Noise Emission and Propagation Modeling

Project 5

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ASCENT
AVIATION SUSTAINABILITY CENTER

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)

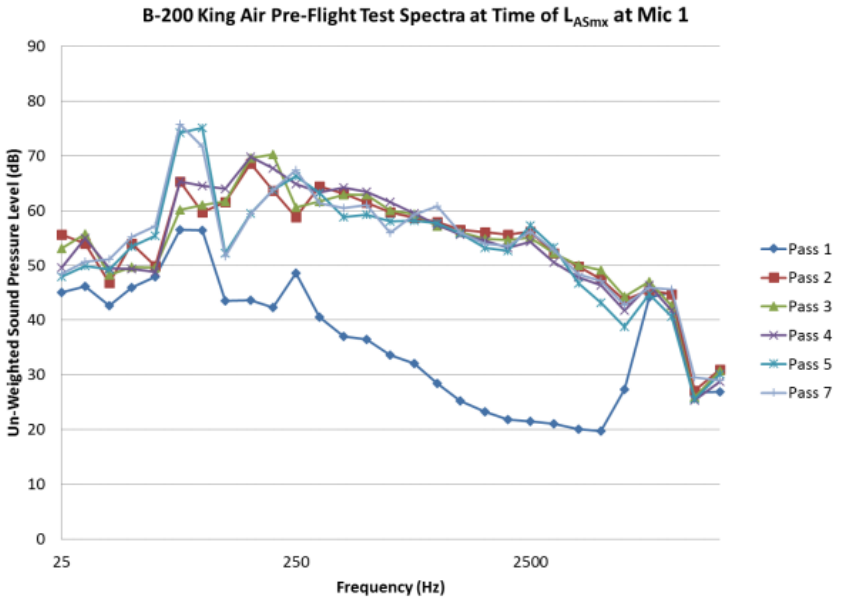
- **Validation of the predicted Doppler effect of en-route aircraft**

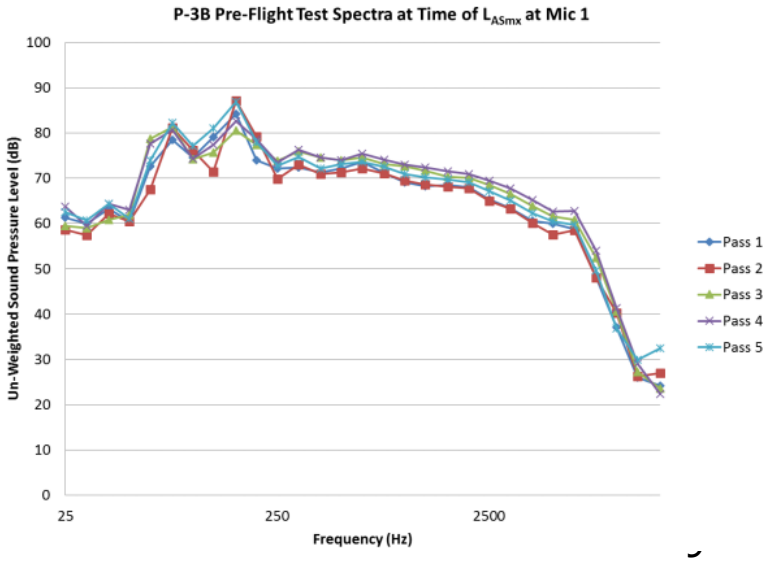
Photos and graphs taken from Discover – AQ Acoustics – Report prepared by VOLPE

