

## MODELING THE DISPERSION OF DUST STORMS AND THEIR IMPACT ON AIR QUALITY IN TERMIZ CITY AND SURKHANDARYA REGION USING DIFFERENTIAL EQUATIONS

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### Abstract

This article investigates the modeling of dust storm dispersion and its impact on air quality in the Surkhandarya region and Termiz city using differential equations. The study is based on the advection-diffusion equations, which were used to analyze the spread of PM10 and PM2.5 dust particles in the atmosphere. Local meteorological and environmental conditions specific to Termiz city — including wind speed, prolonged drought periods, and dust sources resulting from the desiccation of the Aral Sea — were taken into account.

The simulation results revealed that dust storms constitute one of the primary causes of air pollution in Termiz. Furthermore, practical recommendations are proposed for the early warning of dust storms and the enhancement of the air quality monitoring system.

### Keywords

dust storm, advection-diffusion equation, PM10, PM2.5, Termiz, Surkhandarya, mathematical modeling.

### Introduction

In recent years, dust storms resulting from climate change and environmental degradation have emerged as a serious ecological challenge across Central Asia. The southern regions of Uzbekistan, particularly the Surkhandarya region and Termiz city, are among the areas most severely affected by this phenomenon. According to data from Uzhydromet, dust storms occur in Termiz city for an average of 35–40 days per year. During these periods, the concentration of fine dust particles in the air increases dramatically, leading to a significant deterioration in air quality.

The 2025 report published by the United Nations Environment Programme (UNEP) highlights that dust storms are one of the primary causes of air pollution in Termiz. Dust particles not only reduce visibility but also exacerbate respiratory diseases, allergies, and cardiovascular problems in the population. Moreover, they have substantial negative impacts on agricultural productivity and transportation systems.

Consequently, the accurate prediction of dust storms and the analysis of their dispersion patterns have become critically important tasks. Differential equations, particularly the advection-diffusion equations, have proven to be highly effective tools for this purpose. These equations enable researchers to clearly determine the direction and speed at which dust particles are transported by wind.

In this study, an attempt was made to mathematically model the dispersion of dust storms,



using Termiz city as a case study. The model incorporates the specific climatic characteristics of the region, including persistent western winds, prolonged drought conditions, and the influence of dust sources associated with the desiccation of the Aral Sea. Local meteorological parameters were carefully considered during the modeling process. The primary objective of this research is not only to construct a mathematical model but also to demonstrate its potential application in real-time environmental monitoring systems.

### Mathematical Model and Methods

The advection-diffusion equation was selected as the main mathematical tool for modeling dust storms. This equation takes into account not only the diffusion of dust particles, but also their advection under the influence of wind flow, and it more accurately describes the processes occurring in the real atmosphere.

The general form of the equation is as follows:

$$\frac{\partial c}{\partial t} + v \cdot c = (D \nabla^2 c) + S(x, t)$$

Here:

$c$  – coefficient of dust particles in the air,

$v$  – wind speed,

$D$  – turbulent diffusion coefficient,

$S(x, t)$  – dust source function,

$t$  – time.

When constructing the model for Termiz city and Surkhandarya region, local meteorological and ecological conditions were taken into account. The main parameters are as follows:

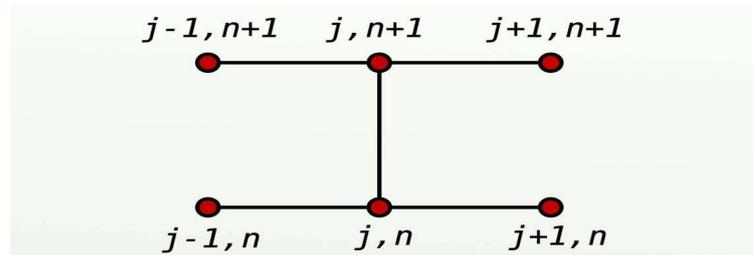
- Average wind speed:  $v = 3 - 8 \text{ m/s}$  (strong winds are mostly observed from the western direction),
- Diffusion coefficient:  $D = 10 - 50 \text{ m}^2 / \text{s}$  (varies depending on air temperature, humidity, and drought level),
- Additional dust sources resulting from the desiccation of the Aral Sea were also included in the model.

