AN INVESTIGATION OF THE IMPACTS OF AVIATION EMISSIONS ON CURRENT AND FUTURE FINE PARTICULATE MATTER IN THE U.S.

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Abstract

Matthew C. Woody: An Investigation of the Impacts of Aviation Emissions on Current and Future Fine Particulate Matter in the U.S.
"Under the direction of J. Jason West and Saravanan Arunachalam"

The impacts of aviation emissions on current and future year fine particulate matter ($PM_{2.5}$) were investigated using the Community Multiscale Air Quality model, accounting for aviation emissions from 99 airports and below 10,000 ft during the landing and takeoff (LTO) cycle. Results indicated that current year aviation emissions increased average $PM_{2.5}$ concentrations by 0.0032 µg m^{-3} (0.05%) in the continental U.S. while projected 2025 aviation emissions increased average $PM_{2.5}$ by 0.0116 µg m^{-3} (0.21%). Nitrate aerosol was the largest contributor to the increase in $PM_{2.5}$ concentrations due to aircraft emissions, particularly in the future year. Using an indicator of inorganic $PM_{2.5}$ change, we attributed nitrate aerosol contributions to excess free ammonia and higher aircraft emissions of NO_x (which when converted to HNO_3 forms ammonium nitrate aerosol) than SO_2 (a precursor of sulfate aerosol).

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Introduction

Aviation is a vital component of the U.S.'s infrastructure, transporting an average of 2.1 million passengers and 210,000 short tons of freight per day (Federal Aviation Administration 2009a) and comprising 5.6% of the U.S.'s gross domestic product in 2007 (Federal Aviation Administration 2009b). Furthermore, the aviation sector continues to grow steadily in the U.S. despite the recent economic downturn nationally and internationally. The Federal Aviation Administration (FAA) projects U.S. passenger enplanements to grow at an average annual rate of 2.5% per year between 2011 and 2030, with 1 billion passengers expected to fly in 2023 (FAA, 2010a). While important economically, aircraft activities are of environmental concern for air quality due to emissions of CO, NO_x, Volatile Organic Compounds (VOC), SO_x, $PM_{2.5}$, and numerous hazardous air pollutants. Considering the level of projected growth and the environmental concern associated with aircraft emissions, it is critical to understand the effects of aircraft on air quality from both an environmental and public health perspective. Here we present an investigation of the impacts of aviation emissions on a current year (2005) and future year scenario (2025), focusing on $PM_{2.5}$ (fine particulate matter less than 2.5 micrometers in diameter), using the Community Multiscale Air Quality (CMAQ) model, aiming to quantify aviation's current contribution to $PM_{2.5}$ and project how it may change in the future.

$PM_{2.5}$ is one of six criteria air pollutants regulated by the U.S. Environmental Protection Agency (EPA) under the National Ambient Air Quality Standards (NAAQS) section of the Clean Air Act (Federal Register, 1997). It has also been linked to adverse health affects, decreasing life expectancy by attacking the cardiovascular and respiratory systems due to its small size and ability to penetrate deep into the lungs (McMurry et al., 2004). The EPA has set annual average and 24-hour average primary standards for $PM_{2.5}$ of 15.0 $\mu g\ m^{-3}$ and 35 $\mu g\ m^{-3}$, respectively, as a means of protecting public health. Here, we quantify the contribution of aircraft emissions to annual $PM_{2.5}$ concentrations because the annual average standard is seen as more restrictive.

A number of recent studies have investigated the impacts of aircraft emissions on air quality (Kentarchos and Roelofs, 2002; Gauss et al., 2006; Søvde et al., 2007; and Hu et al., 2009). In a study performed by Unal et al. (2005), the impacts of aircraft on surface level ozone and $PM_{2.5}$ concentrations were quantified and compared at the Hartsfield-Jackson Atlanta International (ATL) airport by representing aircraft emissions as point sources at the airport and conversely as mobile sources. That study indicated that when aircraft emissions were treated as mobile sources and flight paths, mode, and plume rise were considered, the impacts on both ozone and $PM_{2.5}$ at the surface were reduced considerably during a 10-day episode in 2000 (maximum hourly difference of 41 ppb and 19 $\mu g\ m^{-3}$, respectively), compared to when aircraft emissions were treated as point sources at the airport (Unal et al., 2005). The implications of those results are potentially significant when one considers the traditional approach for modeling aircraft emissions in regional air quality models. The EPA's National Emission Inventory (NEI) (EPA, 2007a), often used for obtaining emission estimates for regional air quality modeling, reports aircraft emissions as ground-level point sources. However, this simplification does not accurately reflect aircraft flight trajectories and could therefore overestimate the impacts of aircraft emissions as suggested by Unal et al. (2005).

More recently, efforts have been made to quantify the localized impact of aviation emissions on air quality. In work performed by Ratliff et al. (2009), impacts of 2005 aircraft emissions below 3,000 feet to $PM_{2.5}$ and ozone concentrations were quantified focusing on non-attainment areas as designated by the EPA. Those results indicated that in areas of non-attainment, aircraft emissions increased $PM_{2.5}$ concentrations by 0.01 $\mu g\ m^{-3}$ and ozone concentrations by 0.11 ppb on average. A similar study performed by Arunachalam et al. (2008, 2010) focused on the ATL, Chicago O'Hare (ORD), and Providence T.F. Green (PVD) airports using a multiscale (36-km, 12-km, and 4-km) modeling approach. In that work, the EDMS2Inv tool (Baek et al., 2007) was developed and implemented as an interface that processes aviation emissions from the FAA's Emissions and Dispersion Modeling System (EDMS) (Federal Register, 1998) and through the Sparse Matrix Operator Kernel Emissions (SMOKE) model (Houyoux et al., 2000) to provide a three-dimensional representation of aircraft emissions. Aircraft emissions were based on landing and take-off (LTO) cycles, which include startup, taxiing, queuing, takeoff, climb-out, and approach, and account for emissions below 10,000 feet (Arunachalam et al., 2008). Results indicated that aircraft emissions increased total $PM_{2.5}$ contributions overall both at and downwind of the 3 airports considered, with decreased nitrate and SOA concentrations near the airports but increased concentrations downwind of them (Arunachalam et al., 2008).

Here we aim to model the contributions of aircraft emissions to ground-level $PM_{2.5}$ in the entire continental U.S. in a current and future year. We use a similar approach to that of Arunachalam et al. (2008; 2010) to quantify the emissions of aircraft below 10,000 feet but expand from localized impacts at three airports to national impacts by including emissions from 99 major U.S. airports in 2005 and 2025. We simulate the impacts of aircraft emissions on $PM_{2.5}$ in a current year, determine how those effects may change in a future year, and compare contributions from changes in non-aviation and aviation emissions in both years.

Methodology

Model and non-aviation emissions description

We used the Pennsylvania State University/NCAR mesoscale v3.7 model (MM5) (Grell et al., 1994), SMOKE v2.5 model, and Community Multiscale Air Quality (CMAQ) (Byun and Ching, 1999; Byun and Schere, 2006) v4.6 model, which includes the ISORROPIA v1.7 thermodynamic equilibrium model (Nenes et al., 1998) for inorganic particulate matter, to estimate the effects of current and future aircraft emissions on air quality within the continental U.S. (Figure 1). CMAQ's treatment of particulate matter is described elsewhere (Binkowski and Roselle, 2003) and we will focus on all components of PM in this study. We also included treatment of hazardous air pollutants in CMAQ for this application, but the results are not presented here. A total of five annual modeling simulations were performed at a 36-km horizontal grid resolution (Table 1). Meteorological inputs, which were based on 2005 conditions, were held constant across all model scenarios. Initial and boundary conditions (IC/BCs) for current and future years were based on output generated by the GEOS-Chem global model (Bey et al., 2001). In the absence of 2025 specific GEOS-Chem simulations, we interpolated the IC/BCs from 2000 and 2050 simulations to obtain 2025 concentrations. Current year base case (base05) emissions from all non-aviation sources were estimated using the EPA's 2005 NEI (EPA, 2007a). Future year base case (base25) emissions were based on EPA's 2020 and 2030 estimated projections, which includes projected growth and controls "on the books" for various sectors on the national and state level, interpolated to 2025 (EPA, 2008).

Table 1. CMAQ modeling scenarios.

Scenario Name	Base Emissions	Aircraft Emissions
base05	2005	---
airc05	2005	2004
b05_a25	2005	2025
base25	2025	---
airc05	2025	2025

Current year aviation emissions description

Aircraft emissions data, based on LTO cycles, were generated from a research version of EDMS, processed through the EDMS2Inv tool, and finally input into SMOKE. Current year aircraft emission estimates (air05) included CO, total organic gases (TOG) (comparable but not equivalent to VOC) speciated using a more recent chemical speciation profile (EPA, 2009a; EPA, 2009b), NO_x, SO_x, primary elemental carbon (non-volatile component of $PM_{2.5}$), and hazardous air pollutants (HAPS). Note, while aircraft emissions used in this study included HAPS, they are not included in the scope of this work. Emissions estimates were based on hourly National Aerospace Standards (NAS) activity data from 99 major airports (Figure 1) for February 19, 2004 and scaled up to compute an annual inventory (CSSI, 2009). The list of airports along with their full names is also available elsewhere (CSSI, 2009). February 19 was identified as a typical day for aircraft activity by CSSI

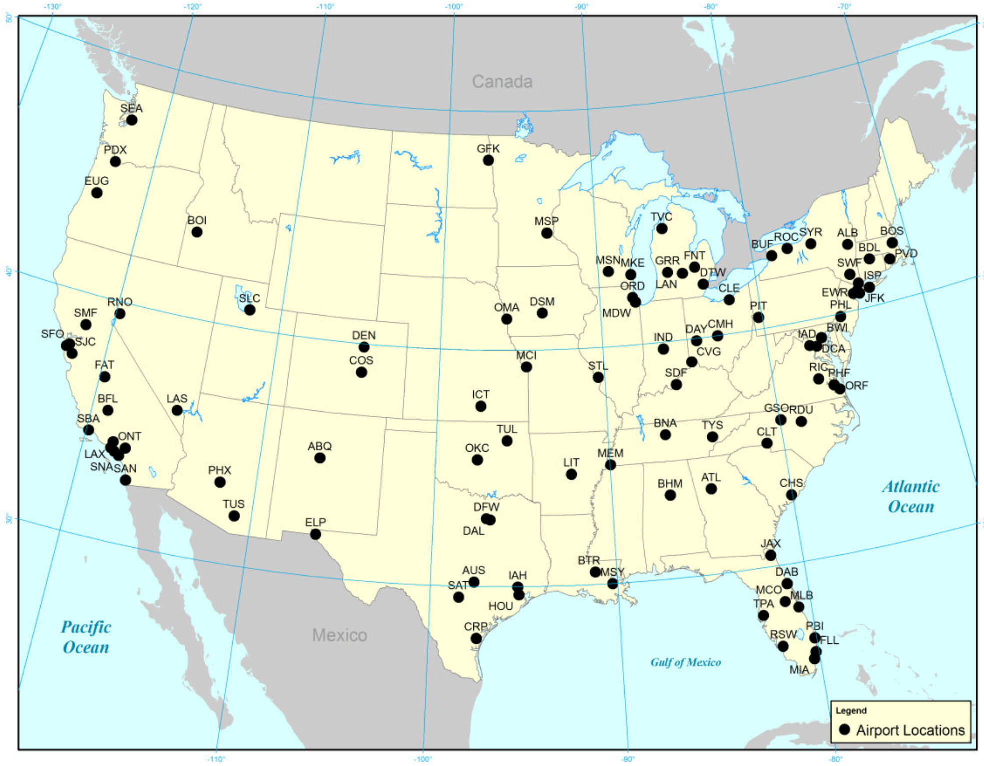

Figure 1. Modeling domain and 99 airports modeled.

(2009) based on relatively heavy aircraft traffic (71st percentile) and light weather conditions (10th percentile for low convective weather). Annual inventory scaling was performed on an individual airport basis using scaling factors specific to each airport and based on flight schedules (CSSI, 2009). While applying 2004 aviation emissions to 2005 non-aviation emissions presents a slight discrepancy, we assume that emissions varied little between the two years. The 99 airports included in this study represent 94% of passenger enplanements and 90% of landed cargo weight in 2004 (FAA, 2009a).

Current year aircraft emissions comparison

To evaluate the 2004 aircraft emissions inventory used here, a comparison was performed against aircraft emissions available from the EPA's 2005 NEI as well as a recent 2006 inventory prepared by Wilkerson et al. (2010). While different methodologies were used to create each inventory, a comparison of the 3 provides a means to evaluate the aircraft inventories used in this study. For the 2005 NEI, EDMS was used to estimate aircraft emissions by county up to 3,000 feet based on LTO cycles from 2002 aircraft activity data reported by the FAA and state and local agencies (EPA, 2005). The counties representing the 99 airports used in this study represent 82-94% (depending on the species) of the total continental U.S. aircraft emissions from the NEI. The Wilkerson et al. inventory used the FAA's Aviation Environmental Design Tool, which incorporates the latest version of the EDMS tool with a number of other FAA environmental tools, and included emissions from both LTO cycles and cruise height activity based on daily global aircraft flight trajectories from 2006 (Wilkerson et al., 2010). Although each inventory is based on flight activity data from different years (2002, 2004, and 2006), passenger enplanements in the U.S. only increased by approximately 10% during the 4 year period (FAA 2009a) and likely composes only a small portion of the differences between inventories. For the purposes of the comparison, we extracted emissions only in the Continental U.S from both the NEI and Wilkerson et al. inventories, and emissions below 10,000 feet (removing cruise altitude emissions) from the Wilkerson et al. inventory. Additionally, TOG from the 99 airport inventory was converted to VOC since the NEI and Wilkerson et al. inventories reported organic gases as VOC.

Figure 2 indicates the total gas phase aircraft emissions from each of the 3 inventories in tons per year and, for the most part, are comparable between the three inventories. The Wilkerson et al. inventory indicated higher levels of gas phase emissions for all species, suggesting higher aircraft activity than that used in 99 airport inventory. While a portion of this can be attributed to the Wilkerson et al. inventory including all airports in the U.S., it would seem that, because the 99 airports comprise a large percentage of passenger enplanements and the vast majority of NEI emissions occur in the counties represented by the 99 airports, this would not fully account for the differences. Therefore, impacts determined using the 99 airport inventory would likely be lower than impacts determined by the portion of the Wilkerson et al. inventory below 10,000 feet.

For $PM_{2.5}$ emissions, each inventory employed a different speciation profile to estimate individual components. The speciation profile for the 99 airport inventory was based on the First

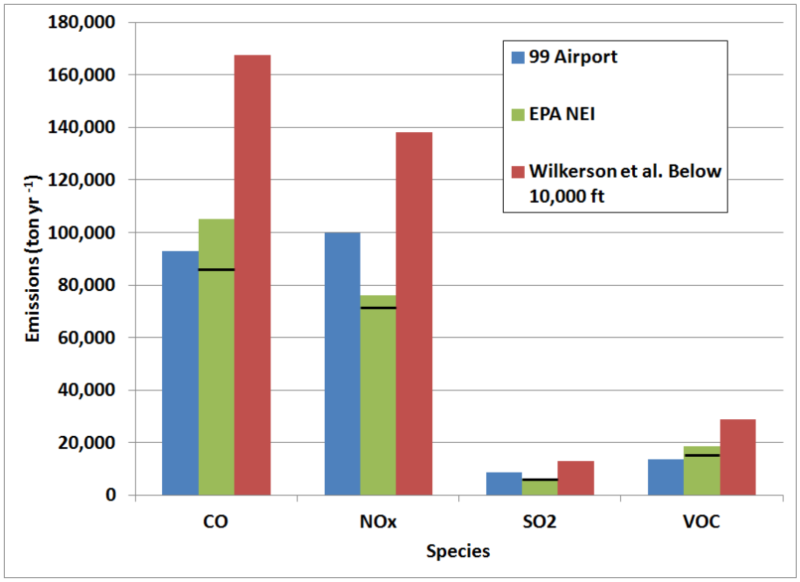

Figure 2. Comparison of total gas phase emissions from aircraft in the continental U.S. The area below the solid black lines for the NEI indicate the portion represented by the counties containing the airports in the 99 airport inventory.

Order Approximation Version 3.0 (Wayson et al., 2009) and is specific for ground level aviation activities (CSSI, 2009). Estimates based on FOA3 include a non-volatile portion composed of PEC and a volatile portion composed of primary sulfate (PSO4) and primary organic aerosols (POA). However, the 99 airport inventory used in this study only includes PEC, excluding PSO4 and POA due to uncertainties associated with the volatile portion of aircraft emissions at the time the inventory was prepared. The speciation profile used by the NEI is not specific to aircraft emissions but is a simplified version of the Heavy Duty Diesel Vehicle speciation profile and includes PEC, POA, PSO4, other primary (PMFINE), and primary nitrate aerosols (PNO3). The Wilkerson et al. inventory used a speciation profile typical of aircraft emissions at cruise altitude and includes PEC, PSO4, and POA. Table 2 summarizes the speciated fraction of $PM_{2.5}$ as estimated by each inventory using their respective speciation profiles.

Figure 3 indicates $PM_{2.5}$ aircraft emissions from the 3 inventories as well as the percent composition of individual species (Note: while the Wilkerson et al. speciation profile included PSO4 and indicated higher amounts of PEC than POA emissions, the supplied emissions data used for the

Table 2. Speciated fractions for $PM_{2.5}$ estimated by speciation profiles.

Inventory	PEC	POA	PSO4	PMFINE	PNO3
99 Airport Inventory	0.461	0.158	0.381	---	---
NEI	0.771	0.176	0.003	0.049	0.001
Wilkerson et al. Inventory	0.312	0.138	0.550	---	---

comparison did not include PSO4 and indicated higher amounts of POA than PEC emissions). While the 99 airport and Wilkerson et al. inventories have comparable emissions of primary elemental carbon (PEC), the similarities end there. The NEI contains much higher emissions of $PM_{2.5}$, 27 times higher than the 99 airport inventory and 3.2 times higher than the Wilkerson et al. inventory, suggesting that the NEI may overestimate aircraft $PM_{2.5}$ emissions. The differences in both the totals and speciation of $PM_{2.5}$ emissions from aircraft from the 3 inventories highlight uncertainties in our study, and suggest that future work to resolve these differences would be important.

Figure 4 indicates the percentage of the Wilkerson et al. inventory below 10,000 feet (as compared to the total inventory in the continental U.S.) through which we can assess limitations

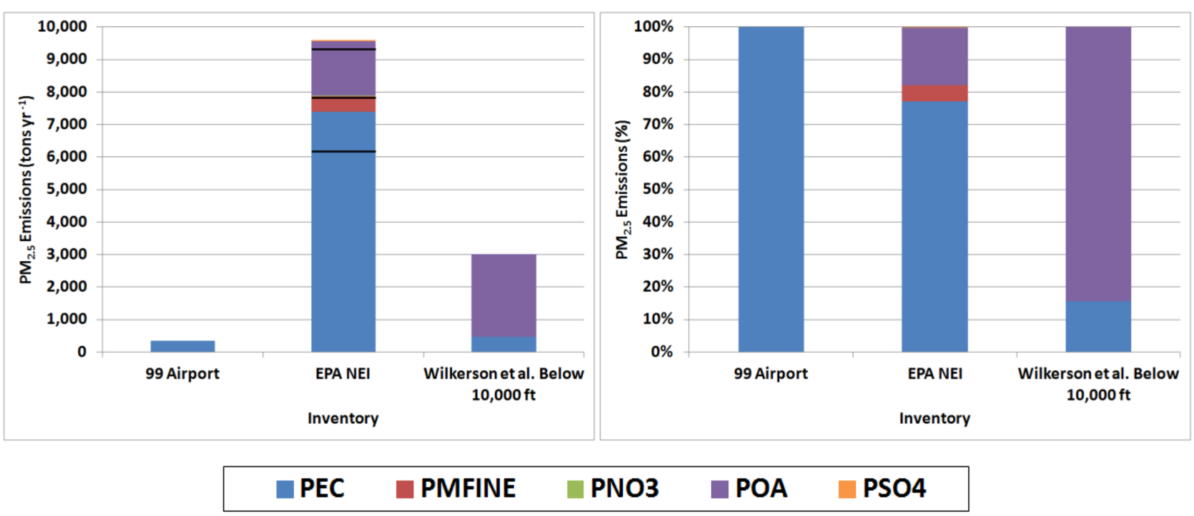

Figure 3. Comparison of total $PM_{2.5}$ emissions from aircraft in the continental U.S. (left) and the $PM_{2.5}$ speciation profile for aircraft emissions used by each inventory (right). The area below the solid black lines for the NEI indicate the portion represented by the counties containing the airports in the 99 airport inventory.

associated with the 99 airport inventory used in this study. Approximately 20% of SO_2 and NO_x emissions occur below 10,000 feet while approximately 50-60% of VOC, $PM_{2.5}$ and CO emissions occur below 10,000 feet. The focus of this paper is to quantify the effects of aircraft emissions in the lowest 10,000 feet (during aircraft LTO cycles) on air quality at the surface, necessary to evaluate effects on public health. Therefore, the inclusion of aircraft at cruise altitude is outside the scope of this paper. However, while the inclusion of emissions below 10,000 feet is a reasonable assumption to assess the ground level concentrations, it also suggests that our results will likely underestimate the true impact, considering that 40-80% of the emissions in the Wilkerson et al. inventory occurred above 10,000 feet.

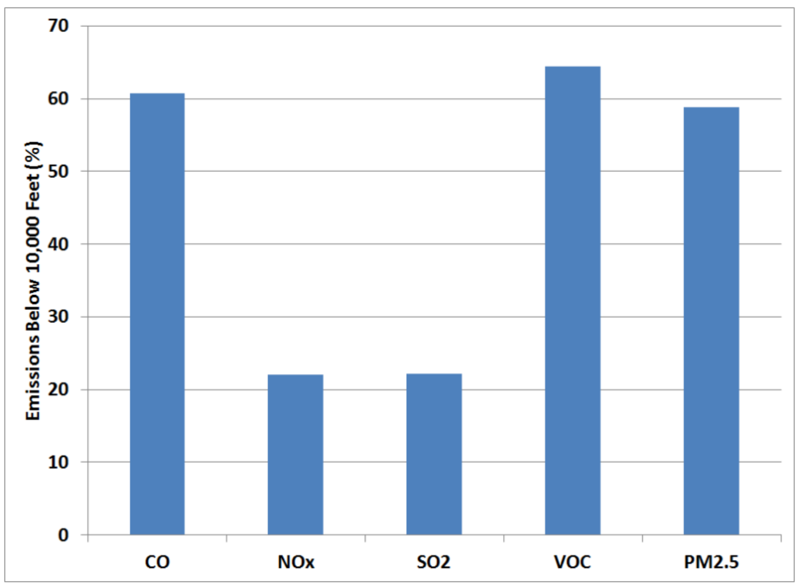

Figure 4. Portion of Wilkerson et al. inventory below 10,000 feet as a percentage of the total inventory in the continental U.S.

Future year aviation emissions description

Future year aviation estimates (airc25) were scaled up using air traffic data based on the FAA Terminal Area Forecasts (TAF) for February 19, 2025. This was one of the several scenarios modeled by the Interagency Portfolio and Systems Analysis Division of NextGen's Joint Planning and

Development Office (JPDO) to assess aviation growth (CSSI, 2009). This future year estimate represents a business-as-usual scenario with no mitigation strategies, policies, or changes in technology and considers only growth in aviation activity. Table 2 provides the total aircraft emission inventory for both the current and future year.

Table 3. Total annual aircraft emission inventory from 99 airports.

Year	CO (ton yr^{-1})	NO_x (ton yr^{-1})	PEC (ton yr^{-1})	SO_2 (ton yr^{-1})	TOG (ton yr^{-1})
2004	92,816	68,145	93	8,536	15,593
2025	188,648	146,842	164	18,071	27,929

Figure 5 summarizes the change in emissions used here from 2005 and 2025 as well as the percentage of aviation as part of the total emission budget in both years. While non-aviation emissions are reduced in the future year with the exception of NH_3 (reductions of 10-37% for gas phase species and 2% for $PM_{2.5}$) due to control and mitigation strategies, aviation emissions increase significantly (increases of 79-116% for gas phase species and 77% for $PM_{2.5}$) due to projected growth. This creates a future year scenario where emissions from most sectors are mitigated while emissions from the aviation sector grow and thus comprise a larger percentage of total emissions in 2025 than 2005 (Figure 5).

Model Evaluation

While the models and methods that we have used in this study are very robust and well established, there are a number of uncertainties associated with the aircraft emissions data used in this study. Given that future year aircraft emissions are estimated in much the same way as current year emissions, any uncertainty in the current year emissions is propagated to the future year. Additionally,

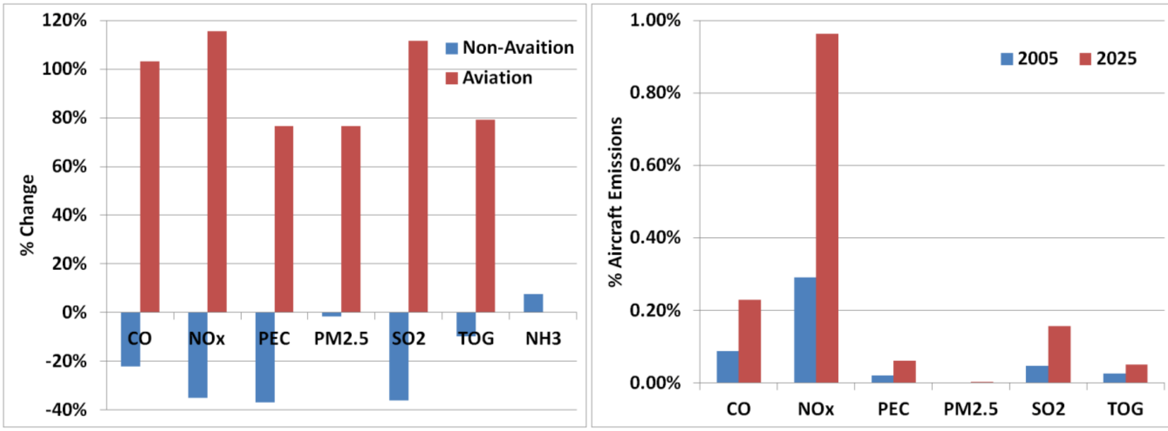

Figure 5. Percent change in non-aviation and non-aviation emissions from 2005 to 2005 (left) and percentage of aviation emissions as part of the total emissions budget in 2005 and 2025 (right).

both future year aircraft and non-aircraft emissions can vary depending on assumptions of which, if any, control strategies, policies, or changes in technology are included.

To evaluate the model for the base year application, the Atmospheric Model Evaluation Tool (AMET) (Appel and Gilliam, 2008a) was used to compare the base05 model output with ambient air quality monitoring data from several networks available within the U.S.; model results from the airc05 case are essentially the same, as shown in the next section. Figure 6 indicates that model performance was relatively good (< 75% normalized mean error and < ±60% normalized mean bias) for O_3, SO_2 (based on one of two networks) NO_2, $PM_{2.5}$, sulfate, ammonium, elemental carbon, and organic aerosols but poor (> 75% normalized mean error and > ±60% normalized mean error) for nitrate aerosol (based on 2 of 3 networks). These results are similar to those of other similar studies (Appel et al., 2008b; Eder and Yu, 2006; Tesche et al., 2006, Foley et al, 2010). Additional details and analysis regarding the model evaluation are provided in the Appendix.

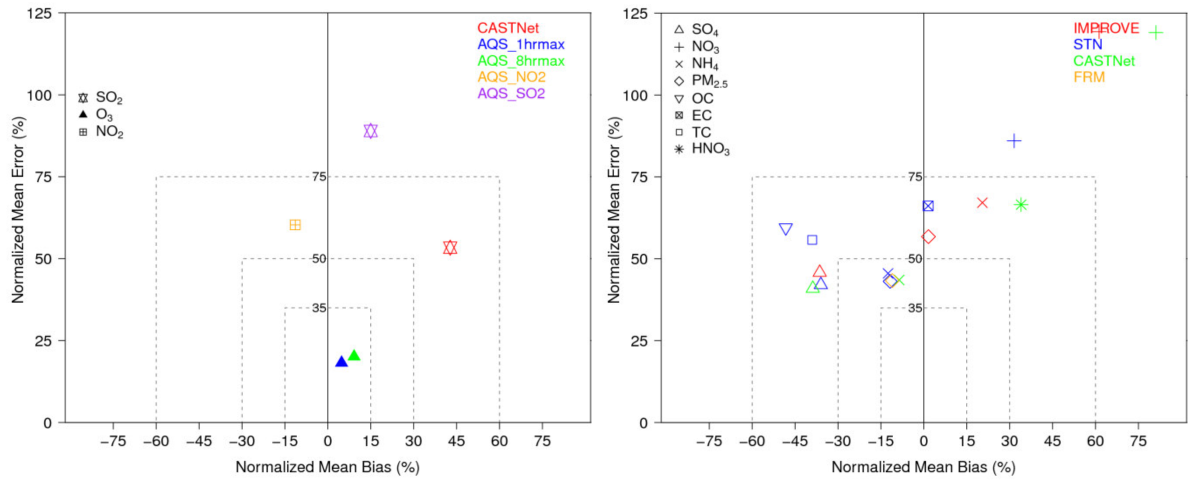

Figure 6. Normalized mean error and normalized mean bias for SO_2, O_3, NO_2, sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), $PM_{2.5}$, organic carbon (OC), elemental carbon (EC), total carbon (TC), and HNO_3.

Results and Discussion

Spatial Impacts

Results presented here indicate incremental contributions to annual average $PM_{2.5}$ concentrations due to aircraft emissions, and were computed by taking the difference between CMAQ simulations with and without aircraft emissions. We considered the contribution of aviation emissions in three cases: the contribution of aviation emissions in 2005 (airc05 minus base05), the contribution of 2025 aviation emissions in 2005 (b05_a25 minus base05), and the contribution of 2025 aviation emissions in 2025 (airc25 minus b05_a25). The purpose of including analysis of 2025 aircraft emissions in 2005 was to investigate how changes to non-aviation or background emissions influence the effects of aviation emissions on air quality. As the focus is on public health, only surface level concentrations over land in the continental U.S. were considered.

Figure 7 indicates the spatial distribution of contributions from aircraft emissions to $PM_{2.5}$ in the continental U.S. Contributions were highest in the eastern U.S. and California, regions with a high density of airports and urban areas, with the maximum impact in all 3 cases occurring in the Los

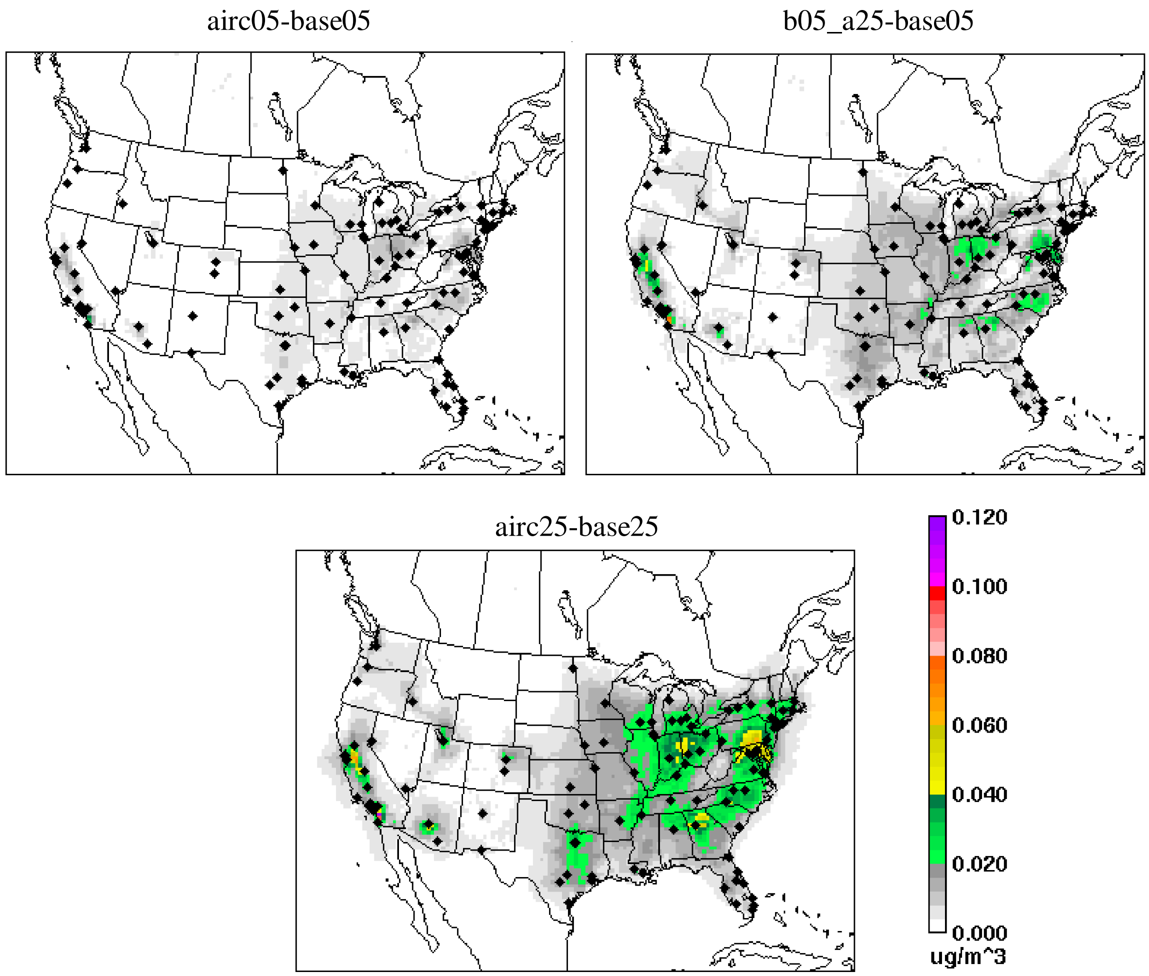

Figure 7. Spatial distribution of annual average contribution from aircraft emissions to $PM_{2.5}$. (black diamonds show locations of 99 airports)

Angeles metropolitan area (0.037 $\mu g\ m^{-3}$, 0.077 $\mu g\ m^{-3}$, and 0.113 $\mu g\ m^{-3}$). Comparing contributions from aircraft in 2025 to those in 2005, the impacts covered greater spatial extents and indicated that in the future year, a higher portion of the population would be exposed to $PM_{2.5}$ from aircraft emissions. Additionally, impacts from 2025 aircraft emissions in 2025, as compared to 2025 aircraft emissions in 2005, covered a larger spatial extent and exhibited a higher maximum value (0.113 $\mu g\ m^{-3}$ versus 0.077 $\mu g\ m^{-3}$) suggesting that the reduction in non-aviation emissions from 2005 to 2025 (i.e. a reduction in non-aviation emissions) led to greater impacts of aviation emissions to $PM_{2.5}$ in 2025.

Continental U.S. Impacts

Contributions averaged across the continental U.S. indicated that aircraft emissions in 2005 (airc05 minus base05) increased $PM_{2.5}$ concentrations by 0.0032 µg m^{-3} (0.05% of total $PM_{2.5}$), 2025 aircraft emissions in 2005 (b05_a25 minus base05) increased $PM_{2.5}$ concentrations by 0.0068 µg m^{-3} (0.11% of total $PM_{2.5}$), and 2025 aircraft emissions in 2025 (airc25 minus base25) increased $PM_{2.5}$ concentrations by 0.0116 µg m^{-3} (0.21% of total $PM_{2.5}$) (Figure 8). The contributions of aircraft emissions in 2005 were in good agreement with those indicated by Ratliff et al. (2009) (which used 325 airports in the U.S.) on a percent basis, which reported a 0.06% (0.01 µg m^{-3}) contribution to $PM_{2.5}$ concentrations in areas of non-attainment. Nitrate aerosol (ANO3) was the largest speciated contributor in all three comparisons, contributing on average 0.0019 µg m^{-3} (0.16%), 0.004 µg m^{-3} (0.35%), and 0.0074 µg m^{-3} (0.85%), respectively (Figure 8). While aircraft emissions were equivalent in the comparisons of 2025 aircraft emissions in 2005 (b05_a25 minus base05) and 2025 aircraft emissions in 2025 (airc25 minus base25), the 2025 aircraft emissions in 2025 led to 0.0048 µg m^{-3} higher contributions to $PM_{2.5}$ as in Figure 7. Ammonium aerosol (ANH4) and ANO3 were responsible for an overwhelming majority (98%) of the difference in contributions from 2025 aircraft emissions in 2005 and in 2025.

