Eruptive flow rate resonance during the Grímsvötn 2011 volcanic eruption in Iceland

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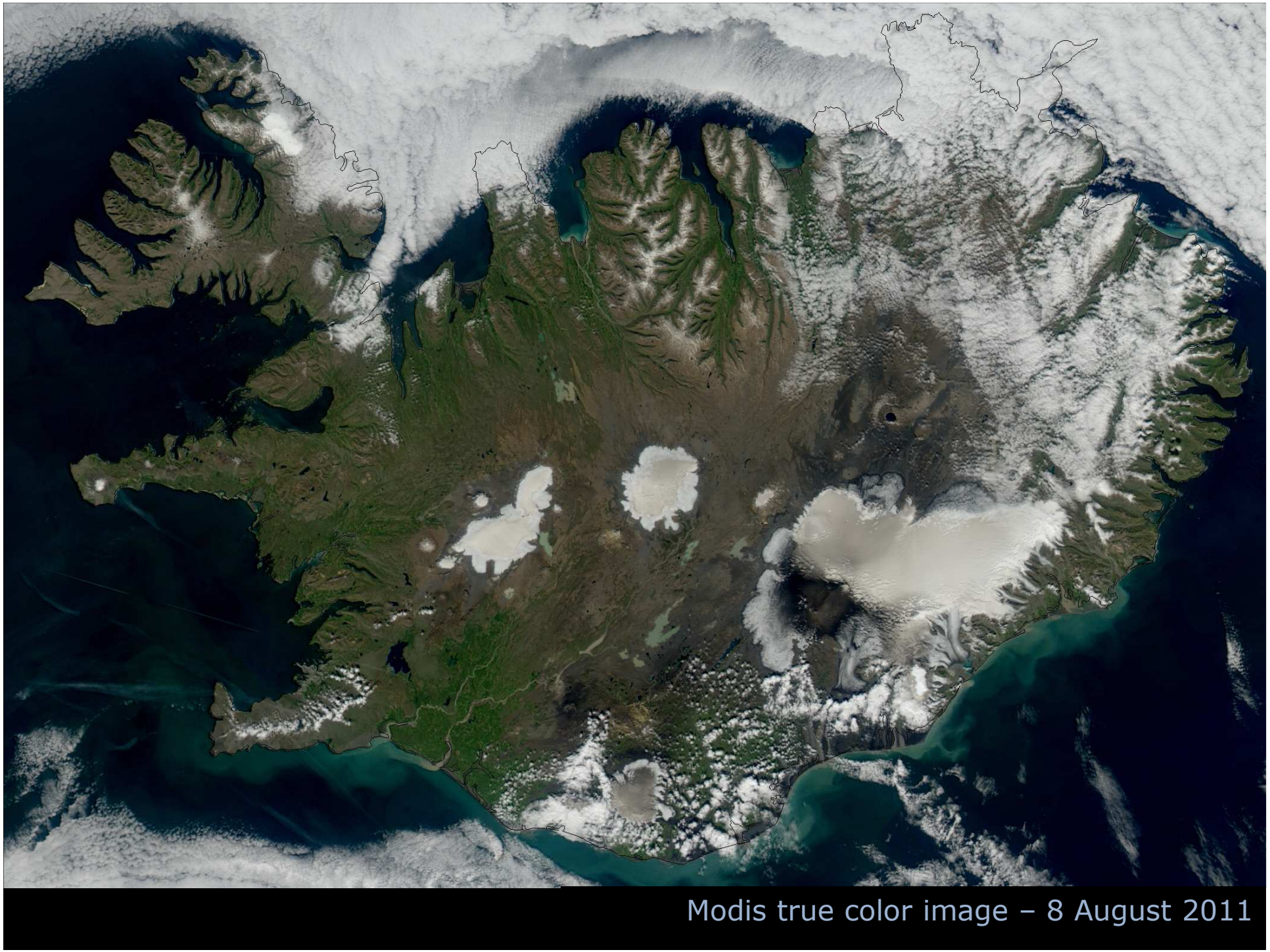
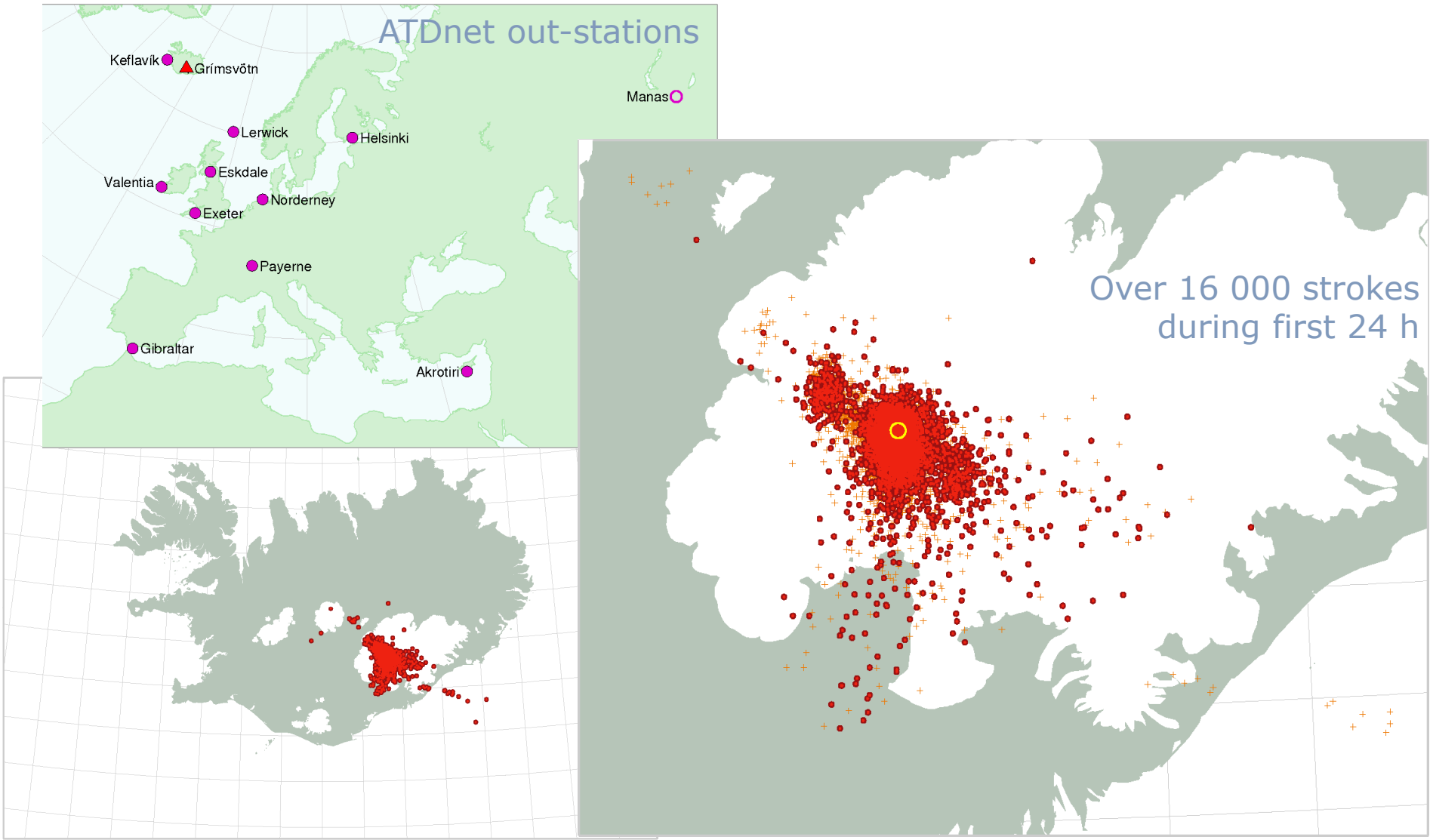
The initial Grímsvötn eruption plume. Photo Bolli Valgarðsson 21 May 2011 at 19:20



