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17. Alpine Meteorology

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17. Alpine Meteorology

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Swiss Meteorological Society

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17.1

Hailstorm Studies in Switzerland Using a High Resolution NWP Model

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Three hailstorms which caused significant damage in Switzerland were simulated with the COSMO (Consortium for Small-scale Modeling) one-moment microphysical scheme as well as with the new COSMO two-moment microphysical scheme and qualitatively verified with real radar measurements of the operational Swiss radar network in order to investigate the model capability to realistically simulate convective storms. To this end, a new COSMO radar forward operator was implemented and applied within this study to compute synthetic radar volume data which are then directly compared with the radar derived reflectivities. This is the first time the COSMO two-moment scheme as well as the COSMO radar forward operator is used for COSMO-2 simulations over Switzerland.

Using the COSMO two-moment microphysical scheme in forecast mode, resulted in the almost complete absence of convective cells in the simulations. Using the same model in analysis mode and investigating the synthetic radar reflectivities, realistic structures were observed. The reasons why the COSMO two-moment scheme does not simulate any convection for all three cases are not understood. Investigations of the vertical structure showed the capability of the COSMO two-moment scheme to simulate hail in the strong updraft areas. High reflectivity cores (≥ 55 dBZ) are simulated similar to the radar data.

The COSMO one-moment microphysical scheme shows the capability to predict the three hailstorms with small deviations in terms of the location and time, but with too low intensity, lifetime and geographical extension. Applied radar-based hail detection algorithms highlight the capability of the COSMO one-moment scheme to forecast whether and where hail can occur within the next hours. The analyses of the COSMO one-moment scheme showed better results than the forecasts but not as good as the case of the COSMO two-moment scheme analysis.

The study also found that probably a wrong mass-size parameterization of the COSMO one-moment scheme results in an underestimation of the convective vertical extent in terms of synthetic reflectivity. In both schemes too high synthetic reflectivities were simulated close to the ground mostly due to high hydrometeor densities of rain.

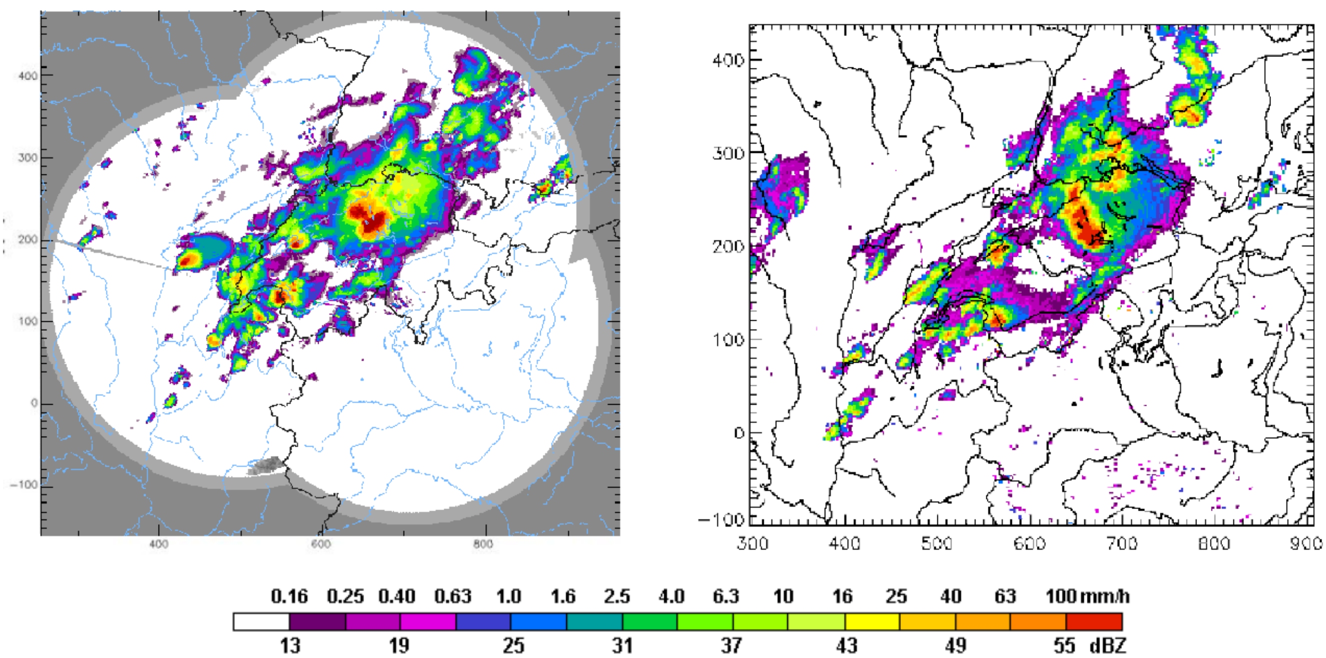

Figure 1: Left panel: maximum reflectivities [dBZ, mm/h] of the COSMO two-moment scheme analysis on July 23, 2009, at 14.45 UTC. Right panel: radar derived reflectivities [dBZ, mm/h] on July 23, 2009, at 14.45 UTC.

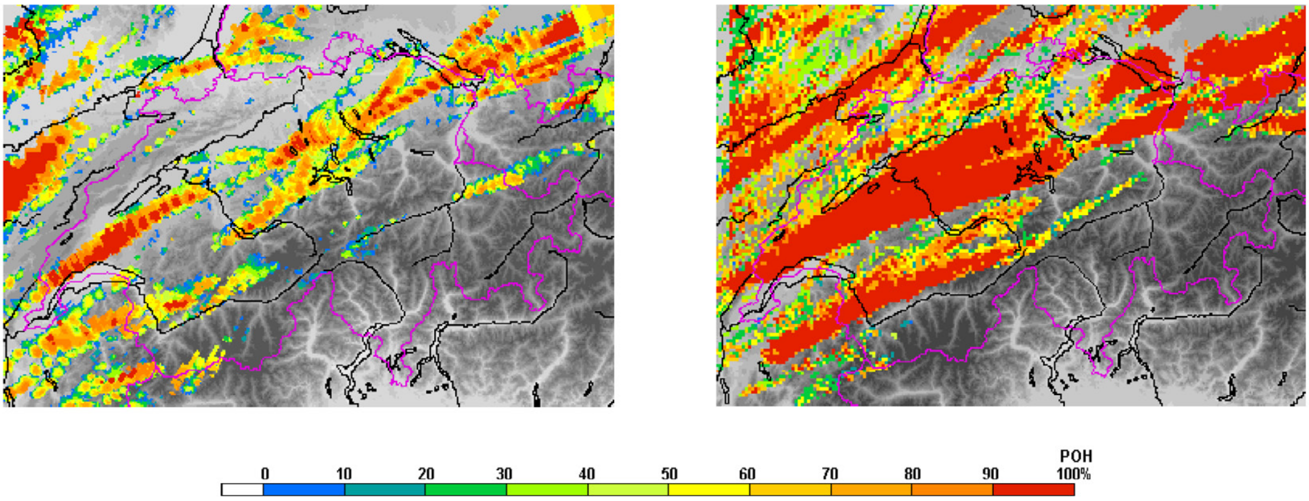

Figure 2: Left panel: Synthetic daily maximum POH (Probability of Hail) product [%] of July 23, 2009, of the COSMO one-moment scheme 12 UTC forecast. Right panel: Daily maximum POH product [%] of the radar on July 23, 2009.

