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15.1
Chemically Mapping Ice Forming Particles

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Precipitation is mostly formed via the ice phase in mixed phase clouds, and ice clouds are very relevant for Earths’ climate. Freezing or prevention of freezing is common to everyday life, e.g. for food and drug storage, icing and de-icing, etc. However, the ice nucleation process is not well understood, since it occurs on the size scale of clusters of molecules and time scales of molecular fluctuations. In this study, we have taken a step toward nanoscale observation of particles that nucleate ice by developing new instrumentation coupled to a scanning transmission X-ray microscope (STXM) at the Swiss Light Source. We employ near-edge X-ray absorption fine-structure spectroscopy (NEXAFS) to map chemical properties of ice nucleating particles with 35 nm spatial resolution. This is the first time ice nucleation has been measured in-situ in an X-ray microscope. The main technical challenge was temperature control, and thus relative humidity control, while maintaining X-ray transparency. A sketch of our setup is shown in the figure below. X-rays are focused onto our sample through an aperture, which was modified to host a jet of nitrogen with a temperature down to 170 K. The cold jet impinges on the back surface of our sample exposed to water vapour. We verified that ice nucleation can occur on iron containing nano-particles, ferrihydrite, in the figure below. This iron mineral is contained in mineral dust, which itself is assumed to be ice active. When coating ferrihydrite with citric acid, mimicking organic coatings aerosol particles obtain throughout their atmospheric lifetime, we observed a reduction in the efficiency to nucleate ice. However, we suspect this is only due to the fact that citric acid will take up water and solubilize leading to a freezing point depression. Using a newly developed ice nucleation model based off of solution water activity, we can predict the relative humidity and temperature that ice forms.

Figure 1. Left: A sketch of the IceCell. Right: Raw STXM images of water condensation and ice nucleation on ferrihydrite particles.
15.2

A new Instrument for Continuous Monitoring of Ice Nucleating Particles

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The limited knowledge of aerosol-cloud interactions introduces large uncertainties when simulating the cloud radiative forcing in climate models (Boucher et al., 2013). The physical and optical properties, as well as the evolution of precipitation of a cloud is a strong function of the hydrometeor phase. One pathway to form ice crystals in the troposphere is via ice nucleating particles (INPs) which make up only a tiny fraction of all tropospheric aerosols. For accurate climate forecasts and projections, the parameterization of cloud processes and information such as the concentrations of INPs are needed (Demott et al., 2010; Phillips et al., 2013). Presently, no continuous online INP counter is available and the data acquisition still requires a human operator.

To address this restriction, we are developing a fully automated online ice nucleation particle counter, through an adaptation of an existing custom-built instrument, the Horizontal Ice Nucleation Chamber (HINC, Lacher et al., 2017), called HINC-Auto. HINC has successfully been used to detect INP concentrations during numerous field campaigns since 2014. HINC-Auto will be collecting data at the High Altitude Research Station Jungfraujoch (JFJ, 3580 m a.s.l., 46°33’ N, 7°59’ E) by mid-2020 with the goal of publishing the data in near real-time on an open access website. We present results from the first campaign in August 2019 where HINC-Auto was run at the JFJ. Furthermore, we will discuss potential of the new device as well as the difficulties faced.

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Quantification of gaseous emissions from diffuse sources, e.g. animal farms, is challenging due to their heterogeneity in space and time. The inverse dispersion technique is a promising option, which is increasingly used to determine gaseous emissions from diffuse sources, as it offers high flexibility at reasonable costs. So far, the inverse dispersion technique was only applied under Monin-Obukhov similarity theory conditions, which are often not fulfilled in central Europe. Here we use a simple backward Lagrangian stochastic (bLS) model in combination with open-path tunable diode laser spectrometers up- and downwind of the source in non-homogeneous horizontal and flat terrain and difficult micrometeorological conditions to model methane emissions from a dairy housing and compare it to simultaneously conducted in-house tracer measurements. We could show that the bLS model works also under non-ideal model conditions and that the method can be used to model emissions of sources in areas for which an emission estimate was not possible so far.
15.4

Photochemical aging processes in iron containing aerosols

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FeIII-citrate plays an important role in aerosol aging processes, especially in the lower troposphere, with low intensities of ultraviolet light. The photochemistry of FeIII-citrate has been widely recognized in both solution and solid states. It can absorb light up to around 500 nm, inducing the reduction of FeIII and the oxidation of carboxylate ligands. In the presence of O2, ensuing radical chemistry will likely lead to more decarboxylation and production of peroxides (e.g., OH•, HO2• and H2O2) and oxygenated volatile organic compounds (OVOC). The peroxides in turn allow the re-oxidation of FeII to FeIII, closing this photocatalytic cycle, in which Fe acts as a catalyst.

Little is known about how the viscosity of an aerosol might slow these catalytic cycles. To investigate this question, we use an electrodynamic balance. A single mixed FeII-citrate/citric acid aerosol droplet (radius ~10 µm) is levitated in this balance with well controlled temperature and relative humidity. During photochemical processing under irradiation in the visible (473 nm), mass and size changes of the particle are tracked. We measure a substantial mass loss (80% over 24 hours) of the droplet during photochemical processing due to the evaporation of volatile (e.g., CO2) and semi-volatile (e.g., ketones) products. We focus the experiments on high viscosity cases (i.e., reduced molecular mobility and low water content), which slows the transport of products and thus affects chemical reaction rates. For a coherent description we developed a numerical model, which includes main equilibria, chemical reactions, and diffusivities of major species. It allows to simulate the concentration gradients of each species inside of the particle, and to derive the size and mass changes. Comparing model output with experimental data enables us to determine or at least constrain some of the crucial parameters, such as equilibrium constants, chemical reaction rates, and liquid phase diffusion coefficients. With such well-defined and physically constrained parameters, we will predict the evolution of products as well as organic acid degradation in the condensed phase under atmospheric conditions.
15.5

