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The Tropical-like Cyclone "Ianos" in September 2020

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Abstract: In this paper, we analyze a Mediterranean TLC (tropical-like cyclone) which occurred between 15 and 20 September 2020 called "Ianos". First, the paper briefly presents the "medicane" phenomenon; then, it analyzes the synoptic situation that produced Ianos initiation and development, as well as its intensity (minimum pressure, wind speed) and trajectory. A comparison with similar past events is also provided. Furthermore, we analyze its lightning activity, rainfall data from some meteorological stations of the areas most affected by Ianos, such as Calabria and the Ionian islands of Greece, and the hydrogeological and hydraulic instability effects caused by the passage of the TLC on these territories.

Keywords: tropical-like cyclone; medicane; Ianos; lighting activity

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1. Introduction

Medicanes (portmanteau for Mediterranean Hurricanes), also known as tropical-like cyclones (TLCs), are mesoscale eddies with hybrid characteristics between extratropical and tropical cyclones [1,2] occurring in the Mediterranean basin [3–6]. The first observations of these phenomena date back to the early 1980s, thanks to the availability of satellite images.

The atmospheric patterns in the Mediterranean initially present prevailing typical baroclinic characteristics; therefore, medicanes mainly stem from extratropical cyclones associated with a large trough of the polar flow. The latter, extending and elongating toward southern latitudes, develops in upper-level lows isolated from the main flow itself (cutoff). Thus, the cold air at medium and high altitudes reaching the Mediterranean basin, interacting with its warm marine surface, causes convective instability, which, in turn, provides the latent heat fluxes necessary for the formation of the warm core typical of tropical cyclones [7]. Numerical simulations of real events have also highlighted the importance of this process [8–11].

Sea surface temperature (SST) is, therefore, one of the key variables in the development of medicanes, even below the threshold of +26.5 °C considered for most tropical cyclones [12]. Several studies [1,9,10] have shown how small SST variations can have a strong impact on the triggering of a Mediterranean tropical-like cyclone, as well as on its intensity. Other studies [7] have identified how the SST must be greater than 15 °C for medicanes to develop.

The "tropical transition" process transforms extratropical cyclones (with baroclinic characteristics) into tropical cyclones or into structures that have hybrid properties (subtropical cyclones), by means of different processes, e.g., warm seclusion. In the latter case, the original extratropical cyclone must present a Shapiro–Keyser structure [13,14], i.e., a warm/occluded front "bent" backward [15]. In their mature stage, medicanes have the following peculiarities [16]:

- a warm core, especially in the lower–middle troposphere;

- a central part free from clouds (“eye”), around which convective cloud bands rotate spiraling almost symmetrically;
- weak vertical wind shear;
- very intense precipitation and surface winds, even higher than 100 km·h^{-1} but only exceptionally capable of reaching hurricane intensity (i.e., higher than 63 kt or 117 km·h^{-1}) [10,17];
- most are characterized by a radius between 70 and 200 km and have an average life between 12 h and 5 days, covering trajectories of 700–3000 km and developing an “eye” for less than 72 h [18].

The frequency of medicanes is low because they originate in a baroclinic environment, but still require weak vertical shear [16]. In particular, this frequency varies according to the type of medicanes considered. When very strict criteria are adopted in order to count only those medicanes with full tropical features, such as cloud structure, degree of symmetry, dimensions, and lifespan on satellite images, studies have shown that about 0.5 events occur per year [11]. With less strict criteria, by including hybrid structures, a frequency of 1.5 medicanes per year emerges [19]. Another study [20] estimated about 1.6 medicanes (with fully tropical characteristics) per year in the Mediterranean basin.

According to some recent studies [19,21], climate change projections would lead to a slight decrease in the frequency of medicanes in the Mediterranean (as well as of tropical cyclones) in the future, but the strongest ones would become even more intense. Consequently, studying these events would assume even greater significance because of their potential to cause widespread hydrogeological and hydraulic instability, with loss of human life and significant infrastructural and economic damage to the affected areas, especially islands and coastal zones.

This article analyzes the weather conditions at a synoptic scale that generated the TLC Ianos, its tropical characteristics, and the evolution of convective activity in relation to lightning produced (Sections 2, 2.1 and 2.3) Its intensity is also analyzed by means of the estimates of wind speed and minimum pressure (Section 2.2). Lastly, Section 3 analyzes the effects on the ground produced by its passage on Italy and Greece.

2. Tropical like Cyclone “Ianos”

The tropical cyclone named “Ianos” by the Greek National Meteorological Service [22,23] or “Udine” following the naming system of the University of Berlin (hereafter referred to as “Ianos”) affected the central Mediterranean basin from 15 to 20 September 2020. Ianos caused extreme events, such as heavy rains, strong winds, and storm surges, particularly in the Italian administrative region of Calabria (but only in the lower Crotone area and in the Locride area), in eastern Sicily, and in Greece (Figure 1).

The cause of its formation was a trough in the perturbed Atlantic flow, which on 6 September extended to France starting a very slow eastward movement, before isolating itself from the Atlantic flow from 11 September (Figure 2a). In particular, on 14 September, the situation at the isobaric surface of 500 hPa appeared as shown in Figure 2b, with the minimum located approximately in front of the coast of Tripoli, close to the Gulf of Sirte.

On that date, the cold-air area moved to a very warm sea surface that at 12:00 a.m. UTC on 14 September had a temperature of about 28 °C (301 K in the figure), i.e., 1.5 °C warmer than average (Figure 3).

The pronounced vertical thermal gradient located for days in front of the coasts of North Africa favored the development of intense convective activity starting on 12/13 September (Figure 4a); this convection, although evidently present, was still quite disorganized, despite being fairly intense as shown in the 14 September image (Figure 4b).

