PAGES Volcanic Impacts on Climate and Society 5th Workshop

"Moving forward by looking back"

22nd-24th May 2023, University of Bern, Switzerland and online

Programme and Abstract Book

VICS

PAGES
PAST GLOBAL CHANGES

Acknowledgements

Many thanks to the staff of the Oeschger Centre for Climate Change Research, Martin Grosjean, Peter Stucki, Kaspar Meuli, Manuela Roten, Ursula Widmer and Isabel Jakob, for all their assistance with many aspects of the workshop. Thanks to Savio Villaverde and Doris Rätz from the Climate and Environmental Physics Secretariat for administrative and logistical support. Thanks to Imogen Gabriel and Evelien van Dijk and our student assistants Chantal Zeppenfeld and Catherine Li for their help running the conference and delivering it in a hybrid format. Thanks also to all our partners and sponsors for financial assistance for running the conference and providing travel funding for invited speakers and early career researchers.

Partners and Sponsors

Scope and Themes

The PAGES VICS Working Group aims to use an interdisciplinary approach to (1) coordinate improved reconstructions of volcanic radiative forcing, (2) enhance our understanding of volcanically-induced climate variability, and (3) deepen our understanding of societal impacts and human responses to volcanic eruptions. We will address these issues at the 5th VICS workshop and extend their range deeper into the past and future.

Selected workshop objectives:

- Summarise the current state of volcanic reconstructions, associated climate forcing and societal impacts.
- Integrate new ice-core reconstructions of volcanic activity and radiative forcing, covering the past 60,000 years, into assessments of natural climate variability and volcanic risk.
- Expand the themes of VICS drawing on evidence from archaeology, palynology and textural sources.
- Introduce new results from CMIP6 and PMIP4 model simulations related to volcanic eruptions and climate impact.
- Development of strategies to engage stakeholders and the general public concerning volcanic hazards.

Keynote Speakers

Eliza Cook (University of Copenhagen, Denmark)

Sebastian Guillet (University of Geneva, Switzerland)

Helen Innes (University of St Andrews, UK)

Lara Mani (University of Cambridge, UK)

Lauren Marshall (University of Durham, UK)

Lee Mordechai (The Hebrew University of Jerusalem, Israel)

Ingar Mørkestøl Gundersen (University of Oslo, Norway)

Mukhamad Nagainul Malawani (Universitas Gadjah Mada, Indonesia)

Alice Paine (University of Oxford, UK)

Charlotte Pearson (University of Arizona, USA)

Christian von Savigny (University of Greifswald, Germany)

Thomas Sheldrake (University of Geneva, Switzerland)

Sönke Stern (University of Auckland, New Zealand)

Organisers

Michael Sigl (Past Volcanism and Climate Impact, Climate and Environmental Physics)

Peter Abbott (Past Volcanism and Climate Impact, Climate and Environmental Physics)

PAGES VICS Steering Committee

Kevin Anchukaitis (University of Arizona, USA)
Allegra LeGrande (NASA Goddard Institute for Space Studies, USA)
Francis Ludlow (Department of History, Trinity College Dublin, Ireland)
Matthew Toohey (University of Saskatchewan, Canada)
Michael Sigl (University of Bern, Switzerland)
Céline Vidal (Department of Geography, University of Cambridge, UK)

Local (OCCR and University of Bern) advisors

Stefan Brönnimann (Climatology)
Jörg Franke (Climatology)
Hubertus Fischer (Past Climate and Biogeochemical Studies on Ice Cores)
Albert Hafner (Prehistoric Archaeology)
Heli Huhtamaa (Climate and Society)
Christoph Raible (Earth System Modelling – Atmospheric Dynamics)
Felix Riede (Prehistoric Archaeology, Aarhus University, sabbatical in Bern early 2023)
Heinz Wanner (Climatology)

Practical Information

In Person Talks

For those presenting talks they will be uploaded to a central Windows computer so please bring the slides on a USB stick at the start of the day or the break prior to your talk. Please check for any compatibility issues and let us know in advance of potential issues.

Virtual Talks

For those presenting virtually please have your slides ready for screen sharing. If possible please email a copy of your talk to Peter Abbott (peter.abbott@unibe.ch) so they are available in case of technical issues. It is possible to use a pre-recorded talk if you feel more comfortable, but we would appreciate it if you were available online for questions.

Posters

Posters can be put up during the coffee break in advance of the session and should be taken down at the end of the session.

Virtual Participation

The conference will use the zoom online platform to deliver the virtual component. A link will be sent to all participants via email prior to the workshop. If you experience any technical issues with the platform during the workshop please email Peter Abbott (peter.abbott@unibe.ch).

Inclusivity

PAGES does not tolerate any sort of discrimination or harassment at workshops, and is committed to an open and welcoming environment for all.

If you feel uncomfortable during the workshop for any reason, you can contact the following people:

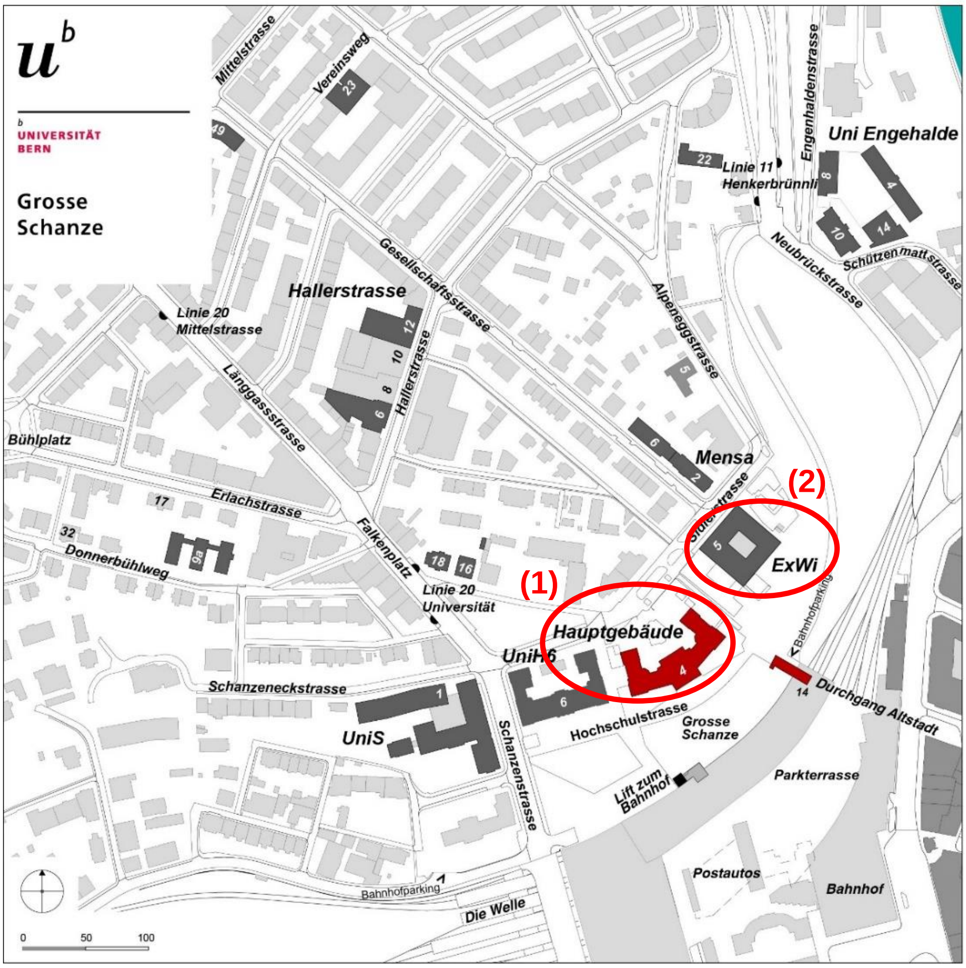
- Michael Sigl: michael.sigl@unibe.ch
- Heli Huhtamaa: heli.huhtamaa@unibe.ch

Workshop Location

The VICS 5th workshop will be hosted at the University of Bern conveniently located above the main train station. The closest public transport stop is Bern, Universität where the number 20 bus from the city centre stops. It is also an ~10 minute walk from the city centre. There is a lift from inside the station up to the Grosse Schanze area in front of the Main Building or you can walk over the station to the north.

The main venue for the oral sessions will be the Kuppelraum on the 5th floor of the Main Building (1) of the University of Bern (Hochschulstrasse 4).

Posters sessions will be held in the Wandelhalle on the ground floor of the Exakte Wissenschaften building (2) next to the Main Building.



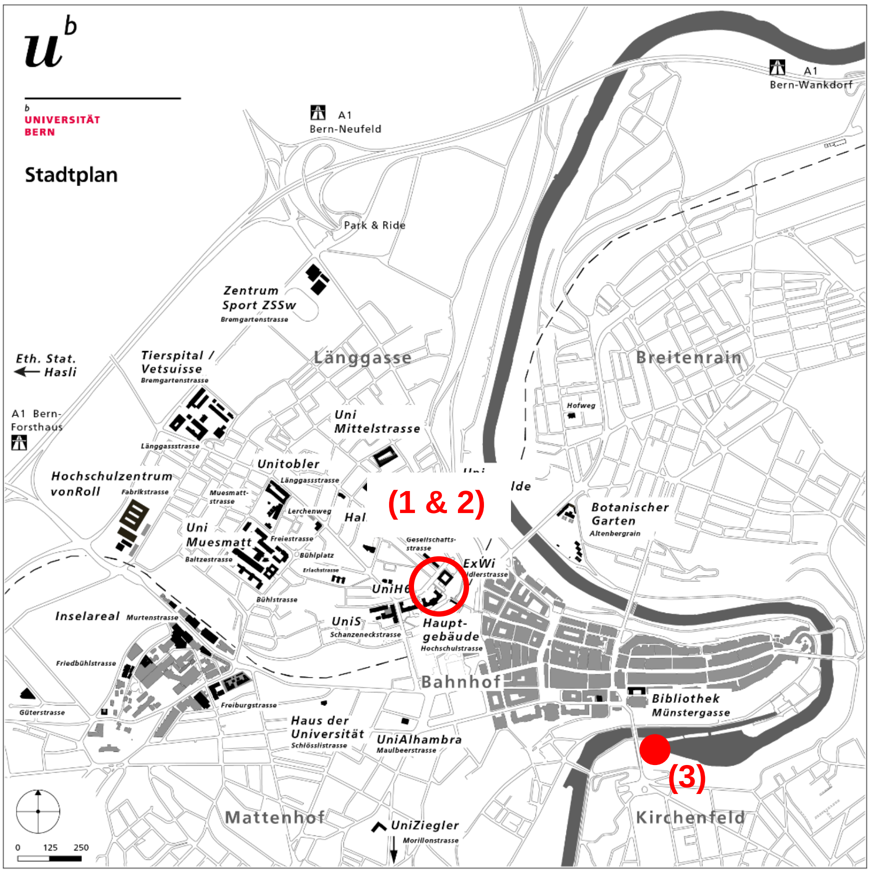
(1) Main building

(2) Exakte Wissenschaften

Conference Dinner

The conference dinner will be held in the event room at the Schwellenmätteli Restaurant (3). The dinner will start with an apero at 18:30 followed by a three-course meal at 19:30.

Directions: The restaurant is an ~25 minute walk from the conference location (1 and 2). The walking route goes around or through the main train station to Christoffelgasse, past the Kleine Schanze and drops down to the river by the Marzilibahn. You then cross the river via the Dalmazibrücke and head east along the south side of the river to the restaurant. You can ride down the Marzilibahn using the Bern Ticket that is provided by most hotels or a single ride is CHF 1.50. Certainly something to consider for the trip back into the city after the meal! Alternatively, the closest tram stop is at Bern, Helvetiaplatz, a 4 minute ride on Tram 7 or 8 from Bern Bahnhof. The restaurant is then a 6 minute walk downhill starting along Englische Anlagen.



(3) Schwellenmätteli event room

PAGES Volcanic Impacts on Climate and Society (VICS) 5th Workshop - Programme Overview

Time Slot	Monday 22nd May 2023	Time Slot	Tuesday 23rd May 2023	Time Slot	Wednesday 24th May 2023
08:30-09:00	REGISTRATION				
09:00-09:15	WELCOME	09:00-09:15	Mukhamad Ngainul Malawani	09:00-09:15	Eliza Cook
09:15-09:30		09:15-09:30	Mike Cassidy	09:15-09:30	Andrea Burke
09:30-09:45	Sébastien Guillet	09:30-09:45	Laura Sobral Verona	09:30-09:45	Laurits Andreasen
09:45-10:00	Ingar Mørkestøl Gundersen	09:45-10:00	Jesper Björklund	09:45-10:00	Claudia Timmreck
10:00-10:15	Sönke Stern	10:00-10:15	Francis Ludlow	10:00-10:15	Helen Innes
10:15-11:00	COFFEE	10:15-11:00	COFFEE	10:15-11:00	COFFEE
11:00-11:10	Christopher Ballard	11:00-11:15	Lee Mordechai	11:00-11:15	Alice Paine
11:10-11:20	Heather Handley	11:15-11:30	Kjetil Loftsgarden	11:15-11:30	Kurt Nicolussi
11:20-11:30	Selga Meta Medenieks	11:30-11:45	Imogen Gabriel	11:30-11:45	Nicolas Maughan
11:30-11:40	Wesley R. Farnsworth	11:45-12:00	Herman Fuglestvedt	11:45-12:00	Rhonda McGovern
11:40-11:50	Hera Guðlaugsdóttir	12:00-12:15	Tom Sheldrake	12:00-12:15	Charlotte Pearson
11:50-12:00	Rob Wilson				
12:00-12:10	Irene Manzella	12:15-12:30	GROUP PHOTO		
12:30-13:45	LUNCH	12:30-13:45	LUNCH	12:30-13:45	LUNCH
13:45-14:00	Will Hutchison	13:45-14:00	Lauren Marshall	13:45-14:00	Christian von Savigny
14:00-14:15	Shih-Wei Fang	14:00-14:10	Igor Collins Djouda	14:00-14:15	Margot Clyne
14:15-14:30	Jörg Franke	14:10-14:20	Alistair Seddon	14:15-14:30	Heli Huhtamaa
14:30-14:45	Richard Michael Warren	14:20-14:30	Ilaria Quaglia	14:30-14:45	Lara Mani
		14:30-14:40	Andrea Kiss		
14:45-15:30	COFFEE	14:45-15:30	COFFEE	14:45-15:30	COFFEE
15:30-17:30	POSTER SESSION 1	15:30-17:30	POSTER SESSION 2	15:30-17:00	GENERAL DISCUSSION
EVENING			CONFERENCE DINNER		
Key:	IN PERSON TALKS		VIRTUAL TALKS		KEYNOTE SPEAKERS

Workshop Programme

Monday 22nd May

08:30-09:00		**Registration**
09:00-09:30		**Welcome** **Michael Sigl** – VICS Steering Committee and Workshop Organiser **Marie-France Loutre** – PAGES Executive Director **Martin Grosjean** – OCCR Director and PAGES Co-Chair **Peter Abbott** – Workshop Organiser
		Oral Session 1 (Chair: Michael Sigl)
09:30-09:45	**Sébastien Guillet (University of Geneva)**	The Dark Side of the Moon: Dating Medieval Volcanic Eruptions Using Astronomical Records (KEYNOTE TALK)
09:45-10:00	**Ingar Mørkestøl Gundersen (University of Oslo)**	Bridging the gap. Disasters and social impact from an archaeological perspective (KEYNOTE TALK)
10:00-10:15	**Sönke Stern (University of Auckland)**	The Kuwae story: evidence at source from geology, geochemistry, and bathymetry (KEYNOTE TALK)
10:15-11:00		**Coffee Break**
		Virtual Oral Session 1 (Chair: Francis Ludlow)
11:00-11:10	**Christopher Ballard (Australian National University)**	Volcanic Traditions: using oral sources in the reconstruction of historical eruptions; the case of the 15th century eruption of Kuwae
11:10-11:20	**Heather Handley (University of Twente, Monash University)**	Past Impacts and Future Risk of Volcanic Hazards to Australia: Evidence from Archaeological, Volcanological, Historical and Indigenous Knowledge
11:20-11:30	**Selga Meta Medenieks (Trinity College Dublin)**	Climate forcing and the ancient Egyptian 'Famine Stela'
11:30-11:40	**Wesley R. Farnsworth (University of Copenhagen, University of Iceland)**	Tephra constrains natural and anthropogenic changes in postglacial Iceland sediments
11:40-11:50	**Hera Guðlaugsdóttir (University of Iceland)**	The modelled response after high latitude volcanic eruptions: Assessing the importance of eruption length
11:50-12:00	**Rob Wilson (University of St Andrews)**	Significant volcanic cooling expressed in a summer temperature reconstruction from Northern Patagonia, Argentina
12:00-12:10	**Irene Manzella (University of Twente)**	The Centre for Disaster Resilience (CDR) for volcanic risk reduction
12:30-13:45		**Lunch Break**
		Oral Session 2 (Chair: Clive Oppenheimer)
13:45-14:00	**Will Hutchison (University of St Andrews)**	Re-evaluating the source, style and impacts of the 1800–1835 eruption cluster with new ice core isotope and cryptotephra analyses

