Improvements in eruption monitoring and eruptive source definition: new instruments, new capabilities

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Using information and data from many colleagues at Nordvulk and IMO

Workshop : Uncertainty estimation and expert judgment for the definition of ash-affected air-space sectors, Icelandic Meteorological Office, Reykjavík, 22 September 2015

SEVENTH FRAMEWORK PROGRAMME

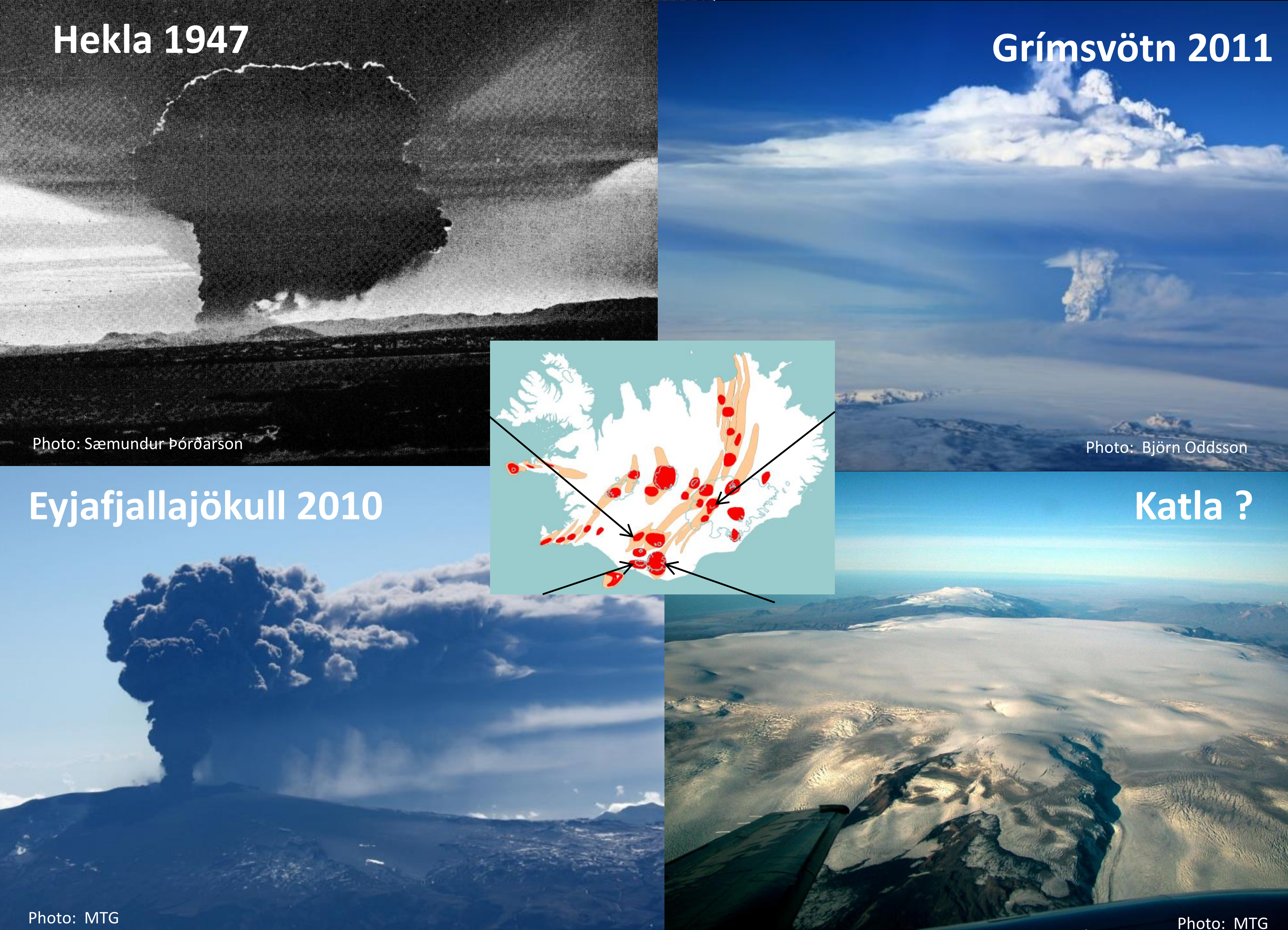
FUTUREVOLC

Eyjafjallajökull 14 April 2010
Photo: Þórdís Högnadóttir

Monitoring volcanic activity

importance of the Mass Eruption Rate (MER)

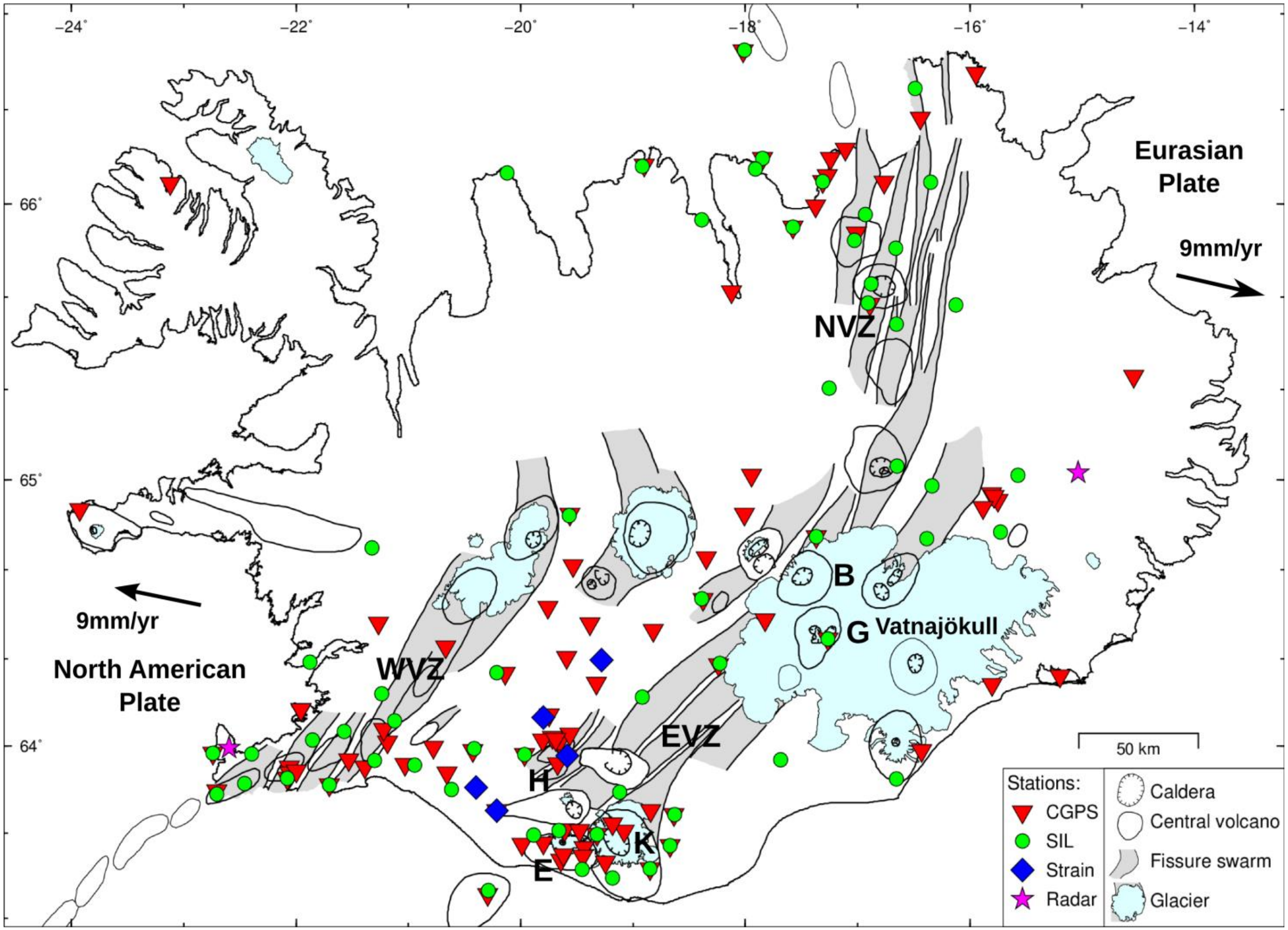
- **Precursors to eruption:** Earthquakes, ground deformation, river chemistry, geothermal signals, gas emission
- **During eruption:** Networks monitoring above + plume/vent monitoring: Visual observations, radar, infrasound, electric signals, gas, satellite
- **Interpretation** – estimates of **MER**: All the above – strong emphasis on plume height
- Advances in all fields in recent years - improved instrumentation + interpretation models (including Futurevolc and other recent large projects)
- Many volcanic areas of the world are still poorly monitored with ground-based instruments – potential of satellite monitoring


