Support of Supersonic Aircraft En route Noise Efforts in ICAO CAEP Project 57

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ASCENT

Project 57

Support of Supersonic Aircraft En route Noise Effects in ICAO CAEP

Pennsylvania State University, Farmingdale State College

PI: Victor Sparrow, Penn State

PM: Sandy Liu, FAA

Cost Share Partner(s): Boom, Gulfstream, Pivotal Supersonic

Previous Cost Share Partner: Exosonic

Key Contributor: NASA

Objective:

Research continues to support FAA in the development of technical standards for civil supersonic aircraft under the ICAO CAEP

Task 1: Procedures for en route supersonic aircraft certification

Task 2: Exercising capability of PCBoom software to model secondary sonic booms

Task 3: Additional CAEP support

Project Benefits:

- Predictive capabilities for sonic boom impacts
- Continued study of secondary sonic boom prediction
- Applicability of certain metrics
- Testing of signal processing methodologies for sonic boom signals
- Scheme assessment for sonic boom certification

Research Approach:

- Task 1: Simulate the effects of turbulence on shaped sonic boom within the atmospheric boundary layer (ABL)
  - Propagate from cruise altitude to ABL with no-turbulence tool and ABL to ground with turbulence tool (involving both vector and scalar contributions to turbulence)
  - Examine effects of Reference Day atmosphere
  - Incorporate methods to handle background noise
- Task 2: Predict secondary sonic boom using realistic meteorological data up to 100 km height; measure secondary sonic booms, to the extent possible.
- Task 3: Monitor ongoing research worldwide.

Major Accomplishments (to date):

- Extended KZKFourier software to use non-homogeneous atmospheres
- Conducted new Reference Day crosscheck in WG1
- Confirmed monthly secondary sonic boom predictions provide sufficient detail for coastal buffer predictions
- Successfully measured secondary booms using existing seismic network

Future Work / Schedule:

- Extend KZKFourier to use improved turbulence models
- Improve secondary boom predictions
  - Understanding secondary booms occurring in Mach cut off conditions.
- Measure primary & secondary booms in conjunction with X-59 flights, if possible
- Process X-59 data as if we were certifying a new supersonic aircraft

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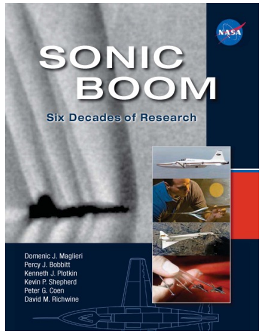
Research Support for SSTG

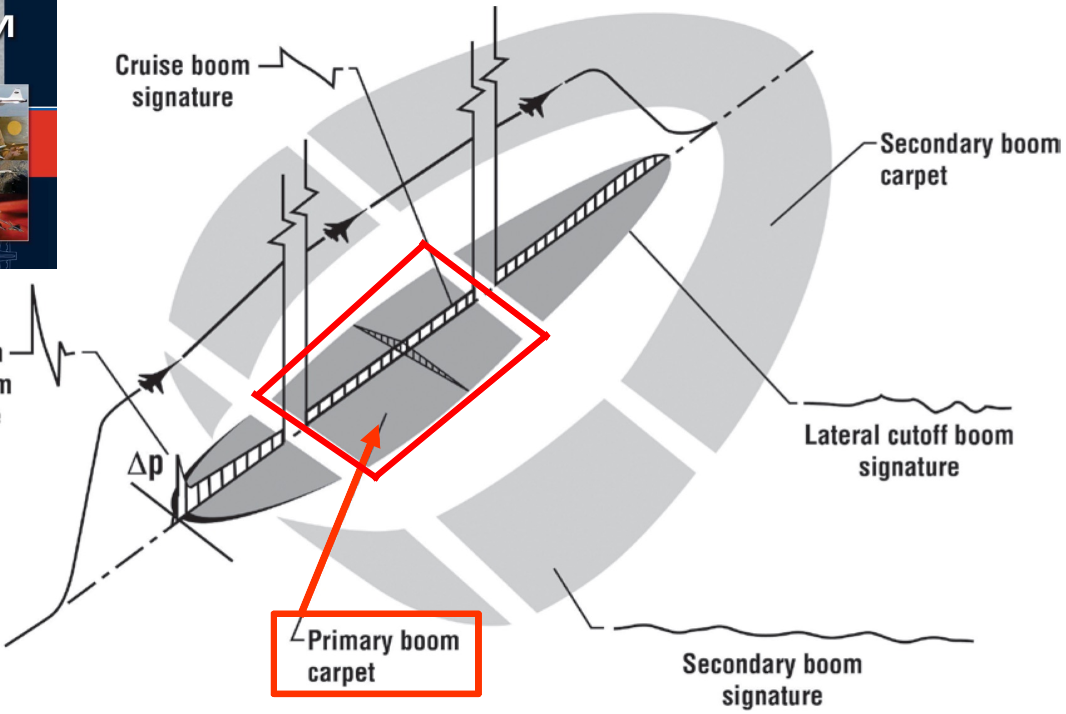
- The Committee on Aviation Environmental Protection (CAEP) has a Noise Technical Working Group (WG1) with a SuperSonic Task Group (SSTG).
- SSTG is trying to develop future certification standards for the en route certification of the sounds from supersonic aircraft.
  - Sorry, but we cannot discuss the details here.
- There are MANY contributors to SSTG. Thank you all.
- ASCENT Project 57 provides overall support and specific research contributions, as needed:
  - Host all the SSTG and subgroup teleconferences.
  - Effects of atmospheric turbulence, and how may affect certification
  - “Other factors” such as secondary sonic boom

