ABSTRACT BOOKLET

Sixth VAO Symposium
21–23 March 2023
Grainau, Germany

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Crespi et al. (eurac)	X-RISK-CC: HOW TO ADAPT TO CHANGING WEATHER EXTREMES AND ASSOCIATED COMPOUND AND CASCADING RISKS IN THE CONTEXT OF CLIMATE CHANGE
Krautblatter et al. (TUM)	ALPSENSE-RELY: CHALLENGING THE PREDICTABILITY OF CLIMATE-INDUCED IMPACTS ON ALPINE HAZARDS (STMUV PROJECT)
Leinauer et al. (TUM)	THE HOCHVOGEL OUTDOOR LABORATORY: DECIPHERING THE PREPARATORY PHASE OF ROCK FALLS
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Lucks et al. (TUM)	MULTITEMPORAL CLUSTERING OF THERMAL IMAGES FOR ANALYSIS OF PERMAFROST OCCURRENCE IN STEEP ROCK WALLS.
Scandroglio et al. (TUM)	CLIMATE CHANGE EFFECTS IN ALPINE PERMAFROST: 15 YEARS OF GEOELECTRICAL MONITORING IN THE KAMMSTOLLEN (ZUGSPITZE, D/A)
Seehaus, Braun (FAU)	MEASURING AND MODELLING MOUNTAIN GLACIERS AND ICE CAPS IN A CHANGINGCLIMATE (INTERNATIONAL DOCTORAL PROGRAM M³OCCA)
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Jobin et al. (UNIBE)	TEMPERATURE DEPENDENT FRACTIONATION EFFECTS ON OXYGEN MEASUREMENTS
Leuenberger et al. (UNIBE)	COMBINED OXYGEN AND CARBON DIOXIDE MEASUREMENTS AS TOOL FOR THE PARTITIONING OF CARBON DIOXIDE EMISSIONS AMONG THE CARBON POOLS ATMOSPHERE, BIOSPHERE AND OCEAN
Nowak et al. (PSI)	VOLATILITY OF ATMOSPHERIC ORGANIC AEROSOL DETECTED AT JUNGFRAUJOCH

Schmidt *et al.* (DLR)	OBSERVATIONS OF OH AIRGLOW AT THE UFS SCHNEEFERNERHAUS:1) LONG-TERM DEVELOPMENT AND 2) ATMOSPHERIC WAVES RELATED TO THE HUNGA TONGA-HUNGA HAPAAI ERUPTION
Sedlmeier et al. (DWD)	TREASURE HUNTING OF SCIENCE: HISTORICAL DATASET FOR THE BERCHTESGADEN NATIONAL PARK
Steinbacher et al. (EMPA)	ATMOSPHERIC TRACE GAS IN-SITU OBSERVATIONS AT JUNGFRAUJCOH – BENEFITS AND CHALLENGES OF SERVING MULTIPLE PROGRAMMES
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Knapp (SEVAN)	THE SEVAN PARTICLE DETECTOR NETWORK
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Ploc et al. (CAS)	CONTRIBUTION OF HIGH-ENERGY ATMOSPHERIC PHENOMENA TO NATURAL RADIATION BACKGROUND ESTIMATED USING GASTRON: GAMMA SPECTROMETRY OF THUNDERSTORM RADIATION OBSERVATORY NETWORK
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Koch et al. (BOKU)	OBSERVING CRYOSPHERIC AND HYDROLOGICAL PROCESSES AND STORAGES AT HIGH-ALPINE CATCHMENT SCALES BY A SUPERCONDUCTING GRAVIMETER AT THE TOP OF MT. ZUGSPITZE
Koehler et al (DLR)	THE POTENTIAL OF EARTH OBSERVATION TO ASSESS THE IMPACT OF CLIMATE CHANGE ON THE ALPINE SNOW LINE ELEVATION
Mejia-Aguilar et al. (eurac)	IN-SITU AND PROXIMAL SENSING INFRASTRUCTURE FOR IMPROVED WATER RESOURCE MANAGEMENT
Zellner et al. (eurac)	THE ALPINE DROUGHT OBSERVATORY: AN ALPINE WIDE OPERATIONAL DROUGHT MONITORING PLATFORM

Wednesday 22 March 2023	
15:10	Wagner et al. (DWD), **INVESTIGATION OF AEROSOL-CLOUD-RADIATION INTERACTION DURING DUST EPISODES IN THE GREATER ALPINE REGION**
15:35	**Coffee break, end of session III**
16:00	**Session IV: Environment and human health** (Session Chair: Prof. Dr. Rudolf M. Huber (LRZ))
16:25	Baier et al. (DLR), **PROJECT ALPAIREO: HEALTH RISK BY AIR POLLUTION AND THERMAL STRESS IN THE ALPS**
16:50	Hierlmeier-Hackl (LfU), **PROTECTALPS- PERSISTENT, BIOACCUMULATIVE AND TOXIC CHEMICALS IN WILD ALPINE INSECTS**
17:15	Kloos et al. (TUM), **ANALYZING THE IMPACT OF TIME AND WEATHER ON DAILY WINTER TOURIST NUMBERS IN THE BAVARIAN ALPS USING WEBCAM IMAGES**
17:40	Knapp (SEVAN), **THE SEVAN PARTICLE DETECTOR NETWORK**
18:05	Ploc et al. (CAS), **CONTRIBUTION OF HIGH-ENERGY ATMOSPHERIC PHENOMENA TO NATURAL RADIATION BACKGROUND ESTIMATED USING GASTRON: GAMMA SPECTROMETRY OF THUNDERSTORM RADIATION OBSERVATORY NETWORK**
18:30	End of session IV
19:30	**Side event – Conference Dinner, Hotel Hammersbach**

Thursday 23 March 2023	
09:00	**Opening speech: ESA (Dr Christian Retscher)**
	Session V: Alpine water cycle (Session Chair: PD Dr habil Sabine Wüst (DLR))
09:15	Groos et al. (FAU), **MONITORING AND MODELLING ALPINE GLACIER CHANGE AT DIFFERENT SPATIAL AND TEMPORAL SCALES**
09:40	Koch et al. (BOKU), **OBSERVING CRYOSPHERIC AND HYDROLOGICAL PROCESSES AND STORAGES AT HIGH-ALPINE CATCHMENT SCALES BY A SUPERCONDUCTING GRAVIMETER AT THE TOP OF MT. ZUGSPITZE**
10:05	Koehler et al. (DLR), **THE POTENTIAL OF EARTH OBSERVATION TO ASSESS THE IMPACT OF CLIMATE CHANGE ON THE ALPINE SNOW LINE ELEVATION**
10:30	**Coffee break / Poster session with author presence**
11:05	Zellner et al. (eurac), **THE ALPINE DROUGHT OBSERVATORY: AN ALPINE WIDE OPERATIONAL DROUGHT MONITORING PLATFORM**
11:30	Mejia-Aguilar et al. (eurac), **IN-SITU AND PROXIMAL SENSING INFRASTRUCTURE FOR IMPROVED WATER RESOURCE MANAGEMENT**
12:00	**End of symposium / Lunch / Side event UFS**

12:27	Departure rack railway – Station Hammersbach
13:28	Arrival Sonnalpin, Zugspitze
14:00 – 15:00 p.m.	Guided tour through the UFS
16:45	Last descent with the cable car from the summit Zugspitze (Individual departure)

Contact

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Registration
Please register at
www.vao.bayern.de
Deadline for registration is 26 February, 2023.
The number of participants is limited to 120 persons

Hosted by
Environmental Research Station
Schneefernerhaus GmbH (UFS)

Virtual
Alpine
Observatory

Programme

Umwelt
Forschungsstation
Schneefernerhaus

6th VAO Symposium,
21–23 March 2023

VENUE

Berghotel Hammersbach
Kreuzeckweg 2–6
82491 Grainau
T. +49 8821 9830
www.haus-hammersbach.de

Tuesday 21 March 2023

09:00	Arrival, welcome coffee & registration	
10:00	**Welcome Notes:** Dr Christian Barth, StMUV	
10:15	**Key Note: Enhancing research in the Alpine regions to deliver on the European Green Deal** (General Secretary Petr Blížkovský, CoR)	
10:30	**Key Note: Destination Earth and opportunities for member states** (Dr Christian Kirchsteiger, EU COM and Franka Kunz, DLR)	
11:00	**Key Note: MRI/GEO Mountains** (James Thornton)	
11:20	**Key Note: VAO** (Prof. Dr Bittner, UAU, DLR)	
11:40	**Key Note: Space physics at observatory LOMNICKY STIT in Slovakia** (Prof Dr Simon Mackovjak)	
12:00	**Group Photo**	
12:10	**Lunch and coffee**	12:20 – 16:30 **Closed side event "Visit of UFS"** (Departure cogwheel train: 12:27 p.m.)
13:00	**Key Note: Climate-resilient Alps** (Prof Dr Kunstmann, UAU, KIT)	
13:35	**Session II: Climate impact on Alpine environment, hazards and risks** (Session Chair: Prof Dr Markus Leuenberger (HFSJG))	
13:35	Barbosa et al. (LMU), **EARLY IDENTIFICATION OF HOTSPOTS USING REMOTE SENSING TECHNOLOGIES WITHIN THE ALPSENSERELY PROJECT.**	
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14:50	Lindner et al. (LMU), **SEISMIC MONITORING OF PERMAFROST AT MT. ZUGSPITZE**	
15:15	**Coffee break**	
15:35	**Session II cont'd** (Session Chair: Prof. Dr Markus Leuenberger (HFSJG))	
16:00	Lucks et al. (TUM), **MULTITEMPORAL CLUSTERING OF THERMAL IMAGES FOR ANALYSIS OF PERMAFROST OCCURRENCE IN STEEP ROCK WALLS**	
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17:40	**End of session II / Session III: Atmospheric and climatic variability** (Session Chair: Dr Hannes Vogelmann (KIT))	
17:40	Bichler, Bittner (DLR), **COMPARISON BETWEEN ECONOMIC GROWTH AND SATELLITE OBSERVATIONS OF NO_2 POLLUTION OVER THE PO VALLEY**	
18:05	**End of session III (part 1)**	

Wednesday 22 March 2023

09:00	**Opening speech: Alpine Convention** (Secretary General Alenka Smerkolj)	
09:15	**Session III cont`d: Atmospheric and climatic variability (part 2)** (Session Chair: Dr Jaroslav Chum (CAS))	
09:15	Frischholz et al. (DLR), **INFLUENCE OF PLANETARY WAVES IN THE TROPOSPHERE ON TEMPERATURE EXTREME EVENTS AT THE GROUND**	
09:40	Wüst et al. (DLR), **HYDROXYL AIRGLOW OBSERVATIONS FOR INVESTIGATING ATMOSPHERIC**	
10:05	Hannawald et al. (DLR), **3D RECONSTRUCTION OF ATMOSPHERIC GRAVITY WAVES AND DERIVATION OF VERTICAL WAVE PARAMETERS WITH TOMOGRAPHY APPLIED TO DATA FROM TWO GROUND-BASED CAMERAS OBSERVING OH AIRGLOW**	
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13:15	**Lunch**	
14:15	**Poster session with author presence**	13:30 – 14:30 **Closed Side-meeting VAO Board**
	Crespi et al. (eurac), **X-RISK-CC: HOW TO ADAPT TO CHANGING WEATHER Extremes**	
	Flentje et al. (DWD), **IDENTIFICATION AND MONITORING OF SAHARAN DUST**	
	Sedlmeier et al. (DWD), **TREASURE HUNTING OF SCIENCE: HISTORICAL DATASET FOR THE BERCHTESGADEN NATIONAL PARK**	
	Krapp et al. (LfU), **PESTICIDES IN THE DEPOSITION AT ENVIRONMENTAL RESEARCH STATION**	
	Olena Velychko et al. (CAS), **STAND-ALONE GAMMA SPECTROMETER GEODOS01 FOR DETECTION OF HIGH-ENERGY RADIATION BURSTS IN MOUNTAINS**	
	Couret (UBA), **50 YEARS OF CO_2 MEASUREMENTS AT STATIONS FROM THE GERMAN ENVIRONMENT**	
14:45	**Session III cont`d: Atmospheric and climatic variability (part 3)** (Session Chair: Dr Jaroslav Chum (CAS))	
14:45	Jobin et al. (UNIBE), **TEMPERATURE DEPENDENT FRACTIONATION EFFECTS ON OXYGEN MEASUREMENTS**	

SPACE PHYSICS AT OBSERVATORY LOMNICKY STIT IN SLOVAKIA

Ján Kubančák, Ronald Langer, Simon Mackovjak, Igor Strhárský, Samuel Štefánik

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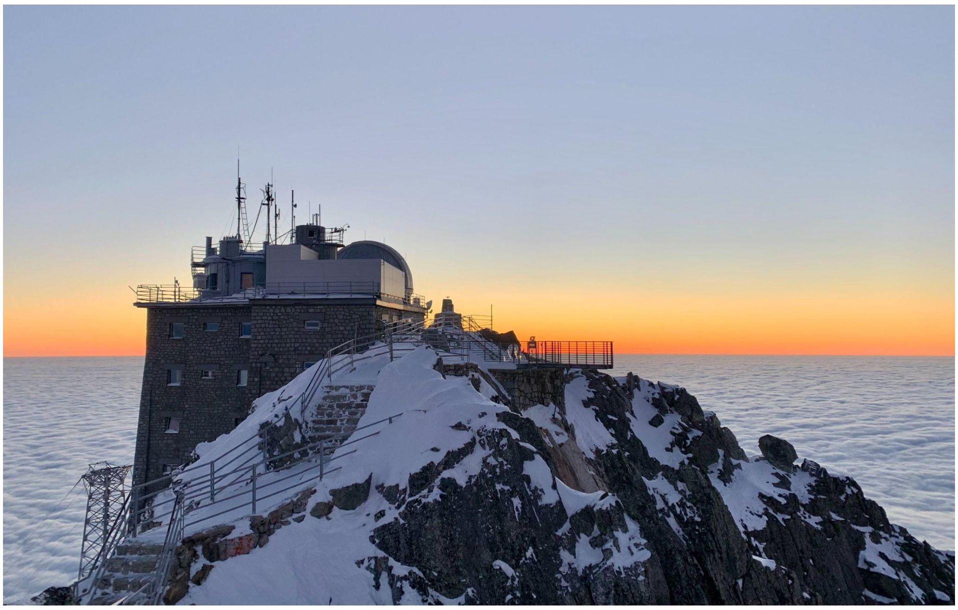
Abstract

The observatory was established at the top of Lomnicky stit (2634 m a.s.l.) in High Tatra Mountains in Slovakia in 1957 (Dubinský et al., 1960). Its primary goal is to provide measurements of space phenomena that are possible only in a high-altitude environment. Specifically, the secondary cosmic rays with cutoff rigidity ~ 4 GV are measured by the 8-tube NM64 Neutron monitor that has been in continuous operation since 1981 (Kudela et al., 2009). Data according to international standards are available with 1 min resolution through the network of neutron monitors (LMKS, https://www.nmdb.eu). The additional cosmic rays instrument SEVAN (Space Environmental Viewing and Analysis Network) has been in operation since 2014. Its capability is to measure various species of secondary cosmic rays and also to detect the geometry of particles' trajectories. In recent years, the data of space radiation are supplemented by measurements of the atmospheric electric field to explore connections between space and atmospheric weather events (Chum et al., 2021). The conditions and available infrastructure at Lomnicky stit allow also the acquisition of various other data such as solar corona images, meteorological, climatological, and geophysical parameters. During the contribution, details of the observation program will be presented and possibilities of contribution to the VAO network will be discussed.

Type of presentation: Oral
Topic of presentation: Improving the VAO infrastructure



Observatory at the top of Lomnicky Stit in the High Tatra Mountains in Slovakia (January 2023).

IN-SITU AND PROXIMAL SENSING INFRASTRUCT ER RESOURCE MANAGEMENT

Abraham Mejia-Aguilar[1], Paul Schattan[2,3], Roberto Mendicino[1], Giovanni Cuozzo[4], Ludovica de Gregorio[4], Claudia Notarnicola[4]

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ABSTRACT

The symbolic concept of world water towers refers to the capacity of mountains and uplands to provide freshwater to lowland watersheds. Rivers, streams, or any other waterbody constitute the watershed. The most emblematic world water towers in Europe are the Alps. Due to the global rise in temperature, the precipitation patterns have changed, resulting in long dry periods and short and very-intense rain events, represented by drought and floods, respectively. In parallel, with the accelerated melting process of glaciers in the mountains and snow shortage periods, freshwater availability will considerably reduce during the following years. Monitoring hydrological parameters in mountain and remote areas mainly relies on measuring water runs off. This variable is insufficient to ingest real-time models for forecasting water supply for many ecosystems. There are many limitations to developing monitoring infrastructure that provides high-quality data, overcomes the terrain's difficulty, and reduces the spatial heterogeneity of precipitation and water storage. One solution is to deploy large soil moisture, snowpack, and weather sensor networks. However, it is costly and difficult to maintain. Another possibility is using remote sensing products to measure soil moisture and snow coverage. Unfortunately, the spatial resolution is too large for the variability of mountain conditions due to terrain changes. Between these two scales, a technique based on measuring the attenuation of cosmic rays. The retrieved signal is related to the interactions with hydrogen, directly proportional to snow water equivalent and soil water content. This technique offers an advantage because it is non-invasive and does not disrupt the environment. Additionally, its considerable horizontal range and ability to penetrate depths of several centimeters, sufficient to reach the typical rooting depth, make it superior to remote sensing estimates. In this work that has been running for three years, we present a hardware and software infrastructure that provides quasi-near-real-time information based on an online system. It consists of a Cosmic Ray Neutron Sensor (CRNS), a photogrammetry station, and additional sensors (soil moisture, snow depth). In addition, we fusion UAV-based orthomosaics and digital surface models produced every year, to understand the footprint of the CRNS that can act as a validation site for an up-scale remote sensing method..

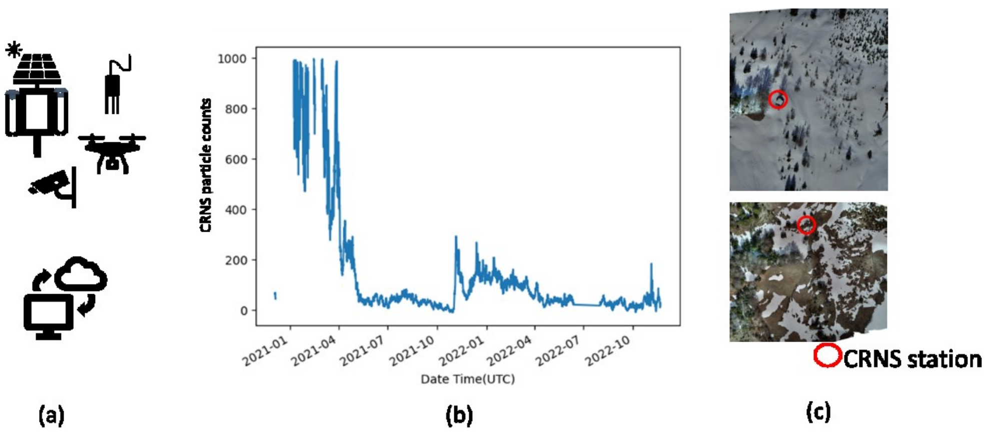

Figure 1. (a) CRNS infrastructure concept with the (b) cosmic counts that will derive in snow water equivalent and (c) UAV-based orthomosaics for data validation, spatial distribution and homogeneity.

