Enhancing the sensitivity of the IMS Infrasound Network using Balloon-Born

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Overview

What new capabilities could balloon-borne sensors bring to existing infrasound monitoring programs?

Advantages:

- No wind noise
- Greater detection range
- Cross inaccessible regions

Drawbacks:

- Constantly moving
- Limited duration
- Large array aperture

Two case studies: SISE/USIE and Heliotrope

SISE/USIE

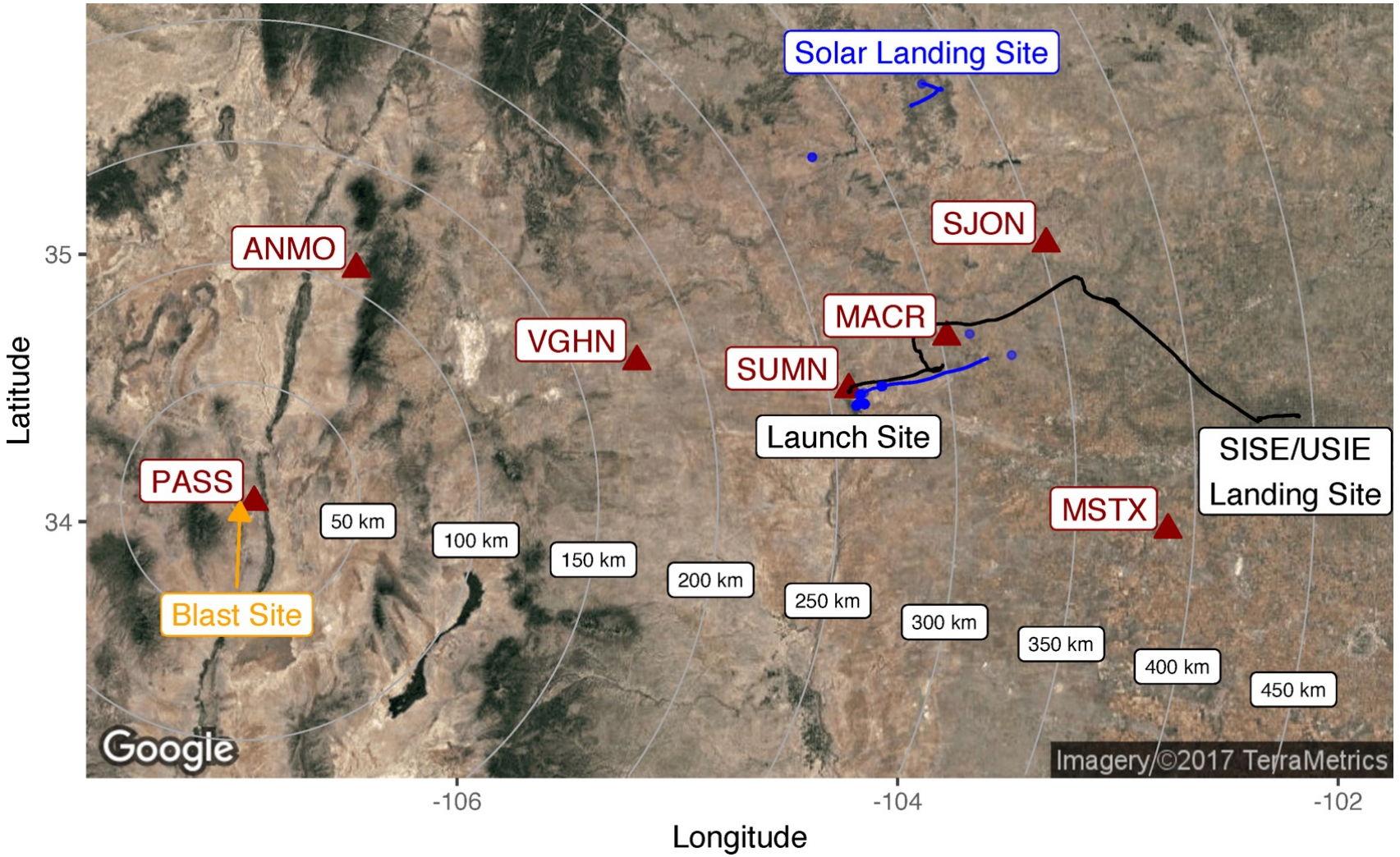
Stratospheric Infrasound Sensitivity Experiment/UNC-Sandia Infrasound Experiment

- Infrasound microphones on NASA helium balloon (34 km asl) and UNC solar hot air balloon (15 km asl)
- Ground infrasound stations in balloon flight path
- Three 1000 kg TNT equivalent surface explosions for ground truth

