NASA2 Benchmark
Comparison of Analysis Results to Date

Case Manager

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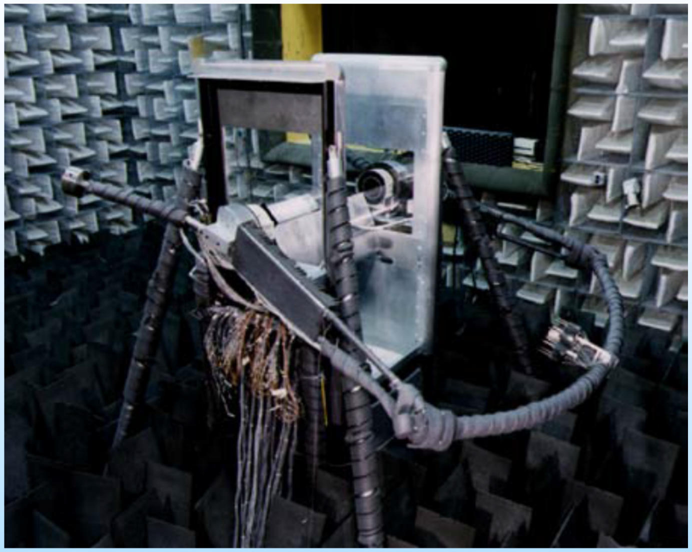
Advanced Measurements and Data Systems Branch

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

29 February, 2016

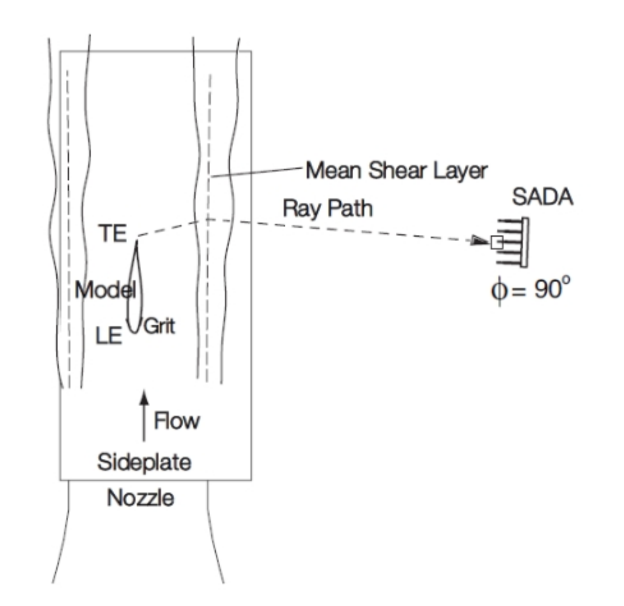
NASA2 Benchmark



- 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^{o} F (26.4^{o} 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

$$\hat{G}_{array} = \begin{bmatrix} G_{m1m1} & G_{m1m2} & \cdots & G_{m1mM} \\ G_{m2m1} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ G_{mMm1} & \cdots & \cdots & G_{mMmM} \end{bmatrix}$$

Cross Spectral Matrix (CSM)

$$Y(\hat{e}) = \frac{\hat{e}^T \widehat{W} \left(\hat{G}_{array}\right)_{diag=0} \widehat{W}^T \hat{e}}{\left(\sum_{m=1}^{M} w_m\right)^2 - \sum_{m=1}^{M} w_m^2}$$

Conventional FD Beamformer with CSM Diagonal Removal

Desired Source Distribution

BF Source Distribution

$$\hat{X} = \hat{A}^{-1}\hat{Y}$$

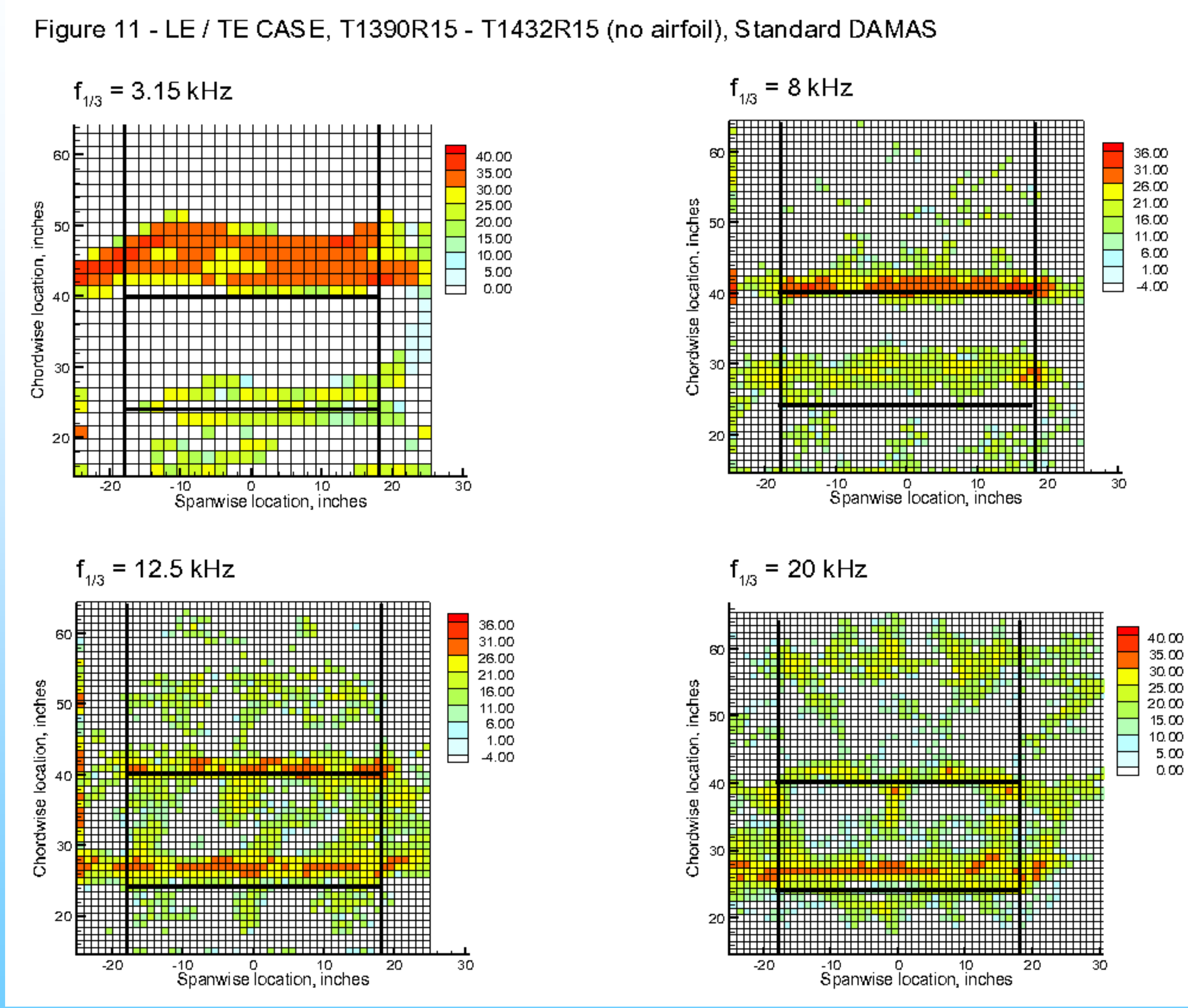
Influence Matrix

$$X_n^{(i)} = Y_n - \left[\sum_{n'=1}^{n-1} A_{nn'} X_{n'}^{(i)} + \sum_{n'=n+1}^{N} A_{nn'} X_{n'}^{(i-1)}\right]$$