14:00-14:15	**Shih-Wei Fang (Max Planck Institute for Meteorology)**	The Contributions of Volcanic Eruptions and Solar Irradiance to the Early 19th Century Cold Climate
14:15-14:30	**Jörg Franke (University of Bern)**	Weather and climate anomalies following the Laki eruption 1783 – insights from early instrumental data, a daily European weather reconstruction and a monthly global reanalysis
14:30-14:45	**Richard Michael Warren (University of Bern)**	From Fire to Famine? The climate and human impacts of the 1831 and 1835 volcanic eruptions in India
14:45-15:30		**Coffee Break**
15:30-17:30		**Poster Session 1**
	Vitor Azevedo (Trinity College Dublin)	Magmatic evolution and Eruption frequency of Campi Flegrei and Ischia over the last 133,000 years based on the varve record of Lago Grande di Monticchio, Italy
	Zhihong Zhuo (University of Oslo)	Simulating a series of Icelandic volcanic eruptions with volatile emissions lasting over a decade as a natural analog to solar radiation modification in the Arctic
	Evelien van Dijk (University of Oslo)	A Tale of Fire and Ice: How clusters of large volcanic eruptions shaped climate and society of the mid to late-Holocene
	Tómas Zoëga (University of Oslo)	Can high latitude effusive volcanic eruptions cause surface winter warming in the Arctic?
	Peter Michael Abbott (University of Bern)	Mid to Late Holocene East Antarctic ice-core tephrochronology: Implications for reconstructing volcanic eruptions and their impacts over the last 5,500 years
	Celeste Juliana Smith (University of St Andrews)	Determining the volcanic sources of the double 1600 CE sulfate peaks in Greenland ice-cores
	Stefan Grab (University of the Witwatersrand)	The Laki 1783 eruption revisited: likely ocean-mediated responses and mechanisms accounting for anomalous post-eruption weather over the SW Cape of South Africa
	Anna de Bode (University of Bergen)	Reconstructing late-Holocene glacier and climate fluctuations in northern Norway using high-resolution climate proxies and cryptotephra from various lake sediment records
	Andrew Ronald Friedman (University of Bern)	Tropical Atlantic hydroclimate impacts of major early-20th century volcanic eruptions
	Christina Victoria Brodowsky (ETH Zürich)	Modeling uncertainties of the sulfate aerosol evolution during the post-Pinatubo period
	Matthew Toohey (University of Saskatchewan)	Progress toward Easy Volcanic Aerosol version 2
	Szabolcs Harangi (Eötvös Loránd University)	Impact of the 1815 Tambora eruption to the Carpathian basin area as shown by contemporary meteorological and historical data as well as dendrochronological results
	Conor Kostick (Trinity College Dublin)	The Babylonian Crisis of 424 BCE Explained

Tuesday 23rd May

Oral Session 3 (Chair: Céline Vidal)

09:00-09:15	**Mukhamad Ngainul Malawani (Universitas Gadjah Mada)**	Reconstruction of the regional and local impacts of the 1257 CE Samalas eruption from indigenous written sources (KEYNOTE TALK)
09:15-09:30	**Mike Cassidy (University of Birmingham)**	Preliminary modelling of the global agricultural impacts following a volcanic winter

09:30-09:45	**Laura Sobral Verona (University of São Paulo, Sorbonne University)**	Atlantic Niño changes after large Last Millennium volcanic eruptions
09:45-10:00	**Jesper Björklund (Swiss Federal Research Institute WSL, University of Bern)**	Volcanic cooling reconstructed from wood anatomical tree-ring proxies over the Common Era
10:00-10:15	**Francis Ludlow (Trinity College Dublin)**	Tropical Explosive Volcanism Drives North Sea Bumper Herring Catches, 1600-1860 CE
10:15-11:00		**Coffee Break**
		Oral Session 4 (Chair: Heli Huhtamaa)
11:00-11:15	**Lee Mordechai (The Hebrew University of Jerusalem)**	The Worst Year to Be Alive? Constructing the 536 CE event (KEYNOTE TALK)
11:15-11:30	**Kjetil Loftsgarden (University of Oslo)**	Uncovering the largest demographic shock in Iron Age Scandinavia
11:30-11:45	**Imogen Gabriel (University of Bern)**	The Icelandic Active Period of 750-950 CE : insights from the Greenland ice cores
11:45-12:00	**Herman Fuglestvedt (University of Oslo)**	Reconstructing the volcanic impacts of the Icelandic Eldgjá eruption in 937-940 CE
12:00-12:15	**Tom Sheldrake (University of Geneva)**	Understanding variations in the rate and magnitude of volcanic eruptions beyond the Common Era (KEYNOTE TALK)
12:15-12:30		**Group Photo**
12:30-13:45		**Lunch Break**
		Virtual Oral Session 2 (Chair: Matthew Toohey)
13:45-14:00	**Lauren Marshall (Durham University)**	Reconstructing the radiative forcing of volcanic eruptions from ice cores: importance of eruption source parameters (KEYNOTE TALK)
14:00-14:10	**Igor Collins Djouda (The University of Yaoundé)**	Modelling the evolution of the volcanic plume height as a function of the eruption time and the seasonal climate
14:10-14:20	**Alistair Seddon (University of Bergen)**	Estimates of past UV-B radiation using pollen biomarkers
14:20-14:30	**Ilaria Quaglia (Cornell University)**	Interactive stratospheric aerosol models' response to different amounts and altitudes of SO2 injection during the 1991 Pinatubo eruption
14:30-14:40	**Andrea Kiss (TuWien)**	Comparing Laki to Tambora: Weather, floods and famine in the Middle-Danube region in 1780s-1810s, in a (Central) European context
14:45-15:30		**Coffee Break**
15:30-17:30		**Poster Session 2**
	Michael Sigl (University of Bern)	Eruptions that Shook the World – Ice-Core Edition
	Khadijeh Alinezhad (Kiel University)	Tracing the Social and Environmental Dimensions of Volcanic-induced Climate Change in the 1st Millennium AD
	Kirstin Krüger (University of Oslo)	Volcanic Eruptions and their Impacts on Climate and Society in 500-1250 CE

	Man Mei Chim (University of Cambridge)	Climate projections underestimate future volcanic forcing and its climatic impacts
	Florian Brouillet (University of St Andrews)	Reassessing the timing and climate impact of the 1783 Laki eruption: new insights from high time resolution ice core analysis
	Ulrike Niemeier (Max Planck Institute for Meteorology)	Simulation of ash clouds after a Laacher See-type eruption
	Peter Stucki (University of Bern)	Dynamical downscaling and regional data assimilation for a cold-air outbreak in the European Alps during the Year Without Summer 1816
	Patrick Fonti (Swiss Federal Research Institute WSL, University of Bern)	The contribution of wood cell anatomy for reconstructing past climate
	Niklaus Emanuel Bartlome (Universität Bern)	Wine, vacherin and volcanoes: impacts of the 17th century large volcanic eruptions
	Ciara Greaves (University of Cambridge)	Remarkably high blue ring occurrence in Estonian Scots pines in 1976 reveals wood anatomical evidence of extreme autumnal cooling
	Stefan Brönnimann (University of Bern)	The volcanic summers of 1690s in daily weather records from Europe
	Stergios Misios (National Observatory of Athens)	Etesian winds after large volcanic eruptions in the last millennium
	Andrés Antico (National University of the Littoral)	Climatic conditions in Santa Fe city, Argentina, after the 1815 Tambora eruption: Insights from a personal diary

Wednesday 24th May

Oral Session 5 (Chair: Gill Plunkett)

09:00-09:15	**Eliza Cook (University of Copenhagen)**	An updated Holocene tephrochronological framework for Greenland, based on investigations of NGRIP, EGRIP and RECAP ice cores (KEYNOTE TALK)
09:15-09:30	**Andrea Burke (University of St Andrews)**	High resolution sulfur isotopes from ice cores: improved estimates of the volcanic forcing of climate
09:30-09:45	**Laurits Andreasen (Aarhus University)**	Increase in storm frequency in Greenland after volcanic eruptions and its societal impacts
09:45-10:00	**Claudia Timmreck (Max-Planck-Institut für Meteorologie)**	When does the volcanic signal on surface climate emerge from internal variability?
10:00-10:15	**Helen Innes (University of St Andrews)**	Timing and climatic impact of the Los Chocoyos supereruption, using high-resolution analysis of sulfur isotopes and cryptotephra in ice cores (KEYNOTE TALK)
10:15-11:00		**Coffee Break**

Oral Session 6 (Chair: Felix Reide)

11:00-11:15	**Alice Paine (University of Oxford)**	Volcanism, climate, and environmental change during the Late Pleistocene (KEYNOTE TALK)

11:15-11:30	**Kurt Nicolussi (Universität Innsbruck)**	Seasonality of large volcanic events – evidence from mid-latitude tree-ring parameters
11:30-11:45	**Nicolas Maughan (Aix-Marseille University)**	Similar Long-Lasting Environmental Effects of the Laki Eruption Across Late 18th century Europe? Comparing Mediterranean France to Italy and Middle-Danube Region
11:45-12:00	**Rhonda McGovern (Trinity Centre for Environmental Humanities)**	Volcanic signatures in Ancient Babylonian texts?
12:00-12:15	**Charlotte Pearson (University of Arizona)**	Re-thinking Thera: Chronological advances through a high-resolution, multi-proxy approach (KEYNOTE TALK)
12:30-13:45		**Lunch Break**
		Oral Session 7 (Chair: Kirstin Krüger)
13:45-14:00	**Christian von Savigny (University of Greifswald)**	Overview of the joint research project VolImpact (KEYNOTE TALK)
14:00-14:15	**Margot Clyne (University of Colorado Boulder)**	The Hunga Tonga-Hunga Ha’apai Volcano Model Intercomparison Project (Tonga-MIP)
14:15-14:30	**Heli Huhtamaa (University of Bern)**	Coincidence or causality? Microhistorical perspective on volcanism-climate-society dynamics
14:30-14:45	**Lara Mani (University of Cambridge)**	Volcanic eruptions as global catastrophic risks (KEYNOTE TALK)
14:45-15:30		**Coffee Break**
15:30-17:00		**Discussion on the Future of VICS**

Abstracts for talks in presentation order

On site keynote talk (Monday 09:30-09:45)

The Dark Side of the Moon: Dating Medieval Volcanic Eruptions Using Astronomical Records

Sébastien Guillet[1], Christophe Corona[2], Clive Oppenheimer[3], Franck Lavigne[4], Myriam Khodri[5], Francis Ludlow[6], Michael Sigl[7], Matthew Toohey[8], Paul Atkins[9], Zhen Yang[6], Tomoko Muranaka[1], Nobuko Horikawa[9], Markus Stoffel[1]

[1]Institute for Environmental Sciences, University of Geneva, Switzerland; [2]Geolab, Université Clermont Auvergne, CNRS, France; [3]Department of Geography, University of Cambridge, United Kingdom; [4]Laboratoire de Géographie Physique, Université Paris 1 Panthéon-Sorbonne, France; [5]Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques/IPSL, Sorbonne Université/IRD/CNRS/MNHN, Paris, France; [6]Trinity Centre for Environmental Humanities, Department of History, School of Histories & Humanities, Trinity College, Dublin, Ireland; [7]Climate and Environmental Physics and Oeschger Centre for Climate Change Research, University of Bern, Switzerland; [8]Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Canada; [9]Department of Asian Languages & Literature, University of Washington, Seattle, USA

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Improving the chronology of past volcanism is crucial for understanding the impacts of large volcanic eruptions on the Earth's climate system and human societies. Despite recent advancements in refining the dating of volcanic signals in ice cores, uncertainties still exist, particularly for six major eruptions in the 12th and 13th centuries. To better constrain the timing of these eruptions, independent dating methods ca be helpful.

The brightness of the moon during an eclipse is extremely sensitive to the amount of aerosols in the stratosphere and lunar eclipses are now regarded as a reliable alternative proxy to detect and date the presence of volcanic aerosols in the upper atmosphere.

Drawing on historical reports of total lunar eclipses brightness – retrieved from European. Middle Eastern and East-Asian historical sources – aerosol model simulations and tree-ring-based climate proxies, we present a methodology allowing to refine the dating of the 12 and 13th century eruptions to sub-annual resolution.

In this keynote, we will discuss the potential, limitations, and challenges of using this method for dating volcanic events, and highlight its significance in advancing our understanding of past volcanic eruptions.

On site keynote talk (Monday 09:45-10:00)

Bridging the gap. Disasters and social impact from an archaeological perspective

Ingar Mørkestøl Gundersen

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During the last decades, there has been a steady increase in geoscientific, archaeological and cross-disciplinary studies focusing on the role of environmental events for social change in prehistory. The development has been made possible by an ever-growing body of high-resolution geoscientific proxies, new opportunities in scientific analysis, and important innovations in computer modelling and big-data management. In archaeology, the development represent a wide-open window of new opportunities for understanding the rate and character of social change in the past. However, the return to environmental and positivistic perspectives has also been criticised for lacking in coherent analytical frameworks able to substantiate claims of deep social impact from environmental events. Admittedly, archaeological records are often plagued by poor spatiotemporal resolutions, which make any direct comparison with geoscientific datasets and environmental events challenging. Furthermore, there is a certain tendency to oversimplify the social processes of the past, and putting too much confidence in singular events, such as climate change, when explaining incidents of societal collapse. A lack of analytical frameworks involves a certain risk for biased and reductionist conclusions, through which modern environmental concerns and lessons inform our understanding of the past rather than the other way around.

However, this is only one part of the picture. In a parallel process, much effort is put into developing new theoretical and methodological perspectives aiming to progress our understanding of the human-environmental dynamics of the past. Important for this development are analytical concepts such vulnerability, resilience, and adaptation. In this talk, I will discuss how vulnerability and a root cause analysis can help us to progress our understanding of environmental change and social change in the past, and bridge between concurrency and causation. However, can analytical refinement alone solve all our problems? A few apparent limitations soon emerge when the method is applied to a fragmented past.

On site keynote talk (Monday 10:00-10:15)

The Kuwae story: evidence at source from geology, geochemistry, and bathymetry

Sönke Stern[1], Shane Cronin[1], Stuart Bedford[2,3], Chris Ballard[2], Robert Henderson[2], Salkon Yona[4], Edson Willie[4], Junior John Niroa[5]

[1]University of Auckland, Auckland, New Zealand; [2]Australian National University, Canberra, Australia; [3]Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany; [4]Vanuatu Cultural Centre, Port Vila, Vanuatu; [5]Vanuatu Meterology and Geo-Hazards Department, Port Vila, Vanuatu
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A large volcanic eruption happened in 1458 CE, causing global climate effects. This eruption represents one of the three largest sulphur-emitting volcanic eruptions of the last 1000 years. Its source remains highly debated to this day, but the submarine caldera volcano of Kuwae, Vanuatu, has been suggested as source volcano since the early 1990s.

Locally, Kuwae is well known as the source of a major even that occurred at some point in the 15th century. Yet, adequate geological studies of the area are still lacking. In order to test the link between Kuwae and the global climate-affecting event, we present physical and chemical characteristics of proximal deposits (incl. estimating emitted sulphur volumes) and results of a recent bathymetric study of the caldera (revealing its structure and potential eruptive volume). We will also use radiocarbon analysis to gain a more precise eruptive date for the 15th century eruption of the Kuwae caldera.

Our work at Kuwae aims to either establish or rule it out as a candidate source for the 1458 CE eruption. Either way, however, the Kuwae caldera experienced a locally catastrophic eruption in the 15th century, and one that still poses a threat today. Our work will not only characterise its past activity, but also help identify potential future hazards – locally, regionally and globally.

Virtual talk (Monday 11:00-11:10)

Volcanic Traditions: using oral sources in the reconstruction of historical eruptions; the case of the 15th century eruption of Kuwae

Christopher Ballard[1], Sandrine Bessis[2], Stuart Bedford[1,3], Shane Cronin[4], Sonke Stern[4]

[1]Australian National University, Australia; [2]Sorbonne nouvelle / Paris III; [3]Max Planck Institute; [4]University of Auckland
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Geomythologists have promoted the value of oral traditions in identifying and reconstructing cataclysmic events such as volcanic eruptions. Claims have been made that oral traditions faithfully describe volcanic events as many as 5,000 years before the present. But sceptical historians have pointed out that the methodologies underpinning these claims are rarely explicit and their findings are seldom verifiable. A recent global review of oral traditions about volcanic eruptions has identified a number of critical conditions that need to be met before oral sources can be incorporated feasibly within the reconstructions modelled by other disciplines. These conditions include in-depth attention to local historical and narrative conventions and to contemporary political interests, and close collaboration with other disciplines including volcanology and archaeology. Oral traditions are inevitably poor as a source of absolute chronologies, but they can provide surprisingly detailed accounts of the impact of events on local societies and environments, and accurate seriation of events in relative sequence, even where local theories of causality differ markedly from those of modern science. Drawing on long-term archival and recent trans-disciplinary field research on the 15th century CE Tombuk eruption of the Kuwae volcano in Vanuatu, this paper explores the rich potential as well as the viable limits for a contribution by oral traditions to our understanding of this major event.

