# The Mediterranean Extreme Events Experiment (M3E)

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## Aims of M3E

M3E is a new project with 10 partners from Europe and the USA. By deploying drifting buoys equipped with barometers into the data-sparse Ionian Sea and central Mediterranean, M3E aims to:

1. improve weather forecasting of extreme events
2. understand cyclone development across the Mediterranean
3. contribute to the Global Atmospheric River Reconnaissance Program (GARRP)

## Buoy types, deployments, and observations

The Global Drifter Program (GDP; Centurioni et al., 2019) provided the Surface Velocity Program Barometer drifters (https://gdp.ucsd.edu/ldl/svpb/) deployed by M3E. The GDP is based at the Scripps Institution of Oceanography and is funded by the National Oceanic and Atmospheric Administration (NOAA). Two MiniMet drifters were also used (Fig. 1).

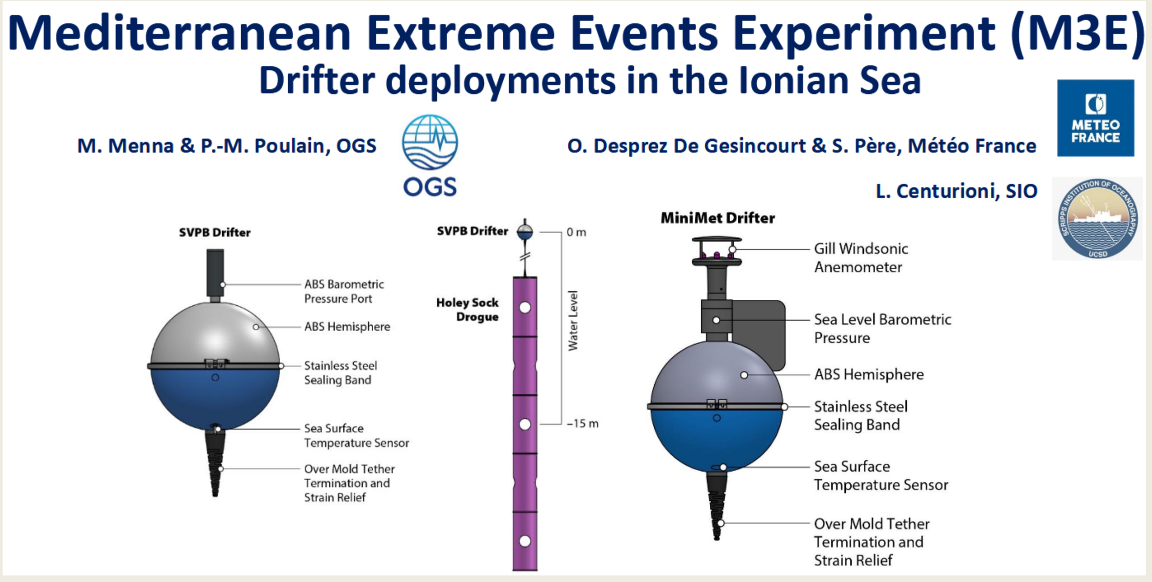



*Fig. 1: Buoy types used in M3E.*

*Fig. 2: A buoy released from the CMA CGM Montoir (September 2025).*

The deployments started in September 2025 and were made from the research vessels Laura Bassi and Meteor and commercial shipping (Fig. 2). In total, 20 buoys have been released.

The drifting buoys measure sea surface temperature (SST) and barometric pressure which are relayed via satellite to shore in near-real time every hour and then uploaded to the World Meteorological Organization Global Telecommunications System within minutes from their collection for assimilation into weather forecast systems.

## Buoy locations

The buoys drifted with the currents (Fig. 3) and the stations providing surface pressure observations across the Mediterranean are shown in Figure 4. The buoys deployed by M3E are filling in a data-sparse region (large navy markers).