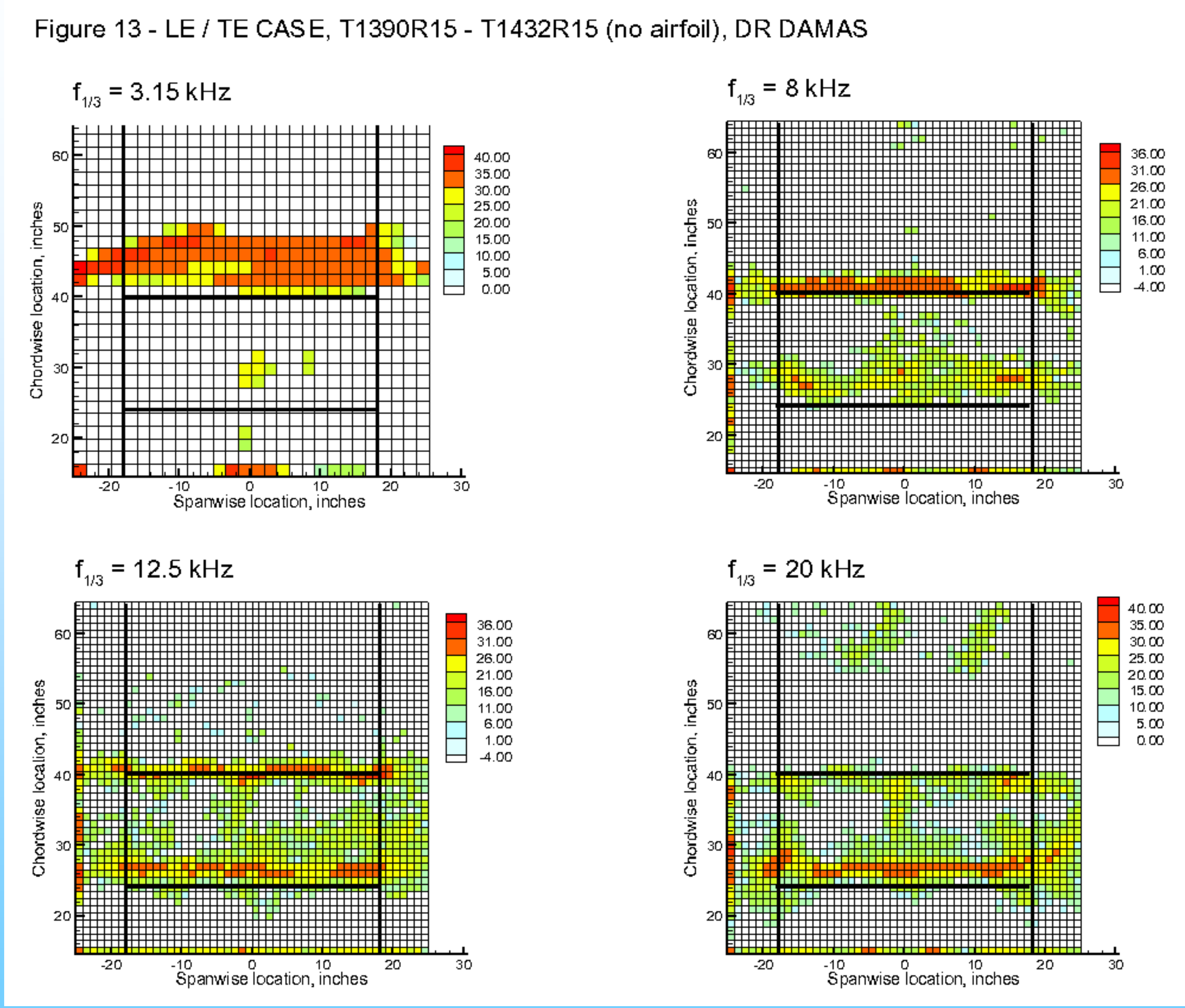
Gauss-Seidel Solver

- 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



Original DAMAS Analysis Results – 2004



Original DAMAS Analysis Results – 2004

- Spatial Integrations

SADA TE

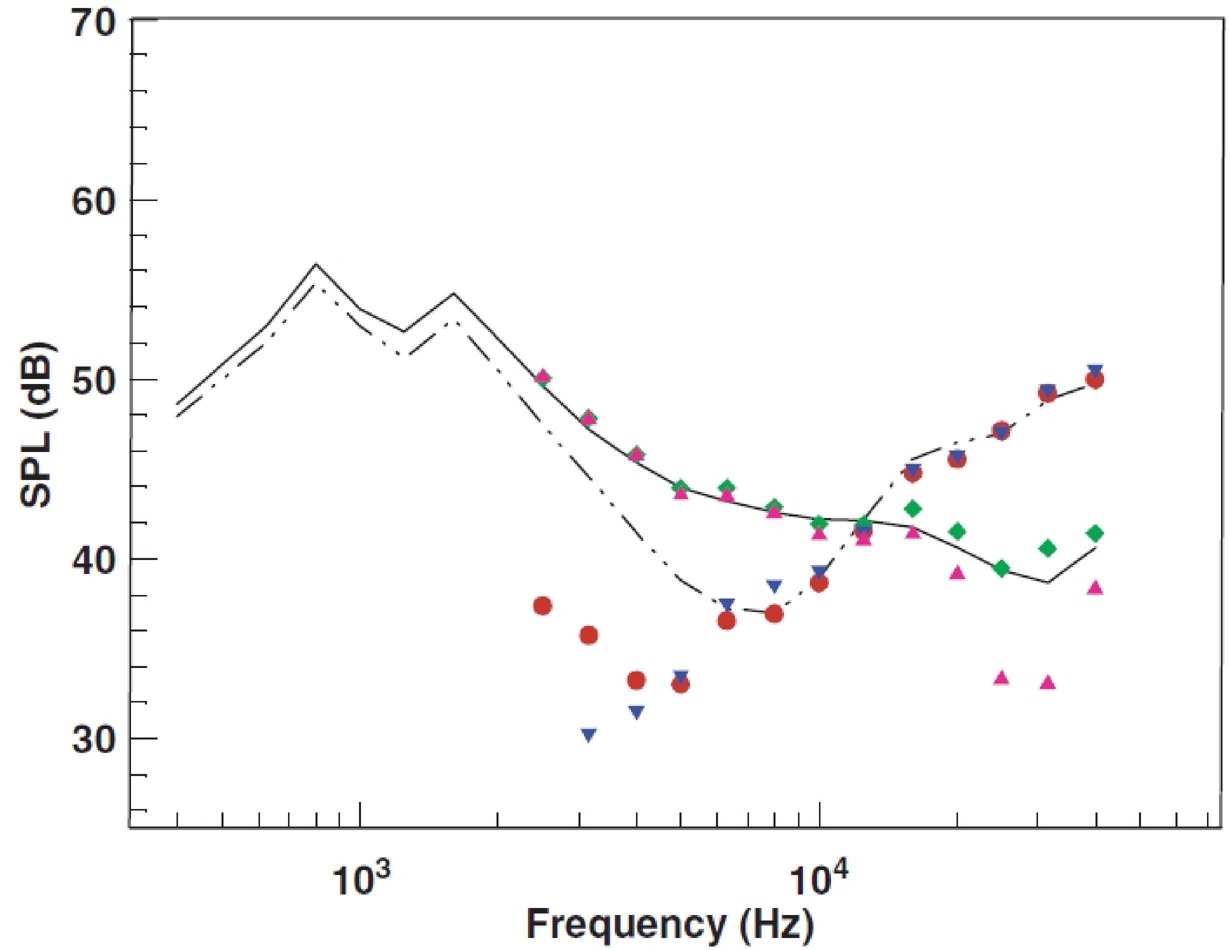
SADA LE

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)

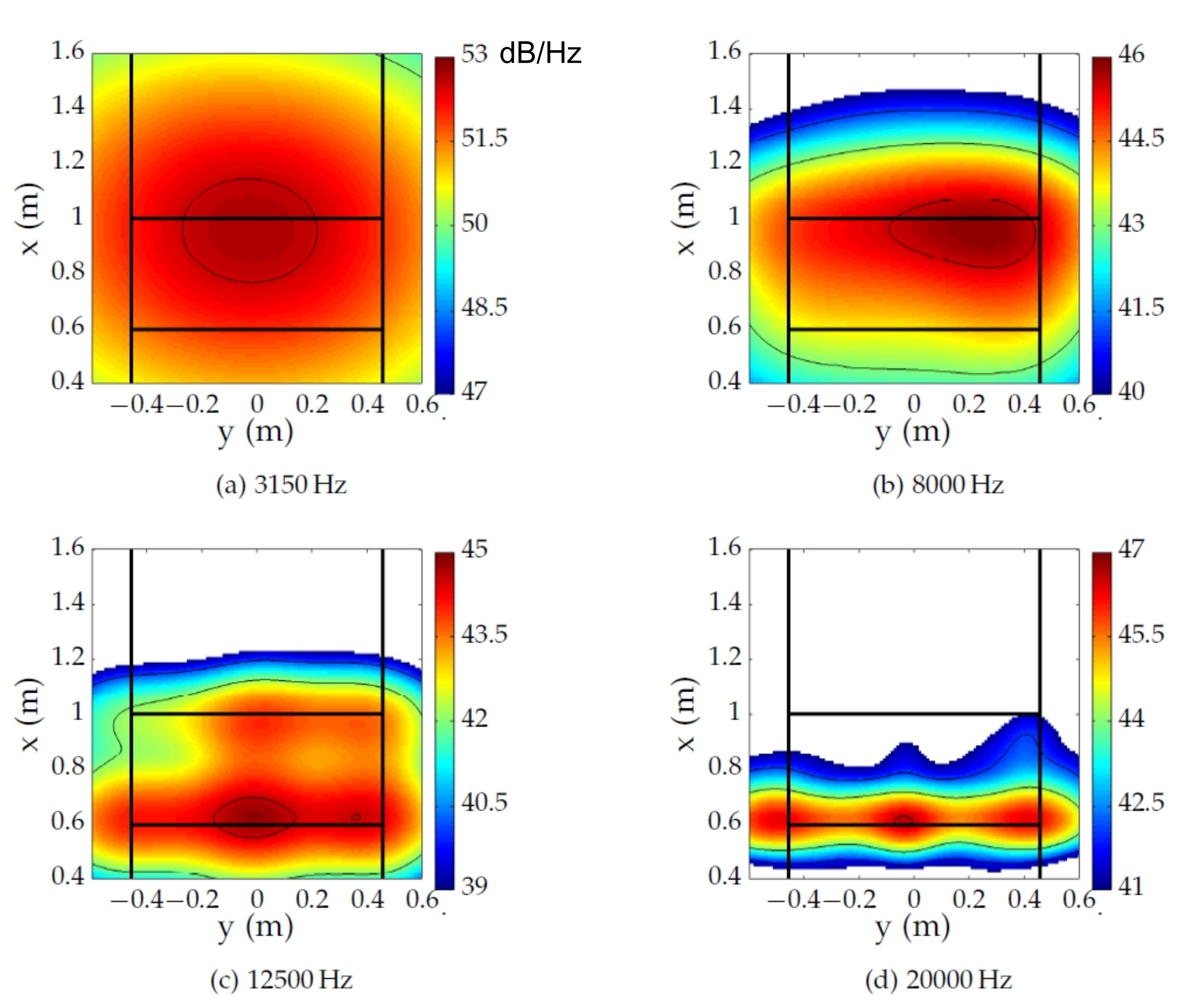
- Deconvolution – CLEAN-SC (Sijtsma, 2007), beamwidth = 4 cm

- Spatial Integrations:

  - Beamform integrations – method of Brooks and Humphreys (1999)
  - CLEAN-SC integrations – direct summation of source maps