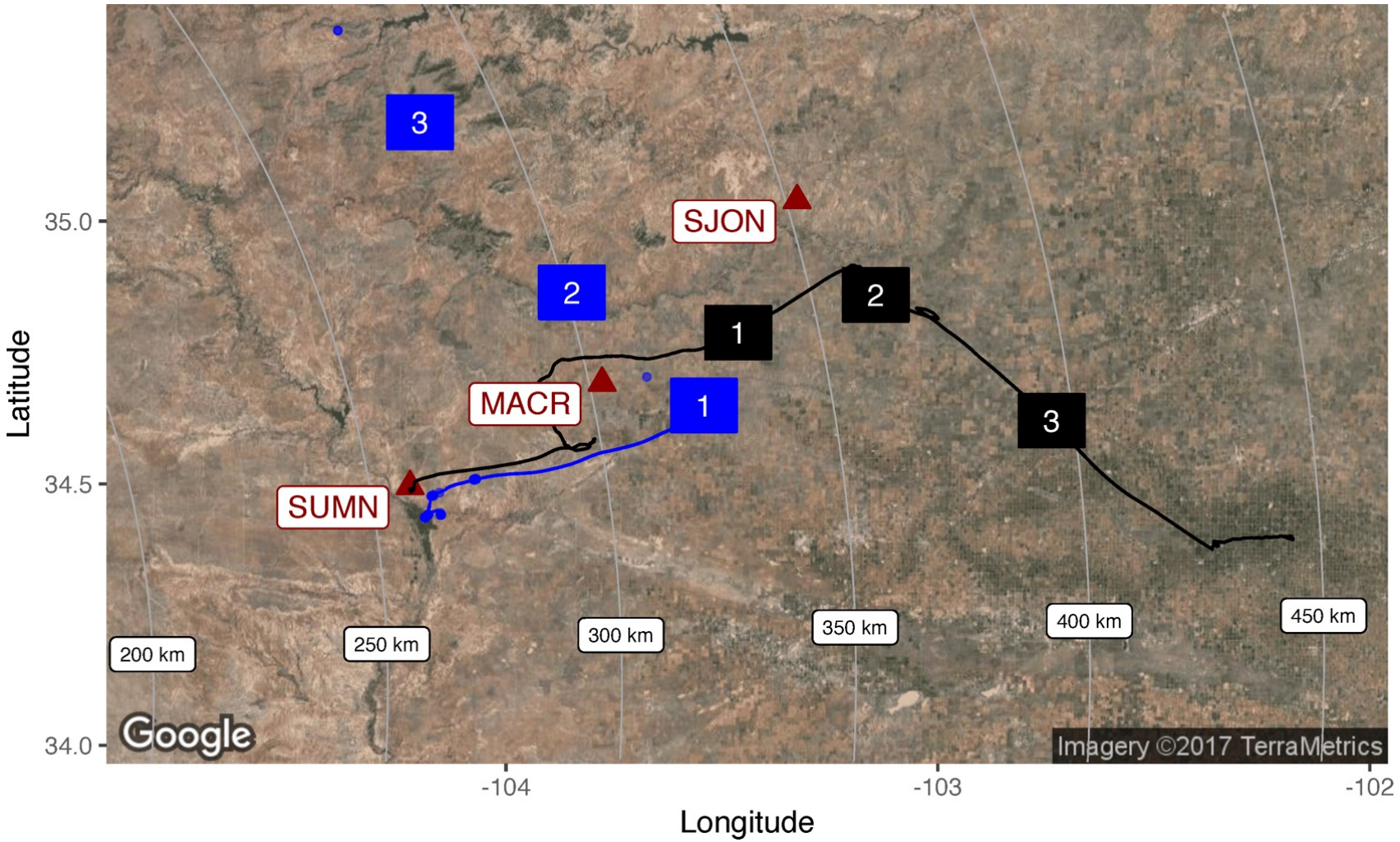
Objective: Determine sensitivity of balloon-borne vs. ground microphones to impulsive acoustic events

A collaboration between Southwest Research Institute, Sandia National Laboratories, and the University of North Carolina at Chapel Hill