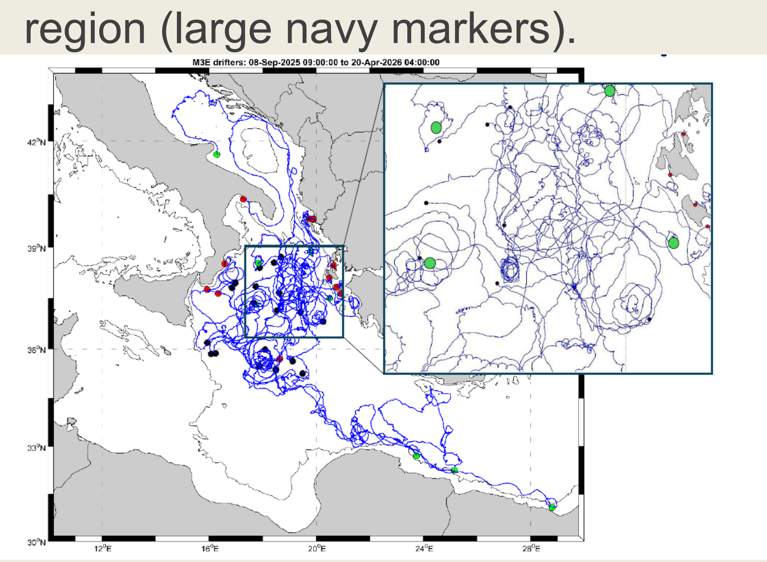


*Fig. 3: Buoy trajectories.*

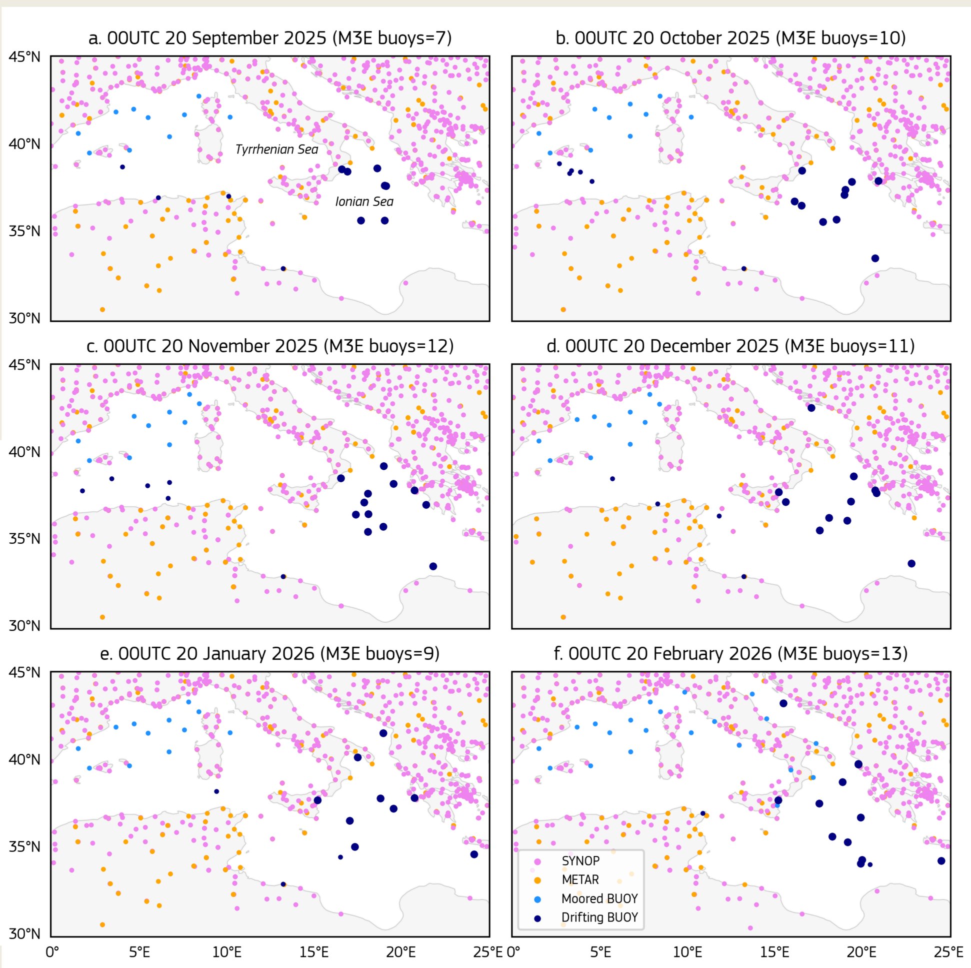



*Fig. 4: Surface pressure stations across the Mediterranean from September 2025 to February 2026. M3E buoys are given by large navy markers.*

## Storm Harry: large-scale circulation

In January 2026, storm Harry caused extreme precipitation and flooding across Italy, Greece, and northern Africa and extreme waves across the Mediterranean. The evolution of the 500-hPa geopotential height, 250-hPa wind speed, mean sea-level pressure and water vapor fluxes are shown in Figures 5 and 6.

