Volcanic Ash Modeling for North Pacific Volcanoes Automated Operational Monitoring and Virtual Globes

Peter Webley

Arctic Region Super Computing Center (ARSC)
Alaska Volcano Observatory (AVO)
Geophysical Institute (GI)
University of Alaska Fairbanks (UAF)

K. Dean, J.E. Bailey and J. Dehn

NOPAC volcanoes

- ~100 active volcanoes in North Pacific (NOPAC)
- 1975 – 2006, >100 separate volcanic ash clouds > 20 kft
- +8000 flights per year of NOPAC flight routes
- In 1999, $12 million cargo over the region

AVO :: Alaska Volcano Observatory

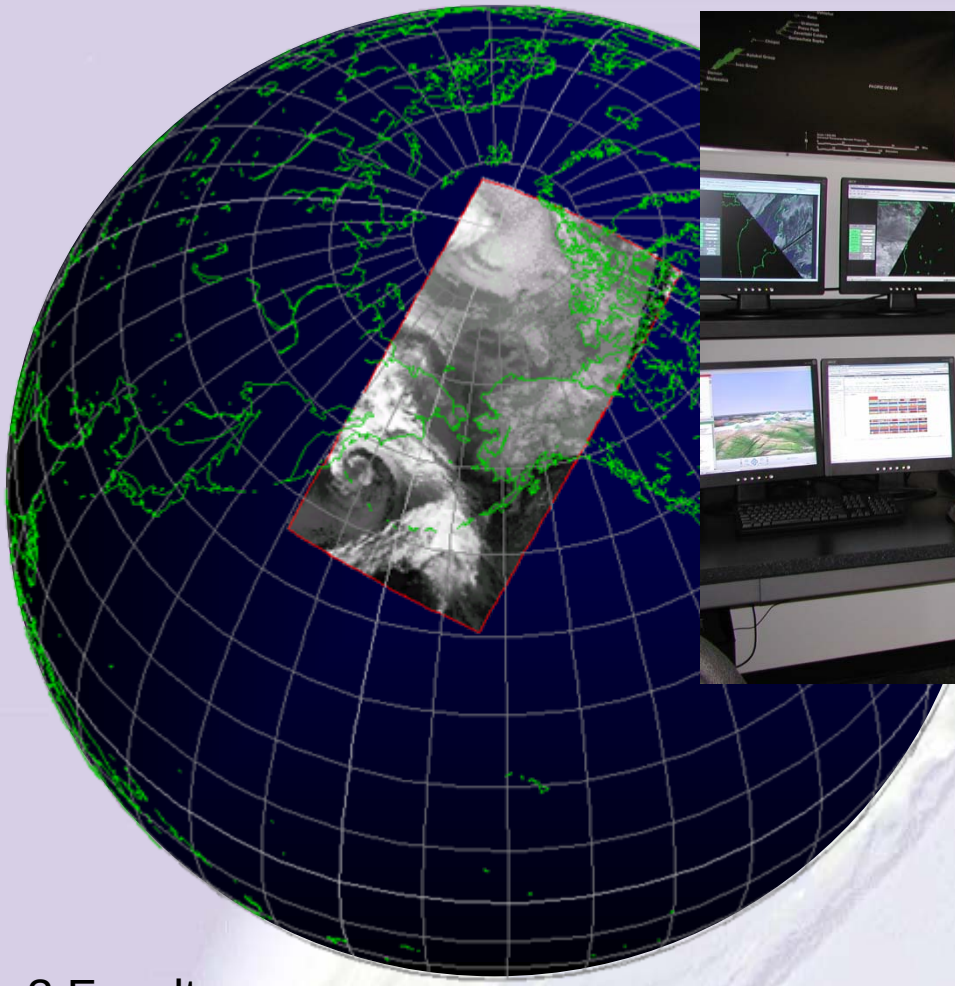
- Three groups
  - University of Alaska Geophysical Institute (UAF-GI)
  - United States Geological Survey (USGS)
  - Alaska Division of Geological and Geophysical Surveys (ADGGS)

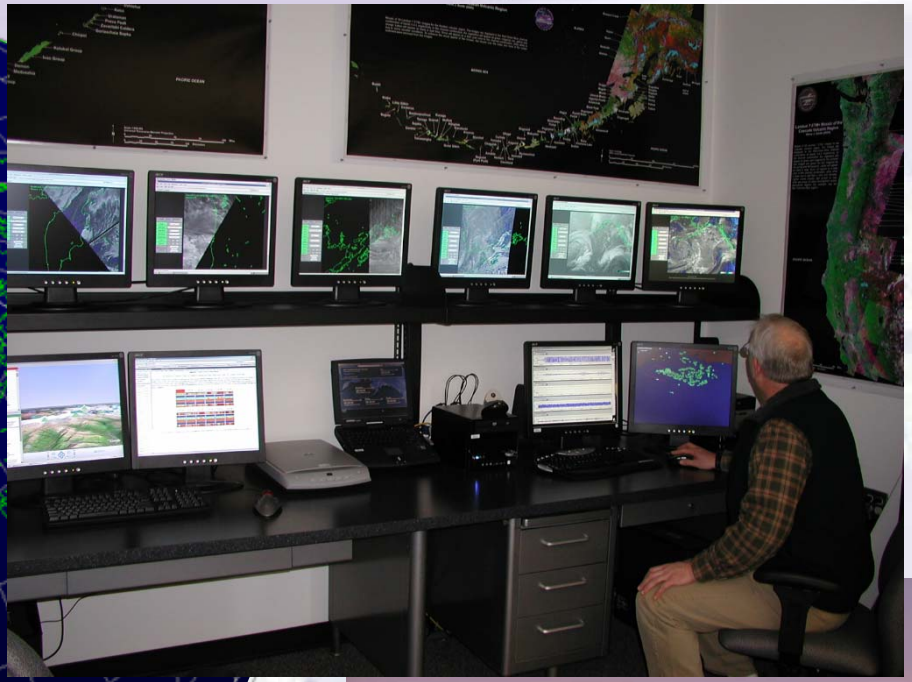
- Responsible for volcano monitoring in NOPAC region

- Liaising with Agencies such as NWS and VAAC

- Seismology, Remote Sensing, Geodesy and Geology

Remote Sensing at AVO-UAF





3 Faculty
2 Staff
3 Post Docs
6 students

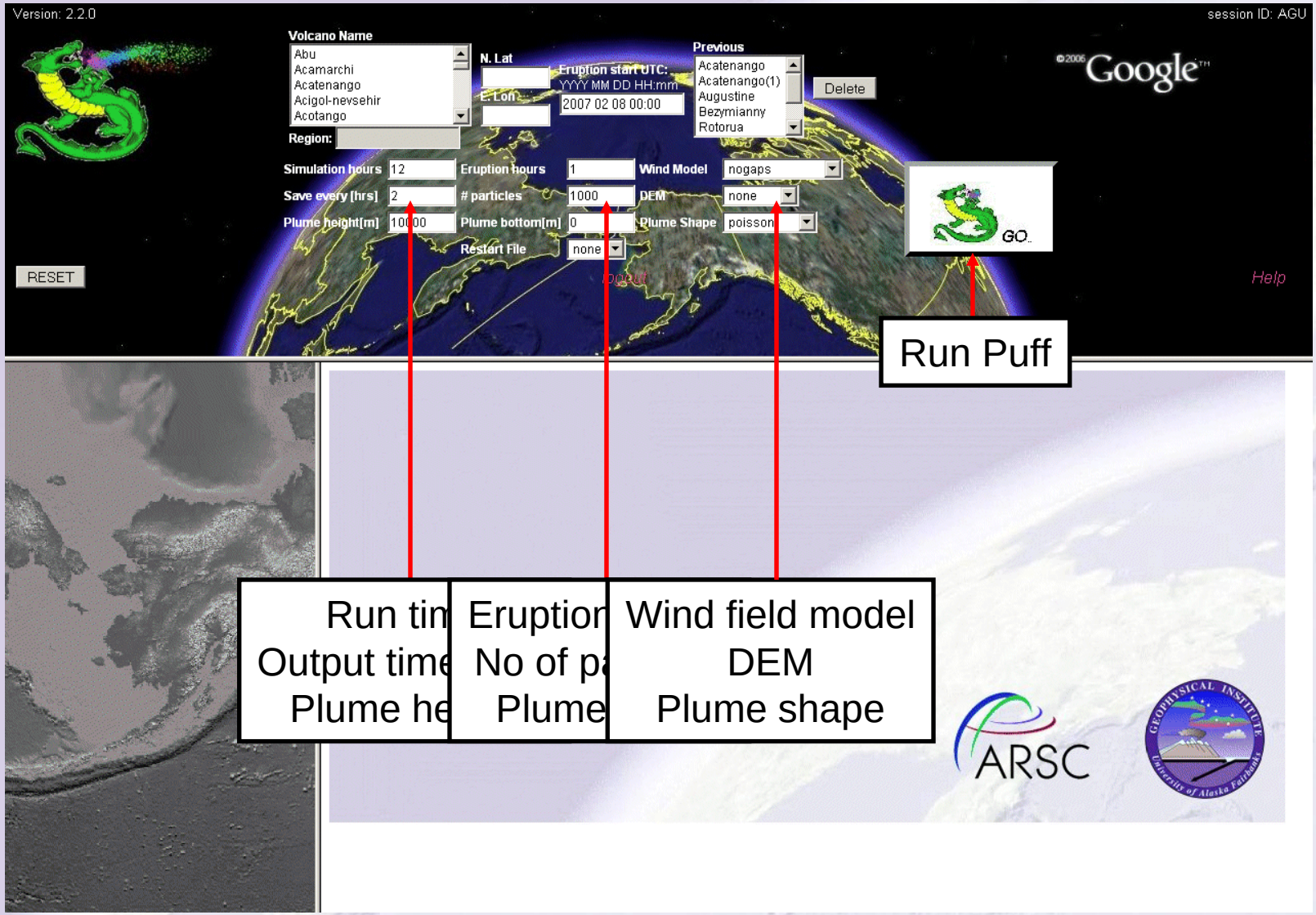
What is the Puff model?

