Observational study and numerical simulations of sea breezes on the coast of Malaga

P. Fernández-Castillo[1,2], C. Román-Cascón[3], **C. Yagüe[2]**

(1) Instituto de Geociencias (IGEO), CSIC-UCM, Madrid, Spain ; (2) Departamento de Física de la Tierra y Astrofísica. Universidad Complutense de Madrid, Spain; (3) Departamento de Física Aplicada, Facultad de Ciencias del Mar y Ambientales, INMAR, CEIMAR, Universidad de Cádiz, 11510, Puerto Real, Spain

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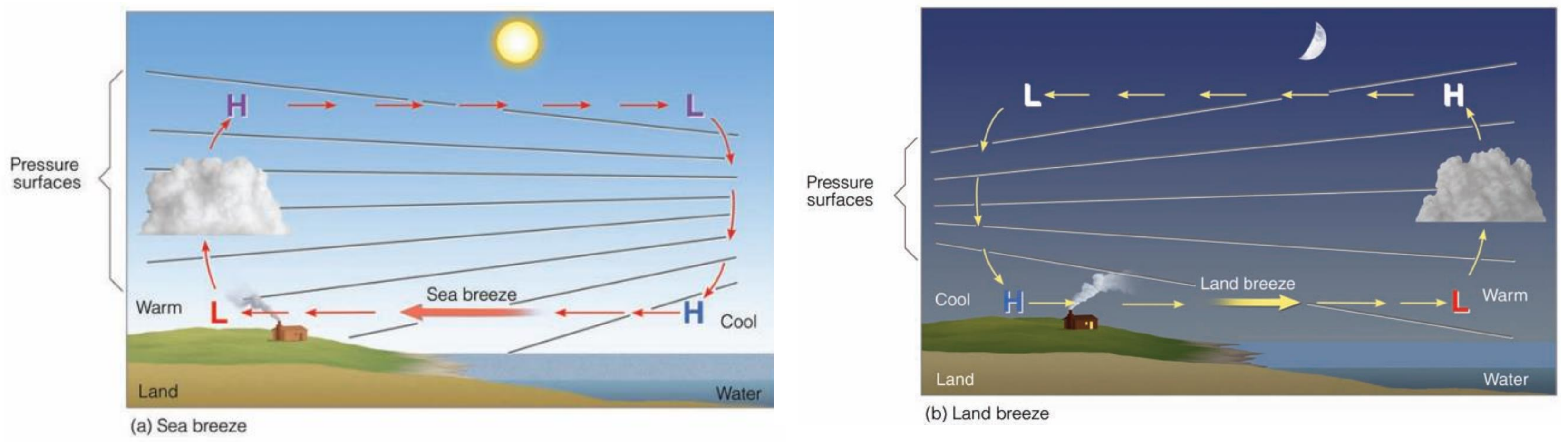
1. Introduction

Sea breezes: mesoscale thermally-driven flows due to difference in heat capacity of land surface and ocean surface



Sea-level pressure (SLP) gradient changes direction at daytime and at nighttime

Figure 1. Schematic representation of daytime sea breeze (left) and nighttime land breeze (right). Figure source: Arhens & Henson (2018) [1]

