

NASA2 Benchmark Comparison of Analysis Results to Date

Case Manager

William M. Humphreys, Jr.
Advanced Measurements and Data Systems Branch

***Phased Array Methods Panel Session
6th Berlin Beamforming Conference
Berlin, Germany***

29 February, 2016



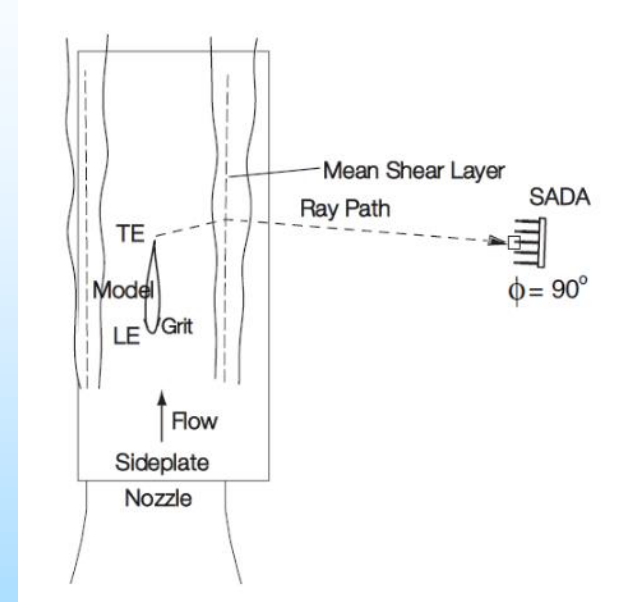
NASA2 Benchmark

- Leading Edge / Trailing Edge Noise Test
- Conducted in LaRC Quiet Flow Facility
- NACA 63-215 Airfoil:
 - 16-inch (40.6-cm) Chord
 - 36-inch (91.4-cm) Span
 - Angle of attack = -1.2 degrees
- Small Aperture Directional Array (SADA)
 - 33 B&K 4138 1/8" microphones
 - Positioned at 90 degrees wrt trailing edge of model



NASA2 Benchmark

- Mach 0.17
- Total Temp = 79.5° F (26.4° C)
- DAS Sample Rate = 142857.71 Hz
- 2048000 Samples Acquired
- Background Runs Acquired
- Flat Mean Shear Layer
- Benchmark Updates for Year 2:
 - Addition of array shading coefficients to dataset
 - Addition of shear layer correction / steering vectors to dataset



Analysis Methods Contributors

- University of Adelaide, South Australia (2015)
(POC: Ric Porteous)
- Laboratoire Vibrations Acoustique (LVA), INSA-Lyon, France (2016)
(POC: Antonio Pereira)
- NASA Langley (2015, 2016)
(POC: Christopher Bahr)



***Original DAMAS Analysis Results – 2004
(Tom Brooks and William Humphreys, NASA LaRC)***

Reference: Brooks and Humphreys, “A Deconvolution Approach for the Mapping of Acoustic Sources (DAMAS) Determined from Phased Microphone Arrays”, Journal of Sound and Vibration, Volume 294, 2006.

Original DAMAS Analysis Results – 2004

$$\hat{G}_{array} = \begin{bmatrix} G_{m1m1} & G_{m1m2} & \dots & G_{m1mM} \\ G_{m2m1} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ G_{mMm1} & \dots & \dots & G_{mMmM} \end{bmatrix} \rightarrow Y(\hat{e}) = \frac{\hat{e}^T \hat{W} (\hat{G}_{array})_{diag=0} \hat{W}^T \hat{e}}{(\sum_{m=1}^M w_m)^2 - \sum_{m=1}^M w_m^2}$$

Cross Spectral Matrix (CSM)

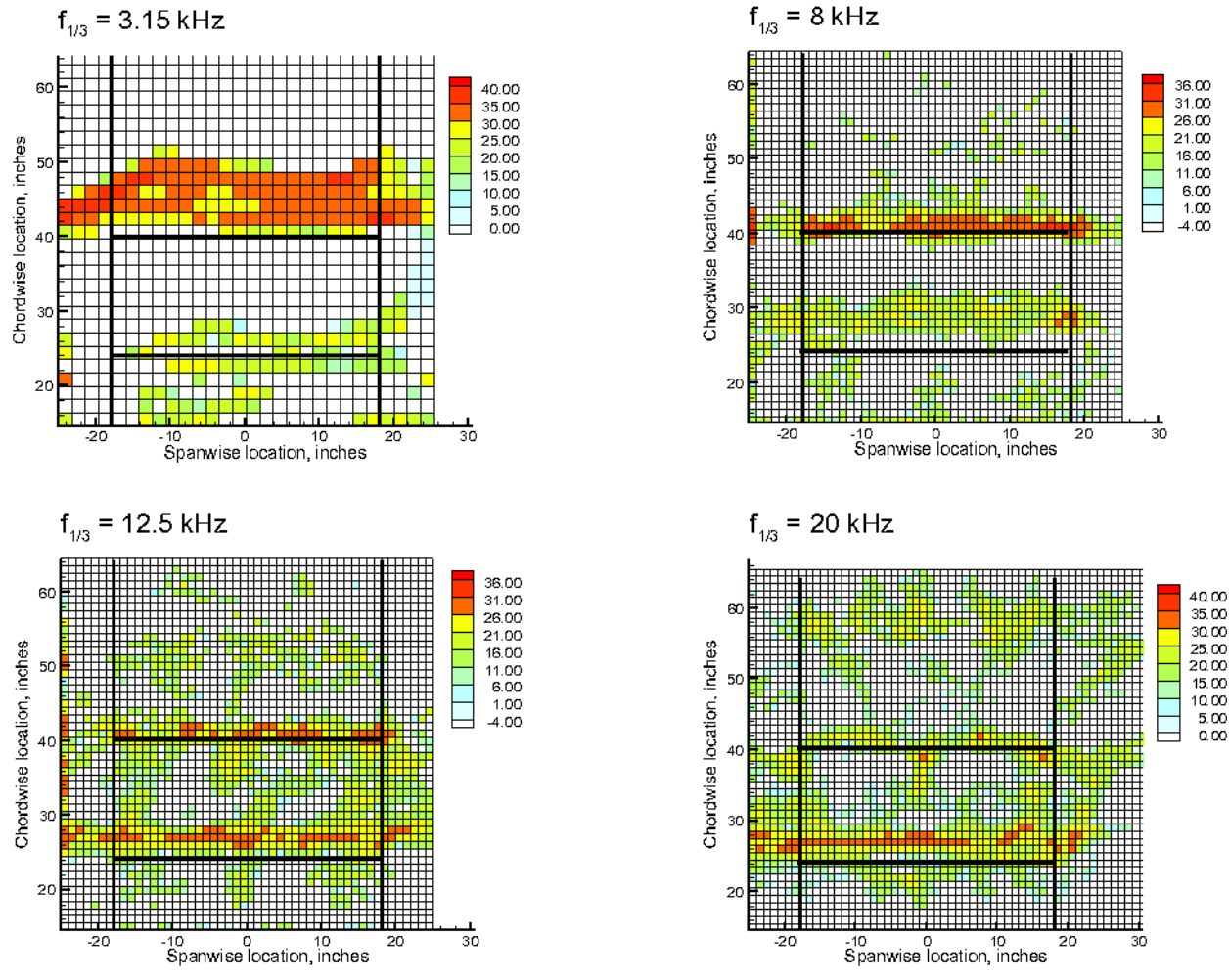
Conventional FD Beamformer
with CSM Diagonal Removal

Desired Source Distribution	BF Source Distribution	
↓	↓	
$\hat{X} = \hat{A}^{-1} \hat{Y}$		→ $X_n^{(i)} = Y_n - \left[\sum_{n'=1}^{n-1} A_{nn'} X_{n'}^{(i)} + \sum_{n'=n+1}^N A_{nn'} X_{n'}^{(i-1)} \right]$
↑		Gauss-Seidel Solver
Influence Matrix		

- Shear layer correction – modified Amiet method (Humphreys et al. ,1998)
- Beamform Integrations – method of Brooks and Humphreys (1999)
- DAMAS Integrations - direct summation of deconvolved source maps

