# Analysis of noise from reusable solid rocket motor (RSRM) firings

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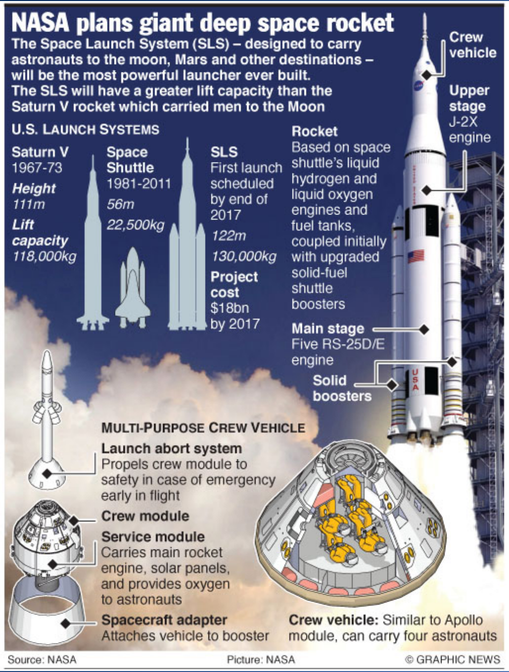
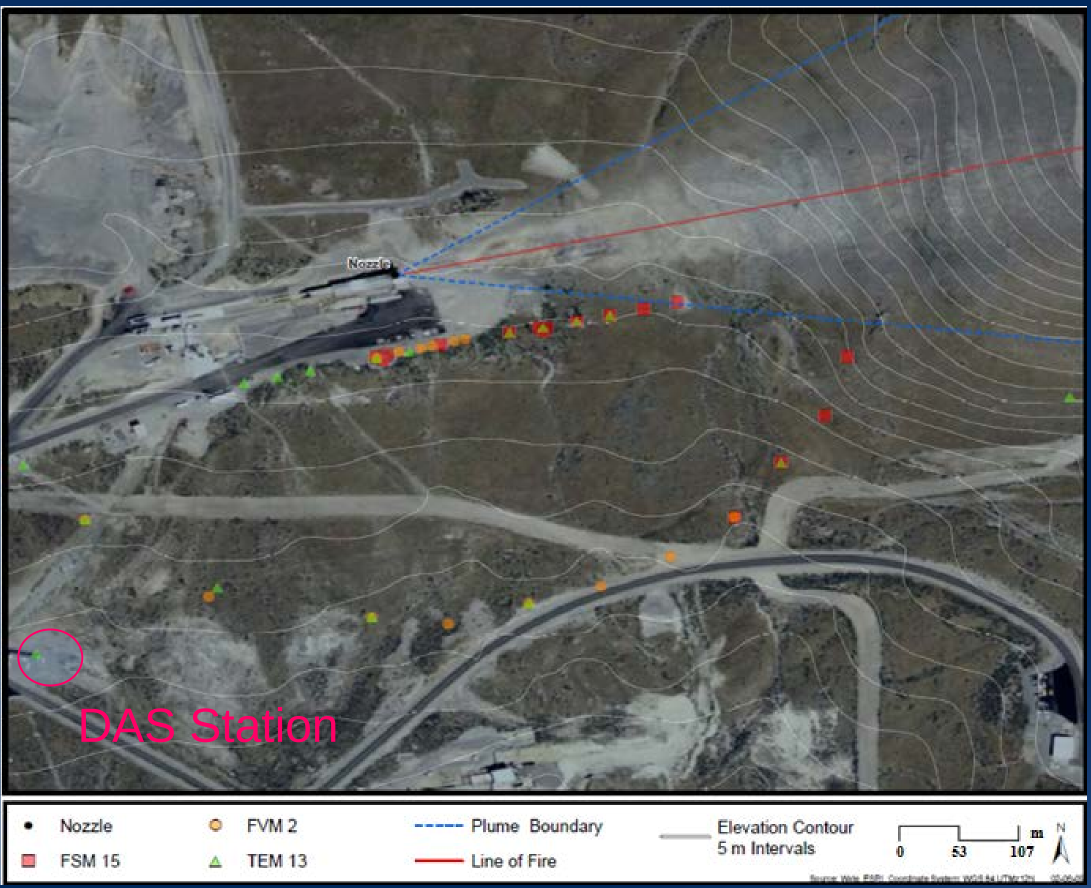
# Introduction

- NASA's Space Launch Vehicle (SLS) program has chosen the Reusable Solid Rocket Motor V (RSRMV) as the booster system for initial flights.
- Lift off acoustics continue to be a consideration in overall vehicle vibroacoustic evaluations and launch pad modifications.
- Work started with the Ares program to understand solid rocket noise mechanisms is continuing through SLS program in conjunction with BYU / Blue Ridge Research Consulting.




# RSRM Acoustic Data Background (1)

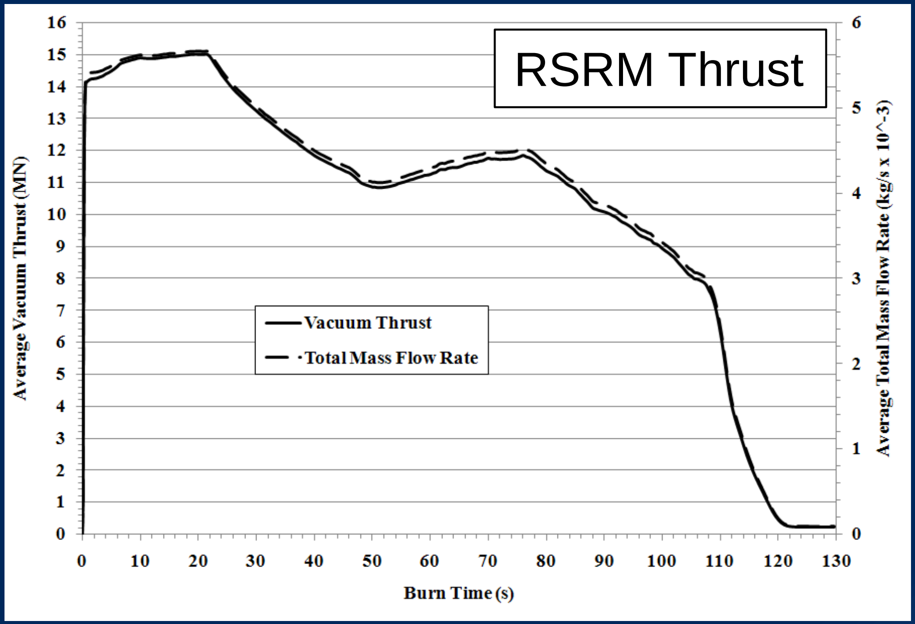
- From 2007 – 2008, NASA and Wyle Labs collected free-field acoustic data from three RSRM static firings at over 20 locations.

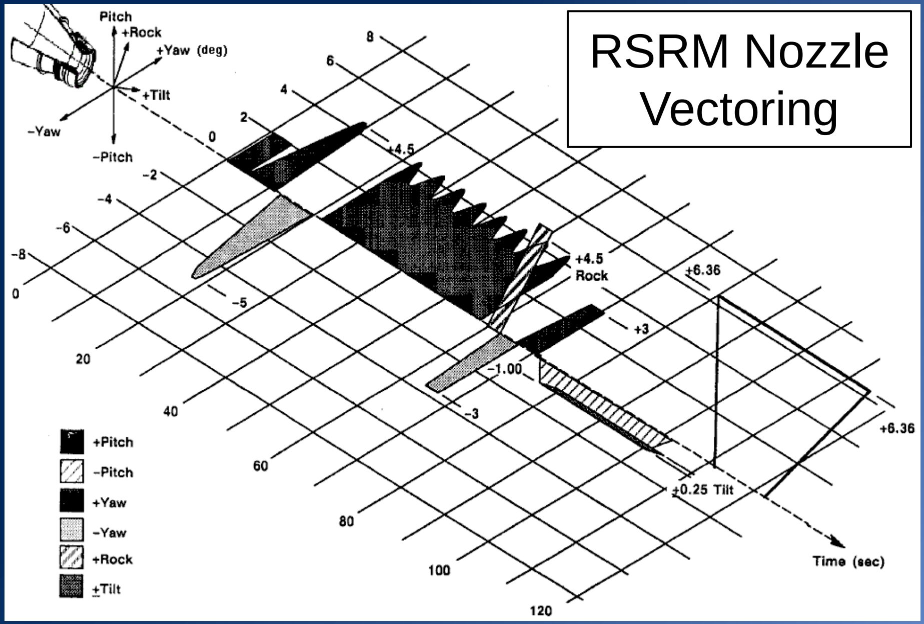




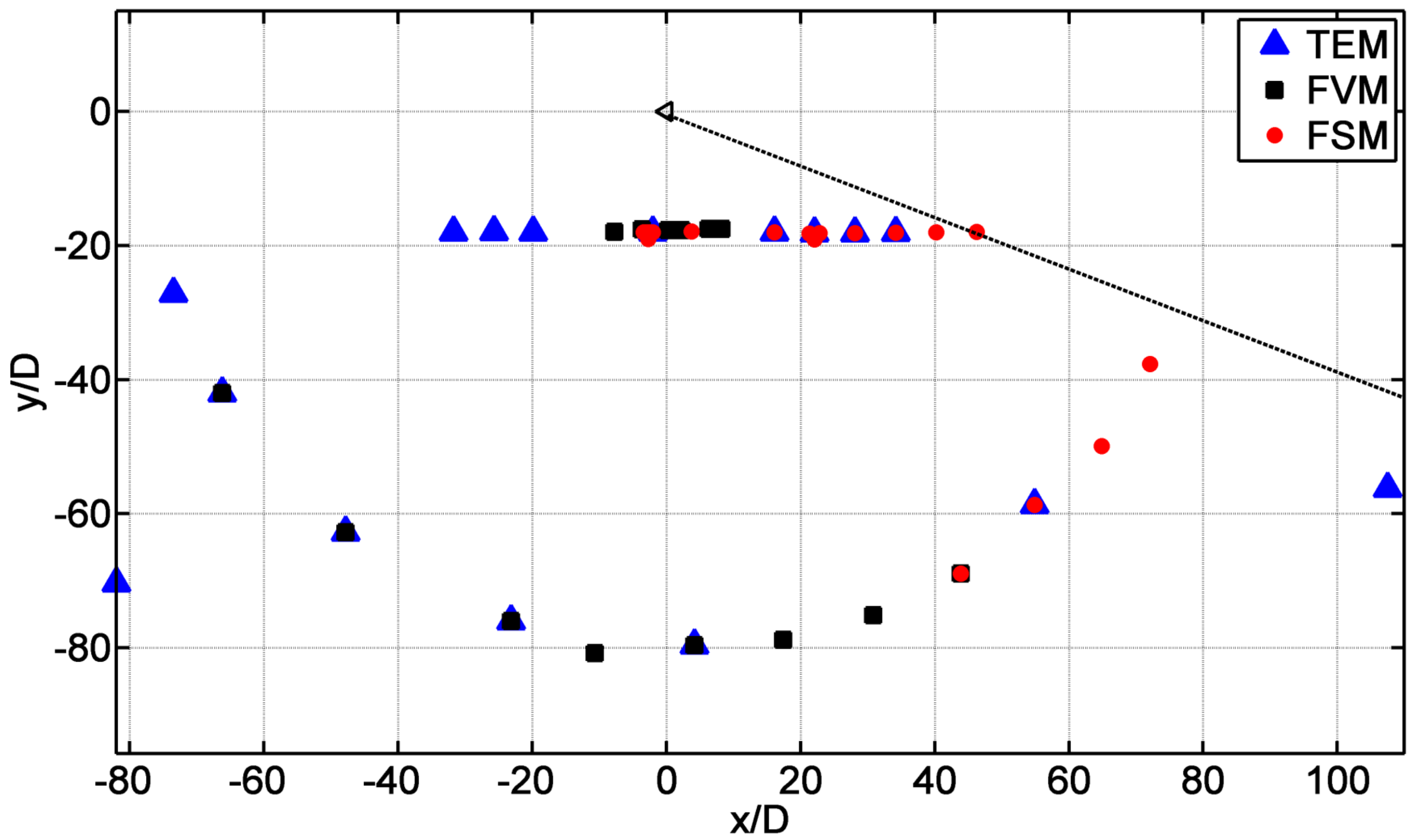
# RSRM Acoustic Data Background (2)

- ¼” microphones for all locations (B&K, GRAS)
- 48,000 and 96,000 sps collection rate
- Detail documented in AIAA 2009 - 3161