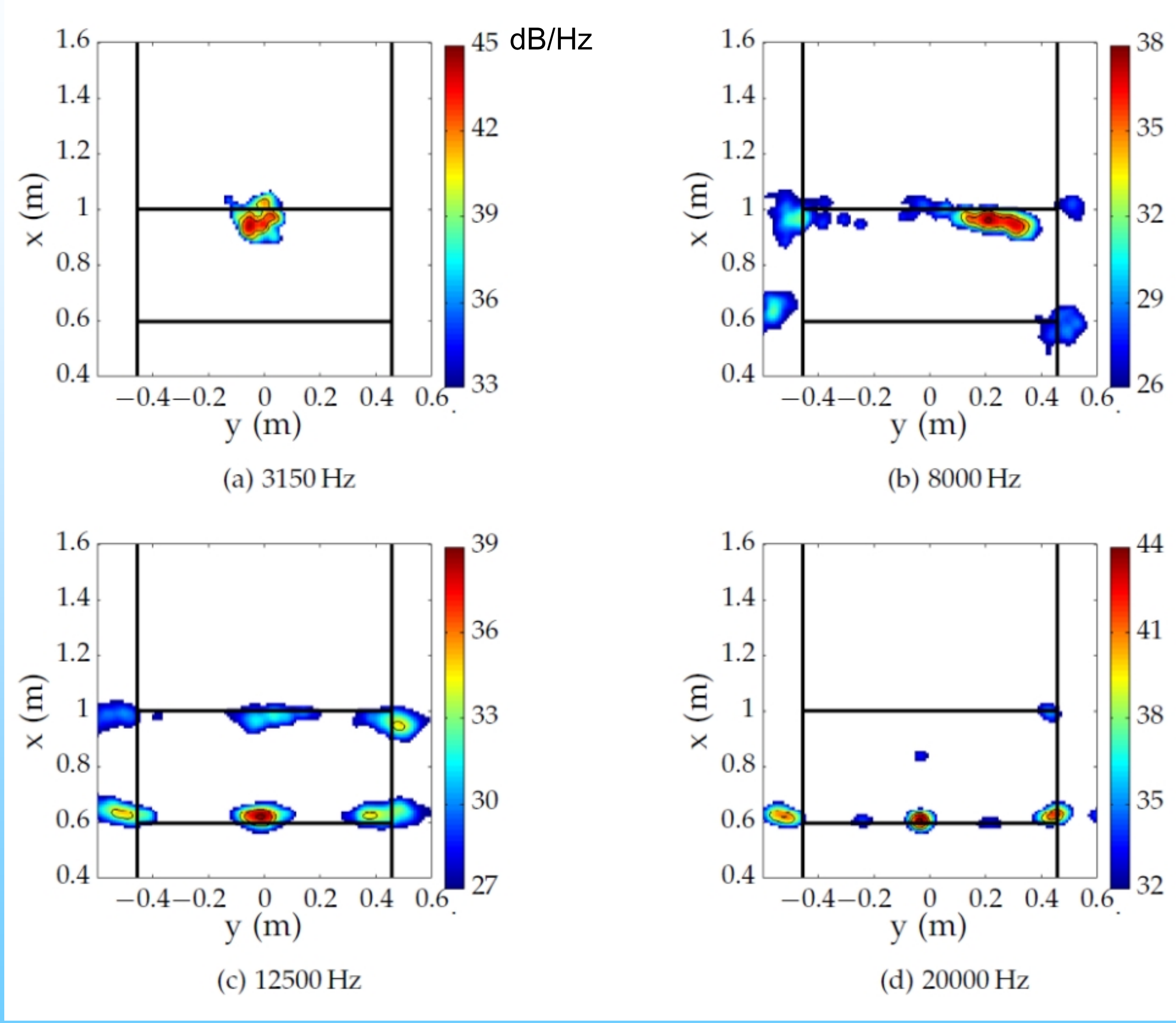
Results from Adelaide / UNSW

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



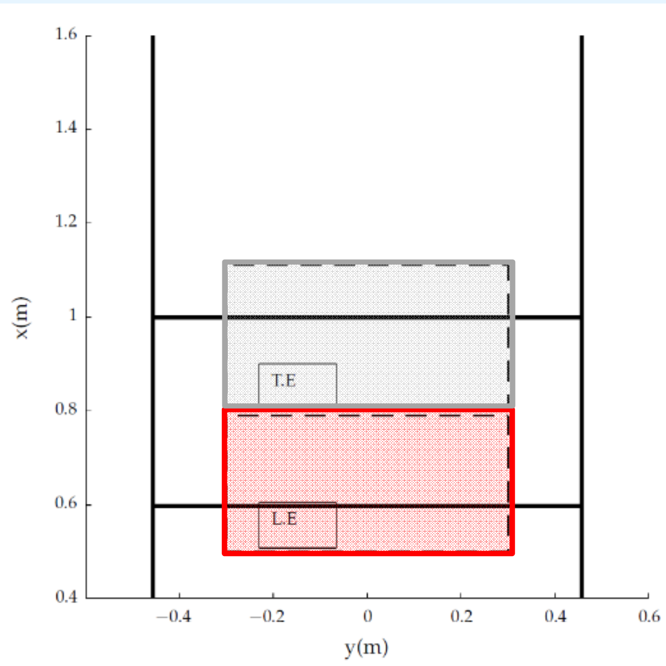
Results from Adelaide / UNSW

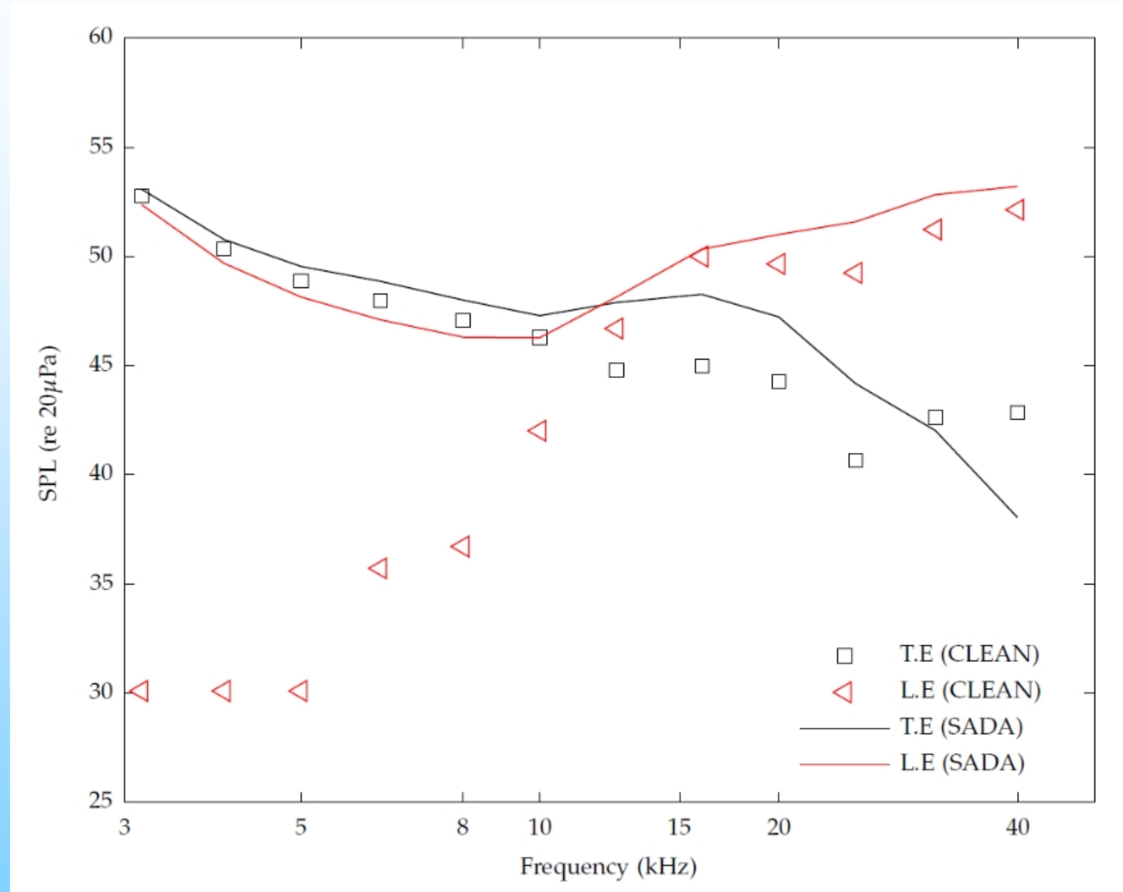
- CLEAN-SC
- Diagonal Removal
- Background Removal
- 1/3-octave Bands



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

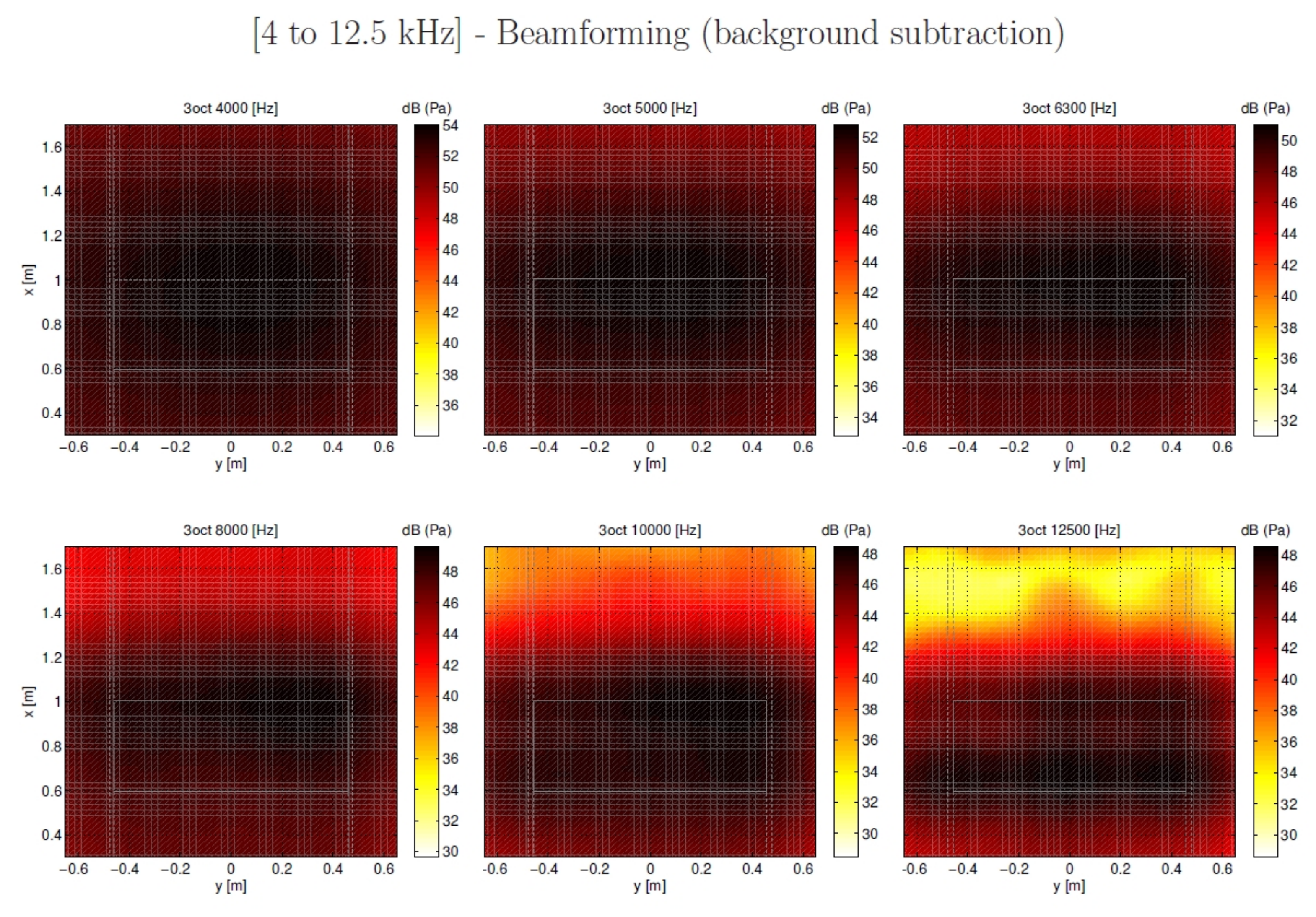
- Techniques:
  1. Conventional Beamforming
  2. Deconvolution using Non-negative Least Squares (NNLS)
  3. Inverse Method using Sparse Bayesian Reconstruction (ℓp-norm with p = 0.9, 1.1)

- Shear layer correction – method of Amiet (1978)

