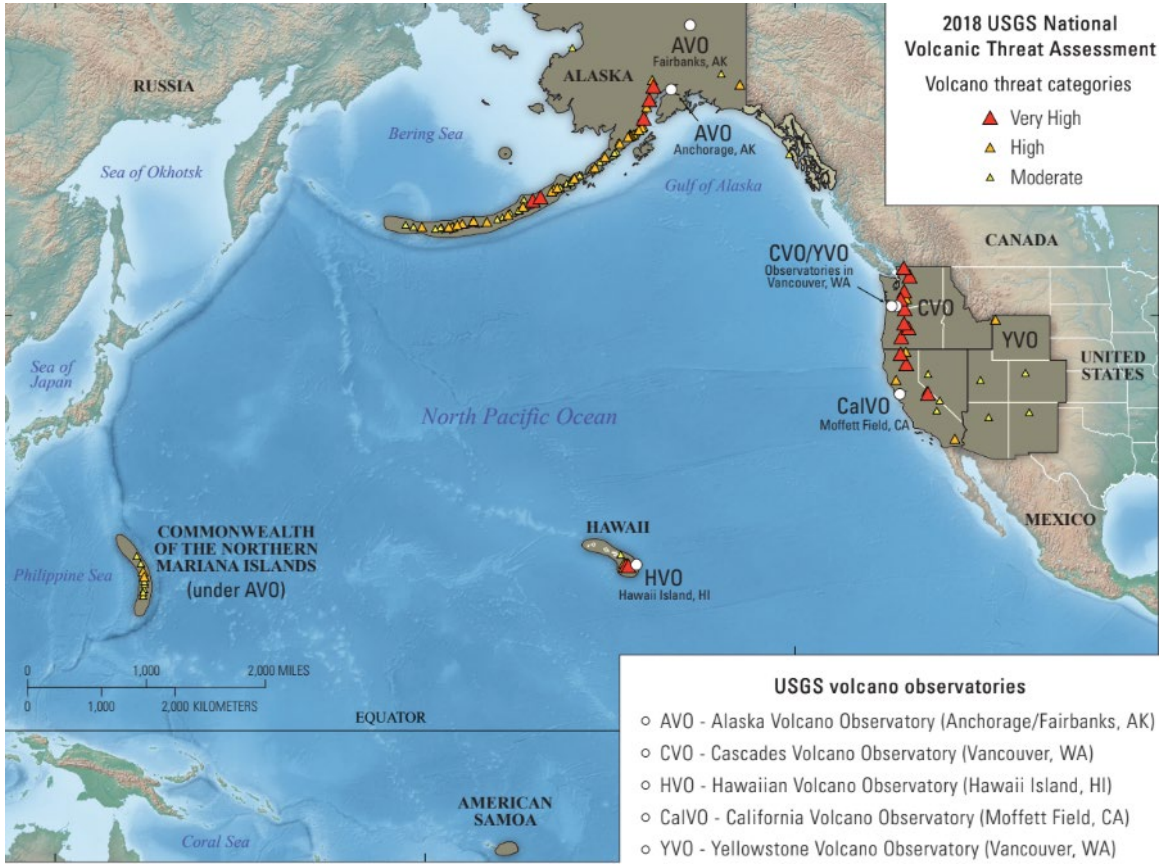
# *Forecasting eruptions at Alaska's volcanoes*

Michelle Coombs
USGS Alaska Volcano Observatory

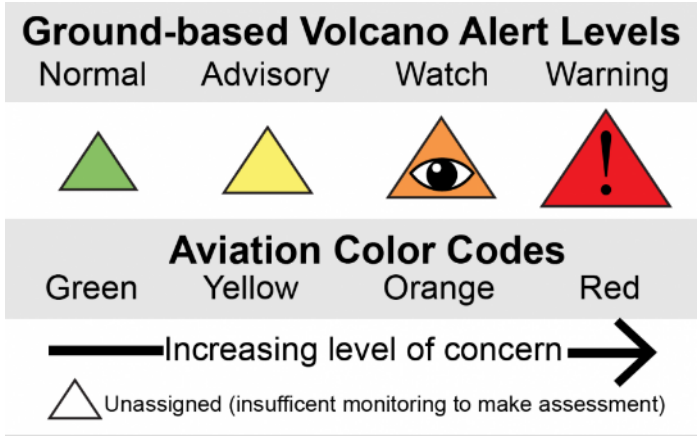
USGS Subduction Zone Science Workshop
January 11, 2023

# AVO one of 5 US volcano observatories

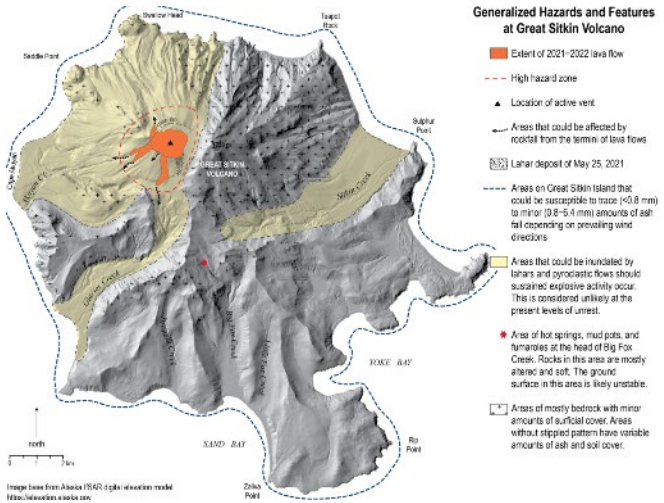



U.S. Geological Open File 2021-1092

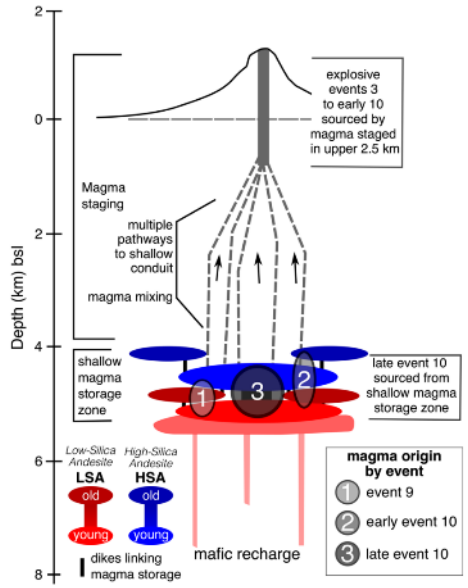
## National Volcano Early Warning System (NVEWS)




## Assessments and research

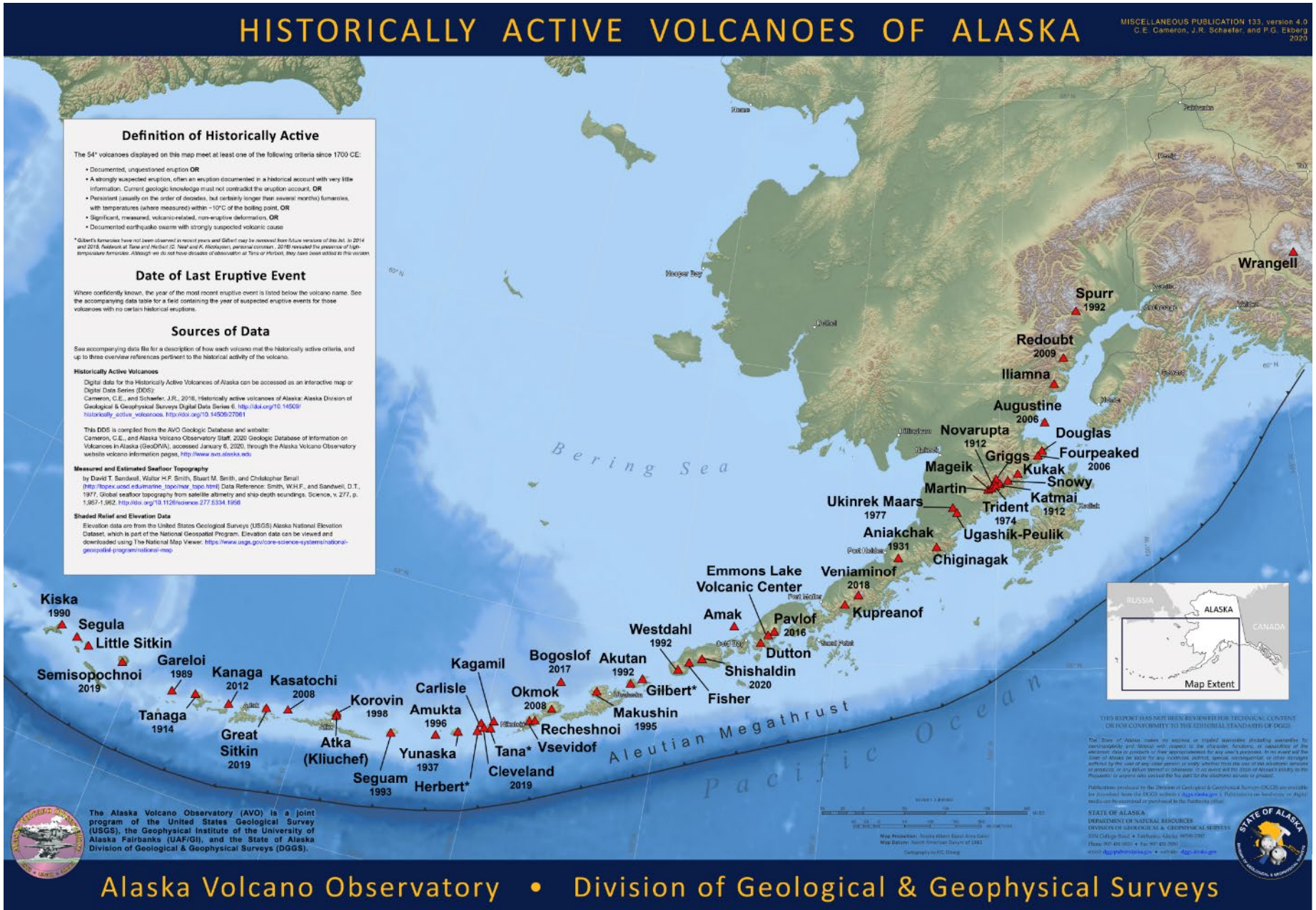



Generalized from Waythomas et al. 2004



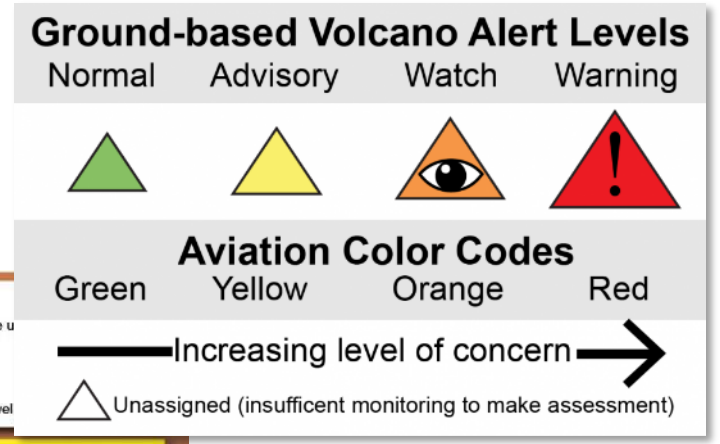

Benage et al., 2021

# Many volcanoes, frequent activity




avo.alaska.edu

# Many volcanoes, frequent activity




## Alaska Volcano Observatory Weekly Update for the week of January 2, 2023

**AVO Color Code**

- Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe u… OR eruption is underway with no or minor volcanic-ash emissions
- Volcano is exhibiting signs of elevated unrest above known background level
- Ground-based instrumentation is insufficient to establish that a volcano is in a typical background level

### Semisopochnoi

- Minor emissions observed
- Low-level seismic activity continues
- Eruptive deposits on flank of North Cone

Web-camera view of north cone, January 4, 2023. View is to the south.

### Takawangha

- Nothing noteworthy observed
- Low-level seismic activity continues


Approximate earthquake locations at Takawangha Volcano over the past two weeks.

### Great Sitkin

- Minor lava production continues
- Low-level seismic activity
- Somewhat restless, but activity appears to be waning

Web-camera view of Great Sitkin Volcano, January 4, 2023. View is to the northeast.

### Cleveland

- Slightly elevated surface temperatures at vent
- Activity at background levels, color code lowered to Unassigned

Web-camera view of Cleveland Volcano, January 4, 2023. View is to the northwest.

### Pavlof

- Slightly elevated surface temperatures at vent
- Slightly above background seismicity
- Somewhat restless, but activity appears to be waning

Web-camera view of Pavlof Volcano, January 4, 2023 View is to the northwest.

