ΕΘΝΙΚΗ
ΜΕΤΕΩΡΟΛΟΓΙΚΗ
ΥΠΗΡΕΣΙΑ
HELLENIC NATIONAL METEOROLOGICAL SERVICE

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Hellenic National Meteorological Service
Climate, Environment and Meteorological Observations Division
Department of Climatology

Notable weather and climate events in Greece 2023

There were few significant weather and climate events in 2023 including heavy rainfall, floods, snowfall and heat waves.

Heavy Precipitation, Storms and Floods

- On **19 to 21 January 2023** a barometric low formed in the central Mediterranean Sea affected mainly the west and north parts of Greece and caused heavy rainfall, hail and thunderstorms. Flooding happened in the areas of Arcadia and Xanthi. Problems occurred in the transportation and electricity network and there were damages in buildings and businesses, and landslides on the road network of Messinia. A tornado destroyed roofs in the town of Paramithia, in the area of Thesprotia.

- On **25 to 27 January 2023** a barometric low, which reached Greece from the west, and specifically from the area of southern Italy, brought about heavy rain and thunderstorms over most parts of the country. Flooding, landslides, tree falls, destruction to the road network and power cuts took place in the area of Laconia and the islands of Zakynthos and Rhodes. Flooding occurred in the northern suburbs of Attica.

- On **04 to 07 September 2023** a barometric low from the northern Balkans with cold unstable air masses moved south to the southern Ionian Sea, and created a surface barometric low called 'Daniel' that affected mainly region of Thessaly with heavy rainfall and thunderstorms accompanied by hail and a high frequency of lightning. The storm caused severe flooding and major destruction to infrastructures, to the transportation and the electricity network and to agricultural production in the area of Thessaly. Greece saw record-breaking rainfall in September and had a flooded area of approximately 700 km^2. Thousands of people were trapped and needed rescue; thousands of animals were dead and 17 people lost their lives.

- On **25 to 28 September 2023** a storm referred as "Elias" caused heavy rainfall, landslides and damages to the transportation network, infrastructure and vehicles in the north Evia island, the city of Volos and the area of Achaia.

Snowfall and cold wave

- On **5 to 7 February 2023** a strong upper atmospheric disturbance (at 500 hPa) starting from the Scandinavian countries and the Baltic accompanied by cold air masses moved south-southeast and formed the barometric low "Barbara" that affected Greece with multi-day snowfalls that caused transportation problems, power outages and school closures mainly in areas of Attica, Thessaloniki, Magnesia, Evia, Viotia, and Fthiotida.

Heat wave and abnormally high temperatures

- On **12 to 26 July 2023:** In mid-July 2023, a long-lasting heat dome settled over the Meditteranean. The latest heat wave was an extension of a continuous heat wave that occurred in three successive phases; however, it never really stopped and took the name “Cleon” by the EUMETNET East Mediterranean Storm Naming Group (this was the first time a storm name was given to a heat wave), affected Greece and lasted 15 days. Temperatures peaked at 45.7°C in Argos station on 23 July and Anchialos station on 26 July (2nd record for the station after 46.2 ^{o}C recorded on 19 July 1973). Also, Skyros station reported its highest ever measured temperature, 44.4 ^{o}C on 26 July 2023.

- **October 2023** was the second warmest October on record in the last 64 years, 0.4^{o}C cooler than the warmest October in 1966. The average temperature was 2.3 ^{o}C above 1981-2010 normal values and the greatest temperature anomalies of 3.0-3.5 ^{o}C occurred in north areas.

1. Temperature Report for 2023

Analyzing the historical temperature data of all available HNMS meteorological stations, which operate continuously from 1960 to the present day the following results are obtained.

Greece surface air temperature highlights:

- 2023 and 2010 are confirmed as the warmest years on record in Greece.
- 2023 had an average annual temperature of 18.4 ^{o}C, 0.12 ^{o}C than the previous highest annual value in 2018.
- 2023 was 1.3^{o}C warmer than the 1981-2010 average.
- Each year from 2007 to 2023 was warmer than the 1981-2010 average.
- Greece winter (December 2022 – February 2023) was the fourth warmest winter on record, 0.7°C cooler than this winter 2023-24 which was the warmest winter on record.
- The average temperature for the Greek summer (June-August) was 27°C; at 1.1°C above average, it was the fourth-warmest on record.
- Greek autumn (September to November) had an average temperature of 20.4°C, which is 2.3°C above 1981-2010 average. This made autumn the warmest on record, 0.26°C warmer than the previous highest autumn record in 2019.
- Monthly mean temperatures in Greece were at least 1.3 ^{o}C above the 1981-2010 average for 8 months in 2023.
- July 2023 was the warmest month on record, with an average temperature of 29.2 ^{o}C, 2.5 ^{o}C above the 1981-2010 average.
- October 2023 was warmer than the corresponding month in any previous year since 1967.
- November 2023 was the month with a temperature deviation above the 1981–2010 average larger than any other month in the year.
- May 2023 was the month with a temperature deviation below the 1981–2010 average larger than any other month in the year.

1.1 Annual Temperature

The year 2023 was the hottest in Greece jointly with 2010, over the last six decades with an average annual temperature of 18.4 °C which is 1.3°C higher than the 1981-2010 average. The graph below shows the average annual temperature from 1960 to 2023 across Greece and the Loess smoothing.

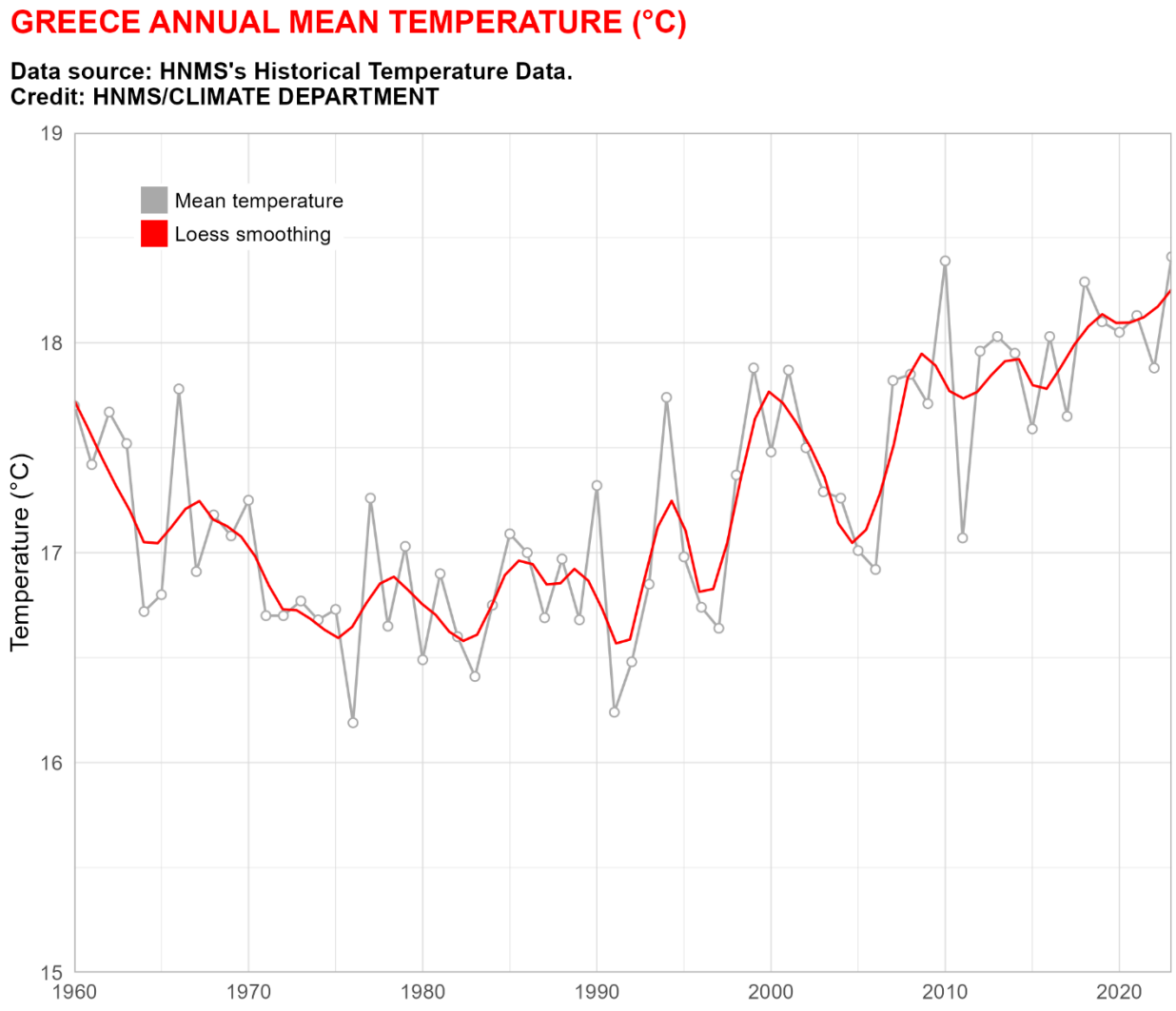

Figure 1: Annual mean temperature in Greece (average of 43 HNMS's met stations) from 1960 to 2023. Grey line shows annual mean temperature and red line γραμμή Loess smoothing.

Greece climate stripes reveal that the period 1971-1997 was predominantly a cold period for the country. 1976 was the coldest year on record following 1991. In contrast, the last 17 years (2007-2023) are generally warmer than normal, as only positive temperature deviations from the 1981-2010 average are observed (Figures 2 and 3).

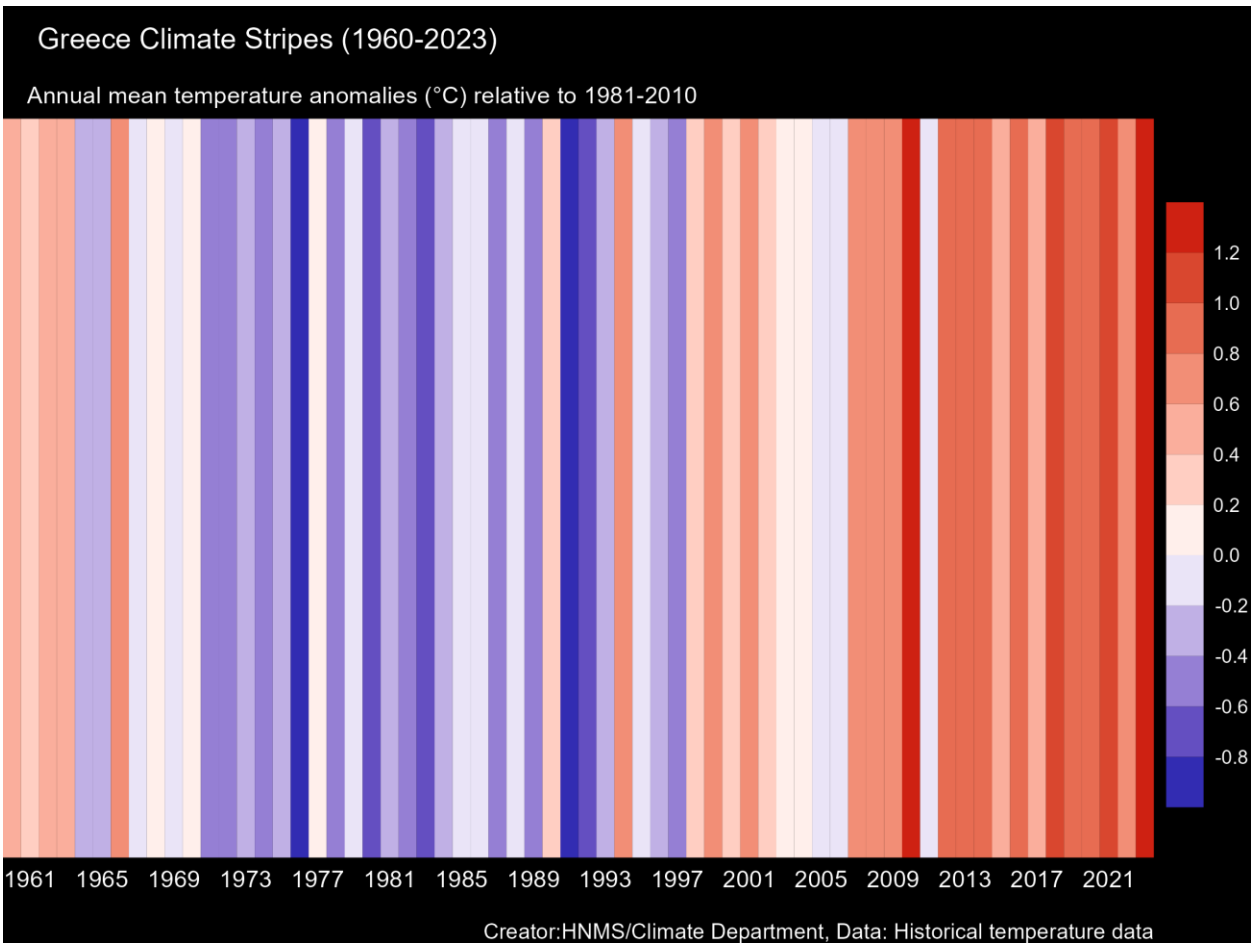

Figure 2: Greece climate stripes taking into account annual mean temperature anomalies relative to 1981-2010. Shades of blue indicate years that were cooler than the 1981-2010 normal value, while shades of red indicate years that were warmer than that – the darker the color, the larger temperature deviation from the normal value.

The third graph illustrates the deviation of annual mean temperatures from the average values of the period 1981-2010 in the country and an increasing trend of 0.18 ^{o}C per decade is depicted.

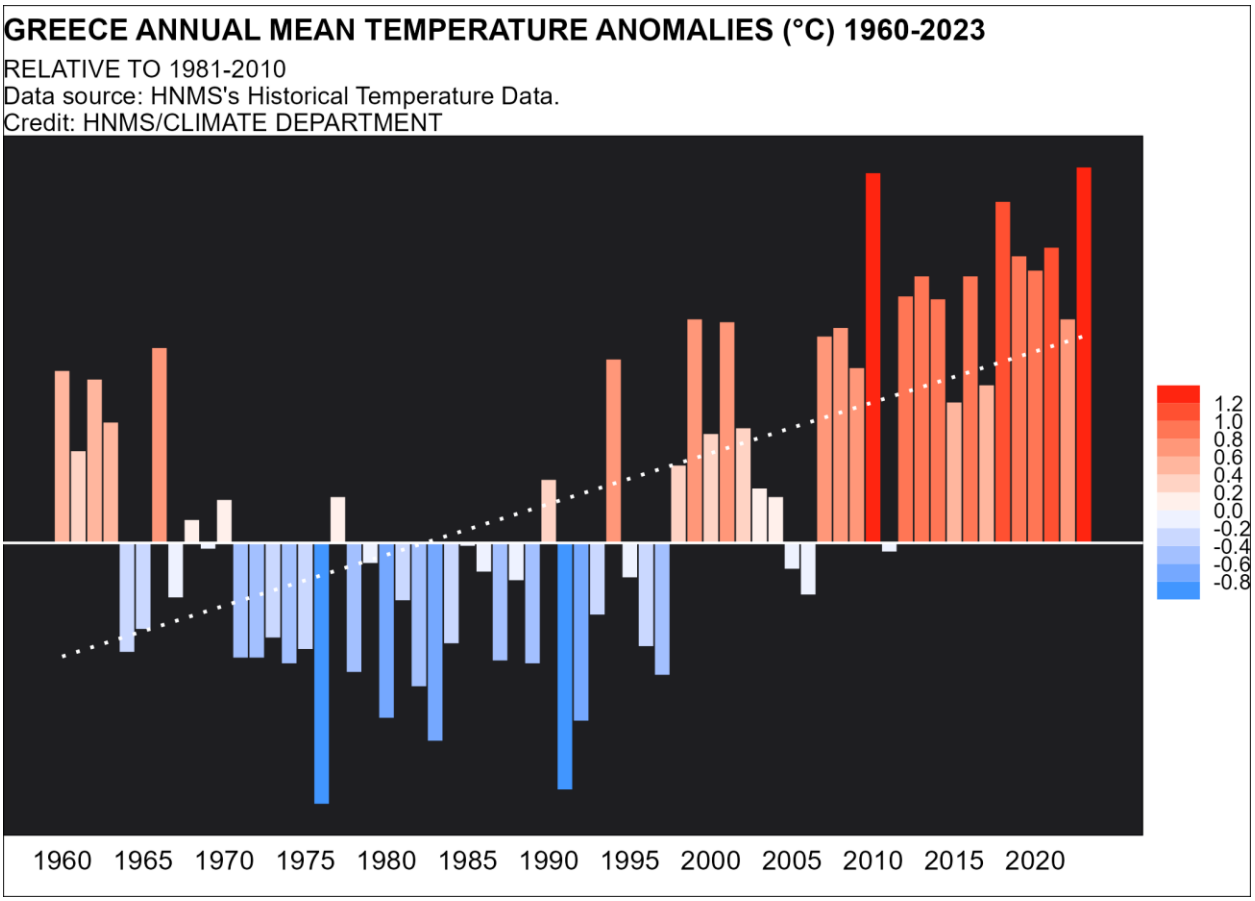

Figure 3: Annual mean temperature anomalies relative to the average of 1981-2010 reference period. Shades of blue indicate years that were cooler than the 1981-2010 normal value, while shades of red indicate years that were warmer than that – the darker the color, the larger temperature deviation from the normal value. The white dashed line depicts the linear trend.

