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Storm Naming in the Eastern Mediterranean: Procedures, Events Review and Impact on the Citizens Risk Perception and Readiness

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Abstract: This paper is devoted to the discussion of the practice of storm naming that has been initiated in January 2017 for the first time in the Eastern Mediterranean Region. Namely the METEO Unit at NOA, taking into consideration that storm naming facilitates meteorologists, researchers, authorities, civil protection officers, the media and citizens to communicate the forecasts of high-impact weather events, started storm naming in January 2017 and has named 35 storms up to September 2021. The criteria of storm naming are discussed, and a synopsis of the events is presented. The monthly distribution shows that 57% of the named storms occurred during the winter period, with January being the month with the highest percentage of occurrence of named storms (28%). The impact of storm naming on citizens risk perception and increased awareness has been also assessed through an internet-based questionnaire that was launched on the fourth year of the storm naming practice in Greece. Overall, results indicate a significant impact of storm naming on the readiness of citizens through the activation of perceptual and cognitive mechanisms.

Keywords: storm naming; weather and climate extremes; weather forecasting; risk perception

Citation: Kotroni, V.; Lagouvardos, K.; Bezes, A.; Dafis, S.; Galanaki, E.; Giannaros, C.; Giannaros, T.; Karagiannidis, A.; Koletsis, I.; Kopania, T.; et al. Storm Naming in the Eastern Mediterranean: Procedures, Events Review and Impact on the Citizens Risk Perception and Readiness. *Atmosphere* **2021**, *12*, 1537. https://doi.org/10.3390/atmos12111537

Academic Editors: Fei Ji, Kevin K. W. Cheung and Nicholas Herold

Received: 25 October 2021
Accepted: 18 November 2021
Published: 21 November 2021

1. Introduction

The practice of naming weather systems has been founded by the Australian Meteorologist Clement Wragge from Queensland who started in 1894 to name both extratropical and tropical cyclones. He intended to help the public track the storms and also remember which of them were associated with impacts [1]. This procedure continued up to the retirement of Wragge in 1907 and restarted in 1944 with the naming of tropical cyclones in the Western Pacific, and in 1947 with the naming of hurricanes in the Atlantic. Beginning in 1953, the US National Hurricane Centre adopted a list of names to be used for the naming of tropical storms, which initially contained exclusively female names. In 1963, the Bureau of Meteorology (BOM, Australia) and the Philippine Atmospheric, Geophysical and Astronomical Services Administration adopted name lists for tropical cyclone/typhoon naming. In 1979, the World Meteorological Organization (WMO) approved the use of male names that are used since then, alternating with female ones. Currently, the list of tropical cyclones for all regions in the world is maintained and updated by an international committee at the WMO [2]. In 2012, the Weather Channel, a private-sector channel, started to officially name winter storms in the US with the aim to increase citizens' awareness [3].

In Europe, the naming of both high and low-pressure systems has been initiated by Karla Wege in 1954 at the Institute for Meteorology of the Free University (FU) Berlin focusing on Central Europe [4]. This procedure was well established since then and remained for more than 60 years the only naming practice in Europe. More recently, in

2015, the UK MetOffice in collaboration with Met Eireann has started naming storms that are expected to produce impacts in the UK and Ireland. Their criteria for storm naming are based on the combined assessment of both the severity of the weather conditions, and the likelihood of expected impacts. Windstorms are named if they have the potential for an Amber ('be prepared') or Red ('take action (danger-to-life)') warning. The 'storm systems' are named based on the impacts by the wind, but also include the impacts of rain and snow. The Dutch Meteorological Agency (KNMI) in the Netherlands has joined this common effort in 2019. Since 2017, the meteorological services of France, Belgium, Spain and Portugal have also started to name windstorms contributing to the initiative of the UK and Ireland. For this initiative, there are two main naming lists: one created by the national meteorological agencies of the United Kingdom, Ireland, and the Netherlands, and another one created by the respective agencies from France, Spain, Portugal, and Belgium. Until recently, no naming of storms existed for the Central and Eastern Mediterranean.

For the storm name selection, various procedures have been used over time. Wragge, the pioneer of storm naming, has initially used letters of the Greek and Hebrew alphabet, then selected names from Greek and Roman Mythology, while later on, he used female names, and lastly names of politicians [5]. For tropical storm naming, a pre-determined list of names for each ocean, maintained by the WMO, is used [2]. For the hurricanes in the Atlantic Ocean, 21 names for each year are available using all the Latin alphabet except the letters Q, U, X, Y and Z, while when a named storm produces noteworthy damages and victims, the name is retired. The names included in the list are short, culturally sensitive, and they do not convey some unintended and potentially inflammatory meaning [6]. When more than 21 cases occurred within a year then the Greek Alphabet was used instead of a name. This latter naming procedure was abandoned in 2020 since several storms named with Greek letters produced many damages and should be retired, so an auxiliary name list is being adopted for each year. The same procedure is followed in the East Pacific, while in the Central and West Pacific there is a perpetual list of names. In Central Europe, since 2002 the Free University of Berlin has initiated the procedure "Adopt-a-Vortex" that invites the citizens to give a name to a high or low-pressure system at a certain cost. Then, the list of suggested names is published in the 'Berliner Wetterkarte' and is used by the weather services or the media [4]. In the UK, Ireland and the Netherlands, a list of names has been compiled. Namely, the UK Met Office and Met Éireann with the aim to increase citizens' engagement have invited them through social media to contribute storm names [7]. Since 2017, the meteorological services of France, Belgium, Spain and Portugal have also started to contribute with their list of names to the aforementioned initiative. The agency that plans to issue the first alert between the two groups gives the name to the storm from the pre-established list. The storm then maintains the same name throughout its life cycle, even if it then affects countries of the other group.

Assessing the impact of storm naming on the general public is of particular interest, as it can highlight how and to what extent the perception of the increased risk and consequently the preparedness of citizens are affected. Additionally, it is particularly useful to evaluate and measure the acceptance of storm naming by citizens. As the practice of naming storms is adopted by more and more meteorological services as well as from the private sector, questions inevitably arise about its usefulness; especially for fear that the name will attract attention instead of increasing alertness and focusing on the actual storm risks [8]. Charlton Perez et al. (2019) who studied the case of the named storm Doris, which affected the UK and Ireland in 2017, have concluded that the procedure of naming storms is not only important and positively contributes to the communication of forecasts, but also benefits scientific research by providing a useful and easily collected target to study the development and evolution of public understanding of extreme weather events. The impact of storm naming on the perception of storm severity, likelihood of damage, behavioral change and perception of hazard has been also investigated by analyzing exemplified aspects of storm warnings in a Twitter feed [9]. The authors found that a sleeper effect may impact the severity perception, likely due to increased memory created by emotional and threatening news depictions. The influence of risk perception, previous experience and trust in prevention measures such as warnings, on individual precautionary behavior, is shown to be important in several studies on weather-related risk reduction [10–14]. The question, therefore, is whether the impact of these parameters on readiness is also enhanced in the context of storm naming.

