噴煙柱数値モデルのベンチマークテスト

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A. van Eaton (USGS, USA)
C. Witham (Met. Office, UK)
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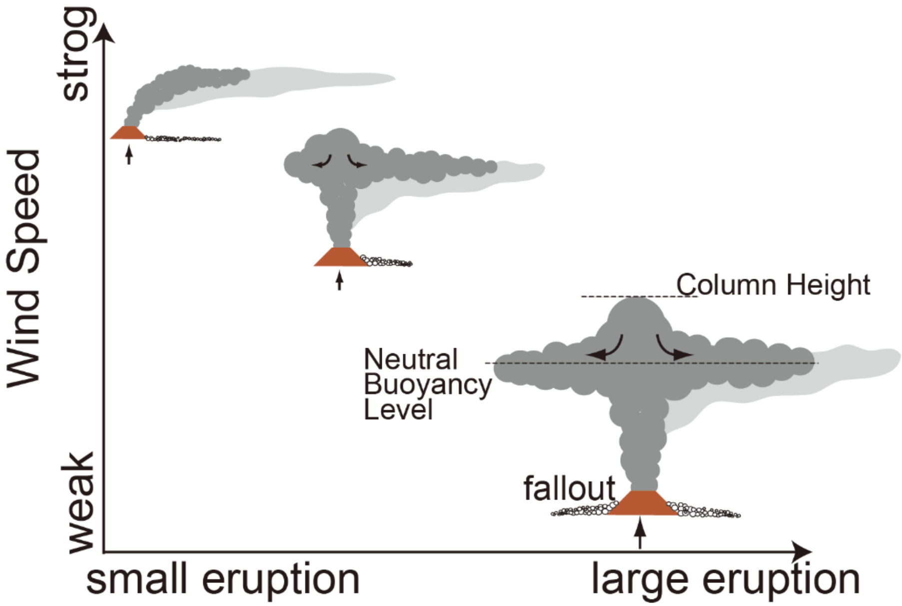
噴煙高度



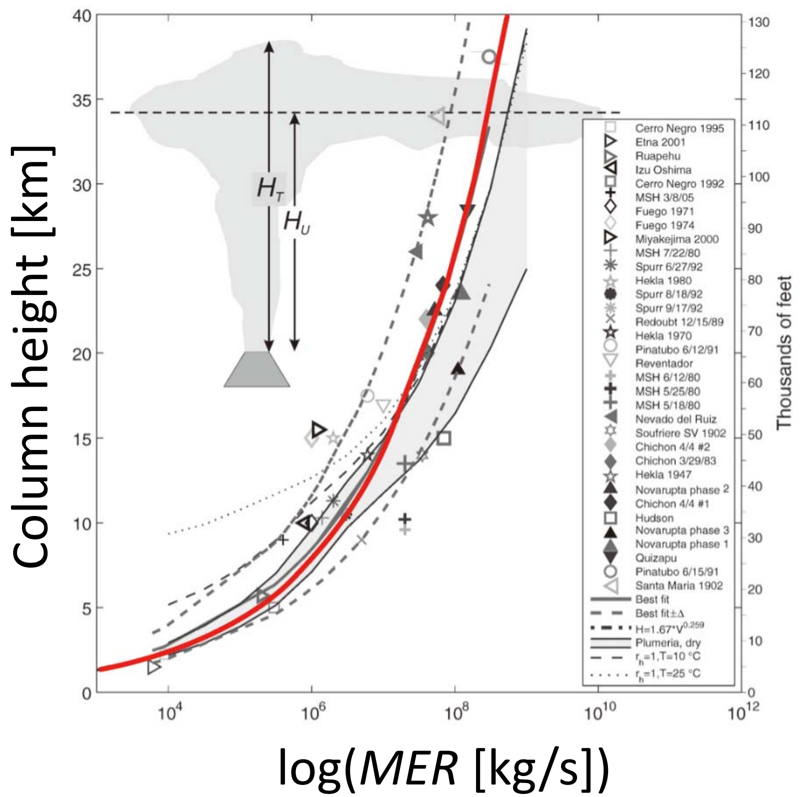
大気中での火山灰拡散分布
地表での堆積分布

噴煙高度

噴出率　(MER [kg/s])

