Project 018 Health Impacts Quantification for Aviation Air Quality Tools

Boston University

Project Lead Investigator

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University Participants

Boston University

- P.I.: Jonathan I. Levy, Professor and Associate Chair
- FAA Award Number: 13-C-AJFE-BU, Amendment 3
- Period of Performance: October 1, 2014 – September 30, 2015
- Tasks:
    - 1. Collaborate with investigators in ASCENT COE-2014-19 to directly model the majority of aviation emissions within the US using CMAQ-DDM atmospheric modeling.
    - 2. Use spatial pollutant concentration surfaces from the subset of airports directly modeled to derive a series of damage functions, using the BenMAP-CE analytical tool and incorporating concentration-response functions derived from the epidemiological literature.
    - 3. Explore variability in damage functions across airports, including through regression models using meteorological and population data.
    - 4. Apply the health damage functions (all airports) and spatial pollutant concentration surfaces (directly modeled airports) to evaluate hypothetical policy scenarios.
    - 5. Compare aviation-related health impacts as well as damage functions with those from other important source sectors.

Project Funding Level

$150,000. Matching funds at 75:25 level from the North American Insulation Manufacturers Association (related to Task 5).

Investigation Team

Principal Investigator: Jonathan I. Levy, Sc.D. (Professor of Environmental Health, Department of Environmental Health, Boston University School of Public Health). Dr. Levy is the Boston University PI of ASCENT. He has primary responsibility for the execution of the project and contributes to manuscripts and reports produced.

Graduate Student/Post-doctoral researcher: Stefani Penn, MS, PhD (BUSPH). Dr. Penn leads the analytical efforts to develop the individual airport health damage function model, as part of her dissertation work, including the effort to design individual airport atmospheric modeling runs and to estimate health damage functions.

Research Assistant: May Woo (BUSPH). Ms. Woo supports both Dr. Levy and Dr. Penn, conducting data management efforts and working with BenMAP-CE.

Project Overview

The objective of this activity, in conjunction with ASCENT COE-2014-19, is to develop flexible modeling tools to leverage outputs from CMAQ-DDM atmospheric modeling and enable quantitation and rapid characterization of airport-specific health impacts from a number of airports across the US to analyze health benefits of alternative policy measures. These tools are meant to provide outputs to relevant decision makers quickly, allowing for analysis of numerous comparative scenarios. The following attributes will be included in the modeling tool:

- Enable the assessment of premature mortality and morbidity risk due to aviation-attributable $PM_{2.5}$ and ozone from aviation landing and takeoff (LTO) emissions;
- Model aviation-related impacts both directly through CMAQ-DDM and indirectly through statistical extrapolation to non-modeled airports;
- Capture airport-specific health impacts at a regional and local scale;
- Allow for the assessment of a wide range of aircraft emissions scenarios, including differential growth rates and emissions indices;
- Compare aviation-related emissions and health impacts with those of other prominent source sectors using the same modeling techniques; and
- Be computationally efficient such that the tool can be used in time-sensitive rapid turnaround contexts and for uncertainty quantitation.

Task 1 - Collaborate with investigators in ASCENT COE-2014-19 to directly model the majority of aviation emissions within the US using CMAQ-DDM atmospheric modeling

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Objective(s)

The primary objective of this task is to optimally design CMAQ-DDM runs to allow for the estimation of concentration impacts and resulting health risks from individual airports, in a form that would allow for extrapolation to unmodeled airports. Specific activities include preliminary work using pilot CMAQ-DDM runs to create optimal run designs (done within an earlier PARTNER project), post-processing of CMAQ-DDM outputs to determine whether plumes from individual airports could be adequately separated, and iterative run refinement to yield a robust set of individual airport health damage function estimates.

