102° Congresso della Società Italiana di Fisica

From field data to numerical modeling: evaluating simplified physical models for assessing pyroclastic density current hazard at Somma-Vesuvio (Italy)

Alessandro Tadini

Neri A., Cioni R., Bevilacqua A., Esposti Ongaro T.

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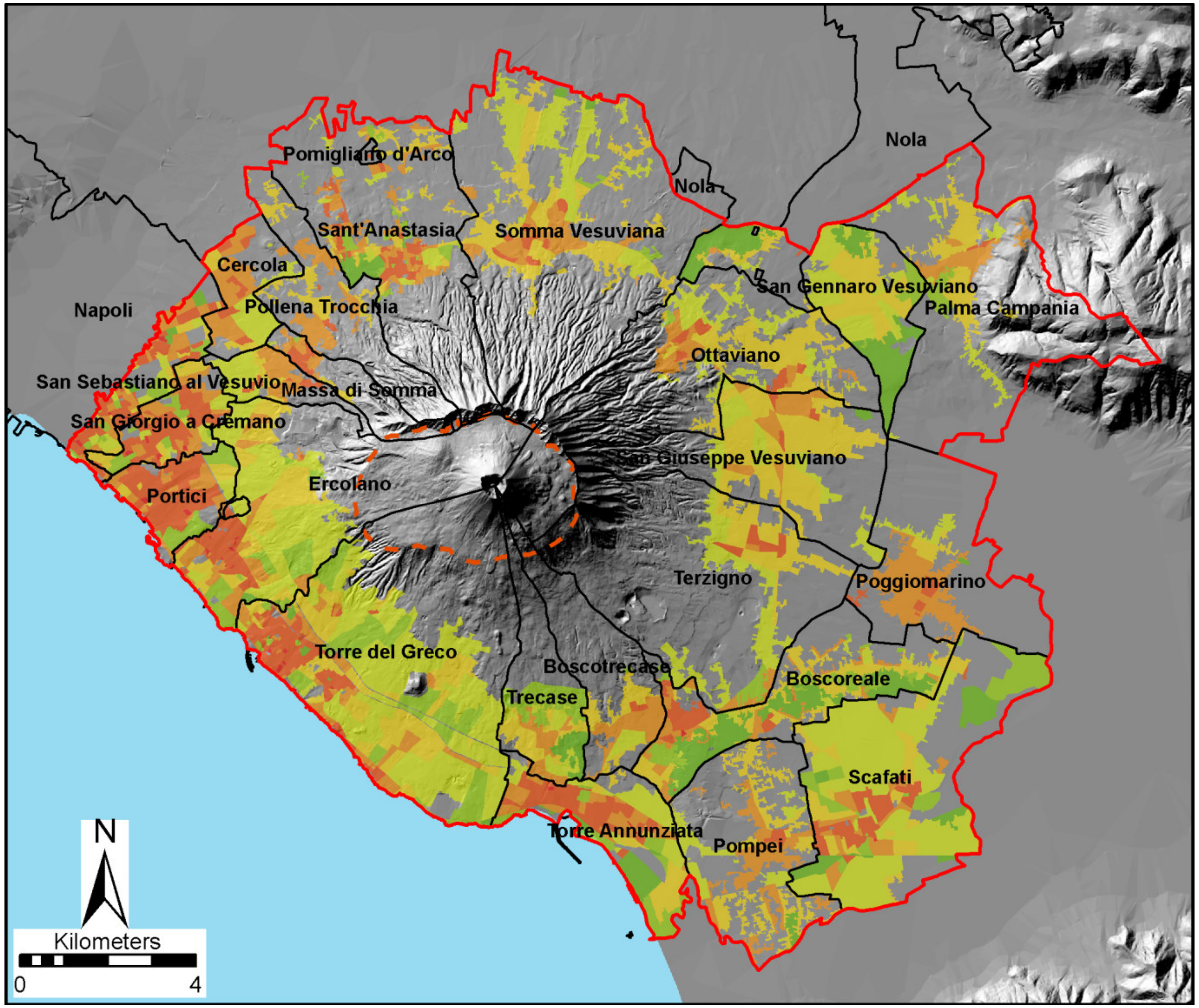
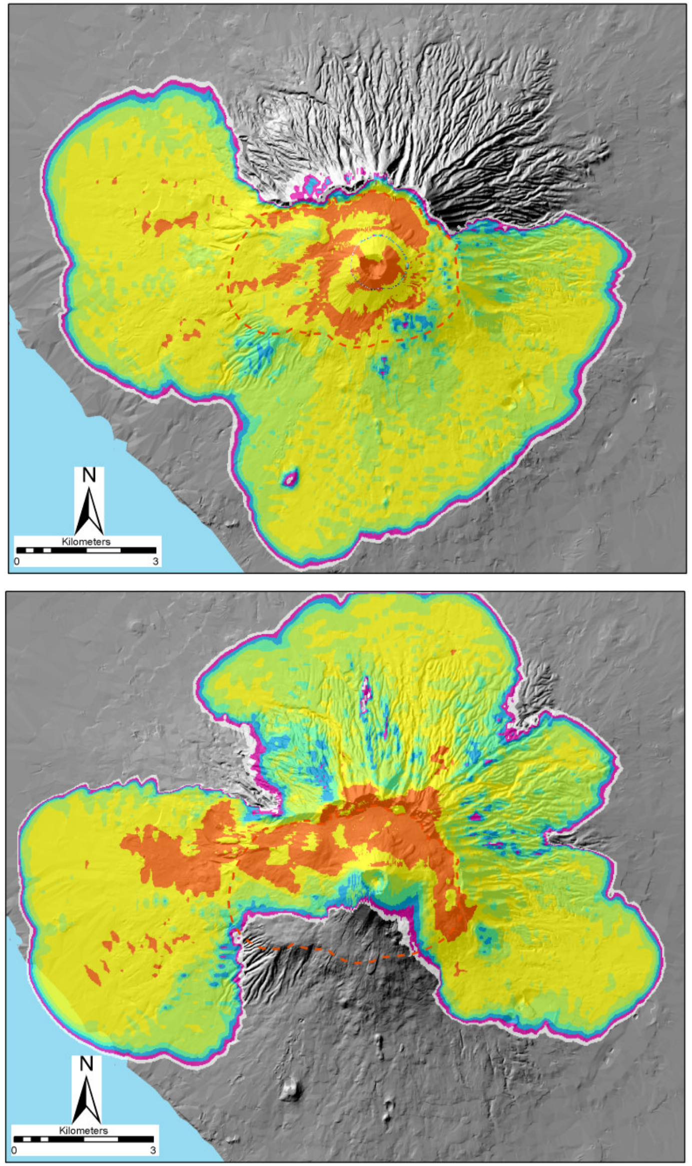
Presentation outline