Mid-IR Laser Spectrometer for Balloon-borne Lower Stratospheric Water Vapor Measurements

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Water vapour is the dominant greenhouse gas and its abundance in the upper tropospheric/lower stratospheric region (UTLS, 8-25 km altitude) is of great importance to the Earth’s radiative balance. Reliable predictions of the climate evolution as well as the understanding of certain cloud-microphysical processes require the accurate and frequent measurement of water vapour concentrations at these altitudes. We present a compact and lightweight instrument based on laser absorption spectroscopy (LAS) that addresses the stringent constraints posed by the harsh environmental conditions found in the UTLS. To accomplish this, fundamental reconsiderations were required with respect to traditional, lab-based spectrometers. The key element for high-precision measurements of low abundance gas concentrations by means of LAS is the multipass cell (MPC). It defines both the performance and the size of a spectrometer. Established designs have serious limitations with respect to compactness, weight and/or optical performance. As part of this project, a highly versatile MPC has been proposed and developed, which supports compact and well-controlled beam folding (Graf 2018). The inherent mechanical symmetry of this segmented circular multipass cell (SC-MPC) makes it predestined for mobile applications and rough environmental conditions. As light source, we use a single mode, continuous-wave quantum cascade laser emitting at 6 µm. The collimated laser beam is reflected 64 times within the SC-MPC resulting in an effective optical path length of 6 m. Water vapour amount fractions of <10 ppm can be measured with a precision better than 1% at 1 Hz. Fast response and reduced interference by spurious water desorbing from surfaces is ensured by operating the cell in open-path configuration. Thus, in a balloon-borne setting, the ambient air flows freely through the cell because of the ascending motion. The overall instrument weighs less than 4 kg (including battery) and has an average power consumption of 15 W. Specifically developed hard- and software guarantee stable and autonomous operation during the flight period. Extensive stability assessments in a climate chamber as well as validation experiments using dynamically generated, SI-traceable water vapour mixtures were performed in collaboration with the Swiss Federal Institute for Metrology (METAS). The instrument is currently prepared for deployment aboard meteorological balloons for in-situ measurement of water vapour in the UTLS. This concept represents a paradigm change in portable laser spectroscopy instrumentation and can target many other compounds and research fields, e.g. detection of methane on UAV based platforms.

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15.6

Meteorological triggers for snow avalanches in the Borzhava and Chornohora massifs of the Ukrainian Carpathians

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Snow avalanches are common natural hazards threatening the tourism mountain areas in the Ukrainian Carpathians. More than 500 avalanche centres are detected here. The sections at altitudes higher than 1,000 m (9.6% of the mountain area) that refer to the Chornohora and Borzhava massifs are the most prone to the avalanche activity and associated ecosystem damages and accidents. Here, 15-20 avalanche events a year are observed. An increasing number of avalanche events and avalanche victims are reported in the past decade. Snow and weather regimes are considered to control avalanche activity (Castebrunet et al. 2012). These areas are covered by only two meteorological and snow-avalanche stations with a continuous data series at Play (1343 m a.s.l.) and Pogegevskaya (1429 m a.s.l.) that include the observation of 41 avalanche centres. Accordingly, this study involves the time series analysis of meteorological variables and synoptic patterns for the identification of dominant snow avalanche triggers and interpolation for other similar areas in the Ukrainian Carpathians.

The majority of detected avalanches take place on the north-eastern and south-eastern steep slopes with high instability of the snow layer. In the region, 70% of precipitation in the avalanche period from December to April constitute snow. For this period in the last decade, three major meteorological triggers were distinguished – intensive snowfalls, snowstorms, and warming episodes that correspond to the results in Southern Carpathians, Romania (Pop et al. 2018). Intensive snowfalls with a 20-cm increase and snowstorms triggering snow avalanches are mainly detected in December and January (Bilanyuk & Tikhanovich 2015.) Warming events with the maximum speed of the surface air temperature increase 1°C per hour are found the dominant trigger in March-April. Besides, differences in the dominance of certain meteorological conditions between the two massifs were found. Snowstorms are the most frequent triggers of snow avalanches in the north-western part of the Ukrainian Carpathians – Borzhava in all the months. Meanwhile, all types of meteorological triggers of snow avalanches are observed in the central part of the Ukrainian Carpathians – Chornohora. Our preliminary results show the increase in the occurrence of wet-snow avalanches associated with intensive precipitation and warming episodes that are correlated with the south-western cyclonic types of regional atmospheric circulation. This work is a contribution to the project ACTIVNEIGE «Activité des avalanches des neige dans les Carpates Orientales Roumaines et Ukrainiennes» (Snow avalanche activity in Romanian and Ukrainian Eastern Carpathians), funded by AUF-IFA RO.

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15.7

Impact of cloud processing on the ice nucleating ability of organic aerosol particles

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Aerosol particles can interact with clouds by acting as ice nucleating particles (INPs) contributing to significant uncertainties regarding future climate projections (Boucher et al., 2013). Ice formation also influences precipitation formation (Mülmenstädt et al., 2015), highlighting the importance of better constraining ice formation processes in clouds. Organic aerosols (OAs) have been shown to be INPs in the troposphere, even below the homogeneous nucleation temperature of 235K (Knopf et al., 2018). They are either formed from organic precursor gases as secondary organic aerosol or can directly be emitted as primary OA from sources such as ocean and lake surfaces, from biomass burning, and coal combustion. The atmospheric burden of OA is estimated to be approximately 1.7 Tg (Textor et al., 2006) and have been observed in both natural remote and anthropogenically impacted regions (Jimenez et al., 2009).

While OA particles can freeze or form a droplet in a (first) cloud formation cycle, its long atmospheric lifetime of about a week renders it likely that such particles are involved in multiple cloud-cycles. The impact of such a cloud processing on OA physicochemical properties, and potentially altered ice nucleating ability is almost unknown. Previous studies report altered, more porous morphology and particle size (Adler et al., 2013), however the impacts of these alterations on ice nucleation are unknown.

