Posters

P-01.1

The effects of directional wind shear on CAT generation by orographic gravity-wave breaking

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Mountain wave breaking, and the mechanisms by which turbulence may be triggered by directional wind shear, are investigated using numerical simulations of idealized, nearly hydrostatic, atmospheric flows over an axisymmetric isolated mountain. These simulations, which use the WRF-ARW model, differ in degree of flow nonlinearity and shear intensity. The aim is to diagnose the conditions for mountain wave breaking in terms of the orography elevation and wind shear, quantified by the dimensionless mountain height and the Richardson number of the background flow, respectively. The simulation results have been used to produce a regime diagram describing the wave breaking behaviour in Richardson number–dimensionless mountain height parameter space. By selecting flow overturning occurrence as a discriminating factor, it was possible to split the regime diagram into sub-regions with and without wave breaking. When mountain waves break, the associated convective instability leads to turbulence generation (which is one of the known forms of clear air turbulence (CAT)). Thus, regions within the simulation domain where wave breaking and the development of CAT are expected have been identified. The extent of these regions increases with terrain elevation and background wind shear intensity. Analysis of the model output, supported by theoretical arguments, suggests the existence of a link between wave breaking and the relative orientations of the incoming wind vector and the horizontal velocity perturbation vector. More specifically, in a wave breaking event, due to the effect of critical levels, the background wind vector and the wavenumber vector of the dominant mountain waves are perpendicular. It is shown that, at least for the wind profile employed in the present study, this corresponds to a situation where the background wind vector and the velocity perturbation vector are also approximately perpendicular.

P-01.2

Comparison of resolved and parameterized orographic gravity waves over New Zealand, the Andes, and the Himalayas

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A deep, 6-km resolution realistic WRF simulation has recently been completed over New Zealand for three months containing the DEEPWAVE period. This simulation was extensively validated against research aircraft, radiosonde, and satellite observations. WRF-resolved gravity wave drag (GWD) was quantified and compared with that parameterized in the MERRA and MERRA-2 reanalysis datasets. The MERRA parameterized GWD was 3-6 times less than that in WRF below z = 30 km. This underrepresentation was reduced in MERRA-2. Additional three month long WRF simulations were completed over the entire Andes and Himalaya mountain ranges in order to further evaluate the parameterized GWD in MERRA and MERRA-2 and to provide context for the New Zealand results.
In the mid-troposphere, the Patagonian Andes produced the largest amplitude mountain waves. In the negative shear region above the sub-tropical jet, GWD is peaked over all mountain ranges. The largest GWD at this level was found over the Himalayas. In the mid- to upper-stratosphere, the largest amplitude mountain waves were found over the Patagonian Andes. Below z = 25 km, parameterized GWD was underrepresented in both MERRA and MERRA-2 over all mountain ranges. Above z = 25 km over the Andes and New Zealand, GWD was overrepresented in MERRA-2 by about an order of magnitude.

P-01.3

Mountain wave events and associated rotors over the Pyrenees during The Cerdanya-2017 field experiment: observations and model simulations

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Mountain waves are topographically generated gravity waves or buoyancy oscillations produced when a stably stratified flow crosses an obstacle, such as a mountain range. They transport momentum and energy farther downstream and/or up in the vertical and several turbulent phenomena may be developed in the lee side of the topographic barrier.
In this study we analyze episodes of gravity waves (GWs) generated at the lee side of the Pyrenees when northern flows cross this mountain barrier, that is oriented from west to east. We use datasets provided by several instrumentation deployed during The Cerdanya-2017 field experiment: an Ultra High Frequency wind profiler, radiosoundings, a radiometer, a lidar, a windrass, an eddy covariance station, a ceilometer and several automatic weather stations, among others. Using the WRF model, numerical simulations are run in order to understand the mesoscale dynamics of the episodes and to validate the model, comparing the results against measurements. We explore the structure and evolution of these GWs, their wavelength and amplitude, and their associated valley circulations, with the possible formation of a low-level rotor. Simulations of previous similar events have shown that the rotor generated by the model is intermittent and brief, and it interacts with other flows coming from multiple directions. We will compare the new field measurements and model simulations with these results.

P-01.4

The importance of boundary layer friction in the representation of lee rotor onset using linear theory

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Linear theory is used to predict the occurrence of flow stagnation associated with the onset of rotors beneath trapped lee waves in flow over 2D mountains, for an atmosphere that is neutral near the ground, has stable stratification aloft, and a sharp temperature inversion dividing the two layers. An inviscid two-layer mountain-wave model developed previously coupled with a bulk boundary-layer model shows some skill in detecting flow stagnation as a function of key input parameters, including the Froude number and the height of the inversion, when compared to numerical simulation data and laboratory experiments performed by previous authors. Flow stagnation crucially depends on the effect of the boundary layer, with the inviscid version of the model severely overestimating the critical dimensionless mountain height for which stagnation occurs. A simplified model including only the effects of mean flow deceleration and velocity perturbation amplification inside the boundary layer predicts flow stagnation much more accurately than the inviscid model in cases where conditions are considerably non-hydrostatic, since the waves seem to be directly excited by the mountains. However, when the flow is more hydrostatic, only a full model including the modified boundary condition imposed on the inviscid flow by the boundary layer predicts flow stagnation adequately in parameter space. This corroborates the idea put forward by previous authors that in such cases the trapped lee waves are not forced directly by the orography, but rather indirectly by nonlinear processes, an effect that is captured to some extent by the full model. Neglecting this effect underestimates the trapped lee wave amplitude in the most hydrostatic conditions, especially when the Fourier transform of the orography has zeros, since this corresponds to weak direct wave forcing. Despite its fairly good performance, in the full model the flow stagnation condition fails to discriminate between rotors and hydraulic jumps. This is explained by differences in the flow perturbations produced at stagnation between the full model and numerical simulations, which are especially pronounced for the most hydrostatic flows, where the waves are generated indirectly. This suggests that the model may not produce flow stagnation for the correct reasons in those cases.

P-01.5

Water tank experiments on stratified flow over double mountain-shaped obstacles at high-Reynolds number

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We present an overview of the HyIV-CNRS-SecORo laboratory experiments carried out in the CNRM large stratified water flume. The experiments were designed to systematically study the influence of double obstacles on stably

stratified flow. The experimental setup consisted of a two-layer flow in the water tank, with a lower neutral and an upper stable layer separated by a sharp density discontinuity. A series of 395 experiments performed for a range of Froude numbers Fr extending from 0.17 to 1.4, and for non-dimensional inversion heights H/Zi from 0.3 to 1.3, in the stratified water tank successfully reproduced the range of phenomena expected to occur with this type of layering, such as trapped lee waves, rotors, hydraulic jumps, lee wave interference and flushing of the valley atmosphere. Here we present the first results of the laboratory experiments with a special focus on lee wave interference and coupling between lee wave amplitude and rotor strength. We develop a regime diagram for flow over single and double obstacles and examine the parameter space where the secondary obstacle has the largest influence on the flow. Particle-image velocimetry (PIV) is used to obtain the velocity field. Obstacle height and ridge separation distance are shown to control lee wave interference. Results, however, differ partially from previous findings on the flow over double ridges reported in the literature due to presence of nonlinearities and possible differences in the boundary layer structure. The secondary obstacle also influences the transition between different flow regimes and makes trapped lee waves possible for higher Froude numbers than expected for an isolated obstacle.

P-01.6

Numerical analysis of a ducted internal gravity-wave package causing an exceptional meteotsunami event in the Adriatic

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Meteotsunamis are long sea surface waves caused by propagating weakly dissipative atmospheric pressure perturbations formed by ducted internal atmospheric gravity waves and/or convection. Several high-amplitude meteotsunamis occurred in the northern Mediterranean countries during a major meteotsunami period from 23-27 June 2014. The largest sea level oscillations were recorded in Vela Luka Bay, Croatia, in the morning of 25 June 2014, where the amplitude of sea level oscillations reached 3 m. Sea level oscillations reaching 2 m were recorded also near Balearic Islands (Spain), Sicily (Italy), and Odessa (Ukraine). The extraordinary spatial dimension of this event shows that meteotsunamis can have a widespread influence that is comparable to other major tsunami-genic mechanisms.
The large-scale setting during the meteotsunami period was characterized by an incoming upper-level trough as well as the upper-level jet aloft and warm low-level advection from the African continent. The numerical analysis of the event was carried out using the Weather and Research Forecasting (WRF) mesoscale non-hydrostatic model. The model was configured with four telescoping domains reaching 0.5 km grid spacing over the Adriatic.
As inferred by comparison with the ECMWF reanalysis, the model represents well these environmental conditions during the meteotsunami period. The dynamically unstable mid-troposphere with Richardson number smaller than 0.25 capped the warm statically stable air in the lower troposphere. These environmental conditions were favorable for sustaining the internal gravity wave which induced on the Apennines mountain range, as lower layer was statically stable and of sufficient depth. The oscillating surface pressure perturbations at the sea level were also well represented in the simulation. Simulated pressure perturbations were sustained and reached amplitudes of several hPa at the mean sea level, which is of sufficient amplitude to cause a meteotsunami.
Finally, we also provide guidance on the model setup requirements necessary for inclusion of numerical weather prediction models in the operational applications of the meteotsunami warning system.

P-01.7

An unexpected severe downslope wind event in Catalonia

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Catalonia is a region located in the north-east of the Iberian Peninsula with a very complex terrain. In the north, it is limited by the Pyrenees, a natural border with France oriented from west to east. The Pre-Pyrenees is a parallel range of mountains located south side, with peaks above 2.500 m. As a result of the interaction between strong northerly airflows with the Pyrenees, severe lee-winds are frequently observed in the Pre-Pyrenees. On 9 December 2014, a northerly episode produced an extraordinary downslope windstorm that reached areas 100 km far from the Pyrenees, close to the Barcelona coast. The southern areas affected included lower orography. At the end of this episode, two deaths and unforeseen forest devastations were caused among others damages. In this study,

different meteorological factors that played a crucial role in this event are analysed: the jet stream, its orientation and strength, the stability present in the atmosphere and the interaction of the mountain waves with successive mountain ranges (downslope of the Pre-Pyrenees). As a result of their confluence, the wind gusts observed on the leeward of the Pre-Pyrenees were up to 48 m/s (175 km/h) and exceed 33 m/s (120 km/h) in the affected area near the coast.

P-01.8

History of the mountain meteorology in Bulgaria

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This study describes briefly the history of the Bulgarian mountainous meteorological stations, the main research carried out there and the perspectives for their future development. There are 5 alpine meteorological stations in the network of the Bulgarian Institute of Meteorology and Hydrology with altitudes from 1700 up to 2900 m a.s.l. The oldest one – peak Mussala was built in 1932 and is the highest meteorological station on the Balkan Peninsula.

P-02.1

Validation of Global Ensemble Precipitation Forecasts and the Implications of Statistical Downscaling over the Western U.S.

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Contemporary operational medium-range ensemble modeling systems produce quantitative precipitation forecasts (QPFs) that provide guidance for weather forecasters, yet lack sufficient resolution to adequately resolve orographic influences on precipitation. In this study, we verify cool-season (October–March) Global Ensemble Forecast System (GEFS) QPFs using daily (24-h) Snow Telemetry (SNOTEL) observations over the western U.S., which tend to be located at upper elevations where the orographic enhancement of precipitation is pronounced. Results indicate widespread dry biases, which reflect the infrequent production of larger 24-h precipitation events ($\gtrsim$ 22.9 mm in Pacific Ranges and $\gtrsim$ 10.2 mm in the Interior Ranges) compared to observed. Performance metrics, such as equitable threat score (ETS), hit rate, and false alarm ratio, generally worsen from the coast toward the interior. Probabilistic QPFs exhibit low reliability, and the ensemble spread captures only ~30% of upper-quartile events at Day 5. In an effort to improve QPFs without exacerbating computing demands, we explore statistical downscaling based on high-resolution climatological precipitation analyses from the Parameter-elevation Relationships on Independent Slopes Model (PRISM), an approach frequently used by operational forecasters. Such downscaling improves model biases, ETSs, and hit rates. However, 47% of downscaled QPFs for upper-quartile events are false alarms at Day 1, and the ensemble spread captures only 56% of the upper-quartile events at Day 5. These results should help forecasters and hydrologists understand the capabilities and limitations of GEFS forecasts and statistical downscaling over the western U.S. and other regions of complex terrain.

P-02.2

Validation and Intercomparison of Quantitative Precipitation Forecasts from the NCAR Cloud-Permitting Ensemble and Operational Models over the Western U.S.

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High-resolution ensemble modeling systems are required to capture the large spatial variability and quantify the inherent uncertainty of precipitation forecasts in areas of complex terrain, however, such systems remain largely untested at cloud-permitting grid spacings (i.e., 4-km or less) over the western U.S. In this study, we assess the capabilities of quantitative precipitation forecasts (QPF) produced by the National Center for Atmospheric Research

(NCAR) high-resolution (3-km horizontal grid spacing), 10-member ensemble forecast system using observations collected by Snow Telemetry (SNOTEL) stations at mountain locations across the western U.S. Emphasis is placed on identifying the capabilities of the control member (and hence individual members) in capturing the characteristics of precipitation events at these locations, as well as the reliability and resolution of probabilistic forecasts derived from the ensemble. Through intercomparison with forecasts produced by operational models run by the National Centers for Environmental Prediction (NCEP) and the Earth System Research Laboratory (ESRL), we highlight the usefulness and potential of a cloud-permitting ensemble over the western U.S.

