REGIONAL ASPECTS OF THE VARIABILITY OF ATMOSPHERIC PRECIPITATIONS IN WINTER AND SUMMER SEASONS IN EUROPE DURING 2001-2090

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ABSTRACT - Regional Aspects of the Variability of Atmospheric Precipitations in Winter and Summer Seasons in Europe during 2001-2090. A large number of studies have shown that precipitation have a spatial and temporal variability higher than temperature. The importance of the analysis regarding this topic emerges from the fact that the spatial-temporal variability of the atmospheric precipitation has a strong impact upon the environment and human society. The aim of this study is to identify the main changes which will occur in the amount of precipitation in Europe in winter, and summer. This study is based on regional climate models used to evaluate the future evolution of precipitation patterns in Europe during 2001-2090. We used the output regional climate model, CLM_B1_1_D3, based on the climate scenario IPCC, B1. Our results have shown that the relative pluviometric differences between the analysed periods reveal a more significant downtrend in the southern Europe and an uptrend at higher latitudes, in summer. In the winter season the amount of precipitation will decrease in the central and southern regions of the continent, while in northern and north-eastern areas precipitation amount either will remain constant or will increase by up to 25%.

Keywords: regional climatic model, climatic simulations, climatic variability, depth of rainfall, Europe

1. INTRODUCTION

Climate change is a critical issue the 21st century is confronting. Over the total history of our planet, climate has not been constant, but over the past few decades the rate of warming was higher than the one preceeding the Industrial Revolution (19th century) and greater anthropogenic impacts with negative side effects on the environment have been observed. Even if global precipitation patterns have a spatio-temporal variability higher than temperature, until 1950, an increasement in the amount of precipitation has been observed in northern Europe, especially in winter and a decreasement in southern areas, in summer (EEA, 2012). There is a medium confidence regarding a specific trend of summer precipitation extremes, because of the contradictory studies and analyses.

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In winter, the precipitation has fallen more as rain over the last decades, and it has been observed an upward trend regarding the heavy precipitation events in the central-western areas of Europe and European Russia (Zolina et al., 2009, quoted by IPCC 2012). During the 1901-2000 time period, increasing trends have been observed in Great Britain, Germany, and East-Central Europe, and decreasing trends in Northern Italy, Poland and coastal Mediterranean areas. The uncertainties are even more significant in Southern Europe and Mediterranean region, because of the low confidence regarding given trends (Maraun et al., 2008; Zolina et al., 2008, Bartholy and Pongracz, 2007; Kysely, 2009; Pavan et al., 2008; Lupikasza, 2010; Toreti et al., 2010 quoted by IPCC, 2012). Projections estimate future decreases up to southern Sweden during summer and increases in the same areas with precipitation falling especially as rain in mountain areas in winter. (Schmidli et al., 2007; Steger et al., 2013; quoted by IPCC, 2014).There is a high confidence regarding the increasement of future heavy precipitation events in northern and central Europe, during all seasons (except summer), but the projections for the southern areas is uncertain regardless of season (Seneviratne et al., 2012; Sillman and Roeckner, 2008; Boberg et al., 2009, quoted by EEA, 2012).

The climate models described in the IPCC reports, concerning the greenhouse gases concentration, are based on three emission scenarios: B1, A1B and A2. The lowest emission rate is expounded in scenario B1 (Busuioc et al., 2010), which we utilised in this study.

The aim of this study is to identify the main changes in the amount of precipitation concerning the entire European continent using a regional climate model, based on an optimistic climatic scenario (B1).