In this work, we investigate if cloud processing impacts the heterogeneous ice nucleation potential of OA particles in either cirrus or mixed-phase cloud environments. A previously used laboratory setup that includes two coupled horizontal ice nucleation chambers described by Mahrt et al. (2019) and atmospherically relevant OA proxies (i.e. levoglucosan and oxalic acid) are used for the measurements. The aim is to determine if there is a detectable change in the ice nucleation ability of OAs in comparison to unprocessed particles. Furthermore, we investigate which properties of the aerosol lead to the any observed change. Experiments are conducted to measure the ice nucleation potential of OA following different relative humidity and temperature trajectories for both the cloud processed particles and unprocessed particles. Our results will aid in furthering our understanding the fate of OA as INPs in relation to their atmospheric lifetime and physicochemical properties.

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Effect of Dew and Fog Water on Swiss Grasslands Using Stable Water Isotopes

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Dew and fog have been proven to be essential water sources for plants. Research so far has mainly focused on the effect of dew and fog on arid and desert ecosystems, but rarely on temperate ecosystems; only very limited information is available for temperate grasslands.

Compared to forests, more open canopies of grasslands are expected to be affected by stronger radiative cooling at night, which promotes the formation of dew on leaf surfaces, and the formation of ground radiation fog at the plant boundary layer. Moreover, the rougher surfaces of grasslands are believed to potentially collect more dew and fog water than forests. Under more frequent no-rain days in future summers, the effect of dew and fog on short-statured grassland species is expected to become more beneficial as an additional water source. In 2018, Switzerland experienced the driest April to August period of the last five decades. Our research using stable water isotopes investigates how dew and ground radiation fog affected Swiss grasslands in the extreme summer-2018.

Focusing on an intensively managed grassland located at a valley bottom close to Chamau (ZG), we measured the isotope ratios (δ2H and δ18O) of near-surface atmospheric water vapor with a cavity ring-down spectrometer (Picarro L2130-i), and the isotope ratios of the liquid-phase water from dew/fog droplets, leaf, root crown and soil with an isotope-ratio mass spectrometer. The isotope signals were then combined with eddy flux and meteorological data to analyze the water vapor dynamics during dew/fog formation, and the interaction of dew/fog with plants and soil. Sampling was carried out during two distinct periods: pre-dew/fog and dew/fog periods. The pre-dew/fog period was defined as the period after sunset before the leaves got wet, while the dew/fog period was defined as the period after leaf wetting before sunrise.

Our results based on the isotope signals of atmospheric water vapor, leaf, root crown and soil water showed that dew/fog water was taken up by leaves, and was also present in top-soil. These results were supported by higher (less negative) leaf water potentials during dew/fog periods than during pre-dew/fog periods. The water vapor isotope signals at the near-surface layer showed deposition and condensation signatures during nights with dew/fog formation, i.e., δ2H and δ18O of water vapor in the atmospheric air gradually decreased. While the deuterium excess (d-excess) values of water vapor (d-excess = δ2H − 8*δ18O) were positive during the day, they became negative during dew nights, pointing towards non-equilibrium fractionation in supersaturated conditions accompanying a H2O deposition flux. During dew nights accompanied with ground radiation fog, the d-excess values were relatively stable compared to the dew nights without fog when d-excess gradually decreased. Furthermore, the isotope signals of dew/fog and leaf water were different from each other during pre-dew/fog periods, but became similar during dew/fog periods.

Our research highlights the importance of dew and ground radiation fog as the water sources in temperate grasslands during rainless summer periods that are expected to become more frequent with global warming.
15.9

Tracking growth phenology and physiology of a cropland in response to experimental drought and different cropping systems

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Plant phenology is highly sensitive to climate change and variability, phenological changes in response to climate change are well documented across all biomes. Drought events, which are projected to increase in both frequency and severity in the future, could strongly affect phenology. Shifts in phenology, such as the length of growing season, might directly link to ecosystem productivity and carbon cycling.

Organic farming and conservation tillage have been proposed as means to better cope with recent agricultural challenges such as environmental impacts from agricultural intensification and the demand for sustainable food production. However, whether drought effects can be mitigated by particular cropping system needs further investigation. Additionally, it is not well understood how growth phenology relates to crop yields and if growth phenology extracted from phenocam images reflects plant physiological changes, especially in arable systems. We therefore aimed at understanding how drought affects growth phenology in different cropping systems.

We compared organic and conventional farming with intensive and conservation tillage and subjected the four cropping systems to a drought treatment. To observe the changes in growth phenology, we installed time-lapse cameras at plots managed under four different cropping systems. The cameras were mounted to wooden poles at 1.5 m of height with an oblique viewing angle (60° from horizontal) towards north, recording hourly images of the central region (1 m * 1.5 m) of the experimental plots (3 m * 5 m). Images were recorded for a pea and barley mixture in 2018 and winter wheat in 2019. We estimated the length of growing season by extracting the greenness index derived from phenocam image. We hypothesized that (1) a longer growing season leads to higher crop yields, (2) drought causes shifts in phenological phases, especially earlier senescence, and therefore shortens the growing season, (3) cropping systems with conservation tillage mitigate drought effects on growing season length and yield due to improved soil water condition.

First results from the pea-barley mixture show that longer growing season resulted in higher yields. Drought significantly shifted growth phenology, so that the peak of greenness and senescence date occurred earlier. This resulted in a shorter growing season and lower yields in plants under drought compared to control plots. Cropping systems showed no effects on the length of growing season. However, conservation tillage significantly reduced yields, while organic farming had no significant effects. We conclude that phenocam images can well record large yield changes resulting from drought, but not the less severe yield change caused by cropping systems. Future analyses will include plant traits, such as LAI and chlorophyll content in both pea and barley mixture and winter wheat to directly link phenology as observed by the phenocams and plant performance under drought.