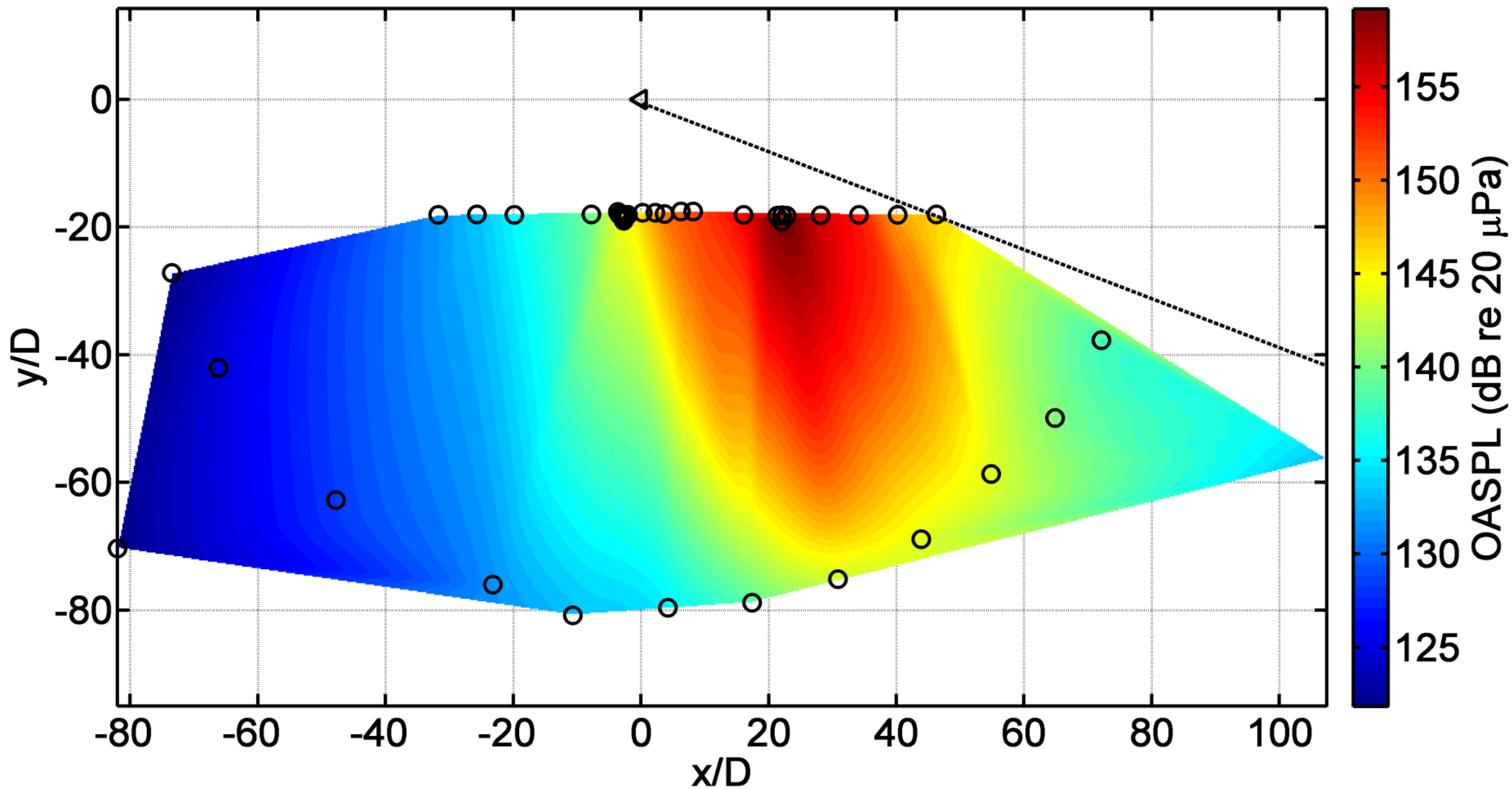



# Combined Mic Locations



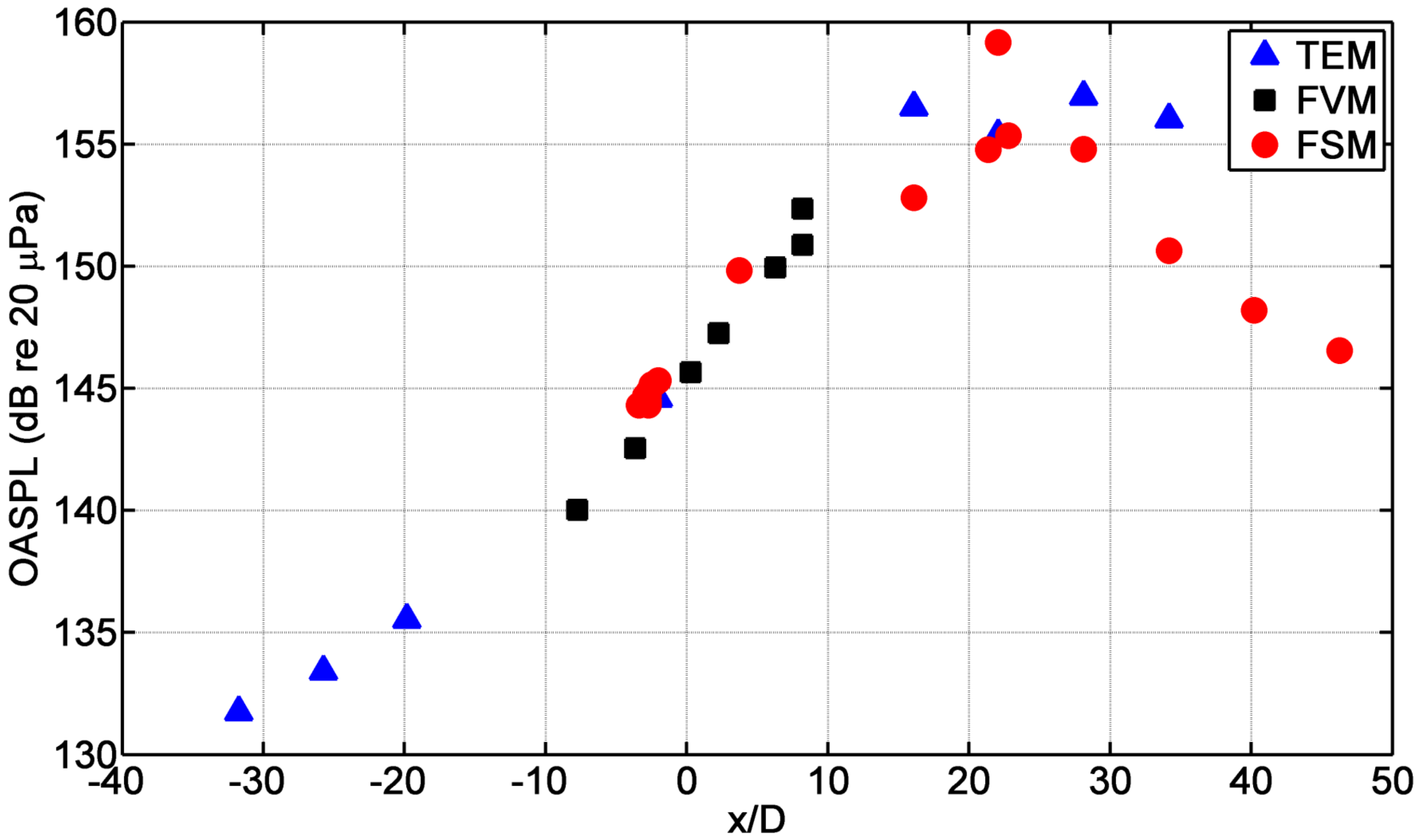
# Combined OASPL

- Spatial data taken from the 50-60 s range for all three firings. Bilinear interpolation carried out using MATLAB.



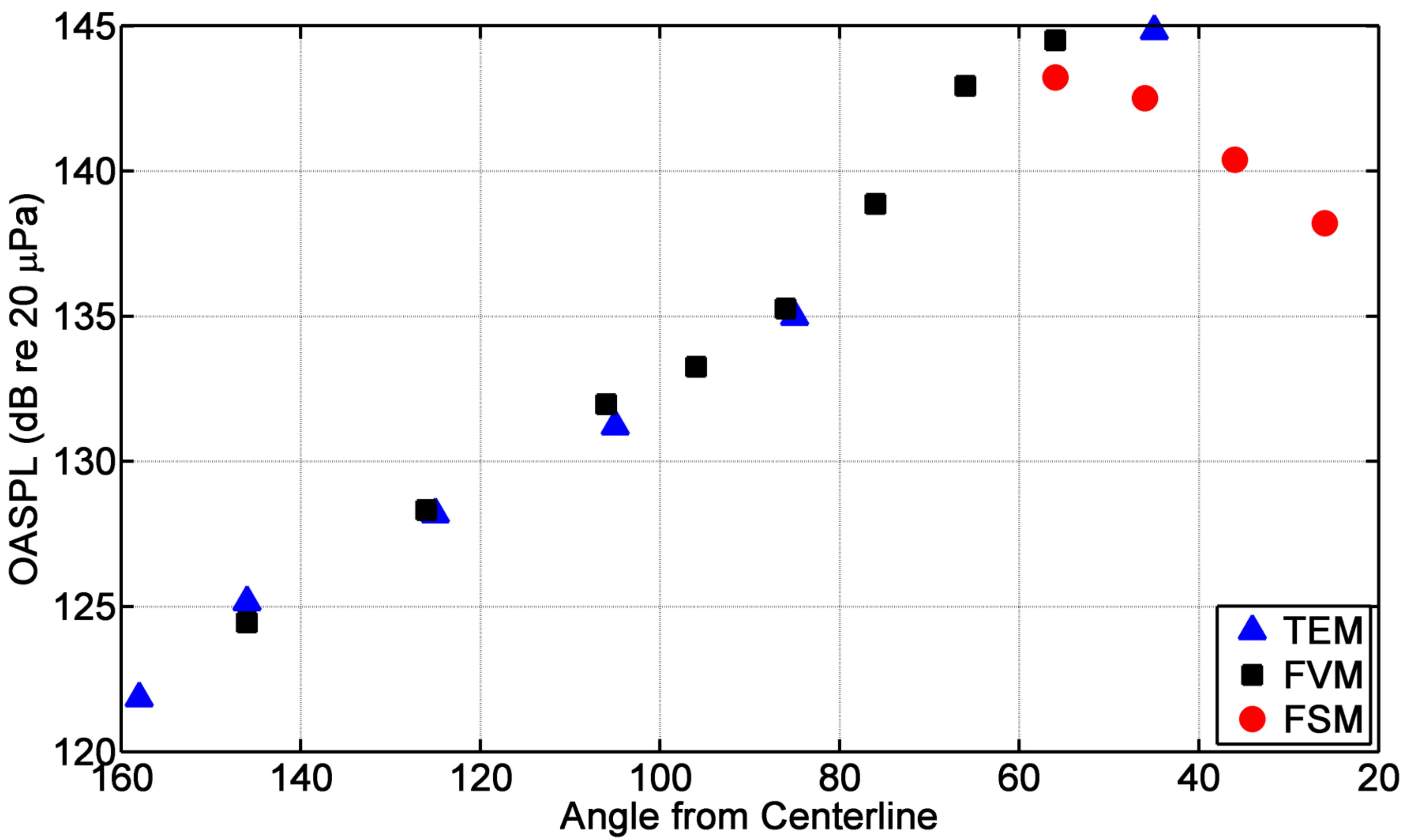
# 18 D OASPL

- Maximum OASPL region ~22 D, extending from 10-35 D.

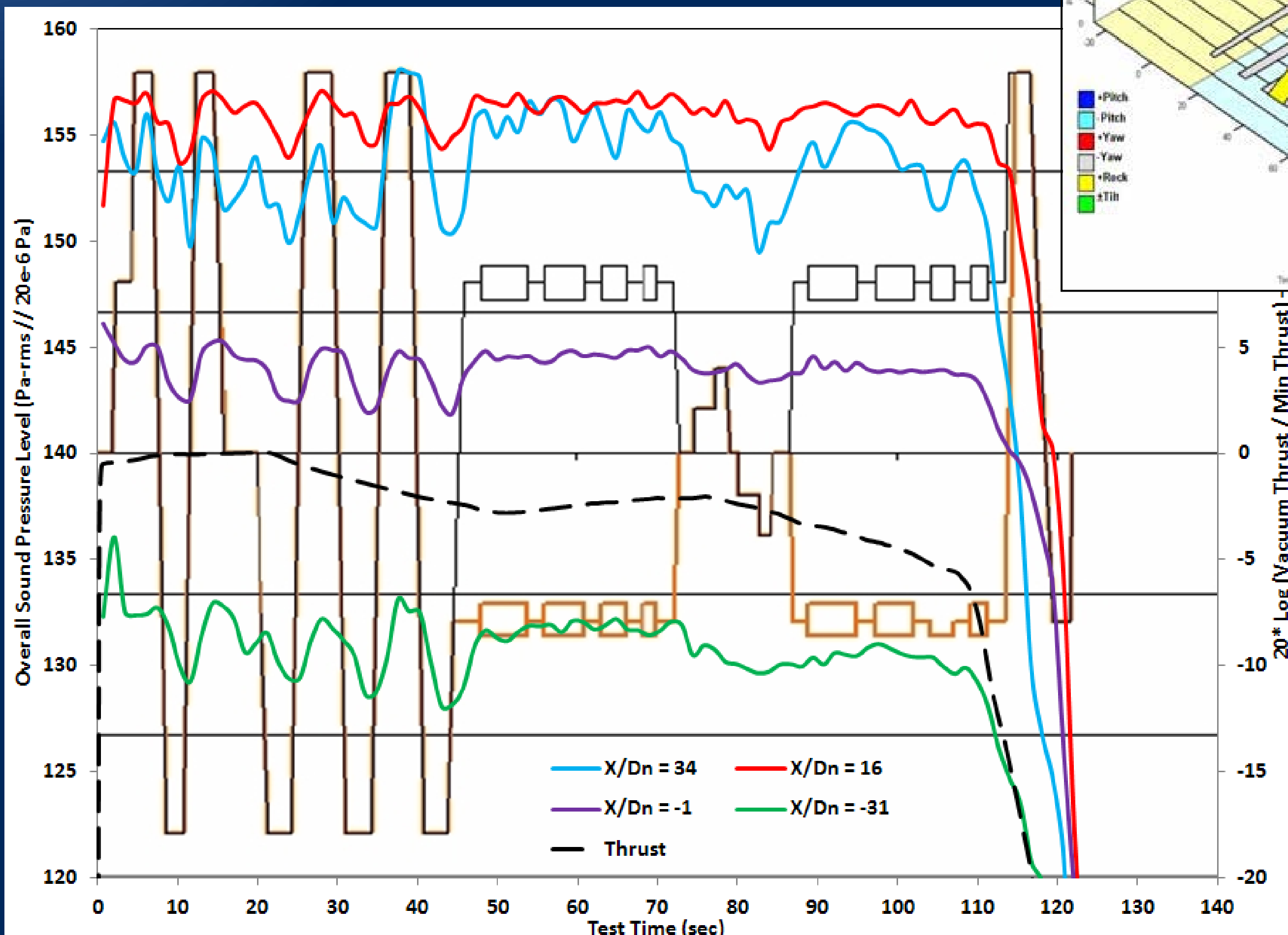


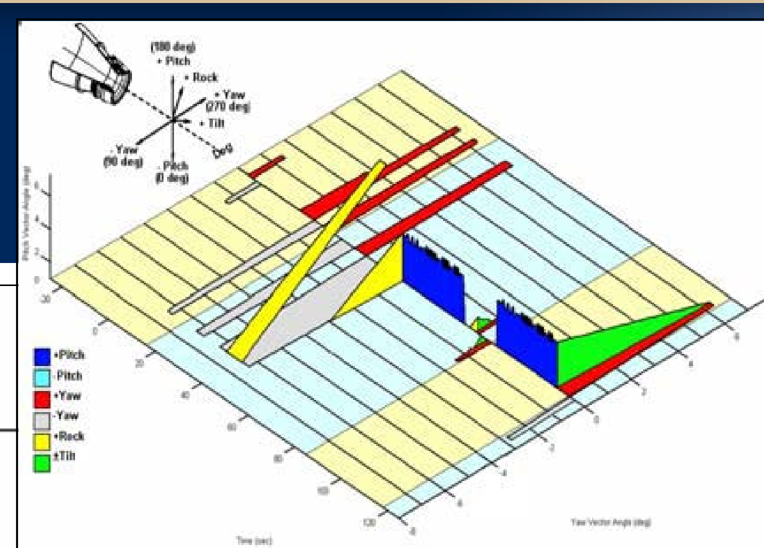
# 80 D Arc OASPL

- Maximum radiation in the 50-60° direction. Is only “directivity” if in the geometric far field. (?)