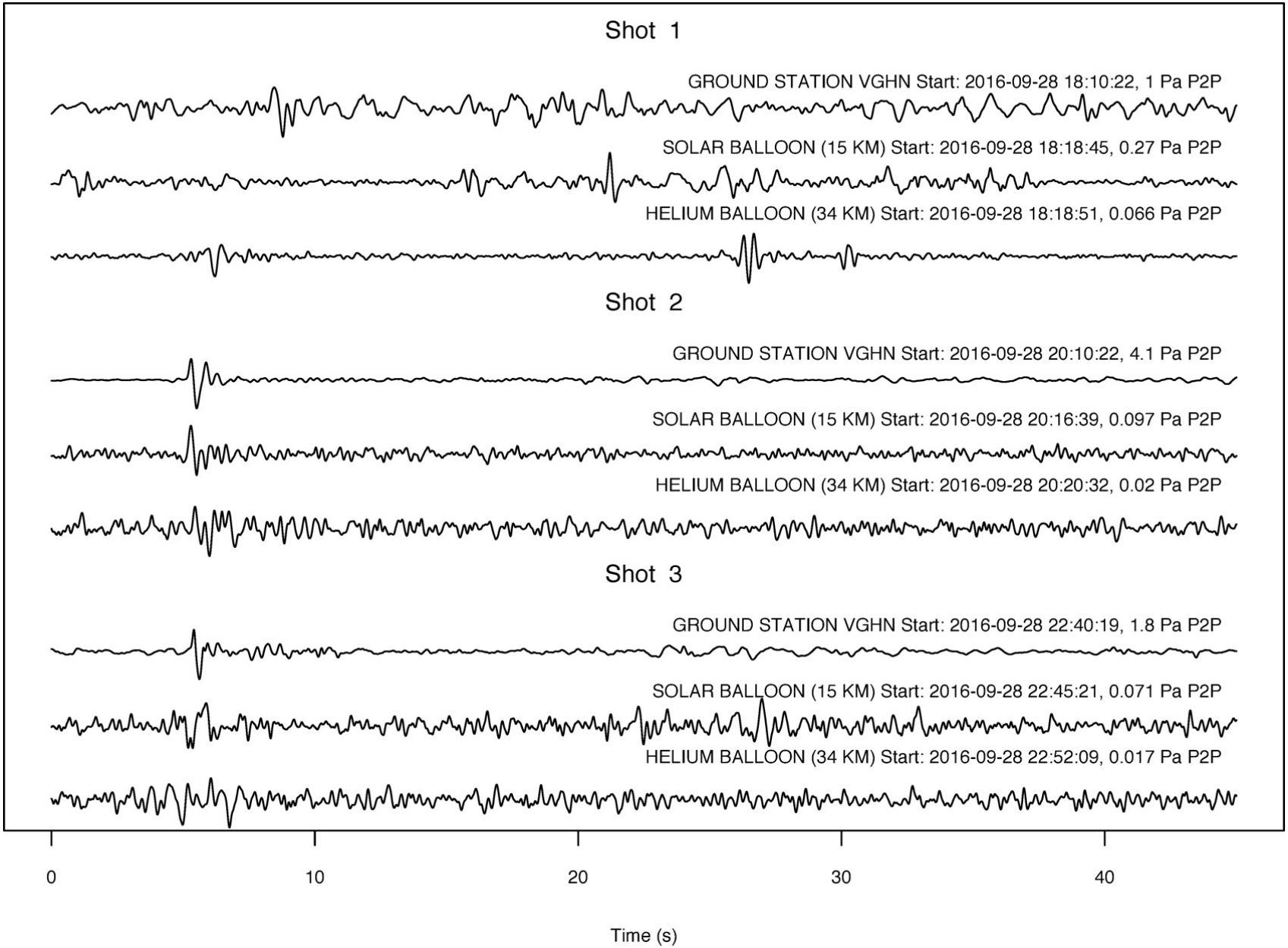
SISE/USIE: Big Picture



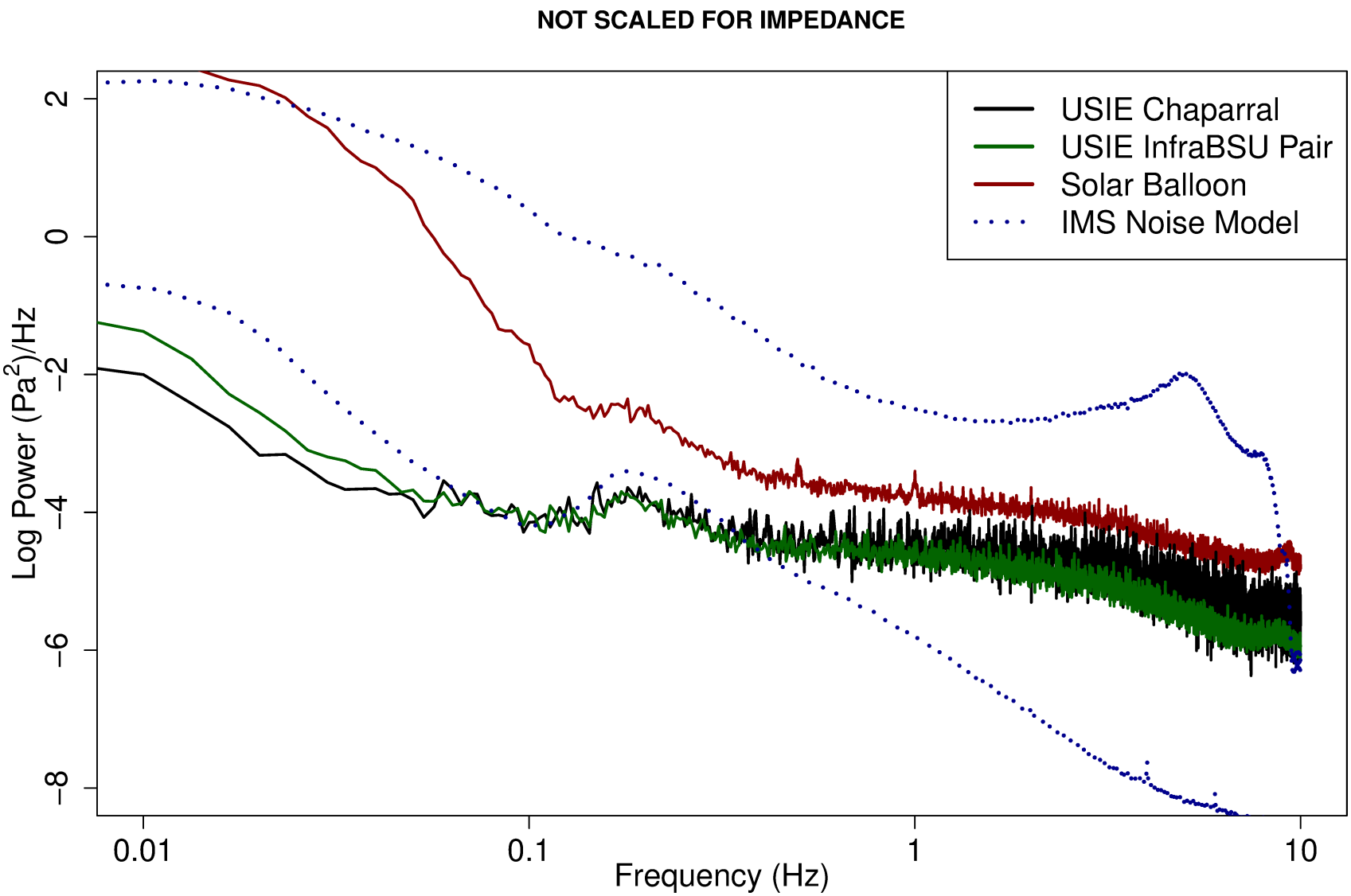
SISE/USIE: Sensor Locations at Shots



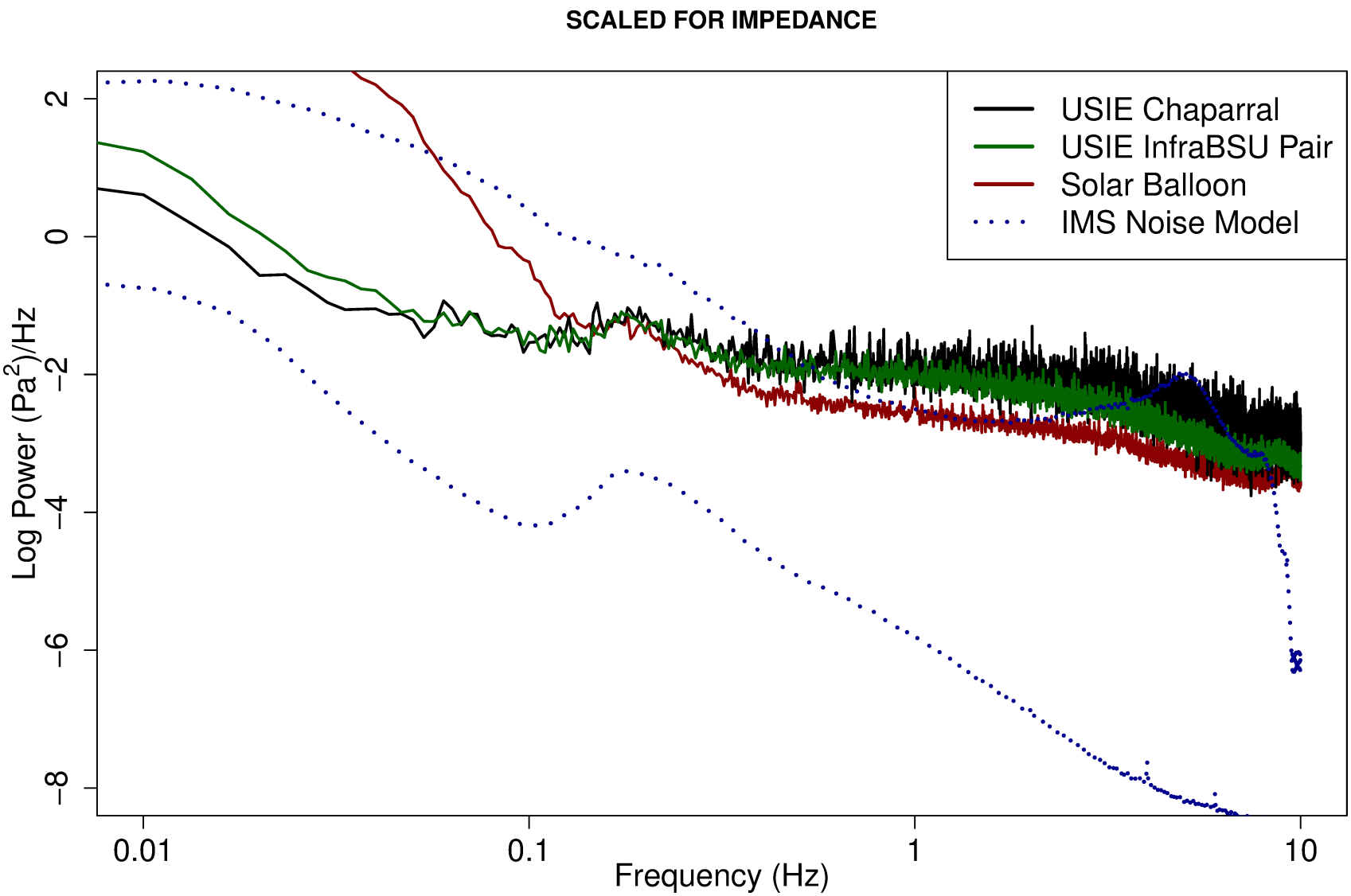
Waveforms


Shot 1
GROUND STATION VGHN Start: 2016-09-28 18:10:22, 1 Pa P2P
SOLAR BALLOON (15 KM) Start: 2016-09-28 18:18:45, 0.27 Pa P2P