ENHANCING RESEARCH IN THE ALPINE REGIONS TO DELIVER ON THE EUROPEAN GREEN DEAL

Petr Blížkovský

Secretary-General of the European Committee of the Regions

ABSTRACT

Despite a substantial increase in the climate change knowledge base, there is still a big knowledge gap on the effects of climate change in mountain ranges, including data on impacts and risks, adaptive capacities, rising population displacement, and the acceleration in biodiversity loss, among many others.

In comparison with other regions, the Alpine region has geographic, economic, demographic and social features that need to be taken into account in the design and implementation of European climate and environment policies. Otherwise, there is a risk of increasing social and economic inequities, which would consequently undermine efforts to achieve sustainable development, particularly for vulnerable and marginalized communities in mountain areas.

In this regard, the Virtual Alpine Observatory ensures the economic, social and environmental interests in the Alpine regions by providing a platform for bringing together various actors, policies and financial resources. The European Committee of the Regions invites the VAO to join its European Groupings of Territorial Cooperation (EGTCs), which is the first European cooperation structure defined by European law and designed to facilitate and promote territorial cooperation.

EARLY IDENTIFICATION OF HOTSPOTS USING REMOTE SENSING TECHNOLOGIES WITHIN THE ALPSENSERELY PROJECT.

Natalie Barbosa[1,2], Juilson Jubanski[3], Ulrich Münzer[4], Florian Siegert[1,3].

[1]Department of Earth and Environmental Sciences, Faculty of Earth Sciences, GeoBio Center, Ludwig-Maximilians-University, Munich, Germany.,[2]Chair of Landslide Research, Technical University of Munich, Munich, Germany., [3]3D RealityMaps GmbH, Munich, Germany., [4]Department of Earth and Environmental Sciences, Section Geology, Ludwig-Maximilians-University, Munich, Germany.

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ABSTRACT

In the last decade, the ongoing effects of climate change have caused significant changes to Alpine landscapes. Glacier retreat and slope instability have disrupted landscape dynamics and increased the potential for natural hazards, making early identification of hazardous areas (hotspots) throughout the Alps essential for developing adaptation strategies for Alpine communities. Through the AlpSenseRely project, we employe multi-temporal, multi-scale monitoring to detect and predict future climate-related natural hazards.

Starting in 2009, German and Austrian survey institutions have acquired high-resolution digital aerial imagery every 2-3 years, with a horizontal resolution of 20 cm. Photogrammetric reconstruction of true-orthophotos and digital elevation models (DEM) enable us to accurately identify landscape changes over 2-10 years across mountain regions. By analyzing changes in topography over time, we identified 28 locations within five test sites representing potential natural hazards in the Alps, including slope instabilities, debris flows, and glacier lake outburst floods (GLOFS). The hotspots areas were later classified according to their climatic control and potential triggering factors.

Early identification of potentially dangerous areas allows for targeted analysis of present risks and enables governmental authorities to recognize and assess future climate-related natural hazards, making optimal decisions in the face of the changing Alpine environment.

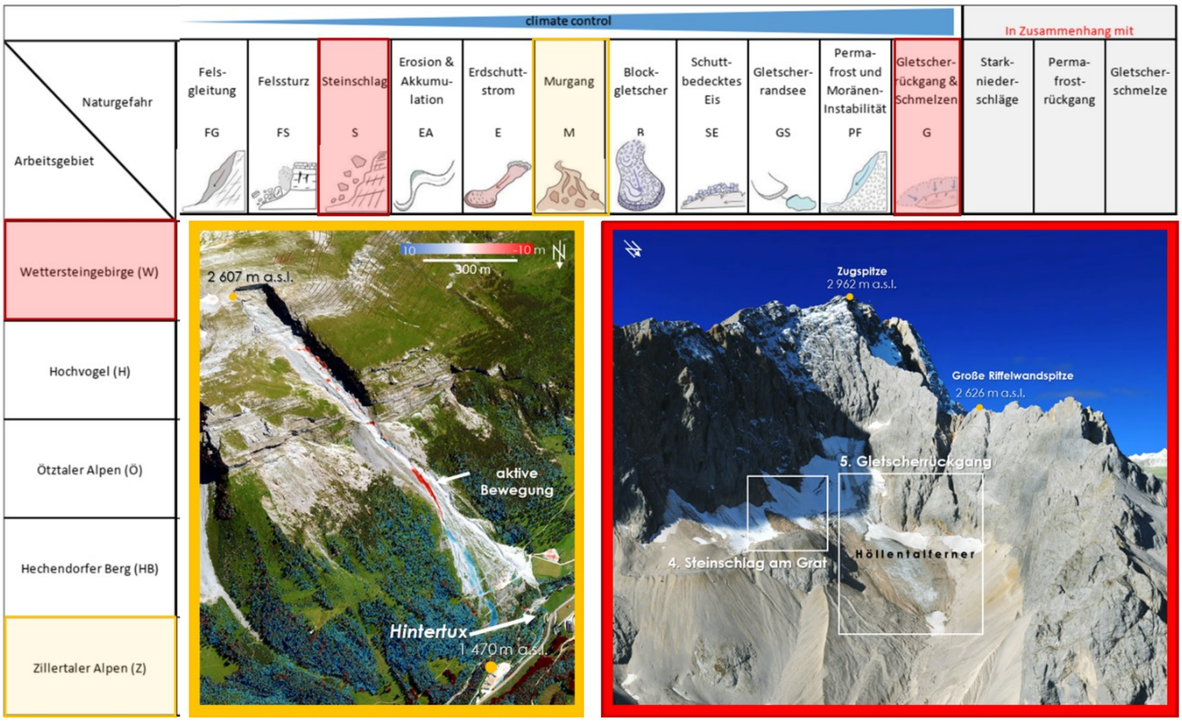

Fig 1. Classification matrix of climate-related natural hazards (after Krautblatter and Leinauer, 2022)[1].

[1]*Krautblatter, M; Leinauer, J; Siegert, F; Münzer, U; Barbosa, N; Mayer, C; (2022), AlpSenseRely report. Identifikation und Klassifizierung von Hotspots anhand von fernerkundlichen Differenzmessungen. 43 pp.*

ALPSENSE-RELY: CHALLENGING THE PREDICTABILITY OF CLIMATE-INDUCED IMPACTS ON ALPINE HAZARDS (STMUV PROJECT)

Krautblatter Michael[1], Leinauer Johannes[1], Braun, Matthias[2], Holst, Christoph[3], Keuschnig Markus[4], Kraushaar Sabine[5], Mayer Christoph[6], Münzer Ulrich[7], Siegert Florian[8,9], Stilla Uwe[10]

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ABSTRACT

Increased frequencies and magnitudes of climate-related alpine hazards in the last three decades significantly threaten alpine communities, infrastructure, and economies. Rock falls, slope failures, debris flows, and other mass movements show increasing response to melting glaciers, degrading permafrost and more frequent heavy rainfall events. In the foreseeable future, alpine hazards beyond our historic recognition will occur and scientific understanding is the only anticipative tool to prepare for the related risks. Therefore, we need dedicated research in risk anticipation, clever early warning strategies and purposive measures. Until now, a systematic analysis of the predictive power of a multi-method approach for climate-induced natural hazards is missing.
AlpSenseRely is a 3-year project funded by the Bavarian STMUV and aims at anticipating climate induced natural hazards comprehensively at an early stage for Bavaria and the European alpine region. AlpSenseRely quantifies the climate forcing and provides all relevant information for preparation of future events. The project systematically explores the capacity of space-borne, air-borne, and terrestrial high-resolution observation and monitoring in a changing climate. For this, we have chosen six representative test sites mostly in the critical 2000-3000+ m a.s.l. range of the eastern Alps, where the effects of climate change are most evident and cause frequent landslides and permafrost- or glacier-degradation related hazards in the vicinity of a dense tourist infrastructure. The test sites all (i) undergo massive environmental change, (ii) cause frequent natural hazards, (iii) have well-established and relatively dense tourist infrastructure and (iv) provide unique long-term observation and monitoring histories often dating back to the 19th century.

Here, we present the setup and preliminary results of the AlpSenseRely project: (i) monitoring at the test sites, (ii) integration of stakeholders, (iii) identification of hazard hotspots, (iv) modelling of hazardous objects, (v) near real-time monitoring and early warning strategies and (vi) 3D visualization.

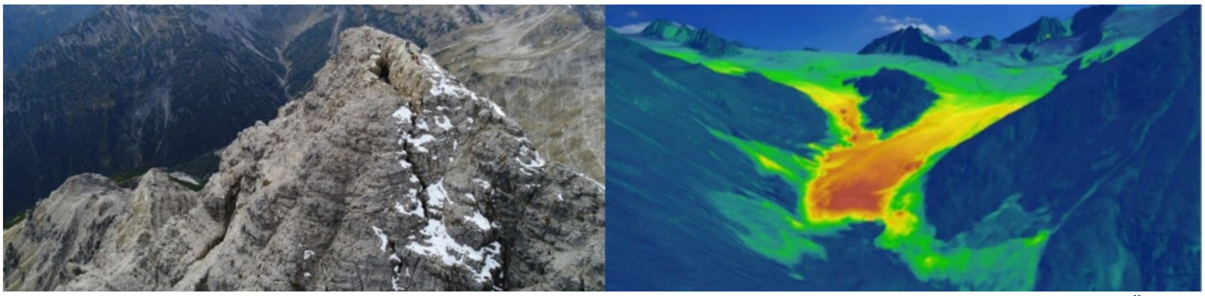

Figure 1: Imminent rock slope failure at the Hochvogel and regional change detection from Ultracam images in the Ötztal valley.

THE HOCHVOGEL OUTDOOR LABORATORY: DECIPHERING THE PREPARATORY PHASE OF ROCK FALLS

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ABSTRACT

In the Alps, numerous historic high-magnitude rock slope failures are known while well-equipped pre-failure research sites are rare. The Hochvogel (2592 m a.s.l., Allgäu Alps, GER/AUT) is paradigmatic of slope failure dynamics in high alpine carbonate rock. The imminent failure and ongoing movement of >200,000 m³ in the range of 1–2 cm/a make this site a benchmark for developing effective monitoring and early warning under the effects of climate change. As part of the AlpSense project (www.cee.ed.tum.de/landslides/alpsense), we are observing the instable mass during failure preparation and until failure since 2018. By combining continuous and periodical observations, we systematically explore the capacity of space-borne, air-borne, and terrestrial high-resolution multi-method monitoring. Our continuous monitoring system includes multiple crackmeters, surface inclinometers, thermistors, a rain gauge, and a webcam which send their data wirelessly every 10 min. A network of 4-7 geophones is additionally monitoring wave velocity changes and the seismic signals of stress release events at the summit. These observations are complemented by the project partners with geodetic, photogrammetric, gravimetric, UAV and remote sensing surveys in epochs during summer months as well as continuous dGNSS measurements with two rovers.

Here we feature a 4-year high-resolution movement record and corresponding measurements from a preparing imminent rock slope failure and their indications for preparation phase process dynamics under climate forcing. The decipherment of anticipative signals at the Hochvogel is contributing to an improvement of reliable early warning.

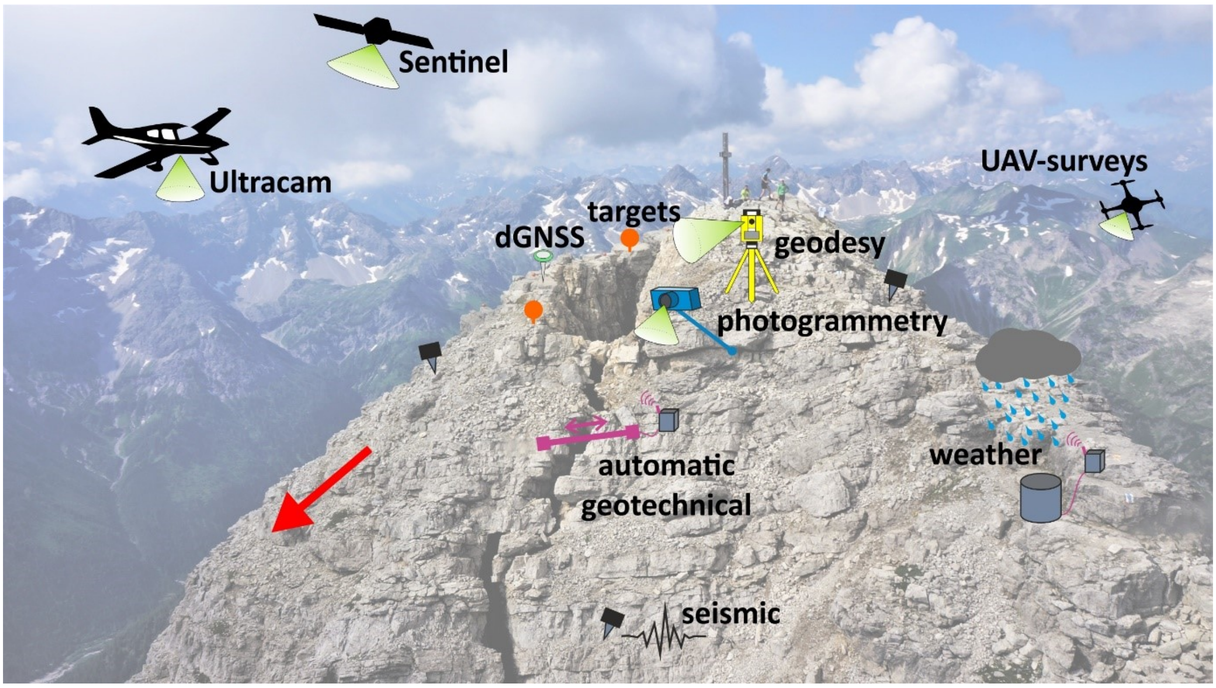

Figure 1: Multi-method approach at the Hochvogel outdoor laboratory.

SEISMIC MONITORING OF PERMAFROST AT MT. ZUGSPITZE

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ABSTRACT

Degradation of mountain permafrost in response to global warming reduces the stability of steep rock slopes, which increases the hazard potential for humans and infrastructure. However, continuous monitoring of permafrost environments remains challenging due to the harsh conditions typically encountered in high Alpine terrain. To monitor permafrost at Mt. Zugspitze in the German/Austrian Alps, we employ passive seismic methods, which require comparatively little field efforts and maintenance, but provide continuous recordings. Using a single seismic station originally installed for earthquake monitoring, we track changes in the seismic wave velocity, which is affected by the thermal properties of the rock mass, in particular we expect a strong velocity change upon thawing and freezing. Our results reveal seasonal freeze-thaw cycles and permafrost degradation over the past 17 years (Fig. 1), consistent with modeled velocity changes using temperature logs from a borehole beneath the summit. To constrain the location of these changes, we installed three small seismic arrays along the ridge of Mt. Zugspitze in summer/fall 2021 and exploit the cable car operations at the summit as seismic sources for our investigations. The results suggest that significant seasonal freeze-thaw cycles associated with permafrost bodies only occur in the western part of the ridge, which is also favored by thermal modeling. To further pinpoint the presence of permafrost, we repeatedly employ distributed acoustic sensing (DAS) along the ridge. DAS is an optical measurement along a fiber-optic cable that allows to sense seismic wave propagation on a meter-scale and thus provides unprecedented spatial resolution for seismic methods. In addition to the thermal rock properties, we find that the seismic velocity is sensitive to the presence of cleft water, which may critically contribute to the stability of rock walls. In contrast to more classical methods like borehole temperature logging and electrical resistivity monitoring, seismology combines high temporal resolution and spatial insights over comparatively large areas and thus constitutes a valuable contribution to permafrost monitoring.

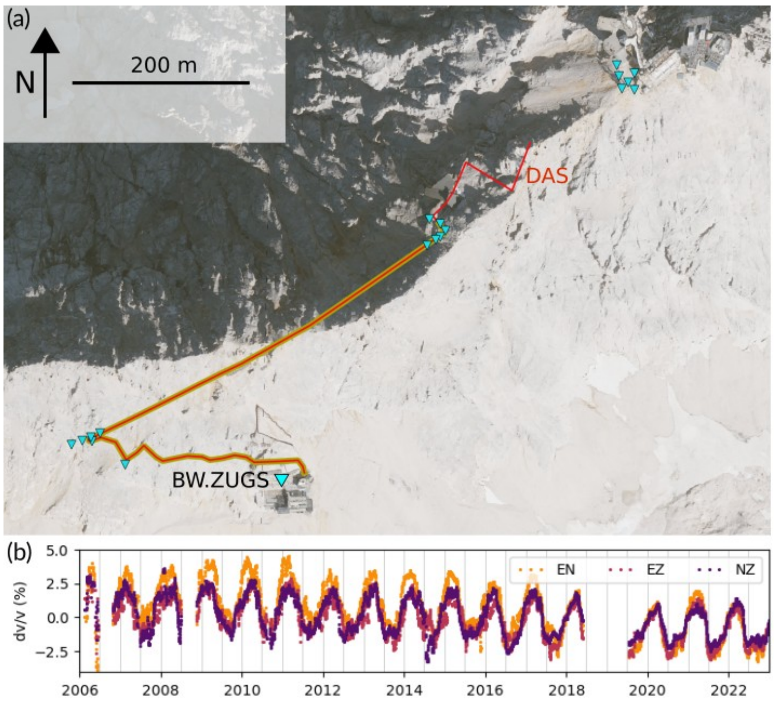

Fig 1: *(a) Orthophoto of Mt. Zugspitze showing the locations of our seismometers (turquoise triangles) and the path of the fiber-optic cable used for distributed acoustic sensing (DAS, red line). (b) Relative changes of the seismic velocity dv/v as determined from station BW.ZUGS.*

MULTITEMPORAL CLUSTERING OF THERMAL IMAGES FOR ANALYSIS OF PERMAFROST OCCURRENCE IN STEEP ROCK WALLS.

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ABSTRACT

The influence of climate change is omnipresent in alpine region. Especially in the region above 2800m, global warming leads to permafrost degradation. This significantly increases the risk of rock falls and landslides. To identify this hazard, thermal monitoring of the ongoing processes is necessary. From thermal cameras, temperature profiles can be generated for steep mountain flanks otherwise impossible to access. An open research question is whether and to what extent such temporal temperature profiles allow conclusions about the presence of permafrost in the underlying rock layers. To this aim, 24-hour monitoring of the steep Zugspitze north flank was carried out using a FLIR T640 camera. Thermal infrared (TIR) images were taken every 15 minutes from a location approx. 150 m away from the rock face, aiming at the area outside the “Kammstollen” tunnel. The occurrence of permafrost here has been recorded and monitored since 2007 with electrical resistivity tomography and temperature loggers. Challenges of TIR data acquisition in high alpine environments included (i) tilting of the camera due to wind and (ii) view occlusion by clouds and fog. For (i) key points were searched in all images to perform a pixel-wise registration for the region of interest. To exclude (ii), an automatic cloud detection procedure was developed based on the image histogram. Finally, k-means clustering was performed based on the temperature of each pixel at each time step, allowing detection of areas with the same thermal behavior. The described procedure was implemented in MATLAB™ in the form of an evaluation tool with an intuitive graphical use interface (Fig. 1). Clear differences are present between night and day, with uniform temperature patter during the night and stronger differences during the daily hours mainly causes by different slope exposition, steepness and material. The k-means algorithm also identified a uniform area at the location of the permafrost body that present relatively low temperatures. This study demonstrates the potential of TIR imaging for an area-based permafrost monitor as an extension of existing punctual geophysical measurements.

