Met Office

Veðurstofa Íslands

Icelandic Meteorological Office

Volcanic lightning during the 2010 Eyjafjallajökull eruption

Þórður Arason[1], **Alec J. Bennett[2,3]** and Laura E. Burgin[2]

[1] Icelandic Meteorological Office, Reykjavík, Iceland
[2] Met Office, Exeter, United Kingdom
[3] BIRAL, Bristol, United Kingdom

92nd American Meteorological Society Annual Meeting
28th Conference on Interactive Information Processing Systems (IIPS)
Presentation 201192, New Orleans, 22-26 January 2012

Recently published papers

- Bennett, A. J., P. Odams, D. Edwards and Þ. Arason (2010), Monitoring of lightning from the April-May 2010 Eyjafjallajökull volcanic eruption using a very low frequency lightning location network, *Environmental Research Letters*, **5**, 044013, doi:10.1088/1748-9326/5/4/044013
- Arason, P., G. N. Petersen and H. Bjornsson (2011), Observations of the altitude of the volcanic plume during the eruption of Eyjafjallajökull, April-May 2010, *Earth System Science Data*, **3**, 9-17, doi:10.5194/essd-3-9-2011
- Arason, P., A. J. Bennett and L. E. Burgin (2011), Charge mechanism of volcanic lightning revealed during the 2010 eruption of Eyjafjallajökull, *Journal of Geophysical Research*, **116**, B00C03, doi:10.1029/2011JB008651

Charge generation in volcanic plumes

Electric charge can be generated by various processes

- magma-water interactions
- fractoemission – magma fracturing into ash
- triboelectrification – collisions of ash-grains
- plume water freezing – thunderstorms

It is difficult to distinguish between these proposed charging processes in real volcanic plumes.

Which of them are strong enough to produce lightning?

Magma-water interactions

Alessandro Volta (1745-1827)

Earliest published scientific research on volcanic electric charge generation was by Volta in 1782, where he mentions lightning during the dreadful eruption of Mt. Vesuvius in 1779. He demonstrated that by pouring water on hot surfaces one could generate electric charge.

He concluded that there would be sufficient water in volcanic eruptions to produce the electricity for the observed plume lightning.

Lightning in the plume of Mt. Vesuvius 8 August 1779.
Oil painting by J. P. Hackert (1737-1807).

Volta, A. (1782), Del modo di render sensibilissima la più debole elettricità sia naturale, sia artificiale (Of the method of rendering very sensible the weakest natural or artificial electricity) (in Italian w. English translation), *Philosophical Transactions*, **72**, 237–280 (vii-xxxiii), doi:10.1098/rstl.1782.0018

Fragmentation and collisions of ash

Fractoemission

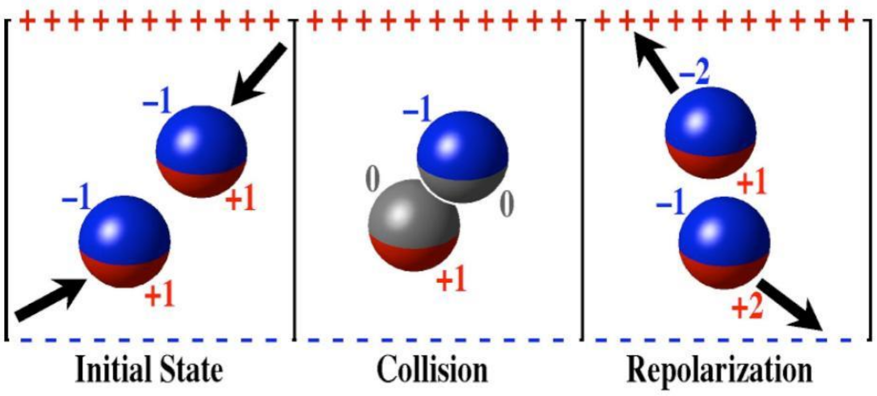
- Fragmentation of material (e.g. gas-rich magma) into ash is powerful in generating electric charge in laboratory experiments

Triboelectrification

- Charge separation after contact between particles of different properties

Inductive charging

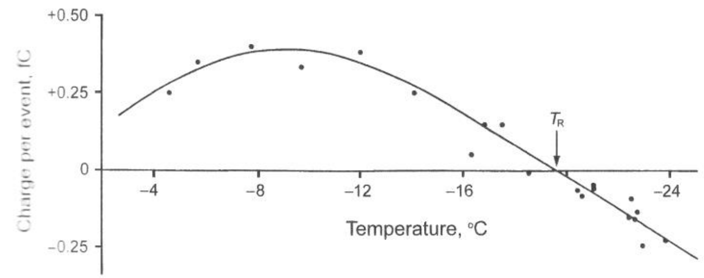
- Small suspended grains polarized by external electric field may also get charged by collisions