2. DATA AND METHODS

We have used a climate model, CLM_B1_1_D3, created by World Data Center for Climate Hamburg (DKRZ) based on the existence of a normal geographical grid which shows climatic regional simulations for the period 2001-2100 in Europe. This model is based on the previous one, improved by adding a few new parameters: convective precipitation amount, number of days with total precipitation more than 10 mm, number of days with total precipitation more than 20 mm, number of days with snow etc. (Hollweg et al, 2008), these being stored as time series on the geographical grid. The database was designed on a non-rotary grid with a spatial resolution of 0.2^o (Lautenschlager et al., 2009). This climate model is using the climate scenario IPCC, B1. This type of scenario describes a convergent world with a continously increasing global population by the middle of the century which then declines, but with quick changes in the economic system in the direction of a service and information economy, introducing clean technologies, targeting efficient resources. The emphasis is laid on global solutions for economic, social, environment durability, without other initiatives in the climatic field (IPCC, 2000). This scenario shows a future increase of greenhouse gases emissions by 2050 (11.7 billion t.) followed by a decrease by 2100 (5.2 billion t.) (IPCC, 2000). The described climate model uses spatial data in NetCDF format which is a multidimensional file (NetCDF*)*. For the engendering of this study we used ArcMap 10.2 software (ESRI, Redlands, CA, USA), converting the file using the option "Make NetCDF Raster Layer" from the "ArcToolbox" menu in an usual raster file. Then, we selected the dates according to each month of every year from the studied period, followed by the use of the "Cell Statistics" option (from Spatial Analyst menu) in order to achieve a cumulative precipitation for every season considered (winter and summer).We determined a few statistical parameters such as mean and standard deviation, dividing the studied period into 30 year subperiods (2001-2030, 2031-2060, 2061-2090) following the WMO (2011) recommendations which implies at least a 30 year analysis of climate change. Finally we calculated the percentage differences in the amount of precipitation for each statistic parameter and period using the "Raster Calculator" option (from Spatial Analyst menu). The first comparative analysis resulted from the mean and standard deviation differences between the 2031-2060 and 2001-2030 periods; the second one considered those differences between the periods of 2031-2060 and 2001-2030 and the third one shows the difference between 2061-2090 and 2001-2030 periods.

3. RESULTS

3.1 The percentage changes in the average amount of precipitation between the three periods

The comparison regarding the percentage difference in terms of average precipitation amounts between the two periods: 2001-2030 and 2031-2060 showed that during the winter season, precipitation will experience an increase by 50% during the second period compared to the previous 30 years over small areas in the Pyrenees, Sierra Morena, Alps, Southern Italian peninsula, eastern Romania - Moldavian Plateau and northern Scandinavian mountain range.

Over the largest european areas, precipitation will either remain steady or decrease by up to 25% (Mediterranean regions, most of the Atlantic Ocean bordering Europe, central and eastern continental areas, especially in Poland, Germany and Austria) (Fig. 1). Instead, during the summer season, precipitation will significantly increase by up to 50% in restricted areas. The amount of precipitation will remain steady over most of the continent except the inslands and peninsulas of southern Europe (Fig. 2).

During the winter months, the increase in total precipitation will not exceed 25%, except for a small Mediterranean area (southern Balearic Islands and the Gulf of Lion). Decreases of up to 50% will occur only in small areas in the Sierra Morena. Over most of the continent, the amount of precipitation will either be unchanged or slightly rise. Throughout the summer, greater decreases in the amount of precipitation are expected, especially in the southwestern part of the continent (up to 10% - Iberian Peninsula, France, northern and central Italy, Tyrrhenian Sea and the Meditteranean islands). Most of the european continent shows future insignificant changes or small decreases in the amount of precipitation, except for its northern part, where precipitation is expected to increase by up to 25%, even though some parts of the Norwegian Sea will experience an increase of up to 75%, along with The Balearic Islands and southern Italy (100%).