P-02.3

Air pressure disturbances that cause meteotsunamis

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Meteorological tsunamis are long-ocean waves generated by intense small-scale air pressure disturbances.The waves can be several metres high and cause substantial damage to coastal towns. The main objective of the MESSI project (Meteotsunamis, destructive long ocean waves in the tsunami frequency band: from observations and simulations towards a warning system") is to build a reliable prototype of a meteotsunami warning system. When an air pressure disturbance of several hPa in amplitude propagates above the sea surface at the speed of long ocean waves (sqrt(g*H) where g is gravity acceleration and H is ocean depth) the long ocean wave amplifies due to Proudman resonance. Therefore, the model should predict the intensity, speed and direction a fast and intensive pressure disturbance. Atmospheric numerical weather prediction models represent one of the main components of any meteotsunami warning system. The non-hydrostatic 2km resolution ALADIN-ALARO forecast is running operationally in Meteorological and Hydrological Service of Croatia since July 2011. The suite predicts propagating small-scale pressure disturbances capable to excite meteotsunamis. However, the comparison of forecast pressure evolution to the measured data shows that the intensity of the observed pressure disturbances is simulated fairly by the model, but at a slightly different position and time, and propagate with slightly different speed and direction. Meteotsunamis are known to be highly sensitive to these parameters. Here we analyse the model disturbance's position, shape, variability in space and time, as well as speed and direction and track it to its origin. The sea surface temperature (SST) used in the model forecast arrives from the global model that is used for lateral boundary conditions. It has been shown that model SST can be quite far from real values over the Adriatic, especially over the coastal areas, such as in the WAC and Kvarner bay. The use of more realistic SST, from OSTIA and MUR analyses and the ROMS ocean model influences the intensity and propagation of the pressure disturbance. Recently, it has been shown that the physiography fields used by the model are of too low resolution and contain errors in the Adriatic area. More realistic physiography of the terrain surrounding the Adriatic sea affects the triggering of the disturbance. Finally, we examine the role of resolved/parametrized deep and shallow convection and turbulence scheme.

P-02.4

Sea surface temperature and forecast precipitation on the surrounding mountains

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Sea surface temperature (SST) influences the model forecast. For example it is important for modelling of land/sea breeze and influences the intensity of precipitation downstream. The operational forecast in Meteorological and hydrological service of Croatia is performed using ALADIN System. The sea surface is treated in a way that keeps the initial SST field unchanged during the model forecast (72 hours). But SST does change from one analysis (model run) to the next one. There are two sets of SST fields and associated two sets of lateral boundary conditions provided in the coupling files from operational forecasts of IFS and ARPEGE, from ECMWF and Meteo-France respectively. In this study we compared the SST from the global models to the values measured in situ on a number of stations in Croatia and Italy. The comparison reveals errors that can reach 10K over the Adriatic. Such errors are expected to have substantial impact on the forecast precipitation on the surrounding mountains.
The ARPEGE operational SST analysis combines AVHRR satellite data and in situ measurements in the operational oceanographic model Mercator. The SST from IFS forecast is derived from the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA) analysis. SST from the Regional Ocean Modelling System (ROMS) was

used over the Adriatic Sea with OSTIA analysis over the rest of the Mediterranean.
The impact of SST on the intensity and location of intensive rainfall is investigated by using alternative SST fields in the initial conditions, first from ARPEGE and IFS. In the first set of experiments, SST effects on forecast precipitation are analysed by modifying the SST field in the initial file by shifting the SST field uniformly. For each model forecast, the SST field obtained from ARPEGE is modified by increasing or decreasing SST values by 2K and 5K and finally decreasing by 10K for all sea points in the model domain. The results show increase in precipitation with warmer SST that is expected due to increase in evaporation from the warmer sea surface. But the surrounding mountains can receive less rainfall when SST is warmer. Warmer sea triggers more convection above the sea surface. Therefore, surrounding mountains do not necessarily receive more moisture.
In the further set of experiments, SST in the model was replaced using OSTIA and MUR analyses as well as ROMS model output. In one experiment we also nudged the SST field towards the measurements in order to test if precipitation forecast can be improved when SST is based on measurements.
The errors in the SST fields from the global models over Adriatic can exceed 10K. In reality, Kvarner Bay and Velebit Channel are often much colder than the rest of the Adriatic. In winter, western Adriatic current (WAC) is much colder too. The sea surface is too warm in the model and, consequently, the evaporation is much stronger yielding excess precipitation on the Velebit mountain. Turbulent fluxes of heat are also too strong above the sea surface. Colder SST in the Velebit Channel reduces the precipitation on the mountain.

P-02.5

Measurements and probabilistic forecasting of ice formation on wind turbines at a hilltop site in Germany

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The formation of ice on wind turbines is a major limiting factor for the operation of wind farms during winter time. Icing alters the aerodynamic behaviour of turbine blades, reduces the energy yield and may cause dangerous ice shedding. It can lead to unplanned downtimes, implying increased balancing costs and severe economic losses to power companies. Forecasts of wind power production loss caused by icing can be obtained from a chain of physical models, consisting of a global and a limited-area numerical weather prediction model, an icing model and a production loss model. Each element of the model chain is affected by significant uncertainty, which can be quantified using a probabilistic forecasting approach. Forecast skill can be evalated using targeted observations. In this contribution, we present preliminary results from the recently launched project ICE CONTROL, an Austrian research initiative on the measurement, probabilistic forecasting, and forecast verification of ice formation on wind turbine blades. ICE CONTROL includes an experimental field phase with measurement campaigns in a wind park in Rhineland-Palatinate, Germany, in the winters 2016/17 and 2017/18. The wind park is located on top of a hill range (Hunsrück) with a prominence of about 300 m over the surroundings. The instrumentation deployed during the campaigns consists of a conventional icing detector on the turbine hub and newly devised ice sensors on the turbine blades, as well as sensors for wind, temperature, humidity, visibility, and precipitation type and spectra. In addition, three cameras document the icing conditions on the instruments and on the blades. Different aspects of icing forecast uncertainty are considered. The uncertainty related to the initial conditions of the weather prediction is evaluated using the existing global ensemble prediction system of the European Centre for Medium-Range Weather Forecasts. Furthermore, observation system experiments are conducted with the AROME model and its 3D-Var data assimilation to investigate the impact of additional observations (such as Mode-S aircraft data, SCADA data and MSG cloud mask initialization) on the icing forecast. The uncertainty related to limited-area model formulation is estimated from a multi-physics and perturbed-physics ensemble based on the Weather Research and Forecasting model. Uncertainties in the icing model and in its adaptation to the rotating turbine blade are also addressed.

P-02.6

Consistent implicit compressible/soundproof EULAG dynamical core for COSMO model - status and challenges

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New EULAG dynamical core for the operational Consortium for Small-scale Modeling (COSMO) model is being

developed at IMGW within the CELO priority project of COSMO. Recently, the COSMO-EULAG was extended to include consistent implicit compressible/soundproof formulation. Its parallel formulation is being reformulated towards the implementation on modern supercomputing architectures using GridTools Domain Specific Language. Further efforts concentrate on research on the realization of surface fluxes within the nonoscillatory forward-in-time numerics of EULAG. Within this presentation I will discuss the current status of COSMO-EULAG performance and on-going efforts conducted within ESCAPE H2020 at Poznan Supercomputing and Networking Center and PROPOZE project conducted at the Institute of Meteorology and Water Management.

P-02.7

Towards an operational method to forecast snow events at low altitude in Catalonia

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Snow episodes at low altitude in Catalonia are one of the main problems to manage properly by civil protection authorities. Consequently, an accurate forecast is necessary to a suitable activation of the emergency plan. Catalonia, located in the north-east of Iberian Peninsula, is limited by the Mediterranean Sea to the east and south and by the Pyrenees in the north. This geographical situation favours the interaction of cold air masses moving from north-west with warmer air masses from the sea. Moreover, the uncertainties of precipitation and snow level forecasted by meteorological models and the Catalan complex orography add some degrees of difficulty to the forecast.
In this work, there are presented the results of applying two different methods to estimate the snow level in Catalonia. The first one uses the wet bulb temperature with a threshold of 1.5 degrees (WBT1.5), and the second one is estimated by using the hourly precipitation rate and the wet bulb zero level (WBZL).
The results show that, when there is a quick change of the air mass, it is better to use WBT1.5. WBZL method shows a better accuracy when the precipitation rate is persistent. This last method seems to work better in complex orography but it is essential a precise precipitation forecast.

P-02.8

Föhn events across the Antarctic Peninsula and their connection to local and regional meteorology

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One year of meteorological measurements with an Automatic Weather Station located on the lee side of the Antarctic Peninsula Mountain range have been analysed in detail with regard to the occurrence of Föhn conditions. These are of interest as they have potentially significant impact on the surface energy balance on the Larsen Ice Shelf. We report on the frequency and characteristics of these events and how their strength is determined by the mesoscale situation. Between January 2011 and March 2012 observations of pressure, temperature, humidity and wind speed and direction have been carried out at the AWS at Cole Peninsula. An algorithm combining regional scale model output of flow conditions with the in-situ measurements has been used to identify Föhn. The observations show Föhn occurring throughout the year, not only when circumpolar westerlies are at their strongest. Comparison with runs of the Weather Research and Forecast model WRF as run for the Antarctic Mesoscale Prediction System found that Föhn conditions and their strength are not satisfactorily captured by the model. As we have found a close correlation of Föhn events with air pressure measurements on the South Shetland Islands, which are a good indicator for the state of the Drake Passage Low, we investigate whether and how this relationship can be on one hand exploited to predict the occurrence and strength of Föhn events, and on the other hand be used to extend Föhn statistics in the region beyond the periods of in-situ measurements.

P-03.1

Terrain-trapped airflows and orographic rainfall along the coast of northern California: Long-term kinematic and precipitation characteristics

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Land-falling extratropical cyclones are responsible for the majority of precipitation that falls in the western United States. The spatial distribution of precipitation from these storms is strongly influenced by the regions' complex terrain. A narrow channel of concentrated horizontal water vapor flux in the lowest 3-4 km MSL is often present immediately ahead of the cold fronts associated with extratropical cyclones. Upon impacting the terrain, these statically-neutral atmospheric rivers (ARs) can facilitate moist orographic uplift that leads to enhanced precipitation. While this relatively simple conceptual model can explain a significant fraction of orographic precipitation that falls in the region, it does not take into account the fact that mountains can produce their own mesoscale circulations that modify the spatial distribution of precipitation. One example is the presence of a terrain-trapped airflow (TTA), which is defined as a relatively narrow air mass flowing in close proximity and approximately parallel to the windward slope of a mountain barrier. TTA impacts on orographic precipitation have been studied extensively in association with several large-scale mountain ranges such as the European Alps, the Southern Alps of New Zealand, the Rocky Mountains of Colorado and the Sierra Nevada of California. In contrast, TTA impacts on orographic precipitation occurring in association with relatively small-scale mountains (altitudes below ~1 km MSL) has received much less attention. It is notable that orographic precipitation over small-scale mountains has the potential to produce rapid runoff and flooding due to the prevalence of precipitation in the form of rain (rather than snow) and the relative scarcity of flood control infrastructure. This is a particularly relevant issue along the coastal mountains of northern California, where unobstructed ARs can directly interact with the coastal terrain (~0.5 km MSL and oriented northwest to southeast) to produce intense rainfall that leads to significant economic impacts.
This study employs observations collected along the California coast north of San Francisco as part of the California Land-Falling Jets (CALJET), Pacific Land-Falling Jets (PACJET) and Hydrometeorology Testbed experiments operated by the National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL). One of the main instruments is a 915-MHz wind-profiling radar located on the coast at Bodega Bay (BBY, 15 m MSL) that provided hourly, high-resolution (~100 m) vertical profiles of horizontal wind up to ~4 km MSL over 13 winter seasons. Supporting information is provided by surface meteorology and rain gauge observations at BBY and in the adjacent coastal mountains at Cazadero (CZD, 478 m MSL). These data allow documentation of the long-term kinematic and precipitation characteristics of TTAs in this area.
Mean wind direction in the lowest 500 m MSL ($WDIR_{500}$) less than 140° is used as the initial criterion to identify TTA conditions based on the average orientation and altitude of topography near BBY and CZD. Employing this threshold reveals a distinct easterly jet structure of zonal-component winds at ~250 m MSL and enhanced meridional-component winds, especially above 500-m MSL. TTA-regime duration varies seasonally between 1.9 h and 3.2 h, with an average duration of 2.5 h. The mountain-to-coast ratio (i.e., CZD/BBY) of rainfall during TTA conditions is 1.4, which is significantly lower than the ratio of 3.2 observed when TTA conditions are not present. A more detailed analysis of the relationship between $WDIR_{500}$ and orographic rainfall reveals that a threshold of 150° more precisely divides the two regimes of orographic enhancement. Additionally, a TTA-duration threshold of at least 2 h filters out insignificant events.

P-03.2

Comparison and optimization of radar based hail detection algorithms in Slovenia

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In this study we evaluated four commonly used radar based hail detection algorithms over Slovenia. The algorithms were verified against ground observations of hail in the period between May-August 2002-2010. The algorithms were optimized by determining optimal values of algorithm parameters. The best performance indexes were given by Waldvogel and SHI methods, followed by VIL and maximum radar reflectivity methods. In the end, using the optimal parameter values, a hail frequency climatology map for the whole Slovenia was produced. The analysis showed that within the Republic of Slovenia there is a considerable variability of hail occurrence. The hail frequency ranges from 0.2 to 1.8 with an average value of 0.9 hail days per year.