Local Impacts

While examining contributions averaged over the entire continental U.S. provides a broad snapshot of impacts from aircraft emissions, regional differences are difficult to ascertain from this type of analysis. To evaluate how impacts vary regionally, local impacts of aviation emissions on air quality are presented from five airports of varying size and geographic regions. The size was based upon a ranking of enplanements at all airports located in areas that are in nonattainment for any one of the criteria pollutants under the FAA Voluntary Airport Low Emissions Program (VALE) (FAA, 2010b). The 5 airports identified are: ATL (large airport located in southeast), Los Angeles

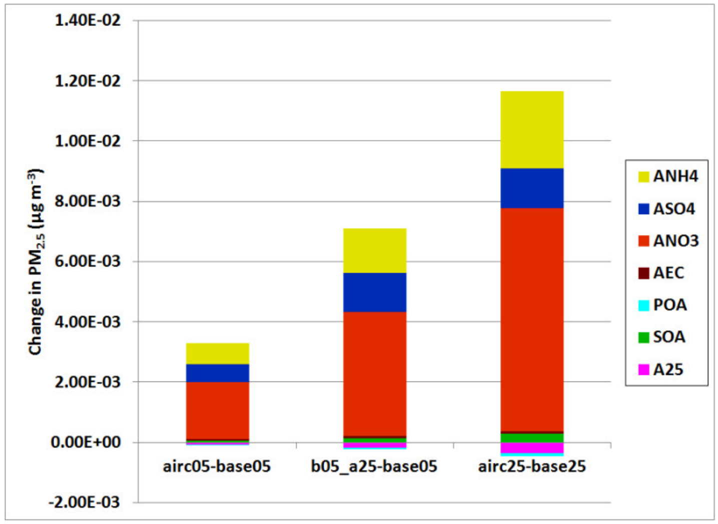

Figure 8. Annual average speciated contribution of aircraft emissions to $PM_{2.5}$ in the continental U.S. for ammonium (ANH4), sulfate (ASO4), nitrate (ANO3), elemental carbon (AEC), primary organic (POA), secondary organic (SOA), and "other" (A25) aerosols.

International Airport (LAX, large airport located in west), ORD (large airport located in Great Lakes region), Albuquerque International Sunport (ABQ) (medium airport located southwest), and PVD (medium airport located in northeast). Figure 9 provides the speciated contributions to $PM_{2.5}$ from aircraft emissions in the grid cell containing each of these five airports, with total contributions in the range of 0.003 to 0.022 $\mu g\ m^{-3}$ in 2005, 0.009 to 0.042 $\mu g\ m^{-3}$ for 2025 aircraft emissions in 2005, and 0.022 to 0.081 $\mu g\ m^{-3}$ in 2025. Similar to the continental U.S. results, ANO3 was typically the largest speciated contributor to $PM_{2.5}$ concentrations from aircraft emissions. However, unlike the continental U.S. results, AEC, the only $PM_{2.5}$ species directly emitted by aircraft, was also a large contributor from aircraft emissions with contributions in the ranges of 0.0003 to 0.008 $\mu g\ m^{-3}$, 0.001 to 0.011 $\mu g\ m^{-3}$, and 0.001 to 0.012 $\mu g\ m^{-3}$, respectively. It is worth noting the reduction of SOA concentrations at ATL due to both current year aircraft emissions and 2025 aircraft emissions in 2005. In our previous work, we investigated this issue at 36-km, 12-km, and 4-km grid resolutions and showed that at the 36-km and 12-km resolutions NO_x emissions from aircraft remove free radicals and slow the production of SOA near the ATL airport (Woody and Arunachalam, 2010).

While the continental U.S. analysis highlighted the importance of changes in non-aviation emissions, individual airport-level results vary. For example, the impacts of 2025 aircraft emissions in 2005 and 2025 at LAX increased only minimally (11% increase). Contrast this to a significant increase in impacts from 2025 aircraft emissions in 2005 and 2025 at ABQ (77% increase), ATL (226% increase), ORD (111% increase), and PVD (253% increase). For these four airports, ANO3 and ANH4 composed the vast majority of the difference in contributions as was the case with continental U.S. results. This suggests that the inorganic $PM_{2.5}$ species (particularly ANO3 and ANH4) exhibit a common response to changes in non-aviation emissions throughout many regions of the U.S.

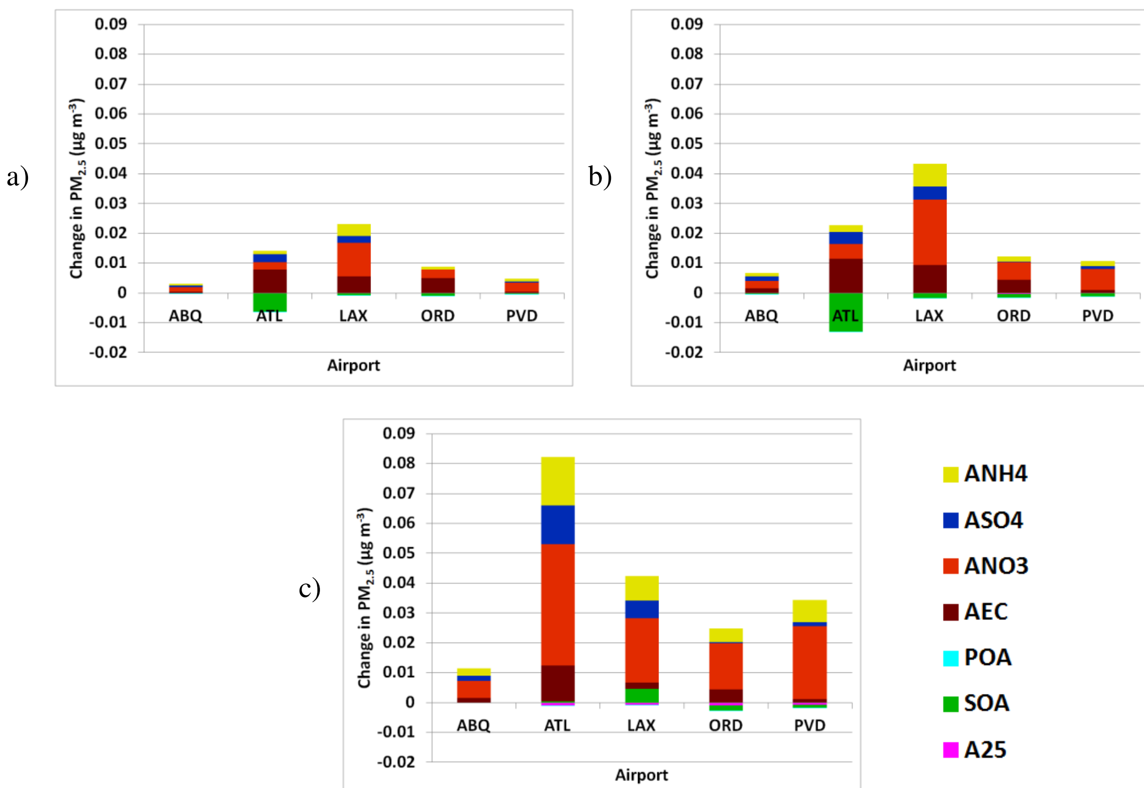

Figure 9. Annual average speciated contributions of aircraft emissions to $PM_{2.5}$ at the grid cell containing the airport for (a) 2004 aircraft emissions in 2005, (b) 2025 aircraft emissions in 2005, and (c) 2025 aircraft emissions in 2025.

Inorganic $PM_{2.5}$ Response

Ammonium, nitrate, and sulfate concentrations can respond non-linearly to changes in emissions and therefore present a difficult challenge in predicting sensitivities (West et al., 1999). Here we aim to explain changes to the modeled $PM_{2.5}$, of which ANO3 was the largest contributor, by analyzing the inorganic aerosol system. Tsimpidi et al. (2007) have shown that a 50% uniform reduction in SO_2 emissions lead to a 26% reduction of $PM_{2.5}$ concentrations in July but only a 6% reduction during January in the eastern U.S. This occurs because, even though SO_2 emissions are reduced, thus reducing H_2SO_4 concentrations and ASO4 formation, ANH4 that was previously associated with ASO4 is now available to neutralize nitrate in the form of HNO_3 and create ANO3. A number of studies have developed parameters to determine how the inorganic $PM_{2.5}$ system at equilibrium (appropriate for analyzing modeled results) might respond to changes in emissions (Ansari and Pandis, 1998; Blanchard et al., 2000; and Pinder et al., 2008).

Previously, Ansari and Pandis (1998) developed the Gas Ratio (GR) metric, which is defined as

$$GR = \frac{free\ ammonia}{total\ nitrate} = \frac{TA - 2\ x\ TS}{TN} \qquad (1)$$

where Total Ammonia (TA) = $NH_3 + NH_4^+$, Total Sulfate (TS) = SO_4^{-2}, and Total Nitrate (TN) = $HNO_3 + NO_3^-$ with each expressed in molar concentrations (as are concentrations in all subsequent equations). TS is assumed to be fully neutralized by ammonium and therefore multiplied by a value of 2. A GR value greater than 1 signifies an excess of free ammonia and changes to particle nitrate are most sensitive to changes in TN whereas a GR less than 1 signifies an abundance of nitrate and particle nitrate is sensitive to changes in TA. Similar to this, Blanchard et al. (2000) developed the excess NH_3 indicator, which is defined as

$$Excess\ NH_3 = TA - 2\ x\ TS - TN - [HCl\ (g)] + 2\,[Ca^{+2}] + 2\,[Mg^{+2}] + [Na^+] + [K^+] + [Cl^-] \qquad (2)$$

Without the minor ions, this formula reduces to an expression similar to the GR indicator but instead of a ratio it is the difference in anions and cations. More recently, Pinder et al. (2008) refined the GR by replacing the 2 associated with TS with the Degree of Sulfate Neutralization (DSN) to form the Adjusted Gas Ratio (AdjGR) defined as

$$AdjGR = \frac{TA - DSN\ x\ TS}{TN} \tag{3}$$

where DSN is defined as

$$DSN = \frac{[NH4^{+}] - [NO3^{-}]}{[SO_4^{-2}]} \tag{4}$$

The AdjGR does not assume TS is fully neutralized but instead calculates sulfate neutralization. The use of DSN is based on Atmospheric Inorganic Model (Clegg et al., 1998) results indicating that, at typical winter conditions in the eastern U.S., particle nitrate will form prior to sulfate being fully neutralized. Others studies have also reported the formation of particle nitrate prior to sulfate being fully neutralized using ambient air quality measurements from the Speciated Trends Network (Chu, 2003) and regional air-quality modeling (Mathur and Dennis, 2003). Contrast this with the assumption that ASO4 is fully neutralized, where ammonium will preferentially neutralize sulfate prior to neutralizing nitrate.

Here, we take a similar approach to that used by Pinder et al. (2008) and replace the 2 associated with TS in equation 2 with DSN and remove the minor ions from the equation based on assumption that their contribution is negligible compared to ammonium, sulfate, and nitrate (Christoforou et al., 2000). Using simple substitution, equation (2) simplifies to what we refer to here as Free Ammonia (FA) where

$$FA\ = [NH_3] - \ [HNO_3] \tag{5}$$

This metric differs from “free ammonia” used by Ansari and Pandis (1998) and Pinder et al. (2008) who refer to the amount of ammonia available to form ammonium nitrate after sulfate is neutralized, whereas we refer to the amount of ammonia available to the system after both nitrate and sulfate are neutralized.. The FA metric assumes chemical equilibrium and is therefore appropriate for modeling applications. A positive FA value indicates free ammonia is available to the system. The advantage to the FA indicator is that no aerosol concentrations are required to calculate it, only concentrations of NH_3 and HNO_3. It also has the added advantage of providing an estimate of the amount of aerosol that could potentially be formed, where an FA of 1 μmol m^{-3} could potentially form 18 μg m^{-3} of ANH4 provided enough sulfate and nitrate are added to the system.

The FA indicator is applied to analyze the response of inorganic $PM_{2.5}$ to changes in aircraft emissions in an effort to account for the large contributions from ANO3 as compared to ASO4. Figure 10 indicates the modeled annual average FA values in the U.S. for the 2005 and 2025 base cases. Large portions of the U.S. exhibited a positive FA value indicating that in both years there was an excess of free ammonia and that changes to ANO3 were sensitive to changes in TN. These results are in agreement with those of a recent study performed by Makar et al. (2009), where model results indicated much of the U.S. to have large excess ammonia in 2002. Figure 10 also indicates that a larger area of the U.S. had a positive annual average FA value in the 2025 base case, as compared to 2005. Areas with a negative FA, such as the eastern U.S. in 2005, indicate locations that ammonia is limited and nitrate added to the system would remain in the gas phase as HNO_3 due to the lack of available ammonia to form ammonium nitrate.

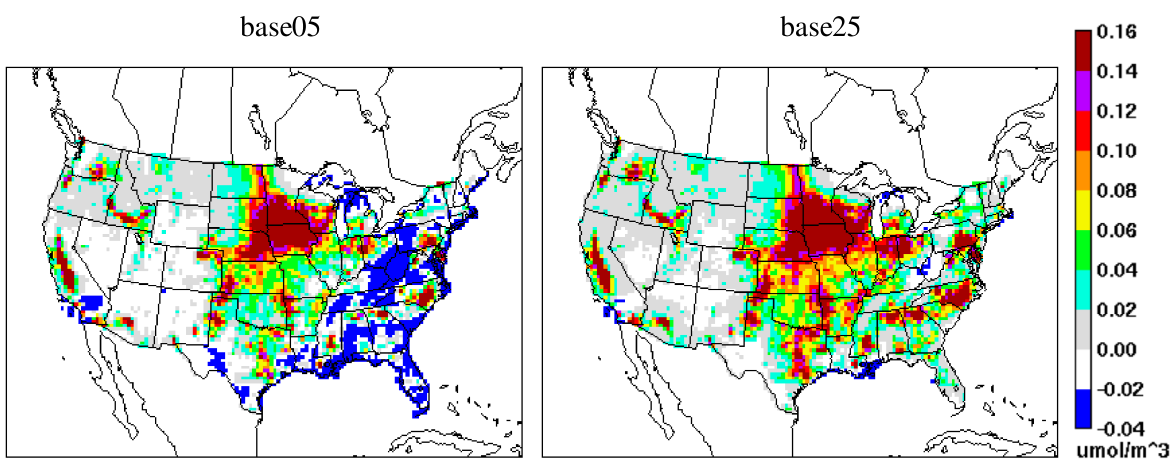

Figure 10. Annual average Free Ammonia for the base05 and base25 modeling scenarios.

The increase in modeled FA in 2025 relative to 2025 is in agreement with the changes in non-aviation emission inventories. While NH_3 emissions increase by 8% between 2005 and 2025, NO_x emissions are significantly reduced (35%) (Figure 5). This reduction in NO_x emissions translates to lower concentrations of HNO_3 in the future year. Given that NH_3 concentrations increase slightly while HNO_3 concentrations are reduced, future year FA values are higher and more widespread spatially.

Figure 11 provides the changes in both NO_x and SO_2 due to aircraft emissions in 2005 and 2025, showing that the change in NO_x concentration is much greater, consistent with the difference in emissions (Table 3). Due to an excess of free ammonia (H_2SO_4 would therefore already be fully neutralized in the model), the HNO_3 formed from aircraft NO_x emissions was readily neutralized by ammonia to form ammonium nitrate aerosols. In the event that there was no excess free ammonia,

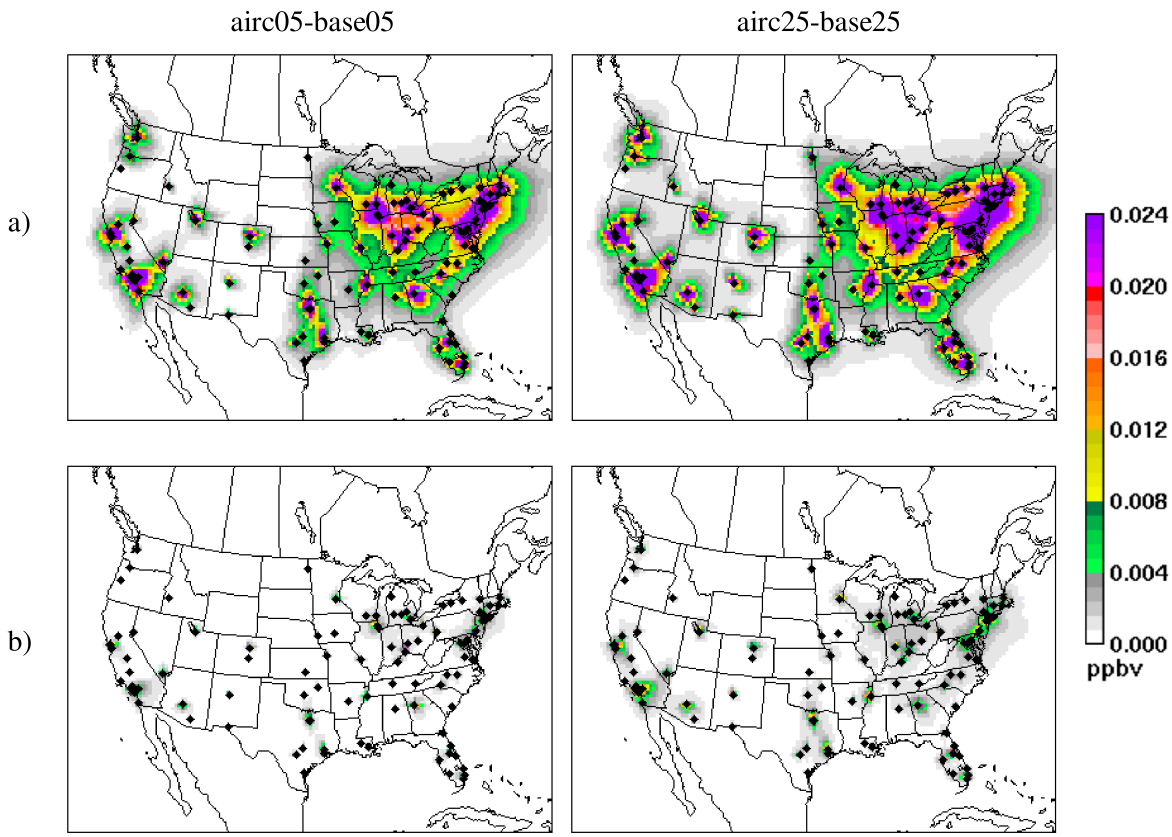

Figure 11. Changes in annual average (a) NO_x concentrations and (b) SO_2 concentrations due to aircraft emissions in 2005 (left) and 2025 (right). (black diamonds show locations of 99 airports)

HNO_3 would remain in the gas phase, being outcompeted by H_2SO_4 for ammonia, and the contribution of aircraft emissions to ANO3 and $PM_{2.5}$ would likely be much smaller. Aircraft contributed more NO_x than SO_2 (Figure 11), and this increase corresponds spatially with the changes in ANO3 and ASO4 (Figure 12). Due to the free ammonia available over much of the country (Figure 10), and higher NO_x emissions than SO_2 emissions, ANO3 is a larger contributor to the inorganic portion of $PM_{2.5}$ as compared to ASO4.

The FA metric also provides insight into the discrepancy between contributions of 2025 aircraft emissions in 2005 and 2025. As previously mentioned, 2025 aircraft emissions in 2005 contributed 0.0068 $\mu g\ m^{-3}$ to $PM_{2.5}$ concentrations while 2025 aircraft emissions in 2025 contributed 0.0116 $\mu g\ m^{-3}$. Of the 0.0048 $\mu g\ m^{-3}$ difference between 2005 and 2025, 0.0047 $\mu g\ m^{-3}$ or 98% was comprised of ANH4 and ANO3. Figure 10 indicates that FA values are generally more positive (less negative) throughout the U.S. in 2025 compared to 2005, particularly in the eastern U.S. (areas with a high density of airports). Consequently, NO_x emissions from aircraft in 2025, converted to HNO_3, combined more readily with the more abundant FA, than in 2005, to form ANO3 and ANH4.

Conclusions

Overall, aircraft emissions below 10,000 feet from 99 airports in the continental U.S. contributed on average 0.0032 $\mu g\ m^{-3}$ (0.05% of total $PM_{2.5}$) to $PM_{2.5}$ in 2005, 0.0068 $\mu g\ m^{-3}$ (0.11% of total $PM_{2.5}$) for 2025 aircraft emissions in 2005, and 0.0116 $\mu g\ m^{-3}$ (0.21% of total $PM_{2.5}$) for 2025 aircraft emissions in 2025, with ANO3 as the largest speciated contributor. Contributions from aircraft emissions at five airports of various sizes across the U.S. ranged from 0.003 to 0.022 $\mu g\ m^{-3}$ for 2004 aircraft emissions in 2005, 0.009 to 0.042 $\mu g\ m^{-3}$ for 2025 aircraft emissions in 2005, and 0.022 to 0.081 $\mu g\ m^{-3}$ for 2025 aircraft emissions in 2025, with ANO3 and AEC as important contributors.

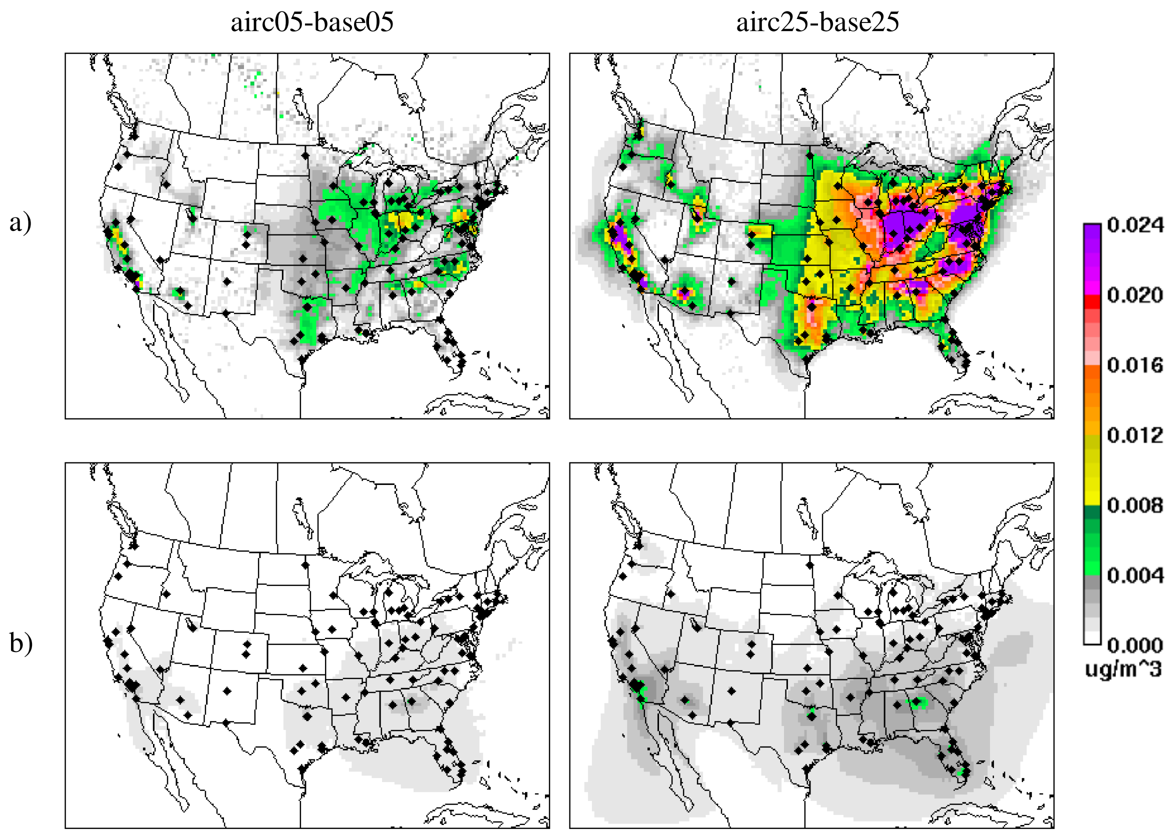

Figure 12. Changes in annual average (a) ANO3 concentrations and (b) ASO4 concentrations due to aircraft emissions in 2005 (left) and 2025 (right). (black diamonds show locations of 99 airports)

While these contributions appear small, they likely underestimate the total contributions from aircraft on ambient air quality as cruise altitude emissions were not considered. Furthermore, large uncertainties associated with estimating aircraft emissions both at ground level and aloft limit the ability to quantify total impacts. Therefore, it is important to continue to investigate the contributions of total aircraft emissions to both total $PM_{2.5}$ and speciated components. As aviation's usage continues to grow, impacts on air quality and public health have the potential to grow as well. Additionally, understanding the speciated contributions of aircraft emissions to $PM_{2.5}$ is critical in developing effective mitigation strategies.

We used the Free Ammonia indicator to explain the larger contributions of ANO3 than ASO4 from aircraft emissions to $PM_{2.5}$, as well as impacts caused by changes in background emissions. This indicator determined that in both the current and future years, excess ammonia was present throughout large portions of the U.S. With the addition of more NO_x than SO_2 from aircraft emissions, the subsequent higher amount of HNO_3 formed as compared to H_2SO_4 was neutralized by the excess ammonia available to form higher concentrations of ANO3 than ASO4. The indicator was also useful in explaining the greater impact of 2025 aircraft emissions in 2025 than in 2005 due to increased contributions from ANO3 and ANH4 attributed to more positive FA values in 2025.

Future expansion of this work could include modeling each aircraft individually using a plume-in-grid technique, or other alternate approaches to include sub-grid variability, to track the formation of aerosols due to aircraft emissions near the aircraft engine as well as downstream. Specifically, this would include obtaining additional information from previous and ongoing field campaigns that include measurement of volatile components of PM from aircraft engines (Kinsey, 2009) and ongoing projects funded by the Transportation Research Board's Airport Cooperative Research Program (ACRP) and the U.S. Department of Defense Strategic Environmental Research and Development Program (SERDP), and using this new information to enhance the modeling approaches discussed here. A second expansion would involve including aircraft emissions at cruise altitude as opposed to only up to 10,000 feet. However, modeling at higher altitudes presents a new set of limitations and uncertainties as regional scale models such as the one used here are typically designed to predict surface level concentrations. A final consideration would be to include climate change as part of the future year scenario to access how changes in climate and meteorology would impact the contributions of aviation emissions on future air quality.

Additional information regarding this work is located in the appendices. Appendix A provides additional spatial plots of various gas and aerosol species. Appendix B indicates the speciated contributions of aircraft emissions to $PM_{2.5}$ at each of the 99 airports. Appendix C provides a comparison of CMAQ predicted contributions to $PM_{2.5}$ from aircraft emissions to CMAQ results post-processed using the Speciated Modeled Attainment Test. Finally, Appendix D contains the model evaluation used to determine model performance.

Appendix A - Additional Spatial Plots

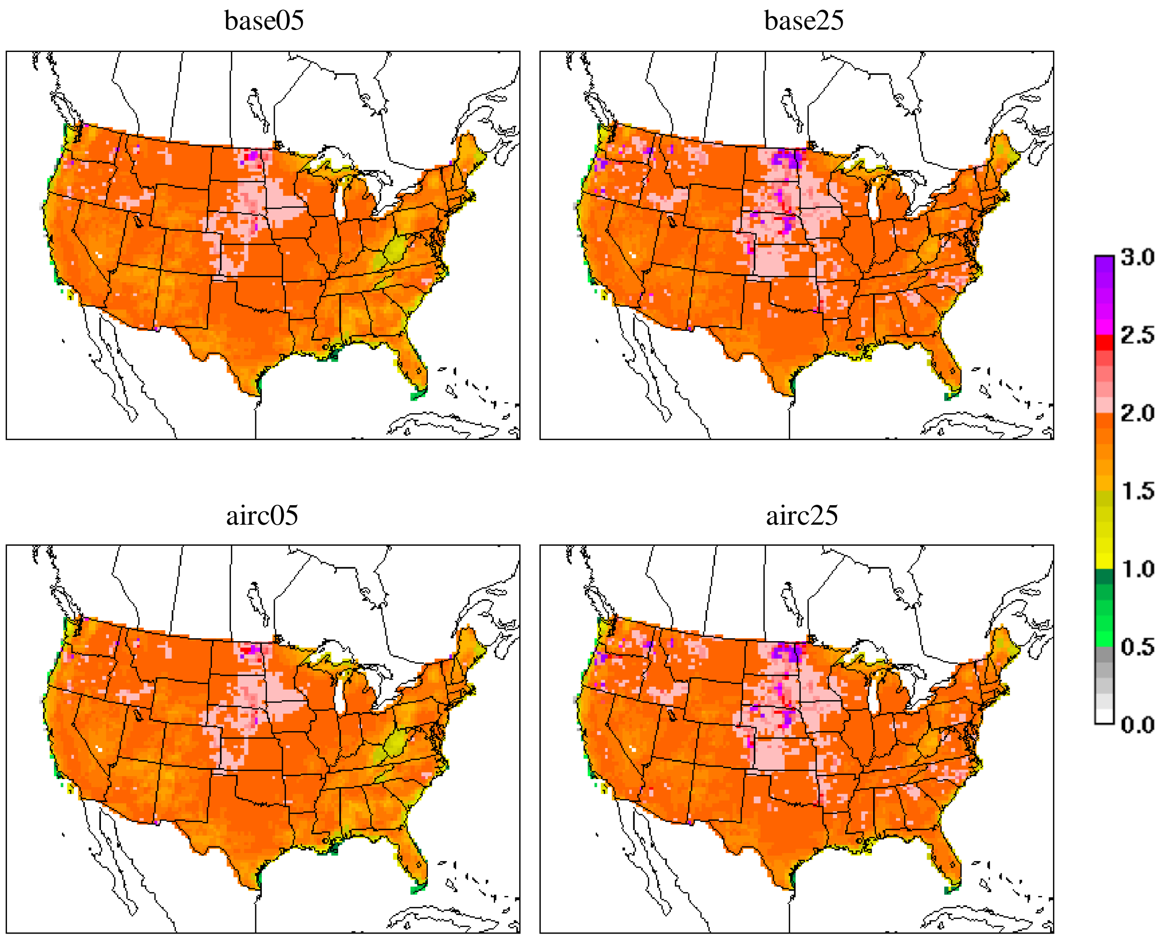

Figure 13. Degree of Sulfate Neutralization where a value of 2 indicates sulfate is fully neutralized by ammonium.

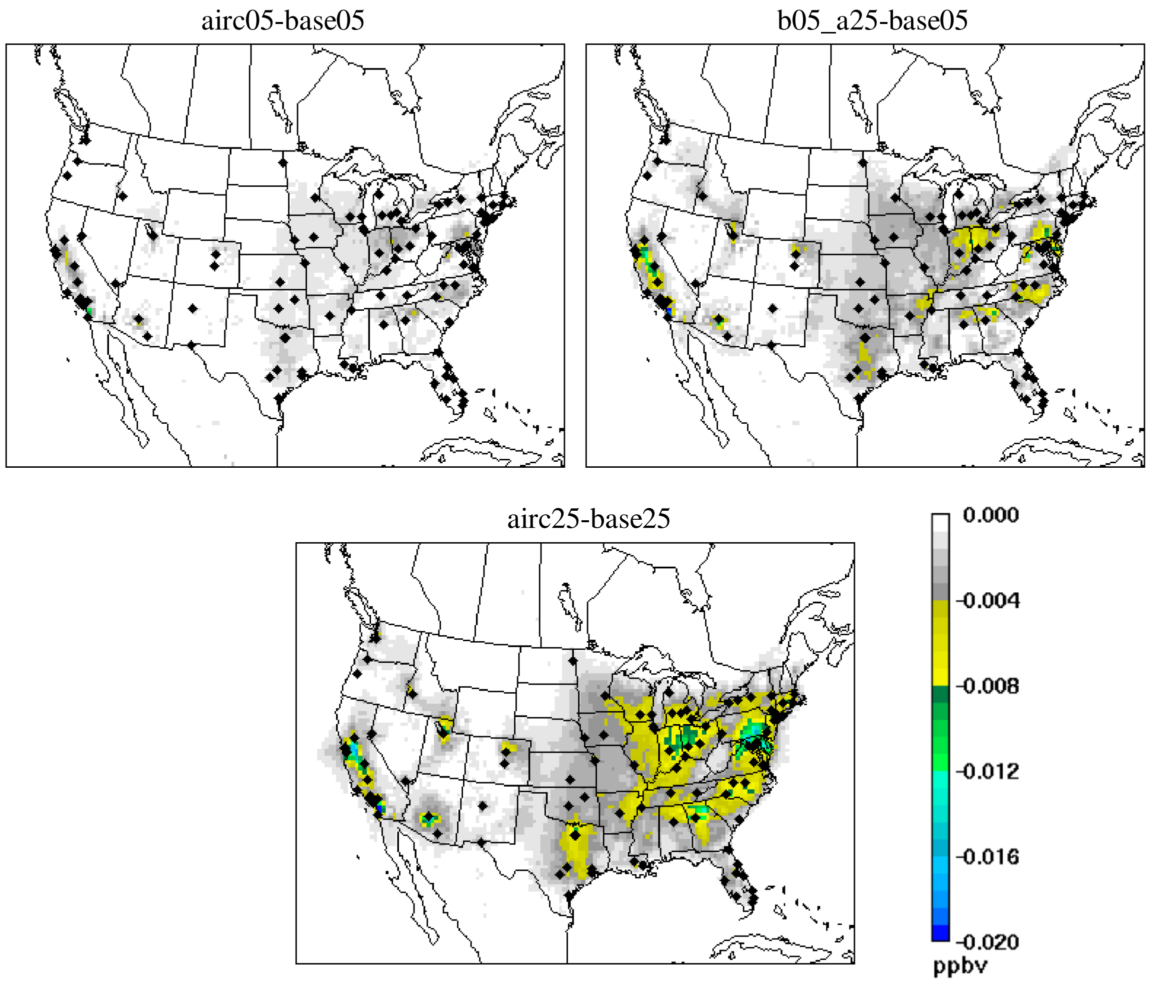

Figure 14. Changes in gaseous ammonia concentrations due to aircraft emissions. Lower concentrations of ammonia gas correspond to an increase in ANH4 concentrations.

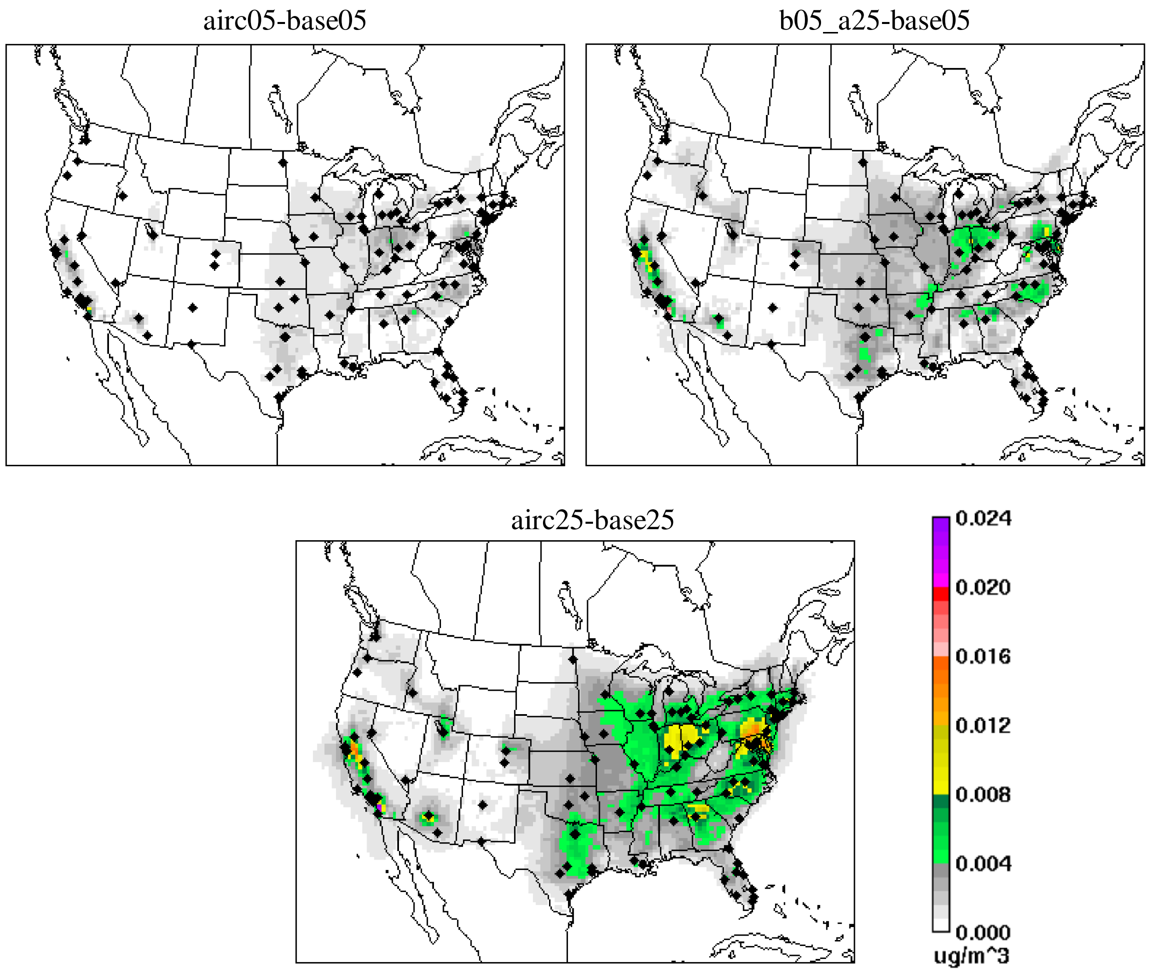

Figure 15. Change in ANH4 concentrations due to aircraft emissions.