Robbie Cowart

To certify, need to acquire data & process, compared to a limit

Maglieri *et al.,* Figure 1.3:



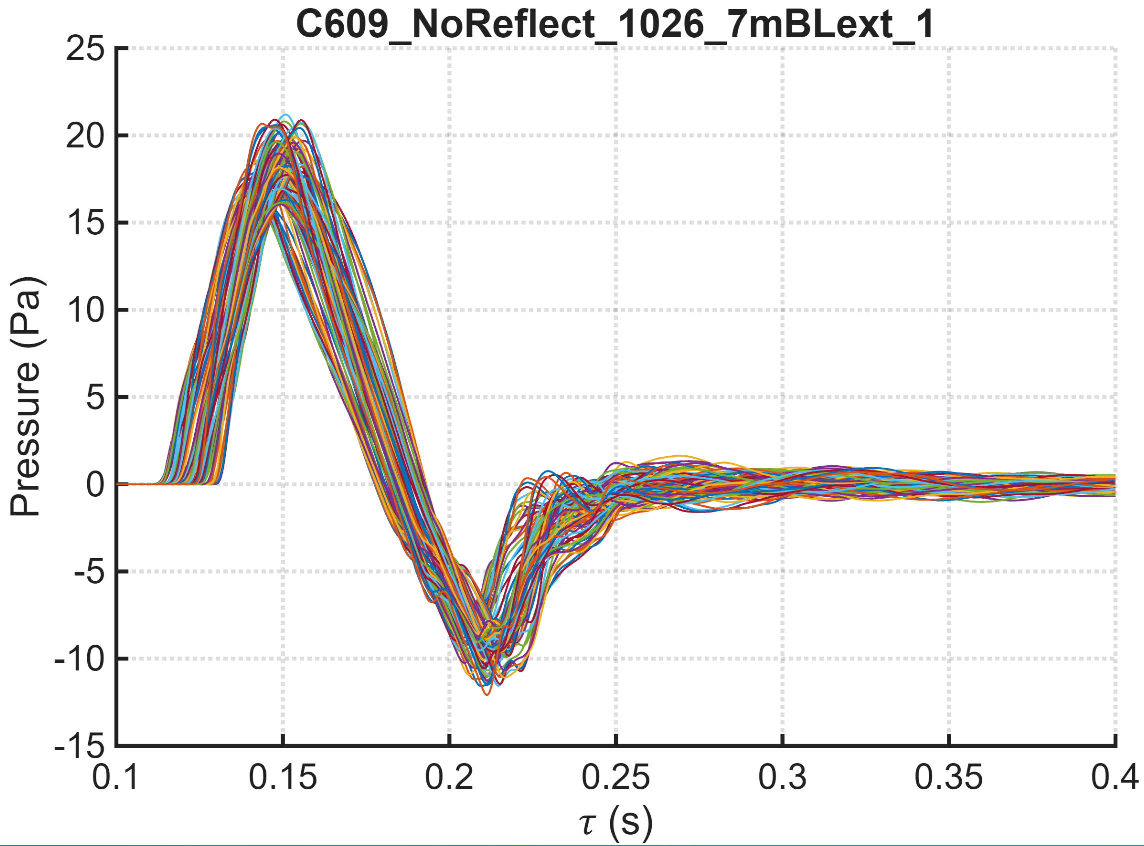


Understand primary carpet, atmospheric turbulence included

- It is important to include the effects of a realistic atmospheric profile during sonic boom simulation.
  - Atmospheric variables such as humidity, pressure, density, and temperature realistically vary by altitude.
- NASA requested we investigate improving the atmospheric turbulence model in KZKFourier. Now we have some results to show.
- In Spring 2025 presentation, focused on buoyant turbulence. Today we focus on friction velocity in surface layer (10% of ABL just above the ground).
- Friction velocity u_* is the meteorological turbulence value that prescribes the variance of shear-induced vector turbulence as $\sigma_s^2 = 3.0u_*^2$.
  - Friction velocity is constant in the original version of KZKFourier!

