Linden Wike 2020

General Astronomy with EAS Concentration

Using The ASTER Instrument's Satellite Thermal Remote Sensing to Monitor Volcanoes

Over Time

Abstract

Volcanic eruptions pose a threat to populations living within range of these eruptions and affect the Earth globally by altering climate. Our ability to understand the precursory signs of eruptions has so far been limited; however, many eruptions show signs that can be studied, such as thermal anomalies. Ground-based monitoring instruments have been used most effectively in the past, but they are limited to regions that are physically accessible regions that do not endanger scientist who monitor these volcanoes. Using thermal anomaly data obtained by the satellite-based instrument ASTER, the AVTOD database provides a method of predicting eruptions. Through the study of ASTER data, thermal anomalies can be identified and monitored over time to develop a database of thermal anomaly evolution prior to eruptions. This database can then be used by research groups to form computer algorithms to predict eruptions, or it can be used as a foundation for more thermal anomaly experiments. In my research, I use AVTOD data to identify thermal anomalies of Holocene volcanoes and monitor their respective kinetic surface temperatures and areas over time. My role is to fill the database with datasets that subsequent groups can draw on for their projects. Thus, I provide a resource with which volcanic eruptions will be more accurately monitored and predicted in the future.

Biographical Sketch

I am a junior majoring in Astronomy with a concentration in Earth and Atmospheric Sciences and a minor in Archaeology. I came to Cornell University with the intention of majoring in Biology and Linguistics, but after taking Professor Squyres' introductory astronomy course I decided that my true passion lay among the stars. I hope to use my astronomy background with experience in earth sciences to pursue graduate studies in planetary sciences, and then conduct research on exoplanets, stars, or black holes. However, my interests are not limited to the otherworldly. As my minor in archaeology indicates, I am interested in analyzing artifacts and remnants of civilizations to better understand humanity's past. My extra-scholastic interests have ranged from travelling to over twenty foreign countries, to working at Cornell's Synchrotron this past summer and fall, and to my current study of Holocene Epoch volcanoes. I have lived in France and Cameroon – home to Mt. Cameroon, an active volcano that I hiked- where I gained an understanding of both the physical and cultural diversity of our planet. I hope to extend my understanding of the Earth and subsequently the universe throughout my academic career.

Statement of Purpose

This summer I will be engaging in research pertaining to the monitoring and studying of Holocene volcanoes, both active and quiescent. The Smithsonian Global Volcanism program cites 1432 volcanoes with eruptions during the last 10,000 years, or Holocene period. Many of these volcanoes are currently active and can affect the Earth on large scales. An abundance of volcanic aerosols in the atmosphere following an eruption can have a global cooling effect, but on the more local scale volcanoes affect their surrounding landscapes through "ash clouds, volcanic bombs, pyroclastic flows, lava flows, lahars, debris avalanches and magma intrusion induced earthquakes" (Reath et al., 2019, p. 2). According to Brown, et al., (2016) there are 800 million people within a 100 km radius of Holocene volcanoes and even around 30 million within a smaller 10 km radius. Given the hazards that these volcanoes are capable of, it is necessary for the safety of these populations that there are accurate methods of predicting eruptions.

Monitoring of volcanoes can take the form of both ground-based and satellite-based instruments; however, according to Reath et al,. (2019, p. 2) "ground-based monitoring instruments are available at less than half of the volcanoes considered to be potentially active". This paired with uncertainty arising from not all volcanic eruptions being preceded by the same patterns or types of anomalies leads to a need for multiple forms of monitoring. Volcanoes, as stated above, come with many risks to ground-based operations, leaving satellite-based monitoring as the safer option for a large amount of Holocene volcanoes. One such satellite is ASTER, the Advanced Spaceborne Thermal Emission and Reflection Radiometer. ASTER is one of NASA's Terra satellite's imaging instruments; it obtains thermal infrared data that can be used to find kinetic surface temperatures.

