

## 1 HYSPLIT parameters

### Kasatochi

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Kasatochi: Aleutian Islands
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP200808.gbl
- Input units: meters
- Number of concentration layers: 1
- Deposition/Ashfall: Yes
- Option to change particle size distribution: No
- Use non-uniform vertical ash distribution: No
- Calculate eruption rate from eruption height: No
- Other HYSPLIT options: No
- Start time (UTC): 08/08/2008, hour 4
- Source Latitude: 52.177
- Source Longitude: -175.5
- Ash column top: 19 km (Pavolonis, personal communication)
- Ash column bottom: 313 m (summit)
- Eruption duration: 1 hour
- Eruption ash quantity: 1 Tg (1,000,000,000 kg) (Pavolonis, personal communication)
- Total duration: 48 hours
- Sampling type: Snapshot
- Average period/Snapshot interval: 3
- Concentration Grid Resolution (decimal degrees): -1
- Concentration grid domain size (decimal degrees): -1, -1
- Top of layer: 30000 m
- Bottom of layer: 0 m
- Wet del of particle: 3.2E+05, 5.0E-05
- Sum deposition over total run time? Yes
- Ash bulk density? 2.5 grams/cubic cm
- Deposition/Ashfall Output units: mass/area
- Concentration output units: kg/cubic m
- Plot projection: default
- Plot resolution: 96
- Zoom factor: 70
- US county borders?: No
- Google Earth output of contours?: No
- PS file?: Yes
- Create PDF file of graphics?: Yes

### Okmok

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Okmok: Aleutian Islands
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP200807.gbl
- Input units: meters
- Number of concentration layers: 1
- Deposition/Ashfall: Yes

- 1 • Option to change particle size distribution: No
- 2 • Use non-uniform vertical ash distribution: No
- 3 • Calculate eruption rate from eruption height: No
- 4 • Other HYSPLIT options: No
- 5 • Start time (UTC): 07/12/2008, hour 20
- 6 • Source Latitude: 53.43
- 7 • Source Longitude: -168.13
- 8 • Ash column top: 15000 m (GVP)
- 9 • Ash column bottom: 1072 m (summit)
- 10 • Eruption duration: 1 hour
- 11 • Eruption ash quantity: 0.07 Tg (Prata et al., 2010)
- 12 • Total duration: 48 hours
- 13 • Sampling type: Snapshot
- 14 • Average period/Snapshot interval: 3
- 15 • Concentration Grid Resolution (decimal degrees): -1
- 16 • Concentration grid domain size (decimal degrees): -1, -1
- 17 • Top of layer: 30000
- 18 • Bottom of layer: 0
- 19 • Wet del of particle: 3.2E+05, 5.0E-05
- 20 • Sum deposition over total run time? Yes
- 21 • Ash bulk density? 2.5 grams/cubic cm
- 22 • Deposition/Ashfall Output units: mass/area
- 23 • Concentration output units: kg/cubic m
- 24 • Plot projection: Default
- 25 • Plot resolution: 96
- 26 • Zoom factor: 70
- 27 • US county borders?: No
- 28 • Google Earth output of contours?: No
- 29 • PS file?: Yes
- 30 • Create PDF file of graphics?: Yes

### 31 Grímsvötn

- 32 • Meteorological Data: Reanalysis (global, 1948-present)
- 33 • Volcano: Grímsvötn: Iceland-NE
- 34 • Use USGS-assigned Eruption Source Parameters (ESP)? No
- 35 • GDAS1 Meteorological File: RP201105.gbl
- 36 • Input units: meters
- 37 • Number of concentration layers: 1
- 38 • Desposition/Ashfall: Yes
- 39 • Option to change particle size distribution: No
- 40 • Use non-uniform vertical ash distribution: No
- 41 • Calculate eruption rate from eruption height: No
- 42 • Other HYSPLIT options: No
- 43 • Start time (UTC): 05/21/2011, Hour 19
- 44 • Source Lat: 64.43
- 45 • Source Long: -17.33
- 46 • Ash column top: 20000 m
- 47 • Ash column bottom: 1724 m (summit)
- 48 • Eruption duration: 24 hours (Moxnes et al., 2014)