Lockheed P-38 Orion

Discover-AQ Acoustics NASA/VOLPE

Beechcraft B-200 Super King Air

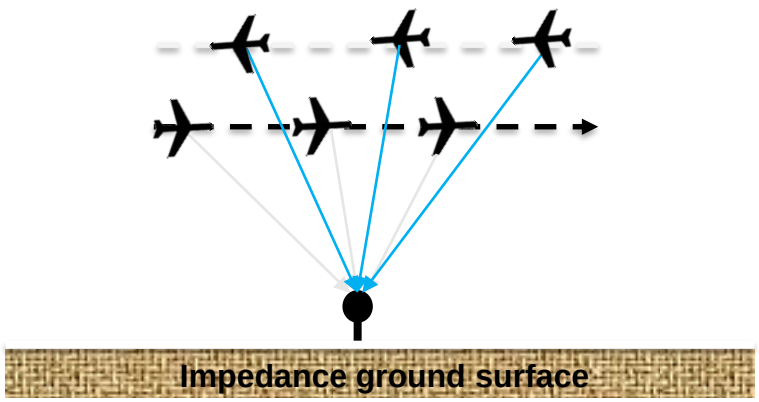




Research Summary (Purdue)

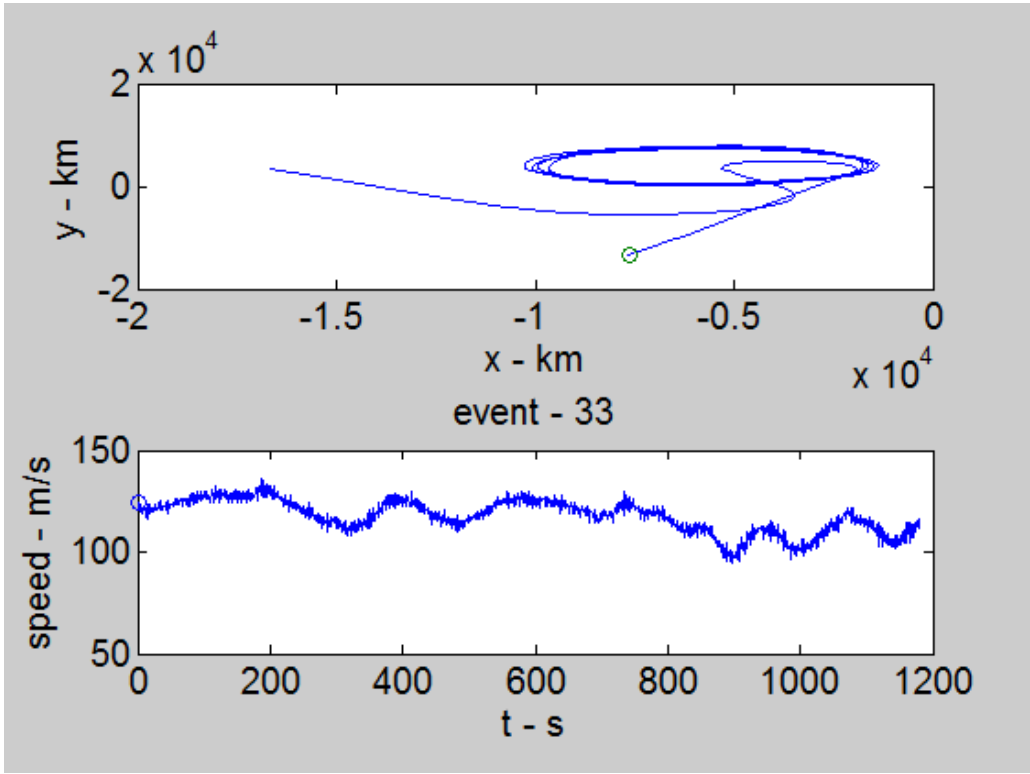
- **Prediction method**
  - The vertical speed is assumed to be negligible
  - In-coherent model is used

Arrival time at each sampling point of the aircraft is calculated



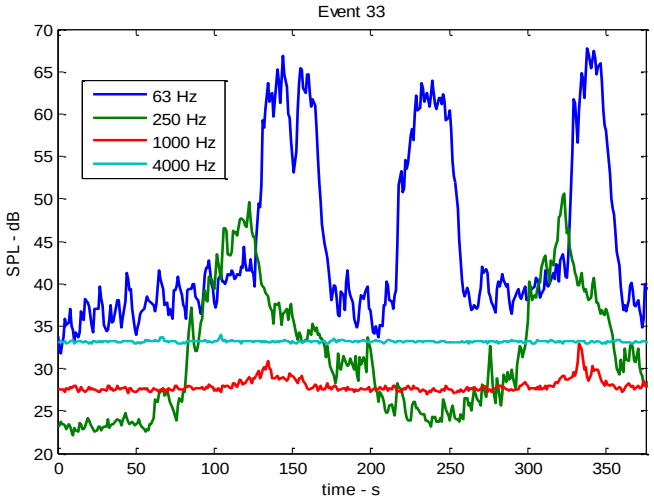
Doppler factor at each aircraft location are calculated from the current aircraft speed

