ASCENT Project 57

Support of Supersonic Aircraft En-route Noise Efforts in ICAO CAEP

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PM: Sandy Liu, FAA

Cost Share Partners: Boom, Gulfstream

Objective:

- Research continues to support FAA in the development of technical standards for civil supersonic aircraft under the ICAO CAEP
  - Task 1: Efforts focus primarily in the area of en-route sonic boom noise assessment
  - Task 2: Testing capability of PCBoom software to model secondary sonic booms

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
  - Propagate from cruise altitude to ABL with no-turbulence tool and ABL to ground with turbulence tool (involving both vector and scalar types)
- Task 2: Currently looking at prediction of secondary sonic boom for supersonic aircraft approaching U.S. coastlines, using flight conditions similar to Concorde.
- Task 3 (Volpe): Recover Concorde secondary boom signatures recorded by Volpe in 1979.

Major Accomplishments (to date):

- Extended KZKFourier software to eliminate artifacts from some "turbulized" signatures
  - Used visualization to help find artifacts
- Database provided to WG1/SSTG/PrSG for C609
- Learning new things about secondary sonic boom predictions
  - Effect of different aircraft headings
  - Inaccuracies in PCBoon's predictions of caustics

Future Work / Schedule:

- Running KZKFourier for wider range of altitudes, atmospheric profiles, & turbulence conditions
- Working with NASA/Volpe to improve PCBoom secondary boom predictive capability

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Investigation team includes

- Dr. Kim Riegel, Queensborough Community College
  - Secondary boom simulations via PCBoom
- Mr. Joshua Kapcsos, Penn State Research Assistant
  - Atmospheric turbulence propagation simulations via KZKFourier
- Mr. Robert Downs, Volpe
  - PCBoom support and Concorde recording recovery
- Secondary boom teleconference regular attendees:
  - Sandy Liu (PM), Ed Haering, Alexandra Loubeau, Joe Salamone, Marshall Gusman, Michael Rybalko, Brian Cook, Sophie Kaye, and other students
  - Let us know if you want to join in!

Turbulence Methodology

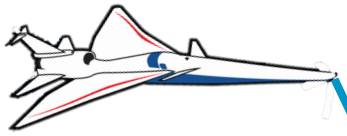
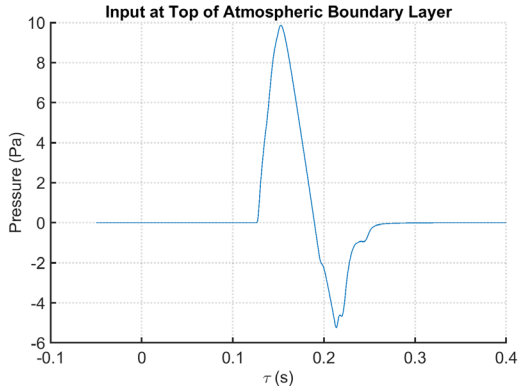


*Image courtesy of NASA

No Turbulence Tool: PCBoom 6.7.1.1

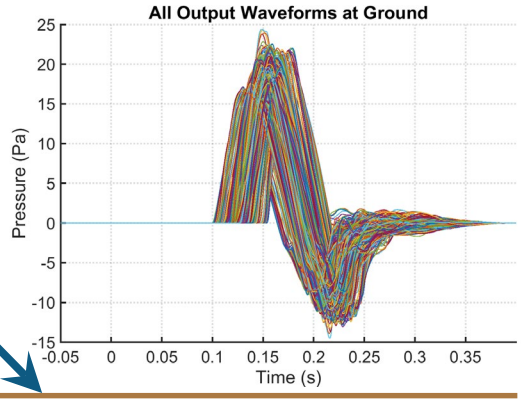
- Run from cruise altitude (54,000 ft) to top of ABL
- C609 shaped boom input waveform provided by NASA
- C609 models the NASA X-59 aircraft



Atmospheric Boundary Layer (ABL)
(268.2, 411.4, 1026.7 m)

Turbulence Tool: KZKFourier 2D2.4

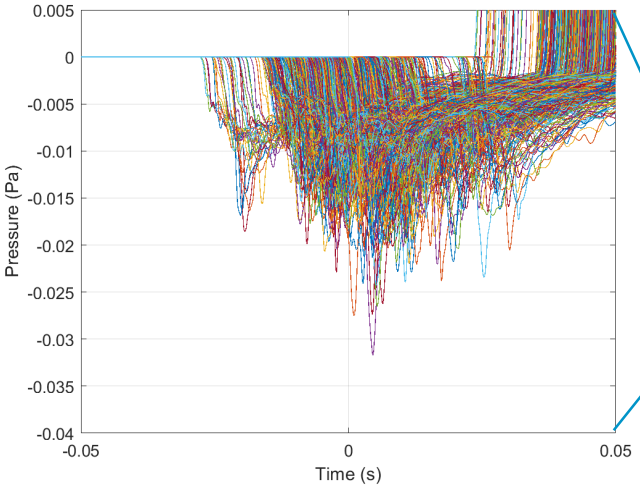
- Applied 10% taper to KZKFourier input
- 10 random seeds to simulate turbulent atmospheres
- Considers both velocity and temperature fluctuations
- Run from top of ABL to ground altitude
- Applied 25% taper to KZKFourier output
- Output 100 ground pressure waveforms per turbulence condition



