



Coupled ICON-A/ICON-O-LAM experience at CMCC

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COSMO GM
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ICON-O-LAM: the regionalization of ICON-O



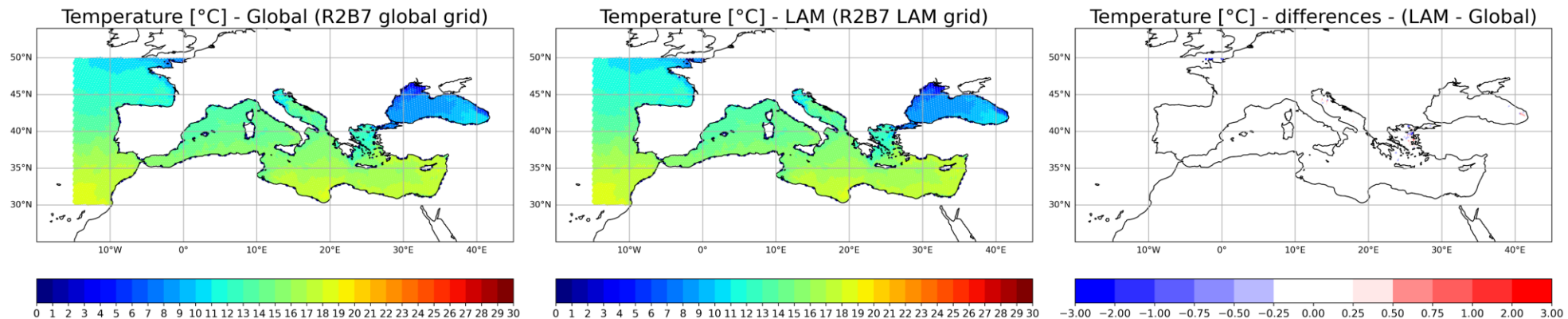
ICON-O (Korn et al, 2022) is the global ocean component of the ICON climate model, using an unstructured icosahedral grid. The regional version **ICON-O-LAM (Limited Area Model)**, designed for high-resolution ocean simulations in specific areas is now available and is currently being consolidated.

The **regionalization of ICON-O has several beneficial aspects:**

- **It allows for finer solved scales**, especially near the coast (e.g., the complex shoreline of the Mediterranean coast),
- **The increase in resolution comes with lower computational cost** compared to the global version of ICON-O at the same resolution
- **The coupling of the ICON ocean LAM component with its atmospheric LAM counterpart is already supported by the established coupler YAC** (Hanke et al., 2016), providing the necessary infrastructure for seamless integration.

ICON-O (Global) vs ICON-O-LAM (regional) same spatial resolution (19.7 km)

Negligible difference after 20 days of simulation



Computational cost: **20 days of simulation**

- Global ocean runtime - **4.5h** on 144 cores of CMCC HPC
- Regional ocean runtime - **6min** on 144 cores of CMCC HPC

The regional coupled ocean–atmosphere configuration of ICON at CP scale: Central Mediterranean domain



Online coupling ICON-A-LAM and ICON-O-LAM through YAC:

- Atmosphere: ICON-A-LAM, setup ICON-D2 (Chen et al., 2024, Campanale et al., 2025)
- Ocean: ICON-O-LAM, setup with 50 levels from 0.5 to 54965 m (Korn et al., 2022, Jungclaus et al., 2022)
- Coupler: YAC (Hanke et al., 2016)
- IC and BC from IFS analysis for atmosphere component (6hr)
- IC and BC from CMEMS reanalysis for ocean component (24 hr)



ATMO2OCE

Total heat flux, 10m wind speed, surface fresh water flux, sea level pressure, surface stresses

ICON

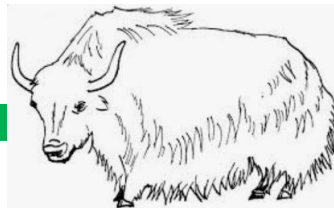
OCE2ATMO

Sea surface temperature, zonal and meridional sea water velocity



ICON-A-LAM

atmo. grid (R2B10, 2.5km)