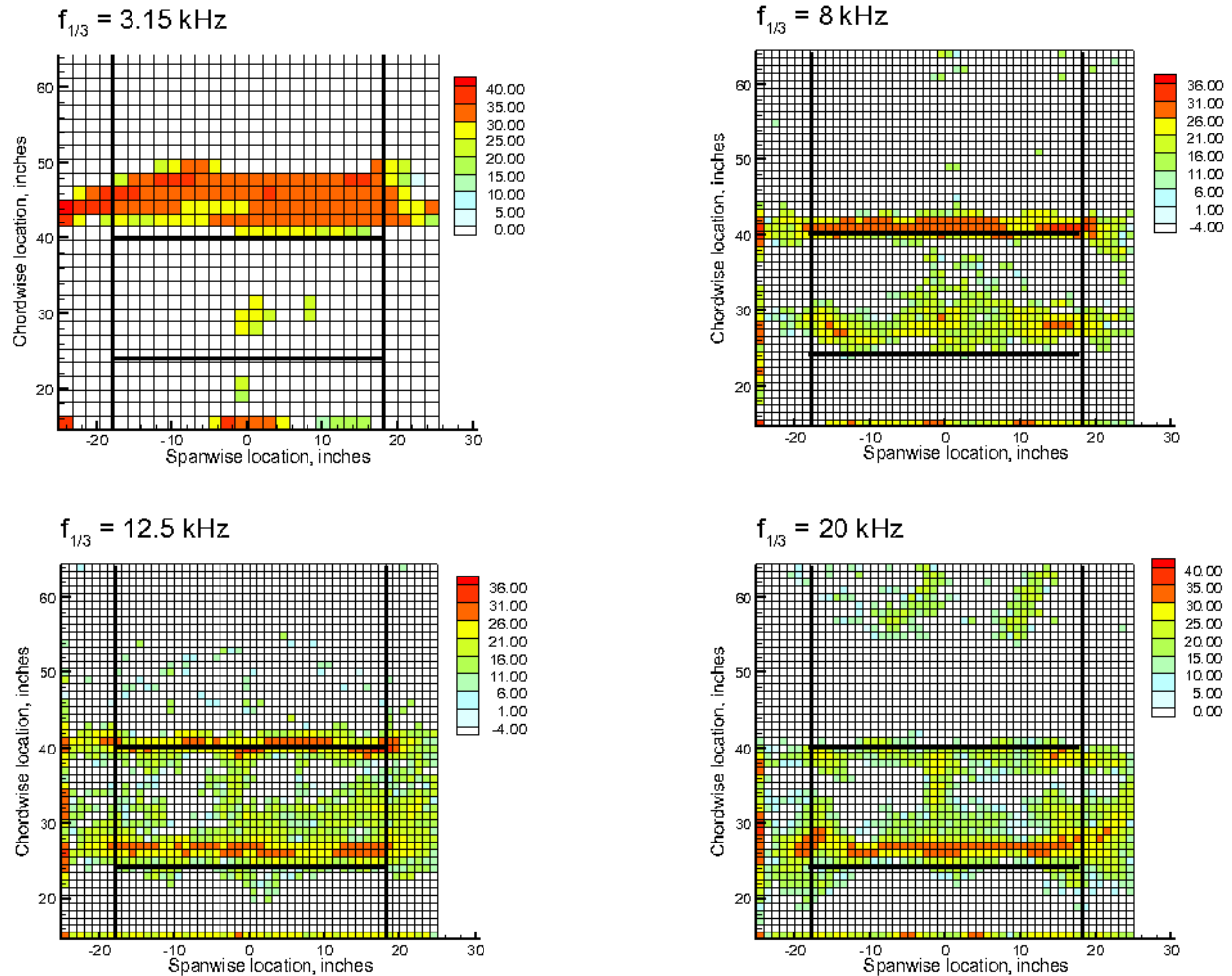
Original DAMAS Analysis Results – 2004

Figure 11 - LE / TE CASE, T1390R15 - T1432R15 (no airfoil), Standard DAMAS



Original DAMAS Analysis Results – 2004

Figure 13 - LE / TE CASE, T1390R15 - T1432R15 (no airfoil), DR DAMAS



Original DAMAS Analysis Results – 2004

• Spatial Integrations

— SADA TE

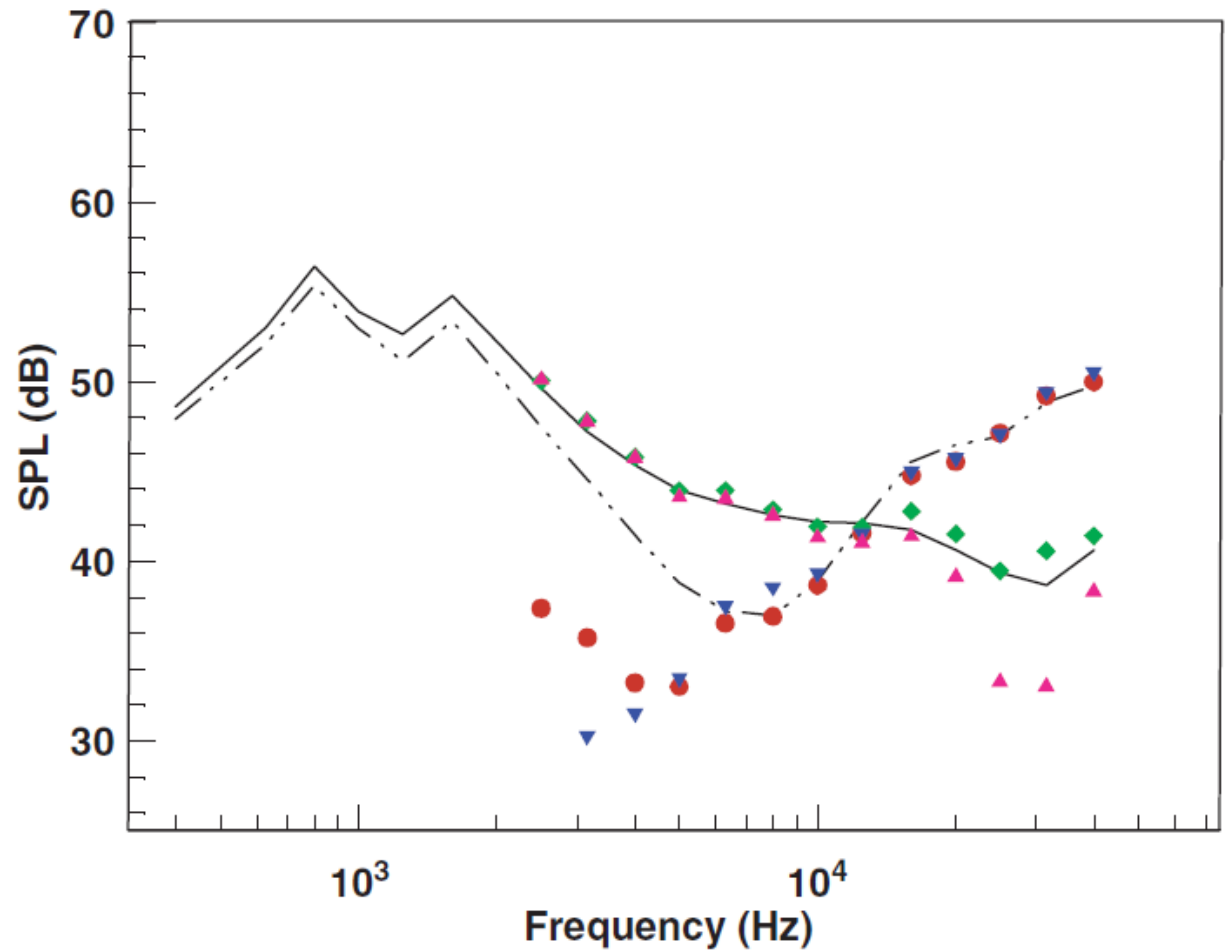
- · - · SADA LE

● STD DAMAS LE

◆ STD DAMAS TE

▼ DR DAMAS LE

▲ DR DAMAS TE



**Results from University of Adelaide /
University of New South Wales
(*Ric Porteous, Adelaide
Zebb Prime, Con Doolan, and Danielle Moreau, UNSW*)**

Originally Presented at Dallas, 2015 Workshop

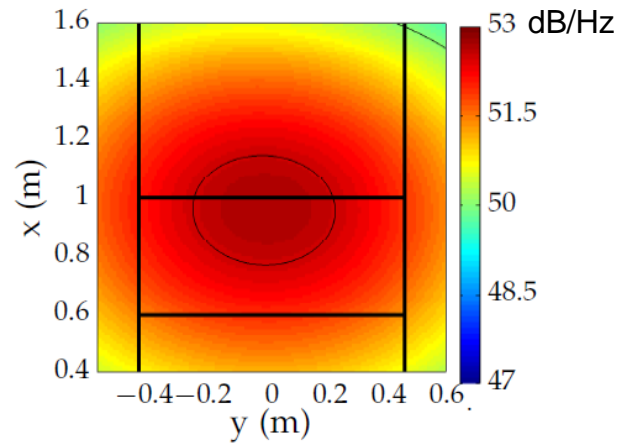


Results from Adelaide / UNSW Analysis Method

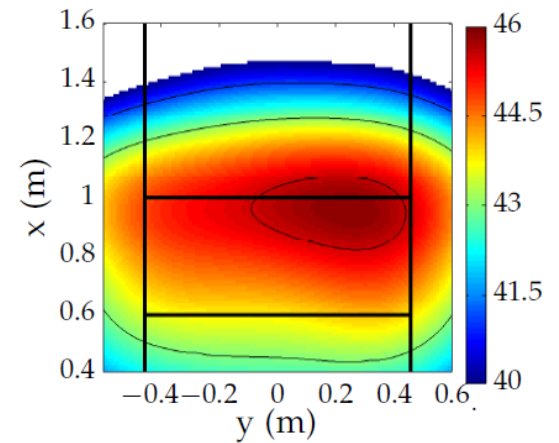
- Techniques:
 1. Conventional Beamforming
 2. CLEAN-SC Deconvolution
- Shear layer correction – method of Amiet (1978)
- Deconvolution – CLEAN-SC (Sijtsma, 2007), beamwidth = 4 cm
- Spatial Integrations:
 - Beamform integrations – method of Brooks and Humphreys (1999)
 - CLEAN-SC integrations – direct summation of source maps

Results from Adelaide / UNSW

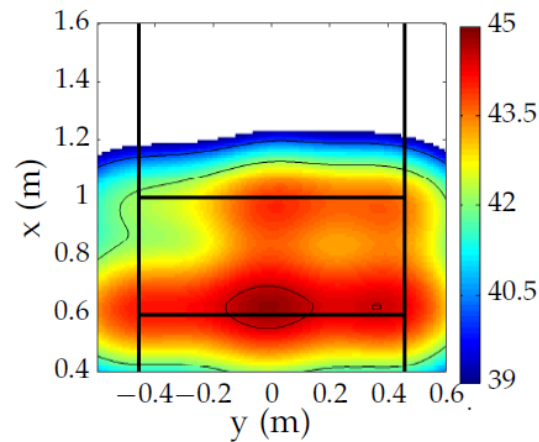
- Conventional Beamforming
- Diagonal Removal
- Background Removal
- 1/3-octave Bands



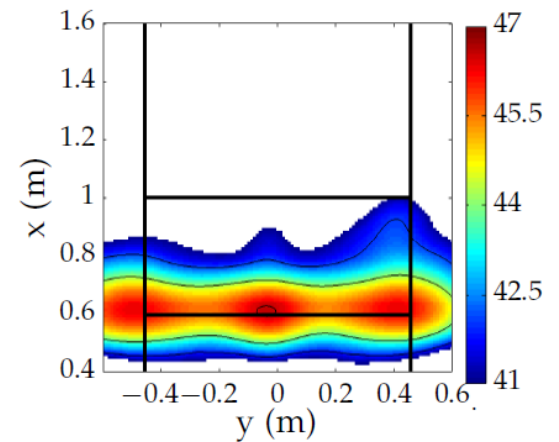
(a) 3150 Hz



(b) 8000 Hz



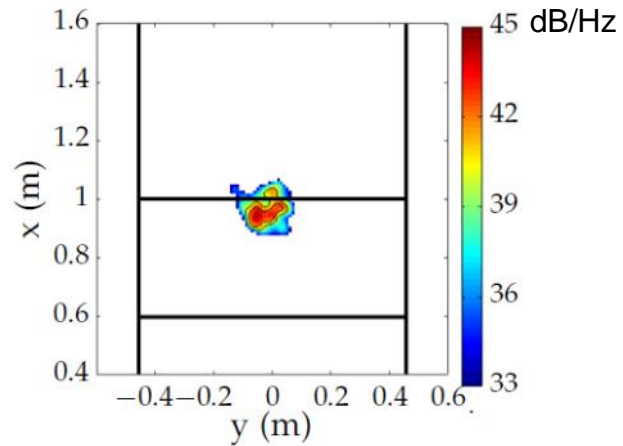
(c) 12500 Hz



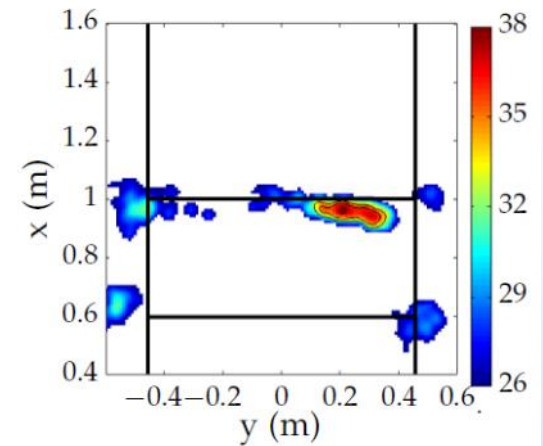
(d) 20000 Hz

Results from Adelaide / UNSW

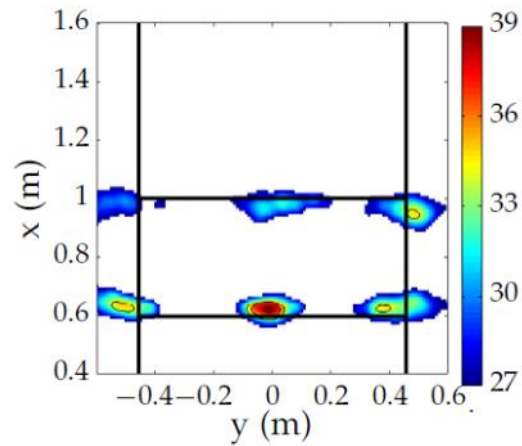
- CLEAN-SC
- Diagonal Removal
- Background Removal
- 1/3-octave Bands



