environmental sciences proceedings

MDPI

Proceeding Paper

Extreme Weather Affecting Sea Chlorophyll: The Case of a Medicane †

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† Presented at the 16th International Conference on Meteorology, Climatology and Atmospheric Physics—COMECAP 2023, Athens, Greece, 25–29 September 2023.

Abstract: Sea surface chlorophyll concentrations are indicative of phytoplankton growth and can be impacted by extreme weather events. Hurricanes and typhoons have been widely studied for such an influence on the marine environment; chlorophyll increases and even phytoplankton blooms have been reported. In this study, a tropical-like Mediterranean cyclone, the medicane Ianos of September 2020, that affected a large oligotrophic area of the Ionian Sea, is examined from this perspective. A numerical model and satellite data were used for delineating the study area and assessing chlorophyll variations, respectively. On a smaller geographical scale in respect to tropical cyclones, the medicane-triggered chlorophyll increases comparable to those of hurricanes when affecting oligotrophic open sea waters.

Keywords: medicane Ianos; sea surface temperature; satellite data; Ionian Sea; oligotrophic waters; tropical-like cyclones; phytoplankton

1. Introduction

Extreme weather events can have an impact on sea surface chlorophyll concentrations that are indicative of phytoplankton growth. A lot of studies have assessed hurricanes and typhoons from this perspective, and chlorophyll increases and even phytoplankton blooms have been reported [1].

In rare cases, Mediterranean cyclones exhibit tropical cyclone characteristics, such as an "eye", axisymmetry with spiral cloud bands, very strong surface winds, and a warm core; due to their similarity to hurricanes, they are known as Mediterranean hurricanes or medicanes [2]. While they are much weaker than hurricanes, some have reached Category 1 on the Saffir–Simpson scale. Climatological studies have estimated that medicanes occur approximately 1.5 times per year throughout the basin, mainly in autumn and winter, and the Ionian Sea is one of the most common regions for their formation [3].

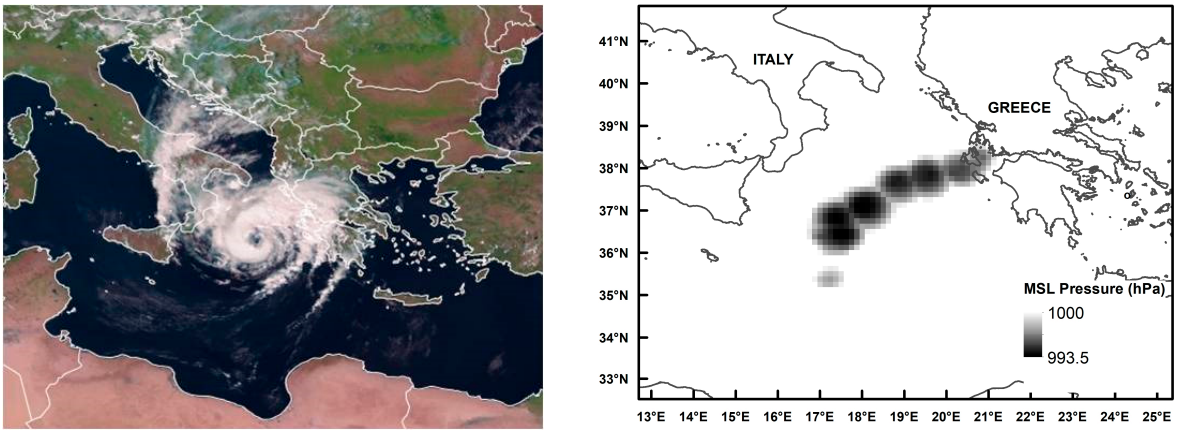
The first attempt to assess the possible impact of a couple of medicanes on chlorophyll concentrations in the central and eastern parts of the Mediterranean indicated that they can trigger remarkable increases in sea surface chlorophyll [4].