- 1 • Eruption ash quantity: 0.4 Tg (400,000,000 kg) (Moxnes et al., 2014)
- 2 • Total duration: 48 hours
- 3 • Sampling type: Snapshot
- 4 • Average period/Snapshot interval: 3 hours
- 5 • Concentration Grid Resolution (decimal degrees): -1
- 6 • Concentration grid domain size (decimal degrees): -1, -1
- 7 • Top of layer: 30000 m
- 8 • Bottom of layer: 0
- 9 • Wet del of particle: 3.2E+05, 5.0E-05
- 10 • Sum deposition over total run time? Yes
- 11 • Ash bulk density? 2.5 grams/cubic cm
- 12 • Deposition/Ashfall Output units: /area
- 13 • Concentration output units : kg/cubic m
- 14 • Plot projection: Default
- 15 • Plot resolution: 96
- 16 • Zoom factor: 70
- 17 • US county borders?: No
- 18 • Google Earth output of contours?: No
- 19 • PS file?: Yes
- 20 • Create PDF file of graphics?: Yes

#### 21 Chaitén

- 22 • Meteorological Data: Reanalysis (global, 1948-present)
- 23 • Volcano: Chaiten: Chile-S
- 24 • Use USGS-assigned Eruption Source Parameters (ESP)? No
- 25 • GDAS1 Meteorological File: RP200805.gbl
- 26 • Input units: meters
- 27 • Number of concentration layers: 1
- 28 • Deposition/Ashfall: Yes
- 29 • Option to change particle size distribution: No
- 30 • Use non-uniform vertical ash distribution: No
- 31 • Calculate eruption rate from eruption height: No
- 32 • Other HYSPLIT options: No
- 33 • Start time (UTC): 05/06/2008, Hour 12
- 34 • Source Latitude: -42.83
- 35 • Source Longitude: -72.646
- 36 • Ash column top: 30000 m (GVP)
- 37 • Ash column bottom: 1121 m (summit height)
- 38 • Eruption duration: 1 hour
- 39 • Eruption ash quantity: 0.2 Tg (200,000,000 kg) (Durant et al., 2012)
- 40 • Total duration: 24 hours
- 41 • Sampling type: Snapshot
- 42 • Average period/Snapshot interval: 3 hours
- 43 • Concentration Grid Resolution (decimal degrees): -1
- 44 • Concentration grid domain size (decimal degrees): -1, -1
- 45 • Top of layer: 32000 m
- 46 • Bottom of layer: 0
- 47 • Wet del of particle: 3.2E+05, 5.0E-05
- 48 • Sum deposition over total run time? Yes

- 1 • Ash bulk density? 2.5 grams/cubic cm
- 2 • Deposition/Ashfall Output units: mass/area
- 3 • Concentration output units: kg/cubic meter
- 4 • Plot projection: Default
- 5 • Plot resolution: 96 dpi
- 6 • Zoom factor: 70
- 7 • US county borders?: No
- 8 • Google Earth output of contours?: no
- 9 • PS file?: yes
- 10 • Create PDF file of graphics?: yes
- 11 Puyehue-Cordón Caulle
- 12 • Meteorological Data: Reanalysis (global, 1948-present)
- 13 • Volcano: Puyehue Cordon Caulle: Chile-C
- 14 • Use USGS-assigned Eruption Source Parameters (ESP)? No
- 15 • GDAS1 Meteorological File: RP201106.gbl
- 16 • Input units: meters
- 17 • Number of concentration layers: 1
- 18 • Deposition/Ashfall: Yes
- 19 • Option to change particle size distribution: No
- 20 • Use non-uniform vertical ash distribution: No
- 21 • Calculate eruption rate from eruption height: No
- 22 • Other HYSPLIT options: No
- 23 • Start time (UTC): 06/04/2011, Hour 18
- 24 • Source Latitude: -40.56
- 25 • Source Longitude: -72.117
- 26 • Ash column top: 12000 m (GVP)
- 27 • Ash column bottom: 2236 m (summit)
- 28 • Eruption duration: 48 hours
- 29 • Eruption ash quantity: 17280000000 kg (USGS ESP)
- 30 • Total duration: 48 hours
- 31 • Sampling type: Snapshot
- 32 • Average period/Snapshot interval: 3 hours
- 33 • Concentration Grid Resolution (decimal degrees): -1
- 34 • Concentration grid domain size (decimal degrees): -1, -1
- 35 • Top of layer: 30000 m
- 36 • Bottom of layer: 0 m
- 37 • Wet del of particle: 3.2E+05, 5.0E-05
- 38 • Sum deposition over total run time? Yes
- 39 • Ash bulk density? 2.5 grams/cubic cm
- 40 • Deposition/Ashfall Output units: mass/area
- 41 • Concentration output units: kg/cubic m
- 42 • Plot projection: Default
- 43 • Plot resolution: 96
- 44 • Zoom factor: 70
- 45 • US county borders?: No
- 46 • Google Earth output of contours?: No
- 47 • PS file?: Yes
- 48 • Create PDF file of graphics?: Yes