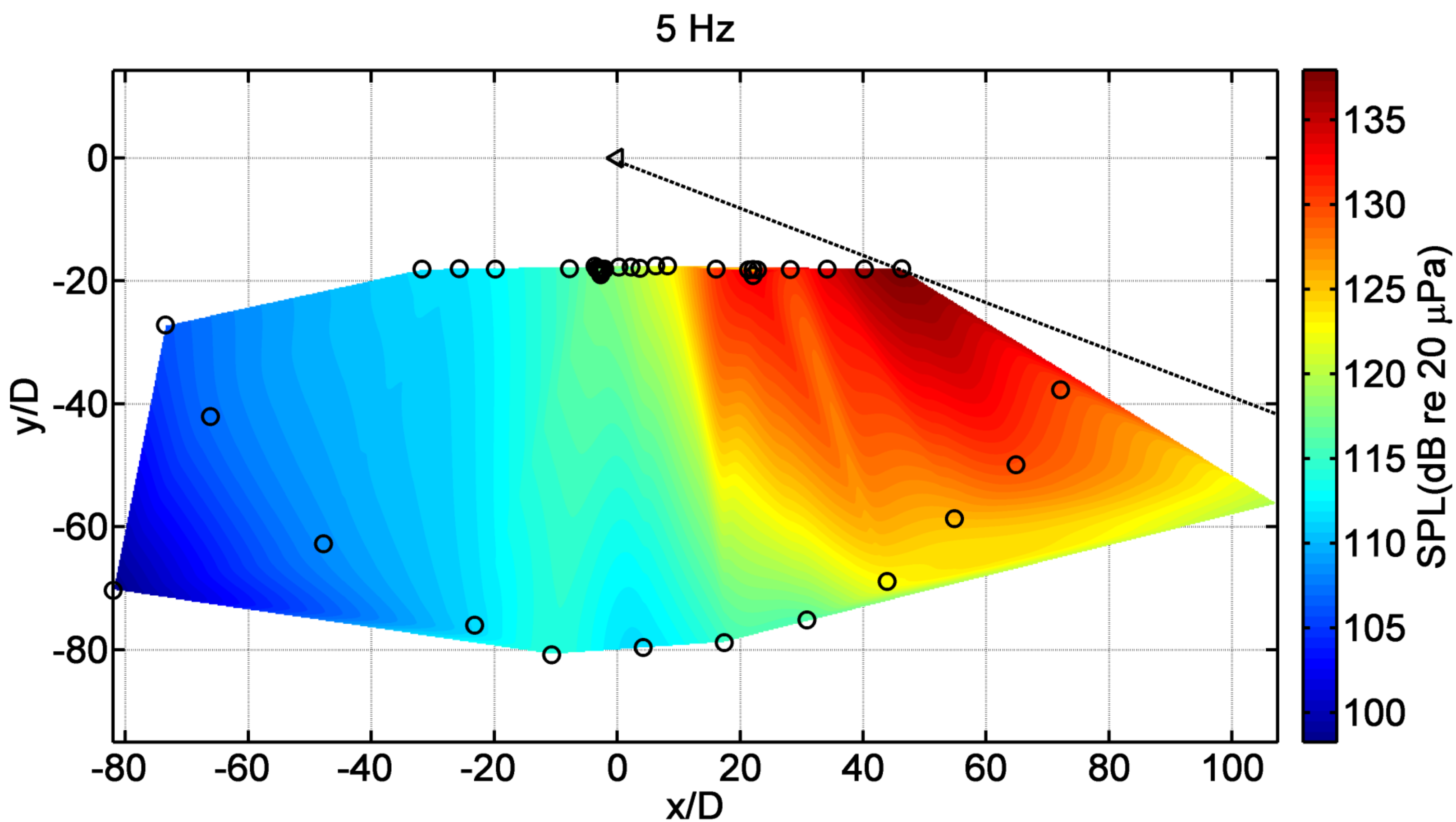
# Running OASPL – TEM13 Firing



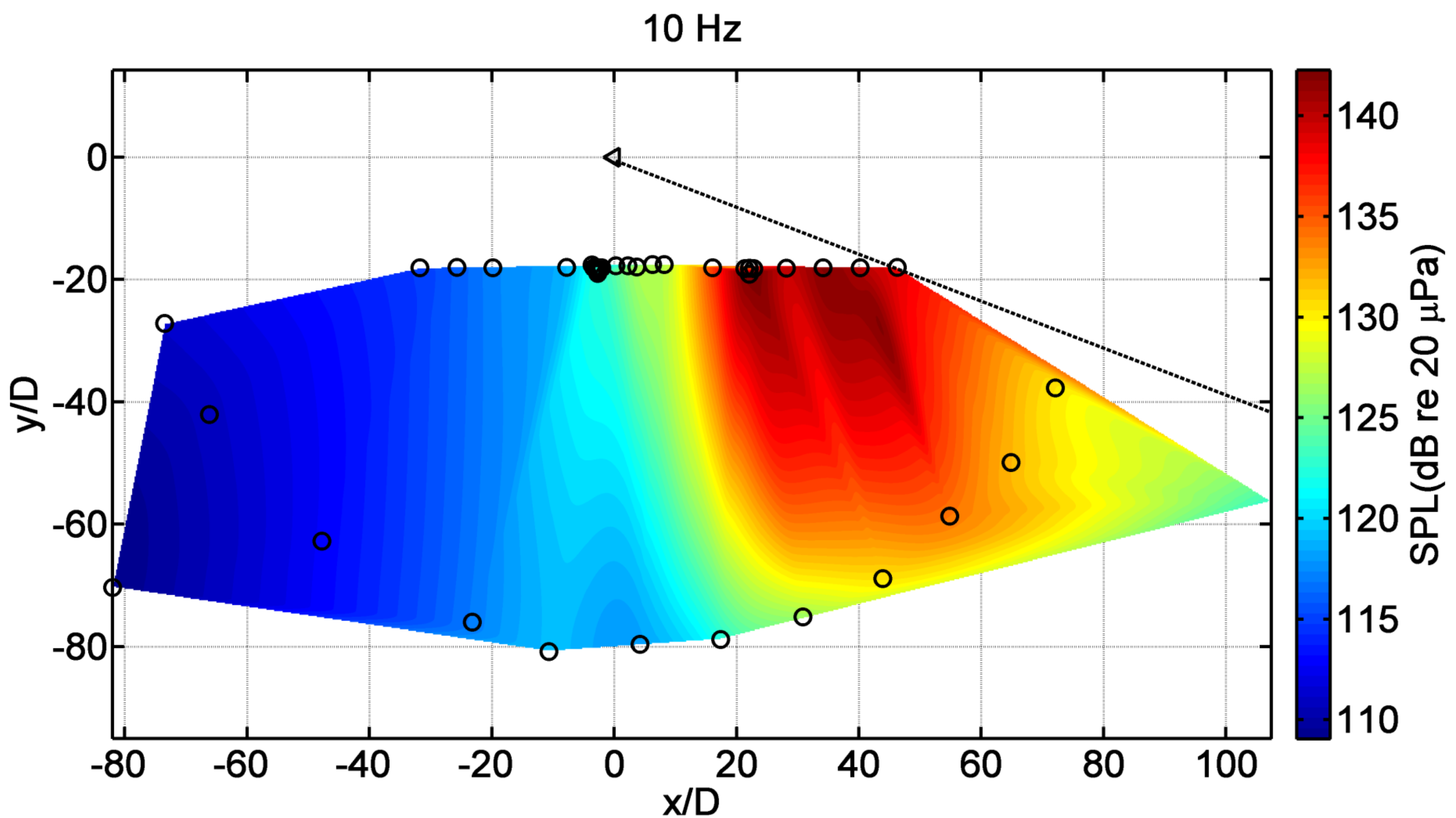



# Band Pressure Levels

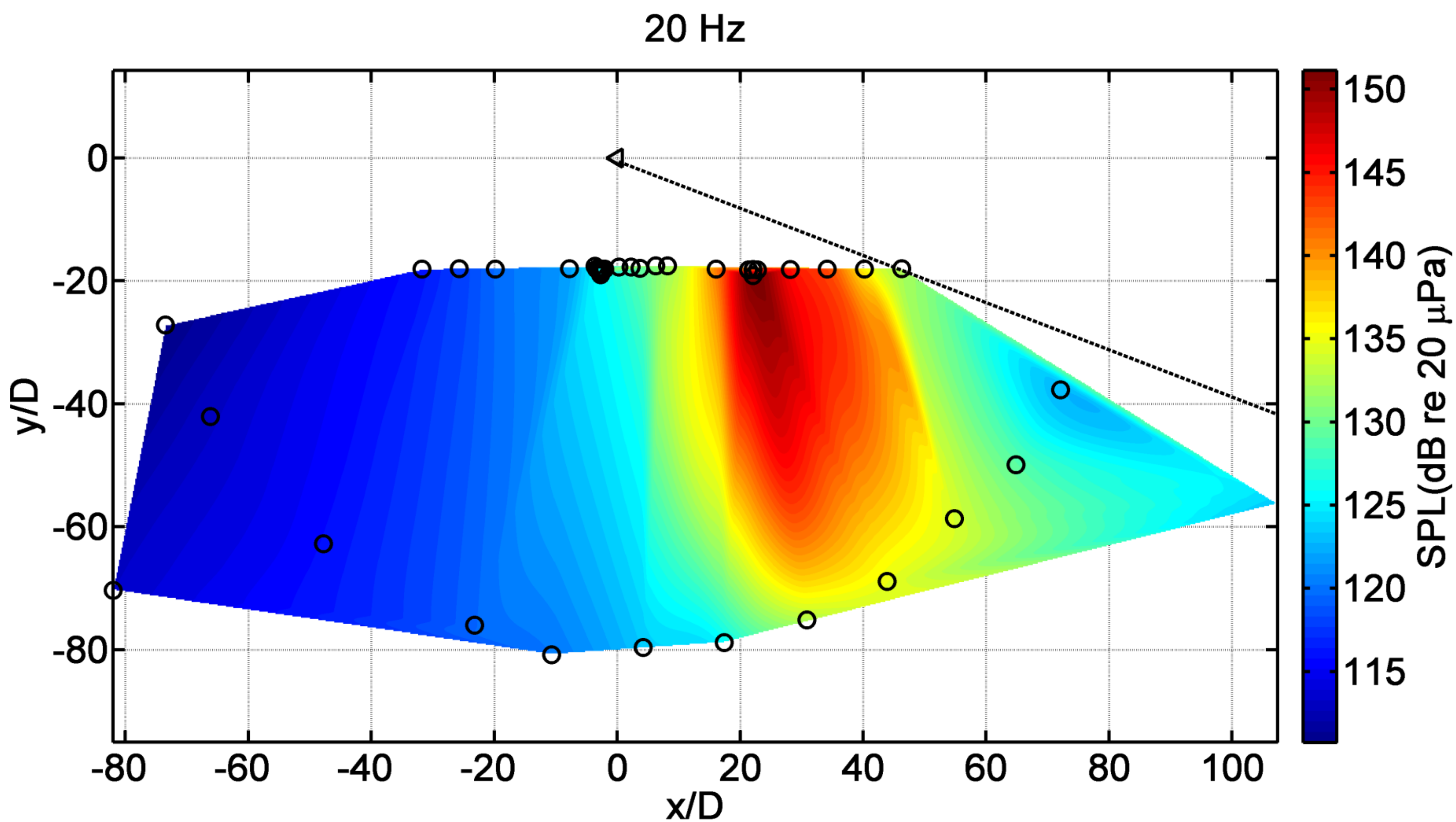
- One-third octave band plots reveal typical shift in max location/directionality but also curious behavior at high frequencies and the far aft angles.