次元解析モデル

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



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

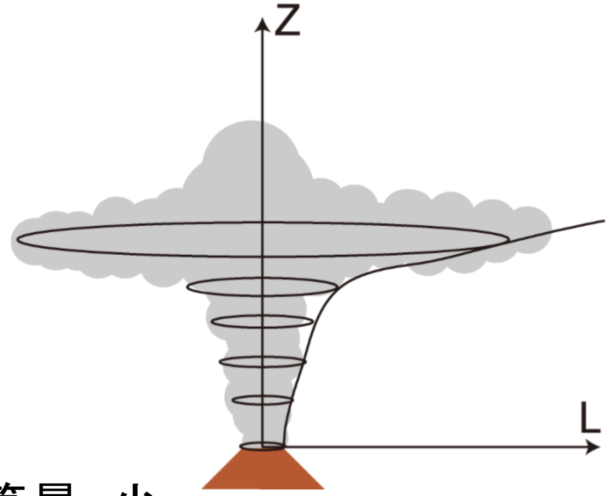
噴煙柱モデル

1D model

*Morton et al. (1956)のBuoyant Plume Theoryに基づく

*定常噴煙

*中心軸に沿った保存則



計算量：少

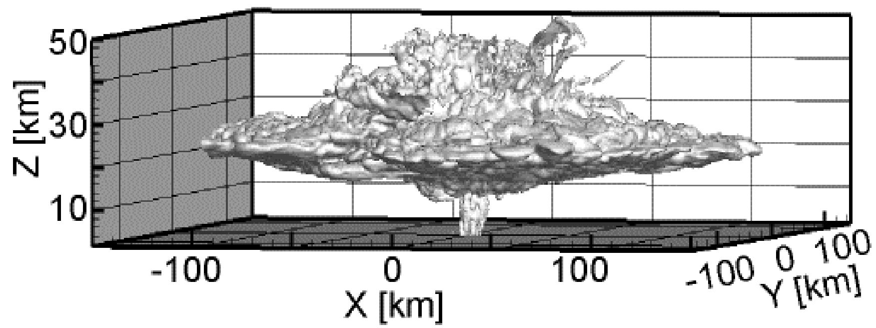
エントレインメント仮説に基づく

-> 実用的

3D model

*非定常

*Navier-Stokes 方程式



計算量：大

流れ場の直接計算

-> ダイナミクス理解に有用

異なるモデルから得られる結果を比較

モデル間の不確定性を評価

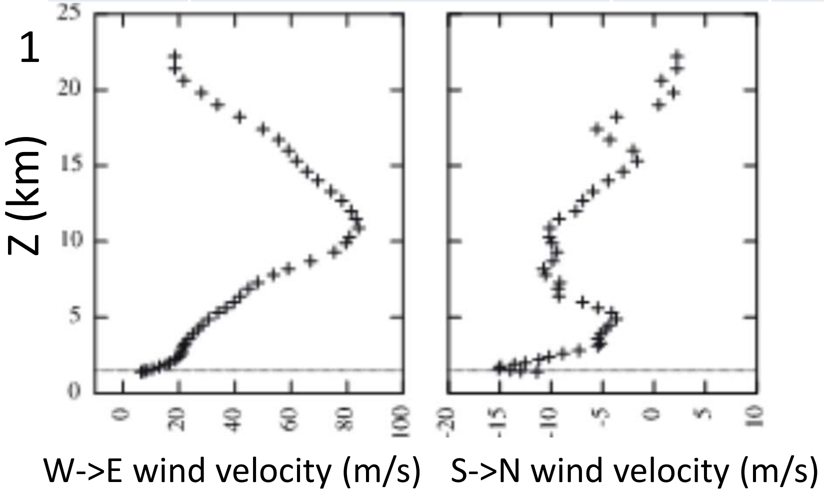
様々な噴煙柱モデル

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

計算条件

	#	噴火強度	風	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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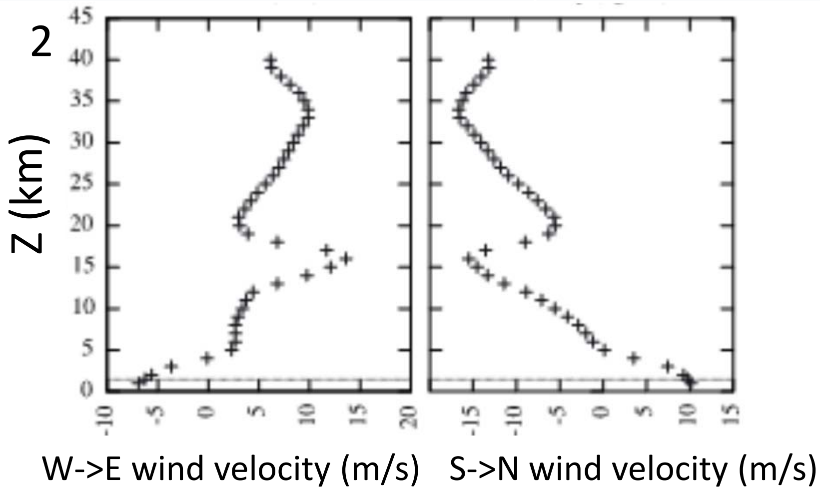
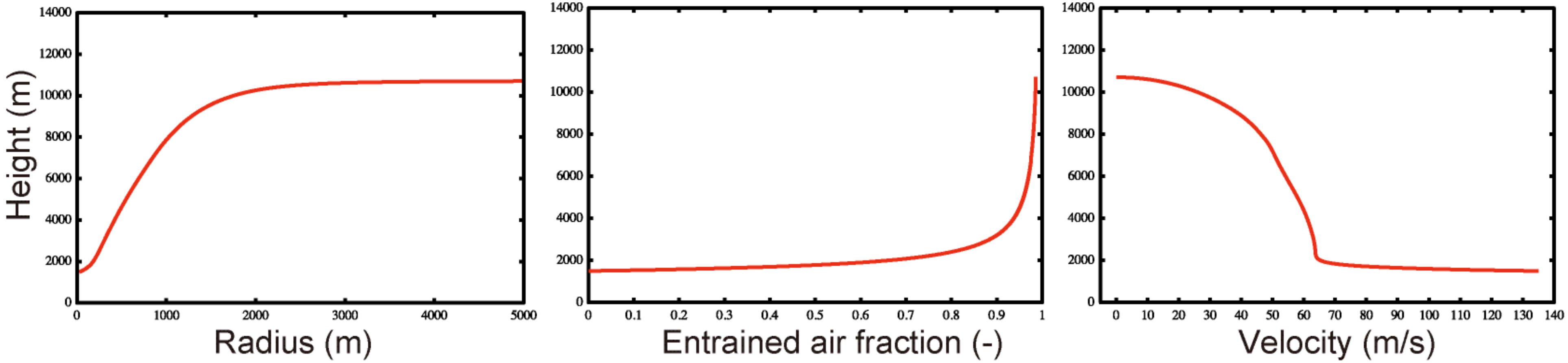
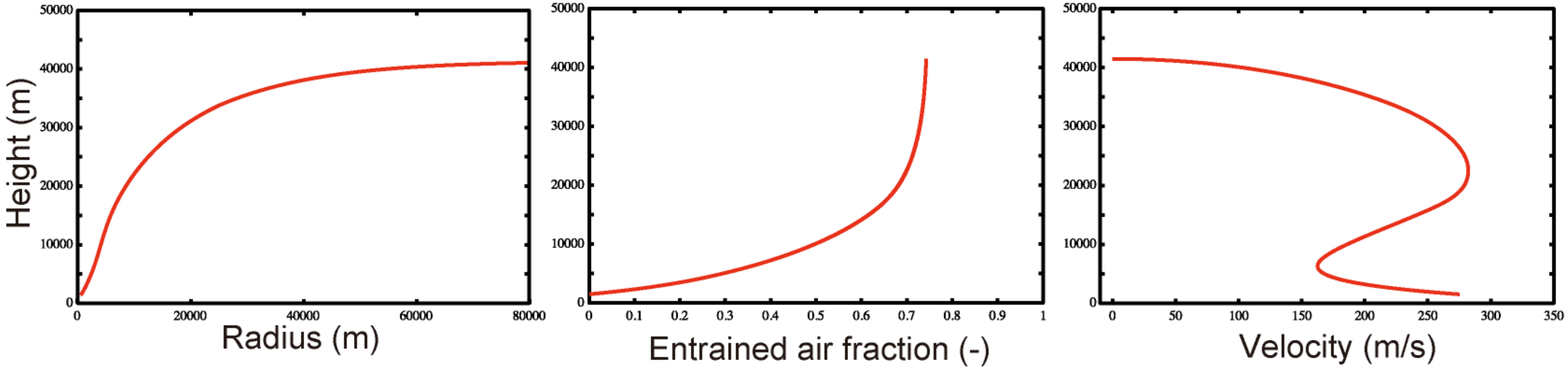