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17.2

People love spring! Can Facebook and a diversity of responses to climate change make them love phenology networks?

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Signs of spring make people happy! Every year every newspaper, every radio and TV show and all the different social media channels are full of pictures and exclamations when spring signs show up. This creates an interesting opportunity for geographically dense as well as spread-out phenology data collection. We already know that many keep notes on spring signs and during the last two decades such notes have generated a long list of scientific publications. So, do we need more data?

I will present results from a collaborative project, where we have analyzed phenological time series for over 1600 species (Wolkowich et al. 2012; Cook et al. in press; Mazer in review; Davies et al. in prep.). The data was collected in tropical to alpine regions and we analyzed phylogenetic and geographic patterns as well as contrasted observational with experimental data. The geographic and phylogenetic studies suggest some potential for generalizations, thereby reducing the need for additional data collection. However, an important contrast between the observational and experimental studies, where experimental studies seems to have underestimated phenological sensitivity, highlights the importance of continued collection of observational data for validation purposes. In another study, where we analyzed a 73-year long dataset (Bolmgren et al. 2012), we show that good statistical estimates of phenological temperature sensitivity need to be based on fairly long temperature series, again supporting continued efforts for collecting phenology observation data.

Our research has originated from the idea that biological diversity will also lead to a diversity of responses to changing climatic conditions. This diversity of responses will have fundamental effects on many aspects of society in addition to effects on nature itself. It is easy to communicate to the public that increasing temperatures lead to phenological changes. Still, most people are surprised when they hear about the far-reaching effects of such simple changes, ranging from pollen-related health effects, effects on the biosphere/atmosphere gas exchange, economic effects for forestry due to changing growth conditions and frost risks and to effects on timing-dependent ecological interactions.

When building the Swedish National Phenology Network, we have used the public interest for nature's calendar. We use this obvious interest for symbolic seasonal signs and patterns when recruiting, and the easily understandable links between phenology and fundamental ecosystem services and processes to spur observers and increase motivation. We also highlight the lack of knowledge about the diversity of responses between phases and between seasons as an important reason for documenting phenological variation.

By using social media, we have reached far beyond the networks traditionally available via NGO:s, and I will present some of the web applications and social media strategies the network has been using. The obvious focus is to canalize anyone interested in nature's calendar to the web application (www.blommar.nu), where they can submit observations. We prioritized making it simple to submit an observation (also anonymously) as well as easy to visualize data from the database. This makes it easy to do campaigns and for journalists to access and understand the operation. The fact that the public can assist climate change research and environmental monitoring by straightforward observations of spring signs etcetera helps making the operation attractive for media both at the local and national level. We added a Facebook-group to create an interactive group for the 'community', and we just released a smartphone application, which we expect will make the operation more accessible and at the same time improve the accuracy of geographic positioning of the submitted reports.

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17.3

Altdorf foehn climatology: the long series (1864-2008) and comparison to further sites

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In Altdorf, in the Uri part of the Reuss Valley, foehn observations have been recorded from 1864 to 2008 at stations whose positions changed only marginally during this time. Hence, with 145 years, this is the longest time series of foehn events in the Alpine massif.

First, the method by which foehn was observed, the changes of the foehn definitions during the course of time, and the different locations of the station are presented. Based on the three main parameters temperature, humidity, and wind, the occurrence of foehn was originally determined subjectively at the so-called climate observation times in the morning, at noon, and in the evening. Today, in the time of automatic observation networks, special software allows the identification of foehn in 10-minute intervals.

The main part deals with the climatological aspects: Over the 145 years, there is no discernible significant trend in foehn occurrence. Foehn frequencies show a high variability both in time and location. In the long-term mean, there were 60 occurrences per year (minimum 1955 with 27, maximum 1872 with 114). The months March to May, in recent times April and May, show the highest numbers of foehn events during the year. During the summer months June to August, foehn is rare. The diurnal variations are extreme in the months April and May (minimum in the morning, maximum in late afternoon). As for wind speed, the gust maxima for each hour were analyzed: neither a long-term trend nor a clear inter-annual variation was found. The highest gust speed since 1955 was measured on December 13, 1981 with 157 km/h.

Finally, the occurrence of foehn in Altdorf is compared with different stations north of the Alps. During the period 1973 to 1982, 20 stations were investigated using a semi-quantitative method; Guttannen in the Haslital had 116 (maximum), Interlaken and Sarnen had each 3 (minimum) foehn events at the three climatological observation times, these numbers being the yearly means. During the 25-year period 1984 to 2008, the automated, quantitative method was applied to 15 stations. As yearly means, Davos had 86 (maximum) and Zurich had 2 (minimum) foehn occurrences.

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17.4

Interpolation of surface air temperature in mountainous terrain: A km-scale, daily dataset for Switzerland

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Surface air temperature is a key factor for many natural processes and there is a popular demand for spatially distributed datasets of temperature as input for models of environmental system components (e.g. in hydrology, glaciology, agronomy). Meteorological phenomena in mountainous terrain are often accompanied by strong horizontal variations and non-linear vertical temperature dependence, which poses a significant challenge to the construction of such datasets.

In this contribution a new technique is presented for the spatial interpolation of temperature in high-mountain regions. It's modelling design involves two steps: The first addresses the meso-beta scale vertical-only structure and builds on a non-linear parametric profile function, capable of describing inversions of variable height, depth and contrast. The second step addresses the smaller-scale structures and adopts a weighting scheme with non-Euclidean distances. To this end a novel distance metric is introduced, which can account for the topographic obstruction of air mass exchange in the interpolation (e.g. pooling of cold air in valleys). The interpolation scheme is systematically applied for the construction of a km-scale dataset of daily mean temperature for the period 1961-2010 over the territory of Switzerland.

Results of the interpolation technique are illustrated for a series of challenging meteorological conditions in Switzerland. They show empirically plausible temperature distributions, including the signatures of cold-pools at the floor of high-Alpine valleys, inversions over the Swiss Plateau and anomalous warmth in valleys during Föhn. The presentation will also discuss results of a systematic cross-validation and provide aids for the application of the dataset. The dataset is available from MeteoSwiss.

17.5

Atmospheric Precursors to Floods in Switzerland

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It is important to learn more about flood triggering weather patterns in Switzerland for two reasons: (i) projections of flood frequencies in a warmer climate are strongly limited by the ability of climate models to represent the complex small-scale processes associated with typical flood triggers like heavy precipitation and snow melt. Information about flood triggering weather situations can be used in a more indirect approach to estimate changes in future flood frequencies.

(ii) Flood frequencies in Switzerland show strong decadal variability suggesting that decadal variations in the synoptic atmospheric flow might influence flood probabilities (Schmocker-Fackel & Naef, 2010). However relations with temperature trends or typical climate indices are complex and ambiguous and Schmocker-Fackel & Naef expressed the need for a better understanding of the synoptic-scale atmospheric flood triggers.

