Numerical Simulation of Volcanic Ash Plume Dispersal from Kelud Volcano in Indonesia on 13 February 2014

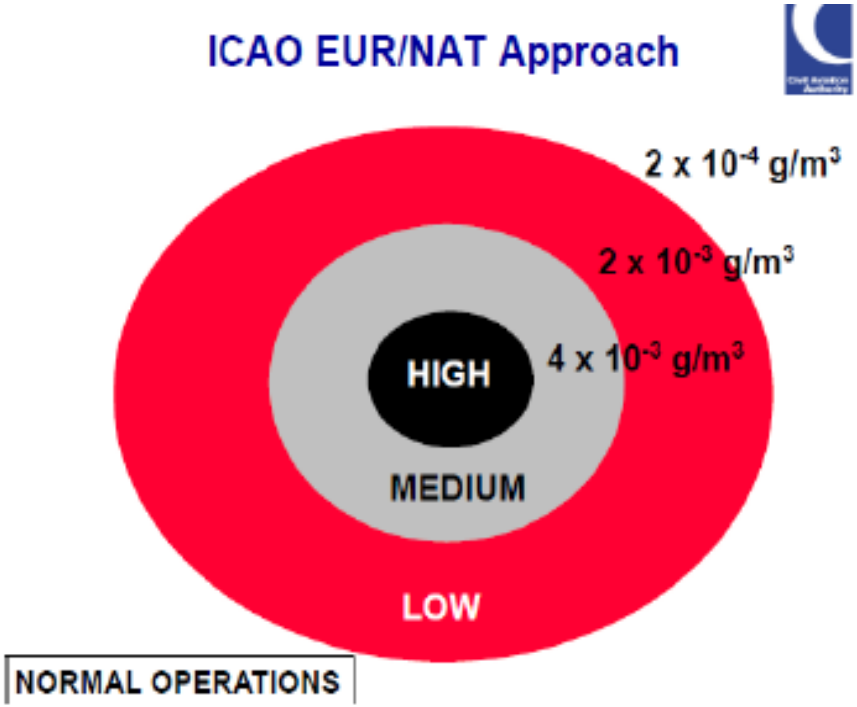
Hiroshi L. Tanaka (University of Tsukuba, Japan)
Masato Iguchi (Kyoto University, Japan)
Setsuya Nakada (University of Tokyo, Japan)

Gunung Kelud Volcano
S07° 56′ 10 latitude
112° 18′ 50 longitude
1731 m altitude

Eruption started at
2014/2/13 22:50 LTC
2014/2/13 15:50 UTC

17.056 km initial plume height
2.17×10^7 ton/hr emission rate

Volcanic Ash and Aviation Safety



■: No Fly Zone (NFZ) > 4mg / m^3

■: Enhanced Procedure Zone (EPZ; Prior Permission)
2～4mg / m^3

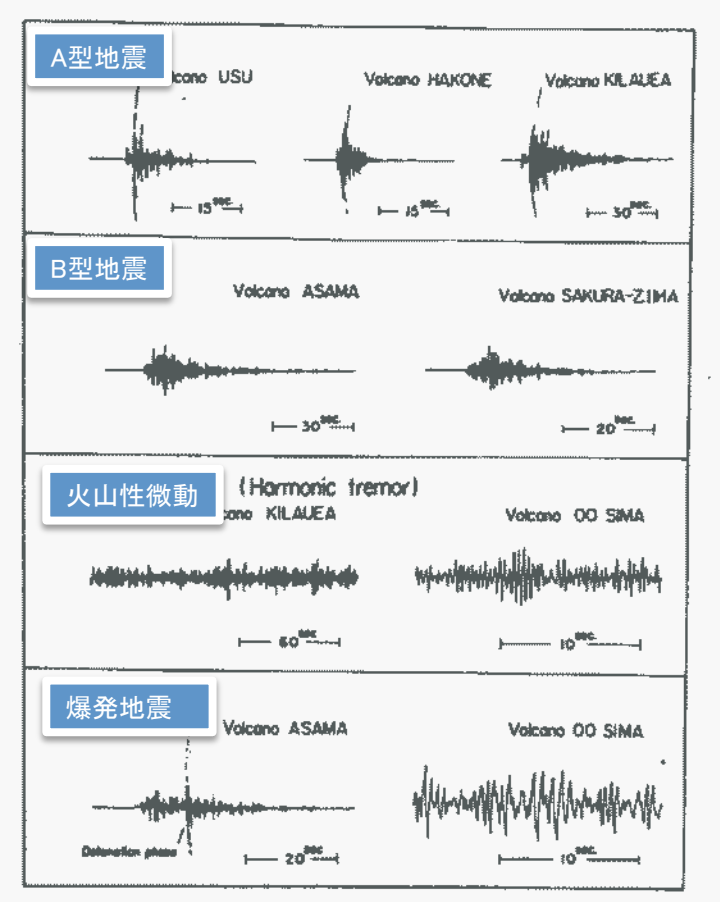
■: Enhanced Procedure Zone (EPZ; Time limited)
0.2～2 mg / m^3

□: Normal Zone < 0.2 mg / m^3

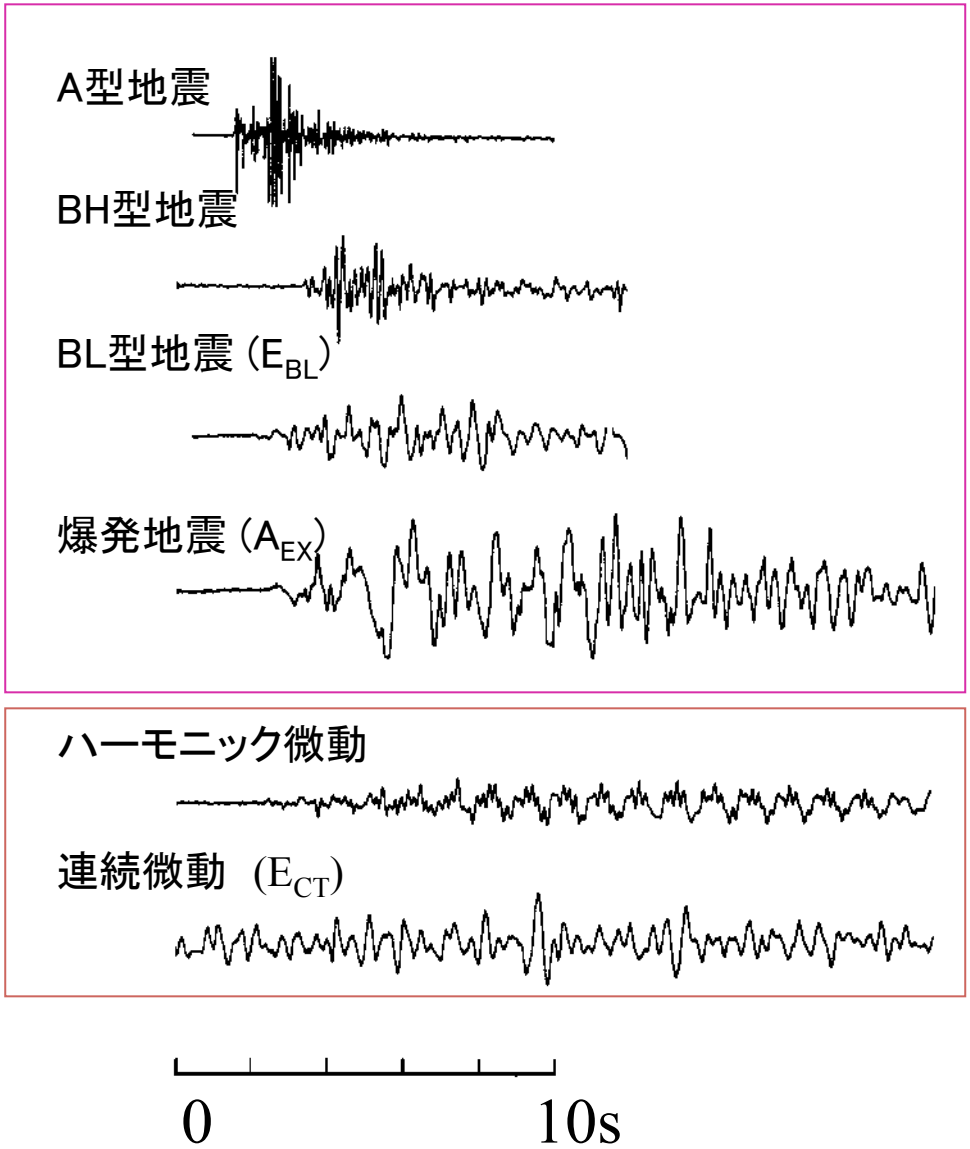
Kelud Eruption Data provided by Dr. Iguchi

Local time	Emission（ton/hr）	Plume height（m）	Accumulation (ton)
（UTC+7 hr）			
2014/2/13 23:00	2.17E+07	17,056	2.2E+07
2014/2/14 00:00	1.41E+07	15,321	3.6E+07
2014/2/14 01:00	9.39E+06	13,839	4.5E+07
2014/2/14 02:00	6.37E+06	12,562	5.2E+07
2014/2/14 03:00	4.41E+06	11,453	5.6E+07
2014/2/14 04:00	3.09E+06	10,486	5.9E+07
2014/2/14 05:00	2.21E+06	9,636	6.1E+07
2014/2/14 06:00	1.60E+06	8,885	6.3E+07
2014/2/14 07:00	1.17E+06	8,219	6.4E+07
2014/2/14 08:00	8.65E+05	7,625	6.5E+07
2014/2/14 09:00	6.48E+05	7,093	6.6E+07

Seismic Record of Eruption



Minakami (1974)



Estimation formulae for emission rate

$$V = k\,(E_{CT} + \beta E_{BL} + \varepsilon A_{EX}^{2})$$

V : Emission rate（10^4 ton）

E_{CT} : Energy for continuous tremor

E_{BL} : Energy for BL type tremor

A_{EX} : Amplitude of explosive tremor

k : Coefficient for energy

β : Coefficient for BL type

ε : Coefficient for explosive type

$$V = 0.0018\,(E_{CT} + 0.08E_{BL} + 0.16A_{EX}^{2})$$

PUFF model

Particle tracking Lagrangian

Volcanos in Alaska

Governing Equation

$$r\downarrow i\,(0)= S,\ \ i=1 \sim M \quad (\mathrm{t}=0),\quad Sz(t)=z2-(z2-z1)\exp(-t/t0\,)$$

$$r\downarrow i\,(t+\Delta t)= r\downarrow i\,(t)+V\,\Delta t+D\,\Delta t+G\,\Delta t \quad (i=1 \sim M,\ t>0)$$

$r\downarrow i\,(t)$: position vector of *i*-th particle at time *t*

Δt : time step of the model (5 min)

M : total number of particle

$V=(u, v, w\,)$: wind velocity by GPV/JMA

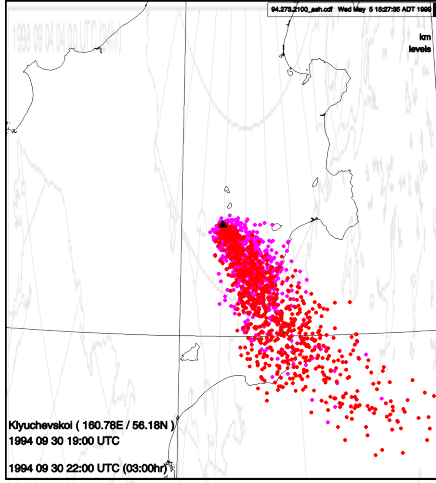
$D=(c\downarrow h\,, c\downarrow h\,, c\downarrow v\ )$, diffusion speed $c\downarrow h\,' = c\downarrow h$