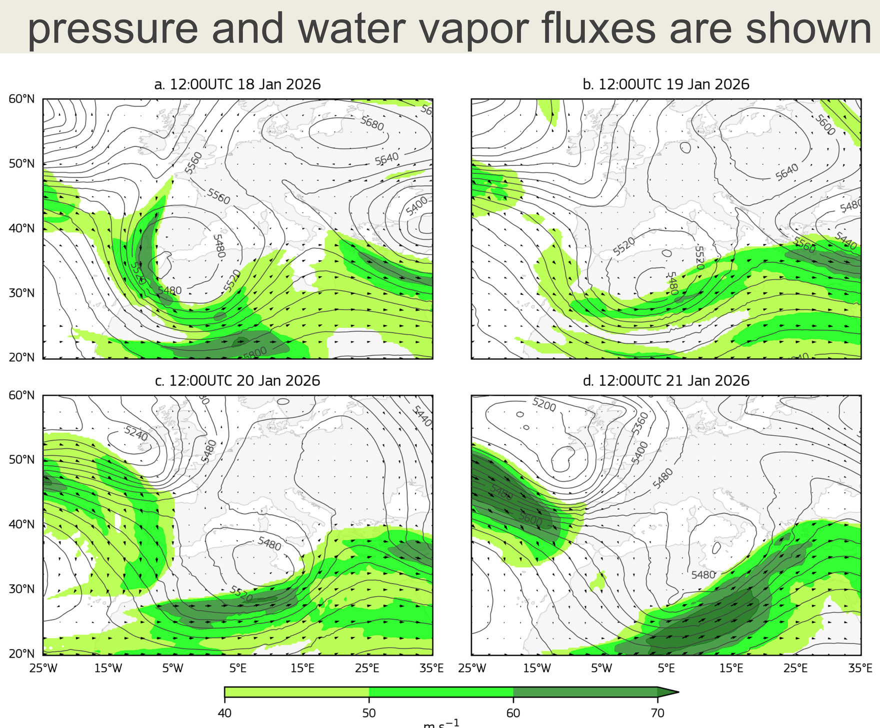



*Fig. 5: The 500-hPa geopotential height (in metres; line contours) and 250-hPa wind speeds (filled contours) at the 12UTC analysis time from 18–21 January 2026 in the ECMWF model. The arrows denote the wind direction at 250 hPa.*

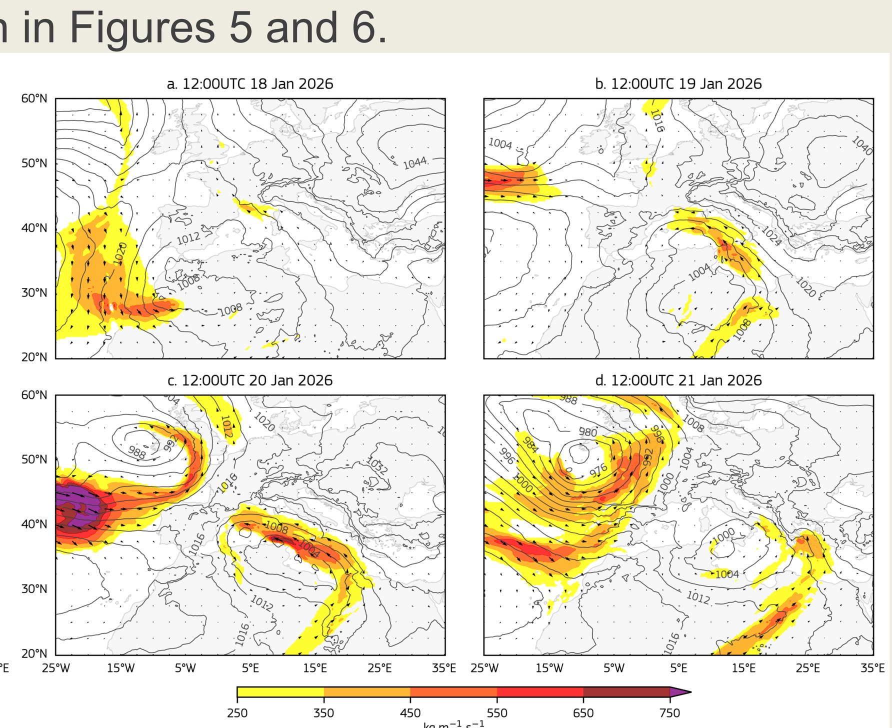



*Fig. 6: The mean sea-level pressure (MSLP in hPa; line contours) and vertically-integrated water vapour flux (filled contours) at the 12UTC analysis time from 18–21 January 2026 in the ECMWF model. The arrows denote the direction of the water vapour flux.*