We aim to determine typical atmospheric flood precursors for specific regions of Switzerland and specific types of floods by combining atmospheric reanalysis from the ECMWF with dense networks of rain gauges and river discharge measurements and existing hydrological classifications of annual maximum floods in Swiss rivers (see Diezig & Weingartner, 2007 and Helbling et al., 2006 for more information).

We performed a series of case study analyses which showed promising results. Four catchments have been selected, each representing a preferred hydrological flood type (e.g. shower, long lasting rain, rain on snow, pure melt) and for each catchment many of the annual maximum floods share a common weather triggering situation (see Fig. 1 for a typical example). This weather situation varies moreover remarkably between the different catchments.

In a second step, we will extend the investigation by comparing the flood relevant atmospheric parameters (rain and properties of atmospheric flow) with their climatological distribution. We also aim to determine objectively the best set of atmospheric flood precursors and end up with an ingredient-based flood forecasting model. To reach that goal we consider diverse approaches including weather types classifications, composites over several events and principal component analysis.

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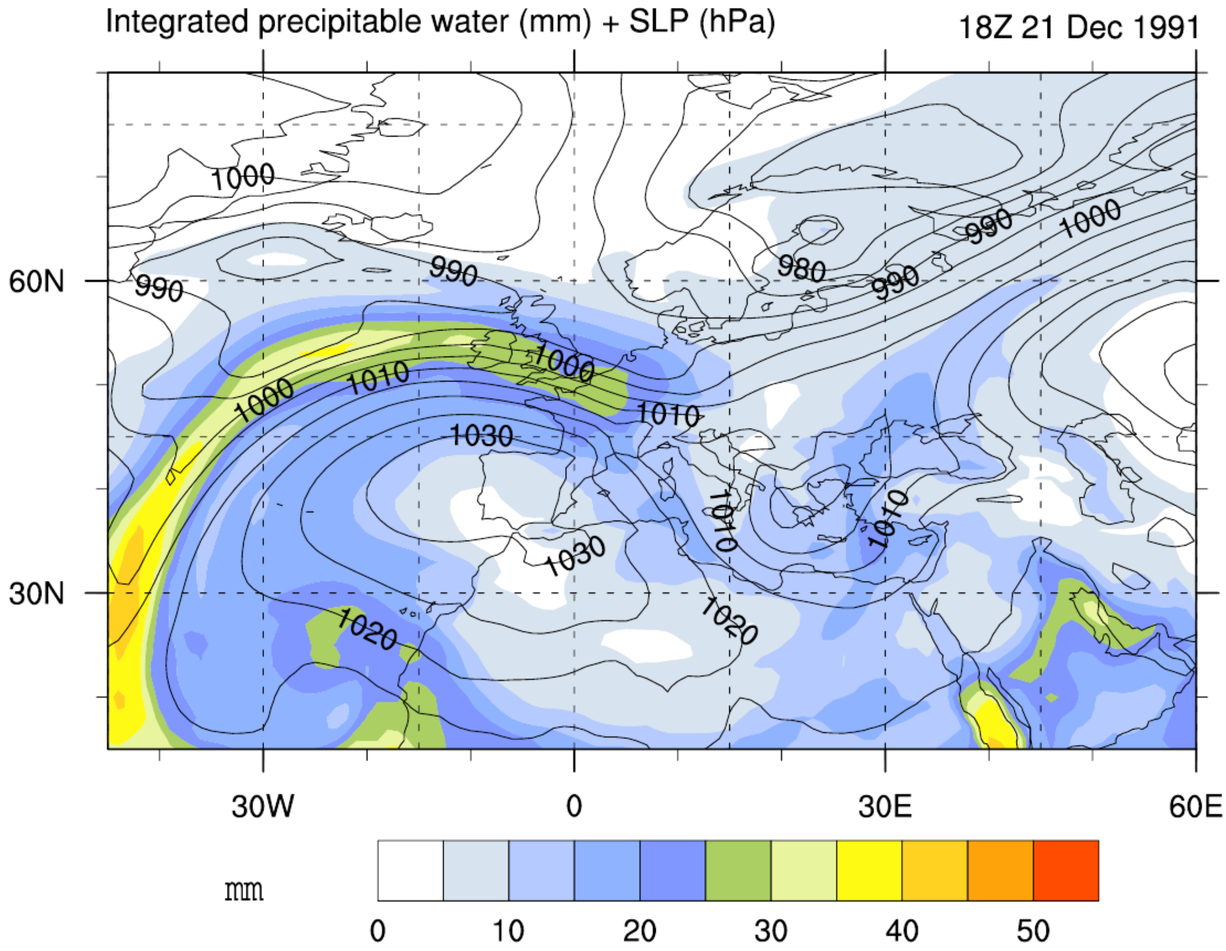

Figure 1. So-called atmospheric rivers are typical precursors to winter floods over the Jura mountains. We call “atmospheric rivers” thin bands of high precipitable water spreading from the tropics towards the extratropics. Here an atmospheric river (yellow-green band) makes landfall and brings very moist air to North-Western Europe, triggering (together with other factors) the highest recorded flood in the Suze river (Jura) in December 1991.

17.6

Precipitation measurements with the new fourth-generation Swiss weather radar network: strategy and first results

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Measuring precipitation at ground in an operational manner is one of the most demanding tasks of a weather radar network, especially in a mountainous region such as the European Alps. It puts high requirements on many aspects in the whole system design. This goes from optimum siting, rapid volumetric scanning, high hardware stability, automatic hardware monitoring and remote control, to meticulous quality control and physically-based radar-reflectivity-to-precipitation-at-ground transformation techniques. In the Alps particular attention must be given to visibility and ground clutter issues.

MeteoSwiss is presently renewing and extending its operational C-band weather radar network. The radar systems are replaced by state-of-the-art polarimetric Doppler radars with receiver-over-elevation design. Two new radar sites are built on mountain tops in order to improve radar coverage in the inner-alpine regions. The software architecture is completely renewed and the algorithms are re-written. This is a welcome opportunity to revisit the strategy for quantitative precipitation estimation (QPE) by combining experience from the past with recent findings from science and technology.

- The paper presents the adopted QPE strategy and first results from the new fourth Swiss radar generation. The major elements of the strategy are:
- a new scan program to obtain over the whole country as many high quality measurements close to the terrain as possible,
- an external transceiver system which is used as part of the acceptance test procedures to verify several system specifications including polarimetric parameters,
- a revised algorithm for the rejection of non-weather echoes and the combination and compositing of all remaining valid measurements in order to get robust estimates of precipitation at ground,
- a plan how to obtain quantitative precipitation measurements from the two new inner-alpine radar sites at 2900 meters above sea level,
- a (co-)kriging-with-external-drift technique developed for real-time radar-raingauge merging in the Alps, and finally,
- first thoughts about the benefits and limitations from polarimetry in a mountainous context.

17.7
Heavy precipitation events in northern Switzerland

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Heavy precipitation events in Switzerland often cause floods, rock-falls and mud slides with severe consequences to the population and the economy. Breaking synoptic Rossby waves located over western Europe, can trigger such heavy precipitation events in southern Switzerland (e.g. Massacand et al. 1998, Martius et al. 2006). In contrast, synoptic scale structures triggering heavy precipitation on the north side of the Swiss Alps and potential precursor Rossby wave trains have so far not been studied comprehensively.