Hekla 1947
Photo: Sæmundur Þórðarson
Grímsvötn 2011
Photo: Björn Oddsson
Eyjafjallajökull 2010
Photo: MTG
Katla ?
Photo: MTG

Volcanic eruptions in Iceland in the last 100 years

Red = Explosive Black = Effusive Blue = Subglacial

Year	Volcano	VEI	note	style of activity
2014-15	Bárðarbunga-Holuhraun	1	(ice)	effusive
2011	Grímsvötn	4	ice	explosive
2010	Eyjafjallajökull	3	ice	explosive/effusive
2004	Grímsvötn	3	ice	explosive
2000	Hekla	3		effusive/explosive
1998	Grímsvötn	3	ice	explosive
1996	Gjálp (Grímsvötn)	3	ice	subglacial-explosive
1991	Hekla	3		effusive/explosive
1983	Grímsvötn	2	ice	explosive
1980-81	Hekla	3		effusive/explosive
1975-84	Krafla fires (9 eruptions)	1		effusive
1973	Heimaey	2		effusive/explosive
1970	Hekla	3		effusive/explosive
1963-67	Surtsey	3	ocean	explosive/effusive
1961	Askja	2		effusive
1947-48	Hekla	4		effusive/explosive
1938	Gjálp (Grímsvötn)	-	ice	subglacial
1934	Grímsvötn	3	ice	explosive
1922-29	Askja (5-6 eruptions)	2	(lake)	effusive/explosive
1922	Grímsvötn	3	ice	explosive
1918	Katla	4	ice	explosive

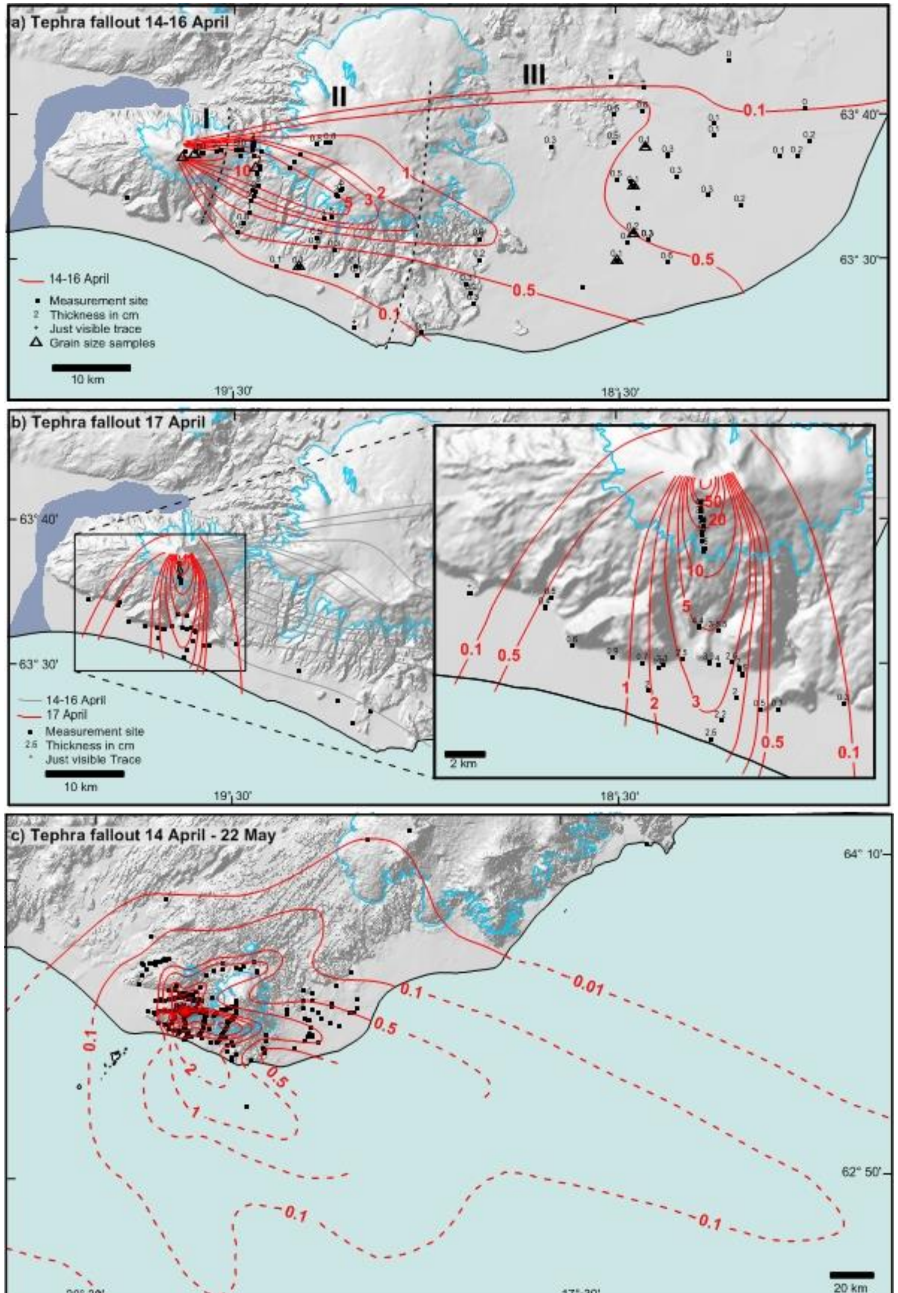


Iceland, volcanoes, plate boundary, present long-term monitoring stations. Volcanic zones: Western Eastern, and Northern (WVZ, EVZ, NVZ).

Most active volcanoes are Grímsvötn (G) and Bárðarbunga (B) under the Vatnajökull ice cap, Katla (K) under Mýrdalsjökull ice cap, and Hekla (H).