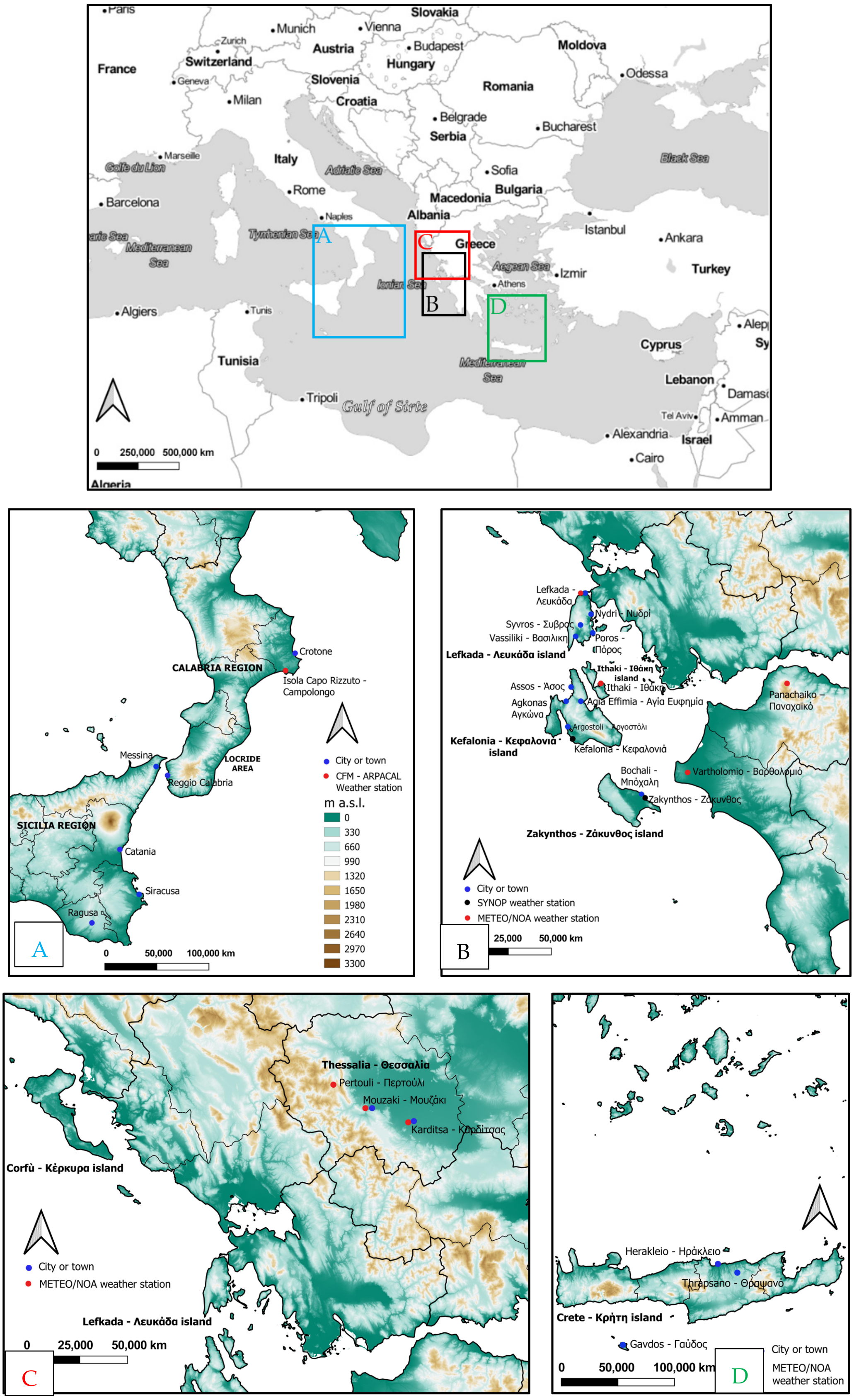
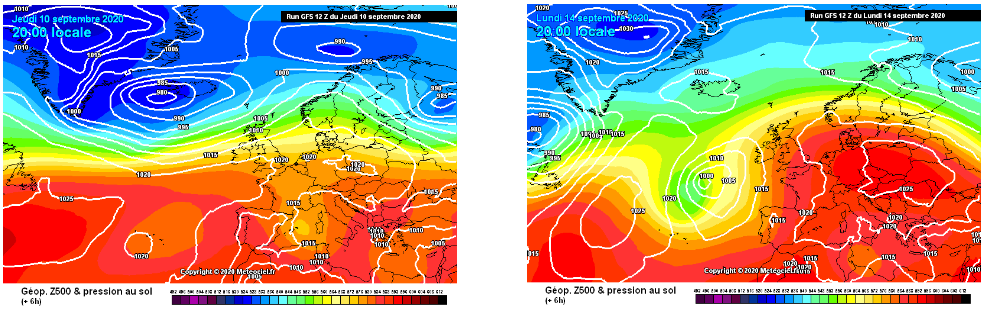
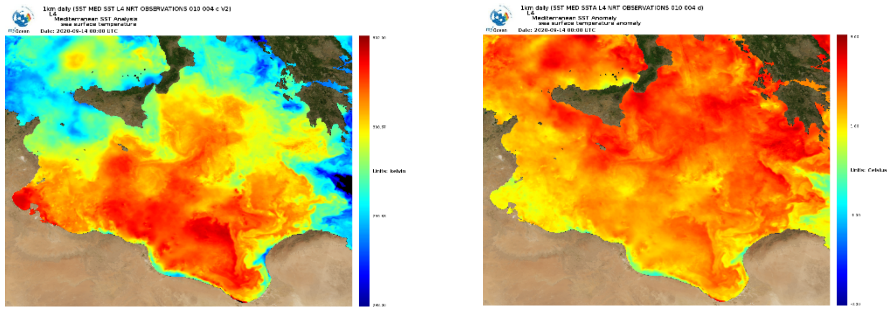


Figure 1. Map of the locations and weather stations mentioned in the article.



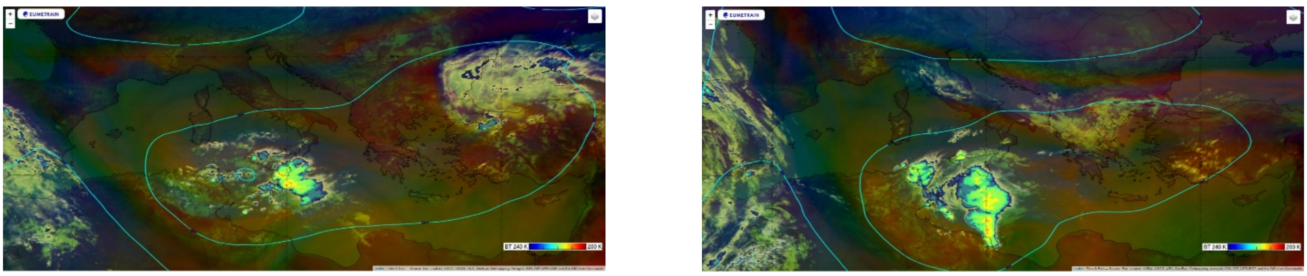
(**a**) (**b**)

Figure 2. Geopotential height at the isobaric surface of 500 hPa (shaded areas) and surface pressure (white lines) of the GFS model (the Global Forecast System (GFS) is a numerical weather prediction (NWP) model produced by the US National Weather Service (NWS); the forecast component uses the FV3 model with a resolution of ~13 km. The model is divided into 127 vertical layers): (**a**) on 10 September at 6:00 p.m. UTC; (**b**) on 14 September at 6:00 p.m. UTC (www.meteociel.fr accessed on 23 September 2020).



(**a**) (**b**)

Figure 3. (**a**) Sea surface temperature values and (**b**) relative temperature anomalies on 14 September at 12:00 a.m. UTC, as detected, at night, by different satellite platforms on the infrared channel (https://resources.marine.copernicus.eu/ accessed on 8 February 2022). The climatologic field is given by a daily pentad climatology built from 21 years (1985–2005) of AVHRR Pathfinder data [24].

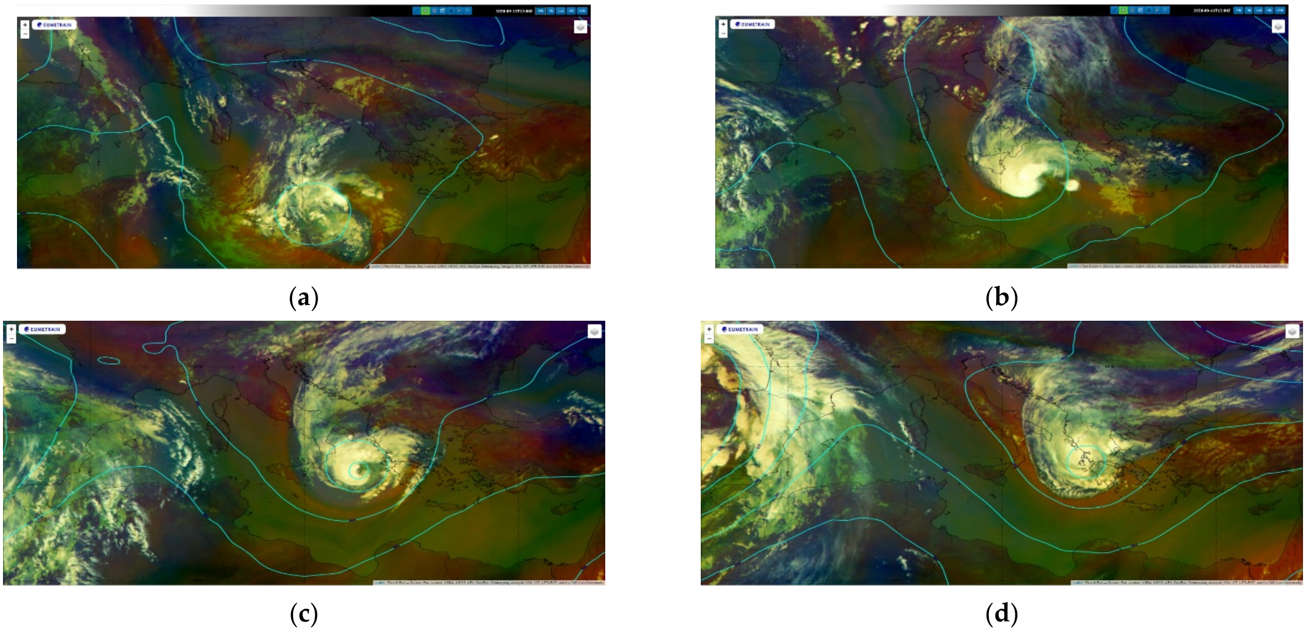


(**a**) (**b**)

Figure 4. RGB Airmass composite, with the superimposed infrared channel 10.8, enhanced with the use of colors (making it possible to identify the most intense storm nuclei in red) and the geopotential isolines at the isobaric surface of 500 hPa (blue) (**a**) on 13 September at 12:00 p.m. UTC and (**b**) on 14 September at 12:00 p.m. UTC (http://eumetrain.org/ePort_MapViewer/ accessed on 8 February 2022).

