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

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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

[Image description: Webpuff Interface interface with various input fields and options for simulation parameters such as eruption timescale, no of particles, plume height, wind field model, DEM, and plume shape. The interface also shows a map and a button labeled 'Run Puff'.]
Webpuff Interface: View Prediction

- Once run Puff, display results..

Select the run.....

Select timing.....
Multiple eruption capabilities

Puff model run for Jan 13th – 14th 2006

1st operational use of multiple eruptions
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
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
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

- 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)

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

No need for personnel to be running the model 24 hrs a day
http://puff.images.alaska.edu/
KVERT June 30, 2007 for Kliuchevskoi

Kamchatka and Northern Kuriles Volcanic Activity
KVERT INFORMATION RELEASE 30.67
Saturday, June 30, 2007, 01:15 UTC (11:15 KST)

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 Klyuchevskoy was at the medium level (less than 4-7×10⁻⁶ m/s²) 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 21:00 UTC on June 29 and present time. According to satellite data, ash plumes extended for 300 km (186 mi) to the east from Klyuchevskoy volcano.

Approximate plume altitude is 5000 m (16,400 ft) ASL (by atmosphere).

Based on past eruptions, this could continue for some hours or days, according to MTSAT the plume is moving to east and west for last 6 h. All local aviation authorities have urgent information from KVERT.

Strong terminal paroxysmal eruptions of the volcano occurred in 1845 (lasting for 1 month), 1884-1885 (18 months), 1907 (2), 1930 (1), 1984 (1), 1990 (7), 1994 (1), 1996 (6) and 2005 (6). Ash plumes during these eruptions rose up to 7.0-8.0 km (23,000-26,000 ft) ASL but were briefly as high as 10.0-13.0 km (33,000-42,900 ft) ASL.

IF YOU HAVE ANY QUESTIONS OR CONCERNS, PLEASE CONTACT:
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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 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.kvbnet.ru/kVERT/index_en.html

Archive of daily information KB GS RAS: http://krims.kvbnet.ru/AVO/Arch/ArchVol/reg

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.
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.
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: Top View
Auto runs

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

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

An example for Kluchevskoi, Kamchatka is ->

Directory: Puff Predictions as kml

WMO Radiosonde data

These are kml files that show plumes 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 Klyuchi, Kamchatka is ->

Directory of Actual radiosonde as kml

Radiosonde KML: [http://puff.images.alaska.edu/static_kml.shtml](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.

<table>
<thead>
<tr>
<th>Timing</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:40 AST</td>
<td>Airplane begins descent from 35,000 ft</td>
</tr>
<tr>
<td>11:46 AST</td>
<td>Airplane encounters ash cloud at 25,000 ft</td>
</tr>
<tr>
<td>11:47 AST</td>
<td>Airplane loses power on all four engines after climbing to 27,000 ft</td>
</tr>
<tr>
<td>11:52 AST</td>
<td>Airplane engines 1 and 2 restart at 17,000 ft</td>
</tr>
<tr>
<td>11:55 AST</td>
<td>Airplane engines 3 and 4 restart at 13,000 ft</td>
</tr>
<tr>
<td>12:25 AST</td>
<td>Airplane lands at Anchorage International Airport</td>
</tr>
</tbody>
</table>
PILOT KLM B-747 – "KLM 867 WE HAVE FLAME OUT, ALL ENGINES AND WE ARE DESCENDING NOW!"

ANCHORAGE CENTER – "KLM 867 HEAVY, ANCHORAGE?"

PILOT KLM B-747 – "KLM 867 HEAVY WE ARE DESCENDING NOW... WE ARE IN A FALL!"

PILOT KLM B-747 – "KLM 867 WE NEED ALL THE HELP YOU HAVE SIR. GIVE US RADAR VECTORS PLEASE!"

Redoubt ash and KLM aircraft
Google Earth

Mount St Helens :: May 1980

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
  – Spurr 1992
  – Kliuchevskoi 1994
  – Bezymianny 1995
  – Cleveland 2001
Aircraft and Airport Encounters

Aircraft encounter 01:00 UTC 28 Jan 1976

KLM-867 flight encounter ~21:00 UTC 15 Dec 1989

Encounters @ ~14:00 UTC 20 Feb 2001 (11 km)

Encounter @ ~14:00 UTC 22 Feb 2001
Volcanic Eruptions in North Pacific Region

Puff Volcanic Ash Dispersion Model

Time Series

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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/](http://puff.images.alaska.edu/)
- Automatic operational KML [http://puff.images.alaska.edu/kml.shtml](http://puff.images.alaska.edu/kml.shtml)
- Past eruption event KML [http://puff.images.alaska.edu/Google_Earth2.shtml](http://puff.images.alaska.edu/Google_Earth2.shtml)
- ESP working group wiki [http://avo.images.alaska.edu/source_eruption_wiki/](http://avo.images.alaska.edu/source_eruption_wiki/)
- AGU sessions

Thanks