Annex 1: List of most important publications of the NCCR

ANNEX 1 of WP1

Publication 1:
Luterbacher, J., D. Dietrich, E. Xoplaki, M. Grosjean, H. Wanner, 2004: European seasonal and annual temperature variability, trends, and extremes since 1500, Science, 303, 1499-1503.
Abstract: Multiproxy reconstructions of monthly and seasonal surface temperature fields for Europe back to 1500 show that the late 20th- and early 21st-century European climate is very likely (>95% confidence level) warmer than that of any time during the past 500 years. This agrees with findings for the entire Northern Hemisphere. European winter average temperatures during the period 1500 to 1900 were reduced by similar to 0.5 degrees C (0.25 degrees C for annual mean temperatures) compared to the 20th century. Summer temperatures did not experience systematic century-scale cooling relative to present conditions. The coldest European winter was 1708/1709; 2003 was by far the hottest summer.
Relevance of the publication/result: Summer temperature extremes affect the local to regional natural environment, society, and economy, including most vital aspects such as water supply, agriculture- and human health. The study provides evidence, that the European summer of 2003was very likely the warmest over the last half millennium. Within the period fromJune to August 2003 thousands of people died of heat. Despite previous effortsundertaken by a few cities to implement warning systems, the dramatic episode withrecord heat waves has highlightedthe widespread un-preparedness of most civil and health authorities to cope withsuch large events. Given this, the study contributes to several of the major goals of NCCR Climate during the phase 1.

Publication 2:
Raible, C. C., M. Yoshimori, T. F. Stocker, C. Casty, 2007: Extreme midlatitude cyclones and their implications to precipitation and wind speed extremes in simulations of the Maunder Minimum versus present day conditions, Clim. Dyn., 28, 409-423, DOI: 10.1007/s00382-006-0188-7.
Abstract: Extreme midlatitude cyclone characteristics, precipitation, wind speed events, their interrelationships, and the connection to large-scale atmospheric patterns are investigated in simulations of a prolonged cold period, known as the Maunder Minimum from 1640 to 1715 and compared with today. An ensemble of six simulations for the Maunder Minimum as well as a control simulation for perpetual 1990 conditions are carried out with a coupled atmosphere-ocean general circulation model, i.e., the Climate Community System Model (CCSM). The comparison of the simulations shows that in a climate state colder than today the occurrence of cyclones, the extreme events of precipitation and wind speed shift southward in all seasons in the North Atlantic and the North Pacific. The extremes of cyclone intensity increase significantly in winter in almost all regions, which are related to a stronger meridional temperature gradient and an increase in lower tropospheric baroclinicity. Extremes of cyclone intensity in sub regions of the North Atlantic are related to extremes in precipitation and in wind speed during winter. Moreover, extremes of cyclone intensity are also connected to distinct large-scale atmospheric patterns for the different sub regions, but these relationships vanish during summer. Analyzing the mean 1,000 hPageopotential height change of the Maunder Minimum simulations compared with the control simulation, we find a similar pattern as the correlation pattern with the cyclone intensity index of the southern Europe cyclones. This illustrates that changes in the atmospheric high-frequency, i.e., the simulated southward shift of cyclones in the North Atlantic and the related increase of extreme precipitation and wind speed in particular in the Mediterranean in winter, are associated with large-scale atmospheric circulation changes.
Relevance of the publication/result: This study is an example of how model simulation can be used in order to help in understanding different evidences of proxy data. During the Maunder Minimum, an exceptional cold period in the last 500 years, we know from proxies that storminess has increased over Northern Europe, but the mean atmospheric circulation (based on other proxies) superficially suggests less storm activity. We applied our model and were able to show that due to the increased north-south temperature contrast Atlantic storms get intensified, while the number of storm is reduced in the north as sea ice extends further south. The study fulfils the aims of better understanding atmospheric circulation modes as well as to deepen our understanding in changes of extremes, here mid latitude storms.

Publication 3:
Frank, D., J. Esper, C. C. Raible, U. Buentgen, V. Trouet, B. Stocker, and F. Joos, 2010: Ensemble temperature reconstruction constraints on CO2 feedbacks, Nature, 463 527-530.

Abstract: The processes controlling the carbon flux and carbon storage of the atmosphere, ocean and terrestrial biosphere are temperature sensitive and are likely to provide a positive feedback leading to amplified anthropogenic warming. Owing to this feedback, at time scales ranging from interannual to the 20–100-kyr cycles of Earth's orbital variations, warming of the climate system causes a net release of CO_2 into the atmosphere; this in turn amplifies warming. But the magnitude of the climate sensitivity of the global carbon cycle (termed γ), and thus of its positive feedback strength, is under debate, giving rise to large uncertainties in global warming projections. Here we quantify the median γ as 7.7 p.p.m.v. CO_2 per ºC warming, with a likely range of 1.7-21.4 p.p.m.v. CO_2 per ºC. Sensitivity experiments exclude significant influence of pre-industrial land-use change on these estimates. Our results, based on the coupling of a probabilistic approach with an ensemble of proxy-based temperature reconstructions and pre-industrial CO_2 data from three ice cores, provide robust constraints for γ on the policy-relevant multi-decadal to centennial timescales. By using an ensemble of >200,000 members, quantification of γ is not only improved, but also likelihoods can be assigned, thereby providing a benchmark for future model simulations. Although uncertainties do not at present allow exclusion of γ calculated from any of ten coupled carbon–climate models, we find that γ is about twice as likely to fall in the lowermost than in the uppermost quartile of their range. Our results are incompatibly lower ($P<0.05$) than recent pre-industrial empirical estimates of ~40 p.p.m.v. CO_2 per ºC, and correspondingly suggest ~80% less potential amplification of ongoing global warming.
Relevance of the publication/result: In this study, we utilized all tree-ring and multi-proxy hemispheric-scale temperature reconstructions and high-resolution CO_2 measurements from three Antarctic ice-cores, to i) define the amplitude of natural and natural + anthropogenic temperature variability, and ii) provide comprehensive empirical constraints on the temperature - CO_2 feedback strength during the past millennium. This study contributed to NCCR Climate and International research agendas by characterizing and narrowing empirical uncertainty on the strength of past feedbacks and by providing a welcome assessment of the relative skill of ten different coupled carbon-climate models. We found that for every °C temperature increase, CO_2 increased by ~8 parts per million – a value 80% smaller than most recent estimates of the climatic sensitivity of the carbon-cycle based upon paleodata, and thereby suggests reduced risk of future catastrophic feedbacks. This study is an important example how data of the past climate can be used to validate or falsify climate model simulations and thus reduce uncertainties in climate projections.