Research Approach

Given the initial design of experiments based on pilot CMAQ-DDM runs (completed as part of PARTNER and described elsewhere), we received CMAQ-DDM output files that included 66 airports across 30 runs, which collectively accounted for 77% of the total annual fuel burned from commercial passenger flights in 2005. CMAQ-DDM runs therefore included 1-4 airports per run, with the need to separate the contribution of individual airports. To do so, we developed and applied image segmentation techniques using MATLAB 8.1.0, R2013a (MathWorks, Natick, MA). For each emitted precursor / ambient pollutant relationship for each group and month (January and July), a region growing algorithm was developed to determine the concentration regions attributable to each individual airport. The algorithm used an iterative region growing technique with threshold values for inclusion, which continued until at least 95% of the total mortalities from the run were included and the threshold values were less than 10% of the maximum nearby concentration for all airports. The algorithm accounted for both positive and negative concentrations, as seen for secondary pollutant formation, and had modules to ensure that smaller airports could have the full extent of their health impacts captured. In post-processing, regions were masked by the land of the contiguous United States and small holes within each region (< 3 grid cells in any direction) were filled to form contiguous concentration areas for each individual airport to include areas with smaller emissions-related sensitivities that were not originally picked up by the algorithm yet are within the geographical region of emissions from that airport. We conducted multiple quality assurance analyses, including visual inspection of attributable concentration surfaces and examination of resulting health damage function distributions. CMAQ-DDM runs that were deemed to include airports whose emissions overlapped were removed post-hoc and re-run individually.

Milestone(s)

The major milestone for this task was the development of the statistical approach to separate individual airport plumes, a necessary step for the estimation of individual airport health damage functions. This approach was developed and evaluated in a timely fashion, allowing for other tasks to be completed as indicated.

Major Accomplishments

The novel image segmentation technique, drawn from medical imaging, coupled with the insights available from CMAQ-DDM runs, allowed us to develop the first set of precursor-specific and airport-specific estimates of health damages. This provides the foundation of all subsequent tasks as well as information that could directly inform FAA policy.

Publications

None (precursor to future tasks)

Outreach Efforts

- S. Boone, S. Penn, J. Levy, S. Arunachalam. Calculation of sensitivity coefficients using CMAQ-DDM for individual airport emissions in the United States. ITM 2015, Montpellier, France, May 2015.

Awards

Stefani Penn - 10th Annual Joseph A. Hartman Student Paper Competition Award, 1st Place (2014)

Student Involvement

Work led by Stefani Penn as a doctoral student (graduated 9/15).

Plans for Next Period

None – task completed as proposed.

Task 2 - Use spatial pollutant concentration surfaces from the subset of airports directly modeled to derive a series of damage functions, using the BenMAP-CE analytical tool and incorporating concentration-response functions derived from the epidemiological literature

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Objective(s)

With the completion of Task 1, we have a series of files linking individual emitted pollutants (e.g., NOx, SO_2, VOC, PEC, POC, PSO4) with concentration surfaces of $PM_{2.5}$ and ozone for individual airports. The primary objective of Task 2 is to construct the related health damage functions, merging the concentration surfaces with concentration-response functions, population data, and baseline morbidity/mortality rates.

Research Approach

To determine the relationship between the change in air quality associated with individual airport emissions and human health impacts, we used standard health damage function modeling approaches where i is row number, j is column number, N is total number of rows and M is total number of columns in the CMAQ grid. Δy is the change in mortality across the continental US, y_0 is the all-cause baseline mortality incidence rate in grid cell at location ij, β is the concentration-response function as derived from the epidemiological literature, Δx is the change in air quality for a given precursor in grid cell ij, and Pop is the population of interest in grid cell ij.

$$\Delta y = \sum_{i=1}^{N} \sum_{j=1}^{M} (y_{0ij}(e^{\beta \cdot \Delta x_{ij}} - 1) \cdot Pop_{ij})$$

