

Variation in Sonic Boom Metrics due to Atmospheric Turbulence during CarpetDIEM III

Kaylee Nyborg¹, Kent L. Gee¹, and Alexandra Loubeau²

¹Brigham Young University

²NASA Langley Research Center

2025 AIAA Aviation Forum

July 21-25, 2025

Introduction

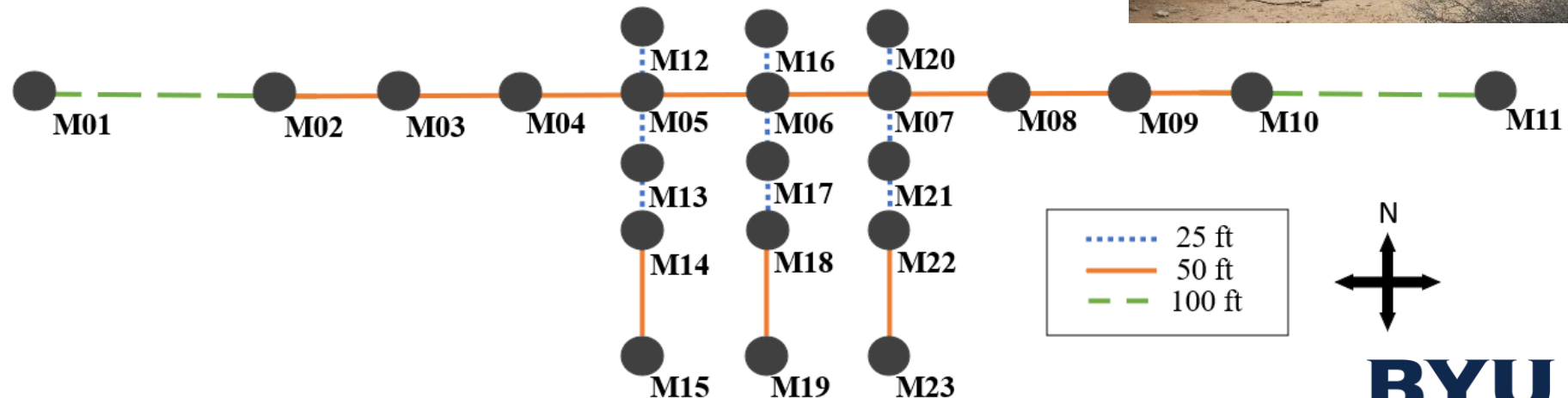
- NASA Quesst Mission
- ARray Instrumentation for Sonic Thump Observations in TurbuLence (ARISTOTLE)
 - Measure X-59 sonic “thumps”
 - Analyze variability due to atmospheric turbulence
- Carpet Determination In Entirety Measurement (CarpetDIEM) III
 - F-15
 - 6 flights
 - Measured 5 flights with ARISTOTLE Jr.



NASA

ARISTOTLE Jr. at CarpetDIEM III

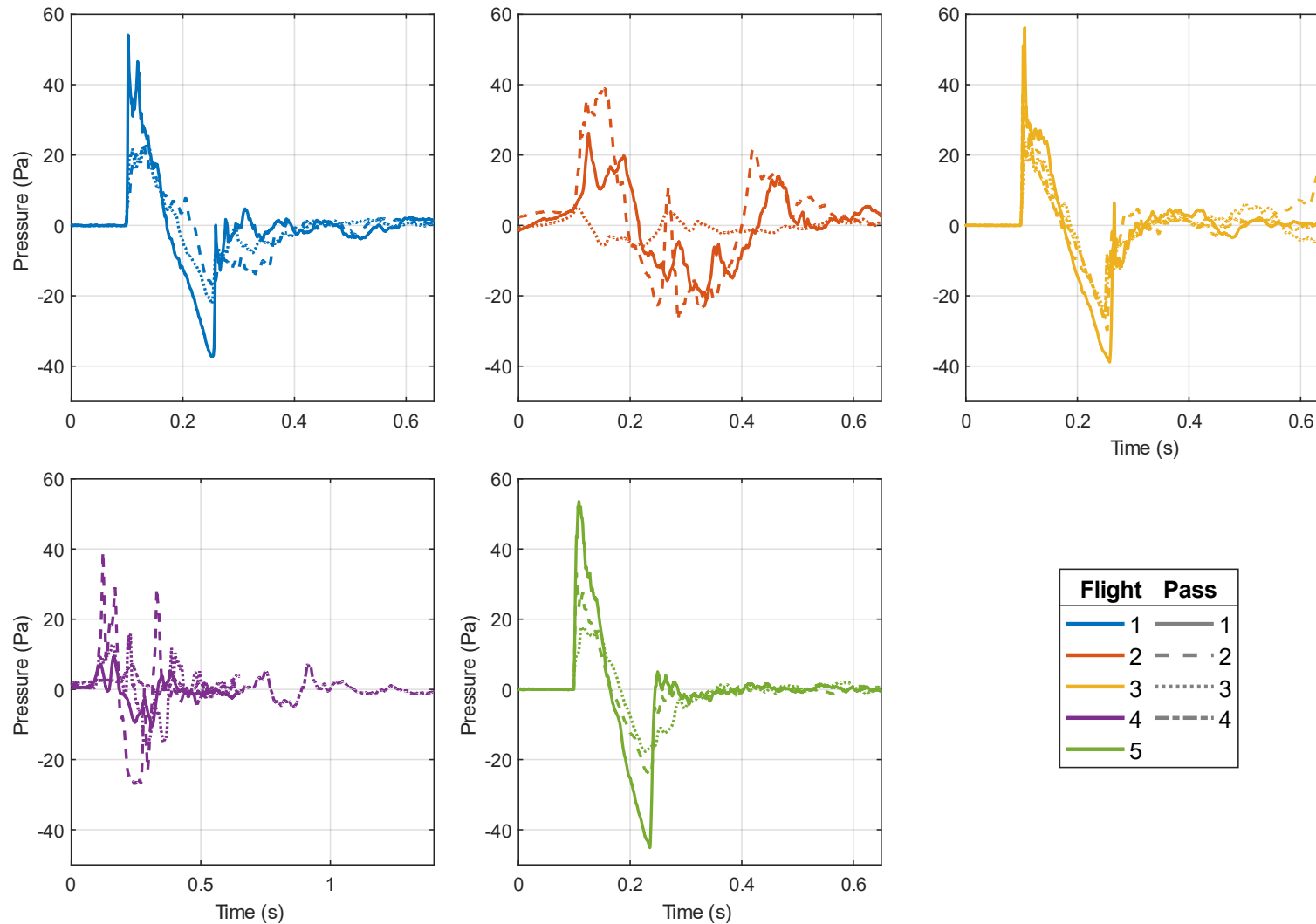
- Limited dataset
 - Measured flights 1-5 (17 booms)
 - Risk reduction test in preparation for future tests
- 23-microphone array
 - 2D
 - 25 ft, 50 ft, and 100 ft spacing
 - Span of 600 ft x 125 ft



