

NASA2 Benchmark Comparison of Analysis Results

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

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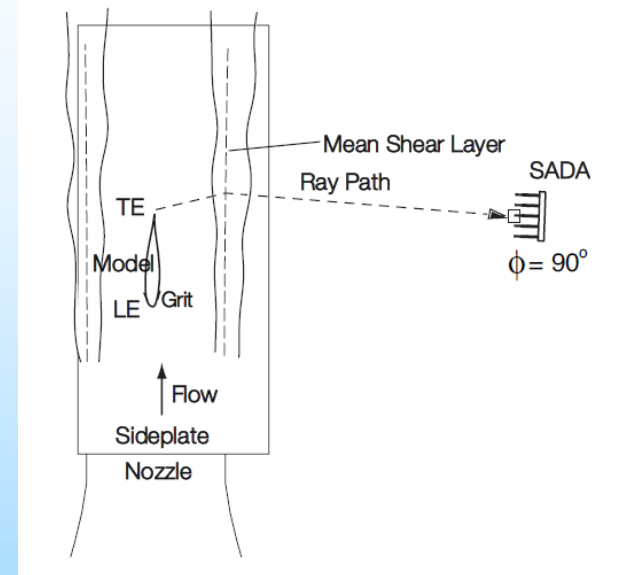
NASA2 Benchmark

- Leading Edge / Trailing Edge Noise Test
- Conducted in LaRC Quiet Flow Facility
- NACA 63-216 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 deg F (26.4 deg C)
- DAS Sample Rate = 142857.71 Hz
- 2048000 Samples Acquired
- Flat Shear Layer Assumption
- Background Runs Acquired without Model Present



Analysis Methods Contributors

- University of Adelaide, South Australia (POC: Ric Porteous)
- NASA Langley (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

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

Desired Source
Distribution

BF Source
Distribution



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



Influence Matrix

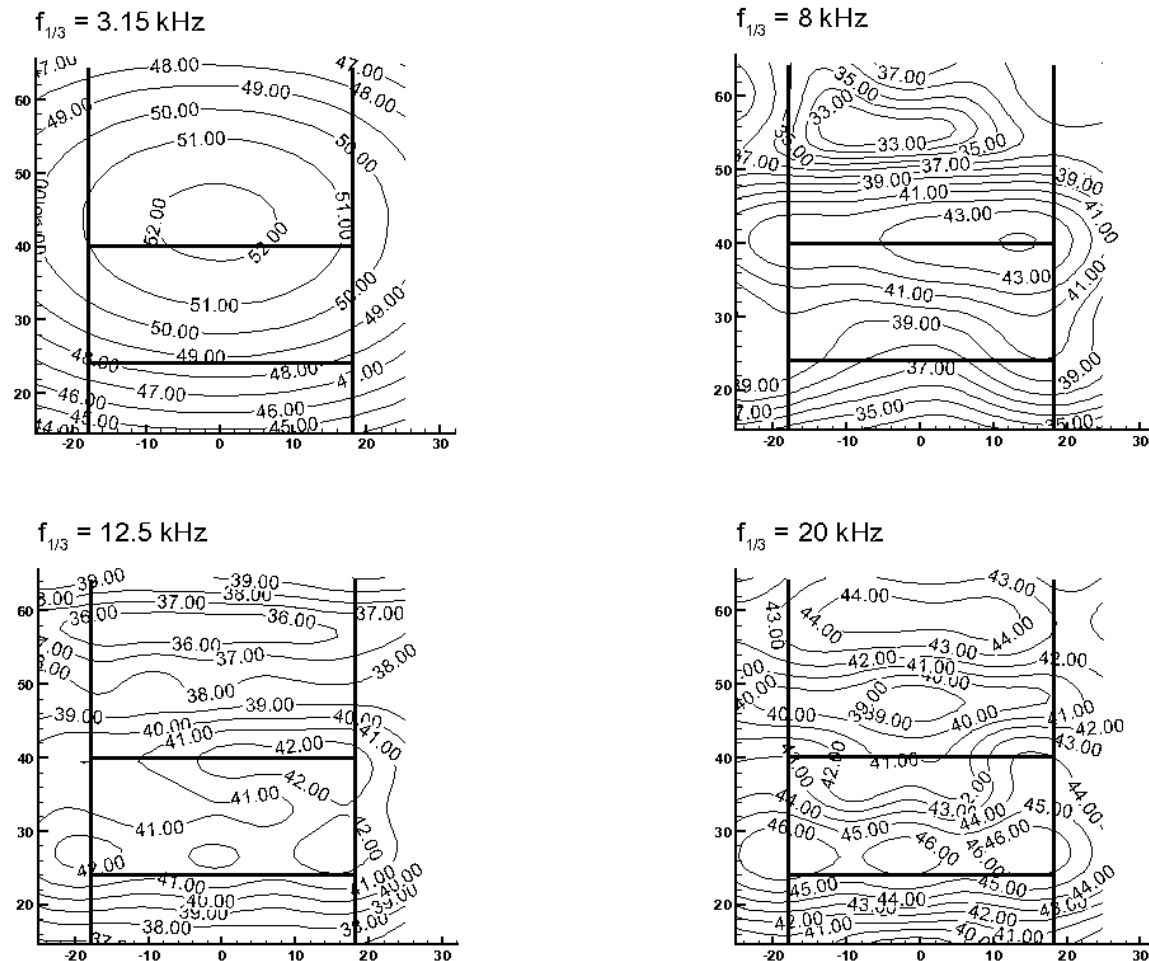


$$X_n^{(i)} = Y_n - \left[\sum_{n'=1}^{n-1} A_{nn'} X_{n'}^{(i)} + \sum_{n'=n+1}^N A_{nn'} X_{n'}^{(i-1)} \right]$$