## Storm Harry: precipitation

On the 19 and 20 January 2026 (Fig. 7a-b) the largest precipitation totals occurred in the eastern parts of Sardinia and Sicily and in the southern tip of Calabria. By the 21 January 2026 (Fig. 7c), the storm and the main precipitation-affected area had moved to the east and was over Greece. The 3-day period (Fig. 7d) highlights the extreme nature of the precipitation; 23 stations recorded more than 300 mm of precipitation (orange markers in Fig. 7d). It was the persistent, south-easterly and east-southeasterly strong water vapour fluxes (Fig. 6b-c) impinging on the significant orography in Sardinia, Sicily, and Calabria that led to orographic enhancement of precipitation and the large resulting totals.

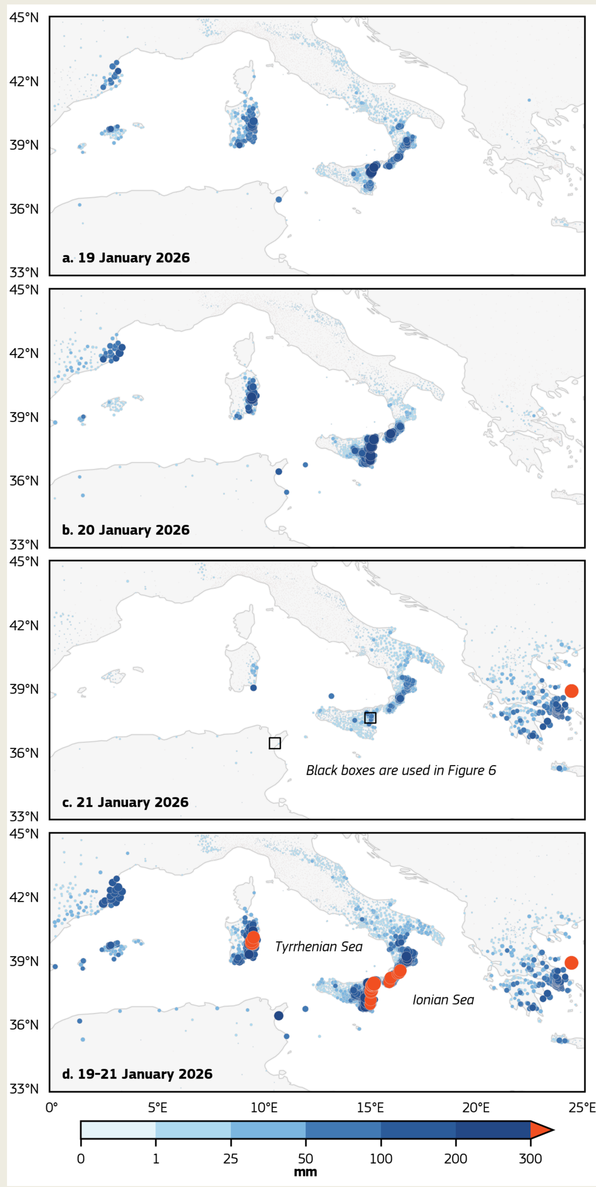



*Fig. 7: Daily precipitation accumulated from 00–00UTC on (a) 19 January 2026, (b) 20 January 2026, (c) 21 January 2026, and (d) the 3-day precipitation accumulation from 19–21 January 2026. The marker sizes correspond to the precipitation totals.*

## Observation impacts: FSOI and OSE

The Forecast Sensitivity to Observation Impact (FSOI) analysis is used at ECMWF to estimate the impact of observations on the forecasts. The FSOI is an efficient tool for day-to-day monitoring, and its 'adjoint-based' approach uses a global dry energy norm to approximate the contribution of different types of observations to the increase or decrease in 24-hr forecast error. A negative FSOI value implies a deterministic forecast error reduction and hence a benefit to the system.

