

## **Climate Change and Extreme Events in the Mediterranean Region**

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### ***Abstract***

Climate change is a significant and lasting change in the distribution of weather patterns over periods ranging from decades to millions of years and affects dissimilar each region. It may be a change in average weather conditions, or in the distribution of weather around the average conditions, for instance more or fewer extreme weather events. Climate change is caused by factors that include oceanic processes, biotic processes, variations in solar radiation received by Earth, plate tectonics, volcanic eruptions, and human-induced alterations of the natural world. According to many researches, people contribute more to the current climate change, thus this paper focuses on the human-induced climate change.

Climate change increases the frequency and intensity of the weather events such as heat and precipitation. The changing climate impacts society and ecosystems in a broad variety of ways. For instance, climate change can increase or decrease rainfall thus influencing agricultural crop yields, affect human health, cause changes to forests and other ecosystems, affect the water resources or even impact on the energy supply. Climate-related impacts are occurring across regions of the country and across many sectors of economy.

In this paper, the study area is the Mediterranean region because it has shown large climate shifts in the past and it has been identified as one of the most prominent “Hot-Spots” in future climate change projections. In the continuity, some of the extreme events will be analyzed; heat waves, heavy precipitation, floods, droughts and the rising of sea level.

### ***Introduction***

Since the early stages of ancient civilizations, the environment is effected by land-use changes and modifications of the solar budget due to albedo changes. For a very long time these kinds of anthropogenic activities induced climate change, but was limited to local scale effects. With the beginning of industrialization around the mid-18<sup>th</sup> century, the impact of atmospheric pollution and the increase of greenhouse gases emissions have gradually lead to large scale changes in radiative forcing on the global climate system and initiated the man-made era. According to the chemical and physical properties of the emitted substances, feedbacks to radiative forcing can be

either positive (e.g., carbon dioxide-CO<sub>2</sub>, methane-CH<sub>4</sub>, nitrous oxide-N<sub>2</sub>O) or negative (e.g., aerosols, sulfur dioxide), resulting in either overall climate warming or cooling, respectively. Global atmospheric concentrations of greenhouse gases such as CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O have increased markedly and now exceed pre-industrial values determined from ice cores over the last approximately 1,000,000 years. During the last decades these changes have induced an overall undeniable warming of air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level <sup>[1,2]</sup>.

At continental and regional scales, numerous changes in climate have been observed. Climate change refers to any significant change in the measures of climate lasting for an extended period of time. These include a widespread mean temperature increase, changes in precipitation, wind patterns among other effect, and especially aspects of extreme weather events such as heat waves, droughts, heavy precipitation or tropical cyclones.

Climate change detection modified its focus from records of changes in monthly and annual averages to the analysis of extreme events. However, the understanding of climate change is complicated by interactions between changes in the mean and variability <sup>[1]</sup>.

According to Intergovernmental Panel on Climate Change, earth's average temperature has risen by 0.74°C over the past century, and is predictable to raise another 2-4°C over the next hundred years. It is important to notice that small changes in the average temperature of the planet lead to large and potentially dangerous shifts in climate and weather.

This paper will focus on the extreme weather events in the Mediterranean region due to lies in a transition zone between the arid climate of North Africa and the temperate and rainy climate of central Europe and it is affected by interactions between mid-latitude and tropical processes. Even relatively minor modifications of the general circulation, e.g. shifts in the location of mid-latitude storm tracks, can lead to substantial changes in the Mediterranean climate. This makes the Mediterranean a potentially vulnerable region to climatic changes <sup>[3]</sup>.

## ***1. Causes of Climate Change***

Extreme weather events do not have a single cause but instead have various possible contributing factors and one of those factors is the human contribution to climate change. Rigorous analyses have shown that natural contribution alone cannot explain the observed long-term trends of changing extremes in temperature, precipitation, etc. Humans are largely responsible for the recent climate change, which over the past century human activities have released large amounts of CO<sub>2</sub> and other greenhouse gases into the atmosphere that can warm the Earth's surface. The majority of these greenhouse gases come from burning fossil fuels for energy, deforestation, industrial processes, and some agricultural practices.

Greenhouse gases act like a blanket around the Earth, trapping energy in the atmosphere and causing it to warm. This phenomenon is called the greenhouse effect and is natural and necessary to support life on Earth. However, the buildup of greenhouse gases can change Earth's climate and result in dangerous effects to human health and welfare and to ecosystems <sup>[4, 5]</sup>.