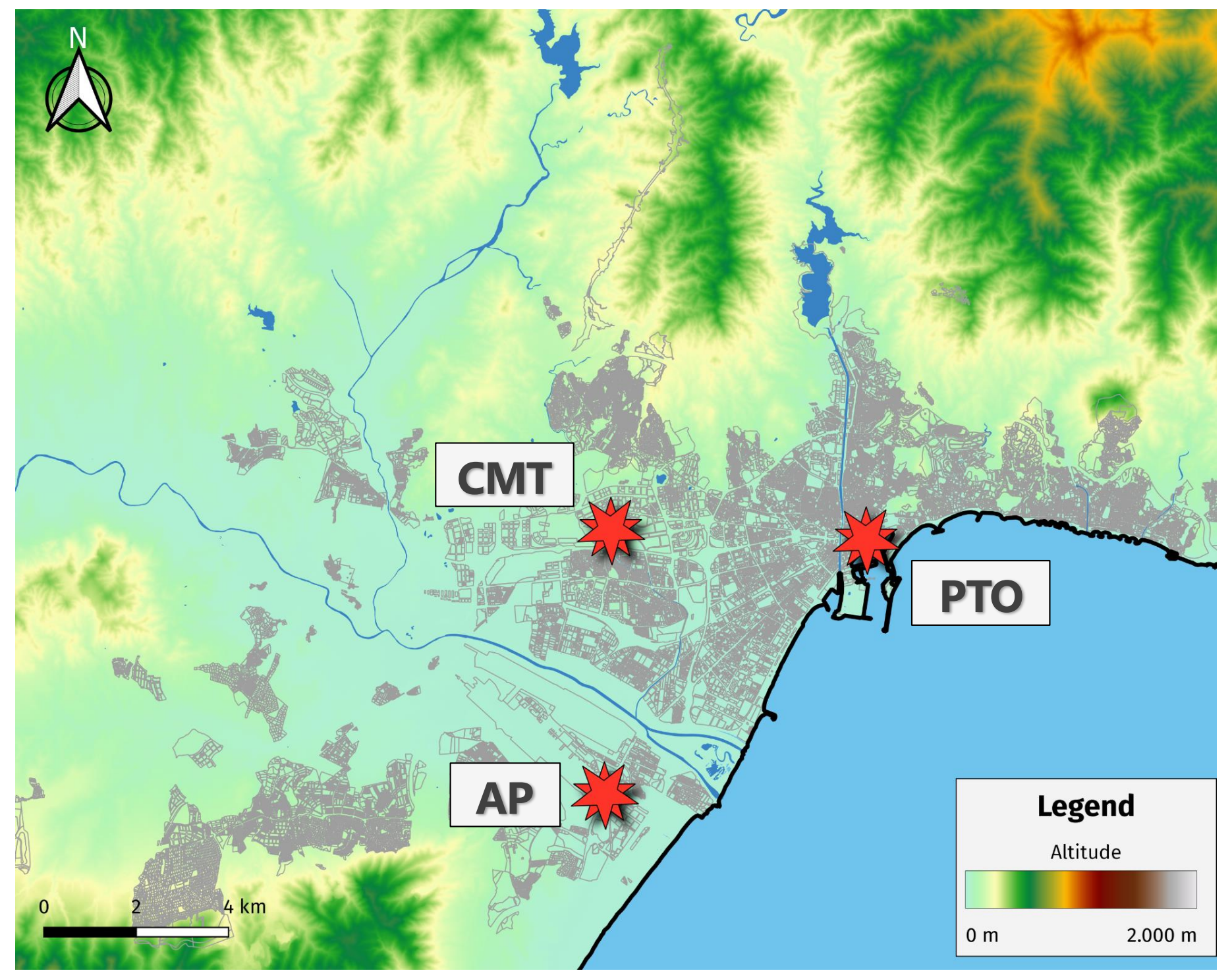
Sea breezes are very relevant for: Diffusion of pollutants[2], wind energy production[3], coastal thermal regime and comfort[4], convection triggering[5] and transport and recirculation of gasses[6]

Motivation: No in-depth studies of sea breezes in Malaga (Spanish southern Mediterranean coast), an area that features several complexities

MAIN OBJECTIVE

Study the characteristics of sea breezes on the coast of Malaga by means of observational data analysis and numerical simulations