- Specifically tailored for 3D tracking of volcanic ash particles
- Ash particles released over volcano and tracked over time
- Uses meteorological wind fields
- Initialization parameters include
  - Volcano name and location
  - Number of particles
  - Mean Particle size and spread
  - Plume dimensions (height, width and shape)
  - Length of model prediction and length of eruption
  - Output time step
  - Horizontal and Vertical Diffusion
  - Wind field model

(http://puff.images.alaska.edu)

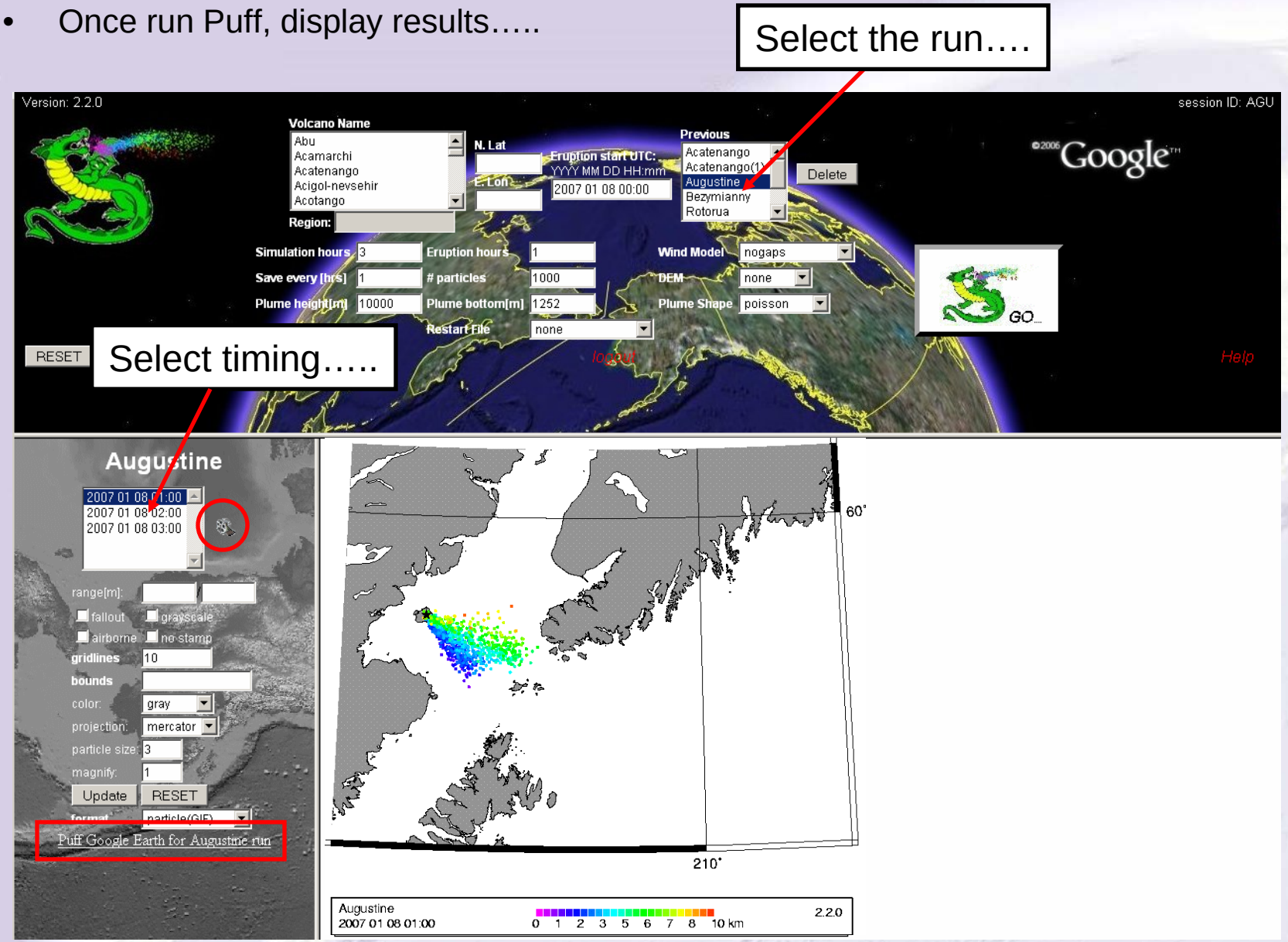
Webpuff Interface : Run Puff

- Accessed via Puff website

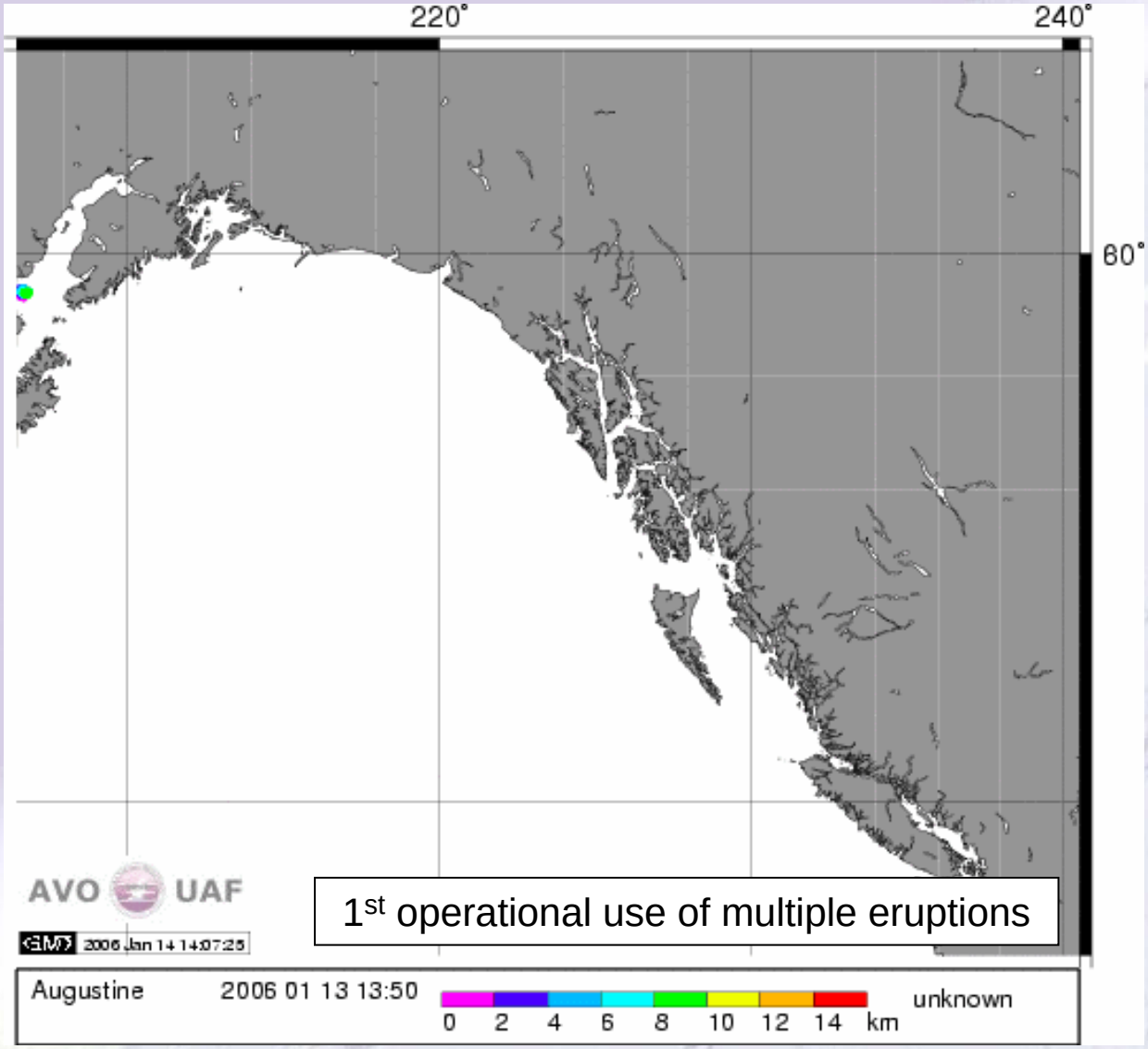


Webpuff Interface : View Prediction

- Once run Puff, display results…..

