

Plume Tracking Algorithm: Parameterisation of Volcanic Plume Dynamics

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LIMOS: Laboratoire d'Informatique, Modélisation et Optimisation des Systemes

LMV: Laboratoire Magmas et Volcans

29 June 2015



Introduction

Problematic

Volcanic plumes are hazardous (Health, Transportation)
Key processes are unconstrained

Objectives

Extract plume/vent parameters (morphology, velocity)
Follow evolution of these parameters during an eruption
Use parameters to constrain plume models

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Plume ascent at Sakurajima

Camera Properties

Thermal camera: Forward Looking Infrared Red (FLIR)

Spatial resolution FOV	:	(10m:4.25m)
Frame rate	:	30 Hz
Image dimension	:	640×480 pixel
Temperature range	:	-40° – 1500°C
Detector spectral range	:	7.5–13 μm



Datasets

Volcanoes

- Santiaguito ^a
- Stromboli ^b

^a[Sahetapy-Engel et al., 2008]

^b[Harris et al., 2013]

Experiments

- Overpressure shock-tube ^c
- Buried explosive charges ^d
- Bent-over plume ^e

^c e.g., [Cimarelli et al., 2013]

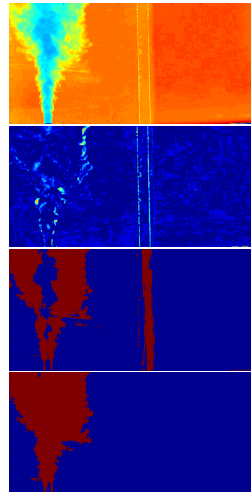
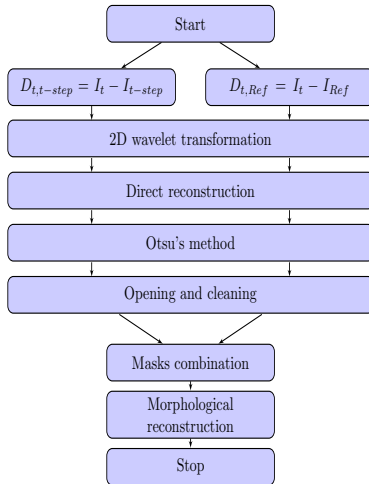
^d [Valentine et al., 2015]

^e [Carazzo et al., 2014]

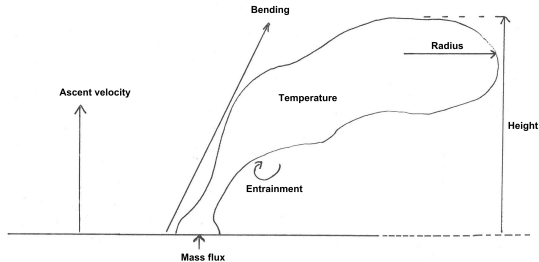
Dilemma

Distance
Safety

Resolution
Field of View



Parameters of interest



Based on [Morton, 1956] and [Turner, 1962;1973]

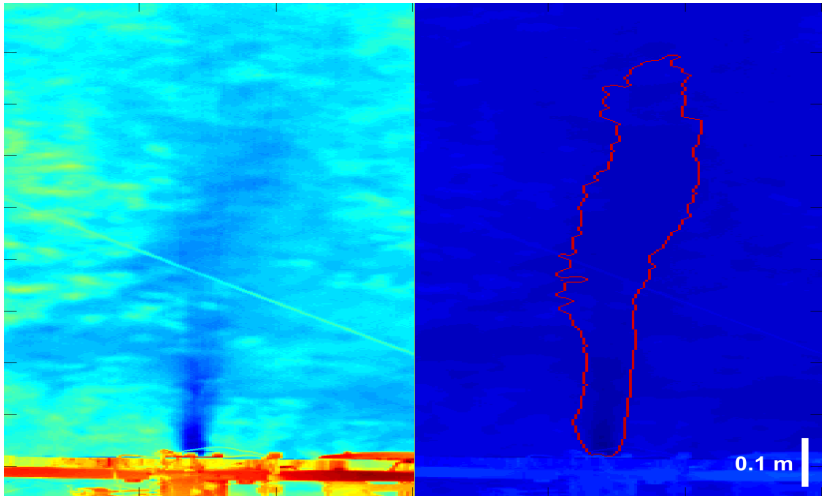
$$\frac{db}{dh} = \begin{cases} 2\alpha_e \\ \frac{6}{5}\alpha_e \\ \alpha_e \end{cases}$$

