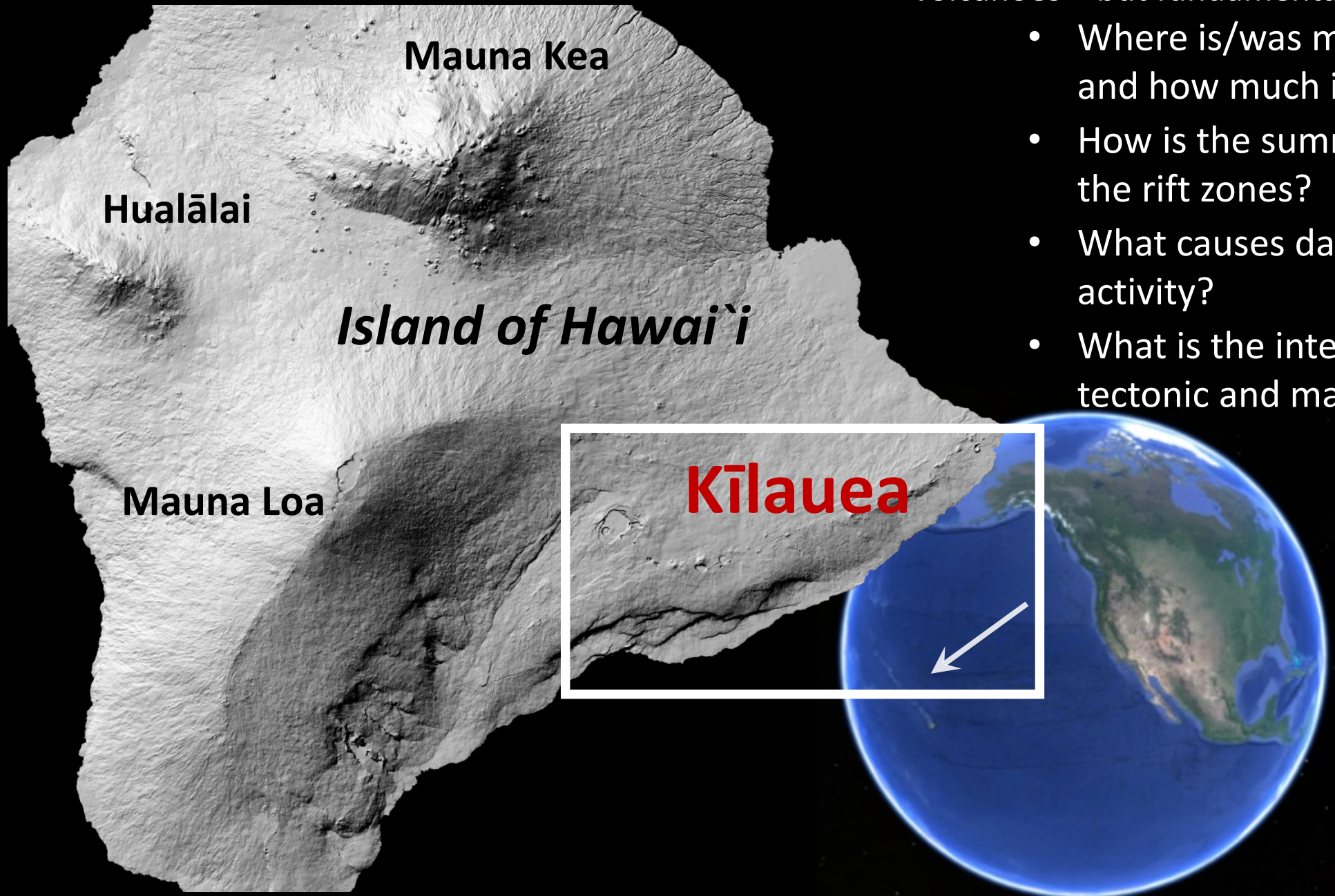
Hawai'i 1983 to now: Multidisciplinary observations and monitoring of long-lived Kīlauea eruptions

Thanks to the HVO science response teams 1983-2018

Bruce Houghton, Tina Neal, Kyle Anderson

Kīlauea volcano 1983-2018



One of the world's most active and monitored volcanoes – but fundamental questions remain:

- Where is/was magma storage, and how much is/was there?
- How is the summit connected to the rift zones?
- What causes dangerous explosive activity?
- What is the interplay between tectonic and magmatic forces?

Two great eruptions:

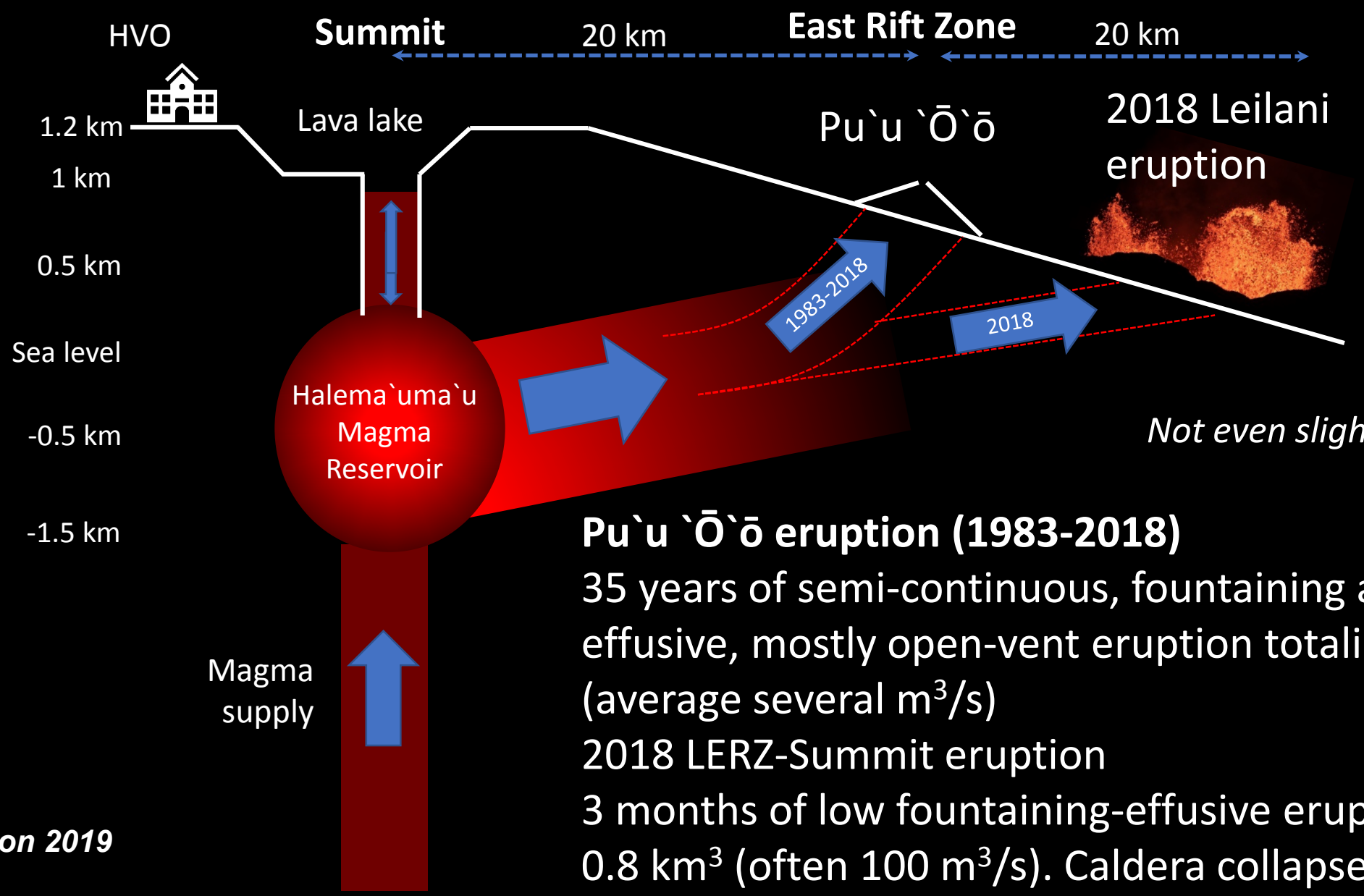
1983-2018

- 1983 Pu‘u ‘Ō‘ō + Royal Gardens
- 1990-1992 Kupaianaha + Kalapana
- 2008- 2018 Summit
- 2011 Kamoamoa

2018

- LERZ
- Summit

Schematic cross section: Summit to LERZ



Not even slightly to scale!