- Brief outline of the research project
  - Vent opening probability maps
- Eruptive units chosen
  - AD 79 «Pompeii» (EU3pf, EU4)
  - AD 472 «Pollena» (Fg «Cupa Fontana»)
- Numerical simulation
  - The Box-Model code
  - The TITAN2D code
- Validation of numerical models
- Conclusions

THE SOMMA-VESUVIO AREA



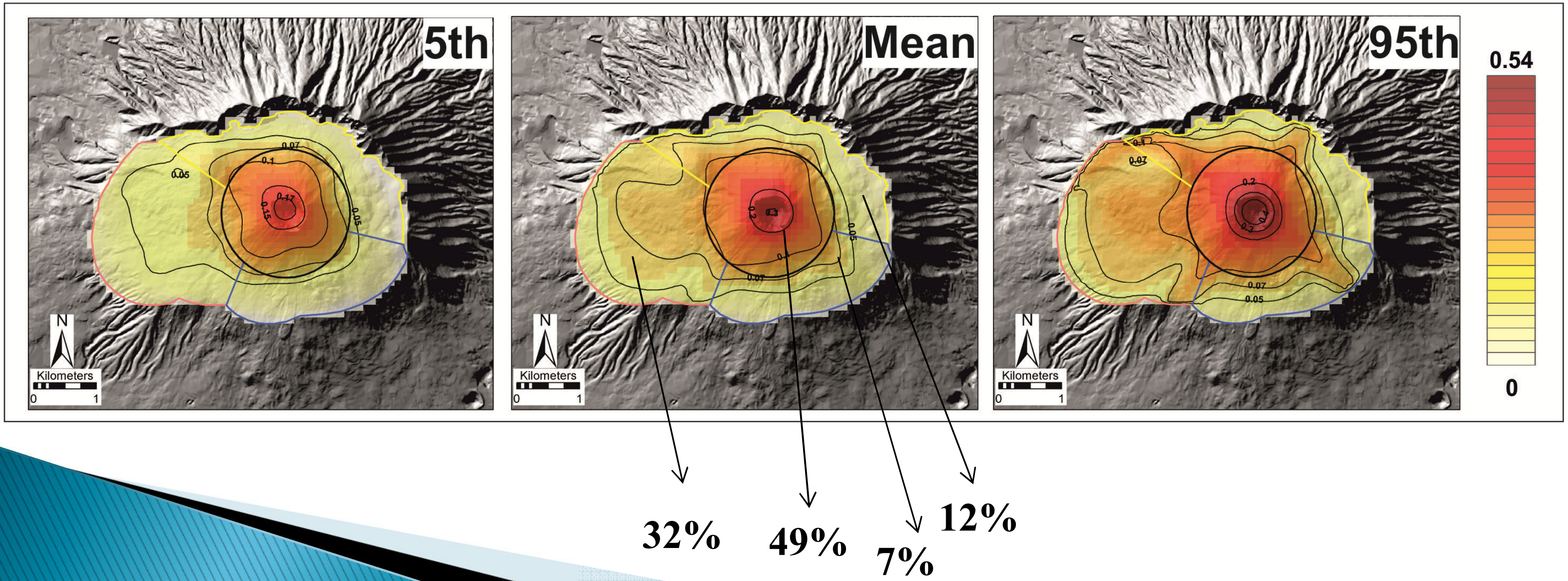
- **More than 700,000 people living inside the Red Zone (DPC 2014)**
- **4D multiphase numerical modeling show how PDC dispersal area could be significantly influenced by vent position (inside SV caldera)**



Esposti Ongaro et al. (2008)

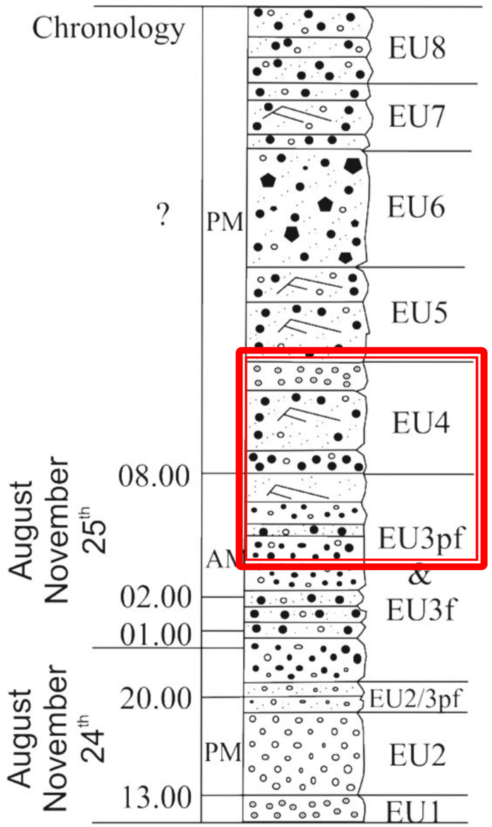
A vent opening probability map for next Plinian/sub-Plinian eruption at SV caldera

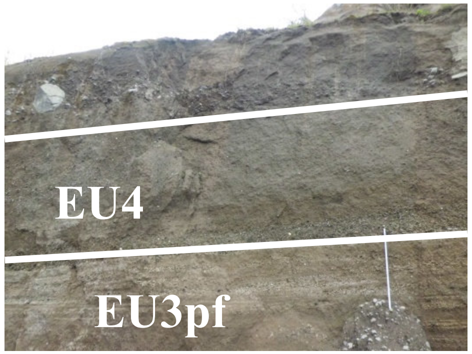
- 8 volcanological/structural datasets (distribution of past volcanic activity and deep faults) with uncertainty areas on feature locations (epistemic uncertainties) and an homogeneous map (for unknown variables)
- Gaussian kernels applied to single datasets
- Expert elicitation for dataset weight attribution for their linear combination
- Other maps for possible caldera enalrgements after a Plinian eruption



