Supplementary Material

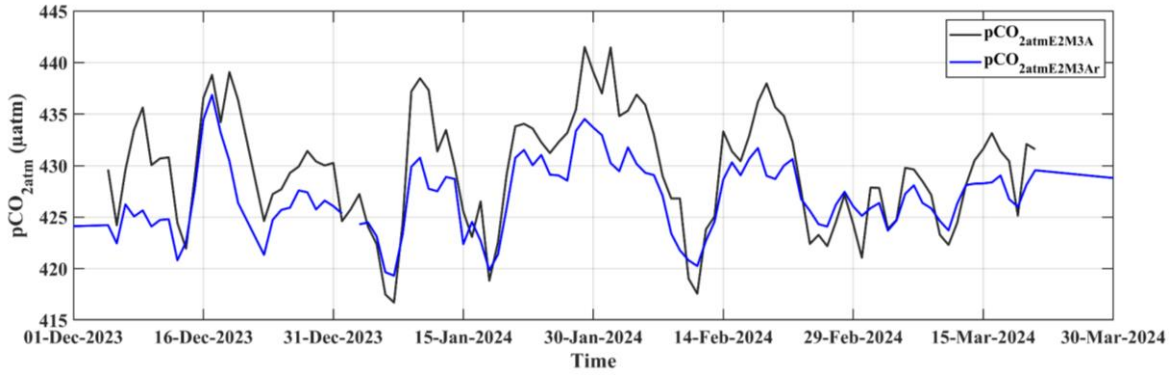
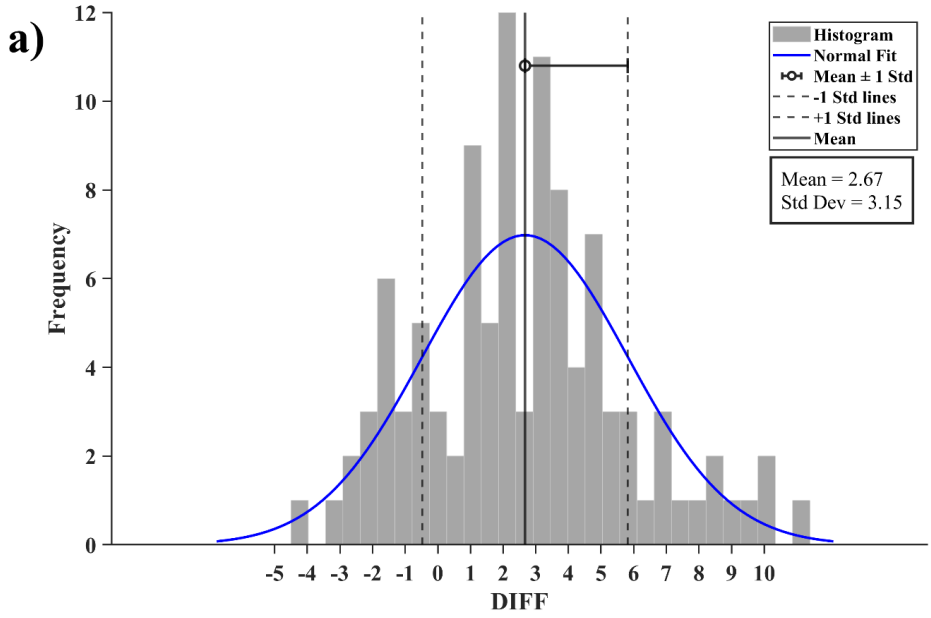


Figure S1. Time series of daily pCO_{2atm} measured at the EMSO-E2M3A (pCO_{2atm_E2M3A}, µatm) in black and the pCO_{2atm} calculated from xCO_2 from Lampedusa (pCO_{2atm_E2M3Ar}, µatm) in blue between December 2023 and March 2024. pCO_{2atm_E2M3Ar} have been calculated according to Eq. 1 and Eq. 2.



