Emma Nicholson

Investigating eruptive behavior at Soufriere Hills Volcano, Montserrat: a study into simultaneous processes occurring both at depth and at shallow sea levels.

Montserrat, Caribbean.

2011

Emma Nicholson is a third year undergraduate in Earth Sciences, at Oxford University. She hopes to carry on to a PhD position in this field.

Emma investigated the eruptive behavior at Soufriere Hills Volcano on the island of Montserrat in the Caribbean. The aim of her project was to simultaneously compare seismic data with proxies for eruptive activity at both shallow levels and at depth within the conduit. Gas geochemical studies will provide indications of volcanic processes, from with eruptive activity can be established.

She hopes that the project will contribute a significant advancement to the field of volcanic prediction, by improving our understanding of the interplay between deep and shallow activity, and the recognition of the associated seismic signature.

Below is Emma's report on her work.

Timeseries Analysis of Gas Fluxes at Soufriere Hills Volcano

Comparison with seismic, strain and visual observations to constrain conduit processes – Emma Nicholson

Montserrat is a small island in the Caribbean, and is part of the Leeward Islands of the Lesser Antilles. It is one of the British Overseas Territories, with a population of only 5,000 inhabitants. It is also home to one of the world's most active volcanoes…

Project:
My research project, as part of the final year of my MESci Earth Sciences, is based in the field of volcanology and allows me to realise my lifelong dream of working on active volcanoes. This is an exciting and rapidly developing area of research, and I was fortunate enough to have the opportunity to work with the Montserrat Volcano Observatory. During my visit, I collected data for my project whilst learning valuable fieldwork skills that can only be achieved with practical hands-on experience.
My passion for volcanoes began when I was very young. Visiting the steaming crater of Mt. St Helens with my family, and discovering the damage and loss of life that resulted, convinced me that I wanted to dedicate my life to studying these extreme forces of nature. My work here in Montserrat is the first step towards realising that dream.

Fieldwork on the volcano requires the use of a helicopter

Soufriere Hills Volcano:

The island itself is entirely volcanic, and made up of three volcanoes. The two most northerly volcanoes are the oldest, and are now long extinct, but the third is most definitely still awake. It is known as Soufriere Hills Volcano, and, following no eruptions since recorded history began, it dramatically burst into life on 18 July 1995. Soufriere Hills Volcano is a stratovolcano, similar to Mt. St Helens, and erupts explosively; its' activity is very different to systems such as Hawaii and Etna. While Hawaiian volcanoes quietly extrude runny lava flows and produce stunning lava lakes, stratovolcanoes are characterised by periodic explosive gas release accompanied by phenomena known as pyroclastic flows. These flows are superheated clouds of gas and ash, which sweep away from the volcano at speeds of up to 450mph and temperatures approaching 1,000°C. It is one of these flows that destroyed the capital city of Plymouth in 1997, burying the town under several tens of metres of volcanic debris. The initial eruption left approximately two-thirds of the population homeless, with most evacuated to Britain or the United States. Since 2000, some have returned, but only the northern part of the island remains inhabitable, and rebuilding the economy continues to be an uphill struggle. The volcano has continued to erupt periodically, on average every two years, with the most recent eruption beginning in October 2009 and culminating in a massive dome collapse in February 2010.

Soufriere Hills Volcano viewed from the Montserrat Volcano Observatory

Above: Mobile GPS station to monitor ground deformation on the flanks of the volcano.

Below: FTIR spectrometer measuring fluxes of HCl and SO_2 in the volcanic plume.

Above: View of the volcano from Garibaldi Hill. There are several instruments and cameras set up permanently at this location.

Below: Long exposure image of the volcanic dome, showing vent incandescence.

Fieldwork and Data Collection:

My work focuses on studying the composition and flux of volcanic gases being released from the volcano, in order to learn more about the processes governing the ascent of magma beneath the island. The most ubiquitous volcanic gases are water vapour and carbon dioxide; however, these are very difficult to measure due to the high background concentrations in the atmosphere. Instead, we measure sulphur dioxide (SO_2) and hydrogen chloride (HCl), using a system of ultraviolet spectrometers installed around the volcano. SO_2, for example, strongly absorbs light with a wavelength of 315nm, and so its presence in the volcanic plume can be determined by comparing the total amount of 315nm light reaching the spectrometer from under clear sky, with that from beneath the plume. Combining estimates of gas concentration with independent wind speed measurements allows the total instantaneous gas flux to be derived.