The Crank-Nicolson scheme was selected for the numerical solution of this model. This scheme is based on the central difference method in time, ensures first- and second-order accuracy, and possesses the property of unconditional stability.

Figure 1. Crank-Nicolson scheme: time discretization principle.



The time discretization of the equation is performed as follows:



$$\frac{c^{n+1} - c^n}{\Delta t} = \frac{1}{2} L(c^{n+1}) + L(c^n)$$

Where:

$c^n$  – concentration at the n-th time step,

$\Delta t$  – time step,

$L(c)$  – the diffusion and advection operators on the right-hand side of the equation.

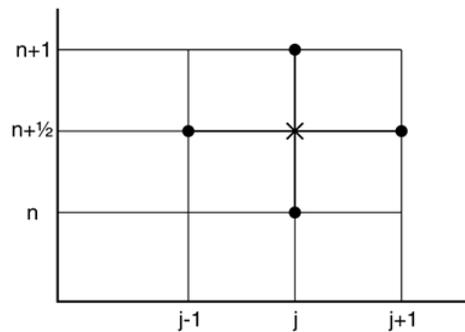


Figure 2.

The Crank-Nicolson scheme provides a more accurate and efficient solution compared to the explicit Euler method, especially in long-term simulations. Therefore, this scheme was specifically used in the present study.

The calculations were performed in the Python programming environment. Initial and boundary conditions were selected based on real monitoring data. In this way, the model can provide practical benefits not only theoretically, but also in predicting and monitoring real dust storms in Termiz city.

## Results and Analysis

In this section, the dispersion of dust storms in Termiz city and its surrounding areas was



simulated based on the advection-diffusion equation. The calculations were carried out taking into account different wind speeds and local parameters. The simulation was implemented in the Python programming environment using the numpy and matplotlib libraries.

1. The dispersion of dust particles with distance at a wind speed of 7.0 m/s is shown in the following graph:

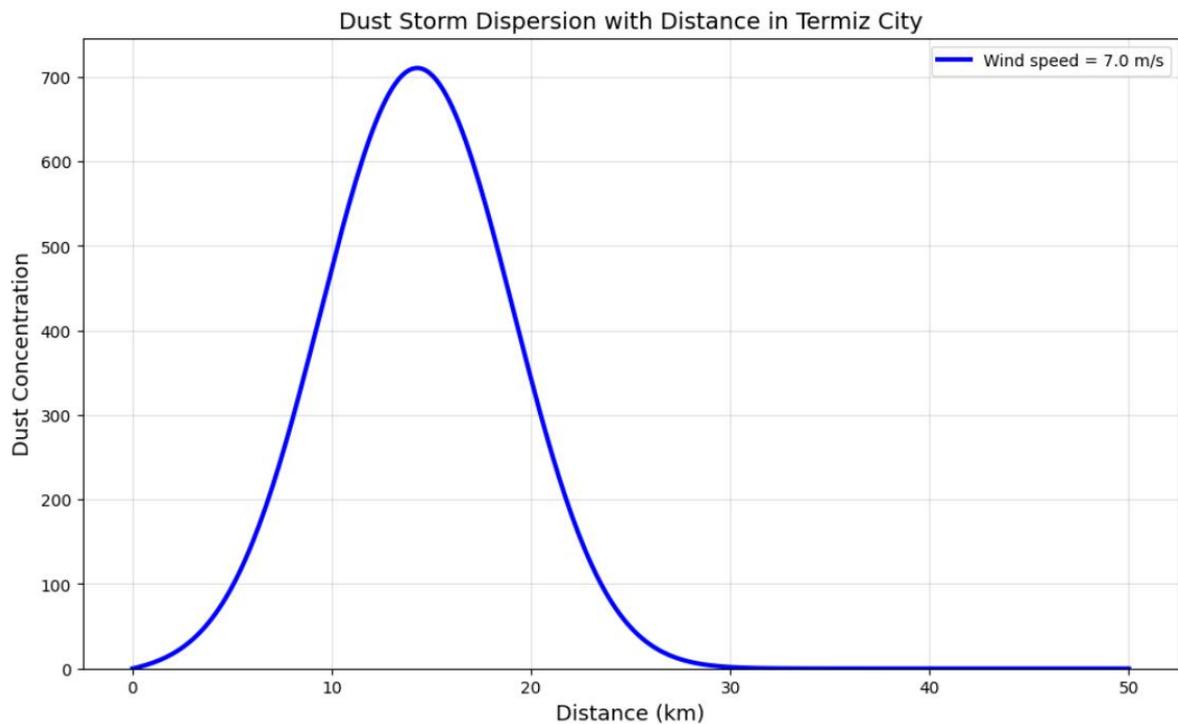


Figure 3. Dust storm dispersion with distance in Termiz city.