Choosing eruptive units for model validations

AD 79 «Pompeii» eruption

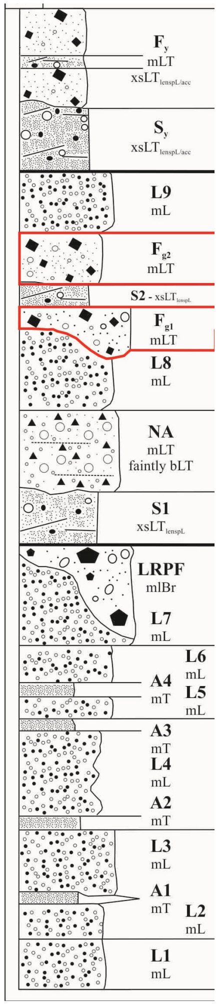


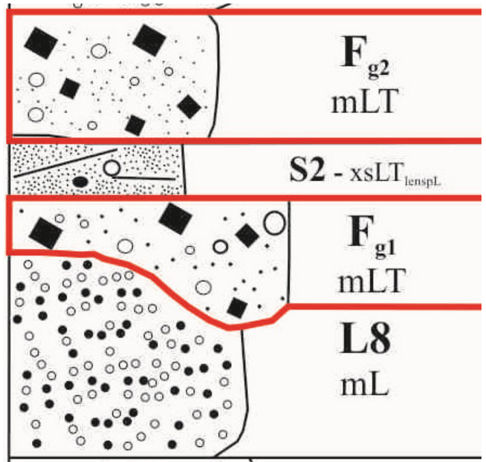


«Dilute»
end-members of the PDC spectra

Modified from Gurioli et al. (2005)

AD 472«Pollena» eruption

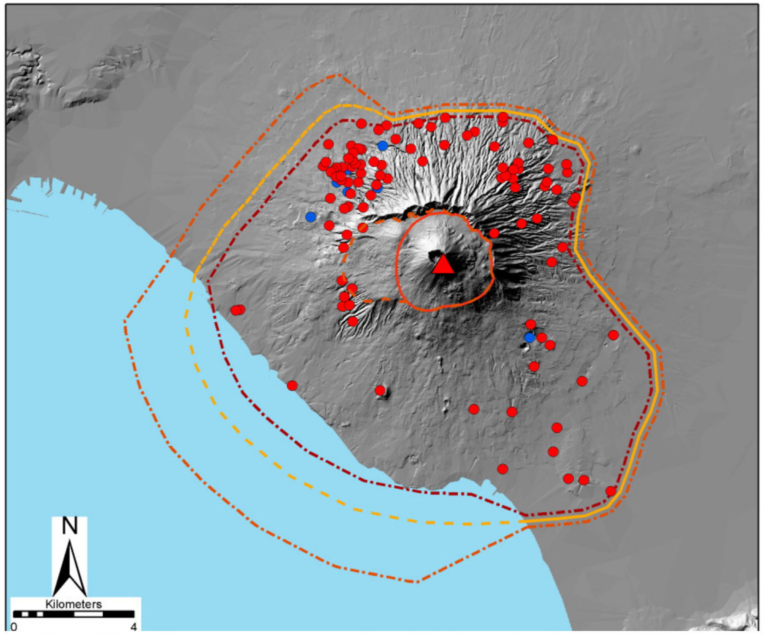


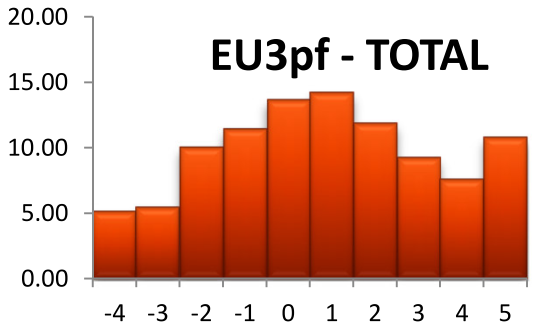


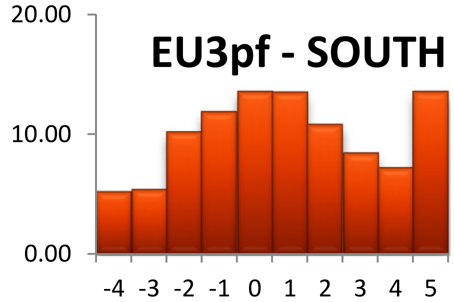
«Dense» end-member of the PDC spectra

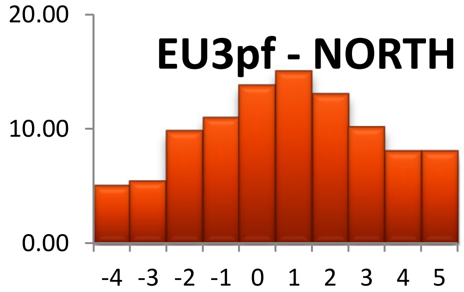
Modified from Sulpizio et al. (2005)