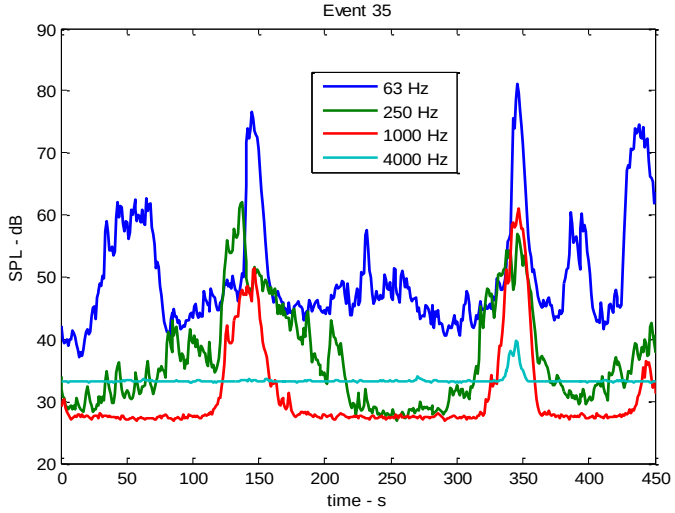
The path and the velocity of the aircraft

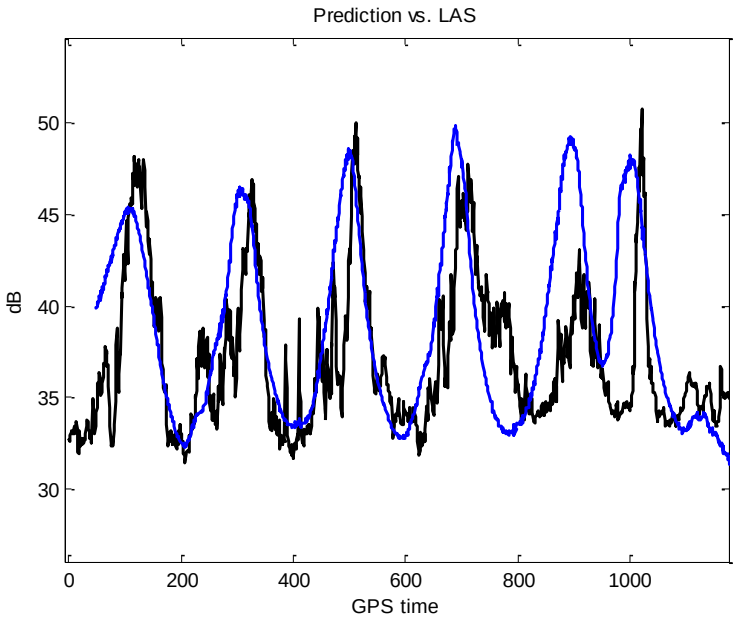


Preliminary Results (Purdue)