Keywords: phenology, drought, cropping systems, yield, physiology

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Do warmer winters induce more forest and crop pests in Switzerland?

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While many studies focus on the effect of global warming on diverse ecological systems during the spring-summer period, very few are investigating the winter period and its potential changes induced by climate change. With current global warming, warmer winters in Switzerland are already occurring and their frequency might increase. Some insect species which are sensitive to extreme cold events in winter could benefit from this by increasing their winter survival rate. Forest pests, such as the pine processionary moth (Thaumetopoea pityocampa), the green spruce aphid (Elatobium abietinum), and some crop pests, such as the southern green stink bug (Nezara viridula) might react to warmer winters. These species are known to be negatively affected by temperatures going from -8°C, for the green stink bug (Chanthy, Martin et al. 2012), to -12°C, for the green spruce aphid (Halldórsson, Docherty et al. 2001) and for the processionary moth (Huchon and Déminolin, 1970).

In this study, we examine the trends for winter temperatures in Switzerland, with a special focus on extreme cold events (days with minimal air temperature below -8°C and -12°C). We first analyse daily air temperature between 1975 and 2018 using homogenized data from 18 MeteoSwiss stations. Then, we use available data from CH2018 climatic scenarios to estimate possible trends along the coming century.

Preliminary results showed that a -8°C threshold is still regularly reached at all elevations in Switzerland for the winter period 1975-2018, with a frequency of 100% of the winters above 800m and 86% at lower elevations), except in the South Alps. Climatic scenarios indicate that this frequency might decrease during the next decades under 800m, with less and less winter reaching temperature below -8°C. By the end of the century, this threshold could be reached less than one year every two years at low elevations. The -12°C threshold is already quite unusual under 800 m (frequency of 39%), but occurs almost every winters at higher elevations (frequency of 97%). This frequency might also decrease in the next decades for elevations up to 1700m, and the threshold between 800 and 1700m could be reached only in 50% of the winters by the end of the century. These results might suggest that (1) crop pests such as the southern green stink bug could overwinter more easily at low elevations in Switzerland, and (2) that forest pests such as green spruce aphid and pine processionary moth could reach higher elevations by the end of the century.

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15.11

Large regional differences of soil water limitation effect on ozone induced yield loss for wheat and potato in Switzerland

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Elevated Ozone (O₃) concentrations are generally prevalent during the crop growing season and can cause significant yield reductions in important food crops. To assess the potential risk, plant stomatal O₃ uptake rates are favorably calculated with deposition models. The species-specific hourly stomatal conductance is calculated based on the Jarvis-type multiplicative algorithm, including meteorological effects and crop phenology. The resulting phytotoxic ozone dose values over a flux threshold (POD₆) allow the estimation of crop specific O₃ induced yield losses.

Given that wheat and potato are among the economically most important food crops and the most O₃ sensitive, the study focused on these two crops. We used data of thirteen O₃ and meteorological measurement sites, distributed among the most important crop growing areas of Switzerland. The DO₃SE model was used for flux calculations and parameterized according to experimental data recorded across Europe, including some adjustments for Switzerland. As shown in earlier studies, soil water limitation is largely influencing the stomatal O₃ uptake by altering the stomatal aperture. To partly validate the soil water model, the modelled wheat evapotranspiration rates were compared with eddy covariance measurements of water fluxes. Different years were modelled to disentangle the influence of contrasting seasonal environmental conditions. Based on the site specific O₃ uptake rates and the respective crop growing area per district an average area weighted potential yield loss for Switzerland was calculated.

Regional and inter-annual differences in meteorological conditions led to considerable variations in soil water conditions and hence also in POD₆ values for wheat. Potato stomatal uptake was much less influenced by soil water and showed a more even distribution of POD₆ values across sites and years. It was found that soil water deficit, observed frequently in the western part of Switzerland, had a large attenuation effect on stomatal O₃ uptake by wheat and on corresponding yield losses. The comparison of modelled evapotranspiration with the water flux measurements over a wheat field showed a reasonable agreement concerning the temporal pattern and the magnitude. However, it was also shown that the model might overestimate stomatal closure in very dry conditions. The estimated nationally and temporally average yield loss was 3.2 ± 1.2% for wheat and 2.4 ± 0.8% for potato.
Phenology is the phenomenon of recurring plant and animal life cycle stages, especially their timing and relationships with the environment. Various environmental factors can drive phenological events mainly temperature, relative humidity, daylength, rainfall. Thus, weather and climate play a dominant role in determining both the average timing and specific date in which phenological event will occur at specific locations and years. The connections between phenology and climate go back as far as the beginnings of agriculture, when farmers looked to seasonal biological signs to guide their farming activities. Changes in their phenology in the predicted direction under current climate change (Parmesan and Yohe, 2003). Changes in phenological events like flowering and forced maturity are among the most sensitive biological responses to climate change. This strong dependence on climate have the highest portion of species shifting their phenology in the predicted direction under current climate change (Parmesan and Yohe, 2003). Changes in phenological events like flowering and forced maturity are among the most sensitive biological responses to climate change. A phenological study records the dates on which seasonal phenomena occur which provides important information on how climate change affects ecosystems over time. Phenology has been used as an indicator of climatic difference between two regions and global change over the earth surfaceswith the help of European Environmental Agency and Intergovernmental Panel on Climate Change (IPCC, 2007). Since few studies have assessed the effect of other environmental factors such as precipitation, photoperiod, availability of soil nutrients or soil physical properties and consequently evidence for their impact on phenology remains scarce (Badeck et al., 2004).