Modis true color image – 8 August 2011

Located lightning 21-28 May 2011

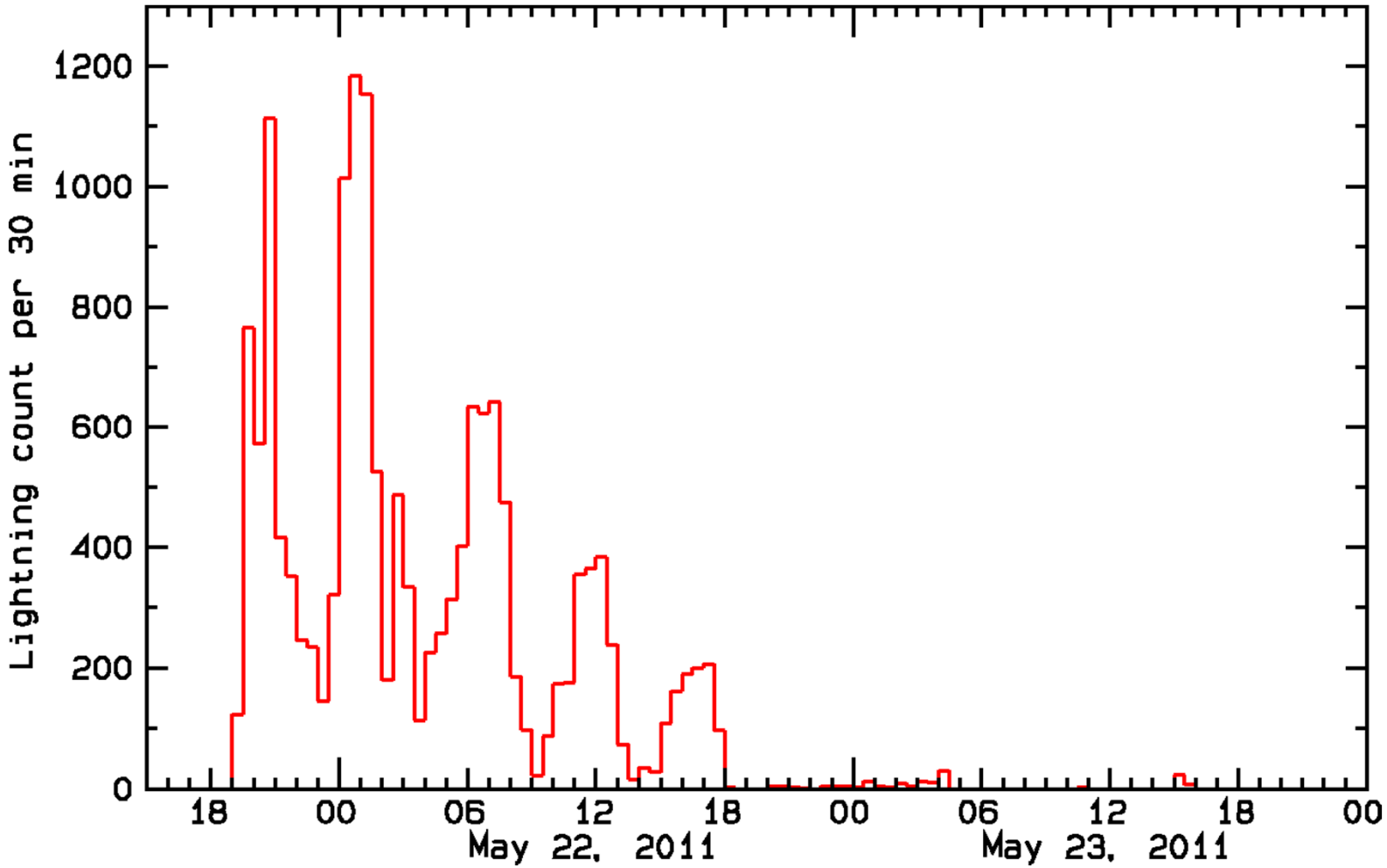
From the ATDnet system of the UK Met Office



