FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Development of Aviation Air Quality Tools for Airport-Specific Impact Assessment

Project 19

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AVIATION SUSTAINABILITY CENTER

Motivation

- Recent measurement campaigns at several airports have shown significant levels of Ultrafine Particulate Matter (UFP) due to aircraft LTO operations at LAX, Boston, Amsterdam, Rome, Tianjin, etc.
  - Hudda et al 2014, 2016; Staffogia et al, 2016; Ren et al, 2016
- AERMOD, the current dispersion model integrated within FAA's Aviation Environmental Design Tool (AEDT) for local scale AQ studies has several limitations
  - AERMOD/AEDT is the current regulatory model for airport operators
- FAA's Aspirational Goal: Achieve an absolute reduction in aviation emissions induced "significant health impacts"
- For ICAO's Committee on Aviation Environmental Protection (CAEP), tools to assess global aviation-attributable health impacts needed

➢ In both cases, science-based tools are required to report year-over-year changes in health impacts

➢ Need to identify airport-specific trends in adverse health impacts for developing mitigation strategies

Objectives

- Long term
  - Develop tools for AQ and health impacts reporting and analyzing potential aviation policy scenarios for FAA, ICAO CAEP, and for NEPA Analyses
- Near term
  - **T1: Develop new modeling framework for dispersion modeling of aircraft sources during LTO cycles**
  - T2: Assess/quantify modeled aviation-attributable UFP, and compare with new measurements from field campaign at Boston Logan airport

ICAO: International Civil Aviation Organization
CAEP: Committee on Aviation Environmental Protection
NEPA: National Environmental Policy Act

Schedule and Status

- Task 1: Develop **new framework** for dispersion modeling
  - Initial Draft **[Completed]**
  - Model development **[Getting Started]**

- Task 2: Perform monitor-model comparisons of UFP from Boston Logan airport
  - Using SCICHEM **[Completed]**
  - Using CMAQ **[On Hold due to pending funds for ASCENT18]**

Task 1: New Dispersion Modeling Framework

- Objective
  - Demonstrate that a robust, improved pollutant dispersion model for aircraft can be developed for U.S. regulatory compliance purposes
- Known limitations
  - Several studies have shown limitations with AERMOD – the current local scale dispersion model used for airport-level assessments
  - Problems identified in issues related to:
    - Source representation: area vs. volume
    - Lack of plume rise for hot buoyant plumes
    - Limited treatment of chemistry, etc.
- Motivation
  - Airports need dispersion modeling system that incorporates all physical and chemical processes related to LAQ around airports
  - NEPA Analyses

Task 1: Approach

- Focus on 3 aspects of LAQ Models
  - Source Characterization
  - Physical Processes
  - Chemical Processes

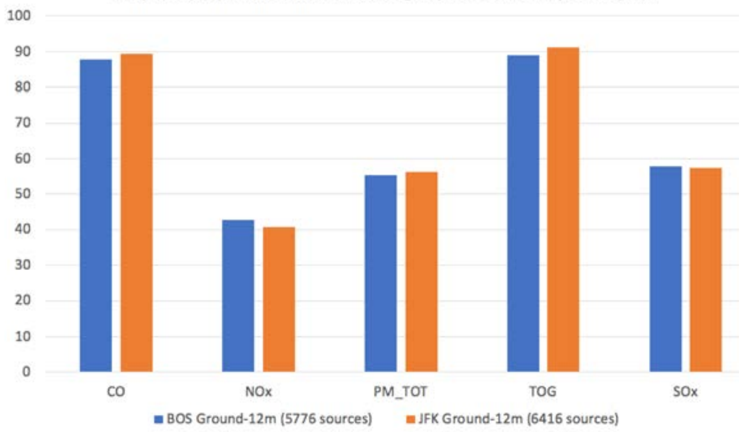
- Develop a series of options for tasks that can be accomplished in a 2-year timeframe