YAC coupler

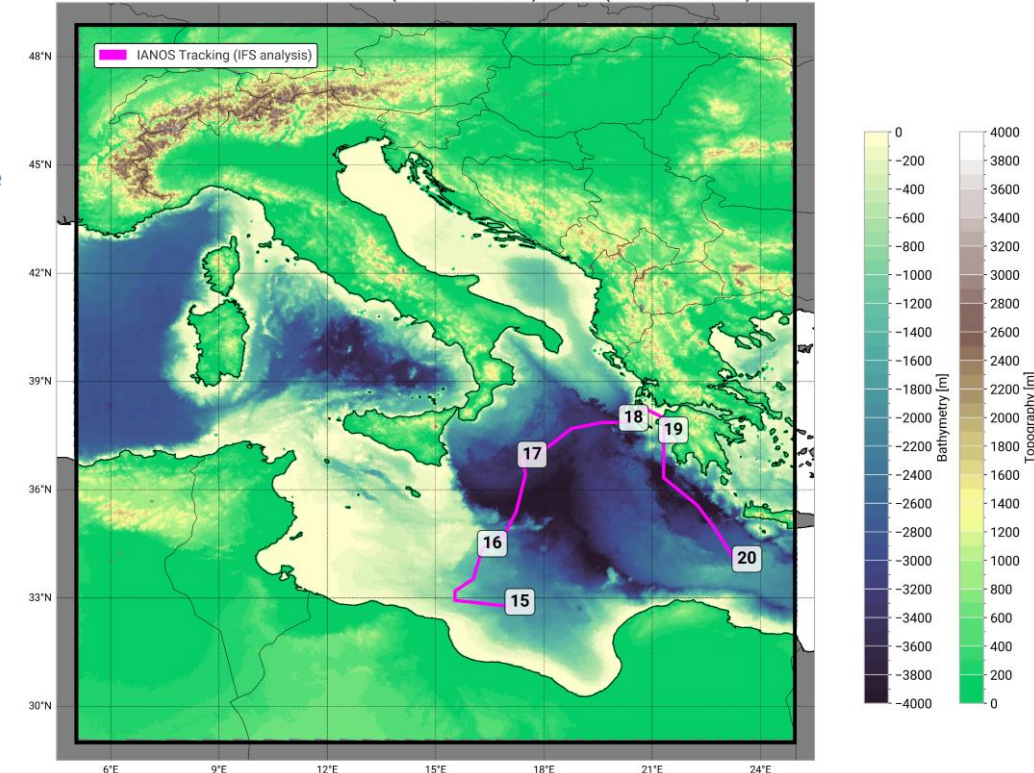


ICON-O-LAM

Oce. grid (R2B10, 2.5km)

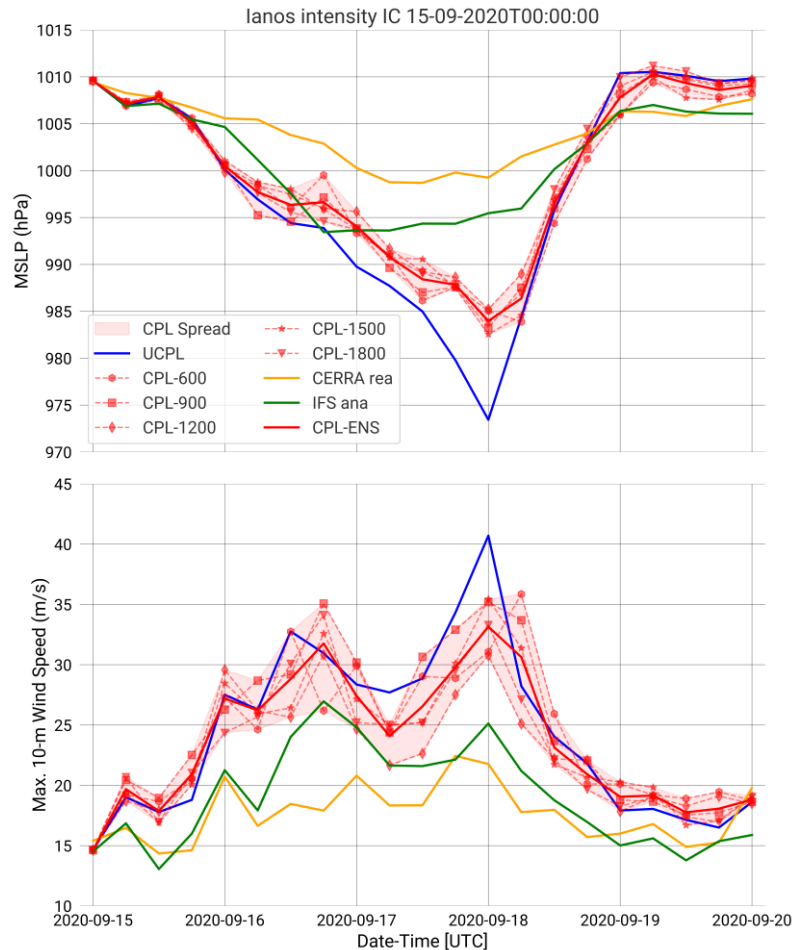
ICON-LAM domains: bathymetry and topography