HELIUM BALLOON (34 KM) Start: 2016-09-28 18:18:51, 0.066 Pa P2P
Shot 2
GROUND STATION VGHN Start: 2016-09-28 20:10:22, 4.1 Pa P2P
SOLAR BALLOON (15 KM) Start: 2016-09-28 20:16:39, 0.097 Pa P2P
HELIUM BALLOON (34 KM) Start: 2016-09-28 20:20:32, 0.02 Pa P2P
Shot 3
GROUND STATION VGHN Start: 2016-09-28 22:40:19, 1.8 Pa P2P
SOLAR BALLOON (15 KM) Start: 2016-09-28 22:45:21, 0.071 Pa P2P
HELIUM BALLOON (34 KM) Start: 2016-09-28 22:52:09, 0.017 Pa P2P
0
10
20
30
40
Time (s)

Spectra: Unscaled



Spectra: Scaled



Heliotrope

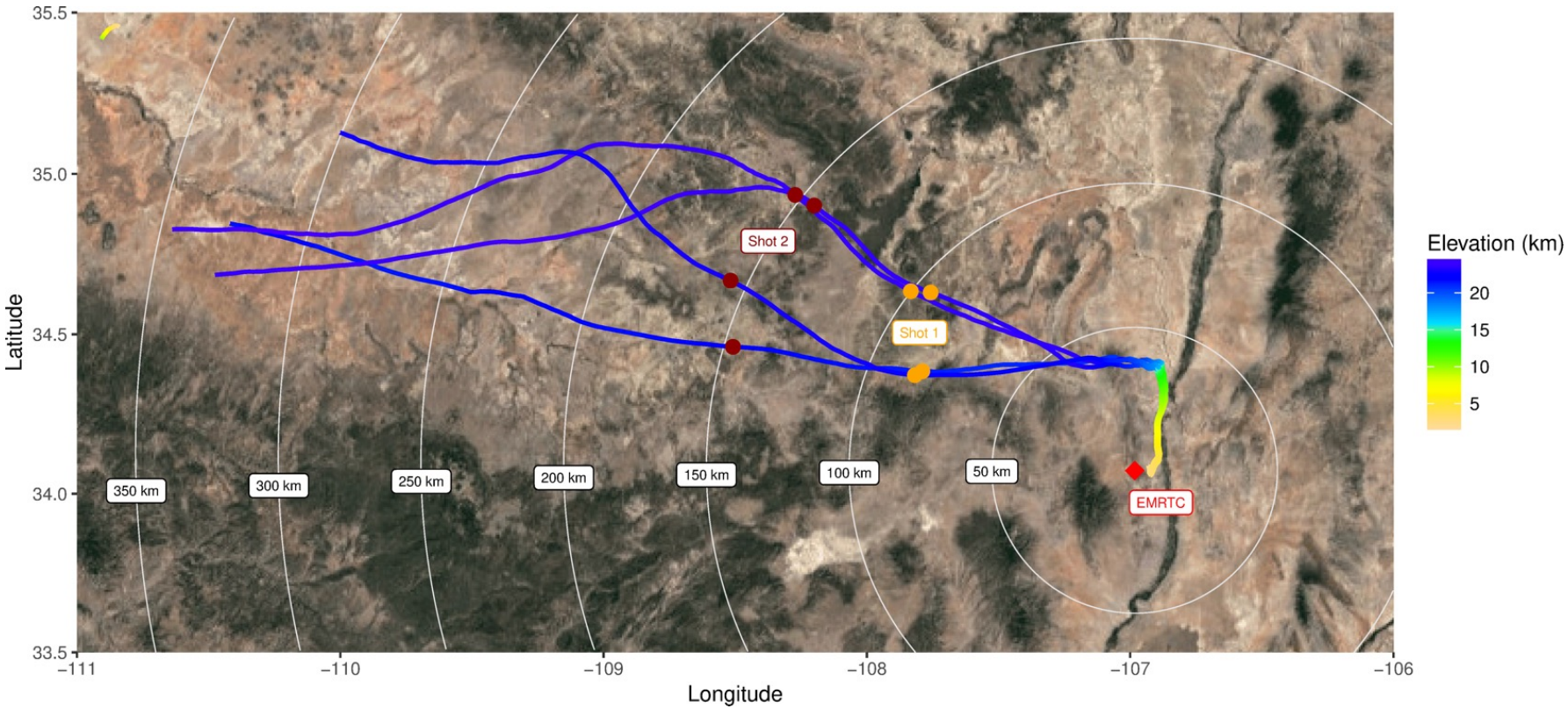
Evaluating the Capability of High-Altitude Infrasound Platforms to Cover Gaps in Existing Networks