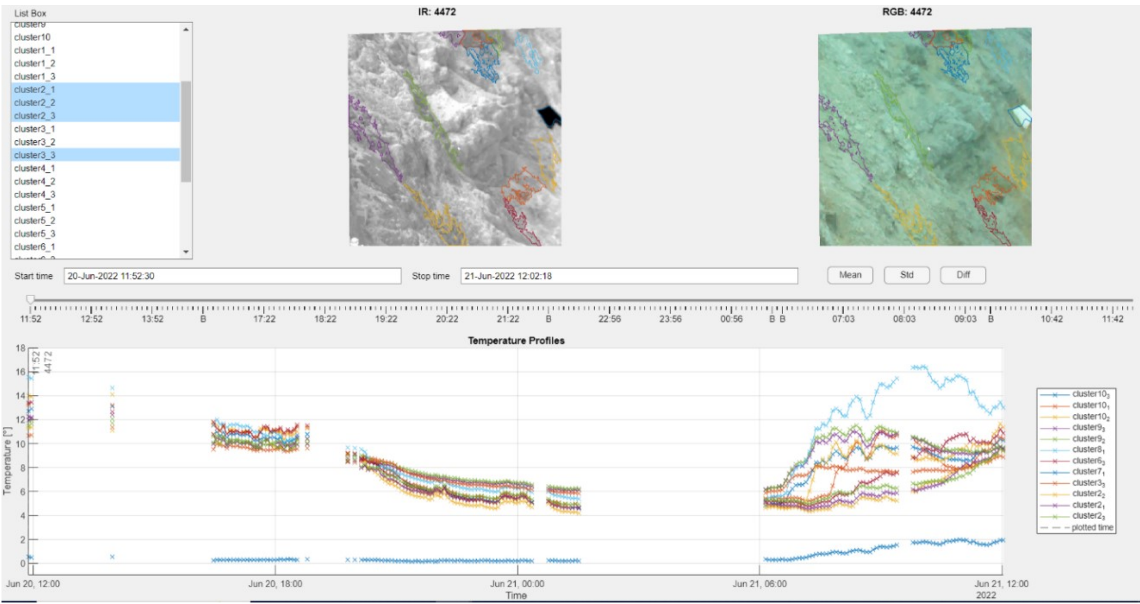

Fig. 1 Developed evaluation tool for the analysis of thermal images using k-means clustering. The observed section is shown as a thermal and color image (top), as well as the clusters found with the corresponding temperature profiles (bottom).

Submission for an oral presentation in the session “Climate impact on Alpine environment, hazards and risks”

CLIMATE CHANGE EFFECTS IN ALPINE PERMAFROST: 15 YEARS OF GEOELECTRICAL MONITORING IN THE KAMMSTOLLEN (ZUGSPITZE, D/A)

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ABSTRACT

While climate change driven increase in air temperature has been correctly modeled in recent decades, the extent of its consequences is still uncertain. In high alpine environments, especially in steep rock walls, permafrost degradation reduces slope stability with critical consequences for people and infrastructures: to properly assess the risk, the rate of these changes must be monitored. In the last decades, electrical resistivity tomography (ERT) has been used in more than hundred studies to detect permafrost, but there are only limited long-term monitoring cases that mostly do not provide quantitative information.

Here we present ERT measurements from the Kammstollen Tunnel at the Mt. Zugspitze (2750 m asl, DE/AT). Standard procedures and permanently installed electrodes allow the collection of a unique dataset of consistent measurements since 2007. Supporting information like resistivity-temperature calibration from former studies, rock surface and borehole temperatures enable an advanced quantitative interpretation of the results.

Permafrost is close to disappearing, resistivity changes are evident and in good agreement with air temperature increase. The monthly 2D monitoring of the north face of Mt. Zugspitze shows slow constant decrease in summer (~15% of the surface in 15 years) and a strong variation in winter in correlation with snow-height. These datasets help to better understand the different characteristics of the thermal responses to the climate change induced stress on alpine permafrost environments.

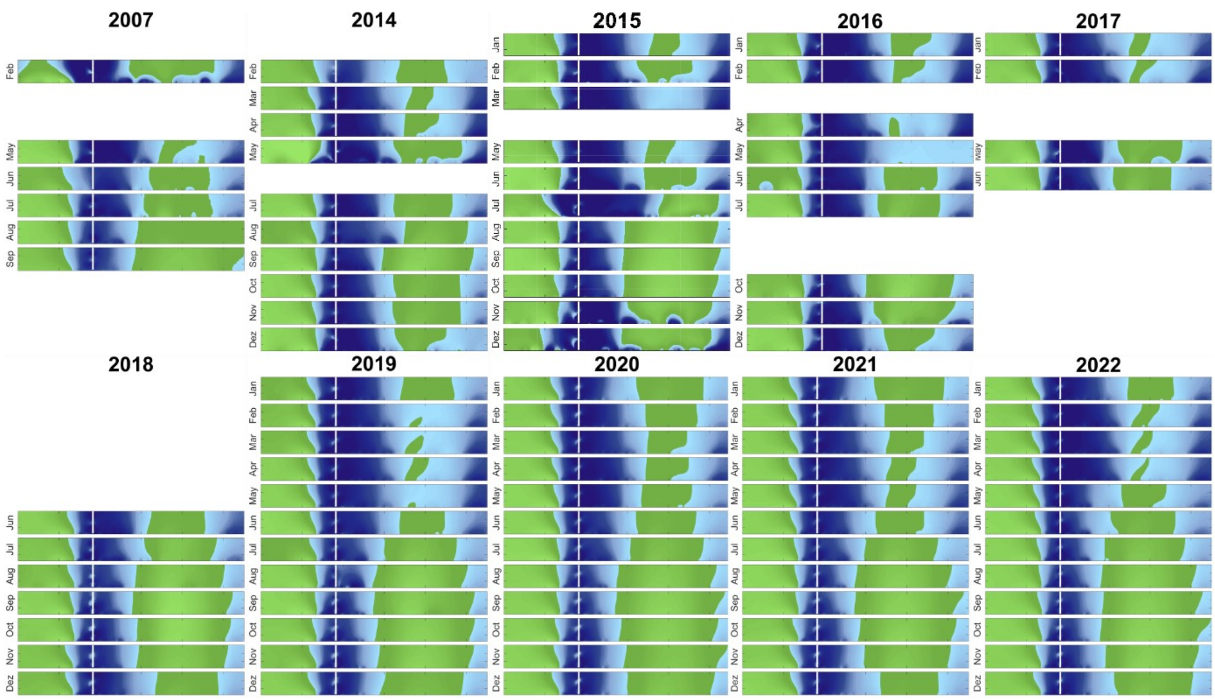

Figure: results from the monthly resistivity measurements in the Kammstollen. These measurements allow to detect long-term trends of permafrost degradation as well as seasonal evolution, as a consequence of air temperatures and snow cover.

MEASURING AND MODELLING MOUNTAIN GLACIERS AND ICE CAPS IN A CHANGING CLIMATE (INTERNATIONAL DOCTORAL PROGRAM M³OCCA)

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ABSTRACT

Mountain glaciers and ice caps outside the large ice sheets of Greenland and Antarctica contribute about 41% to the global sea level rise between 1901 to 2018 (IPCC 2021). While the Arctic ice masses are and will remain the main contributors to sea level rise, glacier ice in other mountain regions can be critical for water supply (e.g. irrigation, energy generation, drinking water, but also river transport during dry periods). Furthermore, retreating glaciers also can cause risks and hazards by floods, landslides and rock falls in recently ice-free areas. As a consequence, the Intergovernmental Panel of Climate Change (IPCC) dedicates special attention to the cryosphere (IPCC 2019; IPCC 2021).

The International Doctorate Program (IDP) “Measuring and Modelling Mountain glaciers and ice caps in a Changing ClimAte (M³OCCA)” substantially contributes to improving our observation and measurement capabilities by creating a unique inter- and transdisciplinary research platform. We address main uncertainties of current measurements of the cryosphere by developing new instruments and future analysis techniques as well as by considerably advancing geophysical models in glaciology and natural hazard research. The IDP has a strong component of evolving techniques in the field of deep learning and artificial intelligence (AI) as the data flow from Earth Observation (EO) into modelling increases exponentially. IDP M³OCCA is a focal point for mountain glacier research in Germany and educates emerging talents with an interdisciplinary vision as well as excellent technical and soft skills. Within the IDP we combine cutting edge technologies with climate research. We develop future technologies and transfer knowledge from other disciplines into climate and glacier research to place Bavaria at the forefront in the field of mountain cryosphere research. IDP M³OCCA leverages on Bavaria’s existing long-term commitment via the super test site Vernagtferner in the Ötztal Alps run by Bavarian Academy of Sciences (BAdW). In addition, we cooperate with the University of Innsbruck and its long-term observatory at Hintereisferner. At those super test sites, we perform joint measurements, equipment tests, flight campaigns and cross-disciplinary trainings and exercises for our doctoral researchers.

DEVELOPMENT OF AN EARLY WARNING SYSTEM FOR CLIMATE-INDUCED ALPINE HAZARDS. ALPSENSERELY PROJECT.

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ABSTRACT

Alpine natural hazards related to climate change pose significant threats to alpine communities, infrastructure, residents, tourists and the local economy. The AlpSenseRely research project intends to supports authorities to identify and address the risks associated with climate-induced landscape changes thus safeguarding the natural environment and the local communities. We develop a remote sensing based multi-scale and multi-temporal monitoring system for early detection of potentially dangerous areas in various test site in Bavaria and Austria. We use time series of very high resolution aerial imagery with 20 cm spatial resolution acquired by land surveying agencies over the past 12 years to continuously screen for and monitor landscape changes such as landslides, rockfall areas and glaciers. Close up monitoring is done with repeated measurements with unmanned aerial vehicles (UAVs) with up to 2.5 cm resolution. A multi-temporal analysis of the digital terrain models generated by digital photogrammetry and the aerial imagery allows us to detect even minor changes at landscape level. A web based photorealistic 3D visualization plattform allows better interpretation of present risks and comprehensive communication with governmental authorities and stakeholders.

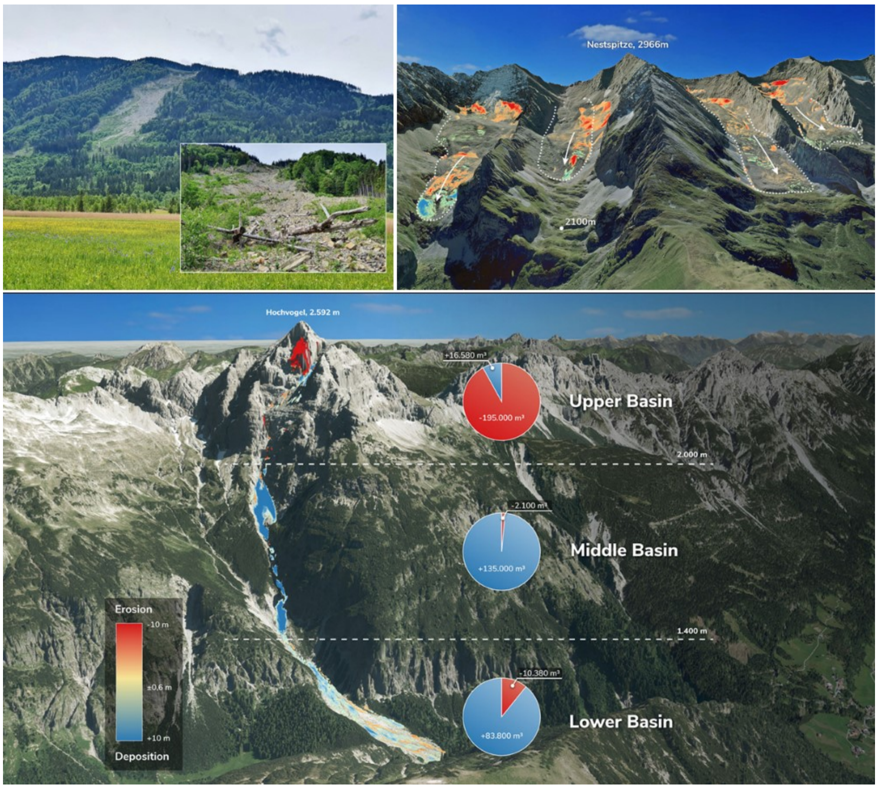

Fig 1. Upper left. Multi-scale monitoring at the Hechendorfer Landslide (DE). Upper right. Rock glaciers displacement in the Zillertal alps (AT). Lower. Quantification of massive sediment transport after a cliff fall in the Hochvogel summit (DE/AT).

X-RISK-CC: HOW TO ADAPT TO CHANGING WEATHER EXTREMES AND ASSOCIATED COMPOUND AND CASCADING RISKS IN THE CONTEXT OF CLIMATE CHANGE

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ABSTRACT

The Alpine region experienced extraordinary compound extreme weather events in the recent years. Compound events, such as storms with heavy precipitation or heat waves combined with drought, demonstrated to have an immense potential to impact socio-economic and natural systems and cause unexpected and severe consequences. These events highlighted that their consequences are likely to exceed current risk management capacities in the alpine territories, which are usually not yet designed to consider climate change effects on extreme events or long-term changes in the affected system components. Subsequent emergent risks have a strong compound and cascading component that is currently not considered in conventional emergency protocols. There is scientific evidence that the frequency and intensity of such events and the related impacts on socio-economic and natural systems have already increased due to climate change (CC) and will further increase in the future. However, the knowledge and management of their cascading impacts and risks under CC are still insufficient.

The Alpine Space project X-RISK-CC aims to support risk managers and policy makers in addressing the compound risks of weather extremes under CC by developing new knowledge, local risk-management actions and transnational guidelines. They are based on newly generated and harmonized Alpine-wide data and knowledge on past and future extremes, their drivers and impacts which will be made accessible into an open web-GIS platform. The actions for upgrading current risk management instruments are designed with risk managers in five pilot cases, representative for vulnerable areas, from municipalities to transboundary regions, recently affected by extreme events in different socio-economic assets. X-RISK-CC partnership establishes a close collaboration among regional risk managers, national authorities, members of EUSALP and PLANALP/Alpine Climate Board of the Alpine Convention and scientists from six Alpine countries. Outputs are co-developed by and disseminated through EUSALP Action Group 8, PLANALP as well as through the EUSALP Climate Adaptation Platform for the Alps. This contribution introduces the overall project aim, its structure and the expected outputs.
X-RISK-CC ("How to adapt to changing weather eXtremes and associated compound and cascading RISKs in the context of Climate Change") received funding from Interreg Alpine Space Program 2021-27 under the project number ASP0100101.

MEASUREMENTS OF CARBON DIOXIDE, CARBON MONOXIDE, AND METHANE CONCENTRATIONS IN THE ATMOSPHERE AT THE GIMMIZ WATER TOWER

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ABSTRACT

Since February 2013 continuous concentration measurements of different greenhouse gases (GHGs) in the atmosphere have been conducted on the Gimmiz water tower. During 2013 – 2016 these measurements were part of the CarboCount-CH project financed by the Swiss National Science Foundation through its Sinergia Programme. The Gimmiz site is located on flat terrain within an agricultural region and close to a sugar factory. Over the last ten years a dataset of CO, CO_2, CH_4, and H_2O concentrations as well as meteorological parameters has been recorded which gives insights about emissions in an agricultural used region and the influence of the nearby sugar factory. The presentation includes the characterization of seasonality, monthly diurnal evolutions, correlations of measured parameters, and analysis of trends. We will discuss local influences from agricultural activities and soil oxidation as well as from the sugar factory. These values are compared to data from other Swiss stations such as Bern, Beromünster and Jungfraujoch.

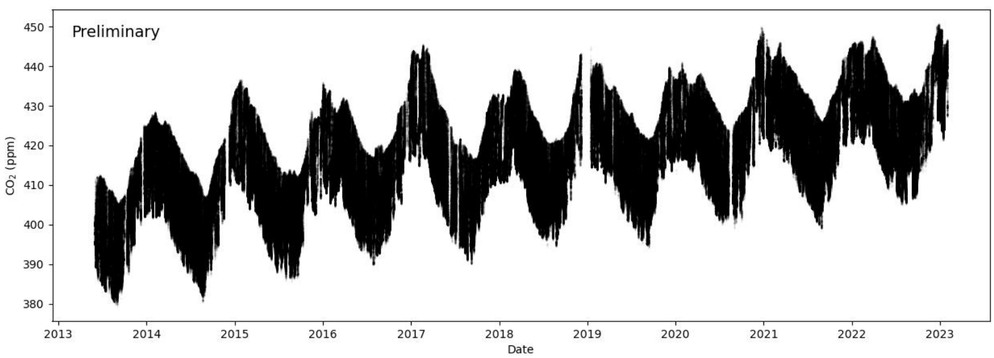

Figure 1 Background signal of CO_2 concentration in ambient air measured at Gimmiz water tower from Feb 2013 to Feb 2023.

for oral presentation in session *Atmospheric and climatic variability*

COMPARISON BETWEEN ECONOMIC GROWTH AND SATELLITE OBSERVATIONS OF NO2 POLLUTION OVER THE PO VALLEY

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ABSTRACT

Is there a relationship between economic development and air quality? - Especially in mountainous areas such as the Po Valley in northern Italy, air pollutants can easily accumulate. Nitrogen dioxide (NO_2) is one of the prominent trace gases in our atmosphere. Within this research study satellite based tropospheric NO_2 column densities obtained from the ERS-2, ENVISAT, MetOp-A and MetOp-B satellites ranging from 1996 to 2017 over the Po Valley are analyzed. Since most of the NO_2 emissions are caused by anthropogenic processes, the results of the spectral analysis methods were compared with the gross domestic product (GDP) as an economic indicator. Furthermore, natural influences on the tropospheric NO_2 pollution such as the annual cycle are considered. It is found that two major events occurred within the GDP growth rate and the NO_2 variability at the same time. The first significant relation occurred in around 2008, caused by the global financial crisis, and was followed by a second correlation which appeared between 2009 and 2014. The findings for the area of interest indicate that for strong economic events such as the global financial crisis or by decreasing foreign investments, it is possible to observe significantly fewer NO_2 pollution at the same time. Moreover, results of other study areas reveal decoupling processes between NO_2 pollution and GDP development. Those findings are especially of interest for political measures as well as political initiatives such as the European Green Deal or the UN Sustainable Development Goals (UN SDGs) to support a green and circular economy.

