Summary of Session 29 climate change and water systems

Theme 4. Preparing for impacts: Adapting to the Inevitable

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Introduction:

Section 29 (Climate Change and Water Systems) focused on three main research areas: a) better understanding the current state of knowledge regarding predicted impacts of climate change on fresh water systems; b) exploring the nature of water vulnerability in the context of multiple stressors, especially in less developed countries; and c) examining governance mechanisms that can improve fresh water systems' ability to respond, cope and adapt to climate variability and change. The section was divided into three separate sub-sessions organized around two main intersecting themes: impacts/vulnerability/adaptation and developed/developing regions. Accordingly sub-session one focused on climate impact modelling and socio-economic implications and responses in less developed regions; sub-session two focused on impact modelling on developed countries; and sub-session three focused on governance, vulnerability and adaptation options in both developed and less developed regions.

Overall, the three sub-sessions yielded important findings that have critical implications both for future research in the area and policy design and implementation, including:

Expected Impacts and limitations of current approaches to model them. The effects of climate change on water systems in all parts of the world are already with us, and many of them will accelerate and intensify over the coming 20 years, irrespective of future agreements and actions to reduce emissions. Many of the presentations focusing on impact modelling used different GCM models and SRES scenarios as the driving force for the regional scenarios and predictions. The highest risks in developing countries are expected to come from droughts (Africa), river floods (Bangladesh and Nile deltas), and coastal flood driven by sea level rise and increased intensity of cyclones and sea storms (e.g. Bangladesh). A number of presentations focused on the big deltas in Africa and Asia as extremely vulnerable areas where current "initial conditions" combine high climate variability, high population density and poverty and intense (agricultural) production. Bangladesh for example (03) is double-exposed to river floods and cyclone risks. Even more developed areas like South Africa are at risk of loosing their hard earned position in global markets due to drought impacts (07). For Europe scenarios predict extreme floods and droughts, showing serious impacts may happen even when mitigation strategies are realistically successful and CO2 concentrations restricted at 400-450 ppm (10). From the physical side, existing models (GCMs) are better at accounting for expected changes in a large scale. However, when it comes to predictions at the local and regional levels, all presentations identified too high uncertainties, which limit their ability to meet decision-makers' expectations and needs for information to support adaptation planning. This includes not only farmers at the local level but also managers in the national or even trans-.national levels. The existing models are still too coarse; and while several RCM models can provide good guidance on specific regional and temporal resolution, more research is needed to improve the reliability of forecasts and scenarios--relevant for today's actions. One direction where research to improve reliability is going is towards ensemble modelling exercises rather than relying on a single model approach to make predictions. A common limitation noted by presenters is lack of observations and data to better validate and calibrate models—a problem particularly acute in less developed regions of the world but also relevant in developed countries. Finally a few of the presentations highlighted high levels of uncertainty do not automatically translate into decision paralysis; there is a need for decision-makers to better understand the range of decision, especially concerning adaptation options, that can be made within the current levels of uncertainty in predicting impact of impact.

Climate change is only one of the stressors shaping vulnerability and adaptive capacity, especially in less developed countries; we need integrated approaches to better understand positive and negative feedbacks between social, physical and environmental processes affecting *water sustainability and resilience to climate impacts*. The presentations focusing on developing countries identified several limits, barriers and opportunities to realise operational and direct success in adaptation and to ensure water security. In these regions adaptation and vulnerability have to be considered in relation to economic developments and market strategies. Developing countries are often characterise by very high population density, high poverty index, instable political systems often lacking democracy, public participation and efficient communication and also often lacking technological and scientific knowledge (13 –18). In order to understand the interconnectedness of the many stressors shaping the vulnerability of less developed regions and of vulnerable groups and systems within these regions, an interdisciplinary and integrated approach to measuring vulnerability and designing adaptation options needs to be adopted. Without understanding underlining causes of vulnerability and constraints to building adaptive capacity and the current intersections between adaptation policy and development, the ability to make better-informed decisions is impaired. In addition it is necessary to better understand the interrelated nature of the complex processes shaping water vulnerability and resilience under climate variability and change. The sustainability of water systems is shaped by both supply and demand across scales, ranging from the local to the global. To inform adaptation, climate impact models need to be linked to land use scenarios, economic models and information on economic and societal feedbacks, and it must be realized that uncertainties come not only from the physical modelling, but also from the modelling and other analyses of the economic, environmental and social consequences. The right balance has to be found between adaptation options focusing on infrastructure such as water storage and transfer, sea walls, levies, relocation, etc and governance such as demand management and a range of local measures identified through proper stakeholder participation and communication. For successful adaptation both aspects have to be considered equally, and both are important for increasing water use efficiency. From a socio-economic perspective, we need to understand how institutions, values and behaviour shape water resources governance (e.g., consumption, conservation, valuation and equitable distribution of water) and influence adaptation options and adaptive capacity building.