ICON-LAMs domain: Atmo (R2B10-2.5km) - Oce (R2B10-2.5km)

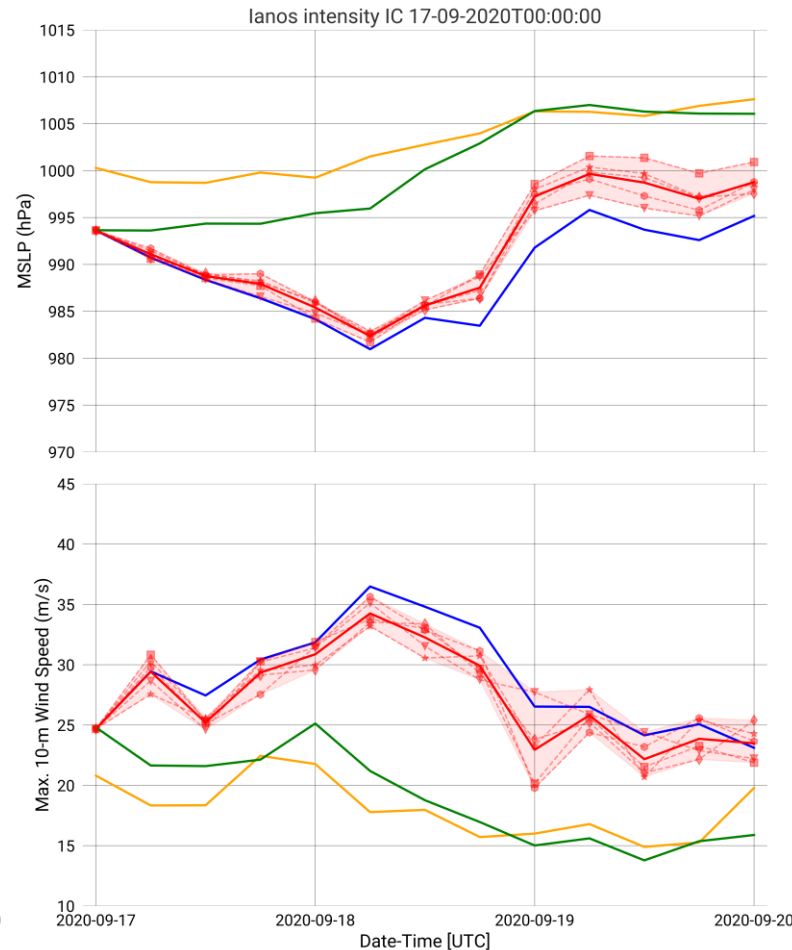


Both atmo and oce
share same resolution
(2.5km) and domain
extension

Intensity Comparison: Wind speed at 10m and MSLP



Minimum of MSLP and maximum of 10m wind speed (IC 15-09-2020 00:00)



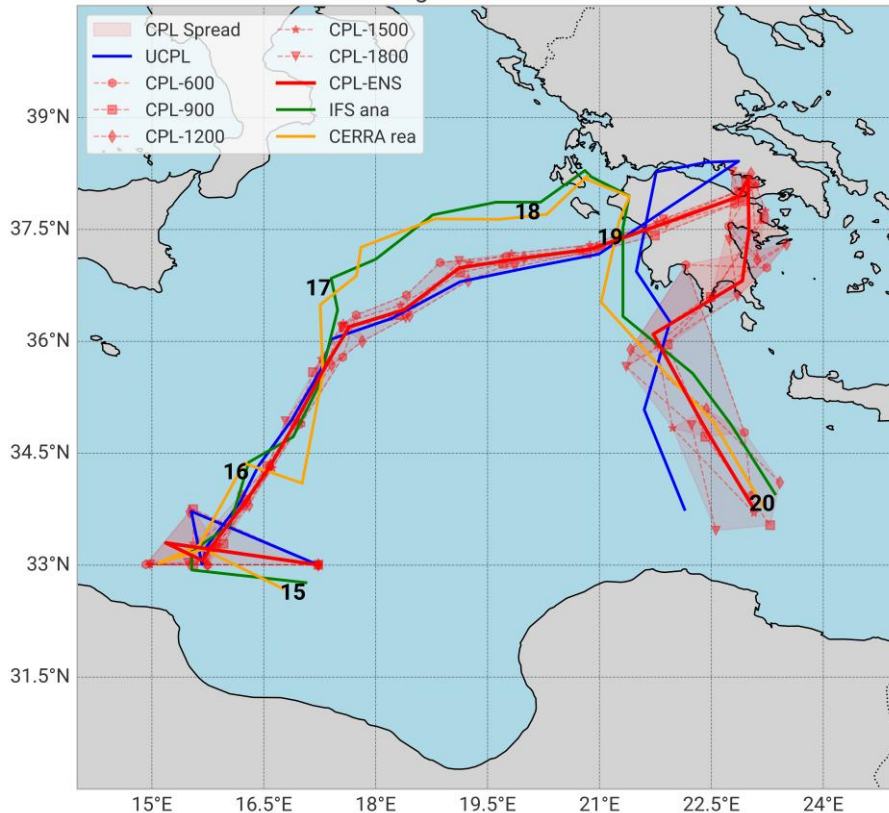
Minimum of MSLP and maximum of 10m wind speed (IC 17-09-2020 00:00)

