INVESTIGATION OF ATMOSPHERIC HUMIDITY TRANSPORT ON THE BASIS OF AEROLOGICAL MEASUREMENTS

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ABSTRACT. – Investigation of atmospheric humidity transport on the basis of aerological measurements. The global upper-air data base over the last 40 years is available by courtesy of College of Engineering and Applied Sciences at the University of Wyoming. Considering the fact, that in the atmospheric moisture transport between the oceans and the continents the humidity flow is much stronger towards the mainland than in the reverse direction, therefore it is reasonable to look for some correlation between the moisture transport and precipitation climate of the continents. For Europe, this is not easy because of the highly indented coastlines. According to laws of physics moisture transport influx to a (part of a) continent i.e. through the border of a closed curve occurs as rain falling out in the water balance of the geographical area investigated. We are interested in quasi-stationary temporal changes showed by the stationary approach mentioned above that can be related to climate change. In Europe the precipitation regime of the rainy coast in Western Balkans can be described as a stationary approach, while the relationship between the moisture coming from the seas and the precipitation climate of Central and Eastern Europe in the past 40 years can be examined as a quasi-stationary process. This change in our region moves towards more frequent droughts having great economic influences, mainly in agriculture and hydrology. The aim of this study is to analyse the relationship between moisture convergence calculated by the radiosonde measurements and the precipitation climate of a selected area of land.

Keywords: upper-air, radiosonde measurement, moisture transport.

1. INTRODUCTION

Radiosonde records have an advantage of starting in the 1940s regionally, and near-globally from about 1958. They monitor the troposphere and lower stratosphere (IPCC, 2007).

The basis of our investigation is the global upper-air data set uploaded to internet by College of Engineering and Applied Sciences at the University of Wyoming. This data base contains the most aerological measurements required to TEMP messages over the last 40 years. Our study focuses on Europe this year, emphasizing the Central and Eastern European region.

Low rainfall caused problem in this part of the continent for several decades, more precisely the dry and drought years are becoming more common.

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Nevertheless, there are years when there were a large amount of rainfall creating inland inundations and floods, such as 2010 and 2014. Forecast of exact occurrence of the dry and wet years is impossible. However, the question arises how the behavior of the upper atmosphere shows correlation with weather parameters measured on the ground, such as precipitation, which is a rhapsodic element having large economic impact.

IPCC 5th report (IPCC, 2013) makes the following statements to hydrological cycle:

- Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has likely increased since 1901;
- It is very likely that global near surface and tropospheric air specific humidity have increased since the 1970s;
- It is likely that since about 1950 the number of heavy precipitation events over land has increased in more regions than it has decreased.

Forefront of our investigations is the changes and longer-term trends can be seen during the 40 years examined. Media often broadcasts exaggerated rumors that current trends point towards climate catastrophe, but since the mid-20th century, there is undeniably a unidirectional change in climate, with respect to both temperature and precipitation.

Climatological investigations mainly focus on the surface climate parameters and much less research turn to changes occurring in the upper air. We are trying to do stop-gap work by creating aerological climate data series from the measurements available.

2. DATA AND WORKING METHODS

We calculated annual statistics for Europe from the data series of the last 40 years. In the first iteration we concentrated on the main isobaric surfaces and studied the moisture transport in the hope that we can find the relationship between the surface precipitation measurements and the water (water content) flow in the atmosphere.

Although emphasis by the main isobaric surfaces is a favourite method in aerology but it is not expedient in all aspects. For example, examination of the temperature of levels 850, 700 hPa etc. to some extent may bring misleading results in the case where we do not take into account the fact that a hypothetical climate warming in the lower troposphere (Fig. 1.) causes level increase to the isobaric surfaces themselves so their temperature will apply higher geopotential. Disregard of this fact leads to apparent contradiction, which is reflected in the different results in calculation for isobars and isohypses.

