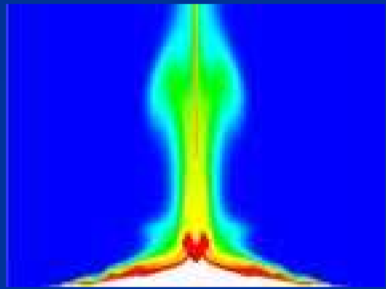
Plinian Eruption Scenario

Propagation of pyroclastic flows over urban structures



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Urban Habitat Constructions Under Catastrophic Events

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Modeling objectives

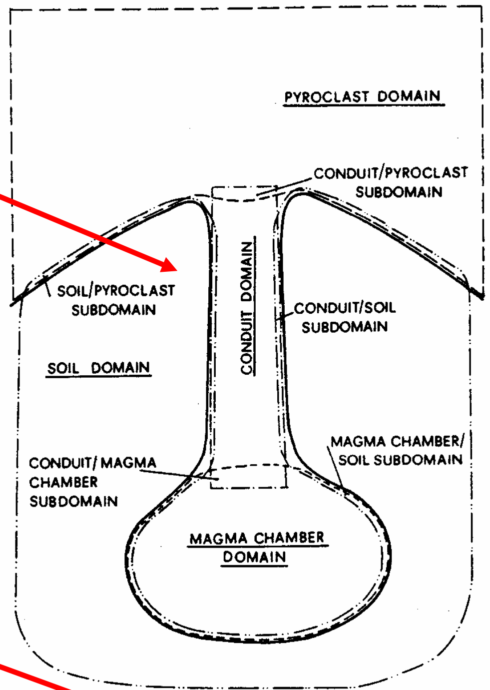
- Global Volcanic Simulator for producing eruption scenarios
- Seismic Zonation models for producing seismic loads
- Structural mechanics models for designing urban structures subjected to volcanic and seismic loads

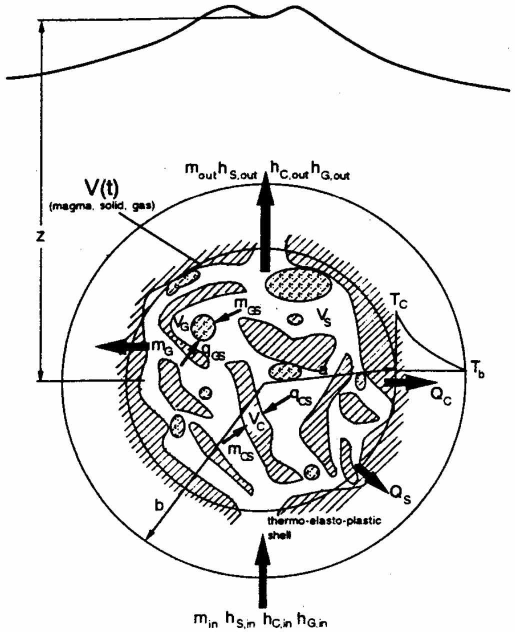
Global Volcanic Simulator

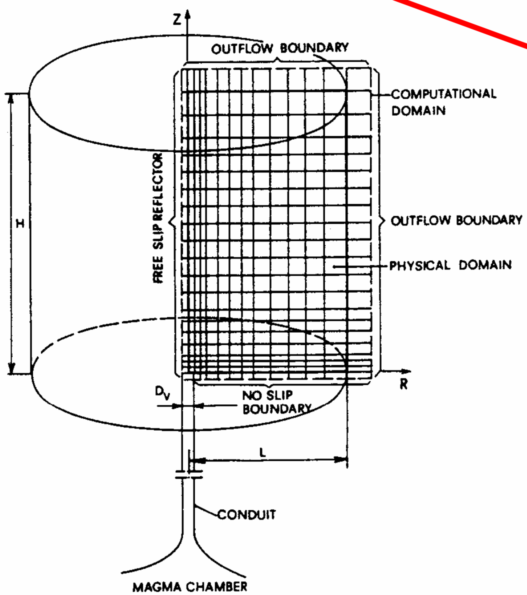
Dobran (1993, 1994, 2001, 2006)

- Physico-mathematical-computer model of volcanic system
- Determine scenarios and their likelihoods
  - Magma chamber dynamics
  - Opening of volcanic conduits
  - Conduit flow dynamics
  - Dispersion of pyroclasts in the atmosphere
  - Ash fall from eruption column
  - Propagation of pyroclastic, lava and mud flows
  - Dispersion of ballistic blocks