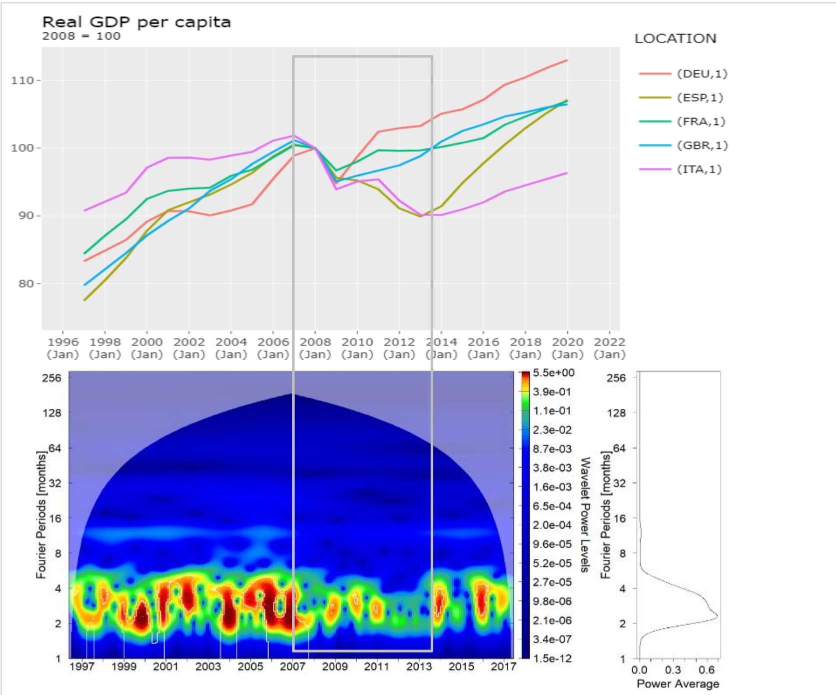

Figure 1: (A) Development of the real GDP per capita for several European countries with the reference year 2008 (OECD, 2021) (B) Wavelet spectrogram of the monthly mean tropospheric NO_2 column density. Plot on the right shows the related average wavelet power in the frequency domain (averages over time) over the entire period from 1996 to 2017(Roesch & Schmidbauer, 2018; Bichler & Bittner, 2022)

Bichler, R., Bittner, M., 2022. Comparison between economic growth and satellite-based measurements of NO2 pollution over northern Italy. Atmospheric Environment, 272, 118948. https://doi.org/10.1016/j.atmosenv.2022.118948

Roesch, A., Schmidbauer, H., 2018. WaveletComp: Computational Wavelet Analysis. R package version 1.1 Online: https://cran.r-project.org/web/packages/WaveletComp/WaveletComp.pdf (last access: 22-Sep-2020)

OECD, 2021. GDPVD_CAP: Gross domestic product per capita, volume in USD, at constant purchasing power parities. Online: https://stats.oecd.org/Index.aspx?DataSetCode=EO104_INTERNET (last access: 31-Mar-2021)

ARAGATS SPACE ENVIRONMENTAL CENTER (ASEC)

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ABSTRACT

Eighty years ago, in 1943, amid World War II, one of the world's largest high-mountain research stations was established on Mt. Aragats, at 3,200 m elevation. Since then, expeditions on Aragats have continued uninterruptedly, despite insufficient funding and shortage of electricity and fuel during the recent history of Armenia. Currently, physicists of the Cosmic Ray Division of Yerevan Physics Institute, with reequipped and renewed facilities, continue research in the field of galactic and solar cosmic rays, solar-terrestrial connections, high-energy atmospheric physics, and space weather. Aragats physicists enlarged the possibilities for space accelerators research by simultaneously detecting the electrical and geomagnetic fields, radio emission from atmospheric discharges, rain rate, temperature, relative humidity, and other meteorological parameters. The adopted multivariate approach of investigations allows for connecting different fluxes, fields, and lightning occurrences and finally establishing a comprehensive model of the TGE.

During experiments on Mt. Aragats have discovered mechanisms and characteristics of long-lasting particle multiplication and acceleration produced within thunderstorms. For the first time have measured the energy spectra of electrons and gamma rays of particle avalanches of atmospheric origin that reach the Earth's surface. A new topic of CRD research is the enigmatic atmospheric electric field. We use particle fluxes traversing thunderous atmospheres for screening (like X-ray screening) embedded charge structures and fields. The new approach gives exciting results on the vertical and horizontal profiles of the atmospheric electric fields, supported by the exact methods of particle physics and well-established theory of electromagnetic interactions. The synergy of cosmic ray and atmospheric physics, which can become a leading direction in HEPA, allows explaining all types of particle bursts within one framework, i.e., as consequences of extensive air showers entering regions of strong atmospheric electric fields. Research on Aragats in 2019-2022 allows the discovery of substantial ionizing fluxes incident upon the terrestrial atmosphere during thunderstorms and vast electric fields(up to 200 kV/m) nearby the earth's surface (50-150m), which can have significant consequences on the safety of launching rockets and operation of the aircraft during thunderstorms.

Figure Aragats research station, 3200 asl, in the background bible Mt. Ararat, 100 km apart

SOLAR CYCLE AND LIGHTNING ACTIVITY

Jaroslav Chum[1], Ronald Langer[2], Ivana Kolmašová[1.3], Jan Rusz[1]

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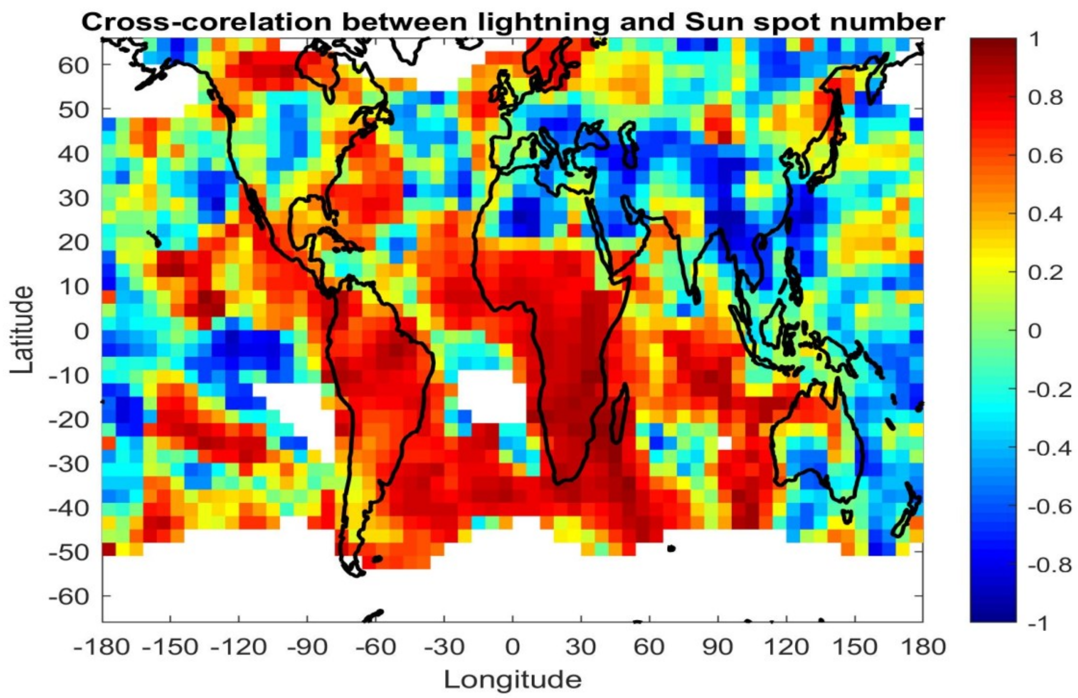
ABSTRACT

We investigate cross-correlation between lightning occurrence and solar activity on a global scale using data from the World Wide Lightning Location Network (WWLLN) for the period 2009 to 2021. It is shown that the cross-correlation coefficients vary depending on the position on the globe. Positive cross-correlation is found in most of Africa, South and Central America, while in parts of Europe and Southeast Asia the cross-correlation is negative. The highest values of the cross-correlation coefficients are around 0.9 using smoothed one-year averages. Modulation of lightning activity by secondary cosmic rays and heliospheric magnetic field is also discussed. The results show that the observed changes in cosmic ray intensity play an insignificant role for the global occurrence of lightning.

ILLUSTRATIONS, GRAPHS, AND PHOTOGRAPHS



FURTHER INSTRUCTIONS

- Topic: Atmospheric and climatic variability
- I prefer oral presentation

50 YEARS OF CO2 MEASUREMENTS AT STATIONS FROM THE GERMAN ENVIRONMENT AGENCY

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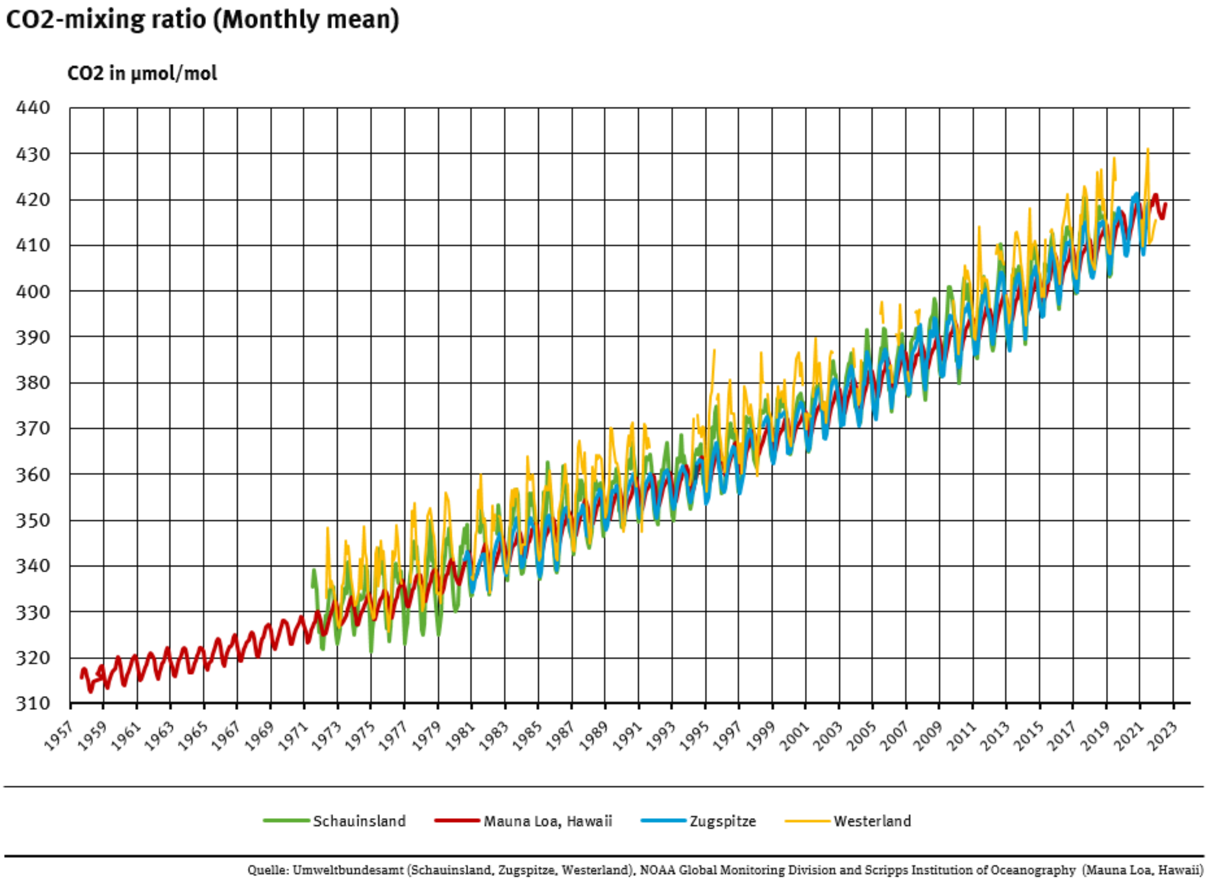
ABSTRACT

Carbon dioxide (CO2) is the most important anthropogenic greenhouse gas in the atmosphere. Measurements of air enclosed in ice cores show a pre-industrial CO2 concentration of 278 ppm. Current measurements from international monitoring networks determine an average global CO2 concentration of 415.7 ppm for the year 2021, corresponding to an increase of almost 50%.
Long-term measurements of atmospheric CO2 have been carried out by the German Environmental Agency at the stations Schauinsland (Black Forest) and Westerland (Sylt) since 1972. These are thus the longest continuous CO2 time series in Europe, and only a few stations worldwide have longer measurement series, such as Mauna Loa (Hawaii), which started observations in 1958. Since 2021, the German Environmental Agency has joined the European research infrastructure ICOS (Integrated Carbon Observation System) with the stations Schauinsland, Westerland and Zugspitze. At the Zugspitze, the first CO2-Measurement was carried out more than 40 years ago,in 1981.



3D RECONSTRUCTION OF ATMOSPHERIC GRAVITY WAVES AND DERIVATION OF VERTICAL WAVE PARAMETERS WITH TOMOGRAPHY APPLIED TO DATA FROM TWO GROUND-BASED CAMERAS OBSERVING OH AIRGLOW

Patrick Hannawald (1, 2), Stefan Noll (2, 1), Sabine Wüst (1), Michael Bittner (1, 2)
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ABSTRACT

Atmospheric gravity waves transport energy and momentum throughout the atmosphere and can travel large horizontal and vertical distances from the troposphere to the mesosphere and above. They contribute to atmospheric dynamics and drive the global circulation in the mesosphere. Knowing about the gravity wave characteristics and their interaction with the atmospheric background is attracting more and more attention in order to further improve climate and even meteorological models.

In the upper mesosphere / lower thermosphere (UMLT) region around 80km to 100km altitude, OH airglow can be utilized for passive remote sensing and continuous nightly observations of gravity waves. The OH airglow layer is a chemiluminescent layer with a strong emission in the short wave infrared spectral range. The layer is located in about 86km altitude with a layer width of about 8km. The OH airglow intensity is modulated by traversing atmospheric gravity waves which change the chemical reaction rates, e.g., by temperature and pressure changes and by the transport of molecular oxygen which heavily contributes to the chemical reactions. Thus, observing OH airglow with short-wave infrared imagers allows characterising the gravity waves. From these observations the horizontal wave parameters (horizontal wavelength, horizontal direction of propagation, etc.) can be derived.

In this study we present measurements of two ground-based FAIM (Fast Airglow IMager) systems, fast cameras sensitive in the short-wave infrared observing the OH airglow layer. The cameras are located at Oberpfaffenhofen, Germany and Otlica, Slovenia, about 300km apart from each other and are pointing to the same volume in about 86km altitude located in the Alpine region above Northern Italy. We developed a novel tomographic algorithm to allow for a three-dimensional reconstruction of the airglow layer by combining images from the two viewing angles. In particular, this allows us to derive the vertical wavelength of the waves, their three-dimensional propagation direction, and see their three-dimensional structure. With the derivation of the vertical wave parameters, the wave can then be fully characterised.

We will explain the tomographic reconstruction method and will present a detailed case study showing a 3D-reconstructed gravity wave and the derivation of its parameters.

This work received funding from the Bavarian State Ministry of the Environment and Consumer Protection.

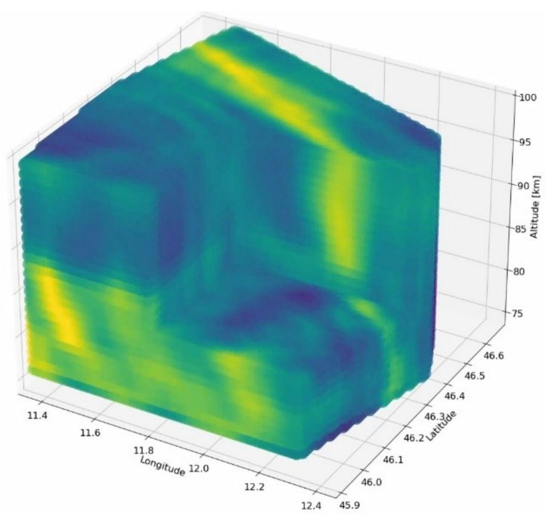

Figure 1 Tomographic 3D reconstruction from two overlapping ground-based airglow images which allows us to derive also vertical gravity wave parameters like the vertical wavelength which is not possible from usual airglow observations.

Temperature dependent fractionation effects on oxygen measurements

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ABSTRACT

This study investigates the correction of temperature-dependent deviations observed in O_2 in situ continuous measurements at high altitude research station Jungfraujoch (3580m asl). It was noticed that during the period 2015 to 2019 the gas inlet temperature control was mal-functioning. The study analyzed the relationship between gas inlet temperature variations and O_2 gas concentration measurement using paramagnetic cell at high altitude, identifying a pronounced temperature dependency of the measurement deviation from the expected trend and seasonality (see Figure below) as well as from independently measured flask air samples taken at Jungfraujoch (not shown). Corrections based on both approaches lead to a significant shift of the data (blue dots in Figure). The results show that the correction method substantially reduces the temperature-dependent deviation, improving the accuracy of O_2 measurements. After the correction, the standard deviation from the expected value decreased from 83.3 permeg to 41.4 permeg, resulting in a 51% reduction of deviation. The correction method presented in this study improves the accuracy of O_2 measurements at Jungfrauchjoch research station for the above-mentioned time.

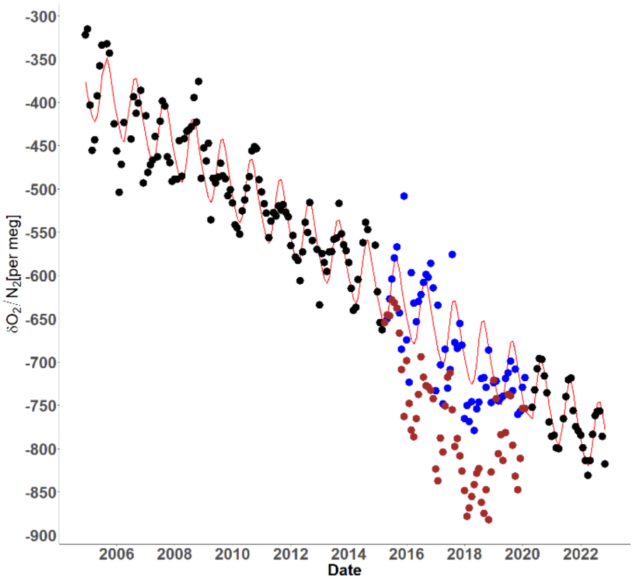

Figure 1: This figure shows the time series of continuous in situ O_2 measurement data for the years 2005-2020 at the high altitude research station Jungfraujoch (3580 m asl). The black dots represents the measured data, during period ((2005 – 2014), (2021-2022)) respectively. The brown dots represent measured data for the period 2015 -2020, which shows a temperature-dependent deviation. The blue dots represent corrected data for the

period 2015 -2020, which was obtained after applying a correction function dependent on air temperature. The values of months with no coverage were calculated using 2-harmonic fit functions, which are represented by the red (O_2) lines.

for oral presentation in session Atmospheric and climatic variability

COMBINED OXYGEN AND CARBON DIOXIDE MEASUREMENTS AS TOOL FOR THE PARTITIONING OF CARBON DIOXIDE EMISSIONS AMONG THE CARBON POOLS ATMOSPHERE, BIOSPHERE AND OCEAN

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ABSTRACT

The airborne fraction (AF) is the part of the carbon dioxide emissions by human activities that remains in the atmosphere. Ecosystems and the ocean take up the rest. AF varies significantly on a year-to-year basis from 20 to 80 percent. However, on longer time scales a mean value of 42% with no visible trend is observed, indicating that the ecosystem and the ocean CO_2 sinks have been increasing along with the human-made CO_2 emissions. The question remains whether this the ecosystem and ocean uptake will behave the same way under further future emissions. CO_2 uptake by land ecosystems and the ocean might be reduced by climate change and related feedbacks like droughts and wildfires on land and by increased surface ocean temperatures and decreased pH. Information is available from combined CO_2 and O_2 observations (or additionally isotope composition of CO_2). We will present measurements from Jungfraujoch, Bern and the Beromünster tower sites.