Task 1: Source Characterization: Optimization of number of sources

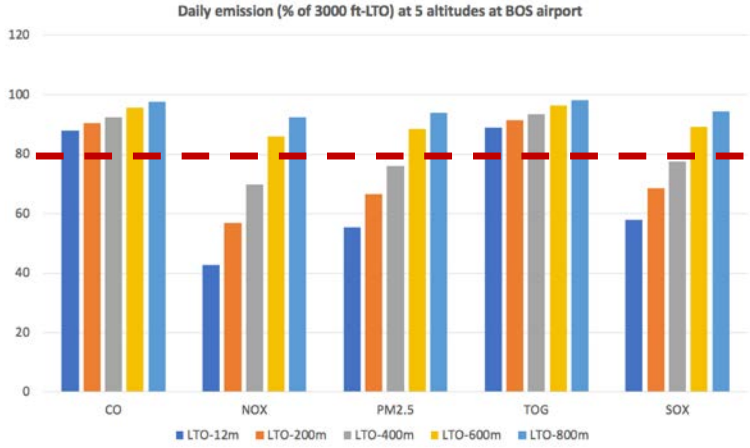
Boston Airport	With zero-emission sources	Without zero-emission sources	% Change in removing zero-emission sources
Ground-12m	5,776	959	-83%
LTO-915m (3,000 ft LTO)	7,011	2,194	-69%

- ❑ Taxi emissions alone can vary from ~40% (NOx) to 90% (TOG) of LTO emissions at an airport
- ❑ AEDT produces many emission sources having zero-emission which increases computational cost
- ❑ Emission sources having zero-emissions can be removed which can decrease number of sources by 70 to 83%

Emission at BOS and JFK within 12-m height



Emission at BOS within 5 LTO-heights



Task 1: Approach: Source Characterization

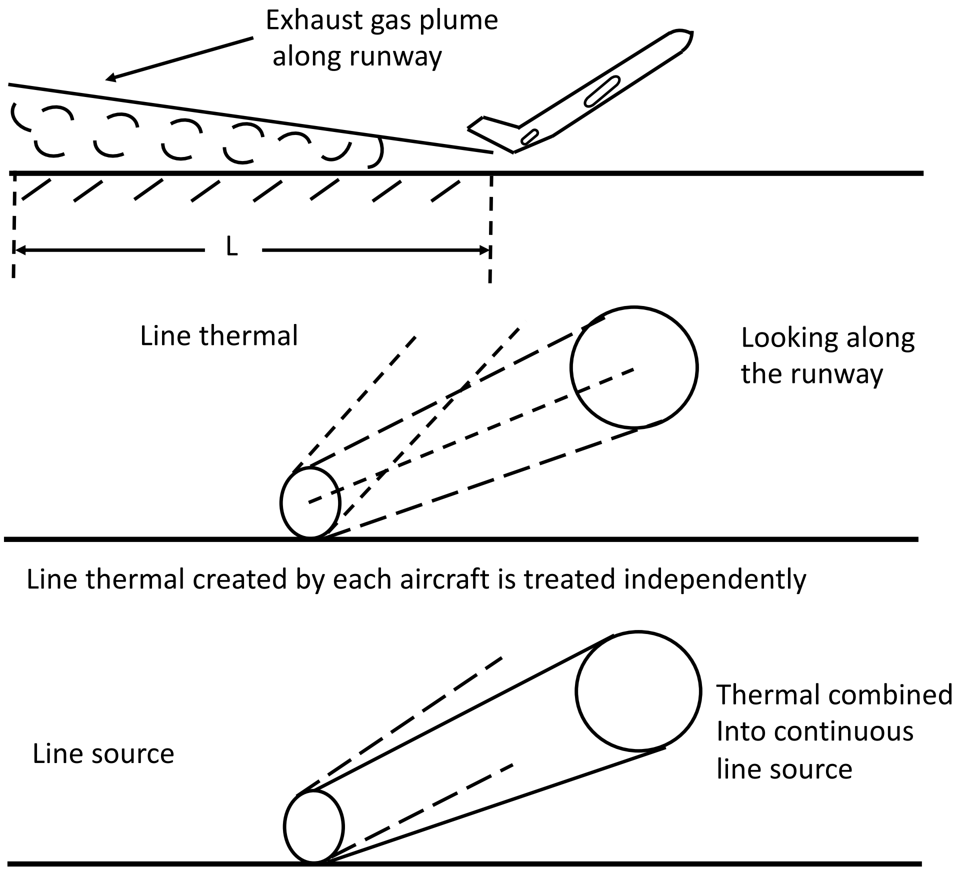
Source type	**Current AEDT/AERMOD model source**	**Current ADMS-Airport model source**	**Future AEDT/AERMOD Model source (Opt 1)**	**Future Line-puff model source (Opt 2)**
Landing, Take-off (including ground rolls)	Area	Jet source	Moving-line (Jet source)	Line-puff
Climb, Approach (airborne)	Area	Volume	Moving-line (Jet source), volume	Line-puff
Taxing	Area	Line, area	Moving-line (Jet source), stationary line or area	Line-puff
Stationary	Point, volume, area	Point, line, area, volume or aggregated grid	Point, volume, area	Point, volume, area
Gate	Volume		Volume	Volume
Terminal	Area		Area	Area
Parking facility	Area	Volume, area	Area	Area
Roadway	Area	Road, aggregated grid	Area	Area