In 2017, the METEO Operational Unit at the National Observatory of Athens has decided to start naming the weather systems/storms, which are expected to produce impacts in Greece, following the existing procedure in other parts of Europe and of the world. Since then, 35 weather systems have been named. This paper aims to: (a) present the procedures followed for storm naming in Greece, (b) review the named systems in terms of the intensity of the meteorological hazard, but also of the severity of the impacts and (c) assess the impact of storm naming on the general public. Specifically, to meet the third objective of the present work, we utilized an original survey targeting Greek citizens. The aim of the survey was mainly to measure the change in risk perception and the level of vigilance, and to estimate the effect on the citizens' readiness when a storm is named, taking into account the overall acceptance of storm naming and previous experience of such events.

The present work is articulated as follows: Section 2 is devoted to the presentation of the methodology and datasets used both for storm naming and also for the assessment of the impact of storm naming on the general public; Section 3 presents a review of the named events and the results of the survey on storm naming, while Section 4 is devoted to the description of a case study of a recent and high-impact named storm. The last section is devoted to the discussion and concluding remarks.

2. Data and Methods

2.1. Criteria for Storm Naming & Name Selection

In January 2017, the METEO unit at the National Observatory of Athens (NOA) took the initiative to start naming low-pressure systems and atmospheric disturbances, which are expected to cause significant social and economic consequences in Greece. For that purpose a number of criteria have been established for a weather system to be named that relate to both the level of the meteorological hazard, but also to the size of the affected area and population at risk. Namely, as it concerns the meteorological hazard the criteria focus on: (a) rainfall, by assessing if the forecasted rainfall amounts may reach/exceed levels that have proved by experience to produce flooding, (b) snowfall, by assessing if the forecasted snowfall is expected to affect large urban areas and cities, highway hubs and airports causing disruptions of economic and social activities, (c) wind, by assessing if the forecasted wind intensity is expected to exceed 75 km h^{-1} (9th grade on the Beaufort empirical scale) over maritime areas producing disruptions of maritime services or the threshold of 50 km h^{-1} (7th grade on the Beaufort empirical scale) over land that could have significant impact to infrastructures.

Once the above meteorological hazards are forecasted to occur, then the spatial extent of the high-impact weather phenomena is assessed. Namely, we evaluate if the high-impact weather is expected to affect a large part of the country and/or parts of the country with a large population density (e.g., the two largest Greek cities, Athens and Thessaloniki). In addition, the timing of the high-impact weather events is also important as during festivities and also summertime increased citizens' and tourists' mobility is expected, and thus the level of exposure to danger increases as well as the likelihood for a weather system to be named. Naming of a storm is issued 48–72 h before the storm is expected to impact Greece in order to ensure increased confidence on the forecast and a decreased chance of false alarms.

In Greece, when the naming of a forthcoming weather event is decided, the names selected derive from Greek Mythology, Ancient Greek and Roman History, in alphabetical order, alternating female and male names. When all 24 letters of the Greek alphabet have been used from A to Ω, then the naming restarts from letter A again. The same name is not used twice.

2.2. Data Sources

As already discussed in the previous subsection, the first criterion used to name a weather system relates to the level of the forecasted meteorological hazard which is assessed based on the consultation of a series of available Numerical Weather Prediction (NWP) data that are available at various time scales.

Namely, up to 7 days before the event, guidance from a variety of global-scale models (namely NCEP/GFS and ECMWF/IFS) allows us to identify potential high-impact weather patterns across Europe and the broader area of eastern Mediterranean and southern Balkans. Ensemble forecasts provided by these two global models further assist the forecasters to assess the level of uncertainty and reliability of the forecasts.

Up to 2–3 days before the event, high-resolution regional models allow us to assess more detailed characteristics of the upcoming weather event, providing more robust model guidance. Namely, the METEO unit at NOA has implemented three operational high-resolution NWP model chains based on: (a) BOLAM model (operational since 2000, [15]), (b) WRF (operational since 2005, and updated continuously since 2014 [16–18]) and (c) MOLOCH model [19]. The final decision to name a storm is made upon the model guidance provided by these three models.

When the high-impact weather event starts, its evolution is closely monitored by a series of observational platforms. The METEO unit at NOA operates in Greece a network of more than 430 automatic surface weather stations [20] that allows a real-time assessment of the evolution of all basic weather parameters. Moreover, lightning data, provided by ZEUS lightning detection network [21,22] are of vital importance in the case of thunderstorms. Finally, satellite imagery, including specific satellite products such as NWC-SAF (https://www.nwcsaf.org/, accessed on 25 October 2021 [23]) is of paramount importance for the monitoring clouds and their motion, cloud top-height, probability of precipitation, etc. This nexus of all available observational data have a threefold use: (a) assist the forecasting unit in the monitoring of the evolution of the specific weather event, (b) provide information to the general public, with the aim to further increase their awareness and preparedness, and (c) assess the level of the meteorological hazard after the end of the event.

2.3. Survey on the Impact of Storm Naming

In the frame of this work, in the first semester of 2021, a survey was performed to measure the change in risk perception and in the level of vigilance and their effect on the citizens' readiness when a weather system/storm is named. To this end, a 17-question internet-based questionnaire was constructed and released, gathering a nationwide sample of 2088 respondents. The questionnaire was released through the website www.meteo.gr (accessed on 25 October 2021) and it was structured around 4 themes:

- The increased readiness triggered by the named storms compared to the non-named ones,
- The perception of increased risk,
- The triggering of access to risk information, and
- The acceptance of the storm naming practice.

Socio-demographic characteristics, previous negative experience, and knowledge on the subject were also recorded.

Survey questionnaire items were closed-ended and, except for the socio-demographic and experiential ones, were treated with a 5-point Likert rating scale. Three items were combined to measure risk perception and acceptance of storm naming, to ensure reliable and valid methodological treatment as they constitute psychometric variables. Principal Factor Analysis (PFA) was applied to validate each multi-item variable and Cronbach's alpha (α) was applied to examine the scale internal reliability. Only items with factor loadings above 0.6 were accepted in PFA to ensure a very good fit with the factor [24].

Readiness and access to information were also developed from more than one question (2 items) to increase their scale reliability. To produce each model variable, the mean rating of all items comprising the variable was calculated [24]. Scale reliability was considered excellent for α above 0.7 [25].