1     Kelut

2         •     Meteorological Data: Reanalysis (global, 1948-present)

3         •     Volcano: Kelut: Java

4         •     Use USGS-assigned Eruption Source Parameters (ESP)? No

5         •     GDAS1 Meteorological File: RP201402.gbl

6         •     Input units: meters

7         •     Number of concentration layers: 1

8         •     Deposition/Ashfall: Yes

9         •     Option to change particle size distribution: No

10        •     Use non-uniform vertical ash distribution: No

11        •     Calculate eruption rate from eruption height: No

12        •     Other HYSPLIT options: No

13        •     Start time (UTC): 02/13/2014, Hour 16

14        •     Source Latitude: -7.93

15        •     Source Longitude: 112.308

16        •     Ash column top: 17000 m (GVP)

17        •     Ash column bottom: 1730 m (summit)

18        •     Eruption duration: 1 hour

19        •     Eruption ash quantity: 17280000000 kg (USGS ESP)

20        •     Total duration: 48 hours

21        •     Sampling type: Snapshot

22        •     Average period/Snapshot interval: 3 hours

23        •     Concentration Grid Resolution (decimal degrees): -1

24        •     Concentration grid domain size (decimal degrees): -1, -1

25        •     Top of layer: 30000 m

26        •     Bottom of layer: 0

27        •     Wet del of particle: 3.2E+05, 5.0E-05

28        •     Sum deposition over total run time? Yes

29        •     Ash bulk density? 2.5 grams/cubic cm

30        •     Deposition/Ashfall Output units: /area

31        •     Concentration output units : kg/cubic m

32        •     Plot projection: Default

33        •     Plot resolution: 96

34        •     Zoom factor:70

35        •     US county borders?: No

36        •     Google Earth output of contours?: No

37        •     PS file?: yes

38        •     Create PDF file of graphics?: yes

39     Sangeang Api

40        •     Meteorological Data: Reanalysis (global, 1948-present)

41        •     Volcano: Sangeang Api: Lesser Sunda Islands

42        •     Use USGS-assigned Eruption Source Parameters (ESP)? No

43        •     GDAS1 Meteorological File: RP201405.gbl

44        •     Input units: meters

45        •     Number of concentration layers: 1

46        •     Desposition/Ashfall: Yes

47        •     Option to change particle size distribution: No

48        •     Use non-uniform vertical ash distribution: No

- 1 • Calculate eruption rate from eruption height: No
- 2 • Other HYSPLIT options: No
- 3 • Start time (UTC): 05/30/2014, Hour 9
- 4 • Source Lat: -8.2
- 5 • Source Long: 119.07
- 6 • Ash column top: 15200 m (GVP)
- 7 • Ash column bottom: 1948 m (summit)
- 8 • Eruption duration: 1 hour
- 9 • Eruption ash quantity: 864000000 kg (USGS ESP)
- 10 • Total duration: 48 hours
- 11 • Sampling type: Snapshot
- 12 • Average period/Snapshot interval: 3 hours
- 13 • Concentration Grid Resolution (decimal degrees): -1
- 14 • Concentration grid domain size (decimal degrees): -1, -1
- 15 • Top of layer: 30000 m
- 16 • Bottom of layer: 0
- 17 • Wet del of particle: 3.2E+05, 5.0E-05
- 18 • Sum deposition over total run time? Yes
- 19 • Ash bulk density? 2.5 grams/cubic cm
- 20 • Deposition/Ashfall Output units: /area
- 21 • Concentration output units : kg/cubic m
- 22 • Plot projection: Default
- 23 • Plot resolution: 96
- 24 • Zoom factor:70
- 25 • US county borders?: No
- 26 • Google Earth output of contours?: NO
- 27 • PS file?: yes
- 28 • Create PDF file of graphics?: yes