Task 1: Approach: Physical Processes

- Develop line thermal model for aircraft sources
  - Most "realistic" treatment of these emissions in which the emissions are released as a set of line puffs along the LTO paths
  - Each puff, corresponding to a single aircraft, would undergo plume rise and dispersion as it is transported by the mean wind
  - Modeling of the fate of these puffs can be computed with an unsteady trajectory puff model that is already incorporated in CALPUFF *(Scire et al., 2000)*
  - Comparison of results from this computationally demanding simulation for varying receptor distances from the runway will provide important information on the usefulness of the simpler representations of aircraft emissions
- Explore other options including jet source for treatment of aircraft sources
  - Based on ADMS-Airport model
- Other updates
  - Treatment of aircraft wake (wing-tip vortex)
  - Incorporation of building effects
  - Accounting for shoreline effects

Task 1: Physical Processes: Trajectory based Jet source (moving line source) model for AERMOD

Treatment of aircraft emissions



Exhaust gas plume along runway

L

Line thermal

Looking along the runway

Line thermal created by each aircraft is treated independently

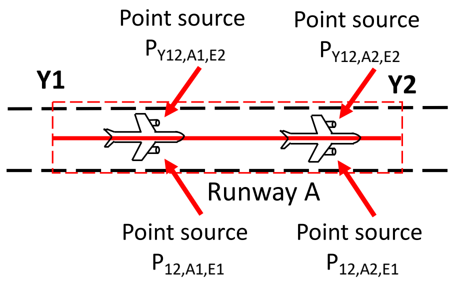
Line source

Thermal combined Into continuous line source

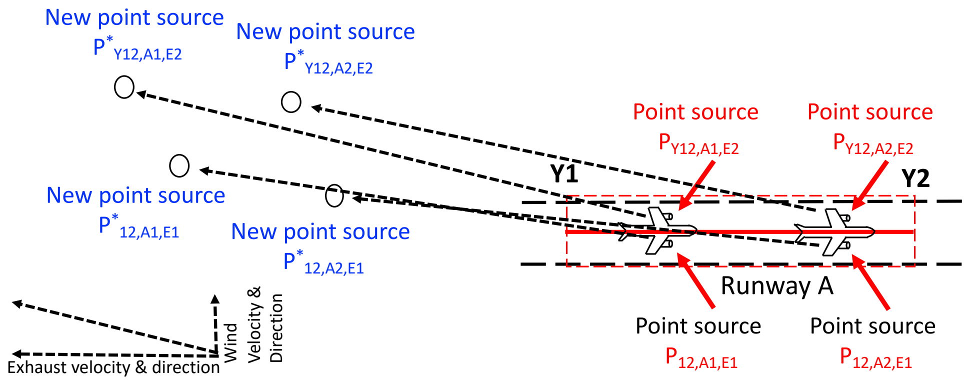
Task 1: Approach: Physical Processes: Trajectory based Jet source (moving line source) model for AERMOD

