Array Processing in the Near-field

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A non-planar problem

A considerable problem for acoustic localization is that of explosives to a precision of order 10 m.

- current methods allow for ±100 m precision
- localization must be timely (efficient)
- localization must be robust (cluttered environment)

Then current state of the art

- Acoustic localization
  - Efficient & inexpensive

- Data fusion (BAZ)
  - Traditional & commonly used
  - Multiple small microphone arrays
  - Plane-wave assumption (far-field)
  - Multiple back azimuths yield localization

- BAZ is currently fielded & well-tested
  - Nuclear treaty monitoring (CTBTO & SMDC)
  - Civil & military counter-gunfire applications

Then current state of the art

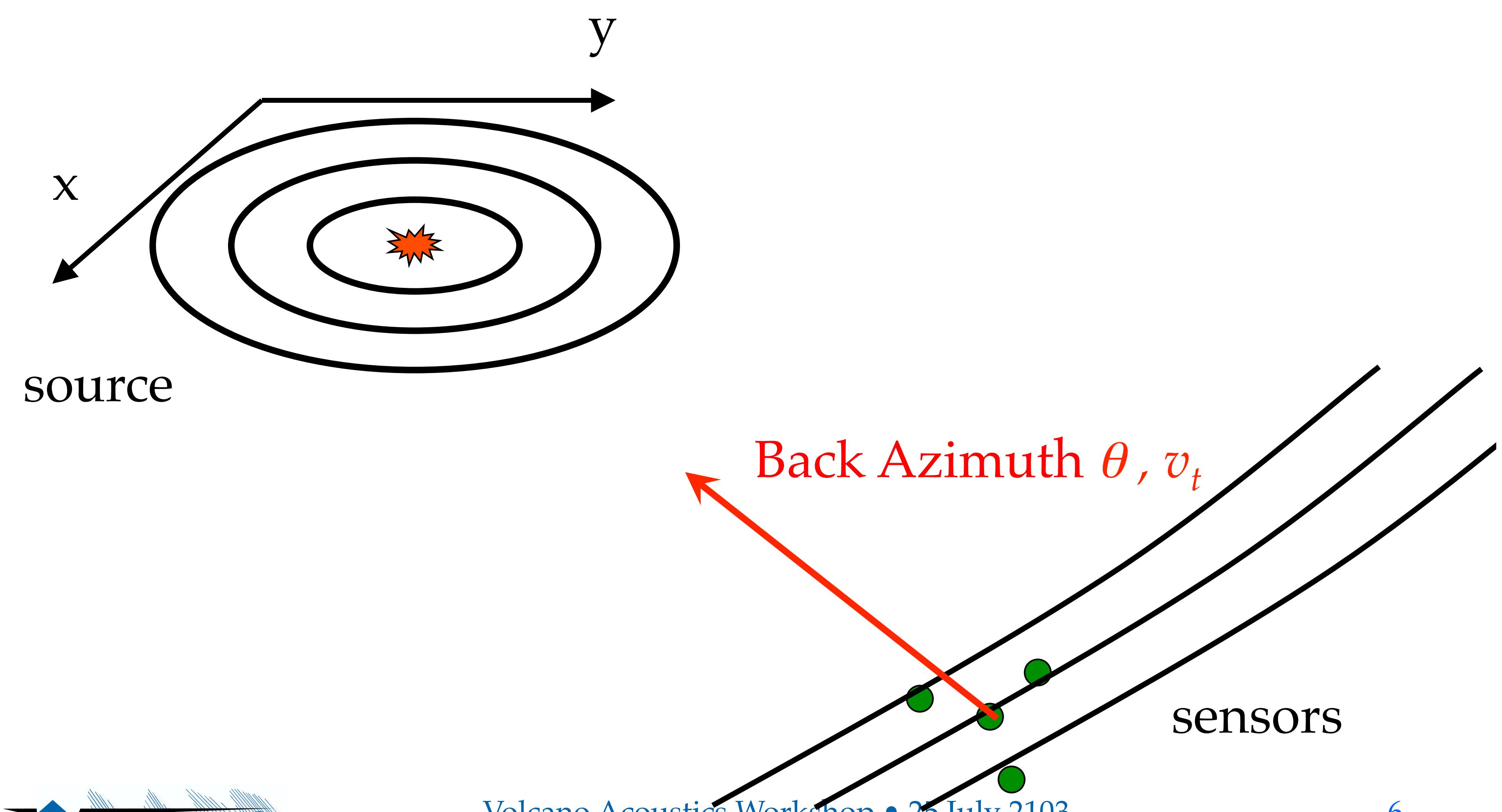
- Acoustics at mid-range
  - Mainstream acoustics: “long-range” ~100 m
  - Nuclear treaty monitoring: “near-field” ~100 km
  - “Mid-range” acoustics ~1-10 km
    - **Problem is not well studied**
  - Spatiotemporal correlation
    - Required for precise localization
    - Is it sufficiently preserved?

