PROJECTED TRENDS IN HEAT AND COLD WAVES UNDER EFFECT OF CLIMATE CHANGE

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Abstract: *Global average temperatures increased by 0.8°C in 2016 as compared to the period of 1961-1990 and 1.1°C from the pre-industrial period (1850-1899).They hit records for three consecutive years in 2014, 2015 and 2016, and the year 2016 ranks as the warmest on record. Climate models expect a temperature increase between 1.5°C-2.5°C and between 2.5°C-3.6°C based on RCP4.5 and RCP8.5 scenarios respectively by end of the century. It is projected that the increased temperatures may cause increases in the frequency and severity of some meteorological extreme events. Heat waves accounted for 43% of meteorological disasters in 2016 in Turkey. In this study, future trends of periods of heat and cold waves are studied with respect to RCP4.5 and RCP8.5 scenarios of HadGEM2-ES Global Climate Model. The results showed while number of heat waves are expected to increase, a decreasing trend of cold waves will dominate in future periods in Turkey.*

Keywords: *Heat wave, cold wave, climate change*

INTRODUCTION

The global average surface temperature has risen about 1.1 °C since the late 19th century, a change driven largely by anthropogenic emissions into the atmosphere. Most of the warming occurred during the last three decades, with 16 of the 17 warmest years on record occurring since 2001. Scientists agree that global temperatures will continue to rise for decades to come, largely due to greenhouse gases produced by human activities. The IPCC predicts that increases in global mean temperature of less than 1 to 3 °C above 1990 levels will produce beneficial impacts in some regions and harmful ones in others (IPCC, 2013). Global warming is expected to bring more frequent and severe heat waves, which could impact vulnerable populations. Last quarter of the 20th century already witnessed negative effects of climate change probably more than any other period during the same century. Global warming has serious negative effects on all human activities such as health, agriculture, urbanization and tourism. WMO reported 2014, 2015 and 2016 as the warmest years since instrumental measurement of temperatures began (WMO, 2017). With the increasing global surface temperatures, the possibility of more droughts and increased intensity of storms will likely occur. If global climate change causes the global average temperature to rise as projected by climate models, there will be fewer cases of cold wave and a greater probability of more intense and frequent heat waves.

Heat waves are among the most dangerous of natural hazards, but rarely receive adequate attention (WMO, 2015b). Heat-cold waves cause serious health problems and lead to deaths. In the last 10 - 15 years, many severe heat waves have occurred in the world. One of the most severe was the European heat wave of July and August 2003, which occurred during an unusually dry summer (Black et al., 2004). Due to heat wave incidents in Europe, 14,800 people lost their lives in Germany, Spain, France and England in July and August 2003 (Bölük et al., 2013). The 2003 European heat wave was followed in 2010 by an even more intense and widespread heatwave, which scorched enormous areas across Eastern Europe (Barriopedro et al., 2011). A number of major heat wave events have occurred over the past decade, some of which have had devastating effects, such as that of Europe in 2003 and that of the Russian Federation in 2010 (WMO, 2015a; Robine et al., 2008; Osborn, 2010).

A heat wave has various definitions, depending on regional climate, among other factors. WMO defines a heat wave as five or more consecutive days in which the average daily maximum temperature is exceeded by at least 5 °C from normal (Alexander et al 2006; WMO, 2015b).

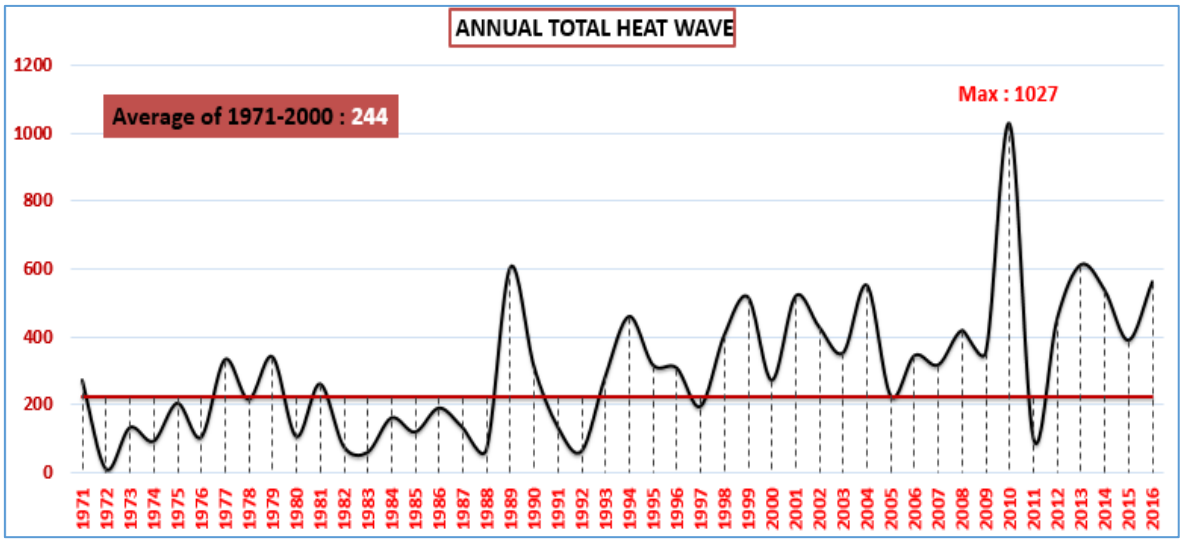

Figure 1 The number of annual total heat wave

The frequency of heat waves are increasing by year by year in Turkey. According to the data from 224 meteorological stations, the annual average number of heat waves is 224 in the period 1971-2000, and there have been just 2 years of heat wave below normal since 1993 (Figure 1).