On 13 September, a 1011 hPa surface low developed along the ascending branch of the trough. In the following days, this low initiated the loop process, characterized by "positive feedback", typical of the formation of tropical cyclones (a mechanism called "WISHE" [25,26]), whereby the pression minimum intensifies the surface convergence which enhances evaporation from the sea surface, upward movements, and therefore, the release of latent heat, which, in turn, warming the core of the system, intensifies the aforementioned upward movements and, therefore, the convergence in lower layers. This process deepens the minimum, which, in fact, in the following days, reached estimated values of about 993 hPa or lower (see Section 2.2) on 17 September at 3:00 a.m. UTC.

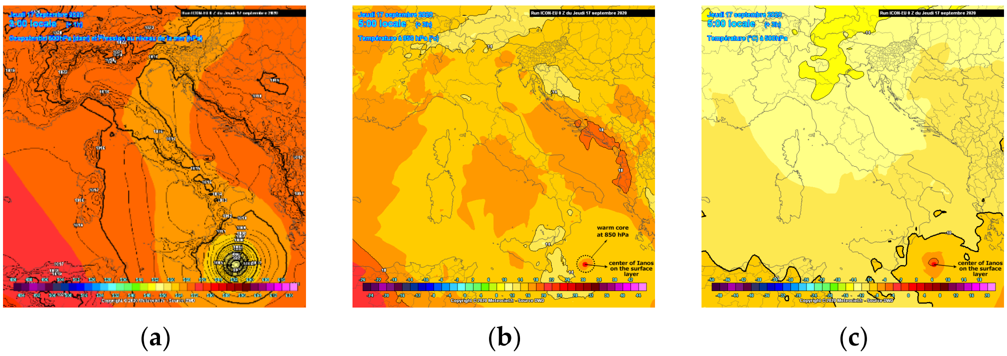
At the same time, starting on 15 September, the first sketches of spiraling cloudiness began to be identified. These became well defined in the following days (Figure 5a–d).



(**a**) (**b**) (**c**) (**d**)

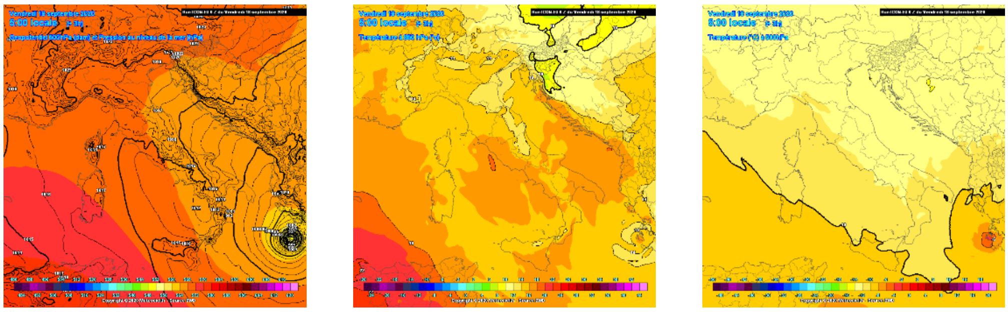
Figure 5. (**a**–**d**) RGB Airmass composite with the geopotential isolines superimposed on the isobaric surface of 500 hPa (blue) (**a**) on 15 September at 12:00 p.m. UTC, (**b**) on 16 September at 12:00 p.m. UTC, (**c**) on 17 September at 12:00 p.m. UTC, and (**d**) on 18 September at 3:00 a.m. UTC (http://eumetrain.org/ePort_MapViewer/ accessed on 8 February 2022).

It is precisely in these situations that the system takes on more typically tropical characteristics. In particular, on the morning of 17 September, the surface and upper minima aligned on a subvertical line, presenting a closed conformation (Figure 6a) and a weak warm core at 850 hPa and 500 hPa (Figure 6b,c). This situation was accentuated at the time of the landfall on 18 September (Figure 7).



(**a**) (**b**) (**c**)

Figure 6. Situation of 17 September at 3:00 a.m. UTC: (**a**) geopotentials at 500 hPa (shaded areas) and mean sea level pressure (black lines), (**b**) temperature at 850 hPa, and (**c**) temperature at 500 hPa, according to ICON-EU model (ICON-EU is a regional NWP (numerical weather prediction) model for Europe, produced by the German Weather Service or DWD (Deutscher Wetterdienst); this model provides forecasts with a grid spacing of 6.5 km and 60 layers at a total of 39.5 million grid points) (http://www.meteociel.fr/ accessed on 8 February 2022).



(**a**) (**b**) (**c**)

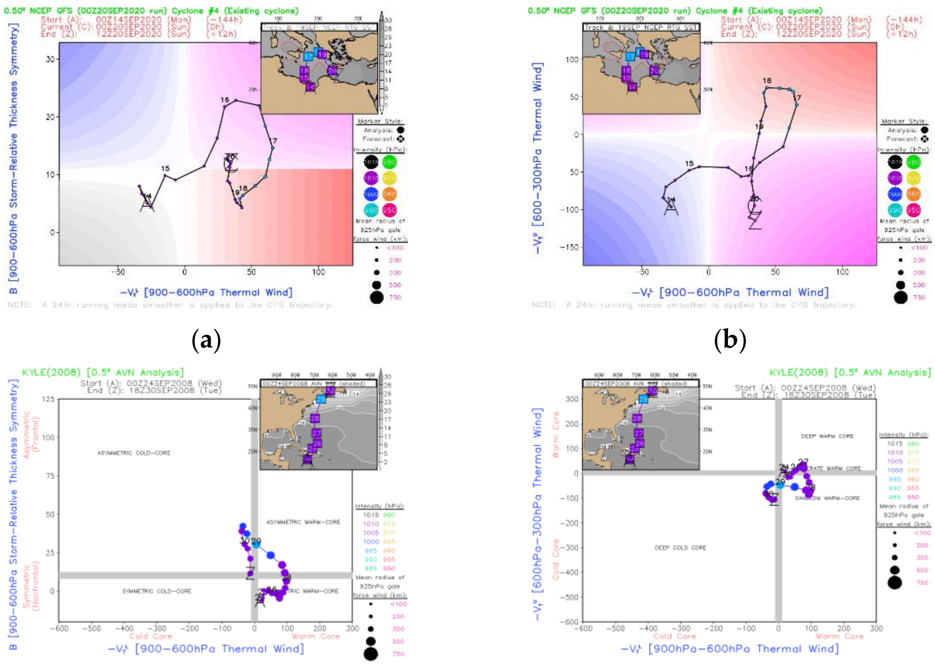
Figure 7. Situation on 18 September at 3:00 a.m. UTC: (**a**) geopotentials at 500 hPa (shaded areas) and mean sea level pressure (black lines), (**b**) temperature at 850 hPa, and (**c**) temperature at 500 hPa according to ICON-EU model (ICON-EU is a regional NWP (numerical weather prediction) model for Europe, produced by the German Weather Service or DWD (Deutscher Wetterdienst); this model provides forecasts with a grid spacing of 6.5 km and 60 layers at a total of 39.5 million grid points) (http://www.meteociel.fr/ accessed on 8 February 2022).

The transition phase is also confirmed by Hart's phase diagrams [27], widely used by the scientific community to identify current and predicted cyclone characteristics (tropical, extra-tropical or hybrid).