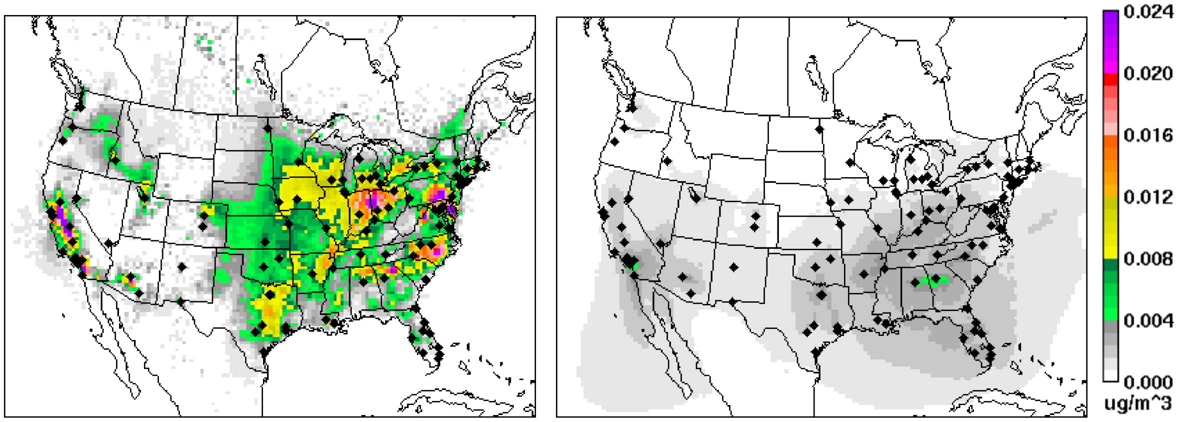

Figure 16. Changes in ANO3 (left) and ASO4 (right) due to 2025 aircraft emissions in 2005.

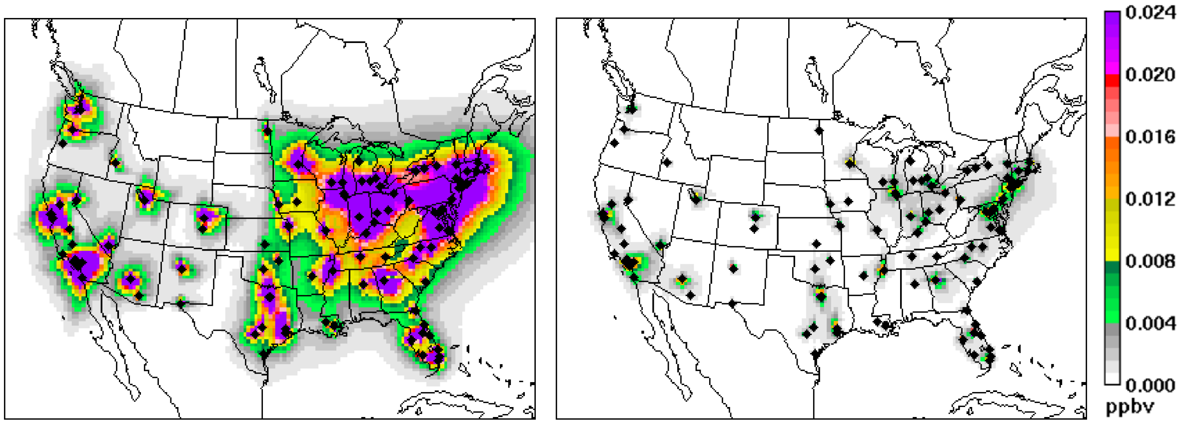

Figure 17. Changes in NO_x (left) and SO_2 (right) due to 2025 aircraft emissions in 2005.

Appendix B - Contributions from aircraft emissions to $PM_{2.5}$ at each of the 99 airports

Table 4. Absolute and percent increases due to aircraft emissions in 2005 at grid cell containing the airport.

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ABQ	**0.0000 (0.00%)**	**0.0003 (0.06%)**	**0.0006 (0.15%)**	**0.0016 (0.34%)**	**-0.0001 (-0.02%)**	**0.0000 (0.00%)**	**0.0006 (0.09%)**	**0.0030 (0.04%)**
ALB	-0.0001 (0.00%)	0.0002 (0.04%)	0.0012 (0.09%)	0.0039 (0.16%)	-0.0001 (-0.03%)	0.0000 (0.00%)	0.0004 (0.02%)	0.0054 (0.04%)
ATL	**-0.0001 (0.00%)**	**0.0079 (0.77%)**	**0.0012 (0.07%)**	**0.0025 (0.13%)**	**-0.0062 (-0.45%)**	**0.0000 (0.00%)**	**0.0025 (0.07%)**	**0.0078 (0.05%)**
AUS	-0.0001 (0.00%)	0.0008 (0.30%)	0.0015 (0.14%)	0.0038 (0.25%)	-0.0001 (-0.04%)	0.0000 (-0.01%)	0.0013 (0.08%)	0.0072 (0.08%)
BDL	-0.0001 (0.00%)	0.0007 (0.12%)	0.0007 (0.06%)	0.0025 (0.10%)	-0.0005 (-0.10%)	0.0000 (0.00%)	0.0004 (0.02%)	0.0036 (0.03%)
BFL	-0.0001 (-0.01%)	0.0000 (-0.01%)	0.0022 (0.33%)	0.0063 (0.41%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0010 (0.16%)	0.0092 (0.12%)
BHM	-0.0002 (0.00%)	0.0003 (0.04%)	0.0010 (0.06%)	0.0023 (0.16%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0020 (0.06%)	0.0054 (0.04%)
BNA	-0.0002 (-0.01%)	0.0007 (0.09%)	0.0010 (0.06%)	0.0028 (0.12%)	-0.0001 (-0.03%)	0.0000 (0.00%)	0.0014 (0.04%)	0.0055 (0.04%)
BOI	0.0000 (0.00%)	0.0002 (0.02%)	0.0009 (0.15%)	0.0026 (0.20%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0005 (0.07%)	0.0041 (0.03%)
BOS	0.0000 (0.00%)	0.0022 (0.16%)	0.0011 (0.07%)	0.0052 (0.18%)	-0.0011 (-0.21%)	0.0000 (0.00%)	0.0001 (0.00%)	0.0074 (0.04%)
BTR	-0.0001 (0.00%)	0.0000 (0.00%)	0.0009 (0.07%)	0.0022 (0.17%)	0.0001 (0.02%)	0.0000 (0.00%)	0.0011 (0.04%)	0.0042 (0.04%)
BUF	-0.0002 (0.00%)	0.0003 (0.07%)	0.0014 (0.07%)	0.0049 (0.14%)	-0.0002 (-0.04%)	-0.0001 (0.00%)	0.0005 (0.02%)	0.0068 (0.05%)
BUR	-0.0002 (-0.01%)	0.0005 (0.05%)	0.0038 (0.39%)	0.0114 (0.54%)	-0.0002 (-0.05%)	-0.0002 (-0.01%)	0.0014 (0.14%)	0.0165 (0.17%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
BWI	-0.0002 (-0.01%)	0.0011 (0.16%)	0.0011 (0.06%)	0.0041 (0.14%)	-0.0005 (-0.12%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0057 (0.04%)
CHS	-0.0001 (0.00%)	0.0002 (0.03%)	0.0005 (0.05%)	0.0015 (0.20%)	0.0001 (0.01%)	0.0000 (0.00%)	0.0011 (0.04%)	0.0032 (0.04%)
CLE	-0.0003 (-0.01%)	0.0007 (0.13%)	0.0026 (0.11%)	0.0085 (0.19%)	-0.0002 (-0.07%)	-0.0001 (-0.01%)	0.0008 (0.02%)	0.0120 (0.08%)
CLT	-0.0001 (0.00%)	0.0016 (0.06%)	0.0022 (0.12%)	0.0065 (0.27%)	-0.0013 (-0.11%)	-0.0001 (0.00%)	0.0023 (0.06%)	0.0111 (0.06%)
CMH	-0.0002 (-0.01%)	0.0005 (0.08%)	0.0020 (0.09%)	0.0064 (0.16%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0013 (0.04%)	0.0099 (0.06%)
COS	0.0000 (0.00%)	0.0001 (0.03%)	0.0004 (0.12%)	0.0017 (0.47%)	0.0001 (0.02%)	0.0000 (0.00%)	0.0005 (0.08%)	0.0028 (0.04%)
CRP	-0.0001 (0.00%)	0.0001 (0.03%)	0.0005 (0.07%)	0.0013 (0.24%)	0.0000 (-0.01%)	0.0000 (0.00%)	0.0005 (0.03%)	0.0023 (0.04%)
CVG	-0.0003 (-0.01%)	0.0025 (0.33%)	0.0017 (0.07%)	0.0053 (0.14%)	-0.0002 (-0.10%)	-0.0001 (-0.01%)	0.0013 (0.03%)	0.0102 (0.06%)
DAB	0.0000 (0.00%)	0.0001 (0.03%)	0.0002 (0.04%)	0.0002 (0.26%)	0.0000 (0.01%)	0.0000 (0.00%)	0.0012 (0.06%)	0.0016 (0.04%)
DAL	-0.0002 (0.00%)	0.0027 (0.38%)	0.0018 (0.13%)	0.0039 (0.21%)	-0.0002 (-0.10%)	0.0000 (0.00%)	0.0021 (0.09%)	0.0100 (0.07%)
DAY	-0.0002 (-0.01%)	0.0008 (0.15%)	0.0018 (0.08%)	0.0059 (0.15%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0013 (0.04%)	0.0095 (0.06%)
DCA	-0.0002 (0.00%)	0.0013 (0.12%)	0.0009 (0.04%)	0.0032 (0.10%)	-0.0005 (-0.10%)	-0.0001 (0.00%)	0.0001 (0.00%)	0.0047 (0.03%)
DEN	-0.0001 (0.00%)	0.0023 (0.33%)	0.0017 (0.31%)	0.0045 (0.53%)	-0.0006 (-0.08%)	0.0000 (0.00%)	0.0008 (0.11%)	0.0087 (0.11%)
DFW	-0.0002 (0.00%)	0.0021 (0.26%)	0.0017 (0.13%)	0.0040 (0.20%)	-0.0001 (-0.07%)	0.0000 (0.00%)	0.0019 (0.09%)	0.0093 (0.07%)
DSM	-0.0002 (-0.01%)	0.0002 (0.06%)	0.0013 (0.09%)	0.0036 (0.13%)	0.0000 (-0.03%)	0.0000 (-0.01%)	0.0007 (0.04%)	0.0056 (0.06%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
DTW	-0.0002 (-0.01%)	0.0042 (0.46%)	0.0015 (0.07%)	0.0048 (0.12%)	-0.0004 (-0.12%)	-0.0001 (-0.01%)	0.0007 (0.03%)	0.0105 (0.07%)
ELP	0.0000 (0.00%)	0.0004 (0.15%)	0.0005 (0.12%)	0.0011 (0.24%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0006 (0.07%)	0.0026 (0.06%)
EUG	0.0000 (0.00%)	0.0000 (0.01%)	0.0004 (0.19%)	0.0013 (0.31%)	0.0003 (0.02%)	0.0000 (0.00%)	0.0002 (0.06%)	0.0023 (0.03%)
EWR	-0.0002 (0.00%)	0.0022 (0.21%)	0.0015 (0.08%)	0.0051 (0.15%)	-0.0007 (-0.17%)	-0.0001 (0.00%)	0.0001 (0.00%)	0.0079 (0.05%)
FAT	-0.0001 (0.00%)	0.0002 (0.03%)	0.0017 (0.23%)	0.0048 (0.29%)	0.0000 (0.00%)	-0.0001 (0.00%)	0.0009 (0.13%)	0.0074 (0.08%)
FLL	0.0000 (0.00%)	0.0013 (0.24%)	0.0003 (0.06%)	0.0007 (0.51%)	-0.0002 (-0.13%)	0.0000 (0.00%)	0.0005 (0.04%)	0.0027 (0.05%)
FNT	-0.0002 (-0.01%)	0.0003 (0.06%)	0.0012 (0.07%)	0.0040 (0.12%)	-0.0001 (-0.04%)	0.0000 (-0.01%)	0.0005 (0.02%)	0.0056 (0.05%)
GFK	-0.0001 (0.00%)	0.0000 (0.00%)	0.0003 (0.04%)	0.0009 (0.06%)	0.0000 (-0.01%)	0.0000 (0.00%)	0.0001 (0.02%)	0.0012 (0.02%)
GRR	-0.0002 (-0.01%)	0.0002 (0.04%)	0.0019 (0.09%)	0.0062 (0.17%)	-0.0001 (-0.03%)	0.0000 (-0.01%)	0.0004 (0.02%)	0.0084 (0.06%)
GSO	-0.0001 (-0.01%)	0.0001 (0.01%)	0.0021 (0.11%)	0.0063 (0.23%)	0.0000 (-0.01%)	-0.0001 (0.00%)	0.0013 (0.04%)	0.0096 (0.07%)
HOU	-0.0001 (0.00%)	0.0007 (0.07%)	0.0009 (0.07%)	0.0025 (0.22%)	-0.0002 (-0.06%)	0.0000 (0.00%)	0.0006 (0.02%)	0.0044 (0.03%)
HPN	-0.0001 (0.00%)	0.0009 (0.12%)	0.0007 (0.04%)	0.0026 (0.09%)	-0.0006 (-0.14%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0036 (0.03%)
IAD	-0.0002 (0.00%)	0.0032 (0.35%)	0.0012 (0.06%)	0.0042 (0.13%)	-0.0008 (-0.16%)	-0.0001 (0.00%)	0.0005 (0.01%)	0.0081 (0.05%)
IAH	-0.0001 (0.00%)	0.0022 (0.29%)	0.0008 (0.08%)	0.0017 (0.15%)	-0.0014 (-0.19%)	0.0000 (0.00%)	0.0015 (0.07%)	0.0048 (0.03%)
ICT	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0012 (0.11%)	0.0034 (0.17%)	0.0000 (-0.01%)	-0.0001 (0.00%)	0.0007 (0.04%)	0.0051 (0.05%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
IND	-0.0003 (0.00%)	0.0014 (0.21%)	0.0017 (0.07%)	0.0054 (0.13%)	-0.0003 (-0.12%)	-0.0001 (-0.01%)	0.0007 (0.02%)	0.0087 (0.05%)
ISP	-0.0001 (-0.01%)	0.0007 (0.09%)	0.0007 (0.05%)	0.0031 (0.12%)	-0.0004 (-0.11%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0040 (0.03%)
JAX	-0.0001 (0.00%)	0.0003 (0.07%)	0.0008 (0.09%)	0.0017 (0.28%)	0.0013 (0.10%)	0.0000 (0.00%)	0.0014 (0.06%)	0.0053 (0.06%)
JFK	-0.0001 (0.00%)	0.0044 (0.35%)	0.0010 (0.05%)	0.0036 (0.12%)	-0.0020 (-0.38%)	0.0000 (0.00%)	0.0002 (0.01%)	0.0071 (0.05%)
LAN	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0019 (0.09%)	0.0063 (0.16%)	-0.0001 (-0.03%)	0.0000 (-0.01%)	0.0004 (0.01%)	0.0083 (0.06%)
LAS	-0.0001 (0.00%)	0.0023 (0.25%)	0.0007 (0.18%)	0.0009 (0.21%)	-0.0010 (-0.21%)	0.0000 (0.00%)	0.0015 (0.21%)	0.0044 (0.06%)
LAX	**0.0000 (0.00%)**	**0.0056 (0.49%)**	**0.0039 (0.29%)**	**0.0113 (0.39%)**	**-0.0008 (-0.24%)**	**0.0000 (0.00%)**	**0.0023 (0.16%)**	**0.0222 (0.17%)**
LGA	-0.0001 (0.00%)	0.0023 (0.16%)	0.0014 (0.07%)	0.0047 (0.14%)	-0.0009 (-0.20%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0074 (0.05%)
LGB	-0.0004 (-0.01%)	0.0015 (0.08%)	0.0086 (0.52%)	0.0278 (0.76%)	-0.0005 (-0.12%)	-0.0002 (-0.01%)	0.0017 (0.10%)	0.0384 (0.22%)
LIT	-0.0002 (-0.01%)	0.0002 (0.04%)	0.0014 (0.10%)	0.0035 (0.20%)	0.0000 (0.00%)	0.0000 (-0.01%)	0.0015 (0.06%)	0.0064 (0.06%)
MCI	-0.0002 (0.00%)	0.0010 (0.15%)	0.0014 (0.08%)	0.0046 (0.15%)	-0.0002 (-0.08%)	-0.0001 (0.00%)	0.0003 (0.01%)	0.0068 (0.05%)
MCO	-0.0001 (0.00%)	0.0011 (0.17%)	0.0009 (0.12%)	0.0016 (0.36%)	-0.0002 (-0.05%)	0.0000 (0.00%)	0.0020 (0.11%)	0.0051 (0.07%)
MDW	-0.0003 (0.00%)	0.0008 (0.09%)	0.0012 (0.06%)	0.0042 (0.13%)	-0.0002 (-0.10%)	-0.0001 (0.00%)	0.0001 (0.00%)	0.0058 (0.04%)
MEM	-0.0001 (0.00%)	0.0033 (0.50%)	0.0007 (0.05%)	0.0019 (0.10%)	-0.0005 (-0.14%)	0.0000 (0.00%)	0.0015 (0.05%)	0.0068 (0.06%)
MIA	0.0000 (0.00%)	0.0019 (0.33%)	0.0004 (0.08%)	0.0005 (0.38%)	-0.0004 (-0.32%)	0.0000 (0.00%)	0.0010 (0.08%)	0.0032 (0.07%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
MKE	-0.0002 (-0.01%)	0.0006 (0.11%)	0.0007 (0.05%)	0.0027 (0.10%)	-0.0002 (-0.07%)	-0.0001 (0.00%)	0.0000 (0.00%)	0.0036 (0.03%)
MLB	0.0000 (0.00%)	0.0001 (0.03%)	0.0004 (0.09%)	0.0008 (0.52%)	0.0001 (0.04%)	0.0000 (0.00%)	0.0013 (0.08%)	0.0028 (0.06%)
MSN	-0.0002 (-0.01%)	0.0003 (0.06%)	0.0019 (0.10%)	0.0061 (0.16%)	-0.0001 (-0.04%)	-0.0001 (0.00%)	0.0005 (0.02%)	0.0084 (0.06%)
MSP	-0.0002 (0.00%)	0.0031 (0.33%)	0.0010 (0.06%)	0.0032 (0.12%)	-0.0003 (-0.09%)	0.0000 (0.00%)	0.0001 (0.01%)	0.0069 (0.05%)
MSY	-0.0001 (0.00%)	0.0006 (0.11%)	0.0004 (0.04%)	0.0007 (0.14%)	-0.0001 (-0.02%)	0.0000 (0.00%)	0.0011 (0.04%)	0.0026 (0.03%)
OAK	0.0000 (0.00%)	0.0024 (0.23%)	0.0009 (0.11%)	0.0022 (0.12%)	-0.0004 (-0.09%)	0.0000 (0.00%)	0.0012 (0.14%)	0.0062 (0.06%)
OKC	-0.0002 (0.00%)	0.0003 (0.08%)	0.0011 (0.11%)	0.0026 (0.16%)	0.0000 (-0.02%)	0.0000 (0.00%)	0.0011 (0.07%)	0.0049 (0.05%)
OMA	-0.0002 (-0.01%)	0.0002 (0.06%)	0.0011 (0.08%)	0.0034 (0.14%)	0.0000 (-0.02%)	0.0000 (-0.01%)	0.0004 (0.02%)	0.0049 (0.05%)
ONT	-0.0004 (-0.01%)	0.0012 (0.08%)	0.0074 (0.50%)	0.0233 (0.66%)	-0.0008 (-0.16%)	-0.0003 (-0.01%)	0.0019 (0.15%)	0.0324 (0.21%)
ORD	**-0.0002 (-0.01%)**	**0.0049 (0.61%)**	**0.0008 (0.05%)**	**0.0028 (0.09%)**	**-0.0007 (-0.25%)**	**0.0000 (0.00%)**	**0.0002 (0.01%)**	**0.0078 (0.06%)**
ORF	-0.0001 (0.00%)	0.0004 (0.07%)	0.0008 (0.05%)	0.0021 (0.11%)	-0.0001 (-0.03%)	0.0000 (0.00%)	0.0007 (0.02%)	0.0038 (0.03%)
PBI	0.0000 (0.00%)	0.0005 (0.12%)	0.0003 (0.08%)	0.0004 (0.65%)	0.0000 (-0.02%)	0.0000 (0.00%)	0.0011 (0.08%)	0.0022 (0.06%)
PDX	0.0000 (0.00%)	0.0006 (0.05%)	0.0006 (0.11%)	0.0016 (0.15%)	-0.0010 (-0.05%)	0.0000 (0.00%)	0.0004 (0.06%)	0.0023 (0.01%)
PHF	-0.0001 (0.00%)	0.0001 (0.03%)	0.0010 (0.07%)	0.0033 (0.17%)	-0.0001 (-0.02%)	0.0000 (-0.01%)	0.0007 (0.03%)	0.0049 (0.05%)
PHL	-0.0002 (0.00%)	0.0023 (0.27%)	0.0017 (0.07%)	0.0063 (0.16%)	-0.0006 (-0.15%)	-0.0001 (0.00%)	-0.0004 (-0.01%)	0.0090 (0.05%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
PHX	-0.0001 (0.00%)	0.0032 (0.27%)	0.0020 (0.37%)	0.0046 (0.43%)	-0.0011 (-0.22%)	0.0000 (0.00%)	0.0019 (0.28%)	0.0106 (0.12%)
PIT	-0.0002 (-0.01%)	0.0007 (0.15%)	0.0011 (0.05%)	0.0040 (0.13%)	-0.0002 (-0.08%)	-0.0001 (-0.01%)	-0.0007 (-0.02%)	0.0046 (0.03%)
PVD	**-0.0001 (0.00%)**	**0.0004 (0.08%)**	**0.0008 (0.07%)**	**0.0030 (0.13%)**	**-0.0004 (-0.08%)**	**0.0000 (0.00%)**	**0.0005 (0.03%)**	**0.0042 (0.04%)**
RDU	-0.0001 (-0.01%)	0.0007 (0.04%)	0.0019 (0.12%)	0.0067 (0.27%)	-0.0003 (-0.04%)	-0.0001 (0.00%)	0.0013 (0.05%)	0.0101 (0.07%)
RIC	-0.0001 (0.00%)	0.0004 (0.06%)	0.0014 (0.07%)	0.0047 (0.17%)	-0.0002 (-0.03%)	0.0000 (0.00%)	0.0009 (0.02%)	0.0070 (0.05%)
RNO	0.0000 (0.00%)	0.0004 (0.10%)	0.0008 (0.23%)	0.0021 (0.39%)	0.0004 (0.04%)	0.0000 (0.00%)	0.0008 (0.15%)	0.0045 (0.07%)
ROC	-0.0002 (-0.01%)	0.0003 (0.08%)	0.0010 (0.06%)	0.0033 (0.13%)	-0.0002 (-0.04%)	-0.0001 (-0.01%)	0.0005 (0.02%)	0.0047 (0.04%)
RSW	0.0000 (0.00%)	0.0006 (0.09%)	0.0005 (0.10%)	0.0007 (0.40%)	0.0000 (-0.01%)	0.0000 (0.00%)	0.0013 (0.09%)	0.0030 (0.05%)
SAN	0.0000 (0.00%)	0.0015 (0.22%)	0.0008 (0.13%)	0.0015 (0.17%)	-0.0003 (-0.13%)	0.0000 (0.00%)	0.0019 (0.15%)	0.0054 (0.07%)
SAT	-0.0001 (0.00%)	0.0005 (0.10%)	0.0011 (0.11%)	0.0029 (0.23%)	0.0000 (-0.03%)	0.0000 (0.00%)	0.0009 (0.05%)	0.0051 (0.05%)
SBA	-0.0001 (0.00%)	0.0000 (0.01%)	0.0007 (0.21%)	0.0016 (0.34%)	0.0000 (0.01%)	-0.0001 (0.00%)	0.0007 (0.12%)	0.0030 (0.06%)
SDF	-0.0002 (0.00%)	0.0011 (0.07%)	0.0012 (0.05%)	0.0035 (0.10%)	-0.0003 (-0.12%)	0.0000 (0.00%)	0.0012 (0.03%)	0.0065 (0.04%)
SEA	0.0000 (0.00%)	0.0017 (0.16%)	0.0003 (0.06%)	0.0003 (0.03%)	-0.0019 (-0.12%)	0.0000 (0.00%)	0.0006 (0.10%)	0.0009 (0.01%)
SFO	0.0000 (0.00%)	0.0024 (0.23%)	0.0009 (0.11%)	0.0022 (0.12%)	-0.0004 (-0.09%)	0.0000 (0.00%)	0.0012 (0.14%)	0.0062 (0.06%)
SJC	-0.0001 (0.00%)	0.0009 (0.10%)	0.0014 (0.17%)	0.0044 (0.24%)	-0.0004 (-0.08%)	0.0000 (0.00%)	0.0005 (0.05%)	0.0068 (0.07%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
SLC	-0.0001 (0.00%)	0.0018 (0.35%)	0.0019 (0.30%)	0.0052 (0.37%)	-0.0008 (-0.10%)	0.0000 (0.00%)	0.0011 (0.19%)	0.0092 (0.12%)
SMF	-0.0001 (0.00%)	0.0006 (0.08%)	0.0017 (0.21%)	0.0051 (0.25%)	-0.0002 (-0.02%)	0.0000 (0.00%)	0.0007 (0.11%)	0.0079 (0.07%)
SNA	-0.0001 (0.00%)	0.0017 (0.15%)	0.0029 (0.28%)	0.0074 (0.36%)	-0.0005 (-0.14%)	0.0000 (0.00%)	0.0024 (0.19%)	0.0138 (0.13%)
STL	-0.0002 (0.00%)	0.0011 (0.13%)	0.0013 (0.07%)	0.0036 (0.12%)	-0.0002 (-0.08%)	0.0000 (0.00%)	0.0009 (0.03%)	0.0064 (0.04%)
SWF	-0.0001 (0.00%)	0.0003 (0.05%)	0.0007 (0.04%)	0.0022 (0.08%)	-0.0003 (-0.07%)	0.0000 (0.00%)	0.0004 (0.02%)	0.0031 (0.02%)
SYR	-0.0002 (-0.01%)	0.0004 (0.10%)	0.0013 (0.08%)	0.0045 (0.15%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0004 (0.02%)	0.0062 (0.05%)
TPA	-0.0001 (0.00%)	0.0009 (0.13%)	0.0008 (0.09%)	0.0020 (0.38%)	-0.0002 (-0.05%)	0.0000 (0.00%)	0.0014 (0.05%)	0.0049 (0.06%)
TUL	-0.0002 (0.00%)	0.0003 (0.05%)	0.0012 (0.10%)	0.0033 (0.16%)	0.0000 (-0.02%)	-0.0001 (0.00%)	0.0009 (0.05%)	0.0054 (0.04%)
TUS	0.0000 (0.00%)	0.0003 (0.08%)	0.0010 (0.29%)	0.0030 (0.82%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0008 (0.13%)	0.0051 (0.11%)
TVC	-0.0001 (-0.01%)	0.0001 (0.04%)	0.0003 (0.03%)	0.0010 (0.08%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0005 (0.03%)	0.0017 (0.03%)
TYS	-0.0001 (0.00%)	0.0002 (0.04%)	0.0008 (0.06%)	0.0021 (0.14%)	0.0001 (0.01%)	0.0000 (0.00%)	0.0015 (0.04%)	0.0045 (0.04%)

*$PM_{2.5}$ does not equal the sum of species shown in chart due to a scaling factor (1.167) applied to POA when computing $PM_{2.5}$.

Table 5. Absolute and percent increases due to 2025 aircraft emissions in 2005 at the grid cell containing the airport.