- Domain decomposition
  - magma chamber
  - conduit
  - soil and rock
  - atmosphere
- 3-dimensional
  - transient
  - multiphase
  - nonequlibrium
  - eulerian
  - lagrangean (ballistics)
- Numerical implementation
  - implicit
  - parallel computer architectures







Law	Mass	Linear Momentum	Angular Momentum	Energy	Entropy
$\mathbf{\Psi}^{(\alpha\delta)}$	1	$\mathbf{v}^{(\alpha\delta)}$	$\mathbf{r}\times\mathbf{v}^{(\alpha\delta)}$	$\epsilon^{(\alpha\delta)}+\frac{1}{2}\mathbf{v}^{(\alpha\delta)}\cdot\mathbf{v}^{(\alpha\delta)}$	$s^{(\alpha\delta)}$
$\mathbf{J}^{(\alpha\delta)}$	0	$-\mathbf{T}^{(\alpha\delta)}$	$-\mathbf{r}\times\mathbf{T}^{(\alpha\delta)}$	$\mathbf{q}^{(\alpha\delta)}-\mathbf{T}^{(\alpha\delta)T}\mathbf{v}^{(\alpha\delta)}$	$\mathbf{h}^{(\alpha\delta)}$
$\mathbf{\Phi}^{(\alpha\delta)}$	0	$\mathbf{b}^{(\alpha\delta)}$	$\mathbf{r}\times\mathbf{b}^{(\alpha\delta)}$	$\mathbf{b}^{(\alpha\delta)}\cdot\mathbf{v}^{(\alpha\delta)}$	$R^{(\alpha\delta)}$
$\mathbf{B}^{(\alpha\delta)}$	0	$\mathbf{0}$	$\mathbf{0}$	$r^{(\alpha\delta)}$	$\zeta^{(\alpha\delta)}$
$\mathbf{\Delta}^{(\alpha\delta)}$	0	$\mathbf{\Delta}_m^{(\alpha\delta)}$	$\mathbf{r}\times\mathbf{\Delta}_m^{(\alpha\delta)}$	$\Delta_\epsilon^{(\alpha\delta)}$	$\Delta_s^{(\alpha\delta)}$

$$\mathbf{\Delta}_m^{(\alpha\delta)}=(2H\nu\mathbf{n}+\nabla_s\nu)^{(\alpha\delta)},\qquad R^{(\alpha\delta)}=r^{(\alpha\delta)}/\theta^{(\alpha\delta)},\qquad \zeta^{(\alpha\delta)}\geq ($$

$$\Delta_\epsilon^{(\alpha\delta)}=(2H\nu\mathbf{n}\cdot\mathbf{S}+\nabla_s\nu\mathbf{S}+\nu\nabla_s\cdot\mathbf{S})^{(\alpha\delta)},\qquad \Delta_s^{(\alpha\delta)}\geq 0$$

$$\frac{\partial}{\partial t}(\rho^{(\alpha\delta)}\mathbf{\Psi}^{(\alpha\delta)})+\nabla^o\cdot(\rho^{(\alpha\delta)}\mathbf{\Psi}^{(\alpha\delta)}\mathbf{v}^{(\alpha\delta)})+\nabla^o\cdot\mathbf{J}^{(\alpha\delta)}$$

$$-\rho^{(\alpha\delta)}\mathbf{\Phi}^{(\alpha\delta)}=\rho^{(\alpha\delta)}\mathbf{B}^{(\alpha\delta)}$$

$$(m^{(\alpha\delta)}\mathbf{\Psi}^{(\alpha\delta)}+\mathbf{J}^{(\alpha\delta)}\mathbf{n}^{(\alpha\delta)})+(m^{(\beta\eta)}\mathbf{\Psi}^{(\beta\eta)}+\mathbf{J}^{(\beta\eta)}\mathbf{n}^{(\beta\eta)})=\mathbf{\Delta}^{(\alpha\delta)}$$

$$m^{(\alpha\delta)}=\rho^{(\alpha\delta)}(\mathbf{v}^{(\alpha\delta)}-\mathbf{S}^{(\Lambda\delta)})\cdot\mathbf{n}^{(\alpha\delta)}$$

Pyroclastic Dispersion Code

- Development stages

  1. Verification (solve PDE's correctly)

     mass and species conservation for gases and particulates, momentum balance equations for gas and particulates, energy balance equations for gas and particulates, granular kinetic energy equation