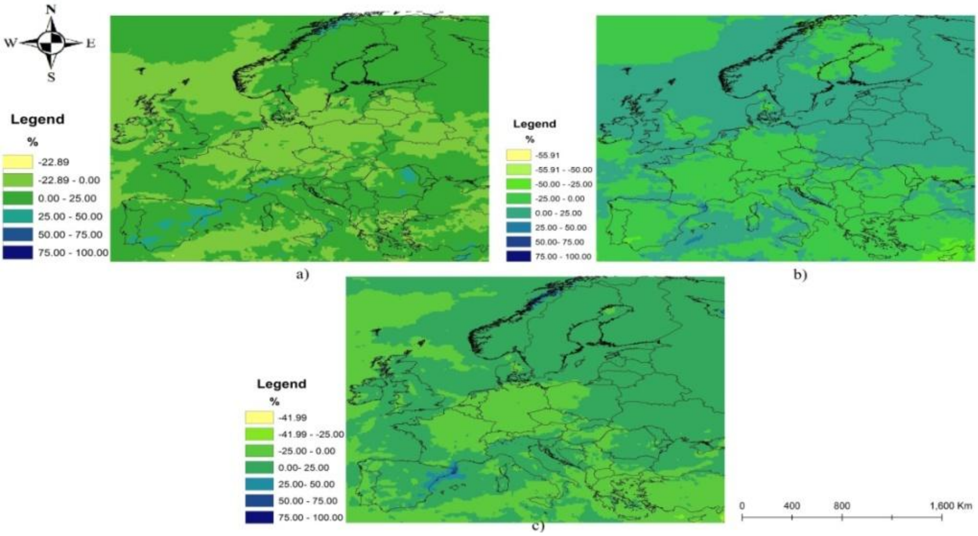

Fig. 1. ***The percentage changes in the average amount of precipitation between the three periods during the cold season;***

Note: a = the percentage difference between the two periods: 2031-2060 and 2001-2030; b = the percentage difference between the two periods: 2061-2090 and 2031-2060; c = the percentage difference between the two periods: 2061-2090 and 2001-2030

During the last analyzed period, the southern european areas will experience winter precipitation decreases of up to 25% (Mediterranean Sea, the Balkan Peninsula, the southern area of the Italian Peninsula and southwestern Iberian Peninsula) along with the Central Europe (Germany, France, Switzerland) and the Atlantic Ocean bordering the United Kingdom. The amount of precipitation will increase by up to 75% over north-eastern coastal area of the Iberian Peninsula and the northwestern mountains of Scandinavia. As it can be observed, the amount of precipitation will either remain unchanged, or slightly increase over most of the continent at the end of the analyzed period. The warm season shows a future slightly increase (northern Europe, small areas in Great Britain and southwestern Romania). Decreases of up to 100% will happen in most of southern Europe. Elsewhere across Europe, (especially the central region), the amount of precipitation will slightly decrease (25%).

3.2 The percentage changes in the amount of precipitation according the standard deviation between the three periods

The first analyzed period in terms of standard deviation, during the winter season shows high deviations from the mean values between 25 and 100% over south-western and northern Europe. Over the mediterranean and baltic regions the deviations will be reduced by up to 50% (Fig.3).

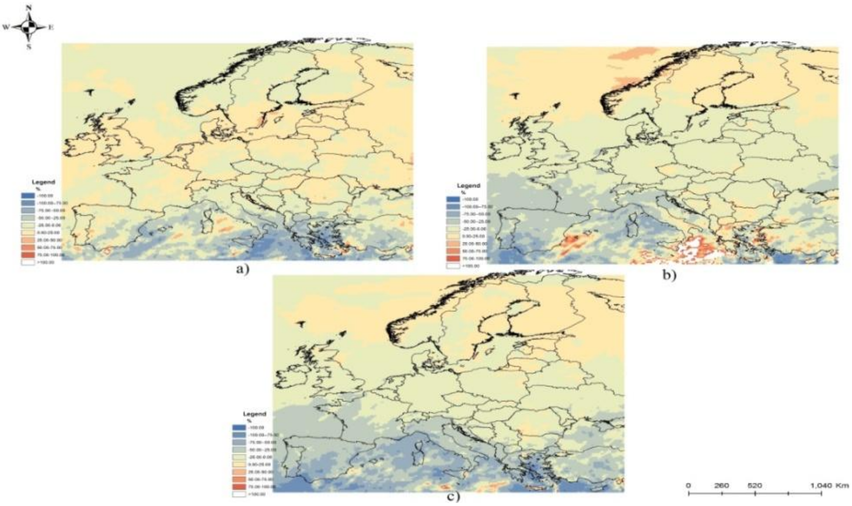

Fig. 2. ***The percentage changes in the average amount of precipitation between the three periods during the warm season;***

