Inter-comparison exercise of volcanic eruption column models

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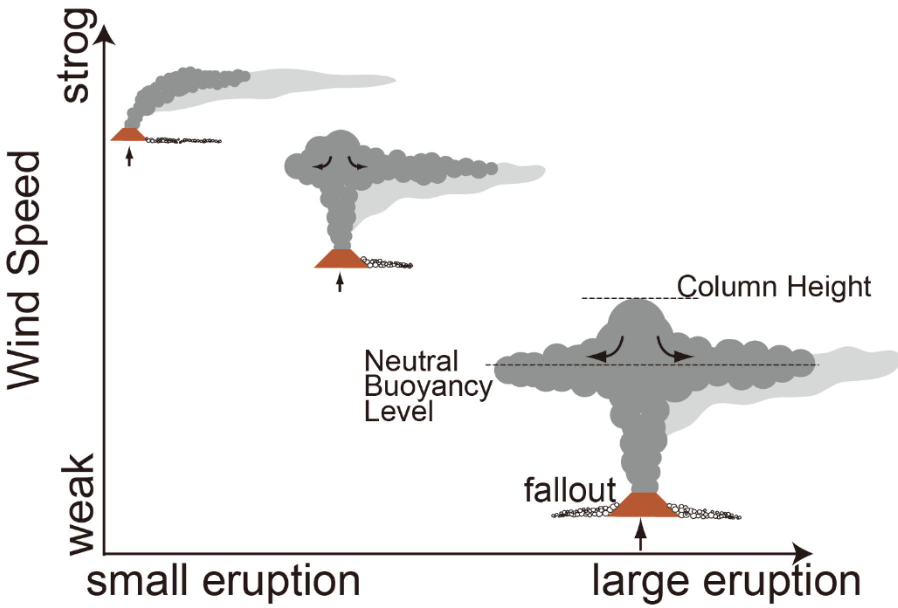
Eruption Column Height



Concentration level of fine ash in atmosphere
Distribution of fall deposits on the ground

↑

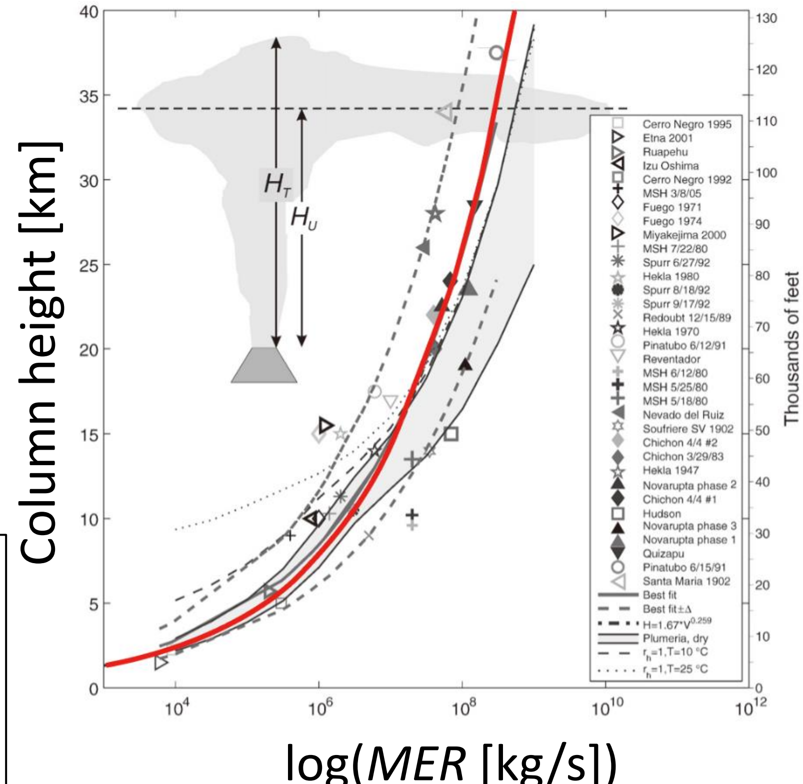
Eruption column height

↑

Mass Eruption Rate (MER [kg/s])

Analytical model with empirical constant

$H_C = C_0(MER)^{1/4}$ (Morton et al., 1956)

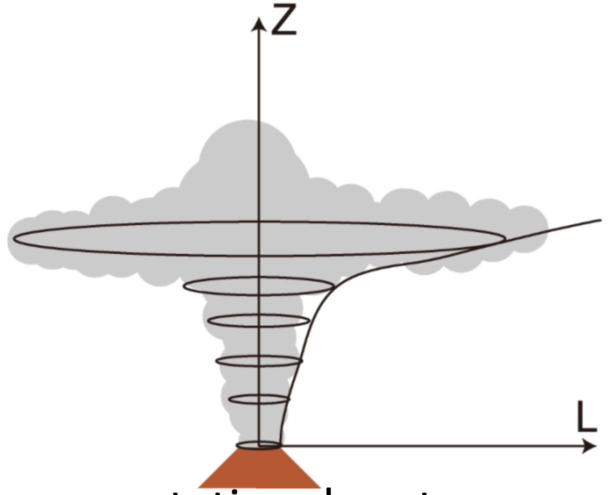


Modified from Fig. 1 in Mastin et al. (2009)

Volcanic eruption column models

1D model

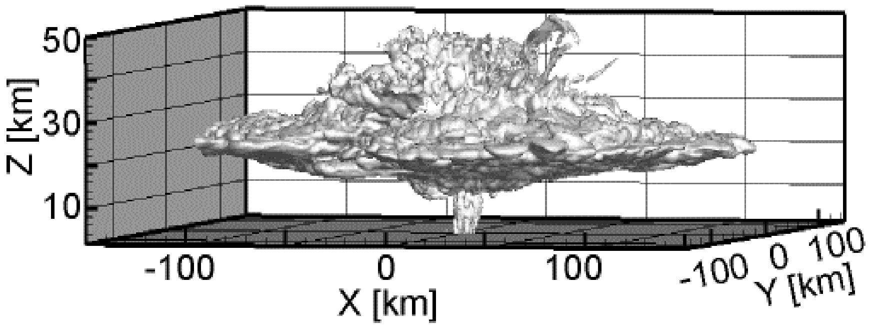
*Based on the Buoyant Plume Theory of Morton et al. (1956)
*Steady-state
*Conservation eq. along the flow axis



Low computational costs
Based on some assumptions (entrainment)
-> Useful for operational purpose

3D model

*Unsteady
*Navier-Stokes eqs. in 3D domain



High computational costs
Direct simulation of flow
-> Useful for basic research

We aim to compare the results derived from different models and reveal the problematic points in the column models.

