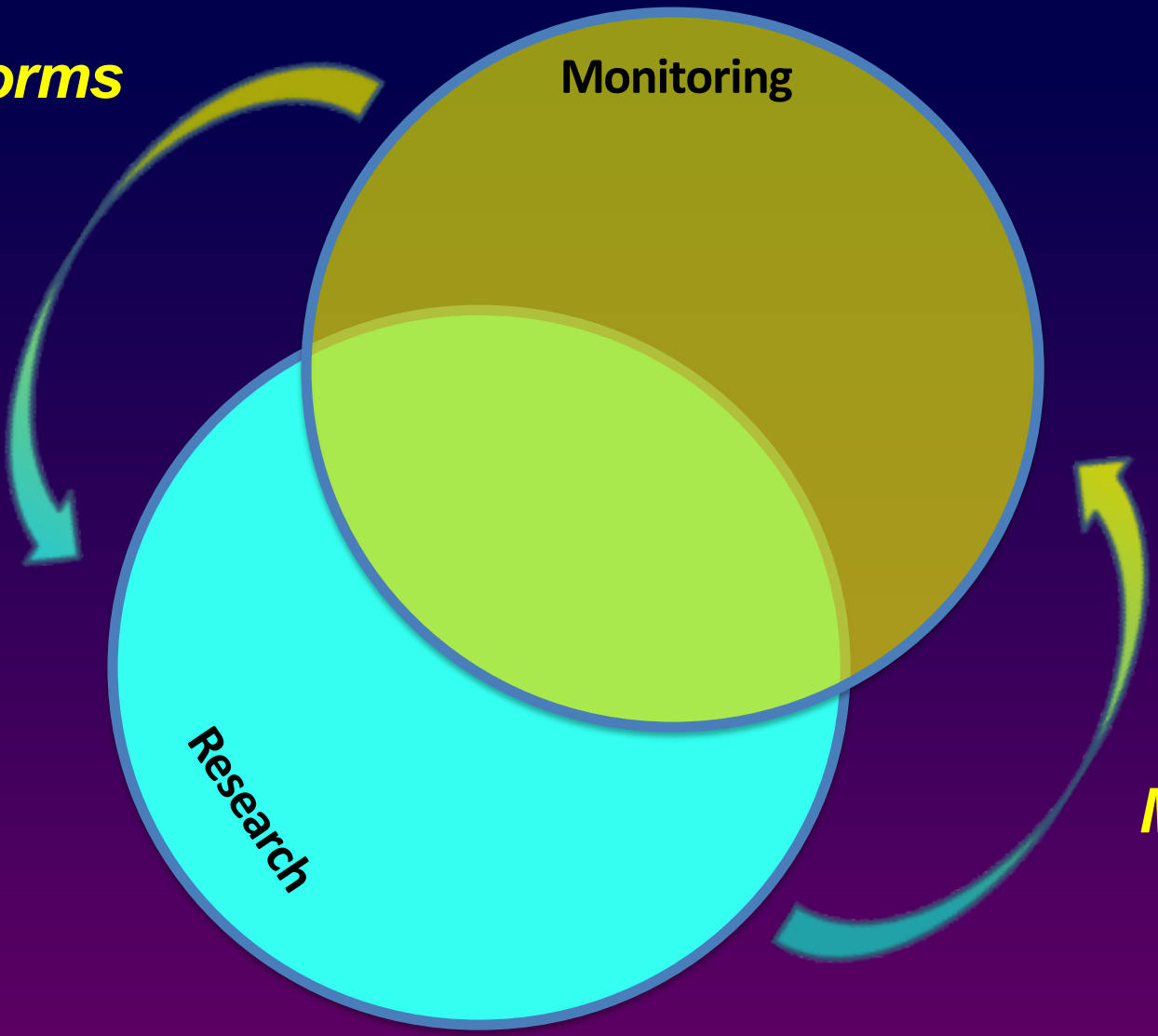
Mitigating Volcanic Hazards Through Geophysical Monitoring and Research

Seth Moran
Scientist-in-Charge
USGS Cascades Volcano Observatory

Mitigating Volcanic Hazards

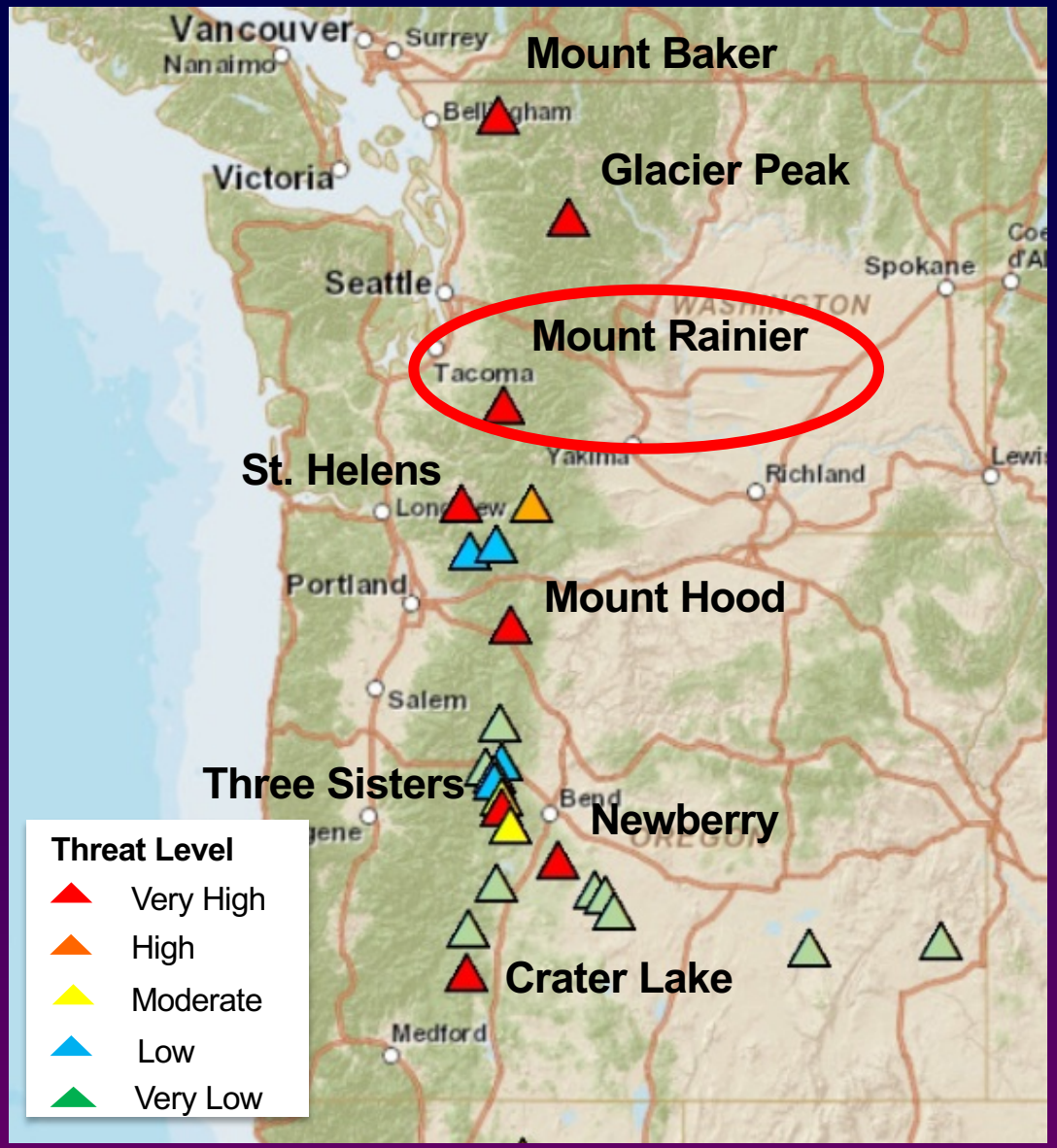
Monitoring informs Research



Research informs Monitoring Strategies

USGS

Cascade Range Volcanoes

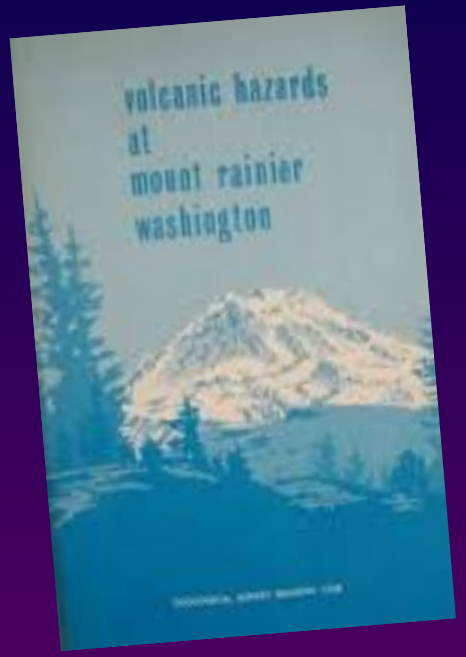


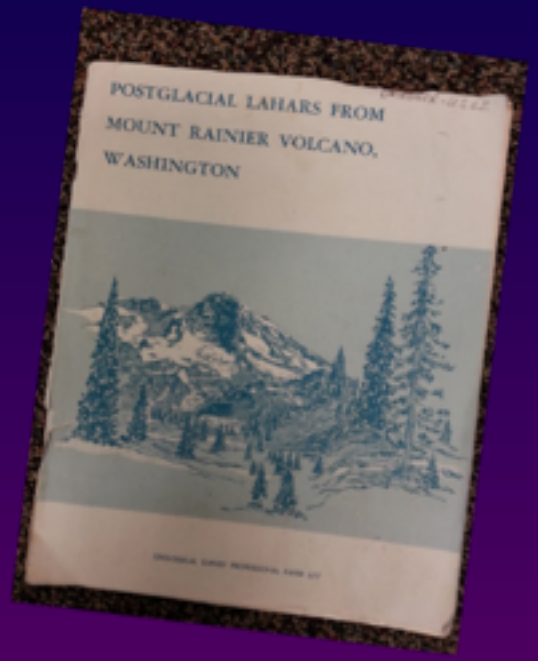
USGS

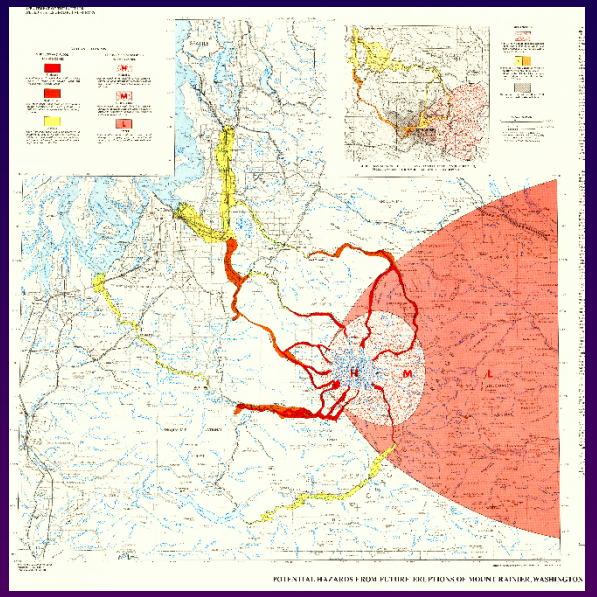
Mount Rainier Hazards: Research

Crandell, D. R. and Waldron, H. H., 1956, A Recent volcanic mudflow of exceptional dimensions from Mount Rainier, Washington: Am. Jour. Sci., v. 254, p. 349–362.

1967 hazard assessment; 1971 professional paper; 1973 hazard map







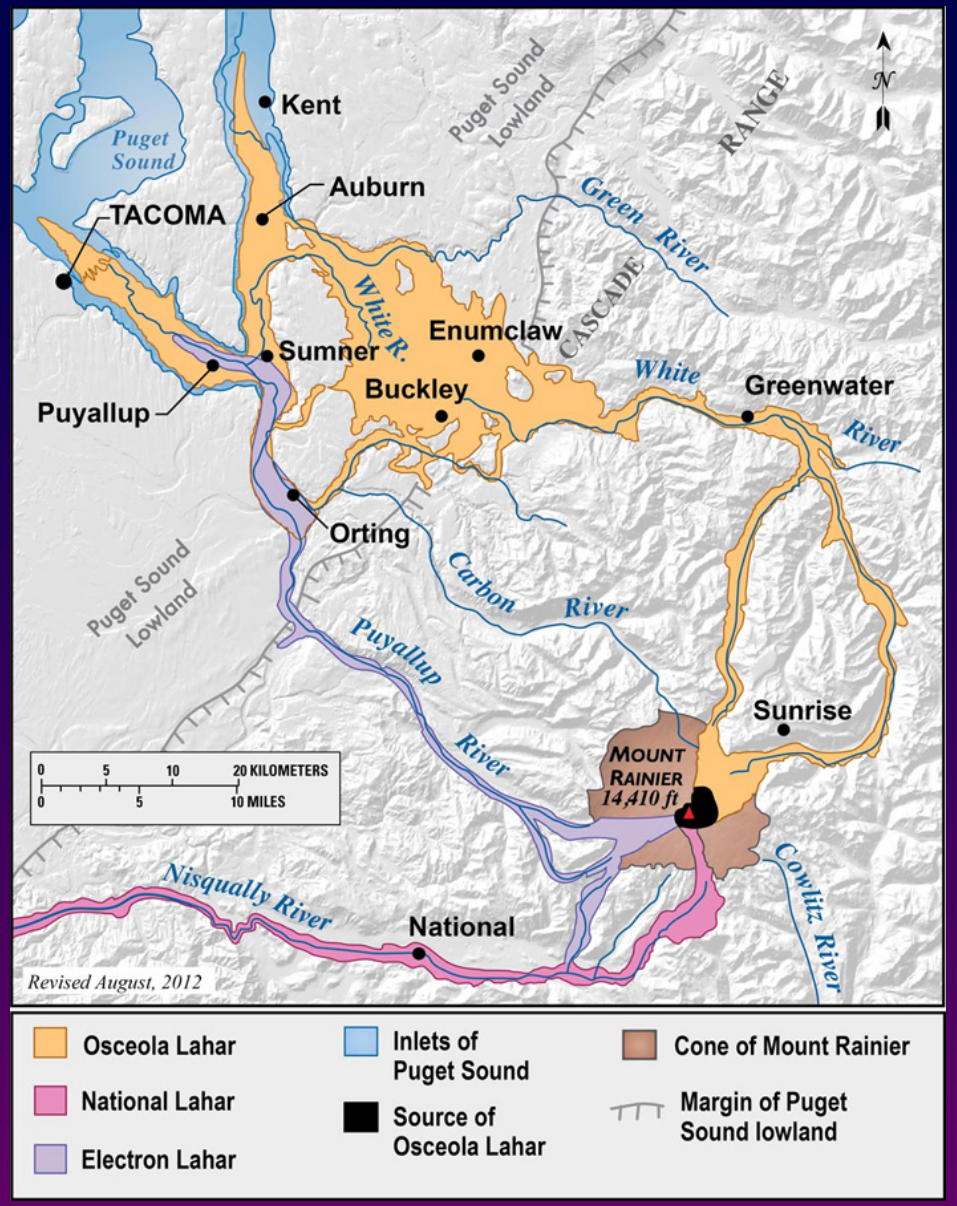
➔ The Mount Rainier hazard assessment and map were the first geology-based volcano assessment in modern times.