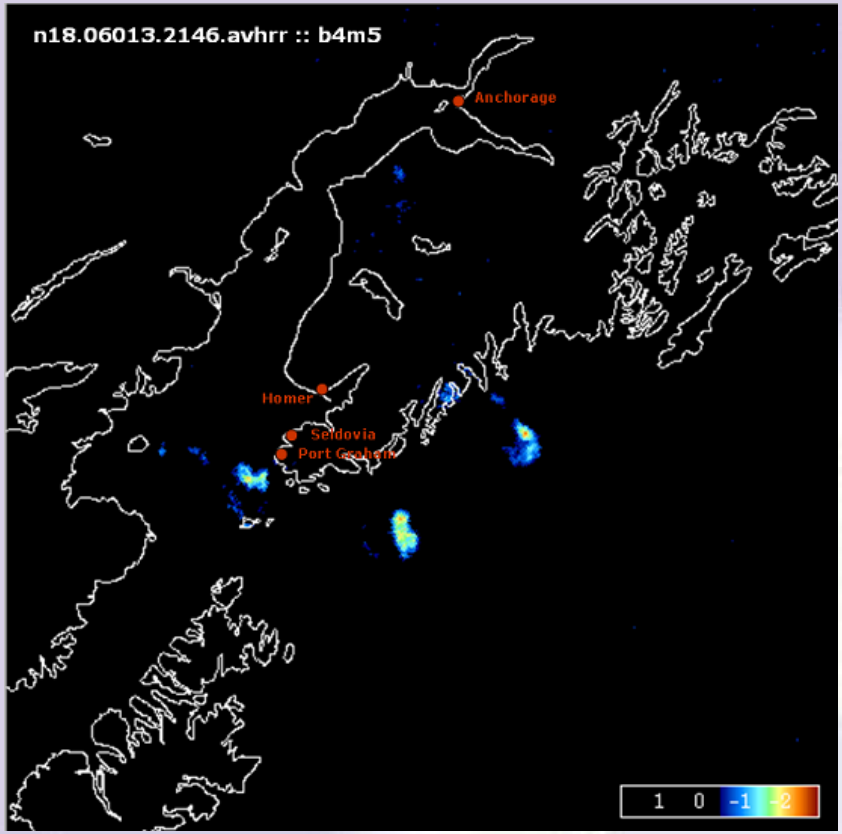


Multiple eruption capabilites

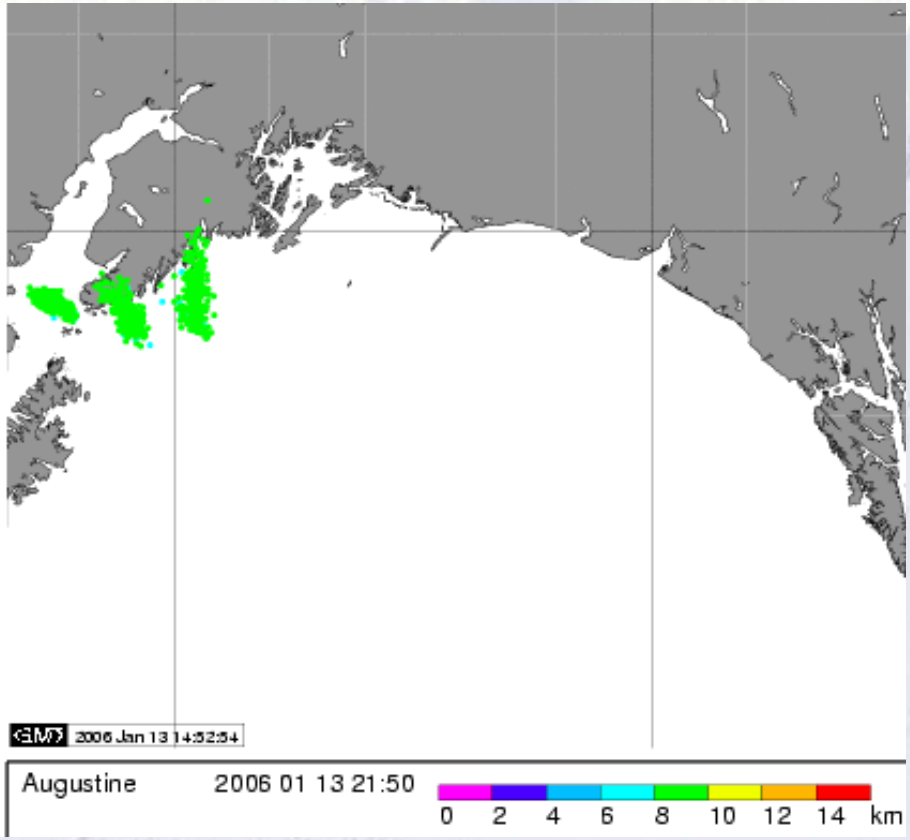


Puff model run for Jan 13th – 14th 2006

AVHRR Ash signal on 13 Jan 2006, 2146 UTC

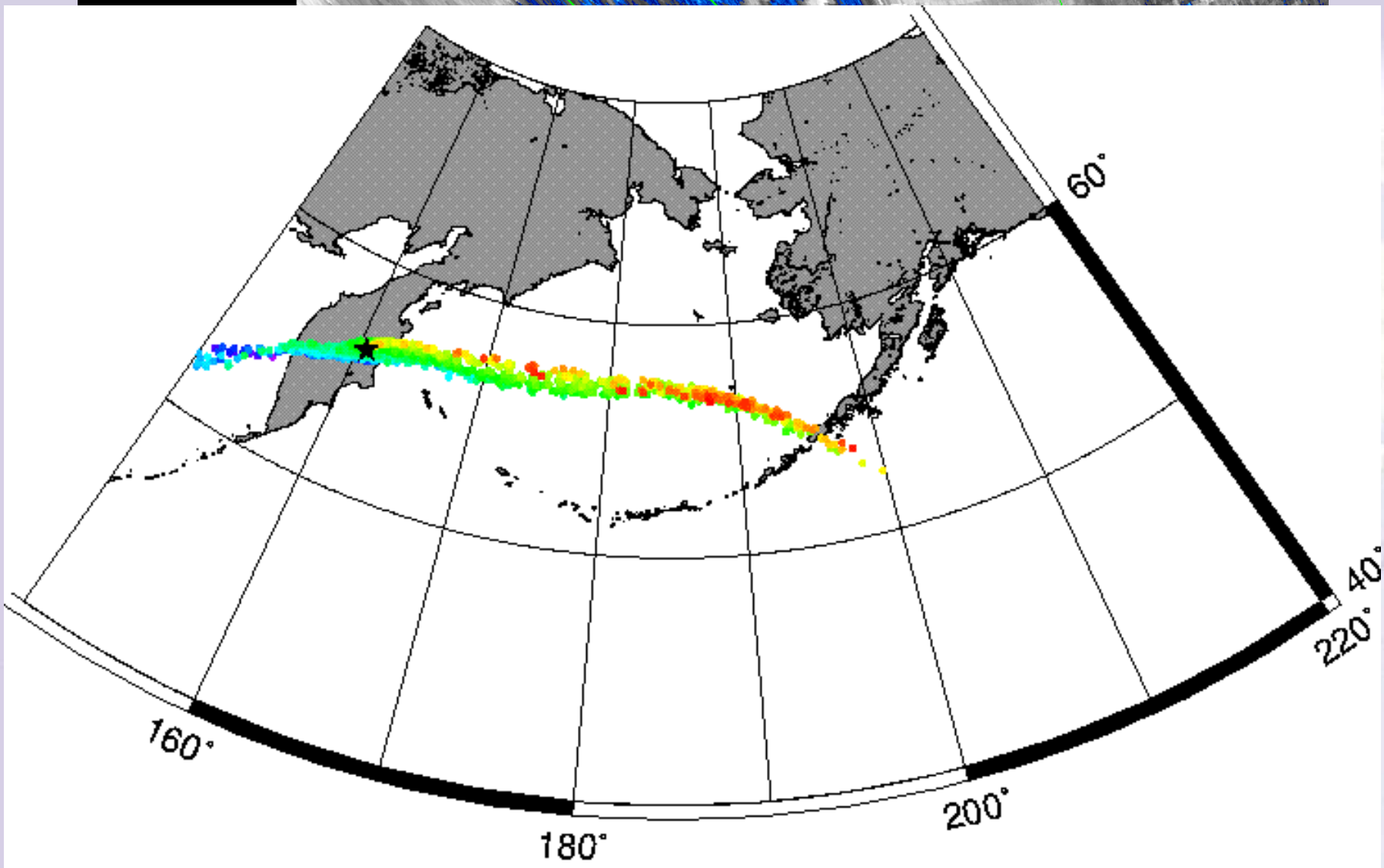


Puff output on Jan 13th 2006, 2150 UTC (8 – 10 km)



Kliuchevskoi volcano, 28 June – 2 July 2007

- AVO working with KVERT group on monitoring the eruption
- Seismic data collected in Russia
- Satellite data at AVO and KVERT
- Webcam data from Russia
- Puff model predictions from AVO



Kliuchevskoi
2007 06 29 19:00

0 1 3 4 6 7 9 10 12 km

2.2.0

Puff System pre 2006

- Run Puff when an event occurs
- What do we use as initial conditions?
  - Wind field [Regional or Global]
  - Plume height [8, 10 or 16 km]
  - Duration [1, 3 or 24 hrs]
  - Start time [Now, 3 hrs past, yesterday]
- Can we get someone to run the model at 3am?
- Region of interest for ash movement?
- How long to run for? ---- 6, 12, 24 hrs
- When do we do the next update? ---- 1, 3, 6 hrs

The 5 minute warning

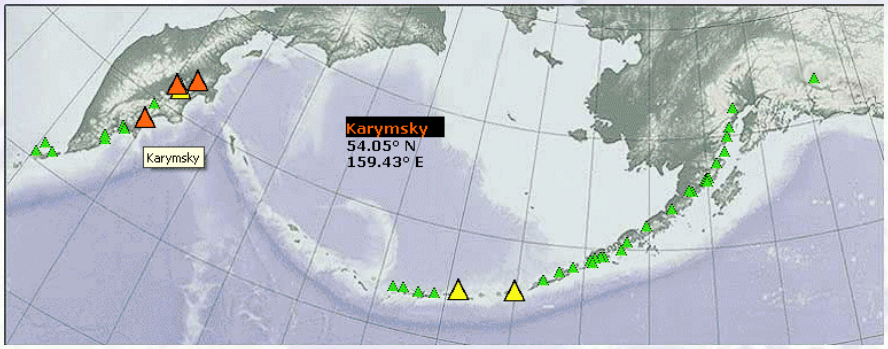
- In USA, NWS and FAA work together
- In Alaska, the AAWU and Air traffic controllers in same room
- When an eruption has been confirmed, they want to know where the ash is ASAP
- AAWU would run Puff or Hysplit or contact AVO

National Weather Service

Alaska Aviation Weather Unit

Automated Monitoring

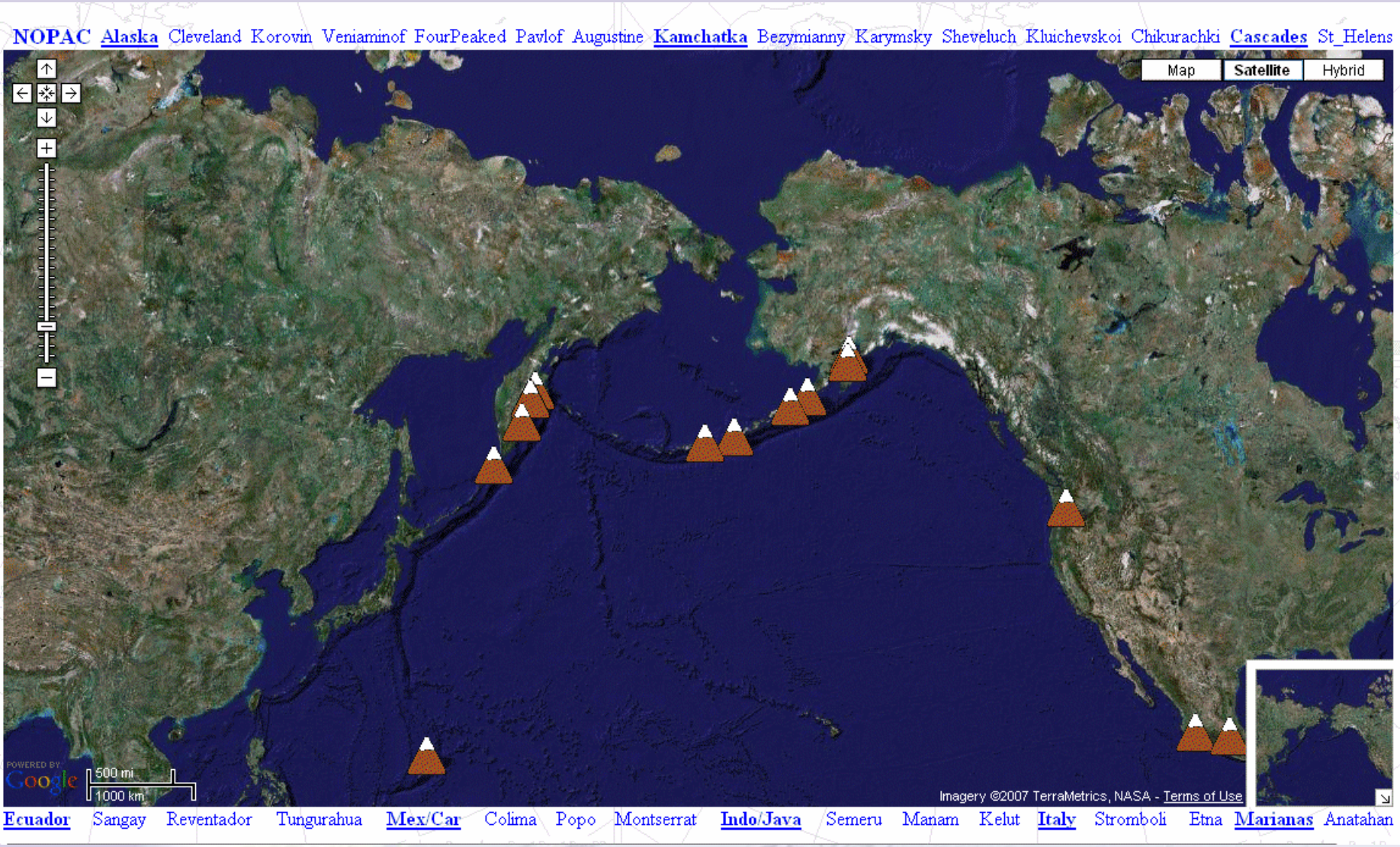
- 12 volcanoes in NOPAC
  - Alaska : Augustine, Cleveland, Korovin, Veniaminof, Pavlof and FourPeaked
  - Kamchatka : Bezymianny, Chickurachki, Karymsky, Kliuchevskoi and Shiveluch
  - Cascades : St Helens
- 4 in Indonesia Region
  - Anatahan, Kelut, Semeru and Manam
- 3 in Ecuador
  - Reventador, Sangay and Tungurahua
- 1 in Caribbean
  - Soufriere Hills
- 2 in Italy
  - Etna and Stromboli
- 2 in Mexico
  - Popocatepetl and Colima



Volcanoes : Alaska and Kamchatka at elevated alert (June 2007)

- NOPAC volcanoes updated Puff model forecast every 3 hrs
- Worldwide volcanoes updated Puff model forecast every 6 hrs
- Plume heights range from 4 – 16 km (up to 20 km for SHV)
- NWP wind fields
  - NAM 216 fields for NOPAC (45 km resolution)
  - AVN for Worldwide (~100 km resolution)

No need for personnel to be running the model 24 hrs a day



http://puff.images.alaska.edu/

KVERT June 30, 2007 for Kliuchevksoi

Kamchatkan and Northern Kuriles Volcanic Activity
KVERT INFORMATION RELEASE 30-07
Saturday, June 30, 2007, 01:15 UTC (14:15 KDT)

KLYUCHEVSKOY VOLCANO; 56°03'N, 160°39'E; Elevation 4,750 m
CURRENT LEVEL OF CONCERN COLOR CODE IS RED

The strong explosive-effusive eruption of the volcano continues. Ash explosions more than 10 km (32,000 ft.) ASL could occur at any time and could affect international and low-flying aircraft.

Seismic activity of Kluchevskoy was at the medium level (less than 4-7x10-6 mps) at 00:00 UTC on June 29 and remains at this level to present time, 01:00 UTC on June 30. According to visual and video data, continuous ash emission to more than 10 km (or 32,000 ft) and extended to the west began to observed from 21:06 UTC on June 29 till present time. According to satellite data, ash plumes extended for 300 km (187 mi) to the east from Klyuchevskoy volcano. Approximate plume altitude: 9000 m (29,500 ft) ASL (by atmospheri

According to the puff prediction for potential eruption a

e for about 10 km (or 32000 ft) will move to south-west from volcano. According to Based on past eruptions, this could continue for some hours or days. view from MTSAT the plume is moving to east and west for last 6 ho
All local aviation authorities have urgent information from KVERT.

