Exploring the role of the ocean and model resolution in the prediction of medicanes using the global IFS model

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1. Introduction

Medicanes are rare, tropical-like storms in the Mediterranean that can cause heavy rainfall, strong winds, and high waves. Accurate forecasting of these storms requires considering factors such as the timing of the forecast, the parameters used, and the storm's intensity and duration. While atmospheric conditions significantly influence medicanes, ocean-atmosphere interactions can also play a crucial role, especially in light of climate warming in the Mediterranean.

This study examines the impact of ocean conditions on the prediction of medicane Ianos in September 2020 by testing different levels of atmosphere-ocean coupling. Ianos displayed characteristics akin to a category-1 hurricane. The research highlights the importance of ocean conditions in global models for accurately forecasting Ianos' development. Additionally, the study investigates the effect of different horizontal resolutions (9 vs. 4.4 km) using the IFS ECMWF deterministic forecast and extends some ocean experiments to ensemble members to assess the impact of model uncertainties.

2. Effects for Ianos on the SST

The SST of the Eastern Mediterranean was up to 1 degrees warmer than normal in September 2020 before Ianos. Below is the SST from the ECWMF operational ocean analysis (ORAS5) for Sept 15th, 2020 showing the ocean grid (left) and the difference in SST 7 days later (right). It is clearly seen that the passage of Ianos cools down the SST by more than 2 degrees in a large area in the region.

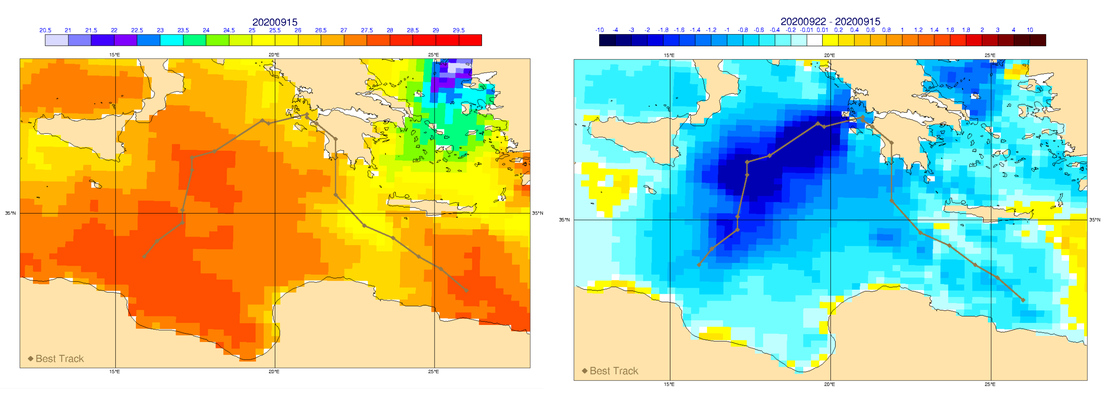

Figure 1. SST from ORAS5 on the 20200915 (left) and the difference in SST 7 days later showing a cold wake along the track of Ianos.

3. Forecast experiments

All experimental forecasts used in this study are based on the IFS version CY48R1, with the following configuration for the atmosphere and ocean models.

	Atmosphere	Ocean
Initial conditions	ECMWF 4D-Var	ECMWF ORAS5
Horizontal resolution	4.4 km*, 9 km	~25 km
Vertical resolution	137 levels	75 levels, 1-m thick top layer

** Configuration only used for deterministic forecasts.*

The ensemble experiments consist of 10 perturbed + 1 control forecasts and include only initial condition perturbations (from SV + EDA), which allows to better isolate the impact of changes in SSTs on the evolution of Ianos. Ocean-atmosphere interactions are modelled with three different approaches.

Uncoupled	Partial coupling	Full coupling
SST fixed at ICs	ICs generated from OSTIA, nudged to NEMO ICs after day 4	5 different ICs from NEMO equally spread across the 10 perturbed members

4. Deterministic forecasts

First predictions of Ianos are found in forecasts initialised on 14 Sept 12UTC. Overall, forecasts predict a lower core pressure, i) the higher the resolution, and ii) the weaker the degree of coupling.

