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

Project 19

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ASCENT
AVIATION SUSTAINABILITY CENTER

Motivation

Previous PARTNER work showed that Aviation-attributable health impacts due to $PM_{2.5}$ will be ~6x in 2025 compared to 2005 (Woody et al, 2011, Levy et al, 2012)

- 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 emissions-attributable health impacts are needed

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

➢ Need to quantify
  - ➢ airport or airshed-specific adverse health impacts of aircraft emissions, and
  - ➢ benefits of developing mitigation strategies (e.g. operational changes), and identify trends

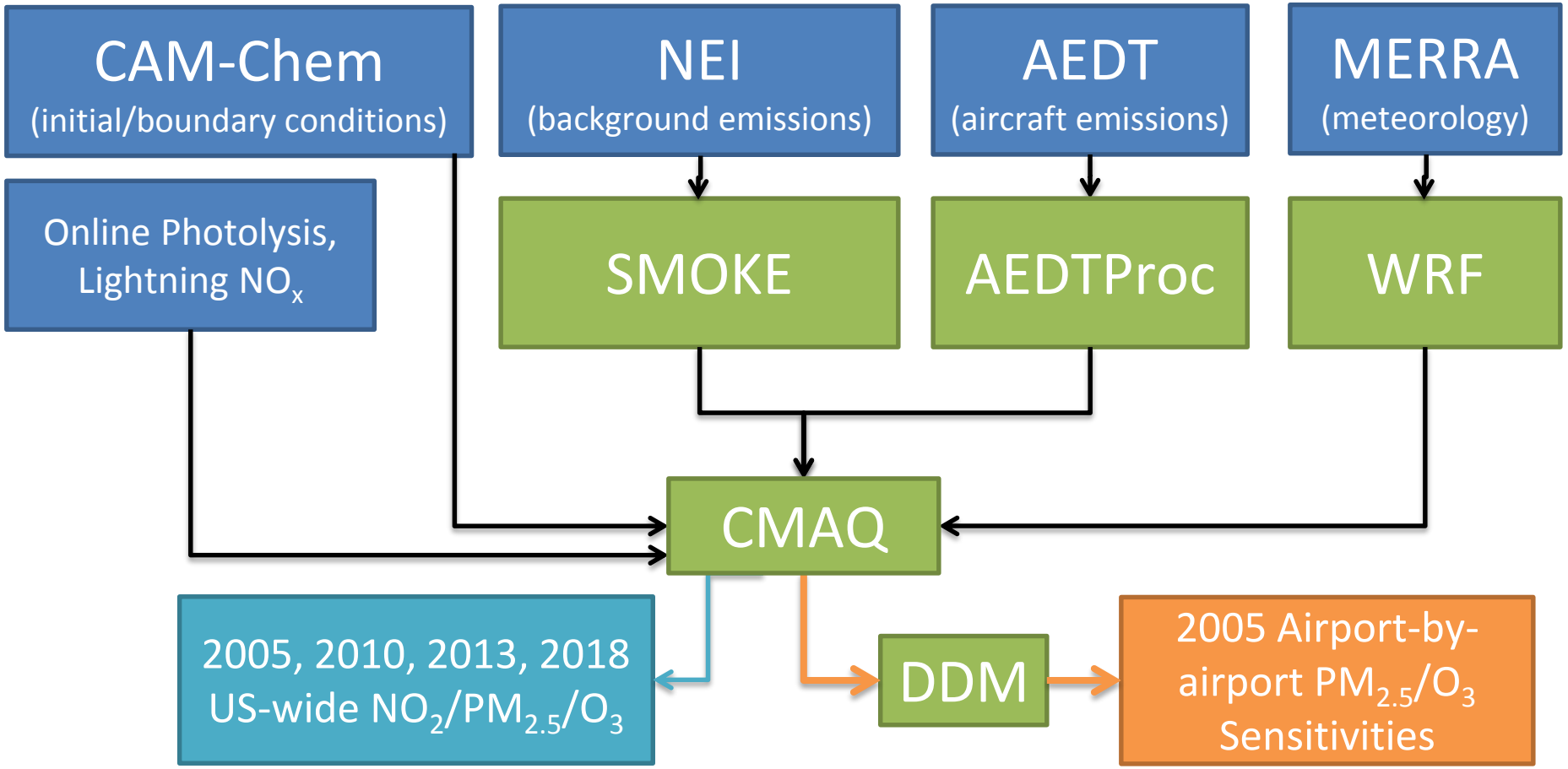
Objectives

- Long term
  - Develop tools for AQ and health impacts reporting and analyzing potential aviation policy scenarios for FAA and ICAO CAEP
- Near term
  - Adapt modeling tools to estimate AQ impacts due to aviation emissions NAS-wide to facilitate year-to-year reporting and scenario analysis
  - Develop implementation of advanced sensitivity tools in CMAQ (such as the Decoupled-Direct Method [DDM]) to allow for sub-regional AQ and health impact characterization
  - Develop sensitivities for aviation scenario analyses
  - Assess impacts of coupled meteorology-chemistry models on aircraft-attributable air quality
  - Enhance AEDT-2b to use high fidelity weather inputs

