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Study of the origin and structure of a nocturnal atmospheric density current from observations and numerical simulations

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Density currents are flows generated when a dense fluid passes through a less dense surrounding, under the influence of gravity. They usually appear as a consequence of sea-breeze circulations, thunderstorm outflows or katabatic flows. Density currents acquire a particular relevance during nocturnal stable situations, as their onset causes a significant turbulence increase (both from buoyancy and shear) and they occasionally produce turbulence intermittency through the formation of gravity waves.

In this work, the arrival of a density current on 23 September 2015 is analysed in the CIBA site (Spain), which is located in the Spanish Northern Plateau, approximately 200 km away from the sea and 100 km away from the closest mountain ranges. Previous studies at this location associated similar nocturnal events with daytime sea breeze in the eastern Cantabrian coast [1]. Micrometeorological measurements from sonic anemometers and different sensors at multiple levels up to 100 m agl provide a solid database.

In this specific case, the outbreak of the density current occurs 2 hours after sunset, causing an abrupt increase of the wind speed and a significant weakening of the surface-based thermal inversion. Besides, turbulent parameters and fluxes such as the friction velocity, the sensible heat flux and the Turbulent Kinetic Energy (TKE) are sharply altered with its arrival. The latter, indeed, increases by two orders of magnitude and the Multi Resolution Flux Decomposition (MRFD) of this and other turbulent variables gives the approximate size of the contributing eddies. Furthermore, simulations with the WRF model, which is tested for different Planetary Boundary Layer (PBL) schemes and the topo_wind option for complex topography [2], give meaningful information about the vertical structure and origin of this density current.

[1] Udina, M., Soler, M.R., Viana, S. & Yagüe, C. (2013). Model simulation of gravity waves triggered by a density current. Q J R Meteorol Soc, 139, 701-714.

[2] Jiménez, P.A., Dudhia, J., González-Rouco, J.F., Navarro, J., Montávez, J.P., García-Bustamante, E. (2012). A revised scheme for the wrf surface layer formulation. Mon Weather Rev, 140, 898–918.