What we could do better

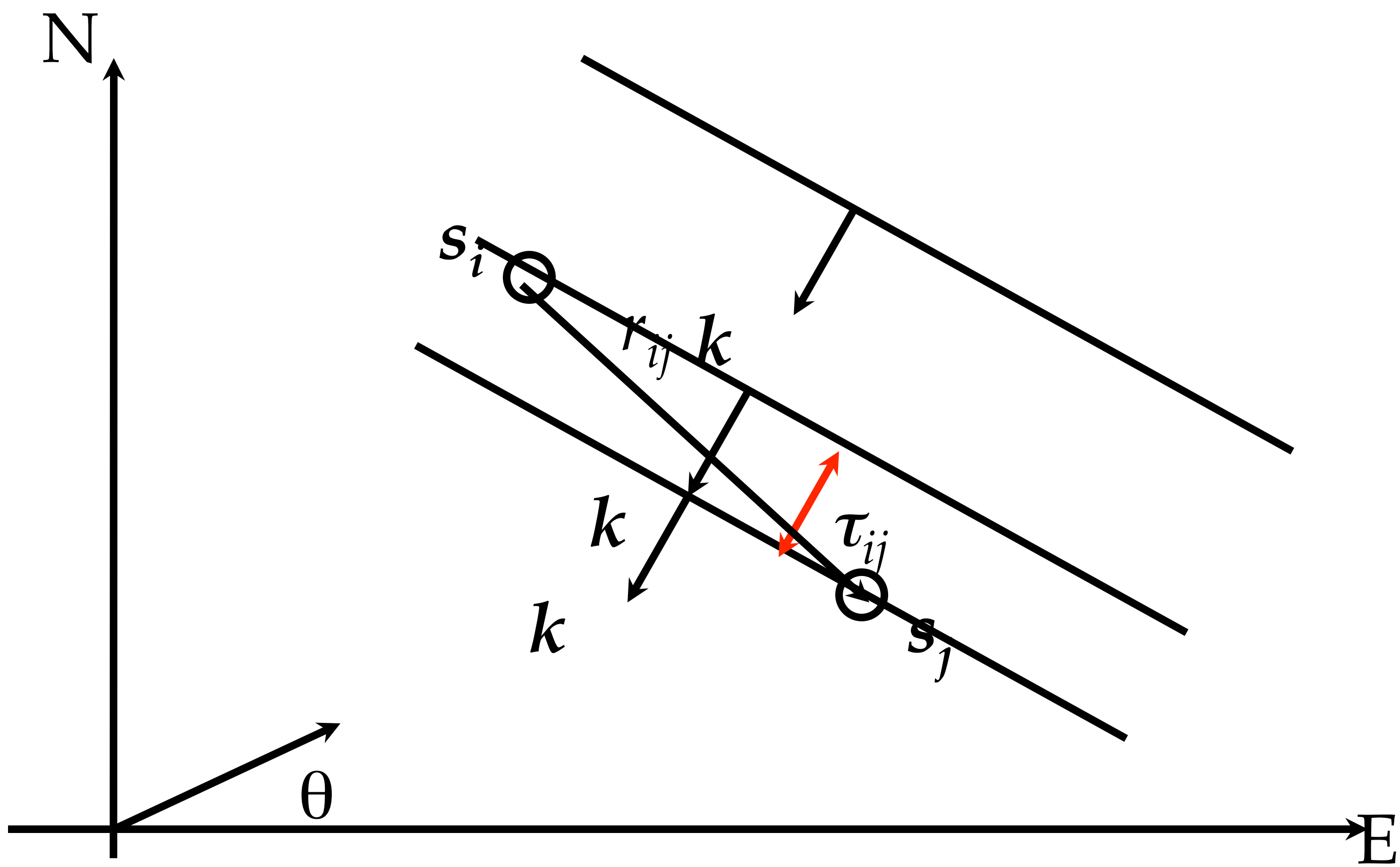
- UAF source locator (srcLoc†)
  - Novel approach using all sensors (meta array)
  - Insensitive to r^{-1} problems (vegetation & terrain)
  - Efficient algebraic seed & optimization solution
  - Insensitive to model assumption violations
  - Infrasound ($f < 16$ Hz) provides advantages
  - Offers *order-of-magnitude* improvement over BAZ