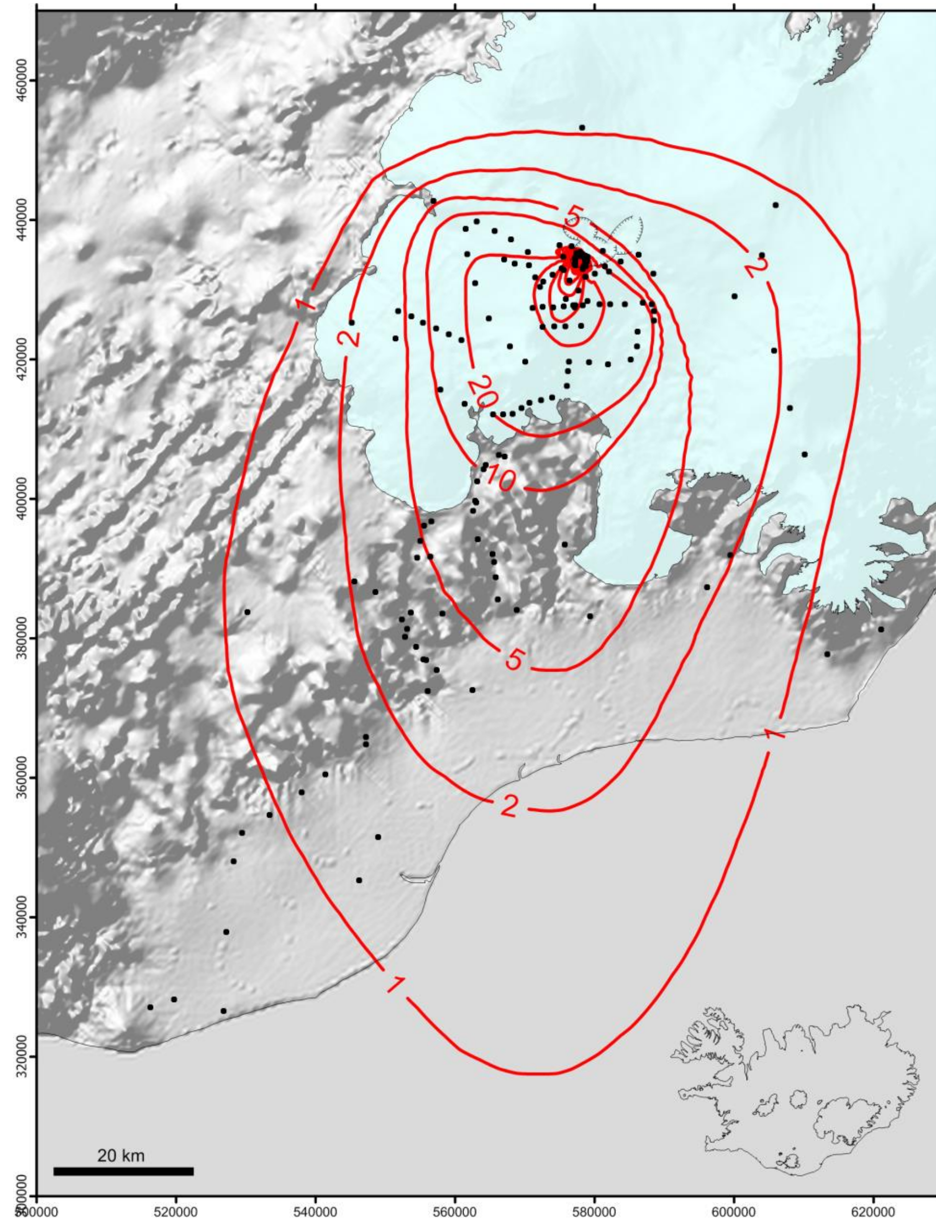
Eyjafjallajökull vocano is labelled E

Eyjafjallajökull 2010



Gudmundsson et al. 2012

Grímsvötn 2011



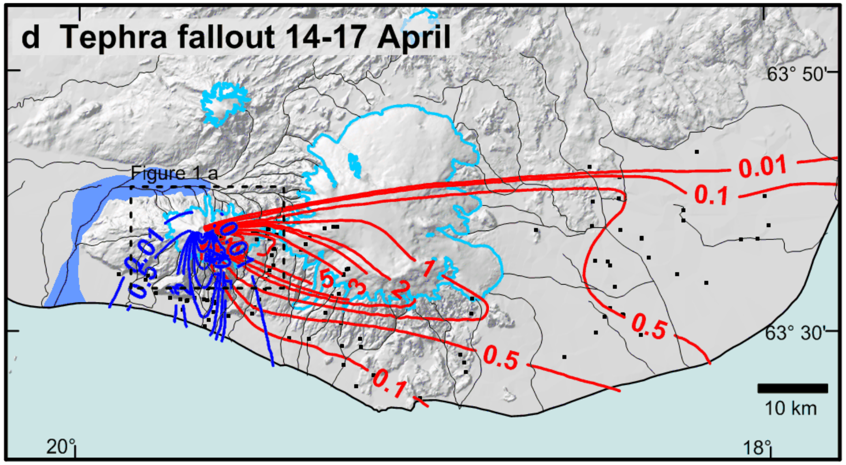
Institute of Earth Sciences, UoI, unpublished

Challenges in eruption source magnitude determination

Eruption rate – example of Eyjafjallajökull 2010 – first explosive phase

Method	MER (kg/s)	Reference
Ground sampling *Temporal distribution using scaled Mastin eq.*	$0.5\text{-}1 \times 10^6$	Gudmundsson et al. (2012)
Plume model (wind effect)	$>1 \times 10^7$	Bursik et al. (2012)
Plume model (wind effect)	$5\text{-}9 \times 10^6$	Woodhouse et al. (2012)

Mapping of mass of erupted material does not support the high eruption rates

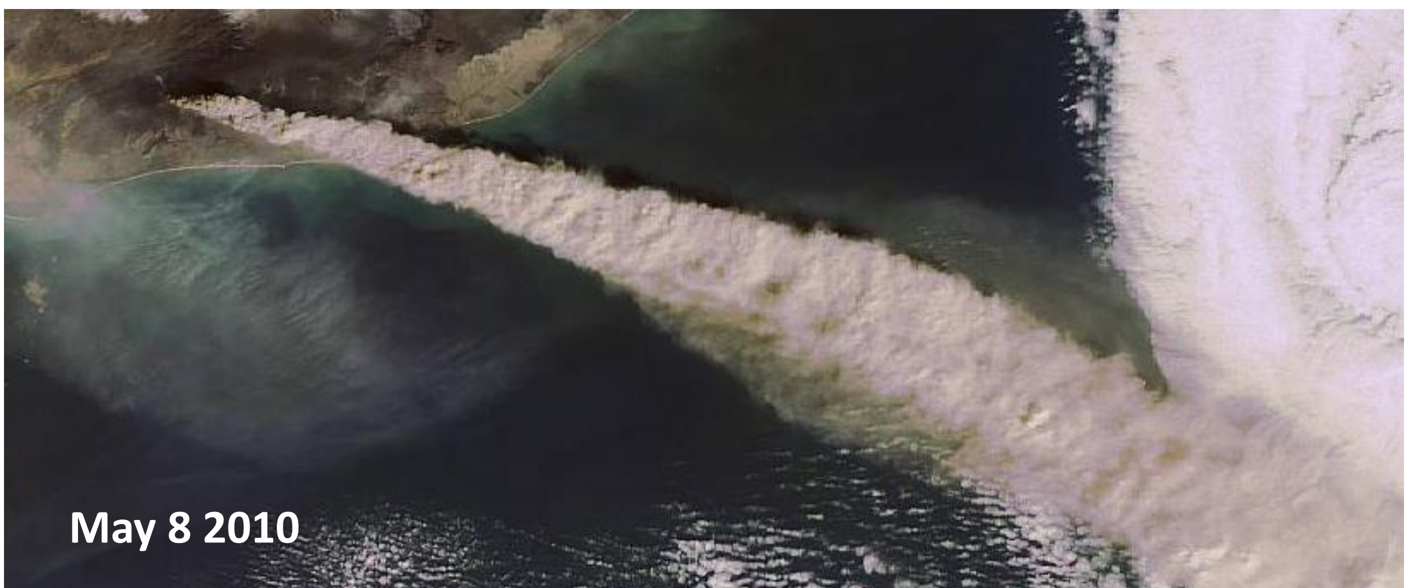


Challenges in eruption source magnitude determination

Magnitudes of <30 µm ash emitted from volcano

Method	mass of <30µm	Reference
Ground sampling + grain size distributions	70 Tg	Gudmundsson et al. (2012)
Satellite derived	8 Tg	Stoll et al., (2011) Schumann et al. (2011)

