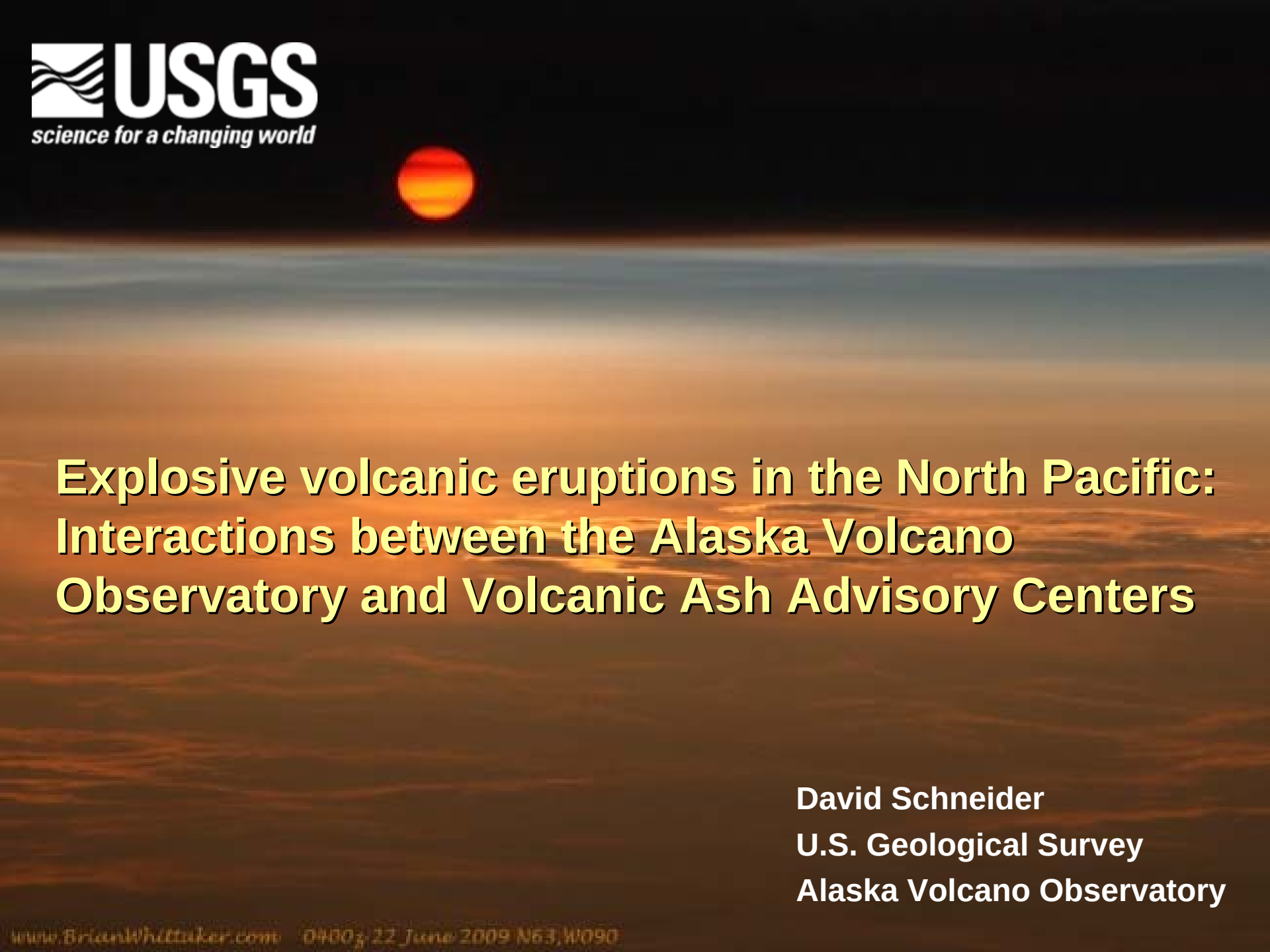
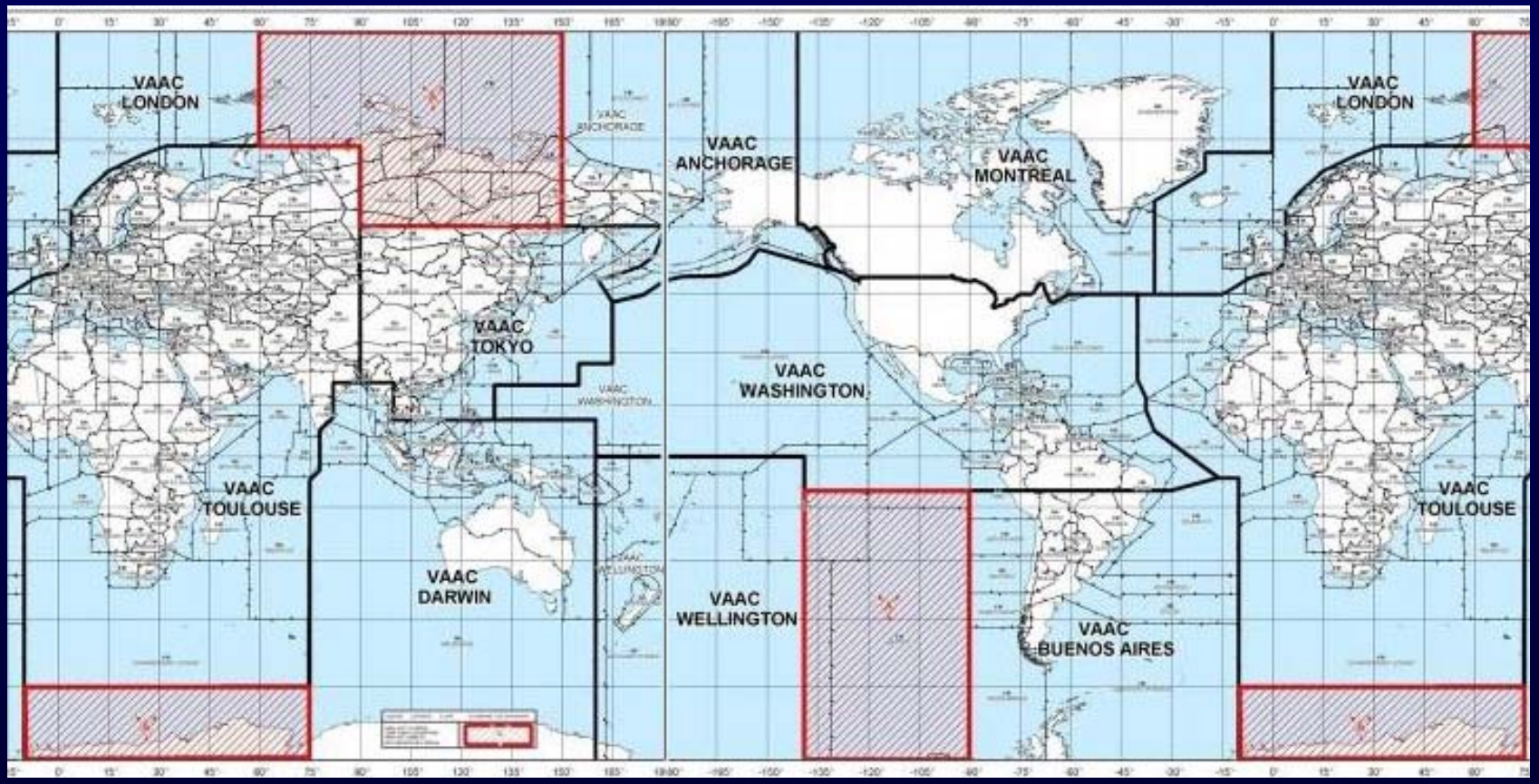


Explosive volcanic eruptions in the North Pacific: Interactions between the Alaska Volcano Observatory and Volcanic Ash Advisory Centers

David Schneider
U.S. Geological Survey
Alaska Volcano Observatory

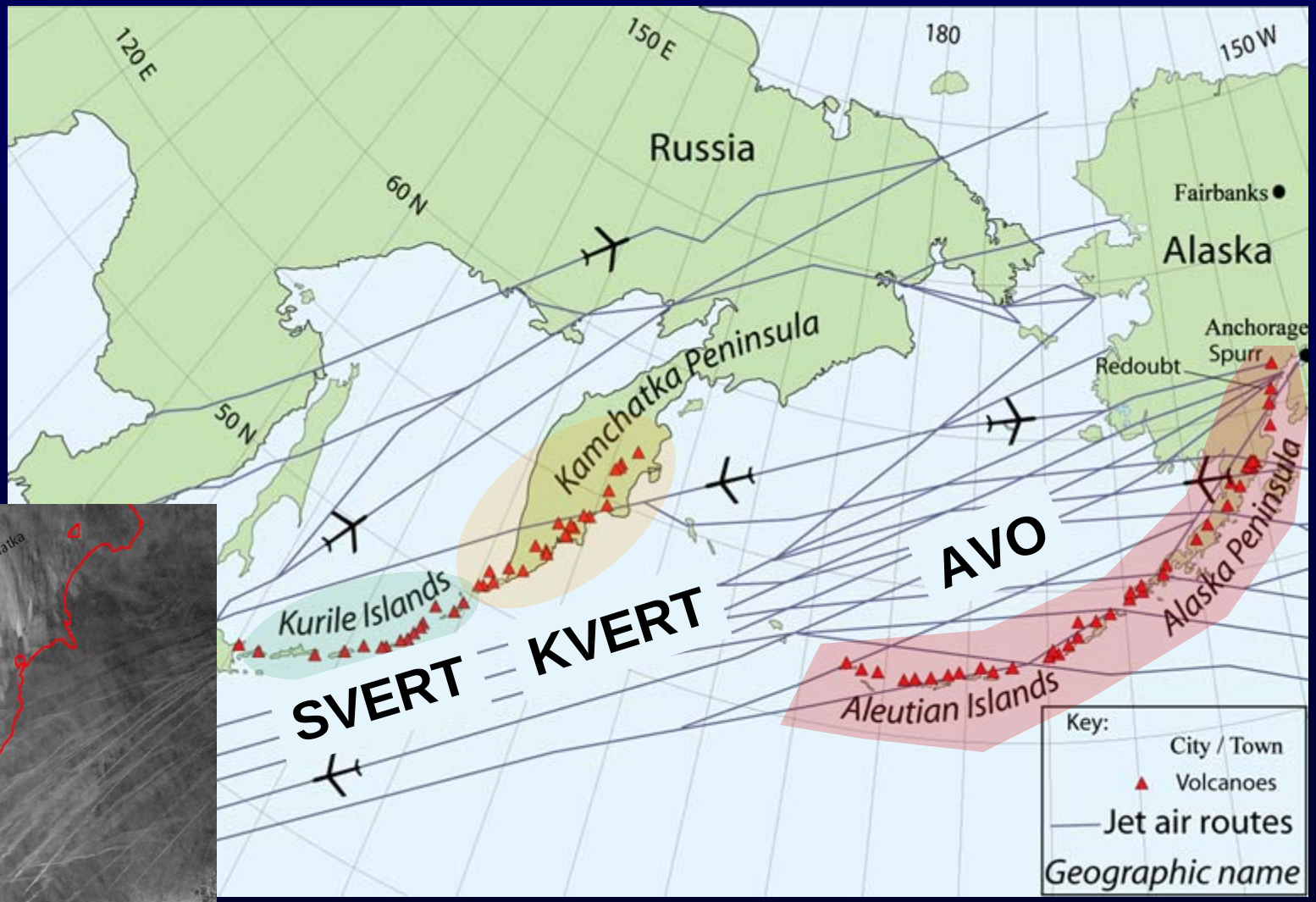
Volcanic Ash Advisory Centers

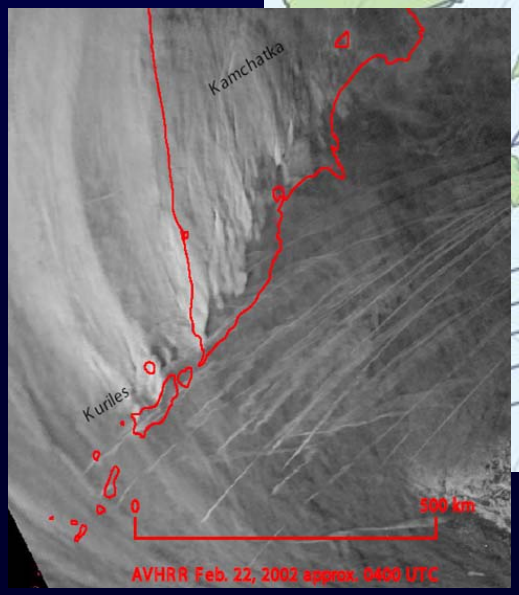


VAACs created by ICAO & WMO in mid-1990's to coordinate information flow to MWOs on global scale. Primary responsibility for forecasting ash movement.