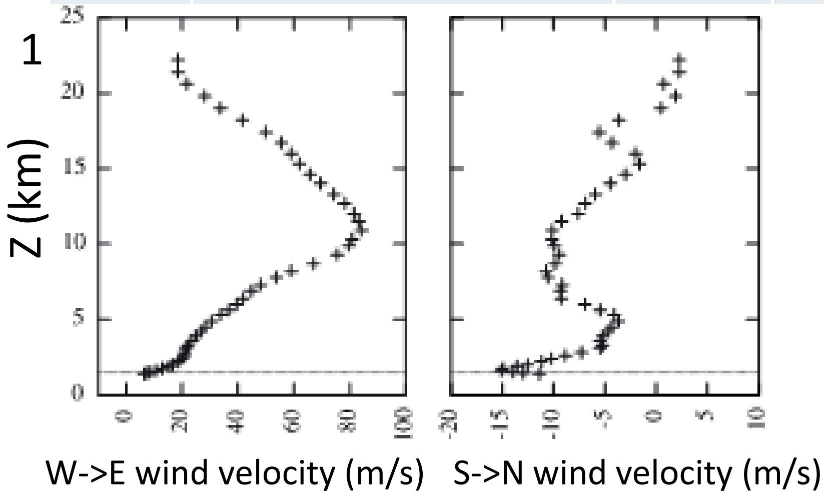
Models used in the exercise

Label	Name	Dimension	Air Entrainment	Corr. Author
1	Puffin	1D	$\alpha = 0.15$, $\beta = 1.0$	M. Bursik
2	Degruyter&Bonadonna	1D	$\alpha = 0.10$, $\beta = 0.5$	W. Degruyter
3	PlumeMoM	1D	$\alpha = 0.09$, $\beta = 0.6$	M. de'Michieli Vitturi
4	Devenish	1D	$\alpha = 0.10$, $\beta = 0.5$	B. Devenish
5	FPluMe	1D	$\alpha = f(\mathrm{Ri})$, $\beta = g(\mathrm{Ri})$	A. Folch
6	PPM	1D	$\alpha = f(\mathrm{Ri})$, $\beta = 0.5$	F. Girault
7	Plumeria	1D	$\alpha = 0.09$, $\beta = 0.5$	L. Mastin
8	PlumeRise	1D	$\alpha = 0.09$, $\beta = 0.9$	M. Woodhouse
9	Cerminara1D	1D	$\alpha = 0.10$, $\beta = 0.0$	M. Cerminara
10	ATHAM	3D	LES	M. Herzog
11	SK-3D	3D	no-LES	Y. J. Suzuki
12	ASHEE	3D	LES	M. Cerminara
13	PDAC	3D	LES	T. Esposti Ongaro
14	Mastin et al. (2009)	0D		L. G. Mastin
15	Degruyter&Bonadonna(2012)	0D	$\alpha = 0.10$, $\beta = 0.5$	W. Degruyter
16	Woodhouse et al. (2013)	0D		M. Woodhouse

Exercise cases

	#	Eruption Strength	Wind	Fixed parameter	Used models
Ser.A	WP2	Weak	-	Column height (6,000 m)	1D, 0D
	WP4	Weak	✔[1]	Column height (6,000 m)	1D, 0D
	SP2	Strong	-	Column height (37,000 m)	1D, 0D
	SP4	Strong	✔[2]	Column height (37,000 m)	1D, 0D
Ser.B	WP1	Weak	-	MER (1.5×10^6 kg/s)	1D, 3D, 0D
	WP3	Weak	✔[1]	MER (1.5×10^6 kg/s)	1D, 3D, 0D
	SP1	Strong	-	MER (1.5×10^9 kg/s)	1D, 3D, 0D
	SP3	Strong	✔[2]	MER (1.5×10^9 kg/s)	1D, 3D, 0D

1



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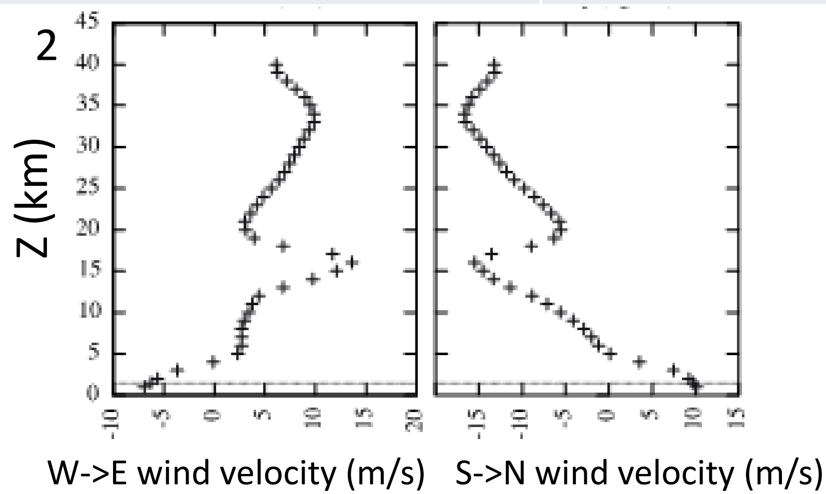
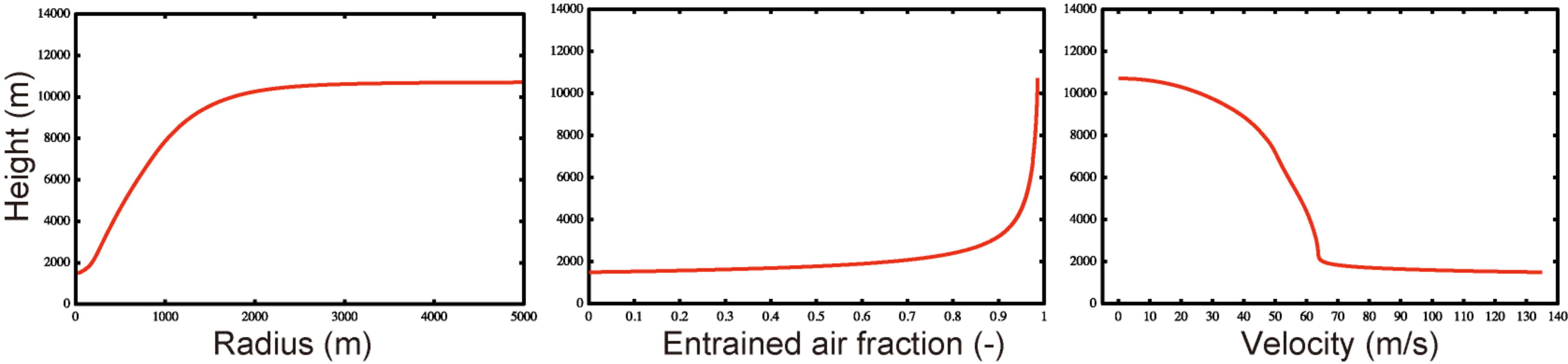
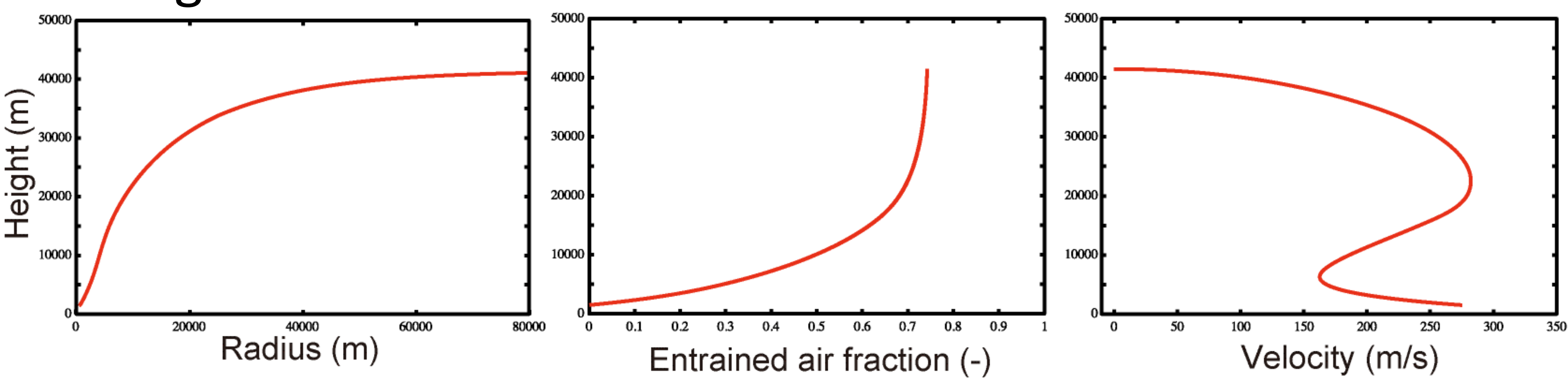