## ***2. Extreme Weather Events***

### ***2.1 Heat Waves***

Heat wave is defined as a period of several days to weeks of unusually hot weather. Numerous studies have documented that humans have increased the frequency and severity of heat waves across the globe. In the past 3-4 decades, there has been an increasing trend in high-humidity heat waves, which are characterized by the persistence of extremely high night-time temperature. The combination of high humidity and high temperature during the night can affect human population and especially the elderly. Extreme heat events are responsible for more deaths annually than hurricanes, lightning, tornadoes, earthquakes and floods combined <sup>[6]</sup>.

In a normal climate the probability for extreme events can be visualized like a usual bell curve, as illustrated in the *Figures 1, 2* below. Nevertheless, even a small change in average global temperature leads to significant change in the frequency of extreme events. Climate change shifts the curve to the right/to the hottest side and increasing the average temperature. Moreover, the curve become flatter (higher variability), which means a greater spread of events. The *Figure 2* demonstrates the historical temperature data from the Northern Hemisphere in different years. A “positive temperature anomaly” refers to temperatures higher than the long-term average and a

“negative temperature anomaly” means temperatures lower than the standard. As is obvious, over the years the temperature is increasing and extreme events become more common [6,7].

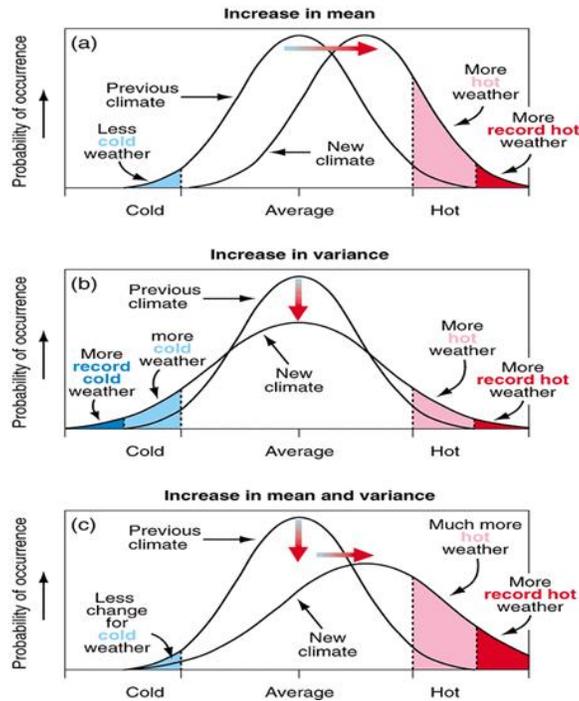


Figure 1: The probability of extreme events as a function of the shift of a probability distribution of temperatures [7].

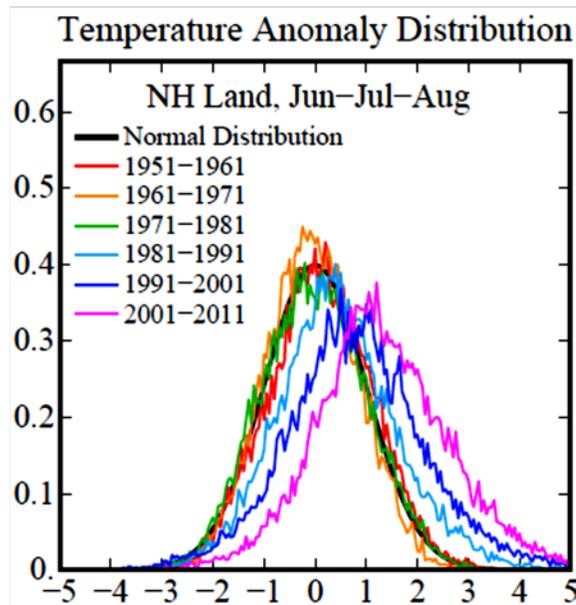


Figure 2: Frequency of summer temperature anomalies compare with the historical normal of 1951-1980 over the summer months in the northern hemisphere (Hansen et al. 2012/NASA).