†US Patent 7,746,225

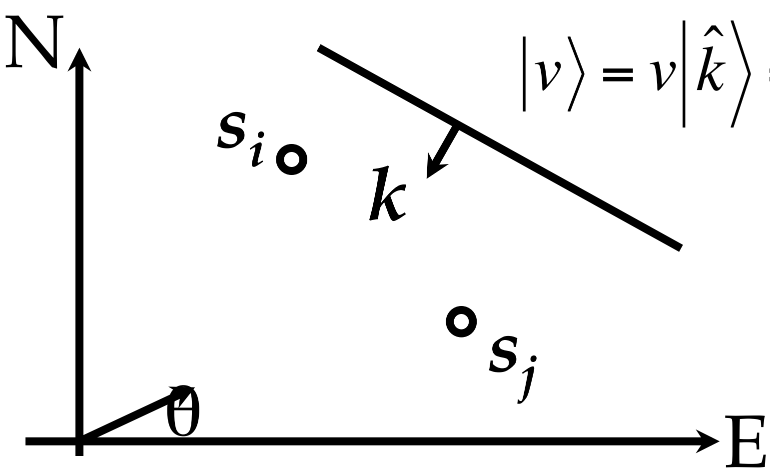
BAZ (plane wave)



Planar arrivals



Planar least squares solution



$$|v\rangle = v|\hat{k}\rangle = v\begin{bmatrix}\cos\theta \\ \sin\theta\end{bmatrix}$$