Good governance is key to successful adaptation, building on integrated and adaptive approaches, where top-down meets bottom-up, and where the need for open and transparent sharing of information between all stakeholder groups is recognized. Despite the need to improve impact modelling to better meet the needs of decision-makers, acting now only partially depends on more knowledge on climate change impacts; we also need to improve our knowledge, communication, and understanding of local processes to ensure longer-term sustainable solutions. Where the physical, environmental and socio-economic sides of water sustainability come together, we need to figure out how prepare societies for more rapid changes that affect their daily life to increase resilience in both rural and urban areas. In addressing the critical role of water in adaptation, communication and cooperation has to take place in a river basin context, from the local catchment to the trans-boundary river basin. The *integration* in the participatory process has to work in three different directions: horizontally within and between river basins, horizontally between different sectors (agriculture, domestic water supply, energy, tourism, industry…), and vertically between national, regional, local governments and the civil society. The key element of successful cooperation and management is *information sharing* on the operational management level between all stakeholders: politicians, technicians, private sector, civil society, farmers etc. To ensure equity the sharing of information requires an equal understanding by all stakeholders.

Session 1—Impact modelling and Vulnerability in less developed regions.

Buontempo et al. (SP29.03) presentation focused on a methodology for the downscaling of GCM model ensembles applied to four different deltas in Africa and Asia. The starting point were atmosphere ocean ensembles which were combined with a RCM and hydrological models in a probabilistic approach to account e.g. for summer rainfall probability. The regional models bring added value, in particular in areas with steep topography. Buontempo et al showed that the joint use of a selected ensemble of GCM runs with a RCM and a hydrological model can represent an affordable way for many countries to assess their vulnerability to climate change. The ensemble approach offers the advantage over deterministic modelling of providing an estimate of the confidence level associated with the predictions.

Karsten Havno et al. (SP29.04) presented on the importance of reliable forecast in particular for flood risks. He presented an overview of the recorded and envisaged consequences of climate change in Bangladesh and discussed some appropriate measures for adaptation. One of the instruments is a flood forecasting model input from remote sensing and in-situ measurements (FFWC). It gives daily forecast on risk for flooding and predicts flood heights. It was established after the last big cyclone in 1991. Following the established of the forecasting flood shelter provided protection in stable concrete construction and helped to cope with flood events. Still problems exist in communication and acceptance of this protection. Another important problem is the erosion of rivers and the breaking of embankments to be tackled by appropriate damming with large flood plans, which again causes social problems.

The feedback mechanisms and inter-linkages with the economic system where highlighted in two presentations given by Ludwig et al. (SP29.05) and Louw et al. (SP29.07). Ludwig (SP29.05) described drops in GDP, in particular the agricultural GDP, comparing precipitation and GDP development for 4 areas in southern, eastern, coastal West Africa and Sahel. Highest impact of droughts was shown for South Africa, coastal West Africa getting slightly wetter would benefit. The comparison showed a limit for water security at 750m3/capita. To reduce the impact of climate variability and change on African countries significant investment in water storage infrastructure is necessary in addition to a range of other non-structural measurers.