Virtual talk (Monday 11:10-11:20)

Past Impacts and Future Risk of Volcanic Hazards to Australia: Evidence from Archaeological, Volcanological, Historical and Indigenous Knowledge

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Australia and the Australian people are at risk from volcanic hazards from future eruptions of domestic and international volcanoes, but our understanding of the characteristics, extent and magnitude of the risk has until now been very poor. This limits our ability to accurately forecast future eruptive activity and impacts, potentially leading to delayed, costly and/or ill-informed decision-making, with associated consequences. In this study we improved our understanding of the wide range of direct and indirect impacts to Australia from volcanic hazards and identified possible future risks by considering information from volcanological and geological studies, archaeology, archival media, government organisations, monitoring authorities and traditional sources of knowledge of volcanic eruptions. Australia has been directly impacted by volcanic ash from historic eruptions in countries such as Chile, Indonesia, The Kingdom of Tonga, Papua New Guinea and New Zealand (Kermadec Islands), with volcano-triggered tsunami and pumice rafts previously washing ashore and presenting a range of social, economic and environmental risks. Significant numbers of Australian nationals have encountered volcanic risk when overseas. The 2019 Whakaari/White Island eruption led to the tragic deaths of 17 Australian tourists. Less well known and appreciated are the risks posed to Australia from active volcanic regions in mainland Australia. Based on the known ages of eruptions, there are at least two volcanic provinces in the southeast and northeast Australian mainland still considered active and that could see a future eruption. The presence of mantle rock fragments (xenoliths) carried by the magma erupted in both regions alongside oral records of volcanism witnessed by Indigenous peoples suggest that warning times prior to an eruption may be short with little precursory activity. This improved knowledge now needs to be translated into proactive emergency management and preparedness so that Australia can respond to volcanic risks from a future eruption at home or abroad.

Virtual talk (Monday 11:20-11:30)

Climate forcing and the ancient Egyptian 'Famine Stela'

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The inscription of the so-called 'Famine Stela', carved into rock on Sehel Island in Egypt, describes a seven-year period when the annual Nile River flood was insufficient to fertilise its banks, consequently afflicting the population with a catastrophic famine. The text is usually attributed to the reign of Ptolemy V Epiphanes (r. 205-180 BCE); however, an alternative possibility is that the stela dates to his successor Ptolemy VI Philometor (r. 180-145 BCE) and that its contents should be considered in the light of an entirely different set of circumstances. Recent refinements to the dating of volcanic eruptions in antiquity and new research on their climate forcing effects identifies an extended period of environmental instability in Egypt in the 160s BCE. It is argued that the circumstances of this decade, in which a trio of significant volcanic events precipitated low temperatures, rainfall anomalies, and repeated crop failures, catalysed a prolonged food crisis – and that this time provides a more likely context than earlier periods for the concerns of the authors of the Famine Stela. That text may now be reassessed as a response to the famine that afflicted the First Cataract of the Nile in the mid-second century BCE.

Virtual talk (Monday 11:30-11:40)

Tephra constrains natural and anthropogenic changes in postglacial Iceland sediments

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Iceland is an ideal setting to investigate naturally occurring shifts in climate and environment due to; *i*) its sensitive climatic location in the middle of the North Atlantic, *ii*) the geochronological (and correlative) potential of tephra visible in various sedimentary archives and *iii*) the lack of human influence until the documented settlement *c.* 871 AD. As Iceland was uninhabited during the majority of the Holocene, the island is a model location to study natural climatic variation and its impact on the landscape as well as to disentangle the complex effects humans and land-use have on the Earth-system following settlement. While studies have investigated Iceland's climatic and environmental history through the last 10 ka BP, key knowledge gaps remain, particularly during the transition from Late Glacial to Early Holocene (14–10 ka BP). Iceland's coastal areas became ice free *c.* 14.5 ka BP however, as of yet only few sedimentary records extend back beyond *c.* 10 ka BP.

Here we introduce a new project within *Queen Margrethe's and Vigdís Finnbogadottir's Interdisciplinary Research Centre on Ocean, Climate and Society* (ROCS). The aims of this project are twofold: *i*) to better understand the glacial and volcanic history of Iceland following its dynamic deglaciation during the Late Glacial –Early Holocene and *ii*) investigate the impact of explosive volcanism, humans and land-use on the pristine natural environment. This investigation is based on a strategic network of tephrochronologically constrained lake records from around Iceland which span the Late Glacial and Holocene. While these lake records are high resolution multiproxy recorders of natural and anthropogenic shifts through the last 14 ka BP, the application of environmental DNA on the sediment sequences allows for an unprecedented understanding of species migration, vegetation establishment / resilience, as well as human impact and land-use.

Virtual talk (Monday 11:40-11:50)

The modelled response after high latitude volcanic eruptions: Assessing the importance of eruption length

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Iceland has many different volcanic systems that are preparing for an eruption in the nearest future. Effusive eruptions are quite common (and well known) in parts of these volcanic systems, where such eruptions can last from months and up to several years (e.g. Eldgjá 940, Laki 1783, Holuhraun 2014). It is therefore of great importance to assess the importance of an eruption length within the climate system following such eruptions. Here I will address the potential importance of the length of an eruption by presenting results from perturbation experiments in an Earth System Model (CESM1.2.2). The main focus will be on experiments simulating idealized, 6 month-long, eruption at 65°N.

Virtual talk (Monday 11:50-12:00)

Significant volcanic cooling expressed in a summer temperature reconstruction from Northern Patagonia, Argentina

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No traditional tree-ring (TR) density-based reconstruction of past summer temperatures exists for the Southern Hemisphere. It is therefore no surprise that current published ring-width (RW) based temperature reconstructions provide ambiguous evidence for past volcanic forcing in the Southern Hemisphere. In this study we present a new January-March summer temperature reconstruction (1381-2016) for Northern Patagonia based on RW and Blue Intensity (BI) parameters measured from Araucaria Araucana trees from 6 locations across the middle to southern end of the species' range. The multi-TR-Parameter reconstruction explains 53% of the summer temperature variance (1902-2016) which is on par with similar TR based reconstructions from the Northern Hemisphere. The reconstruction coheres strongly with surface mean air temperatures for a large region in South America from 48-37S / 75-65W including sea surface temperatures well into the eastern Pacific for these latitudes. The warmest 11-year period is 2006-2016 while the coldest period is 1454-1464. The coldest reconstructed year is 1459. Superposed Epoch Analysis focussing on significant tropical eruptions since the 1400s indicates a significant mean cooling of ca. 0.5-0.6 degrees Celsius, depending on which volcanic events are used. The degree of relative cooling is on par with the cooling represented by individual TR records used in the Northern Hemisphere N-TREND reconstruction suggesting that the volcanic response in northern Patagonia over the last 6 centuries is equivalent, or even more extreme, to what is observed in many Northern Hemisphere locations.

Virtual talk (Monday 12:00-12:10)

The Centre for Disaster Resilience (CDR) for volcanic risk reduction

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Our growing population and our deeply interconnected society is increasingly affected by the occurrence and impacts of complex disasters, calling for more effective approaches to build resilience. This is particularly true for volcanic hazards that can have immediate and long term effects at the local and global scales. This requires innovative and effective tools to monitor disasters, assess damages, manage and mitigate multiple and dynamic risks with community based approaches and participatory co-production and implementation.

The Centre for Disaster Resilience (https://www.itc.nl/cdr) of the University of Twente, aims at reaching a tangible impact by developing tools and approaches that embody geo-information technologies. This is achieved through synergetic collaborations with groups and institutions working on disaster resilience nationally and internationally, in academia, policy and practice. By following open science principles, the products of our work is open and accessible for communities, scientists and practitioners. Examples of such outputs include real-time monitoring systems for natural, complex and cascading hazards using spaceborne and airborne observations, 4D modelling of multi hazard processes and risk, collaborative decision support systems for risk reduction. Thanks to recent expertise brought in by new colleagues and to our international network, we are aiming to apply those tools in volcanic settings where multiple and complex hazards are particularly present.

In addition, because of the intrinsic interdisciplinarity of disaster management and resilience, the development of new communication strategies and the implementation of a collaborative and transdisciplinary approach is at the core of our Centre and we work to fuse academic cultures in geoscience, engineering, data science, social science, health, humanities, media and the creative arts while engaging with non-scientific stakeholder communities.

Ultimately, together with our partners we develop, support and implement strategies and activities with the overarching aim of increasing the well-being of communities worldwide, enhancing sustainability and resilience by significantly decreasing disaster risk.

On site talk (Monday 13:45-14:00)

Re-evaluating the source, style and impacts of the 1800–1835 eruption cluster with new ice core isotope and cryptotephra analyses

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1800–1850 CE is the coldest period in the last 500 years and marks the final phase of the Little Ice Age. A cluster of major volcanic events took place at this time and include the 1815 eruption of Tambora, in Indonesia, the 1835 eruption of Cosigüina, in Nicaragua, and two unidentified eruptions in 1809 and 1831. Although these events are linked to global climate impacts, major uncertainties remain about the source of the unidentified eruptions, and whether all events were indeed represented by stratospheric sulfur emissions.

Polar ice cores provide exceptional archives of past volcanism. A key development is the analysis of sulfur isotopes in ice core sulfate which encodes detailed information about the eruption source and plume height which can be used to determine climate impact. Cryptotephra deposited alongside the sulfur peaks can also be extracted and analysed in conjunction and used to pinpoint the volcanic source of these emissions and their precise timing.

Here, we undertake a high time resolution isotopic and cryptotephra analysis of the 1800–1835 period in Antarctic and Greenlandic ice cores. Our initial results show clear sulfur isotope ($\Delta^{33}S$) anomalies for all volcanic events which indicate stratospheric S injections. For 1815, 1831 and 1835, $\Delta^{33}S$ shows a large time-evolving $\Delta^{33}S$ signal, consistent with a single low-latitude eruption and the known source volcanoes (i.e., Cosigüina and Tambora). For 1809, $\Delta^{33}S$ is muted and shows a more complex time-evolving pattern suggestive of multiple eruptions. Importantly, ice core cryptotephra extracted for 1809 corroborate this hypothesis and suggest distinct geochemical tephra populations around this time. Ultimately, this combination of high-time-resolution S isotopes and cryptotephra offer exciting new insights into the source and style of these major volcanic events, and the role of volcanism at the end of the Little Ice Age.

On site talk (Monday 14:00-14:15)

The Contributions of Volcanic Eruptions and Solar Irradiance to the Early 19th Century Cold Climate

Shih-Wei Fang[1], Johann Jungclaus[1], Kirstin Krüger[2], Hauke Schmidt[1], Michael Sigl[3,4], Matthew Toohey[5], Davide Zanchettin[6], Claudia Timmreck[1]

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Large volcanic eruptions, clusters of small-to-moderate eruptions, and reductions in solar radiation all exert a negative radiative forcing on Earth's climate with global cooling. The climatic response to solar and volcanic forcing is then also shaped by dynamical processes and mechanisms, including feedbacks triggered by the initial perturbation, which are especially relevant for regional scale responses. Whereas the individual climatic responses to these forcings have been evaluated in the scientific literature, the effects of their interplay has hardly been investigated. In this study, we focus on the early 19th century (1791-1830) when a cluster of small-to-moderate eruptions (six identified eruptions over 1812-1819), large tropical volcanic events (the 1809 unidentified eruption and the 1815 Tambora eruption) and a grand solar minimum (Dalton minimum from 1790-1830) coincide. We simulate the climate of this period using the Max Planck Institute Earth System Model (MPI-ESM1-2-LR). We find that the large eruptions are the dominant contributors to the early 19th century cooling, but small-to-moderate eruptions and solar irradiance help explaining the long-lasting cooling. The enhanced Arctic sea-ice extent further contributes to the persistence of northern extra-tropical temperature cold anomalies during the latter post-volcanic period, highlighting the influence of Arctic amplification. Regional surface responses can be significantly different when combining forcing agents even though the impacts of small-to-moderate eruptions and solar irradiance are relatively weak compared to the large eruptions.

On site talk (Monday 14:15-14:30)

Weather and climate anomalies following the Laki eruption 1783 – insights from early instrumental data, a daily European weather reconstruction and a monthly global reanalysis

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Possible climatic effects of high-latitude eruptions are still under discussion. Two new reconstructions, both based on newly digitized early instrumental data, now allow us to study the climate impacts of Laki fissureeruption of 1783 in detail. First, a daily temperature and pressure fields are generated with an analog resampling method. For each day in the historical period, the closest analog days in a present-day reference period are determined based on a set of historical observations across Europe. These best analog days are improved by assimilating the historical observations using an offline Kalman filter. Second, the global, monthly resolved, multivariate reanalysis ModE-RA combines our understanding of physics coming from an ensemble of atmospheric model simulations with all available direct and indirect climate observations. We assimilate up to ~100000 monthly to annual observations per year. These consist of multivariate instrumental measurements, historical data and annually resolved climate proxies.

With the daily weather reconstruction, we can study the synoptic conditions leading to the warm summer of 1783 and the following cold winters in more detail. The daily temperature fields, for example, allow us to reconstruct the development of the heatwave in July 1783 and relate it to blocking in the upper troposphere. ModE-RA can provide the longer-term perspective. October 1783 has the coldest temperature anomaly in the extratropical northern hemisphere average since the year 1420 C.E. The comparison of forced model simulations and two versions of ModE-RA - one which sees the aerosol forcing and one without – allow us to disentangle the role of internal climate variability from climatic consequences of the eruption as well as circulation changes related to the observed temperature anomalies. These data sets suggest that the colder winters are probably due to the eruption because simulations and forcing independent reconstructions show the same spatial temperature anomaly pattern.

On site talk (Monday 14:30-14:45)

From Fire to Famine? The climate and human impacts of the 1831 and 1835 volcanic eruptions in India

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1831 and 1835. Two massive eruptions send vast plumes of sulphur into the atmosphere, forming a layer of aerosols that reaches around the globe. In the following years, terrible famines visit vast tracts of India, leading to reported deaths of over a million people. Just a coincidence? Perhaps. Combining historical accounts with the latest ModE-RA climate reanalysis, we can attempt to identify the contribution of volcanic activity to the droughts and famines in India following these eruptions. This study first summarises the teleconnections between eruptions and the Indian monsoon, before attempting to reconstruct the climate impact of the 1831 and 1835 eruptions. It then charts the progress of the subsequent famines through the historical sources - how the populace and the authorities reacted and how this produced feedbacks that worsened an already dire climatological situation. The results demonstrate a strong physical basis for a link between the eruptions and Indian monsoon failure in 1832, 1833, 1836, 1837 and 1838. However, there is minimal supporting evidence in the climate reanalysis data. It seems that while the eruptions **may** have triggered monsoon failure, the El Niño Southern oscillation and other climate factors were also significant. As the rains failed, it was then the policies of the ruling East India Company that turned the repeated droughts into in a human disaster.

On site keynote talk (Tuesday 09:00-09:15)

Reconstruction of the regional and local impacts of the 1257 CE Samalas eruption from indigenous written sources

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Three indigenous written sources from Lombok (Babad Lombok, Babad Suwung, and Babad Sembalun) are among the few Indonesian texts that provide detailed descriptions of volcanic eruptions that were originally transmitted orally before being documented in writing. The sources depict the pre-, onset-, and post-eruption phases of a catastrophic volcanic eruption, the 1257 CE Samalas eruption. Several narrations on the *babad* from Lombok describe various responses of the residents to the eruption, such as fleeing to the hills, avoiding hazards, and migrating to neighboring villages and islands. A number of geographical features and toponyms are mentioned in *babad*, allowing us to reconstruct the evacuation process during the crisis. The sources also highlight post-eruptive recovery strategies, such as governance strategies, city and village reconstruction, and agriculture intensification. Despite the fact that many of the descriptions appear exaggerated, we believe that these manuscripts are accurate in specific details and can be used as a reliable source regarding the 1257 CE Samalas eruption. These reconstructions may help strengthen Lombok's and the larger community's preparedness and recovery strategies in the event of a volcanic eruption.