Jet
Steady (buoyant) plume
Discrete thermal

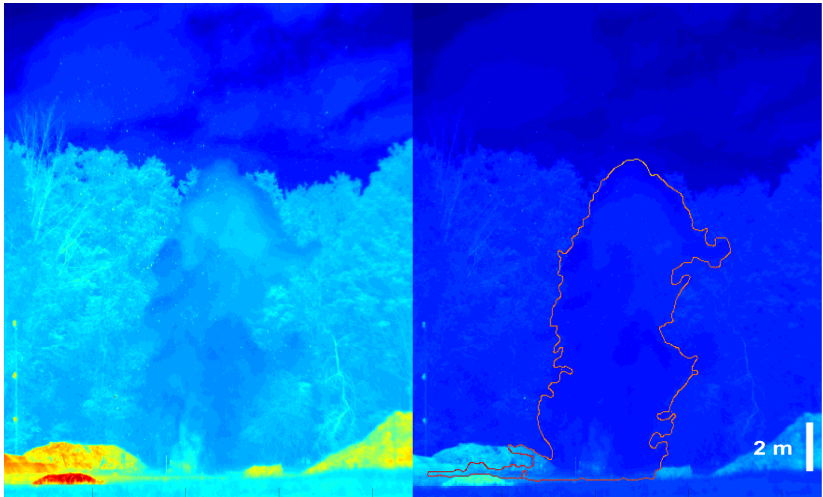
Santiaguito Volcano

Stromboli Volcano

Munich Experiment

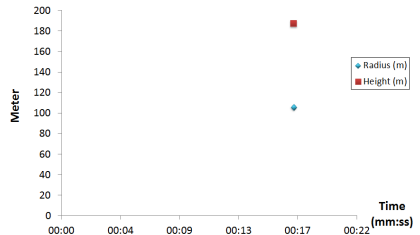
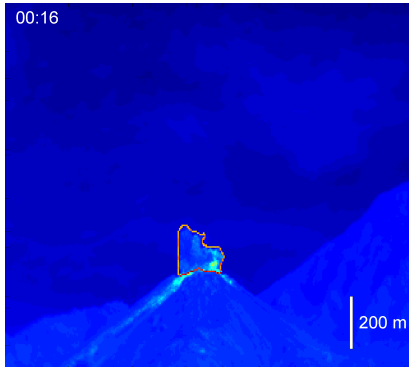


Buffalo Experiment

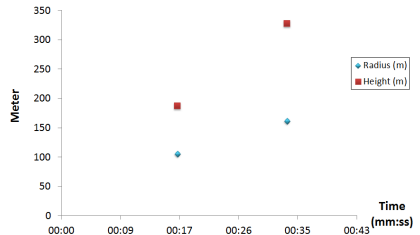
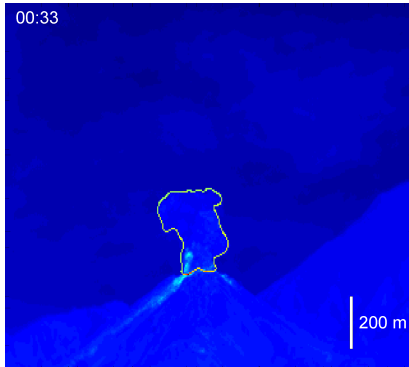


