ASCENT Project 57

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

Pennsylvania State University, Farmingdale State College, Volpe

PI: Victor Sparrow, Penn State

PM: Sandy Liu, FAA

Cost Share Partners: Boom, Gulfstream, Exosonic (new for 2022!)

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 (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
- Task 2: Currently looking at prediction of secondary sonic boom for supersonic aircraft approaching U.S. coastlines, using flight conditions similar to Concorde using realistic meteorological data up to 100 km height
- Task 3 (Volpe): Support PCBOOM & 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
- Updated and expanded database provided to WG1/SSTG/PrSG for C609 in February 2022
- Conducted new Reference Day crosscheck in WG1
- Confirmed monthly secondary sonic boom predictions provide sufficient detail for coastal buffer predictions

Future Work / Schedule:

- Extending KZKFourier to incorporate inhomogeneous atmosphere
- Improving secondary boom predictive capability focusing on coastal buffer distances
- Predicting secondary booms for X-59 flights (if possible)

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Investigation team includes

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

Turbulence Methodology

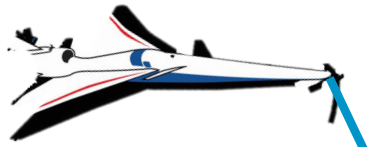
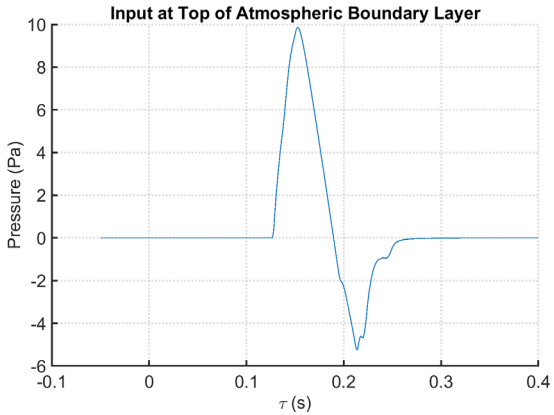


*Image courtesy of NASA

No Turbulence Tool: PCBoom 6.7.1.1

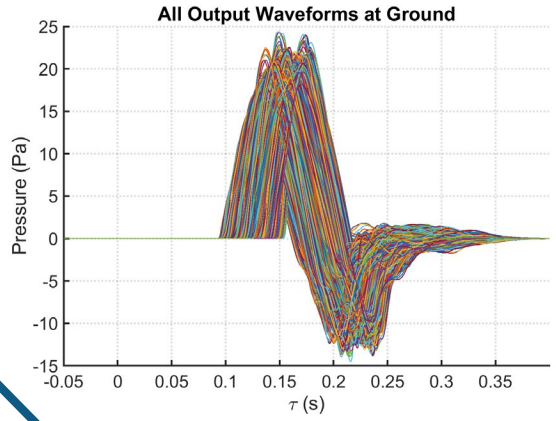
- Run from cruise altitude (54,000 ft) to top of ABL
- C609 shaped boom input waveform provided by NASA
- C609 models the NASA X-59 aircraft



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

Turbulence Tool: KZKFourier 2D2.4

- Applied 10% taper to KZKFourier input
- 20 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



