C-Band Dual-Polarization Observations of a Massive Volcanic Eruption in South America

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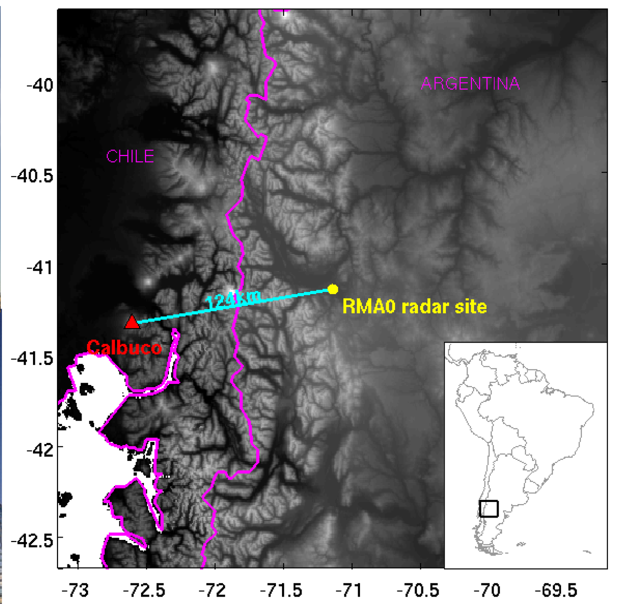
1. Motivation & Objective

Several volcanic eruptions worldwide have been observed by ground based weather radars, however most of these observations were performed by single polarization radars.

*This work shows results of the **first massive eruption observed by a dual polarized weather radar in South America** related to **Calbuco volcano**, which occurred between **22-23 April 2015**.*

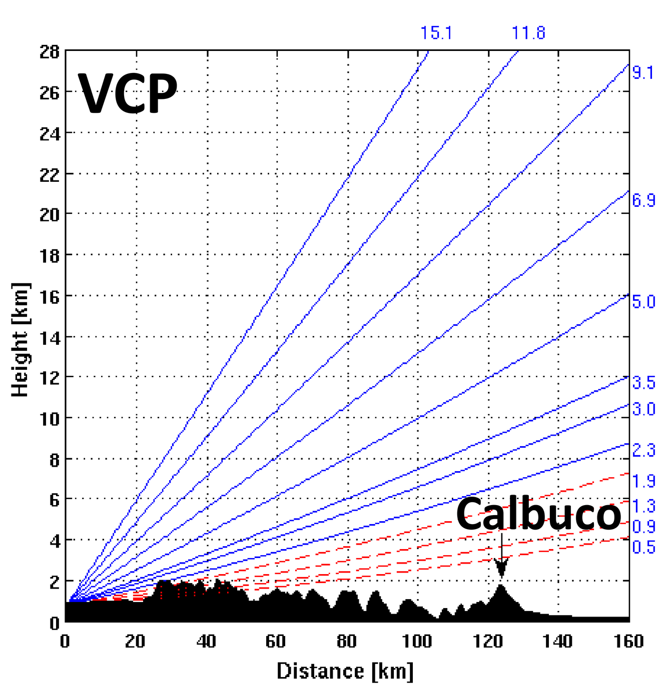
2. Calbuco volcano



- **Stratovolcano** located in southern Chile with an altitude of **2003 m amsl**.
- In the evening, on **22 April 2015 at 21:04 UTC** (18:04 LT), it had the first eruption after more than 50 years.
- Seven hours later, a massive second eruption occurred on **23 April 2015 at 04:00 UTC** (01:00 LT)

3. RMA Bariloche Weather Radar

PARAMETER	SPECIFICATION
Location	41,14°S / 71,15°W
Radar Type	*INVAP RMA Dual Polarisation Weather Radar*
Polarisation	*Dual (Horizontal/Vertical STAR)*
Wavelength	*5,635 cm (C-band)*
Power	*350 kW*
Maximum Range	*247 km*
Range Bin Spacing	*0,5 km*
Beam Width	*0,98/0,98 degrees*
Pulse Repetition Time	*2000 µs*
Pulse Width	*2 µs*
Radar Height	*840 m*
Beam Elevations	*12 elevations from 0,5 to 15,1 degrees*
Recorded Fields	*Horizontal Reflectivity (Z_{HH}), Radial Velocity (V), Differential Reflectivity (Z_{DR}), Cross-Correlation Coefficient (ρ_{HV}), Differential Phase (Φ_{DP}), Specific Differential Phase (K_{DP}).*
Task Cycle Time	*9 minutes*
Distance from Calbuco Volcano	*124 km*