Field Data/1

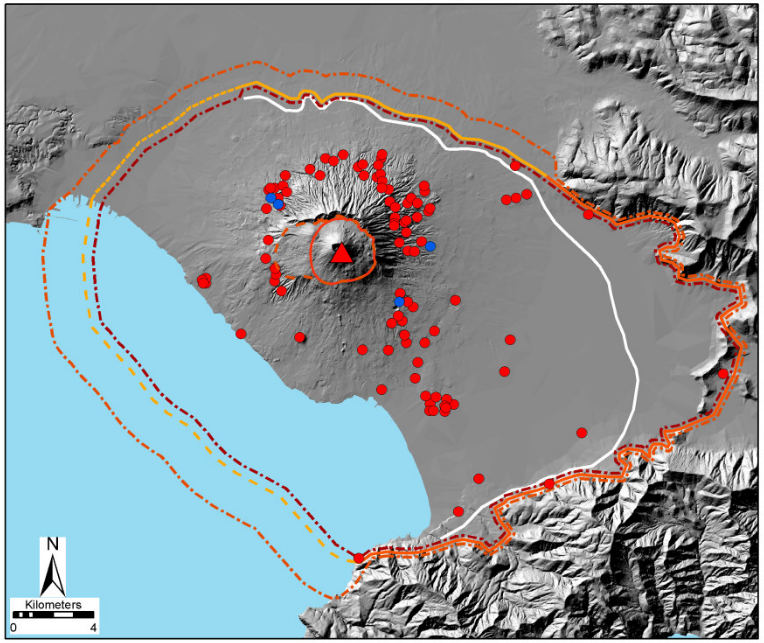


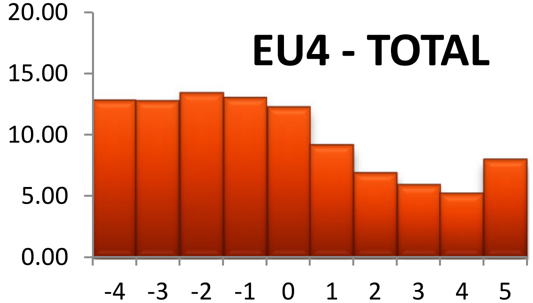


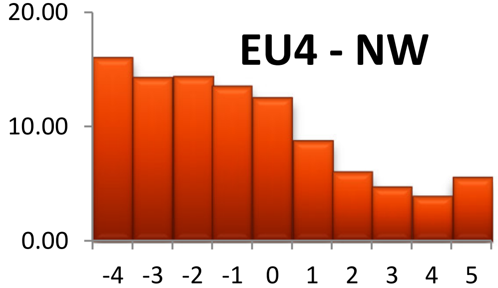


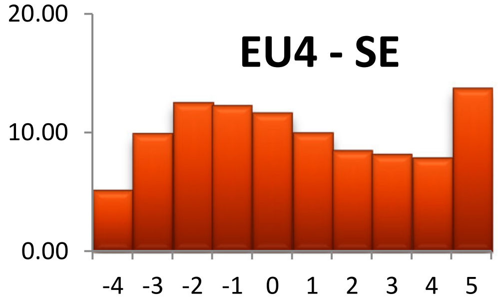


Total volume (modal area)
0.188 km^3



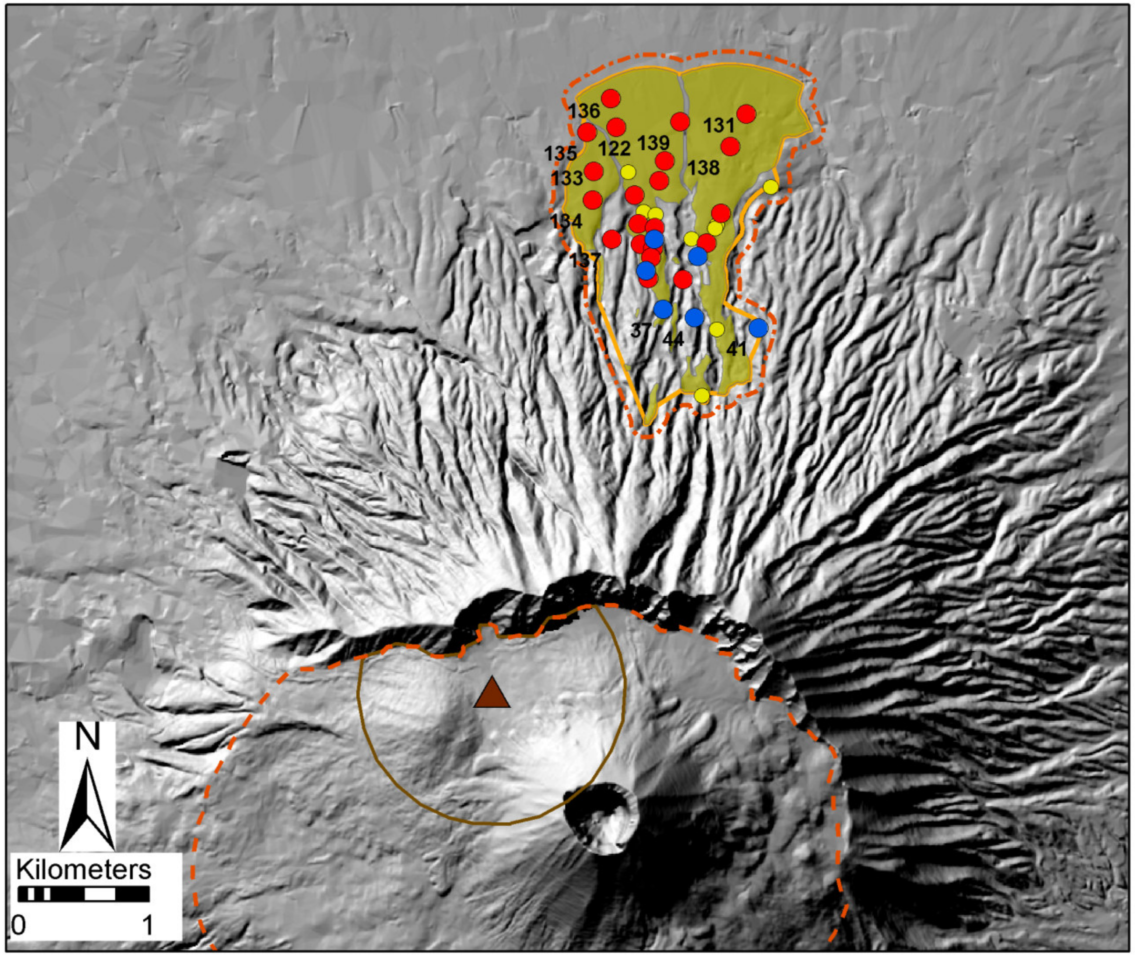




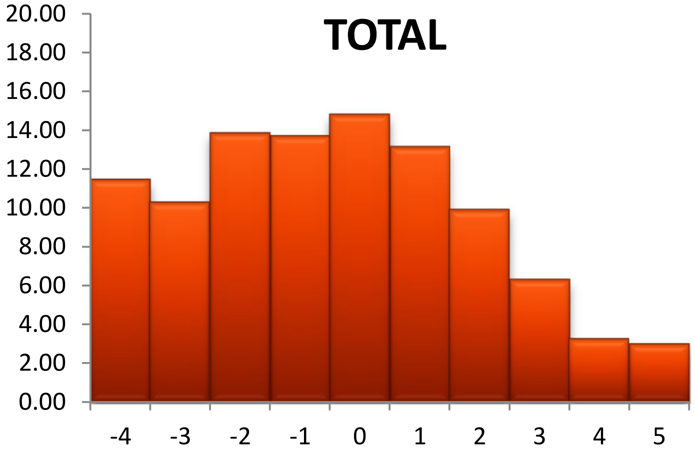


Total volume (modal area)
0.306 km^3

Field Data/2



Total volume (modal area)
0.0026 km^3



Choosing numerical models

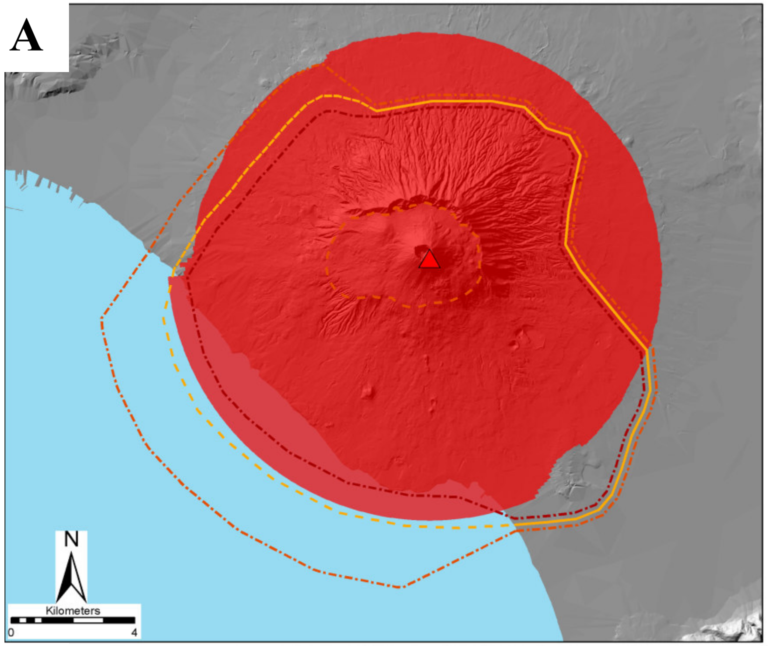
Box Model

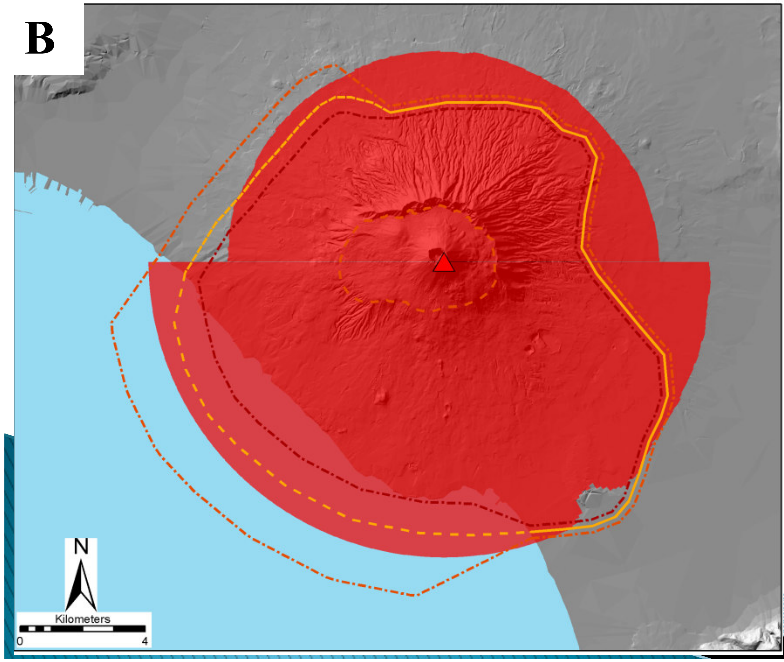
- Advanced version of the classical kinematic approach (e.g. Energy cone)