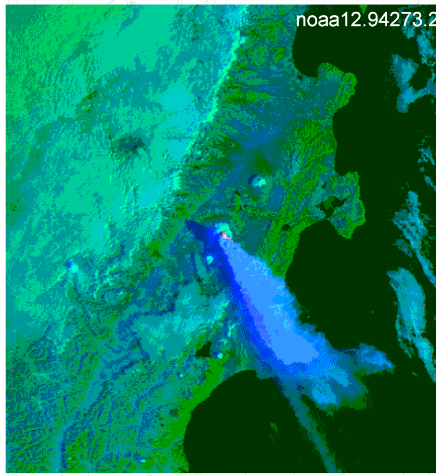
1. Puff Simulation using default values
   Horiz. dispersion = 20,000
   Vertical dispersion = 10
   Height = 16 km
   Mean Particle size = 0.01 mm (10 um)

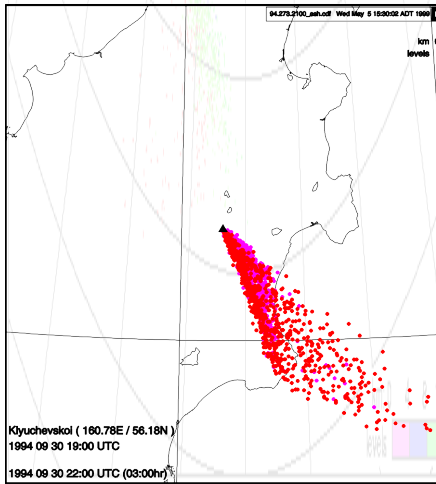
2. Validation of Puff Model:
   AVHRR Satellite image of volcanic cloud
   (Kliuchevskoi V. 1994)

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



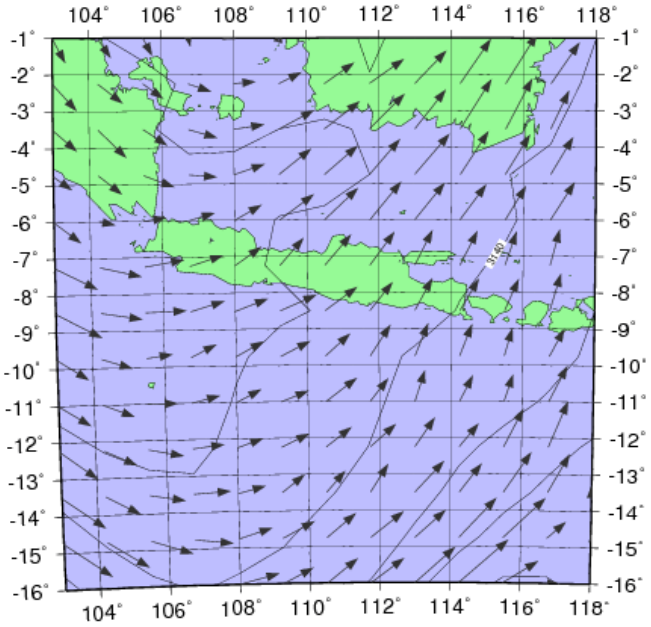




Wind Vector (700 hPa)

GPV/JMA 201404418

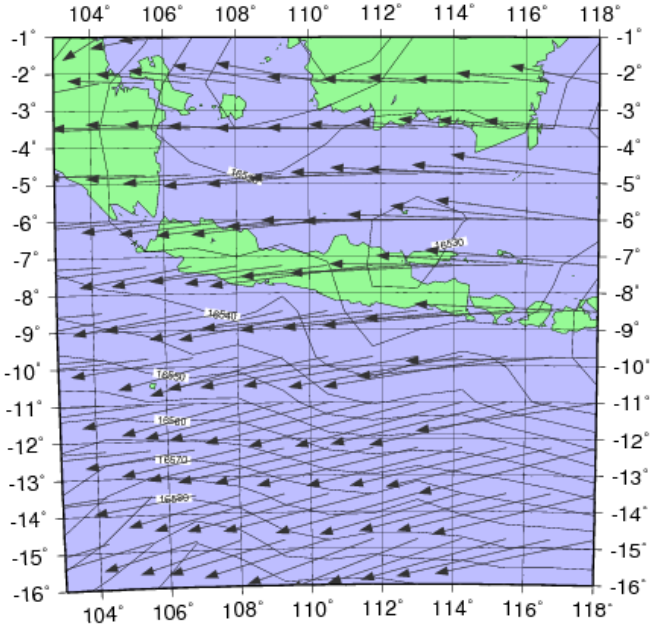
Scale: 10 m/s



Wind Vector (100 hPa)

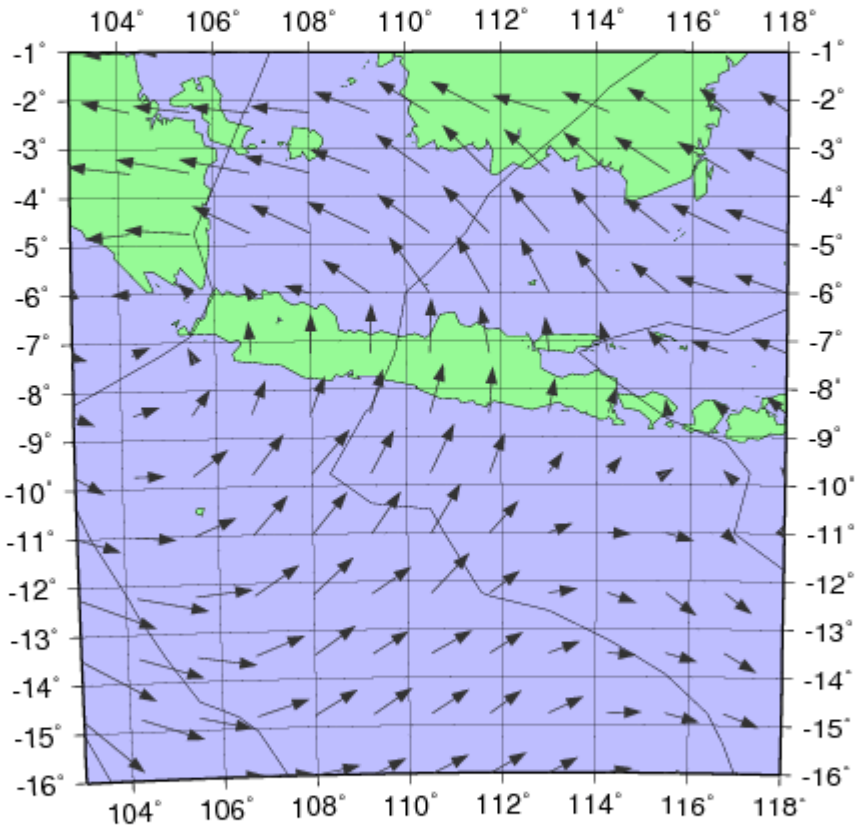
GPV/JMA 201404418

Scale: 10 m/s



Wind Vector (500 hPa)

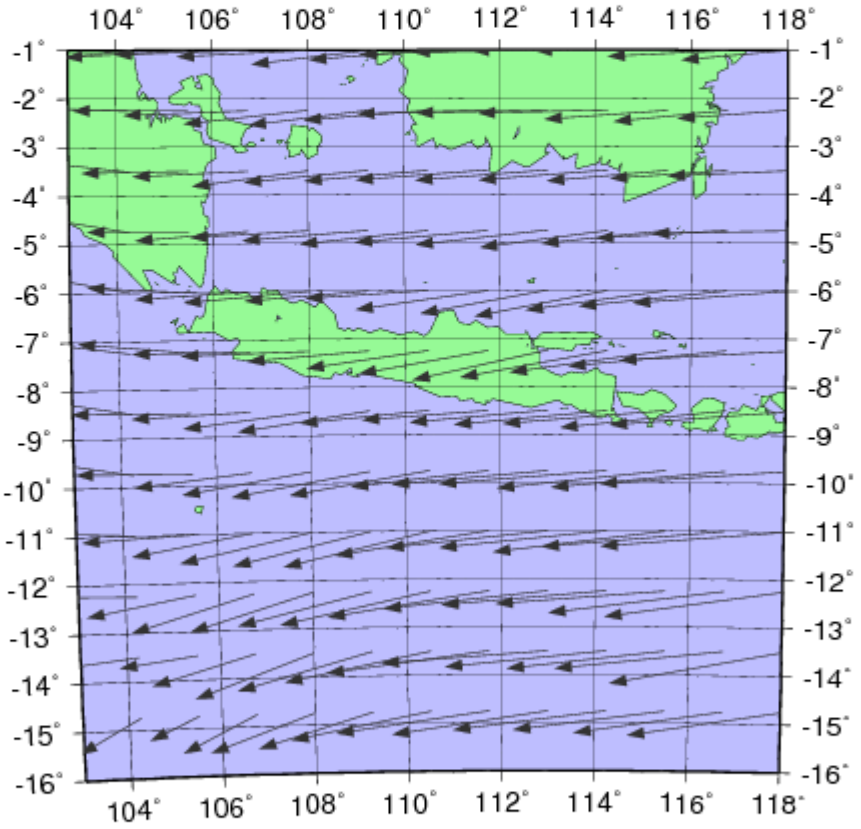
GPV/JMA 201404400



Wind Vector (100 hPa)

GPV/JMA 201404400

Animation of wind

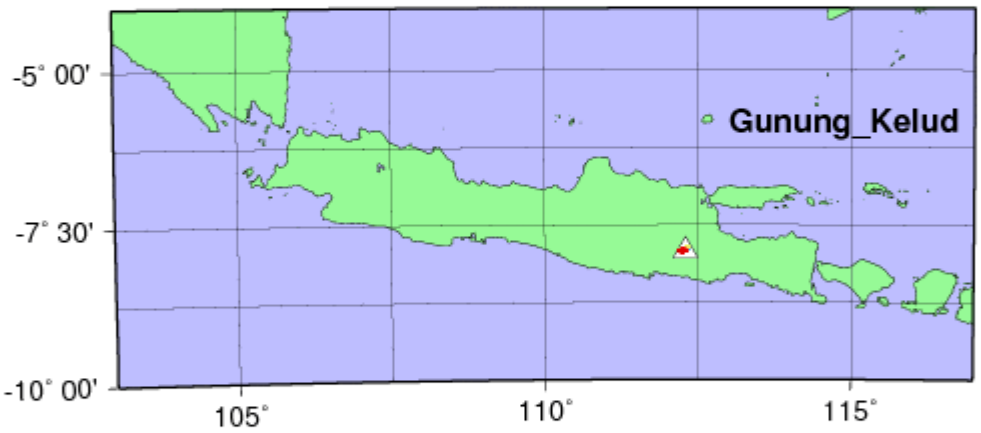


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +1 hours

Plume Height (feet)

