Symposium The Water Cycle in a Changing Climate
ETH Zürich - July 1-2, 2013

Modelling Anthropogenic Aerosol Radiative Impacts on Oceanic Surface Energy Fluxes

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Session: Global aspects

Numerous studies show through observational as well as modelling evidence that changes in anthropogenic aerosol emissions likely affect the Earth's radiative budget and hydrological cycle through direct (e.g. scattering, absorption) and indirect effects (e.g. acting as cloud condensation nuclei). To what degree aerosol radiative forcing can affect sea surface temperatures (SSTs) is debated. Model results suggest, for example, that anthropogenic aerosols may alter Indian Ocean SSTs, which in turn can affect precipitation patterns. Modelling studies over the North Atlantic using coupled ocean-atmosphere model runs suggest that anthropogenic aerosols are an important driver of SSTs. However, these results are still subject to debate. Thus, the question remains, to what extent SSTs variability is the result of either aerosol radiative forcing or internal ocean variability.

The aim of the present work is part of the regional to global research cluster within the second stage of the Collaborative, Highly Interdisciplinary Research Projects (CHIRP II) of C2SM. The work aims at furthering the understanding of potential anthropogenic aerosol effects on climate (climate forcing) with emphasis on remote and fairly pristine regions such as oceans. The radiation balance in regions with low aerosol content is particularly sensitive to an increase in aerosol burdens, since even small amounts of aerosol can induce large relative changes through aerosol-cloud interactions. We performed sensitivity experiments with the global climate model ECHAM5 combined with the interactive aerosol module HAM using prescribed sea surface temperatures (Hadley Centre), and run at a resolution of T42L19 for the years 1870-2000. We compared ensembles of simulations using transient anthropogenic aerosol emissions (from NIES, National Institute for Environmental Studies, Japan) with ensembles using pre-industrial anthropogenic aerosol emissions, i.e. emissions held constant at levels of 1870. This allows us to quantify the transport of anthropogenic aerosols to

remote regions and identify regions where the radiation balance was significantly affected by anthropogenic aerosol burdens during the last century. The aerosol transport capabilities of the model are assessed by comparing present day model results to satellite observations.

Our findings serve as basis for future modelling efforts using a coupled atmosphere-ocean modelling framework. In doing so, we aim to gauge the potential radiative impacts of anthropogenic aerosols on sea surface temperatures, and the hydrological responses thereof.

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Modeling aerosol effects on 20th century climate: a consistent picture?

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Session: Global aspects

Population growth and industrialization in recent decades were accompanied by a substantial increase in aerosol emissions. We use transient sensitivity studies with the global atmosphere only climate model ECHAM-HAMMOZ to investigate potential implications on surface solar radiation (SSR), surface air temperature (SAT), and precipitation. The aerosol emission data are taken from NIES (National Institute of Environmental Studies, Japan), prescribed, observation based sea surface temperatures (SSTs) are from the Hadley Center. Note that these observation based SSTs may already encapsulate some aerosol effects. The simulations cover the time from 1870 to 2005. As expected, mean global land SSR, SAT, and precipitation trends are reduced by increasing aerosol emissions.

Analyzing the model data for different regions, in particular Europe, China, India, and the Sahel, reveals a mixed picture regarding the relevance of changing aerosol emissions as compared to transient SSTs. And while comparison with observations favors the inclusion of aerosols in the model for some variables and / or regions, it disfavors their inclusion for others. For example, the observed 'northern drought, southern flood' pattern in Eastern China is captured by the model, but only in the absence of increasing aerosol emissions. By contrast, increasing aerosol emissions are crucial in the model to reproduce observed SSR changes in Eastern China since 1960. If included, modeled SSR first decreases by about -7 W/m2, before increasing again in the late 1990s. Modeled SAT reflects this decrease in SSR in recent decades but carries also a substantial SST signature, in particular in the first half of the 20th century but also in recent decades. Comparison of modeled and observed SAT benefits in some regions of increasing aerosol emissions but not in others. Here, and for precipitation, model resolution plays some role. We discuss what these (in-)consistencies of modeled aerosol effects across variables and regions may imply for the prescribed aerosol emissions, the model results, and the observed data.

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Investigating changes in dryness by a comprehensive synthesis of available data sets

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Session: Global aspects

Changes in the climatological land water balance affect a wide range of socio-economical sectors. Thus, the identification of regions undergoing a substantial increase or decrease in dryness is of major interest in climate science. Here we study changes in either precipitation (P) or potential evaporation (Ep) in relation to changes in evapotranspiration (E), thereby considering both the water and the energy balance. However, global estimates derived from observations or from models of P, Ep and especially E are characterized by high uncertainties, partly leading to inconsistent results in previous studies.

Our major objective is therefore to identify those regions which show robust trends across a large number of global data sets, yielding more than 700 possible combinations for E together with P and Ep for the period from 1948 to 2008. To examine the realism of the individual combinations of E, P and Ep, we evaluate them within the Budyko framework, which provides an empirical relationship between E/P and Ep/P. We use the combinations which perform well in this framework to study decadal changes in the water balance (ΔP - ΔE) and the energy balance (ΔEp - ΔE). Changes at the grid box level are quantified by the minimum Mahalanobis-distance between a fitted bivariate normal distribution to the estimates of the individual combinations of ΔP and ΔE (or ΔEp and ΔE, respectively), and the line of no change.

Our results reproduce findings from previous studies regarding long-term changes in the water balance, e.g. drying trends in the Mediterranean and East Asia and wetting in Central North America, but also highlight trends over India (drying), parts of Africa (drying) and Southeast South America (wetting).

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Lower tropospheric humidity: Climatology, trends and the relation to the ITCZ

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Session: Global aspects

The tropical region is an area of maximum humidity and serves as the major humidity source of the globe. Among other phenomena it is governed by the so-called Inter-Tropical Convergence Zone (ITCZ) which is commonly defined by converging low-level winds or enhanced precipitation. Given its importance as a humidity source, we investigate the humidity fields in the tropics in two different reanalysis data sets, deduce the climatology and variability, and assess the relationship to the ITCZ. Therefore, a new analysis method of the specific humidity distribution is introduced which allows detecting the location of the humidity maximum, the strength, and the meridional extent. The results show that the humidity maximum in boreal summer is strongly shifted northwards over the warm pool/Asia Monsoon area and the Gulf of Mexico. These shifts go along with a peak in the strength in both areas; however the extent shrinks over the warm pool/Asia Monsoon area, whereas it is wider over the Gulf of Mexico. In winter, such connections between location, strength, and extent are not found. Still, a peak in strength is again identified over the Gulf of Mexico in boreal winter. The variability of the three characteristics is dominated by inter-annual signals in both seasons. Using ERA-interim only we detect a positive trend in the Gulf of Mexico/Atlantic region from 1979-2010, showing an increased northward shift in recent years. Although the trend is only weakly confirmed by the results using MERRA reanalysis data, it is in phase with a trend in hurricane activity – a first hint of the importance of the method. This hypothesis needs a more detailed study in the future. However, in most areas the position of the maximum humidity coincides with the one of the ITCZ. One exception is the western and central Pacific, where the area is dominated by the double ITCZ in boreal winter. Nevertheless, the new method enables us to gain more insight in the humidity distribution, its variability and the link to ITCZ characteristics.

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The impact of ocean boundary conditions on the aerosol climate response in ECHAM5-HAM and CAM-Oslo

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Session: Global aspects

Aerosol particles constitute one of the major uncertainties in our understanding of the climate system. Not only do they have a considerable impact on the energy balance of the atmosphere by their ability to both scatter and absorb incoming solar radiation, by their effect on energy balance they also have the potential to affect the global hydrological cycle as well as the circulation in the atmosphere. Because of their short residence time, the aerosol particle concentration shows a large variation both spatially and temporally, as does the aerosol radiative forcing. This highly varying radiative forcing pattern might modify temperature and pressure gradients and thereby the atmospheric circulation and precipitation patterns.