Strong terminal paroxysmal eruptions of the volcano occurred in 1945 (lasting for 1 month), 1984-1985 (18 months), 1987 (2), 1990 (7), 1994 (< 1), 1998 (8) and 2005 (3). Ash plumes during these eruptions rose up to 7.0-8.0 km (23,000-26,200 ft) ASL but were briefly as high as 10.0-13.0 km (33,000-42,600 ft) ASL.

IF YOU HAVE ANY QUESTIONS OR CONCERNS, PLEASE CONTACT:

Sergey Ushakov, KVERT, IVS FED RAS
E-mail: ushakov@kcsnet.ru
Tel. (41522) 58627

Tat'yana Kozhevnikova, KVERT, KB GS RAS
E-mail: ssl@emsd.iks.ru
Tel. (41522) 59523

Tom Murray, Scientist-in-Charge, AVO
E-mail: tlmurray@usgs.gov
Tel. 907-786-7497

The Kamchatkan Volcanic Eruption Response Team (KVERT) is a non-commercial cooperative program of the Alaska Volcano Observatory (AVO, USA), the Institute of Volcanology and Seismology (IVS) FED RAS and the Kamchatkan Branch of Geophysical Survey (KB GS) RAS (Russia).
KVERT staff is available in the office from 8:30 AM till 6:00 PM (KST or KDT) and by phone during the evenings. KVERT uses daily satellite imagery, information from remote scientific observation stations, real-time seismic data for 10 volcanoes, and other information to monitor activity at Kamchatkan and Northern Kuriles Volcanoes.

The official web-page of KVERT (the Institute of Volcanology and Seismology FED RAS): http://www.kscnet.ru/ivs/kvert/index.html
Archive of daily information KB GS RAS: ftp://emsd.iks.ru/pub/DATA/RTS/Volcanoes
KVERT Information Releases at the web-page of AVO (Alaska Volcano Observatory): http://www.avo.alaska.edu/activity/avoreport.php?view=kaminfo

From Alaska Interagency Plan

2.5.3 ASH TRAJECTORY FORECASTS FROM NUMERICAL MODELS

The AAWU should initiate the PUFF trajectory model available on the local area network at the VAAC when a volcanic eruption is suspected or has occurred. The PUFF is intended to provide guidance to forecasters for preparing the initial ash SIGMET and VAA. It is also useful for minor ash producing eruptions with the potential to affect airports within 40 nautical miles of the volcano.

From IAVW

Wellington VAAC

VAAC WELLINGTON

Executive Summary

The only substantive activity occurring during the period covered by this report were the eruptions of the **Lopevi** volcano in Vanuatu during January and May 2006 and the **Raoul Island** volcano northeast of New Zealand in March 2006. There was volcanic activity less significant to aviation at **Aoba** volcano in Vanuatu and at **Home Reef** undersea volcano in Tonga. Volcanic Ash Advisories (VAA) were issued by the Wellington VAAC for the significant activity. VA SIGMET were issued by the Wellington Meteorological Watch Office in response to the Raoul Island VAA issued.

There have been no significant changes in the operational status, methods or area of responsibility of the Wellington VAAC. The VAAC continues to use the CANERM, HYSPLIT, and PUFF models for trajectory forecast information.

The Wellington VAAC has remained operational for the period with no outages resulting from internal or external issues. Periodic testing of VAAC procedures were undertaken and the results used to further develop the procedures.

A website for the Wellington VAAC has been completed containing the IAVW descriptive information, current VAA and links to other VAACs.

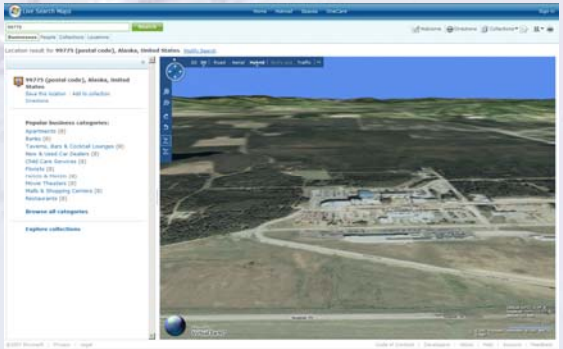
MTSAT imagery remains under evaluation for use by the VAAC.

Virtual Globes

- They have become widely used for visualization in the scientific environment.
- They have become a tool for displaying three dimensional geophysical data both operationally and retrospectively.
- In the recent past, Puff forecasts have been displayed as two dimensional maps of ash location, color-coded by altitude and/or relative ash concentration.
- This is a useful tool for operational analysis but does not take full advantage of the three dimensional nature of the data.
- Google Earth is one of the many “Virtual Globes” available.
- Use the Google Maps API to centralize all the Puff model runs for the NOPAC and how Google Earth can be used to display VATD simulations in both two and three dimensions.

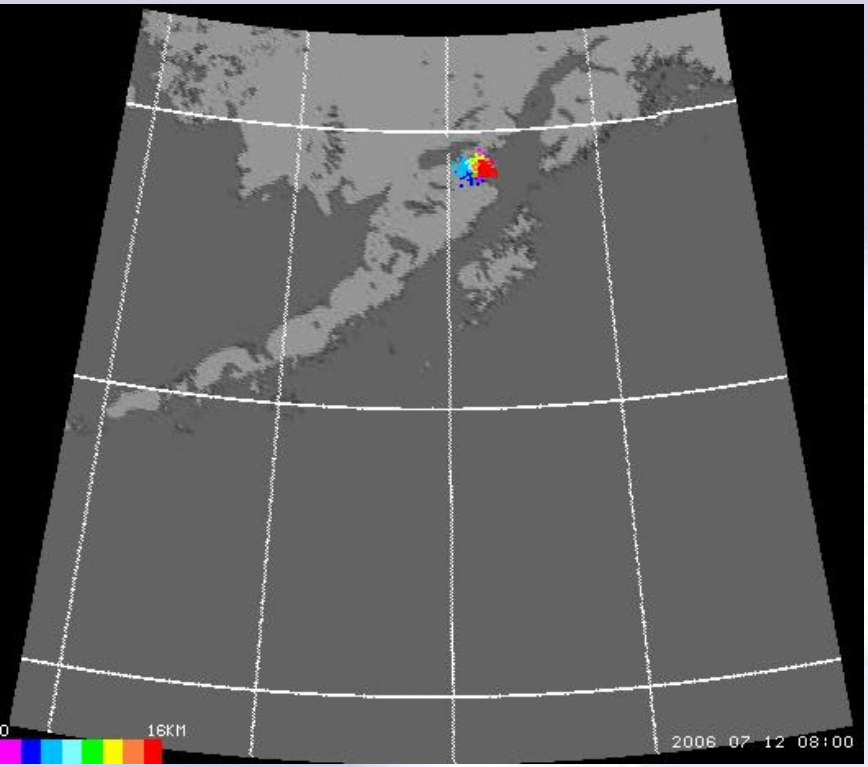
NASA World Wind

Google Earth

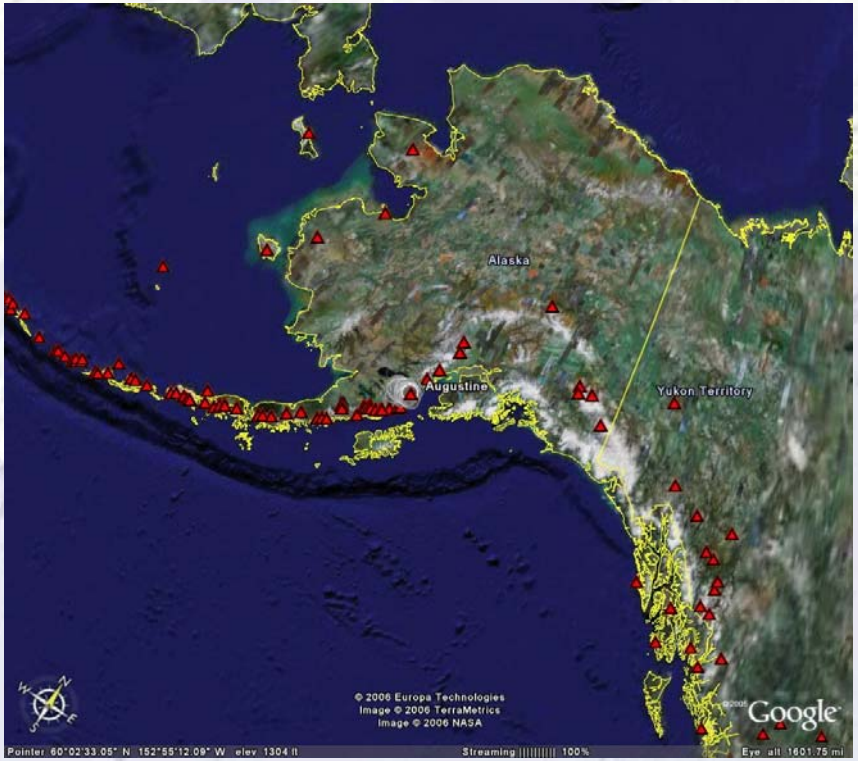


Microsoft Virtual Earth

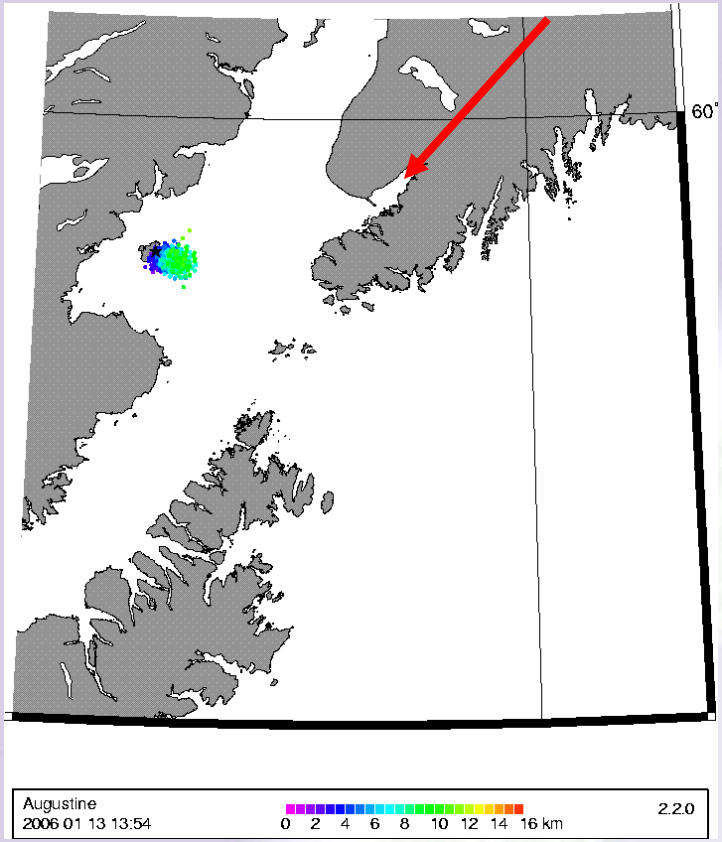
Stage 1 development: Puff in Google Earth



