Current Air Quality Research at FAA

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ABSTRACT

The purpose of this paper is to outline the local air quality research and model development activities planned over the next 5 years by the Federal Aviation Administration (FAA) and briefly report on work accomplished to date. The activities are loosely categorized into two functional areas:

- Model Development: Model development refers to physical and functional enhancements planned for incorporation into the FAA promulgated air quality model, the Emission and Dispersion Modeling System (EDMS). This plan addresses major model enhancements and releases. Interim model releases will also occur but the changes to the model will be minor. These minor releases are not scheduled releases and are not discussed in this paper.

- Research and Analysis: Research and analysis activities are both underway and planned for future years. As these research and analysis activities are carried out and yield increased insights, they will become candidates for EDMS enhancements. Research on ground support vehicles emissions, aircraft particulate matter estimation, model validation for a new version of the Emission and Dispersion Modeling System using the EPA dispersion methodology AERMOD, and inclusion of more accurate aircraft profiles for modeling of air quality are all discussed.

While the work is just beginning, some initial results are included in the paper. These results

include the inclusion of AERMOD into EDMS, initial findings on aircraft particulate matter emission factors, implementation of more accurate aircraft profiles during landing and takeoff, and initial work completed on a screening model.

INTRODUCTION

Air quality planning in the vicinity of airports has been done in the United States since the 1970s to determining compliance with Federal and local requirements. The tools used have continued to be improved over this time period. The air quality model required by the Federal Aviation Administration (FAA) for analysis in the vicinity of airports is the Emissions and Dispersion Modeling System (EDMS) [1]. EDMS is used to inventory emissions and model air dispersion at an airport based upon the emissions of aircraft, auxiliary power units, ground support equipment, motor vehicle accessing the airport, fueling operations, and other sources operating on the airport property or in the nearby vicinity.

EDMS incorporates EPA-approved emission factors and calculation methodologies (e.g., dispersion algorithms). At the time this paper was written, the most current version was 3.23. The primary sources of emission factors are those reported by MOBILE5a for motor vehicles [2], the International Civil Aviation Organization for aircraft [3], and AP-42 for other sources [4]. Version 3.23 uses algorithms from PAL2.0 [5] for most sources during dispersion modeling. Aircraft taxing and motor vehicles dispersion modeling is done with CALINE3 [6]. However, the model development needs to be continued since multi-million dollar decisions are being made based on the results and more refined analysis are needed. Version 4.0 is planned to be released in the spring of 2001 and several upgrades are planned. To accomplish these upgrades, and continue to improve air quality methodologies used at airports, a comprehensive, long-term plan is required.

In order to provide this comprehensive, long-term plan, and provide a better understanding of aviation's impact on local air quality, the FAA Office of Environment and Energy has completed a Five-Year Research and Development Plan which includes many pieces including the enhancement of EDMS [7]. Activities are grouped into the following fiscal year time periods: 2001, 2002-2003, and 2004-2005. Activities range from more simplistic one-year efforts to more complex multi-year efforts. Activities were evaluated for inclusion and implementation year based on several factors including priority, availability of information, and extent of effort. The order in which they are presented in no way reflects their perceived importance. It is important to note that planned activities are based on "requested" funding levels. Actual research and model development activities will be determined based on annual appropriations of funds.

MODEL DEVELOPMENT

Fiscal Year 2001 Activities

One significant model development activity in fiscal year 2001 is the release of EDMS, Version 4.0. Beginning with Version 4.0, the older PAL and CALINE3 methodologies will be stripped and replaced with AERMOD [8]. This will allow EDMS to utilize the current state-of-the-art dispersion modeling process and should help to improve accuracy of the model. This change will require different inputs, especially for meteorology. At the same time as this change is being made, aircraft performance parameters will be changed to more accurately reflect the flight profiles of each aircraft type on landing and takeoff. Additionally, expanded and updated auxiliary power unit (APU) emission factors and better allocation of APUs to specific aircraft will be added. As such, the "look" of EDMS will also change as the Graphical User Interface (GUI) is changed to meet the new input data requirements. Care is being taken to make the GUI as user friendly as possible. These user friendly changes to the GUI will include such items as a redesigned aircraft operations window and wizards to help with data input.

In addition, many of the more advanced EDMS users find that the EDMS GUI is useful for entering a small number of sources, but can become cumbersome for entering large amounts of data. As with many other models from both EPA and the FAA, in FY2001 EDMS will be enhanced to include more options for importing data from files as opposed to requiring the user to manually input the information. Also, the current EDMS airport view provides a crude representation of the sources included in the study. This view will be enhanced in FY2001 to include labeling of sources and receptors. Finally, the online help will also be updated to reflect the changes made to the model.