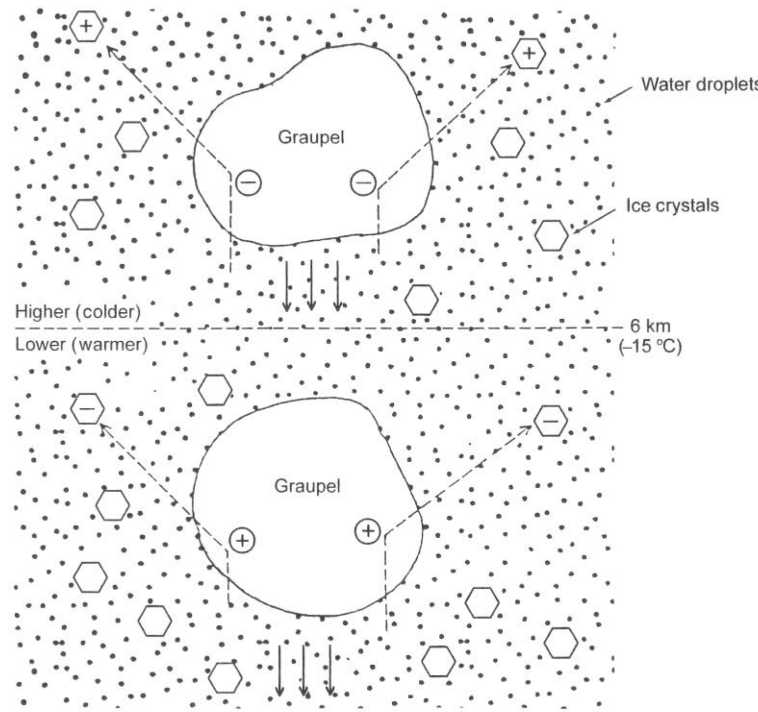


From Pähtz et al. (2010)

Electrification in meteorological thunderclouds

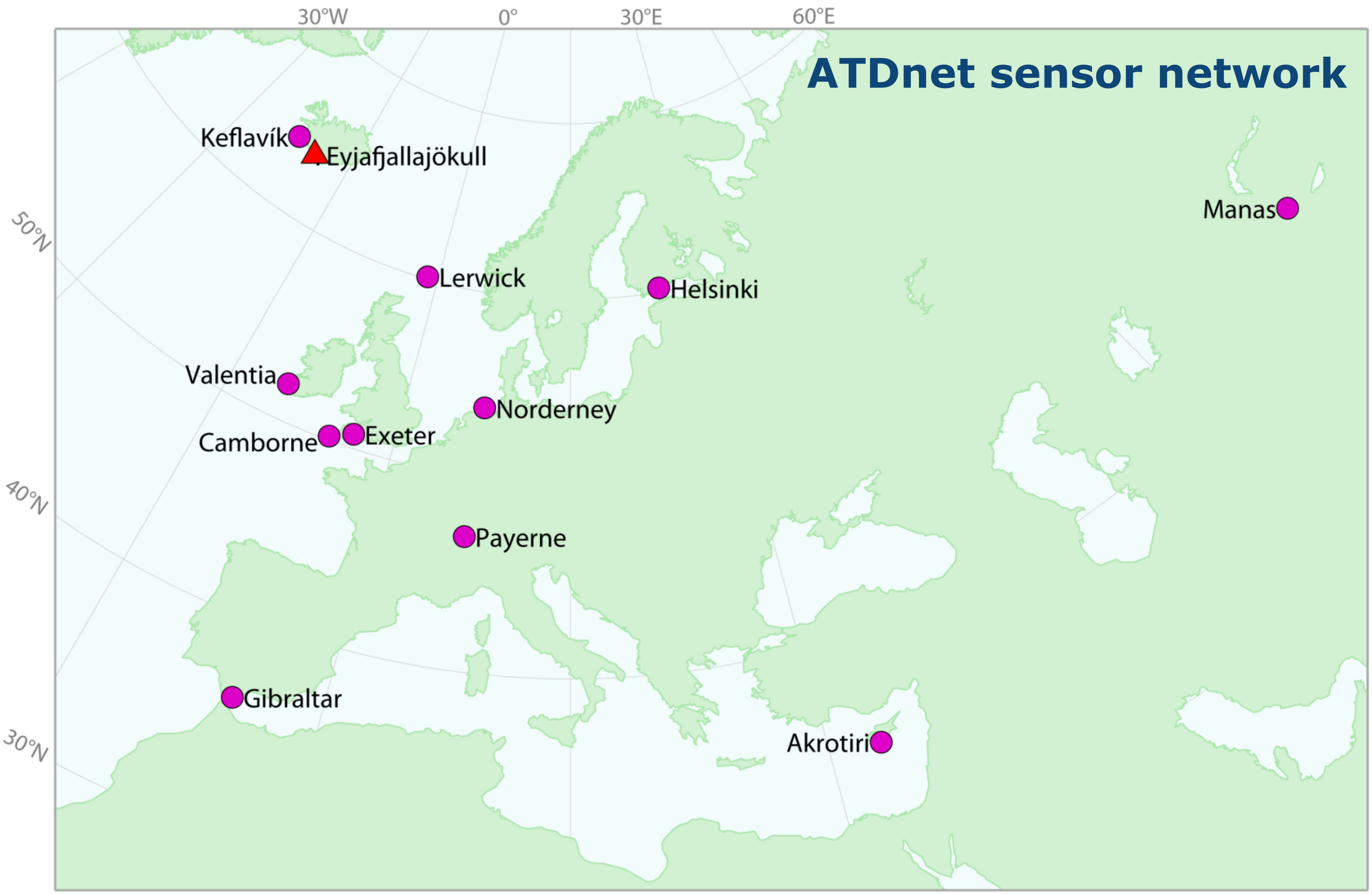
- Due to their small size, cloud droplets stay supercooled well below 0°C. Usually they freeze at -15 to -20°C
- Both the polarity and charge generation efficiency of a falling graupel appears to be temperature dependent
- The temperature controls freezing of cloud droplets, charge generation and charge distribution in thunderclouds
- Volcanic plumes being “Dirty Thunderstorms” originally suggested by Williams and McNutt in 2004