P-03.3

Isotope Fractionation and Orographic Precipitation over New Zealand

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The Southern Alps of New Zealand is one of the best defined and best studied regions for orographic enhancement of mid-latitude cyclone precipitation. Due to the frequent occurrence of moist NWly airstreams, the west coast "Westland" receives nearly ten times the annual precipitation of the eastern "Canterbury Plains" . The SALPEX program in the 1990's advanced our understanding and the DEEPWAVE project in 2014 added some aircraft, radar and sounding data. High resolution convection-permitting models WRF and NZCSM are now run in forecast and research mode over NZ.
In this study, an unconventional "isotope" approach is used. Stream water samples from four transects across the Southern Alps were analyzed for deuterium and 18-O ratios giving estimates of the Drying Ratio from DR=30 to 50%. This rather large DR value will be compared with other lines of evidence such as rain gauges and convection-permitting mesoscale models. Several issues will be examined to explain any discrepancy. First, the weighting of heavy rain events in the isotope signal is included. Second, a linear model is used to estimate the cloud time delay between ascent and precipitation. Third, the role of convection and the seeder-feeder process will be analysed.

P-03.4

What causes weak orographic rain shadows? Insights from case studies in the cascades and idealized simulations.

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Recent studies have shown that weak rain shadows in the Cascade Mountains are associated with passing warm fronts, but the specific mechanisms responsible for this connection have eluded consensus. One theory maintains that weak rain shadows are the result of enhanced precipitation over eastern slopes caused by easterly upslope flow; the other suggests that condensation is produced primarily over the western slopes, with enhanced east-slope precipitation occurring in dynamical regimes that minimize descent and evaporation east of the crest. Here these mechanisms are investigated through numerical simulations involving both real and idealized topography. Consistent with the second theory, storms with weak rain shadows are found to exhibit much weaker mountain waves in the lee of the Cascades than storms with strong rain shadows, with correspondingly weaker lee-side evaporation. The muted wave activity during weak-rain-shadow storms is found to be caused by cold, zonally-stagnant air at low levels in the lee, which precedes the warm front, and remains in place as the progression of the front is impeded by the mountains. As the front brings warmer air aloft, the static stability of the zonally-stagnant layer increases, making it more resistant to erosion by the overlying flow. This in turn allows the weak rain shadow to persist long after the front has passed. If the mid-latitude storm tracks shift poleward in a warmer climate, our results suggest there could be an increase in the strength of the rain shadow in mountainous regions astride the current storm tracks.

P-03.5

Winter precipitation efficiency of mountain ranges in the Colorado Rockies under climate change

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Orographic precipitation depends on both the environmental conditions and the barrier shape. As a measure of precipitation efficiency of a mountain range we use the drying ratio (DR), defined as the ratio of precipitation to incoming water flux. In this study, we explore the winter precipitation efficiency of mountain ranges in the Colorado Rockies under the current and future warmer and moisture conditions. The sensitivity of the DR to the barrier shape, temperature, stability, and horizontal velocity of the incoming air mass is examined for a number of individual mountain ranges in the Colorado Rockies. This analysis is based on the results of the Colorado Headwaters Simulations, carried out with the Weather Research and Forecasting (WRF) model run at the 2 km grid spacing over the inter-mountain west region of the US for four different winter seasons. For studying future climate scenarios, a pseudo-global warming (PGW) technique was applied.
For given environmental conditions, we find the DR to be primarily dependent on the upwind slope for wider mountain ranges, and on the width of the barrier for narrower ranges. Temperature is found to exert an influence on the DR for all Colorado mountain ranges, with DR decreasing with increasing temperature, under both the current

and future climate conditions. Finally, while the DR of the Colorado mountain ranges is found to be sensitive to temperature, the predicted decrease of DR is less than 0.5% per degree K of warming for all examined mountain ranges.

P-03.6

Precipitation impacts of atmospheric rivers on the west coast of southern South America

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Similar to other mountainous west coast around the world, the west coast of southern South America (SA) is strongly affected by heavy orographic precipitation events that result from the landfalling Atmospheric Rivers (AR). An AR is a narrow and long corridor of enhanced moisture transport over the oceans that often, but not always, develops just ahead of midlatitude cold fronts. When frontal systems develops an AR over southeastern Pacific ocean and it strikes the Andes mountains, orographic processes enhance precipitation over the upstream and the windward and immediate lee slopes sectors that occasionally produce floods, landslides, and at worst irrecoverable losses and fatalities. On the other hand, these heavy orographic precipitation events are a major contributor to water resources in the region, especially at the subtropical latitudes where the Andes are higher and melted snow irrigates the desert lands on both flanks of the range. Despite their importance, the SA region has a significant gap in the knowledge of AR phenomena and their impacts compared to North America and western Europa. In this study, we will discuss results from the quantification of how AR storms contribute to the annual total and extreme precipitation along the west coast of SA, between the southern tip of the continent and 30ºS, and across the Andes from the west coast (Chile) to the leeside (Argentina). The Integrated Water Vapor Transport (IVT), derived from Climate Forecast System Reanalysis (CFSR) data, is used for the AR identification over the period of 2001-2016; while daily and snow precipitation data networks of Chile and Argentina are used to quantify the impact of AR on precipitation over the region.

P-04.1

Using a cosmic ray sensor and weather radar composites to estimate the snow water equivalent on a Swiss glacier

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Precipitation estimates in high-mountain regions are essential for environmental studies in many research fields (glaciology, meteorology, hydrology, climate risk and adaptation). Although precipitation data exist for the Swiss Alps, accuracy is limited by data sparsity and measurement challenges in high-mountain regions. We propose a novel approach to estimate the snow water equivalent (SWE) on glaciers and to spatially integrate these measurements.
Reliable and continuous measurements of SWE are indispensable for inferring temporal snow-accumulation dynamics. Therefore, we investigate the application of a cosmic ray sensor to directly measure SWE continuously on the Glacier de la Plaine Morte in Switzerland. The sensor is located on the surface of the glacial ice below the snowpack and counts low-energy neutrons at an hourly interval. The neutron count is negatively correlated to SWE. Initial results show good agreement with independent measurements of SWE using conventional surveys in snow pits.
We use operational weather radar composites compiled by MeteoSwiss to spatially integrate our SWE measurements. These weather radar composites show precipitation estimates over Switzerland at a horizontal grid resolution of one kilometre and a temporal grid resolution of one hour. This grid resolution is sufficient to directly compare precipitation estimates with SWE measurements from the field site. In addition, several grid cells in the weather radar composites cover the glacier area, and, therefore, we can evaluate the spatial variability in precipitation measured by the weather radars. Snow height data collected on the glacier allows us to verify the spatial variability of snow-accumulation data.
In summary, we present precipitation data derived by combining in-situ continuous SWE measurements with operational weather radar composites. This will complement existing precipitation data and improve their representation in high mountain regions.

P-04.2

Accuracy of high-resolution gridded precipitation and temperature datasets in the Alps: evaluation by hydrological modelling in the Adige catchment (Italy)

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A good accuracy of gridded climate datasets is of crucial importance to climate studies, for the analysis of past and present climate, as well as for the validation, bias correction and/or statistical downscaling of climate models. Achieving accurate estimates for climate variables is especially challenging in the Alpine region, where spatio-temporal variability is exacerbated by complex topography and peculiar weather phenomena, and surface observations are rather scarce. This work aims to (1) assess the uncertainty of different high-resolution precipitation and temperature gridded products available over the Alps and (2) indirectly evaluate their accuracy by means of hydrological modelling. The HYPERstream model *(Piccolroaz et al. 2016)* is calibrated and run for the Alpine catchment of the river Adige (Italy), according to daily meteorological inputs from five datasets, namely E-OBS *(Haylock et al. 2008)*, MSWEP *(Beck et al. 2016)*, MESAN *(Landelius et al. 2016)*, APGD *(Isotta et al. 2014)* and ADIGE (a regional dataset), for the period 1989-2008. The datasets with the highest observational density, APGD and ADIGE, show similar spatio-temporal patterns of precipitation and provide high modeling efficiencies and small biases in simulated streamflow, at both catchment and sub-catchment scales. On the other hand, despite showing reasonable (albeit non optimal) results at the large catchment scale (thanks to counterbalancing effects), at smaller scales E-OBS, MESAN and MSWEP are found to be not accurate enough. Thanks to the use of hydrological modelling as an indirect and integrated evaluation tool, the different climate datasets are thus ranked according to their accuracy. In addition, their suitability for possible hydrological applications in impact studies is also determined.
[References: Beck et al. (2016), MSWEP: 3-hourly 0.25° global gridded precipitation (1979–2015) by merging gauge, satellite and reanalysis data, Hydrol. Earth Syst. Sci., Discuss., 21, 589-615, doi:10.5194/hess-21-589-2017. Haylock et al. (2008), A European daily high-resolution gridded dataset of surface temperature and precipitation, J. Geophys. Res., 113, D20119, doi:10.1029/2008JD10201. Isotta et al. (2014), The climate of daily precipitation in the Alps: development and analysis of a high-resolution grid dataset from pan-Alpine rain-gauge data, Int. J. Climatol., 34, 1657–1675, doi:10.1002/joc.3794. Landelius et al. (2016), A high-resolution regional reanalysis for Europe. Part 2: 2D analysis of surface temperature, precipitation and wind, Q.J.R. Meteorol. Soc., 142, 2132–2142, doi:10.1002/qj.2813. Piccolroaz et al. (2016), HYPERstream: a multi-scale framework for streamflow routing in large-scale hydrological model, Hydrol. Earth Syst. Sci., 20, 2047–2061, doi:10.5194/hess-20-2047-2016.]

P-04.3

Forcing snow cover models with meteorological data to derive snow instability for avalanche forecasting

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In mountain regions in winter, snow avalanches are relatively frequent and widespread. To warn the public, avalanche forecasts are issued in many regions on a daily basis. The forecasting process is data-driven, but mainly experience-based. For example, snow instability is assessed by linking present snow stratigraphy with future weather. While information on snow stratigraphy plays a key role, obtaining such data is difficult and time consuming. The ability to forecast avalanches, i.e. predicting snow instability, is limited by current experience-based forecasting practices and the poor resolution in space and time of snow stratigraphy data that can only be overcome with numerical modeling. In this study, we therefore investigated the ability of the snow cover model SNOWPACK driven with meteorological data from automatic weather stations (AWS) to evaluate snow instability. Throughout two winter seasons we collected data on snow instability at two field sites above Davos, Switzerland. Both sites are equipped with an AWS and stability was assessed by evaluating the critical crack length from modeled snow properties and compared to results of in-situ propagation saw tests. Overall, the modeled temporal evolution of the critical crack length compared quite well with field measurements, although the increase in stability with time was overestimated by up to 40%. The discrepancy was explained by an overestimation of the density of the critical weak layer in the snow cover simulation. Using density derived from daily in-situ snow micro-penetrometer measurements improved the stability estimates to an error of 15%. This study shows that it is feasible to predict the critical crack length from snow cover simulations solely driven with meteorological data. Operational use of spatially distributed snow instability data derived from a numerical weather prediction model for numerical avalanche forecasting

requires to further investigate influences of input uncertainties on modeled snow density and subsequently modeled snow instability.

P-04.4

Measured and modeled snow cover properties across the Greenland Ice Sheet

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The Greenland ice sheet (GrIS) is known to contribute to sea level rise in a warming climate. The snow cover on the ice sheet, which is the direct link between a potentially warmer atmosphere and the ice itself, is, however, poorly investigated and little is known about the microstructure and especially about the spatial and temporal variability of the snow cover, except from indirect evidence from remote sensing. During a field campaign in 2015 spatially distributed snow observations of the GrIS were gathered. This data set consists of high-resolution snow profiles located at stations of the Greenland Climate Network (GC-Net). Resistance profiles were measured with the SnowMicroPen (SMP) and used to estimate the density of the upper snow cover. In addition, snow samples from the upper snow cover were analyzed with regard to the specific surface area (SSA) using the IceCube. This data set of high-resolution snow microstructure measurements represents the first detailed dataset of observations since the 1950's. The snow cover model SNOWPACK was forced with reanalysis data from the model NHM-SMAP. The measured mean density of the upper snow cover was in good agreement with the simulations using constant densities for new snow deposition depending on the geographical location on the GrIS. However, the observed stratigraphy in terms of density and SSA could not be reproduced suggesting the need of a better understanding of the processes relevant in the formation of the snow stratigraphy and their model implementation. Furthermore, homogenous climatological conditions across the Greenland Ice Sheet might indicate that local post-depositional processes are more relevant for the formation and evolution of the snow stratigraphy than the meteorological conditions during precipitation events.

P-04.5

On forecasting wet-snow avalanche activity using simulated snow cover data

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Wet-snow avalanches are relatively poorly understood and difficult to forecast. By definition, liquid water is a prerequisite for wet-snow avalanche formation, thus assessing the liquid water content of the snow cover is of paramount importance for wet-snow avalanche forecasting. While evaluating wet-snow instability through field measurements is difficult, physically based snow cover models can be used to estimate the amount of liquid water within the snow cover using meteorological input. Recently, an index based on the liquid water content of the snow cover was suggested showing high potential to predict the onset of wet-snow avalanche activity. However, as the snow cover model was forced with data from automated weather stations (AWS) only a now-cast was possible. As snow cover conditions quickly change during snow melt, a forecast would be useful. For this study, we therefore force the snow cover model SNOWPACK with data from the high-resolution numerical weather prediction model COSMO and investigate whether forecasting regional patterns of the onset of wet-snow avalanche activity is feasible. To validate the index, we compared simulations performed at the location of numerous AWS in the Swiss Alps with wet-snow avalanche observations from the corresponding region. By forcing SNOWPACK with data from automated weather stations up to the actual day and then adding the forecasted input data to produce a forecast lead to results comparable to the simulations with station data only. While using this combined setup, the index was able to predict the onset of wet-snow avalanching with reasonable accuracy (up to 74%) for three winters between 2013 and 2016 and for two different climate regions in Switzerland. In addition, we will present preliminary results on the first operational winter season 2016-2017.

