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Current inversion and wind relaxation events along the western inner shelf of the Gulf of Cadiz

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At Eastern Boundary Upwelling Systems, warm counter-currents leaning along the coast are recurrently observed inshore of previously upwelled cold water. This feature is well-evidenced in summer by SST satellite imagery along the western part of the northern continental margin of the Gulf of Cadiz, Southern Iberia. At this location, wind driven upwelling prevails roughly from April till October, producing a typical equatorward (eastward) alongshore coastal circulation. This flow temporally alternates with a warm coastal counter-current propagating poleward (westward) that develops during non-upwelling (relaxation) wind conditions. These opposed circulation regimes occur also in winter but without the generation of thermal fronts.
The onset of counter-currents along the inner shelf of the Gulf of Cadiz is driven by complex processes. It is generally assumed that inversion events develop when a background alongshore pressure gradient resulting from local wind or large scale atmospheric pressure systems becomes unbalanced during relaxation events. Additional mechanisms may include: strong upwelling jets producing local pressure gradients in the lee of capes and promontories; advection of warm water from very shallow inland areas in the eastern Gulf of Cadiz; and, flow response to short but strong westward wind events (Leventer) that typically occur after upwelling favourable winds.
Until now, relatively short (less than 1 month) hydrodynamic observations were available for the study of the processes driving current inversions. The present research compiles 6 Acoustic Doppler Current Meter (ADCP) deployments of 2 to 3 months duration at a single location on the inner shelf (20 m water depth), constituting about 18 months of hourly records. Wind data from an offshore buoy (Cadiz) are also used to define relaxation periods, based on selected thresholds. The excellent correspondence between inversion periods and relaxations confirms that the circulation regime in this area is strongly related to wind conditions. This dataset is used to statistically characterise the seasonal patterns of the current inversion periods (e.g., timing, peak velocity, duration, temperature variations), to investigate the seasonality of these patterns, and to relate them with the wind conditions. Principal Component Analysis (PCA) is also applied to the velocity profiles to depict the dynamics of the barotropic (1 layer-) and baroclinic (2 layer-) flows during inversion events. The results give detailed insights about the mechanisms that drive the coastal counter current. The observed current inversions are produced by the interplay of a variety of factors whose relevance as drivers has a strong seasonal variability.