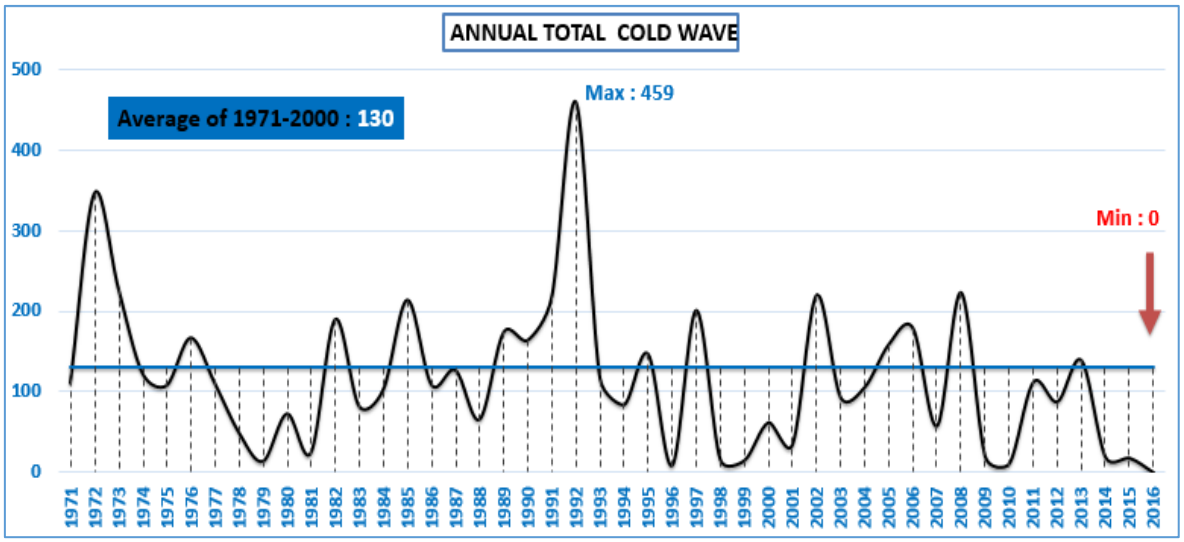

Figure 2 The number of annual total cold wave

There has been a decrease trend in the number of cold waves compared to the average of 1971-2000 period in recent years. 2016 was recorded as first year with no cold wave in the period of 1971-2016. In the period of 46 years (1971-2016), a cold wave was observed above the average in 16 years and below the average in 30 years (Figure 2).

In this study, the trends of heat-cold wave occurrences were studied based on climate model projections for Turkey.

DATA AND METHODS

Initially three GCM models were considered for the study, and then after performing verification on temperature parameter, HadGEM2-ES Global Climate Model has been chosen along with RCP4.5 and RCP8.5 scenarios. HadGEM2 stands for the Hadley Centre Global Environment Model version 2. Members of the HadGEM2 family were used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). The standard atmospheric component has 38 levels, with a horizontal resolution of 1.25 degrees of latitude by 1.875 degrees of longitude. This is equivalent to a surface resolution of about 208 km x 139 km at the Equator, reducing to 120 km x 139 km at 55 degrees of latitude. (MetOffice, 2014; Demircan et al., 2014)

In order to obtain high-resolution climatic parameters from the low-resolution global model data, nesting method (Nested simulations) was employed with Regional Climate Model (RegCM4). In next step, temperature projections were produced for 2016-2040, 2041-2070, 2071-2099 periods, relative to the 1971-2000 reference period at 20 km resolution. The results were mapped separately for the each period.

APPLICATION AND RESULTS

The HadGEM2-ES global climate model data were used in the study for the future projections of the heat-cold waves. The results are mapped on the basis of scenario and period selected. The results show that an increase of heat wave occurrences in Turkey in all the future periods (2013-2040, 2041-2070, 2071-2098). During the period of 2013-2098 based on RCP 4.5 scenario; the number of days with heat wave per year is expected to increase between 20-110 days with an average of 42 days.

Results of change of the heat waves days based on RCP4.5;

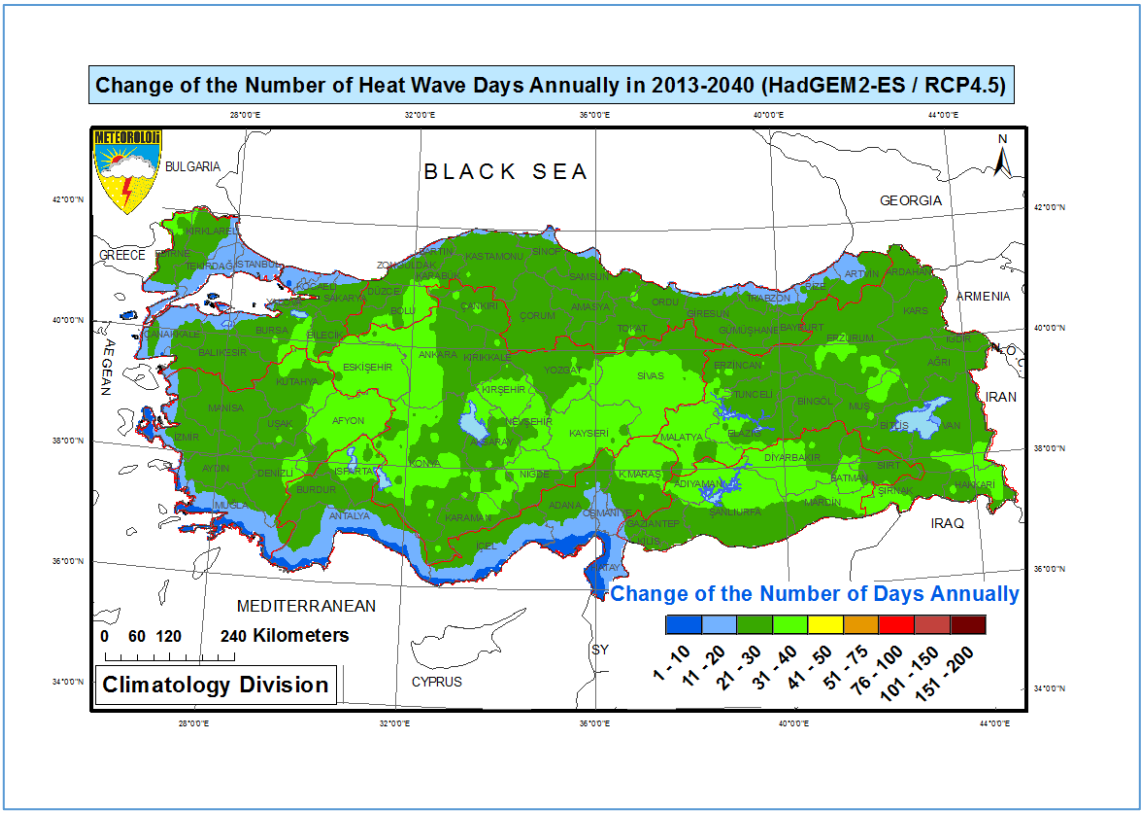

Figure 3 Change of the number of heat wave days annually in 2013-2040 (HadGEM2-ES / RCP4.5)

In the period of 2013-2040, increases in the number of heat waves are expected to attain nearly 40 days. Especially, in inland regions expected increases are significant (Figure 3).