Louw et al. (SP29.07) presented a planned project for integrated environmental- economic assessments in the Berg River catchment in South African, an agricultural area for high quality crops and high competition for water. The assessment compares costs of inaction (CC damages) with costs of adaptation and its benefits by combining a RCM, a hydrological model, and routines for water management including investments. The model results show clear benefits of a market-based strategy of implementing functioning water markets against building up of more storage capacities.

Smathkin et al. (SP29.14) focused on understanding the impact of climate change on the worldwide agricultural production in the context of increasing demand from food security and bio fuel production. The work distinguishes between physical scarcity (the main areas in North and south Africa, Middle America, the Arab Countries and Asia) and economic water scarcity (in central Africa and Asia where 1/3 of the population are living in basins that have to deal with water scarcity). A case study on the Blue Nile basin, where the scarcity is mainly economic, shows that Climate Change could even increase water flows. The key challenge is how to make best use of resources, maybe increasing, water flows using storage capacities in surface and groundwater more efficient. This will be even more important when in the future all commitments of the Western World to increase their bio-fuel use will be need to be met. 30 M ha more land and 180 km3 more water will be necessary globally to meet these targets. In many cases, bio-fuel targets and food production targets will not be possible to be met at the same time.

The study stressed as one part of the problem, the insufficient availability/accessibility of data e.g. in transboundary river basins. Only 20 of 170 members of WMO share their data.
This presentation concluded that, first, the quantification of local CC impacts is imperative for the design of adaptation measures, and second that conventional water management measures, like storage, need to be back to the agenda. However, they need to be re-thought as adaptation options for CC-related impacts. In addition, bio fuels and other climate change related interventions, may have significant implications for agriculture and water management and need to be better evaluated. Overall CC might be a new context that facilitates the solution to old problems in the water sector.

Session II. Impact Modelling in Europe and Implications for Adaptation.

Alcamo et al. (SP29.11) presented an updated version of the water –GAP model
WaterGAP computed that the return period of the current 100-year hydrologic drought could decline to around 5 to 30 years over much of Southern Europe. The new version of the model combines global climate change models, hydrological models and estimates of water use in a higher spatial resolution. Current flood events were used for calibration. The impact assessments, shown as future return periods until 2050, showed very high variations between the different driving GCMs. The remaining robust result of areas for which agreement could be found between all runs showed 37% less frequent flooding events for the northern Alps and 18% more frequent events with focus on Britain, Ireland the eastern Pyrenees and mid-Sweden. These results might be explained by the fact that now snow pack analysis is better included into the model. This work also shows that drought predictions for Europe differ greatly. This large area of uncertainties supports again the argument for carrying out ensemble approaches. But beyond that, the authors argue that adaptation policy should recognize the fact that actions are needed now even under high levels of model uncertainty. Another conclusion of this research is that impact assessment and/or any forecast and adaptation policies have to be carried out on a continental scale. European River basin Authorities have to cooperate and work together in a EU Flood alert system to ensure efficient use of national resources. Finally, the presenter concluded that although this research focused in Europe, the principle of transboundary cooperation can also be applied to the developing world. Currently extension of this kind of research to less developed regions is constrained by lack of data (e.g. remote sensing data) and international/regional integration—when these two factors improve, it will be possible to move towards a regional or even global early warning system.

The EU flood alert system was presented in more detail by Luc Feyen et al ***(SP.29.08)***
He presented a modelling approach to calculate costs of damage and benefits of adaptation for changing flood frequencies. The work uses GCMs, regional downscaling with hydrological modelling and a socio economic model to assess vulnerability, impact and exposure for a risk assessment. The distribution of flood frequencies is different from the assessment in the previous presentation (Alcamo et al.), which could be explained by the fact again that they different GCM models. Land use data were used to provide estimates of damage due to a given relationship between level of inundation and land use class. By imposing different levels of protection, i.e., by truncating the damage-probability functions at different return periods, the monetary benefits of adaptation to increasing flood hazard were evaluated. Results indicate that, under the SRES A2 and B2 scenarios, most countries in Europe will see an increase in the expected annual damage (EAD) in the coming century. For EU27 as a whole, the current EAD of 6.5 billion € is projected to reach 18 billion € (in constant prices of 2006) under the A2 scenario and 14 billion € under the B2 scenario by the end of this century. Increasing flood protection will reduce future flood risks considerably, depending on the level of protection imposed and the projected increase in flood

hazard. The comparison of costs and benefits shows in a 10 year period for EU 27 an increase of 31 billion € or 75%: In summary, the presenter concluded that:

- Ensemble approaches to modelling are needed
- The scale of the hydrological model used and the database for the statistical estimates of damage has to be improved.
- Longer time series or resembling techniques would improve the estimated of return period of 30 years.
- Better information is needed to factor in the existing level of protection. Protection

While the work did not consider transboundary effects or inter-sectoral cooperation, it showed clearly the urgent need to model land and water systems in a holistic approach.

Another indication for the need of ensemble modelling approaches was given by van Roosmalen et al. (SP29.09) whose presentation focused on the future effect of climate change on the groundwater resources in Denmark. The work used an application of MIKE-SHE, a physical deterministic model of ground water hydrology, to downscale the driving GCM (so far only one model is used) in two case study areas in Jutland and Northern Zealand. Currently the Zealand area is dryer that Jutland, but Jutland has more permeable soils. The “delta change approach” was used to transfer the climate scenario data for the hydrological model simulations. The results of the downscaling approach show a significant increase in mean annual groundwater recharge, but with decreased values in the summer months. The magnitude of the hydrological response to the simulated climate change is highly dependant on the geological setting of the model area. In the Jutland area, characterized by sandy top soils and large interconnected aquifers, groundwater recharge increases significantly, resulting in higher groundwater levels and increasing groundwater-river interaction. On Zealand, where the topsoil is dominated by low-permeability and the aquifers are protected by thick clay layers of regional extent, only minor changes in groundwater levels are predicted. The primary effect in this area is the change in stream discharge caused by changes in drain flow and overland flow, with up to 50% increase in winter and 50% decrease in summer. The main message from this presentation is, that on top of the variability of GCMs and RCMs local geological conditions have to be taken into account when accounting for Groundwater resources, which in many case studies are neglected. Furthermore the author gave another plea for the use of an ensemble approach as the use of only one GCM showed to be not sufficient.

A further statement on the necessity of an ensemble approach was given by Rachel Warren et al. (SP29.10), whose presentation focused on drought regimes under mitigated and unmitigated CC-scenarios, using an integrated assessment model. Their research shows that using different GCM patterns produces different emphases on the precise locations of increased drought: The projections showed pronounced increases in all drought measures in Southern Europe, especially around the Mediterranean and the Black Sea, in the second half of the 21st century. They also project strong drying in NW Europe including the south of England. The frequency of droughts between 5 and 12 months in duration is projected to rise from fewer than 5 events per 50-year period, to greater than 30 in southern and central Europe. The number of months of a 50-year period during which droughts in excess of 12 months in duration are being experienced is projected to increase from 50 to over 300 (which means that year-long drought is projected to occur for more than 50% of the time) in the worst affected parts of Southern Europe if no emission reduction occurs. Mitigation drastically reduces these drought increases, but significant impacts still occur except for the most stringent scenarios with stabilization at 400-450 ppm CO_2. These conclusions are robust to the use of a range of GCM patterns. The study also highlighted the wide range of potential drought climates that adaptation planners currently need to consider in both the first and the second halves of the 21st century, considering the uncertainties in climate prediction resulting from the use of various GCMs as well as the uncertainties in future emissions.

