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The impact of atmospheric circulation on wind energy resource using self-organizing maps

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The sensitivity of wind to the Earth's energy budget and the changes it causes in the climate system has a significant impact on the wind energy sector. The scope of this work is to examine the association of atmospheric circulation with the wind speed distribution characteristics on different timescales over Greece. Emphasis is given to the effect of specific regimes on the wind speed distributions at different locations. The work is based on using synoptic climatology as a tool for providing information regarding wind variability. This approach allows a more detailed description of the effect of changes in large-scale atmospheric circulation on wind energy potential. The atmospheric classification methodology, upon the selection of relevant atmospheric variables and domains, includes a Principal Components Analysis for dimension reduction purposes and subsequently, the classification is performed using an artificial neural network and in particular self-organizing maps. In the resulting feature map, the neighboring nodes are interconnected and each one is associated with the composites of the selected large-scale variables. Upon the assignment and the characterization of each day in one of the resulting patterns, a daily catalog is constructed and frequency analysis is performed. In the context of estimating wind energy potential variability for each atmospheric pattern, the fit of multiple probability functions to the surface wind speed frequency distributions is performed. The most suitable function is selected based on a set of difference and correlation statistical measures, along with the use of goodness-of-fit statistical tests. The study employs the ERA5 reanalysis dataset with a 0.25° spatial resolution from 1979/01/01 up to 2019/12/31 and the wind field data are extracted at the 10m and the 100m levels. The approach could be valuable to the wind energy industry and can provide the required scientific understanding for the optimal siting of Wind Energy Conversion Systems considering the atmospheric circulation and the electricity interconnection infrastructure in the region. Considering the emerging issue of energy safety, accurate wind energy production estimates can contribute towards the establishment of wind as the primary energy source and in meeting the increasing energy demand.