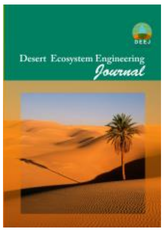
DEEJ (2025) 14 (2) 1-2

University of Kashan

Desert Ecosystem Engineering Journal

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



Analysis of the Relationship between Synoptic Patterns Entering Iran and Dust Events in Lorestan Province with Emphasis on the Role of the Sudanese Low-Pressure System

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Received: 10/05/2025 Accepted: 04/10/2025

Extended Abstract

Introduction: The Sudanese low-pressure system is a critical synoptic-scale driver of weather and climate in the Middle East, including Iran. Originating over tropical Africa, this system propagates eastward and northeastward, frequently inducing dry, unstable atmospheric conditions. Its characteristic dryness, coupled with strong surface winds, facilitates the entrainment and uplift of fine particulate matter, leading to the formation of extensive dust storms. Particularly during warm seasons, these conditions significantly increase atmospheric aerosol concentrations, which adversely affect human health and regional climate by modifying atmospheric radiation and optical properties. Recent studies indicate a rising trend in the frequency and intensity of such dust events, a phenomenon often attributed to intensified droughts and broader climate change.

This research investigates the causal relationships between predominant synoptic patterns and the spatiotemporal distribution of atmospheric aerosols in Lorestan Province, with a specific focus on the role of the Sudanese low-pressure system. By analyzing the associated atmospheric dynamics and thermodynamic mechanisms that govern aerosol transport and dispersion, this study seeks to provide a comprehensive understanding of regional climatic variability. Key investigative aspects include the analysis of pressure patterns, convective processes, and temperature and humidity gradients, alongside their collective influence on drought severity and dust storm occurrence.

A significant research gap exists in the detailed examination of the link between synoptic patterns—especially the Sudanese low-pressure system—and the increase in atmospheric aerosols and drought intensification within Lorestan Province. While previous research has explored the impact of this system on precipitation patterns across broader regions like western Iran, its direct connection to aerosol loading and drought in a topographically and climatically distinct area such as Lorestan remains inadequately studied. The province's unique geographical setting renders it particularly vulnerable to these phenomena. Furthermore, the specific pathways and mechanisms by which dust and aerosols are transported from source regions—such as the arid expanses of Iraq and Saudi Arabia—into Lorestan require further elucidation through targeted regional analysis.

Addressing these gaps, this research concentrates on Lorestan Province to analyze the mechanisms of aerosol transport orchestrated by the Sudanese low-pressure system. By delineating the relationship between synoptic-scale circulations and drought conditions, the study aims to propose practical strategies for water resource management and drought mitigation. The findings are expected to enhance the foundational understanding of the climatic impacts associated with the Sudanese low-pressure system and contribute to the development of effective strategies for reducing the adverse effects of drought in Lorestan.

Methodology: This study employs a comprehensive methodology to analyze the relationship between synoptic patterns and drought events in Lorestan Province, with a focus on the Sudanese low-pressure system.

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DOI: 10.22052/deej.2025.256364.1096

Meteorological data from a 30-year period (1991–2020) were used, including relative humidity, sea-level pressure, and omega values at three atmospheric levels (1000, 850, and 700 hPa). These data were obtained from Middle Eastern regional systems and NCEP/NCAR reanalysis datasets with a spatial resolution of 2.5 × 2.5 degrees.

To identify drought and dust events, horizontal visibility (less than 5000 meters) and atmospheric aerosol levels (above 0.5) were used as indicators. Horizontal visibility was prioritized due to its long-term record compared to other measurements like particulate matter and aerosol optical thickness. The year with the highest pollution levels in the study area was selected, and composite maps of sea-level pressure, geopotential height, streamlines, and wind speed at various atmospheric levels were plotted and analyzed.

The study also utilized vorticity tracking methods to examine the movement paths of the Sudanese low-pressure system for sample days of each synoptic pattern. GIS was employed to analyze land-based phrenic events (e.g., microdust) during different seasons in Lorestan Province. The geographical scope of the study covers the Middle East, Iran, and Lorestan, providing a regional perspective on synoptic patterns and their impacts.

Results and Discussion: This study adopts a comprehensive analytical approach to investigate the relationship between synoptic-scale atmospheric patterns and dust events in Lorestan Province, with a specific focus on the Sudanese low-pressure system. The analysis utilized meteorological data spanning a 30-year period (1991–2020), obtained from the NCEP/NCAR reanalysis dataset and Middle Eastern regional systems. Key variables included sea-level pressure, relative humidity, and vertical velocity (omega), analyzed at three atmospheric levels (1000, 850, and 700 hPa). The data has a spatial resolution of 2.5° × 2.5°.

Dust events were identified using two primary indicators: horizontal visibility reduction to less than 5,000 meters and elevated atmospheric aerosol indices. A visibility threshold of <5,000 meters was prioritized due to the consistent long-term availability of this data, which offers a reliable record for climatological analysis compared to other metrics like particulate matter (PM) concentration or aerosol optical depth (AOD). The year with the highest frequency of low-visibility events within the study period was selected for detailed synoptic analysis.

For this peak pollution year, composite maps of sea-level pressure, geopotential height, wind streamlines, and wind speed at various atmospheric levels were generated and analyzed to identify the prevailing synoptic patterns. To further trace the genesis and movement of dust-transporting systems, vorticity advection and tracking methods were applied to sample days' representative of each pattern. Additionally, Geographic Information Systems (GIS) were employed to analyze the spatiotemporal distribution of land-surface phenomena, such as fine dust (microdust), across different seasons in Lorestan Province. The geographical scope of the study encompasses the Middle East, Iran, and Lorestan, providing a multi-scale regional perspective on synoptic patterns and their impacts.

Conclusion: This study demonstrates that the influence of the Sudanese low-pressure system on Lorestan Province's climate is critically dependent on its intensity and structure. When the system is weak and shallow, it fails to advect sufficient moisture into the region, resulting in dry conditions that favor the entrainment and transport of atmospheric aerosols. Furthermore, the frequent dominance of high-pressure systems, particularly the Siberian and Azores highs, acts as a synoptic-scale barrier. This blocking mechanism prevents the vital convergence of the Sudanese low with moisture-bearing systems from the Mediterranean, exacerbating aridity. These dry, stable atmospheric conditions, characterized by subsidence (positive omega values) and weak vertical motions, lead to the accumulation and persistence of pollutants and dust within the planetary boundary layer, significantly degrading air quality.

An analysis of dusty days from 1991 to 2020 reveals the tangible impact of these patterns, with the annual number of dust events in Lorestan Province varying widely from 0 to 140 days. This high variability underscores the region's susceptibility to synoptic-driven environmental hazards.

By detailing the vertical structure of the atmosphere, humidity fluxes, and the positive feedback loop between dry air and aerosol production, this research advances the understanding of regional climate dynamics. The findings highlight the critical role of synoptic patterns, particularly the interaction between the Sudanese low and blocking highs, in shaping Lorestan's climatic conditions and air quality. Consequently, this study provides a robust foundation for improving dust and drought prediction models. The insights gained are vital for developing informed public health strategies, agricultural planning, and environmental risk management policies aimed at mitigating the adverse effects of dust storms and aridity in Lorestan Province. Future work should focus on quantifying the contribution of local versus transboundary dust sources under these identified synoptic regimes.
Keywords: Sudanese system, dust event, Lorestan.