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

- 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): 07/12/2008, hour 20
- Source Latitude: 53.43
- Source Longitude: -168.13
- Ash column top: 15000 m (GVP)
- Ash column bottom: 1072 m (summit)
- Eruption duration: 1 hour
- Eruption ash quantity: 0.07 Tg (Prata et al., 2010)
- 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
- Bottom of layer: 0
- 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

Grímsvötn

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Grimsvotn: Iceland-NE
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP201105.gbl
- Input units: meters
- Number of concentration layers: 1
- Desposition/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): 05/21/2011, Hour 19
- Source Lat: 64.43
- Source Long: -17.33
- Ash column top: 20000 m
- Ash column bottom: 1724 m (summit)
- Eruption duration: 24 hours (Moxnes et al., 2014)

- Eruption ash quantity: 0.4 Tg (400,000,000 kg) (Moxnes et al., 2014)
- Total duration: 48 hours
- Sampling type: Snapshot
- Average period/Snapshot interval: 3 hours
- Concentration Grid Resolution (decimal degrees): -1
- Concentration grid domain size (decimal degrees): -1, -1
- Top of layer: 30000 m
- Bottom of layer: 0
- 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: /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

Chaitén

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Chaiten: Chile-S
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP200805.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): 05/06/2008, Hour 12
- Source Latitude: -42.83
- Source Longitude: -72.646
- Ash column top: 30000 m (GVP)
- Ash column bottom: 1121 m (summit height)
- Eruption duration: 1 hour
- Eruption ash quantity: 0.2 Tg (200,000,000 kg) (Durant et al., 2012)
- Total duration: 24 hours
- Sampling type: Snapshot
- Average period/Snapshot interval: 3 hours
- Concentration Grid Resolution (decimal degrees): -1
- Concentration grid domain size (decimal degrees): -1, -1
- Top of layer: 32000 m
- Bottom of layer: 0
- 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 meter
- Plot projection: Default
- Plot resolution: 96 dpi
- Zoom factor: 70
- US county borders?: No
- Google Earth output of contours?: no
- PS file?: yes
- Create PDF file of graphics?: yes

Puyehue-Cordón Caulle

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Puyehue Cordon Caulle: Chile-C
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP201106.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): 06/04/2011, Hour 18
- Source Latitude: -40.56
- Source Longitude: -72.117
- Ash column top: 12000 m (GVP)
- Ash column bottom: 2236 m (summit)
- Eruption duration: 48 hours
- Eruption ash quantity: 17280000000 kg (USGS ESP)
- Total duration: 48 hours
- Sampling type: Snapshot
- Average period/Snapshot interval: 3 hours
- 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

Kelut

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Kelut: Java
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP201402.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): 02/13/2014, Hour 16
- Source Latitude: -7.93
- Source Longitude: 112.308
- Ash column top: 17000 m (GVP)
- Ash column bottom: 1730 m (summit)
- Eruption duration: 1 hour
- Eruption ash quantity: 17280000000 kg (USGS ESP)
- Total duration: 48 hours
- Sampling type: Snapshot
- Average period/Snapshot interval: 3 hours
- Concentration Grid Resolution (decimal degrees): -1
- Concentration grid domain size (decimal degrees): -1, -1
- Top of layer: 30000 m
- Bottom of layer: 0
- 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: /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

Sangeang Api

- Meteorological Data: Reanalysis (global, 1948-present)
- Volcano: Sangeang Api: Lesser Sunda Islands
- Use USGS-assigned Eruption Source Parameters (ESP)? No
- GDAS1 Meteorological File: RP201405.gbl
- Input units: meters
- Number of concentration layers: 1
- Desposition/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): 05/30/2014, Hour 9
- Source Lat: -8.2
- Source Long: 119.07
- Ash column top: 15200 m (GVP)
- Ash column bottom: 1948 m (summit)
- Eruption duration: 1 hour
- Eruption ash quantity: 864000000 kg (USGS ESP)
- Total duration: 48 hours
- Sampling type: Snapshot
- Average period/Snapshot interval: 3 hours
- Concentration Grid Resolution (decimal degrees): -1
- Concentration grid domain size (decimal degrees): -1, -1
- Top of layer: 30000 m
- Bottom of layer: 0
- 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: /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

2 Neural network parameters

Ash-Detection Neural Network Settings:

- Number of repetitions: 100
- Size of used subset in % of train data: 10
- Percentage of used test data: 100
- Shift step in % of subset size: 5
- If_Threshold_Increase_Subset selected
- If_No_Modification_Shift_Subset selected
- Corr_threshold, transformed_data selected
- Threshold of correlation: 96
- Threshold of no_modification (%): 0.0005
- Number of hidden neurons: 25
- Gamma: 0
- Alpha: 4
- Temperature: 10
- I.-BIAS selected