On site talk (Tuesday 09:15-09:30)

Preliminary modelling of the global agricultural impacts following a volcanic winter

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Potentially one of the most consequential impacts from large magnitude eruptions is their effect on the agricultural system through sulfate aerosol cooling. The association between volcanic winters and famines is well established in history, with the agricultural loss following the 1815 Tambora eruption estimated to be 75% in the UK alone. In this contribution, we ask how modern global agriculture might be impacted by a large magnitude eruption in the near future. This contribution will highlight the first of such studies to model agricultural impacts in this way, using climatic and agricultural modelling following a 110 Tg sulfur eruption (akin to Samalas sized eruption). Climate variables such as rainfall, surface temperature and radiative flux were obtained from a UKESM-VPLUME climate model were inputted into a dynamic vegetation model (LPJ-GUESS) over a 10 year period. LPJ-GUESS simulates the effect of atmospheric carbon dioxide, nitrogen fertilisation, and climate on the yield of several main crops like maize, wheat, rice and soybean. We will discuss the regional and global agricultural losses from such event and its potential implications for global food price hikes and famines. Only by quantifying the potential global impacts from large eruptions, can we hope to progress global policy change and investment for global warning and preparedness for large magnitude volcanic eruptions.

On site talk (Tuesday 09:30-09:45)

Atlantic Niño changes after large Last Millennium volcanic eruptions

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Volcanism is one of the main forcings driving the climate variability over the pre-industrial millennium (850 to 1849 CE). This period is vastly studied with respect to the responses to natural forcing, suitable to understand the relative contribution from the forced and internal natural variability. Large volcanic eruptions affect the global climate through changes in atmospheric and ocean circulation. Understanding their influence on the dynamics of the Atlantic Niño, one of the most important modes of variability in the Tropical Atlantic, is of great scientific and social importance considering the strong links between SST variability and the precipitation pattern of the surrounding continents (e.g. North Brazil rainfall). The dynamics of Tropical Atlantic air-sea interactions are dominated by the Bjerknes Feedback. We investigate changes in the Atlantic Niño in terms of the Bjerknes Feedback Index after large eruptions in the Last Millennium IPSL-CM6A-LR simulation. By isolating the intrinsic signal of the Atlantic Niño from the volcanically induced surface cooling, we observe the onset of a consistent negative Atlantic Niño in the year following the eruption. In the second and third years following the eruption, there is a rebound effect and formation of a strong and positive Atlantic Niño. The precipitation anomalies respond to it, during the first year after the eruption the equatorial precipitation shows negative anomalies, while during the positive Atlantic Niño a wetter pattern in the equatorial Atlantic is observed. We identified weaker Thermal Damping during the eruption and following first year, which is linked to the volcanically triggered cold anomaly. Further, we observed weaker Ekman and Thermocline Feedbacks related to less responsive subsurface temperature to changes in the thermocline depth, because of the eruption-related cold anomaly propagation. Overall, the Bjerknes Feedback Index gets weaker for two years after the eruption, however, subject to large variability coming mainly from the Dynamical Damping component.

On site talk (Tuesday 09:45-10:00)

Volcanic cooling reconstructed from wood anatomical tree-ring proxies over the Common Era

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Tree rings are often used to estimate climate impact of volcanism prior to when meteorological measurements were systematically done. Simple tree-ring widths are often used but, during the past decades, they have been shown to underestimate the immediate impact and to overestimate the long-term impact over the following decade. Tree-ring measurements of wood density in the latewood have instead been used more successfully, and now form the basis for a substantial portion of our understanding of the climate sensitivity to volcanism over the past millennium.

In this study, we probe deeper in the tree rings, analyzing the anatomy of the woody cells to further refine our knowledge of post-volcanic climate, especially at a finer temporal scale within the growing season. In constructing two wood anatomical datasets covering the Common Era in Scandinavia and North-western Siberia (Yamal), we described the temporal evolution of the impact of major eruptions on climate, and how the impact varies between these locations. These results were also compared with Earth System Model (ESM) simulations. Preliminary results showed that wood anatomy is very sensitive to climate impact from large eruptions, and that eruptions, like Tambora, differently impacted the two regions. This contrasts to the corresponding ESM simulations where the major eruptions of the CE invoke modest but very similar responses at the two locations. Although, tree-ring anatomy and model simulations agree on the average climate response to volcanism, they do so for different reasons.

On site talk (Tuesday 10:00-10:15)

Tropical Explosive Volcanism Drives North Sea Bumper Herring Catches, 1600-1860 CE

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Increasing concern exists over the impacts of projected climatic changes on marine ecosystems and higher trophic level species (e.g., cod and herring) exploited by fisheries that feed a substantial proportion of global population. Combining data from historical archives and paleoenvironmental proxies can help to advance our knowledge of links between marine ecosystems and human economies in periods of sudden climatic change. Explosive volcanic eruptions can induce severe short-term climatic changes that influence marine environments and ecosystems, and we thus examine the impact of major explosive tropical volcanism on North Atlantic sea-surface-temperatures (SSTs) using the Norwegian Earth System Model, and on North Sea Herring (1600-1860 CE) populations using rigorously reconstructed catch data from written sources. Explosive tropical eruptions identified by elevated sulfate deposition in polar ice cores are shown to have impacted North Sea temperatures and triggered population booms in herring in the first post-eruption decade. This response appears consistent with expected increases in zooplankton abundance (a key food source for herring) under reduced SSTs. We complement our analyses with herring population modelling that also predicts a population boom in the first decade following a "positive" ecosystem disturbance (e.g., increased zooplankton availability for herring, promoting increased survivorship). We also examine historical herring prices and identify notable price spikes in the first two post-eruption years, suggesting that demand for herring increased as a substitute for terrestrial agriculture likely impacted by poor growing seasons. But in occurring on average between 5- and 7-years post-eruption, the observed bumper catches could not be of direct assistance during volcanically induced years of food scarcity. This work has been funded by the ERC NorFish (ID 669461) and 4-OCEANS (ID 951649) projects.

On site keynote talk (Tuesday 11:00-11:15)

The Worst Year to Be Alive? Constructing the 536 CE event

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This contribution examines the construction of the 536 CE event, increasingly portrayed in interdisciplinary scholarship as a catastrophic event. An analysis of the discourse surrounding this event reveals how scholars have transformed an ambiguous occurrence in the sixth century sources into a major turning point in global history, associated with the end of antiquity and the beginning of the middle ages. The talk will sidestep the debate about what happened or did not happen in 536 and focus instead on how scholars from a wide range of disciplines have used the 536 event over the past four decades to extract meaning from the past and speak to each other and the public about their present-day concerns regarding the environment. The sum of the actions of these scholars has repeatedly reconstructed the 536 event to fit public discourse outside academia. The contibution argues that the cutting edge of interdisciplinarity is a fertile ground for colorful and provocative - but also uncritical and dangerous - narratives that can create pervasive misunderstandings that hobble research for decades.

On site talk (Tuesday 11:15-11:30)

Uncovering the largest demographic shock in Iron Age Scandinavia

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It is often stated that abrupt changes in climate following large volcanic eruptions had severe societal impacts; yet, owing to a scarcity of sources, these are seldom explicitly defined or quantified. This includes prehistoric demographic patterns, which have long remained hidden. However, the availability of large archaeological data sets and new tools and methods has given us the opportunity to look behind the veil of the past and uncover the demography of the Iron Age in Scandinavia.

In order to identify and understand the long-term societal responses to sudden shifts in climate, we make use of a systematic approach to large archaeological datasets covering South-Norway. Specifically, we explore the ebb and flow of the population in the wake of the volcanic eruptions in 536 and 540 CE.

In Scandinavia, the dead was buried in furnished graves up until Christianity became widespread in the 11th century. We have compiled a dataset of c. 7,000 burials from the period 400–1000 CE in South-Norway. This comparatively homogenous grave material gives a unique, and largely unused, approach to uncover relative changes in population size – as well as the spatial development of settlements and inhabitation over time. In addition, we have analysed large datasets of radiocarbon dates from archaeologically excavated sites in Southeastern-Norway. The assumption being that the modelled radiocarbon data will reflect variations in human activity.

By combining these approaches, we provide a unique insight into the consequences of the climate and environmental changes of the 6th century and uncover the largest demographic shock in Iron Age Scandinavia.

On site talk (Tuesday 11:30-11:45)

The Icelandic Active Period of 750-950 CE : insights from the Greenland ice cores

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The period 700 to 1050 CE was a time of significant societal and climatic changes across the North Atlantic region, encompassing the Viking expansion to Iceland, Greenland, and North America and the transition into the Medieval Warm Period. Despite this, volcanism during this period is poorly understood, with this period previously considered to be volcanically quiescent.

Analysis of Greenland ice core records, where evidence of eruptions may be preserved through sulphate aerosols and tephra, has revealed that this was in fact a period of heightened Icelandic volcanic activity, and includes the greatest lava flood eruption of the Common Era, Eldgjá. However, uncertainties persist over the nature of several of these eruptions, i.e. their total duration, plume height, and the responsible volcanic centre(s), which has ultimately hindered the construction of detailed eruption records and robust climate impact assessments of events throughout this period.

Here, we adopted a multi-parameter approach across several Greenland ice cores. We (1) determined the total duration of these events using the annually resolved high-resolution ice core chronologies; (2) undertook targeted sampling for cryptotephra geochemical analysis to pinpoint the source volcano; and (3) conducted high-resolution sulphur isotope analysis to constrain volcanic plume heights.

The adoption of this multi-parameter approach has allowed us to better understand and characterise volcanic activity during the period 700 to 1050 CE, revealing that volcanic activity and related atmospheric gas emissions in Iceland peaked between 750 and 950 CE with unprecedented levels in at least the past 4000 years. Moreover, it has provided us with the necessary information to assess the climatic impacts of these eruptions when utilised alongside paleoenvironmental archives and historical written records from across Europe and North Africa. Ultimately, the wider application of this approach (i.e. other time-periods and regions) may facilitate the reconstruction of past volcano-climatic impacts.

On site talk (Tuesday 11:45-12:00)

Reconstructing the volcanic impacts of the Icelandic Eldgjá eruption in 937-940 CE

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The episodic eruption of Eldgjá in the 10th century is the largest basaltic flood lava eruption on Earth in the Common Era. The eruption released approximately 200 Tg of sulphur dioxide into the atmosphere, a substantial emission that is likely to have had severe impacts on the climate and environment. Several accounts, such as observations of haze over Europe, suppressed flow of the Nile, and a minimum in tree-ring temperature reconstructions, indicate that the eruption had impacts on regional and global scales. Petrological evidence from Iceland quantifies the emissions of sulphur and halogens from the eruption site, and subsequent deposition is recorded in Greenland ice cores. Additionally, new analyses of cryptotephra and sulphur isotopes in Greenland ice shed light on the date, duration, and injection height of the eruption. In combination, these constraints provide key information about the eruption's nature but they do not directly quantify its climate forcing or environmental effects. To bridge this gap, we model the Eldgjá eruption using a fully coupled Earth system model with interactive volcanic aerosol and atmospheric chemistry, constrained by the existing evidence. We simulate the volcanic aerosol and atmospheric composition changes resulting from long-lasting, combined stratospheric and tropospheric emissions of sulphur, chlorine, fluorine, and bromine in a pre-industrial Earth system, sampling different initial states of North Atlantic climate and the Northern Hemisphere polar vortex. Our results help improve our understanding of prolonged Icelandic eruptions and can provide clues about how the Eldgjá eruption may have affected the population and environment at the time.

On site keynote talk (Tuesday 12:00-12:15)

Understanding variations in the rate and magnitude of volcanic eruptions beyond the Common Era

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Characterising the rate and magnitude of volcanic activity is important to estimate the future hazard at a local, regional and global scale, and to improve the understanding of the magmatic processes culminating in volcanic eruptions. As one goes back in time beyond the Common Era (C.E.), however, written records of volcanic eruptions are sparse, with little information about the magnitude or intensity of such events. Instead, the most accurate method of reconstructing these events is through geological or environmental records. Global environmental records such as ice cores suggest the global rate of volcanic eruptions is stationary, but these observations are limited to only the largest eruptions produced on earth. This implies the formation of the largest volcanic eruptions are dominated by intrinsic properties of magmatic systems that remain constant over geological timeframes, likely linked to the generation of melts at the base of the crust. For smaller eruption magnitudes, however, this assumption of stationarity is difficult to determine due to incompleteness in the geological eruption record and the fact that these events are not recorded in environmental records. This incompleteness varies in both space (e.g., between different regions and volcanoes) and time, but we can account for this by considering individual volcanoes as exchangeable between a set of analogous volcanoes. In doing so it is shown that although the absolute impact of under-recording varies in time, the effect on the proportion of different magnitude eruptions is negligible within the Holocene. By using this temporal record, variation in the magnitude of eruptions can be observed between different regions on earth, and explained by tectonic controls on the generation, transport and storage of magma in earth's crust.

Virtual keynote talk (Tuesday 13:45-14:00)

Reconstructing the radiative forcing of volcanic eruptions from ice cores: importance of eruption source parameters

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Ice core records of sulfate deposition are essential for reconstructing past explosive volcanic eruptions, but how these signals are translated into volcanic sulfur emissions and aerosol optical properties remains uncertain. The climatic impact of an eruption depends on many properties of the eruption, so called eruption source parameters, including the magnitude of the sulfur emission, the eruption latitude, eruption season and emission altitude. These properties also affect the amount of sulfate that is deposited on the polar ice sheets. Here I will present work using interactive aerosol modelling and novel statistics on how eruption source parameters impact our ability to constrain past radiative forcing from polar sulfate deposition. Our results suggest that there is a wide range of eruptions that can lead to sulfate deposition that will match ice core records, with important implications for reconstructing radiative forcing and consequent climate effects.

Virtual talk (Tuesday 14:00-14:10)

Modelling the evolution of the volcanic plume height as a function of the eruption time and the seasonal climate

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The forecasting of the volcanic plume height is the topic of many studies in physical volcanology. Therefore, several physical and mathematical models have been used; one of the leading physical models derived from observations is the Woods model since 1988 which includes a gas thrust region, a buoyancy driven region and an entrainment region. In the same way, a second physical study was published showing that the atmospheric boundary layer is made up of three layers: the surface layer, the mixing layer or convective layer and the free atmosphere whose thicknesses vary according to the time of day and the seasonal climate. By comparing these two models, we find a similarity and we wonder if one can justify the other or if these two models are complementary. In this project we use the Reynolds Averaged Navier Stokes equations separating the turbulent fluctuations from the stationary evolution of the different variables to model and simulate the evolution of the lower atmosphere as a function of the daytime. The results show that the height of the atmospheric boundary layer increases from midnight to twelve o'clock where it reaches its maximum and then decreases to its minimum at midnight. From the data analysis method, we were able to determine a first pattern in winter. In particular, we find that the volcanic plume height is weakly affected by the wind speed which is known to be a major factor in the forecast of volcanic plume height. We plan to redefine the seasonal climate in order to find other patterns, to identify the seasonal factors that control the dynamics of the volcanic plume height. Our mathematical model based on the Navier Stokes equations has also allowed us to simulate the evolution of plume velocity as a function of height, this will allows us to predict the duration of an eruption in the light of the known results.

Virtual talk (Tuesday 14:10-14:20)

Estimates of past UV-B radiation using pollen biomarkers

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Variations in UV-B at the Earth's surface are likely to have had major consequences for ecological patterns and biosphere dynamics in the geological past. They are also an important indicator for understanding patterns of global and regional climate change. However, there is no systematic method to quantitatively reconstruct UV-B beyond the instrumental record. This is severely hindering our ability infer the extent of UV-B and associated climate dynamics in the past, and their impacts on ecological change.

A promising new approach uses the chemical compounds of pollen grains to reconstruct UV-B radiation. However, based on current understanding it remains impossible to quantitatively estimate the magnitude of terrestrially received UV-B radiation using fossil pollen grains. This is because palaeo-UV-B studies have mainly used correlative methods to infer the pollen-chemical response to UV-B radiation. A new approach is required which integrates understanding of the biochemical response at the plant level, in order to provide quantitative reconstructions which areunderpinned by process-based understanding.

Here, we present the first results from the ongoing RCN-funded QUEST-UV project. Our goal is to develop the first quantitative reconstruction model for UV-B based on fossil pollen, using a combination of greenhouse and field experiments to better understand the sensitivity of UV-B absorbing compounds to UV-B radiation in fossil *Pinus* pollen.

Virtual talk (Tuesday 14:20-14:30)

Interactive stratospheric aerosol models' response to different amounts and altitudes of SO2 injection during the 1991 Pinatubo eruption

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A previous model intercomparison of the Tambora aerosol cloud has highlighted substantial differences among simulated volcanic aerosol properties in the pre-industrial stratosphere and has led to questions about the applicability of global aerosol models for large-magnitude explosive eruptions prior to the observational period. Here, we compare the evolution of the stratospheric aerosol cloud following the well-observed June 1991 Mt. Pinatubo eruption simulated with six interactive stratospheric aerosol microphysics models to a range of observational data sets.