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## 30 **2 Neural network parameters**

### 31 Ash-Detection Neural Network Settings:

- 32 • Number of repetitions: 100
- 33 • Size of used subset in % of train data: 10
- 34 • Percentage of used test data: 100
- 35 • Shift step in % of subset size: 5
- 36 • If\_Threshold\_Increase\_Subset selected
- 37 • If\_No\_Modification\_Shift\_Subset selected
- 38 • Corr\_threshold, transformed\_data selected
- 39 • Threshold of correlation: 96
- 40 • Threshold of no\_modification (%): 0.0005
- 41 • Number of hidden neurons: 25
- 42 • Gamma: 0
- 43 • Alpha: 4
- 44 • Temperature: 10
- 45 • I.-BIAS selected

1 • H.-BIAS selected  
2 • No\_Weight\_Decay selected  
3 • QCK selected  
4  
5 SO<sub>2</sub>-Rich-Ash-Detection Neural Network Settings:  
6 • Number of repetitions: 100  
7 • Size of used subset in % of train data: 10  
8 • Percentage of used test data: 100  
9 • Shift step in % of subset size: 5  
10 • If\_Threshold\_Increase\_Subset selected  
11 • If\_No\_Modification\_Shift\_Subset selected  
12 • Corr\_threshold, transformed\_data selected  
13 • Threshold of correlation: 96  
14 • Threshold of no\_modification (%): 0.0005  
15 • Number of hidden neurons: 25  
16 • Gamma: 0  
17 • Alpha: 4  
18 • Temperature: 10  
19 • I.-BIAS selected  
20 • H.-BIAS selected  
21 • No\_Weight\_Decay selected  
22 • QCK selected  
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1 **3 Neural network training dataset**

VOLCANO	OVERPASS (UTC) yyyy-mm-ddThh:mm:ss	SATELLITE	HYSPLIT TIME
Kasatochi	2008-08-08T13:40:00	Aqua	2008-08-08T13:00:00
Kasatochi	2008-08-08T23:05:00	Terra	2008-08-08T22:00:00
Kasatochi	2008-08-09T12:45:00	Aqua	2008-08-09T13:00:00
Kasatochi	2008-08-09T22:10:00	Terra	2008-08-09T22:00:00
Kasatochi	2008-08-09T23:55:00	Aqua	2008-08-09T22:00:00
Puyehue-Cordón Caulle	2011-06-05T05:55:00	Aqua	2011-06-05T06:00:00
Puyehue-Cordón Caulle	2011-06-05T17:55:00	Aqua	2011-06-05T18:00:00
Puyehue-Cordón Caulle	2011-06-06T03:20:00	Terra	2011-06-06T03:00:00
Puyehue-Cordón Caulle	2011-06-06T05:00:00	Aqua	2011-06-06T06:00:00
Puyehue-Cordón Caulle	2011-06-06T14:25:00	Terra	2011-06-06T15:00:00
Puyehue-Cordón Caulle	2011-06-06T18:40:00	Aqua	2011-06-06T18:00:00
Sangeang Api	2014-05-30T14:05:00	Terra	2014-05-30T15:00:00
Sangeang Api	2014-05-30T17:10:00	Aqua	2014-05-30T18:00:00
Sangeang Api	2014-05-31T02:35:00	Terra	2014-05-31T03:00:00

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#### 4 Other volcanoes

Kasatochi, a stratovolcano located in the Aleutian Islands (Sigurdsson, 2000), began erupting on August 7, 2008, with three distinct pulses. The third pulse, beginning at 0435 UTC, August 8, 2008, was the largest of the three, with a plume height of 19 km (Pavolonis, M.J., personal communication, September 12, 2014), and continued for 14 hours (Prata et al., 2010). This pulse released the most ash of the three pulses (Fee et al., 2010), and released around 1.7 Tg of SO<sub>2</sub> (Corradini et al., 2010), the highest amount observed since the eruption of Hudson in 1991 (Fee et al., 2010).