- H.-BIAS selected
- No_Weight_Decay selected
- QCK selected

SO_2-Rich-Ash-Detection Neural Network Settings:

- Number of repetitions: 100
- Size of used subset in % of train data: 10
- Percentage of used test data: 100
- Shift step in % of subset size: 5
- If_Threshold_Increase_Subset selected
- If_No_Modification_Shift_Subset selected
- Corr_threshold, transformed_data selected
- Threshold of correlation: 96
- Threshold of no_modification (%): 0.0005
- Number of hidden neurons: 25
- Gamma: 0
- Alpha: 4
- Temperature: 10
- I.-BIAS selected
- H.-BIAS selected
- No_Weight_Decay selected
- QCK selected

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

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_2 (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_2-rich ash signal. Although this eruption was characterized by the highest SO_2 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_2 (Corradini et al., 2010). In addition, when ash and SO_2 are collocated or when SO_2 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_2 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_2 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_2 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_2-rich cloud from the ambient atmosphere with clear boundaries and little overestimation (Figure 3).

References

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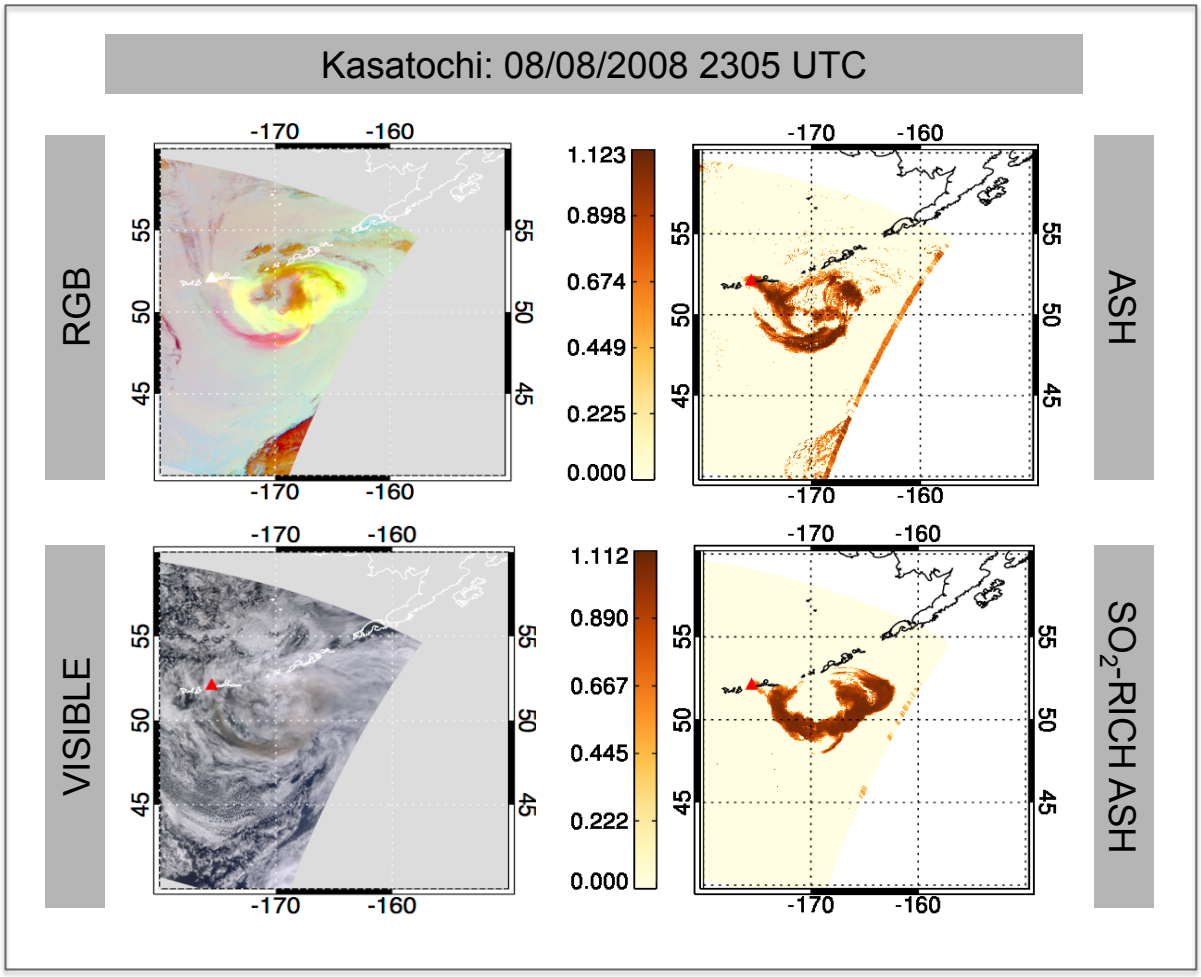