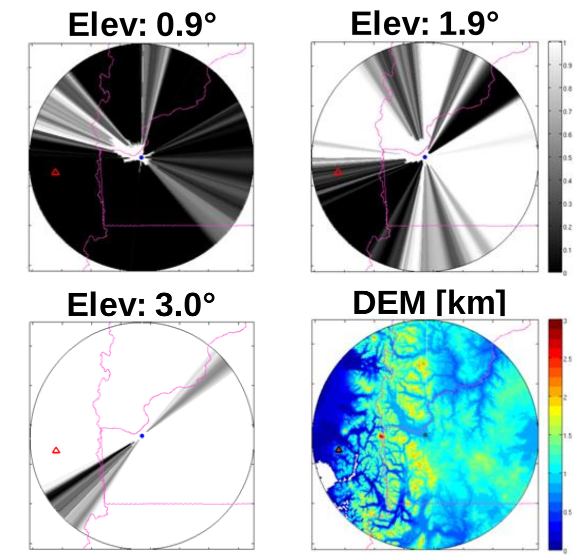


Representation of the theoretical radar ray paths in a range-height reference system for the elevation angles scanned by the radar antenna.

Note that the first four tilts are totally blocked by topography. In this case, the radar signal is assumed to propagate in the standard atmosphere.