General circulation models are widely used to investigate the effect of anthropogenic aerosol forcing on the climate. These models usually use different physical parameterisations and aerosol descriptions as well as different representations of the ocean surface. Fixed Sea Surface Temperatures (SSTs) are often used to represent the ocean surface due to the computational efficiency. While providing realistic ocean surface temperatures, changes in surface energy fluxes in response to aerosol radiative forcing may be misrepresented. Coupling the atmospheric model with a thermodynamic slab-ocean models provides a more realistic representation of ocean-surface energy fluxes but could potentially lead to exaggerated temperature responses due to the lack of ocean dynamics. However, a realistic representation of energy fluxes should be crucial for modelling the effect of aerosols on the total earth-system energy budget and thereby latent heat fluxes and precipitation.

To investigate the impact of using a slab-ocean model versus fixed SSTs two climate models, ECHAM5-HAM and CAM-Oslo, are used in the present study. By comparing experiments with the same aerosol-emission changes but different ocean surface representations in the two models, the differences stemming from either using fixed SSTs or a slab ocean can be identified. Many of the atmospheric circulation and precipitation changes observed in modelling studies of the anthropogenic aerosol effect on the climate are likely dependent on the surface temperature response. The choice of oceanic boundary condition may therefore have a profound effect on the modelled climate impact since it will strongly influence this temperature response.

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Predictability of changes in precipitation on different time scales and their impacts

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Session: Global aspects

Forecasting or predicting precipitation is challenging, no matter what time scales are considered. On a shorter time scale, there are several issues when forecasting precipitation information that is relevant to users. The highly variable nature of precipitation is just one of them. On a longer time scale, the large variability leads to a noisy signal and is quite challenging to detect on a local scale. With the aid of climate model output we analyze on a local scale, when the signal of change in precipitation will emerge from the background variability. As climate models offer the possibility to take future changes into account we can estimate when the emergence of the signal is happening beyond the climate we know today.
These changes, together with the changes in temperature, lead to shifts in climatic regions. These shifts will happen faster and faster, the more the global mean temperature increases. Changes is climate zones will have an impact on biomes, and when theses changes are happening faster, species might face an increased risk of extinction.

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Feedback of aerosol processing in clouds on cloud water path and lifetime

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Session: Global aspects

Aerosol processing in stratiform clouds by uptake into cloud particles, collision-coalescence, chemical processing inside the cloud particles and release back into the atmosphere changes the aerosol concentration, size distribution, chemical composition and mixing state. The change in the aerosol influences cloud droplet and ice crystal number concentrations and subsequently cloud liquid and ice water paths as well as cloud lifetime.

We have implemented aerosol processing into the current version of the general circulation model ECHAM6 (Stevens et al., 2013) coupled to the aerosol module HAM (Stier et al., 2005). We extended ECHAM6-HAM by an explicit representation of aerosol particles in cloud droplets and ice crystals in stratiform clouds similar to Hoose et al. (2008a,b). Aerosol particles in cloud droplets resp. ice particles are each represented by 5 tracers for sulfate, black carbon, organic carbon, sea salt and mineral dust. Aerosol mass transfers by freezing and evaporation of cloud droplets and melting and sublimation of ice crystals are treated explicitly. A new aspect is that aerosol particles from evaporating precipitation are released to modes which correspond to their size.

In standard ECHAM6-HAM like in many other general circulation models, prescribed scavenging ratios are used for wet deposition in clouds. These are replaced by an explicit treatment of collision of cloud droplets/ice crystals with interstitial aerosol particles and nucleation scavenging of aerosol particles by acting as cloud condensation nuclei or ice nuclei. This results in a dependence of the scavenged aerosol fraction on cloud history as aerosol particles are not necessarily scavenged every time step but only when nucleation or collisions take place. Also many clouds do not form precipitation and also much of the precipitation evaporates before it reaches the ground.

The water soluble part of the aerosol particles concentrates in the hydrometeors and together with the insoluble part forms a single, mixed, larger particle, which is released.
These changes in the aerosol result in changes in the cloud droplet number and ice crystal number concentrations in ECHAM6-HAM which in turn leads to altered condensation/deposition rates of water vapor mass and thereby influence the cloud liquid and ice water paths as well as cloud lifetime. We will present results for changes in cloud liquid and ice water paths as well as cloud lifetime by in-cloud aerosol processing at the symposium.

Hoose et al., JGR, 2008a, doi: 10.1029/2007JD009251
Hoose et al., ACP, 2008b, doi: 10.5194/acp-8-6939-2008
Stevens et al., 2013, submitted
Stier et al., ACP, 2005, doi: 10.5194/acp-5-1125-2005

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The role of cyclones and fronts for Southern Ocean precipitation and its variability

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Session: Global aspects

Exploring the relationship between the occurence of extratropical cyclones, fronts and precipitation can help to constrain trends in precipitation over the Southern Ocean, as future changes in the cyclone frequencies can likely be identified more easily. Based on the ERA-Interim dataset and objective analysis of cyclones and fronts therein, we present a novel method to attribute intense precipitation (75th percentile) to these weather systems. Our method allows to quantify the amount of intense precipitation falling in association with extratropical cyclones and along fronts outside of cyclones separately.

As will be shown, in certain regions of the Southern Ocean a major portion of intense precipitation is caused by fronts. In particular in the cyclone sparse mid-latitudes of the South Indian Ocean, intense cold fronts, related to cyclones moving more southwards along the coast of Antarctica, account for up to 70% of precipitation. In contrast during austral winter along the northern branch of the split storm track in the Pacific, both cyclones and fronts contribute equally about 40% each. In a high-latitude band bending uniformly around the coast of Antarctica, cyclones account for up to 80% of the precipitation.

We relate inter-annual variability of seasonal precipitation to changes in storm track activity, i.e., in cyclone and front frequencies. Large variability is found in the south Atlantic and the south Pacific, where the storm track is strongly influenced by ENSO. In JJA 1998 the Pacific sub-polar storm track was exceptionally strong, causing intense frontal precipitation between 45°S and 60°S. A potential cause of this storm track anomaly was an amplified Eady growthrate off the ice edge related to SST anomalies, leading to the re-intensification of cyclones from the Indian Ocean, combined with a strong polar front jet, typical for La-Nina conditions.

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Towards a coherent framework for evaluating Lagrangian evaporative moisture source diagnostics

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Session: Global aspects

Identifying the evaporative sources of atmospheric water vapor is an important research theme, for instance in understanding precipitation extremes. However, moisture origin is not a quantity that is readily observable in nature. While stable water isotopes can provide useful hints in some cases, their interpretation is often complicated by the fact that they represent the integrated evaporation and condensation history of atmospheric water vapour and by atmospheric mixing processes. Moisture diagnostics are thus a crucial tool to access this information. A major concern is to evaluate how representative the information from different diagnostics is for the total precipitation in a study area.

In this work, a new way for consistently validating Lagrangian model simulations is explored. An Eulerian simulation of a regional climate model with artificial water source tracers is thereby applied as a common testbed for several tested Lagrangian moisture source diagnostics. Encouraging agreement between Lagrangian and Eulerian models points to consistent information delivered from the two conceptually fundamentally different approaches to trace moisture origins. Differences in the quantitative contributions of more distant moisture sources in different Lagrangian models are related to the assumptions made for identifying moisture uptake events.

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Impact of secondary organic aerosols on the equilibrium response of the climate system

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Session: Global aspects

Aerosols can influence the solar radiation fluxes and nature, amount and lifetime of clouds. In this way, they can have a strong impact on climate including the hydrological cycle. A substantial fraction of the aerosols in the troposphere are organic. These can either be directly emitted into the atmosphere (referred to as Primary Organic Aerosols – POA) or formed in the atmosphere after oxidation of gas-phase precursors (referred to as Secondary Organic Aerosols – SOA). SOA represents an important fraction of organic carbon (estimated to be roughly 30 to 60% of the total organic input to the atmosphere), yet their formation in global models is not always included.

Our objectives are (1) to investigate the impact of SOA on sea surface temperatures (SST) and the response of the climate system using the global climate-aerosol model ECHAM5.5-HAM2 coupled to a Mixed Layer Ocean (MLO); and (2) to asses how these responses depend on the level of detail included in the model to represent SOA.