Publication 4:
Trachsel, M., C. Kamenik, M. Grosjean, D. McCarroll, A. Moberg, R. Brázdil, U. Büntgen, P. Dobrovolný, J. Esper, D. C. Frank, M. Friedrich, R. Glaser, I. Larocque-Tobler, L. Nicolussi, D. Riemann, 2012: Multi-archive summer temperature reconstruction for the European Alps, AD 1053 – 1996, Quaternary Science Reviews, 46, 66-79. doi:10.1016/j.quascirev.2012.04.021.
Abstract: We present a multi-site, multi-archive summer temperature reconstruction for the European Alps covering the period AD 1053-1996 using tree-ring and lake sediment data, and compare it with a fully independent reconstruction based on documentary data AD 1500 – 1996. Summer temperatures of the last millennium are characterised by two warm (AD 1053 to 1171 and 1823 to 1996) and two cold phases (AD 1172 to 1379 and 1573 to 1822). Highest pre-industrial summer temperatures are recorded in the 12th century and are similar to the 20th century mean. Lowest temperatures are recorded at the end of the 16th century and were 1°C lower than the 20th century mean. In the light of the reconstruction presented in this study, the high summer temperatures of the late 20th century seem exceptional and unprecedented, and we conclude that they exceed the range of natural climate variability of the last millennium. This result is based on nine different calibration approaches, conservative error estimation and a reconstruction that errors on the side of high, rather than low amplitude of long-term climate change.
Relevance of the publication/result: This study nicely summarizes our efforts in the area of generating climate sensitive proxy records and combining them to a multi-proxy reconstruction. Further the study exploits the combination of different natural archives (annually laminated lake sediments and tree rings) at high time-resolution. This was a major aim of phases 1 and 2 of WP1. Moreover it sheets light on the climate history of Switzerland and the alpine region, another focal point of NCCR Climate.

Publication 5:
Steinhilber, F., J.A. Abreu, J. Beer, I. Brunner, M. Christl, H. Fischer, U. Heikkila, P. W. Kubik, M. Mann, K. G. McCracken, H. Miller, H. Miyahara, H. Oerter, F. Wilhelms, 2012: 9,400 years of cosmic radiation and solar activity from ice cores and tree rings, PNAS, 109, 5967-5971.
Abstract: Understanding the temporal variation of cosmic radiation and solar activity during the Holocene is essential for studies of the solar-terrestrial relationship. Cosmic-ray produced radionuclides, such as Be-10 and C-14 which are stored in polar ice cores and tree rings, offer the unique opportunity

to reconstruct the history of cosmic radiation and solar activity over many millennia. Although records from different archives basically agree, they also show some deviations during certain periods. So far most reconstructions were based on only one single radionuclide record, which makes detection and correction of these deviations impossible. Here we combine different Be-10 ice core records from Greenland and Antarctica with the global C-14 tree ring record using principal component analysis. This approach is only possible due to a new high-resolution Be-10 record from Dronning Maud Land obtained within the European Project for Ice Coring in Antarctica in Antarctica. The new cosmic radiation record enables us to derive total solar irradiance, which is then used as a proxy of solar activity to identify the solar imprint in an Asian climate record. Though generally the agreement between solar forcing and Asian climate is good, there are also periods without any coherence, pointing to other forcings like volcanoes and greenhouse gases and their corresponding feed-backs. The newly derived records have the potential to improve our understanding of the solar dynamics and to quantify the solar influence on climate.
Relevance of the publication/result: This study contributes to goals of the phase 2 and 3 of NCCR Climate. It provides a 9400 years long reconstruction of solar activity by combining high-resolution radionuclide records from different archives, i.e., ice cores and tree rings. Such time series are necessary to assess the role of the sun on climate variability. In particular the modelling part of WP relies on such data records in order to realistically force the simulations for the last millennium - another milestone of NCCR Climate.

Publication 6:
Auchmann, R., Brönnimann, S., Breda, L., Bühler, M., Spadin, R., and Stickler, A.: Extreme climate, not extreme weather: the summer of 1816 in Geneva, Switzerland,Clim. Past Discuss., 7, 3745-3774, doi:10.5194/cpd-7-3745-2011, 2011.
Abstract. We analyze weather and climate during the "Year without Summer" 1816 using sub-daily data from Geneva, Switzerland, representing one of the climatically most severely affected regions. The record includes twice daily measurements and observations of air temperature, pressure, cloud cover, wind speed, and wind direction as well as daily measurements of precipitation. Comparing 1816 to a contemporary reference period (1799–1821) reveals that the coldness of the summer of 1816 was most prominent in the afternoon, with a shift of the entire distribution function of temperature anomalies by 3–4 °C. Early morning temperature anomalies show a smaller change for the mean, a significant decrease in the variability, and no changes in negative extremes. Analyzing cloudy and cloud-free conditions separately suggests that an increase in the number of cloudy days was to a significant extent responsible for these features. A daily weather type classification based on pressure, pressure tendency, and wind direction shows extremely anomalous frequencies in summer 1816, with only one day (compared to 20 in an average summer) classified as high-pressure situation but a tripling of low-pressure situations. The afternoon temperature anomalies expected from only a change in weather types was much stronger negative in summer 1816 than in any other year. For precipitation, our analysis shows that the 80% increase in summer precipitation compared to the reference period can be explained by 80% increase in the frequency of precipitation, while no change could be found neither in the average intensity of precipitation nor in the frequency distribution of extreme precipitation. In all, the analysis shows that the regional circulation and local cloud cover played a dominant role. It also shows that the summer of 1816 was an example of extreme climate, not extreme weather.
Relevance of the publication/result: The paper is a contribution to phase 3 of NCCR and focuses on one of the hydrological most extreme seasons of the past 400 years, namely the "year without summer" of 1816. The paper is based on recently digitized, sub-daily data from this event. These data allow constructing a daily weather type chronology, thus contributing to better understanding the roles of atmospheric circulation for past hydrological extremes in Europe (one of the key questions in Phase 3).