# Band Pressure Levels



# Band Pressure Levels



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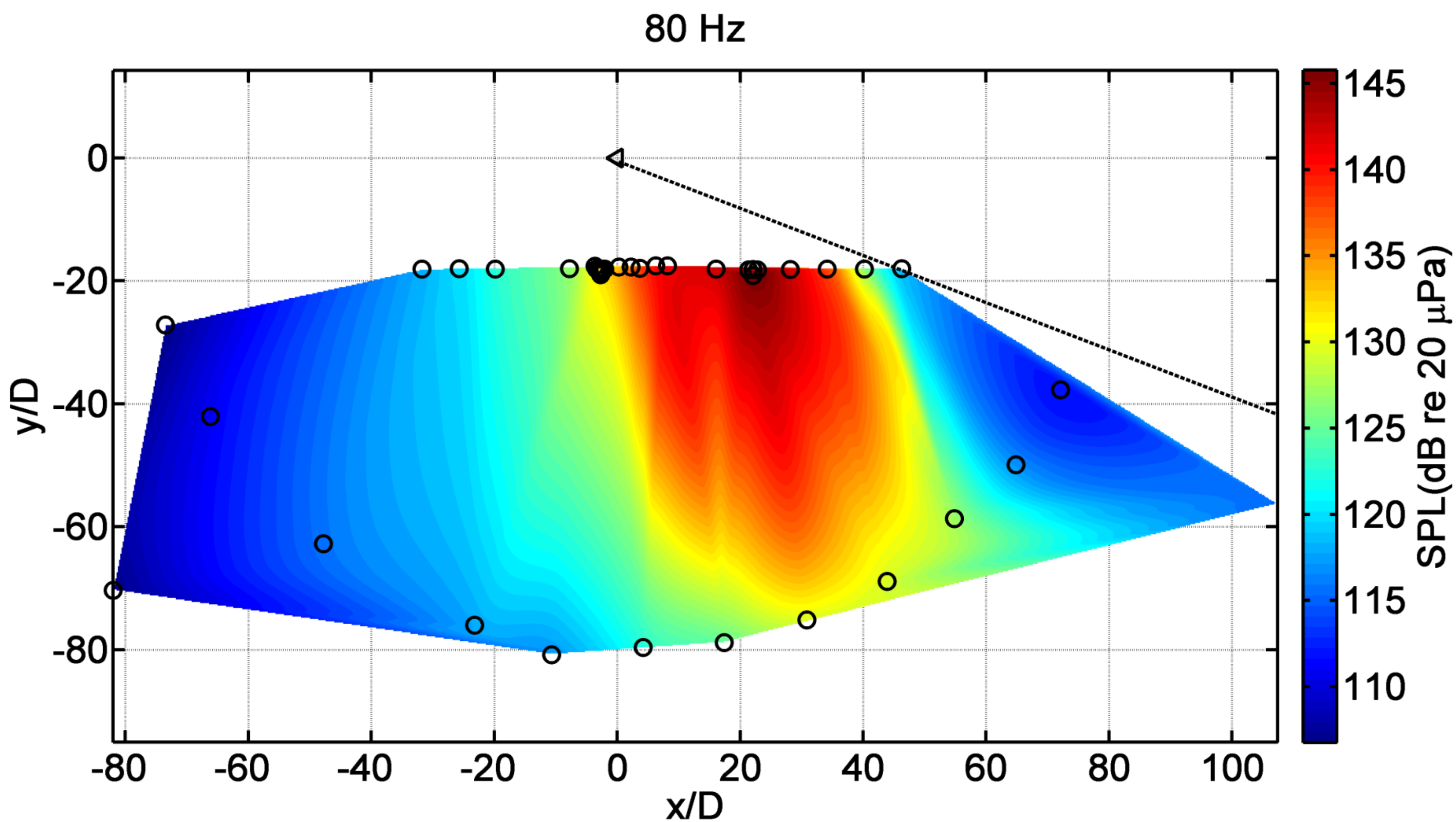
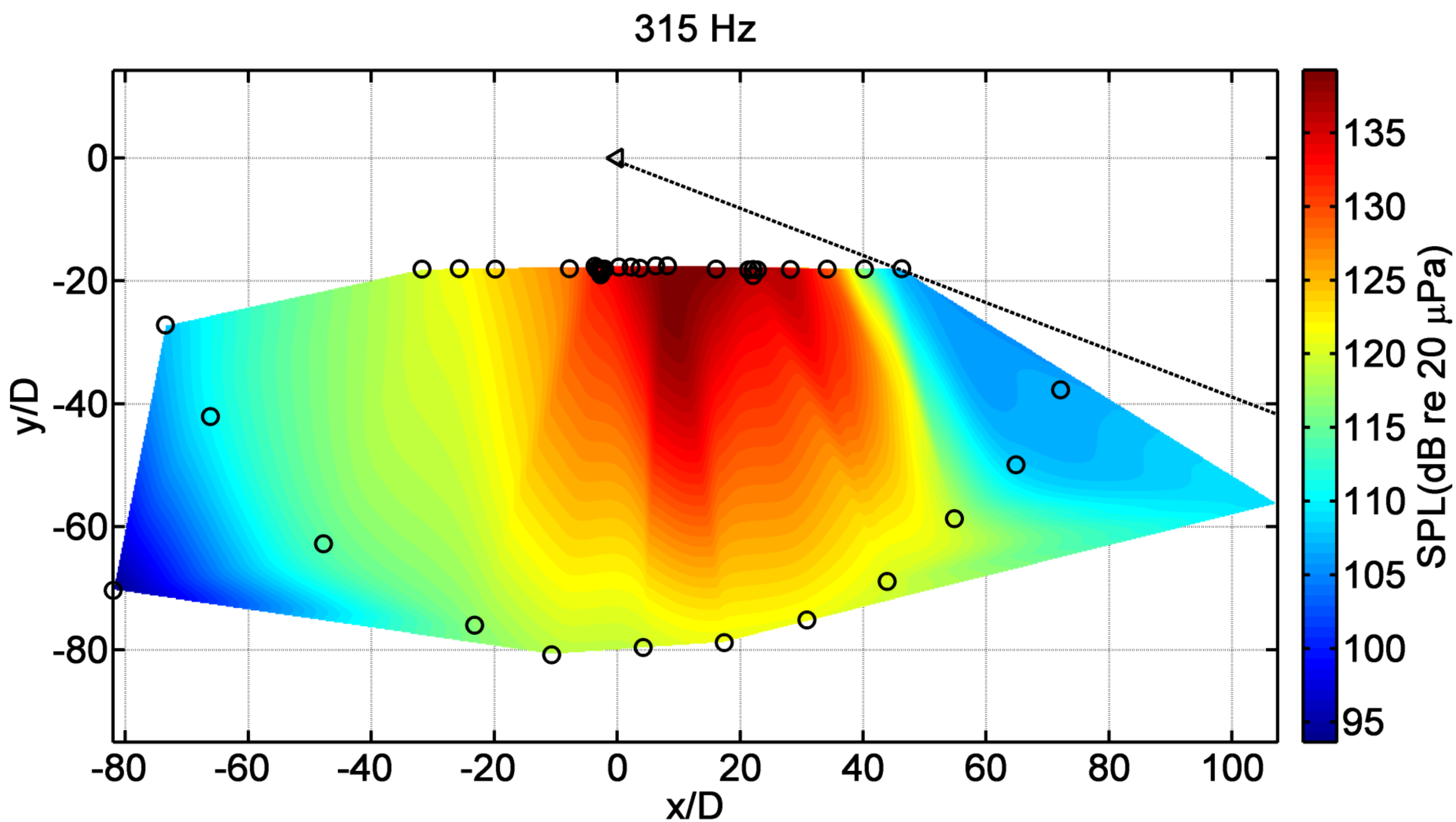


# Band Pressure Levels



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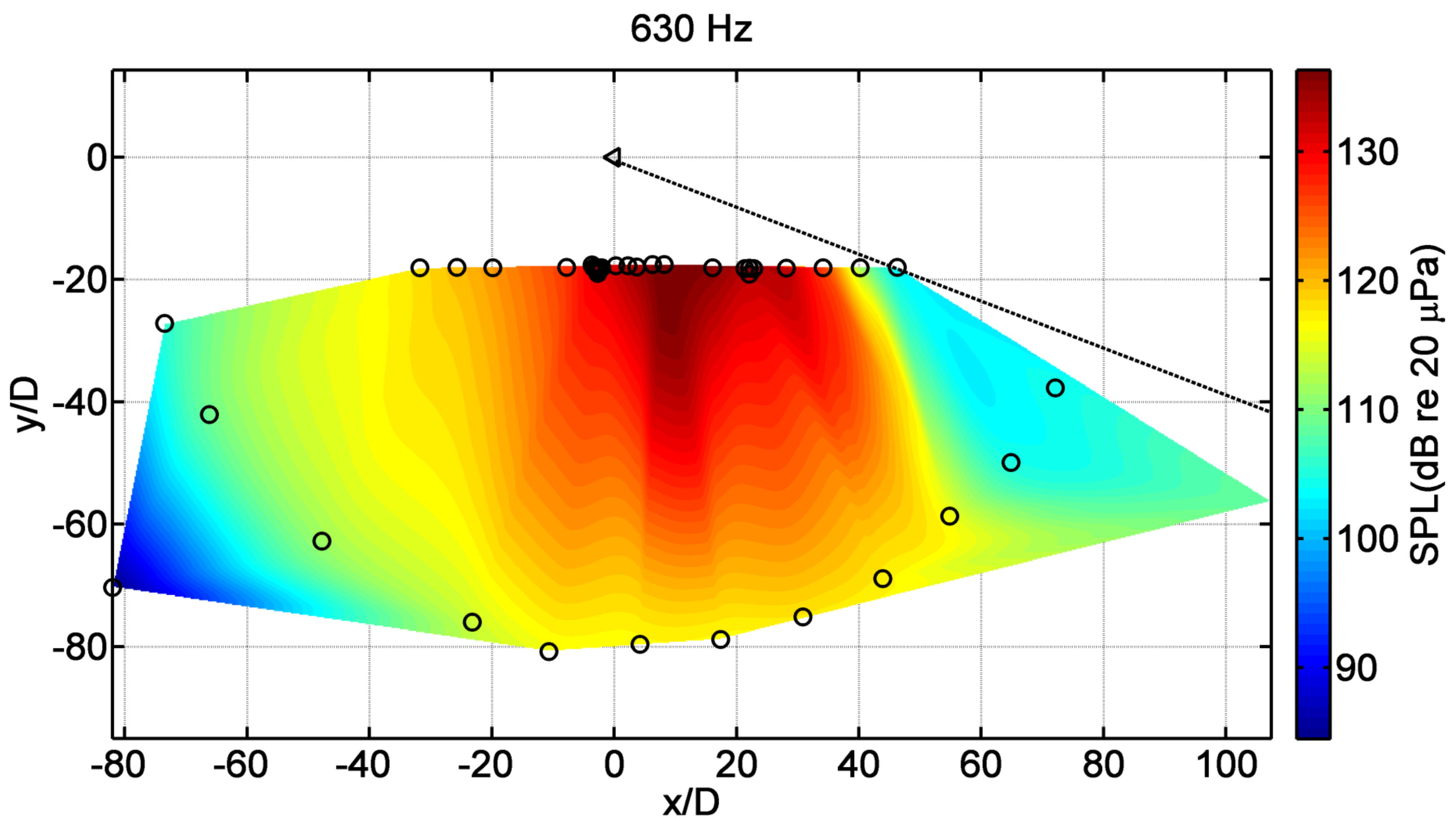
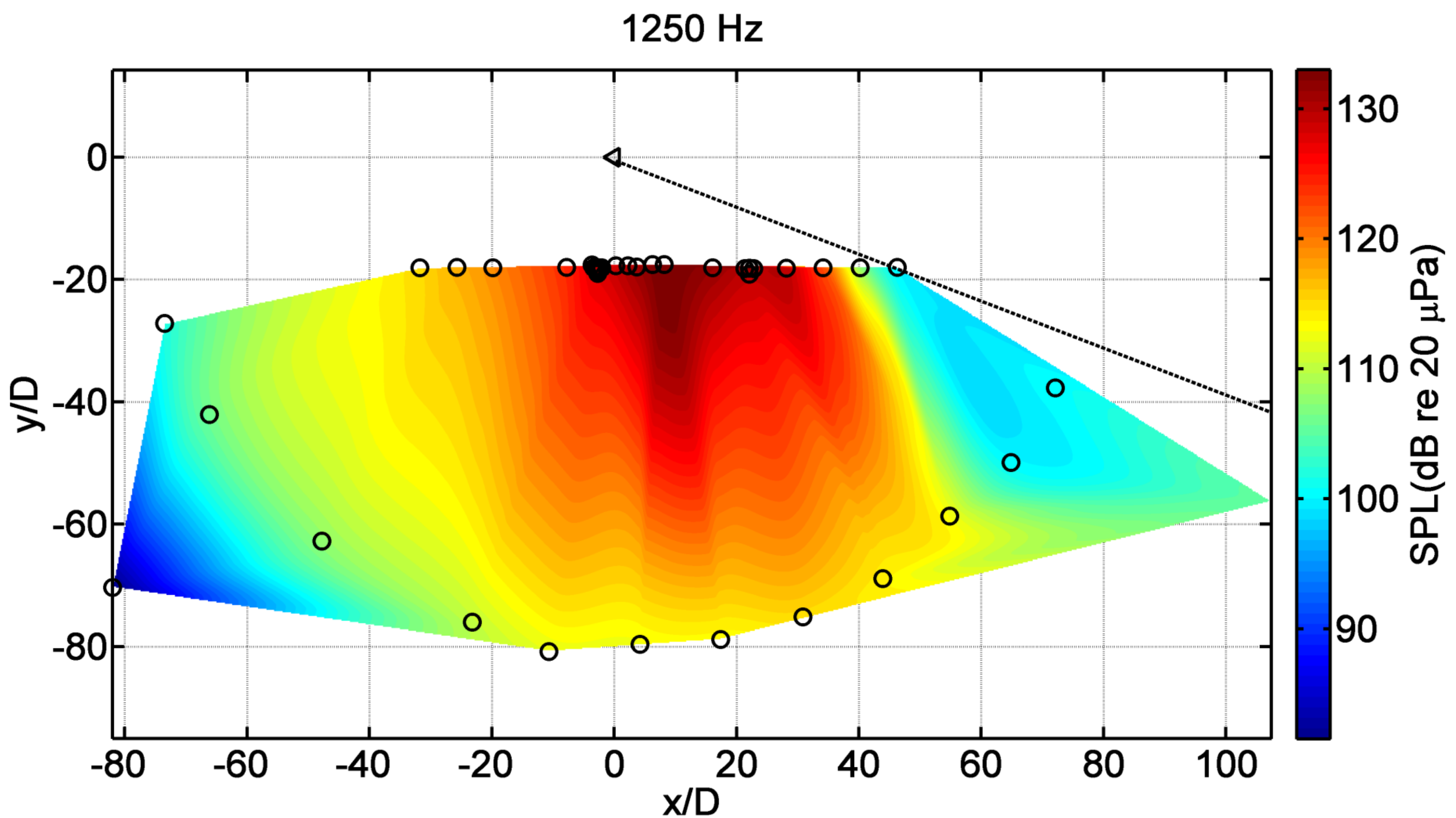
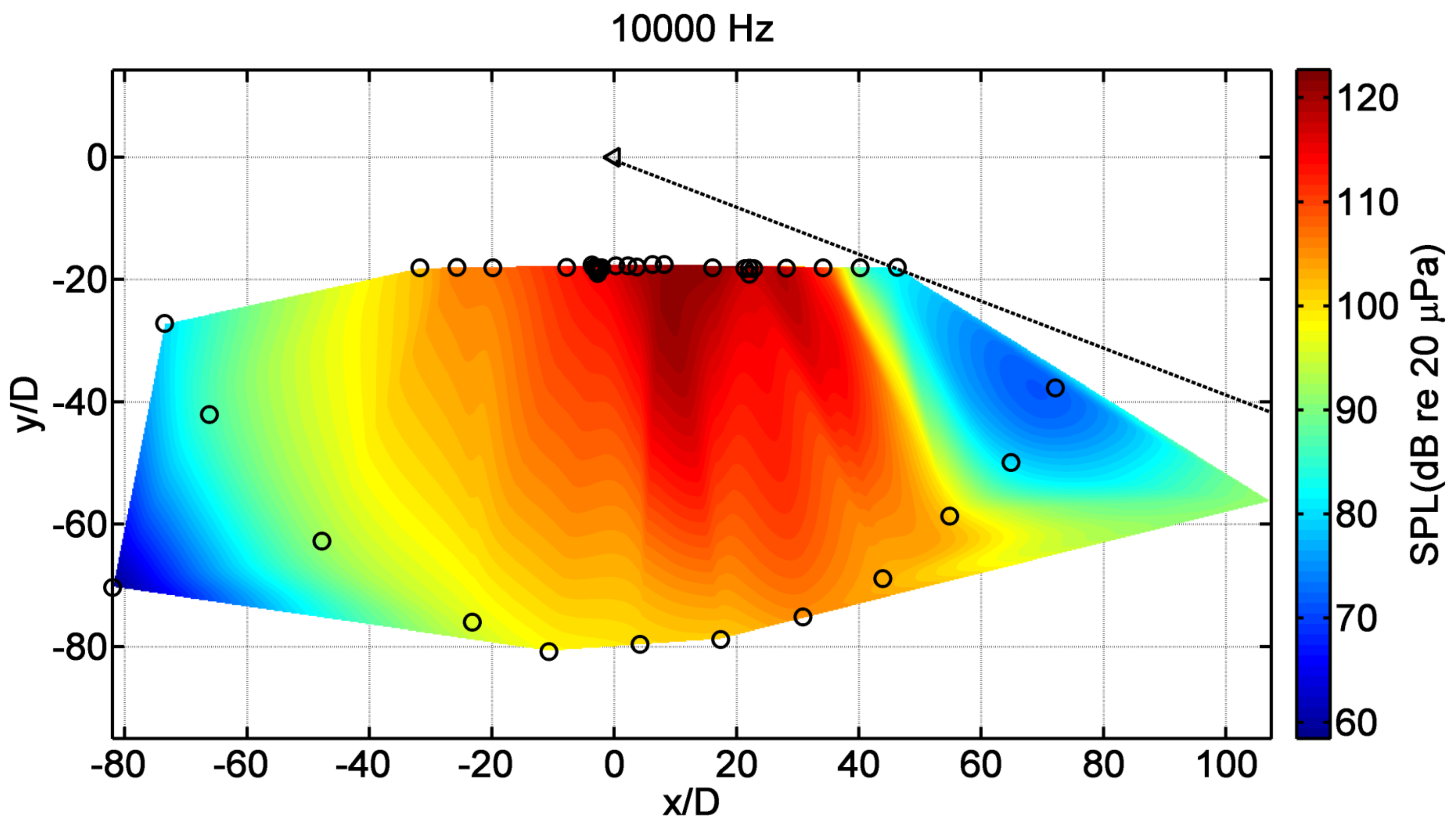