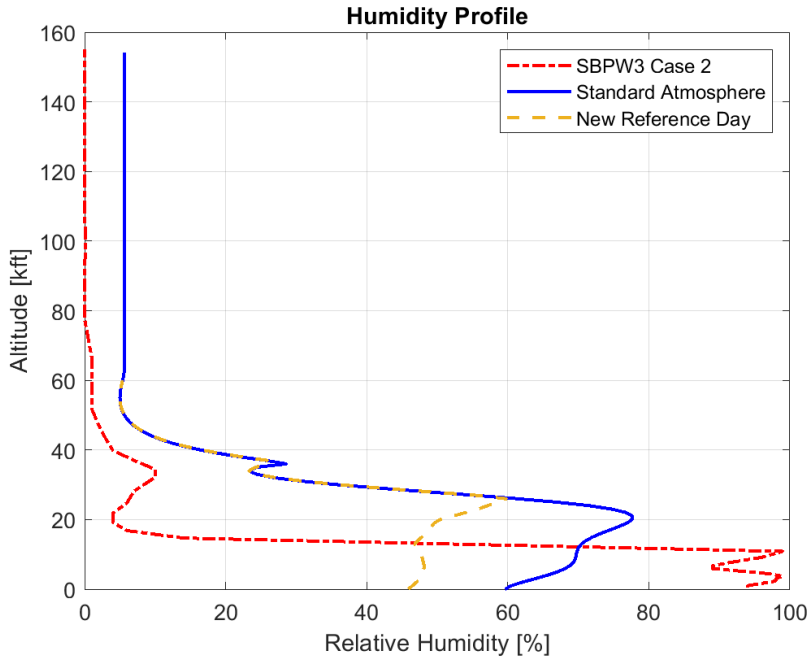
Ground

Establishment of a Reference Day

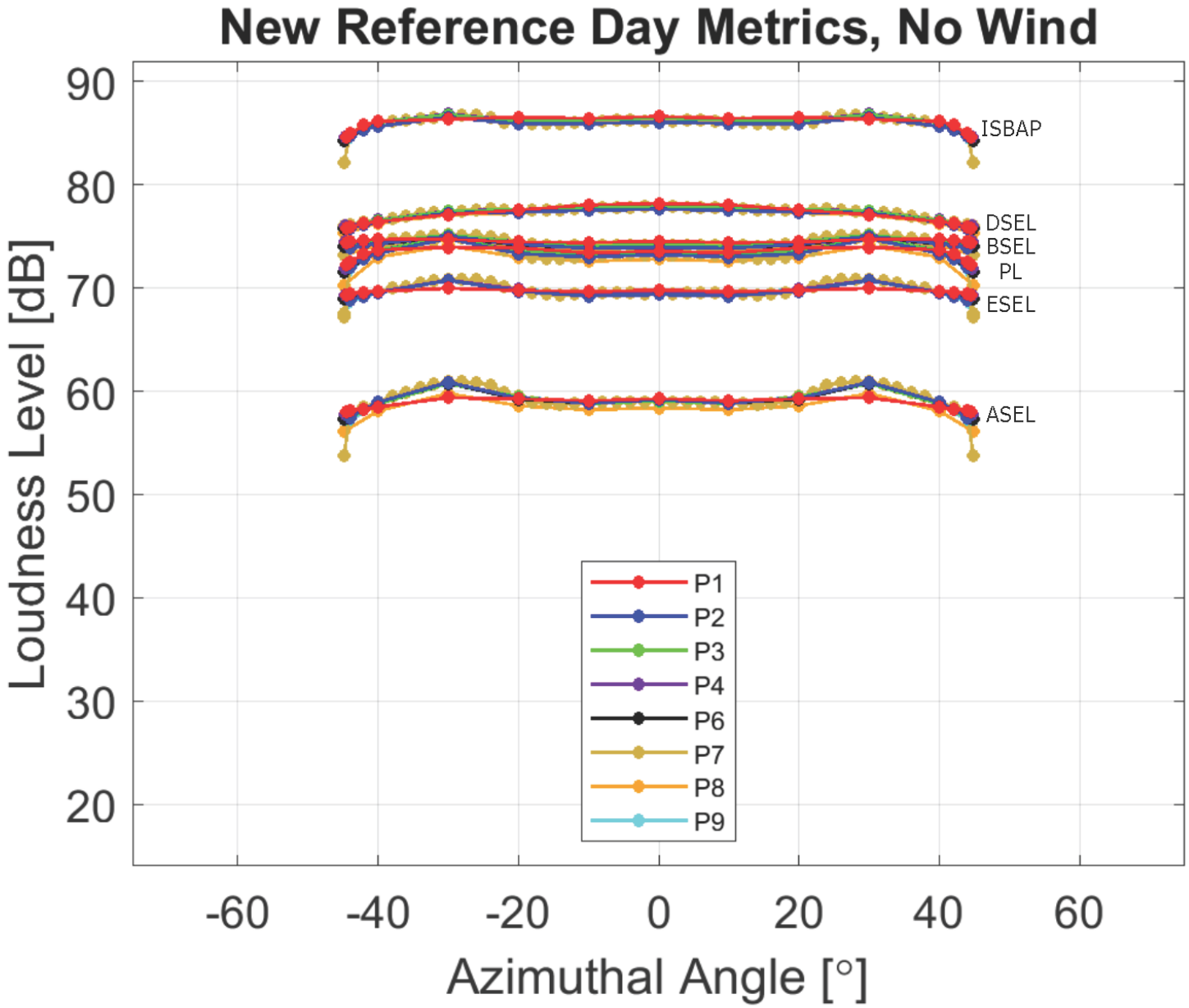
- Future en-route supersonic certification will occur in all types of weather conditions.
- To provide a level playing field for those applying for certification, the certification procedure will need to refer to a Reference Day, an agreed upon atmospheric condition that will be used by all applicants.
- CAEP's WG1 (Noise Technical) agreed upon a standardized, Reference Day Atmosphere in 2021.
- However, the community has no experience actually USING this Reference Day.