In these diagrams, each cyclone is quantified using three fundamental measures of its phase: B is the storm-motion-relative 900–600 hPa thickness gradient across the cyclone (a parameter that measures the strength of the frontal nature of the cyclone); $-V_T^L$ and $-V_T^U$ are the magnitude of the cyclone lower and upper troposphere thermal wind (they measure the fundamental cold, neutral, or warm core structure of the cyclone in the lower/middle and middle/upper troposphere, respectively). The first phase diagram shows B versus $-V_T^L$; the second phase diagram shows $-V_T^U$ versus $-V_T^L$.

For Ianos, the diagrams show how between 17 and 18 September, the hot core became symmetrical (first phase diagram, Figure 8a), while the warm core tended to extend in the upper levels (second phase diagram, Figure 8b). In this case, the values assumed by these parameters are comparable to those of tropical cyclones with category 1 hurricane intensity, as shown, for example, in the Hart's phase diagram of the category 1 hurricane named "Kyle" (Figure 8c,d), which occurred between 25 and 30 September, 2008 affecting Puerto Rico, Hispaniola, Bermuda, New England, and Canada.

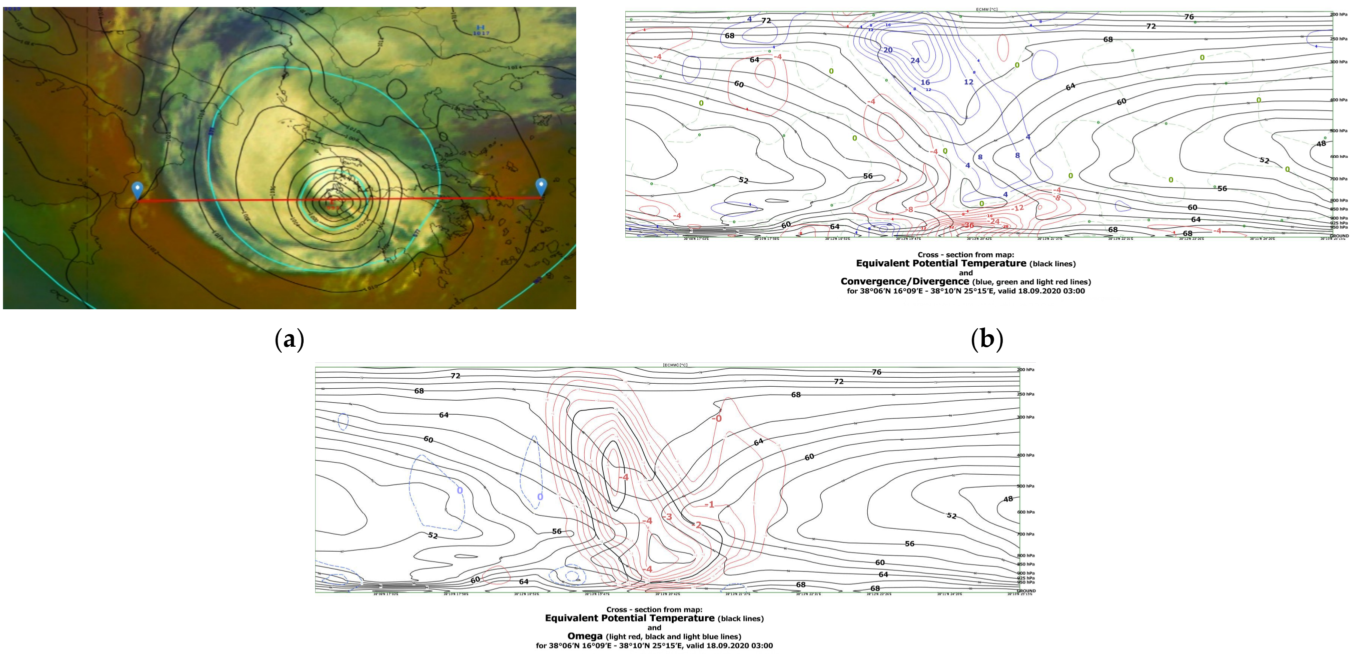
Shortly, starting approximately from the middle hours of the day of 17 September, the tropical system "Ianos" assumed purely tropical characteristics: symmetrical structure and a deep warm core. Figure 9 shows the isentropic divergence (Figure 9b) and omega (upward motions, Figure 9c), along the cross-section indicated in Figure 9a on 18 September at 3:00 a.m. UTC. In addition, it underlines the very high values of surface convergence and upper-level divergence, and the consequent intense upward motions. It can be noted how, at the time of landfall, when "Ianos" assumed full tropical characteristics, there was a nonperfect vertical alignment between the upper divergence core (about 275 hPa) and the surface convergence core. The high values of potential vorticity near the cyclone core (greater than 4 PVU) caused by the diabatic heating processes (Figure 10a), resulting from the release of latent heat in the condensation process inside the cloud, are also worth observing. The release of latent heat is confirmed by the high relative humidity values within the core itself (Figure 10b), thus excluding its stratospheric origin [28].



(**a**) (**b**)

(**c**) (**d**)

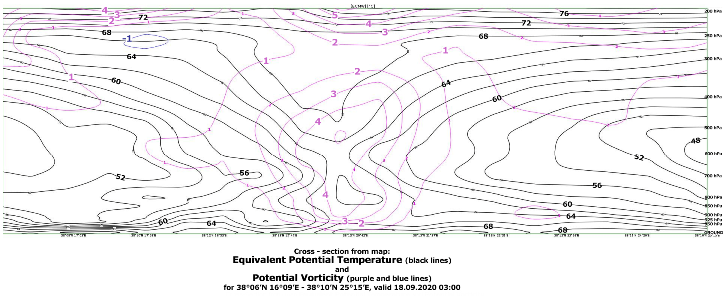
Figure 8. (**a**,**b**) Hart diagrams for the Mediterranean TLC "Ianos" (on 20 September at 12:00 a.m. UTC) and, in comparison, (**c**,**d**) Hart diagrams for the tropical cyclone with hurricane intensity of category 1 "Kyle" of 2008 (http://moe.met.fsu.edu/cyclonephase/index.html accessed on 8 February 2022).



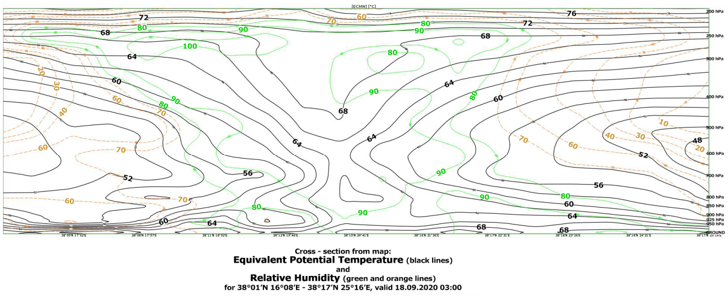
(**a**) (**b**)

(**c**)

Figure 9. Situation on 18 September at 3:00 a.m. UTC: (**a**) RGB composite called "Airmass" with surface pressure superimposed (black lines) and the geopotential isolines at the isobaric surface of 500 hPa (blue); (**b**) equivalent potential temperatures and convergence along the section in (**a**); (**c**) equivalent potential temperature and omega along the section in (**a**) (http://eumetrain.org/ePort_MapViewer/ accessed on 8 February 2022).