From Rakov & Uman (2003)

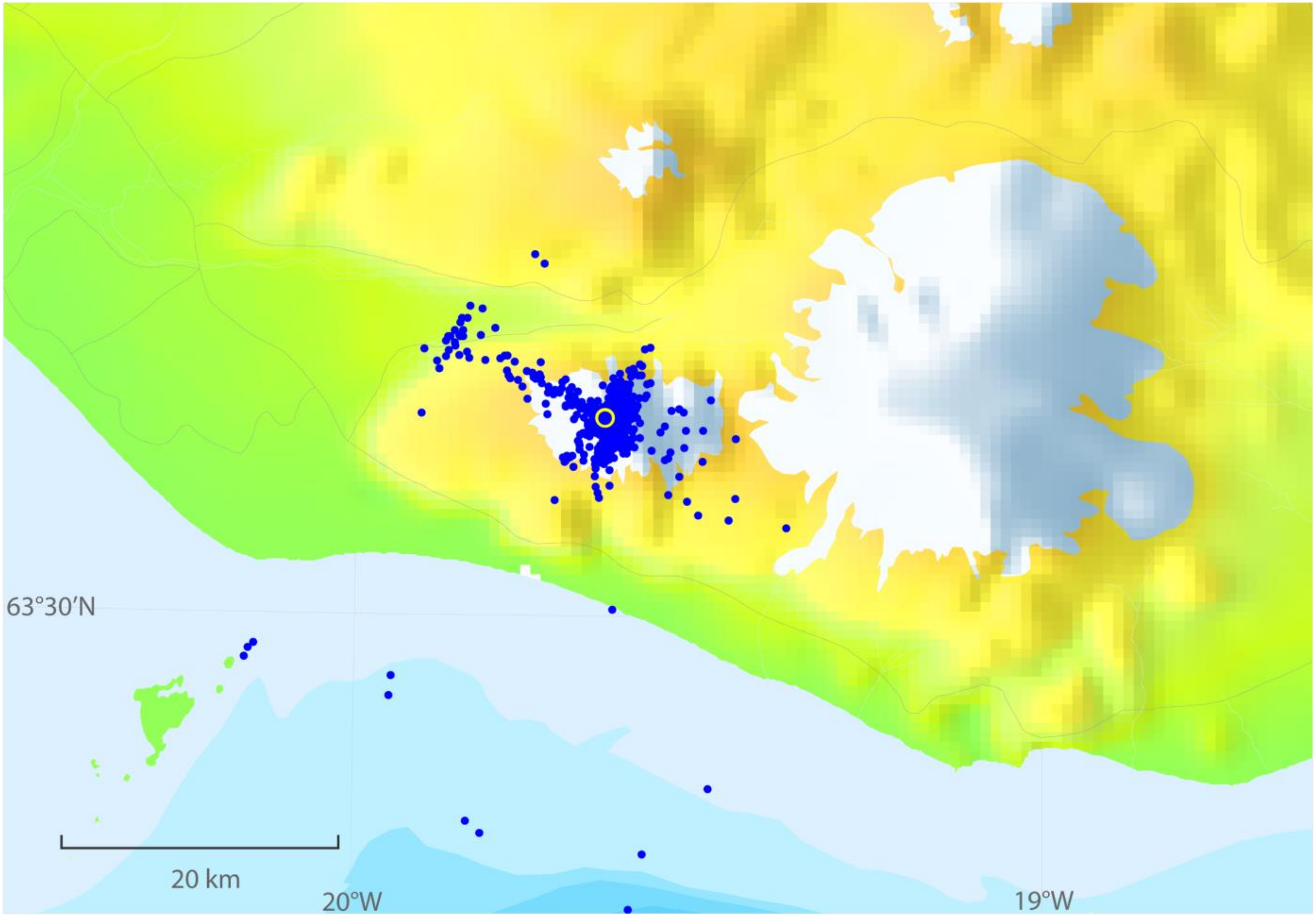
Lightning location using the UK Met Office ATDnet



Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 2)

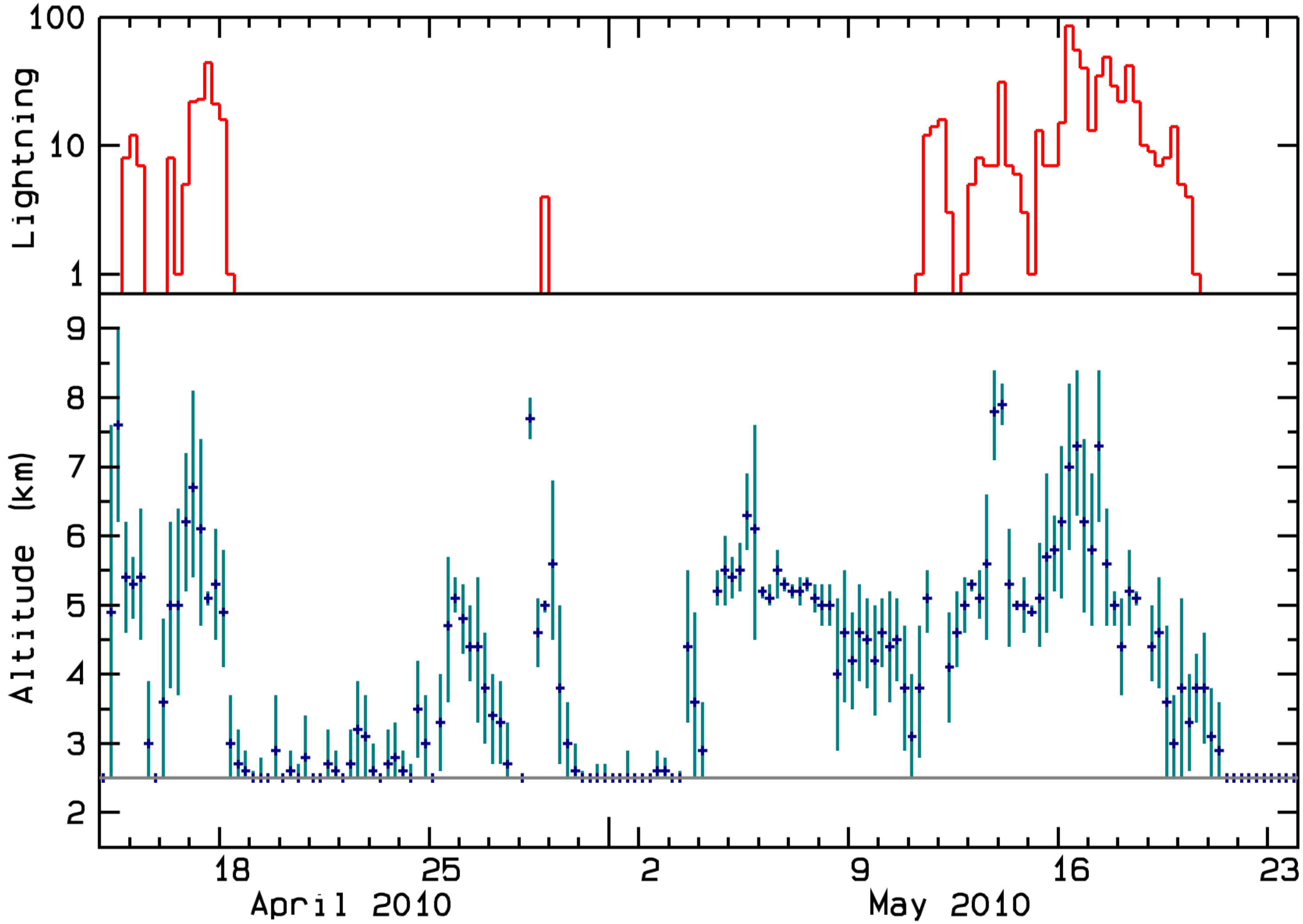
Located lightning during April-May 2010 eruption