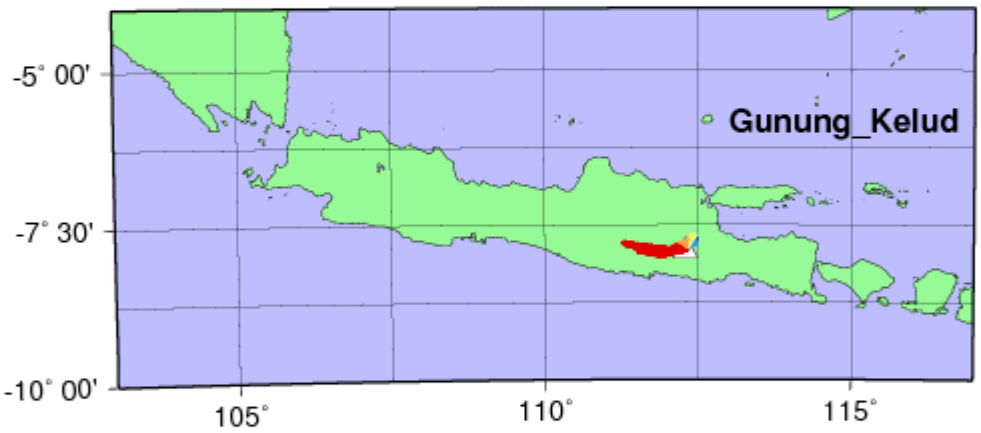


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +2 hours

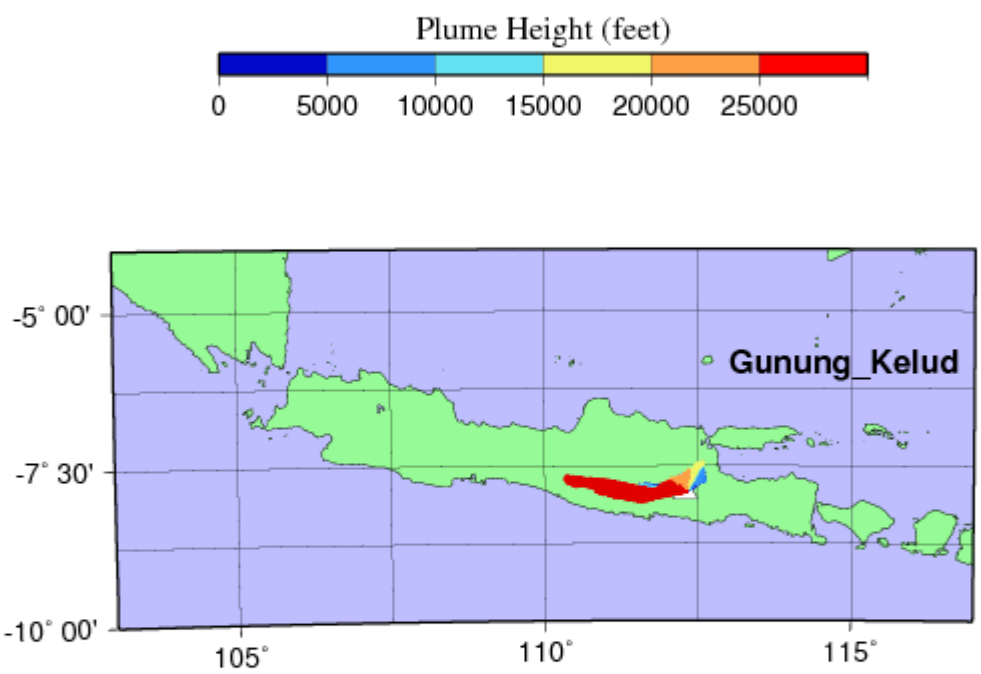
Plume Height (feet)



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

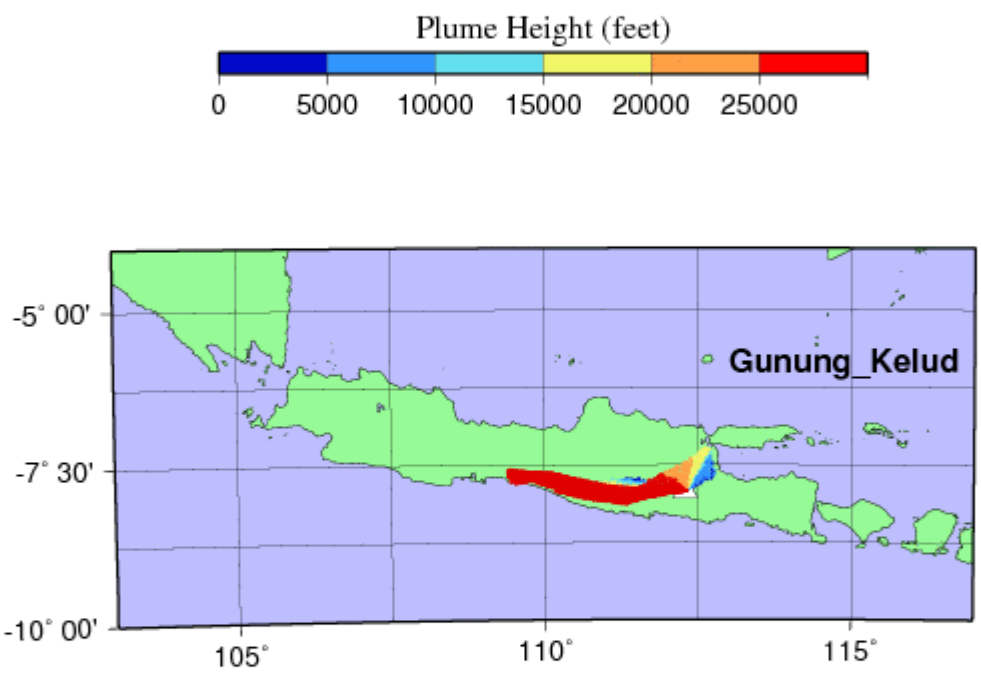
Prediction: +3 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

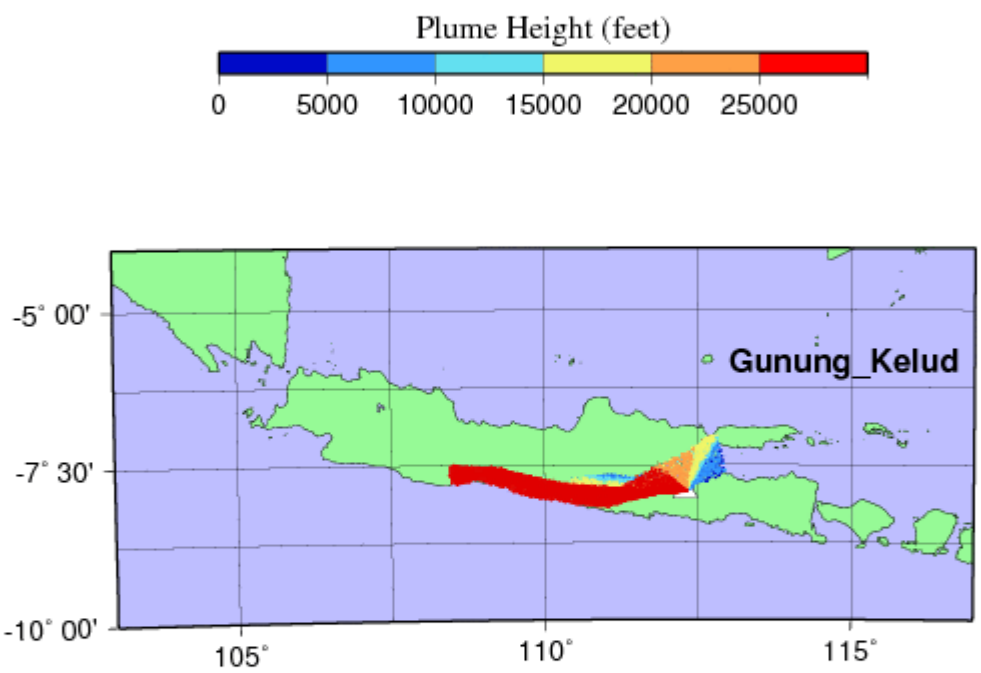
Prediction: +4 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

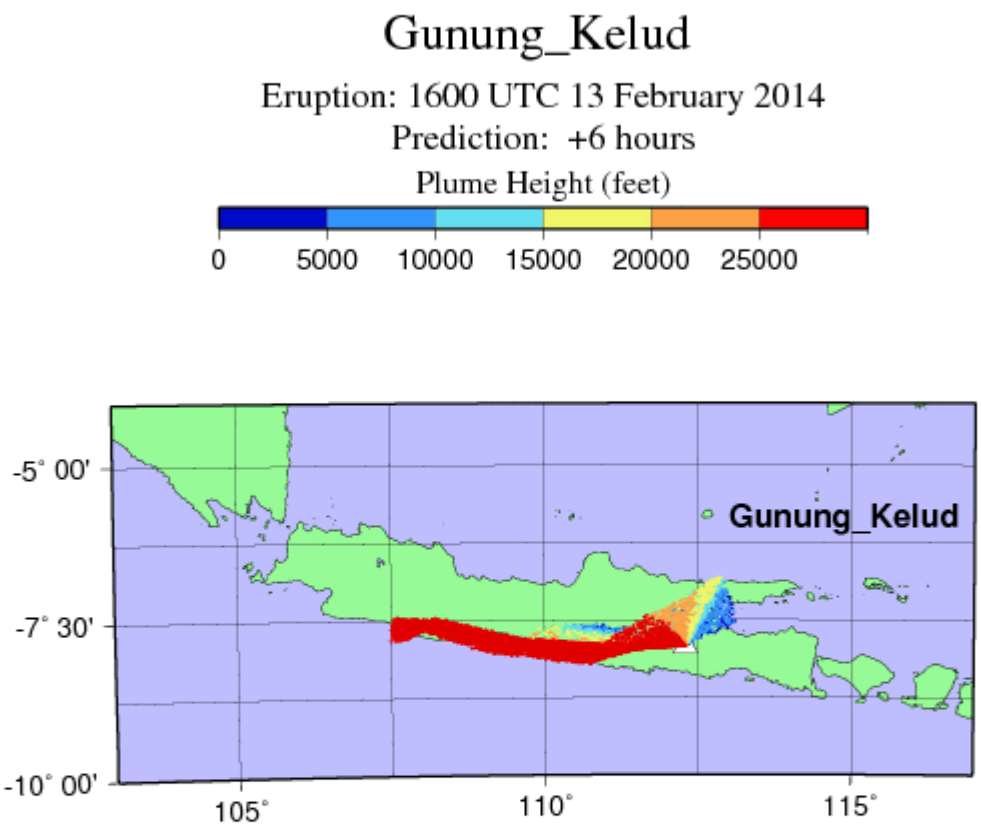
Prediction: +5 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

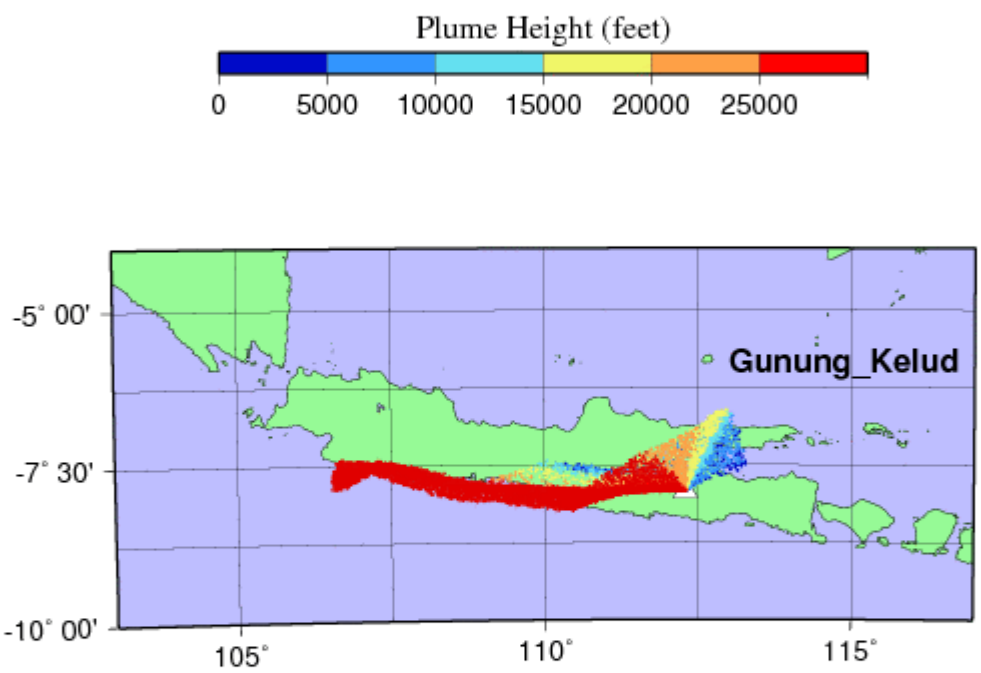
Prediction: +6 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

