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A comparison between monitoring and dispersion modeling approaches to assess the impact of aviation on concentrations of black carbon and nitrogen oxides at Los Angeles International Airport

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HIGHLIGHTS

- We compare monitoring and dispersion modeling for predicting aviation contributions.
- Regression models show that aircraft departures impact near-runway concentrations.
- Aviation contributions to 1-hour average BC and NOx differ between approaches.
- Multi-pollutant modeling at multiple monitors provides insight on model performance.
- Update of plume treatment and BC emissions inventory can improve AERMOD estimates.

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ABSTRACT

Aircraft activity and airport operations can increase combustion-related air pollutant concentrations, but it is difficult to distinguish aviation emissions from traffic and other local sources. Emission inventories are uncertain and dispersion models may not capture aircraft plume complexity; ambient monitoring data require detailed statistical analyses to extract aviation signals. The goal of this study is to compare two modeling approaches including monitoring-based regression models and the EDMS/AERMOD dispersion model, informing improvements and allowing quantitation of aviation impacts on air quality through multi-pollutant sensitivity and multi-monitor fate/transport analyses. Aggregate concentration comparisons are similar, though diurnal patterns show potential weaknesses in near-field dispersion, treatment of overnight conditions, and emission inventory accuracy.

1. Background and introduction

Concentrations of combustion-related air pollutants may be elevated in proximity to major airports due to emission contributions from the aircraft themselves, ground support equipment and auxiliary power units, and airport-related vehicle traffic. Air pollution management requires information regarding contributions of various sources to ambient concentrations, which can be evaluated using monitoring-based or dispersion modeling-based approaches.

Monitoring studies have used various methods and study designs to evaluate influence of aircraft emissions on ambient concentrations. Mobile-monitoring has been used in conjunction with fixed-monitoring sites near roadways to tease out traffic-related background concentrations and determine pollutants most closely related to airport activity (Westerdahl et al., 2008), providing source attribution approaches without quantification over time. A far-field mobile-monitoring study found increased particle number concentrations up to 10 km downwind of an airport, but did not specifically identify aviation sources and their relative contributions (Hudda et al., 2014). Other fixed-site ambient monitoring studies used regression modeling

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approaches to determine marginal source contributions to pollutant concentrations based on real-time flight activity and meteorology (Diez et al., 2012; Dodson et al., 2009; Hsu et al., 2012). Studies using 1-minute averaging times found positive relationships between flight activity and ultrafine particulate matter (Hsu et al., 2012) and other combustion pollutants (Diez et al., 2012), yielding quantitative source contributions, but challenges remained in capturing spatial and temporal variability of background pollutant concentrations.

While these studies have been able to observe and predict pollutant concentrations during different seasons and meteorological conditions at both small and large airports, regression models informed by monitoring data are resource intensive and can only account for limited time periods, spatial coverage, meteorological conditions, and flight activities. Especially if impacts of aviation emissions may be observed over a broad geographic domain (Hudda et al., 2014), the most efficient method for determining pollutant concentrations near airports is utilizing accurate emission inventories to populate atmospheric dispersion models. Some studies have focused on construction of emission indices (Herndon et al., 2005, 2008) under various activity profiles, demonstrating variability across aircraft types and over the landing and take-off (LTO) cycle. For local-scale airport air quality assessment, previous studies have used the Emissions and Dispersion Modeling System (EDMS) emission inventory and American Meteorological Society and Environmental Protection Agency Regulatory Model (AERMOD) dispersion modeling (Cimorelli et al., 2005; Federal Register Notice, 1998; Kim et al., 2012; Steib et al., 2007; Wayson et al., 2001). While AERMOD has suitably estimated traffic-pollutant concentrations (Venkatram et al., 2009), dispersion modeling for aircraft may be more challenging, given greater uncertainties for aircraft than for motor vehicles due to differential plume characteristics, including high exhaust temperature and velocity, rapid source movement, and complexity of plume formation and dynamics.

Due to significant uncertainties, validation of dispersion models using airport-related monitoring data with methods to quantify aviation contributions is a necessary step. Comparisons between dispersion model outputs and monitoring-based regression models have been performed in non-aviation settings (Beelen et al., 2010), showing moderate agreement. However, comparable spatiotemporally-resolved validation methods have not been used in aviation.