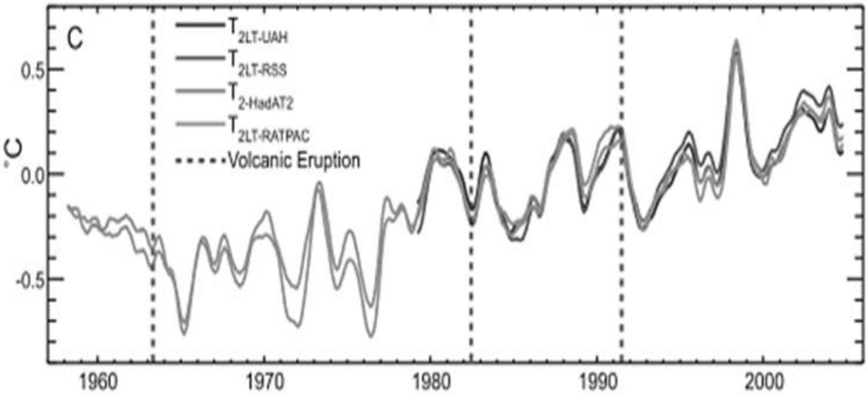


Fig. 1. ***Observed air temperature anomalies in the lower troposphere (IPCC, 2007)***

The situation is different if we analyse meteorological parameters acting in the vertical cross-section of the atmosphere, such as water content, particulate matter or trace gases playing important role in air chemistry. Of course, distribution by height has importance in this case, however, isobaric surfaces linked to the continuum or materials give proper measure (coordinate system) here. Let us consider for example information we got from the TEMP messages related to level of 850 hPa that represents the layer of finite thickness between 800 and 900 hPa, while data of 700 hPa give information for the layer between 600 and 800 hPa and isobar of 500 hPa for parameters transported in the layer between 400 and 600 hPa.

Currently we examine only one component between the relative topographies: the H_2O content of the atmosphere.

In this approach, first, wind fields are prepared then moisture content will be merged in these wind fields as a vector and a scalar parameter multiplied. So we get humidity flux, whose direction is the same as the direction of the wind, while the quantity of water flowing through the unit cross-section per unit time is obtained by multiplying the wind intensity by the water content in the unit volume.

Secondly, the wind direction, wind speed, relative humidity, temperature and air pressure getting from the pressure level itself in our data base are applied. So we get wind patterns different from the fields of humidity flux. For example relatively intensive humidity flux can occur at the border of a continent and a sea above North Africa well-known to be dry however it will not result in abundant rainfall in that territory. But that is about in case of relatively balanced airflow delivers extremely dry air from the land compared to the wetter air flowing from the sea. On the other hand, the flow can blow towards the mainland parts of known to dry relatively high moisture content (Fig 2.) while that in absence of orographic barriers will not more than only partly be felt out. Fig. 2 shows considerable moisture transport from north to south in the Mediterranean. The length of arrows is proportional to the quantity of moisture flux.

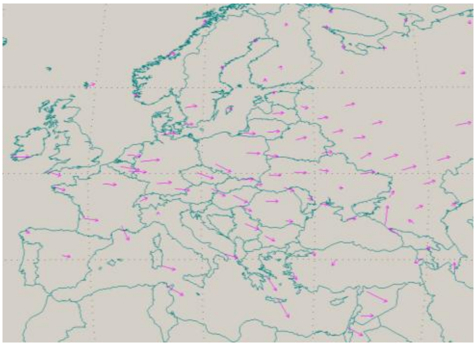


Fig. 2. ***Annual average of moisture flux at the level of 850 hPa in 1978***

Wind patterns and fields of humidity flux of the levels of 850 hPa, 700 hPa and 500 hPa are described in the map of Europe for whole years as well as for vegetation growing seasons defined as from the beginning of April to the end of September. It is important to note that because of the differences particularly in the lower levels we tried to omit mixing radiosonde data carried out predominantly at midnight and noon, so in our investigations we confine ourselves to the midnight measurements.