Representative 1D results (Plumeria)

Weak Plume without Wind

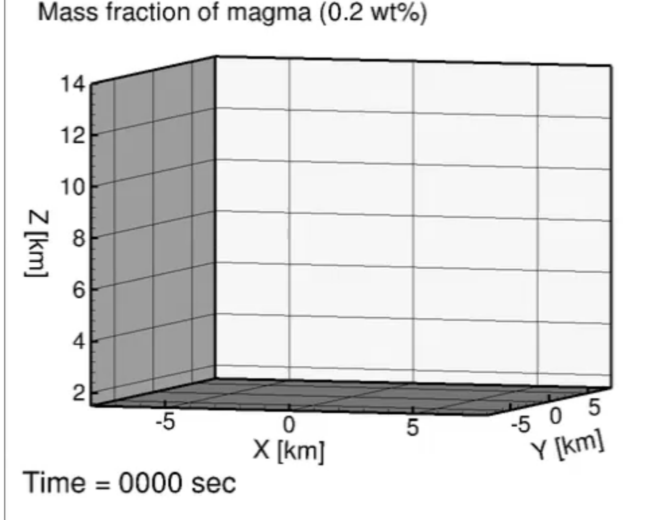


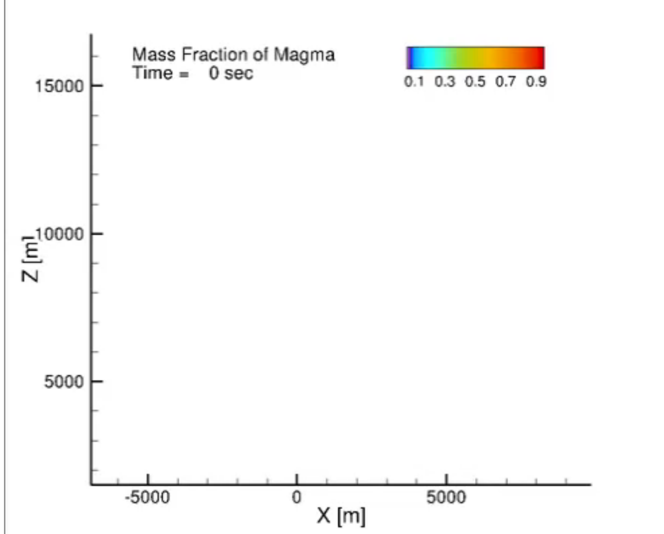
Strong Plume without Wind



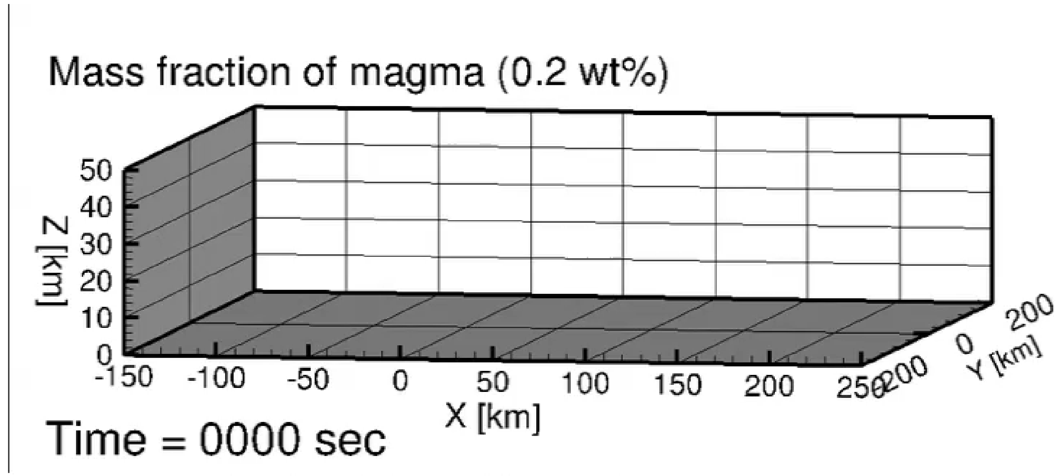
Representative 3D results (SK-3D)