Gauss-Seidel Solver

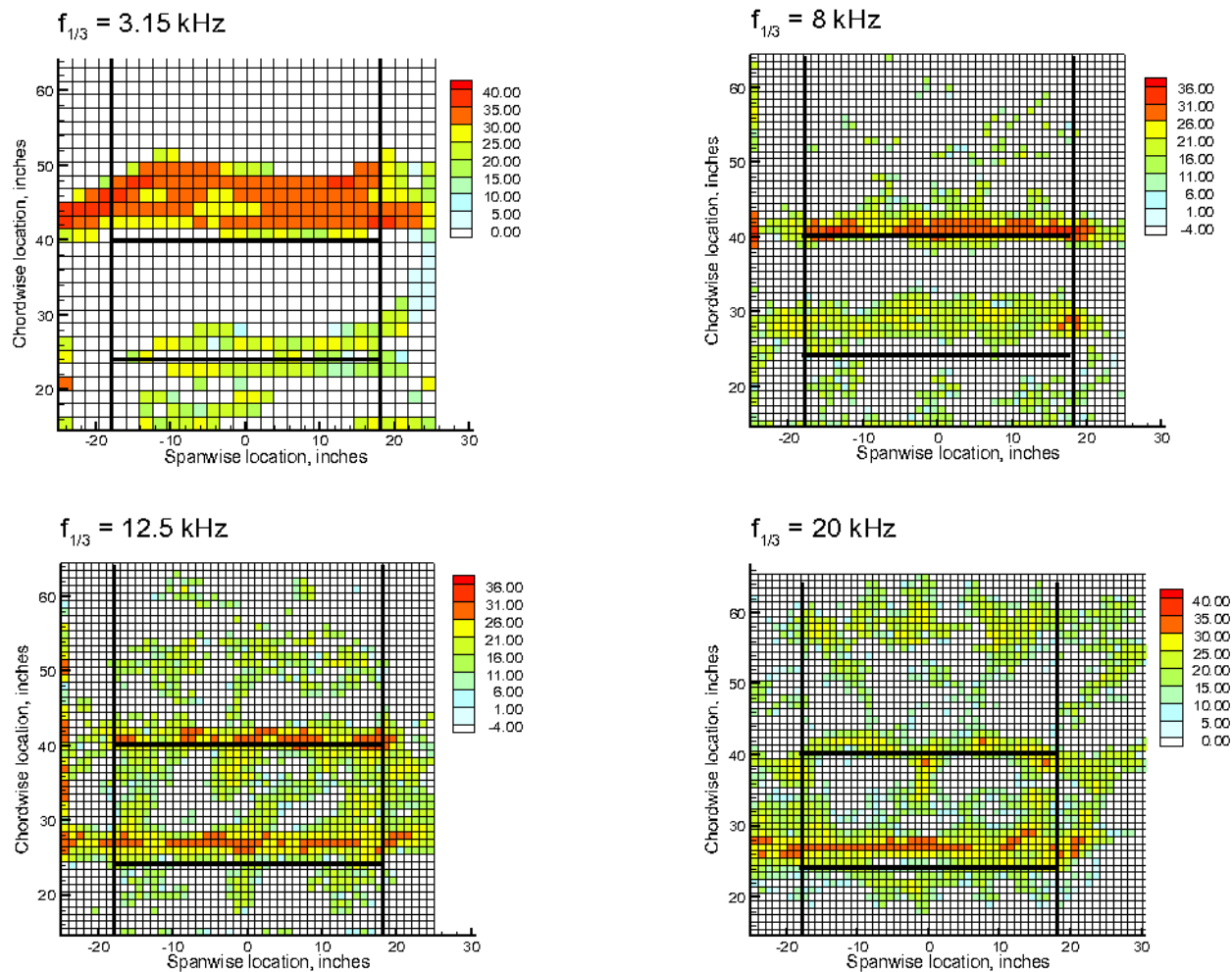
Original DAMAS Analysis Results – 2004

Figure 10 - LE / TE CASE, T1390R15 - T1432R15 (no airfoil), Standard Beamforming



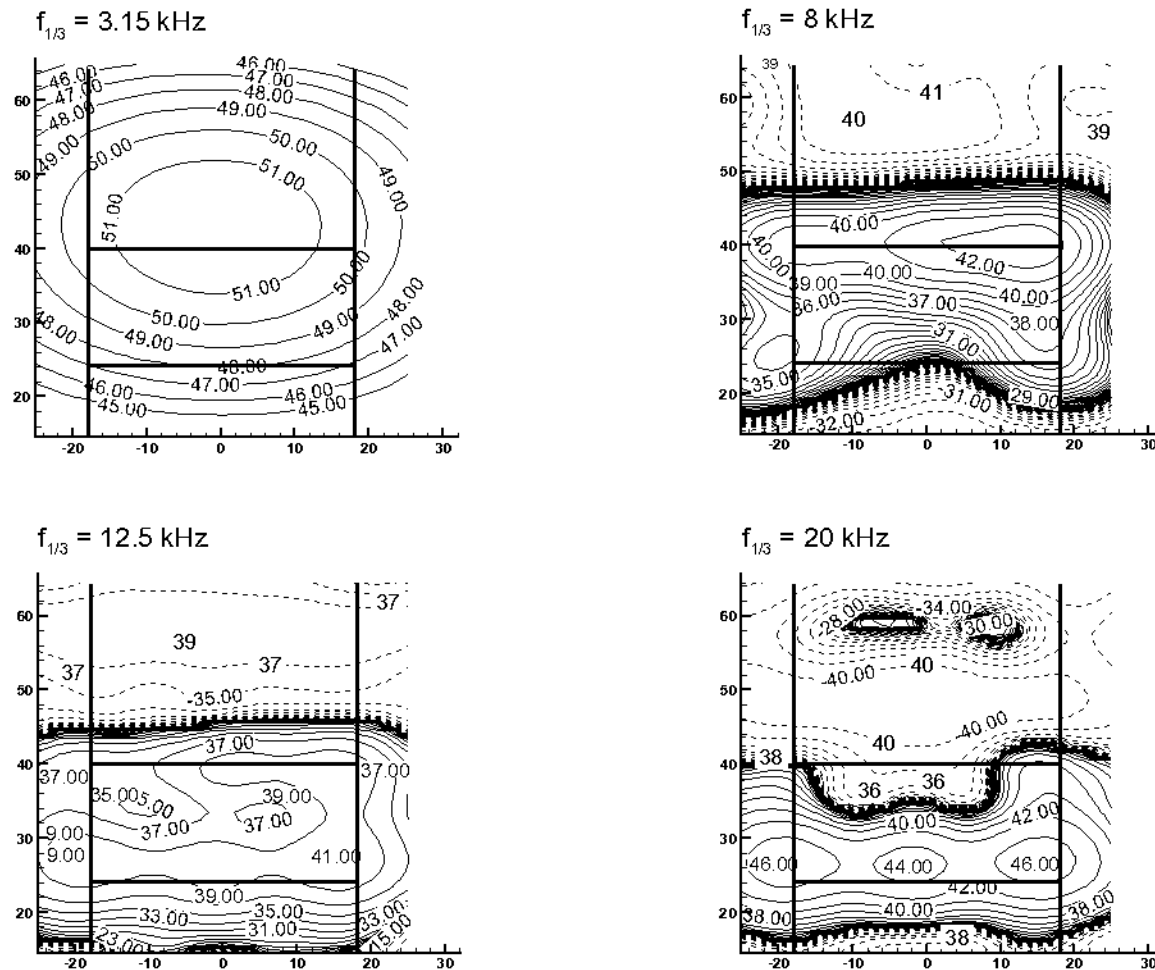
Original DAMAS Analysis Results – 2004