$$|s\rangle = |v\rangle / v^2$$

$$|\tau\rangle = X'|s\rangle + |\varepsilon_\tau\rangle$$

$$|s\rangle = (XX')^{-1} X|\tau\rangle$$

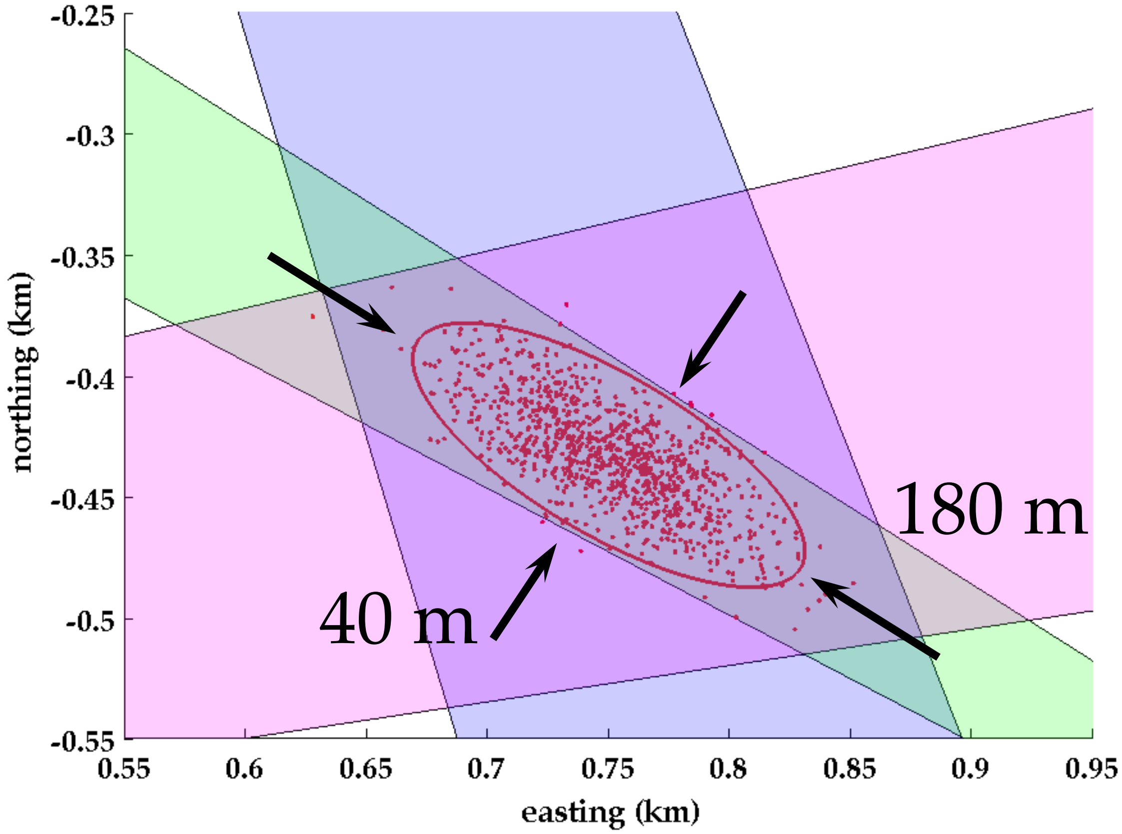
$$\tau_{ij} = \langle r_{ij}|\hat{k}\rangle / v \qquad |r_{ij}\rangle = \begin{bmatrix} x_j - x_i \\ y_j - y_i \end{bmatrix}$$