This study aims to further explore the impact of Mediterranean tropical-like cyclones on surface chlorophyll concentrations by examining medicane Ianos of 16–18 September 2020 (Figure 1a), which affected a large oligotrophic area of the Ionian Sea between Sicily and Greece.

Citation: Kotta, D. Extreme Weather Affecting Sea Chlorophyll: The Case of a Medicane. *Environ. Sci. Proc.* **2023**, *26*, 192. https://doi.org/10.3390/environsciproc2023026192

Academic Editors: Konstantinos Moustris and Panagiotis Nastos

Published: 15 September 2023



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

Figure 1. (**a**) Medicane Ianos. Source: EUMETSAT. (**b**) The study area.

2. Materials and Methods

The study area (Figure 1b) was delineated by the higher isobar (1010 hPa), presenting circular symmetry at the time of minimum pressure (993.5 hPa) plus 10 m gale force winds (>17.5 m/s) adjacent to the low pressures, with the use of the European Centre for Medium-Range Weather Forecasts ECMWF IFS operational analysis numerical model data. The whole area is oligotrophic, and its trophic regime is characterized as no blooming [5].

Variations in sea surface chlorophyll concentration were assessed using satellite-derived products of the Copernicus Marine Environment Monitoring Service (CMEMS). The percentage differences between the maximum concentrations of five days after the event (19–23 September 2020) and five days before (11–15 September 2020) were calculated. Chlorophyll percentage differences of the maximum values 5 days after the medicane and September climatology were also estimated to highlight the significance of the influence. Absolute chlorophyll percentage differences that exceed 50% were considered separately as more significant (the absolute percentage error between satellite-derived data and in situ measurements is about 50%).

In order to further evaluate the response of the marine environment, differences in sea surface temperature (SST) were calculated between the minimum values observed 5 days before and after the event. The data used were the high-resolution SST daily mean product of CMEMS.

A geographic information system (GIS) was used for data processing.

3. Results and Discussion

Chlorophyll increased over 99.6% of the study area (over 10.7% was more than doubled); absolute percentage differences > 50% covered 60.9% of the area, and they were all increases (by 17.5% indicated doubled values) (Figure 2). The area-averaged chlorophyll concentration presented a 64.2% increase, which is analogous to the maximum increases reported for hurricanes in the Atlantic Ocean when affecting ologotrophic waters [1] but on a much smaller geographical scale.

The maximum chlorophyll values observed up to 5 days after the event were higher than climatology over 96.0% of the area (more than double over 4.5%) (Figure 3). Absolute percentage differences >50% covered 24.4% of the area, and they were all higher than climatology. The averaged chlorophyll concentration presented a 39.1% increase in respect to its climatological value.

SST dropped throughout the study area, more than 2 °C over 74.6% of the area (Figure 4); the whole area-averaged SST presented a 2.54 °C decrease. It is noted that the largest SST drop observed in a hurricane study over oligotrophic Atlantic was 2.6 °C [1]. The latter is indicative of upwelling, vertical mixing and deepening of the mixed layer, suggesting that the main mechanisms proposed for explaining the chlorophyll increases

caused by hurricanes are valid for medicanes as well. Through these procedures, nutrients are provided from below to the upper sea layers, resulting in increased phytoplankton growth and chlorophyll concentration.

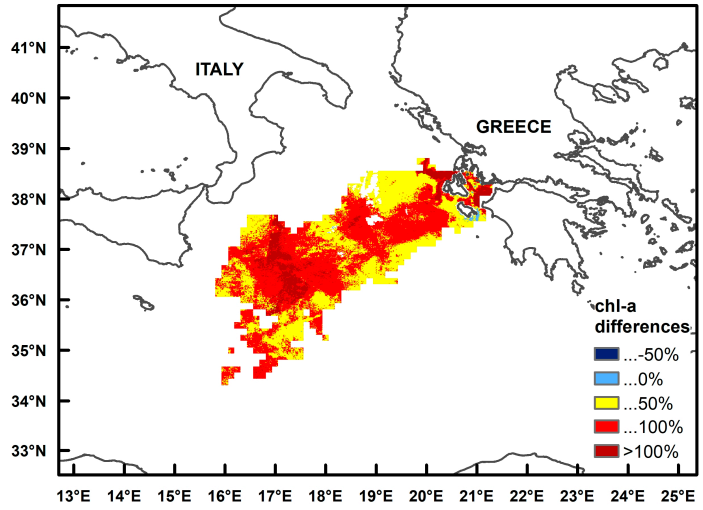


Figure 2. Percentage differences of sea surface chlorophyll concentrations of the maximum values 5 days after the medicane in respect to 5 days before.