USGS

Mount Rainier Lahars: Research

Rainier Lahar Hazards

- 9 large lahars have reached now-populated areas in last 5600 years
- > 90,000 people live in Rainier lahar hazard zones (Diefenbach et al., 2015)



USGS

Detect Lahars & Track Flow Front Position

August 13, 2015, debris flow (Tahoma Creek)

USGS

Mount Rainier Lahars: Research

Orting – built on ~520-year-old lahar deposits

USGS

Mount Rainier Lahars: Research

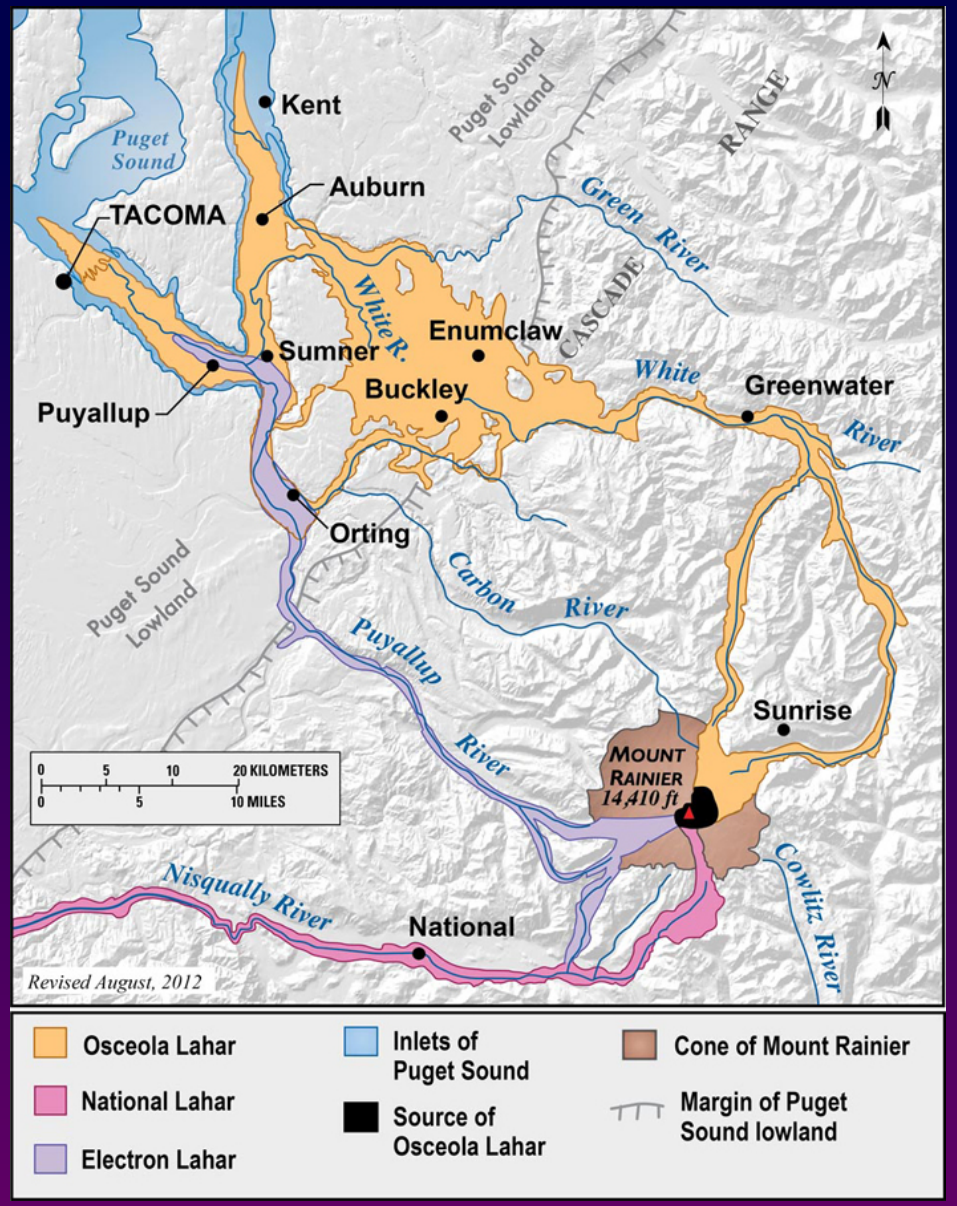
Pat Pringle, WA DNR

USGS

Mount Rainier Lahars: Research

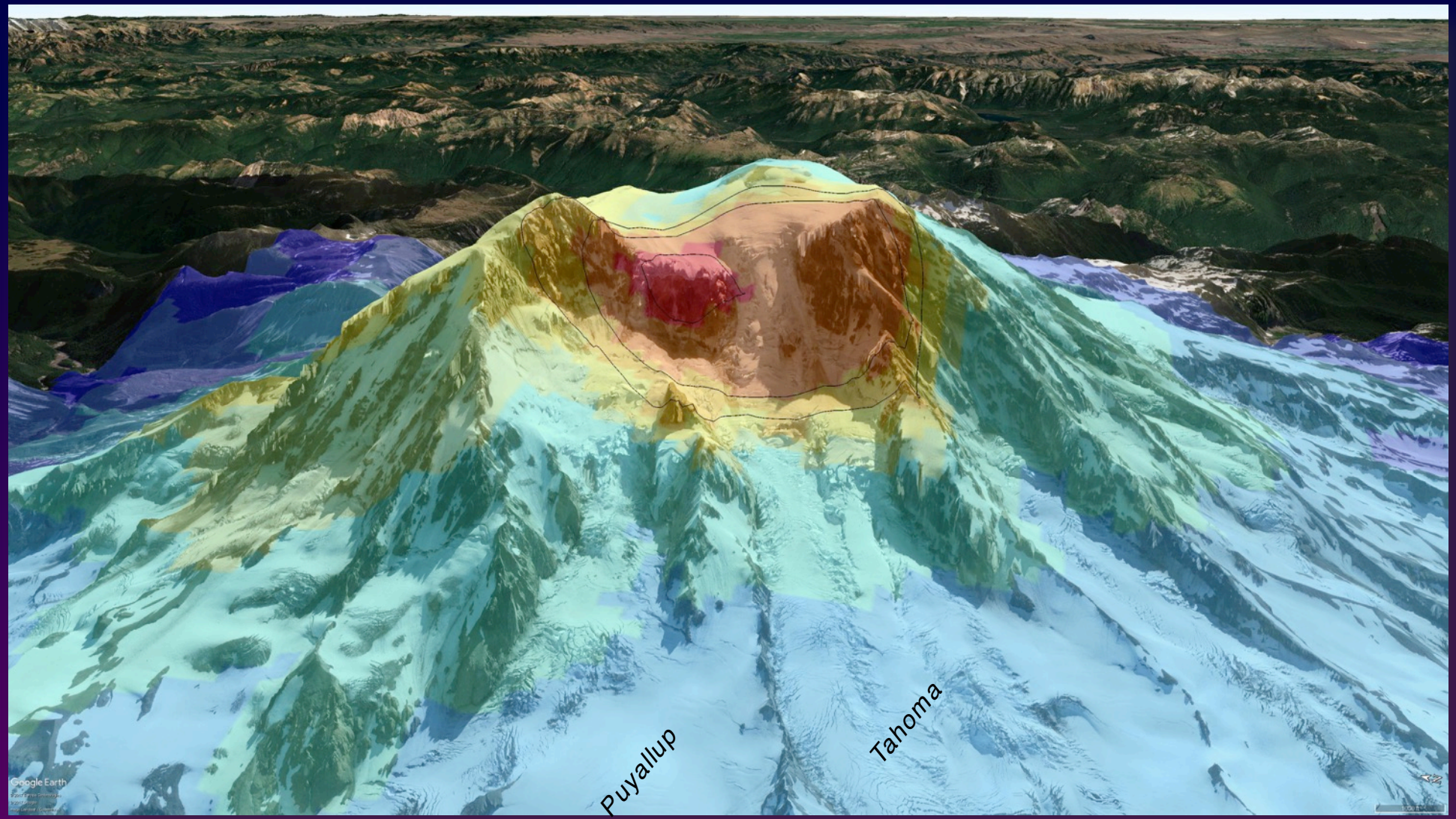
Rainier Lahar Hazards

- 9 large lahars have reached now-populated areas in last 5600 years
- > 90,000 people live in Rainier lahar hazard zones (Diefenbach et al., 2015)
- 8 lahars associated with eruptions; 1 was not (Electron, 1501 A.D.)
- Half associated with large landslides



USGS

Mount Rainier Lahars: Research

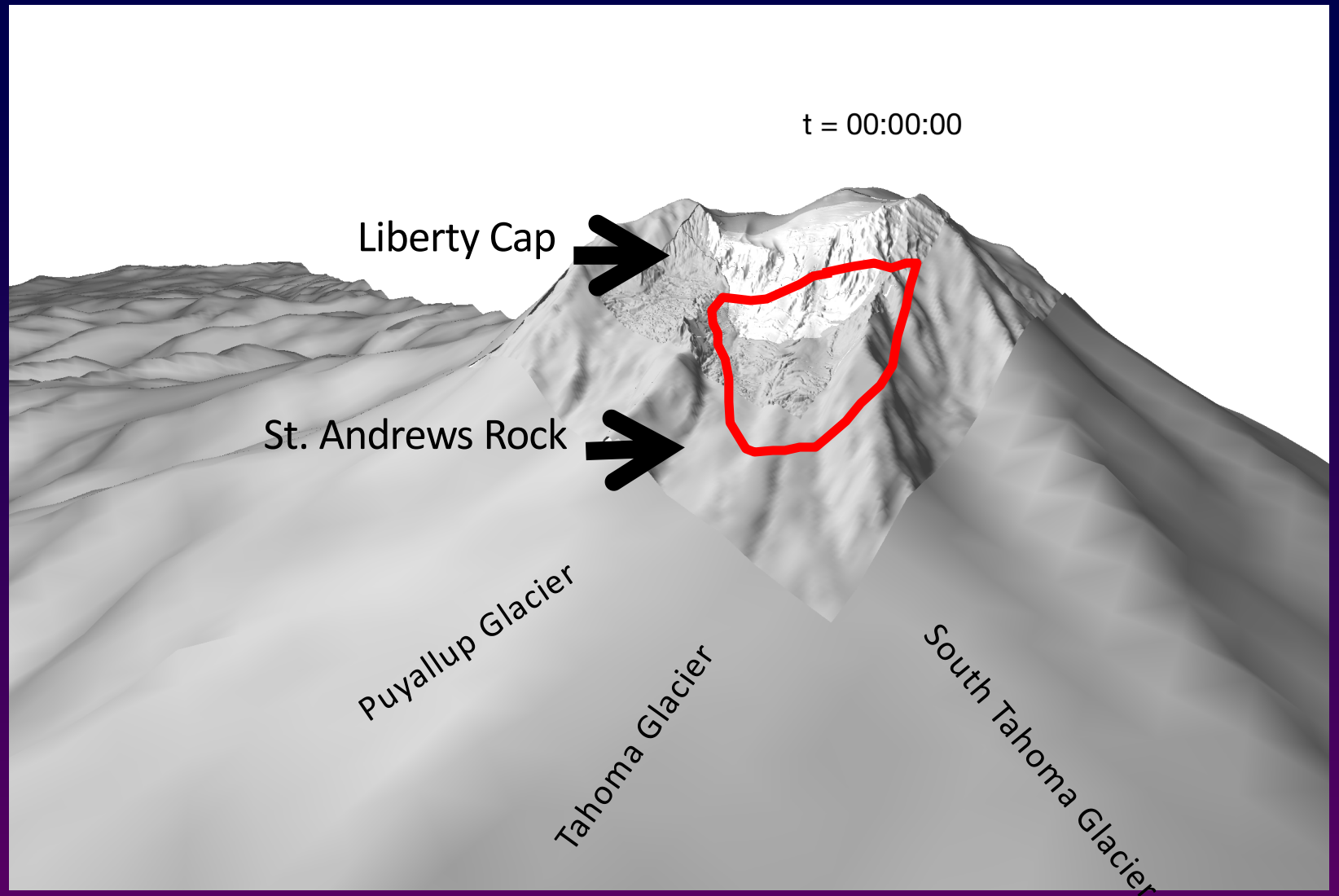


Reid et al. (2001), Finn et al (2001) – area of instability on west flank

USGS

Mount Rainier Lahars: Research

260 M m^3 debris avalanche in least-stable source region



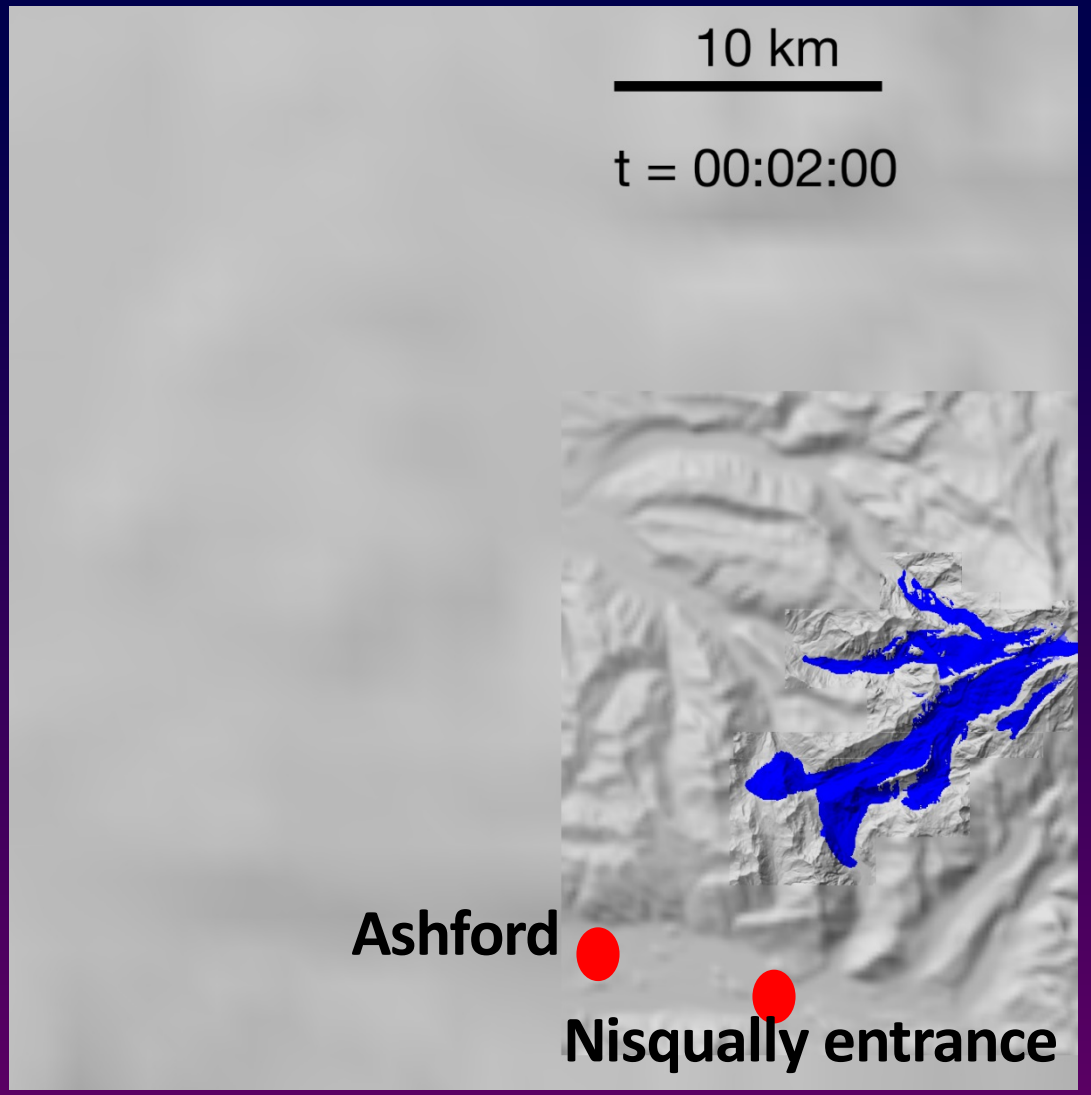
"D-Claw" simulations of collapse-driven lahars courtesy of Dick Iverson and David George (USGS-CVO)