USGS

North Pacific Air Routes





Significant North Pacific Eruptions
Aviation Color Code Red

2009 Sarychev; Redoubt; Shiveluch; Bezymianny
2008 Kasatochi; Okmok; Kliuchevskoi
2007 Kliuchevskoi; Shiveluch; Bezymianny
2006 Augustine; Shiveluch, Bezymianny
2005 Shiveluch
2004 Shiveluch
2003 Bezymianny
2001 Cleveland; Bezymianny; Shiveluch
1999 Shishaldin
1997 Bezymianny
1994 Klichevskoi; Cleveland
1993 Bezymianny; Shiveluch
1992 Spurr
1990 Bezymianny
1989 Redoubt

27 Episodes of unrest
Most episodes had multiple explosive events

USGS

Alaska Interagency Operating Plan for Volcanic Ash Episodes

- Alaska Volcano Observatory
- Federal Aviation Administration
- National Weather Service (Anchorage VAAC, Anchorage MWO, Center Weather Service Unit)
- National Oceanic and Atmospheric Administration (Washington VAAC)
- Department of Defense (U.S. Air Force and Air Force Weather Unit)
- U.S. Coast Guard
- State of Alaska (Emergency Management, Environmental Conservation)

USGS

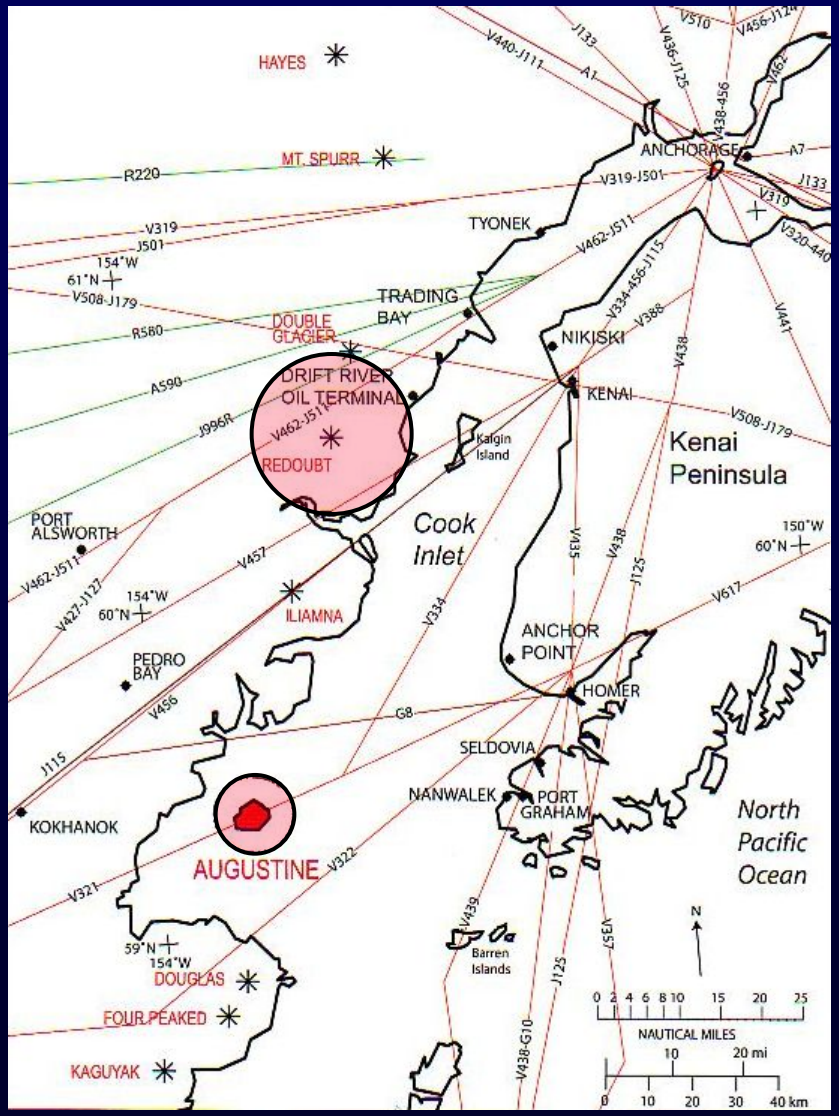
Steps of Ash Hazard Warning

- Eruption onset forecast (if possible): VO
  - VONA
- Eruption detection: VO, VAAC, Pilot
- Determine altitude of ash emission: VO, VAAC, Pilot
- Issue initial warning message: VO, VAAC and MWO
  - VONA, VAA, SIGMET
- Ash dispersion modeling: VAAC
- Issue forecast of ash movement warning message: VAAC and MWO
  - VAA, SIMGET
- Validation of dispersion forecast (satellite, visual): VAAC, VO, Pilot
- Update warning message: VAAC and MWO
- Continue until *"event is over"*

USGS

Airspace Closures in the US

- Airspace closures (TFR) for volcanic activity is typically limited to the immediate vicinity of the volcano at a radius of 5-10 nautical miles from the surface to FL600.
- Keeps aircraft from using routes that could be impacted by an explosive event.
- Protect observatory air operations (fixed wing and helicopter) for monitoring activity.



USGS

VAAs and SIGMETS

- **“The official VAAC products, informed by dispersion modeling, remote sensing, pilot reports, etc define a threat area in which ash may be encountered, without regard to concentration” A. Tupper**
- **Volcanic ash advisories issued by the VAAC guide issuance of the volcanic ash SIGMET my the appropriate Meteorological Watch Office.**
- **In Alaska, the Anchorage VAAC and the MWO (Alaska Aviation Weather Unit), are the same group and issue both products.**

USGS

Capabilities & Challenges

- Eruption Detection
  - Seismic, pressure sensors, satellite, radar, web camera, lightning
- Eruption characterization (ash and height)
  - Satellite, seismic, radar, web camera, lightning
- Forecasting and evaluation
  - Dispersion models, satellites (ash, so2 and aerosols)

- Need to rapidly integrate and analyze these data in real-time.
- How to communicate the results in a way that will improve warning products?

USGS

Basic Questions
Complicated Answers

- Where?
- When?
- How high?
- How long?
- Where is it going?
- When will it be over?

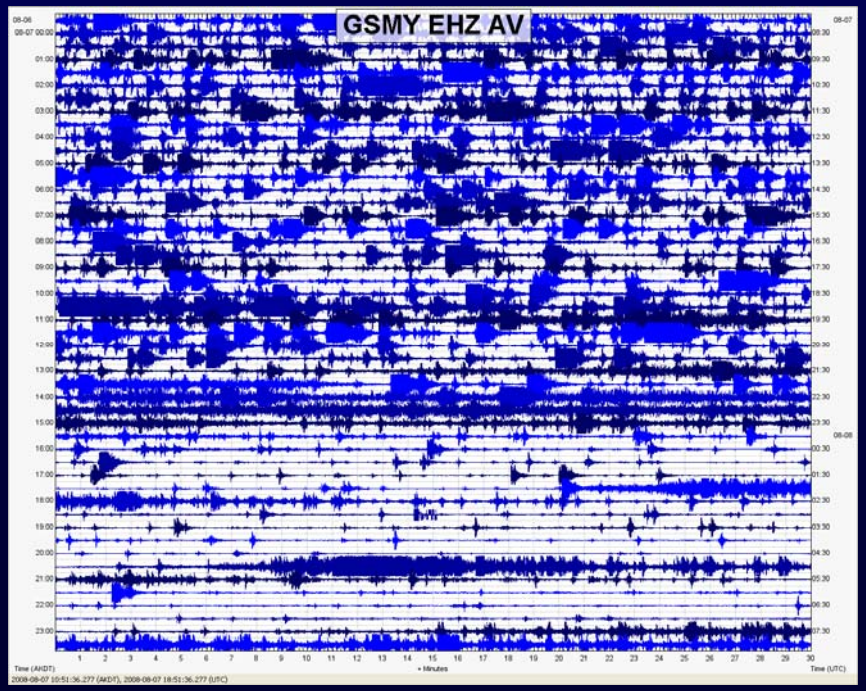
- New Question:
  What is the concentration?

USGS

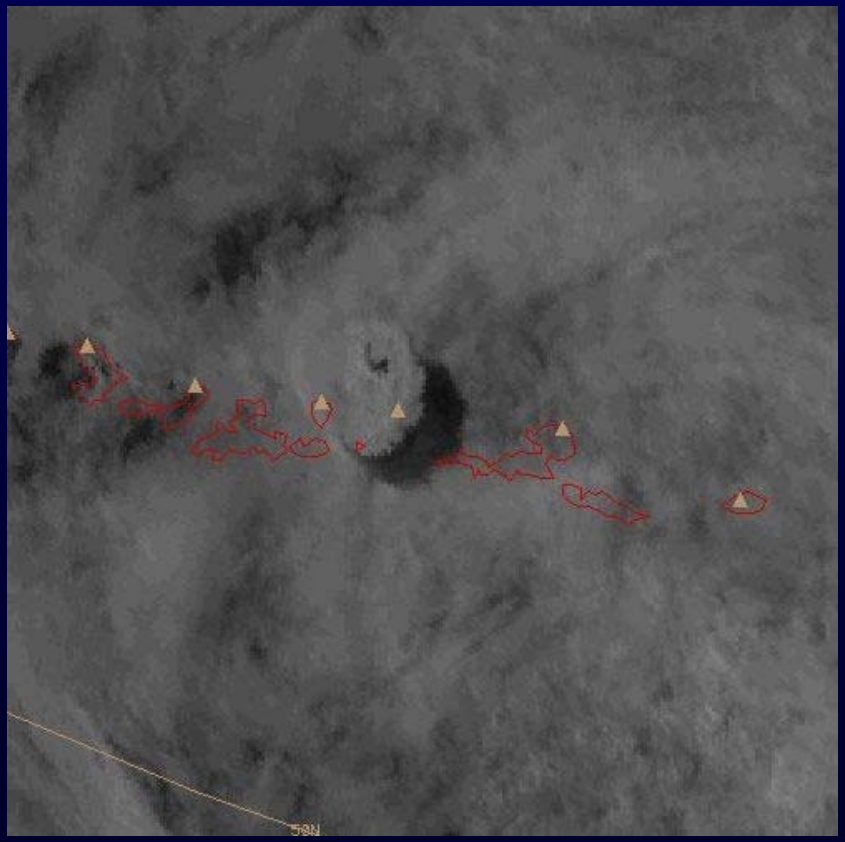
Where?