$$\langle\tau| = \begin{bmatrix}\tau_{12} & \tau_{13} & \tau_{14} & \cdots & \tau_{N-1,N}\end{bmatrix}$$

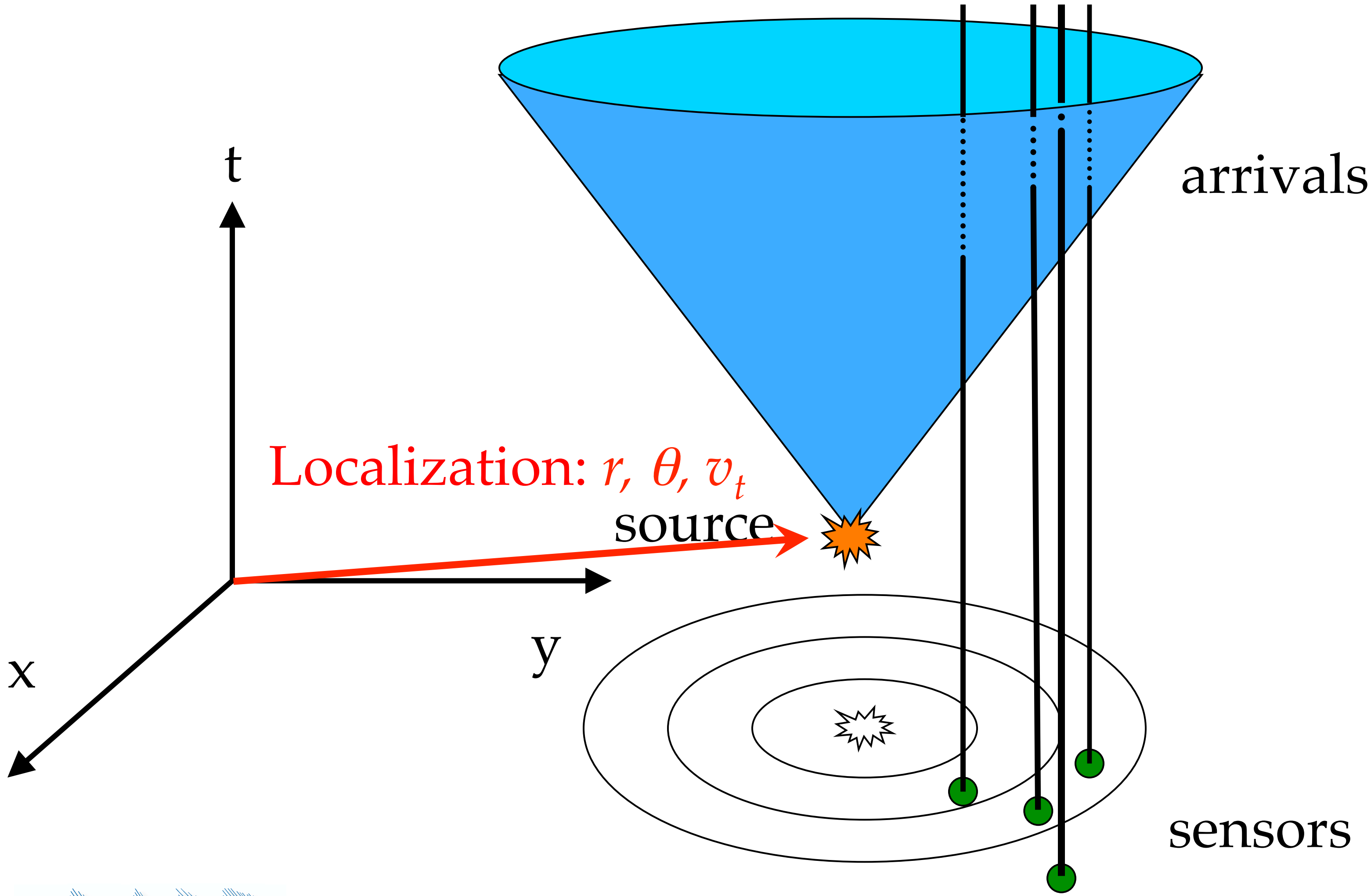
$$X = \begin{bmatrix}|r_{12}\rangle & |r_{13}\rangle & |r_{14}\rangle & \cdots & |r_{N-1,N}\rangle\end{bmatrix}$$