ATDnet is unlikely to detect weak lightning with peak current <3 kA



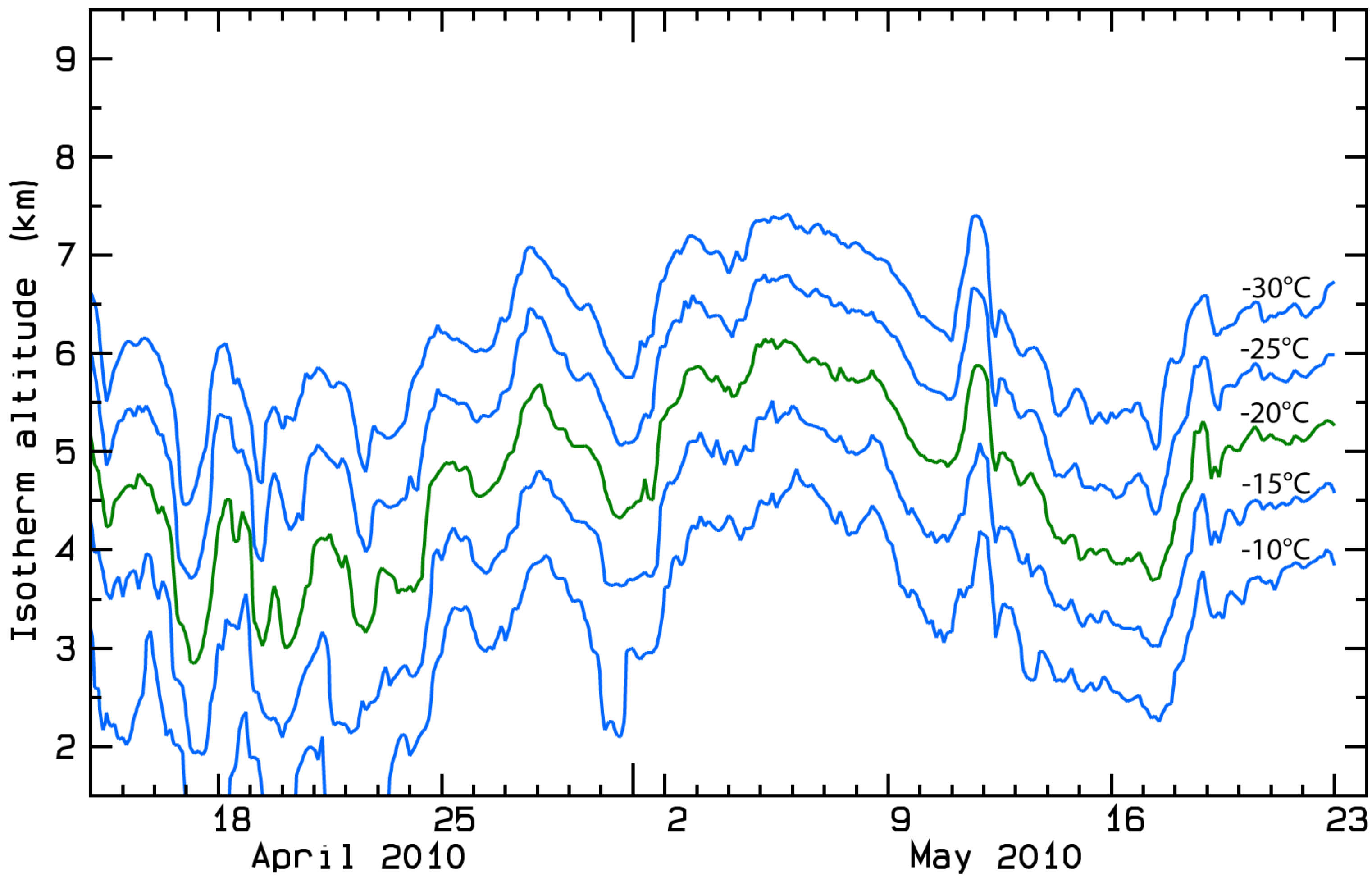
Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 3)