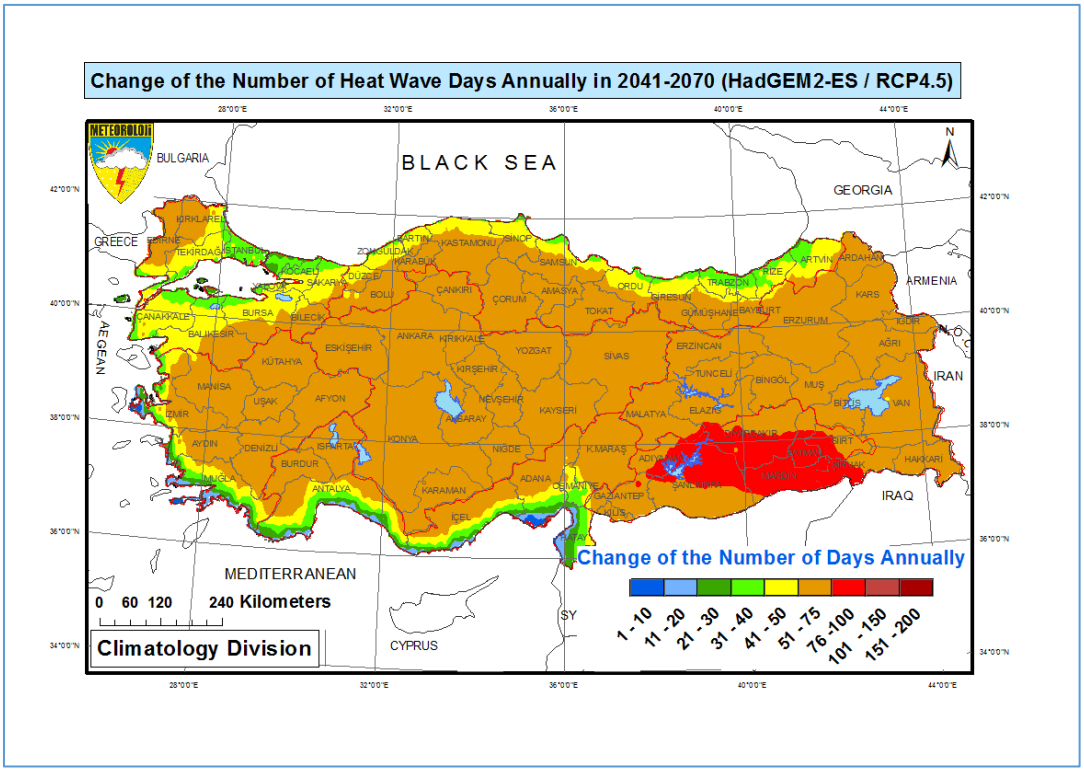

Figure 4 Change of the number of heat wave days annually in 2041-2070 (HadGEM2-ES / RCP4.5)

In the period of 2041-2070, increases in the number of heat waves are expected to reach nearly to 100 days. In the large part of the country, the increase is expected to take place around 51-75 days and in the southeast region 75 - 100 days (Figure 4).

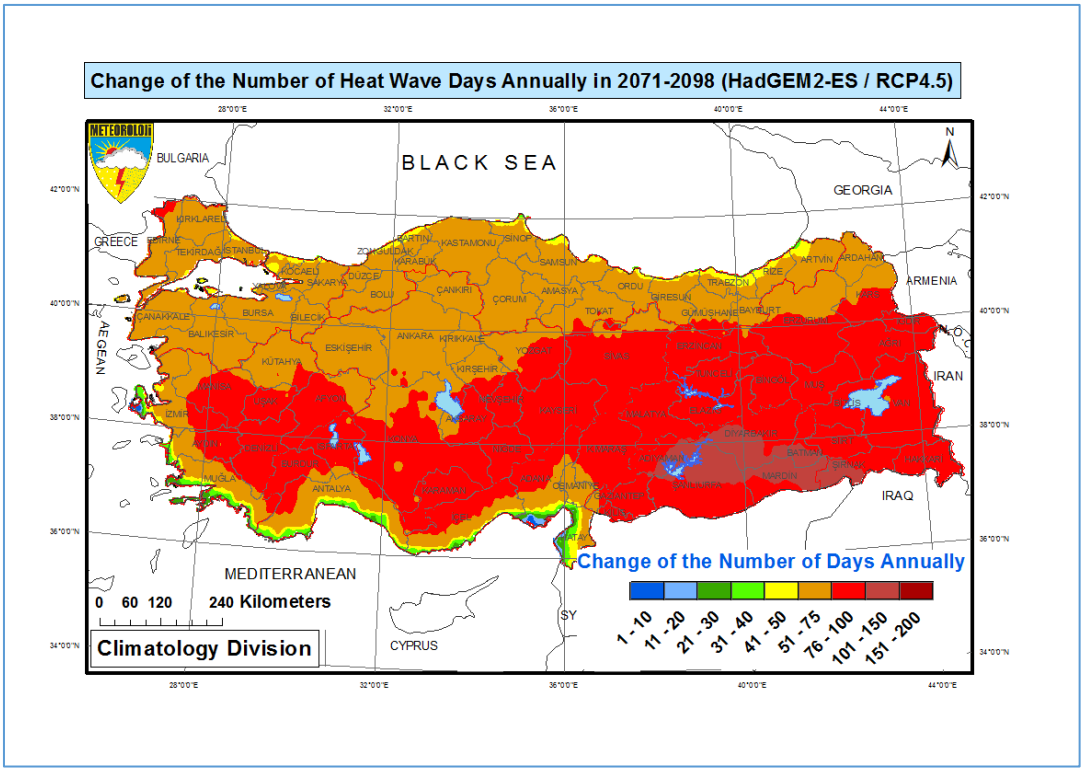

Figure 5 Change of the number of heat wave days annually in 2071-2098 (HadGEM2-ES / RCP4.5)

In the last period, southern regions are expected to be most vulnerable parts of Turkey. Especially in part of south eastern region, number of heat waves days are expected to change 101-150 days (Figure 5).