We compare two model setups: the standard setup in which SOA are released as POA in the model surface layer; a second setup in which SOA formation is computed interactively (following a 2-product scheme in which the two oxidation products can condense on existing particles). The interactive calculation compared to prescribed SOA results in a increase in burden of 0.77Tg to 1.5Tg in total organic aerosol. We find that including SOA as POA or using an interactive scheme results in significant differences in the impact on the radiation budget and in the aerosol processing in clouds. Prescribed SOA results in a direct solar radiative effect at TOA (Top-of-the-atmosphere) of +0.18W/m^2 while for SOA calculated interactively it is -0.44W/m^2. We will report on this and the impact on other climate variables.

The Influence of Orographic Stationary Rossby Waves on Precipitation Climatology and on the Erosion of Large Scale Topography

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Global Aspects

ABSTRACT

A map of observed annual mean precipitation is strikingly asymmetric in the zonal direction. Understanding the cause of this asymmetry and its response to changes in global greenhouse gas concentrations requires an understanding of how zonal asymmetries such as mountain ranges and continental boundaries affect the transport of heat and moisture. We use an idealized GCM with a slab ocean to study the effect of a Gaussian mountain ridge and a large midlatitude continent on the regional climatology around the globe across a wide range of climates. We find that in addition to the well known orographic precipitation effect near the mountain range, precipitation patterns are affected globally due to moisture transported by topographically driven stationary Rossby waves. Because Rossby waves propagate equatorward, there is a particularly large influence on precipitation patterns in the subtropical region south and southeast of the mountain range. With an increase in greenhouse gas concentrations, represented in our model by optical thickness in a grey atmosphere, the amplitude of the stationary Rossby wave decreases while the overall specific humidity of the atmosphere and the associated moisture fluxes increase due in part to the Clausius-Clapeyron relation. This leads to a peak in the amplitude of the stationary wave induced precipitation pattern near the present value of optical thickness. Changing optical depth can also lead to changes in the relative phasing of multiple stationary wave sources, leading to strong local precipitation anomalies far from either stationary wave source.

Understanding such regional precipitation pattern changes in a changing climate is essential for understanding changes in surface hydrology and corresponding changes in surface processes. In particular, because of large changes in hydrology near mountain ranges, it is interesting to consider the influence of changes in hydrology on long-term erosion rates. Recent work has shown that erosion rates depend not just on time-mean climate, slope, and lithology, but also on the storminess of the climate. The influence of storminess comes from the presence of erosion thresholds with critical river discharges

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needed to dislodge material. The frequency and magnitude of storms thus governs how often these thresholds are exceeded. By considering erosion thresholds, we derive a modified form of the stream power erosion law with a power law relation between erosion rate and mean climate, the exponent depending on storminess. We then apply this model to estimate global fractional changes in erosion rate with a given climate change, assuming nothing about the existing topography other than that it is in steady state with uplift. These results give an idea which regions globally will be most affected by changes in precipitation and erosion hazards with changing climate.

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Warm conveyor belts in a global climate model with a complex representation of aerosol-cloud interactions

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Session: Global aspects

Extratropical cyclones (ETCs) are weather systems that are respon- sible for most of the precipitation in midlatitudes. More precisely, within ETCs warm conveyor belts (WCBs) are responsible for trans- port of moisture and aerosols from the surface to the upper tropo- sphere and the formation of clouds and precipitation. The interac- tions between aerosols and cloud processes within the WCB may alter precipitation.

In this study the ECHAM6-HAM model is used to look at the effects of aerosols on precipitation formation in WCBs. The ECHAM6-HAM is a global climate model with a two-moment cloud microphysics and aerosol scheme. The model results are used as an input for the La- grangian model LAGRANTO to calculate 48h forward trajectories identifying the WCB as the trajectories that ascend 600hPa or more in the 48h. Furthermore, only trajectories that ascend in the vicinity of an ETC are considered. The area of interest is the northwestern Pacific Ocean because of the high frequency of ETCs and the strong increase of anthropogenic aerosols in East Asia since the 1950's. With conducting present day and preindustrial simulations we analyse how individual WCBs look like in the Pacific Ocean. This study will show how microphysical processes look like along the Lagrangian evo- lution of WCBs and how cloud structures and precipitation in WCBs are changed with different aerosol loadings..

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Propagation of climate change effects on water resources across the catchment: The upper Rhone case study

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Session: Impacts

A distributed long-term hydrological balance of the upper Rhone basin was investigated including forcing due to climate change and anthropogenic disturbances (reservoirs, river diversions and irrigated areas) simulated at an unprecedented level of detail for catchment of this size and complexity. We downscaled climate model realizations using a methodology that allows us to account for stochastic variability of climate. The analysis aimed to propagate until the middle of the 21st century climate change effects on streamflow from high elevation headwater catchments to rivers in the major valleys. Despite a large uncertainty induced by stochastic climate variability, we identified an elevational dependence of climate change impacts on streamflow with a severe reduction at high-elevation, due to the missing contribution of water from ice melt, and a strongly dampened effect downstream. A decrease of summer discharge and an increase of maximum flows appear as the most robust projected changes for the different parts of the catchment. However, it is unlikely that major changes in total discharge from the entire upper Rhone basin will occur in the next decades. Finally, changes in the natural hydrological regime imposed by the existing hydraulic infrastructure are likely larger than climate change signals expected by the middle of the 21st century in most of the river network.

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Determination of processes causing the climate change signal in the surface water temperature of Lake Constance

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Session: Impacts

The mean surface water temperature of Lake Constance increased by 1.6 °C during the period 1981 to 2011. This change strongly correlates to observed trends in mean air temperatures of about 1.8 °C in the same period. Thus, it is assumed that climate change causes an reconfiguration of the heat balance components and an intensification of heat exchange processes at a lake's surface. Higher temperatures in the surface layer, longer annual stratification periods, stronger stratification stabilities, and less intense deep water renewal during winter mixing are some of the implications. This study explores the dominant variations of heat exchange processes, their compositions, and their evolution during the last decades. It is finally the aim to answer the question of which processes cause the climate change signal in the lake's temperature. For this purpose a heat balance model was developed for Lake Constance. This enabled the calculation of all relevant heat fluxes, their changes, and their contributions to the total heat balance. After calibration and validation the model was forced by measured meteorology of the period 1984 to 2011. Beside a first detailed analysis of a mean heat balance composition the results show, that the relevant processes that determine the effect of climate change on the water temperature could be reduced to increasing absorption of solar radiation and of long wave radiation. Absorption of solar radiation increased by 0.7 W m^{-2} a^{-1}. Long wave radiation absorption (prevailingly determined by clouds and air temperature) increased by 0.4 W m^{-2} a^{-1}. Heat loss by long-wave emission of the water body due to higher water temperatures increased by 0.22 W m^{-2} a^{-1}. The contribution of non-radiative processes and their changes is little. But reduction of latent heat flux by 0.17 W m^{-2} a^{-1} is comparable with the changes in long-wave emission. Little

changes in mean sensible heat flux are negligible. The Alpine Rhine’s cooling effect significantly decreased in summer, but it’s contribution is small. In general, climate change enhance heat fluxes at Lake Constance surface with the tendency to more radiative heat exchanges.