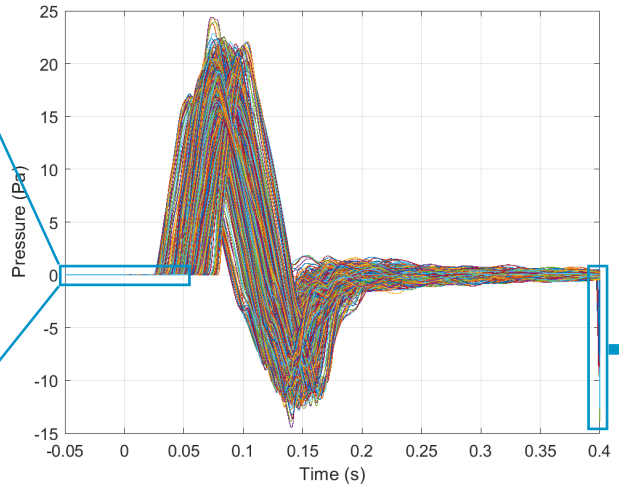
Ground

Artifact Diagnosis

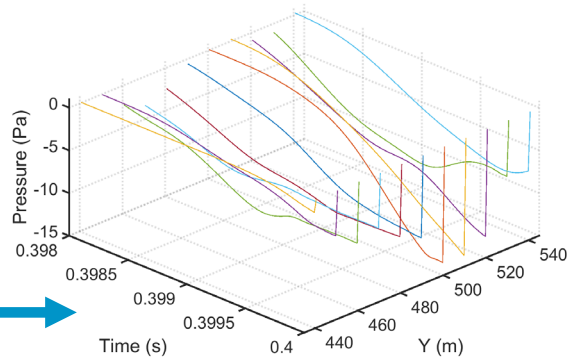
Problem #1: Pre-signature Distortion



Sonic Boom Signatures

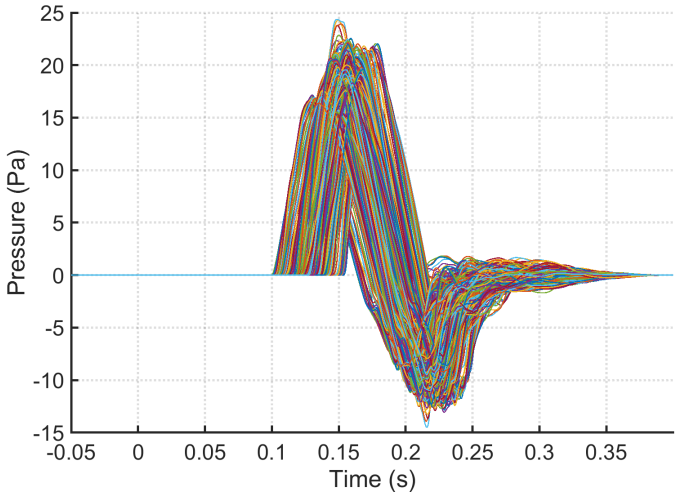


Problem #2: Post-signature Distortion



- Application of taper to KZKFourier extended waveform input addresses pre-signature distortion
- Tapering outputs during post-processing ensures waveforms smoothly begin and end at zero acoustic pressure
- Post-signature distortions are circumvented by replacing affected random seeds when generating turbulent atmospheres

Problem Solved!



