the values of the isobaric level heights of 1000 and 500 hPa were selected for the study, since they best reflected the characteristics of the thermobaric field of the lower troposphere. This is consistent with the operational use of these two isobaric levels in synoptic meteorology.

In the initial stage of the study a preliminary evaluation of the data from the NCEP–NCAR Reanalysis was carried out by comparing them with measurement data. A comparison of the air temperature and the thickness of the troposphere (500-1000 hPa) at the point of 50.0°N 20.0°E with an areal mean from the synoptic stations of southern Poland was carried out. The concordance of the data of the geopotential height of selected isobaric levels from the point of 52.5°N 20.0°E with the corresponding data from the aerological station in Legionowo was also verified. In both cases, the obtained results confirmed the high accuracy of the data from the NCEP–NCAR Reanalysis, which is consistent with the studies of Woyciechowska and Bąkowski (2006).

In order to achieve the aim, a simple but effective method of analysis using Pearson's correlation coefficient, describing mutual relationships between the variables examined, was selected. On this basis, correlation maps for months characteristic in the context of respective seasons (January - winter, April - spring, July - summer, October - autumn) were developed, using the ordinary kriging interpolation method. It should be noted that the values of the correlation coefficients obtained are statistically significant at $p<0.05$.

Results

The relationships between the thermobaric field in the lower troposphere and the air temperature at the Earth's surface in Europe showed significant spatial differentiation, varied in respective seasons (Fig. 1. a–d). The weakest relationships together with the largest diversification of Pearson's correlation coefficient occurred in the summer (July, Fig. 1 c) very clearly indicating the differences in the relationship between the two variables studied over the land and the ocean. The continental part of the study area was characterized generally by a high correlation coefficient reaching 0.8, with a maximum of 0.9 (Bavaria) what is important from the human point of view. A strong relationship over the area of land, which forms the natural habitat for life and activity, is just more important as it provides the possibility of better weather forecasts while using the atmosphere factors in mesometeorological models. However the spatial distribution of the correlation

