Horizontal and vertical analysis of sea breezes in the Gulf of Cádiz from surface stations and radiosoundings

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Observational strategy

Coastal long-term stations strategically deployed to analyse the horizontal extension of the breezes, including both the location and pictures. Note how **La Jara station** includes a sonic anemometer at 10 m above sea level (asl) and the **Chipiona station** an IRGASON to measure energy fluxes from a lighthouse (68 m above sea level). All the stations were installed to avoid perturbations from winds coming from the sea. **Radiosoundings** were launched from coastal locations during sea breeze events.

Blue and yellow arrows represent a schematic picture of the typical conditions leading to sea breeze formation in the northern area of the region, with a clear "line" of separation (dashed line) between **daytime breezes** and **easterly** winds (locally known as *Levante*) close to the Strait of Gibraltar. Note how the latitudinal position of this separation line is variable, depending on the intensity of the easterly winds and other factors.

From Google Earth. Data IO. NOAA. U.S Navy. NGA, GEBCO. Satellite image from Landsat / Copernicus.

Research Questions

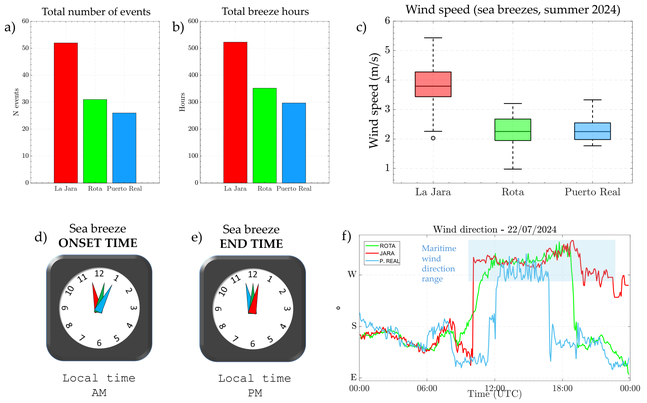
1. How do the sea breezes spread **horizontally** under different **synoptic** conditions? How do the breezes impact the **2m temperature** **along the coast** and **inland**?

2. How are the surface (oceanic) **turbulent fluxes** under breeze conditions? How are the turbulent measurements at the **surface** and at **70 m asl (lighthouse)**? What are the impacts of **tidal variations**?

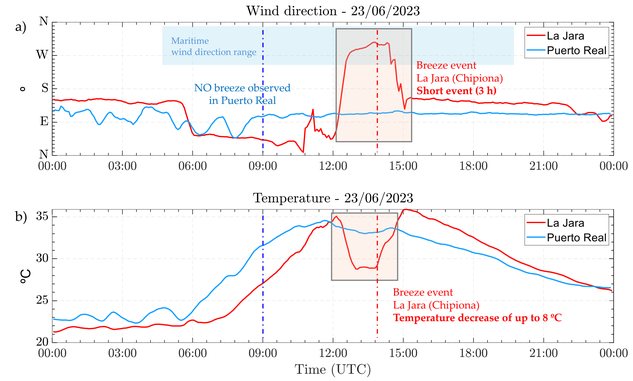
3. What are the breeze's **vertical thermodynamic** characteristics? How does the **ABL evolve** during the events?