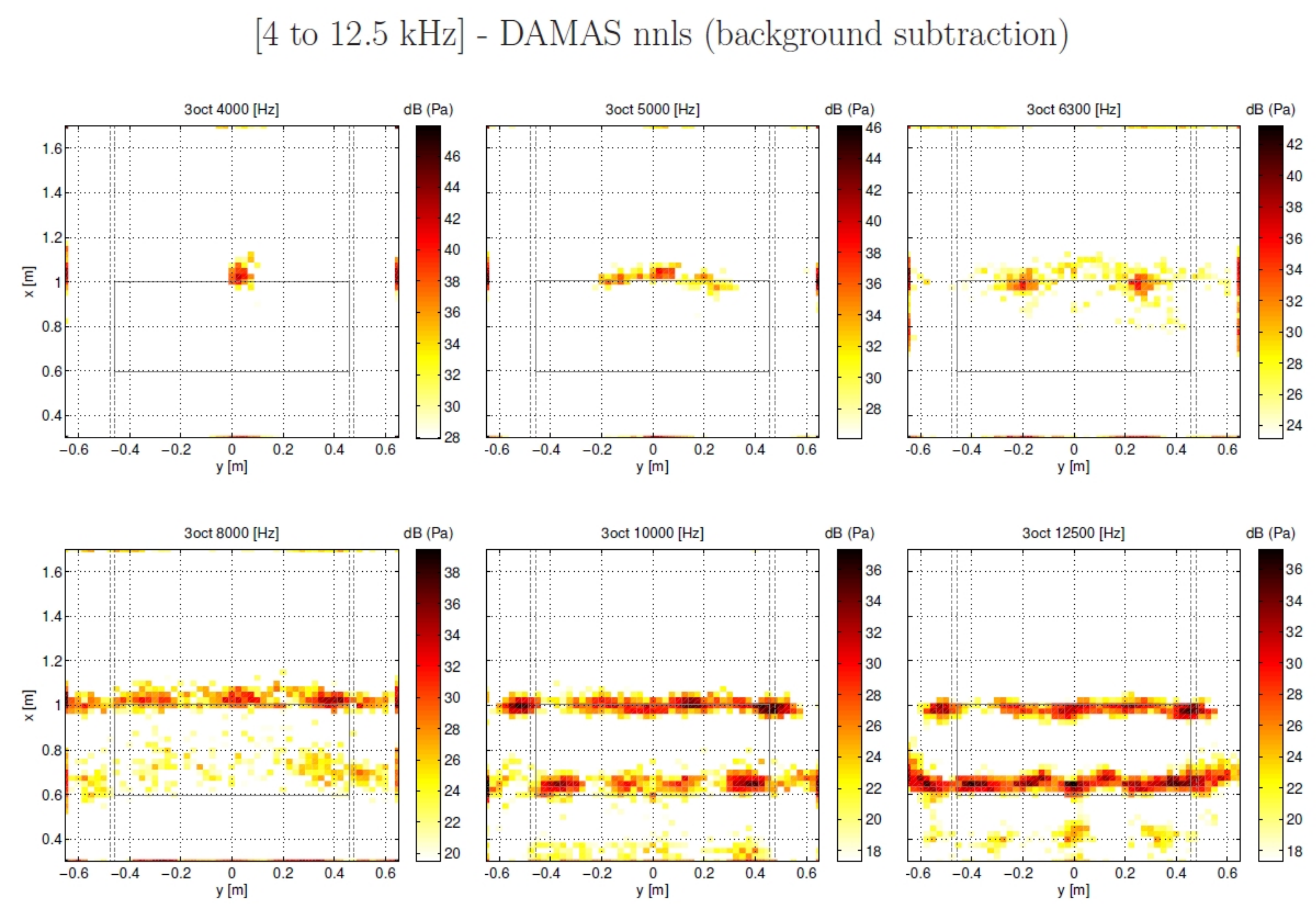
- Background subtraction – method of Bahr and Horne (2015)