ASCENT 57 Reference Day Crosscheck

- Early in 2022 PSU initiated a Reference Day check to see if WG1 participants could use the new Reference Day atmosphere and get similar results between participants.
- The major difference between the new Reference Day and previously used atmospheres was the humidity profile:



Good agreement between 8 international participants

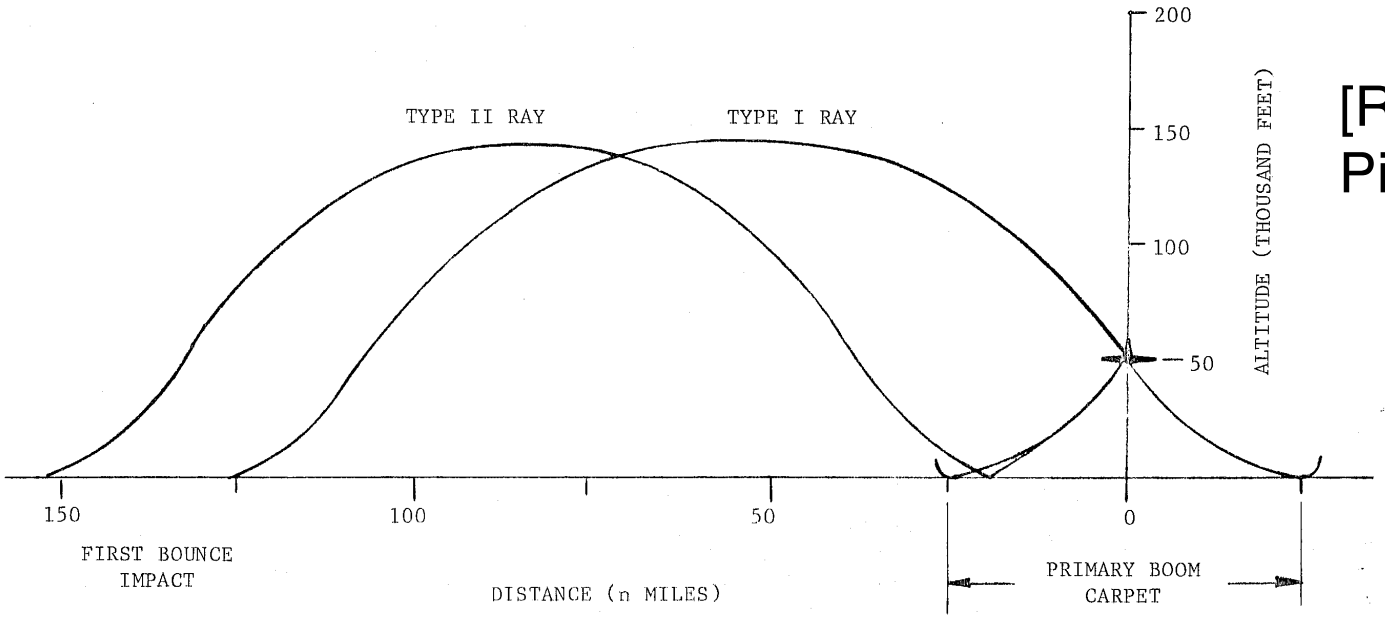


Takeaways from Ref. Day Crosscheck

- These international participants in WG1 now have the agreed-upon Reference Day atmosphere in their sonic boom codes.
- The participants' results were not identical, but did agree closely.
- The work toward en-route supersonic certification schemes can now continue to develop, knowing that the schemes can safely rely upon an agreed upon Reference Day atmosphere.
- Additional details have been shared with CAEP/WG1.