Not all volcanoes are monitored

Seismic record from Great Sitkin



From Kasatochi or submarine eruption?

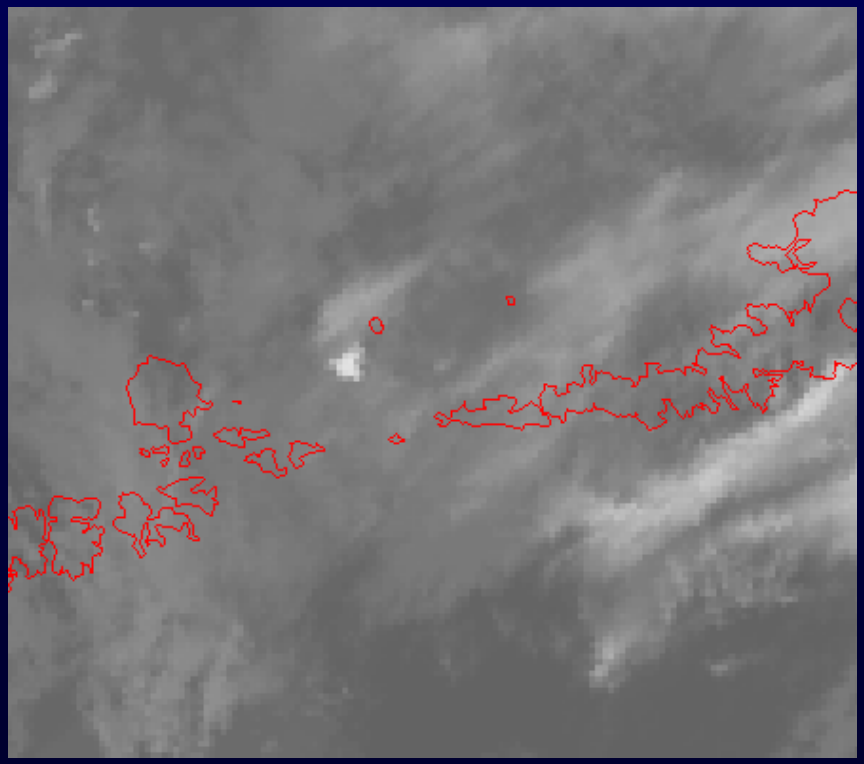


USGS

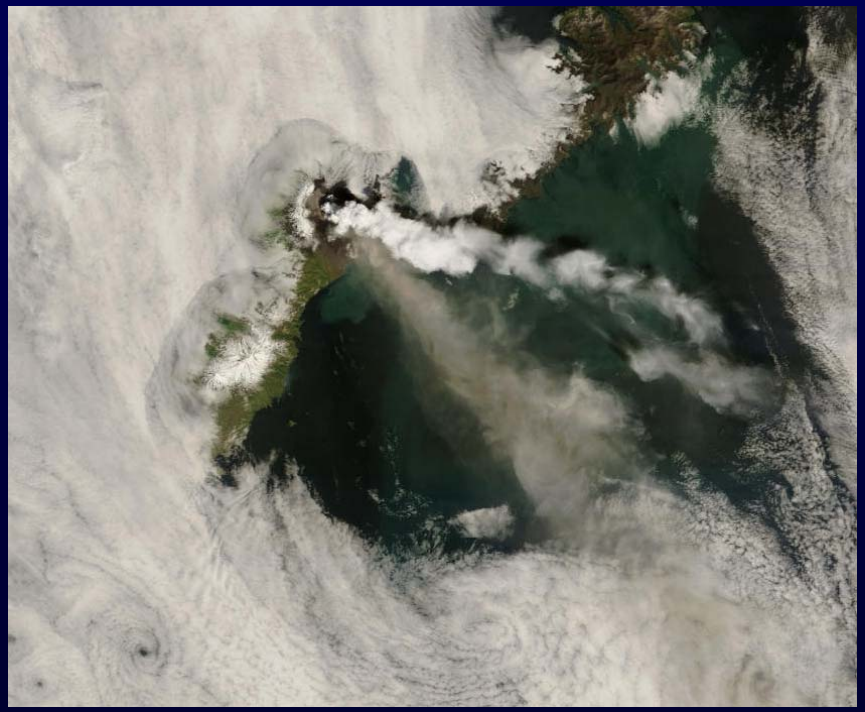
When?

Seismic tremor does not always correlate with ash eruption

Kasatochi after 20 minutes of tremor



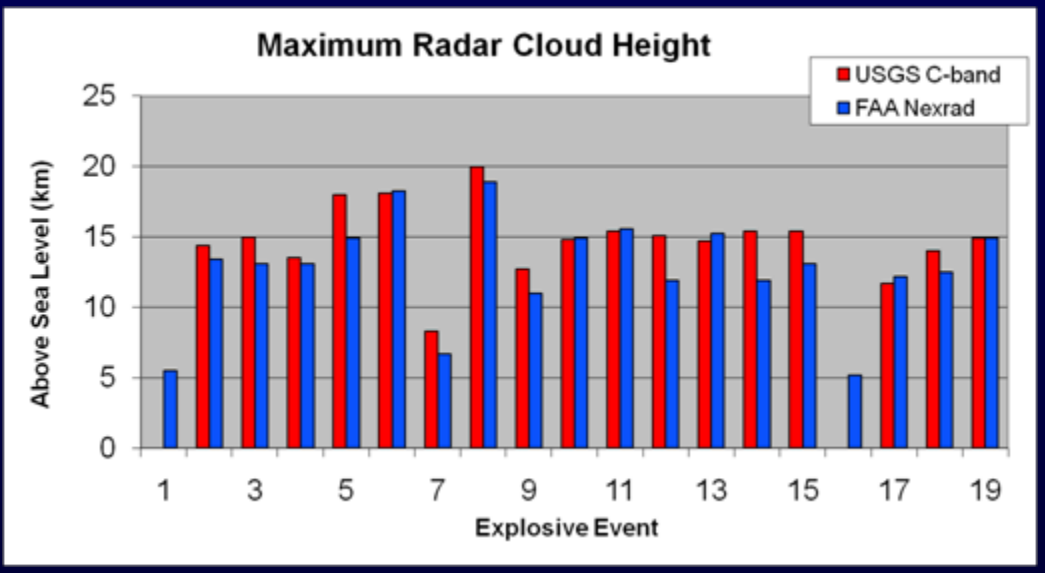
Multiple vents and tremor sources



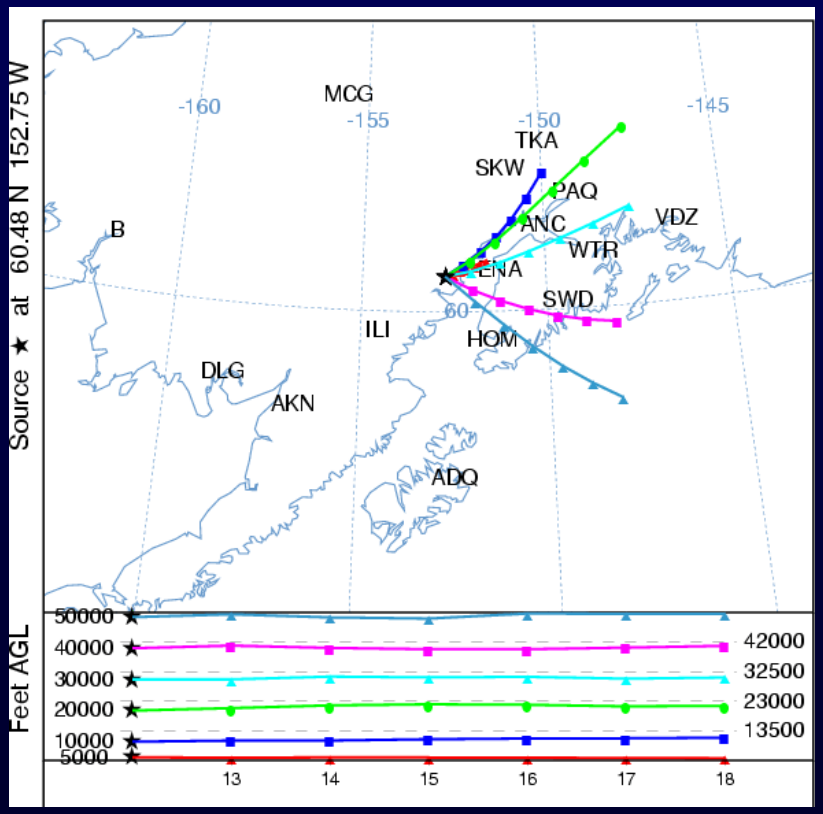
USGS

How high?
Different methods provide different answers

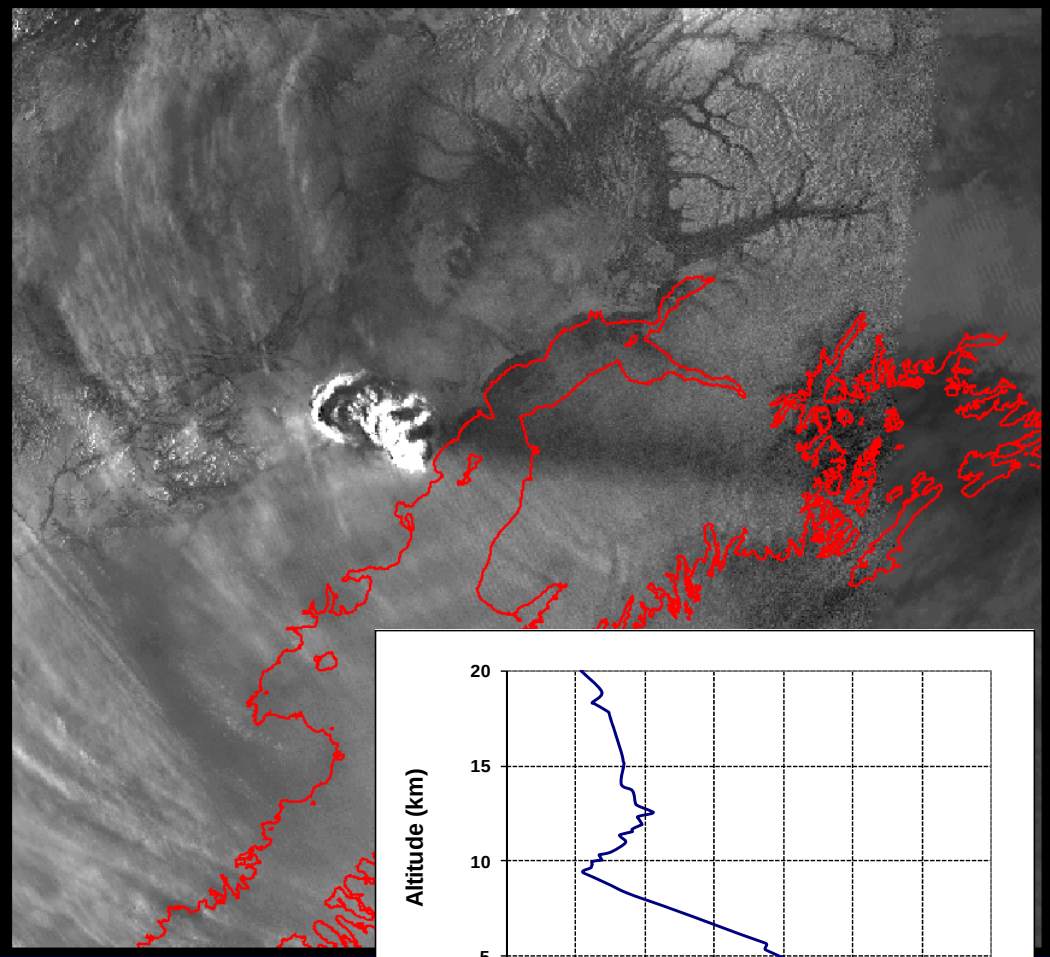
Redoubt: Radar cloud observations higher than satellite-based estimates