**Colours used in each question are associated with specific data (colour points on the map above)*

Question 1. Horizontal extension of breezes and effect in temperature

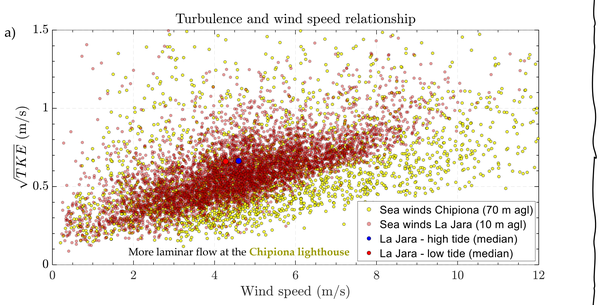


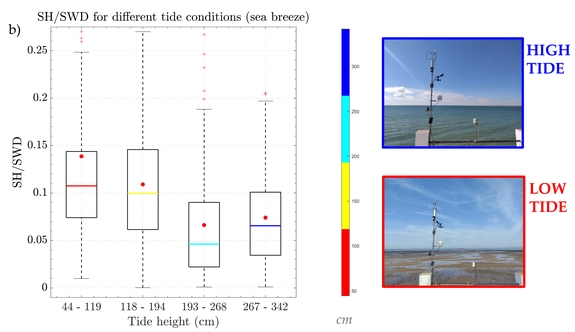
Basic statistics of sea breezes formed in the area during June, July and August 2024. a) Number of events in each station; b) Total hours with sea breezes; c) Wind speed distribution during the breezes; d, e) Onset and end mean time of the events for each site; f) Example of a sea breeze event (wind direction) observed at the three sites, with the corresponding delay in Rota and Puerto Real



Horizontal heterogeneities of breezes and impact on temperature (example for the event of 23rd June 2023): wind direction (a) and surface temperature (b) for the northernmost station (La Jara, red) and the southernmost one (Puerto Real, blue). Vertical blue and red dashed lines indicate the time of radiosoundings launched in La Jara on the same day (see figure below).

Question 2. Oceanic turbulent fluxes & tides impact

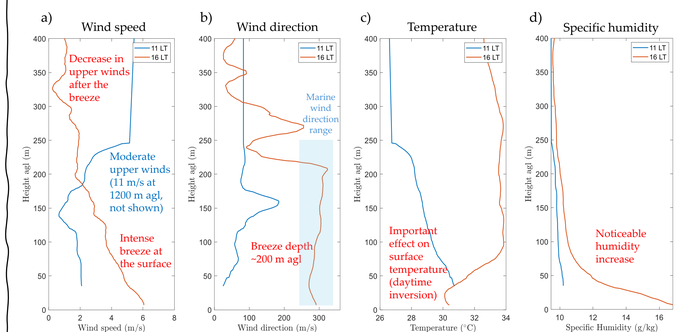




a) Wind speed versus $TKE^{1/2}$ using data from La Jara station (Young 81000 sonic anemometer) and Chipiona lighthouse (IRGASON). For La Jara station, the median values have also been separated for high and low tide conditions (blue and red points, respectively). Note the lower slope of the scatter plot for the Chipiona lighthouse data. Note also how during low tide (red point), the turbulence remains the same as during high tide (blue point), even for a lower median wind speed. The data period is not coincidental for both locations; the comparison should be done with caution.

b) Distribution of sensible heat flux (SH) measured by the sonic anemometer installed at the coastline in La Jara station for different tide conditions (x-axis, see also colorbar and pictures on the right side) during sea breezes. The SH is divided by the downward short-wave radiation (SWD) to (somehow) eliminate the effect of the radiation diurnal cycle in SH. Only daytime data were used. The red points in boxplots are the main values; the horizontal-coloured lines are the median ones.

Question 3. Breeze's vertical features



Example of vertical profiles during a sea breeze event (coastal radiosoundings launched from La Jara station during the 23rd June 2023). The event was characterised by synoptic wind from the east. a) Wind speed; b) Wind direction; c) Temperature; d) Specific humidity.
Blue: before formation, 09 UTC (11 LT);
Red: breeze well formed, see lower layers, 14 UTC (16 LT);

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PRELIMINARY

High variability at the coast: the southernmost stations are more affected by synoptic easterly winds, while **clearer, more numerous, stronger and longer sea breezes are observed in the northern area**.
Larger **temperature impact** in the northern area (clearer breezes).
FUTURE: Analyse differences with the **new inland stations**.

More laminar sea winds **(less turbulent) at higher heights** (lighthouse).
FUTURE: Detailed analysis during sea breeze **events**.

The **tide impact** is well observed in the **SH** in the intertidal area.
FUTURE: Investigate the impact on breeze **formation**.

The breeze's **maximum wind speed** is located very **close to the ground**.
FUTURE: Characterisation of more events (**new field campaigns**).

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