Topic 1 Days

Wednesday 21 June 2023 - Friday 23 June 2023

Telegrafenberg

Book of Abstracts

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Interplay of precipitation and catchment response shapes heavy tails of flood distributions

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Large and surprising extremes emerge more often from heavy-tailed distributions compared to the light-tailed distributions. Heavy-tailed distributions are characterized by a right tail which decays slower than the exponential one. Distributions of flood and precipitation records in Germany often show heavy-tail behavior. For sound flood risk management, controls of heavy-tail behavior need to be understood. Based on past records and re-analysis data, we stratify precipitation events into stratiform and convective types. Annual maxima of precipitation records tend to heavy-tail behavior if the tail of the distribution is dominated by convective events. Heavy-tail behavior of flood distributions is primarily controlled by runoff generation processes such as runoff concentration and exceedance of catchment storage. For high return periods, heavy tail of precipitation is dominating the tail of flood distributions when catchment storage is exceeded.

Poster Session / 2

A new model approach to simulate forest drought legacy-effects from tree hydraulic damage

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A hydraulic module is presented to simulate stomatal and non-stomatal impacts of drought stress in trees, including sapwood- and leaf senescence.

Poster Session / 4

Atmospheric Tides in Space Geodetic Applications

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Atmospheric tides are thermally excited oscillations induced mainly by solar radiation absorption by ozone and water vapor, and latent heat release due to deep convection. We study atmospheric tides by their manifestations, which instigate high-frequency harmonics in atmospheric density and

its spatial gradients. These mass variations excite variations in the gravity field which can be observed from space (e.g., GRACE-FO) and from the ground (e.g., superconducting gravimeters); the crustal deformation due to surface loading; the atmospheric delays estimated during the analysis of microwave-based space geodetic measurements; and Earth rotation parameters observed e.g., by VLBI. We have modeled these effects employing numerical weather models including ECMWF's ERA5 and DWD's ICON. We have estimated the impact of these effects on space geodetic observations such as GRACE-FO's laser ranging interferometer, and GNSS. The presentation provides a glimpse into the modeling of these effects as well as the validation thereof employing space geodetic observations.

Poster Session / **5**

Precipitation event extremity evaluation across Germany: analysis of observed and synthetic data from a stochastic weather generator

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In order to estimate the frequency of the precipitation event responsible for the devastating flood that struck western Germany and surrounding areas in mid-July 2021. The extremeness of the various precipitation events occurred in the last 71 years (1951-2021) was estimated utilizing the recently developed cross space-time scale weather extremity index xWEI. The probability analysis based on GEV distribution indicates that the 2021 precipitation event, with the estimated return period exceeding 2000 years, is the most extreme event in the Ahr and Erft catchments over the specified period. The set-up stochastic weather generator can reproduce precipitation events with similar xWEI to mid-July 2021 event, while it tends to underestimate very-extreme precipitation events and overestimate less-extreme events.

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What will an extreme rainfall event in West Africa look like by 2100?

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In West Africa, the effects of climate change are already being felt, with increases in the intensity of extreme rainfall observed in rain gauge and satellite datasets over the last few decades. Given the region's high vulnerability, an understanding of how extreme rainfall events may change further in the future climate is vital.

West Africa receives the majority of its rainfall via convection, which is not well-represented in global climate models (GCMs). As an alternative to GCMs, pseudo-global-warming (PGW) experiments add the climate change signal from GCMs to present-day high-quality reanalysis and use this to drive high-resolution model runs of present-day extreme events in an end-of-century climate.

Initial results from PGW case studies performed using the ICOsahedral Nonhydrostatic (ICON) model will be presented. Overall, the most intense rainfall rates show the largest increase under end-of-century conditions and cannot be explained by Clausius-Clapeyron scaling alone.

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Hailstorms in South America

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Severe thunderstorms over South America are among the most intense worldwide. However, due to low population density and limited research activities their distribution and characteristics are less understood than in other regions, although this information is crucial, for instance for insurance companies. We use a well-established hail hazard modeling approach, which has already been used over Europe, Australia, and South Africa. Thunderstorm overshooting top data from NASA satellites are combined with ERA5 reanalysis to produce a hail climatology and hail event dataset. In collaboration with insurers, the dataset serves as a basis to assess the characteristics and threat of hail. Furthermore, the unique 28-year satellite dataset facilitates a trend analysis to quantify the impact of climate change on severe hailstorms in South America.

Climate engineering and nature-based solutions & Linking meteorology and hydrology / 9

Developing a Non-Stationary Weather Generator for Central Europe: Using Large-Scale Circulation Patterns and Downscaling Future Climate Model Projections

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This study presents the development of a non-stationary gridded weather generator for Central Europe region conditioned on large-scale weather circulation patterns and the regional average temperature. The generator is then employed to downscale the future meteorological fields such as precipitation and temperature for the region accounting their variability. An ensemble of the nine most skillful models from the Climate Model Inter-comparison Project Phase 6 (CMIP6), two shared socio-economic pathways, and two future periods until 2100 are considered. Based on that, future changes in these fields for the five major catchments in Germany including Donau, Elbe, Ems, Rhine and Weser are assessed. This analysis is expected to provide valuable inputs for future flood risk assessments in the region.

Earth system modelling / 10

A Missing Dusk-side Loss Process in the Electron Ring Current

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The terrestrial electron ring current, a circular flow of charged particles trapped by the Earth's magnetic field, exhibits enhanced activity during geomagnetic storms. Despite extensive research, the mechanisms driving this enhancement remain unclear due to the complex dynamics involved. This study reveals that existing models of the ring current overestimate electron flux on the nightside during storm onset, primarily due to a missing loss process operating in the pre-midnight sector. By analyzing electron drift trajectories, we demonstrate that accurate reproduction of observations requires the loss process to reach the theoretical upper limit over a broad region in space. Understanding these processes is crucial for accurately simulating the ring current's behavior during geomagnetic storms and its impact on Earth's magnetic field and space environment.