USGS

Mount Rainier Lahars: Research

Map view D-Claw simulation of 260 million m^3 lahar originating in least-stable source region, Mount Rainier

t = 2 minutes



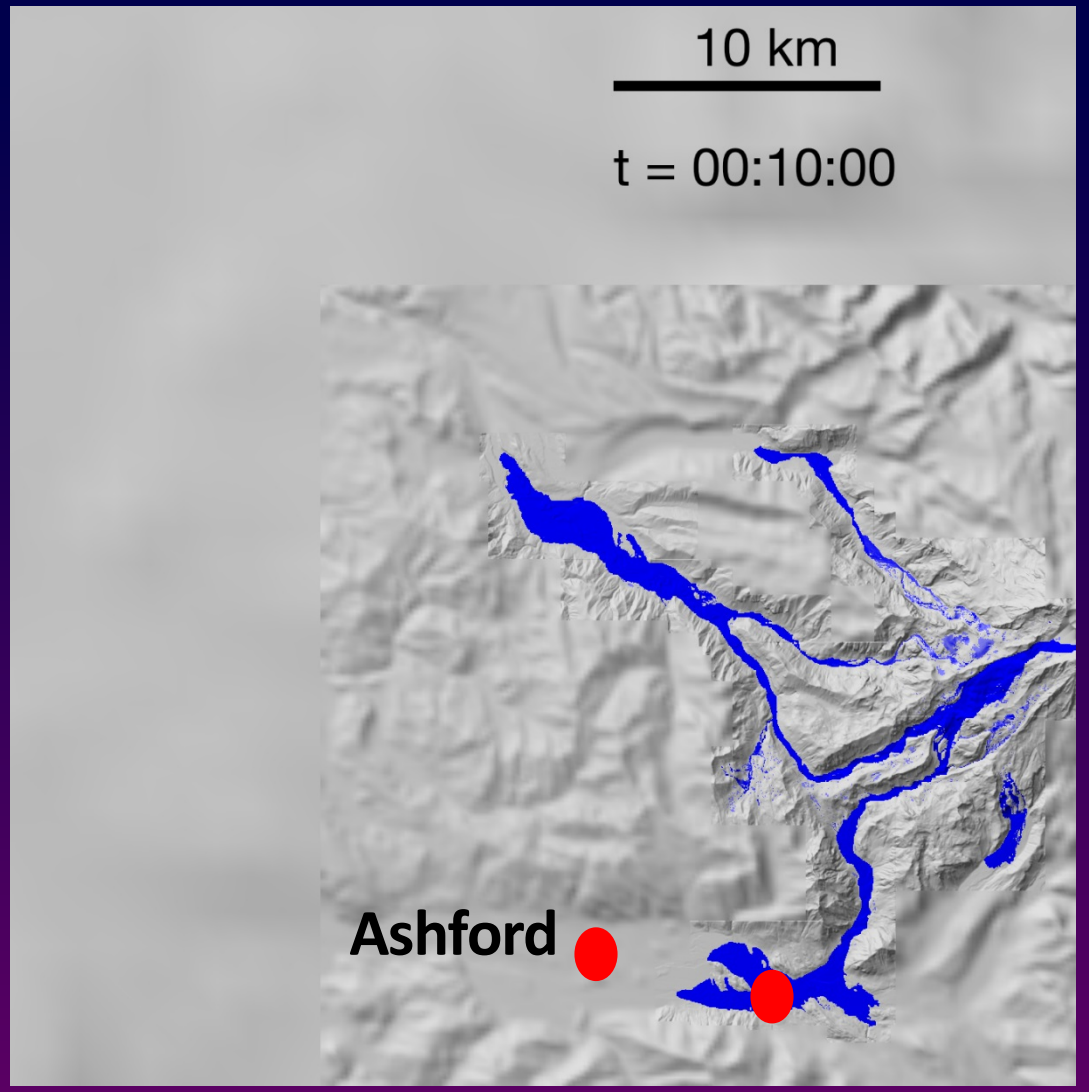
Iverson and George, in prep

USGS

Mount Rainier Lahars: Research

Map view D-Claw simulation of 260 million m^3 lahar originating in least-stable source region, Mount Rainier

t = 10 minutes



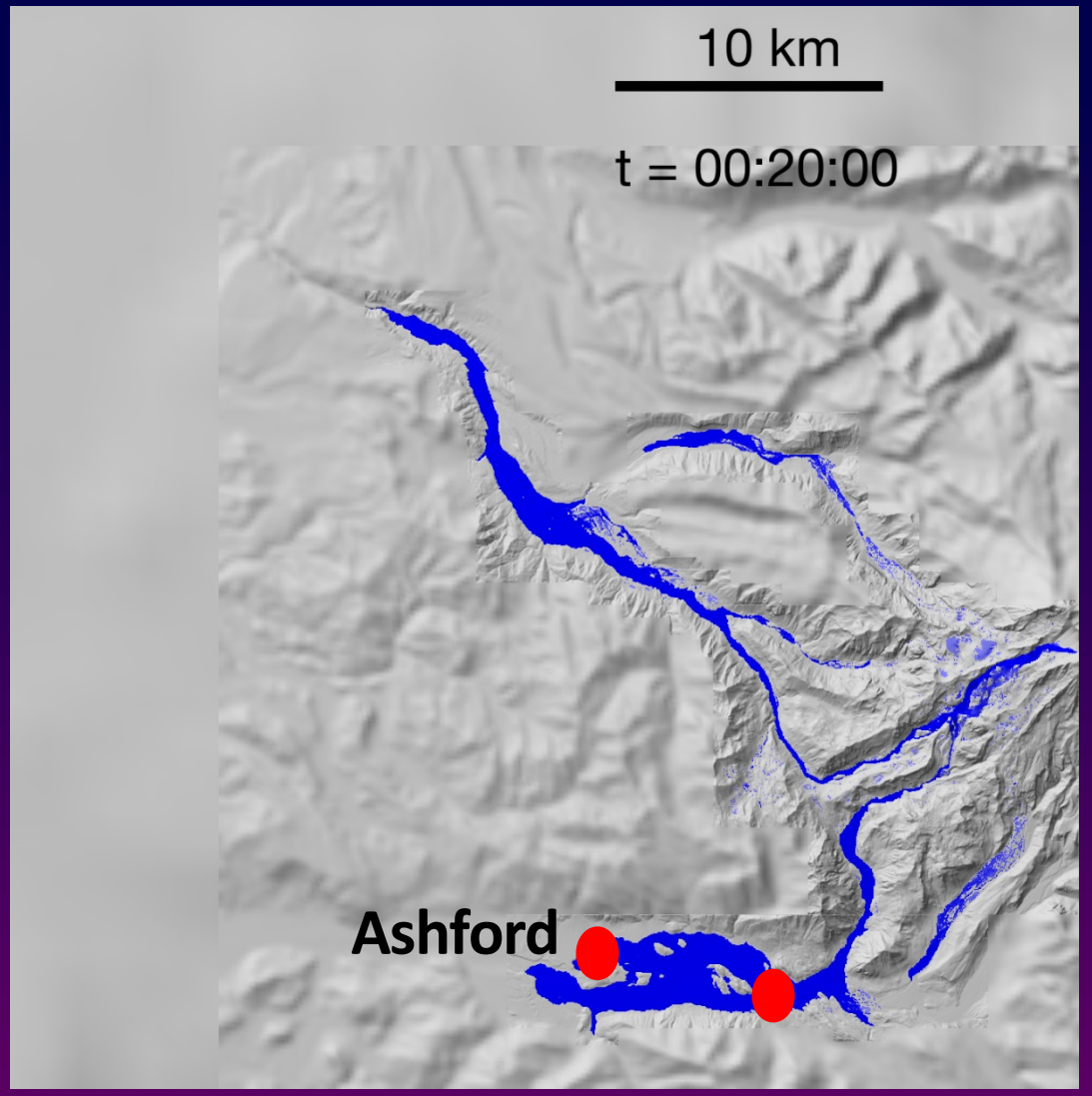
Iverson and George, in prep

USGS

Mount Rainier Lahars: Research

Map view D-Claw simulation of 260 million m^3 lahar originating in least-stable source region, Mount Rainier

t = 20 minutes



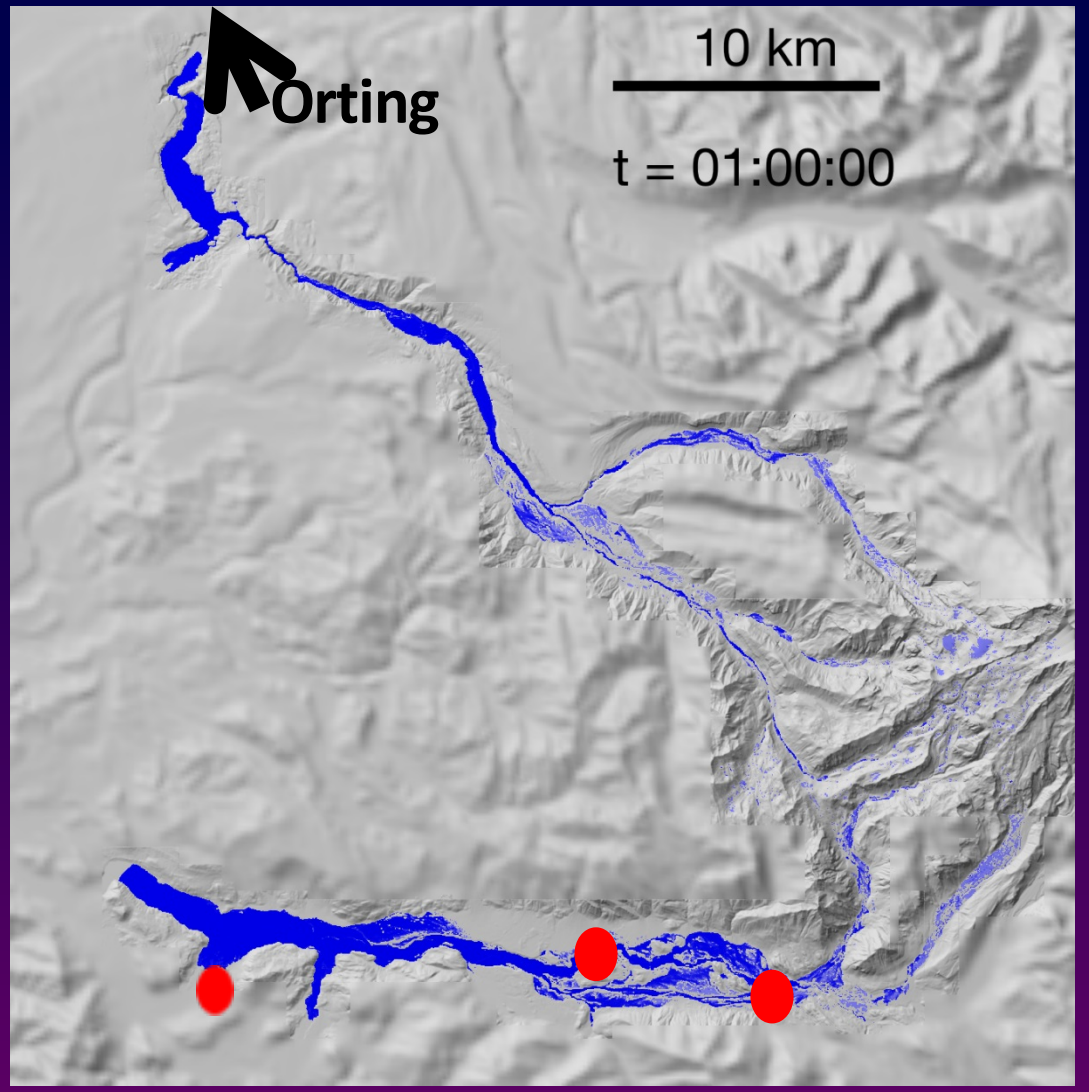
Iverson and George, in prep

USGS

Mount Rainier Lahars: Research

Map view D-Claw simulation of 260 million m^3 lahar originating in least-stable source region, Mount Rainier

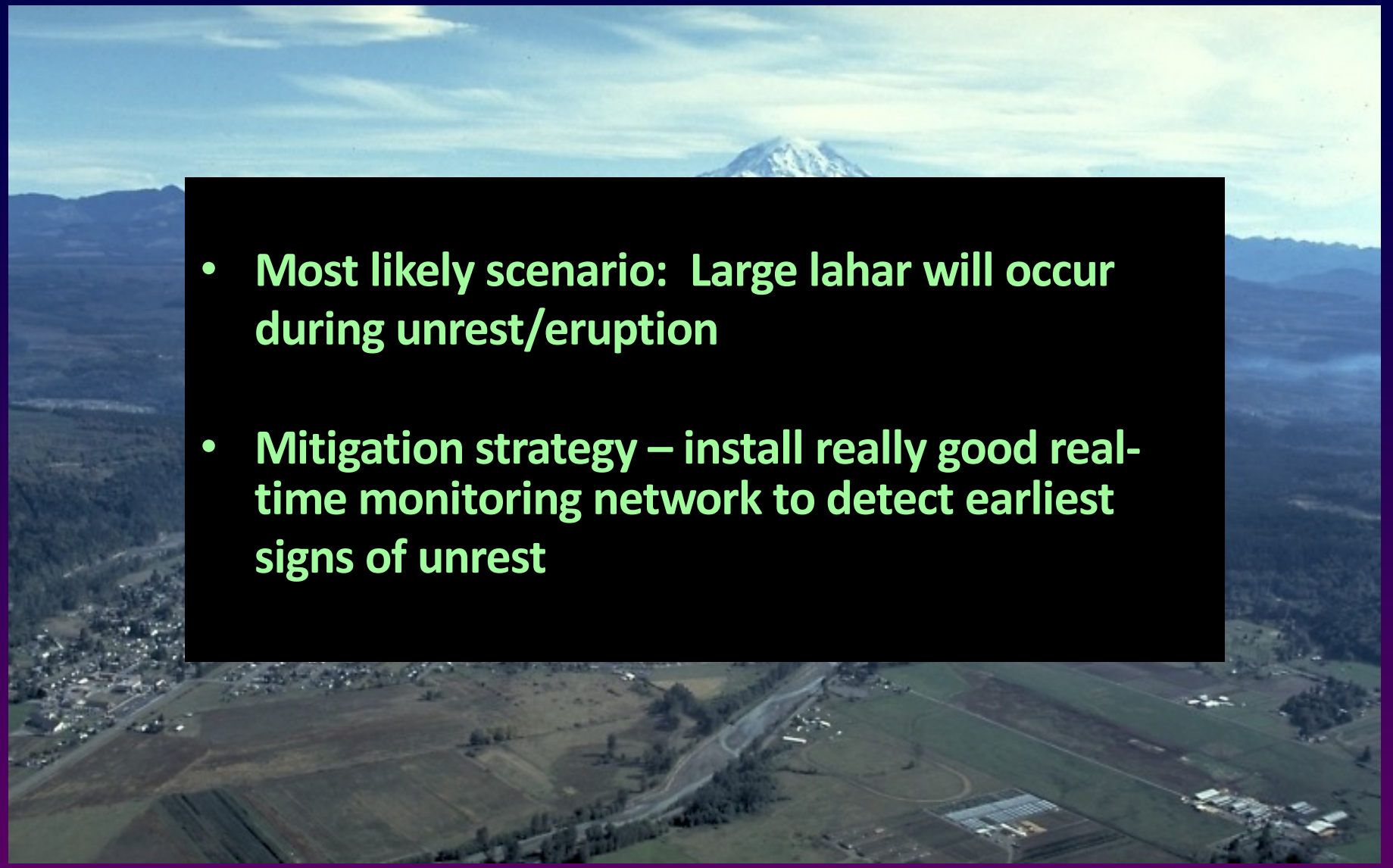
t = 60 minutes



Iverson and George, in prep

USGS

Mount Rainier Lahars: Research



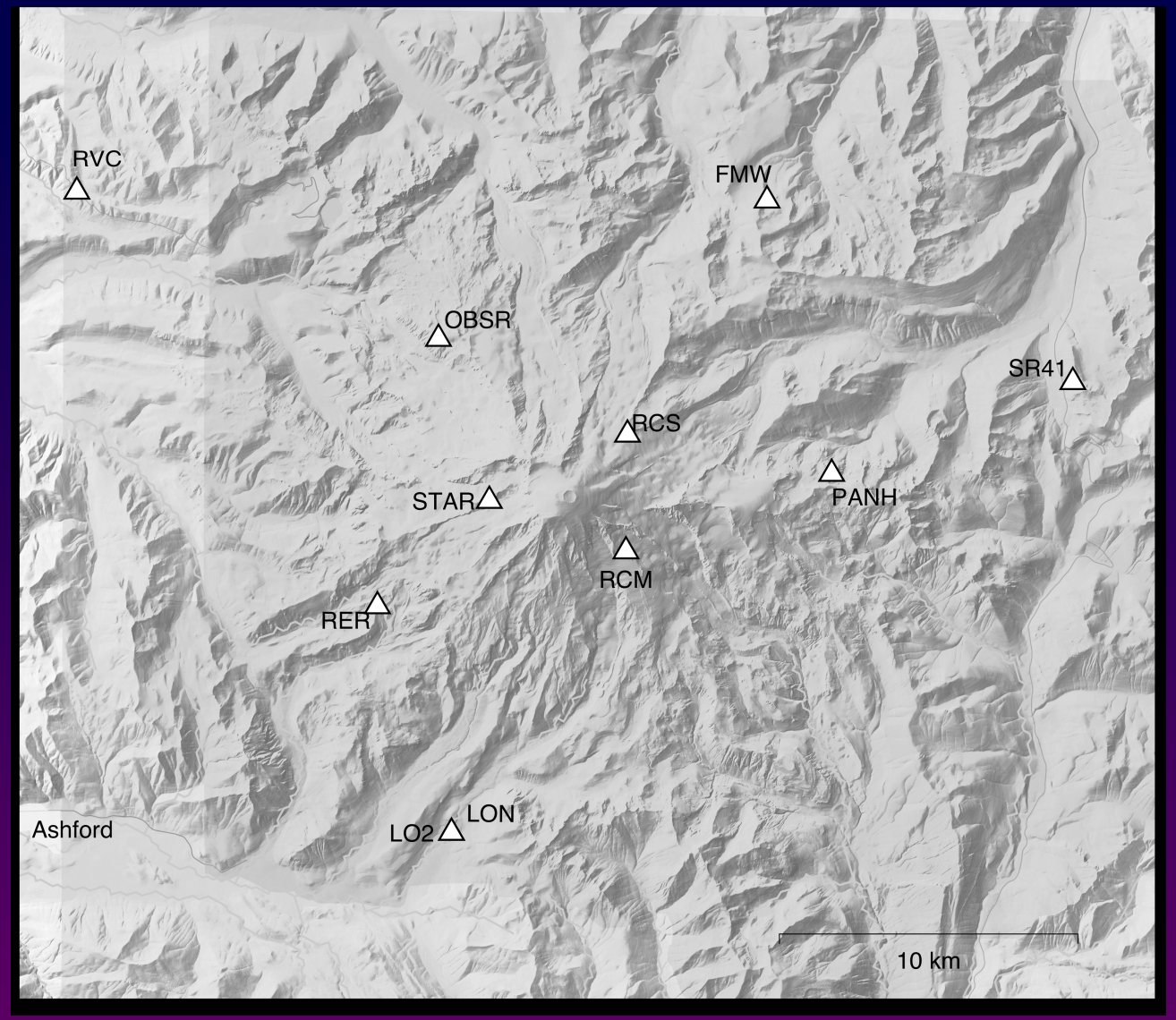
- Most likely scenario: Large lahar will occur during unrest/eruption
- Mitigation strategy – install really good real-time monitoring network to detect earliest signs of unrest