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





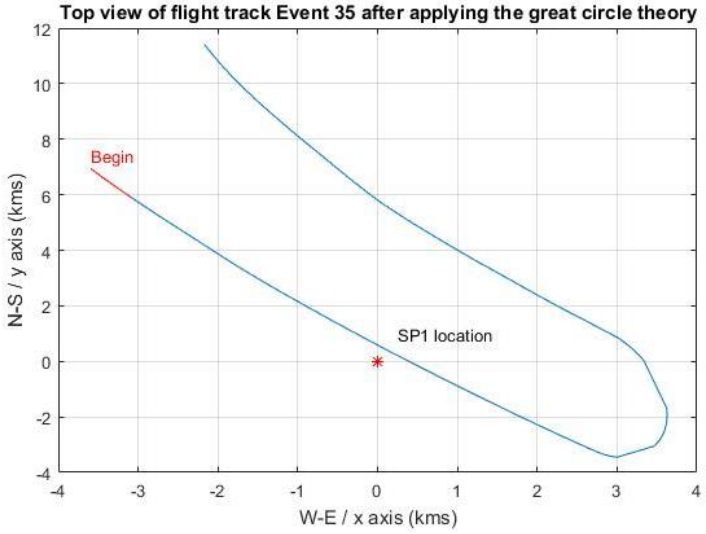


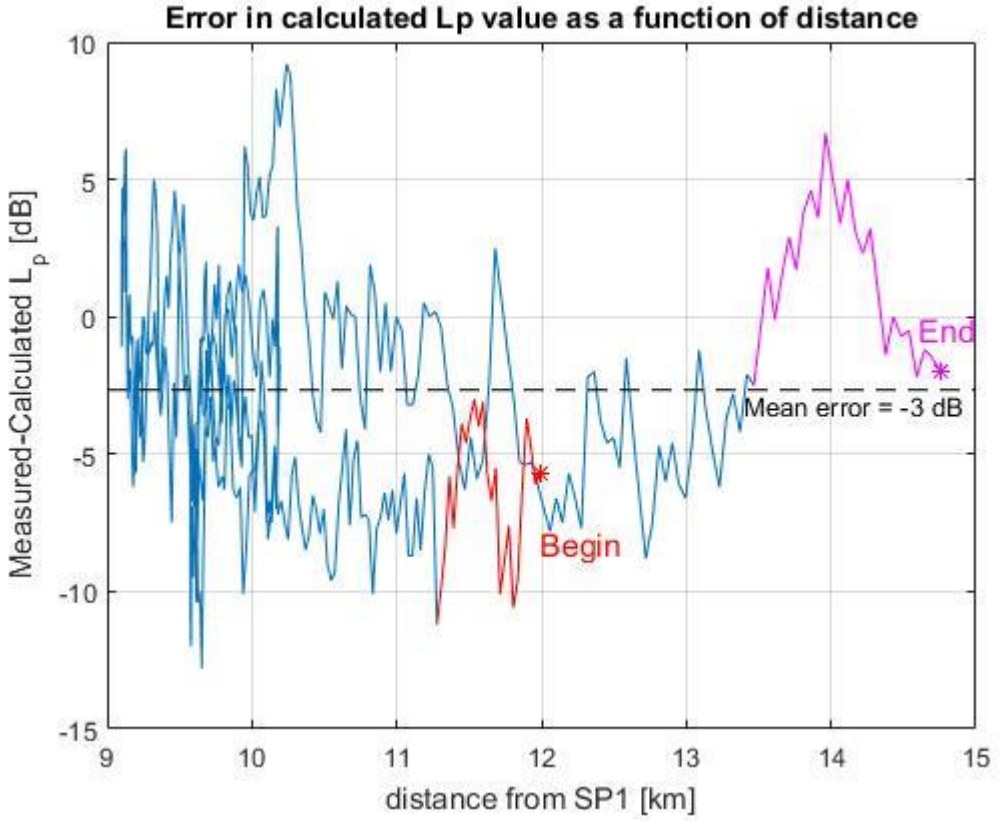
(II) Comparison of overall noise levels

- The peak location has been predicted well
- Currently assume simple atmosphere and omnidirectional source

Analysis Path for Event 35 (Penn State)

Assume spherical spreading → Use the value of L_p at point closest to SP1 → Find L_p at 10 m from aircraft → Find L_p at all points along the flight path

