

COMPARATIVE ANALYSIS OF THE CLIMATIC CHARACTERISTICS OF WIND IN THE REGIONS OF IMERETI AND KAKHETI

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Abstract. *The present study aims to conduct a comparative analysis of the climatic characteristics of wind in the regions of Imereti and Kakheti, based on long-term data on wind speed and direction. The study examines periodic data from 1961 to 2022 and discusses seasonal variability, spatial differences, energy potential, and natural hazards, including tornadoes. The results show that Kakheti is characterized by predominantly eastern airflows and high wind speeds, contributing to its notable energy potential. In contrast, wind directions in Imereti vary seasonally, and its energy potential is more localized. The findings of this research provide a valuable basis for the development of renewable energy, urban planning, and climate risk management.*

Key words: *wind speed, direction, Imereti, Kakheti, renewable energy, tornado, climate risks.*

Introduction

Wind is one of the key climatic factors that influences both weather formation and various sectors of human activity – including energy, urban planning, infrastructure, and agriculture. The characteristics of wind speed and direction determine local climatic conditions and participate in atmospheric circulation processes. Moreover, the efficient utilization of wind's energy potential represents an important strategic direction in the development of renewable energy [6].

In Georgia, wind climatic characteristics exhibit high geographic and seasonal variability, caused by complex topography and the influences of the Black Sea and the Caucasus Mountains. The aim of this study is to analyze long-term data on wind speed and direction in the regions of Imereti and Kakheti, to examine extreme wind events (including tornadoes), and to comparatively assess these data from the perspective of practical application – including climate risk management and the assessment of renewable energy potential [2].

Methodology

The study is based on the analysis of meteorological station data in Georgia covering the period 1961–2022. Data from the National Environment Agency of Georgia and the Hydrometeorology Institute, as well as international climate databases (e.g., MERRA-2), were utilized. Key parameters included average and extreme values of wind speed and direction, analyzed seasonally and geographically.

Statistical analysis was performed using the following methods:

- Measures of central tendency: mean, median, mode, standard deviation;
- Frequency analysis: recurrence of wind directions and distribution of wind speed ranges;
- Trend analysis: The Mann-Kendall test was utilized to identify temporal trends.
- Comparative analysis: data from Imereti and Kakheti were analyzed individually and comparatively.

For the analysis of tornadoes and other natural hazards, expeditionary research and contemporary scientific literature were used [1, 3, 4].

Results and Discussion

Analysis of wind. Directions show that in Imereti, wind directions vary seasonally. Westerly and southwesterly winds dominate in spring and summer, while easterly and northeasterly winds prevail in autumn and winter. For example, in Kutaisi, easterly winds occur up to 70% during nighttime hours [2, 8].

In Kakheti, wind directions are much more uniform. The region is dominated year-round by easterly and northeasterly air masses, due to the orographic conditions of the Alazani Valley and the influence of the Caucasus Ridge [9].

Wind speed variation and geographical distribution. In Imereti, average wind speeds in lowland areas range between 2.5 and 4.5 m/s. In mountainous zones such as Mta-Sabue, speeds reach up to 9.2 m/s. The background frequency of winds in Kutaisi is approximately 120 days per year [5, 8].