Results of change of the heat waves days based on RCP8.5;

According to RCP 8.5 scenario; the number of days of heat wave per year is expected to increase between 27-204 days with an average of 78 days during the period of 2013-2098.

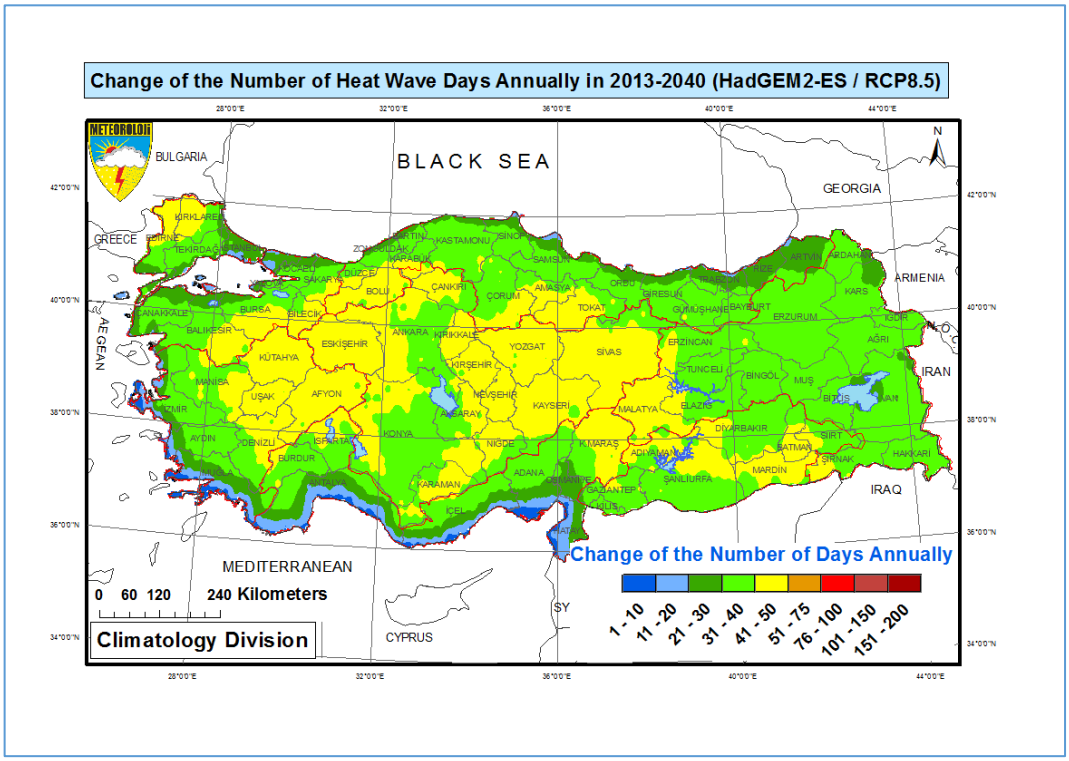

Figure 6 Change of the number of heat wave days annually in 2013-2040 (HadGEM2-ES / RCP8.5)

Sensitive regions during the period 2013-2040 are similar to RCP4.5 in the same period. Increasing trend in the number of heat waves days are expected to reach up to 50 days (Figure 6).

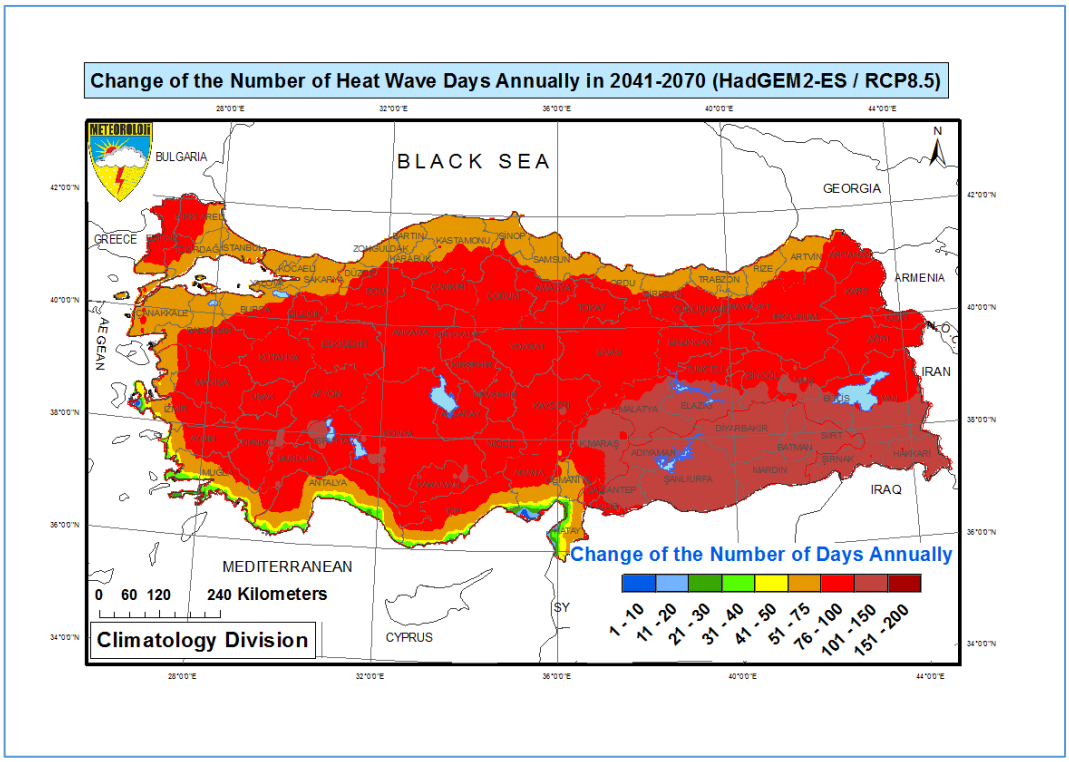

Figure 7 Change of the number of heat wave days annually in 2041-2070 (HadGEM2-ES / RCP8.5)

According to the projections of the period of 2041-2070, change of the number of days are expected to vary between 76-100 days. In addition, more than 100 days (101-150) of increasing trend is expected in the Southern East Anatolia region (Figure 7).