The accuracy of EDMS not only depends on the algorithms it uses, but also the data that feeds those algorithms. During FY2001 the aircraft and APU databases are being updated with the currently available information including aircraft-engine combinations, engine emission factors, and aircraft-APU combinations. Keeping the EDMS databases current is a continuous process that does not necessarily need to coincide with a new release of the model.

The EPA is continuing development of their "non-road" model in response to increased regulation during the 1990s of construction, logging, and other off-road equipment [9]. In many ways, airport GSE also fall into the same category as other non-road sources calculated by EPA's NONROAD model. While EDMS currently associates GSE with individual aircraft, and then calculates the emissions in relation to the number of aircraft operations, NONROAD takes a population-based approach, with the ability to assign operating times to individual pieces of equipment. In FY2001, the EDMS GSE data inputs and calculation methodology will be enhanced to be more consistent with the development of EPA's NONROAD model.

Although it is not reasonable to attempt to include every potential source of airport emissions into EDMS, it is important that the sources that EDMS models provide benefit to the user. Currently, EDMS treats stationary sources in a relatively simple manner that often requires the advanced user to seek other models to complete their analysis. In order to better accommodate

the EDMS user-base, in FY2001 an improved means of assessing emissions from stationary sources within EDMS will be developed. The use of AERMOD should also greatly enhance the modeling of point sources.

Obviously, the changes made to EDMS during FY2001 will need to be thoroughly documented to fully benefit the users. Documentation of the research and changes will be accomplished and made available.

Fiscal Years 2002-2003 Activities

Model development work will continue throughout the Five-Year Plan. The fiscal year 2002-2003 work will be crucial in the planned changes in EDMS. As such, several key activities are planned for FY2002-2003 and are discussed here: enhancement of dispersion algorithms, database updates, more accurate aircraft particulate matter estimation, enhanced user flexibility, and updated model documentation.

It is envisioned that modifications to AERMOD will be made by EPA as the model continues to be used and replaces other models now in use. EDMS will remain compatible with EPA's most-recent release of AERMOD by continual incorporation of the latest version of AERMOD into EDMS. The performance of EDMS will also continue to be researched as model validation work continues. The validation work, and other research activities, are discussed later in this paper.

Transparent to the user, APU databases will be updated with newly available information including aircraft-engine combinations and engine emission factors. GSE databases will be updated and supplemented to reflect FY2001 analysis results of existing and newly available data. EDMS system databases will be enhanced through such activities as including annual average taxi time data for available airports from FAA's Consolidated Operations and Delay Analysis System (CODAS) [10].

Based on FY2000 and FY2001 research and coordination on aircraft PM, an aircraft PM emissions estimation methodology will be incorporated in EDMS. This methodology will be a first order approximation based on the literature review that is now underway and discussed later in this paper.

Many users are finding that it would be useful to overlay EDMS source and receptor information on an actual layout of the airport. As the FAA continues to provide more such diagrams in electronic format, a new version of EDMS will allow some airport layout diagrams to be imported directly into the study. Users have also requested enhancements to the user-created aircraft screen to offer more flexibility with importing the emission factors for their new aircraft. User flexibility will be enhanced in FY2002-FY2003 and future years through several activities including the capability to import airport map files, expanded airport viewing capability, and an improved user-created aircraft screen.

Again, the EDMS User Manual and Online-Help will be updated to be consistent with FY2002 and FY2003 model enhancements.

Fiscal Years 2004-2005 Activities

Several model development activities are planned for fiscal year 2004-2005. These include: updated dispersion algorithms, database updates, refined aircraft particulate matter estimation, assessment of aircraft performance methodologies, operational modeling, aircraft plume characterization, enhanced user flexibility and updated model documentation.

To continue to stay current with any changes in AERMOD, EDMS will be changed to remain compatible with the most-recent release of EPA's AERMOD. In addition, the FAA's advanced evaluation of algorithmic performance and ongoing model validation effort will be incorporated into EDMS as required.

It is very likely that by FY2004-2005 new data will be available on aircraft, APU, and GSE emission factors. As previously mentioned, it is a key element of EDMS to have up-to-date data for its calculations. FAA will continue to update and enhance EDMS system databases with newly available information on aircraft, APUs, and GSE during FY2004-2005

Based on research and coordination on aircraft PM, any new data or developments in estimating aircraft PM emissions will be carefully reviewed and implemented into EDMS as deemed necessary. This will be a significant enhancement to the model, since EDMS is currently unable to estimate aircraft PM emissions due to the lack of data.

Based on industry agreement of advances in research being performed for aircraft noise modeling and analysis purposes, the use of a dynamic aircraft profile generator within EDMS will be explored. During FY2001, a static lookup-table of aircraft profiles for a fixed set of aircraft weights will be provided in EDMS. While this is a significant improvement to the model, in order to offer the user complete flexibility for modeling specific aircraft operations, it is desirable to include the profile generator.