Pu`u `Ō`ō eruption (1983-2018)

35 years of semi-continuous, fountaining and effusive, mostly open-vent eruption totaling ~4 km^3 (average several m^3/s)

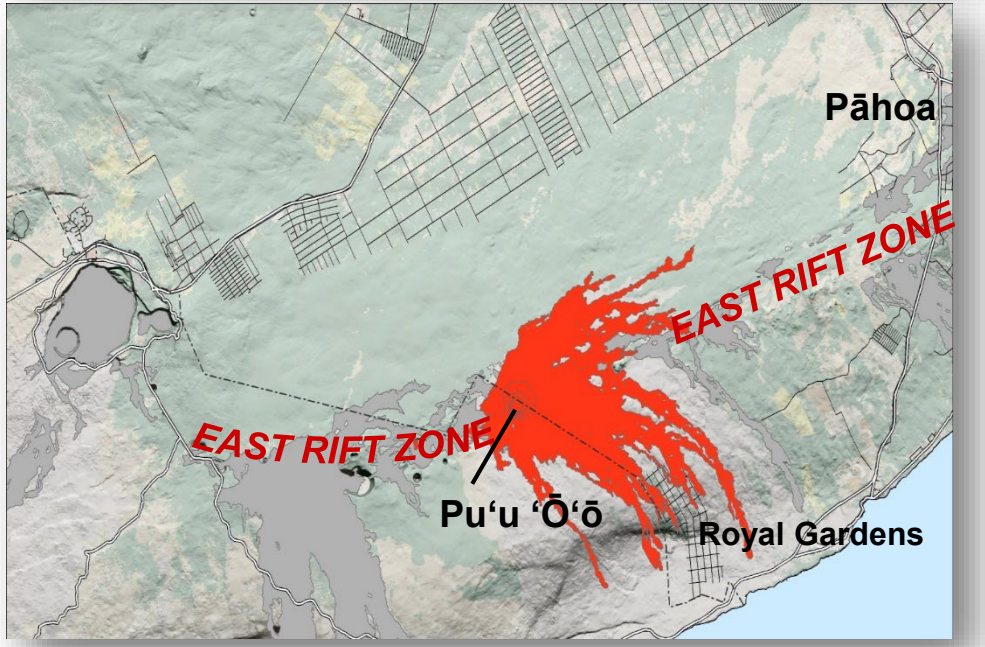
2018 LERZ-Summit eruption

3 months of low fountaining-effusive eruption total 0.8 km^3 (often 100 m^3/s). Caldera collapse.

Kyle Anderson 2019

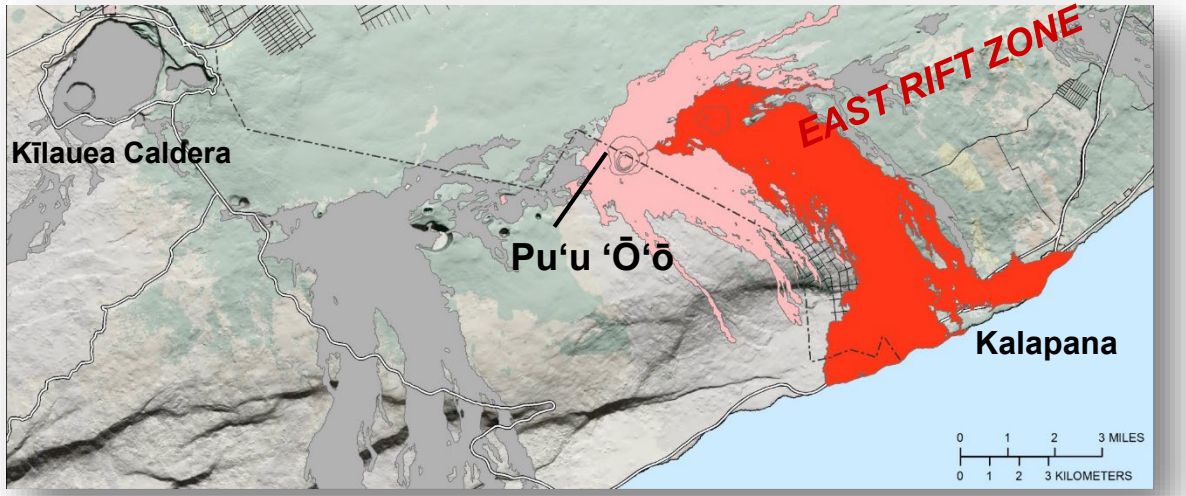
Pu‘u ‘Ō‘ō: 1983–1986

44 high fountaining episodes
Lava flows destroyed 16 structures



New insight into episodic patterns of fountaining eruptions

Kupaianaha: (1986-) 1990 –1992



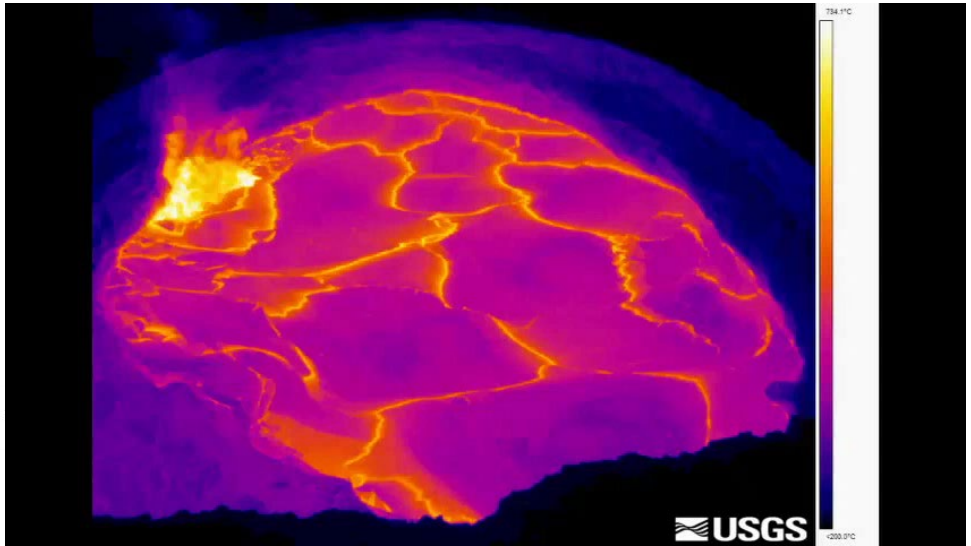
Kupaianaha: 5.5 years of quiet effusion
Lava reaches the Pacific November 1986;
Lava flows destroyed 168 structures: Kalapana

Kalapana and
Kaimū Bay
May 1990

Focused attention on dynamics of slow-advancing, thermally efficient pahoehoe lavas

