Noise Emission and Propagation Modeling

Project 5

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Opinions, findings, conclusions and recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of ASCENT sponsor organizations.
Motivation

- There are gaps in current FAA tools to model en-route flights and include altitude-dependent atmospheric conditions
- Need to develop improved models and validate models for the emission of sound from aircraft and propagation from source to receiver
- Help enhance AEDT and its impact on aviation environmental management
Modeling needs

• For en-route, need to predict noise over broad area
  - current aircraft
  - future advanced propulsions, such as open rotor

• Need integrated databases for use by both noise and emissions models for all phases of flight

• Need to include source motion effects

Objectives

• Study effect of source motion and further develop numerical modeling methods

• Process field measurement data (e.g., EU’s BANOERAC) and begin validating numerical models

• Continue linking AEDT weather databases for noise
Schedule and Status

• Ongoing for Year 3
  **Penn State and Purdue**
  – Assess usability and quality of data obtained from DiscoverAQ and Vancouver Airport Authority for future validation activities

  **Penn State**
  – Assess use of meteorological reanalysis datasets for inclusion in noise prediction tools

  **Purdue**
  – Develop a simplified model for the effect of ground impedance on enroute aircraft noise

• Summary for Years 1&2
  **Penn State**
  – Determine best practices for use of atmospheric absorption models
  – Include simplified atmospheric inputs to noise modeling

  **Purdue**
  – Provide a fast and reliable numerical model for predictions of sound field in a 3-dimensional space.
Outcomes and Practical Applications

• Outcomes
  – Penn State
    • New understanding of links between noise and emissions and relationship to altitude-dependent atmosphere
    • Validation of existing propagation models with experimental databases
    • Reports and codes
  – Purdue:
    • New understanding of source motion, time domain, 3-D prediction, and ground impedance influences
    • Validation of existing propagation models with experimental databases
    • Reports and codes

• Practical applications
  – Improvements to AEDT
  – Better prediction of noise in National Parks
  – Work useful for future use modeling noise from open rotor or other new propulsion systems
Approaches

- Penn State (began September 2014)
  - Evaluate alternative atmospheric profiles in comparison to current FAA/Volpe approaches
  - Assess model links between noise tools and AEDT weather databases
  - Prepare for and identify avenues for propagation model validation using 4-D \((x,y,z,t)\) aircraft trajectory data using databases such as EU’s BANOERAC database

- Purdue (began August 2014)
  - Study the combined effect of source motion, source directivity, atmospheric and terrain profiles on the propagation of en-route noise
  - Analyze and examine existing databases, DiscoverAQ for example, for validating the numerical models developed
  - Investigate the effect of terrain profile and microphone placement on noise measurements
Status of databases

• U.S. government acquired data
  – NASA/FAA Discover AQ (Data released in late 2015)
  – 8 complete sets of data conducted in September 2013

• Vancouver, Canada airport data
  – Owned by a non U.S. airport, but easily accessible
  – Extensive measurements of aircraft terminal-area noise with
    • Ground noise data
    • Radar tracking data (NAV Canada)
    • Local weather data
  – Agreements between Penn State, Purdue and Vancouver Airport Authority have been reached in April 2016

• BANOERAC database
  – Owned by EASA, distributed by ANOTEC
  – Negotiations restarted for agreements (May 2016)
Updated Schedule and Status

August 2015: The research team has been working on the project at its 3rd year
Sept. 2015: Continue liaisons with the Vancouver Airport Authority for the release of noise data
Oct. 2015: Fall 2015 ASCENT advisory committee meeting
Dec. 2015: Moving source prediction models have been completed
Jan. 2016: Discover AQ data became available. (Thank you, Volpe!)
Feb. 2016: Underway: Analyze Discover AQ data, both Purdue and Penn State
March 2016: Initial agreements have been reached between Penn State, Purdue, and Vancouver Airport Authority
April 2016: Spring 2016 ASCENT advisory committee meeting
June 2016: Assessment of Vancouver Airport Authority datasets
June 2016: Second technical report is submitted
Validation of Source Motion Modeling (Purdue)

- Validation of the predicted Doppler effect of en-route aircraft

Photos and graphs taken from Discover-AQ Acoustics – Report prepared by VOLPE

Lockheed P-38 Orion

Discover-AQ Acoustics NASA/VOLPE

B-200 King Air Pre-Flight Test Spectra at Time of $L_{A,SNR}$ at Mic 1

B-3P Pre-Flight Test Spectra at Time of $L_{A,SNR}$ at Mic 1

- Lockheed P-38 Orion
- Beechcraft B-200 Super King Air

Photos and graphs taken from Discover-AQ Acoustics – Report prepared by VOLPE
Research Summary (Purdue)