Orting – built on ~520-year-old lahar deposits

USGS

Mount Rainier – Current monitoring network

- First station installed 1963, 2nd in 1972
- Four installed by PNSN in 1989-1993.
- Three installed by CVO in 2007-2008
- PNSN-CVO network: 9 stations w/in 20 km
- Also 7 CGPS stations

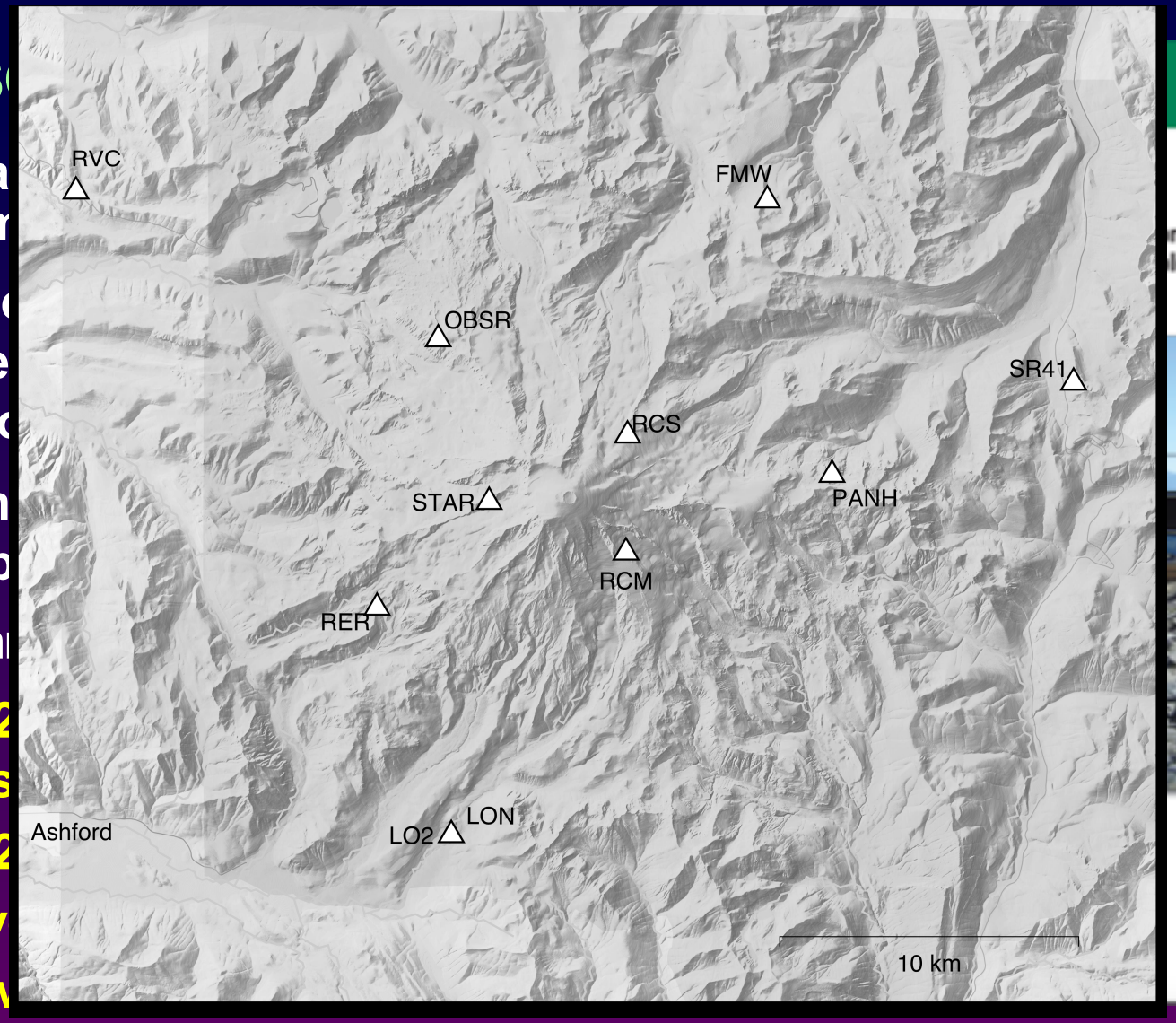


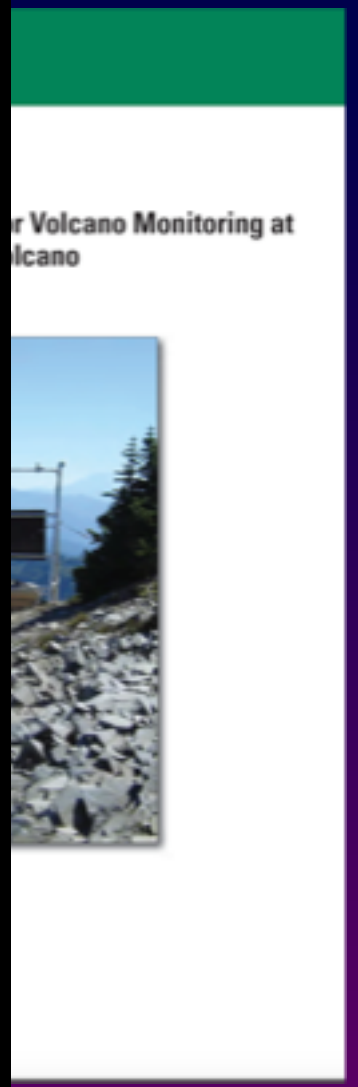
USGS

What is a "good" monitoring network?

2008 US

- 10 co-a
  academ
- Identifi
  given e
  volcano
- Determ
  to enab
- Recom
  - 12-2
    seis
  - 12-2
  - Sev
  - All v





Moran et al., 2008

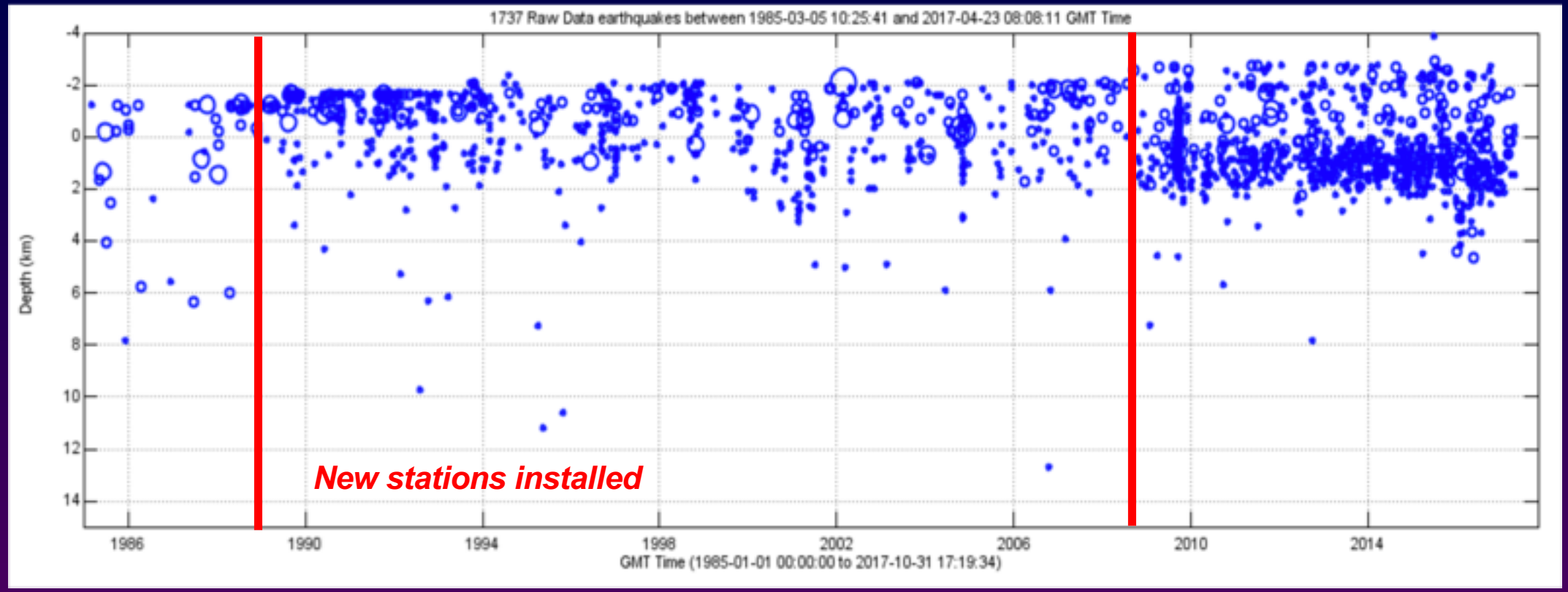
USGS

Mount Rainier – Volcano monitoring

USGS

USGS

Mount Rainier Seismicity



1985-2017 “good” locations (>4 P picks, < 150° gap)

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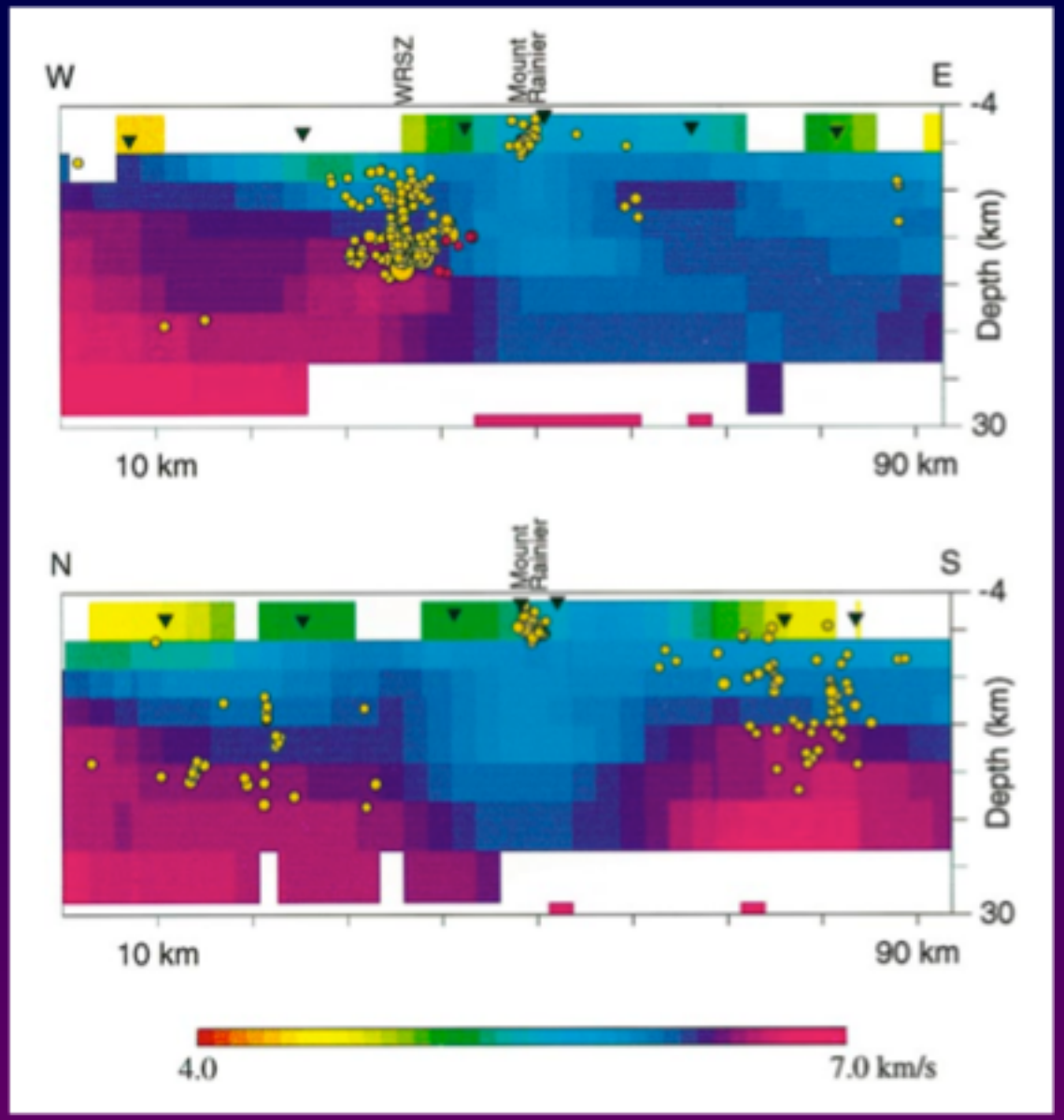
Mount Rainier – Tomography Model

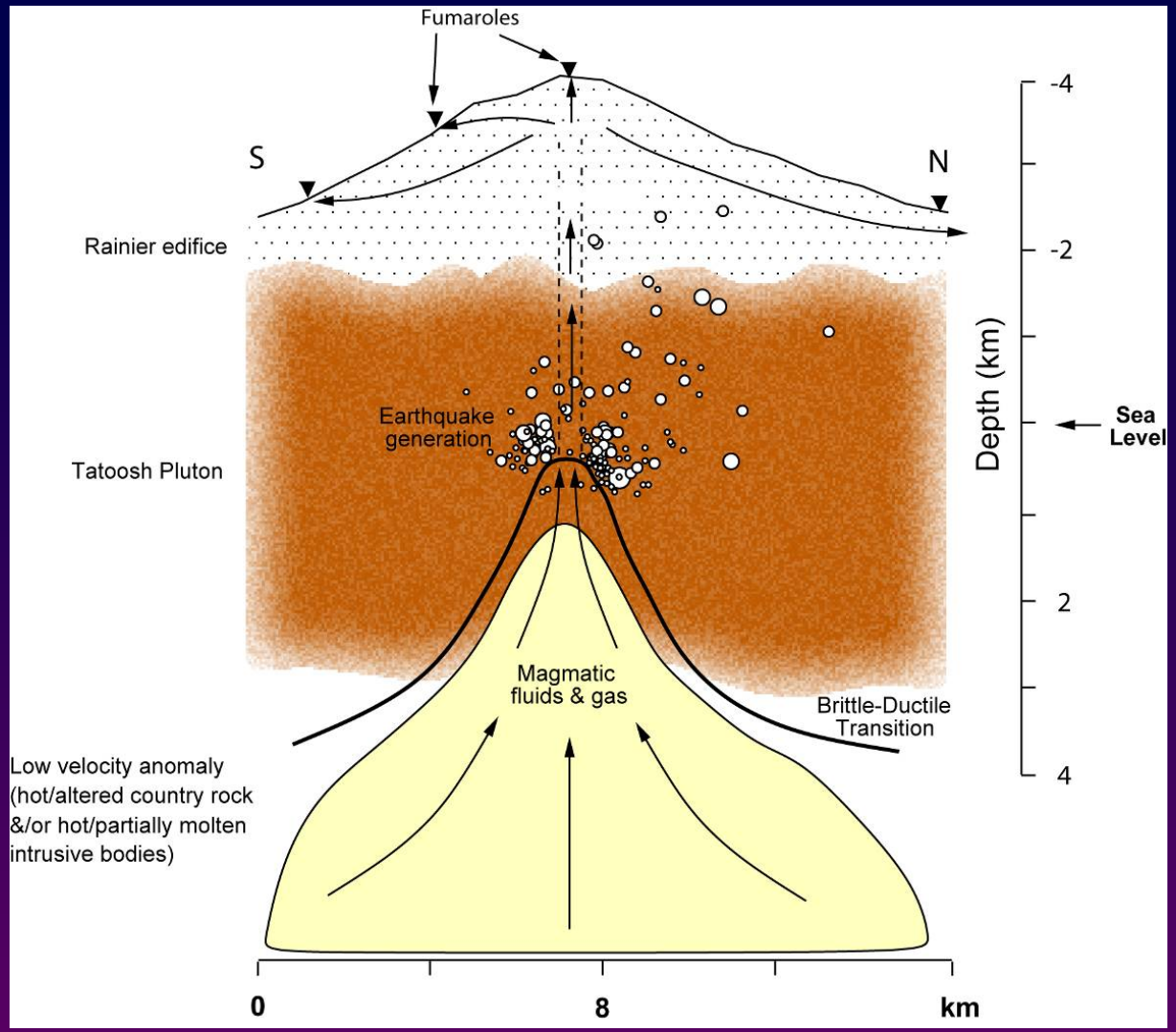
- Low velocities aren't low enough for sedimentary lithologies
- Low velocities aren't high enough for igneous lithologies
- Igneous rock + partial melt?