2. Data and methods



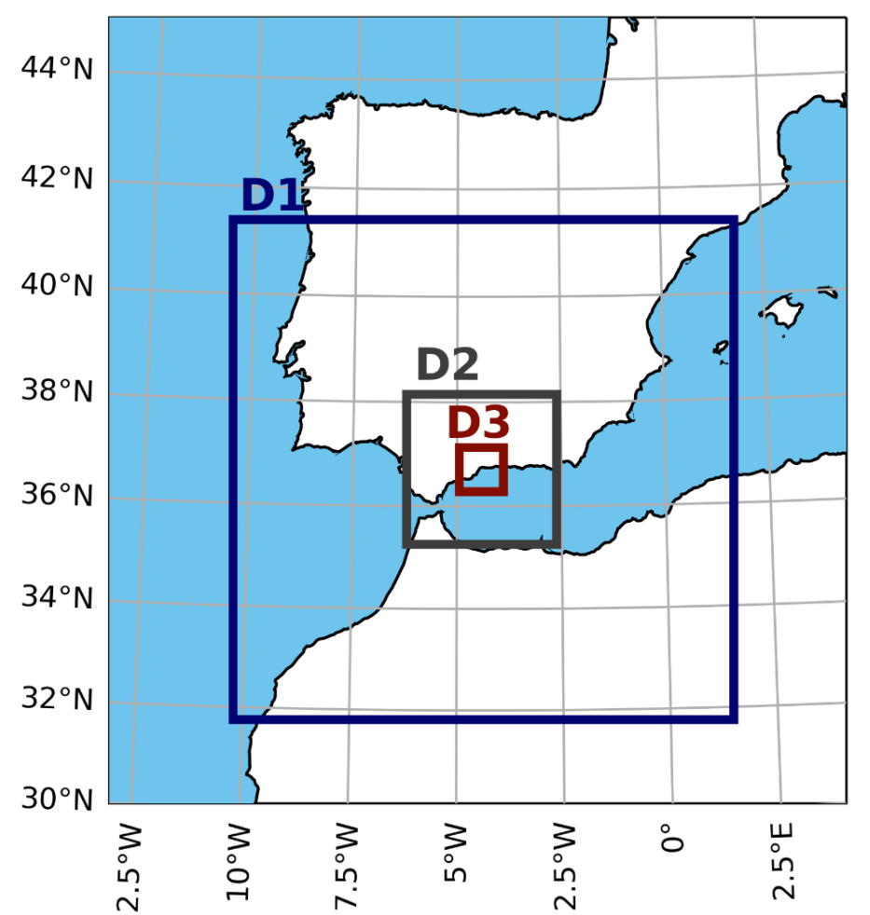
Study area features complex orography, enhanced sea-surface temperature (SST) variability due to coastal upwelling, complex shoreline orientation and high density of buildings

Observational data for 3 relatively close sites in the city of Malaga: Airport (AP), Port (PTO) and Meteorological Centre (CMT)

Study of variables on sea breeze days during summer 2022:

- 2-m temperature (T2m)
- 10-m wind speed (WS10) and direction (WD10)
- 2-m specific humidity (q2m)

Figure 2. Study area map. Points indicate the three observational sites employed. Topography data, which corresponds to a digital elevation model with 5 m resolution are provided by the Spanish National Cartographic System (MDT05 2008-2015 & IGR HIDROGRAFIA 2016 CC-BY 4.0 scne.es



Study case of interest is simulated with the Weather Research and Forecasting (WRF) model

- 3 nested domains (horizontal resolution 9, 3 and 1 km)
- Boundary conditions: NCEP FNL analysis 0.25° 6-hourly
- 48-hours integration (24 hours for spin-up)
- Configuration: As in Román-Cascón et al., 2022 [7]
- Event to simulate: August 14, 2022