Lightning rate

Oscillations became evident during real-time monitoring

Icelandic Met Office



Resonance period of about 5 hours

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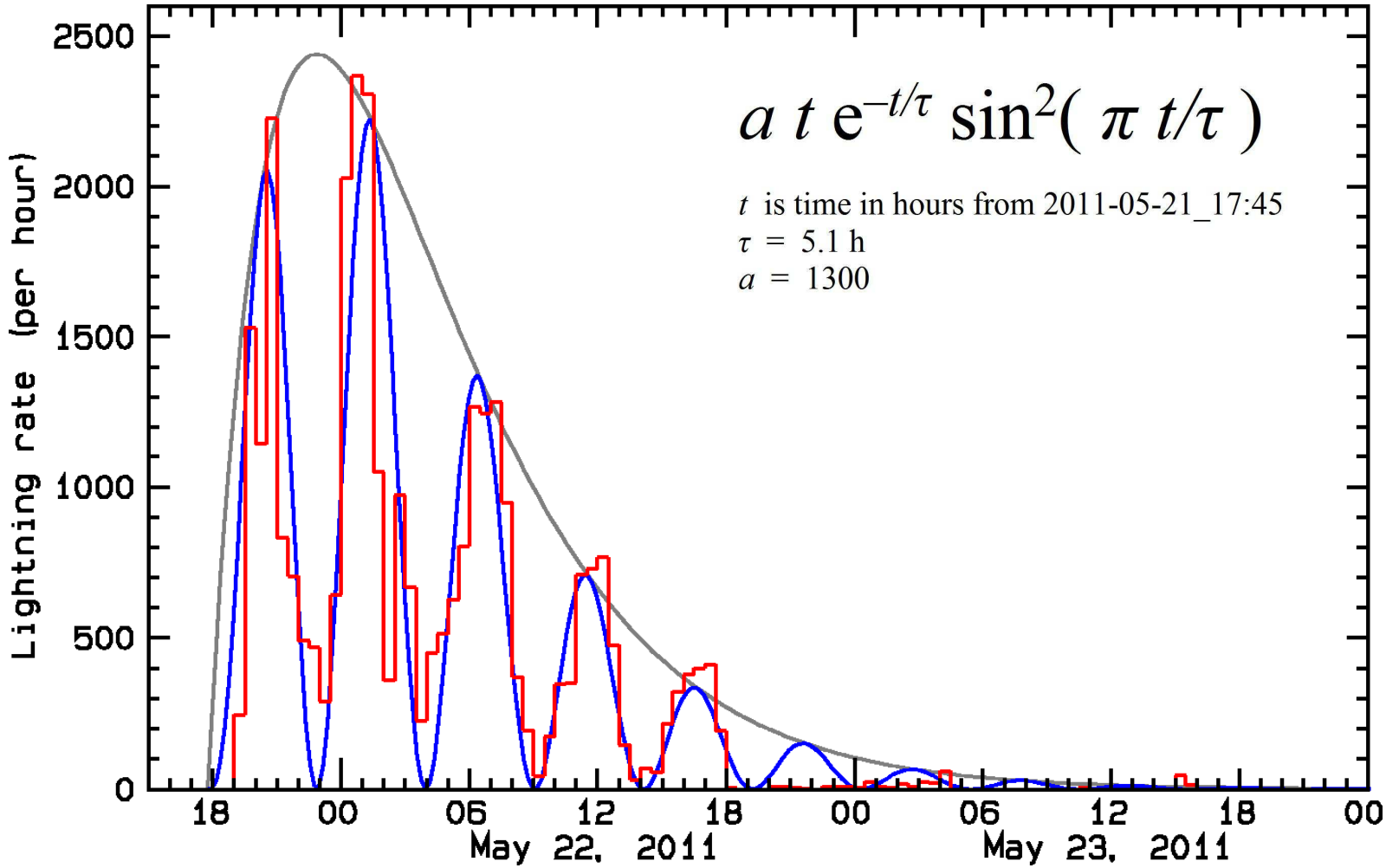
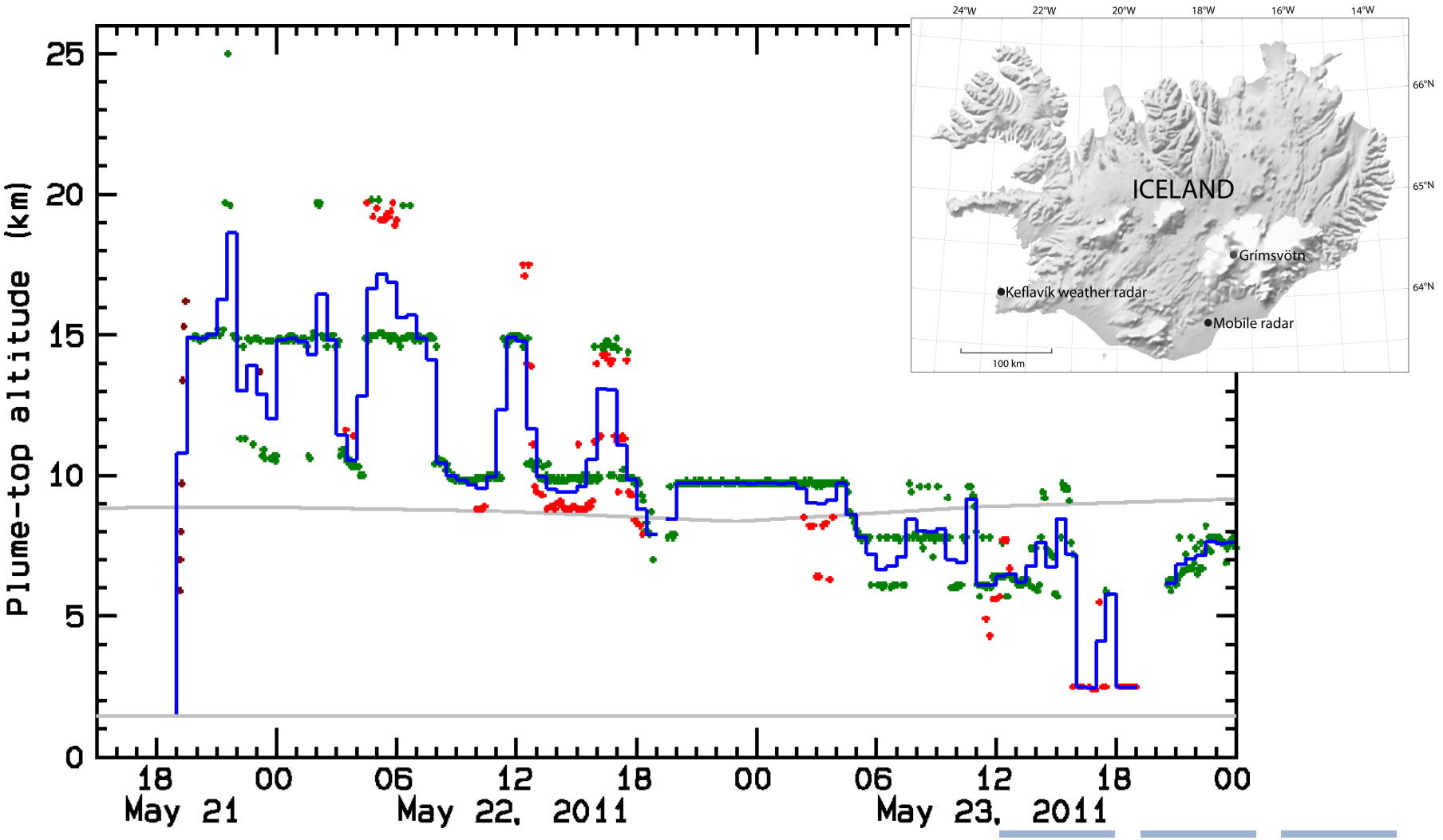