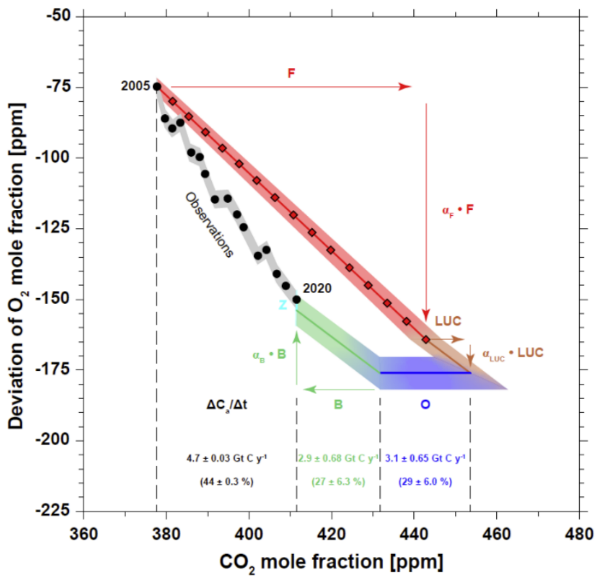

Figure 1: The outcome of the analysis shows that over the 16-year period the percentage of emissions remaining in the atmosphere is 44% ($\Delta Ca/\Delta t = 0.44$), global biosphere uptake (B) is 27% and global ocean uptake (O) is 29%. The red line depicts the theoretical changes in CO_2 and O_2 levels in response to fossil fuel emissions (F) and emission associated with land-use change (LUC). (Z) shows changes in O_2 level due to ocean thermal outgassing.

for oral presentation in session Atmospheric and climatic variability

OBSERVATIONS OF OH AIRGLOW AT THE UFS SCHNEEFERNERHAUS: 1) LONG-TERM DEVELOPMENT AND 2) ATMOSPHERIC WAVES RELATED TO THE HUNGA TONGA-HUNGA HAPAAI ERUPTION

Carsten Schmidt[1], Anna Moser[1,2], Leon Knez[1,2], Patrick Hannawald[1], Lisa Küchelbacher[1], Sabine Wüst[1], Michael Bittner[1,2]

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ABSTRACT

Observations of OH airglow provide an important opportunity for tracing the variability of the mesosphere lower thermosphere (MLT, ~80-100 km height) on time scales from minutes to decades. While OH rotational temperatures are derived on a routine basis, precise absolute radiances of OH airglow are usually only available from satellite missions or astronomical sites. In order to provide traceability also to the ground-based Network for the Detection of Mesosphere Change (NDMC) a new calibration approach was developed and applied to observations performed at Environmental Research Station (UFS) Schneefernerhaus (11.0°E, 47.0° N).

On time scales of decades, the correlation of OH temperatures and OH radiances with solar activity (i.e. with F10.7cm) at UFS is particularly striking. Compared to similar observation sites in France, Italy and Georgia this correlation is clearly more pronounced at UFS than at these other sites. During solar cycle 24 the increase of MLT temperatures was of similar magnitude as reported for previous cycles. However, the solar forcing was much weaker than during the previous cycles which leads to a strong relative forcing term of approximately 6°K/100 sfu.

On short time scales, the eruption of the Hunga Tonga-Hunga Hapaai in January 2022, which included the emission of atmospheric waves travelling several times around the globe, was a truly remarkable event. Unique wave features were simultaneously observed in OH airglow at many VAO observatories. Especially, a remarkable wave of ca. 2 mHz (~ 8 minutes period) was observed for several hours at UFS Schneefernerhaus, Germany, at Sonnblick Observatory, Austria, at the Observatoire de Haute-Provence, France and at Otlica Observatory, Slovenia. These simultaneous observations provide an opportunity to conduct a detailed study of the complex dynamics associated with this event, which are discussed in this presentation.

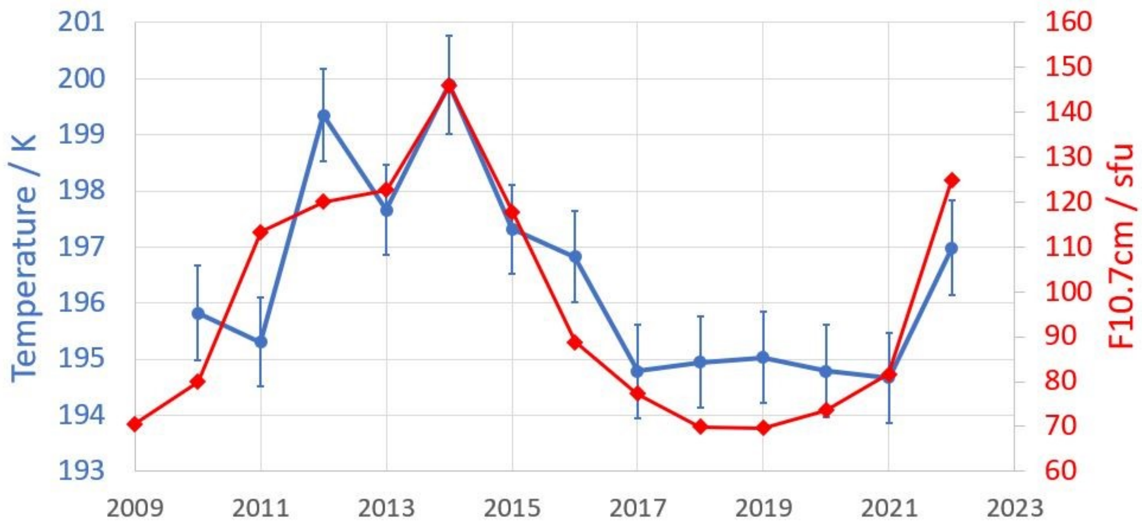

Figure: Long-term development of OH temperatures at UFS Schneefernerhaus versus the solar cycle.

ATMOSPHERIC TRACE GAS IN-SITU OBSERVATIONS AT JUNGFRAUJCOH – BENEFITS AND CHALLENGES OF SERVING MULTIPLE PROGRAMMES

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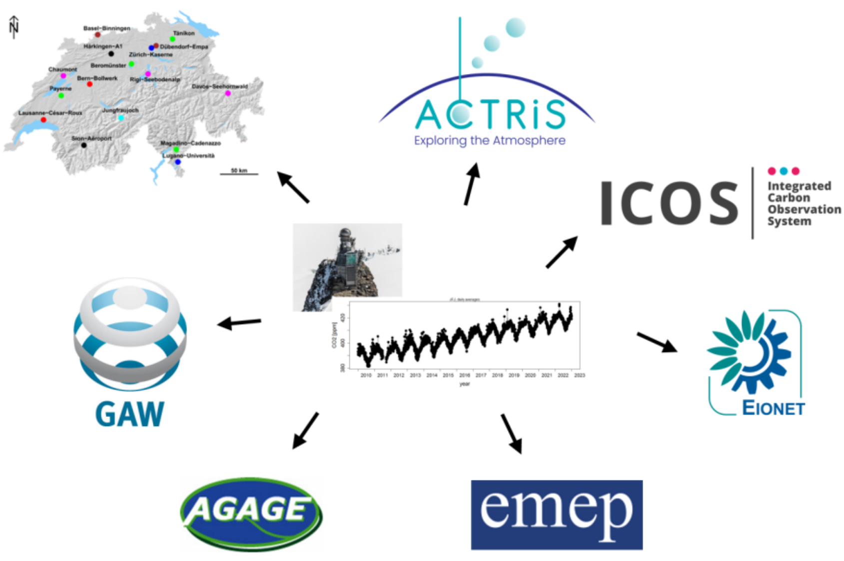
ABSTRACT

Empa started its continuous atmospheric measurements at Jungfraujoch as part of an early engagement of Switzerland in a programme on long range transport of air pollutants initiated by the Organisation for Economic Co-operation and Development (OECD) in 1973. Initially, activities mainly focused on sulfur dioxide and particulate matter. Later, the measurement programme was extended and the observations became part of the National Air Pollution Monitoring Network (NABEL), which was initiated as a joint activity of Empa and the Swiss Federal Office for the Environment (FOEN) in 1978.
Nowadays, Empa's measurements at Jungfraujoch contribute not only to the NABEL network but also to European initiatives, like the European Monitoring and Evaluation Programme (EMEP), the European air quality monitoring network (Euroairnet / Eionet) of the European Environment Agency, European Research Infrastructures such as Integrated Carbon Observation System (ICOS) and Aerosols, Clouds, and Trace gases Research Infrastructure Network (ACTRIS), and global initiatives like the World Meteorological Organization (WMO)'s Global Atmosphere Watch (GAW) programme and the Advanced Global Atmospheric Gases Experiment (AGAGE). Operation and maintenance profits from substantial synergies when serving different programmes. The different engagements allow and require observing a broad spectrum of parameters, and analysis of the extended datasets facilitates the interpretation of the time series.
However, challenges occur for example (i) when observations must comply with various programme-specific needs like specific measurement techniques or traceability to different reference scales, (ii) when different data streams are implemented to allow for in-house and centralized programme-wide data processing, (iii) when quality assurance and quality control strategies need to account for different programme-specific data quality objectives, or (iv) when data require different metadata and documentation and need to be released in different data repositories.
The presentation will give examples for the above and provide a comprehensive overview of the situation at Jungfraujoch and the associated strategies, benefits and challenges of Empa's observations.



Schematic illustration of Empa's observations at Jungfraujoch and the contribution to different programmes.

The Saharan Dust Event in March 2022 at Mt. Zugspitze from a Lidar Perspective

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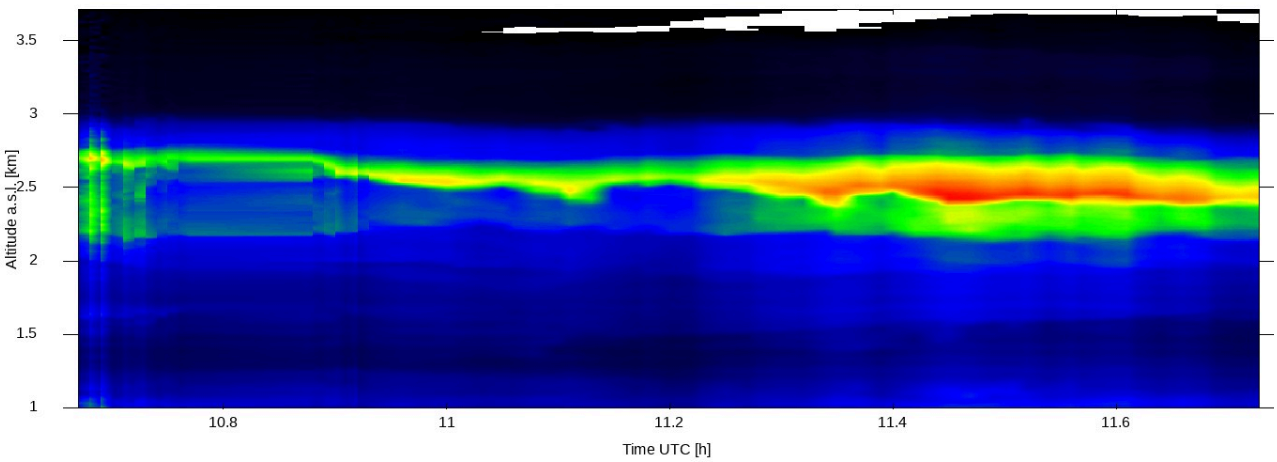
Saharan dust is by far the most important atmospheric load of mineral aerosols in the Alpine region. Beyond its effect on air quality, most importantly, due to albedo effects, its sedimentation on snow and ice is amplifying the snowmelt. Particular in spring and summer, when no fresh snow is covering the contaminated layer, this can significantly accelerate the loss of snow and subsequently the melting of glaciers after the loss of snow cover. The Saharan dust outbreak in March 2022 was one of the most significant dust events in the last decades. Although weather conditions were difficult for lidar remote sensing during this 2 day period, the vertical structure of some Saharan dust plumes around Zugspitze was measured with both the NDACC Aerosol lidar at Schneefernerhaus and the ATMONSYS lidar at Garmisch-Partenkrichen. Remote sensing of dust plumes provides information for comparison and evaluation of models forcasting transport and concentration / optical depth of Saharan dust (e.g. ICON-ART, WRF-Chem).



Saharan dust layer above Garmisch-Partenkirchen on March 17, 2022 recorded with the ATMONSYS lidar. The top of the dust plume is close to the summit level of Mt. Zugspitze.

INVESTIGATION OF AEROSOL-CLOUD-RADIATION INTERACTION DURING DUST EPISODES IN THE GREATER ALPINE REGION

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In the context of a transition towards renewable energy production, accurate weather forecasts for wind and photovoltaic power production are increasingly important. The majority of the operational weather forecast systems are not considering prognostic aerosol and aerosol-cloud-radiation interaction, however. This can lead to forecast errors during special weather conditions that involve aerosol, such as strong Saharan dust episodes or biomass burning events.

The Project **PermaStrom** (funded by the Federal Ministry for Economic Affairs and Climate Action) works on the operational introduction of prognostic aerosol species in the ICON model and experiments on the parametrization of aerosol-cloud-radiation interaction.
For model validation, amongst others, we make use of ground- based ceilometer data.

This contribution will give an overview of the model development activities within the **PermaStrom** project. Furthermore, we will discuss a newly developed sub-grid parametrization for the formation of "dusty cirrus" clouds during two major Saharan dust episodes and address the challenges in the use of ceilometer measurements for the validation of modelled cloud fraction.

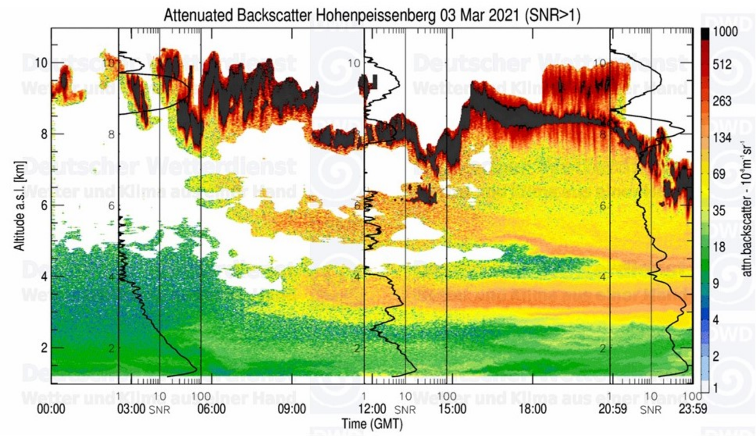

Figure1: Attenuated backscatter of the ceilometer Hohenpeissenberg during a dust event in March 2021. The backscatter of dust is shown in yellow, and clouds appear in black and dark red.

HYDROXYL AIRGLOW OBSERVATIONS FOR INVESTIGATING ATMOSPHERIC DYNAMICS: RESULTS AND CHALLENGES

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2 Universität Augsburg, Institut für Physik, Germany
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ABSTRACT

Ground-based OH* airglow measurements have been carried out for almost 100 years. At some sites they are available for decades. Advanced detector technology has greatly simplified the automatic operation of OH* airglow observing instruments and significantly improved the temporal and, in the case of imagers, the spatial resolution of these measurements.
In the Alps and the vicinity of the Alps, OH* airglow instruments are deployed at six sites: Oberpfaffenhofen (48.09°N, 11.28°E), the observatory Hohenpeißenberg (47.8°N, 11.0°E), the Environmental Research Station Schneefernerhaus (47.42°N, 10.98°E), Germany, the observatories Haute Provence (43.93°N, 5.71°E), France, Sonnblick (47.05°N, 12.95°E), Austria, and Otlica (45.93°N, 13.91°E), Slovenia (see figure 1).

Studies based on long-term measurements (i.e., ten years or more) or including a network of instruments were reviewed especially in the context of deriving gravity wave properties. The results are presented. Furthermore, today's challenges are identified.

To a large extent, those challenges lie in the field of analyses: Improved temporal and spatial resolution reduces averaging effects in space and time, therefore, more non-stationary processes become evident in the data. Processes, which could not have been observed before, can be investigated now.
The horizontal resolution of ca. 10–20 m, for example, which is achieved today in the best case by OH* airglow imagers, makes it possible to identify turbulence eddies and to estimate the energy emitted by gravity waves and thus the corresponding heating rates. However, for the analysis of larger data sets, the automatic detection of these vortices is necessary.
The temporal resolution of less than 1 s provides insights into the infrasound range. However, its observation with the help of OH* airglow measurements is currently still quite difficult. Especially in the context of observing and learning more about natural hazards, the detection of infrasound is of interest.

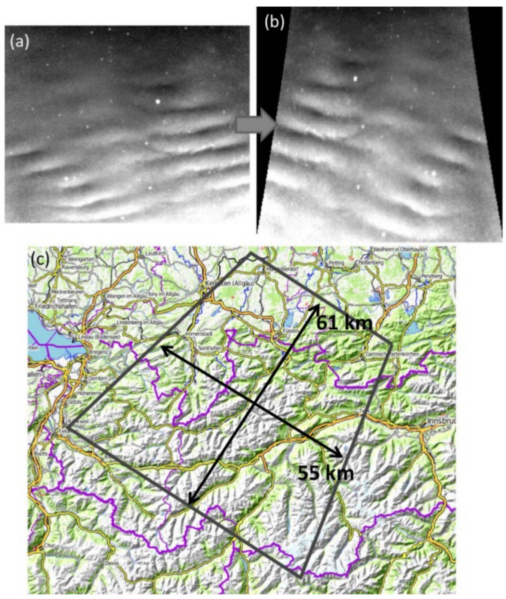

Figure 1 *(a) OH*-layer measurement above the Alpine region (as depicted in part c, source: www.opentopomap.org, October 2015) from Oberpfaffenhofen. (b) shows the satellite perspective. These pictures are published in Hannawald et al. (2016), AMT, https://doi.org/10.5194/amt-9-1461-2016, under the Creative Commons Attribution 3.0 License*

Topic: Atmospheric and climatic variability
Preferred: Oral presentation

IDENTIFICATION AND MONITORING OF SAHARAN DUST

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ABSTRACT

Mineral dust affects climate and weather via radiation transfer and cloud formation, enhances photochemical smog and, at higher concentrations, may disrupt air traffic, cause health risks and deposit at exposed surfaces with consequences to e.g. solar (PV) power production or glacier melt. It contributes significantly to EU-legislated PM concentrations and threshold exceedances, rising motivation to monitor, analyze and quantify its sources, transport and sinks as a prerequisite for reliable modelling and forecasting. Nearly all airborne mineral dust observed over central Europe originates in the Saharan desert. On up to 100 days per year Saharan dust (SD) layers occur in the free troposphere over central Europe, about > 50% of which reach down to the lower mixing layer where mountain stations are more often affected then lowlands (Flentje et al., 2015).