IANOS case study:

- Tropical-like cyclone: perfectly axisymmetric warm core
 - Cyclogenesis fueled by strong SST anomaly
 - Formation started on 15 September 2020 in the Gulf of Sydra
 - Damping phase on 21 September 2020
- **Big added value of the coupled simulations in terms of medicane intensity** (cpl system closer to analysis and reanalysis)
 - While with constant SST, the deepening of IANOS (especially during its mature phase) is too strong in the atmo only simulations
 - Less advantage when IANOS is forecasted starting from 17 September 2020, when the uncoupled system is initialized with better SST state

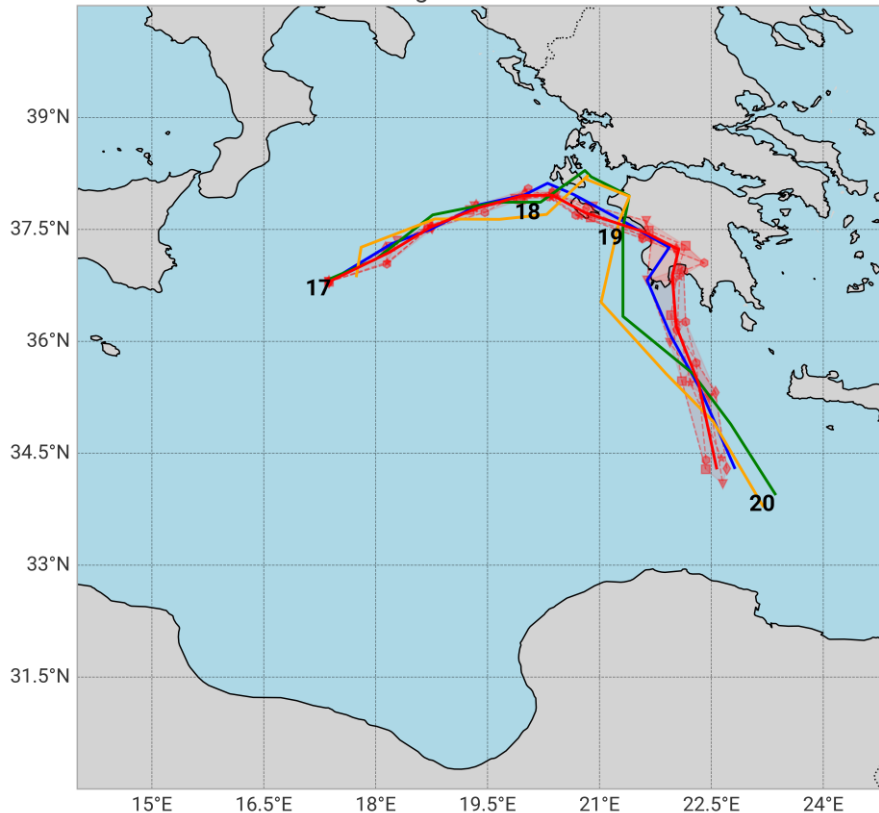
Tracking comparison

Ianos tracking IC 15-09-2020T00:00:00



Tracking of IANOS (minimum MSLP)
(IC 15-09-2020 00:00)