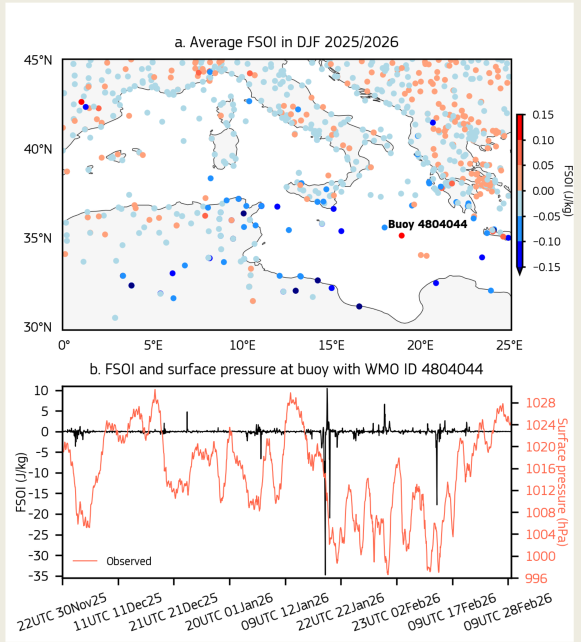
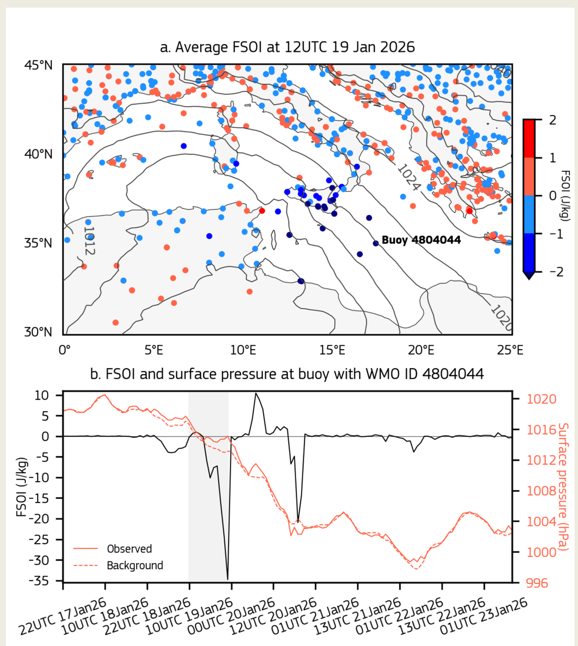



*Fig. 8 (left): (a) Average FSOI per datum at stations with at least 100 observations during boreal winter 2025/2026. (b) Time series of the FSOI (black line) and observed surface pressure (red line) at the buoy with WMO ID 4804044 from 2200UTC 30 November 2025 to 2100UTC 28 February 2026.*

*Fig. 9 (right): Average FSOI per datum at stations with at least six observations in the 1200UTC 19 January 2026 ECMWF long window data assimilation system. (b) Time series of the FSOI (black line) and observed and background (3-15 hr forecast) surface pressure (red lines) at the buoy with WMO ID 4804044 from 0200UTC 17 January to 0900UTC 23 January 2026.*




The average FSOI values in boreal winter 2025/2026 show that the buoys deployed by M3E were generally beneficial to the ECMWF model (Fig. 8). In storm Harry, the buoys' observations were useful for better resolving the surface pressure (Fig. 9).

Observing System Experiments (OSEs) are a technique to determine the forecast impact of a particular set of observations. These are undertaken by comparing the forecasts from an experiment using the full observing system – a control run – against an experiment in which certain components of the observing system have been removed – a denial run.

An OSE withholding all drifting buoys in the Mediterranean suggests that the buoys' surface pressure observations were important in capturing the mesoscale low-pressure systems near the Balearic Islands (Fig. 10c).