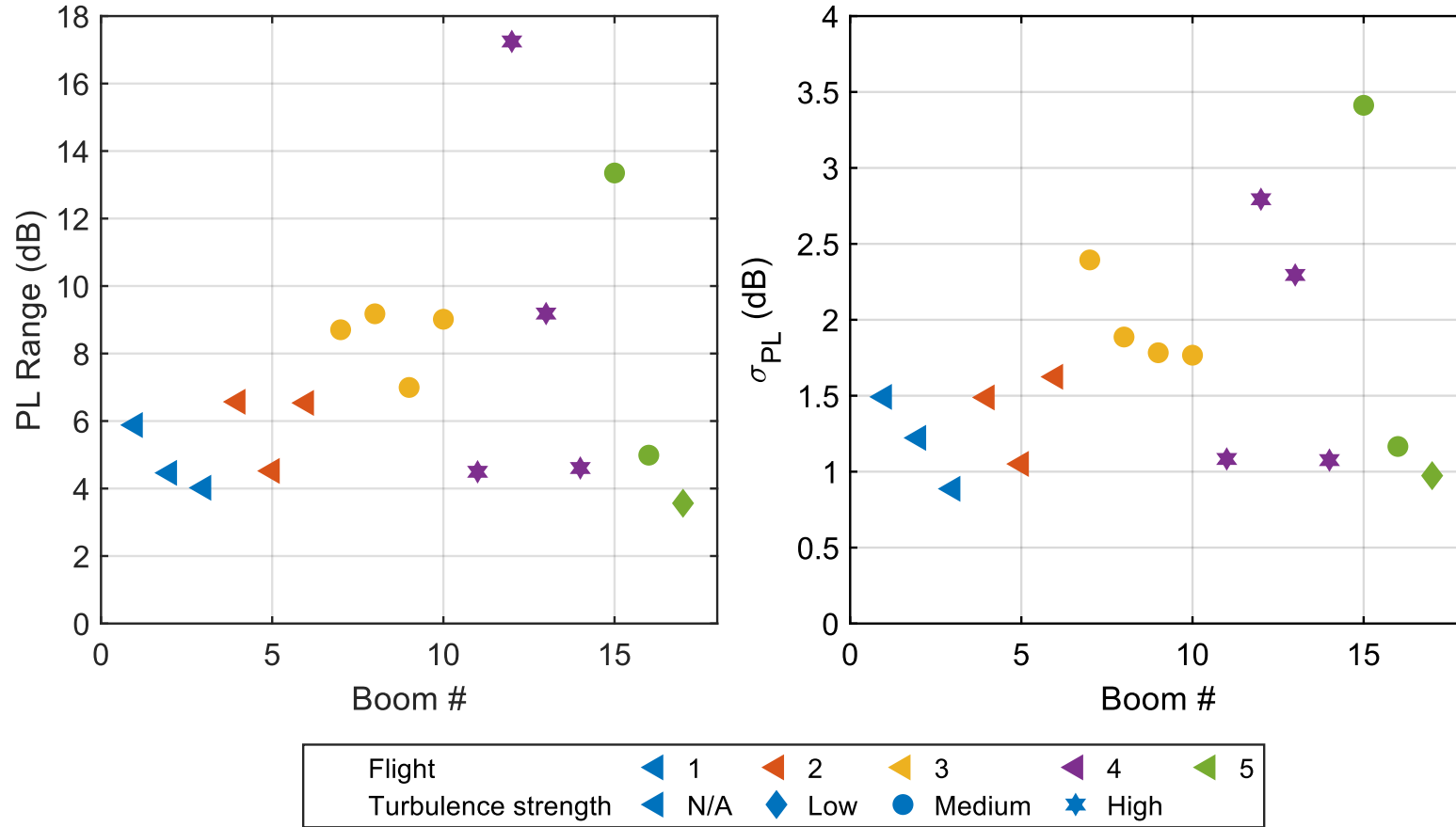
Weather conditions

- **Surface weather**
 - Temperature ranged from 8.9°C to 20.2°C
 - Wind speed ranged from 0.4 m/s to 7.3 m/s
- **Weather balloon**
 - Successfully launched for flights 1, 2, 3, and 5
 - Trends are similar for temperature and wind speed
- **Turbulence**
 - Sonic anemometer measured 3D wind speed
 - ~15 nmi south of array
 - Used 10-min average to calculate turbulence parameters
 - Measurements for flights 3, 4, and 5
 - σ_{vector} ranged from 0.68 m/s to 1.97 m/s
 - Turbulence strengths¹
 - Flight 3: medium
 - Flight 4: high
 - Flight 5: low and medium

