ON THE EXTREME SUMMER PRECIPITATION IN UKRAINE OVER THE LAST DECADES

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I. INTRODUCTION

Frequency of extreme weather events has been increasing over the past decades, accordingly to previous reports of the Intergovernmental Panel on Climate Change (IPCC, 2007), and recently published special report on the problems of adaptation to natural hazards (2012). It states that on the background of general minor changes in total precipitation, daily intensity can increase. In the last decade, events with strong summer rains as well as snowfalls are frequented in Ukraine according to observational data (Extreme events, 2006). Latest examples are summer flood in July, 2008, heat waves and droughts in consecutive years 2009-2012, and the latest example of heavy snowfall in March, 2013.

Recent climate change, including near-surface air temperatures (SAT) rise is connected with the large-scale atmospheric circulation change, (Domonkos et al., 2003); including intensification and eastward shift in NAO and expansion of subtropic high to the East Europe including winter season (Jung et al., 2002, Martazinova et al., 2008) Increased frequency of summer extreme events in the latest decade occurs on the background of more pronounced changes in the upper-tropospheric circulation.

The purpose of this paper is to analyze recent decades' changes in extreme precipitation in Ukraine and to study responsible large-scale atmospheric circulation to create the basics of forecast of situations with potential threat of extreme weather. Comparison with climatology is carried out. Some results of regional modelling are presented

Data. Daily precipitation data at stations in Ukraine were used, as a combination of The European Climate Assessment Dataset project, ECA&D**)**; and original observer's records in Archive of Central Geophysical Observatory, Kiev. Homogeneity – non-parametric criteria and spatial correlations have been applied, and reference series were constructed. Intensive precipitation was determined from daily data from 20-station network. Precipitation amount exceeding a threshold value 10 and 20 mm were used; days with exceeding threshold were calculated as well as daily intensity (they are called Extreme indices). These data has been checked against closest stations. In summer conditions when precipitation can have spotted structures, conclusions about Homogeneities made up when spatial analysis was made and finally when atmospheric circulation has been analyzed, whether it or not favourable for significant rainfall (see text).

Data. Daily mean sea level pressure (MSLP) and 500 hPa geopotential data were taken from ECMWF ERA-40 archive, 2.5X2.5º regular grid. Online resource NCEP-NCAR was used for visualization of monthly fields.

II. PRESENTATION OF RESEARCH

First, compare climatology of summer precipitation in Ukraine during summer months.

Trends in the total precipitation amount, days with precipitation and its daily amount were obtained for the summer season of 1951-2010; June and July showed growth in precipitation amount at majority of stations is statistical insignificant, and August - weak negative trend, (-0.83 days / decade and statistically significant. However trends are intensified during 2001-2010

Similarly, an increase in days with precipitation occurs in June, weak changes in July, and decrease – in August The daily intensity of total precipitation In June and July is largest, and these months contribute greatly to extreme precipitation events in Ukraine:

Since long-term changes in rainfall and days with precipitation have the same sign in the appropriate month and number of days with precipitation increases less rapidly in June and July, the trend of daily rainfall intensity is positive in June, and July however statistically insignificant. The daily intensity of precipitation in August increased by reducing days with precipitation events and is 0.20 mm / day per decade.

Latest decade 2001-10 was of a special attention because of numerous events with precipitation and great interannual variability; and has been compared to 1990s.

In June, maximum precipitation over 10 mm, defined as the average of the stations in Ukraine has been growing in the last decade, with a peak in 2006-2010, and significantly greater than in 1990s (Fig.1).

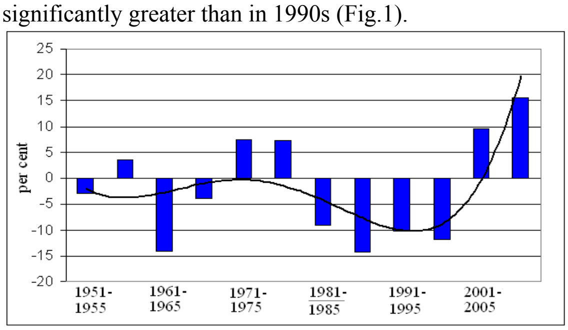

Fig. 1: Maximum amount of precipitation over 10 mm at stations in Ukraine, June, by 5years' periods

Below we present difference charts between decades for precipitation greater 20mm in June and July, and greater then 10 mm in August, as number of events in August has been smaller, and results could be insignificant.