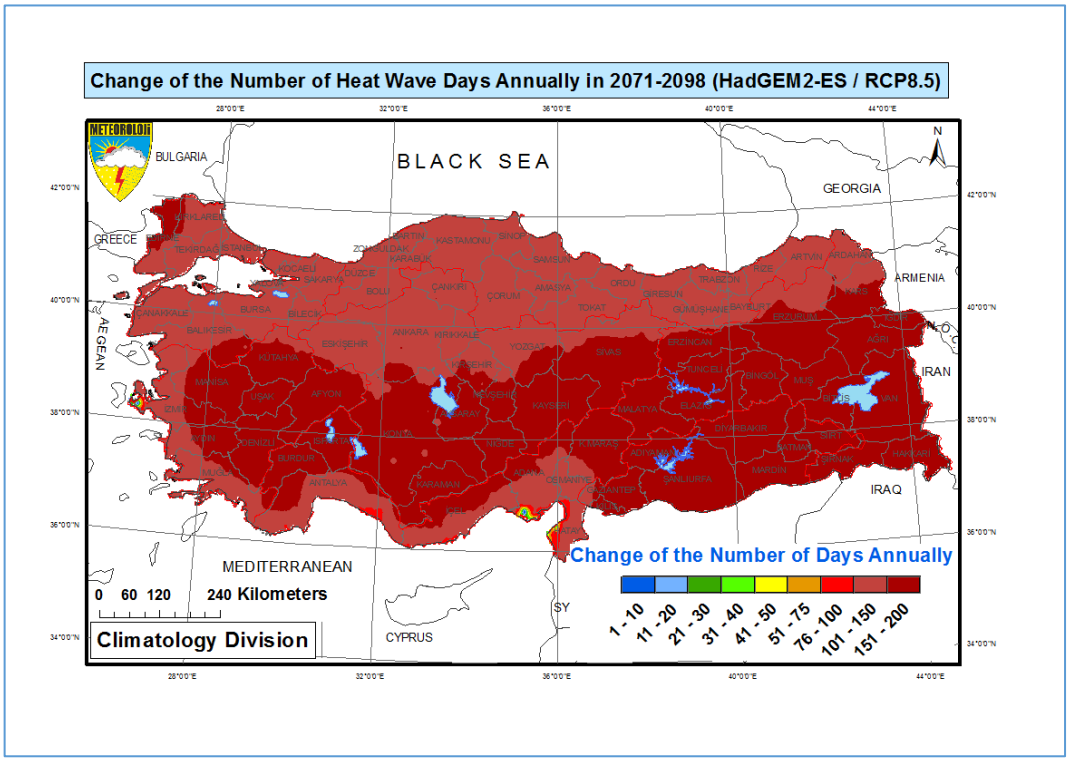

Figure 8 Change of the number of heat wave days annually in 2071-2098 (HadGEM2-ES / RCP8.5)

Projections of the last quarter of the century, shows that the change in the number of heat wave days exceed 100 days in the entire country. East Anatolia, South Eastern Anatolia, inland part of the Aegean region and southern part of Central Anatolia are expected to be affected seriously. In these regions, change in the number of heat wave days are expected to be between 151 and 200 days (Figure 8).

Results of change of the cold waves days based on RCP4.5;

Due to climate change and global warming, it is expected that the frequency of cold waves will decrease in future periods. Obtain results from the both scenarios (RCP4.5 and RCP8.5) indicate that no increase in the number of cold waves are expected throughout the country. RCP4.5 shows a decrease between 3-10 days per year for the entire period is projected. According to RCP8.5 scenario the number of days of cold wave per year is expected to decrease between 2 - 14 days. These results can have a positive impact on various sectors, especially human health and agriculture.

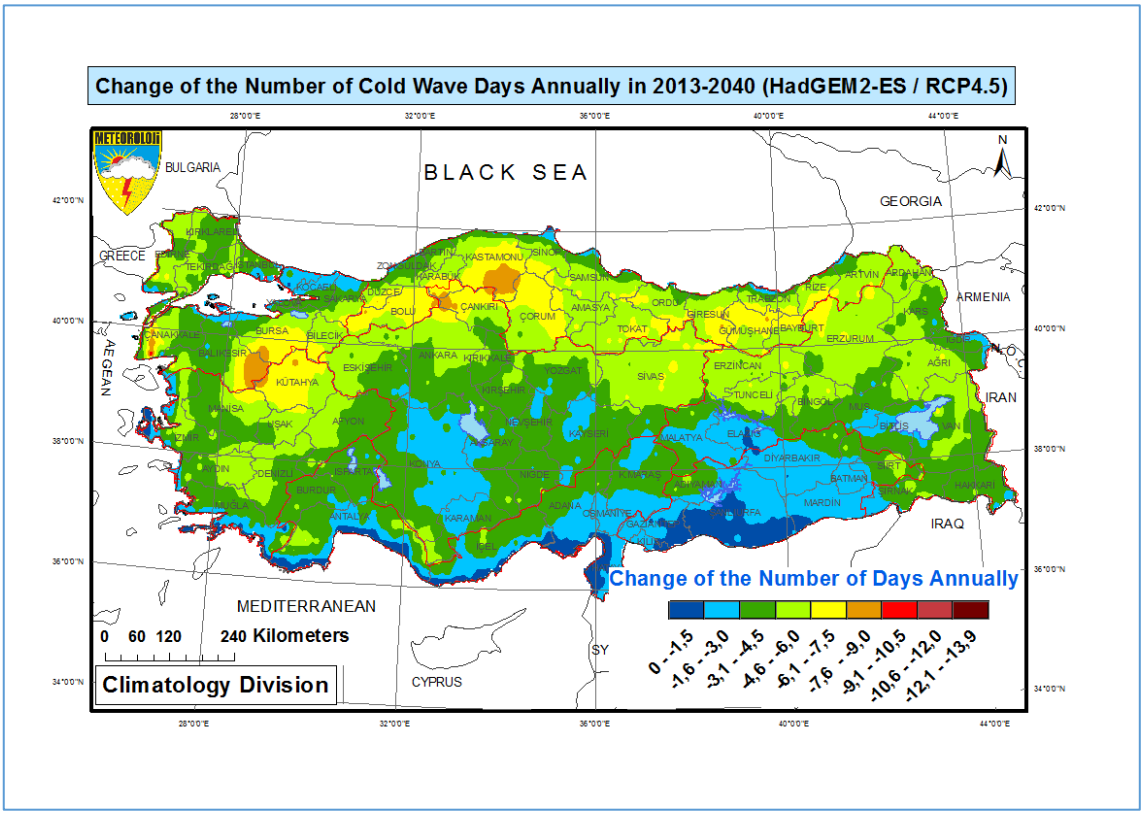

Figure 9 Change of the number of cold wave days annually in 2013-2040 (HadGEM2-ES / RCP4.5)

In the first future period, there is no significant change throughout the coastal parts of Mediterranean region and some southern border of country. The regions where maximum declines are expected in inner parts of the Black Sea Region and the southern parts of Marmara region (Figure 9).