To measure readiness, participants were asked to rate their level of vigilance and prevention when storm naming was applied. To measure the risk perception, participants were asked 3 questions regarding: (a) the perceived increased hazard, (b) the perceived increased impact and (c) the increased worry they felt in the case of a named storm. Thus, the measure of risk perception includes both cognitive and emotional aspects, the combined effect of which on preventive behavior has been shown to be significant [13].

To measure acceptance of the storm naming, participants were asked to rate: (a) the usefulness of the naming practice, (b) its reliability in terms of the predicted intensity, and (c) their satisfaction with the naming procedure.

To measure access to information, participants were asked to what extend storm naming prompted them to be informed (a) timely compared to other severe weather events, (b) extensively as the phenomena progressed.

To provide an overview of the participants' perspectives, we first performed descriptive data analyses. Next, we conducted a multiple regression analysis to investigate whether readiness associated with storm naming is affected by risk perception, access to information, and acceptance of storm naming while controlling for demographic attributes and negative experiences.

At this point, we should mention that the results of this analysis might be biased by the fact that the questionnaire has been released on a website about weather (www.meteo.gr, accessed on 25 October 2021), and thus the sample has not been randomly selected.

3. Results

3.1. Characteristics of Named Storms 2017–2021

During the period starting in January 2017, when storm naming was initiated, until September 2021, the METEO unit has named a total number of 35 high-impact weather systems. The full list of the named storms/weather systems is provided in Supplementary Materials S1. Three of them: ZENON (18–19 September 2017), XENOPHON (25 September–1 October 2018) and IANOS (16–20 September 2020, see [26] for details) evolved into Mediterranean tropical-like cyclones (medicanes).

Figure 1 shows the monthly distribution of the 35 named storms and the year of their occurrence. The highest number of events, 12 named storms, occurred during 2019. Eight and seven events occurred during 2018 and 2017, respectively, while only six weather systems met the criteria for being named during the last twenty-one months of the examined period. On a seasonal basis, most of the named storms (20 out of the 35; ~57% of the total) occurred during the winter period. January is characterized by the highest frequency of occurrence of named storms. In particular, 10 high-impact weather systems have been named during the first month of the year. Figure 2 shows the monthly distribution of the named events and the main weather-related hazards associated with each named storm. Most of the January named storms have produced snowy and frosty conditions both in mountainous and lowland areas of Greece. In addition, significant amounts of rain affected many areas of the country during six out of the ten named storms in January. Rain was also a major meteorological hazard during the February and December events (11 in total).

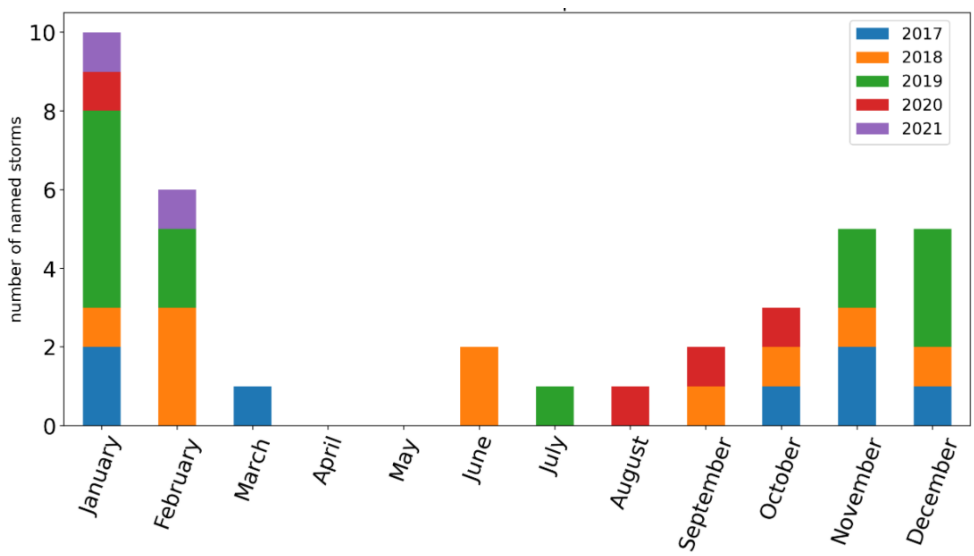

Figure 1. Number of named storms in Greece per month between January 2017 and September 2021. Color bars denote the year of occurrence of each named storm.

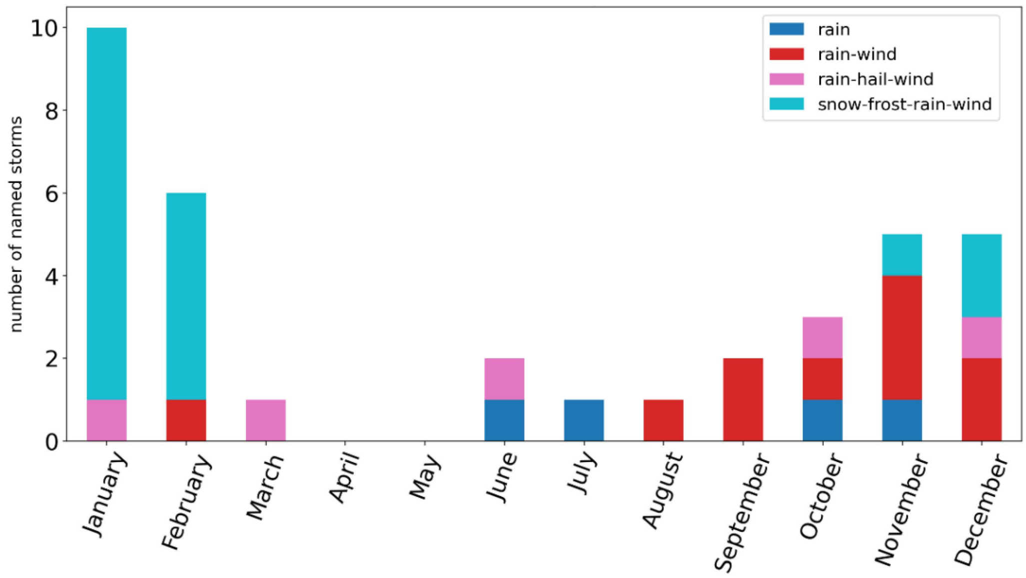

Figure 2. Number of named storms in Greece per month between January 2017 and September 2021. Color bars denote the main hazards associated with each storm.

Concerning spring and summer, both seasons are characterized by a low number of occurrence of named storms (one and four, respectively), which were mainly associated with convective rainfall, damaging hail and strong winds. This is something that was expected, as the atmospheric conditions during the dry period of the year do not favor the development of large-scale high-impact weather systems. However, during spring and summer periods of increased instability associated with an upper-level low or the passage of a long trough can lead to severe convective events. On the contrary, the most intense cyclonic activity and the highest mesoscale convective systems activity are found in autumn and winter [27]. Thus, it is not surprising that 10 out of the 35 named storms (~29% of the total), including the three aforementioned medicanes, have occurred during the autumn season. Huge amounts of rainfall and stormy winds characterized most of these events.

