Emissions Inventories for Dispersion Modeling of Aviation Gas Turbine Engine Emissions

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Introduction

The projected growth of the airline industry necessitates further research into jet emissions and into options for mitigating their effects on climate change, local air quality, and human health. Dispersion modeling is a good tool to determine pollutant concentrations at small spatial scales. This project models the effects of alternative aviation fuels (alt-fuels) on particulate matter (PM) concentrations near the Hartsfield-Jackson Atlanta International Airport (ATL) using the Emissions and Dispersion Modeling System (EDMS).

Input Data

Flight schedule data was obtained from the Bureau of Transportation Statistics for the present study. Gates were assigned to each flight based on the airline and runways were assigned by EDMS based on the weather conditions. Weather data for this project were taken from databases maintained by NOAA. Emissions data for standard and alt-fuels were gathered by our group over multiple experimental campaigns. Measurements of PM levels at the engine exit plane for different fuels were used to generate emissions ratios between fuels. These ratios were applied to the emissions inventories generated by EDMS.

Model Setup

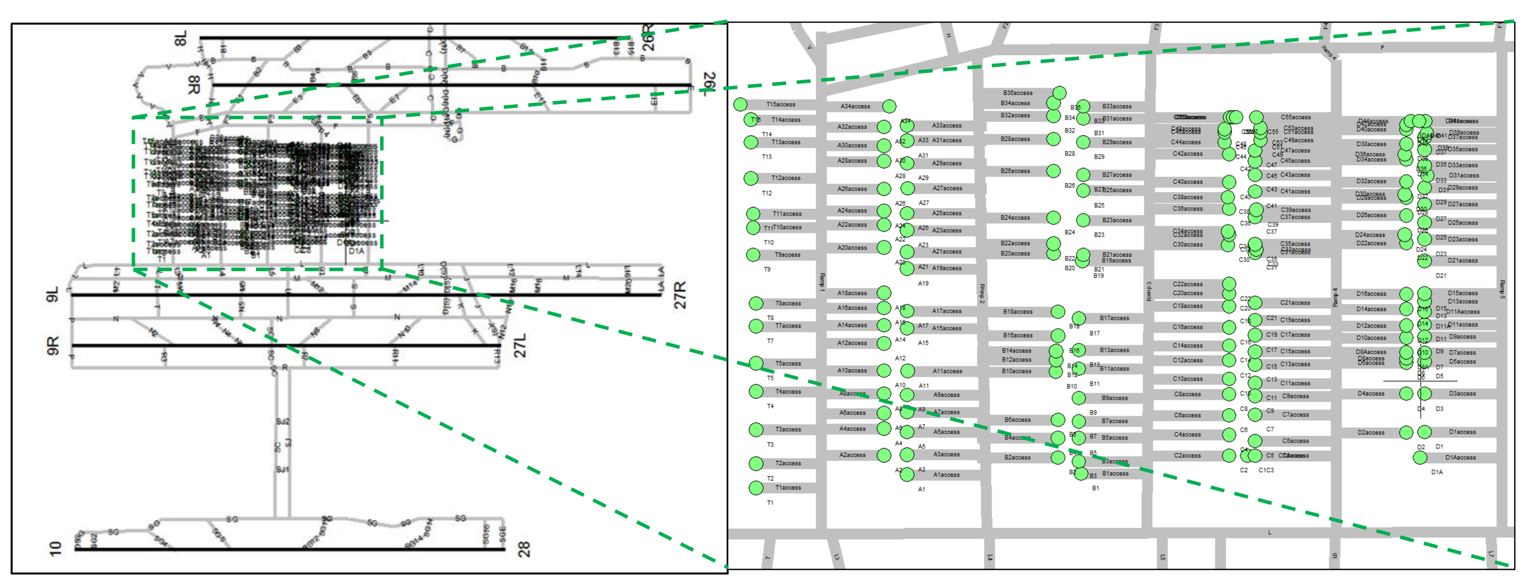


Figure 1: The model of ATL used by EDMS. The left panel shows the entire airport, while the right panel shows the terminal area.

The model of the airport shown in Figure 1 includes each individual gate at ATL as a point source of emissions. EDMS models the movement of each aircraft between the assigned gates and runways, taking into account different paths through the taxiway network and events such as delays and traffic jams. This detailed treatment of emissions was necessary to see if the PM concentration levels would reflect the complicated layout of ATL.