In the space, precipitation amount increase in west, central and east Ukraine, up to 40-60%, fig.2a. In July , excess in precipitation amount more than 20 mm is registered in Central and east part, up to 100% and ever more; western Ukraine is almost without changes. Interdecadal changes in August are somewhat different, with growth in amount more than 10 mm in the west part by 20-40% and some deficit in the center and weak changes in the East (fig.2c). Greater precipitation deficit has been registered in 2006-10 accompanied with heat waves and droughty conditions in the east part.

In June, days with precipitation greater 20mm increased over the country; the rainfall amount has increased in the west Ukraine, daily intensity has increased only by places (here not shown). In the south daily intensity has decreased, and fewer days with extreme significant precipitation, compared to the 90s.

In July, an increase of days with extreme precipitation is observed, as well as the daily intensity increasing over the large area of east and central Ukraine and Crimea Peninsula. In August clearly apparent contrast between west and east Ukraine is seen, and the daily intensity in 2001-2010 is in general greater than in 90s.

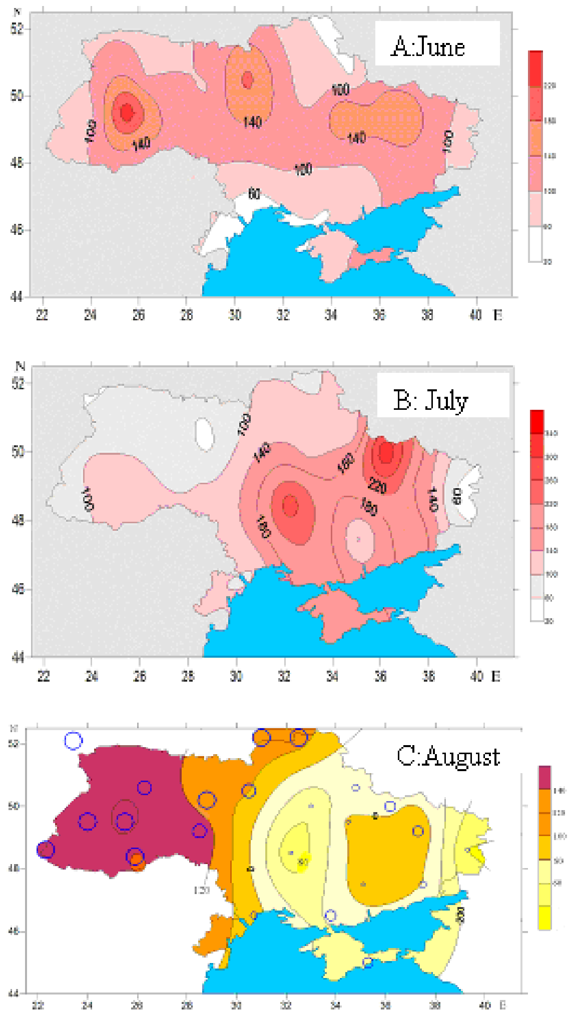

Fig 2: The ratio (2001-2010 to 1991-2000s) of daily rainfall amount over 10 mm in June, July, August.

Greatest growth in the daily intensity occurred between 1990s and 2000s in central-southeast Ukraine; this parameter can be used for regionalization of changes in space in current climate conditions.

Comparing results with the near-surface air temperature behaviour we can conclude, that New seasonal features of near-surface warming were identified: Both maximum and minimum Summer SAT showed further growth in the recent decade, greater than winter season. The greatest warming Is registered in August, and smallest – in June. Combination of dry weather and warmer temperatures results in greater frequency of droughty events in August, there were 5 years with droughts during 2006-2012 at least in one region of Ukraine.