Waveforms for one microphone



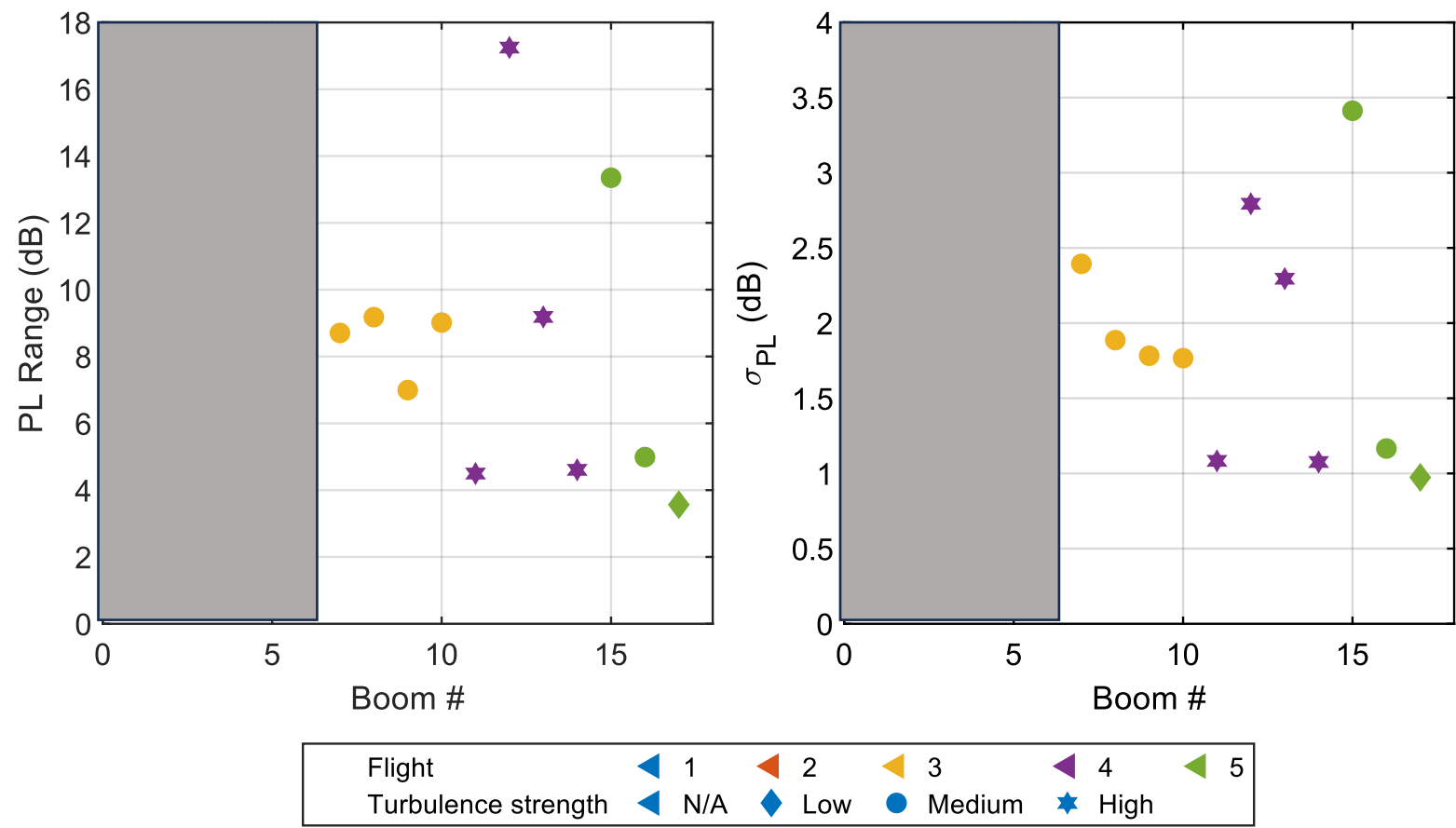
PL range and standard deviation



Average PL range: 7.3 dB

Average σ_{PL} : 1.7 dB

PL range and standard deviation

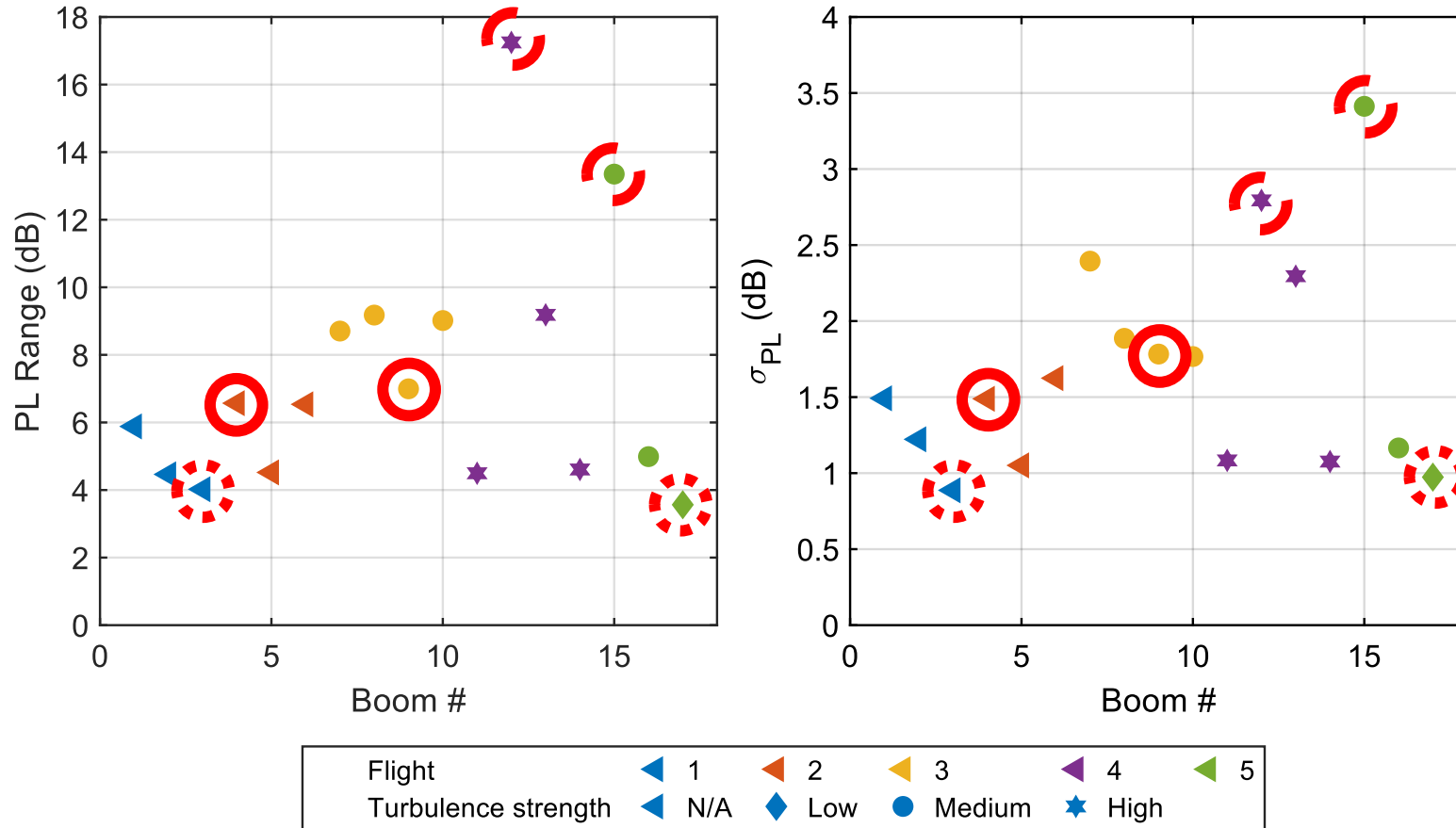


For flights 3-5

Turbulence strength	Number of booms	Average PL range (dB)	Average PL standard deviation (dB)
Low	1	3.6	1.0
Medium	6	8.7	2.1
High	4	8.9	1.8

Average PL range: 7.3 dB
Average σ_{PL} : 1.7 dB

PL range and standard deviation



PL variability examples:

Low (<5 dB)

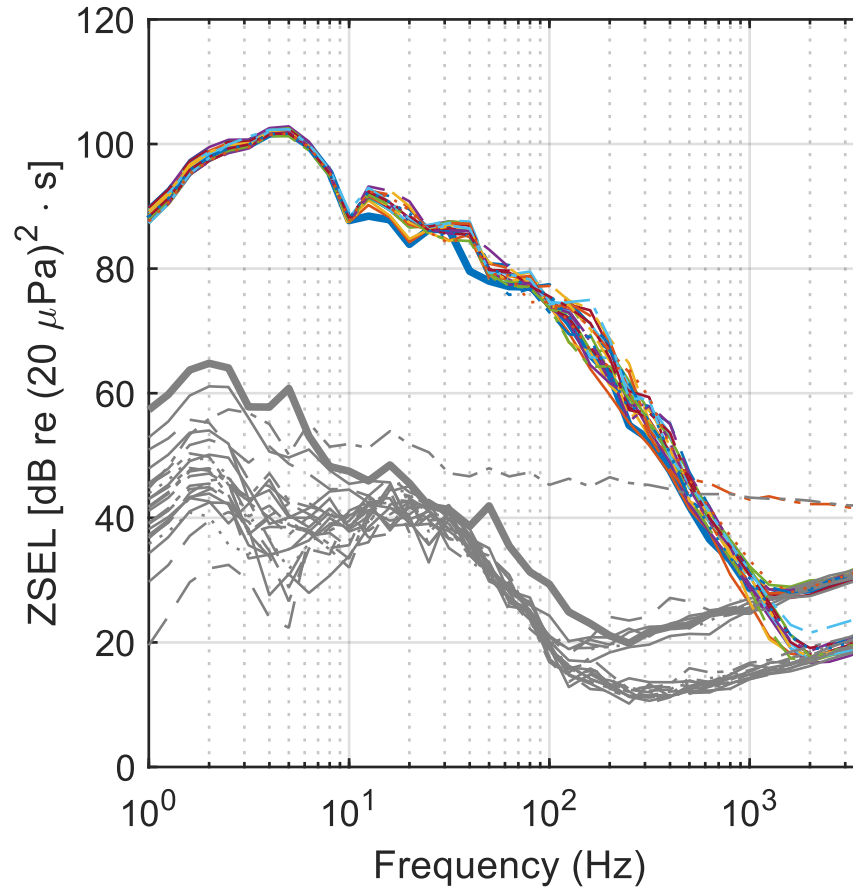
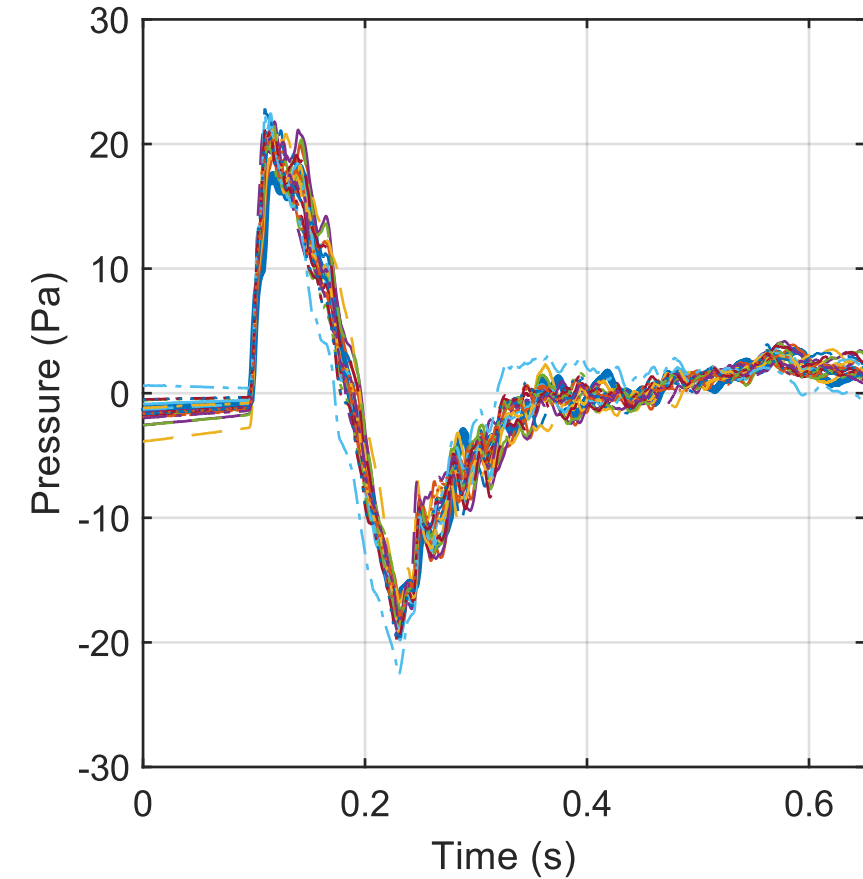
Medium (> 5 dB ,<10 dB)