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ABQ	**0.0000 (0.00%)**	**0.0015 (0.31%)**	**0.0012 (0.33%)**	**0.0025 (0.52%)**	**-0.0003 (-0.05%)**	**0.0000 (0.00%)**	**0.0016 (0.24%)**	**0.0065 (0.08%)**
ALB	-0.0002 (-0.01%)	0.0007 (0.13%)	0.0023 (0.17%)	0.0065 (0.26%)	-0.0119 (-2.12%)	-0.0001 (-0.01%)	0.0009 (0.05%)	-0.0019 (-0.02%)
ATL	**-0.0002 (-0.01%)**	**0.0114 (1.11%)**	**0.0022 (0.13%)**	**0.0051 (0.25%)**	**-0.0011 (-0.08%)**	**-0.0001 (0.00%)**	**0.0040 (0.12%)**	**0.0212 (0.14%)**
AUS	-0.0003 (-0.01%)	0.0016 (0.61%)	0.0038 (0.35%)	0.0090 (0.61%)	-0.0011 (-0.74%)	-0.0001 (-0.01%)	0.0039 (0.22%)	0.0169 (0.20%)
BDL	-0.0002 (-0.01%)	0.0027 (0.52%)	0.0015 (0.12%)	0.0056 (0.23%)	-0.0006 (-0.12%)	-0.0001 (-0.01%)	0.0011 (0.06%)	0.0100 (0.09%)
BFL	-0.0003 (-0.02%)	-0.0001 (-0.02%)	0.0052 (0.77%)	0.0149 (0.97%)	0.0000 (-0.01%)	-0.0002 (-0.01%)	0.0023 (0.38%)	0.0217 (0.29%)
BHM	-0.0003 (-0.01%)	0.0006 (0.08%)	0.0020 (0.13%)	0.0049 (0.34%)	-0.0002 (-0.01%)	-0.0001 (-0.01%)	0.0041 (0.11%)	0.0110 (0.07%)
BNA	-0.0003 (-0.01%)	0.0009 (0.12%)	0.0021 (0.12%)	0.0060 (0.25%)	-0.0002 (-0.05%)	-0.0001 (-0.01%)	0.0025 (0.08%)	0.0110 (0.09%)
BOI	-0.0001 (0.00%)	0.0010 (0.10%)	0.0031 (0.49%)	0.0086 (0.69%)	-0.0015 (-0.08%)	0.0000 (0.00%)	0.0015 (0.21%)	0.0126 (0.09%)
BOS	-0.0001 (0.00%)	0.0044 (0.32%)	0.0019 (0.12%)	0.0101 (0.35%)	-0.0009 (-0.17%)	-0.0001 (0.00%)	-0.0003 (-0.01%)	0.0150 (0.09%)
BTR	-0.0002 (-0.01%)	0.0000 (0.00%)	0.0020 (0.15%)	0.0049 (0.39%)	-0.0003 (-0.05%)	-0.0001 (-0.01%)	0.0023 (0.08%)	0.0087 (0.07%)
BUF	-0.0003 (-0.01%)	0.0009 (0.18%)	0.0031 (0.16%)	0.0109 (0.32%)	-0.0006 (-0.13%)	-0.0001 (-0.01%)	0.0009 (0.03%)	0.0147 (0.10%)
BUR	-0.0004 (-0.02%)	0.0018 (0.17%)	0.0072 (0.75%)	0.0209 (0.98%)	-0.0012 (-0.28%)	-0.0003 (-0.02%)	0.0035 (0.36%)	0.0315 (0.32%)
BWI	-0.0004 (-0.01%)	0.0029 (0.41%)	0.0022 (0.11%)	0.0087 (0.29%)	-0.0004 (-0.09%)	-0.0001 (-0.01%)	0.0004 (0.01%)	0.0133 (0.09%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
CHS	-0.0002 (-0.01%)	0.0004 (0.07%)	0.0009 (0.09%)	0.0026 (0.35%)	-0.0002 (-0.03%)	-0.0001 (-0.01%)	0.0025 (0.09%)	0.0059 (0.07%)
CLE	-0.0006 (-0.02%)	0.0011 (0.23%)	0.0052 (0.21%)	0.0164 (0.36%)	-0.0022 (-0.80%)	-0.0001 (-0.02%)	0.0019 (0.06%)	0.0217 (0.15%)
CLT	-0.0003 (-0.01%)	0.0033 (0.13%)	0.0042 (0.22%)	0.0129 (0.53%)	-0.0004 (-0.04%)	-0.0001 (-0.01%)	0.0040 (0.11%)	0.0235 (0.14%)
CMH	-0.0005 (-0.01%)	0.0011 (0.19%)	0.0039 (0.17%)	0.0122 (0.31%)	0.0002 (0.07%)	-0.0001 (-0.01%)	0.0026 (0.08%)	0.0194 (0.13%)
COS	0.0000 (0.00%)	0.0002 (0.05%)	0.0010 (0.29%)	0.0022 (0.60%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0013 (0.20%)	0.0045 (0.06%)
CRP	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0011 (0.16%)	0.0029 (0.54%)	-0.0003 (-0.51%)	0.0000 (-0.01%)	0.0011 (0.07%)	0.0047 (0.07%)
CVG	-0.0005 (-0.01%)	0.0026 (0.34%)	0.0034 (0.14%)	0.0107 (0.29%)	-0.0002 (-0.08%)	-0.0001 (-0.01%)	0.0019 (0.05%)	0.0177 (0.11%)
DAB	-0.0001 (-0.01%)	0.0001 (0.04%)	0.0004 (0.08%)	0.0005 (0.58%)	-0.0002 (-0.07%)	0.0000 (-0.01%)	0.0024 (0.13%)	0.0030 (0.07%)
DAL	-0.0004 (-0.01%)	0.0028 (0.39%)	0.0036 (0.26%)	0.0082 (0.44%)	-0.0003 (-0.13%)	-0.0001 (-0.01%)	0.0039 (0.17%)	0.0177 (0.13%)
DAY	-0.0005 (-0.01%)	0.0007 (0.12%)	0.0035 (0.16%)	0.0112 (0.28%)	-0.0008 (-0.32%)	-0.0001 (-0.01%)	0.0026 (0.07%)	0.0166 (0.11%)
DCA	-0.0004 (-0.01%)	0.0021 (0.20%)	0.0022 (0.11%)	0.0079 (0.25%)	-0.0018 (-0.35%)	-0.0001 (-0.01%)	0.0008 (0.02%)	0.0106 (0.06%)
DEN	-0.0001 (0.00%)	0.0051 (0.75%)	0.0029 (0.55%)	0.0075 (0.87%)	-0.0007 (-0.09%)	0.0000 (0.00%)	0.0016 (0.21%)	0.0163 (0.21%)
DFW	-0.0004 (-0.01%)	0.0024 (0.30%)	0.0035 (0.26%)	0.0083 (0.42%)	-0.0002 (-0.08%)	-0.0001 (-0.01%)	0.0036 (0.17%)	0.0172 (0.13%)
DSM	-0.0004 (-0.01%)	0.0002 (0.05%)	0.0028 (0.19%)	0.0079 (0.28%)	-0.0005 (-0.31%)	-0.0001 (-0.02%)	0.0014 (0.08%)	0.0113 (0.11%)
DTW	-0.0005 (-0.01%)	0.0046 (0.50%)	0.0028 (0.13%)	0.0087 (0.23%)	-0.0003 (-0.09%)	-0.0001 (-0.01%)	0.0012 (0.04%)	0.0164 (0.11%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
ELP	0.0000 (0.00%)	0.0006 (0.25%)	0.0012 (0.29%)	0.0026 (0.55%)	0.0007 (0.20%)	0.0000 (0.00%)	0.0013 (0.17%)	0.0065 (0.14%)
EUG	0.0000 (0.00%)	0.0001 (0.02%)	0.0011 (0.48%)	0.0033 (0.79%)	-0.0008 (-0.04%)	0.0000 (0.00%)	0.0004 (0.13%)	0.0041 (0.06%)
EWR	-0.0003 (-0.01%)	0.0033 (0.31%)	0.0028 (0.14%)	0.0102 (0.30%)	-0.0008 (-0.18%)	-0.0001 (-0.01%)	-0.0004 (-0.01%)	0.0146 (0.10%)
FAT	-0.0002 (-0.01%)	0.0002 (0.03%)	0.0041 (0.56%)	0.0115 (0.69%)	-0.0003 (-0.04%)	-0.0001 (-0.01%)	0.0021 (0.30%)	0.0172 (0.19%)
FLL	-0.0001 (0.00%)	0.0028 (0.49%)	0.0007 (0.14%)	0.0014 (1.02%)	-0.0002 (-0.14%)	0.0000 (0.00%)	0.0012 (0.08%)	0.0058 (0.11%)
FNT	-0.0004 (-0.01%)	0.0003 (0.05%)	0.0022 (0.12%)	0.0075 (0.23%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0009 (0.04%)	0.0102 (0.08%)
GFK	-0.0002 (-0.01%)	0.0010 (0.42%)	0.0015 (0.21%)	0.0043 (0.28%)	-0.0001 (-0.06%)	0.0000 (-0.01%)	0.0006 (0.09%)	0.0071 (0.12%)
GRR	-0.0004 (-0.01%)	0.0003 (0.06%)	0.0036 (0.18%)	0.0121 (0.33%)	-0.0003 (-0.08%)	-0.0001 (-0.01%)	0.0007 (0.03%)	0.0160 (0.12%)
GSO	-0.0003 (-0.01%)	0.0002 (0.03%)	0.0044 (0.23%)	0.0130 (0.47%)	-0.0006 (-0.07%)	-0.0001 (-0.01%)	0.0027 (0.09%)	0.0193 (0.14%)
HOU	-0.0002 (0.00%)	0.0014 (0.14%)	0.0020 (0.16%)	0.0054 (0.47%)	-0.0008 (-0.22%)	-0.0001 (0.00%)	0.0013 (0.05%)	0.0090 (0.06%)
HPN	-0.0002 (-0.01%)	0.0013 (0.17%)	0.0014 (0.09%)	0.0057 (0.20%)	-0.0024 (-0.53%)	-0.0001 (-0.01%)	0.0001 (0.00%)	0.0057 (0.05%)
IAD	-0.0003 (-0.01%)	0.0062 (0.68%)	0.0021 (0.10%)	0.0075 (0.23%)	-0.0040 (-0.82%)	-0.0001 (-0.01%)	0.0006 (0.02%)	0.0120 (0.08%)
IAH	-0.0002 (0.00%)	0.0057 (0.75%)	0.0017 (0.15%)	0.0032 (0.28%)	-0.0002 (-0.03%)	-0.0001 (0.00%)	0.0032 (0.15%)	0.0133 (0.10%)
ICT	-0.0005 (-0.01%)	0.0000 (0.01%)	0.0027 (0.23%)	0.0076 (0.37%)	-0.0004 (-0.27%)	-0.0001 (-0.01%)	0.0013 (0.09%)	0.0107 (0.10%)
IND	-0.0005 (-0.01%)	0.0025 (0.37%)	0.0030 (0.12%)	0.0111 (0.28%)	-0.0007 (-0.30%)	-0.0001 (-0.01%)	0.0001 (0.00%)	0.0154 (0.08%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
ISP	-0.0003 (-0.01%)	0.0011 (0.15%)	0.0016 (0.10%)	0.0062 (0.24%)	0.0026 (0.71%)	-0.0001 (-0.01%)	0.0001 (0.00%)	0.0111 (0.10%)
JAX	-0.0002 (-0.01%)	0.0009 (0.19%)	0.0019 (0.22%)	0.0043 (0.72%)	-0.0030 (-0.22%)	-0.0001 (-0.01%)	0.0033 (0.15%)	0.0072 (0.08%)
JFK	-0.0002 (-0.01%)	0.0073 (0.58%)	0.0017 (0.09%)	0.0071 (0.23%)	-0.0028 (-0.54%)	-0.0001 (-0.01%)	-0.0006 (-0.02%)	0.0124 (0.08%)
LAN	-0.0004 (-0.01%)	0.0001 (0.03%)	0.0035 (0.18%)	0.0117 (0.30%)	-0.0013 (-0.47%)	-0.0001 (-0.01%)	0.0007 (0.03%)	0.0143 (0.11%)
LAS	-0.0001 (0.00%)	0.0038 (0.40%)	0.0016 (0.42%)	0.0027 (0.60%)	-0.0012 (-0.25%)	0.0000 (-0.01%)	0.0028 (0.39%)	0.0095 (0.14%)
LAX	**-0.0001 (0.00%)**	**0.0094 (0.83%)**	**0.0077 (0.56%)**	**0.0220 (0.75%)**	**-0.0016 (-0.50%)**	**-0.0001 (0.00%)**	**0.0043 (0.30%)**	**0.0416 (0.33%)**
LGA	-0.0003 (-0.01%)	0.0027 (0.20%)	0.0027 (0.14%)	0.0099 (0.30%)	-0.0015 (-0.33%)	-0.0002 (-0.01%)	0.0000 (0.00%)	0.0133 (0.08%)
LGB	-0.0007 (-0.02%)	0.0029 (0.16%)	0.0165 (1.00%)	0.0524 (1.43%)	-0.0006 (-0.14%)	-0.0005 (-0.02%)	0.0037 (0.23%)	0.0737 (0.43%)
LIT	-0.0003 (-0.01%)	0.0006 (0.13%)	0.0034 (0.25%)	0.0085 (0.47%)	-0.0003 (-0.05%)	-0.0001 (-0.01%)	0.0035 (0.14%)	0.0152 (0.15%)
MCI	-0.0005 (-0.01%)	0.0022 (0.34%)	0.0030 (0.18%)	0.0100 (0.33%)	-0.0007 (-0.32%)	-0.0001 (-0.01%)	0.0002 (0.01%)	0.0141 (0.10%)
MCO	-0.0001 (-0.01%)	0.0029 (0.46%)	0.0019 (0.27%)	0.0036 (0.81%)	-0.0003 (-0.06%)	-0.0001 (-0.01%)	0.0045 (0.25%)	0.0124 (0.17%)
MDW	-0.0005 (-0.01%)	0.0014 (0.16%)	0.0024 (0.11%)	0.0081 (0.25%)	-0.0015 (-0.60%)	-0.0001 (-0.01%)	0.0003 (0.01%)	0.0101 (0.06%)
MEM	-0.0003 (-0.01%)	0.0054 (0.81%)	0.0014 (0.09%)	0.0038 (0.19%)	-0.0008 (-0.24%)	-0.0001 (-0.01%)	0.0028 (0.10%)	0.0121 (0.10%)
MIA	0.0000 (0.00%)	0.0035 (0.61%)	0.0008 (0.16%)	0.0010 (0.82%)	-0.0005 (-0.36%)	0.0000 (0.00%)	0.0019 (0.15%)	0.0066 (0.14%)
MKE	-0.0004 (-0.01%)	0.0009 (0.16%)	0.0015 (0.10%)	0.0054 (0.19%)	0.0001 (0.02%)	-0.0001 (-0.01%)	0.0001 (0.01%)	0.0074 (0.06%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
MLB	-0.0001 (-0.01%)	0.0002 (0.06%)	0.0009 (0.17%)	0.0016 (1.00%)	-0.0001 (-0.02%)	0.0000 (-0.01%)	0.0029 (0.17%)	0.0054 (0.11%)
MSN	-0.0004 (-0.01%)	0.0002 (0.04%)	0.0036 (0.19%)	0.0119 (0.31%)	-0.0005 (-0.17%)	-0.0001 (-0.01%)	0.0007 (0.03%)	0.0153 (0.11%)
MSP	-0.0004 (-0.01%)	0.0052 (0.57%)	0.0019 (0.13%)	0.0063 (0.23%)	-0.0003 (-0.12%)	-0.0001 (-0.01%)	0.0002 (0.01%)	0.0128 (0.09%)
MSY	-0.0001 (-0.01%)	0.0011 (0.22%)	0.0008 (0.09%)	0.0016 (0.32%)	-0.0007 (-0.27%)	0.0000 (-0.01%)	0.0022 (0.08%)	0.0048 (0.06%)
OAK	-0.0001 (0.00%)	0.0055 (0.52%)	0.0026 (0.32%)	0.0066 (0.35%)	-0.0004 (-0.09%)	-0.0001 (0.00%)	0.0026 (0.31%)	0.0167 (0.16%)
OKC	-0.0004 (-0.01%)	0.0007 (0.16%)	0.0025 (0.24%)	0.0058 (0.35%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0024 (0.16%)	0.0107 (0.12%)
OMA	-0.0004 (-0.01%)	0.0007 (0.19%)	0.0026 (0.19%)	0.0080 (0.32%)	-0.0012 (-0.84%)	-0.0001 (-0.01%)	0.0009 (0.05%)	0.0106 (0.10%)
ONT	-0.0007 (-0.02%)	0.0031 (0.20%)	0.0149 (1.00%)	0.0467 (1.33%)	-0.0014 (-0.28%)	-0.0005 (-0.02%)	0.0040 (0.30%)	0.0659 (0.42%)
ORD	**-0.0004 (-0.01%)**	**0.0044 (0.54%)**	**0.0017 (0.09%)**	**0.0059 (0.18%)**	**-0.0005 (-0.20%)**	**-0.0001 (-0.01%)**	**0.0002 (0.01%)**	**0.0111 (0.08%)**
ORF	-0.0002 (-0.01%)	0.0010 (0.17%)	0.0016 (0.11%)	0.0048 (0.25%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0013 (0.04%)	0.0083 (0.07%)
PBI	-0.0001 (-0.01%)	0.0009 (0.23%)	0.0005 (0.15%)	0.0007 (1.10%)	-0.0022 (-1.61%)	0.0000 (0.00%)	0.0023 (0.17%)	0.0021 (0.05%)
PDX	-0.0002 (0.00%)	0.0018 (0.14%)	0.0016 (0.28%)	0.0041 (0.38%)	-0.0008 (-0.04%)	-0.0001 (0.00%)	0.0011 (0.15%)	0.0076 (0.04%)
PHF	-0.0002 (-0.01%)	0.0003 (0.07%)	0.0018 (0.13%)	0.0061 (0.32%)	-0.0013 (-0.24%)	-0.0001 (-0.01%)	0.0016 (0.06%)	0.0081 (0.08%)
PHL	-0.0003 (-0.01%)	0.0049 (0.58%)	0.0028 (0.12%)	0.0112 (0.28%)	-0.0024 (-0.57%)	-0.0001 (-0.01%)	-0.0018 (-0.05%)	0.0143 (0.08%)
PHX	-0.0002 (-0.01%)	0.0069 (0.57%)	0.0047 (0.85%)	0.0110 (1.03%)	-0.0008 (-0.16%)	-0.0001 (-0.01%)	0.0040 (0.60%)	0.0256 (0.29%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	PM$_{2.5}$* (µg m^{-3})
PIT	-0.0004 (-0.01%)	0.0008 (0.17%)	0.0024 (0.12%)	0.0084 (0.27%)	-0.0007 (-0.23%)	-0.0001 (-0.01%)	0.0001 (0.00%)	0.0104 (0.07%)
PVD	**-0.0002 (-0.01%)**	**0.0010 (0.20%)**	**0.0017 (0.14%)**	**0.0070 (0.31%)**	**-0.0011 (-0.24%)**	**-0.0001 (-0.01%)**	**0.0009 (0.05%)**	**0.0092 (0.09%)**
RDU	-0.0003 (-0.01%)	0.0012 (0.06%)	0.0038 (0.23%)	0.0121 (0.48%)	-0.0005 (-0.05%)	-0.0001 (-0.01%)	0.0027 (0.09%)	0.0188 (0.13%)
RIC	-0.0003 (-0.01%)	0.0007 (0.12%)	0.0031 (0.16%)	0.0105 (0.39%)	0.0009 (0.14%)	-0.0001 (-0.01%)	0.0019 (0.05%)	0.0166 (0.11%)
RNO	0.0000 (0.00%)	0.0012 (0.29%)	0.0021 (0.58%)	0.0050 (0.93%)	-0.0003 (-0.02%)	0.0000 (0.00%)	0.0020 (0.36%)	0.0099 (0.15%)
ROC	-0.0004 (-0.01%)	0.0008 (0.20%)	0.0020 (0.13%)	0.0071 (0.29%)	-0.0003 (-0.08%)	-0.0001 (-0.01%)	0.0008 (0.03%)	0.0100 (0.08%)
RSW	-0.0001 (-0.01%)	0.0008 (0.13%)	0.0010 (0.21%)	0.0015 (0.89%)	-0.0002 (-0.09%)	-0.0001 (0.00%)	0.0027 (0.18%)	0.0056 (0.10%)
SAN	-0.0001 (0.00%)	0.0029 (0.42%)	0.0022 (0.34%)	0.0045 (0.51%)	-0.0006 (-0.23%)	-0.0001 (-0.01%)	0.0042 (0.33%)	0.0132 (0.18%)
SAT	-0.0003 (-0.01%)	0.0009 (0.19%)	0.0027 (0.27%)	0.0072 (0.58%)	0.0000 (-0.03%)	-0.0001 (-0.01%)	0.0019 (0.11%)	0.0123 (0.13%)
SBA	-0.0002 (-0.01%)	0.0000 (0.00%)	0.0018 (0.52%)	0.0040 (0.82%)	-0.0006 (-0.25%)	-0.0001 (-0.01%)	0.0018 (0.30%)	0.0066 (0.13%)
SDF	-0.0004 (-0.01%)	0.0020 (0.13%)	0.0022 (0.09%)	0.0067 (0.20%)	-0.0042 (-1.47%)	-0.0001 (-0.01%)	0.0015 (0.04%)	0.0076 (0.04%)
SEA	0.0000 (0.00%)	0.0036 (0.33%)	0.0006 (0.12%)	0.0003 (0.03%)	-0.0015 (-0.09%)	0.0000 (0.00%)	0.0014 (0.23%)	0.0045 (0.04%)
SFO	-0.0001 (0.00%)	0.0055 (0.52%)	0.0026 (0.32%)	0.0066 (0.35%)	-0.0011 (-0.22%)	-0.0001 (0.00%)	0.0026 (0.31%)	0.0160 (0.15%)
SJC	-0.0001 (0.00%)	0.0029 (0.31%)	0.0036 (0.43%)	0.0109 (0.59%)	-0.0014 (-0.31%)	-0.0001 (0.00%)	0.0013 (0.15%)	0.0169 (0.17%)
SLC	-0.0001 (-0.01%)	0.0029 (0.56%)	0.0043 (0.69%)	0.0119 (0.84%)	-0.0010 (-0.14%)	-0.0001 (-0.01%)	0.0024 (0.42%)	0.0203 (0.28%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
SMF	-0.0001 (0.00%)	0.0023 (0.28%)	0.0045 (0.55%)	0.0131 (0.64%)	-0.0008 (-0.11%)	-0.0001 (0.00%)	0.0019 (0.29%)	0.0209 (0.20%)
SNA	-0.0001 (0.00%)	0.0049 (0.42%)	0.0053 (0.52%)	0.0129 (0.62%)	-0.0009 (-0.25%)	-0.0001 (0.00%)	0.0052 (0.41%)	0.0273 (0.25%)
STL	-0.0005 (-0.01%)	0.0014 (0.16%)	0.0027 (0.15%)	0.0079 (0.26%)	-0.0005 (-0.19%)	-0.0001 (-0.01%)	0.0018 (0.06%)	0.0127 (0.08%)
SWF	-0.0002 (-0.01%)	0.0004 (0.07%)	0.0016 (0.10%)	0.0058 (0.21%)	-0.0006 (-0.13%)	-0.0001 (-0.01%)	0.0006 (0.02%)	0.0074 (0.06%)
SYR	-0.0004 (-0.01%)	0.0004 (0.10%)	0.0030 (0.18%)	0.0100 (0.35%)	-0.0005 (-0.12%)	-0.0002 (-0.01%)	0.0009 (0.04%)	0.0133 (0.11%)
TPA	-0.0001 (-0.01%)	0.0015 (0.21%)	0.0017 (0.19%)	0.0041 (0.77%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0026 (0.10%)	0.0095 (0.11%)
TUL	-0.0004 (-0.01%)	0.0003 (0.06%)	0.0027 (0.21%)	0.0072 (0.35%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0018 (0.09%)	0.0114 (0.09%)
TUS	-0.0001 (0.00%)	0.0006 (0.13%)	0.0020 (0.57%)	0.0050 (1.36%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0019 (0.29%)	0.0093 (0.20%)
TVC	-0.0002 (-0.01%)	0.0002 (0.07%)	0.0006 (0.06%)	0.0021 (0.17%)	0.0001 (0.01%)	0.0000 (-0.01%)	0.0009 (0.05%)	0.0034 (0.05%)
TYS	-0.0002 (-0.01%)	0.0004 (0.06%)	0.0015 (0.11%)	0.0038 (0.25%)	0.0000 (-0.01%)	-0.0001 (-0.01%)	0.0033 (0.10%)	0.0086 (0.07%)

*$PM_{2.5}$ does not equal the sum of species shown in chart due to a scaling factor (1.167) applied to POA when computing $PM_{2.5}$.

Table 6. Absolute and percent increases due to aircraft emissions in 2025 at the grid cell containing the airport.

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ABQ	**0.0000 (0.00%)**	**0.0015 (0.61%)**	**0.0024 (0.72%)**	**0.0057 (1.42%)**	**-0.0001 (-0.01%)**	**0.0000 (0.00%)**	**0.0018 (0.31%)**	**0.0113 (0.14%)**
ALB	-0.0009 (-0.02%)	0.0004 (0.12%)	0.0060 (0.58%)	0.0200 (1.12%)	0.0012 (0.20%)	-0.0004 (-0.02%)	0.0008 (0.05%)	0.0270 (0.24%)
ATL	**-0.0009 (-0.02%)**	**0.0121 (2.56%)**	**0.0162 (1.43%)**	**0.0406 (2.90%)**	**-0.0012 (-0.08%)**	**-0.0003 (-0.02%)**	**0.0130 (0.66%)**	**0.0796 (0.65%)**
AUS	-0.0006 (-0.02%)	0.0017 (1.21%)	0.0056 (0.71%)	0.0137 (1.28%)	-0.0004 (-0.25%)	-0.0001 (-0.02%)	0.0045 (0.35%)	0.0243 (0.33%)
BDL	-0.0009 (-0.03%)	0.0025 (0.87%)	0.0076 (0.71%)	0.0249 (1.26%)	-0.0006 (-0.11%)	-0.0004 (-0.03%)	0.0021 (0.15%)	0.0352 (0.36%)
BFL	-0.0004 (-0.02%)	0.0000 (-0.01%)	0.0052 (1.04%)	0.0144 (1.47%)	0.0011 (0.23%)	-0.0002 (-0.02%)	0.0028 (0.47%)	0.0228 (0.35%)
BHM	-0.0006 (-0.01%)	0.0006 (0.16%)	0.0048 (0.43%)	0.0122 (1.15%)	-0.0001 (-0.01%)	-0.0002 (-0.01%)	0.0039 (0.17%)	0.0206 (0.16%)
BNA	-0.0008 (-0.03%)	0.0009 (0.29%)	0.0055 (0.43%)	0.0159 (0.91%)	0.0009 (0.28%)	-0.0002 (-0.02%)	0.0032 (0.15%)	0.0254 (0.26%)
BOI	-0.0001 (0.00%)	0.0010 (0.12%)	0.0041 (0.80%)	0.0122 (1.30%)	-0.0023 (-0.13%)	0.0000 (0.00%)	0.0015 (0.24%)	0.0165 (0.13%)
BOS	-0.0007 (-0.02%)	0.0044 (0.56%)	0.0071 (0.55%)	0.0264 (1.17%)	-0.0020 (-0.34%)	-0.0003 (-0.01%)	-0.0013 (-0.07%)	0.0336 (0.23%)
BTR	-0.0003 (-0.01%)	0.0000 (0.00%)	0.0027 (0.23%)	0.0068 (0.67%)	-0.0003 (-0.06%)	-0.0001 (-0.01%)	0.0025 (0.09%)	0.0111 (0.11%)
BUF	-0.0008 (-0.02%)	0.0008 (0.25%)	0.0058 (0.39%)	0.0187 (0.77%)	-0.0007 (-0.13%)	-0.0003 (-0.02%)	0.0012 (0.06%)	0.0247 (0.19%)
BUR	-0.0005 (-0.02%)	0.0020 (0.34%)	0.0067 (1.01%)	0.0185 (1.55%)	-0.0012 (-0.27%)	-0.0003 (-0.02%)	0.0042 (0.47%)	0.0293 (0.37%)
BWI	-0.0014 (-0.04%)	0.0027 (0.70%)	0.0097 (0.65%)	0.0311 (1.25%)	0.0002 (0.04%)	-0.0005 (-0.03%)	0.0029 (0.13%)	0.0446 (0.36%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
CHS	-0.0005 (-0.02%)	0.0003 (0.12%)	0.0030 (0.39%)	0.0079 (1.39%)	-0.0002 (-0.03%)	-0.0001 (-0.02%)	0.0027 (0.15%)	0.0131 (0.18%)
CLE	-0.0013 (-0.04%)	0.0011 (0.52%)	0.0088 (0.50%)	0.0290 (0.91%)	0.0013 (0.43%)	-0.0003 (-0.04%)	0.0014 (0.06%)	0.0400 (0.35%)
CLT	-0.0007 (-0.02%)	0.0036 (0.82%)	0.0113 (0.93%)	0.0325 (2.04%)	-0.0004 (-0.04%)	-0.0002 (-0.02%)	0.0053 (0.26%)	0.0513 (0.46%)
CMH	-0.0012 (-0.03%)	0.0011 (0.44%)	0.0082 (0.49%)	0.0261 (0.90%)	0.0005 (0.18%)	-0.0003 (-0.03%)	0.0020 (0.09%)	0.0364 (0.30%)
COS	-0.0001 (0.00%)	0.0004 (0.13%)	0.0019 (0.63%)	0.0047 (1.47%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0014 (0.25%)	0.0082 (0.13%)
CRP	-0.0003 (-0.01%)	0.0001 (0.06%)	0.0016 (0.28%)	0.0040 (0.97%)	-0.0005 (-0.76%)	-0.0001 (-0.02%)	0.0013 (0.10%)	0.0061 (0.11%)
CVG	-0.0012 (-0.03%)	0.0028 (1.02%)	0.0079 (0.46%)	0.0254 (0.91%)	-0.0002 (-0.07%)	-0.0003 (-0.03%)	0.0022 (0.09%)	0.0366 (0.29%)
DAB	-0.0002 (-0.02%)	0.0001 (0.05%)	0.0010 (0.30%)	0.0013 (2.15%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0025 (0.24%)	0.0046 (0.14%)
DAL	-0.0007 (-0.01%)	0.0028 (0.86%)	0.0075 (0.72%)	0.0196 (1.42%)	-0.0005 (-0.22%)	-0.0002 (-0.01%)	0.0051 (0.29%)	0.0335 (0.29%)
DAY	-0.0012 (-0.03%)	0.0006 (0.28%)	0.0079 (0.47%)	0.0255 (0.88%)	-0.0009 (-0.37%)	-0.0003 (-0.03%)	0.0019 (0.08%)	0.0335 (0.28%)
DCA	-0.0012 (-0.03%)	0.0019 (0.39%)	0.0098 (0.61%)	0.0317 (1.23%)	-0.0017 (-0.33%)	-0.0004 (-0.02%)	0.0024 (0.10%)	0.0423 (0.31%)
DEN	-0.0001 (0.00%)	0.0052 (1.75%)	0.0056 (1.19%)	0.0165 (2.32%)	-0.0008 (-0.11%)	0.0000 (0.00%)	0.0022 (0.31%)	0.0285 (0.40%)
DFW	-0.0007 (-0.01%)	0.0023 (0.82%)	0.0072 (0.71%)	0.0192 (1.33%)	-0.0002 (-0.11%)	-0.0002 (-0.01%)	0.0043 (0.27%)	0.0318 (0.28%)
DSM	-0.0008 (-0.03%)	0.0002 (0.13%)	0.0039 (0.35%)	0.0121 (0.61%)	-0.0009 (-0.61%)	-0.0001 (-0.03%)	0.0011 (0.08%)	0.0155 (0.18%)
DTW	-0.0010 (-0.03%)	0.0041 (1.35%)	0.0063 (0.38%)	0.0210 (0.71%)	-0.0004 (-0.12%)	-0.0002 (-0.02%)	0.0011 (0.05%)	0.0309 (0.25%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
ELP	0.0000 (0.00%)	0.0007 (0.46%)	0.0022 (0.60%)	0.0055 (1.50%)	0.0012 (0.33%)	0.0000 (0.00%)	0.0016 (0.23%)	0.0112 (0.25%)
EUG	0.0000 (0.00%)	0.0001 (0.02%)	0.0012 (0.64%)	0.0033 (1.37%)	-0.0014 (-0.07%)	0.0000 (0.00%)	0.0005 (0.15%)	0.0037 (0.06%)
EWR	-0.0010 (-0.03%)	0.0032 (0.68%)	0.0072 (0.46%)	0.0262 (1.00%)	-0.0011 (-0.24%)	-0.0004 (-0.02%)	-0.0008 (-0.04%)	0.0333 (0.26%)
FAT	-0.0003 (-0.01%)	0.0002 (0.06%)	0.0050 (0.90%)	0.0139 (1.30%)	-0.0001 (-0.01%)	-0.0002 (-0.01%)	0.0025 (0.38%)	0.0210 (0.26%)
FLL	-0.0001 (-0.01%)	0.0028 (1.07%)	0.0025 (0.72%)	0.0039 (3.50%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0040 (0.44%)	0.0129 (0.33%)
FNT	-0.0009 (-0.03%)	0.0003 (0.13%)	0.0051 (0.36%)	0.0177 (0.71%)	-0.0003 (-0.09%)	-0.0002 (-0.03%)	0.0003 (0.02%)	0.0220 (0.21%)
GFK	-0.0004 (-0.02%)	0.0011 (0.91%)	0.0018 (0.33%)	0.0055 (0.47%)	-0.0001 (-0.05%)	-0.0001 (-0.02%)	0.0007 (0.11%)	0.0085 (0.16%)
GRR	-0.0009 (-0.03%)	0.0004 (0.17%)	0.0065 (0.42%)	0.0219 (0.84%)	0.0002 (0.08%)	-0.0002 (-0.03%)	0.0005 (0.02%)	0.0283 (0.26%)
GSO	-0.0008 (-0.03%)	0.0001 (0.03%)	0.0084 (0.69%)	0.0254 (1.41%)	-0.0003 (-0.03%)	-0.0003 (-0.02%)	0.0029 (0.15%)	0.0354 (0.37%)
HOU	-0.0004 (-0.01%)	0.0016 (0.33%)	0.0034 (0.30%)	0.0095 (0.91%)	-0.0010 (-0.27%)	-0.0001 (-0.01%)	0.0018 (0.08%)	0.0148 (0.11%)
HPN	-0.0009 (-0.03%)	0.0011 (0.30%)	0.0064 (0.46%)	0.0224 (0.86%)	-0.0027 (-0.56%)	-0.0004 (-0.02%)	0.0005 (0.03%)	0.0264 (0.23%)
IAD	-0.0012 (-0.03%)	0.0057 (1.40%)	0.0120 (0.81%)	0.0379 (1.47%)	-0.0026 (-0.50%)	-0.0004 (-0.03%)	0.0038 (0.19%)	0.0552 (0.44%)
IAH	-0.0004 (-0.01%)	0.0055 (1.54%)	0.0046 (0.48%)	0.0098 (0.89%)	-0.0002 (-0.02%)	-0.0001 (-0.01%)	0.0053 (0.30%)	0.0246 (0.19%)
ICT	-0.0007 (-0.02%)	0.0001 (0.02%)	0.0033 (0.38%)	0.0098 (0.66%)	-0.0006 (-0.36%)	-0.0002 (-0.02%)	0.0011 (0.10%)	0.0127 (0.14%)
IND	-0.0014 (-0.02%)	0.0024 (0.81%)	0.0089 (0.47%)	0.0297 (1.00%)	-0.0012 (-0.48%)	-0.0002 (-0.03%)	0.0013 (0.05%)	0.0395 (0.26%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
ISP	-0.0009 (-0.03%)	0.0009 (0.26%)	0.0068 (0.51%)	0.0235 (1.03%)	0.0062 (1.57%)	-0.0004 (-0.03%)	0.0004 (0.02%)	0.0365 (0.35%)
JAX	-0.0004 (-0.02%)	0.0009 (0.27%)	0.0039 (0.66%)	0.0091 (2.11%)	-0.0047 (-0.38%)	-0.0002 (-0.01%)	0.0036 (0.28%)	0.0123 (0.17%)
JFK	-0.0007 (-0.02%)	0.0072 (1.46%)	0.0055 (0.35%)	0.0231 (0.86%)	-0.0056 (-0.99%)	-0.0002 (-0.01%)	-0.0025 (-0.11%)	0.0267 (0.20%)
LAN	-0.0010 (-0.03%)	0.0001 (0.07%)	0.0066 (0.43%)	0.0224 (0.82%)	-0.0007 (-0.25%)	-0.0002 (-0.03%)	0.0005 (0.03%)	0.0278 (0.27%)
LAS	-0.0001 (0.00%)	0.0038 (0.98%)	0.0045 (1.18%)	0.0113 (2.57%)	-0.0018 (-0.40%)	-0.0001 (-0.01%)	0.0034 (0.50%)	0.0211 (0.32%)
LAX	**-0.0002 (-0.01%)**	**0.0094 (1.44%)**	**0.0099 (0.88%)**	**0.0289 (1.31%)**	**-0.0024 (-0.75%)**	**-0.0001 (-0.01%)**	**0.0046 (0.33%)**	**0.0500 (0.45%)**
LGA	-0.0010 (-0.02%)	0.0026 (0.44%)	0.0081 (0.50%)	0.0285 (1.03%)	-0.0025 (-0.49%)	-0.0004 (-0.02%)	0.0000 (0.00%)	0.0352 (0.25%)
LGB	-0.0007 (-0.02%)	0.0034 (0.32%)	0.0160 (1.25%)	0.0504 (2.04%)	-0.0006 (-0.13%)	-0.0005 (-0.02%)	0.0041 (0.27%)	0.0720 (0.50%)
LIT	-0.0007 (-0.03%)	0.0006 (0.22%)	0.0049 (0.50%)	0.0125 (1.01%)	-0.0003 (-0.06%)	-0.0002 (-0.02%)	0.0036 (0.21%)	0.0204 (0.25%)
MCI	-0.0008 (-0.02%)	0.0021 (0.72%)	0.0049 (0.37%)	0.0163 (0.74%)	0.0004 (0.17%)	-0.0002 (-0.01%)	0.0005 (0.03%)	0.0232 (0.19%)
MCO	-0.0003 (-0.02%)	0.0030 (0.91%)	0.0044 (0.95%)	0.0087 (2.99%)	-0.0001 (-0.02%)	-0.0001 (-0.01%)	0.0054 (0.52%)	0.0210 (0.37%)
MDW	-0.0010 (-0.02%)	0.0015 (0.43%)	0.0046 (0.26%)	0.0167 (0.66%)	-0.0015 (-0.61%)	-0.0002 (-0.02%)	-0.0008 (-0.03%)	0.0192 (0.13%)
MEM	-0.0008 (-0.02%)	0.0054 (1.68%)	0.0052 (0.44%)	0.0141 (0.95%)	-0.0005 (-0.16%)	-0.0002 (-0.02%)	0.0042 (0.21%)	0.0275 (0.27%)
MIA	-0.0001 (-0.01%)	0.0034 (1.38%)	0.0032 (0.93%)	0.0048 (5.01%)	-0.0002 (-0.16%)	-0.0001 (-0.01%)	0.0052 (0.58%)	0.0162 (0.43%)
MKE	-0.0009 (-0.03%)	0.0009 (0.33%)	0.0044 (0.34%)	0.0153 (0.71%)	0.0006 (0.19%)	-0.0002 (-0.02%)	0.0003 (0.02%)	0.0204 (0.19%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
MLB	-0.0002 (-0.02%)	0.0003 (0.13%)	0.0019 (0.52%)	0.0030 (2.86%)	0.0000 (0.01%)	-0.0001 (-0.01%)	0.0032 (0.33%)	0.0081 (0.22%)
MSN	-0.0009 (-0.02%)	0.0003 (0.11%)	0.0058 (0.39%)	0.0202 (0.76%)	-0.0008 (-0.29%)	-0.0002 (-0.02%)	-0.0003 (-0.01%)	0.0240 (0.21%)
MSP	-0.0007 (-0.01%)	0.0053 (1.16%)	0.0030 (0.24%)	0.0084 (0.40%)	-0.0005 (-0.18%)	-0.0002 (-0.01%)	0.0015 (0.09%)	0.0167 (0.13%)
MSY	-0.0003 (-0.01%)	0.0011 (0.37%)	0.0017 (0.20%)	0.0034 (0.74%)	-0.0011 (-0.41%)	-0.0001 (-0.01%)	0.0024 (0.12%)	0.0072 (0.10%)
OAK	-0.0001 (0.00%)	0.0056 (0.95%)	0.0037 (0.58%)	0.0122 (0.99%)	-0.0008 (-0.15%)	-0.0001 (0.00%)	0.0014 (0.16%)	0.0219 (0.24%)
OKC	-0.0007 (-0.02%)	0.0007 (0.29%)	0.0038 (0.49%)	0.0100 (0.81%)	-0.0001 (-0.06%)	-0.0002 (-0.02%)	0.0025 (0.22%)	0.0160 (0.20%)
OMA	-0.0007 (-0.02%)	0.0008 (0.47%)	0.0035 (0.33%)	0.0102 (0.57%)	-0.0018 (-1.36%)	-0.0001 (-0.02%)	0.0016 (0.11%)	0.0134 (0.15%)
ONT	-0.0007 (-0.02%)	0.0036 (0.40%)	0.0152 (1.27%)	0.0481 (1.84%)	-0.0020 (-0.34%)	-0.0005 (-0.02%)	0.0041 (0.34%)	0.0676 (0.50%)
ORD	**-0.0009 (-0.03%)**	**0.0043 (1.47%)**	**0.0046 (0.31%)**	**0.0156 (0.61%)**	**-0.0008 (-0.29%)**	**-0.0002 (-0.02%)**	**0.0002 (0.01%)**	**0.0228 (0.20%)**
ORF	-0.0006 (-0.02%)	0.0008 (0.27%)	0.0058 (0.46%)	0.0191 (1.10%)	-0.0002 (-0.05%)	-0.0002 (-0.02%)	0.0011 (0.05%)	0.0260 (0.26%)
PBI	-0.0001 (-0.01%)	0.0009 (0.39%)	0.0016 (0.59%)	0.0021 (4.06%)	-0.0022 (-1.69%)	-0.0001 (-0.01%)	0.0031 (0.40%)	0.0053 (0.17%)
PDX	0.0000 (0.00%)	0.0019 (0.24%)	0.0029 (0.53%)	0.0080 (0.87%)	-0.0007 (-0.04%)	0.0000 (0.00%)	0.0016 (0.21%)	0.0138 (0.07%)
PHF	-0.0009 (-0.04%)	0.0001 (0.04%)	0.0055 (0.49%)	0.0178 (1.10%)	-0.0018 (-0.35%)	-0.0003 (-0.04%)	0.0015 (0.08%)	0.0219 (0.26%)
PHL	-0.0011 (-0.03%)	0.0047 (1.20%)	0.0084 (0.46%)	0.0301 (1.00%)	-0.0017 (-0.38%)	-0.0004 (-0.03%)	-0.0009 (-0.03%)	0.0391 (0.28%)
PHX	-0.0002 (-0.01%)	0.0068 (1.62%)	0.0148 (3.77%)	0.0438 (7.20%)	-0.0010 (-0.21%)	-0.0001 (-0.01%)	0.0057 (0.97%)	0.0698 (0.98%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
PIT	-0.0011 (-0.03%)	0.0007 (0.32%)	0.0059 (0.37%)	0.0204 (0.82%)	-0.0005 (-0.19%)	-0.0003 (-0.03%)	0.0007 (0.03%)	0.0258 (0.22%)
PVD	**-0.0008 (-0.03%)**	**0.0011 (0.39%)**	**0.0074 (0.71%)**	**0.0245 (1.29%)**	**0.0004 (0.09%)**	**-0.0003 (-0.03%)**	**0.0013 (0.10%)**	**0.0336 (0.38%)**
RDU	-0.0008 (-0.03%)	0.0012 (0.32%)	0.0080 (0.73%)	0.0237 (1.47%)	-0.0001 (-0.01%)	-0.0003 (-0.02%)	0.0032 (0.19%)	0.0349 (0.37%)
RIC	-0.0010 (-0.03%)	0.0005 (0.16%)	0.0085 (0.61%)	0.0279 (1.33%)	0.0019 (0.28%)	-0.0003 (-0.03%)	0.0017 (0.08%)	0.0391 (0.35%)
RNO	0.0000 (0.00%)	0.0012 (0.56%)	0.0037 (1.20%)	0.0101 (2.69%)	-0.0004 (-0.04%)	0.0000 (0.00%)	0.0019 (0.35%)	0.0164 (0.26%)
ROC	-0.0009 (-0.03%)	0.0007 (0.29%)	0.0049 (0.39%)	0.0161 (0.88%)	-0.0002 (-0.05%)	-0.0003 (-0.02%)	0.0013 (0.07%)	0.0215 (0.21%)
RSW	-0.0002 (-0.01%)	0.0008 (0.24%)	0.0019 (0.57%)	0.0029 (2.89%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0031 (0.35%)	0.0083 (0.19%)
SAN	-0.0001 (-0.01%)	0.0029 (0.80%)	0.0037 (0.66%)	0.0085 (1.69%)	-0.0006 (-0.26%)	-0.0001 (-0.01%)	0.0055 (0.43%)	0.0197 (0.29%)
SAT	-0.0005 (-0.01%)	0.0009 (0.40%)	0.0041 (0.51%)	0.0108 (1.14%)	0.0000 (-0.01%)	-0.0001 (-0.01%)	0.0027 (0.19%)	0.0178 (0.21%)
SBA	-0.0002 (-0.01%)	0.0000 (0.01%)	0.0022 (0.78%)	0.0050 (1.43%)	-0.0007 (-0.29%)	-0.0002 (-0.01%)	0.0020 (0.39%)	0.0081 (0.18%)
SDF	-0.0011 (-0.02%)	0.0020 (0.64%)	0.0070 (0.40%)	0.0226 (0.87%)	-0.0056 (-1.95%)	-0.0002 (-0.02%)	0.0019 (0.07%)	0.0264 (0.20%)
SEA	0.0000 (0.00%)	0.0039 (0.76%)	0.0018 (0.34%)	0.0044 (0.46%)	-0.0022 (-0.13%)	0.0000 (0.00%)	0.0013 (0.20%)	0.0091 (0.09%)
SFO	-0.0001 (0.00%)	0.0056 (0.95%)	0.0037 (0.58%)	0.0122 (0.99%)	-0.0015 (-0.30%)	-0.0001 (0.00%)	0.0014 (0.16%)	0.0211 (0.23%)
SJC	-0.0002 (-0.01%)	0.0029 (0.56%)	0.0051 (0.81%)	0.0176 (1.50%)	-0.0006 (-0.12%)	-0.0001 (0.00%)	0.0002 (0.03%)	0.0250 (0.28%)
SLC	-0.0002 (-0.01%)	0.0029 (1.13%)	0.0101 (1.85%)	0.0312 (2.84%)	-0.0017 (-0.23%)	-0.0001 (-0.01%)	0.0029 (0.47%)	0.0450 (0.66%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
SMF	-0.0002 (-0.01%)	0.0022 (0.45%)	0.0082 (1.28%)	0.0254 (1.83%)	-0.0012 (-0.18%)	-0.0001 (-0.01%)	0.0022 (0.34%)	0.0364 (0.39%)
SNA	-0.0002 (-0.01%)	0.0049 (0.76%)	0.0057 (0.76%)	0.0135 (1.06%)	-0.0013 (-0.33%)	-0.0001 (-0.01%)	0.0058 (0.53%)	0.0282 (0.31%)
STL	-0.0010 (-0.02%)	0.0016 (0.48%)	0.0054 (0.36%)	0.0160 (0.71%)	-0.0005 (-0.17%)	-0.0002 (-0.02%)	0.0025 (0.11%)	0.0237 (0.17%)
SWF	-0.0009 (-0.03%)	0.0003 (0.07%)	0.0064 (0.48%)	0.0222 (0.93%)	-0.0009 (-0.18%)	-0.0004 (-0.02%)	0.0005 (0.03%)	0.0272 (0.23%)
SYR	-0.0010 (-0.02%)	0.0003 (0.12%)	0.0055 (0.42%)	0.0191 (0.94%)	-0.0003 (-0.07%)	-0.0003 (-0.03%)	0.0004 (0.02%)	0.0237 (0.20%)
TPA	-0.0003 (-0.01%)	0.0015 (0.42%)	0.0038 (0.62%)	0.0083 (2.29%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0041 (0.29%)	0.0172 (0.27%)
TUL	-0.0007 (-0.02%)	0.0003 (0.07%)	0.0037 (0.39%)	0.0104 (0.72%)	0.0001 (0.05%)	-0.0002 (-0.01%)	0.0018 (0.13%)	0.0154 (0.14%)
TUS	0.0000 (0.00%)	0.0008 (0.48%)	0.0028 (0.98%)	0.0062 (2.53%)	0.0001 (0.05%)	0.0000 (0.00%)	0.0024 (0.41%)	0.0123 (0.30%)
TVC	-0.0005 (-0.03%)	0.0001 (0.06%)	0.0017 (0.21%)	0.0058 (0.54%)	0.0004 (0.11%)	-0.0001 (-0.02%)	0.0008 (0.06%)	0.0083 (0.14%)
TYS	-0.0005 (-0.02%)	0.0003 (0.10%)	0.0040 (0.37%)	0.0106 (0.87%)	0.0000 (0.00%)	-0.0001 (-0.02%)	0.0032 (0.16%)	0.0174 (0.19%)