For $PM_{2.5}$, we applied a 1% increase in mortality associated with a 1 $\mu g/m^3$ increase in annual ambient $PM_{2.5}$ concentrations, a central estimate used in many previous health damage function models that is consistent with expert opinions and bounded by reported values from major cohort studies. For O_3, we developed a concentration-response function central estimate of a 0.4% increase in daily mortality per 10 ppb increase in daily 8-hour maximum O_3 concentrations, based on an average of 6 major meta-analyses or multi-city studies. In work to date, we have not yet incorporated morbidity outcomes but have developed the concentration-response functions and assembled the necessary baseline incidence/prevalence data to allow us to do so if of interest to FAA and other stakeholders

County-resolution populations and baseline mortality rates for individuals age 25 and over were retrieved from CDC WONDER for 2001-2010 to estimate mortality for 2005. Using ArcMap v.10.1, mortality rate and population data by county were projected as Lambert conformal conic and intersected with CMAQ grid cells and mortality and population values were determined for each grid cell, assuming uniform density of population and mortality rates within counties.

Health damages were then calculated for summer and winter months separately to showcase seasonal variability, as well as on average per year by assuming that each of the January and July concentration surfaces represented half of the year, and dividing the total annual mortality risk by the total annual emissions for each precursor type for each airport. Health damage functions were reported per 1,000 tons of precursor emissions for ease of interpretation.

Milestone(s)

The major milestone for this task was the calculation of airport-specific health damage functions for all 66 modeled airports by precursor. This milestone was completed as proposed.

Major Accomplishments

Health damage functions for each precursor and season were successfully modeled for each of the 66 airports. These health damage functions varied across airports for each precursor-pollutant relationship modeled, as well as across the different types of precursor-pollutant relationship (i.e. primary $PM_{2.5}$, secondary $PM_{2.5}$ formation, O_3 formation). The boxplots in Figure 18-1 on the following page show variance in health damage function values for primary $PM_{2.5}$ precursors PEC, POC, and PSO4 (Figure 18-1a), secondary $PM_{2.5}$ precursors NOx, SO_2, and VOCs (Figure 18-1b), and O_3 precursors NOx and VOCs (Figure 18-1c). Both January and July values are shown in lieu of an annual average damage function to demonstrate seasonal differences.