Information on all Alaska volcanoes is available at: http://www.avo.alaska.edu.
For definitions of Aviation Color Codes and Volcano Alert Levels, see: http://www.avo.alaska.edu/color_codes.php
SUBSCRIBE TO VOLCANO ALERT MESSAGES by email: http://volcanoes.usgs.gov/vns/
FOLLOW AVO ON FACEBOOK: https://facebook.com/alaska.avo
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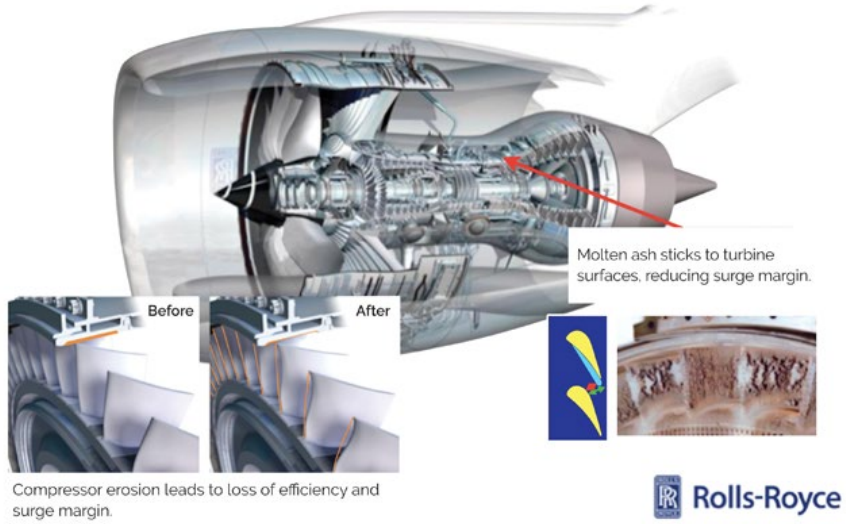
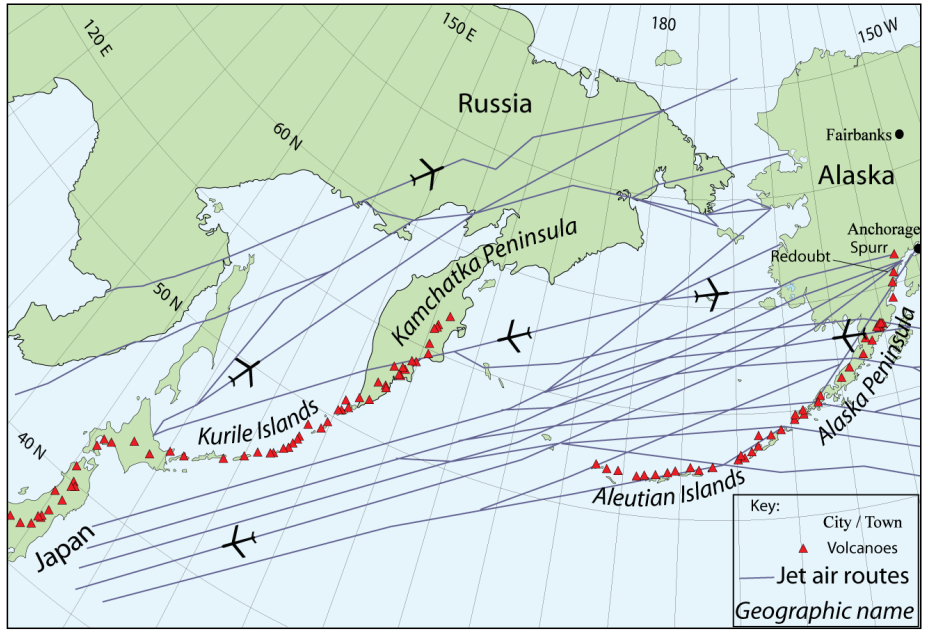
The Alaska Volcano Observatory is a cooperative program of the U.S. Geological Survey, the University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological and Geophysical Surveys

# Main hazard from Alaska eruptions is volcanic ash

- Up to 50,000 passengers per day fly over the North Pacific (Ewert et al., 2018)
- Ash reaches altitudes to be of concern to aviation 10-12 days per year

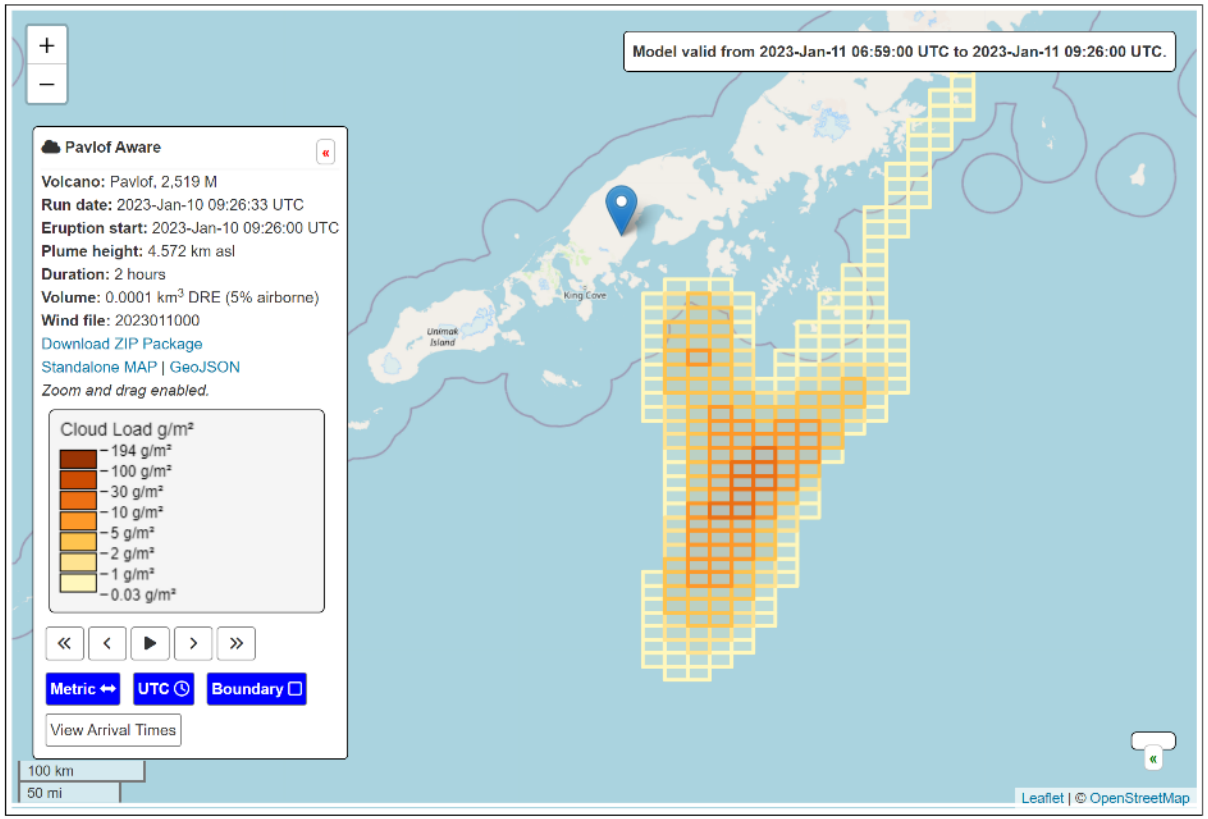


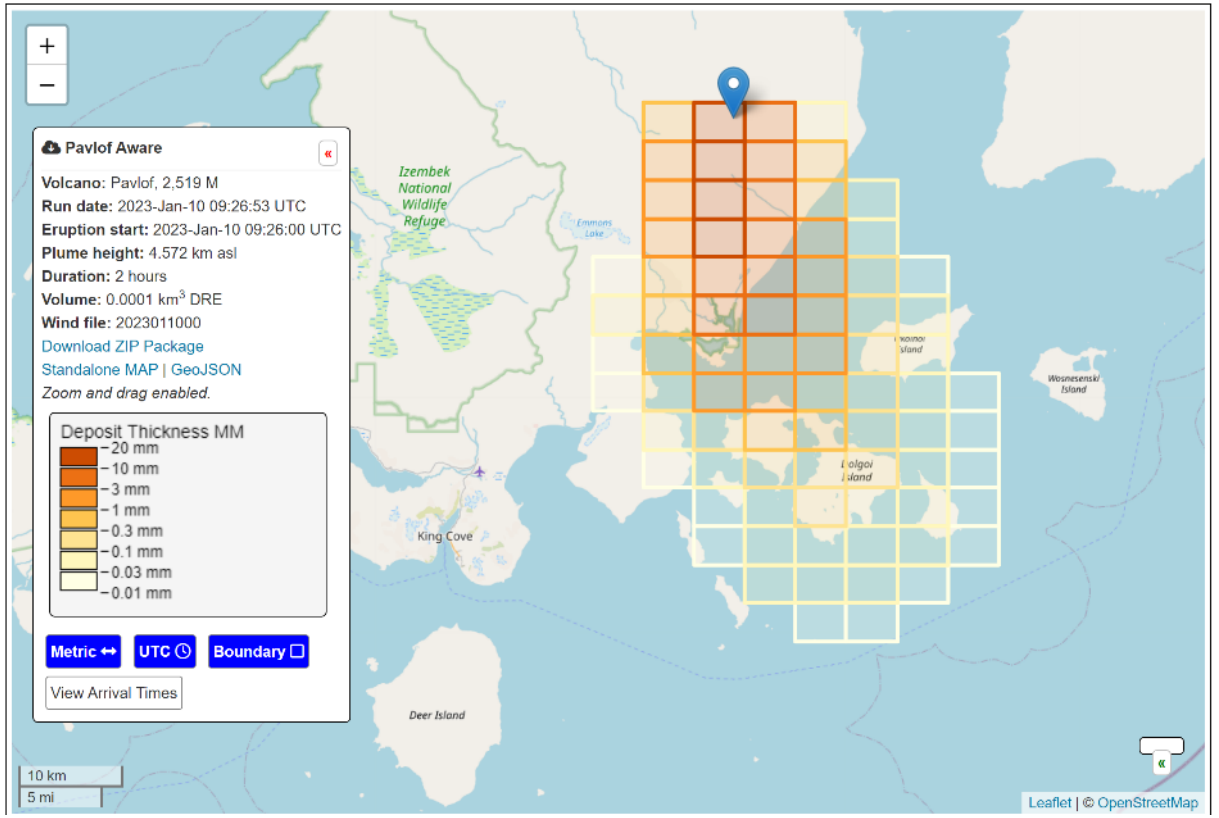

*North Pacific air routes (blue lines) pass over or near more than a hundred potentially active volcanoes (red triangles).*

*When ash enters jet engines, it can wear down and even mangle blades in the turbines and reduce airflow as it builds up.*

# Ash dispersion modeling (Ash3D)




Ash cloud concentration




Ash fall thickness

# Good news! Volcanoes (usually) provide warning before they erupt

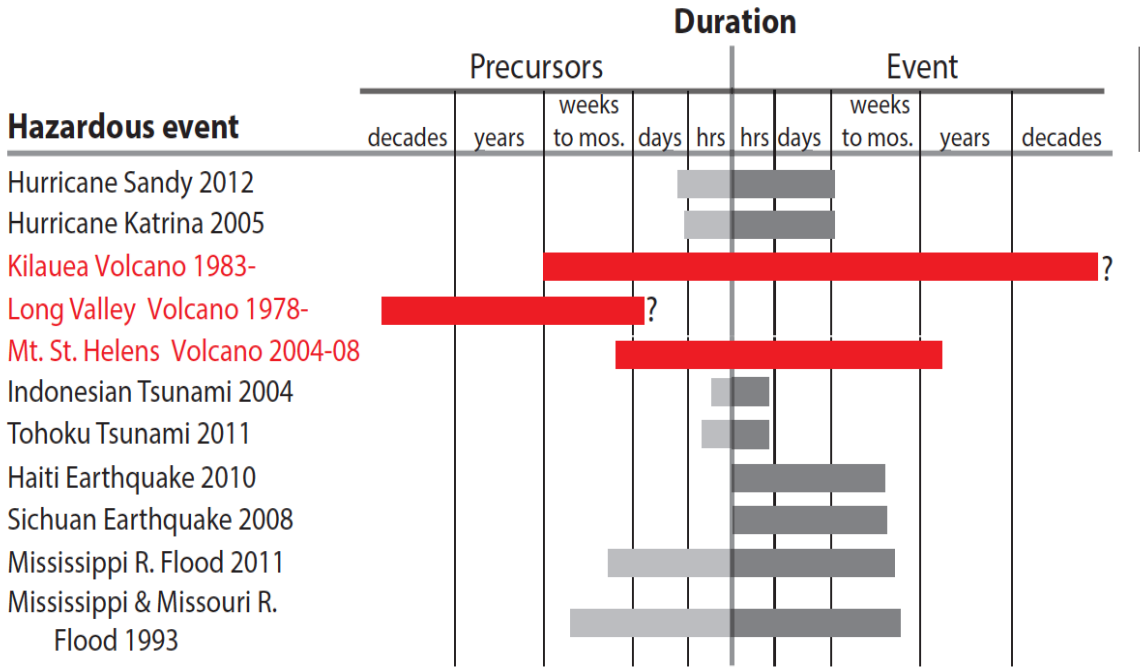
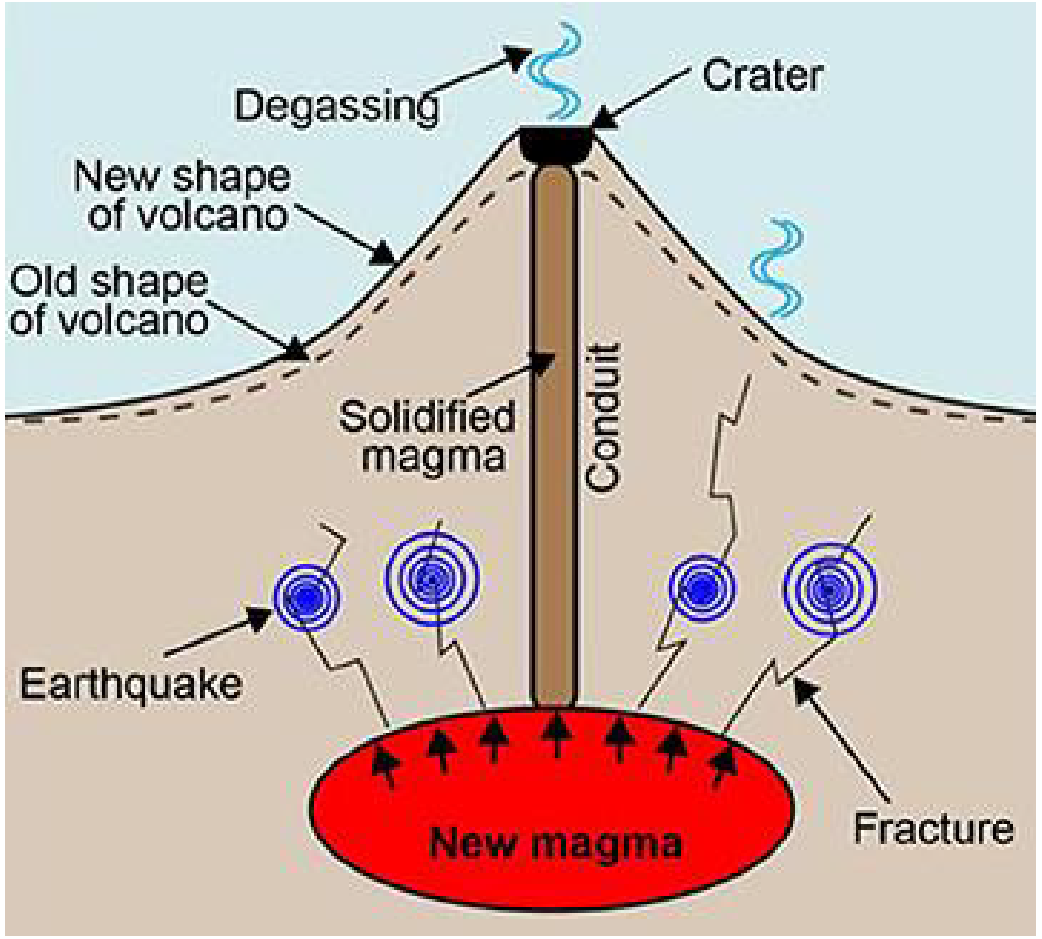