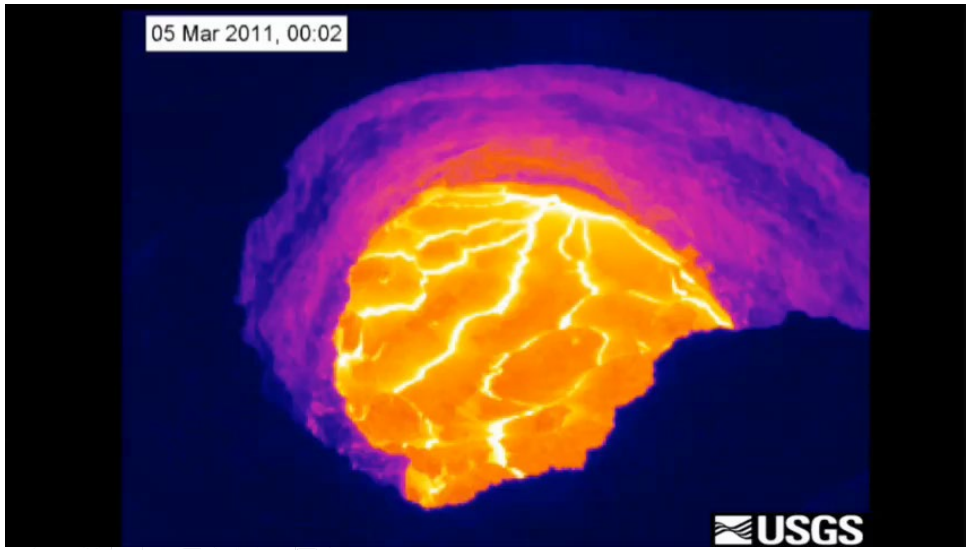
Summit: 2008–2018

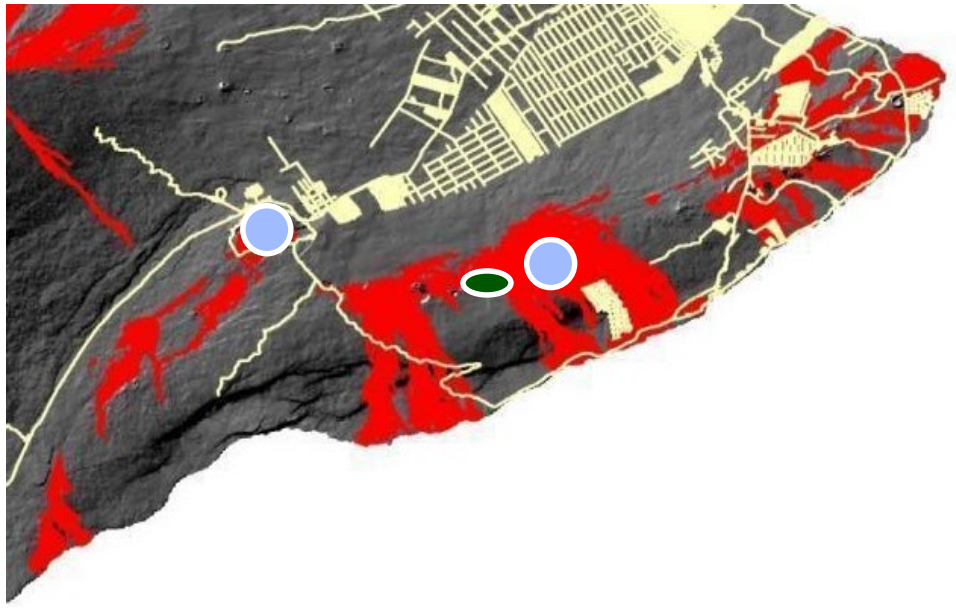
Transformation of ground-based multidisciplinary investigations. Most intensive study to-date of lava lake dynamics in ranges of time/length scales



Kamoamoa: 5-10 March 2011

5-8 March 2011





Proof of well-connected vent structures along East Rift Zone

Eruption Statistics: *Jan. 1983–Mar. 2018*

Total area covered …….. **130 square km**

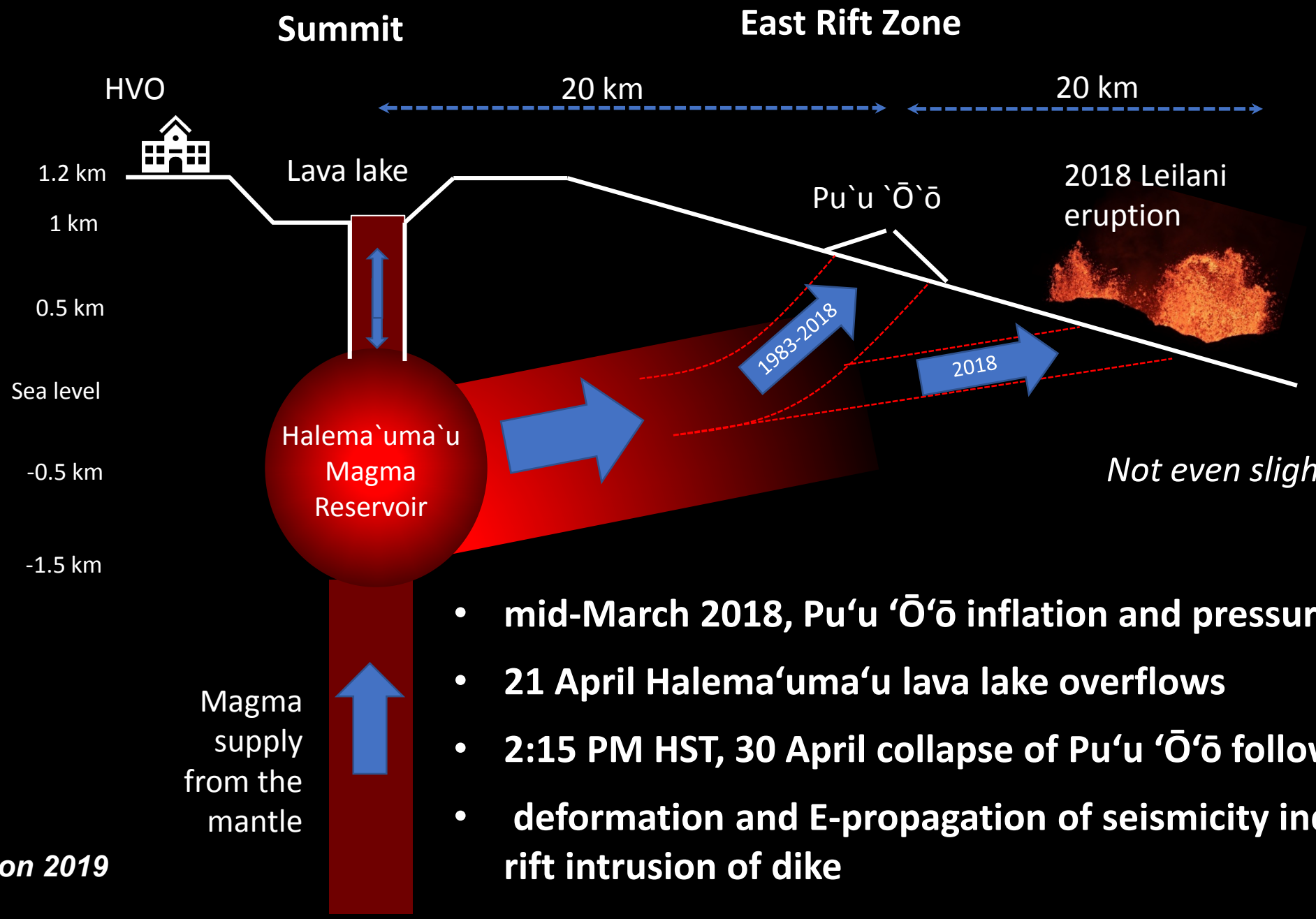
Total volume erupted …….. **~ 4.4 cubic km**

Land added to the island … **~ 200 hectares**

Structures destroyed …….. **214**

(homes, church, store, visitor center, etc.)

Schematic cross section: Summit to LERZ



Not even slightly to scale!