Bent-over plume Experiment

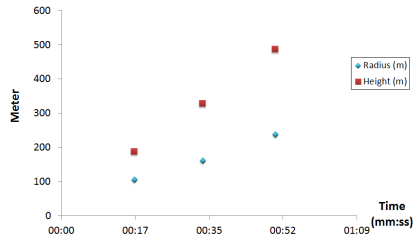
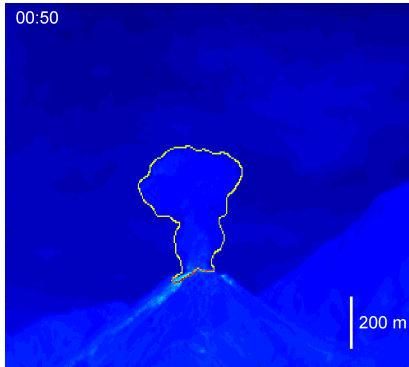
Height versus Width at Santiaguito



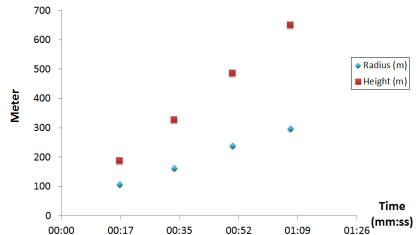
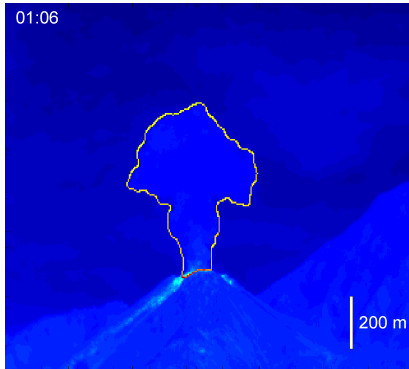
Height versus Width at Santiaguito



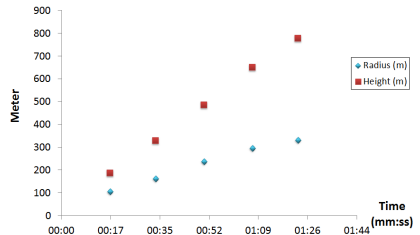
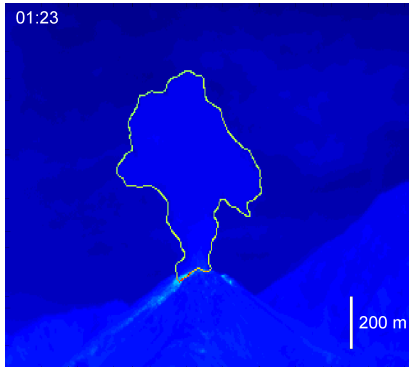
Height versus Width at Santiaguito



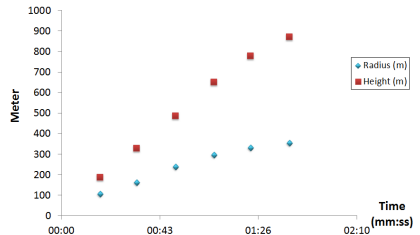
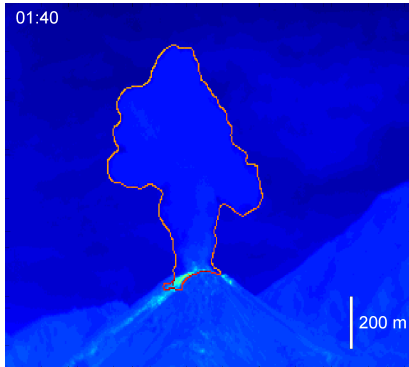
Height versus Width at Santiaguito