ANNEX 1 of WP2

Publication 7:
Altenhoff, A.M., Martius, O., Croci-Maspoli, M., Schwierz, C., Davies, H.C. 2008: Linkage of atmospheric blocks and synoptic-scale Rossby waves: a climatological analysis. Tellus Series A, 60, 1053-1063, DOI: 10.1111/j.1600-0870.2008.00354.x
Abstract: The link between atmospheric blocking and propagating and breaking synoptic-scale Rossby waves (termed PV streamers) are explored for the climatological period 1958-2002, using the ERA-40 re-analysis data. To this end, potential vorticity (PV) based climatologies of blocking and breaking waves are used, and features of the propagating waves are extracted from Hovmoller dia-

grams. The analyses cover the Northern Hemisphere during winter, and they are carried out for the Atlantic and Pacific basins separately. The results show statistically significant wave precursor signals, up to 5 d prior to the blocking onset. In the Atlantic, the precursor signal takes the form of a coherent wave train, emanating approximately 110 degrees upstream of the blocking location. In the Pacific, a single long-lived (10 d) northerly velocity signal preludes the blocking onset. A spatial analysis is conducted of the location, frequency and form of break-ing synoptic-scale Rossby waves, prior to the onset, during the lifetime and after the blocking decay. It reveals that cyclonic streamers are present to the southwest and anticyclonic streamers to the south and southeast, approximately 43% (36%) of the time in the Atlantic (Pacific) basin, and this is significantly above a climatological distribution.
Relevance of the publication/result: Atmospheric blocks, which are quasi-stationary and long lasting high-pressure systems, quite often result in extreme temperatures and very dry conditions at the surface. Because these systems move very slowly and have a long life time, the impact of the extreme temperature conditions can be significant. This paper addresses the question why these blocks can remain so stationary and how they form. The paper discusses the link between atmospheric blocking and cyclonic disturbances (e.g. low pressure systems) located upstream and downstream of the blocks. These disturbances have a central role. They can both help to establish a block and then help to stabilize the blocks against the mean flow and thereby ensure that the block remains stationary.

Publication 8:
CH2011 (2011): Swiss Climate Change Scenarios CH2011. Published by C2SM, MeteoSwiss, ETH, NCCR Climate, and OcCC; Zurich, Switzerland; 88 pp, ISBN: 978-3-033-03065-7, avail-able from www.ch2011.ch
Abstract: In the course of the 21stcentury, Swiss climate is projected to depart significantly from present and past conditions. Mean temperature will very likely increase in all regions and sea-sons. Summer mean precipitation will likely decrease by the end of the century all over Switzer-land, while winter precipitation will likely increase in Southern Switzerland. In other regions and seasons, models indicate that mean precipitation could either increase or decrease. The projections of future temperature and precipitation are consistent with past observations. Along with these changes in mean temperature and precipitation, the nature of extreme events is also expected to change. The assessment indicates more frequent, intense and longer-lasting summer warm spells and heat waves while the number of cold winter days and nights is expected to de-crease. Projections of the frequency and intensity of precipitation events are more uncertain, but substantial changes cannot be ruled out. In addition a shift from solid (snow) to liquid (rain) precipitation is expected, which would increase flood risk primarily in the lowlands.
Toward the end of the 21stcentury, Swiss climate will be strongly affected by the future course of global greenhouse gas emissions. Even if global temperature change is stabilized below 2°C relative to pre-industrial levels through strong mitigation efforts (the RCP3PD emission scenario, which requires cutting global greenhouse gas emissions by at least 50 % by 2050 relative to 1990), models project further warming for Switzerland of 1.4°C toward the end of the century (most probable value with respect to 1980–2009). This is about the same magnitude of warming as already observed. In the two scenarios without mitigation, the warming would be twice to three times as large.
The CH2011 scenarios are based on a new generation of global and European-scale regional climate models. The model data have been provided by several international projects. New statistical methods were used to generate multimodel estimates of changes, and associated uncertainties, in seasonal mean temperature and precipitation for three representative Swiss regions. This was also done for changes in daily mean values at individual meteorological station sites. Along with the CH2011 assessment, digital scenario data is provided for the three different emission scenarios.
Relevance of the publication/result: The main collaborative component of WP2 is the new Swiss Climate Change Scenarios (CH2011, 2011) initiative. Climate projections at a spatial scale relevant for Switzerland are needed for climate change impact studies, and for the elaboration of an effective and scientifically sound adaptation strategy to climate change. The aim of the CH2011 initiative was to develop, document, and make available a new set of climate projections using most recent data and methodologies. The initiative was developed jointly by C2SM, MeteoSwiss, ETH, NCCR Climate, and OcCC. The updated Swiss climate scenarios employed the newest available set of global and regional climate simulations and were derived using new and improved statistical methods to enable a better quantification of uncertainties in climate projections. CH2011 was released on September 28, 2011 at a major event that attracted several hundred people and received impressive media coverage. The report, the summaries and the associated scenario data are avail-able through a website (http://www.ch2011.ch). It is expected that the new CH2011 scenarios will serve as a basis for a variety of climate change impact studies ranging from health, agriculture, water resources, to glacier retreat. The scenarios will be used as a basis for the CH2014-Impact initiative.Unlike previous climate scenarios for Switzerland, the new scenarios present results for three different emission scenarios.