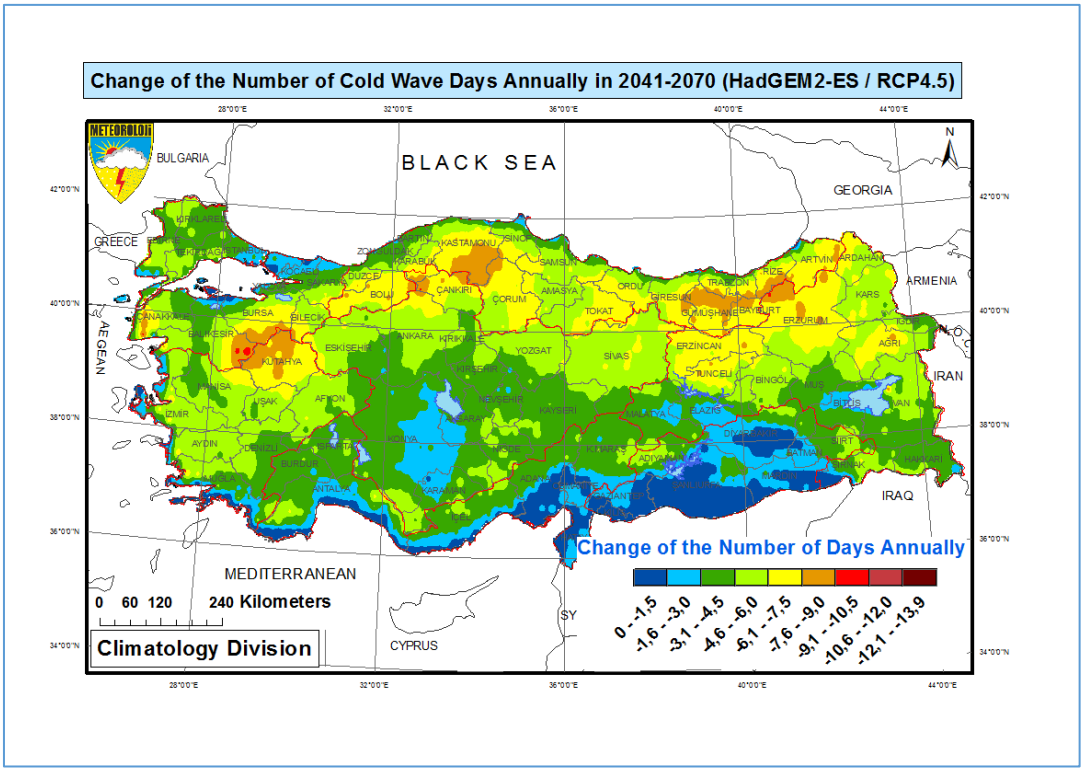

Figure 10 Change of the number of cold wave days annually in 2041-2070 (HadGEM2-ES / RCP4.5)

In the period of 2041-2070, the decrease in the northern regions of the country is expected to be more. As well as a decline up to 10 days is expected in the south of Marmara region (Figure 10).

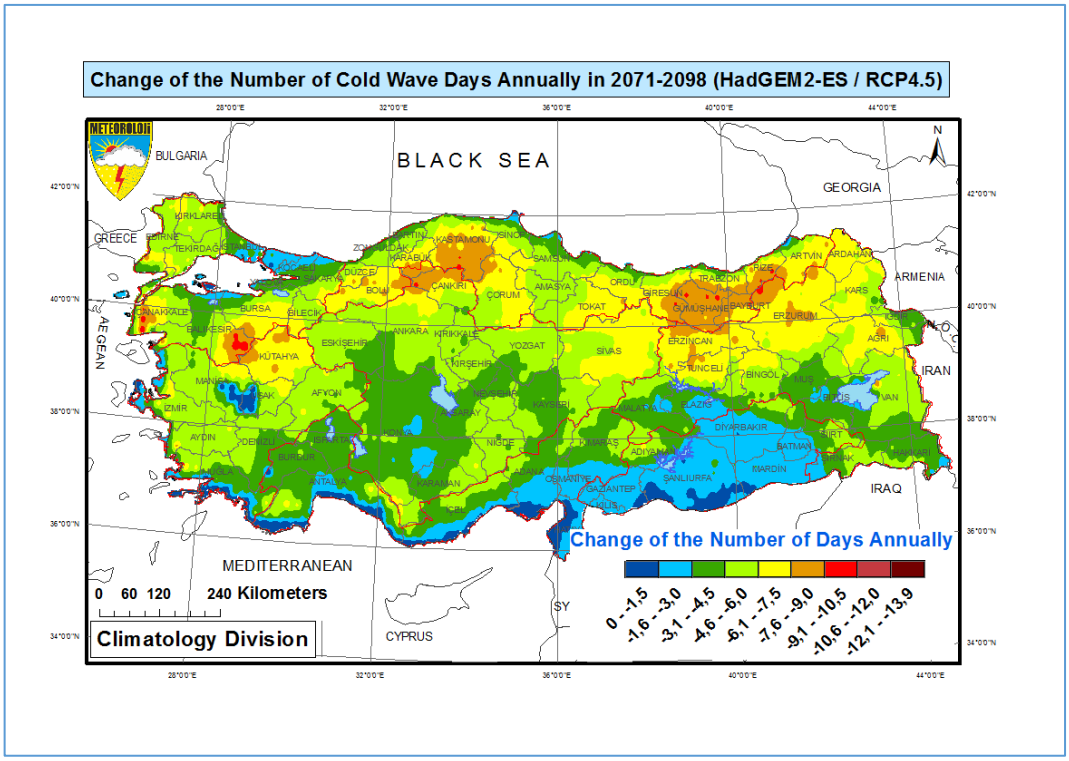

Figure 11 Change of the number of cold wave days annually in 2071-2098 (HadGEM2-ES / RCP4.5)

According to projections of last period (2071-2098), the regions to be affected positively due to decrease in the number of cold wave days are mostly the inner parts of the Black Sea Region and the southern parts of the Marmara Region (Figure 11).