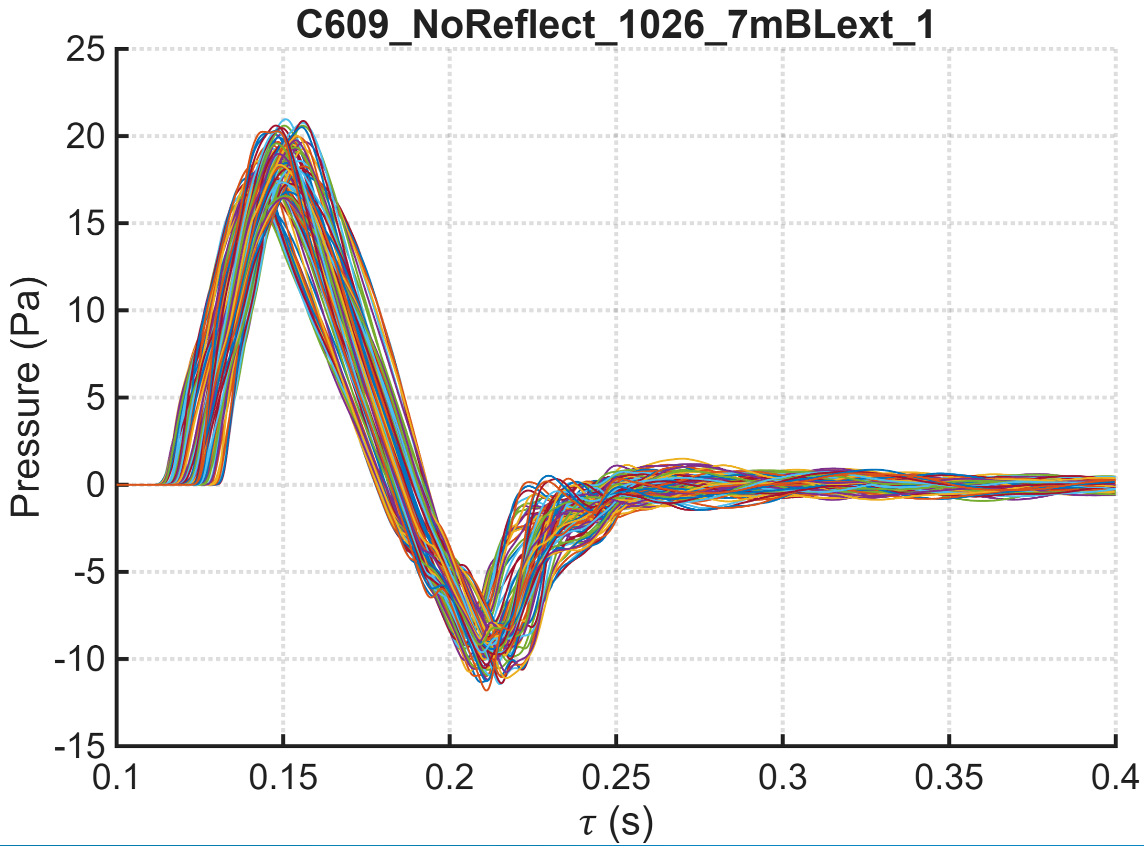
Original Code (u_* is constant)

- Average over 100 waveforms: 66.60 PLdB, 81.65 ISBAP



With decay of u_*

- Average over 100 waveforms: 66.65 PLdB, 81.72 ISBAP



Summary of shear investigation

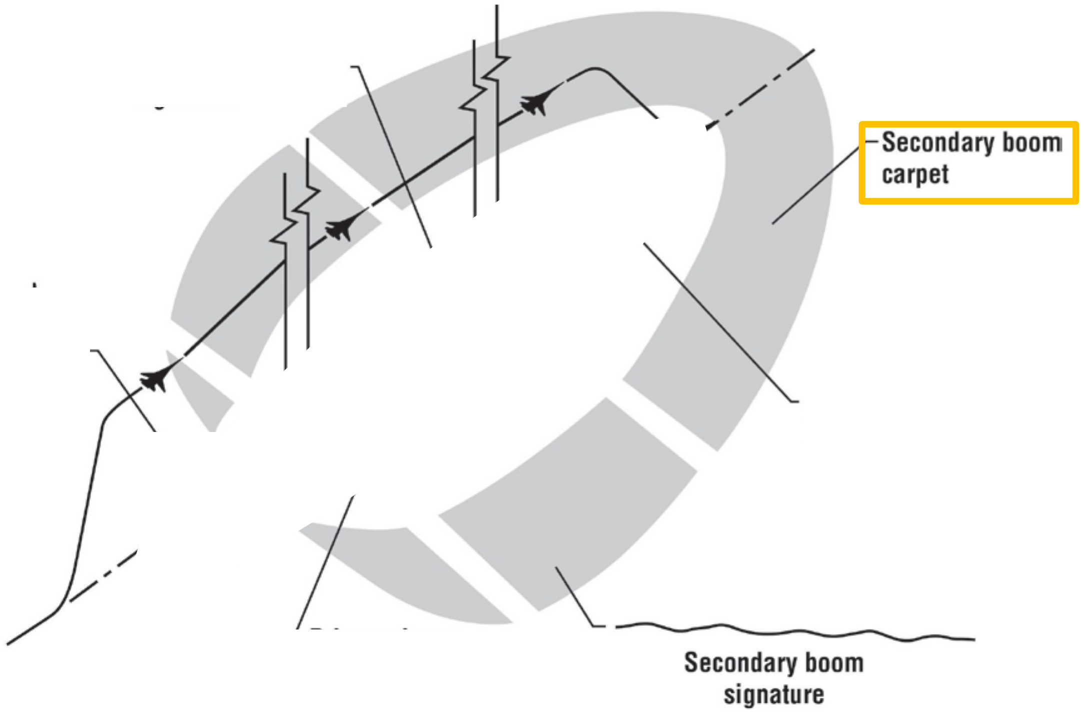
- Applying the square root of a linear decay with height to friction velocity u_* results in decay to zero of the shear turbulence spectrum at top of the ABL.
  - Decay of u_* with increasing height eventually counteracts the growth of the shear length scale.
- Less overall shear turbulence results in slightly increased (0.1 dB) average sound metrics.