- Spatial Integrations – direct summation of source maps

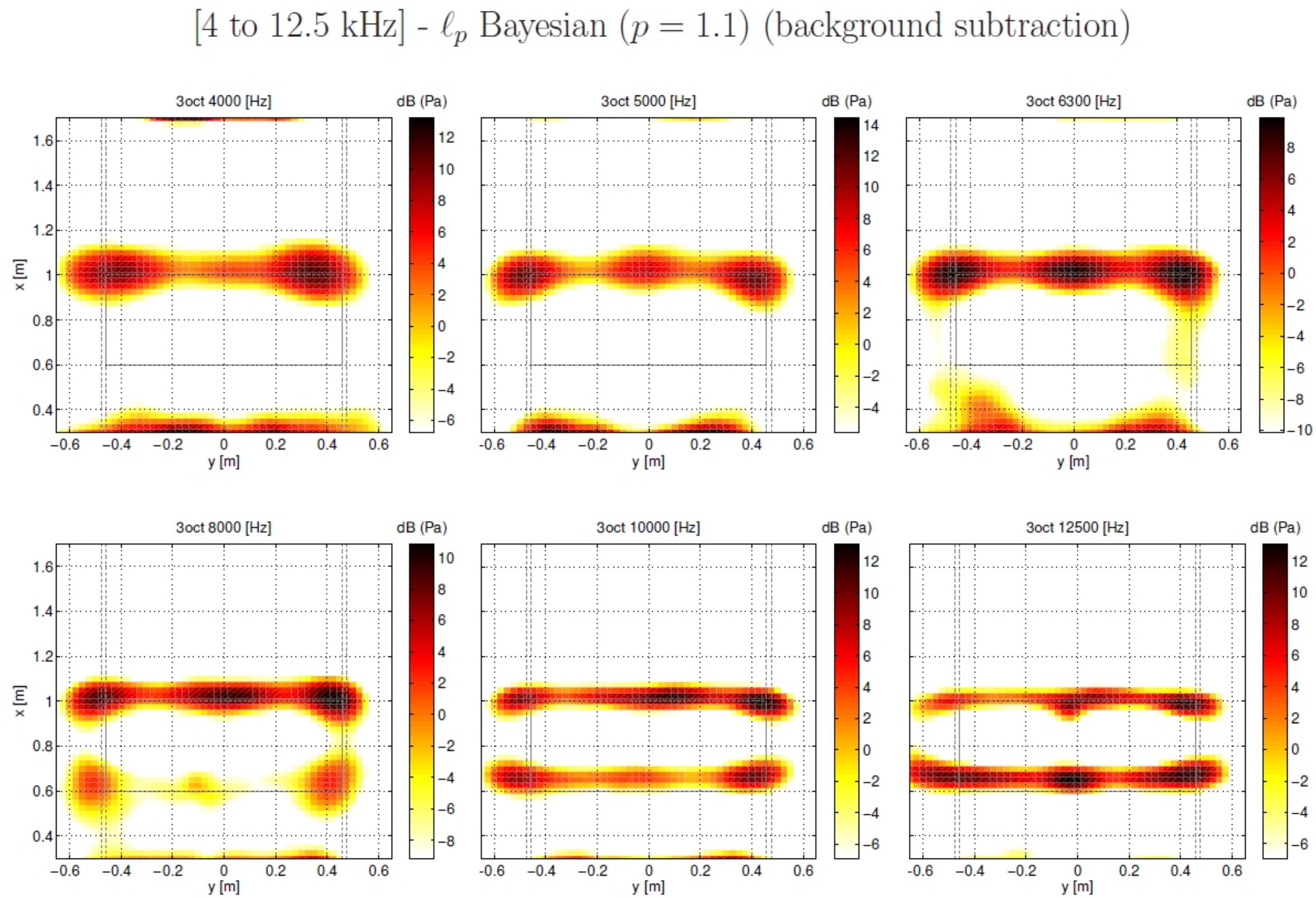
Results from INSA-Lyon



Results from INSA-Lyon

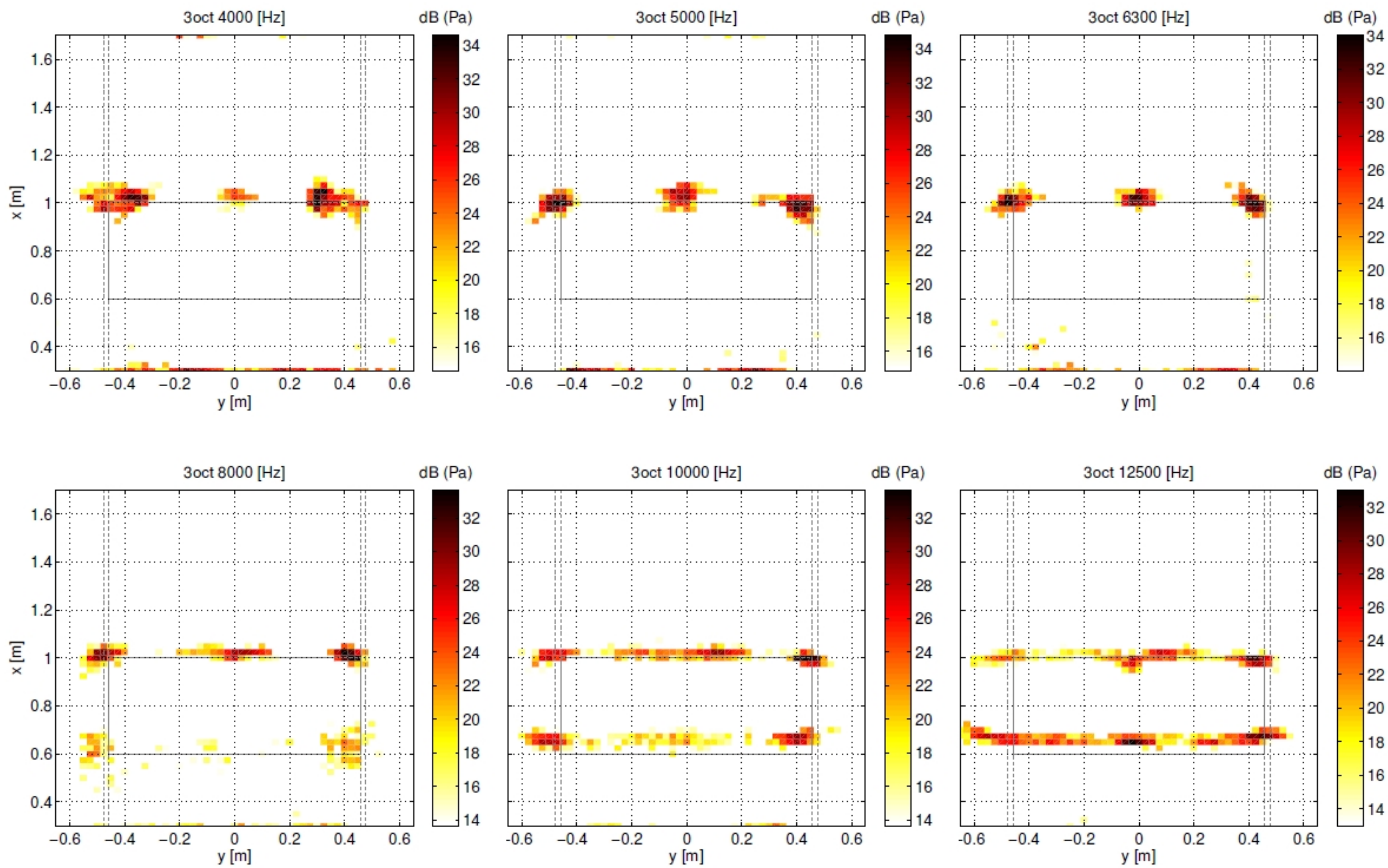


Results from INSA-Lyon



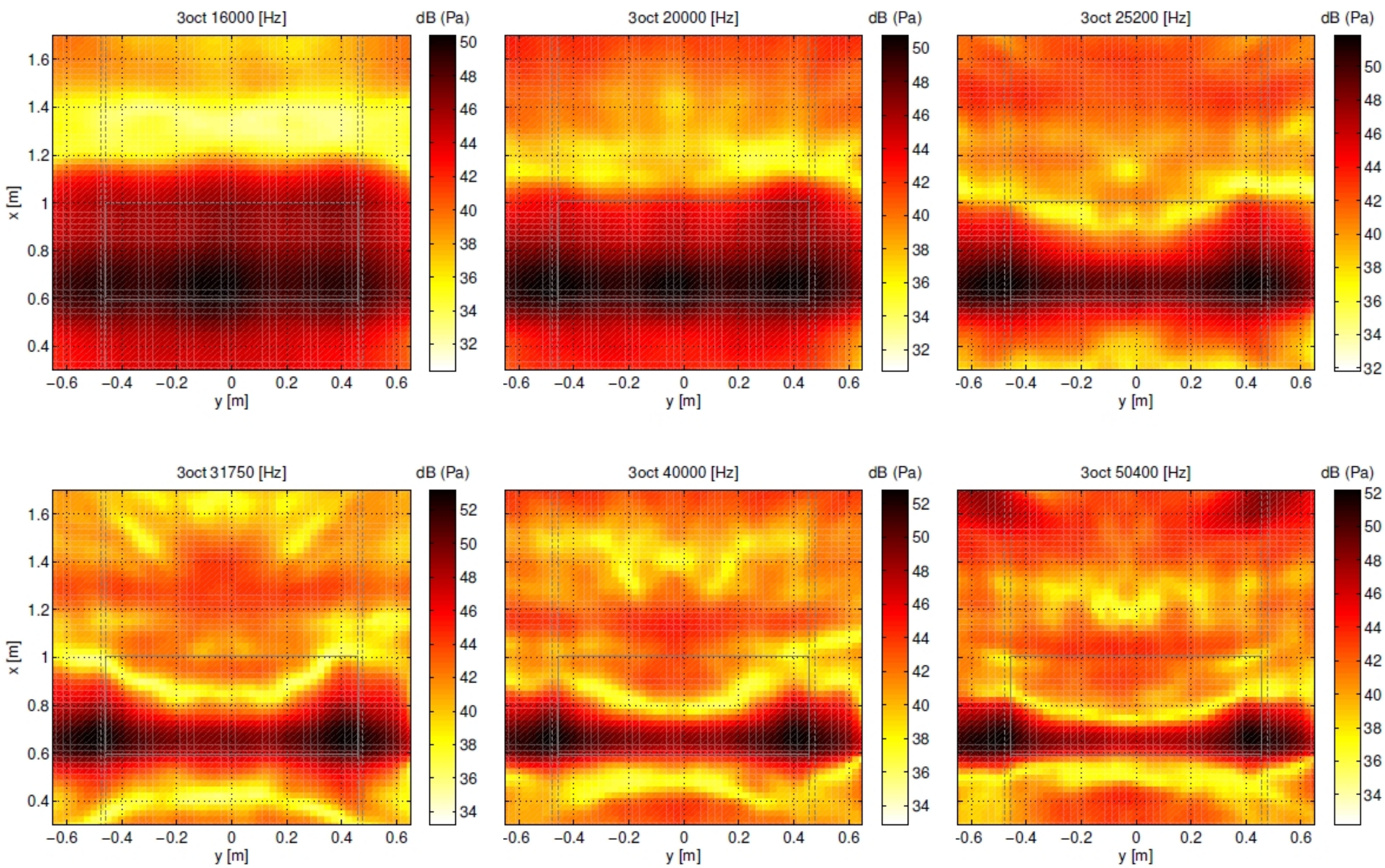
Results from INSA-Lyon

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

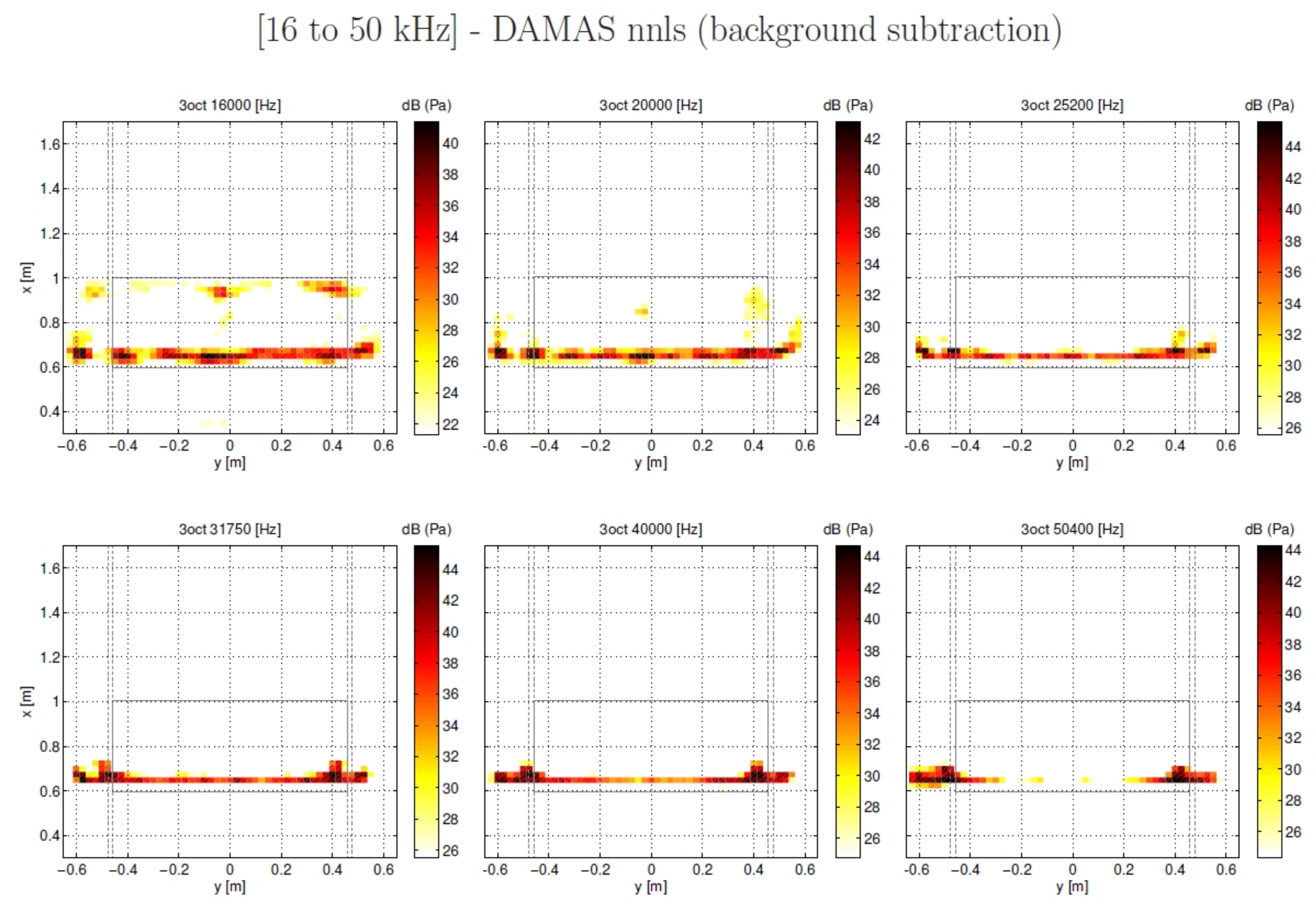


Results from INSA-Lyon

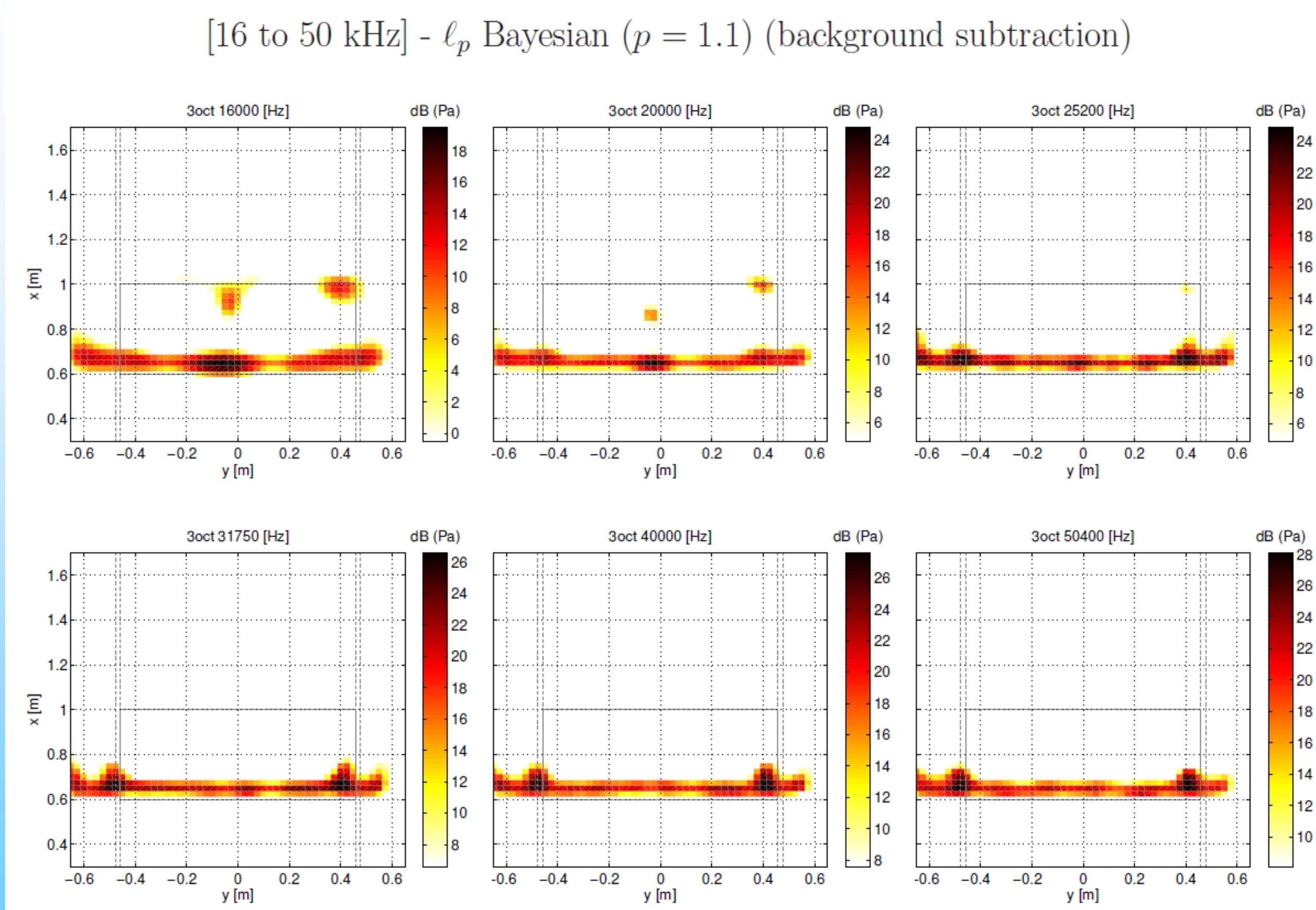
[16 to 50 kHz] - Beamforming (background subtraction)