Our primary focus is on the uncertainties regarding initial SO2 emission following the Pinatubo eruption, as prescribed in the Historical Eruptions SO2 Emission Assessment experiments (HErSEA), in the framework of the Interactive Stratospheric Aerosol Model Intercomparison Project (ISA-MIP). Six global models with interactive aerosol microphysics took part in this study: ECHAM6-SALSA, EMAC, ECHAM5-HAM, SOCOL-AERv2, ULAQ-CCM, and UM-UKCA. Model simulations are performed by varying the SO2 injection amount (ranging between 5 and 10 Tg S) and the altitude of injection (between 18–25 km).

The comparisons show that all models consistently demonstrate faster reduction from the peak in sulfate mass burden in the tropical stratosphere. Most models also show a stronger transport towards the extratropics in the Northern Hemisphere, at the expense of the observed tropical confinement, suggesting a much weaker subtropical barrier in all the models, which results in a shorter e-folding time compared to the observations. Furthermore, simulations in which more than 5 Tg S in the form of SO2 is injected show an initial overestimation of the sulfate burden in the tropics and, in some models, in the Northern Hemisphere and a large surface area density a few months after the eruption compared to the values measured in the tropics and the in situ measurements over Laramie. This draws attention to the importance of including processes such as the ash injection for the removal of the initial SO2 and aerosol lofting through local heating.

Virtual talk (Tuesday 14:30-14:40)

Comparing Laki to Tambora: Weather, floods and famine in the Middle-Danube region in 1780s-1810s, in a (Central) European context

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The atmospheric, weather and weather-related environmental impacts of the Lakigigar eruption in 1783 are clearly detectable in the contemporary documentation of the subsequent years in the Middle-Danube area, covering the countries of the Hungarian Crown in the Carpathian Basin. This is also true for the 1815 Tambora eruption; however, the impacts and the multiannual – both the (hydro)climatic and the regional-international socio-economic, political – processes and context were rather different in the 1780s and the 1810s. The period of the 1780s-1810s alone in itself comprised one of the major climatic anomalies of the Little Ice Age. Clearly influenced by volcanic eruptions, the wet period with a high number of (Danube) floods already started years before the Lakigigar eruption, but both the Laki and the Tambora (and preceding) eruptions were followed by an outstanding number of temperature, precipitation and flood extremes, harvest problems and an increase of socio-economic tension in the Carpathian Basin. Both periods following the two major eruptions were characterised by significant flood-rich years. Nevertheless, the type of weather extremes (and leading flood types) were rather different in the two cases: hard but changeable subsequent winters were accompanied by warm summers in the 1780s, and mild winter(s) with great temperature and precipitation extremes and cooler summers prevailed in the mid-1810s. Although the consequences of the Laki eruption were responsible for increased difficulties particularly in riverine areas, these difficulties did not lead to such a large-scale famine as the one in the mid-1810s, when already the unfavourable years before the Tambora eruption, combined with the Europe-wide effects of the Napoleonic Wars, prepared the ground for the greatest famine of the century.

On site keynote talk (Wednesday 09:00-09:15)

An updated Holocene tephrochronological framework for Greenland, based on investigations of NGRIP, EGRIP and RECAP ice cores

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This presentation will provide an overview of recent efforts to update the Holocene Greenland tephrostratigraphy record, through the characterisation of individual ash deposits in the NGRIP, EGRIP and RECAP ice cores. The tephra sampling strategy for NGRIP was based on contiguous sampling over wide depth intervals between 9.5 to 5.3 ka b2k, at a relatively low resolution. EGRIP and RECAP sampling has so far been based on targeting conductivity peaks and visible ash-type deposits/cloudy bands.

So far, we have geochemically characterised 72 deposits by EPMA from the different ice cores, which translates to 63 individual volcanic events (since some deposits are found in multiple cores). Fifty deposits are from Iceland, from different volcanic centres with an early to mid-Holocene dominance of basaltic volcanism, with ash originating from both the southern flank zone (typically alkali – transitional alkali basalt composition) and the eastern rift zone (typically tholeiitic basalt composition). Key contributing centres include Grímsvötn, Hekla and Kverkfjöll. Between 7 and 9.5 ka BP we find a cluster layers of volcanic ash (tephra) from 7 explosive eruptions in Greenland ice cores with a typical Kamchatkan geochemical composition as well as others from the northern Pacific region, including two from Japan and two from North America. One of the events is has a bipolar SO4 signature, and is clearly linked to a negative isotope anomaly in Greenland's water isotope records, which lasted a decade. Later Holocene deposits have mixed geochemical compositions, including well-known historical events such as Öræfajökull 1362 AD, Hekla 1104 AD, Bárðarbunga 1477, in addition to a number of Kamchatkan and unknown silicic deposits.

On site talk (Wednesday 09:15-09:30)

High resolution sulfur isotopes from ice cores: improved estimates of the volcanic forcing of climate

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The record of the volcanic forcing of climate over the past 2500 years is reconstructed primarily from sulfate concentrations in ice cores. Of particular interest are stratospheric eruptions, as these afford sulfate aerosols the longest residence time and largest dispersion in the atmosphere, and thus the greatest impact on radiative forcing. Sulfur isotopes can be used to distinguish between stratospheric and tropospheric volcanic sulfate in ice cores since stratospheric sulfur aerosols are exposed to UV radiation which imparts a mass independent fractionation (Savarino et al., 2003). Thus, sulfur isotopes in ice cores provide a means to identify stratospheric eruptions and calculate the proportion of sulfate deposited from a volcanic event that came the stratosphere, allowing us to refine the historic record of explosive volcanism and its forcing of climate. Here we present high-resolution (sub-annual) sulfur isotope data from both Greenland and Antarctica across a suite of unidentified eruptions from the anomalously cold decades of the 530s CE, 1450s CE and 1600s CE, as well as the newly identified eruption of Okmok in 43 BC (McConnell et al., 2020), to investigate the stratospheric sulfur loading and climate forcing potential of these eruptions.

Savarino, J., Romero, A., Cole Dai, J., Bekki, S., & Thiemens, M. H. (2003). UV induced mass-independent sulfur isotope fractionation in stratospheric volcanic sulfate. *Geophysical Research Letters*, *30*(21). http://doi.org/10.1029/2003GL018134

McConnell, J. R., Sigl, M., Plunkett, G., Burke, A., Kim, W. M., Raible, C. C., et al. (2020). Extreme climate after massive eruption of Alaska's Okmok volcano in 43 BCE and effects on the late Roman Republic and Ptolemaic Kingdom. *Proc Natl Acad Sci USA*, *117*(27), 15443.

On site talk (Wednesday 09:30-09:45)

Increase in storm frequency in Greenland after volcanic eruptions and its societal impacts

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Explosive volcanic eruptions are well known to influence Earth's temperature. How such eruptions influence the atmosphere's circulation patterns, especially at the scale of everyday weather is, however, less well understood. Changing Earth's temperature can affect temperature gradients which in turn could affect baroclinicity and hence high- and mid-latitude weather. Yet, to what extent volcanic eruptions do in fact exert such an influence is not clear. To address this, we pursued two independent lines of investigation: First, we query the Greenland ice-core proxy record for indications of increased extra-tropical cyclone frequency that correlates temporally with evidence for volcanism. This is done by comparing the storm proxy sea salt (a substance transported to the ice sheet by wind) with the eruption proxy sulfur. Secondly, we simulate eruptions with the an Earth System Model (MPI-ESM1.2) and use an algorithm (TRACK) for identification of relative vorticity extrema to explore how extra-tropical cyclone frequency is affected in the model experiments. Both approaches suggest that volcanic eruptions increase the number of extra-tropical cyclones at higher latitudes in the North Atlantic region. A detailed interrogation of the simulated eruption scenarios suggests that this increase in cyclone frequency is linked to a sea ice expansion and to steeper isentropes derived from an increase in baroclinicity. Furthermore, our simulations suggest that an eruption of the size of the largest Holocene eruptions could roughly double the number of winter and spring storms in the high latitude parts of the North Atlantic region for several years. As such an increase would happen extremely rarely due to natural variability, it could potentially have a large human impact. The historical and ethnographic records do hint at such impacts; the Medieval Norse struggled to remain in regular contact with their homeland as storm frequencies increased during the Little Ice Age, while ethnographic reports from Greenlandic Inuit hint at storminess as a major threat to lives and livelihoods. Beyond volcanically induced temperature declines, a post-eruption increase in storminess could therefore act as an additional mechanism linking explosive eruptions, climate and societal change, at least in high latitudes.

On site talk (Wednesday 09:45-10:00)

When does the volcanic signal on surface climate emerge from internal variability?

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Large explosive volcanic eruptions are a potential source of uncertainty in future climate projections as they cannot be predicted in advance, but eventually will occur, causing short-term climatic impacts on both local and global scale. Still, an open topic is the volcanic impact on tropical climate variability, in particular El Niño Southern Oscillation (ENSO) and tropical precipitation and the combined effect of both. Sufficient large-ensemble simulations with the same model and radiative forcing scenario but varying initial conditions have become a great tool in recent years to disentangle forced and internal variability. Here we use 100-member ensembles of the MPI-ESM-LR for idealized volcanic eruptions of different eruption strength to investigate whether there is a linear volcanic signal on tropical precipitation dependent on the eruption strength, and when does it emerge from tropical internal variability. Our results show that for Idealized tropical eruptions global and large hemispheric mean 2m temperature and precipitation anomalies seemed to be scalable with the sulfur emission strength in a certain size range. 10 Tg S emission, the upper estimate of the 1991 Pinatubo eruption, seems to be a threshold where the signal is discernible from internal variability. We find that seasonal and ensemble mean pattern correlation of 2m temperature and precipitation anomalies are highly correlated, in particular for larger emission strengths in the tropics and strongly modulated by ENSO with an increasing tendency for a warm ENSO increases with eruption strength. Emergence of the volcanic signal appears for smaller eruption strength when looking to ENSO composites. While the emergence of cooling appears on a hemispheric scale, the precipitation response is more localized and mainly confined to the tropics and subtropics.

On site keynote talk (Wednesday 10:00-10:15)

Timing and climatic impact of the Los Chocoyos supereruption, using high-resolution analysis of sulfur isotopes and cryptotephra in ice cores

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The Los Chocoyos supereruption (LCY) of Atitlán Caldera in Guatemala is thought to be one of the largest volcanic events of the last 100,000 years. Recent radiometric age estimates for LCY of 75 ± 2 ka (1σ) are within age uncertainty of the Younger Toba Tuff eruption (YTT) (73.7 ± 0.3 ka (1σ)) and the onset of Greenland Stadial 20 (GS-20; 74.1 ka), leading to questions about the role that supereruptions play in global climate forcing.

Ice cores provide a means of testing this hypothesis, by identification of volcanic sulfate aerosol peaks deposited in a highly resolved climate record. High-resolution sulfur isotope analysis can be used to identify volcanic sulfate derived from the stratosphere, and distinguish between high latitude and tropical eruptions, while geochemical fingerprinting of cryptotephra can robustly tie an ice core deposit to its source volcano.

We apply these techniques to a large volcanic aerosol peak deposited synchronously in Greenland and Antarctic ice cores at 79.5 ± 1.7 ka (AICC2012; Antarctic Ice Core Chronology 2012). Major-oxide analysis of cryptotephra has identified 6 shards consistent with geochemistry of LCY (2 in Antarctica and 4 in Greenland). This hypothesised source is supported by sulfur isotope analysis that shows one of the largest, sustained mass independent fractionation anomalies seen in ice core records, indicating a climatically significant tropical latitude eruption.

Our ice core age of 79.5 ± 1.7 ka rules out back-to-back supereruptions at the transition to GS-20. Highly resolved $\delta^{18}O$ ice core records further indicate LCY was not a driver of sustained global cooling. However, our ice core calculated stratospheric sulfur loading estimate of 192 ± 43 Tg S is one of the largest of the past 100,000 years, suggesting multi-annual to decadal scale cooling in the years following the supereruption.

On site keynote talk (Wednesday 11:00-11:15)

Volcanism, climate, and environmental change during the Late Pleistocene

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The late-Pleistocene (120–11.65 ka) was the most recent glacial in Earth's history. During this time, the climate system underwent rapid and aperiodic shifts between relatively cool (stadial) and warm (interstadial) conditions with a speed and amplitude larger than any known climate excursion within the more recent Holocene (0-11.65 ka), shifts known as Dansgaard-Oeschger (D-O) events. They demonstrate that the climate system can undergo global-scale reorganisation over <100-year timescales, meaning they provide a basis for understanding the drivers of abrupt environmental change, and key constraints for the models on which modern climate projections are based. However, what triggers D-O events remains a key unresolved question. Models can adequately explain how driving sequences of non-linear feedbacks could theoretically generate the abrupt climate signals; however, many are unable to produce D-O events with the same aperiodicity observed in paleoclimate records, and must rely on an unknown trigger to initiate the driving feedbacks. The idea that volcanism could represent the missing trigger has received comparatively little research attention, despite hints that indirect climatological impacts of large explosive eruptions could far exceed the lifetime of aerosols in the atmosphere. This talk presents the 'volcanic perspective'. First, by unifying existing mechanistic frameworks that seek to explain the underlying driving causes of D-O events, and subsequently assessing the extent to which volcanism could provide the initial perturbation missing from these frameworks. It will also explore how integration of datasets gleaned from cognate research fields can effectively determine whether volcanism can be dismissed as a plausible D-O event trigger and, if not, ascertain key unknowns for future exploration. Specific focus is given to recent advances in two areas: (1) statistical testing of time-associations between volcanism and abrupt climate transitions, and (2) use of speleothems as records of past eruptions and their environmental effects.

On site talk (Wednesday 11:15-11:30)

Seasonality of large volcanic events – evidence from mid-latitude tree-ring parameters

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Large volcanic events of the past can cause massive climatic disturbances, which may be detected by tree ring analyses. The main focus of such analyses is on the one hand the dating of these volcanic events and on the other hand the quantitative estimation of the caused climatic disturbance. Usually, tree-ring based dating is limited to a calendar year, since tree-ring growth in the mid and high latitudes is restricted to the corresponding summer season. However, different tree-ring parameters, such as total tree-ring width or maximum tree-ring density, reflect different parts of the growing season. This can be shown, for example, with data from temperature-sensitive mid-latitude trees. Comparative analysis of different parameters thus has the potential for more precise seasonal determination of the occurrence of climatic disturbances as well as the associated volcanic events.

Using the effects of the Novarupta event 1912 CE, with an intensity of VEI 6 often considered as the strongest volcanic event in the 20th century, the potential of such a comparison is discussed. For this purpose, tree-ring width and density data (MXD, Blue intensity data) of trees from temperature-sensitive sites in the Alps are used. For the Novarupta event, the timing of the eruption is known, and at the same time instrumental climate measurement data with daily resolution can be used to trace the evolution of the climatic disturbance in the Alps.

Comparative to the 1912 CE Novarupta event, results are discussed for the -2035/-2034 BCE event, which is shown in tree-ring width data from the Eastern Alpine Conifer Chronology as one of the strongest cooling events of the last 10,000 years and was caused by a massive volcanic event, according to ice core data.

On site talk (Wednesday 11:30-11:45)

Similar Long-Lasting Environmental Effects of the Laki Eruption Across Late 18th century Europe? Comparing Mediterranean France to Italy and Middle-Danube Region

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The 1783-84 Lakagígar flood lava eruption in Iceland was one of the most powerful of its kind in recorded history and it had substantial effects on global climate. Consecutive severe climatic anomalies influenced crop growth, contributed to poor harvests and led to subsistence crises. For example, in the Carpathian Basin, the eruption was followed by an outstanding number of temperature, precipitation and flood extremes. In Italy, the volcanic aerosols released at the same time by the Italian volcanoes Stromboli, Vulcano, and Vesuvio, were added to those emitted by the Icelandic Laki. The dry fog persisted till 1785, causing severe damage to the agriculture and morbidity, in particular to sheep and other herbivorous animals. It was considered a burning haze that generated a black rust on maize, grapes and fruits.

The aim of this paper is, on the one hand to present, for the first time, an analysis of the weather related environmental impacts of this eruption on Mediterranean agro-ecosystems, and on the other hand to provide an overview of its agricultural impacts based on a comparison between three different geographical areas.

We first investigate the specific post-eruption weather perturbations and their impact on harvest of main crops, subsistence crises and human life in Southeastern France for the subsequent years of the eruption but also throughout the next decade. Climatic effects are evaluated thanks to available long-term homogenized data series of daily instrumental observations from regional meteorological stations, and mean French series in the short and long term. Environmental data derived from specific documentary sources related to crop yields, grain prices (e.g. agricultural surveys) and food availability were used for the analysis of adverse agricultural consequences.