Publication 9:
Ruckstuhl, C., Philipona, R., Behrens, K., CollaudCoen, M., Dürr, B., Heimo, A., Mätzler, C., Nyeki, S., Ohmura, A., Vuilleumier, L., Weller, M., Wehrli, C., and Zelenka, A., 2008: Aerosol and Cloud Effects on Solar Brightening and the Recent Rapid Warming, Geophys. Res. Lett., 35, L12708, doi:10.1029/2008GL034228
Abstract: The rapid temperature increase of 1°C over mainland Europe since 1980 is considerably larger than the temperature rise expected from anthropogenic greenhouse gas increases. Here we present aerosol optical depth measurements from six specific locations and surface irradiance measurements from a large number of radiation sites in Northern Germany and Switzerland. The measurements show a decline in aerosol concentration of up to 60%, which have led to a statistically significant increase of solar irradiance under cloud-free skies since the 1980s. The measurements confirm solar brightening and show that the direct aerosol effect had an approximately five times larger impact on climate forcing than the indirect aerosol and other cloud effects. The overall aerosol and cloud induced surface climate forcing is ~+1 W m-2 dec-1 and has most probably strongly contributed to the recent rapid warming in Europe.
Relevance of the publication/result: Over Europe a clear relation between declining aerosols and rising solar radiation was observed since the mid-1980s. The measurements show that declining aerosol concentrations primarily increase solar radiation under cloud-free skies, and that clouds have a smaller effect on the observed solar brightening. Follow on NCCR studies have also shown that increasing humidity measured at the surface and a related increase of atmospheric longwave downward radiation enhance the anthropogenic greenhouse effect. This factor increases temperatures over central Europe.

Publication 10:
Schär, C., P.L. Vidale, D. Lüthi, C. Frei, C. Häberli, M.A. Liniger and C. Appenzeller, 2004: The role of increasing temperature variability for European summer heat waves. Nature, 427, 332-336
Abstract: Instrumental observations and reconstructions of global and hemispheric temperature evolution reveal a pronounced warming during the past 150 years. One expression of this warming is the observed increase in the occurrence of heatwaves. Conceptually this increase is under-stood as a shift of the statistical distribution towards warmer temperatures, while changes in the width of the distribution are often considered small. Here we show that this framework fails to explain the record-breaking central European summer temperatures in 2003, although it is consistent with observations from previous years. We find that an event like that of summer 2003 is statistically extremely unlikely, even when the observed warming is taken into account. We pro-pose that a regime with an increased variability of temperatures (in addition to increases in mean temperature) may be able to account for summer 2003. To test this proposal, we simulate possible future European climate with a regional climate model in a scenario with increased atmospheric greenhouse- gas concentrations, and find that temperature variability increases by up to 100%, with maximum changes in Central and Eastern Europe.
Relevance of the publication/result: This study provides an analysis of the record-breaking European heatwave of the summer 2003. Using long-term surface observations from Switzerland, it demonstrates the extreme nature of the event.Even when the mean warming of the past decades is accounted for, it is difficult to reconcile the heatwave with the past climate record. The study suggests that the heatwave might be associated with increases in interannual (year-to-year) summer temperature variability. This hypothesis is supported by regional climate model simulations for the end of the century whichshow a dramatic increase in summer temperature variability in response to anthropogenic greenhouse gas forcing. The study is the first to demonstrate that regional climate models project an increase in European climate variability during the summer season. It has motivated numerous studies addressing the role of such changes for extreme temperature and precipitation.

Publication 11:
Weigel, A. P., Knutti, R., Liniger, M. A. and Appenzeller, C. (2010): Risks of model weighting in multimodel climate projections. J. Clim. Vol. 23, 4175-4191.
Abstract: Multimodel combination is a pragmatic approach to estimating model uncertainties and to making climate projections more reliable. The simplest way of constructing a multimodel is to give one vote to each model ("equal weighting"), while more sophisticated approaches suggest applying model weights according to some measure of performance ("optimum weighting"). In this study, a simple conceptual model of climate change projections is introduced and applied to discuss the effects of model weighting in more generic terms. The results confirm that equally weighted multimodels on average outperform the single models, and that projection errors can in principle be further reduced by optimum weighting. However, this not only requires accurate knowledge of the single model skill, but

the relative contributions of the joint model error and unpredictable noise also need to be known to avoid biased weights. If weights are applied that do not appropriately represent the true underlying uncertainties, weighted multimodels perform on average worse than equally weighted ones, which is a scenario that is not unlikely, given that at present there is no consensus on how skill-based weights can be obtained. Particularly when internal variability is large, more information may be lost by inappropriate weighting than could potentially be gained by optimum weighting. These results indicate that for many applications equal weighting may be the safer and more transparent way to combine models. However, also within the presented framework eliminating models from an ensemble can be justified if they are known to lack key mechanisms that are indispensable for meaningful climate projections.
Relevance of the publication/result: The MeteoSwiss research focused on aspects relevant for operational probabilistic weather and climate prediction to foster the establishment of climate risk management. The research lead to pioneering work in analysis of climate variability, to improved verification metrics and the development of prototype applications in close collaboration with industry partners. The project could clarify why single models can be outperformed by multi-models through an enhancement of reliability. However, the common praxis of weighting models according to their past performance has been shown to deteriorate the predictive skill (Weigel et al., 2010). These findings also apply to climate change projections. Consequently, MeteoSwiss could substantially contribute to the scientific basis for the new Swiss climate change scenarios CH2011.