Moran et al., 2000

USGS

Mount Rainier – Conceptual Model

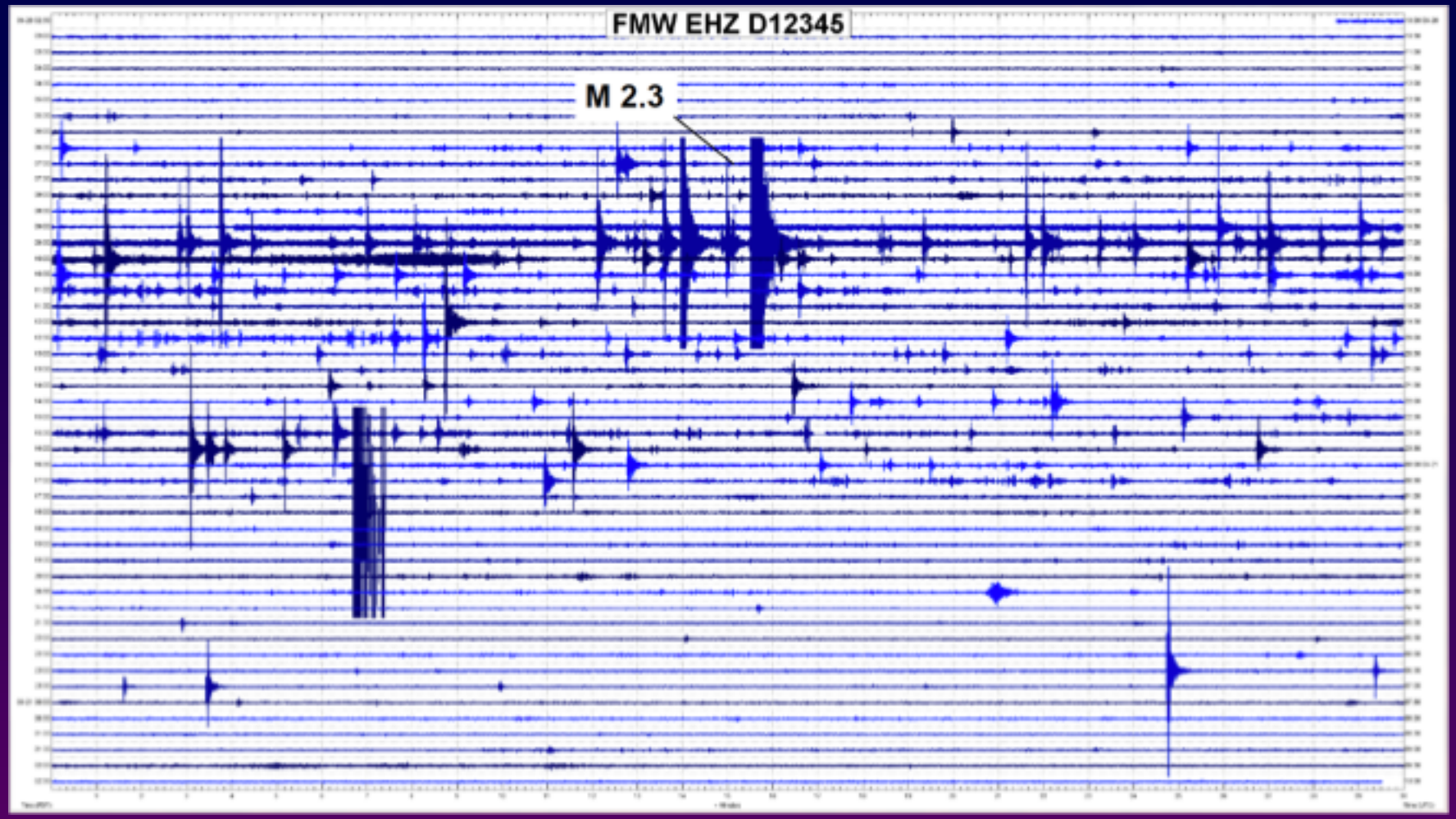


Moran et al., 2000

USGS

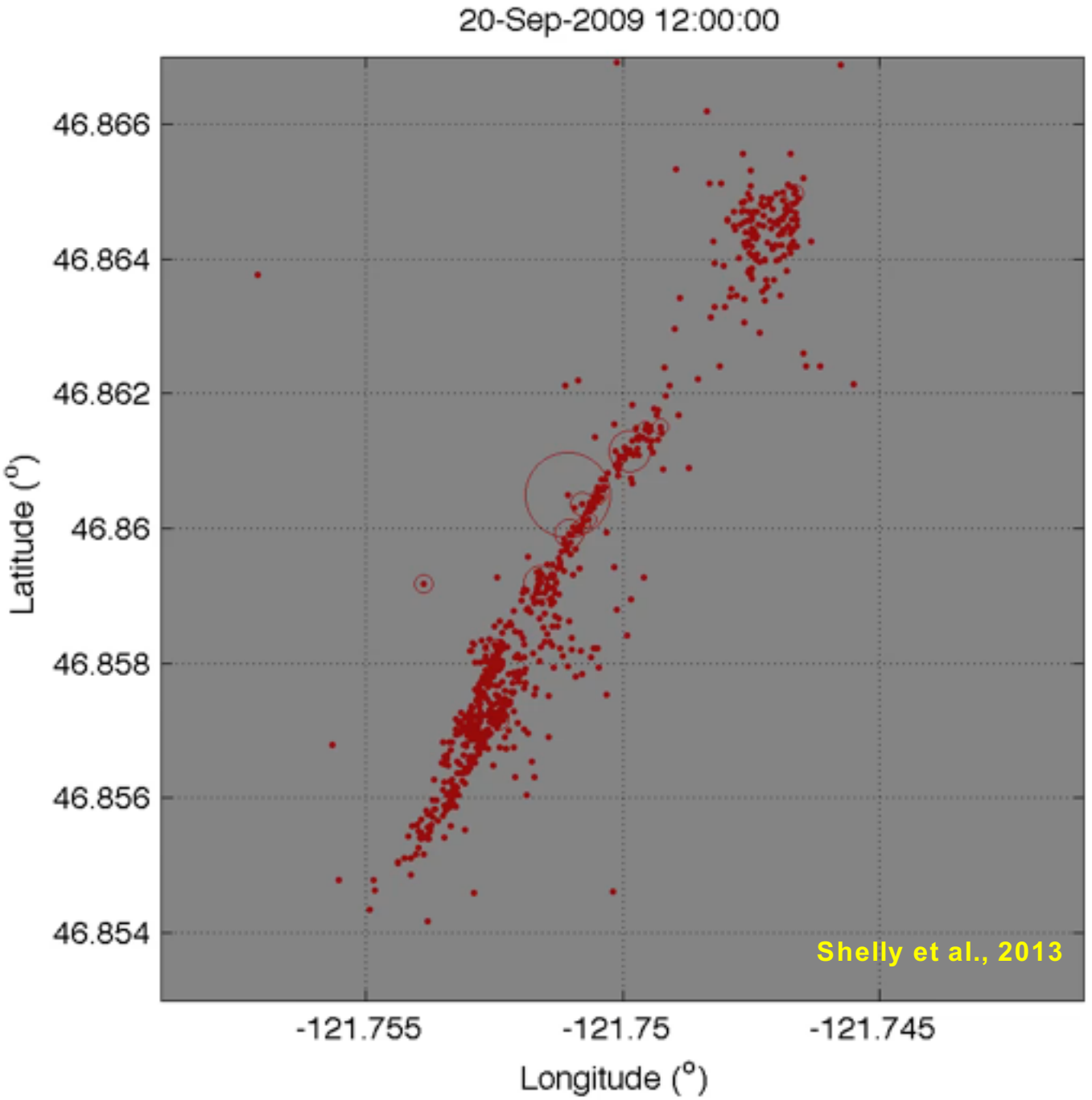
Mount Rainier – Sept 20-22, 2009, swarm

- ~1000 quakes in 3 days (~100 located by PNSN)
- Most significant swarm since monitoring began
- Cause == ??



Shelly et al., 2013

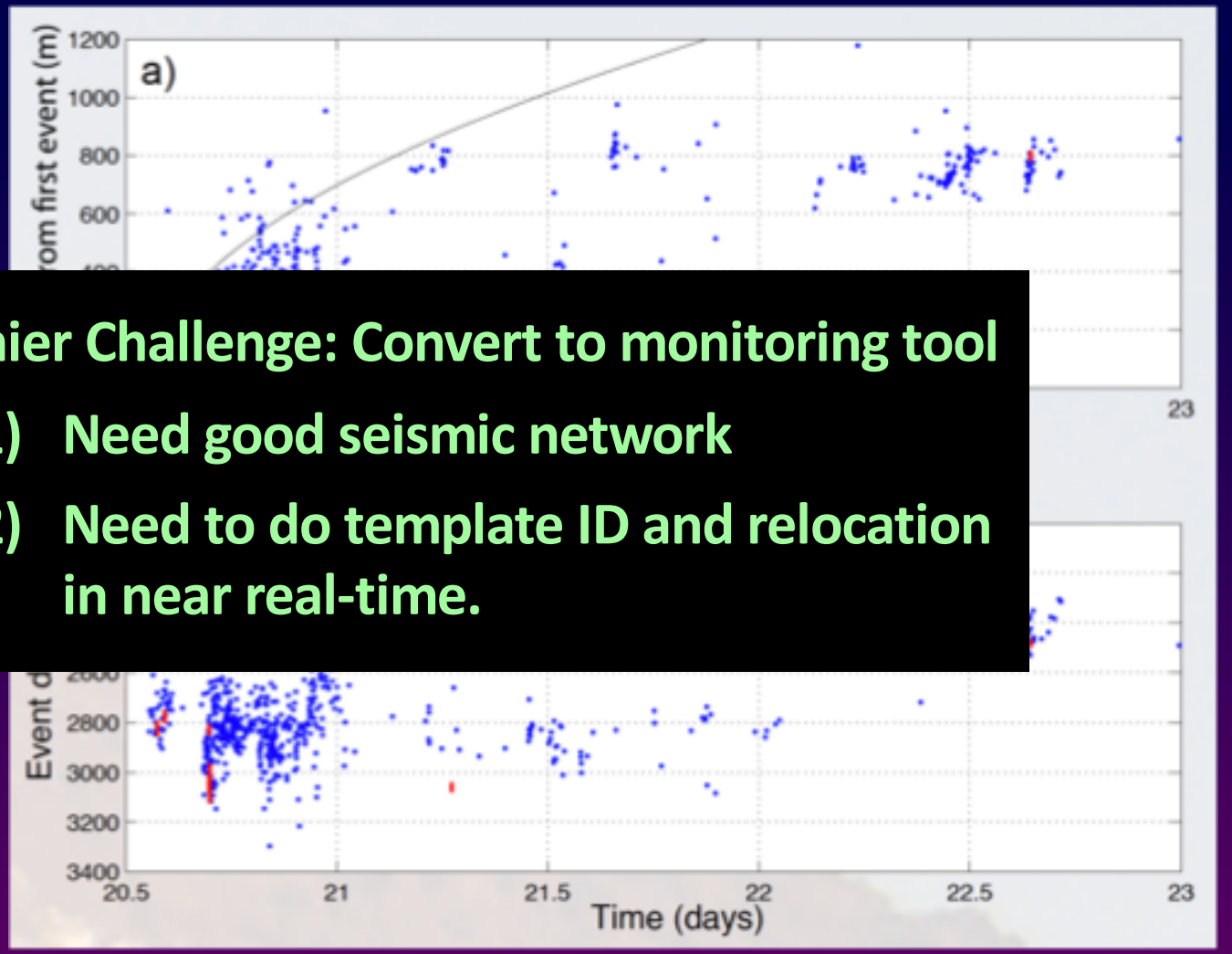
USGS


20-Sep-2009 12:00:00
46.866
46.864
46.862
46.86
46.858
46.856
46.854
Latitude (°)
-121.755
-121.75
-121.745
Longitude (°)
Shelly et al., 2013

USGS

Mount Rainier – Sept 20-22, 2009, swarm

- Event migration front: ~1 m²/sec
- Rate consistent with fluid flow (to fast for magma)



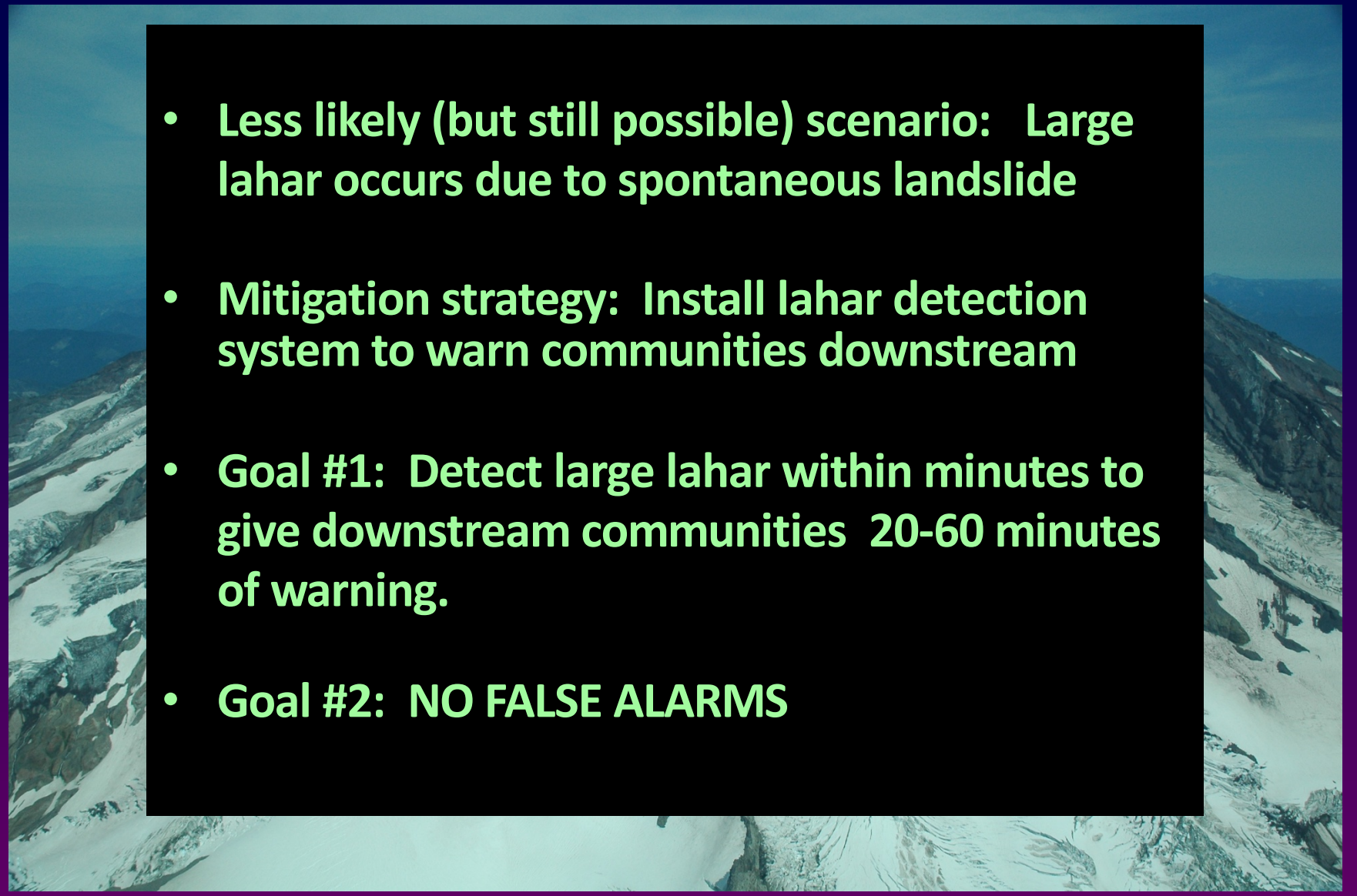
Rainier Challenge: Convert to monitoring tool

1) Need good seismic network
2) Need to do template ID and relocation in near real-time.