Earth system modelling / **11**

Ring current electron precipitation into the Earth's atmosphere

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The particle flux in the near-Earth environment can increase by orders of magnitude during geomagnetically active periods, which leads to intensification of particle precipitation into Earth's atmosphere and can further affect atmospheric chemistry and temperature. In this research, we concentrate on ring current electrons and investigate precipitation mechanisms using a numerical model based on the Fokker-Planck equation.

We investigate a time period that covers 4 corotating interaction region and 2 coronal mass ejection storms. Our results are validated against observations from the POES satellite mission, low Earth orbiting meteorological satellites, and Van Allen Probes. Maps of precipitating modeled fluxes for different energies allow us to understand in which regions on Earth precipitation is the most intensive. The output of the model is further used for calculation of ionization rates at different altitudes, allowing it to estimate effects of geomagnetically active periods on chemical and physical variability near the polar areas.

Earth System Modelling & New observational systems and sources of information / **12**

Wind lidar observations in the vicinity of convective systems during Swabian MOSES

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The Swabian MOSES field campaign investigated atmospheric drivers responsible for the frequently observed initiation of severe thunderstorms between the Black Forest and the Swabian Jura. A suspected triggering mechanism is lee-side flow convergence, but detailed observational evidence of this phenomena is largely missing. To gain insight into flow characteristics, first measurements with a new airborne wind lidar system were conducted in the summer of 2021.

This contribution presents a novel combination of airborne and ground-based wind lidar measurements. The airborne wind observations contribute high spatial resolution and coverage, to which the ground-based lidars add the temporal evolution context. Overall, unique insight into meso-scale flow processes in thunderstorm environments can be obtained. The influence of orography on flow is detectable, with both local valley circulations and mountain convergence effects observed. The combination with radar and satellite observations provides further context for the thunderstorm activity associated with the flow field.

Climate engineering and nature-based solutions & Linking meteorology and hydrology / 13

Planetary Salvage. An anthropological perspective on climate engineering.

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The past decade has seen growing interest in climate engineering as less of a dubious last resort than a reasonable supplement to emissions reduction. This interest finds wide expression—in high-level reports, massive capital investments, best-selling novels, and scholarship that urges context upon engineering promises (cf. "transboundary effects,""moral hazard). It seems the question is no longer "whether"but "how"climate engineering should happen. What becomes of scientific inquiry when its task is not putative description but righteous intervention at the whole earth-scale? Why, how, and for whom is climate engineering becoming a normal thing to want to do? Drawing on ethnographic fieldwork, this paper explains climate engineering as planetary salvage—whereby the presumed destructiveness of planetary forces acts as the warrant for their reinvention. Key to this style of reasoning, it argues, is conjecture about ostensibly decisive "gaps"(e.g., between research and deployment, measurement and accountability, nature- and technology-based solutions).

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Impact of GNSS tropospheric gradients on severe weather forecasts

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The assimilation of Zenith Total Delays (ZTDs) has a positive impact on weather forecasts. On the other hand, tropospheric gradients are not yet assimilated by the weather agencies. In this work we study the impact of tropospheric gradients on weather forecasts. To do so we implemented the required operators into the Weather Research and Forecasting (WRF) Data Assimilation (DA) system and conducted three experiments: 1) Control run with only conventional data; 2) ZTD assimilation on top of control run, and; 3) ZTD and tropospheric gradient assimilation on top of control run. Initial tests are performed with a rapid update cycle framework with six hourly intervals based on the three-Dimensional Variational (3DVar) DA system. Results from the assimilation experiments are presented.

Deep/Machine learning and data science / 15

Using explainable artificial intelligence (xAi) to determine drivers of fog and low stratus clouds (FLS) occurrence and life cycle

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While clouds are a key component of the climate system, cloud processes and aerosol-cloud interactions are still poorly understood. This is also the case for fog and low stratus clouds, which are particularly affected by aerosol emissions at the surface and by land-atmosphere interactions.
In this study, Extreme gradient boosting (XGBoost) and xAI methods such as SHapley Additive exPlanations (SHAP) are applied to satellite-based FLS and aerosol data sets and reanalysis data to distill the effects of environmental conditions and aerosols on FLS occurrence and life cycle. The analysis is conducted over the Po valley (Italy), in winter and fall from 2006-2015.
The XGBoost model skillfully predicts FLS duration with an R^2>0.7. The sensitivity analysis identifies temperature and humidity as the most important predictors. A higher amount of aerosols seems to prolong FLS duration. This analysis showcases the potential of xAI to the analysis of nonlinear relationships in cloud systems.

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Atmospheric composition research with ICON-ART

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This presentation reviews the recent developments in the model system ICON-ART (ICOsahedral Nonhydrostatic model with Aerosols and Reactive Trace gases) with respect to the detailed treatment of emissions, chemistry, aerosol dynamics and aerosol-radiation-cloud interactions from large

eddy to global scale. The results show that the ability of the model to precisely simulate cross-scale interactions determines its success or failure in reproducing certain observations. The conclusion focuses on the implications and plans towards seamless atmospheric composition modeling.

Poster Session / **17**

Supervised habit classification of PHIPS stereo-microscopic ice crystal images

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Clouds play a major role in the global radiative budget. Microphysical properties, such as the shape (or habit), of individual ice crystals define their optical properties and consequently affect the cloud radiative effect. Therefore, a better understanding of ice crystal morphology is crucial in improving climate modelling.