Outcomes and Practical Applications

- Outcomes
  - Provide tools that combined will:
    - Enable the assessment of exposure and mortality/morbidity risk due to aviation-attributable $PM_{2.5}$ and ozone
    - Allow for the assessment of a wide range of aircraft emissions scenarios, including differential growth rates and emissions indices
    - Account for changes in non-aviation emissions and allow for assessing sensitivity to meteorology
    - Provide NAS-wide and airport-by-airport results
- Practical applications
  - Tools for policy-makers considering various potential aviation policy scenarios
  - Improved understanding of aviation impacts in terms of air quality and public health
  - Updated metrics to track aviation air quality impacts

Approach


CAM-Chem
(initial/boundary conditions)
NEI
(background emissions)
AEDT
(aircraft emissions)
MERRA
(meteorology)
Online Photolysis, Lightning NO_x
SMOKE
AEDTProc
WRF
CMAQ
2005, 2010, 2013, 2018 US-wide NO_2/$PM_{2.5}$/O_3
DDM
2005 Airport-by-airport $PM_{2.5}$/O_3 Sensitivities

Schedule and Status

- NAS-wide analyses
  - Develop preliminary modeling framework for NAS-wide analyses for 2005 and 2010 [**Completed**]
  - With revised AEDT inputs, implement framework for future years [**Awaiting revised AEDT inventories**]
- Airport or Airshed-specific analyses
  - Complete CMAQ-DDM simulations, modeling and analyses for 66 individual airports in 30 groups [**Completed**]
  - Explore 2nd order sensitivities [**In Progress**]
- Assess impacts of coupled chemistry-climate models on aircraft-attributable air quality [**In Progress**]
- High Fidelity Weather Processing and Support for AEDT-2b
  - Assess issues and recommendations for future implementation [**Completed**]
  - Support for implementation [**Jan 2016 Start**]

Interfaces and Communications

- External
  - Multiple presentations at Annual CMAS Conference, 2013 and 2014 in Chapel Hill
  - Additional presentations:
    - ISES Conference, 2013, 2014
    - NSF's XSEDE Conference, 2014 (Best paper award)
    - AGU Conference, 2014
    - ITM Conference, May 2015
    - TAC-4 Conference, June 2015
    - ANERS Conference, September 2015
  - ICAO CAEP ISG Meeting, February 2015
- Within PARTNER / ASCENT
  - ASCENT NOI 18 (BU) and 20 (MIT)
  - ACCRI, Post-ACCRI Activities

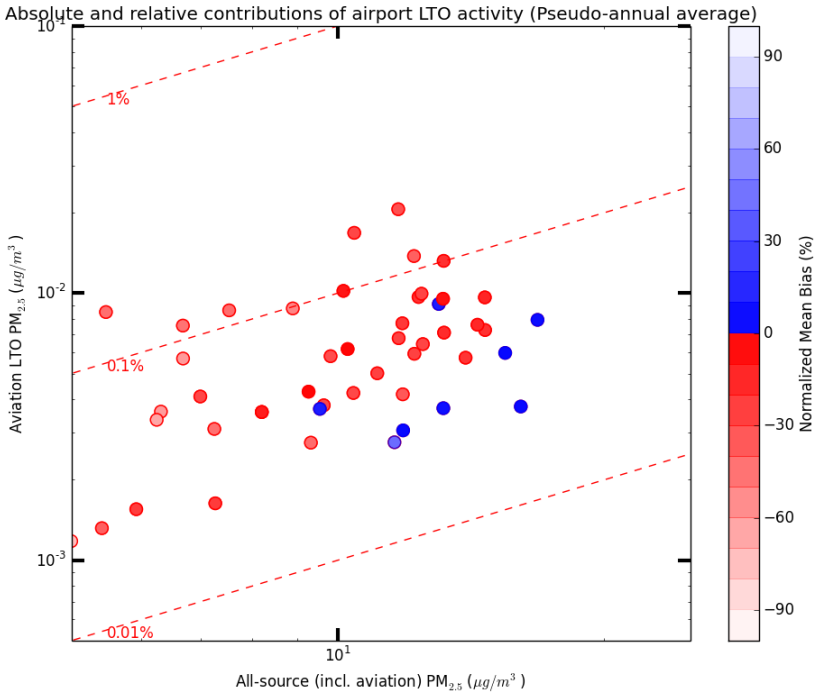
Recent accomplishments (1 of 3)