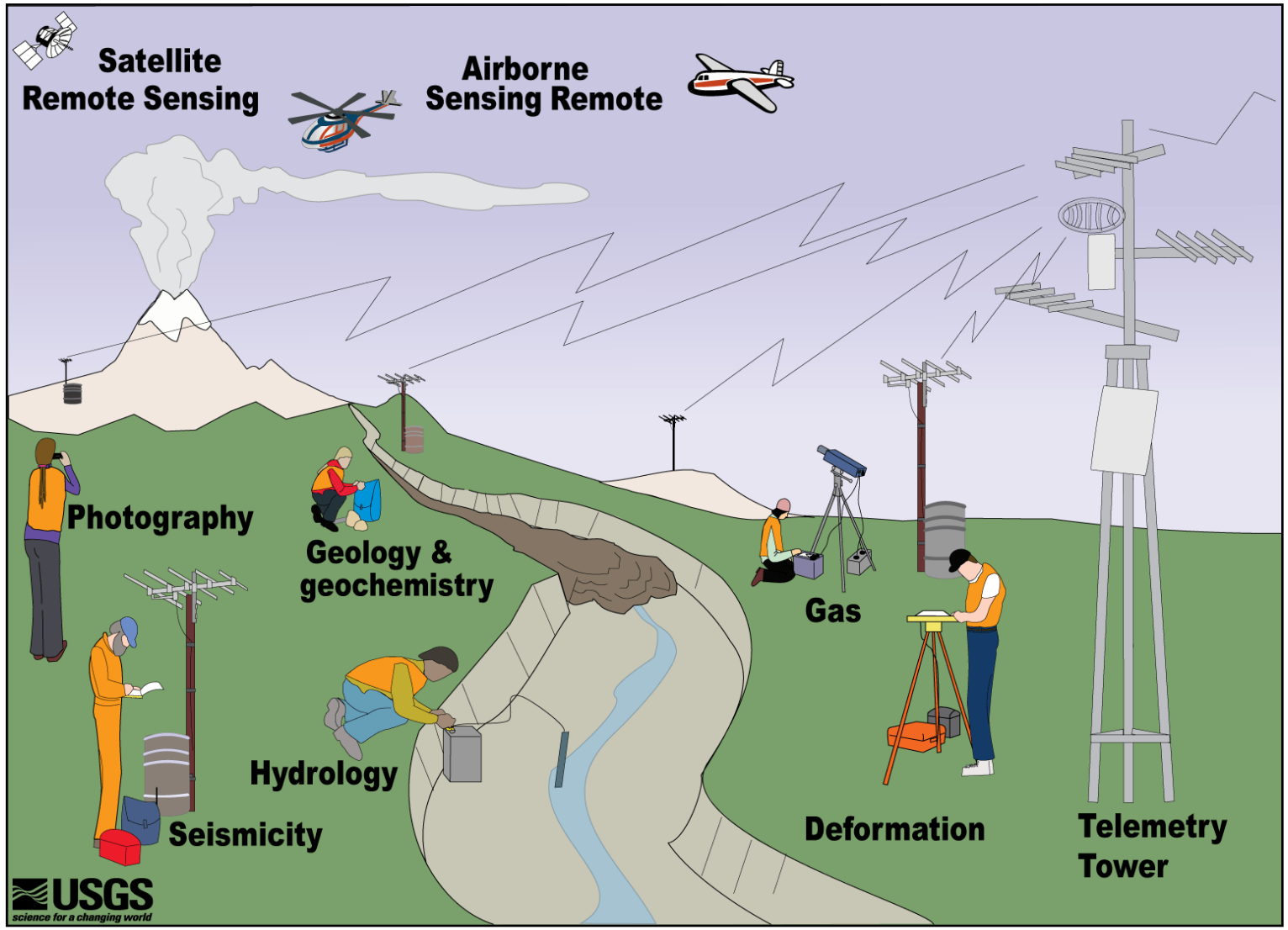

**FIGURE 1.3** Duration of precursors and events for selected natural hazards, including hurricanes, volcanic eruptions, earthquakes, and floods.

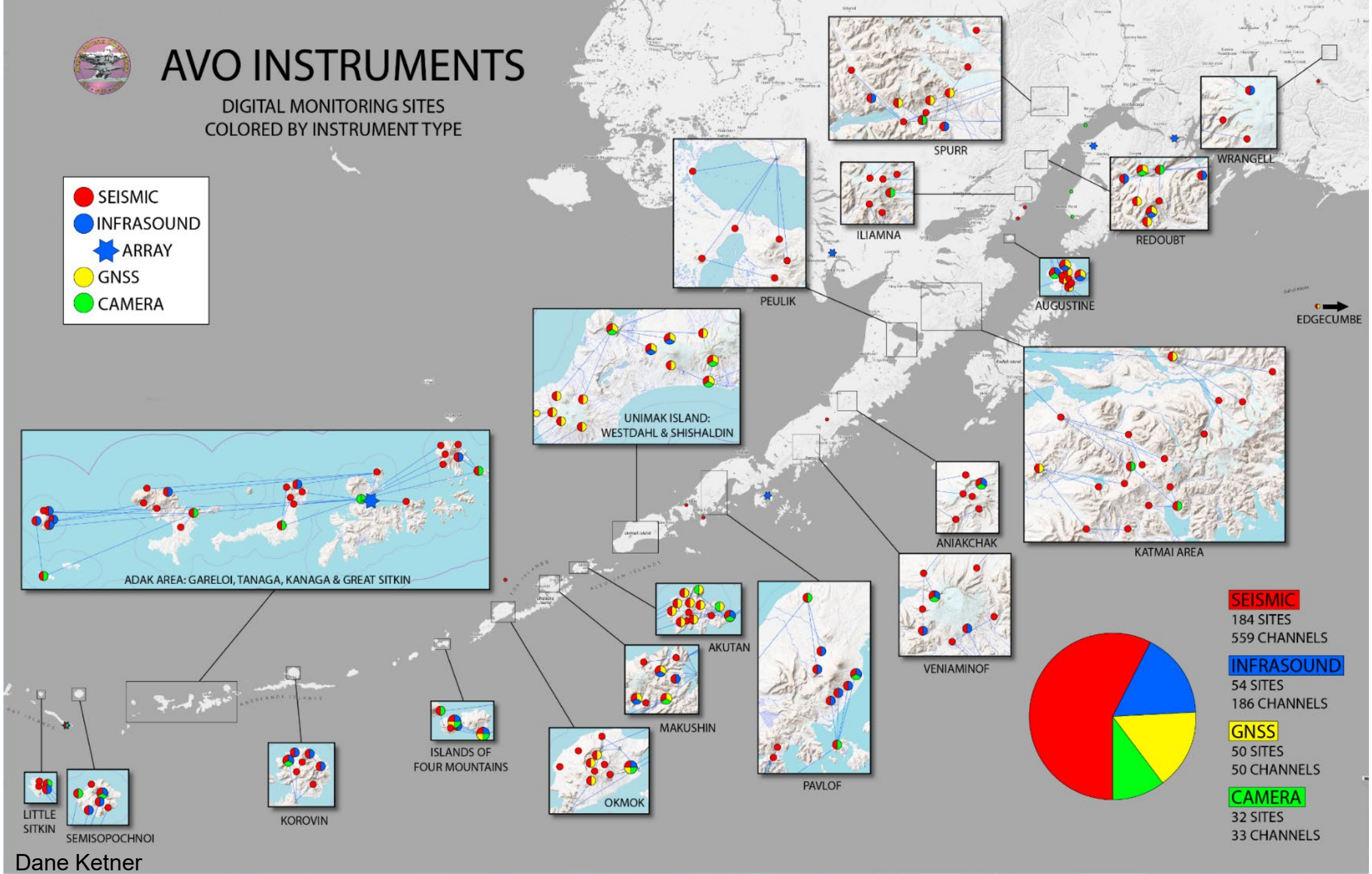
National Academy of Sciences, 2017



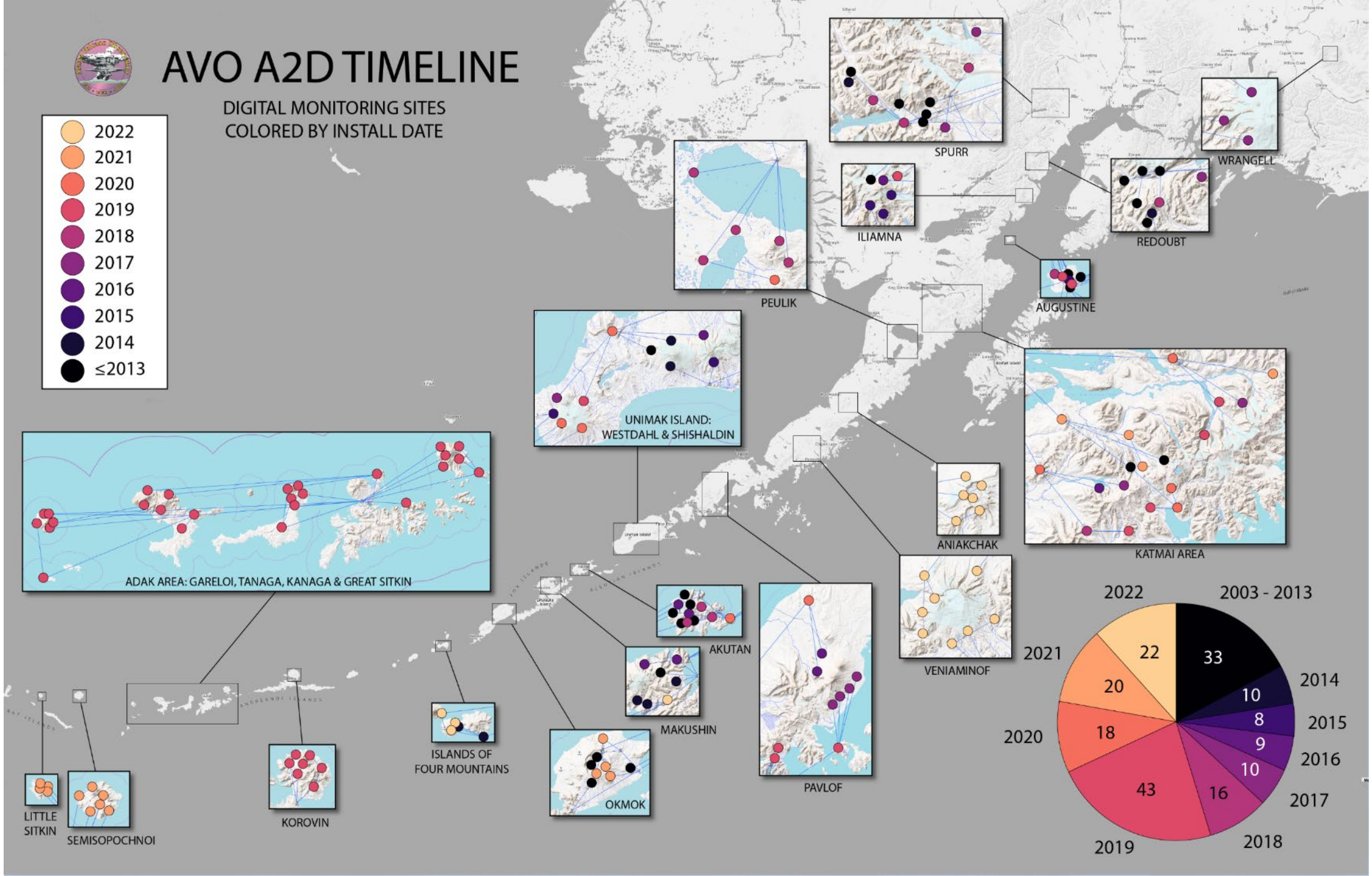

Acocella 2022

# A diverse suite of monitoring tools




AVO INSTRUMENTS
DIGITAL MONITORING SITES
COLORED BY INSTRUMENT TYPE
SEISMIC
INFRASOUND
ARRAY
GNSS
CAMERA
SPURR
WRANGELL
ILIAMNA
REDOUBT
PEULIK
AUGUSTINE
EDGECUMBE
UNIMAK ISLAND:
WESTDAHL & SHISHALDIN
ADAK AREA: GARELOI, TANAGA, KANAGA & GREAT SITKIN
ANIAKCHAK
KATMAI AREA
AKUTAN
MAKUSHIN
VENIAMINOF
PAVLOF
ISLANDS OF
FOUR MOUNTAINS
OKMOK
KOROVIN
LITTLE
SITKIN
SEMISOPOCHNOI
SEISMIC
184 SITES
559 CHANNELS
INFRASOUND
54 SITES
186 CHANNELS
GNSS
50 SITES
50 CHANNELS
CAMERA
32 SITES
33 CHANNELS