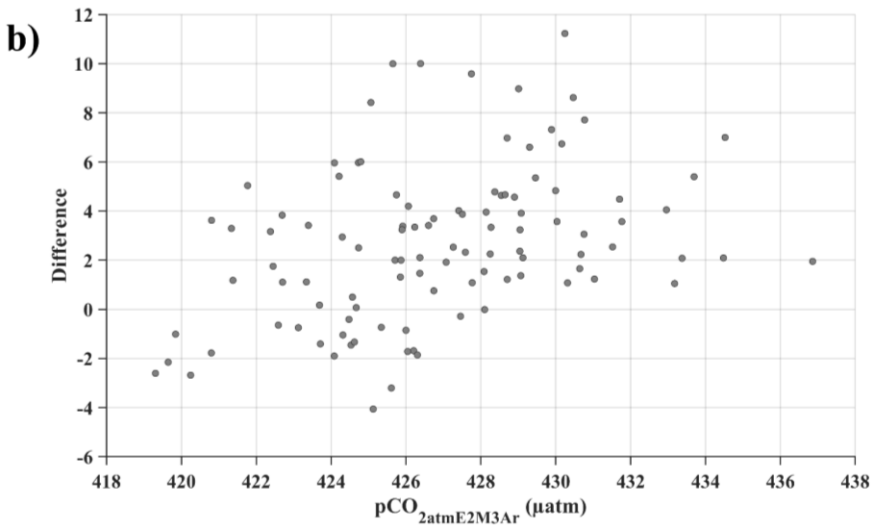


Figure S2. a) Histogram of the difference between pCO_{2atm_E2M3A} (µatm) and pCO_{2atm_E2M3Ar} (µatm) including standard deviation (Std Dev) and mean of the difference (Mean); and b) Scatterplot of the difference against pCO_{2atm_E2M3Ar} (µatm). The calculations were performed considering the data in the period from December 2023 to March 2024.

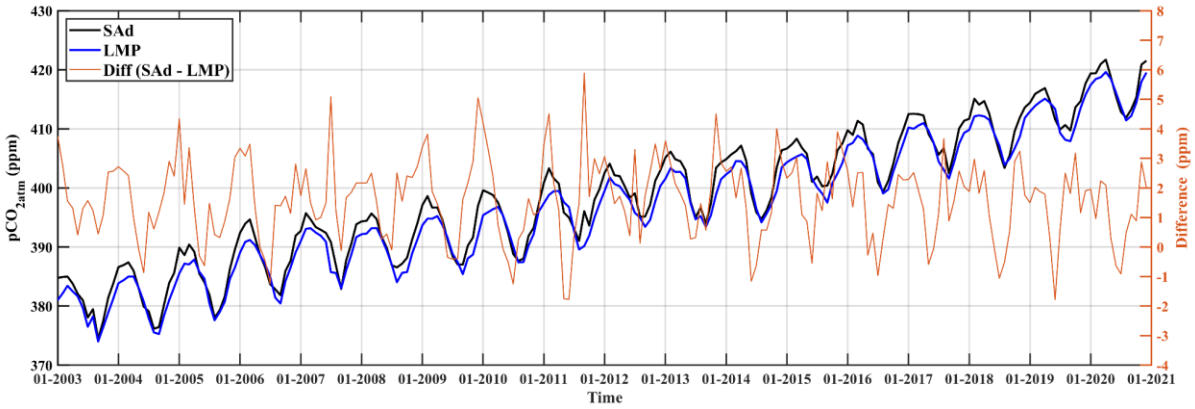
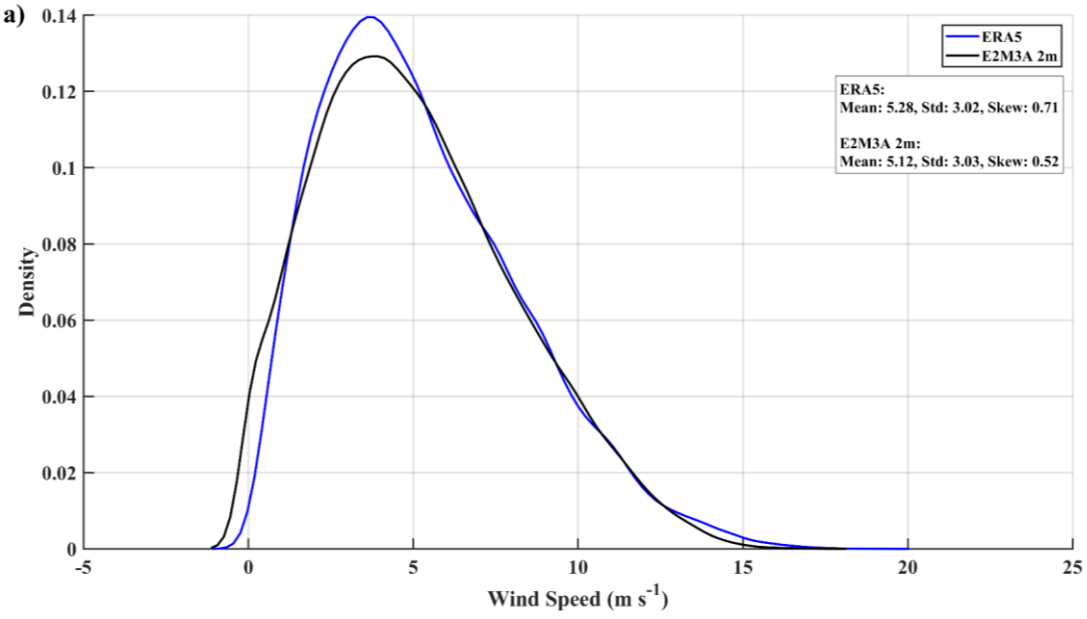