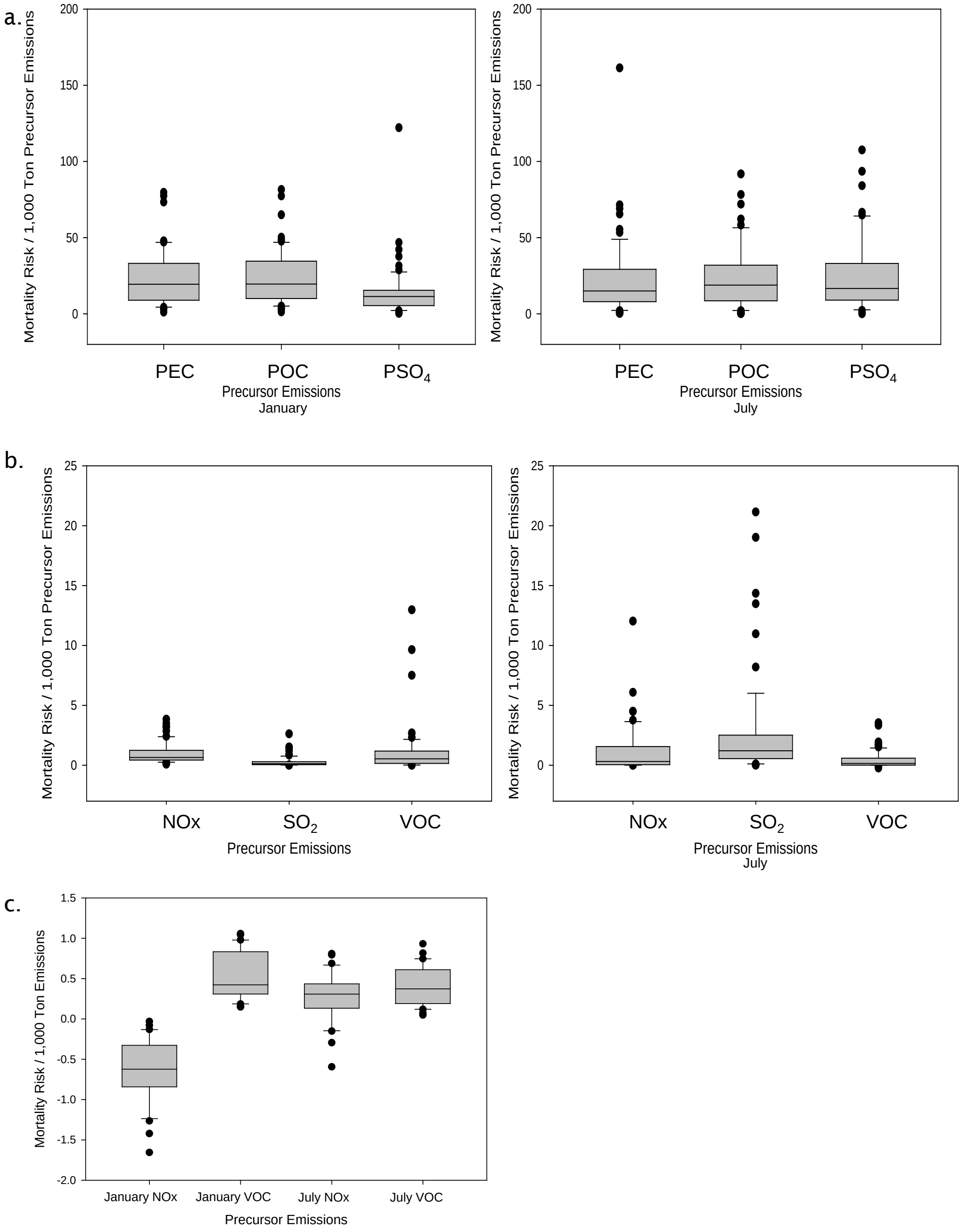

Figure 18-1. Boxplots of health damage functions for 66 individual airports during January and July in mortality risk per thousand tons of precursor emissions. Panel a shows primary $PM_{2.5}$ precursors; Panel b secondary $PM_{2.5}$ precursors, and Panel c O_3 precursors. Boxplots show 5%, first quartile, median, third quartile, and 95% values for each precursor/pollutant damage function with horizontal lines, and dots show values outside of 95%.

Airports with the largest health damage functions for primary $PM_{2.5}$ precursors are located near large population centers. On the other hand, for secondary $PM_{2.5}$ from both NOx and SO_2 emissions in January, the largest health damage functions are not near larger cities, although the pattern differs in July. Patterns are less discernible for health damage functions related to $PM_{2.5}$ sensitivity to VOC emissions. Health damage functions associated with O_3 formation from NOx emissions in January are largest in warmer climates, while negative values were found in big cities in colder climates. In July, the largest health damage functions associated with O_3 formation from NOx emissions were at smaller airports. For health damage functions associated with O_3 from VOC emissions, larger values were seen at larger airports.

The range, mean, and median annual average health damage functions are shown in Table 18-1 below. The annual health damage functions for primary $PM_{2.5}$ precursors are approximately 20 times the annual health damage functions for secondary $PM_{2.5}$ precursors, which are comparable in magnitude to one another and to the ozone health damage functions. For each precursor-pollutant combination, annual average health damage functions vary significantly across airports. In total, these directly modeled health damage functions account for 88% of total mortality risk for the entire source sector.

Table 18-1. Yearly health damage functions for 66 individual airports in mortality risk per thousand tons of precursor emissions.

