Operational Implementation of the Heat-Alarm System in Greece

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ABSTRACT

Extreme heat events represent an escalating risk for public health in Southern Europe, with Greece being particularly vulnerable. In the framework of the HEATMETEO-GR project**,** funded by the European Climate Foundation (ECF), a biometeorological early warning system for extreme heat was operationally implemented at the national scale for summer 2025. The system integrates high-resolution meteorological forecasts with human-biometeorological indices (Modified Physiologically Equivalent Temperature, mPET) to provide impact-based heat-health warnings, disseminated via www**.**meteo.gr**.** This paper presents the design, operational chain, and examples from its implementation, highlighting representative heat episodes of summer 2025 and discussing lessons learned for future improvements.

INTRODUCTION

In recent years, extreme heat events have become a critical threat to public health and urban resilience across Europe, with Mediterranean countries like Greece particularly affected. The summer of 2021 alone saw over 2,300 excess deaths in Greece due to extreme heat, underscoring the urgent need for proactive measures that reduce vulnerability and enhance preparedness. Amidst this challenge, the METEO Unit at the National Observatory of Athens (NOA) has made substantial progress in building the foundations for a heat-health early warning system, culminating in the successful development of:

- The HEAT6C- system, an innovative early warning tool designed to mitigate the impacts of extreme heat on public health. Initially funded by the Adrienne Arsht-Rockefeller Resilience Center of the Rockefeller Foundation, this system reflects a broader commitment to enhancing climate resilience in vulnerable regions. Following its initial deployment in Athens, it has been extended to cover six major cities across Greece. The Hellenic Red Cross endorsed this system during its operations in these cities during summer 2024.
- The HEAT-ALARM pilot project (Giannaros, 2024; Giannaros et al, 2024; Galanaki et al., 2024), which integrates high-resolution meteorological forecasts with epidemiological

data to assess and communicate heat-related health risks. At the heart of the system lies the Modified Physiologically Equivalent Temperature (mPET) index, which incorporates multiple environmental factors affecting human thermal comfort. Through this synthesis, HEAT-ALARM delivers location-specific, impact-based heat warnings to support timely, targeted actions for at-risk populations.

The development of these systems represents a milestone in Greece's ability to address the health impacts of climate change. Leveraging support from the Rockefeller Foundation and the Hellenic Foundation for Research and Innovation (ELIDEK), the METEO Unit has laid the groundwork for advancing heat-health risk assessment and communication. In this context the HEAT-ALARM system was further expanded and operationalized under the HEATMETEO-GR project **funded by the** European Climate Foundation (ECF)**.** The summer of 2025 marked the first full national-scale deployment of the system, with daily warnings communicated to the public and authorities through www.meteo.gr, a platform with more than 300,000 daily visitors.

SYSTEM DESCRIPTION

The stress imposed on the human body due to hot environmental conditions and/or increased metabolic activity (e.g., outdoor labor in agriculture) constitutes a significant threat to human health. For this reason, the HEAT-ALARM system**,** provides operational warnings issued for each regional unit of Greece on days when heat stress may lead to serious health problems (e.g., heat exhaustion) or even death (heat stroke). Four warning levels are defined, each of which assesses the intensity and health risk of heat stress, taking into account both meteorological parameters (temperature, humidity, wind, radiation) and human characteristics (sex, age, weight, height), clothing insulation, and physical activity of representative individuals from different population groups. These groups include women, the elderly, and outdoor workers, who are among the most vulnerable categories of the population.

Namely, the HEAT-ALARM system integrates:

- Numerical Weather Prediction (NWP): High-resolution simulations with the WRF model, including the BEP/BEM urban canopy schemes, to capture local microclimatic and urban heat island effects.
- Biometeorological Indices: The Modified Physiologically Equivalent Temperature (mPET) index serves as the core indicator of thermal stress, translating meteorological conditions into human health-relevant impacts.
- Risk Categorization: mPET thresholds were defined using epidemiological evidence and short-term acclimatization considerations, allowing warnings to be issued in four risk levels (from low to very high).