Shelly et al., 2013

USGS

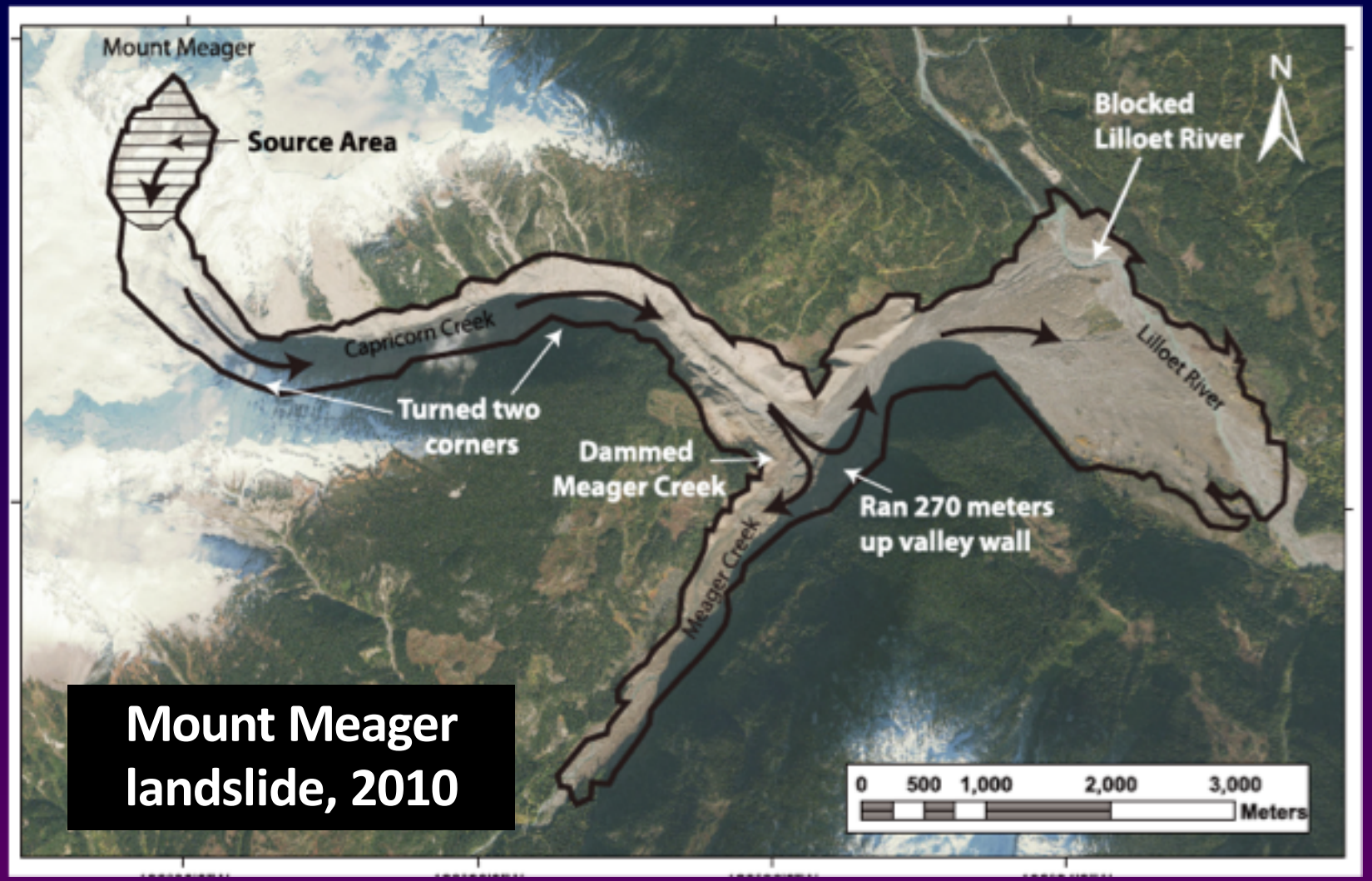
Mount Rainier – Volcano monitoring



- Less likely (but still possible) scenario: Large lahar occurs due to spontaneous landslide
- Mitigation strategy: Install lahar detection system to warn communities downstream
- Goal #1: Detect large lahar within minutes to give downstream communities 20-60 minutes of warning.
- Goal #2: NO FALSE ALARMS

USGS

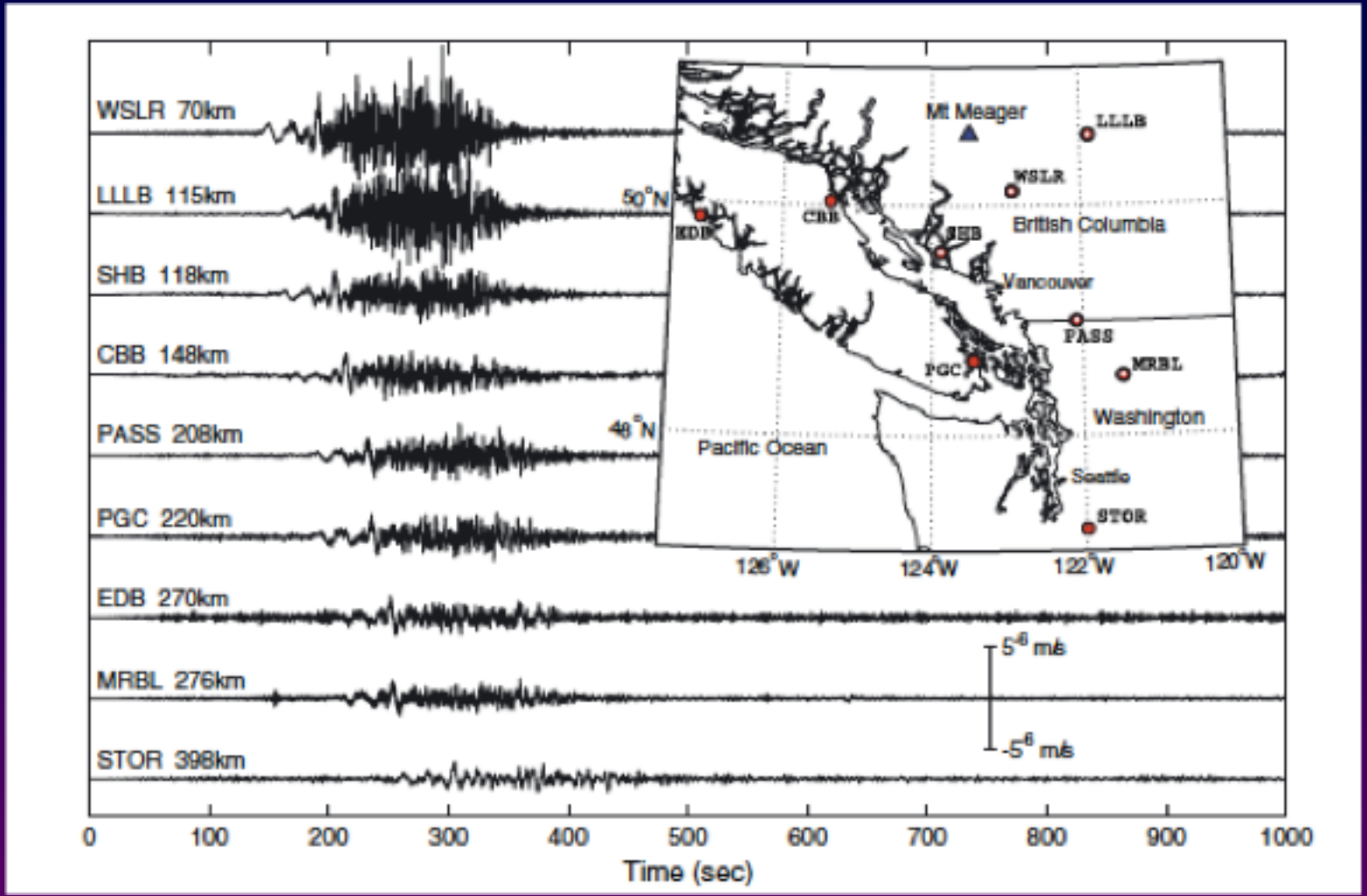
Detect Large Moving Landslides



Allstadt et al., 2015

USGS

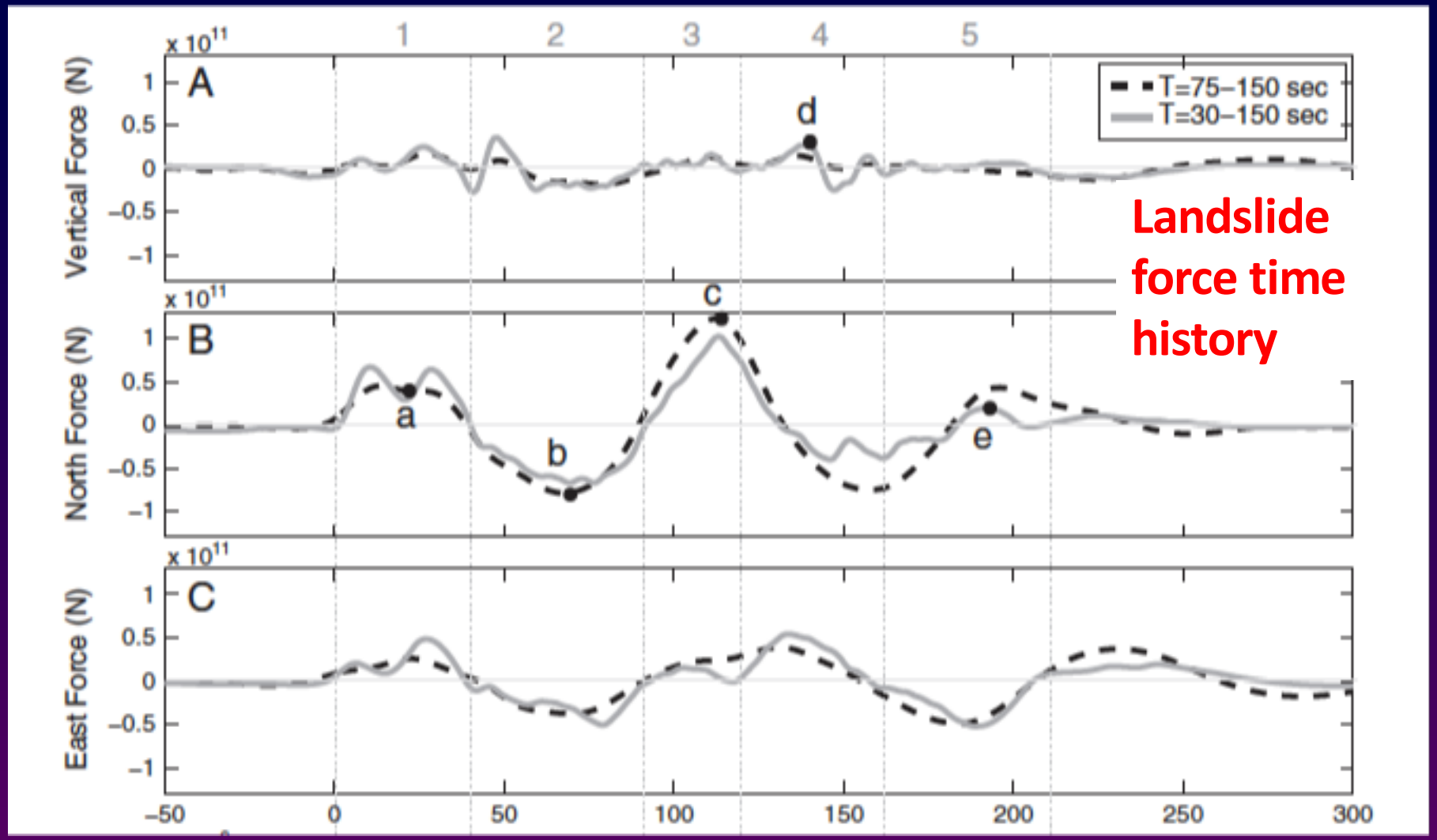
Detect Large Moving Landslides



Allstadt et al., 2015

USGS

Detect Large Moving Landslides

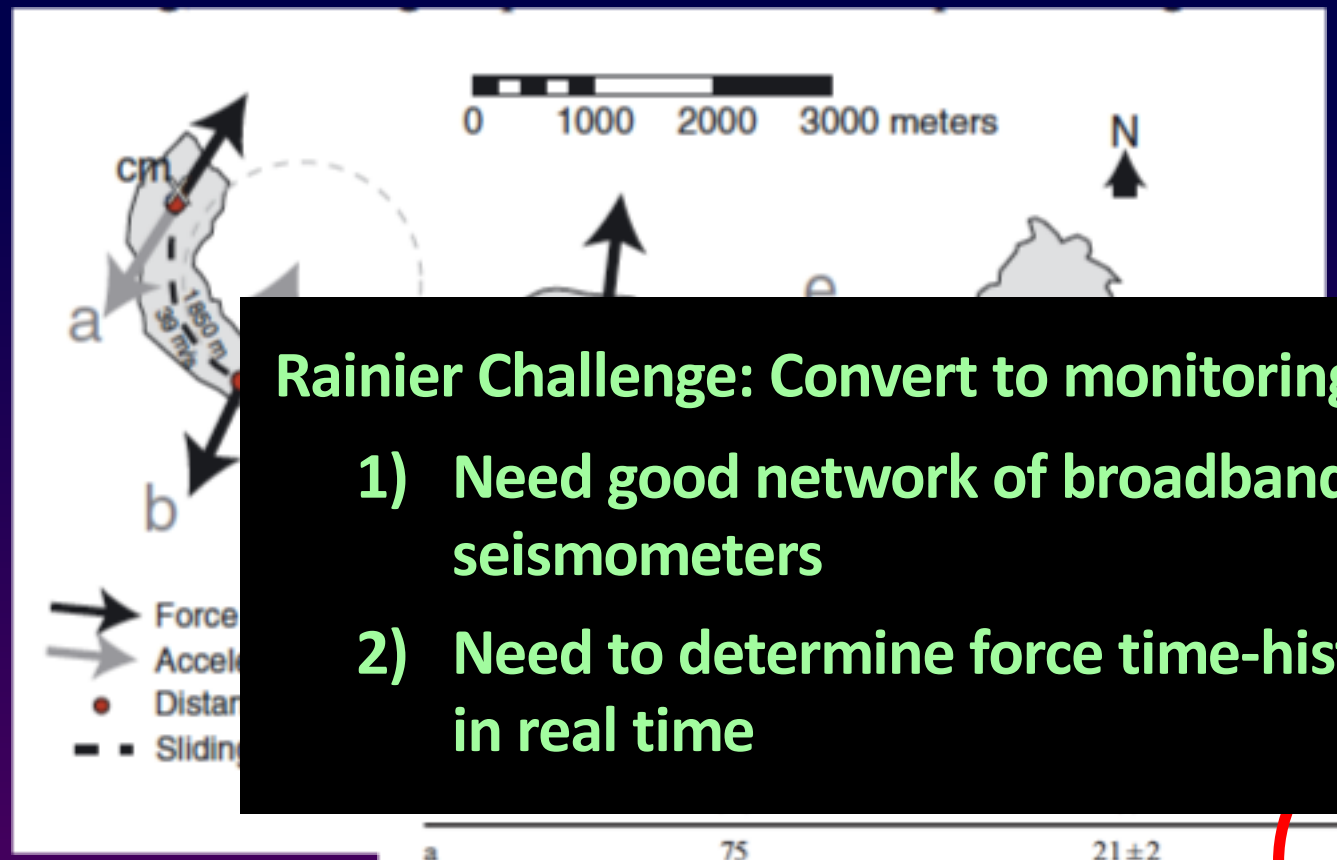


Landslide force time history

Allstadt et al., 2015

USGS

Detect Large Moving Landslides



Rainier Challenge: Convert to monitoring tool

1) Need good network of broadband seismometers
2) Need to determine force time-history in real time

imuth of the For

			d, Best Estimate m/s)
a	75	21 ± 2	4
b	1850 ± 400	48 ± 2	39
c	3360 ± 400	44 ± 2	76
d	2400 ± 400	26 ± 2	92
e	700 ± 350	52 ± 2	13

[a]Refer to Figure 8 for the timing and Figure 11 for the location of points a–e.

