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Air-sea CO_2 fluxes from pCO_2 continuous measurements in a coastal area: the role of atmospheric forcing under different wintry seasons

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While confidence in estimating air–sea CO_2 fluxes in open sea environments is increasing, a large uncertainty remains in defining the role played by coastal ecosystems as CO_2 sinks or sources. This is due to their highly variable oceanographic and climatic characteristics and to the effects of continental inputs.

In the framework of JERICO and JERICO-NEXT projects, several stations located in European coastal and marginal seas were equipped with automated $p\mathrm{CO_2}$ sensors and they are currently working together, in order to acquire comparable data and to explore the role of biological and atmospheric drivers in determining the observed variability. Within this network, the PALOMA station, located in the northernmost area of the Adriatic Sea, inside the Gulf of Trieste (25 m of depth), is continuously collecting dissolved $p\mathrm{CO_2}$ data at 3 m below sea surface since 2012.

The Northern Adriatic is a shallow, semi-enclosed continental shelf in the northernmost part of the Mediterranean Sea subject to strong anthropogenic pressure. The effect of the atmospheric forcing on its waters is remarkable, resulting in a great variability of temperature, salinity and stratification of the water column. During winters characterized by low river discharges, cold temperatures and strong wind from the north-east (i.e. Bora), very cold and dense water masses (density anomalies $>$ 29.2 kg m-3) may form and flow towards south as a subsurface buoyancy-driven current contributing to the formation of the bottom waters of the Eastern Mediterranean basin. These conditions promote the absorption of atmospheric CO_2 due to low seawater temperatures that enhance CO_2 solubility, making the sub-basin acting as a CO_2 sink. Recent studies have shown that this process could represent a preferential path for the absorption and transfer of anthropogenic CO_2 in the deep thermohaline cells of the Mediterranean.

In this work, we present and discuss the effects of meteorological conditions on CO_2 air-sea fluxes, using the data collected in four wintry seasons from 2012 to 2016.

In winter 2012-2013, the presence of lower temperatures and the occurrence of several events of Bora (wind speed $>$ 15 ms^{-1}) produced a decrease of the sea surface temperature down to 8.3 C leading to more favorable conditions for CO_2absorption.

The following winter was characterized by a higher air temperature, weaker winds, intense precipitation and river discharges larger than the average of the previous decade. These distinct hydrological and meteorological conditions significantly affected the sea surface $p\mathrm{CO_2}$ that was lower in 2012-2013 (median $p\mathrm{CO_2}$ = 324 $\pm$8.9 μatm) than in 2013-2014 (median $p\mathrm{CO_2}$ = 343 $\pm$ 9.0 μatm). Sea always absorbed CO_2 from the atmosphere, but average daily fluxes were almost doubled during the colder winter 2012-2013 (F = -6.4 mmol – CO_2 $\mathrm{m}^{-2}\mathrm{d}^{-1}$) than in the milder winter 2013-2014 (F = -3.7 mmol –CO_2 $\mathrm{m}^{-2}\mathrm{d}^{-1}$).

Our results highlight the sensitivity of the CO_2 sink in the northern Adriatic to changes in the meteorological conditions and suggest that its capability of sequestering CO_2 could dramatically decrease in the next decades under a climate change scenario.