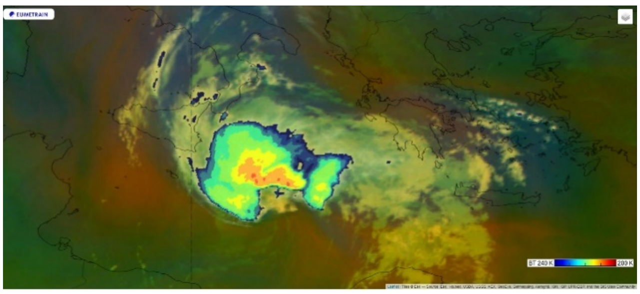
(**a**)



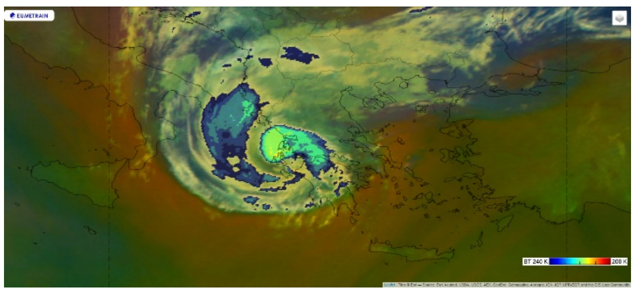
(**b**)

Figure 10. Situation on 18 September at 3:00 a.m. UTC: (**a**) potential equivalent temperatures and potential vorticity along the section in (**a**) of Figure 9; (**b**) potential equivalent temperatures and relative humidity along the section in (**a**) of Figure 9 (http://eumetrain.org/ePort_MapViewer/ accessed on 8 February 2022).

Lastly, it should be noted that the most intense convective activity occurred in the early development stages, in particular between 14 and 16 September, when, at the top of the cumulus clouds, temperatures of only 207 K (approximately −66 °C) on 14 September at 6:00 p.m. UTC, 205 K (approximately −68 °C) on 15 September at 12:00 a.m. UTC, and 206 K (approximately −67 °C) on 16 September at 6:00 a.m. UTC were measured (Figure 11a). In the maturity phases, at the time of the landfall (18 September at 3:00 a.m. UTC), the values measured at the top of the clouds were higher at 216 K (approximately −57 °C, Figure 11b), a sign of a weakening convective activity, already starting from 17 September. Similar results for past tropical-like cyclones over the Mediterranean Sea were shown in [12,29,30].



(**a**)



(**b**)

Figure 11. (**a**,**b**) RGB Airmass composite with the image superimposed on the infrared channel 10.8, "enhanced" with the use of colors (allowing to identify the most intense storm nuclei in red) (**a**) on 16 September at 6:00 a.m. UTC and (**b**) on 18 September at 3:00 a.m. UTC (http://eumetrain.org/ePort_MapViewer/ accessed on 8 February 2022).

The lightning activity was measured using the Italian Air Force Weather Service sensor network "LAMPINET" which detects cloud-to-ground (CG) and intra-cloud (IC) lightning flashes.

According to the data of the "LAMPINET" network, the number of lightning flashes within two regions was calculated: the first valid for 24 h on 15 September with vertices of coordinates 32.1° N, 13.6° E and 37.9° N, 21.95° E; the second valid on 16 and 17 September and with vertices of coordinates 33.6° N, 13.1° E and 41.1° N, 23.4° E in order to follow the trajectory of the cyclone. Each of these two areas was identified in such a way as to largely contain the TC center and its more extreme convective cloud bands, along their trajectories.

Figure 12 shows the 1 h flash rate in the time interval between 15 September at 12:00 a.m. UTC and 19 September at 12:00 a.m. UTC, in the regions indicated above, in comparison with the minimum sea-level pressure of Ianos as estimated by different numerical forecasting models, and as observed at the Airport of Kefalonia—Κεφαλονιά (see Section 2.2).

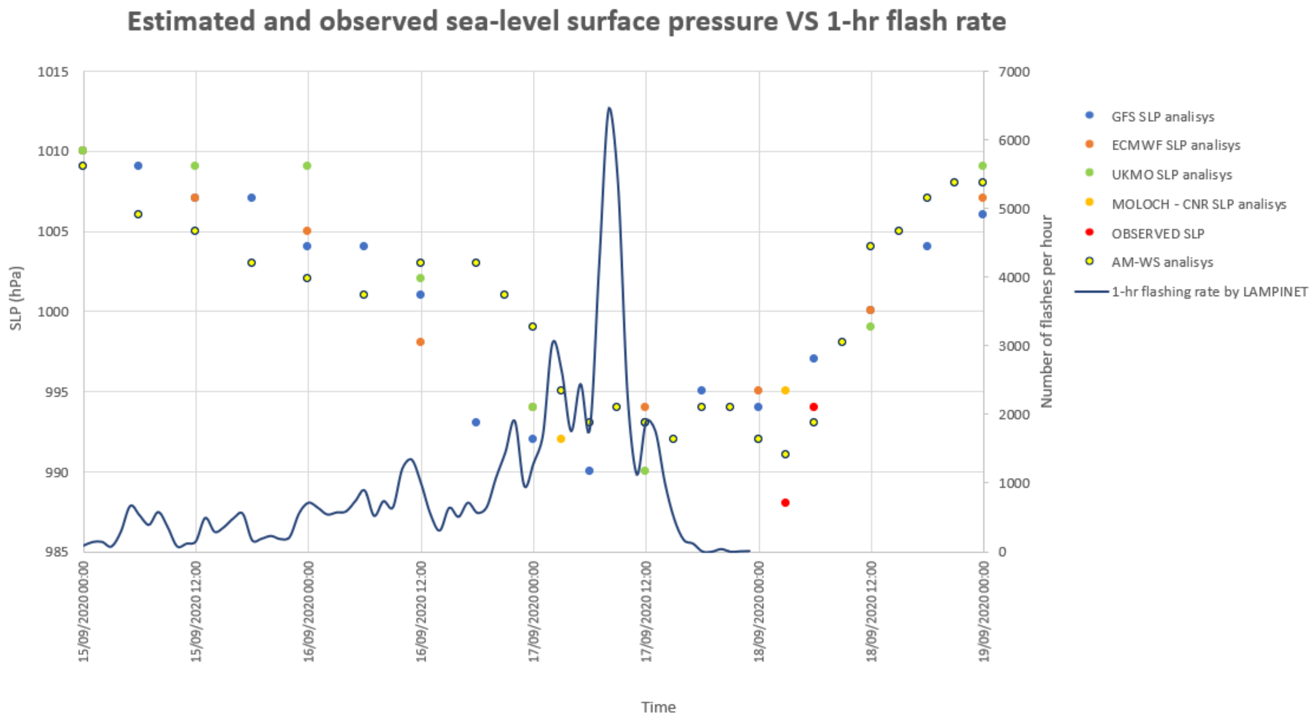


Figure 12. The 1 h flash rate measured by the "LAMPINET" network (solid blue line), compared to the minimum sea-level pressure between 15 September at 12:00 a.m. UTC and 19 September at 12:00 a.m. UTC, as estimated by different numerical forecasting models and by the SLP charts from the Italian Air Force Weather Service (AM-WS). Additionally, the pressure value detected by the synoptic station of Airport of Kefalonia—Κεφαλονιά is added.

It emerges that the peak of the 1 h flash rate occurred at 8:00 a.m. on 17 September and preceded the minimum pressure of 991 hPa as estimated by the SLP charts from the Italian Air Force Weather Service (not shown) by about 19 h. Note also that the minimum pressure of 988 hPa was simultaneously measured at the Airport of Kefalonia—Κεφαλονιά.

These results fully agree with Price [31] who, by analyzing 56 tropical cyclone events worldwide, showed how the lightning activity (linked to the intensity of the convective motions) and the maximum sustained winds are significantly correlated, with an average value, calculated on all hurricanes examined, with a linear correlation coefficient of 0.82. Moreover, the maximum winds and, therefore, the minimum pressure values show a time lag of about 24 h with respect to the increase in the lightning activity [12].

2.1. Dynamic Analysis

Many elements lead to rapid deepening in a TLC. Among these, we identify the occurrence of a jet streak crossing the low. With the main polar jet branch kept away from the central Mediterranean, the jet streak was associated with a secondary jet branch (Figure 13). This increased the system vorticity and caused a lowering of the dynamic tropopause with a consequent dry intrusion. Dry-air intrusion and the associated PV streamers influence the early stages of TLC formation and subsequent development; however, while the PV anomalies cause an intensification of the cyclones, the dry-air intrusions could cause a weakening [32]. In their deepening phase, during the passage over the warm waters of the Mediterranean, the cyclones absorb a large quantity of latent heat released by the intensification of convective motions inside the low. In the initial phase of Ianos, a moderate wind shear, induced by the passage on its southernmost edge of a branch of the subtropical jet, prevented the development. The shear cut the convection out of the eye, pushing it north-northeastward. Moving further north, Ianos entered an area on the central Ionian Sea characterized by weaker wind shear, which did not affect its development.