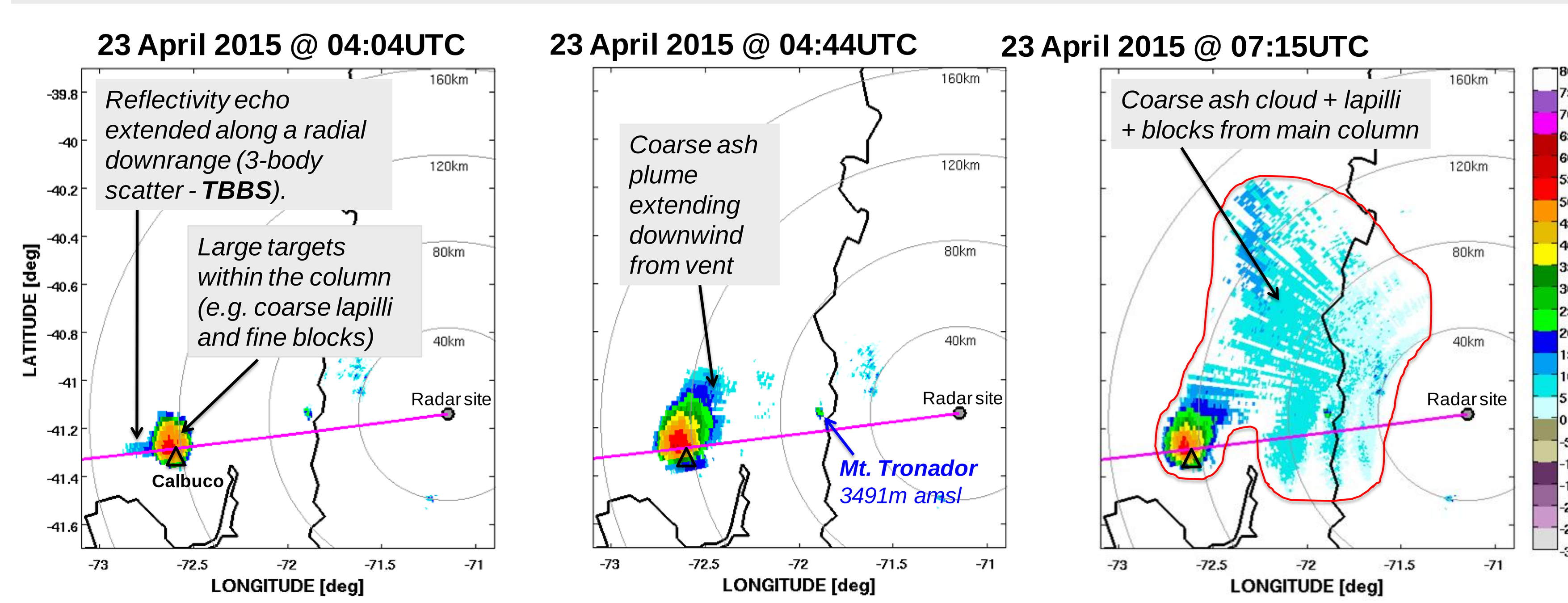
4. Data processing

- Partial beam blocking (PBB) correction from fixed targets is applied following Fulton et al. (1998).
- Figures show PBB map for three elevation angles as well as DEM map for comparison. PBB map is used to compensate, up to 60%, the radar reflectivity using the simplified obstruction function.
- Radar echoes generated by ground clutters (e.g., topography) are filtered out applying a threshold on the correlation coefficient.
- Finally, Z_{DR} calibration was double checked during a snowfall case on July 17 and 18 2015 obtaining a value close to +4 dB and Z_{DR} vertical point calibration was calculated at +4.26 dB