Precursor-Pollutant	Mean	Median	Minimum	Maximum
PEC $PM_{2.5}$	24.4	18.2	3.1	76.1
POC $PM_{2.5}$	28.1	22.7	3.5	156.5
PSO_4 $PM_{2.5}$	20.5	15.2	1.6	75.8
NOx $PM_{2.5}$	0.9	0.6	0.1	2.7
SO_2 $PM_{2.5}$	1.0	0.9	0.1	2.8
VOC $PM_{2.5}$	0.7	0.5	0.1	6.3
NOx O_3	0.3	0.3	-0.1	1.0
VOC O_3	0.5	0.5	3×10^{-3}	1.3

Publications

None (precursor to future tasks)

Outreach Efforts

None (precursor to future tasks)

Awards

Stefani Penn - 10th Annual Joseph A. Hartman Student Paper Competition Award, 1st Place (2014)

Student Involvement

Work led by Stefani Penn as a doctoral student (graduated 9/15).

Plans for Next Period

None – task completed as proposed.

Task 3 - Explore variability in damage functions across airports, including through regression models using meteorological and population data.

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Objective(s)

For the airports directly modeled using CMAQ-DDM under Tasks 1 and 2, the health damage functions provide convenient summary metrics, but the availability of robust concentration surfaces means that we could examine exposures and health outcomes directly. However, we also have the goal to determine damage functions for airports that could not be modeled directly using CMAQ-DDM, either because resources are insufficient or because the emissions are too low to reliability estimate values using CMAQ-DDM. Having these damage functions for all airports would allow for rapid evaluation of the health implications of any policy measure yielding any combination of emissions across airports in the US, a powerful decision tool.

Research Approach

The goal of regression modeling for health damage functions for each precursor-pollutant relationship is two-fold. We aim to a) quantify and understand the variability between health damage functions for directly-modeled airports, and b) use physically interpretable predictors to extrapolate health damage function values to unmodeled airports across the US. Physically interpretable independent variables including downwind and upwind population, atmospheric chemistry regimes, and meteorology are combined in a linear regression model to predict mortality risk values normalized by airport emissions.

After testing correlation between population cut points and mortality risk, population variables were created by calculating population within 100 km, 100-500 km, and 500-1200 km of each airport using ArcMap v10.1. Background concentrations of NOx, VOCs, sulfate, nitrate, and ammonium including all sources other than aviation emissions, as well as air temperature, were averaged over these same population domains. Wind vectors were averaged over each domain and used to determine the prevailing wind direction for each airport. Each of the variables, as extracted from the WRF outputs that were also used to drive CMAQ, were broken into downwind, defined as the 90° quadrant in which the wind was most often directed, and upwind, defined as the three quadrants (270°) in which the wind was not most often directed. SO_4, NO_3, and NH_4 background concentrations were combined into two variables: the molar ratio between SO_4/NH_4 and the molar ratio between NO_3/NH_4 for inclusion in secondary $PM_{2.5}$ models. VOC and NOx background concentrations were combined as the ratio of VOC/NOx for inclusion in O_3 models. A categorical variable defining whether an airport lies east or west of the Rocky Mountains was also tested to account for meteorological differences.

Due to the small sample size, predictor variables were tested in models based on *a priori* assumptions regarding the relationship between predictor variables and health damage functions from known precursor-pollutant relationships. Population variables were tested first, then interactions between population variables and meteorological and chemistry terms were tested. For example, the ratio of VOC/NOx is a known predictor of O_3 formation, as areas with high VOC/NOx ratios are NOx-limited and require NOx emissions to form O_3, while areas with low VOC/NOx ratios are VOC-limited and require VOC emissions to form O_3. Best fit models were created associating airport-specific health damage functions with the aforementioned predictors for each of the 8 precursor-pollutant pairs, with $p < 0.05$ and variance inflation factors between model predictors less than 3, indicating a lack of multicollinearity between predictors. Within each model, observations with studentized residuals > 3 or Cook's D > 1 were determined to be influential points and were removed. As a sensitivity analysis, regression models were re-run including influential points to ensure model conclusions were not changed. Statistical analyses were carried out using SAS v9.3.