Publication 12:
Wild, M., Gilgen, H., Roesch, A., Ohmura, A., Long, C., Dutton, E., Forgan, B., Kallis, A., Russak, V., and Tsvetkov, A., 2005: From dimming to brightening: Decadal changes in solar radiation at the Earth's surface. Science, 308, 847-850.
Abstract: Variations in solar radiation incident at Earth's surface profoundly affect the human and terrestrial environment. A decline in solar radiation at land surfaces has become apparent in many observational records up to 1990, a phenomenon known as global dimming. Newly avail-able surface observations from 1990 to the present, primarily from the Northern Hemisphere, show that the dimming did not persist into the 1990s. Instead, a widespread brightening has been observed since the late 1980s. This reversal is reconcilable with changes in cloudiness and atmospheric transmission and may substantially affect surface climate, the hydrological cycle, glaciers, and ecosystems.
Relevance of the publication/result: This study presents long-term observations of incident solar radiation at the Earth's surface. It is shown that the dimming trend, which has been observed since the late 1950s, has reversed around 1990 to become a brightening trend. One likely contributor to this trend is a reduction in sulphate emissions in response to the decay of the Soviet Union, which have led to a reduction of aerosol concentrations. The paper argues that the dimming has contributed to a cooling of global mean surface temperatures and has thus masked the warming trend associated with anthropogenic greenhouse gas emissions. After the reversal this masking of the greenhouse effect may no longer have been effective, enabling the greenhouse signals to become more evident during the 1990s. The study is one of the first to make this argument and has led to a series of follow-on publications, both within and beyond NCCR Climate.

ANNEX 1 of WP3

Publication 13:
Leuzinger, S., Körner, C. 2010, Rainfall distribution is the main driver of runoff under future CO2-concentration in a temperate deciduous forest, Global Change Biology 16, 246–254.
Abstract:Reduced stomatal conductance under elevated CO2 results in increased soil moisture, provided all other factors remain constant. Whether this results in increased runoff criticallydepends on the interaction of rainfall patterns, soil water storage capacity and plant responses. To test the sensitivity of runoff to these parameters under elevated CO2, we combine transpiration and soilmoisture data from the Swiss Canopy Crane FACE experiment (SCC, 14 30–35m tall deciduous broad-leaved trees under elevated CO2) with 104 years of daily precipitation data from an adjacent weather station to drive a three-layer bucket model (mean yearly precipitation 794mm). The model adequately predicts the water budget of a temperate deciduous forest and runoff from a nearby gauging station. A simulation run over all 104 years based on measured sap flow responses resulted in only 5.5mm (2.9%) increased ecosystem runoff under elevated CO2. Out of the 37 986 days (1 January 1901–31 December 2004), only 576 days produce higher runoff in the elevated CO2 scenario. Only 1 out of 17 years produces a CO2-signal >20mma_1, which mostly depends on a few single days when runoff under elevated CO2 exceeds runoff under ambient conditions. The maximum signal for a double preindus-

trial CO2-concentration under the past century daily rainfall regime is an additional runoff of 46mm. More than half of all years produce a signal of <5mma-1, because trees consume the 'extra' moisture during prolonged dry weather. Increased runoff under elevated CO2 is nine times more sensitive to variations in rain pattern than to the applied reduction in transpiration under elevated CO2. Thus the key driver of increased runoff under future CO2-concentration is the day-by-day rainfall pattern. We argue that increased runoff due to a first-order plant physiological CO2-effect will be very small (<3%) in a landscape dominated by temperate deciduous forests, and will hardly increase flooding risk in forest catchments. Monthly rainfall sums are unsuitable to realistically model such CO2 effects. These findings may apply to other ecosystems with comparable soil water storage capacity.
Relevance of the publication/result: An increasing CO2 concentration in the atmosphere affects the water fluxes in forests through reductions in leaf transpiration. However, the present study reveals that under real field conditions, this effect leads to only very small changes in the hydrology oft the forested catchment and that changes in runoff are more influenced by the day-by-day variation in rainfall. These results help to better understand the response of forests to climate change and higher CO2 levels in the atmosphere, and can help to improve models that relate processes at the earth surface to the regional climate.

Publication 14:
Haldimann, P., Feller, U. 2004.Inhibition of photosynthesis by high temperature in oak (Quercuspubescens L.) leaves grown under natural conditions closely correlates with a reversible heatdependent reduction of the activation state of ribulose-1,5-bisphosphate carboxylase/oxygenase. Plant, Cell and Environment27, 1169–1183.
Abstract: Inhibition of the net photosynthetic CO2 assimilation rate (Pn) by high temperature was examined in oak (Quercuspubescens L.) leaves grown under natural conditions. Combinedmeasurements of gas exchange and chlorophyll (Chl-a) fluorescence were employed to differentiate between inhibition originating from heat effects on components of the thylakoid membranes and that resulting from effects on photosynthetic carbon metabolism. Regardless of whether temperature was increased rapidly or gradually,Pndecreased with increasing leaf temperature and was morethan 90% reduced at 45°C as compared to 25°C. InhibitionofPnby heat stress did not result from reduced stomatalconductance (gs), as heat-induced reduction ofgswasaccompanied by an increase of the intercellular CO2concentration(Ci). Chl-afluorescence measurements revealedthat between 25 and 45°C heat-dependent alterations ofthylakoid-associated processes contributed only marginally,if at all, to the inhibition ofPnby heat stress, with photosystemII being remarkably well protected against thermalinactivation. The activation state of ribulose-1,5-bisphosphatecarboxylase/oxygenase (Rubisco) decreased fromabout 90% at 25°C to less than 30% at 45°C. Heat stressdid not affect Rubiscoper se, since full activity could berestored by incubation with CO2and Mg2+. Western-blotanalysis of leaf extracts disclosed the presence of twoRubiscoactivase polypeptides, but heat stress did not alterthe profile of the activase bands. Inhibition ofPnat highleaf temperature could be markedly reduced by artificiallyincreasingCi. A highCialso stimulated photosynthetic electrontransport and resulted in reduced nonphotochemicalfluorescence quenching. Recovery experiments showedthat heat-dependent inhibition ofPnwas largely, if not fully,reversible. The present results demonstrate that inQ. pubescensleaves the thylakoid membranes in general and photosyntheticelectron transport in particular were wellprotected against heat-induced perturbations and that inhibitionofPnby high temperature closely correlated with areversible heat-dependent reduction of the Rubisco activationstate.
Relevance of the publication/result: To understand the possible effect of climate extremes such as heat or drought periods on forests, it is important to determine if and by what mechanism tree species can tolerate such extremes. Because the deciduous sub-Mediterranean pubescent oak is known to increasingly dominate low-elevation pine forests in the dry Valais, at the expense of the more sensitive Scots pine, it is interesting see that at least to some extent tolerance of stress is due to protection of the photosynthetic apparatus, which enables a rapid recovery of photosynthesis after the end of the stress period. In the long run and with further warming and more frequent dry periods, this may promote this species in many regions, which could lead to significant changes in forest tree composition.