- The jet source (moving line source) model for aircrafts are based on the same approach of stationary line source model for emission
- A line source represents the emission from an aircraft travelled in a line path from Y1 location at time t1 to Y2 location at time t2.
- The only exception in the jet source model (moving line source model) is that it's source location, $P_{Y12,A1,E1}(x, y, z)$ will be moved by the exhaust velocity, aircraft velocity, wind velocity, and exhaust temperature to a new location $P^*_{Y12,A1,E1}$
- All aircraft types are binned and trajectory data and emissions are calculated (Arunachalam et al., 2019)

a) Stationary line source model



b) Moving line source model (Jet source model)



Arunachalam et al., 2019

Task 2: Approach: Physical Processes: Treatment of aircraft wake (wing-tip vortex)

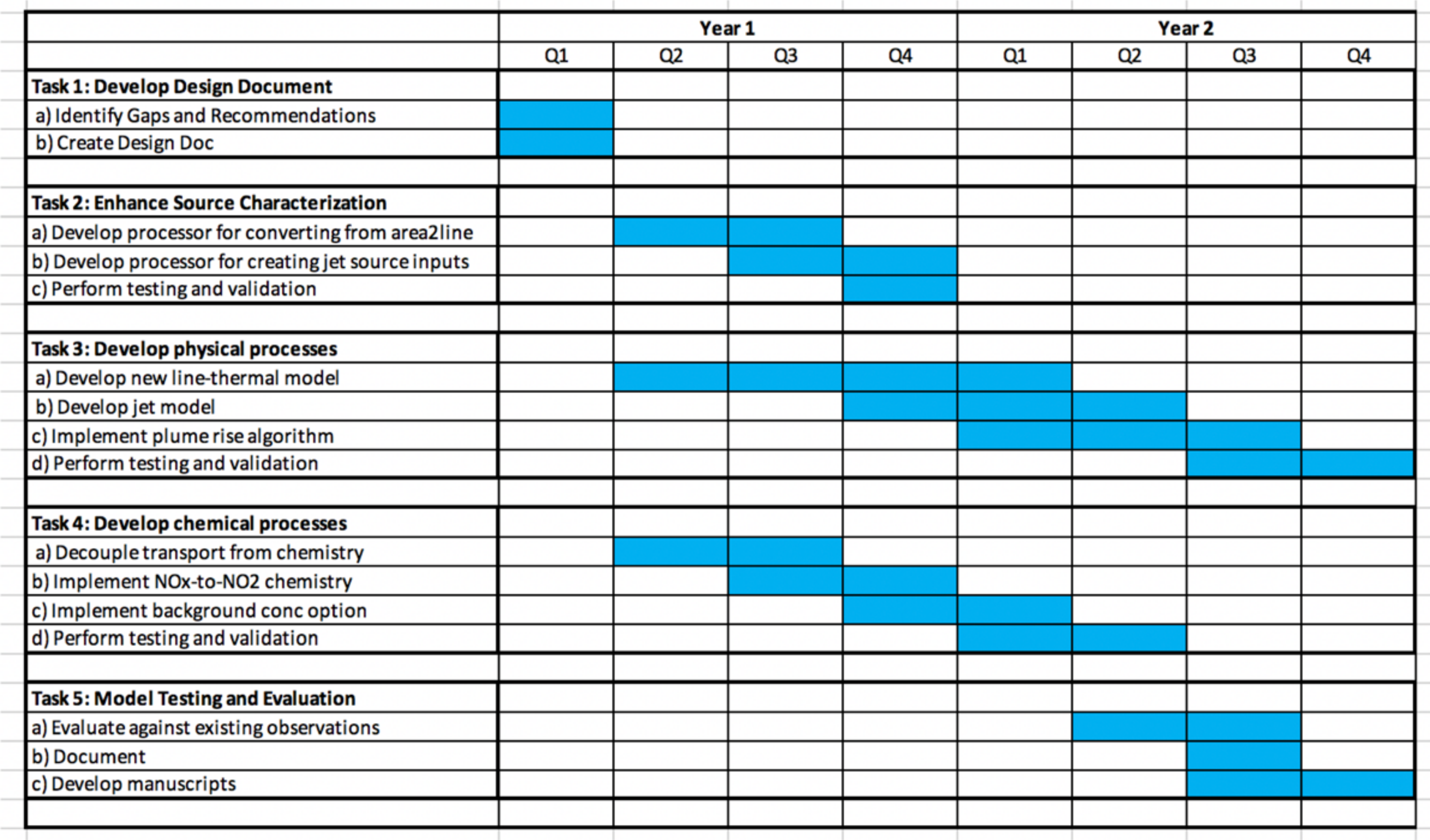
- Develop a new coupled plume rise—wake model for assessing the effects of wake vortices on plume rise, dispersion, and ground-level concentrations
  - Modify simple FEM plume rise model to include wake effects (*Arunachalam et al., 2017)*
- Analyze existing large eddy simulation results of wake vortices for aircraft on or near the ground for use in guiding development and testing of coupled plume rise and wake model
- Conduct further analysis of observed near-runway surface concentrations of aircraft pollutants (at any airport)
  - Determine if high concentrations occur near the runway take-off
  - Compare with those near the runway starting end (x = 0)
- Consider potential field experiment deploying a dense array of near-runway surface monitors of aircraft pollutant to be measured in real time (e.g., NOx)
  - Assess if high concentrations occur near take-off end of the runway
  - Compare with concentrations near the aircraft starting position (x = 0)