Atmospheric circulation. Recent warming episode is characterized by specific atmospheric circulation regime over Europe and is differed from that in previous decades after mid-XX century. Increased stability of predominant weather patterns is detected throughout the year; this causes favorable background for extreme and durative precipitation as well as for summer heat waves and/or droughty conditions.

Atmospheric circulation has been changed In 2001-2010 firstly in the mid-tropospheric level [Spanos et al., 2003]. Anomaly of 500 hPa geopotential I June shows deepening of trough over the North Russia, with trough extending Mediterranean Sea; cutting-off low is possible (fig.3). Contrast between west and East Europe is also seen.

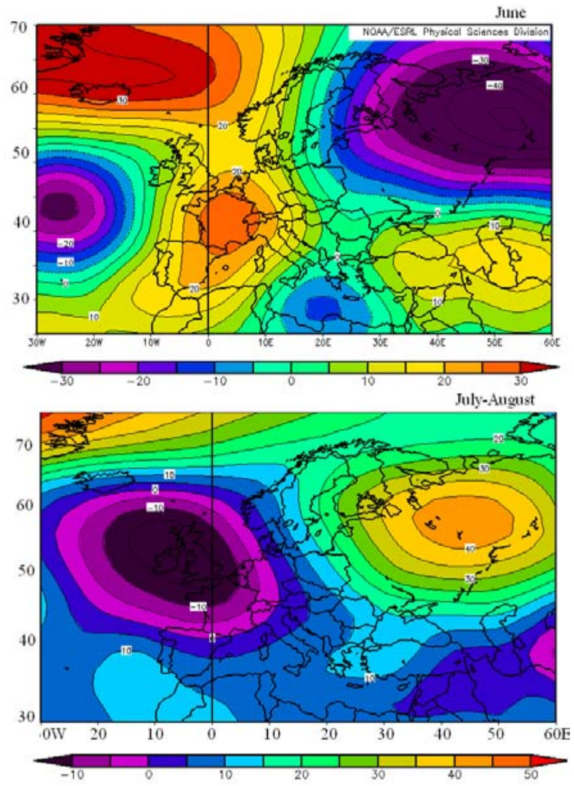

Fig. 3: Difference 500 hPa 2001-10 minus 1991-2000, June, and July-August (lower panel)

In July-August, Cross-European Contrast is intensified, however with alternative sign: (Fig. 3), with negative anomalies 500 hPa over North Atlantic and Western Europe, and higher geopotential over Eastern Europe, centered over Central Russia .

Next, consider synoptic patterns of days with extreme precipitation over Ukraine. They are presented in Fig. 4, as composites 500 hPa geopotential fields,

June, July: Composite 500 hPa field days with precipitation more 20 mm. shows typical ω-shape field with cut-off cyclone centered over Romania-Hungary in June, and over central Ukraine in July. Simultaneously, two ridges are seen – at east Atlantic, over UK, and east (Ural-north-west Kazakhstan). The area of the upper-level cyclone is cloudy and filled in with cold air, making favorable conditions for convection. Migrating from west, the cyclone firstly influences western Ukraine, fast separation of cut-offs is also noted over Central Europe. Thunderstorms can develop in cyclonic field near surface, or weakly expressed MSLP field.. Another local effect is more frequent cyclogenesis at the Black Sea, because orographic factors