Milestone(s)

The major milestone for this task was the construction of physically interpretable regression models for individual airport health damage functions. This milestone was completed as proposed.

Major Accomplishments

Linear regression models for health damage functions for each precursor-pollutant relationship include population, meteorology, and atmospheric chemistry regime predictors. Meteorological and atmospheric chemistry regime predictors were included only as interaction terms with population variables, as health risk will only occur in the presence of an exposed population.

Across primary $PM_{2.5}$ models, downwind population either within 100 km of the airport or between 100-500 km of the airport and upwind population (i.e., not in the predominant wind direction) within 100-500 km of the airport are predictive of health damage functions. Models provide better fit for January versus July. In models with significant intercepts, variability not otherwise represented by predictor variables is captured. Sensitivity analyses of models with influential points removed (1 or 2 points for primary $PM_{2.5}$ models only) indicate parameter estimates changed slightly with inclusion of each point, though predictor variables remained significant in each model.

Secondary $PM_{2.5}$ model structures differ more from one another than those for primary $PM_{2.5}$. In the model predicting health damage functions from secondary $PM_{2.5}$ related to NOx in January, downwind populations 500-1200 km from the airport predict increased health damage functions, although only if the sulfate/ammonium molar ratio is less than 0.5. Upwind populations 500-1200 km from the airport are negatively associated with the health damage function. In July, the health damage functions from secondary $PM_{2.5}$ related to NOx are only associated with population 100-1200 km from the airport. For secondary $PM_{2.5}$ related to SO_2 in January, the health damage function is positively associated with the upwind population 100-500 km from the airport, but only if the sulfate/ammonium molar ratio exceeds 0.5. In July, the upwind population 100-500 km from the source remains significant but is diminished with a sulfate/ammonium molar ratio over 0.5, and the downwind population < 100 km from the airport is significant and has a heightened effect with a sulfate/ammonium molar ratio over 0.5. For $PM_{2.5}$ related to VOC in July, the downwind population < 100 km from the airport increases health damage functions. No defined independent variables were predictive of health damage functions associated with VOC-related $PM_{2.5}$ in January.

Health damage functions for NOx-related O_3 are increased in January where downwind populations < 100 km from the airport are exposed to average temperatures greater than 65°F, and decreased downwind at lower temperatures and in the far field upwind. Downwind populations within 100 km of the airport similarly decreased health damage functions for NOx-related O_3 in July, with a lesser decrease where VOC/NOx ratio is greater than 15 and a positive contribution from upwind populations 100-500 km from the airport. Health damage functions for VOC-related O_3 are increased in the far field in January, though decreased where populations are exposed to high VOC/NOx ratios 500-1200 km downwind. In July, downwind populations < 100 km from the airport experience decreased health damage functions, while those upwind < 100 km from the airport experience increased health damage functions.

Publications

Conference presentation: Penn S, Arunachalam S, Boone S, Kamai E, Levy J. Modeling Variability in Air Pollution-Related Health Damages from Individual Airport Emissions. International Society of Exposure Science Annual Meeting, Cincinnati, Ohio, October 2014.

Doctoral dissertation: S. Penn. Modeling Contributions of Major Sources to Local and Regional Air Pollutant Exposures and Health Effects. Boston University School of Public Health, Boston, MA, September 2015.

Peer-reviewed publication: Penn S, Boone S, Harvey B, Heiger-Bernays W, Tripodis Y, Arunachalam S, Levy J. Modeling variability in air pollution-related health damages from individual airport emissions. Submitted September 2015.

Outreach Efforts

Presentation of work at AEC Roadmap, External Tools meeting.

Awards

Stefani Penn - 10th Annual Joseph A. Hartman Student Paper Competition Award, 1st Place (2014)

Student Involvement

Work led by Stefani Penn as a doctoral student (graduated 9/15).

Plans for Next Period

None – task completed as proposed.

Task 4 - Apply the health damage functions (all airports) and spatial pollutant concentration surfaces (directly modeled airports) to evaluate hypothetical policy scenarios.