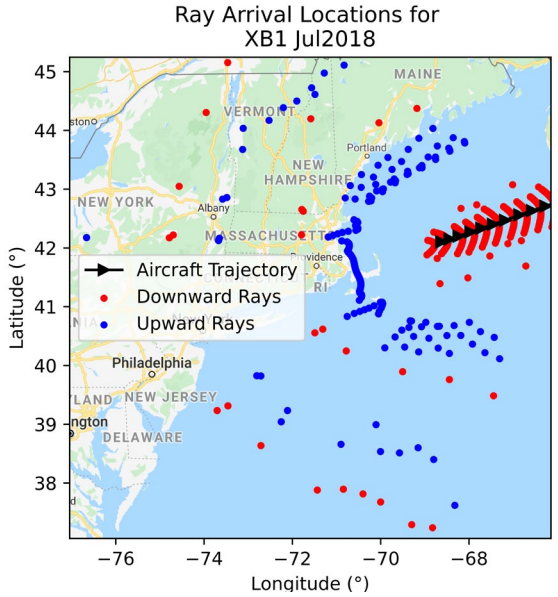
Improved Viewing Capabilities

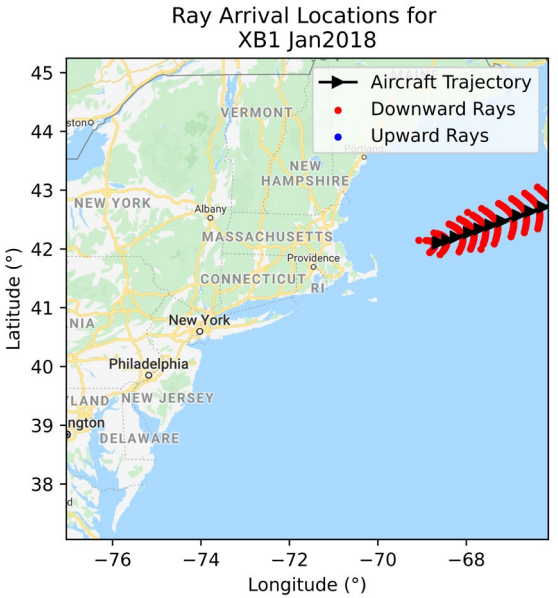
- Waveform data was converted from retarded time to real time and saved to video in order to visualize evolution of previously discovered spiking artifact
  - Contour plot displays turbulence effects
  - Shaped sonic boom propagates from top of atmospheric boundary layer to ground altitude

- Efforts are ongoing to convert post-processing taper to KZKFourier language in order to prevent spiking artifacts from forming regardless of random seed

Boom XB-1 Secondary Booms in 2018

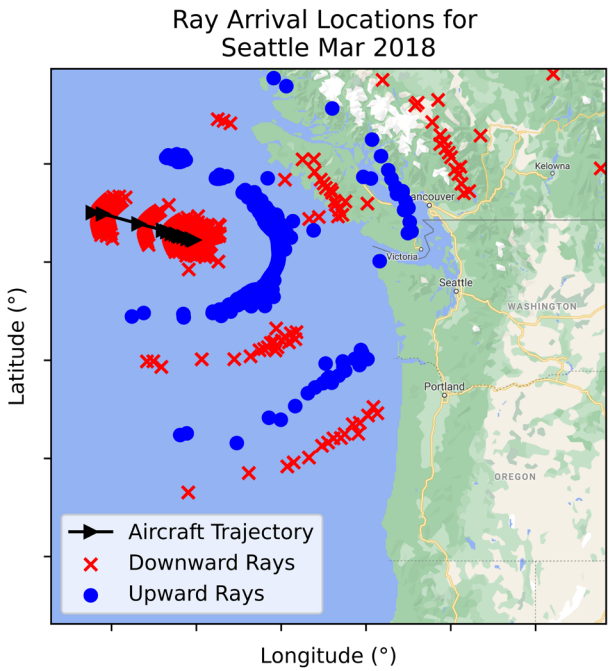
- Boom provided the CFD data for several trajectory points for their XB-1 demonstrator aircraft
- CFD data was translated into compatible cylinder input to be read by PCBoom
- Secondary boom propagation was completed through PCBoom for the year 2018
- Arrivals were predominantly in the summer months and no arrivals were detected in the winter months.