- **mid-March 2018, Pu‘u ‘Ō‘ō inflation and pressurization**
- **21 April Halema‘uma‘u lava lake overflows**
- **2:15 PM HST, 30 April collapse of Pu‘u ‘Ō‘ō followed by**
- **deformation and E-propagation of seismicity indicate down-rift intrusion of dike**

Kyle Anderson 2019

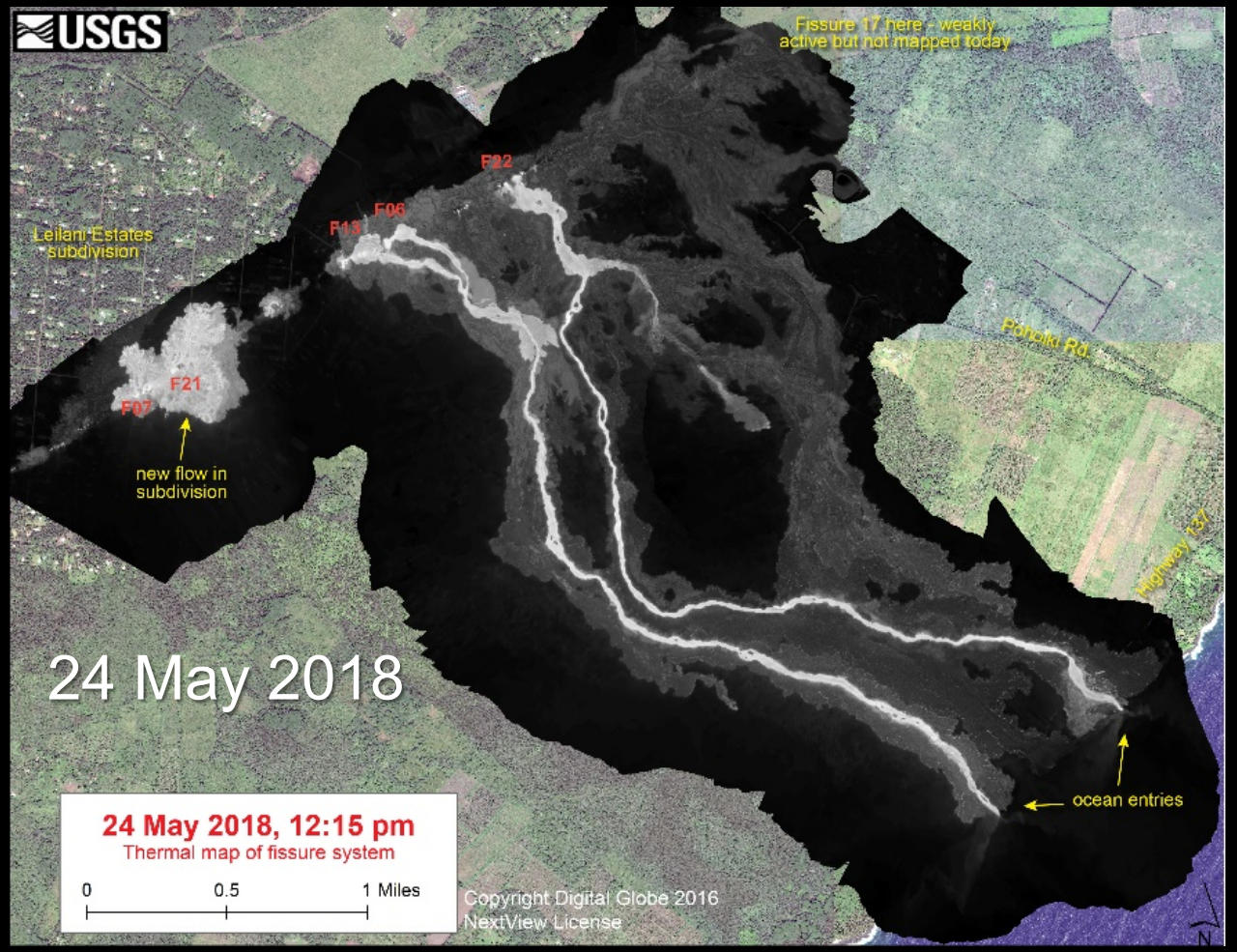
HVO and partners

- **primary** role in support of the eruption response
- 24/7 real-time **advice** to emergency management
- limited opportunities for **process-focused** observation

The 2018 LERZ/summit eruption (s)

May chaos!

- newly established immature conduits
- dominance of rift-stored magma
- wide range of rheology, style, intensity
- short-lived fissures & sluggish lava



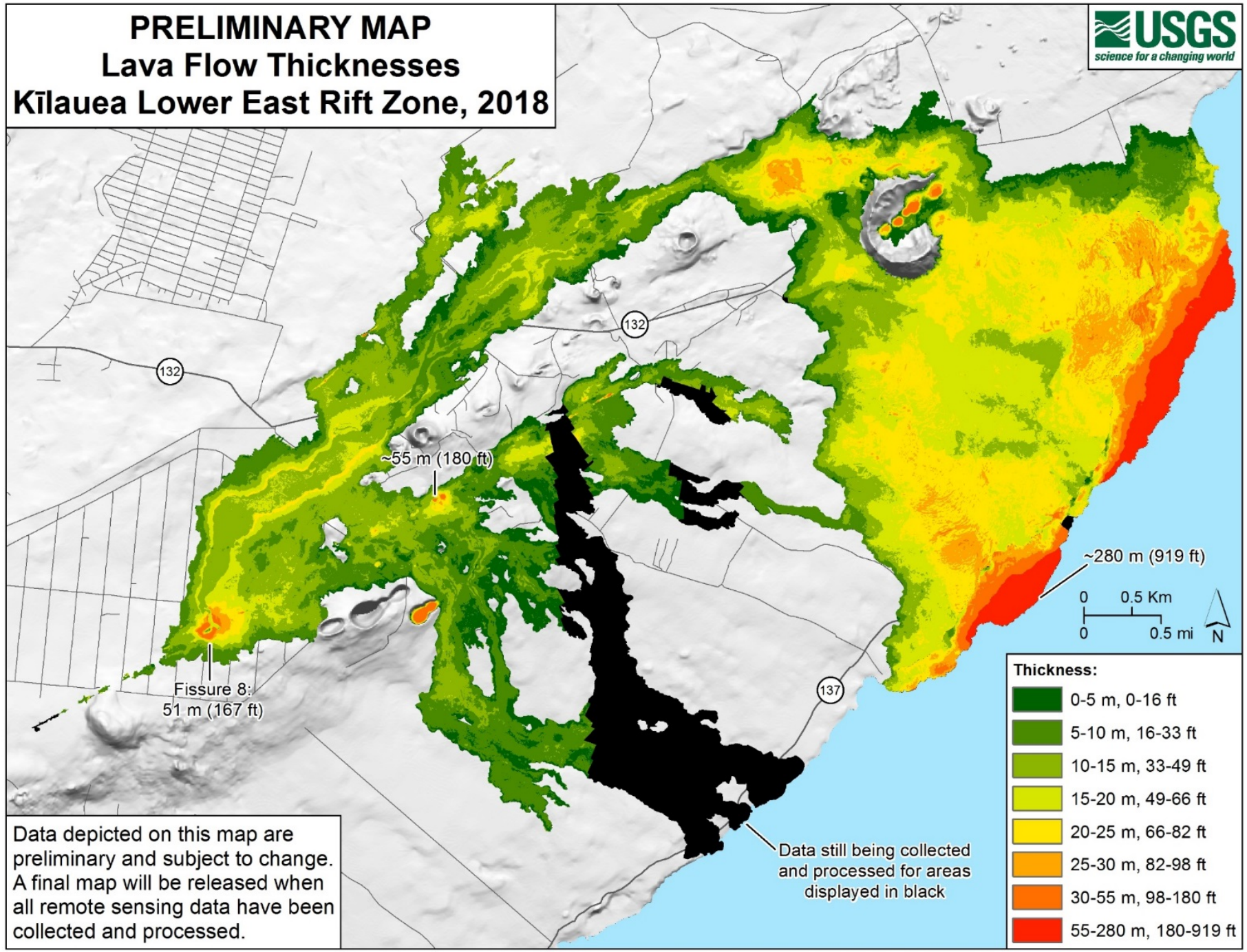
May: rapid semi-random shifts

Up to 6 segments in simultaneous eruption. Sudden shifts in locations = Challenge for field volcanologists and first responders.