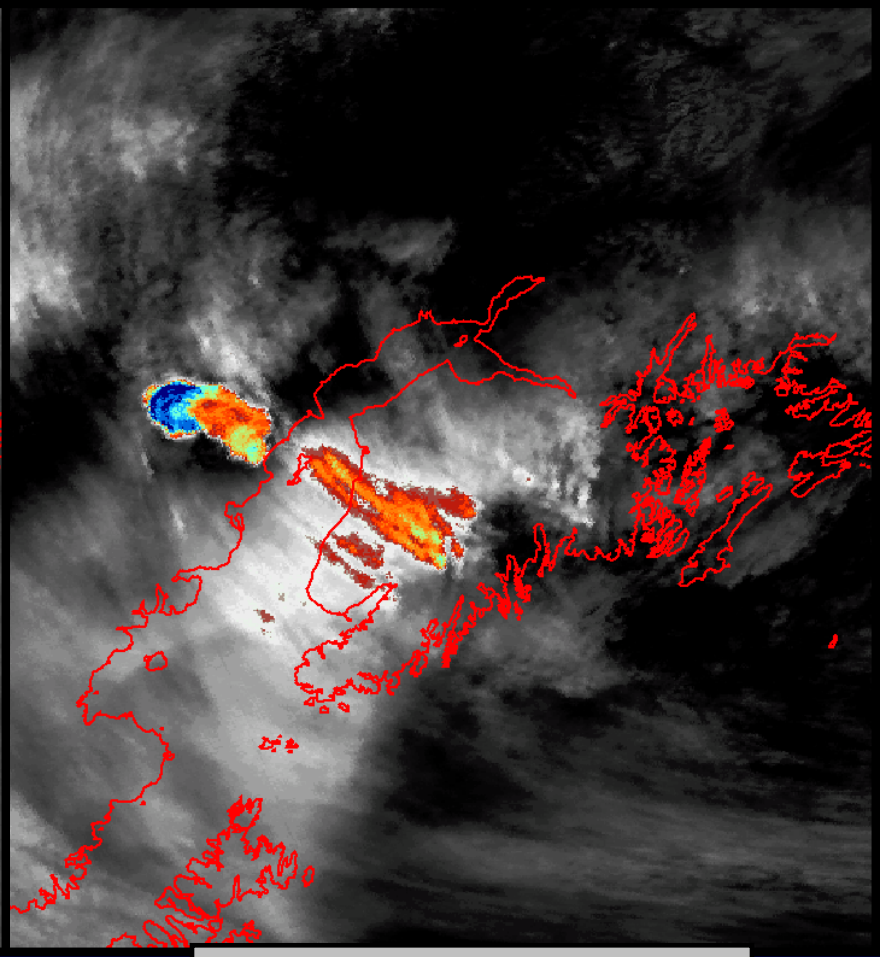


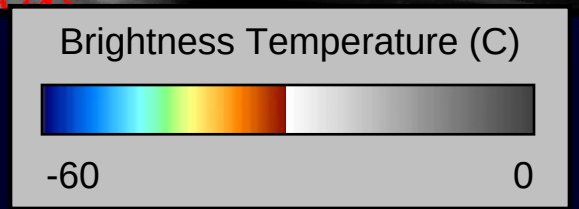
Trajectory Forecast



How high?
Thermal method: Problems for clouds in UTLS





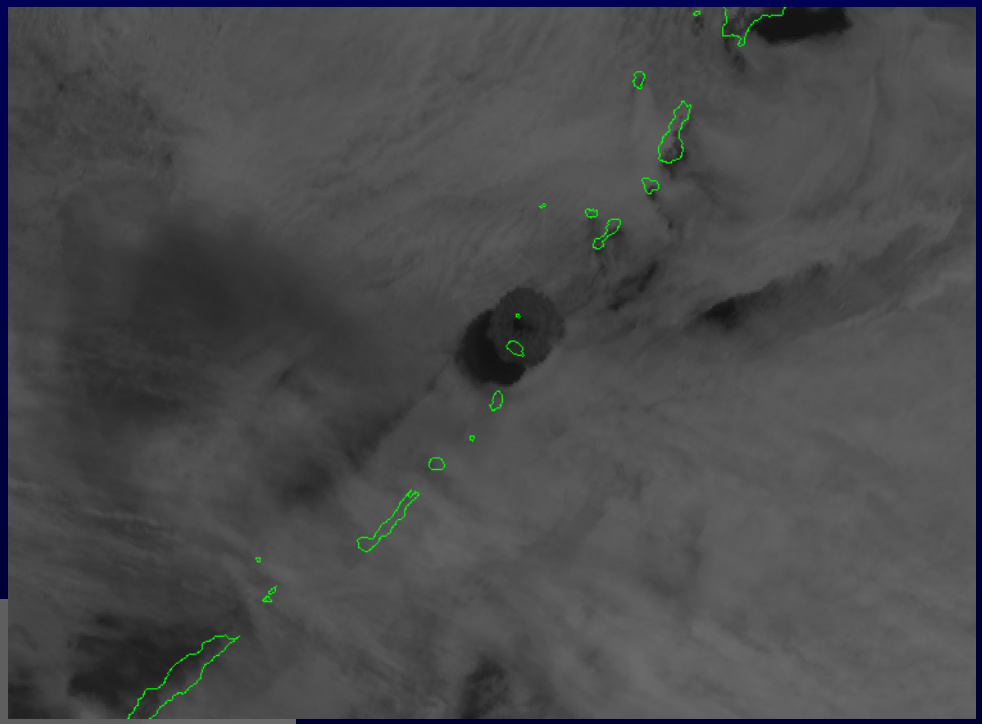


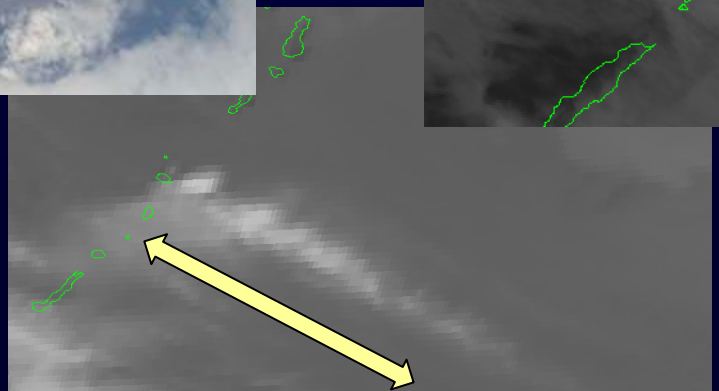
USGS

How high?
Typically evolves over time

Sarychev: Series of discrete events ~13 km asl

Seven larger events: 10 to 20 km asl

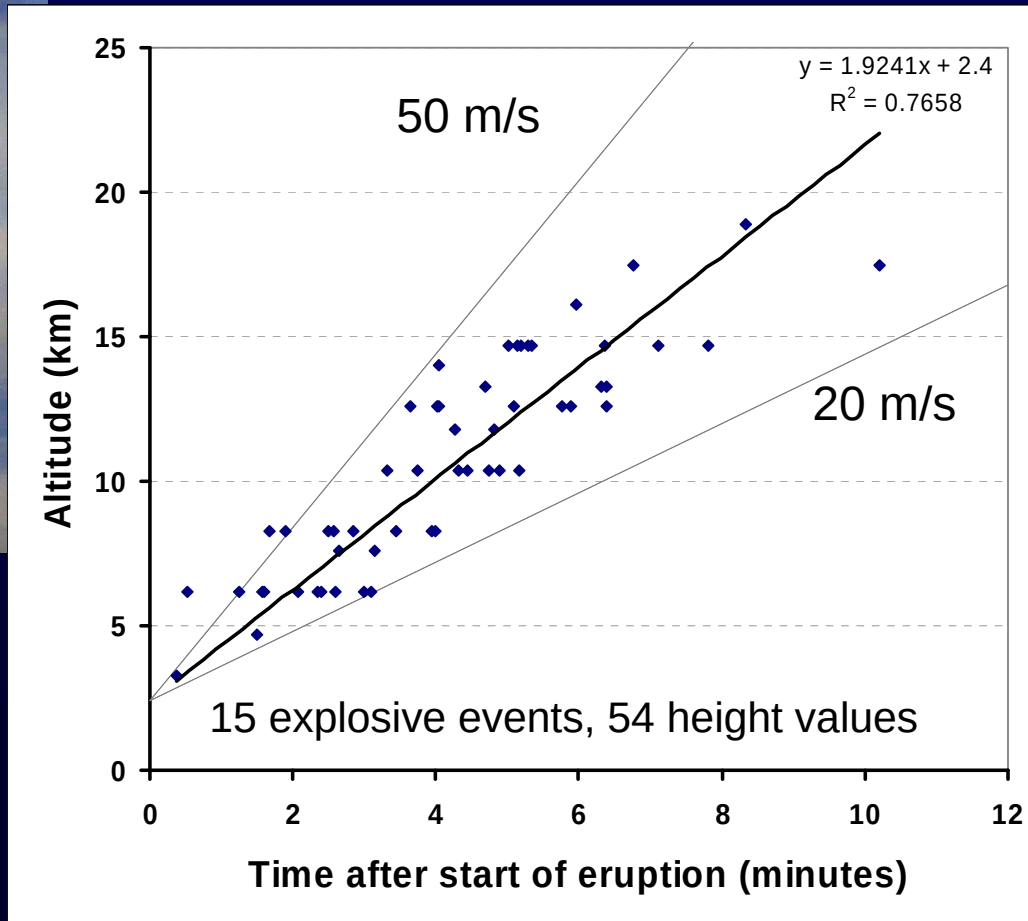




USGS

How high?
Rapid cloud rise

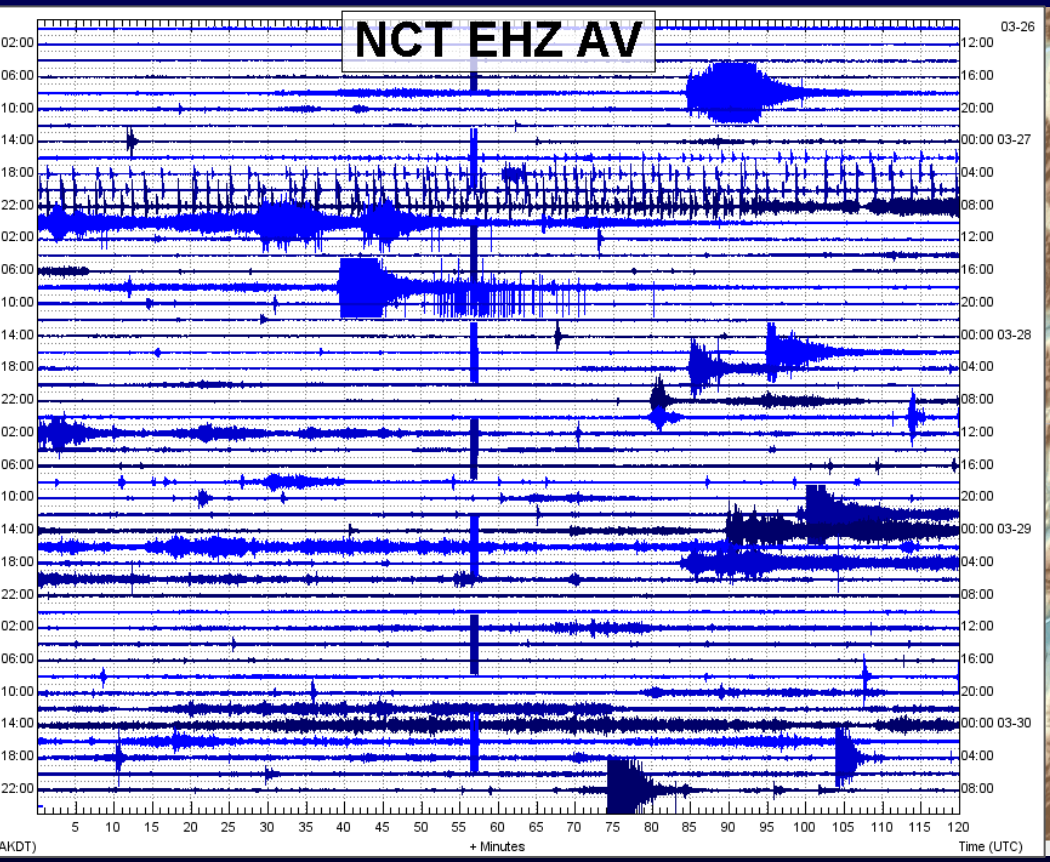