Early 2006



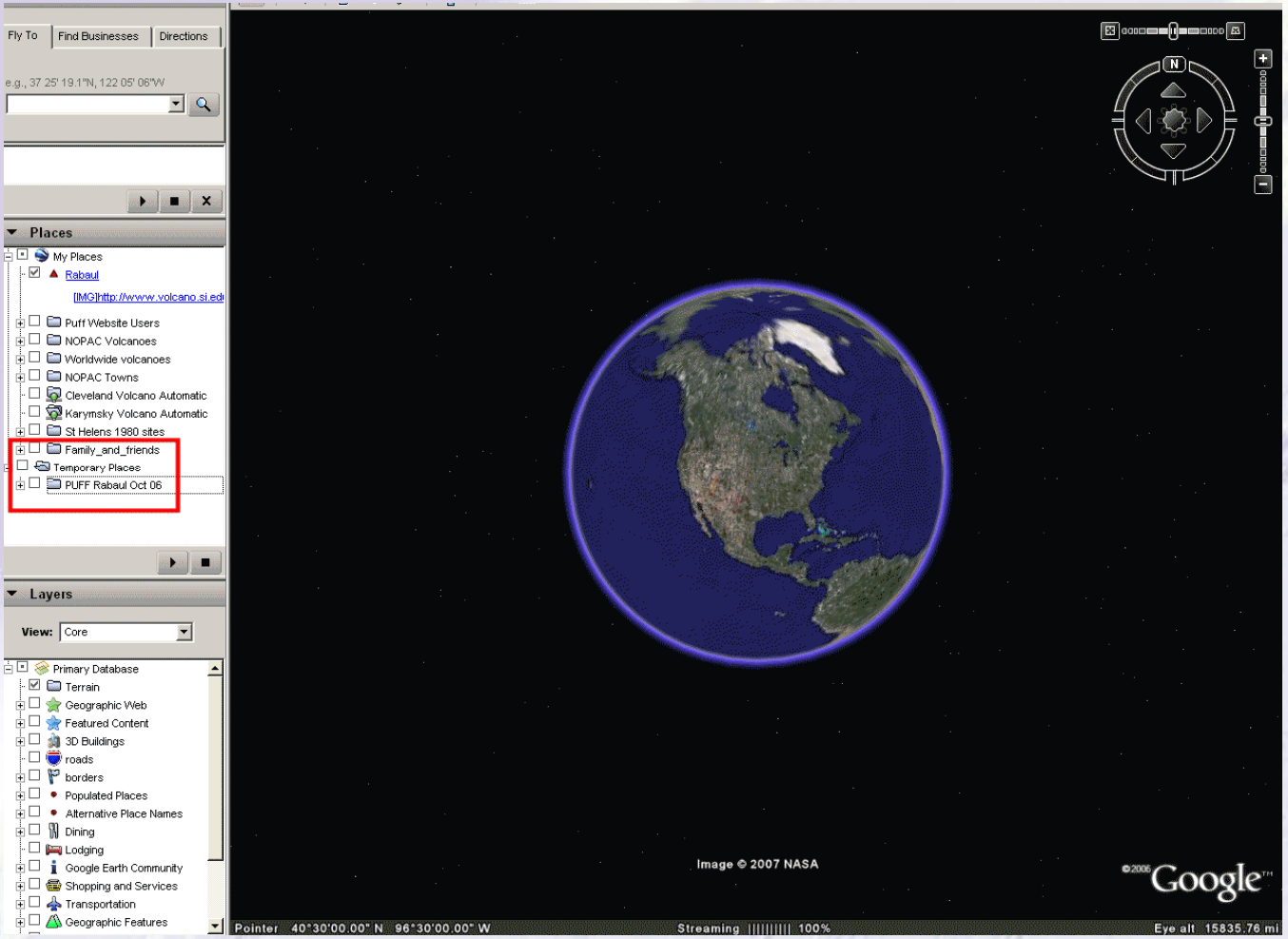
Stage 2: Current method for 3D Puff in Google Earth



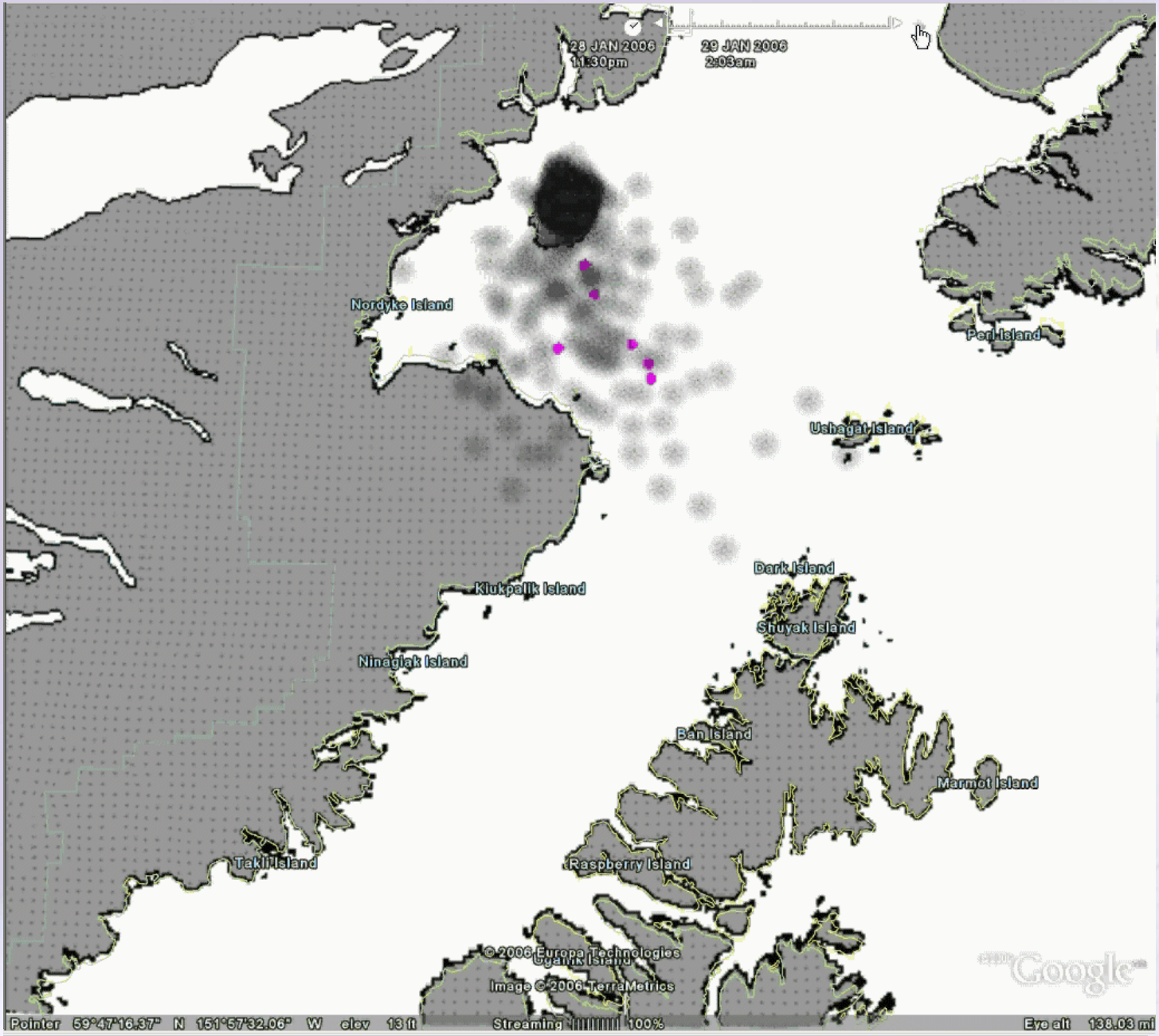
Mt Augustine 2006 eruptive event

Puff → Google Earth generation

- Puff model produces three dimensional data set (latitude, longitude, altitude)
- Google Earth™ (GE) allows displaying of Puff model output in 3D
- Each ‘Ash’ particle represented by separate placemarker
- Time stamped to allow ‘animation’ with GE [GE Version 4+]