1Dモデルの計算例 (Plumeria)

Weak Plume without Wind

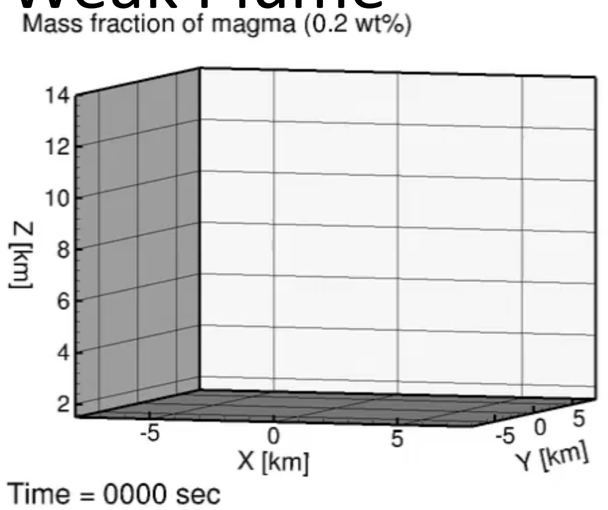


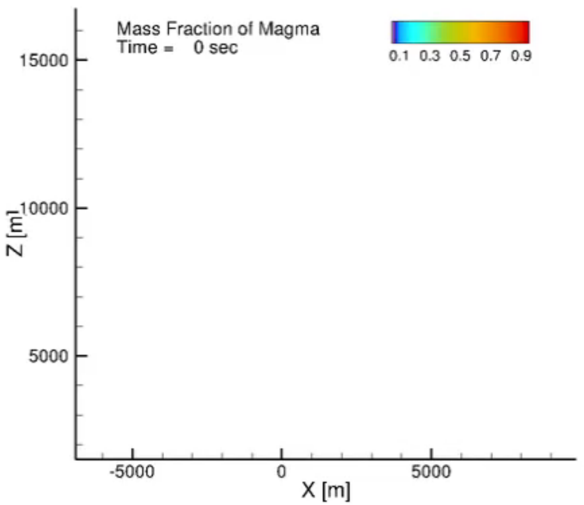
Strong Plume without Wind



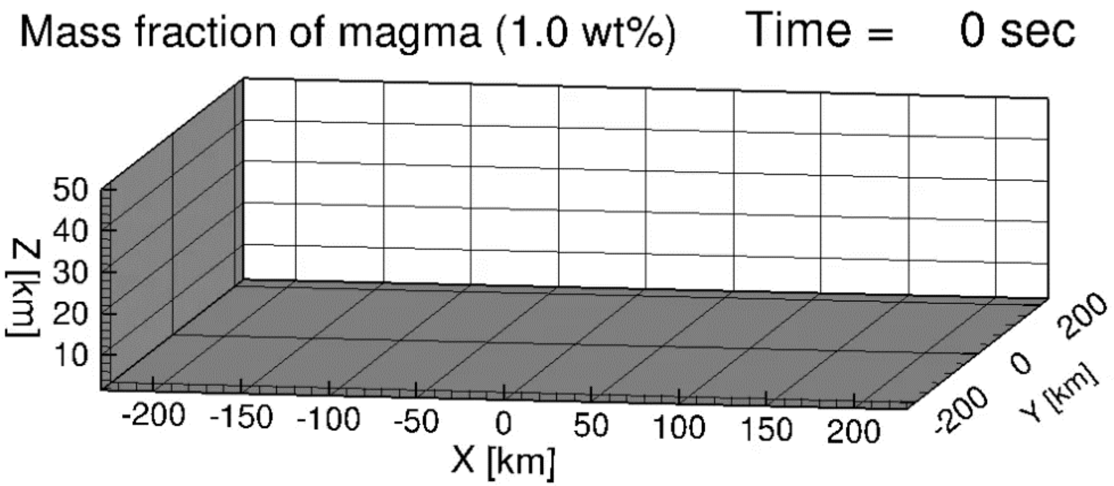
3Dモデルの計算例 (SK-3D)