  2. Validation (solve the right PDE's)

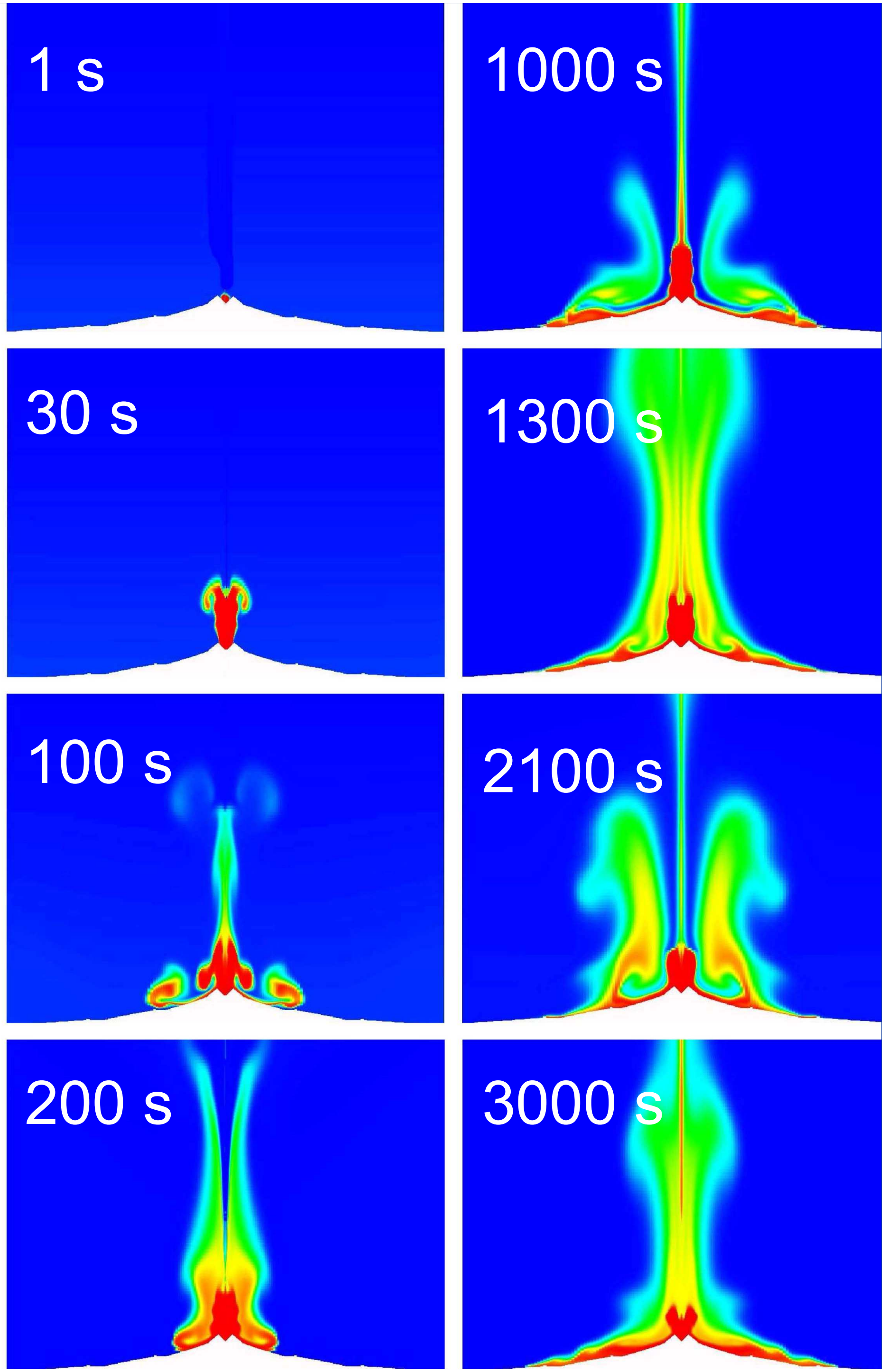
- This work (preliminary results)

➢ Simulation parameters

- 2-phase nonequilibrium flow of particulates and water vapor discharging into a stratified atmosphere
- 2 dimensional axis-symmetric flow domain 7km x 12 km
- nonuniform computational grid (33,728 cells)
- Vent conditions from magma chamber and magma ascent model of plinian eruption (m = 10^8 kg/s)
  - D = 100 m
  - V = 118 m/s
  - T = 1123 K
  - P = 1.3 MPa
- Topography: Torre del Greco
- 30 m high structures placed at 3 and 5 km from the vent