The eruption of Grímsvötn, a basaltic caldera (Sigurdsson, 2000) lying below the Vatnajökull icecap in Iceland (GVP), began erupting around 1900 UTC, May 21, 2011 (Petersen et al., 2012). The plume quickly reached 20 km (GVP), but decreased strength soon afterwards and the plume fell to 10 km within 24 hours (Petersen et al., 2012).

Puyehue-Cordón Caulle, a volcanic complex, began erupting from a fissure on June 4, 2011 (GVP; Klüser et al., 2012; Sigurdsson, 2000). This basaltic-to-rhyolitic eruption continued for several months (Diaz et al., 2014), but initially sent ash 12 km into the atmosphere (GVP; Klüser et al., 2012). Within ten days, Puyehue's ash cloud had circled the globe (Klüser et al., 2012).

The eruption of Kasatochi in 2008 is depicted in Figure 1. This particular volcanic cloud, 2 km thick, was located over a dense meteorological cloud system (Corradini et al., 2010). In the RGB, Figure 4-A, created using MODIS infrared bands, there is a significant SO<sub>2</sub>-rich ash signal. Although this eruption was characterized by the highest SO<sub>2</sub> release since Hudson in 1991 (Lara, 2009), volcanic ash can reduce the radiance for all channels in the thermal infrared spectral range, leading to an overestimation of SO<sub>2</sub> (Corradini et al., 2010). In addition, when ash and SO<sub>2</sub> are collocated or when SO<sub>2</sub> is located above ash, ash will appear bright yellow in RGBs created using the band combinations in Figure 3. This is due to the strong SO<sub>2</sub> absorption in 8.6 μm combined with the lack of absorption in 11 and 12 μm (Pavolonis, 2014).

The eruption of Grímsvötn, 2011, found in Figure 2, occurred about 43 hours prior to the images in the figure. Two days earlier, ash at lower altitudes was observed to drift to the south while ash at higher altitudes drifted east (GVP). The next day, May 22, most ash drifted south and southwest (GVP). An ash signature is seen to the south of the volcano in both the RGB and the visible image (Figure 2). An SO<sub>2</sub> signal is not observed in the RGB (Figure 2). The

neural network detects ash in the correct location with little overestimation, and also does not place any SO<sub>2</sub> in the atmosphere at this particular time (Figure 2).

Figure 3 depicts the volcanic cloud resulting from Puyehue-Cordón Caulle about 48 hours after the initial eruption. On June 4, 2011, ash located at 5 km drifted to the south while ash at 10 km drifted west and east (GVP). On this same day gas was observed drifting west while ash drifted east-southeast (GVP). Ash was again observed drifting east-southeast on June 5, 2011. Winds shifted on June 6, 2011, and ash drifted to the east-northeast while a previous volcanic cloud continued east-southeast over the ocean (GVP). The neural network detects both faint and strong ash signatures in Figure 3, while not overestimated in the presence of high meteorological clouds to the west of the volcano. The neural network distinguishes the SO<sub>2</sub>-rich cloud from the ambient atmosphere with clear boundaries and little overestimation (Figure 3).

