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MONITORING FOR LOCAL SEISMICITY IN CENTRAL KANSAS USING THE LOW-COST, RASPBERRY SHAKE 3-COMPONENT SEISMOMETERS

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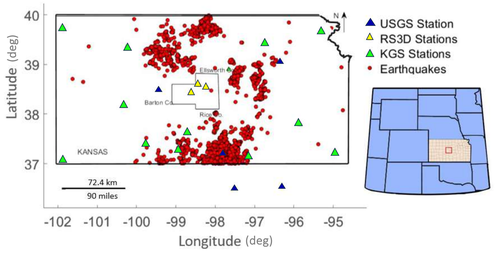
Introduction

- The growing interest in geologic carbon dioxide (CO_2) sequestration raises the concern that high-rate fluid injections may induce seismicity.
- To mitigate seismic hazard risk, it is recommended that seismic monitoring networks are installed at injection sites, which will require efficient and affordable earthquake monitoring technology.
- This study evaluates the low-cost Raspberry Shake 3D seismometer and readily available components, such as wireless modems, solar panels, and weather-resistant housing (~$3,500) as a suitable alternative to the traditional and more costly broadband stations (~$35,000).
- A seismic network of five RS3D stations monitored local seismicity in Bushton, Kansas, at an industrial facility of potential future CO_2 sequestration operations. This study presents results of monitoring continuously background seismicity for an eleven-month period.

Background

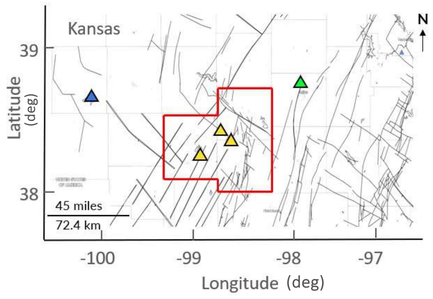
Kansas Recent Seismicity Map and Monitoring Stations



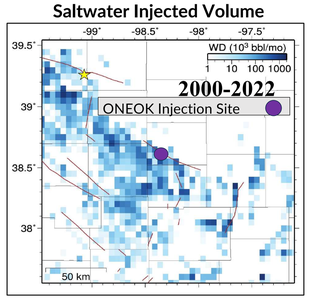
Seismicity map of Kansas showing recorded earthquakes (red circles) from 2013 to 2023 (from the Kansas Geological Survey Interactive Earthquake Map https: //maps. kgs.ku.edu /earthquakes/) and seismic monitoring stations (triangles). Earthquakes occur in clusters located in south-central Kansas, and north-central Kansas. The area of interest (grey outline) appears to lack recorded seismicity.

Map of Faults and Earthquake Stations in Central Kansas

A zoomed in map of the central Kansas study area (red outline). Yellow triangles represent the RS3D station locations. Blue triangles represent any nearby USGS seismic stations, and green triangles represent any nearby KGS seismic stations. Interpreted fault locations in central Kansas trending NE-SW and NW-SE obtained from Dicken et al. (2001).



Saltwater Injected Volume



Map of total injected saltwater disposal volumes in the Arbuckle. (Fasola, 2023 pers. Comm.)

Raspberry Shake Seismometer (3-Component)

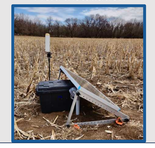
Cost	$1300
Dimensions	140 x 130 x 60 mm x 0.6 kg
Storage	8Gb Device + memory card
Timing	NTP or GPS
Type	Outdoor; 3-component/4.5 HZ
Samples per second	100 sps
Bandwidth	-3dB points at 0.7 - 39 Hz
Threshold	0.06 um/sec RMS 1 to 20 Hz @ 100 sps

