Desert Model Intercomparison Project benchmark framework version 1.0 for assessing land-surface dynamics and surface memory in monthly dust aerosol optical depth over North Africa

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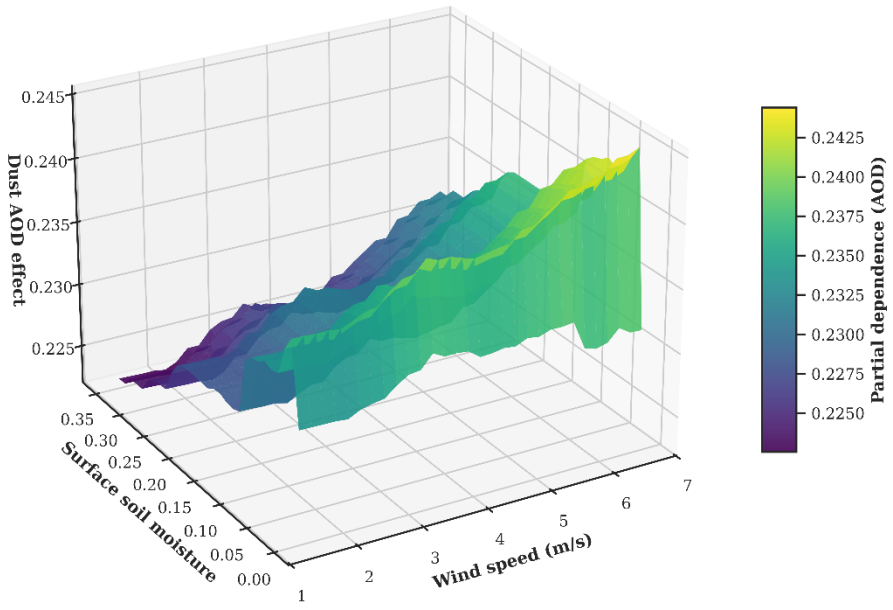

Figure S1. Three-dimensional partial-dependence surface illustrating the interaction between wind speed and soil moisture. High AOD values occur primarily under conditions characterized by strong winds and very low surface moisture.

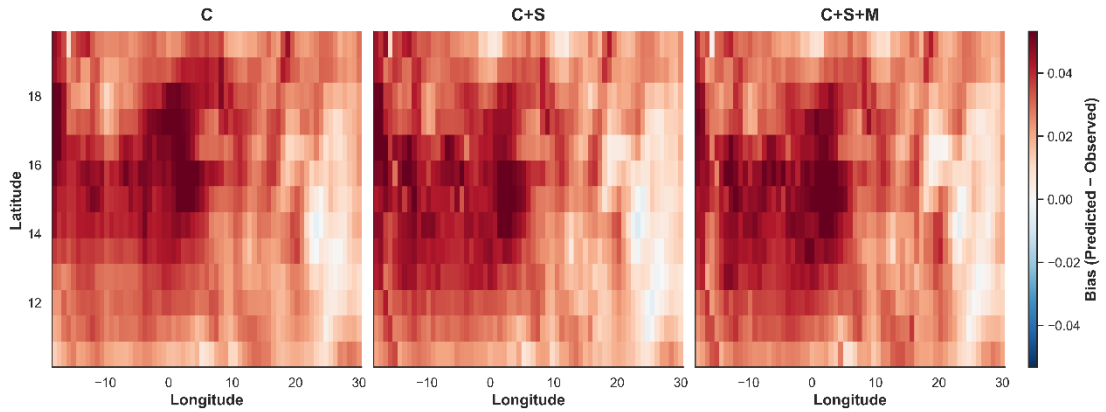

Figure S2. Spatial distribution of prediction error across the three model configurations. From left to right: climate-only model (c), climate + surface configuration (C+S), and the full climate + surface + memory model (C+S+M). The inclusion of surface and memory predictors reduces the red overestimation clusters and increases the agreement between model predictions and observational data.