This graph analysis shows that the highest concentration of dust particles is located at approximately 12–18 km distance. The maximum concentration reaches around 710 units. This result indicates that when the wind is strong, dust spreads rapidly and widely across the city area.

2. The change in dust concentration over time is shown in the following figure:



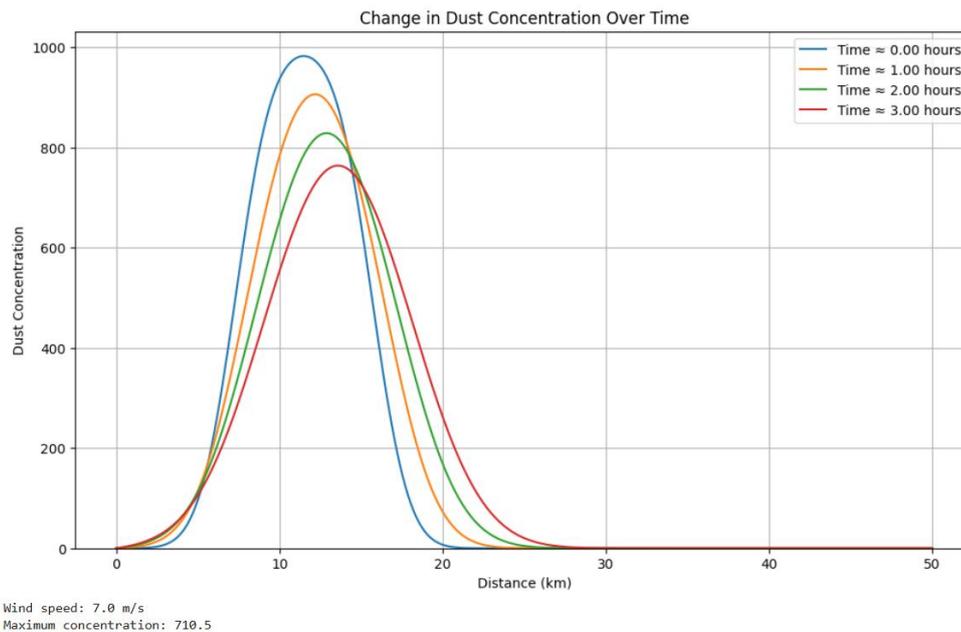


Figure 4. Change in dust concentration over time.

The results show that after the dust storm begins, the concentration increases sharply within the first 1–3 hours and then decreases gradually. The highest level of pollution is observed when the wind is strong.

The obtained results indicate that as wind speed increases, both the dispersion distance of dust particles and their concentration in the air increase significantly. In particular, at wind speeds in the range of 6–8 m/s, the concentration of PM10 and PM2.5 particles may exceed dangerous levels. In addition, it was found that additional dust sources from the dried areas of the Aral Sea contribute up to 25–30% to the deterioration of air quality in the region.

These results demonstrate the practical importance of improving the early prediction of dust storms and the air quality monitoring system in Termiz city.

### Conclusion and Recommendations

In this study, the dispersion of dust storms in Termiz city and Surkhandarya region was modeled using the advection-diffusion equation. The simulation results showed that as wind speed increases, both the concentration of dust particles and the dispersion distance increase significantly. The highest level of pollution was observed at wind speeds in the range of 6–8 m/s.

Based on the obtained results, the following scientific and practical recommendations can be made:

- a) Strengthen the dust storm monitoring system in Termiz city and Surkhandarya region and introduce real-time data analysis;
- b) Develop local forecast models taking into account dust sources from the dried areas of the Aral Sea;
- c) Increase the number of air quality monitoring stations and implement an automatic warning system for PM10 and PM2.5 particles.

This model can be further used in real-time mode and integrated with meteorological data



to make dust storm forecasts more accurate.

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