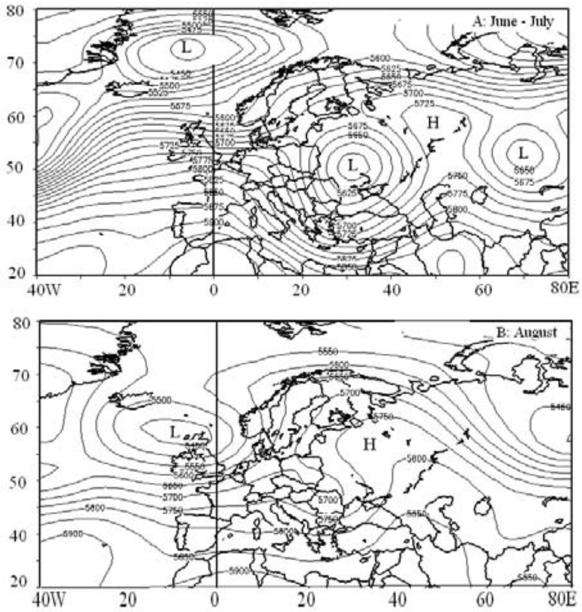

Fig. 4: Composites 500 hPa geopotential fields, days with precipitation > 20mm, June-July (A), and August (B)

August: Composite 500 hPa Field for days with extreme precipitation is characteristic by upper-level trough over the central Europe, which stretched to western Ukraine, however in contrast to previous months low pressure is less developed. The main feature of August is much more pronounced ridge in Eastern Europe (Ural high) which extended from tropical to polar latitudes, having a blocking character. These large-scale Synoptic systems divide Ukraine on west and east parts, with Precipitation most probable mainly in the western part of the country, and droughty conditions – in the east, in accordance with spatial picture of precipitation change (fig. 2c). Note developed Iceland depression, which creates larger-scale contrast between Western and Eastern Europe. Such a situation is typical for last several consecutive years.

Weather contrast across Europe strongly sharpened In August when rains and flood events are frequented in western part (from UK to Germany, Slovakia and western Ukraine), and droughts, high temperatures and fires – in eastern part (some latest consecutive years in West Russia, East Ukraine, Romania,. Greece).

Recent heat waves are frequented however they don't occupy all continent and do not occur during consecutive months. However it could be considered as a manifestation of climate change in frames of 'greenhouse climate' (Beniston, 2004).

Types of mesoscale fields responsible for strong precipitation are recognized within the larger-scale synoptic systems, such as convergence lines caused by topography, or mesocyclones. Transition between atmospheric scales can be used to assessing general threat of extreme precipitation.

Special attention was paid to extreme precipitation and conditions leading to flood events in mountain regions. Latest event of durative precipitation in Carpathian Mts. significantly exceeded monthly norms is analyzed; it resulted in the out-of-season flood event in summer, 2008, with easterly flow and ascention in Prikarpattya (slopes faced to east), in presence of upper-level cut-off low accompanied by high centered over Scandinavia. Short-range modeling of this event has been made via Weather Research and Forecasting model and showed adequate ability to simulate the event in 24h and 48h lead, with some overestimate in the leeside and underestimate in the windward slopes.

III. RESULTS AND CONCLUSIONS

Weak long-term changes in total precipitation in summer months are detected: insignificant positive trend in June and negative in August,

Comparison is made between two recent decades. Precipitation has been intensified during 2001-2010 along with great annual variability.

Significant intraseasonal contrast is detected, with rainy June and droughty August, as well as spatial weather contrast across Europe is enhanced during 2006-2010.

Trends in total summer precipitation amount, exceeding thresholds, days with precipitation and single daily intensity were obtained; Significant difference among individual months is detected, with an increase in extreme indexes in June and July, and decrease – in August. Greatest growth in the daily intensity occurred between 1990s and 2000s in the East part of Ukraine.

Extreme precipitation becoming more frequent represents greatest threat to agriculture during the spring/summer vegetation period.

Specific upper-tropospheric circulation regime over Europe in 2001-2010 is detected, and is differed from that in previous decade. Two responsible synoptic patterns were distinguished, comprising blocking (high) and cut-off (low) patterns.

Deep European trough with cut-off low causes the growth in the daily precipitation in June or July. On the other hand blocking high is dominated in the East Europe in late July-August, providing great weather contrast between West and East Europe. This cause smaller frequency of droughts in east Europe in the early summer, and greater frequency in August.

Creation of warning system on early detection and nowcasting of severe convective storms can be developed on the basis of catalogue of the synoptic circulation types and typical transitions between larger and meso- (local) atmospheric scales.

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