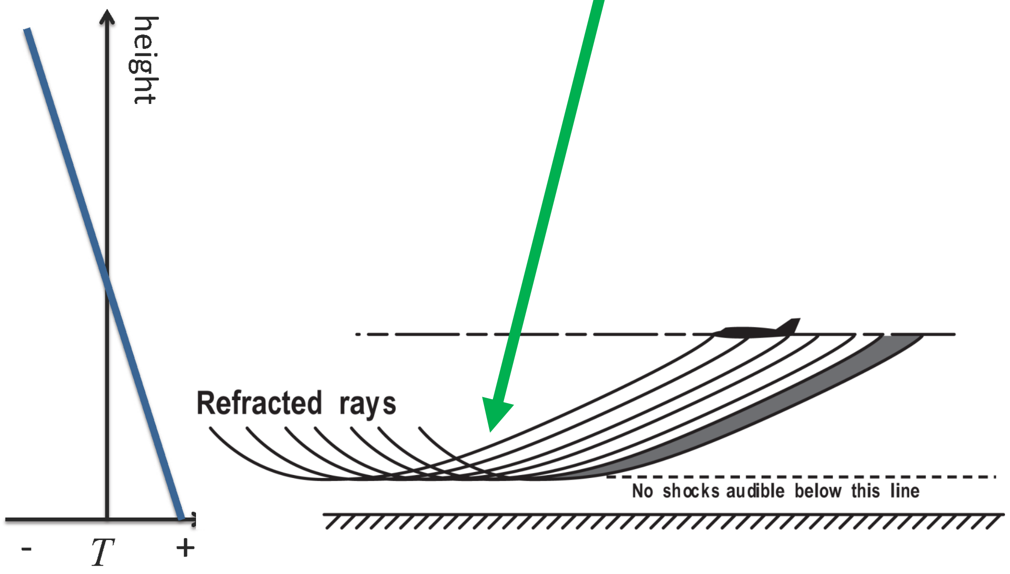
Josh Kapcsos

This material will be presented at the joint meeting of ASA and ASJ in Honolulu, December 1-5, 2025.

Preliminary results! Please do not cite or quote.

Now shift gears!   Look at secondary booms from Mach cut off



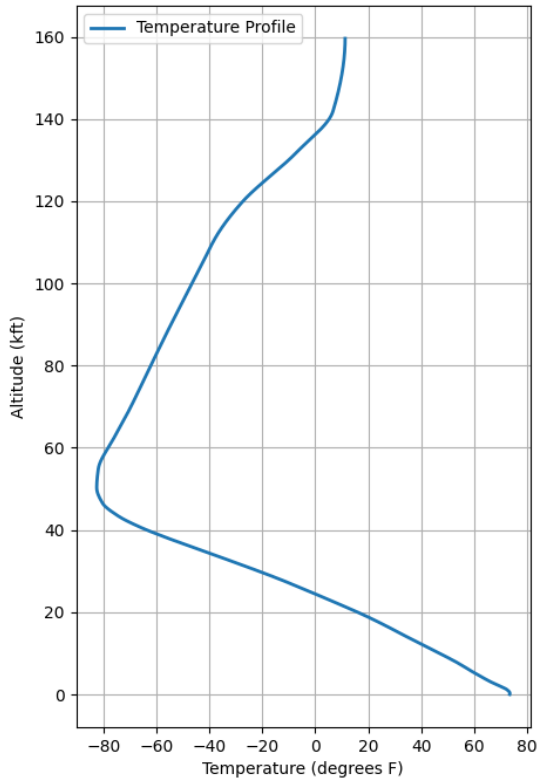


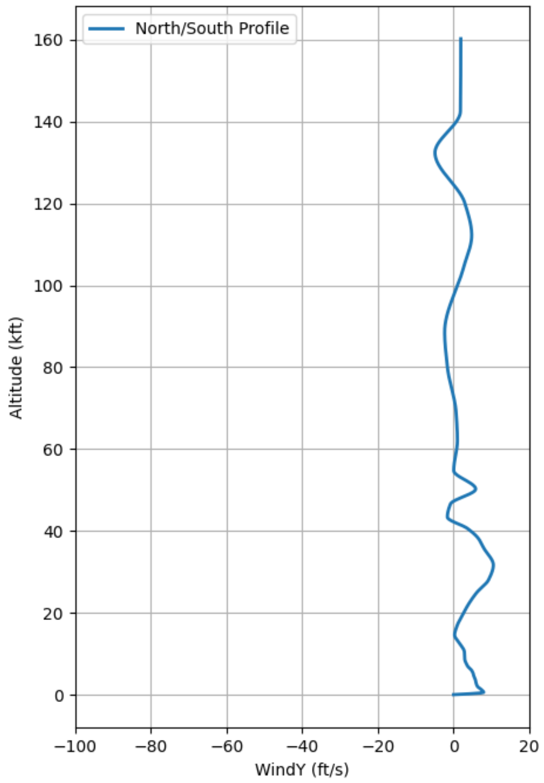
This will occur under certain circumstances. When?