Weak Plume

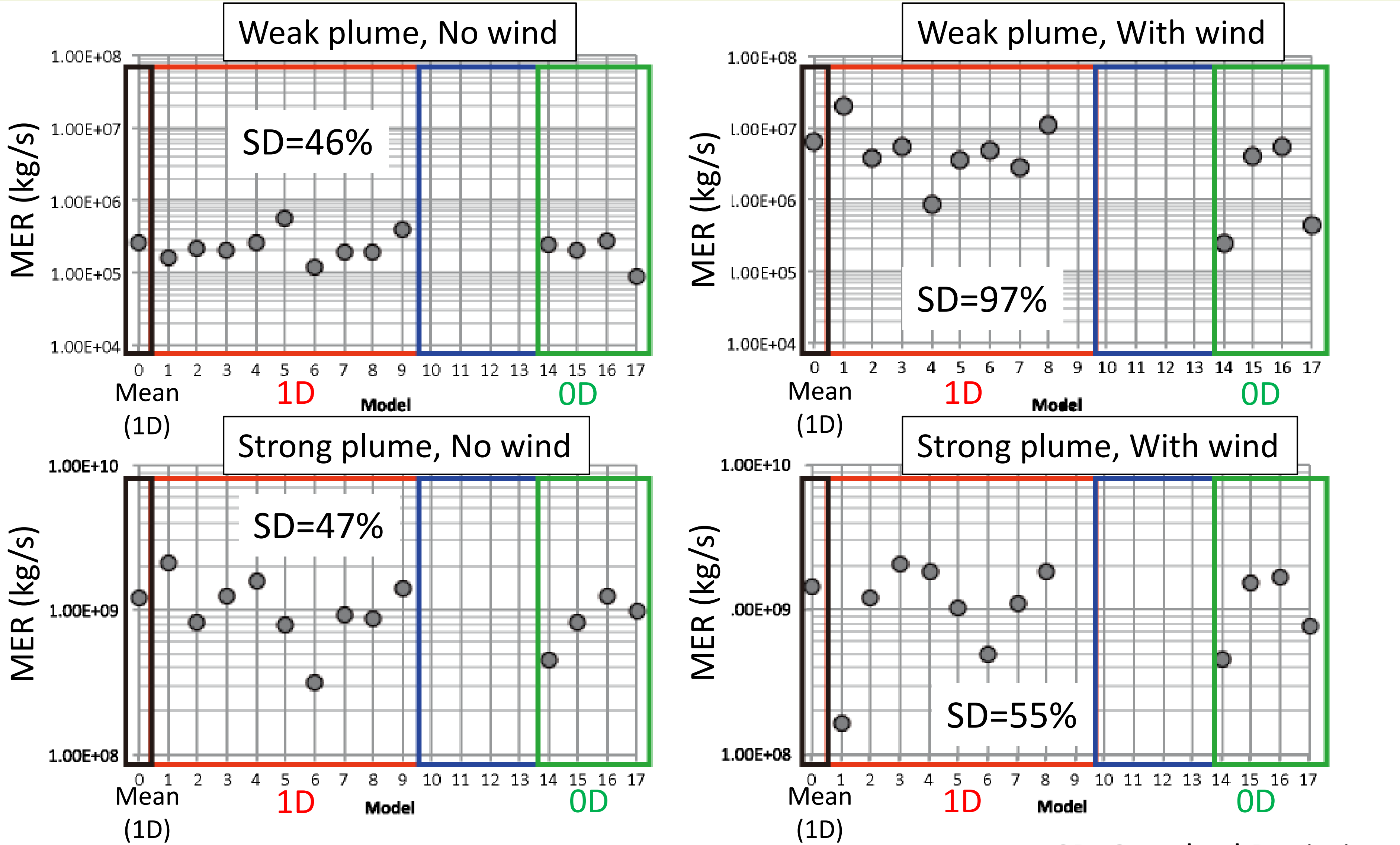




Strong Plume

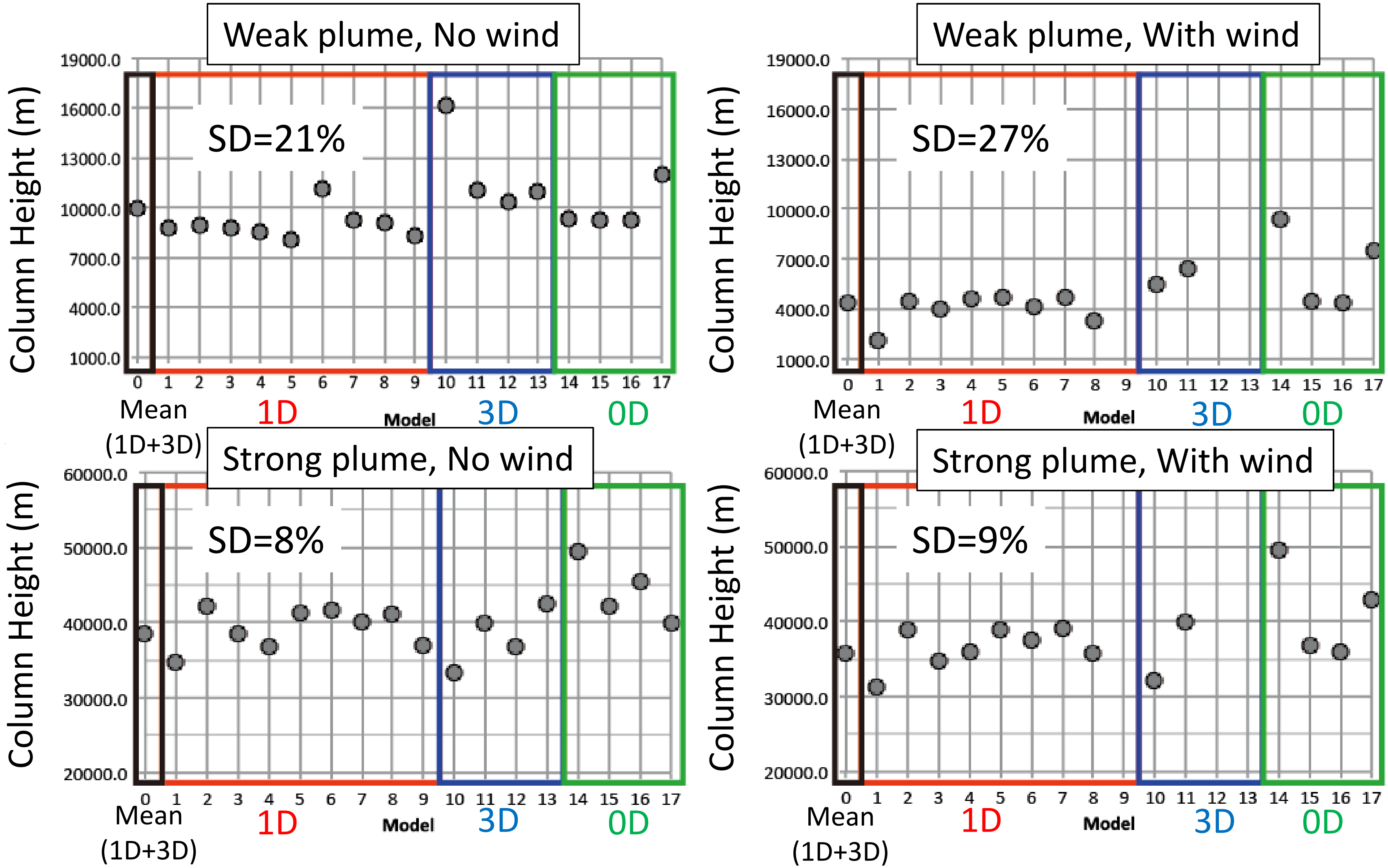


MERs for Fixed Column Heights



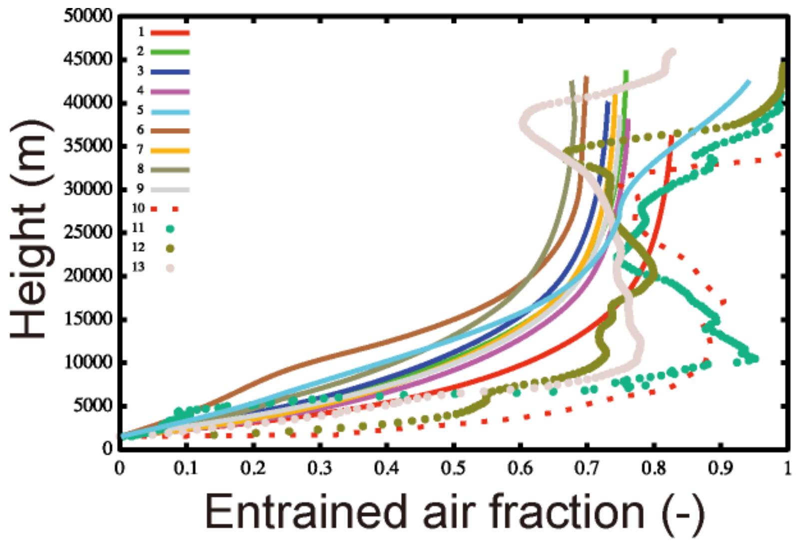