Fieldwork on the volcanic deposits from the most recent 2010 eruption

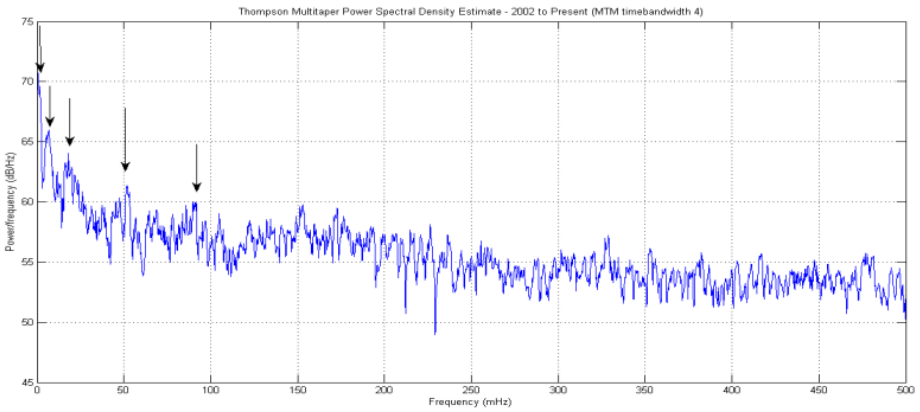
Monitoring gas fluxes is an important part of eruption prediction, as changes in either the composition or total amount of volcanic gas can signal that changes are occurring within the volcano. For example, SO_2 is released from magma at much greater depths and higher pressures than HCl, and therefore the HCl/SO_2 ratio can be used as a proxy for magma ascent. An increase in the HCl/SO_2 ratio over time indicates that magma is moving to much shallower depths, suggesting the possibility of an imminent eruption.

As well as gas emissions, earthquake seismicity and borehole strain is also monitored at the Montserrat Volcano Observatory. I have been investigating a possible link between short timescale fluctuations in gas emissions (hours/weeks/months) and both particular types of earthquake and abrupt strain changes. Understanding these relationships will hopefully help us to learn more about the mechanisms by which gas migrates to the surface, and about the permeability of the magma. Distinctive strain changes have been documented preceding eruptions at Hekla, Iceland (Linde et al. 1993), and it will be interesting to compare results from Soufriere Hills Volcano. I will be continuing to work on this until the end of April, and I am hopeful that my work, both in Montserrat and over the coming year, will provide a valuable contribution to eruption prediction worldwide.

Gas Sampling in Plymouth, which was destroyed by volcanic activity in 1997

Preliminary Results:

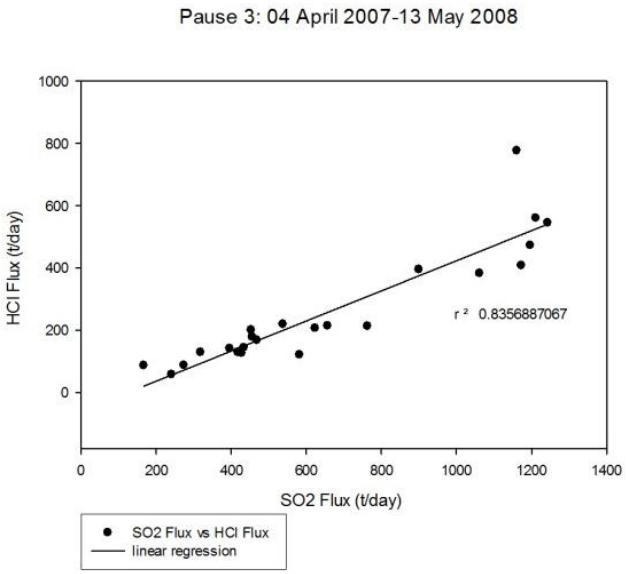
Continuous SO_2 monitoring with the DOAS network began in early 2002, during the final stages of Phase 2 extrusion. The creation of a continuous, regularly sampled, dataset facilitates spectral timeseries analysis to determine whether any periodicities are present in the data. The relatively low daily sample rate is partially negated by the long observation period, resulting in a well-populated dataset. Therefore, even after dividing the data into individual pause and extrusion phases, there are still sufficient samples for robust spectral analysis.



Multi-taper periodogram illustrating the dominant cycle frequencies for the Phase 3 Extrusion phase. Similar plots have been calculated for all phases of the eruption.

Spectral timeseries analysis involves the use of the Fast Fourier Transform (FFT) to calculate the 'power spectral density' of the dataset, or the relative dominance of cycles of particular frequency. Detailed analysis of the SO_2 timeseries at Soufriere Hills Volcano has revealed strongly cyclic behaviour on previously unidentified timescales. In addition to the dominant 2-3 year foam collapse cycles, higher frequency periodicities appear to be present at ~20 days, 30-60 days and 130-170 days, with a component of temporal frequency modulation evident in the latter two cycles.