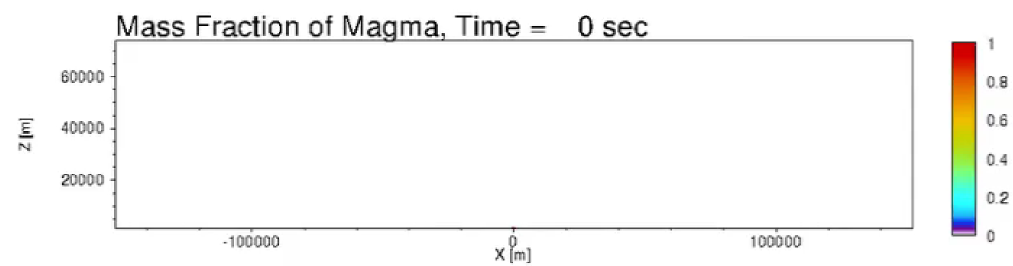
Weak Plume



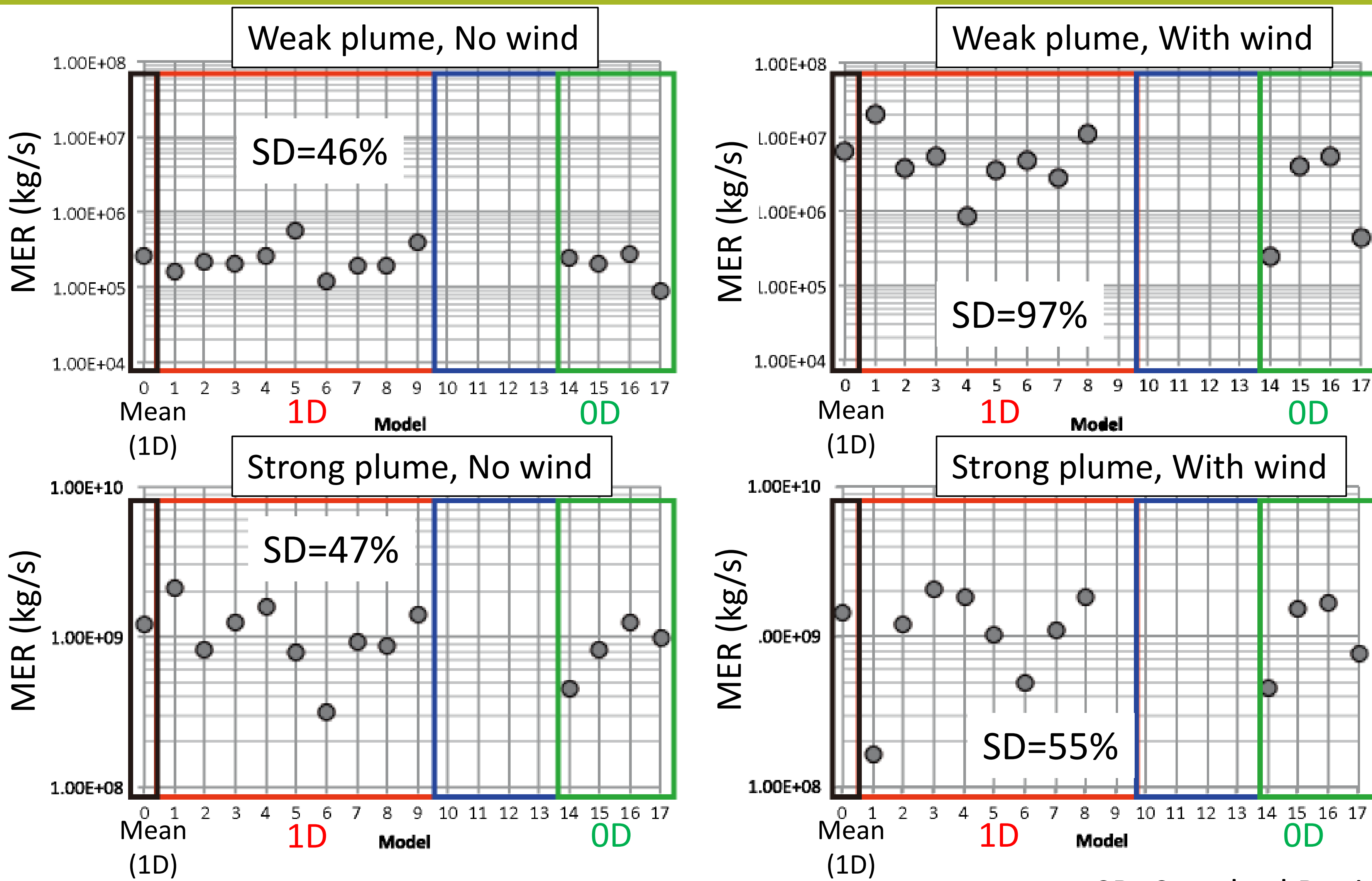


Strong Plume



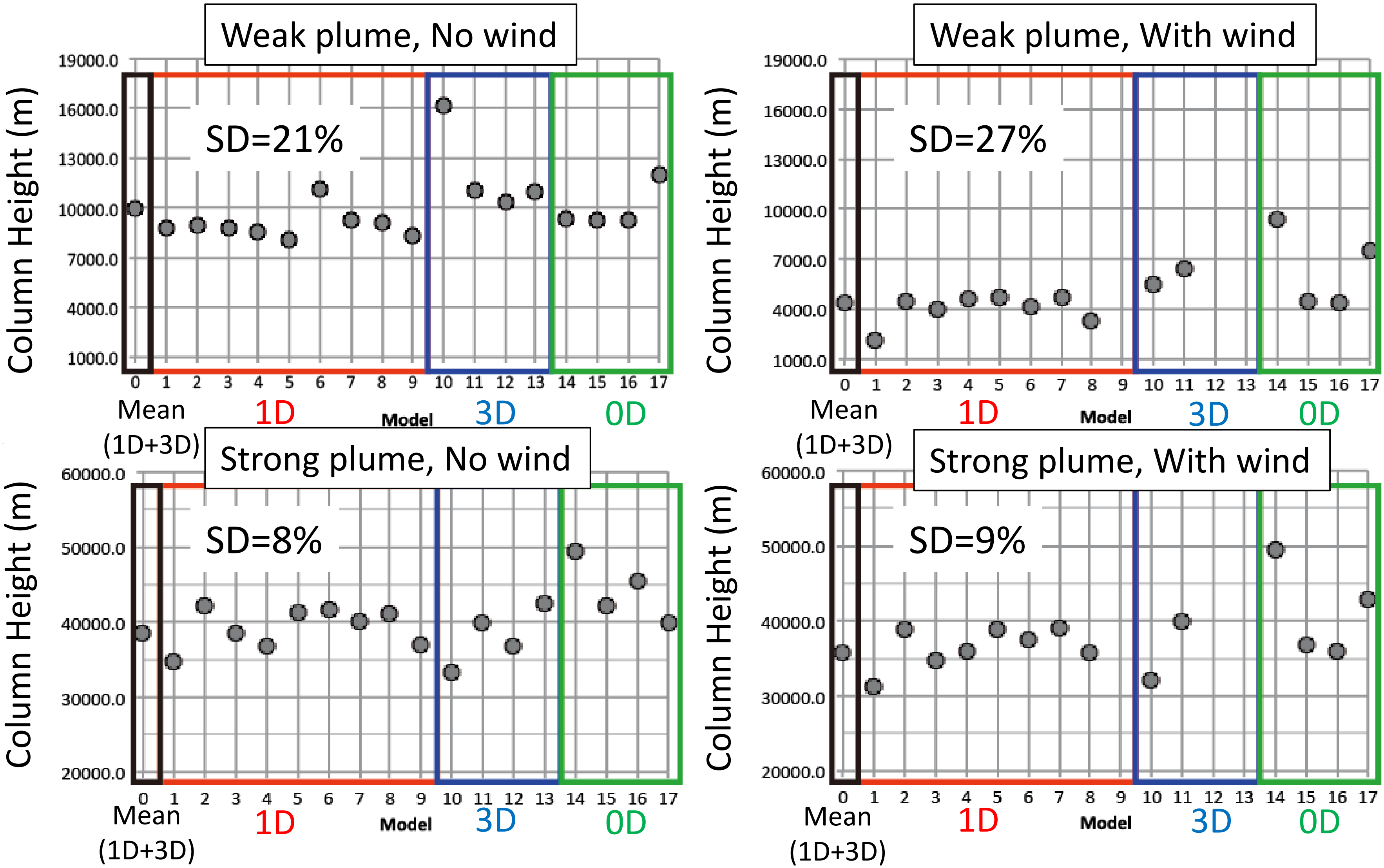


MERs for Fixed Column Heights