Results of change of the cold waves days based on RCP8.5;

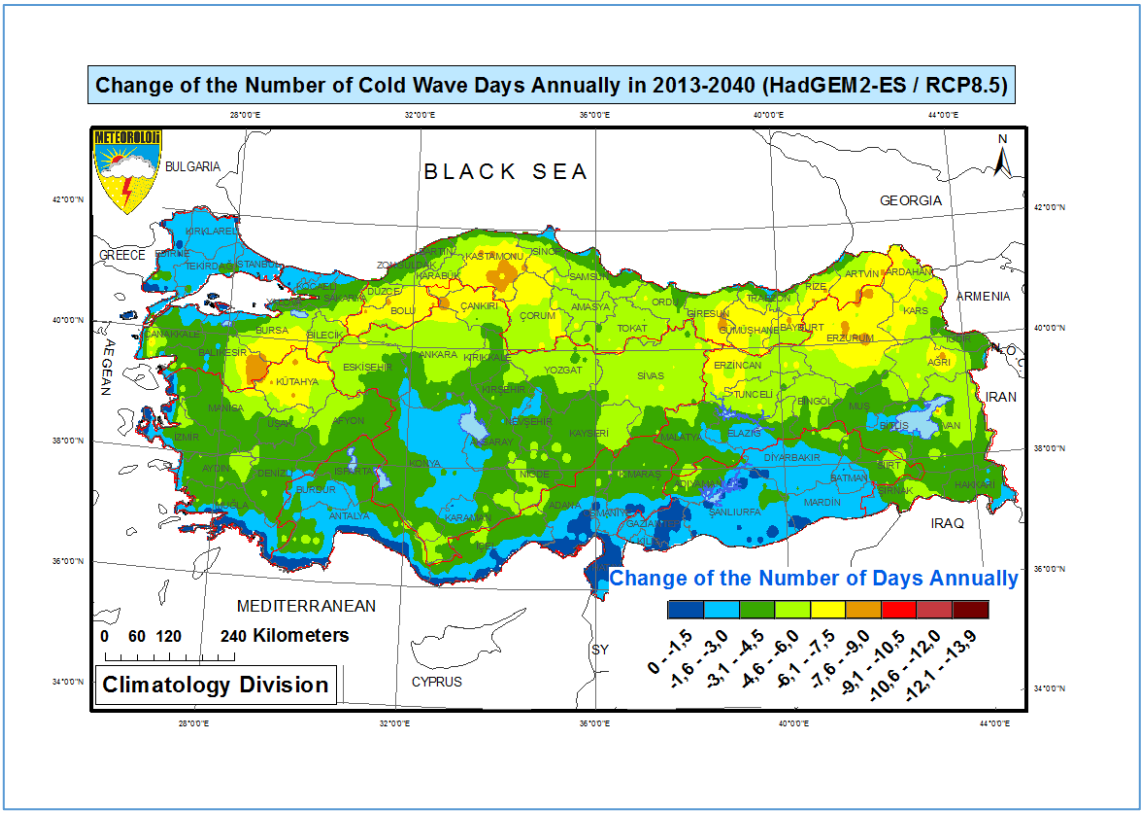

Figure 12 Change of the number of cold wave days annually in 2013-2040 (HadGEM2-ES / RCP8.5)

In the period of 2013-2040, it is noteworthy that the number of declines in the northern regions will be higher (Figure 12).

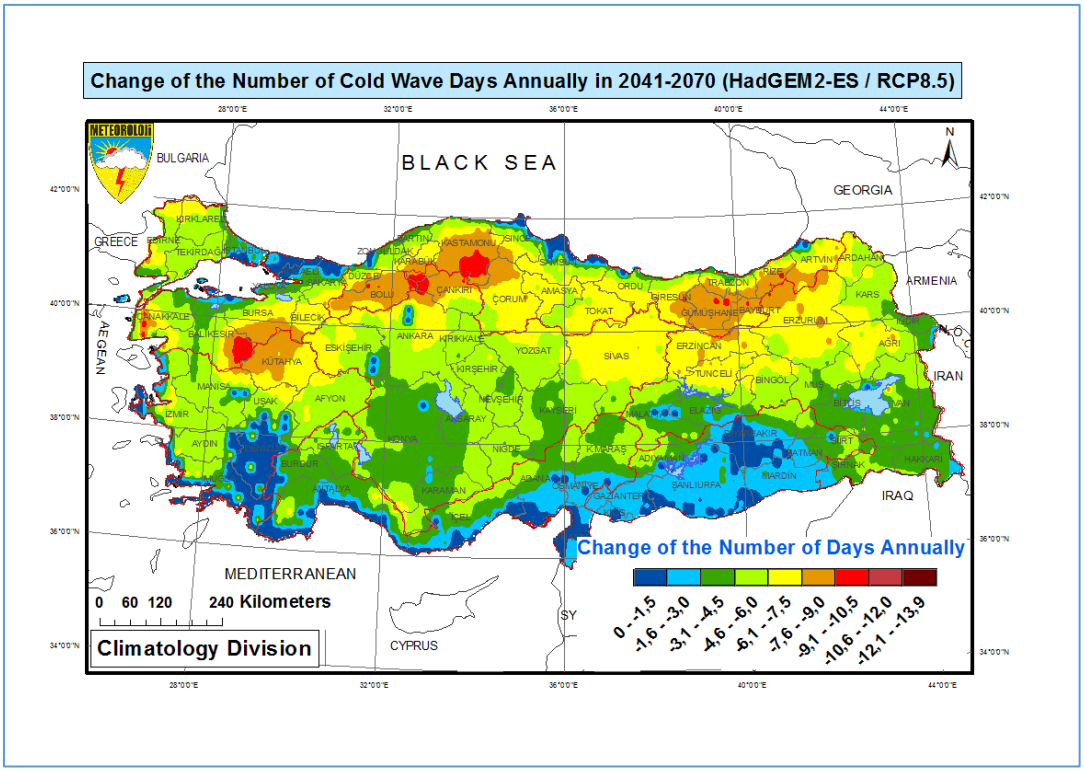

Figure 13 Change of the number of cold wave days annually in 2041-2070 (HadGEM2-ES / RCP8.5)

According to projections of 2041-2070 period, it is expected that the decrease in cold wave days will be over 10 days in the inner parts of the Black Sea Region and south of the Marmara Region. The change is very few in the southern regions (Figure 13).