Dane Ketner


AVO A2D TIMELINE
DIGITAL MONITORING SITES
COLORED BY INSTALL DATE
2022
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≤2013
SPURR
WRANGELL
ILIAMNA
REDOUBT
PEULIK
AUGUSTINE
UNIMAK ISLAND:
WESTDAHL & SHISHALDIN
ANIAKCHAK
KATMAI AREA
ADAK AREA: GARELOI, TANAGA, KANAGA & GREAT SITKIN
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ISLANDS OF
FOUR MOUNTAINS
OKMOK
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SEMISOPOCHNOI
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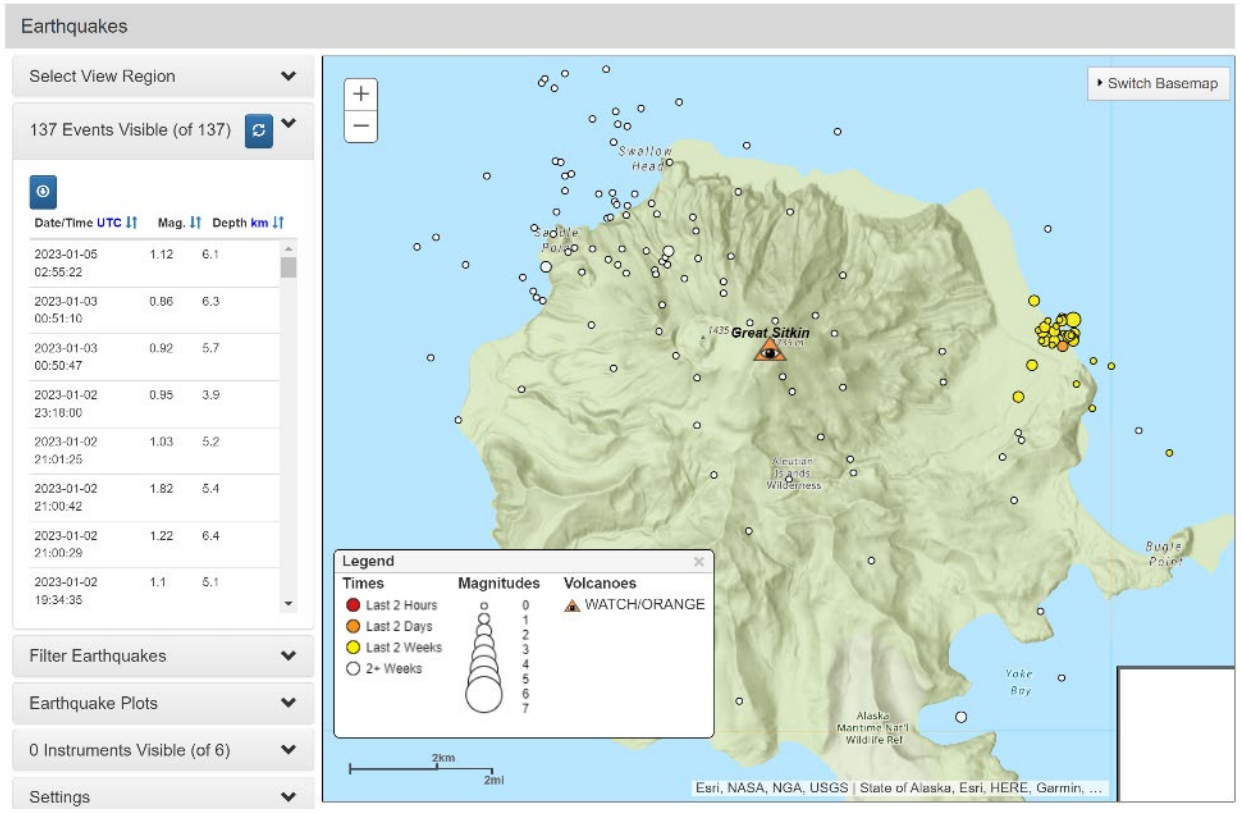
43
16