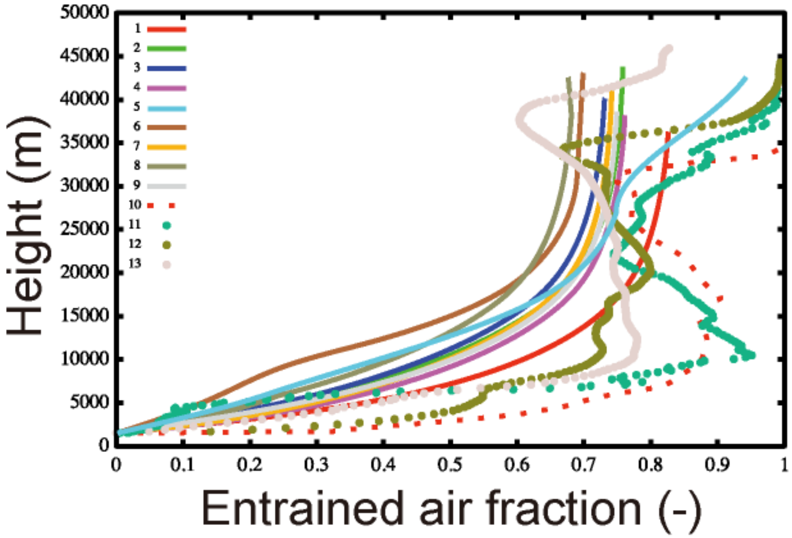
SD: Standard Deviation

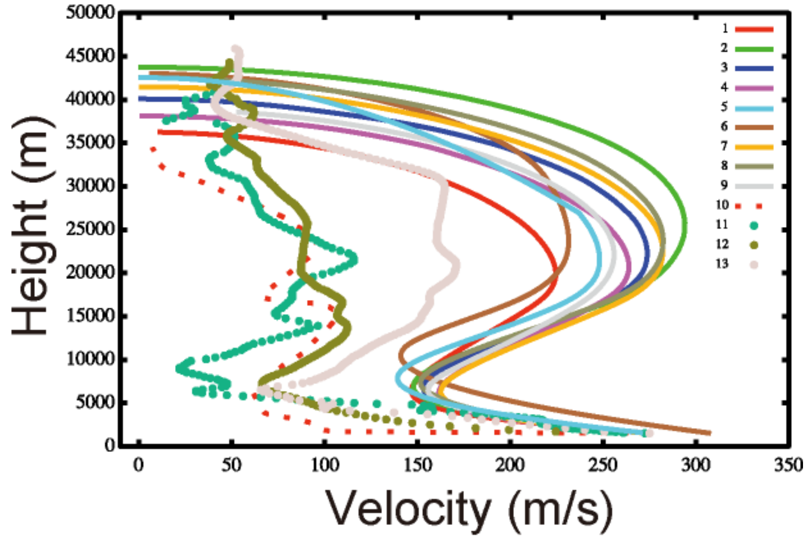
Column heights for Fixed MERs



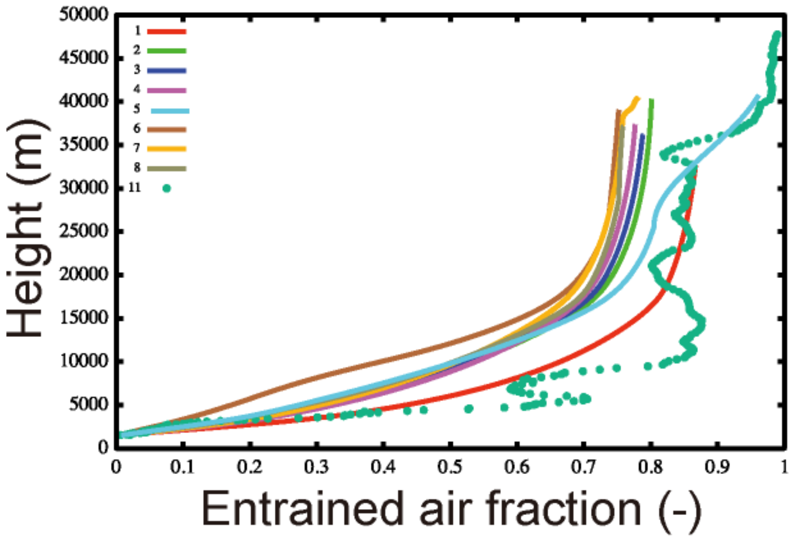