Studies are underway . . . Secondary booms & Mach cut off

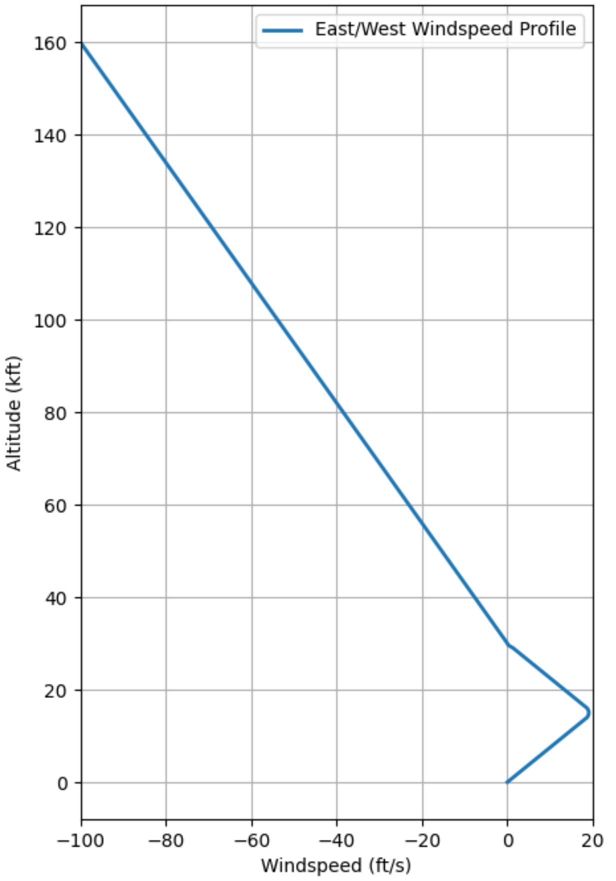
- Aircraft trajectory
  - Steady level flight at Mach 1.15
  - Altitude = 40,000 ft
  - Heading = Due west
  - Rays shown are from last trajectory position
- Temperature profile is standard
  - North/South winds remain constant
  - East West winds were varied
    - Upper atmospheric winds between -100 and 100 ft/s
    - Lower atmospheric winds between -100 and 100 ft/s
    - The altitude of the peak lower atmospheric winds between 10 and 20 kft

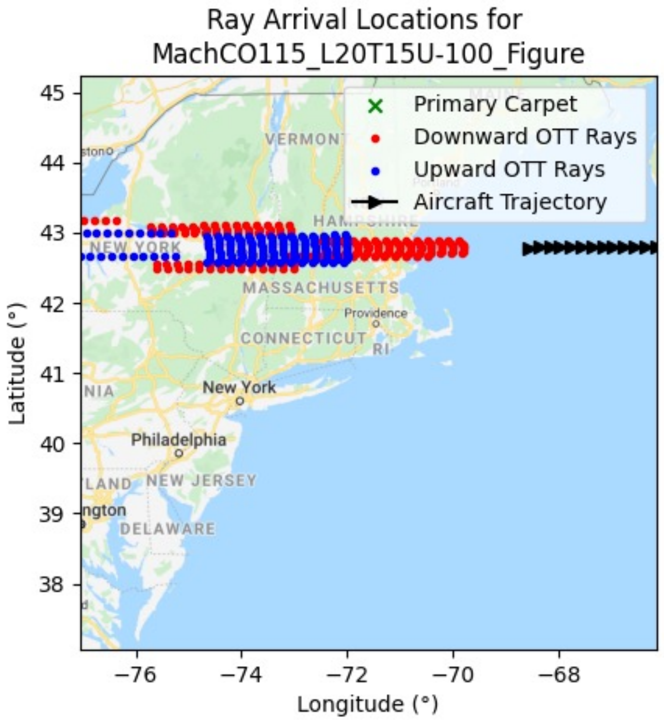
Temperature and North/South wind profiles (FYI)





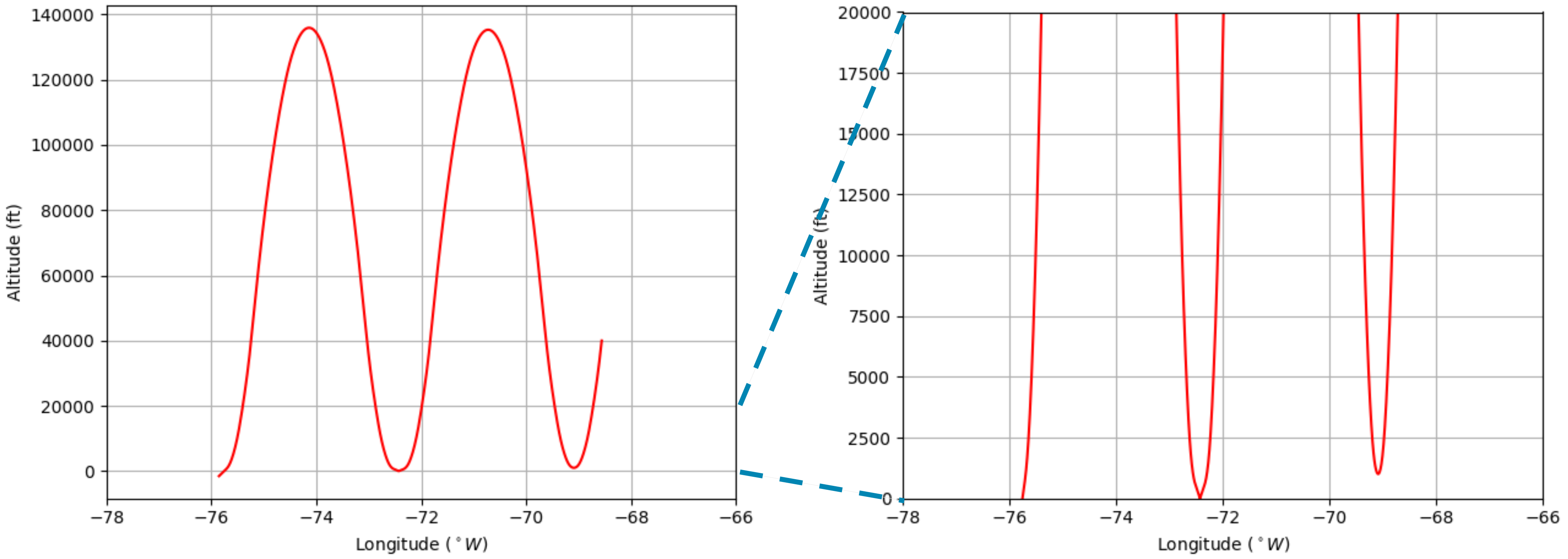
East/West wind profile #1:
Lower is 20 ft/s w max winds at 15 kft; Upper max is -100 ft/s