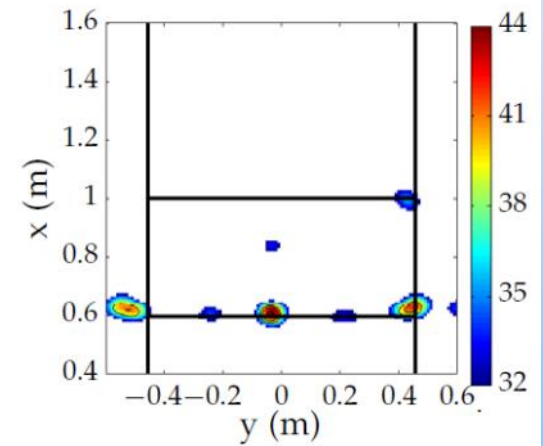
(a) 3150 Hz



(b) 8000 Hz



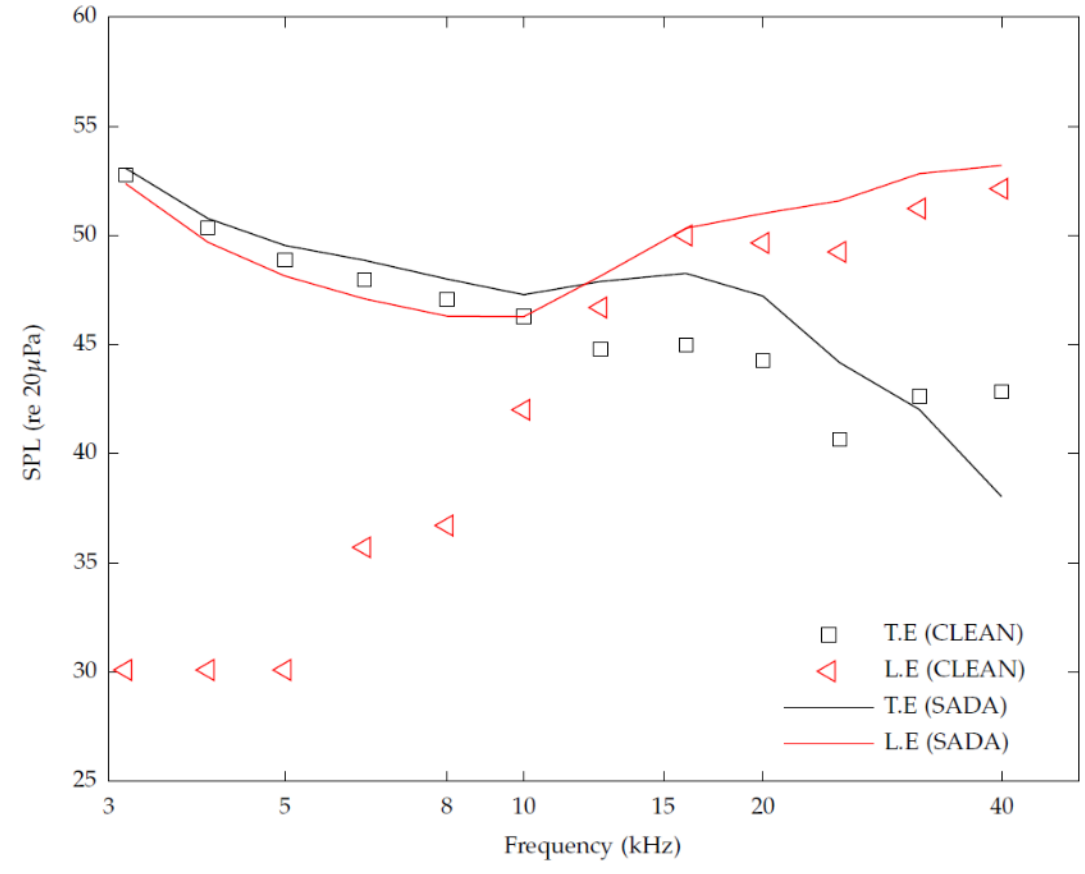
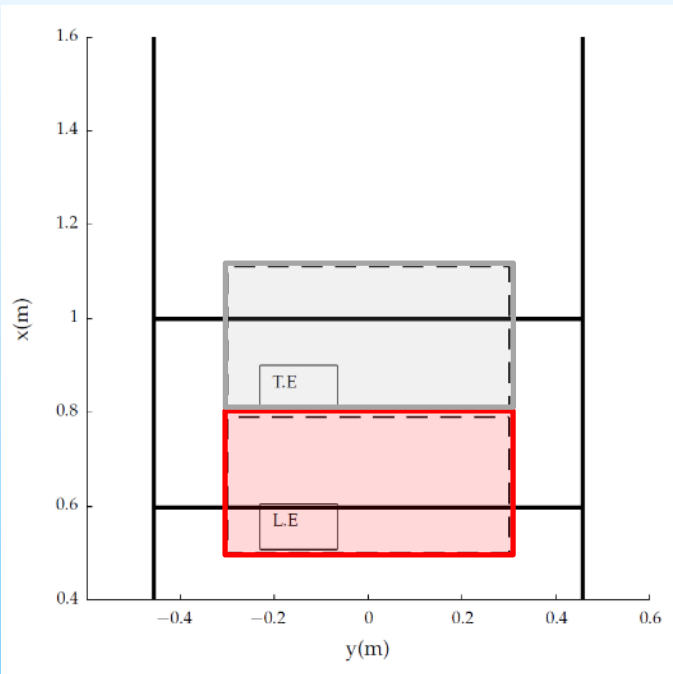
(c) 12500 Hz



(d) 20000 Hz

Results from Adelaide / UNSW

- Spatial Integrations



**Results from Plateforme d'Antennerie
AéroAcoustique, Laboratoire Vibrations Acoustique,
INSA-Lyon, France
(*Antonio Pereira, Quentin Leclère*)**

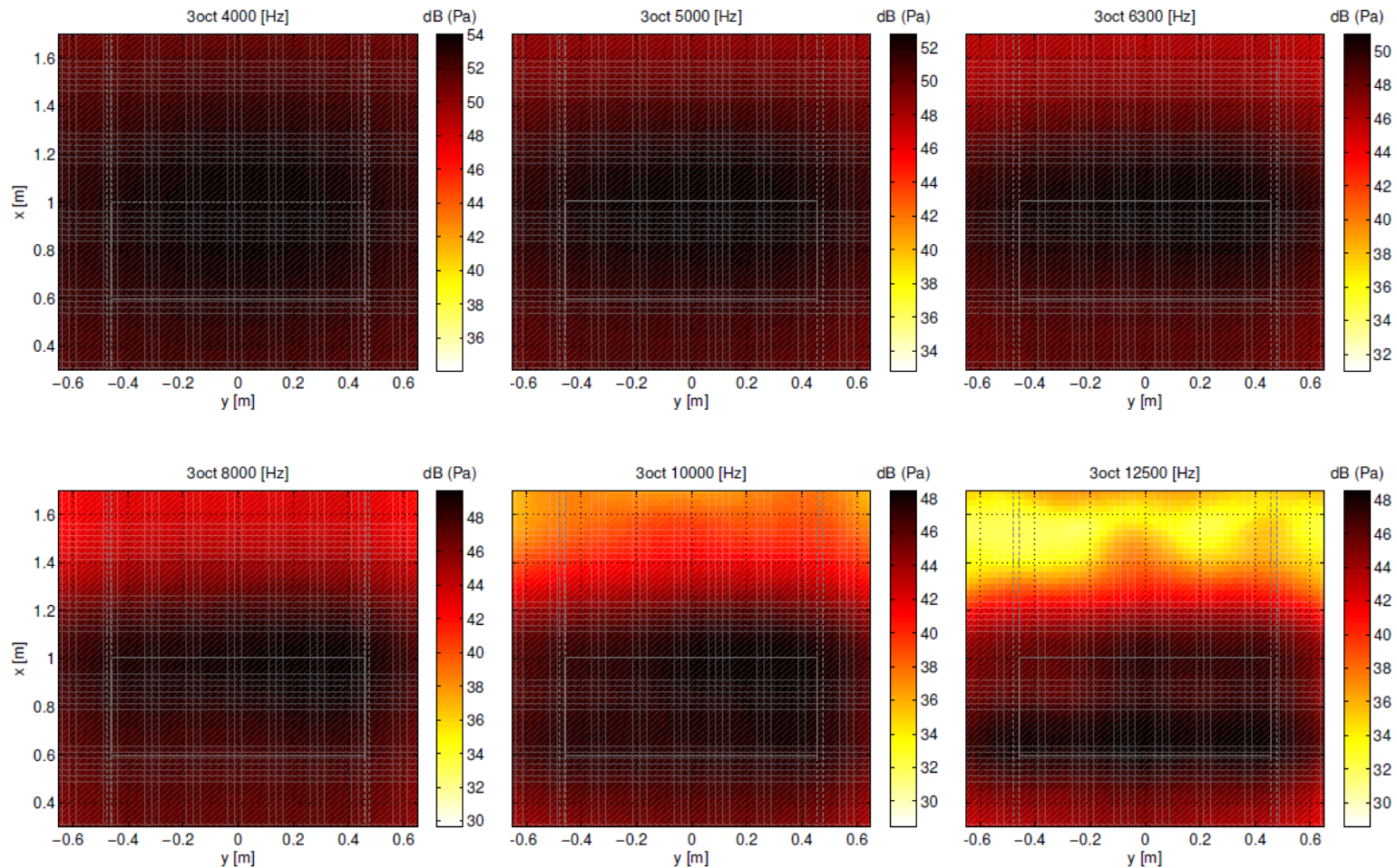


Results from INSA-Lyon Analysis Method

- Techniques:
 1. Conventional Beamforming
 2. Deconvolution using Non-negative Least Squares (NNLS)
 3. Inverse Method using Sparse Bayesian Reconstruction (ℓ_p -norm with $p = 0.9, 1.1$)
- Shear layer correction – method of Amiet (1978)
- Background subtraction – method of Bahr and Horne (2015)
- Spatial Integrations – direct summation of source maps

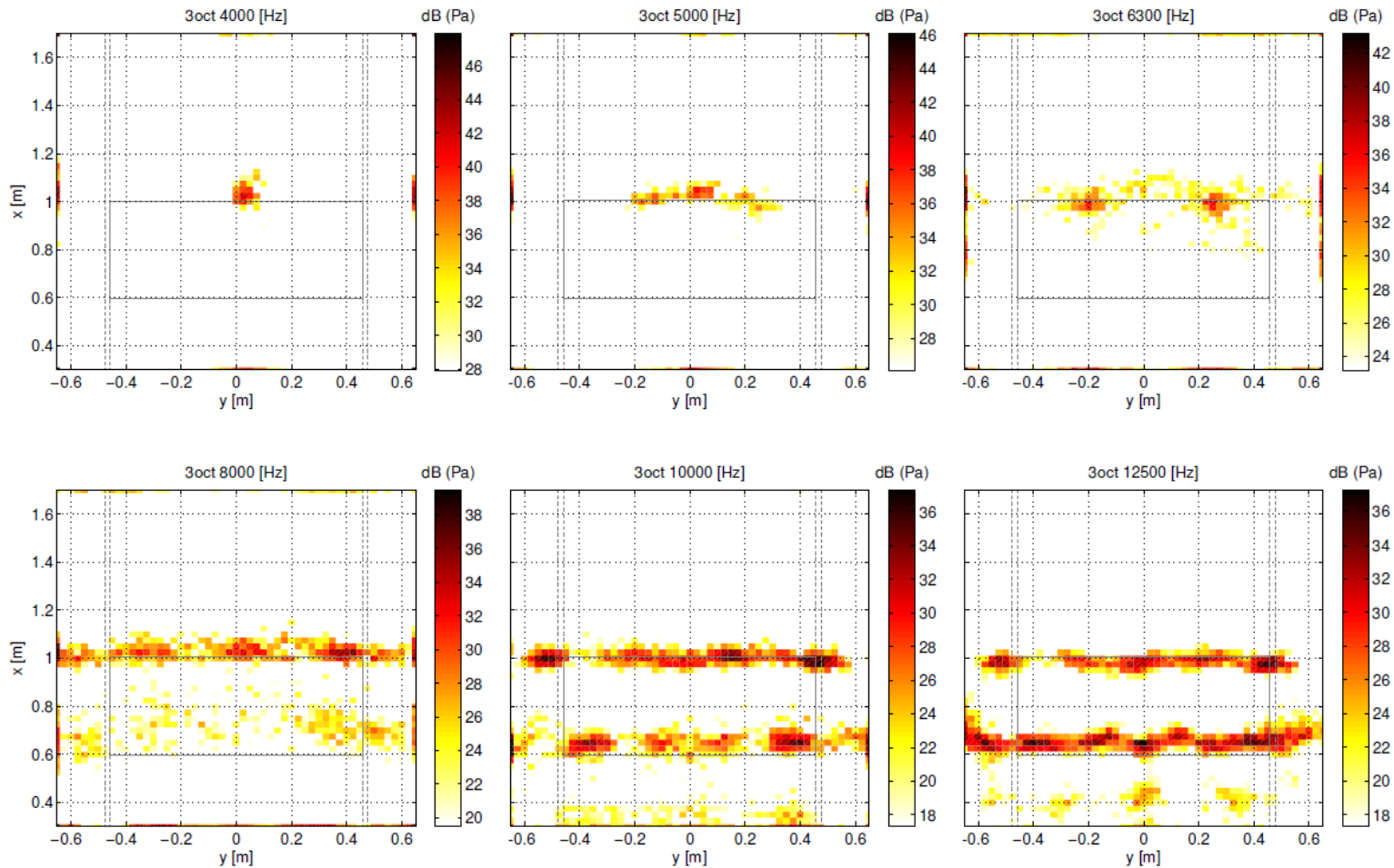
Results from INSA-Lyon

[4 to 12.5 kHz] - Beamforming (background subtraction)