- Gem infrasound loggers on solar hot air balloons
- Four independent stations
- Elevation 20-24 km
- Two 800 kg TNT ground blasts

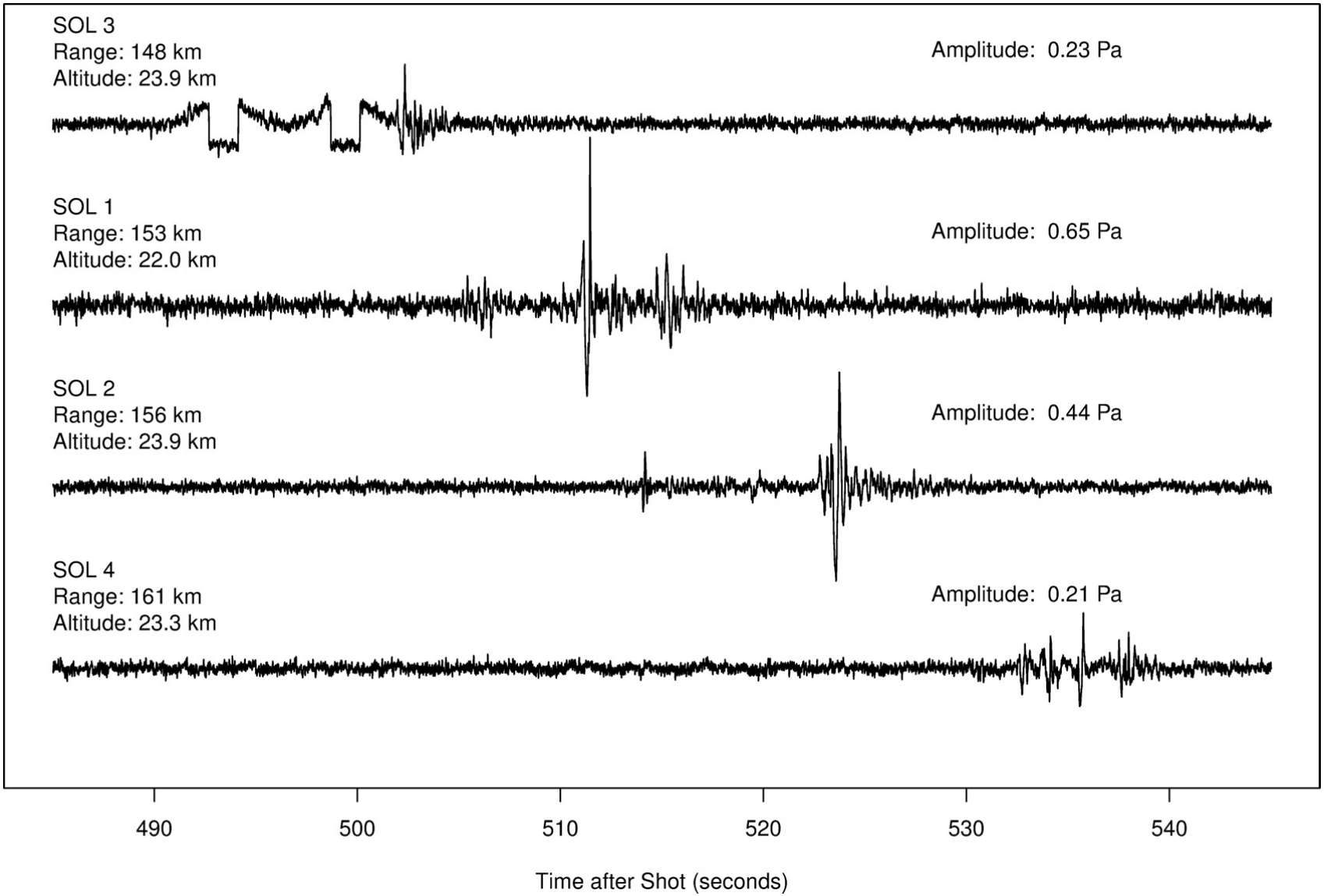
Objective: create a free flying acoustic network.