Grímsvötn crater. Photo Þórður Arason 11 June 2011

Plume-top altitude

Estimates from weather radar echo tops

Icelandic Met Office



Flow rate

Calculated using mean plume height and Mastin et al. (2009)

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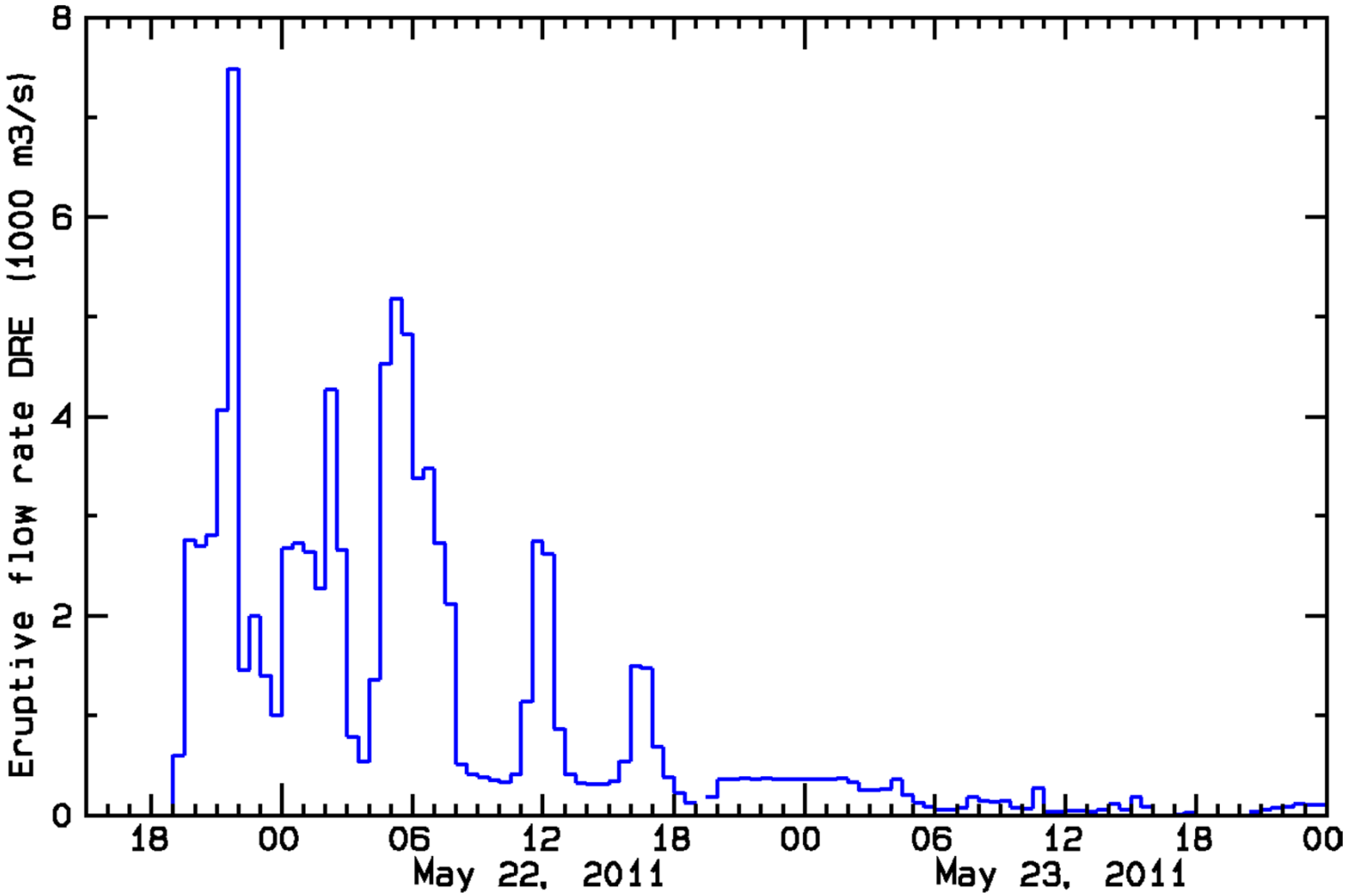
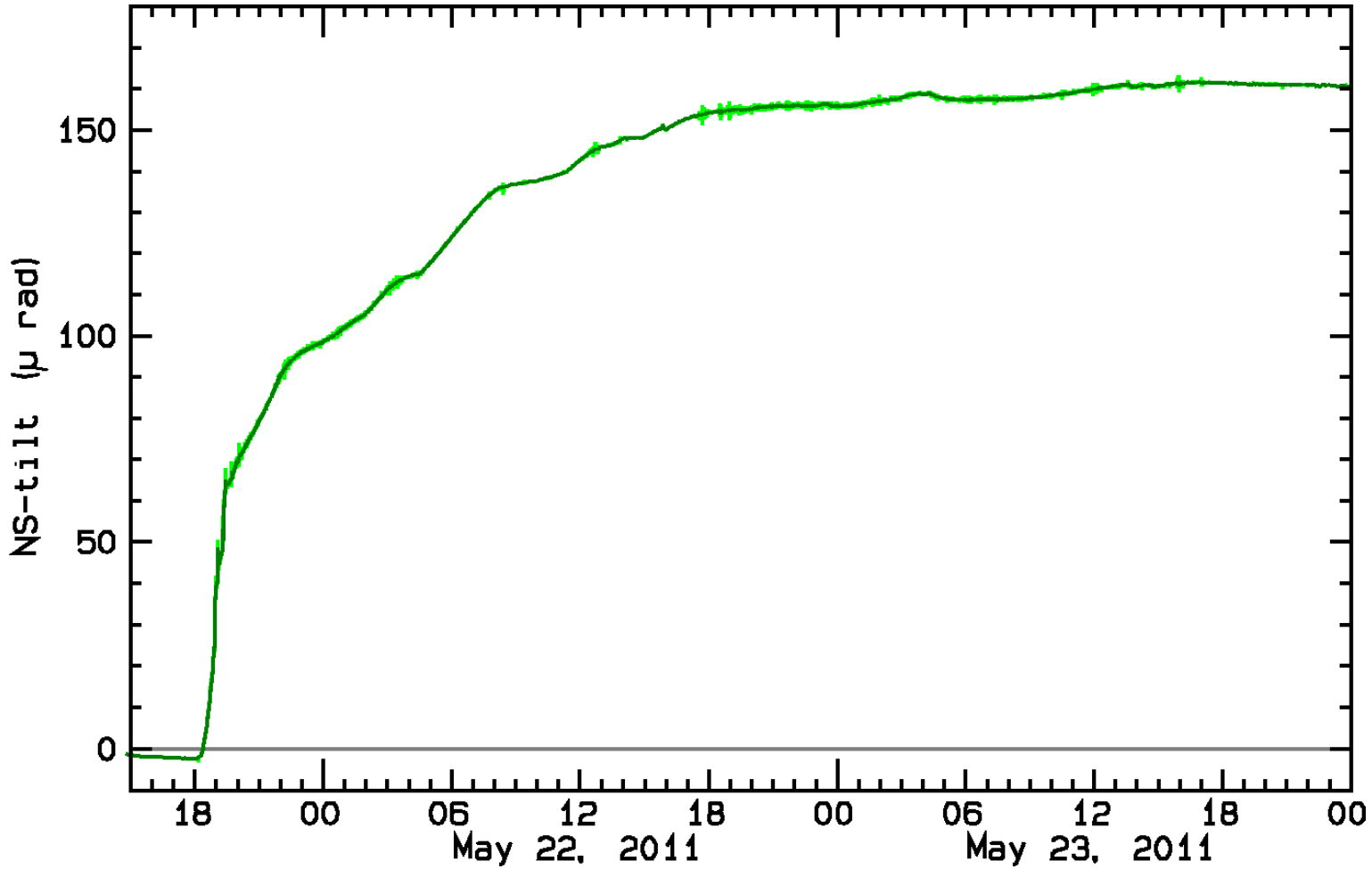