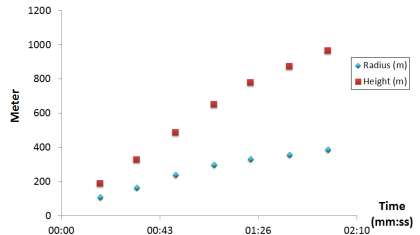
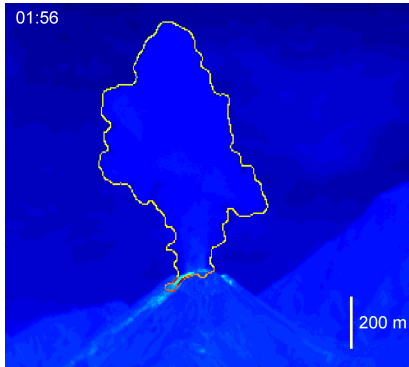
Height versus Width at Santiaguito



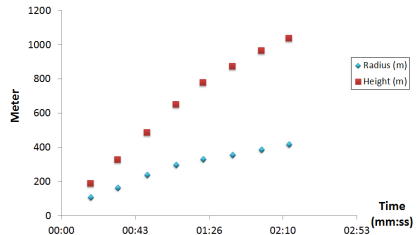
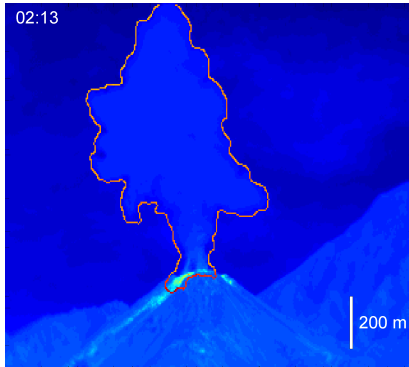
Height versus Width at Santiaguito



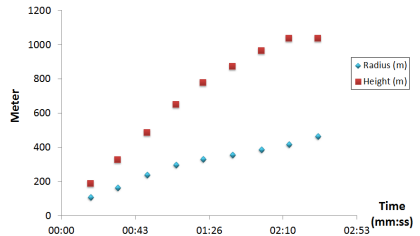
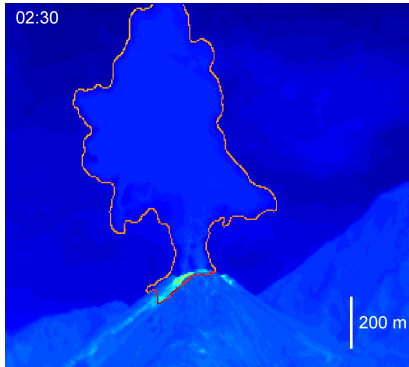
Height versus Width at Santiaguito



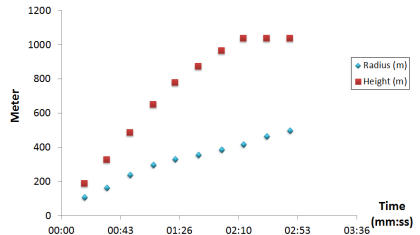
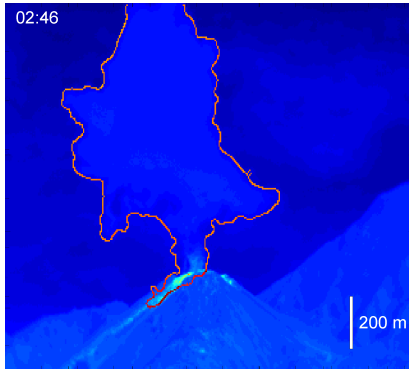
Height versus Width at Santiaguito



Height versus Width at Santiaguito

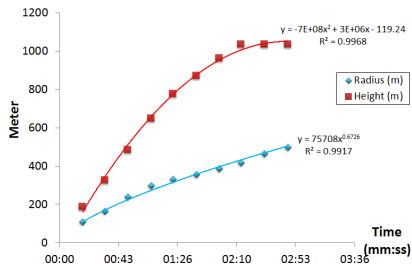


Height versus Width at Santiaguito



Height versus Width at Santiaguito

Frame	Relative Time	Height (m)	Radius (m)
500	00:00:16	117	66
1000	00:00:33	204	100
1500	00:00:50	303	148
2000	00:01:06	405	184
2500	00:01:23	485	206
3000	00:01:40	543	221
3500	00:01:56	602	241
4000	00:02:13	645	259
4500	00:02:30	645	288
5000	00:02:46	645	309



Air coefficient calculation

Location	α_e	Plume type [Patrick et al., 2007]
Munich	0.03	True jet
Stromboli	0.11	Transitional
Santiaguito	0.21	Slow plume
Buffalo	0.28	Slow plume

Consistent with max entrainment

Due to vent structure and low energy explosion

(vent $\approx$ circular with hollow middle in which to trap air).