Arunachalam et al., 2017 (ACRP Report)

Task 1: Approach: Chemical Processes

- Modeling chemistry and aerosol microphysics in steady-state model such as AERMOD is challenging as
  - Chemical reaction rate is faster which needs solving ODE
  - Gaussian model does not have any time step to solve ODE
  - Current AERMOD has only empirical chemistry: NO-NO_2 (OLM, PVMRM)
- Enhance Chemical Processes for NO_2
  - Scheme that separates transport and chemistry using concept of species age *(Venkatram et al., 1997)* currently being incorporated into AERMOD *(Carruthers et al., 2017)*
  - Previously evaluated with observations *(Valencia et al., 2018)*
  - Incorporate this scheme into AEDT and test with measurements from airport-relevant field studies
- Including chemistry and aerosol microphysics in the Lagrangian non-steady state dispersion model such as SCICHEM, CALPUFF model is easier
  - Decouple transport from chemistry
  - SCICHEM has the detailed chemistry used in CTM model
  - Enhance line-puff model with detailed chemistry and aerosol microphysics

Proposed Schedule



	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Develop Design Document								
a) Identify Gaps and Recommendations	🟦							
b) Create Design Doc	🟦							
Task 2: Enhance Source Characterization								
a) Develop processor for converting from area2line		🟦	🟦					
b) Develop processor for creating jet source inputs			🟦	🟦				
c) Perform testing and validation				🟦				
Task 3: Develop physical processes								
a) Develop new line-thermal model		🟦	🟦	🟦	🟦			
b) Develop jet model				🟦	🟦	🟦		
c) Implement plume rise algorithm					🟦	🟦	🟦	
d) Perform testing and validation							🟦	🟦
Task 4: Develop chemical processes								
a) Decouple transport from chemistry		🟦	🟦					
b) Implement NOx-to-NO2 chemistry			🟦	🟦				
c) Implement background conc option				🟦	🟦			
d) Perform testing and validation					🟦	🟦		
Task 5: Model Testing and Evaluation								
a) Evaluate against existing observations						🟦	🟦	
b) Document							🟦	
c) Develop manuscripts							🟦	🟦

Summary

- Draft framework for new dispersion model developed
  - Systematic approach to focus on key processes
- Next steps
  - Finalize framework
  - Develop detailed design document
  - Start model development
  - Plan for comprehensive field study for further validation

Challenges seeking assistance from ASCENT Advisory Board

- Cost-share for new project

Interfaces and Communications

- External
  - – Multiple presentations at Annual CMAS Conference, and UC Davis Aviation Noise and Emissions Symposium, ITM Conference
  - – Additional presentations:
    - NC-BREATHE Conference, April 2019
  - – National Aviation University, Kyiv, Ukraine
- Within ASCENT
  - – ASCENT NOI 18 (BU)

Contributors

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