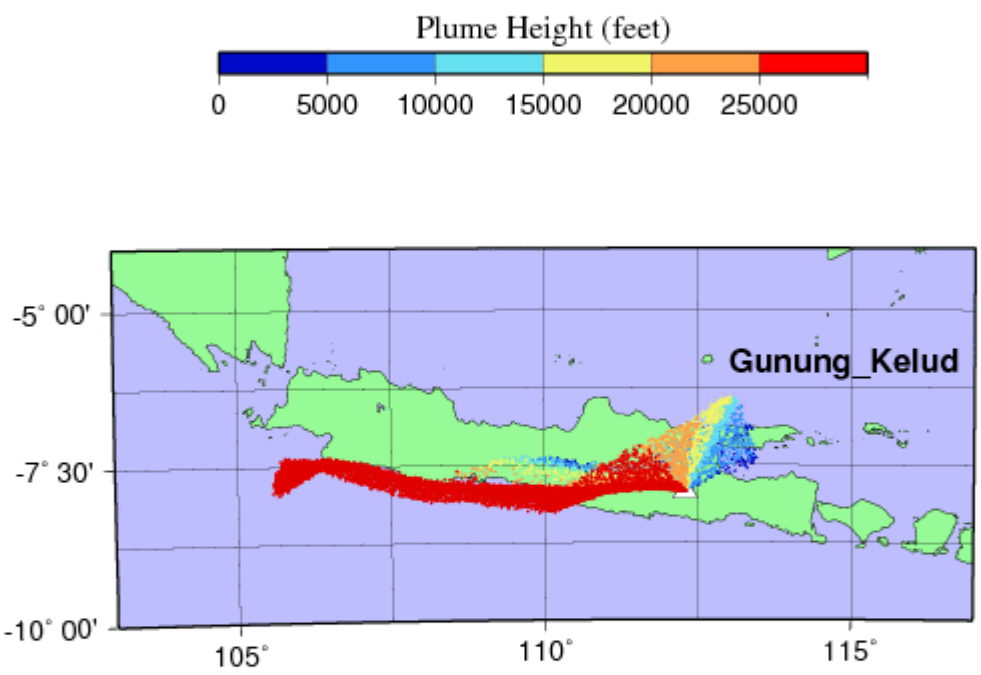
Prediction: +7 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

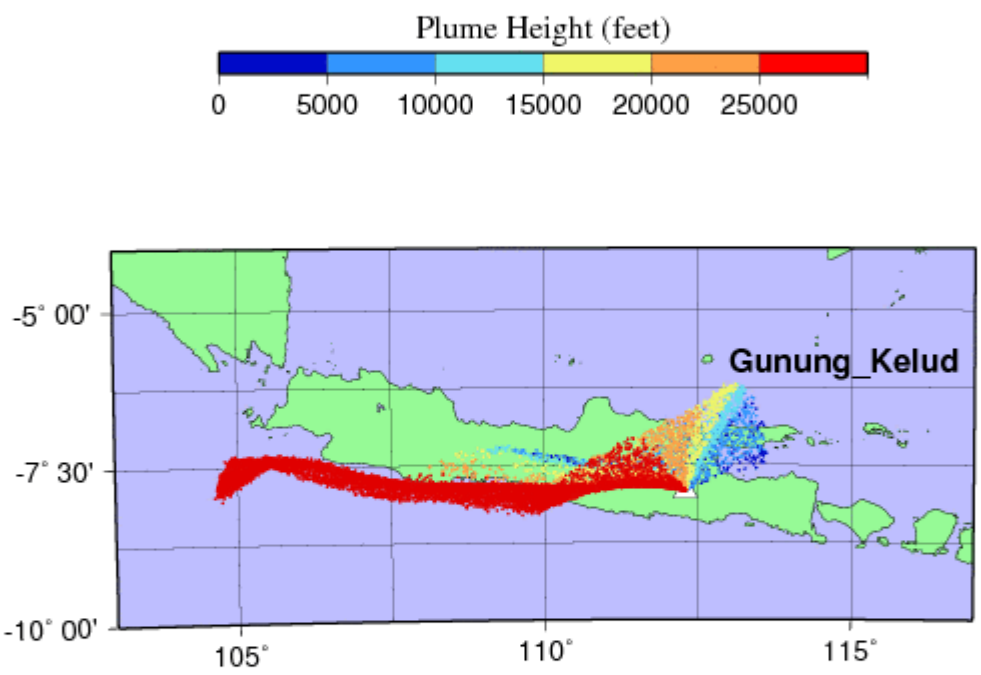
Prediction: +8 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +9 hours

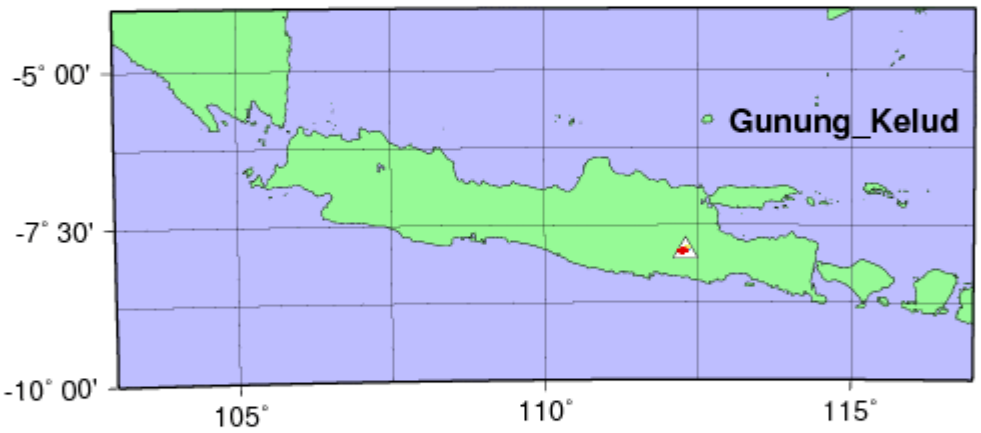


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +1 hours

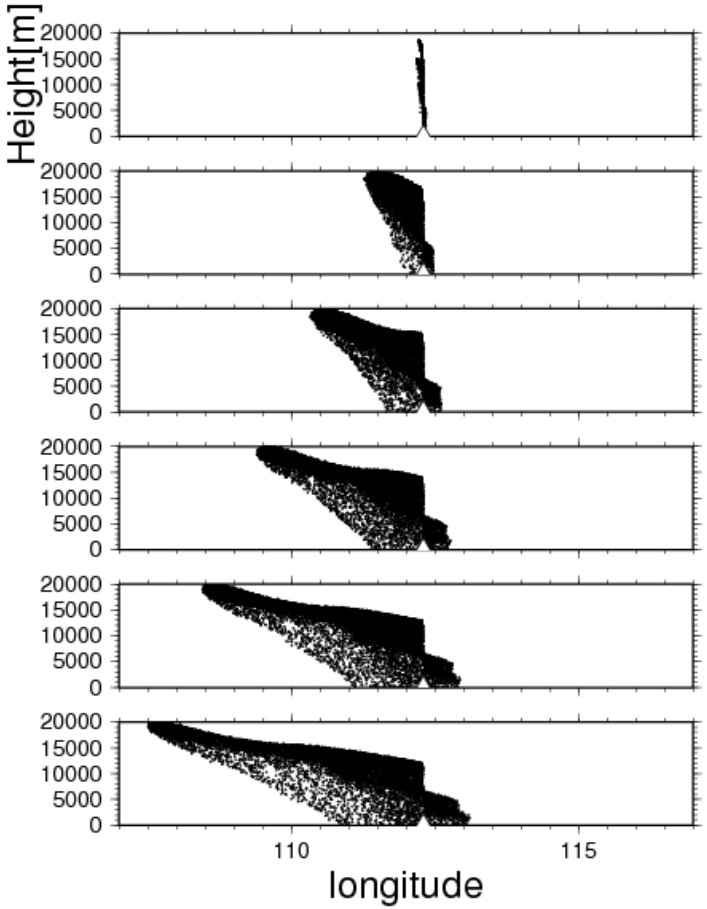
Plume Height (feet)



X-Z section for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

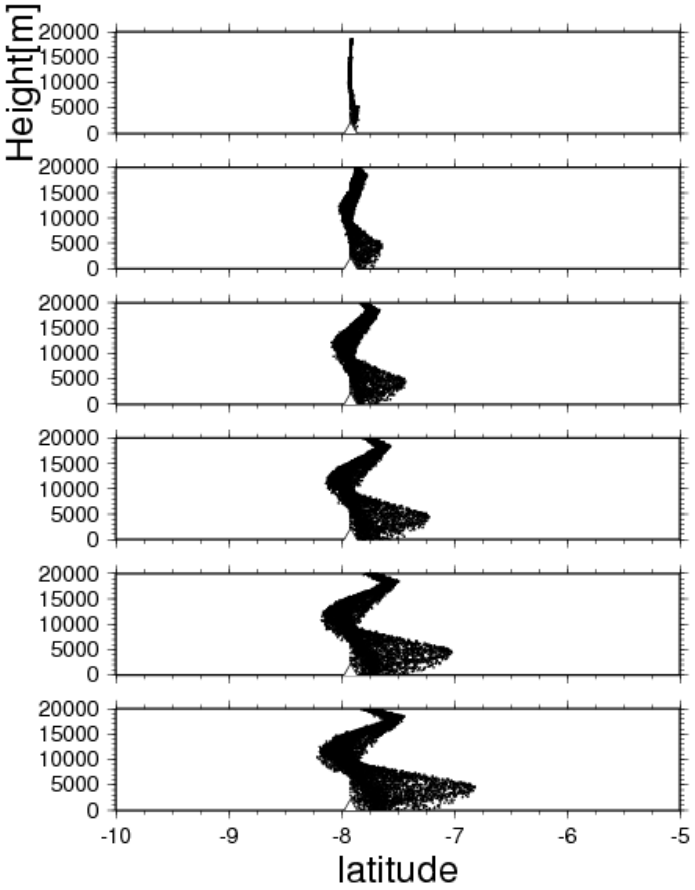
Prediction: Every one hour from eruption



Y-Z section for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

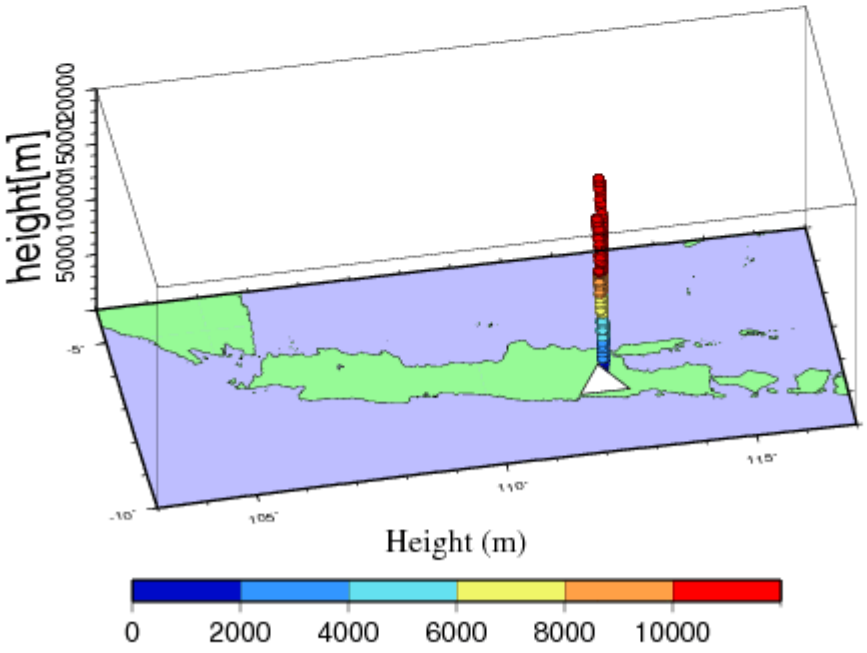
Prediction: Every one hour from eruption