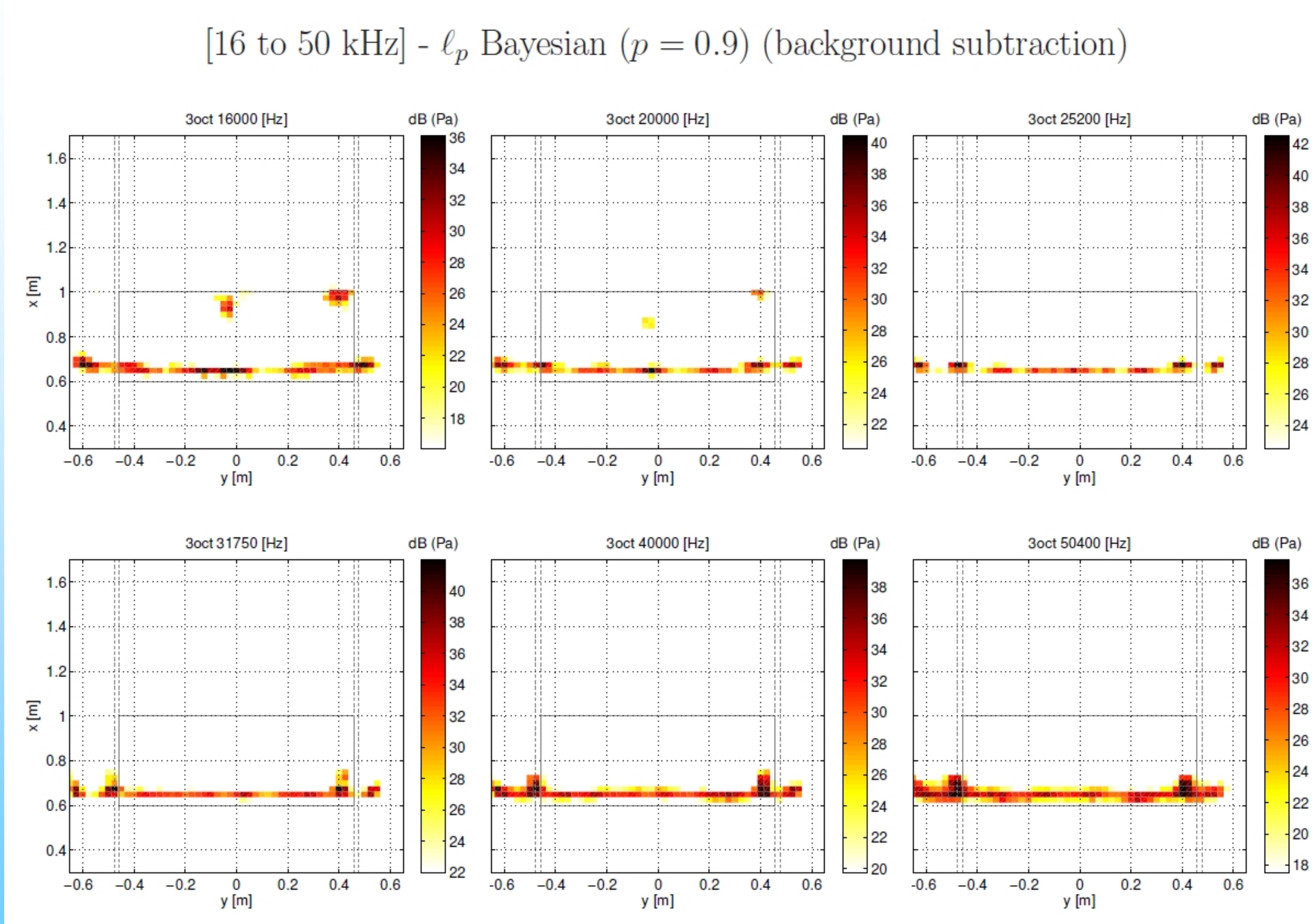
Results from INSA-Lyon



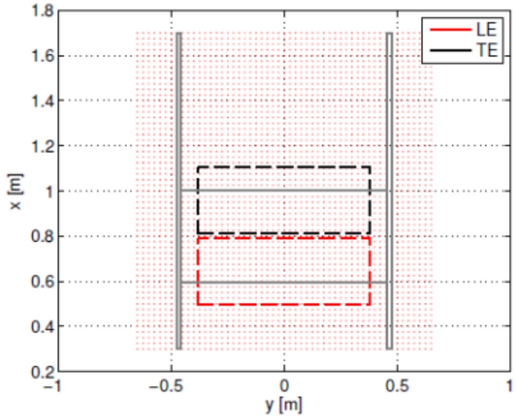
Results from INSA-Lyon



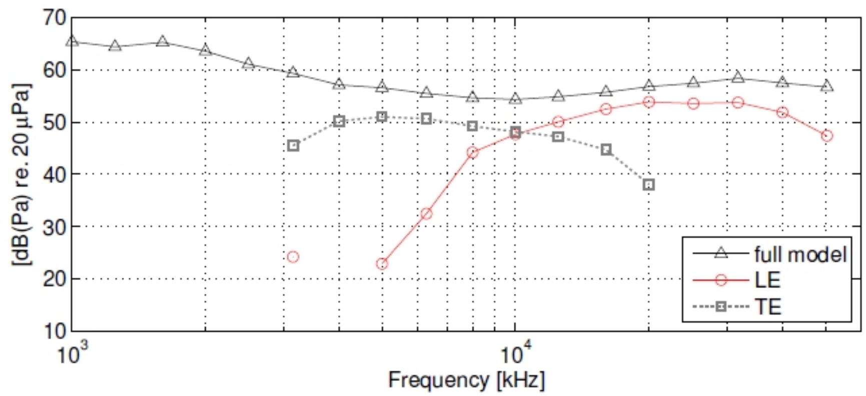
Results from INSA-Lyon



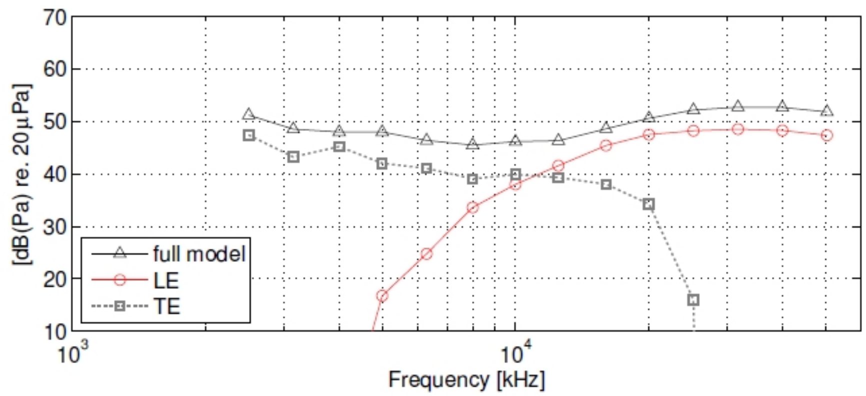
Results from INSA-Lyon
Source Integrations



Integration Regions



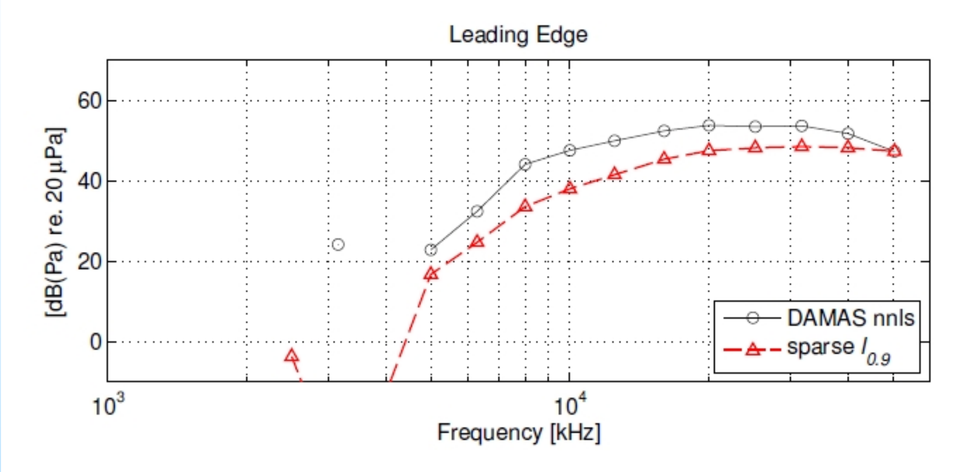
NNLS Algorithm

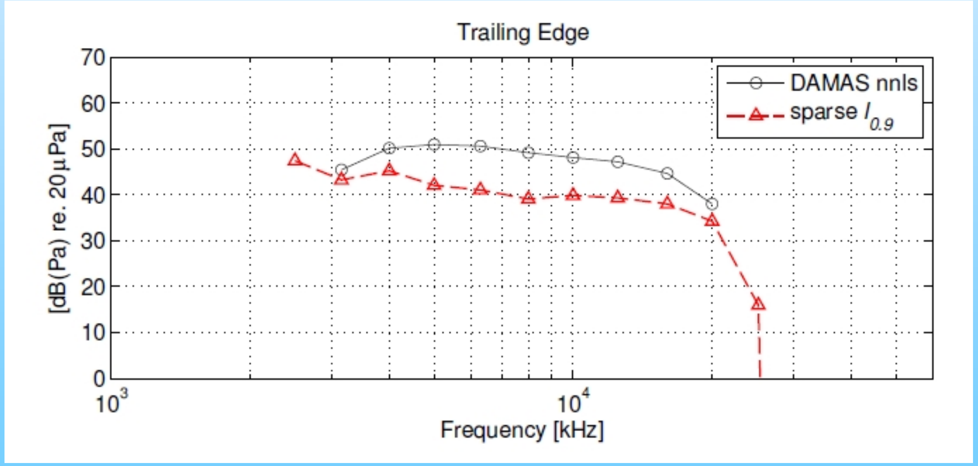


Sparse Bayesian Reconstruction

Results from INSA-Lyon

Source Integrations





Results from NASA Langley – 2016

(Christopher Bahr)

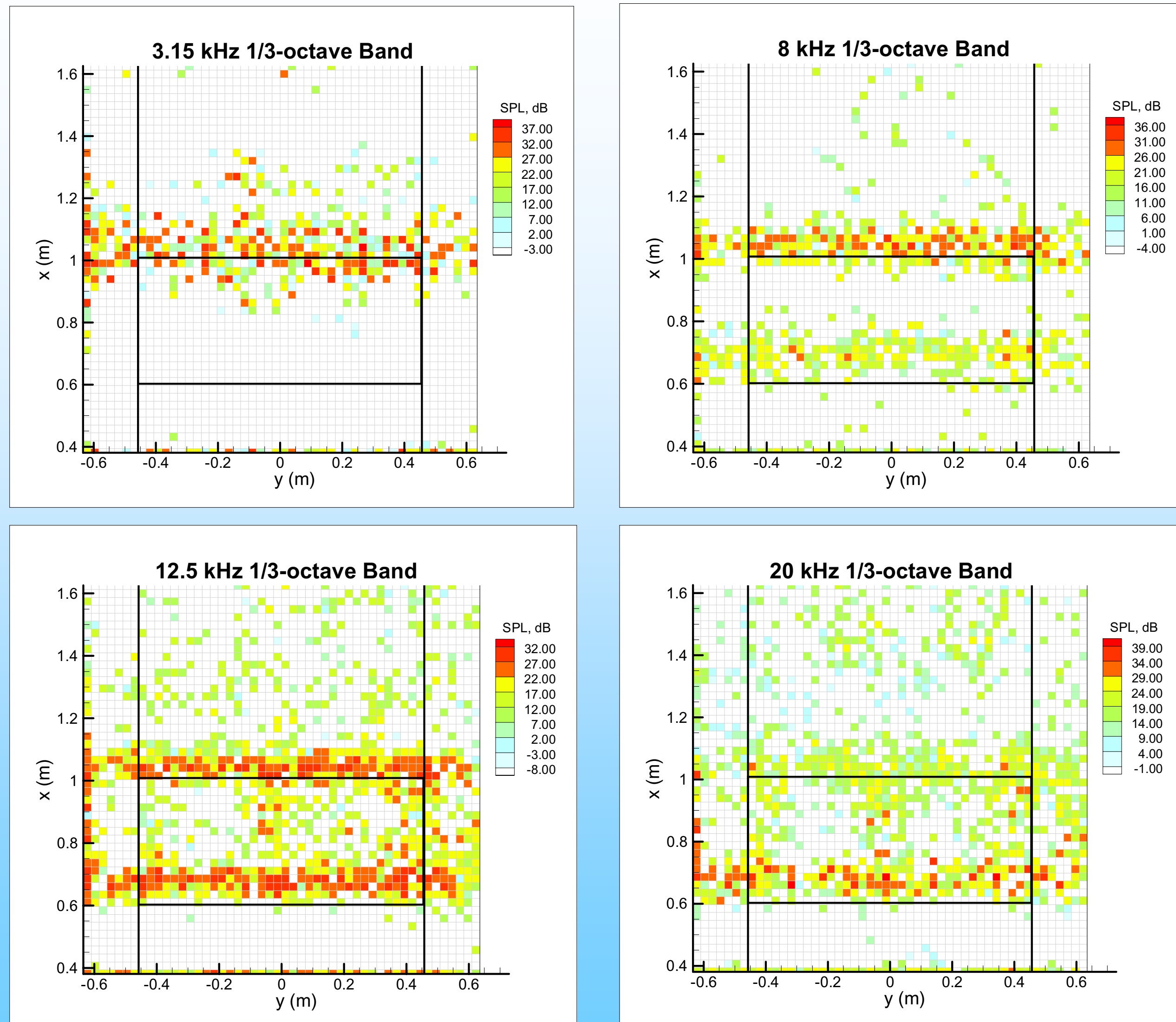
Results from NASA Langley – 2016
Analysis Methods