By enabling EDMS to interface with AERMOD for dispersion calculations, it became possible to model significantly more complex studies. AERMOD allows the user to model terrain and topography impacts, which increases the accuracy. Advanced users will be able to take full advantage of these features with the FY2004-2005 release of EDMS, while users not requiring this level of fidelity will be able to continue using EDMS without terrain and topography data.

Currently, it is not possible to model plume rise from jet engine exhaust in EDMS. However, many users believe that being able to model this would dramatically improve the accuracy of the model. Based on FAA research, it is anticipated that it will be possible to model aircraft plume rise in a FY2004-2005 release of EDMS. Although EDMS currently allows the user to characterize the initial release of the aircraft plume (i.e., the initial sigma values), FAA also

anticipates that research will lead to a more refined characterization in a FY2004-2005 release of EDMS.

EDMS user flexibility will continue to be enhanced in FY2004-FY2005 through several activities including additional importing capabilities, expanded viewing capabilities, and improved input screens.

Finally, the EDMS User Manual and Online-Help will be updated and enhanced to be consistent with FY2004 and FY2005 model enhancements.

RESEARCH AND ANALYSIS

Fiscal Year 2001 Activities

During FY2001, rigorous testing and sensitivity analysis of the algorithmic performance of new EPA dispersion algorithms (i.e., AERMOD) recently incorporated into EDMS will be completed. This testing is necessary to quantify the impact of these new algorithms on EDMS results. After testing and evaluating the new dispersion algorithms incorporated into EDMS, the findings of the effort will be documented. The assessment of new modeling concepts as a possible long-term enhancement to EDMS also will continue.

As previously discussed, initial implementation of a multi-year plan for validation of EDMS 4.0 dispersion algorithms and associated databases will begin in FY2001. These validation efforts will be in three major work areas: comparison with other models, determination of initial plume characteristics, and comparisons with measured concentrations in the vicinity of the airport. The comparison with other models that are also used for airports, will allow a comparison of the results to other models that have already been compared to measured values. This will provide insight into the model algorithms for different sources types (e.g., aircraft, motor vehicles, fueling operations, etc.). The second major area, initial plume characterization, will allow the initial plume spread, height of release, and plume rise to be better quantified. All of these inputs are needed to run AERMOD and have a significant impact on dispersion. The final part of the validation effort in the first fiscal year will be to measure carbon monoxide at selected receiver sites around the airport. Twenty to twenty-five concurrent sites are envisioned at this time. Carbon monoxide has been selected because of its non-reactive nature and that the validation will be primarily aimed at verifying dispersion algorithms. The results of the three major validation areas will allow EDMS to be tested and changed if necessary to become a more accurate, state-of-the-art model.

The flight profiles used in previous version of EDMS have been lacking. Version 4.0 will have specific flight profiles (landing and take-off) for each aircraft type. These profiles, based on full-throttle take-off, have been developed as part of the Society of Automotive Engineers [11] and have successfully been implemented into the FAA's Integrated Noise Model [12]. As a follow-up to the

inclusion of aircraft performance data and static aircraft flight profiles in EDMS 4.0, EDMS developers will keep apprized of related research being performed for aircraft noise modeling and analysis purposes, and consider refinements to the static flight profile approach. The ultimate, long-term goal will be to include a dynamic aircraft profile generator in EDMS capable of taking into account user-supplied airport conditions and specific flight procedures.

Often, a quick review of the air quality impact of changing the number of operations or the fleet mix is needed. As part of the on-going multi-year effort, an air quality screening tool to facilitate quick and easy assessments of apparently minor changes in aircraft-related activity, will be created. The prototype of the tool will be completed by the end of FY2001.

Particulate matter emission factors has also been severely lacking. The aircraft certification process require the measurement of a smoke number, but this parameter does not permit direct mass calculations needed for NEPA or conformity documentation. As part of a longer-term research effort to evaluate methods for computing aircraft particulate matter (PM) emissions, FAA will collaborate with EPA, European counterparts, and others to research appropriate methodologies for estimating particulate emissions given available data. By the end of FY2001, FAA plans to develop a short-term recommendation for estimating aircraft PM emissions using available data. FAA also will continue with activities and coordination aimed at filling the aircraft PM emission factor data gap.

Results to date show that four methods have been used to quantify emission factors for particulate matter. These include:

- A factor multiplied by each landing / take-off cycle (LTO);
- A factor based on various operational parameters, such as smoke number, multiplied by the fuel flow for each aircraft type;
- Actual measurements based on grab samples and nearby deposition; and,
- Actual measurement based on the EPA Method 5 or similar methodologies.