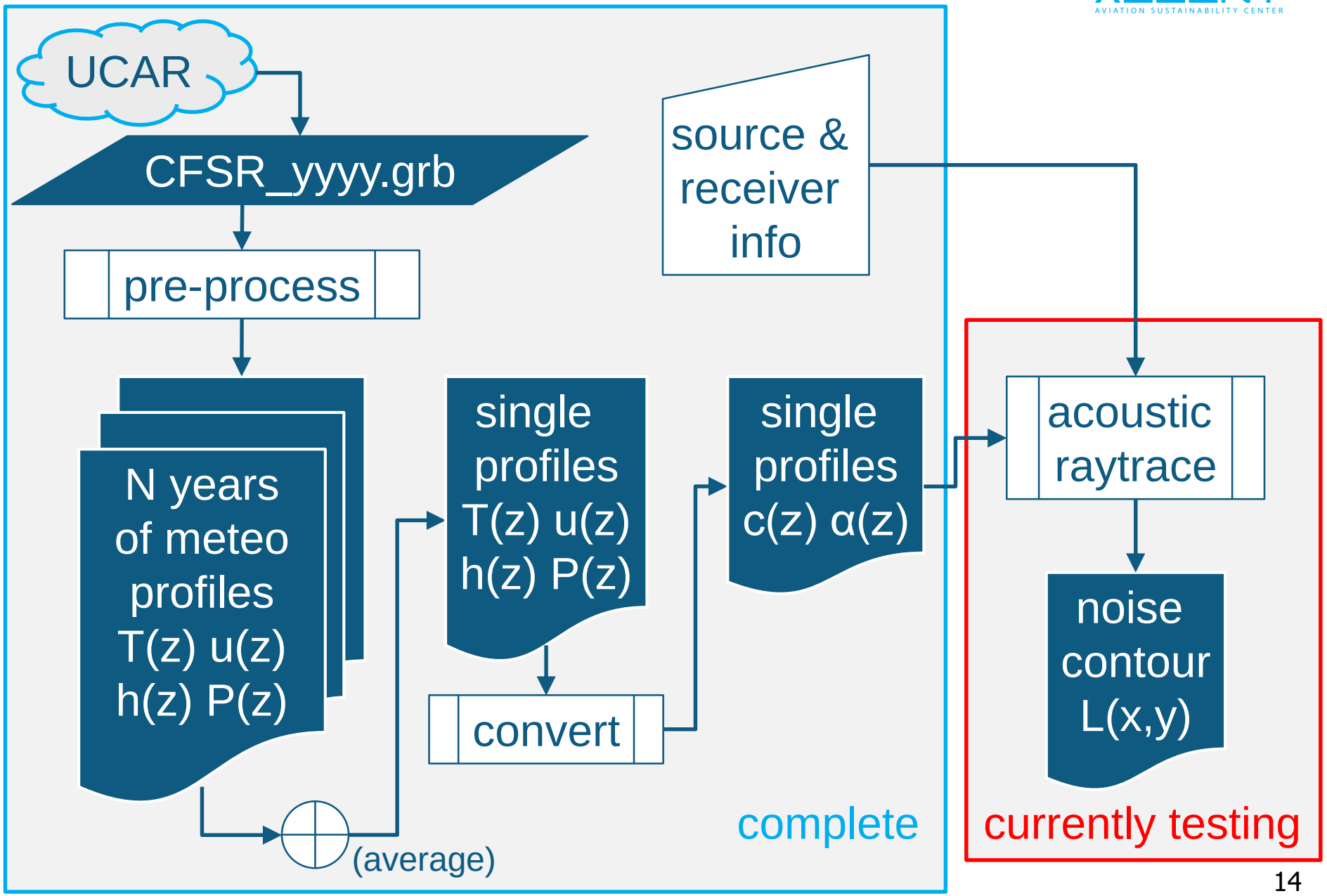




Use of Reanalysis Data for Noise Modeling (Penn State)