On visualising the continental wind and humidity flux patterns, at first glance we often get surprisingly orderly flow picture of what might be called a statistical standing wave (similar to Rossby long wave). This is a surprising result because these sinusoidal wave patterns described by dynamical meteorology are known in the temperate zone of the northern hemisphere for a specific time or a short period, while our results give similar formations in annual and semi-annual statistics. However, such harmonic distributions are obtained not every year, there are time periods when separation is more typical respect to sub-continentality.

Although the almost orderly wave formations delight our eyes but the latter may be for us more relevant result, since we hope in geographical separation of the wind field and with it the humid or arid features of the affected area. The latter separation gave the idea to differentiate regions in the continent (clusters in statistical sense) where humidity flux and precipitation regimes show similarities. The regions are separated in the maps based on shades of gray (Fig. 3). Flags in the maps represent regional average vectors.

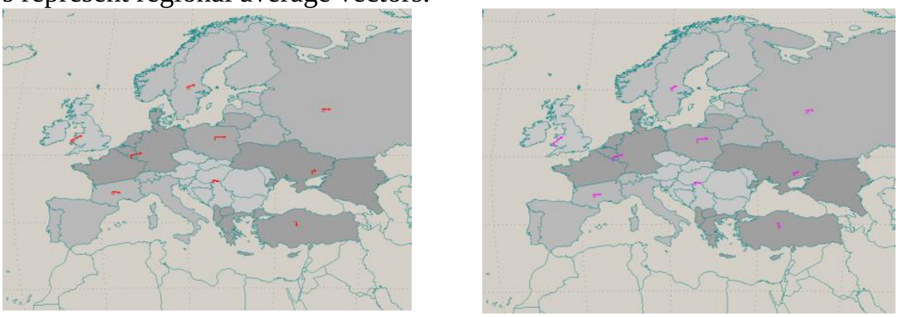


Fig. 3. ***Annual average wind field (left) and moisture flux (right) at the level of 850 hPa for the nine regions in 1994***

In this part of our study temporal variations of the regional averages for the Central European region over the last four decades are demonstrated. Graphs are prepared for four parameters: temperature, relative humidity, wind velocity and a ratio proportional to moisture content.