Phenology is important because it affects whether plants and animals survive in their environments. It is important because our food supply depends on the timing of phenological events. The changes in the timing of phenological events can be used as an indicator of changing climates. Phenology records can help scientists fill in gaps and verify trends in other sources of data to get a more complete picture of the local effects of global climate change. They also help scientists predict changes that may come in the years and decades ahead. It helps to understand, respond and prepare for changing climate conditions. This information might be helpful for the practices of farmers, resource managers and others stakeholders.

The observations on the phenological events of the mustard crop reflected the influence of weather elements. The dates of sowing make difference significantly in all phenophases. Early sown crop took less number of days for emergence than the normal and late sown crop due to low temperature in late sowing dates. Duration of the reproductive stage became shorter as the date of sowing delayed in the season. This was due to higher temperature experienced in middle and later phenophases under delayed sowing which caused reduction in duration of reproductive phase. High temperature reduced

Phenological development in mustard (Brassica juncea) crop under varying thermal times

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the days to flowering and days to maturity thus shortening the seed formation period. A higher temperature leads to higher respiration rates, reduces biomass production resulting in smaller and lighter grain therefore lower crop yield. The accumulated growing degree days was less at emergence in late sowing due to comparatively low temperature. The accumulated growing degree days was higher under early sown crop at all the phenophases due to more growing period available to early sown mustard.

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15.13

Implication of air pollutants in resilient and sustainable crops production

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Greenhouse gases (GHGs) warm the surface and the atmosphere with significant implications for rainfall, retreat of glaciers and sea ice, sea level, among other factors. It is well established and recognized that the increase in tropospheric ozone from air pollution (NOx, CO and others) is an important greenhouse forcing term. In addition, the recognition of chlorofluorocarbons (CFCs) on stratospheric ozone and its climate effects linked chemistry and climate strongly (Ramanathan and Feng, 2016). Climate change is a serious and long-term challenge that has the potential to affect every part of globe. Increased human activity in the last century altered the concentration of atmospheric greenhouse gases and aerosols, amplifying the process of global warming and climate change. Ever since the Green Revolution first staved off famines in the 1960s, Indian rice and wheat systems have grown over the past half century to play critical roles in the world food economy: India’s 1.2 billion people depend primarily on food produced within the country, and other Asian and African nations rely heavily on imports of Indian rice. Rising temperatures because of increased emissions of greenhouse gases (GHGs) have had and will continue to have significant negative impacts on crop yields. The problem of air pollution to has attracted special attention in India due to tremendous increase in size of population, industrialization and urbanization since last few decades. Air pollutants emitted in varying forms adversely affect growth and yield of crops (Singh et al., 2018).

Agricultural crops can be injured when exposed to high concentrations of various air pollutants due to intensive developmental activities. Injury ranges from visible markings on the foliage, to reduced growth and yield, to premature death of the plant. The development and severity of the injury depends various factors including the concentration of the particular pollutant. To analyze the air quality at Hisar, air samples were collected using Air Sampler PM1.0. The total mass concentration of PM1.0 samples recorded was above 115 µg/m³ during the winter season of 2016-17 (115.4 µg/m³ on 6th Jan, 145.0 µg/m³ on 7th Feb and 138.0 µg/m³ on 8th Feb) well above the acceptable limit of 40-60 µg/m³. Among the total PM concentration, Sulphate contribution was maximum (3.236 to 4.140 µg/m³) during the season. The pollutants and particulate matter reduces the radiation quality and alter the stomata activities in crops plants consequently more detrimental for plant biological activities. Due to air pollution and anthropogenic climate change impact on crops in India, the yields have levelled off or decreased in recent decades despite continued improvements in agricultural technology (Burney and Ramanathan, 2014). There is an acute need to not only increase the monitoring programs across all domains, but also to publicly disseminate the information among various stake holders. Air pollution risk assessment of agricultural crops will bring together experts and specialists on air pollution, to discuss the likely impacts of air pollution on agricultural crop production. It will help the decision makers to formulate necessary policy options to reduce the vulnerability of crops to air pollution. While the monitoring stations can be established, legislations amended, and standards improved, these efforts will be a waste, if the regular dissemination of the information is not practiced to raise the awareness for pollution control.

Field experiments on farm scale for GHG emissions estimation under various farming system with agrometeorological interventions will also help immensely for further planning, execution and testing so as to achieve sustenance and resilience crop production.

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15.14

Exploring accumulation-mode $H_2SO_4$ versus $SO_2$ stratospheric sulfate geoengineering in a sectional aerosol–chemistry–climate model

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The continuously increasing dismal prospects for climate change mitigation have boosted research on SSG during the last decade. Stratospheric solar geoengineering (SSG) is a technique that proposes to inject aerosols into the stratosphere to increase the Earth’s albedo. SSG could contribute to avoiding some of the adverse impacts of climate change. So far, research has primarily focused on SSG by $SO_2$ injection due to the natural analogue of volcanos.

In this study, we used the SOCOL-AER global aerosol–chemistry–climate model (Sheng et al. 2015) to compare 21 different SSG scenarios, of which each injected 1.83 Mt S/yr either in the form of accumulation-mode $H_2SO_4$ droplets (AM $H_2SO_4$) gas-phase $SO_2$ or as combinations of both. For most scenarios, the sulfur was continuously emitted at an altitude of 50 hPa (about 20 km) in the tropics and subtropics. We assumed emissions to be zonally and latitudinally symmetric around the Equator. Emissions were injected with a spread between 3.75°$S$ – 3.75°$N$ to 30°$S$ – 30°$N$.