www.raspberryshake.org

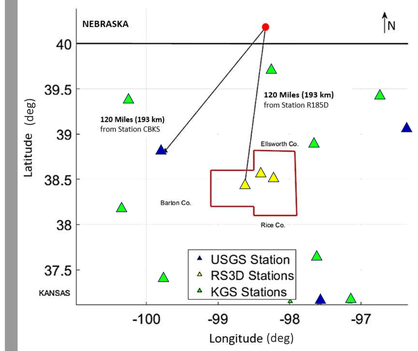
RS3D Seismic Station

Power & Connectivity

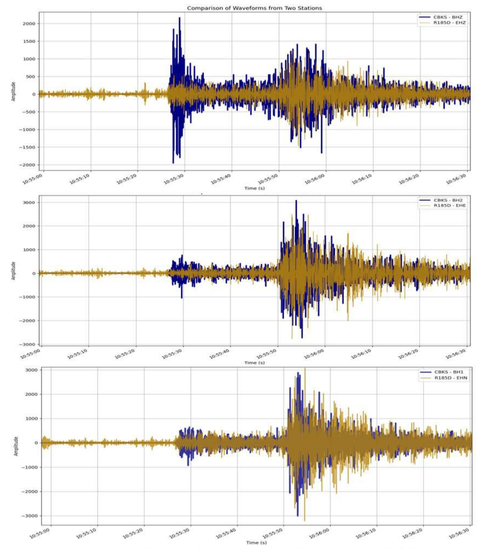
Field Installation



Comparison of Earthquake Recordings



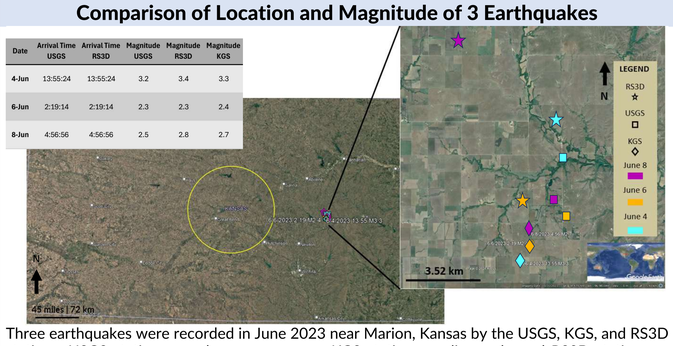
Location map of a regional earthquake recorded (red circle) by the USGS (blue triangles) and the RS3D Network (yellow triangles). Due to the earthquake epicenter being in Nebraska, the KGS did not report it. The event occurred on September 19th, 2023, with the USGS reporting a 3.2M and the RS3D reporting a 3.4M. The USGS station in Cedar Bluff, Kansas is a broadband station. The event is approximately equal distance and at comparable azimuth from the broad band station and the RS3D station allowing comparison of waveform recordings.



Overlay of waveforms from the Sept. 19 earthquake. Broadband USGS station waveforms are shown in blue, RS3D waveforms in gold. (Top) Vertical component recording. (Middle) North-south component recording. (Bottom) East-west component recording. A bandpass filter (frequency minimum = 5Hz, frequency maximum = 20 Hz) was applied for plotting the waveforms to help visualize the arrival of the P and S waves on each component.

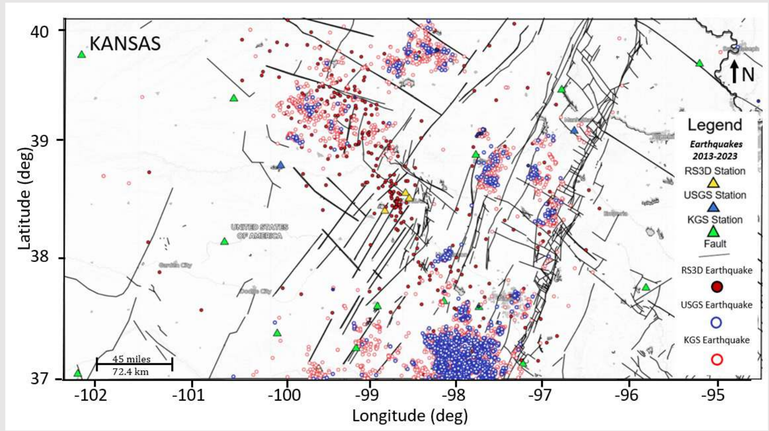
Comparison of Location and Magnitude of 3 Earthquakes

Date	Arrival Time USGS	Arrival Time RS3D	Magnitude USGS	Magnitude RS3D	Magnitude KGS
4-Jun	13:55:24	13:55:24	3.2	3.4	3.3
6-Jun	2:19:14	2:19:14	2.3	2.3	2.4
8-Jun	4:56:56	4:56:56	2.5	2.8	2.7



Three earthquakes were recorded in June 2023 near Marion, Kansas by the USGS, KGS, and RS3D stations. USGS stations are shown as squares, KGS stations as diamonds, and RS3D stations as stars. The earthquake on June 4th is represented as cyan in color, June 6th as orange, and June 8th as magenta.