SD particles are relatively large (up to few µm) and constitute a distinct coarse mode in particle size distributions and a wavelength independent scattering coefficient at visible wavelengths (Angstrom Exponent near zero). It's yellow-brownish color results from enhanced absorption at blue/UV wavelengths. Dissolved in water, Ca^{2+} ions (from calcite $CaCO_3$ and gypsum $CaSO_4$) and a basic pH are associated with SD in particles. Also back-trajectories, satellite imagery and lidar may hint to the existence of SD, but all these criteria lack specificity (are neither necessarily fulfilled nor sufficient), and even more complicating identification, SD reaching the surface layer in mid-Europe mostly is externally mixed and sometimes coated with condensing material, obscuring it's original characteristics. Thus SD identification and quantification in observations remains kind of a circumstantial case – synopsis in an aerosol model yields powerful qualitative representation, however fails to quantify SD mass concentration within factors, typically 2 – 5.

To this end, we will reveal a concept for SD quantitative identification, based on different widely observed aerosol in-situ parameters, and present an inventory and climatology of SD representative for the Alpine region, summarized for example in tables of SD indices as shown in the figure below for year 2022. It seems desirable to define a composite SD index reflecting presence and significance of SD events. Besides typical fingerprints, thresholds of detection, uncertainties and variability between cases will be discussed.

Januar		Februar		März		April		Mai		Juni	
01 Sa	SDI: 0.68	01 Di	SDI: 0.55	01 Di	SDI: 1.99	01 Fr	SDI: 1.54	01 So	SDI: 1.15	01 Mi	SDI: 1.44
02 So	SDI: 1.24	02 Mi	SDI: 1.11	02 Mi	SDI: 3.41	02 Sa	SDI: 1.36	02 Mo	SDI: 1.21	02 Do	SDI: 1.56
03 Mo	SDI: 1.21	03 Do	SDI: 0.64	03 Do	SDI: 3.35	03 So	SDI: 1.21	03 Di	SDI: 1.19	03 Fr	SDI: 4.15
04 Di	SDI: 0.82	04 Fr	SDI: 1.51	04 Fr	SDI: 2.52	04 Mo	SDI: 1.91	04 Mi	SDI: 1.03	04 Sa	SDI: 5.42
05 Mi	SDI: 1.03	05 Sa	SDI: 1	05 Sa	SDI: 1.69	05 Di	SDI: 1.04	05 Do	SDI: 1.12	05 So	SDI: 7.17
06 Do	SDI: 0.61	06 So	SDI: 0.71	06 So	SDI: 14.7	06 Mi	SDI: 1.08	06 Fr	SDI: 0.7	06 Mo	SDI: 0.76
07 Fr	SDI: 1.08	07 Mo	SDI: 1.44	07 Mo	SDI: 5.52	07 Do	SDI: 1.36	07 Sa	SDI: 0.5	07 Di	SDI: 0.36
08 Sa	SDI: 0.94	08 Di	SDI: 0.83	08 Di	SDI: 6.7	08 Fr	SDI: 0.75	08 So	SDI: 0.49	08 Mi	SDI: 0.97
09 So	SDI: 0.75	09 Mi	SDI: 1.89	09 Mi	SDI: 3.93	09 Sa	SDI: 0.26	09 Mo	SDI: 1.64	09 Do	SDI: 0.44
10 Mo	SDI: 0.53	10 Do	SDI: 3.7	10 Do	SDI: 3	10 So	SDI: 0.13	10 Di	SDI: 3.13	10 Fr	SDI: 0.91
11 Di	SDI: 0.41	11 Fr	SDI: 21.39	11 Fr	SDI: 7.41	11 Mo	SDI: 1.03	11 Mi	SDI: 3.82	11 Sa	SDI: 1.02
12 Mi	SDI: 1.37	12 Sa	SDI: 0.59	12 Sa	SDI: 4.02	12 Di	SDI: 4.23	12 Do	SDI: 5.39	12 So	SDI: 1.48
13 Do	SDI: 1	13 So	SDI: 1.14	13 So	SDI: 3.12	13 Mi	SDI: 17.25	13 Fr	SDI: 2.54	13 Mo	SDI: 2.3
14 Fr	SDI: 0.99	14 Mo	SDI: 2.35	14 Mo	SDI: 9.24	14 Do	SDI: 7.94	14 Sa	SDI: 3.02	14 Di	SDI: 3.18
15 Sa	SDI: 0.84	15 Di	SDI: 0.31	15 Di	SDI: 69.29	15 Fr	SDI: 2.87	15 So	SDI: 3.81	15 Mi	SDI: 7.37
16 So	SDI: 0.98	16 Mi	SDI: 0.47	16 Mi	SDI: 121.11	16 Sa	SDI: 0.77	16 Mo	SDI: 2.75	16 Do	SDI: 6.84
17 Mo	SDI: 0.91	17 Do	SDI: 1.18	17 Do	SDI: 125.32	17 So	SDI: 1.76	17 Di	SDI: 2.88	17 Fr	SDI: 13.16
18 Di	SDI: 0.65	18 Fr	SDI: 0.85	18 Fr	SDI: 30.58	18 Mo	SDI: 1.03	18 Mi	SDI: 3.15	18 Sa	SDI: 17.76
19 Mi	SDI: 1.61	19 Sa	SDI: 0.66	19 Sa	SDI: 3.87	19 Di	SDI: 2.6	19 Do	SDI: 4.7	19 So	SDI: 14.51
20 Do	SDI: 0.97	20 So	SDI: 0.35	20 So	SDI: 3.35	20 Mi	SDI: 2.73	20 Fr	SDI: 10.41	20 Mo	SDI: 8.61
21 Fr	SDI: 1.29	21 Mo	SDI: 0.99	21 Mo	SDI: 9.88	21 Do	SDI: 3.24	21 Sa	SDI: 6.35	21 Di	SDI: 10.64
22 Sa	SDI: 0.33	22 Di	SDI: 0.54	22 Di	SDI: 4.68	22 Fr	SDI: 3.31	22 So	SDI: 5.82	22 Mi	SDI: 11.26
23 So	SDI: 0.55	23 Mi	SDI: 0.86	23 Mi	SDI: 9.04	23 Sa	SDI: 2.08	23 Mo	SDI: 7.43	23 Do	SDI: 3.55
24 Mo	SDI: 0.88	24 Do	SDI: 1.26	24 Do	SDI: 4.72	24 So	SDI: 0.74	24 Di	SDI: 2.08	24 Fr	SDI: 2.3
25 Di	SDI: 1.24	25 Fr	SDI: 0.89	25 Fr	SDI: 10.46	25 Mo	SDI: 0.58	25 Mi	SDI: 0.66	25 Sa	SDI: 0.78
26 Mi	SDI: 2.02	26 Sa	SDI: 0.84	26 Sa	SDI: 5.21	26 Di	SDI: 0.6	26 Do	SDI: 1.43	26 So	SDI: 3.78
27 Do	SDI: 1.81	27 So	SDI: 0.63	27 So	SDI: 4.12	27 Mi	SDI: 1.36	27 Fr	SDI: 1.83	27 Mo	SDI: 9.74
28 Fr	SDI: 1.34	28 Mo	SDI: 1.7	28 Mo	SDI: 11.17	28 Do	SDI: 0.57	28 Sa	SDI: 1.64	28 Di	SDI: 6.12
29 Sa	SDI: 0.8			29 Di	SDI: 16.01	29 Fr	SDI: 2.04	29 So	SDI: 0.81	29 Mi	SDI: 4.33
30 So	SDI: 1.48			30 Mi	SDI: 13.23	30 Sa	SDI: 1.1	30 Mo	SDI: 1.06	30 Do	SDI: 3.57
31 Mo	SDI: 0.55			31 Do	SDI: 4.48			31 Di	SDI: 2.04		

Juli		August		September		Oktober		November		Dezember	
01 Fr	SDI: 2.11	01 Mo	SDI: 2.14	01 Do	SDI: 1.52	01 Sa	SDI: 0.28	01 Di	SDI: 5.19	01 Do	SDI: 0.33
02 Sa	SDI: 1.54	02 Di	SDI: 1.03	02 Fr	SDI: 5.71	02 So	SDI: 0.14	02 Mi	SDI: 1.41	02 Fr	SDI: 0.34
03 So	SDI: 2.84	03 Mi	SDI: 4.04	03 Sa	SDI: 0.69	03 Mo	SDI: 0.5	03 Do	SDI: 1.07	03 Sa	SDI: 0.47
04 Mo	SDI: 1.84	04 Do	SDI: 3.61	04 So	SDI: 1.01	04 Di	SDI: 0.49	04 Fr	SDI: 0.44	04 So	SDI: 0.53
05 Di	SDI: 1.86	05 Fr	SDI: 4.51	05 Mo	SDI: 3.88	05 Mi	SDI: 1.18	05 Sa	SDI: 0.14	05 Mo	SDI: 0.35
06 Mi	SDI: 5.42	06 Sa	SDI: 0.48	06 Di	SDI: 4.22	06 Do	SDI: 5.68	06 So	SDI: 0.24	06 Di	SDI: 0.4
07 Do	SDI: 0.99	07 So	SDI: 0.8	07 Mi	SDI: 1.83	07 Fr	SDI: 2.28	07 Mo	SDI: 0.8	07 Mi	SDI: 0.47
08 Fr	SDI: 1.77	08 Mo	SDI: 1.96	08 Do	SDI: 0.93	08 Sa	SDI: 3.49	08 Di	SDI: 0.62	08 Do	SDI: 0.89
09 Sa	SDI: 1.7	09 Di	SDI: 3.46	09 Fr	SDI: 1.06	09 So	SDI: 2.1	09 Mi	SDI: 0.64	09 Fr	SDI: 0.45
10 So	SDI: 1.28	10 Mi	SDI: 3.85	10 Sa	SDI: 0.77	10 Mo	SDI: 4.13	10 Do	SDI: 0.57	10 Sa	SDI: 0.3
11 Mo	SDI: 1.82	11 Do	SDI: 15.29	11 So	SDI: 0.28	11 Di	SDI: 3.76	11 Fr	SDI: 0.95	11 So	SDI: 0.27
12 Di	SDI: 3.15	12 Fr	SDI: 5.16	12 Mo	SDI: 1.61	12 Mi	SDI: 3.49	12 Sa	SDI: 0.58	12 Mo	SDI: 0.45
13 Mi	SDI: 5.08	13 Sa	SDI: 3.83	13 Di	SDI: 5.29	13 Do	SDI: 2.53	13 So	SDI: 0.39	13 Di	SDI: 0.68
14 Do	SDI: 21.79	14 So	SDI: 4.04	14 Mi	SDI: 3.75	14 Fr	SDI: 0.87	14 Mo	SDI: 0.67	14 Mi	SDI: 0.19
15 Fr	SDI: 6.04	15 Mo	SDI: 1.16	15 Do	SDI: 0.66	15 Sa	SDI: 0.29	15 Di	SDI: 1.22	15 Do	SDI: 0.16
16 Sa	SDI: 5.13	16 Di	SDI: 3.11	16 Fr	SDI: 0.47	16 So	SDI: 0.86	16 Mi	SDI: 0.41	16 Fr	SDI: 0.42
17 So	SDI: 3.59	17 Mi	SDI: 3.47	17 Sa	SDI: 0.44	17 Mo	SDI: 1.53	17 Do	SDI: 0.44	17 Sa	SDI: 0.24
18 Mo	SDI: 36.23	18 Do	SDI: 2.64	18 So	SDI: 0.51	18 Di	SDI: 4.28	18 Fr	SDI: 0.35	18 So	SDI: 0.35
19 Di	SDI: 20.58	19 Fr	SDI: 1.06	19 Mo	SDI: 0.84	19 Mi	SDI: 2.43	19 Sa	SDI: 0.32	19 Mo	SDI: 0.57
20 Mi		20 Sa	SDI: 0.41	20 Di	SDI: 1.03	20 Do	SDI: 5.99	20 So	SDI: 0.36	20 Di	SDI: 0.33
21 Do	SDI: 30.9	21 So	SDI: 1.03	21 Mi	SDI: 0.74	21 Fr	SDI: 3.9	21 Mo	SDI: 0.44	21 Mi	SDI: 0.73
22 Fr	SDI: 8.03	22 Mo	SDI: 2.2	22 Do	SDI: 0.95	22 Sa	SDI: 0.53	22 Di	SDI: 0.37	22 Do	SDI: 0.5
23 Sa	SDI: 2.41	23 Di	SDI: 2.52	23 Fr	SDI: 2.32	23 So	SDI: 4.77	23 Mi	SDI: 0.5	23 Fr	SDI: 0.38
24 So	SDI: 2.48	24 Mi	SDI: 2.58	24 Sa	SDI: 0.7	24 Mo	SDI: 2.97	24 Do	SDI: 0.42	24 Sa	SDI: 0.21
25 Mo	SDI: 3.66	25 Do	SDI: 3.4	25 So	SDI: 0.23	25 Di	SDI: 0.94	25 Fr	SDI: 0.46	25 So	SDI: 0.2
26 Di	SDI: 2.15	26 Fr	SDI: 4.36	26 Mo	SDI: 0.33	26 Mi	SDI: 5.07	26 Sa	SDI: 0.4	26 Mo	SDI: 0.27
27 Mi	SDI: 3.15	27 Sa	SDI: 1.15	27 Di	SDI: 0.3	27 Do	SDI: 3.75	27 So	SDI: 0.4	27 Di	SDI: 0.58
28 Do	SDI: 1.78	28 So	SDI: 1.31	28 Mi	SDI: 0.35	28 Fr	SDI: 8.64	28 Mo	SDI: 0.5	28 Mi	SDI: 0.43
29 Fr	SDI: 2.27	29 Mo	SDI: 3.57	29 Do	SDI: 0.16	29 Sa	SDI: 7.6	29 Di	SDI: 0.19	29 Do	SDI: 0.58
30 Sa	SDI: 2.57	30 Di	SDI: 3.67	30 Fr	SDI: 0.44	30 So	SDI: 5.83	30 Mi	SDI: 0.25	30 Fr	SDI: 0.49
31 So	SDI: 3.2	31 Mi	SDI: 1.76			31 Mo	SDI: 3.66			31 Sa	SDI: 0.32

Flentje et al, Identification and monitoring of Saharan dust: An inventory representative for south Germany since 1997, Atmospheric Environment 109, 87-96, 2015.

TREASURE HUNTING OF SCIENCE: HISTORICAL DATASET FOR THE BERCHTESGADEN NATIONAL PARK

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ABSTRACT

The Berchtesgaden National Park located in the Bavarian Alps in Southeastern Germany is a highly interesting study field due to its extreme topography (~ 600 - 2700 m.a.s.l.) and locally most variable climate conditions. Due to the research objective of the national park and the cooperation with the German Meteorological Service (DWD) we find a dense measurement infrastructure compared to other alpine regions. Ground measurements of temperature, relative humidity, precipitation and wind conducted by both partners go back as long as the 1980s with stations in different altitudes covering the complex terrain. Altogether, data of almost 100 stations is available, albeit with different record lengths (some only have short records of a few years). However, up to now, the datasets of the two institutions have only been used separately and lack a stringent quality control which takes into account the challenges of measurements in complex terrain.

New efforts are now underway to create a quality controlled, homogenized dataset for the Berchtesgaden National Park which will be openly available for the research community. Additionally, a gridding of the station data is planned which is of high importance to cover complex high mountain areas as adequately as less complex regions

The efforts also include the assessment of uncertainties, both of the measurement devices and of the digitization of thermohygrograph charts, as well as the compilation of metadata. Data from the operational Networks of the German and Austrian Meteorological Services, as well as other available station networks in the region are included in the processing of data.

This contribution will introduce this unique dataset which in future can be used as common historical reference e.g. for climate change studies, as boundary conditions for impact models or for the validation of climate models in complex terrain. It will also highlight some of the challenges of measurements in complex terrain and their data processing.

VOLATILITY OF ATMOSPHERIC ORGANIC AEROSOL DETECTED AT JUNGFRAUJOCH

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ABSTRACT

Particulate and gaseous organic carbon species are key players in chemical processes in the atmosphere and thereby affect climate, ecosystem and human health. While they mostly enter the atmosphere as volatile gases, subsequent cascades of oxidation reactions generate a plethora of chemical species in the gas phase as well as in the particle phase. The resulting oxidized species are either deposited through atmospheric removal processes or fully oxidized to CO or CO_2. To better constrain these processes in atmospheric models and thereby reduce their uncertainties, a complete characterization of this dynamic chemical mixture is needed.

During the carbon balance campaign 2022, we measured the chemical composition of the atmosphere at the Jungfraujoch (JFJ) High Alpine Research Station (3571 m.a.s.l.) in late summer. Both, gas and particle phase were analyzed. However, here we focus on particulate matter. The chemical composition of non-refractory PM1 was measured by two time of flight aerosol chemical speciation monitors (ToF-ACSMs) with and without a thermal denuder (TD) installed upfront.

We detected air masses from the free troposphere, mixed with the planetary boundary layer during the afternoons due to vertical transport. In addition, we sampled a wildfire plume and two short Saharan dust events as shown in Fig. 1a. From the measured thermograms (Fig. 1b), we will determine volatility distributions, which serve as a basis to simulate the partitioning of organics between gas and particle phases under variable ambient conditions (temperature, aerosol mass concentration, relative humidity). These data from Jungfraujoch provide unprecedented information on organic aerosol volatility from the lower free troposphere. In combination with the average carbon oxidation state, which we deduced from the recorded mass spectra (Fig. 1c), this can serve as valuable insights for "atmospheric aging" to benchmark respective model simulations.

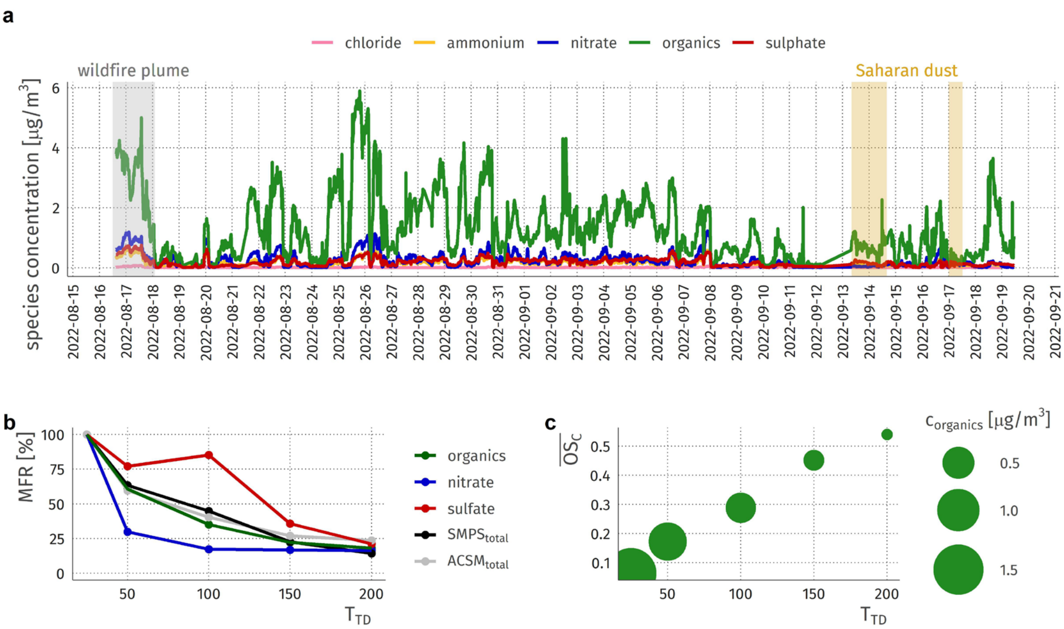

Figure 1: a) Aerosol composition at JFJ during the Carbon Balance Campaign. b) Thermograms obtained from TD-ACSM measurements (campaign average). c) Average carbon oxidation state of organic aerosol for different TD temperatures.