An order of magnitude discrepancy – work needed to resolve the differences



FUTUREVOLC approach – better and faster estimates of ongoing processes – before eruptions and during eruptions

Long term magma tracking

Imminent eruptive activity, eruption onset and early warning

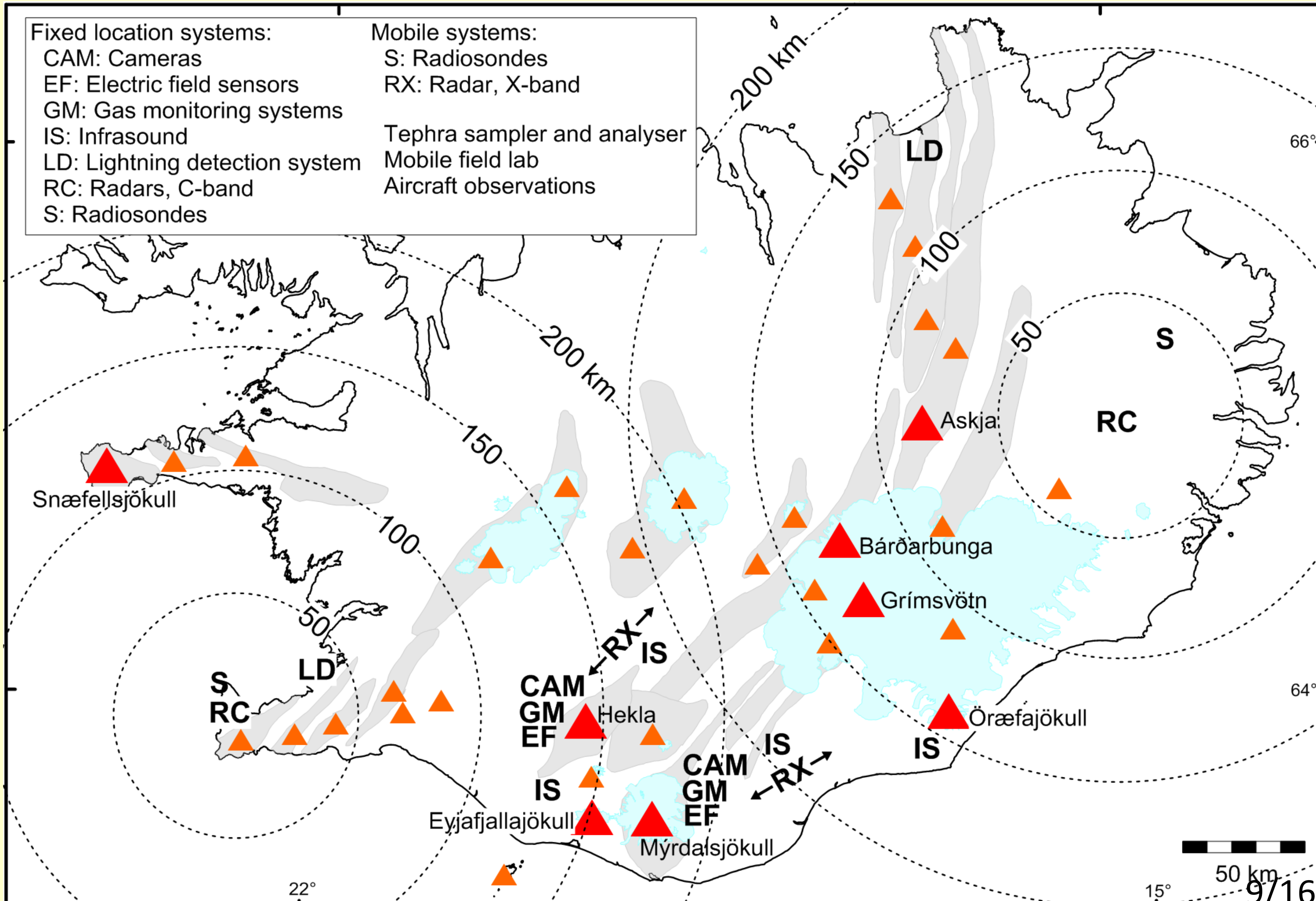
Determination and evolution or eruption source parameters

- In real-time or near real-time provide quantiative estimates of mass eruption rate
- Fast delivery of composition, grain size distribution and volatile emission
- Explosive, effusive and subglacial eruptions

Distribution and description of eruptive products

- Fast quantitative information on atmospheric ash and sulphur dioxide concentrations in near and far field

Futurevolc plan for observations of plumes – determination of MER In near real time