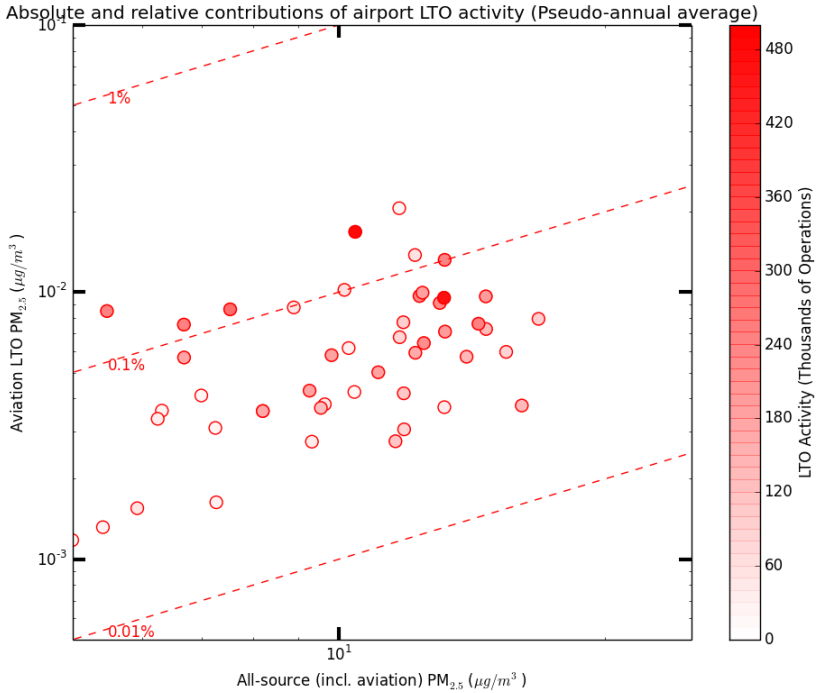
- NAS-wide modeling framework refined and ready
  - CAM-Chem based boundary conditions ready for 2005 and 2050
  - Modeling platform migrated to CMAQ v5.0.2
  - Preliminary modeling assessment complete for 2005, 2010
  - Waiting for AEDT emissions for future years
- CMAQ-DDM based modeling for individual airport assessment completed for 2005
  - Calculated 1st order sensitivities
  - Results vetted against prior NAS-wide work
  - Ability to track total $PM_{2.5}$ impacts to individual aircraft precursor
  - 2 papers finalized
- Supported ATAC in developing recommendations for AEDT High Fidelity weather
  - Identified potential of using MERRA-based inputs and possible limitations

Recent Accomplishments and Contributions (2 of 3)

Individual Airport-attributable $PM_{2.5}$ due to LTO emissions from each of 66 airports

(Average of January and July 2005)



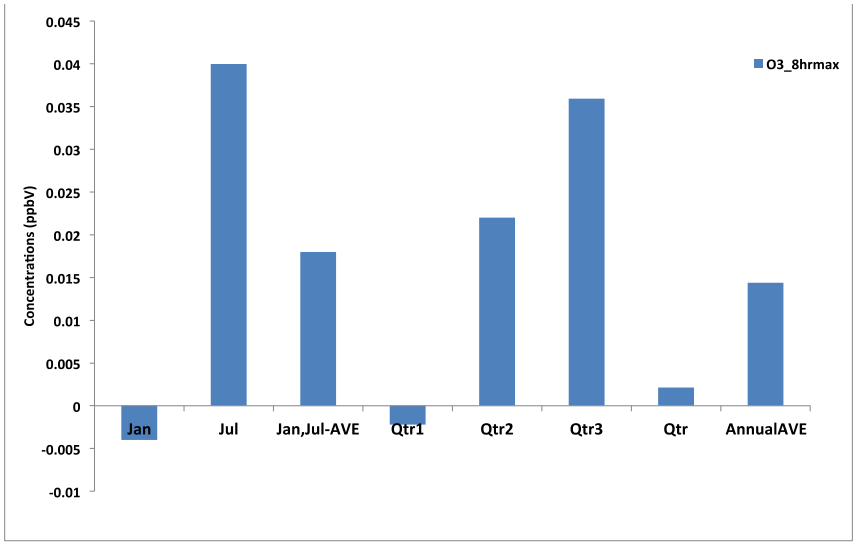


- **Able to estimate individual airport-by-airport sensitivity to primary and secondary $PM_{2.5}$**
- **9 airports have at least 0.1% contribution to total $PM_{2.5}$ at home grid-cell**
- **Substantial heterogeneity exists in airport-specific impacts**