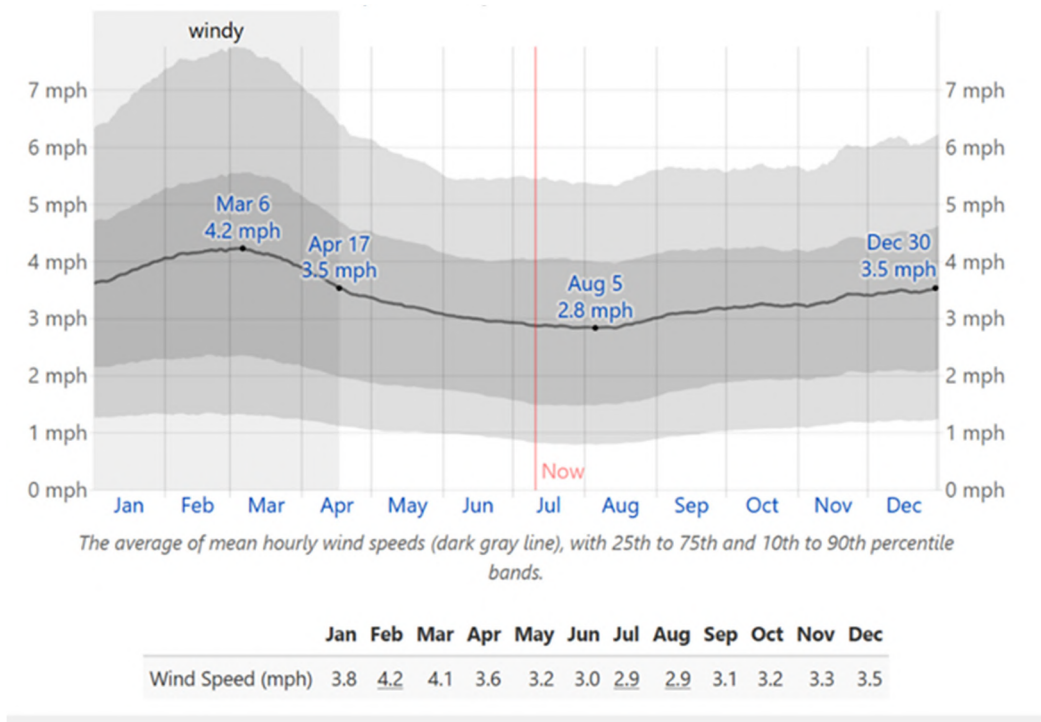


Fig. 1. Average Wind Speed [8].

In Kakheti, average wind speeds are considerably higher. In Sagarejo, wind speeds of up to 9.5 m/s were recorded during the summer, while in Telavi, the minimum values in winter reached as low as 0.7 m/s. Eastern Kakheti is characterized by the most intense windiness [9].

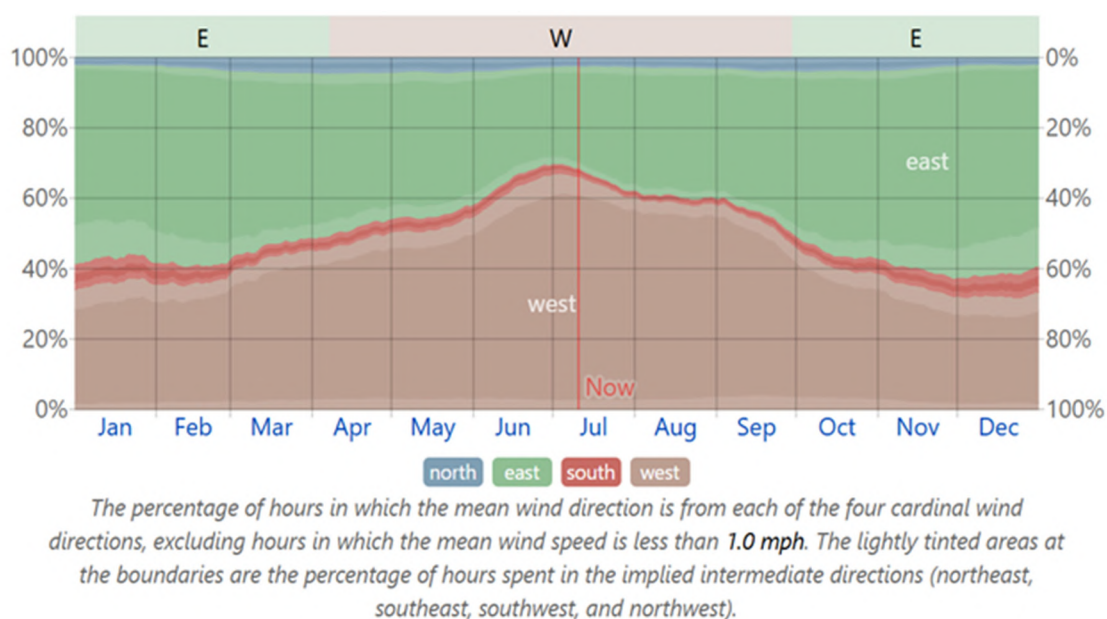


Fig. 2. Wind Direction [8]