An observation based high resolution precipitation data set for Switzerland and the Alps (Frei and Schär 1998) is used to identify heavy precipitation events affecting the north side of the Swiss Alps for the time period 1961-2010. For these events a detailed statistical and dynamical analysis of the upper level flow is conducted using ECMWFs ERA-40 (Upala et al. 2005) and ERA-Interim (Dee et al. 2011) reanalysis data sets. For the analysis north side of the Swiss Alps is divided in two investigation areas north-eastern and western Switzerland (Fig.1) following the Swiss climate change scenarios CH2011 (Bey et al. 2011). A first analysis of the basic properties of precipitation data set shows that the seasonal distribution of heavy and extreme precipitation events in western part of northern Switzerland differs from this of north-eastern part. The highest frequency of extreme events is found in autumn in western side and in summer in north-eastern side. There is no trend in the frequency of heavy precipitation events during the time period 1961-2010. In a next step a subjective classification of upper level atmospheric precursors triggering heavy precipitation events for the northern part of Switzerland and its sub-regions is held.

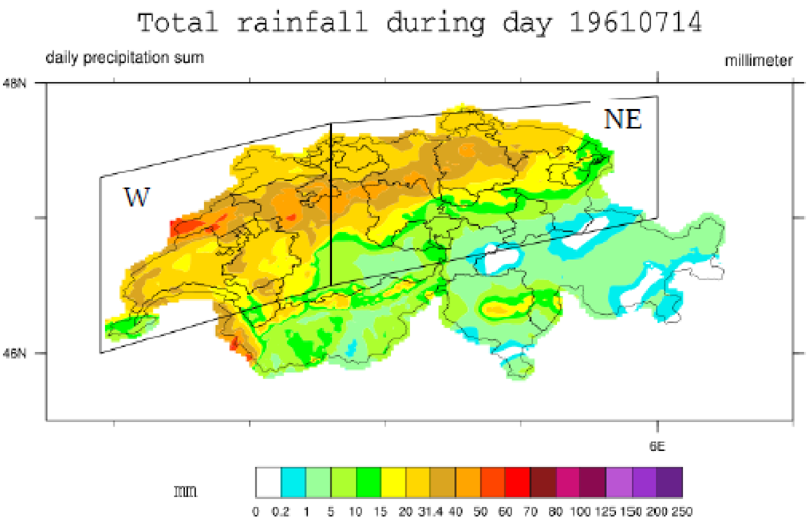

Figure 1. The two investigation areas: Western and North-Eastern Switzerland. Accumulated daily precipitation (mm) on 17/07/1961, a heavy precipitation event occurred in northern Switzerland.

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17.8

Mountain size and atmospheric Conditions' Impact on the diurnal Cycle of Clouds and Precipitation

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The influence of different topography sizes and wind profiles on the diurnal cycle of mid-latitude, summertime, moist convection is investigated in an idealized framework using cloud-resolving model with a horizontal grid spacing of 2 km. In this framework, the atmosphere is continuously relaxed towards prescribed reference profiles of temperature, specific humidity and wind speed. This relaxation mimics the influence of a steady large-scale flow. The strength of the relaxation varies with height. It is relatively strong in the stratosphere and upper troposphere (relaxation time is 2 days), but very weak in the lower troposphere. Apart from its influence on the mean environment, the relaxation has only a minimal influence on the diurnal evolution of the planetary boundary layer and moist convection. The simulations are run for 30 days. During the last 20 days a quasi-steady diurnal cycle is obtained, the diurnal equilibrium. Here, we investigate the influence of different topographies (mountain height and half-width) and wind profiles on the diurnal equilibrium evolution of clouds, precipitation and the associated net vertical fluxes of energy and water. As expected, in comparison to the simulation of flat terrain clouds and precipitation occur earlier over topography and total precipitation amounts are substantially increased. A particular focus will be on the analysis of the mountain effects as a function of the distance from the mountain (e.g. near-field and far-field effects).

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17.9

Precipitation in the Alpine region as seen from a trans-national multi-decadal rain-gauge dataset

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The analysis and monitoring of precipitation is fundamental for meteorology and climatology, and for applications such as hydrology, energy and agriculture. It is a challenge to obtain precipitation fields of high-resolution in space, in particular in mountainous regions such as the Alps.
The utility of currently available climate datasets in Europe is further complicated either by the constraint of regional data products to national territories, or by restrictions in the station data available to continental scale data products. These limitations are particularly relevant in the Alpine region, because of the complex and non-congruent geo-political and climatological segmentation.

In this presentation we report on the development towards a gridded trans-Alpine dataset of daily precipitation that covers the entire Alpine area and utilizes data from high-resolution national rain-gauge networks. The station dataset encompasses more than 6000 stations from Austria, Croatia, France, Germany, Italy, Slovenia and Switzerland. In this recent effort the data coverage could be significantly enhanced in space and time compared to the dataset presented in Frei & Schär (1998). Regions and periods with previously inferior coverage could be improved. The data set now covers the entire period 1971-2008. The processing chain from data collection and data organization and the chosen approaches for quality control will be presented.

This unique data set will then be employed for a climatological analysis of selected heavy precipitation events and extreme precipitation indices such as the frequency of intense precipitation days and long consecutive dry periods. The analysis offers interesting insights into regional peculiarities, topographic effects and the annual cycle of the Alpine climate of precipitation with unprecedented detail and spatial coverage.

It is foreseen to generate a new gridded data set of daily precipitation on a 5-km grid. By the time of the conference, a preliminary version of the complete daily grid dataset is expected to be ready for first evaluations. This work has been undertaken in the framework of the EU FP7 project EURO4M.

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17.10

Temperature and Humidity trends over the Swiss Alps and the troposphere above - from 1959 to 2011

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Recently reevaluated Payerne radiosonde measurements and homogenized series from Alpine surface stations allow investigations of temperature and humidity trends in the Swiss Alps and the troposphere above. The new radiosonde dataset is the result of a technical reprocessing on the basis of detailed station documentation, complemented by statistical homogenization using a break analysis as a diagnostic tool. The comparison between surface stations at different altitudes, particularly Säntis and Jungfraujoch, and radiosonde measurements at corresponding altitude levels provides interesting results with respect to temperature and humidity changes. The two independent data sources show very consistent temperature evolution and almost identical positive trends. Radiosonde measurements extend the temperature trend analysis through the whole troposphere over the entire investigated period. Radiosonde humidity reevaluation is more challenging and the comparison with Alpine surface stations is more difficult in the first two decades. Absolute humidity trends over the five decades are slightly positive, but the increase mainly occurred in the period 1981 to 2011.

17.11

Heavy precipitation in the Alpine area

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Heavy precipitation events in the Alpine area are often high-impact events that cause significant socio-economic damages. Heavy precipitation events can result in floods and they can trigger avalanches and a wide range of geomorphological activity. This presentation will give a brief overview of the current state of research regarding the dynamical and microphysical processes that govern heavy precipitation evens in the Alpine area and a very short discussion of future trends. The main focus will be on the interaction between the topography and the atmospheric flow.