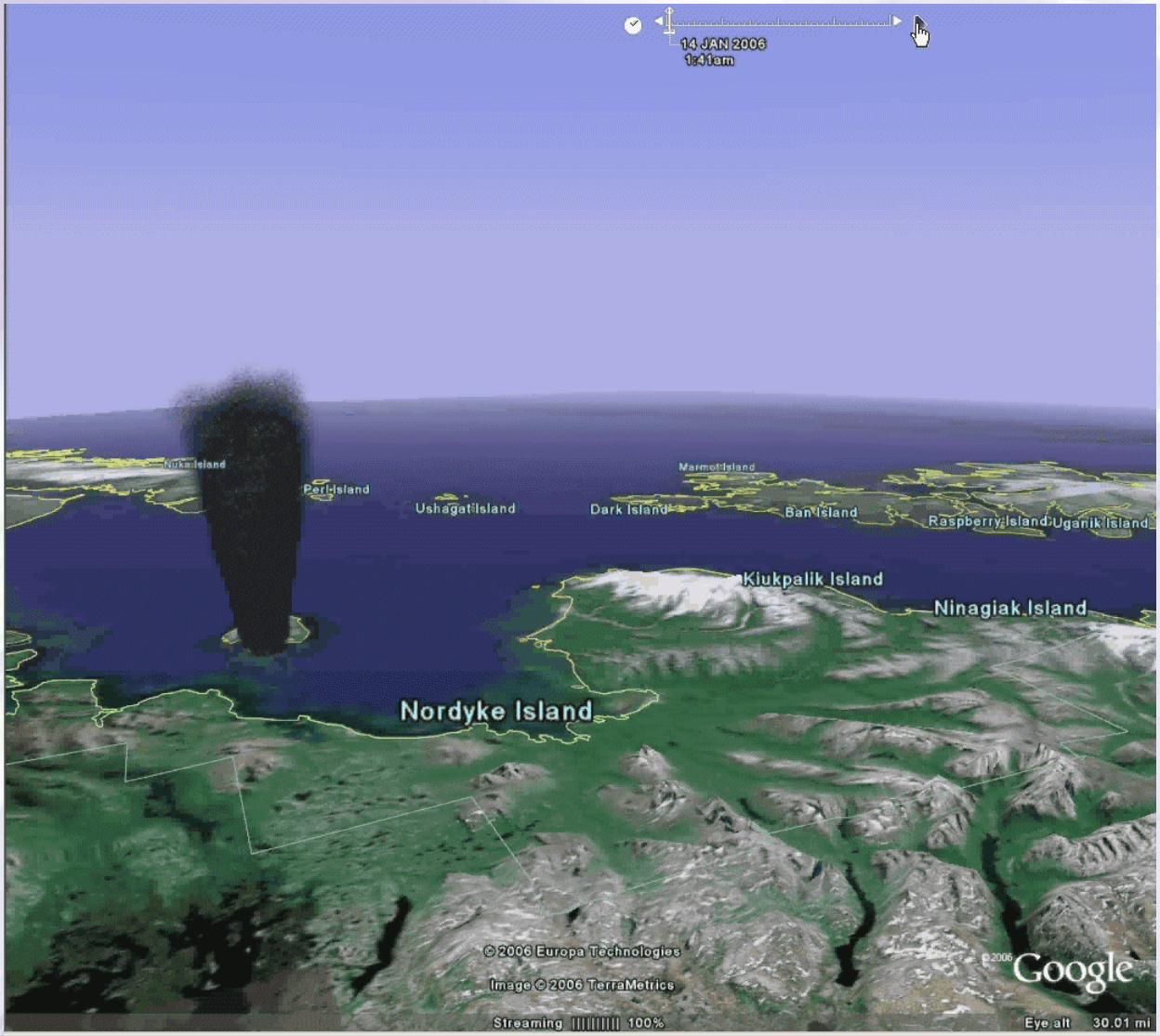


Puff images in GE

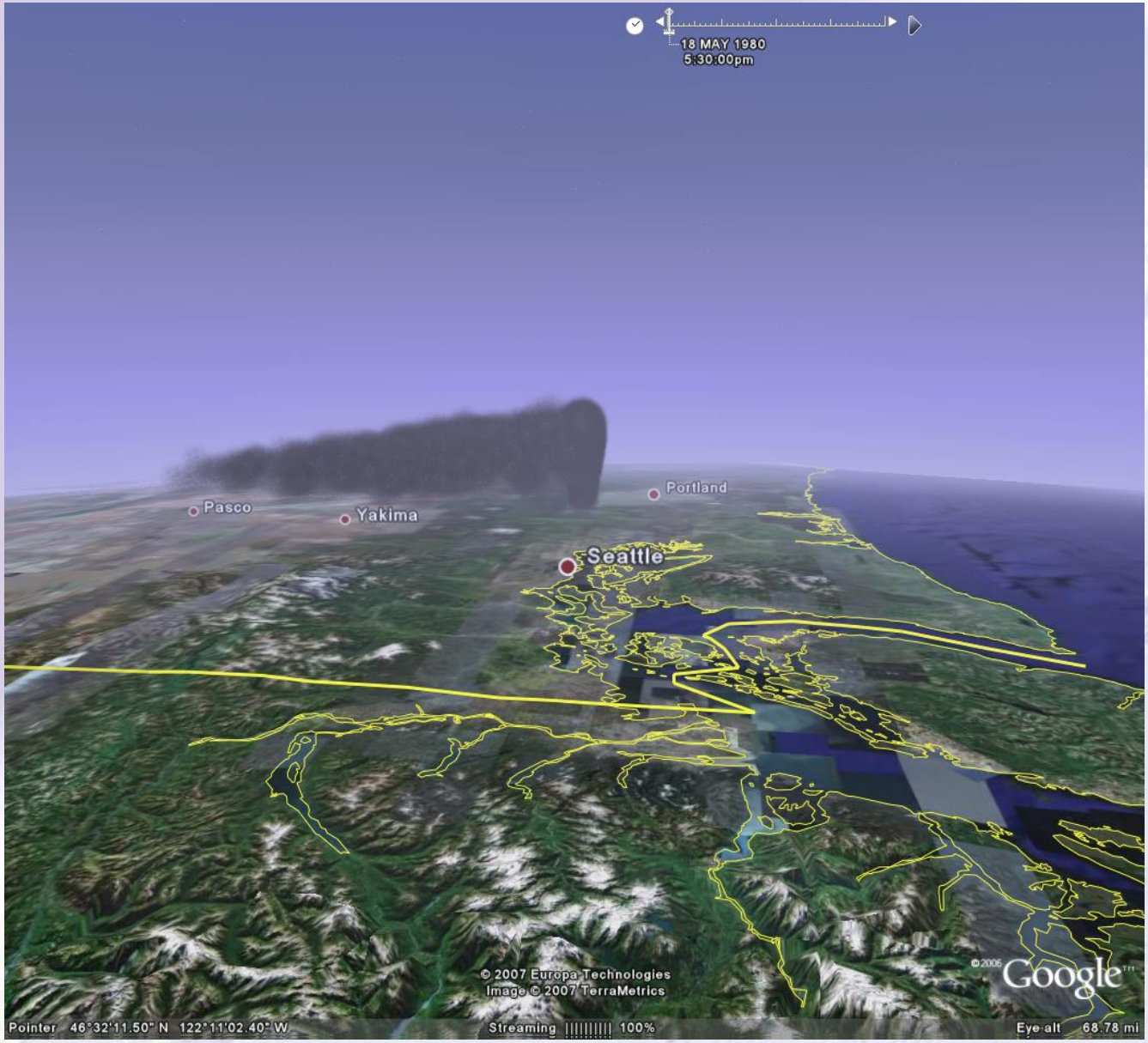


Mount Augustine January 2006

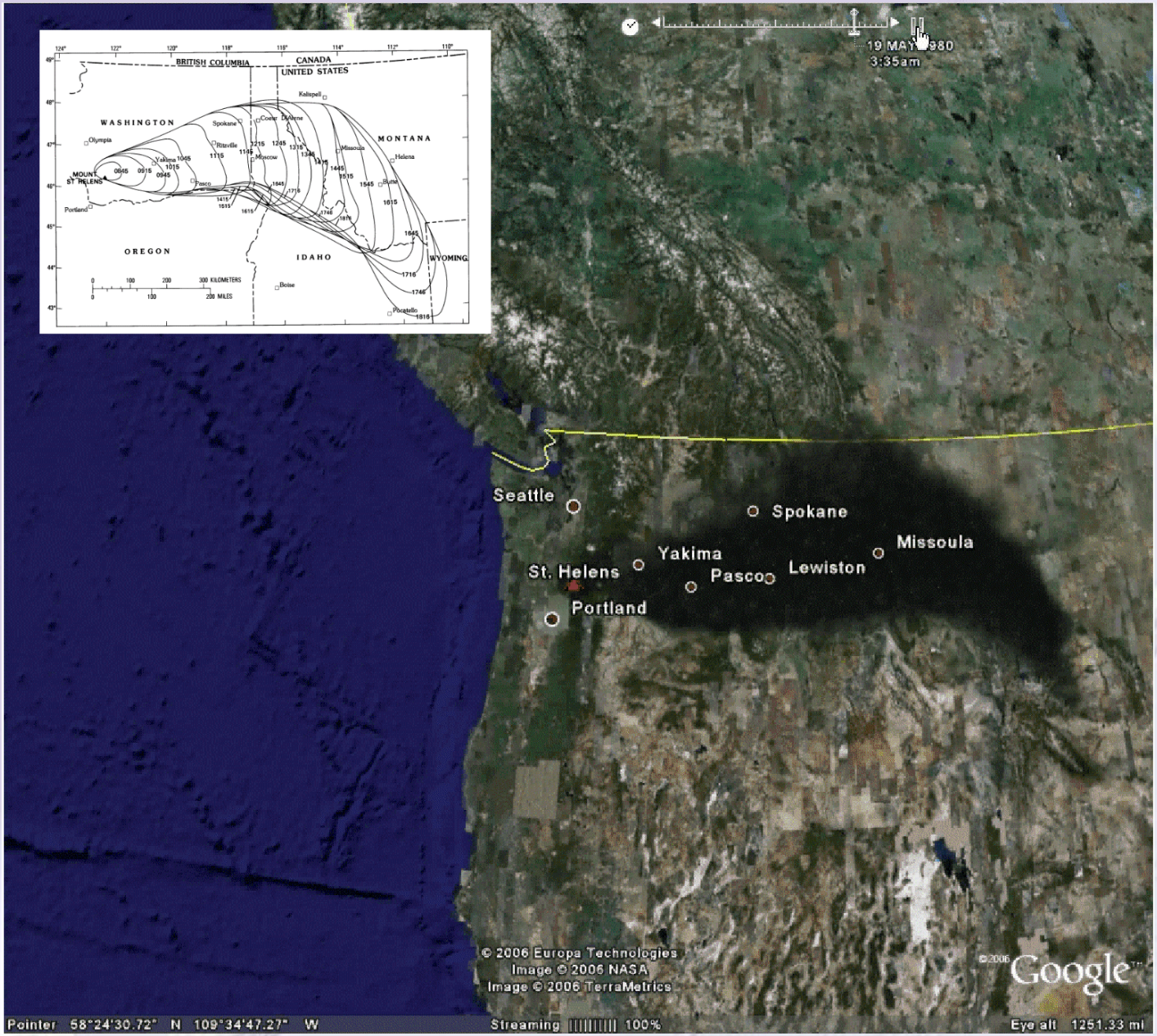
- 13 separate eruption clouds
- Jan 11th – 28th 2006
- Displayed here is 01:40 UTC on Jan 14th 2006
- Seismic event lasted for 4 mins
- Plume to 34,000 ft from radar data

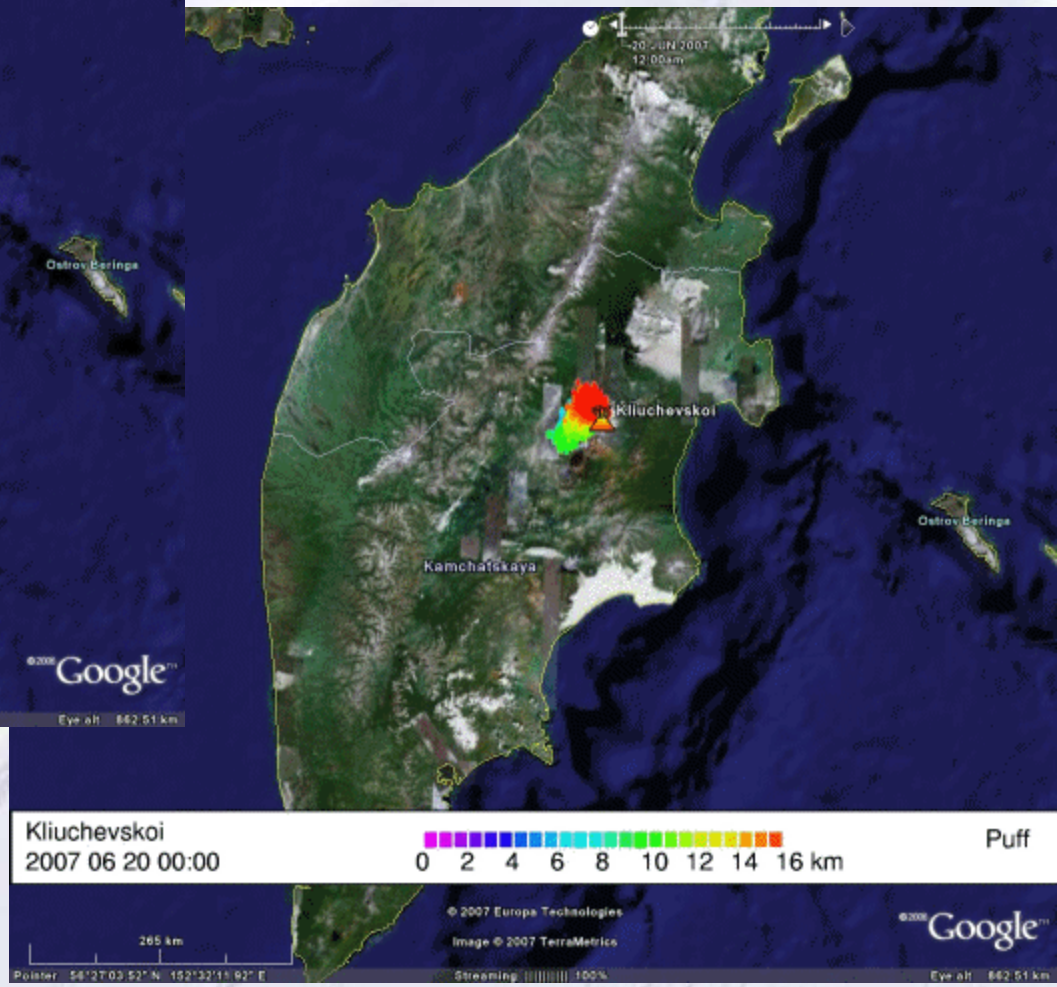


St Helens 1980 : Side View



St Helens 1980 : Top View





Auto runs

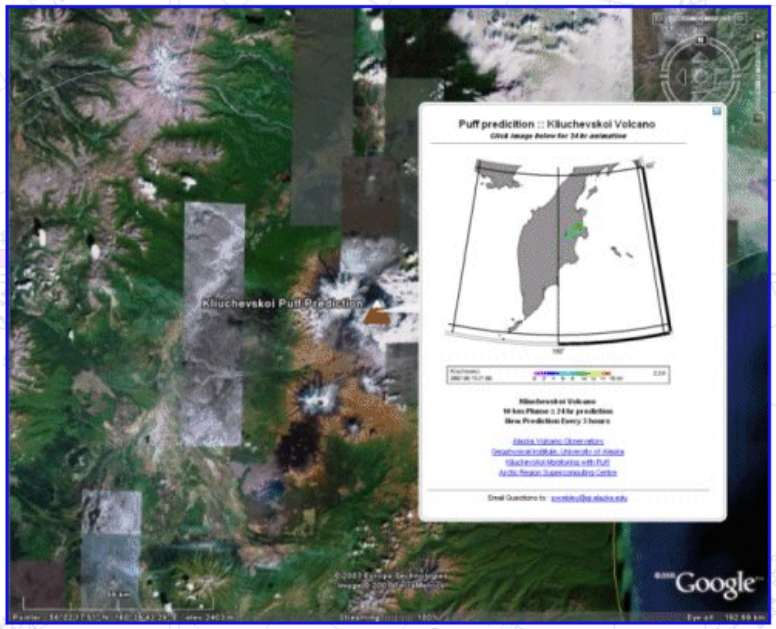
http://puff.images.alaska.edu/dynamic_kml.shtml

Puff Predictions

These are kml files that show ballons of the Puff model predictions for sites across the NOPAC and beyond.