Figure 3. Domain configuration used for the simulation of a study case with

3. Results

3.1 Observational study of the sea breeze

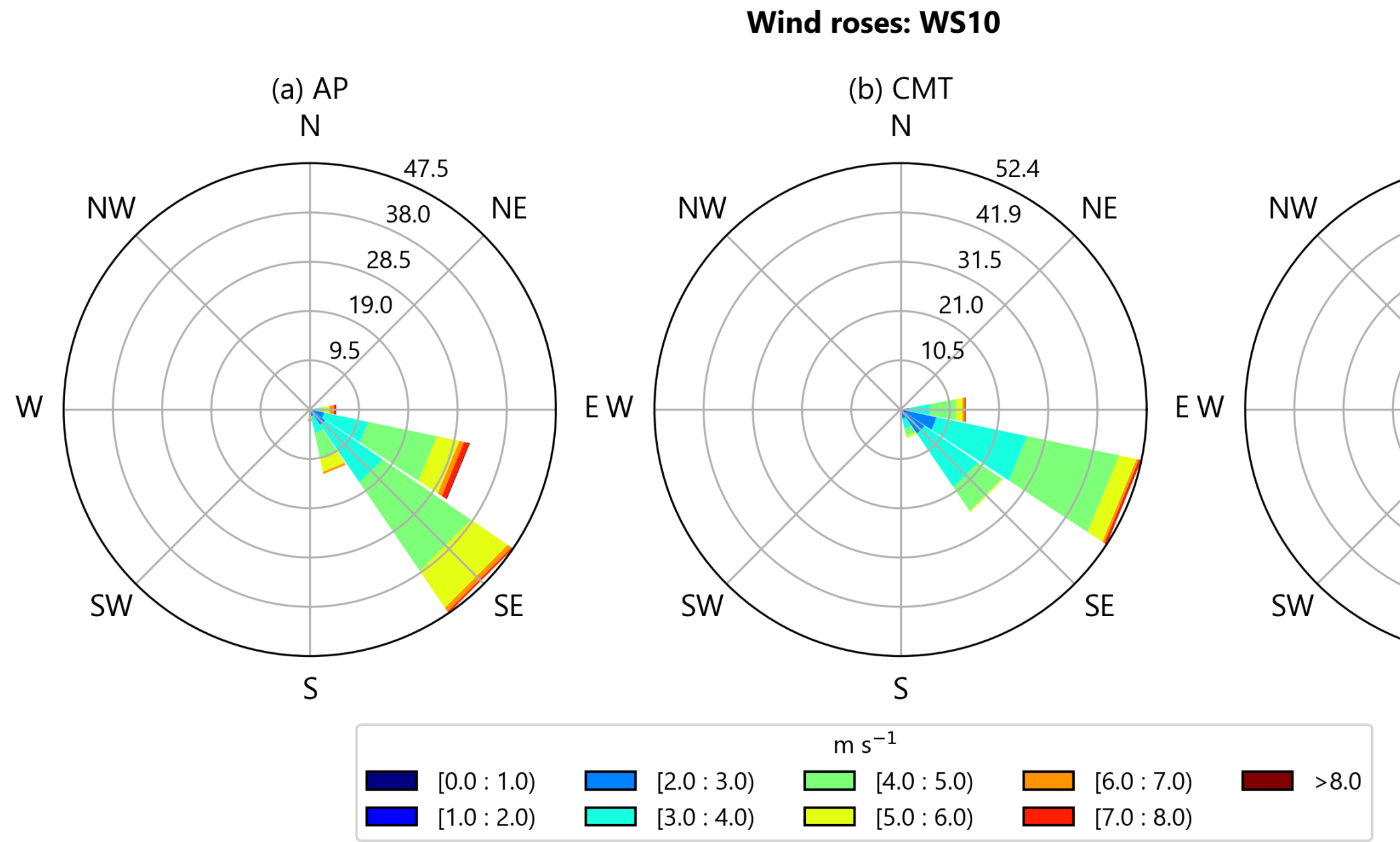


Figure 4. Wind roses of WS10 on sea breeze days using 10-minute-frequency data

Sea breeze shows as a south-easterly wind. WD10 more variable at PTO due to shoreline orientation (see Fig. 2).