In the $SO_2$ emission scenarios, continuous production of tiny nucleation-mode particles results in increased coagulation, which together with gaseous $H_2SO_4$ condensation, produces coarse-mode particles (see Figure 1). These large particles are less effective for backscattering solar radiation and have a shorter stratospheric residence time than AM $H_2SO_4$ particles. The green aerosol size range in Figure 1 depicts the sulphate aerosol radius range at which backscattering of solar radiation is at least 70% of the peak efficiency at 0.3 $\mu$m. AM-$H_2SO_4$ size distributions show larger particles concentrations and larger aerosol mass fractions than the equivalent $SO_2$ emission scenarios. On average, the stratospheric aerosol burden and corresponding all-sky shortwave radiative forcing for the AM $H_2SO_4$ scenarios are about 37% larger than for the $SO_2$ scenarios. Sensitivity of the latitudinal spread of the emissions was found to be small. Emitting between 30° N/S instead of 10° N/S only decreases stratospheric burdens by about 10%. This is because an increase in cross-tropopause transport via tropopause folds in scenarios with broad emission spread is nearly compensated by increased gravitational settling rates due to larger coagulation in scenarios that only emit at the Equator. In the case of gaseous $SO_2$ emissions, limiting the sulfur injections spatially and temporally in the form of point and pulsed emissions reduces the total global annual nucleation, leading to less coagulation and thus smaller particles with increased stratospheric residence times. Pulse or point emissions of AM $H_2SO_4$ have the opposite effect: they decrease the stratospheric aerosol burden by increasing coagulation and only slightly decrease clear sky radiative forcing.

This study shows that direct emission of AM $H_2SO_4$ results in higher radiative forcing for the same sulfur equivalent mass injection strength than $SO_2$ emissions, and that the sensitivity to different injection strategies varies for different forms of injected sulfur. Prospective studies will focus on investigating various materials for SSG such as solid alumina or calcite particles. Due to their chemical, optical and microphysical properties they show the potential of resulting in more effective SSG while simultaneously reducing their adverse effects on stratospheric chemistry.
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Figure 1. Wet aerosol size (a) and mass (b) distributions of stratospheric aerosol under various scenarios from Vattioni et al. (2019). The AM-H$_2$SO$_4$ emission scenarios emitting between 15° N and 15° S (GEO_AERO_15 in blue), the equivalent SO$_2$ emission scenarios (GEO_SO2_15 in red) and the reference run (BACKGROUND in black) are zonally averaged over 10 years between 15° N and S (continuous lines) and between 40° N and 60° N (dashed lines). Values shown are at 50 hPa in the tropics and at 100 hPa in the northern midlatitudes, i.e., at the levels of peak aerosol mass concentration in the vertical profile. The green size range is defined as the radius at which backscattering efficiency on sulfate aerosols is at least 70% (i.e., 0.12–0.40 µm) of its maximal value (solid green line at 0.30 µm) following Dykema et al. (2016).

REFERENCES
15.15

Using the eddy covariance technique to determine the nitrous oxide emissions of an intensively used pasture in Switzerland

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Nitrous oxide (N₂O) is a very potent greenhouse gas, and the majority of the emissions are associated with intensive livestock production. The magnitude of the emissions typically depends on the nitrogen (N) input to the soil, and on grazed pastures the largest share of the emissions is typically originating from the N applied via fertilization and excreta of the grazing animals. The uneven spatial distribution of the excretion leads to emission hot spots on grazing systems and makes the quantification of the gaseous emissions challenging. Thus, micrometeorological methods that integrate emissions over a larger area like the eddy covariance (EC) method are well suited to quantify the field-scale N₂O emissions of grazed pastures.

We present results of a field experiment carried out in western Switzerland in the years 2013 to 2017. The investigated pasture was grazed by dairy cows in an intensive rotational management. The field was additionally fertilized with organic and mineral fertilizer each year, according to the N requirement of the grassland. The field-scale N₂O fluxes were quantified with the EC technique using a fast response Quantum cascade laser spectrometer for N₂O concentration measurements.

The experimental setup and the environmental conditions resulted in high temporal and spatial dynamics of the N₂O fluxes with highest values typically occurring after mineral fertilization events in the summer month. Using N₂O background parametrizations retrieved from chamber measurements by Voglmeier et al. (2019) for the same site in 2016 and subtracting the background emission from the measured N₂O fluxes allowed us to calculate excreta-related emission factors (EFs) according to the IPCC guidelines. EFs for fertilizer N input were calculated using a pre-defined time window after the fertilizer was applied. The subtracted background emissions during the fertilization events were calculated from the EC measurements outside this time window. We will attribute the observed emissions to the different N inputs and we will discuss potential reasons for the supposedly higher emissions after mineral fertilizer applications in comparison to organic fertilizer emissions.

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Warming, cooling, irrigation and N-deposition effects on the ecosystem C-cycle of subalpine grassland

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We ran a five-year warming × moisture × atmospheric N-deposition experiment with turf monoliths (ML) from 6 different Alps of equal altitude (2150m) and exposure (S). On the S slope of Piz Cotschen (Unterengadin) 216 ML were replanted at 6 sites along an altitudinal gradient, representing an April - Oct. -1.4°C to +3.0°C temperature change (equivalent annual mean -1.7°C to +2.4°C). Plant growth was indifferent to -1.4°C cooling, but was rising to c. 40% above control with +1.8°C warming. Surprisingly, neither irrigation, nor +15kg ha⁻¹ a⁻¹ atmospheric N-deposition treatments yielded a significant growth response.

We quantified the ecosystem CO₂ flux responses using dynamic CO₂ concentration cuvettes and parameterized NEP for the whole period, using light intensity, soil moisture and temperature. We compared the parameterization to soil organic C stock measurements at the beginning and at the end of the experiment.

Soil C stock was found to be slightly reduced with cooling, but was increasing with moderate warming. When April - Oct. warming was greater 1.5°C, after 5 yrs. 0.6 kg C were lost out of a 6.3 kg C m⁻² stock (0-10cm). NEP parameterizations suggested that Rₑcosystem was less susceptible to drought than GPP. As a result, we observed a decreased assimilation, but continued respiration under very warm and dry conditions, resulting in substantial ecosystem C loss.