Strong plume

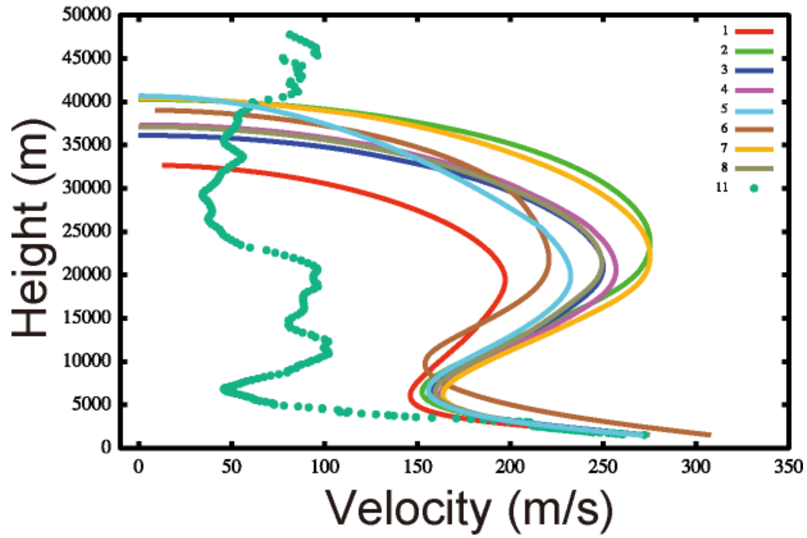
Windless





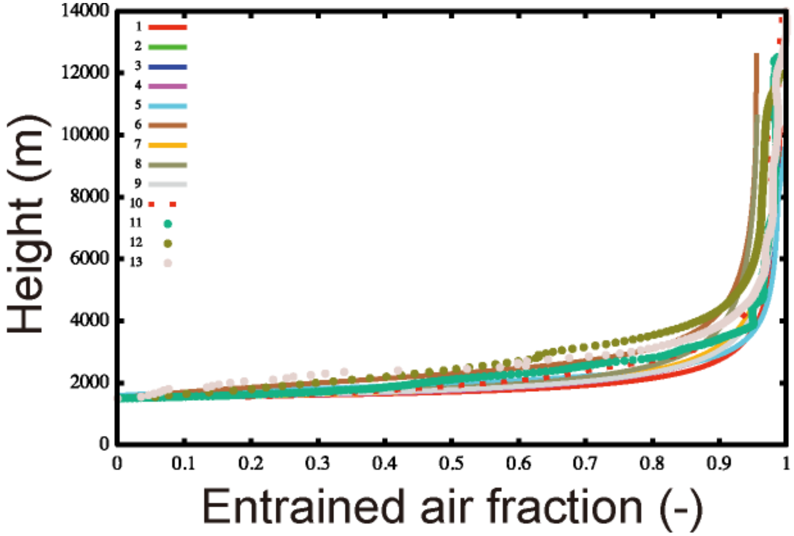
Windy

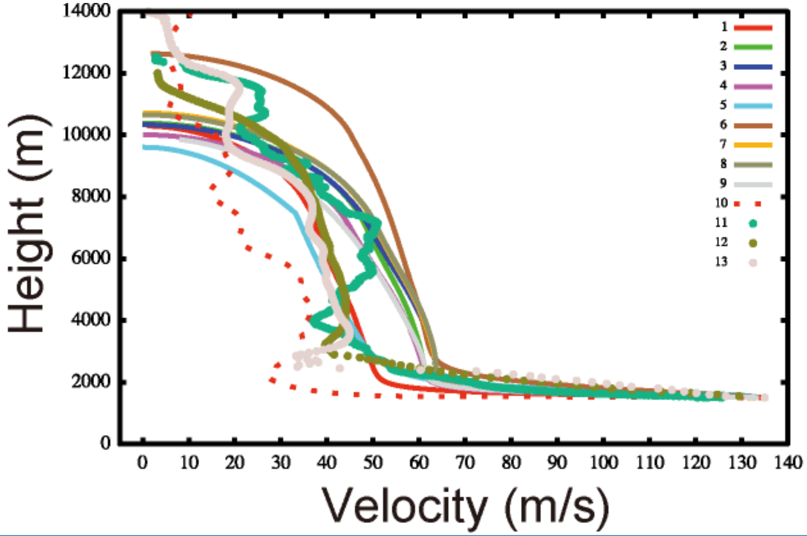