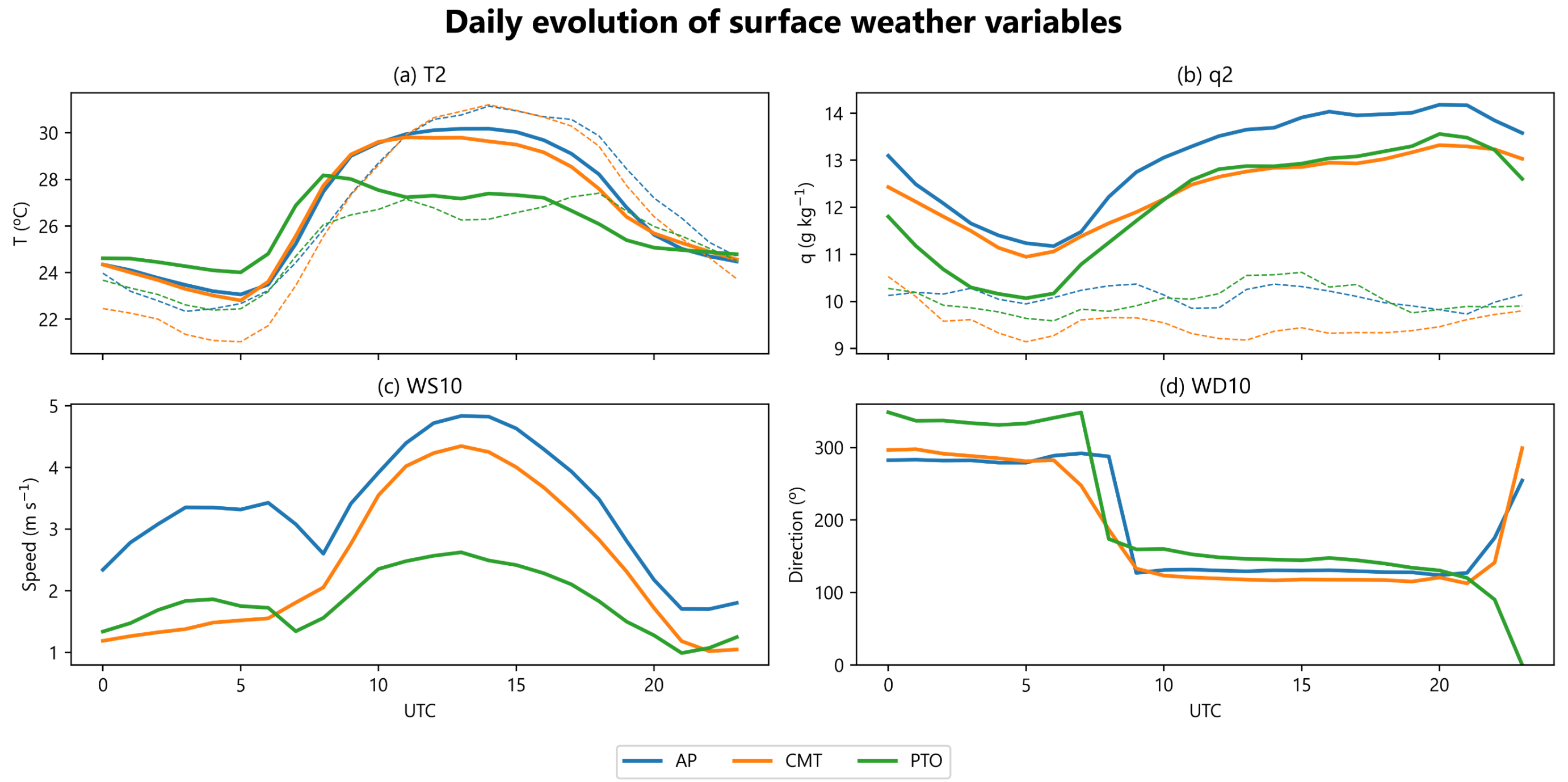


Figure 5. Daily evolution of (a) T2, (b) q2, (c) WS10 and (d) WD10 on sea-breeze days (solid lines) and no sea-breeze days (dotted lines) at the three observational sites.

- Sea breeze contributes to smooth daytime T2 increase, especially closer to the shoreline (PTO)
- Sea breeze also results in moisture advection
- Increase in WS10 on arrival of the sea breeze