The next figure illustrates the spatial distribution of annual mean temperatures anomalies of the last year (2023) in the country. In areas of Northeast Greece, the average deviation was 1.7-1.9 °C above the average value of the period 1981-2010. In the rest of the country, temperatures positively deviated 0.7-1.5 °C.

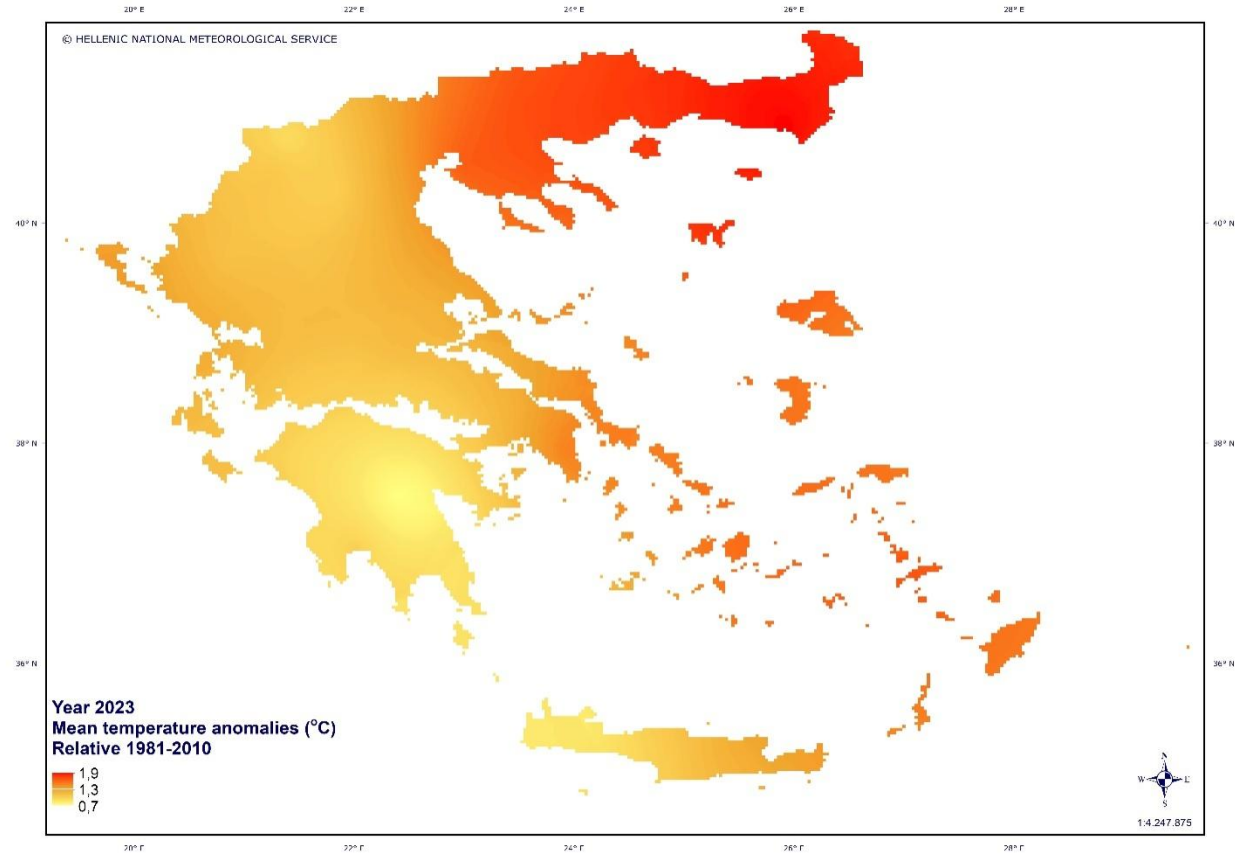

***Figure 4**: **Spatial distribution of annual mean temperature anomalies (°C) in 2023 in Greece according to the 1981-2010 climatology**.*

1.2 Winter Temperature

Winter 2022/23 was the fourth warmest winter on record. The mean temperature was 10.9 ^{o}C on average i.e 1.6 ^{o}C above 1981-2010 normal value (Figures 5 and 7).

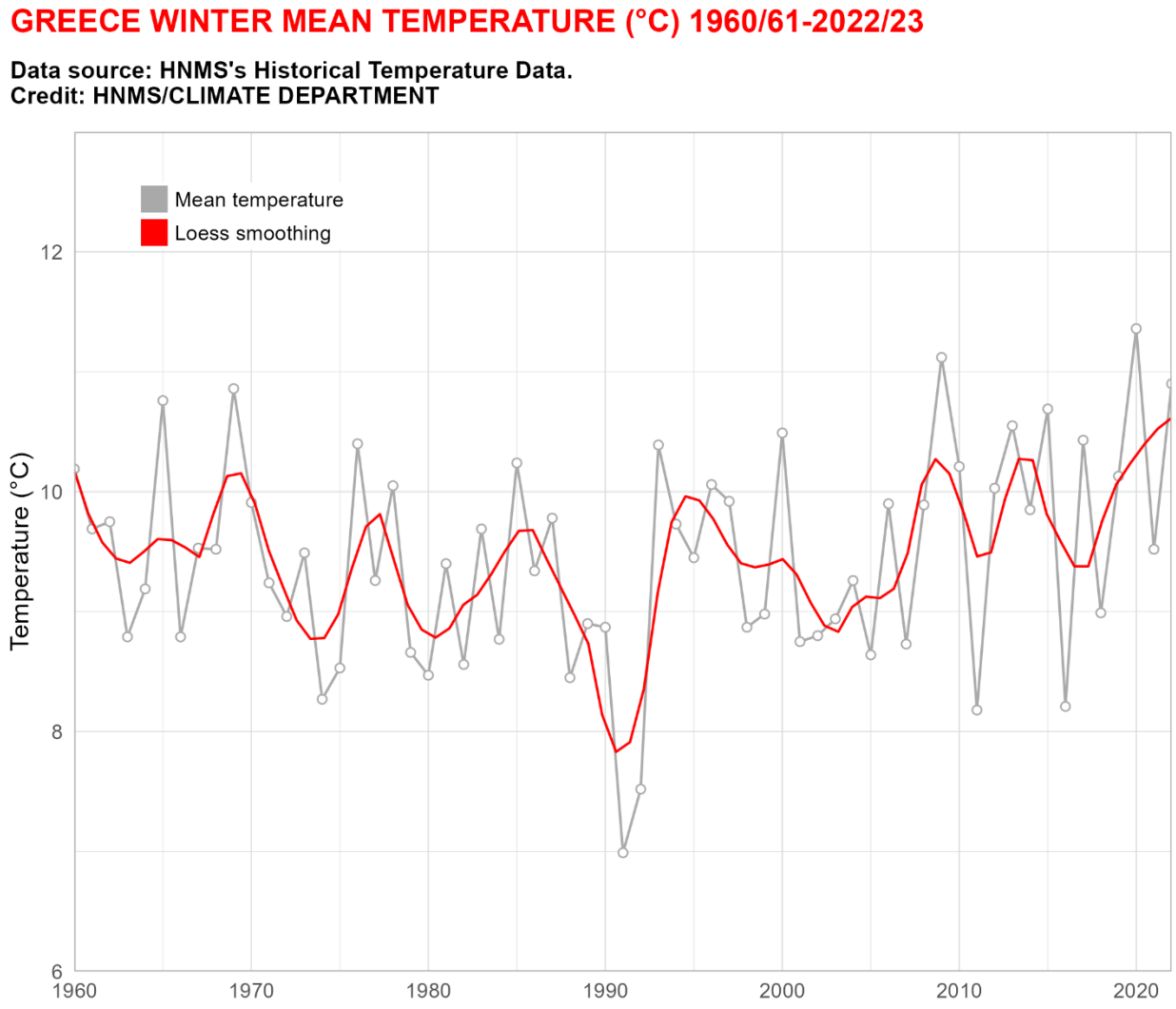

Figure 5: Winter (December previous year-January-February) mean temperature in Greece (average of 43 HNMS's met stations) from 1960/61 to 2022/23. Grey line shows annual mean temperature and red line γραμμή Loess smoothing.

The winter of 1991/1992 was the coldest winter on record; the mean temperature was about 2.3 ^{o}C lower than 1981-2010 average. In contrast, the 2020/21 winter was the warmest winter on record until recently i.e before winter 2023/24 (Figures 6 and 7). It is notable that 3 of the warmest winter seasons of all time have been recorded in the past 15 years.

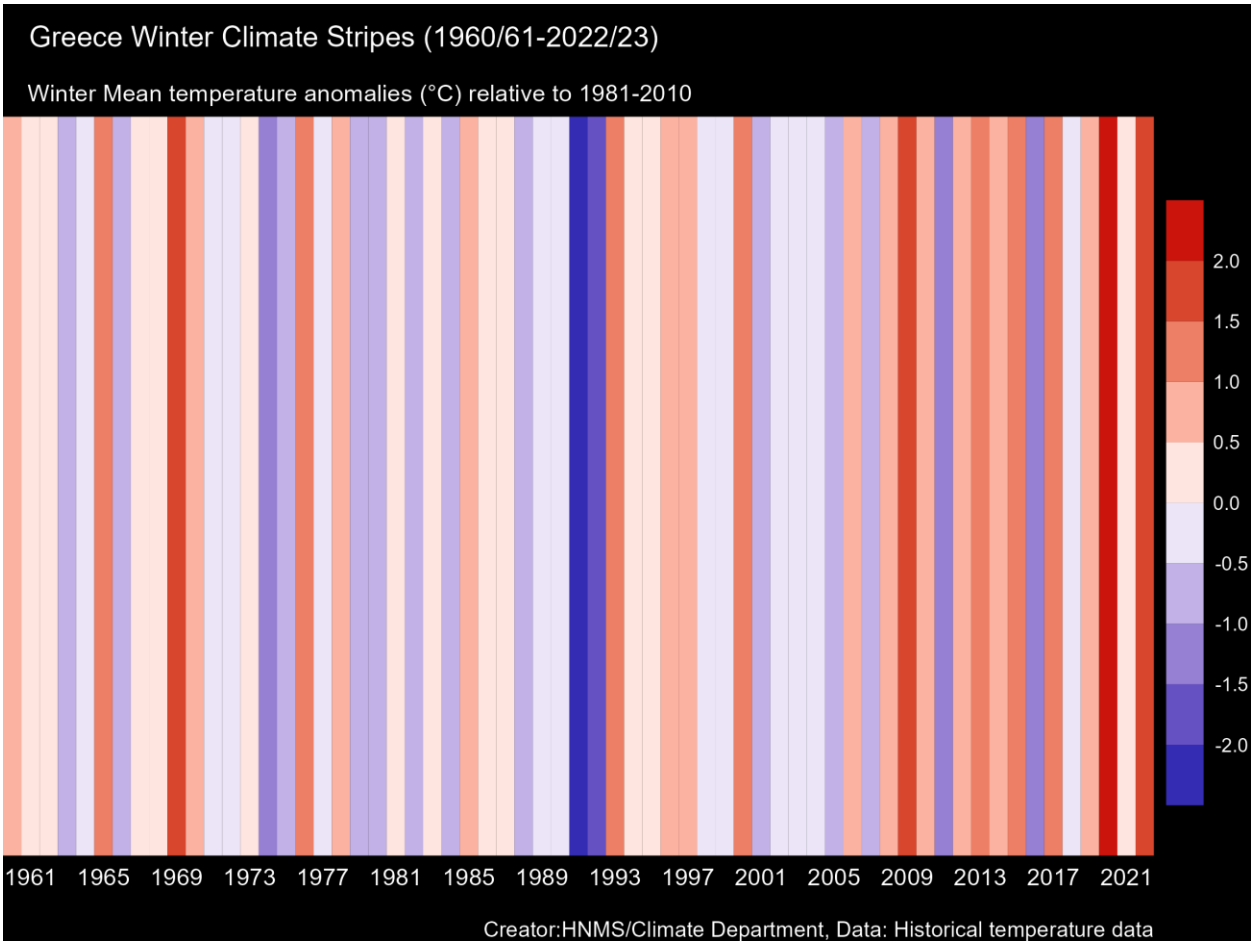

Figure 6: Greece climate stripes taking into account winter mean temperature anomalies relative to 1981-2010. Shades of blue indicate winters that were cooler than the 1981-2010 normal value, while shades of red indicate winters that were warmer than that – the darker the color, the larger temperature deviation from the normal value.

The graph below shows the average temperature anomalies for winter periods from 1960/61 to 2022/23 across Greece, which demonstrates an average increase of 0.5 °C during that timeline. It is notable that temperatures were at least 0.5 °C above1981-2010 for 11 winters in the past 15 years.

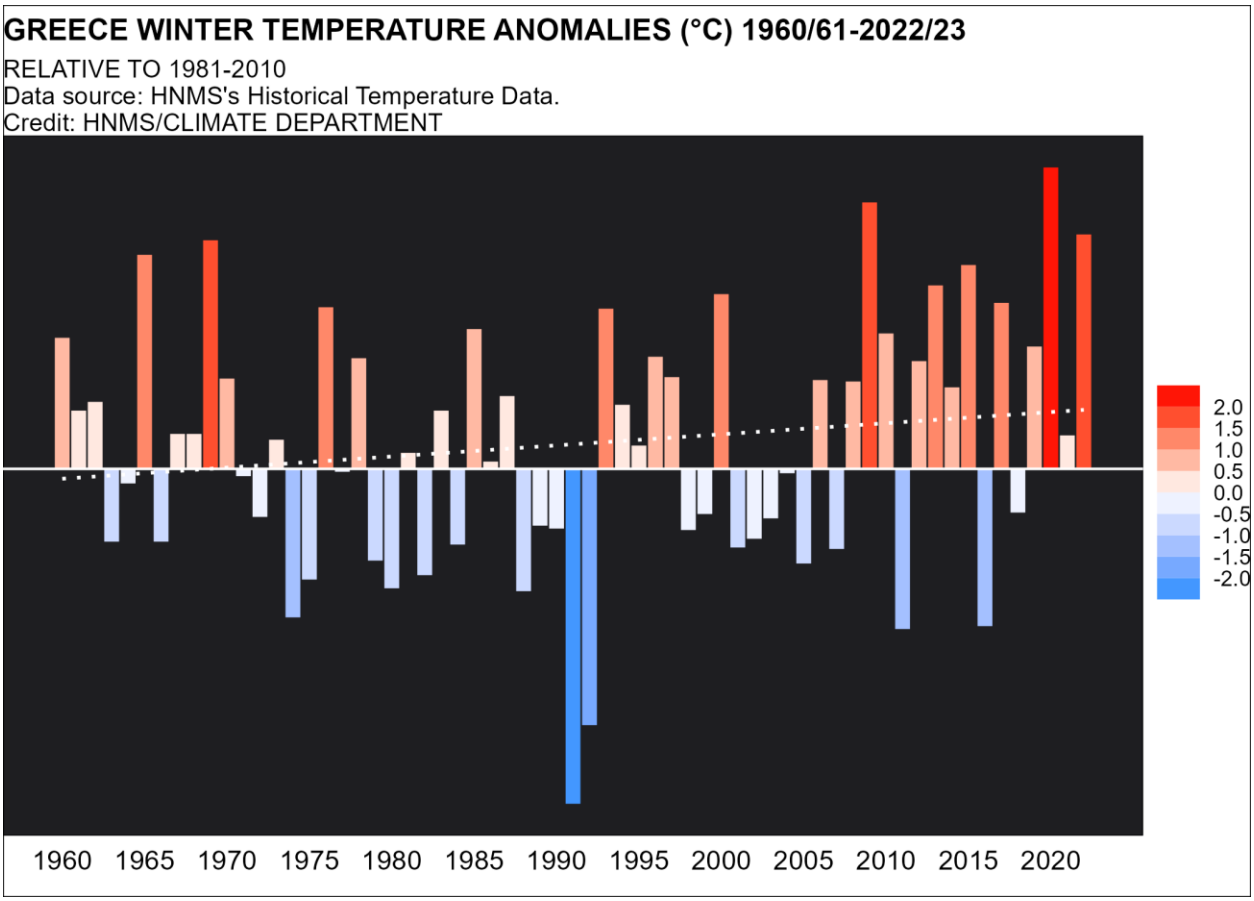

Figure 7: Winter mean temperature anomalies relative to the average of 1981-2010 reference period. Shades of blue indicate winters that were cooler than the 1981-2010 normal value, while shades of red indicate winters that were warmer than that – the darker the color, the larger temperature deviation from the normal value. The white dashed line depicts the linear trend.