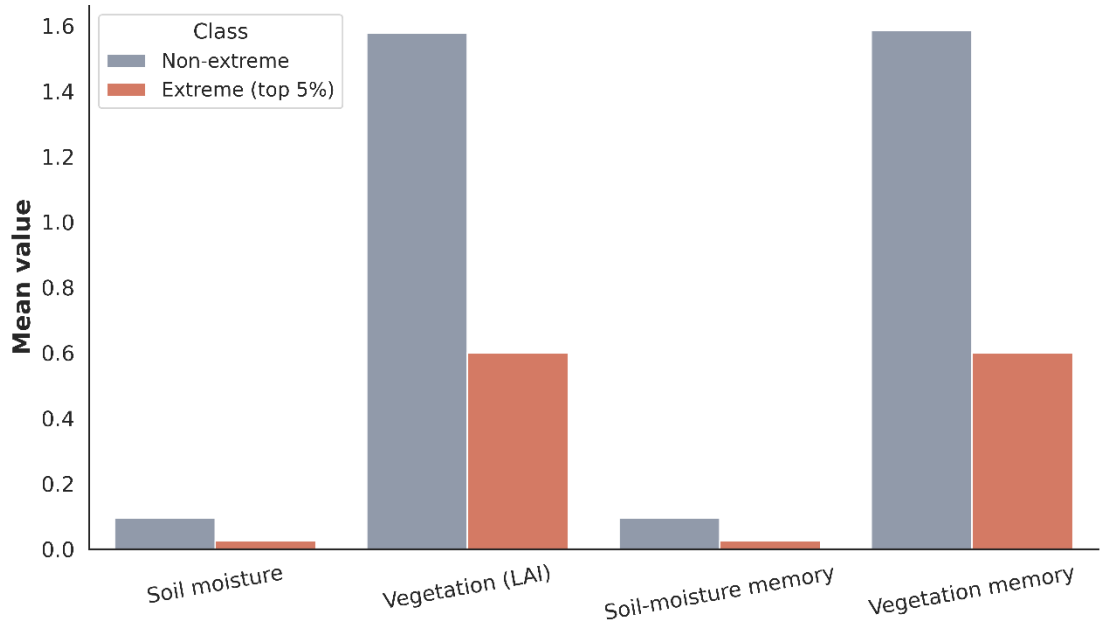

Figure S3. Comparison of antecedent land-surface conditions during extreme dust events (upper 5% of the AOD distribution) and non-extreme conditions. Mean soil moisture, LAI, and their lagged memory components appear substantially lower before extreme events. These patterns highlight the role of cumulative dry periods and vegetation decline in preparing the land surface for severe dust storms.

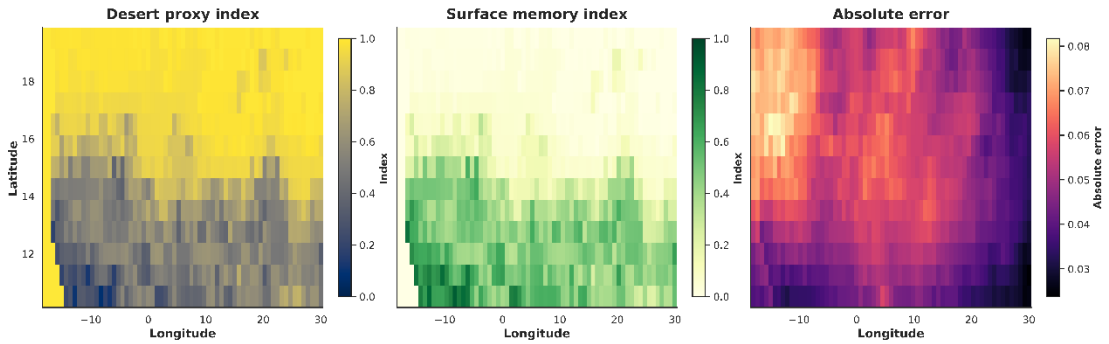

Figure S4. Spatial relationship between land-surface characteristics and model error.

The left panel shows the Desert Proxy Index, which represents the spatial gradient of aridity and desert influence. The middle panel shows the Surface Memory Index derived from lagged soil-moisture and vegetation conditions. The right panel shows the spatial distribution of absolute model error in dust AOD reconstruction. Regions with stronger desert characteristics generally exhibit larger errors, whereas areas with stronger surface memory tend to show reduced errors.