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Implications of climate change scenarios for agriculture in alpine regions – a case study in the Swiss Rhone catchment

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Session: Impacts

Coping with climate change in agriculture requires knowledge of trends in agro-climatic conditions with a focus at the smaller scales where decisions are taken. As part of the EU FP7 ACQWA project, the situation was analyzed for agriculture in the case of the Swiss Rhone catchment (Valais) where cultivation of permanent crops (orchards and vineyards) and livestock production are the most important agro-economic activities. The aim of this study was to use daily data from four downscaled and bias corrected transient climate change scenarios form the ENSEMBLES database to analyze changes in water and temperature related indices over the period 1951-2050 for three locations (Aigle, Sion, Montana) that are representative of different production zones in the catchment. Two of these (MPI_REMO_ECHAM5-r3, ICTP_RegCM_ECHAM5-r3) forced by the global climate model ECHAM5-r3 were the agreed common scenarios for the ACQWA project. Both represent mild changes in temperature and marginal changes in precipitation, relative to the reference. The other two scenarios driven by the Hadley climate model HadCM3Q0 (ETHZ_CLM_HadCM3Q0) and HadCM3Q3 (SMHI_RCA_HadCM3Q3) were used to capture a larger range of scenario uncertainty. They represent similar but more pronounced changes in temperature, and ETHZ represents a stronger reduction in summertime precipitation compared to the other scenarios.
The results indicate that most relevant implications are caused by projected changes in temperature and not in precipitation. They indicate an extension of the thermal growing season with potentially positive effects on pasture and livestock production, most pronounced at the mountain site (Montana), but a trend towards increasing risks of frost in permanent crops and in heat stress for livestock at the valley bottom (Aigle, Sion). The atmospheric water budget (P-ET_o) for April-September shows strong inter-annual fluctuations, a clear difference between the three sites, and a declining trend at all sites (Fig. 3B). The largest negative seasonal budget of between -300 and -400 mm was found for the warmest and driest site (Sion). The related increase in water requirement for irrigation in 2021-2050 relative to 1981-2009 is moderate (4-16%, depending on location). However, in years with low amounts of snow and rain, in small catchments with a nival regime, reduced water supply by rivers could restrict the sur-

face area of grassland than can be irrigated, particularly during springtime. It is concluded that coping with heat-related risks may be most needed at the lower elevations while water-related issues would become more relevant in more elevated locations where pasture-based livestock production are the dominant type of agricultural land use.

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Optimizing agricultural land management for climate change adaptation – A multi-functional approach

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Session: Impacts

Climate change poses new challenges to agriculture in Switzerland. With increasing temperatures and a likely decrease in summer precipitation, irrigation demands will probably increase. River discharges used as source of irrigation water will decrease at the same time, and thus water conflicts may increase. Adaptation options beyond irrigation may be required to cope with climate change (e.g. change in crop choice and management). In the Broye catchment in Western Switzerland, we investigate how climate projections for the time horizon 2036-2065 using two climate scenarios could affect agricultural productivity and other agricultural functions (i.e. soil and water protection). Optimum adaptation options are identified using a regional multi-objective optimization approach.
Results show a decrease in agricultural productivity, higher water demand, and an increase in soil loss and nitrate leaching if no adaptation measures are implemented. However, a wide scope for adaptation exists through changes in crop choice, crop management, and spatial allocation. If the primary focus is set on the production function, agricultural productivity can be increased by about 30 % compared to the current situation. Nevertheless, this goes at the expense of increased leaching, soil loss and overuse of water due to highly intensive management. Shifts to grassland and extensive management can prevent negative environmental impacts at the cost of reduced agricultural productivity. Provided that it is a prerequisite to maintain productivity in the region, compromises are necessary. An optimum trade-off solution is presented that could be seen as a possible goal scenario for the development of adaptation strategies. With this scenario agricultural productivity could even be increased compared to the current level, irrigation needs can be satisfied from available river discharge, and erosion and nitrate leaching are kept to a minimum. Measures contributing to achieving this goal scenario include (i) reduced soil management to reduce nitrate leaching, (ii) increased proportion of grassland to reduce soil loss and enhance organic matter and nitrogen

availability in the soil for subsequent crops in the rotation, (iii) reduced proportion of irrigated spring crops in favor of non-irrigated winter crops, and (iv) increased irrigation to reduce production risks of high-value spring crops.

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Impact of Input Data on Distributed Hydrologic Modeling under Future Climate Change Scenarios

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Session: Impacts

In the process of calibration of hydrological models, accounting for uncertainties existing in input data is both important and challenging. Usually different sources of data are available for a single watershed, which can affect the simulation and calibration process. Selecting the appropriate data set is an important issue which is often neglected by the modelers. This paper assesses the effects of different sources of climate and land use data on discharge simulations in the Karkheh River Basin (KRB) located in semiarid region of Iran.

We used the program Soil and Water Assessment Tool (SWAT) in combination with the Sequential Uncertainty Fitting program (SUFI-2) inherent in SWAT-CUP to calibrate the hydrologic model of the study area. Three available sources of climate data were assessed with four different scenarios and their influences on discharge value simulations were evaluated both before and after the calibration process with different criteria. The data sets with higher performance were selected to assess the sensitivity of land use on the model performance which revealed that locally obtained land-use map outperformed in simulating discharge values.

The results of all scenarios led to obtain four data sets with approximately similar performance but different parameter values. All four sets were used to model blue and green water availability based on climate change scenarios. Future climate scenarios for the period from 2005 to 2099 were generated from Geographic Fluid Dynamic Laboratory- Earth System Models (GFDL-ESM2M) for four new Representative Concentration Pathways (RCPs) emission scenarios of IPCC termed as Rcp2.6, Rcp4.5, Rcp6.0 and Rcp8.5.

We concluded that the uncertainties associated with input data propagate in the modeling processes, parameter estimation and subsequent management policies. Future situations are highly dependent on the sources of input data

and calibration processes. Therefore, careful attention to uncertainties at the simulation and calibration stages is crucially important. They need to be addressed at the outset of any hydrological modeling before they are used in subsequent management policies and climate change impact assessments.

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Title: The impacts of a climate-dependent parameterization of a conceptual hydrological model on discharge projections

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Session: Impacts

As different hydrological processes dominate under different climatic conditions, it is unclear whether the parameterization of a conceptual hydrological model performing well under present conditions is suitable for projections in a future climate. For instance, as drier and hotter summers are expected in Switzerland, it can be argued that a parameterization tuned for hydrological modeling in drier and hotter conditions is required to produce reliable summer projections. This study investigates whether the parameterization of the conceptual and semi-distributed hydrological model HBV should be conditioned on the future climate. Such a conditional parameterization is developed and its potential added-value is evaluated.

First, all the years of the reference period 1980-2009 were plotted on a mean annual temperature vs. total annual precipitation plot, defining four quadrants (dry and cold, dry and hot, wet and cold, wet and warm). HBV was then calibrated for the years of each quadrant using a genetic algorithm generating optimized parameter sets by an evolutionary mechanism. The operation was performed for eight Swiss catchments. Changes of the parameter values could often be related to hydrological processes that become dominant/negligible under particular climatic conditions.

Second, HBV was run for one emission scenario (A1B) for the eight catchments for the 2070-2099 period using CH2011 data. Constant parameters and climate-dependant parameter values were used. The differences in the projected discharge between the two experiments (with constant and climate dependent parameters) are examined. Limitation of the model with respect to parameter identifiability, stability, predictability and equifinality are discussed.

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Half of the world's population affected by changes in the water cycle by the end of the century

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Session: Impacts

Water is one of the most valuable resources on Earth. Thus it is not only important to know what the projected changes are but also how robust these changes are. Further it is also of advantage to know where these changes occur and how many people are affected by these changes. In this study we use the CMIP5 archive to investigate the changes of the water cycle. As a measure of significance we use two different quantities. The first one is called robustness and is adapted from weather forecasting evaluation. The second quantity is the number of models, which project a significant change. Several variables of the water cycle such as evaporation and relative humidity show a robust change already with a warming of 1C over more than 50% of the land surface. A warming of 2C, which corresponds roughly to the warming excepted by the mid-century in a RCP8.5 scenario, shows that more than half of the world's population is affected by robust changes in the water cycle. Interestingly the population affected are well distributed over the globe and not concentrated in a few hot-spots. This means also that the changes of the hydrological cycle are distributed over the whole land mass.