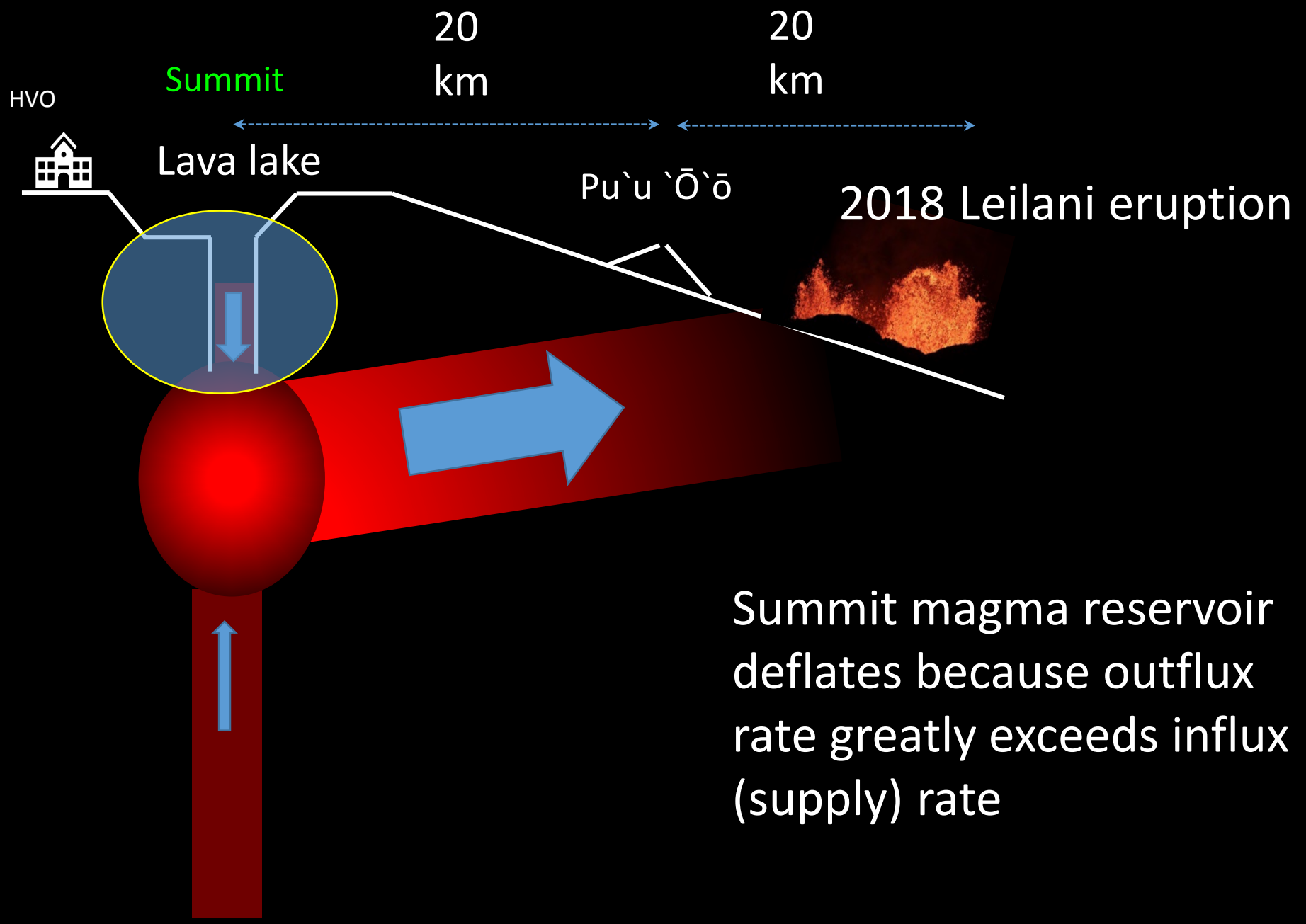
(27-) 29 May-July: more steadiness

- conduit stabilizes and focuses
- dominance of newer hotter melt
- low but prolonged fountaining
- stable (surging) lava channel

5 June


PRELIMINARY MAP
Lava Flow Thicknesses
Kīlauea Lower East Rift Zone, 2018
USGS
science for a changing world
132
132
137
~55 m (180 ft)
Fissure 8:
51 m (167 ft)
~280 m (919 ft)
0 0.5 Km
0 0.5 mi
N
Thickness:
0-5 m, 0-16 ft
5-10 m, 16-33 ft
10-15 m, 33-49 ft
15-20 m, 49-66 ft
20-25 m, 66-82 ft
25-30 m, 82-98 ft
30-55 m, 98-180 ft
55-280 m, 180-919 ft
Data still being collected and processed for areas displayed in black
Data depicted on this map are preliminary and subject to change. A final map will be released when all remote sensing data have been collected and processed.

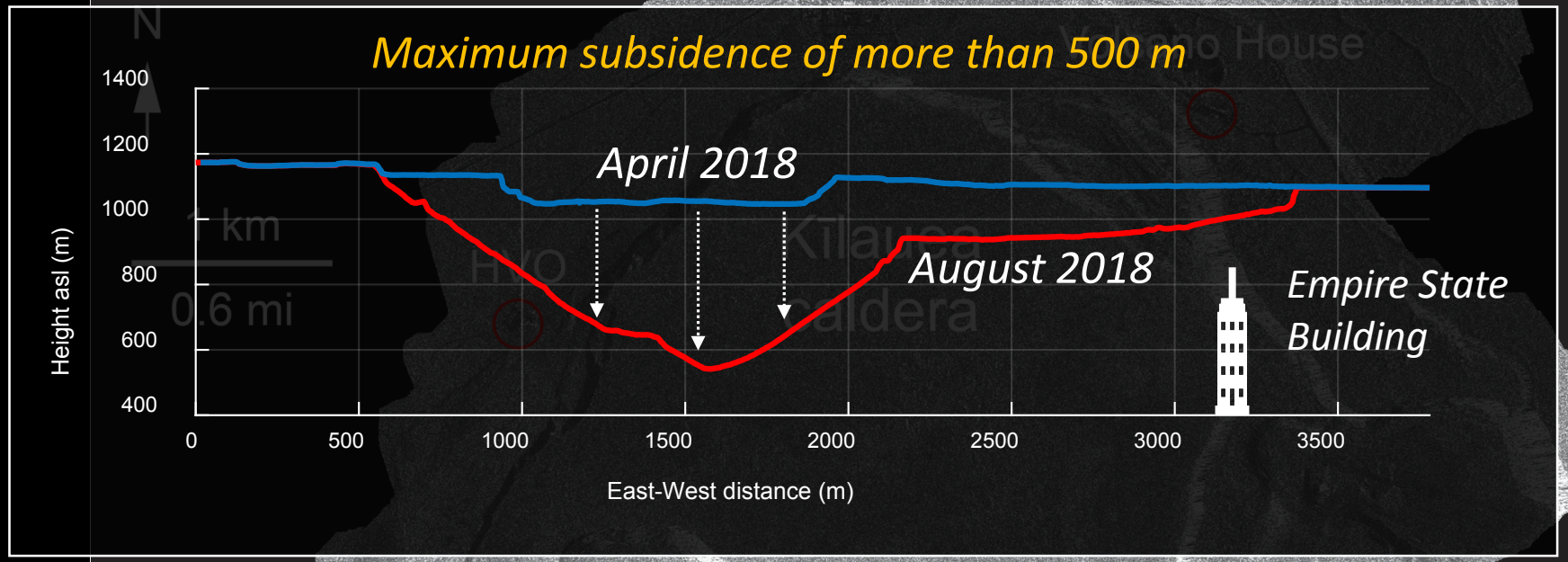
Summit



Summit magma reservoir deflates because outflux rate greatly exceeds influx (supply) rate

