The September 2020 Medicane Ianos predicted by the Copernicus Mediterranean Forecasting systems

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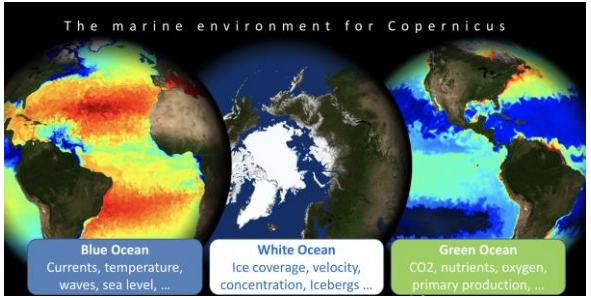
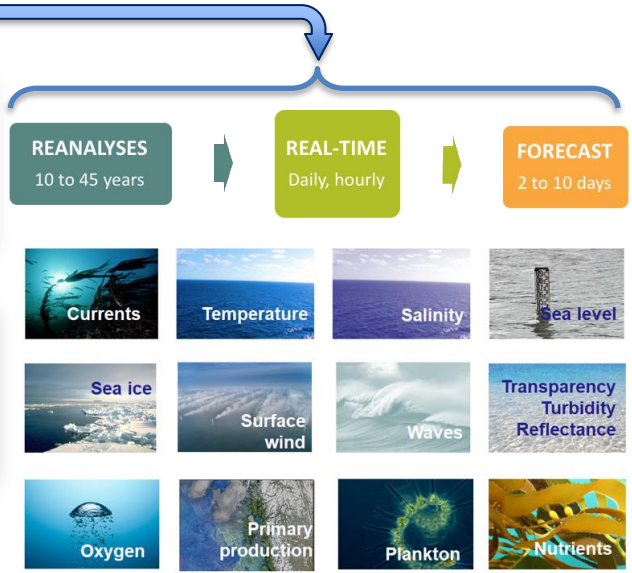
Copernicus Marine Service: *https://marine.copernicus.eu*

The Copernicus Marine Service provides free, regular and systematic authoritative information on the state of the **Blue** (physical), **White** (sea ice) and **Green** (biogeochemical) ocean, on **global** and **regional** scales.
It is funded by the European Commission (EC) and implemented by Mercator Ocean International





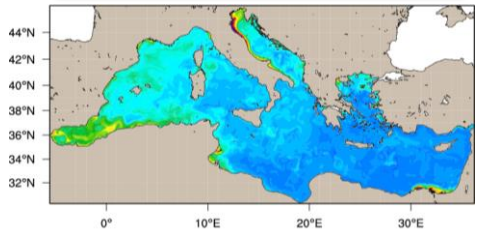
Copernicus Marine Med-MFC Consortium

MED-MFC
~40 experts

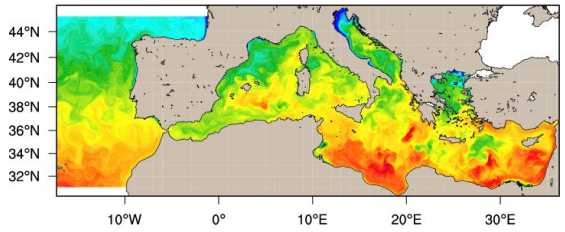
The Med-MFC is one of the 7 MFCs
A consortium of 4 institutes

CMCC (Leader of the consortium and responsible for the Physical product) → **Med-PHY**
OGS (Responsible for the Biogeochemical product) → **Med-BIO**
HCMR (Responsible for the Wave product) → **Med-WAV**
CINECA Support to operational production (new from 2022)

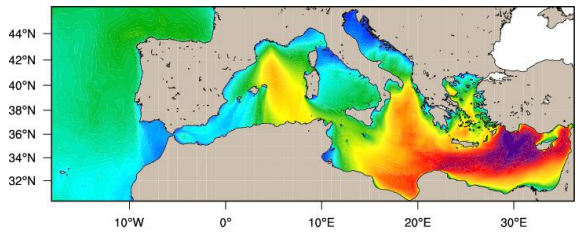
Med-Biogeochemistry PU



Med-Physics PU



Med-Wave PU



The modelling systems are based on **state-of-the-art community models**, **assimilate *insitu* and satellite observations** and are forced by **high resolution atmospheric fields**.
Improvements and functioning of the Med-MFC systems are based on the **full consistency among the three components** which **are jointly upgraded** and include a **continuous amelioration** of the accuracy of the products.