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An approach for transient consideration of forest change in hydrological impact studies

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Session: Impacts

Several approaches have been recently presented to include transient glacier retreat scenarios in the context of modeling the impacts of climate change on water resources in mountainous areas. Only few studies attempted evaluating the impacts of forest change. We developed a conceptual framework in order to explore the impacts of tree migration on the hydrology of two large Swiss catchments (Rhône and Ticino).
We run the spatio-temporal forest evolution model TreeMig for the period 1400 to 2100 with input from observations and from the A1b "Ensembles"-Scenario ECHAM5-REMO. Within the period 1950 to 2100 maps of forest biomass and leaf- area-index (LAI) have been processed to obtain differential maps as compared to the forest coverage and LAI adopted in the hydrological model PREVAH. PREVAH has been recently used to realize climatology of hydrological resources for entire Switzerland for the periods 1980-2009 (control period), 2021-2050 (near future) and 2070-2099 (far future). Climate scenarios were available for 10 different realizations of regional scenarios (A1b "Ensembles"-Scenarios) including the realization ECHAM5-REMO. Rules relying on the change in biomass and LAI have been developed in order to remove or add forested areas to the domain of PREVAH. Every 5 year forest coverage and LAI have been updated.
Analyses show a degradation of forest for the 2070–2099 period in the lowest elevation ranges (< 1200 m) as a result of increased drought stress. This result in lower LAI, reduced interception and increased discharge as compared to a baseline run without implementation of forest scenarios. For elevation ranges above 1500 m TreeMig predicts higher biomasses and LAI. The simulated tree-line elevation might increase of up to 200 m. PREVAH computes in these areas higher evapotranspiration and less runoff as compared to the baseline run. Consideration of forest change yields in both areas changes in simulated discharge of -5 to -10 mm per year and changes

in evapotranspiration of +5 to +10 mm per year. However, changes at specific elevation bands are up to four times higher.

Further research is needed to achieve more robust results concerning magnitudes of change in both forest dynamics and hydrological cycle. A major issue to account for is a better representation of drought and its effects on tree physiology in TreeMig, up to a full coupling with PREVAH to close the feedback loop forest dynamics – hydrology – forest dynamics.

The strong impact of single extreme drought events indicates that for sound climate change assessments ensemble type simulation runs with several replicates of climate change scenarios are necessary.

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COSMO-NExT, the future short-range NWP system of MeteoSwiss

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Session: Regional to local aspects

The COSMO-based future short-range numerical weather prediction (NWP) system at MeteoSwiss will consist of a O(1km) mesh-size deterministic model ("COSMO-1") and a O(2km) mesh-size ensemble component ("COSMO-E") for the Alpine domain, both planned to be operational in 2016.

The poster will present the specifications of these two model components as well as of the data assimilation system planned to provide the initial data for both models. Latest results of the research and development work within the MeteoSwiss-project COSMO-NExT will be shown, with special emphasis on the water cycle.

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Seasonal Evaporation Variability in the South Atlantic.

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Session: Regional to local aspects

Climatological averages of evaporation from the ocean surface in the South Atlantic region show a strong seasonal variability, doubling from 2-3 mm/day in austral Spring/Summer to 5-6 mm/day in Autumn/Winter. The question is, are the seasonal variations in evaporation determined by the atmospheric state over the large, basin-scale sea surface temperature (SST) gradients or do small scale SST anomalies associated with fronts and meso-scale eddies play a significant role? This is particularly evident in Brazil-Malvinas confluence zone, where the warm poleward flowing Brazil and the cold equatorward Malvinas current meet, producing a strong sea surface temperature (SST) front, but also generates energetic mesoscale eddies that propagate with an associated warm or cold SST anomaly compared with the surrounding water. Here we present results from a recently developed, regional Ocean-Atmosphere coupled model (COSMO-ROMS) in the South-Atlantic compared with atmospheric (COSMO) simulations forced with and without an eddy SST field.

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Does increased RCM resolution lead to a better representation of heavy precipitation?

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Session: Regional to local aspects

The present contribution is part of a study developed in the framework of the Euro-CORDEX initiative. The main objective is to compare several regional climate models (RCMs) at different target spatial scales over the Alpine area. For this purpose, downscaled precipitation is evaluated at two horizontal resolutions (0.11º corresponding to approx. 12 km, and 0.44º corresponding to approx. 50 km) in simulations from the Euro-CORDEX RCM ensemble, all of them using the ERA-Interim reanalysis as boundary conditions.

We focus on the European Alps because of their special climate characteristics and their high vulnerability to changes in climate. In this region, a high-resolution gridded observational data set recently became available. It has been constructed by MeteoSwiss within the EURO4M project and provides daily precipitation at a horizontal resolution of 5 km. These gridded observations were spatially averaged to match the Euro-CORDEX grid cells.

The comparison will not only be accomplished in terms of validation against observations in both resolutions. Also the ability of the high-resolution RCM simulations (0.11°) to represent observed precipitation is assessed at their skillful scale by aggregating the 0.11° grid to the 0.44° resolution and evaluating the added value with respect to the low resolution (0.44°) runs. The study will especially consider heavy precipitation characteristics and will assess the effect of model resolution on the tails of the probability distribution function. Additionally, the analysis might include preliminary results concerning the resolution effect in statistical downscaling methods.

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Propagation of climate change effects on water resources across the catchment: The upper Rhone case study

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Session: Regional to local aspects

A distributed long-term hydrological balance of the upper Rhone basin was investigated including forcing due to climate change and anthropogenic disturbances (reservoirs, river diversions and irrigated areas) simulated at an unprecedented level of detail for catchment of this size and complexity. We downscaled climate model realizations using a methodology that allows us to account for stochastic variability of climate. The analysis aimed to propagate until the middle of the 21st century climate change effects on streamflow from high elevation headwater catchments to rivers in the major valleys. Despite a large uncertainty induced by stochastic climate variability, we identified an elevational dependence of climate change impacts on streamflow with a severe reduction at high-elevation, due to the missing contribution of water from ice melt, and a strongly dampened effect downstream. A decrease of summer discharge and an increase of maximum flows appear as the most robust projected changes for the different parts of the catchment. However, it is unlikely that major changes in total discharge from the entire upper Rhone basin will occur in the next decades. Finally, changes in the natural hydrological regime imposed by the existing hydraulic infrastructure are likely larger than climate change signals expected by the middle of the 21st century in most of the river network.

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Climatology of extreme hourly precipitation in Switzerland

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Session: Regional to local aspects

Intense hourly precipitation in the Alpine region can lead to flash floods, mudslides, and landslides; in the form of snow, it can help trigger avalanches. Despite the dire need for information on the frequency of such events, systematic analyses of extreme hourly precipitation have been hindered by the lack of long records of data at high temporal resolution. Since the 1980s, MeteoSwiss has at its disposal a network of automatic stations that record precipitation at 10-minute intervals, thus providing a collection of relatively long time-series of precipitation at sub-daily resolution. Our purpose is to provide a climatology of extreme hourly precipitation based on Extreme Value Theory.

Hourly precipitation at 59 stations of the MeteoSwiss observational network are analyzed with the Peaks-over-Threshold (POT) approach over the period 1981-2010. The winter (December-January-February) and summer (June-July-August) seasons are considered separately. The Generalized Pareto Distribution (GPD) is fitted to independent exceedances over a high threshold. Independence is achieved by first defining clusters as groups of exceedances separated by an arbitrarily chosen number of non-exceedances called the run parameter; only the maximum of each cluster is then retained. The joint selection of threshold and run parameter is performed automatically, using an automated variation of an existing graphical method.

In addition to extreme value analysis, the temporal dependence at extreme levels of each time series for different lags is also examined, revealing the lag at which dependence dies out. This provides information on the duration of the extreme events and helps validate the run parameter selection to some extent.

The resulting climatology reflects known aspects of the Swiss climate: extreme precipitation reaches higher levels in the Swiss Plateau and along the northern and southern Alpine rims, while the inner Alpine valleys display much lower values. In summer, this contrast is reinforced by remarkable extremes in the Ticino and the Swiss Plateau. An unexpected result of the present study is that - unlike is generally known for daily precipitation - the shape parameter is mostly negative in winter and positive in summer. Temporal dependence at extreme levels reveals prolonged dependence in winter extreme events, sometimes up to 3 days. In summer, dependency does not extend beyond 10-15 hours in the Swiss Plateau and 20-30 hours in the Ticino area. These features are reflected in the run parameters selected by the automatic method.