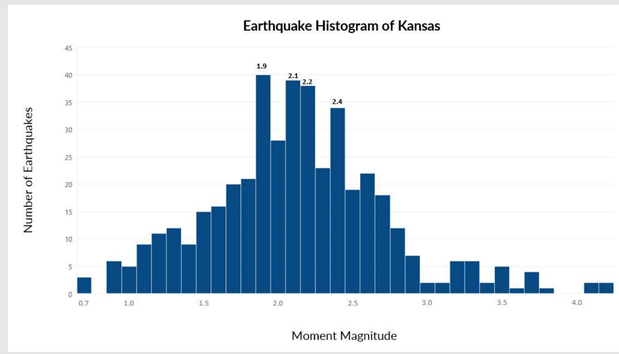
RS3D Earthquake Catalog



Map of Kansas earthquakes reported by the USGS and KGS from 2013 through 2023.

The RS-3D earthquakes were recorded from May 17, 2023, through April 30, 2024.

The earthquake clusters from the USGS and KGS suggest that central Kansas was seismically quiet for a decade while the RS-3D stations recorded 140 earthquakes in the area surrounding Bushton KS (yellow triangles).

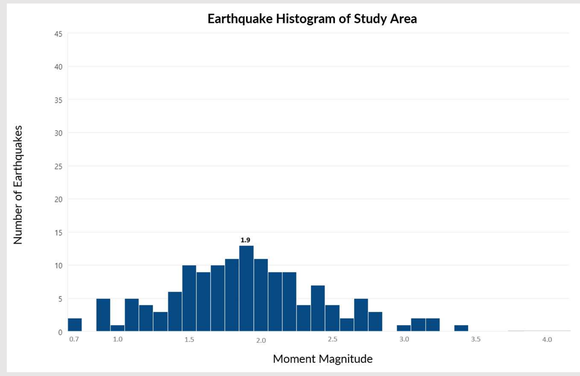


Histogram of Earthquake Magnitudes Recorded in Kansas by the RS3D Network

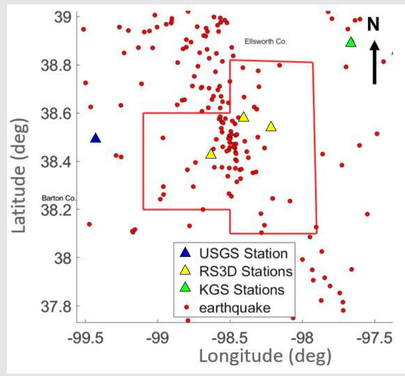
Within the entire state of Kansas, the RS3D seismometers detected a total of 440 earthquakes, with magnitudes ranging from 0.7 Mw to 4.2 Mw. The histogram shows most earthquakes detected by the RS3D stations across the State of Kansas ranged from 1.5 Mw to 2.7 Mw.

Local Earthquakes Detected by the RS3D Network: May 2023 – April 2024

Histogram of Recorded Earthquakes by Raspberry Shake Stations



Local Earthquakes



A map zoomed into the study area of the project showing the 140 earthquakes located within the red study area boundaries. The study area for this project is approximately a 72.4 km radius centered on Bushton, Kansas. The histogram shows that local earthquakes recorded ranged in magnitude from 0.7 Mw to 3.4 Mw, with most detected earthquakes in the range from 1.4 Mw to 2.2 Mw.

Acknowledgements:

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Templeton, D.; Schoenball, M.; Layland-Bachmann, C.; Foxall, W.; Guglielmi, Y.; Kroll, K.; Burghardt, J.; Dilmore, R.; White, J. Recommended Practices for Managing Induced Seismicity Risk Associated with Geologic Carbon Storage; NRAP-TRS-I-001-2021; DOE.NETL-2021.2839; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Pittsburgh, PA, 2021; p 80. DOI: 10.2172/1834402.

Dicken, C.L., Pimley, S.G., and Cannon, W.F., 2001, Precambrian basement map of the northern midcontinent, U.S.A. -- A digital representation of the 1990 P.K. Sims map: U.S. Geological Survey Open-File Report

Conclusions:

- The installation of low-cost seismic stations utilizing RS3D seismometers demonstrates the capability to monitor both local and regional seismic activity effectively.
- 440 earthquakes were recorded in the state of Kansas with 140 of those occurring within the study area. The range of magnitudes by the RS3D seismometers were 0.7 Mw – 4.2 Mw.
- Over an eleven-month period, Central Kansas experience low magnitude seismicity ranging from 0.7 Mw – 3.4 Mw.