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

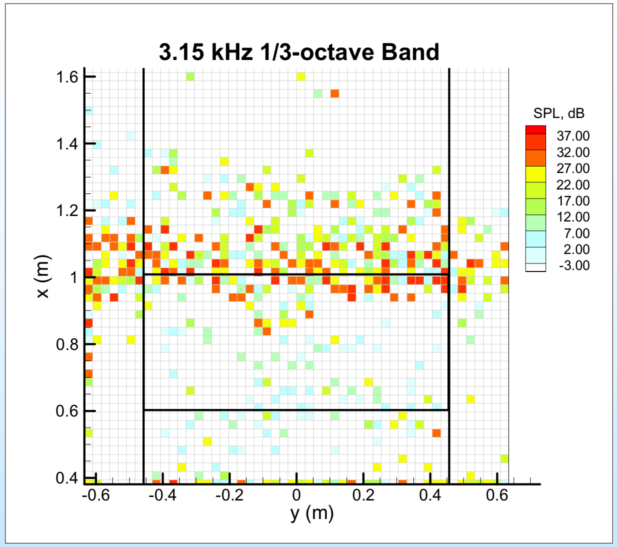
Results from NASA Langley – 2016

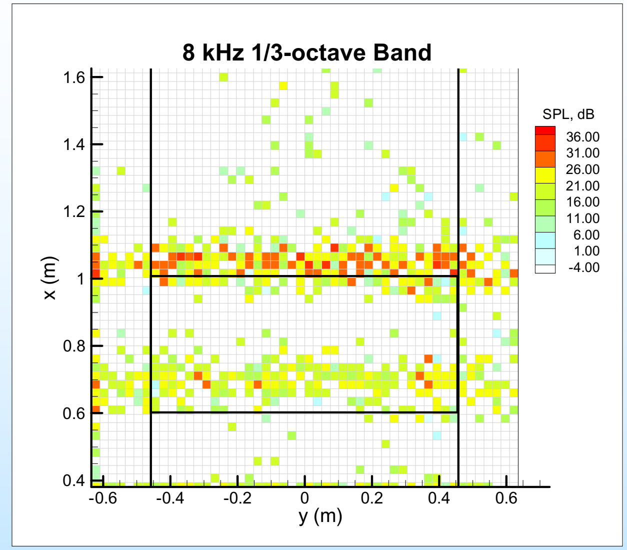
- Method 1
- DAMAS
- Diagonal Removal
- Conventional Background Subtraction
- Band Combining
- 200 iterations