- The conservation of mass is obtained through equal area geometrical elements that stretches out through time
- Comparison between the topography and the decay of kinetic energy with distance («Energy conoid»)
- Capable of reproducing PDCs with volume fraction of solid particles from 1% to 5%

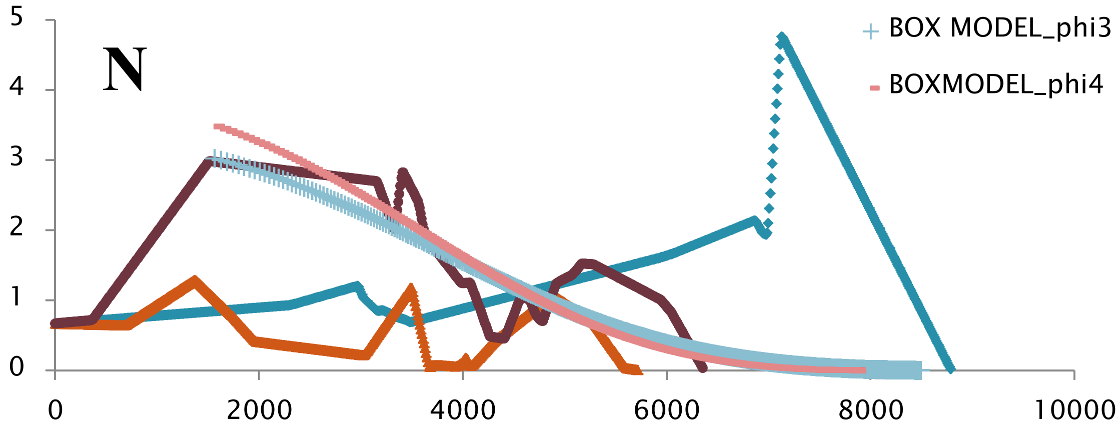
TITAN2D

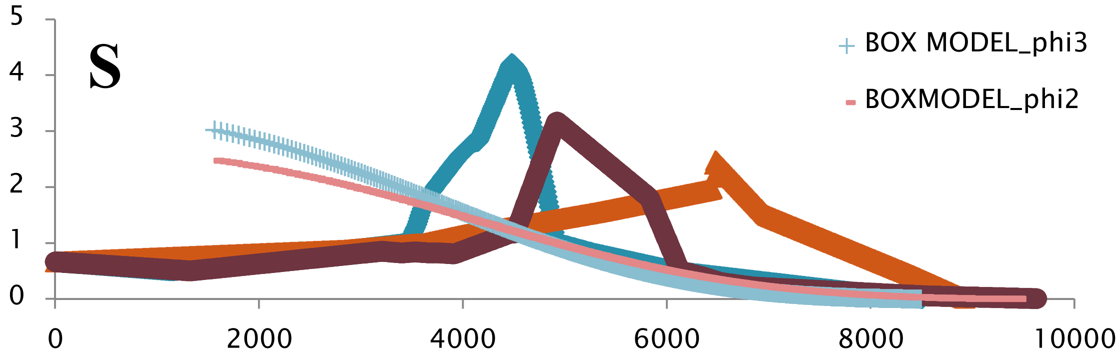
- Depth-averaged approach
- Shallow-water derived governing equations
- Coulomb-like friction law
- Flux source with a continuos feeding for a fixed amount of time
- More suitable for the numerical modeling of PDCs with volume fraction of solid particles >10%