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



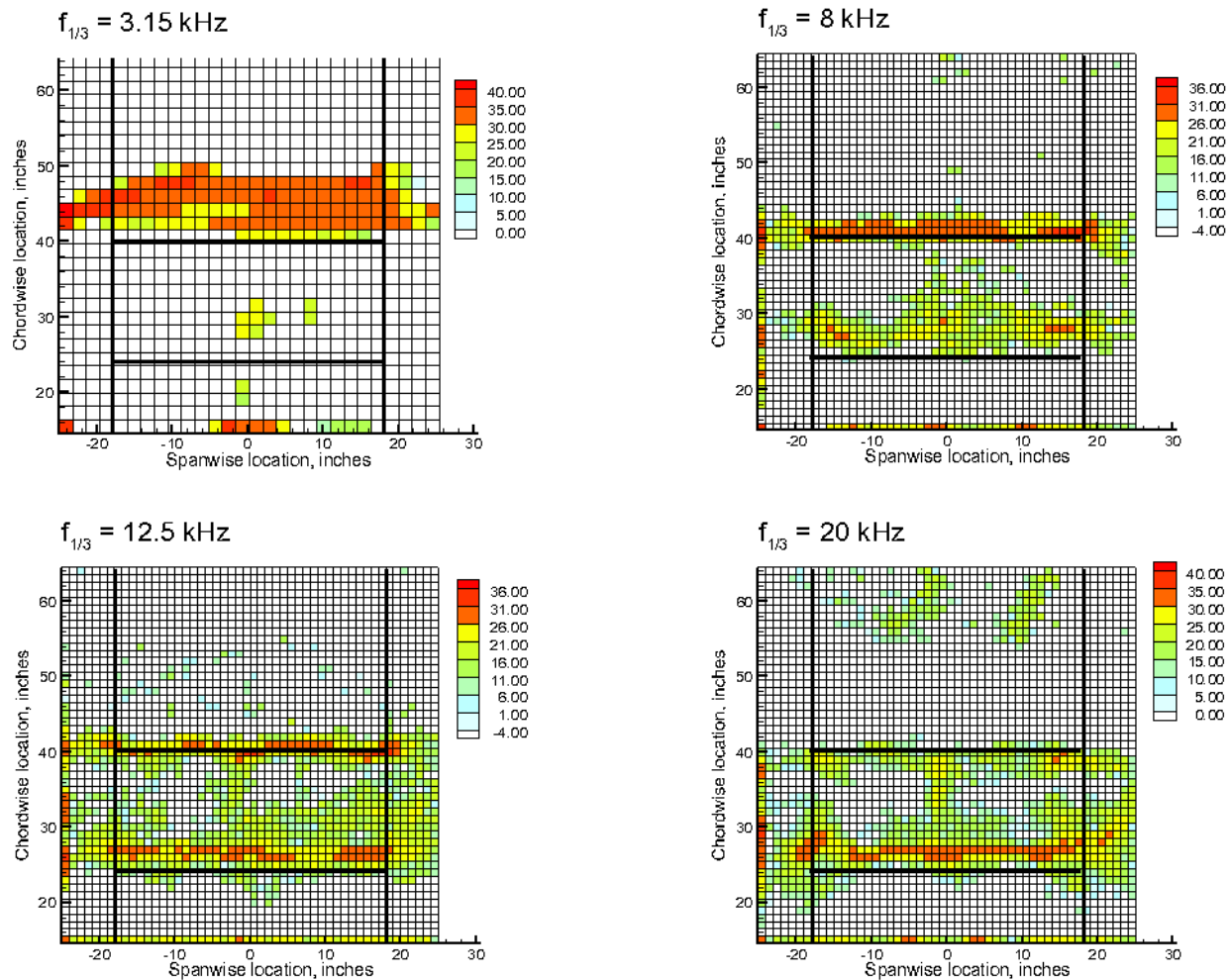
Original DAMAS Analysis Results – 2004

Figure 12 - LE / TE CASE, T1390R15 - T1432R15 (no airfoil), DR Beamforming
(Dashed Lines - Negative p^2 Regions)



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