17.12

A Lagrangian Perspective on Orographic Precipitation

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The Lagrangian perspective on atmospheric processes has become a frequently used way to investigate air streams in the atmosphere since the middle of the 20th century. However, in past studies it became clear that the trajectory calculation in mountainous terrain is rather difficult due to the strong spatial and temporal gradients of the velocity fields. It is shown that the representation of flow patterns above orography can be largely improved by reducing the integration timestep to several tens of seconds and by minimizing the temporal interpolation, i.e. by including the trajectory calculation in the Eulerian model (so-called online trajectories).
The air parcel trajectories can now be used to obtain new insights in the basic physical processes involved in orographic precipitation formation. The principals behind this approach are demonstrated with the aid of a strongly simplified model, which represents the essential ingredients of an orographic cloud in stable atmospheric flow.

17.13

Classification of alpine hydrometeors in 2 dimensional videodisdrometer data

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Alpine winter storms can produce a large amount of snowflakes of different shapes and sizes. These solid hydrometeors (needles, plates, dendrites, rimed particles, graupel and aggregates) determine the characteristics of the snow pack and furthermore the amount of water stored in mountainous regions. Snowfall (and its liquid water equivalent) is difficult to measure. The variety of shapes and densities of snowflakes makes radar remote sensing of snowfall a challenging task.

A 2 dimensional video disdrometer (2DVD) providing two perpendicular side views of each recorded particle can be used to automatically classify the dominant hydrometeor type within a precipitation event. This reveals new possibilities to study the microphysical structure within a precipitation event in general and for snow events in particular, for example for comparison with polarimetric radar measurements.

In the present approach, a supervised classification technique allows to classify the dominant type of hydrometeors within specified intervals (at 1 minute resolution). A large dataset corresponding to two winter seasons collected in the Swiss Alps is used. After careful filtering and rematching of unrealistic particles, the values for 12 descriptors, related to their respective distribution according to the width, length and velocity, are used to classify each time interval. Furthermore, statistical parameters (mean, variance, quantiles) are calculated to describe the time evolution of each descriptor (and its distribution). The five classes are: large aggregates, normal aggregates, dendrite-like particles, graupel-like particles and small particles. A training dataset according to these classes has been manually determined. The comparison between the automatic classification algorithm and a manually classified reference set consisting of about 190 one-minute intervals (more than 3 hours) shows good reliability. Further work will include a comparison of the classification based on the 2DVD with nearby polarimetric radar measurements.

17.14

Severe convection in the Alpine region: the approach COALITION for nowcasting the storm severity

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During the warm season of the year, intense thunderstorms regularly affect the Alpine region. Such high impact convective phenomena can produce local flash floods causing considerable damages. The need to increase lead time in predicting severe convection is well acknowledged. Numerical weather prediction models provide good forecasts on regional to global scales, but have difficulties in predicting the exact time and location of small-scale phenomena like thunderstorms. Current heuristic methods such as satellite and radar imagery, model output post-processing, satellite nowcasting products, neuronal methods or other statistical methods focus on specific aspects. For example, existing radar-based solutions are well suitable for detecting and extrapolating already existing thunderstorms, when hydrometeors occur. The detection of convective features in early stage and the nowcasting of the storm severity still remains a difficult task, especially in complex terrain. Information characterizing the storm environment, in particular retrieved by satellite data, can become very useful for detecting the early stages of a convective process and predict their development.

COALITION (**Co**ntext and Sc**al**e Or**i**ented **T**hunderstorm Satell**i**te Predict**o**rs Developme**n**t) is an innovative object-oriented model developed in the context of the EUMETSAT Fellowship program. The main purpose of this project is to increase the lead time in nowcasting storm severity over complex terrain. Data provided by different sources (e.g. Meteosat Second Generation Rapid Scan, Weather Radar, Numerical Weather Prediction and climatology) are merged into a heuristic model. Furthermore, the orographic forcing (often neglected in heuristic nowcasting models) is considered and included in the system as an additional convection triggering mechanism. This is particularly important over areas characterized by complex terrain like the Alps.

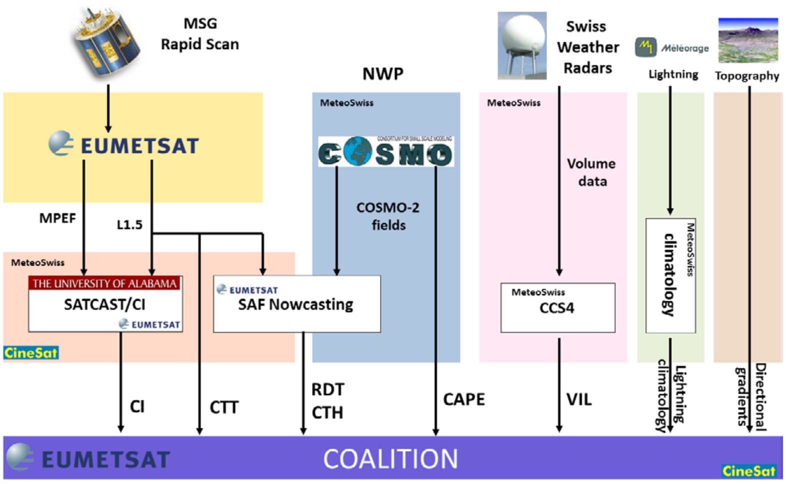

Figure 1. COALITION input data ingested in the current version of the algorithm (CI: Convection Initiation, CTT: Cloud Top Temperature, RDT: Rapid developing Thunderstorm; CTH: Cloud Top Height; CAPE: Convective Available Potential Energy; VIL: Vertical Integrated Liquid content

The COALITION methodology borrows the approach from the physics of general dynamic systems. The algorithm merges evolving thunderstorm properties with selected predictors. The storm evolution is the result of the interaction between convective signatures (objects) and their surrounding environment. The interaction of the environment on the object, e.g. forcing, is modelled as a particle-field interacting system. The results are a probabilistic forecast of intensity evolution of the detected convective cells.

Eight different "object-environment" interactions are described in eight modules, providing ensemble forecast of thunderstorm attributes (satellite- and radar-based) for the next 60 minutes. The different ensemble forecasts are combined with a fuzzy logic approach and then summarized into one single map to facilitate user's interpretation. Convective cells, which have a high probability to develop into a severe thunderstorm, are highlighted on a map, which is provided to the users (weather forecasters) and used for taking important decision about storm warnings.

The first version of COALITION is fully automatic and has been tested on 80 convective cells randomly selected from a database: a preliminary validation shows useful probability of detection (POD) and an acceptable false alarm rate (FAR) for lead-times until 20 minutes before the thunderstorm reaches the severe stage. The system was tested in real-time during summer 2012 and is becoming operational at MeteoSwiss.