## References

- Corradini, S., Merucci, L., Prata, A. J., and Piscini, A.: Volcanic ash and SO<sub>2</sub> in the 2008 Kasatochi eruption: Retrievals comparison from different IR satellite sensors, *Journal of Geophysical Research*, 115, 2010.
- Diaz, S. B., Paladini, A. A., Braile, H. G., Dieguez, M. C., Deferrari, G. A., Vernet, M., and Vrsalovic, J.: Global and direct UV irradiance variation in the Nahuel Huapi National Park (Patagonia, Argentina) after the eruption of Puyehue-Cordon Caulle (Chile), *Journal of Atmospheric and Solar-Terrestrial Physics*, 112, 47-56, 2014.
- Fee, D., Steffke, A., and Garces, M.: Characterization of the 2008 Kasatochi and Okmok eruptions using remote infrasound arrays, *Journal of Geophysical Research*, 115, 2010.
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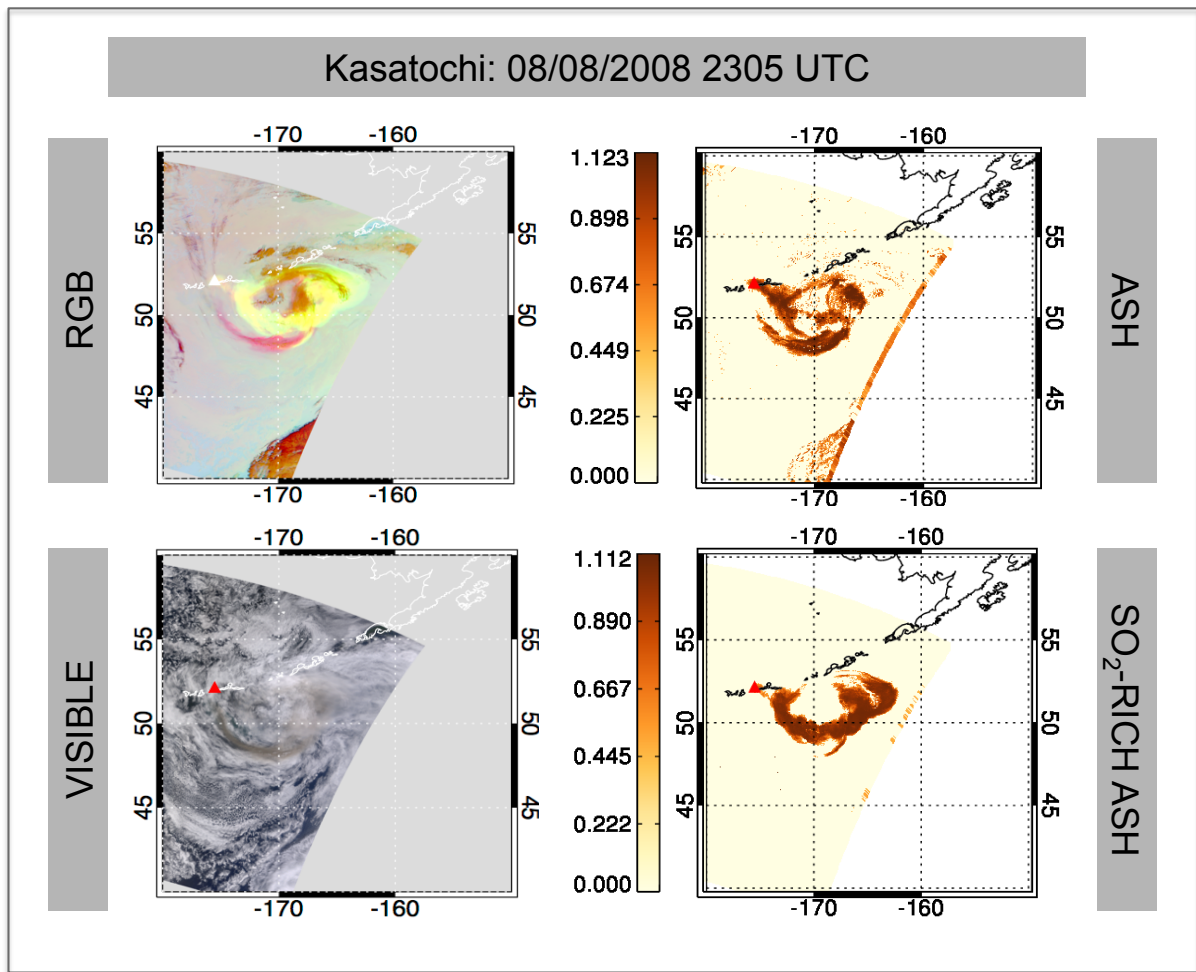
1 Pavolonis, M. J.: Development of Satellite Remote Sensing Techniques for Quantifying  
2 Volcanic Ash Cloud Properties, Ph.D. dissertation, University of Wisconsin-Madison,  
3 Madison, WI, 2014, 307 pages.

4 Petersen, G. N., Bjornsson, H., Arason, P., and von Löwis, S.: Two weather radar time series  
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9 measurements, Journal of Geophysical Research, 115, 2010.

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11 pages.  
12

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4 Figure 1. (Top Left) RGB created using MODIS bands 32-31, 31-29, and 31 for the eruption  
 5 of Kasatochi, August 8, 2008, 2305Z; (Bottom Left) Visible image created using MODIS  
 6 bands 1, 4, and 3 for the same eruption and time; (Top Right) Ash-detection neural network  
 7 output for the same eruption and time; (Bottom Right) SO<sub>2</sub>-rich-ash-detection neural network  
 8 output for the same eruption and time.