This study aims to determine relative strengths and weaknesses of two alternate modeling approaches through analytical comparison between dispersion modeling and monitoring-based regression modeling. We focus on black carbon (BC) and nitrogen oxides (NOx) concentrations at Los Angeles International Airport (LAX), leveraging data collected as part of the Demonstration Project of the LAX Air Quality Source Apportionment Study (AQSAS) between June and August 2008 (Jacobs Consultancy, 2013). BC and NOx are prominent near-airport pollutants produced via combustion and have potential elevations in concentrations relative to background as well as discernible health effects, warranting further investigation. Five-minute averaged measurements of BC and NOx, as well as minute-resolved meteorological conditions and real-time flight activity data, were collected at monitoring sites located sequentially behind LAX's main departure runway and used to populate statistical models predicting pollutant concentrations. An EDMS/AERMOD dispersion modeling system was used to predict concentrations at the same monitoring receptor sites during the same time period. A crucial feature of our analysis is the availability of multiple pollutants at multiple monitoring sites. Comparing regression and dispersion model estimates for BC and NOx at the same site allows us to comment on potential relative biases in the emission inventory, as AERMOD does not differentiate between these pollutants in the near-field. Comparing regression and dispersion models for BC at different monitoring sites allows us to examine issues with either the dispersion model or the ability of the regression models to capture aviation contributions at a range of distances, as emission inventory issues are controlled. These comparisons allow understanding of differences between two modeling methodologies, informing improvements to both and allowing quantitation of aviation impacts on air quality.

2. Methods

2.1. Study design

BC and NOx concentration data were collected as part of a large monitoring study conducted by Los Angeles World Airports (LAWA) through the LAX AQSAS over 42 days during summer 2008. LAX is a large airport with more than 2300 flights arriving and departing daily. Runway 25R is the main departure runway, with 48% of departures, and runway 25L is the main arrival runway, with 45% of arrivals during the monitoring study. Runways are aligned with prevailing winds from the west-southwest so aircraft may optimally take off into the wind and land against the wind. Sampling was performed at 3 monitoring sites located sequentially downwind of runway 25R, along the same 250° trajectory as the runway. The SR site is located directly downwind of this main departure runway, with the P4 site 250 m east of SR, and the P5 site another 250 m downwind of the P4 site (Fig. 1). At the SR site, BC was monitored between June 26 and July 23; NOx was monitored between July 7 and July 28. At the P4 site, BC was monitored between August 14 and August 22, and at the P5 site, BC was monitored between August 23 and September 1. Collocated measurements of NOx and BC were only collected at SR.

BC measurements were averaged over 5-minute periods using Magee Model AE-31 multi-channel aethalometers, which estimate real-time BC concentrations using optical attenuation. The AE-31 used an 880-nm wavelength, and particle mass was calculated by determining attenuation of light transmitted through the sampling filter (Hansen et al., 1984), operating in the 0–1000 μg/m^3 range with a sensitivity of <0.1 μg/m^3.

Ambient NOx concentrations were measured at 1-minute averages using the Thermo-Electron Corporation Model 42C NOx analyzer. The Thermo 42C detects nitrous oxide (NO) in ambient air by reacting NO with ozone, producing chemiluminescent reactions viewed by a photomultiplier tube. The device's microprocessor utilizes an algorithm to calculate species outputs from NO or NOx signals. The NOx analyzer operated in the 0–.500 ppm range with a level of detection of .001 ppm (Weston Solutions, 2009).

Meteorological data and flight activity were measured to allow for prediction of variability in pollutant concentrations. High-resolution wind speed and wind direction data were collected from an Automated Surface Observing Systems weather station located on the south airfield. Sampling was performed at 5- or 10-second averaging times then rolled up to 1-minute averages. One-second resolution flight activity data were provided by the airport, including specific aircraft and engine types.

To account for differential emissions from different sized aircraft and engine types, the 2010 ICAO Aircraft Engine Emissions Databank (International Civil Aviation Organization Committee on Aviation Environmental Protection, 2012) was used to create fuel-burn values as a proxy for emissions via multiplying number of engines by estimated fuel burned during the LTO cycle for each aircraft that arrived and departed from LAX during the study period (Hsu et al., 2012). Data were combined by 5-minute averaging times for creation of regression models. BC and NOx values were collected on a 5-minute basis, while 1-minute wind speed and wind direction values were averaged over 5-minute periods for use in the models, and aircraft operations and associated fuel-burn terms were summed over 5-minute periods.

2.2. Regression modeling

The goal of regression modeling for each pollutant is to analyze the relationship between flight activity, meteorology, and pollutant