- **Prediction method**
  - The vertical speed is assumed to be negligible
  - In-coherent model is used

Arrival time at each sampling point of the aircraft is calculated

Doppler factor at each aircraft location are calculated from the current aircraft speed

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**The path and the velocity of the aircraft**

![Diagram of aircraft paths and velocity](image)
Preliminary Results (Purdue)

(I) Measured Noise Spectra of the pass-by aircraft

(II) Comparison of overall noise levels

- The peak location has been predicted well
- Currently assume simple atmosphere and omnidirectional source
Analysis Path for Event 35 (Penn State)

1. Assume spherical spreading
2. Use the value of $L_p$ at point closest to SP1
3. Find $L_p$ at 10 m from aircraft
4. Find $L_p$ at all points along the flight path

For the given flight path:

- Top view of flight track Event 35 after applying the great circle theory
- Error in calculated $L_p$ value as a function of distance
  - Mean error $= -3$ dB
Use of Reanalysis Data for Noise Modeling (Penn State)

- Current Models: assume homogeneous atmosphere based on surface values
- Aircraft Noise Propagation: mostly far above surface layer
- Next Step: variable atmosphere with height (profiles)
- CFSR Reanalysis: consistent, QCed global sets of profiles
  - Temperature
  - Humidity
  - all vs. altitude
  - 0.5° horizontal resolution
  - vertical resolution depends on altitude
    - ~100 m near surface, ~1 km near cruise alt (10 km ≈ 33,000 ft)
- Now: insert into AERNOM raytracing propagation model
  - aircraft source sound power & spectrum
  - annual-average profiles (T,P,h,u vs. z)
Reanalysis modeling (Penn State)

UCAR

CFSR_yyyy.grb

pre-process

N years of meteo profiles
T(z) u(z) h(z) P(z)

(source & receiver info)

convert

single profiles T(z) u(z) h(z) P(z)

single profiles c(z) α(z)

convert

acoustic raytrace

noise contour L(x,y)

currently testing

(average)

complete
Reanalysis Approach and Results (Penn State)

- Extract & average 1 year of T profiles
- Assume for now
  - $h(z) = 0$ (dry air)
  - $u(z) = 0$ (no wind)
- Calculate fits of T
  - homog (as in AEDT)
  - linear fit
  - full polynomial fit
  - ICAO standard atmos
- Ground $L_p$ is different for different fits of T
Interfaces and Communications

• External
  – B. N. Tong (Purdue) and E. Petersen (Penn State) presented papers at Internoise 2015, San Francisco, CA in August 2015.
  – New participation in FAA/Volpe Modeling Tools teleconferences

• Within ASCENT
  – Congratulations to Graduate Research Assistants
    • Bao Tong for passing his Ph.D. defense in August 2015
    • Erik Petersen, receiving his M.S. in December 2015
  – New relationship with Vancouver Airport Authority
  – Continuing relationship with ANOTEC Engineering of Motril, Spain
  – Continuing interface with Volpe Center
  – Ongoing discussions with Penn State Dept. of Meteorology
    • Recommendations regarding atmospheric re-analysis data sets
  – Ongoing discussions with University of North Carolina (emissions)
  – Conversations with ASCENT Project 23
Summary

- Propagation modeling project is ongoing
  - New work on source motion affecting ground impedance (Purdue)
  - New work on atmospheric effects and noise modeling approaches (Penn State)
  - Assessment of DiscoverAQ dataset underway
  - Assessment of Vancouver Airport Authority dataset begins soon
    • Now have a data sharing agreement with Vancouver (YVR)

- Key challenges/barriers
  - Getting international data agreements in place can be challenging
    • Still working on gaining EASA approval for accessing BANOERAC database (en-route)
  - Would like to identify additional industrial partners who can provide supporting data or expertise
References

• B. N. Tong and K M Li, “Sound field predictions for a monopole source moving uniformly in a stratified medium above an impedance plane,” Internoise 2015; San Francisco, CA, August 10-12, 2015.

Contributors

• Penn State: Victor Sparrow, Rachel Romond, Manasi Biwalkar, Erik Petersen
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