Finally, Markus Muerthet al. (SP29. 12***)*** provide further insight into aspects of adaptation in Europe. The work investigated Low flow conditions in the upper Danube (Bavaria, Germany) in an integrated project including social-economic aspects focusing in particular on the changes for hydropower production. Hydropower production from Danube accounts to the electricity supply of 70 % for Austria and 15% for Bavaria. The group did set up the decision support system Danubia, combining spatial explicit, physical model of the water system including its water management infrastructure, driven by regional CC scenarios. Stakeholders are engaged by providing specific adaptation strategies, which are fed into reruns of the model. The downscaling aspect of the work showed that Bavaria in these models has a higher risk of warming than predicted in global scenarios. It is also shown, that hydropower production, especially in the Alpine tributaries of the Danube, is strongly reduced by more frequent and more severe future low-flows and runoff regime changes especially when the simulations are based on today's operation rules for the existing water management structures. Two major adaptation measures were investigated: a) changes the operation rules of the infrastructure to take into account and buffer future low-flow conditions; and b) scenarios, which explore the adaptation potential of extending the water storage capacities in the alpine part of the watershed.. These scenarios show that parts of the expected climate change induced loss in hydropower production can also be compensated by the build-up of additional storage capacities.

Session III Vulnerability/Adaptation in the fresh water sector

Most contributions in the third part of the session focused on the operational boundary conditions for adaptation strategies in developing countries including governance, adaptive management, communication and networks. The session was opened by a contribution by the Danish Ministry of development (see document attached) who highlighted intersection between development and adaptation in less developed regions and the need for more observations (physical, environmental and social), data organization and sharing across the world.

Goulden and Conway (SP29.06) showed that unilateral actions are in many areas still the first choice but in the long-term perspective multilateral cooperation between regional institutions (for example the Permanent Joint Technical Committee between Sudan and Egypt, the East African Community and the Nile Basin Initiative) are important for cooperation and potentially also for climate change adaptation. The Nile basin is characterised by conflicting interests from Egypt (downstream long term water security), Ethiopia (food security under droughts), Sudan (extreme events), and the Lake Victoria Region (hydropower effected by extreme events). In general crises situations triggered by climate variability should be seen as "windows of opportunity" to overcome increased tension and improve cooperation in a long term. The findings highlight the benefits of supporting cooperation between river basin countries and suggest that factors that limit cooperation may also limit future adaptation.

The principle of information and knowledge sharing was first addressed by Lemos et al. (SP29.13). The study focused on how information and knowledge is used to make decisions and increase the resilience of fresh water systems using as empirical evidence decision making within Brazilian watershed committees. The guiding question is how knowledge could be unpacked and used in an integrated way, so that water management is not done in an isolated way. Another focus is the trade-off between use of technical knowledge and democracy (both determinants of adaptive capacity) within committees' decision making process. Public participation is a key element for better governance and integration. The study is based on survey of 18 watershed committee members, which include representatives of civil society, state and large water users. This study finds that: a) effective participation will only be achieved through the transparent and accessible use of techno-scientific knowledge by these councils. The knowledge must be there, but it must also be understood; b) past experience, higher levels of education and participation in networks by council members influence this understanding and the use of techno-scientific knowledge within councils; c) while members of river basin councils find that the use of techno-scientific knowledge improves decision making at the basin level, they also find that it introduces significant levels of inequality, even higher than political and economic power, which might again stress the importance of knowledge accessibility (in contrast with knowledge availability).

Pfaff et al. (SP29.17) also focused on knowledge and information sharing in another example from a semi-arid area and the northeast of Brazil, looking at the Jaguaribe Valley in the state of Ceará. In a situation where the build up of water infrastructure has been stable for some time, the question was how the existing water resources are distributed between rural user groups in the valley and urban uses by tourism and small industries. In both valley and city uses low efficiency dominates, but the tourism industry in the city offers high value return, whereas the agricultural production (e.g. flood-irrigated rice) has low value return. The water allocation between those groups was in the centre of the study, which investigating how the actual allocation in a public participation process is dependent on the level of knowledge, information and understanding between those groups. Obviously the key actors in this allocation tend to act in favour of water resources for the city. After applying a classic bargaining game, enriched with the element of information from water resource forecasts, the study showed, that in many cases key actors win in allocation process, by holding back information, e.g. about drought forecasts. This stressed again the importance of equity in information sharing, but also the value of education.