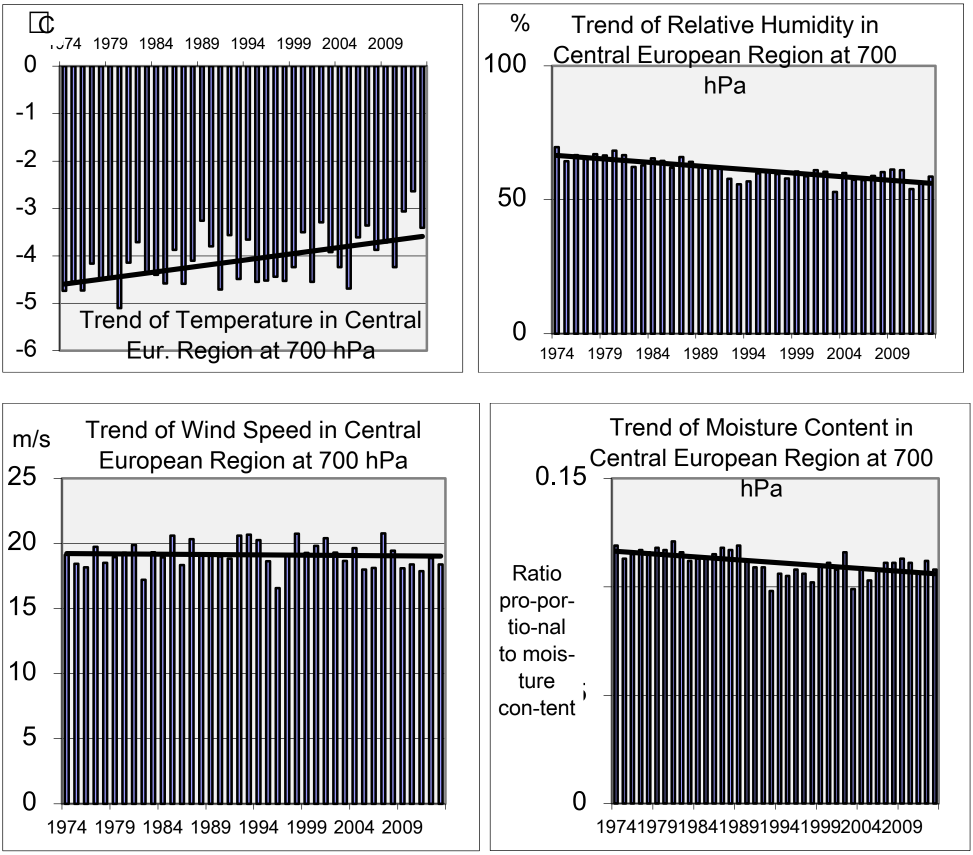
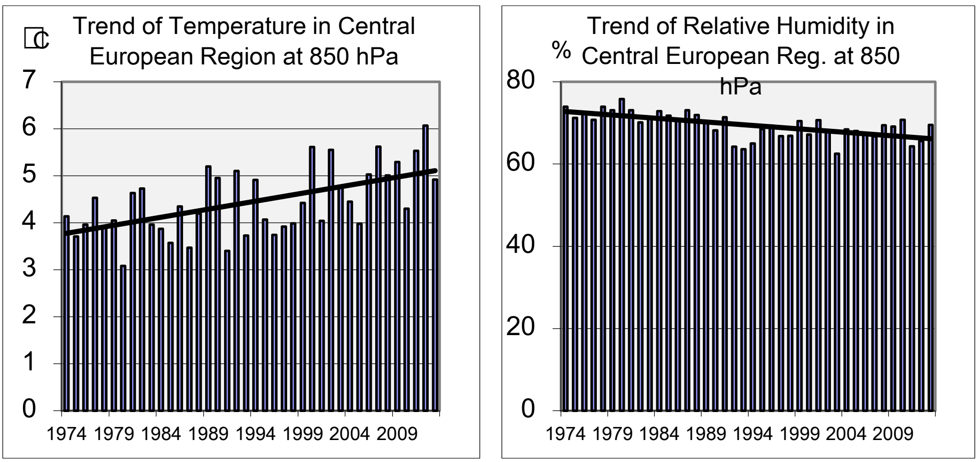
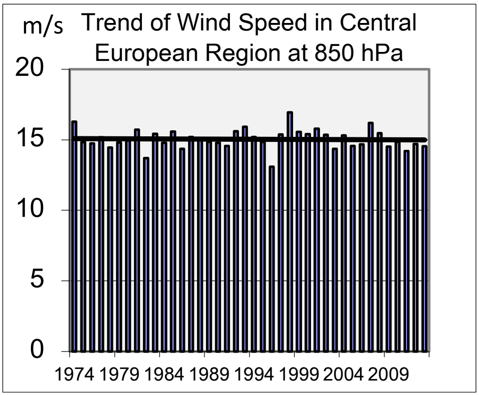


Fig. 4. ***Temporal variations of the regional averages at the level of 700 hPa for Central Europe***





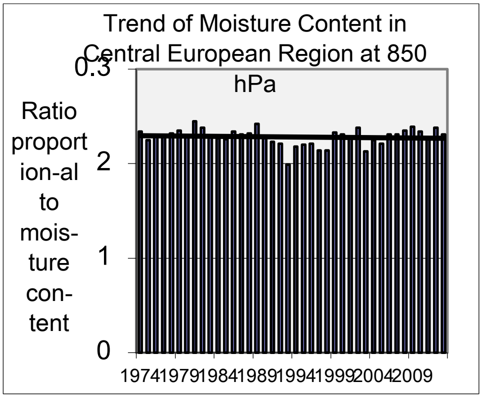


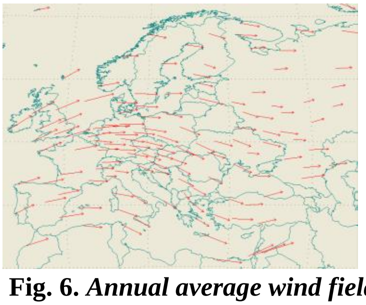
Fig. 5. ***Temporal variations of the regional averages at the level of 850 hPa for Central Europe***