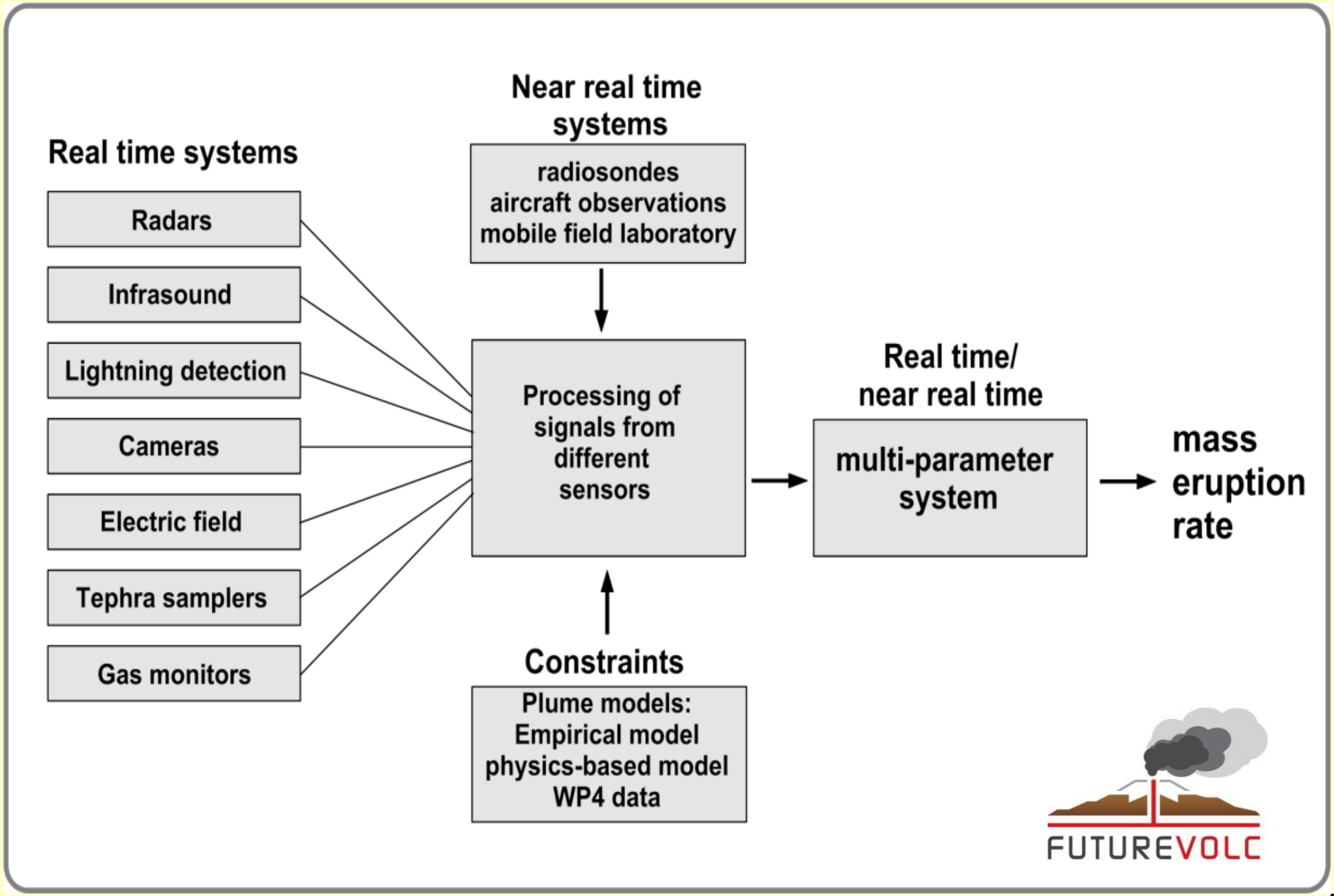


C3

Futurevolc: Sensors, types of volcanic eruptions, and contribution to multi-parameter system for near real time determination of eruption source parameters.

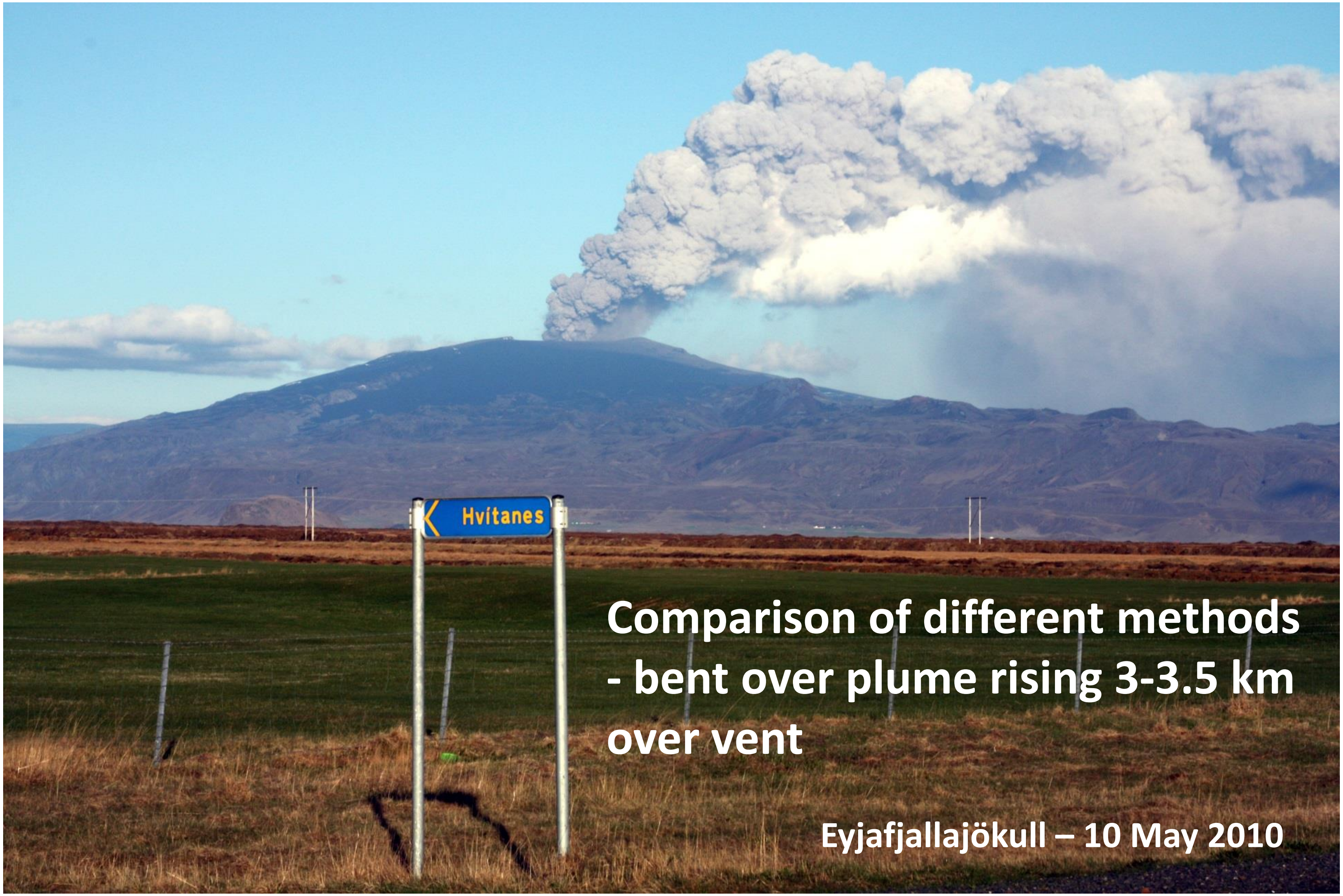
Method/sensor	Observed parameters	Explosive	Eff-usive	Sub-glacial	Data streaming
Infrasound	Acoustic waves	X	(X)		real time
Cameras	Optical and infrared	X	X	(X)	real time
Electric field sensors	Electric field gradients	X	(X)		real time
Radiosondes	Data on ambient atmosphere	X			near-real time
Tephra sampler and analyser	fallout magnitude and grain sizes	X			real time
Gas monitoring systems	release of volatiles	X	X	X	real time
Radars	microwave reflection signals	X			real time
Lightning detection system	electric field spikes	X			real time
Mobile field lab.	magma type, grain sizes	X	X		near-real time
Aircraft observations	visual, optical, infrared, SAR radar	X	X	X	near-real time
Empirical plume model calibration	plume height – mass discharge	X			calibration of system
Physics-based plume models	plume – vent – mass discharge	X			calibration of system
Multi-parameter system	All above	X	X	X	real time / near-real time

Multi-parameter system estimating mass eruption rate using data from all sensors – the Futurevolc approach