The next figure illustrates the deviation of mean temperatures of winter 2022/23 from the average values of the period 1981-2010 in the country. In areas of Northern Greece, the average deviation was 2.5-3.0 °C above the average value of the period 1981-2010. In the rest of the country, temperatures positively deviated 1-2 °C, while in no part of Greece was there a deviation less than +0.6 °C.

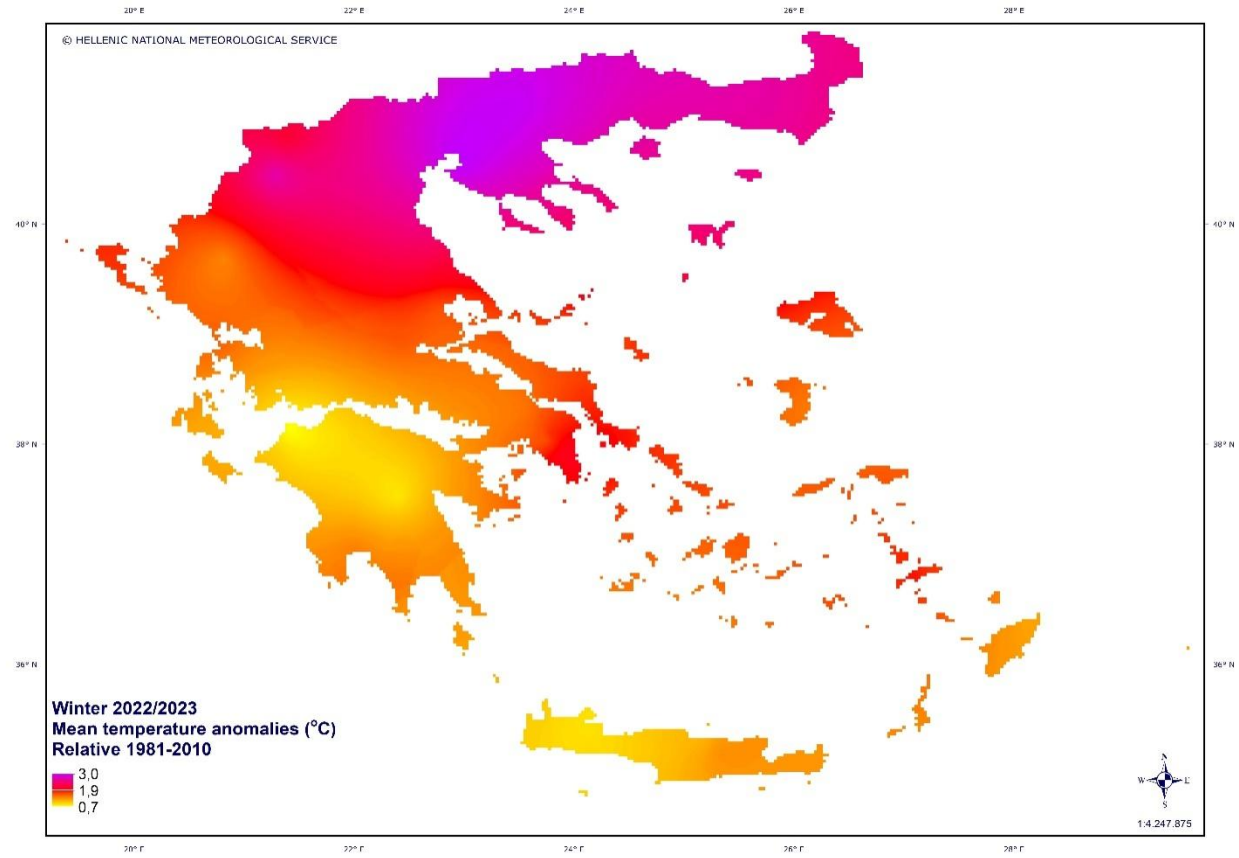

Figure 8: Spatial distribution of mean temperature anomalies (°C) for winter 2022/23 (December 2022- January 2023- February 2023) in Greece according to the 1981-2010 climatology.

1.3 Spring Temperature

The average temperature in spring 2023 was about 15.5 ^{0}C (Figure 9). Overall, spring 2023 was just 0.2^{0}C warmer than the 1981-2010 average and doesn't rank among the 10 warmest on record. The graph below shows the average seasonal temperatures from 1960 to 2023 across Greece and an increasing trend for the period 1997-2018 is observed.

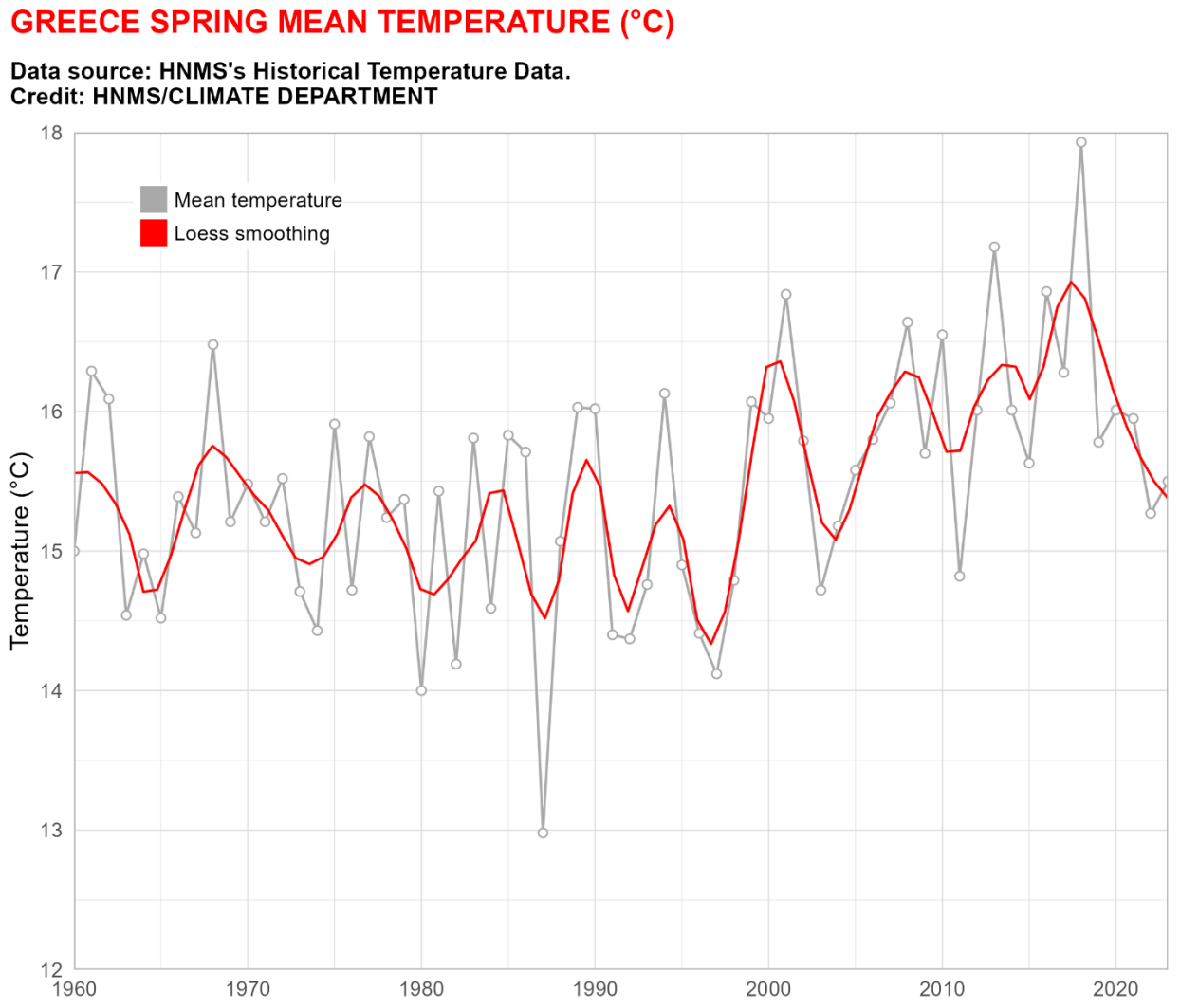

Figure 9: Spring (March-April-May) mean temperature in Greece (average of 43 HNMS's met stations) from 1960/61 to 2022/23. Grey line shows annual mean temperature and red line γραμμή Loess smoothing.

Spring 1987 was the coldest spring on record and spring 2018 was the warmest spring on record according to Greece spring climate stripes (Figure 10). It is notable only 4 springs were cooler than 1981-2010 average during the last 25 years.

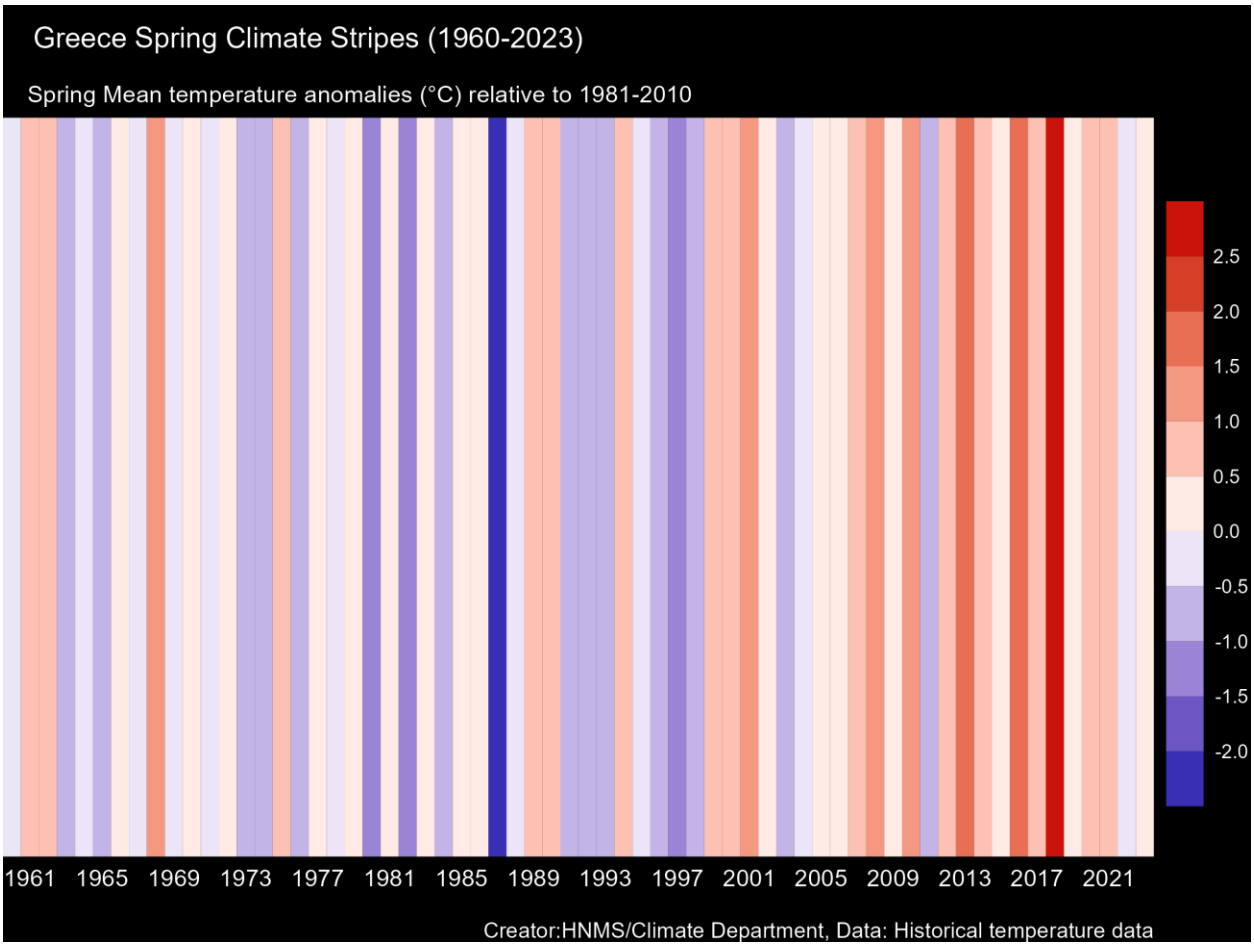

Figure 10: Greece climate stripes taking into account spring mean temperature anomalies relative to 1981-2010. Shades of blue indicate spring seasons that were cooler than the 1981-2010 normal value, while shades of red indicate spring seasons that were warmer than that – the darker the color, the larger temperature deviation from the normal value.

Although spring 2023 wasn't much warmer than the 1981-2010 average, an increasing seasonal temperature trend of about 0.17 °C per decade is demonstrated (Figure 11). It is notable that 3 of the warmest spring seasons of all time have been recorded in the past 11 years.