Some health effects that are associated with heat waves are heat edema, heatstroke, heat rash, heat cramps, heat syncope and hyperthermia. In addition heat waves, contribute to the human mortality, physical stress, the excessive heat causes psychological stress, to a degree which affects performance, and is associated with an increase in violent crime. Also, cause widespread economic impacts, inconvenience, and discomfort <sup>[8]</sup>.

The low-humidity heat waves associated with droughts which dries out vegetation and fueled in part by climate change contribute to the dry conditions that are driving wild fires and bushfires. Similarly, heat waves can affect the marine ecosystem with serious consequences; as the temperature in the oceans is increased above the normal level <sup>[8]</sup>.

One example is the heat wave in Europe in summer 2003, the hottest of the past 500 years, with mean temperatures exceeding the late-20<sup>th</sup> century baseline by up to 5 standard deviations. Excess deaths totaled more than 30,000 fatalities with 15,000 in France only. This event began in early June 2003 and lasted until mid-August, with air temperature records about 3-6°C above the seasonal average in many parts of Europe. This heat wave had dramatic social, economic, and environmental consequences in the whole of Europe, including an increase in heat-related human morbidity and mortality, forest fires, and widespread parasites. Moreover, it caused an anomalous warming in the Northwestern Mediterranean region seawater, which reached the highest temperatures ever recorded in the studied regions, between 1-3°C above the climatic value. During this catastrophic heat wave, fires raged through Portugal, destroying over 3,010 km<sup>2</sup> of forest and 440 km<sup>2</sup> of agricultural land, causing an estimated €1 billion worth of damage <sup>[9]</sup>.

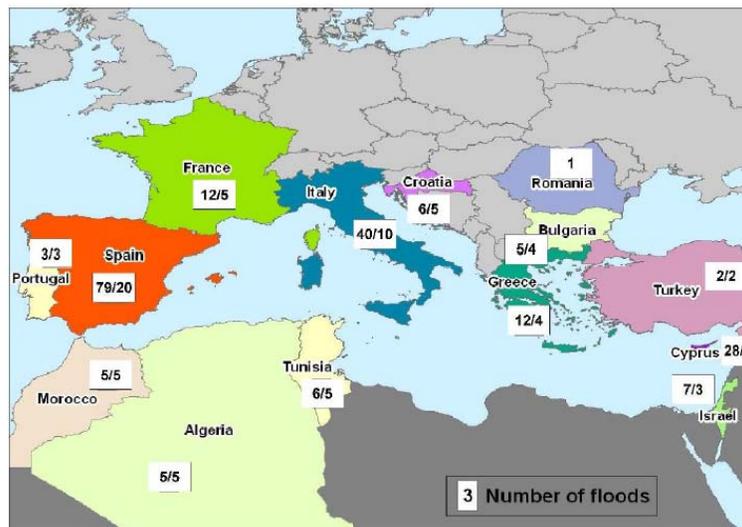
In a future warmer climate with increased mean temperatures, it seems that heat waves would become more intense, longer lasting, and/or more frequent. The increase in hot weather is a direct result of climate change, and human influence is estimated to have more than doubled the likelihood of the warming trends experienced recently in virtually every region of the globe.

## ***2.2 Heavy Precipitation and Floods***

Heavy precipitation is one of the extreme events that affect the globe, as a consequence of climate change/global warming. Due to the fact that warmer air can hold more moisture heavier precipitation is expected in the years to come. A 4% increase in atmospheric moisture has been

observed and that is consistent with a warming climate. Natural variability cannot account for the changes, but the fingerprint of human influence has been identified in these changes. In the Midwest and Northeast, huge storms that historically would only be seen once every 20 years are projected to occur as much as every 4-6 years by the end of the 21<sup>st</sup> century <sup>[10]</sup>.

Heavy precipitation contributes to increased flooding, a pattern that has already been observed around the Mediterranean region (*Figure 3*). The frequency of great floods (100-year floods in large basins) increased substantially during the 20<sup>th</sup> century. However, flooding is also affected by various other human activities, such as deforestation which may exacerbate flooding, while changes in land use can greatly influence runoff, which can either increase or reduce the risk of flooding <sup>[10, 11]</sup>.