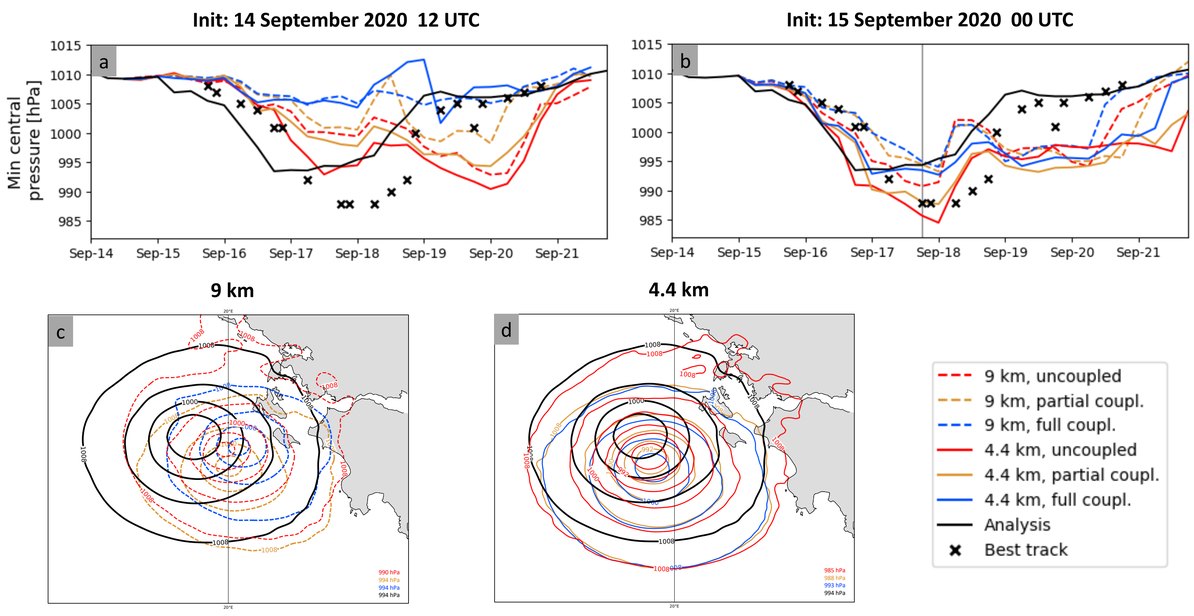

Figure 2. Minimum central pressure (hPa) evolution for forecasts of Ianos initialised (a) 14 Sept 12 UTC and (b) 15 Sept 00 UTC, and spatial patterns for (c) 9 and (d) 4.4 km resolution runs initialised 15 Sept 00 UTC, valid after 66 h.

The Ianos case shows that, in addition to atmospheric factors, ocean-atmosphere interactions can also play a significant role in accurately predicting medicane intensity. But how did the warm SST affect the core pressure differently?

Hypothesis: through a wind-induced surface heat exchange (WISHE)-type process chain.

As the uncoupled runs saw a warmer SST, they produced stronger surface latent and sensible heat fluxes, which fostered convection to a stronger degree. The latent heat release then built up a warmer core and caused a stronger pressure fall. Note that the effect of cold wake is clearly visible for partial and full coupling.