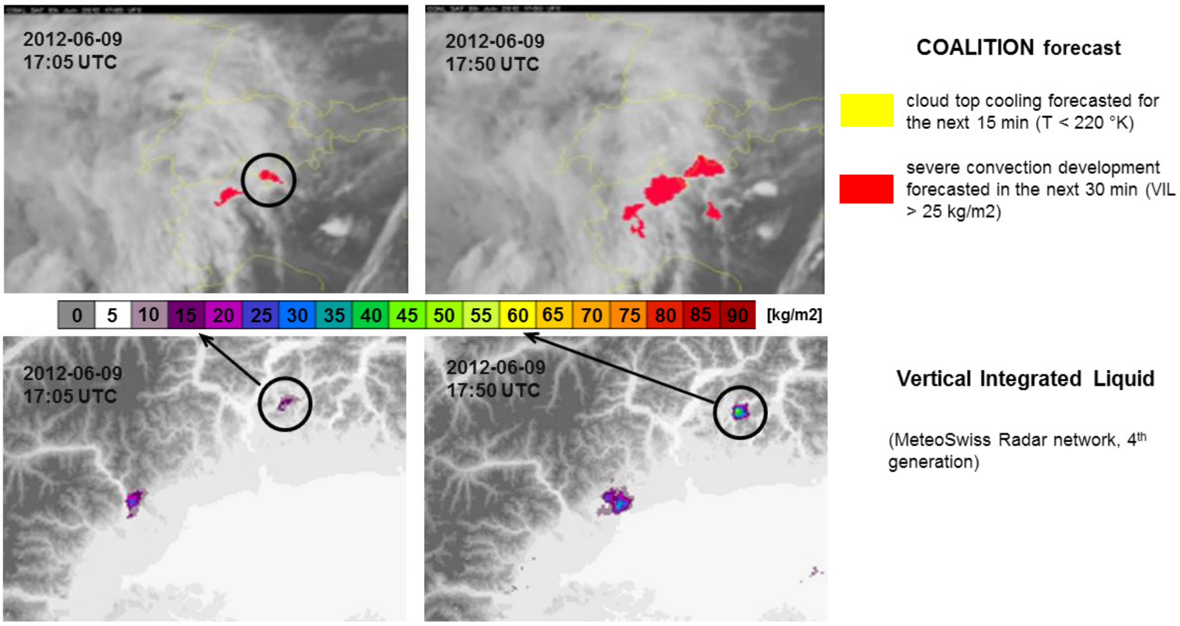

Figure 2. COALITION object-based nowcast, which highlights (in red) some cells for which an increase of convection intensity is very probable for the next 30 minutes. As reference the radar based vertical integrated liquid is shown. In this show case a convective cell is developing over south Switzerland: at 17:05 UTC a particular cell shows a VIL value of 15 kg/m^2 and COALITION indicates that this cell will develop into a severe thunderstorm in the next 30 minutes. At 17:50 UTC this cell increased the VIL values to about 60 kg/m^2.

17.15

Greenhouse warming and solar brightening in and around the Alps

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At low elevations (500 m a.s.l.) central Europe's surface temperature increased about 1.3°C since 1981. Interestingly, at high elevations (2200 m a.s.l.) in the Alps, temperature rose less than 1°C over the same period. Detailed investigations of temperature, humidity and the radiation budget at lowland and alpine climate stations now show that the difference in temperature rise is likely related to unequal solar- and greenhouse warming. The analysis shows that the important decline of anthropogenic aerosols in Europe since the mid 1980s led to solar brightening at low elevations, whereas inherent low aerosol concentrations at high elevations led to only minor changes of solar radiation in the Alps. In the Lowland absolute humidity and also total net radiation show an about 6 % K^{-1} Clausius-Clapeyron conform increase with temperature since the 1980s. In the Alps however, the percentage increase rate of humidity and total net radiation is more than twice as large. This large water vapour increase in the Alps is likely related to strong warming and thermal advection in the Lowlands, and may also have increased due to atmospheric circulation changes. Hence, while in the Alps temperature increased primarily due to strong water vapour enhanced greenhouse warming, solar brightening combined with anthropogenic greenhouse gas and water vapour feedback greenhouse warming led to a higher temperature increase at low elevations in Central Europe.

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17.16

Foehn - extremes, trajectories and representation in NWP models

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South Foehn is a well-known phenomenon in the northern Alpine valleys. In this presentation we give an overview of recent Foehn studies, which in particular address the following questions: (i) How well is Foehn represented in the NWP model COSMO-2?; (ii) What is the climatology of extreme Foehn, whereby the extremeness of Foehn is defined in terms of different characteristics - e.g. maximum wind speed, duration, lowest relative humidity?; (iii) In which respect do synoptic weather situations differ for extreme and non-extreme Foehn cases?

17.17
Satellite-based monitoring of solar irradiance over complex terrain

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Surface incoming solar irradiance (SIS) is an essential climate variable highly relevant for applications such as solar energy, agriculture or climate monitoring. SIS retrieved from geostationary satellites has continuous spatial and temporal coverage and complements station-based estimates.

MeteoSwiss calculates SIS climatologies from Meteosat SEVIRI observations on board of the Meteosat Second Generation (MSG) satellites by use of a modified HELIOSAT algorithm, which enables the separation of clouds from snow and which accounts for terrain shadowing and the radiative effects of snow-covered surfaces. This data set is available over Switzerland for 2004 till recently at 15 minute temporal and 0.02 degree (approximately 1.5 x 2.2 km) spatial resolution and will be continuously updated.

A recently developed analysis and visualization application will pre presented. The tool allows the graphical representation of this data for entire Switzerland or a choice of sub-regions. The application offers either a map display or a time series representation of SIS as wells as surface radiation components (direct radiation, diffuse radiation, direct normal irradiance DNI or clear sky radiation, see for instance Figure 1).

The application can calculate climatological quantities such as means or anomalies. Station-based observations can be displayed on top of the satellite data maps for validation purposes. The MeteoSwiss-internal tool is used to serve the climate monitoring products on www.meteoswiss.ch and for user specific evaluations. These public products might be extended based on capabilities of the tool.

It is planned to further enhance the application for the downscaling of surface radiation quantities at specific locations within Switzerland by accounting for local-scale terrain effects. This includes the estimation of surface radiation on tilted planes – a feature particularly interesting for solar energy as well as agriculture applications.