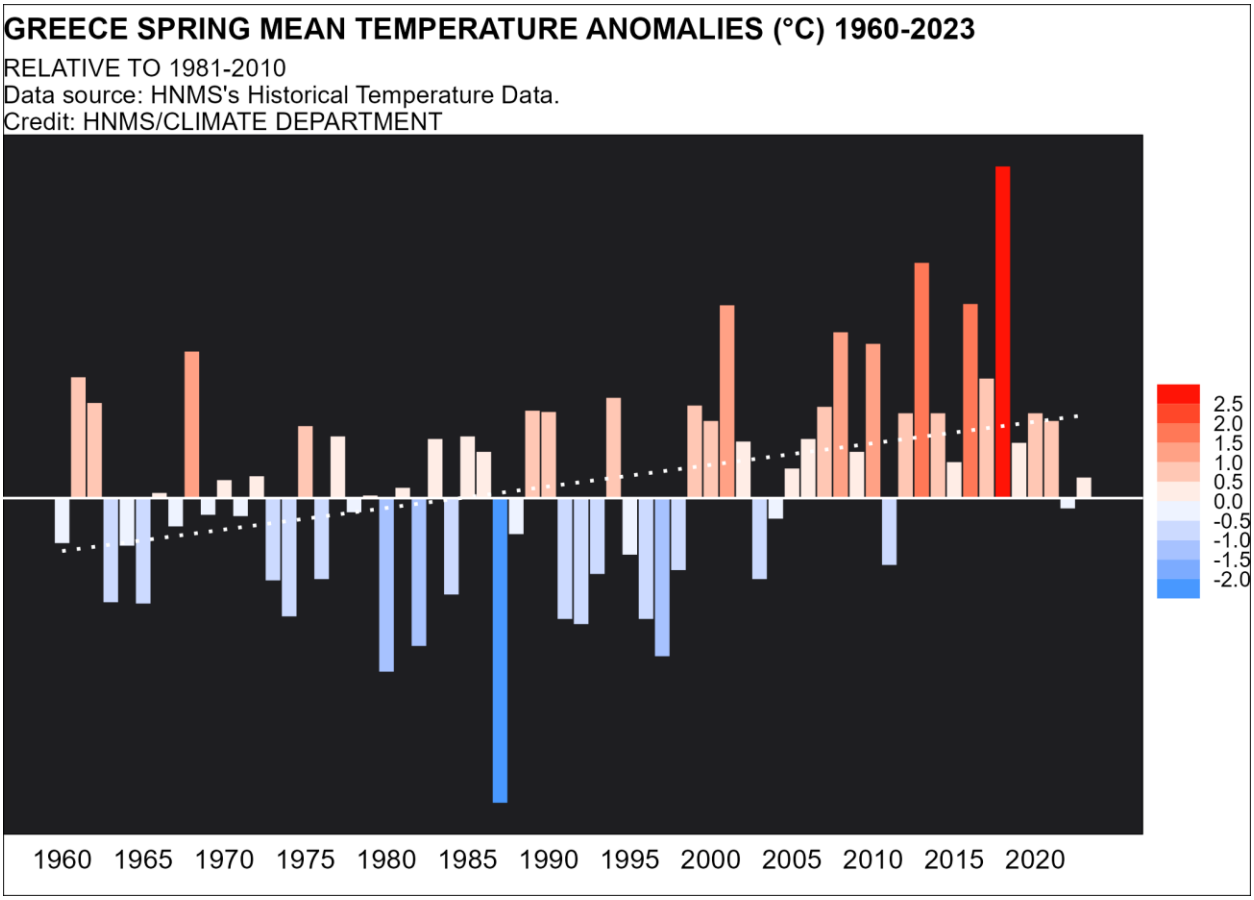

Figure 11: Spring mean temperature anomalies relative to the average of 1981-2010 reference period. Shades of blue indicate years that were cooler than the 1981-2010 normal value, while shades of red indicate years that were warmer than that – the darker the color, the larger temperature deviation from the normal value. The white dashed line depicts the linear trend.

The figure below illustrates the deviation of mean temperatures of spring 2023 from the average values of the period 1981-2010 in the country. Temperature in spring 2023 were near or slightly below 1981-2010 normal values in most of Greece especially northwest areas and clearly above normal values only in southeast Aegean islands.

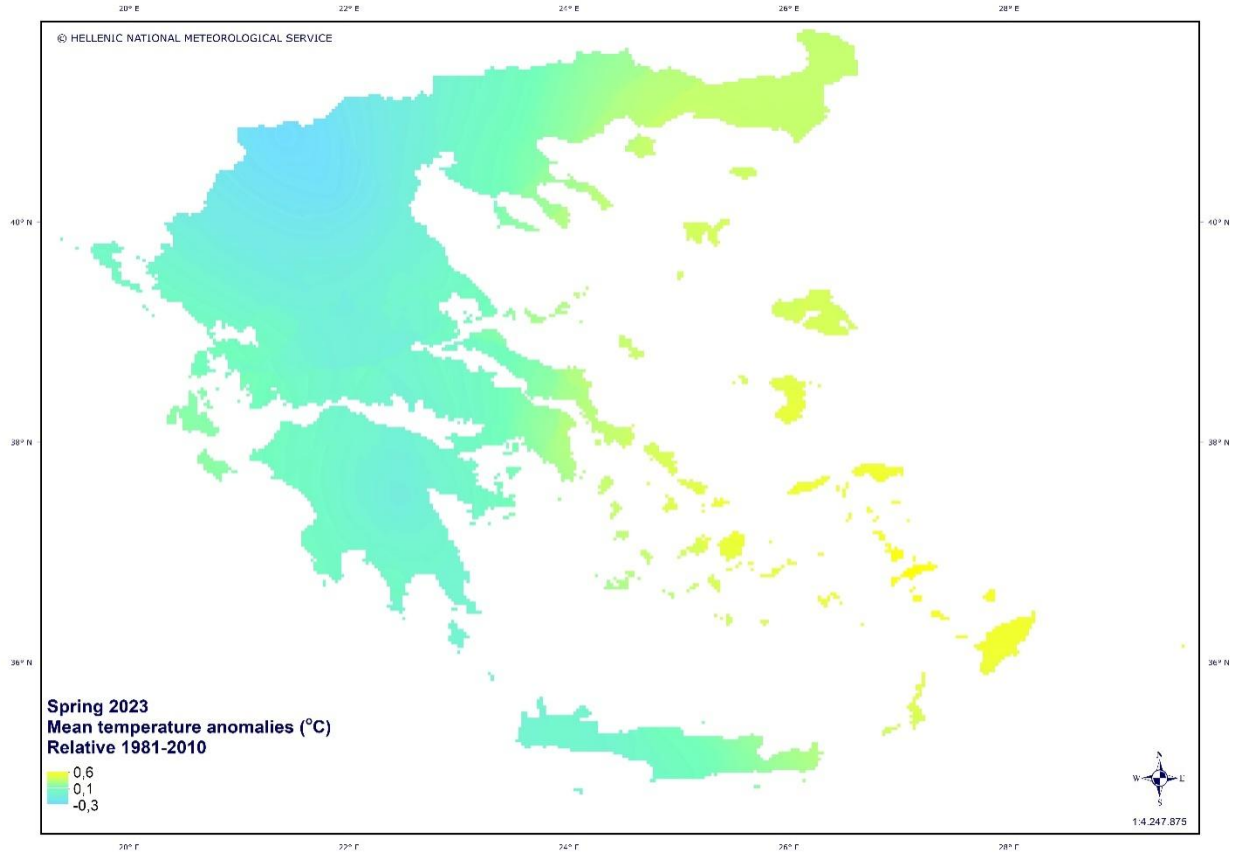

Figure 12: Spatial distribution of mean temperature anomalies (°C) for spring 2023 in Greece according to the 1981-2010 climatology.

1.4 Summer Temperature

The summer 2023 was the 4th warmest summer jointly with 2003 and it was just 0.34 °C cooler than 2021 which was the 3rd warmest summer (Figures 13 and 15). The graph below shows the average summer temperature from 1960 to 2023 across Greece and an increasing temperature trend is clear since the middle of the 80s.

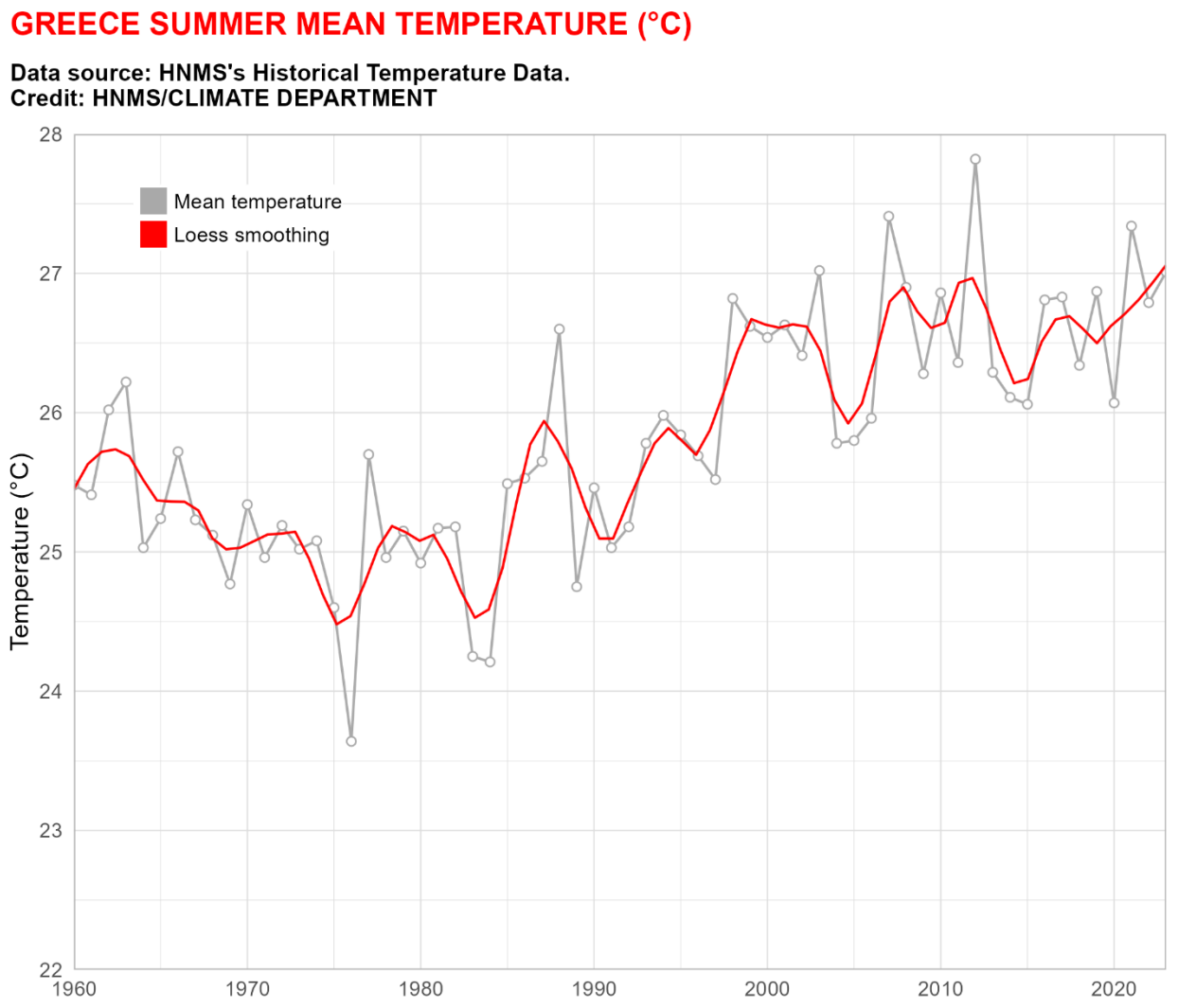

Figure 13: Summer (June-July-August) mean temperature in Greece (average of 43 HNMS's met stations) from 1960/61 to 2022/23. Grey line shows annual mean temperature and red line γραμμή Loess smoothing.

The period 1960-1992 was predominantly a cold period for the country and 1976 was the coldest summer on record according to Greece summer climate stripes. In contrast, the period after 1997 up to 2023 was predominantly a warm period and it is worth to note that summer temperatures were at least 0.5 ^{o}C above the 1981-2010 average for 16 summers during that period. Summer 2012 is confirmed as the warmest summer on record.

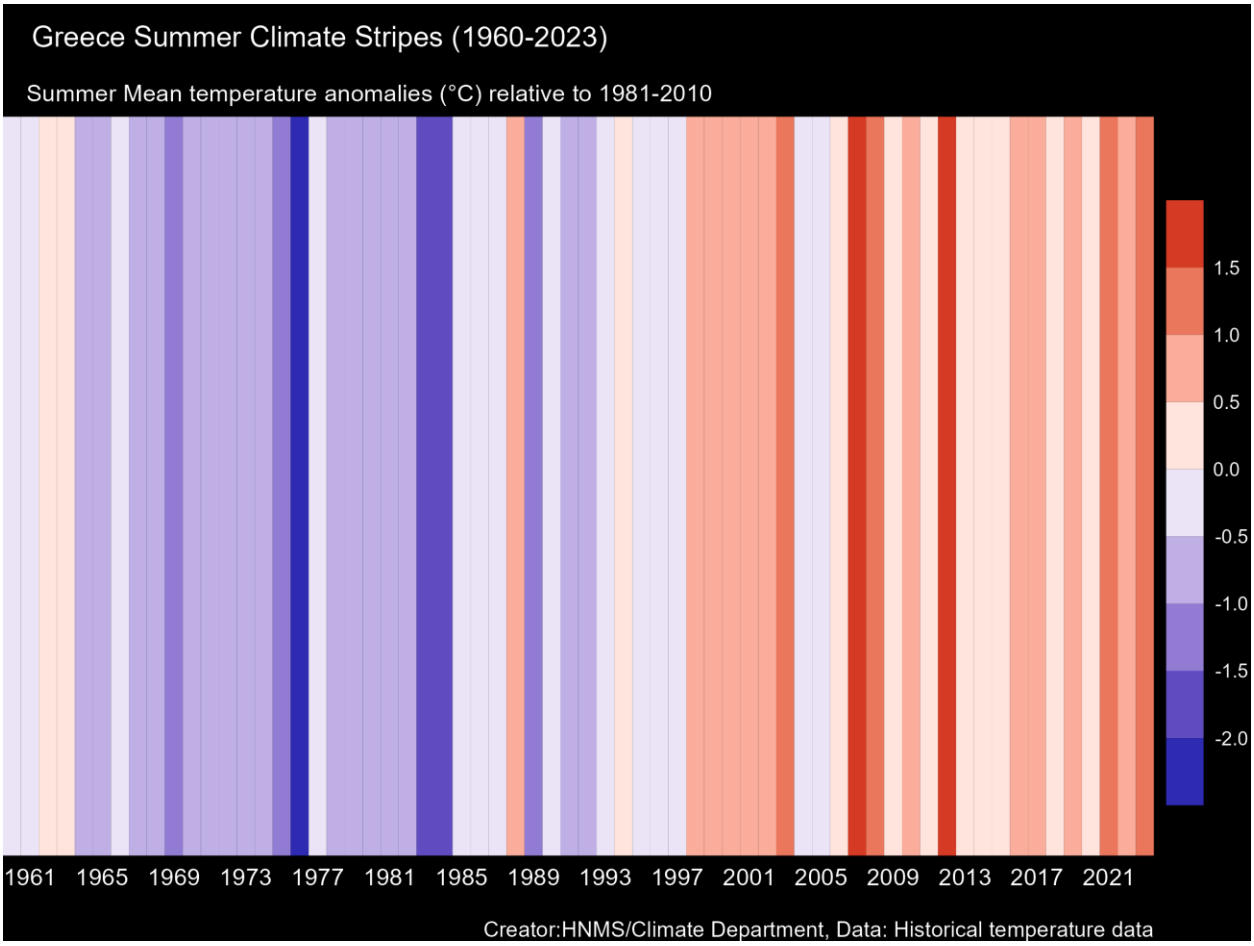

Figure 14: Greece climate stripes taking into account summer mean temperature anomalies relative to 1981-2010. Shades of blue indicate summers that were cooler than the 1981-2010 normal value, while shades of red indicate summers that were warmer than that – the darker the color, the larger temperature deviation from the normal value.

The graph below shows the average temperature anomalies for summer periods from 1960 to 2023 across Greece; an average increase of 2°C is demonstrated during that timeline. It is also obvious that the summer mean temperature remained relatively low before 1992, and then started to rise and reached a local peak in 2012. The average mean temperature anomaly in summer 2007, relative to 1981-2000 normal value, exceeded 1.5 ^{o}C for the first time since 1960 (Figure 15).