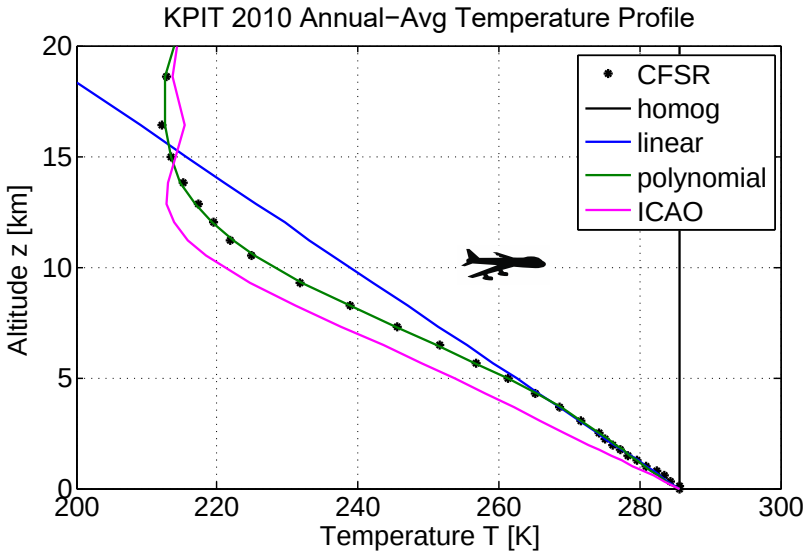
- Current Models: assume homogeneous atmosphere based on surface values
- Aircraft Noise Propagation: mostly far above surface layer
- Next Step: variable atmosphere with height (profiles)
- CFSR Reanalysis: consistent, QCed global sets of profiles
  - Temperature
  - Humidity
  - all vs. altitude
  - 0.5° horizontal resolution
  - vertical resolution depends on altitude
    - ~100 m near surface, ~1 km near cruise alt (10 km ≈ 33,000 ft)
  - Atmospheric Pressure
  - Wind Speed & Direction
  - every 6 hours, 1979 - present
- Now: insert into AERNOM raytracing propagation model
  - aircraft source sound power & spectrum
  - annual-average profiles (T,P,h,u vs. z)

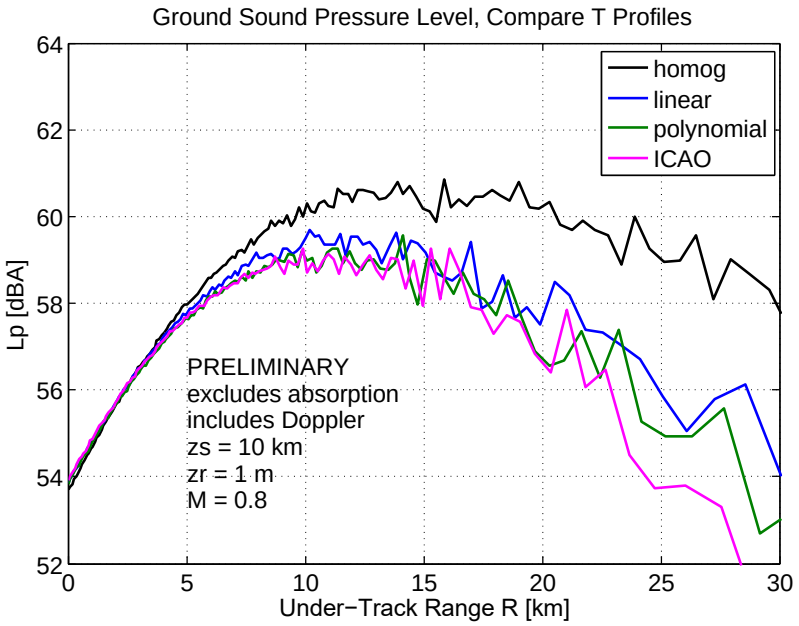
Reanalysis modeling (Penn State)



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 <u>is different for different fits of T</u>





Interfaces and Communications

- External
  - B. N. Tong (Purdue) and E. Petersen (Penn State) presented papers at Internoise 2015, San Francisco, CA in August 2015.
  - Y Wang will present paper at Noise Con 2016, Providence, RI, in June 2016.
  - 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

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- Y. Wang, B. N. Tong and K. M. Li, "Sound field generated by a 3-dimensional moving monopole point source above a locally reacting surface," Noise Con 2016, Providence, RI, June 13-15 (2016).

Contributors

- Penn State: Victor Sparrow, Rachel Romond, Manasi Biwalkar, Erik Petersen
- Purdue: Kai Ming Li, Yiming Wang
- Volpe: Eric Boeker
- Industry partners: Mark Cheng (Vancouver Airport Authority)
  Nico van Oosten (ANOTEC)