

The Tephra2 simulation code

Eruption Parameters
Particle Parameters
Atmospheric Parameters
Fallout (Grid) Parameters

Advection
Diffusion

Mass per Unit
Area
WT.% Phi Size

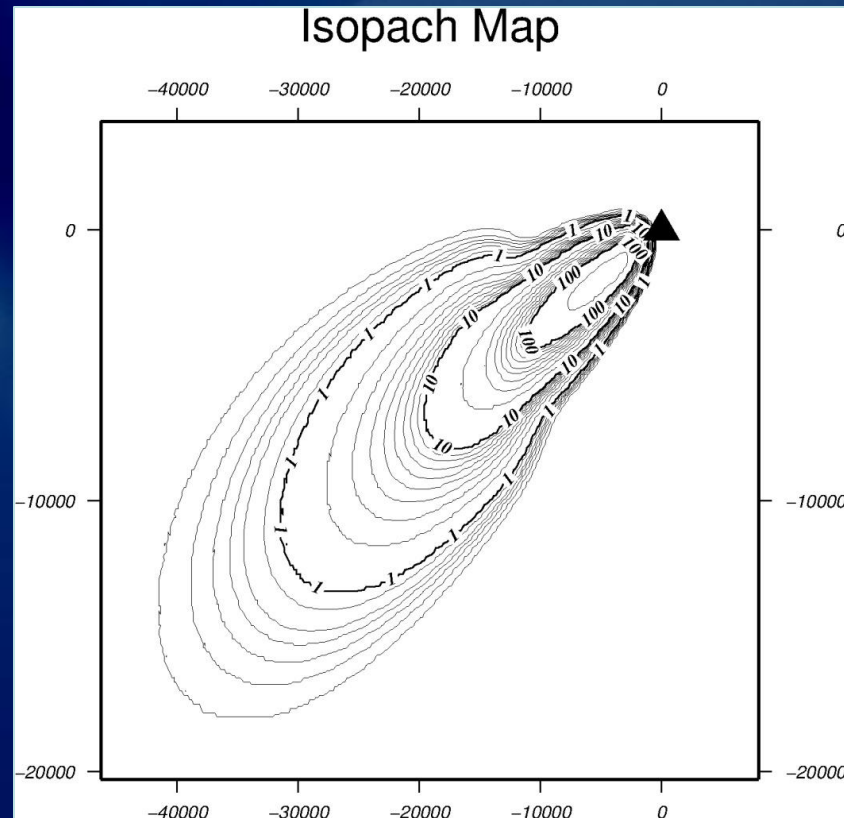
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Chuck Connor, & Costanza
Bonadonna



Cerro Negro Volcano, Nicaragua

Goal

- Calculate the accumulation of tephra around the volcano in the case of an eruption



How the model works

$$M(x,y) = \sum_{i=1}^H \sum_{j=\varnothing_{\min}}^{\varnothing_{\max}} M_{i,j}^0 f_{i,j}(x,y)$$