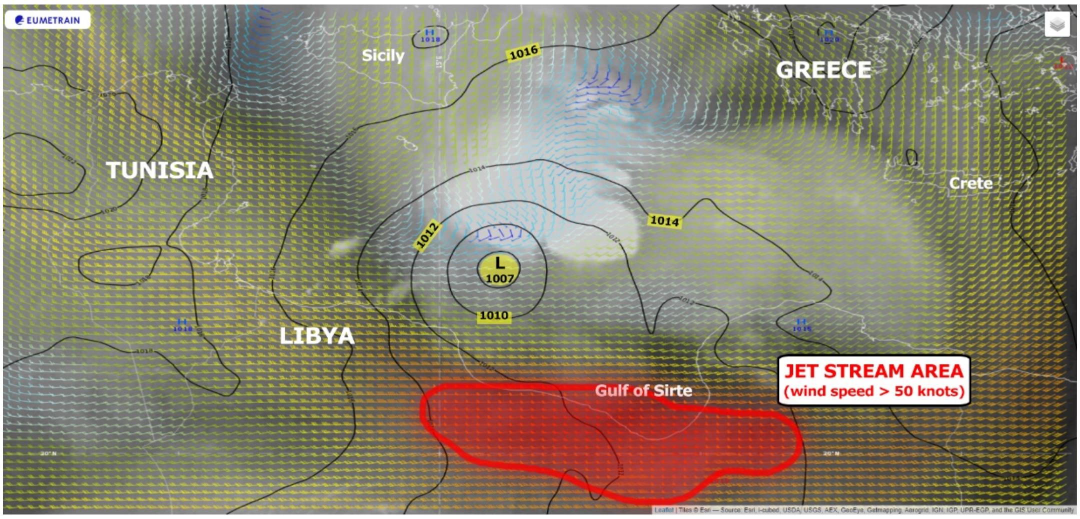
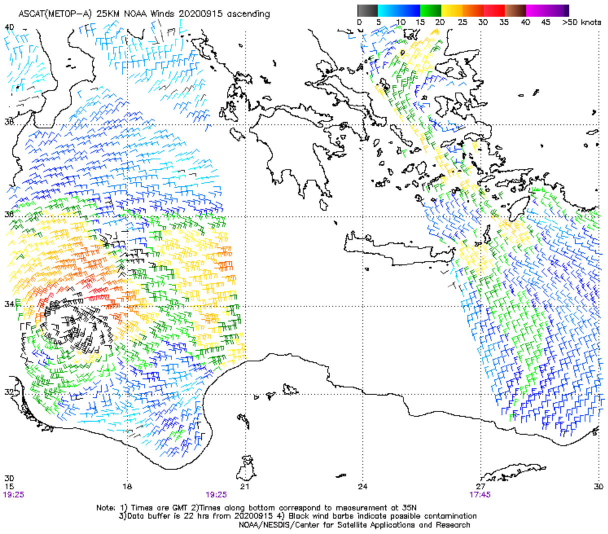


Figure 13. Image from water vapor 6.2 channel with surface pressure superimposed (black lines) and the wind barbs at 300 hPa on 15 September at 9:00 p.m. UTC (http://eumetrain.org/ePort_MapViewer/ accessed on 8 February 2022).

2.2. Cyclone Intensity

Due to lack of surface observations, ASCAT wind data at different stages of the TLC development (Figure 14) were used. On 15 September 2020 (Figure 14a), the cyclone began to intensify, moving toward the Ionian Sea, with average sustained winds up to 65 km·h^{-1} (35 knots) and an SLP that began to drop below 1010 hPa. On 16 September, the cyclone deepened on the southern Ionian Sea, with consequent intensification of winds surrounding the eye; Figure 14b shows wind speeds above 74 km·h^{-1} (40 knots). According to ASCAT data, at this stage, the cyclone can be classified as a tropical storm. On 17 September, the cyclone approached the Italian coast, with extended rain bands reaching the coast of Calabria during the morning and very consistent rainfall occurring (see Section 3.1), with an estimated minimum pressure of 992 hPa and winds of about 90 km·h^{-1} according to the initialization of the CNR (National Research Council) numerical model "MOLOCH" for 17 September at 3:00 a.m. UTC (see Figure 15a,b). ASCAT data suggest that "Ianos", before approaching the Ionian islands (Figure 14c), still maintained high intensity. This seems to be also confirmed by the data provided by the initialization of the numerical model "MOLOCH" for 18 September at 3:00 a.m. UTC, which estimated a minimum pressure at landfall of about 995 hPa and winds of 90 km·h^{-1} (Figure 15c,d).



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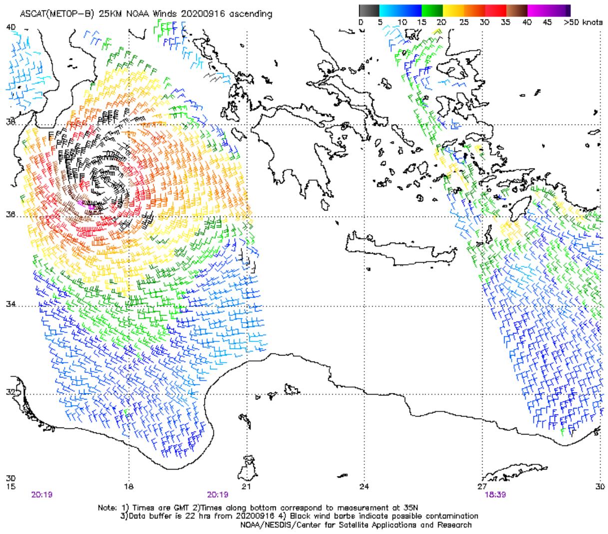

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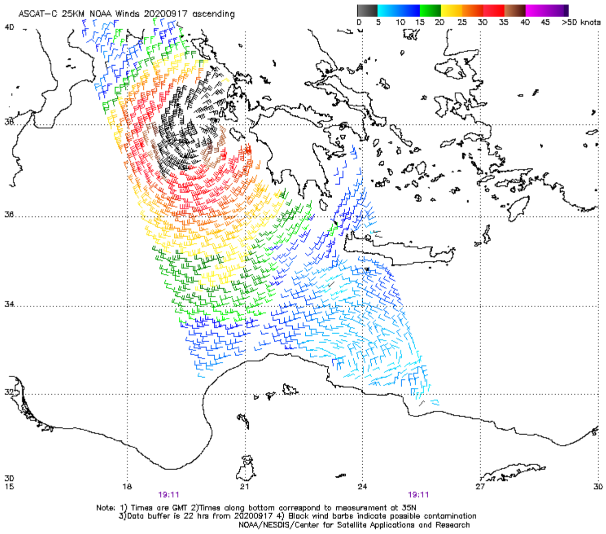

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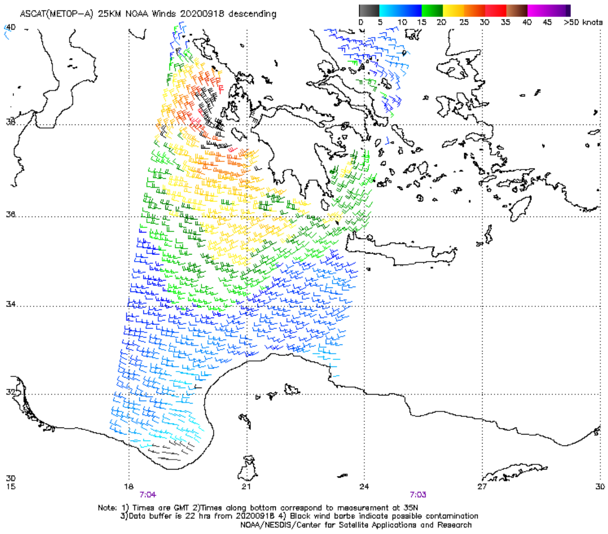
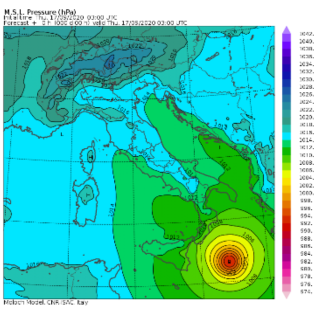


(**d**)

Figure 14. Wind speed for (**a**) ASCAT on 15 September at 7:25 p.m. UTC (Metop-A), (**b**) ASCAT on 16 September at 8:19 p.m. UTC (Metop-B), (**c**) ASCAT-C on 17 September at 7:11 p.m. UTC, and (**d**) ASCAT on 18 September at 7:04 a.m. UTC (Metop-A) (https://manati.star.nesdis.noaa.gov/datasets/ASCATCData.php accessed on 8 February 2022).