Med-MFC NRT (Analysis & Forecast) Systems

MED-BGC
BFM v5.1 (Biogeochemical Flux Model)
OGSTM v4.3 (Transport Model)
Hor. Res. = **1/24º** (~4 km)
Vert. Res. = **125 z*** vertical
DA.: 3DVAR-BIO v3.3
Chlorophyll from satellites
Chlorophyll + **Nitrate** from *insitu* floats

ECMWF 1/10º atmospheric forc.

Land river inputs:
39 major **rivers**: monthly clim. values (Po daily obs)

Physical fields:
Daily NRT analyses and forecasts from **Med-PHY-NRT**: T, S, U/V/W

BDY in Atlantic & Dardanelles Strait:
Climatologies

MED-PHY
NEMO v3.6 (tides) <-> WW3 v3.14
Hor. Res. = **1/24º** (~4 km)
Vert. Res. = **141 z*** vertical
D.A.: OceanVar (3D-VAR)
SLA Satellite and **T/S** *insitu* floats
+ Non-solar heat flux correction (sat. **SST**)

ECMWF 1/10º atmospheric forc.
Temporal resolution:
Forecasts: 1hr - 3hrs - 6hrs
Analysis: 6 hrs

Land river inputs:
Surface boundary condition for **39** major **rivers** runoff: monthly clim. values (Po daily obs)

BDY in Atlantic & Dardanelles Strait:
Daily NRT analyses and forecasts from **Copernicus GLO-PHY-NRT**

MED-WAV
WAM 4.6.2 Spectral model
Hor. Res. = **1/24º** (~4 km)
32 Frequencies
24 Directions
D.A.: Optimal Interpolation Scheme
Satellite Along-Track
Significant Wave Height

ECMWF 1/10º atmospheric forc.
Temporal resolution:
Forecasts: 1hr - 3hrs - 6hrs
Analysis: 6 hrs

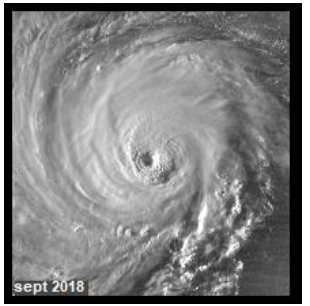
Physical fields:
Daily NRT analyses and forecasts from **Med-PHY-NRT**: Sea Level & surface currents

BDY in Atlantic:
Daily NRT analyses and forecasts spectra from **GLO-WAV-NRT** every 4 min

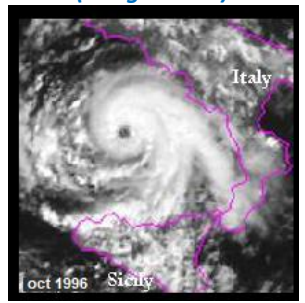
Medicanes Introduction

- The Mediterranean Sea is one of the most cyclogenetic regions in the world
- Tropical-like cyclones generating in this region are known as ***medicanes*** or ***Mediterranean hurricanes***
  - cloudless "eye" at the centre of a spiral cloud coverage
  - cyclonic systems with symmetric, warm core structure
  - typical size of the order of 300 Km in diameter
  - more frequent during autumn and winter
  - are characterized by a combination of intense winds, heavy precipitation and enhanced ocean waves
- Such warm cores have been shown to form due to the process of warm seclusion or due to the development of deep convection close to the cyclone's centre→ similar to tropical cyclones

Tropical cyclone
(image NASA)