Publication 15:
Gilgen, A.K., Buchmann, N. 2009. Response of temperate grasslands at different altitudes to simulated summer drought differed but scaled with annual precipitation. Biogeosciences, 6, 2525–2539.
Abstract: Water is an important resource for plant life. Since climate scenarios for Switzerland predict an average reduction of 20% in summer precipitation until 2070, understanding ecosystem responses to water shortage, e.g. in terms of plant productivity, is of major concern. Thus, we tested the effects of simulated summer drought on three managed grasslands along an altitudinal gradient in Switzerland from 2005 to 2007, representing typical management intensities at the respective altitude. We assessed the effects of experimental drought on above- and below-ground productivity, stand structure

(LAI and vegetation height) and resource use (carbonand water). Responses of community above-ground productivity to reduced precipitation input differed among the three sites but scaled positively with total annual precipitation at the sites (R^2=0.85). Annual community above-ground biomass productivity was significantly reduced by summer drought at the alpine site receiving the least amount of annual precipitation, while no significant decrease (rather an increase) was observed at the pre-alpine site receiving highest precipitation amounts in all three years. At the lowland site (intermediate precipitation sums), biomass productivity significantly decreased in response to drought only in the third year, after showing increased abundance of a drought tolerant weed species in the second year. No significant change in below-ground biomass productivity was observed at any of the sites in response to simulated summer drought. However, vegetation carbon isotope ratios increased under drought conditions, indicating an increase in water use efficiency. We conclude that there is no general drought response of Swiss grasslands, but that sites with lower annual precipitation seem to be more vulnerable to summer drought than sites with higher annual precipitation, and thus site-specific adaptation of management strategies will be needed, especially in regions with low annual precipitation.
Relevance of the publication/result: Grasslands are important elements of the Swiss landscape. Their sensitivity to climate change and, in particular, to extremes such as droughts, is relevant for agriculture and for conservation. The results of this study are based on experimental simulation of drought by excluding rain during the growing season. They show that the sensitivity to this reduction in water availability differs between sites located at different altitudes, and that at presently moist sites in the sub-alpine regions the reduction in precipitation may have positive effects on biomass production, while at the drier sites in the lowlands the effect is negative. However, grassland plots recovery from these short-term effects which makes them quite resilient to expected changes in climate.

Publication 16:
Hirschi, M., Seneviratne, S.I., Alexandrov, V., Boberg, F., Boroneant, C., Christensen, O.B., Formayer, H., Orlowsky, B., and Stepanek, P. 2011. Observational evidence for soil-moisture impact on hot extremes in southeastern Europe. Nature Geoscience 4, 17–21.
Abstract: Climate change is expected to affect not only the means of climatic variables, but also their variabilities and extremes such as heat waves. In particular, modelling studies have postulated a possible impact of soil-moisture deficit and drought on hot extremes. Such effects could be responsible for impending changes in the occurrence of heat waves in Europe. Here we analyse observational indices based on measurements at 275 meteorological stations in central and southeastern Europe, and on publicly available gridded observations. We find a relationship between soil-moisture deficit, as expressed by the standardized precipitation index, and summer hot extremes in southeastern Europe. This relationship is stronger for the high end of the distribution of temperature extremes. We compare our results with simulations of current climate models and find that the models correctly represent the soil-moisture impacts on temperature extremes in southeastern Europe, but overestimate them in central Europe. Given the memory associated with soil moisture storage, our findings may help with climate-change-adaptation measures, such as early-warning and prediction tools for extreme heat waves.Climate change is expected to affect not only the means of climatic variables, but also their variabilities and extremes such as heat waves. In particular, modelling studies have postulated a possible impact of soil-moisture deficit and drought on hot extremes. Such effects could be responsible for impending changes in the occurrence of heat waves in Europe. Here we analyse observational indices based on measurements at 275 meteorological stations in central and southeastern Europe, and on publicly available gridded observations. We find a relationship between soil-moisture deficit, as expressed by the standardized precipitation index, and summer hot extremes in southeastern Europe. This relationship is stronger for the high end of the distribution of temperature extremes. We compare our results with simulations of current climate models and find that the models correctly represent the soil-moisture impacts on temperature extremes in southeastern Europe, but overestimate them in central Europe. Given the memory associated with soil moisture storage, our findings may help with climate-change-adaptation measures, such as early-warning and prediction tools for extreme heat waves.
Relevance of the publication/result: Changes in the properties of the land surface may feed back to the atmosphere and could have a profound effect on the regional climate. Such changes may be related to soil moisture. As soil moisture declines due to low precipitation and high evapotranspiration, the cooling of the atmosphere caused by evapotranspiration declines. In turn, this leads to an even stronger warming of the atmosphere and causes extreme heat and further drying of the soil. This study confirms this relationship by analyzing observational data for precipitation and summer hot extremes across southeastern Europe. Understanding these links between the land surface and the atmosphere helps to improve longer-term weather forecasts and climate projections using regional climate models that are coupled to land surface models.