1 For each step up the eruption column (i) [VENT to MAX COLUMN HEIGHT (H)]

2 For each particle size (j) [MAX \varnothing to MIN \varnothing]

3 Calculate probability of particle size release at each column step

4 Calculate particle fall time from a point release source

5 Modify by column diffusion spreading

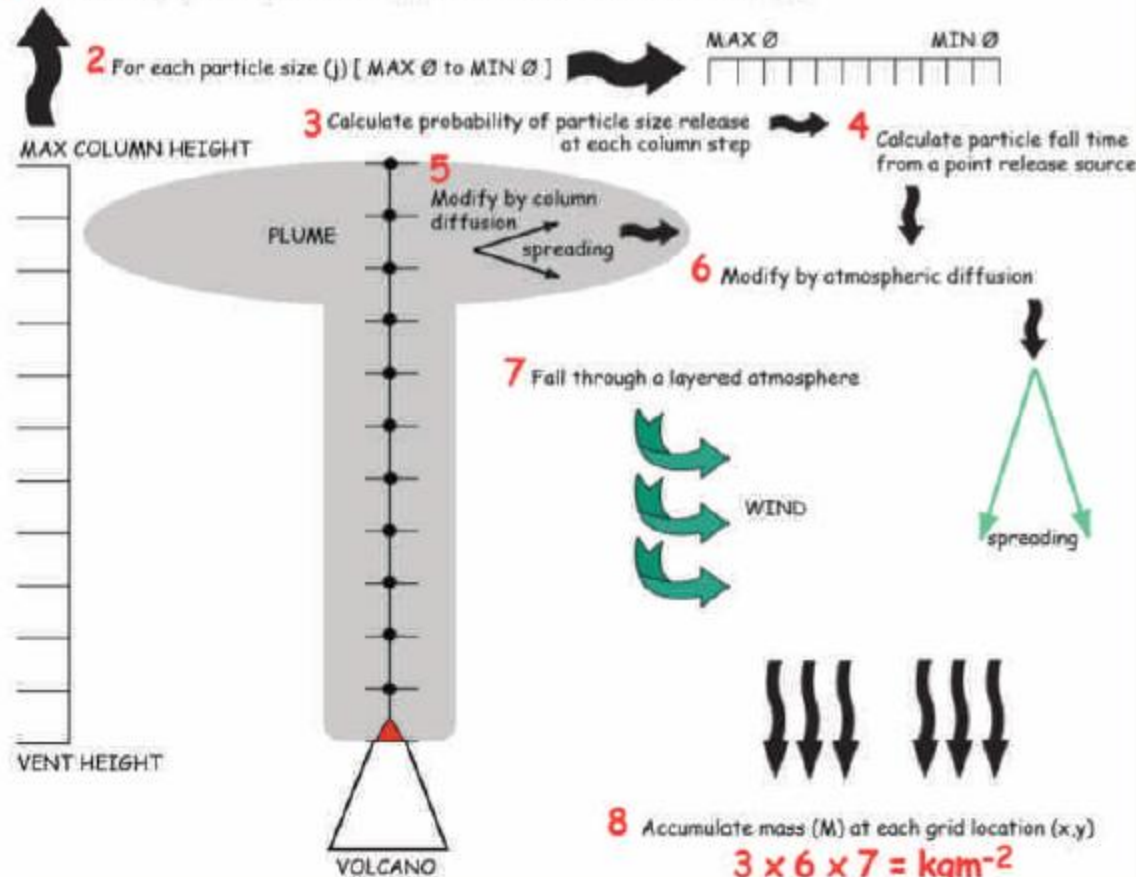
6 Modify by atmospheric diffusion

7 Fall through a layered atmosphere



8 Accumulate mass (M) at each grid location (x,y)

$$3 \times 6 \times 7 = \text{kgm}^{-2}$$



- A series of vertical steps
- A range of particle sizes
- Drops particles, pushes them downwind, spreads them, and then accumulates the mass

How the model works

Advection-diffusion equation:

$$\frac{\partial C_j}{\partial t} + w_x \frac{\partial C_j}{\partial x} + w_y \frac{\partial C_j}{\partial y} - v_{l,j} \frac{\partial C_j}{\partial z} = K \frac{\partial^2 C_j}{\partial x^2} + K \frac{\partial^2 C_j}{\partial y^2} + \Phi$$

C_j : mass concentration of particles, in kg m^{-3} , of a given particle size class, j .

w_x, w_y : downwind and crosswind components of wind velocity in atmospheric level l (m s^{-1})

$v_{l,j}$: terminal settling velocity, in m s^{-1} , for particles of size class, j , as these particles fall through a level in the atmosphere, l .

K : horizontal diffusion coefficient for tephra in the atmosphere ($\text{m}^2 \text{s}^{-1}$)

Φ : change in particle concentration at the source with time, t ($\text{kg m}^{-3} \text{s}^{-1}$)

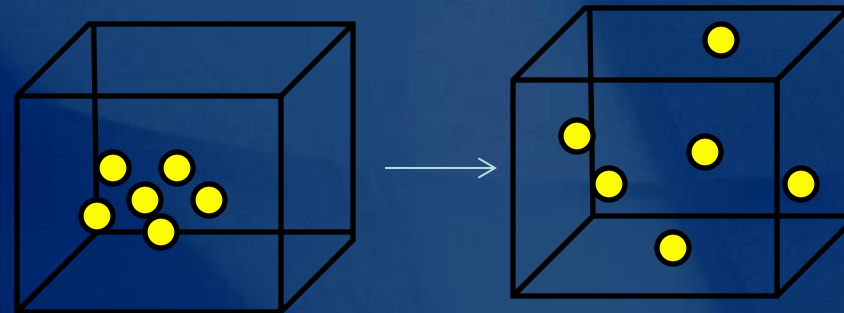
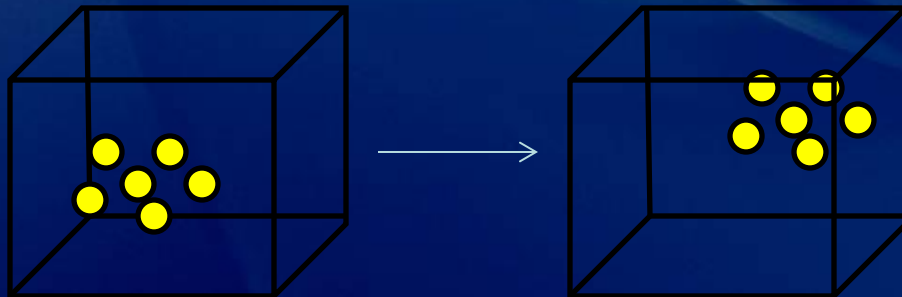
How the model works