*$PM_{2.5}$ does not equal the sum of species shown in chart due to a scaling factor (1.167) applied to POA when computing $PM_{2.5}$.

Table 7. Absolute and percent increases due to aircraft emissions in 2005 at the 9 grid cells surrounding the airport.

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
ABQ	**0.0000 (0.00%)**	**0.0001 (0.03%)**	**0.0003 (0.10%)**	**0.0006 (0.22%)**	**0.0001 (0.02%)**	**0.0000 (0.00%)**	**0.0005 (0.09%)**	**0.0016 (0.03%)**
ALB	-0.0001 (0.00%)	0.0001 (0.01%)	0.0008 (0.06%)	0.0026 (0.12%)	-0.0001 (-0.02%)	0.0000 (0.00%)	0.0004 (0.02%)	0.0035 (0.04%)
ATL	**-0.0002 (0.00%)**	**0.0015 (0.20%)**	**0.0010 (0.07%)**	**0.0025 (0.14%)**	**-0.0007 (-0.05%)**	**0.0000 (0.00%)**	**0.0026 (0.08%)**	**0.0068 (0.05%)**
AUS	-0.0001 (0.00%)	0.0002 (0.06%)	0.0013 (0.12%)	0.0036 (0.24%)	0.0000 (-0.01%)	0.0000 (-0.01%)	0.0009 (0.05%)	0.0058 (0.07%)
BDL	-0.0001 (0.00%)	0.0003 (0.05%)	0.0006 (0.05%)	0.0022 (0.09%)	-0.0003 (-0.06%)	0.0000 (0.00%)	0.0003 (0.02%)	0.0030 (0.03%)
BFL	-0.0001 (-0.01%)	0.0000 (-0.01%)	0.0018 (0.31%)	0.0052 (0.38%)	0.0000 (0.01%)	-0.0001 (-0.01%)	0.0009 (0.17%)	0.0077 (0.13%)
BHM	-0.0001 (0.00%)	0.0001 (0.02%)	0.0009 (0.07%)	0.0022 (0.16%)	0.0002 (0.02%)	0.0000 (0.00%)	0.0019 (0.06%)	0.0052 (0.04%)
BNA	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0010 (0.06%)	0.0027 (0.12%)	-0.0001 (-0.02%)	0.0000 (-0.01%)	0.0013 (0.04%)	0.0049 (0.04%)
BOI	0.0000 (0.00%)	0.0000 (0.01%)	0.0007 (0.16%)	0.0020 (0.22%)	0.0003 (0.02%)	0.0000 (0.00%)	0.0003 (0.07%)	0.0033 (0.04%)
BOS	-0.0001 (0.00%)	0.0004 (0.05%)	0.0006 (0.05%)	0.0027 (0.13%)	-0.0004 (-0.07%)	0.0000 (0.00%)	0.0003 (0.01%)	0.0035 (0.03%)
BTR	-0.0001 (0.00%)	0.0000 (-0.01%)	0.0011 (0.08%)	0.0027 (0.19%)	0.0001 (0.02%)	0.0000 (0.00%)	0.0010 (0.04%)	0.0048 (0.05%)
BUF	-0.0002 (-0.01%)	0.0001 (0.02%)	0.0012 (0.07%)	0.0042 (0.14%)	-0.0001 (-0.02%)	-0.0001 (-0.01%)	0.0005 (0.02%)	0.0058 (0.05%)
BUR	-0.0002 (-0.01%)	0.0011 (0.11%)	0.0036 (0.37%)	0.0107 (0.51%)	-0.0003 (-0.08%)	-0.0001 (-0.01%)	0.0016 (0.16%)	0.0163 (0.16%)
BWI	-0.0002 (-0.01%)	0.0005 (0.07%)	0.0015 (0.08%)	0.0054 (0.16%)	-0.0003 (-0.07%)	-0.0001 (0.00%)	0.0005 (0.01%)	0.0073 (0.05%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
CHS	-0.0001 (-0.01%)	0.0000 (0.01%)	0.0004 (0.05%)	0.0012 (0.18%)	0.0001 (0.02%)	0.0000 (-0.01%)	0.0010 (0.04%)	0.0027 (0.04%)
CLE	-0.0002 (-0.01%)	0.0002 (0.04%)	0.0020 (0.09%)	0.0063 (0.16%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0007 (0.02%)	0.0087 (0.06%)
CLT	-0.0001 (0.00%)	0.0003 (0.03%)	0.0021 (0.12%)	0.0060 (0.26%)	0.0000 (0.00%)	-0.0001 (0.00%)	0.0018 (0.05%)	0.0099 (0.07%)
CMH	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0018 (0.08%)	0.0058 (0.15%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0012 (0.03%)	0.0085 (0.06%)
COS	0.0000 (0.00%)	0.0001 (0.03%)	0.0003 (0.12%)	0.0010 (0.34%)	0.0001 (0.02%)	0.0000 (0.00%)	0.0005 (0.09%)	0.0020 (0.05%)
CRP	-0.0001 (-0.01%)	0.0000 (0.02%)	0.0004 (0.08%)	0.0011 (0.22%)	0.0000 (-0.01%)	0.0000 (-0.01%)	0.0005 (0.04%)	0.0020 (0.04%)
CVG	-0.0002 (-0.01%)	0.0006 (0.11%)	0.0015 (0.07%)	0.0046 (0.14%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0015 (0.04%)	0.0077 (0.05%)
DAB	0.0000 (0.00%)	0.0001 (0.02%)	0.0002 (0.05%)	0.0003 (0.26%)	0.0001 (0.03%)	0.0000 (0.00%)	0.0012 (0.06%)	0.0018 (0.04%)
DAL	-0.0002 (0.00%)	0.0011 (0.20%)	0.0016 (0.12%)	0.0038 (0.21%)	-0.0001 (-0.06%)	0.0000 (0.00%)	0.0016 (0.07%)	0.0078 (0.06%)
DAY	-0.0002 (-0.01%)	0.0003 (0.07%)	0.0023 (0.10%)	0.0073 (0.17%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0013 (0.04%)	0.0109 (0.07%)
DCA	-0.0002 (0.00%)	0.0009 (0.12%)	0.0010 (0.05%)	0.0034 (0.12%)	-0.0004 (-0.08%)	-0.0001 (0.00%)	0.0005 (0.01%)	0.0051 (0.04%)
DEN	0.0000 (0.00%)	0.0005 (0.11%)	0.0011 (0.25%)	0.0027 (0.39%)	0.0000 (0.01%)	0.0000 (0.00%)	0.0007 (0.12%)	0.0050 (0.09%)
DFW	-0.0002 (0.00%)	0.0012 (0.21%)	0.0017 (0.13%)	0.0038 (0.21%)	-0.0001 (-0.06%)	0.0000 (0.00%)	0.0017 (0.08%)	0.0081 (0.07%)
DSM	-0.0002 (-0.01%)	0.0000 (0.01%)	0.0013 (0.09%)	0.0037 (0.13%)	0.0000 (-0.02%)	0.0000 (-0.01%)	0.0006 (0.03%)	0.0053 (0.05%)
DTW	-0.0002 (-0.01%)	0.0009 (0.15%)	0.0015 (0.07%)	0.0048 (0.13%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0006 (0.02%)	0.0074 (0.05%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ELP	0.0000 (0.00%)	0.0001 (0.04%)	0.0004 (0.10%)	0.0010 (0.20%)	0.0000 (0.01%)	0.0000 (0.00%)	0.0005 (0.06%)	0.0020 (0.04%)
EUG	0.0000 (0.00%)	0.0000 (0.01%)	0.0003 (0.14%)	0.0010 (0.25%)	0.0003 (0.01%)	0.0000 (0.00%)	0.0002 (0.04%)	0.0018 (0.02%)
EWR	-0.0001 (0.00%)	0.0013 (0.14%)	0.0011 (0.06%)	0.0038 (0.12%)	-0.0007 (-0.15%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0055 (0.04%)
FAT	-0.0001 (0.00%)	0.0000 (0.01%)	0.0020 (0.26%)	0.0057 (0.31%)	0.0001 (0.02%)	-0.0001 (0.00%)	0.0008 (0.14%)	0.0084 (0.11%)
FLL	0.0000 (0.00%)	0.0005 (0.12%)	0.0003 (0.07%)	0.0004 (0.47%)	-0.0001 (-0.04%)	0.0000 (0.00%)	0.0011 (0.09%)	0.0021 (0.05%)
FNT	-0.0002 (-0.01%)	0.0002 (0.05%)	0.0013 (0.07%)	0.0045 (0.13%)	-0.0001 (-0.03%)	0.0000 (-0.01%)	0.0004 (0.02%)	0.0061 (0.05%)
GFK	-0.0001 (0.00%)	0.0000 (-0.02%)	0.0003 (0.05%)	0.0011 (0.07%)	0.0000 (-0.01%)	0.0000 (-0.01%)	0.0001 (0.01%)	0.0013 (0.02%)
GRR	-0.0002 (-0.01%)	0.0001 (0.02%)	0.0017 (0.09%)	0.0056 (0.16%)	-0.0001 (-0.03%)	0.0000 (-0.01%)	0.0005 (0.02%)	0.0075 (0.06%)
GSO	-0.0001 (-0.01%)	0.0000 (0.01%)	0.0018 (0.10%)	0.0053 (0.22%)	0.0000 (0.00%)	-0.0001 (0.00%)	0.0013 (0.04%)	0.0082 (0.07%)
HOU	-0.0001 (0.00%)	0.0005 (0.08%)	0.0009 (0.08%)	0.0024 (0.20%)	-0.0002 (-0.05%)	0.0000 (0.00%)	0.0009 (0.04%)	0.0044 (0.04%)
HPN	-0.0001 (0.00%)	0.0006 (0.08%)	0.0008 (0.05%)	0.0033 (0.12%)	-0.0005 (-0.11%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0044 (0.03%)
IAD	-0.0002 (0.00%)	0.0008 (0.11%)	0.0010 (0.06%)	0.0036 (0.12%)	-0.0003 (-0.07%)	-0.0001 (0.00%)	0.0006 (0.02%)	0.0054 (0.04%)
IAH	-0.0001 (0.00%)	0.0005 (0.09%)	0.0009 (0.08%)	0.0023 (0.19%)	-0.0002 (-0.03%)	0.0000 (0.00%)	0.0010 (0.05%)	0.0044 (0.04%)
ICT	-0.0002 (-0.01%)	0.0000 (0.00%)	0.0011 (0.10%)	0.0032 (0.16%)	0.0000 (-0.01%)	-0.0001 (0.00%)	0.0006 (0.04%)	0.0047 (0.04%)
IND	-0.0003 (-0.01%)	0.0003 (0.07%)	0.0018 (0.08%)	0.0058 (0.15%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0010 (0.03%)	0.0085 (0.05%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ISP	-0.0001 (0.00%)	0.0012 (0.17%)	0.0006 (0.04%)	0.0024 (0.10%)	-0.0006 (-0.16%)	0.0000 (0.00%)	0.0002 (0.01%)	0.0035 (0.03%)
JAX	-0.0001 (0.00%)	0.0001 (0.02%)	0.0004 (0.06%)	0.0008 (0.22%)	0.0007 (0.06%)	0.0000 (0.00%)	0.0012 (0.05%)	0.0031 (0.04%)
JFK	-0.0001 (0.00%)	0.0014 (0.17%)	0.0009 (0.06%)	0.0033 (0.12%)	-0.0007 (-0.17%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0049 (0.04%)
LAN	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0018 (0.09%)	0.0060 (0.16%)	-0.0001 (-0.03%)	0.0000 (-0.01%)	0.0003 (0.01%)	0.0079 (0.06%)
LAS	0.0000 (0.00%)	0.0005 (0.16%)	0.0005 (0.20%)	0.0005 (0.27%)	0.0000 (-0.01%)	0.0000 (0.00%)	0.0013 (0.22%)	0.0027 (0.08%)
LAX	**-0.0001 (-0.01%)**	**0.0012 (0.14%)**	**0.0027 (0.31%)**	**0.0076 (0.44%)**	**-0.0003 (-0.09%)**	**-0.0001 (0.00%)**	**0.0017 (0.16%)**	**0.0128 (0.15%)**
LGA	-0.0001 (0.00%)	0.0014 (0.16%)	0.0009 (0.05%)	0.0035 (0.12%)	-0.0007 (-0.17%)	-0.0001 (0.00%)	0.0002 (0.01%)	0.0051 (0.04%)
LGB	-0.0002 (-0.01%)	0.0014 (0.12%)	0.0040 (0.36%)	0.0116 (0.49%)	-0.0005 (-0.11%)	-0.0001 (-0.01%)	0.0019 (0.16%)	0.0181 (0.16%)
LIT	-0.0002 (-0.01%)	0.0000 (0.01%)	0.0013 (0.10%)	0.0033 (0.18%)	0.0000 (0.00%)	0.0000 (-0.01%)	0.0014 (0.06%)	0.0059 (0.06%)
MCI	-0.0002 (0.00%)	0.0002 (0.04%)	0.0012 (0.08%)	0.0036 (0.13%)	-0.0001 (-0.03%)	0.0000 (-0.01%)	0.0005 (0.03%)	0.0051 (0.04%)
MCO	-0.0001 (0.00%)	0.0003 (0.06%)	0.0007 (0.10%)	0.0013 (0.32%)	0.0001 (0.01%)	0.0000 (0.00%)	0.0014 (0.08%)	0.0036 (0.05%)
MDW	-0.0002 (-0.01%)	0.0009 (0.14%)	0.0011 (0.06%)	0.0037 (0.11%)	-0.0003 (-0.11%)	0.0000 (0.00%)	0.0003 (0.01%)	0.0055 (0.04%)
MEM	-0.0002 (-0.01%)	0.0007 (0.15%)	0.0012 (0.08%)	0.0033 (0.16%)	-0.0001 (-0.03%)	0.0000 (0.00%)	0.0015 (0.06%)	0.0064 (0.06%)
MIA	0.0000 (0.00%)	0.0005 (0.15%)	0.0002 (0.07%)	0.0003 (0.46%)	-0.0001 (-0.07%)	0.0000 (0.00%)	0.0010 (0.08%)	0.0020 (0.05%)
MKE	-0.0002 (-0.01%)	0.0003 (0.07%)	0.0009 (0.06%)	0.0035 (0.12%)	-0.0001 (-0.05%)	0.0000 (0.00%)	0.0001 (0.00%)	0.0045 (0.04%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
MLB	0.0000 (0.00%)	0.0001 (0.03%)	0.0003 (0.07%)	0.0006 (0.38%)	0.0001 (0.03%)	0.0000 (0.00%)	0.0012 (0.07%)	0.0022 (0.05%)
MSN	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0018 (0.10%)	0.0059 (0.16%)	-0.0001 (-0.04%)	0.0000 (-0.01%)	0.0003 (0.02%)	0.0077 (0.06%)
MSP	-0.0002 (0.00%)	0.0007 (0.12%)	0.0010 (0.07%)	0.0033 (0.12%)	-0.0001 (-0.05%)	0.0000 (0.00%)	0.0002 (0.01%)	0.0049 (0.04%)
MSY	-0.0001 (0.00%)	0.0001 (0.03%)	0.0003 (0.04%)	0.0005 (0.12%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0011 (0.04%)	0.0019 (0.03%)
OAK	0.0000 (0.00%)	0.0006 (0.09%)	0.0011 (0.16%)	0.0033 (0.19%)	-0.0002 (-0.03%)	0.0000 (0.00%)	0.0006 (0.08%)	0.0053 (0.07%)
OKC	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0011 (0.11%)	0.0026 (0.16%)	0.0000 (-0.01%)	0.0000 (-0.01%)	0.0010 (0.07%)	0.0045 (0.05%)
OMA	-0.0002 (-0.01%)	0.0000 (0.01%)	0.0011 (0.08%)	0.0034 (0.14%)	0.0000 (-0.02%)	0.0000 (-0.01%)	0.0003 (0.02%)	0.0046 (0.05%)
ONT	-0.0002 (-0.01%)	0.0008 (0.07%)	0.0043 (0.39%)	0.0129 (0.52%)	-0.0004 (-0.08%)	-0.0002 (-0.01%)	0.0018 (0.16%)	0.0191 (0.16%)
ORD	**-0.0002 (-0.01%)**	**0.0011 (0.16%)**	**0.0011 (0.06%)**	**0.0035 (0.11%)**	**-0.0003 (-0.11%)**	**0.0000 (0.00%)**	**0.0003 (0.01%)**	**0.0053 (0.04%)**
ORF	-0.0001 (0.00%)	0.0001 (0.03%)	0.0006 (0.05%)	0.0017 (0.11%)	-0.0001 (-0.02%)	0.0000 (0.00%)	0.0007 (0.02%)	0.0030 (0.03%)
PBI	0.0000 (0.00%)	0.0002 (0.04%)	0.0002 (0.07%)	0.0003 (0.51%)	0.0000 (0.03%)	0.0000 (0.00%)	0.0011 (0.09%)	0.0018 (0.04%)
PDX	0.0000 (0.00%)	0.0001 (0.02%)	0.0005 (0.11%)	0.0013 (0.15%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0003 (0.06%)	0.0021 (0.02%)
PHF	-0.0001 (0.00%)	0.0001 (0.03%)	0.0008 (0.06%)	0.0022 (0.12%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0007 (0.03%)	0.0037 (0.04%)
PHL	-0.0002 (-0.01%)	0.0005 (0.07%)	0.0018 (0.08%)	0.0062 (0.16%)	-0.0003 (-0.07%)	-0.0001 (-0.01%)	0.0003 (0.01%)	0.0081 (0.05%)
PHX	-0.0001 (0.00%)	0.0006 (0.08%)	0.0022 (0.48%)	0.0060 (0.75%)	-0.0002 (-0.05%)	0.0000 (0.00%)	0.0013 (0.21%)	0.0099 (0.16%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
PIT	-0.0002 (-0.01%)	0.0002 (0.04%)	0.0011 (0.06%)	0.0040 (0.13%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0005 (0.01%)	0.0054 (0.04%)
PVD	**-0.0001 (0.00%)**	**0.0002 (0.04%)**	**0.0008 (0.06%)**	**0.0026 (0.12%)**	**-0.0002 (-0.05%)**	**0.0000 (0.00%)**	**0.0004 (0.02%)**	**0.0036 (0.03%)**
RDU	-0.0001 (-0.01%)	0.0001 (0.01%)	0.0019 (0.11%)	0.0059 (0.23%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0010 (0.04%)	0.0088 (0.07%)
RIC	-0.0001 (-0.01%)	0.0001 (0.03%)	0.0011 (0.07%)	0.0033 (0.14%)	-0.0001 (-0.01%)	0.0000 (-0.01%)	0.0008 (0.03%)	0.0051 (0.04%)
RNO	0.0000 (0.00%)	0.0001 (0.04%)	0.0005 (0.19%)	0.0010 (0.28%)	0.0006 (0.05%)	0.0000 (0.00%)	0.0006 (0.15%)	0.0028 (0.06%)
ROC	-0.0002 (-0.01%)	0.0001 (0.02%)	0.0010 (0.07%)	0.0035 (0.14%)	-0.0001 (-0.02%)	-0.0001 (-0.01%)	0.0005 (0.02%)	0.0048 (0.05%)
RSW	0.0000 (0.00%)	0.0002 (0.04%)	0.0004 (0.09%)	0.0005 (0.42%)	0.0000 (0.01%)	0.0000 (0.00%)	0.0012 (0.08%)	0.0022 (0.04%)
SAN	-0.0001 (-0.01%)	0.0004 (0.07%)	0.0020 (0.30%)	0.0052 (0.44%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0017 (0.17%)	0.0090 (0.13%)
SAT	-0.0001 (0.00%)	0.0001 (0.05%)	0.0010 (0.11%)	0.0026 (0.23%)	0.0000 (-0.02%)	0.0000 (0.00%)	0.0008 (0.05%)	0.0044 (0.06%)
SBA	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0007 (0.24%)	0.0017 (0.36%)	0.0000 (0.00%)	0.0000 (-0.01%)	0.0007 (0.13%)	0.0031 (0.08%)
SDF	-0.0002 (-0.01%)	0.0003 (0.04%)	0.0013 (0.06%)	0.0040 (0.12%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0014 (0.04%)	0.0066 (0.05%)
SEA	0.0000 (0.00%)	0.0003 (0.05%)	0.0004 (0.09%)	0.0008 (0.09%)	-0.0006 (-0.03%)	0.0000 (0.00%)	0.0004 (0.08%)	0.0013 (0.02%)
SFO	0.0000 (0.00%)	0.0006 (0.09%)	0.0011 (0.16%)	0.0033 (0.19%)	-0.0002 (-0.03%)	0.0000 (0.00%)	0.0006 (0.08%)	0.0053 (0.07%)
SJC	0.0000 (0.00%)	0.0006 (0.09%)	0.0011 (0.15%)	0.0030 (0.18%)	-0.0002 (-0.04%)	0.0000 (0.00%)	0.0006 (0.09%)	0.0050 (0.06%)
SLC	0.0000 (0.00%)	0.0004 (0.11%)	0.0012 (0.24%)	0.0032 (0.30%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0008 (0.15%)	0.0056 (0.10%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
SMF	0.0000 (0.00%)	0.0001 (0.02%)	0.0016 (0.22%)	0.0047 (0.27%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0006 (0.10%)	0.0069 (0.07%)
SNA	-0.0001 (-0.01%)	0.0014 (0.14%)	0.0033 (0.34%)	0.0094 (0.46%)	-0.0005 (-0.13%)	-0.0001 (-0.01%)	0.0020 (0.18%)	0.0155 (0.16%)
STL	-0.0002 (0.00%)	0.0002 (0.05%)	0.0011 (0.07%)	0.0032 (0.12%)	-0.0001 (-0.03%)	0.0000 (0.00%)	0.0010 (0.04%)	0.0052 (0.04%)
SWF	-0.0001 (0.00%)	0.0003 (0.05%)	0.0006 (0.04%)	0.0028 (0.11%)	-0.0003 (-0.08%)	0.0000 (0.00%)	0.0003 (0.02%)	0.0035 (0.03%)
SYR	-0.0002 (-0.01%)	0.0001 (0.04%)	0.0011 (0.08%)	0.0039 (0.15%)	-0.0001 (-0.02%)	-0.0001 (-0.01%)	0.0004 (0.02%)	0.0053 (0.05%)
TPA	-0.0001 (0.00%)	0.0002 (0.05%)	0.0007 (0.09%)	0.0016 (0.36%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0013 (0.06%)	0.0037 (0.05%)
TUL	-0.0002 (0.00%)	0.0001 (0.01%)	0.0011 (0.09%)	0.0029 (0.15%)	0.0000 (-0.01%)	0.0000 (0.00%)	0.0008 (0.05%)	0.0046 (0.04%)
TUS	0.0000 (0.00%)	0.0001 (0.05%)	0.0006 (0.20%)	0.0010 (0.36%)	0.0000 (0.01%)	0.0000 (0.00%)	0.0007 (0.12%)	0.0024 (0.07%)
TVC	-0.0001 (-0.01%)	0.0000 (0.02%)	0.0003 (0.03%)	0.0009 (0.08%)	0.0000 (0.00%)	0.0000 (-0.01%)	0.0005 (0.03%)	0.0016 (0.03%)
TYS	-0.0001 (0.00%)	0.0001 (0.02%)	0.0006 (0.05%)	0.0018 (0.13%)	0.0001 (0.01%)	0.0000 (0.00%)	0.0014 (0.04%)	0.0038 (0.04%)

*$PM_{2.5}$ does not equal the sum of species shown in chart due to a scaling factor (1.167) applied to POA when computing $PM_{2.5}$.

Table 8. Absolute and percent increases due to 2025 aircraft emissions in 2005 at the 9 grid cells surrounding the airport.