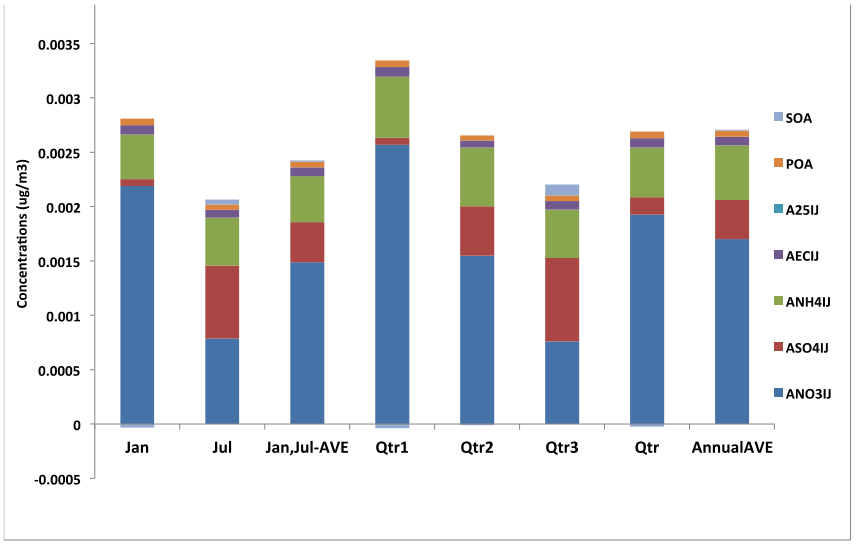
Recent Accomplishments and Contributions (3 of 3)

Comparison of 2-month averages versus 12-month averages of NAS-wide aviation-attributable O_3 and $PM_{2.5}$

Daily Max 8-hr O3



Daily Ave $PM_{2.5}$



- **Individual airport assessment used Jan and Jul months to represent winter and summer months, and used the average of these 2 months to represent annual averages**
- **Based upon comparison with a true 12-month based annual average, the 2-month average is a reasonable approximation (125% for O3, and 90% for PM2.5)**

Summary

- Summary statement
  - Completed development of NAS-wide tool
  - Completed assessing airport-specific O_3, $PM_{2.5}$ from top 66 airports in the U.S.
- Next steps
  - Use NAS-wide framework to model AQ impacts for the years 2005, 2010, 2013, and 2018 using AEDT-based emissions inventories from FAA's Goals and Targets
  - Explore second order sensitivities using CMAQ-DDM
  - Begin expanding CMAQ to use coupled model for assessing impacts of feedbacks on aviation-attributable AQ
- Key challenges/barriers
  - Consistent IC/BCs from Global models for years of interest
  - Ongoing delays in AEDT inventories
  - Coordination/comparison between adjoint and CMAQ-DDM work will require additional steps

References

- Woody, M., B.H. Baek, Z. Adelman, M. Omary, Y.-F. Lam, J. West and S. Arunachalam (2011). An Assessment of Aviation Contribution to Current and Future Fine Particulate Matter in the United States, *Atmos. Environ., 45 (20):*3424-3433
- Levy JI, Woody M, Baek BH, Shankar U, Arunachalam S. Current and future particulate matter-related mortality risks in the United States from aviation emissions during landing and takeoff. Risk Anal 32: 237-249 (2012).
- Zhang, W., Capps, S. L., Hu, Y., Nenes, A., Napelenok, S. L., and Russell, A. G.: Development of the high-order decoupled direct method in three dimensions for particulate matter: enabling advanced sensitivity analysis in air quality models, Geosci. Model Dev., 5, 355–368, doi:10.5194/gmd-5-355-2012, 2012.

Contributors

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Acronyms

- AEDT: Aviation Environmental Design Tool
- AEDTProc: AEDT Processor
- CAMChem: Community Atmospheric Model with Chemistry
- CMAQ: Community Multiscale Air Quality Model
- DDM: Decoupled Direct Method
- MERRA: Modern Era Retrospective Analysis for Research and Applications
- NEI: National Emissions Inventory
- SMOKE: Sparse Matrix Operator Kernel Emissions
- WRF: Weather Research Forecast Model