Validation: Box Model/1









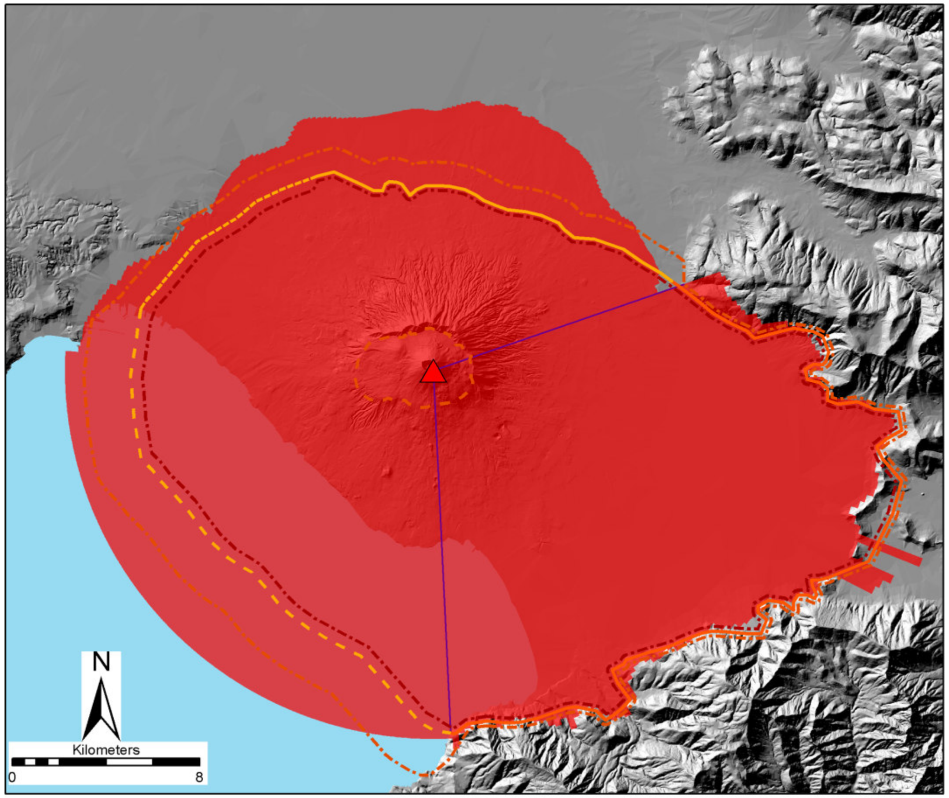
A

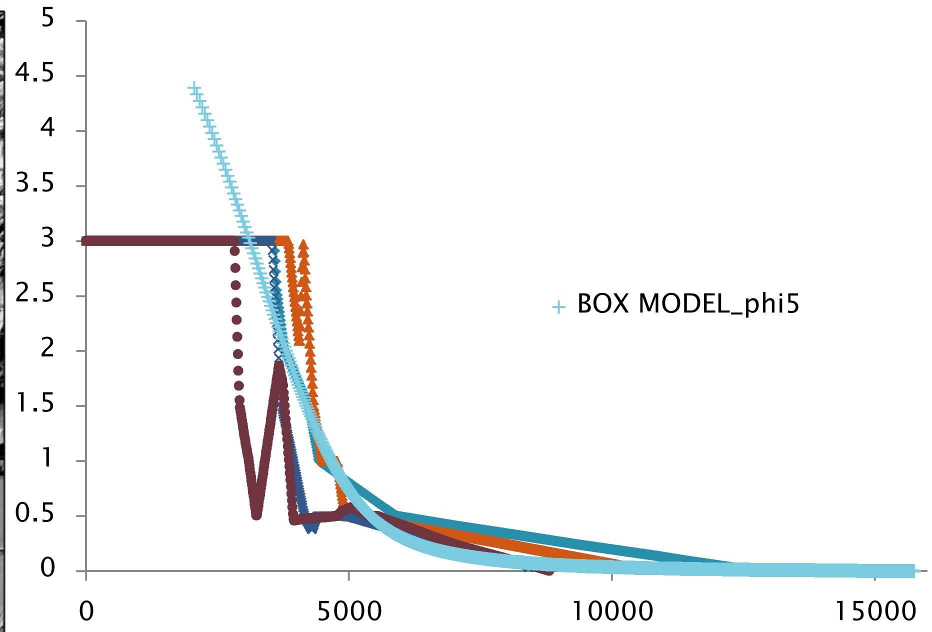
Percentile	True Positive	False Positive	True Negative
5°	69.42%	27.30%	3.28%
Modal	75.55%	18.20%	6.24%
95°	67.94%	11.64%	20.42%

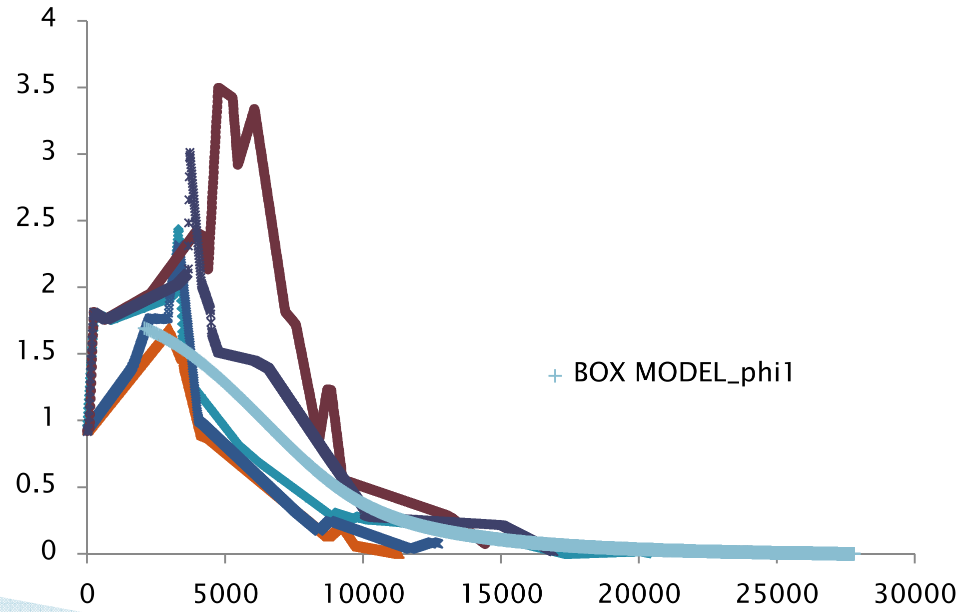
B

Percentile	True Positive	False Positive	True Negative
5°	68.83%	30.45%	0.72%
Modal	78.77%	19.82%	1.41%
95°	77.10%	9.93%	12.97%