Confidence building in secondary sonic boom predictions

- Recall that secondary sonic booms travel much further through the atmosphere, through the stratosphere:



[Rickley and Pierce, 1980]

FIGURE 1. SCHEMATIC OF REFRACTIVE SONIC BOOM PROPAGATION

Source: BA 171, June 20, 1979, Ray Vector Azimuth Angle 278 Degrees

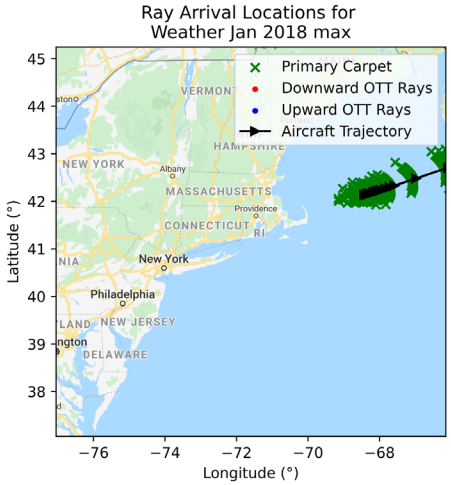
- Reviewer feedback received on manuscript to the Journal of the Acoustical Society of America on our work thus far.

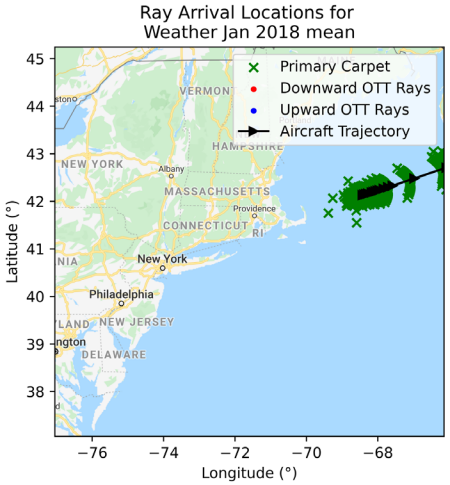
Stability of Weather Profiles

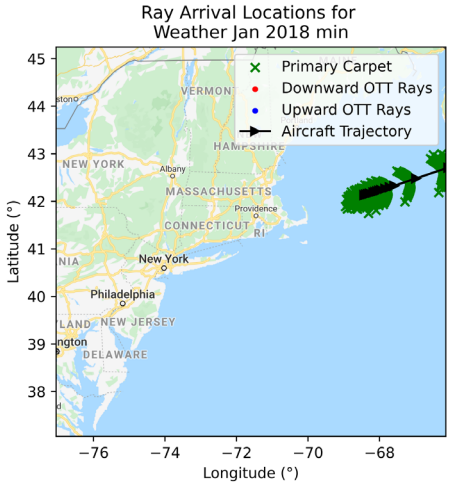
- Ran comparisons of daily or hourly atmospheric profiles to monthly averages to determine the stability of the atmospheric profiles.
- Compared several factors to determine the variability of atmospheric profiles and the resulting sonic boom arrivals
  - Max and Min values of the month
  - Time of day
  - Daily Variations
- PCBoom was used to predict the resulting secondary boom arrivals.
  - East coast approach into NYC (like Concorde)
  - Speed reduces from Mach 2.0 to 1.18

Comparison to Monthly Average

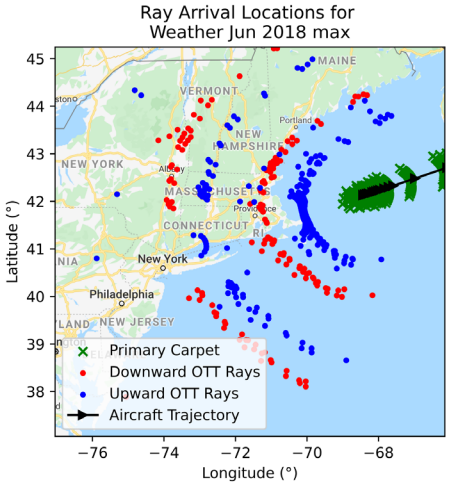
- Most months the **max**, **mean**, and **min** showed similar arrivals
- Winter