Conclusion

Results

A fast and autonomous algorithm

Robust across different environments and contrast conditions

Prospects

Entrainment dynamics in terms of source conditions:

Height, width, temperature, vent geometry

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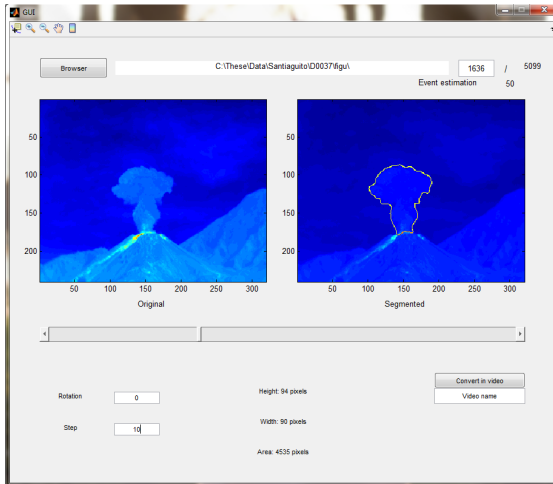
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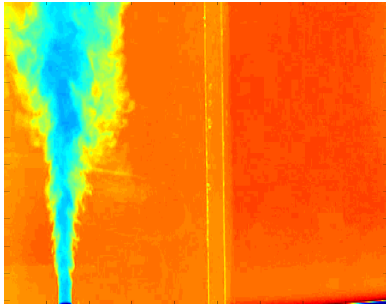


Graphical User Interface

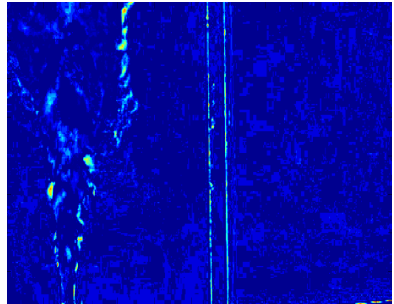


Segmentation

Coefficient computation



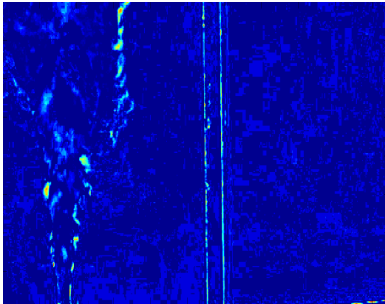
(a) Original



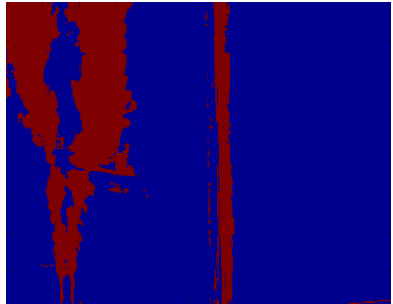
(b) Approximation coefficient matrix

Segmentation

Mask extraction



(c) Approximation coefficient matrix



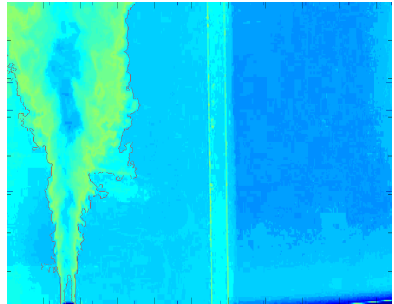
(d) Mask

Segmentation

Edges definition



(e) Cleaned up



(f) Final edges

Buffalo Experiment