Further examining the key features of the 2017–2021 named storms, Figure 3 shows the monthly distribution of the events combined with the number of prefectures, the maximum population that was potentially affected, and the resulted fatalities. According to our analysis, the most widespread events, based on the total number of affected prefectures, occurred during the cold season (November–February). A maximum of 52 prefectures were affected in total during January, while more than 15,000,000 people were potentially affected by the named storms during February (Figure 3).

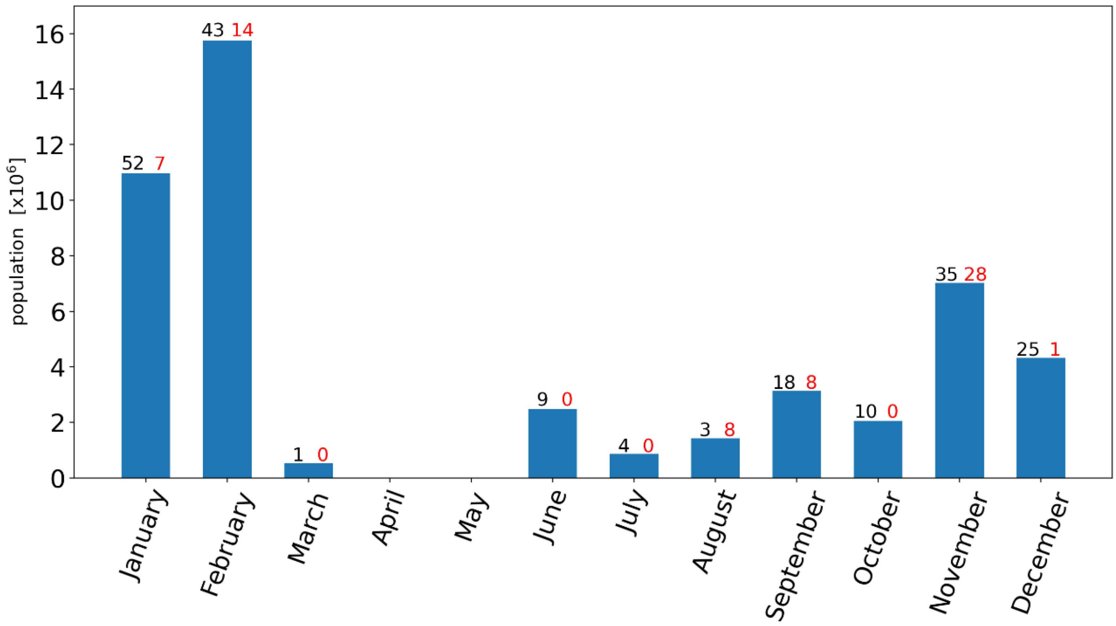

Figure 3. Total population affected by named storms in Greece per month January 2017 and September 2021. Black numbers on the top of the bars denote the number of prefectures affected by the storms for each month and the red numbers show the total number of fatalities for each month.

If we classify the events depending on the number of affected prefectures, we find that more than 10 prefectures have been affected by four events. Three of them occurred during the winter season, and one (EURIDICE) during autumn (in November 2017). EURIDICE produced an intense local storm in Mandra (West Attica), which led to the overflow of two small ephemeral streams in the area. The aftermath of the EURIDICE-induced flash flood in Mandra included the tragic loss of 24 citizens, and thus this was the most hazardous event in terms of human casualties (Figure 3).

Fifteen named storms negatively influenced five to ten prefectures. The majority of these events occurred in the course of winter and autumn, provoking the death of 19 people in total. Each one of the rest of the events (16 in total) affected less than five prefectures in Greece. Most of them took place during spring and summer. Among these named storms, THALIA, which occurred in August 2020, should be highlighted, as although it affected only four prefectures (1,575,933 total population), it resulted in eight deaths due to a flash flood event in Evia island.

3.2. *Impact of Storm Naming on the General Public*

This subsection is devoted to the discussion of the results of the survey that was performed to measure the change in risk perception and level of vigilance when a weather system/storm is named. As already mentioned, this survey resulted in 2088 responses to the internet-based questionnaire. Based on the analysis of these responses, we found that regarding the sample profile: (a) males were overrepresented, accounting for 73% of the respondents, (b) respondents were approximately normally distributed among the age categories, with 15% being over 60 years old, 41% belonging to the 45–60 years category, 32% to the 30–45 years category and 12% being less than 30 years old, (c) the vast majority of the respondents (80%) live in urban areas and (d) 23% of the respondents had been adversely affected by at least one named storm.

Table 1 presents the statistical description of variables and the associated items, the scale reliability of variables, and item factor loadings where applicable (i.e., 3 items involved). On a 1 to 5 scale, readiness, risk perception, and access to information are activated to a moderate degree due to storm naming (mean rate M = 2.86–2.95), while acceptance of naming is above average (M = 3.27).

Table 1. Statistics (mean (M), standard deviation (SD), min–max, scale reliability (α) and construction (item factor loadings) for readiness and all explanatory variables (*n* = 2088, for each variable).

Variables	Items	M	SD	Min	Max	Cronbach's Alpha	Factor Loadings
Readiness		2.92	1.33	1	5	0.90	
	Vigilance	2.99	1.38	1	5		n/a
	Prevention	2.85	1.40	1	5		n/a
Risk perception		2.95	1.27	1	5	0.89	
	Perception of hazard	3.08	1.36	1	5		0.88
	Perception of impact	2.94	1.37	1	5		0.89
	Feelings of worry	2.84	1.47	1	5		0.77
Acceptance of storm naming		3.27	1.14	1	5	0.79	
	Useful	3.04	1.50	1	5		0.80
	Reliable	3.22	1.12	1	5		0.65
	Satisfactory	3.53	1.43	1	5		0.71
Access to information		2.86	1.30	1	5	0.95	
	Timely informed	2.81	1.33	1	5		n/a
	Extensively informed	2.91	1.32	1	5		n/a
Negative experience		0.23	0.42	0	1		

n/a: not applicable.

Inspection of the distributions of the variables according to experience (Figure 4), shows an increased activation of the reflexes of the citizens who had experienced negative effects from a named storm in the past. Specifically, the Wilcoxon signed-rank tests showed statistically significant increases in readiness ($z = -9.86$, $p < 0.00$), risk perception ($z = -9.54$, $p < 0.001$), acceptance of storm naming ($z = -6.98$, $p < 0.001$), and access to information ($z = -6.94$, $p < 0.001$), among the citizens who had already a negative experience of adverse impacts from a named storm. Among the examined variables, acceptance of storm naming presents the lowest variation regardless of previous negative experience, suggesting that the respondents have a higher level of agreement among them regarding the acceptance of storm naming. Moreover, acceptance of storm naming is rated very high compared to the other variables, with more than 50% of participants contributing to a score above 4 when there is a previous negative experience.