# Band Pressure Levels



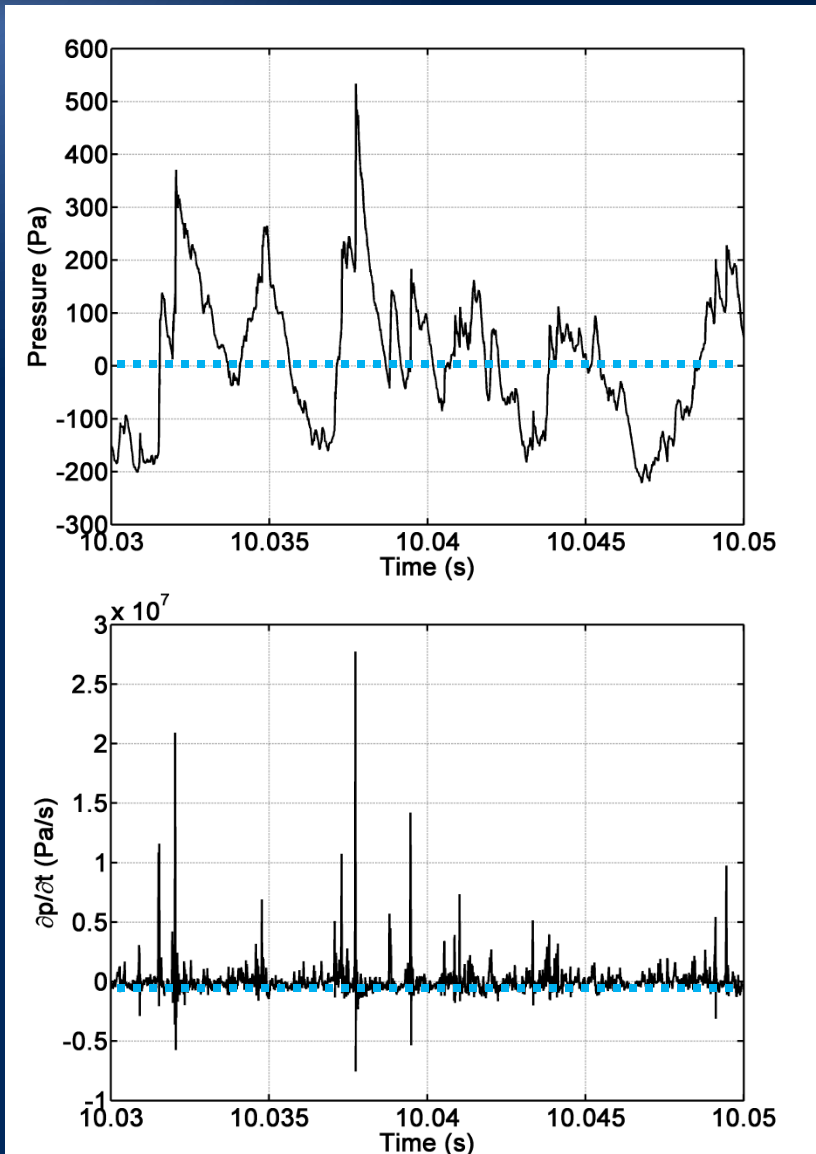
# Band Pressure Levels

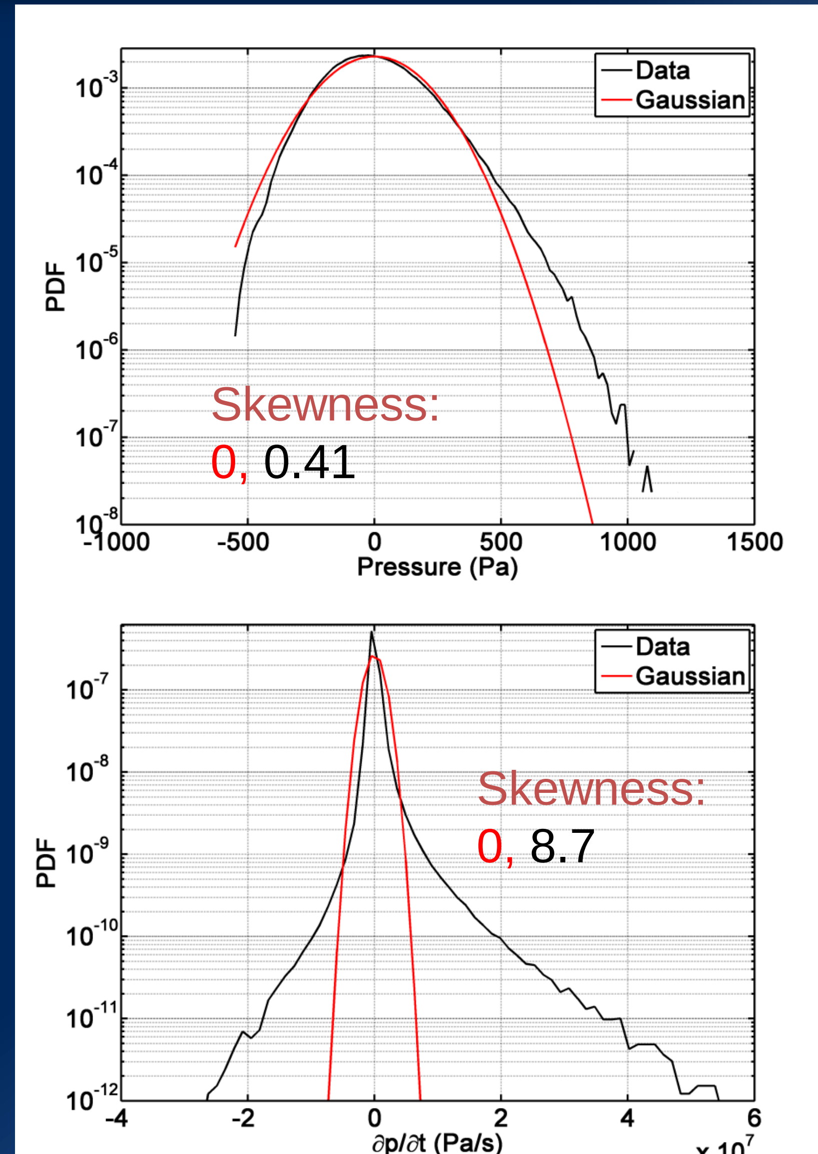


# Statistical Behavior

- Skewness
  - the normalized third-central moment of the probability density function
  - Measure of the "asymmetry" of the distribution
- Positive waveform skewness is a feature of high-amplitude noise radiated from supersonic jets and rockets.  Its cause is not fully known
- Skewness of the waveform derivative has been used as an indicator of relative shock strength and extreme non-Gaussian behavior.

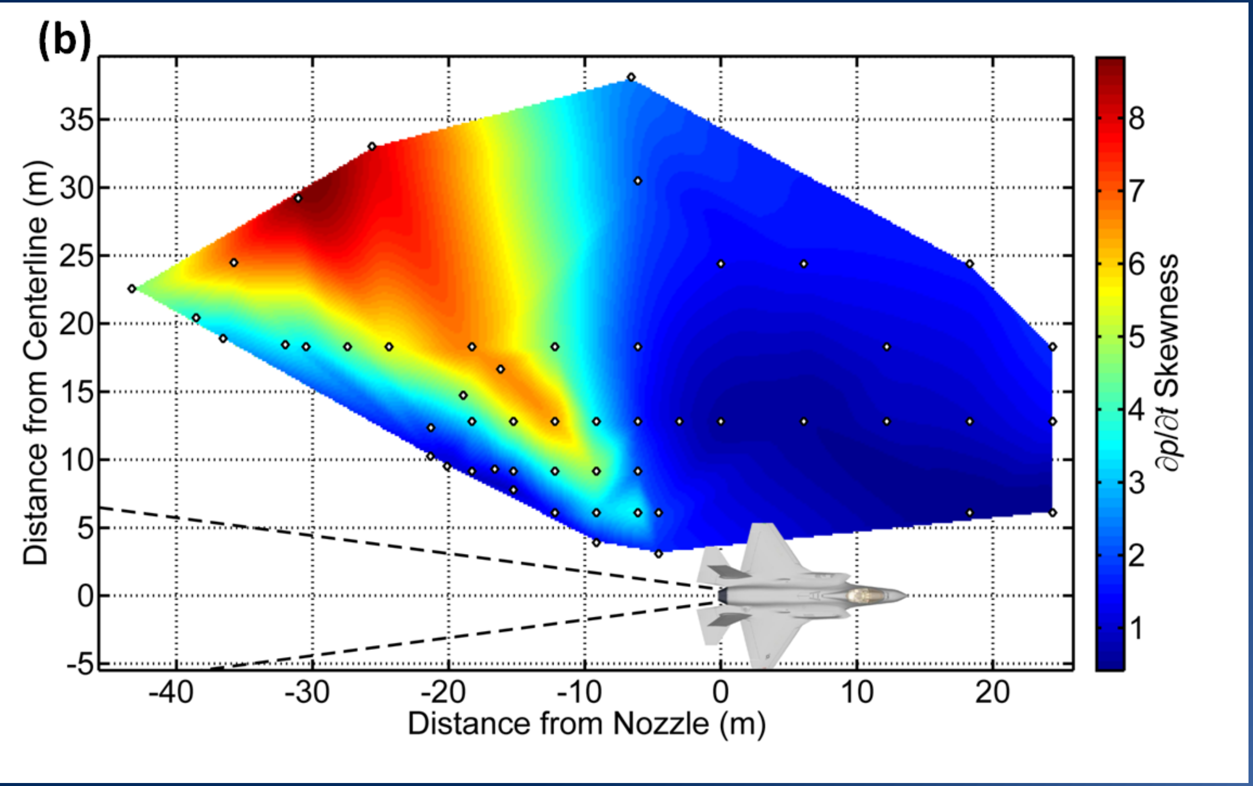
# F-35 MIL Power Example



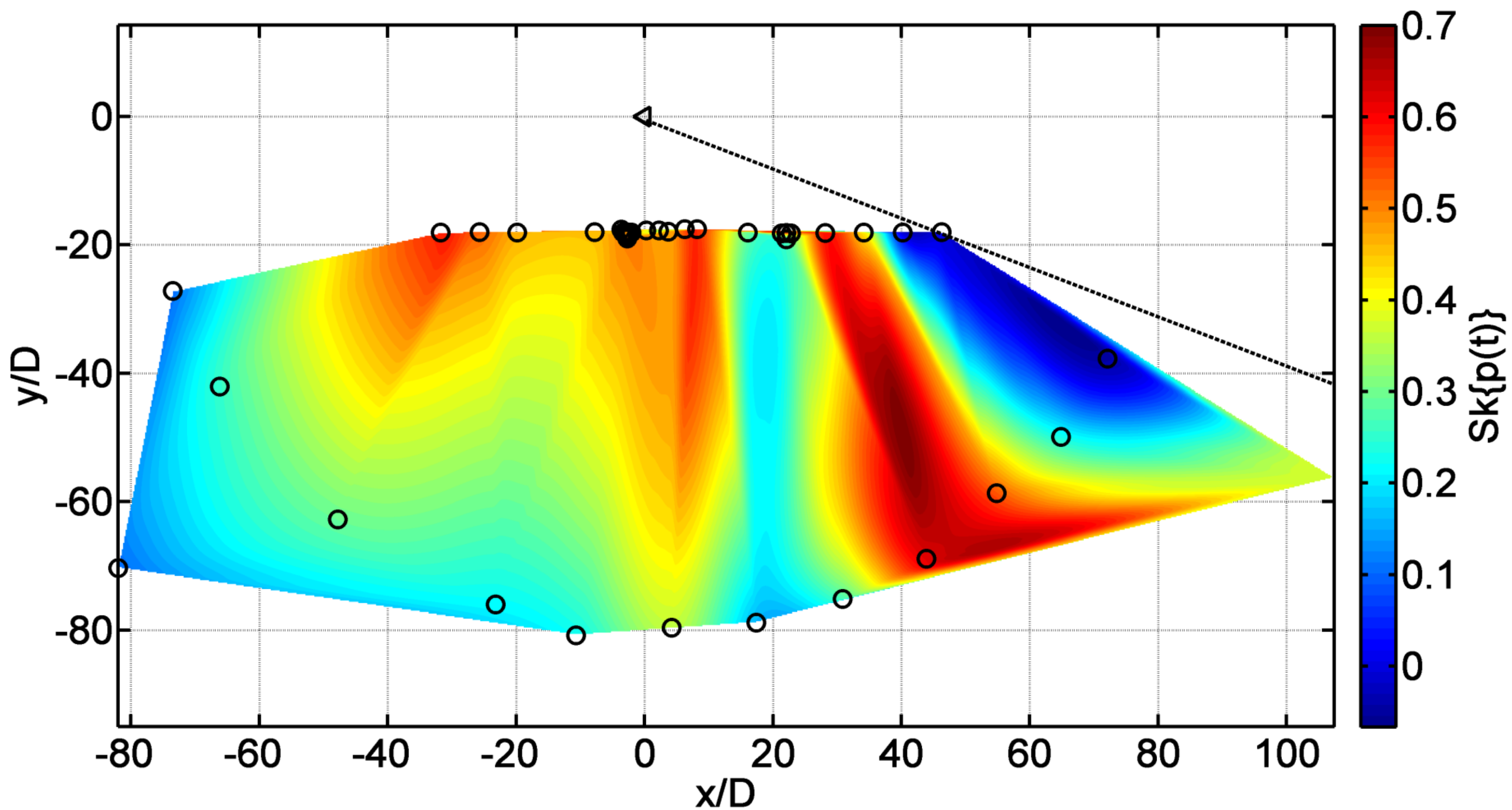
# F-35 Comparison

- Also growth in derivative skewness, but much lower values at comparable scaled distances