3-D image for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +1 hours

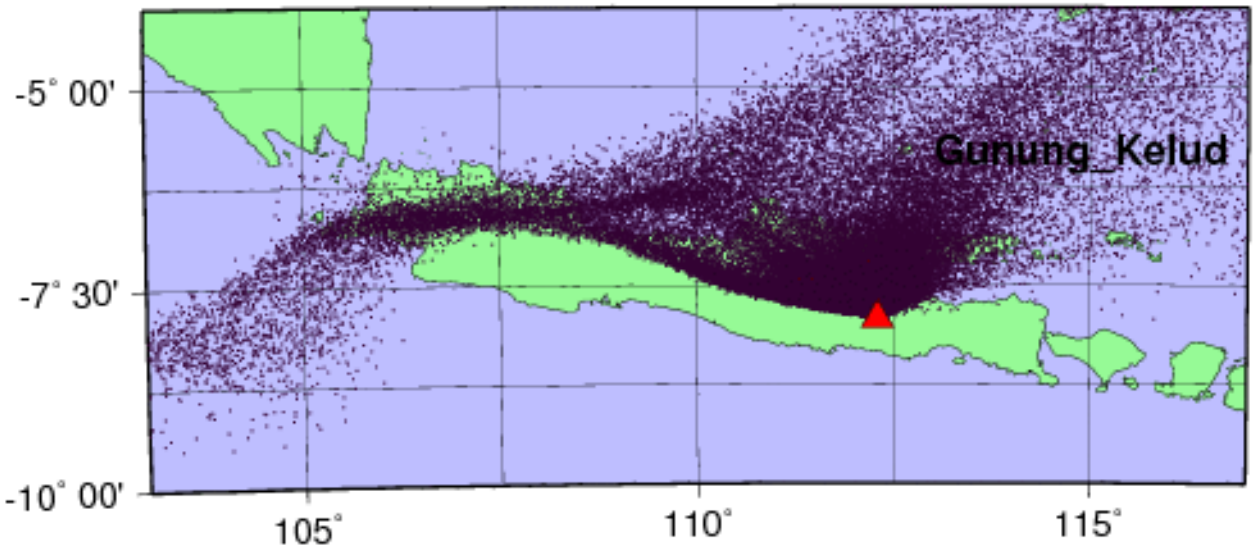


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Duration: + 56 hours

Ash Fallout

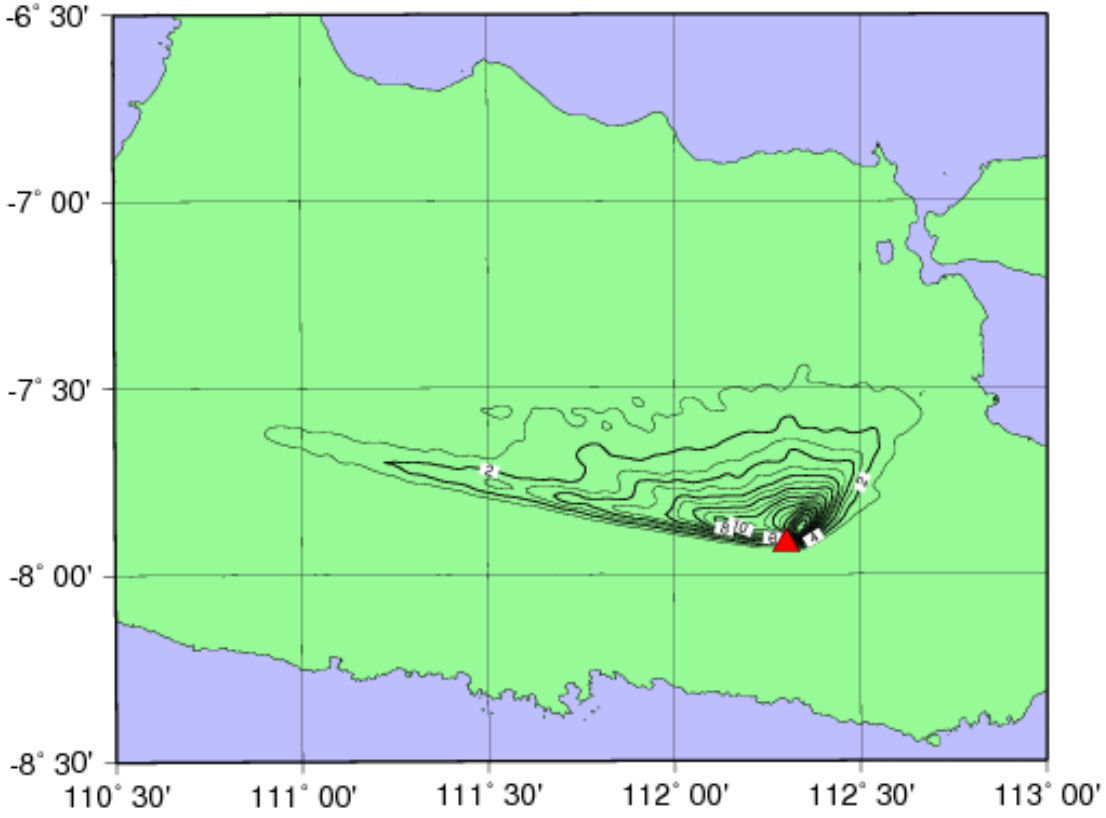


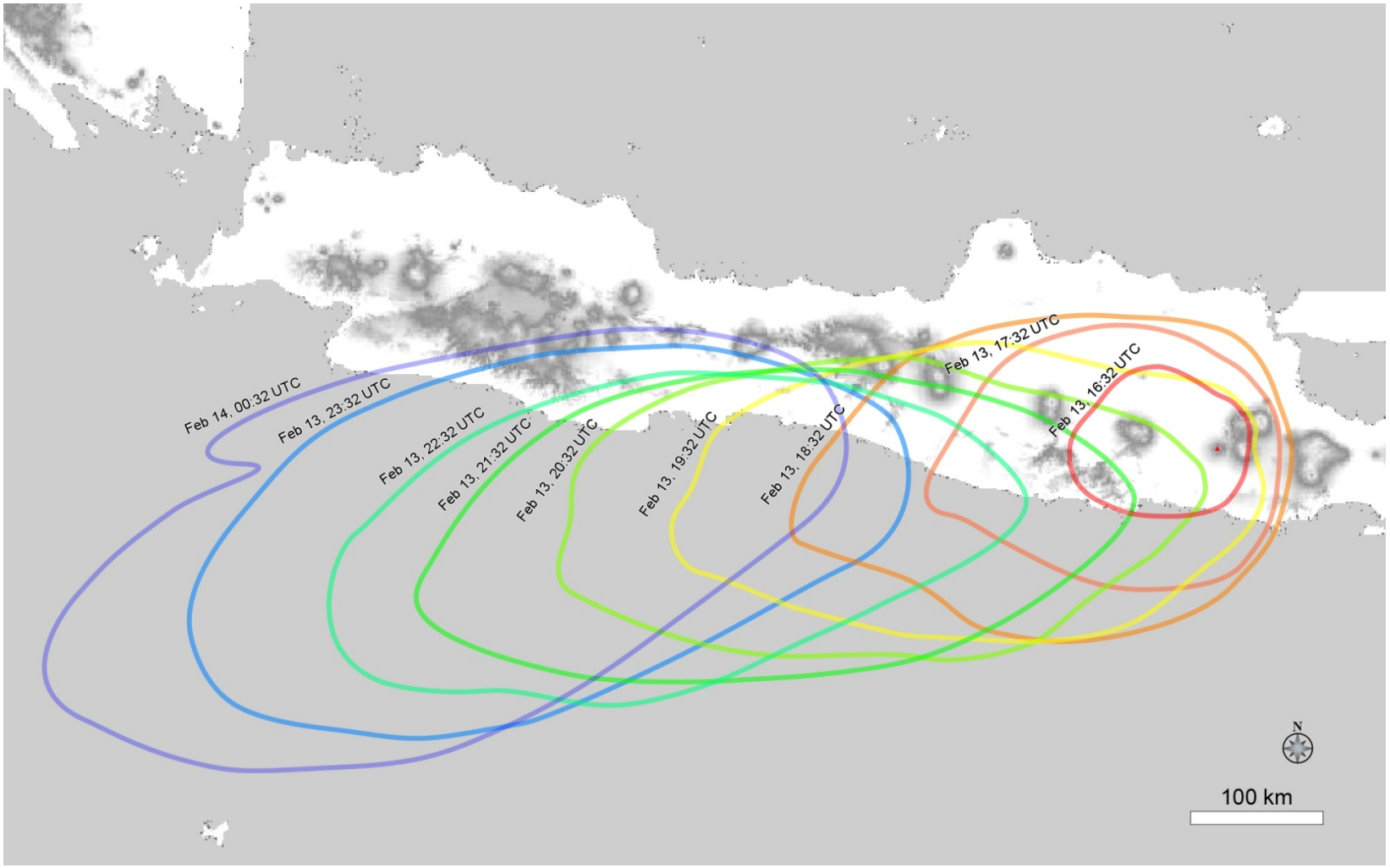
Gunung_Kelud

Eruption: 16:00 UTC 13 February 2014

Duration: +56 hours (Kg/m2)