Figure 1. (Top Left) RGB created using MODIS bands 32-31, 31-29, and 31 for the eruption of Kasatochi, August 8, 2008, 2305Z; (Bottom Left) Visible image created using MODIS bands 1, 4, and 3 for the same eruption and time; (Top Right) Ash-detection neural network output for the same eruption and time; (Bottom Right) SO_2-rich-ash-detection neural network output for the same eruption and time.

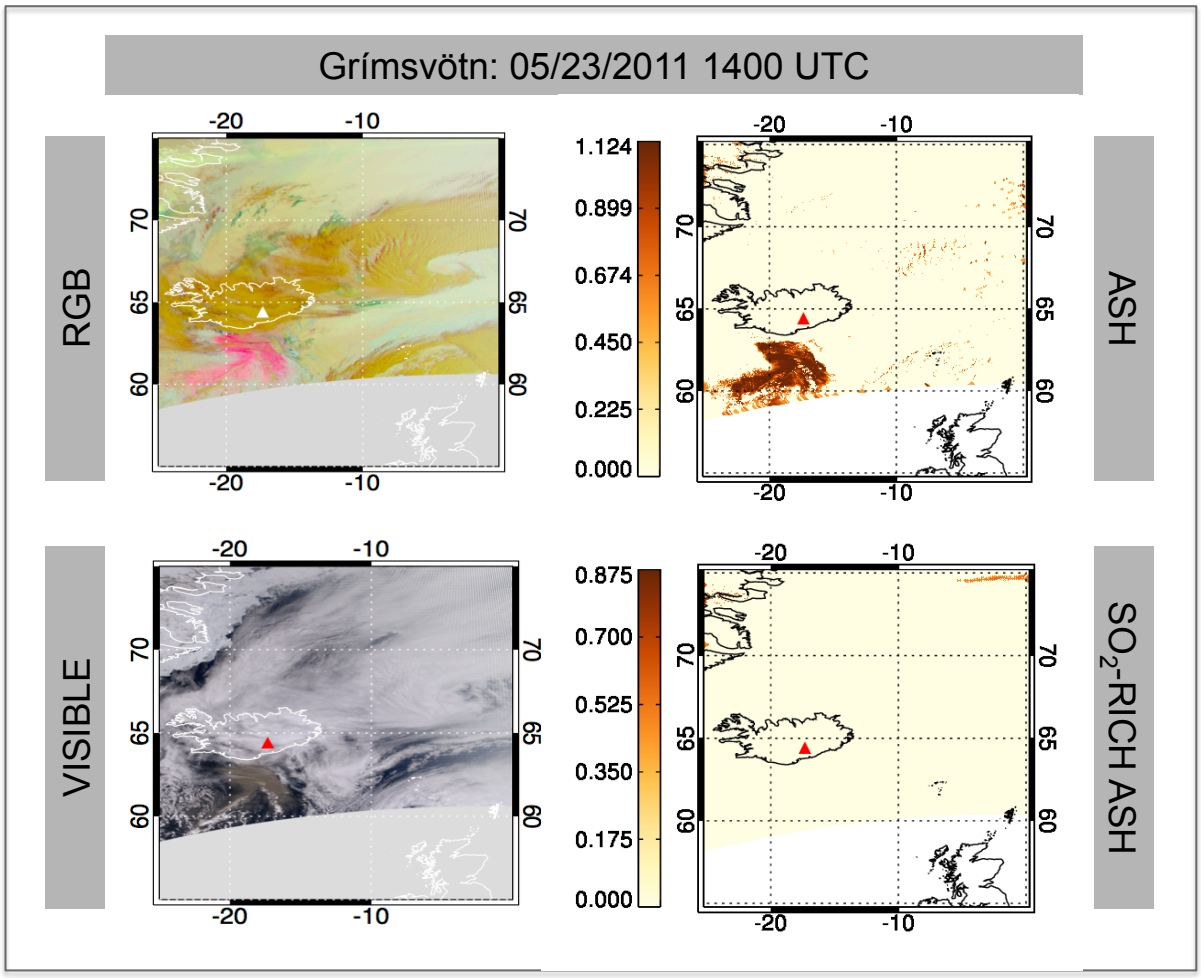

Figure 2. (Top Left) RGB created using MODIS bands 32-31, 31-29, and 31 for the eruption of Grímsvötn, May 23, 2011, 1400Z; (Bottom Left) Visible image created using MODIS bands 1, 4, and 3 for the same eruption and time; (Top Right) Ash-detection neural network output for the same eruption and time; (Bottom Right) SO_2-rich-ash-detection neural network output for the same eruption and time.