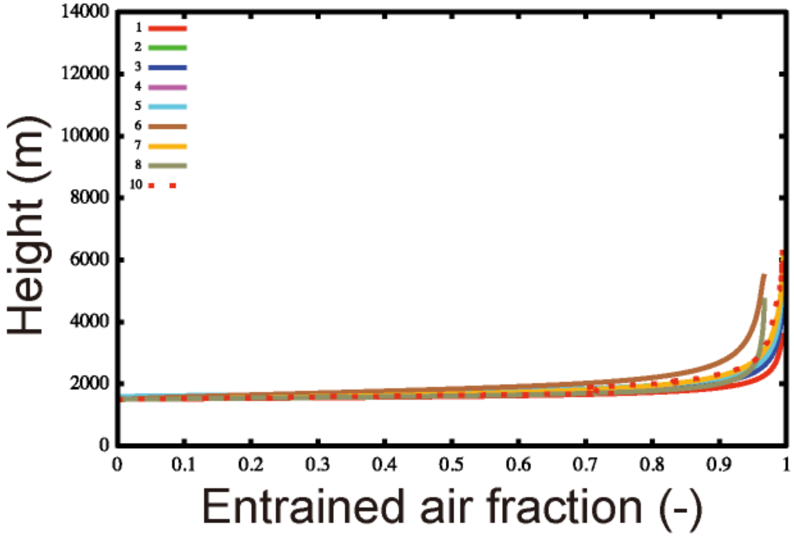
Weak plume

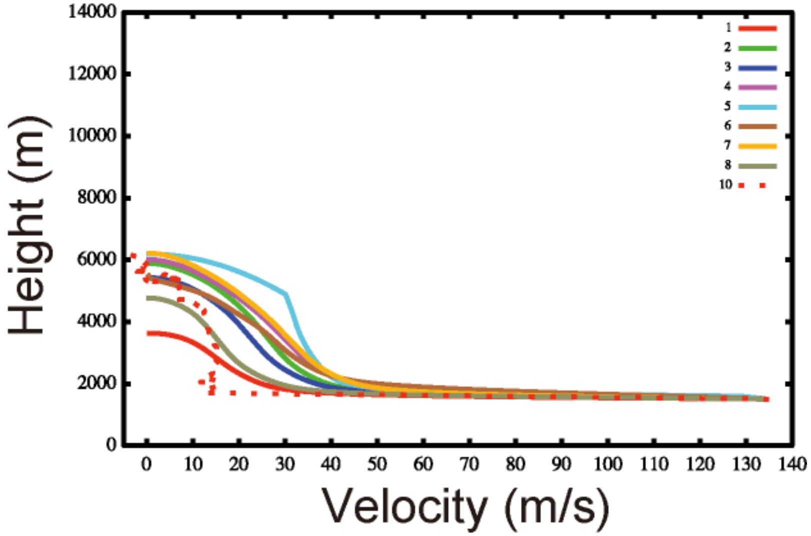
Windless





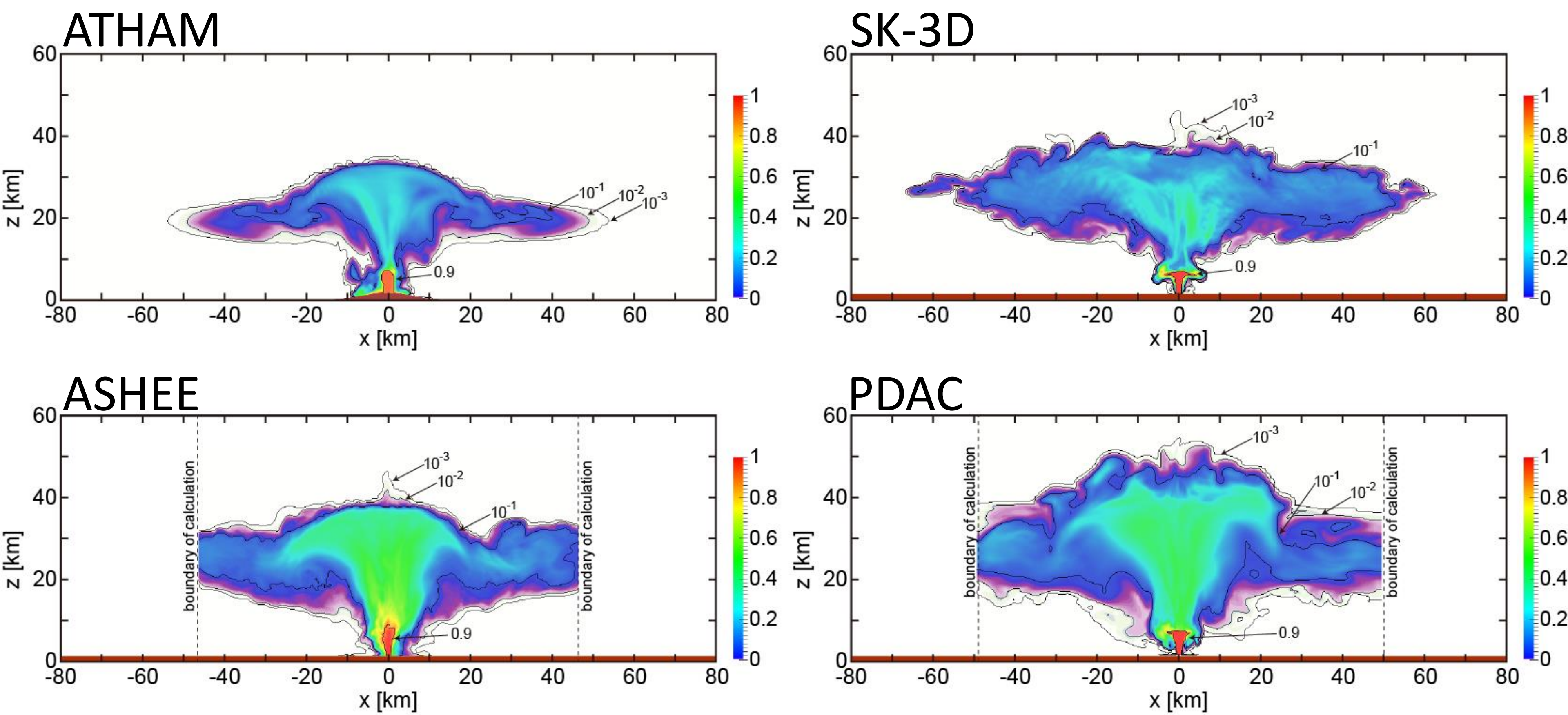
Windy





Inter-comparison of 3D models (1)