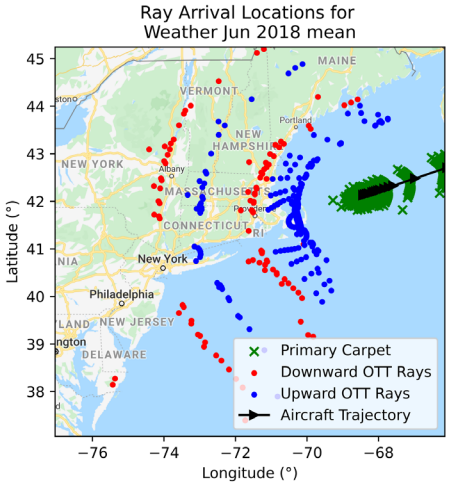


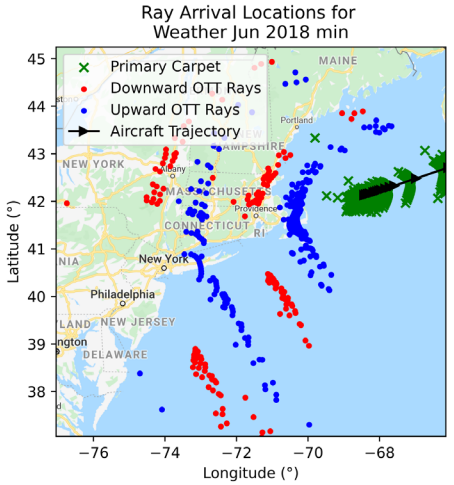




- Summer

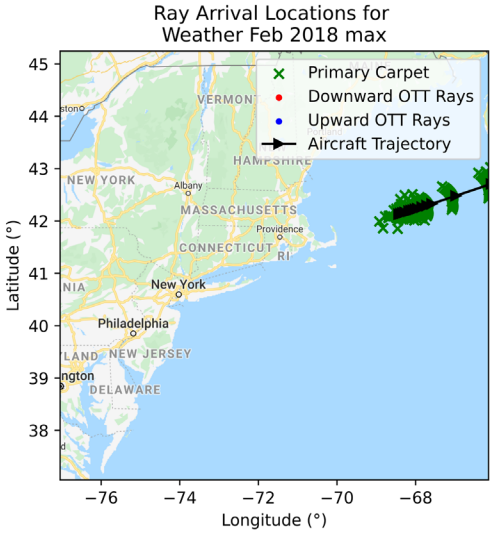


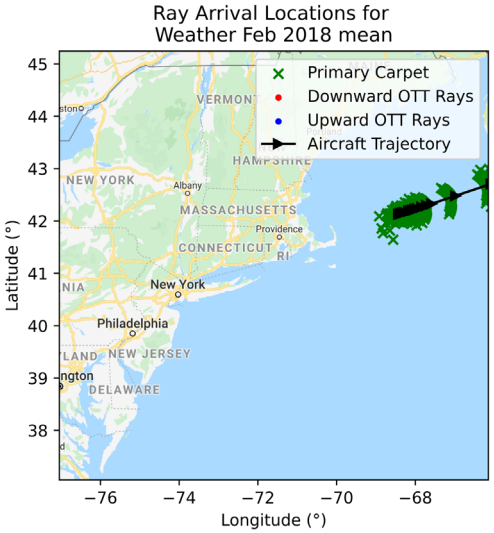


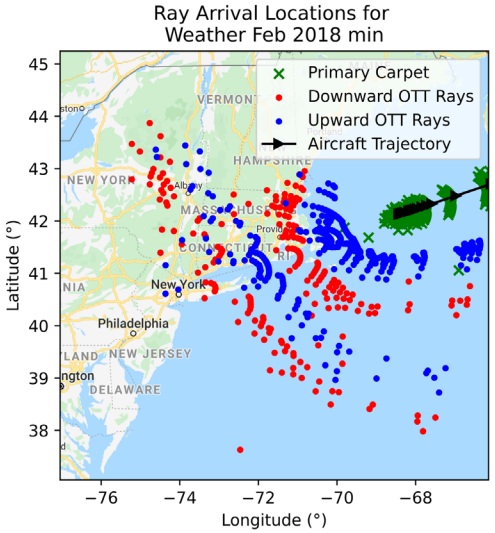


Exceptions

- Three months showed differences between monthly averages and the extreme profiles
  - February, December and April







- These months were further broken down to look at time of day and daily averages

Results – Weather Stability

- Secondary booms show little variation with time of day
  - Current results agree with Rickely &. Pierce (1980)
- Daily averages showed occasional differences, arrivals for daily averages agreed with monthly
  - For February
    - Agreement was 82% of the time.
  - For December
    - Agreement was 84%
  - For April
    - Agreement was 87%.
    - Days that impacted the coastline were very late in the month
- The rest of the months were 100%.
- For the year, the agreement was at 96.5%.
- Can conclude that monthly averages are an acceptable predictor of when secondary booms might be heard.