- Least squares solution
- Estimates of v, θ, & ϕ

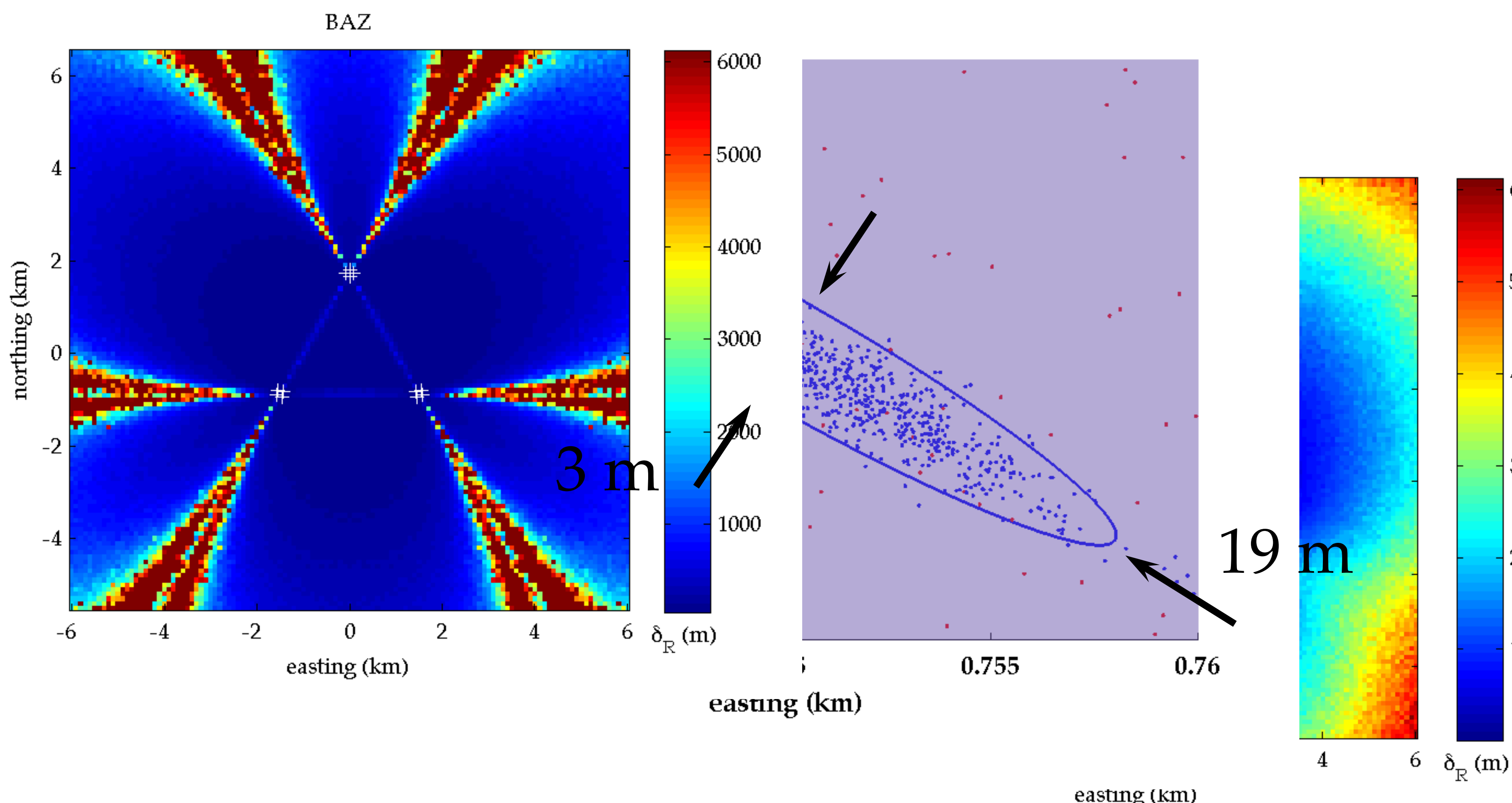