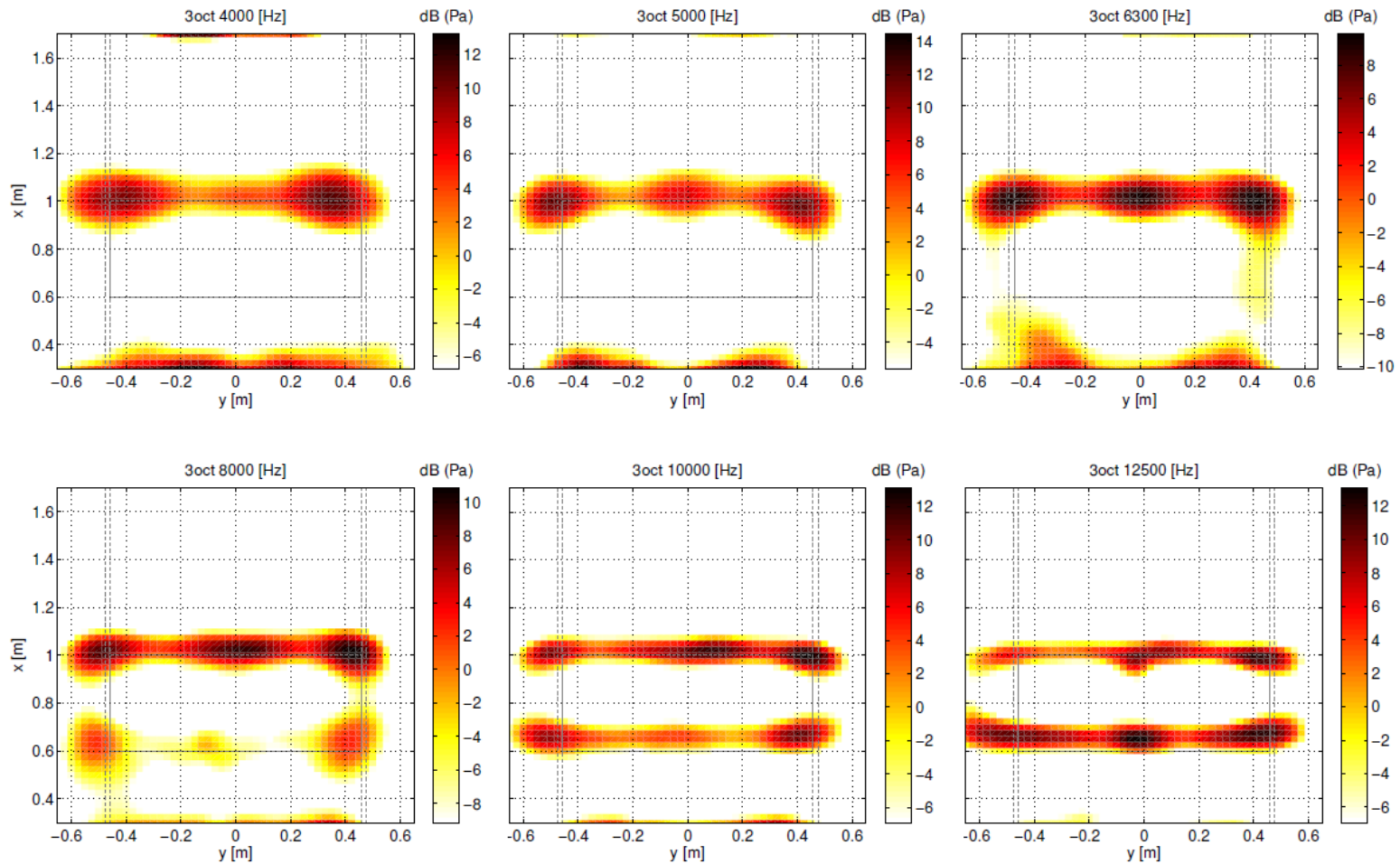
Results from INSA-Lyon

[4 to 12.5 kHz] - DAMAS nls (background subtraction)



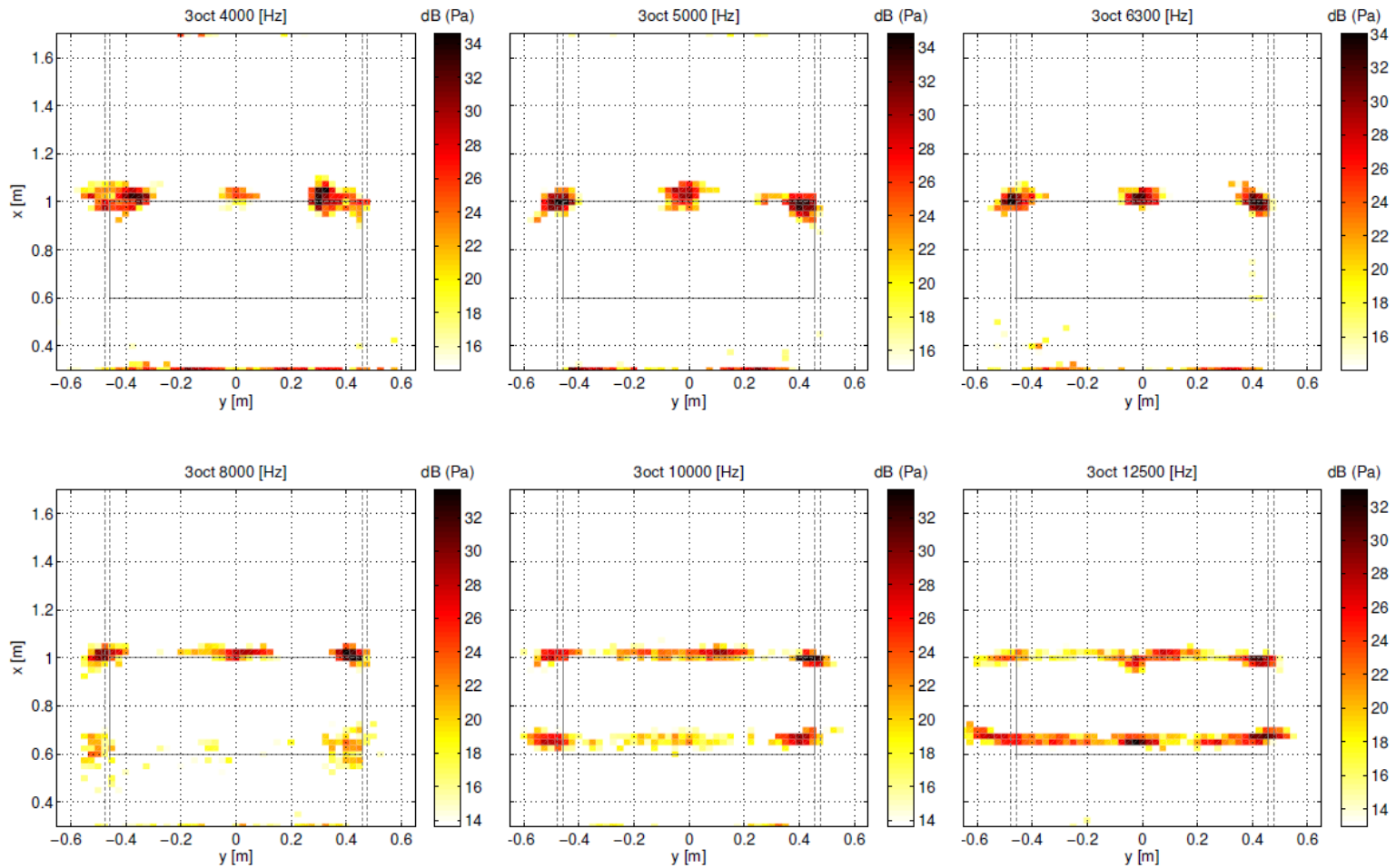
Results from INSA-Lyon

[4 to 12.5 kHz] - ℓ_p Bayesian ($p = 1.1$) (background subtraction)