Publication 17:
Torriani, D.S., Calanca, P., Schmid, S., Beniston, M., Fuhrer, J. 2007. Potential effects of changes in mean climate and climate variability on the yield of winter and spring crops in Switzerland. Climate Research 34, 59–69.
Abstract: Climate change is expected to affect both the average level and the variability of crop yields. In this modelling study, we quantified mean and inter-annual variability of grain yield for maize Zea mays L., winter wheat Triticum spp. L. and winter canola Brassica napus L. for climatic conditions corresponding to current and doubled atmospheric CO2 concentrations. Climate scenarios with and without taking into account changes in the inter-annual variability of climate were developed from the output of a regional climate model for the time window 2071 to 2100. Climate change effects on the mean yield of maize and canola were consistently negative, but a positive impact was simulated for mean yield of winter wheat for elevated CO2 concentration. The coefficient of yield variation increased in the scenarios for maize and canola, but decreased for wheat. Higher thermal time requirements increased mean yield and reduced yield variability for all crops. Shifts in the sowing dates had a beneficial impact on the yield of maize, but not on the yield of canola and wheat. It is concluded that in the Alpine region, the potential effect of climate change is crop-specific. However, the introduction of new cultivars may provide means by which to maintain or even increase current productivity levels for most of the crops.
Relevance of the publication/result: Crop yields are directly affected by weather and climate, and it is expected that changes in climate will alter the potential productivity of major crops in Switzerland. However, management changes can help to mitigate negative effects. The present study using a well-calibrated model for crop simulations show that shifting sowing date or using cultivars that require higher temperatures to develop may be efficient measures to counteract negative effects of heat and drought on productivity. At the same time, yield variability from year-to-year is smaller when using these adjustments, as compared to a situation with no changes in management. This and similar studies carried out in the NCCR Climate provide important hints about the most efficient tactical option in crop production, which need to be realized in coming decades to cope with climate change.

Publication 18:
Kapphan, I., Calanca, P., Holzkaemper, A., 2012. Climate change, weather insurance design and hedging effectiveness. The Geneva Papers37, 286–317.
Abstract: Insurers have relied on historical data to design weather insurance contracts. In light of climate change, we examine the effects of this practice on the hedging effectiveness and profitability of insurance contracts. Using synthetic crop and weather data for today's and future climatic conditions we derive adjusted weather insurance contracts that account for shifts in the distribution of weather and yields. In our scenario, hedging benefits from adjusted contracts almost triple and expected profits increase by about 240 per cent. We further investigate the effect on risk reduction (for the insured) and profits (for the insurer) from hedging future weather risk with non-adjusted contracts based on historical data. In this case, insurers generate profits that are significantly smaller than for adjusted contracts, or even face substantial losses. Moreover, non-adjusted contracts that create higher profits than the adjusted counterparts cause negative hedging benefits for the insured.
Relevance of the publication/result: With increasing climate-related production risks, new insurance options may be necessary for Swiss farmers to hedge related economic risks. The effectiveness of weather derivatives as new instruments was analyzed on the basis of simulated yield data and an economic model. The simulated data replaced observational data are traditionally used to design insurance contracts because of the limited availability of such data and because observed yields not only depend on weather and climate, but also on management. The results show that for a future climate properly designed contracts would be beneficial for both the insured and the insurer. This result is of great value for the Swiss insurance industry and may have important practical consequences for climate change adaptation in Swiss agriculture.

ANNEX 1 of WP4

Publication 19:
Aerni P., Boie B., Cottier T., Holzer K., Jost D., Karapinar B., Matteotti S., Nartova O., Payosova T., Rubini L., Shingal A., Temmerman F., Xoplaki E., Bigdeli S.Z., 2011: Climate Change and International Law: Exploring the Linkages between Human Rights, Environment, Trade and Investment, in Giegerich T. and Proelss A. (eds.): German Yearbook of International Law (Berlin: Duncker&Humblot), pp.139-188.

Abstracts: The article is written by a team of economists and lawyers from the NCCR Trade Regulation and NCCR Climate. It explores the links between climate change, trade, investment and human rights contributing to a greater coherence between different fields of public international law and to a better coordination between different areas of public policy aimed at tackling climate change. The analysis of fundamental principles of international environmental law, human rights protection as well as international investment and trade law and their relevance to the protection of climate clearly shows that principles of public international law provide justification for a global action against climate change. The article also argues that trade instruments and trade rules can play a significant role in facilitating climate change mitigation and adaptation. It discusses a role the WTO can play in encouraging the use of green technologies through liberalisation of trade in environmental goods and services, elimination of fossil fuel subsidies, permission - under certain conditions - of subsidies for renewable energy and enforcement of intellectual property rights. It argues that the transition to a low-carbon economy can be facilitated by the conclusion of a framework energy agreement within the WTO or with its participation. Finally, the article examines the possibility to adapt international investment rules to the needs of emissions reduction policy. It concludes that the currently fragmented nature of investment law and its narrow focus mainly on investment protection precludes accommodation of climate policy needs in the international legal framework for investment.
Relevance of the publication/result: This paper in particular contributes to Task 2 of CITEL: Interaction of International Trade Regulation and Climate Policy. It shows that international trade regulations as established by WTO encourages transferring climate-related technologies through liberalisation of trade in environmental goods and services. Furthermore it allows, under certain conditions, boarder adjustment measures (BAMs) such as subsidies for renewable energy and enforcement of intellectual property rights.