High (>10 dB)



Examples: low metric variability

Flight 5 Pass 3

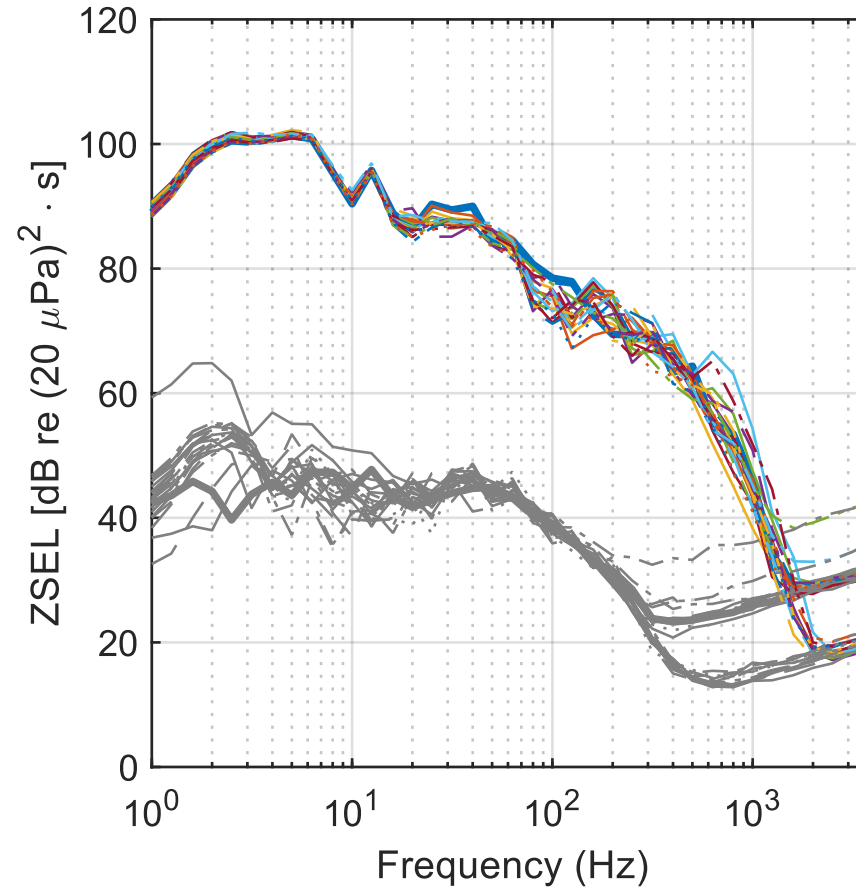
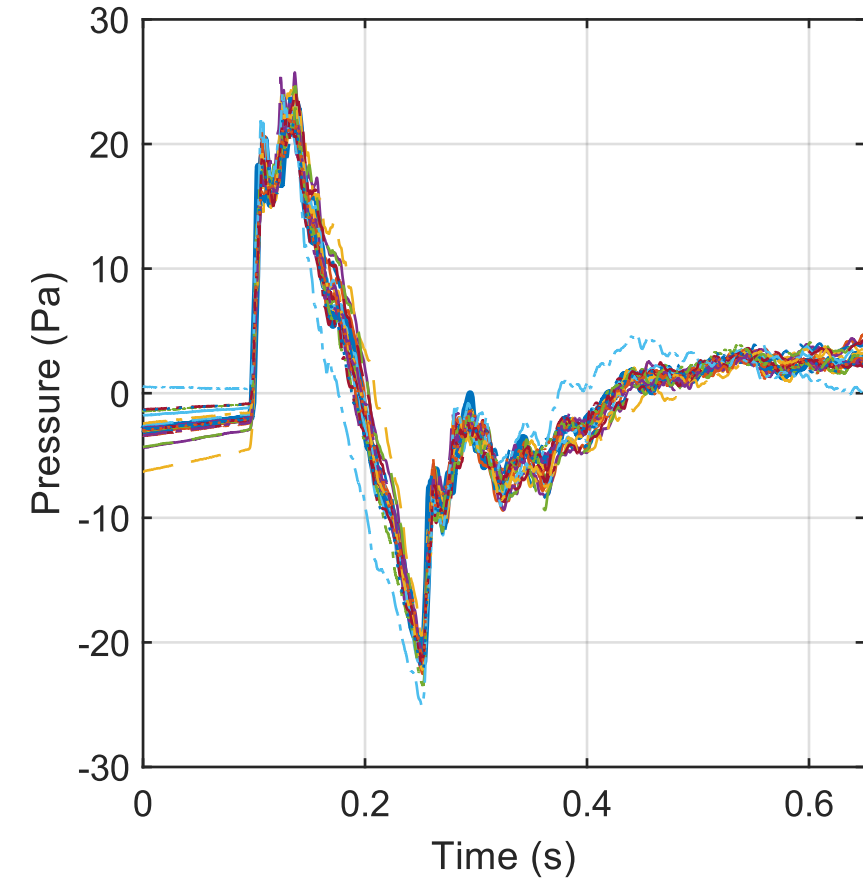


Measured spectrum: color
Ambient spectrum: gray

- Low turbulence
 - $\sigma_{vector} = 0.68$ m/s
- Surface weather
 - Wind speed = 1.4 m/s
 - Temperature = 16.2°C