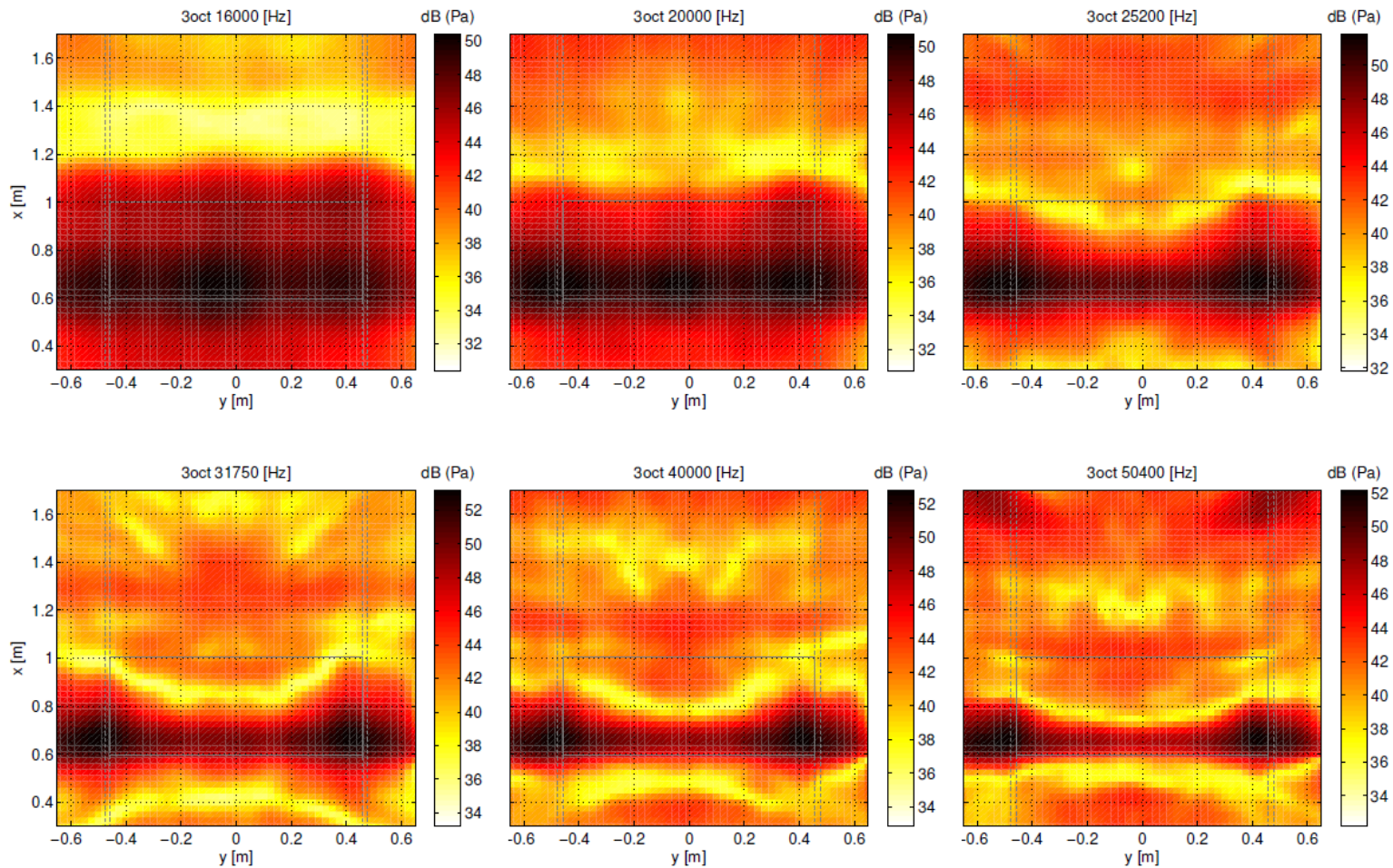
Results from INSA-Lyon

[4 to 12.5 kHz] - ℓ_p Bayesian ($p = 0.9$) (background subtraction)



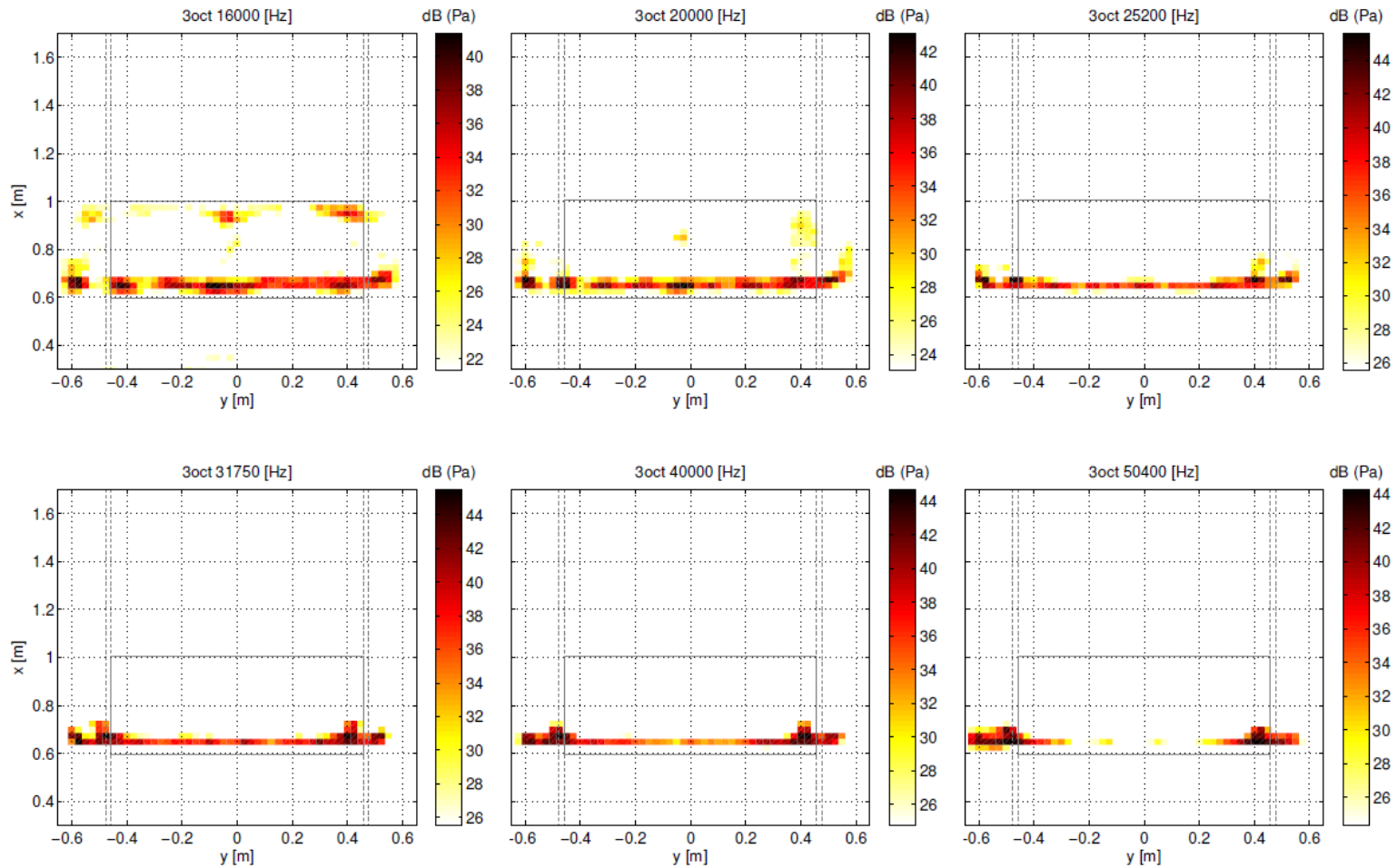
Results from INSA-Lyon

[16 to 50 kHz] - Beamforming (background subtraction)



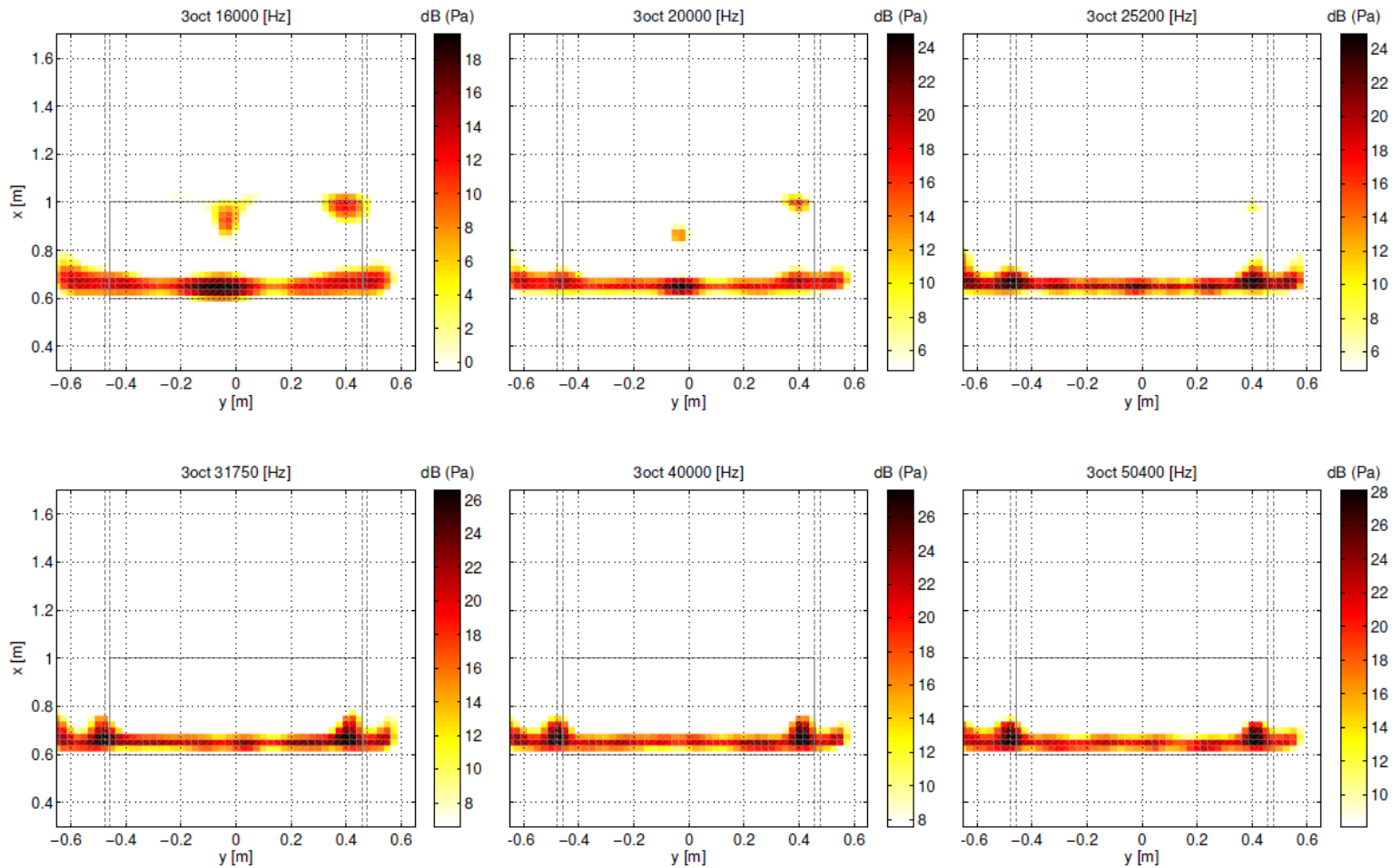
Results from INSA-Lyon

[16 to 50 kHz] - DAMAS nns (background subtraction)