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Do land parameters matter in large-scale hydrological modeling?

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Session: Regional to local aspects

Many of the most pending issues in large-scale hydrology are concerned with estimating hydrological variability at locations without observations. However, current-generation hydrological and land surface models that are used for their estimation suffer from large uncertainties. These models rely on mathematical approximations of the physical system as well as on mapped values of land parameters (e.g. topography, soil types, land cover) to predict hydrological variables (e.g. evapotranspiration, soil moisture, stream flow) as a function of atmospheric forcing (e.g. precipitation, temperature, humidity). Despite considerable progress in recent years, it remains unclear whether better estimates of land parameters can improve predictions – or – if a refinement of model physics is necessary. To approach this question we suggest scrutinizing our perception of hydrological systems by confronting it with the radical assumption that hydrological variability at any location in space depends on past and present atmospheric forcing only, and not on location-specific land parameters. This so called "Constant Land Parameter Hypothesis (CLPH)" assumes that variables like runoff can be predicted without taking location specific factors such as topography or soil types into account. We demonstrate using a modern statistical tool that monthly runoff in Europe can be skilfully estimated using atmospheric forcing alone, without accounting for locally varying land parameters – and – that the inclusion of available land parameters does not increase model skill. The resulting runoff estimates are used to benchmark state-of-the-art process models. These are found to have inferior performance, despite their explicit process representation. This suggests that progress in the theory of hydrological systems is likely to yield larger improvements in model performance than more precise land parameter estimates. The results also question the current modelling paradigm that is dominated by the attempt to account for locally varying land parameters in ever greater detail. While improved physically-based models are under development, the proposed statistical model can be used to produce full space-time estimates of monthly runoff in Europe, contributing to practical aspects of the discipline including water resources monitoring and seasonal forecasting.

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Sea ice freshwater fluxes: An underestimated driver of the Southern Ocean water cycle and its recent changes

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Session: Regional to local aspects

The formation, lateral transport, and melting of sea ice represent a substantial redistribution of freshwater in time and space and a key process for the determination of upper ocean stratification in the Southern Ocean. Sea ice is transported northward in large parts the Southern Ocean due to strong near-surface winds and then melts south of the Polar Front. Here, we estimate the annual sea ice-induced freshwater flux in the period 1979 to 2006 by merging ice concentration and drift data from satellite observations with ice thickness estimates from model simulations that assimilate the observed ice distribution. In the net over the annual cycle, sea ice removes freshwater from the surface ocean all along the Antarctic coast in polynya regions and releases it at lower latitudes, in particular in the Ross and Weddell Seas. When comparing the fluxes associated with sea ice to atmospheric reanalysis data, we find that they can locally exceed the atmospheric fluxes by up to one order of magnitude. Over recent decades, these sea ice-induced freshwater fluxes have strongly increased in most of the southern Pacific along the ice edge. We hypothesize that this increased northward freshwater flux by sea ice caused an increased stratification south of the Polar Front. This interpretation is consistent with the observed freshening of surface and intermediate water masses exported from the Southern Ocean. The increased vertical stability of the upper ocean due to increased sea ice flux and an associated reduced vertical heat transport would also support the observed cooling of the surface and warming of the deeper layers. As no consistent trends have been detected in the atmospheric freshwater fluxes or in the ocean circulation which could explain the observed changes in the water masses, sea ice freshwater flux trends provide a potential missing key mechanism to understand hydrographic changes in the Southern Ocean.

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Precipitation forcing fields for the Alpine region: Methods and insights from a new transnational dataset

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Session: Regional to local aspects

High-mountain ranges efficiently extract precipitable water from the atmosphere, and they take an important role in storing and providing freshwater water to their larger surrounding. The need to quantify precipitation variability and to model hydrological processes calls for spatially comprehensive datasets of observed precipitation, preferably represented on a regular grid. Existing grid datasets for the region of the European Alps are often segmented between national territories, or they are of comparatively coarse resolution.
Here we present a new gridded precipitation dataset for the Alpine region that is suitable for climate and hydrological research with a trans-national area of interest. The dataset is a fundamental renewal and extension of an earlier pan-Alpine dataset, developed at ETH Zürich. It covers the Alpine sectors of seven countries (Austria, Croatia, France, Germany, Italy, Slovenia and Switzerland), makes use of rain-gauge data from high resolution national networks (8300 time series in total, 5500 stations on average), and expands over 38 years (1971-2008) at a daily time resolution. Our presentation introduces the station data used for this new dataset, it elaborates on the method of spatial analysis employed, and discusses the potential and limitations of the dataset for climatological analysis and modeling. We also illustrate insights on the Alpine precipitation climate that were gained from the new dataset, with an emphasis on indicators for heavy precipitation and long dry periods. This study is part of EU project EURO4M. The grid dataset is available for scientific use from the web-site of MeteoSwiss.

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Stochastic modeling of future precipitation fields for Switzerland

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Session: Regional to local aspects

Regional climate models (RCM) are useful tools to generate physically and spatially consistent information about possible future climate change at a horizontal scale of several tens of kilometers. However, RCM data often suffer from substantial biases and in light of effective climate adaptation planning, their spatial scale is often too coarse to model the impact of climate change at the local scale. Ideally, probabilistic projections of potential future weather situations should be available locally and at least in daily resolution. Statistical downscaling approaches based on weather generators are particularly appealing to generate large ensembles of local scenarios with reduced mean biases in the control period. However, they often do not guarantee temporal and spatial coherence of the downscaled weather variables and the dependencies between them. The spatial coherence is of particular importance over climatologically heterogeneous topographies such as the Swiss Alps.

To meet some of the manifold needs of the impact community, we explore here the potential of a statistical downscaling approach for precipitation that combines a multi-site weather generator (WG) with a conditional resampling approach. This hybrid approach aims at generating future daily precipitation fields for Switzerland based on RCM simulations (from ENSEMBLES) and gridded, high-quality and high-resolution (~2 km x 2 km) observational data from MeteoSwiss.

We present the underlying concept of this approach which is to apply the multi-site WG to aggregated regions in Switzerland in order to generate daily wet-dry patterns. The analysis of observed transition probabilities reveals a

large spatial, seasonal and inter-annual variability. In general, the latter exceeds those of space and season, including both sampling uncertainty and changes from one year to another. There is also a clear distinction between high-elevated regions and the lowlands. RCM simulations reproduce altitude- and season-dependent transition probabilities of daily precipitation. They differ, however, largely on the geographic manifestation depending on the model's topography. On the other hand, the analysis of future changes in these WG parameters reveals remarkably homogenous changes in space and season. We use the observed transition probabilities and their changes together with the observed spatial correlation structure in order to generate spatially coherent future dry-wet fields with daily resolution. These can for instance be used for improved projections of summer droughts.

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Evaluation of cloud-resolving simulations of summer convection with SEVIRI and GERB satellite data

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Session: Regional to local aspects

Diurnal moist convection is an important part of precipitation over Central Europe and the Alps, in particular in summer when the synoptic forcing is weak. This convection is poorly represented in current models using parameterized convection often leading to large biases and a too early onset and peak of precipitation. These biases raise questions regarding the robustness of important aspects of European climate change scenarios for the summer season. Preliminary experience with cloud-resolving models has shown promising results. Here we use the COSMO-CLM model in a cloud-resolving setup to investigate the diurnal cycle of moist convection and validate the model simulations using a variety of observations with a focus on satellite data. The satellite data used comes from the SEVIRI and GERB sensors onboard the Meteosat Second Generation geostationary satellites. SEVIRI provides high temporal and rather high spatial resolution information on fast developing convective cells. GERB provides information about the top-of-the-atmosphere energy budget which is strongly influenced by clouds. We investigate the influence of model setup, lateral boundary and initial conditions on the diurnal cycle of moist convection over the European Alps and adjacent regions. Large differences in cloud amounts are found for different model configurations, while the timing of convection onset is, however, quite similar. It is found that the lateral boundary conditions have the largest influence on the simulated diurnal cycle, even though the period investigated was dominated by weak synoptic forcing. The mean energy flux over the whole domain in the model is quite similar to the energy flux measured by GERB, although larger differences exist at smaller scales. The results are used to define an optimized model configuration.