We can make the following statements to the diagrams:

- there is a clear increase in temperature at both levels of 700 and 850 hPa;
- while there is a definite decrease in relative humidity;
- not surprisingly the moisture content shows no significant change, it proved approximately constant;
- the situation related to the wind is complex; in Central Europe we can see a very minor decreasing trend while in other regions the drop is more considerable; diagrams show the absolute values of wind speed, which directly influences fall-out of moisture content transported by the air related to orographic barriers or frontal activities.

We should also emphasize the fact that we can get significant correlation between the dry and wet zones in Europe as well as the moisture carried by air when considering the orographic conditions. We can go beyond this trivial specification, which is a diagnostic image if we prepare the statistics of several decades examining shorter periods and trends as well.

The simplest case of how to describe the temporal changes is if individually, annual course of climatic parameters are formed for each specific station (Fig. 6-8).



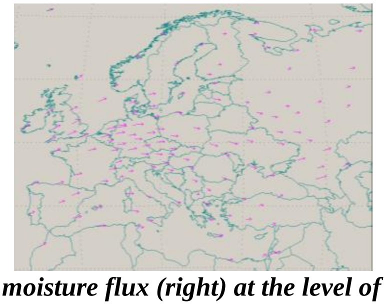


Fig. 6. ***Annual average wind field (left) and moisture flux (right) at the level of 500 hPa observed at the stations in 2003***

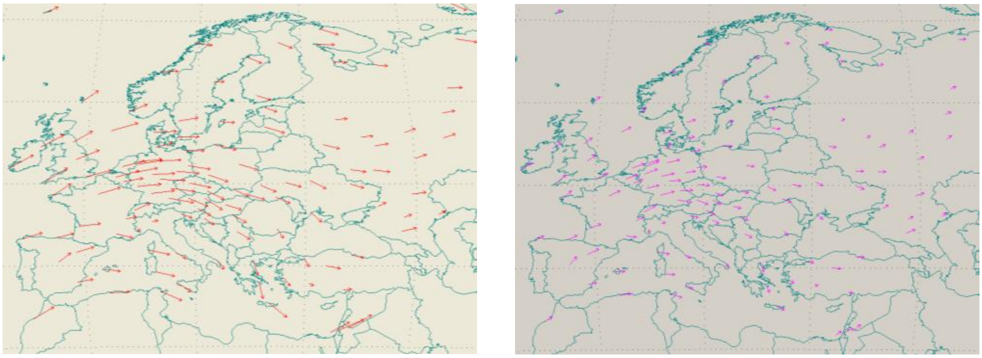


Fig. 7. ***Annual average wind field (left) and moisture flux (right) at the level of 700 hPa observed at the stations in 2003***

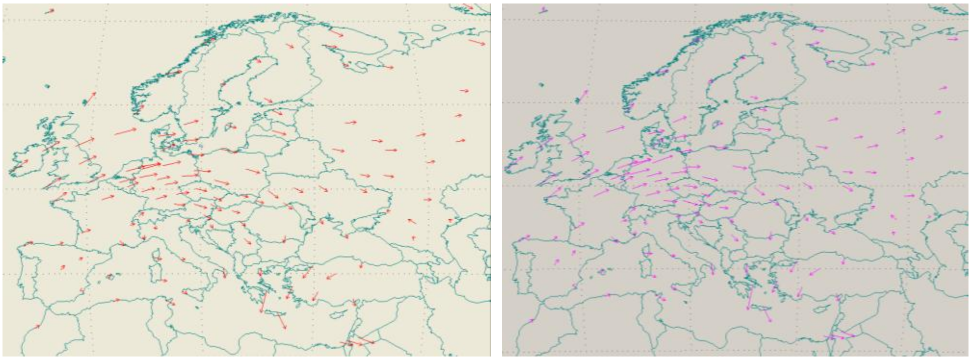


Fig. 8. ***Annual average wind field (left) and moisture flux (right) at the level of 850 hPa observed at the stations in 2003***