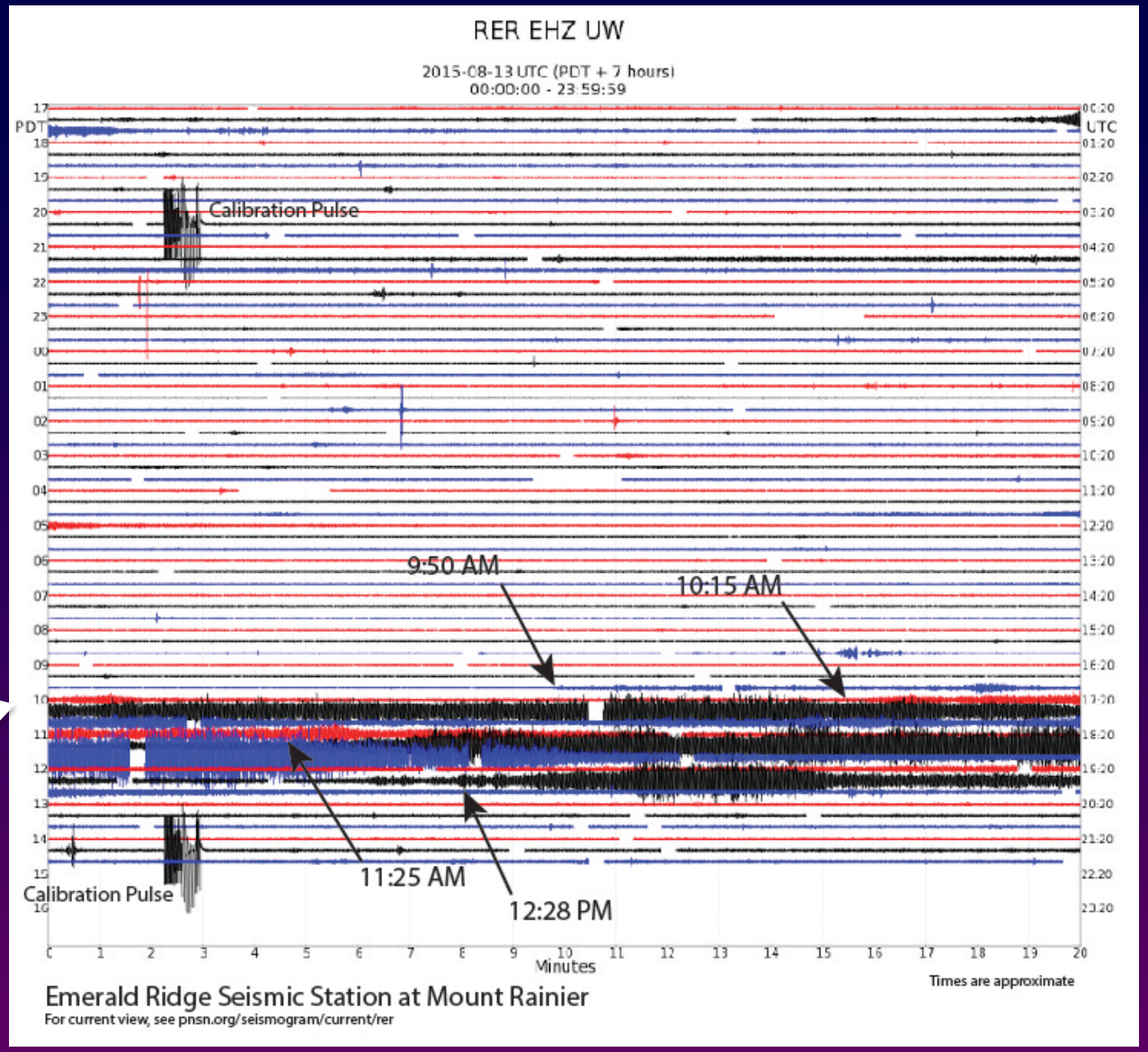
Allstadt et al., 2015

USGS

Detect Lahars & Track Flow Front Position

- Seismometers have to be close to drainages to record lahars
- Need multiple stations to be sure (no false alarms)

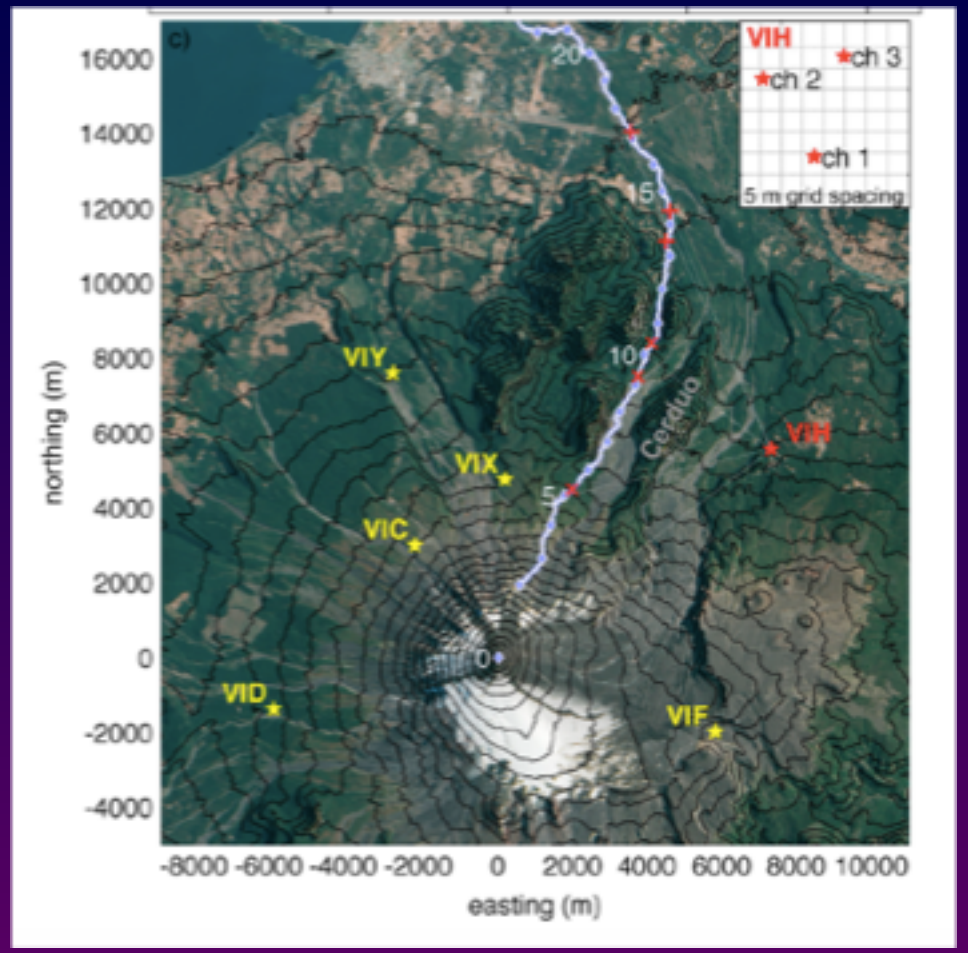
August 13, 2015, debris flow

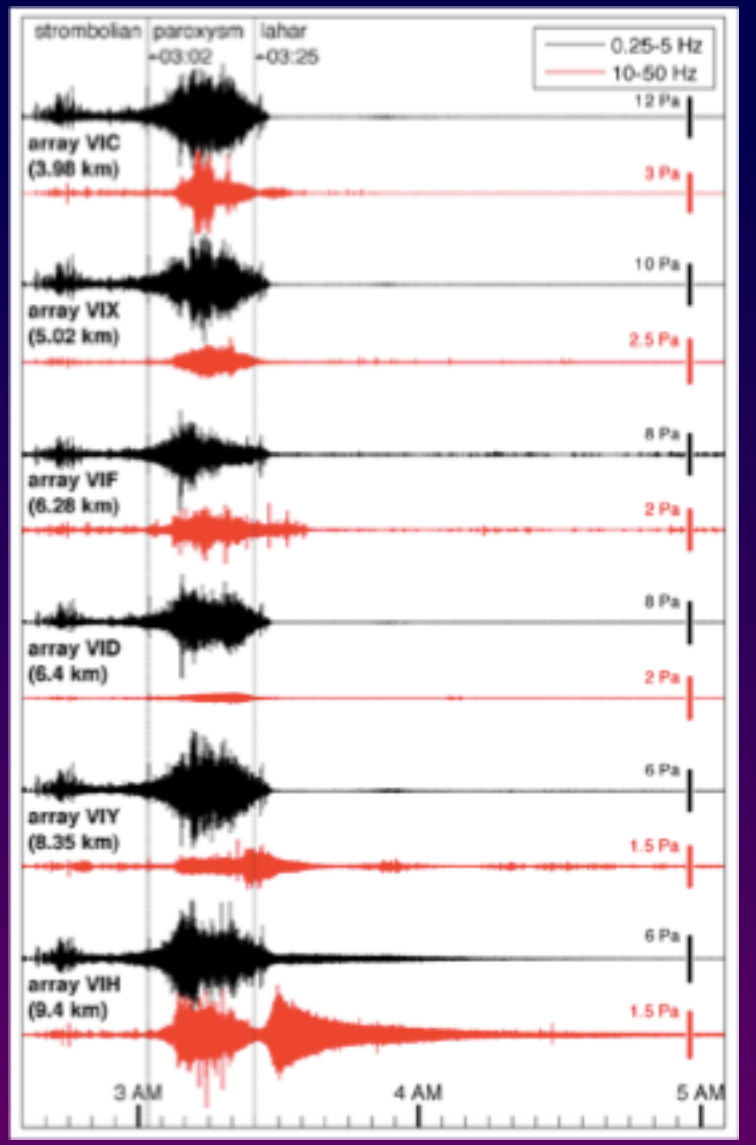


USGS

Detect Lahars & Track Flow Front Position

Volcan Villarrica 2015 eruption

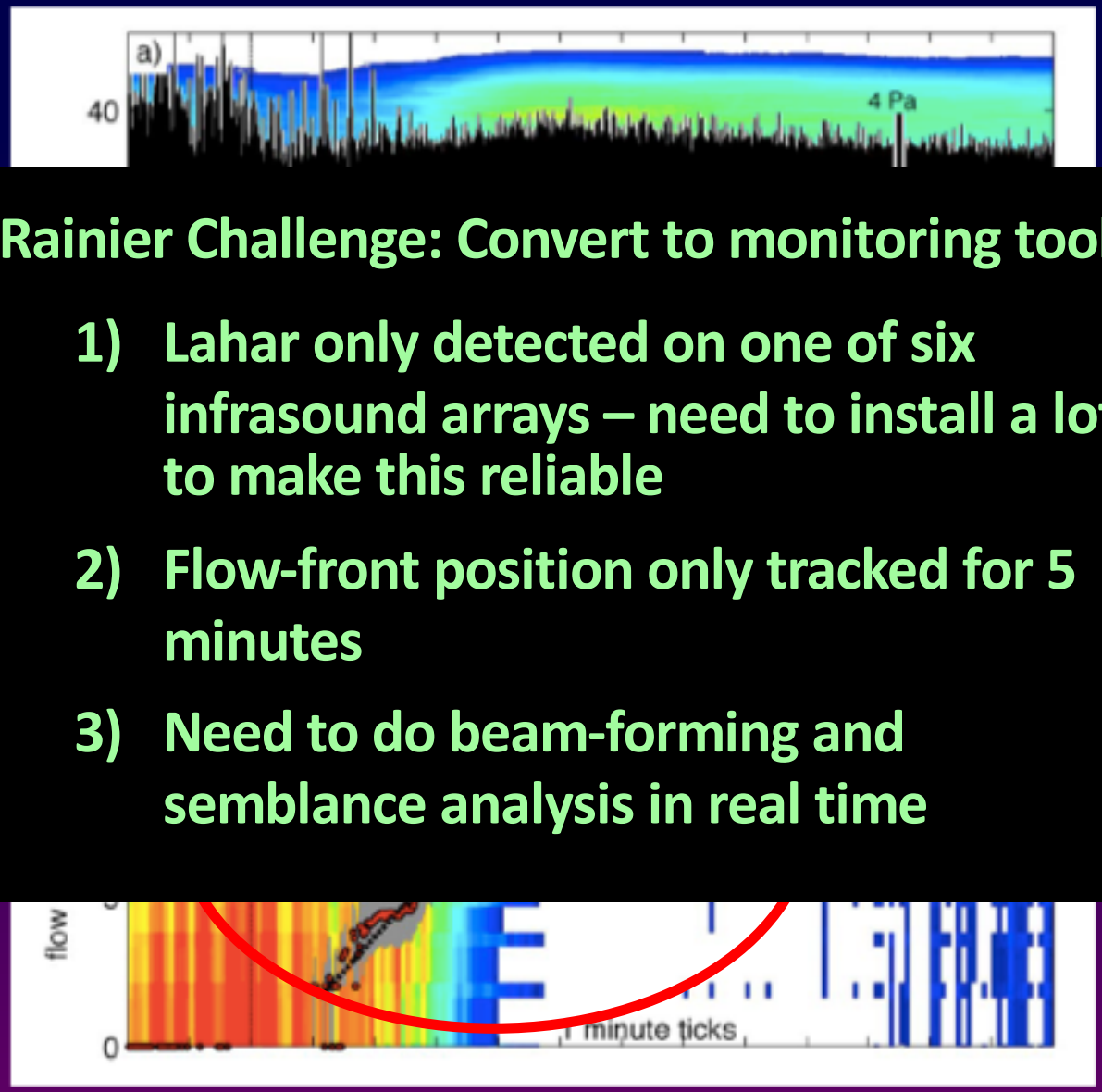




Johnson et al., 2015

USGS

Detect Lahars & Track Flow Front Position



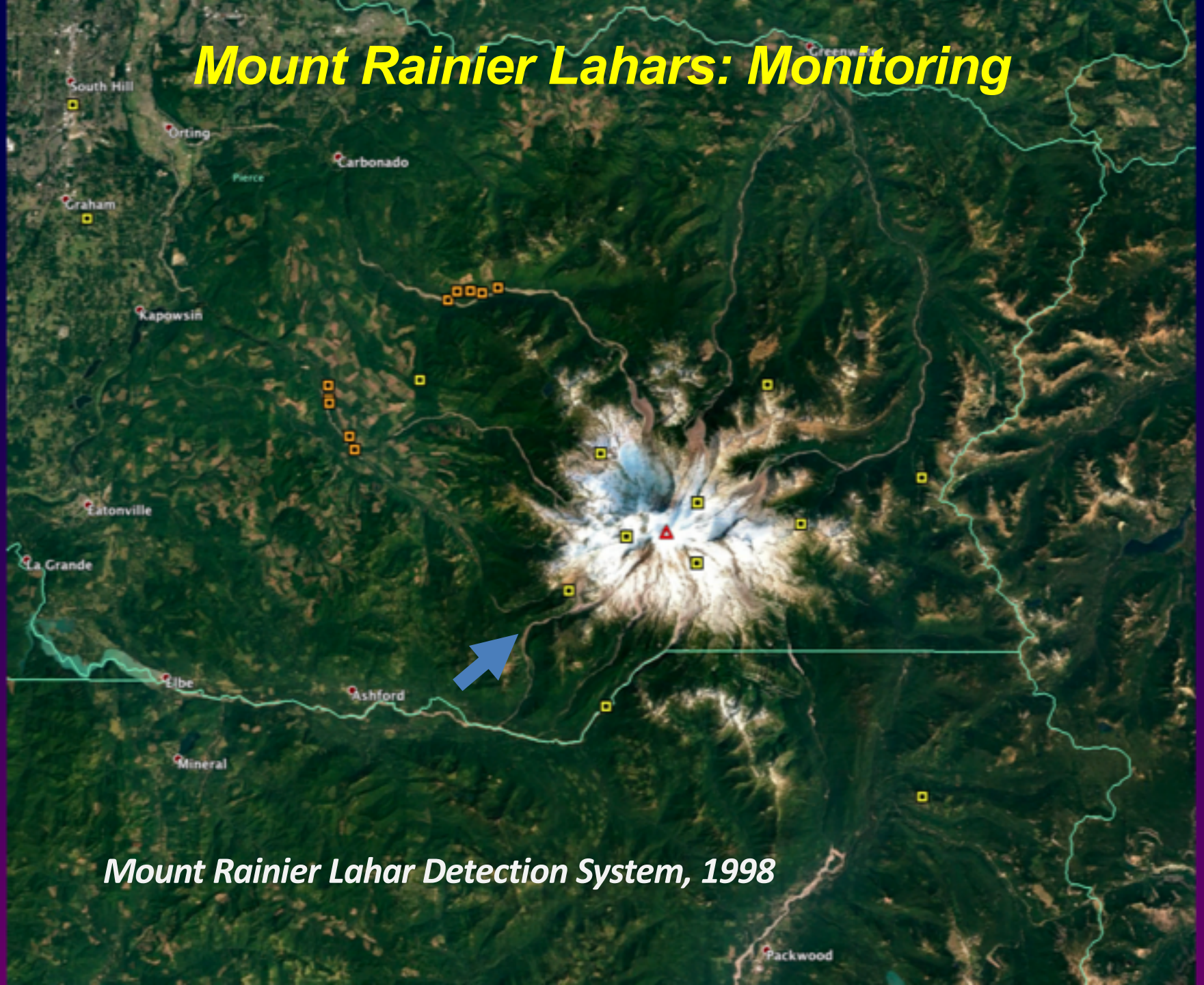
Rainier Challenge: Convert to monitoring tool

1) Lahar only detected on one of six infrasound arrays – need to install a lot to make this reliable
2) Flow-front position only tracked for 5 minutes
3) Need to do beam-forming and semblance analysis in real time