Lightning (6hr) & plume-top altitude



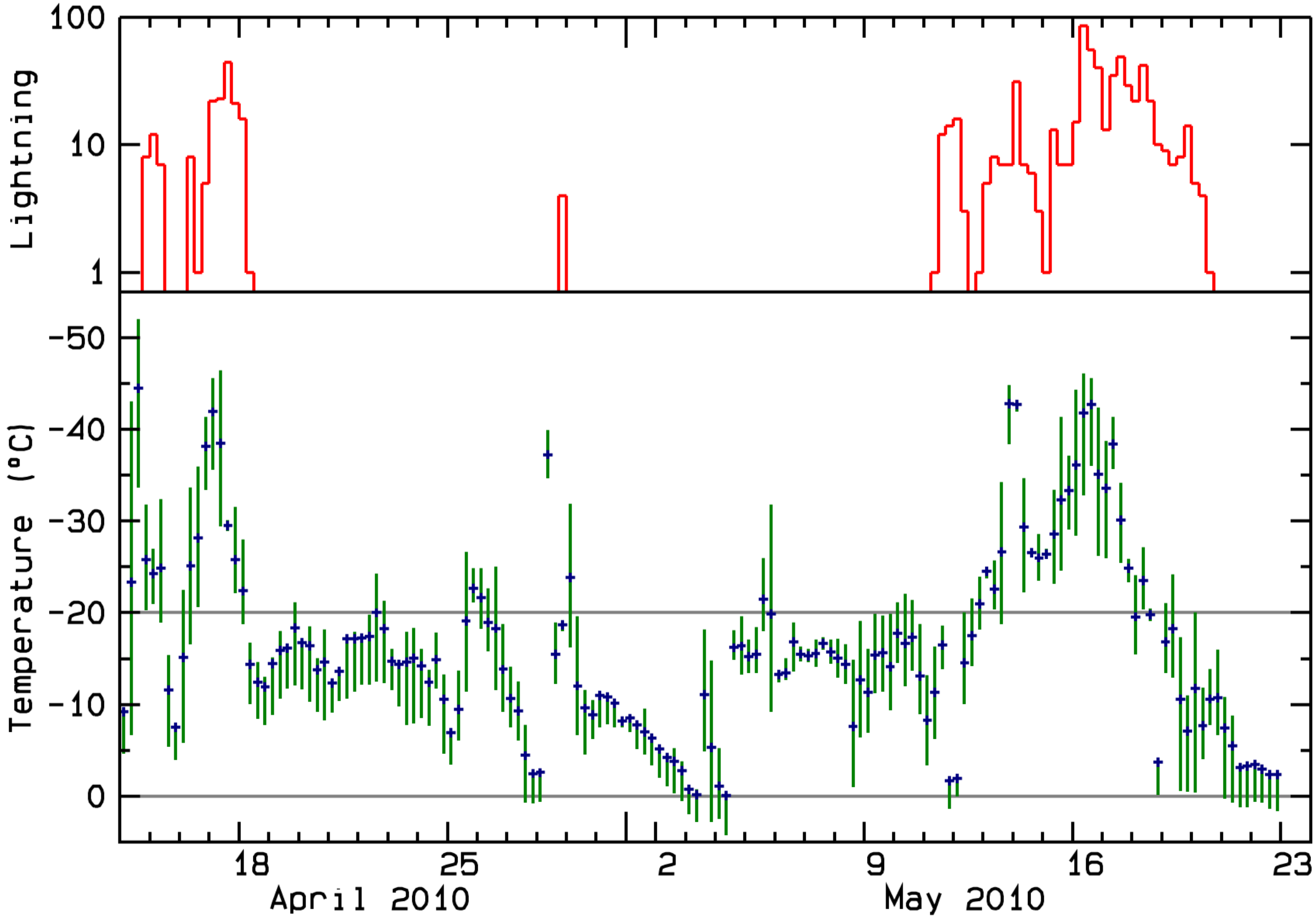
Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 7)