P-04.6

The impact of foehn winds on the Larsen C ice shelf, Antarctic Peninsula

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The Antarctic Peninsula (AP) is a narrow, elongated mountain range stretching ~1500km, and orientated roughly north-south. The AP acts as a physical barrier to the prevailing circumpolar westerly winds. Föhn winds frequently flow down the eastern slopes of the AP due to the interaction of the mountain range and the westerly airflow. The collapse of Larsen A and B ice shelves from the east coast of the AP in 1995 and 2002 (respectively) became a symbol for climate change in the Polar Regions. A proposed theory for the destabilisation of the eastern AP ice shelves is surface melting induced by föhn winds. The work presented here uses near-surface observations and simulations using the Weather Research and Forecasting (WRF) model to assess the impact of föhn winds on the surface of Larsen C ice shelf.
Observations from an automatic weather station on Larsen C ice shelf (67.02°S, 61.5°W) were ingested into a SEB model to estimate values of the energy balance components, prior to this study. Daily averaged values of all SEB components from 2009-2012 were provided for the project. Annual and seasonal analysis of these components has highlighted the impact of föhn winds on the ice shelf.
The increased downward shortwave radiation due to the cloud-clearing effect and the increased (positive) sensible heat flux during föhn winds lead to residual energy available for melt. When surface temperatures reach 0°C, this residual energy is used to melt the ice shelf surface. During austral spring (SON), föhn events cause earlier onset of the melt season, increase the number of melt days and increase the intensity of the surface melt. Surface melt is observed up to 100km from the foot of the AP. Surface melt from föhn events is greatest in years with multiple consecutive föhn events in late spring.
Numerical simulations accurately capture the number of melt days in a season but fail to capture the increased amount of surface melt during föhn events. Largely this is due to the low albedo value used in WRF, and the lack of a feedback effect once surface melting ensues. A presentation of the impacts of föhn winds on the Larsen C ice shelf and the representation of föhn-induced surface melt in numerical simulations is discussed.

P-04.7

Recent Tendencies in the Regime of the Snow Cover Seasonal Maxima in the Mountain Regions of Bulgaria - Preliminary Results

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This study represents the preliminary results of an ongoing research of the snow cover characteristics in the mountainous regions of Bulgaria. The period of investigation spans over more than 50 years (1962-2016) and covers regions with altitudes form 900 up to 2400 m a.s.l. The following characteristics of the seasonal maximums of the snow cover have been investigated: time change and assessment of the trend of their values and date of appearance. Some remarkable differences in both characteristics for different altitudes have been observed.

P-04.8

The Global Cryosphere Watch

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The cryosphere, and its variability and change, is a key component of weather, climate and water from local to global scales, including the mountainous regions of the world. Changes in the cryosphere have significant impacts on water supply, food production, hydropower production, transportation, infrastructure, hunting, fisheries, recreation, ecology and natural hazards. Changing snow and ice regimes affect atmospheric and ocean circulation and the Earth's water cycle. Freshwater runoff to the North Atlantic Ocean through increased melting of the Greenland Ice Sheet and its potential effects on the thermohaline circulation in the oceans is causing concern, while the effects of the melting of mountain glaciers and diminishing snow cover on water supply to densely populated areas of the world have recently been the subject of several assessments. Glacial meltwater is utilized for hydropower production in several countries and estimates of future runoff changes due to glacier volume reductions are crucial for optimum use of this resource.
Several bodies coordinate research and modeling studies of the cryosphere or its components, but up to now no international mechanism has existed that supports all key cryospheric *in-situ* and remote sensing observations, including measurement best practices, data exchange and quality management as well as network interoperability. In 2011, the World Meteorological Organization (WMO) launched the Global Cryosphere Watch initiative (GCW – www.globalcryospherewatch.org), which is currently developing a network of surface observations called CryoNet. Stations operating according to specified requirements form the basic components of this network. These stations measure at least one variable (e.g. snow depth) of one cryosphere component (snow, glaciers, ice sheets, sea ice, lake/river ice, permafrost, seasonally frozen ground, solid precipitation) and must also carry out ancillary meteorological observations. GCW also defines CryoNet "sites", which encompass an area greater than a conventional observing station and may cover several micro-climatological regions or extend over larger altitudinal gradients. Presently, 77 CryoNet stations, 43 GCW contributing stations, and 14 CryoNet sites form the network on five continents. All stations and sites as well as candidate stations are listed on the GCW website.
Many of these are in mountainous regions, on ice sheets, and on highland plateaus, where measurement methods, reliability, and sustainability vary widely. This presentation will give an overview of the structure and objectives of the Global Cryosphere Watch and provide examples of meta- and data exchange, monitoring, and research at alpine CryoNet stations.

P-04.9

Characteristics of Heavy Snowfall and Snow Crystal Habits in the ESSAY (Experiment on Snow Storms At Yeongdong) Campaign in Korea

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The Yeongdong region in Korea has frequent heavy snowfall in winter, which usually results in societal and economic damages such as collapses of the greenhouse and the temporary building due to heavy snowfall weights and traffic accidents due to snow-slippery road condition. Therefore we have conducted an intensive measurement campaign of 'Experiment on Snow Storms At Yeongdong (ESSAY)' using radiosonde soundings, several remote sensors, MASC (Multi-Angle Snowflake Camera) and a digital camera with a magnifier for taking a photograph of snowfall crystals in the region. The analysis period is mainly limited to every winter from 2014 to 2017
The typical synoptic situation for the heavy snowfall is Low pressure system passing by the far South of the Korean peninsula along with the Siberian High extending to northern Japan, leading to the northeasterly or easterly flows frequently accompanied by the long-lasting snowfall in the Yeongdong region. The snow density in Yeongdong region has a range of 90 ~ 200kg/m^3. As the 850hPa height temperature increase, the density increase because snow crystal has rimed.
The snow crystal habits observed in the ESSAY campaign are mainly dendrite, consisting of about 70% of the entire habits, indicative of relatively warmer East Sea effect. Meanwhile, the rimed habits are frequently captured specifically when two-layered clouds are observed. The homogeneous habit such as dendrite is shown in case of shallow clouds with its thickness below 500 m, whereas various habits are captured such as graupel, dendrites, rimed dendrites, etc in the thicker cloud with its thickness greater than 1.5 km. The association of snow crystal habits with temperature and supersaturation in the cloud will be more discussed.

P-05.01

Nocturnal cooling in a very shallow cold air pool

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Cold air pools (CAPs) may develop during nights in very shallow depressions. The depth of the stagnant air within a CAP influences the process of the cooling of nocturnal air and the resulting minimum temperature. A seven-month long field experiment was performed during winter 2013/2014 in an orchard near Krško, Slovenia, located inside a very shallow basin only a few meters deep and approximately 500 m wide. Two locations at different elevations inside the basin were selected for measurement. The results showed that the nights (in terms of cooling) can be classified into three main categories; nights with overcast skies and weak cooling, windy nights with clear sky and strong cooling but with no difference in temperatures between locations inside the basin, and calm nights with even stronger cooling and significant temperature differences between locations inside the basin. On calm nights with clear skies, the difference at two measuring sites inside the basin can be up to 5 °C but the presence of even weak winds can cause sufficient turbulent mixing to negate any difference in temperature. To better understand the cooling process on calm, clear nights, we developed a simple 1-D thermodynamic conceptual model focusing on a very shallow CAP. The model has 5-layers (including two air layers representing air inside the CAP), and an analytical solution was obtained for the equilibrium temperatures. Sensitivity analysis of the model was performed. As expected, a larger soil heat conductivity or higher temperature in the ground increases the morning minimum temperatures. An increase in temperature of the atmosphere also increases the simulated minimum temperatures, while the temperature difference between the higher and lower locations remains almost the same. An increase in atmosphere humidity also increases the modelled equilibrium temperatures, while an increase of the humidity of the air inside the CAP results in lower equilibrium temperatures. The humidity of the air within the CAP and that of the free atmosphere strongly influence the differences in equilibrium temperatures at higher and lower locations. The more humid the air, the stronger the cooling at the lower location compared to the higher location.

P-05.02

Exchange processes in the boundary layer over a mountainous island - observations and high-resolution simulations

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Comprehensive in situ and remote sensing measurements were performed on the mountainous island of Corsica during the HYdrological cycle in Mediterranean EXperiment (HyMeX) field campaign in late summer and autumn 2012 to investigate the evolution of the mountain atmospheric boundary layer (mountain ABL) in a valley under fair weather conditions.
The observations show that convection, thermally-driven circulations and topographic and advective venting determine the diurnal cycle of temperature, humidity and wind over complex terrain in the mountain ABL. The mountain ABL was found to be deeper than an ABL over homogeneous flat terrain under equal surface forcing. The observations also indicate that combined transport processes on different scales result in vertical exchange processes in a valley which extend those found in a surface-based, buoyancy-driven convection layer over flat terrain. High-resolution (100 m grid spacing) simulations with the Consortium for small scale modelling (COSMO) were conducted (i) to investigate whether the model was able to reproduce the observed ABL characteristics and (ii) to verify the hypothesized underlying processes deduced from the observations. Both, observations and simulations will be presented.

P-05.03

LANFEX: Understanding fog behaviour in a region of small hills.

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The LANFEX (Local And Non-local Fog EXperiment) campaign is an attempt to improve our understanding of radiation fog formation through a combined field and numerical study. The field trial was deployed in the UK for 18 months using an extensive range of surface based equipment, including some novel measurements (e.g. dew measurement and thermal imaging). In a region of hills we instrumented flux towers in four adjacent valleys to observe the evolution of similar, but crucially different meteorological conditions at the different sites, and correlated these with the formation and evolution of fog which formed within the valley cold pools. The results presented show certain locations are more prone to fog, as expected, but that the overriding condition for in situ fog formation within the cold pool is that turbulence must remain be below a certain threshold. The presence of orography does not appear to affect the value of this threshold. Once fog formed locally it was sometimes seen to advect within the

valley systems, and at some sites the occurrence of fog was due to advection as much as insitu development.

P-05.04

High resolution modelling of fog formation in complex terrain

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We present results from high-resolution simulations with the Met Office Unified Model (UM) of fog evolution in the complex valley systems of Shropshire, measured as part of the Local and Non-Local Fog Experiment (LANFEX). Simulations at a range of horizontal resolutions, down to 100m, are presented to show how the fog evolution is closely tied to terrain induced flows (such as valley cooling), and the extent to which the UM is able to simulate this. It is shown that whilst horizontal resolution is clearly important in the representation of flows in narrow valleys, vertical resolution is equally important in the simulation of the near-surface drainage flows and cooling which leads to fog formation. We also show how model parametrizations, such as that of subgrid turbulence, can have large affects on the evolution of fog and its location within the valley system.

P-05.05

Temperature and wind speed oscillations at Arizona's Meteor Crater

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The Meteor Crater basin in northern Arizona is almost circular with a diameter of approximately 1.2 km, a depth of about 170 m, and a crater rim that extends approximately 30-50 m above the surrounding terrain. The crater is located on a large plain that slopes slightly upward toward the southwest so that a southwesterly katabatic flow develops over the plain during quiescent, clear-sky nights, which interacts with the crater basin and its rim. The Second Meteor Crater Experiment (METCRAX II) field campaign took place at the Meteor Crater in October 2013 to study these interactions of the nocturnal katabatic flow with the crater topography.
The typical nocturnal vertical temperature structure in the Meteor Crater is influenced by cold air draining over the southwest crater rim into the basin as a result of the southwesterly katabatic flow over the surrounding plain. The temperature profile consists of a strong and shallow surface-based inversion and a near-isothermal layer that extends almost to the top of the crater. Periodic oscillations in the nocturnal surface temperature and wind fields have been observed within the crater-floor inversion during several nights, with a typical periodicity of about 15--20 min. The phase shift between these oscillations over the southwest sidewall and the opposite northeast sidewall indicates a sloshing of the crater-floor inversion, induced by the cold air draining down the southwest crater sidewall. Oscillations with a similar periodicity have also been observed in the upstream katabatic flow coming over the crater rim. In this presentation, we will look at the origin of these oscillations in the katabatic flow and whether they influence the sloshing frequency of the crater-floor inversion.

P-05.06

Meteorological observations in a valley during the 21 August 2017 solar eclipse

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On 21 August 2017, a total solar eclipse will occur over the continental United States for the first time since 1979. This presents a rare opportunity for atmospheric scientists to collect atmospheric measurements in a quasi-laboratory setting, as the timing of the eclipse is known with accuracy to fractions of a second. Meteorological data have been collected over flat terrain during past eclipse events, but a comprehensive dataset from a mountainous site does not exist.
This project will focus on the convective boundary layer (CBL) in a valley in the Great Smoky Mountains, which fall within the path of totality for the 2017 eclipse. We are particularly interested in observing the evolution of the vertical

structure of the valley atmosphere, as well as the response time of slope and valley winds to radiative forcing changes during the eclipse event. Eclipse totality occurs at approximately 15:00 local time at the study site, which allows time for slope and valley flows to fully develop prior to the eclipse.
This presentation will discuss some initial modeling results of an idealized valley with a focus on the daytime evolution of the CBL during a simulated eclipse event. Additionally, a description of the field campaign plans will be presented, with details on instrumentation, site selection, and meteorological variables of focus.