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Objective(s)

The successful completion of Task 3 allows us to assign health damage functions to each individual airport in the US. This would allow us to determine the health implications of any set of aviation LTO emissions in the US. The objective of this task is to conduct a series of analyses to illustrate the utility of the tool and to provide insight to FAA and others regarding the optimal strategies for reducing the public health impacts of aviation emissions.

Research Approach

In general, the approach for this task is dependent on the interests of FAA and other stakeholders, in terms of policy scenarios to analyze and ways in which individual airport health damage functions could be used. Through a series of discussions, it was determined that policy analyses utilizing individual airport health damage functions were not yet warranted, and the preferred geographic aggregate for health damage functions was census divisions. While this contributes significant error in health damage estimation given considerable heterogeneity within census divisions, it avoids identifying specific airports and their associated contributions to health. Therefore, to meet this objective, we calculated aggregated health damage functions by constituent and census division as the sum of the health impacts across all airports within a census division divided by the sum of emissions across all airports within that census division. This effectively upweights larger airports and provides a value that would correspond with the health implications of percentage changes in emissions across all airports. We also calculated an NAS-wide value to allow for broad-scale national policy analyses.

Milestone(s)

The major milestone for this task, given the modification in scope per FAA discussion, was the construction of census division health damage function estimates. This has been completed for the 66 modeled airports, and ongoing work is focusing on incorporating the unmodeled airports through application of the regression models developed in Task 4. Our long-term milestones for future policy analyses, described below, include identifying policy and what-if scenarios by 12/31/15, applying health damage function models to evaluate policy scenarios by 4/30/16, and completing a policy analysis manuscript by 9/30/16.

Major Accomplishments

To date, we have calculated census division average health damage functions for the 66 modeled airports. We have also calculated health damage functions based on a Jan/Jul NAS-wide 2005 run, noting that these values would not simply reflect a weighted average of the census division values given the exclusion of unmodeled airports to date.

Given this framework, the resulting values are listed in Table 18-2 on the following page. The values reflect the mortality risks per 1,000 tons of emissions, comparable to the values presented in Table 18-1 above.

Table 18-3. Yearly health damage functions per 1000 tons of emissions, by census division and NAS-wide

Census Division	**PEC**	**POC**	**PSO4**	**NOx**	**SO2**	**VOC**	**O3 NOx**	**O3 VOC**
East North Central	28.80	30.28	19.92	1.35	1.84	0.80	0.17	0.93
East South Central	20.60	20.56	16.49	0.88	1.30	0.36	0.52	0.60
Middle Atlantic	38.58	41.24	35.24	0.68	1.03	0.77	0.13	0.72
Mountain	6.27	6.47	5.31	0.27	0.32	0.32	0.17	0.11
New England	17.77	20.00	14.06	0.54	0.79	0.35	0.32	0.33
Pacific	32.43	33.63	30.07	1.00	1.20	0.68	0.16	0.82
South Atlantic	25.60	25.89	20.99	1.12	0.96	0.33	0.47	0.46
West North Central	15.55	17.93	13.69	1.37	0.85	0.85	0.17	0.66
West South Central	13.36	13.04	10.61	0.32	0.86	0.38	0.33	0.44

NAS-Wide	**PEC**	**POC**	**PSO4**	**NOx**	**SO2**	**VOC**	**O3 NOx**	**O3 VOC**
All Airports	16.50	15.58	15.21	0.89	1.13	0.28	0.18	0.38

As anticipated, there is geographic heterogeneity across census divisions, based in part on population patterns as well as differences in atmospheric chemistry and meteorological regimes. The patterns for PEC, POC, and PSO4 are exclusively related to population patterns combined with meteorology, while the patterns for secondary pollutants include the atmospheric chemistry components. Given the individual airport health damage function values reported previously, these values also emphasize the considerable heterogeneity within census divisions.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

Work led by Stefani Penn as a doctoral student (graduated 9/15).