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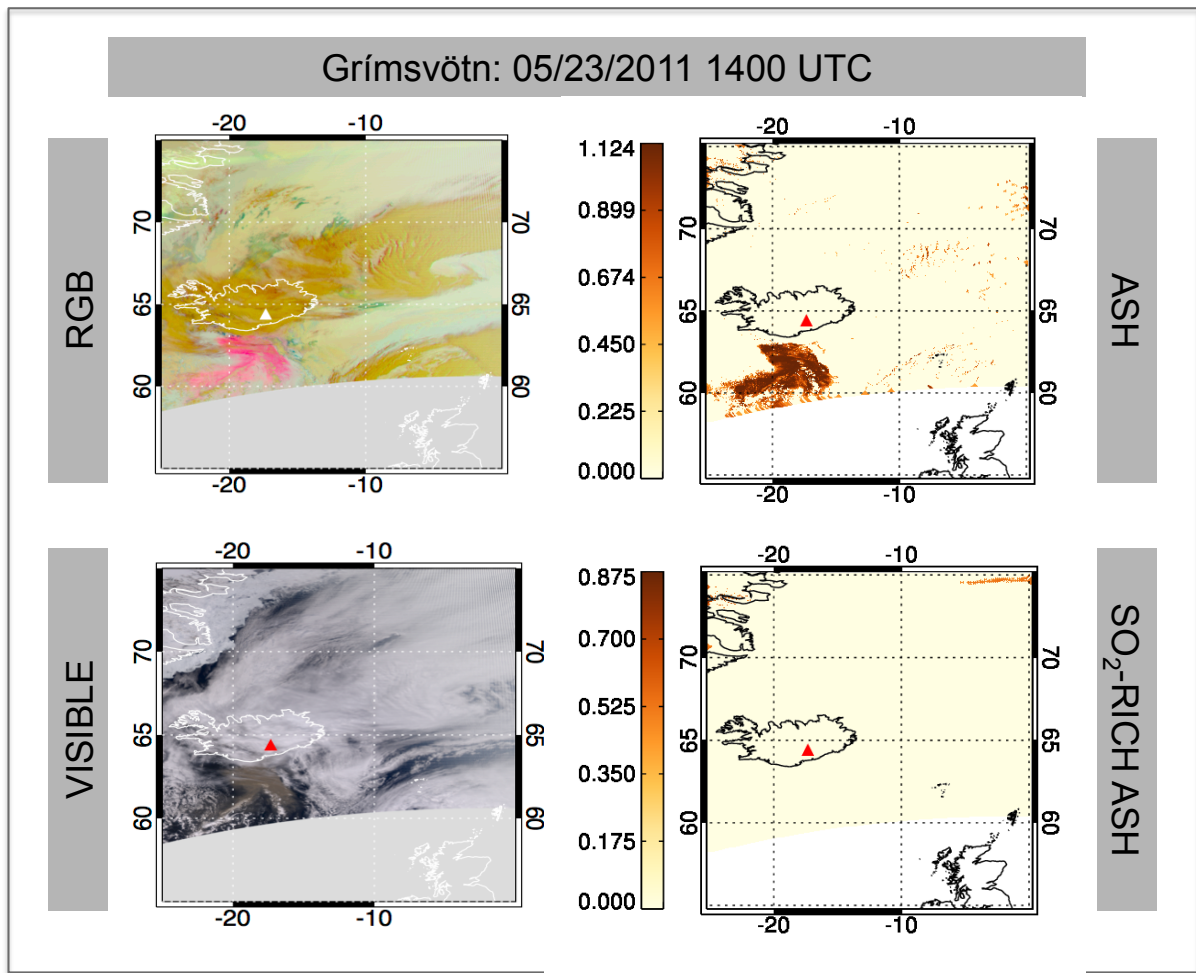


Figure 2. (Top Left) RGB created using MODIS bands 32-31, 31-29, and 31 for the eruption of Grímsvötn, May 23, 2011, 1400Z; (Bottom Left) Visible image created using MODIS bands 1, 4, and 3 for the same eruption and time; (Top Right) Ash-detection neural network output for the same eruption and time; (Bottom Right) SO<sub>2</sub>-rich-ash-detection neural network output for the same eruption and time.