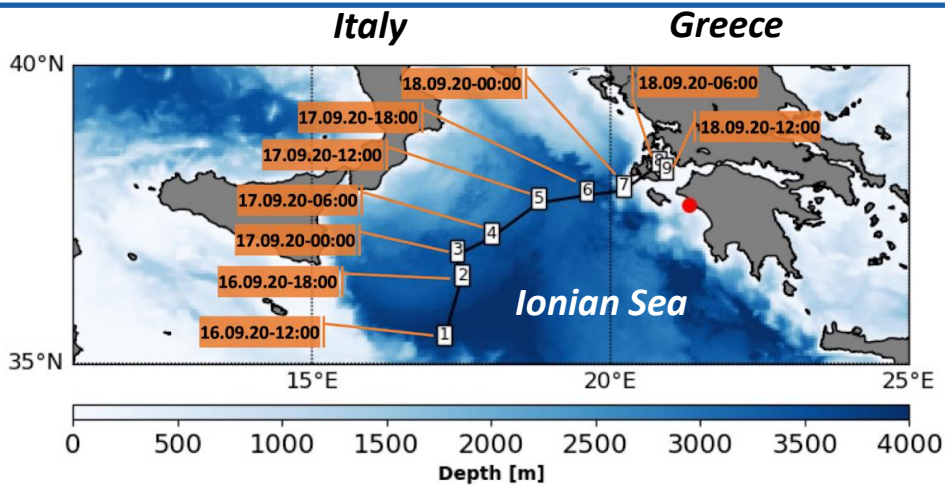
Medicane
(image NASA)



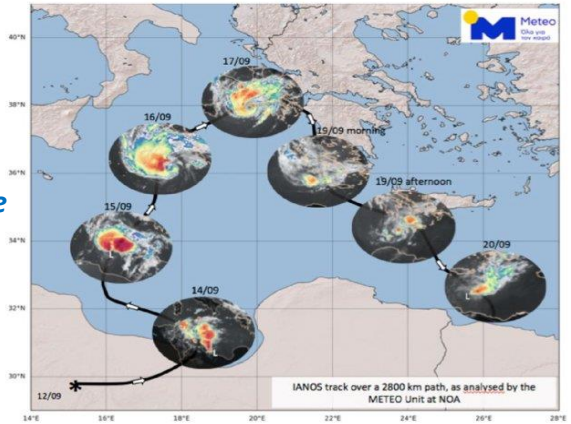
While cyclones have devastating effects when passing over coastal areas, over the ocean they might have a positive effect by enhancing productivity in oligotrophic areas

Medicane Ianos

- A record Mediterranean tropical-like cyclone
- 17th to 20th September 2020
- Impacting Ionian Sea & Greece
- Wind speeds up to 110 km/h, torrential rain and flooding → damages and death
- One of the strongest such storms recorded since 1969 (beginning of satellite observations) in terms of duration and intensity



Investigating the cyclone impacts by using observational data may have some obvious limitations → 3D ocean models can provide insights on its evolution and on the coupling mechanisms driving ecosystem productivity