SD: Standard Deviation

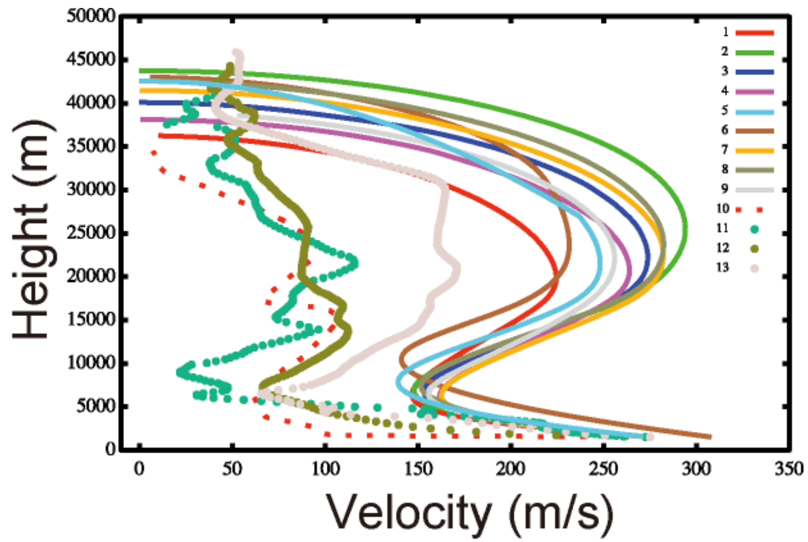
Column heights for Fixed MERs



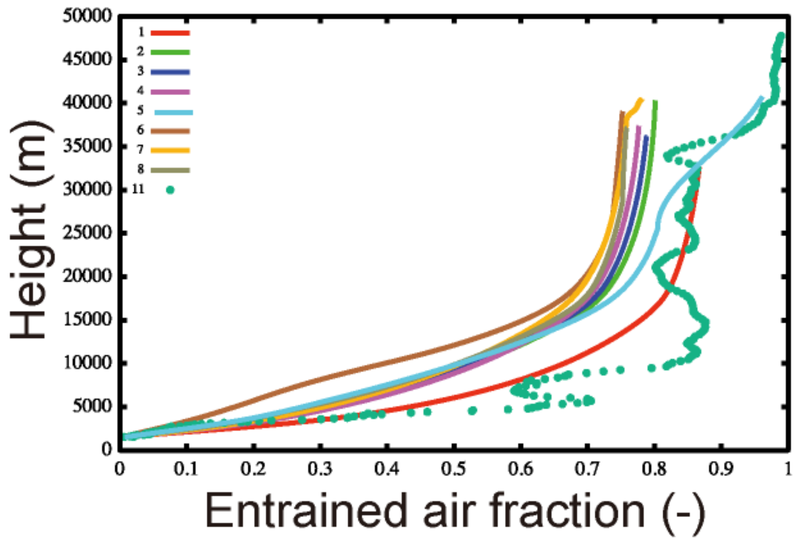
Strong plume

