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What is the accuracy of the boundary layer diurnal cycle in meteorological analyses over West Africa?

Françoise Guichard (1), Fleur Couvreux (1), Amanda Gounou (1), Dominique Bouniol (1), Anna Agustí-Panareda (2), and Jean-Marcel Piriou (1)

(1) CNRM-GAME (CNRS & Météo-France), Toulouse, France (francoise.guichard@meteo.fr), (2) ECMWF, Reading, UK

The diurnal cycle of the low atmospheric levels is a major mode of variability over land in the Tropics where it is associated with strong modulations of convective processes. Meteorological analyses and re-analyses currently provide information on these atmospheric layers with a time frequency of 6 hours or less.

However not much is known about the accuracy of these products at this sub-diurnal time scale nor about how inaccuracies in the diurnal cycle may affect errors at larger time scales. Meanwhile, analyses are widely used by a number of studies; e.g. for the initialization and boundary conditions of mesoscale models or for the evaluation of climate models.

This study aims (i) to compare the diurnal cycles of the atmospheric low levels in operational analyses and re-analyses provided by numerical weather forecast models and (ii) to evaluate them with data. It focuses on the ECMWF-IFS (integrated forecast system) and Météo-France operational model ARPEGE-Tropiques as well as re-analyses (notably the AMMA ECMWF re-analysis, Agustí-Panareda et al. QJRMS 2010). The high-frequency and high-resolution soundings acquired during the AMMA project over West Africa (Parker et al. BAMS 2008) are used for this purpose. This dataset allows covering a wide variety of tropical and subtropical climatic environments, from dry to moist and finally wet (rainy) conditions, as encountered during a full seasonal cycle.

In broad agreement with previous studies, all the analyses and reanalyses point to strong diurnal fluctuations in the low levels, especially in the Sahel, where daytime boundary-layer growth is large while the nocturnal jet appears as a climatic feature. However, the vertical resolution provided by standard pressure levels can be inoperative at distinguishing the differences observed in the low levels between dry, moist and wet conditions during a seasonal cycle.

A more in-depth evaluation is conducted with the vertical profiles of the analyses (as obtained on model grids). Boundary-layer diagnostics and convective indexes are systematically computed in the same way for analyses and soundings. This comparison reveals that the daytime convective boundary-layer growth is significantly larger in the ECMWF analyses than in the ARPEGE-Tropiques analysis, and larger than observed. The daytime boundary layer is thus typically higher, warmer and drier in the ECMWF analyses. Conversely, the nocturnal circulation and convective instability are both enhanced in ARPEGE-Tropiques.

The diurnal cycle of the low-levels is largely controlled by surface processes taking place at diurnal time scales. The balance of these processes in turn changes substantially according to the climatic area and season. It also displays large differences among forecast models and reanalyses which seem to be at least partly reflected in the differences among analysed profiles. The vertical structure of the analysed temperature is typically better captured in the early morning at 0600 UTC than in the subsequent synoptic hours. More broadly, the largest biases in the thermodynamics are generally obtained during daytime.

These inaccuracies in the depiction of the diurnal cycle will be presented quantitatively and their causes and consequences will be discussed.