Table 2 provides the results of the multiple regression analysis performed to assess the explanatory power and specific effects of the several examined independent variables on readiness triggered by storm naming. The F value for the model is highly significant ($p < 0.001$), indicating a very good fit of the data. The adjusted R square (R2) is 75%, showing, thus, a high explanatory power (Table 2). To assess multicollinearity, we computed the variance inflation factor (VIF) scores, which were below the accepted cut-off of 10, ranging from 1.00 to 2.48. The respective correlations are provided in Supplement S2 (Table S2.1).

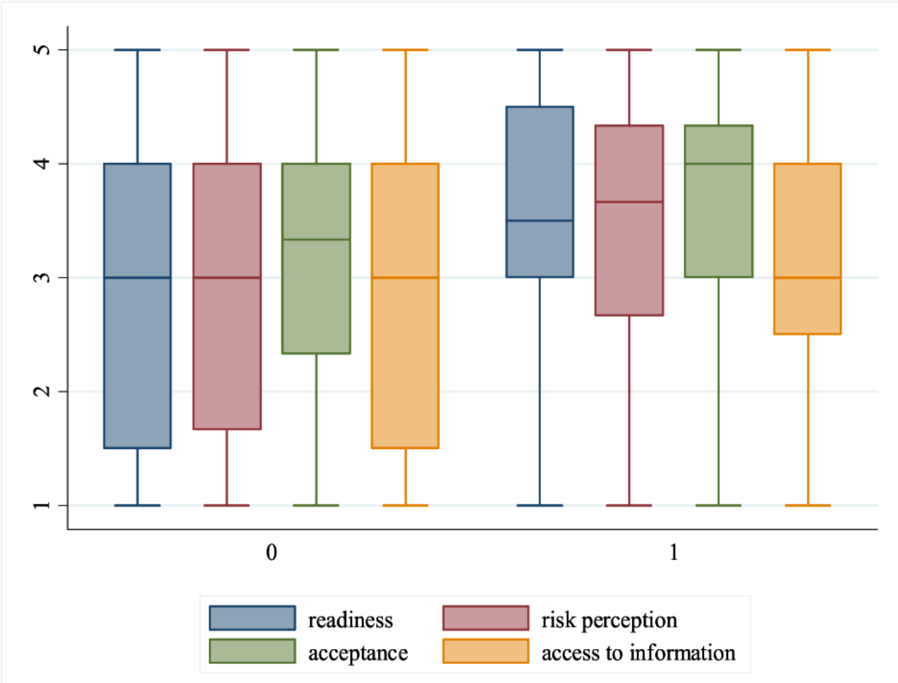

Figure 4. Box plots of the model variables readiness, risk perception, acceptance of storm naming, and access to information, among the population sample without previous negative experience (0) and with previous negative experience (1).

Table 2. Regression results explaining individual readiness for named storms.

Variable	Readiness		
	B	SE B	β
Risk perception	0.48	0.02	0.46 ***
Acceptance of storm naming	0.16	0.02	0.14 ***
Access to information	0.37	0.02	0.36 ***
Negative experience	0.14	0.04	0.04 ***
Gender	−0.10	0.03	−0.03 **
Age	0.03	0.02	0.02 +
Urban fabric	−0.03	0.04	−0.01 +
_cons	0.00	0.10	
n = 2088			
F(7, 2080) = 910.77 ***			
Adj. R2 = 0.75			

Note: β are standardized beta coefficients. Explanatory variables in Table 2 are sorted in descending order with respect to β. Statistical significance, p-value, is symbolized as + $p > 0.05$ (not significant), ** $p \leq 0{:}01$, *** $p < 0.001$.

According to the results, readiness is explained to a large extent by the examined variables, although age and urbanization were not found to have statistically significant effects. Results are in line with previous studies showing that demographics are occasionally found to have only a marginal effect on risk perception and preparedness against flood risk ([11,28,29]). Risk perception was found to have the most important effect on citizens' readiness, closely followed by access to information. The effects of acceptance of storm naming and previous negative experience on readiness were found to be less important, but statistically equally significant. Overall, results indicate a significant impact of the storm naming on the readiness of citizens through the activation of perceptual and cognitive mechanisms.

4. The Case-Study of MEDEA

In the period 13–17 February 2021, Greece was affected by an intense and long-lasting cold-air intrusion (Figure 5). The advection of cold air masses from northern Europe was associated with a long-wave trough in eastern Europe between 12 and 17 February 2021 (Figure 6). The extremely low temperatures and the forthcoming intense phenomena were well-forecasted several days in advance by global and regional models. This led the METEO unit to name the adverse meteorological event MEDEA, after the name of a princess of the Greek Mythology. The first public announcement was released on 10 February, three days before the onset of the phenomena, namely the dramatic temperature drop shown in Figure 5.

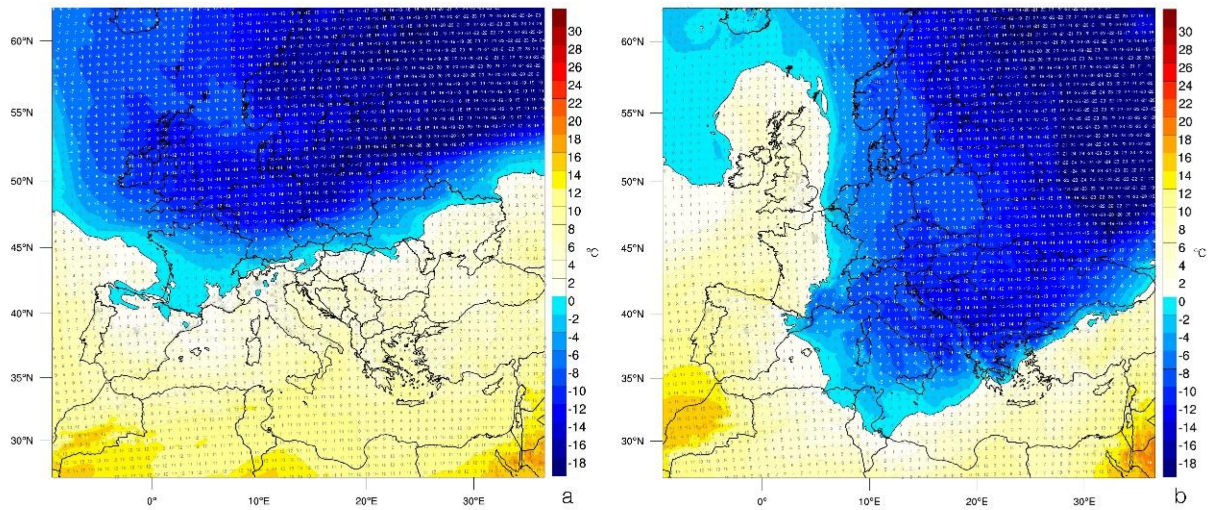

Figure 5. Forecast of 850 hPa temperature (at 2 K intervals) valid on: (**a**) 10 February 2021 at 1200 UTC, and (**b**) 14 February 1200 UTC based on BOLAM model initialized on 10 February 2021 at 0000 UTC.