P-05.07

Convective plumes in a daytime valley atmosphere: Structure, scaling and flux contributions

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Near-surface turbulent flow in the convective boundary layer (CBL) is usually characterized by a high degree of stochasticity, resulting in the need for a statistically oriented approach to describe its attributes. Even so, this turbulent flow oftentimes organizes itself in deterministically more describable formations. The most common example of these formations are coherent structures, defined as an organized three-dimensional region of turbulent flow in which some property (e.g. temperature) is highly correlated with itself at a time scale larger than the smallest scale of the flow. Daytime near-surface coherent structures (convective plumes) have received considerable attention over flat terrain and across the forest-canopy interface. On the other hand, convective plumes over complex terrain (e.g. a valley) have received very little attention. It is unknown to what degree convective plumes are influenced by flows in complex terrain. Interactions between coherent structure and complex terrain flows may cause substantial deviations in the flux contributions from those observed over flat terrain. Here we present preliminary results, with the aim to elucidate the structure of complex terrain convective plumes (frequency of occurence, mean duration) and their scaling properties.
The main dataset we analyze is comprised of high-frequency turbulence measurements obtained during the Terrain-Induced Rotor Experiment, conducted in the spring 2006 in Owens Valley, CA. Specifically, we analyze sonic temperature time series obtained on three 34-m towers. Each tower was equipped with 6 levels of sonic anemometers. Convective plumes are most easily discernible in the sonic temperature time series, with well defined ramp-like signatures. To determine their properties and contributions to vertical fluxes, we employ three methods: quadrant analysis, multiresolution flux decomposition and the wavelet covariance technique. To determine the scaling variables necessary for generalizing the parameterization relationships, we use: the inertial dissipation method to estimate viscous dissipation; detection of the peak in the velocity spectra for the determination of the CBL depth; and the Theodorsen ejection-amplifier (TEAL) scaling framework. The TEAL scaling, Monin-Obukhov scaling, free-convection scaling and mixed-layer scaling are compared and initial conclusions are drawn pertaining to the possibility of scaling convective plume properties and flux contributions in complex terrain.

P-05.08

Comparison of different configurations of the TOUCANS system of turbulence parametrizations

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Third Order moments Unified Condensation Accounting and N-dependent Solver – TOUCANS is a compact 2.5 level parametrization of turbulence, which integrates several ideas into its framework: non existence of critical Richardson number (Ri_{cr}), anisotropy of turbulence, prognostic treatment of Turbulent Kinetic Energy (TKE) and Total Turbulent Energy (TTE), inclusion of moisture influence on turbulence, as well as the possibility of prognostic treatment of mixing length and 3D turbulence parametrization. TOUCANS is based on the framework of four free parameters which influence the basic properties of the scheme and three functional dependencies which define the shape of stability functions. By adjusting the scheme parameters and modifying the stability component in functional dependencies, TOUCANS is able to emulate more advanced turbulence parametrizations like Quas-Normal Scale Elimination (QNSE) and Energy- and Flux-Budget (EFB). On the other hand, TOUCANS is able to go step backwards, i.e. it can emulate its long term predecessor – diagnostic Louis scheme.
In this work we use the emulation property of the TOUCANS system and compare the performance of turbulence parametrizations mentioned above, focusing on the TKE and covariances, along with the terms of the TKE budget equation. For this purpose we run the non-hydrostatic regional NWP ALADIN-HR 2 km horizontal grid spacing model with 37 vertical levels during the episode of bora downslope windstorm. Furthermore, we compare the performance of the currently operational Geleyn-Cedilnik mixing length formulation against TKE-based formulations, e.g. Bougeault-Lacarrere and Deardorff. Model outputs are verified against the three level (10, 22 and 40 m AGL)

3D 5 Hz ultrasonic tower measurements at the top of Pometeno Brdo (≈ 600 ASL) in the hinterland of Split, Croatia. Additionally, the results are compared to the WRF-LES simulations.
The observational and model analysis suggests dominant contribution of mechanic production and TKE dissipation terms of the TKE budget, but large portion of TKE also originates from the non-local turbulence. We discuss the applicability of the simplified 1D TKE budget equation to this bora case, as well as the impact of different configurations of the TOUCANS system to the TKE forecast, with an emphasis on the link between the TKE and mixing length.

P-05.09

Air quality management along the Brenner corridor in the Italian Alps: the BrennerLEC project

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“BrennerLEC” (Brenner Lower Emissions Corridor) is an European LIFE project aiming at testing and applying an advanced “environmental traffic management” system on the Italian A22 highway, in order to reduce pollutants, and in particular NOx emissions. The A22 highway is one of the main North-South transit route crossing the Alps and connecting Austria to the Po Plain through the Brenner Pass and the Adige Valley. In the region road traffic is responsible for about 60% of all NOx emissions, one third of which being generated by highway traffic. Air pollutant emissions generated by road traffic are the main cause of the exceedances of the annual NO_2 average law limits registered in the past years: this situation is particularly critical since conditions of poor air quality mainly refer to locations where the majority of the inhabitants live.
A dense network of meteorological, including sonic anemometers, and air quality sensors is going to be implemented for the project, aiming at fully characterising air quality conditions along the highway and traffic-induced turbulence. The air quality network will be composed not only of conventional sensors but also of innovative and low-cost instruments for monitoring NOx. During the project the performance of this kind of sensors under true ambient conditions will be continuously monitored, by comparing their measurements against the conventional stations, providing the basis for enhanced understanding of the accuracy of these instruments in changing environmental conditions. In fact, evaluation of the performance of innovative instruments is still limited and mainly based on laboratory experiments. Another innovative aspect connected to environmental monitoring is the measurement of black carbon (BC), which will be performed using aethalometers working at different wavelengths, in order to discriminate between BC emitted from traffic and from biomass burning.
Moreover, during the project an advanced modelling chain, composed of integrated meteorological, air quality and traffic models, will be developed to support the extensive testing and application of temporary reduction of speed limits connected to critical air quality situations. Meteorological forecasts will be performed using the Weather Research and Forecasting (WRF) model, down to a resolution of 1 km. Operational meteorological forecasts will take advantage of data assimilated by a dense network of surface stations, both installed specifically for the project and operated by the local meteorological offices, including a thermal profiler and a wind profiler. Air quality forecasts, performed using the CALPUFF and AUSTAL2000 dispersion models, will provide the decision support tool for the application of reduced speed limits on the highway, in order to maximize the benefits of the policies implemented limiting negative impacts for the highway users, by putting in action measures only when necessary and anticipating environmental issues.

P-05.10

Greenhouse gas budgets and convective boundary layer heights in mountainous terrain

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The rise of greenhouse gases, like carbon dioxide (CO2), has led to an increasing interest in CO2 budget estimations from both science and policy perspectives. Studies have indicated that half or more of the US gross primary production of CO2 is from mountainous regions. Currently, regional-to-continental scale CO2 budgets are estimated using coarse global models that have horizontal grid spacings on the order of 50-100 km. A correct

simulation of planetary boundary layer is crucial for the accurate estimation of CO_2 budgets. Duine and De Wekker (2017) showed that as a consequence of terrain smoothing, convective boundary layer (CBL) depths are overestimated in coarse grid domains and physical and dynamical processes that are important for the transport and mixing of CO_2 are poorly simulated in mountainous terrain. This inevitably leads to errors in CO_2 budget calculations. In this poster, we use simulations of the Weather Research & Forecasting (WRF)-Chem model to investigate the impact of horizontal grid spacing on trace gas budgets in mountainous terrain using the boundary-layer budget method. A better understanding of this impact and its representation in large scale models would lead to an improved simulation and understanding of the location and quantification of North American and global carbon sources and sinks.

P-05.11

Predicting local winds in a deep Alpine valley under fair weather conditions

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Under fair weather conditions, thermally driven local winds often dominate the wind climatology in mountain regions. In deep valleys, such as the Rhone valley in south-western Switzerland, their impact is seen in all seasons. In a previous study, we showed that the thermally driven along-valley winds during a one-month summer period (July 2006) are generally well represented in numerical simulations at 1.1 km resolution for most locations in the larger valleys in the Swiss Alps, provided that high-resolution land surface datasets are used for the simulations. In contrast, the skill at 2.2 km resolution was poor. The study nicely demonstrated the potential benefit of going to 1.1 km resolution for numerical weather prediction of local weather in Alpine regions. While their was a clear benefit of going to higher resolution for most locations, for one station in particular (Sion in the Rhone valley) little improvement in the mean diurnal evolution of the simulated along-valley winds was found. Despite this poor skill for the mean diurnal evolution, on some days the diurnal evolution is well represented by the model. In this study we take a closer look at the wind climatology in Sion and investigate the causes leading to good skill on some days and poor skill on other days.

P-05.12

Influence of a valley exit jet on the experimental site of the BLLAST field campaign

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The Boundary Layer Late Afternoon and Sunset Transition (BLLAST) field campaign was an experiment conducted in June-July 2011 in Lannemezan, France, with the main objective to study the convective boundary-layer decay to a night-time stable boundary layer during the late afternoon and evening transition. The experimental site was located on an elevated plateau at the northern foothills of the Pyrenees, few km far from the mountain range and, therefore, particularly influenced by the mountain-plain wind circulation. During several Intensive Observation Periods (IOPs), a strong flow with a jet-like structure arrived to the experimental site from southern directions at night.

High-resolution mesoscale simulations performed for the IOPs free of rain and clouds show that this low-level jet has its origin on the exit jet generated at the Aure's valley. This is a 40-km long pyrenean valley located 10 km south of Lannemezan, with the main axis oriented in the N-S direction. It has a v-shape valley cross-section with a maximum distance between ridges of 10 km, a depth up to 900 m and with the highest peaks rising above 2500 m above sea level (asl). This topographical configuration generates a diurnal valley wind system that has been characterised for the different synoptic conditions developed during particular IOPs.

When background winds are weak, thermally-driven down-slope and down-valley winds organise inside the valley around sunset and feed the valley exit jet that generates two hours later over the plateau. When background winds aloft are moderate or strong, they are channelised down the Aure valley axis, producing a dynamically-driven exit jet. Both types are able to reach Lannemezan depending on the intensity and direction of the general wind over the plateau. The characteristics of the exit jet (intensity, maximum height) also depend on the general wind conditions and exit jet type. In this communication, we will show the most relevant results from the numerical outputs, which agree well with the observations in Lannemezan taken during the BLLAST field campaign.

P-05.13

Scale interactions in katabatic flows

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Stable boundary layers pose a significant challenge to numerical weather prediction. The reasons are subgrid scale interactions (from mesoscale through sub-mesoscale to turbulence scale) that characterize stable boundary layers and are not only unrepresented in models, but also not well understood. This is particularly true for very stable boundary layers where turbulence is sporadic and submeso motions are one of its major triggering factors.
Over sloping surfaces stable boundary layers are characterized by katabatic flows. Due to strong near-surface wind shear katabatic flows are able to generate sustained turbulence even in very stable conditions. Still, strong stability associated with near surface cooling is conducive to gravity waves and other submeso motions that can propagate and interact with katabatic winds.
In this contribution we examine katabatic winds over slopes of different steepness from the Metcrax II campaign (1° slope) and i-Box project (slopes of 10° and 27°) and their interaction with motions on scales larger than the turbulent scales. For this purpose we employ a recently developed statistical approach that allows for a clustering of turbulence data into periods with different influence of the sub-mesoscale motions on the turbulent fluctuations. Multi-resolution flux decomposition is then used to examine the interacting scales of motion in each identified cluster, and examine the scale separation or lack of separation of turbulent and sub-mesoscale processes.

P-05.14

Scaling the downslope flows in mountainous terrain

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Orography presents a significant forcing to the atmosphere above and around it, spanning a wide range of scales, from large scale to turbulence. In mountainous terrain turbulence is by definition considered to be heterogeneous inhibiting efforts of developing a unified similarity theory for complex terrain. This heterogeneity of turbulence stems from local surface characteristics such as changes in slope angle and vegetation cover and inhomogeneity in the thermal forcing as well as different type of dynamic forcing: under low synoptic forcing thermally driven flows develop in mountain valleys and on the slopes whereas under strong synoptic forcing downslope windstorm-type flows can develop. The question remains whether these effects cause the flows in mountainous terrain to have different turbulence characteristics to those over flat terrain and how this influence is manifested.
In this contribution we present results from long-term turbulence measurements from the Inn Valley, Austria, as part of the i-Box project. We focus on the difference between the turbulence generated by thermally and dynamically driven winds at the valley floor and on the steep slope where towers with multiple levels allow the examination of the non-dimensional wind shear. We then compare the scaling to that over flat terrain. The results from stable stratification on the steep slope suggest scaling for both dynamically and thermally driven types of flow diverges from the flat terrain scaling. This divergence is, however, more pronounced for stronger stabilities, corresponding to shallow thermally driven flows. On the other hand, more neutrally stratified flows caused by strong dynamic forcing, although more horizontally inhomogeneous, correspond better to flat terrain scaling.

P-06.01

Earthquake-triggered avalanches along Central Apennines (Italy) in January 18th, 2017.

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The strong and long-lasting seismic sequence that has affected central Italy from the end of August 2016, besides widespread severe damages to building and infrastructures, also triggered of many mass movements of different

typology and dimension. Namely, in January 18th four shocks (Mw ranging between 5.0 and 5.5, epicenters in the Laga Mts., depth from 9 to 11 Km) occurred between 10:25 and 14:33 (UTC+1) resulted in the activation of some snow avalanches, one of which also caused a casualty in Ortolano di Campotosto (AQ). The above earthquakes strongly shaked a complex mountain range, extending itself for nearly 200 km (from the Sibillini Mts. to the Matese Mts.). Since heavy snowfalls were almost uninterrupted all along the Adriatic side of Central Apennines from the morning of January 16th up to the afternoon of January 19th, the area was covered by a rather thick blanket of snow (thickness approximatively ranging between 150 and 320 cm at an elevation of 1500 m). In this paper, the spatial distribution of the above avalanches, whose co-seismicity has been confirmed by several testimonies, have been analyzed and compared with local morphologies, seismic events, meteorological features and known data on snow cover and stratigraphy.

P-06.02

Objective climate classification of Slovenia

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In the study the climate regions of Slovenia were determined. The regionalization was based on the gridded climate data for the reference period 1981–2010. The climatic regionalization was performed predominately objectively with a combination of two statistical methods; the factor analysis which was followed by k-means clustering. With the use of factor analysis the initial number of 31 climate variables was reduced to 4 variables or factors, which comprised the input for the cluster analysis where Slovenia was divided into 6 climate regions: Submediterranean climate region, Wet climate of hilly region, Moderate climate of hilly region, Subcontinental climate region, Subalpine climate region and Alpine climate region. Compared to previous climatic regionalization studies for Slovenia, the presented study uses a higher degree of objectivity in the determination of the extent and borders between climate regions. The current study was based purely on climate data, while in the previous studies, the borders were defined more subjectively, based on the authors' expertise of local climate.