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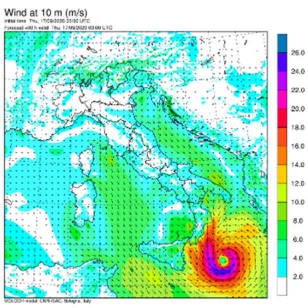

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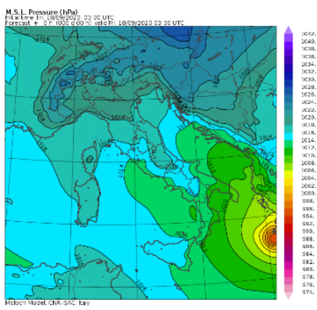

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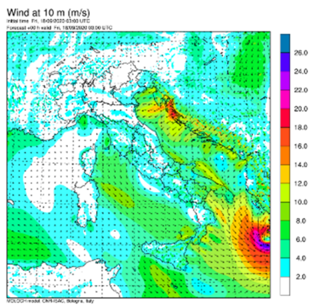


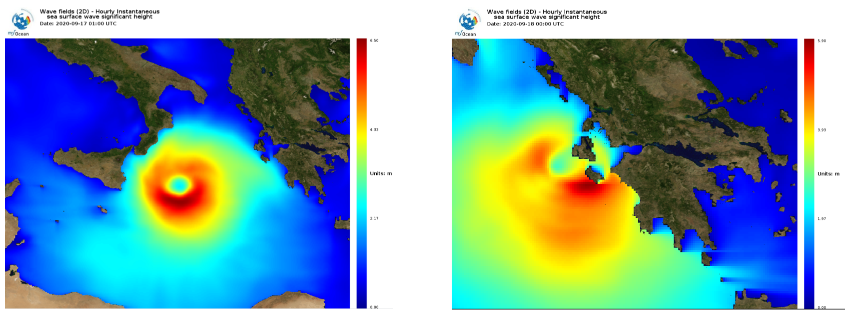
(**d**)

Figure 15. SLP and winds at 10 m a.s.l. for (**a**,**b**) 3:00 a.m. UTC on 17 September and for (**c**,**d**) 3:00 a.m. UTC on 18 September (https://www.isac.cnr.it/dinamica/projects/forecasts/moloch/ accessed on 8 February 2022).

Upon its landfall in Greece, Ianos caused intense winds observed by synoptic weather stations and by the network of automatic meteorological stations operated by the METEO Unit at NOA [33]. The SYNOP messages of the Airport of Kefalonia—Κεφαλονιά, reported at 6:00 a.m. UTC a pressure of 994.5 hPa, with a barometric trend of the previous 3 h equal to +6.5 hPa; a minimum pressure of 988 hPa can, thus, be considered as confirmed. In addition, a maximum daily gust of 111.2 km·h^{-1} was measured at the same station, identical to that recorded in the station of Zakynthos—Ζάκυνθος. However, these data may be underestimated, since the observing activity was interrupted for a few hours (for the first station, the observations on 17 September at 9:00 p.m. UTC and 18 September at 12:00 a.m. UTC and 3:00 a.m. UTC are missing; for the second station, the observation on 18 September at 3:00 a.m. UTC is missing).

As per the METEO unit observations of Ithaki—Ιθάκη, Lefkada—Λευκάδα, Vartholomio—Βαρθολομιό, and Panachaiko—Παναχαϊκό (1588 m a.s.l), they reported maximum gusts of 90.1 km·h^{-1} at 5:20 a.m. LT, 83.7 km·h^{-1} at 7:40 a.m. LT, 78.9 km·h^{-1} at 7:50 a.m. LT, and 104.6 km·h^{-1}, respectively.

Strong winds associated with Cyclone Ianos caused surface currents to increase sevenfold the average conditions, along with a sea level rise of 0.25 m, with peaks of 0.30 m near the Ionian Islands, thus generating a storm surge. The maximum significant wave height reached 6.5 m on 17 September at 1:00 a.m. UTC (Figure 16a), while Ionian Islands were affected by significant wave height up to 5.9 m, like those that hit Zante, according to the Mediterranean Sea Waves Forecasting system. This system is composed of hourly wave parameters at 1/24° horizontal resolution covering the Mediterranean Sea and extending up to 18.125 W into the Atlantic Ocean, and it includes two forecast cycles, providing twice per day (at 6:00 a.m. and 8:00 p.m. UTC) a Mediterranean wave analysis and 10 days of wave forecasts [34].



(**a**) (**b**)

Figure 16. Significant wave heights as estimated by the Mediterranean Sea Waves Forecasting system (**a**) on 17 September at 1:00 a.m. UTC and (**b**) on 17 September at 11:00 p.m. UTC (https://doi.org/10.25423/CMCC/MEDSEA_ANALYSIS_FORECAST_WAV_006_017 accessed on 8 February 2022).

2.3. Last Days of Ianos

After its landfall on the western Greek coast, heading south-southeast, Ianos returned to sea and started to reorganize, beginning to weaken very gradually soon after. Although the cyclone weakened considerably, losing most of its tropical characteristics, its structure survived the landfall, as the synoptic flow then forced it to move southward. Returning over still quite warm surface waters, the reorganization of its convective activity succeeded only in part. In the early morning hours of 19 September, Cyclone Ianos intensified again with still strong a convective activity, albeit no longer symmetrical, while transiting just south of Crete. During this stage, the depression ended up in an area with intense wind shear off the Cyrenaica and Egyptian coasts that cut the convection out of the system core, leading to slow but inexorable weakening. Cyclone Ianos then dissipated on the stretch of sea off the Cyrenaica coast, after following a relatively linear trajectory. Among historical TLC events, Ianos was quite a long-lived one, considering that Mediterranean TLCs exhibit an average lifetime between 12 h and 5 days, as indicated in Cavicchia and Von Storch [18].

3. Rainfall and Effects on the Territory

3.1. Calabria and Sicily

The passage of Ianos off the coast of southern Italy caused damage and disruption, due to heavy rainfall which mainly affected the Ionian coast of Calabria, especially the Crotone area. In the small town of Isola Capo Rizzuto, flash flooding struck the streets, turning them into rivers, with considerable consequences for road traffic. At the port of Le Castella, the strong wind and waves caused problems for boats, some of which broke their moorings and sank in the port.

In particular, the station of "Campolongo" (operated by C.F.M.–ARPACAL) recorded 73.8 mm of rainfall from 6:10 to 7:10 a.m. and recorded 50 mm of rainfall from 7:20 to 8:20 a.m., as shown in the pluviogram in Figure 17.