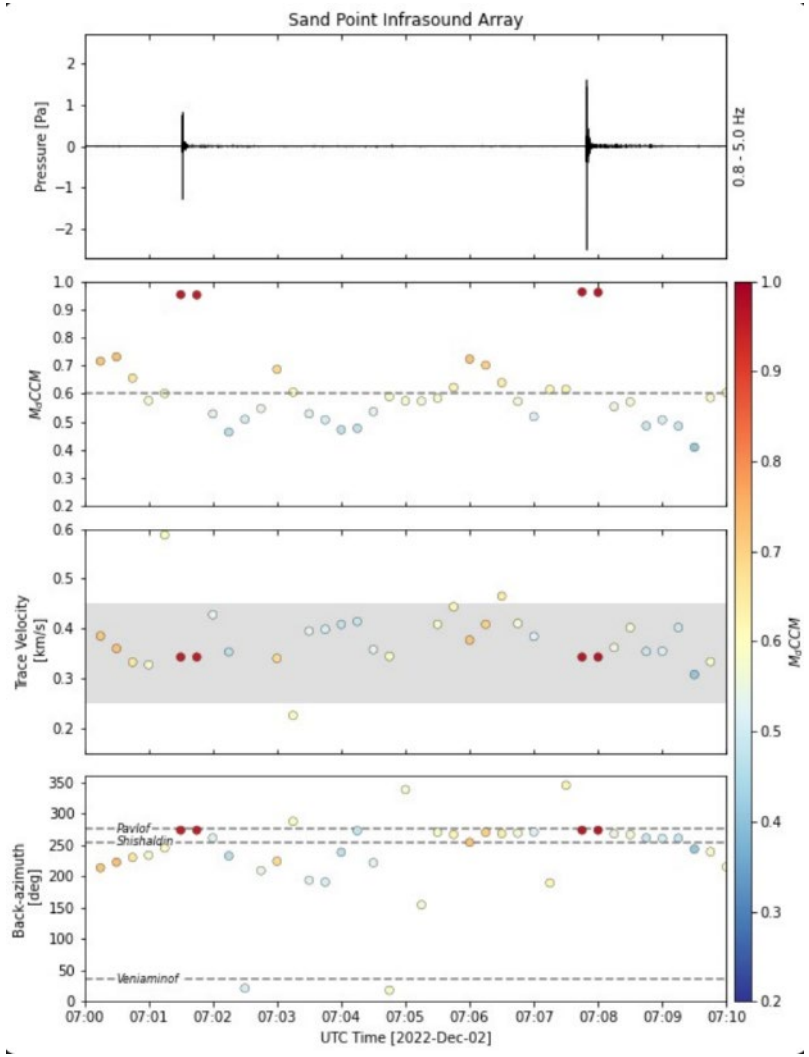
# Seismicity


Seismic spectrogram mosaic from Great Sitkin

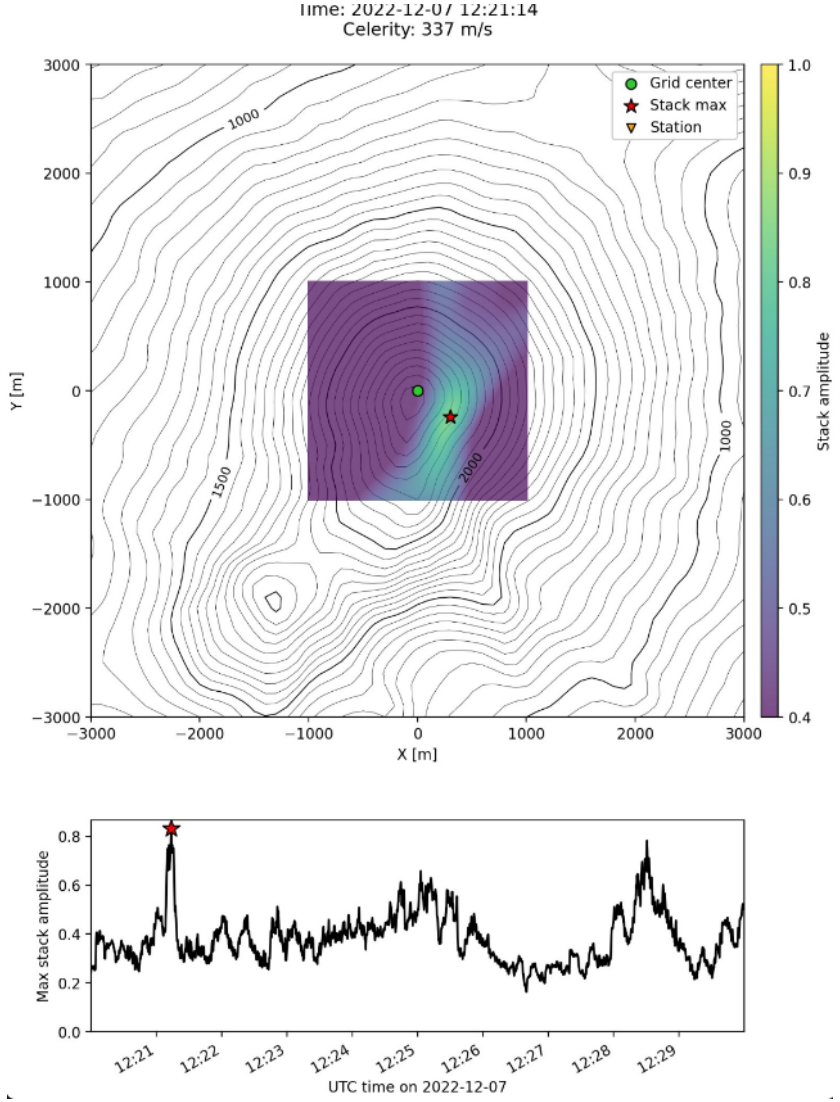



Hypocenter display for recent Great Sitkin quakes

# Infrasound

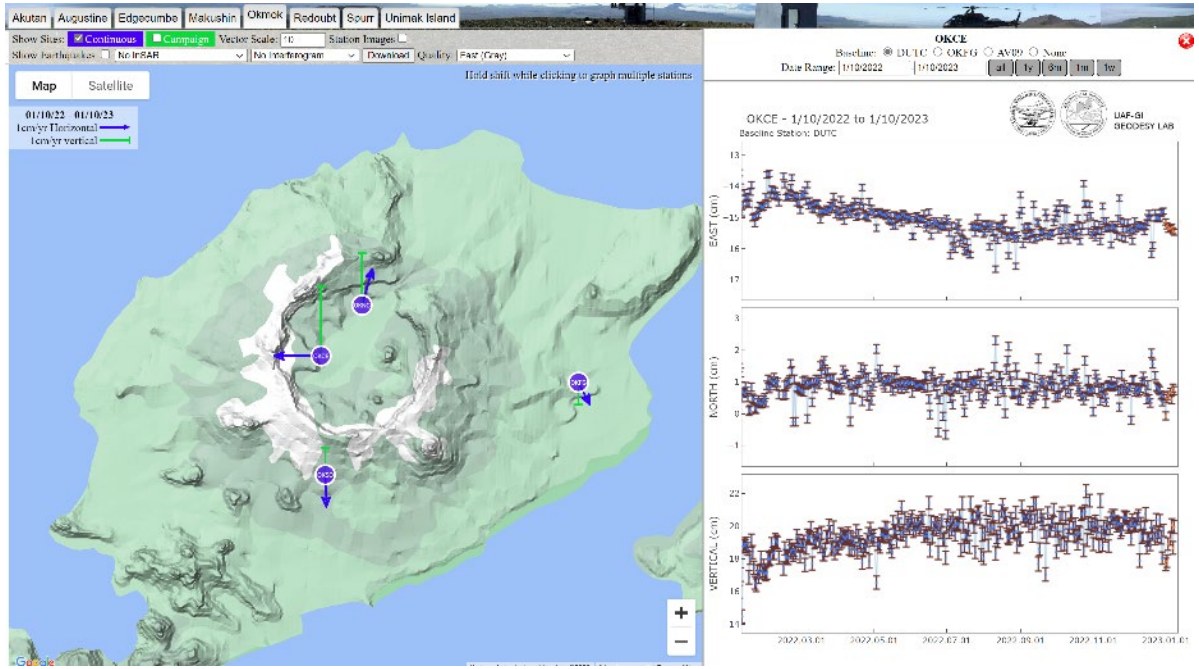


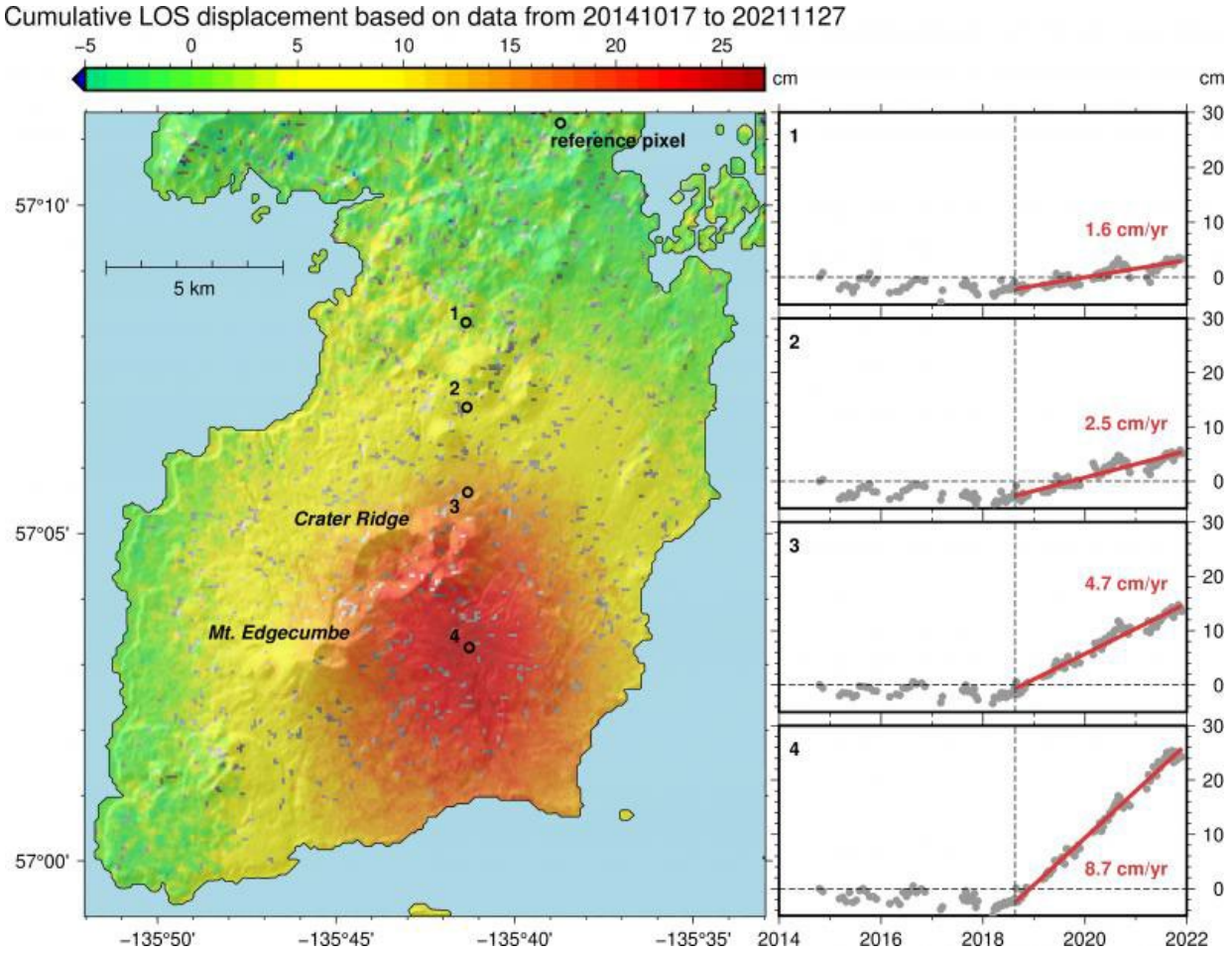

Regional array processing




Locations using local infrasound sensors

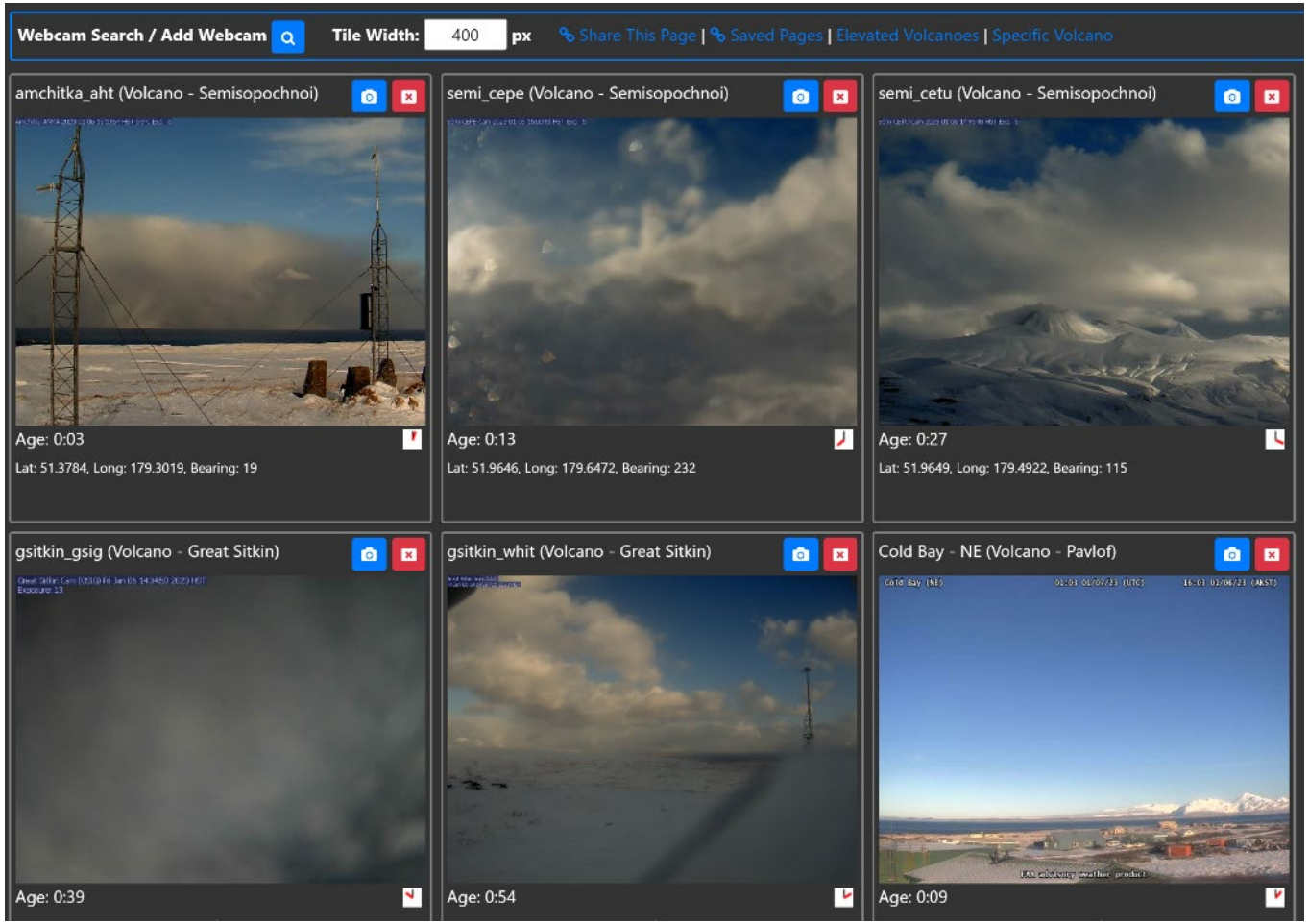
# Deformation



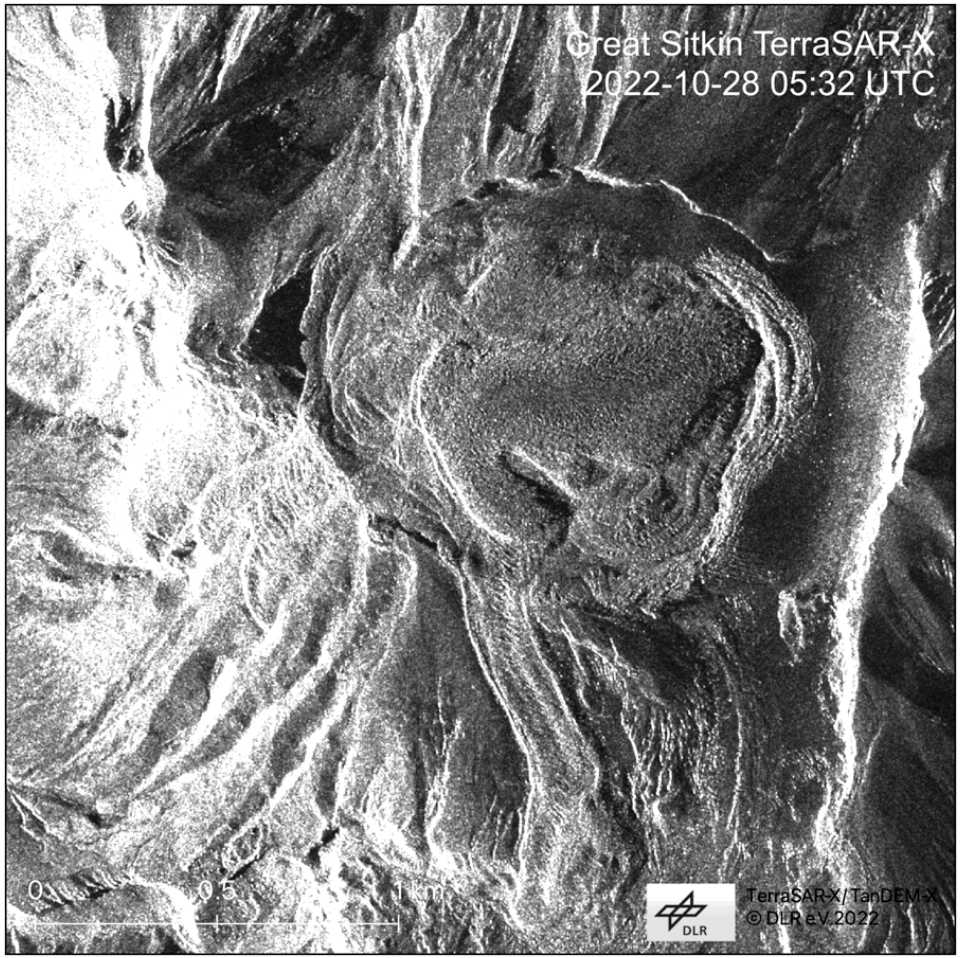




Grapenthin et al., 2022

# Remote sensing

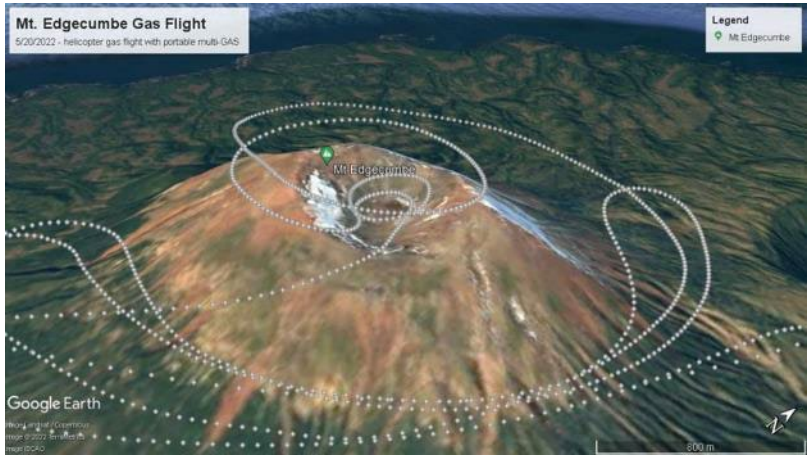



Ashcam: https://volcview.wr.usgs.gov/ashcam-gui/

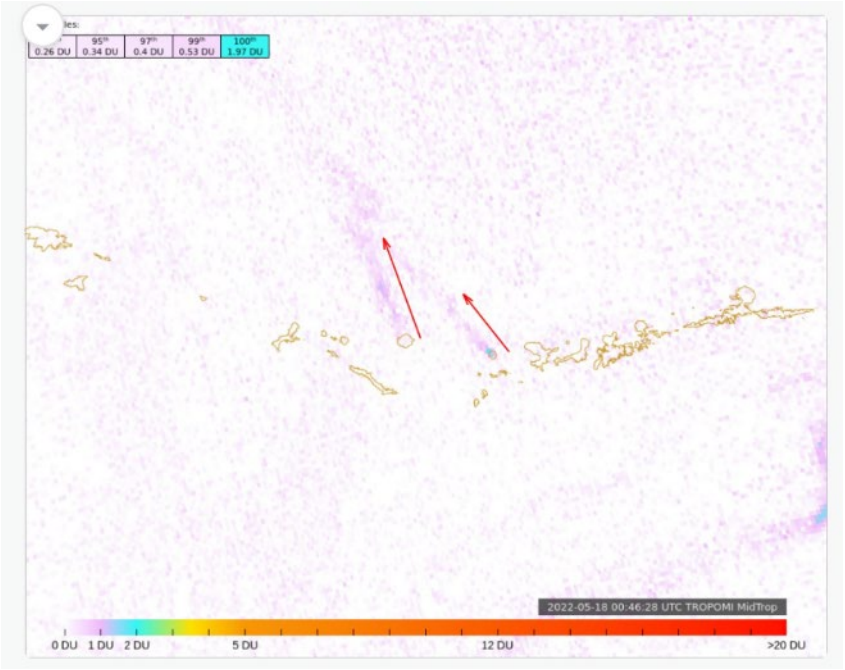



Dome growth from a series of satellite radar images, Fall 2022.
Courtesy of Simon Plank (German Aerospace Center, DLR). TerraSAR-X/TanDEM-X © DLR e.V. 2021.

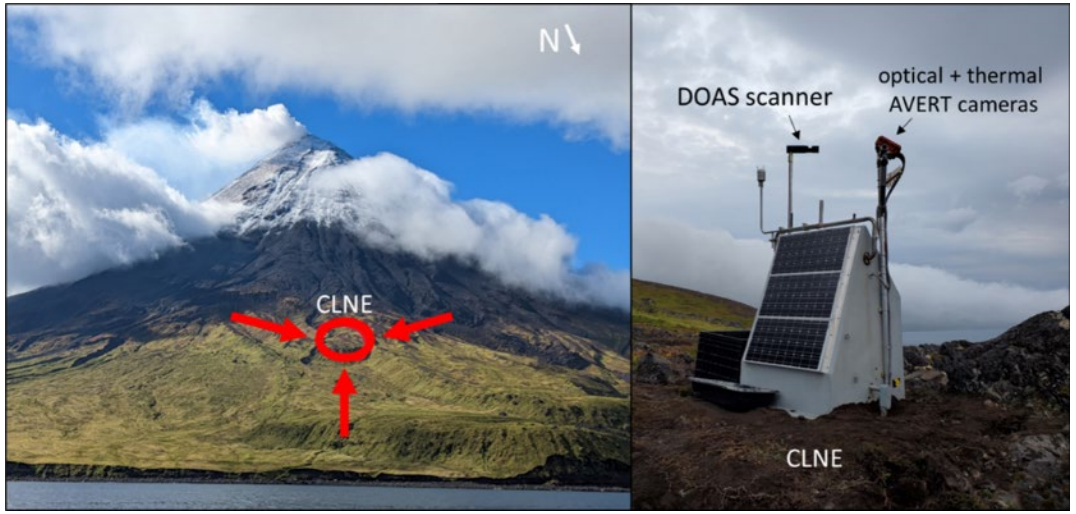
# Gas



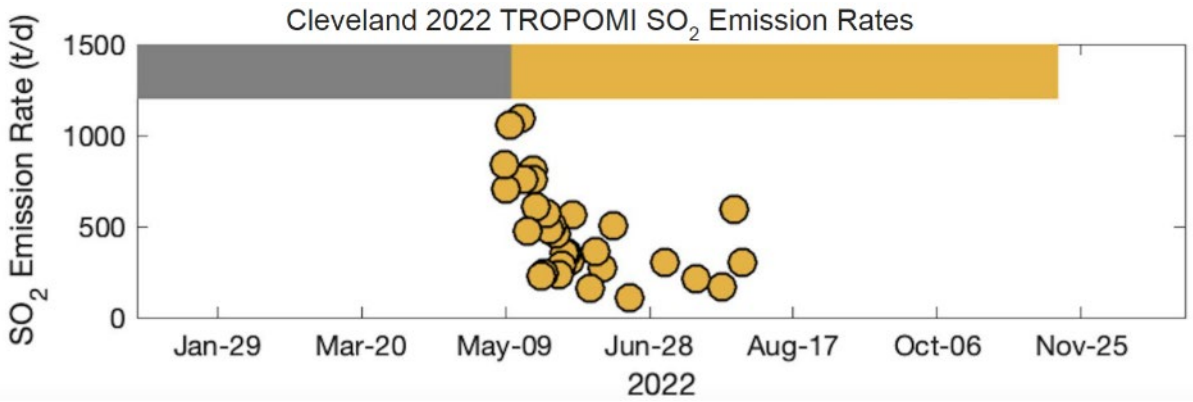

GPS track from gas flight at Edgecumbe volcano, May 2022




May 18, 2022 TROPOMI data show SO2 degassing at Semisopochnoi and Gareloi volcanoes




Scanning DOAS at Cleveland station CLNE (AVO-AVERT)




Compiled TROPOMI data for Cleveland volcano showing declining emissions in 2022

# Alarms and automated alerts

avo_alarms 18:40

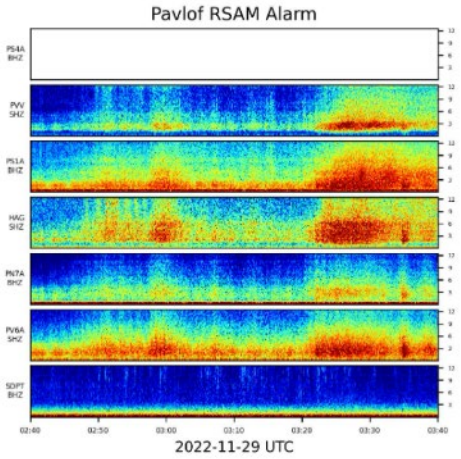
## Pavlof RSAM

Start: 2022-11-29 03:35 (UTC)
End: 2022-11-29 03:40 (UTC)

Start: 2022-11-28 18:35 (AKST)
End: 2022-11-28 18:40 (AKST)

- ☐ PS4A: 0/400
- ☑ *PVV: 2269/1500*
- ☑ *PS1A: 480/375*
- ☐ HAG: 21/1225
- ☐ PN7A: 294/450
- ☐ PV6A: 741/1225

Arrestor: SDPT 68/200




Matt Haney 18:51
@jlyons @Jeremy Pesicek my quick guess is these are lahars? im walking my dog and will look close when i return home

csearcy 18:57
AAWU has been contacted.