Redoubt from FL350
Eruption + 5 minutes



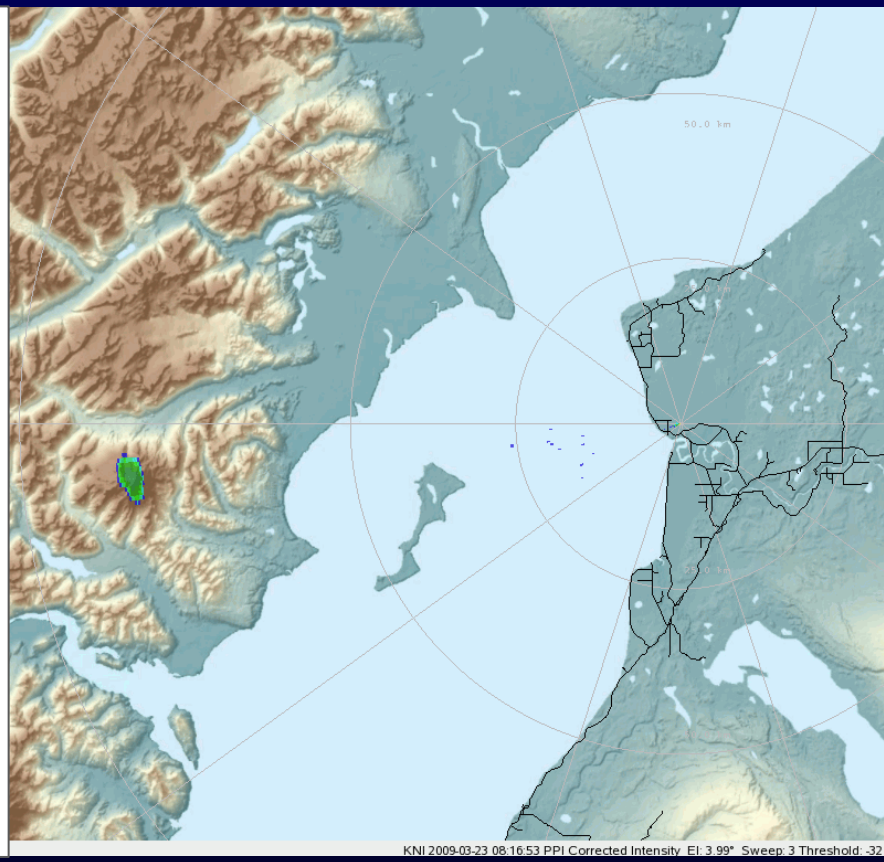
USGS

How long?
Unknown at the onset

Seismic durations are commonly used



Satellite and Radar can be ambiguous

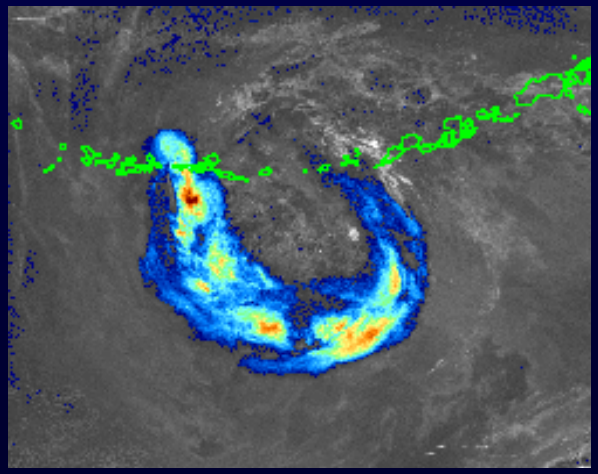


USGS

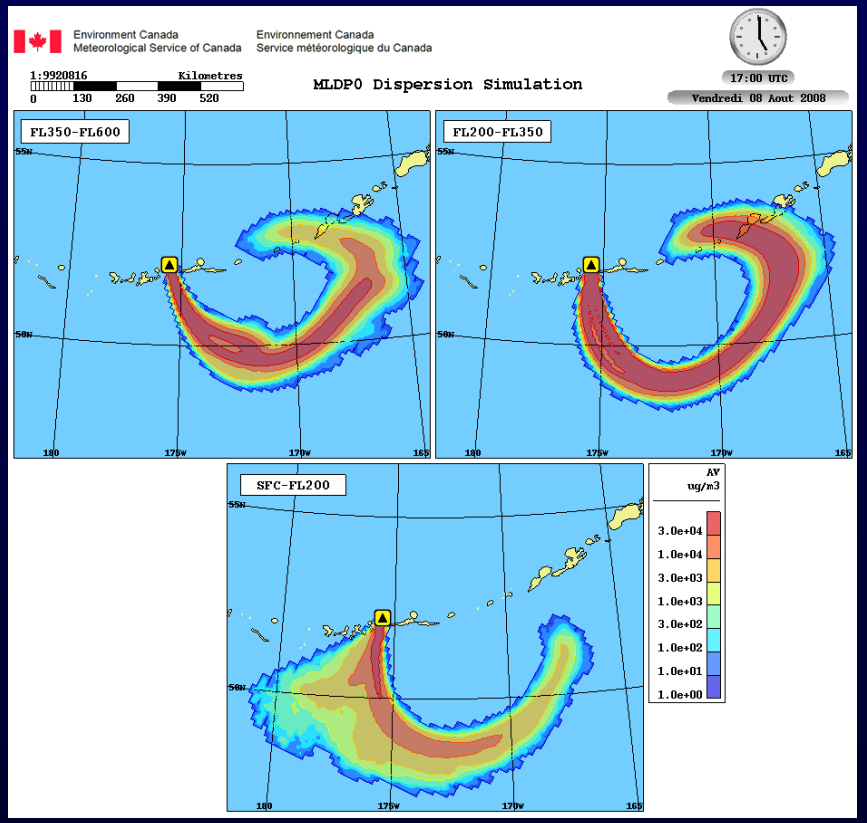
Where is it going?

Ash Dispersion Modeling

- Models require input parameters: Height, duration
- May include: vertical mass distribution, size distribution.
- Simple ash fallout