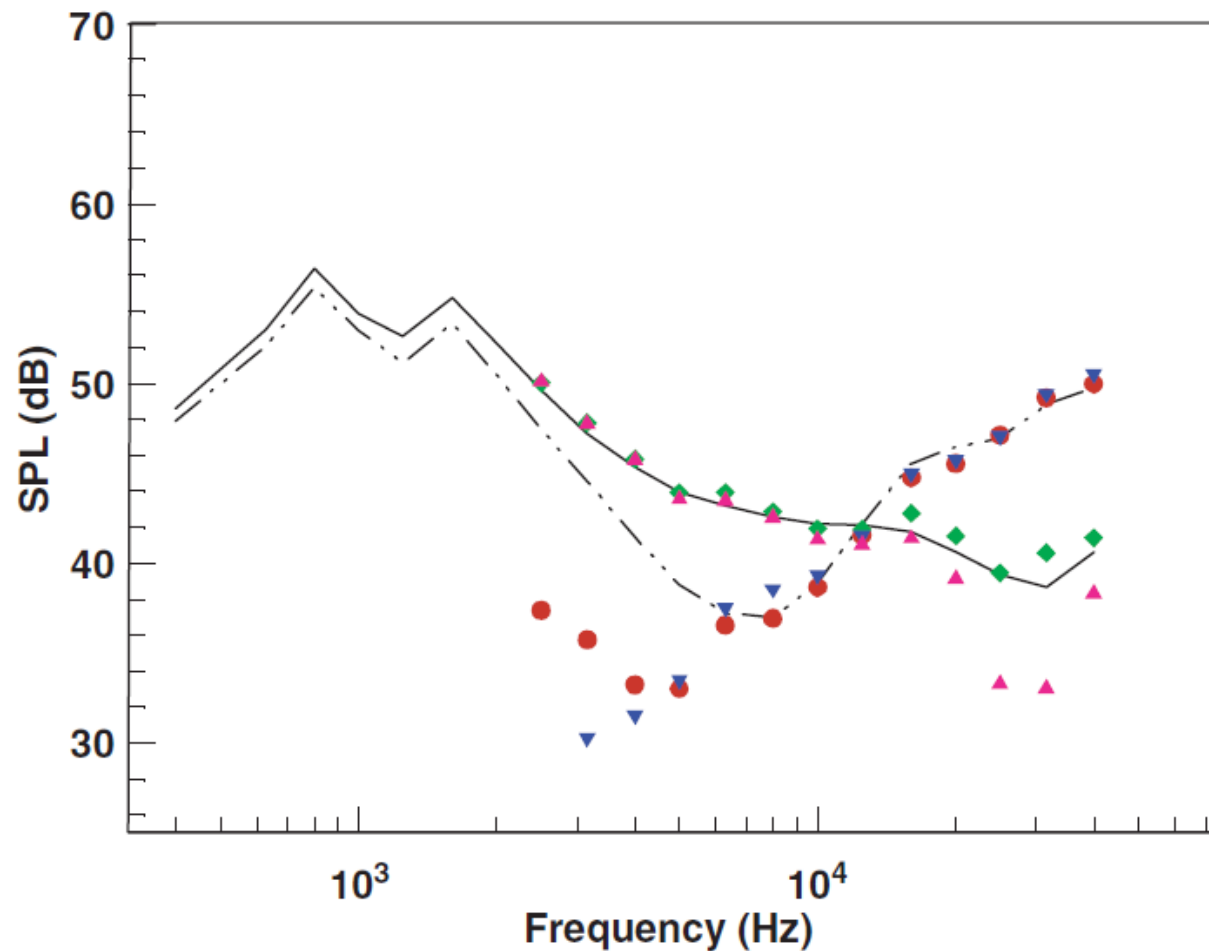
- · - · SADA LE

● 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*)**

Results from Adelaide / UNSW

Analysis Method

To generate the sound maps, conventional beamforming with diagonal removal was performed using Equation 1.