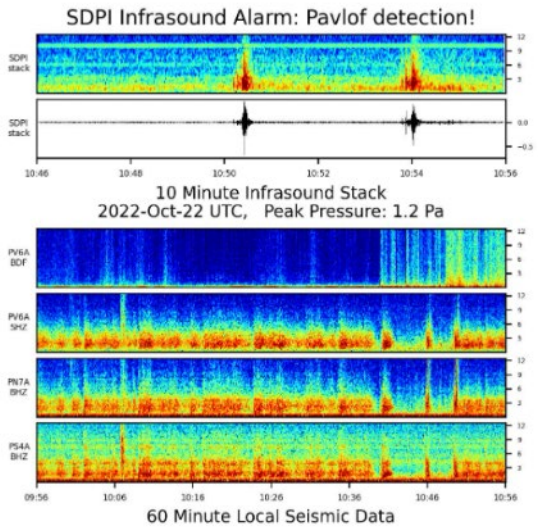
## Pavlof Airwave Detection

SDPI Infrasound alarm:
Pavlof detection!

Start: 2022-10-22 10:53 (UTC)
End: 2022-10-22 10:56 (UTC)

Start: 2022-10-22 02:53 (AKDT)
End: 2022-10-22 02:56 (AKDT)

Azimuth: +275.6 degrees
d_Azimuth: +0.2 degrees
Velocity: 343 m/s
Max Pressure: 1.2 Pa
Travel Time: 4 min 30 s



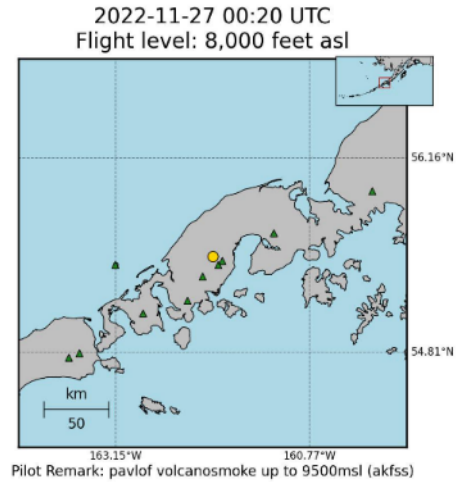

John Power 02:58
More small explosions.

avo_alarms 15:28

## URGENT! Activity possible at: Pavlof, Pavlof Sister, Emmons Lake

2022-11-27 00:20 UTC
2022-11-26 15:20 AKST
Flight level: 8,000 feet asl
Pilot Remark: pavlof volcanosmoke up to 9500msl (akfss)
Latitude: 55.481
Longitude: -161.961
Nearest volcanoes: Pavlof, Pavlof Sister, Emmons Lake

--Original Report--
KVC UUA /OV CDB057031 /TM 0020 /FL082 /TP PA31 /RM PAVLOF VOLCANOSMOKE UP TO 9500MSL (AKFSS)



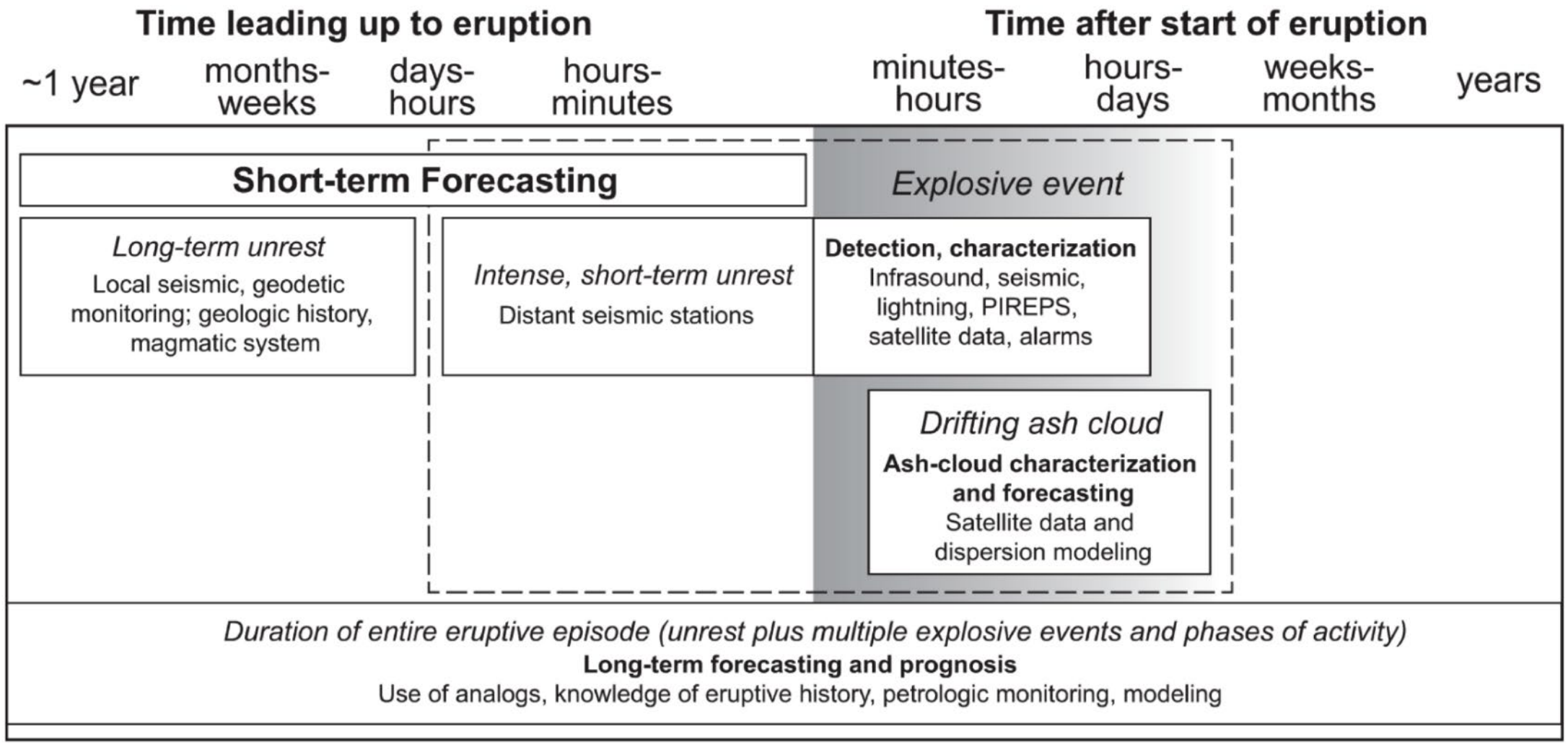

csearcy 16:00
I see no major changes in seismicity. Tremor ongoing.