Comparison of fluxes of HCl and SO_2 shows distinctly coupled behaviour prior to Phase 5 extrusion, likely constraining the source of short term periodicities in degassing to depths shallower than ~2km. The lack of correlation between fluxes of the two species during the current pause phase suggests a fundamental shift in the depth of processes controlling degassing.



Plot illustrating the strong correlation between variation in SO_2 and HCl. The linear regression line shows the best fit relationship. Similar plots have been calculated for all phases of the eruption.

Examination of the relationship between gas flux and other monitoring parameters, such as seismicity, strain, and visual observations, has indicated that gas flux may show responses on hourly timescales. Positive flux excursions have been observed in association with VT string seismicity and ashventing episodes. However, the lower temporal resolution of SO_2 monitoring means it often remains uncertain as to whether SO_2 changes precede or lag seismic events. Constraining these relationships will improve not only our understanding of the nature of VT strings, but also how gas flux responds to changes in conduit permeability.

Strainmeter data provide significant insights into conduit processes on timescales from hours to days. Immediately prior to the onset of Phase 5 extrusion, strain decreased markedly during ashventing, before recovering to values in excess of previous stable background values following the onset of extrusion. A similar signal of smaller magnitude is evident associated with individual ashventing episodes, whereby an abrupt strain reduction, correlating with the peak in seismic amplitude, is followed by a gradual strain recovery corresponding to the duration of the seismic coda. These results provide further evidence for cycles of pressurisation and release accompanying gas sealing prior to extrusion

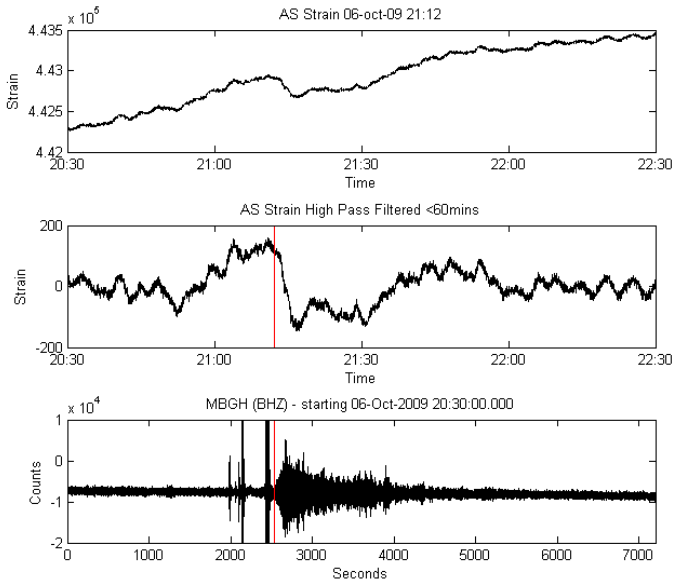


Figure illustrating the abrupt strain change coincident with the onset of ashventing at Soufriere Hills Volcano. Similar signals have been observed during many venting episodes.

Note: These results are highly preliminary, and further analysis is required to confidently apply interpretations.

Local Culture and Wildlife:

Since arriving in Montserrat I have been amazed by the beauty and peace of the island. Tourism is not well developed, so local culture and traditions still thrive. The beaches are dark with volcanic sand, and a short hike can take you to many secluded spots.

The wildlife on the island is also so varied, ranging from goats and chickens to exotic hummingbirds and iguanas. On a sunny day, as many as thirty iguanas could be seen sunbathing in the garden. Fortunately for me, July/August is the season where giant sea turtles come up onto the beaches to lay their eggs, and it was magical to sit and watch them for hours under the full moon, whilst taking care not to disturb them.

Food and festivals are a big part of Montserratian life. I have discovered so many exotic new fruits during my time here, including papaya, guava, breadfruit and okra. Fresh mangoes are also plentiful at this time of year, and you are free to just pick them off the trees. Festivals are held on many weekends throughout the summer, with steel bands and masquerade dances, as well as a showcase of local cuisine. Parties will often carry on late into the night, and even through to the following day!

This opportunity to undertake fieldwork in Montserrat has been a once in a lifetime experience, and has introduced me to an exciting new culture, in addition to developing my career as a volcanologist. This trip was only made possible, however, through the generosity of the Lydia Press Foundation, receiving a travel bursary has helped me to cover the significant financial costs of a trip such as this, and for that I am extremely grateful.