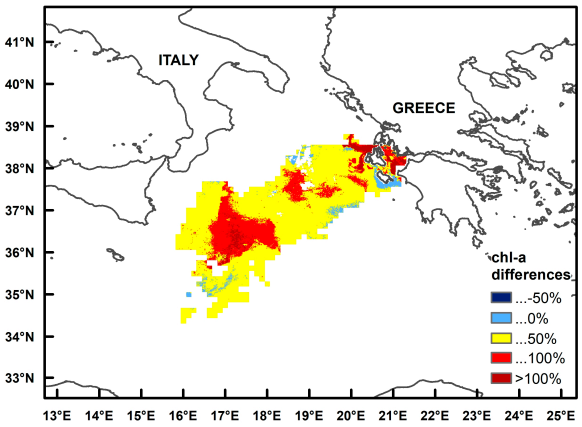


Figure 3. Percentage differences of sea surface chlorophyll concentrations of the maximum values 5 days after the medicane in respect to September climatology.

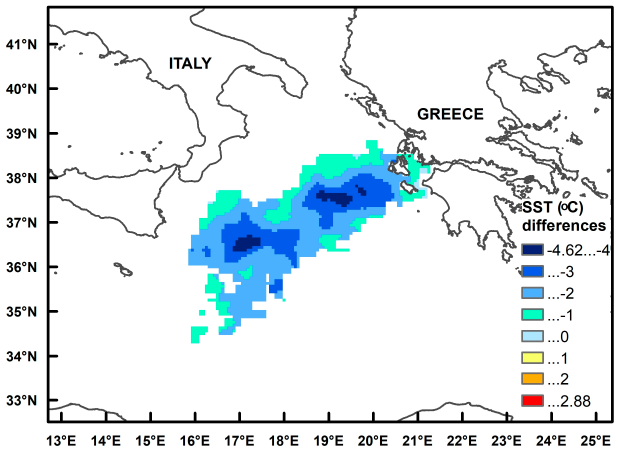


Figure 4. Sea surface temperature differences between the minimum values recorded 5 days after the medicane and 5 days before.

Ianos induced larger chlorophyll increases and SST drops than the three medicanes examined in the previous relevant study [4]. There are two probable reasons: its lower speed and the time of its occurrence (when the mixed layer is still shallow). The model results showed that slower-moving storms induce deeper mixed layers and larger chlorophyll increases [6]. During September, the mixed layer depth of the study area is shallow, up to 30 m [7]. The study of 13 hurricanes in the oligotrophic Atlantic waters revealed the highest chlorophyll increases during September and October, when the stratification started breaking down [1]. In the previous Mediterranean study, the medicane of November presented larger increases in chlorophyll in respect to the medicanes that occurred in December when the mixed layer was deeper. Ianos not only presented the most pronounced chlorophyll increase in respect to the medicanes studied until now but also one of the greatest if compared to the Atlantic hurricanes over oligotrophic waters, where only 3 out of 13 cases were characterized by area-averaged chlorophyll increases > 50% [1].

4. Conclusions

The so-far-conducted research gives strong evidence that medicanes cause increases in sea surface chlorophyll concentrations in the oligotrophic Eastern Mediterranean. These increases are of the same order as the ones caused by hurricanes, though obviously on a smaller geographical scale.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data used are available on request through ECMWF and CMEMS.

Acknowledgments: ECMWF and CMEMS are acknowledged for the data.

Conflicts of Interest: The author declares no conflict of interest.

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