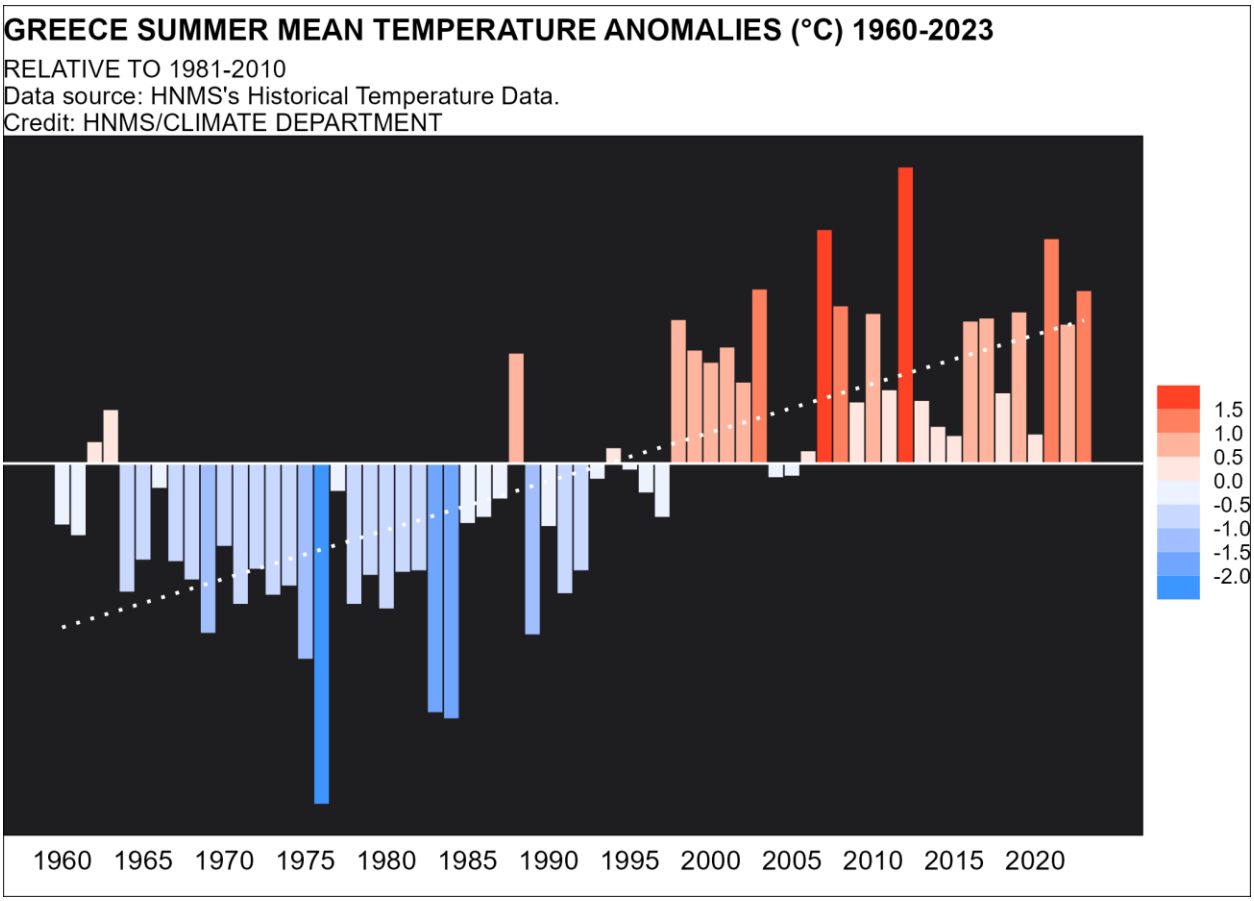

Figure 15: Summer mean temperature anomalies relative to the average of 1981-2010 reference period. Shades of blue indicate summers that were cooler than the 1981-2010 normal value, while shades of red indicate summers that were warmer than that – the darker the color, the larger temperature deviation from the normal value. The white dashed line depicts the linear trend.

Temperature anomalies in summer 2023 in Greece fluctuated above 1981-2010 normal values for the whole country, with the greatest values occurring at the central and northern parts (Figure 16).

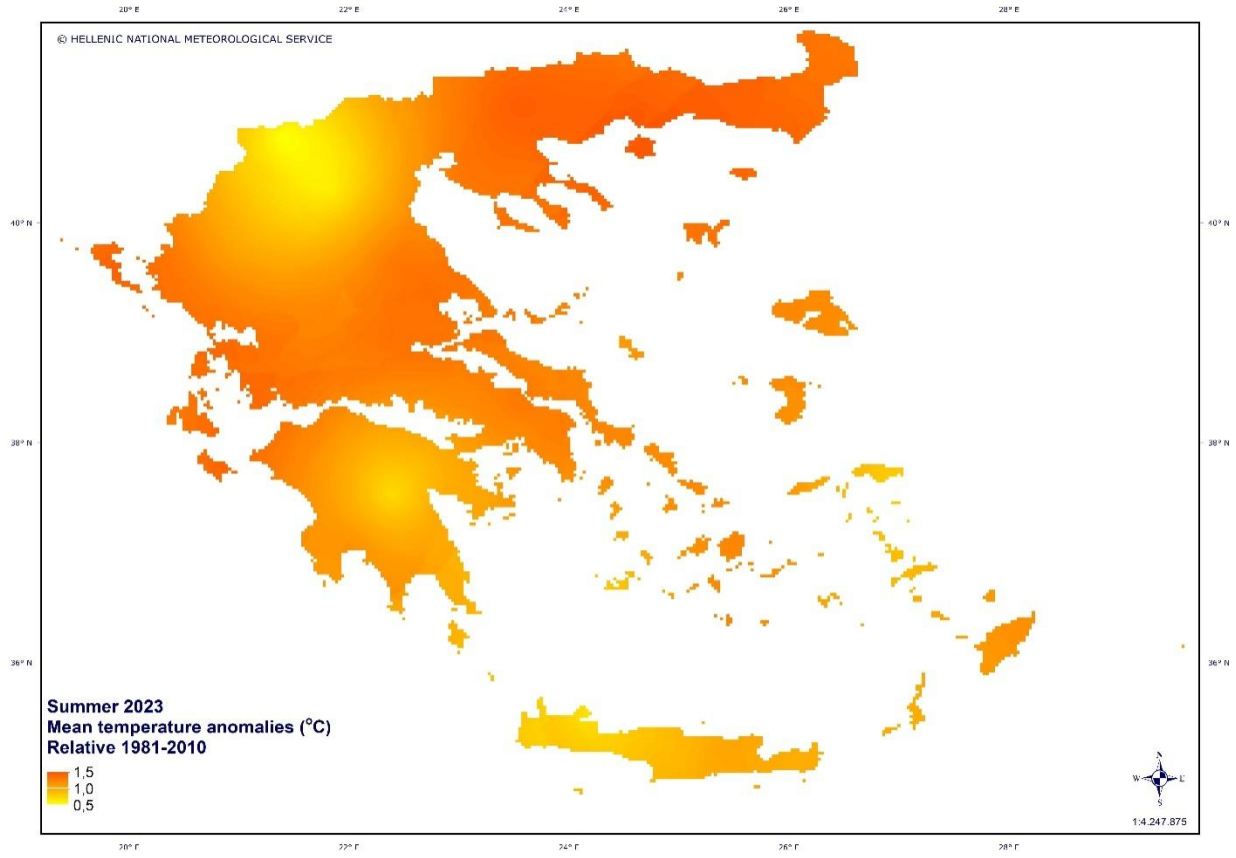

Figure 16: Spatial distribution of mean temperature anomalies (°C) for summer 2023 in Greece according to the 1981-2010 climatology.

1.5 Autumn Temperature

Autumn 2023 is confirmed as the warmest autumn on record since it was 0.26°C warmer than the previous highest seasonal record in 2019. The average autumn temperature was 20.4°C, which is 2.3°C above the 1981-2010 average.

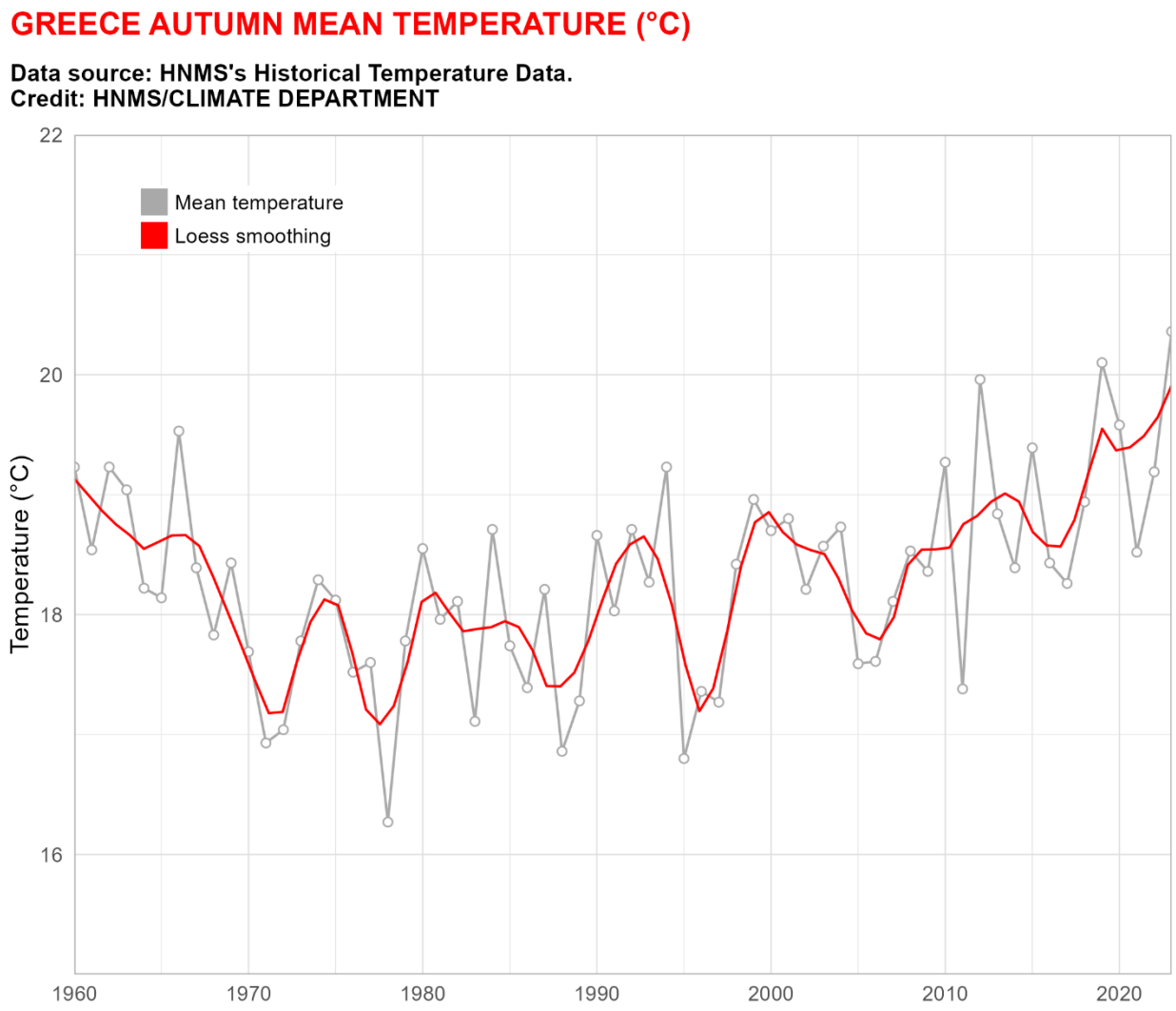

Figure 17: Autumn (September-October-November) mean temperature in Greece (average of 43 HNMS's met stations) from 1960/61 to 2022/23. Grey line shows annual mean temperature and red line γραμμή Loess smoothing.

The period from 1970 to 1989 was predominantly a cold period for the country and 1978 was the coldest autumn on record according to autumn climate stripes. In contrast, the last 15 years is predominantly a warm period since only autumn 2011 had a clear negative deviation from the 1981-2010 average and six of the warmest autumns of all time have been recorded during that timeline.

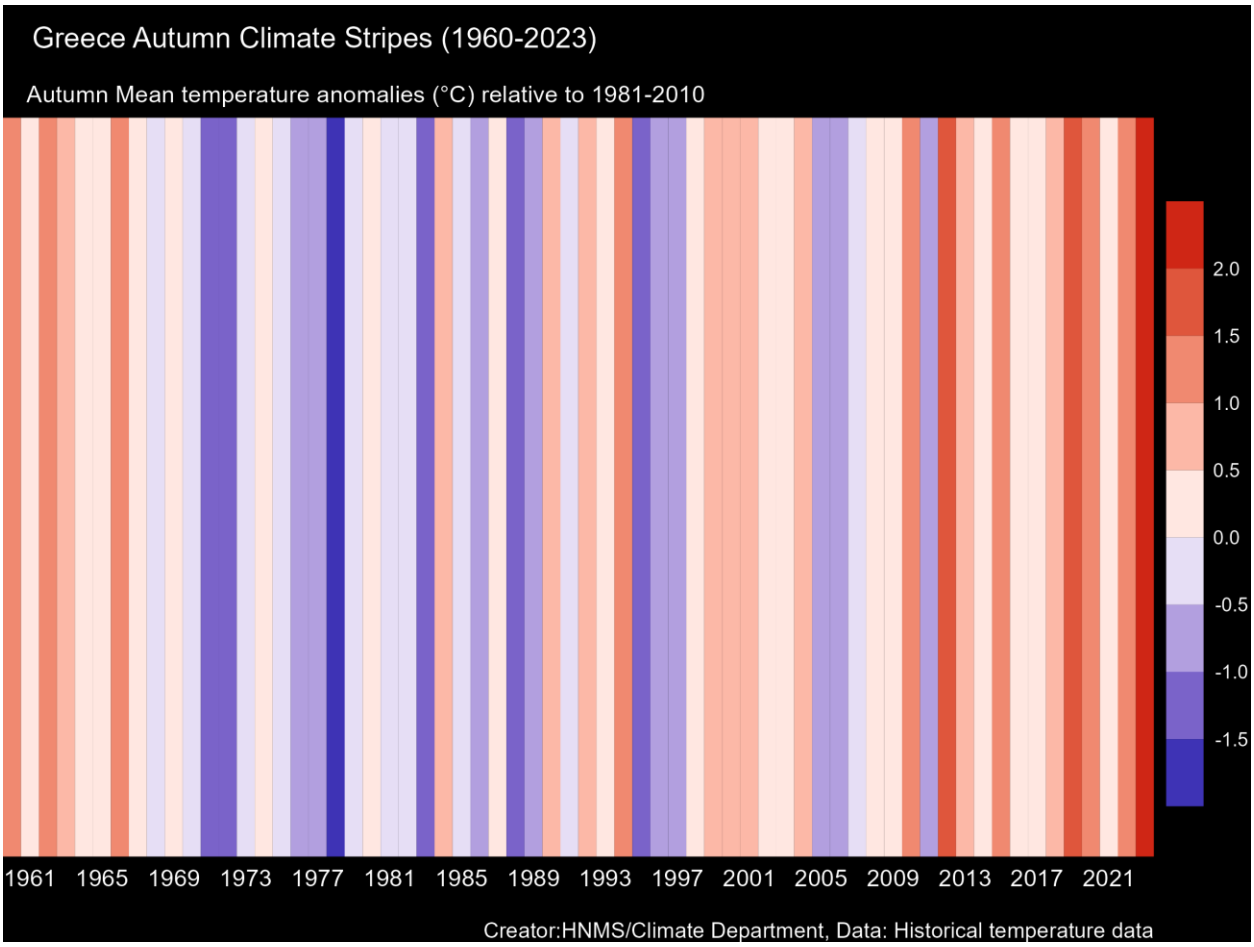

Figure 18: Greece climate stripes taking into account autumn mean temperature anomalies relative to 1981-2010. Shades of blue indicate autumn seasons that were cooler than the 1981-2010 normal value, while shades of red indicate autumn seasons that were warmer than that – the darker the color, the larger temperature deviation from the normal value.

An average autumn temperature increase of 0.15°C per decade is demonstrated in the following graph showing the average autumn temperature anomalies from 1960 to 2023 across Greece.