Figure S3. Monthly time series of pCO_{2atm} (ppm) at EMSO-E2M3A (SAd) and at Lampedusa (LMP) in blue and black respectively from the CAMS reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF). The difference between the values in the two sites (SAd - LMP) is represented by the orange line.



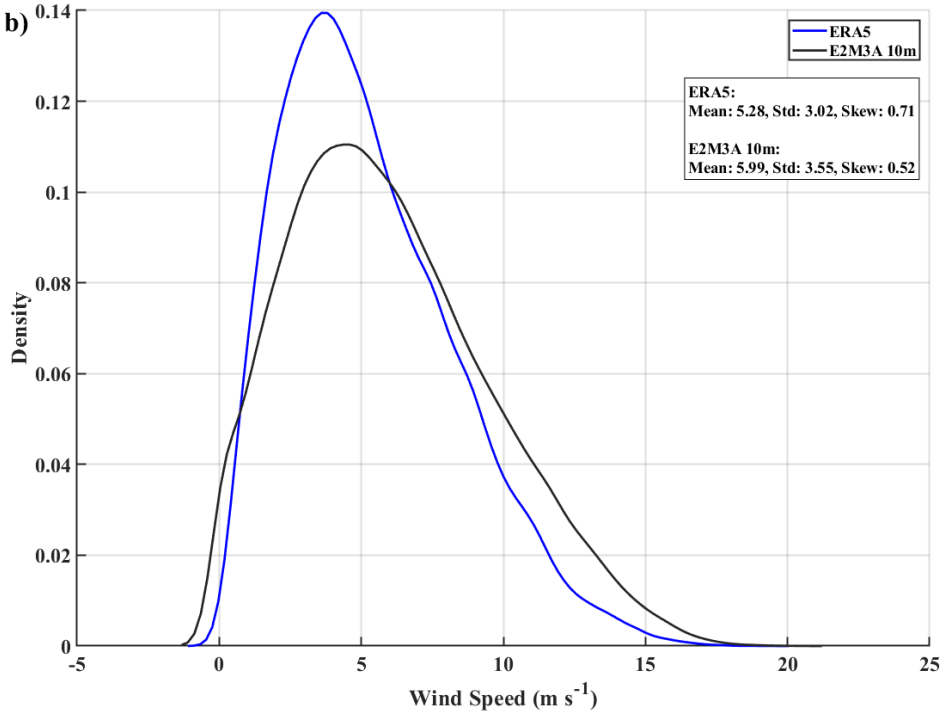


Figure S4. Distribution of a) wind speed data (m s^{-1}) measured at EMSO-E2M3A at 2 m height and from ERA5, b) Wind speed data (m s^{-1}) measured at EMSO-E2M3A at 10 m height and from ERA5. WSPD measured at EMSO-E2M3A is represented by the black curve, while WSPD from ERA5 is represented by the blue curve in both panels. The distribution refers to hourly data in the period from 2015 to 2024. For every panel, the mean difference (Mean), standard deviation (Std Dev), and skewness (Skew) is also presented.