3.2 Case study analysis with WRF

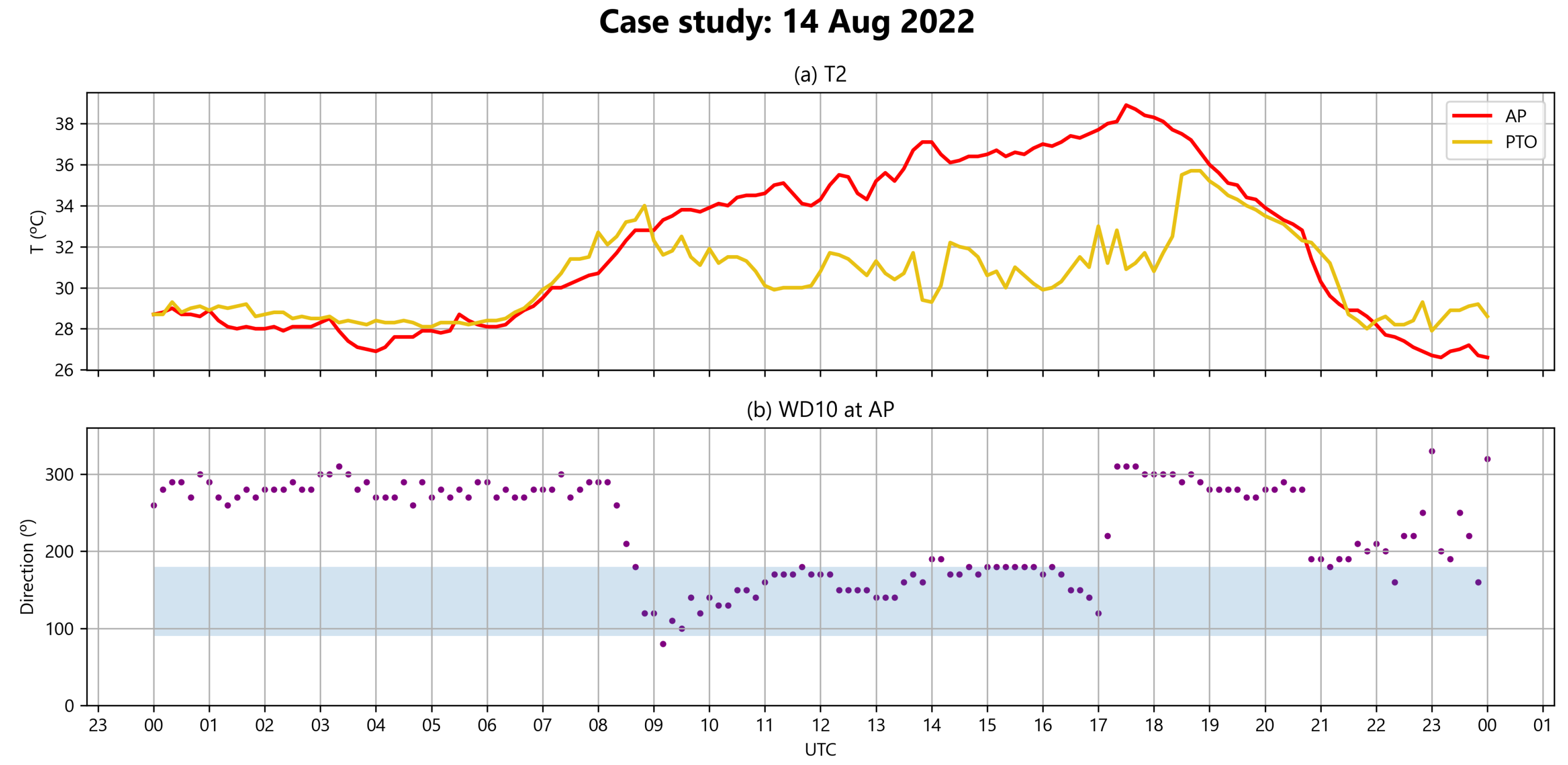


Figure 6. Daily evolution (14 August 2022) of T2 (a) at PTO and AP and of WD10 at AP (b). On (b), blue shading denotes onshore wind direction.

Big difference in T2 (up to 7 ºC) between AP and PTO and very high T2 at AP (38 ºC) despite onshore winds.