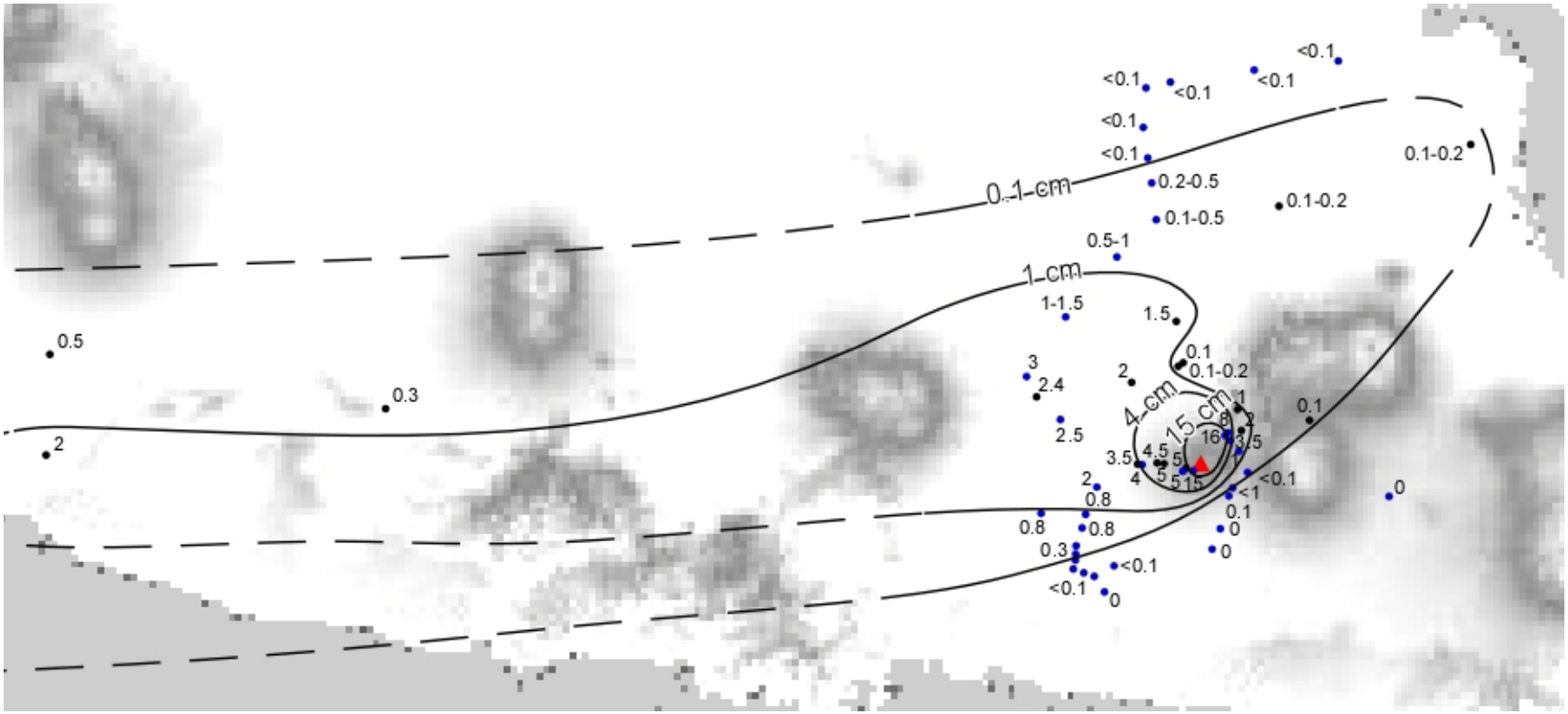
Ash Fallout





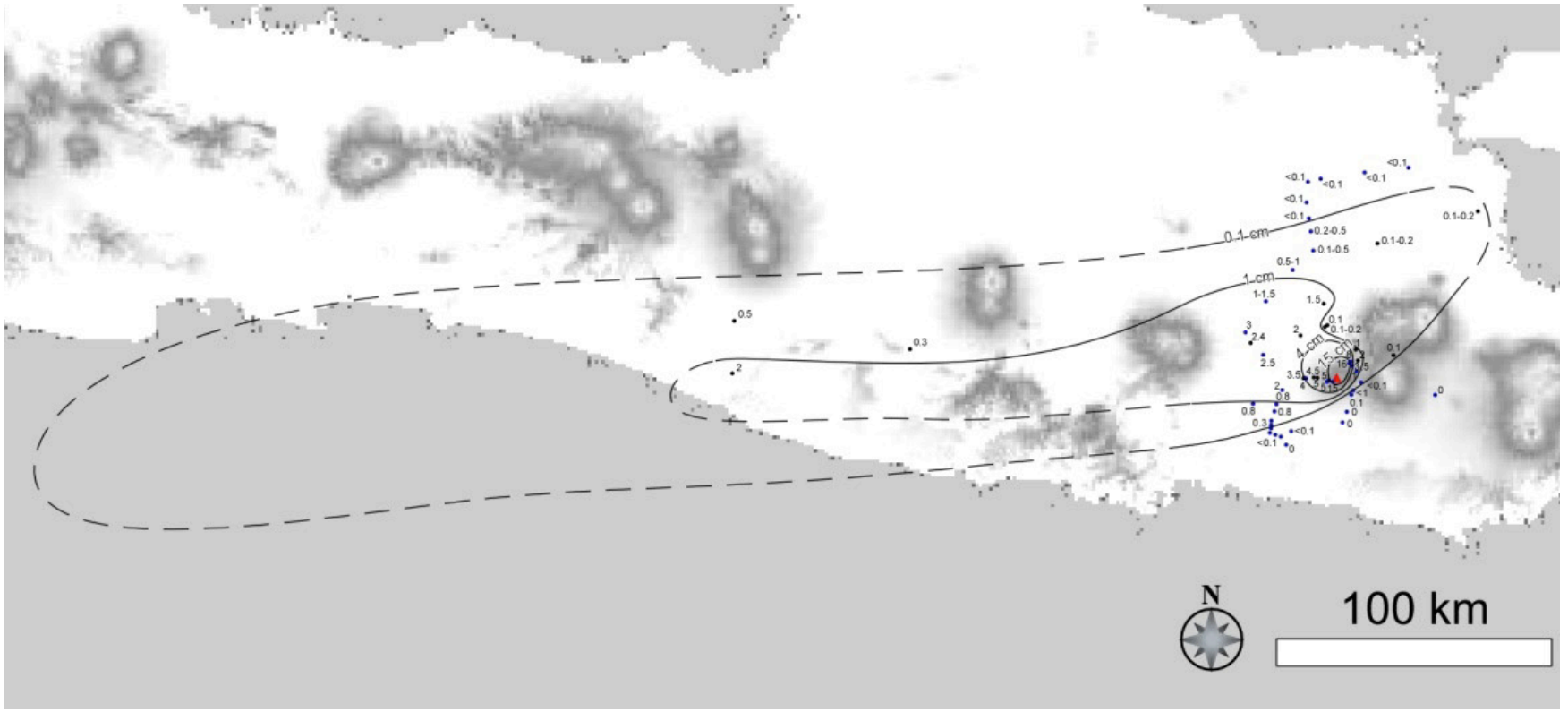
Sequence of tephra dispersal from the Kelud volcano, produced based on satellite images by JMA. (by F. Maeno and others, under preparation)

Isopach maps of fallout tephra



Contours (0.1, 1, 4, 5 cm) are made based on geological survey and hearing.
(by F. Maeno and others, under preparation)

Isopach maps of fallout tephra

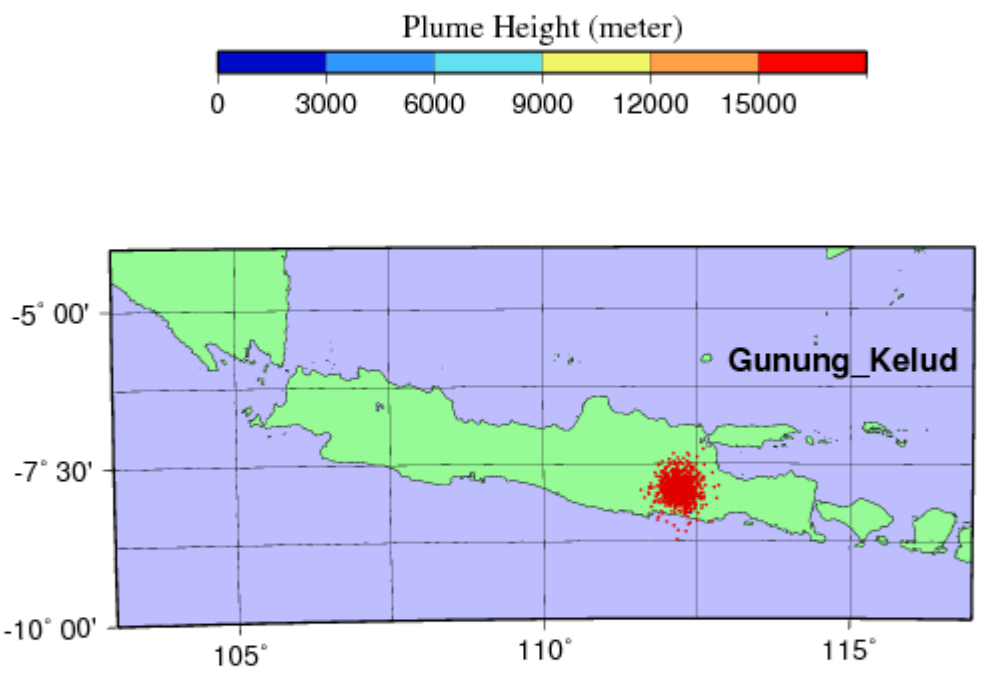


Contours (0.1, 1, 4, 5 cm) are made based on geological survey and hearing.
(by F. Maeno and others, under preparation)

Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

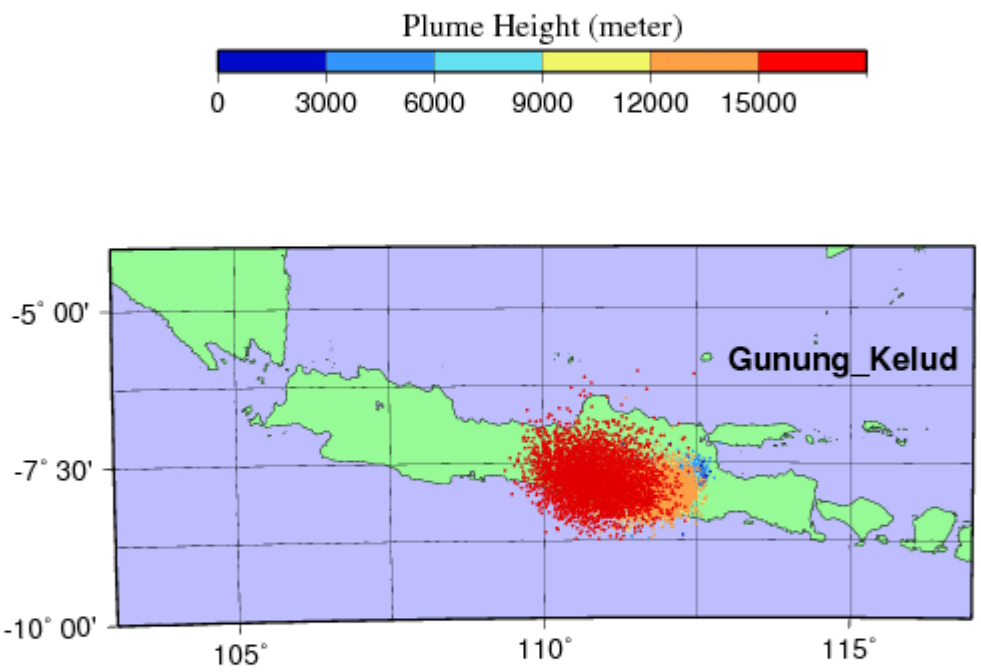
Prediction: +1 hours



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +3 hours

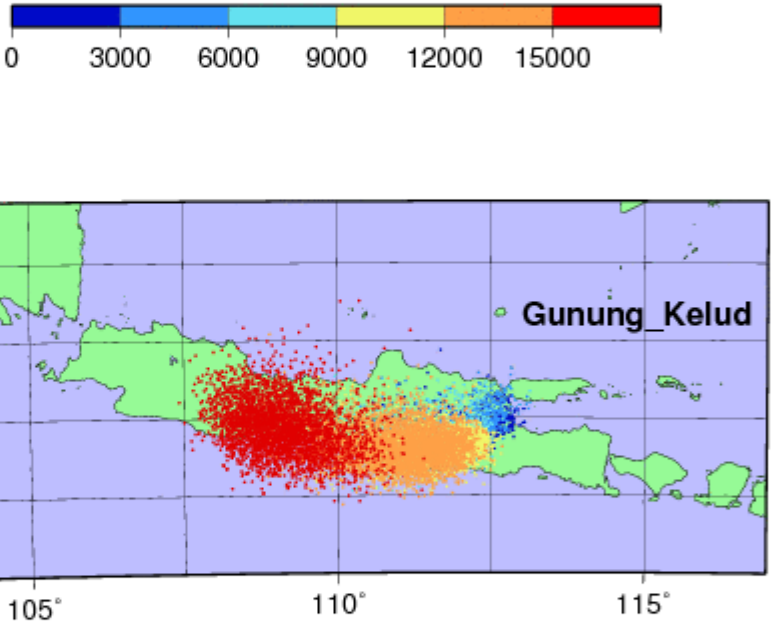


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +5 hours

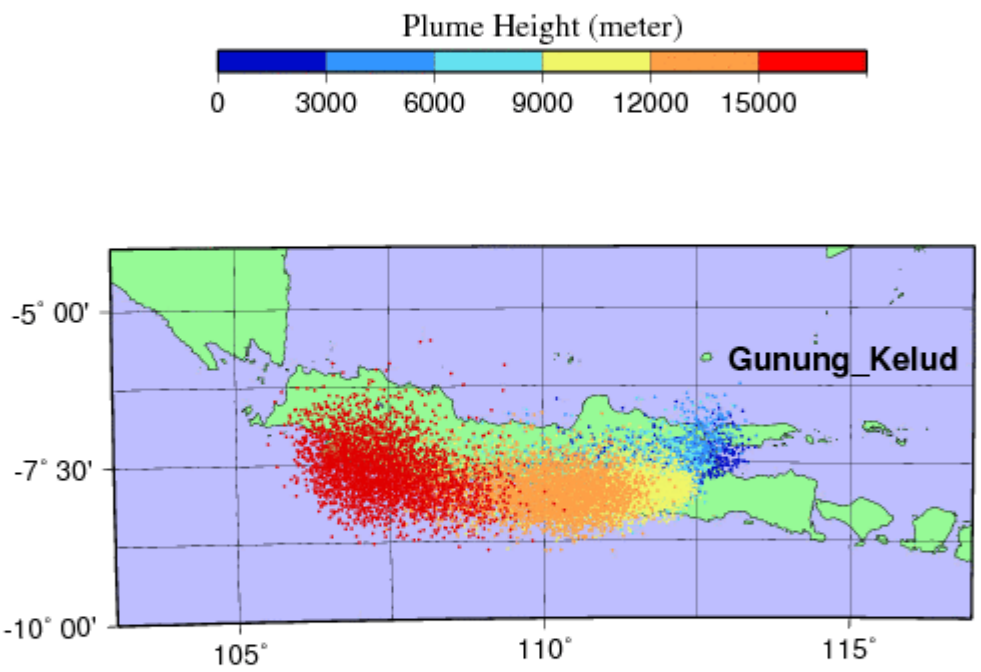
Plume Height (meter)



Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +7 hours

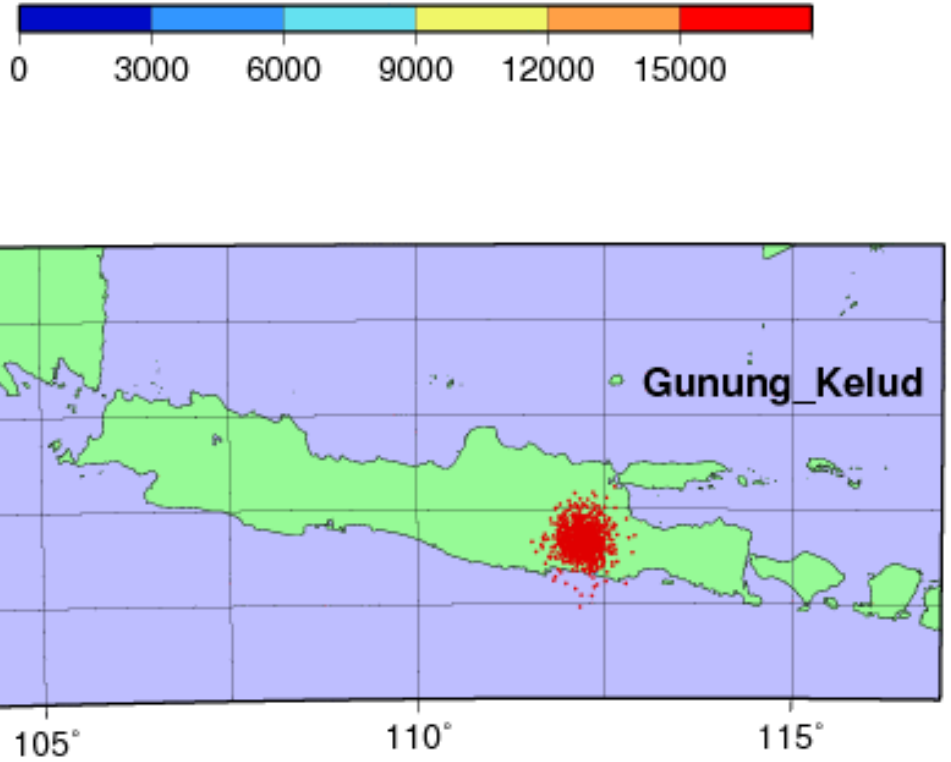


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +1 hours

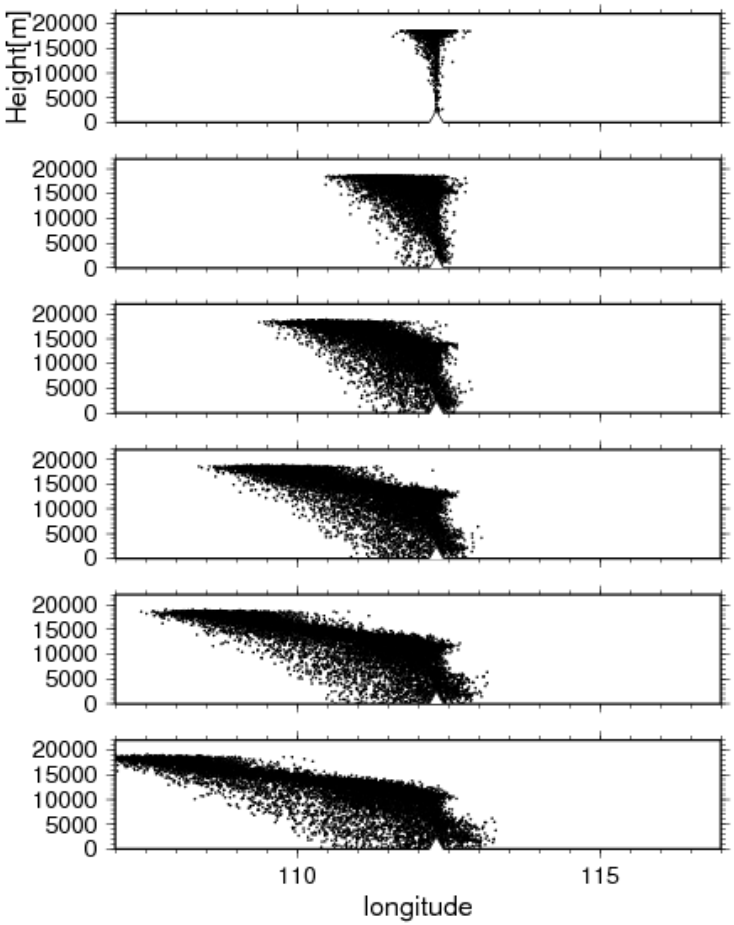
Plume Height (meter)



X-Z section for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

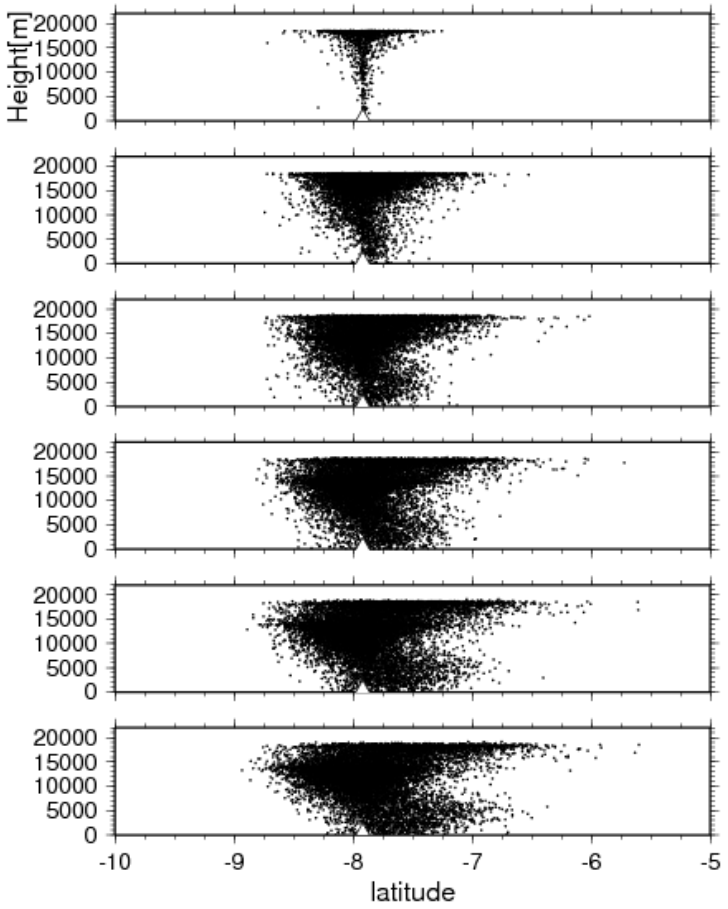
Prediction: Every one hour from eruption



Y-Z section for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: Every one hour from eruption

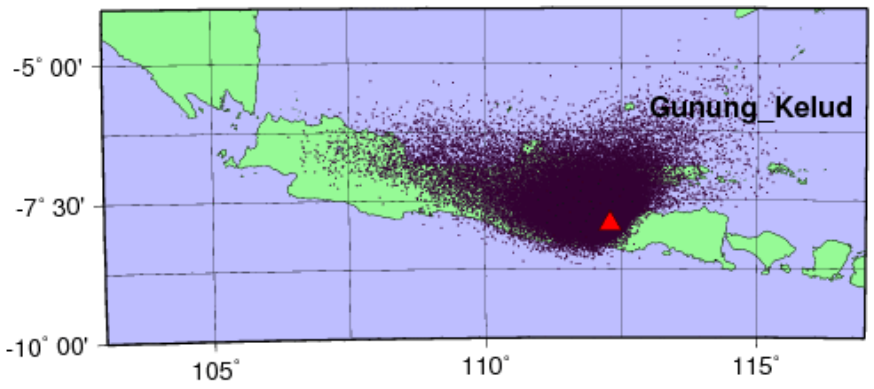


Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Duration: + 56 hours

Ash Fallout

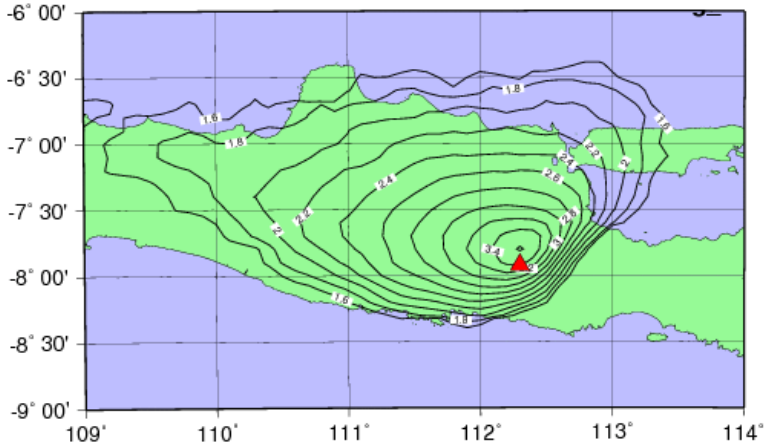


Gunung_Kelud

Eruption: 16:00 UTC 13 February 2014

Duration: +56 hours

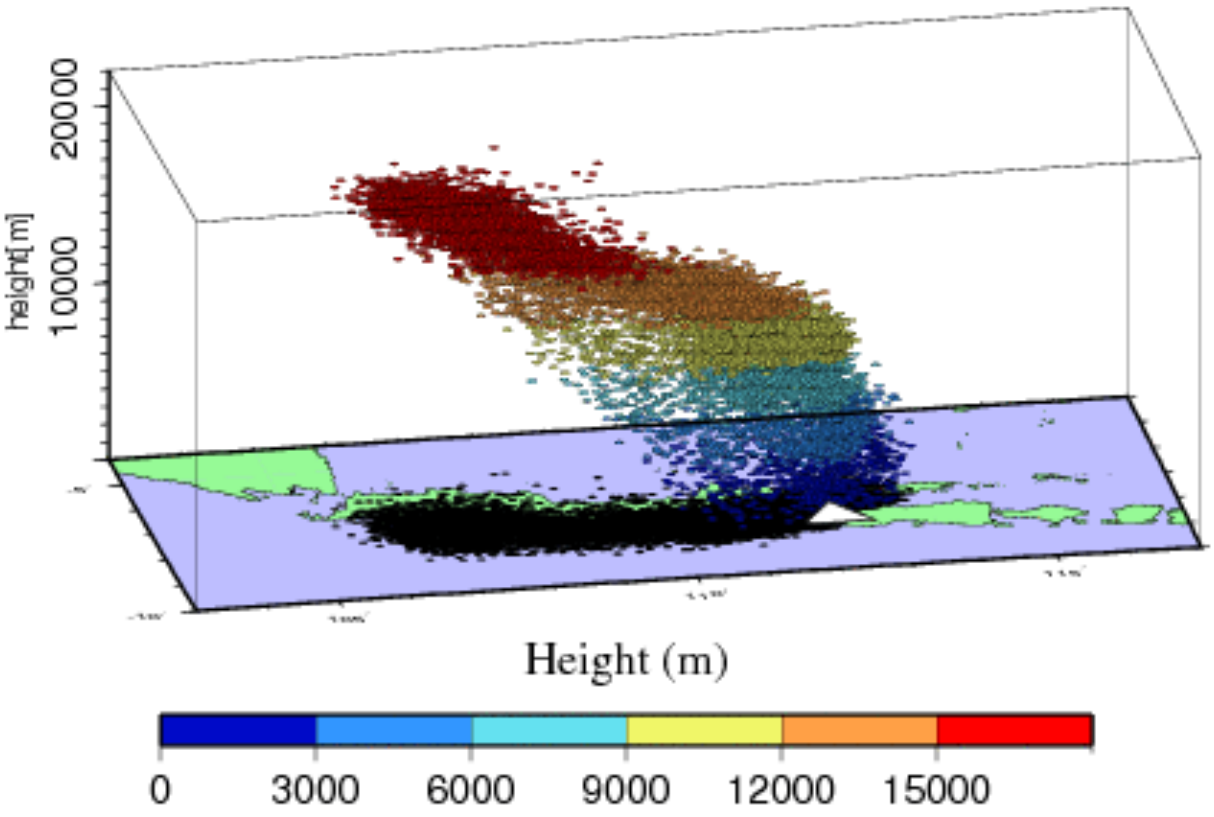
Ash Fallout log10(g/m2)