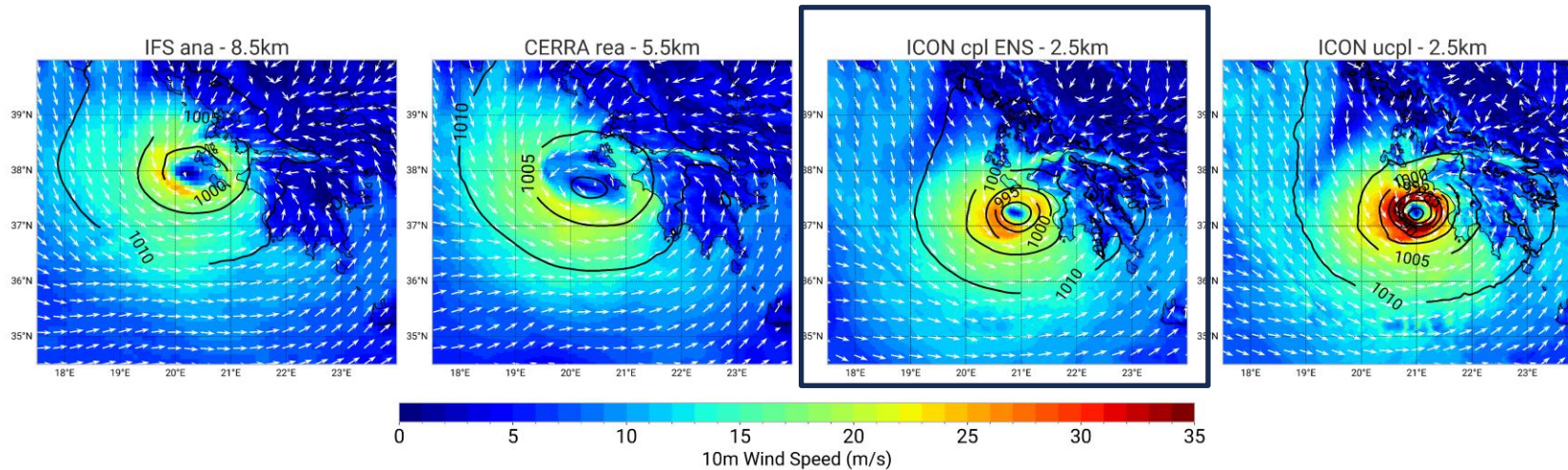
Ianos tracking IC 17-09-2020T00:00:00



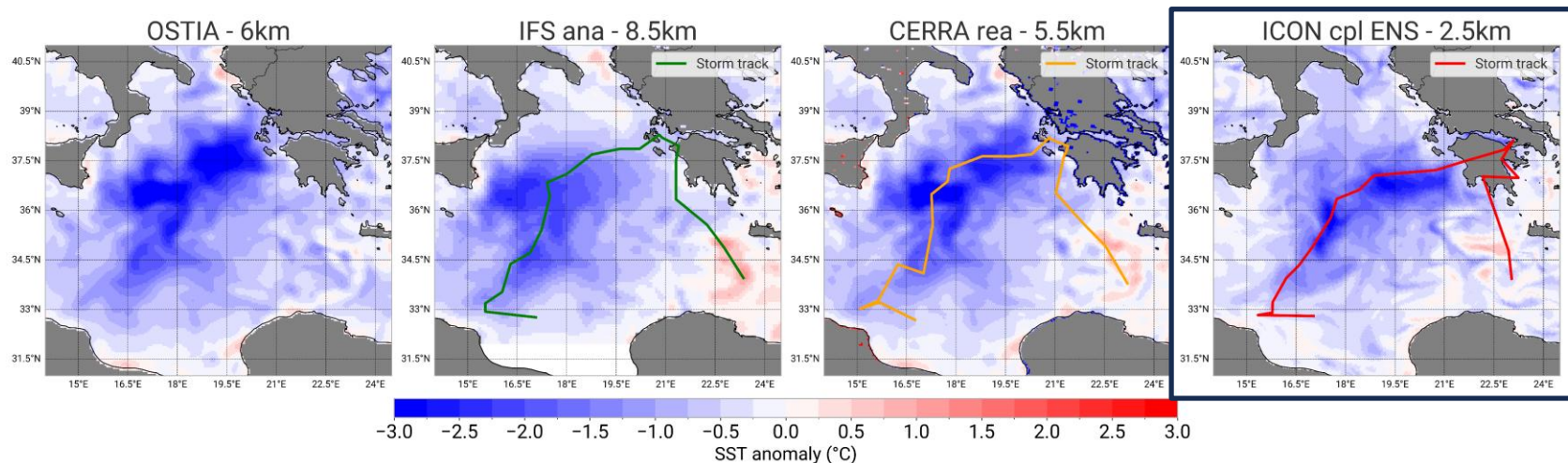
Tracking of IANOS (minimum MSLP)
(IC 17-09-2020 00:00)