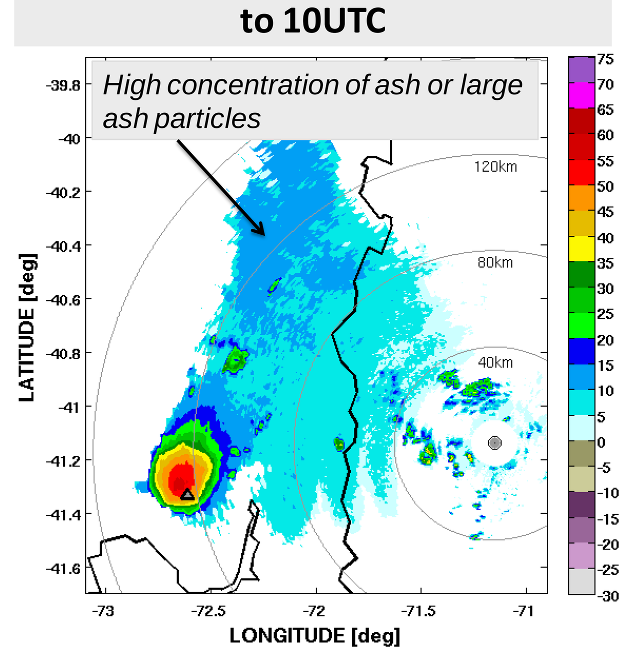


5. Characterization of eruptions

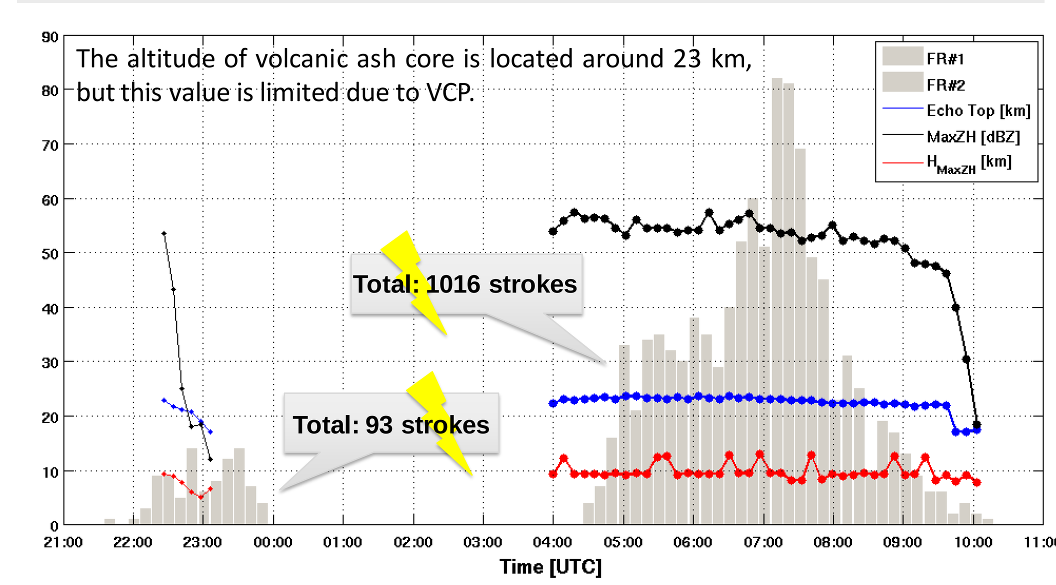
Time evolution of COLMAX



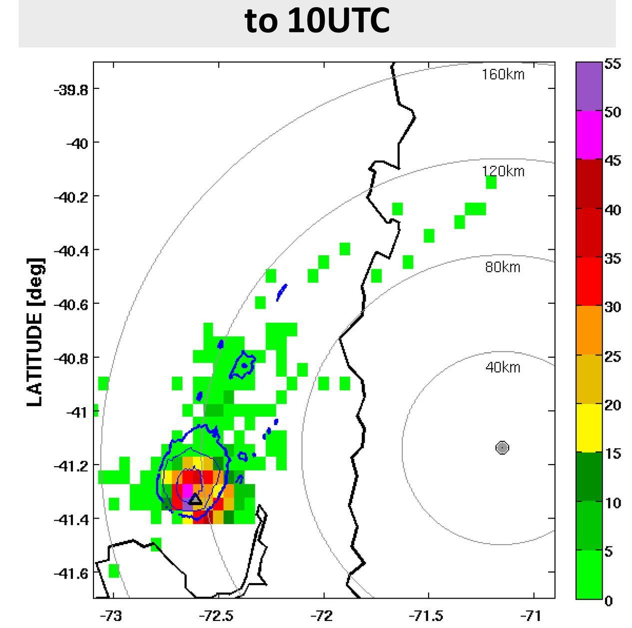
Extreme MaxZ_{HH} value from 04UTC to 10UTC



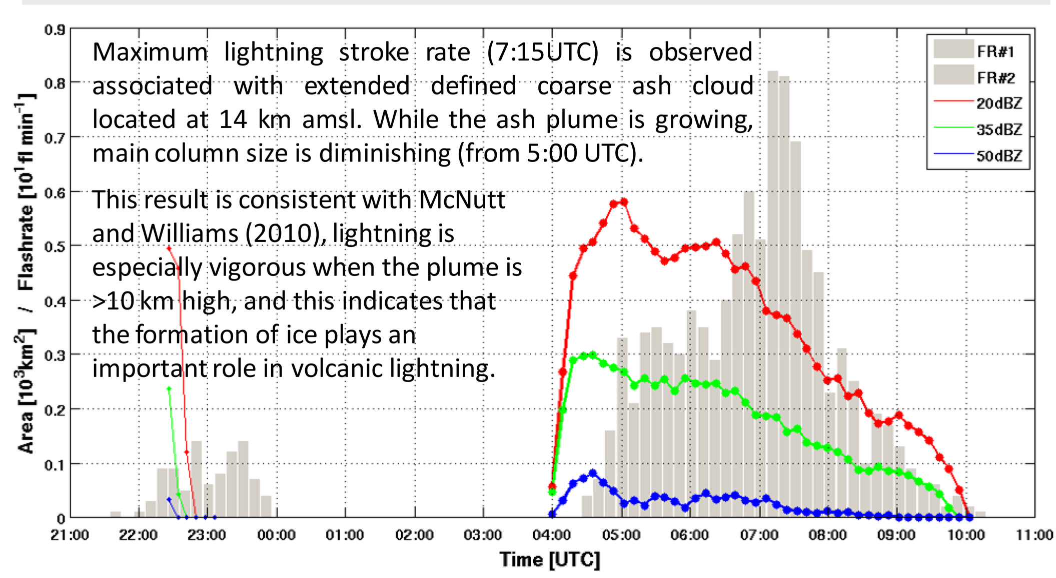
Time evolution of lightning stroke rate and echo top parameters