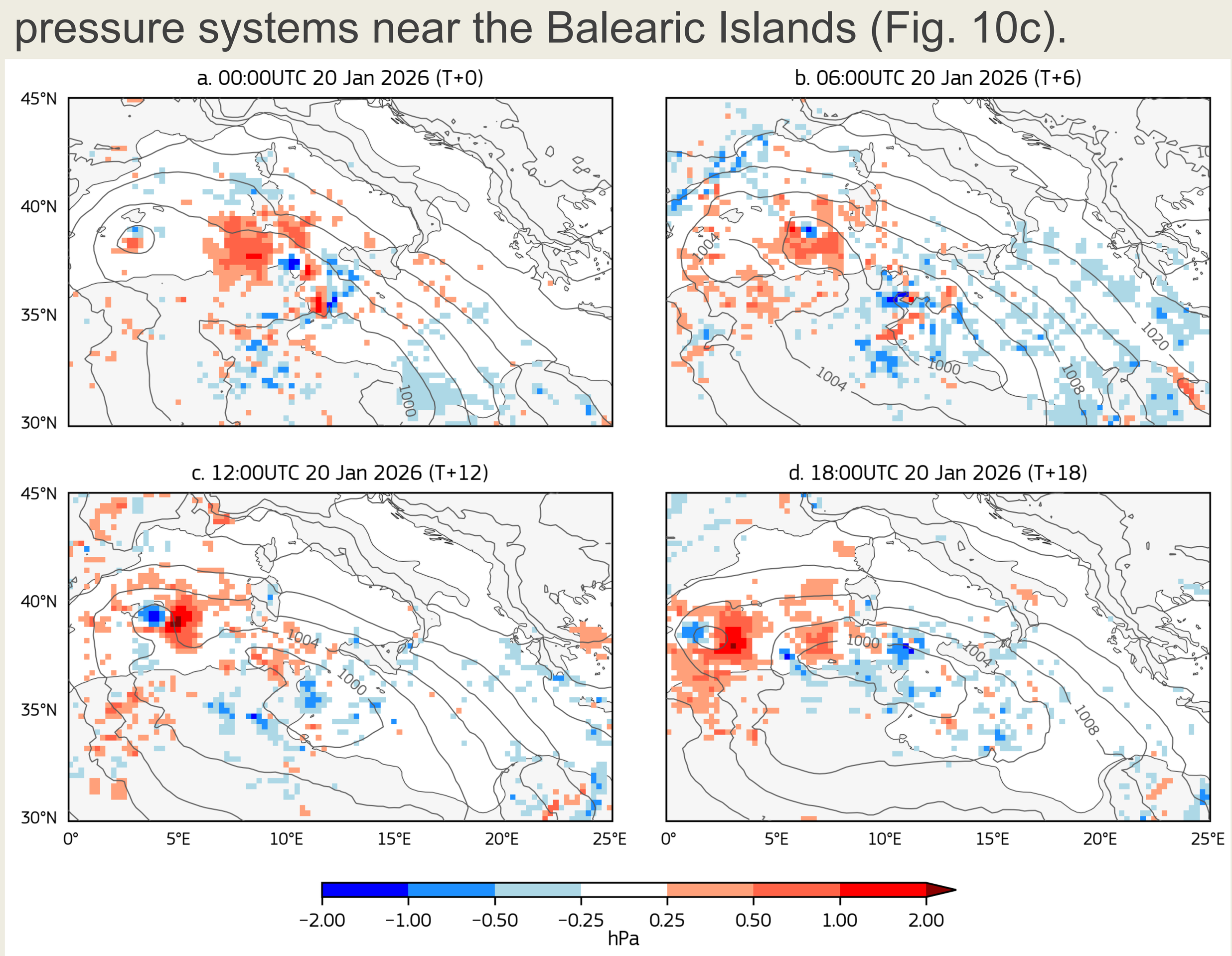



*Fig. 10: The MSLP in the OSE control forecast (in hPa; line contours) and the control-minus-denial MSLP differences (filled contours) at (a) T+0, (b) T+6, (c) T+12, and (d) T+18 from the 00UTC 20 January 2026 OSE forecasts.*

## Conclusions and M3E plans

- M3E has helped to fill in a data-sparse part of the Global Observing System
- 20 drifting buoys have been deployed since September 2025
- Storm Harry caused extreme precipitation, flooding, and extreme waves
- M3E surface pressure observations were beneficial during storm Harry
- Future buoy deployments are planned for the Tyrrhenian and Ionian Seas
- Additional partners are being approached across the Mediterranean

## Further Reading

Centurioni, L. R. et al. (2019) Global in situ observations of essential climate and ocean variables at the air-sea interface. Frontiers in Marine Science, 6, 419. Available from: https://doi.org/10.3389/fmars.2019.00419.

Lavers, D. A. et al. (2025) Increasing observation coverage in the Mediterranean, ECMWF Newsletter 185. Available from: https://www.ecmwf.int/en/newsletter/185/news/increasing-observation-coverage-mediterranean.