Altitude of isotherms above the volcano from UK Met Office Unified Model



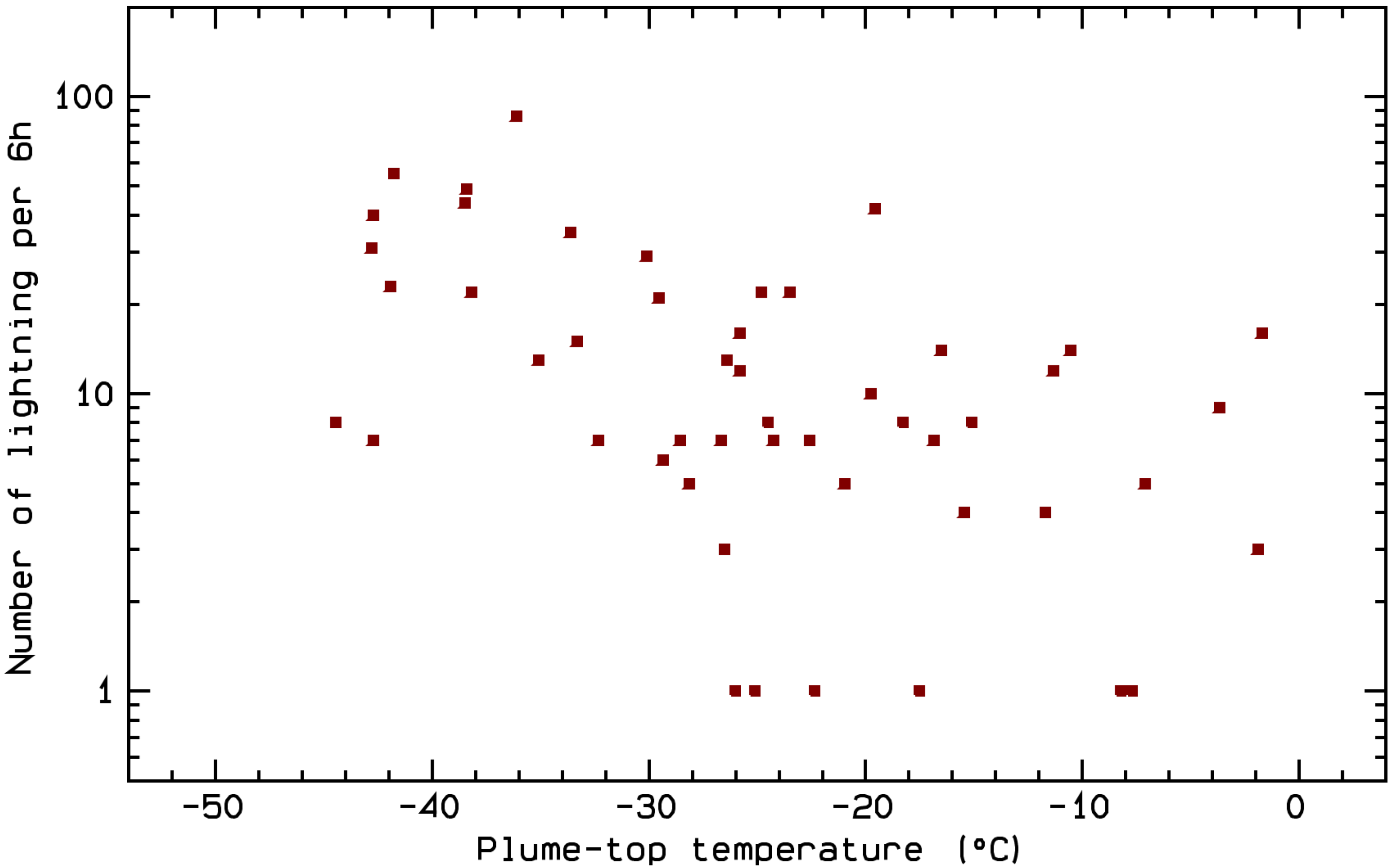
Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 11)