Distribution of Emissions

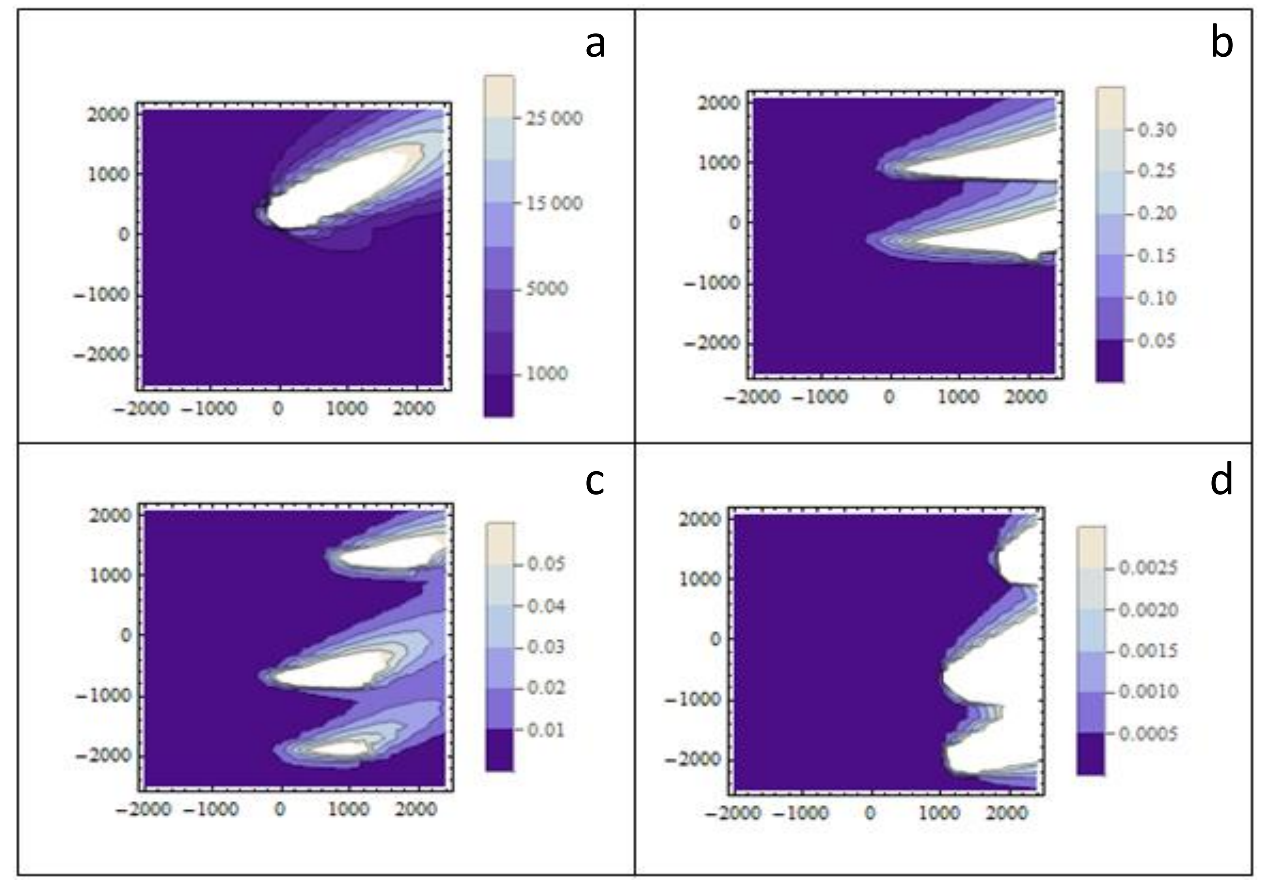
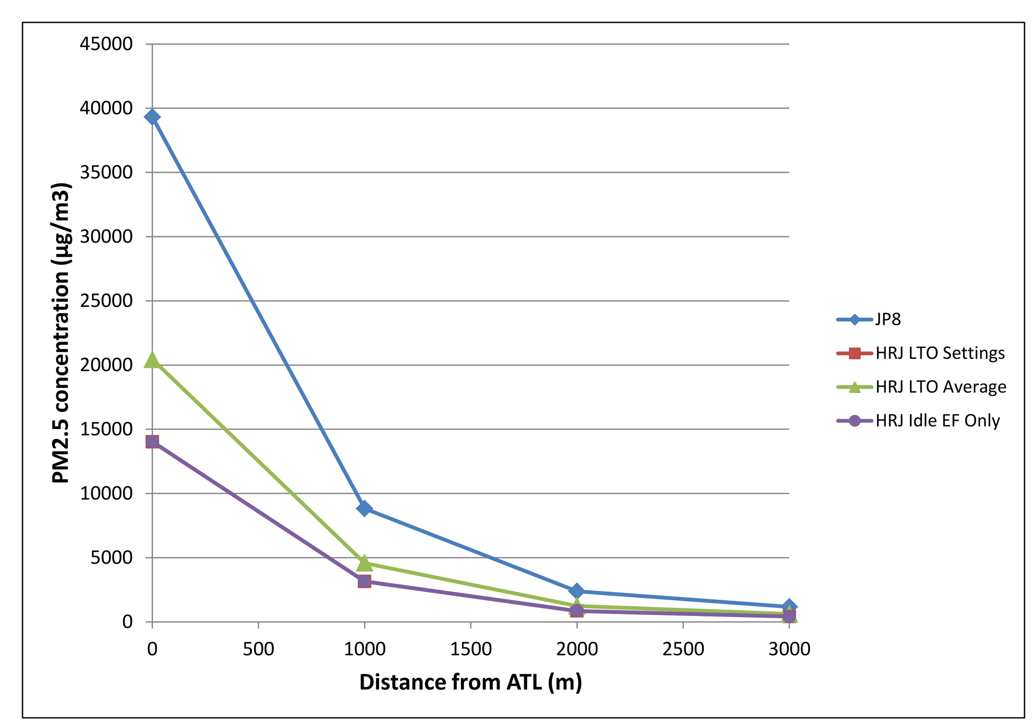