Validation: Box Model/2

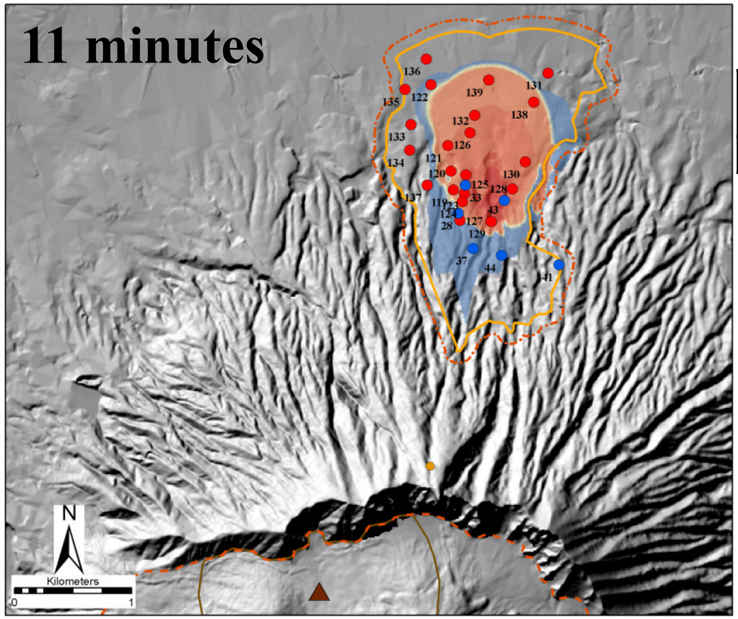


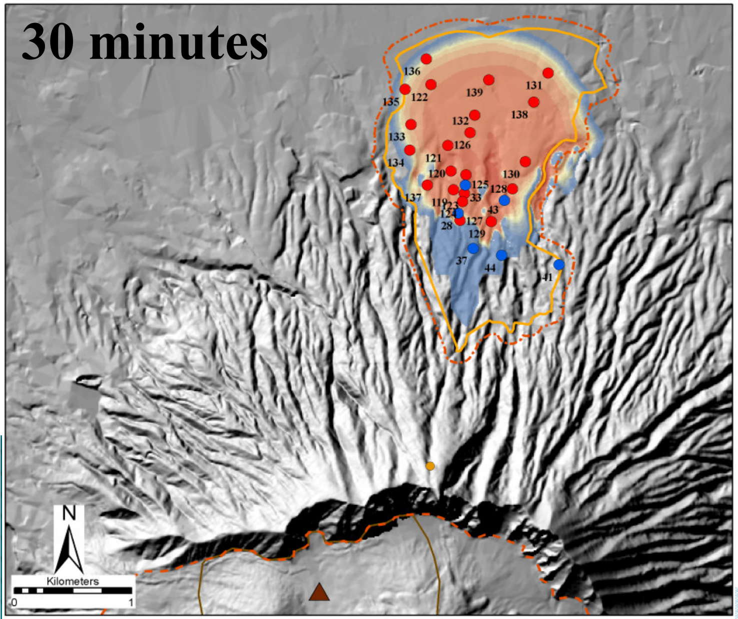




Percentile	True Positive	False Positive	True Negative
5°	73.22%	26.17%	0.62%
Modal	76.82%	22.13%	1.05%
95°	86.94%	10.39%	2.67%

Validation: TITAN2D/1





Simulation ST19

Basal Radius (m)	ϕ_{bed} (°)	Extrusion vel (m/s)	Initial speed (m/s)	Time extrusion (s)	Initial direction (°)
25	13	8.73	8.73	600	79

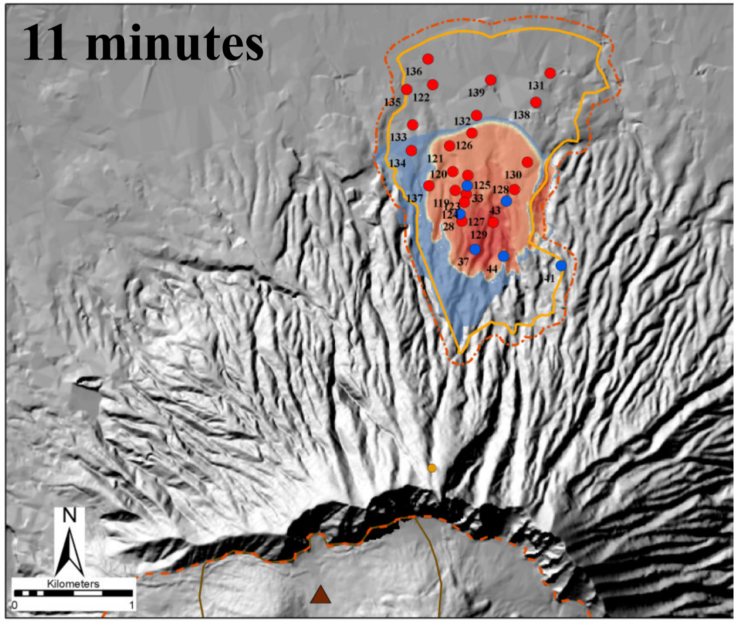
ST19_11min			
Section	Thick_sect (m)	Thick_model (m)	Diff. (%)
28	2.00	0.27	-76.21%
33	4.00	2.76	-18.34%
37	0.80	0.01	-97.53%
41	0.20	0.00	-100.00%
43	0.30	4.30	86.96%
44	0.60	0.01	-96.72%
119	2.89	1.17	-42.36%
120	3.30	1.60	-34.69%
121	3.30	1.88	-27.41%
122	1.10	0.10	-83.33%
123	3.00	2.46	-9.89%
124	4.80	1.94	-42.43%
125	3.00	2.76	-4.17%
126	2.00	2.21	4.99%
127	1.00	0.01	-98.02%
128	0.25	3.04	84.80%
129	0.25	4.01	88.26%
130	0.25	2.32	80.54%
131	0.01	0.00	-100.00%
132	1.94	2.03	2.27%
133	1.24	0.00	-100.00%
134	1.20	0.00	-100.00%
135	1.20	0.00	-100.00%
136	0.50	0.00	-100.00%
137	3.00	0.00	-100.00%
138	1.30	1.51	7.47%
139	1.00	1.56	21.88%
MEAN			-35.33%