Kyle Anderson 2019

May 05 06:12 HST

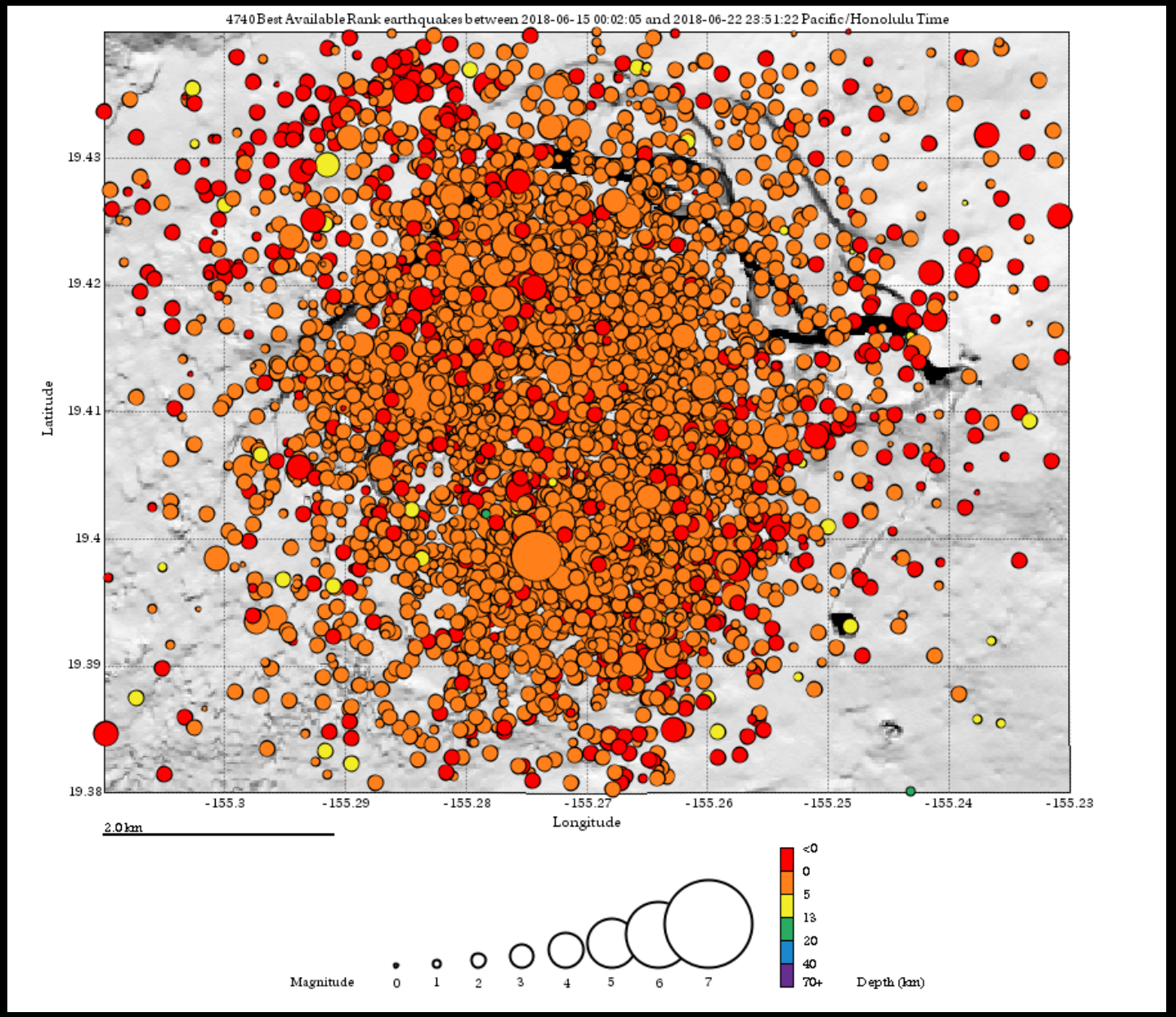


Halemaʻumaʻu crater

Formation of a caldera

Collapse of caldera floor from Keanakāko`i

4,740 earthquakes over 8 days

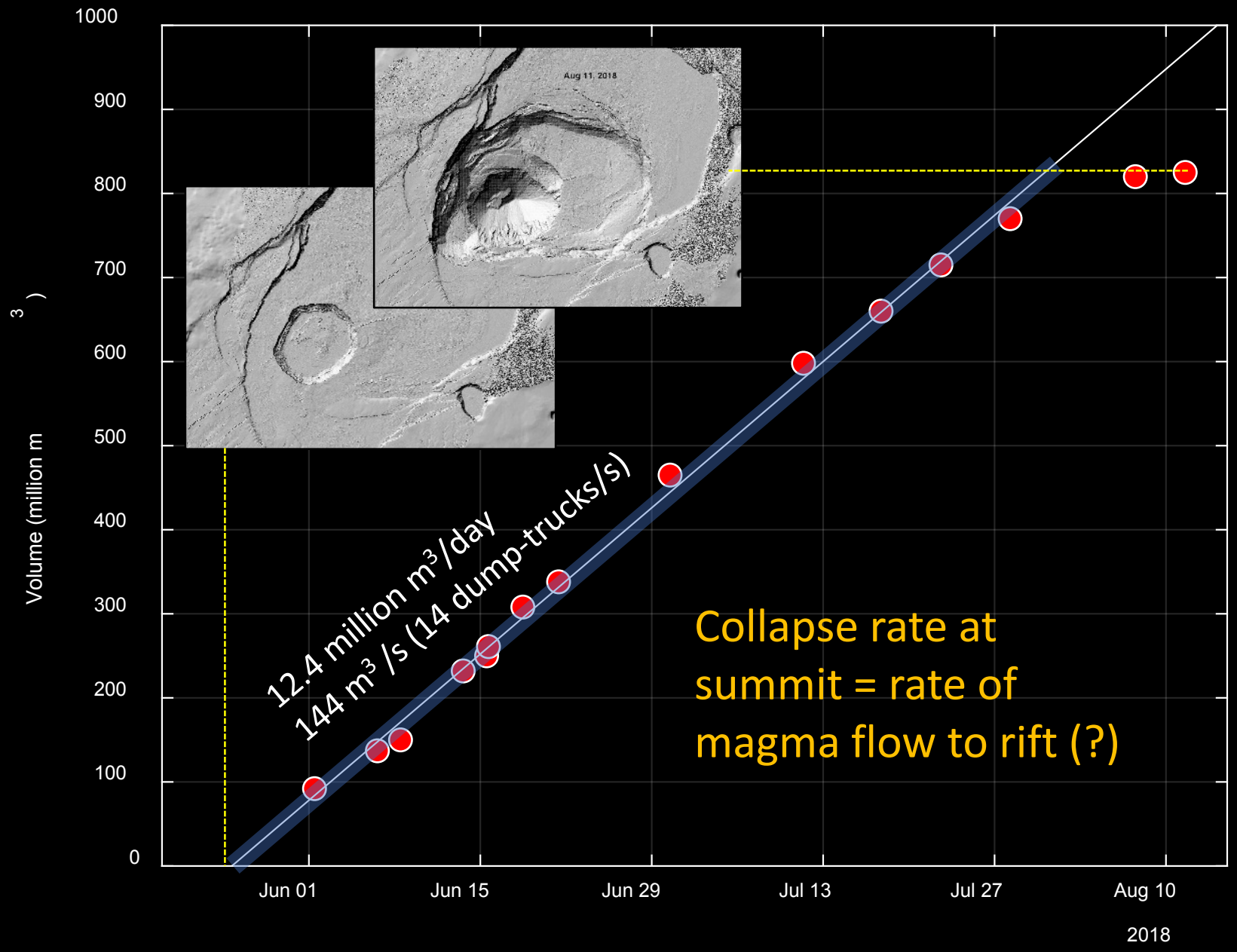


