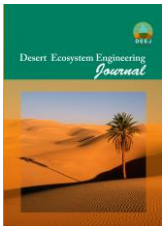
DEEJ (2026) 51 (2) 1-2

University of Kashan

Desert Ecosystem Engineering Journal

Journal homepage: http://deej.kashanu.ac.ir



Spatiotemporal Projections of Dust Aerosol Dynamics over Iran Using the RegCM4 Model under RCP4.5: 2030–2060

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Receive: 2026/05/10 Accept: 2026/06/29

Extended Abstract

Introduction

This study provides a dynamic projection of seasonal and annual dust aerosol distributions over Iran using the coupled RegCM4 regional climate model under the RCP4.5 emission scenario for the 2030– 2040 and 2050–2060 horizons. This research addresses a critical knowledge gap, as previous assessments in Iran have largely relied on global model outputs or simulations of historical conditions without the benefit of dynamical downscaling. By employing a high-resolution regional climate model (RCM) capable of resolving local-scale physical processes, this study captures the complexities of dust emission, atmospheric transport, and deposition, offering a more nuanced understanding of future dust dynamics in the region.

Methodology

The study utilized boundary conditions derived from global RegCM climate simulations, with 6-hourly temporal resolution extending to 2100. The RegCM4 model was configured with a 40-km horizontal grid resolution, balancing computational feasibility with the requirement to resolve major regional dust sources. Simulations were driven by the RCP4.5 scenarios—representing a moderate greenhouse gas emission pathway—covering the Iranian domain (25°N–45°N and 44°E–64°E). Key physical parameterizations included the Emanuel convection scheme, the Holtslag planetary boundary layer scheme, the NCAR-CCM3 radiation scheme, and the BATS1e land surface scheme. Following a 3-month spin-up period

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DOI: 10.22052/deej.2026.258710.1143

to ensure initialization stability, decadal averages for 2030–2040 and 2050–2060 were analyzed to determine dust trends.

Results

The modeling results successfully identified multiple internal and external dust hotspots. Internal sources were notably active in Sistan and Baluchestan, Kerman, South/Razavi Khorasan, Khuzestan, Bushehr, Hormozgan, and Isfahan provinces. Among these, the Sistan and Baluchestan and Khuzestan regions exhibited the highest frequency and intensity of dust events. External dust contribution was found to be significant from northern Saudi Arabia, the Iraq-Kuwait border, and northeastern regions adjacent to Turkmenistan. Seasonal analysis highlighted distinct behaviors: Sistan and Baluchestan remains active year-round, with peak intensities in autumn and winter linked to the strengthening of the Levar wind system. Conversely, the Khuzestan source, characterized by extensive dry marshlands, exhibits peak mobilization in spring due to the Shamal wind system, which facilitates dust transport from the Tigris-Euphrates basin.

Discussion and conclusion

The projections indicate a clear intensification in both dust production volumes and event frequency throughout the 2030s and 2050s, driven by climate-change-induced declines in soil moisture, altered vegetation cover, and intensified wind patterns under RCP4.5. Furthermore, the identification of emerging dust sources in Turkmenistan poses a heightened risk to northeastern Iran. While the model successfully delineates regional hotspots, it is subject to spatial constraints; the 40-km resolution limits the detection of localized sources smaller than 1,600 km². Consequently, while the model provides a robust assessment of regional-scale dynamics, smaller sources may be underrepresented or smoothed. Despite this, the study's findings corroborate the urgent need for transboundary cooperation and localized dust mitigation strategies. These results suggest that by 2054, Iran will experience a shift toward significantly warmer and drier conditions, necessitating the integration of these projections into national water resource management and sustainable land-use planning.

Keywords: Dust prediction, RegCM4, RCP4.5, Dynamical downscaling, Iran, Dust hotspots, Seasonal distribution