*Figure 3: The number of floods in Mediterranean region during 1990-2006. The left number is the number of available information and the right number the total number of flood events selected by the MEDEX database (1996–2004).*

The primary effects of flooding include loss of life, damage to buildings and other structures, for instance bridges, sewerage systems and roadways. Infrastructure damage also frequently damages power transmission and sometimes power generation, which then has knock-on effects caused by the loss of power. This includes loss of drinking water treatment and water supply, which may result in loss of drinking water or severe water contamination. It may also cause the loss of sewage disposal facilities. Lack of clean water combined with human sewage in the flood

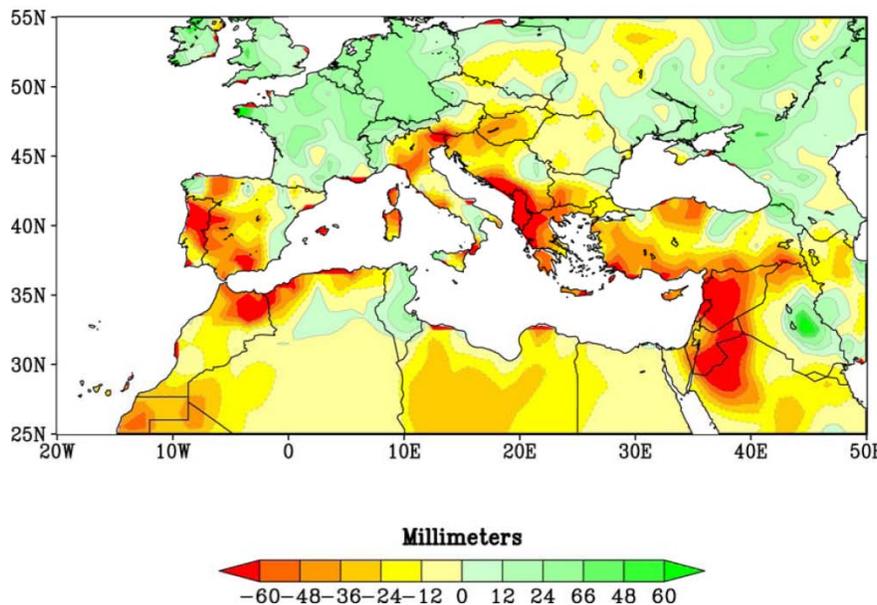
waters raises the risk of waterborne diseases, which can include typhoid, giardia, cryptosporidium, cholera and many other diseases depending upon the location of the flood. Moreover, damage to roads and transport infrastructure may make it difficult to mobilize aid to those affected or to provide emergency health treatment. Lastly, entire harvests for a country can be lost in extreme flood circumstances and some tree species may not survive prolonged flooding of their root systems. Furthermore, long-term effect to the country's economy due to a temporary decline in tourism, rebuilding costs, or food shortages leading to price increases is a common after-effect of severe flooding. The impact on those affected may cause psychological damage to those affected, in particular where deaths, serious injuries and loss of property occur<sup>[11]</sup>.

Some measures taken to protect human population and to reduce the risks to riverfront communities are: discouraging development in flood-prone areas and protecting the natural systems, such as wetlands, that help to buffer against floods.

### ***2.3 Droughts***

Despite the increase in precipitation in some areas, in other regions the climate change contributes to droughts. The conditions that drive droughts are lack of rain and increased evaporation from soil and vegetation associated with warming. Increased heating leads to greater evaporation of moisture from land, thereby increasing the intensity and duration of drought. The increase in drier, hotter areas and the trend in which dry areas are becoming drier can both be traced to the human influence. There are also important feedbacks that amplify drought and heat and set the stage for wildfires. This is a direct contribution to the drying and high temperatures in the absence of evaporative cooling. Particularly, the greenhouse gases have contributed significant to recent drying by driving warming over land and ocean. Recently, the work by Altava-Ortiz et al. (2010) highlights the occurrence of very dry decades in the western and central Mediterranean since 1984/8<sup>[12, 13, 14]</sup>.

The *Figure 4* illustrates the lands around the Mediterranean with reds and oranges highlight that experienced significantly drier winters during 1971-2010 than the comparison period of 1902-2010 <sup>[15]</sup>.