STAND-ALONE GAMMA SPECTROMETER GEODOS01 FOR DETECTION OF HIGH-ENERGY RADIATION BURSTS IN MOUNTAINS

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ABSTRACT

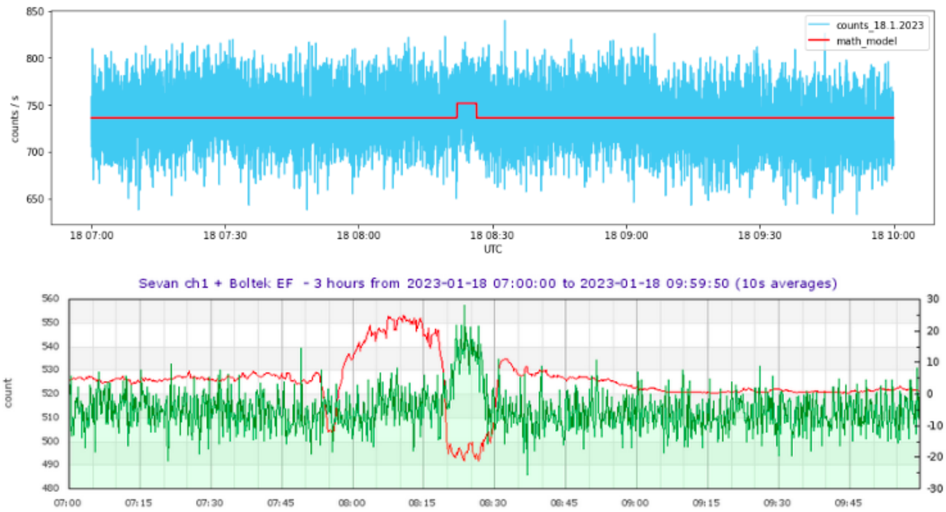
One of the goals of the CRREAT project (Research Centre of Cosmic Rays and Radiation Events in the Atmosphere) is to monitor radiation originated in thunderstorms. Thunderstorms can cause an increase in the background radiation level lasting from a few milliseconds (called terrestrial gamma ray flashes - TGFs) to minutes (called thunderstorm ground enhancements TGEs). Mountain peaks are ideal locations for such detectors because (1) they are closer to the clouds, (2) mountains are usually far from populated areas and industrial zones, which reduces electromagnetic interference caused by sources in cities and industrial facilities, (3) mountains usually have large areas of open sky, providing good visibility for detectors. Scientific observatories located in the mountains, such as in the Alps, are of interest from this point of view.

As part of the CRREAT project, the Geodos01 detector was developed and implemented for measuring high-energy gamma radiation. It is self-powered using solar cells, thus, it can be placed in hard-to-reach locations without connections to electricity and internet. Detectors of this type are currently successfully used in various installations located at Lomnický štít, Šumava, and Milešovka.

The report will consider methods for processing data from the Geodos01 detector to identify time intervals when TGF or TGE occur, during which the number of detected particles increases. The graph shows the number of particles over time containing these phenomena and the results of the program we developed, which allows such outbursts to be automatically detected with high probability. In this detector, unlike more sensitive detectors, the outburst is weakly pronounced and not visible without mathematical processing of the results. But our developed software allowed us not to miss these differences.

The developed methodology can also be used to analyze the operation of other similar detectors. There is also a program option that allows real-time detection of the start of an outburst, which can be useful for predicting various weather anomalies.

DETECTED TGE, LOMNICKÝ ŠTÍT 18.1.2023



PROJECT ALPAIREO: HEALTH RISK BY AIR POLLUTION AND THERMAL STRESS IN THE ALPS

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Oleg Goussev, and Ehsan Khorsandi

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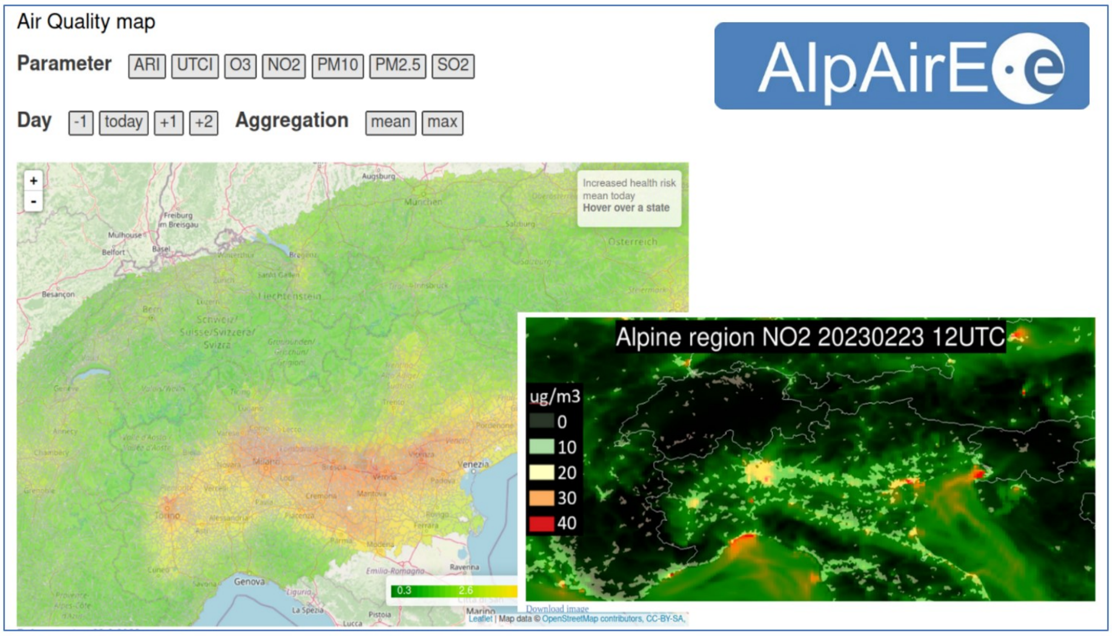
ABSTRACT

AlpAirEO is a project granted by the European Space Agency ESA eo4alps program. Its main goal is the provision of near-real-time information and forecasts of air quality, as well as on the associated health risks at a local administrative level. We describe the service online platform and report on the main project findings.

As contribution to ESA's regional initiative "EO science for Society", AlpAirEO shall demonstrate the added value of satellite remote sensing for investigating the link between the environment and human health by developing innovative science and information services for the general public and health services in particular, thereby improving the quality of life in the Alps. The main outputs are information on the current status of the air quality and the associated health risk in the alpine region. This is done in parallel by development of an interactive web platform, capable of providing near real time information at local administrative level, and analyzing trends in health risk indicators and air pollution for Alpine countries. The AlpAirEO online service (https://www.wdc.dlr.de/AlpAirEO) provides information on actual conditions and a three-day forecast.

Trend analyses for years between 2013 – 2018, show for ozone, in contrast to other main pollutants, a sustained positive trend in all data sets considered. Elevated ozone values were present in urban, background, and remote areas, with the highest levels exceeding the limit values of the European Environmental Agency during summer months. High NO2 mainly affects areas with strong emissions from combustion processes, such as heating systems, energy production, and transportation. The southern side of the Alps generally experiences higher pollution levels, especially fine particulate matter, in both alpine and transalpine regions. Preliminary results from the investigation of the potential correlation between yearly trends in air pollution and health risk indicators for Switzerland and Italy are not conclusive. On the other hand, total death counts, for example, are clearly linked to elevated aggregated risk values and show a general increase with city size.

ALPAIREO SERVICE: AIR POLLUTION AND HEALTH INDICATORS' STATUS AND FORECAST



PROTECTALPS- PERSISTENT, BIOACCUMULATIVE AND TOXIC CHEMICALS IN WILD ALPINE INSECTS

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ABSTRACT

Persistent, bioaccumulative and toxic chemicals (PBTs), such as mercury (Hg) and polychlorinated biphenyls (PCBs), can have a negative impact on insects. PBTs tend to bioaccumulation in the bodies of insects and are considered toxic (Hierlmeier et al. 2022). PBTs are long-range transported via the atmosphere and cold climates as well as high precipitation favor the deposition. This leads to a high pollution in alpine ecosystems, although the sources of the chemicals are far away (Kirchner et al. 2020).

Within the project “protectAlps”, the contamination levels and effects of PBTs on body structures of insects in alpine ecosystems were investigated. On Zugspitze in Germany and on Hoher Sonnblick in Austria, where the air concentrations of PBTs are measured since 2005 (Kirchner et al. 2020), insects were sampled. To examine the bioaccumulation of PBTs along the food chain, insects of different trophic levels were included: Bumblebees as primary consumers, ants as representatives of the intermediate trophic level and carrion beetles as secondary consumers. The concentration of PBTs in the bodies of the insects were determined by chemical analysis. To detect morphological changes as response to PBTs as chemical stressors, basically symmetric body structures of the insects, such as the wings of bumblebees or the heads of ants, were examined for asymmetry. In order to exclude inbreeding as a relevant factor for asymmetry, the insects were additionally analyzed for genetic fitness.

In total, more than 40 substances from different substance groups could be detected in the samples. The values along the food chain indicate bioaccumulation in insects. Significant correlations between concentration levels and asymmetry were found for some PBTs such as PCBs. The inbreeding values of the populations were low and did not show any correlations to the asymmetries.

With the developed methodologies, ProtectAlps established the basis for long-term monitoring of PBTs in insects in the Alps as early-warning tool.

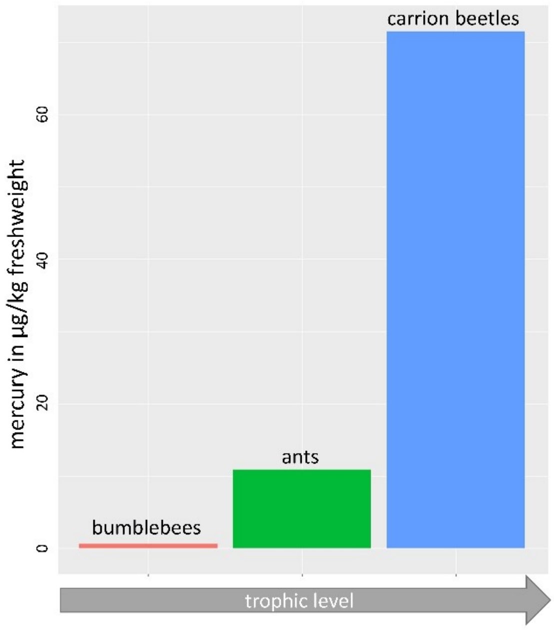

Fig. 1: Average concentrations of mercury (Hg) in the samples of bumblebees, ants and carrion beetles, combined from Zugspitze and Hoher Sonnblick, in µg/kg freshweight. Representing the enrichment of PBTs via the trophic levels.

References:

Hierlmeier, V.R., Gurten, S., Freier, K.P., Schlick-Steiner, B.C., Steiner, F.M., 2022. Persistent, bioaccumulative, and toxic chemicals in insects: Current state of research and where to from here? Sci. Total. Environ. 825, 153830. https://doi.org/10.1016/j.scitotenv.2022.153830.

Kirchner, M., Freier, K.P., Denner, M., Ratz, G., Jakobi, G., Körner, W., Ludewig, E., Schaub, M., Schramm, K.W., Weiss, P., Moche, W., 2020: Air concentrations and deposition of chlorinated dioxins and furans (PCDD/F) at three high alpine monitoring stations: Trends and dependence on air masses. Atmos. Environ., 223, 117199. https://doi.org/10.1016/j.atmosenv.2019.117199.

ANALYZING THE IMPACT OF TIME AND WEATHER ON DAILY WINTER TOURIST NUMBERS IN THE BAVARIAN ALPS USING WEBCAM IMAGES

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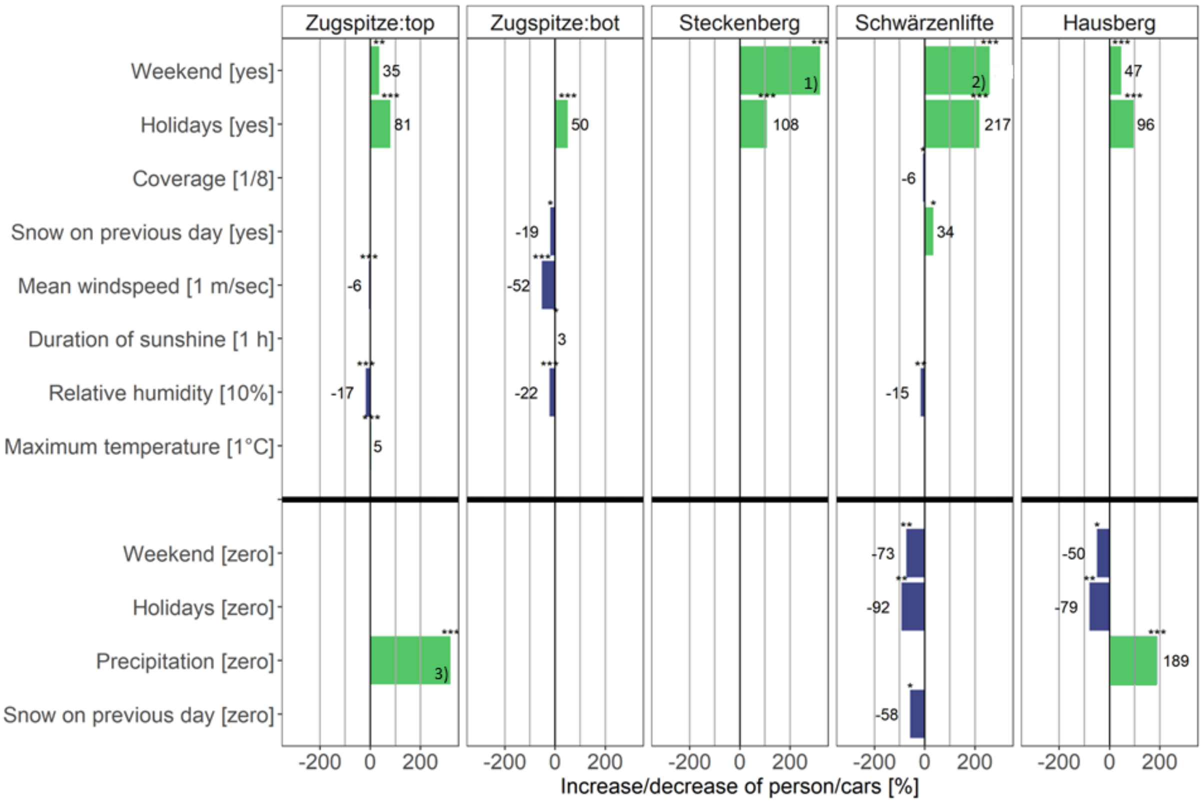
ABSTRACT

Climate change affects the European Alpine regions and its tourism industry. Especially winter tourism depends on stable weather conditions and snowfall. However, how a changing climate and weather might affect daily tourist numbers is still uncertain, which is also due to the poor data situation for day tourists. In this study, we determined daily tourist and car numbers from 1513 webcam images of five winter tourism sites in the Bavarian Alps over three winters via object detection and analyzed the relationship of these with meteorological and time-related variables. Precipitation, cloud coverage, snow on the previous day, windspeed, the duration of sunshine, relative humidity and temperature were significant meteorological variables determining the number of daily tourists. However, weekends and holidays showed a much stronger effect on visitor numbers for most of the sites. Consequently, weather does influence daily winter tourism numbers in the Bavarian Alps, but only to a certain extent.



*Change of numbers of persons or cars influenced by different meteorological and time-related variables in %. The upper part of the figure shows the significant variables of the count parts of the applied models, the lower part, separated by the black bolt line, shows the significant variables of the zero-inflated part of the ZINB. The asterisks describe the significance level of the variables: * = p-value < 0.05; ** = p-value < 0.01; * = p-value < 0.001. For Steckenberg and Zugspitze:bot, a negative binomial model was applied. Thus, zero inflation was not measured. 1): 283 %; 2): 258 %; 3): 671 %.*

CONTRIBUTION OF HIGH-ENERGY ATMOSPHERIC PHENOMENA TO NATURAL RADIATION BACKGROUND ESTIMATED USING GASTRON: GAMMA SPECTROMETRY OF THUNDERSTORM RADIATION OBSERVATORY NETWORK

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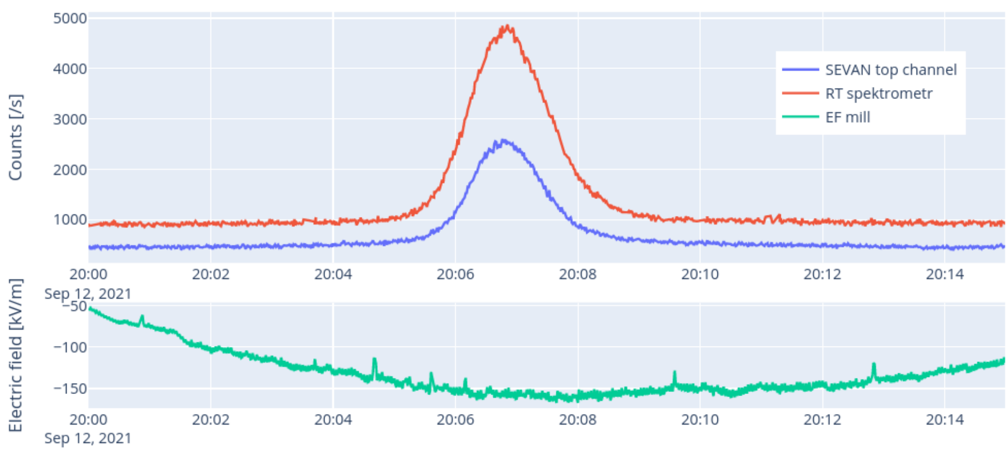
ABSTRACT

Natural ionizing radiation background negatively affects human health. Currently, only cosmic radiation, naturally occurring radioactive elements in the Earth's crust (such as uranium, thorium, and potassium), and radiation from radon gas are considered as sources of natural radiation background.
Thunderclouds are the largest natural particle accelerators on Earth due to differently charged areas that create high voltage between them. In this electric field, when an initial electron reaches a high enough energy, it can trigger electron avalanches known as relativistic Runaway Electron Avalanches (RREA), which are large populations of high-energy electrons. These avalanches are driven by electric fields in thunderstorms and propagate through matter (air) but are decelerated and deflected by atoms in the atmosphere. The lost energy is emitted in the form of gamma radiation known as bremsstrahlung. Two basic thunderstorm radiation phenomena have been recognized: brief and intense high-energy emissions called Terrestrial Gamma-ray Flashes (TGFs) and seconds to minutes lasting emissions called Gamma-Ray Glows (GRGs) or Thunderstorm Ground Enhancements (TGEs).
Detection probability and intensity of the thunderstorm radiation increases with altitude due to shorter distances to the thundercloud, making high-mountain observatories ideal measurement sites. The authors therefore intended to create a network of gamma spectrometers in Europe called GASTRON (Gamma Spectrometry of Thunderstorm Radiation Observatory Network), which currently has spectrometers in observatories in Czechia (Milesovka 837 m, Poledník 1315 m, Košetice 750 m), Slovakia (Lomnicky stit 2634 m), Bulgaria (Musala 2925 m), Germany (Zugspitze 2670 m), and Switzerland (Jungfraujoch 3579 m).
The objective is to detect and describe high-energy atmospheric phenomena, including their energies and other characteristics like radiation dose. In our contribution, we will present an overview of GASTRON, selected results obtained using our GASTRON network in all mentioned destinations, and a method evaluating the contribution of high-energy atmospheric phenomena to natural radiation exposure. Focus will be given on data from Zugspitze and comparisons with the SEVAN detector.