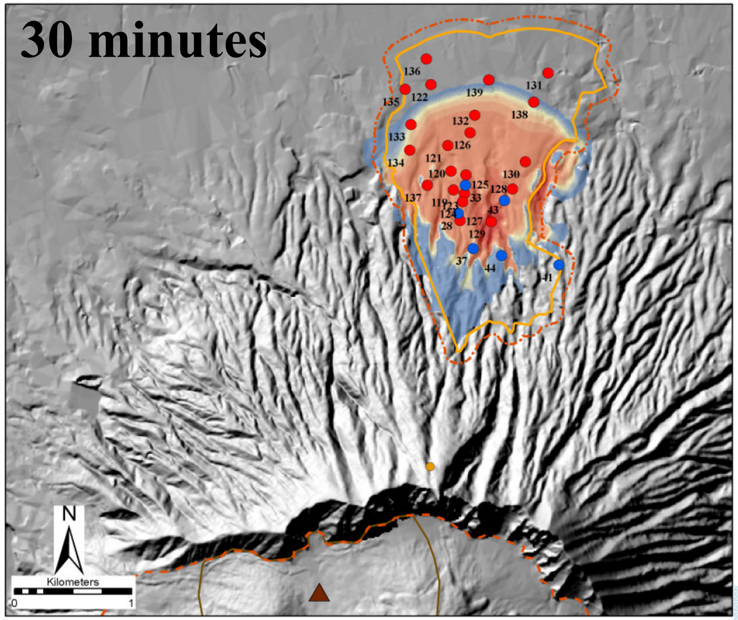
ST19_30min			
Section	Thick_sect (m)	Thick_model (m)	Diff. (%)
28	2.00	0.33	-71.67%
33	4.00	1.55	-44.14%
37	0.80	0.11	-75.82%
41	0.20	0.00	-100.00%
43	0.30	1.65	69.23%
44	0.60	0.01	-96.72%
119	2.89	1.33	-36.97%
120	3.30	1.66	-33.06%
121	3.30	1.75	-30.69%
122	1.10	0.96	-6.80%
123	3.00	1.33	-38.57%
124	4.80	1.21	-59.73%
125	3.00	2.17	-16.05%
126	2.00	1.53	-13.31%
127	1.00	0.04	-92.31%
128	0.25	0.80	52.38%
129	0.25	2.30	80.39%
130	0.25	1.18	65.03%
131	0.01	0.88	97.75%
132	1.94	1.23	-22.40%
133	1.24	0.88	-16.98%
134	1.20	0.46	-44.58%
135	1.20	0.64	-30.43%
136	0.50	0.56	5.66%
137	3.00	0.87	-55.04%
138	1.30	1.07	-9.70%
139	1.00	1.06	2.91%
MEAN			-19.32%

ST19_11min			
Percentile	True Positive	True Negative	False Positive
5°/Modal	53.18%	43.78%	3.05%
95°	44.89%	54.68%	0.42%

ST19_30min			
Percentile	True Positive	True Negative	False Positive
5°/Modal	71.29%	19.69%	9.02%
95°	64.91%	32.51%	2.58%

Validation: TITAN2D/2





Simulation ST22

Basal Radius (m)	ϕ_{bed} (°)	Extrusion vel (m/s)	Initial speed (m/s)	Time extrusion (s)	Initial direction (°)
25	15	8.73	8.73	600	79

ST22_11min			
Section	Thick_sect (m)	Thick_model (m)	Diff. (%)
28	2.00	2.51	11.31%
33	4.00	2.23	-28.41%
37	0.80	4.32	68.75%
41	0.20	0.00	-100.00%
43	0.30	2.88	81.13%
44	0.60	2.69	63.53%
119	2.89	2.02	-17.72%
120	3.30	1.79	-29.67%
121	3.30	1.41	-40.13%
122	1.10	0.00	-100.00%
123	3.00	2.37	-11.73%
124	4.80	2.56	-30.43%
125	3.00	1.99	-20.24%
126	2.00	1.16	-26.58%
127	1.00	3.00	50.00%
128	0.25	1.94	77.17%
129	0.25	6.58	92.68%
130	0.25	1.34	68.55%
131	0.01	0.00	-100.00%
132	1.94	0.00	-100.00%
133	1.24	0.00	-100.00%
134	1.20	0.09	-86.05%
135	1.20	0.00	-100.00%
136	0.50	0.00	-100.00%
137	3.00	0.84	-56.25%
138	1.30	0.00	-100.00%
139	1.00	0.00	-100.00%
MEAN			-27.19%

ST22_30min			
Section	Thick_sect (m)	Thick_model (m)	Diff. (%)
28	2.00	1.79	-5.54%
33	4.00	1.95	-34.45%
37	0.80	0.59	-15.11%
41	0.20	0.00	-100.00%
43	0.30	2.56	79.02%
44	0.60	0.08	-76.47%
119	2.89	1.84	-22.20%
120	3.30	1.68	-32.53%
121	3.30	1.22	-46.02%
122	1.10	0.00	-100.00%
123	3.00	2.09	-17.88%
124	4.80	2.01	-40.97%
125	3.00	1.76	-26.05%
126	2.00	1.19	-25.39%
127	1.00	1.85	29.82%
128	0.25	1.22	65.99%
129	0.25	5.31	91.01%
130	0.25	1.10	62.96%
131	0.01	0.00	-100.00%
132	1.94	1.03	-30.64%
133	1.24	0.52	-40.91%
134	1.20	0.86	-16.50%
135	1.20	0.00	-100.00%
136	0.50	0.00	-100.00%
137	3.00	1.40	-36.36%
138	1.30	0.14	-80.56%
139	1.00	0.00	-100.00%
MEAN			-30.33%

ST22_11min			
Percentile	True Positive	True Negative	False Positive
5°/Modal	46.00%	48.08%	5.93%
95°	42.38%	56.97%	0.65%

ST22_30min			
Percentile	True Positive	True Negative	False Positive
5°/Modal	57.04%	30.89%	12.08%
95°	54.91%	40.89%	4.19%

Conclusions and Future work

- Model validations have been performed for two different codes (BoxModel and TITAN2D)

- Field data from two eruptive units at SV have been employed as input parameters, representing PDCs with different degrees of solid particles concentrations

- The BoxModel provides better results especially with respect to total inundation areas, and its high computational speed encourage its application for volcanic hazard evaluation purposes

- TITAN2D still suffers from some limitations, despite some acceptable results have been achieved

- Future steps will include the employment of the BoxModel code for the production of PDC invasion maps at SV considering vent variability.

GRAZIE PER L’ATTENZIONE!