A more detailed analysis of the different wind datasets, i.e., in situ wind speed measured at the EMSO-E2M3A observatory at 2 m height ($WSPD_{E2M3A2m}$, m s^{-1}) and the converted wind speed at 10 height ($WSPD_{E2M3A10m}$, m s^{-1}) and ERA5 ($WSPD_{ERA5}$, m s^{-1}) wind speed was performed. A better agreement was found between $WSPD_{E2M3A2m}$ and $WSPD_{ERA5}$ (mean difference of -0.16 m s^{-1}), while a higher difference of 0.71 m s^{-1} between $WSPD_{E2M3A10m}$ and $WSPD_{ERA5}$ was highlighted. Both datasets displayed considerable variability, with the largest discrepancies occurring at the distribution tails during high wind events. Specifically, ERA5 tended to report stronger winds than $WSPD_{E2M3A2m}$ for velocities > 15 m s^{-1}, whereas $WSPD_{E2M3A10m}$ exceeded ERA5 under the same conditions (Fig. S4a, S4b). In addition, ERA5 data showed greater skewness compared to in situ observations, suggesting a systematic tendency to capture with a higher frequency strong wind speed events. The differences between $WSPD_{E2M3A}$ at both heights and $WSPD_{ERA5}$ were also evaluated by classifying wind speeds according to the Beaufort scale (https://www.rmets.org/metmatters/beaufort-wind-scale), in order to assess whether discrepancies were more pronounced under specific wind conditions, particularly extreme events. The Beaufort scale, widely used in meteorology, relates mean wind speed at 10 m height to observed conditions at sea or on land, and categorizes winds into discrete intervals. When $WSPD_{E2M3A}$ and $WSPD_{ERA5}$ values did not fall exactly within these intervals, they were assigned to the

closest category based on proximity to the category mean. Consistent with previous results, differences between datasets were small across most categories, but tended to increase at higher wind speeds.