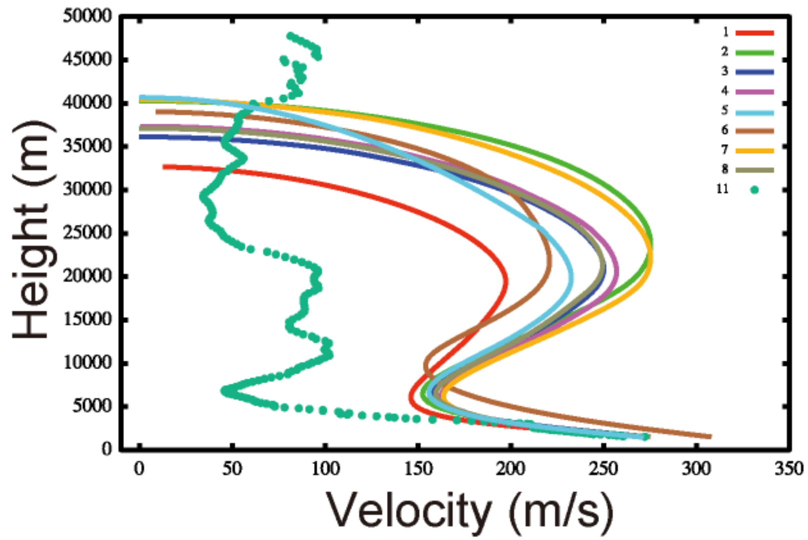
Windless





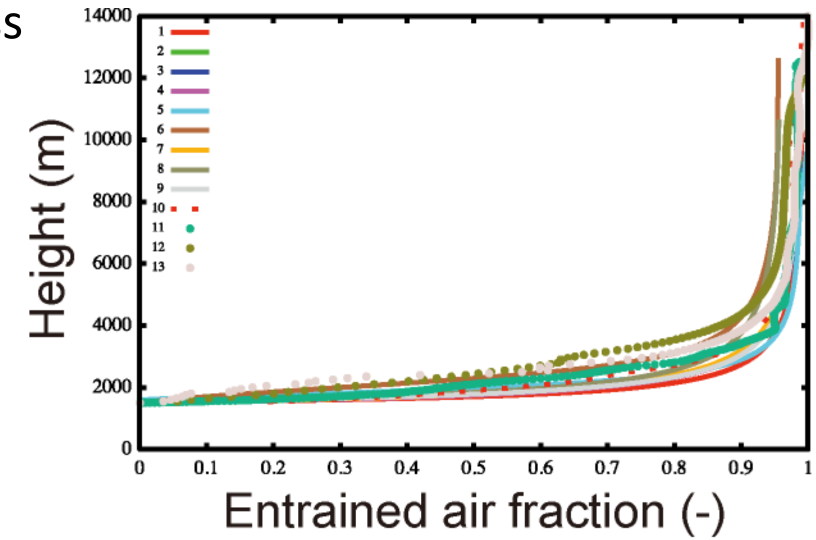
Windy

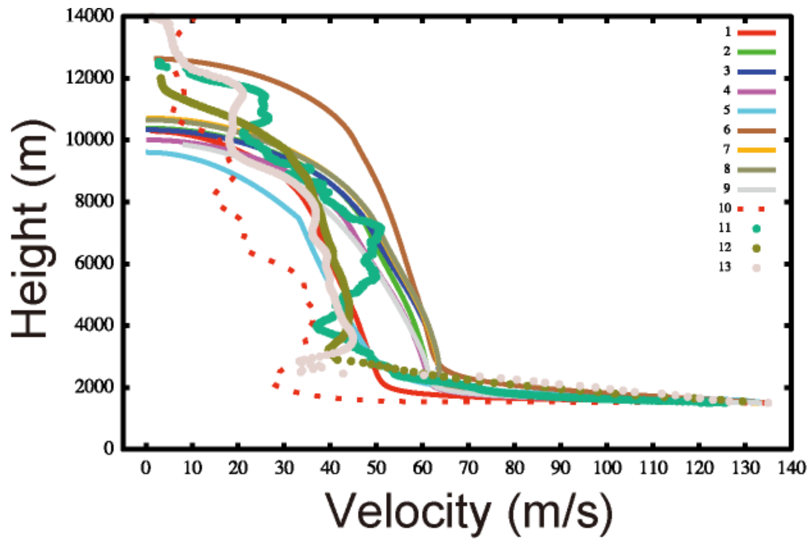




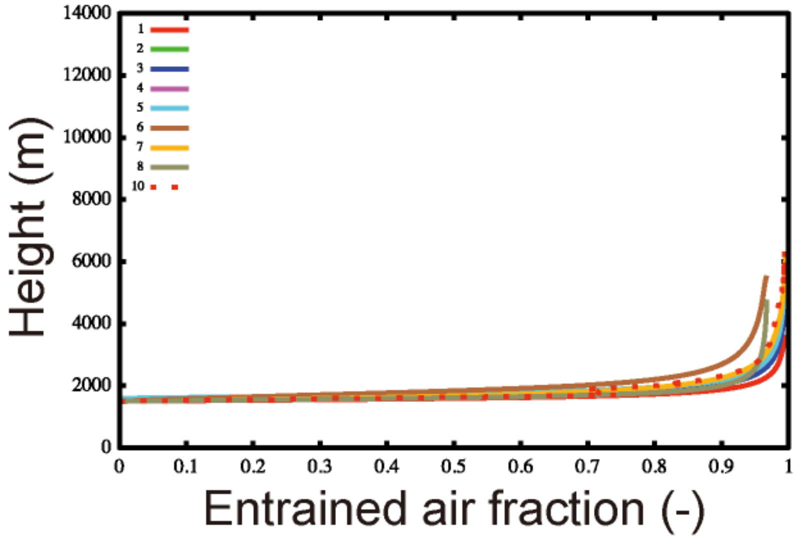