3-D image for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

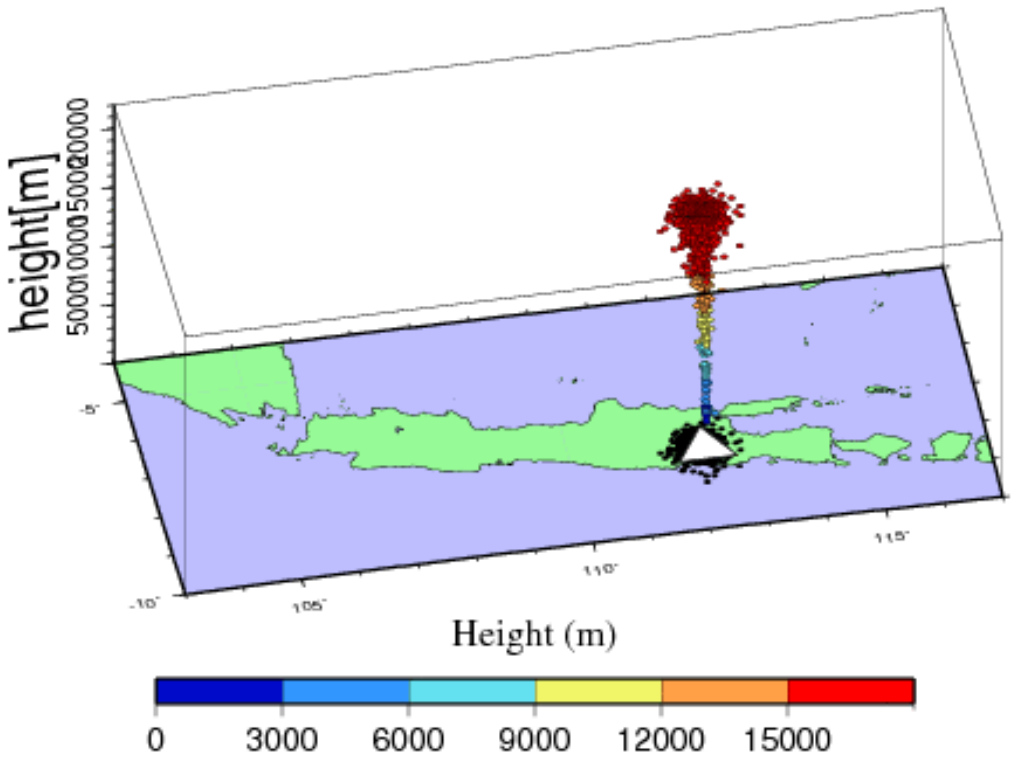
Prediction: +7 hours



3-D image for Gunung_Kelud

Eruption: 1600 UTC 13 February 2014

Prediction: +1 hours

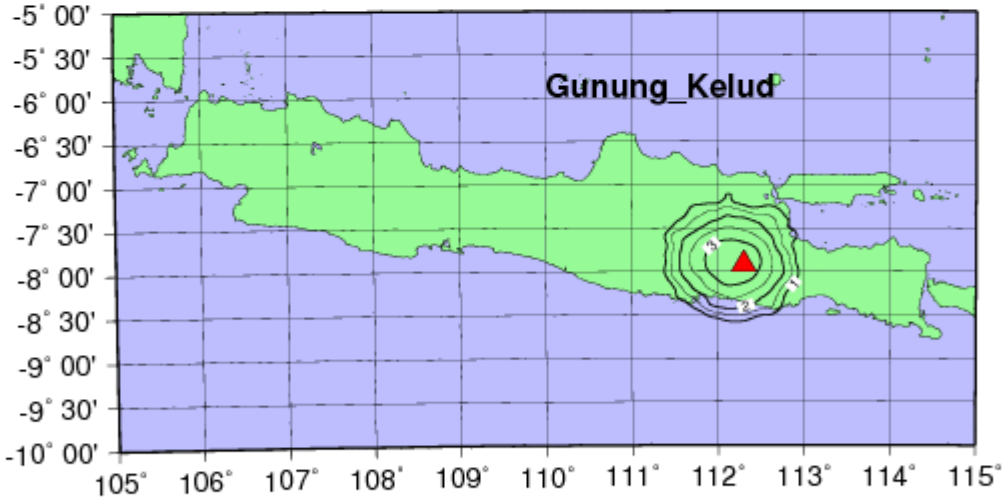


Gunung_Kelud

Eruption: 16:00 UTC 13 February 2014

Prediction : 1 hour

Maximum density log10(mg/m3)

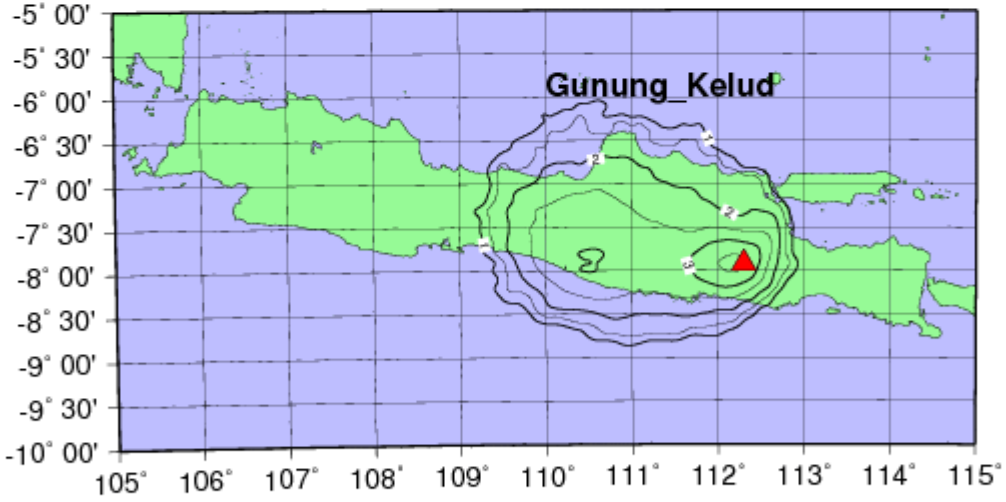


Gunung_Kelud

Eruption: 16:00 UTC 13 February 2014

Prediction : 3 hour

Maximum density log10(mg/m3)

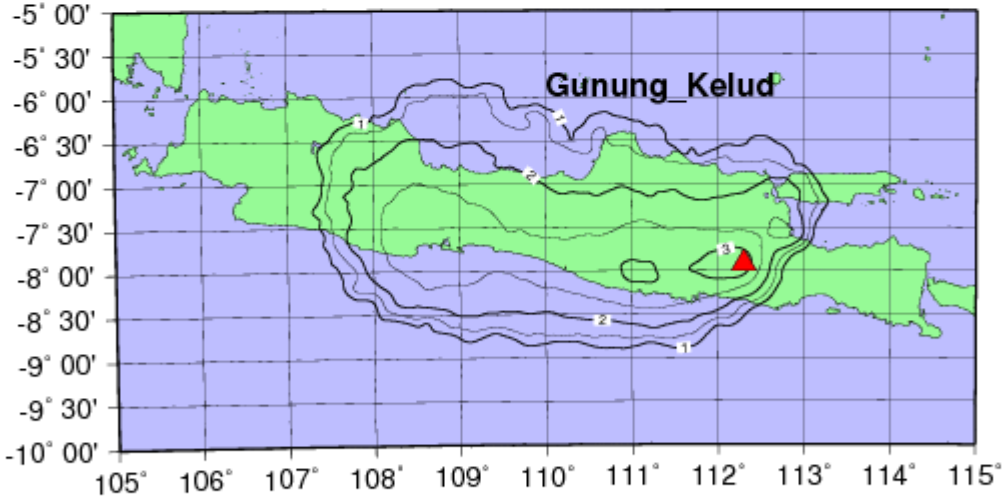


Gunung_Kelud

Eruption: 16:00 UTC 13 February 2014

Prediction : 5 hour

Maximum density log10(mg/m3)

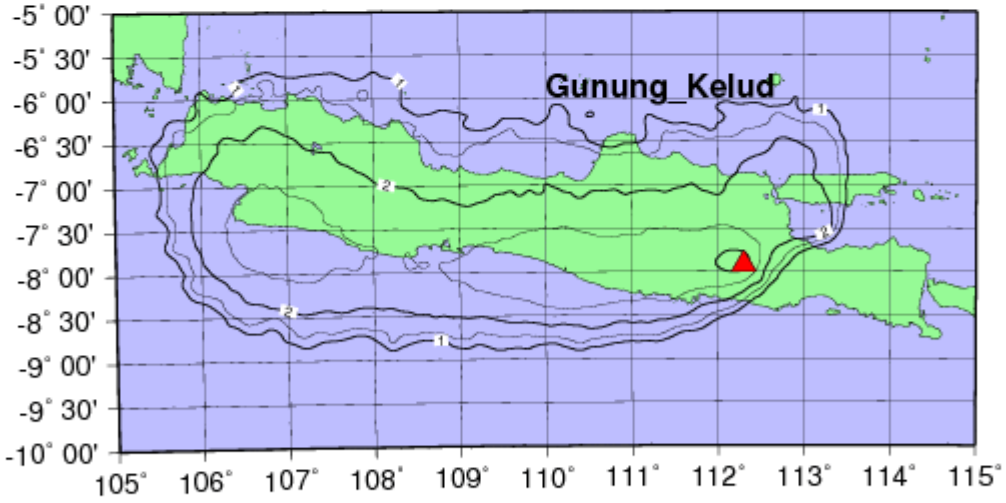


Gunung_Kelud

Eruption: 16:00 UTC 13 February 2014

Prediction : 7 hour

Maximum density log10(mg/m3)



Summary

1. PUFF model is applied to Kelud volcano
2. Max particles: 5000/5min = 60000/hr
3. Emission rate: 2.17×10^{7} ton/hr, 360 ton/particle
4. Fallout mass : 2.858×10^{7} ton
5. Fallout of 100 g/m^{2} extended to 200 km in west
6. Airborne ash of 4.0 mg/m^{3} is identified
7. Initial umbrella shape is parameterized
8. Wind data is most sensitive to the prediction