# Interoperable tools for managing and serving volcano data and information in the works

National Volcano Information Service

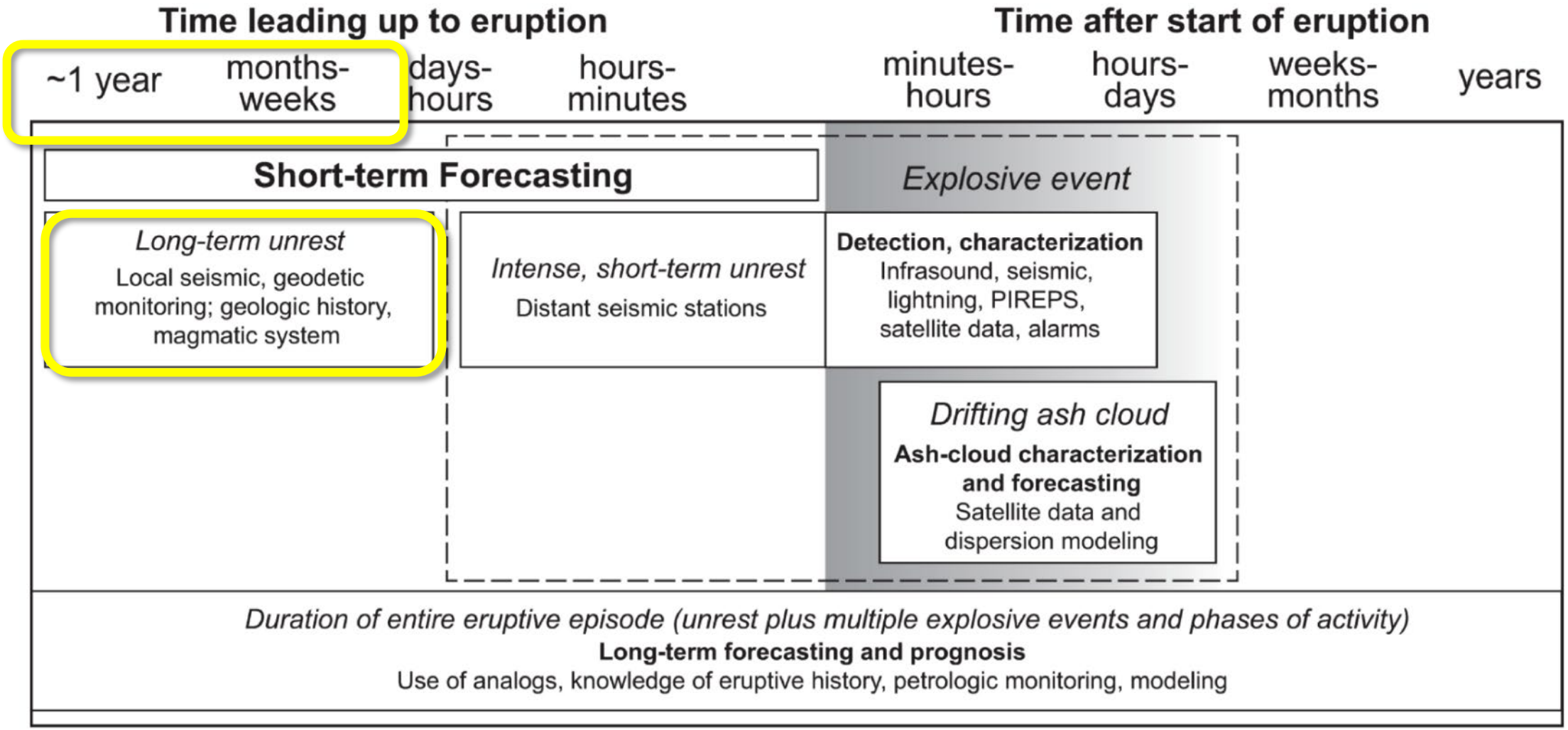

In development as part of NVEW

# Timeline of an eruption forecast



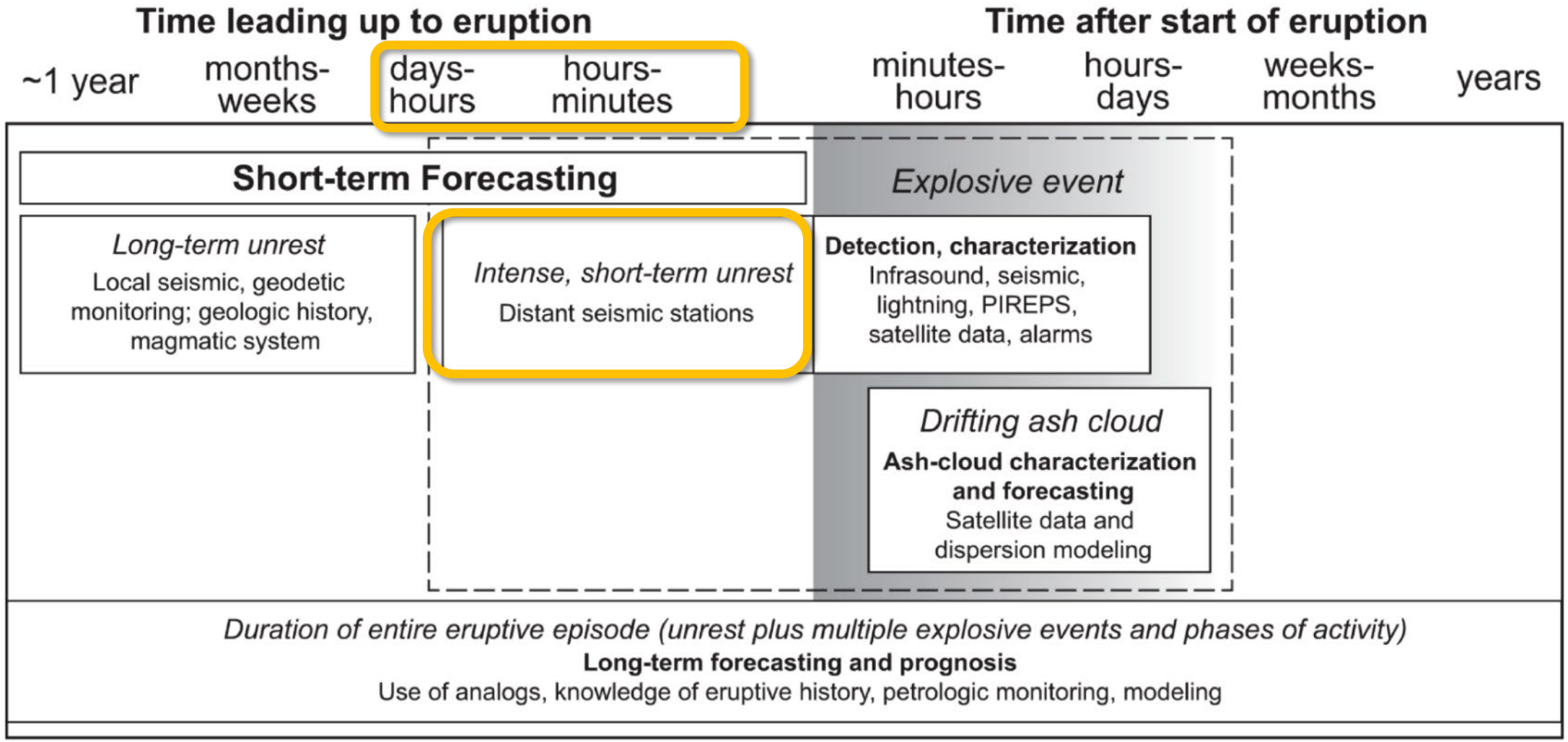

Coombs et al., 2018

# Timeline of an eruption forecast



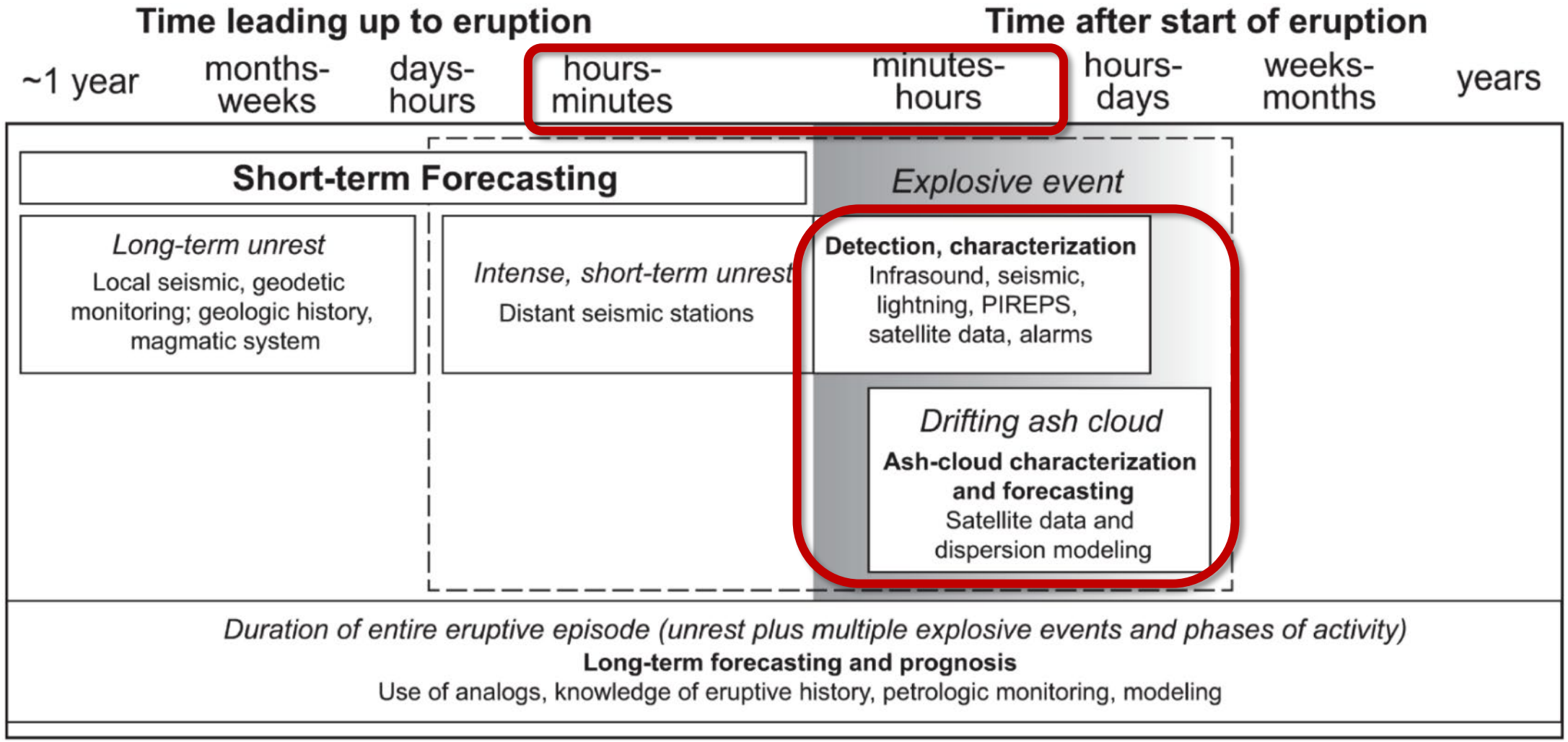

Coombs et al., 2018

# Timeline of an eruption forecast



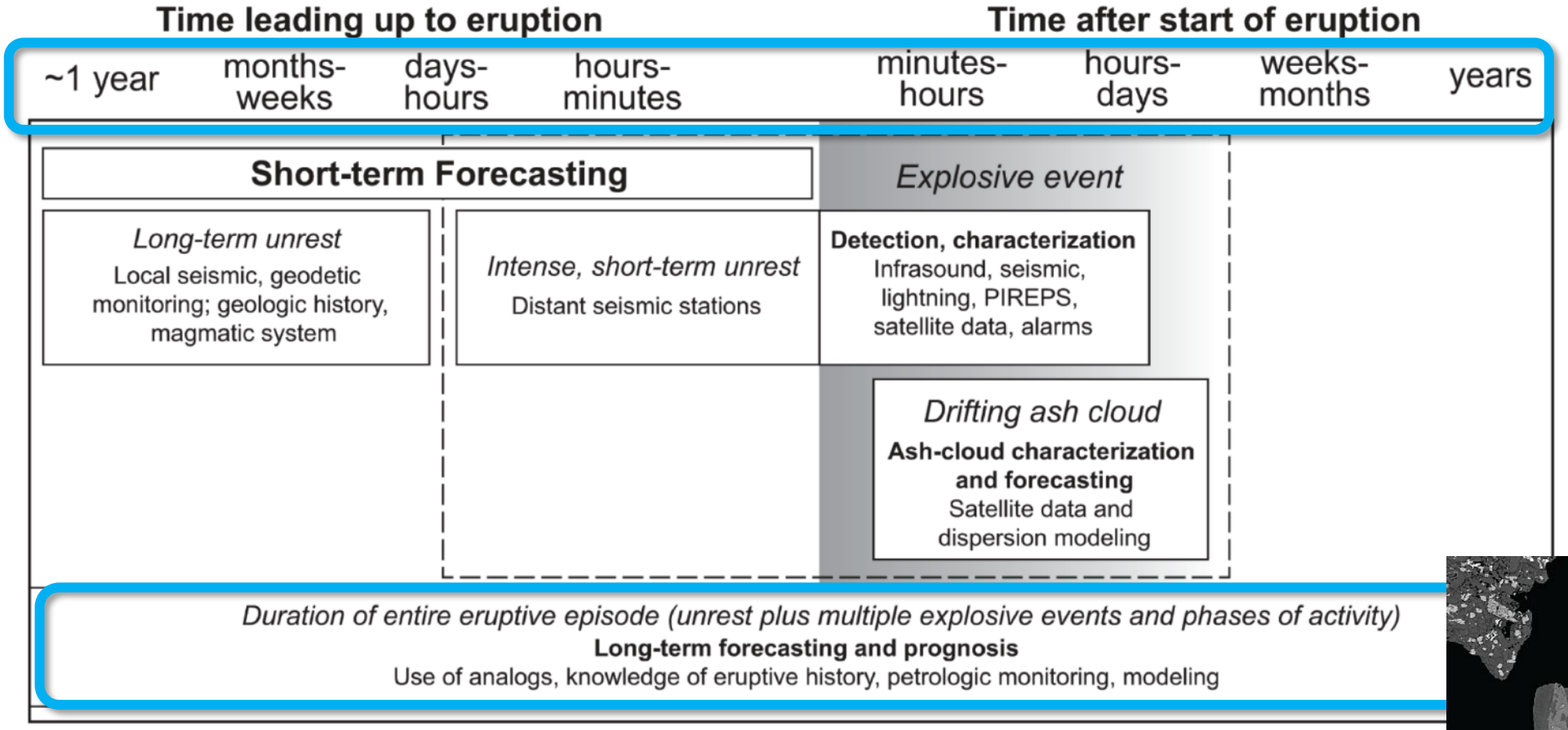

Coombs et al., 2018

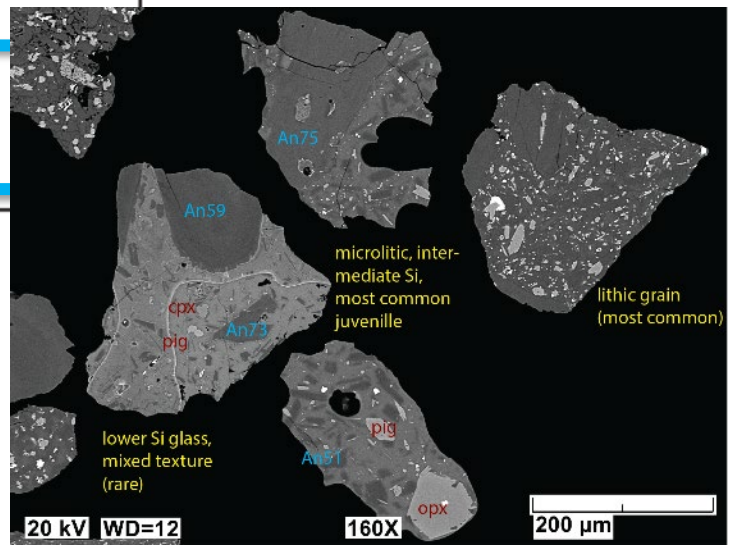
# Timeline of an eruption forecast




Coombs et al., 2018

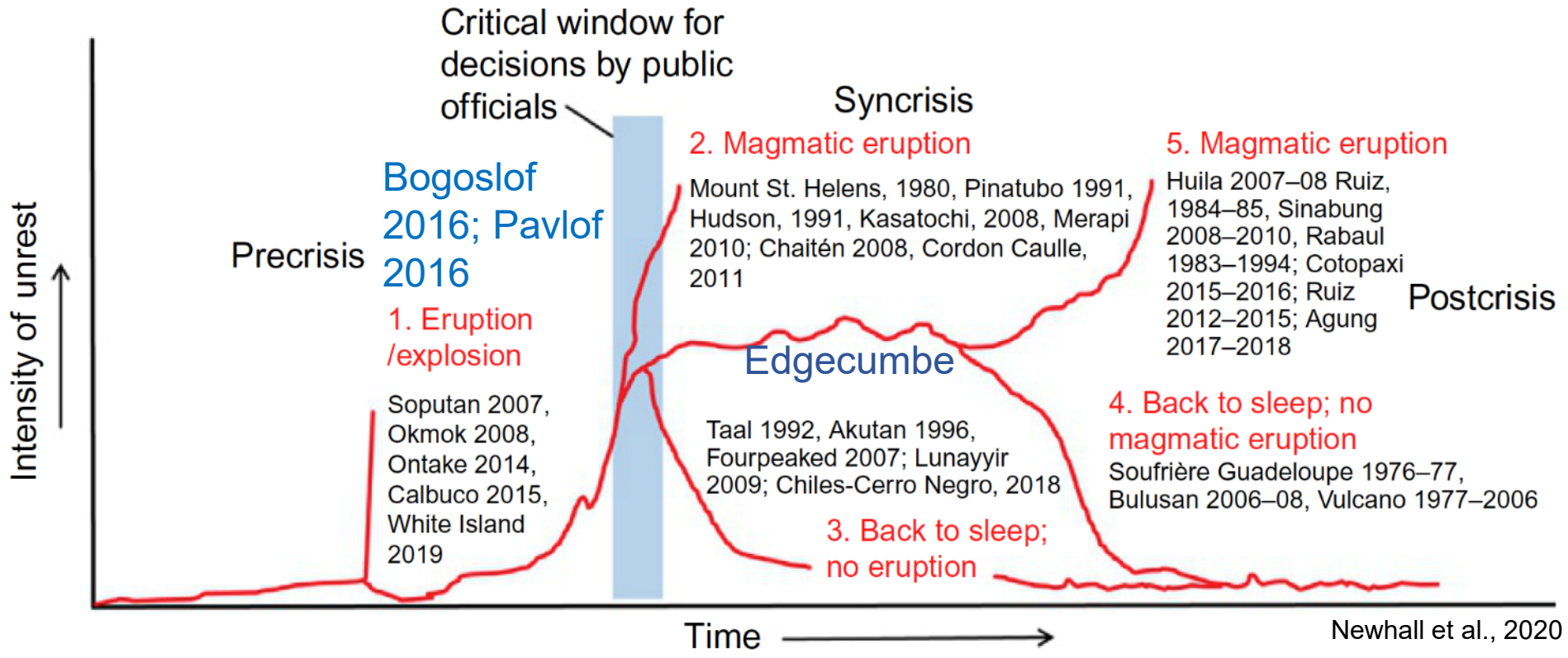
# Timeline of an eruption forecast



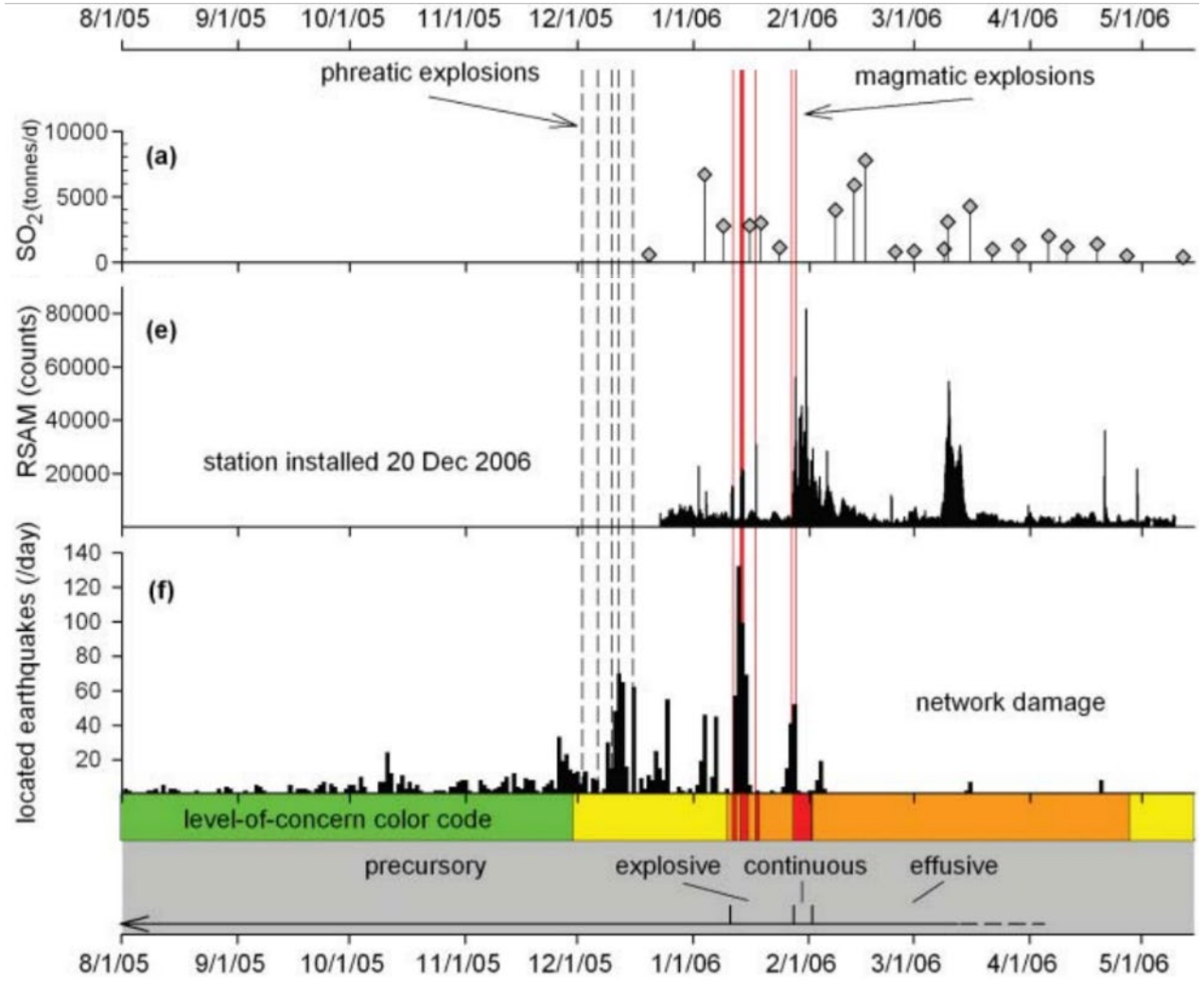

Ash from 2021 Semisopochnoi eruption indicates juvenile component, shallow crystallization. Courtesy of Matt Loewen

# Responses to volcanic activity occur over a wide range of timescales




Newhall et al., 2020

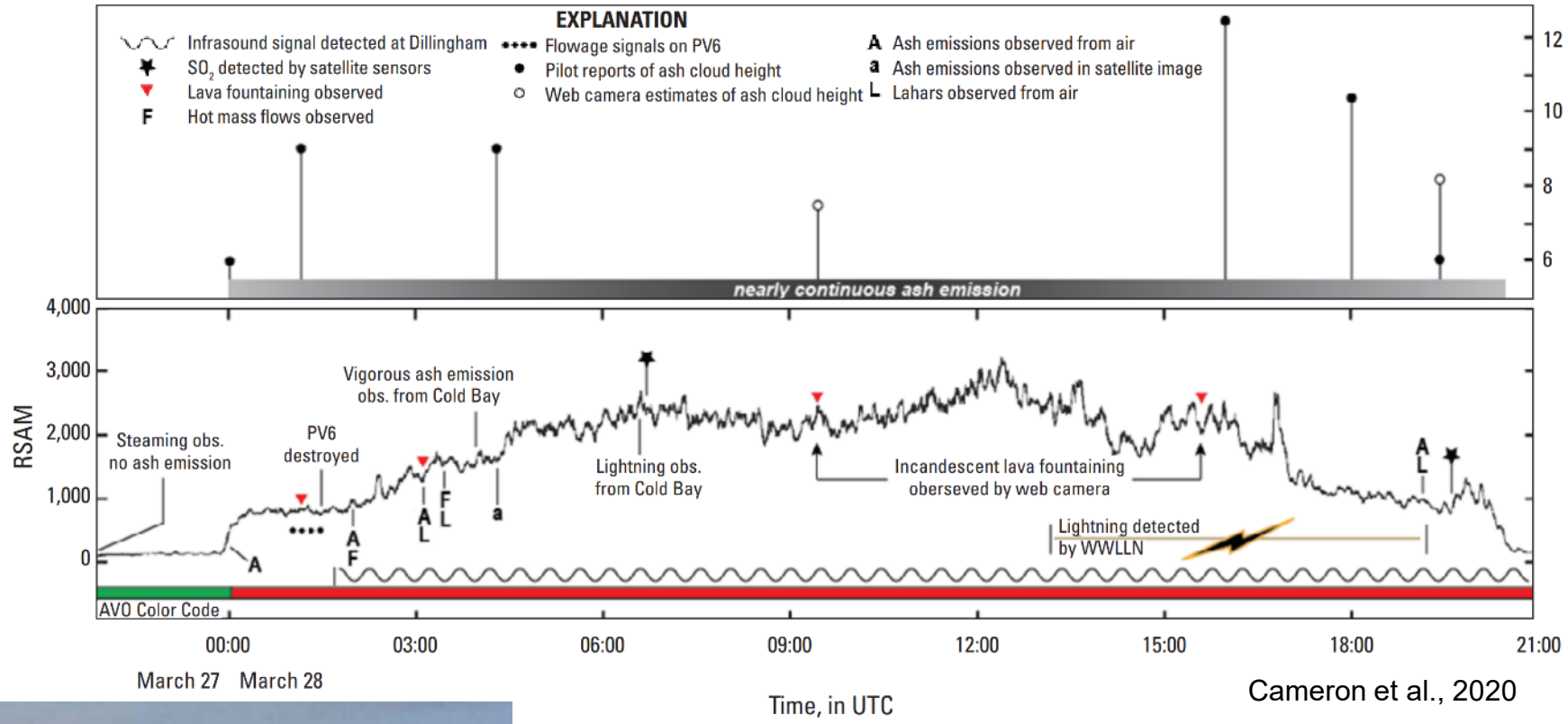
# Augustine 2006




Modified from Power et al., 2006

**Monitoring status:** local seismic and GPS network
**Repose time:** 19.7 years
**VEI:** 3
**Composition:** andesite
**Forecasting:** Good (first notice 3 days before first phreatic explosion, 40 days before first magmatic eruption

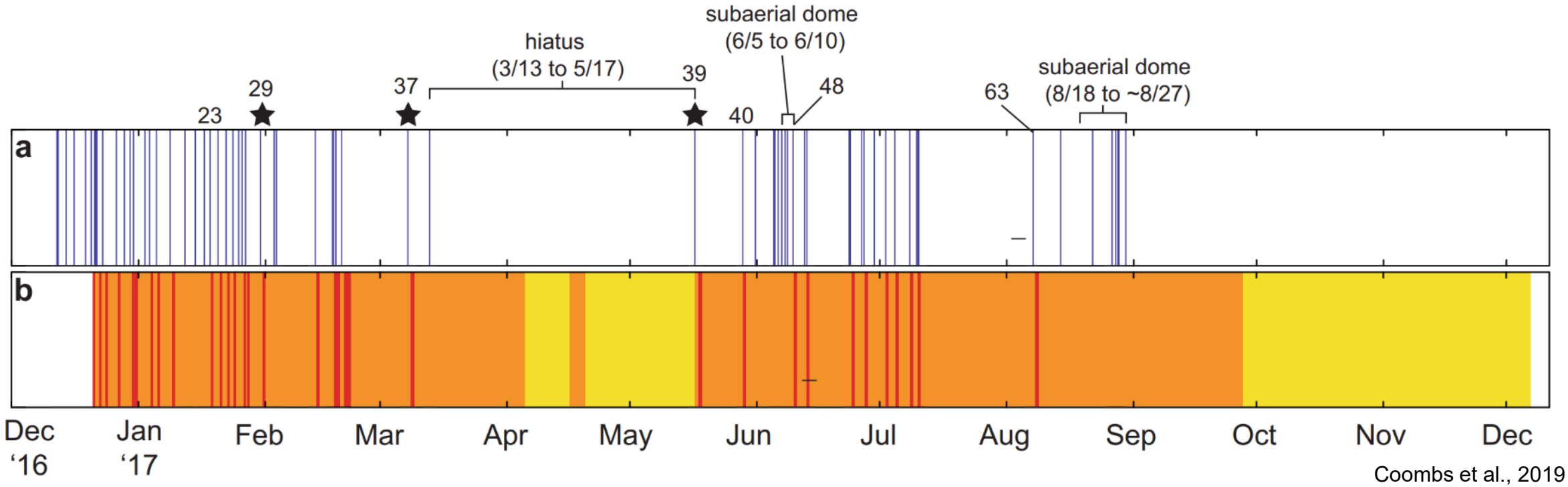
# Pavlof 2016




Cameron et al., 2020

**Monitoring status:** local seismic network
**Repose time:** 1.8 years
**VEI:** 2
**Composition:** basaltic andesite
**Forecasting:** Detect only (first notice 0.125 days after onset)

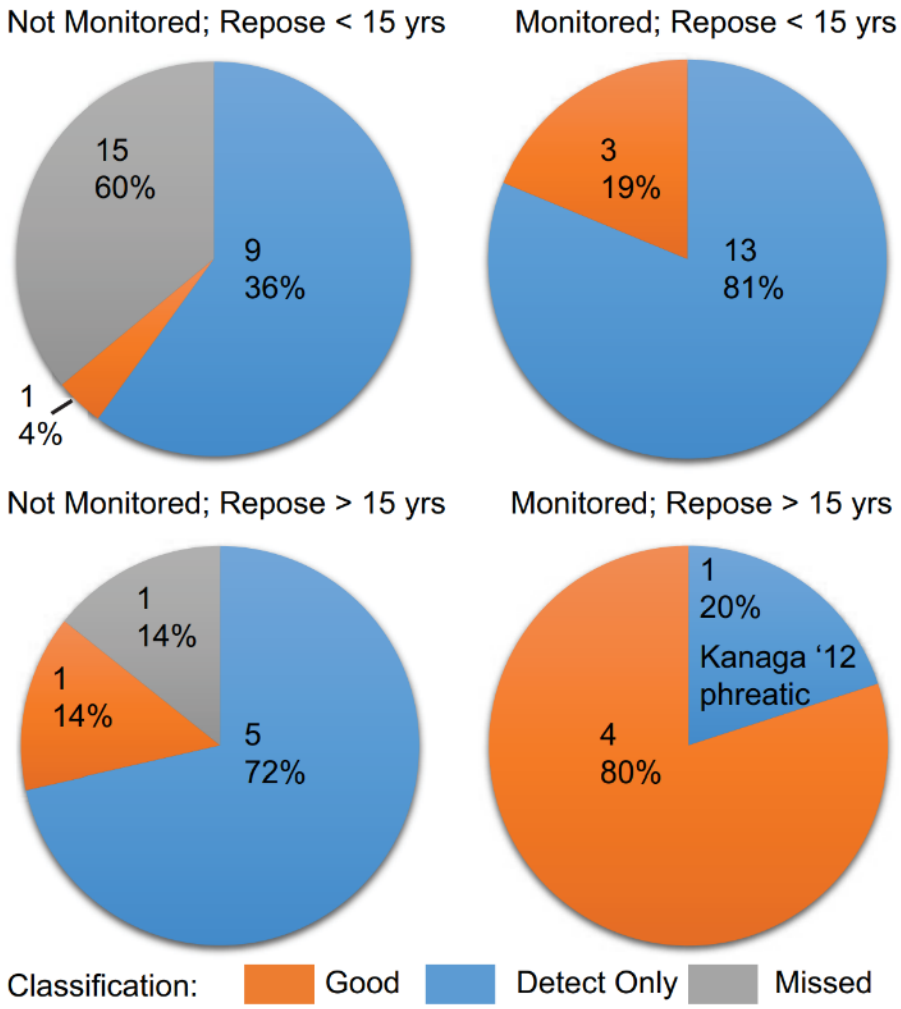