Examples: low metric variability

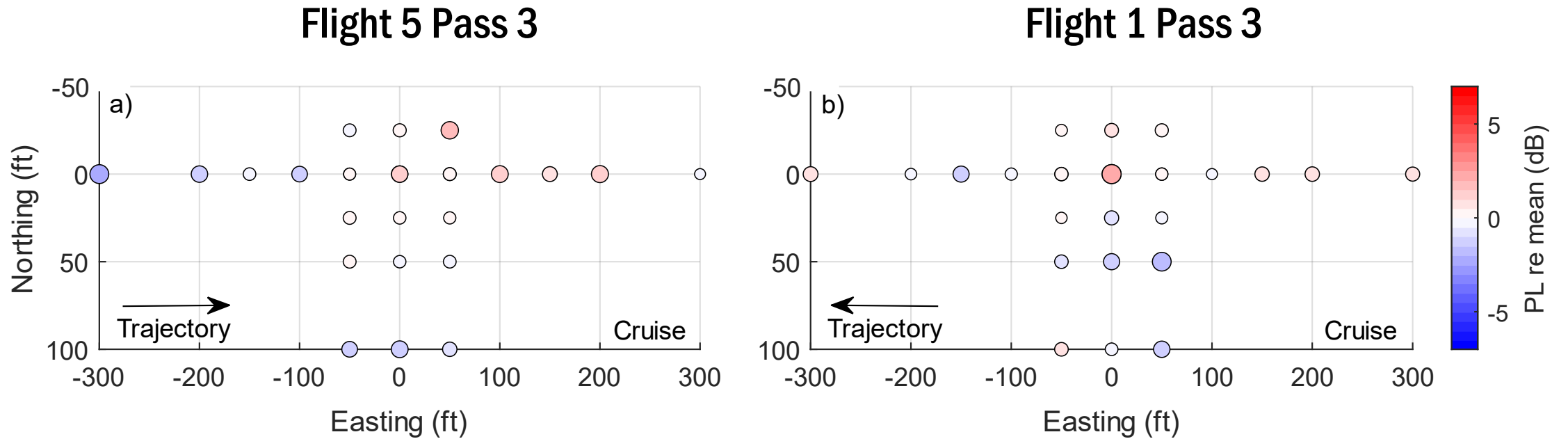
Flight 1 Pass 3



Measured spectrum: color
Ambient spectrum: gray

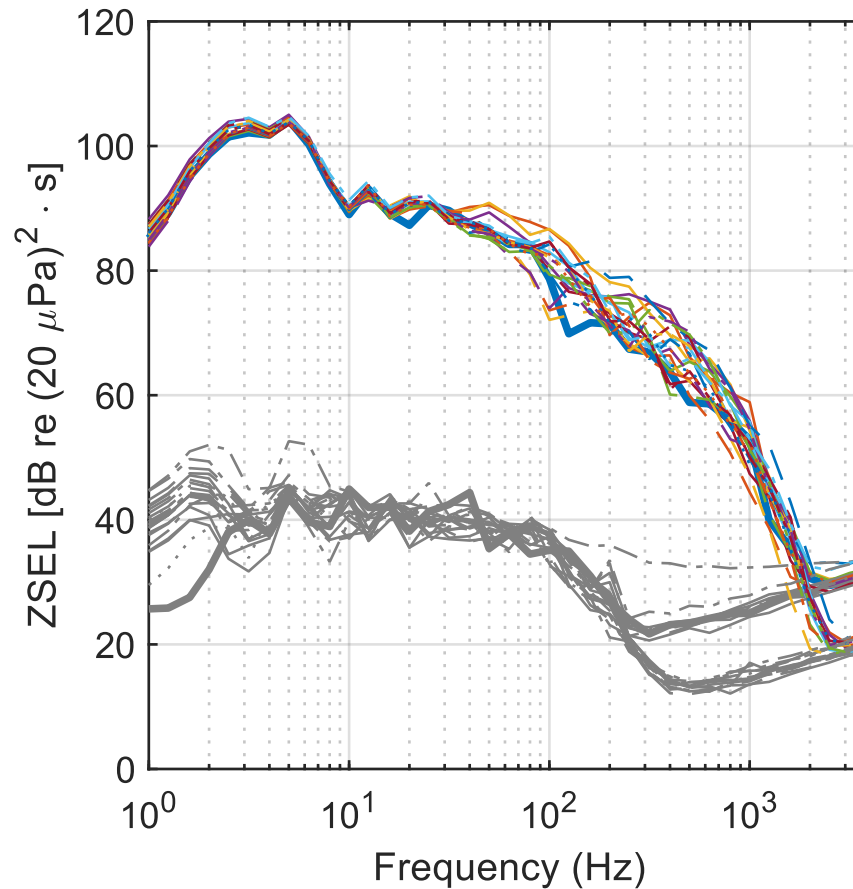
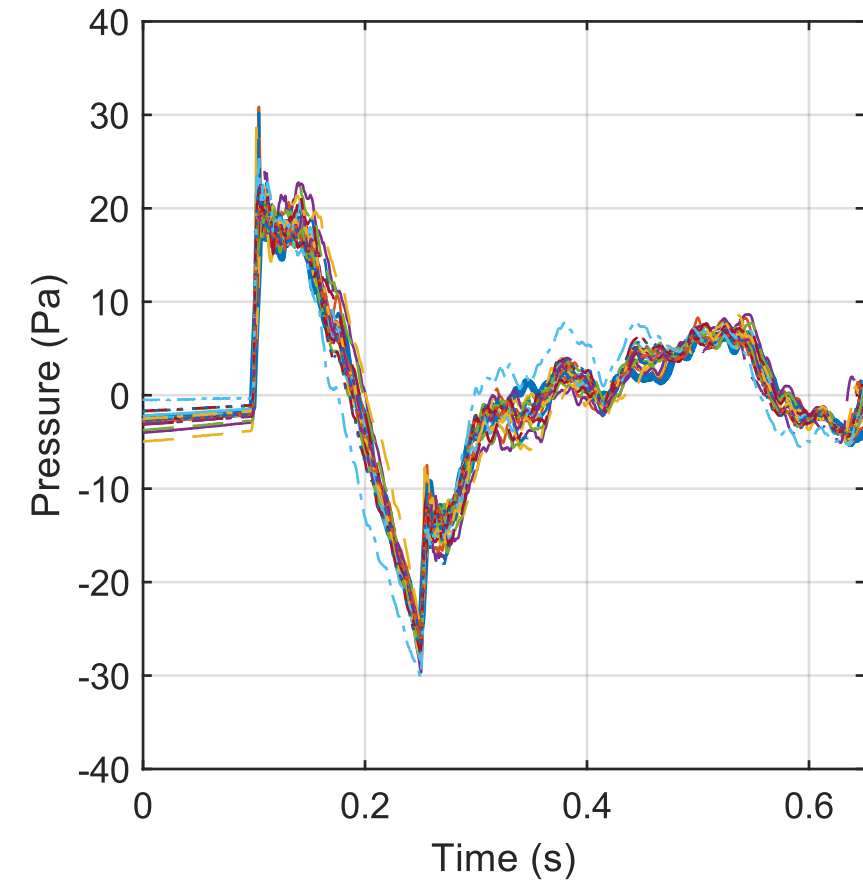
- No turbulence data
- Surface weather
 - Wind speed = 2.0 m/s
 - Temperature = 12.3°C