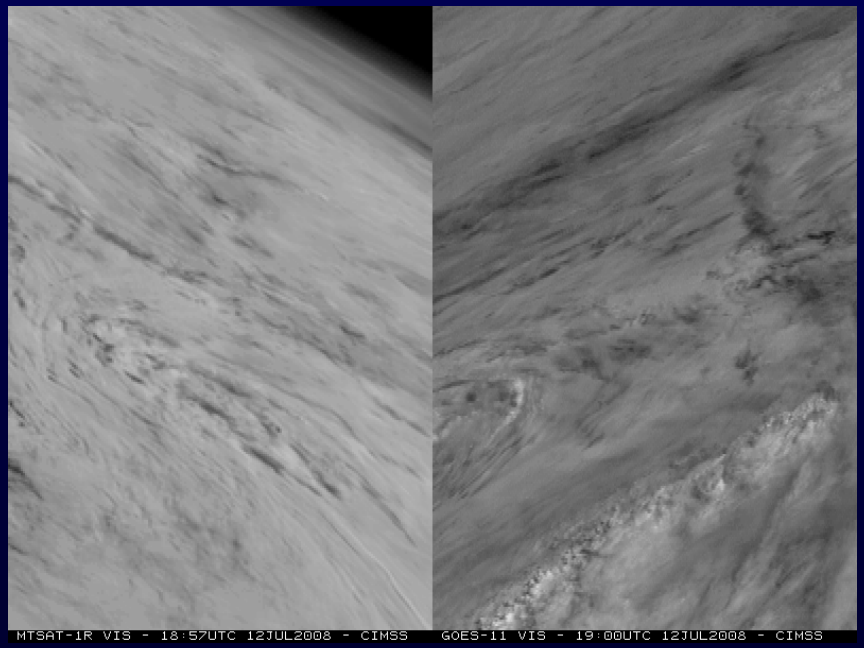
Model by Environment Canada



USGS

When will it be over?
Ash removal rate

Water in eruption clouds



Enhanced removal of fine grained ash near vent

USGS

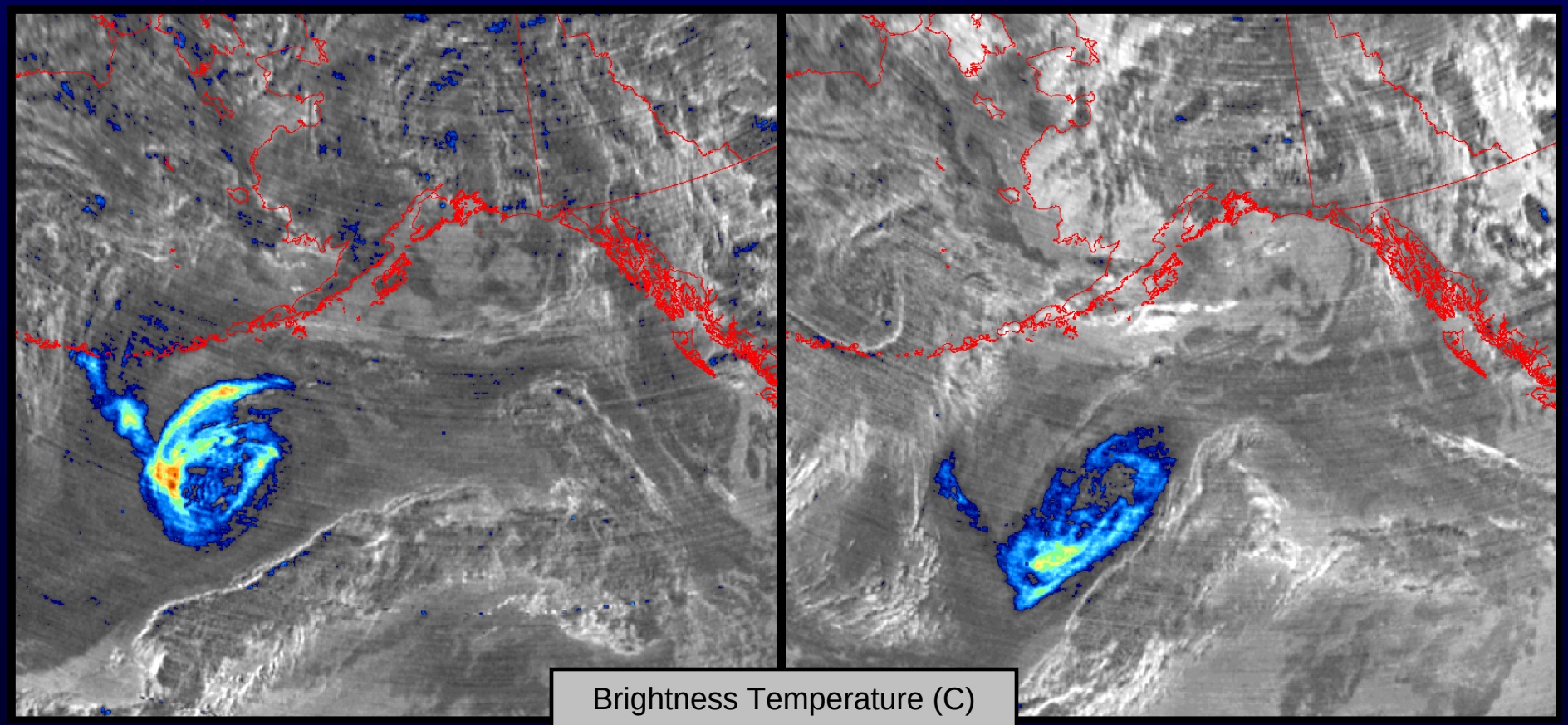
Photo: K. Wallace

When will it be over?

Ash signal fades over several days

09 Aug 1200 UTC

10 Aug 0000 UTC

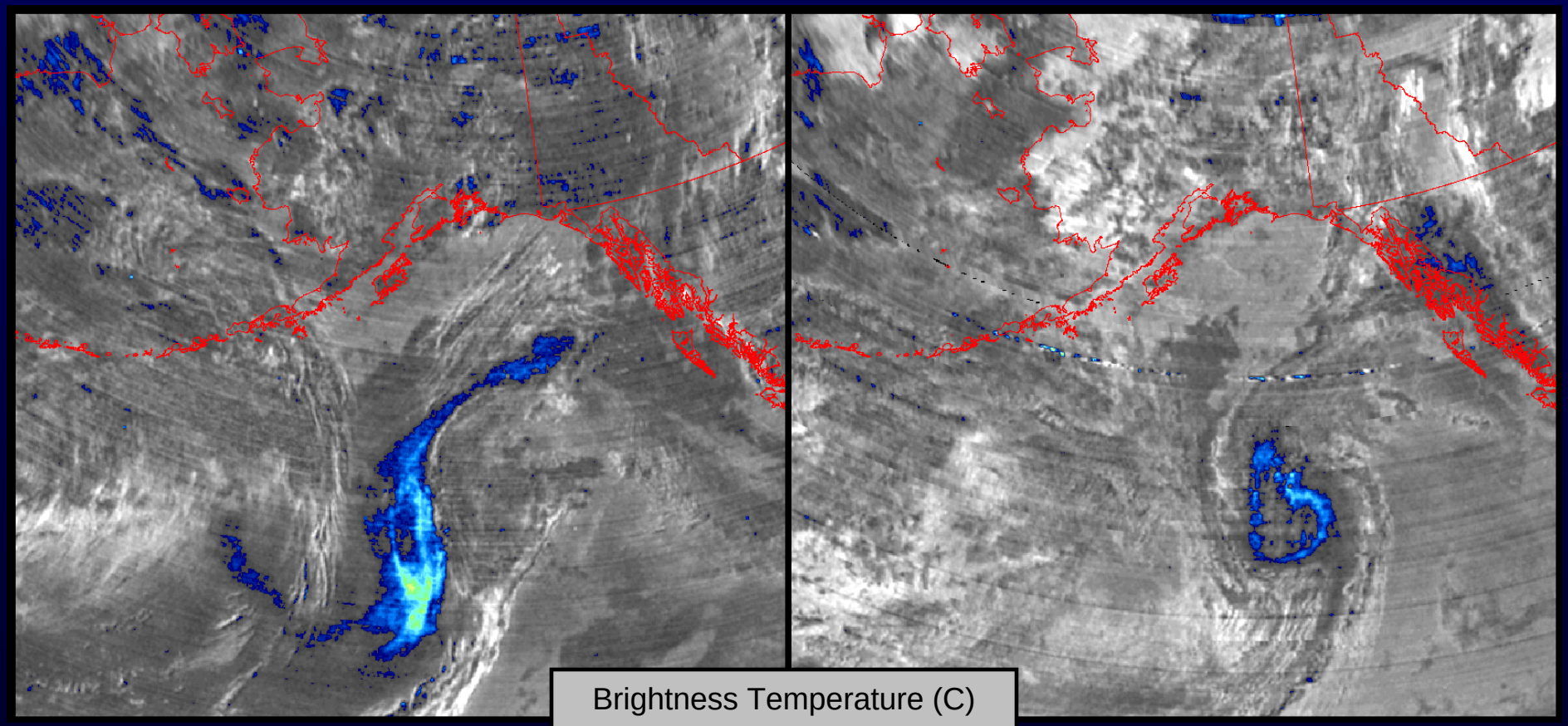


USGS

When will it be over?

Ash signal fades over several days

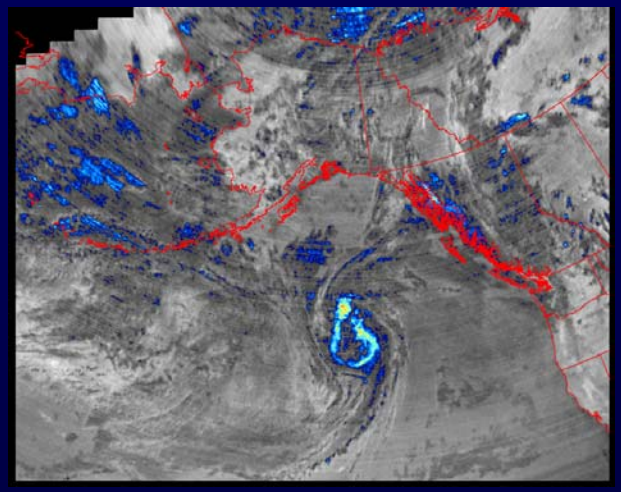
10 Aug 1200 UTC **11 Aug 0000 UTC**

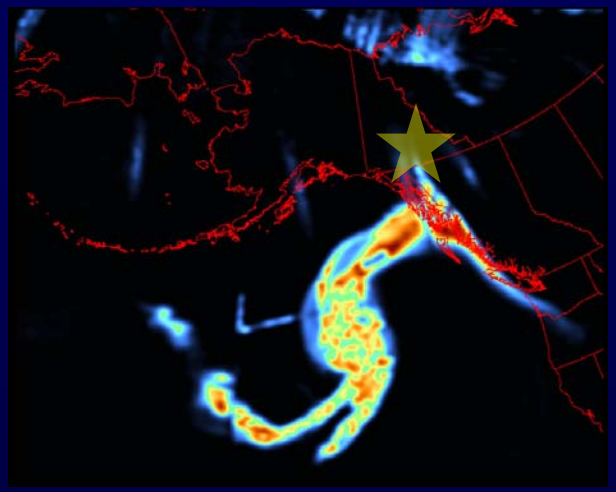


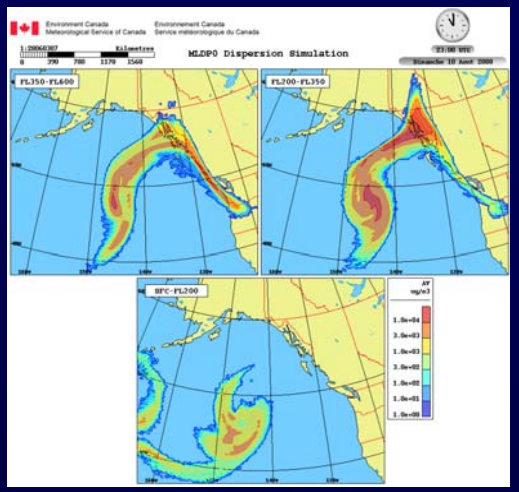
USGS

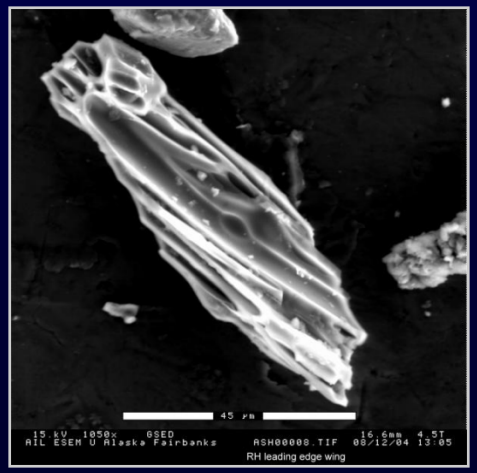
When will it be over?