15-22 June 2018

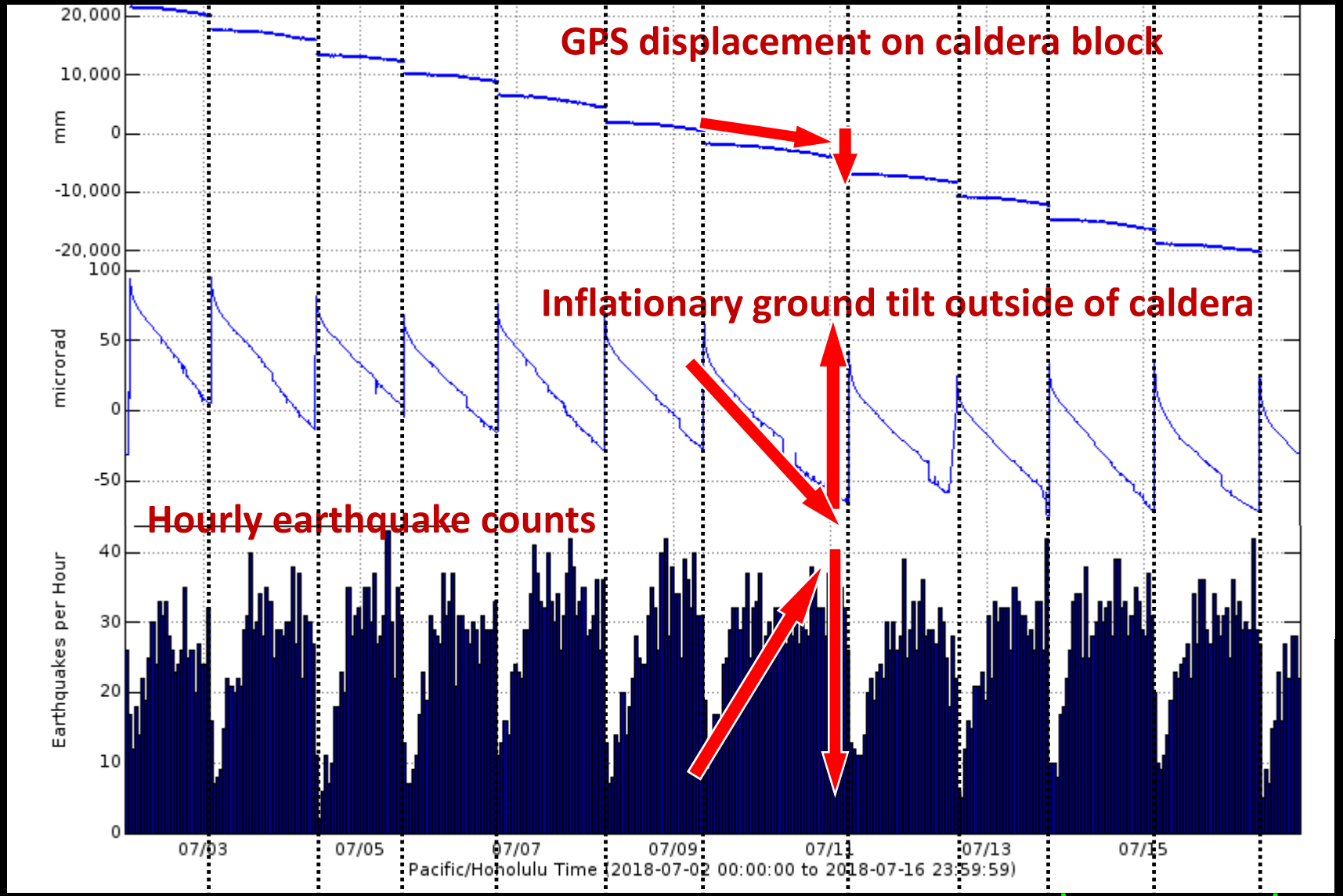
to 5 km depth

generally MM<4

Near-constant overall caldera growth rate



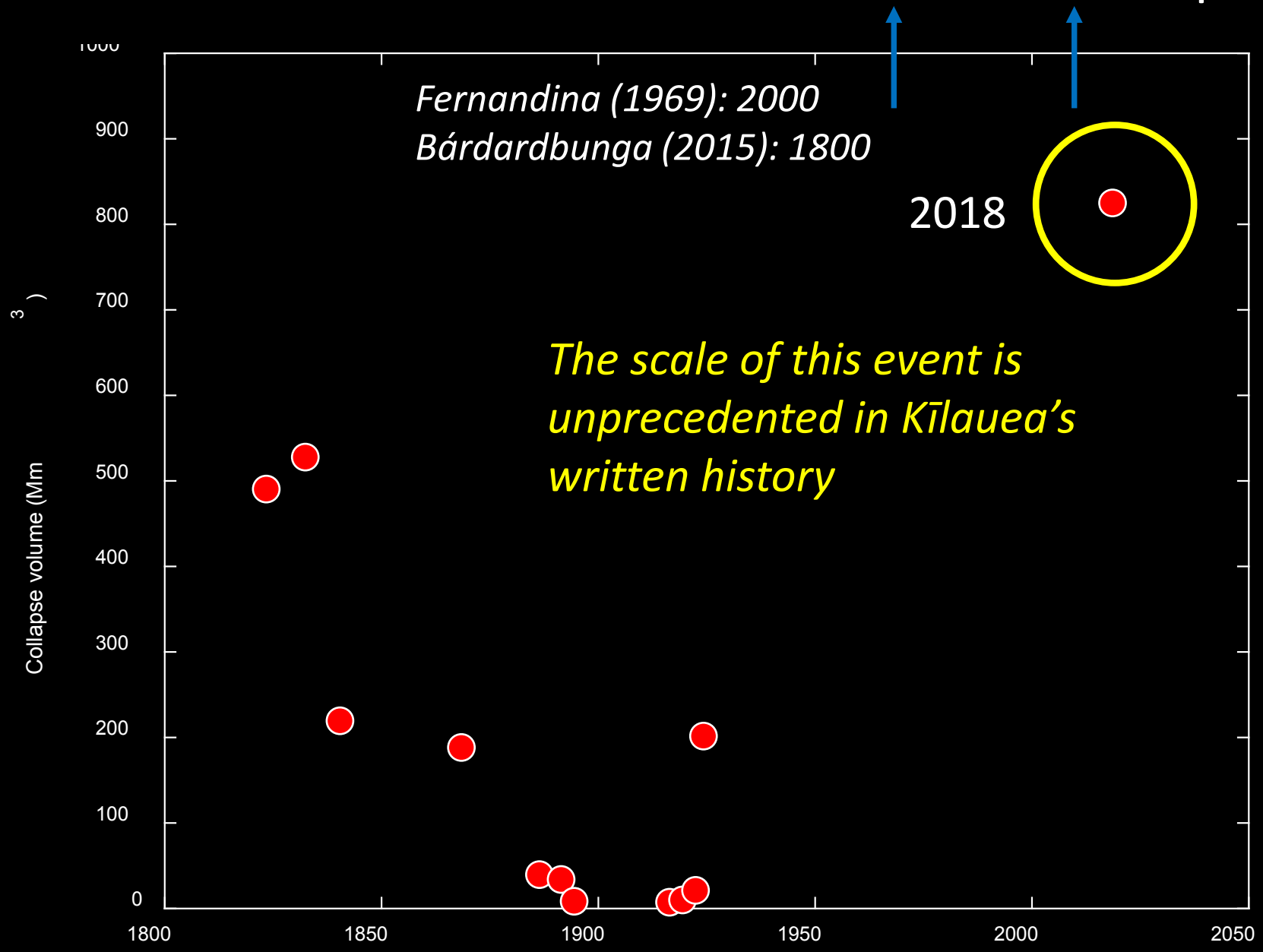
…yet the caldera formed episodically!



Caldera collapse events (~M5.3 Eqs)

