Development of PUFF Model and the Application to Wild Fire

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The PUFF mode was developed for the real-time volcanic plume tracking in 1990 during the eruption of Mt. Redoubt in Alaska.
Eruption Cloud Characteristics Observed on Satellite Imagery and the Puff Tracking Model

Presented By: Ken Dean, University of Alaska Fairbanks, Geophysical Institute
## Satellite Data Used to Validate and Calibrate Puff Model

<table>
<thead>
<tr>
<th>SATELLITE</th>
<th>TEMPORAL RES.</th>
<th>SPATIAL RES.</th>
<th>SPECTRAL RES.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polar Orbiter:</strong></td>
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<tr>
<td>AVHRR</td>
<td>1 / 3 hr. Avg.</td>
<td>1 km</td>
<td>5 channels, mm</td>
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<td></td>
<td></td>
<td></td>
<td>1: visible; 0.58 - 0.68</td>
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<td></td>
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<td>2: visible-NIR; 0.725 - 1.1</td>
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<td>3: SW-TIR; 3.55 - 3.93</td>
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<td>4: TIR; 10.3 - 11.3</td>
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<td></td>
<td></td>
<td></td>
<td>5: TIR; 11.4 - 12.4</td>
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<tr>
<td>MODIS</td>
<td>1 km - 250 m</td>
<td></td>
<td>36 channels, mm</td>
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<td>01-19: Vis.-NIR; 0.405 - 2.155</td>
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<td>20 - 36: TIR; 3.660 - 14.385</td>
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<td><strong>Geostationary:</strong></td>
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<tr>
<td>GOES</td>
<td>1/0.25-.05 hr</td>
<td>2-8 km at 60° N</td>
<td>5 channels, mm</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1: visible; 0.52 - 0.72</td>
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<td></td>
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<td></td>
<td>2: SW-TIR; 3.78 - 4.03</td>
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<td></td>
<td></td>
<td></td>
<td>3: TIR; 6.47 - 7.02</td>
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<td>4: TIR; 10.2 - 11.2</td>
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<td>5: TIR; 11.5 - 12.5</td>
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<tr>
<td>GMS</td>
<td>1/0.25-.05 hr</td>
<td>2-8 km at 60° N</td>
<td>5 channels, mm</td>
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</table>
Volcanoes, eruption clouds (1990 to 1996) and aircraft routes in the North Pacific Region. These are only some of the larger eruptions during that period.
Satellite Images

Shishaldin 1999: 1000 km long

Kluichevskoi V. 1994
500 km long

Cleveland V.
150 km long

Plumes come in many different shapes and sizes and are composed of ash and gas
Ash Dispersion Models

• There are many ash dispersion models including; Puff, VAFTAD, CAMERM and HYSPLIT

• All require current wind fields to model the movement of volcanic clouds.

• The accuracy of the models depends on the of the wind fields.

• All require satellite data for validation.

• Puff differs from others: higher spatial resolution, physics, implementation, and it is used in research and operational settings

• Puff is currently in use at:
  University of Alaska Fairbanks (Geophysical Institute)
  University of Tsukuba
  University of Messina, Sicily
  US Geologic Survey
  Japan Weather Association
  National Weather Service
  Japan Airlines
Evaluating Composition and Structure of an Eruption Cloud

1. Puff Simulation using default values
   - Horiz. dispersion = 20,000
   - Vertical dispersion = 10
   - Height = 16 km
   - Mean Particle size = 0.01 mm (10 um)

2. Validation of Puff: Model:
   AVHRR Satellite image of volcanic cloud
   (Kliuchevskoi V. 1994)

3. “Tuning” input parameters to match the satellite image of the cloud: Dispersion = 2000

4. “Tuning” may provide relative information on the distribution of particles observed on satellite images
Puff Animation of Mt. Cleveland Eruption 19 February 2001
Aircrafts encountered ash cloud
Aircraft near San Francisco (4,000 km away)

- Reports sulfur smell
- GOES data shows not likely
- Puff models say possible
Initial AVO Observation (AVHRR):
- B4 shows opaque cloud blowing to NW
- Cloud temperature –53 C = 8km altitude
- B4m5 shows ash-rich cloud blowing to SE
- Puff model shows winds shear at 6 - 7 km
Errors on wind field models lead to Puff errors

1. Wind field errors produce inaccurate Puff runs.
2. Satellite data needed to validate model
3. 19 March 2001 Cleveland eruption Puff did not predict the east drifting portion of the plume seen on satellite data.
Airborne Hazard Map of Shishaldin Volcano
Based on Puff simulations run daily using 1 year of data
Realtime prediction in on the Internet
Vertical sections (x-z) and (y-z)
Demonstration of the PUFF model prediction for Usu volcano in February 2000

- Sakura-jima
- Asama-yama
- Usu volcano
- Miyake-jima
Usu volcano hypothetical eruption

Eruption: 23 Feb. 2001, 0600UTC
Plume height: 12,000 feet

Fig.1  30min. After the eruption
Fig.2  60min. After the eruption
Usu volcano  hypothetical eruption

Eruption: 27 Apr. 2000, 2100UTC
Plume height: 10,000 feet

Fig.1  30min. After the eruption
Fig.2  2hr. After the eruption
Miyake-jima eruption compared with image

Eruption: 09 Aug. 2000, 2100UTC

Plume height: 10,000 feet

Real Eruption: 09 Aug. 2000, 2159UTC

Fig.1 Prediction: 10 Aug. 2000, 0000UTC

Fig.2 satellite image: 10 Aug. 2000, 0000UTC
Sakura-jima

Eruption: 22:00 UTC 3 January 2007
Prediction: +1 hours
3-D image for Sakura-jima

Eruption: 22:00 UTC 3 January 2001
Prediction: +00 hours
A red sun observed at Sapporo on 23 May 2003 was speculated to have been caused by wildfire in Siberia, but who knows the truth.
A report of wildfire near the Lake Bykal

Forest Fire
Start Time: 0:00 UTC 18 May 2003
Prediction: +0 hours

We found it’s not from the Lake Bykal
The smoke came from the Lake Khanka

Forest Fire
Start Time: 00:00 UTC 18 May 2003
Prediction: +0 hours

PUFF model is useful for the wildfire
3-D image for Forest_Fire
Start time: 0:00 UTC 18 May 2003
Prediction: +0 hours
3-D image for Forest_Fire
Start time: 0:00 UTC 18 May 2003
Prediction: +0 hours

Red sun at Sapporo
Wildfires in Indonesia

Accumulated Hot Spots
August 2005
Indonesia

Start Time: 00:00 UTC 3 September 2006
Prediction: +6 hours

(By Hayasaka)
Indonesia
Start Time: 0:00 UTC 6 October 2006
Prediction: +6 hours
3-D image for Indonesia

Start time: 0:00 UTC 6 October 2006
Prediction: +6 hours
Accurate wind data is essential
Conclusions

1. **Puff model** may provide information on the relative distribution of airborne particles observed on satellite images.

2. **Puff** predicts the movement of volcanic ash and aerosols, some of which are detected on satellite images.

3. The height of smoke can be estimated by comparing the morphology of simulations to observed on satellite.

4. Puff can predict the location of aerosols on satellite images so analysts can target that area for further processing.

5. Satellite data are critical to validating Puff models. Incorrect wind field will produce erroneous Puff simulations.

6. Airborne hazard maps can be generated by Puff using multiple years of wind field data.
Thanks