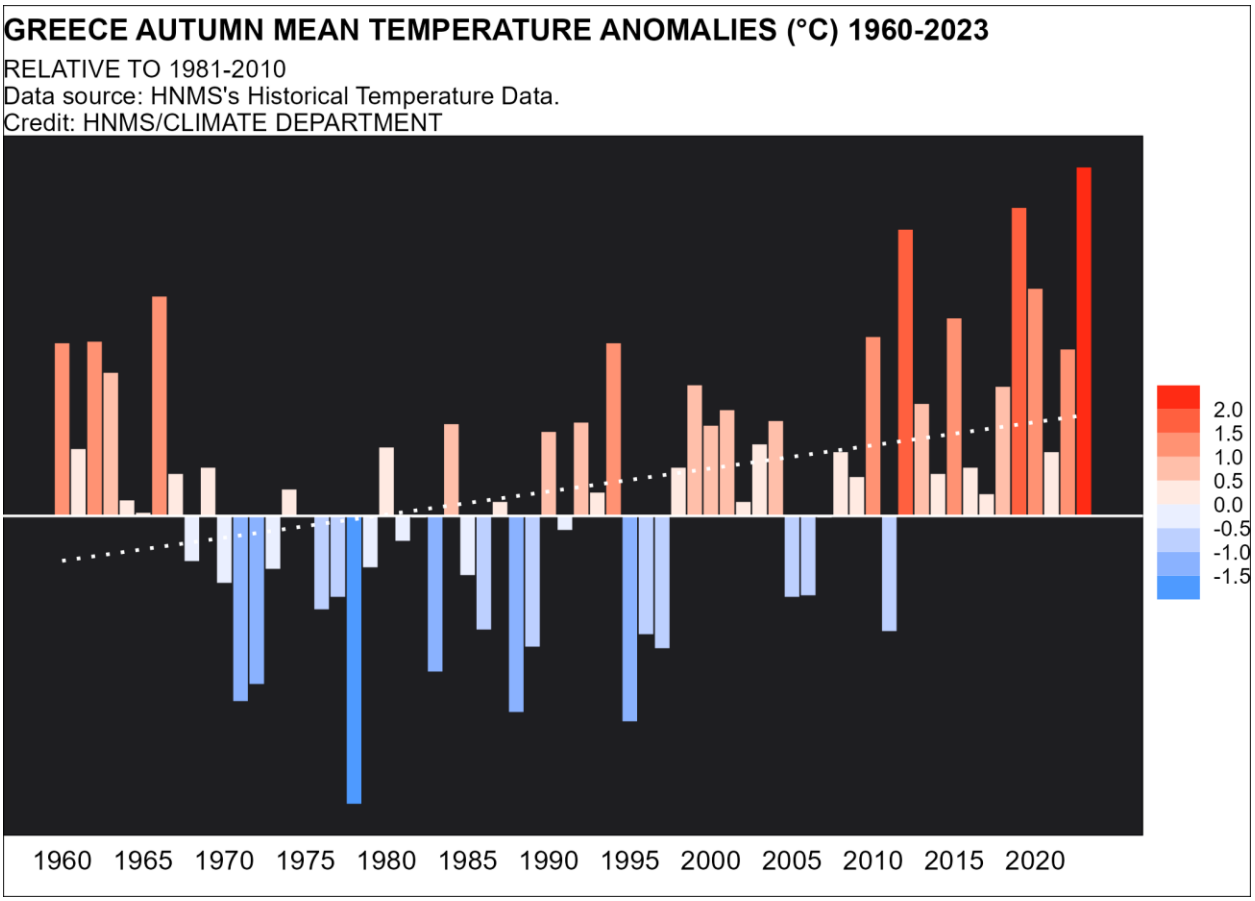

Figure 19: Autumn mean temperature anomalies relative to the average of 1981-2010 reference period. Shades of blue indicate autumns that were cooler than the 1981-2010 normal value, while shades of red indicate autumns that were warmer than that – the darker the color, the larger temperature deviation from the normal value. The white dashed line depicts the linear trend.

The next figure illustrates the deviation of mean temperatures of autumn 23 from the average values of the period 1981-2010 in the country. In areas of Northeast Greece, Aegean and North Ionian Islands, the average deviation was 2.5 to 3.5 °C above the average value of the period 1981-2010. In the most of the rest areas of the country, temperatures positively deviated 1.5 - 2.5 °C.

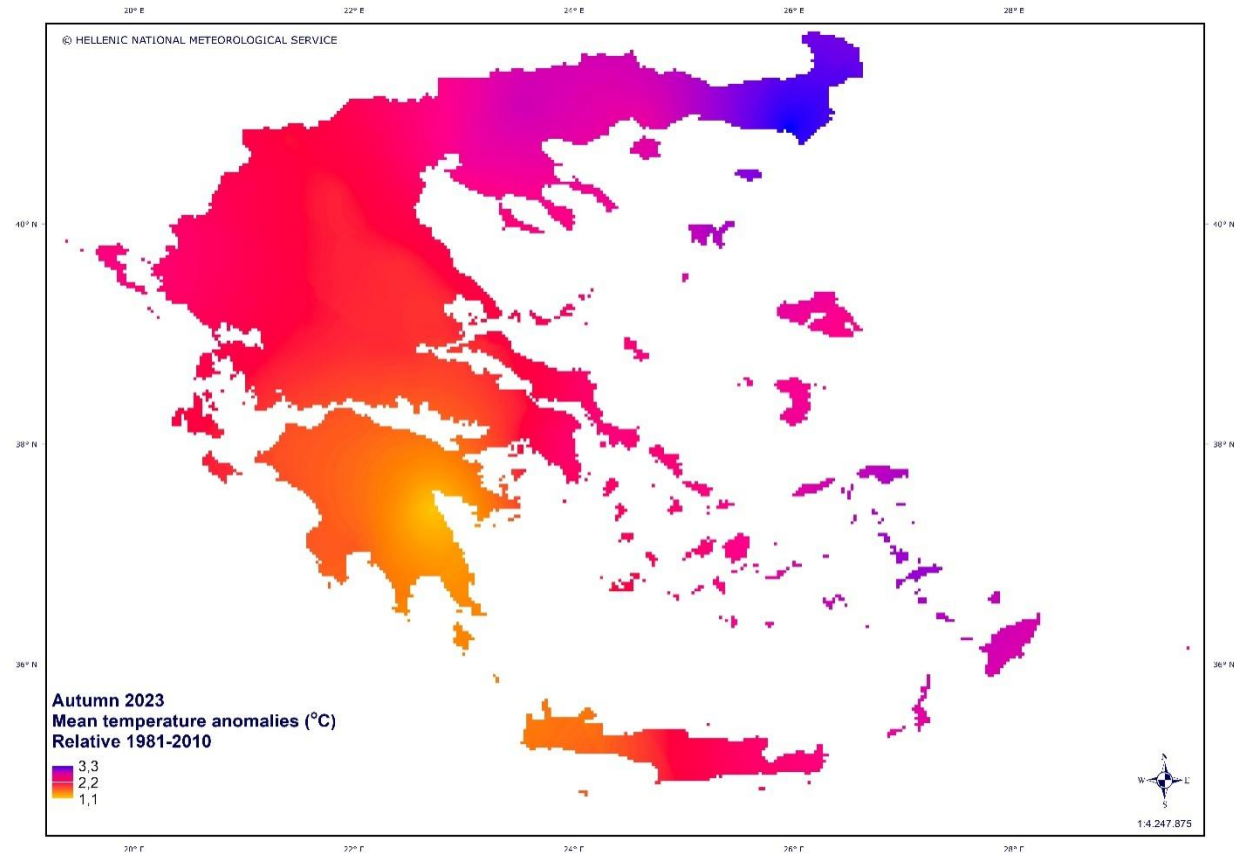

Figure 20: Spatial distribution of mean temperature anomalies (°C) for autumn 2023 in Greece according to the 1981-2010 climatology.

2. Precipitation Report for 2023

Analyzing the historical temperature data of all available HNMS meteorological stations, which operate continuously from 1960 to the present day the following results are obtained.

Greece total precipitation highlights:

- The year 2023 was the 11th driest year on record.
- Winter 2022/2023 was the 7th driest winter on record since 1960.
- Spring 2023 felt like a wet prolonged winter. It was the 13th wettest spring on record.
- Summer 2023 saw precipitation above average over north Greece and Aegean islands; however it was drier that summer 2022.
- Despite the much above-average precipitation in September, autumn 2023 was relatively dry mainly in central and south Aegean islands and parts of central Macedonia.
- February 2023 was the 4th driest on record. The anomalies were particularly pronounced in regions of the Ionian Islands and west Greece reaching more than 80% below average.
- September 2023 was the month with the largest wet anomaly, which was observed in the region of Thessaly after extreme rainfall associated with the storm Daniel; this event led to an exceptional amount of rainfall and was responsible for the devastating flooding. Total precipitation in Anchialos station accounts for 1540% of the 1981-2010 normal value.
- October 2023 was the month with a significant lack of precipitation since average total precipitation accounted for less than 25% of the 1981-2010 normal value in many regions. Despite below-average precipitation, surface soil moisture in central areas showed a pronounced wet anomaly, a legacy of September's extreme precipitation amounts.

2.1 Annual Precipitation

The year 2023 was the 11th driest year on record since 1960. Figure 21 presents the annual total precipitation anomalies in percent (average of 43 meteorological stations) from 1960 to 2023; a decreasing total precipitation trend of 103 mm is demonstrated during that timeline. The year 1989 was the driest year in Greece, to be followed by 1992 and 2000, while the year 1962 was the wettest year on record and 1968 the 2nd wettest year.

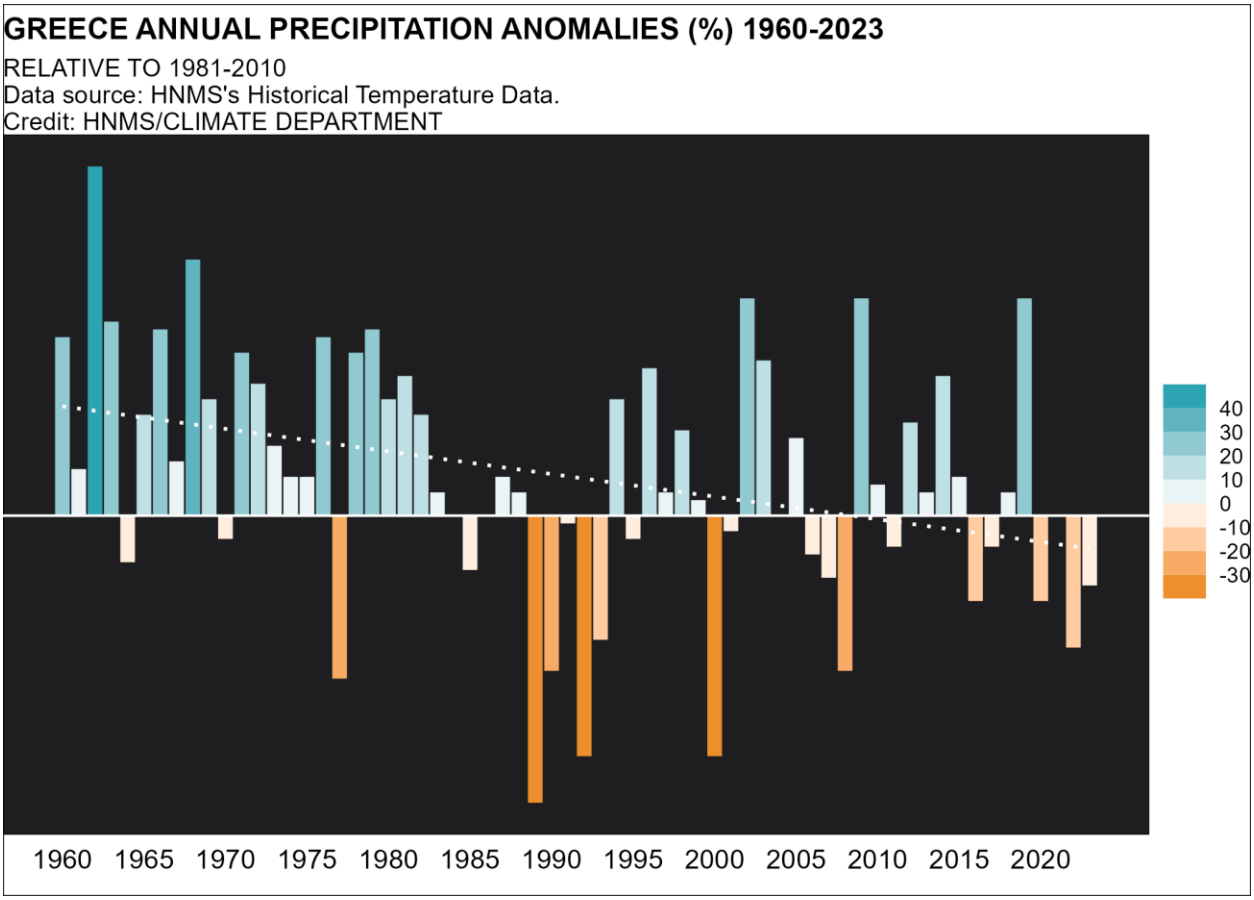

Figure 21: Annual precipitation anomalies (%) from 1960 to 2023 relative to the average of 1981-2010 reference period. Shades of greenish-blue indicate years that were wetter than the 1981-2010 normal value, while shades of orange indicate years that were drier than that – the darker the color, the larger precipitation deviation from the normal value. The white dashed line depicts the linear trend.

The next figure depicts the spatial distribution of annual precipitation anomalies in the year 2023 expressed as percentage of 1981-2010 average. Central parts of Greece and mainly the region of Thessaly saw wetter-than-average conditions following extreme rainfall associated

with storm Daniel in September 2023. Drier than normal conditions prevailed mainly over south Aegean islands where precipitation accounted for less than 70 % of normal values (1981-2010).

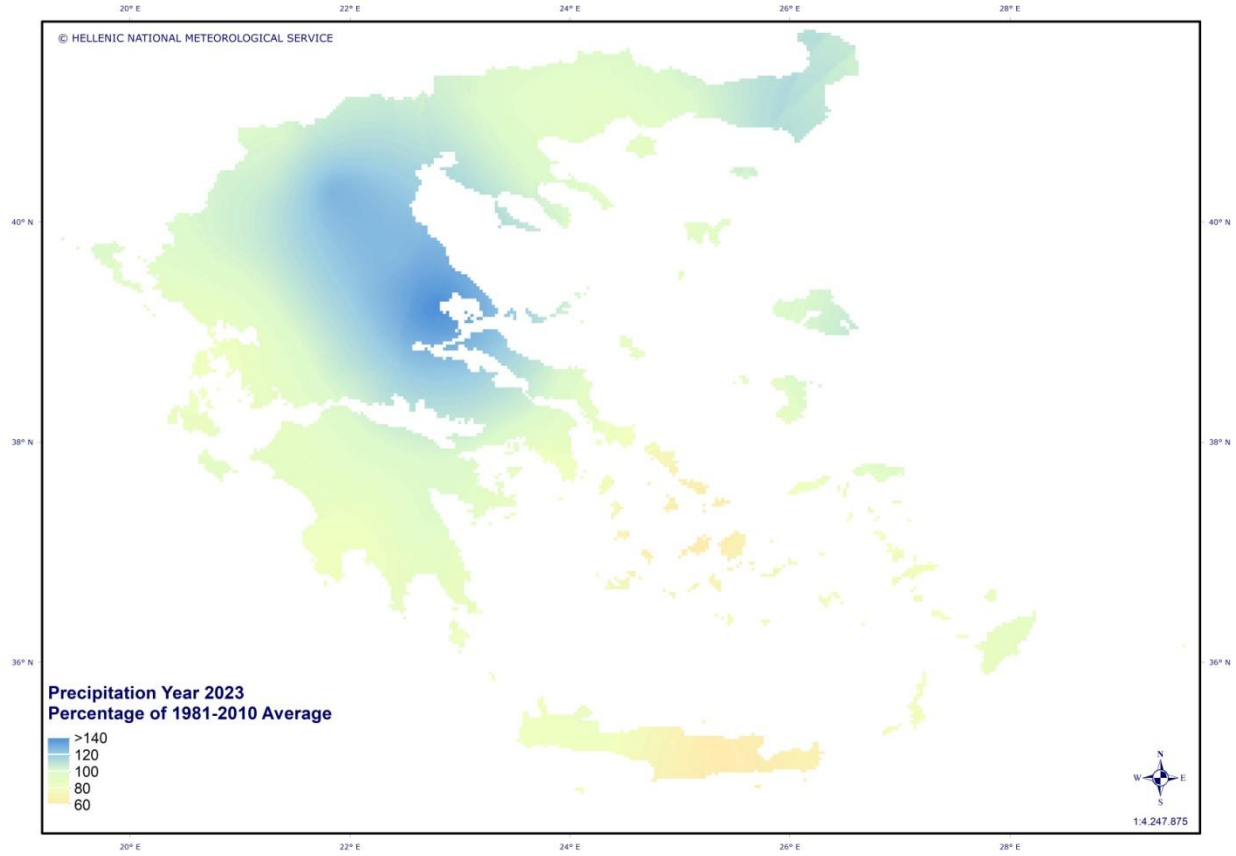

Figure 22: Spatial distribution of annual precipitation anomalies in Greece given in percentage of 1981-2010 average.