The ASTER Volcano Thermal Output Database (AVTOD) is a project designed to monitor and predict volcanic eruptions. For the purposes of AVTOD we are using ASTER's kinetic surface temperature data to identify thermal anomalies. These thermal anomalies are classified as areas with temperature 2K or more above background. Background temperature is acquired using an image processing system, ENVI, and is calculated by averaging the temperature of a 10x10 pixel area next to the anomaly (Reath et al., 2019, p. 6). The area of these thermal anomalies is then found by removing background temperature from an image and calculating how many of the remaining pixels have a kinetic surface temperature value of 2K or more. The ASTER images used in the AVTOD project are limited to cloud-free and nighttime images. Daytime images are scrapped due to interference of sunlight with surface temperature accuracy, and the ASTER instrument is not reliable enough at getting TIR data through clouds. Although ASTER can image with a spatial resolution of 90m in thermal infrared, it has a limited temporal resolution that leads to volcanoes not being consecutively imaged on a timescale of days to weeks (Reath et al, 2019, p. 6). Fortunately, many volcanic eruptions are preceded by thermal anomalies on timescales larger than this.

My current role is in generating datasets for the AVTOD database through identifying thermal anomalies and recording their temperature above background and area over time. An AVTOD database saturated with data is necessary to begin work on computer algorithms and more advanced methods of predicting eruptions, I am helping to create this database. All of the resources necessary for me to carry out my research are available on Cornell's campus. The ASTER images can be downloaded off of NASA's Earthdata cite as GeoTiff files and then I use these images on a program called ENVI at Pritchard's volcano lab or the Bradfield computer lab. The process is entirely virtual, dealing with programs such as Earthdata, ENVI, Glovis, and Google Earth Pro to compare and evaluate images of volcanoes. Therefore the project can be carried out virtually anywhere, with my staying on campus being a convenience to allow me to compare data with my fellow researchers. I will be meeting with postdoc Kevin Reath and my fellow undergraduate researchers once a week to go over what I accomplish per week and what the expectations are for the next. On average I will look at 5-10 volcanoes per week, gathering and interpreting images daily. I will also keep in contact with Professor Matthew Pritchard, the head researcher on this project.

I began research on the AVTOD database this past January, we have finished the data for Latin American and African Holocene volcanoes, and will be moving on to New Zealand and Indonesia. We hope to provide GNS Science of New Zealand with the data required for their observatory to work on predicting volcanic processes. As a research team we hope to submit a paper this semester on how our data will be useful to them and other research groups that want to use a database such as AVTOD to study volcanic anomalies. One other such group is a team at the University of Bristol that wishes to work with datasets such as ours to create machine learning algorithms that monitor and predict eruptions. In this sense alone, I am engaging in this project as a way to lay the foundation for further research, and hopefully as a byproduct of the AVTOD database bring about a way to forecast volcanic events. My interest in this research also stems from my interest in volcanic processes in general. Once this summer has come to a close, I hope to more formally present my research's goals and results in an article or paper.

Immediately after final exams period ends and before I return to Ithaca for research I will be visiting the national parks of Mt. Rainier and Mt. St. Helens to obtain my own experience of visiting volcano centers, and seeing with my own eyes what the thermal images I am studying represent. The trip will last for ten days, allowing me to return to Ithaca for the majority of the summer to conduct this research. During my trip, I will also be visiting the University of Washington Department of Earth and Space Sciences and the Department of Astronomy. I plan on applying to this program, among others, for graduate school as I hope to later on go into planetary sciences to unite my interest in Earth processes with how they compare on other bodies in the universe.

As an Astronomy major with a concentration in Earth and Atmospheric Sciences this research interests me more generally in how I can apply it later in my life. As I stated above I intend to attend graduate school and obtain a degree in planetary sciences, and then go on to do research on exoplanets. Volcanoes are not purely an Earthly phenomenon, they have been confirmed on other celestial bodies such as the moons Io, Triton, and Enceladus; in studying exoplanets I am sure to encounter volcanic activity elsewhere in the universe. Although these celestial bodies are varying distances away and the resolution necessary to image all of them for volcanic activity may not currently be available, research on the volcanoes of Io has already been made a reality. The Juno mission looking at Io has the Jovian Infrared Auroral Mapper that is reported to have "high enough spatial resolution to allow researchers to monitor volcanism on Io" and combined with Earth-based observations and older New Horizons data this Juno data can be used to categorize and identify hotspots imaged by Juno (Perry, 2018). Whatever avenue I intend to take as a planetary scientist, the experience gained working with infrared images on the AVTOD project will be invaluable.

Bibliography

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