Note: a = the percentage difference between the two periods: 2031-2060 and 2001-2030; b = the percentage difference between the two periods: 2061-2090 and 2031-2060; c = the percentage difference between the two periods: 2061-2090 and 2001-2030

Throughout the summer, large deviations up to 100% will be recorded in the following areas: northeastern, central and southern Europe and southern Scandinavian Peninsula. Over the southern Europe, the deviations from the mean values will be small to insignificant (Fig. 4).

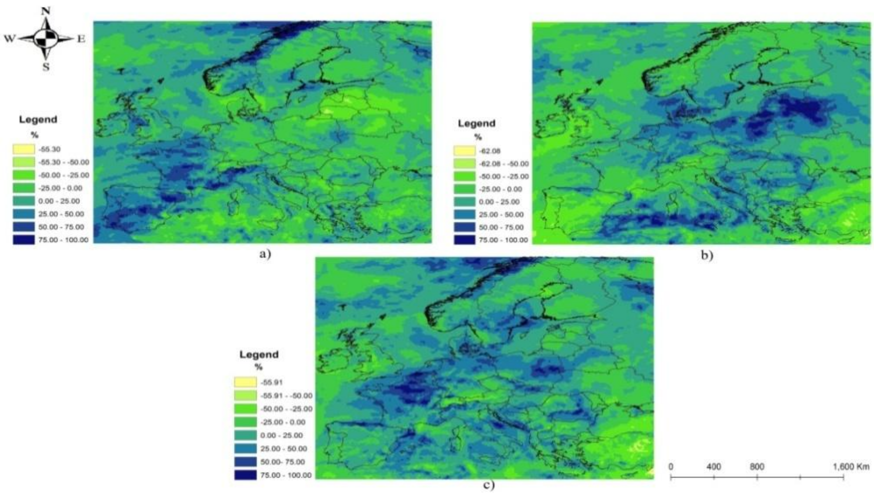

Fig. 3. ***The percentage changes in the amount of precipitation regarding the standard deviation between the three periods during the cold season***

Note: a = the percentage difference between the two periods: 2031-2060 and 2001-2030; b = the percentage difference between the two periods: 2061-2090 and 2031-2060; c= the percentage difference between the two periods: 2061-2090 and 2001-203

The second period considered shows the greatest deviations of the values from their mean during the cold season, over Mediterranean regions and the countries bordering the Baltic Sea. The values closest to their mean will be seen across areas of the Iberian Peninsula, Great Britain and Ireland, southeastern and northern Europe. Instead, summer maximum deviations will be shown across areas of northern and southeastern Europe, while southwestern and central Europe will show small deviations up to 50 or even up to 100%.

The last period considered shows a high standard deviation during the winter season (100%) in large areas of the southern and northern Europe. The smallest standard deviations will be shown in central and western Europe (up to 90%). Small deviations will be shown during the warm season over large areas of southern Europe and across restricted northern and central areas of the continent. The largest standard deviations will be seen over the northern part of the continent and also Romania.