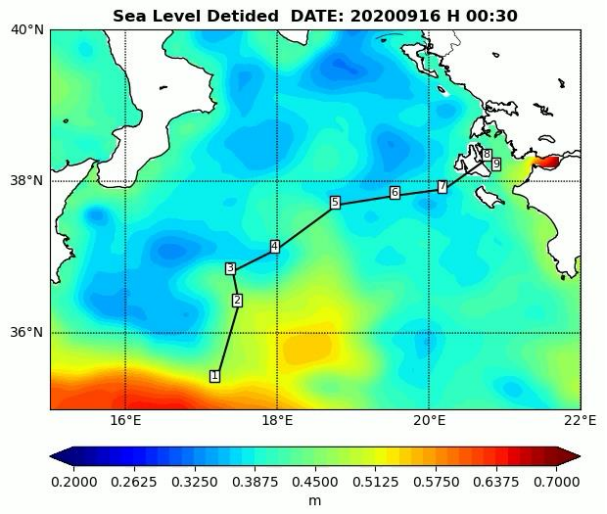


Ianos track as analyzed by the METEO unit of IERSD/NOA

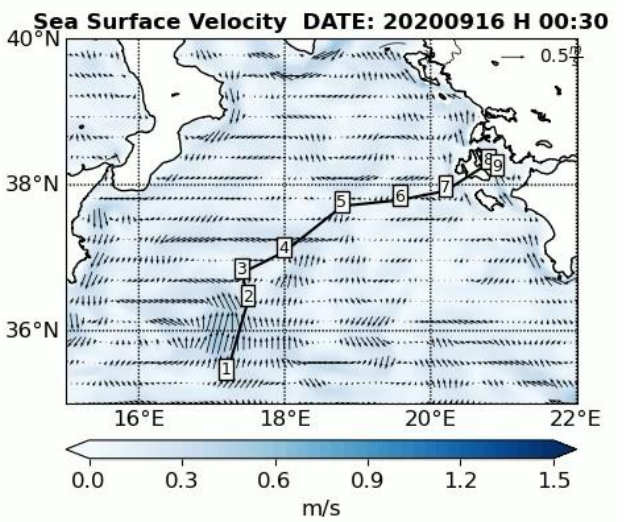
Med-MFC numerical analysis data are used to analyse Ianos impacts on the physical, wave and biogeochemical upper layers fields

Medicane Ianos Evolution

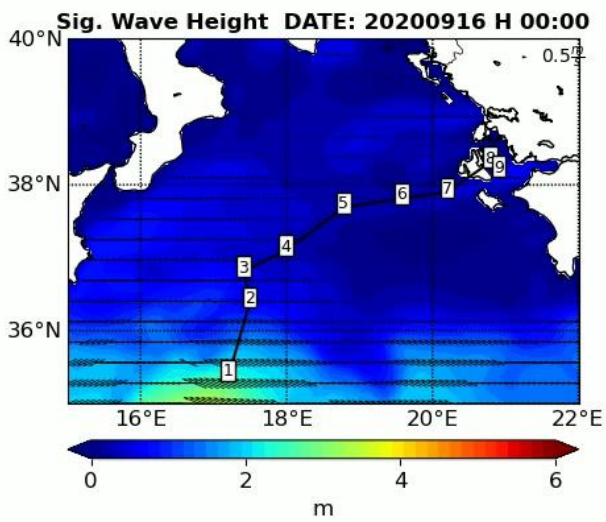
SEA LEVEL



SURFACE CURRENTS



SIG. WAVE HEIGHT



Impact of Medicane Ianos' passage clearly captured by hydrodynamic and wave models

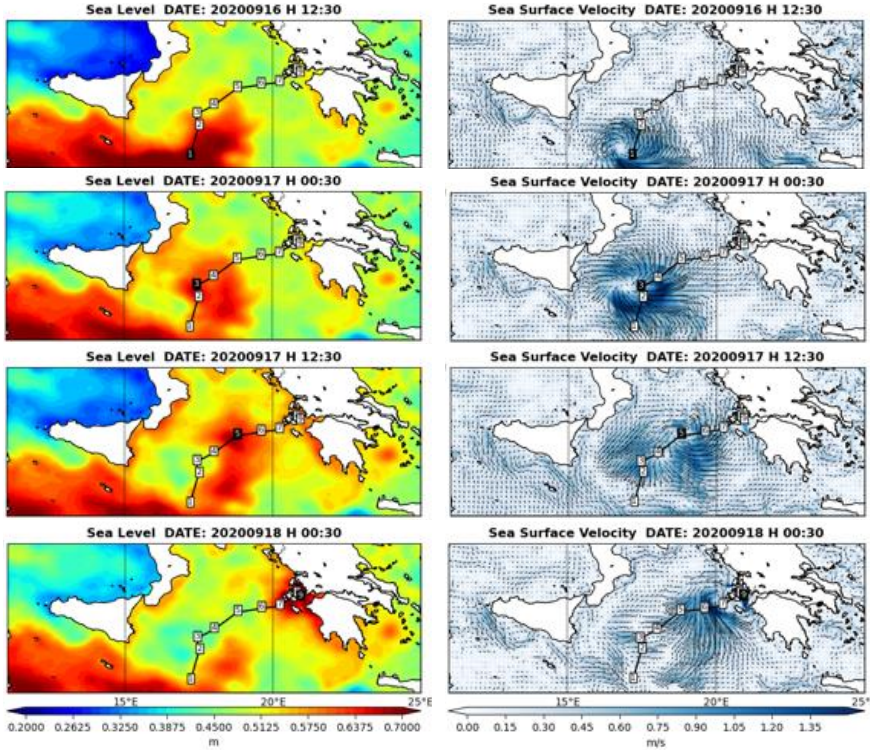
→ increase of the sea level and significant wave height