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
ABQ	**0.0000 (0.00%)**	**0.0003 (0.13%)**	**0.0007 (0.24%)**	**0.0012 (0.42%)**	**0.0002 (0.04%)**	**0.0000 (0.00%)**	**0.0012 (0.21%)**	**0.0036 (0.06%)**
ALB	-0.0002 (-0.01%)	0.0001 (0.04%)	0.0017 (0.14%)	0.0056 (0.25%)	-0.0003 (-0.05%)	-0.0001 (-0.01%)	0.0008 (0.04%)	0.0076 (0.08%)
ATL	**-0.0003 (-0.01%)**	**0.0022 (0.28%)**	**0.0022 (0.14%)**	**0.0054 (0.31%)**	**-0.0014 (-0.10%)**	**-0.0001 (-0.01%)**	**0.0048 (0.14%)**	**0.0127 (0.09%)**
AUS	-0.0003 (-0.01%)	0.0004 (0.12%)	0.0031 (0.29%)	0.0084 (0.57%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0022 (0.12%)	0.0136 (0.16%)
BDL	-0.0002 (-0.01%)	0.0007 (0.13%)	0.0013 (0.10%)	0.0048 (0.20%)	-0.0008 (-0.16%)	-0.0001 (-0.01%)	0.0006 (0.03%)	0.0062 (0.06%)
BFL	-0.0003 (-0.02%)	-0.0001 (-0.02%)	0.0045 (0.76%)	0.0127 (0.92%)	0.0000 (0.01%)	-0.0002 (-0.02%)	0.0022 (0.41%)	0.0189 (0.31%)
BHM	-0.0003 (-0.01%)	0.0002 (0.03%)	0.0020 (0.15%)	0.0049 (0.36%)	0.0004 (0.03%)	-0.0001 (-0.01%)	0.0037 (0.11%)	0.0107 (0.09%)
BNA	-0.0003 (-0.01%)	0.0002 (0.04%)	0.0020 (0.12%)	0.0058 (0.25%)	-0.0001 (-0.04%)	-0.0001 (-0.01%)	0.0024 (0.08%)	0.0099 (0.09%)
BOI	-0.0001 (0.00%)	0.0002 (0.04%)	0.0023 (0.51%)	0.0066 (0.71%)	0.0008 (0.06%)	0.0000 (0.00%)	0.0009 (0.20%)	0.0106 (0.13%)
BOS	-0.0002 (-0.01%)	0.0009 (0.12%)	0.0011 (0.10%)	0.0046 (0.22%)	-0.0008 (-0.16%)	-0.0001 (0.00%)	0.0004 (0.02%)	0.0060 (0.05%)
BTR	-0.0002 (-0.01%)	-0.0001 (-0.02%)	0.0023 (0.18%)	0.0059 (0.41%)	0.0002 (0.03%)	-0.0001 (-0.01%)	0.0021 (0.08%)	0.0102 (0.10%)
BUF	-0.0003 (-0.01%)	0.0002 (0.06%)	0.0027 (0.15%)	0.0091 (0.29%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0011 (0.04%)	0.0123 (0.10%)
BUR	-0.0004 (-0.02%)	0.0021 (0.22%)	0.0072 (0.74%)	0.0208 (0.99%)	-0.0008 (-0.19%)	-0.0003 (-0.02%)	0.0035 (0.34%)	0.0321 (0.32%)
BWI	-0.0004 (-0.01%)	0.0010 (0.14%)	0.0032 (0.16%)	0.0113 (0.34%)	-0.0007 (-0.16%)	-0.0001 (-0.01%)	0.0010 (0.03%)	0.0152 (0.10%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
CHS	-0.0002 (-0.01%)	0.0001 (0.02%)	0.0008 (0.09%)	0.0024 (0.35%)	0.0003 (0.03%)	-0.0001 (-0.01%)	0.0022 (0.08%)	0.0053 (0.07%)
CLE	-0.0005 (-0.02%)	0.0002 (0.05%)	0.0039 (0.17%)	0.0123 (0.31%)	-0.0002 (-0.08%)	-0.0001 (-0.02%)	0.0016 (0.05%)	0.0171 (0.12%)
CLT	-0.0003 (-0.01%)	0.0006 (0.07%)	0.0041 (0.24%)	0.0121 (0.52%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0033 (0.10%)	0.0198 (0.15%)
CMH	-0.0005 (-0.01%)	0.0002 (0.04%)	0.0034 (0.16%)	0.0109 (0.29%)	-0.0002 (-0.07%)	-0.0001 (-0.01%)	0.0023 (0.07%)	0.0161 (0.11%)
COS	0.0000 (0.00%)	0.0001 (0.03%)	0.0008 (0.30%)	0.0022 (0.79%)	0.0003 (0.06%)	0.0000 (0.00%)	0.0012 (0.21%)	0.0046 (0.11%)
CRP	-0.0002 (-0.01%)	0.0000 (0.02%)	0.0010 (0.17%)	0.0025 (0.50%)	0.0000 (-0.04%)	0.0000 (-0.02%)	0.0011 (0.08%)	0.0043 (0.10%)
CVG	-0.0005 (-0.01%)	0.0006 (0.12%)	0.0028 (0.13%)	0.0090 (0.27%)	-0.0003 (-0.12%)	-0.0001 (-0.01%)	0.0027 (0.07%)	0.0143 (0.10%)
DAB	-0.0001 (-0.01%)	0.0001 (0.03%)	0.0004 (0.10%)	0.0007 (0.59%)	0.0002 (0.06%)	0.0000 (-0.01%)	0.0024 (0.13%)	0.0037 (0.07%)
DAL	-0.0004 (-0.01%)	0.0012 (0.22%)	0.0034 (0.25%)	0.0082 (0.45%)	-0.0002 (-0.10%)	-0.0001 (-0.01%)	0.0031 (0.14%)	0.0152 (0.12%)
DAY	-0.0005 (-0.01%)	0.0003 (0.06%)	0.0045 (0.19%)	0.0140 (0.33%)	-0.0002 (-0.10%)	-0.0001 (-0.01%)	0.0026 (0.08%)	0.0205 (0.13%)
DCA	-0.0004 (-0.01%)	0.0018 (0.24%)	0.0019 (0.10%)	0.0071 (0.25%)	-0.0010 (-0.20%)	-0.0001 (-0.01%)	0.0011 (0.03%)	0.0104 (0.07%)
DEN	-0.0001 (0.00%)	0.0011 (0.26%)	0.0024 (0.58%)	0.0063 (0.90%)	0.0000 (0.00%)	0.0000 (0.00%)	0.0016 (0.27%)	0.0114 (0.21%)
DFW	-0.0004 (-0.01%)	0.0014 (0.23%)	0.0035 (0.26%)	0.0083 (0.45%)	-0.0002 (-0.12%)	-0.0001 (-0.01%)	0.0033 (0.16%)	0.0157 (0.13%)
DSM	-0.0004 (-0.02%)	0.0000 (0.00%)	0.0027 (0.19%)	0.0080 (0.28%)	-0.0001 (-0.05%)	-0.0001 (-0.02%)	0.0011 (0.07%)	0.0112 (0.12%)
DTW	-0.0005 (-0.01%)	0.0010 (0.16%)	0.0028 (0.13%)	0.0089 (0.24%)	-0.0003 (-0.11%)	-0.0001 (-0.01%)	0.0012 (0.04%)	0.0130 (0.09%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
ELP	0.0000 (0.00%)	0.0001 (0.06%)	0.0011 (0.24%)	0.0025 (0.51%)	0.0001 (0.03%)	0.0000 (0.00%)	0.0011 (0.14%)	0.0049 (0.10%)
EUG	0.0000 (0.00%)	0.0000 (0.01%)	0.0009 (0.37%)	0.0025 (0.64%)	0.0006 (0.03%)	0.0000 (0.00%)	0.0004 (0.11%)	0.0045 (0.06%)
EWR	-0.0003 (-0.01%)	0.0019 (0.22%)	0.0021 (0.12%)	0.0078 (0.25%)	-0.0017 (-0.38%)	-0.0001 (-0.01%)	0.0001 (0.00%)	0.0098 (0.07%)
FAT	-0.0002 (-0.01%)	0.0000 (0.00%)	0.0050 (0.67%)	0.0147 (0.79%)	0.0003 (0.04%)	-0.0001 (-0.01%)	0.0020 (0.34%)	0.0215 (0.27%)
FLL	0.0000 (0.00%)	0.0011 (0.23%)	0.0006 (0.15%)	0.0007 (0.95%)	-0.0001 (-0.08%)	0.0000 (0.00%)	0.0022 (0.18%)	0.0044 (0.10%)
FNT	-0.0004 (-0.01%)	0.0002 (0.04%)	0.0025 (0.13%)	0.0082 (0.25%)	-0.0002 (-0.07%)	-0.0001 (-0.01%)	0.0009 (0.04%)	0.0111 (0.09%)
GFK	-0.0002 (-0.01%)	0.0002 (0.08%)	0.0011 (0.16%)	0.0034 (0.22%)	0.0000 (-0.02%)	0.0000 (-0.01%)	0.0003 (0.05%)	0.0046 (0.08%)
GRR	-0.0004 (-0.01%)	0.0001 (0.02%)	0.0032 (0.17%)	0.0105 (0.30%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0008 (0.03%)	0.0139 (0.12%)
GSO	-0.0003 (-0.01%)	0.0001 (0.01%)	0.0036 (0.21%)	0.0109 (0.44%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0026 (0.08%)	0.0168 (0.14%)
HOU	-0.0002 (0.00%)	0.0011 (0.18%)	0.0020 (0.18%)	0.0052 (0.42%)	-0.0006 (-0.13%)	-0.0001 (0.00%)	0.0019 (0.09%)	0.0094 (0.08%)
HPN	-0.0003 (-0.01%)	0.0009 (0.12%)	0.0018 (0.11%)	0.0069 (0.24%)	-0.0011 (-0.26%)	-0.0001 (-0.01%)	0.0002 (0.01%)	0.0083 (0.07%)
IAD	-0.0004 (-0.01%)	0.0015 (0.21%)	0.0021 (0.11%)	0.0073 (0.25%)	-0.0009 (-0.19%)	-0.0001 (-0.01%)	0.0013 (0.04%)	0.0109 (0.07%)
IAH	-0.0002 (0.00%)	0.0013 (0.22%)	0.0019 (0.17%)	0.0047 (0.39%)	-0.0005 (-0.08%)	-0.0001 (0.00%)	0.0022 (0.10%)	0.0093 (0.08%)
ICT	-0.0004 (-0.01%)	-0.0001 (-0.02%)	0.0025 (0.22%)	0.0071 (0.35%)	0.0000 (-0.03%)	-0.0001 (-0.01%)	0.0013 (0.09%)	0.0102 (0.10%)
IND	-0.0005 (-0.01%)	0.0005 (0.11%)	0.0035 (0.15%)	0.0115 (0.29%)	-0.0003 (-0.14%)	-0.0001 (-0.01%)	0.0017 (0.05%)	0.0162 (0.10%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
ISP	-0.0002 (-0.01%)	0.0018 (0.26%)	0.0011 (0.08%)	0.0047 (0.20%)	-0.0016 (-0.42%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0057 (0.05%)
JAX	-0.0001 (-0.01%)	0.0002 (0.04%)	0.0009 (0.13%)	0.0021 (0.54%)	0.0015 (0.13%)	-0.0001 (-0.01%)	0.0025 (0.11%)	0.0070 (0.09%)
JFK	-0.0003 (-0.01%)	0.0022 (0.26%)	0.0017 (0.11%)	0.0067 (0.24%)	-0.0018 (-0.43%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0084 (0.07%)
LAN	-0.0004 (-0.01%)	0.0001 (0.02%)	0.0033 (0.17%)	0.0110 (0.30%)	-0.0002 (-0.07%)	-0.0001 (-0.01%)	0.0007 (0.03%)	0.0144 (0.12%)
LAS	-0.0001 (-0.01%)	0.0008 (0.25%)	0.0010 (0.39%)	0.0009 (0.51%)	0.0000 (0.00%)	0.0000 (-0.01%)	0.0024 (0.43%)	0.0050 (0.15%)
LAX	**-0.0002 (-0.01%)**	**0.0025 (0.29%)**	**0.0054 (0.62%)**	**0.0147 (0.84%)**	**-0.0006 (-0.21%)**	**-0.0002 (-0.01%)**	**0.0036 (0.35%)**	**0.0252 (0.29%)**
LGA	-0.0003 (-0.01%)	0.0021 (0.24%)	0.0018 (0.11%)	0.0071 (0.25%)	-0.0018 (-0.43%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0088 (0.07%)
LGB	-0.0003 (-0.01%)	0.0030 (0.27%)	0.0079 (0.72%)	0.0226 (0.96%)	-0.0011 (-0.28%)	-0.0002 (-0.01%)	0.0041 (0.36%)	0.0359 (0.32%)
LIT	-0.0003 (-0.01%)	0.0001 (0.02%)	0.0032 (0.23%)	0.0081 (0.45%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0031 (0.13%)	0.0140 (0.14%)
MCI	-0.0004 (-0.01%)	0.0004 (0.08%)	0.0026 (0.18%)	0.0078 (0.29%)	-0.0002 (-0.08%)	-0.0001 (-0.01%)	0.0011 (0.06%)	0.0112 (0.09%)
MCO	-0.0001 (-0.01%)	0.0008 (0.16%)	0.0014 (0.21%)	0.0028 (0.72%)	0.0001 (0.02%)	-0.0001 (-0.01%)	0.0031 (0.17%)	0.0080 (0.12%)
MDW	-0.0005 (-0.01%)	0.0009 (0.14%)	0.0022 (0.11%)	0.0075 (0.23%)	-0.0004 (-0.18%)	-0.0001 (-0.01%)	0.0005 (0.02%)	0.0101 (0.07%)
MEM	-0.0004 (-0.01%)	0.0011 (0.24%)	0.0027 (0.19%)	0.0076 (0.38%)	-0.0003 (-0.10%)	-0.0001 (-0.01%)	0.0033 (0.13%)	0.0140 (0.13%)
MIA	0.0000 (-0.01%)	0.0011 (0.28%)	0.0005 (0.14%)	0.0007 (0.97%)	-0.0002 (-0.14%)	0.0000 (0.00%)	0.0020 (0.17%)	0.0040 (0.10%)
MKE	-0.0004 (-0.01%)	0.0003 (0.07%)	0.0018 (0.11%)	0.0063 (0.22%)	-0.0003 (-0.10%)	-0.0001 (-0.01%)	0.0003 (0.01%)	0.0079 (0.07%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
MLB	-0.0001 (-0.01%)	0.0002 (0.06%)	0.0006 (0.14%)	0.0012 (0.81%)	0.0002 (0.06%)	0.0000 (-0.01%)	0.0025 (0.15%)	0.0045 (0.10%)
MSN	-0.0004 (-0.01%)	0.0001 (0.02%)	0.0034 (0.19%)	0.0113 (0.31%)	-0.0002 (-0.07%)	-0.0001 (-0.01%)	0.0005 (0.03%)	0.0146 (0.12%)
MSP	-0.0004 (-0.01%)	0.0011 (0.19%)	0.0020 (0.14%)	0.0065 (0.23%)	-0.0003 (-0.10%)	-0.0001 (-0.01%)	0.0004 (0.03%)	0.0093 (0.08%)
MSY	-0.0001 (-0.01%)	0.0002 (0.06%)	0.0006 (0.08%)	0.0013 (0.30%)	0.0000 (-0.01%)	0.0000 (-0.01%)	0.0022 (0.09%)	0.0041 (0.06%)
OAK	-0.0001 (0.00%)	0.0014 (0.22%)	0.0030 (0.42%)	0.0088 (0.52%)	-0.0004 (-0.09%)	-0.0001 (0.00%)	0.0013 (0.20%)	0.0139 (0.17%)
OKC	-0.0004 (-0.01%)	0.0001 (0.04%)	0.0024 (0.23%)	0.0058 (0.36%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0021 (0.14%)	0.0098 (0.12%)
OMA	-0.0004 (-0.01%)	0.0001 (0.03%)	0.0025 (0.19%)	0.0078 (0.31%)	-0.0001 (-0.05%)	-0.0001 (-0.02%)	0.0007 (0.04%)	0.0105 (0.11%)
ONT	-0.0004 (-0.02%)	0.0021 (0.18%)	0.0085 (0.75%)	0.0246 (0.99%)	-0.0012 (-0.24%)	-0.0003 (-0.01%)	0.0041 (0.36%)	0.0373 (0.32%)
ORD	**-0.0004 (-0.01%)**	**0.0011 (0.15%)**	**0.0021 (0.11%)**	**0.0070 (0.22%)**	**-0.0004 (-0.18%)**	**-0.0001 (-0.01%)**	**0.0004 (0.02%)**	**0.0097 (0.07%)**
ORF	-0.0002 (-0.01%)	0.0003 (0.07%)	0.0012 (0.09%)	0.0034 (0.22%)	-0.0002 (-0.05%)	-0.0001 (-0.01%)	0.0014 (0.05%)	0.0057 (0.06%)
PBI	-0.0001 (-0.01%)	0.0003 (0.08%)	0.0004 (0.14%)	0.0006 (1.04%)	0.0001 (0.05%)	0.0000 (0.00%)	0.0023 (0.18%)	0.0036 (0.09%)
PDX	-0.0001 (0.00%)	0.0004 (0.06%)	0.0012 (0.29%)	0.0032 (0.40%)	-0.0001 (-0.01%)	0.0000 (0.00%)	0.0007 (0.15%)	0.0053 (0.05%)
PHF	-0.0002 (-0.01%)	0.0003 (0.06%)	0.0015 (0.11%)	0.0045 (0.25%)	-0.0002 (-0.03%)	-0.0001 (-0.01%)	0.0015 (0.05%)	0.0073 (0.07%)
PHL	-0.0004 (-0.01%)	0.0009 (0.14%)	0.0035 (0.17%)	0.0125 (0.33%)	-0.0008 (-0.18%)	-0.0001 (-0.01%)	0.0003 (0.01%)	0.0160 (0.11%)
PHX	-0.0001 (-0.01%)	0.0013 (0.17%)	0.0047 (1.01%)	0.0126 (1.56%)	-0.0004 (-0.11%)	-0.0001 (-0.01%)	0.0028 (0.44%)	0.0206 (0.33%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
PIT	-0.0004 (-0.01%)	0.0001 (0.03%)	0.0023 (0.12%)	0.0081 (0.27%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0015 (0.04%)	0.0112 (0.08%)
PVD	**-0.0002 (-0.01%)**	**0.0004 (0.07%)**	**0.0016 (0.13%)**	**0.0059 (0.27%)**	**-0.0006 (-0.14%)**	**-0.0001 (-0.01%)**	**0.0006 (0.03%)**	**0.0075 (0.07%)**
RDU	-0.0003 (-0.02%)	0.0001 (0.02%)	0.0040 (0.24%)	0.0123 (0.48%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0021 (0.08%)	0.0180 (0.15%)
RIC	-0.0003 (-0.01%)	0.0002 (0.05%)	0.0022 (0.13%)	0.0071 (0.31%)	-0.0003 (-0.04%)	-0.0001 (-0.01%)	0.0018 (0.06%)	0.0107 (0.09%)
RNO	0.0000 (0.00%)	0.0003 (0.13%)	0.0013 (0.48%)	0.0026 (0.71%)	0.0014 (0.12%)	0.0000 (0.00%)	0.0016 (0.36%)	0.0071 (0.15%)
ROC	-0.0003 (-0.01%)	0.0002 (0.07%)	0.0022 (0.15%)	0.0074 (0.30%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0011 (0.05%)	0.0102 (0.10%)
RSW	-0.0001 (-0.01%)	0.0002 (0.05%)	0.0007 (0.17%)	0.0011 (0.84%)	0.0001 (0.03%)	0.0000 (0.00%)	0.0024 (0.17%)	0.0044 (0.09%)
SAN	-0.0002 (-0.01%)	0.0008 (0.13%)	0.0043 (0.64%)	0.0111 (0.94%)	-0.0003 (-0.10%)	-0.0001 (-0.01%)	0.0037 (0.36%)	0.0193 (0.29%)
SAT	-0.0003 (-0.01%)	0.0003 (0.08%)	0.0024 (0.26%)	0.0063 (0.54%)	-0.0001 (-0.05%)	-0.0001 (-0.01%)	0.0018 (0.11%)	0.0103 (0.13%)
SBA	-0.0002 (-0.02%)	0.0000 (0.00%)	0.0018 (0.59%)	0.0042 (0.87%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0017 (0.32%)	0.0074 (0.20%)
SDF	-0.0005 (-0.01%)	0.0004 (0.07%)	0.0026 (0.12%)	0.0079 (0.25%)	-0.0003 (-0.12%)	-0.0001 (-0.01%)	0.0026 (0.07%)	0.0126 (0.09%)
SEA	0.0000 (0.00%)	0.0007 (0.12%)	0.0008 (0.20%)	0.0017 (0.20%)	-0.0015 (-0.08%)	0.0000 (0.00%)	0.0010 (0.20%)	0.0026 (0.03%)
SFO	-0.0001 (0.00%)	0.0014 (0.22%)	0.0030 (0.42%)	0.0088 (0.52%)	-0.0004 (-0.09%)	-0.0001 (0.00%)	0.0013 (0.20%)	0.0139 (0.17%)
SJC	-0.0001 (-0.01%)	0.0015 (0.23%)	0.0027 (0.39%)	0.0078 (0.46%)	-0.0006 (-0.12%)	-0.0001 (0.00%)	0.0014 (0.22%)	0.0127 (0.16%)
SLC	-0.0001 (0.00%)	0.0006 (0.18%)	0.0028 (0.56%)	0.0076 (0.71%)	0.0000 (0.00%)	0.0000 (-0.01%)	0.0018 (0.34%)	0.0127 (0.23%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
SMF	-0.0001 (0.00%)	0.0005 (0.08%)	0.0042 (0.57%)	0.0124 (0.71%)	-0.0001 (-0.01%)	-0.0001 (0.00%)	0.0016 (0.25%)	0.0184 (0.20%)
SNA	-0.0003 (-0.01%)	0.0030 (0.30%)	0.0065 (0.67%)	0.0178 (0.88%)	-0.0011 (-0.31%)	-0.0002 (-0.01%)	0.0043 (0.38%)	0.0300 (0.31%)
STL	-0.0005 (-0.01%)	0.0003 (0.06%)	0.0024 (0.14%)	0.0068 (0.25%)	-0.0002 (-0.07%)	-0.0001 (-0.01%)	0.0020 (0.07%)	0.0106 (0.08%)
SWF	-0.0002 (-0.01%)	0.0004 (0.07%)	0.0013 (0.09%)	0.0053 (0.21%)	-0.0008 (-0.19%)	-0.0001 (-0.01%)	0.0005 (0.02%)	0.0063 (0.06%)
SYR	-0.0004 (-0.02%)	0.0001 (0.02%)	0.0026 (0.17%)	0.0089 (0.33%)	-0.0002 (-0.06%)	-0.0001 (-0.01%)	0.0009 (0.04%)	0.0117 (0.11%)
TPA	-0.0001 (-0.01%)	0.0004 (0.08%)	0.0015 (0.19%)	0.0034 (0.78%)	0.0000 (0.01%)	-0.0001 (-0.01%)	0.0027 (0.12%)	0.0078 (0.11%)
TUL	-0.0004 (-0.01%)	0.0000 (0.01%)	0.0024 (0.20%)	0.0065 (0.34%)	-0.0001 (-0.03%)	-0.0001 (-0.01%)	0.0017 (0.10%)	0.0100 (0.09%)
TUS	-0.0001 (-0.01%)	0.0001 (0.06%)	0.0013 (0.45%)	0.0024 (0.90%)	0.0000 (0.02%)	0.0000 (0.00%)	0.0017 (0.27%)	0.0055 (0.15%)
TVC	-0.0002 (-0.01%)	0.0001 (0.04%)	0.0005 (0.06%)	0.0016 (0.14%)	0.0000 (-0.01%)	0.0000 (-0.01%)	0.0008 (0.05%)	0.0027 (0.04%)
TYS	-0.0002 (-0.01%)	0.0001 (0.03%)	0.0012 (0.09%)	0.0032 (0.23%)	0.0001 (0.02%)	-0.0001 (-0.01%)	0.0028 (0.09%)	0.0072 (0.07%)

*$PM_{2.5}$ does not equal the sum of species shown in chart due to a scaling factor (1.167) applied to POA when computing $PM_{2.5}$.

Table 9. Absolute and percent increases due to aircraft emissions in 2025 in the 9 grid cells surrounding the airport.

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ABQ	**0.0000 (0.00%)**	**0.0004 (0.22%)**	**0.0013 (0.52%)**	**0.0028 (1.10%)**	**0.0005 (0.10%)**	**0.0000 (0.00%)**	**0.0014 (0.27%)**	**0.0064 (0.12%)**
ALB	-0.0009 (-0.03%)	0.0000 (0.00%)	0.0049 (0.52%)	0.0166 (1.01%)	-0.0001 (-0.03%)	-0.0004 (-0.02%)	0.0008 (0.06%)	0.0209 (0.23%)
ATL	**-0.0007 (-0.02%)**	**0.0021 (0.53%)**	**0.0082 (0.77%)**	**0.0215 (1.74%)**	**0.0046 (0.33%)**	**-0.0002 (-0.02%)**	**0.0060 (0.31%)**	**0.0415 (0.37%)**
AUS	-0.0005 (-0.02%)	0.0004 (0.24%)	0.0043 (0.54%)	0.0117 (1.09%)	-0.0001 (-0.04%)	-0.0001 (-0.02%)	0.0025 (0.19%)	0.0181 (0.25%)
BDL	-0.0009 (-0.03%)	0.0005 (0.17%)	0.0060 (0.56%)	0.0202 (1.03%)	-0.0005 (-0.10%)	-0.0004 (-0.03%)	0.0011 (0.07%)	0.0261 (0.26%)
BFL	-0.0003 (-0.02%)	0.0000 (-0.01%)	0.0047 (1.10%)	0.0129 (1.56%)	0.0002 (0.03%)	-0.0002 (-0.02%)	0.0026 (0.50%)	0.0197 (0.38%)
BHM	-0.0006 (-0.02%)	0.0001 (0.04%)	0.0045 (0.46%)	0.0118 (1.19%)	0.0014 (0.13%)	-0.0002 (-0.02%)	0.0034 (0.18%)	0.0205 (0.22%)
BNA	-0.0008 (-0.03%)	0.0001 (0.04%)	0.0049 (0.40%)	0.0146 (0.86%)	-0.0001 (-0.04%)	-0.0002 (-0.03%)	0.0024 (0.11%)	0.0208 (0.23%)
BOI	-0.0001 (0.00%)	0.0002 (0.06%)	0.0026 (0.74%)	0.0077 (1.19%)	0.0013 (0.09%)	0.0000 (0.00%)	0.0010 (0.22%)	0.0127 (0.17%)
BOS	-0.0007 (-0.02%)	0.0007 (0.16%)	0.0052 (0.53%)	0.0177 (1.06%)	-0.0010 (-0.20%)	-0.0003 (-0.02%)	0.0005 (0.04%)	0.0221 (0.21%)
BTR	-0.0003 (-0.01%)	-0.0001 (-0.03%)	0.0030 (0.29%)	0.0079 (0.69%)	0.0004 (0.07%)	-0.0001 (-0.01%)	0.0022 (0.11%)	0.0130 (0.15%)
BUF	-0.0008 (-0.03%)	0.0001 (0.05%)	0.0047 (0.35%)	0.0153 (0.71%)	-0.0003 (-0.05%)	-0.0003 (-0.02%)	0.0011 (0.05%)	0.0197 (0.19%)
BUR	-0.0005 (-0.02%)	0.0023 (0.42%)	0.0076 (1.04%)	0.0220 (1.59%)	-0.0009 (-0.22%)	-0.0003 (-0.02%)	0.0039 (0.42%)	0.0341 (0.40%)
BWI	-0.0013 (-0.04%)	0.0008 (0.21%)	0.0104 (0.67%)	0.0337 (1.28%)	-0.0008 (-0.18%)	-0.0004 (-0.03%)	0.0021 (0.10%)	0.0444 (0.36%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	PM$_{2.5}$* (μg m^{-3})
CHS	-0.0004 (-0.03%)	0.0000 (0.02%)	0.0026 (0.39%)	0.0069 (1.37%)	0.0007 (0.11%)	-0.0001 (-0.02%)	0.0024 (0.15%)	0.0120 (0.20%)
CLE	-0.0011 (-0.04%)	0.0002 (0.09%)	0.0071 (0.42%)	0.0239 (0.82%)	-0.0003 (-0.11%)	-0.0003 (-0.03%)	0.0009 (0.04%)	0.0304 (0.27%)
CLT	-0.0007 (-0.03%)	0.0005 (0.16%)	0.0078 (0.69%)	0.0229 (1.56%)	0.0016 (0.15%)	-0.0002 (-0.02%)	0.0034 (0.18%)	0.0354 (0.36%)
CMH	-0.0012 (-0.03%)	0.0002 (0.07%)	0.0073 (0.45%)	0.0238 (0.84%)	-0.0003 (-0.10%)	-0.0003 (-0.03%)	0.0015 (0.07%)	0.0310 (0.27%)
COS	-0.0001 (-0.01%)	0.0001 (0.09%)	0.0015 (0.62%)	0.0040 (1.55%)	0.0006 (0.11%)	0.0000 (0.00%)	0.0012 (0.26%)	0.0074 (0.20%)
CRP	-0.0003 (-0.02%)	0.0001 (0.06%)	0.0014 (0.31%)	0.0037 (0.93%)	0.0000 (-0.04%)	-0.0001 (-0.03%)	0.0012 (0.11%)	0.0060 (0.16%)
CVG	-0.0012 (-0.03%)	0.0005 (0.22%)	0.0071 (0.43%)	0.0230 (0.87%)	-0.0004 (-0.18%)	-0.0002 (-0.03%)	0.0020 (0.08%)	0.0308 (0.26%)
DAB	-0.0002 (-0.02%)	0.0001 (0.04%)	0.0012 (0.34%)	0.0018 (2.22%)	0.0007 (0.18%)	-0.0001 (-0.01%)	0.0026 (0.24%)	0.0060 (0.16%)
DAL	-0.0007 (-0.01%)	0.0012 (0.49%)	0.0062 (0.63%)	0.0168 (1.27%)	-0.0003 (-0.13%)	-0.0001 (-0.02%)	0.0035 (0.22%)	0.0266 (0.26%)
DAY	-0.0012 (-0.03%)	0.0002 (0.11%)	0.0088 (0.50%)	0.0287 (0.93%)	-0.0003 (-0.14%)	-0.0002 (-0.03%)	0.0017 (0.07%)	0.0375 (0.31%)
DCA	-0.0012 (-0.04%)	0.0016 (0.41%)	0.0095 (0.66%)	0.0305 (1.28%)	-0.0011 (-0.21%)	-0.0004 (-0.03%)	0.0025 (0.12%)	0.0412 (0.35%)
DEN	-0.0001 (-0.01%)	0.0011 (0.51%)	0.0038 (1.03%)	0.0105 (1.88%)	0.0005 (0.07%)	0.0000 (0.00%)	0.0020 (0.36%)	0.0177 (0.36%)
DFW	-0.0007 (-0.01%)	0.0014 (0.53%)	0.0065 (0.67%)	0.0175 (1.29%)	-0.0003 (-0.14%)	-0.0002 (-0.02%)	0.0040 (0.26%)	0.0282 (0.27%)
DSM	-0.0008 (-0.03%)	0.0000 (-0.01%)	0.0037 (0.34%)	0.0116 (0.58%)	-0.0001 (-0.07%)	-0.0001 (-0.03%)	0.0010 (0.08%)	0.0153 (0.19%)
DTW	-0.0010 (-0.03%)	0.0009 (0.36%)	0.0059 (0.36%)	0.0198 (0.71%)	-0.0006 (-0.18%)	-0.0002 (-0.02%)	0.0008 (0.04%)	0.0257 (0.21%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
ELP	0.0000 (0.00%)	0.0001 (0.09%)	0.0015 (0.40%)	0.0035 (0.91%)	0.0002 (0.06%)	0.0000 (0.00%)	0.0013 (0.18%)	0.0066 (0.15%)
EUG	0.0000 (0.00%)	0.0001 (0.02%)	0.0010 (0.52%)	0.0029 (1.21%)	0.0010 (0.05%)	0.0000 (0.00%)	0.0005 (0.12%)	0.0054 (0.08%)
EWR	-0.0009 (-0.03%)	0.0018 (0.45%)	0.0073 (0.51%)	0.0257 (1.00%)	-0.0028 (-0.59%)	-0.0004 (-0.02%)	0.0000 (0.00%)	0.0306 (0.27%)
FAT	-0.0003 (-0.02%)	0.0001 (0.03%)	0.0057 (1.08%)	0.0167 (1.47%)	0.0004 (0.07%)	-0.0002 (-0.01%)	0.0024 (0.43%)	0.0249 (0.37%)
FLL	-0.0001 (-0.01%)	0.0011 (0.40%)	0.0018 (0.65%)	0.0022 (3.79%)	0.0003 (0.15%)	-0.0001 (-0.01%)	0.0037 (0.46%)	0.0089 (0.24%)
FNT	-0.0009 (-0.03%)	0.0002 (0.09%)	0.0053 (0.37%)	0.0180 (0.72%)	-0.0003 (-0.09%)	-0.0002 (-0.03%)	0.0006 (0.03%)	0.0227 (0.22%)
GFK	-0.0003 (-0.02%)	0.0002 (0.16%)	0.0013 (0.24%)	0.0040 (0.36%)	-0.0001 (-0.03%)	-0.0001 (-0.02%)	0.0004 (0.07%)	0.0055 (0.11%)
GRR	-0.0010 (-0.03%)	0.0001 (0.04%)	0.0059 (0.41%)	0.0200 (0.82%)	-0.0002 (-0.07%)	-0.0002 (-0.03%)	0.0004 (0.02%)	0.0250 (0.26%)
GSO	-0.0007 (-0.03%)	-0.0001 (-0.03%)	0.0071 (0.62%)	0.0216 (1.33%)	0.0006 (0.07%)	-0.0002 (-0.03%)	0.0026 (0.14%)	0.0308 (0.34%)
HOU	-0.0004 (-0.01%)	0.0011 (0.34%)	0.0035 (0.37%)	0.0091 (0.86%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0025 (0.14%)	0.0157 (0.15%)
HPN	-0.0009 (-0.03%)	0.0007 (0.20%)	0.0068 (0.50%)	0.0237 (0.97%)	-0.0015 (-0.32%)	-0.0004 (-0.02%)	0.0005 (0.03%)	0.0289 (0.25%)
IAD	-0.0012 (-0.03%)	0.0013 (0.34%)	0.0099 (0.69%)	0.0316 (1.31%)	-0.0009 (-0.18%)	-0.0004 (-0.03%)	0.0025 (0.13%)	0.0427 (0.37%)
IAH	-0.0004 (-0.01%)	0.0013 (0.40%)	0.0036 (0.38%)	0.0090 (0.86%)	0.0004 (0.07%)	-0.0001 (-0.01%)	0.0029 (0.16%)	0.0166 (0.15%)
ICT	-0.0007 (-0.02%)	-0.0001 (-0.02%)	0.0031 (0.36%)	0.0091 (0.62%)	0.0000 (-0.03%)	-0.0002 (-0.01%)	0.0012 (0.11%)	0.0124 (0.14%)
IND	-0.0013 (-0.03%)	0.0005 (0.23%)	0.0082 (0.47%)	0.0268 (0.92%)	-0.0005 (-0.21%)	-0.0002 (-0.03%)	0.0015 (0.06%)	0.0349 (0.26%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
ISP	-0.0007 (-0.03%)	0.0017 (0.51%)	0.0052 (0.42%)	0.0189 (0.89%)	-0.0026 (-0.65%)	-0.0003 (-0.02%)	-0.0001 (0.00%)	0.0221 (0.22%)
JAX	-0.0003 (-0.02%)	0.0002 (0.06%)	0.0023 (0.42%)	0.0050 (1.59%)	0.0028 (0.26%)	-0.0001 (-0.01%)	0.0026 (0.20%)	0.0125 (0.19%)
JFK	-0.0008 (-0.03%)	0.0020 (0.55%)	0.0063 (0.46%)	0.0226 (0.97%)	-0.0030 (-0.68%)	-0.0003 (-0.02%)	-0.0002 (-0.01%)	0.0264 (0.25%)
LAN	-0.0010 (-0.03%)	0.0001 (0.05%)	0.0064 (0.43%)	0.0217 (0.82%)	-0.0002 (-0.09%)	-0.0002 (-0.03%)	0.0004 (0.02%)	0.0272 (0.27%)
LAS	-0.0001 (-0.01%)	0.0008 (0.50%)	0.0018 (0.75%)	0.0029 (1.54%)	0.0004 (0.11%)	-0.0001 (-0.01%)	0.0028 (0.55%)	0.0087 (0.27%)
LAX	**-0.0003 (-0.01%)**	**0.0026 (0.52%)**	**0.0061 (0.94%)**	**0.0168 (1.44%)**	**-0.0008 (-0.27%)**	**-0.0002 (-0.01%)**	**0.0040 (0.44%)**	**0.0281 (0.38%)**
LGA	-0.0009 (-0.03%)	0.0020 (0.50%)	0.0065 (0.46%)	0.0232 (0.95%)	-0.0029 (-0.65%)	-0.0004 (-0.02%)	-0.0002 (-0.01%)	0.0273 (0.24%)
LGB	-0.0004 (-0.02%)	0.0032 (0.49%)	0.0085 (1.03%)	0.0243 (1.53%)	-0.0014 (-0.31%)	-0.0003 (-0.02%)	0.0046 (0.44%)	0.0385 (0.40%)
LIT	-0.0007 (-0.03%)	0.0001 (0.02%)	0.0045 (0.46%)	0.0116 (0.93%)	0.0001 (0.02%)	-0.0002 (-0.02%)	0.0031 (0.19%)	0.0185 (0.23%)
MCI	-0.0008 (-0.02%)	0.0004 (0.15%)	0.0040 (0.34%)	0.0126 (0.64%)	-0.0002 (-0.10%)	-0.0002 (-0.02%)	0.0009 (0.06%)	0.0166 (0.16%)
MCO	-0.0002 (-0.02%)	0.0008 (0.27%)	0.0030 (0.65%)	0.0060 (2.28%)	0.0010 (0.23%)	-0.0001 (-0.01%)	0.0036 (0.34%)	0.0140 (0.27%)
MDW	-0.0010 (-0.02%)	0.0010 (0.37%)	0.0049 (0.30%)	0.0169 (0.65%)	-0.0007 (-0.27%)	-0.0002 (-0.02%)	0.0000 (0.00%)	0.0209 (0.17%)
MEM	-0.0008 (-0.03%)	0.0010 (0.39%)	0.0056 (0.51%)	0.0157 (1.06%)	-0.0003 (-0.09%)	-0.0002 (-0.02%)	0.0036 (0.19%)	0.0246 (0.27%)
MIA	-0.0001 (-0.01%)	0.0011 (0.54%)	0.0017 (0.66%)	0.0021 (3.98%)	0.0001 (0.12%)	-0.0001 (-0.01%)	0.0036 (0.48%)	0.0085 (0.28%)
MKE	-0.0008 (-0.03%)	0.0003 (0.16%)	0.0043 (0.33%)	0.0153 (0.69%)	-0.0003 (-0.11%)	-0.0002 (-0.02%)	0.0001 (0.00%)	0.0187 (0.19%)

Airport	A25 (μg m^{-3})	AEC (μg m^{-3})	ANH4 (μg m^{-3})	ANO3 (μg m^{-3})	SOA (μg m^{-3})	POA (μg m^{-3})	ASO4 (μg m^{-3})	$PM_{2.5}$* (μg m^{-3})
MLB	-0.0002 (-0.02%)	0.0002 (0.08%)	0.0015 (0.45%)	0.0024 (2.46%)	0.0006 (0.23%)	-0.0001 (-0.01%)	0.0029 (0.30%)	0.0073 (0.21%)
MSN	-0.0009 (-0.03%)	0.0001 (0.04%)	0.0056 (0.41%)	0.0194 (0.76%)	-0.0002 (-0.08%)	-0.0002 (-0.02%)	0.0001 (0.00%)	0.0238 (0.24%)
MSP	-0.0007 (-0.02%)	0.0011 (0.38%)	0.0033 (0.29%)	0.0100 (0.47%)	-0.0005 (-0.16%)	-0.0001 (-0.01%)	0.0011 (0.08%)	0.0142 (0.13%)
MSY	-0.0002 (-0.01%)	0.0002 (0.08%)	0.0013 (0.20%)	0.0028 (0.74%)	0.0000 (0.00%)	-0.0001 (-0.01%)	0.0023 (0.13%)	0.0064 (0.11%)
OAK	-0.0001 (-0.01%)	0.0015 (0.37%)	0.0049 (0.91%)	0.0159 (1.42%)	-0.0005 (-0.10%)	-0.0001 (-0.01%)	0.0012 (0.17%)	0.0226 (0.32%)
OKC	-0.0007 (-0.02%)	0.0001 (0.06%)	0.0035 (0.46%)	0.0094 (0.79%)	-0.0001 (-0.04%)	-0.0002 (-0.02%)	0.0022 (0.19%)	0.0143 (0.20%)
OMA	-0.0006 (-0.02%)	0.0002 (0.10%)	0.0032 (0.32%)	0.0095 (0.54%)	-0.0001 (-0.06%)	-0.0001 (-0.02%)	0.0012 (0.09%)	0.0132 (0.16%)
ONT	-0.0005 (-0.02%)	0.0023 (0.33%)	0.0093 (1.09%)	0.0271 (1.62%)	-0.0012 (-0.22%)	-0.0004 (-0.02%)	0.0046 (0.45%)	0.0412 (0.41%)
ORD	**-0.0009 (-0.02%)**	**0.0011 (0.41%)**	**0.0047 (0.31%)**	**0.0164 (0.64%)**	**-0.0007 (-0.26%)**	**-0.0002 (-0.02%)**	**0.0000 (0.00%)**	**0.0204 (0.17%)**
ORF	-0.0007 (-0.03%)	0.0001 (0.06%)	0.0048 (0.46%)	0.0156 (1.08%)	-0.0002 (-0.04%)	-0.0002 (-0.03%)	0.0014 (0.07%)	0.0208 (0.27%)
PBI	-0.0001 (-0.01%)	0.0003 (0.12%)	0.0011 (0.46%)	0.0013 (3.32%)	0.0003 (0.22%)	-0.0001 (-0.01%)	0.0028 (0.36%)	0.0057 (0.17%)
PDX	-0.0001 (0.00%)	0.0004 (0.10%)	0.0020 (0.52%)	0.0057 (0.90%)	0.0007 (0.04%)	0.0000 (0.00%)	0.0009 (0.16%)	0.0095 (0.09%)
PHF	-0.0008 (-0.04%)	0.0001 (0.04%)	0.0054 (0.49%)	0.0175 (1.12%)	0.0000 (0.00%)	-0.0003 (-0.04%)	0.0014 (0.08%)	0.0233 (0.28%)
PHL	-0.0012 (-0.04%)	0.0008 (0.24%)	0.0094 (0.60%)	0.0319 (1.12%)	-0.0010 (-0.22%)	-0.0004 (-0.03%)	0.0007 (0.03%)	0.0401 (0.33%)
PHX	-0.0001 (-0.01%)	0.0014 (0.51%)	0.0085 (2.65%)	0.0248 (5.93%)	0.0001 (0.01%)	-0.0001 (-0.01%)	0.0035 (0.65%)	0.0381 (0.76%)