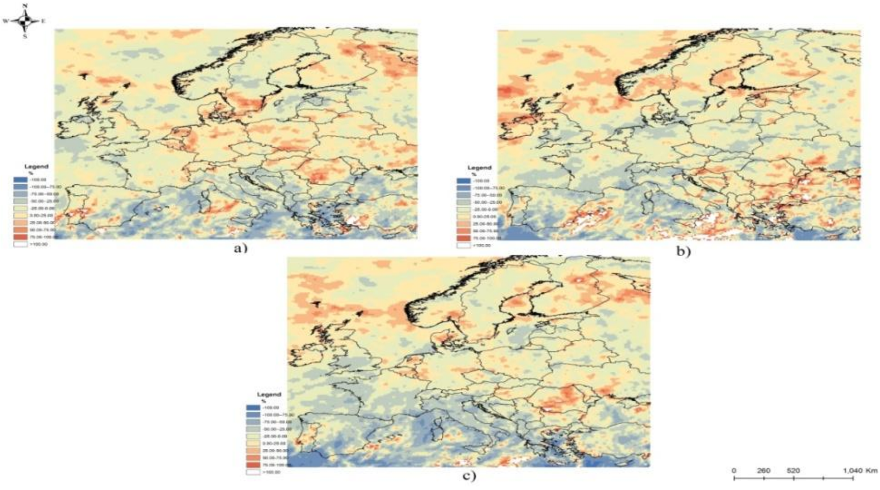

Fig. 4. ***The percentage changes in the amount of precipitation regarding the standard deviation between the three periods during the warm season***

Note: a = the percentage difference between the two periods: 2031-2060 and 2001-2030; b = the percentage difference between the two periods: 2061-2090 and 2031-2060; c = the percentage difference between the two periods: 2061-2090 and 2001-203

4. DISCUSSION

Studies which deal with the same subject are very numerous, but many of them were conducted taking into account the extreme values. For example Heinrich et al (2012) noticed that north-eastern and southern european areas will respond most quickly to climate change by the end of the 21st century, using climate indices which were calculated for 26 regions, relying on the changes that have occurred not only in the mean, but also in the interannual variability of precipitation and air temperature. Similar findings were made by Burke along with Brown in 2008 (quoted by Heinrich et al. 2012) who associated the increase of the number and duration of droughts with the decrease of the amount of precipitation over the

Mediterranean regions; Sheffield and Wood in 2008 (quoted by Heinrich et al. 2012), relying on changes occurring in soil moisture; Warren et al. in 2009 (quoted by Heinrich et al. 2012) whose study revealed strong increases in droughts and Lehner et. al in 2006 (quoted by Heinrich et al. 2012) who found an increasing frequency of high-risk events such as floods in northern and eastern Europe or drought in the south and southeast areas of the continent (Heinrich et al. 2012). Also (Christensen et al., 2007, quoted by Lehtonen et al., 2014) said that there is a strong possibility that phenomena such as heavy precipitation events will intensify in the future both in terms of frequency and its character in the northern part of Europe, while droughts are expected to increase in the southern areas, although most of the studies are uncertain (Lehtonen et al., 2014).

Another study based on thermal and precipitation extremes in Italy shows a meticulous analysis of expected extreme climate future events using extreme indicators. The authors analyzed the ability of the model to statistically represent a subset of climate indicators for precipitation and temperature defined by the Team of Experts on Climate Change and Detection Indicators (ETCCDI). The analysis on the climate change concluded that extreme weather events are expected to increase in frequency, and this is a crucial point for impact studies (Zollo et al., 2015).

5. CONCLUSIONS

The carried out study revealed the future main changes in precipitation patterns in Europe by the year 2090. To this end, we used a regional climate model, CLM_B1_1_D3 developed by World Data Center for Climate Hamburg (DKRZ).This climate model is based on an optimistic climate scenario, B1.

We found that the differences regarding the amount of precipitation in relative terms, between the considered periods show a progressively decreasing trend in southern Europe, while higher latitudes areas are more prone to a future increase during summer. The amount of winter precipitation will decrease in the central and southern european areas, while in northern and northeastern areas the changes will most likely be quite small. Some of this northern and northeastern european areas show increases of approximately 25%. Although a comparison with other studies is limited, given the different models and scenarios used, our findings are largely consistent with those works indicating future dry periods in the Mediterranean regions, increasingly wet periods in the northern european areas and insignificant precipitation patterns future changes in central ones.

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