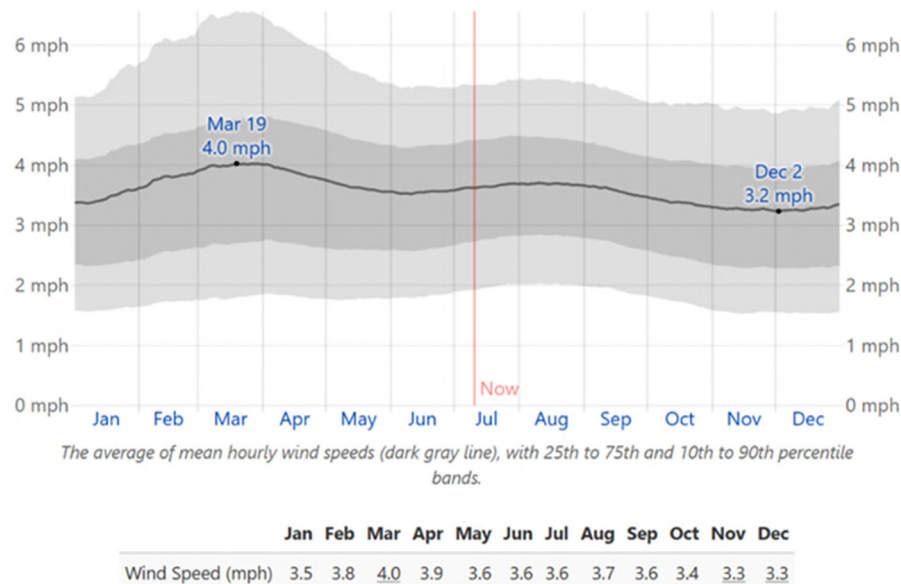


Fig. 3. Average Wind Speed [9].

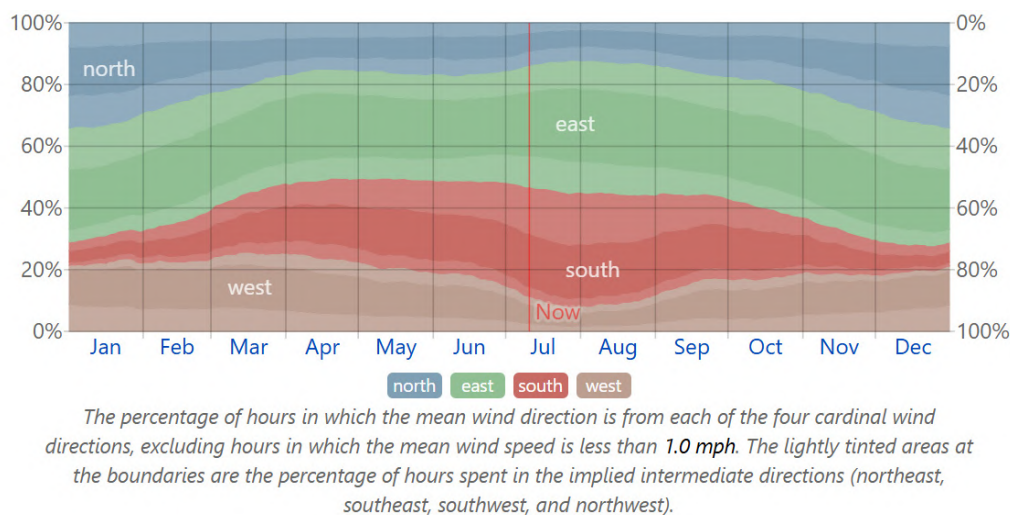


Fig. 4. Wind Direction [9].

Wind Energy Potential. In the mountainous zones of Imereti, the use of small-scale wind turbines is possible; however, the energy potential is localized and requires detailed zonal studies [7, 10].

In Kakheti, the technical potential for wind energy is high. There are extensive areas where the average wind speed exceeds 7–10 m/s, which is favorable for the installation of medium and large capacity turbines [7, 10].

Extreme Wind Events. Extreme wind occurrences in Imereti are rare and mostly localized. Maximum wind speeds, such as the 66 m/s event recorded in Kutaisi, are exceptions [2, 5].

In 2024, a tornado was recorded in the village of Alaverdi, Akhmeta Municipality, Kakheti. Field studies classified it as an F2 category tornado. The region has also experienced severe storms in 2012, 2021, and 2022, indicating a trend toward increasing frequency of extreme events [2].

Prospects for Use. Wind data from both regions should be integrated into spatial and urban planning. In Imereti, it is recommended to consider ventilation corridors and to implement local turbines in mountainous zones. In Kakheti, large-scale wind energy projects are feasible, requiring the development of appropriate infrastructure and refinement of risk management systems.

Conclusion:

- ❖ Wind direction in Imereti varies seasonally, while in Kakheti it remains stably easterly;
- ❖ Kakheti is characterized by higher wind speeds and greater renewable energy potential;

- ❖ Tornadoes and severe storms are primarily characteristic of Kakheti;
- ❖ Using wind data is advisable in both regions for energy and urban planning purposes.
- ❖ Zonal planning, investment research, and development of adaptation mechanisms are necessary for managing climate risks.

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