Weak plume

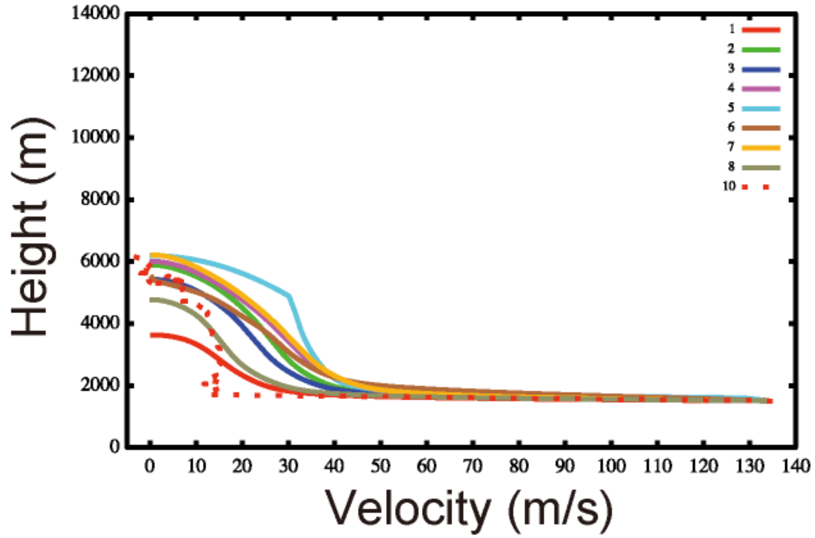
Windless





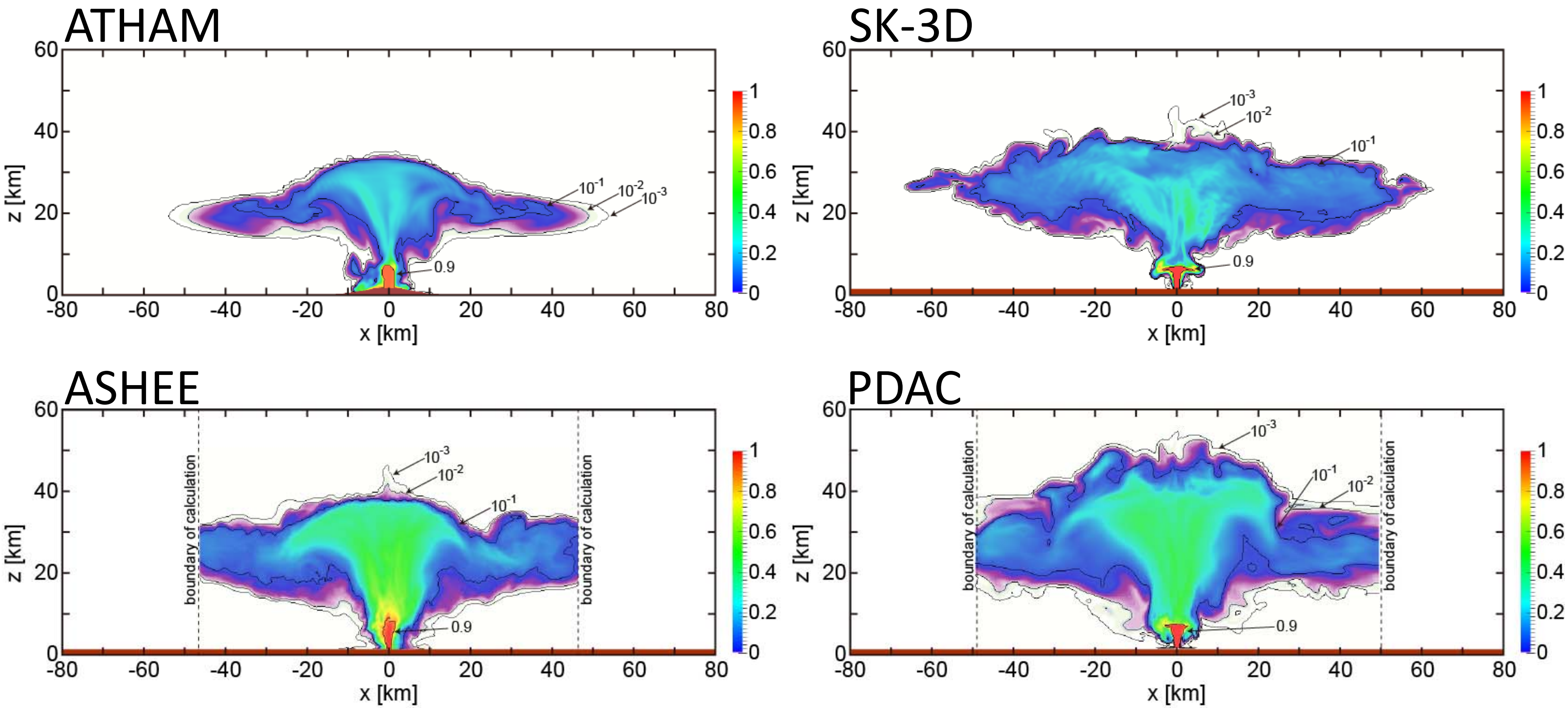
Windy





Inter-comparison of 3D models (1)