Lightning & plume-top temperature



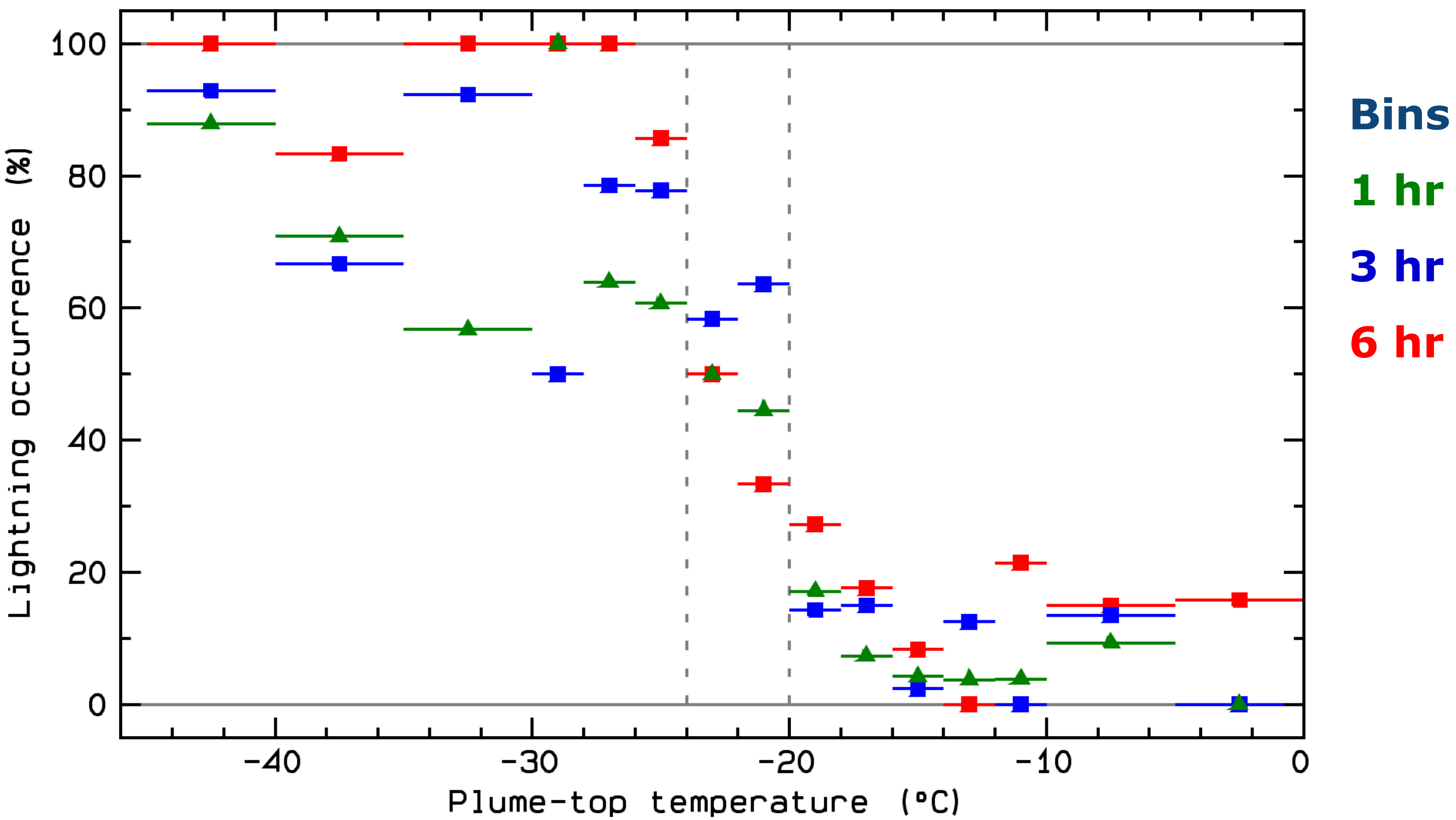
Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 13)

Lightning rate vs. plume-top temp.



Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 15)

Critical temperature: -20°C to -24°C



Arason, Bennett & Burgin (2011), *J. Geophys. Res.*, (Fig. 16)

Plume lightning during the Eyjafjallajökull eruption seen from a distance of 72 km. Notice the characteristic anvil shape of the plume top. Photo Þórður Arason, 17 April 2010 at 04:47:09 UTC.

Ash-infused hail on the glacier about 5 km east of the Eyjafjallajökull crater. Photo Thor Thordarson 22 April 2010

Conclusions

- Conditions of the ambient atmosphere appear to have controlled the occurrence of >3 kA lightning during the Eyjafjallajökull 2010 eruption

- The plume needed to reach heights with ambient temperatures of -20°C to -24°C for lightning to be generated

- Electrification of the volcanic plume during the Eyjafjallajökull 2010 eruption appears analogous to that of meteorological thunderclouds, in agreement with the “dirty thunderstorm” proposal of Williams and McNutt (2004)