P-06.03

Carpathian mountain forest vegetation and its responses to extreme climate stressors

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The altitude and the shape of the Carpathian mountain chain in Romania are responsible of significant climate disturbances in the zonal climate and in the general atmospheric circulation.
Have been reported variations of the thermal vertical lapse according to the aspect, slope and land cover, which can be reflected in the local conditions and in the other meteorological variables, such as relative humidity, wind speed, and snow cover. Due to anthropogenic and climatic changes, Carpathian Mountains areas in Romania are experiencing environmental degradation. Mountain forests represent unique areas for the detection of climatic change and the assessment of climate-related impacts. Forest systems are all sensitive to climatic factors and extreme events and are likely to have different vulnerability thresholds according to the species, the amplitude, and the rate of climatic stressors.
As a result of global climate change, there is a growing evidence that some of the most severe weather events could become more frequent in Romania over the next 50 to 100 years. In the case of Carpathian mountain forests, winter storms and heat waves are considered key climate risks, particularly in prealpine and alpine areas. Effects of climate extremes on forests can have both short-term and long-term implications for standing biomass, tree health and species composition. The preservation and enhancement of mountain forest vegetation cover in natural, semi-natural forestry ecosystems is an essential factor in sustaining environmental health and averting natural hazards
This paper aims to (i) describe observed trends and scenarios for summer heat waves, windstorms and heavy precipitation, based on results from simulations with global circulation models, regional climate models, and other downscaling procedures, and (ii) discuss potential impacts on mountain forest systems in Romania. In montane forests, the more frequent occurrence of dry years may accelerate the replacement of sensitive tree species and reduce carbon stocks, and the projected slight increase in the frequency of extreme storms by the end of the century could increase the risk of windthrow. Some possible measures to maintain goods and services of forest ecosystems are mentioned, but it is suggested that more frequent extremes may have more severe consequences than progressive changes in means. In order to effectively decrease the risk for social and economic impacts, long-term adaptive strategies in silviculture, investments for

prevention, and new insurance concepts seem necessary.

P-06.04

Climate changes impacts on mountain vegetation land cover from time-series satellite imagery

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This paper addresses a number of issues related to current and future climatic change and its impacts on mountain vegetation land cover, focusing on the Carpathian region in Romania. Mountains are important sources of water, energy, minerals, forest and agricultural products and areas of recreation. They are storehouses of biological diversity, home to endangered species and an essential part of the global ecosystem. Due to global warming and climate changes Carpathian zones in Romania are experiencing environmental degradation. However, climate change effects like increased precipitation, moth attacks, freezing and thawing events during winter and long-transported air pollution (e.g. nitrogen) as well as heat wave event during summer period may also have reinforced the changes in biomass. Use of vegetation indicators derived from remotely sensed imagery, give us the possibility to forecast shifts in the future distribution of mountain vegetation due to climate changes. Remotely sensed metrics representing cumulative greenness, seasonality, and minimum cover have successfully been linked to species distributions over broad spatial scales. Climatic variables from regional weather stations and NOAA AVHRR satellite data for the 2000-2016 period together with Normalized Difference Vegetation Index (NDVI) and leaf area index (LAI) time- series MODIS Terra/Aqua satellite data revealed some consistent changes. So, mountain vegetation had a nonlinear response to changing climate, this response of vegetation to climatic factors was varying in different seasons and also related to different land cover vegetation characteristics and climatic conditions. Anyway, mountain ecosystem functions regulated the relationships between vegetation and climate.

P-06.05

Meteorological controls on local and regional volcanic ash dispersal

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Volcanic ash has the capacity to impact human health, livestock, crops and infrastructure; in addition to disrupting international air traffic. For recent major eruptions, information on the plume and ash distribution has typically been combined with relatively coarse-resolution meteorological model output to provide simulations of regional ash dispersal, with reasonable success on the scale of hundreds of kilometres. Here, we will present results from a dynamic meteorology-ash-dispersion model configured with sufficient resolution to represent local topographically-forced flows and initialised with realistic atmospheric and ash-distribution structures. We focus on an archetypal volcanic setting, Soufriere, St. Vincent, and draw on the exceptional historical record of the 1902 and 1979 eruptions to compare with our simulations. We find that the evolution and characteristics of ash deposition on St Vincent and nearby islands can be accurately simulated when the wind shear associated with the Trade Wind inversion and topographically-forced flows are represented. Sensitivity tests demonstrate that the wind shear has a primary role in local ash dispersal, with topographic flows an important secondary role, for ash fall on both St Vincent and Barbados. Consequently we propose a new explanation for secondary ash deposition maxima, a common observation in volcanic eruptions, namely a result of interactions between mesoscale meteorology and the ash plume.

P-06.06

Extreme temperatures in the cold air pool of the central Apennines (Italy): comparison with those of the Veneto Pre-Alps during winter 2016-17

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Despite Mediterranean latitude, the Italian peninsula shows geomorphological situations that determine the presence of cold air pool, where are observed extreme and mean minimum temperatures comparable to those of the cold poles of the pre-alps and even of Central Europe. In the Central Apennines and in particular in the Abruzzo and Molise region- at latitudes N between 41°30 'and 42°15', plateau tectonic - karst are present, at altitudes between 1200 and 1500 meters (less than 500 meters in the case of the Boiano valley) which, in recent years, are densely monitored by official and amateur meteorological monitoring networks, that still adhere perfectly to the WMO standard. The coldest areas are found in the "Pezza", "Campo Felice" and "Cinquemiglia" plateau on Abrusses Apennine and in the Campitello Matese and Boiano plateau in the Molise Apennine. It is almost completely disabled areas but which are wery popular for the practice of winter sports, being situated a short distance from cities such as Rome and Naples. In the presence of specific synoptic situations, characterized by advection of continental polar air - especially if amplified by an extended snowmaking - is possible to reach several times, during every winter, absolute minimum values lower than -25 ° C and exceptionally lower than -35 ° C - with an absolute minimum of - 37.4 ° C at Piani di Pezza, the morning of February 15, 2012. Already during a polar pulse that has reached Central Italy in August 2016, they were observed repeated night frost; meteo - climatic the analysis performed on data from several monitoring stations for winter 2016-17 and comparison with the thermal values recorded in the highlands karst of the Venetian Pre-Alps confirmed the peculiarities at the local scale of these Apennine sites.

P-06.07

Intense snowfalls of January 2017 along the central-southern Apennines (Italy), in comparisons with the 2015, 2012 and 205 events.

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During the first two decades of 2017, along the central-southern Apennines (Italy) very intense end abundant snowfalls took place, confirming once more the trend toward extreme meteorological phenomena of the Mediterranean basin.
After a mild and almost dry beginning of winter, starting from January 4th the Azores anticyclone expands itself with the main axis toward northern Europe. Contemporaneously, a dynamic depression centered on Poland started to expand and deepen; intensively attracting polar air currents that start to take a cyclonic curvature. In the meanwhile, however, the polar vortex progressively became bilobed, creating ideal conditions for its freezing air to flow more than once in the Mediterranean area.
As a consequence, in Italy extremely cold nuclei affected twice both the Adriatic and Jonian regions: first between January 5th and 11th and a second time between January 16th and 20th.
During the former advection, pressure maxima at the ground level were observed over the Scandinavian peninsula while the depression followed a retrograde motion to reach southern Italy. The subsequent advection assumed polar continental characteristics: weather become unstable, with snowfalls that in January 6th and 7th affected coastal areas too, from the Marche to the Lucania Regions, and temperatures marking the lowest record of the last thirty years. Snowfalls were particularly abundant on the Molise and Apulia reliefs: up to one meter in the Murge highlands, were they were really exceptional.
After a temporary expansion to the East of the Azores high pressure, starting from the 14th Arctic high pressure started again to deepen toward the Mediterranean somehow responding to the rise of the above said anticyclone toward Scandinavia. "Intermediate" polar air, slightly less cold but more humid of that of a few days before, reaches the central Mediterranean, where a depression is generated over the northern Tyrrhenian Sea. This resulted in very intense precipitations lasting from the morning of January 16th to the whole 20th. The above snowfalls were particularly intense in the hilly and mountain areas between central Marche and southern Abruzzi, where locally they exceeded the exceptional ones recorded in 2015 and 2012. They also contributed to the activation of many snow avalanches, among which that of Rigopiano resulting in 29 casualties.
Using the data provided by the Meteomont service managed by the Forestal Guards of the Carabinieri and by local meteorological services it was possible to evaluate with a fair approximation the outcome of the above meteorological phenomena and to compare them with those referring to the most intense snowfalls of the last decade in the same area.

P-06.08

Environmental Research and Monitoring at Sonnblick Observatory

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Introduction

The Sonnblick Observatory was founded in 1886 by the Austrian climatologist Julius Hann at the summit of Hoher Sonnblick (3106 m asl). Among a larger number of mountain observatories established that time, Sonnblick is the only station located in a high alpine environment which survived without any breaks until today. Besides of the long time-series of meteorological measurements, miscellaneous other research disciplines identified the great experimental potential of this site: experiments on cosmic rays, glaciological studies and the investigaton of climatological trends, atmospheric chemistry and climate impacts in the Alpine environment. Today, the Sonnblick Observatory is part of the Global Atmosphere Watch Program (GAW) of the World Meteorological Organization. The Observatory serves as a research platform for many national and international science institutions and universities focusing on research and monitoring in areas of atmospheric physics, chemistry, glaciology and biological studies. Due to its unique exposed location, the high altitude observatory is an important measurement location within several monitoring networks, such as the early nuclear radiation warning system and the air pollution monitoring network.

The research program "ENVISON" (Environmental Research and Monitoriung SONnblick) summarizes the research focus in the field of Atmosphere, Biosphere and Cryoshpere. An overview of ongoing monitoring activities and research projects is given in this presentation.

Monitoring activities and research projects

The environmental monitoring and related research projects grew significantly since the late 1990s and show the internationally outstanding position of Sonnblick in the fields of climatology, atmospheric research and glaciology, which is reflected in the increasing number of publications:

The long climate time-series from 1886 until now allow the investigation of climate change in the Alpine region from the pre-industrial level to the period of significant anthropogenic impact. The position of the atmospheric monitoring platform at 3100m at the summit of Sonnblick is unaffected by any local pollution sources around.

Highly interlinked monitoring and research programmes investigating the atmosphere, the hydrosphere, the lithosphere and the biosphere, take advantage of the easy access to all environments – thus enabling to study not only temporal trends but also exchange and cycling processes in the environment. Onsite technical staff enables permanently supervised measurements or sampling campaigns.

ENVISON covers three main research fields:

Climate change including its natural and anthropogenic driving forces and of climate impact on various spheres of the nature in the Alps as the region with most significant changes observed based on the advantage of using long term data series

Anthropogenic impact on concentration levels of trace species (gases, aerosols) as well as on processes and biogeochemical cycles in the background environment (with special focus on the atmosphere, the cryosphere and the biosphere)

Outstanding events (e.g. dust falls, volcanic activity, long range transport, active layer thickness, extreme glacier melt) and understanding of their impact on the environment

The Sonnblick Observatory is participating in involved in various international programs and networks:

WMO-GAW (Global Atmosphere Watch http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html)

GAW-DACH (GAW-cooperation Germany, Austria, Switzerland)

NDACC (Network for the Detection of Atmospheric Climate Change http://www.ndsc.ncep.noaa.gov)

WGMS (World Glacier Monitoring Service http://www.wgms.ch)

GTN-P (Global Terrestrial Network for Permafrost http://www.gtnp.org)

Copernicus (Monitoring atmospheric composition and climate http://www.gmes-atmosphere.eu)

BSRN (Baseline Surface Radiation Network http://www.gewex.org/bsrn.html)

WMO GCW (Global Cryospheric Watch http://www.globalcryospherewatch.org)

LTER (European Long-Term Ecosystem Research Network http://www.lter-europe.net)

INTERACT (International Network for Terrestrial Research and Monitoring in the Arctic and adjacent forests and alpine regions http://www.eu-interact.org)

MONET (Monitoring Network of persistent organic compounds http://www.recetox.muni.cz)

The Sonnblick Observatory holds strategic partnerships to MRI (Mountain Research Initiative), VAO (Virtuelles Alpenobservatorium) and Nationalpark Hohe Tauern.

Acknowledgements

ENVISON-2 is not a funding program by itself. It is based on a synergy of running and already funded monitoring programs and research projects as well as, considering future activities and research foci of Austrian funding agencies. The authors acknowledge the contributions of all members of the Sonnblick Advisory Councel and the substantial support of the Sonnblick Association.

The majority of measurements of the ENVISON monitoring are funded by the national GAW-DACH MoU, which is funded by the BMLFUW, the BMWFW, the province of Salzburg, the province of Carinthia and the Austrian Environmental Agency. The cryospheric monitoring is performed with funding from BMLFUW including the projects GCW-G and PERSON-GCW. The operation of Sonnblick Observatory is a sovereign function of ZAMG. A PhD project within the framework of the FWF DK GIScience (University Salzburg) is carried out during ENIVISON-2. The

Austrian Academy of Sciences (ÖAW) is supporting ENVISON for permafrost monitoring.
References
Sonnblick Beirat, 2016: ENVIronmental Research and Monitoring SONnblick -Program 2016-2020, Zentralanstalt für Meteorologie und Geodynamik (ZAMG) , Vienna, August 2016, pp 17.