Linear regression, higher degree polynomial curve or transcendent function types are fitted to these annual courses. We mostly applied the linear trend description. In order to reduce inhomogeneities in radiosonde data we formed combined temporal statistics of more, geographically relatively close stations. Thus, any measurement gaps could also be smoothed. Secondly, this method gives a succession of years characterising the aforementioned cluster as a whole, ensuring mathematical meaning to the principle of classification by types of the area.

An essential description method is the map showing spatial distribution of a shorter time period while another one is the function curve pointing temporal variations in the specific geographical location or area. In the first case the time dimension is constant while in the second case the spatial location is given or the region is specified. Finally, the synthesis could be a structural analysis in this multidimensional system.

3. CONCLUSIONS

On the basis of climatic parameters formed in space and time we can conclude there have been certain changes in temperature, humidity and wind conditions in the atmosphere over Europe for the last 40 years. The structure of changes is approximately linear. Temperature rose while relative humidity, intensity of wind decreased. Moisture content of air shows constant value so it can be considered as a conservative diagnostic parameter. However, moisture flux transported by the horizontal movement of air decreases since its value depends on the moisture content and the statistical average of the wind.

As expected, more regular wind fields are obtained in higher altitudes outlining periodic wave (Rossby) shapes in annual average along the latitudes of the temperate zone. At lower elevations these large-scale periodic waves have not drawn up characteristically. Closer to the Earth's surface orographic effects in Europe as well as the not regular geometric ridge of seashores become dominant.

Ruling blast from Atlantic Ocean is very decisive in North Western Europe, because it will precipitate. Intensity of this precipitation only slightly dropped in the last four decades while in the Mediterranean it decreased significantly particularly where the wind patterns of troposphere are more diverse. This circumstance corresponds to the map of EEA (Fig. 9), where the southern part of the continent shows a greater drop in annual rainfall statistics.

We observed certain climate change in the upper air over our continent although we examined only a relatively short time period. This work can be continued and extend on hemispheric or global scale on the basis of data set available.

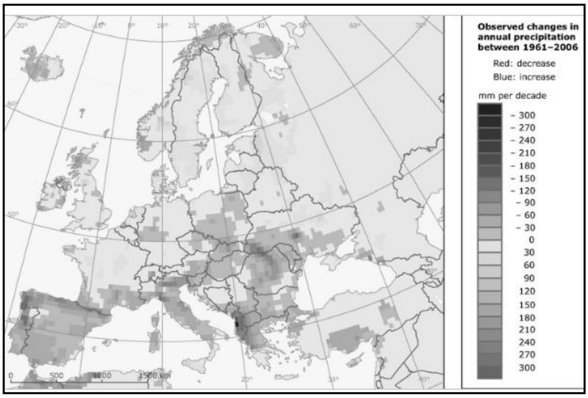


Fig. 9. ***Observed changes in annual precipitation between 1961-2006 (Home page of European Environment Agency)***

REFERENCES

1. IPCC (2013), *Climate Change 2013: The Physical Science Basic, Chapter 2. Observations: Atmosphere and Surface, p. 162*
2. IPCC (2007), *Climate Change 2007: The Physical Science Basic,3.4.1.1 Radiosondes Fig. 3.17*
3. European Environment Agency: Home / Data and maps / Maps and graphs / Trends in annual precipitation across Europe between Jan 1960 and Jan 2012 (http://www.eea.europe.eu).