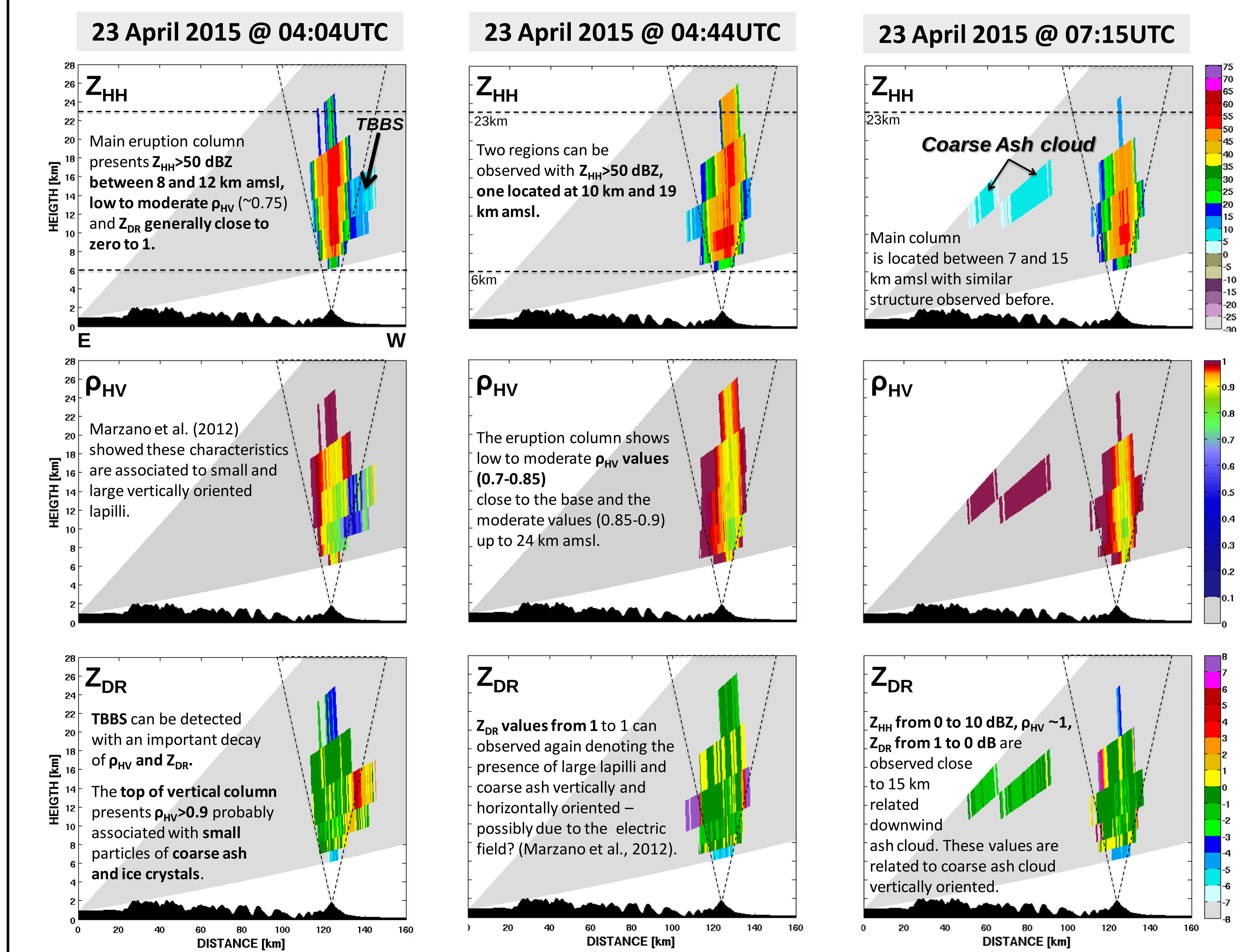
WWLLN total lightning from 04UTC to 10UTC



Time evolution of lightning stroke rate and Z_{HH} areal coverage



6. Vertical cross sections: 2nd eruption



The interpretation and evaluation of the geophysical information content of polarimetric radar observables is not an easy task, especially if limited to the few available experimental analyses.

From the available ash measurements on the ground, a microphysical model of volcanic clouds for radar observation purposes can be defined in terms of five main classes (or modes) of ash size: fine ash, coarse ash, small lapilli, large lapilli, and blocks (Marzano et al., 2013).

Table I. Main characteristics of volcanic pyroclasts (adapted from Rose et al. 2000 and Marzano et al. 2012b).

Tephra	Particle type	Typical particle size	Distance from the volcano vent	Residence time in the atmosphere
Ash	FA	<64 µm	Hundreds to thousands of kilometers	Days to months or years
	CA	64–532 µm	Tens to hundreds of kilometers	Days
Lapilli	SL	0.532–2.56 mm	Few to tens of kilometers	Few minutes
	LL	2.56–32 mm	Hundreds of meters to a few kilometers	Seconds to minutes
Blocks	BB	>32 mm	Tens to hundreds of meters	Tens of seconds

7. Conclusions

- The implementation of an algorithm that provide information about classification from coarse ash to blocks particles during volcano eruptions using ground based radar information is a crucial tool for aviation forecast and emergency managers.
- The sensitivity of this system to particle concentrations could be an important information to be ingested/assimilated in particle dispersion model (e.g. FALL3D, FLEXPART, HYSPLIT, among others).
- This case provides an excellent example that C-band dual polarization radar system can provide emerging scientific requirement to detect ash and lapilli categories.
- Future work is needed in order to assess the particle evaluations and surface information from field campaigns will be incorporated.

8. Acknowledgements

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