With the Particle Habit Imaging and Polar Scattering (PHIPS) instrument, a unique airborne measurement probe that simultaneously captures optical and microphysical properties of single ice crystals, we collected a large dataset of high resolution in-situ stereo-microscopic images of natural ice crystals.

Over 100,000 stereo images from multiple field campaigns have already been manually classified. To automate classifying our images, we apply deep learning methods to our data and use convolutional neural networks (CNNs).

A description of our classification system of ice crystal morphology will be given. In addition, preliminary performance results of the CNN models will be shown.

New observational systems and sources of information / **18**

The IMK/IAA MIPAS version 8 data set as source of information on the meridional mean circulation

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Vertical profiles of temperature and trace gase concentrations, including O3,H2O, CH4, N2O, CO, HNO3, NO2, NO, HNO4, BrONO2, N2O5,PAN, ClONO2, ClO, CH3Cl, COCl2, CFC-11, CFC-12, HCFC-22, CFC-113, C2H6, C2H2, HCN, OCS, SF6, and others, as well as several aerosol products, are based on improved level-1 calibration and level-2 processing of MIPAS measurements. This global data set provided by IMK/IAA covers the upper troposphere, stratosphere, mesosphere, and for some products also the thermosphere. These data are provided along with TUNER-compliant diagnostics including averaging kernels and a detailed error budget. A novel application of these data is the

inference of stratospheric meridional circulation by the direct inversion of the continuity equation. This method uses zonal mean fields of tracers to find those effective meridional velocities that best reproduce the measured fields. A ten-year climatology of stratospheric transport has been generated and shows more detail than available from other observation-based methods.

Deep/Machine learning and data science / 19

Overfitting and overextending –reframing the potential of machine-learning techniques in calibrating low-cost sensors

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Machine-learning (ML) techniques have been recently applied to the calibration of low-cost sensors (LCS). Many studies report successes in calibration with ML techniques such as random forests (RF), neural networks (NN), and support vector regression (SVR). We find that calibrating LCS for the measurement of nitrogen dioxide (NO2) and particulate matter (PM) with ML techniques is not as beneficial as previously reported. While some hierarchical tree-based methods such as RF and gradient-boosting machines (GBM) find success, they also have substantial limitations. Others such as NN and SVR are prone to overfitting, such that prediction with these models on new data is inadvisable. Instead, we find in calibrating for NO2 and PM2.5, multiple linear regression (MLR) is the most reliable, transparent, and consistent. Though many ML techniques have potential for use in a variety of applications, they may not always be appropriate, as shown here with the calibration of LCS.

Poster Session / 20

Effects of Anthropogenic Stratospheric Ozone Changes on Tropospheric Oxidation Capacity: Simulations with ICON-ART

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The ICOsahedral Non-hydrostatic (ICON) modelling system was developed by DWD and MPI-M to study various weather forecast and climate applications. The Aerosol and Reactive Trace Gases (ART) submodule, integrated within ICON, was contributed by KIT to analyze composition interactions in the atmosphere. ICON-ART model configurations employ flexible options for horizontal and vertical grids and allow seamless predictions from local to global scales. Accordingly, ICON-ART provides more comprehensive understanding of atmospheric processes. Here, we present a collection of outcomes obtained from different ICON-ART configurations, focusing on the impact of anthropogenic changes in stratospheric ozone or tropospheric temperature changes on tropospheric OH. For this, we performed and analyzed a couple long-term simulations based on AMIP and another considering 4K increase in tropospheric temperatures affecting chemistry. Through analysis of simulations without/with interactive ozone, we investigate the changes in OH concentrations and find the significant role for stratospheric ozone in how ozone influences OH.

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Summer ozone loss under geoengineering conditions

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The occurrence of heterogeneous chlorine activation through the presence of aerosol particles could cause stratospheric ozone destruction in summer. This chemical process requires low temperatures and is accelerated by an enhancement of the stratospheric water vapour and sulphate amount. We report on these processes based on the results of the Geoengineering Large Ensemble Simulations (GLENS) and the Chemical Lagrangian Model of the Stratosphere (CLaMS). Geoengineering will enhance the sulphate aerosol abundance in the stratosphere. The sulphate abundance is furthermore strongly dependent on the sulphate injection strategy. In the GLENS simulations, the lowermost stratospheric mixing layer will warm and moisten in future scenarios with a larger effect when a potential geoengineering scenario is considered. However, the ozone loss has a minor impact on the midlatitude ozone column for both today's conditions and future geoengineering conditions.

Poster Session / **22**

Current Status of COCCON (COllaborative Carbon Column Observing Network)

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Atmospheric increases in CO2 and CH4 due to anthropogenic emissions are the dominant factor in global warming. Reliable ground-based measurements of these greenhouse gases (GHGs) are of utmost importance for the validation of space borne GHG observations. Therefore, the COllaborative Carbon Column Observing Network (COCCON) was initiated by KIT in cooperation with ESA. The instrumental standard of the network is the portable FTIR spectrometer EM27/SUN. COCCON supplements the coverage of the existing Total Carbon Column Observing Network (TCCON) built on far more demanding spectrometers in terms of logistics. In addition, campaign applications of several portable spectrometers in variable configurations are possible. COCCON defines common network standards for instrumental calibration and quality. Consistent data processing is guaranteed by the open-source code PROFFAST and the wrapper PROFFASTpylot provided by KIT via the COCCON web portal and a GIT repository. At this point, we present the status of COCCON with exemplary scientific results.