BAZ simulation



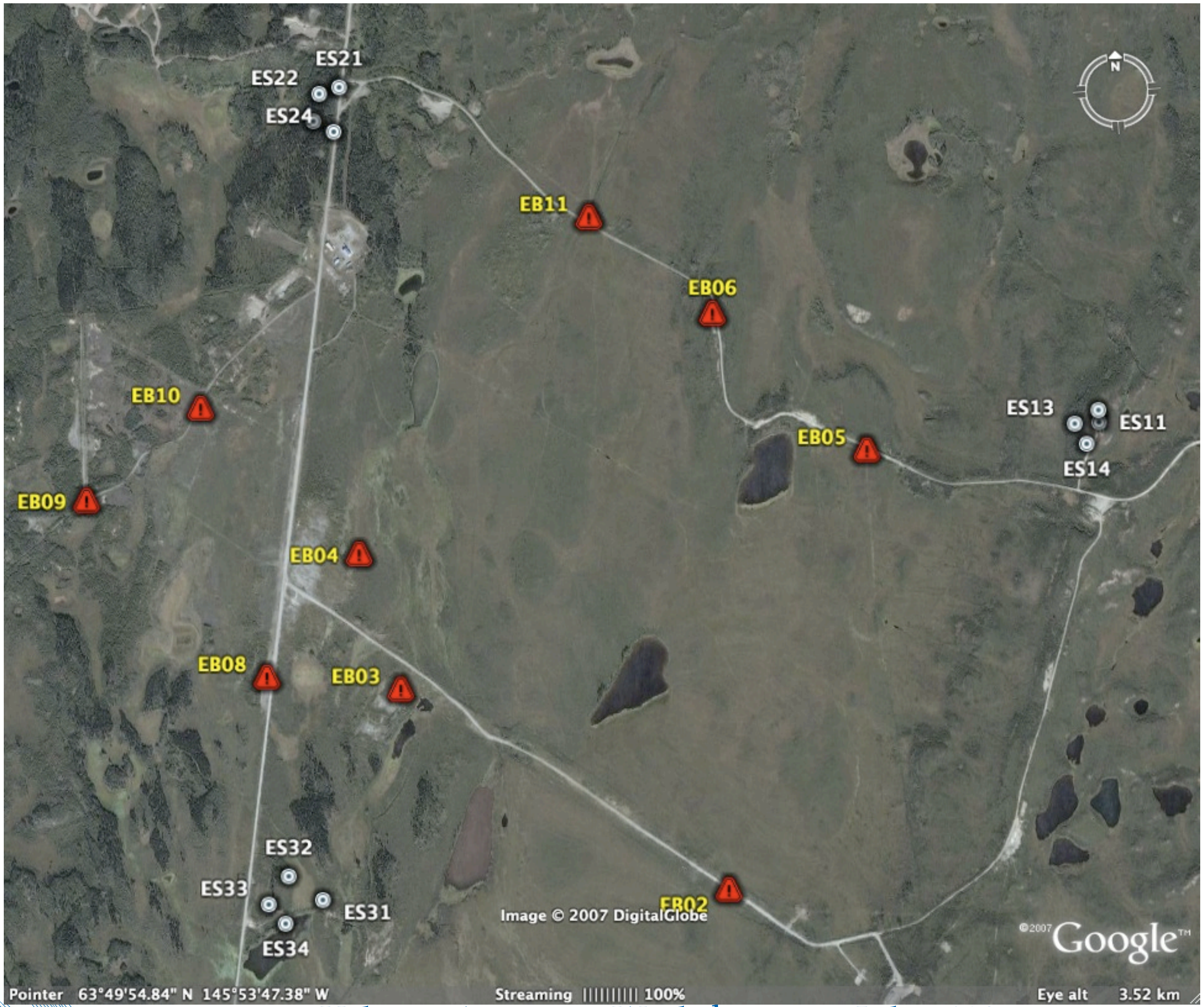
srcLoc (spacetime approach)