Tilt measurements at Grímsfjall

about 6 km East of the vent

Icelandic Met Office



Tilt rate

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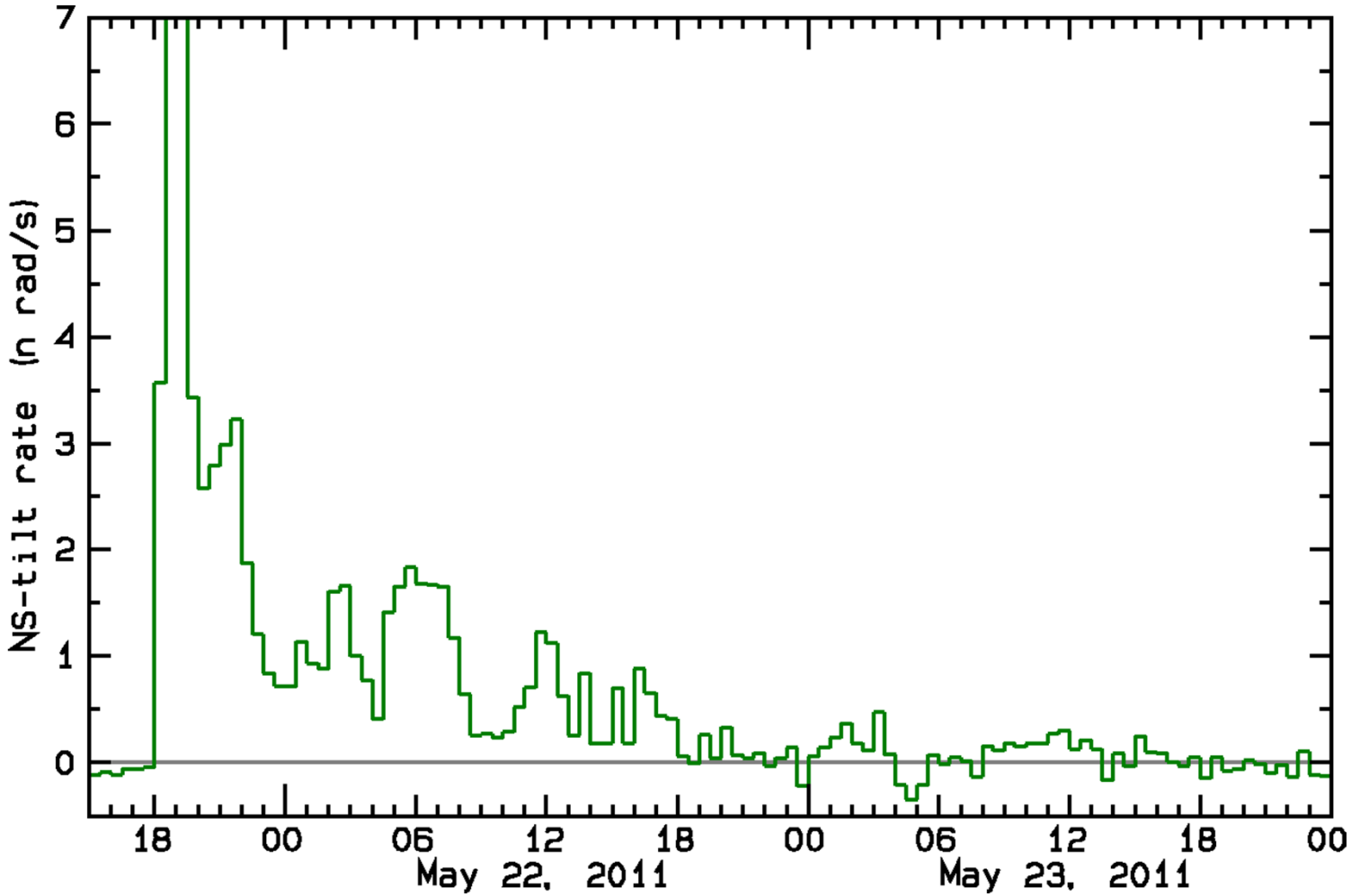
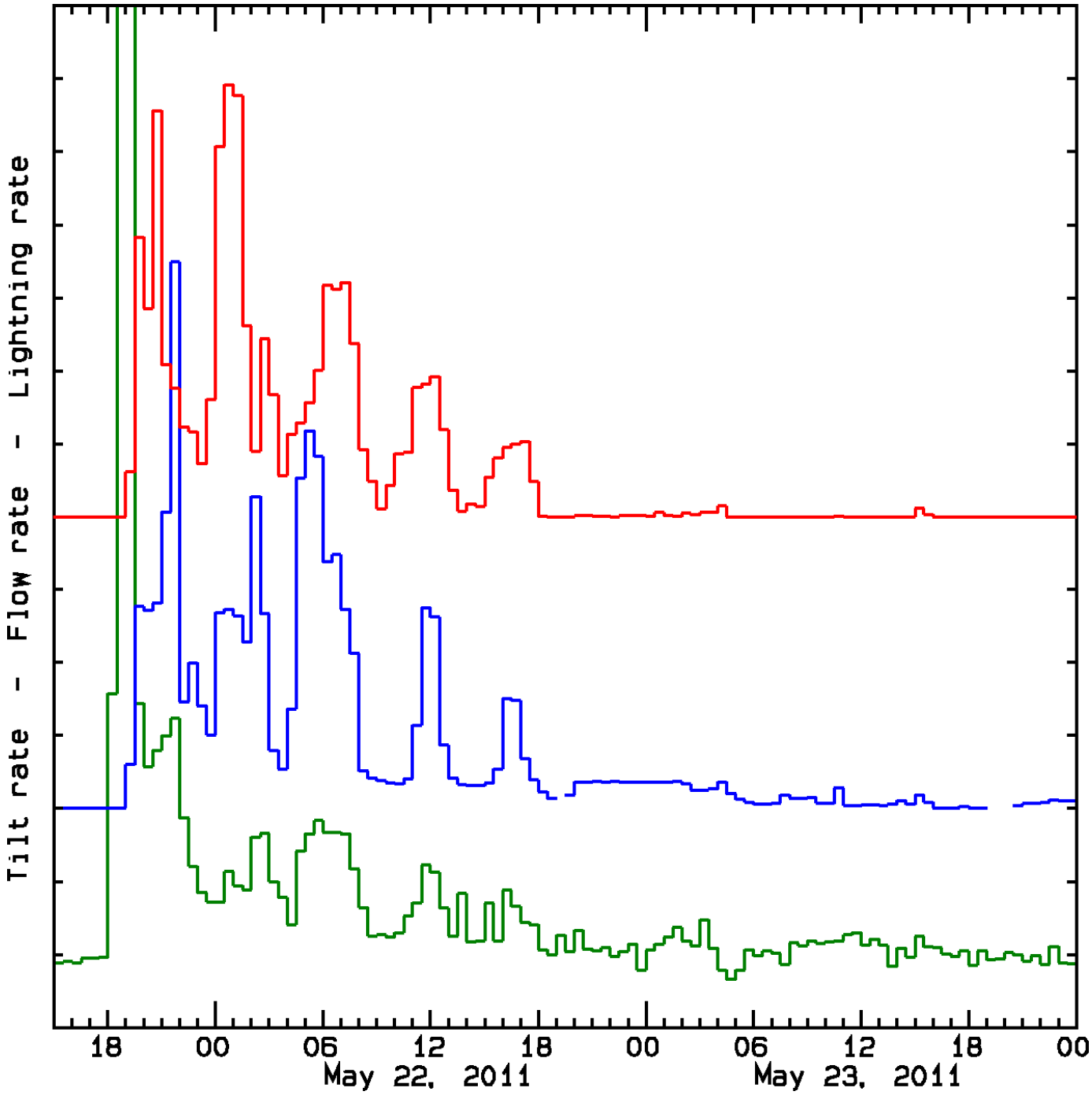
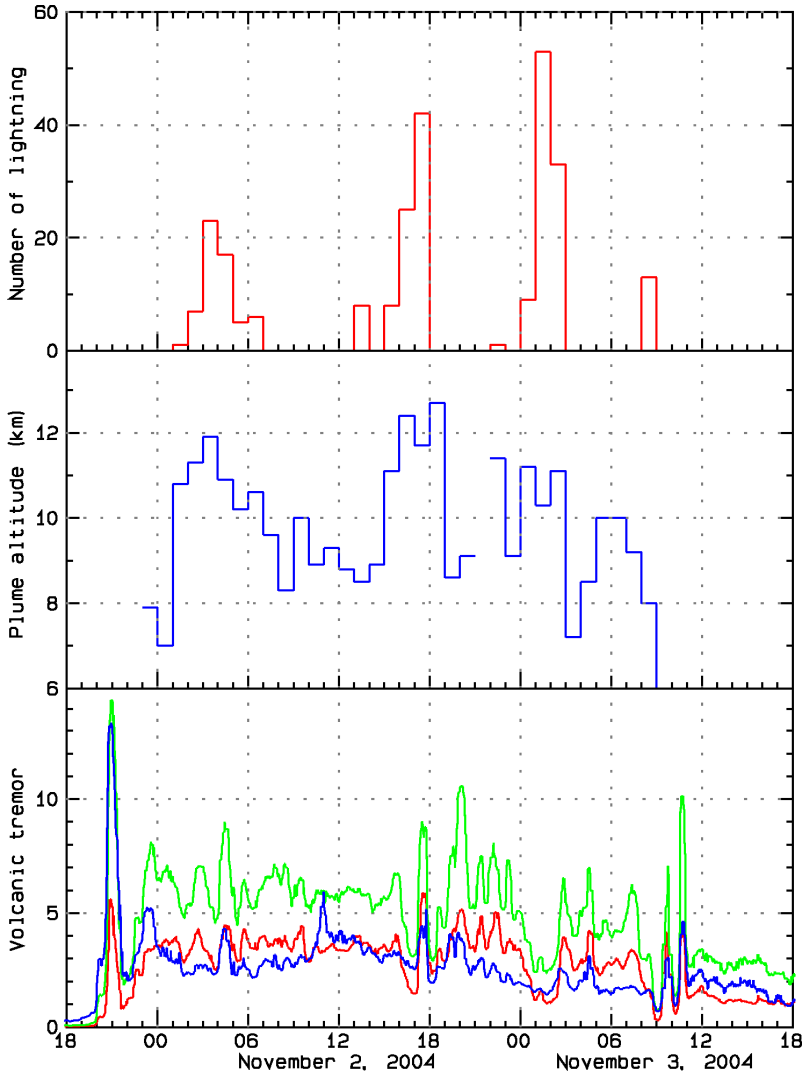