P-06.09

CLIM'PY: Characterization of the evolution of climate and provision of information for adaptation in the Pyrenees

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The cross-frontier CLIM´PY project aims to investigate the Pyrenees's climate evolution under the context of global change. The main objective is to analyse present and future trends in temperature, precipitation and snow cover in the Pyrenees. This goal will be achieved by considering different priority actions: i) the database generation of daily quality-controlled and homogenized series; ii) developing climate indices for present and future evaluation of climate extremes in this area; iii) performing a detailed analysis of the snow cover distribution (i.e., spatio-temporal variability, trends, and local differences), using satellite imagery and in-situ measurements, and complemented with a snowpack modeling. Finally, iv) we will apply downscaling methodologies for the computation of regionalised climate change projections, using models (EUROCORDEX, CMIP5 and HARMONIE) and empirical algorithms, under different future climate change scenarios over the Pyrenees, which will be crucial to explore future temperature, precipitation and snowpack trends.
CLIM´PY (EFA 081/15) is funded by the European Regional Development Fund (FEDER) through the Interreg Program V-A Spain-France-Andorra (POCTEFA 2014-2020). It gives continuity to the climate action of the OPCC-EFA235/11 project, and relies on the cooperation established between the main research centers on both sides of the Pyrenees. At the same time, it fits the need to offer a long-term, updatable initiative that will enable the possibility to perform a valuable assessment of future climate projections. The results will contribute to the development of the strategy and plan of the Pyrenees Climate Change Observatory (OPCC). In addition, they will provide knowledge that allows to evaluate the impacts on water resources, ecosystems, biodiversity, tourism, energy, among others, and implement both regional policies and adaptation strategies to climate change.

P-06.10

BOU: a low-cost tethered balloon sensing system for monitoring the lower atmospheric boundary-layer

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The study of nocturnal thermal inversions and thermally-driven flows often requires the observation of vertical profiles of the main meteorological variables for the first 500 m. Typically, these needs are covered with the use of captive balloons but the commercial version of such instrumental platforms are scarce and expensive. Recent advancements in electronics allow for low-cost alternatives like the device that we present in this communication: BOU (tethered **B**alloon sonde **O**WL-**U**IB).
This system has been developed in the last years in a joined effort between the Universities of Applied Sciences of Ostwestfalen-Lippe (OWL) and of Balearic Islands (UIB). It has been configured to sample temperature, humidity, air pressure and wind speed at 1 second, although the system is easily reconfigurable, and more sensors can be added. The sonde is able to operate up to 1000 m and a polymer battery allow the device to work autonomously for more than 6 hours. This device has been successfully used in different campaigns, showing its potential for monitoring the lower atmospheric boundary layer (ABL) over complex terrain. In this poster, we will present details on the sensor package, data acquisition system and hardware aspects, as well as some data comparison against other devices like an unmanned aerial vehicle and a remote sensing device.

P-06.11

Identification of the annual 0°C and -1°C isotherms current elevation and recent altimetric trends in the

Italian Eastern Alps

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IN THE LAST CENTURY, the temperatures recorded in the alpine domain increased on average twice that measured for the northern hemisphere and is estimated at about 2 °C. This signal is almost homogeneous throughout the Alpine region and has been particularly marked since 1980, with average annual rates of about 0.35 °C per decade. Evident effects are found in the very quick melting of glaciers, in temporal and spatial uneven snowmaking, in the modified thermodynamic genesis of precipitation and in an evident change in meteoric regimes, with consistent impacts and growing uncertainties on sustainable development of mountain areas. At high altitudes, the Italian alpine sectors have been particularly affected by global warming, to such an extent that the percentage of glacier retreat has increased to 89% and most of the glaciers of the Southern Alps will likely disappear during this century. Based on these evidences, this study aims to provide a quantification of the increase in temperature in the Tridentine Alps - which include the data of Trentino - Alto Adige, Veneto and Friuli. Thanks to the remarkable improvement of meteo-climatic monitoring at medium to high elevation , which occurred since the beginning of this century, it was possible to make a preliminary study of the thermal climate from January 2003 to December 2015 and to determine the variation of the elevation of the 0 ° C and -1 ° C. annual isotherms. Fifteen groups, consisting of 3 to 6 meteo climatic station, and located in the valley bottom, slope and peak,respectively, were thus identified so as to calculate the number of frost and ice days, the average vertical thermal gradients and extrapolate the elevation of the already mentioned temperature thresholds. The altitude of the stations considered varies between 640 and 3015 m asl for an average of 1556 m asl; the average annual temperature is 5.3°C, the minimum 0.9°C and the maximum 9.7°C. For the period of study, the increase is 0.22°C. The mean temperature gradient is about 0:46°C/100 m, while the number of days of frost and ice is 153 and 46, respectively. Finally, the average elevation of annual isotherms 0 ° C and -1 ° C are 2660 and 2867 m. The trends show a strong increase of the elevation, estimated at 41 and 44 myr^{-1}, respectively and often up to about 90 myr^{-1} in Venetian Dolomites. A slight opposite trend is observed in the high Fassa valley (north - eastern Trentino). Evidently, to confirm these preliminary results, would be advisable to extend this simple methodology to other sectors of the mountain chain, to understand even if it is a signal at the regional scale rather than whole Alpine domain.

P-06.12

Glacial morpho-climatic system analysis of the swedish lapland using remote sensing technology

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Average annual temperatures have risen globally over the past century, with the most rapid changes occurring at high elevations and latitudes. Glaciers are particularly sensitive to current climate change, resulting in glacial retreat. Swedish glaciers are mainly located in the Swedish Lapland, a sparsely populated area, which has not been thoroughly studied. Storglaciären, Mårmaglaciären, Riukojieknaglaciären, Tarfalaglaciären and Rabotglaciären are located in the Sarek and Kebnekaise areas, two mountain chains on the border with Norway and ~100 km north of the Arctic Circle.
The aim of this study includes the morpho-climatic analysis of the Swedish Lapland through the examination of 5 glaciers over the 1984-2010 period, and statistical analysis of the correlation between glacial area extent and their mass balance.
Remote Sensing Technology and GIS platform (ArcGIS and ENVI) were used for this study; Supervisor Classification was essential to distinguish the glacial surfaces and thereby calculate their areas.
We found that each glacier shows areal and volumetric regression, relative to the 1984-2010 period. This is mainly due to the significant increase in annual average temperatures recorded at the three analysed weather stations (≈+1.2°C).
The average loss of these glaciated areas is around 20%, with much higher values for the Tarfalaglaciären (~50%), which is the only continental and slope glacier type with purely Scandinavian characteristics. The absence of peaks surrounding the glacier determines the total exposure of its surface to solar radiation, and the lack of avalanche injections contributes to the definition of this substantial retreat. Surprisingly, most of the glaciers studied here have morphological characteristics of valley glaciers, and are thus similar to Alpine glaciers rather than Scandinavian and/or circus types. The other Scandinavian type glacier, the Riukojieknaglaciären, does not exhibit the same significant, negative trend of the Tarfalaglaciären but rather exhibits a more modest, negative trend similar to the other Alpine-type glaciers. This is likely due to higher snowfall, attributed to the Atlantic moisture from the west. We find a strong relationship between the glacial area and the mass balance trend, demonstrated by both high correlation and determination coefficients, which are close to 1. The areal trend of the glaciers examined here shows

increasing areal extent until the end of the 1990s and rapid decline over the last 10-15 years. Further aerial analyses of six glaciers, of which we do not have mass balance data, fully confirm the aforementioned trends. It is important to emphasize that the strong relationship between glacial area and mass balance refers only to the last 30 years, in the presence of strong global warming.

P-06.13

Orography as a source of predictability of deep convection

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Predictability of convective weather depends on the interaction between synoptic forcing and local-scale flow characteristics influenced by surface inhomogeneities like orography. In this study the role of orography as a source of predictability is investigated using the idealized convective-scale ensemble data assimilation and forecasting system COSMO-KENDA. This integrated system offers the possibilty to introduce physical consistent uncertainties at different scales. The impact of small scale errors provided by assimilating radar data taken from a nature run on the intensity and position of deep convection during airmass convection is compared to a free forecast ensemble as reference, both with and without orography. First results suggest that the orography increases the predictability of precipitation in the free forecasts, whereas the efficient, ensemble based data assimilation of radar reflectivites and wind exerts a very strong constraint on the position of deep convection surmounting the influence of orography.

P-06.14

Strong Relationship Between Dry-Season Rainfall Over West Africa And Extratropical Disturbance.

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The recent concerns for food security over Africa related to several climatic factors, such as the strength of the flood and drought within the growing and harvesting seasons and the long-term rainfall variability have motivated the study of identifying the extratropical causes of “anomalous” dry-season precipitation for the region. The paper examines the role of upper level disturbance in the unusual rainfall over the tropical region of West Africa in the dry-season for the month of December, 2014. The rainfall is examined using the global precipitation climatology project (GPCP) merged satellite-gauge daily precipitation estimate and station rain-gauge measurements obtained from Nigeria Meteorological Agency. While the atmospheric circulation features are determined by using the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP-NCAR) reanalysis dataset. Composites of NCEP/NCAR Reanalysis wind fields, pressure, temperature, humidity and moisture fluxes suggest that rainfall event that affected few countries (Nigeria, Ghana & Cote d’Ivoire) during the period is linked with an enhanced on-shore westerly low-level flow from the Gulf of Guinea into inland, northward displacement of Inter-Tropical Discontinuity (ITD), intensification of the weak dry-season Sahara heat-low and upper-cyclonic vortex which help the generating of convection over the region. The influence of synoptic systems was also evident in the rainfall analysis for December, 2014. During the periods of study, the observed low-level flow over West Africa is likely to be an important contributor to the observed dry-season heavy rainfall, regulated by extra-tropical synoptic scale disturbances. The results provide an important basis for further studies on several cases over the past decade years producing heavy rainfall exceeding some kind of climatological, statistically-based threshold.

P-07.01

Winter and high-altitude dust size distributions with the balloon-borne Light Optical Aerosol Counter (LOAC)

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Iceland has the largest area of volcaniclastic sandy desert on Earth where dust is originating from volcanic, but also glaciogenic sediments. Total Icelandic desert areas cover 44,000 km^2 which makes Iceland the largest Arctic as well as European desert. The mean frequency of days with dust suspension was to 135 dust days annually in 1949-2011. The annual dust deposition was calculated as 31 - 40.1 million tons yr^{-1} affecting the area of > 500,000 km^2. About 50% of the suspended PM10 are submicron particles. Icelandic dust is of volcanic origin; it is very dark in colour and contains sharp-tipped shards with bubbles. Such properties allow even large particles to be easily transported long distances as revealed on the satellite MODIS images with dust plumes traveling over 1000 km at times. There is a need to understand better the vertical distribution of such aerosols as well as their residence time in the atmosphere, especially during occasions such as polar vortex.
Four LOAC flights were performed under meteorological balloons during the Iceland Polar Vortex 2016 campaign in January 9-13 2016 when stratospheric polar vortex occurred above Iceland. LOAC is an optical aerosol counter that uses a new optical design to retrieve the size concentrations in 19 size classes between 0.2 and 100 µm, and to provide an estimate of the main nature of aerosols. Vertical profile of aerosol size distribution showed the presence of volcanic dust particles up to altitudes of 8 km for two of the flights (9-10 January). The MODIS satellite images confirmed a dust plume present above the southern coast from the deposits of September 2015 glacial outburst flood (jökulhlaup) while the rest of the country was covered by snow. These deposits had been actively suspended in November and December 2015. The ground PM10 mass concentration measurements in Reykjavik showed elevated PM measurements over 100 µg m^{-3}, confirming the particle presence 250 km far from the source.
The number concentration exceeded 200 particles cm-3 at altitude of 1 km and 60 particles cm-3 at altitude of 5 km, which is at least 5 times higher than during background conditions. The particles were <3 µm in size at >1 km altitude while largest particles, up to 20 mm, were detected close to the ground. Such high number concentrations in several km height were captured by LOAC only during Saharan dust plume with larger particles (around 5 µm). Our results show that fine volcanic glacially reworked dust can reach high altitudes relatively close to the dust source and reside in terms of days under the stratospheric polar vortex conditions. The remaining question is the further transport of these high altitude particles outside Iceland.

P-07.02

GWOP'17: Gravity Waves, Orographic Precipitation and related processes in The Cerdanya-2017 field experiment

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The Pyrenees massif plays an important role in the atmospheric circulation usually triggering extreme meteorological phenomena. In the framework of the cross-frontier subproject GWOP'17 a field campaign has been devoted to Gravity Waves and Orographic Precipitation from December 2016 to April 2017. The 5 month field campaign took place over the Cerdanya Valley (Eastern Pyrenees) and was complemented with an intensive observation period from 10 January to 3 February 2017. The ground-based and remote sensing observing strategy was devised to characterize the gravity waves and associated phenomena as well as the description of the processes leading to orographically induced precipitation effects, including both enhancement and rain-shadow effects.
The main goals of GWOP'17 are to improve the knowledge of: 1) lee mountain waves and associated processes as rotors and subrotors and boundary layer separation, 2) the dynamics and microphysics of the precipitation processes influenced by orographic effects, with emphasis on heavy precipitation events, and 3) the interaction of gravity waves with cloud structures and its influence on precipitation processes in the Pyrenees.
An overview of the field campaign and a database of the selected case studies for process understanding and fine scale numerical modeling are presented in this work. Examples of observations recorded during selected events will be included, covering wind-profiler, microwave-radiometer, micro-rain radar and disdrometer datasets and preliminary results comparing field-campaign behavior with previous climatological observations.

P-07.03

How do orographic and non-orographic gravity wave events during DEEPWAVE compare in measurements and ECMWF model data?

