Weather Clim. Dynam., 2, 609–630, 2021
https://doi.org/10.5194/wcd-2-609-2021

Large-scale drivers of the mistral wind: link to Rossby wave life cycles and seasonal variability

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Received: 25 January 2021 – Discussion started: 29 January 2021
Revised: 1 June 2021 – Accepted: 20 June 2021 – Published: 22 July 2021

Abstract. The mistral is a northerly low-level jet blowing through the Rhône valley in southern France and down to the Gulf of Lion. It is co-located with the cold sector of a low-level lee cyclone in the Gulf of Genoa, behind an upper-level trough north of the Alps. The mistral wind has long been associated with extreme weather events in the Mediterranean, and while extensive research focused on the lower-tropospheric mistral and lee cyclogenesis, the different upper-tropospheric large- and synoptic-scale settings involved in producing the mistral wind are not generally known. Here, the isentropic potential vorticity (PV) structures governing the occurrence of the mistral wind are classified using a self-organizing map (SOM) clustering algorithm. Based upon a 36-year (1981–2016) mistral database and daily ERA-Interim isentropic PV data, 16 distinct mistral-associated PV structures emerge. Each classified flow pattern corresponds to a different type or stage of the Rossby wave life cycle, from broad troughs to thin PV streamers to distinguished cutoffs. Each of these PV patterns exhibits a distinct surface impact in terms of the surface cyclone, surface turbulent heat fluxes, wind, temperature and precipitation. A clear seasonal separation between the clusters is evident, and transitions between the clusters correspond to different Rossby-wave-breaking processes. This analysis provides a new perspective on the variability of the mistral and of the Genoa lee cyclogenesis in general, linking the upper-level PV structures to their surface impact over Europe, the Mediterranean and north Africa.

1 Introduction

The mistral is a northerly gap wind regime located at the Rhône valley in southern France. The Rhône valley separates the Massif Central from the Alpine ridge by a ~ 50 km wide canyon, channeling northerly winds into the Gulf of Lion (GOL) in the Mediterranean. The mistral winds yield the potential to deliver extreme weather impacts such as wildfires (Ruffault et al., 2017), heavy precipitation (Berthou et al., 2014, 2018) and direct wind damage (Obermann et al., 2018). It poses a frequent threat to agriculture and is one of the most renowned weather phenomena in France. The mistral is seen as the primary source of severe storms and Mediterranean cyclogenesis (Drobinski et al., 2005) and is recognized as the most dangerous wind regime in the Mediterranean (Jiang et al., 2003). The mistral outflow, composed of continental air masses, picks up moisture at intense evaporation rates over the GOL, before flowing towards the lee cyclone in the Gulf of Genoa (see Fig. 1) and further destabilizing it. Indeed, precipitation response to the mistral can be seen at the Dolomite Mountains in eastern Italy, where the mistral outflow is often headed, and the warm front of the Genoa low is often active. Rainaud et al. (2017) related strong mistral events to heavy precipitation events occurring along the European–Mediterranean coastline. This relationship is manifested mainly by the remoistening during mistral events and the following flow of this moist air towards the European mountain slopes scattered along the coast. Classified as a dry air outbreak (Flamant, 2003), the mistral brings relatively dry and cold continental air masses