$$\frac{\partial C_j}{\partial t} + w_x \frac{\partial C_j}{\partial x} + w_y \frac{\partial C_j}{\partial y} - v_{l,j} \frac{\partial C_j}{\partial z} = K \frac{\partial^2 C_j}{\partial x^2} + K \frac{\partial^2 C_j}{\partial y^2} + \Phi$$



Advection: downstream flow of particles in fluid

Diffusion: spread of particles across density gradient



How the model works

$$\frac{\partial C_j}{\partial t} + w_x \frac{\partial C_j}{\partial x} + w_y \frac{\partial C_j}{\partial y} - v_{l,j} \frac{\partial C_j}{\partial z} = K \frac{\partial^2 C_j}{\partial x^2} + K \frac{\partial^2 C_j}{\partial y^2} + \Phi$$

Gravitational settling:
changes in settling velocity
at different elevations
(based on Reynolds
number)

Mass ejected during the
eruption

How the model works

$$\frac{\partial C_j}{\partial t} + w_x \frac{\partial C_j}{\partial x} + w_y \frac{\partial C_j}{\partial y} - v_{l,j} \frac{\partial C_j}{\partial z} = K \frac{\partial^2 C_j}{\partial x^2} + K \frac{\partial^2 C_j}{\partial y^2} + \Phi$$

Change in mass concentration at a location throughout the eruption: this is the interesting parameter (i.e., the result)

How the model works

$$\frac{\partial C_j}{\partial t} + w_x \frac{\partial C_j}{\partial x} + w_y \frac{\partial C_j}{\partial y} - v_{l,j} \frac{\partial C_j}{\partial z} = K \frac{\partial^2 C_j}{\partial x^2} + K \frac{\partial^2 C_j}{\partial y^2} + \Phi$$