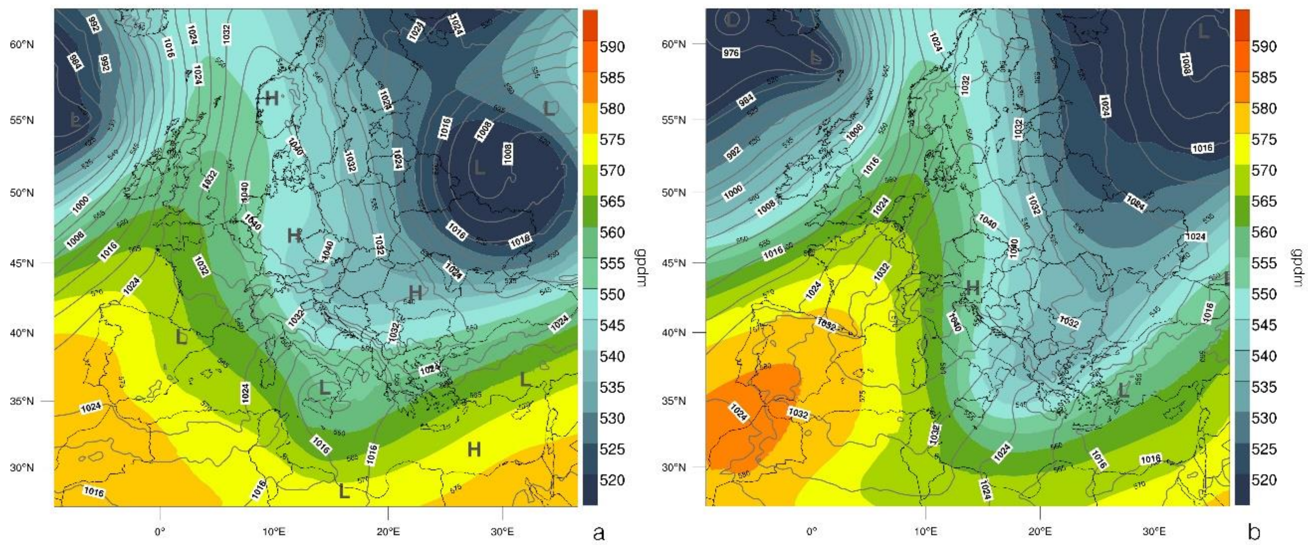

Figure 6. Forecasts of 500 hPa geopotential height (color shade every 5 gpdm) and mean sea-level pressure (grey contours every 4 hPa) valid on: (**a**) 13 February 2021 at 0000 UTC and (**b**) 15 February 0000 UTC based on BOLAM model initialized at 10 February 2021 at 0000 UTC.

During MEDEA, Greece was affected by a low-pressure surface system that on 14 February 2021 moved quickly eastwards from southern Italy towards southern Greece (Figure 6a,b). The system produced heavy rainfall and snowfall in a large part of the country. Gale-force winds were recorded over the maritime and insular areas. On 15 February 2021, the low-pressure system moved over the southwestern parts of Turkey (Figure 6b) and a strong northeasterly flow was established over the Aegean Sea. At the same time, the positively tilted mid-tropospheric trough over Eastern Europe reached Greece, further destabilizing the underlying unstable air masses over the sea. The southern and eastern parts of the country experienced heavy snowfall with significant accumulations of snow on the ground, heavy rainfall and strong winds exceeding 100 km h^{-1}. The most important meteorological characteristics of MEDEA were the following:

- A rapid temperature drop of more than 10 °C in less than 24 h.
- Extremely low temperatures with record-breaking values in several weather stations. The lowest temperature (−25.1 °C) was recorded in Northwestern Greece on 16 February 2021. This is the lowest temperature recorded by the METEO network in the last 15 years. Freezing conditions at low elevations lasted for several days after the end of the event.
- High accumulations of snow on the ground, especially in the eastern parts of continental Greece and in mountainous parts of Crete.
- Strong gale-force winds for several days in the Aegean Sea and Islands, reaching gusts of 121 km h^{-1} in Tinos Island in Cyclades.

Several municipalities declared a State of Emergency to receive help and face the numerous impacts from MEDEA. The socio-economic impacts of the event included:

- Four casualties.
- Disruption of traffic in highways and provincial roads.
- Disruption of main passenger and commercial ship traffic in the Aegean Sea due to gale-force winds.
- Agricultural losses due to unseasonable frost and persisting low temperatures for several days.
- Power outages, even in the capital city of Athens, that in some highly populated areas lasted for more than 4 days.
- Significant damage to forests of pine trees due to the weight of the heavy wet snow, uprooting of thousands of trees and/or breaking of branches.

In total, METEO released 18 public announcements for MEDEA: Four before the onset of the event, 13 during the event and one after its end. The four first announcements were aiming to inform about the main characteristics of MEDEA, and contribute to the increase of preparedness of the state authorities, private stakeholders and general public. The next 13 were providing up-to-date information about the meteorological situation and also detailed forecasts for the following 12 to 36 h to increase awareness and coping capacity. The final announcement summarized the main characteristics along with the most important socio-economic impacts and lessons learned from MEDEA (Figure 7). In the period 10–19 February 2021, 650,000 users per day (on average, with a peak at 749,000) visited www.meteo.gr (accessed on 25 October 2021) to be informed for MEDEA and more than 1,252,000 users of the METEO social media accounts read the aforementioned announcements on Facebook (879,000 users) and on Twitter (373,000 users).