USGS

Johnson et al., 2015

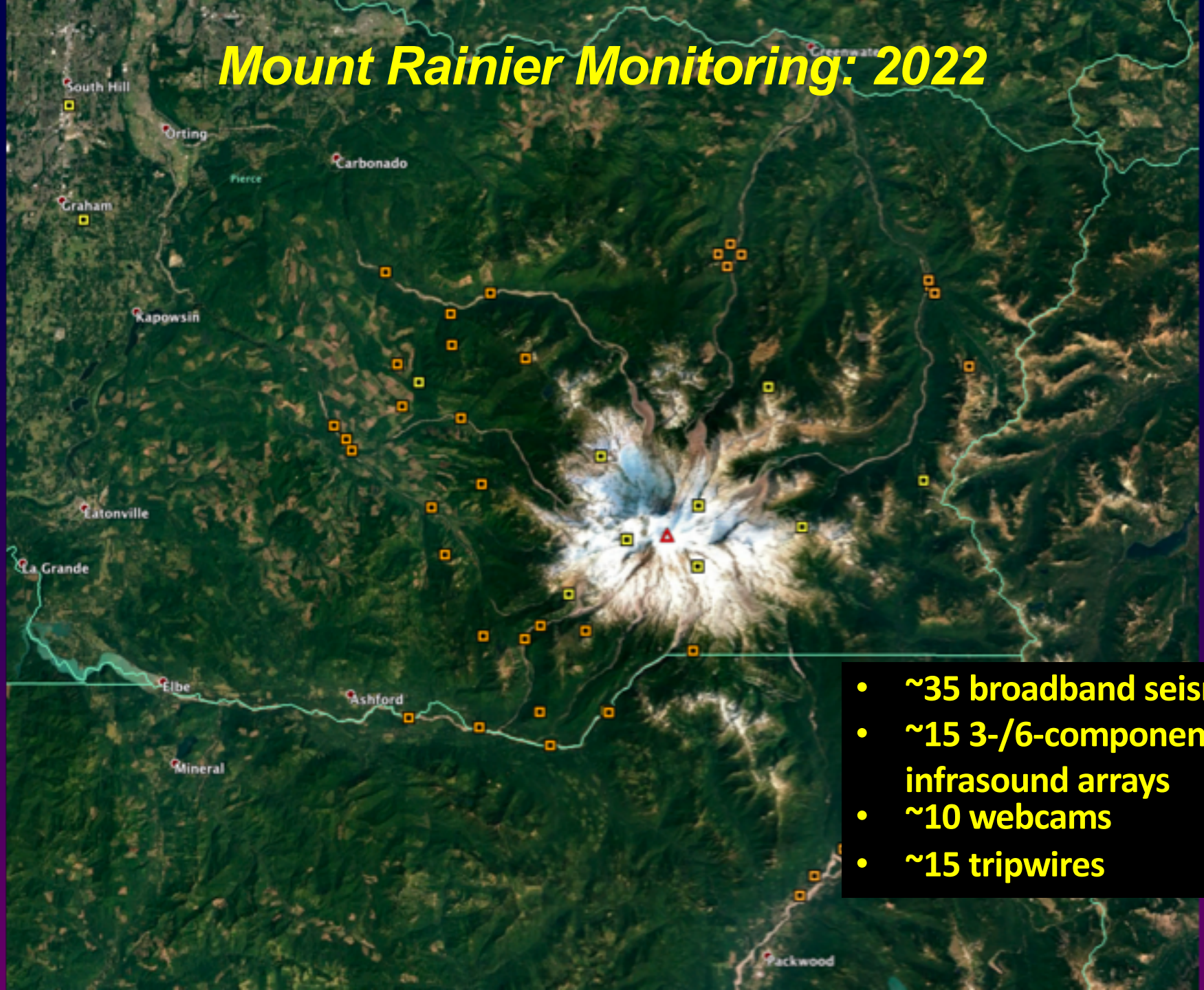
Mount Rainier Lahars: Monitoring



Mount Rainier Lahar Detection System, 1998

USGS

Mount Rainier Monitoring: 2022

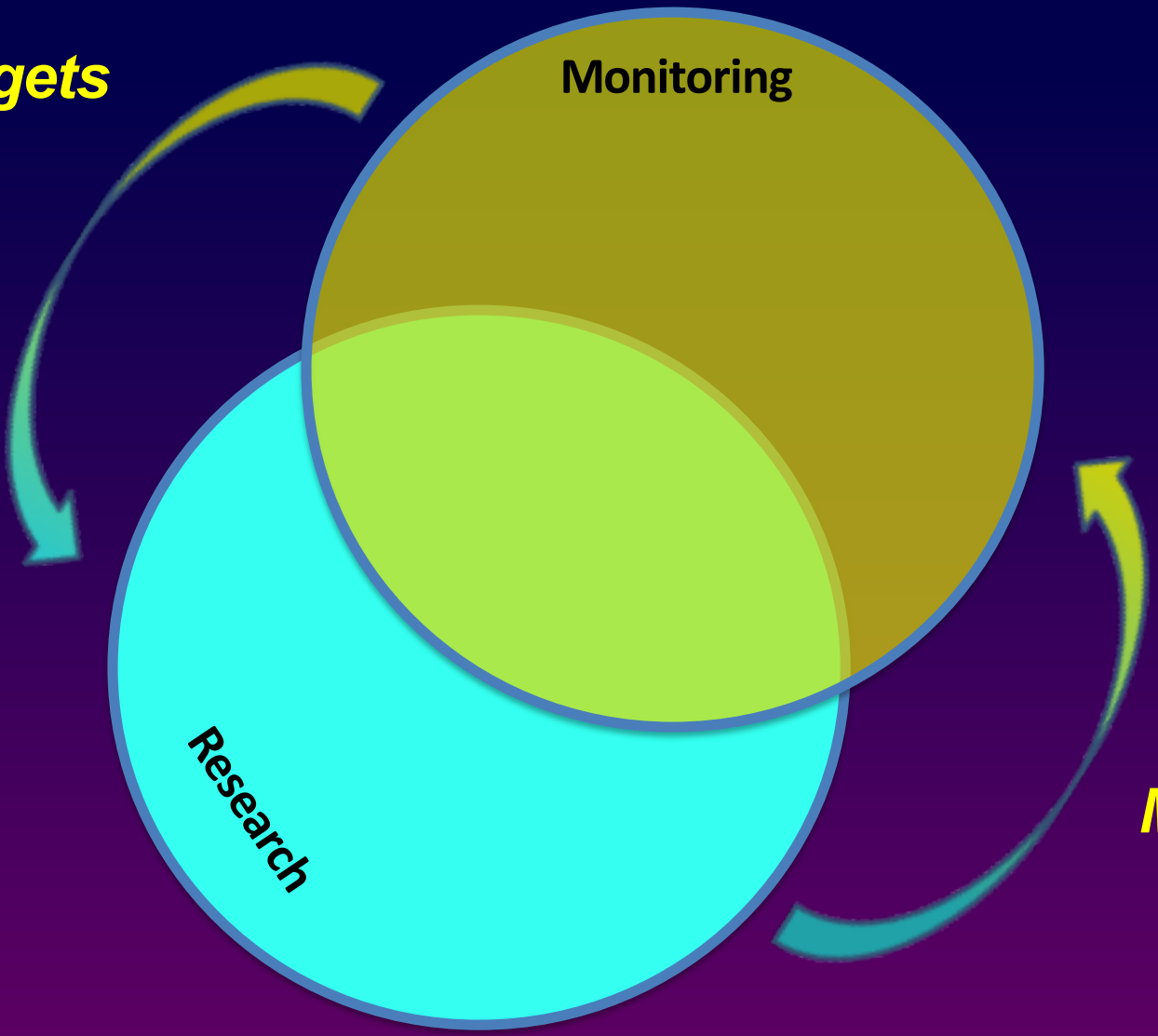


- ~35 broadband seismometers
- ~15 3-/6-component infrasound arrays
- ~10 webcams
- ~15 tripwires

USGS

Mitigating Volcanic Hazards

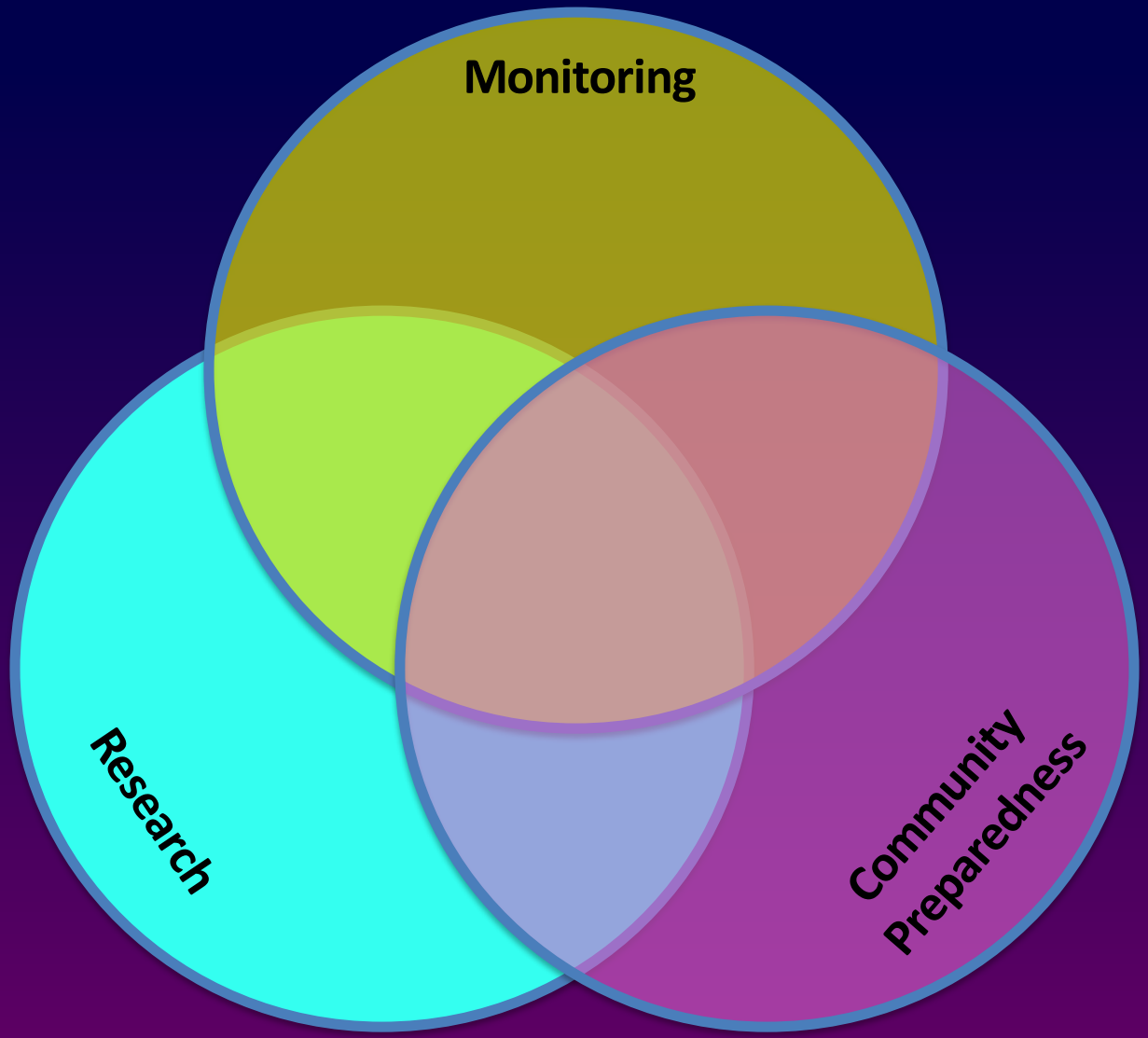
Monitoring begets Research



Research informs Monitoring Strategies

USGS

Mitigating Volcanic Hazards



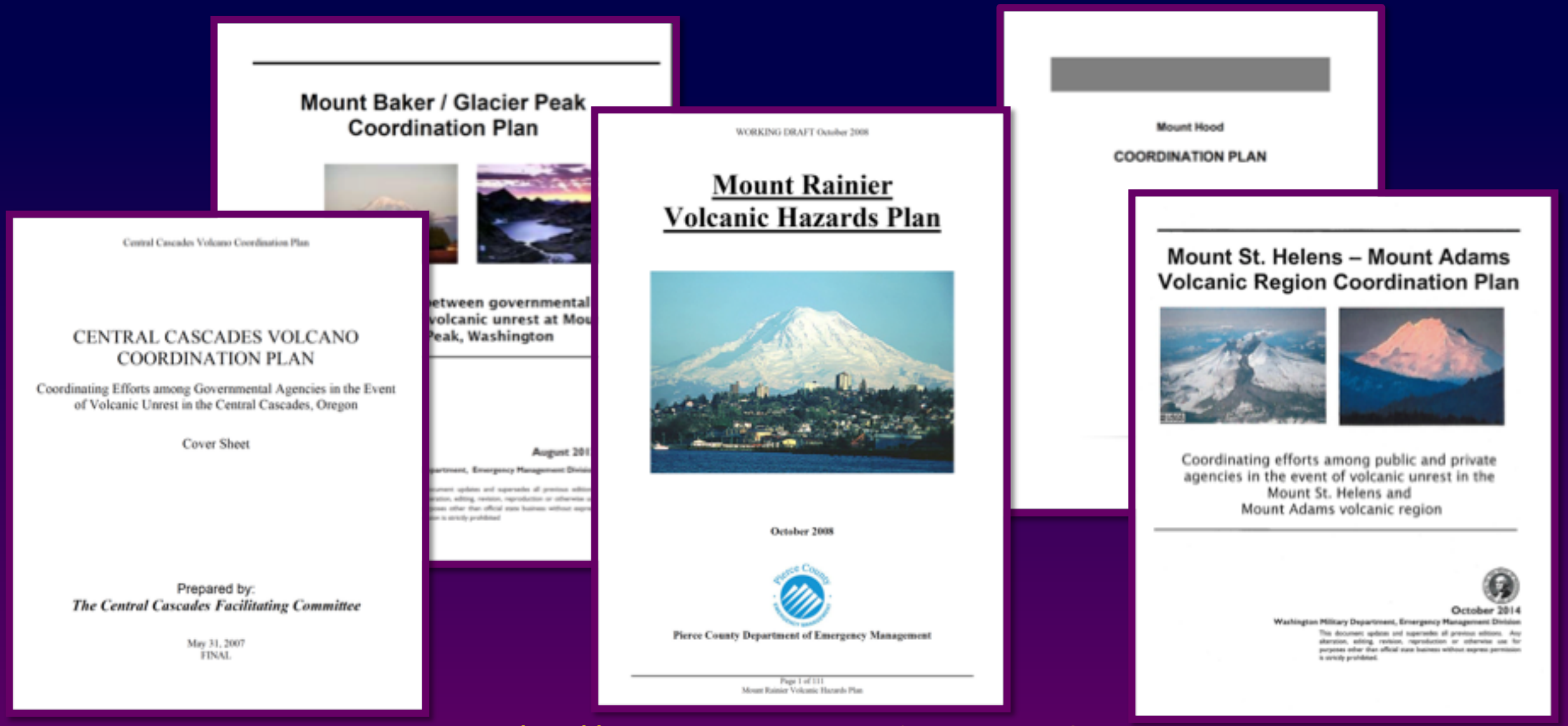
USGS

Community Preparedness: The Reason It's Important

Armero, Colombia – 1985 lahar, ~20,000 dead

USGS

Community Preparedness: Response Plans



Produced by WA EMD, WA DNR, Pierce County & other counties, USGS, land managers, etc.

USGS

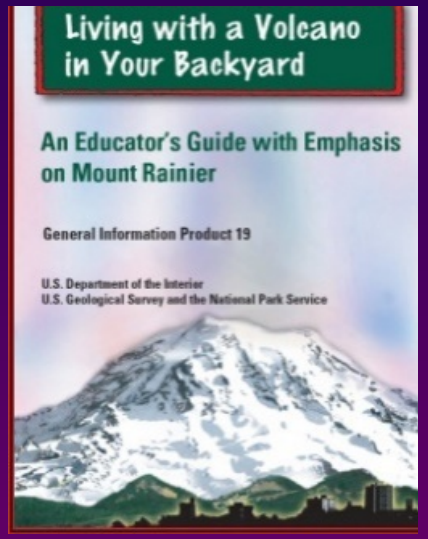
Community Preparedness: Outreach

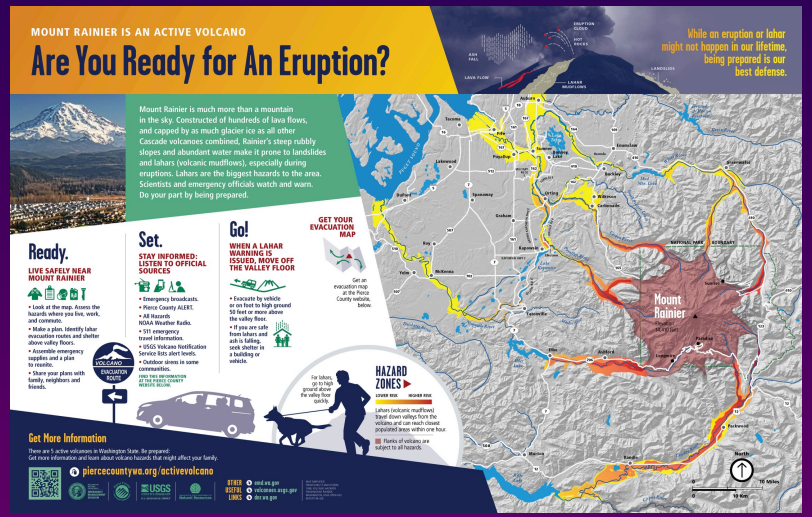
Policy Makers and Planners

News & social media

Hazards products

Education Resources





USGS

Mount Rainier Lahar: Community Preparedness

USGS

USGS, Liz Westby, 2017