Low variability: PL across the array



Examples: medium metric variability

Flight 3 Pass 3

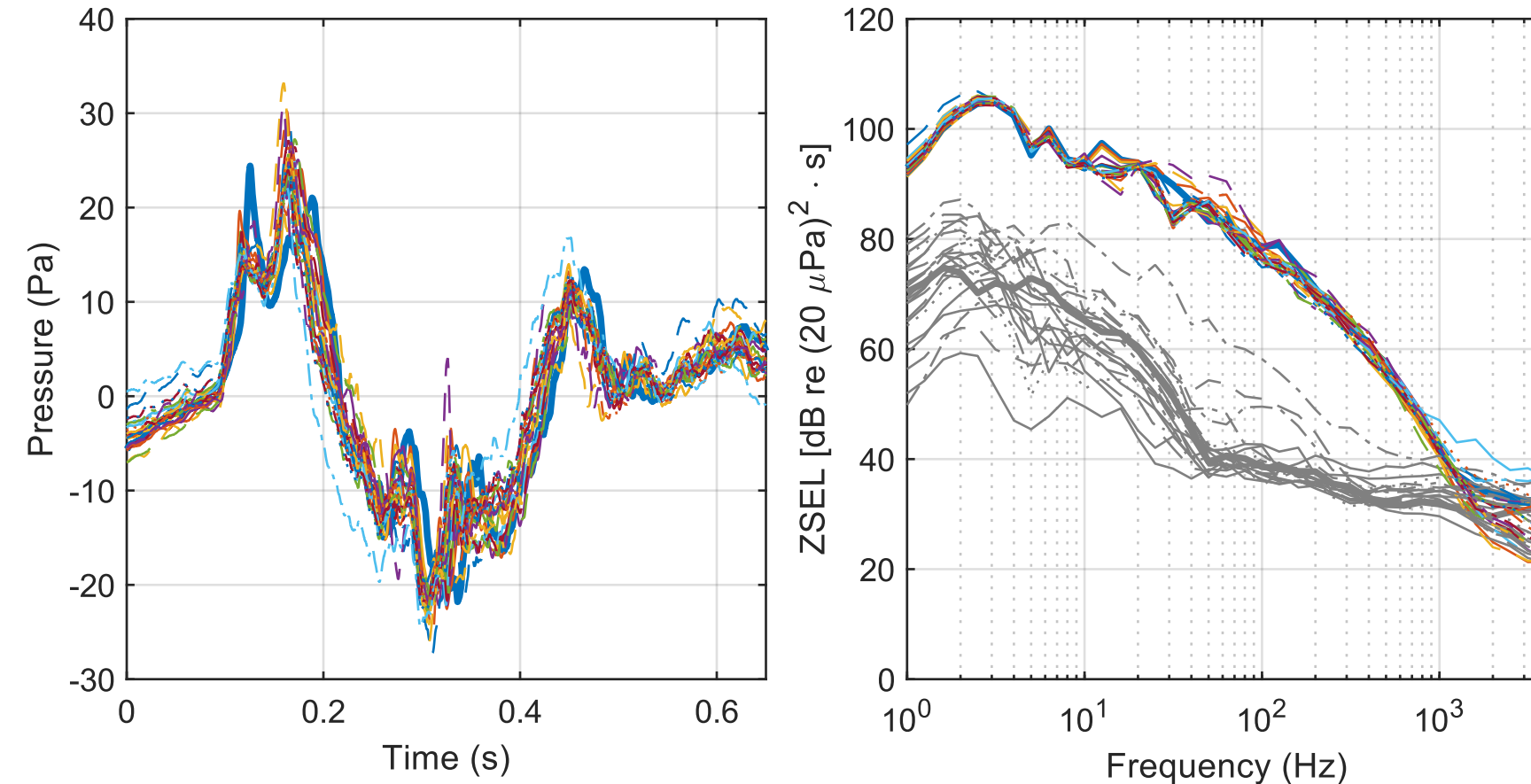


Measured spectrum: color
Ambient spectrum: gray

- Medium turbulence
 - $\sigma_{vector} = 1.00$ m/s
- Surface weather
 - Wind speed = 0.4 m/s
 - Temperature = 20.2°C

Examples: medium metric variability

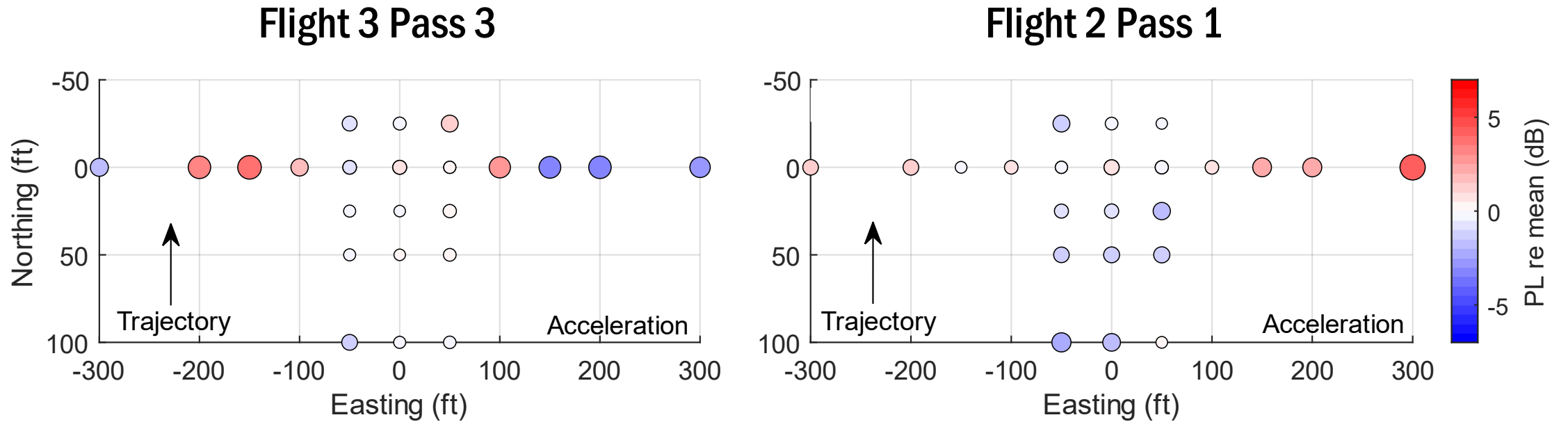
Flight 2 Pass 1



Measured spectrum: color
Ambient spectrum: gray

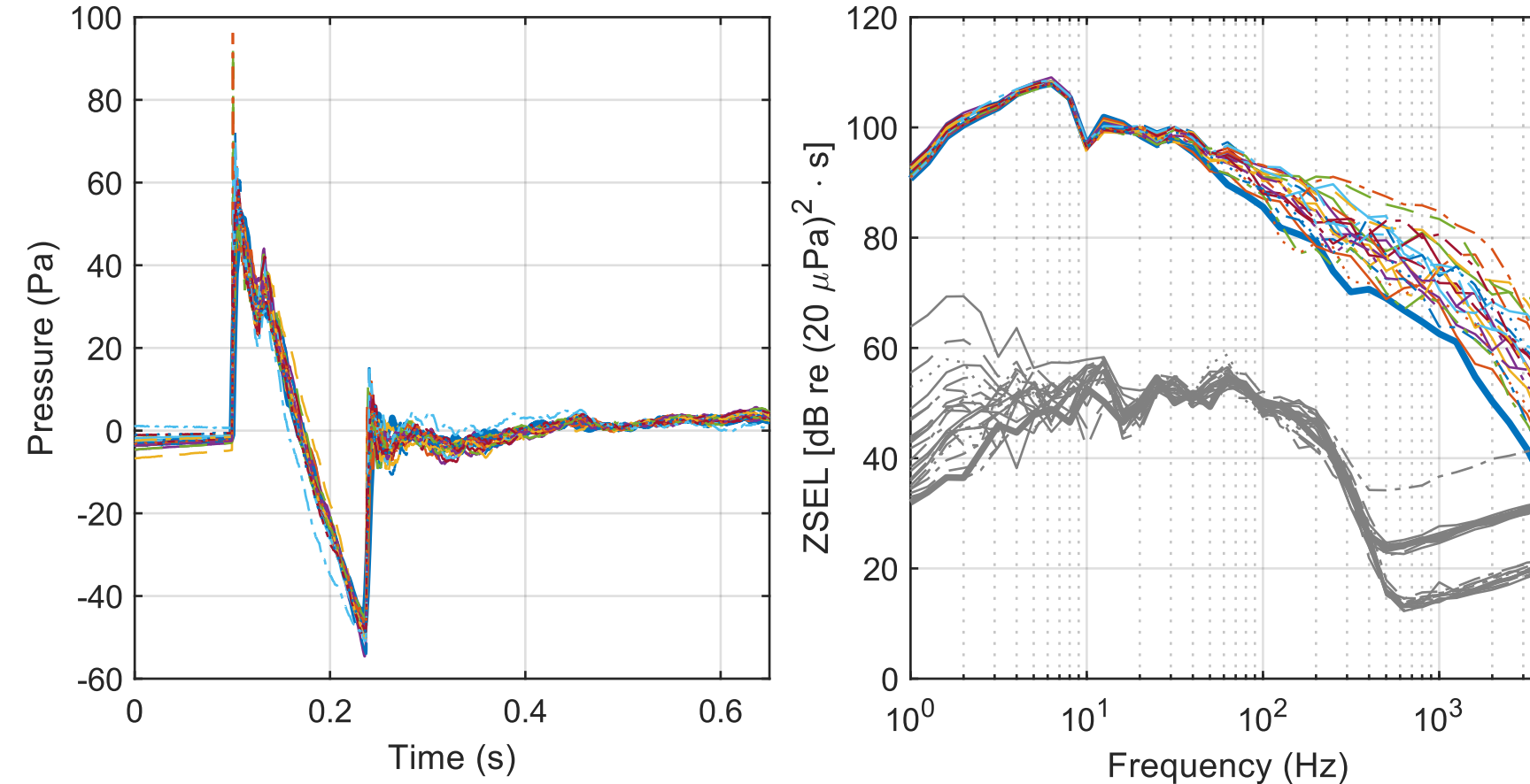
- No turbulence data
- Surface weather
 - Wind speed = 5.1 m/s
 - Temperature = 9.0°C
- High ambient noise