MER estimates acccording to different methods

Eyjafjallajökull 8-10 May 2010



MER estimates acccording to different methods
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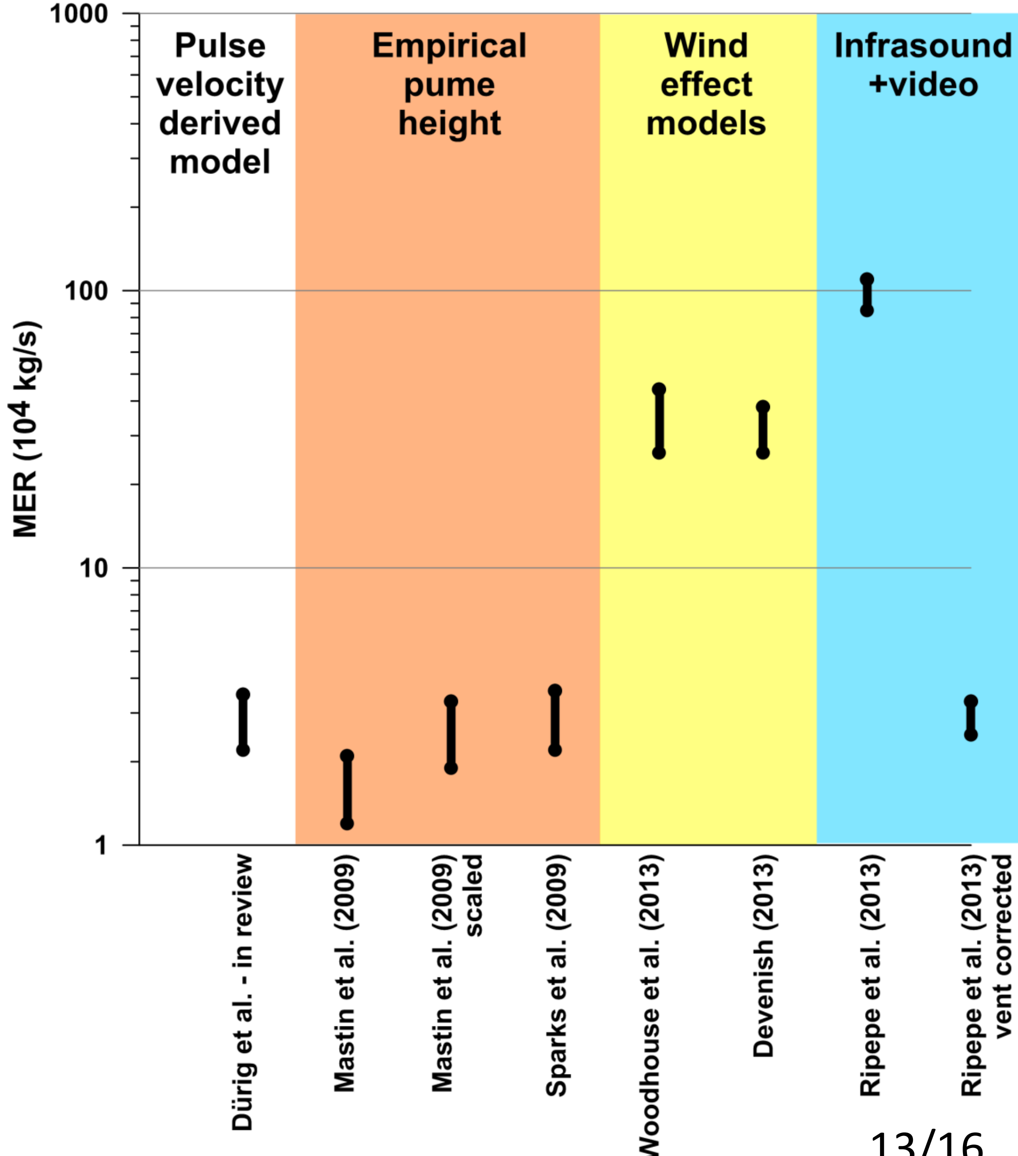
Based on Dürig et al. (in review) (video analysis)
Plume height ~5 km a.s.l.
Wind speed at 500 hPa 20 m/s

Variations over almost two orders of magnitude



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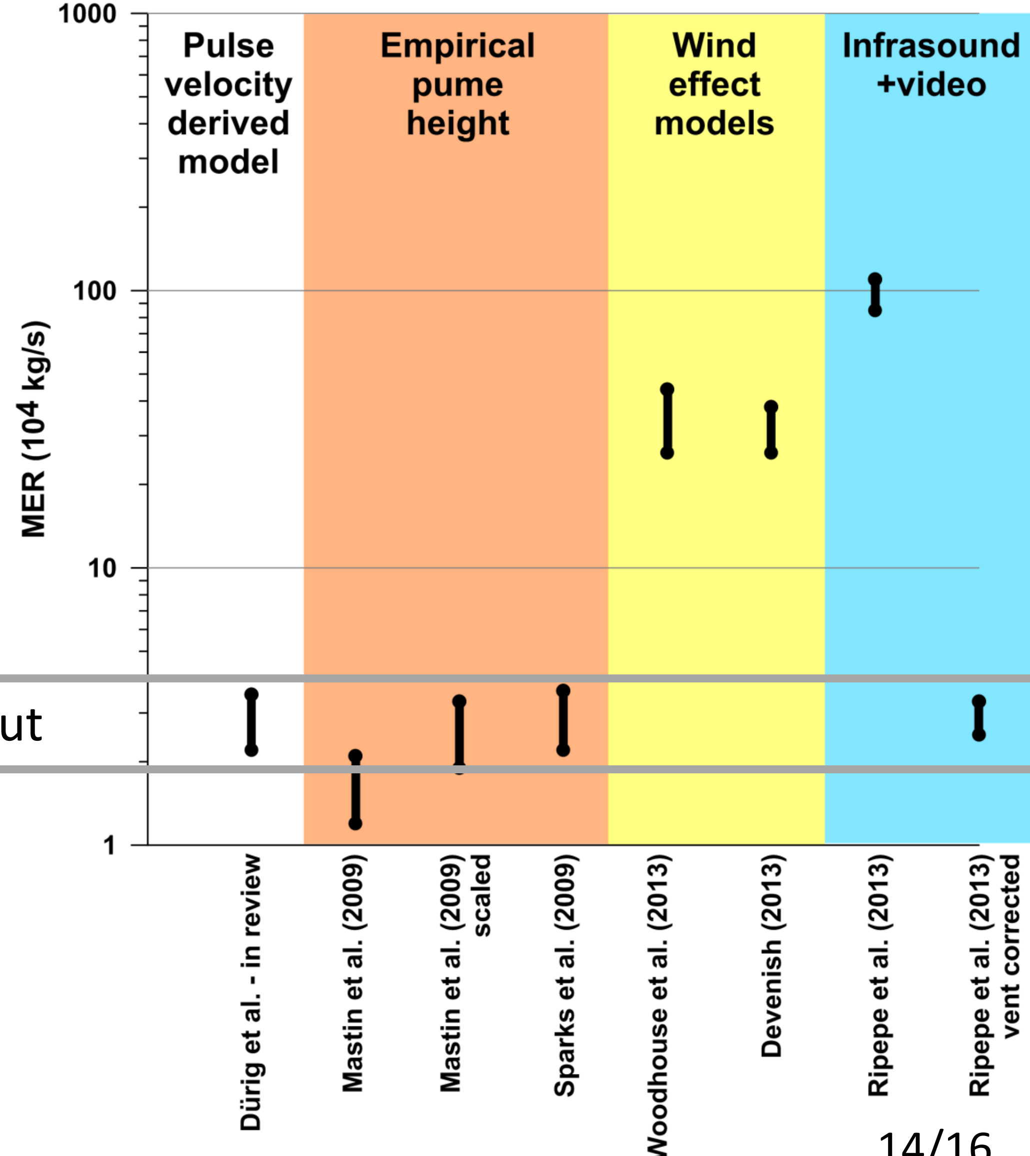
Expected range from observed fallout