A Sandia LDRD Express project.
Flight photo courtesy Guide Star Engineering, LLC.

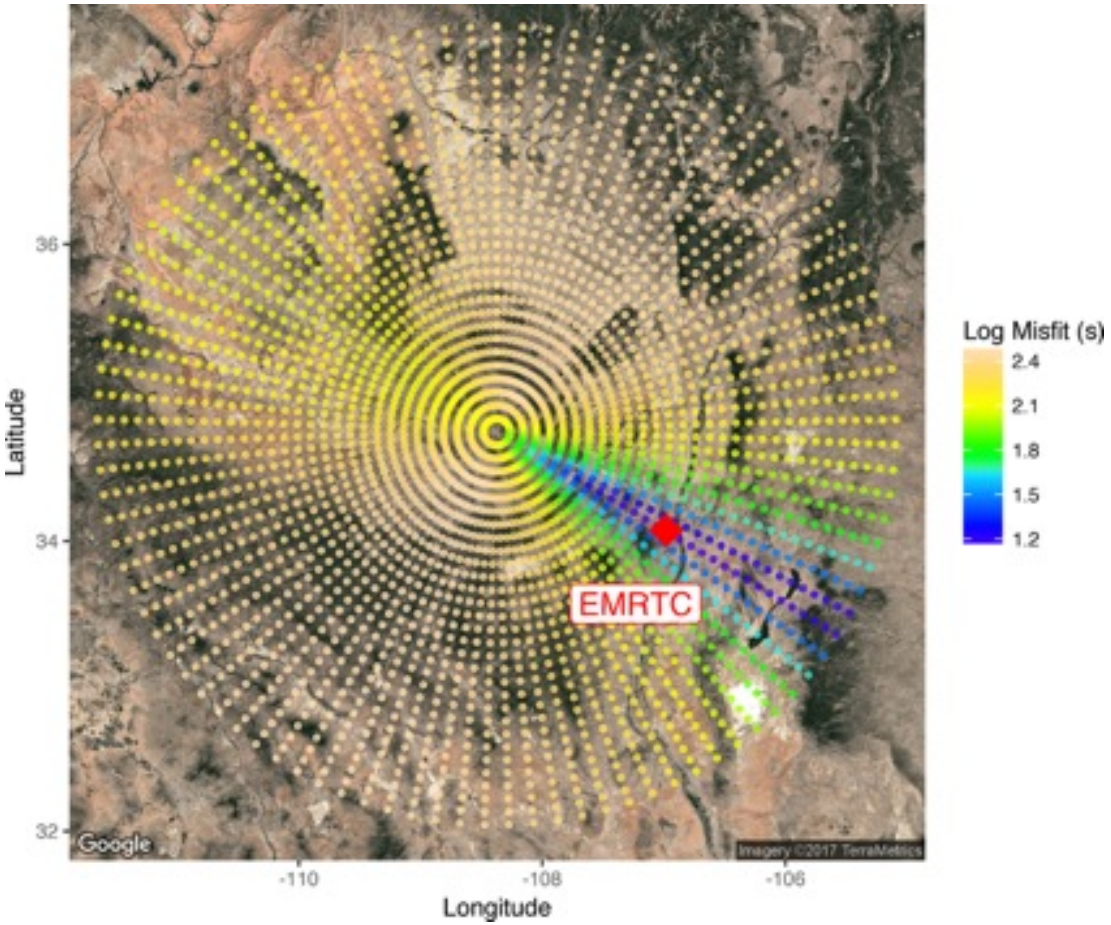
Flight Path


35.5
35.0
34.5
34.0
33.5
Latitude
−111
−110
−109
−108
−107
−106
Longitude
Shot 2
Shot 1
EMRTC
350 km
300 km
250 km
200 km
150 km
100 km
50 km
Elevation (km)
20
15
10
5

Waveforms


SOL 3
Range: 148 km
Altitude: 23.9 km
Amplitude: 0.23 Pa
SOL 1
Range: 153 km
Altitude: 22.0 km
Amplitude: 0.65 Pa
SOL 2
Range: 156 km
Altitude: 23.9 km
Amplitude: 0.44 Pa
SOL 4
Range: 161 km
Altitude: 23.3 km
Amplitude: 0.21 Pa
490
500
510
520
530
540
Time after Shot (seconds)