Then, results from Mediterranean France are compared with recently produced data from two other European regions, with different climatic conditions: Italy and the Middle-Danube area. The resilience of societies (and their food system) to these extreme climatic disturbances, in light of their respective political and socio-economic context and past experiences at that time, is discussed.

On site talk (Wednesday 11:45-12:00)

Volcanic signatures in Ancient Babylonian texts?

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The *Astronomical Diaries and Related Texts from Babylonia* is a compilation of translations from cuneiform tablets originating in Babylon in the first millennium BCE. These diaries contain not only astronomical and historical data, information on river heights of the Euphrates, and market price values for six commodities, but also provide one of the oldest continuous written records of weather in the ancient era. The diaries range from 652-61 BCE, but with a majority of those that survive spanning 390-61 BCE. The meteorological information in these diaries has now been extracted, categorized and quantified in dataset that comprises over 10,000 individual units of data. This data is currently being analysed with a view to reconstructing the historical climate for the region. Initial analysis has uncovered some intriguing findings regarding terms that are as of yet, untranslated, such as *ZI IR*, as well as evidence that the Ancient Babylonians adopted a 'departure from the norm' methodology in recording meteorological phenomena. Another exciting line of inquiry is the possibility of identifying the signature of volcanic impacts on the weather of Ancient Babylon. Evidence from sulphate deposition onto the polar ice sheets indicate that over 40 explosive (and potentially climatically effective) volcanic eruptions occurred across the same timeframe represented by this unique dataset. Ongoing analysis suggests the aspects of the region and period's climate that most notably registered the impact of these eruptions, including the incidence of severe cold, as well as other environmental phenomena likely to represent observations of volcanic dust veils. In the context of this dataset, missing data is as important as available data. This paper will present these initial findings, while also providing a context for the background normal signature of weather for the region and period. The clues provided by missing data, along with the gaps in knowledge, will also be discussed.

On site keynote talk (Wednesday 12:00-12:15)

Re-thinking Thera: Chronological advances through a high-resolution, multi-proxy approach

Charlotte Pearson[1], Michael Sigl[2], Matthew Salzer[1], Andrea Burke[3], Lilliana Siekacz[4], Siwan Davies[5], Andrei Kurbatov[6], Mirko Severi[7], Jihong Cole-Dai[8], Helen Innes[3], Paul Albert[5], Meredith Helmick[6]
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The study of volcanic forcing and tree-ring growth response began with time-series of frost damaged cells in North American bristlecone pine and the suggestion that a particularly severe event at 1627 BCE could mark the eruption of Thera in the Mediterranean Sea. The question of when, exactly, Thera erupted still rages today, but one thing we now know for certain is that the 1627 BCE event in bristlecone pine was not caused by Thera, but rather Alaska's Aniakchak II. In reviewing the interwoven history of the Minoan Eruption of Thera and Aniakchak II, we will consider the multi-proxy evidence drawn together to shed new light on the possible impacts of these events on climate and people over 3500 years ago. We will also focus on the role of annual-resolution radiocarbon analysis and enhanced proxy development in improving chronological frameworks for these events and others like them.

On site keynote talk (Wednesday 13:45-14:00)

Overview of the joint research project VolImpact

Christian von Savigny[1], Claudia Timmreck[2], Stefan Bühler[4], John Burrows[5], Corinna Hoose[3], Akos Horvath[4], Ali Hoshyaripour[3], Christopher Kadow[7], Ulrike Niemeier[2], Christine Pohl[5], Johannes Quaas[6], Alexei Rozanov[5], Hauke Schmidt[2], Felix Wrana[1], Bernhard Vogel[3], Sandra Wallis[1]
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Volcanic eruptions represent one of the most important natural drivers of climate change on time scales from a few years up to a decade. Within the DFG (Deutsche Forschungsgemeinschaft) funded Research Unit (Forschungsgruppe) VolImpact (FOR 2820), we investigate in five projects different aspects of volcanic eruptions on atmosphere and climate, i.e. (1) the initial development of volcanic plumes on time scales from hours to a few days, (2) the evolution of volcanic aerosol layers in the stratosphere, (3) the interactions of volcanic aerosols and tropospheric clouds, (4) dynamic and thermal effects of volcanic eruptions on the middle atmosphere as well as (5) volcanic effects on the hydrological cycle.

This talk will first provide a brief overview of the VolImpact project and then focus on research activities most relevant for the objectives of the VICS working group. This includes retrievals of the stratospheric sulfate aerosol layer from passive optical satellite measurements, comparisons of the plume evolution observed by satellites and simulated using global models, unusual optical phenomena such as blue suns or green sunsets, or the possibility to infer information on the stratosphere's aerosol loading from color ratios in historic paintings.

On site talk (Wednesday 14:00-14:15)

The Hunga Tonga-Hunga Ha'apai Volcano Model Intercomparison Project (Tonga-MIP)

Margot Clyne[1], Owen Brian Toon[1], Timofei Sukhodolov[2], Graham Mann[3], Sandip Dhomse[3], Peter Colarco[4], Kostas Tsigardis[5], Simone Tilmes[6], Michael J. Mills[6], Yunqian Zhu[1]

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With its extreme explosivity, record height in the satellite era, and massive injection of water to the stratosphere, the Hunga Tonga-Hunga Ha'apai (HTHH) eruption of January 2022 provides a significant opportunity for model advancement. The HTHH Model Intercomparison Project (Tonga-MIP) aims to uncover modeling differences and errors for volcanic simulations in interactive stratospheric aerosol chemistry climate models. Tonga-MIP consists of a set of coordinated simulations of the HTHH eruption at multiple tiers of complexity. The experiments prevent intermodel differences in volcanic injection parameters, and are designed to provide a common ground for modeling groups throughout the community to refer to when discussing their own simulations of either the HTHH event itself or of other eruptions. **The goals of Tonga-MIP are: 1)** Establish a baseline of how well the models agree on AOD results for a basic case of injecting a small amount of SO_2 at a coordinated altitude, duration, and location. **2)** Determine what happens to the models' results and to their intermodel spread when the novel aspects of the HTHH eruption are incorporated. **3)** Figure out why the models disagree (it's inevitable), which ones are more trustworthy, and what needs fixing. At the VICS5 conference we will present results for the first two goals from the models CESM2-WACCM6-MAM, CESM2-WACCM6-CARMA, SOCOLv4, G4 UM-UKCA, GEOS-V, and GISS ModelE. We will discuss hypotheses for why the models disagree, and are eager to receive input from the VICS community.

On site talk (Wednesday 14:15-14:30)

Coincidence or causality? Microhistorical perspective on volcanism-climate-society dynamics

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Arguably, the main theme in volcanism-climate-society research is famine. We have hundreds - if not thousands - of publications that link some past volcanic eruption event to a famine. In these studies, the connection between distal volcanic eruptions and society appear rather straightforward. First, the cold pulse due to volcanic forcing causes harvest failures, this affects food availability, and eventually the situation leads to a famine. However, if we hope the past informing the assessment of possible long-range societal effects of future explosive volcanism, these narratives of historical famines may have little relevance for today. Furthermore, with these large-scale studies, it is difficult to distinguish what accounts as a coincidence and what accounts as a causal relationship.

In our recent publication (Clim. Past, 18), we investigated the human consequences of distant 17th century volcanic eruptions (1600 Huaynaputina, 1640/1641 Koma-ga-take/Parker, and 1695 unidentified) in northern Fennoscandia on a micro-regional scale. We found that these eruptions caused significant summer season temperature cooling and poor grain harvest overall on the region. Yet, we found that the societal consequences varied considerably among the eruptions as well as in time, space, and within the society. Above all, we discovered that a micro-regional scale has a clear added value as it can provide deeper understanding of why and among whom the distal volcanic eruptions resulted in different societal impacts, and hence strengthen the causal reasoning between eruptions, climate, and society.

Consequently, in this presentation, I will dig deeper on these causalities and investigate the societal dynamics even on a higher resolution: on a farmstead level. The preliminary results of this research suggest that **immaterial factors** dictated much more the human consequences than we have previously considered. For example, social status and networks influenced the economic effects on a grassroots level. Furthermore, cultural beliefs and control dictated the demographic consequences. As a conclusion, I hope to raise discussion among the VICS community on the perspective we should address the societal impacts within volcanism-climate-society studies - in order to make the societal aspects the most relevant for the research on the past, present and the future

Volc2Clim is computationally inexpensive and outputs both simple metrics and figures characterizing the radiative forcing and climate response, as well as full 4-dimensionnal fields of aerosol optical properties required to run climate models. We will showcase Volc2Clim's main functionalities and discuss how well it performs for recent eruptions such as that of Raikoke in 2019.

On site keynote talk (Wednesday 14:30-14:45)

Volcanic eruptions as global catastrophic risks

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The threat posed by volcanic eruptions to humanity has long been neglected within the field of global catastrophic risk. The narrative of colossal-scale VEI 8+ eruptions pushing humanity towards extinction has long prevailed and contributed to a deprioritisation of the risk. Although these eruptions continue to pose a potential future threat to humanity, they are considered relatively rare. However, the recurrence of large magnitude eruptions (VEI 7+), with the potential to affect our global climate, is much higher, with ice core records suggesting these eruptions to be as frequent as 1 in 6 per century. Further, a greater understanding of the mechanisms by which volcanic eruptions can disrupt our global climate and interact with our societal vulnerabilities suggests that eruptions of even lower magnitudes may also change the future trajectory of humanity.

Viewed through the lens of vulnerability, human society now closely intersects with regions of volcanic activity, potentially forging new pathways for volcanic eruptions to cause global disruption. Increased globalisation in our modern world has resulted in our over-reliance on global critical systems – networks and supply chains vital to the support and continued development of our societies (e.g. submarine cables, global shipping routes, transport, and trade networks). We observe that many of these critical infrastructures and networks converge in regions where they could be exposed to volcanic eruptions. These regions of intersection, or 'pinch points', present localities where we have prioritised efficiency over resilience and have forged new scenarios for global risk propagation.

With climate change increasing the frequency and intensity of volcanic eruptions globally and enhancing their impacts, more must be done to accelerate our preparedness for such events.

Abstracts for posters

On site poster (Poster session 1 - Monday 15:30-17:30)

Magmatic evolution and Eruption frequency of Campi Flegrei and Ischia over the last 133,000 years based on the varve record of Lago Grande di Monticchio, Italy.

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The Campanian Ignimbrite eruption from the Campi Flegrei, southern Italy, was the most explosive eruption in southern Europe during the last 200,000 years. Its impact and volcanic ash (tephra) distribution are well studied throughout the region, especially near the source of the eruption. The knowledge of the eruptive activity before this eruption came about, however, is still fragmental mainly due to the scarcity of preserved deposits in the near-vent area, especially the less evolved and explosive eruptions. Here we use the distal, annually laminated sediment record of Lago Grande di Monticchio (MON), southern Italy, to chemically characterise tephra from the Campi Flegrei and Ischia for the last 133 ka. Major- and trace-element glass compositions of visible tephra layers were used to determine compositional-frequency trends in between, immediately before and after caldera-forming eruptions at the Campi Flegrei. In addition, we find that across the 133 ka volcanic history recorded at MON, the magmatic composition of the Campi Flegrei shifted several times between two distinct compositional groups, which are very similar to the Campanian Ignimbrite (G1) and Neapolitan Yellow Tuff (G2) compositional ranges. A transitional group, sitting between G1 and G2 is also recorded, suggesting a continuous or mixing trend between these groups at certain periods. The distal tephra record also allows for a comparison of compositional-frequency trends of different volcanic sources. We show that similar magmatic compositional groups have been erupted at Ischia since the Monte Epomeo Green Tuff at 56 ka. Our results demonstrate the high potential of well-dated and high-resolution distal tephra records for a more detailed understanding of caldera cycles, long term magmatic evolution and regional volcanic linkages.

On site poster (Poster session 1 - Monday 15:30-17:30)

Simulating a series of Icelandic volcanic eruptions with volatile emissions lasting over a decade as a natural analog to solar radiation modification in the Arctic

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Analysis of trace elements, crypto-tephra and sulfur isotopes of ice cores from Greenland and historic analogues (e.g., Eldgjá) suggest that sustained volcanic episodes with mixed (effusive/explosive) character occurred in the past. Such eruptions can thus be seen as natural experiments for “solar radiation modification”, i.e., the envisaged intentional injection of aerosols into the atmosphere in order to counterbalance global warming.

To understand volcanic forcing of such long-lasting Icelandic eruptions and its potential environmental and climate impacts, we use the fully coupled Earth System model CESM2-WACCM6 with prognostic stratospheric aerosols and chemistry to simulate an Icelandic eruptive episode with continuous tropospheric volatile emissions including sulfur, chlorine, fluorine and bromine over 12 years, accompanied by three explosive phases throughout this period. We analyze the transport and formation of volcanic aerosols from the emitted volcanic volatiles and compare their deposition on Greenland with ice-core records. Then, we combine our model output with available paleoclimate data and historical records to study their environmental and climate impacts. Our results will be important for understanding the volcanic forcing and potential impacts of such Icelandic eruptions better and shade important light on solar radiation modification at high latitudes.

On site poster (Poster session 1 - Monday 15:30-17:30)

A Tale of Fire and Ice: How clusters of large volcanic eruptions shaped climate and society of the mid to late-Holocene

Evelien van Dijk[1], Johann Jungclaus[2], Michael Sigl[3], Claudia Timmreck[2], Kirstin Krüger[1]

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Throughout recent history, large volcanic eruptions affected climate and society around the world. However, from ice core records we know that much larger eruptions occurred during the Holocene. Additionally, clusters of volcanic eruptions have the potential to induce long-lasting cooling, like during the Little Ice Age (LIA) or the mid-6th century. These long-lasting cold periods are connected to changes in society throughout Europe. However, less is known about causal relationship between volcanic-induced global cooling, regional climate, and local societal changes in Scandinavia.

With new and improved volcanic forcing data sets, new model simulations for the past two millennia (PMIP4) and the mid to late-Holocene were run using the Max Planck Institute Earth System Model, which are analyzed in this study. Here, we aim to improve the understanding of the climate response to large volcanic eruptions in the first millennium and the mid to late-Holocene, by determining the impact volcanic-induced cooling has on the coupled climate system and on societies, as well as placing long-lasting cold periods like the LIA in perspective to the mid to late-Holocene.

We find a multi-decadal cooling after the large eruptions of the mid-6th century, which caused a heterogeneous response of society in different study areas in southern Norway. This is in line with other studies that investigated societal change in this period around Scandinavia and shows that the impact of climate on society is complex. We identify 12 LIA-like periods in the Northern Hemisphere during the mid to late-Holocene. These cold periods are found to be the integrated effect of the volcanic forcing. Clusters of large volcanic eruptions impacting the coupled climate system are needed to produce long-lasting cold events. The occurrence of these periods once or twice per millennium, depending on the eruption frequency, potentially had great implications for societies living during those times.

On site poster (Poster session 1 - Monday 15:30-17:30)

Can high latitude effusive volcanic eruptions cause surface winter warming in the Arctic?

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Following deglaciation in the early Holocene there was a surge in volcanism in Iceland. This period was characterised by long lasting effusive eruptions but their impact on climate is poorly understood. The recent and well observed 2014-15 Holuhraun fissure eruption can serve as an analogue to these past events and help shed light on their climatic impacts. It happened in the central highlands of Iceland and lasted from late August 2014 to late February 2015. During this time it emitted up to 9.6 Tg of SO2, mainly into the lower troposphere.

We performed two sets of experiments to estimate the climate impacts of the 2014-15 Holuhraun eruption using the Community Earth System Model, version 2.1.3 (CESM2.1.3). In one set, only the atmospheric component was active (CAM6) and the horizontal winds were nudged towards the MERRA-2 reanalysis. For the other set we produced ten ensemble members from free-running, fully-coupled historical simulations.

In our model simulations, the eruption lead to the formation of sulphate aerosols which interacted with clouds in the vicinity of the eruption. Since the eruption started in the fall and continued throughout the winter, sunlight was scarce in the domain which was mostly affected, namely the Arctic. The resulting cloud changes (mainly increased liquid water path and droplet number concentration, and decreased cloud droplet effective radius) therefore had little effects on radiative transfer in the shortwave spectrum but substantial in the longwave. In both sets of experiments we found that the 2014-15 Holuhraun eruption resulted in an increased surface flux of downward longwave radiation, leading to surface warming in the Arctic. In the case of the free-running simulations, this warming amounted to 0.75 +/- 0.57 ˚C (95% confidence) north of 65°N for the September to November mean.