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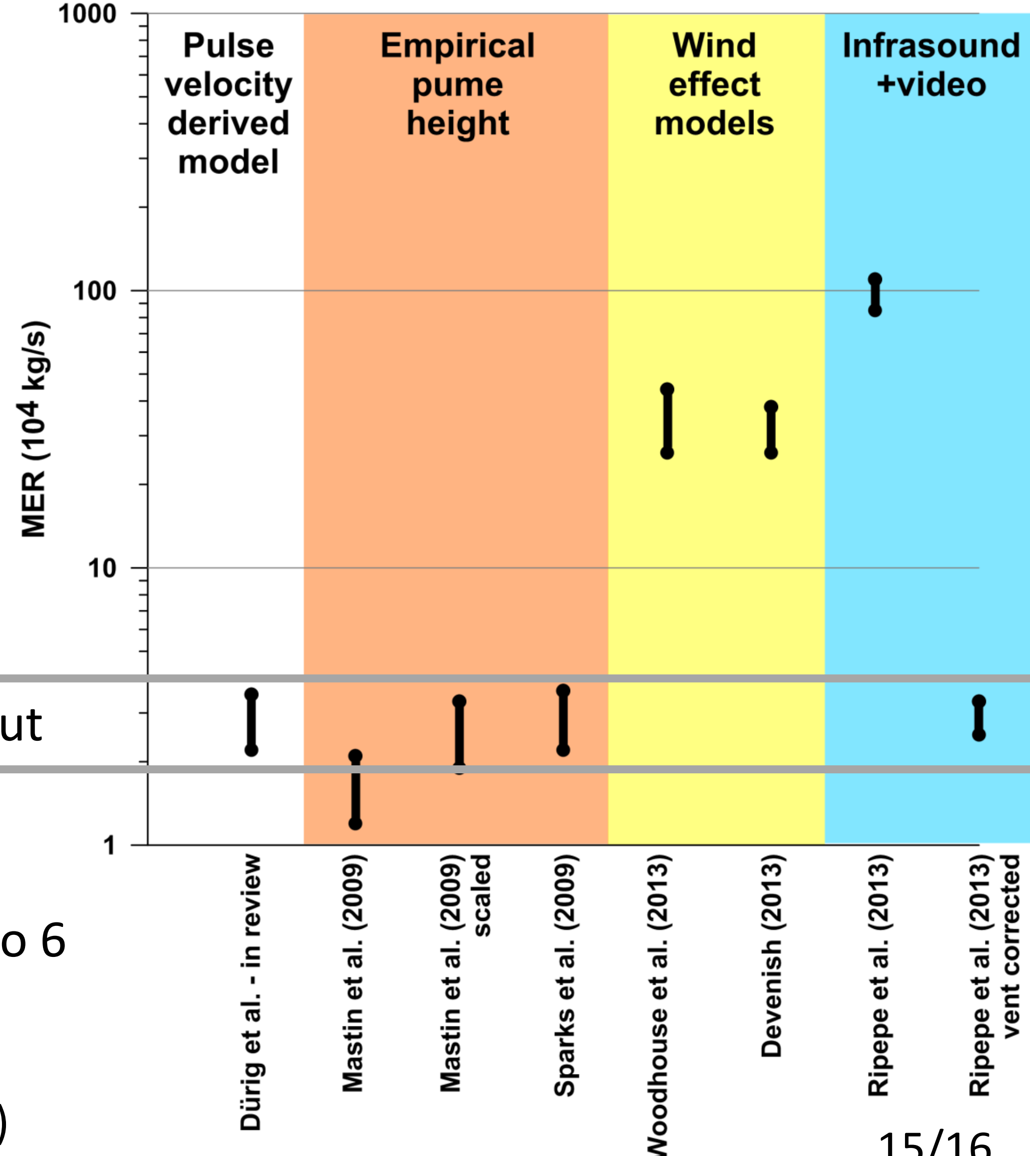


Infrasound – falls into place when:
Vent diameter reduced from 50 m to 6 m
(lower value in agreement with video analysis of ballistics – Dürig et al. (2015)

Present state

- Precursors and early warning – advanced only in well monitored areas
- Methods measuring critical parameteres being tested
- MER models based on real-time observation – in state of development and calibration
- Improvements considerable since 2010

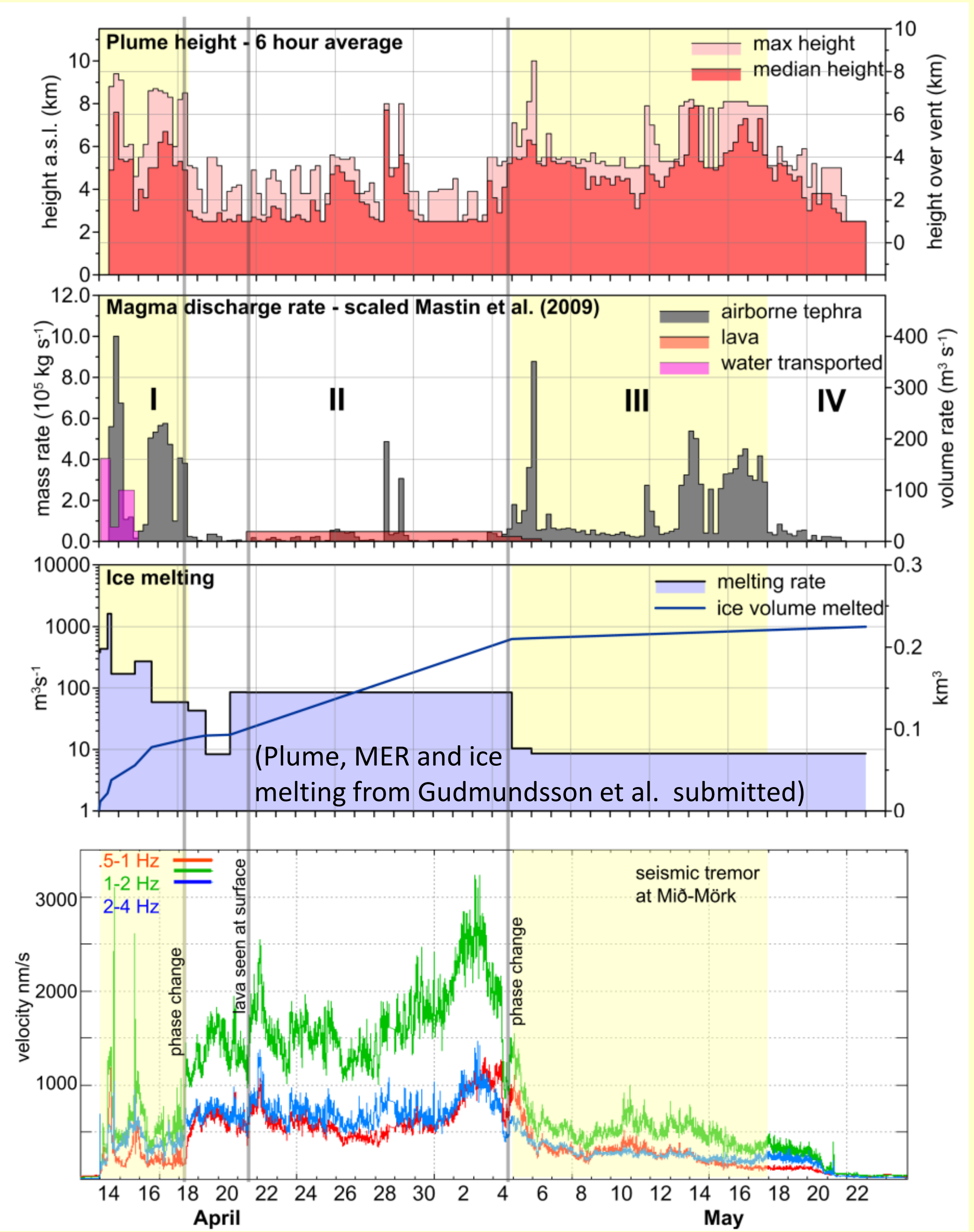
Eyjafjallajökull 2010

Plume height, mass discharge rate, ice melting and seismic tremor

Plume height equation (a scaled version of the Mastin equation) used for mass discharge – corrected with fallout data

Seismic tremor – to first order – **inverse relationship** between mass discharge rate and strength of seismic tremor

