Assessment of ECMWF model bias in the AMMA region with observations from the ARM mobile facility at Niamey

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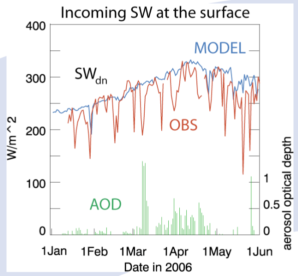
1) Introduction

The ECMWF short-term forecast in the AMMA region quickly develops biases, intensifying the Saharan heat low, placing the ITCZ further south than observed, and underestimating the frequency and intensity of the intermittent deep convection and associated precipitation in the Sahel region.
Observations from the ARM mobile facility at Niamey provide an opportunity to assess how physical processes in the model contribute to the developing bias.

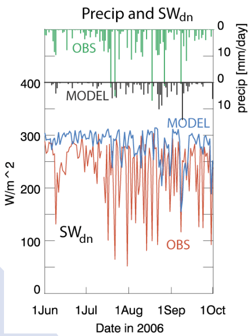


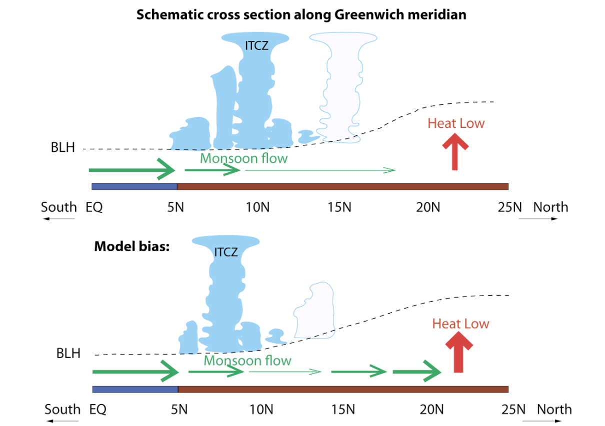
2) Lack of aerosol

In the model, too much solar radiation reaches the surface. The model uses climatological values for aerosol optical depth and cannot represent events with heavy aerosol loading that significantly reduce the incoming solar radiation. This is particularly evident during the dry season.

3) Lack of cloud cover

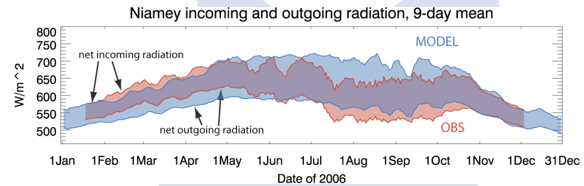
The model fails to produce the intermittent deep convection typical for the Sahel region with sufficient frequency and intensity. Precipitation is underestimated, and the lack of cloud cover associated with convective episodes leads to an overestimation of surface solar radiation in the wet season as well.





4) Excessive net surface radiation

The shaded areas in this figure show the amount of net radiative energy absorbed by the surface. Overall, the ground absorbs too much energy, which in turn must be released into the atmosphere through the surface heat fluxes.



8) Summary

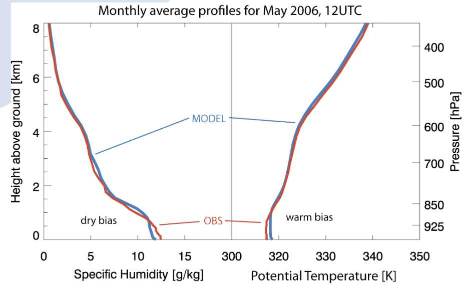
Even during the dry season - the “simpler” problem - the ECMWF model rapidly develops biases. Lack of aerosol interacting with radiation may be a contributing factor to the intensification of the heat low and the development of a deep, dry-convective boundary layer driven by excessive surface fluxes. With its deep, accelerating low-level flow, the model lacks the near-surface moisture and convergence to fuel deep convection in the Sahel with sufficient frequency and intensity.
At some locations in the Sahel, the analysis acts to inhibit convective motion further by inducing a localized sinking circulation.

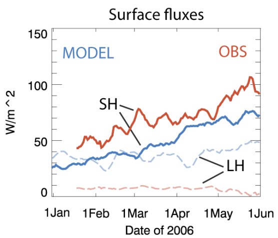
7) Non-local influences

The low-level monsoon flow carries moist air from the Atlantic ocean towards the Saharan heat low. This flow is a source of moisture for the Sahel region. In the model, the heat low intensifies with forecast time and the low-level flow accelerates, leading to moisture divergence in the Sahel (center schematic). In the model, the deep, well-mixed boundary layer in Niamey reflects a deeper flow whose moisture is distributed throughout, rather than being concentrated near the surface as observed. Less moisture is available overall in the model, and near-surface parcels lack the latent energy for deep convective growth.

5) Dry and warm bias at the surface

The model quickly develops a warm and dry bias near the surface. The boundary layer becomes more well-mixed and deeper than observed.





6) Influence of analysis on short-term forecast

The analysis tries to correct the warm and dry bias at the surface by adjustment of the soil moisture increments. This artificially increases the latent heat flux and reduces the sensible heat flux, even in the dry season, when the observed latent heat flux is close to zero.
Because observations are so sparse in the area, the localized near-surface cooling achieved in the analysis induces low-level sinking and divergence at grid points near isolated sonde stations (though not at Niamey), which act to suppress convective motion.

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