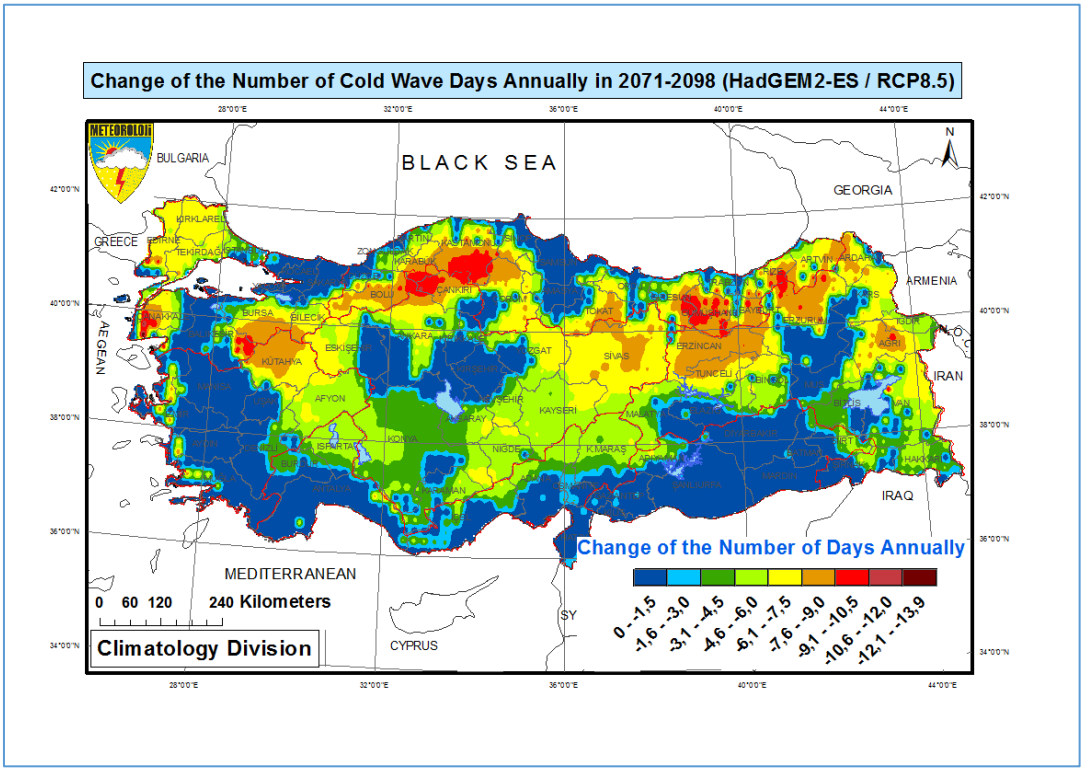

Figure 14 Change of the number of cold wave days annually in 2071-2098 (HadGEM2-ES / RCP8.5)

In the last period of the century (2071-2098), it is expected that the decreases will reach up to 14 days in northern regions. At the same time, it is also noteworthy that regions of no significant change in the number of days of cold wave days cover wider region (Figure 14).

CONCLUSIONS AND RECOMMENDATIONS

Climate change causes adverse impacts on human activities in many parts of the world. Temperature increases associated with global warming are among the main causes for the increase in frequency of meteorological disasters, and the most frequent increase in meteorological disasters in recent years is the heat wave.

It is expected that climate change will make heat waves worse in terms of their impacts on people, property, communities and the environment. Heatwaves have widespread impacts, ranging from direct impacts on our health to damage to ecosystems, agriculture and infrastructure (Anonymous, 2014).

In this study, projections were generated for the possible future trends of heat-cold waves. According to the results of the projections, the number of days of heat wave is expected to increase significantly. It is envisaged that the increase will be both for RCP4.5 and RCP8.5 scenarios especially after 2040s. Our study concludes that Central Anatolia, Eastern Anatolia and Southeastern Anatolia regions will be more sensitive in terms of increases in the heat waves. In the case of cold wave days, similar changes are expected in the both scenarios. The results indicate that the number of days of cold waves will decrease. The projection results reveal an optimistic situation in terms of cold waves throughout Turkey.

It is expected that the change in cold waves is expected to be less than the change in heat waves. According to RCP 4.5 and RCP 8.5 scenarios, the change in heat waves is between 0 - 110 days and 0 - 200 days respectively; the change in the cold wave remains at 0 - (-11) days and 0 - (-14) days. The increase in the number of days of heat wave is in a level that can cause serious problems throughout the country. According to the average of the reference period (1971-2000), increases of up to 200 days may cause adverse effects on human life throughout the year. Heat wave is projected to become more frequent throughout the century. It is inevitable that that will cause negative effects on many sectors such as agriculture, energy and urbanization.

According to the projection results, the number of cold wave days is expected to decrease. Declines are expected to occur mostly in the northern part of the country, on the contrary no significant change is expected in the southern parts of country. Because in the current climate conditions, the frequency of cold waves in southern regions is very low. Decreasing the number of cold wave days can be considered as one of the rare positive effects of climate change.

Heat & cold waves also cause record temperatures. Mega-heatwaves' such as the 2003 and 2010 events likely broke the 500-year-long seasonal temperature records over approximately 50% of Europe (Barriopedro et al., 2011).

The projections of change in the number of heat wave days reveal that Turkey is located in one of the most vulnerable geographical regions in terms of climate change and associated increases of temperatures. It is inevitable that the resulting figures would lead to negative effects on human activities if they occur as projected.

The projection results show that Turkey will encounter hotter, more frequent and more severe heatwaves in the future. For this reason, necessary precautions must be taken to adapt to heat waves. Mitigation, early warning and public awareness of all meteorological disasters are important for adaptation to climate change. Heat waves can cause serious problems especially in elderly and children. In many countries early warning systems

for heat-cold waves are being developed and trainings are held on what people should do in case of an emergency. It is important to plan to mitigate adverse impacts of heat waves that we are exposed to more and more every year.

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