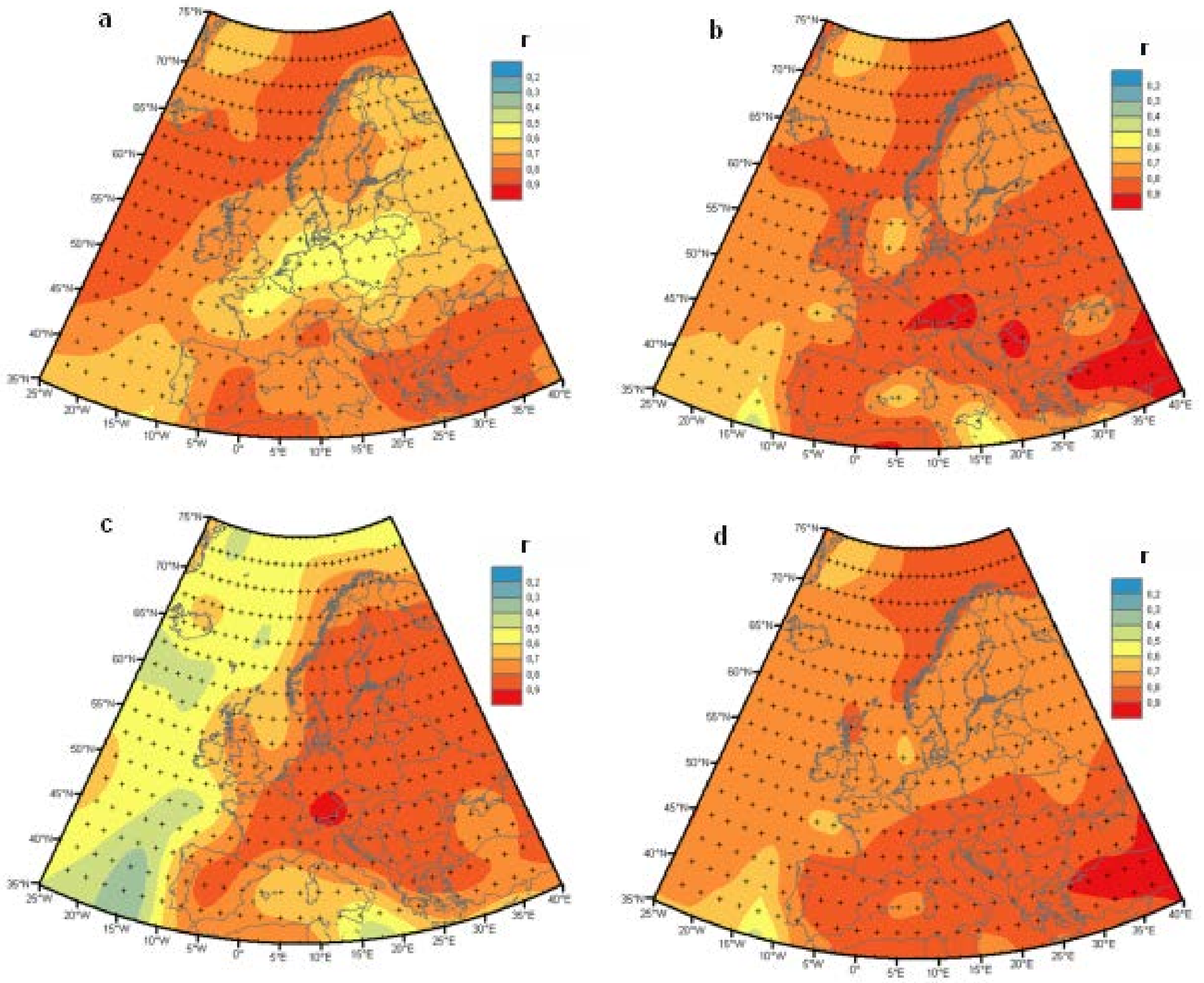

Figure 1. *The correlation coefficient between the tropospheric thermobaric field and the air temperature in months: January (a), April (b), July (c), October (d) in the period 1961–2010.*

coefficient in July has the largest proportion of lower values with regard to the total area of research. The coefficient over the Atlantic Ocean usually did not exceed the value of 0.6, and in the south-western part of the study area reached just as little as 0.3.

Quite a different situation occurred in the winter (January, Fig. 1 a). Then the higher values of the correlation coefficient (r>0.8) occurred particularly over the Atlantic Ocean along the main course of the North Atlantic Current, and over a significant part of the Mediterranean region. However, the region of weaker relationships of the thermobaric field with the temperature at the Earth's surface encompassed most area of continental Europe with a minimum of about 0.5–0.6, extending over a strip of lowlands from northern France to Lithuania. In the spring and (in particular) in the autumn (Fig. 1 b, d) the differences between the area of the land and the ocean is not so clear. The spatial distribution of the correlation coefficient becomes more blurred referring to the transitional nature of these seasons. It is worth mentioning, however, that it is exactly then that very strong relationships between the thermobaric field and the temperature at the Earth's surface occur.

Conclusions

The relationship between the thermobaric field of the lower troposphere and the air temperature at the Earth's surface is relatively strong, while significantly spatially diversified and variable throughout the year. In the summer, this relationship is stronger over land areas than over the sea, and in the winter it is the other way round. This translates into a spatially diversified role of the thermobaric field of the lower troposphere in the formation of air temperature at the surface of the Earth. Weaker relationships indicate a growing share of elements other than the temperature and pressure fields in the free atmosphere, and the other way round in the case of stronger relationships. For example, this role is bigger over the land in the summer, while in the winter over the sea. In the spring and (especially) autumn this diversification becomes smaller, thus rendering the transitional nature of these seasons.

In view of the above, the results obtained allow us to assume that the factors such as the distribution of pressure systems (in particular, stationary highs in the winter), thermal inversions and ocean currents (the warm North Atlantic one strengthens the relationships in the winter and weakens it in the summer, whereas the cold Canary Current weakens it throughout the whole year) may have a significant impact on the relationship between the thermobaric field of the lower troposphere and the air temperature at the Earth's surface.

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