Tremor apparently mainly related to effusive eruption



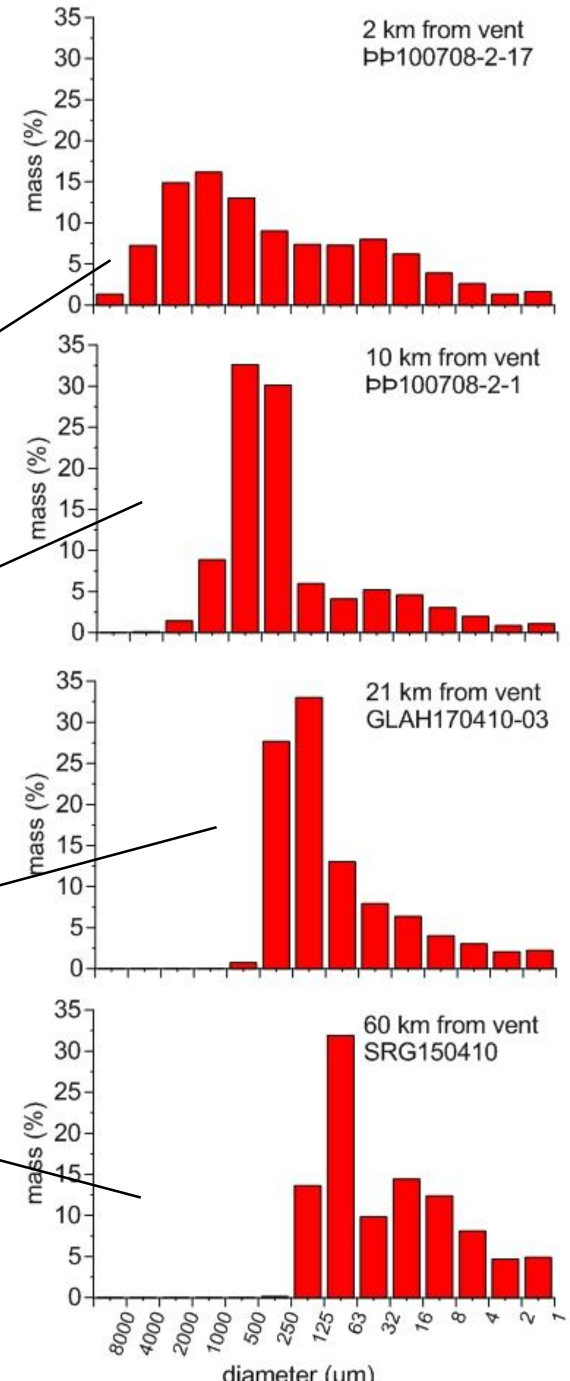
(tremor data from Icelandic Meteorological Office (IMO))

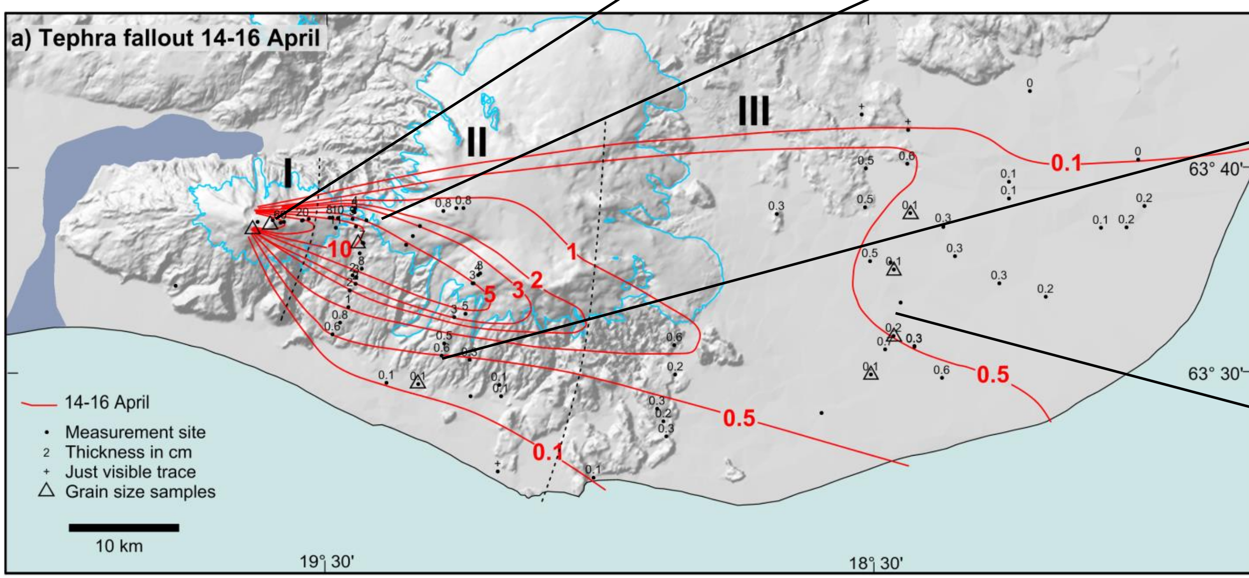
Eyjafjallajökull 2010:

14-16 April – grain size distribution

If total volume of phase 70 Million m^3

<30 µm ash: ~35% of total ~ 35 Tg





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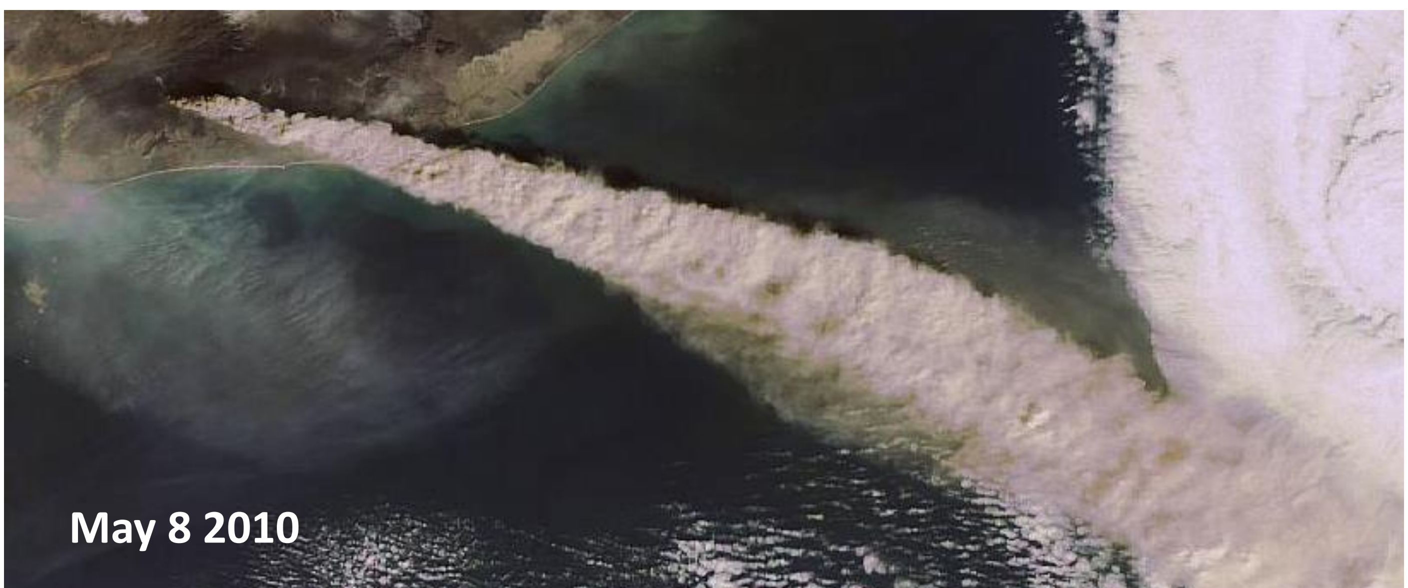


Hvítanes