2.2 Winter Precipitation

Strongly reduced winter precipitation was observed in Greece during winter 2022/23. Winter 2022/2023 was the 7th driest winter on record since 1960. The next graph presents the average total precipitation anomalies for winter seasons relative to the 1981-2010 average from winter 1960/61 to winter 2022/23; a tendency to drier winters is demonstrated. The winter 1989/1990 was the driest winter in Greece, and the winter 2002/2003 was the wettest winter on record.

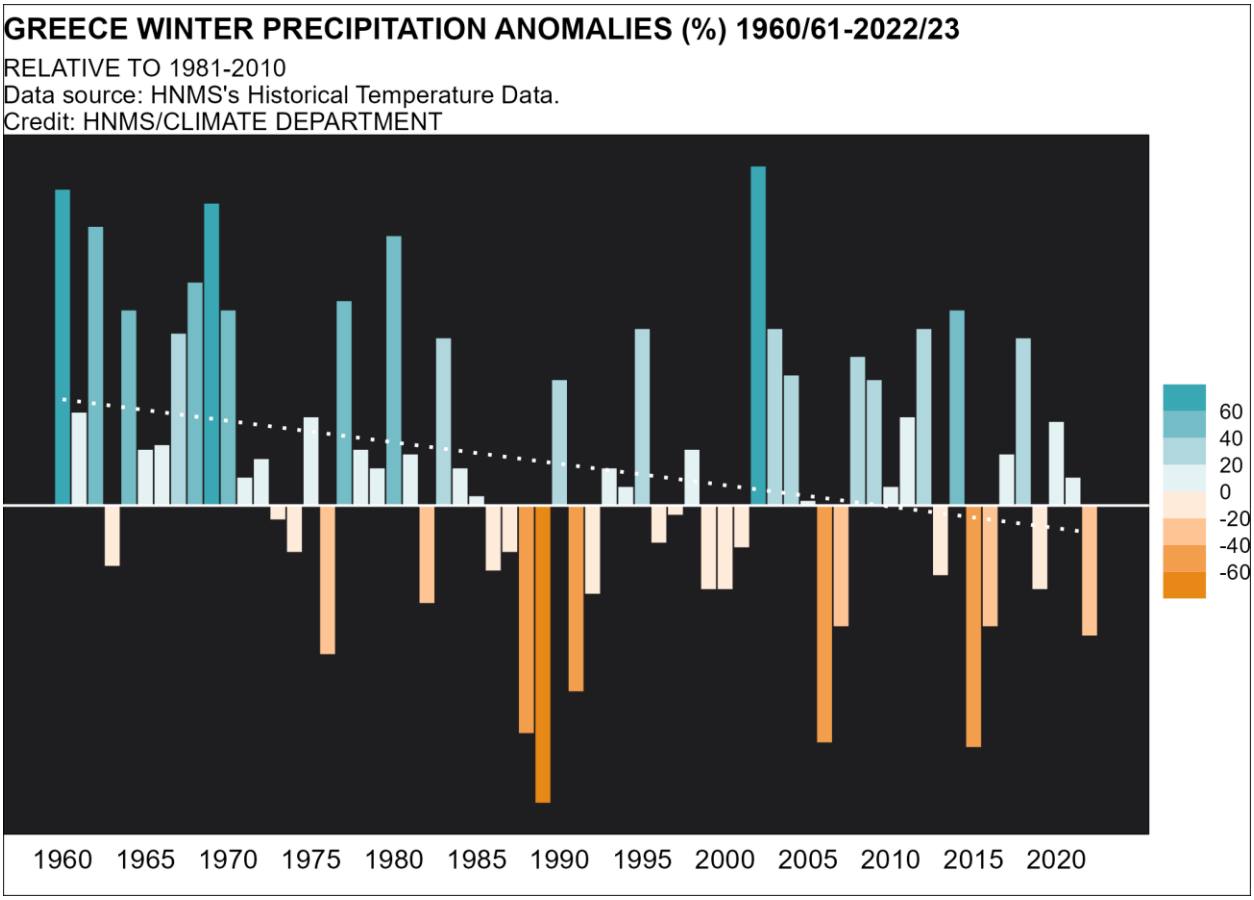

Figure 23: Winter precipitation anomalies (%) from 1960/61 to 2022/23 relative to the average of 1981-2010 reference period. Shades of greenish-blue indicate winters that were wetter than the 1981-2010 normal value, while shades of orange indicate winters that were drier than that – the darker the color, the larger precipitation deviation from the normal value. The white dashed line depicts the linear trend.

The next figure presents the spatial distribution of winter 2022/23 precipitation anomalies. Most regions of Greece experienced drier than normal conditions in winter 2022/23, with only isolated pockets of wet anomalies.

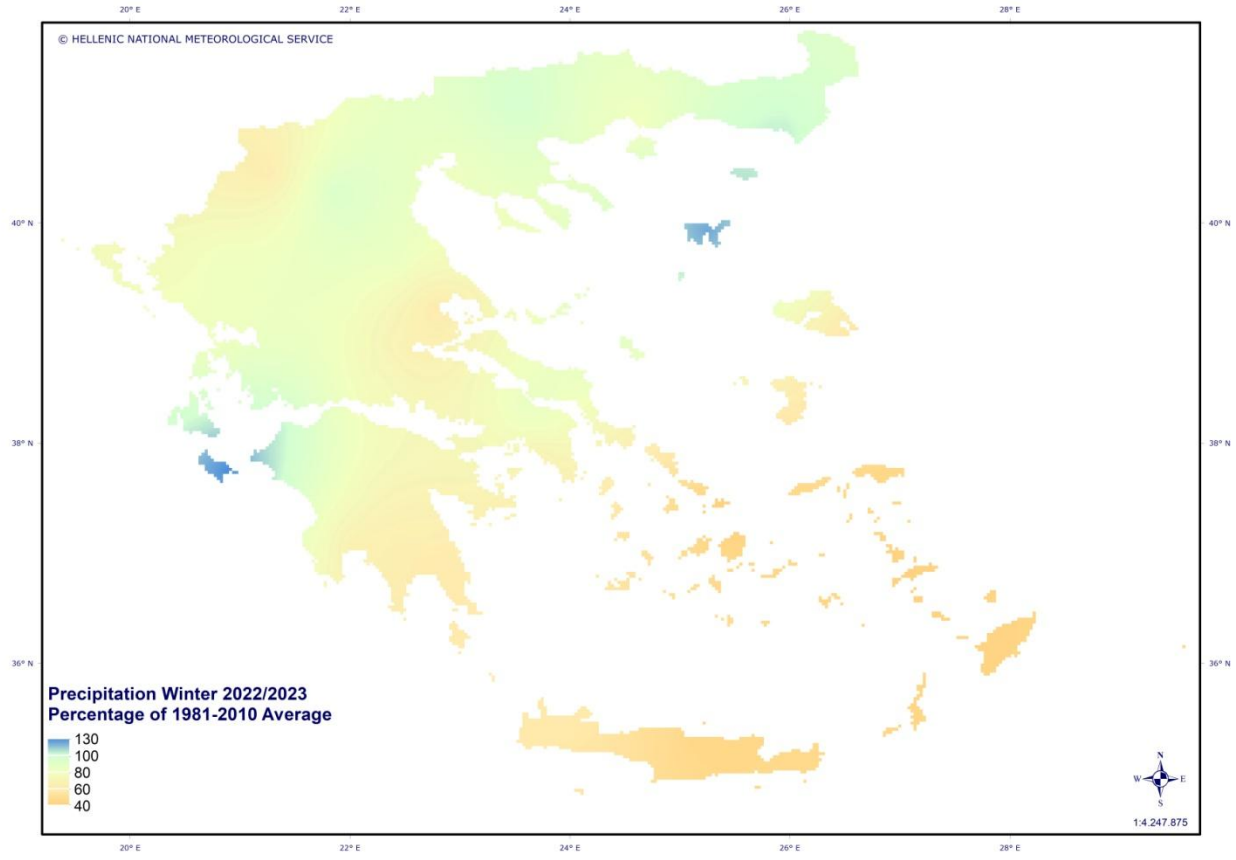

Figure 24: Spatial distribution of winter 2022/23 precipitation anomalies in Greece given in percentage of 1981-2010 average.

2.3 Spring Precipitation

In most of Greece the wetter-than-average spring 2023 offered partial relief after a dry winter. It was the 13th wettest spring on record according to average total precipitation of 43 HNMS meteorological stations (Figure 25). Parts of west and north Greece and northeast Aegean islands received total precipitation accounting for more than 150 % of the 1981-2010 average (Figure 26).

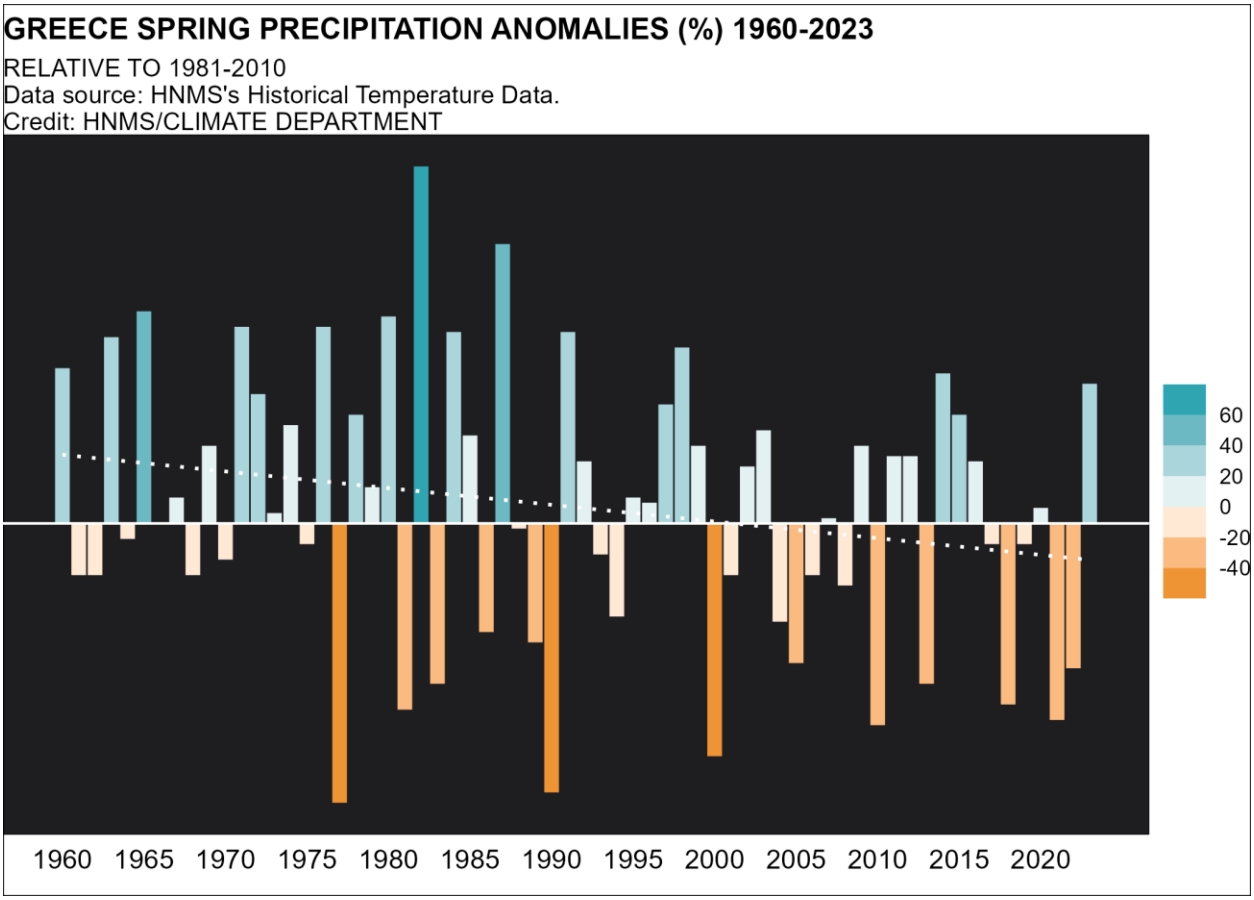

Figure 25: Spring precipitation anomalies (%) from 1960 to 2023 relative to the average of 1981-2010 reference period. Shades of greenish-blue indicate spring seasons that were wetter than the 1981-2010 normal value, while shades of orange indicate spring seasons that were drier than that – the darker the color, the larger precipitation deviation from the normal value. The white dashed line depicts the linear trend.

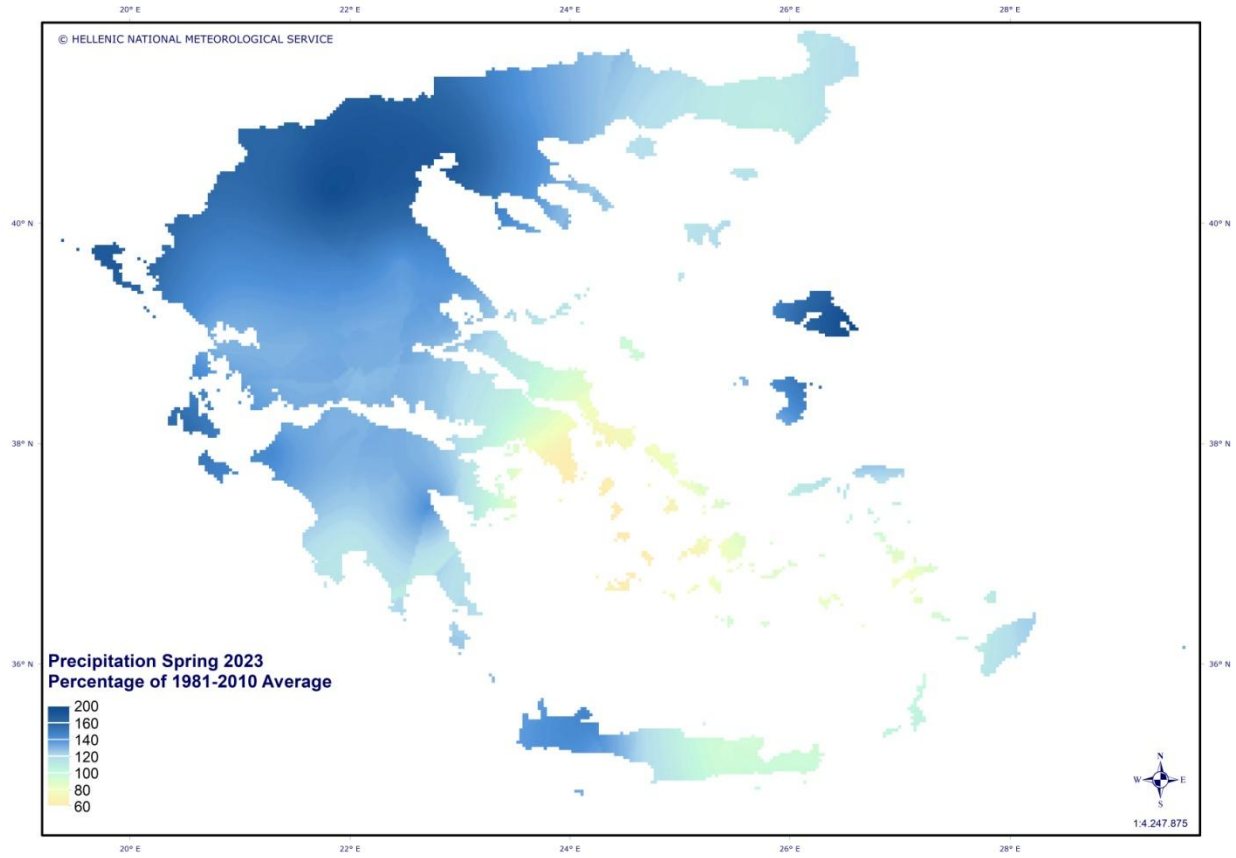

Figure 26: Spatial distribution of spring precipitation anomalies in Greece given in percentage of 1981-2010 average.