On site poster (Poster session 1 - Monday 15:30-17:30)

Mid to Late Holocene East Antarctic ice-core tephrochronology: Implications for reconstructing volcanic eruptions and their impacts over the last 5,500 years

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Ice cores are powerful archives for reconstructing volcanism and developing tephrochronological frameworks, as they can preserve both the soluble and non-soluble products of volcanic eruptions. In addition, high-precision annually resolved chronologies permit ages to be assigned to eruptions. The identification of tephra in direct association with chemical indicators of volcanism can significantly enhance volcanic reconstructions as tephra can be linked to an eruptive source. Such source attributions can provide the location of the eruptions, the magnitude of aerosol emissions at the source and help assess any climatic impact. In addition, they can aid the reconstruction of volcanic histories and the assessment of future hazard risk.

The tephra record for the interior of East Antarctica over the last 5,500 years is potentially underexploited, as prior research has focussed on visible horizons and deep ice cores that cover longer time spans. Here we discuss ongoing tephrochronological investigations of two ice-cores, B53 and B54, retrieved from the interior of the East Antarctic Plateau. High-resolution, sub-annual chemical records have been measured from both cores using a continuous melter system. These data were used to identify and sample > 50 potential cryptotephra horizons from ice containing coeval peaks in fine insoluble particles and non-sea-salt sulphur.

Thus far, more than 15 cryptotephra horizons have been identified, geochemically characterised and linked to regional sources. One cryptotephra derives from North Victoria Land, Antarctica and can be linked to the Rittmann Tephra (1252 CE), the ~3.5 ka Vostok Tephra has been traced in both cores as a visible layer and a cryptotephra can be definitively linked to an eruption from Mount Hudson, Chile. More detailed investigations are being conducted on samples from specific volcanic signals of interest that may derive from eruptions of ultra-distal volcanic sources. Such eruptions could have deposited very small glass tephra shards over Antarctica, which poses significant analytical challenges and necessitates the use of innovative approaches for tephra identification and geochemical analysis.

On site poster (Poster session 1 - Monday 15:30-17:30)

Determining the volcanic sources of the double 1600 CE sulfate peaks in Greenland ice-cores

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Volcanic aerosols from large-scale eruptions, particularly stratospheric sulfates, are key drivers of past climate perturbation through their impact on radiative forcing. Records of the fallout from massive eruptions are preserved in polar ice-cores as sulfate peaks. Identifying the source of these peaks in ice-cores is challenging and, in the past 2500 years, only 6 of the 25 largest ice-core sulfate peaks have been linked to a known eruption. One known event is the 1600 CE eruption of Huaynaputina in Perú. Speculated to be one of the largest eruptions of the past 500 years, Huaynaputina is firmly linked through climate proxy data derived from ice-core and Northern Hemisphere (NH) tree-ring chronologies to the anomalous period of NH cooling present at the dawn of the 17th century. However, it remains complicated to assess the true climate forcing of this eruption due to eruption timing uncertainty as well as the presence of a distinct doublet sulfate peak in the Greenland ice-cores. As the glass compositions found in context of the ice-core's earlier peak do not match Huaynaputina, past studies suggest that another contemporaneous, NH eruption took place. Recent work regarding extratropical eruptions and their impact on hemisphere scale cooling demonstrate that a large NH eruption, instead of reducing the radiative forcing, works primarily to focus the radiative impacts within the NH and amplifies the climate impacts on a hemisphere scale. This means that an unidentified NH eruption at the start of the 17th century may be the culprit for the cooling.

We aim to disentangle these dual volcanic sulfate signals and identify the eruptions responsible through novel methods in cryptotephra extraction and microanalysis, and through high resolution multiple sulfur isotopes. By analyzing cryptotephra chemistry in ice-cores, we may be able to discern the source volcano of the earlier peak. We have found the glass shards preserved in ice-cores to be sufficient for high-precision chemical analysis by both electron microprobe (EPMA) and laser ablation (LA-ICP-MS). Additionally, we will use sulfur isotope measurements to constrain eruption latitude which will give insight into the transport and residence time of sulfate aerosols from the unidentified earlier eruption.

On site poster (Poster session 1 - Monday 15:30-17:30)

The Laki 1783 eruption revisited: likely ocean-mediated responses and mechanisms accounting for anomalous post-eruption weather over the SW Cape of South Africa

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There has been some belief that high latitude Northern Hemisphere eruptions (such as Laki 1783) are unlikely to have impacted climates of the Southern Hemisphere (SH). Our aim is to present evidence-based scenarios of ocean-mediated responses and mechanisms that would have made it possible for the Laki eruption to have had significant climatic impact on at least some SH regions.

We demonstrate the anomalous weather and climate over Cape Town (South Africa) during years following the Laki 1783 eruption. Conditions allude to a strengthening (i.e. more northerly displaced; more frequent and longer lasting) of storm tracks originating from the far southern Atlantic Ocean. While ENSO has a strong climatic influence over summer rainfall in southern Africa, the Southern Annular Mode (SAM) is a more important driver of inter-annual variability over South Africa's southwestern Cape region. Given that there seems to be a tendency toward a negative SAM polarity during El Niño and a more positive polarity during La Niña phases, it would imply that major volcanic eruptions indirectly affect the SAM through their impacts on ENSO. We note the strongly negative SAM index values for 1784/85 (associated with El Niño phases) and considerably less strongly negative SAM index values during the subsequent 1786/87 La Niña years. We argue that conditions during 1784/85 were conducive to the SAM assuming a negative mode, which favoured a northward displacement of strong and frequent storm tracks during 1786/87. In addition, apart from the multi-year impact on ENSO, the global cooling following the Laki eruption would have resulted in a stronger meridional temperature gradient in the Southern Hemisphere. This, via the thermal wind relationship, would have contributed to a negative SAM, and the associated northward displacement of storm tracks in the Southern Ocean.

On site poster (Poster session 1 - Monday 15:30-17:30)

Reconstructing late-Holocene glacier and climate fluctuations in northern Norway using high-resolution climate proxies and cryptotephra from various lake sediment records

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Understanding the climate of recent centuries and the forcing factors leading to climatic shifts can give important insights into present-day and future climate variabilities. Various studies using paleoclimatic archives including ice cores, tree rings and lake sediments have shown periods of cooling to occur during both the Little Ice Age (LIA) and the Late Antique Little Ice Age (LALIA). These are driven by multiple factors such as volcanic forcing and solar irradiance. Climatic variations during the LIA (c. 1300-1920 CE) are known to have caused worldwide glacier advances, whereas less is known about glacier response to the LALIA (c. 536-660 CE).

Lake sediment records from a proglacial-threshold lake and two control lakes are analysed to reconstruct the climate and glacial history during the last 2000 years of Tjønnbreen glacier, northern Norway, focusing on the LIA and the LALIA. The lake sediment sequences are analysed for cryptotephra to establish a high-precision chronology of these climate and glacier variations. Methods used for palaeoclimatic reconstructions include various sediment analyses such as X-ray fluorescence, CT-scanning, loss-on-ignition, magnetic susceptibility and grain-size analysis. These will be supported by a chronology based on radiocarbon dates and potentially cryptotephra, where the latter aims to provide distinct time markers for the age-depth model. However, preliminary results indicate that cryptotephra from the late Holocene are challenging to find in the current study lake. Plausible causes include the small catchment size of the lake and sloping of the lake floor at the coring location.

This study aims to enhance the understanding of glacier response to periods of climate cooling and to obtain a more accurate chronology of the climate and glacial history in the area. Furthermore, finding cryptotephra would not only aid the chronology of Tjønnbreen glacier fluctuations, but would also improve the accuracy of palaeoclimatic records in northern Norway.

On site poster (Poster session 1 - Monday 15:30-17:30)

Tropical Atlantic hydroclimate impacts of major early-20th century volcanic eruptions

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The tropical Atlantic Basin is fundamental for the planetary biosphere and climate, with the surrounding continents holding the largest planetary rainforests, major rivers, and vital agricultural regions. Here, we revisit the hydroclimate impacts in the greater tropical Atlantic region (encompassing the Atlantic Ocean, Africa, and the Americas) of the major Santa Maria (1902) and Katmai (1912) eruptions, which were among the largest eruptions in the 20th century. Through understanding the hydrological cycle responses to these eruptions we aim to contextualize the hydroclimate impacts of better-observed large eruptions in recent decades, and anticipate the impacts of future large eruptions.

We investigate the eruption hydroclimate impacts in using a suite of recently-updated early instrumental datasets, historical reanalysis output, and global climate models. Long-term observational datasets examined include gridded and station precipitation, tropical-Atlantic-flowing river discharge (Amazon, Congo, Paraná, Niger, and Senegal), and tropical Atlantic sea surface salinity, which provides insight into the marine surface freshwater balance (evaporation minus precipitation and surface runoff). We also study the mechanisms of hydroclimate impacts using latest-generation historical atmospheric reanalysis output and a medium-sized ensemble of prescribed volcanic-forcing experiments with the atmospheric general circulation model ECHAM6.

We find that both these volcanic eruptions caused detectable reductions in precipitation and discharge around the tropical Atlantic Basin; however, there were significant differences due to the eruption location and seasonality. In particular, the high-latitude Katmai eruption induced northern hemisphere cooling, driving a southward displacement of the Atlantic intertropical convergence zone (ITCZ) and Hadley circulation, weakening the West African summer monsoon; in contrast, the low-latitude Santa Maria eruption did not induce a comparable displacement of the marine ITCZ or summer monsoon response.

On site poster (Poster session 1 - Monday 15:30-17:30)

Modeling uncertainties of the sulfate aerosol evolution during the post-Pinatubo period

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Volcanic activity is a major natural climate forcing and an accurate representation of volcanic aerosols in global climate models is essential. This is a complex task involving many uncertainties in the model design and setup, as well as in observations. Modeling biases mean that there are knowledge gaps in our understanding of the stratospheric aerosol evolution, which also affects the interpretation of volcanic impacts on the climate system. The post-Pinatubo period was well-covered by satellite observations, which can be helpful to address these gaps. In our study, we use the aerosol-chemistry-climate model SOCOL-AERv2 to investigate the evolution of the sulfate aerosol burden in the recent past. We focus on three medium-sized volcanic eruptions (Kasatochi, Sarychev and Nabro), as well as on the behavior of the aerosol layer under volcanically quiescent conditions. The latter is additionally analyzed within the modeling intercomparison activity ISA-MIP to better understand the physical drivers of stratospheric aerosol modeling biases. For the three volcanic eruptions, we address the modeling issues related to the model vertical resolution, uncertainties in the available information concerning the mass of emitted SO_2 and its vertical profiles. We show that the simulated aerosol layer is very sensitive to both the model set-up and the forcing parameters, leading to differences of more than a factor of 2 in the volcanic peaks of aerosol mass in the stratosphere. Observations, however, are also rather uncertain, which complicates the validation of models. Our multi-model analysis of the volcanically unperturbed aerosol layer reveals large inter-model differences concerning all of its aspects, such as vertical distribution, seasonality and microphysical and transport processes. Our study highlights the necessity of further model intercomparison studies focusing on the stratospheric aerosol layer, which will also help to improve the inter-model agreement concerning volcanic impacts and their attribution in the past climate.

On site poster (Poster session 1 - Monday 15:30-17:30)

Progress toward Easy Volcanic Aerosol version 2

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The Easy Volcanic Aerosol (EVA) family of simple models offers an approach to the generation of stratospheric aerosol fields from estimates of volcanic emissions. EVA takes as input a time series of volcanic eruption data, including the mass of sulfur injected into the stratosphere and location of the eruptions, and outputs aerosol optical properties as a function of time, latitude, height and wavelength. These aerosol properties are tailored for use in climate models, but are useful generally as quantitative estimates of the impact of volcanic eruptions on climate and societies. The space-time distribution of aerosol properties is based on a simple box model of stratospheric transport. EVA version 1 was based on observations of the aerosol from the 1991 Mt. Pinatubo eruption, while EVA_H was parameterized to improve agreement with a range of eruptions observed over the 1979-2015 period, taking account of the estimated injection height of the emitted sulfur. Here, we introduce EVA version 2, an updated version of EVA which improves the fidelity of its output based on new methods for incorporating eruption height and its impact on aerosol growth and evolution based on up-to-date observational data. We compare the results of EVA2 with observational data sets, and quantify the impact of updates on reconstructions of volcanic forcing over the Common Era and Holocene. The impact of uncertainties in eruption magnitudes and source parameters will be discussed.

On site poster (Poster session 1 - Monday 15:30-17:30)

Impact of the 1815 Tambora eruption to the Carpathian basin area as shown by contemporary meteorological and historical data as well as dendrochronological results

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The Tambora eruption in 1815 was one of the largest in the historical time and had major global impacts for the following years. Its climatic effects are well known in Europe although less information is available about the impact to the society. The Carpathian basin area in eastern-central Europe was among the regions, which was severely affected by the cold and the particularly unusual meteorological events. The annual average temperature values calculated from the regular records in Wien and Budapest show a major drop in 1815-1816, although cold years were detected also during the previous periods. Contemporary documents report unusually cool and wet summer with frequent heavy hailstorms and even tornados in 1815. Continuous rains resulted in major floods, which damaged crops and caused starvation all over the region. The Tisza, the second largest river of this region flooded over 6 months. Grain prices rose significantly. Although there was a good grape production, grapes were so sour that the wines were undrinkable. This was followed by an unusually cold winter, when thousands of domestic animals were died. The 1816 was a year without summer also in the Carpathian basin. Dry fog frequently covered the basin areas. Unique optical observations were documented around the Sun and Moon during August. The starvation due to the shortage of food was so severe that initiated flees of people. The mortality index shows a sharp increase at many parts of the region during the 1816-1817 years (e.g., over 50,000 deaths just only in Eastern Hungary). We examined also a well replicated multicentennial ring width dataset built from living and subfossil stone pine (Pinus cembra) samples from the Calimani Mts (E Carpathians). An extreme negative anomaly ($<2\sigma$) of pine growth was detected in 1818 that could be related to the cataclysmic events of Tambora. In addition, further negative anomalies were observed (e.g., 1258, 1462, 1871, 1876, 1913) that closely follow large volcanic eruptions.

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On site poster (Poster session 1 - Monday 15:30-17:30)

The Babylonian Crisis of 424 BCE Explained

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In the year 424 BCE civil war broke out in the Near East in the aftermath of the death of the Persian great king Artaxerxes. Xerxes II became ruler of a vast empire, but he held power for just forty-five days before his assassination plunged the empire into a crisis that was eventually resolved by the victory of Ochus, crowned Darius II, in the autumn of 423 against the conspirators who had assassinated Xerxes II.

This period of turmoil was a particularly deep crisis, extending well beyond the manoeuvres of the highest ranking figures. To judge by a contemporary archive of 'mortgages', many small landowners in the region of Nippur, Central Babylonia, who held their fields and orchards in return for military service were ruined in 424 BCE.

Insofar as historians have examined this crisis, they have assumed that the pressure on the feudatory class came from the top down: as the rivals for the throne mobilised for civil war, they made demands of those owing military service who were obliged to raise cash by mortgaging their lands. The argument presented here is that in fact the crisis was driven from the bottom up. Utilising data extracted from polar ice cores and tree rings, we can identify an eruption c.426 BCE on par with the greatest known volcanic eruption of the late Holocene, that of Samalas 1257 CE, which produced large scale climate impacts in the northern hemisphere. Crop failure - particularly that of the date - in the wake of this eruption is likely to have been the cause for the ruin of the landowners.

