Aviation activity has grown steadily, and will likely continue to grow in the future. Aviation-related air pollutants occurring during full-flight (landing and takeoff, as well as cruise) can impact air quality, human health and climate. The overall goal of this dissertation is to study the air quality impacts of aviation at local, regional and global scales. The central hypothesis of this study is that fine scale modeling provides better characterization of aviation emissions impacts on air quality and health. To test this hypothesis, a model-based assessment of aviation emissions impacts was conducted at multiple scales ranging from local (4 × 4 km²) to hemispheric (108 × 108 km²) scales.

Firstly, we focused on key risk-prioritized Hazardous Air Pollutants (HAPs) and assessed their impacts near a mid-sized U.S. airport using a chemistry-transport model at a fine scale (4 × 4 km²). Overall modeled aircraft-attributable HAPs contributions are in the range of 0.5 – 28% near this airport. Second, we concentrated on the full-flight emissions impacts on air quality near surface for O₃ and PM₂.₅ at a resolution of 108 × 108 km², spanning the Northern hemisphere (NH). Including full-flight aviation emissions at the hemispheric scale contributed 1.3% and 0.2% for O₃ and PM₂.₅ at the surface on an annual domain-wide basis. Our comparison of these predictions with 36 × 36 km² application over North America highlighted that the coarse scale resolution was unable to capture non-linearities in chemical processes near airport locations and other major urban areas. Lastly, we conducted a tracer study to understand the role of dynamic processes on cruise altitude aviation emissions (CAAE) impacts at the surface using a hemispheric scale application. Model predictions indicated that < 0.6% of CAAE tracer in the total atmospheric column was transported to the surface in the NH and ~40% was transported to mid-troposphere during all four seasons. This intercontinental tracer-tagging approach provided quantitative evidence that North America and Europe CAAE tracers can impact the surface (~0.5 – 1% of total column burden) near high terrain regions like Tibet Plateau and relatively lower aviation emissions regions such as Middle East, North Africa and South East Asia.

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