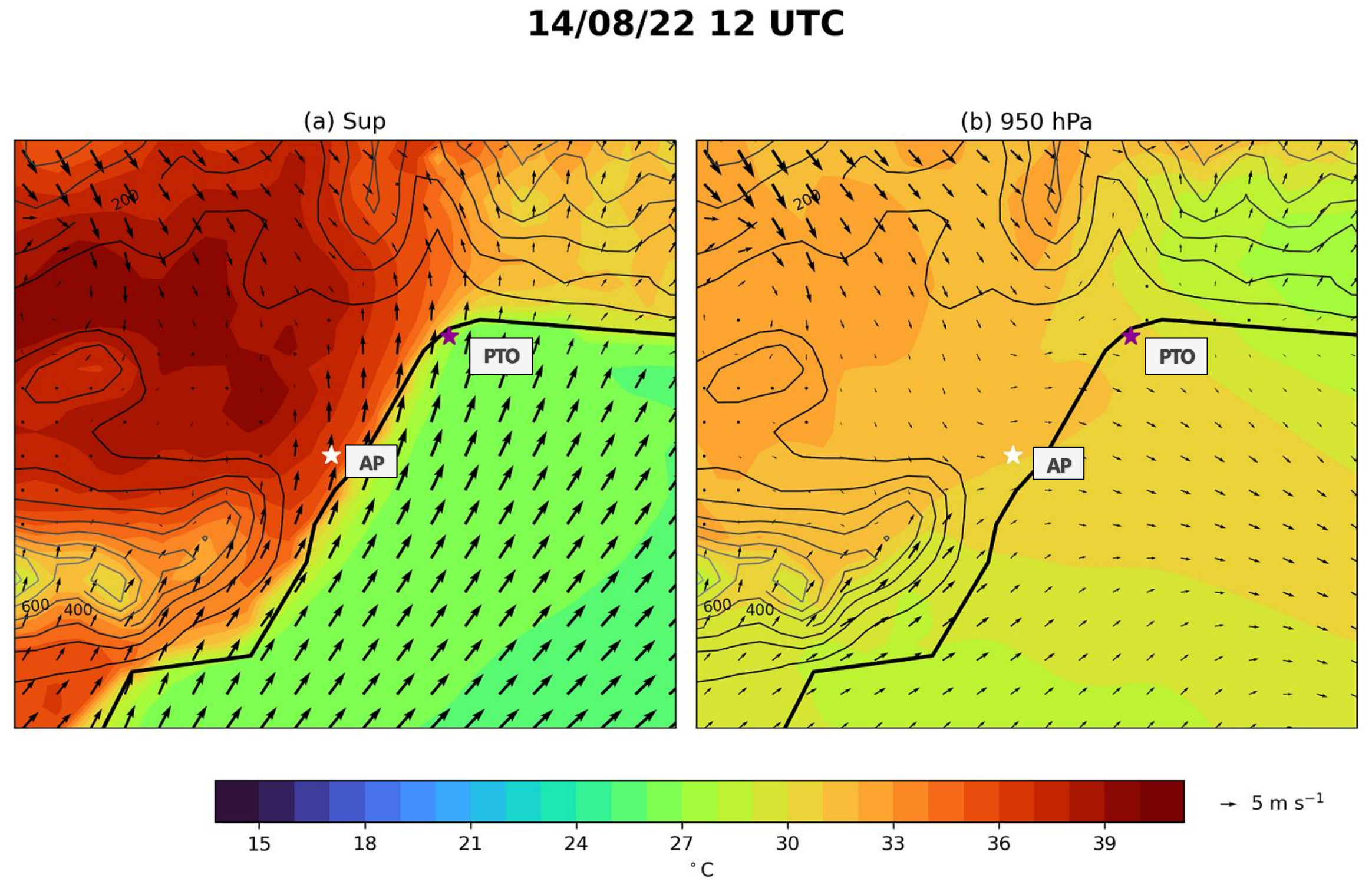


Figure 7. WRF temperature and wind fields at surface level (a) and 950 hPa (b) for 14 August 2022 at 12 UTC. The location of AP and PTO are indicated with a white and purple star, respectively. Model terrain is depicted with isolines.

Careful analysis of surface wind field (Fig. 7a) reveals southerly wind has no onshore component at AP. Downslope winds support very high temperatures around the AP area. Onshore winds advect maritime air mass towards PTO, explaining the important T2 difference between both sites.

4. Conclusions

- **Sea breeze results in south-easterly wind in the study area.**
- **Despite relatively close to each other, observed differences in surface weather variables on sea breeze days show the complexity of the area.**
- **Sea breeze has a clear impact on surface weather variables, i.e. increase in WD10, q2 increase and moderate T2 through advection of maritime air mass.**
- **High-resolution numerical simulation enabled us to find physical processes driving very different T2 behaviour between AP and PTO, and again highlight the complexity of this area.**

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3. National Centers for Environmental Prediction (NCEP), for providing the initial and boundary conditions for the numerical simulations.

References

References can be found by scanning the QR below: