HamSCI

http://hamsci.org

Amateur Radio Flash Mob

Citizen Radio Science Response to a Solar Eclipse

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13 DEC 2017

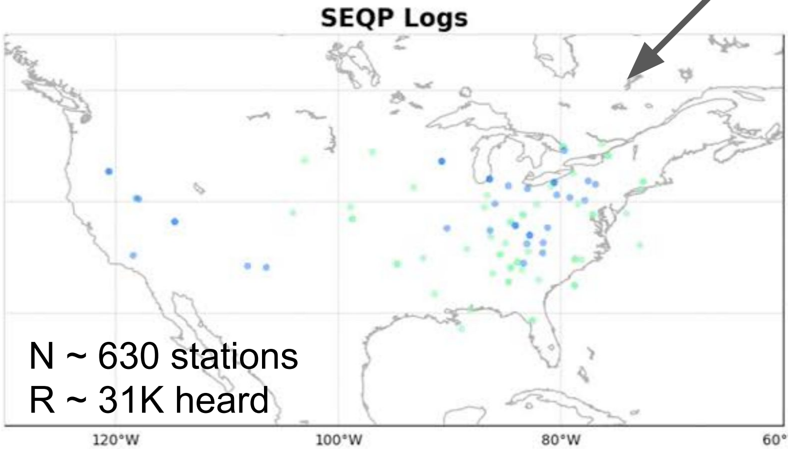
SciVision

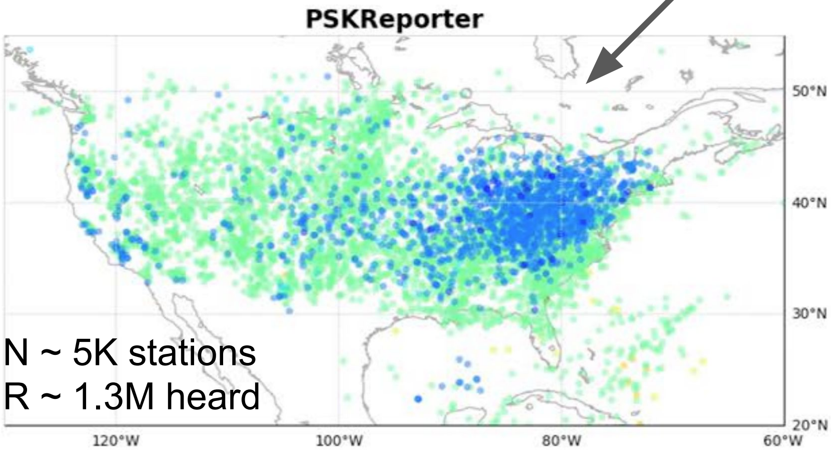
NJIT New Jersey Institute of Technology

C·S·P

Citizen Science: Heterogenous Observations

	Best for Science	Hi-Tech Citizen Observer	Citizen Observer
Temporal	Always on	Usually on	Varies
Spatial	Very dense	Sparse, denser near cities	Customizable
Cost	$100,000/node	$1,000's/node	$100's / node





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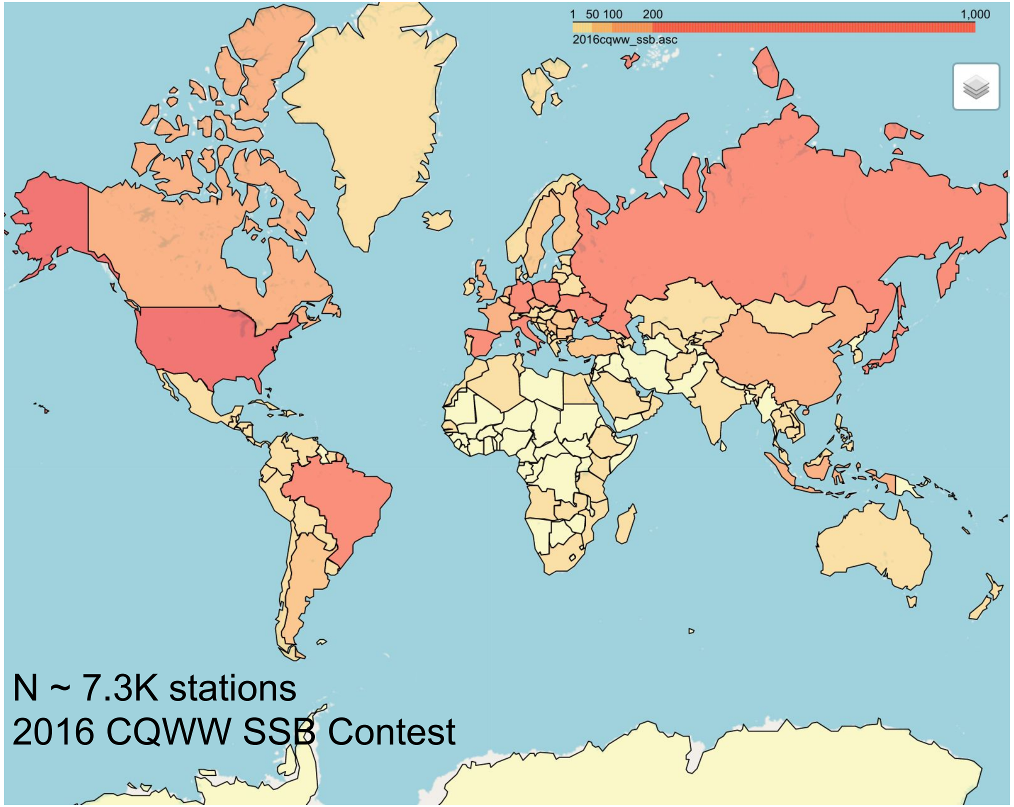
(N. Frissell, hamsci-eclipse list, 30 Oct. 2017)

Citizen Science: Global potentials

Feasibility checks:

- how many *active* amateur radio stations vs time of year?
    - Contest Logs
    - PSKreporter.info
    - WSPRnet.org

- Many studies benefit from “always on” long-term observations
    - Data storage and upload getting more convenient. Bigger, cheaper HDD, Zenodo.org, et al



https://www.cqww.com/publiclogs/2016ph/

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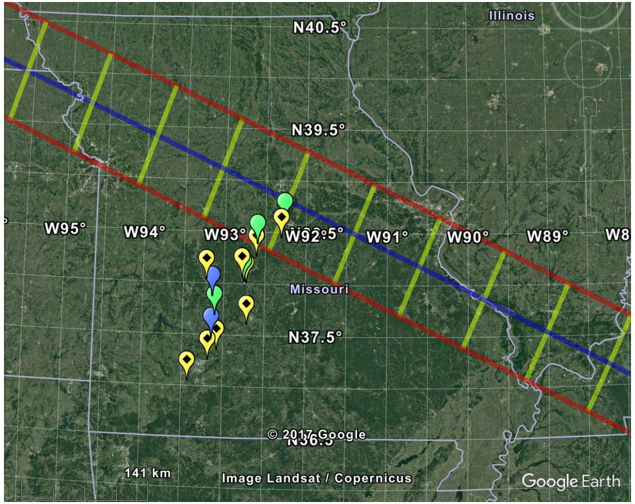
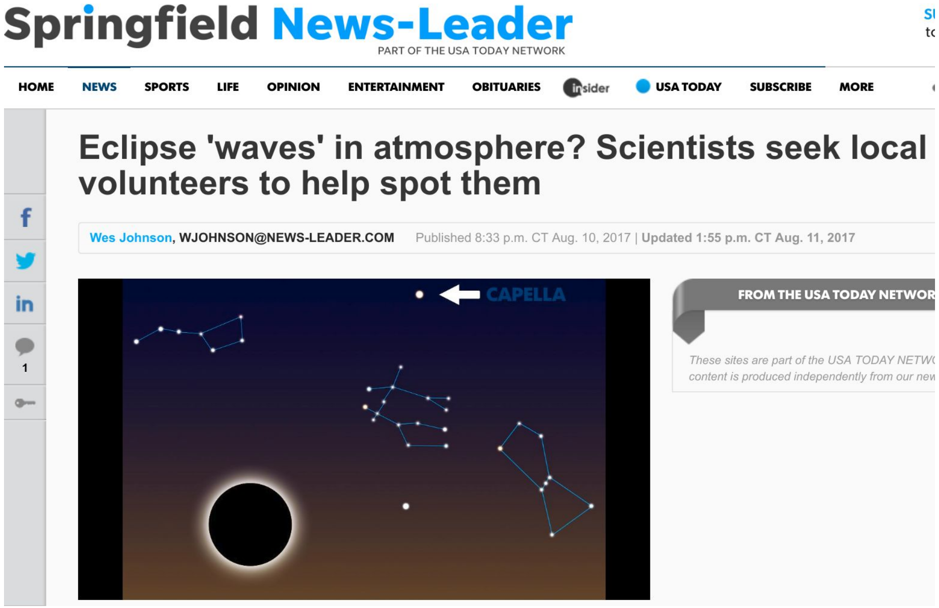
Publicity → Scientist Deployed

- S. Mrak (Boston Univ.): deployed 15 $150 GNSS receivers, including 10 Missouri households
  - few days notice on local new media
  - 2 scientists, 2 days to deploy




Springfield News-Leader
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Eclipse 'waves' in atmosphere? Scientists seek local volunteers to help spot them

Wes Johnson, WJOHNSON@NEWS-LEADER.COM Published 8:33 p.m. CT Aug. 10, 2017 | Updated 1:55 p.m. CT Aug. 11, 2017

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[Springfield (Missouri) News-Leader, Aug 10, 2017]

[Eclipse KML: Kevin Addison, NASA GSFC]

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Gamify: Radio contest

- Solar Eclipse QSO Party
- “Points” awarded based on operating frequency, modulation best for eclipse science

@100 points: During local eclipse maximum, outdoor, public place

@50 points: antenna info, HFTA terrain profile, ground conductivity, ERP, run wide-band receiver

@1 point: contacts > 1 deg lat, 2 deg long, @freq, @mode

ARRL QST Aug 2017, >160K circulation

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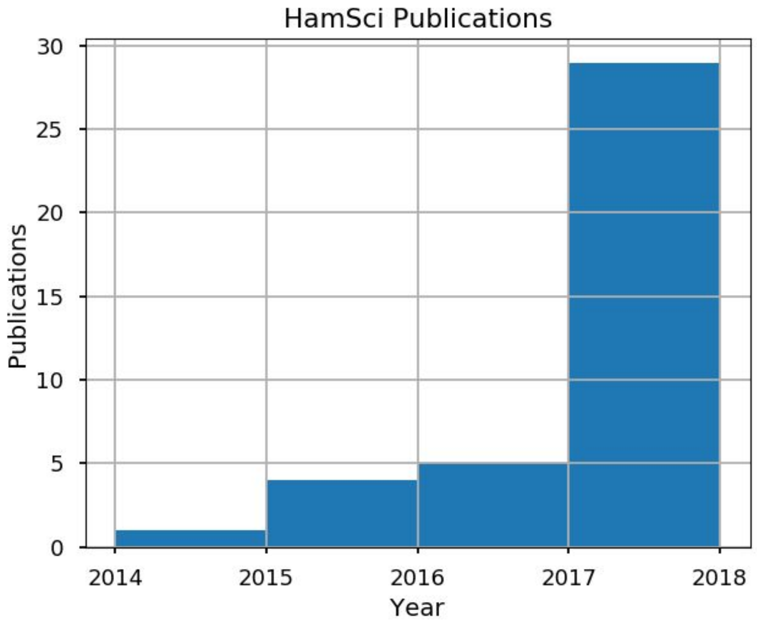
HamSCI

- HamSCI experiments typically use "HF" radio $f_{radio} < f_{plasma}$
  - 20 organizations + scientists
- Exploits high-altitude reflection of radio waves from targets such as ionosphere and meteor trails
  - Including wave behavior and fine structure
- Each transmitter received by many receivers
  - like a camera!



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Methodology (1)

Several layers/types of analysis

- Go/no go: Did usable path exist between two points sampled over time span
  - Forward modeling including ray tracing necessary for physical quantity extraction
  - Reveals density gradients, TIDs
  - reveals the largest structures and trends with better spatiotemporal resolution than earlier possible, due to large number of spatially diverse TX/RX pairs

- Channel analysis: Broadband data recording, “free” data storage @ Zenodo
  - Enables vast array of statistical studies with no additional hardware cost to scientist
  - Software defined radios are common in modern ham radio stations
  - Commercial ham SDR: 15 years ago. Affordable, open-source, commonplace: past decade
  - Study Small Scale Disturbances (<100km lateral structure) at far better spatial resolution

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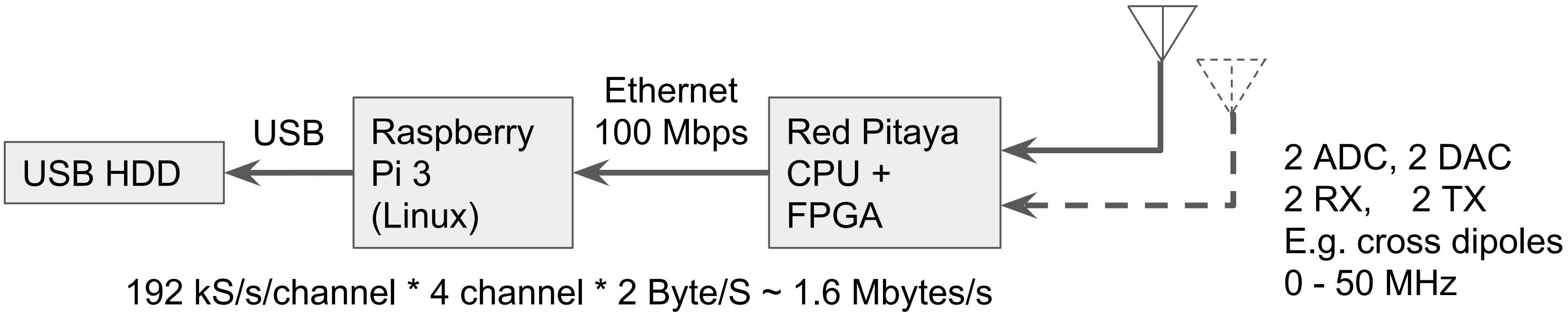
Methodology (2)

- Data Archiving: Zenodo upload via web browser or Python API
  - > 10 MB/sec throughput generally
- On-site preprocessing: managed by Raspberry Pi 3 to USB HDD
- Limits: Red Pitaya CPU (Cortex A9), Raspi Ethernet throughput (<100 Mbps)
  - Heat sink + fan cooling mandatory. CPU utilization: Raspi 3: ~ 300% (quad core)



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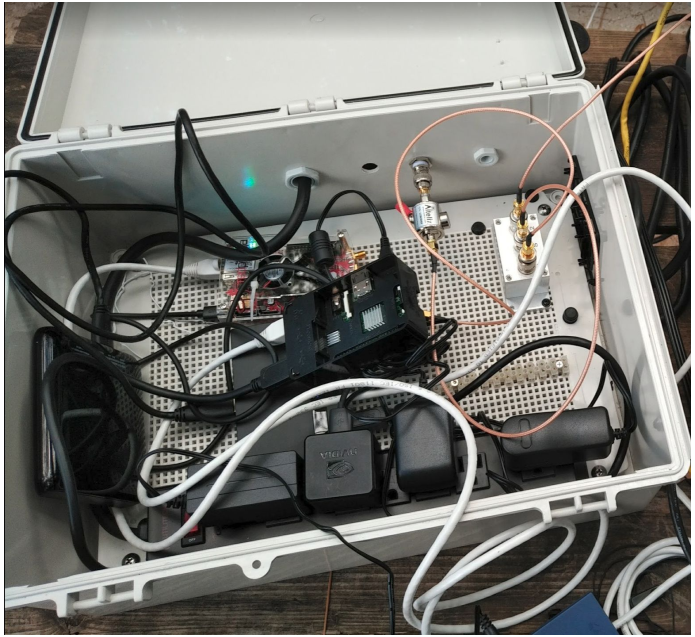
Deployment (1)

Initial form/fit/function verification



Aug 2017:
Virginia Tech Transmitter

- 2, 3, 4, 5 MHz
- ~5 watt transmit
- 25 kHz LFM
- 250 us pulse

Winter 2017:
Own Transmitter

- 2, 3, 4, 5 MHz
- 0.1 watt transmit
- 5-1000 kHz BW
- 1 sec. coded pulse

- Hams could TX ~ 6 kHz BW.
  - Experimental license for wider BW
- 3-10 MHz coherence times allow more energy on volume target: long coded pulse
  - say 10 us chip and 0.1-1 sec. length

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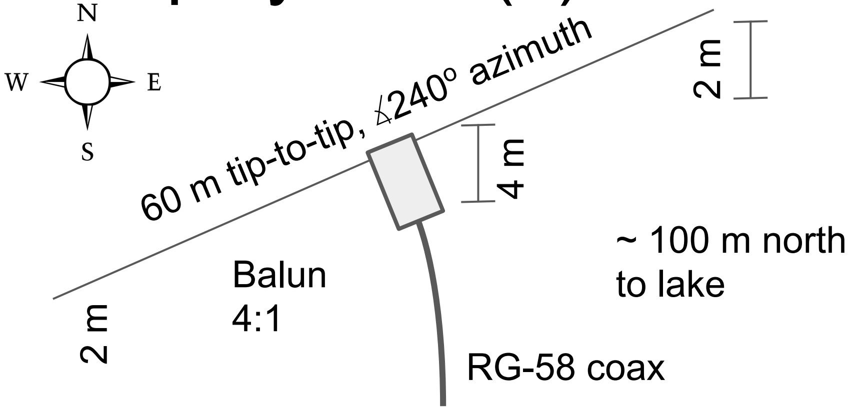
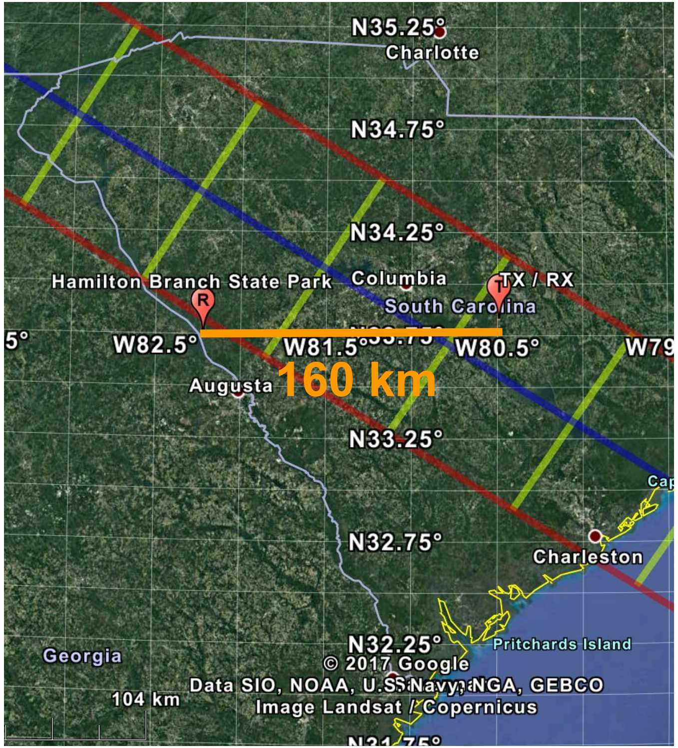
Deployment (2)





G. Earle, et al, [SA11B-07 HF Band Observations and Modeling of the 2017 Eclipse], 2017 AGU FM

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Preliminary Results

Eclipse Radio Contest:

- Data processing under way, GRL submission in days.
- See Frissell et al talk from Monday:

http://hamsci.org/sites/default/files/publications/2017_AGU_Frissell.pdf

PiRadar:

- Data processing under way, winter experiments with new receiver, new waveforms optimized for milliwatt transmit power
- substantially more resilient receiver vs. first gen. Red Pitaya