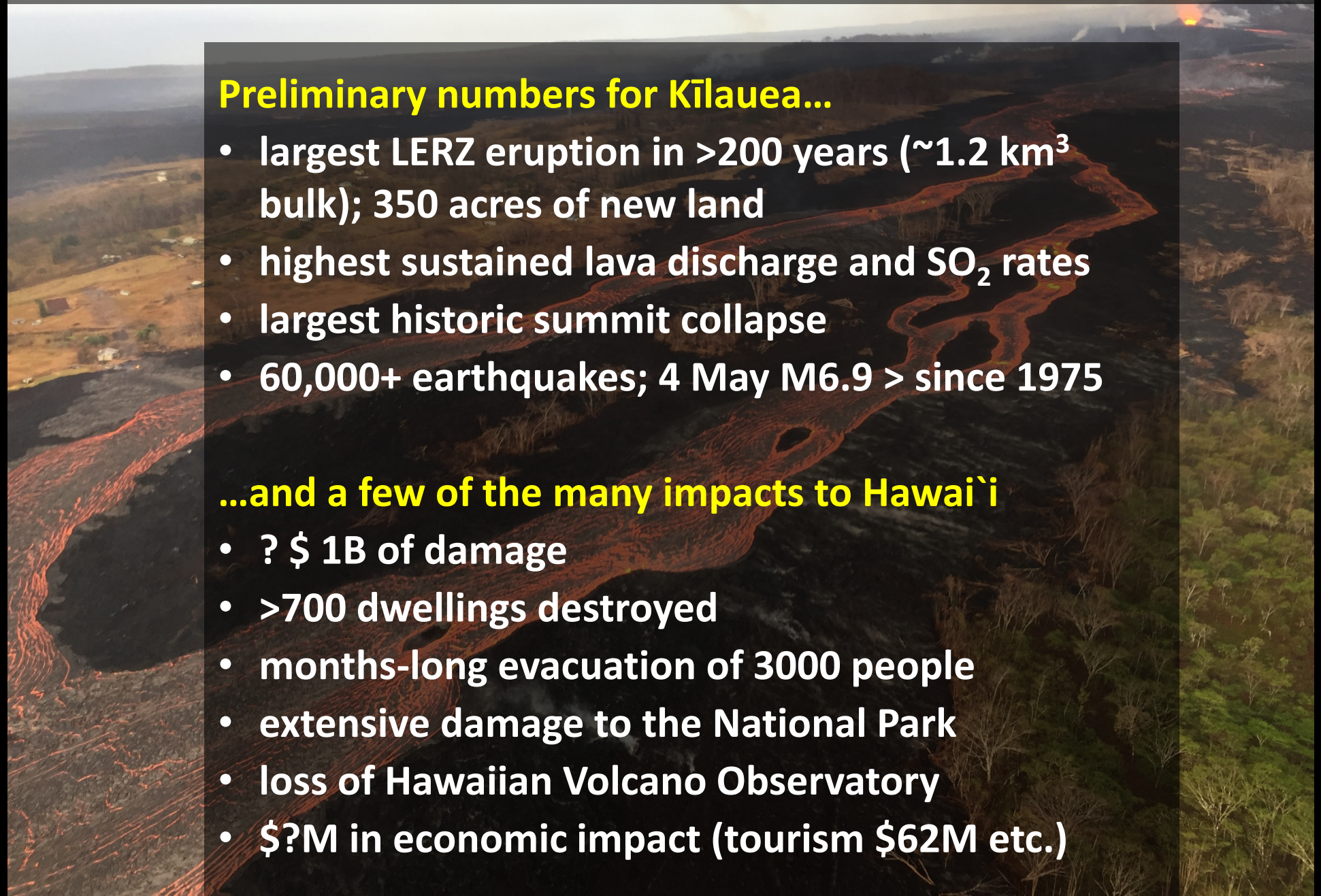
EQ swarms exceeding 700 ≤M4.0 events

How historic was Kīlauea's 2018 collapse?



Summit collapse volumes at Kīlauea Volcano, 1800-present

Some numbers – and their impact



Preliminary numbers for Kīlauea…

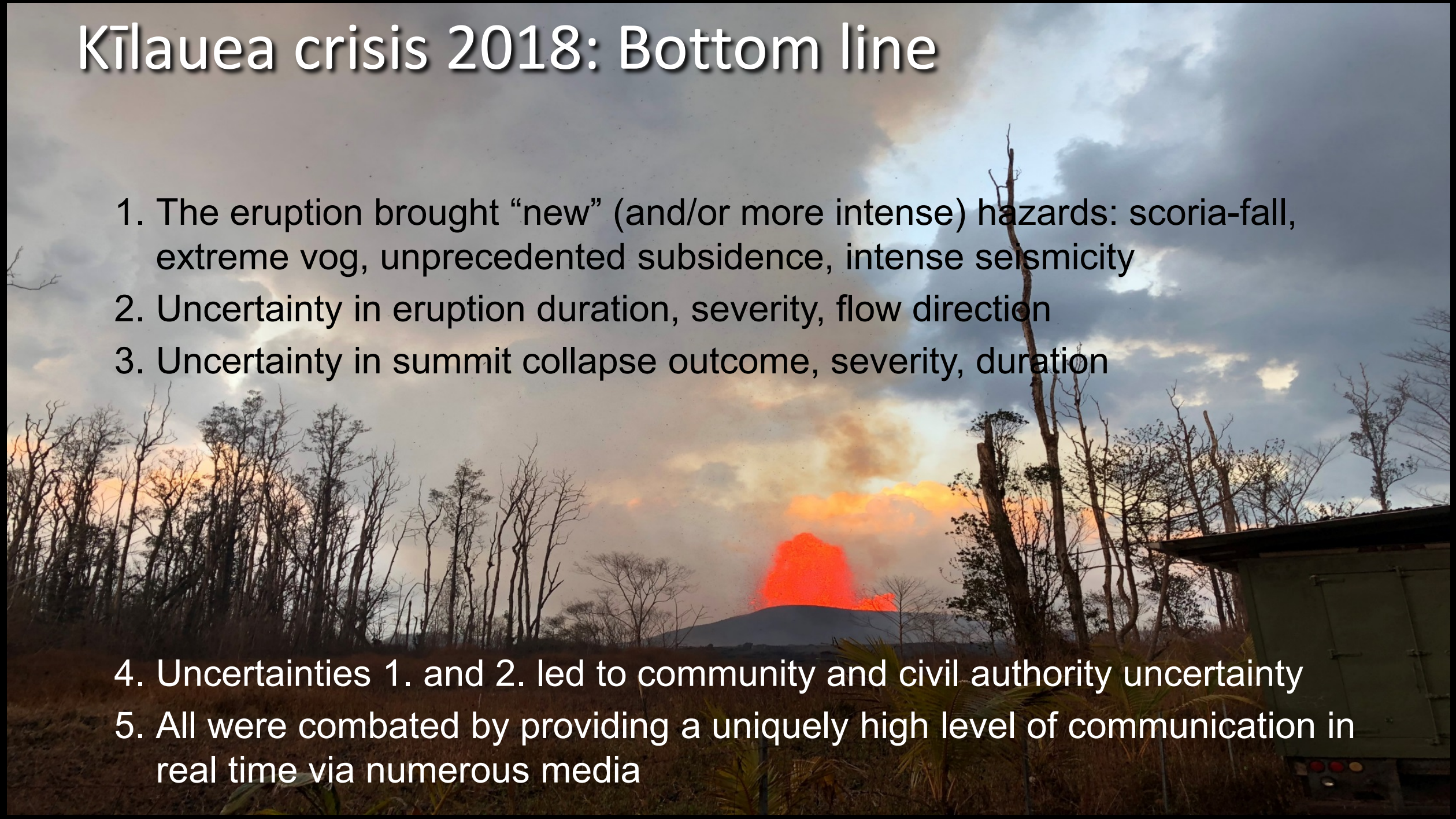
- largest LERZ eruption in >200 years (~1.2 km^3 bulk); 350 acres of new land
- highest sustained lava discharge and SO_2 rates
- largest historic summit collapse
- 60,000+ earthquakes; 4 May M6.9 > since 1975

…and a few of the many impacts to Hawai`i

- ? $ 1B of damage
- >700 dwellings destroyed
- months-long evacuation of 3000 people
- extensive damage to the National Park
- loss of Hawaiian Volcano Observatory
- $?M in economic impact (tourism $62M etc.)

Kīlauea crisis 2018: Bottom line

1. The eruption brought “new” (and/or more intense) hazards: scoria-fall, extreme vog, unprecedented subsidence, intense seismicity
2. Uncertainty in eruption duration, severity, flow direction
3. Uncertainty in summit collapse outcome, severity, duration



4. Uncertainties 1. and 2. led to community and civil authority uncertainty
5. All were combated by providing a uniquely high level of communication in real time via numerous media

Long-term volcano monitoring pays dividends

Thomas A. Jaggar founded HVO in 1912 with the belief that careful, long-term scientific observation and investigation are key to understanding and forecasting hazardous geologic processes

Jaggar in his office, 1925

Three (of many possible) messages

1. Real-time monitoring data coupled with insights from a century of careful study allowed USGS/HVO to issue timely and accurate warnings; no lives were lost (transformative role of UAVs)

2. The largest eruption at Kīlauea in more than 200 years was also the world's best-observed caldera collapse (by far); this event will be studied for decades to come

3. The magma system at Kīlauea has changed in important ways

Kīlauea volcano

One of the world's most active and monitored volcanoes – but fundamental questions remain:

- What was the mechanism that initiated the eruptions (MERZ barrier?) ?
- What drives variety in fountaining behaviors?
- Where is/was magma stored, and how much, and what is its role in subsequent eruptions?
- How is the summit connected to the rift zones?
- What causes dangerous explosive activity?
- What is the interplay between tectonic and magmatic forces?

Thank you to everyone involved in Kīlauea eruption responses