Example of intense TGE event detected with RT gamma spectrometer and SEVAN detector on Lomnicky stit.

THE SEVAN PARTICLE DETECTOR NETWORK

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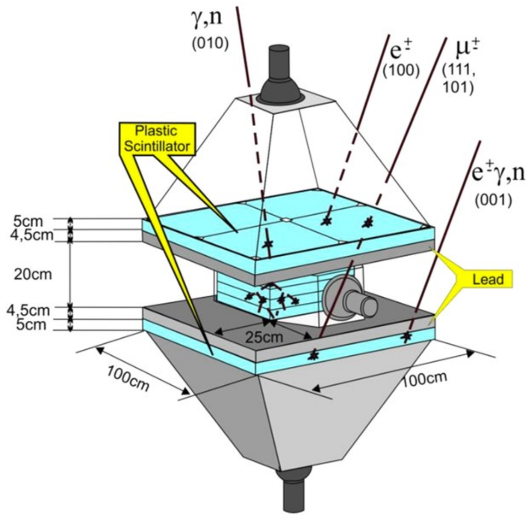
ABSTRACT

SEVAN (Space Environmental Viewing and Analysis Network) is a network of detectors to monitor particle fluxes and understand and interpret their variability due to the complex interplay between primary and secondary cosmic rays, space weather effects, the atmosphere and its electrical state. Phenomena, such as particle avalanches due to cosmic rays in the atmosphere, flux variations due to coronal mass ejections and magnetic storms from the Sun, as well as effects of thunderstorms and particle multiplication within its strong electric fields are identified and studied. Especially high-energy muons produced from very high-energy (relativistic) mass ejecta may allow forewarning times of hours (rather than days).

Currently, these stations take data: Armenia (Yerevan 1000 m asl, Byurakan 2000 m asl, Aragats station 3200 m asl), Bulgaria (Moussala 2900 m asl), Czech Republic (Mileskovka 836 m asl), Slovakia (Lomnicky Stít 2600 m asl), Germany (Hamburg ≈10 m asl, Berlin ≈30 m asl, soon: UFS 2650 m asl), stretching over 3500 km. A few others may join, too. They register particle fluxes and energy spectra of electrons, photons, protons, neutrons and muons on second-timescales. Through different trigger conditions these particles can be selected / enriched.

The detectors, designed and built at the Cosmic Ray Department in Yerevan, are largely identical and are complemented locally by lightning detectors, electrical field mills, weather stations, full-sky cameras and high-precision NaJ spectrometers. Data taken around the clock from all stations are stored in a central database, available for analysis through all project partners.

A few interesting results from the past years will be presented.



A SEVAN detector for recording particles reaching the ground level (DESY Zeuthen, 2019) .

[1]*for the SEVAN Network*

PESTICIDES IN THE DEPOSITION AT ENVIRONMENTAL RESEARCH STATION SCHNEEFERNERHAUS

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ABSTRACT

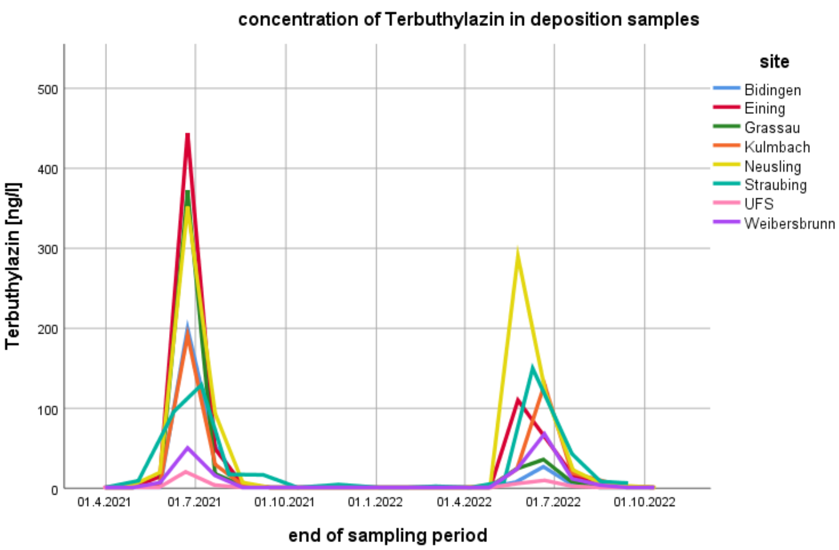
Pesticides are used in substantial quantities for crop cultivation in agricultural areas. Due to the large-scale use and atmospheric long-range transport, residues of those substances unintentionally reach non-target areas that are far away from the application areas like mountain peaks or even the arctic. The substances are deposited with precipitation and can potentially have direct and indirect adverse effects on individual or ecosystems.

The Bavarian Environment Agency runs a permanent monitoring for pesticide deposition at selected stations covering various regions of Bavaria. Since March 2021 deposition samples were also collected at the Environmental Research Station Schneefernerhaus (UFS) at Zugspitze/Germany at an altitude of 2650 meters. The samples were collected from a bulk precipitation sampler and taken regularly after a sampling period of 28 days. They were analyzed for more than 130 pesticides and pesticide metabolites.

Between 03/2021 and 09/2022, 20 different pesticides and pesticide metabolites were detected at UFS, mainly herbicides and fungicides. Nine pesticides were detected more than once such as the herbicide terbuthylazine which is usually used in corn and its metabolite desethylterbuthylazine. Maximum concentrations were in the double-digit ng/l-range which correspond to deposition rates of some hundred ng/(m^2*d).

Almost all pesticides found at UFS are also found in the lowlands. Their concentrations and deposition rates of pesticides are usually one to two orders of magnitude higher than at UFS. The substances are found in the same season, mainly in early summer which indicates a fast transport from application areas to mountainous regions like the UFS.

In March 2022, a large quantity of Saharan dust was deposited at UFS. In the respective sampling period some pesticides were only found at UFS and not in the other Bavarian regions, which indicates a particle-bound atmospheric long-range transport of these pesticides.



MONITORING AND MODELLING ALPINE GLACIER CHANGE AT DIFFERENT SPATIAL AND TEMPORAL SCALES

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Topic / Session: Alpine water cycle (oral presentation)

ABSTRACT

Mountain glaciers are known to be strongly affected by global climate change. Particularly glaciers located at low to medium elevations, such as in the European Alps, have experienced a substantial ice mass loss during past decades and are expected to partially disappear by the end of the 21st century. The on-going glacier recession raises challenges for future water supply and likely increases the frequency of natural hazards. Changes in meltwater runoff affect the hydrological regime in mountain regions and alter the seasonal availability of freshwater. In the European Alps, glacial meltwater contributes particularly to late-summer runoff. Furthermore, hazards, such as slope failures and rockfalls in destabilized deglaciated areas and outburst floods from temporary meltwater lakes, are often associated with rapid glacier melting. For the alpine countries and regions downstream, changes in meltwater runoff raise new challenges for the production of renewable energy, agriculture and tourism industry.

For the systematic monitoring of the alpine cryosphere and the reliable projection of future glacier evolution and freshwater availability, satellite-, drone- and ground-based observations are combined with numerical modelling at FAU. Large-scale remote sensing observations of glacier surface elevation and volume change provide important insights into the response of alpine glaciers to climate change on regional scales. Moreover, information on glacier surface topography and volume change enable numerical reconstructions of regional glacier ice thickness and volume distribution. As an example, we show latest regional ice thickness reconstructions for the Alps and provide an overview of the ice mass loss of almost all alpine glaciers during the early 21st century from contemporaneous glacier area and elevation change measurements. At individual glaciers, well-established glaciological measurements are complemented by drone-based photogrammetry, thermography and atmospheric sounding to monitor glacier changes in high spatial and temporal resolution, and to study local feedback mechanisms between the cryosphere and atmosphere. Both remote sensing and in-situ observations are harnessed in numerical models to project the future mass balance and evolution of glaciers from local to global scales. This is crucial to assess the emerging risk of local hazards, to reveal alterations in the regional water cycle, to estimate the timing of deglaciation in certain mountain ranges and to constrain uncertainties in projected sea level rise.

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Observing cryospheric and hydrological processes and storages at high-alpine catchment scales by a superconducting gravimeter at the top of Mt. Zugspitze

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Snow water equivalent (SWE) is an essential climate variable and has vital importance on the water cycle and the wellbeing of billions of people living in and downstream of mountain catchments worldwide. However, estimating the amount of snow and its spatiotemporal distribution in complex high-alpine terrain is currently considered as one of the most important challenges in alpine hydrology. In addition, it is extremely difficult to estimate alpine water storage components such as karst water reservoirs, permafrost and glaciers, and to examine the relationship between precipitation, evapotranspiration, storages, internal fluxes and discharge. Hydrogravimetry is the method of observing temporal gravity variations after reduction of all other geophysical signals as the integral of all hydrological mass variations on a wide spectrum from 1 s to several years. So far, the terrestrial hydrogravimetric method has been applied successfully for the direct, integral and non-invasive monitoring of water storage variations at several lower lying sites within footprints up to approx. 50 km². At the Zugspitze Geodynamic Observatory Germany (ZUGOG) with its worldwide unique installation of a superconducting gravimeter at a high-alpine summit, this method is applied for the first time on top of a well-instrumented, snow-dominated high-alpine catchment. In general, we want to investigate to what extent hydrogravimetry can contribute to a better understanding and quantification of cryospheric and hydrological processes and storages in high-alpine catchments. Specifically, in this study we will use this unique instrumental setup in synthesis with in situ measured data, detailed physically-based snowpack modelling as well as satellite-based snow depth maps derived by stereo photogrammetry. We will give an introduction into the novel sensor setup and will show first results, including the sensitivity of the integrative gravimetric signal regarding the spatially distributed snowpack and the cryo-hydro-gravimetric signal changes over the last 5 years.

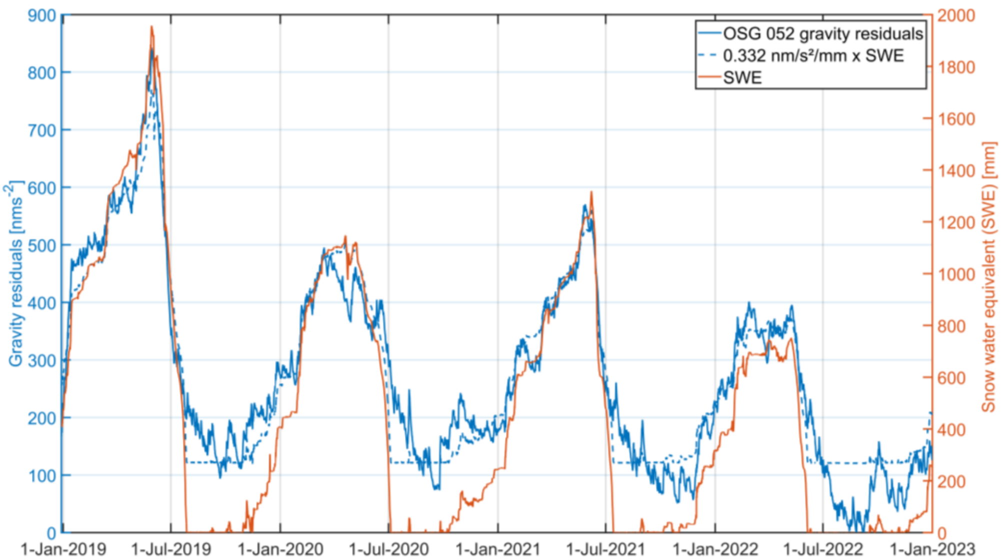

Figure: Gravity residuals (solid blue line) representing gravity variations, after the reduction of all other geophysical signals, as the integral of all hydrological mass variations observed at the Zugspitze Geodynamic Observatory Germany (ZUGOG), snow water equivalent (SWE, solid red line) measured by a snow scale at the LWD station at Zugspitzplatt and SWE multiplied with the estimated regression factor of 0.332 nms^{-2} mm^{-1} between gravity residuals and SWE (dashed blue line) for a 5-year period until 01.01.2023.

THE POTENTIAL OF EARTH OBSERVATION TO ASSESS THE IMPACT OF CLIMATE CHANGE ON THE ALPINE SNOW LINE ELEVATION

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ABSTRACT (ORAL PRESENTATION)

Snow plays a crucial environmental, societal and economical role in mountainous regions. It has an important impact on the local climate due to its albedo, strongly influences natural habitats, ensures the availability of freshwater and, last but not least, is the basis for the tourism-based economies of entire regions. At the same time, mountainous regions and especially snow cover are subject to dramatic changes in the context of climate change. These can be observed continuously at variable spatial scales using remote sensing. Long-term satellite missions such as the multispectral Landsat sensor family have been recording dynamics on the Earth's surface at high-resolution for almost 40 years. From this openly accessible data archive we have derived monthly time series of Snow Line Elevation (SLE) dynamics on a catchment basis for the entire Alps from 1985 until today. This multi-decadal SLE dataset is utilized in a variety of ways: We analyzed long-term trends of SLE which was found to be retreating to higher elevations at rates of several meters per year in a majority of the Alpine catchments. In the context of the drought in Northern Italy we compared the SLE dynamics of early 2022 to the long-term observations and found the SLE to be located up to almost 1000m higher than usual. Based on these findings we discussed the SLE as a complementary parameter in drought early warning systems. Ultimately, we aim at the prediction and projection of future spatio-temporal SLE dynamics in the context of climate change. To do this, we are currently identifying and assessing the environmental drivers of Alpine SLE dynamics in an extensive time-series correlation analysis. First results show that the strongest linear links exist between SLE and temperature as well as snow related variables such as snow cover fraction and snow depth, and that the correlation strength can vary considerably between different regions.
These efforts will contribute to estimations about Alpine snow cover change in the future and its impacts on natural habitats, the occurrence of hydrological droughts, or snow reliability for winter tourism under a changing climate.

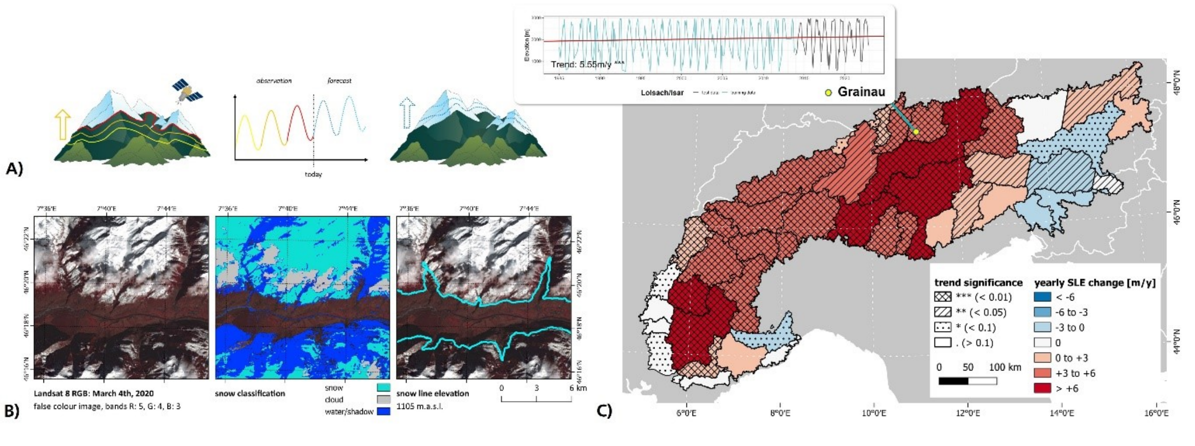

Figure: Alpine Snow Line Elevation: (A) concept, (B) estimation from satellite data, (C) long-term Mann-Kendall trend significance and yearly change rates (Theil-Sen slope) for all Alpine catchments. Detail shows SLE time series example of the Loisach/Isar catchment, Germany (Koehler et al. 2022).

References:

Koehler, J.; Bauer, A.; Dietz, A.J.; Kuenzer, C. Towards Forecasting Future Snow Cover Dynamics in the European Alps—The Potential of Long Optical Remote-Sensing Time Series. Remote Sensing 2022, 14, 4461, doi:10.3390/rs14184461.

THE ALPINE DROUGHT OBSERVATORY: AN ALPINE WIDE OPERATIONAL DROUGHT MONITORING PLATFORM

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ABSTRACT

Droughts are becoming an increasing concern in the Alps and in the lowland areas that receive Alpine water. Therefore, the monitoring and management of droughts are indispensable in securing the wellbeing of society and environment. The ADO Project (Alpine Drought Observatory, https://www.alpine-space.org/projects/ado/) provides a scientifically sound operational drought information web platform aiding decision makers on an alpine to regional level in managing water resources and drought impacts. The project is led by Eurac Research and combines the experience and competences of research institutes of six alpine countries.
The ADO platform is integrating climate models, satellite data observations, ground station measurements and historical records from all Alpine countries to produce a set of scientifically proven indices suitable for monitoring droughts. The drought index data is harmonized and operationally updated daily or weekly depending on the observation index. All data is offered as open access under the CC-BY 4.0 license. ADO provides the following data for the entire alpine space on political and hydrological relevant boundaries as well as the original gridded data: (i) Meteorological indicators such as SPI (precipitation), SPEI (evaporation), and SSPI (snow conditions), (ii) Satellite based vegetation indicators VHI and VCI, (iii) Hydrological data from monitoring stations along most rivers in the Alps, (iv) Historical database on drought impacts from scientific articles and media reports, (v) Vulnerability analysis and relevant data for its assessment.
The data is openly available through an interactive web platform (https://ado.eurac.edu) curated for public usage. For experts, the raw data is also freely available through the Environmental Data Platform (https://edp-portal.eurac.edu), which allows for direct processing and analysis. The usability of the platform has been showcased in multiple use cases carried out by hydrological offices across the alps.