Results will be discussed in the light of our earlier work, that suggests increased C sequestration at low N deposition, but decreased C sequestration at high N deposition (Volk et al., 2016; Volk et al., 2018). At the same time, the effect of rising temperature, accompanied by reduced soil moisture, is expected to make the ecosystem a CO₂ source to the atmosphere (Volk et al., 2011), or at least to reduce potential ecosystem C gains.

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15.17

The impact of cover fill on $\text{N}_2\text{O}$ emissions in drained peatland

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Drainage for agriculture has converted peatlands from a carbon sink to one of the world’s main greenhouse gas (GHG) sources. In order to improve the sustainability of managed peatlands in agriculture, and to counteract soil subsidence, mineral soil coverage is becoming a common practice in Switzerland. Cover fills may change the GHG balance from the corresponding organic soil. To explore the effect of cover fill on soil $\text{N}_2\text{O}$ emission, a field experiment is carried out at the border of Switzerland and Austria, Rüthi SG to measure the soil – borne $\text{N}_2\text{O}$ balance from two adjacent sites: drained organic soil without mineral soil cover (DN), and drained organic soil with mineral soil cover (DC). Mineral soil material was applied 12 years ago and varies in thickness between 20 – 80 cm. Both sites have the same farming practice. In our experiment, an automatic chamber system is used for collecting the soil - borne $\text{N}_2\text{O}$ at an interval of 3 h. Soil moisture, expressed as volumetric water content (VWC), is recorded every 10 min. After six-month’s (171 days) of continuous measurement, it appears that: (1) The average $\text{N}_2\text{O}$ emission from DN is $11.72 \pm 3.31 \text{ mg N}_2\text{O-N m}^{-2} \text{ day}^{-1}$, and for the DC site it is $1.38 \pm 0.68 \text{ mg N}_2\text{O-N m}^{-2} \text{ day}^{-1}$. Hence, mineral soil cover of organic soil seems to induce a strong reduction in $\text{N}_2\text{O}$ emissions. (2) Exogenous N inputs (mineral nitrogen fertilizer and cow slurry) are the main drivers of $\text{N}_2\text{O}$ emissions. The post exogenous N input $\text{N}_2\text{O}$ emission peak (post N-input $\text{N}_2\text{O}$ emission) was found in summer. $\text{N}_2\text{O}$ peaks occurred shortly after the N application and lasted for 2 to 3 weeks before returning to background $\text{N}_2\text{O}$ emission. At the DC site post N- input $\text{N}_2\text{O}$ emissions accounted for 79% of the total $\text{N}_2\text{O}$ emission over the whole measurement period. An equivalent of around 2% of the exogenous N- input was emitted as N$_2$O. At the DN site, emission peaks after fertilization accounted for 81% of the total N$_2$O emission, equivalent to around 18% of the exogenous N- input. Background emissions between peak events were $2.60 \pm 2.16 \text{ mg N}_2\text{O-N m}^{-2} \text{ day}^{-1}$ at DN and $0.33 \pm 0.30 \text{ mg N}_2\text{O-N m}^{-2} \text{ day}^{-1}$ at DC. The comparison of peak and background fluxes tentatively indicates that higher average emission rates from the DN site are not only related to fertilization directly, but also to a different response of soil-N. Finally, soil moisture content differed between sites. During the experimental period, the mean daily soil moisture ranged from 15.8%VWC - 49.6%VWC and from 22.6%VWC% - 57.2%VWC for DC and DN, respectively. Background $\text{N}_2\text{O}$ emission increased with soil moisture. In summary, our data from this first experimental period suggest that mineral cover fill could strongly reduce the $\text{N}_2\text{O}$ emission from drained organic soil, and may therefore be an interesting mitigation option in agriculture.
Determining the greenhouse gas budget of two neighboring pastures using the eddy covariance technique

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Intensive livestock production is a large source of the greenhouse gases (GHG) methane (CH₄) and nitrous oxide (N₂O). However, optimizing grassland management is seen as a potential cost-effective mitigation strategy to counteract these emissions by increasing the soil carbon stock.

We present results of GHG flux measurements in a paired field experiment of two neighboring grazing systems in 2016. Each system was grazed by 12 dairy cows in a rotational grazing management. The systems differed in the energy to protein balance of the diet for the cows (grass with additional maize silage: system M; full grazing system without additional forage: system G) which resulted in different N excretion rates. The field scale emissions of CO₂, CH₄ and N₂O were quantified using two eddy covariance towers, which were installed in the middle of the two systems. The paired field design allowed for a precise comparison of the two systems, as only random uncertainties had to be taken into account. In order to calculate the net ecosystem carbon budget (NECB) of the pasture systems, additional non-gaseous carbon fluxes were either measured (harvest, slurry application) or estimated based on an animal feed demand model (carbon removal/return by grazing/excreta). For the investigated year, the NECB resulted in a significant C sink for system M whereas system G was carbon neutral. We conclude, that this difference was mainly triggered by the external carbon import to the system M through the additionally provided maize silage. Taking the emissions of CH₄ and N₂O into account resulted in a neutral net GHG budget for both pastures.

We will show the individual contributions to the NECB, explain the importance of the individual GHGs to the net GHG budget and illustrate the advantages of a paired field design. Furthermore, we will discuss the outcomes of the study in the context of a similar study on the same pasture in 2013.
P 15.2

Icelandic volcanism and climate from Greenland ice cores over the past 3 ka

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Volcanic eruptions are considered one of the main causes that can lead to short-term variations in global temperatures. The effects of volcanism on climate can be studied from proxy archives such as polar ice cores, where sulphates and ash layers (tephra) are deposited. Moreover, volcanic layers can provide important absolute chronostratigraphic markers for the ice-record, because they are erupted and deposited instantaneously with respect to geological time-scales.