- Slight improvement of the coupled system in terms of tracking during its most intense phase
- In the first initialization setting, after 48 hours of lead time, the tracks of both the coupled and uncoupled systems begin to deviate
- **Better tracking performance is observed when both systems, coupled and uncoupled, are initialized closer to IANOS most intense phase**

The case of medicane Ianos



MSLP (black isobars in hPa) and **10m wind speed and direction** (IC 15-09-2020 00:00)



SST anomaly: daily mean SST of 20-09-2020 - daily mean SST of 15-09-2020

- **Possibility to simulate SST cooling effect after IANOS passage allow for better forecast of medicane intensity**

- **Modulating SST cooling can also improve vertical structure representation, enthalpy fluxes and precipitation** (see Campanale et al. 2026, Atmospheric Research article for more details: <https://doi.org/10.1016/j.atmosres.2026.108975>)

The case of medicane Daniel

- **4 September 2023**

Daniel developed from a depression associated with an omega-blocking configuration over Europe, with the pressure minimum located over the Ionian Sea.

- **5-6 September - Extreme rainfall**

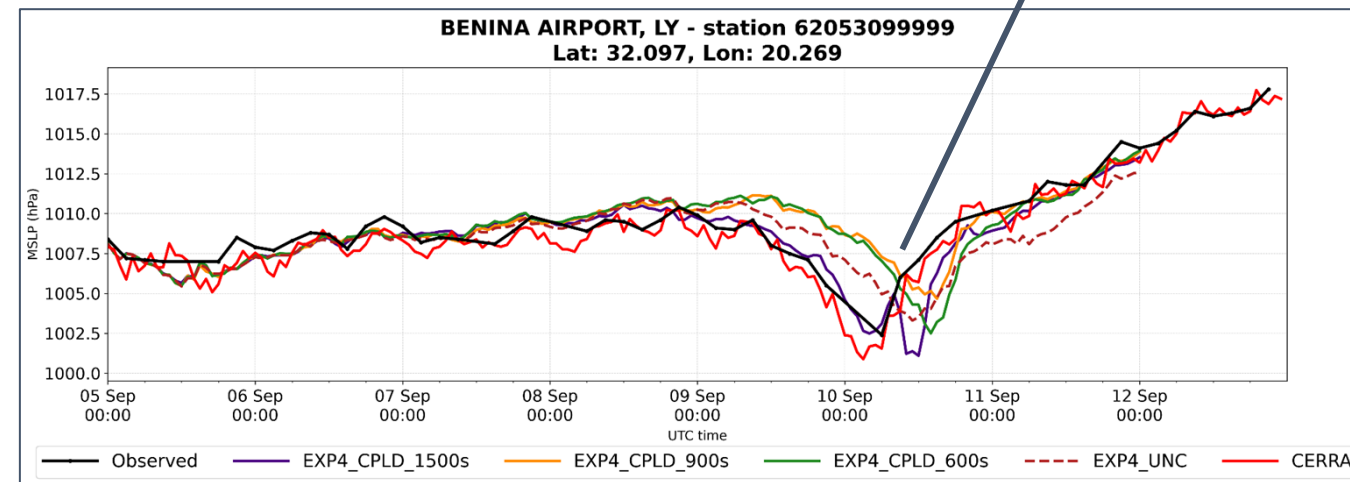
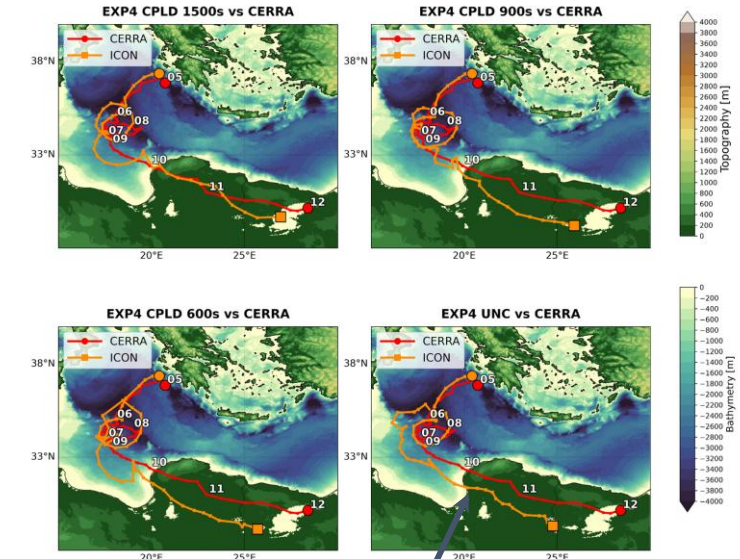
Greece experienced exceptionally high accumulated precipitation, with value over 750 mm in a single day and up to 1235 mm in 4 days.