Tilt rate - Flow rate - Lightning rate
18
00
06
12
18
00
06
12
18
00
May 22, 2011
May 23, 2011

Grímsvötn – November 2004
Lightning – Plume-top altitude – Volcanic tremor



Helmholtz cavity resonator

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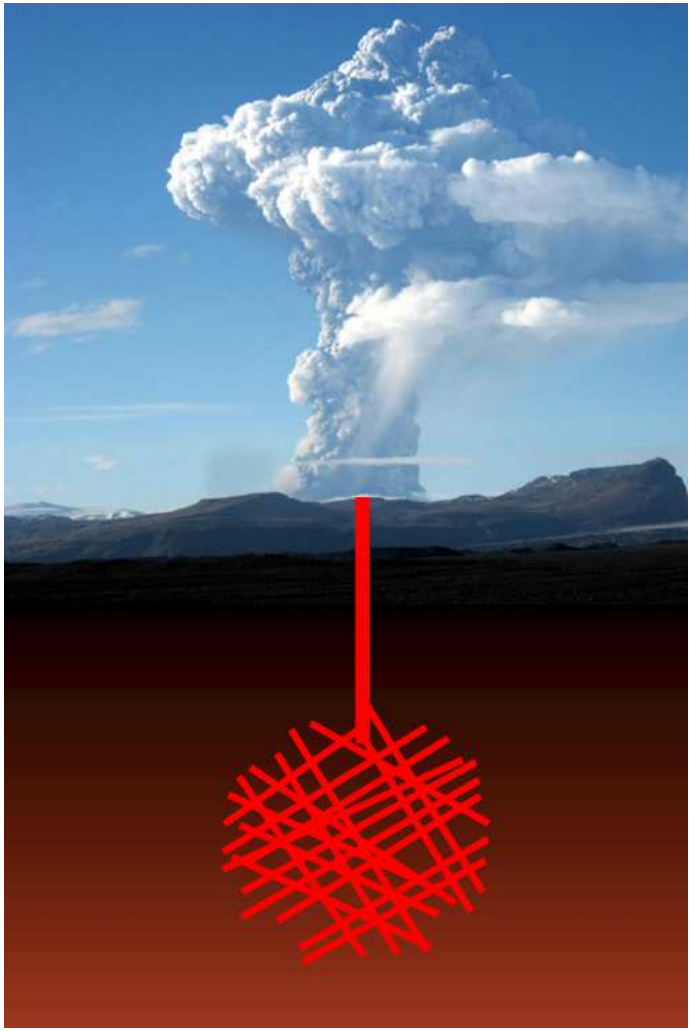
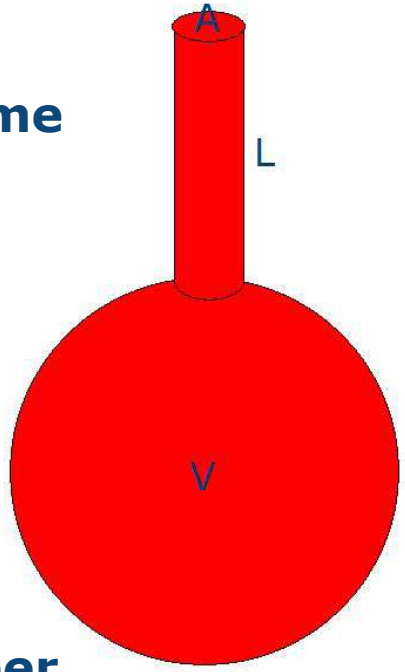


19th century physics: Acoustic resonance in some musical instruments



$$\tau = 2\pi\sqrt{\frac{L\,V}{v^2 A}}$$

Realistic values for a Grímsvötn magma chamber result in Helmholtz resonance periods of 1-10 minutes – Two orders of magnitude lower than observed

Water-dyke interaction

Quenching of feeding dykes and boiling in geothermal system

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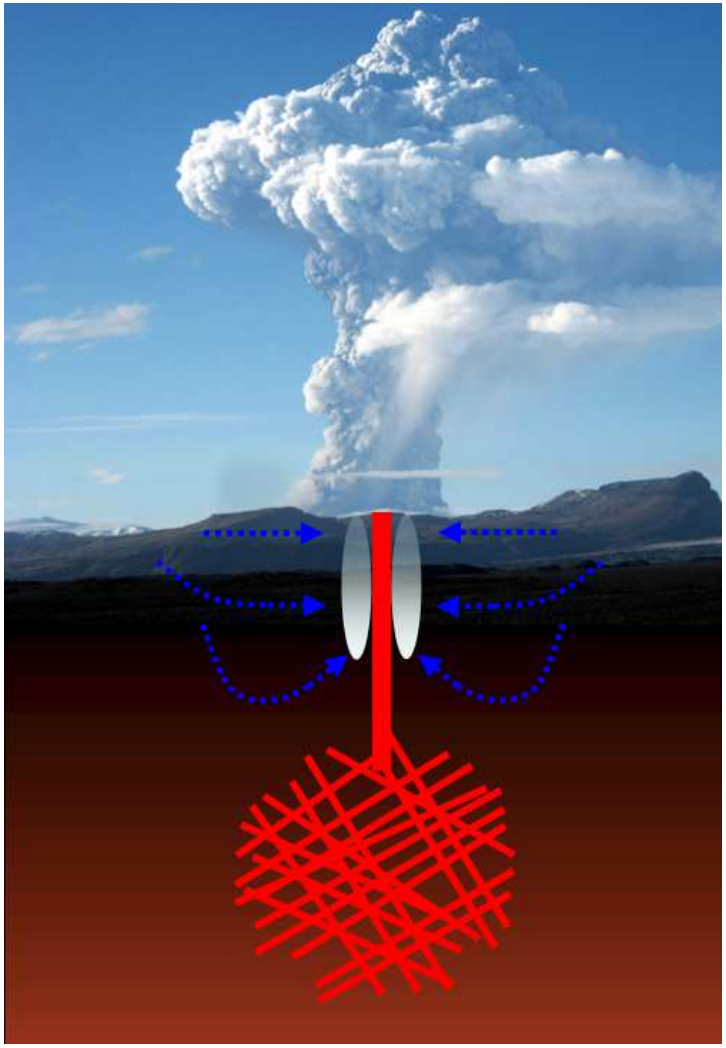