Airport	A25 ($\mu g\ m^{-3}$)	AEC ($\mu g\ m^{-3}$)	ANH4 ($\mu g\ m^{-3}$)	ANO3 ($\mu g\ m^{-3}$)	SOA ($\mu g\ m^{-3}$)	POA ($\mu g\ m^{-3}$)	ASO4 ($\mu g\ m^{-3}$)	$PM_{2.5}$* ($\mu g\ m^{-3}$)
PIT	-0.0011 (-0.04%)	0.0000 (0.02%)	0.0057 (0.37%)	0.0192 (0.80%)	-0.0003 (-0.09%)	-0.0003 (-0.04%)	0.0011 (0.05%)	0.0244 (0.23%)
PVD	**-0.0008 (-0.03%)**	**0.0003 (0.09%)**	**0.0062 (0.61%)**	**0.0208 (1.15%)**	**-0.0005 (-0.12%)**	**-0.0003 (-0.02%)**	**0.0009 (0.07%)**	**0.0265 (0.28%)**
RDU	-0.0008 (-0.04%)	0.0001 (0.02%)	0.0070 (0.65%)	0.0214 (1.35%)	0.0008 (0.09%)	-0.0003 (-0.03%)	0.0022 (0.13%)	0.0303 (0.35%)
RIC	-0.0010 (-0.04%)	0.0000 (0.00%)	0.0072 (0.59%)	0.0233 (1.26%)	0.0001 (0.02%)	-0.0003 (-0.04%)	0.0016 (0.08%)	0.0308 (0.33%)
RNO	0.0000 (0.00%)	0.0003 (0.17%)	0.0021 (0.93%)	0.0052 (2.13%)	0.0022 (0.20%)	0.0000 (0.00%)	0.0016 (0.38%)	0.0113 (0.25%)
ROC	-0.0008 (-0.03%)	0.0001 (0.05%)	0.0046 (0.41%)	0.0151 (0.85%)	-0.0003 (-0.09%)	-0.0003 (-0.03%)	0.0010 (0.06%)	0.0193 (0.22%)
RSW	-0.0001 (-0.01%)	0.0002 (0.08%)	0.0015 (0.47%)	0.0020 (2.47%)	0.0003 (0.14%)	-0.0001 (-0.01%)	0.0029 (0.33%)	0.0066 (0.16%)
SAN	-0.0003 (-0.02%)	0.0008 (0.25%)	0.0063 (1.23%)	0.0172 (2.40%)	-0.0001 (-0.05%)	-0.0002 (-0.02%)	0.0043 (0.46%)	0.0280 (0.48%)
SAT	-0.0004 (-0.01%)	0.0003 (0.16%)	0.0035 (0.49%)	0.0094 (1.08%)	-0.0001 (-0.04%)	-0.0001 (-0.02%)	0.0021 (0.17%)	0.0146 (0.21%)
SBA	-0.0002 (-0.02%)	0.0000 (0.00%)	0.0021 (0.89%)	0.0050 (1.60%)	0.0000 (0.02%)	-0.0001 (-0.02%)	0.0019 (0.41%)	0.0086 (0.26%)
SDF	-0.0012 (-0.03%)	0.0003 (0.14%)	0.0065 (0.41%)	0.0207 (0.84%)	-0.0004 (-0.17%)	-0.0002 (-0.03%)	0.0021 (0.09%)	0.0278 (0.24%)
SEA	-0.0001 (0.00%)	0.0007 (0.21%)	0.0023 (0.59%)	0.0066 (0.90%)	-0.0005 (-0.03%)	0.0000 (0.00%)	0.0010 (0.21%)	0.0100 (0.13%)
SFO	-0.0001 (-0.01%)	0.0015 (0.37%)	0.0049 (0.91%)	0.0159 (1.42%)	-0.0005 (-0.10%)	-0.0001 (-0.01%)	0.0012 (0.17%)	0.0226 (0.32%)
SJC	-0.0002 (-0.01%)	0.0015 (0.41%)	0.0050 (0.98%)	0.0161 (1.51%)	-0.0006 (-0.12%)	-0.0001 (-0.01%)	0.0013 (0.20%)	0.0231 (0.33%)
SLC	-0.0001 (-0.01%)	0.0006 (0.32%)	0.0054 (1.21%)	0.0159 (1.94%)	0.0003 (0.04%)	-0.0001 (-0.01%)	0.0020 (0.37%)	0.0239 (0.46%)

Airport	A25 (µg m^{-3})	AEC (µg m^{-3})	ANH4 (µg m^{-3})	ANO3 (µg m^{-3})	SOA (µg m^{-3})	POA (µg m^{-3})	ASO4 (µg m^{-3})	$PM_{2.5}$* (µg m^{-3})
SMF	-0.0002 (-0.01%)	0.0005 (0.12%)	0.0062 (1.12%)	0.0192 (1.67%)	0.0001 (0.01%)	-0.0001 (-0.01%)	0.0017 (0.28%)	0.0276 (0.34%)
SNA	-0.0003 (-0.01%)	0.0031 (0.54%)	0.0077 (1.01%)	0.0215 (1.51%)	-0.0013 (-0.36%)	-0.0002 (-0.01%)	0.0047 (0.46%)	0.0351 (0.41%)
STL	-0.0010 (-0.02%)	0.0002 (0.11%)	0.0045 (0.32%)	0.0133 (0.65%)	-0.0002 (-0.09%)	-0.0002 (-0.02%)	0.0021 (0.09%)	0.0187 (0.16%)
SWF	-0.0009 (-0.03%)	0.0003 (0.09%)	0.0060 (0.49%)	0.0207 (0.93%)	-0.0009 (-0.20%)	-0.0004 (-0.03%)	0.0006 (0.04%)	0.0253 (0.25%)
SYR	-0.0010 (-0.03%)	0.0000 (-0.01%)	0.0050 (0.44%)	0.0170 (0.91%)	-0.0004 (-0.09%)	-0.0003 (-0.03%)	0.0007 (0.04%)	0.0210 (0.22%)
TPA	-0.0002 (-0.02%)	0.0004 (0.14%)	0.0027 (0.49%)	0.0058 (1.92%)	0.0003 (0.11%)	-0.0001 (-0.01%)	0.0034 (0.25%)	0.0123 (0.23%)
TUL	-0.0007 (-0.02%)	0.0000 (0.00%)	0.0033 (0.37%)	0.0093 (0.68%)	-0.0001 (-0.03%)	-0.0002 (-0.02%)	0.0016 (0.12%)	0.0132 (0.14%)
TUS	0.0000 (0.00%)	0.0003 (0.19%)	0.0022 (0.90%)	0.0050 (2.76%)	0.0002 (0.08%)	0.0000 (0.00%)	0.0019 (0.36%)	0.0096 (0.29%)
TVC	-0.0005 (-0.04%)	0.0000 (0.01%)	0.0016 (0.21%)	0.0058 (0.55%)	0.0000 (0.00%)	-0.0001 (-0.03%)	0.0006 (0.04%)	0.0075 (0.14%)
TYS	-0.0005 (-0.02%)	0.0000 (0.02%)	0.0035 (0.35%)	0.0098 (0.85%)	0.0004 (0.07%)	-0.0001 (-0.02%)	0.0026 (0.14%)	0.0157 (0.20%)

*$PM_{2.5}$ does not equal the sum of species shown in chart due to a scaling factor (1.167) applied to POA when computing $PM_{2.5}$.

Appendix C - Comparison of CMAQ Predicted Contributions to $PM_{2.5}$ from Aircraft Emissions to CMAQ Results Post-Processed Using the Speciated Modeled Attainment Test

The Speciated Modeled Attainment Test (SMAT) is a model post-processor algorithm developed by the U.S. Environmental Protection Agency (EPA) that applies modeling data in a relativistic sense rather than an absolute sense to investigate air quality changes between two scenarios (EPA, 2007b). To do this, SMAT uses the ratio between two modeling scenarios and applies these ratios to ambient monitoring data. SMAT has been used in a number of EPA policy relevant studies, such as regulatory impact analyses performed to support the Clear Skies, the Clean Air Interstate Rule (CAIR), and Low Sulfur Diesel Rule. Furthermore, the EPA requires states to apply SMAT in their State Implementation Plan (SIP) in conjunction with air quality modeling to demonstrate attainment of the National Ambient Air Quality Standards (NAAQS) for criteria air pollutants, including $PM_{2.5}$, as part of the Clean Air Act (EPA, 2007b). SMAT is routinely used in attainment demonstrations and health impact assessments in the U.S. and therefore we compare the air quality concentrations before (CMAQ results) and after applying SMAT to assess the significance of SMAT for aviation applications. SMAT was chosen because of its previous use in policy relevant work, because it is considered best practice by the EPA, its ability to produce speciated $PM_{2.5}$ fields, and its combination of ambient data and modeling results. The primary objective of this work is to quantify the influence of SMAT on the $PM_{2.5}$ concentrations attributed to aircraft emissions.

Methodology

MATS is a modeling post-processor tool that uses speciated $PM_{2.5}$ CMAQ output to determine model predicted changes to ambient conditions by applying the SMAT process. SMAT results are available as point estimates and spatial estimates. Point estimates are calculated at CMAQ

Table 10. Quarterly average $PM_{2.5}$ concentrations at LAX based on VNA interpolated FRM data from 2004 to 2006.

Quarter	1	2	3	4
$PM_{2.5}$ Mass ($\mu g\ m^{-3}$)	14.6178	12.0437	14.448	16.843

grid cells containing Federal Reference Method (FRM) monitoring sites while spatial estimates are calculated at each grid cell in the CMAQ domain.

To illustrate the SMAT process, an example is given for the spatial estimate results for the CMAQ grid cell containing the Los Angeles International Airport (LAX). The first step in SMAT is to establish a baseline quarterly $PM_{2.5}$ mass (Table 10). This mass is obtained from the FRM air quality monitors and is the quarterly average typically calculated over a three year period. In CMAQ grid cells that do not contain a FRM monitor (as is the case with LAX), the FRM monitor data is spatially interpolated to the grid cell using Voronoi Neighbor Averaging (VNA), an inverse weighted nearest-neighbor technique (Abt Associates Inc., 2009). FRM monitors are used to determine attainment of the NAAQS and therefore used in the SMAT process to establish a baseline $PM_{2.5}$ mass. A primary difference in the FRM network and other $PM_{2.5}$ monitoring networks, such as the Speciated Trends Network (STN) and Interagency Monitoring of Protected Visual Environments (IMPROVE) network, is that only total $PM_{2.5}$ mass are available and not $PM_{2.5}$ speciation. To calculate speciated $PM_{2.5}$ concentrations at FRM monitors, speciated fractions are derived from STN and IMPROVE monitoring network data. These speciated fractions are calculated on a quarterly basis and are typically based on 3 years of monitoring data. Approximately 80% of FRM monitors are not co-located with STN or IMPROVE monitors and again interpolation is required (Figure 18) (EPA, 2006). For SMAT's spatial estimates, the VNA technique is used to interpolate speciated data to FRM sites.

There are, however, issues with using speciated data from monitoring networks due to limitations of the sampling methodologies. For example, sampling filters do not retain portions of volatile compounds, such as ammonium nitrate, and therefore lead to sampling artifacts (Frank,

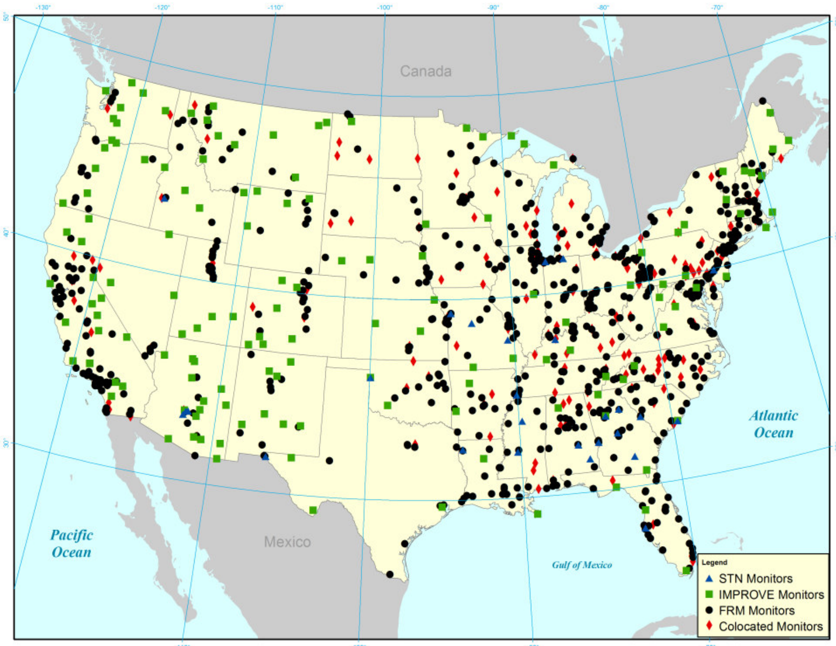

Figure 18. Location of Ambient Air Quality Monitors Used in SMAT.

2006). To alleviate this and other issues with sampling techniques, SMAT uses the sulfate, adjusted nitrate, derived water, inferred carbonaceous material balance (SANDWICH) technique (Frank, 2006) to calculate speciated $PM_{2.5}$ concentrations (Table 11). The speciation of SO_4, EC, and crustal material are relatively straightforward and the data from the speciated monitors can be directly applied. For NO_3, the reported speciated monitor data are adjusted to account for volatilization using a simple thermodynamic model (EPA, 2006). NH_4 is derived using a calculation based on the Degree of Neutralization (DON), or ratio of NH_4 neutralized by SO_4. DON is defined as

$$\mathrm{DON} = \mathrm{NH}_{4,\mathrm{SO}_4} / \mathrm{SO}_4 \tag{1}$$

where NH_{4,SO_4} is NH_4 associated with SO_4 and SO_4 is measured SO_4. The DON calculation is required because NH_4 and SO_4 can combine to form ammonium sulfate ($(NH_4)_2SO_4$), ammonium bisulfate (NH_4HSO_4), or letovicite ($(NH_4)_3H(SO_4)_2$), depending on ambient conditions. NH_4 and NO_3 combine to form only ammonium nitrate (NH_4NO_3) and because of the one to one molar ratio, NH_4 associated with NO_3 can be calculated on a mass basis as

$$\mathrm{NH}_{4,\mathrm{NO}_3} = 0.29 * \mathrm{NO}_{3,\mathrm{Retained}} \tag{2}$$

where NH_{4,NO_3} is the mass of NH_4 associated with NO_3 and $NO_{3,Retained}$ is the adjusted NO_3 mass as calculated by the thermodynamic model. NH_4 associated with SO_4 can then be calculated by taking the difference of measured NH_4 and NH_4 associated with NO_3, or

$$NH_{4,SO_4} = NH_{4,measured} - 0.29 * NO_{3,Retained} \tag{3}$$

Table 11. a) Spatially estimated speciated fractions at the LAX grid cell as calculated by the SANDWICH technique using speciated monitoring data from 2004-2006. b) Spatially estimated speciated concentrations of FRM $PM_{2.5}$ mass at the LAX grid cell calculated by

a)

Quarter	Crustal ($\mu g\ m^{-3}$)	EC ($\mu g\ m^{-3}$)	NH_4 ($\mu g\ m^{-3}$)	OC ($\mu g\ m^{-3}$)	SO_4 ($\mu g\ m^{-3}$)	NO_3 ($\mu g\ m^{-3}$)	PBW ($\mu g\ m^{-3}$)
1	0.056	0.09	0.118	0.294	0.124	0.253	0.058
2	0.069	0.065	0.134	0.243	0.301	0.083	0.1
3	0.054	0.064	0.131	0.254	0.339	0.029	0.122
4	0.06	0.104	0.089	0.431	0.122	0.15	0.042

b)

Quarter	Crustal ($\mu g\ m^{-3}$)	EC ($\mu g\ m^{-3}$)	NH_4 ($\mu g\ m^{-3}$)	OC ($\mu g\ m^{-3}$)	SO_4 ($\mu g\ m^{-3}$)	NO_3 ($\mu g\ m^{-3}$)	PBW ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)
1	0.7906	1.2706	1.6659	4.1506	1.7506	3.5718	0.8188	14.6178
2	0.7965	0.7503	1.5469	2.8051	3.4747	0.9581	1.1544	12.0437
3	0.7532	0.8927	1.8272	3.5428	4.7284	0.4045	1.7017	14.448
4	0.9806	1.6997	1.4545	7.0438	1.9938	2.4515	0.6864	16.843

Finally, NH_4 can be calculated using the equation

$$NH_4 = DON * SO_4 + 0.29 * NO_{3,Retained} \tag{4}$$

The second speciated interpolation in SMAT is to calculate particle bound water (PBW). Ammonium sulfate and ammonium nitrate are hygroscopic and a portion of their mass as measured by ambient monitors include PBW (Abt Associates, Inc., 2009). PBW is derived from SO_4, NO_3, and NH_4 concentrations using a polynomial regression equation fit to data generated by the Aerosol Inorganic Model (AIM) (Clegg et al., 1998) (Abt Associates Inc. 2009.). The AIM PBW calculations were performed at ambient conditions of 35% relative humidity and 22 degrees Celsius, the conditions at which typical filter equilibration occurs (EPA, 2006).

Finally, because of uncertainties in estimating carbonaceous mass from carbon measurements and differences in carbon measurement protocol between urban (STN) and rural (IMPROVE) monitoring locations, OC is estimated in the SANDWICH technique (Abt Associates, Inc., 2009). To estimate OC, a mass balance approach is used that subtracts all other estimated species from the total FRM $PM_{2.5}$ measured mass using the equation

$$\mathrm{OC} = \mathrm{PM}_{2.5} - (\mathrm{SO}_4 + \mathrm{NO}_{3,\mathrm{Retained}} + \mathrm{NH}_{4,\mathrm{Retained}} + \mathrm{PBW} + \mathrm{Crustal} + \mathrm{EC} + \mathrm{Blank\ Mass} + \mathrm{Salt}) \quad (5)$$

Because there is a possibility equation 5 could calculate too large or small (or even negative) of a value for OC, OC is limited by both floor and ceiling values. The default floor value is set to 1 times the measured organic mass, based on the assumption that a portion of organic mass is volatile/semi-volatile and not completely retained on the filter (Abt Associates, Inc., 2009). The default ceiling value is set to 80% of the total $PM_{2.5}$ mass (Abt Associates, Inc., 2009). In cases where either the floor or ceiling values are used, all other $PM_{2.5}$ species are adjusted up or down by equivalent percentages to maintain a mass balance.

Once quarterly speciated masses are estimated for the base year using the SANDWICH technique, sensitivities derived from the model are applied to determine forecasted concentrations. In this application, the sensitivity case refers to CMAQ cases that include aircraft emissions (airc05 and airc25) and the base case refers to the CMAQ cases without aircraft emissions (base05 and base25). Because the only difference between the sensitivity and base cases are the addition of aircraft emissions, the differences between the two cases can therefore be defined as the contribution from aircraft emissions, or sensitivity of the model to aircraft emissions. In SMAT, this sensitivity is expressed as a relative reduction factor (RRF) as

$$\mathrm{RRF} = \frac{\mathrm{Model}_{\mathrm{sens}}}{\mathrm{Model}_{\mathrm{base}}} = \frac{x_s}{x_b} \quad \text{(RRF can be > 1)} \quad (6)$$

where $\mathrm{Model}_{\mathrm{sens}}$ is the speciated concentration as predicted by the model in the sensitivity case and $\mathrm{Model}_{\mathrm{base}}$ is the speciated concentration as predicted by the model in the base case (Table 12). The CMAQ-based RRF is then applied to SMAT's estimated baseline Crustal, EC, OC, SO_4, and NO_3 masses by multiplying each by their corresponding RRF to estimate SMAT concentrations in the sensitivity case (Table 13). For NH_4, the default approach for calculating forecasted concentrations is by applying the same DON value used in the base mass calculation to the forecasted SO_4 and NO_3 masses. The forecasted PBW is calculated by using the polynomial regression mentioned previously. This procedure is applied on a quarterly basis with the average of the four values serving as the annual average. Thus, at the end of the SMAT process, we have a difference in monitored values from the base year to a forecasted year (or scenario), based upon modeled changes.

Table 12. a) Quarterly averaged base05 and airc05 model based concentrations at the grid cell containing LAX. b) RRFs at the grid cell containing LAX as calculated by taking the ratio of the modeled sens case (airc05) concentration to the modeled base case (base05)

a)

Quarter	Crustal ($\mu g\ m^{-3}$)	EC ($\mu g\ m^{-3}$)	OC ($\mu g\ m^{-3}$)	SO_4 ($\mu g\ m^{-3}$)	NO_3 ($\mu g\ m^{-3}$)
base05 concentrations (2005 case without aircraft emissions)					
1	3.2855	1.3971	2.7157	1.3949	3.5015
2	2.4177	0.7919	1.9297	1.5882	2.8364
3	2.9115	0.9295	2.2282	1.6191	2.5491
4	4.2934	1.4373	3.4483	1.2118	2.8029
airc05 concentrations (base05 case plus aircraft emissions)					
1	3.2854	1.4019	2.715	1.3972	3.5117
2	2.4177	0.7964	1.9289	1.5904	2.8496
3	2.9115	0.9356	2.2274	1.6218	2.564
4	4.2933	1.444	3.4474	1.2136	2.8097

b)

Quarter	Crustal	EC	OC	SO_4	NO_3
1	1.0	1.0035	0.9997	1.0017	1.0029
2	1.0	1.0057	0.9995	1.0014	1.0047
3	1.0	1.0066	0.9996	1.0017	1.0058
4	1.0	1.0047	0.9998	1.0014	1.0024

Table 13. Spatially estimated values at LAX in 2005 with aircraft emissions as calculated by multiplying the SMAT base values by their estimated RRF.

Quarter	Crustal ($\mu g\ m^{-3}$)	EC ($\mu g\ m^{-3}$)	NH_4 ($\mu g\ m^{-3}$)	OC ($\mu g\ m^{-3}$)	SO_4 ($\mu g\ m^{-3}$)	NO_3 ($\mu g\ m^{-3}$)	PBW ($\mu g\ m^{-3}$)	$PM_{2.5}$ ($\mu g\ m^{-3}$)
1	0.7906	1.275	1.6719	4.1496	1.7535	3.5822	0.8226	14.6301
2	0.7965	0.7546	1.5457	2.8038	3.4795	0.9626	1.1542	12.0662
3	0.7532	0.8985	1.8231	3.5415	4.7364	0.4069	1.7032	14.4465
4	0.9806	1.7077	1.4494	7.0422	1.9967	2.4574	0.6914	16.8581

Particle Bound Water Adjustment

Due to the methods for calculating and reporting particle bound water by CMAQ and SMAT, a direct comparison of $PM_{2.5}$ becomes difficult. Typically, CMAQ $PM_{2.5}$ is reported as dry $PM_{2.5}$, which excludes PBW. SMAT on the other hand, reports $PM_{2.5}$ as wet $PM_{2.5}$ mass and includes PBW. To further complicate the comparison, CMAQ uses the ISORROPIA thermodynamic model (Nenes et al., 1998) to determine inorganic apportionment and particle bound water whereas SMAT uses the AIM inorganic model. Particle bound water in CMAQ is calculated at the local ambient conditions for each time step and location of the model whereas SMAT calculates PBW at 35% relative humidity and 22 degrees Celsius on a quarterly averaged basis. Thus, CMAQ predicted PBW estimates are typically much higher than those estimated by SMAT. To better compare CMAQ and SMAT estimated PBW, box model simulations were performed using ISOREV (courtesy, Uma Shankar, UNC-IE), where ISORROPIA was run in reverse mode using CMAQ predicted concentrations of ammonium, sulfate, and nitrate from these scenarios to estimate PBW concentrations at the same ambient conditions used in SMAT. We used this mass of PBW to apportion between the nitrate-bound and sulfate-bound CMAQ aerosol concentrations (from each model simulation) to compute wet $PM_{2.5}$ concentrations that would be comparable with SMAT results.

Results

Continental U.S.

Results presented here indicate the change in annual $PM_{2.5}$ concentrations due to aircraft emissions. SMAT results are potential changes in ambient monitored concentrations due to a modeled change from the contribution of aviation emissions. For the CMAQ predicted results, which are calculated as the difference in modeling scenarios, please refer to the main body of this paper.

SMAT point estimate results (at FRM monitored locations alone) for $PM_{2.5}$ concentrations in the continental U.S. indicated aircraft contributed on average 0.0036 µg m^{-3} in 2005 (0.03% increase in total $PM_{2.5}$) and 0.0157 µg m^{-3} (0.13% increase in total $PM_{2.5}$) in 2025. Sulfate was the largest speciated component in 2005, contributing an average of 0.0013 µg m^{-3} (0.04% increase in SO_4). In 2025, nitrate was the largest speciated component, contributing an average of 0.0060 µg m^{-3} (0.88% increase in NO_3) (Figure 19).

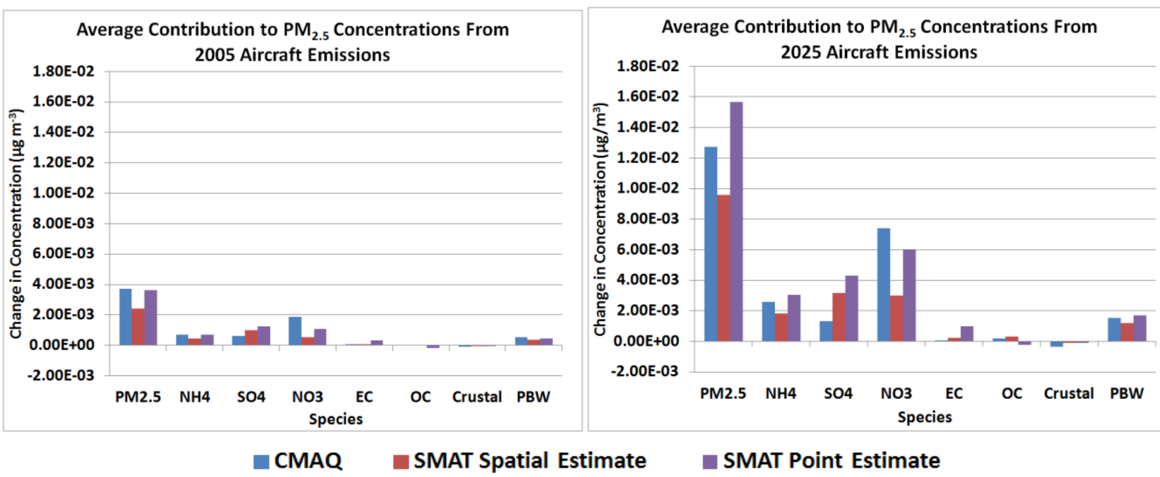

Figure 19. Average change in concentrations due to aircraft emissions in 2005 (left) and 2025 (right).

Spatial estimate SMAT results for $PM_{2.5}$ concentrations indicated an average increase of 0.0024 µg m^{-3} (0.03% increase to total $PM_{2.5}$) due to aircraft emissions in 2005 and an average increase of 0.0096 µg m^{-3} (0.11% increase to total $PM_{2.5}$) from 2025 aircraft emissions in the continental U.S. Sulfate was the largest speciated component in both years, contributing on average 0.0010 µg m^{-3} (0.05% increase to SO_4) and 0.0032 µg m^{-3} (0.15% increase to SO_4), respectively (Figure 19).

Figure 20 indicates regional differences in CMAQ and SMAT results for 2005 and 2025 by plotting the ratio of contributions from aircraft for spatial estimate SMAT results to CMAQ results. SMAT estimates of $PM_{2.5}$ contributions from aircraft are approximately one-fourth to three-fourths of those as predicted by CMAQ across much of the central and eastern portions of the U.S. Areas where

SMAT results appear larger than CMAQ results occur primarily in the western U.S., notably in areas where SMAT predicts higher contributions of NO_3 from aircraft than those predicted by CMAQ. SMAT contributions from aircraft to NO_3 are sharply reduced as compared to CMAQ, particularly in the southeastern U.S., where SMAT predicted contributions of aircraft to NO_3 are approximately one-tenth of those as estimated by CMAQ.

Comparison of Hartsfield-Jackson Atlanta International Airport and Los Angeles International Airport

To better quantify the regional differences in CMAQ results after applying SMAT, presented here is a comparison of results from Atlanta Hartsfield International (ATL) (the busiest airport in the world based on 2008 passenger traffic) and LAX (the 6th busiest airport in the world based on 2008 passenger traffic) (Airports Council International, 2010). Additionally, these 2 airports are situated in

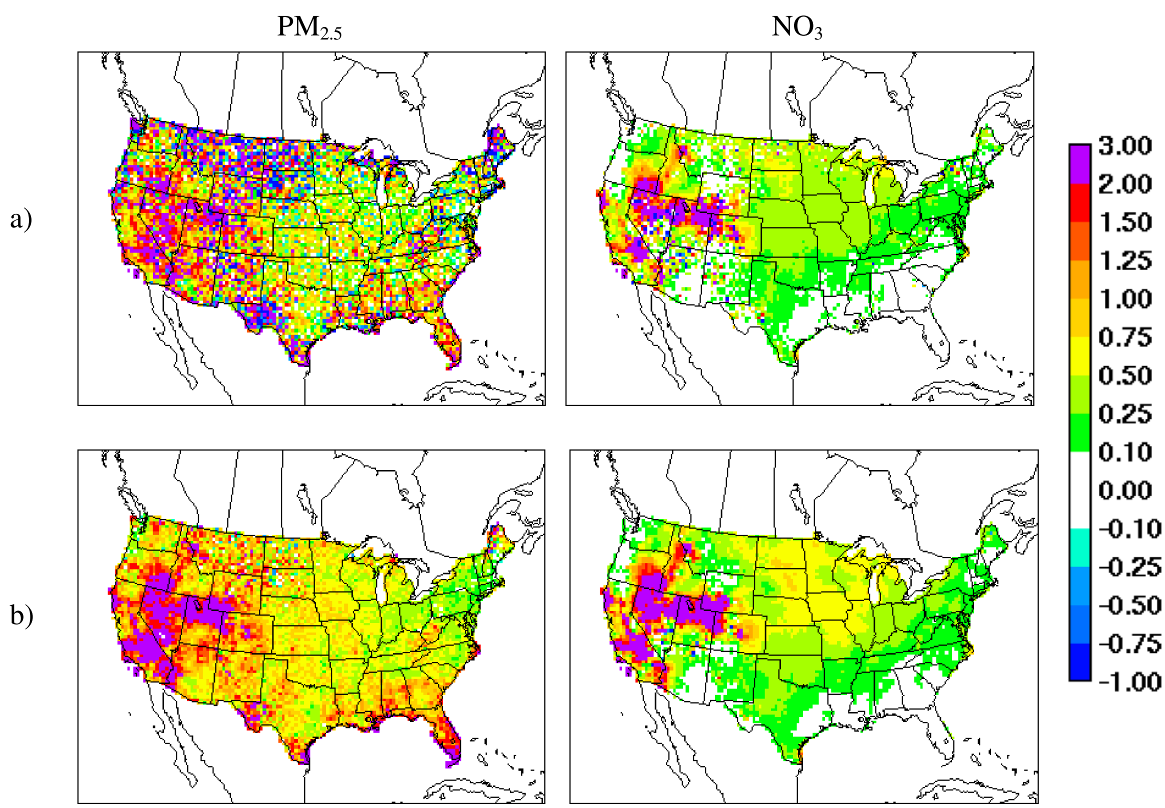

Figure 20. Ratio of changes due to aircraft as predicted by spatially estimated SMAT results to CMAQ results for $PM_{2.5}$ (left) and NO_3.(right), for a) airc05-base05, and b) airc25-base25

locations that have distinct chemical regimes during the summer and winter seasons. In summer, the inorganic portion of $PM_{2.5}$ is dominated by sulfate in the eastern U.S. while sulfate and nitrate are approximately equivalent in the western U.S. (Bell et al., 2007). In winter, sulfate and nitrate are approximately equivalent in the eastern U.S. while nitrate dominates in the western U.S. (Bell et al., 2007).

At ATL, SMAT spatial estimates of $PM_{2.5}$ increased by 0.0016 µg m^{-3} (0.01% increase in total $PM_{2.5}$) and 0.0907 µg m^{-3} (0.57% increase in total $PM_{2.5}$), respectively. EC had the largest contribution in 2005 with a concentration of 0.009 µg m^{-3} (0.79% increase to EC). SO_4 had the highest contribution in 2025, with an increase of 0.0351 µg m^{-3} (0.76% increase to SO_4) (Figure 21).

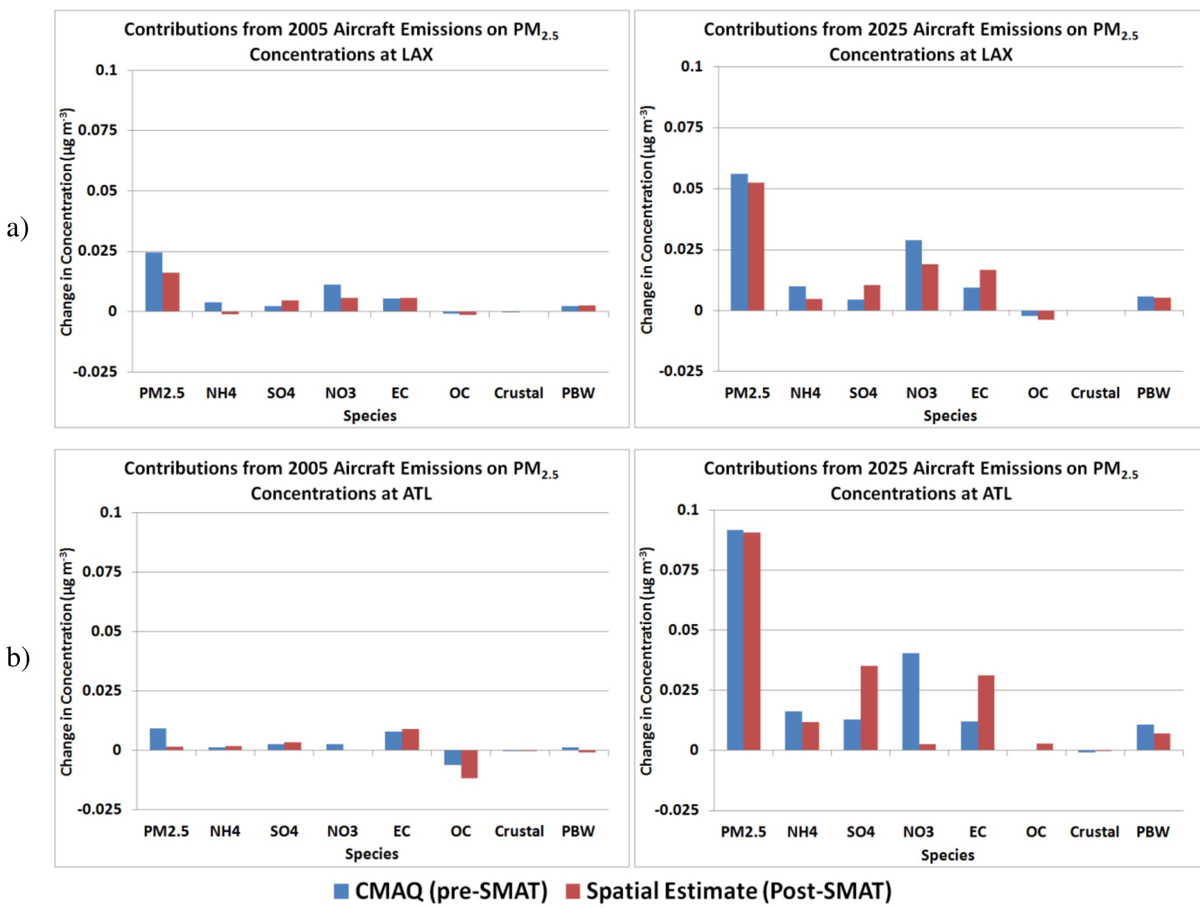

Figure 21. Change in $PM_{2.5}$ concentrations due to aircraft emissions in 2005 (left) and 2025 (right) at a) LAX, and b) ATL.