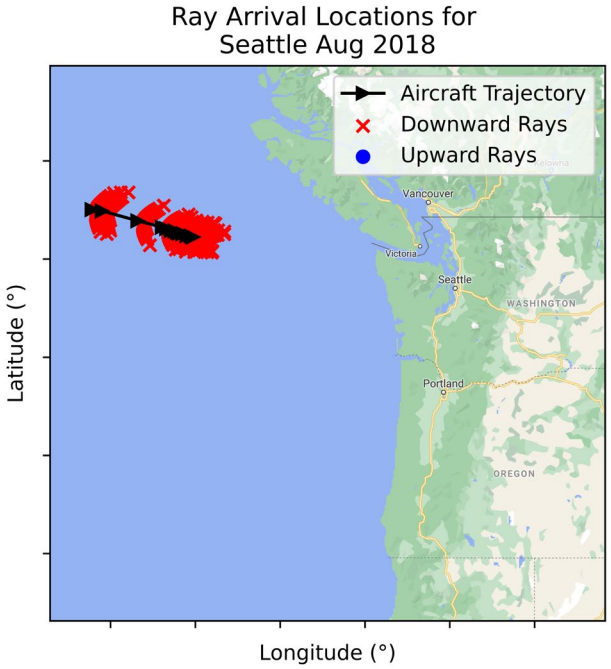




Additional Arrivals on West Coast

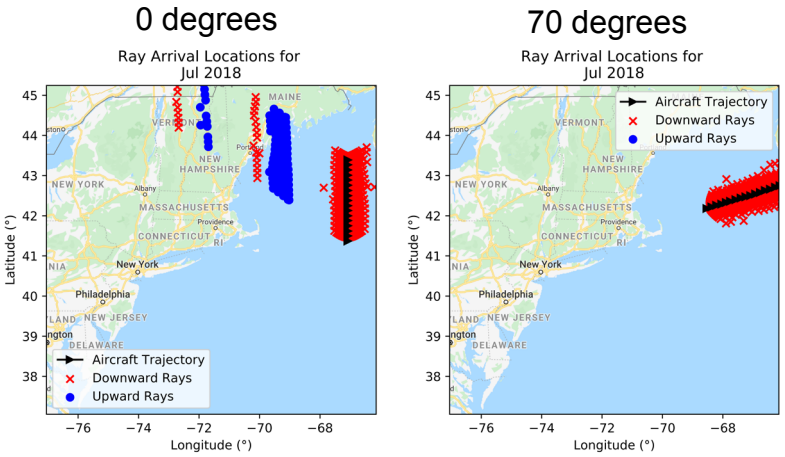
- Obtained weather data from CFSv2 for the year 2018
- Using PCBoom, determined secondary boom arrival locations approaching Seattle (SEA) from Tokyo
- The results were consistent with the Los Angeles arrivals
  - the most arrivals detected on the coast Oct – March
  - the least arrivals detected on the coast Apr – Sept

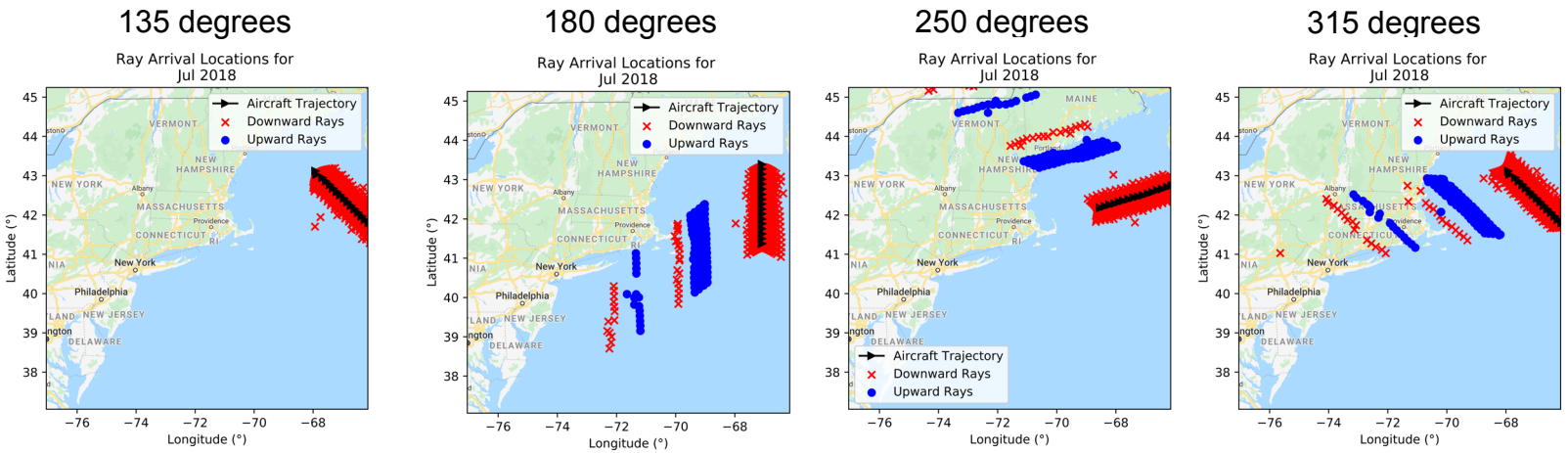




Impact of heading on arrival locations

- Using PCBoom and the speed and weather data supplied by the Rickley and Pierce report.
- Determined the arrival locations for several headings
  - For the headings approaching the coastline and due north and south were impacted during the summer months
  - The headings traveling away did not impact the coastline





Ray Trajectories to Check Ray Tube Areas

- The next step is to determine if PCBoom is correctly predicting the caustics
- Using trajectory and atmosphere provided by the Rickley and Pierce 1980 report
  - Chose one trajectory (Mach 1.25) and phi (160.0 deg) point that created OTT arrivals and launched 9 rays close together
  - Compare the locations that PCBoom identifies caustics with locations of ray crossings

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444.000   159.900    1     (Tac, Phi, iphi)  kmode = 3
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ifoc        Sfoc             Tfoc          Radcurve   bounce   caust long     caust lat    caust height
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   883     Ray points  Reached ground
```