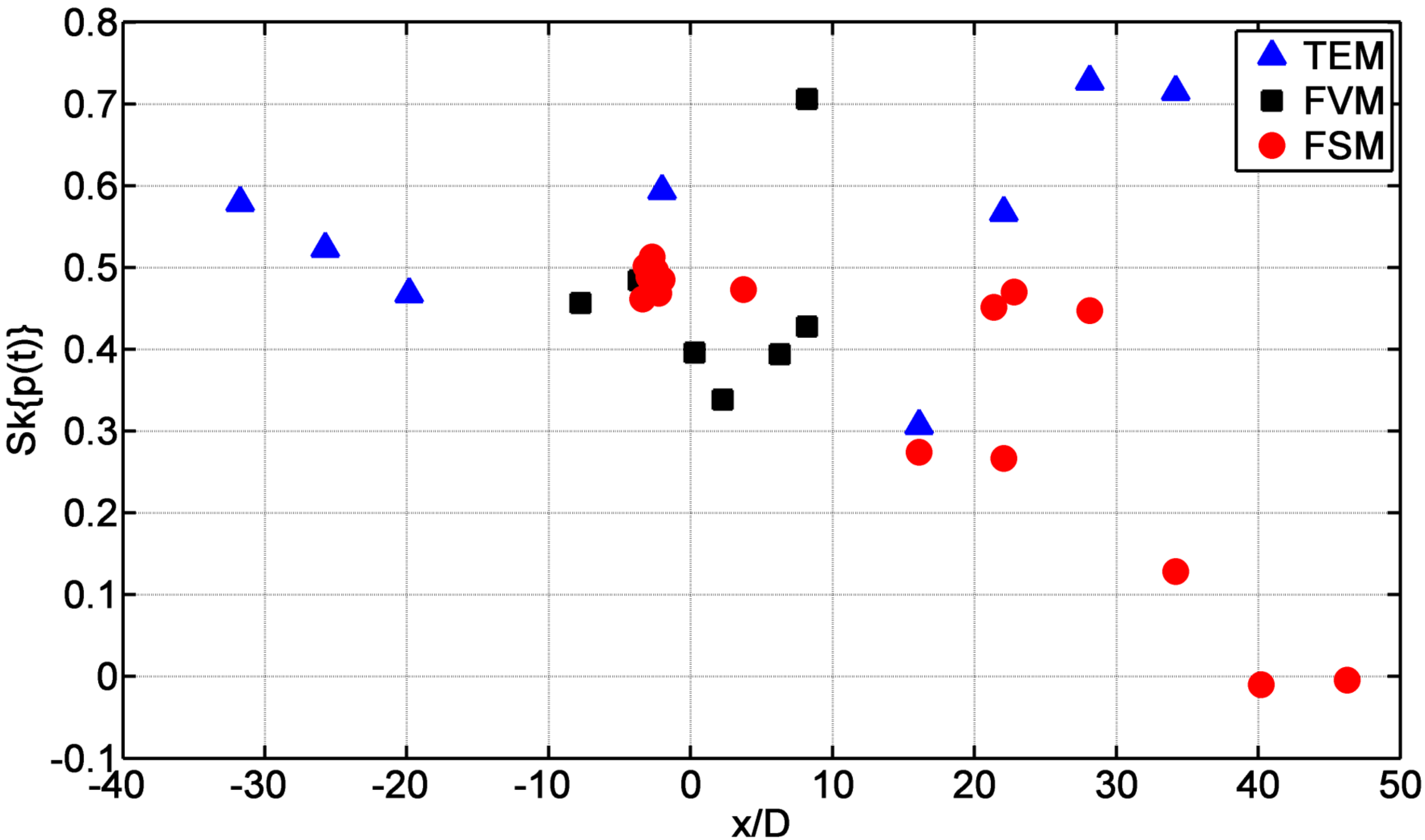
# Combined Waveform Skewness

- Maximum skewness around maximum radiation region and the rapid drop-off aft.



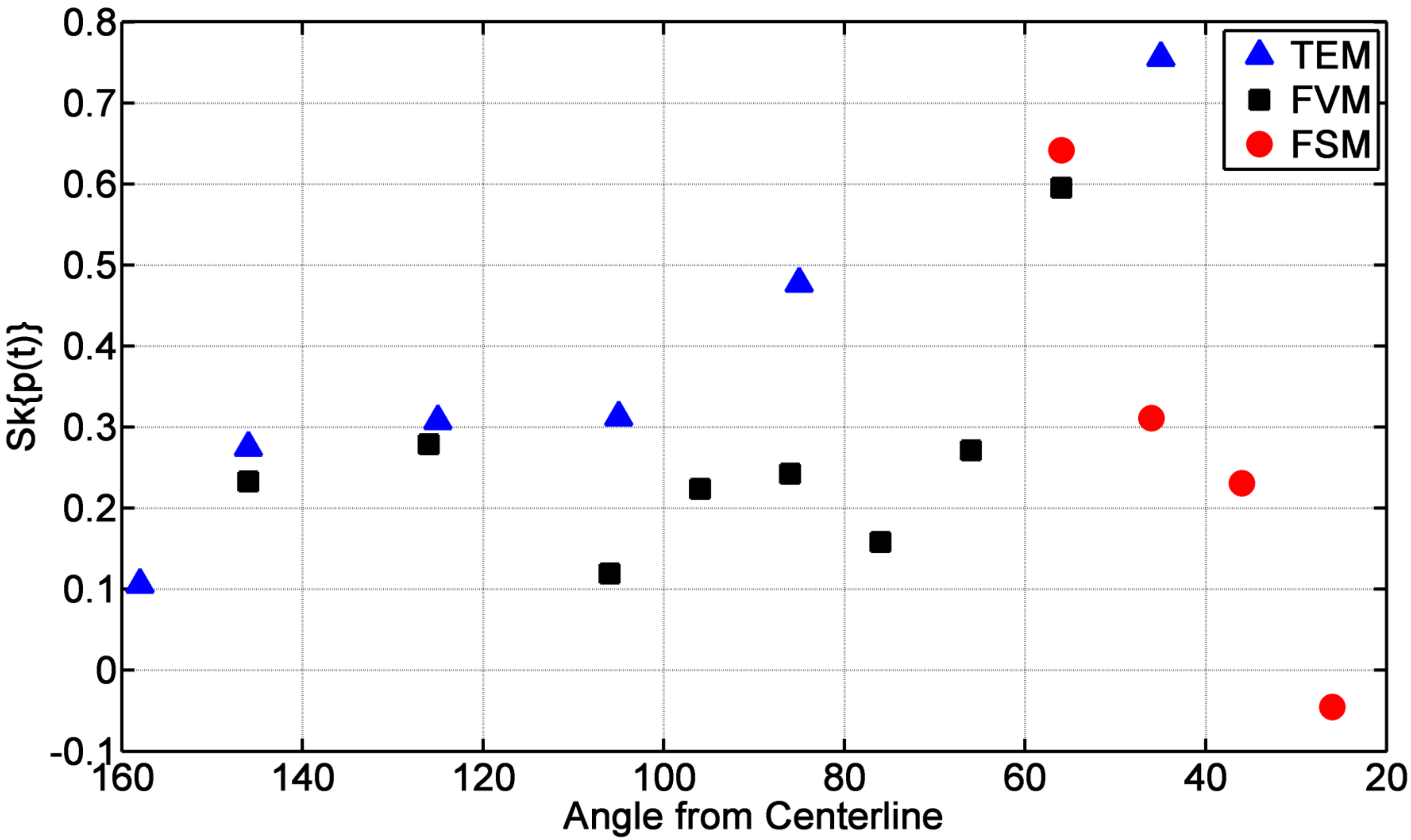
# 18 D Skewness

- High variability in the aft region.



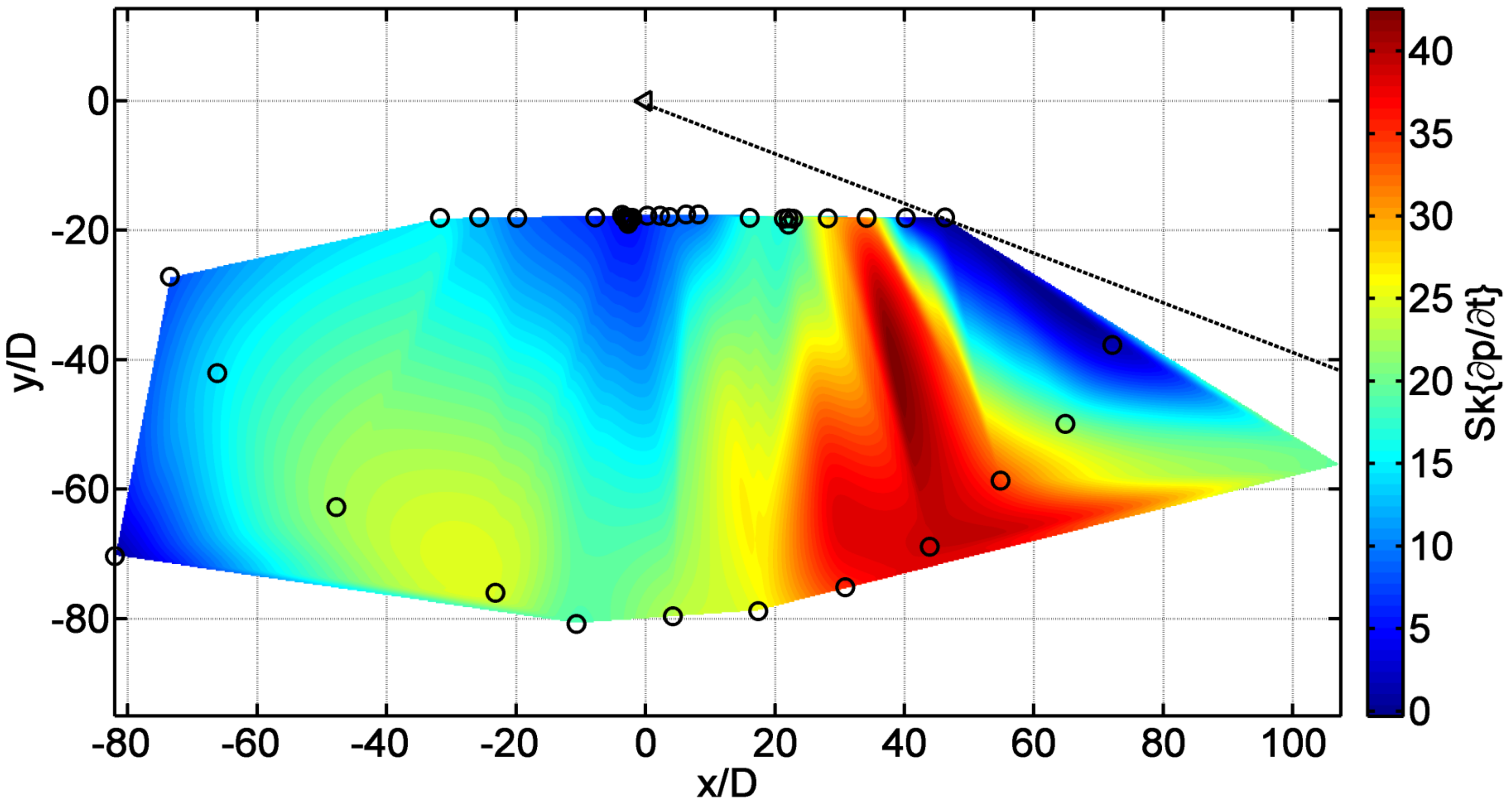
# 80 D Arc Skewness

- Increasing skewness from upstream to downstream until far aft angles.