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21st century climate change in Europe and the Alps: First results from a EURO-CORDEX COSMO-CLM ensemble

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Session: Regional to local aspects

Rising greenhouse gas concentrations during the 21st century are expected to lead to significant climatic changes on global and regional scales, including components of the atmospheric and the terrestrial water cycle. The estimation and quantification of these changes using climate models is subject to considerable uncertainties originating from factors such as emission scenario uncertainty, internal climate variability and model uncertainty. The respective uncertainty ranges can partly be assessed by analyzing ensembles of experiments that sample the above mentioned uncertainty sources to some extent.

We here present a first analysis of an ensemble of the regional climate model COSMO-CLM in terms of 21st century climate change over Europe in general and over the European Alps in particular. The ensemble has been carried out within the frame of EURO-CORDEX, the European branch of the WCRP CORDEX initiative (*http://wcrp-cordex.ipsl.jussieu.fr*). It consists of several transient COSMO-CLM experiments covering the period 1950-2099 and carried out at two different resolutions (12 km and 50 km), assuming different greenhouse gas emission scenarios and applying the outputs of different global climate models as lateral boundary forcing. Changes of the standard parameters 2m temperature and precipitation as well as of further parameters relating to the regional water cycle such as cloud cover, snowfall and surface snow cover are analyzed. The ensemble analysis confirms the basic findings of previous studies, but allows to address the influence of individual uncertainty sources in a more systematic way. Furthermore, the comparatively high spatial resolution of the 12 km experiments allows to better resolve the spatial variability of future climate change particularly over the European Alps.

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Extending water vapor trend observations over Boulder into the tropopause region: trend uncertainties and resulting radiative forcing

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Session: Regional to local aspects

Thirty years of balloon-borne measurements over Boulder (40°N, 105°W) are used to investigate the water vapor trend in the tropopause region. This analysis extends previously published trends, usually focusing at altitudes above 16 km, to lower altitudes. Two new concepts are applied: 1) Trends are presented in a thermal tropopause (TP) referenced coordinate system from 2 km below to 10 km above the TP. 2) Sonde profiles are characterized according to tropical and midlatitude TP heights to take into account the jet stream location. A data selection into a tropical branch (Tpz>14km), mid-latitude branch (Tpz<12km), and transitional branch (12km<TPz<14km), reveals three different water vapor reservoirs.

The analysis based on these concepts reduces the dynamically-induced water vapor variability at the TP and principally favors refined water vapor trend studies in the upper troposphere and lower stratosphere. Nonetheless, this study shows how uncertain trends are at altitudes -2 to 4 km around the TP. This uncertainty in turn has an influence on the uncertainty and interpretation of water vapor radiative effects at the TP, which are locally estimated for the 30 year period to be of uncertain sign -0.13+-0.50 W/m².

The much discussed decrease in water vapor at the beginning of 2001 is not

visible between -2 to 2 km around the TP. At higher altitudes, a decrease in water vapor is most obvious within the transitional branch. This suggests a possible link of water vapor decrease with changing dynamics above the jet stream such as the shallow branch of the Brewer-Dobson circulation.

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Modeling future climatic time-series according to climate change scenarios.

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Session: Regional to local aspects

The modeling of climatic variables is a key topic for hydrological and climate science applications: the challenge is to simulate synthetic time-series honoring the reference statistics as well as respecting the seasonality and the persistence from the daily to the annual scale.

The direct sampling technique (DS) belongs to the family of multiple point geostatistics (MPS) techniques. It is proposed as a non parametric alternative to the classical autoregressive and Markov chain based models for time-series simulation. The rationale of the DS is the use of a search window to directly find and compare similar patterns between the training dataset (the past record) and the simulated data. The strong point of this approach is the capability of simulating complex statistical relations by simply respecting the similarity of multiple scales patterns. Moreover, the DS allows the coupled simulation of multiple variables, honoring their complex correlations.

In this presentation, we show the application of the DS to the simulation of present and future temperature, radiation and humidity time-series from the Buchs station (Aargau, Switzerland), using high spatial resolution predictions on future temperature change from the project ALADIN (CNRM, France, downscaled values from CH2011, Bosshard 2011). In the first example, a stationary simulation is performed in order to simulate many realizations of the present record. In the second one, we make use of the predictions on temperature change until 2085 to model the future change in radiation and humidity. This is accomplished by imposing the future change using the linear relations (regressions) between the variables, while the complex structure of the residuals is modeled using the DS.

It is demonstrated that the DS technique without any parameters optimization allows to simulate the present climate record respecting the overall statistics and the relations between the variables accurately. Moreover, the proposed method can easily incorporate the information from climate change predictions to generate realistic future changes respecting the annual seasonality and the correlations between variables. These changes are visible in the central tendency as well as in the extreme values.

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Using soil moisture forecasts for sub-seasonal summer temperature predictions in Europe

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Session: Regional to local aspects

Soil moisture exhibits outstanding memory characteristics and plays a key role within the climate system. These attributes make soil moisture an important variable in the context of weather- and climate forecasting. Especially through its impacts on the evapotranspiration of soils and plants, it may influence the land energy balance and therefore surface temperature. In this study we investigate the importance of (initial) soil moisture information for sub- seasonal temperature forecasts using a mostly observation-driven approach. For this purpose we employ a simple water balance model to infer soil moisture from streamflow observations in 100 catchments across Europe. Running this model with forecasted atmospheric forcing, we derive soil moisture forecasts which we translate into temperature forecasts using simple linear relationships. The resulting temperature forecasts show skill beyond climatology up to 2 weeks in almost all considered catchments. Even if there is significant skill only in a few catchments at the highest investigated lead time of 4 weeks, this is an improvement compared to the monthly ECMWF temperature forecasts at that lead time. In addition, also the average forecast skill of all catchments is slightly higher than in the ECMWF product. We find better forecast performance in the case of extreme events, especially at long lead times and for dry anomalies. The forecasts skills are mainly controlled by the strength of (i) the soil moisture- temperature coupling and (ii) the soil moisture memory. The negative relationship between these controls weakens the forecast skills, nevertheless there is a middle ground between both controls in several catchments, as shown by our results.

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Sensitivity of extreme precipitation events in Switzerland to moisture variations – simulations with the high-resolution numerical model COSMO

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Session: Regional to local aspects

Dimensioning of flood protections is based on the estimation of the probable maximum flood (PMF). A reliable estimate of this quantity can only be made using a realistic estimate of the probable maximum precipitation (PMP) in the considered catchment. However, traditionally used procedures to estimate the PMP are not well suited for mountainous regions. These procedures typically transfer an extreme precipitation event observed in a nearby area to the catchment of interest with some adaptation for the differing topography. But the complex terrain does strongly affect the precipitation distribution and impose strong nonlinearities for the precipitation resulting from small variations in the atmospheric flow conditions. Therefore an in-depth knowledge of the precipitation characteristics of a catchment is needed to obtain realistic estimates of the PMP and eventually the PMF.

We use the high-resolution numerical weather prediction model COSMO to study small-scale processes induced by topography-flow interactions. A sensitivity analysis is performed to determine the influence of subtle variations in atmospheric parameters such as specific humidity, wind direction, and temperature on the precipitation distribution. For this purpose, various approaches are used to modify either the initial and boundary conditions of humidity and temperature, or the wind field via a synthetic PV modification and PV inversion. Simulations are performed for different flood events in Switzerland, including the December 1991 event in the La Suze catchment in the Jura mountains and the October 2011 event in the Lütschine catchment in the Bernese Oberland.

The results show that, for instance an increase of the specific humidity of the incident flow does not necessarily produce an increase of precipitation in the target catchment. Indeed, with increased ambient moisture, smaller mountains upstream of the catchment can be more efficient in triggering precipitation and therefore reduce the moisture available downstream. This novel approach with a set of synthetic sensitivity experiments allows estimating, for a particular catchment, the physical limits of the PMP value.