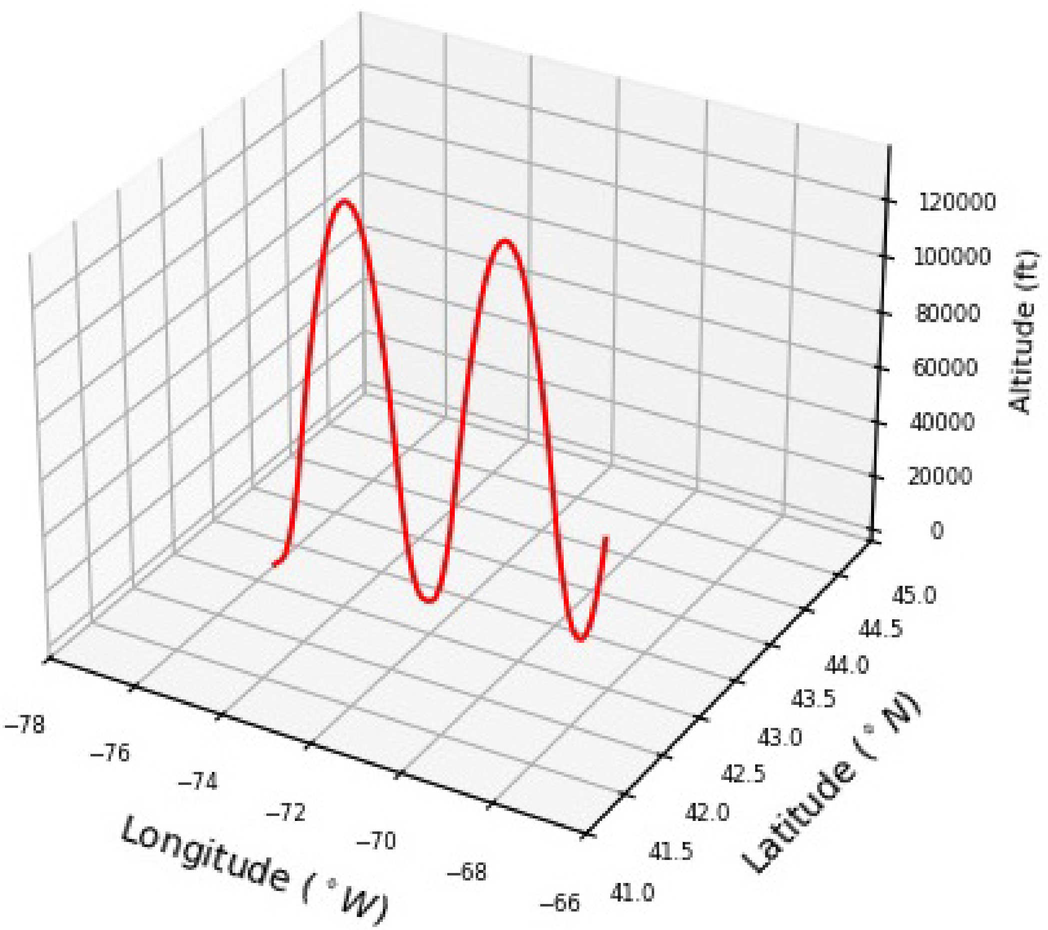
Ray trace of sound for profile #1

Mach Cut off Height – 1008 ft

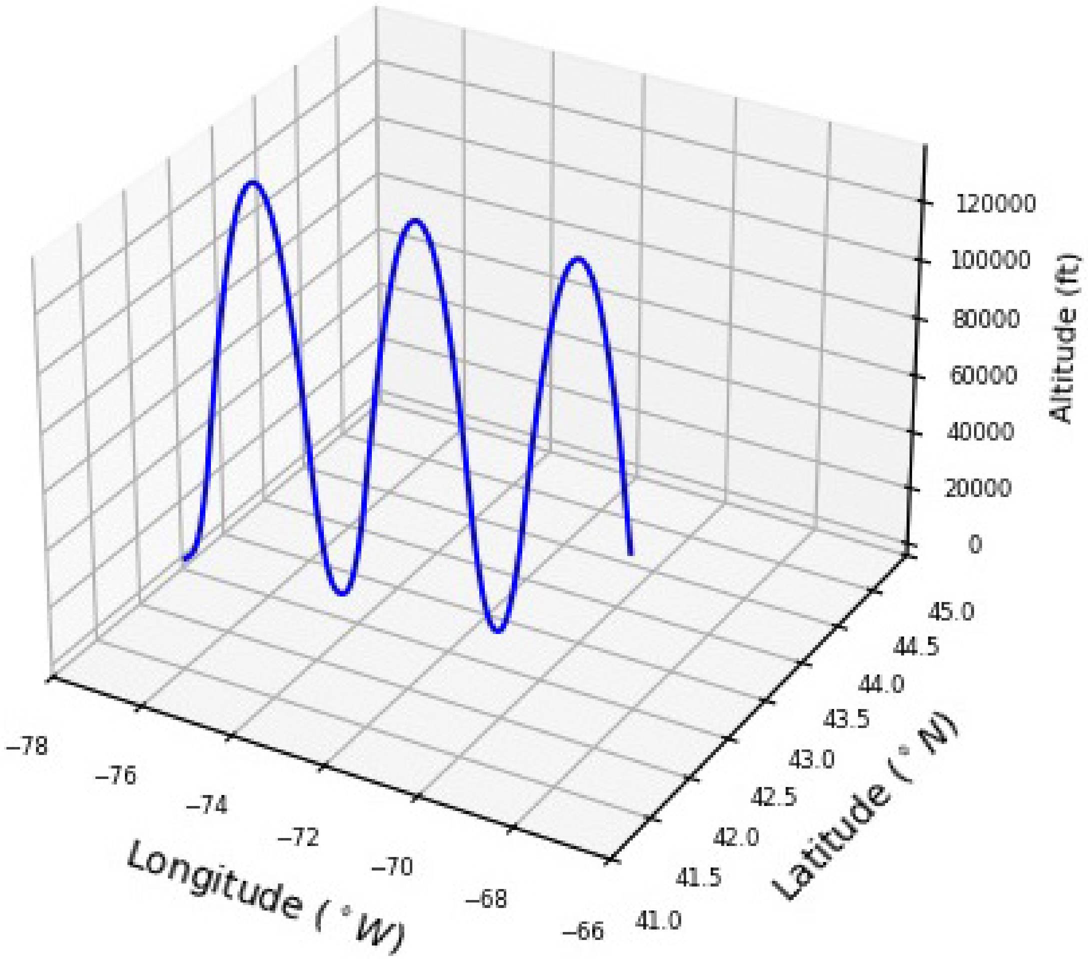


3D ray trace

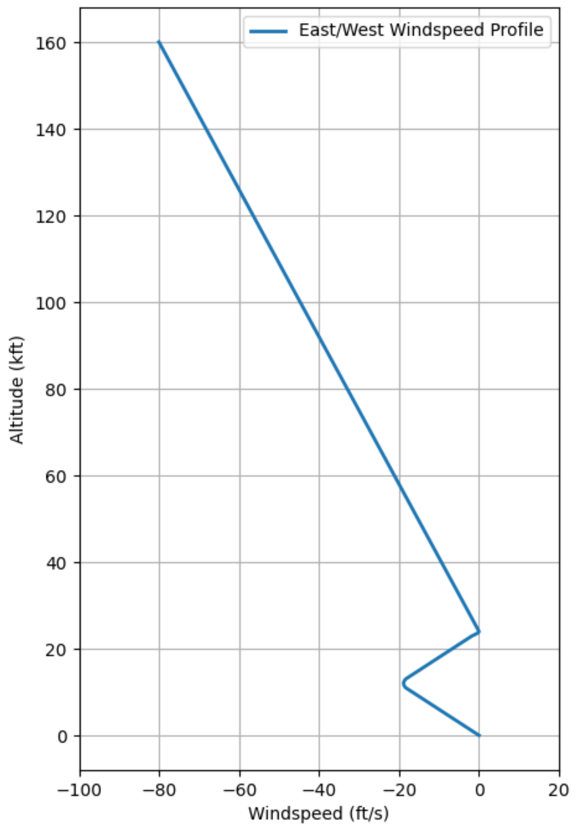
Initially downward

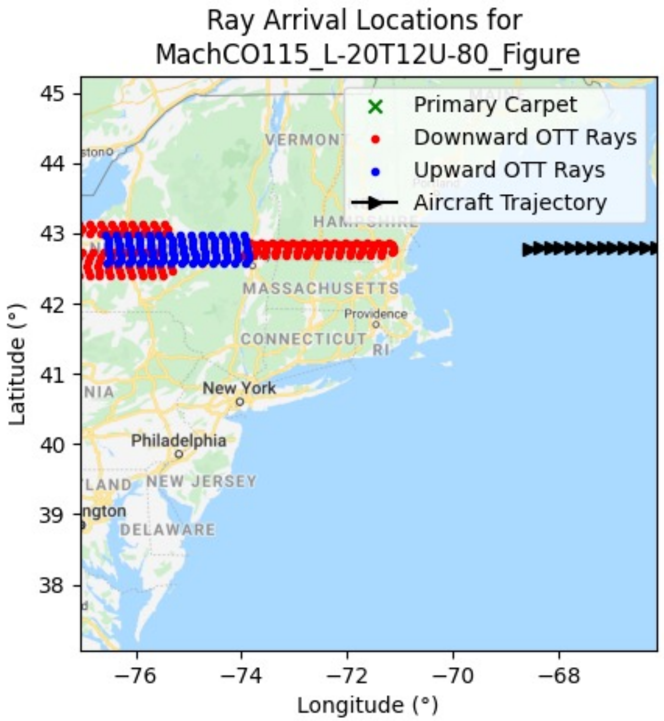


Initially upward



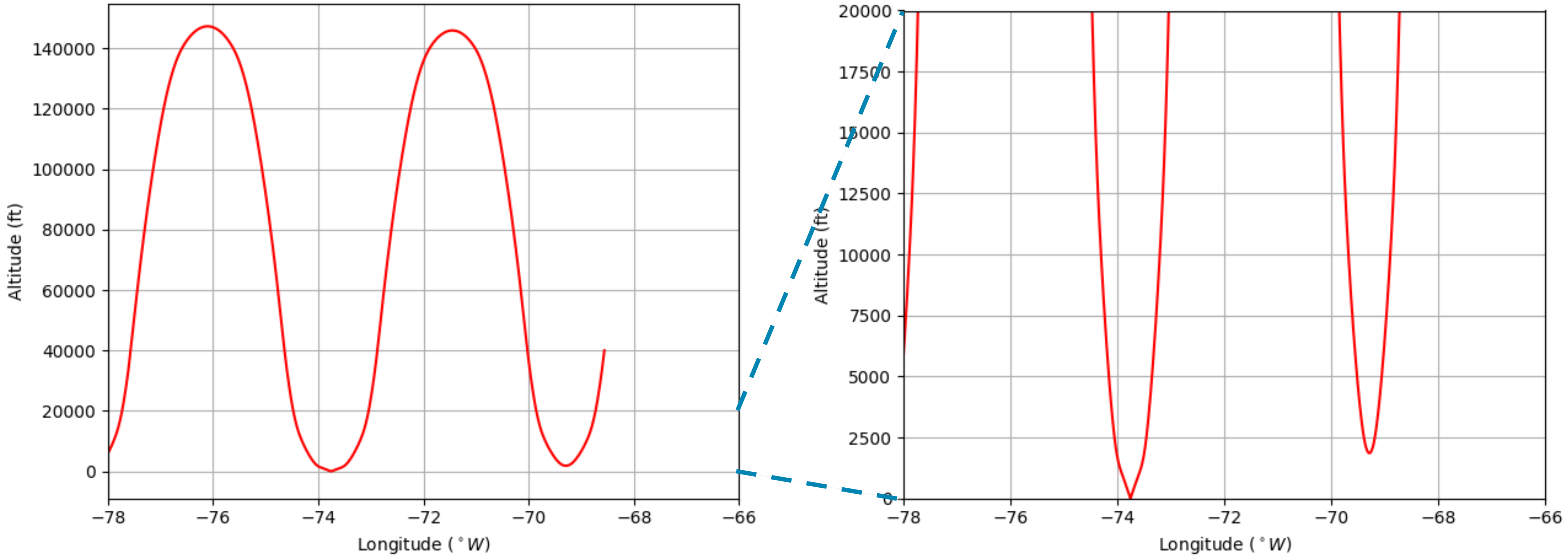
East/West wind profile #2:
Lower is -20 ft/s w max winds at 12 kft; Upper max is -80 ft/s





Ray trace of sound for profile #2

Mach Cut off Height – 1860 ft



Preliminary conclusions from MCO secondary boom studies

- Definitely, we see situations where Mach cut off operations produce secondary sonic booms
- Now searching the parameter space. Seem to get this when have strong tailwind at high altitudes.
- Typically we would only expect to produce secondary sonic booms about half of the time (whether flying along with or against a high upper wind).