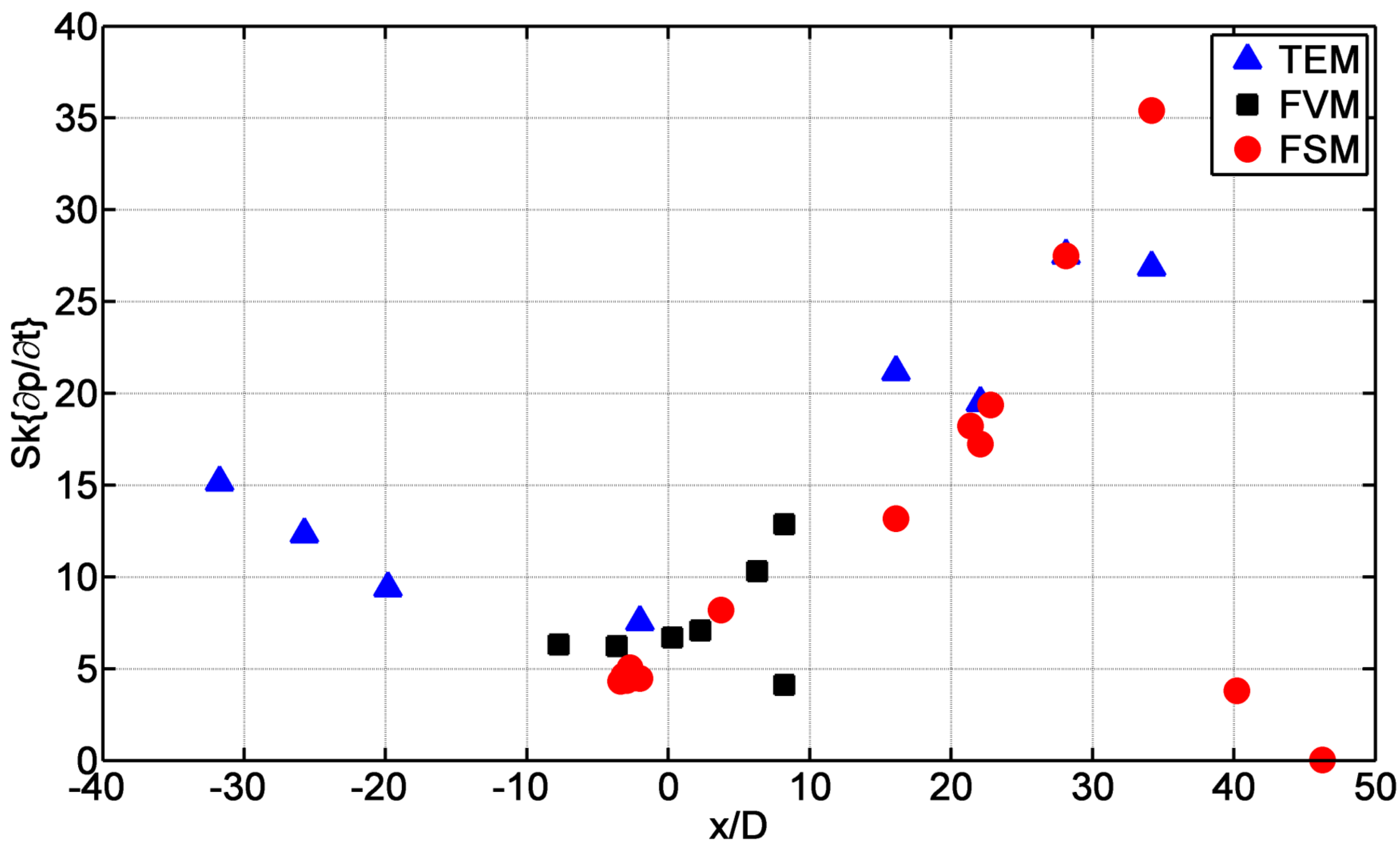
# Combined Derivative Skewness

- Growth of skewness from sideline until 80 D arc, particularly in max radiation region.



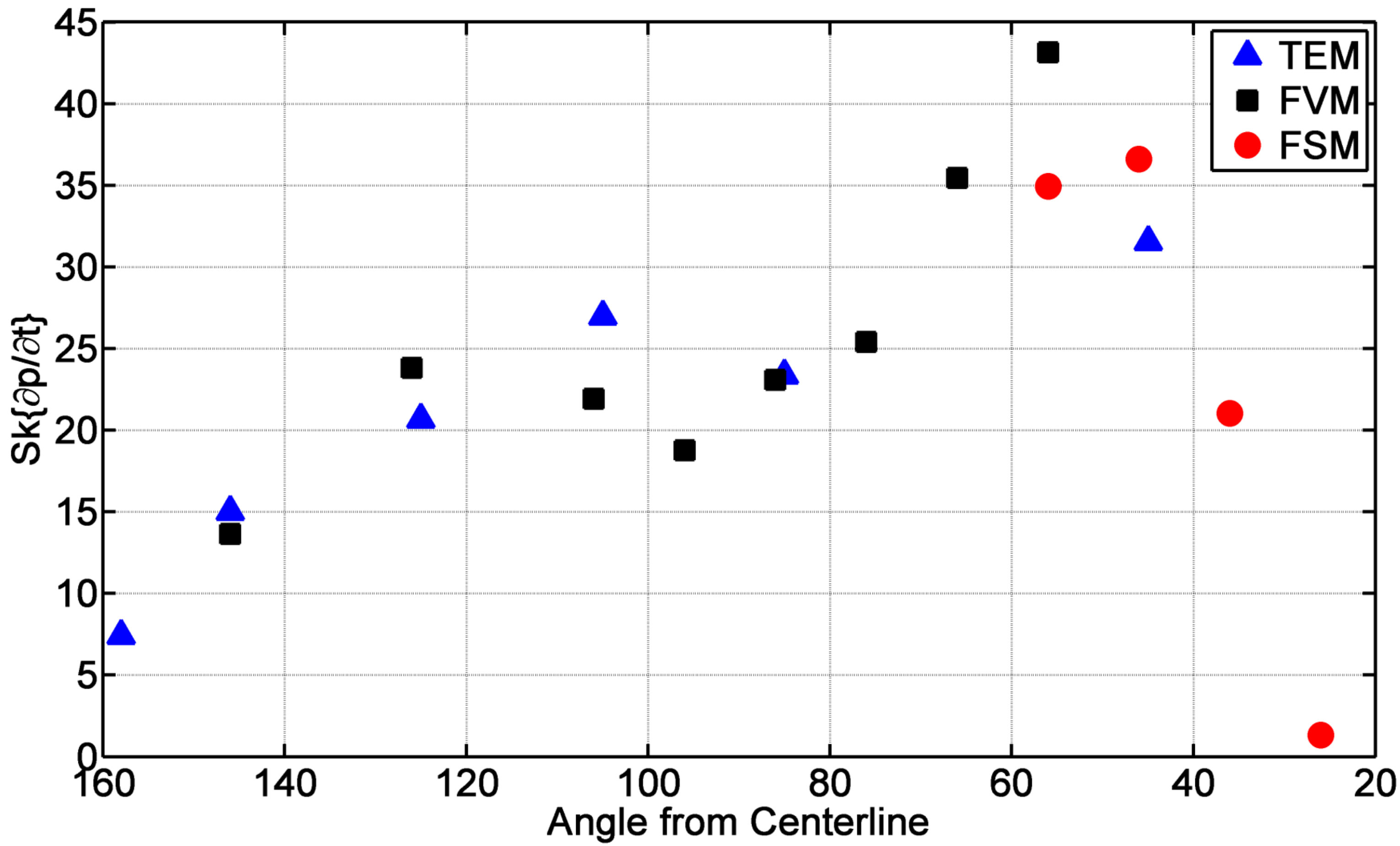
# 18 D Derivative Skewness

- Minimum at sideline, growth downstream until 40 D.

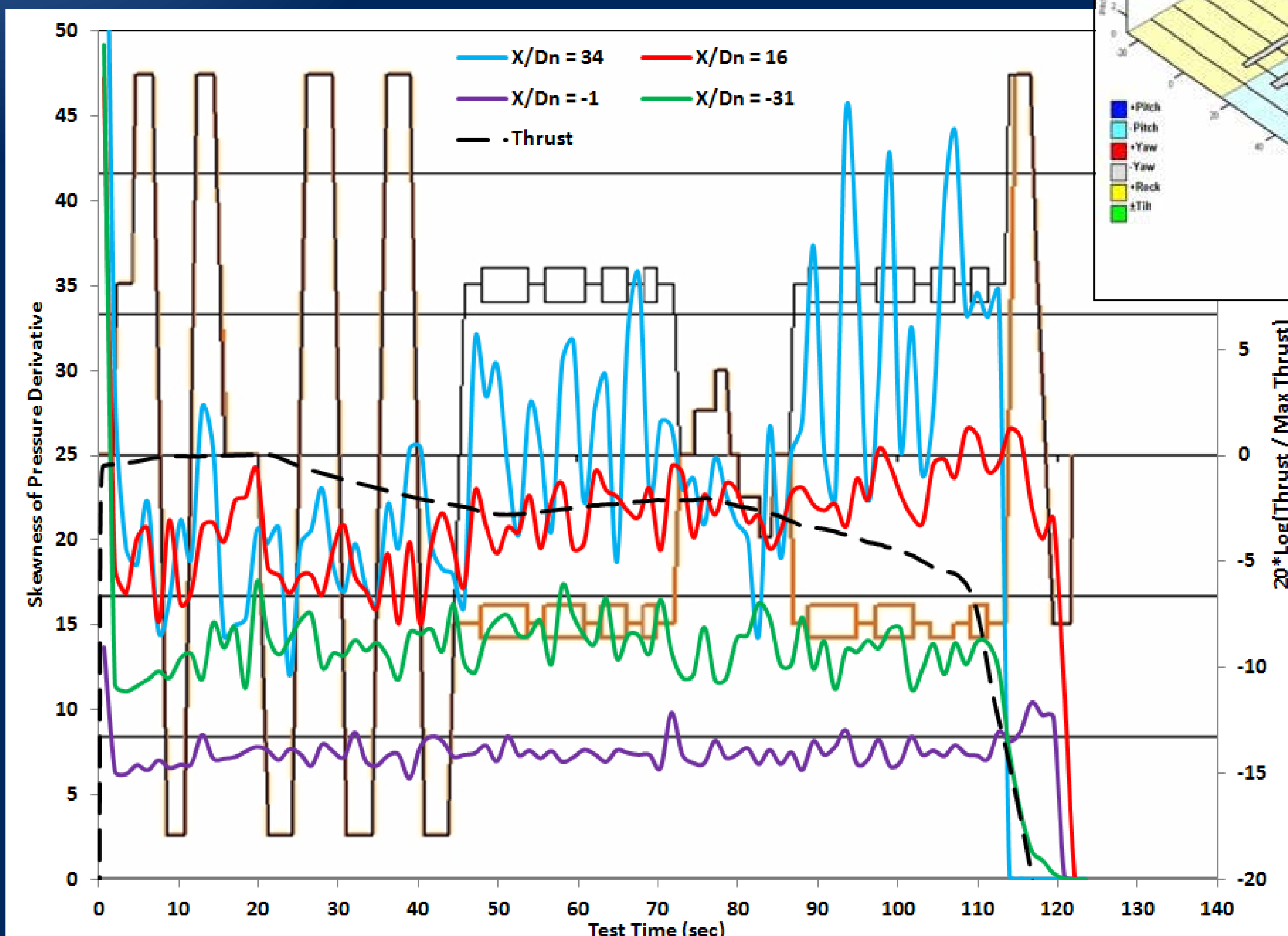


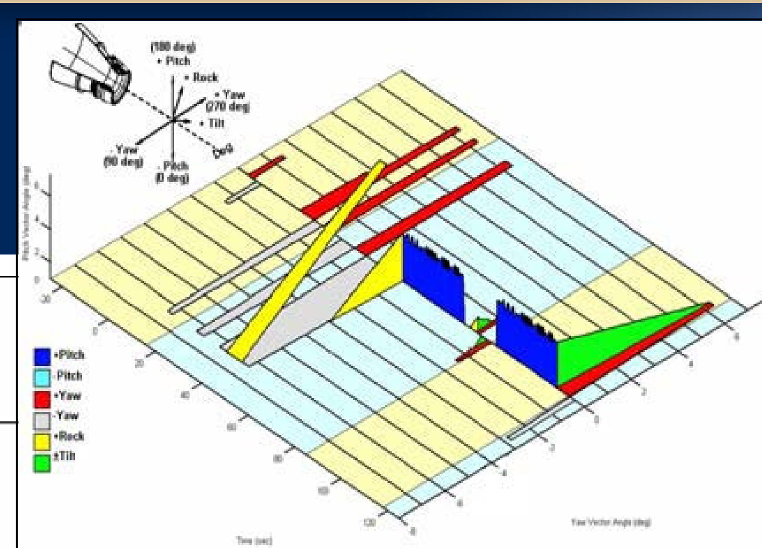
# 80 D Arc Derivative Skewness

- Growth going from upstream to downstream until 40°.