→ intensification of the surface currents

along the Medicane path

Medicane Ianos Impacts

Sea Level and Surface Currents increase along the Min. Atm. Pressure path starting from 16/09/2020 (every 6hours)



18th Sept at around 00:00 UTC Medicane Ianos hits the coasts of the Ionian islands causing huge damages

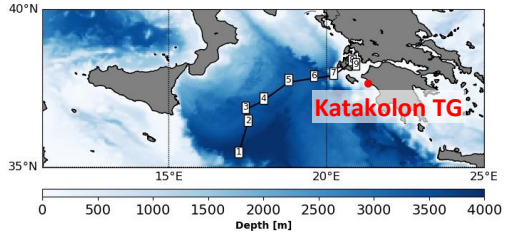
- surface currents of around 1.8 m/s
- sea level of 0.7 m

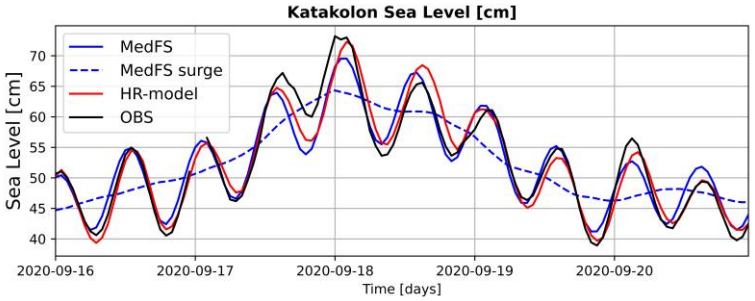
Medicane Ianos:

- radius to max stress (R) = 50 km,
- stress magnitude = 0.64 N/m2
- translation speed = 5 m/s
- inertial period ~= 0.8 days.
- non-dimensional storm speed (ratio of the Medicane residence time to the local inertial period) ~=0.5 → surface mixed layer would be more dominated by the geostrophic currents rather than inertial motion (Price 1991).

Model comparison with Observations

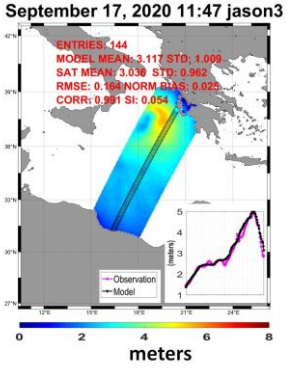
SEA LEVEL

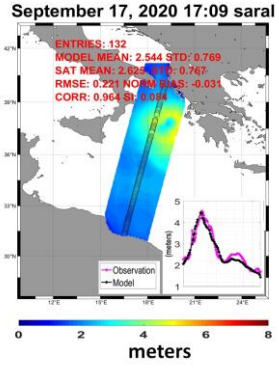


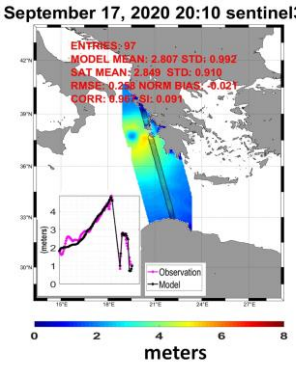


- Model hourly sea level in agreement with observations @ Katakolon TG
- Model Underestimation ~ 4 cm at peak
- MedFS used to force high res. (3km to 100m) unstructured grid model (based on the SHYFEM) → reduced error at peak

SIG. WAVE HEIGHT







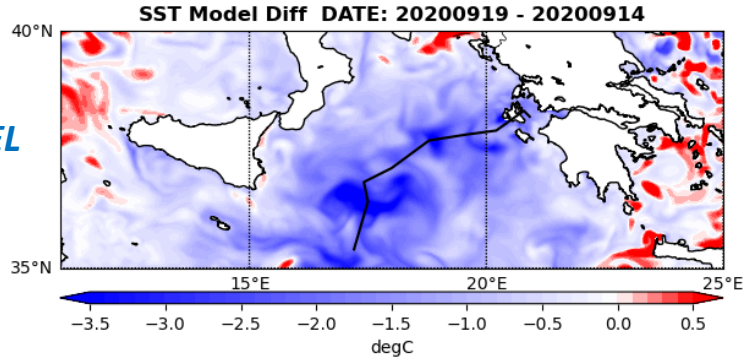
- The accuracy of the modelled sig. wave height is very good
- Correlation between the observed and modelled data ranges from 0.96 to 0.99
- Model bias is close to zero