- **6-9 September - Intensification towards to Tropical-Like Cyclone**

Daniel progressively intensified over the warm Mediterranean Sea with sustained winds reaching 74 km/h, according to satellite observations. During this phase, the cyclone gradually evolved from baroclinic to a barotropic system, developing a tropical-like structure on the afternoon of 9 September. Daniel subsequently reached the northeastern Libyan coast and moved inland. The dissipation occurred on 11/09/2023.

Human impact

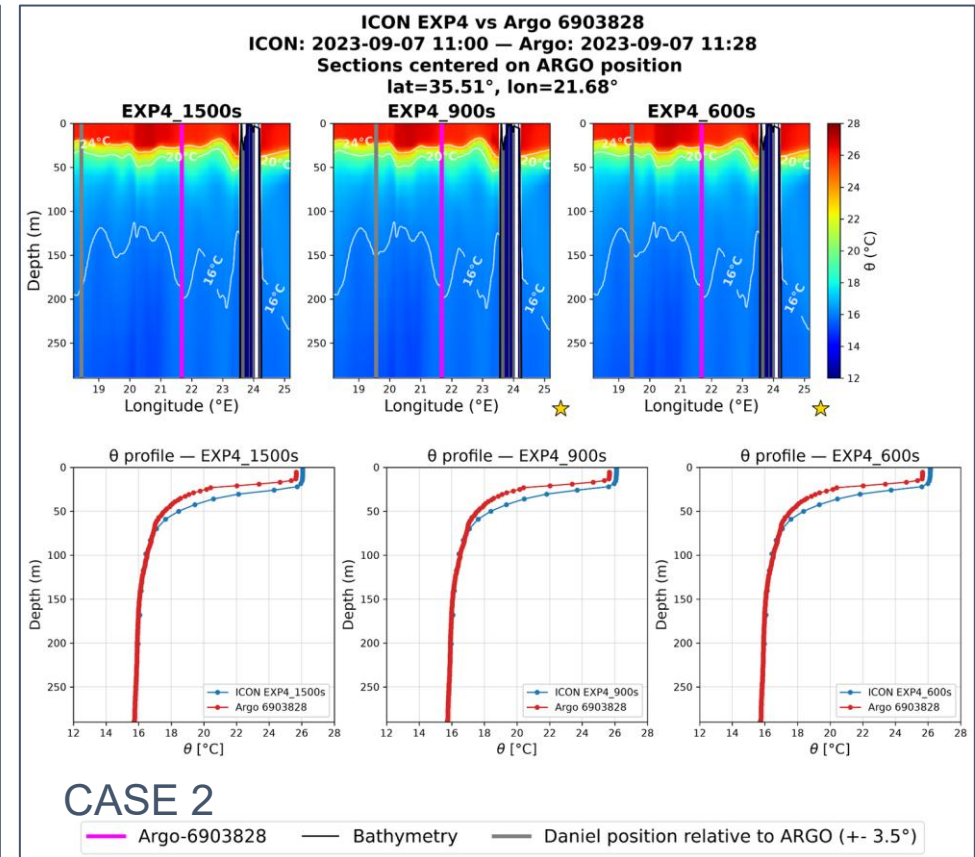
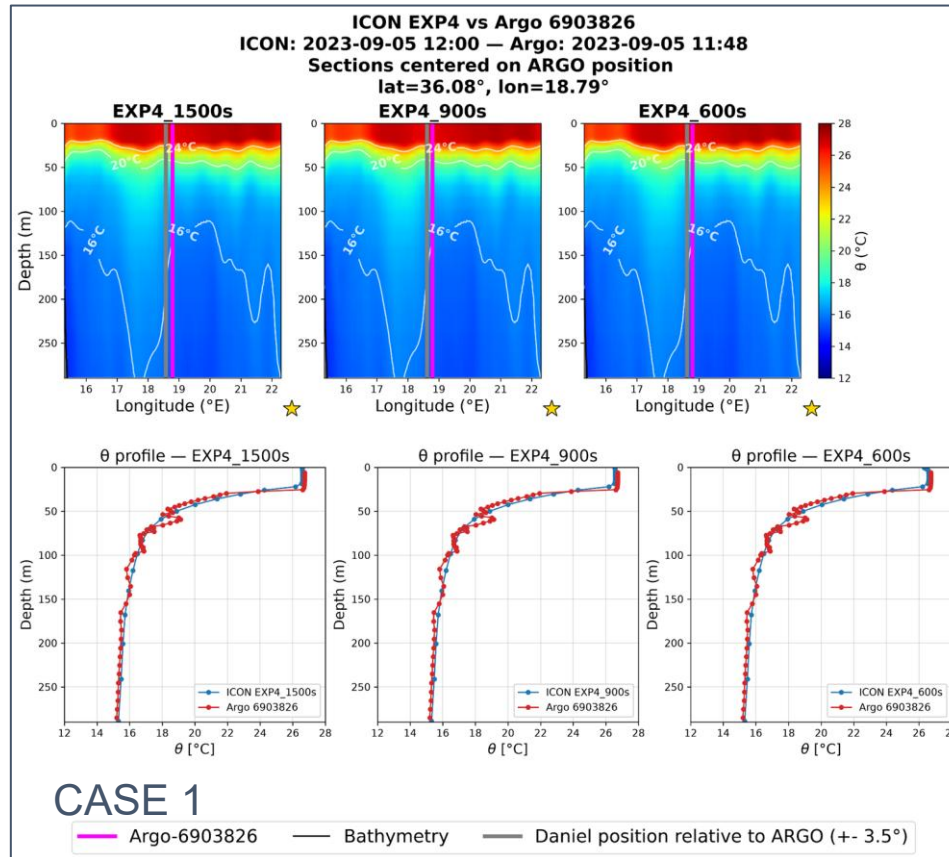
- ~ **11000 confirmed fatalities** were reported across the affected region (United Nations).
- In Libya, nearly **6000 deaths** were attributed to the collapse of the Derna and Mansour dams.
- More than **43000 people were displaced** across Greece, Turkey, Bulgaria, and Libya (United Nations).