Plans for Next Period

In the short term, we plan to calculate health damage functions for unmodeled airports, updating the census division aggregated values and providing a foundation for future policy analyses. We will also examine the NAS-wide health damage functions using annual CMAQ-DDM runs.

Over the next 12 months, we propose to apply our estimates to a series of hypothetical policy scenarios. We will work closely with FAA and other stakeholders to determine realistic scenarios, including some that have been evaluated using other modeling approaches, which would allow us to do model inter-comparisons and general quality assurance checks. Along with the defined scenarios, we propose to conduct a series of “what if” analyses meant to determine the importance of the individual airport insights. For example, we could examine the minimum percentage reduction of various pollutants needed to achieve a defined percentage reduction in health outcomes; the difference in health impacts from a uniform emissions reduction vs. a health-optimal allocation of the same magnitude of emissions reduction; or the implications of optimizing from a population health vs. an individual health perspective. For the subset of directly modeled airports, we will be able to conduct additional analyses, including investigations of the spatial patterns of concentrations before and after hypothetical policy measures, which could provide insight about NAAQS violations, equity issues, and other questions. Because of the importance and sensitivity of this work, we will present both our hypothetical policy scenarios and set of “what if” analyses to FAA and the ASCENT advisory board, gathering feedback before conducting the analyses.

Task 5 - Compare aviation-related health impacts as well as damage functions with those from other important source sectors.

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Objective(s)

For any analyses of the health effects of aviation emissions, it is important to be able to place the output in context. In this case, the output includes both the total public health impacts, which have been previously compared with other source sectors, and the damage functions normalized by emission rate, which have not been previously compared with other source sectors. For this task, we will compare the distribution of values for airports with those from power plants and residential combustion sources, derived using identical CMAQ-DDM modeling platforms. As aviation LTO emissions include some contributions at ground level, paralleling residential combustion sources, and some elevated contributions, paralleling high stack power plants, the comparisons should prove interesting.

Research Approach

In an ongoing study funded external to ASCENT, investigators on Projects 18 and 19 are applying CMAQ-DDM to aggregates of power plants and residential combustion sources within individual states or sub-regions within states. Methods are analogous to those described under Tasks 1 and 2, including the image segmentation algorithm, the concentration-response functions, and the baseline population data. We will first consider the damage functions across source sectors within states to get a sense of how the normalized values compare with one another, recognizing that differences across sectors could be related to source characteristics (i.e., ground-level emissions vs. elevated stack emissions vs. aviation sources) or differential geographic locations within states (i.e., residential emissions which correspond with population density vs. defined locations for power plants and airports). For the 66 directly modeled airports, we will also be able to evaluate concentration surfaces and compare directly with the concentration surfaces for residential combustion and power plants, which will allow for evaluations of relative contributions to ambient concentrations at varying distances from airports, as well as the general spatial patterns and spatial extent of impact. The comparisons under this task will provide significant insight to the aviation community regarding the air quality and health impacts of aircraft relative to other source sectors.

Milestone(s)

The major milestone for this task would be the development of formal comparisons among source sectors for both total health damages and health damage function models. As the CMAQ-DDM work for the external study was slightly delayed relative to original plans, the completion of this task has been deferred, with a defined milestone to complete a manuscript comparing damage functions across source sectors by 6/30/16.

Major Accomplishments

To date, we have completed all CMAQ-DDM runs for power plants and residential combustion sources, including some re-runs for states that could not be adequately separated using the plume separation algorithm. We have completed health damage function models for 43 states for power plants and 44 states for residential combustion, and the remaining states (which were re-run in CMAQ-DDM) are in the process of being compiled.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement

Work led by Stefani Penn as a doctoral student (graduated 9/15).

Plans for Next Period

We plan to complete all health damage function models in the fall of 2015, conduct all comparative analyses in the winter of 2015/2016, and complete a manuscript comparing these values by 6/30/16.