# Bogoslof 2016-2017




Coombs et al., 2019

**Monitoring status:** no local network
**Repose time:** 24 years
**VEI:** 3
**Composition:** basalt to tracyandesite
**Forecasting:** Missed first 5 events; mixture of detect and Good for remaining 69 events

# Factors affecting forecasting efficacy




Cameron et al., 2018

| More warning | Less warning |
|---|---|
| Well monitored | Poor monitoring |
| Volcano well studied | No knowledge |
| Slow magma ascent | Fast ascent |
| Closed system (long repose) | Open system (short repose) |
| Viscous magma | Fluid magma |
| Large volume | Small volume |

# Takeaways

- Timeliness of alerts is imperative for the main hazard in Alaska (volcanic ash)
- AVO uses a diverse and geographically extensive ground-based network combined with remote sensing to monitor Alaska's volcanoes and issue warnings
- Local monitoring is key!


Winter solstice 2022 webcam view of active Mount Young on Semisopochnoi Island

# Takeaways 2

- Management and synthesis of increasing volumes of monitoring data poses challenges and opportunities
- Open system volcanoes are sneaky and will require new approaches
- Forecasting eruptive style, volume, and duration remains fruitful avenue for further work

*Please find Matt Haney, John Power, or Aaron Wech to discuss AVO seismic and infrasound data!*


Station BLHA, Pavlof