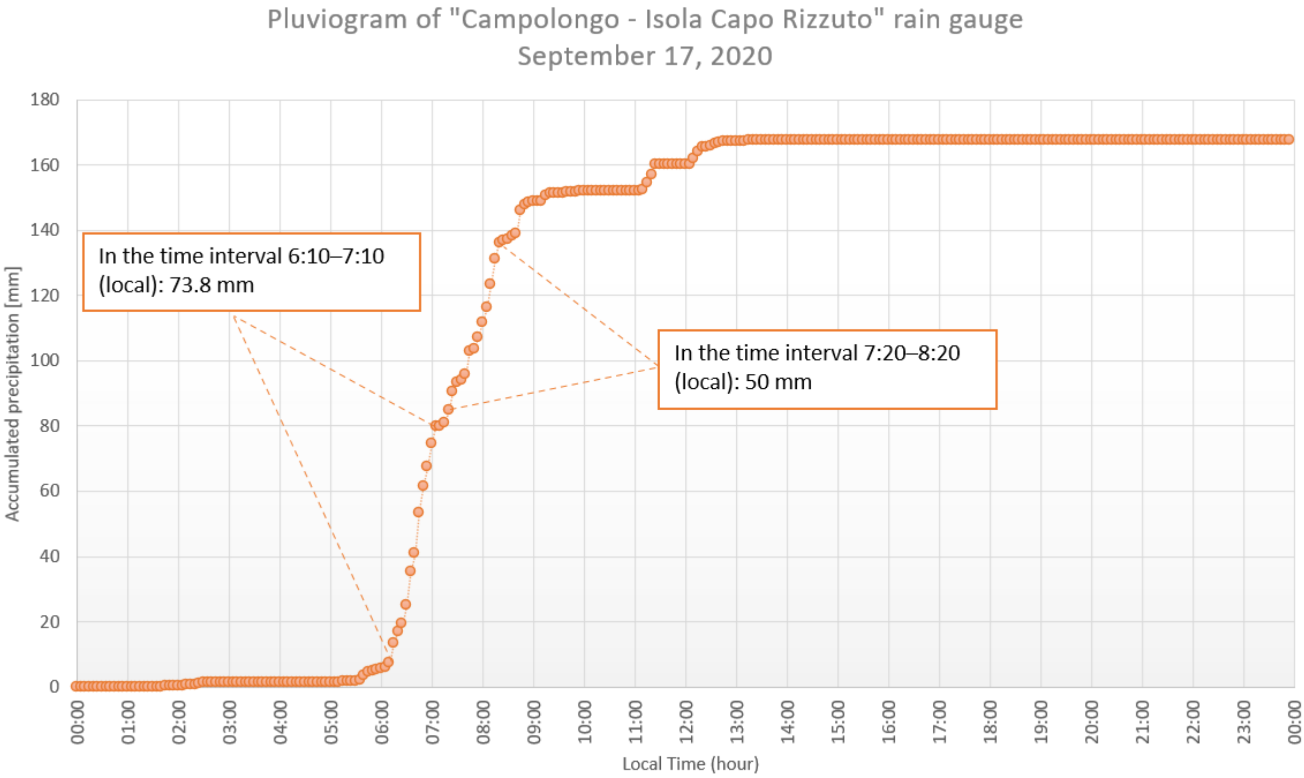


Figure 17. Pluviogram of the station "Campolongo, Isola Capo Rizzuto" on 17 September 2020 (our graph on data from www.cfd.calabria.it accessed on 8 February 2022).

In Sicily, the cyclone's close passage as it moved northward caused significant damage, especially due to the storms that hit the eastern coast. During the nights of 16 and 17 September, the massive waves raised by the strong easterly winds, active along the northern quadrant of the deep cyclone, headed toward the coasts of eastern Sicily, in the form of long or very long waves (swell), up to more than 3 m high. They caused sudden sea storms between the Ionian coasts of Messina, Catania, and Siracusa and part of the Ragusa coast.

3.2. Greece

Ianos struck Greece on 17–19 September 2020 with substantial rainfall recorded by the network of automatic weather stations operated by the METEO unit at NOA [33].

In Ithaki—Ιθάκη, an island in the Ionian Sea in western Greece, the total accumulated rainfall (storm total) according to METEO was 228 mm. Nearby stations on mainland western Greece recorded more than 120 mm in less than 24 h. Over central Greece, the METEO station of Pertouli—Περτούλι, in the region of Thessaly—Θεσσαλία, recorded 317 mm in the period 17 and 19 September, while storm maxima of 274 mm and 213 mm were recorded in the same time interval at the stations of Mouzaki—Μουζάκι and Karditsa—Καρδίτσα, respectively [35]. In the latter two cases, up to 158 mm fell in a single day (18 September) at Mouzaki—Μουζάκι, and up to 188 mm also fell in a single day (18 September) at Karditsa—Καρδίτσα [23,36].

In Kefalonia—Κεφαλονιά, damage was reported to coastal infrastructures such as the ports of Assos—Άσος and Agia Effimia—Αγία Ευφημία, road networks (the destruction of a bridge in Agkonas—Αγκώνα was reported), widespread coastal erosion, landslides, flooding (Peratata area—Περατάτα on the Argostoli peninsula—Αργοστόλι), boat drifts, damage to buildings, dozens of fallen trees, and widespread power cuts. As it approached the Greek coasts, the islands of Ithaki—Ιθάκη, Zakynthos—Ζάκυνθος, and Kefalonia—Κεφαλονιά were hit by tidal waves which flooded the coastal roads and many seaside villages. Significant damage occurred on the island of Ithaki—Ιθάκη, where large waves displaced large masses of decaying organic matter that, on the coastline, produced huge amounts of foam, blown by strong gusts of wind up to the built-up area, and where significant coastal erosion, sunken boats, damage to buildings, and uprooting of trees occurred [23,36].

On the island of Zakynthos—Ζάκυνθος, felled trees caused damage to the cemetery of Bochali—Μπόχαλη. The island of Crete—Κρήτη was also affected by river overflows (in the area of Thrapsano—Θραψανό), collapsed parts of buildings, flooding of roads, power blackouts (for 13 h) in the territory of Herakleio—Ηράκλειο, interruptions of ferry connections to Gavdos—Γαύδος, and other hydrogeological instability phenomena [23,36].

Heavy damage was observed on the island of Lefkada—Λευκάδα, particularly in Vassiliki—Βασιλικη, Syvros—Συβρος, and Poros—Πόρος, while part of the town of Lefkada—Λευκάδας was flooded. A boat sank in the port of Nydri—Νυδρί, with damage to boats in the ports of Vassiliki—Βασιλικη and Lefkada—Λευκάδα. The road network of most of the island was damaged due to torrential rains that caused landslides [23,36].

Inland areas were also affected by extensive damage. In the region of Thessaly—Θεσσαλία, there was the overflow of the river Pamisos—Πάμισου in Mouzaki—Μουζάκι, where the partial destruction of the building housing the Health Center occurred due to extensive erosion of the foundations. The cyclone also caused extensive flooding in Karditsa—Καρδίτσας, flooding of the road network, damage to houses and road infrastructure, landslides, and power outages [23,36]. In Greece, "Ianos" caused the death of four people and one person was reported missing.

4. Summary

The cyclone "Ianos", which affected the central Mediterranean, hitting the Ionian Islands and the coasts of western Greece with particular violence from 15–18 September 2020, took on typically tropical characteristics presenting a perfectly symmetrical structure and a deep warm core. The values assumed by the surface pressure and sustained winds in its maturity phase are comparable to those of tropical cyclones with category 1 hurricane intensity observed in the Atlantic Ocean and the Caribbean area. High values of potential vorticity were also estimated near the cyclone core, caused by the diabatic heating processes resulting from the release of latent heat in the condensation process inside the cloud. This hypothesis is confirmed by the high relative humidity values within the core itself.

This article demonstrated how the most intense convective activity occurred in the early stages of its development, between 15 and 17 September 2020, when temperatures up to −67 °C were measured at the top of cumulus clouds (on 16 September at 6:00 a.m. UTC) corresponding to a height of the top of the clouds of about 13 km a.s.l. This result is also confirmed by the analysis of the hourly lightning frequency as measured by the "LAMPINET" networks, which detected a peak at 8:00 a.m. on 17 September 2020, approximately 19 h before the minimum measured pressure of 988 hPa at Kefalonia—Κεφαλονιά airport.

This result fully agrees with other studies showing how, for tropical cyclones, the frequency of lightning and the maximum sustained winds are correlated.

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