17 September 2020	Jason3	Saral	Sentinel3B
Entries	144	132	97
Model Mean / STD [m]	3.12 / 1.01	2.54 / 0.77	2.81 / 0.99
Sat Mean / STD [m]	3.04 / 0.96	2.62 / 0.77	2.85 / 0.91
RMSD [m] / NORM Bias	0.16 / 0.02	0.22 / -0.03	0.26 / -0.02
CORR / SI	0.99 / 0.05	0.96 / 0.08	0.97 / 0.09

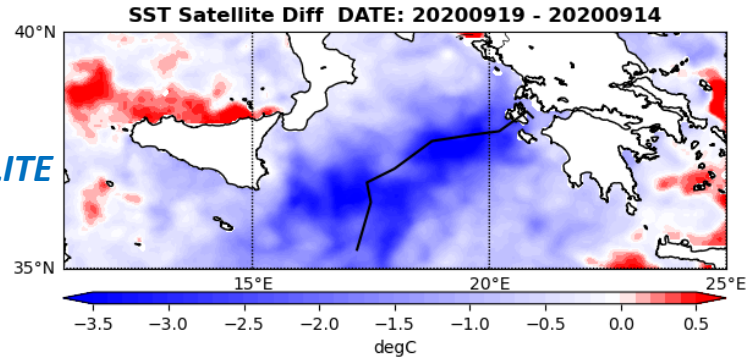
Model comparison with Observations

SEA SURFACE TEMPERATURE DECREASE BETWEEN 19 & 14 SEPT. 2020

MODEL



SATELLITE

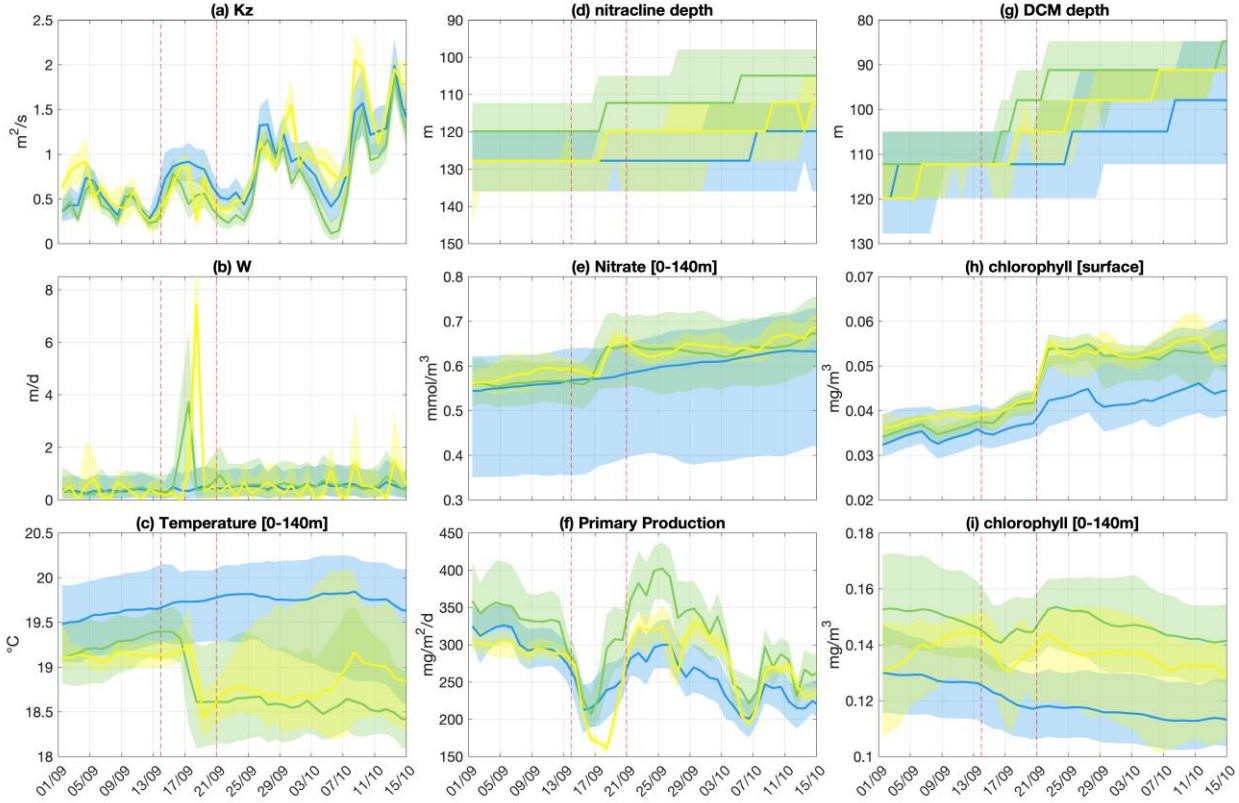


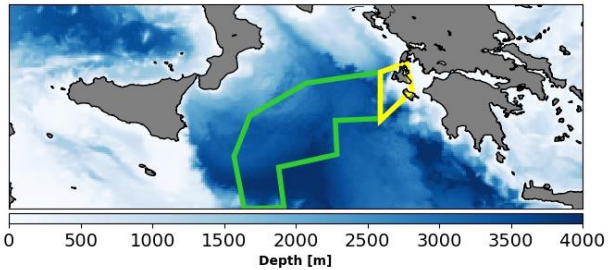
Model Sea Surface Temperature decrease in agreement with satellite observations

- SST decrease around -3.5 °C
- MedFS shows some underestimation compared with the satellite L4 SST dataset
- The observational dataset could not represent the small scale features present in the model solution due to the scarcity of direct observations (cloud covering) → SST L4 is a combination of a first guess field with available data from previous days

Medicane Ianos Impacts

Ianos impacts on Physical and Biogeochemical fields





1. Impacted area:

SST decrease on 20th Sept. >= 1.5°C wrt 1st-19th Sept. mean SST

- **off-shore** → open Ionian Sea
- **in-shore** → approaching Greece

2. Non impacted areas

- ***vertical eddy diffusivity***: no specific changes
- ***upward vertical velocity*** peak on 17/09

→ PHY and BGC properties mostly affected by upwelling associated with wind stress curl

- ***Subsurf. Temp***. decrease ~1°C
- ***Nitrate conc***. increased by about 10-15%
- ***chlorophyll maximum depth***: 20m uplift
- ***chlorophyll conc***. increases ~25% 2-3 days after Ianos