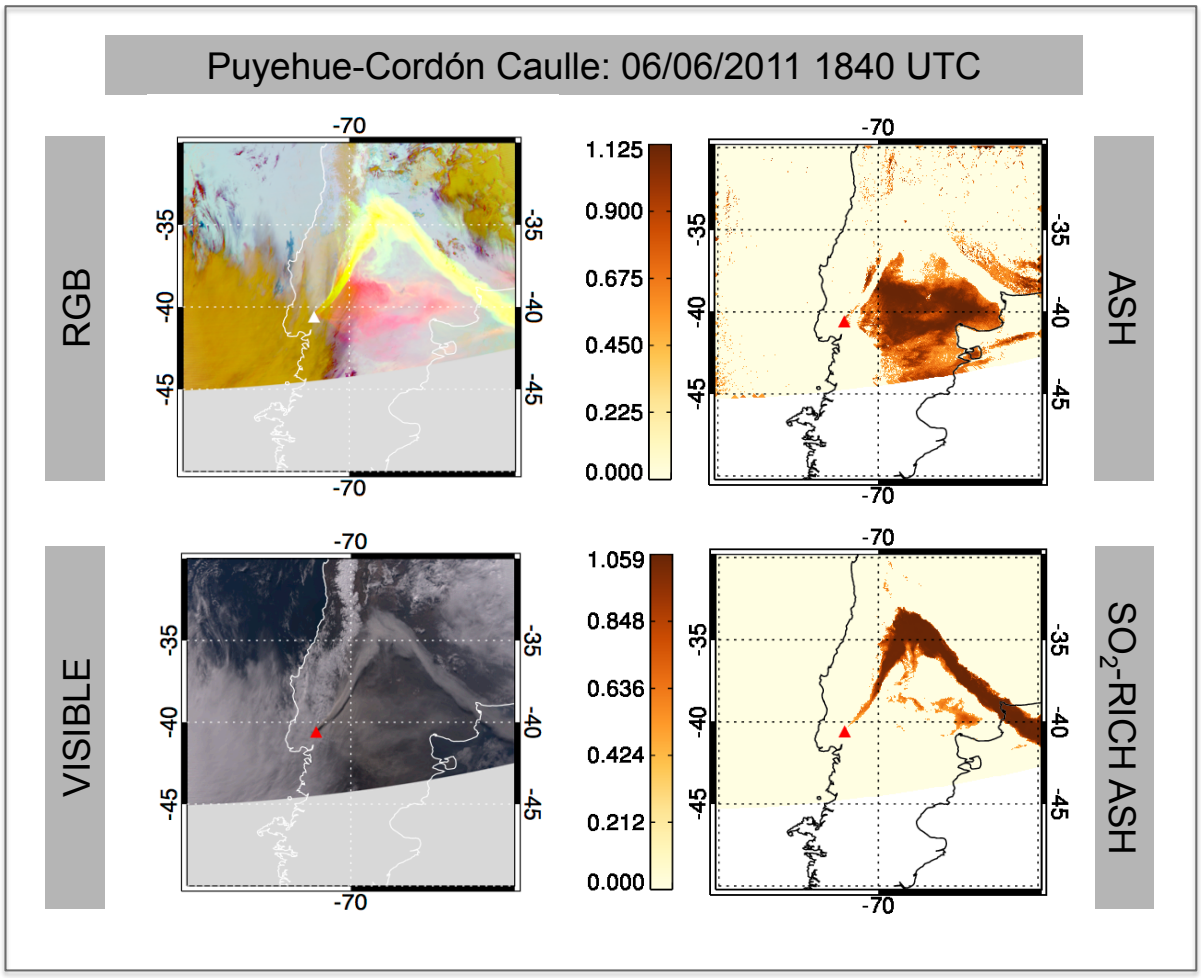

Figure 3. (Top Left) RGB created using MODIS bands 32-31, 31-29, and 31 for the eruption of Puyehue-Cordón Caulle, June 6, 2011, 1840Z; (Bottom Left) Visible image created using MODIS bands 1, 4, and 3 for the same eruption and time; (Top Right) Ash-detection neural network output for the same eruption and time; (Bottom Right) SO_2-rich-ash-detection neural network output for the same eruption and time.