Medium variability: PL across the array



Examples: high metric variability

Flight 5 Pass 1

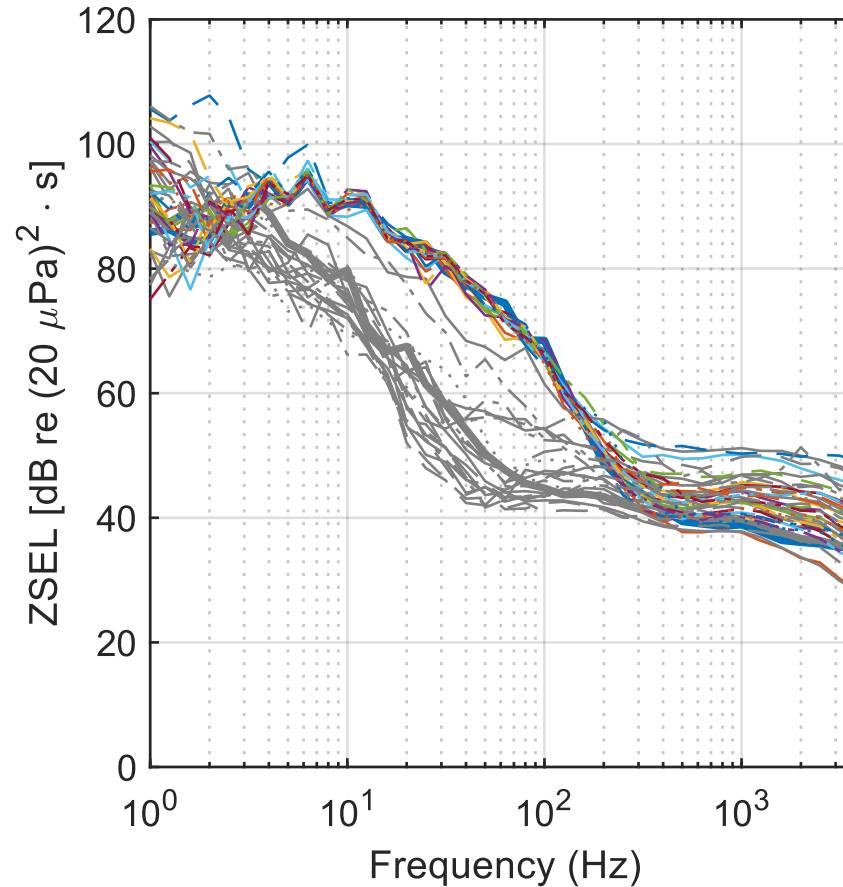
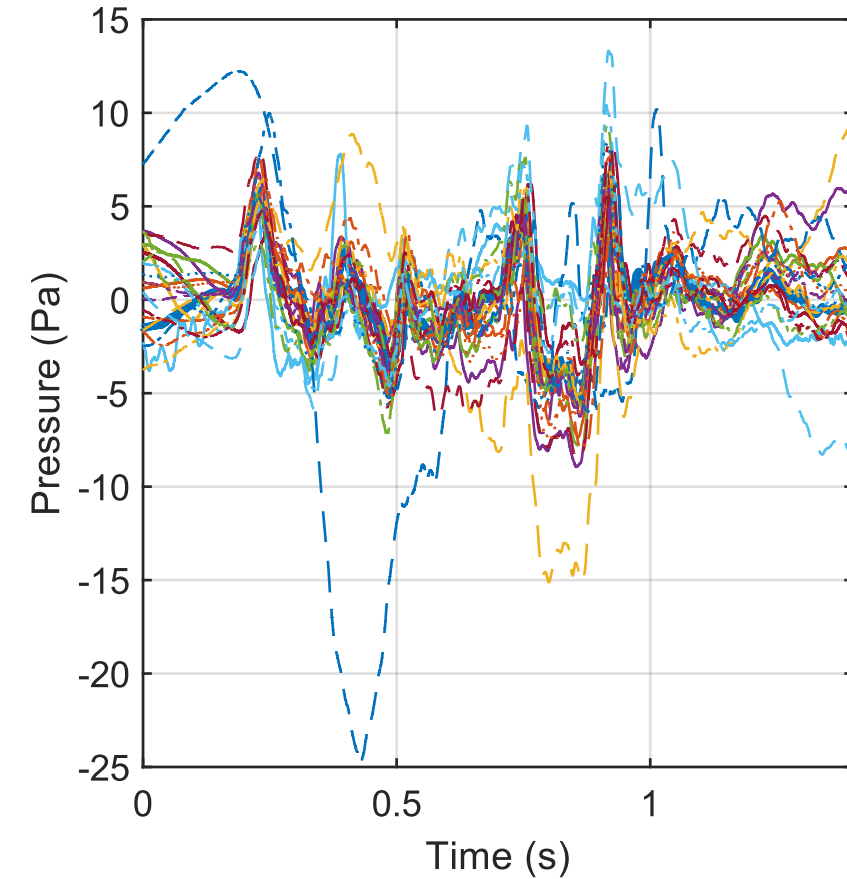


Measured spectrum: color
Ambient spectrum: gray

- Medium turbulence
 - $\sigma_{vector} = 1.00$ m/s
- Surface weather
 - Wind speed = 2.0 m/s
 - Temperature = 16.3°C