- Operational Chain: Forecasts are automatically processed daily, mPET values are computed for major cities and regions, and risk maps are disseminated via www.**meteo.gr/heatalarm**.
- Communication Protocols: Warnings are accompanied by explanatory articles and practical public guidance (e.g., hydration, avoidance of outdoor activities during peak hours), ensuring actionable advice.

This system thus represents a transition from traditional meteorological warnings to **impact-based heat-health warnings** aligned with the EU's adaptation strategy.

EXAMPLES FROM SUMMER 2025 IMPLEMENTATION

The HEAT-ALARM system was operational throughout June–September 2025, issuing several high-level alerts. Representative events include:

- 26-29 June 2025 alert: According to the forecasting data from the METEO Unit at NOA **t**he prevailing atmospheric circulation over the Mediterranean and Europe in late June 2025 resulted in the advection of hot air masses towards Greece. Temperature anomalies at 1500 m reached +10 to +12 °C above the 1979–2010 climatological average. As a result near-surface maximum temperatures reached 39–40 °C on Thursday 26 June, and locally peaked at 41–42 °C on Friday 27 June. Although temperatures gradually decreased from Sunday 29 June, the episode produced widespread heatwave conditions across the country. The HEAT-ALARM biometeorological warning system indicated very high to extreme heat stress during this period. On 26 June, extreme thermal stress was observed in parts of Macedonia and Thrace, while very high stress extended to Thessaly and the Peloponnese. On 27 June, the system highlighted extreme heat stress over Macedonia, Thrace, Thessaly, Epirus, the Peloponnese, and the Eastern Aegean islands, with very high stress prevailing in most of Greece. Figure 1 provides the relevant alerts.

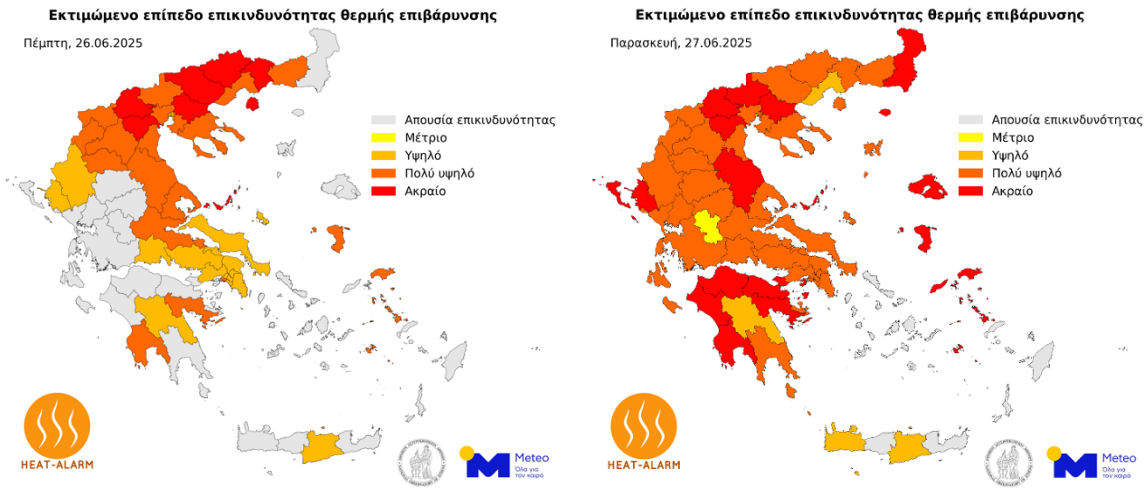

Figure 1. Estimated heat stress risk level for 26 (left) and 27 (right) June 2025.

- <u>8-9 July 2025 alert:</u> During 8–9 July 2025**,** Greece experienced a second severe heat episode, with daytime maximum temperatures exceeding 40 °C in several regions and persistently high nighttime values. The HEAT-ALARM system indicated very high heat stress over Central and Eastern Macedonia, Eastern Thessaly, and Eastern Sterea on 8 July, expanding to include Eastern Peloponnese and Evia on 9 July. The lack of nocturnal cooling amplified health risks, prompting strong recommendations for protective measures, particularly for vulnerable groups such as the elderly, outdoor workers, children, pregnant women, and individuals with chronic illnesses. Figure 2 provides the relevant alerts.