During the Holocene, Greenland has experienced the deposition of numerous ash layers from Iceland. These tephra layers, can provide independent and precise tie-points for the Greenland record that can be used as time-synchronous marker horizons for different palaeo-archives, allowing a better understanding of past climate changes over the Northern hemisphere. The recognition of Icelandic tephra markers is possible thanks to the availability of published reference geochemical datasets for proximal Icelandic volcanic products, such as the ones from lake cores and soils (e.g., Gudmundsdóttir et al., 2018), that allow for the reconstruction of a complete and detailed tephrostratigraphic framework for Greenland ice cores.

Here, we use sulphur and insoluble particle records from three Greenland ice-cores (TUNU2013; NGRIP; NEEM) to recognize the presence of volcanic fallout (i.e., tephra, volatiles) deposited on the ice-sheet during the last 3 ka. Potential tephra layers in the ice-core records are recognized and targeted for geochemical analyses of single glass shards and compared with Iceland proximal tephrochronological frameworks (e.g., Haflidason et al., 2000) to distinguish tephra of potential Icelandic provenance. The volcanic record is further compared with temperature and sea-ice proxies from ice cores (e.g., d18O, MSA) and other archives. We plan to perform geochemical analyses on glass shards from polar ice-cores to define chronostratigraphic markers in the Greenland records and perform detailed multi-proxy analyses linking different records to highlight the effects of Icelandic volcanism on North Atlantic and Northern European climate.

REFERENCES
P 15.3

First eddy covariance flux measurements of gaseous elemental mercury over a grassland

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Direct measurements of the net ecosystem exchange (NEE) of gaseous elemental mercury (Hg0) are crucial to improve our understanding of global Hg cycling and ultimately Hg exposure in humans and wildlife. The lack of long-term, ecosystem-scale measurements causes large uncertainties in Hg0 flux estimates. Today it remains unclear whether terrestrial ecosystems are net sinks or sources of atmospheric Hg0. Here, we present the first successful eddy covariance (EC) NEE measurements of Hg0 over natural, low-Hg background soils (41 - 75 ng Hg g⁻¹ topsoil [0-10 cm]) at a managed grassland site in Chamau, Switzerland. We present a detailed validation of the EC technique for Hg0 based on a Lumex mercury monitor RA-915AM. The flux detection limit derived from a zero-flux experiment in the laboratory was 0.22 ng m⁻² h⁻¹ (maximum) with a 50% cut-off at 0.074 ng m⁻² h⁻¹. The statistical estimate of the Hg0 flux detection limit under real-world outdoor conditions at the site was 5.9 ng m⁻² h⁻¹ (50% cut-off). Based on our analysis we give suggestions to further improve the precision of the EC system and pinpoint challenges and interferences that occurred during the 34-day pilot campaign in summer 2018. The data were obtained during extremely hot and dry meteorological conditions. We estimated a net summertime grassland-atmosphere Hg0 flux from -0.6 to 7.4 ng m⁻² h⁻¹ (range between 25th and 75th percentiles). The measurements revealed a distinct diel pattern with significantly lower nighttime fluxes (1.0 ng m⁻² h⁻¹) compared to daytime fluxes (8.4 ng m⁻² h⁻¹). Drought stress during the campaign induced partial stomata closure of vegetation which led to a midday depression in CO2 uptake which did not recover during the afternoon. We suggest that partial stomata closure dampened Hg0 uptake by vegetation as well, resulting in a NEE of Hg0 dominated by soil emission. The new Eddy Mercury system seems suitable to complement existing research infrastructures such as ICOS RI in Europe or NOAA Observing Systems in the US built to calculate greenhouse gas balances with direct Hg0 deposition and emission measurements. We anticipate our Eddy Mercury system to improve knowledge about Hg cycling between ecosystems and the atmosphere and to challenge model simulations on a regional and global scale.

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P 15.4

Effects of biodiversity on ecosystem functioning across local and landscape scales

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Ecosystem functions facilitate the myriad ecosystem goods and services that benefit humans, such as natural pollination of crops, oxygen production and carbon sequestration. Human activities have resulted in the sixth major mass extinction in the history of life on earth. The biodiversity-ecosystem functioning (B-EF) relationship has been widely studied, albeit with experimental model communities consisting of a few dozen species in small plots (~<100m²) and conducted generally on grasslands or in microcosms (Brose and Hildebrand, 2016). These experiments have shown a positive decelerating B-EF relationship (Tilman et al, 2014; Paquette & Messier, 2011). It is less broadly understood whether these well-studied local and short-term relationships still hold across larger spatio-temporal scales, where large-scale mechanisms may influence landscape diversity (LD) and landscape functioning (LF) and produce emergent mechanisms that alter the B-EF relationship.

We conducted an observational study of the Koeppen-Geigen hot(dfa) and warm(dfb) summer humid continental climate zones of North America, using a quasi-experimental set up. We applied a grid based on the MODIS 250m Vegetation Index pixels on the region, giving a total of ~74 million plots of 250m² extent. Land surface phenology was derived from the 2000-2018 16-day composited MODIS EVI data product (Didan, 2015). Land cover composition was extracted from two 30-m spatial resolution maps of North America, from the North American Land Monitoring System (NALMS), and from GlobeLand30 (Canada Centre for Remote Sensing et al, 2017; Chen et al 2014). A subset of pixels (~140k plots) — for which local BD and LF data was available through the Global Forest Biodiversity Initiative — was chosen to study cross-scale relationships. Plots were optimally picked such that land cover type richness was decorrelated from environmental variables (altitude, slope and aspect), and each composition was equally represented. Preliminary results have shown a positive LD-LF relationship as well as a positive B-LD relationship (Oehri et al, 2017). Further investigation should shed light on any direct LD-LF correlation, or alternatively, indirect facilitation from local biodiversity.

This study furthers the understanding of the effects of biodiversity on ecosystem functioning across the local and landscape scale, as well as understanding the repercussions of biodiversity loss in real-world scenarios, which is of utmost importance to prevent and mitigate its devastating effects on human well-being.

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