Kim Riegel

This material will be presented at the joint meeting of ASA and ASJ in Honolulu, December 1-5, 2025.

Preliminary results! Please do not cite or quote.

Summary

- Making great progress!
  - SSTG continuing forward
  - Making KZK Fourier turbulence model improvements
  - Understanding secondary booms, now including Mach cut off flight
- Next steps:
  - Presentations at fall ASA/ASJ meeting in December
  - Gearing up for NASA's X-59 phase 2 measurements
    - Participate in X-59 measurement program of Gulfstream
    - Accounting for background noise during measurements
    - Process the data for SSTG as if we were certifying the X-59 aircraft to exercise procedures
- Key challenges/barriers:
  - No challenges except those financial barriers facing all of ASCENT

Participants and Acknowledgments

- Dr. Kim Riegel, Farmingdale State College
  - Secondary boom simulations via PCBoom
- Mr. Joshua Kapcsos, Penn State Graduate Research Assistant
  - Atmospheric turbulence propagation simulations and Reference Day atmosphere calculations
- Dr. Sampath Rathnayaka & Dr. Andrew Nyblade, Penn State Dept. of Geosciences
  - Seismology support
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- Dr. Robin Downs, Volpe
  - PCBoom support and Concorde recording recovery
- NASA – Larry Cliatt, Ed Haering, Alexandra Loubeau, Jacob Klos
  - good advice and key data
- Secondary boom teleconference attendees:
  - Sandy Liu (PM), Michael Rybalko, Gustavo Silva, Brian Cook, Matt Nickerson, Steve Ogg, John Morgenstern, Sophie Son, students, *et al.*

The end

Thanks!

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PennState College of Engineering

ASCENT AVIATION SUSTAINABILITY CENTER

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