New observational systems and sources of information / **23**

Towards Tier 3 emission inventories in the agricultural sector - A case study on CH4 and N2O emissions from Rice production in Vietnam

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GHG inventories are important for climate policy. For the agricultural sector, the IPCC defines a Tier system to be followed for UNFCCC reporting. The simplest and most commonly used Tier 1 approach is based on default emission factors, while the most complex and rarely used Tier 3 approach is based on the best available science using process models. Here we present ongoing work on using the LandscapeDNDC process model to calculate CH4 and N2O emission inventories for agricultural rice production in Vietnam. The work focuses on the integration and associated uncertainties of available data products, ranging from high resolution Earth observations to coarse resolution regional statistics. In order to promote the use of Tier 3 to a wider community, despite the increased complexity, we also present the development of a model user interface, which is available online and aims to reduce the barrier to applying the Tier 3 method.

New observational systems and sources of information / 24

GLORIA(-lite) and CAIRT: future observations of pollution in the UTLS from extreme fire events

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Severe biomass burning events are predicted to become more frequent as well as intense in future due to the rapidly changing climate. These will affect also higher atmospheric layers from the upper troposphere to even the mid-stratosphere in extreme cases. In this important region for Earth's radiative budget, aerosols as well as ozone are influenced by the mix of different trace-gases. Remote sounding observations by the GLORIA limb-imaging infrared spectrometer have shown that recent models do not well capture quantitatively many of the involved species. Our new developments of GLORIA-lite and the CAIRT satellite instrument proposed for ESA's Earth Explorer 11 will allow to monitor the distribution of these species up the global scale and, thus, to validate and improve global models.

Poster Session / 25

Challenges of an aerosol closure at an Arctic site

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Aerosol closure studies shall compare aerosol microphysical and optical parameters derived simultaneously via in-situ and remote sensing instruments. Hence, a successful closure explains the radiative forcing of the aerosol, which is unfortunately still only roughly constrained in our climate system.
Due to our incomplete knowledge on the scattering of arbitrarily shaped particles, such a closure must not be given. However, using depolarization of lidar data it can be estimated whether Mie theory may be assumed as an approximation.
Ny-Ålesund is one of the best equipped research sites in the Arctic. It is located at 78.9° N and 11.9° E on Spitsbergen. In this contribution one successful and one unsuccessful example of a closure is presented. In the Arctic probably a low boundary layer and local micrometeorological phenomena at low wind speeds further complicate the comparability of different aerosol measurements.

Deep/Machine learning and data science / 26

Spatio-temporal downscaling of rainfall fields using a conditional generative adversarial network

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Climate models are limited in their ability to accurately represent highly variable atmospheric phenomena on small scales. Downscaling techniques are employed to resolve fine-scale physical processes and reveal local impacts.

We present spateGAN, a conditional generative adversarial network for spatio-temporal precipitation downscaling in Germany. As a so-called video-superresolution approach, it simultaneously enhances the resolution of coarsened gauge-adjusted weather radar data from 32 km to 2 km and from 1 hour to 10 minutes.

Power Spectral Density analyses demonstrate that the ensembles of generated rainfall fields exhibit plausible and temporally consistent structures, hardly classifiable as artificially generated. The Fractions-Skill-Score indicates that spateGAN provides high skill regarding localization and reconstruction of high precipitation intensities.

The ability of the 3D-convolutional model to downscale arbitrary domain sizes and time sequences with high computational efficiency makes spateGAN a fundamental framework for our ongoing endeavors to advance AI-based global climate model downscaling techniques.

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Earth Radiation Management –A future topic for Changing Earth?

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In the light of lacking progress in reaching the climate protection goals, plans for actively cooling Earth‘s climate gain increasing public attention. The contribution is intended to foster internal discussions by introducing the scientific concepts of some of these approaches and highlighting open issues and side effects of climate interventions with a focus on Cirrus Cloud Thinning (CCT) in the Arctic.

New observational systems and sources of information / 28

The Contributions of IAGOS to Air Quality and Climate Monitoring, and Sustainable Aviation

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The European Research Infrastructure IAGOS utilizes state-of-the-art instruments onboard passenger aircraft to measure trace gases, aerosols, and cloud particles. The vertical profiles of climate- and air quality-relevant species (O3, CO, NO, NO2, NOX, CO2, CH4, and H2O/relative humidity) near airports in highly populated urban areas (e.g., Frankfurt (Main) and Paris) complement surface-based stations or remote-sensing instrumentation for studying the chemical composition of the lower troposphere. The data (O3, CO, H2O, CO2, CH4) is partially transmitted in near-real-time to the Copernicus Atmosphere Monitoring Service (CAMS) to continuously validate CAMS air quality models. The routine measurements of relative humidity and cloud particles at cruising altitudes are also beneficial for understanding the occurrence patterns of contrail cirrus, which are aviation-induced ice clouds that contribute to atmospheric warming. Consequently, they aid research on contrail mitigation through air traffic management. Key examples of IAGOS data used in various atmospheric research topics will be presented.

Poster Session / **29**

Agricultural Impact of Heatwaves in Climate Change Storylines

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With an increasing probability of extreme events, their significance for agricultural production has also grown. Ecosystem models enable us to integrate current knowledge about plant-climate interactions with climate change scenarios. Since impacts of weather extremes differ depending on crop, intensity, length, and timing, a process-based approach is necessary to quantify to what extent extreme events impact agricultural production. We used the ecosystem model LandscapeDNDC to evaluate the effect of extreme conditions, like drought or intense heat waves, on agricultural production. The combination of LandscapeDNDC with pseudo-global-warming storylines is used to assess how the extreme heat wave of 2018 –2022 would have affected yields of maize and wheat in a + 2 K and +4 K warmer world. This exercise identifies which regions are most vulnerable regarding climate extremes and quantifies to what extent extreme climate events can affect crop yields compared to baseline conditions.