*Figure 4: The lands around the Mediterranean that experienced dry winters during 1971-2010 (NOAA).*

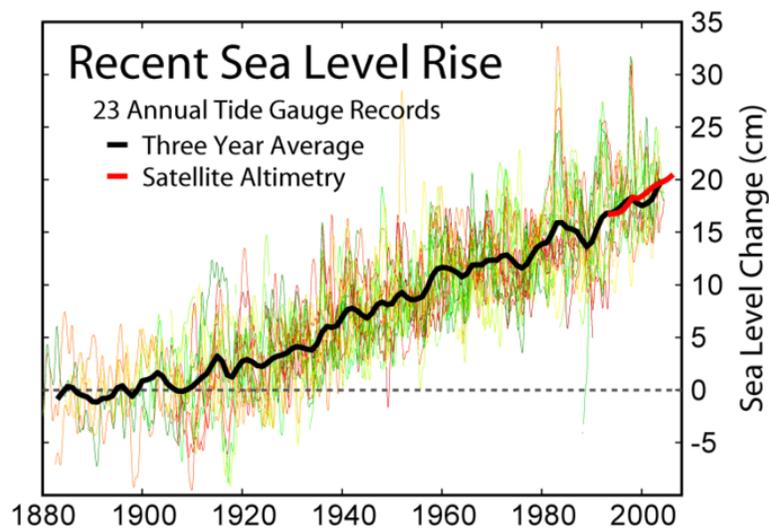
Periods of droughts can have significant environmental, agricultural, health, economic and social consequences. The effect varies according to vulnerability. For example, subsistence farmers are more likely to migrate during drought because they don't have alternative food sources. Areas with populations that depend on as a major food source are more vulnerable to famine. Drought can also reduce water quality, because lower water flows reduce dilution of pollutants and increase contamination of remaining water sources.

#### ***2.4 Increase in Sea Level***

At the end of the 20<sup>th</sup> century, the rise in sea level of the Mediterranean Sea was lower than in the rest of the world due to atmospheric pressure, but since the start of the 21<sup>st</sup> century the levels of the Mediterranean have regained pace and seem to be accelerating. The sea level has increased by between 1-1.5 millimeters each year since 1943, but this doesn't seem set to continue, because it now seems that the speed at which it rises is accelerating (*Figure 5*). As temperatures

rise, the sea will absorb heat from the atmosphere, causing it to expand and therefore creating sea level rises [16, 17].

Climate figures from 1943-2008 using a marine observation system confirms that the Mediterranean is becoming warmer. *Figure 5* illustrates in what manner the Mediterranean Sea level was changed during 1880-2000. As is obvious, the level is increasing over the years. Since the start of the 21<sup>st</sup> century the level has already risen by 20 centimeters. The average increase is 1.64 millimeters per year and in 2100 by 3-5 meters which means by a factor of 27 so far [18].



*Figure 5: The variations of the Mediterranean Sea level during 1880-2000 (NOAA).*

Impacts of sea level rise include increased coastal erosion, higher storm-surge flooding, inhibition of primary production processes, more extensive coastal inundation, changes in surface water quality and groundwater characteristics, increased loss of property and coastal habitats, increased flood risk and potential loss of life, loss of non-monetary cultural resources and values, impacts on agriculture and aquaculture through decline in soil and water quality, loss of tourism, recreation, and transportation functions.

Nonetheless, according to many experts, the changes which occurred in the temperatures are not only due to the effects of climate change, but also to natural and "normal" atmospheric changes. These are changes which are always going to happen; the atmosphere and oceans are chaotic

systems. However, people contribute more and accelerate the rate that the sea level is increasing [19].

### ***3. Conclusion***

Human-induced climate change has contributed to changing patterns of extreme weather across the Mediterranean, from longer and hotter heat waves to heavier rains. According to many studies, in a broad perspective, all weather events are now connected to climate change. While natural variability continues to play a key role in extreme weather, climate change has shifted the odds and changed the natural limits, making certain types of extreme weather more frequent and more intense.

In order to reduce climate change and extreme events some steps can be taken; to reduce greenhouse gas emissions at home, on the road, in the office, as a consequence to diminish the risks associated with climate change. Like changing a light bulb, powering down electronics, using less water, use renewable energy sources in transportation (solar, wind) and recycling. Many of these steps can save money; some, such as walking or biking to work can even improve your health! You can also get involved on a local or state level to support energy efficiency, clean energy programs, or other climate programs.

While the understanding of how climate change affects extreme weather is still developing, evidence suggests that extreme weather may be affected even more than anticipated. Extreme weather is on the rise, and the indications are that it will continue to increase, in both predictable and unpredictable ways.

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