Work is proceeding to document all of these methods and ultimately provide guidance for the airport modeler.

During FY2001, FAA will formally begin researching aircraft plume behavior for potential modeling approaches. Research will include plume rise, initial aircraft plume spread (i.e., initial sigma values) and release heights for use in dispersion modeling. An initial progress report on the aircraft plume behavior research should occur in the third quarter of FY2001.

During FY2001, the current EDMS GSE databases will be evaluated for appropriateness and completeness given a review of existing EDMS data and newly available data. GSE databases will be updated and supplemented as necessary to reflect analysis results.
FAA will begin researching a preliminary method and/or guidance for handling airport construction emissions.

Fiscal Years 2002-2003 Activities

During fiscal year 2002-2003, research activities will continue on topics including dispersion algorithms, model validation, and aircraft performance.

Advanced evaluation of EDMS dispersion algorithms and other modeling concepts will be conducted to improve the operation and accuracy of EDMS. The evaluation will include comparing various approaches, implementing promising approaches into a research model, testing for continuity, performing sensitivity studies, and coordinating with EPA and other US and European researchers.

Continued implementation of the multi-year validation plan for EDMS including implementation of results from the field measurement plan (validation measurements) and analysis of results.

EDMS developers will keep apprized of related research being performed for aircraft noise modeling and analysis purposes with the ultimate goal of including a dynamic aircraft profile generator into EDMS. The dynamic profile generator would be capable of taking into account user-supplied airport conditions and specific flight procedures.

Other accomplishments will include: the review and modifications of the air quality screening tool prototype released in FY2001; continued support of the FAA long-term research effort to evaluate methods for computing aircraft PM emissions, as well as filling the aircraft PM emission factor data gap; continued research into aircraft plume rise and initial plume spread; and, continued research on a preliminary method and/or guidance for handling airport construction emissions.

Fiscal Years 2004-2005 Activities

Activities begun in previous years will be continued in FY2004-2005. If significant changes to the dispersion algorithms within AERMOD are implemented, then an evaluation of their continued applicability to the unique sources within EDMS will be required. In addition, if new dispersion models suitable for use in EDMS are introduced and approved by EPA, then they will need to be considered as well.

Continued implementation of the multi-year validation effort for EDMS including implementation of the field measurement plan and analysis of results will be needed. As more data is collected, more changes to EDMS may be needed. The end result should be a continual improvement in accuracy for EDMS and better methodologies for airport planners.

Based on industry agreement of related research being performed for aircraft noise modeling and analysis purposes, it is envisioned that the development of an initial dynamic aircraft profile generator for inclusion in EDMS will be completed.

Other research during this time period will include: continued research and development of a refined air-quality screening tool for assessment of apparently minor changes in aircraft-related activity; continued support of FAA's long-term research effort to evaluate methods for computing aircraft PM emissions and fill aircraft PM data gaps; and, development of a method and guidance for handling airport construction emissions.

SUMMARY

The final section of this document provides a summary of major activities and milestones.

FAA anticipates the release of version 4.0 of EDMS in the second quarter of FY2001. Based on model development activities in FY2000, Version 4.0 will include several significant improvements to the modeling system including new EPA dispersion algorithms and aircraft performance data. The new dispersion algorithms will be the use of EPA's most recent dispersion model, AERMOD. Aircraft performance data included in Version 4.0 will be used to calculate aircraft-specific takeoff, climbout, and approach times as well as dispersion from in-flight emissions of aircraft during takeoff, climbout, and approach. To quantify the model input for AERMOD, an initial progress report on aircraft plume rise research will be published in the third quarter of FY2001. After testing and evaluating the new dispersion algorithms incorporated into EDMS, the findings of the effort will be documented.

Two other items will also be done. By the end of fiscal year 2001, a prototype of the air quality screening tool will be completed and FAA plans to develop a short-term recommendation for estimating aircraft PM emissions using available data.

FAA anticipates another major release of a new version of EDMS in the last quarter of FY2002. Based on model development activities in FY2001 and FY2002, the new EDMS release will include improved flight profile capability, dispersion algorithm improvements as a result of the ongoing validation effort, incorporation of a "short-term" approach for computing aircraft particulate matter (PM) emissions, improved and updated databases, and improved methodologies for assessing stationary source and GSE emissions.

FAA anticipates release of a new version of EDMS in FY2005. The improved version of EDMS will include dynamic flight profile generation, enhanced dispersion algorithm improvements as a result of the ongoing validation effort, enhanced operational modeling, aircraft plume rise impacts, a refined characterization of the initial aircraft plume spread, and any new data or developments in estimating aircraft PM emissions.

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