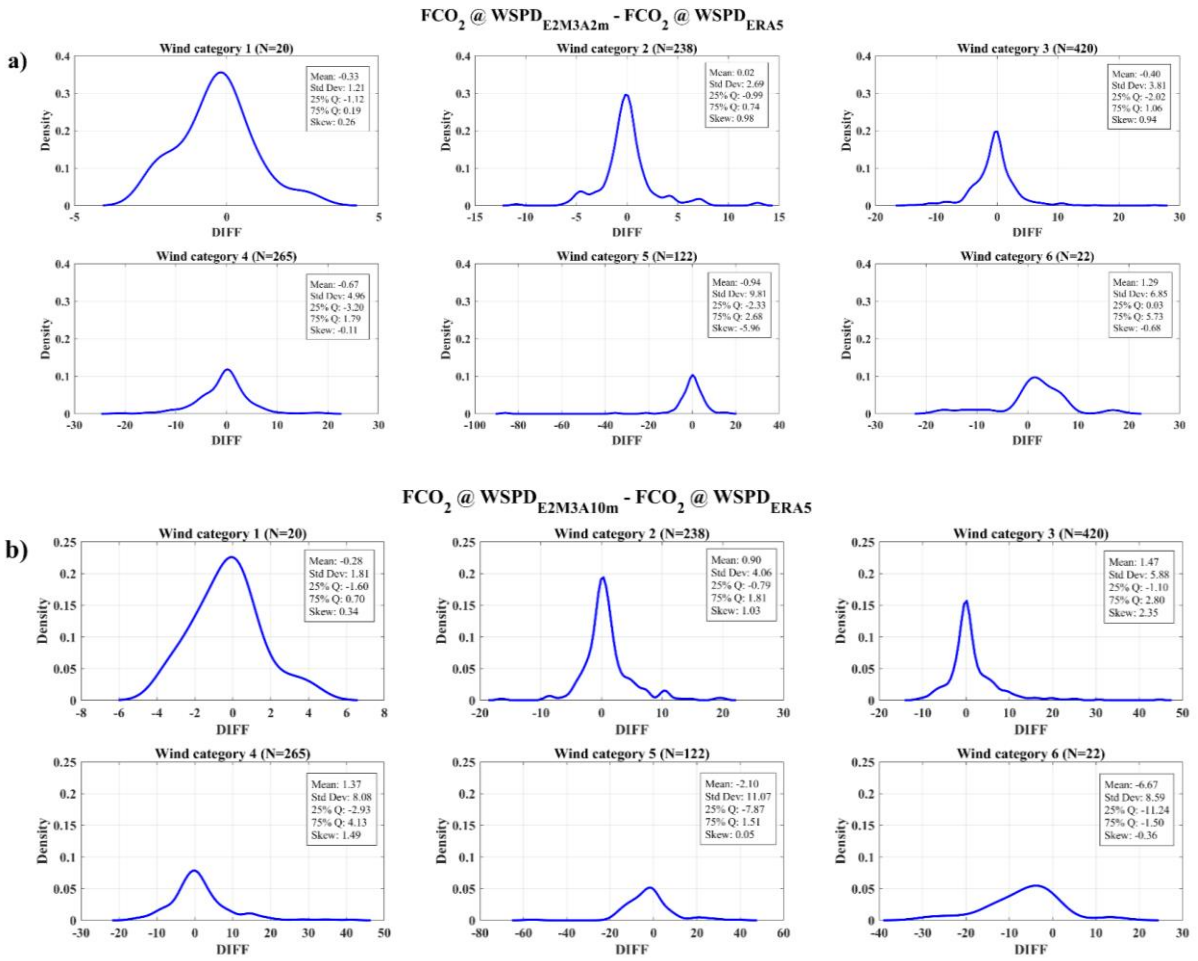


Figure S5. Distribution of the differences of CO_2 flux for each wind category defined according ERA5 wind speed between a) fluxes calculated using $WSPD_{E2M3A2m}$ (m s^{-1}) and $WSPD_{ERA5}$ (m s^{-1}) and b) CO_2 flux calculated using $WSPD_{E2M3A10m}$ (m s^{-1}) and $WSPD_{ERA5}$ (m s^{-1}). Wind categories are defined in Table 3. N refers to the number of events for each wind category in the period 2015-2024. For every panel, the mean difference (Mean), standard deviation (Std Dev), 25 % and 75 % percentile of the distribution and skewness (Skew) is also presented.

The impact on FCO_2 estimates was low within Beaufort categories between 2 and 5 (wind speed between 1.7 and 10.6 m s^{-1}), which encompass the majority of events at EMSO-E2M3A, indicating broad consistency among datasets under typical conditions (Fig. S5). However, larger discrepancies emerged at higher wind categories, especially between $WSPD_{E2M3A10m}$ and $WSPD_{ERA5}$. Both comparisons also showed substantial data dispersion, with standard deviations increasing with wind category, suggesting that variability in FCO_2 estimates derived from different wind products becomes more relevant at higher wind speeds.

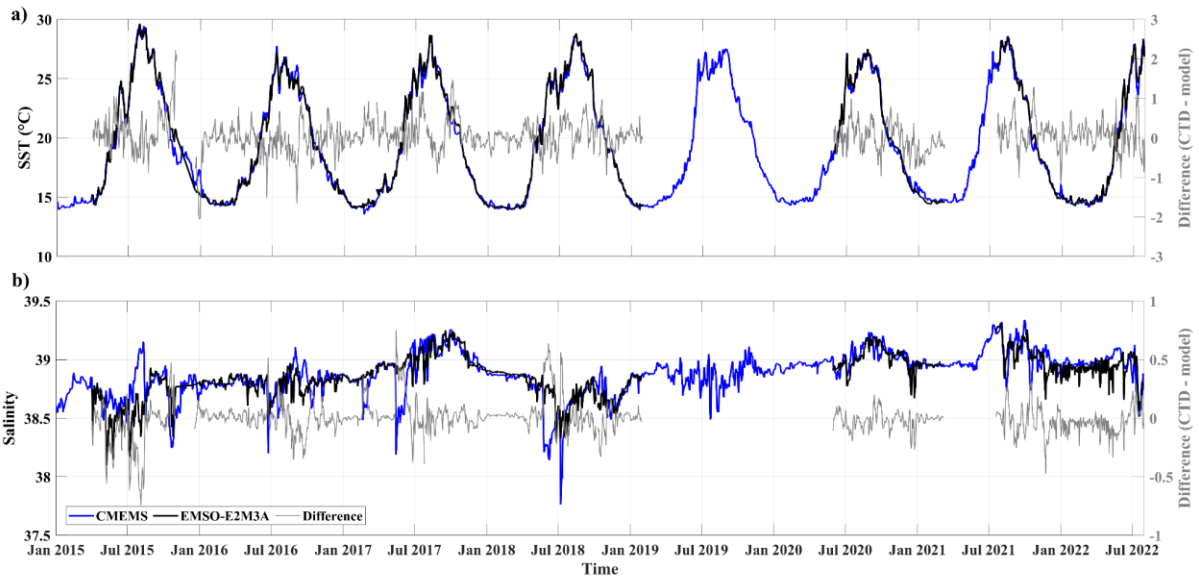


Figure S6. Comparison of daily time series of a) Sea surface temperature (SST, °C) and b) Salinity measured by the SBE ODO sensor installed on the EMSO-E2M3A regional facility and from CMEMS reanalysis in black and grey respectively. The difference between EMSO-E2M3A and model data is displayed in both panels by the blue curves.