

INTRO: References
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0.1 The Importance of Mapping Paleoclimate and -temperature

As climate change and rising temperatures continue to worry scientists it is becoming more and more urgent to be able to develop reliable climate models that can predict and model the world in the coming years. Much of this research is based on the understanding of the past climate and temperature, and this knowledge, luckily, is something that we have access to through not only models, but also hands-on data which is for instance available in the thick ice sheets located around the poles. These massive databases contain information of the state of the worlds climate and atmosphere, among many other things, which can be used to develop and build new predicting models, and are therefore crucial for our continued examination of the future state of our earth.

0.2 Laki and Tambora in Recorded History

In the not-so-distant past two volcanic horizons have been of great importance for this thesis, namely the Laki eruption in 1783 and the Tambora eruption of 1815. Interestingly, these eruptions have not only impacted the geophysical world, but has left their footprints on the history of Man in politics[REFERENCE], sociology[REFERENCE], arts[REFERENCE] and philosophy[REFERENCE]. On the eighth day of June in 1783 a volcanic fissure located in the southern part of Iceland was central for a global climatic change. The fissure Lakagígar or more commonly known as Laki refering to the central mountain, erupted with violent phreagomagmatic explosions due to the basalt magma being exposed to ground water. The eruption was given a Volcanic Explosivity Index(VEI) of 4, corresponding to the magnitude of the much later 2010 Eyjafjallajökull Icelandic eruption. For the next eight months the fissure continued to emit great amounts of sulfuric aerosols into the atmosphere, resulting locally in Iceland in catastrophic mass famine, due to loss of livestock to poisoning, with up to 25 % of the population dying from starvation and poisoning from the volcanic gasses. Globally, the eruption caused a huge amount of sulfur dioxide to be spewed into the northern hemisphere which led to a global drop in temperatures and a generally more extreme climate. In the European regions the following summer was much warmer than usual with many thunderstorms to follow. The winter of 1783-84 was subsequently

extreme, with long periods of continuous frost. In France the late 1780's were marked by several years with droughts in the summer and frost in the winter, which contributed greatly to a rise in poverty and famine, and creating a greater division between the people and the rulers. Along with a growing dismay and distrust in the ruling forces the climatic changes due to Laki and a number of other climatic disruptions the French political situation finally climaxed in the French revolution of 1789. [REFERENCES!!!!]

32 years later on April 5 in 1815 an even more powerful eruption ensued: the eruption of Mount Tambora on the, now, Indonesian island Sumbawa. This eruption had a Volcanic Explosivity Index of 7, which makes it the most powerful in the recorded history of humankind. Considering that the VEI is defined as a logarithmic scale - at least for indices larger than VEI-3 - the Tambora eruption, though located just south of the Equator, impacted the entire globe as well as the European continent in at least the same magnitude as the 32 years prior Laki eruption. Locally, it was estimated to cause at least 10,000 direct deaths and many tens of thousands more due to sulfur dioxide poisoning, famine and disease. In many contexts the year of 1816 following the event became known as "*The Year Without a Summer*", as the ashes from the eruption column dispersed across the world and lowered global temperatures. This significant climate change though was not just a consequence of the Tambora eruption, but was pushed by a number of climatic forcings, some due to several previous volcanic activities around the globe. Combined, these effects coincided in a drop in global temperature by about 0.4 to 0.7 °C. This climatic change affected the entire globe by disrupting the Indian monsoons, causing a number of failed harvests, laying ground to severe typhus epidemics in southeast Europe and destroying crops and causing potato, oat and wheat harvest failure, especially in Ireland. Since the eruption had so severe consequences for the day to day lives of many people, the aftermath all around the world has been one of the greatest documented in recorded time, with a clear impact on the works of many artists, among them Lord Byron and J. M. W. Turner[REFERENCES!!!!]. Although both eruptions caused many a tragedy, there is beauty in using these events as volcanic horizons in ice core records. Given the severity of both eruptions, they have been so well documented in historical records that they make up solid and certain pillars in developing a temporal map of the past life of our ever so active earth. For that and for their brutal beauty they will remain in human history for a great while to come.

0.3 A Rare Gem of Knowledge

The study of ice cores has revealed much information and knowledge about the past behaviors of the world's climate, atmosphere and geology. It has made it possible to also peer into the future of what might lie ahead of us, by modeling and prediction. Many analyses of ice cores focus on large scale changes [REFERENCES] happening over hundreds, thousands or tens of thousands of years. When considering such large-scale changes, it is not of great importance if the dating of the ice core sections is off by a year or two as it is often the general trends over many years that are examined. This is rather lucky, as it is rare to have a very precise dating, especially in very old cores where the annual layer cycles have been extinguished.

INTRO: give examples (glacials to interglacials, climates ...)

The scope of this project, though, has a different focus: When examining ice core data for volcanic eruptions, it is possible to date the ice cores much more accurate and precise than otherwise. Two aspects are in play here: Firstly, if volcanic eruptions are visible in more than one ice core it is possible synchronize these cores by matching the volcanic profiles. This enhances the accuracy of the dating, as more data are taken into consideration. Secondly, if the volcanic eruptions have been recorded in human history, as with Laki and Tambora, the precision of the dating can be highly improved. For this project, both aspects are taken into consideration. The eruptions in Indonesia and Iceland have been very well documented and recorded, and are both visible in a great number of ice cores. This reveals a rare gem of knowledge: as the two eruptions are relatively close in time, well documented and detectable in many cores, it is possible to say with high confidence that any data analyzed in the ice core section between the two visible eruptions, be it isotopic, conductivity, chemical or otherwise, must in time represent the 33 years between the deposition of volcanic material in the ice cores. This allows for in depth analysis of the diffusion and densification processes the ice has been through and makes it possible to develop examine new methods to restore diffused signals and otherwise lost information with high precision and accuracy.

INTRO: Write shortly about conductivity and volcanoes. Figure example.

Figure example or description of exact deposition time

In this thesis an introduction to diffusion of water isotopes in ice cores is firstly presented along with methods for modeling densification and diffusion profiles. Following is a brief examination of different experimental methods for detection of volcanic deposited material and which methods has been used for the data under inspection. The chosen data are then presented along with an argumentation of why they were selected. Then a thorough presentation of data and signal analysis along with important computational methods are presented. These different tools are then combined in the method description, depicting a walk-through and testing of the final algorithm developed

for estimating the diffusion length given the specific number of years. The final method is tested and further developed and fine tuned, and results given the last iteration of the method are presented. On the basis of these results, finally, a temperature reconstruction of the area of the drill sites is attempted.