Figure 2: The distribution of PM emissions at ATL in units of μg/m³. In alphabetical order: the emissions from engines running at the idle, takeoff, landing, and approach power settings.

The concentrations shown in Figure 2 above are 24-hr averages of PM levels at ATL. Though the complicated network of taxiways is not evident in Figure 2a, Figures 2b-2d clearly show the location and orientation of the five runways along with the influence of the wind direction on the emissions. Of note is the scale of each plot; the emissions due to idling aircraft at ATL result in PM concentrations which are orders of magnitude higher (at ground level) than those from the other engine power settings. Because the composition of gas turbine engine PM emissions changes greatly with the engine power, this is a significant result.

Alt-fuels Emissions

Figure 3: Time-averaged PM concentration values as a function of distance from ATL for JP8 and HRJ fuels. The HRJ data series represent three different methods for accounting for changes in PM emissions for the Hydroprocessed Renewable Jet (HRJ) fuel.



The 'HRJ LTO Settings' data series uses engine power-specific HRJ emissions reduction factors for each stage of the Landing and Takeoff cycle. The 'HRJ LTO Average' series employs a single average emissions reduction factor, which is a weighted average based on the fuel burn in each stage. The 'HRJ Idle EF Only' series applies the emissions reduction factor for the idle engine power setting to all emissions.

Alt-fuels Emissions (cont.)

Among the data series in Figure 3, the JP8 fuel scenario clearly shows the highest PM concentrations, as expected. However, the LTO-averaged data yields concentrations which are higher than the other HRJ scenarios by ~1/3. This suggests that the concentrations due to each engine power setting are primarily governed by the dispersion of the emissions, and not simply the fuel burned during each stage. In addition, the near equality between the LTO and Idle scenarios indicates that emissions reductions are influenced primarily by emissions at the idle condition. This matches the conclusions drawn from the contour data shown in Figure 2. Determining the precise reason for the lack of non-idle emissions at ground level will be important.

Conclusions

Gas turbine engine emissions were modeled for ATL for a period of one month in order to examine the impacts of methodology on the resulting emissions concentration estimates, as well as to estimate the impact of alternative fuel use on said concentration estimates. The majority of input data was freely available and the simulation was not resource-intensive, making this project accessible and effective. PM concentrations for alt-fuels scenarios were greatly reduced compared to standard fuel. The complex nature of the airport layout was not represented in the PM concentration data; however, it became evident that concentrations at ground level are dependent primarily on emissions during the taxiing process at the airport. Further work is necessary to verify the reason for low emissions at ground level due to non-idle engine power conditions.

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