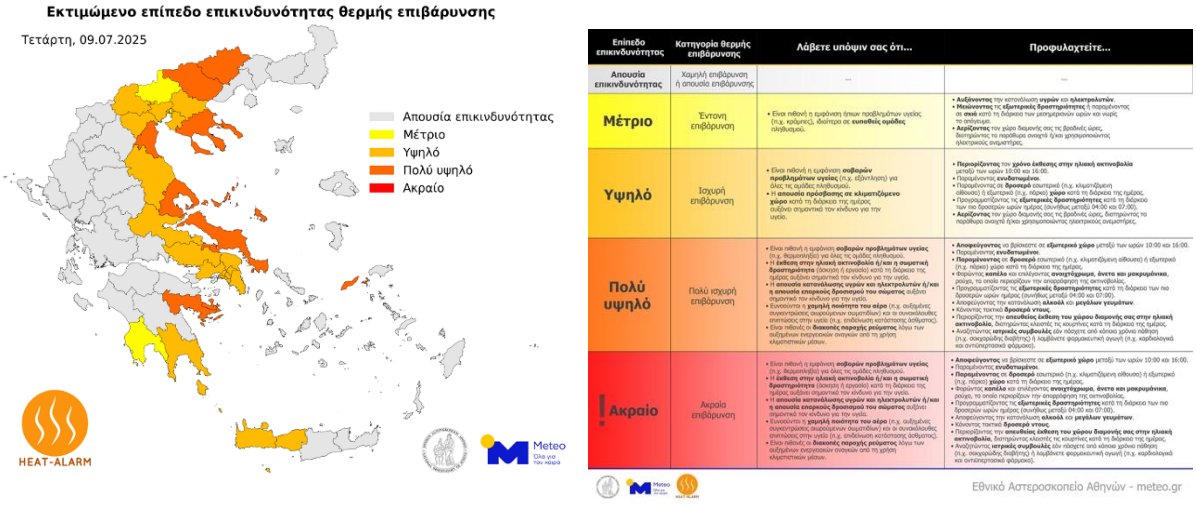

Figure 2. Estimated heat stress risk level for 9 July 2025 (left) and explanatory information provided in Greek.

- 14-28 July 2025: During 14–28 July 2025**,** Greece was affected by an intense heatwave — one of the longest on record in recent years. Analysis revealed that on peak days, over 362 out of the 580 stations (operated by the METEO unit/NOA) recorded maxima above 37 °C, and 167 stations exceeded 40 °C. In urban centers such as Attica, up to 80 % of the hours over the 9-day core period had temperatures ≥ 30 °C, indicating minimal nocturnal cooling. These observations confirm that extreme heat conditions persisted continuously, compounding physiological stress. Beyond issuing heat stress alerts, our system monitored**,** analyzed**,** and evaluated the heatwave's progression using both forecast and observational data. This dual capacity — alert + post-event analysis — strengthens the heat-alarm service's value for preparedness, verification, and improvement. Figures such as station exceedance maps and hourly exceedance ratios (Figure 3) illustrate the heat extremes.

Figure 3: The number of stations that recorded maximum temperatures above 37 °C and 40 °C, according to the records of the automatic weather station network of the METEO Unit/NOA, during the two phases of the heatwave.

Public engagement with the www.**meteo.gr/heatalarm** portal was substantial, with a sharp increase in daily visits during alert periods, confirming strong demand for heat-health information.

CONCLUDING REMARKS

The operational implementation of the HEAT-ALARM system in Greece during summer 2025 demonstrated the feasibility and effectiveness of delivering biometeorological, impact-based heat warnings at the national scale. Key lessons include:

- High public reach: Dissemination through www.meteo.gr ensured rapid and wide communication.
- Improved risk awareness: The mPET-based warnings provided actionable, health-oriented information beyond simple temperature thresholds.
- Operational readiness: Automated workflows ensured reliability and daily updates.

Future work will focus on (i) systematic post-season evaluation of warning accuracy, (ii) integrating user feedback to improve communication, and (iii) expansion of tailored alerts for vulnerable groups.

This work highlights the importance of bridging climate services and public health and sets a precedent for heat adaptation strategies in the Mediterranean.

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