

# **Urbanization-Driven Changes in Fog over the Indo-Gangetic Plain: An Investigation Using Observations and WRF Framework**

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Wintertime fog over the Indo-Gangetic Plain (IGP) exerts profound socioeconomic impacts, particularly on transportation, aviation, and public safety. During the past few decades, the region has experienced rapid urban expansion, accompanied by substantial changes in land use and land cover (LULC) and increasing anthropogenic aerosol emissions. Despite these developments, the extent to which these factors influence the formation, intensity, and evolution of fog remains insufficiently understood. This thesis combines long-term observations with high-resolution Weather Research and Forecasting (WRF/WRF-Chem) model simulations to investigate the impact of LULC change, urban expansion, and enhanced aerosol emissions on winter fog characteristics over the IGP, with a particular focus on the National Capital Region (Delhi). Considered independently, LULC changes promote earlier fog dissipation by enhancing near-surface warming and turbulent mixing, leading to a decline in dense fog occurrences.

In contrast, simulations that include atmospheric chemistry show that aerosol effects outweigh the suppressive influence of LULC, resulting in an overall extension of fog duration. Both drivers also modify the vertical structure of fog by intensifying turbulence and mixing, strengthening upper-level fog (50-100 m). Furthermore, spatial variations in fog optical thickness, represented by liquid water path (LWP), lead to the formation of fog holes, demonstrating that they can develop during any stage of the fog life cycle and are not restricted to urban areas. Overall, the study highlights the importance of representing both land-surface changes and aerosol effects in numerical weather prediction models to improve fog forecasting, with broad implications for aviation safety.