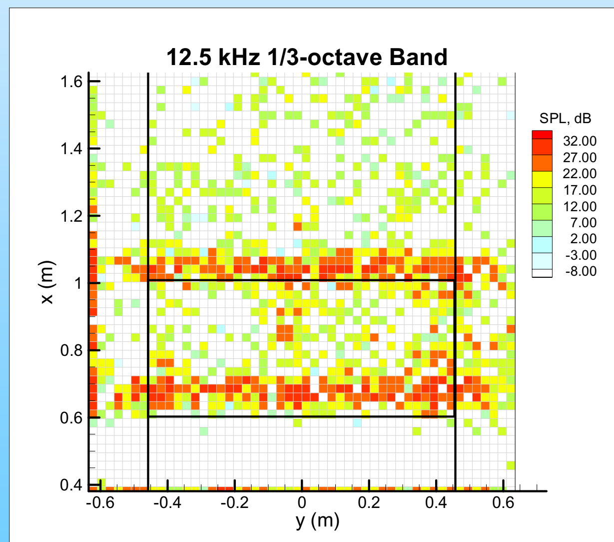


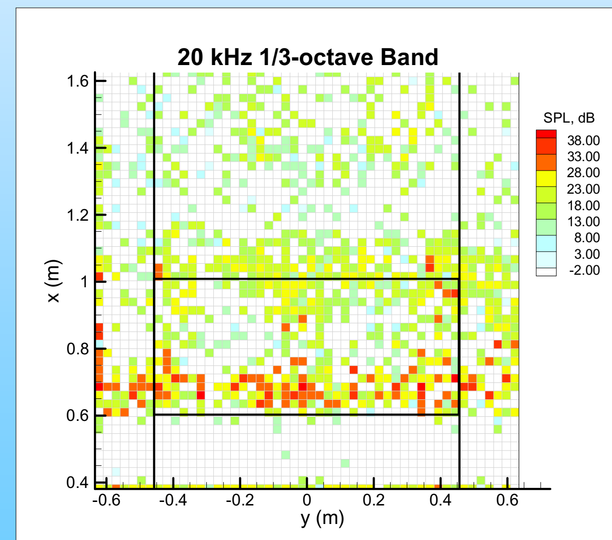
Results from NASA Langley – 2016

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



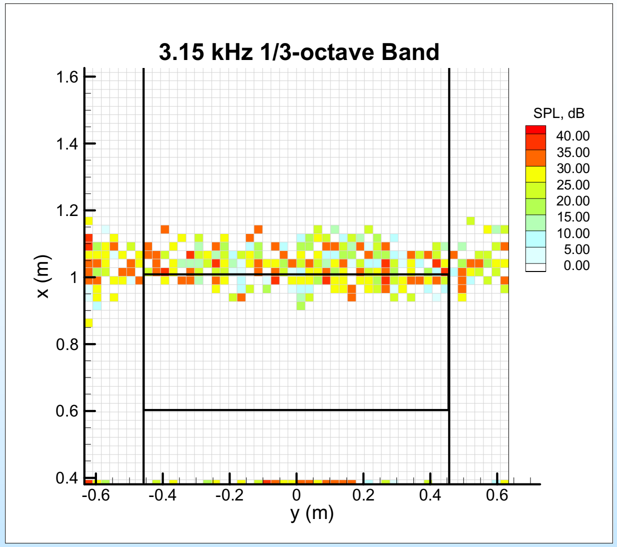


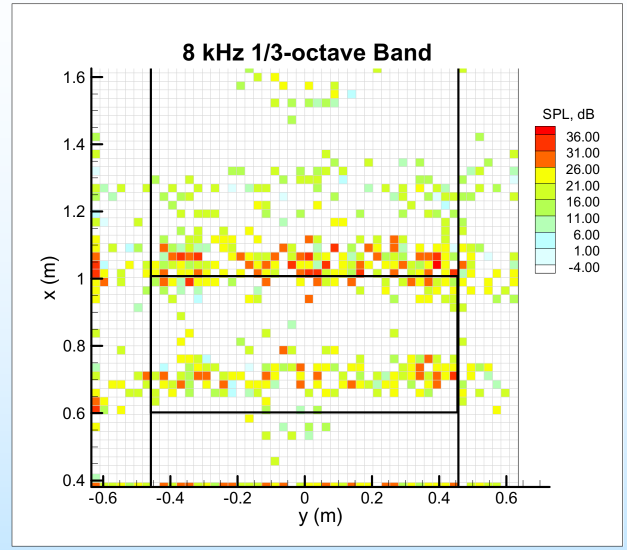


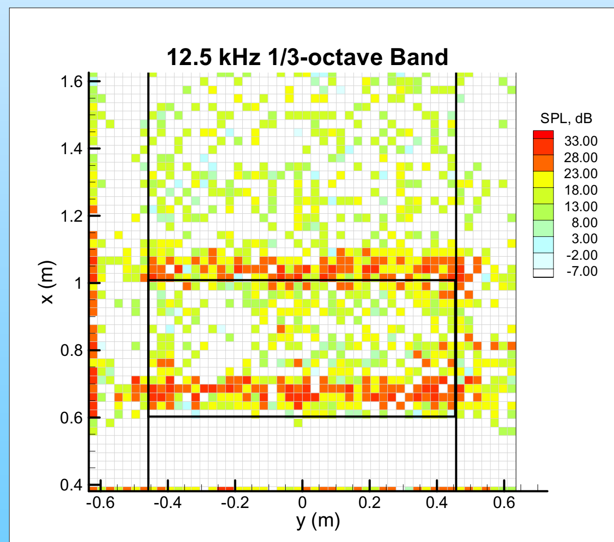


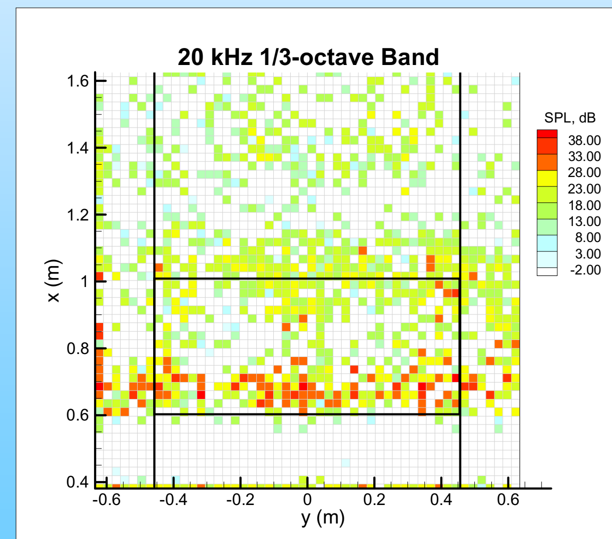
Results from NASA Langley – 2016

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



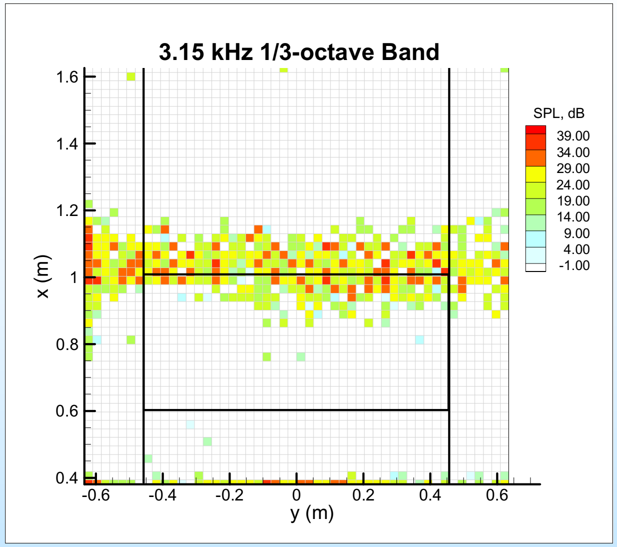


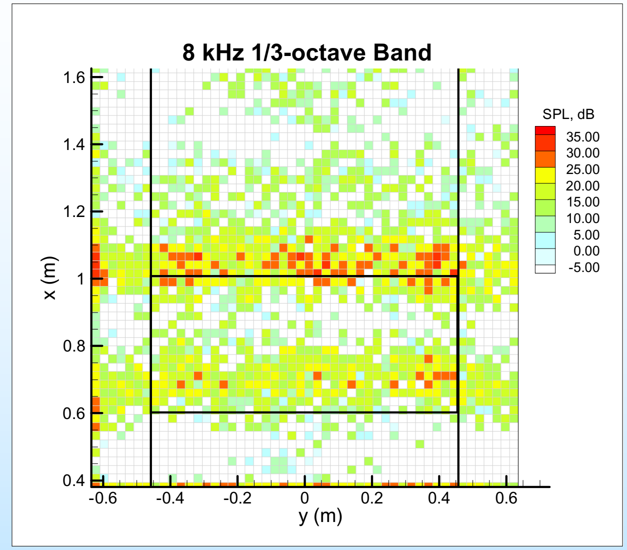


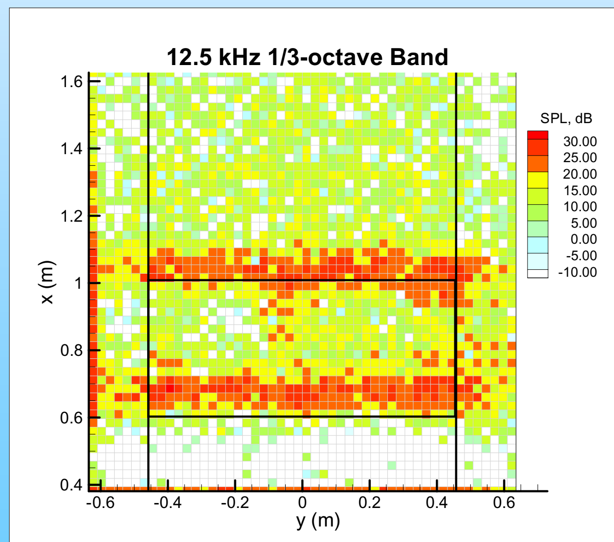


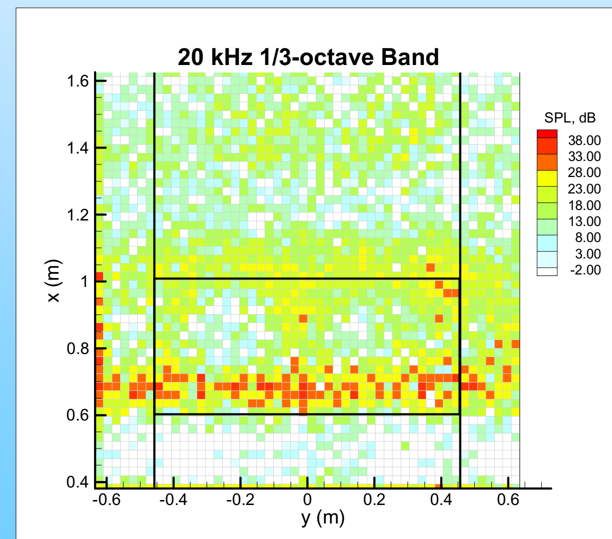
Results from NASA Langley – 2016

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



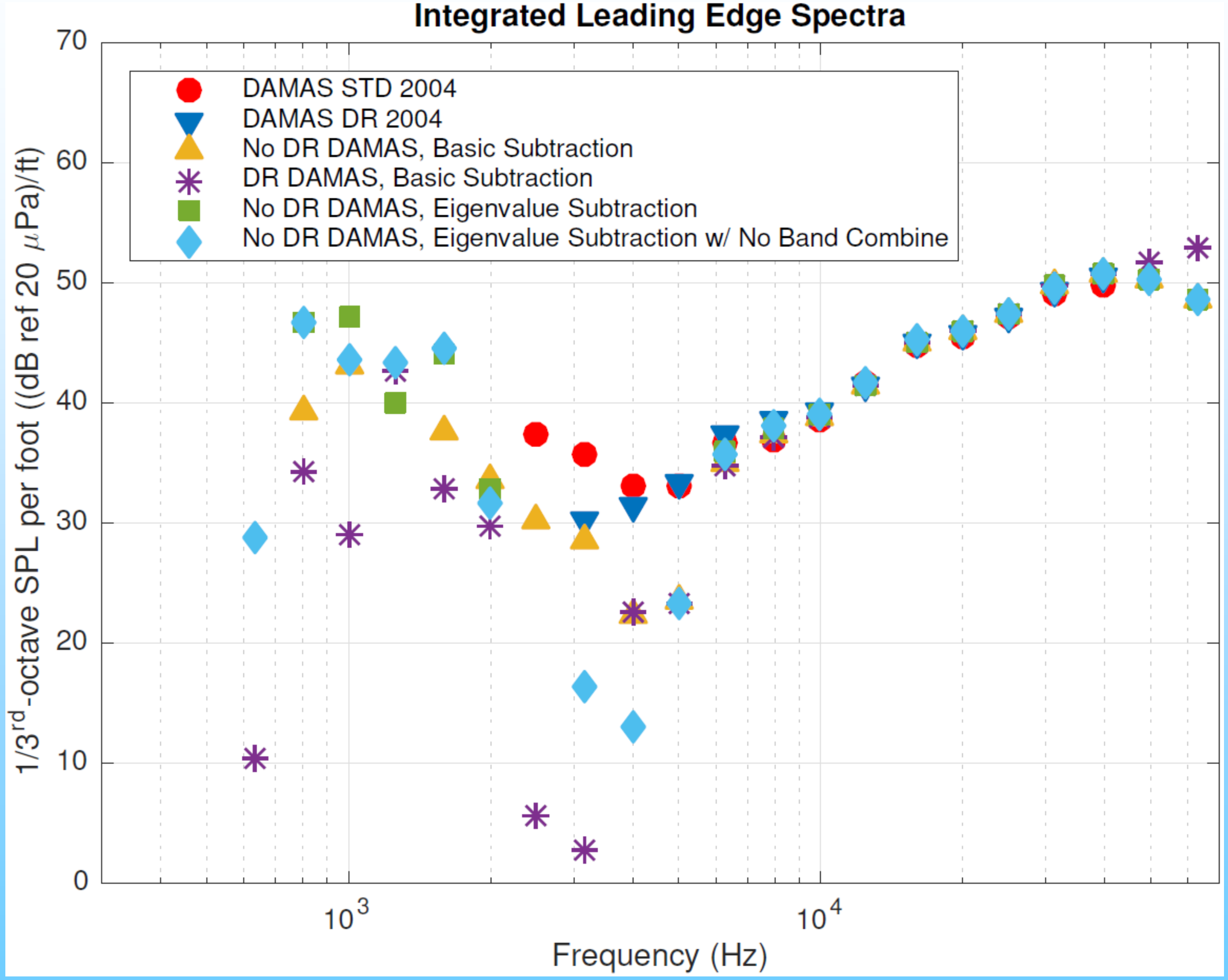






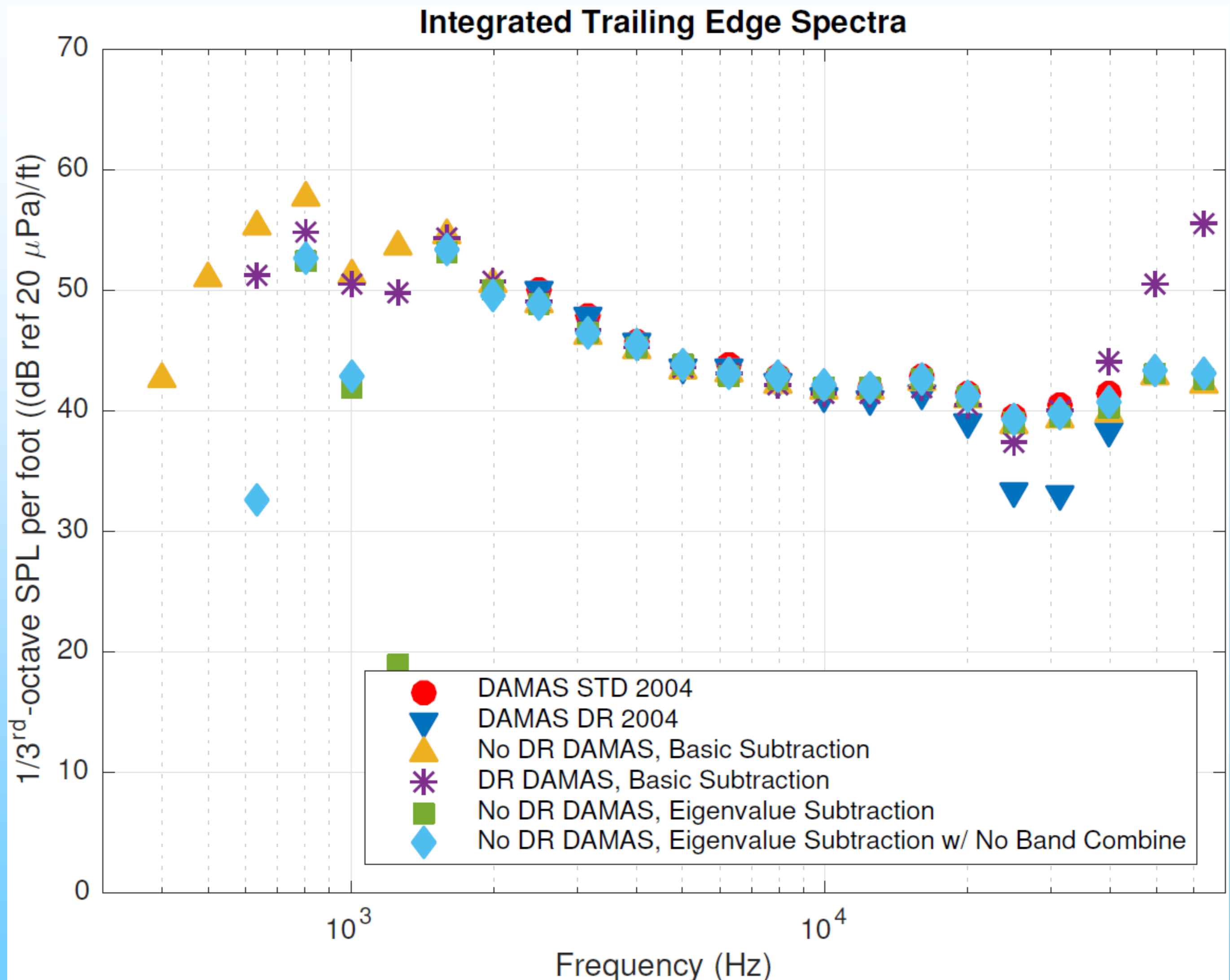
Results from NASA Langley – 2016

- 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