Discussion

On an annual average basis across the continental U.S., one of the primary differences in the contributions predicted by CMAQ and SMAT results is in the inorganic (NH_4, NO_3, SO_4) apportionment of $PM_{2.5}$ mass. CMAQ predicted that the largest speciated contribution from aircraft emissions was from NO_3 while SMAT results indicated that SO_4 had the largest speciated contributions to total $PM_{2.5}$ due to aircraft emissions. Although SMAT uses the predicted changes to inorganic species from CMAQ (RRF values) to ultimately forecast the concentrations of the sensitivity cases, the differences in CMAQ and SMAT results can be attributed to differences in monitoring data and CMAQ predicted base concentrations. Figure 22 plots base case CMAQ concentrations against spatial estimate SMAT base concentrations for NO_3, SO_4, and $PM_{2.5}$ at locations where an airport and speciated monitor are collocated within a grid cell. $PM_{2.5}$ concentrations are roughly equivalent between the two in 2005 while CMAQ base concentrations appear lower than SMAT concentrations in 2025. Sulfate concentrations are typically higher in the SMAT base case than in the CMAQ base case while nitrate concentrations are typically lower for both 2005 and 2025. Also, SMAT base case estimates exhibit higher sulfate concentrations and lower nitrate concentrations overall. While ambient data indicate there are higher concentrations of sulfate than nitrate, uncertainties remain (and possible underpredictions) in nitrate measurements due to its volatility. This limitation with NO_3 measurements has led to a lack of routine speciated $PM_{2.5}$ mass measurements available outside of the U.S. and is one reason as to why SMAT is only applied in the U.S.

CMAQ has typically shown poor performance for predicting nitrate concentrations, overpredicting during winter months when conditions favor nitrate aerosol formation (Tesche et al., 2006). An analysis of the base05 case was performed using the Atmospheric Model Evaluation Tool (AMET), which compares modeled data against monitoring data, and indicated that CMAQ overpredicted NO_3 in winter months with both a high normalized mean bias (~75%) and high normalized mean error (~100%).

It is this combination of overall higher SO_4 to NO_3 concentrations in the SMAT base case as well as higher predicted SO_4 and lower predicted NO_3 concentrations as compared to the CMAQ base case which leads to the difference in organic apportionment. When an RRF is applied to a higher base value (SO_4), the contribution from aircraft will be predicted to be higher than if it were applied to a lower base value (NO_3). Similarly, when an RRF value is applied to a higher base value in SMAT than that predicted

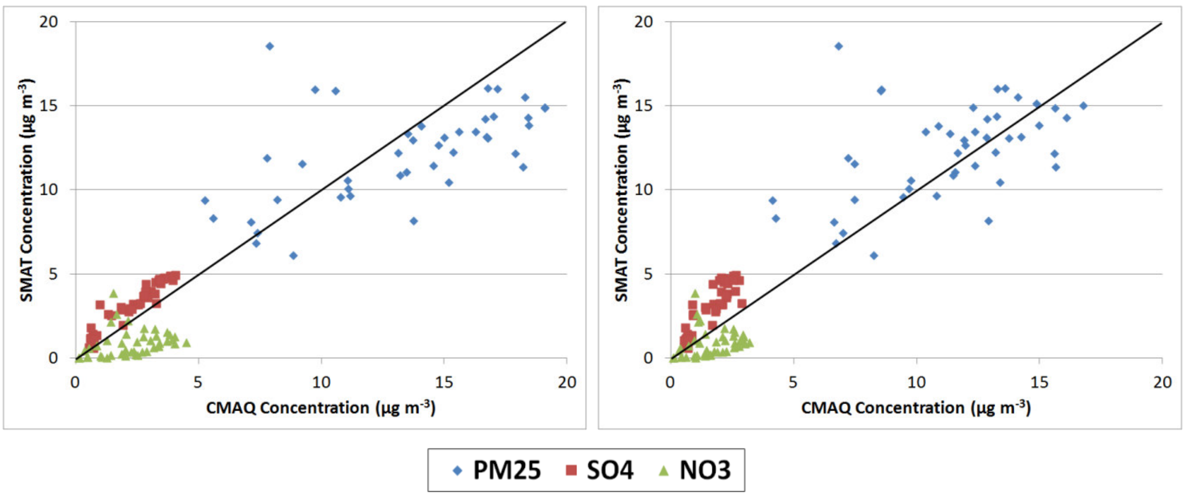

Figure 22. CMAQ vs. SMAT scatter plots of NO_3, SO_4, and $PM_{2.5}$ base concentrations in 2005 (left) and 2025 (right) where airport and speciated monitors are collocated.

by CMAQ, the overall contribution from aircraft as predicted by SMAT becomes greater than that predicted by CMAQ. The opposite is true for a lower value, the overall contribution from aircraft as predicted by SMAT becomes less than that predicted by CMAQ.

Comparing the overall changes in $PM_{2.5}$ mass, it is noteworthy that CMAQ as well as SMAT's point estimates exhibit larger total changes than those calculated by SMAT's spatial estimate. The larger changes in the point estimate can be attributed to the fact that FRM monitors (the points) are typically located in urban areas and lead to an urban bias. Another contributing factor associated with the bias in point estimate is that the points are located near airports considered in the study.

The LAX and ATL comparison illustrates regional differences between CMAQ and SMAT results. The contributions of NO_3 from aircraft are essentially removed by performing SMAT at ATL, while at LAX they are simply reduced. This difference is attributed to ambient nitrate (as measured by the monitor) being significantly lower at ATL. Although similar RRF values for NO_3 are applied (1.0103 at LAX and 1.0194 at ATL for 2025), a smaller base value at ATL propagates to a smaller increase in the estimated contribution from aircraft. Also apparent in the comparison is the reduction of OC concentrations with the addition of aircraft emissions. Our previous investigations into this issue have indicated that aircraft emissions can cause reductions of OC in CMAQ, specifically the Secondary Organic Aerosol (SOA) component. Aircraft emissions at the airport react and remove free radicals that would otherwise participate in the creation of SOA (Woody and Arunachalam, 2010).

Results from this work were provided to the PARTNER's Project 11 team at the Harvard School of Public Health to quantify the health impacts of aircraft emissions as it relates to $PM_{2.5}$ contributions. Because differences in CMAQ and SMAT results cause changes in the relative importance of $PM_{2.5}$ speciated components, these speciated differences affect the health impact analysis. Since the magnitude of potential health impacts are used to identify and develop emissions control strategies, the use of CMAQ or SMAT results become significant as to which speciated component to prioritize to protect public health.

Conclusions

Aircraft emissions are found to increase $PM_{2.5}$ concentrations in 2005 and 2025, using both CMAQ output and those output processed by SMAT, with the largest contributions occurring in the future year. CMAQ predicted aviation contributions to $PM_{2.5}$ in the U.S. were on average 0.0037 $\mu g\ m^{-3}$ in 2005 and 0.0127 $\mu g\ m^{-3}$ in 2025 while SMAT spatially adjusted estimates predicted contributions of 0.0024 $\mu g\ m^{-3}$ in 2005 and 0.0096 in 2025 $\mu g\ m^{-3}$. The combination of higher amounts of aircraft emissions and lower background emissions in the future lead to the increased absolute contributions of $PM_{2.5}$ from aircraft.

The primary differences between predicted $PM_{2.5}$ contributions from aircraft emissions in CMAQ and SMAT are in the inorganic apportionment as CMAQ predicts NO_3 to be the largest speciated contributor (contributing on average 0.0019 µg m^{-3} and 0.0074 µg m^{-3}) to $PM_{2.5}$ while SMAT predicts SO_4 as the largest contributor (contributing on average 0.0010 µg m^{-3} and 0.0032 µg m^{-3}). SMAT also reduces the average $PM_{2.5}$ contribution from aircraft in its spatial estimate. SMAT point estimate results, with its clear urban bias, more closely resembles CMAQ predicted $PM_{2.5}$ aviation contributions. Based on these results, one might conclude that either CMAQ results overpredict or SMAT results underpredict the impact of aircraft emissions on changes to $PM_{2.5}$ concentrations. It is difficult to know which one of these is closer to the actual impacts due to aviation emissions. Furthermore, there are a number of obstacles making a direct comparison between the two difficult.

One such obstacle is that SMAT results include PBW in $PM_{2.5}$ concentrations and calculate PBW at standard conditions. However, we were able to address this key issue in this study, and facilitate a better comparison of CMAQ and SMAT results by including PBW in CMAQ $PM_{2.5}$ concentrations that were calculated at the same standard conditions as those of SMAT.

One advantage to using SMAT is that it removes some of the uncertainties associated with modeling results, by focusing on using models in a relative sense. For example, the accuracy of emission inventories used in models is often questioned. By using SMAT, these uncertainties in the base emissions are reduced because the baseline $PM_{2.5}$ mass is based on ambient monitoring data. However, SMAT has its own set of uncertainties associated with it, such as the uncertainty involved in the volatilization of $PM_{2.5}$ mass and different sampling protocols between networks.

SMAT results are based on ambient measurements taken at monitoring locations across the U.S. and reflect ambient levels that populations are ultimately being exposed to. Therefore, SMAT results could be used to access potential health effects. However, as the results from this case study illustrate, the CMAQ contributions as compared to spatial estimated SMAT contributions indicate greater impacts on air quality. In fact, the CMAQ results are more in line with the urban biased

SMAT point estimate results. Furthermore, the spatial analysis of CMAQ and SMAT results indicate that SMAT aviation contributions were smaller in the eastern U.S. (areas with higher population densities) and higher in portions of the western U.S. (areas of lower population). Thus, SMAT results could cause health impacts to be biased low as compared to CMAQ results due to a higher proportion of the population being exposed to lower contributions of aircraft emissions to $PM_{2.5}$ concentrations.

There are limitations and assumptions both in CMAQ raw results and those post-processed using SMAT. For example, SMAT results are limited by ambient monitoring data available. It would be difficult to investigate scenarios where ambient conditions improve or worsen from currently sampled ambient conditions (e.g. future year conditions with increased regulations and better ambient conditions). CMAQ, on the other hand, represents the current scientific understanding of the environment, and while great strides have been made in the past decade and more, all atmospheric pathways of particulate matter formation are still not fully understood or incorporated in the model at this time.

Is post-processing CMAQ results using SMAT the best practice for determining contributions from aircraft emissions on $PM_{2.5}$ concentrations for performing health risk assessments? SMAT may be a valuable tool in determining current year contributions of aircraft emissions on air quality; however, in the case of future year air quality, ambient conditions may change significantly from current conditions, nullifying SMAT's advantage of results based on ambient conditions. Furthermore, SMAT is typically used to analyze emission reduction strategies on large scale emission sectors. Using it to analyze a relatively smaller emission sector, such as aircraft (compared to other anthropogenic sources), may stretch the limits of the tool. This is evident in the limited precision available in the algorithms used in SMAT where calculations are typically carried out to only 3 decimal places. For $PM_{2.5}$ concentrations, values are reported to 2 decimal places (which may not accurately capture the small incremental contribution from aircraft to $PM_{2.5}$) and require using the sum of speciated components instead of the reported $PM_{2.5}$ values to increase precision. For these reasons, while the SMAT process is a valuable tool that provides a better understanding of model results, we have identified several limitations in its current form for determining contributions of aircraft emissions to air quality, both present and future.

Appendix D - CMAQ Model Evaluation

One of the primary goals of environmental models is to accurately predict real world conditions in order to aid in policy decisions, assess impacts, or provide forecasting. A common method used to evaluate model performance is to compare model results with observed values from ambient air quality monitors. While comparing a grid cell (volumetric) average to a specific location presents a fundamental source of uncertainty, particularly in areas with strong subgrid-scale gradients, the method is currently considered best practice. Here, the Atmospheric Model Evaluation Tool (AMET) (Appel and Gilliam, 2008a) is employed to pair model results and observations in space (no spatial interpolation) and time for 1-h and 8-h peak ozone, nitric acid (HNO_3), fine particulate matter ($PM_{2.5}$), and sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), organic carbon (OC), and element carbon (EC) aerosols.

A 2005 annual simulation was performed using the Community Multiscale Air Quality (CMAQ) (Byun and Ching, 1999; Byun and Schere, 2006) v4.6 model over the contiguous U.S. at a 36-km grid resolution. The model simulation utilized the carbon bond 05 (CB05) mechanism and aerosol 4 module. Meteorological input was generated using the Pennsylvania State University/NCAR mesoscale v3.7 model (MM5) (Grell et al., 1994). Emissions data, based on the Environmental Protect Agency's (EPA) 2005 National Emissions Inventory (NEI) (EPA, 2007a), was processed through the Sparse Matrix Operator Kernel Emissions (SMOKE) v2.5 model (Houyoux et al., 2000).

Observational data was used from five monitoring networks, the Air Quality System (AQS) network, Clean Air Status and Trends Network (CASTNet), Speciated Trends Network (STN), Interagency Monitoring of Protected Visual Environments (IMPROVE) network, and Federal Reference Method (FRM) network. AQS collects hourly data nationwide for a number of species with ozone the only one considered here. CASTNet collects samples of inorganic aerosols (SO_4, NO_3, and

NH_4) and HNO_3 at weekly intervals and is located primarily in rural areas in the eastern U.S. (Eder and Yu, 2006). STN collects daily average samples of SO_4, NO_3, NH_4, EC, OC as well as $PM_{2.5}$ every third day with most monitors located in urban areas (Eder and Yu, 2006). IMPROVE follows a similar sampling pattern to STN and collects daily average samples every third day of $PM_{2.5}$, SO_4, NO_3, NH_4, OC, and EC and is located in National Parks throughout the U.S. with the majority in the western U.S. (Eder and Yu, 2006). For IMPROVE, however, only measurements of $PM_{2.5}$, sulfate, nitrate, and ammonium aerosols are considered here. FRM collects daily average samples of PM2.5 every third day and results are used by the EPA to determine attainment/non-attainment of the EPA's National Ambient Air Quality Standards (NAAQS). No adjustments were made for differences in sampling protocols across the various networks and is beyond the scope of this work.

Performance Metrics

There are a number of performance metrics available when comparing model results with observations. Here, the two primary metrics used are the normalized mean error (NME), which ranges from -100% to +∞ and normalized mean bias (NMB), which ranges from 0% to +∞, defined as:

$$NME = \frac{\sum_{i=1}^{N} |C_m - C_o|}{\sum_{i=1}^{N} C_o}$$

$$NMB = \frac{\sum_{i=1}^{N} (C_m - C_o)}{\sum_{i=1}^{N} C_o}$$

where C_m is the model estimated concentration at station i, C_o is the observed value at station i, and N is the number of observation-model pairs for the time period considered (Boylan and Russell, 2006).

Ozone

Ozone performance was evaluated for May through September, months that typically exhibit high ozone concentrations. Figure 23 indicates the NME and NMB for both 1-h and 8-h max ozone. Low NME and NMB for both the 1-hand 8-h metrics indicate good model performance.

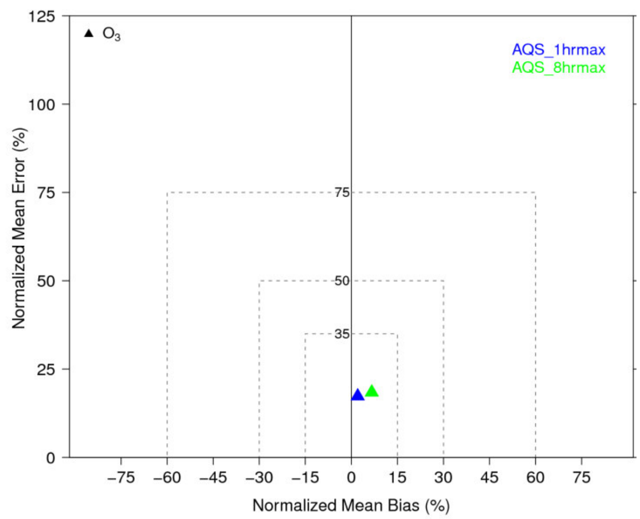

Figure 23. NME and NMB of 1-h and 8-h max ozone averaged across continental U.S. for May through September.

While the NME and NMB averaged across the continental U.S. indicate good model performance, Figure 24 provides the spatial NME for the 1-h ozone values. CMAQ exhibited poor performance in coastal regions by overpredicting 1-h and 8-h max ozone values. Eder and Yu (2006) also reported similar results using CMAQ v4.4 attributing the poor performance along the coast to a poor representation of coastal boundary layers and interaction with land/sea breezes by MM5 (Gilliland et al. 2006).

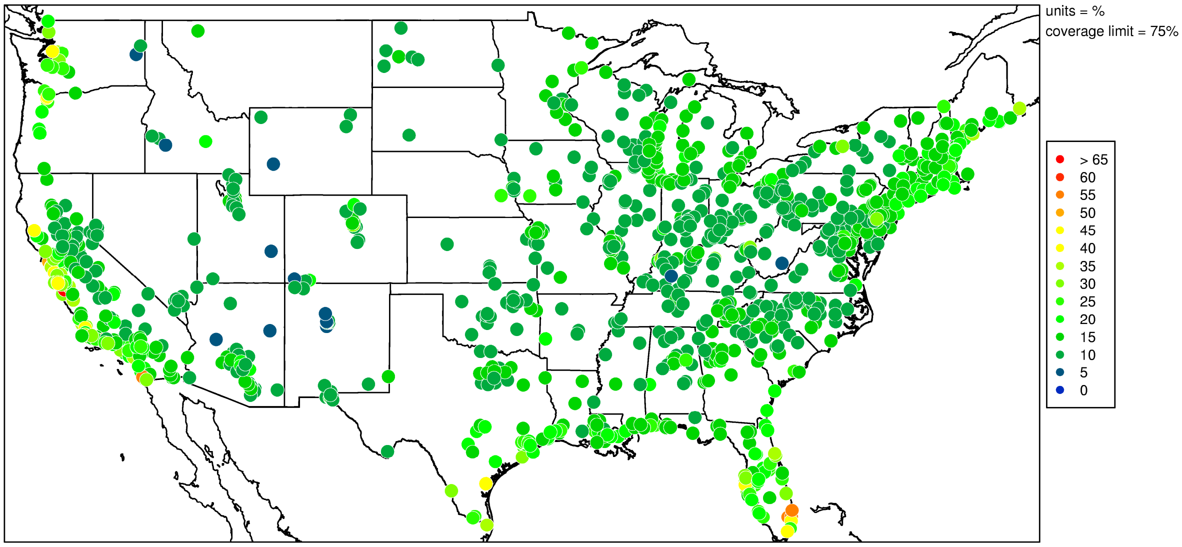

Figure 24. NME for 1-h max ozone values as compared to the AQS monitoring network for May through September.

Sulfate

CMAQ performed reasonably well for SO_4 with annual average NME values of 45.8%, 42%, and 40.9% when compared to observations from IMPROVE, STN, and CASTNet, respectively. NMB values (-36.4%, -36%, and -38.8%, respectively) indicate a tendency to underpredict concentrations. This underprediction occurred throughout the year (Figure 25) with no seasonal or regional bias. However, Figure 26 indicates that CMAQ performed well in the eastern U.S but poorly in the western U.S.

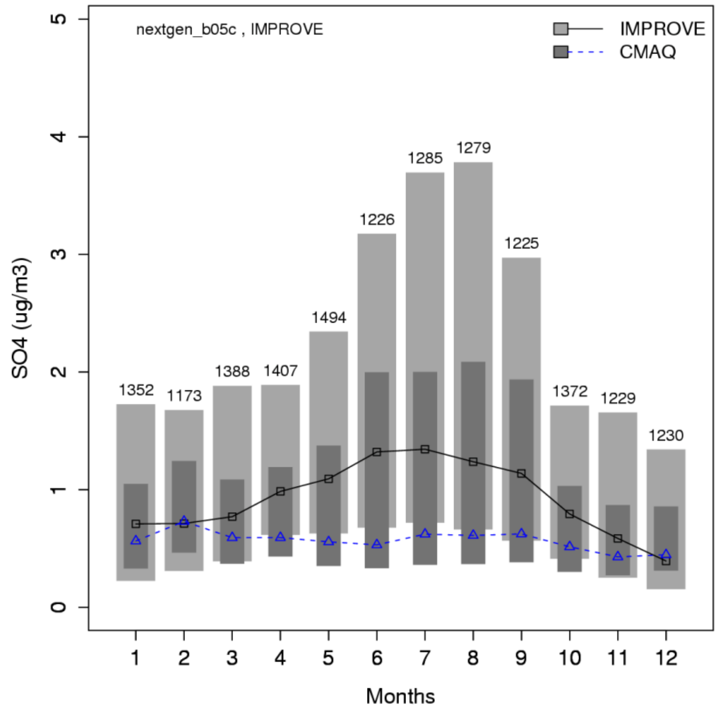

Figure 25. CMAQ and IMPROVE 2005 monthly average SO_4 concentrations at IMPROVE monitoring sites across the continental U.S.

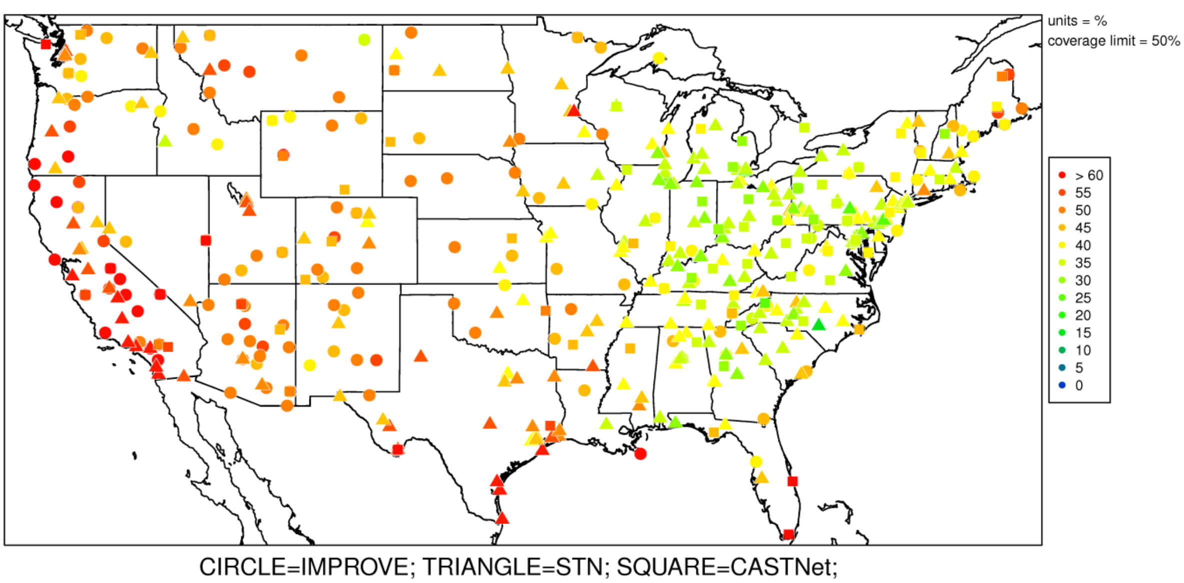

Figure 26. 2005 annual average SO_4 NME.

Nitrate

CMAQ exhibited poor performance for NO_3 when compared against IMPROVE, STN, and CASTNet observations with annual average NMEs of 119.8%, 86.1%, and 119.1% and NMBs of 62.8%, 32.3%, and 81.1%, respectively. Furthermore, CMAQ overpredicted NO_3 concentrations during winter months when NO_3 concentrations are typically higher and underpredicted NO_3 concentrations during summer months (Figure 27). Figure 28 indicates that the overprediction of NO_3 in January occurs primarily in the eastern U.S. Yu et al. (2005) have indicated that errors in model predictions of NH_4^+ and NH_3, SO_4^{-2}, and to a lesser extent HNO_3 and NO_3^- hinder CMAQ's ability to accurately predict NO_3 across the eastern U.S.

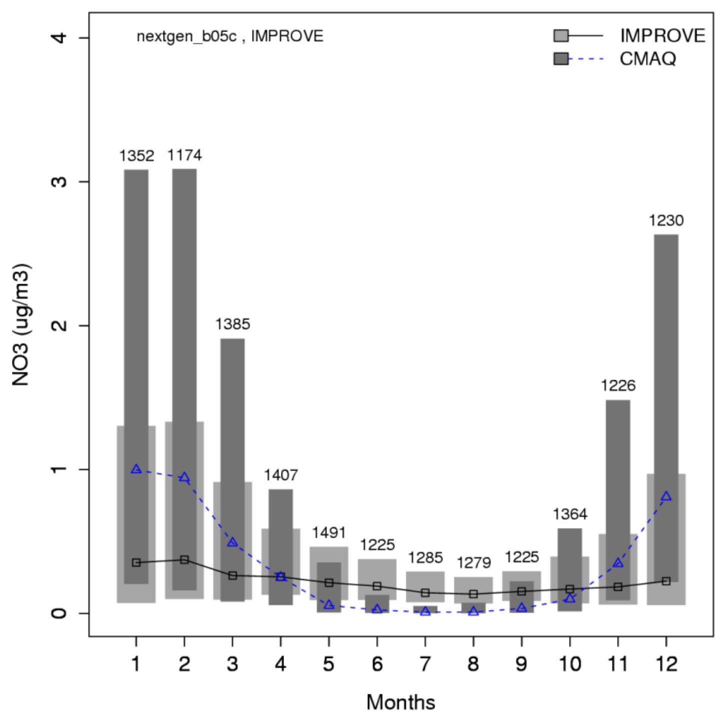

Figure 27. CMAQ and IMPROVE 2005 monthly average NO_3 concentrations at IMPROVE monitoring sites across the continental U.S.

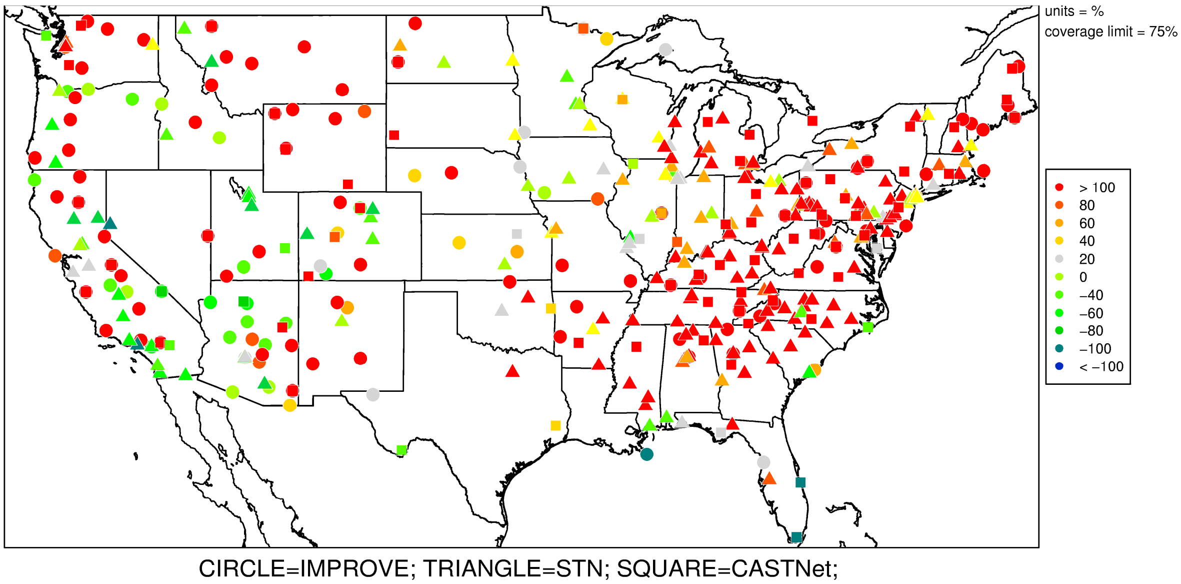

Figure 28. January monthly average NO_3 NMB.

Nitric Acid

While model performance for NO_3 was relatively poor, CMAQ performance relative to HNO_3 was good with a NME of 66.3% and NMB of 33.8% compared against CASTNet observations. CMAQ tended to underpredict HNO_3 concentrations during winter months and overpredict during summer months. This suggests that CMAQ incorrectly predicts nitrate partitioning, predicting excess nitrate in the aerosol phase during winter months and excess nitrate in the gas phase during summer months.

Ammonium

Performance for NH_4 fell somewhere between that of SO_4 and NO_3 with annual NME values of 67.1%, 45.4%, and 43.5% and NMB values of 20.5%, -12.2%, and -8.6% for IMPROVE, CASTNet, and STN, respectively. The high NME and positive NMB associated with the IMPROVE network is associated with monitors located in the southeastern U.S. (Figure 29). Temporally, CMAQ overpredicted NH_4 during winter months due to overpredictions of NO_3 and underpredicted during summer months due to underpredictions of both NO_3 and SO_4.

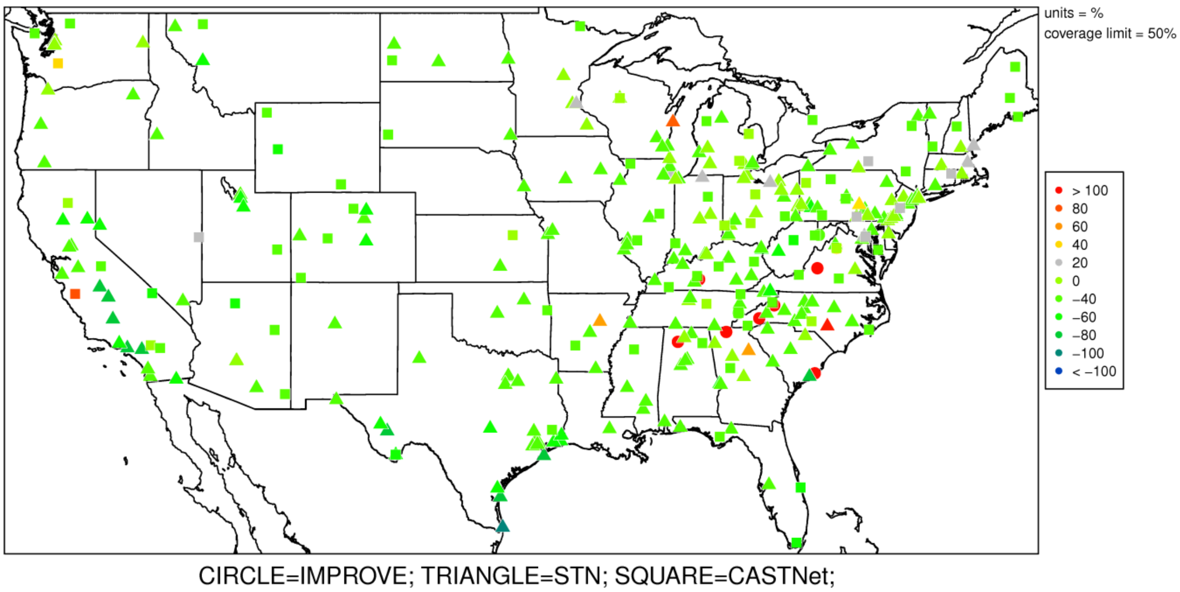

Figure 29. Annual average NH_4 NMB.

Organic Carbon

Comparisons against observations from STN monitors indicates CMAQ exhibited reasonable performance for OC with a NME of 59.5% and a NMB of -48.2. Underprediction occurred throughout the year as well as throughout the U.S. with minimal variation in regional performance. One possible reason as to the underprediction of OC is uncertainty associated with modeling secondary organic aerosols (SOA). Recent updates to CMAQ have attempted to address this issue with the addition of several new SOA formation pathways in CMAQ (v4.7) as part of the aerosols 5 module (Foley et al., 2010).

Elemental Carbon

CMAQ performed relatively well for EC as compared to STN monitors with annual average NME of 65.7% and a NMB of 1.3%. While the low annual average NMB suggests CMAQ tended to only slightly overpredict EC, the value is in fact a combination of overpredictions and underpredictions dispersed spatially and temporally. Given that EC is a primary, non-volatile species in CMAQ, performance issues associated with it likely stem from uncertainties in emission inventories.

$PM_{2.5}$

Given that CMAQ predicted $PM_{2.5}$ concentrations are the sum of SO_4, NO_3, NH_4, EC, OC, and an "other" constituent, it follows that performance is tied to each individual species. Overall performance was good with annual average NME values of 56.7%, 42.7%, and 42.9% and NMB values of 1.7%, -11.4%, and -10.8% compared against IMPROVE, STN, and FRM monitors, respectively. However, the annual average NMB is again misleading, where overpredictions occurred during winter months and underpredictions occurred during summer months, similar to NO_3 (Figure 30). Spatially, sites across the U.S. tended to underpredict $PM_{2.5}$ with IMPROVE sites located in the western U.S. as the primary exceptions (Figure 31).

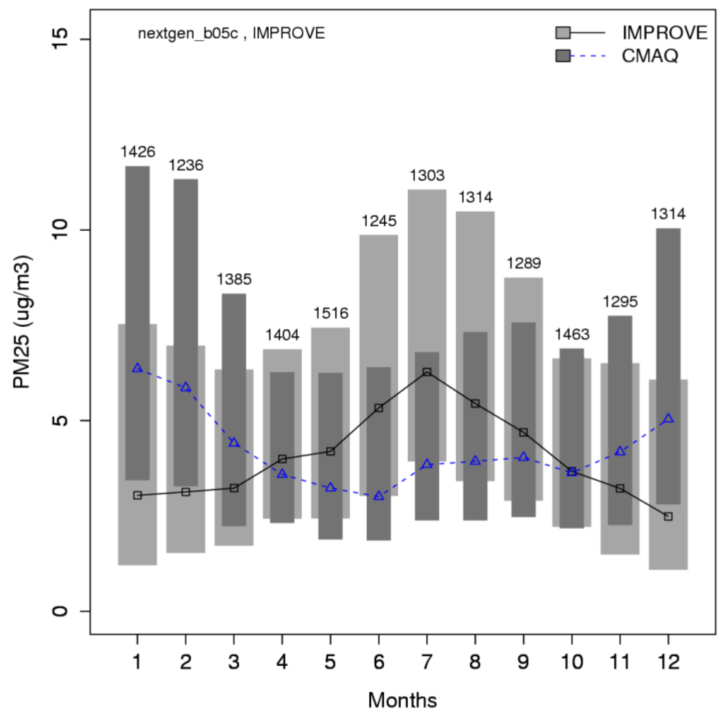

Figure 30. CMAQ and IMPROVE monthly average $PM_{2.5}$ concentrations at IMPROVE monitoring sites located through the continental U.S.

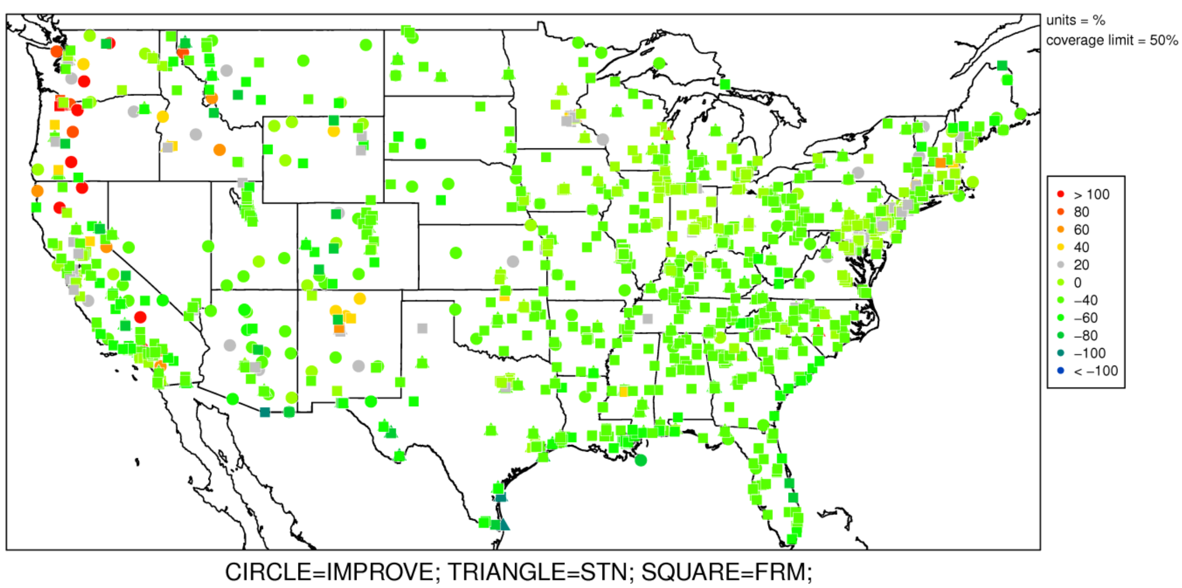

Figure 31. Annual average $PM_{2.5}$ NMB.

Summary

We used the Atmospheric Model Evaluation Tool to compare CMAQ results from a 2005 annual simulation against observations from AQS, STN, IMPROVE, CASTNet, and FRM networks. Results indicated good agreement of model and observations for 1-h and 8-h ozone maxima, reasonable agreement for SO_4, NH_4, HNO_3, OC, EC, and $PM_{2.5}$, and poor agreement for NO_3. Given these results are within the range of those reported by comparable studies (Boylan and Russell, 2006; Eder and Yu, 2006; Tesche et al. 2006; and Appel et al., 2008b, Foley et al., 2010), we conclude that model performance is acceptable.

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