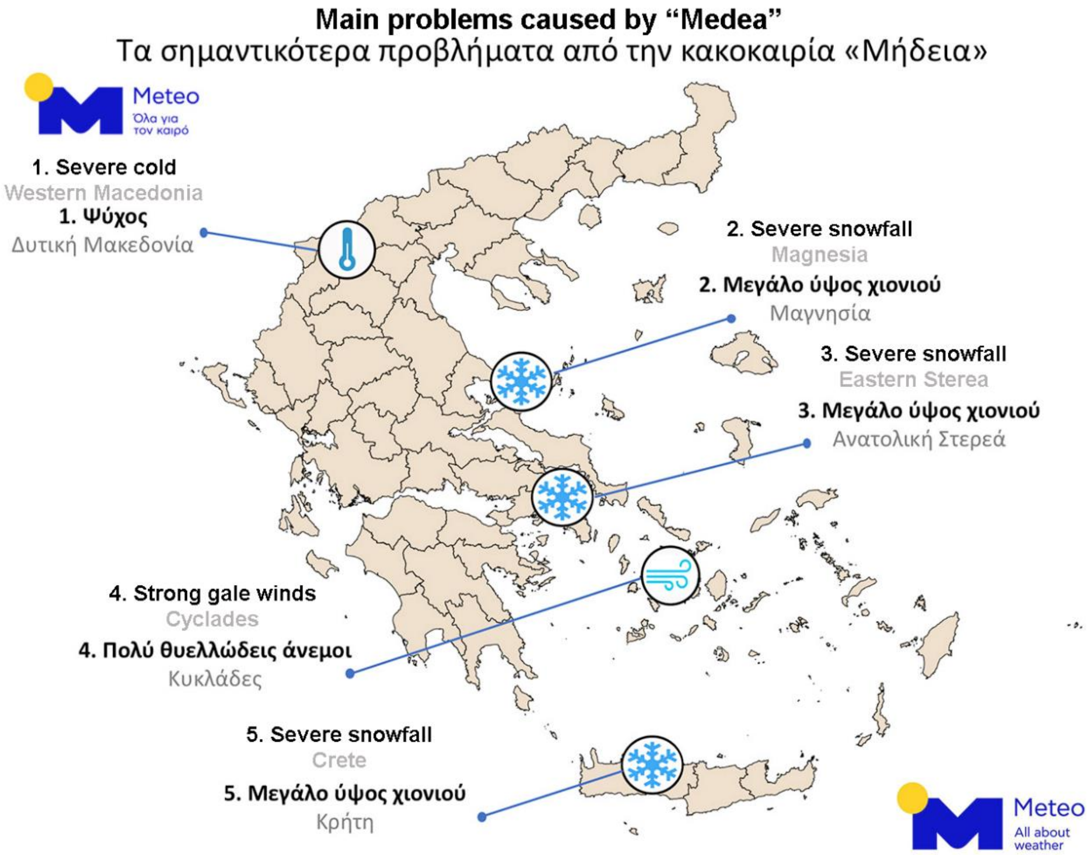

Figure 7. Main problems caused by MEDEA as provided in the original (with English subtitles for the needs of this work).

5. Discussion

According to WMO, which maintains the list of names used for tropical cyclones, naming contributes to the rapid identification of the systems in the warning messages, because names are presumed to be far easier to remember than numbers and technical terms. Naming storms makes it easier for meteorologists, researchers, authorities, civil protection officers, the media and citizens to communicate the forecasts of high-impact weather events and increases the interest in warnings and community preparedness. In Europe, according to the British Meteorological Office [7], naming weather systems has been proven to be able to provide a consistent message to the public and raise awareness of severe weather before it hits, urging citizens to take action to keep themselves, their property and businesses safe.

The METEO unit at NOA, which initiated the high-impact weather system naming in Greece, is confident that naming significantly contributes to increased preparedness of the citizens for an upcoming weather event. The METEO unit published weather reports with a high frequency at the website www.meteo.gr (accessed on 25 October 2021) before and during the evolution of the named storms, using texts, videos, and forecast maps of rain, snow, thunder, wind and temperature in a comprehensible way to maximize the impact of the provided information.

The subjective idea that storm naming increases awareness and preparedness has been quantified in the frame of this work after four consecutive years of such practice in Greece through a dedicated questionnaire. The analysis of the questionnaires showed the positive impact of storm naming on the readiness of citizens through the activation of perceptual and cognitive mechanisms. In this context, negative experience was also shown to increase readiness (Figure 4), in agreement with previous evidence on the positive impact of previous flood experience on individual precautionary behavior ([11,30]). Increased readiness among the citizens is considered an important factor contributing to enhanced community preparedness against weather-related hazards, and thus to disaster risk reduction. The findings of this study indicate that risk reduction can be improved by experts' initiatives (such as storm naming) and previous negative experience that both increase risk perception, as long as risks are effectively communicated.

The storms with the highest impact in terms of the number of respondents who declared they have affected them are MEDEA (13–17 February 2021), IANOS (16–20 September 2020), and ARIADNE (5–11 January 2017) (Figure 8). MEDEA was the most recent one while ARIADNE was the first named storm. If we rank the storms based on the regions and population affected all three events are ranked among the top 10 events. Here, we should note that the questionnaire might have been affected by the most recent memory of the respondents (which explains the first position of MEDEA) and also the representativeness of the respondents by prefecture and thus by affected prefectures. IANOS (ranked 2nd) was the named storm that produced the largest economic impact with more than 30 M Euros of damages while ARIADNE (ranked 3rd) was among the top two in terms of the number of affected prefectures (15 out of 51). The qualitative results, as reflected in the responses to the questionnaire, show that not only the naming contributes to the increased awareness of the citizens, but also constitutes a cognitive mechanism.

