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## Abstract

### Spatiotemporal Precipitation Trends and Associated Large-Scale Teleconnections in Northern Pakistan

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#### Abstract

**Background and Aim:** Climate change poses unprecedented challenges, impacting food production and increasing flood risks. This study focuses on northern Pakistan, assessing observed changes in seasonal and annual precipitation using data from 25 meteorological stations and ERA-5 reanalysis. The aim is to understand spatial trends, analyze oceanic indices' association with precipitation, and provide insights for water resource management.

**Method:** Monthly precipitation data and ERA-5 reanalysis complemented unevenly distributed station data. Trend assessments utilized non-parametric tests (MK, SSE, SQMK), and wavelet analysis explored oceanic index associations from 1960 to 2016.

**Results:** Max precipitation occurred in annual and summer seasons. Overall, NP experienced declining annual, winter, spring, and summer precipitation but an autumn increase at 0.43 mm/decade (1989–2016). Spatial trends aligned in winter, spring, and autumn but diverged in summer and annual trends. Region III saw significant summer and annual increases (1989–2016), contrasting overall NP decreases (1960–2016). An increase in annual precipitation post-1985 was observed, with elevation-dependent variations.

**Conclusion:** Interannual coherence of precipitation with ENSO, AO, and PDO was noted. Winter and spring precipitation correlated with AO and ENSO, while summer precipitation linked to IOD and PDO. The findings inform water resource management policies in NP amid climate change, emphasizing the need for adaptive strategies to ensure sustainable water resources.

**Keywords:** *Precipitation, Cluster analysis, Wavelet coherence, Oceanic indices, Northern Pakistan*

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