Lightning Stroke Rate, Distribution and Energy Release During Volcanic Eruptions at Kelud, Indonesia, and Calbuco, Chile

Kirstin A. Hargie[1], Alexa R. Van Eaton[2], John W. Ewert[2], Robert H. Holzworth[3]

[1]*Portland State University, Department of Geology, Portland, Oregon;* [2]*U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, Washington;*
[3]*University of Washington, Department of Earth and Space Sciences, Seattle, Washington*

INTRODUCTION

Timely detection and reporting of ash cloud dispersal is an ongoing challenge in volcanic hazards monitoring. Ash poses a significant and costly threat to human health and aircraft. Ash can be ingested into a jet engine turbine, melt, and fuse to the engine, causing damage or flame-out. Volcanic eruptions have caused ~$250M in damage to the airline industry since 1982.

Lighting data collected by the World Wide Lightning Location Network (WWLLN) has recently been used to complement data such as weather radar, satellite, and seismic data to improve timeliness of eruption alerts and characterization of eruption style. This is especially important for remote volcanoes with sparse monitoring networks. A current challenge with using WWLLN lightning is that meterological lightning around volcanic vents currently creates false alerts.

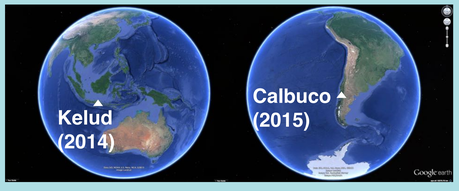
This is the first study to examine the stroke energy of WWLLN-detected volcanic lightning. The aim is to explore characteristics of volcanic lightning energy, and to examine how volcanic lightning relates to meterological lightning.

QUESTIONS

What do lightning stroke energies look like for a volcanic eruption?

Can volcanic lightning be distinguished from meterological lightning?

How does volcanic lightning from one eruption compare to another?



METHODS

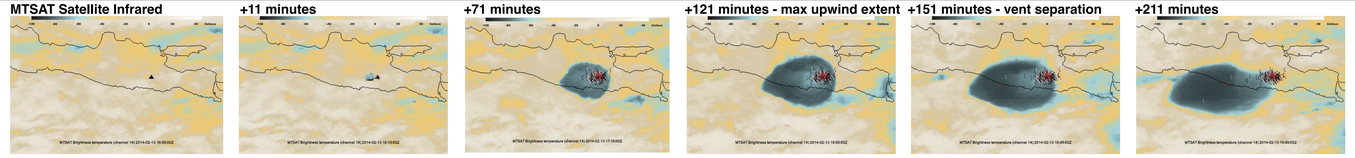
WWLLN (http://www.wwlln.net) collects lightning stroke data from a growing network of 53 sensors around the world. WWLLN utiliizes the Very Low Frequency range detecting sferics at long range (1000s of km). The system favors detection of cloud to ground strokes. Detection efficiency is 40-60% of strokes > 30 kAmps.

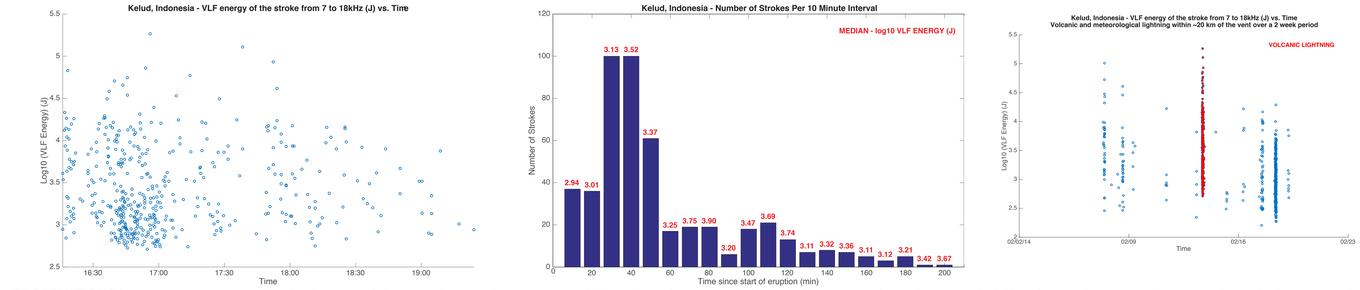
WWLLN Data was analyzed using Matlab for Kelud for a 3 hour period on 13 February 2014 from 16:15 to 19:15 UTC. The data for Calbuco was analyzed between 00:00 22 April 2015 to 24:59 24 April 2015. Radiometric satellite data and lightning stroke data were combined using Unidata IDV to examine umbrella cloud dispersal and stroke distribution over time.

To address the question of how volcanic lightning can be distinguished from meterological lightning a two week window of WWLLN data centered on the the eruption date of Kelud was analyzed within a 100 km radius. The Kelud data included approximately 77000 points of meterological data and 400 points of volcanic lightning data. An initial 2 week window for Calbuco was also examined, but had only one meteorological data point to compare, so the Calbuco data was widened to include an entire year of data centered on the 22 April eruption. The year of Calbuco data included approximately 2200 meterological strokes, and 800 volcanic strokes.

Kelud, East Java, Indonesia

Kelud is a 1731 m stratovolcano located in densely populated (38.5 million) East Java, Indonesia 35 km East of Kediri. It erupted on 13 February, 2014 for approximately 3 hours. The eruption displaced over 200,000 people, caused 7 fatalities, closed 7 airports in Central and East Java, damaged over 25,000 homes, and caused $20 million worth of damage to a commercial A320 flying from Perth to Jakarta that flew through the ash plume approximately 3 hours after the onset of the eruption.