Examples: high metric variability

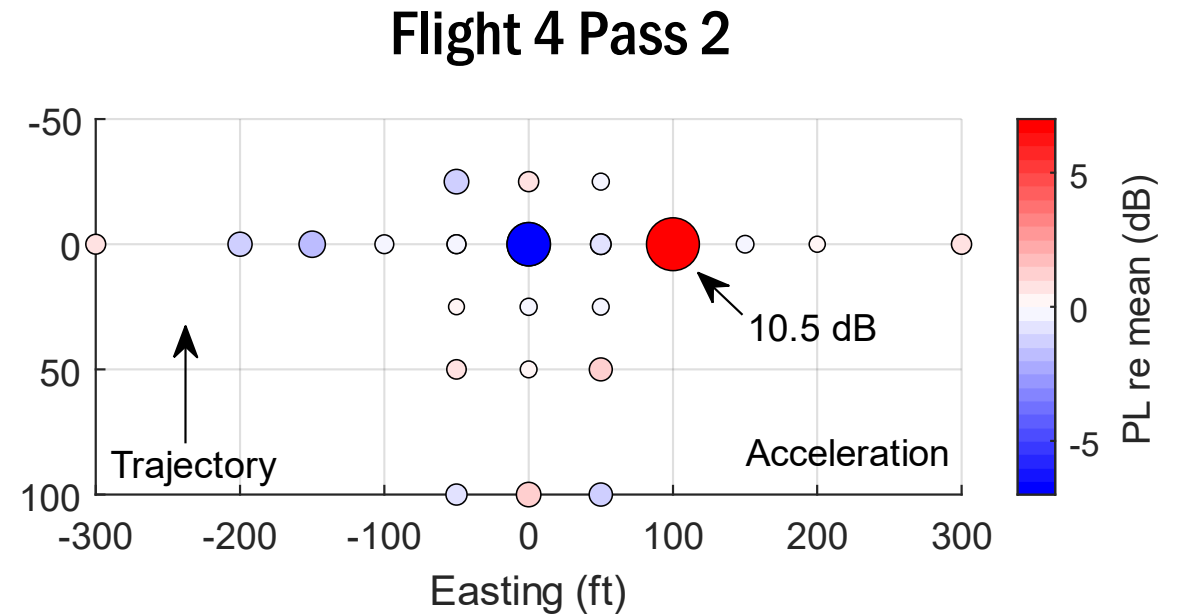
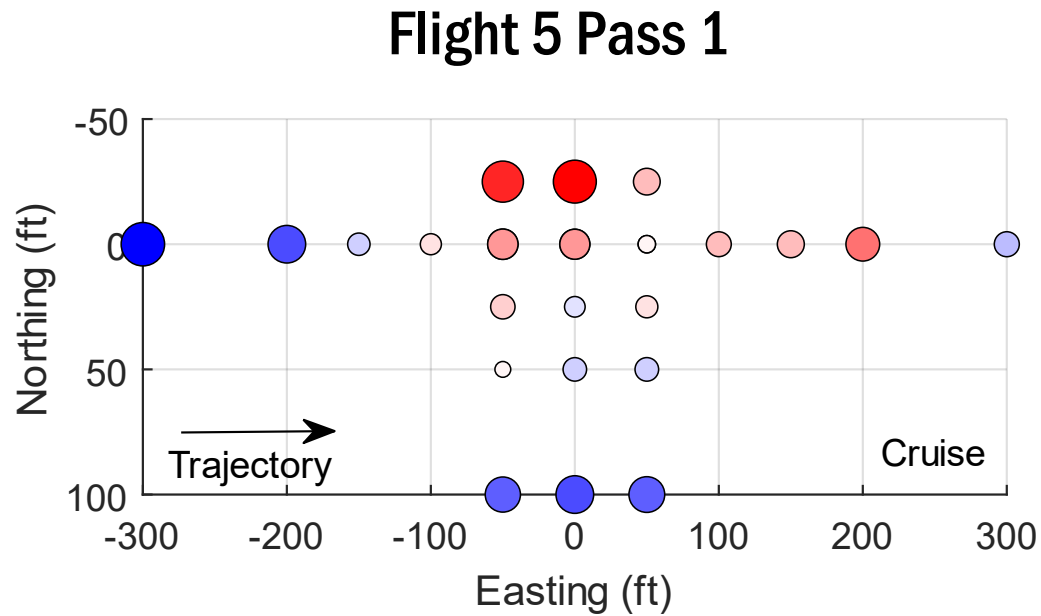
Flight 4 Pass 2



Measured spectrum: color
Ambient spectrum: gray

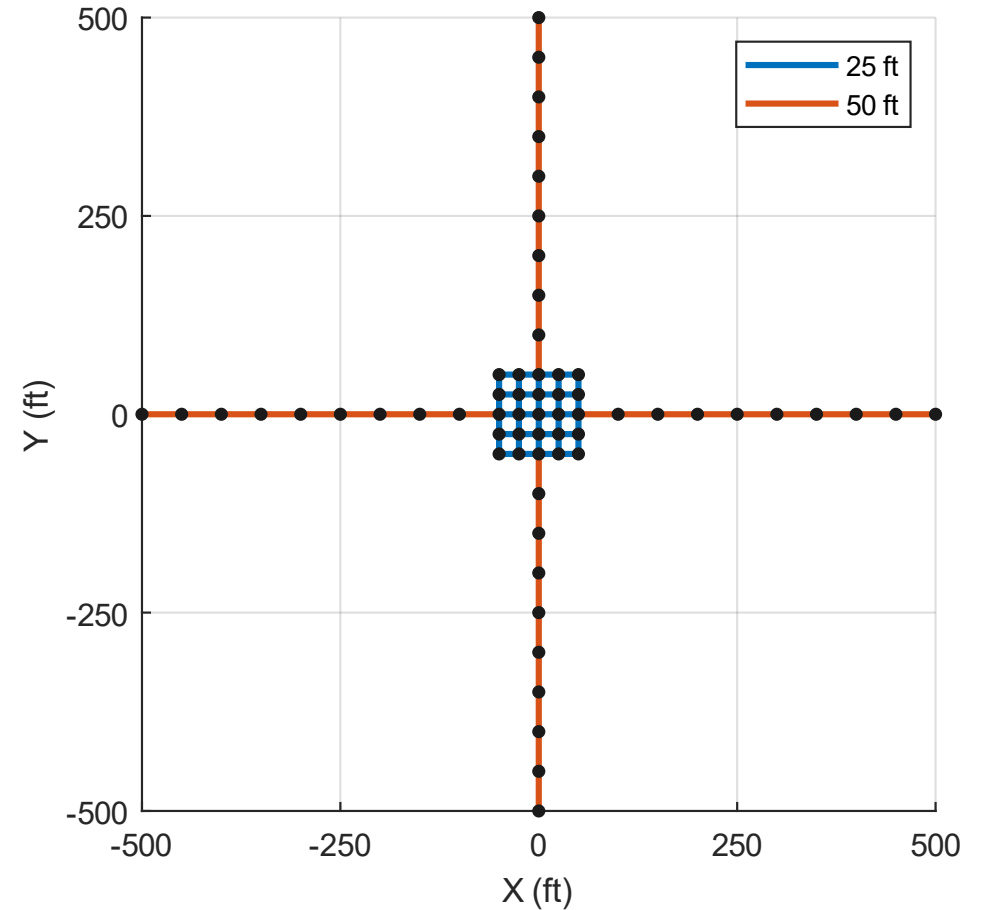
- Medium turbulence
 - $\sigma_{vector} = 1.78$ m/s
- Surface weather
 - Wind speed = 5.3 m/s
 - Temperature = 18.3°C
- High ambient noise

High variability: PL across the array



ARISTOTLE design

- 1,000 ft x 1,000 ft
 - ARISTOTLE Jr. doesn't capture repeating regions of loud and quiet
 - Need larger span than 600 ft x 125 ft
- 61 microphones
- 25 ft and 50 ft spacing
 - Performed a leave-one-out analysis with CarpetDIEM III data
- Array was used in next flight test in June and July 2025
 - Sonic anemometer ~2.5 nmi northwest of array



Conclusions

- **ARISTOTLE Jr.**
 - Limited flights and turbulence data
 - 600 ft x 125 ft
 - Average PL range = 7.3 dB and average $\sigma_{PL}=1.7$ dB
 - High turbulence strengths
 - Average PL range = 8.9 dB and average $\sigma_{PL}=1.8$ dB
- **High variability in loudness level can be caused by ambient noise or atmospheric turbulence**
 - Cases with high PL ranges had medium or high turbulence
 - Some cases with high PL ranges had high ambient noise
- **ARISTOTLE design**
 - 2D array
 - 1,000 ft x 1,000 ft
 - 25 ft and 50 ft spacing