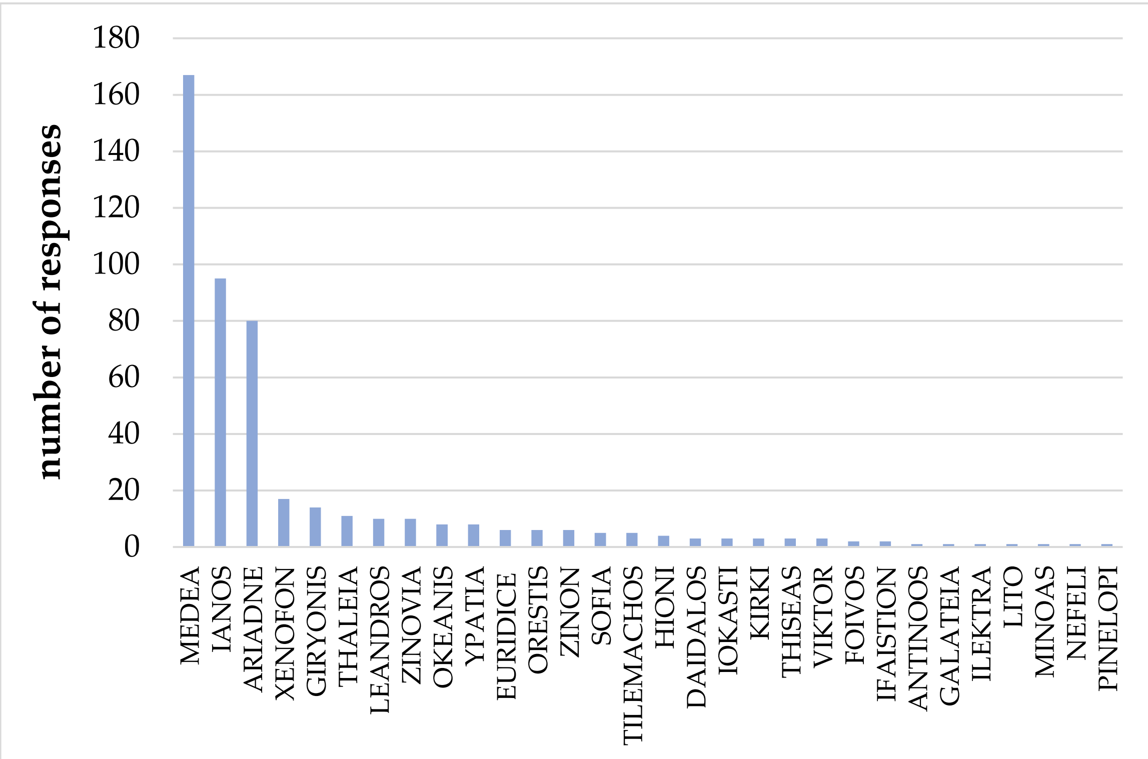

Figure 8. Ranking of the named storms by their impact based on the respondents to the questionnaire.

Figure 9 shows the spatial distribution of the number of named storms that affected each of the 51 prefectures in Greece. From the analysis, it is evident that the most affected area was Attica with 16 events, which is the prefecture with the highest population. The eastern part of continental Greece, including Evia Island and the westernmost prefecture of Crete, are the areas that have been affected by a large number of the named storms during the period spanning from January 2017 up to September 2021. It should be noted that the number of storms was found to be significantly and positively correlated to the number of the questionnaire responses per 100,000 inhabitants at the prefecture level (Spearman's rho = 0.32, $p < 0.05$). This indicates a higher interest of citizens living in more affected regions for being surveyed on a subject that affects their lives. However, the region where they live was not found to statistically correlate to any of the examined factors of readiness.

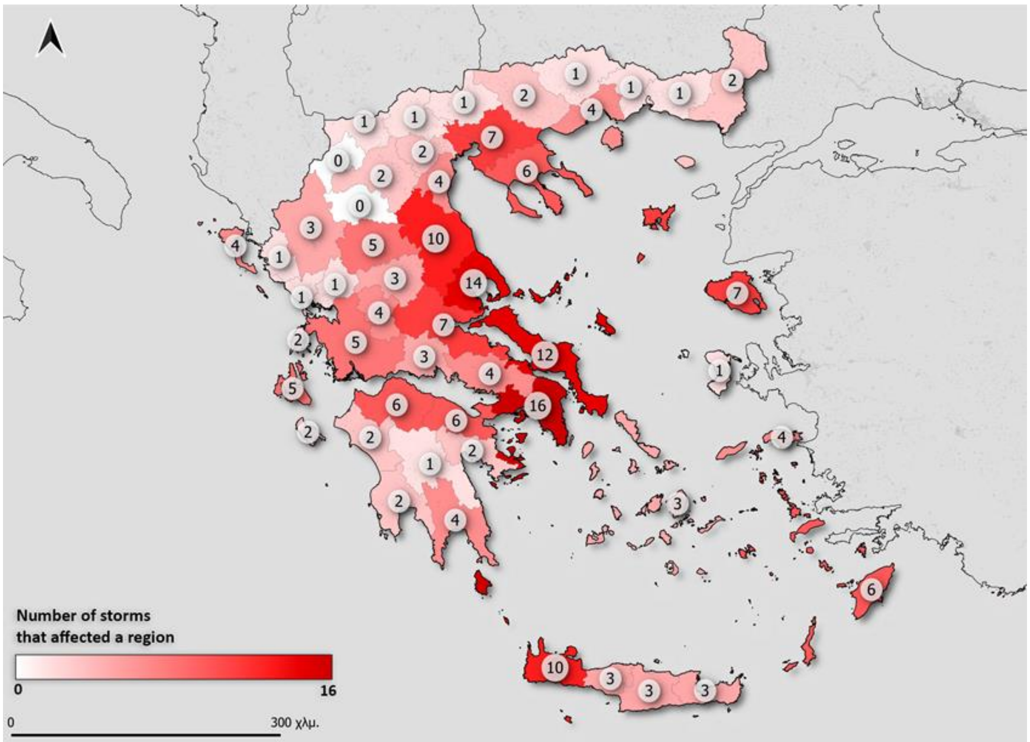

Figure 9. Number of named storms that affected each prefecture in Greece during the period January 2017–September 2021.

At this point, it should be noted that two types of potentially major catastrophic weather situations are not named following the above practice. The first one is associated with high-danger fire weather patterns and the second one with a heat wave event. Both situations may have an impact in terms of losses of lives and economic damages, but there is no previous experience of such a type of naming. Especially for heatwaves, there is currently an initiative of the Arsht-Rock Resilience Centre that is leading the global call for the dangers of extreme heat to be properly recognized [31]. This initiative includes the ranking of heatwaves and their eventual naming, as naming is considered an important contributing factor to risk mitigation of threatened vulnerable populations. Heatwaves are considered as a "silent killer" as the specific weather event is not as violent as storms, floods and hurricanes and does not impact infrastructures, but occasionally, it can also result in fatalities at large numbers and economic and financial losses. This is why NOA is actively participating in this initiative that has also been embraced by the City of Athens.

Finally, the good practice of storm naming in Greece has been recently embraced as an initiative in the Central and Eastern Mediterranean. Indeed the National Meteorological Services of Greece, Cyprus and Israel have decided to name storms that may produce impacts in at least one of the three countries. The tri-lateral collaboration consists in the weekly communication between the respective forecast centers, in order to inform each other about weather issues in the region while at the same time, depending on the intensity of the expected phenomena, the naming (or not) will be decided based on a predefined common list. This decision has been finalized and has been in operation since October 2021. This regional collaboration for storm naming further supports the idea that storm naming is an important factor in risk mitigation against severe weather events.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/atmos12111537/s1, Supplement S1: Short description of named events, Supplement S2: Statistical significance of examined variables in the survey.

Author Contributions: Conceptualization, V.K.; methodology, K.L., I.K., E.V., A.K., K.P.; software and visualization, A.B., S.D., T.G., C.G., A.K., G.P.; investigation, V.K., K.L., A.B., E.G., C.G., T.G., A.K., I.K., T.K., K.P., G.P., V.V., E.V.; writing—original draft preparation-review and editing, V.K., K.L., A.B., E.G., C.G., T.G., A.K., I.K., T.K., K.P., G.P., V.V., E.V.; supervision and funding acquisition, V.K. and K.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The questionnaire and all datasets generated during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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