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Projections of extreme precipitation events in regional climate simulations for Europe and the Alpine region

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Session: Regional to local aspects

Regional climate models (RCMs) from the ENSEMBLES project are analyzed to assess projected changes in 21st century heavy and extreme precipitation events over Europe. A set of 10 RCMs with horizontal grid spacing of 25 km is considered, which are driven by 6 GCMs under an A1B greenhouse gas scenario. The diagnostics include basic precipitation indices (including mean, wet-day frequency, intensity and percentile exceedance) and application of generalized extreme value theory for return-periods up to 100 years. Changes in precipitation climate between present (1970-1999) and future (2070-2099) conditions are presented on a European scale, and in more detail for 11 European regions, including a detailed analysis of changes in Alpine return values of precipitation extremes.

On the European scale, projections show increases (decreases) in mean amounts and wet-day frequency in northern (southern) Europe. This pattern is oscillating with the seasonal cycle. Changes in extremes exhibit a similar pattern, but increases in heavy events reach much further south. For instance, during spring and fall, much of the Mediterranean is projected to experience decreases in mean precipitation, but increases in heavy events. Thus, projected changes in mean and extremes may show different signals.

The inter-model spread is partly attributable to a GCM-dependent clustering of the climate-change signal, but also affected by RCM uncertainties, in particular in summer. Despite these uncertainties, many of the projected changes are statistically significant and consistent across models. For instance, for the Alps, all models project an intensification of heavy events during fall, and these changes are statistically significant for a majority of the models considered.

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The role of Mediterranean cyclones for producing large-scale wind and precipitation extremes

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Session: Regional to local aspects

Extreme wind and precipitation events are associated with the passage of cyclones and their attendant fronts in the Mediterranean region. Particularly, large scale high-impact extremes are of societal importance for their association with a high risk for extended flooding and severe damage. Yet, the majority of current studies analyze local extremes as observed at single stations, or at a grid point, over a short time duration. Thus, key aspects regarding large-scale extremes remain unresolved: 1) what fraction of extreme events are related to cyclones in the different regions of the Mediterranean? 2) what are the special features of cyclones that produce extremes compared to average cyclones? 3) how often do large-scale extremes in wind and precipitation co-occur?
We study these questions by statistical analysis of large-scale extreme precipitation and gust events that are identified objectively using ERA-Interim data for 1979-2012, and with investigation of dynamical processes that occur during the evolution of a few selected cyclones associated with extremes, using both ERA-Interim data and mesoscale model (COSMO) simulations.
We find that Mediterranean cyclones associated with extremes are characterized uniquely by at least one of the following: 1) stationary position, allowing accumulation of precipitation; 2) rapid deepening, creating strong pressure gradients and winds; 3) strong surface fluxes, adding contributions of intense diabatic processes to increase cyclone intensity and precipitation; 4) their location near topography enhances precipitation.
Here we present the statistical analysis results of large-scale extreme precipitation and surface wind gusts and a detailed representative case study.

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Assessment of future snow pack in two Alpine regions

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Session: Regional to local aspects

The snow cover in the Alps is heavily affected by climate change. In this study we present an assessment of the future snow water equivalent and snow depth for the Swiss Canton of Graubünden and the Aare catchment in the central Swiss Alps. The data of 48 automatic weather stations in the Aare catchment, respectively 34 automatic weather stations in Graubünden, have been used as the input for Alpine3D, a spatially distributed model for the high-resolution simulation of alpine surface processes. These catchments have been modeled at 200 m horizontal resolution for a 13 years reference period (1999-2012). Three different emission scenarios for temperature and precipitation (A2, A1B and RCP3PD) and for three different time periods (2020-49, 2045-74, 2070-99) have been taken from the Swiss Climate Change scenarios CH2011 Plus. By applying simple daily shifts of temperature and precipitation to the measured time series, input for the small-scale climate scenarios has been generated.

The model results show a decrease smaller than 20 % in the snow depth for the first time period 2020-49 for all three emission scenarios. For the time 2070-99 however, the relative decrease in snow depth is as high as 70 % for the A2 scenario. The most sensible elevation zone for climate change is located around 800–1200 m, where the simulations show almost no snow for 2070-99. The winter season starts, depending on the emission scenario and the elevation zone, 2-4 weeks later and ends 5-8 weeks earlier. Towards the end of the century the snow cover changes will roughly be equivalent to an elevation shift of 500-700 m or 600-900 m for A1B or A2, respectively. The number of snow days will be halved at an elevation of around 1500 m and is predicted to 0-2 snow days in the Swiss Plateau and the low Rhine valley in Graubünden. The A2 scenario projects a catchment-wide snow water equivalent reduction of up to two thirds towards the end of the century. These changes in snow duration and snow amount will affect changes in the melt water runoff, which has important consequences for winter tourism and hydropower generation.

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On the predictability of hydrological droughts with a conceptual model

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Session: Regional to local aspects

Since the extreme summer of 2003 the importance of early drought warning is increasingly recognized also in apparently water-rich countries like Switzerland. The year 2011 provided additional examples of drought conditions in Switzerland, which are expected to become more frequent in the future. So far, little has been done regarding drought forecasting in Europe. A fundamental question related to drought forecasting is: How long before a hydrological drought actually occurs, can it be predicted? To address this question, we assessed the relative importance of current hydrological state and weather during the prediction period. A conceptual catchment model (the HBV model) was calibrated to 21 Swiss catchments and for each of them two modeling experiments were performed: 1) Streamflow was simulated starting with the same initial hydrological state but with different observed series (i.e. from different years) of precipitation and temperature to derive 'predictions'. 2) Streamflow was simulated using various initial hydrological states, but the same longterm means of precipitation and temperature as forcing. Both experiments were repeated four times, shifting the start of the simulations to different seasons. The relative importance of initial hydrological state and weather during the prediction period was evaluated by estimating the persistence of the initial hydrological states in the prediction for both experiments. To further distinguish between effects of weather and catchment properties, the resulting persistences were tested on their sensitivity to changes in total precipitation amounts and air temperature. For the investigated catchments the persistence in streamflow appeared to be more depending on catchment characteristics and less on the start of the prediction period. Drier initial conditions of soil moisture and deeper groundwater storage resulted for most catchments in longer persistence estimates, while the initial conditions of snow and upper groundwater storage showed no clear effect on the persistence. From the preliminary results of the sensitivity analysis, the persistence estimates seem not sensitive to changes in precipitation..

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A 2000-year long seasonally resolved record of floods in the Southern European Alps: An indication for future flood occurrence

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Session: Regional to local aspects

Knowledge of the past natural flood variability and the underlying controlling climate factors is of high value, since it supports and refines projections on the future flood behavior. These records of past floods triggered by heavy precipitation events can be established using sedimentological archives, which cover a long time period reaching beyond the historically documented interval and are therefore largely unaffected by human activities influencing river and lake systems. In this context, we present a seasonally resolved 2000-year long flood-frequency and -intensity reconstruction from the Southern Alpine slope (Northern Italy) using annually laminated (i.e. varved) lake sediments. The annual lamination allows determining the season during which the flood occurred, as indicated by the stratigraphic position of the flood layer within the sedimentary varve cycle. The reconstructed flood signal reveals a dominance of summer (26.2%) and autumn (63.4%) events, while winter (3.7%) and spring (6.7%) events are rare. The overall flood frequency, as well as the intensity of summer events, is increased during solar minima, proposing solar- and temperature-induced circulation changes resembling a negative state of the North Atlantic Oscillation (NAO) as controlling

atmospheric mechanism on flood occurrence in this South-Alpine study area. Furthermore, the comparison of our data with a sea-surface temperature (SST) reconstruction based on foraminiferal oxygen isotopes from the Mediterranean indicates that positive SST anomalies, and thus increased Mediterranean moisture contribution, are important for triggering extreme (torrential) autumn events at the South-Alpine slope. Applying these results to the present climatic changes, our seasonally resolved flood data set proposes a strong decrease in the occurrence of summer floods but an increase in the intensity of autumn floods with climate warming at the South-Alpine slope.