Earth system modelling / **30**

Stratospheric Water Vapor Affecting Atmospheric Circulation

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Water vapor plays an important role in many aspects of the climate system, by affecting radiation, cloud formation, atmospheric chemistry and dynamics. Even the low water vapor content of the stratosphere provides an important climate feedback, but current climate models have a substantial moist bias in the lowermost stratosphere. Here we present strong sensitivity of the atmospheric

circulation in the stratosphere and troposphere to the abundance of water vapor in the lowermost stratosphere. We show from a mechanistic climate model experiment and inter-model variability that lowermost stratospheric water vapor decreases local temperatures, shifts the subtropical jets, strengthens the stratospheric circulation, and shifts the tropospheric eddy-driven jet poleward. The mechanistic model experiment in combination with atmospheric observations further shows that the prevailing moist bias in current models is likely caused by the transport scheme. The related effects on atmospheric circulation are of similar magnitude to climate change effects.

New observational systems and sources of information / 31

The CAIRT earth explorer 11 mission: a way towards global gravity wave momentum budgets

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The changing-atmosphere infra-Red Tomography (CAIRT) mission candidate for ESA's earth explorer 11 proposes a limb imager for a spatial sampling of 25 km across-track, 50 km along-track, and 1 km in the vertical. From this, we expect to infer directional GW momentum fluxes, as well as trace gases, from the tropopause to 70 km or higher. This will allow longstanding scientific questions to be addressed such as the quantification of tropospheric GW sources and their related phase speed spectra and the identification of secondary wave generation in the stratosphere and lower mesosphere. Considering the momentum flux at higher altitudes, secondary wave generation competes with oblique GW propagation which allows GWs from low latitude sources to reach the high latitudes mesosphere and thus avoid critical levels. In this contribution, we will outline the CAIRT instrument concept, give an overview of the mission's objectives and demonstrate its potential using simulated observations.

Climate engineering and nature-based solutions & Linking meteorology and hydrology / 32

Conflating meteorological and hydrological models for enhanced feedback representation of the water cycle.

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Process-based hydrological and dynamical meteorologic models are highly developed tools that describe meticulously the physical properties and dependencies of their respective realms. However, meso-scale meteorological models often overlook lateral water transport at the land surface and below, while hydrological models typically lack representations of atmospheric dynamics. Fully coupled atmospheric-hydrological modeling systems enable integrated studies of the terrestrial hydrosphere, considering crucial feedback processes. We examine the significance of model coupling on water and energy budgets based on different studies focused on integrated modeling, and land-cover and land-use change.

Earth system modelling / **33**

Evaluation of regional climate model performances in reproducing observed heat wave characteristics for Germany

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The influence of increased model resolution and tailored settings on the reproduction of heat waves is addressed. Therefore, different regional climate model outputs for Germany and the near surroundings between 1980–2009 were evaluated. This included outputs of a six-member EURO-CORDEX ensemble with 12.5 km resolution and outputs from a high resolution (5 km) WRF run, which was especially tailored for the study region regarding the physics configuration. Despite the same forcing, the models exhibited a large spread. Heat wave frequency and duration were captured relatively well, which was not true for the intensity. All models underestimated the spatial extent of the observed increasing trends. WRF mostly did not perform significantly better than the other models. It is concluded that increased model resolution does not add any value to heat wave simulation if the base resolution is already relatively high. Tailored model settings also seemed to play a minor role.

Poster Session / **34**

Supporting researchers in hydrology, meteorology and beyond with targeted data management initiatives

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Water fluxes between the land surface and the atmosphere are intricately linked. Understanding, measuring and modelling the underlying processes requires crossing spatiotemporal scales and relies on the availability, findability, accessibility, interoperability and reusability (FAIRness) of relevant

Earth System Science data.
We actively support data management through different initiatives.

The virtual research environment (VRE) V-FOR-WaTer provides researchers with a predominantly hydrological focus with access, pre-processing and harmonization of diverse data sources for further analyses and hydrological modelling applications. Additionally, we participate in the NFDI4Earth, developing an access portal for Earth System Science (ESS) data, information, tools and services. Lastly, we aim to facilitate publication of diverse ESS data within KIT. We create ESS-discipline-specific templates to ensure appropriate metadata descriptions of these datasets, facilitating publication on the KIT data repository. All these initiatives are interconnected, and we will provide more detailed information on our poster.

Deep/Machine learning and data science / **35**

Artificial Intelligence for GNSS Reflectometry: First insights from the AI4GNSSR project

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As a novel remote sensing approach, GNSS Reflectometry (GNSS-R) offers unique potential for characterizing the complex Earth system with its different spheres on various spatiotemporal scales with numerous geoscientific applications. With the continuous increase of space-borne GNSS-R observation data volume, Artificial Intelligence (AI) offers an alternative data-driven direction of achieving a better understanding of the observations and enhancing the quality of existing GNSS-R products. To better adapt AI techniques to this young remote sensing domain, the Helmholtz AI project, Artificial Intelligence for GNSS Reflectometry: Novel Remote Sensing of Ocean and Atmosphere (AI4GNSSR), was proposed to explore further potentials of AI in the GNSS-R domain. The project aims to implement AI for characterizing geophysical parameters and investigate new GNSS-R applications and approaches. In the first stages of the project, the proposed deep learning models are evaluated by a case study, and the impact of input features is investigated.