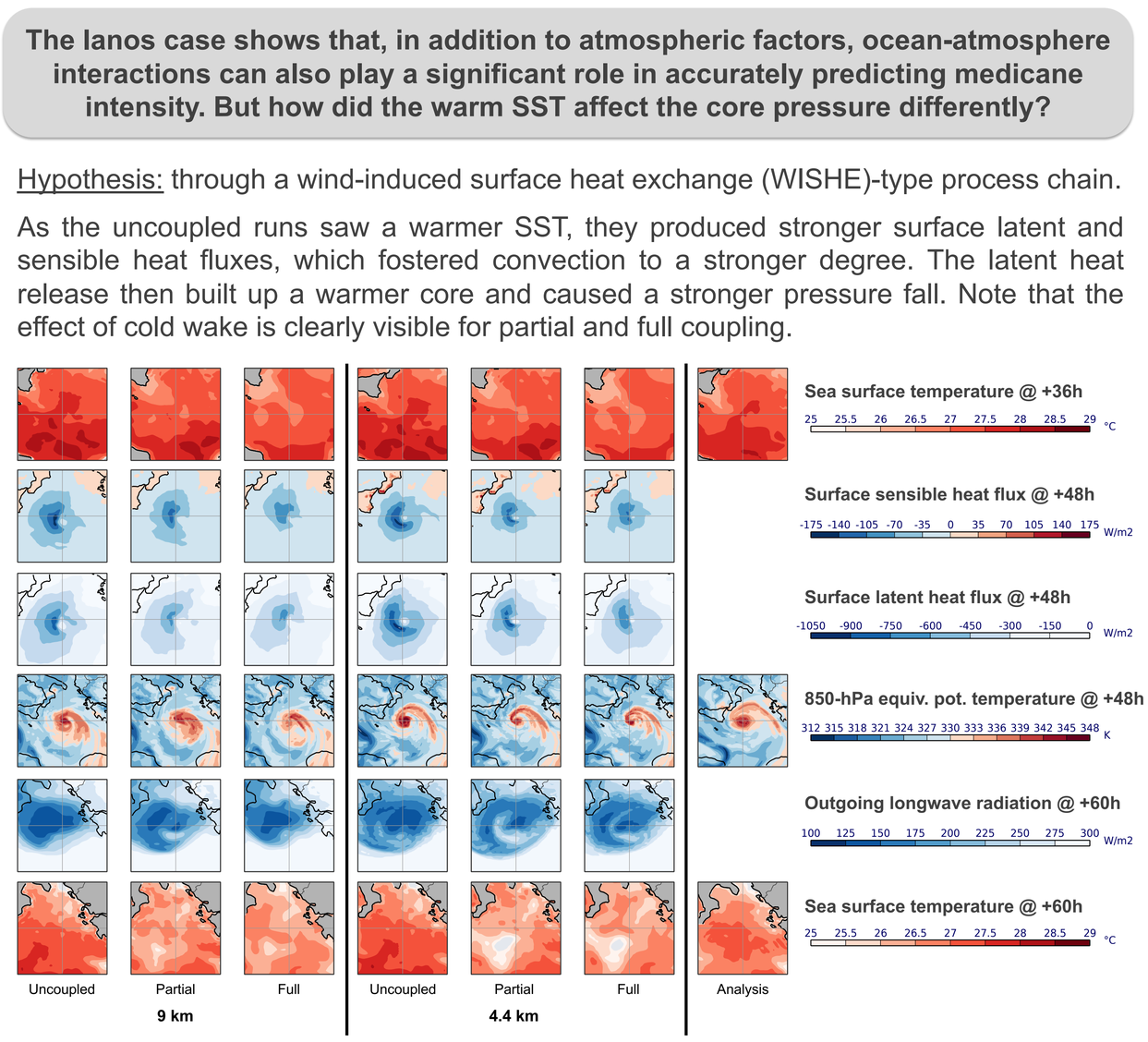

Figure 3. Illustration of the WISHE-type process chain. Storm-centered stamp plot combining various variables (rows) at different lead times for coupling-resolution combinations (columns) from the forecast initialised 15 September 00 UTC.

But was this a lucky deterministic shot?