Double chamber interaction

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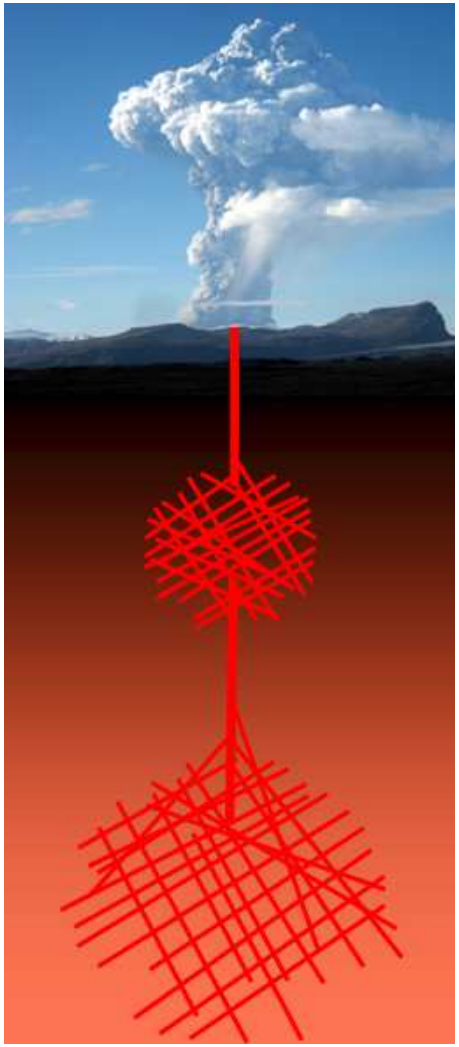

- **Shallow magma chamber emptied in a few hours**
- **Larger deeper source takes similar time to refill the shallow magma chamber**
- **Possibly, such a double chamber system could resonate with the observed period**

Indications of a double chamber

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- **Inversion of GPS and tilt data suggests a magma chamber at 1.8 km depth with a volume change of 38 x 10^6 m^3 [Sigmundsson et al., 2012]**
- **Mineral-melt thermometry indicates that the equilibrium depth for the magma was at 10-15 km [Sigmarsson, pers. comm., 2012]**

- **Using the plume height data we estimate total volume of the first five 5 hour pulses to be 43, 38, 51, 17 and 11 (all x 10^6 m^3 DRE)**
- **The volume of the first three pulses (43, 38, 51) is close to the GPS inversion result (38)**

How big is a 50 x 10^6 m^3 magma chamber?

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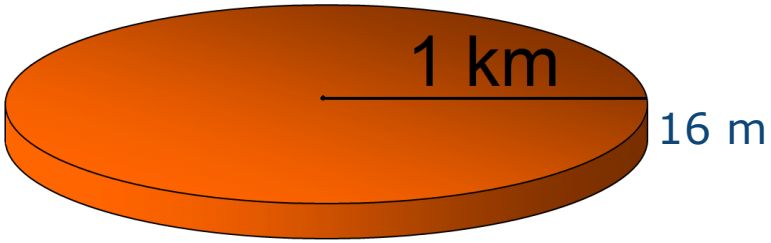
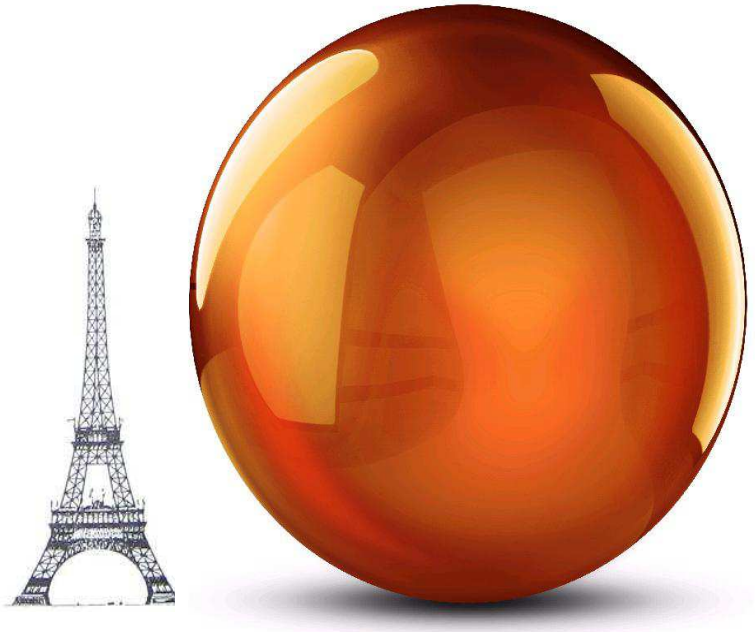
Disk shaped intrusion/chamber



Spherical chamber



diameter 460 m

Conclusions

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- Very regular oscillations with a period of about 5 hours were observed in real-time monitoring of volcanic lightning during the first 24 hours of the Grímsvötn 2011 eruption
- Same oscillations are seen in plume height variations, calculated flow rate and tilt measurements
- The regularity of the oscillations indicate a resonance in the system rather than a random process
- In hindsight, some resonance (with a higher period) can be seen in data from the Grímsvötn 2004 eruption
- The causes of the observed volcanic resonance are not clear