Earth System Modelling & New observational systems and sources of information / **36**

Launching the monitoring of cloud variables: ACTRIS Topical Center for Cloud In Situ Measurements

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The impact of the changing climate on cloud properties is still not fully understood. To improve our knowledge and thus the representation of clouds in models, the goal of ACTRIS (Aerosol, Clouds and Trace gases Research Infrastructure) Topical Center CIS (Cloud In Situ) is to establish a monitoring network for key cloud properties.
CIS consists of four units to measure (1) ice nucleating particles, (2) cloud particle number and size distribution, (3) bulk cloud water chemistry, and (4) liquid water content and cloud droplet effective diameter. Those climate-relevant variables will be measured at research stations all over Europe that are frequently in clouds. In addition, mobile platforms such as instruments in containers, on airplanes and on unmanned aerial vehicles, will allow to conduct specific field observations on the CIS cloud variables. Moreover, atmospheric simulation chambers will allow to investigate aerosol-cloud interactions using highly instrumented facilities under controlled near-real atmospheric conditions.

Poster Session / **37**

Tropical Aerosol in the Arctic

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The Asian summer monsoon is an effective transport pathway for aerosols and gas phase species into the upper troposphere and lower stratosphere. Model simulations by CLaMS (Chemical Lagrangian Model of the Stratosphere) can show the transport and mixing of aerosol particles into the extratropical UTLS by making use of artificial tracers of air mass origin. Occasionally, CLaMS results show filaments of aerosol particles even in the Arctic.
On the northwestern coast of Svalbard in the European Arctic, Lidar measurements by KARL (Koldewey Aerosol Raman Lidar) are carried out during the entire year. Investigations of Arctic aerosol can be performed up to about 30 km altitude. For this study, we compared CLaMS simulations of aerosol transport and profiles measured by KARL. First results from the Lidar measurements reveal a seasonality of the background aerosol concentration in the lower Arctic stratosphere. The comparison between KARL and CLaMS is still ongoing work.

Poster Session / **38**

Space weather impacts on the climate system: Model experiments to the edge of space

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Variations in the strength and speed of the solar wind related to solar coronal holes, coronal mass ejections, or corotating interaction regions, can initiate geomagnetic storms in the Earth's magnetosphere. These enhance electron fluxes and energies in the radiation belts and ring currents, but also precipitation of electrons over a large energy range from keV to MeV into the high-latitude atmosphere. Precipitation of energetic electrons into the mesosphere and lower thermosphere (70—150 km) in turn affects the composition and dynamics, initiating a chain of coupling processes leading

to changes in composition and dynamics throughout the atmosphere, possibly even in tropospheric weather systems.
We combine the magnetospheric model VERB-4D with "high-top"chemistry-climate models to investigate the impact of space weather events on atmospheric composition and dynamics from the magnetosphere down to the surface.

Poster Session / 39

Neural network approach for stiff chemical mechanisms

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Computational efforts for the calculation of chemical reactions are about 30% of the total resource requested to run simulations involving climate models. Finding alternatives to speed up the calculation of the chemistry module is then a crucial task.
Recent studies show that the calculation of the Jacobian matrix is the most computationally demanding part of the related ODEs and then solutions have been sought to overcome this problem.
In this poster results from KPP and ICON-ART (in a box model version) for the stiff H2O2 chemistry and the air-pollution Verwer systems, compared with neural network corresponding results are shown. The H2O2 chemistry mechanism consists of 4 reactions (3 species), while the Verwer system is made of 25 reactions (21 species). The simulations have been initialized with a fixed and a random set of values. These results form the basis to subsequently train the neural network.

Poster Session / 40

The Palau Atmospheric Observatory and its Ozonesonde Record - continuous monitoring of tropospheric composition and dynamics in the Tropical West Pacific

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We introduce the Palau Atmospheric Observatory as an ideal site to detect changes in atmospheric composition and dynamics above the tropical West Pacific, the main global entry point for air masses into the stratosphere in boreal winter. The comprehensive set-up of the site consists of an aerosol and cloud lidar, a sun photometer, a Fourier Transform Infrared Spectrometer and a ground station for balloon soundings with radio-, ozone-, water vapor- and aerosol-sondes. We focus on the ozone sounding program from 2016-2023, which includes our participation in two major aircraft campaigns (POSIDON, ACCLIP). The year-round high convective activity is reflected in dominant

low tropospheric ozone and high relative humidity. According to our analysis, the origin of anomalous ozone-rich and dry air masses is the Tropical Asian troposphere. The seasonal distribution of both constituents and thus air mass origin is unique compared to other sites and modulated by the Intertropical Convergence Zone.

Poster Session / **41**

Spectral filtering of gravity waves in the QBO: results from high resolution ICON simulations

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In order to investigate the driving of the QBO a high-resolution, convection-permitting run of the ICON model with 5km grid spacing was performed. We analyze the GWs in the model by applying a small-volume sinusoidal fit. By using a cascade of cube sizes, horizontal wavelengths of 150km - 2000km are addressed. This acts as a compromise between spectral resolution and spatial location. Phase speed spectra and GWMF can be reconstructed for individual regions and single snap-shots. Via comparison of phases from wave fits of temperature and winds, the vertical propagation direction of individual waves can be separated and ray-tracing can be initialized accordingly.
Using the results of this analysis we study the effect of the critical level GW filtering by comparing the variation of phase speed spectra by means of blocking diagrams.
Despite the generally good agreement, GWs with unexpected phase speeds at altitudes are present. Potential reasons are discussed.

Earth system modelling / **42**

Fast interactive ozone chemistry in ESMs: SWIFT

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SWIFT has been developed based on machine learning approaches to provide a fast interactive stratospheric ozone chemistry. It is developed as separate, easy-to-implement polar and extrapolar modules. Its polar component has been successfully implemented and tested in two atmospheric components of earth system models. Comparative experiments within the Polar Amplification Model Intercomparison Project with and without SWIFT enabled show a slightly improved polar vortex stability and variability with an otherwise consistent model performance. A way forward is to implement SWIFT in future model systems like ICON(-ART) to enable state-of-the-art large-ensemble model projections with comprehensive stratospheric processes included.

