



Atmospheric circulation changes and turbulence modifications over Europe: implications for commercial flight operations in a changing climate

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The unprecedented changes in Earth's climate are reshaping atmospheric dynamics on a global scale, with profound implications for various sectors, including aviation. One of the critical facets of this transformation lies in the alterations to atmospheric circulation patterns and the concurrent modifications in turbulence characteristics.

We investigate the intricate interplay between climate change, atmospheric circulation patterns, and turbulence modifications over Europe, with a specific focus on their implications for commercial flight operations. Drawing upon ERA5 reanalysis data at 200 hPa pressure level we explore the evolving climatic conditions shaping the European airspace. By jointly looking at the cube-rooted eddy dissipation rate, vorticity, and horizontal divergence we evidence increasing trends of anomalously turbulent conditions over UK and Northern Europe. Otherwise, decreasingly frequency anomalies are associated with light-turbulent conditions over Central and Mediterranean Europe. Overall, increasing trends also correspond to increased severity in terms of turbulence strength levels, with a clear increase in moderate-to-severe turbulence episodes, mainly associated with both converging and diverging atmospheric ridges.

The study highlights the region's vulnerability to significant changes in atmospheric pattern dynamics, emphasizing the potential increase in turbulence-related episodes and severity, impacting aviation safety, fuel efficiency, and passenger comfort. Our analysis aims to provide valuable insights for aviation stakeholders, policymakers, and researchers, contributing to the development of adaptive strategies and operational guidelines.