Publication 20
Buob S, Stephan G, 2011: To Mitigate or to Adapt: How to Confront Global Climate Change. European Journal of Political Economy 27:1-16.
Abstract: We analyze the strategic interaction between mitigation and adaptation in a non-cooperative game in which regions are players and mitigation and adaptation are perfect substitutes in protecting against climate impacts. We allow for step by step decision making, with mitigation chosen first and adaptation second, and where the benefits of mitigation accrue only in the future. If marginal costs of adaptation decline with global mitigation, high income regions simultaneously invest in mitigation and adaptation. Low income regions engage in mitigation only.
Relevance of the publication/result: This paper is an important contribution to Task 3 of CVR: Interaction between strategies to combat global climate change. Typically, one would expect that rich countries, which are characterized by low vulnerability to climate change, would prefer investing into adaptation instead of mitigation, because of the public goods character of mitigation. This paper shows, however, that over the long-run despite of adaptation there is still high incentive to engage in mitigation both in the developed and developing world.

Publication 21
Gainza-Carmenates R., Altamirano-Cabrera J.-C., Thalmann P., Drouet, L., 2010: Trade-offs and Performances of a Range of Alternative Global Climate Architectures for post-2012. Environmental Science & Policy 13:63-71.
Abstract: Quantitative assessments help to highlight the main features of climate policies by better identifying their strengths and weaknesses. In this study, we develop a grading system for assessing thirteen proposals for post-2012 climate policy. We believe that these proposals contain appropriate policy instruments which will be considered for discussions about how to design the post-2012 climate agreement. Our grades are based on four criteria: environmental effectiveness, cost effectiveness, distributional considerations and institutional feasibility. We analyze the grades with two complementary methods: principal component and cluster analysis. Our results entail three policy implications. Firstly, the higher the number of policy instruments a proposal comprises, the more difficult might be its implementation. Secondly, proposals which include a meaningful effort by the U.S. tend to fail in environmental effectiveness and institutional feasibility. Thirdly, we identify that the ‘‘first best’’ and the ‘‘second best’’ approaches belong to a stable policy group, and both may be considered as suitable candidates for post-2012 climate policy.
Relevance of the publication/result: From the early beginning it was a task of WP4 to analyze the political dimension of global climate change. In the last proposal, MIADAC has summarized this under Task 1: Analyze the evolution of international climate policy. This paper contributes to that task: (1) through establishing an list of criteria, which allow for a transparent and coherent analysis of policy proposals, (2) by applying this procedure to policy proposal already discussed in the process of post-Kyoto negotiations.

Publication 22
Kypreos S, Turton H, 2011: Climate Change Scenarios and Technology Transfer Protocols. Energy Policy 39:844-853.
Abstract: We apply a specific version of MERGE-Ell, an integrated assessment model, to study global climate policies supported by Technology Transfer Protocols (TTPs). We model a specific formulation of such a TIP where donor countries finance via carbon tax revenues, the diffusion of carbon-free technologies in developing countries (DCs) and quantify its benefits. Industrialized countries profit from increased technology exports, global diffusion of advanced technology (leading to additional technology learning and cost reductions) and reduced climate damages through the likelihood of greater global participation in a new international agreement. DCs experience increased welfare from access to subsidized technology, and profit from the reduction of damages related to climate change and expected secondary benefits of carbon abatement (such as reduced local and regional air pollution). The analysis identifies potential candidate technologies that could be supported under a UP, and the impact of a UP on economic development (including the flow of transfer subsidies) and global emissions. Although a UP may encourage additional participation, such a proposal is only likely to be successful if an increased willingness to pay to avoid climate damages is accepted, first by the present and future generations of the industrialized world and later on, when sufficient economic growth is accumulated, by today's developing countries.
Relevance of the publication/result: This paper contributes to issue of technology transfers in combating climate change, which was a key issue of WP4 in Phase 2. Using an improved version of MERGE it is shows that transferring climate-friendly technologies increases the welfare of both the donor and the recipient, even if the donor fully covers the financial burden of such a transfer.

Publication 23
Müller-Fürstenberger G, Stephan G, 2011: What Really Matters: Discounting, Technological Change and Sustainable Climate. Ecological Economics 70:978-987.
Abstract: This paper discusses the interplay between the choice of the discount rate, greenhouse gas mitigation and endogenous technological change. Neglecting the issue of uncertainty it is shown that the Green Golden Rule stock of atmospheric carbon is uniquely determined, but is not affected by technological change. More generally it is shown analytically within the framework of a reduced model of integrated assessment that the optimal stationary stocks of atmospheric carbon depend on the choice of the discount rate, but are independent of the stock of technological knowledge. These results are then reinforced numerically in a fully specified integrated assessment analysis.
Relevance of the publication/result: This paper contributes to Task 2 of CVR: Global climate change, endogenous discounting and population growth. It extends the existing discussion on the issue of discounting by introducing the concept of a sustainable climate and explicitly takes into account that northern wetland methane emissions will at least double by the end of the 21st century.

Publication 24
Vielle M., Viguier L., 2007: On the Climate Change Effects of High Oil Prices. Energy Policy 35: 844–849.
Abstract: Some commentators claim that the oil market has achieved within a few months what international bureaucrats have struggled to obtain in a decade of international climate negotiations. The fallacy of the oil price argument is that substitutions and income effects that would result from higher oil prices are not considered. Using a computable general equilibrium model, we show that high oil prices cannot serve as substitutes for effective climate policies.
Relevance of the publication/result: Typically it is argued that the world’s high consumption of fossil fuels and hence carbon dioxide emissions is a results of low energy prices. Therefore an important element of any climate policy is to make fossil energy more expensive. However, fossil fuels are exhaustible resources, and hence the Hotelling rule predicts increasing prices over the long term. Does this make climate policies obsolete? The clear answer of this paper, which relates to task 1 of MIADAC, is: No.