BAZ vs. srcLoc simulation



ELVIS: Experimental site

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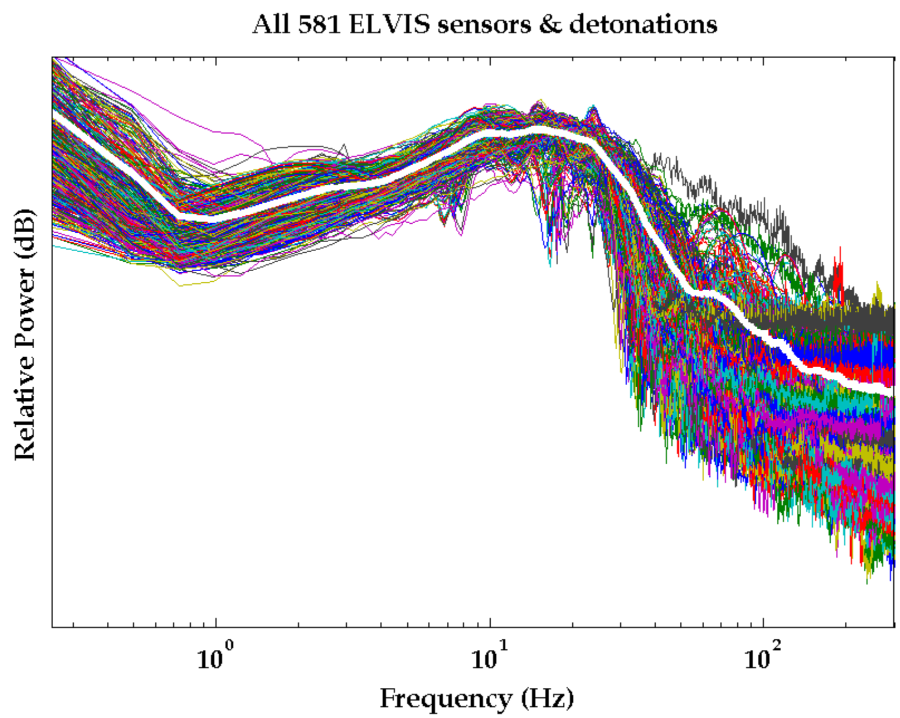
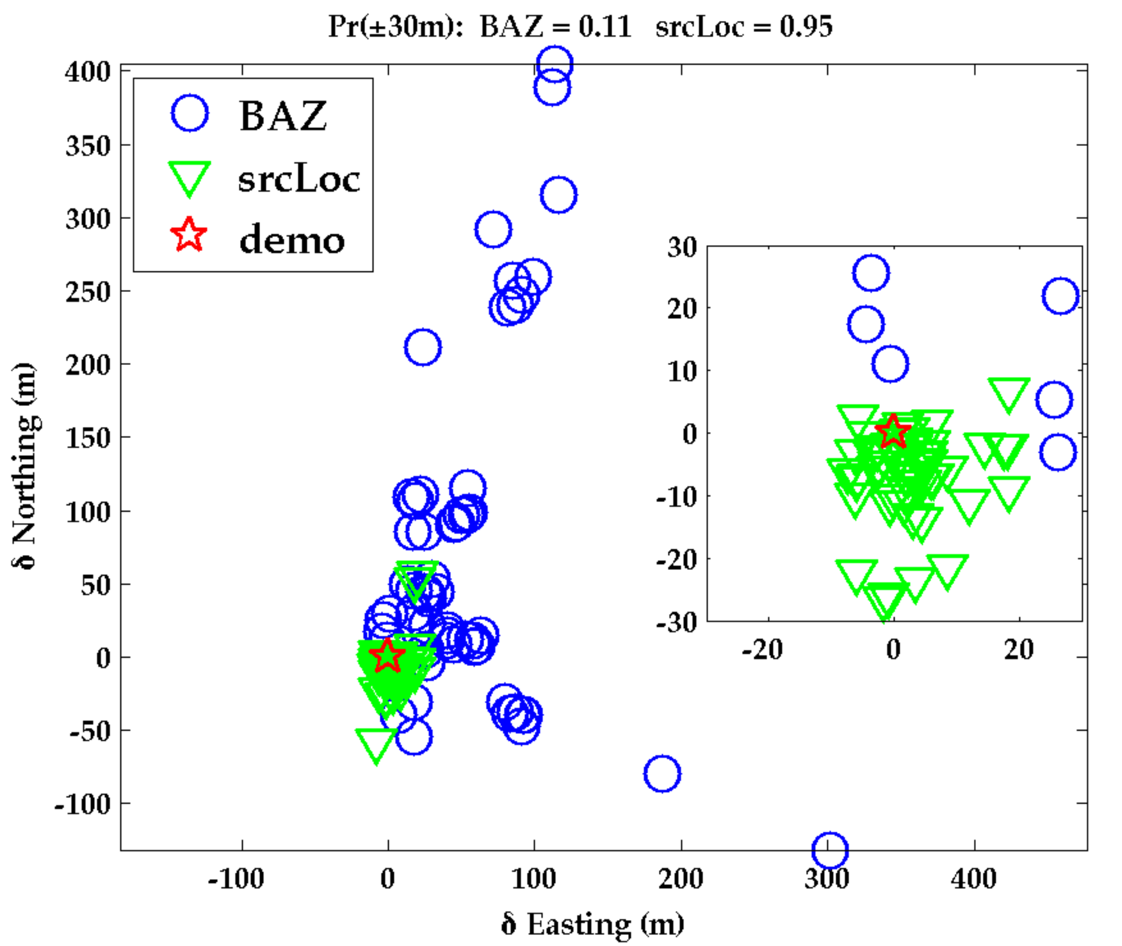
USB DATA LOGGER
Flash Voyager GT
GPS LOCK
ON
OFF
RUN/ERR
STOP
SAFE
+3.3
ANT
POWER
+5.0

Acoustic spectra



Normalized ELVIS results



Honest evaluation

- Verified theoretical performance of srcLoc algorithm (precision to ~10 m)
- UAF srcLoc outperforms BAZ technique by an order of magnitude, on average
- For sources outside meta-array, performance ratio falls off slightly (e.g., from 10:1 to 3:1)
- Testing done under near-ideal conditions (clutter, wind, structures)

Geophysical Institute, UAF
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どうもありがとうございます。

- Volcano applications
  - Talk to Colin Rowell about 3D localization of jetting
  - Fumerole activity detection
  - Precise BAZ with elevated sources
  - Network- vs. array-deployment
- Contact info: caszuberla@alaska.edu