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The DEEP propagating gravity WAVE experiment (DEEPWAVE) took place in and around New Zealand during austral winter 2014. The design of the campaign allowed to measure gravity waves (GW) excited from various sources, and their propagation through the atmosphere up to their dissipation. Extensive surveys were conducted over land and sea. Within 26 missions, the NSF/NCAR Gulfstream V (GV) aircraft performed 2/5 of all flight legs over the Southern Alps of New Zealand and 3/5 over the Tasman Sea and the Southern Ocean. This allows to study both orographically induced and non-orographic gravity waves.
During the DEEPWAVE intensive observing period (IOP) 9, the main focus was on the observation of orographically induced GW over the Southern Alps. Cross-mountain legs were flown within four subsequent research flights by the GV and the DLR Falcon aircraft covering 2 days. During IOP 16, the GV research flight (RF) 25 was performed over the Southern Ocean. This flight was dedicated to the observation of GW without any orographic source. These GW are expected to be either related to a tropopause jet or to the stratospheric polar night jet.
Those two wave events are juxtaposed by means of available measurements (e.g. aircraft insitu, lidar, airglow imager, radiosondes, dropsondes) and the derived wave properties. GW scales and amplitudes, as well as their altitude range of occurrence and their temporal evolution are examined. Those are then compared to their representation in ECMWF IFS operational analyses and forecasts and further analysed using normal modes analysis. This allows to assess the differences between orographic and non-orographic wave representation in ECMWF and their conformity with the observations.

P-07.04

Mountain wave momentum fluxes in evolving large scale flows and complex terrain: perspectives from DEEPWAVE

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While steady-state mountain waves have been studied in detail, non-steady-state mountain waves have not received as much attention due to the increased complexity inherent in their analysis. However, since non-steady-state gravity waves are also observed and are not commonly represented in current parameterizations, more study is necessary.
The DEEP Propagating Gravity WAVE Experiment (DEEPWAVE) was conducted over New Zealand in the austral winter of 2014. Case days with strong wave activity identified from the DEEPWAVE datasets were simulated with high-resolution Weather Research and Forecasting (WRF) model runs with 2 km grid spacing over New Zealand. Diagnostics derived from these simulations as well as observed data from the campaign were used to analyze these cases.
The presence of strongly accelerating mean flows in the DEEPWAVE dataset provide an opportunity to analyze the impacts of non-steady-state waves. Preliminary analyses demonstrate significant temporal variations in the fluxes. In addition, while momentum fluxes integrated only in one dimension (across the mountain) exhibit significant short-wavelength variations in both the horizontal and the vertical, momentum fluxes horizontally averaged over two dimensions in relatively long and narrow bands demonstrate more expected behavior, and are relatively constant with height. These results appear to indicate an influence from the topography normal to the cross-mountain flow, which, while often homogenous in idealized studies, is an important aspect of realistic topographies.

P-07.05

Turbulence characteristics and scaling of katabatic flows on a shallow slope

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On nights with weak synoptic forcing and clear or partly cloudy skies a deep katabatic flow develops on an extensive

tilted 1° mesoscale plain outside Arizona's Meteor Crater. In its fully developed stage, near surface temperature deficit of 8-10 °C causes katabatic flow with a jet maximum height on the plain that ranges typically between 20-50 m AGL and jet maximum speeds exceeding 5 m/s. This katabatic flow was sampled on multiple nights using a variety of research instrumentation including a 50-m-tall, heavily instrumented turbulence tower as part of the Second Meteor Crater Experiment (METCRAX II) in October 2013. The tower was instrumented at 10 levels using 3-D sonic anemometers and aspirated temperature and humidity probes.
Here we examine the turbulence characteristics of these deep katabatic flows focusing in particular on the structure below the jet maximum. We examine the factors that cause the variability in the mean and turbulence structure on different nights as well as within the same night. Of these, Richardson number is shown to play a dominant role in determining the turbulence structure of the flow. In addition, we develop scaling based on the dominant length scale of turbulent eddies. The analyses are compared to work by previous investigators on shallower katabatic flows.

P-07.06

Building 'extreme' bridges in complex terrain - Observing and simulating the atmospheric conditions in Sulafjorden for the E39 project of the Norwegian Public Roads Administration

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In 2014, the Norwegian Public Roads Administration (NPRA) started an evaluation of the environmental conditions i.e. wind, atmospheric turbulence, waves and currents, pertaining to the construction of a 'ferry-free' road connection between Kristiansand and Trondheim on the western coast of Norway. The Norwegian west coast is famous for its fjords, and the project includes crossing of 8 of the largest, with fjord widths between 2 and 7.5 km, depths up to 1300 m and typically surrounded by very steep mountains of up to 1200 m. This requires a detailed description of the wind, wave and ocean current climate at the proposed bridge locations, which will then be used as input to the design of the fjord crossings.
The project started with a downscaling of the state of atmosphere to a resolution of 500 m x 500 m for the last ten years at planned crossings. The simulations are done with the WRF-model forced by the global Interim analysis of the ECMWF and are continuously updated when new global analysis become available. The downscaled data is used in forcing high-resolution wave and ocean current models. At a later stage, the simulated atmospheric data will be corroborated by additional simulated data produced by a CFD-model run by the Norwegian Meteorological Institute. A measurement program started in 2014 in the fjords of Mid-Norway and a considerable increase in measurement effort was initiated in October 2016. The measurement program includes numerous tall meteorological masts equipped with sonic anemometers observing at 10 Hz at several elevations. The most recent masts are 100 m high while the initial masts have an elevation of 50 m. A number of wave buoys with 4 m masts for meteorological measurements are being installed and a campaign including concurrent observations from several scanning LIDARs will commence in the summer of 2017. All observational data will be put in the open domain.
The current analysis includes extreme wind maps for the fjord crossings, analysis of atmospheric turbulence and coherent structures in the flow. The observational data describes in detail the flow structure during numerous storm events in complex terrain. For example, the most recent measurements reveal vertical wind speeds (3 second average) in excess of +10 m/s, and -22 m/s as an extreme value, immediately downstream of a 500 m high mountain at the site of a proposed fjord crossing. The strong vertical winds occur in a rather wide wind sector (180 - 270°, background wind aloft), and a change on the order of 15° in background wind direction leads to horizontal wind shift of 100° at lower levels. In light of the importance for the design of the fjord crossings, atmospheric structures and variability such as this must be mapped in detail, in particular their horizontal and vertical extent across the fjord.

P-07.07

Sensitivity of orographic precipitation to aerosols, a HyMeX case study.

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During Fall 2012, the HyMeX experiment which took place in the South of France, collected a lot of microphysics and precipitation data over medium orography, here the Cevennes ridge of Massif-Central, facing warm and humid southeasterly flows from the Mediterranean (Gulf of Lion). The Cloud-Resolving Mesoscale model MesoNH was then used to simulate in detail many precipitating events. For that purpose, the 2-moment microphysics scheme LIMA of MesoNH was initialized with 3D aerosol analyses taken from the MACC-II database at ECMWF. The poster presents briefly the LIMA scheme and the way Cloud Condensation Nuclei (CCN) and Ice Forming Nuclei (IFN) are

initialized. The case of several experiments is described for short but intense HyMeX events. Then interestingly, doubling and halving the aerosol concentrations, is leading to a visible displacement of the precipitation field with respect to the orientation of the low level flow to the orography. The significance of these results is commented and the role of the aerosol load is emphasized for high resolution rainfalls over orography.

P-07.08

Orographic influence of Greenland on two cyclones

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The orographic infuence will be described.

P-07.09

From where came the ideas of thermally driven coastal flows to Snorri Sturluson?

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Thermally driven coastal flows are described in Egil´s Saga, written by Snorri Sturluson around 1220. The description does not fit reality in the sense that there are no significant katabatic winds in Bergen in the evenings following days with sea-breeze, according to observations from the Bergen School of Meteorology network. This suggest that Snorri may have based his story on theories in meteorology, but from where are these theories?

P-07.10

The Bergen School of Meteorology mesonet

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For several years, about 40 automatic weather stations have been operating in the complex terrain of Bergen, W-Norway. The network has helped describe a multitude of details in the weather and climate of the Bergen area, and it is useful for validation of high-resolution numerical models.
The data is now available on bergensveret.no

P-07.11

Resuspension of Volcanic Ash from the Vatnajökull Ice Cap

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A windstorm on 13 September 2011 led to an exceptional event of resuspension of ash from the Vatnajökull glacier and unique visualization of downslope flow with a hydraulic jump. The windstorm ejected some 65.000 tonnes of dust into the atmosphere of which most was advected over the sea. The flow has been simulated at high resolutions with the WRF model

P-07.12

Persistence of Monthly Mean 2-Meter-Temperatures for Central Europe

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An analysis has been made of persistence of monthly mean 2-meter-temperatures based on the reanalysis data CERA-20C from 1901 to 2010 with a resolution of one degree. There is significant correlation sign from the Alps in the data. In the February/March correlations, there are relatively high values to the north and to the south of the Alps, but lower values in the mountains themselves. In April/May, there is an inverse situation: there are high correlations in the mountains, but lower away from the mountains.
A plausible explanation for the Alpine signal in the reanalysis is the persistence of snow cover which can be expected to act as a „memory“ for the earth-atmosphere system. In the early spring, there is greater interannual variability in the snow cover at low elevations than at high elevations, and this is reflected in relatively high temperature correlation at low elevations. In late spring, the situation is the opposite; there is greater interannual variability in the snow cover and higher correlation at high elevations.

P-07.13

Persistence of 2-Meter-Temperatures in Iceland

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Observations of 2-meter-temperatures from 38 weather stations in Iceland are explored. Only time series with at least 50 years are used. In the spring and summer, there is hardly any correlation in the Northeast (to the north of the mountain plateau), while in the Southwest (to the south of the central mountain plateau), there is high correlation in the middle of the summer. This pattern is not reflected in reanalysis data.

The almost complete lack of correlation to the north of the mountains calls for an explanation and we look for a negative feedback in the circulation. In the summer, northerly winds are in general cold in the north. Observations at Akureyri in NE-Iceland show that the temperature in May is positively correlated with the frequency of northerly winds in June. That correlation may be explained by warm weather melting the snow in the mountains relatively early, favouring the formation of a heat low and the penetration of the cold sea breeze in the lowlands. To the south of the mountains, this effect is not present. Firstly, there is much less snow than in the north and secondly the difference between the temperature in northerly and southerly winds is much less in the south than in the

P-07.14

Forecasting rapid changes in wind speed

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Rapid changes in wind speed are of particular interest from a forecasting perspective, as such events involve relatively high risk for various activities. During the period November 2015 to May 2017, all cases of increase in wind speed of more than 12 m/s in 1h at two weather stations are analyzed and the performance of the NWP model Harmonie (BC: ECMWF) is assessed. There are 2 cases at the coastal station Keflavíkurflugvöllur and 11 cases at the inland station Hveravellir. In the two coastal cases, the model fails to reproduce the exact wind change. In one of these cases, there is a shift of 1 hour in the timing of the windstorm, while in the other case, a 50 km shift in the storm track caused a failure in the forecasts. At the inland station, the model failed to reproduce all 11 cases of rapid changes in wind speed. All of these 11 cases show great orographically generated non-stationary horizontal variability in wind speed. Even though point validation of the model may give relatively large errors, the simulations do in all cases contain information that is very useful from a forecasting perspective.

P-07.15

Forecasting rapid changes in wind speed

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Time series of a large number of automatic weather stations in Iceland were studied in order to investigate rapid changes of wind speed. In this investigation, the threshold for a rapid change of the wind speed was defined as an increase of at least 12 m/s in one hour and moderate to strong windstorms are defined as wind speed of at least 12 m/s. The rapid changes occur mostly in winds in the sector from SE to W and/or downstream of mountains. Rapid increase in wind speed is particularly frequent in N- and E-Iceland, where warm southerly winds may suddenly blow away cold pools on the downstream side of the mountains.

P-07.16

Winter and high-altitude dust size distributions with the balloon-borne Light Optical Aerosol Counter (LOAC)

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LOAC (Light Optical Aerosol Counter) flights were performed in Iceland in January 9-13 2016. Vertical profile of aerosol size distribution showed the presence of volcanic dust particles (confirmed by the LOAC typology) up to altitudes of 8 km for two of the flights (9-10 January). MODIS satellite images confirmed a dust plume present above the southern coast from the deposits of September 2015 glacial outburst flood (jökulhlaup) while the rest of the country was covered by snow. These deposits had been actively suspended in November and December 2015. The ground PM10 mass concentration measurements in Reykjavik showed elevated values over 100 mg/m3, confirming the particle presence 250 km far from the source.

P-07.17

Quantification of dust emissions from Iceland and oceanic deposition of iron rich volcanic materials

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The transport of dust from the Icelandic deserts is estimated from meteorological observations. Total dust emissions from Iceland are 30-40 million tons annually which places Iceland among the most active dust sources on Earth.
Dust deposition to oceans from Iceland is 5.5-13.8 million tons per year. This is the first quantitative estimate of total dust emissions and oceanic deposition from Iceland.
Iron deposition is 0.6-1.4 million tons Fe from fine, poorly crystalline (reactive) volcanic materials. Iron is a limiting nutrient for primary production in the oceans around Iceland and the dust is likely to affect Fe levels in Icelandic ocean waters.

P-07.18

An Orographic Flow Diagram

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Elevated temperature inversions are recognised to potentially have a significant impact on flow over and around mountains. In this study, we devise a new flow diagram for flow over mountains in the presence of such an inversion using a suite of numerical simulations. The simulations are carried out in 3D with the WRF model and open boundary conditions are applied. A neutral boundary layer is capped by a 10K inversion, of which the height varies. The mountain is 1 km high and the upstream wind speeds are 10, 15, 20, 25 or 30 m/s. The surface has a roughness length (Z_0) of 0.01m. Vortices, vortex shedding, lee waves and hydraulic jump are detected and related to values of the height of the inversion and the shallow water Froude number. Cases of real flow are compared to the idealised results.