Result

Advection

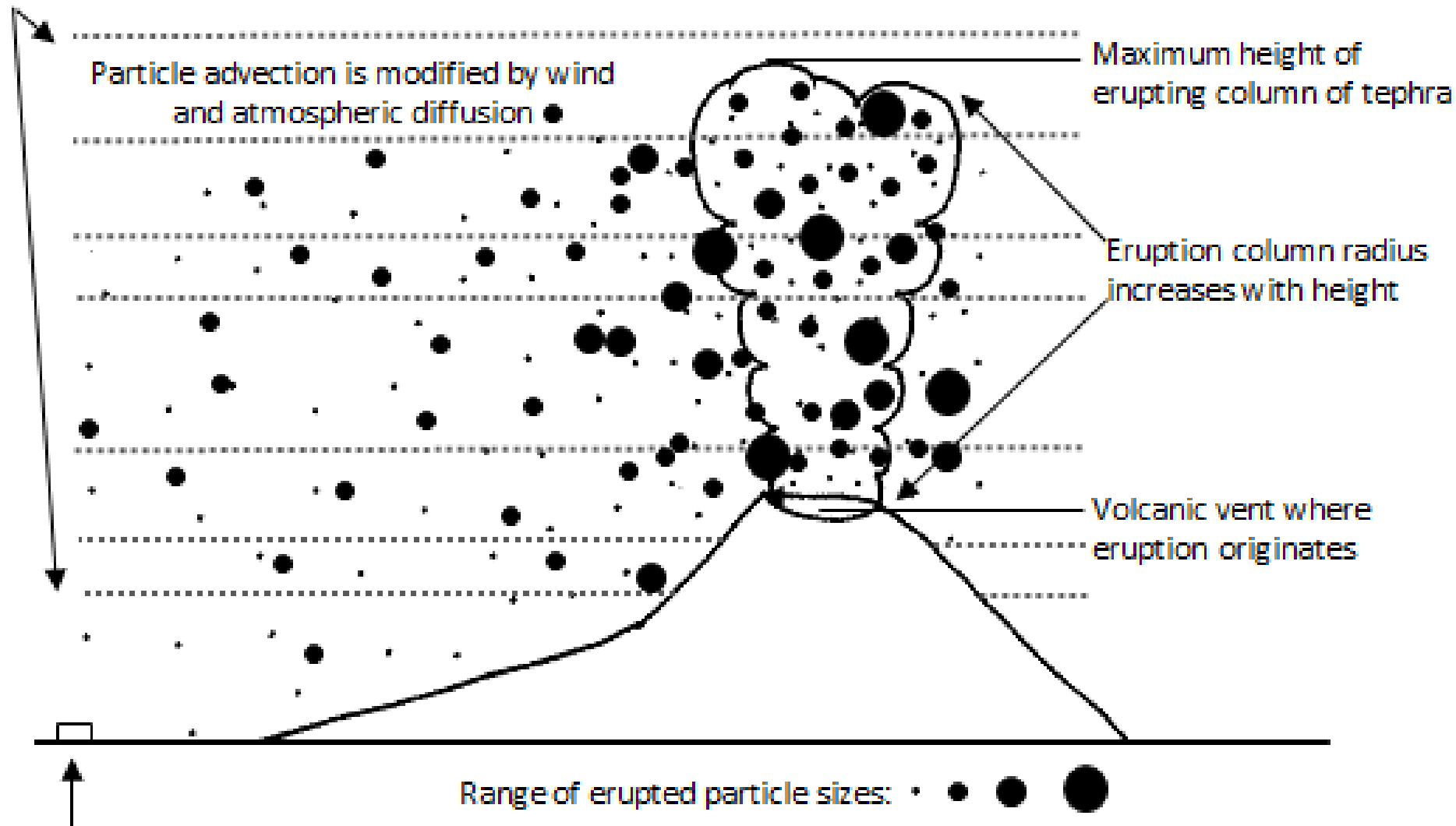
Gravitational Settling

Diffusion

Source Term

Horizontally stratified atmosphere
(varying wind speeds and directions)

The diffusion time of particles within the
erupting column increases with height



Tephra accumulation is
measured/calculated at
specific ground locations

Range of erupted particle sizes: • • • •

The diffusion time of particles through the
atmosphere levels increases as particle size
decreases

Eruption parameters

- Plume height: Maximum eruption column height (meters above sea level, not above vent!)
- Eruption mass (kg)
- Diffusion coefficient (m^2/s)

Tephra 2 is highly sensitive to these parameters!

Tephra2 Inputs

EDDY_CONST Describes atmospheric diffusion
(Fickian diffusion parameter, Earth value = 0.04)

DIFFUSION_COEFFICIENT Term describing the advection and diffusion of particles through the atmosphere (m^2/s)
As this term accounts for multiple processes, values tend to range between 100 and 10000

FALL_TIME_THRESHOLD Defines the transition between linear diffusion and diffusion governed by a power law (s)

LITHIC_DENSITY Density of small particles ejected from the vent (kg/m^3)

PUMICE_DENSITY Density of large particles ejected from the vent (kg/m^3)



Summary

- A series of steps from vent to eruption column top
- For each particle size, determine how much drops out
- Each of those particles pass through a layered atmosphere, pushed by wind and spreading through diffusion

Additional information

Here are some references about the model itself:

Suzuki, T., 1983. A theoretical model for dispersion of tephra, in: D. Shimozuru and I. Yokoyama (eds) *Arc Volcanism: Physics and Tectonics*, Terra Scientific Publishing, Tokyo, 95-116.

Connor, C.B., B.E. Hill, B. Winfrey, N.M. Franklin, and P.C. LaFemina, 2001, Estimation of volcanic hazards from tephra fallout, *Natural Hazards Review*, 2: 33-42.

Bonadonna, C., C.B. Connor, B.F. Houghton, L. Connor, M. Byrne, A. Laing, and T. Hincks, 2005. Probabilistic modeling of tephra dispersion: hazard assessment of a multi-phase eruption at Tarawera, New Zealand, *Journal of Geophysical Research*, 110 (B03203).