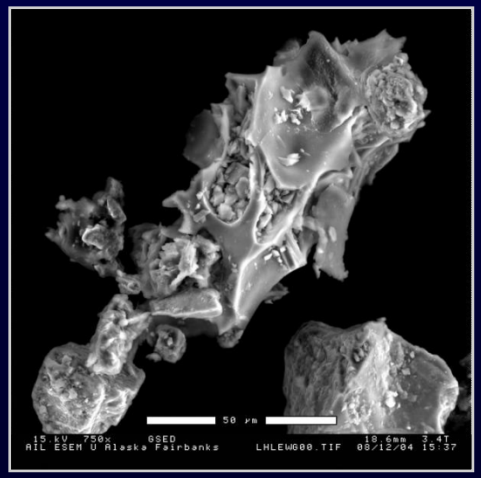
Non-damaging SO2 and minor ash encounter









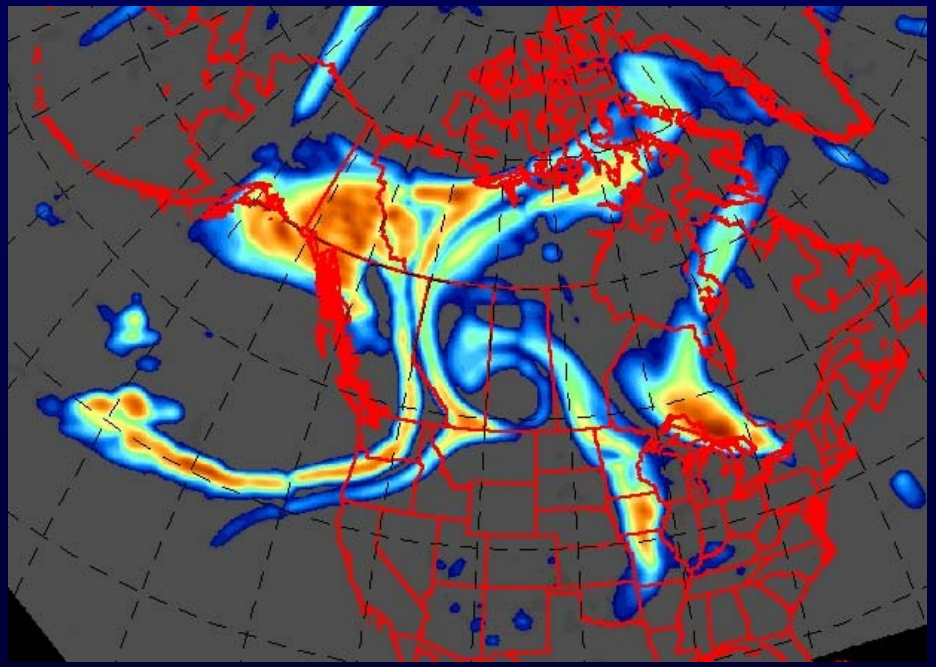


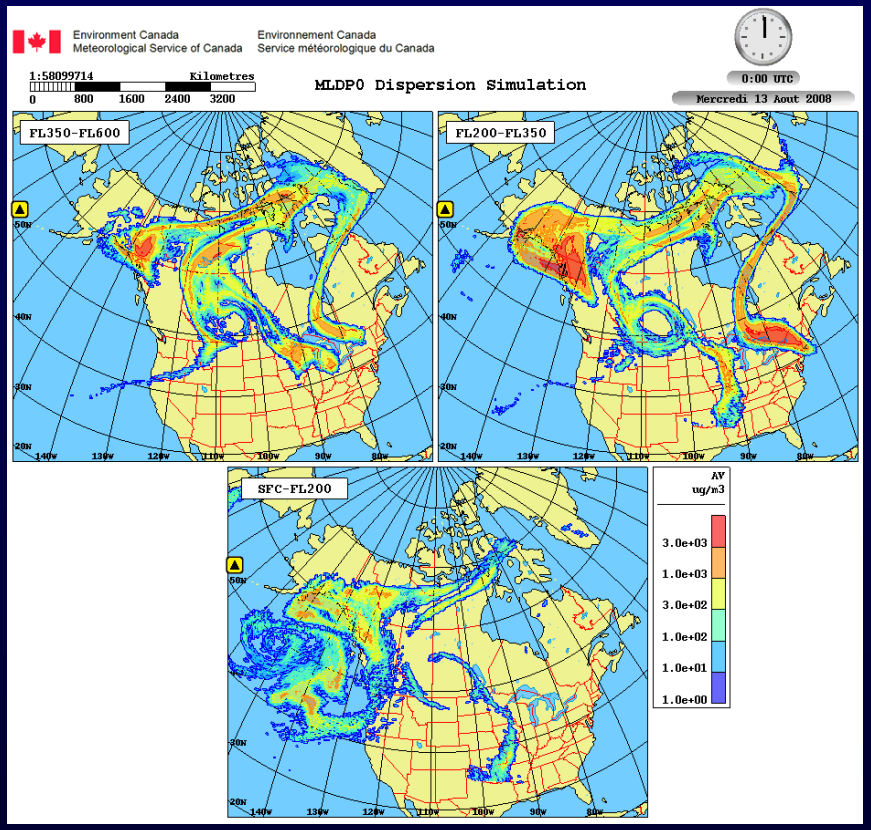
Scanning electron photomicrographs of material collected from the leading edge of the wing of a commercial aircraft that encountered the Kasatochi volcanic cloud at around 0100 UTC on August 11, 2008 over the Yukon region.

USGS

When will it be over?

Kasatochi +1 week: Long-lived gas and aerosol clouds

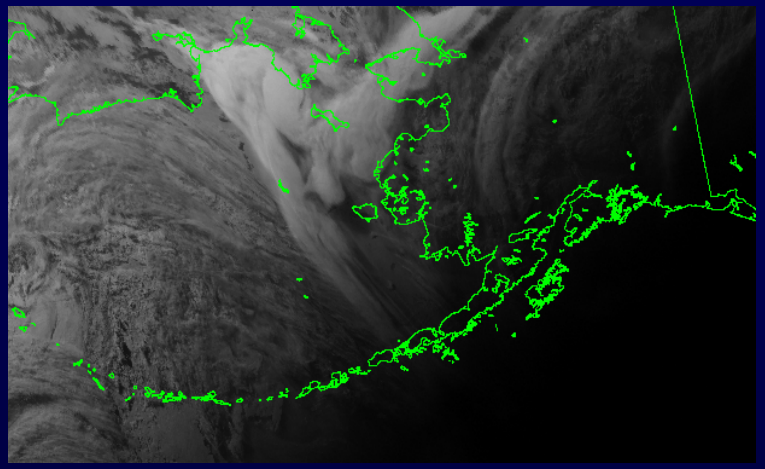


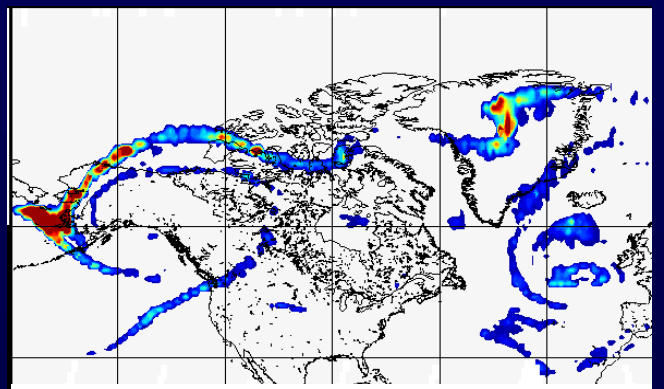


USGS

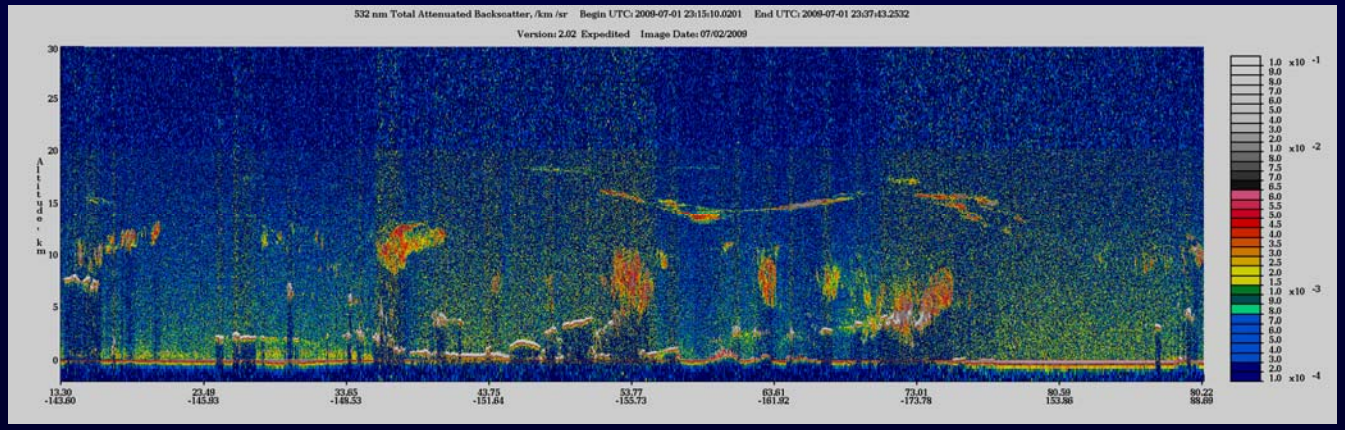
When will it be over?

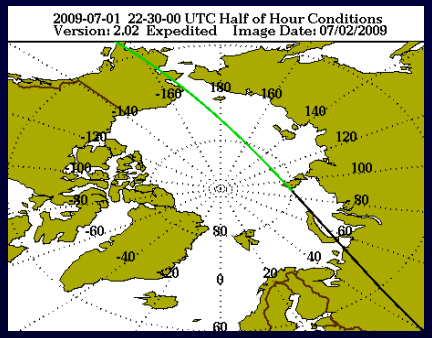
Sarychev +2 weeks: Long-lived gas and aerosol clouds