- ***PP*** decreases during Ianos (dilution of biomass in euphotic layer and decrease of the light availability) & increases from 22-29/09
- ***larger impact in the in-shore area***

Conclusions & Discussions

- **Medicanes** are strong cyclones with subtropical and tropical characteristics that form in the Mediterranean Sea especially during autumn-winter
- Understanding the hydrodynamical, biogeochemical and wave conditions that take place during these extreme events is critical in order to **mitigate the damage they can cause**
- Accurate **numerical modelling is an important and essential tool** in the warning and forecast of these coastal hazards as well as to support risk and damage assessments and the design of coastal structures
- The **Copernicus Marine Mediterranean analysis products** allowed a comprehensive assessment of Medicane Ianos footprint on the Ionian Sea and Greek coastal areas affected by this event
- Model solutions were validated showing a **general good skill** in representing the increased sea level, wave height and decreased temperature in the area → these data can provide accurate boundaries to high resolution coastal applications
- Thanks to the alignment of the 3 Med-MFC components, we show to which extent this **Medicane perturbed the surface ocean fields** in terms of sea level, currents, temperature, wave height and chlorophyll, **but also the vertical dynamics** by increasing the mixing and consequently affecting the biogeochemical properties at depth

Thanks


cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici


OGS


hcmr
ΕΛΚΕΘΕ