$$Y(\mathbf{x}_t, \omega) = \mathbf{h}(\mathbf{x}_t, \omega)^H \mathbf{W}(\omega) (\mathbf{G})_{diag=0} \mathbf{W}(\omega)^H \mathbf{h}(\mathbf{x}_t, \omega) \quad (1)$$

In Equation 1, $\mathbf{G}$ is the cross-spectral matrix with the background cross-spectral matrix removed, $\mathbf{W}$ is the shading matrix (which was set to unity), M_0 is the number of microphones and

$$h_{i,t} = \frac{1}{M_0} \frac{a_{i,t}}{a_{i,t} a_{i,t}^*} \quad (2)$$

where $h_{i,t}$ denotes the element of the steering vector from the i^{th} microphone to the t^{th} scan grid point. The transfer vector $a_{i,t}$ was given by,

$$a_i(\mathbf{x}_t, \omega) = c \frac{e^{-j\omega t_{t,i}}}{r_t} \quad (3)$$

where

$$c = r_{t,ref} e^{j\omega t_{t,ref}} \quad (4)$$

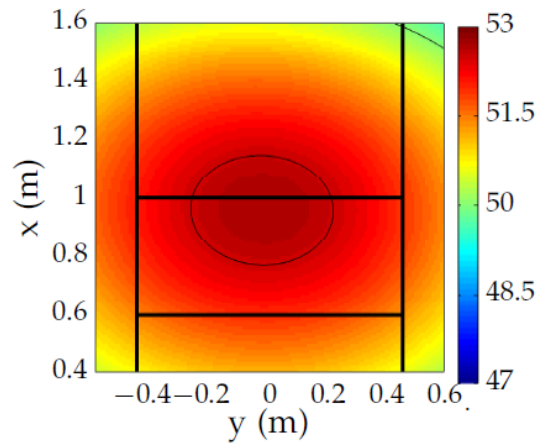
and $t_{t,ref}$ is the emission time from the t^{th} point in the scanning grid to the reference microphone, which in this case is the centre microphone. After Y_t was calculated, the entire map was scaled by $\frac{M_0}{M_0 - 1}$ to account for the loss of power due to diagonal removal.

Results from Adelaide / UNSW Analysis Method

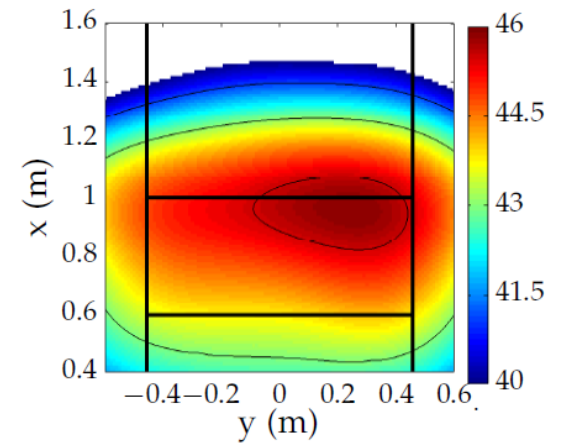
- Shear layer correction – method of Bahr et al. (2011)
- Deconvolution – CLEAN-SC (Sijtsma, 2007), beamwidth = 4 cm
- Spatial Integrations:
 - Beamform integrations – method of Brooks and Humphreys (1999)
 - CLEAN-SC integrations – direct summation of source map

Results from Adelaide / UNSW

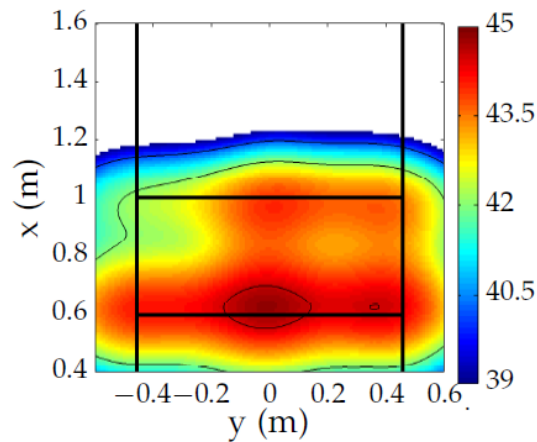
- Conventional Beamforming
- Diagonal Removal
- Background Removal
- 1/3-octave Bands