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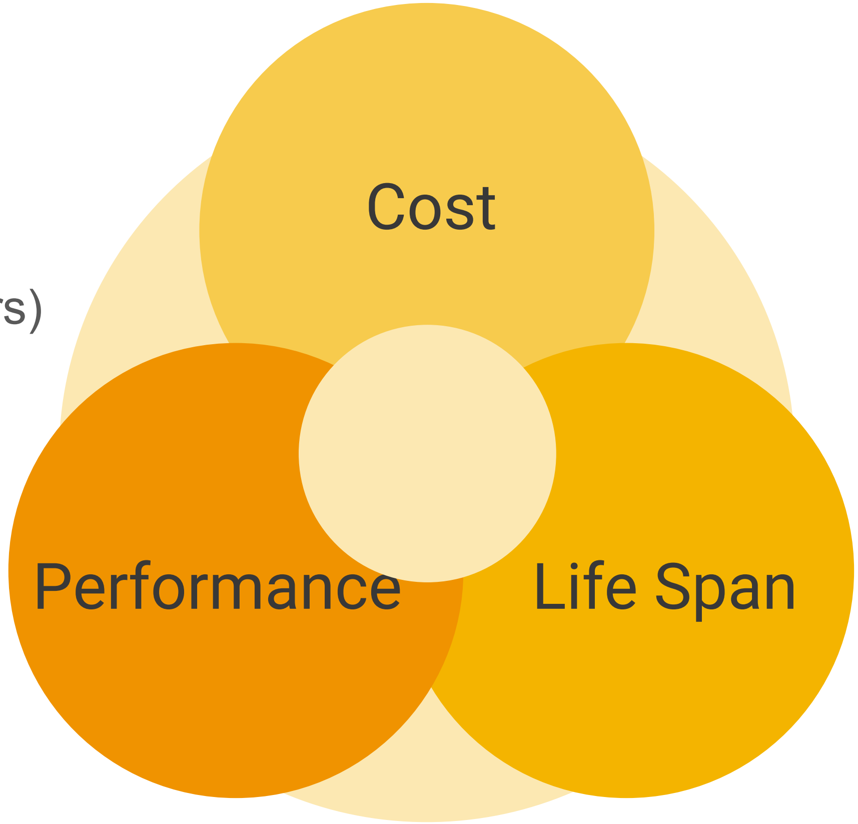
What's next

Scalability

Holy Grail:

- End user deployments (mail box to users)
- Edge computing
  - process at node
  - Auto-upload results
- “Disposable” pricing $300/node



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Future is now

- Everything is a sensor
- Edge computing
- Software defined instruments

Budgets:

- $10 100 mW radios: global license-free 1-10+ km range
- $50 4G LTE modems
- $35 quad-core ARMv8 (Raspberry Pi 3) + WiFi or single core+WiFi ($10)

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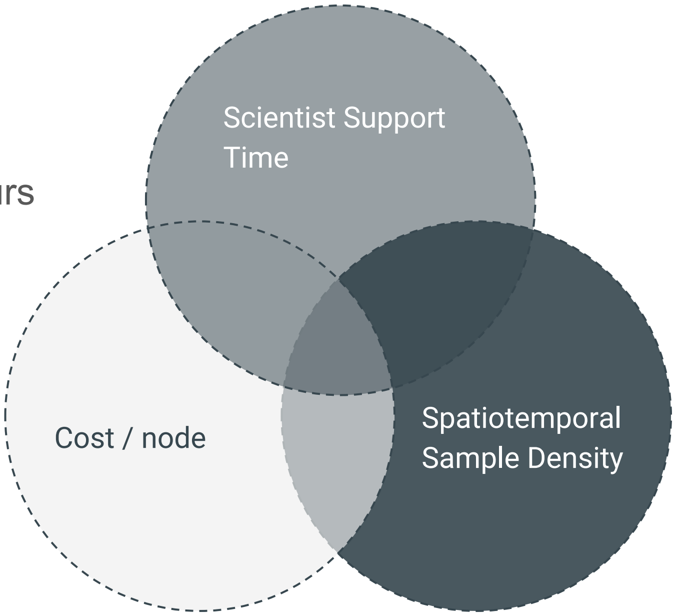
Outcomes & Conclusions

- Citizen science “mob” can be arranged in days with real science outcome
    - Now that they’ve practiced, next time perhaps with hours of notice
- Positive word of mouth messaging
- Geoscience new normals
    - Citizen science
    - AI, ML, CV, computer-aided discovery
    - Edge computing
- Practical way to get global observation scope
    - Very high ROI



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