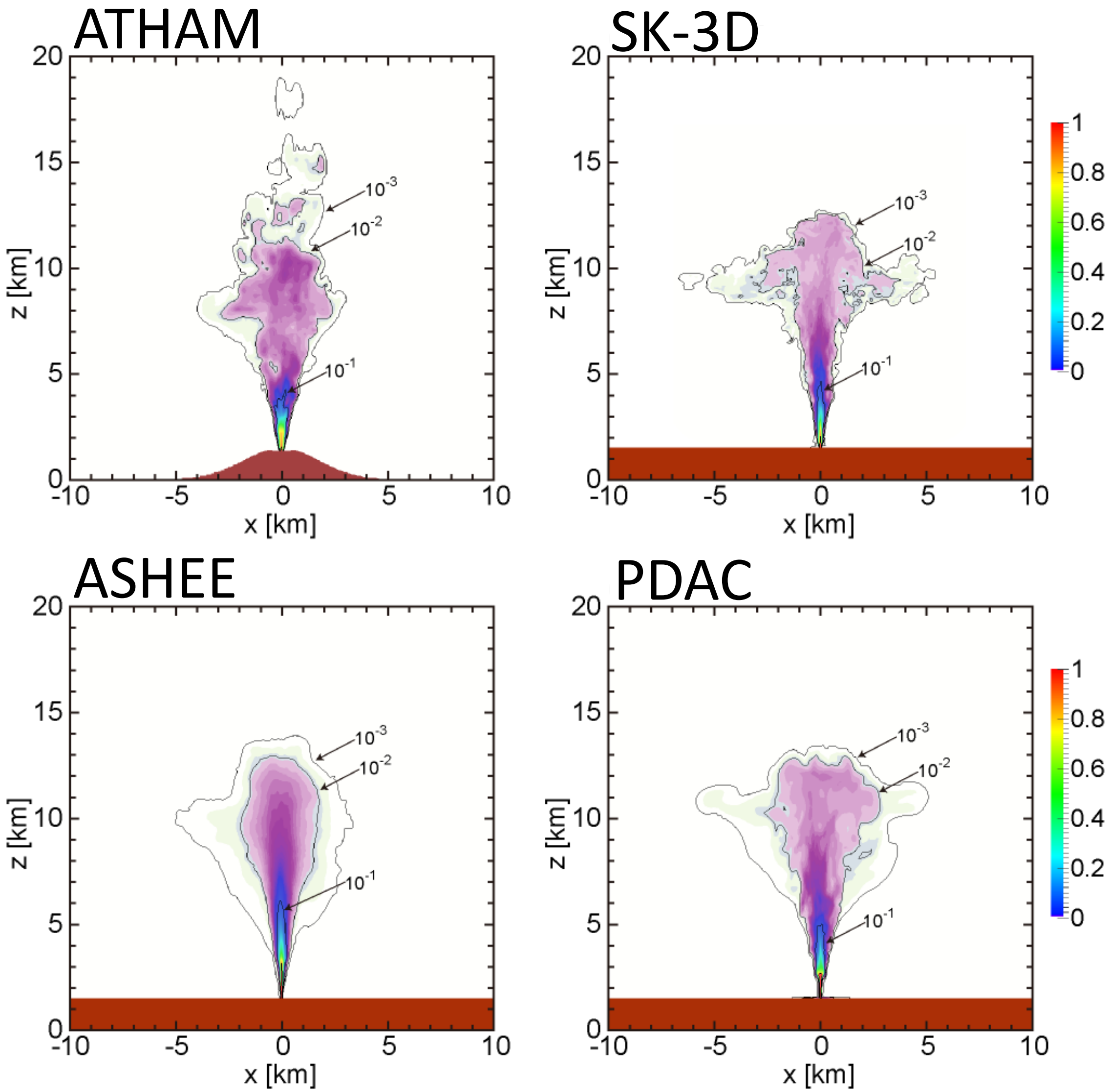
Strong plume without wind



Time averaging between 900 to 960 sec.

Inter-comparison of 3D models (2)

Weak plume
without wind



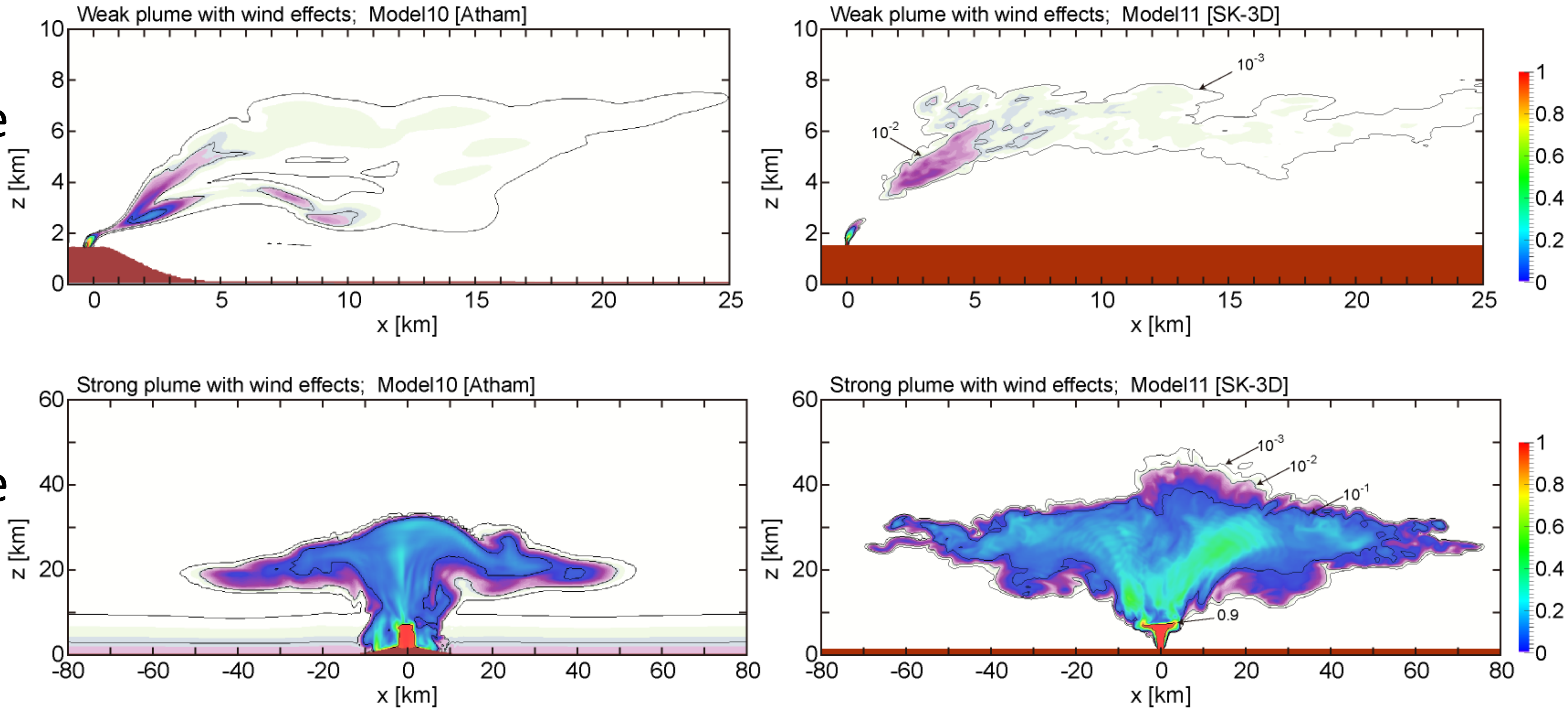
Inter-comparison of 3D models (3)

Windy cases

ATHAM SK-3D

Weak plume

Strong plume



まとめ

* 異なるモデルで「噴出率－噴煙高度」関係を求めた
  - ・噴出率固定：噴煙高度はモデル間で良い一致
  - ・噴煙高度固定：噴出率はモデルに敏感
  - ・小規模噴煙,風速大の条件で違いは顕著
* 小規模噴煙では,1Dと3Dモデルで鉛直プロファイルが類似.
  ただし噴煙高度は異なる
* 3Dシミュレーションを用いたエントレイメント係数決定が
  必要
* 火山灰拡散や降灰予測で噴煙柱モデルを用いる場合には
  モデルによる不確定性があることを認識しなければならな
  い.