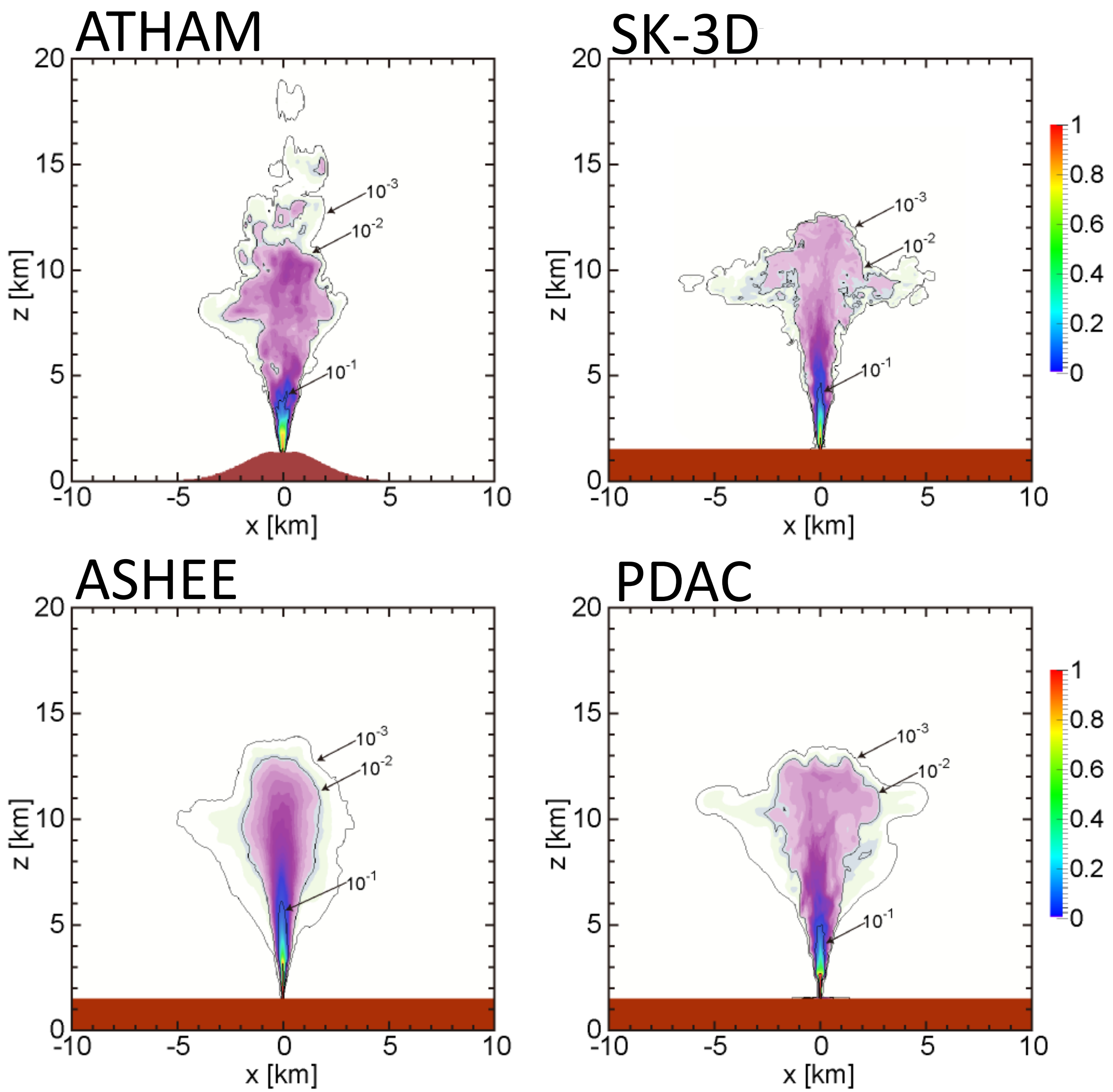
Strong plume without wind



Time averaging between 900 to 960 sec.

Inter-comparison of 3D models (2)

Weak plume
without wind



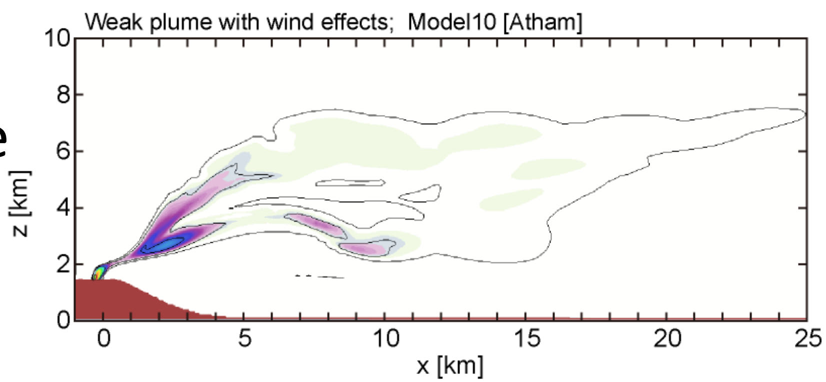
Inter-comparison of 3D models (3)

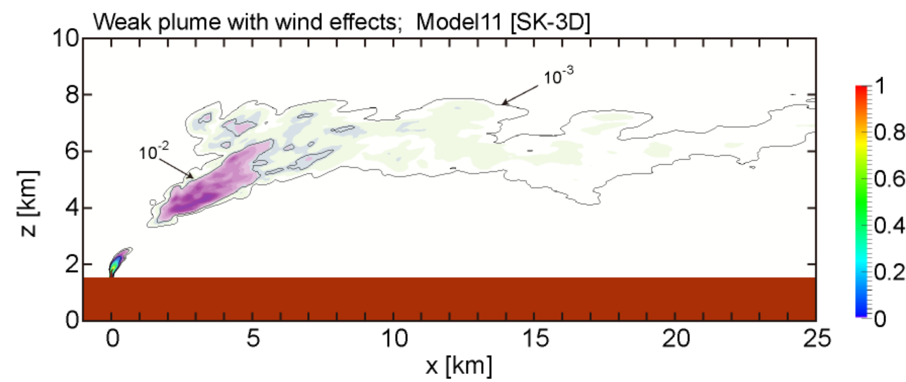
Windy cases

ATHAM

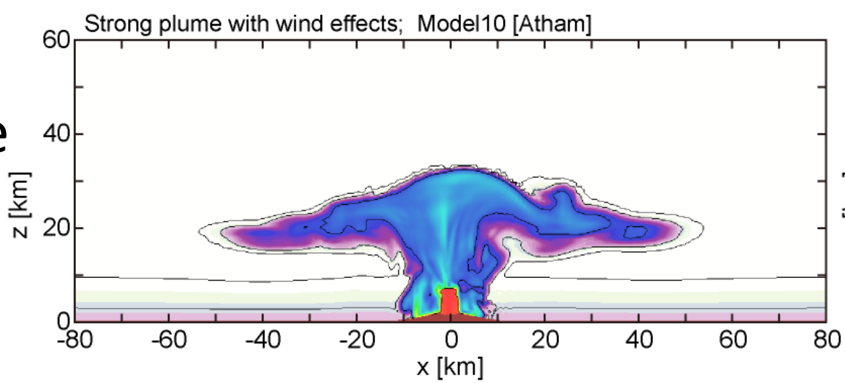
SK-3D

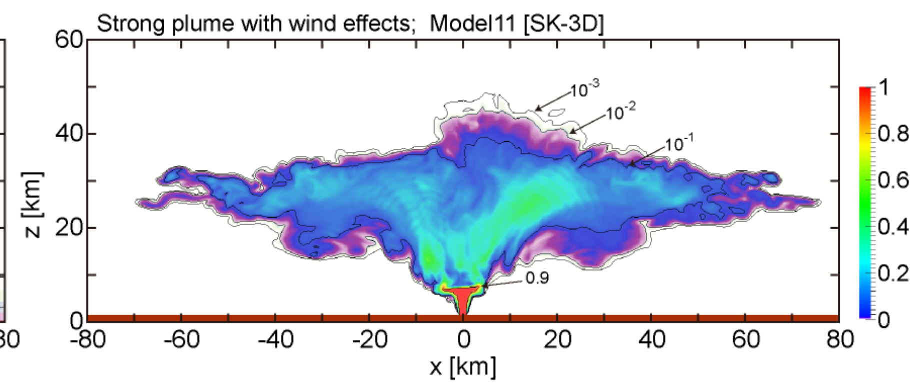
Weak plume





Strong plume





Summary

*For a fixd MER at the vent, the column heights simulated by each model seem showing a relatively good agreement with each other. However, because the strong dependence between MER and H, for a fixed column height, the estimated MER depends on which model is applied (differences are higher for weak plumes and in presence of strong wind).

*Profiles of 1D models for strong plumes differ from the cross-section integrals of 3D models whereas they are quite similar for weak plumes.

*On the basis of the 3D simulation results, it is required to develop new parameterizations of air entrainment assumed in the 1D models.

*We have to pay attention to the uncertainty of eruption column models when we use them for operational purposes.