An example for Kliuchevskoi, Kamchatka is ---------->

Directory Puff Predictions as kml

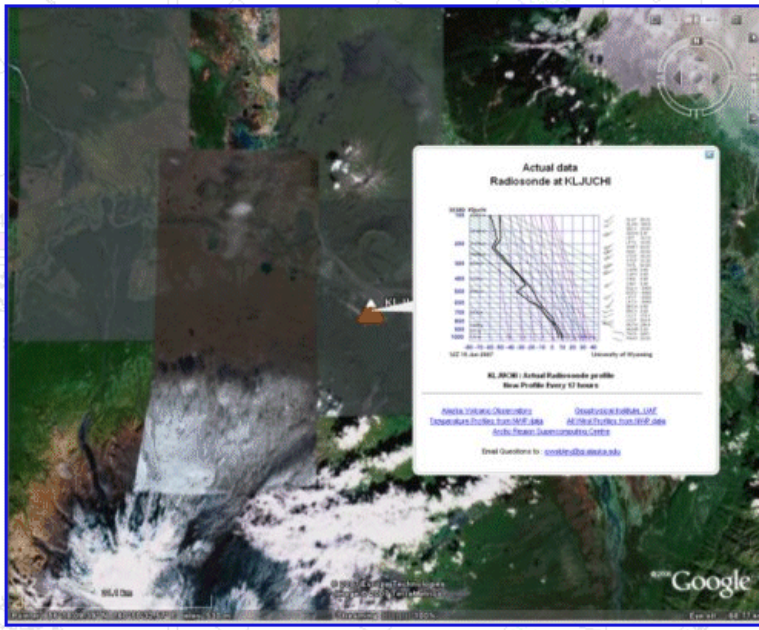


WMO Radiosonde data

These are kml files that show ballons of the WMO radiosondes for sites across the NOPAC and beyond for use in determining cloud heights from volcanic eruption clouds. The radiosondes are updated every 12 hrs from University of Wyoming site.

An example for Kljuchi, Kamchatka is ---------->

Directory of Actual radiosonde as kml



Radiosonde kml

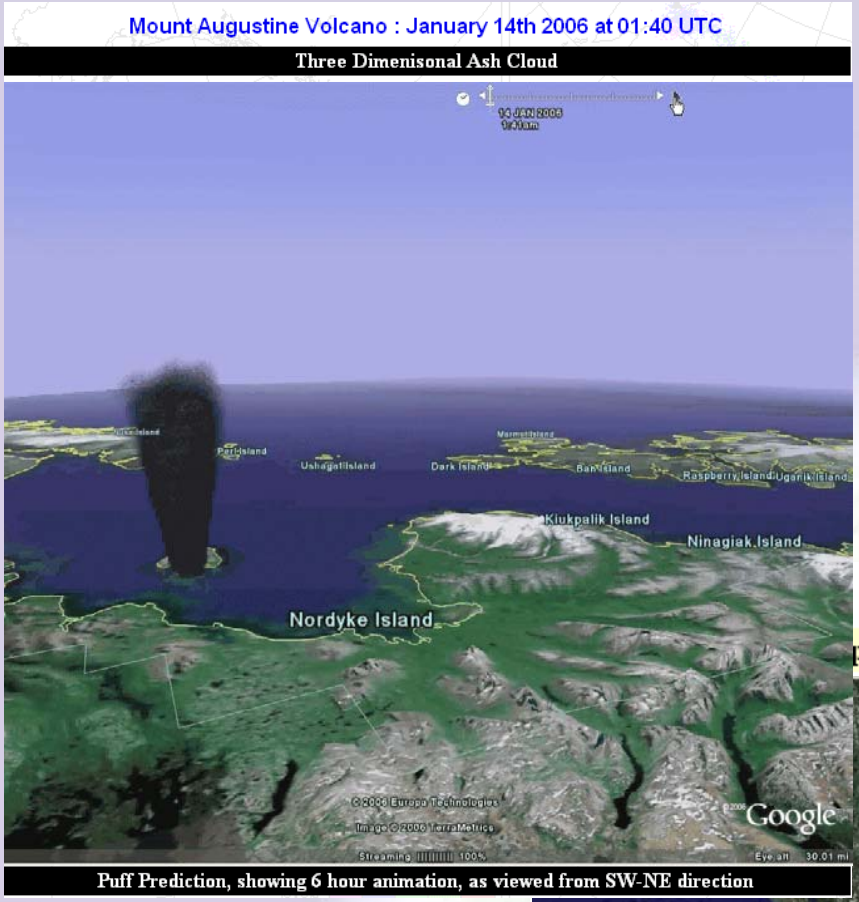
http://puff.images.alaska.edu/static_kml.shtml

Redoubt-KLM ash encounter

- Dec 1989, Mount Redoubt volcano produced numerous volcanic eruptions.
- The flight 867 entered the ash cloud at approximately 25,000 ft 150 miles NNE of Mount Redoubt.
- Immediately the aircrew increased power and attempted to climb out of the ash cloud.
- The aircraft descended approximately 13,000 ft to within a few thousand feet of the ground before the crew restarted the 4 engines.
- Performed an emergency landing at the nearby Anchorage airport.
- Even though there were no injuries to passengers, the damage to engines, avionics, and aircraft structure from this encounter was significant.

Timing	Event
11:40 AST	Airplane begins descent from 35,000 ft
11:46 AST	Airplane encounters ash cloud at 25,000 ft
11:47 AST	Airplane loses power on all four engines after climbing to 27,000 ft
11:52 AST	Airplane engines 1 and 2 restart at 17,000 ft
11:55 AST	Airplane engines 3 and 4 restart at 13,000 ft
12:25 AST	Airplane lands at Anchorage International Airport.

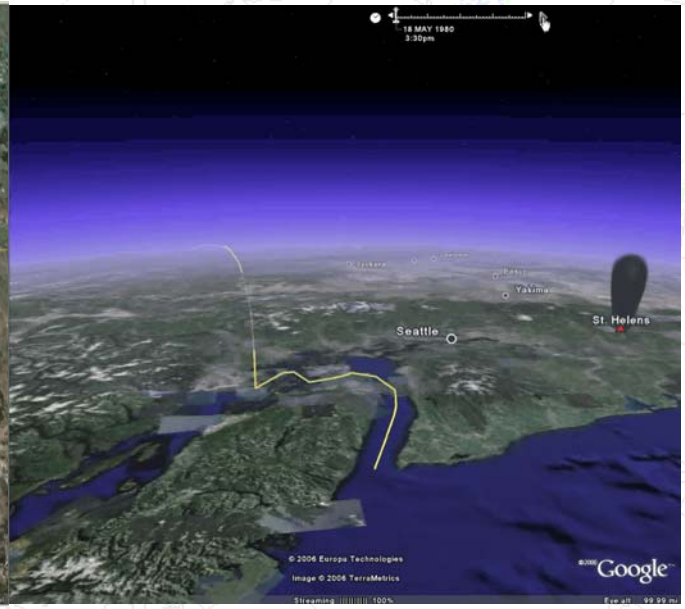
Redoubt ash and KLM aircraft



[Google Earth]

Mount St Helens :: May 1980

Side-on view



Past events kml

http://puff.images.alaska.edu/Google_Earth2.shtml

Puff 1975 – 2006 Time Series Data Description

- Eruptions at North Pacific Volcanoes : January 1976 – December 2006
- Volcanic Clouds reported to be > ~ 6km or 20,000 ft
- Using information from AVO, KVERT and Smithsonian
- Determined start time, plume height and length of eruption
- 237 discrete events over the past 31 years or 7.64 eruptive events per year
- Added aircraft encounters and airport closures to time series
  - Augustine 1976, 1986
  - St Helens 1980
  - Redoubt 1989/1990
  - Spurr 1992
  - Kliuchevskoi 1994
  - Bezymianny 1995
  - Cleveland 2001

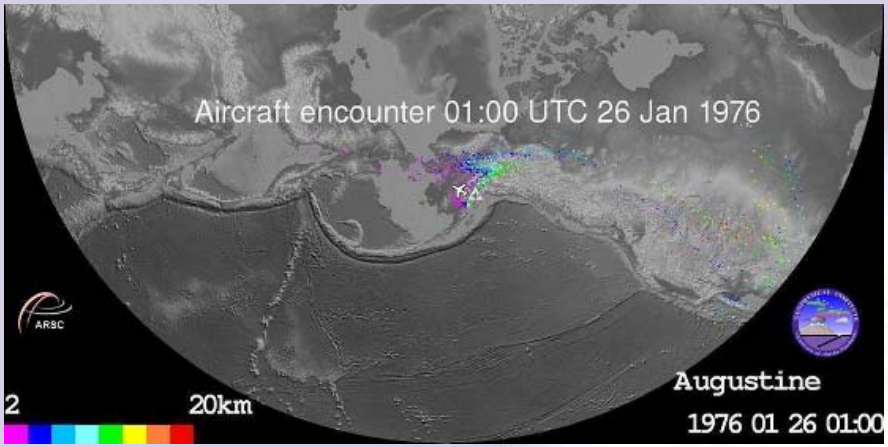
ARSC

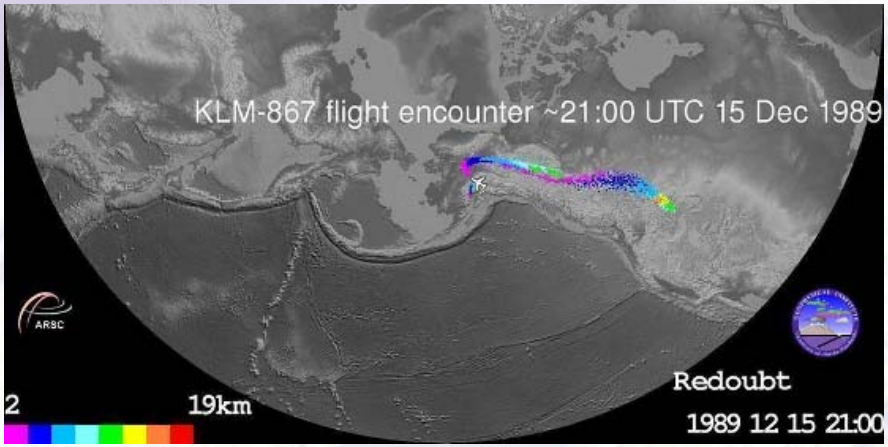
Geophysical Institute, University of Alaska Fairbanks