The case of medicane Daniel

Potential temperature sections (top) and **collocated vertical profiles** (bottom) from three ICON coupled experiments compared with ARGO floats 6903826 and 6903828.

The magenta line marks the Argo float longitude, the grey line the position of Daniel at the closest model timestep. A gold star indicates that Daniel is within 3.5° of the Argo float at that time.



FIRST RESULTS



Potential Sea Surface Temperature

ICON experiments show a slight warm bias compared to ARGO measurements.

The warm bias increases with simulation time, reaching up to 0.5°C at +35h.

Thermocline Depth

ICON places thermocline at greater depths and over wider ranges compared to ARGO.

CASE 1: 24-54 m vs 26-28 m

CASE 2: 24-28 m vs 16-22 m



... the Workshop on regional ICON atm-ocean framework ...

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The Workshop on regional ICON Coupled atm-ocean

Italian initiative



Hosted by the REMHI (Regional Models and GeoHydrological Impact) Division of CMCC, Caserta.

Objective: assess the state of the art of ICON-based coupled regional modelling in Italy, comparing the coupled system in the operational chain of participants and outline a coordinated strategy under the COSMO Consortium.

CMCC

REMHI Division
Institute for Climate Resilience

Caserta



CETEMPS

Centre of Excellence,
University of L'Aquila

L'Aquila



Scope

Assess the state of the art of ICON-based coupled regional modelling in Italy and outline a coordinated strategy under the COSMO Consortium

Key findings

- ICON-O-LAM is a promising and architecturally efficient route to fully coupled regional simulations — integrated atmosphere–ocean namelist, consistent with the global ICON framework
- Campanale et al. (2026) on medicane Ianos: proof of concept and reference benchmark; CMCC–DWD partnership ensures continuity with the official ICON development line
- Building blocks already available (grid preparation, downscaling, initialisation, coupling)
- Priority gaps: missing consolidated documentation and benchmark configurations for ICON-O-LAM; incomplete characterisation under high-impact regimes, including sensitivity to ocean boundary forcing

Arpae

Regional Agency for Prevention,
Environment and Energy of Emilia-
Romagna

Bologna



CNMCA

Italian Air Force
Meteorological Service

Pratica di Mare



Anchored on Campanale et al. (2026, Atmospheric Research) and on the CMCC–DWD collaboration on ICON coupled development at regional scale.



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