➢ Results

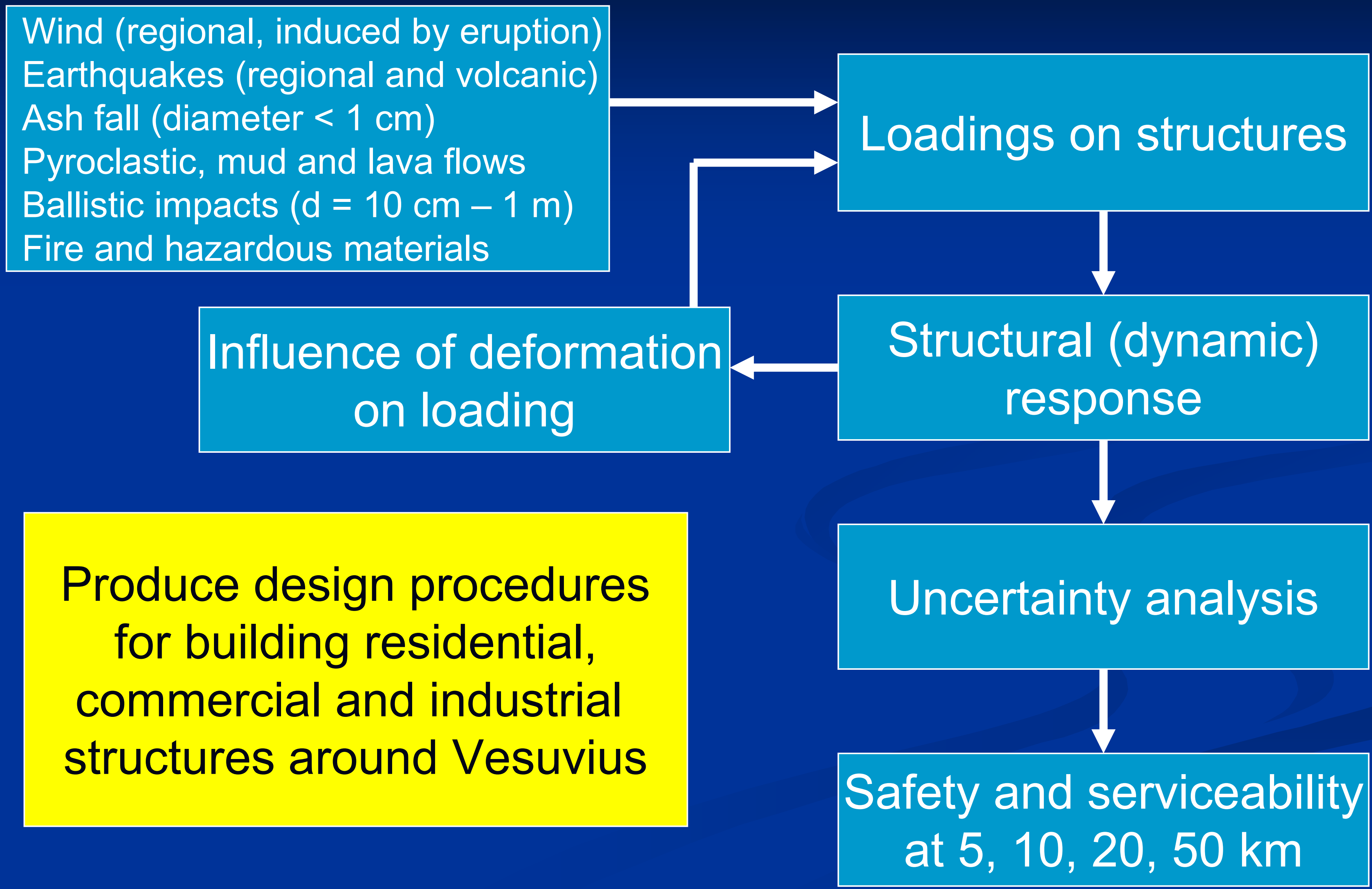
- Strong oscillations of pressure, temperature and velocity in the pyroclastic flow produce dynamic loading on structures at 3 and 5 km from the vent
- Stationary structural mechanics models have limited utility for designing buildings on the slopes of Vesuvius



Structural mechanics issues

- ❑ Clarify modeling strategies
- ❑ Establish usefulness of Zucaro’s work
- ❑ Define responsibilities
- ❑ Produce reproducibility of results

Vulnerability of structures



References:

Dobran, F., 1991. Theory of Structured Multiphase Mixtures. Springer-Verlag (Springer), New York.

Dobran, F., 1993. Global Volcanic Simulation of Vesuvius. Giardini, Pisa.

Dobran, F., 2001. Volcanic Processes: Mechanisms in Material Transport. Kluwer Academic/Plenum Publishers (Springer), New York.

Dobran, F., 2006. Vesuvius: Education, Security and Prosperity. Elsevier, Amsterdam.