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The first Second of a Strombolian Eruption: Doppler Radar and infrasound Observations at Erebus Volcano, Antarctica

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We deployed three continuous wave Doppler radar instruments together with infrasound sensors at Erebus volcano in Antarctica, which is one of the few volcanic open vent systems that allow a direct observation of the source of a volcanic eruption. The recorded data provide new important insights into the mechanism of strombolian eruptions, and help to improve or replace existing eruption models.

The in-situ observation of volcanic eruption dynamics is one of the big challenges in volcano geophysics. Understanding near-vent eruption dynamics means gaining information about the physical structure of the volcano, and understanding the initial dispersal of ejecta during eruptions. Thus it is of special interest to measure eruption processes as close as possible to the top of the magma column, where observations are mostly unaltered by the atmosphere. The exact mechanism of strombolian eruptions is unknown to the present day, and almost no information has previously been gained on pressures and energies involved during an eruption.

Erebus contains a $\sim$1000°C convecting phonolite lava lake, which is connected to a magma chamber at depth. The lava lake varies in size but was 40 m in diameter in 2005/06. It is situated inside a 600 m wide, 220 m deep crater at the summit of the 3794 m high volcano. It is the source of frequent violent strombolian eruptions. Our newly developed rugged and portable radar system consisted of a high temporal resolution and 2 low resolution 24GHz Doppler radar instruments, and was deployed on the crater rim from November 2005 until January 2006. 50 large explosions were recorded from three different angles. The use of 24GHz (K-Band) microwaves allowed for a continuous and undisturbed observation, independent of meteorological or visibility conditions. Data from the remotely controlled system were downloaded in real time through a wireless network. The system delivers a velocity distribution of particles in the radar beam at a sampling rate of 15 to 25 Hz (high resolution) and 1Hz (low resolution).

Preliminary examination of the data shows some intriguing features. The radar detected ejecta speeds in excess of 180 m/s, and revealed that the exploding gas bubbles do not oscillate prior to their burst. In all observed cases they were rapidly expanding and exploding in the last phase of their approach to the free surface. This shows that oscillatory eruption models are not applicable to strombolian systems like Erebus. Measurements of the velocity distribution of the expanding bubble surface membrane allowed for the identification of the moment of rupture, and agreed with recordings of an infrared video camera at the crater rim. Even more spectacular, velocity recordings of the bubble membrane allowed for the calculation of the expected infrasound signal, which is in very good agreement with the true recorded signal. Such comparisons yield important information on the involved burst mechanism. Accelerations in excess of 1300 m/s^2 were found, and a first crude estimation of the bubble overpressure suggests a value of more than 3 atmospheres for a moderate eruption.

Additionally, a 10 minute cycle in the speed of magma circulation was observed in the lava lake, providing insight in internal convection and possibly even resonance mechanisms of the volcano's interior. We expect to gain an even better understanding of the initial phase of a strombolian eruption when all data are processed, which will also include seismic data.