2.4 Summer Precipitation

Summer 2023 saw precipitation above average over many areas; however it was not as wet as the previous summer. Also, it must be noted that summer in Greece is generally dry; however local showers or isolated thunderstorms, mainly during June led to above average summer precipitation in north areas and Aegean islands. The next graph showing summer precipitation anomalies from 1960 to 2023 reveals that summers in Greece over the past decade have generally been wetter than normal. Figure 28 presents the absolute precipitation anomalies because the 1981-2010 average total precipitation in many areas is usually close to zero, so even small amounts of rain lead to large precipitation anomalies expressed as percentage of normal value.

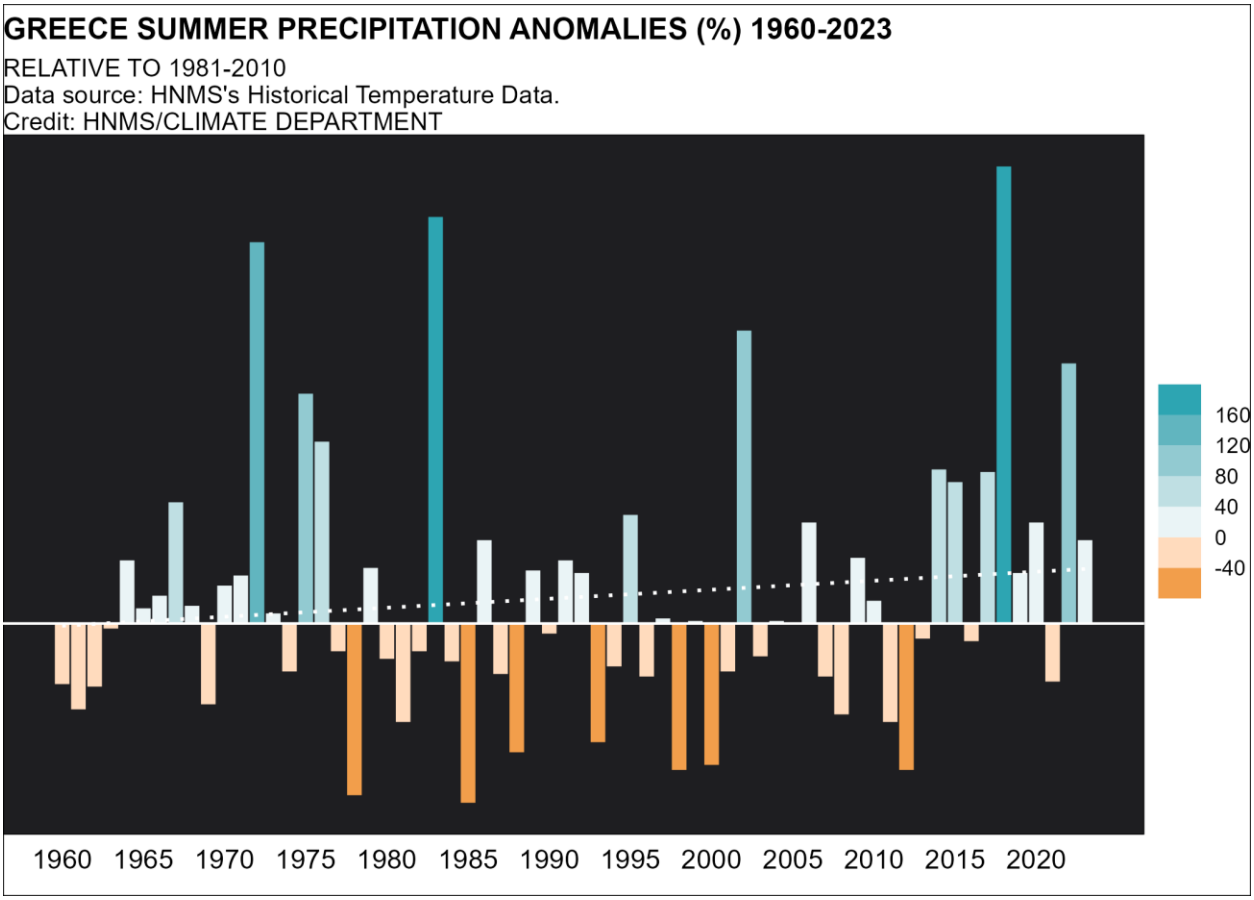

Figure 27: Summer precipitation anomalies (%) from 1960 to 2023 relative to the average of 1981-2010 reference period. Shades of greenish-blue indicate summers that were wetter than the 1981-2010 normal value, while shades of orange indicate summers that were drier than that – the darker the color, the larger precipitation deviation from the normal value. The white dashed line depicts the linear trend.

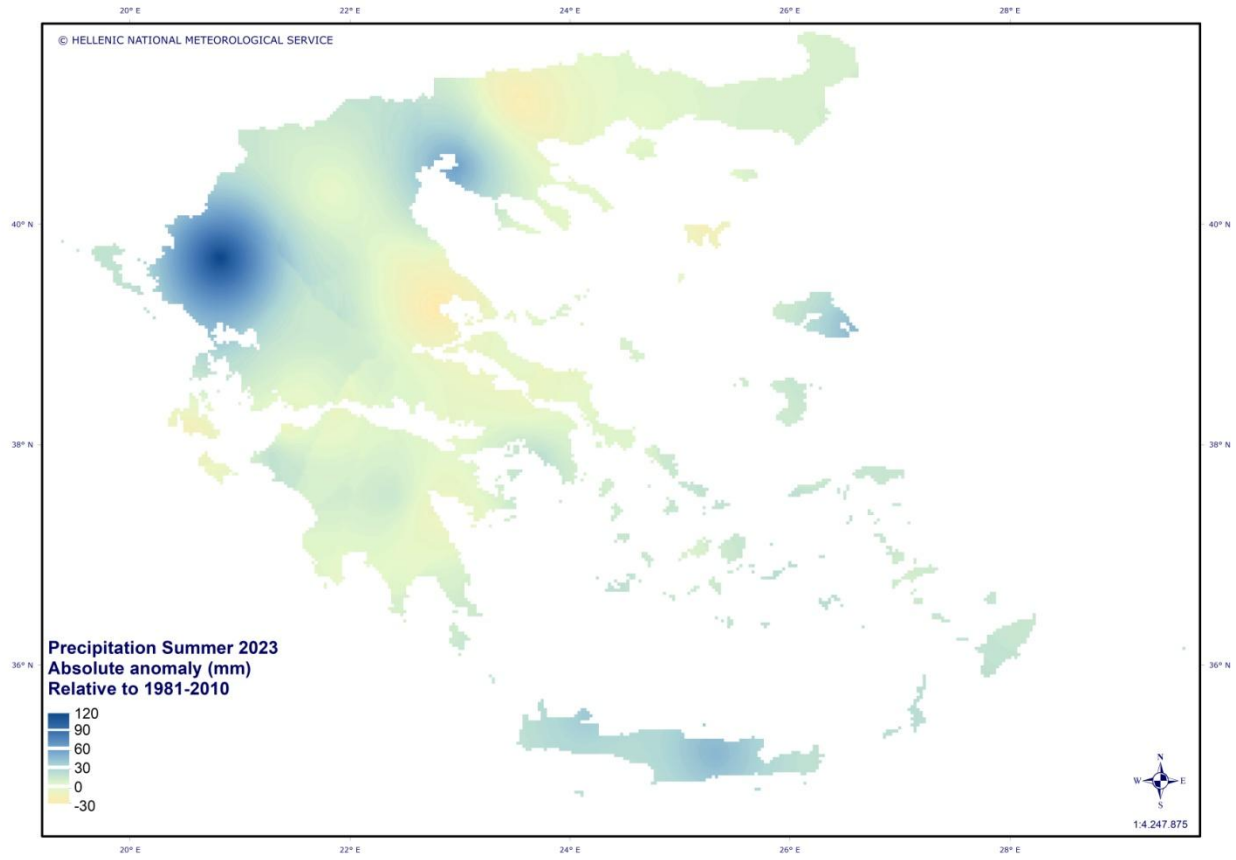

Figure 28: Spatial distribution of absolute summer precipitation anomalies (mm) in Greece relative to the 1981-2010 average.

2.5 Autumn Precipitation

Despite devastating floods in central Greece in September 2023 and much above-average rainfall this month, overall, autumn 2023 was relatively dry for the country (Figure 29). Central Greece (Thessaly and Magnesia regions) experienced wetter than normal conditions as indicated by the precipitation anomalies accounted for more than 300 % of 1981-2010 normal values (Figure 30). Conversely, rest of Greek regions including west areas, Ionian and south Aegean islands and parts of central Macedonia saw drier-than-average anomalies.

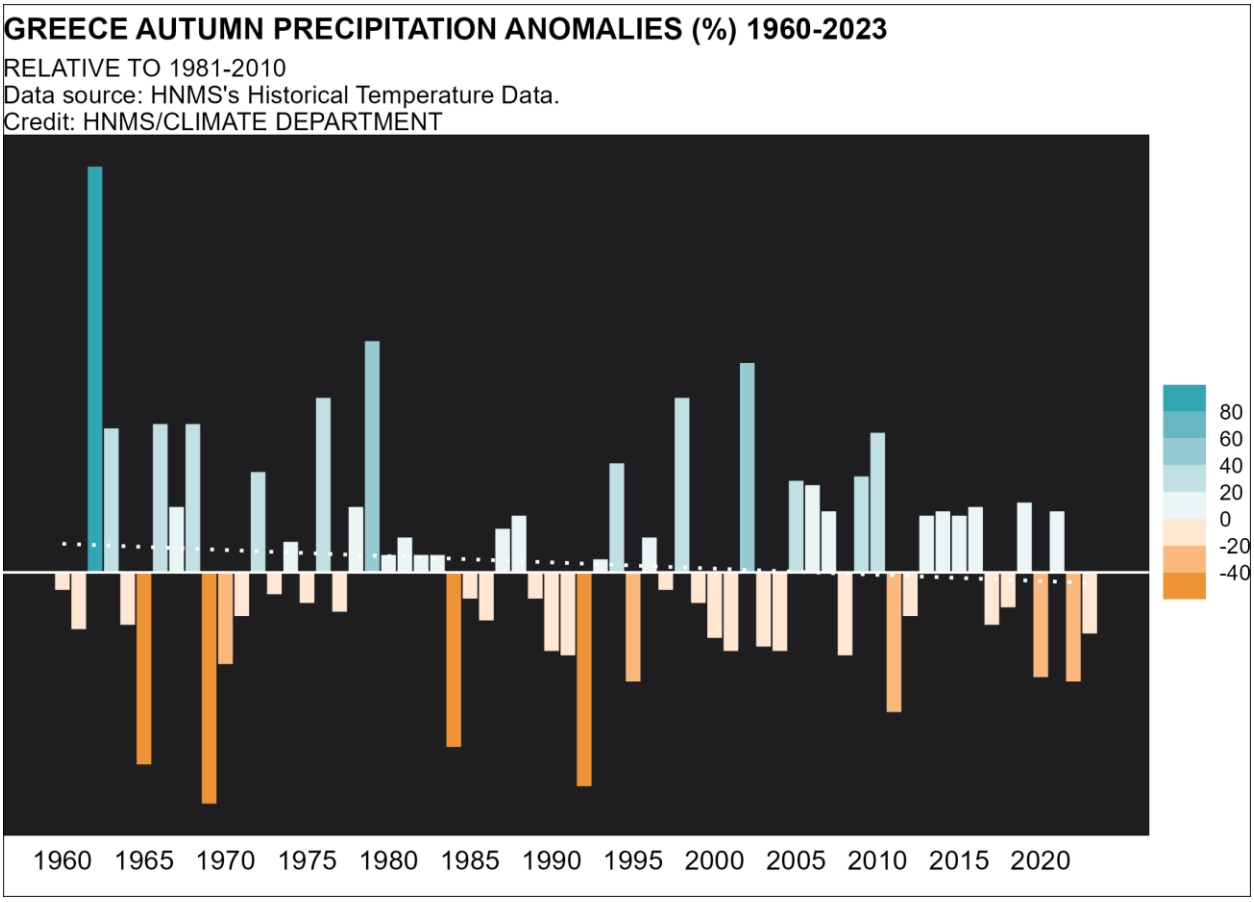

Figure 29: Autumn precipitation anomalies (%) from 1960 to 2023 relative to the average of 1981-2010 reference period. Shades of greenish-blue indicate autumn seasons that were wetter than the 1981-2010 normal value, while shades of orange indicate autumn seasons that were drier than that – the darker the color, the larger precipitation deviation from the normal value. The white dashed line depicts the linear trend.

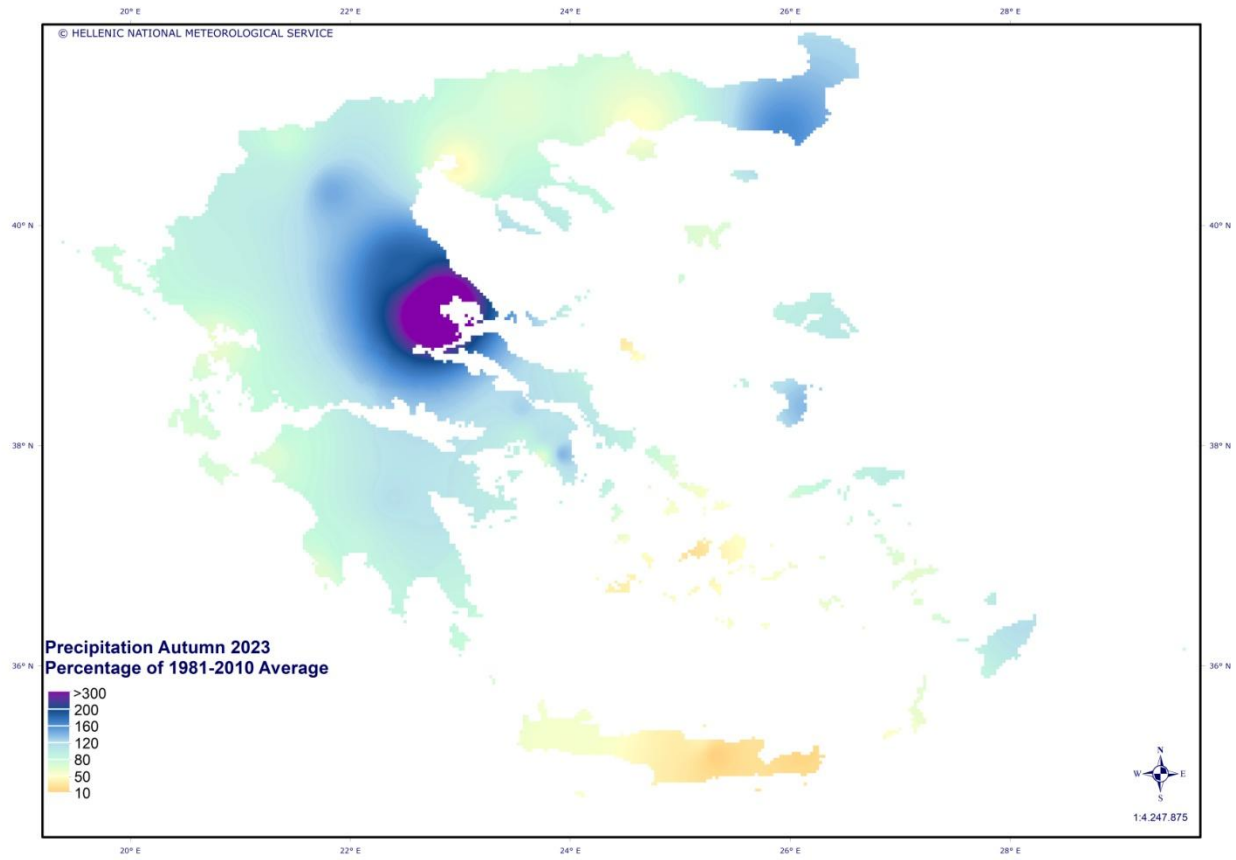

Figure 30: Spatial distribution of autumn precipitation anomalies in Greece given in percentage of 1981-2010 average.