Deep/Machine learning and data science / **43**

Neural network model of Electron density in the Topside ionosphere (NET)

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We present a new empirical model of electron density in the ionosphere, which is a crucial parameter impacting radio signal propagation and GNSS systems. Our model utilizes radio occultation profiles obtained from CHAMP, GRACE, and COSMIC missions. We assume a linear decrease in scale height with altitude and consider four parameters: F2-peak density and height (NmF2 and hmF2), as well as the slope and intercept of the linear scale height decay (dHs/dh and H0). Our model (NET) is based on feedforward neural networks and incorporates as inputs geographic and geomagnetic position, solar flux, and geomagnetic indices. Validation against over several million in-situ measurements from CHAMP, CNOFS, Swarm, and GRACE/KBR data, along with comparisons to the International Reference Ionosphere (IRI) model, demonstrate the NET model's excellent accuracy in reconstructing the topside ionosphere. The model produces unbiased predictions across various locations, seasons, and solar activity conditions.

Poster Session / **44**

Solar-Terrestrial Coupling Processes driving Sporadic E Layer formation in our Atmosphere

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The GNSS radio occultation (RO) technique has been established successfully during the previous two decades. It evolved into a valuable observation tool for precise atmospheric and ionospheric vertical profiling. Until today, there are about 18 million RO recordings available.
GNSS RO signals are very sensitive to vertical electron density gradients in the Earth's ionosphere. They become visible as strong fluctuations in, e.g., signal-to-noise ratio recordings, which allow detecting ionospheric disturbances like sporadic E (Es) layers in the lower ionospheric E region.
According to theory, Es layers result from complex coupling processes between metallic ions of meteoric origin that are compressed into compact layers by vertical shears of the zonal wind and geomagnetic Lorentz forcing. In this poster, we will discuss the solar-terrestrial coupling processes that drive and prevent the sporadic E layer occurrence in our atmosphere.

Deep/Machine learning and data science / **45**

Machine Learning to disentangle drivers of air quality changes in China during the COVID-19 lockdown

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Machine Learning (ML) model is widely used to make predictions of air pollutant concentration in the 'business as usual'scenario. Compared with chemical transport model, ML model cannot be limited by its spatial resolution and potentially outdated emission inventories. To quantify the contribution of the meteorological driver of air pollutants during the COVID-19 lockdown period in China, Gradient Boosting Machine (GBM) was applied to predict the concentrations of NO2 and O3 in the first three months of 2020. To select the best ML model, the time-series split rolling method is selected to execute the cross-validation. The results show that the prediction is reliable with RMSE = 13.2 μg m−3 and PCC (Pearson Correlation Coefficient) = 0.71 for the prediction experiment. Finally, we conclude that the meteorological conditions prevailing in 2020 contribute to an increase in NO2 with an average value of 7.8% when compared to climatological 2015-2019 conditions.

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Global modelling for policy advice: source apportionment of tropospheric ozone

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Tropospheric ozone is harmful to human health and ecosystems. The mixing ratio of ground-level ozone at any given location is influenced by a wide array of factors including local chemical production and long-range transport over intercontinental distances. Here we present a system for the attribution of ground-level ozone to its emitted precursors and use it to show how ozone precursor emissions in different parts of the world influence ground-level ozone globally. The long-range transport of ozone and other pollutants is especially important for policymaking under the UNECE Convention on Long-Range Transport of Air Pollution (CLRTAP). We also present an overview of current activities organised under the CLRTAP Task Force on Hemispheric Transport of Air Pollution (TFHTAP) which may be of interest to Helmholtz researchers.

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Beyond ozone hole impacts: Seamless composition-climate interactions explored with ICON-ART

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The ICOsahedral Non-hydrostatic (ICON) modelling system was originally developed by DWD and MPI-M for a range of weather (forecast) and climate applications. An Aerosols and Reactive Tracers (ART) module was added by KIT to enable a comprehensive assessment of composition interactions within the atmospheric domain. Recognising that atmospheric processes happen on a multitude of temporal and spatial scales, flexible horizontal and vertical grid options are a key element of versatile model configurations in use. Here, we present a selection of results from different ICON-ART configurations that explore (stratospheric) ozone-climate interactions and stratosphere-troposphere coupling –e.g. regional climatic impacts of the ozone hole (and ozone losses in other regions) and global warming induced changes in jet-streams –in different types of integrations. In addition, we

explore the potential to forecast "chemical weather"with ICON-ART, including environmental (UV) indices.

Poster Session / 48

Arctic field campaign to measure the ice-nucleating particle concentration with a high temporal and vertical resolution

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Aerosol-cloud interaction remains the biggest source of uncertainty in radiative forcing estimations. The radiative properties of clouds are dependent on its phase, i.e. whether clouds consist of ice crystals, liquid droplets or a mixture of both. Ice-nucleating particles (INPs) faciliate the nucleation of supercooled cloud droplets at temperatures above -35 ℃, thus promoting the transition from liquid cloud to mixed-phase clouds.
In spring 2023 the INP concentration was measured at the Gruvebadet Atmosphere Laboratory (10 m asl) and Zeppelin Observatory (472 m asl) with the Portable Ice Nucleation Experiment (PINE) in Ny-Ålesund, Svalbard (79 °N). These measurements aim to characterize the INP concentration variability and to investigate the origin and main transport paths into the Arctic. First results of both measurements are shown with an outlook for a future campaign utilizing unmanned aerial vehicles as well as remote sensing in collaboration with the Alfred Wegener Institute.