# Running Derivative Skewness (TEM13)



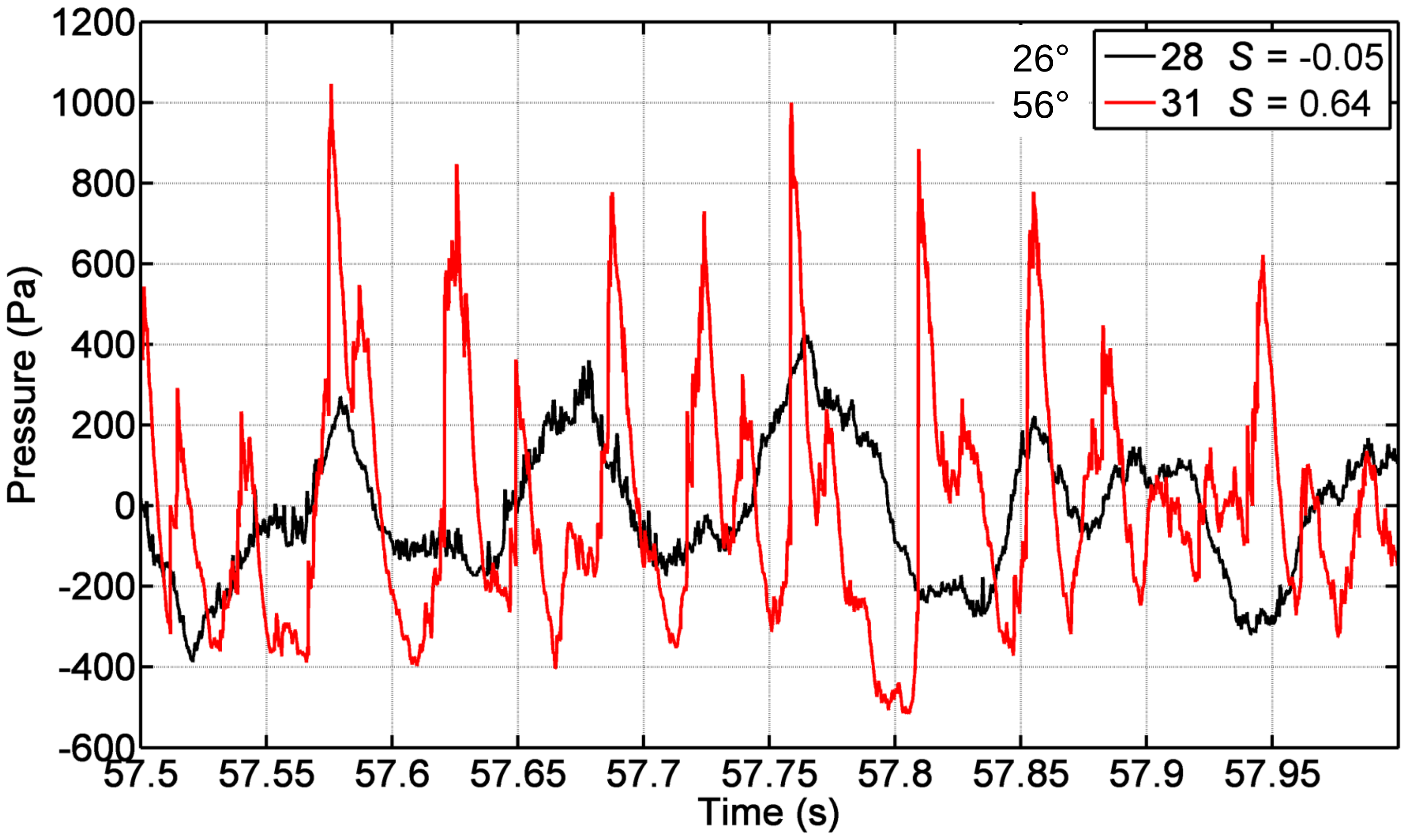



# Investigation of Downstream Behavior

- Why the rapid drop off in high-frequency levels, skewness, skewness of derivative at the far aft angles?
- *All extreme aft data from FSM-15*
- Comparison 26 ° and 56° data along arc (Channels 28 and 31)

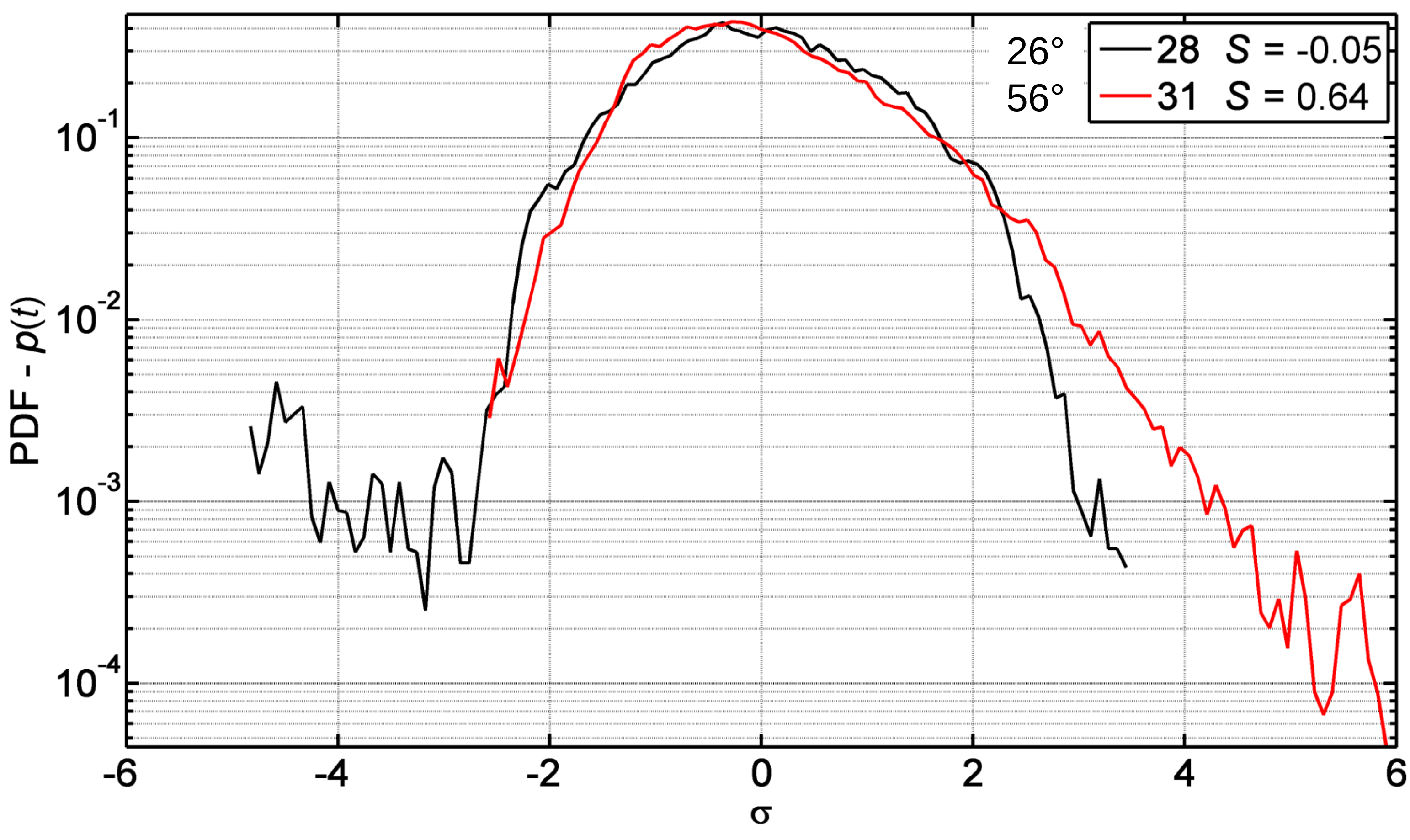
# Time waveforms

- Skewed, shock-like behavior versus randomized noise, as seen in PDFs.



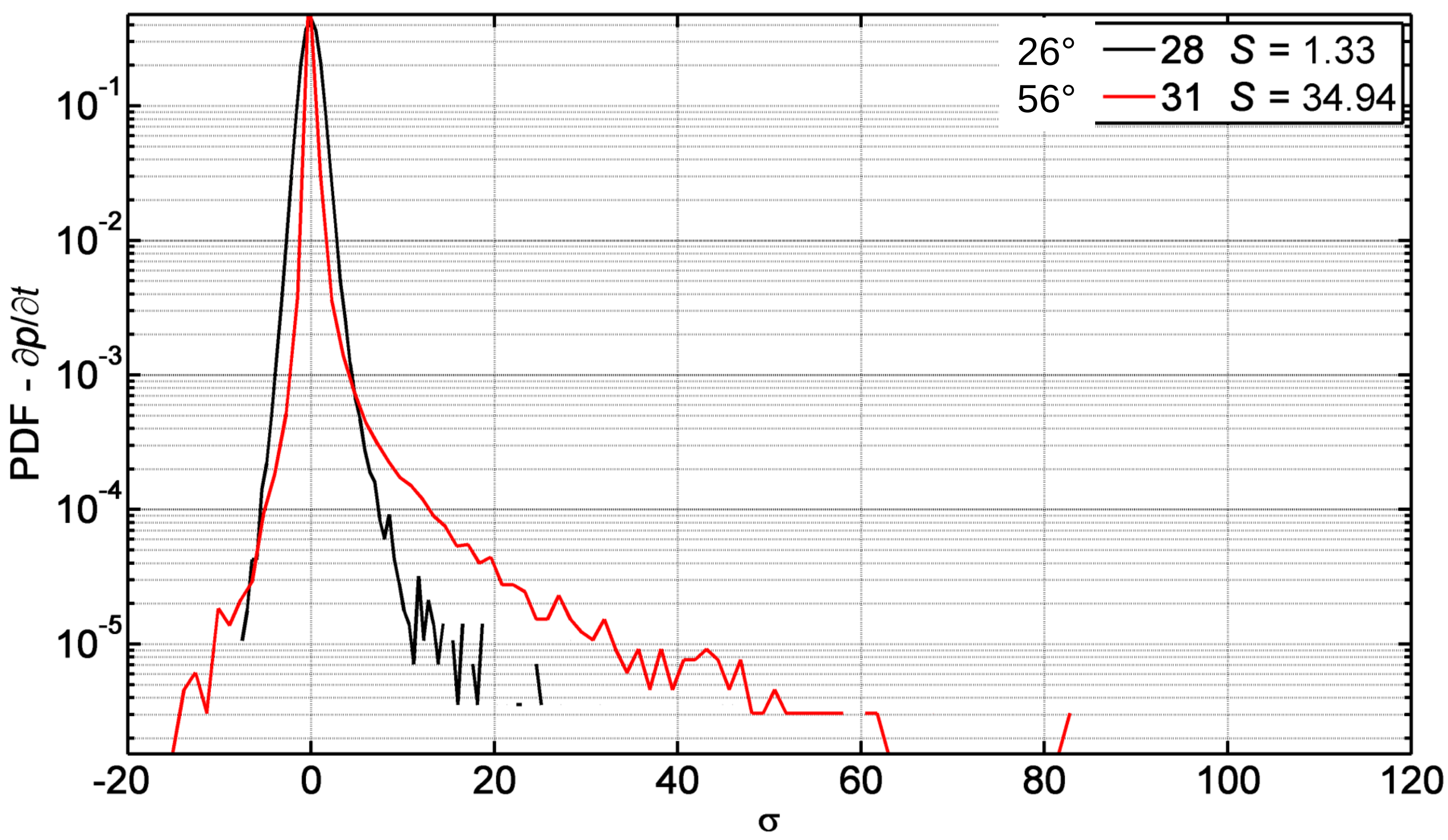
# PDF of p(t)

- Positive skewness in maximum radiation direction, Gaussian behavior at 26 °.



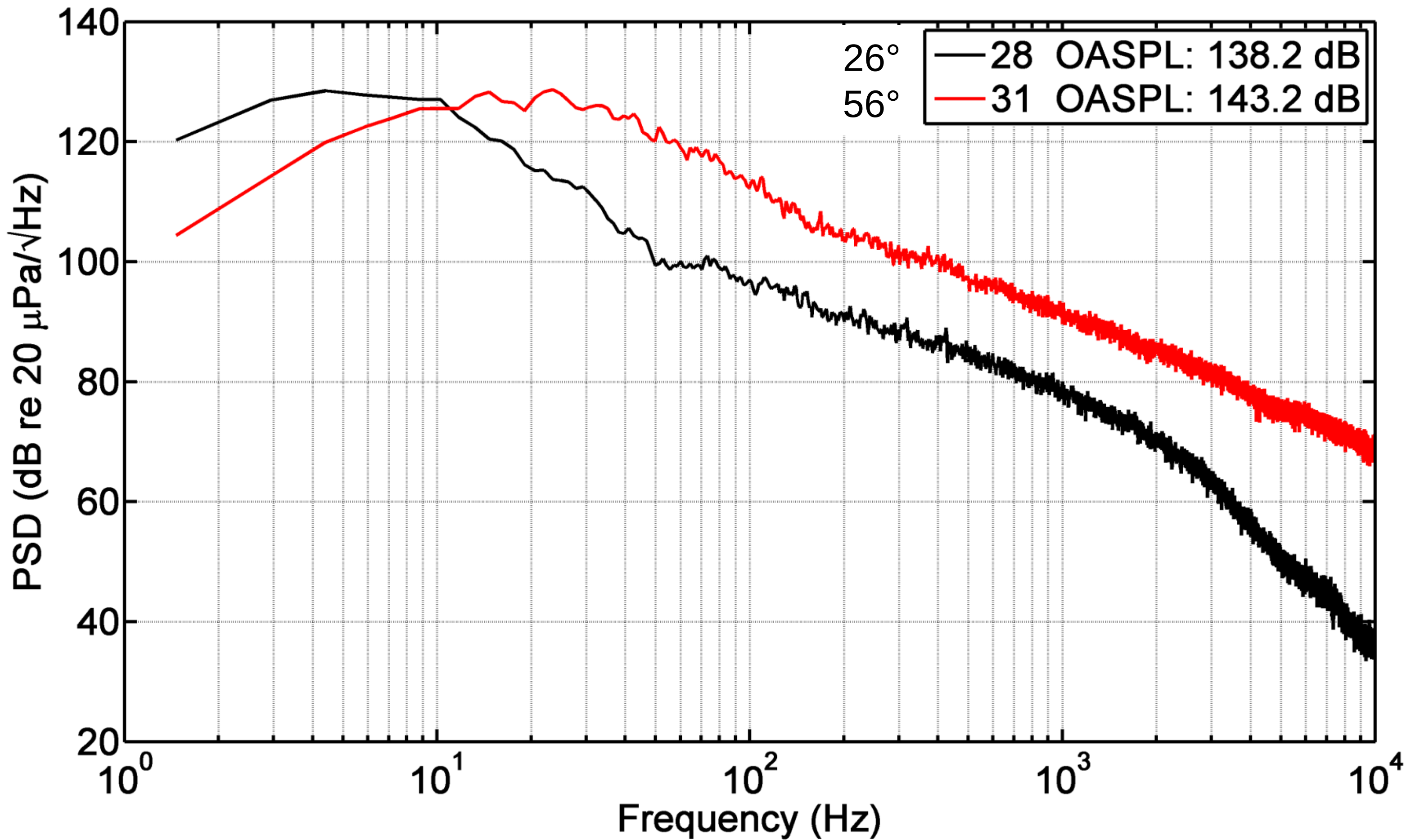
# PDF of dp/dt

- Events beyond 100 standard deviations shows extreme non-Gaussian, shock-like behavior.



# PSD Comparison

- PSDs show a marked high-frequency roll-off above 2 kHz for 26°.



# Insight from Topography

- 40 D downstream is the end of the "bowl"
- Plume impingement affects high frequencies and randomizes noise generation

# Conclusion

- Compilation of data from three firings show consistent behavior
- Overall maximum radiation appears to be
  - ~17-18 D downstream of nozzle
  - Along 50-60° relative to nozzle exit
- Band pressure levels seem similar above ~500 Hz
- Plume impingement from terrain and gimballing has an impact on high-frequency levels, skewness, and derivative skewness
  - Potentially important implications for vertical launch pad environments