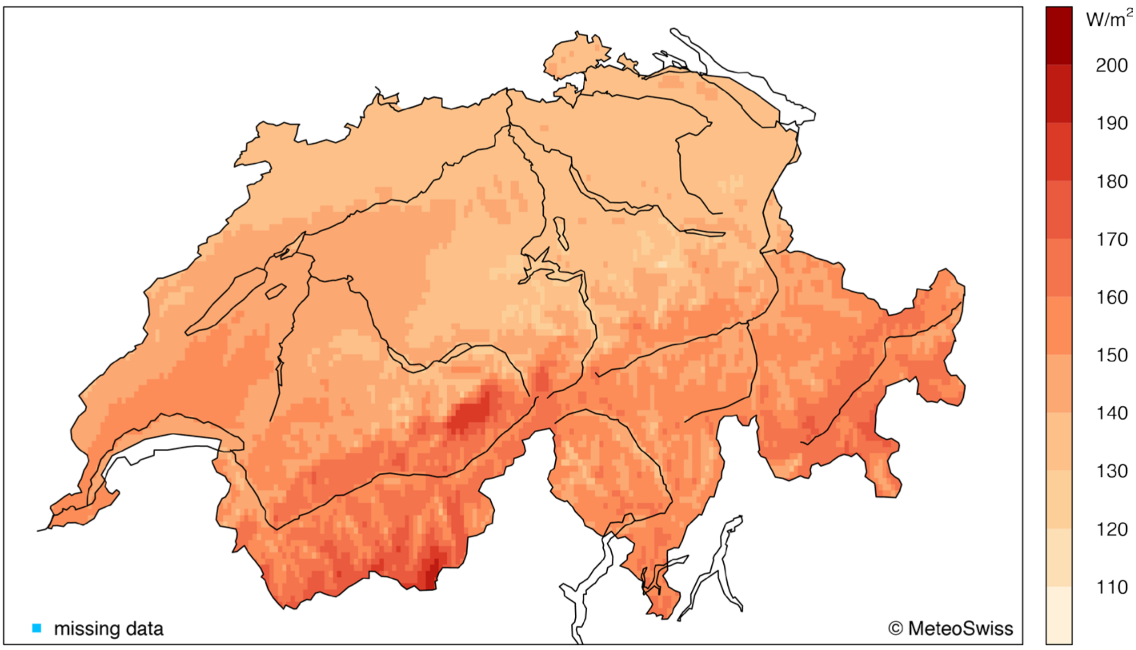

Figure 1. Mean 2004 to 2011 surface incoming shortwave radiation for Switzerland.

P 17.1

Steps toward a process based model for the stable oxygen isotope composition of precipitation over Switzerland

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The stable isotopes of past and present precipitation are important natural tracers in the hydrological cycle on global, regional and local scales. The Alps host the oldest and densest network monitoring stable isotopes of atmospheric precipitation compared to any other mountainous area of the world owing to the good representation of international (GNIP) and national (Switzerland and Austria) networks. Measurements of oxygen isotope ratios in precipitation ($\delta^{18}O_p$) started as early as 1965 at Thonon des Bains (France) and 1971 at Bern (Switzerland). Detailed assessments conducted on these data substantially contributed to our knowledge about isotopic processes acting and interacting at various spatial and temporal scales in the atmosphere, or more generally in geospheres (Siegenthaler & Oeschger 1980, Longinelli & Selmo, 2003, Liebminger et al. 2007). However, the network was very sparse during the first years. Station density significantly improved only from 1973 when more Swiss and Austrian stations were involved. The late 1990s are the best covered period (Fig.1). Exploring to what extent the early and sparse isotope network can capture the spatio-temporal patterns is an open question, yet (Kern et al. 2012).

The main aim of our research is to develop a gridded data set of monthly $\delta^{18}O_p$ over Switzerland and adjacent areas with high spatial resolution back to the early 1970s. To do so homogeneity was carefully checked first by cross-boundary comparisons between nearby station records. Anomalous isotope values and precipitation amount records were rigorously checked.

When precipitation amount weighted mean monthly isotope values were analyzed in order to determine the seasonal difference of empirical oxygen isotopic lapse rates used for spatial modeling unexpected vertical structure was observed. The expected strong altitude dependence (Siegenthaler & Oeschger 1980) was evident only for summer months. Steeper gradient (0.6-0.7 ‰/100m) was observed for winter months over a low elevation belt, while hardly any altitudinal difference is seen over high elevations. This dichotomy can be observed, though less characteristics, during spring and autumn.

A comparison between station locations and monthly average maximum planetary boundary layer (PBL) height data (von Engeln & Teixeira 2012) suggests that different atmospheric conditions/processes above and below the PBL are responsible for the observed pattern. High wind speeds prevailing above PBL could probably maintain well mixed conditions above PBL and cause the large scale isotopic homogeneity. PBL is usually situated at, or above the Alpine summits during summer hence does not affect the vertical isotopic pattern.

Decoupled regimes below and above PBL received little attention in spatial precipitation isotope modeling efforts. Present results point out that PBL location is recommended to be taken into account for future models developed for stable isotope composition of precipitation.

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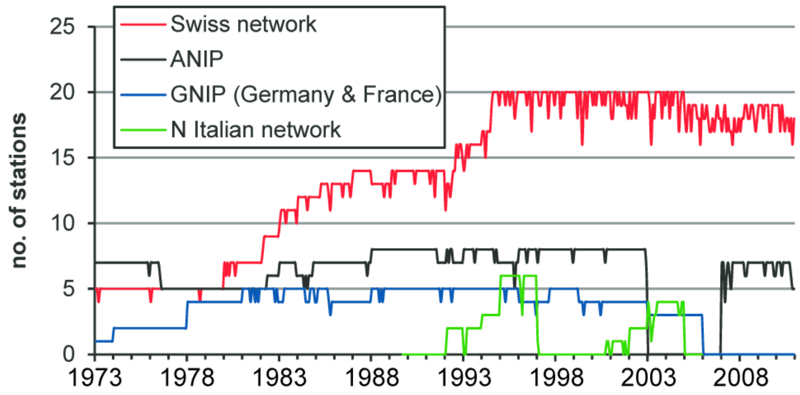

Figure 1. Temporal distribution of the available $\delta^{18}O$ precipitation records. The Swiss network was run by the Climate and Environmental Physics Division (CEP) since the early 1970s. Since 1992 thirteen precipitation stations were monitored with financial support from the Swiss Federal Office of Environment. Those stations were extended by seven additional stations by the CEP network. Therefore 19-20 stations data were available until 2010. This exceptional data set was completed with 25 neighboring stations (8 Austrian, 5 German, 1 French and 11 although relatively short Italian).

P 17.2

Orographic effects on precipitation and atmospheric water cycle in the Weather Research and Forecasting Model

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The Weather Research and Forecasting (WRF) Model (Skamarock et al. 2008) is a next-generation mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. The WRF Model supports two dynamical solvers, the Advanced Research WRF (ARW) and the Nonhydrostatic Mesoscale Model (NMM). We chose the former dynamical solver ARW, more suitable to conduct high-resolution idealized simulations, to assess the effects on orographic precipitation of the different microphysics schemes which the user can select.

The scenario set for our simulations consists in a 2-D atmospheric flow of saturated air interacting with an idealized mountain ridge placed in the middle of the spatial domain. The interaction of the saturated air with the mountain ridge triggers precipitation and at the same time re-evaporation occurs, under favourable temperature conditions, due to accumulation of liquid water on the ground. For the initial profiles of temperature and pressure we used mid-latitudes zonally-averaged profiles taken from ECMWF ERA-Interim reanalysis data, while for the initial wind profile we used a horizontal, single-component wind speed of 10 m/s for all heights. To foster precipitation, the moisture profile was set equal to the saturation vapour pressure profile (which corresponds to 100% relative humidity), according to the already defined temperature and pressure profiles. At the borders of the horizontal domain, periodic lateral boundary conditions were applied so that the air exiting from one side is reinserted at the other side.

The assessment of long-term effects of different microphysics schemes on the water cycle in regional climate simulations is the main aim of our study (Awan et al. 2011). Long-run simulations have been performed and the results are analyzed to compare the total precipitation generated by each scheme. Furthermore, the balance between precipitation and evaporation is discussed for the different schemes. In this way, the microphysics parameterizations available in the WRF Model can be characterized and understood by means of idealized and comprehensible simulations. This leads to a better knowledge of the microphysics schemes which is a precondition for a reliable simulation of the water cycle with the WRF model.