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(Future) Landscapes as Carbon Sinks

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Humans have altered not only the Earth's atmosphere, but also changed the face of our planet - its surface. About three quarters of the Earth's surface has been altered by humans during the last millennium. This has significantly altered biogeochemical cycles and exchange processes between the 'critical zone' and the atmosphere.
Here I will show examples how those processes can be quantified by investigating carbon fluxes in natural lowland river systems and discuss how future landscapes could be used as carbon sinks.

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RIFS'past field campaigns and plans for observations of extreme air pollution in Nepal in a global air pollution hotspot region

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Air pollution from South Asia, in particular heavily polluted Indo-Gangetic Plain (IGP) impact public health, ecosystems, and climate not only in the region but also the downwind regions like the Himalayan and Tibetan Plateau mountain regions. According to the latest IPCC report this region is still one of the least studied regions in the world in terms of atmospheric observations and many air pollution sources are either uncharacterized or under-characterized sources that prevent us from properly understanding the physical/chemical mechanisms of air pollution and mitigating its impacts. In order to advance our understanding of air pollution in the region, RIFS (formerly IASS) organized the SusKat-ABC international air pollution measurement campaign in Nepal in 2013. Many state-of-the-art instruments were deployed in the campaign. There is however strong and urgent need to properly characterize the air pollution outflow from IGP to the Himalayan region, and thus a campaign METTA-G is being planned.

Earth system modelling / **51**

REMO2020 - Towards a Regional System Model

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Climate services for adaptation heavily depend on regional to local information about future developments of the climate. One tool to translate results of coarse global climate models from CMIP into local information is dynamical downscaling with regional climate models. The Climate Service Center Germany (GERICS) has been developing its own regional climate model REMO for many years in order to ensure a solid basis of climate information. Here we will present the latest and last version of REMO that will be used in the current cycle of CORDEX based on CMIP6.

Poster Session / **52**

Atmospheric Aerosol Modelling activities at IEK-8

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Atmospheric aerosols degrade air quality on regional and global scales and play a significant role in climate change. Depending on their composition, aerosols affect the energy budget of the Earth's atmosphere by scattering and absorbing solar radiation (direct effect) and by influencing the reflective properties of clouds, their lifetime, and precipitation formation (indirect effects). Furthermore, exposure to particulate matter is the most significant environmental cause of human premature mortality.

Our modeling activities at the IEK-8: Troposphere, Forschungszentrum Jülich, aim to develop innovative modeling tools for understanding the tropospheric aerosol formation and physicochemical evolution in order to characterize their impact on air quality and climate.

Poster Session / **53**

Unmanned in situ Measurements of Air Pollutants in the Planetary Boundary Layer

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Regional air quality has been historically documented by ground-level monitoring networks around the world. However, such monitoring infrastructures come with high costs and very localized measurements that are limited to ground observations. Higher altitude measurements (up to 1 km) are of great interest for understanding the mixing and transport of pollutants. Unmanned aerial vehicles (UAVs) are promising candidates to fill this gap. Electrochemical sensors (ECS) are lightweight, small, require little energy and are thus an ideal candidate for use on UAVs, but require calibration due to interferences. We did an in-flight evaluation of ECS on a Zeppelin, covering cities, industrial areas, and highways. A correction method based on temperature and humidity dependencies was developed to accurately measure NOx concentrations. Ongoing validation involves controlled laboratory experiments simulating changing meteorological conditions. The combination of UAVs and ECS provides a flexible platform for in situ trace gas measurements in the lower troposphere.

New observational systems and sources of information / **54**

SAPHIR* - first results from a new atmospheric research reactor for mechanistic studies

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In recent years our knowledge of the atmosphere and the underlying processes has grown a lot. However, there are still many open questions. One research field of high complexity is the atmospheric aerosol, and related to it, the topic of aerosol formation, processing, and aging.
In addition to natural sources of aerosol particles like secondary aerosol formation from biogenic precursors, anthropogenic sources might add to or influence above mentioned sources. A future changing climate might further impact on these processes.
To approach and investigate such complex systems and relations on a mechanistic level we have designed and build SAPHIR*, a continuously stirred tank reactor (CSTR) for investigation of secondary aerosol formation.
Here we present some first exiting results that also illustrate the capabilities of this system for investigations and an advancement of our mechanistic understanding. These gains might even help to improve modelling and climate predictions.

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Air quality analysis and emission optimization on regional scales

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Emission data as the main input to air quality forecast models introduce large uncertainties. These data originate from emission inventories that provide estimates of spatially distributed emissions. The impact of fixed temporal distribution functions in contrast to variable societal behavior and meteorological implications are rarely considered. To evaluate the annual emission totals of European and German inventories, we perform a reanalysis of air quality applying chemistry four-dimensional variational data assimilation with the European Air pollution Dispersion –Inverse Model (EURAD-IM). Assimilating ground-based, airborne, as well as satellite observation data, we assess initial value optimizations and emission correction factors for anthropogenic emissions. The analysis is performed on different model grids. Analyzing the emission correction factors reveals that the total NOx emissions are underestimated in Germany, agreeing with missing emissions connected to the Dieselgate. NH3 emissions are found too high, leading to an overestimation of modelled NH3 concentrations using standard emission data.

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Welcome note by Jens Wickert

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Status of Topic 1

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Stable isotopes in aging studies and air pollution 'forensics'

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Field, source and kinetic isotope analyzes are combined with a Lagrangian approach of receptor modeling to separate chemical degradation from changes related to source strength. Eventually, the local vs. long-range transport, as well as biogenic vs anthropogenic contribution of investigated pollutants can be differentiated.