ULB MeTop-a/IASI SO2





USGS

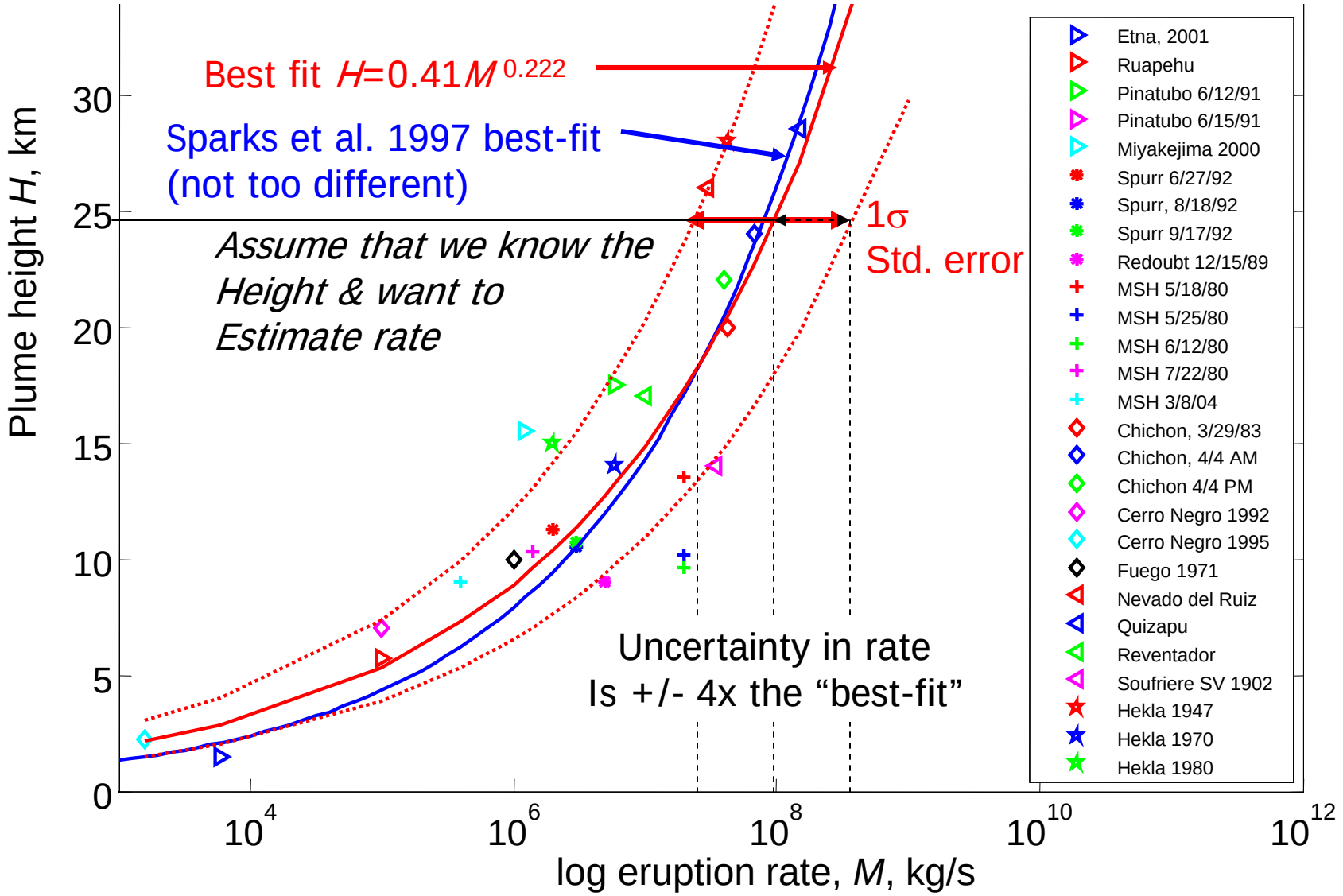
What is the Concentration? Known Unknowns

- Particle size distribution
- Eruption rate
- Vertical mass distribution
- Fine ash removal in the column
- Ash transport and dispersion models typically over-predict the observed area of volcanic ash.
  - Uncertainty in source and sink terms (aggregation).
- VATD models can do a very good job on SO2.

- How can we improve the eruption source terms?

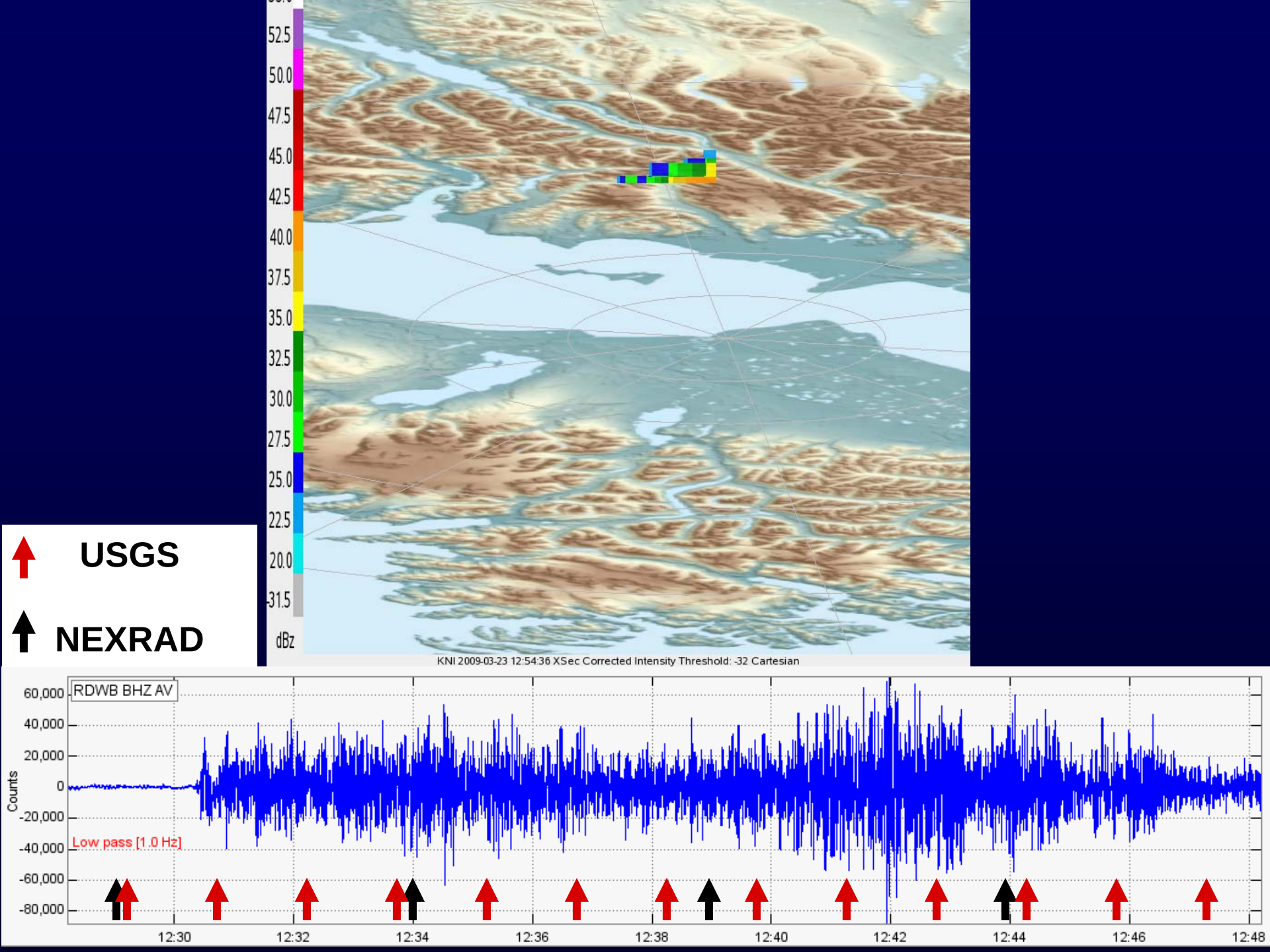
USGS

Eruption Source Parameters
Mastin et al, 2009



Eruption source information from radar:
USGS C-band volcanic ash radar and Nexrad network

USGS


52.5
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45.0
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40.0
37.5
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32.5
30.0
27.5
25.0
22.5
20.0
-31.5
dBz
KNI 2009-03-23 12:54:36 XSec Corrected Intensity Threshold: -32 Cartesian
USGS
NEXRAD
RDWB BHZ AV
Low pass [1.0 Hz]
Counts
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
-80,000
12:30
12:32
12:34
12:36
12:38
12:40
12:42
12:44
12:46
12:48

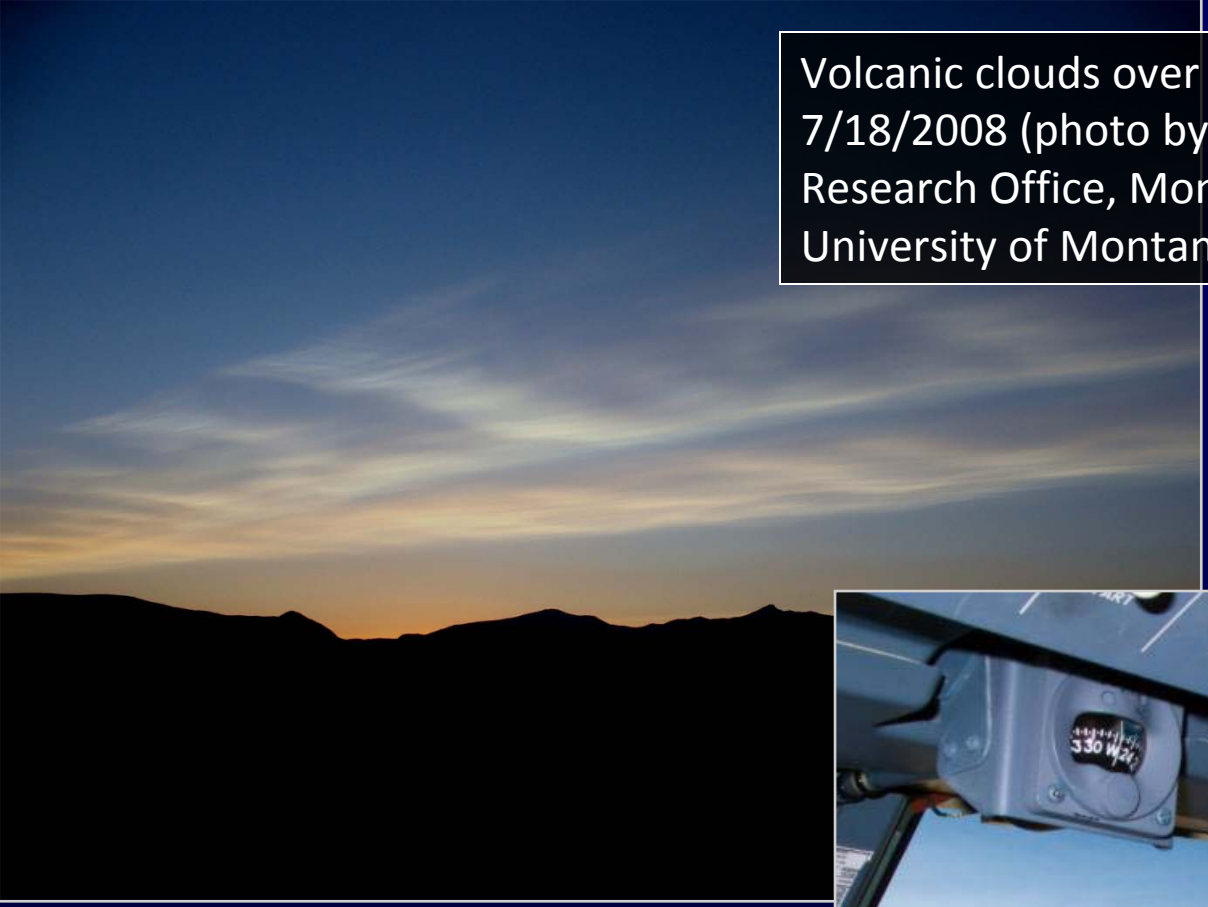
USGS

Rapid decrease in radar cloud height due to accretionary lapilli formation

Concluding Remarks

- ***How can we best analyze new data sources to help forecasters improve the hazard warning messages.***
- ***How can we provide information to help users make informed decisions?***
- ***How best to utilize VATD models and observations?***
- ***Can VATD models utilize the information that is being collected or retrieved?***
- ***Can ensemble modeling help to deal with uncertainty in source and sink terms?***

USGS



Volcanic clouds over western Montana on 7/18/2008 (photo by Margaret Patton, Research Office, Montana Tech of The University of Montana)

Okmok July 12 plume seen from 28,000 ft over Billings, Montana from the cockpit of a commercial passenger flight on the evening of 7/19/2008. (Image courtesy of Bradley Johnson and Alaska Airlines)

Redoubt ash from 15 Dec 1989 event

USGS