
# *A Climatologist Signal from Greece*

Welcome to 112, Climate Tone, a series of podcasts investigating and discussing the phenomenon of climate change in Greece today.

This is a project by NEON for the World Weather Network.

For the first episode in the series, Professor Prodromos Zanis, Atmospheric Scientists at the Aristotle University of Thessaloniki, will present a Micro-Lecture on why the unique topography of Greece and the Mediterranean has meant it has become a climate change hotspot.

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## *1. Global warming*

We have known for decades that the world is warming up. Systematic instrumental observations from the late 19th century show that global temperatures have risen by about 1.1 ° C since the pre-industrial era (with the last decade being the warmest in the observational record).

Meanwhile CO2 concentrations have continued to rise, reaching record levels for 2021 at around 416 ppm. The rate of global temperature and CO2 changes are unprecedented in the last 2 thousand years while the last 100 years are estimated to be the warmest over the last 100,000 years. The

international scientific consensus is that the largest part of the warming since the preindustrial levels is attributable to a change in the atmosphere's composition caused by human activity. These changes induce an imbalance of the earth's energy budget and we know with high confidence the positive RF from the anthropogenic GHGs (such as CO2, CH4, N2O, Halocarbons, O3). Simply Earth's energy budget becomes positive and the climate system is warming. This is commonly referred to as the 'anthropogenic global warming'.

### *2. Climate change at the Mediterranean basin and surrounding counties*

Recent climate change is widespread, rapid and intensifying. The warming trends are regionally inhomogeneous affecting regional climate.

A region's climate is made up of the average weather conditions over a long period of time (at least 20 - 30 years). Climate change refers to a statistically significant shift either in the average state of the climate or in its variability that lasts for a long period of several decades or more.

But how is global warming linked with regional climate change in the Mediterranean and Greece?

Mediterranean is an ecological region with 46.000 km coastline hosting 10% of the global vegetation species and 7% of the marine species. It is surrounded by 22 countries which are inhabited by roughly half billion people with high population density (~60 persons/$km^2$).

The regions around the Mediterranean basin have a particular type of climate, known as 'Mediterranean', characterized for the most part by mild to cool wet winters and warm to hot dry summers. Meteorologically, it is influenced by both subtropical and extra-tropical dynamical processes and the continental regions surrounding Mediterranean basin are situated at the edge of semi-arid zones.

The warming trends over Mediterranean are larger than global warming trends. On average annual near surface temperatures in the Mediterranean region are now approximately 1.5°C higher than the pre-industrial period, well above current global warming trends (1.1°C). Model projections based on Global Climate Models (GCMs) and Regional Climate Models (RCMs) indicate a consistent intensification of warming for the Mediterranean region over the 21st century depending on the various future emission scenarios.

Observed precipitation trends in the Mediterranean are characterized by high variability in space and in time. But climate models clearly indicate a trend towards reduced rainfall in coming decades. This is related to a northward shift of baroclinic instability and the related atmospheric circulation changes due to global warming. Characteristically, we see that the future estimated average annual temperatures in the Mediterranean region exceed the corresponding global warming levels by 0.5 to 1.5 degrees, while the levels of reduction of rain and soil moisture amplify with higher levels of global warming.

Furthermore in the Mediterranean, we already see observed changes in the frequency and intensity of weather and climate extremes such as heat waves and droughts. In the coming future, heat stress and the duration of drought periods tend to further increase in the Mediterranean region.

Last but not least, mean sea level in the Mediterranean sea is projected to rise from 20 cm in the mid 21st century up to 70 cm by the end of the 21st century. However, there are uncertainties which will largely influence the Mediterranean Sea level rise, because of the connection to the global ocean through the Strait of Gibraltar.

Taking into account all the above mentioned future projections, the Mediterranean is commonly characterized as one of the most sensitive and vulnerable to anthropogenic climate change regions on Earth.

### *3. Impacts and challenges from climate change in Mediterranean*

In this region which is sensitive and vulnerable to anthropogenic climate change, several direct and indirect impacts in the coming decades are anticipated (on ecosystems, deforestation, desertification, land degradation, fire risk, natural disasters, water resources and management, energy demand, food security, agriculture, tourism, health and air quality, political conflicts due to migration and cultural heritage).

So, a number of new challenges will arise for us to cope with.

For example, because of the precipitation decrease, the temperature increase, and the population growth, freshwater availability in the Mediterranean Basin will be reduced, especially in the countries with stressed water supply. Furthermore, the coupled effect of warming and drought is expected to lead to a general increase in aridity and subsequent tension for desertification of many Mediterranean land ecosystems.

In addition, there are important coastal risks for humans as one third of the Mediterranean population lives close to the sea,  and the

infrastructures are often very close to mean sea level. Harbors, port cities and other coastal infrastructures, as well as wetlands and beaches around the Mediterranean will be under high risk due to the impact of climate change on rising sea levels, storm-surges, flooding, erosion and local land subsidence.

### *4. Climate change in Greece*

Greece is located in the heart of the Eastern Mediterranean and it is characterized by peculiar topographical features. Its is worth mentioning: the average high altitude of the Greek mainland (close to 600 m), the steep gradient in elevation from the coast to mainland (typically ranging between 100 m to 200 m per km), the impressively lengthy total coastline (about 16,300 km) which is more than one third of the Earth's equatorial perimeter; and the numerous populated islands in the Aegean and Ionian Sea.

This complex topography, together with the prevailing weather systems, accounts for a strong spatial variability of climate conditions varying from maritime to lowland, continental and highland Mediterranean climate within just a few dozens to few hundreds of kilometers.

The warming trends in Greece are larger than current global warming levels. This is clearly indicated by the measurements in two historical stations of our country, at the National Observatory of Athens and at the Aristotle University of Thessaloniki, which show a warming trend of roughly 2 $^{o}$C over the last 50 years.

Furthermore Greece is experiencing the last decades an increasing frequency of heat waves and other extreme events, directly or indirectly related to climate change, which has led to growing public and policy related awareness about the national, regional and local impacts of climate change.

GCMs are the main tools we have for future climate projections. However they still have a coarse horizontal resolution to resolve the effects on regional climate in countries with complex topographic characteristics such as Greece.

To support local/regional climate change impact studies as well as regional adaptation and mitigation strategies, it is necessary to use high resolution future climate data from model projections based on RCMs. This downscaling approach is essential for the complex topography of Greece.

An ensemble of RCM simulations for Greece projects robustly further warming ranging on annual average between 1.2 °C in the near future and 4.3 °C at the of 21st century depending on the anticipated future global

emission scenarios (with no, medium or strong mitigation of greenhouse gases). The warming trends are projected to be even higher at the mainland part of Greece during summer.

As far as it concerns precipitation, on an annual sum, it is projected to decrease marginally over Greece by -3% in the near future, but towards the end of the 21st century a decrease of 6% to 16% is estimated, depending on the scenario.

**Conclusive remarks**

Thanks to increased knowledge, more high-quality observations, and a better understanding of the past climate, we are in a better position than ever to explain the effects of anthropogenic climate change and look to the future.

The Mediterranean is one of the most sensitive and vulnerable regions to anthropogenic climate change on Earth

To limit global warming, a top-down approach is necessary with global commitments for strong, rapid, and sustained reductions in CO2, methane, and other greenhouse gases. This would not only reduce the consequences of climate change but also improve air quality.

It is therefore more relevant than ever to look the present and the future of the commitments aiming to climate neutrality in the middle of the 21st century. The EU as a whole has adopted this target and the new EU climate law, and the Greek national climate law are aligned with the goal of climate neutrality by 2050.

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