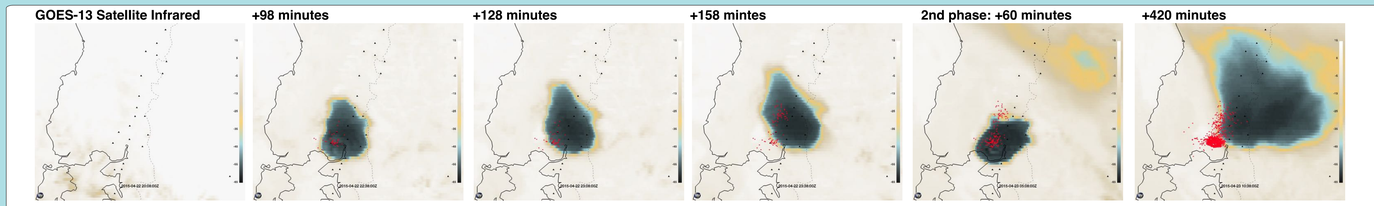


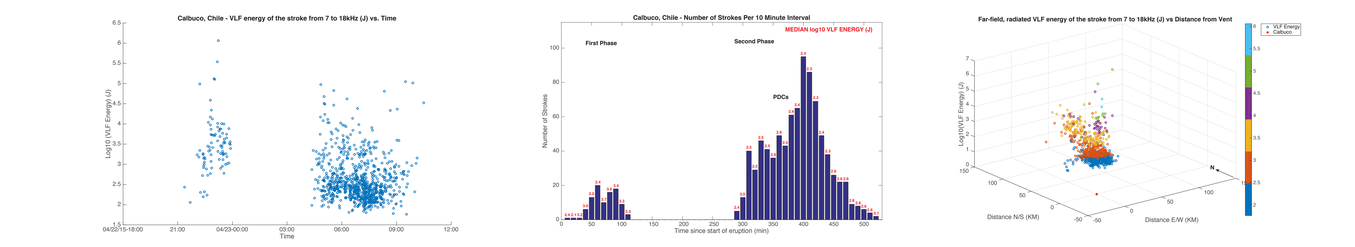
OBSERVATIONS in space: the greatest distribution and highest stroke energies occurred within 20 km of the vent. Bell-curve like energy decay in crosswind direction, and asymmetric energy decay in downwind direction
In time: Stroke rate peaks at 30-49 minutes, and decreases by half after 45 minutes. Max median energy at 80 minutes. Two more pulses of increased stroke rate. Last stroke at ~200 minutes.

Calbuco, Los Lagos Region, Chile

Photograph by Francisco Negroni

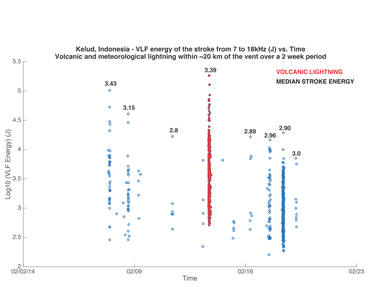
Calbuco is a 2015 m stratovolcano located in the Los Lagos Region of Chile, 30 km East of Puerto Varas. It erupted on 22, 24, and 30 April 2015. Only 1 hour of volcanic earthquakes preceded the 22 April eruption. The eruption caused airline cancellations in Argentina, Chile, and Uruguay, and the evacuation of more than 6,500 people within 20 km of the volcano.

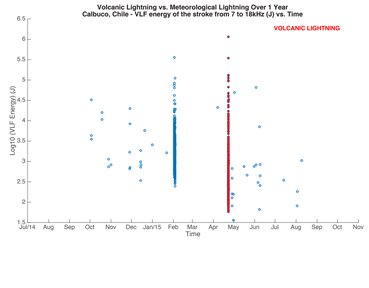




OBSERVATIONS in space: Mostly low energy strokes downwind, particularly in the 2nd eruptive phase.
In time: Stroke rate variable, but decreases after 1st major pulse. 2nd eruption much different character, lower energy, significantly more strokes

VOLCANIC VS. METEOROLOGICAL LIGHTNING





Observations

- **Regional differences between temperate & tropical climates – much less lightning in southern Chile, only one month with lightning with comparable energies.**
- **Volcanic lightning is generally higher energy, particularly close to vent**

CONCLUSIONS

Volcanic lightning stroke energy and distribution can be used to:

(1) Interpret eruption style, particularly multi-phase eruptions.

(2) Evaluate regional differences between volcanic & meteorological lightning at high latitude or temperate-climate volcanoes.

However, delayed onset of high-energy strokes may hinder early alerts, except at volcanoes without much meteorological lightning, where it is safer to assume that any lightning may be associated with an eruption.

FUTURE WORK

- **What do other eruptions & eruption styles look like in terms of volcanic lightning?**
- **Need to characterize regional differences in meteorological lighting for volcanic comparison**
- **Can stroke energy improve auto-alerts?**
- **What processes cause high-energy vs. low-energy volcanic lightning?**

REFERENCES

Van Eaton, A. R. et al., 2016, Volcanic lightning and plume behavior reveal evolving hazards during the April 2015 eruption of Calbuco volcano, Chile, Geophys. Res. Lett., 43. doi:10.1002/2016GL068076.

Behnke, S.A., McNutt, S.R. 2014, Using lightning as a volcanic eruption monitoring tool, Bull Volcanol, 76:847, doi: 10.1007/s0044501408471.

Hutchins, M.L. et al., 2012, Far-Field power of lightning strokes as measured by the World Wide Lightning Location Network, J. Atmos. & Oceanic Tech., 29. doi: 10.1175/JTECHD1100174.1