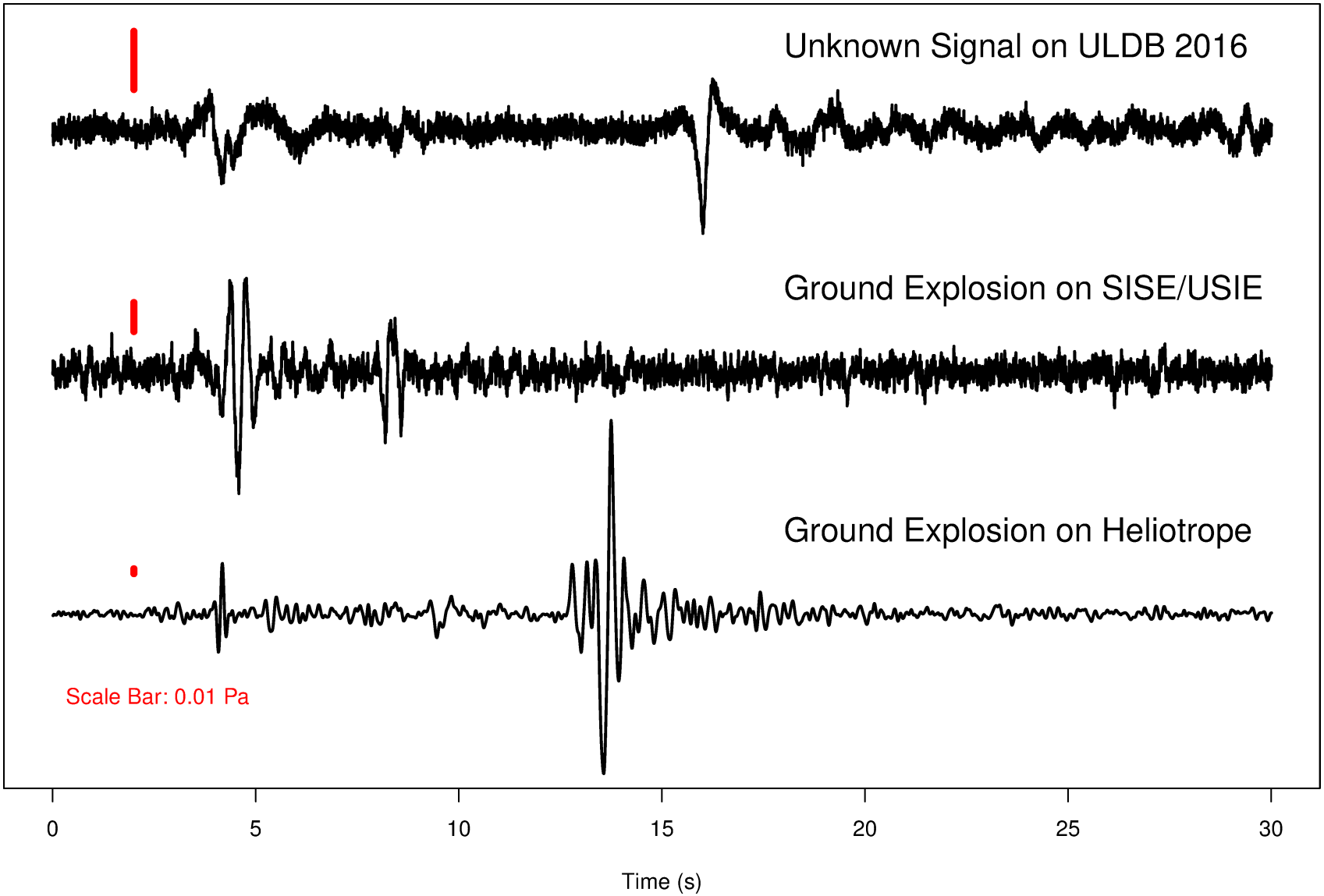
Direction of Arrival Estimation and Event Location



- Sparse array
- Large elevation differences
- Dynamic station spacing
- Multipathing

Each moment takes a different "snapshot" of the network: if two or more events occur in one place, they can be located.

Waveform Comparison



State of Knowledge

Balloon borne stations are very sensitive

- Continuous microbarom
- Superior detection capability vs. nearby ground sensors
- Still suffers from acoustic shadow effects
- Instrument noise an issue above about 1 Hz

Airborne infrasound networks are possible

- Heliotrope array aperture between 50 and 100 km for 10 hours
- Tighter aperture possible by matching flight system masses
- Stratosphere is a better venue: less wind variability
- Network will eventually drift apart

Next Generation Concepts

Maneuverable Arrays

Altitude control systems have been demonstrated before. Here, multiple balloon stations would utilize varying wind directions at different heights to maintain a nominal aperture as well as steering the entire array in a target direction.

Single Sensor Direction of Arrival Methods

Utilize waveform modeling to ascertain the number of caustics the signal encountered between source and receiver, giving a set of possible ranges. General direction of arrival estimation is possible based on stratospheric winds.