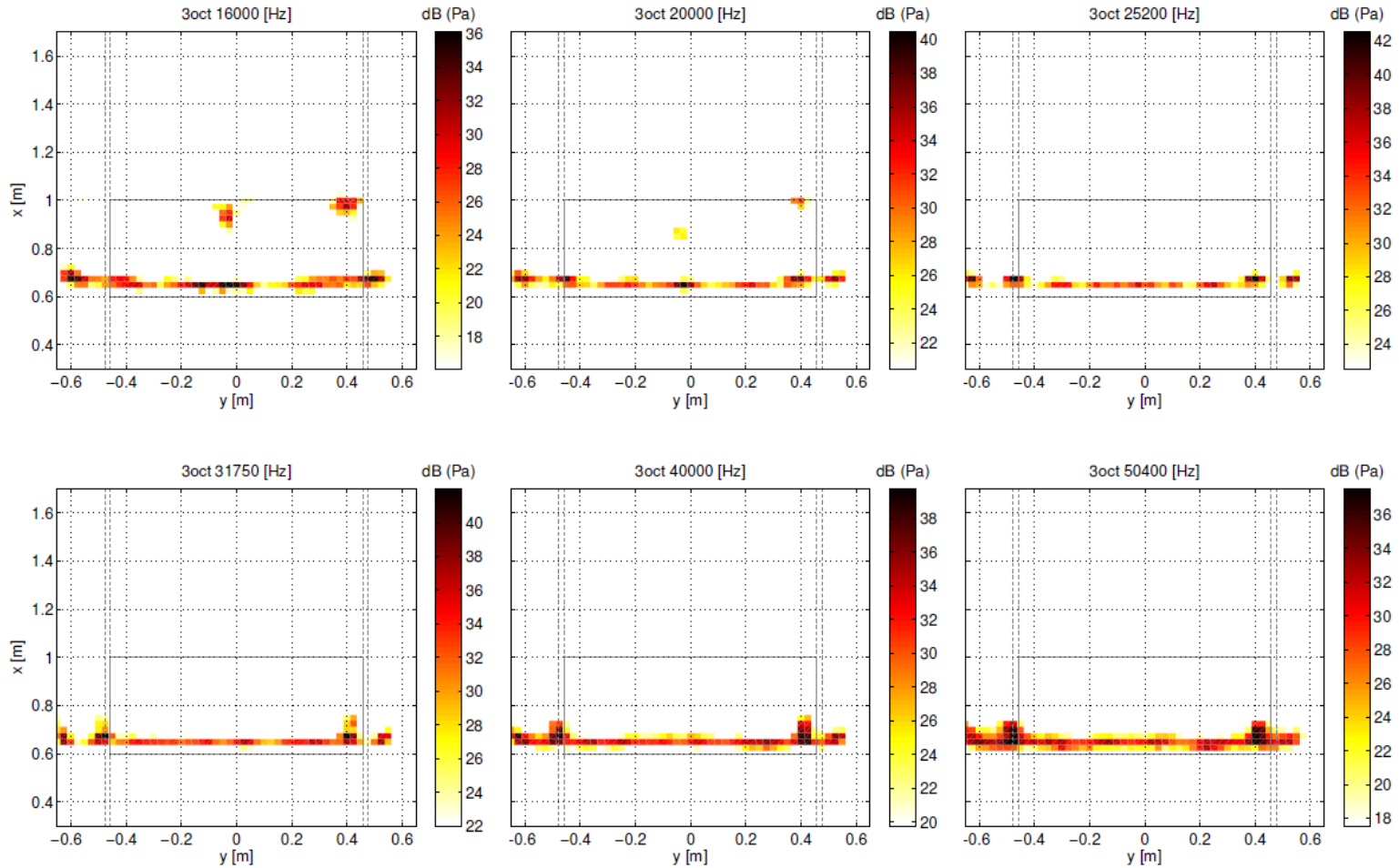
Results from INSA-Lyon

[16 to 50 kHz] - ℓ_p Bayesian ($p = 1.1$) (background subtraction)



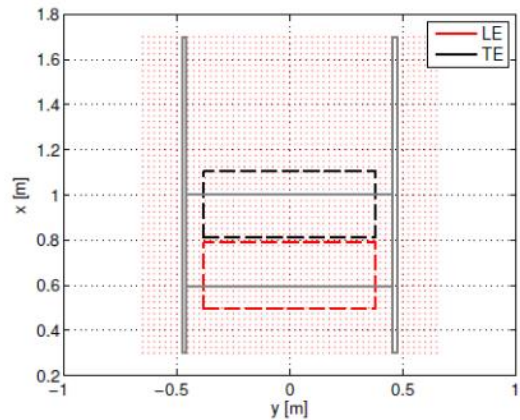
Results from INSA-Lyon

[16 to 50 kHz] - ℓ_p Bayesian ($p = 0.9$) (background subtraction)

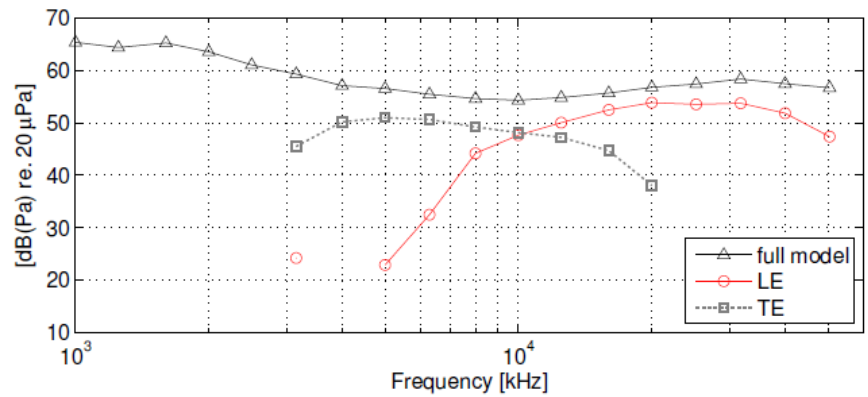


Results from INSA-Lyon

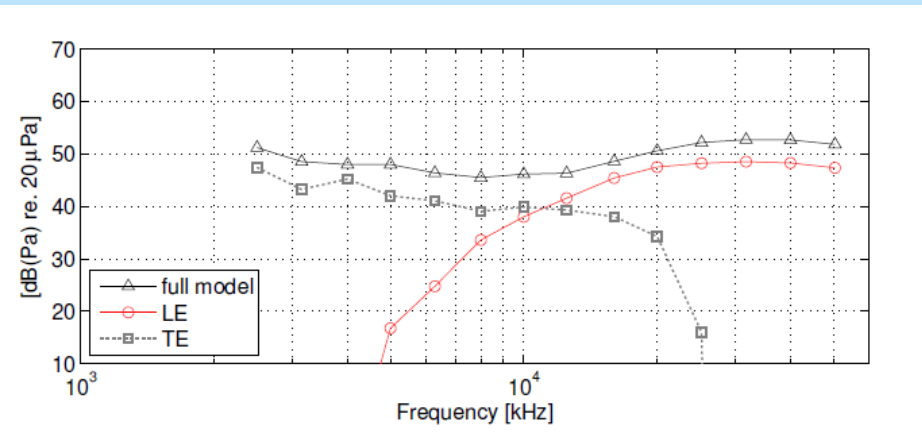
Source Integrations



Integration Regions



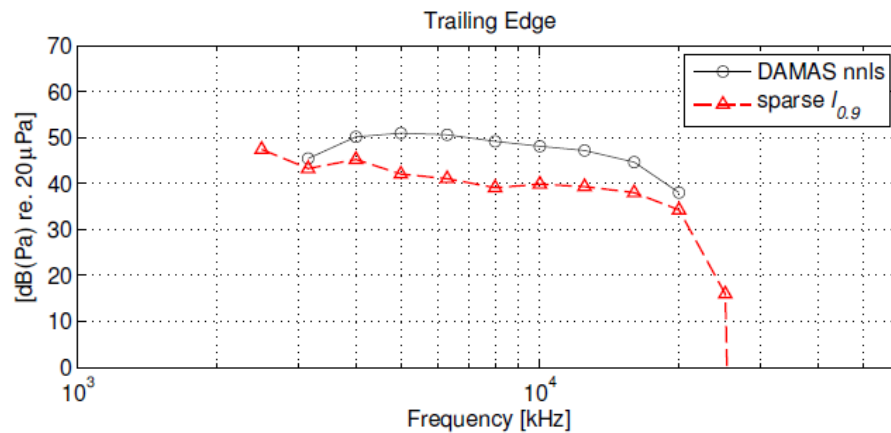
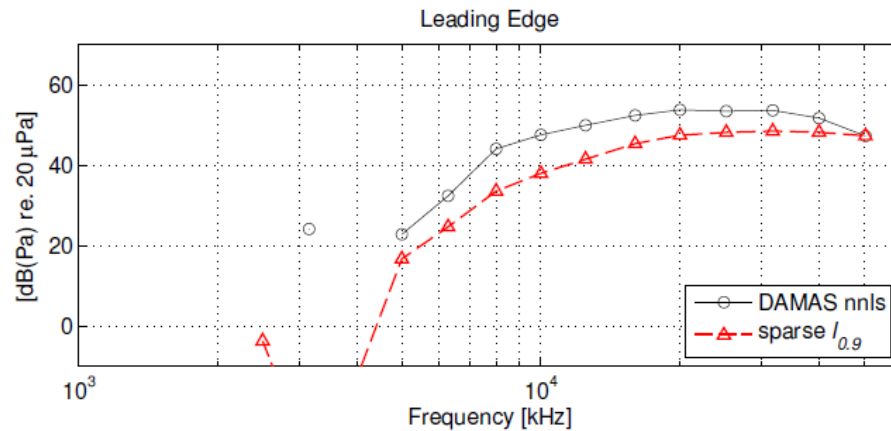
NLS Algorithm



Sparse Bayesian Reconstruction

Results from INSA-Lyon

Source Integrations



Results from NASA Langley – 2016
(Christopher Bahr)



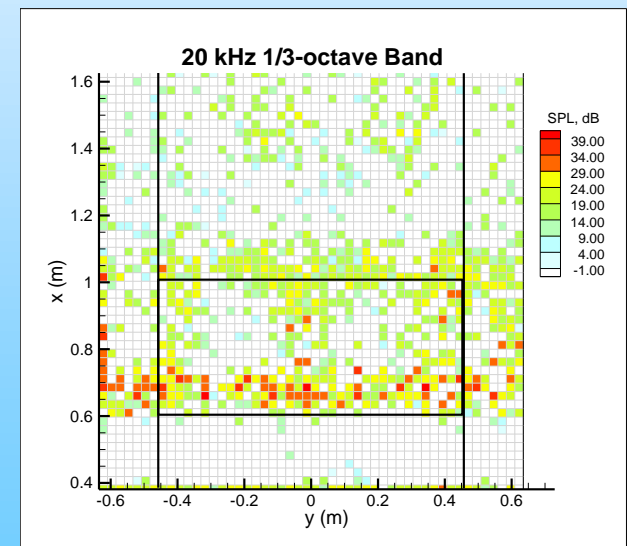
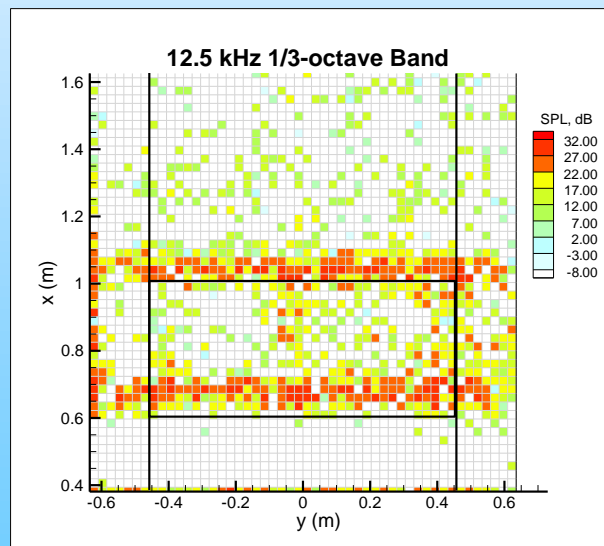
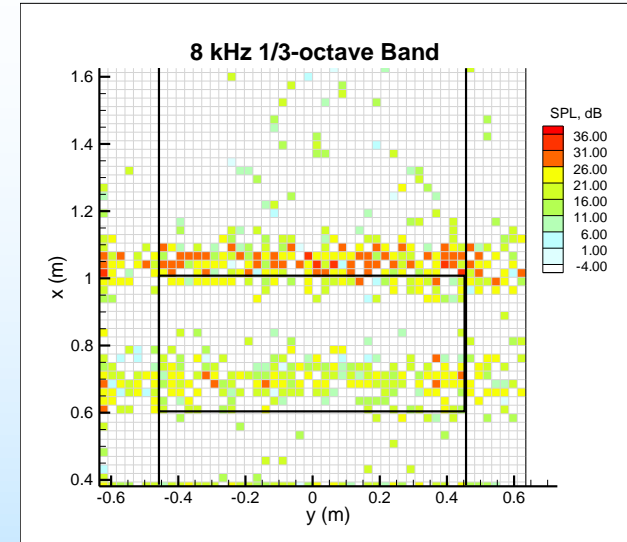
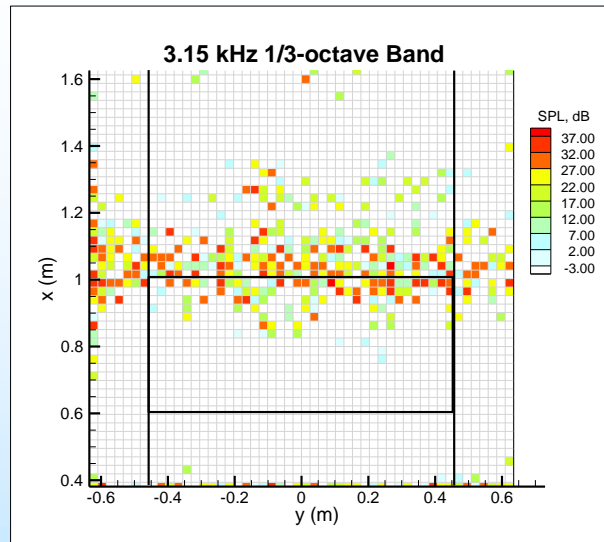
Results from NASA Langley – 2016 Analysis Methods