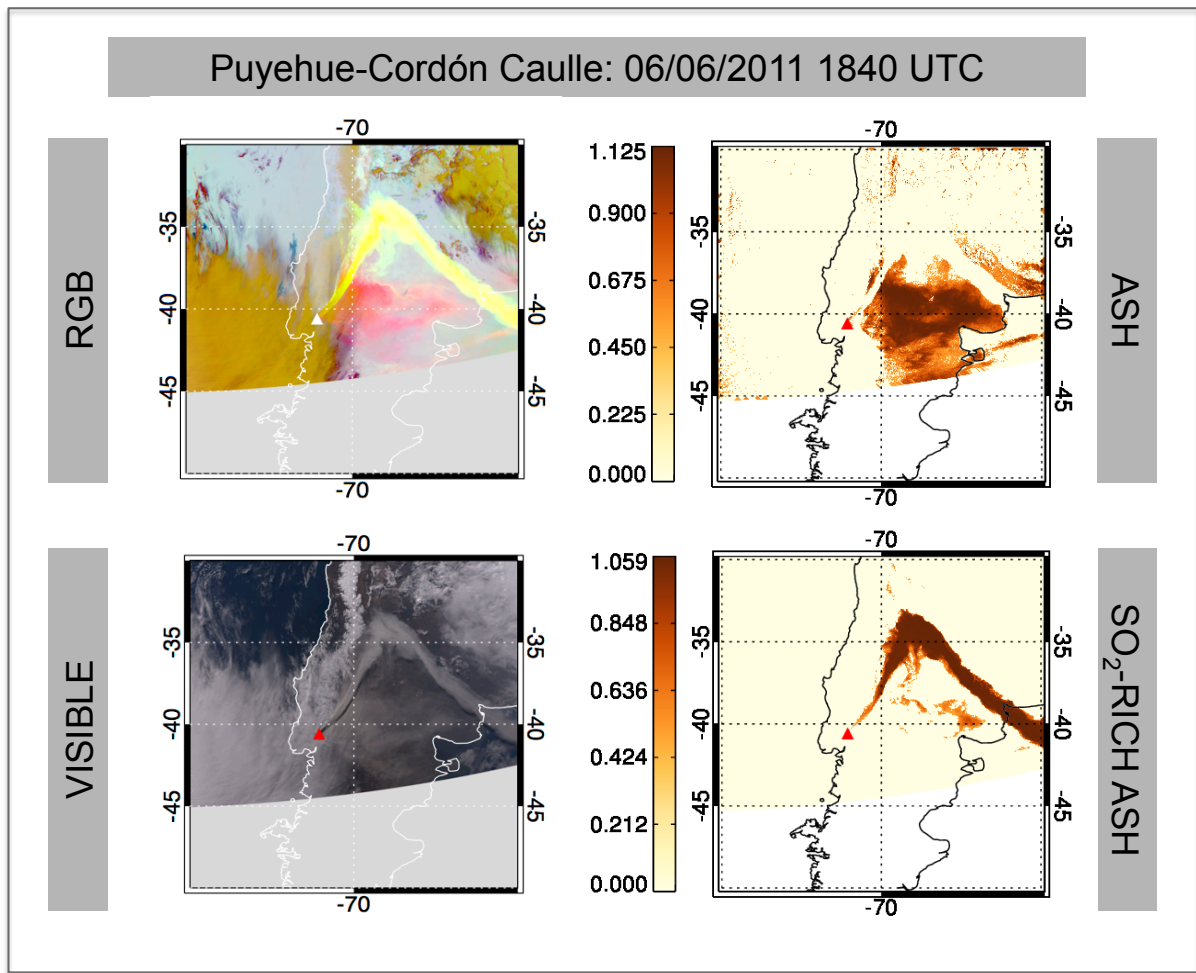


Figure 3. (Top Left) RGB created using MODIS bands 32-31, 31-29, and 31 for the eruption of Puyehue-Cordón Caulle, June 6, 2011, 1840Z; (Bottom Left) Visible image created using MODIS bands 1, 4, and 3 for the same eruption and time; (Top Right) Ash-detection neural network output for the same eruption and time; (Bottom Right) SO<sub>2</sub>-rich-ash-detection neural network output for the same eruption and time.