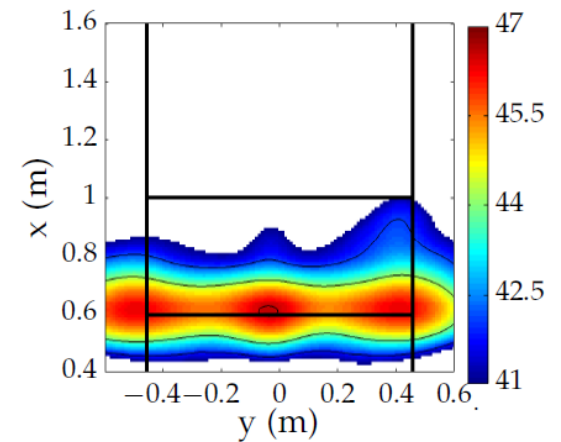
(a) 3150 Hz



(b) 8000 Hz



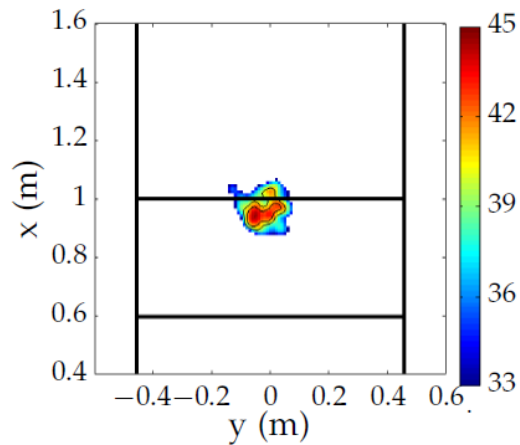
(c) 12500 Hz



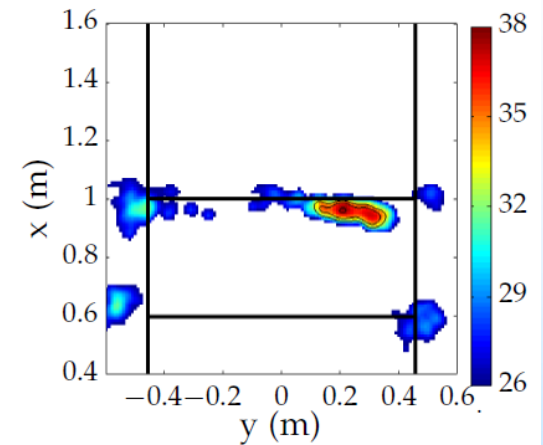
(d) 20000 Hz

Results from Adelaide / UNSW

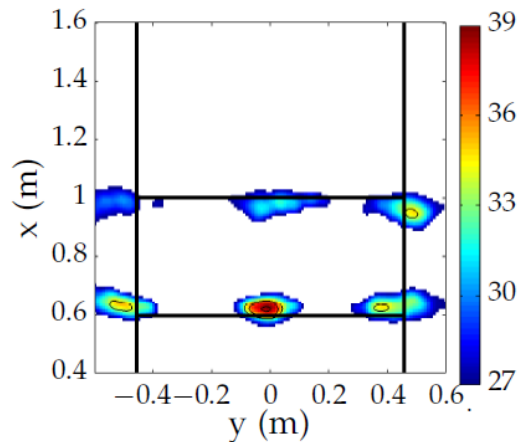
- CLEAN-SC
- Diagonal Removal
- Background Removal
- 1/3-octave Bands



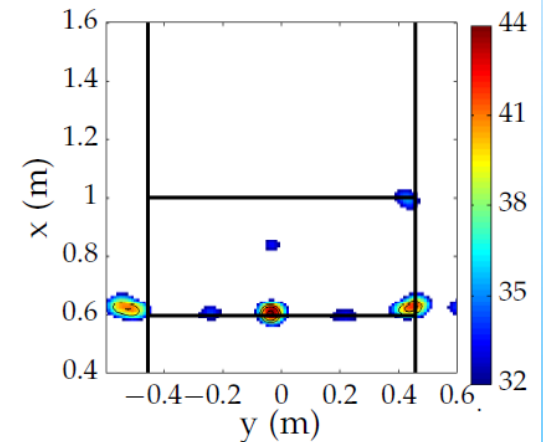
(a) 3150 Hz



(b) 8000 Hz



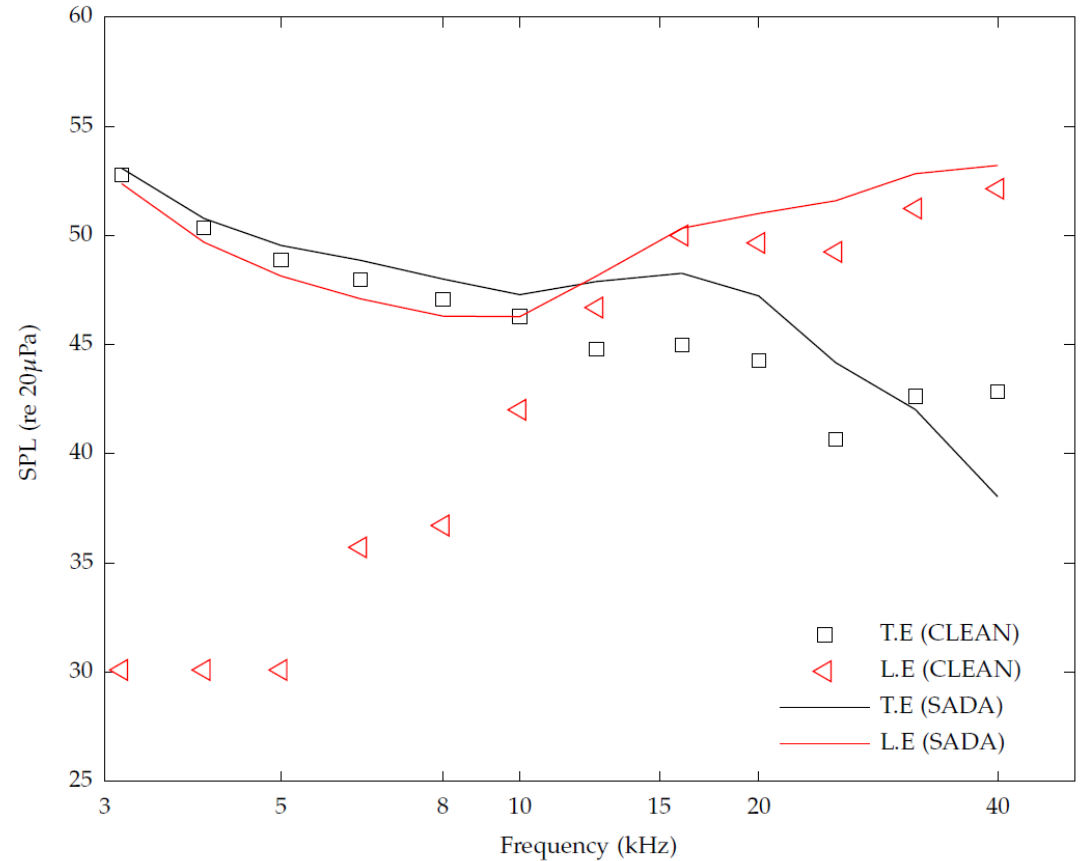
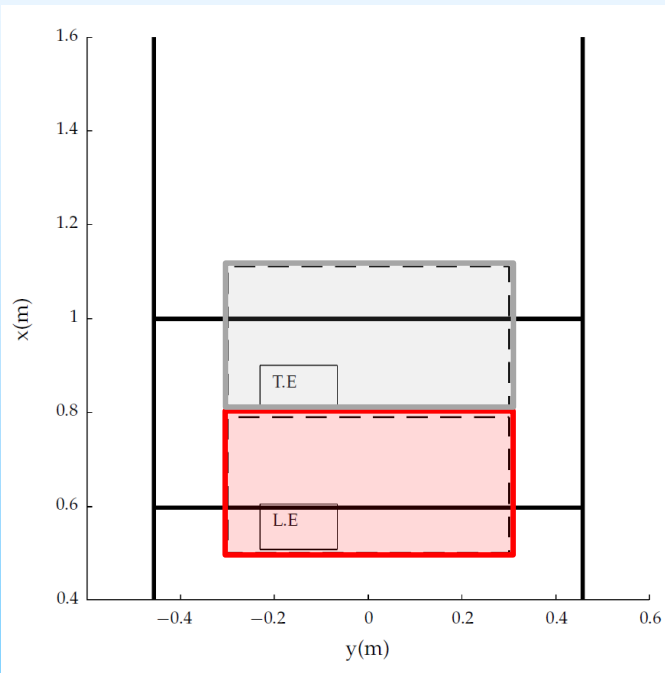
(c) 12500 Hz