Poster Session 2

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Eruptions that Shook the World – Ice-Core Edition

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What does it take for a volcanic eruption to really shake the world? Did volcanic eruptions cause Ice Ages or the Younger Dryas cold snap? Did they contribute to the rise and demise of ancient civilizations? Will volcanic eruptions safe us from global warming? 12 years after Clive Oppenheimer published "*Eruptions that Shook the World*" we are retelling some of the stories behind some of the greatest volcanic events. Harnessed with new forensic clues extracted from the vast ice sheets of Greenland and Antarctica we reveal new insights on the timing, climate impacts and global hazard risks of Earth's largest volcanic eruptions (VEI≥6) of the past 100,000 years. These insights have implications for paleoclimatology, geochronology, volcanology, archeology, history and our preparedness for future extreme events. By reconstructing a comprehensive, continuous and -- for very large eruptions -- complete timeline of global volcanic activity and atmospheric aerosol emissions going back tens of thousands of years we can now provide accurate constraints to guide future catastrophe risk management.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Tracing the Social and Environmental Dimensions of Volcanic-induced Climate Change in the 1st Millennium AD

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Volcanic eruptions are one of the natural disasters that have raised short-lived climate change, which has potentially affected the human-environment relationship in prehistoric and historic times. Many paleoclimatic records are consistent that the first half of the 1st millennium AD is a tumultuous time of environmental, societal, agricultural, and political turbulence. At least three large volcanic eruptions occurred during that period in AD 536, AD 540, and AD 547. Whether or not these volcanic eruptions triggered the Late Antique Little Ice Age and had profound effects on social disruption from AD536-660 in the Northern Hemisphere is a matter of debate. Lake sediments record paleoclimatic and paleoenvironmental dynamics as climate variability, vegetation, settlement history, and trace effects of volcanic eruptions. In this study, an annually laminated sequence from Lake Kleiner Tornowsee, Northeastern Germany, was selected and a multiproxy approach including palynology, tephra analysis, XRF-geochemistry, varve, 14C-AMS dating, and age-depth modeling was conducted for the time window AD 330-1320 to disentangle the potential effects of the volcanic eruptions on climate variability and societal and environmental changes. Our data depict that the 1st millennium AD was a time of climatic, demographic, and environmental changes in North-eastern Germany. The volcanic eruption (tephra in 381cm; AD 364) was followed by a decline of anthropogenic indicators (API) (e.g. *Secale*, and Cereal-type) reflecting the start of the so-called "migration period" in the region. A woodland re-expansion is visible in the time window AD430-580. A high level of environmental impact was experienced during the Slavonic occupation from AD580 to AD 770 and in AD1170-1330 where there is a high value of Anthropogenic indicators (API) is the onset of Germanic colonization.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Volcanic Eruptions and their Impacts on Climate and Society in 500-1250 CE

Kirstin Krüger[1], Manon Bajard[1], Jostein Bakke[2], Eirik Ballo[1], Anna de Bode[2], Sanne Boessenkool[3], Evelien van Dijk[1,4], Herman Fuglestvedt[1], Imogen Gabriel[4], Ingar Gundersen[5,6], William Hagopian[1], Helge Høeg[5], Anne Hope Jahren[1], Kjetil Loftsgarden[5], Anneketer Schure[3], Alistair Seddon[7], Michael Sigl[4], Henrik Svensen[1], Zhihong Zhuo[1], Tómas Zoëga[1], Frode Iversen[5, †]

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This multi-disciplinary paper aims to understand the role of volcanic eruptions and climate change in shaping the early history of Europe. The period 500-1250 CE is characterized by natural disasters, societal unrest, Viking expansion, emerging kingship – and large volcanic eruptions evidenced by geochemical markers in natural archives.

Contemporary reports of a mysterious cloud which dimmed the light of the sun for at least a year were written at the dawn of the Middle Ages which marked the beginning of an unusual cold period in the mid of the 6th century due to the volcanic eruptions in 536 and 540 CE. The societal structure of Scandinavian was radically changed between 400 and 750 CE. Agriculture had to be adapted to a colder climate and population levels are claimed to have been reduced by plague. Tree ring and climate model data identified a prolonged period of cooling up to decades over most of the Northern extratropics. Following was a period of volcanic activity, which was thought to be more quiescent in a global sense, and is marked by the onset of the medieval warm period (950 -1250 CE). However, volcanic eruptions in Iceland were frequently active during 700-1100 CE and must have had severe impacts on climate, environment and society in Northern Europe, which is not supported by available records. Existing studies for central Scandinavia were so far hampered by the lack of both written sources and high-resolution proxy records during 500-1250 CE. So what has happened?

Here, we will present new results from novel paleo (lake sediments, tree rings, ice cores) and archaeology records targeting for very high-resolution (seasonal to multi-decadal). These data will be combined with climate modelling to get more insights of this mysterious period. We will particularly focus on how climate and society in southern Norway were affected compared to other regions and cold periods during the Holocene.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Climate projections underestimate future volcanic forcing and its climatic impacts

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Explosive volcanic eruptions are one of the most important drivers of natural climate variability. In current climate modelling studies (i.e. CMIP6 ScenarioMIP), volcanic eruptions are represented by a constant volcanic forcing inferred from the mean forcing exerted by volcanic eruptions over the period 1850 to 2014. This approach does not account for the sporadic and thus time-variable nature of volcanic forcing. Ice-core measurements of volcanic sulfate deposition throughout the Holocene suggests that the total volcanic sulfur flux can vary by a factor of 25 between centuries. To understand how uncertainty in volcanic forcing affects climate variability up to the year 2100, we generate stochastic future volcanic eruption scenarios by resampling state-of-the-art ice-core, satellite, and geological records of volcanic activity in the Holocene. We then perform simulations for the period 2015 to 2100 using the future eruption scenarios in combination with a new plume-aerosol-chemistry-climate modelling framework ("UKESM-VPLUME") that integrates a 1-D eruptive plume model (Plumeria) into a fully-coupled Earth System Model (UKESM). Using this framework, we find that CMIP6-based climate projection underestimate volcanic forcing by at least a factor of two in a median future eruption scenario. This in turn leads to underestimation of the climate response as a whole including global radiative forcing, surface temperature, ocean circulation, sea level, and sea ice extent. We find that small-magnitude eruptions (emitting < 3 Tg of SO_2), contribute between about 30% and 50% of the volcanic impacts on climate in a median future scenario. Our results highlight the importance of improving the current representation of volcanic forcing in climate projections.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Reassessing the timing and climate impact of the 1783 Laki eruption: new insights from high time resolution ice core analysis

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The 1783 Laki eruption in Iceland is one of the largest eruptions of the Common Era and is estimated to have injected 100-200 MT of sulfate into the atmosphere as well as 15 km^3 of tephra. Various climate anomalies coincide with this eruption, including and an exceptionally hot summer, and cold winter in Europe and various reports of persistent "dry fog" over Western Europe and even North Africa. However, key uncertainties remain about the timing and duration of this event and whether these northern hemisphere climate impacts were directly linked to Laki.

To better understand the timing and climatic impact of Laki we analysed an exceptionally high time resolution record of a key Greenland ice core (NGRIP, which gives us ~10 samples/year). Here we present sulfur isotope records for this event. These analyses can provide detailed information about the eruption timing, injection height and plume chemistry.

Sulfur isotopic results for $\delta^{34}S$ shows a positive trend from -6 ‰ to 4 ‰ through the eruption $\Delta^{33}S$ shows a similar positive trend with values from -0.13‰ to 0.16 ‰ indicating a dominant tropospheric/lower stratosphere transport pathway. We interpret this small but measurable $\Delta^{33}S$ trend as evidence for a SO_2 self-shielding effect and/or a very minor stratospheric S emission. This record present also a good consistency with previous Isotopic record of Laki eruption in Greenland Ice core.

Our ice core proxy evidence suggests a limited north hemisphere climate impact consistent with recent modelling efforts that also suggest Laki eruption would have had little or no direct impact on the climate of the year 1783-1784.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Simulation of ash clouds after a Laacher See-type eruption

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The paroxysmal, magnitude 6 eruption of the Laacher See volcano around 13,000 BP marked the end of explosive volcanism of the volcanic zone in the eastern Eifel (Germany). Recent studies of the effects of extratropical volcanic eruptions on climate and new insights into the dating of the LSE have revived attention to this eruption and its potential influence on climate and contemporaneous hunter-gatherer societies. Detailed reconstructions of the eruption dynamics have been proposed based on sedimentological and petrological analyses of primarily proximal deposits. The eruption may have lasted several weeks, with an initial (~10 h) intense early phase that resulted in deposits over northeastern Germany and the Baltic Sea, and a weaker phase that left deposits south of the volcano toward the Alps. We here review the evidence of the impact of the Laacher See eruption (LSE) with several numerical simulation experiments.

Our interactive stratospheric aerosol model experiments, using ECHAM5-HAM, are based on estimated emissions of 20 Tg of sulfur dioxide (SO2) and 200 Tg of fine ash over two eruption phases in May and June when meteorological conditions are such that the complex distribution of the ash plume is replicated. We find that the fine ash causes a heating of the volcanic could which has a significant downstream impact on the dispersion of the LSE cloud. Depending on the height of the injection, our simulated volcanic cloud begins to rotate shortly after the eruption. These meso-cyclones alter the southward dispersion of the cloud compared to dispersion estimated without the heating of the fine ash. Sulfate transport is similarly affected by ash heating. This results in greater transport to low latitudes, later arrival of the volcanic cloud in Arctic regions, and longer lifetimes compared to cases without injection of fine ash. In part, these results may explain the lack of Laacher See tephra in the Greenlandic ice-cores. In closing, we discuss the impact of this rotating and relatively stationary ash cloud on human populations in the affected region.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Dynamical downscaling and regional data assimilation for a cold-air outbreak in the European Alps during the Year Without Summer 1816

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The "Year Without a Summer" of 1816, attributed to the Tambora eruption, was characterized by exceptionally cold periods in Central Europe and lead to severe crop failures, and famine, among other impacts. Traditional reconstruction of such extreme climate and weather events of the past centuries typically rely on documentary evidence, eye observations and early instrumental measurements, where available.

Here, we provide novel numerical analyses of the atmospheric flows during that summer, e.g., in the form of weather maps with hourly and 3-km horizontal resolution, for a cold weather episode over the European Alps in early June 1816. For this, we nest a regional weather model into a global reanalysis product. Comparisons to sub-daily measurements and observations of air temperature, pressure, cloud cover, sunshine, wind velocity and direction reveals high plausibility of the meso-scale simulation. For instance, freezing levels were mostly around or below 1500 m a.s.l., and daily maxima rarely exceeded 10 °C, even at lower elevations. However, the simulations do not very well mimick observed pressure minima, drops and increases.

Aiming for improvements, recently digitized station series of temperature and pressure are used for a three-dimensional variational data assimilation (3DVAR). Preliminary results from 3DVAR suggest that dynamic downscaling, combined with data assimilation may be a promising approach to obtain physically consistent information about volcano-induced weather at local and sub-daily scales. In turn, this could open the door for applications like crop-growth modeling or other impact assessments.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

The contribution of wood cell anatomy for reconstructing past climate

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Tree rings provide valuable proxies to assess the impact of large volcanic eruptions on climate and societies. The cooling induced by the presence of stratospheric aerosol blocking the incoming solar radiation is recorded by temperature sensitive trees which usually grow narrower rings with a less dense latewood. These characteristics have thus been used to assess the timing, intensity and persistence of the cooling. However, depending on the proxy (TRW vs maximum latewood density) the response may differ slightly due to intrinsic proxy properties, and cause uncertainty in the assessment.

Detailed measurements of the anatomical characteristic of the tracheids forming the annual rings have the potential to provide a more nuanced picture of the spatial and temporal characteristic of the cooling generated by the volcanic event. Frost rings, light rings and blue rings are particularly promising cases of cell-based markers of distinct cold spells.

In our team we have now performed an unprecedented set of measurements of cell anatomical features along millennial long tree-ring chronologies at several sites in the northern hemisphere. The datasets are carefully evaluated to assess their ability to be used for climatic reconstructions, which reveal excellent performance (common and climatic signals). Together with the possibility of increased temporal and spatial resolution, we believe these datasets could contribute to better assess the impact of stratospheric volcanic events over the past millennia. With this poster we would like to share our major findings and discussing the pros and cons of such novel proxy for climatic and volcanic reconstructions.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Wine, vacherin and volcanoes: impacts of the 17th century large volcanic eruptions

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It is today undisputed that the volcanic eruption of Tambora in 1815 caused a year without summer in Central and Western Europe, which led to crop failures, inflation, disease and famine. However, little attention has been paid to the teleconnections of the great volcanic eruptions in the 17th century on agriculture and society in early modern Switzerland.

Using a regional example, the present study attempts to examine the climatological and socio-economic effects of those eruptions and the coping strategies that were developed as a result. For several centuries, the Hôpital des Bourgeois de Fribourg meticulously recorded every year all their harvests of crop, wine and dairy products - such as the famous Vacherin cheese - and the number of cattle slaughtered. These primary or secondary climate proxies can be examined for potential climatological effects.

As an institution, the Hôpital des Bourgeois de Fribourg possesses, in addition to these account books, an archive with an extended corpus of sources documenting the history of this institution. This novel archive material, such as the memorabilia, the manuaux and the regulations, allows us to draw conclusions about the socio-economic impact of the climate crises of the 17th century and the responses of this important social and economic institution. These findings can then be compared with modern climate reconstruction data from the ModE-RA project to better assess the interrelation between the two. In other words, we will see how volcanoes affected Fribourg's viticulture in the plains and their Vacherin production in the mountains.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Remarkably high blue ring occurrence in Estonian Scots pines in 1976 reveals wood anatomical evidence of extreme autumnal cooling

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Blue rings (BRs) are recently discovered, visual reflections of reduced cell wall lignification. They have been associated with ephemeral end of growing season cooling, often following large volcanic eruptions, though much remains unknown about the specific temperature conditions that trigger their formation. Answering this methodological unknown is pinnacle to understanding the potential of BRs as a climate proxy. Here, we analyse incidences of BRs alongside daily-resolution meteorological measurements, applying novel methods (e.g., the trapezoidal rule) to further constrain the temperature conditions associated with their formation. A total of 14 Scots pine (*Pinus sylvestris* L.) trees were sampled from two sites in Estonia, five of which were sampled throughout the tree stem. Occurrences of BRs were analysed alongside local daily-resolution meteorological measurements from 1901-2019 CE. Tree-ring width and density chronologies were developed to explore if these parameters captured the temperature conditions inferred by BRs. Our BR results were inconsistent in most years, with BRs occurring in the minority of trees sampled and presenting irregular distributions throughout the tree stem. However, one year was a clear anomaly: 1976. BRs were present in 11 out of 14 trees sampled in 1976, and were identified in all samples from four of the five trees sampled throughout the tree stem. A paralleled anomaly occurred in the climate analysis, 1976 had the most extreme end of growing season cooling signal of the entire time period studied. Though 1976 is renowned for a summer heatwave in Northwest Europe, we reveal extreme low temperature anomalies spanning Eastern Europe in the autumn, linked with a negative phase of the NAO. The ring width and density results for 1976 were not remarkable however, and these traditional dendrochronological parameters were found to not be sensitive to growing season temperatures in this region. Our findings demonstrate the paleoclimatic value of BRs for recording the most extreme end of growing season cooling, which ring width and density measurements may not necessarily be sensitive to. Applied to volcanism, insights from this study will add further paleoclimatic meaning to the use of BRs as a proxy for cooling following large eruptions.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

The volcanic summers of 1690s in daily weather records from Europe

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The 1690s was a cold decade in Europe. Most noteworthy is the cold and wet summer of 1695, but other seasons and years in this decade were also cold. While several annually or seasonally resolved reconstructions are available for this period, the question arises whether daily weather reconstructions are possible to address not only the general cooling, but the weather variability during this period. For this presentation I will compile information on daily weather in Europe from as many sources as possible and present an overview of the daily weather. I will focus particularly on the weather diary from Georg Christoph Eimmart in Nuremberg and will analyse the summer of 1695 in this diary in the context of the global monthly reconstructions EKF400v2.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Etesian winds after large volcanic eruptions in the last millennium

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The northerly Etesian winds are a stable summertime circulation system in the eastern Mediterranean, emerging from a steep pressure gradient between the central Europe and Balkans high-pressure and the Anatolian low-pressure systems. Etesian winds are influenced by the variability in the Indian summer monsoon (ISM), but their sensitivity to external forcing on interannual and longer timescales is not well understood. We investigate the sensitivity of Etesian winds to large volcanic eruptions in a set of model simulations over the last millennium and reanalysis of the 20th century. We provide model evidence for significant volcanic signatures, manifested as a robust reduction in the wind speed and the total number of days with Etesian winds in July and August. These are robust responses to all strong eruptions in the last millennium, and in the extreme case of Samalas, the ensemble-mean response suggests a post-eruption summer without Etesians. The significant decline in the number of days with Etesian winds is attributed to the weakening of the ISM in the post-eruption summers, which is associated with a reduced large-scale subsidence and weakened surface pressure gradients in the eastern Mediterranean. Our analysis identifies a stronger sensitivity of Etesian winds to the Northern Hemisphere volcanic forcing, particularly for volcanoes before the 20th century, while for the latest large eruption of Pinatubo modelled and observed responses are insignificant.

On site poster (Poster session 2 - Tuesday 15:30-17:30)

Climatic conditions in Santa Fe city, Argentina, after the 1815 Tambora eruption: Insights from a personal diary

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Currently there is a limited knowledge on southeastern South America (SESA) climate responses to the 1815 Tambora eruption. Here we provide new insights on these responses by analyzing a personal diary written from 1815 to 1822 in the Argentinian city of Santa Fe, located in SESA near the Paraná River. The climate information of this document was used to generate four-category indices of rainfall and surface air temperature (SAT). Due to information gaps, these indices were used to analyze interannual climate variability only during 1818–1821. The rainfall index and pro-pluvia rogations recorded in the diary reveal a severe drought that occurred in 1819–1820, at the end of the 1818–1820 La Niña event which was probably related to the 1815 Tambora eruption. This result is consistent with the present-day relationship observed between rainfall and La Niña events in Santa Fe city. Low Paraná River water levels and fires occurred during the 1819–1820 drought. An upward SAT trend found in 1819–1821 may reflect (i) a temperature increase after the post-Tambora eruption radiative cooling, and/or (ii) anomalous low SATs associated with the possibly Tambora-related La Niña event of 1818–1820.