Method	DAMAS	Diagonal Removal	Conventional Background Subtraction	Eigenvalue Background Subtraction	Band Combining
1	✓	✓	✓		✓
2	✓		✓		✓
3	✓			✓	✓
4	✓			✓	

- Used dataset-supplied shear layer corrections / steering vectors
- Band Combining – 7 spectral bins summed prior to DAMAS application
- Spatial Integrations - direct summation of source maps

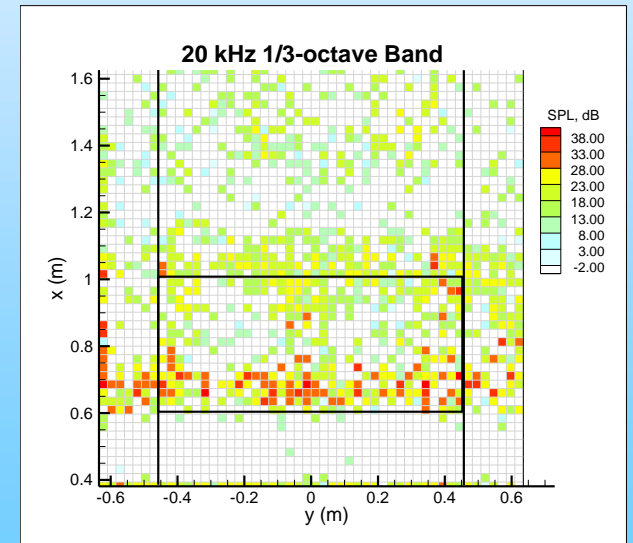
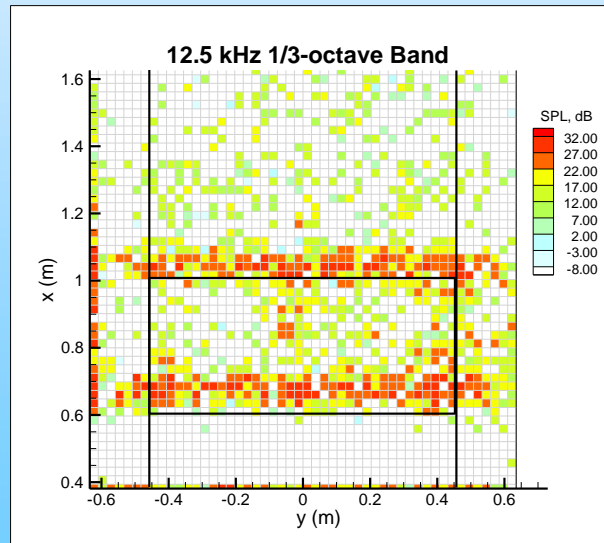
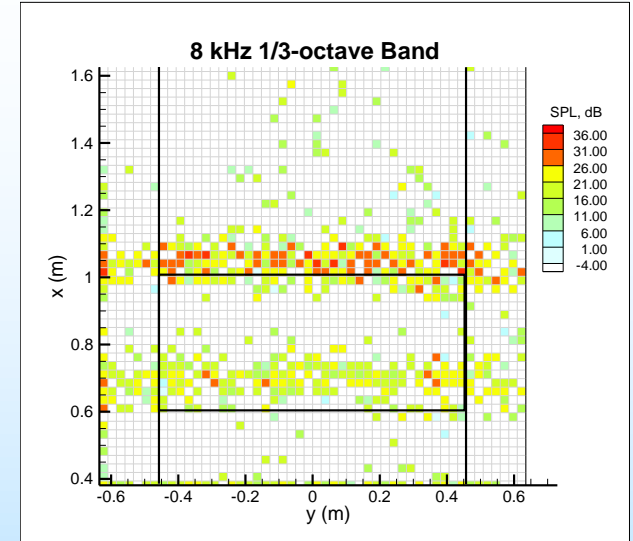
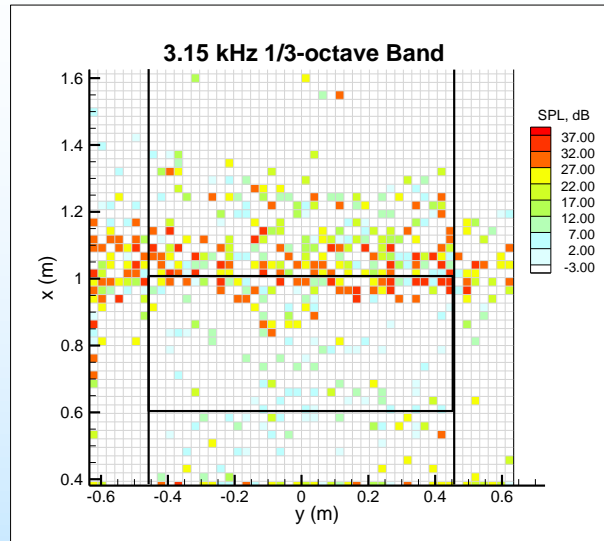
Results from NASA Langley – 2016

- Method 1
- DAMAS
- Diagonal Removal
- Conventional Background Subtraction
- Band Combining
- 200 iterations



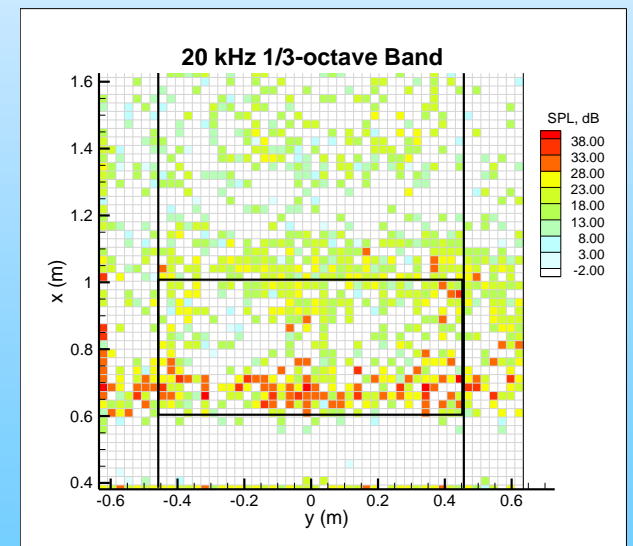
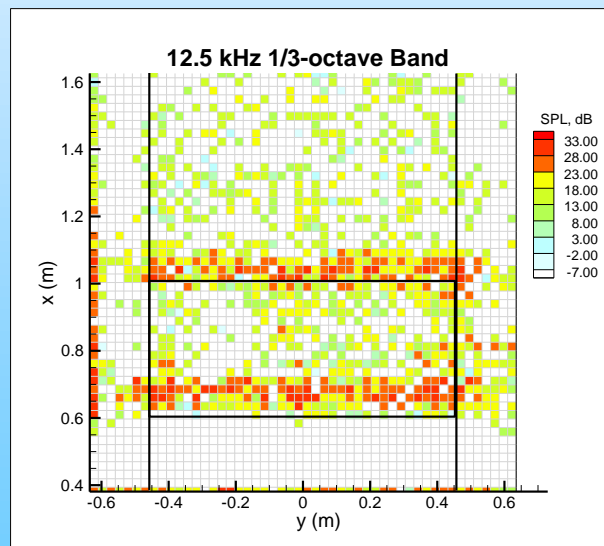
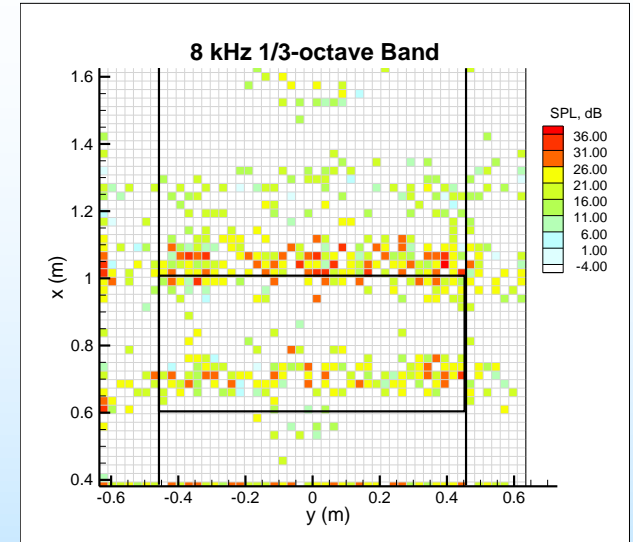
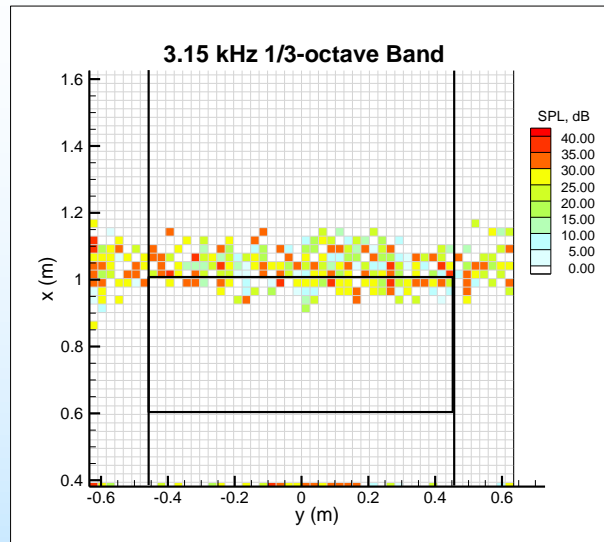
Results from NASA Langley – 2016

- Method 2
- DAMAS
- No Diagonal Removal
- Conventional Background Subtraction
- Band Combining
- 200 iterations