5. Ensemble forecasts

Complementary to the deterministic experiments, we show results from ensemble experiments with partial and full coupling for Ianos (run initialized at 15-09-2020 00 UTC). Figure 4 shows the correlation coefficients and slope obtained from regressions conducted between the differences (member-member pairs of the two experiments) in SST - QE, QE-OLR and OLR-CP. We find that a decrease/increase in SST, lead to lower/higher latent heat fluxes, which in turn increase/decrease OLR and hence increase/decrease minimum core pressure. For SST-QE, we find strong correlations between leadtimes 25-45h (36h before CP max), and between 55 - 63 h (6-12 hours before CP max). For QE-OLR, and OLR-CP relations we find that are correlated between 50 - 68h forecast leadtimes suggesting that differences in latent heat flux and convection intensity affect core pressure when the medicane is close to reaching max intensity.

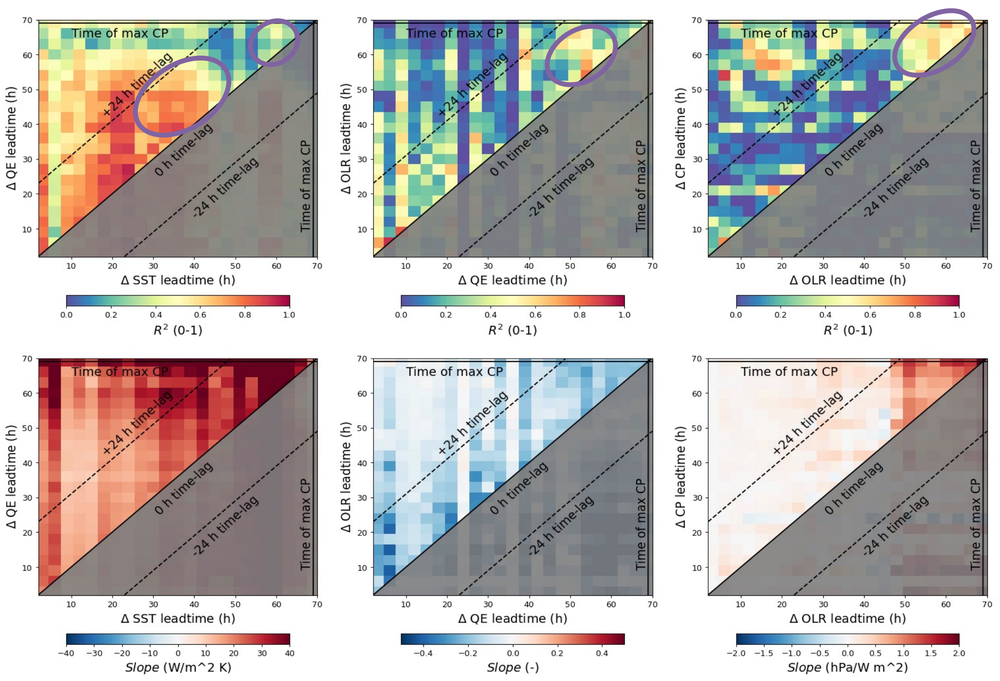

Figure 4. Correlation coefficients (upper row) and slope (lower row) for the relation between differences in sea-surface temperature vs latent heat flux (left), latent heat flux vs outgoing longwave radiation (middle) and outgoing longwave radiation vs core pressure (right) for different lead times. Differences are computed for each member-member pair between the ensemble experiment with partial and full coupling to NEMO for Ianos (initialization 15-09-2020 00 UTC). Results are shown up to time of maximum core pressure in the ensemble mean. Purple circles highlight the areas where there is strong connections (correlation and slope) between variables.

6. Conclusions

This study investigated the role of ocean conditions on the intensity evolution in predictions for medicane Ianos, comparing three different levels of atmosphere-ocean coupling and two horizontal atmospheric resolutions. Using deterministic experiments, the peak intensity of Ianos was shown to be increased by a weaker degree of coupling and higher resolution, differently modulating a WISHE-type process chain. Based on differences calculated between partial and full coupling runs, correlation analysis for variable pairs of this process chain confirmed the findings from an ensemble perspective.

Similar analyses were conducted for other medicanes (incl. Numa, Zorbas, Daniel, Apollo) but they showed less sensitivity to SST and coupling.

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