(d) 20000 Hz

Results from Adelaide / UNSW

- Spatial Integrations



Results from NASA Langley – 2015

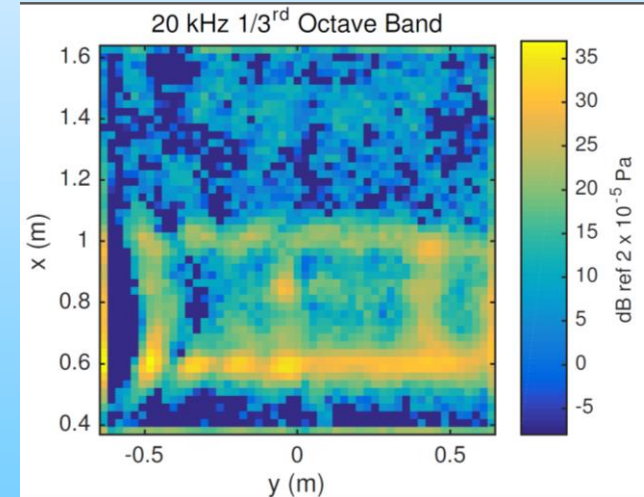
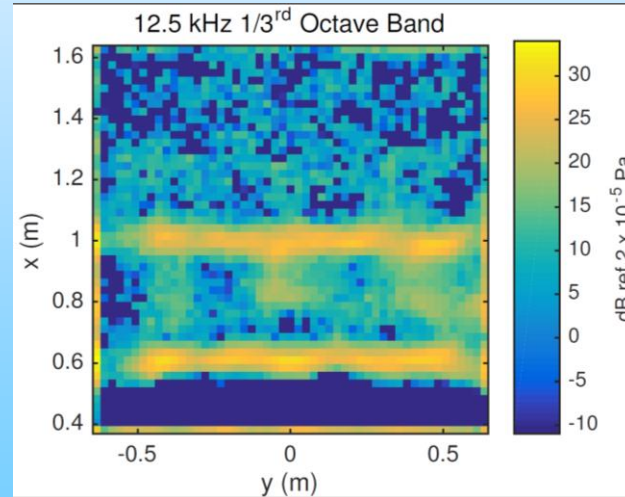
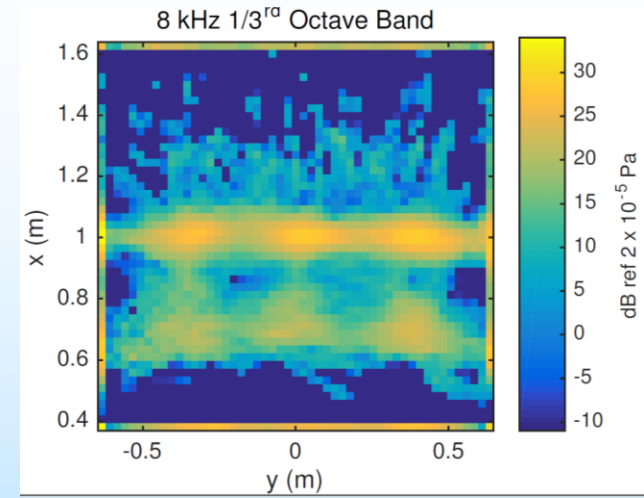
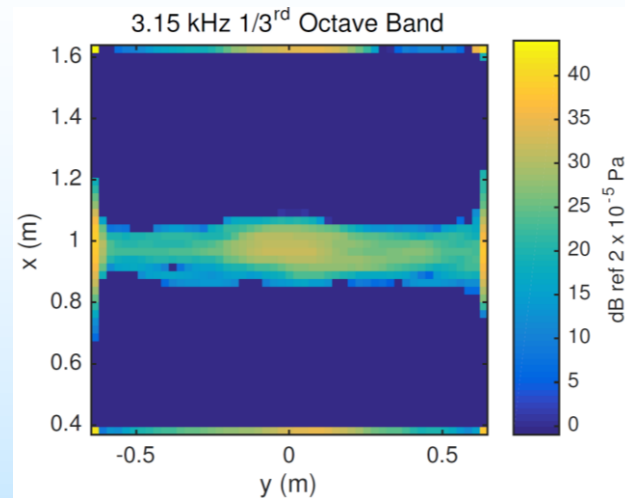
(Christopher Bahr)