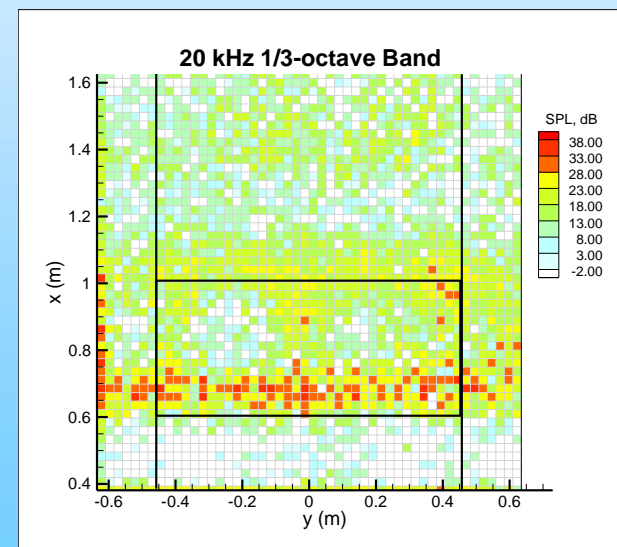
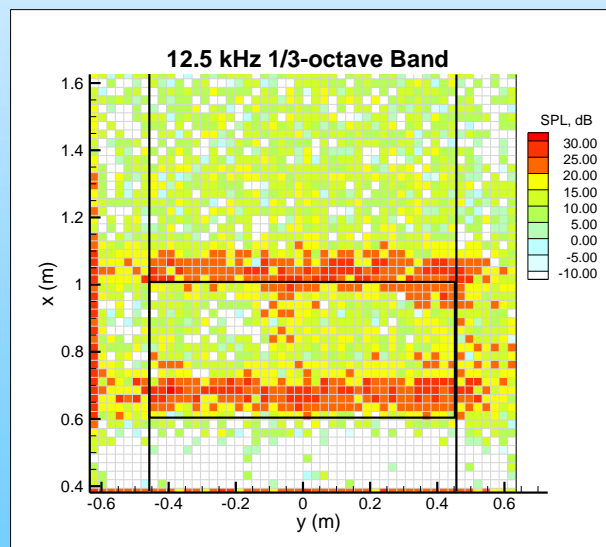
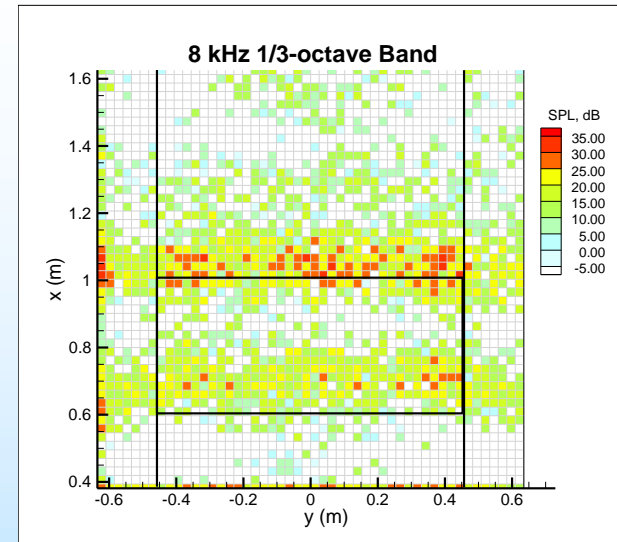
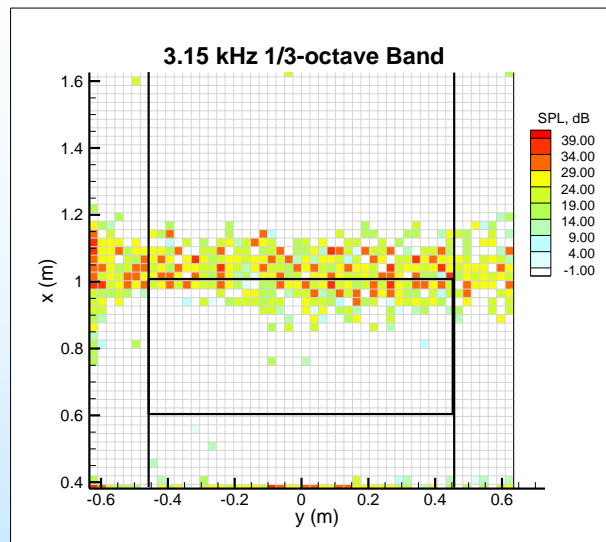
Results from NASA Langley – 2016

- Method 3
- DAMAS
- No Diagonal Removal
- Eigenvalue Background Subtraction
- Band Combining
- 200 iterations



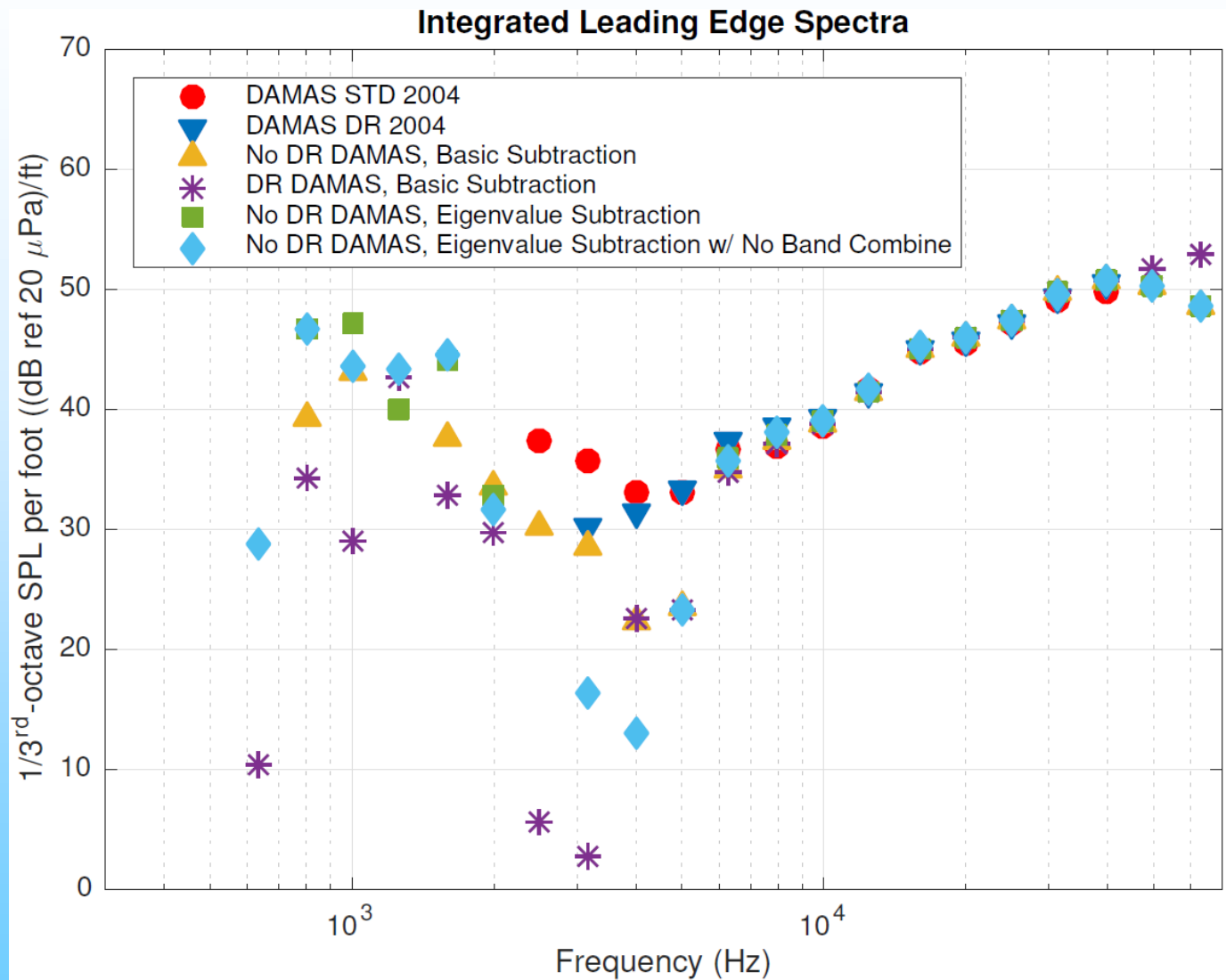
Results from NASA Langley – 2016

- Method 4
- DAMAS
- No Diagonal Removal
- Eigenvalue Background Subtraction
- No Band Combining
- 200 iterations



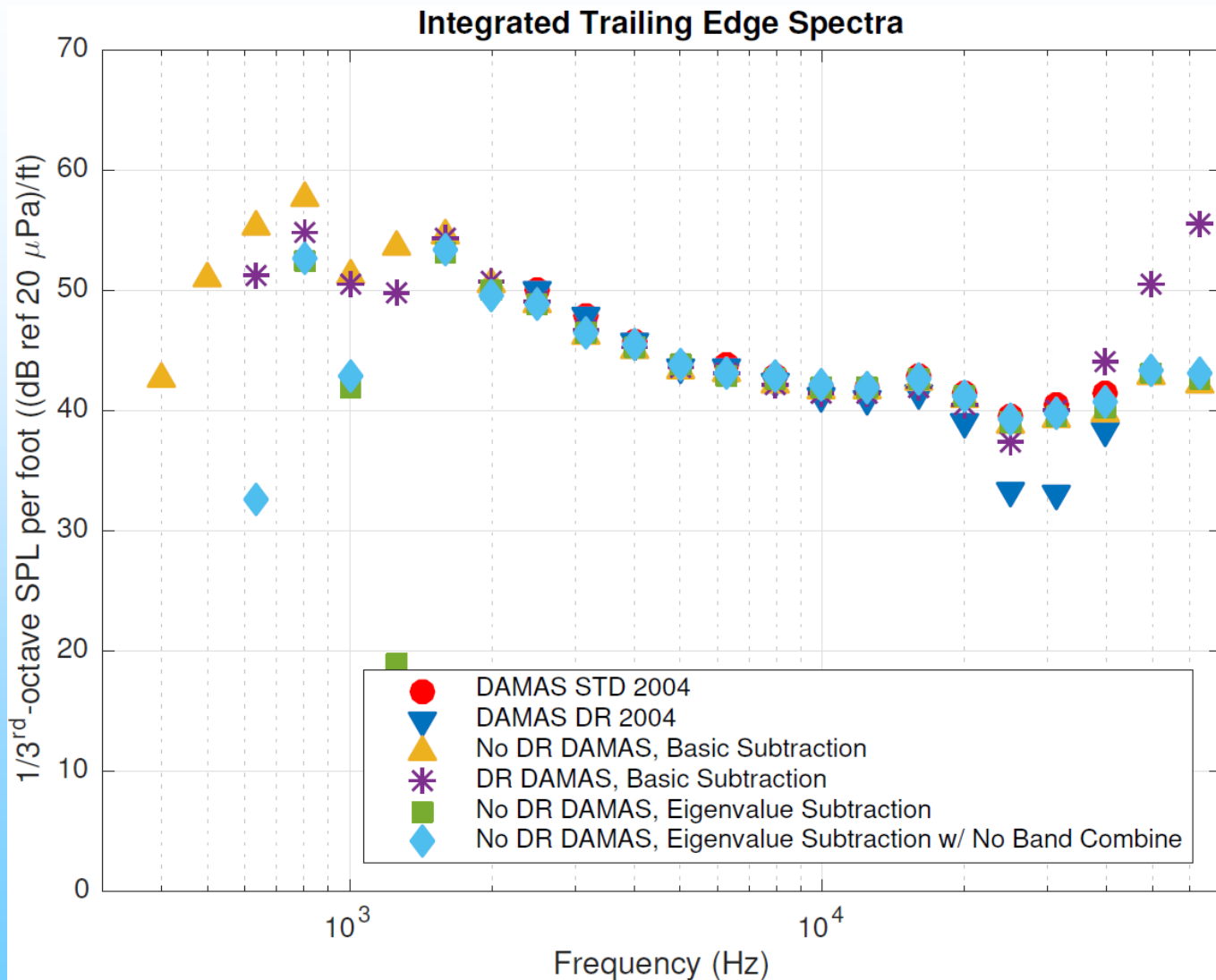
Results from NASA Langley – 2016

- Leading Edge Spatial Integration



Results from NASA Langley – 2016

- Trailing Edge Spatial Integration



General Comments / Discussion

- A variety of analysis methods have now been applied to the benchmark
- In general, many of the visual presentations of source locations are similar between the various analyses
- Most techniques appear to capture consistent source power via spatial integrations at mid- and upper-frequencies
- There are some discrepancies in the integrated source power at lower frequencies, particularly when using DAMAS-types of analyses – causes?
- Traditional CSM diagonal removal can sometimes degrade the visual presentations and lead to discrepancies in integrated source power, especially at higher frequencies