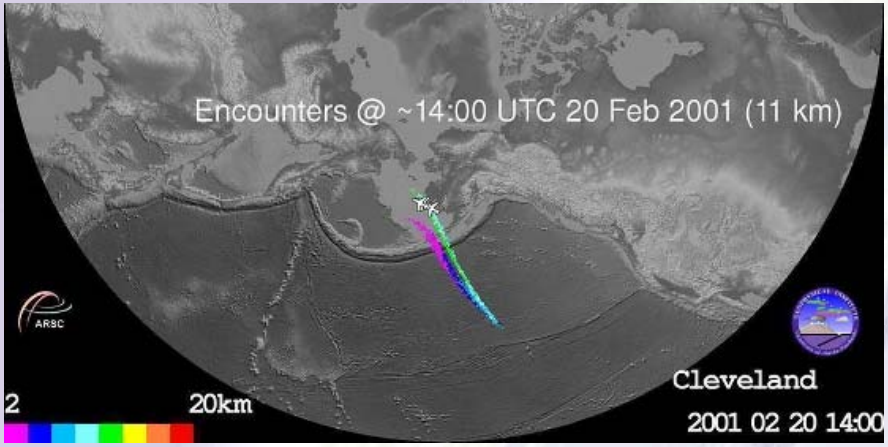
Alaska Volcano Observatory, USGS · UAFGI · ADGGS

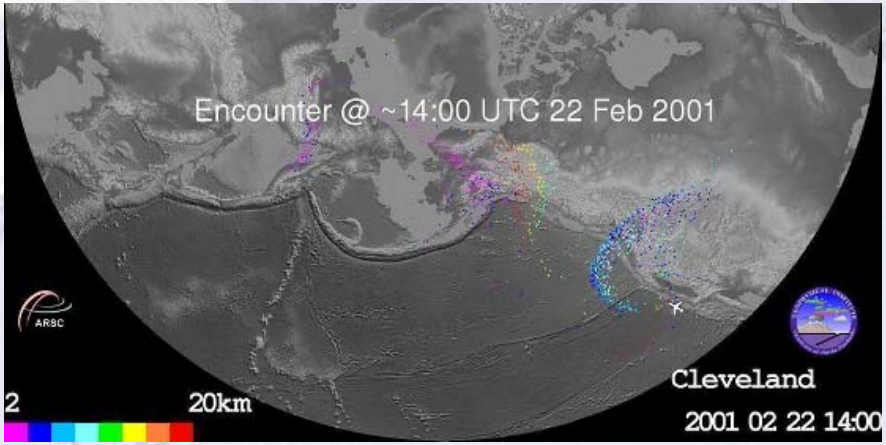
UAF UNIVERSITY OF ALASKA FAIRBANKS

Aircraft and Airport Encounters









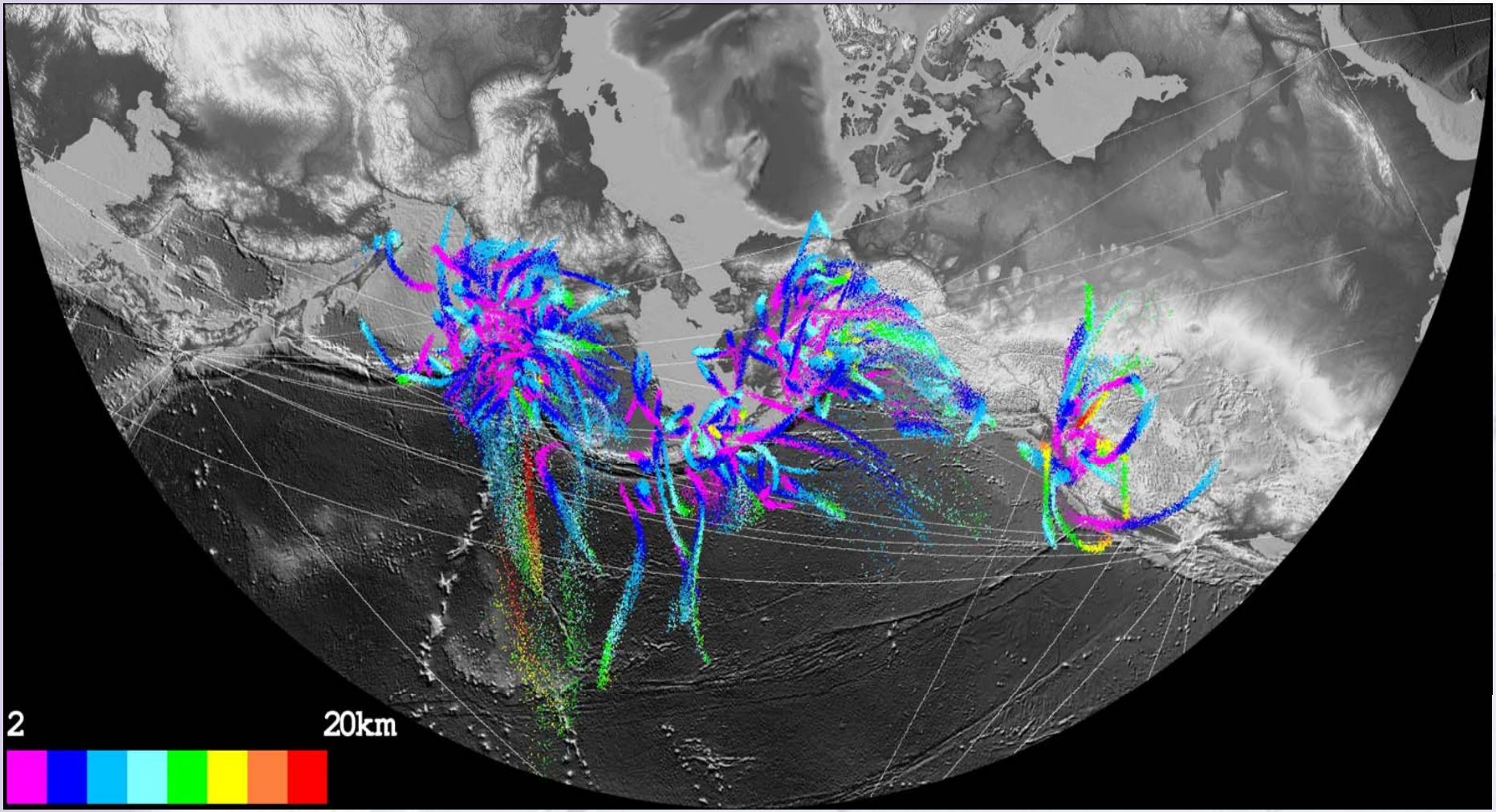
Volcanic Eruptions in North Pacific Region

Puff Volcanic Ash Dispersion Model

Time Series

Peter Webley. ARSC, UAF. (pwebley@gi.alaska.edu)
Rorik Peterson. Mech Eng, UAF. (rorik@gi.alaska.edu)
Ken Dean. GI, UAF. (kdean@gi.alaska.edu)
Jon Dehn. GI, UAF. (jdehn@gi.alaska.edu)

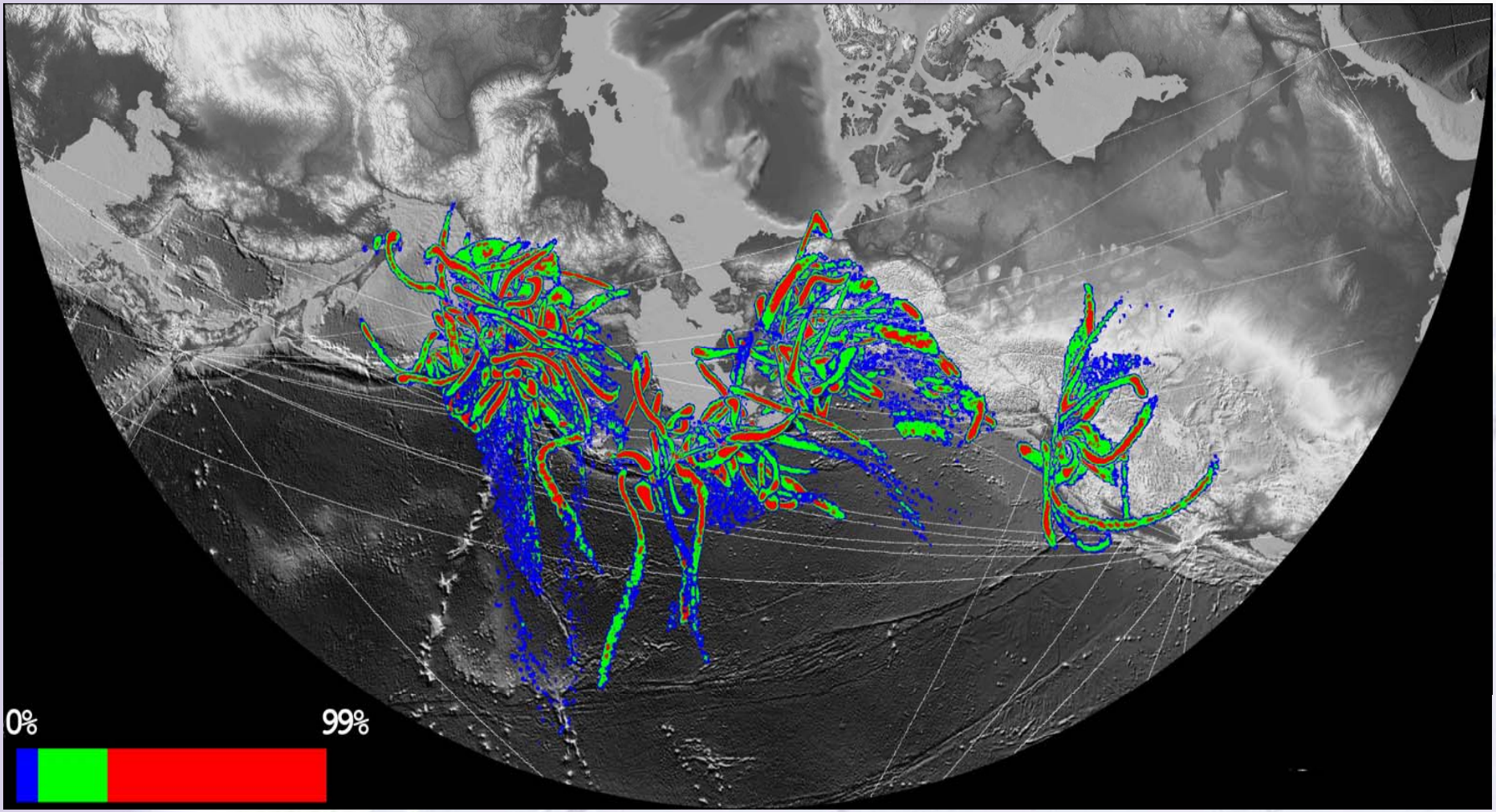
Puff 1975 – 2006 Ash Cloud predictions
Composite :: Airborne Ash color-coded by altitude



237 discrete events from January 1975 – December 2006

Composite image shows location of volcanic ash clouds +12 hrs after the start of each event

Puff 1975 – 2006 Ash Cloud predictions
Composite :: Airborne Ash Concentration



237 discrete events from January 1975 – December 2006

Composite image shows location of volcanic ash clouds +12 hrs after the start of each event

Useful information and links

- Publication in Natural Hazards, SI: Aviation Hazards from Volcanoes
- Puff website http://puff.images.alaska.edu/
- Automatic operational KML http://puff.images.alaska.edu/kml.shtml
- Past eruption event KML http://puff.images.alaska.edu/Google_Earth2.shtml
- ESP working group wiki http://avo.images.alaska.edu/source_eruption_wiki/
- AGU sessions
  - ESP - http://avo.images.alaska.edu/source_eruption_wiki/index.php/AGU_session_2007
  - Virtual Globes http://conferences.images.alaska.edu/agu/2007/schedulesess1.html

Thanks