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P 17.3

Quasi-analytical treatment of spatially averaged radiation transfer in complex terrain

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We provide a new quasi-analytical method to compute the subgrid topographic influences on the shortwave radiation fluxes and the effective albedo in complex terrain as required for large-scale meteorological, land-surface or climate models. We investigate radiative transfer in complex terrain via the radiosity equation on isotropic Gaussian random fields. Under controlled approximations we derive expressions for domain-averaged fluxes of direct, diffuse and terrain radiation and the sky view factor. Domain-averaged quantities can be related to a type of level-crossing probability of the random field which is approximated by longstanding results developed for acoustic scattering at ocean boundaries. This allows us to express all non-local horizon effects in terms of a local terrain parameter, namely the mean squared slope. Emerging integrals are computed numerically and fit formulas are given for practical purposes. As an implication of our approach we provide an expression for the effective albedo of complex terrain in terms of the sun elevation angle, mean squared slope, the area-averaged surface albedo, and the ratio of atmospheric direct beam to diffuse

radiation. For demonstration we compute the decrease of the effective albedo relative to the area-averaged albedo in Switzerland for idealized snow-covered and clear-sky conditions at noon in winter. We find an average decrease of 5.8% and spatial patterns which originate from characteristics of the underlying relief. Limitations and possible generalizations of the method are discussed.

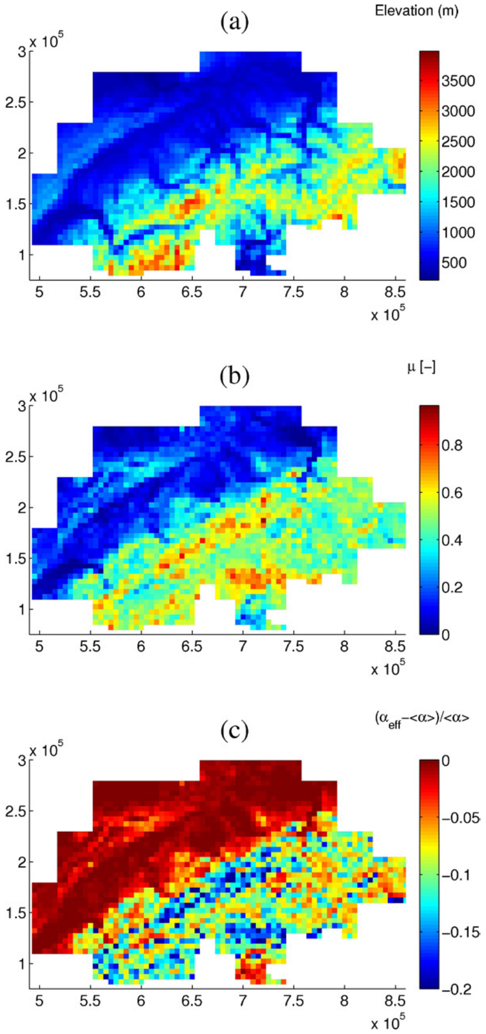

Figure 1. (a) DHM of Switzerland (in Swiss coordinates) with coarse grid size L=5 km obtained from a high resolution DHM with fine grid size dx=25m. (b) Mean squared slope (c) Normalized difference between the effective albedo and area-averaged albedo .

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P 17.4

NCCR Climate related research at MeteoSwiss - The Swiss climate of today and tomorrow

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Switzerland as an Alpine country is particularly sensitive to climate change. There is a demand and a social responsibility to present information about specific changes and possible adaptations. MeteoSwiss supports the public, research and decision makers in business and government by providing high quality climate information on the past, current and future climate conditions on different scales. This climate information and support with its interpretation and use is described as climate services (WMO, 2011).

MeteoSwiss is developing the scientific basis making high quality climate services possible bundling resources from different external fundings and a substantial internal contribution. MeteoSwiss is an active member of the C2SM (Center for Climate Systems Modeling) and participant of various research projects, in particular of the SNF NCCR Climate (Swiss National Center of Competence In Research – Climate), COST-Actions and projects funded by the European Union (FP7). MeteoSwiss coordinated the CH2011 Initiative, an update of climate scenarios for Switzerland within the framework of C2SM and NCCR Climate. The Swiss Climate Change Scenarios CH2011 were published on September 28th.

The research project at MeteoSwiss started 2009 and will end this year. It is divided into four subprojects: Preclim, BiotoP, CombiPrecip and EURO4M. According to the key areas defined by the Stern Review (Stern et al., 2006), it is our goal to provide high resolution climate data (EURO4M, CombiPrecip) and to refine climate scenarios for user needs (BiotoP, PreClim) in order to link the scientific community with real world applications.

Preclim provides climate scenarios for Switzerland for the current century based on regional climate models (Fischer et al., 2011; Weigel et al., 2010). BiotoP links climate change scenario data to plant pest models, in order to investigate the potential threat of plant diseases under conditions of a changing climate. First results for codling moth (a key pest in apple plantations) for Northern Switzerland show a shift of important life phases towards earlier dates and a risk of an additional generation in the future (Hirschi et al., 2011). CombiPrecip combines information from the two classical rainfall measurements – radar and rain gauges – with statistical methods for climatological and near-real time applications such as hydrology (Erdin et al., in press; Schiemann et al., 2010). A Prototype will be available in spring 2013. EURO4M will provide a new high-resolution daily gridded Alpine wide precipitation data set over the last 40 years based on rain gauge observations.

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P 17.5

The integration of the automatic foehn index into the longest time series for foehn (starting 1864 for Altdorf, Switzerland)

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For Altdorf Switzerland, foehn events were recorded carefully since 1864. Three times a day - in the morning, at noon and in the evening - observations were made resulting in a "foehn"/"no foehn" information. Since foehn is a very clear event that manifests itself in sudden increases in temperature and wind, and in a simultaneous drop in relative humidity, the data can be regarded as quite reliable. Furthermore, the observations were made by members of the same family for 85 years. The observations were processed to yield a time series consisting of monthly sums for each of the observation time (morning, noon, evening) and year. Recently the results of the investigations of the long foehn series in Altdorf were published by Gutermann et al. (2012).

Since 1981, data from automatic stations is available. An objective method was developed that allows to determine "foehn"/"no foehn" in 10-minute intervals from which foehn hours can be computed (Dürr, 2008). This foehn index is based on wind direction, wind speed, gust speed, and relative humidity. A further criterion is the difference in potential temperature to the reference station Gütsch (situated on the Alpine ridge). Parallel to the foehn index, "manual" foehn observations at the three observation times were continued until 2008. As a result, two different foehn time series are available: (i) a series of monthly sums of triple observations for 1864-2008 (morning, noon, evening) and (ii) a series of foehn observations for every single hour since 1981. For the overlap period 1981 to 2008, correlations between the two time series were analyzed and transformation functions determined. These latter allow to either convert the monthly sums of triple observations to foehn hours or vice versa. In both cases, the time resolution is fixed to monthly values for three time slices per day. As result, the climatologically very valuable, 145-year-long time series, can be continued without interruption into the future, allowing further climatological analyses of foehn in Altdorf, either in terms of foehn observations or foehn hours.

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