Results from NASA Langley – 2015 Analysis Method

- Two methods:
 - Standard DAMAS
 - Jacobi-style implementation of DAMAS
- Diagonal removal performed
- Advanced background subtraction performed (Bahr et al., 2015)
- Shear layer correction (Bahr et al., 2011)
- No microphone weighting

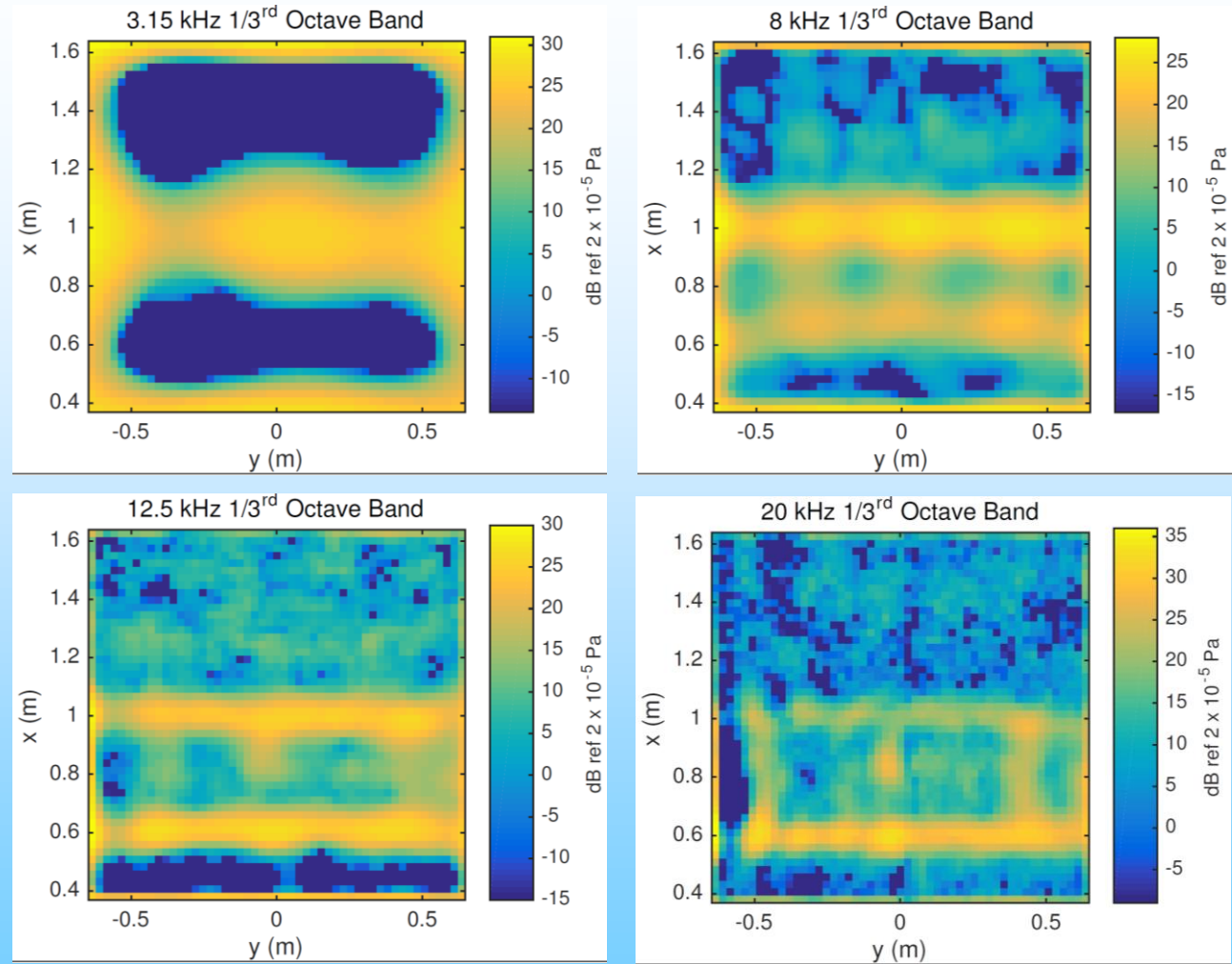
Results from NASA Langley – 2015

- Standard DAMAS
- 200 iterations



Results from NASA Langley – 2015

- Jacobi DAMAS
- 200 iterations



Discussion