The work of Huntjens et al. (SP29.16) also focused on the question of how to organise information sharing in a participatory approach. He presented results from the Newater project (funded under FP 6) showing ways for integrated Water management for adaptation to CC. NeWater studied Adaptive and Integrated Water Management (AIWM) in several large River basins (e.g. Rhine, Mekong, Nile). It looked at elements like Governance, Sectoral Integration, Scale of Analysis and Operation, Information Management, Infrastructure and Finances and Risk in a policy cycle leading to operational management. Core of the study was to compare a Prediction and Control Regime characterized by narrow stakeholder and sector integration with hierarchical and centralized (also financially) structures with an Integrated, Adaptive Regime with wide stakeholder and sectoral integration. Key element in the policy (action) cycle was the learning process (Adaptive management is learning to manage by managing to learn). The several case studies showed that the lack of joint participation is an important obstacle for learning when dealing with adaptation. It showed also, that there is the need for a certain degree of top-down governance (or centralization), where a central authority has the responsibility and resources for issues like: a) Facilitation of participatory processes; b) Setting of standards; c) Capacity building; d) Conflict resolution and cooperation across boundaries. The presentation summarised that the management systems in all case studies seem to be in a process of finding a balance between bottom-up and top-down governance in river basin management. The results suggest that bottom-up governance plays not such a primary role in AIWM as earlier found and a balance between bottom-up and top-down governance is especially relevant for large-scale, complex multiple-use systems, such as river basins.

Feldmann et al. (SP29.15) showed positive examples of the value of information sharing when they investigated how knowledge networks for water systems with different actors help to make use of CC impact information used. To make information useful in an end-to-end transfer information networks must include, the generators, translators, as well as users. In particular the translation is important to bring the information to work. As products and uses become increasingly different in particular between CC Forecast and users like water utility representatives or farmers, a learning process must occur for information to be translated, which the authors describe as Boundary Spanning. This improves the likelihood that scientific results are trusted by the user and integrated into the operational planning cycle. These principles are realised for example in The Advanced Hydrologic Prediction Service (AHPS) and Regional Integrated Science Assessment teams (RISA) in the US, and the International Council for Local Environmental Initiatives for sustainability (ICLEIs). It was concluded, that networks provide a more democratic approach because they take all stakeholders into account. They cross boundaries, producing information that is useful and relevant, integrating between observation and application. They also show that it is possible to blend scientific with other types of information. However, it might be different from what scientists envisioned.

Dessai et al. (SP29.18) also focus on the cost effectiveness of adaptation measures under different climate change scenarios and defined cost thresholds to identify the vulnerability of regional adaptation plans facing uncertainties of climate change impacts. The starting points was again, that the general lines of climate change impacts are well known, scenarios have to improve for the regional details of the predictions, but it is clear, that adaptation to climate change will have to reconcile a certain level of uncertainty in their ability to make decisions. The question is therefore how to make decisions under deep uncertainties in next 25 years. The study looked at two regional adaptation strategies and their long term planning for water resources in L.A. California and in east Suffolk and Essex, UK considering CC and other uncertainties. After checking the water resource plans against about 200 different scenarios the results of shortage costs against supply costs revealed that many response options are insensitive to climate uncertainties, the system is in many ways so sub-optimal today that many decisions make sense anyway meaning they would be no-regret options. It was concluded that even if climate prediction could be better, there is enough information to act now. Robust decision-making methods can help identify sensible strategies regardless of uncertainty, but implementation of robust strategies will require flexibility and cooperation among actors.

Poster Presentations:

The results given in the poster sessions confirmed the key messages given in the presentations. From the diversity of papers focusing on the physics, ecology and management of fresh water resources, it became clear, that we need to look at water systems through integrated and interdisciplinary lenses that take into consideration the interrelated nature of the complex processes shaping water vulnerability and resilience under climate variability and change. The sustainability of water systems is shaped by both supply and demand across scales ranging from the local to the global. Because water is vital to human and ecosystem survival the short and long-term sustainability of existing resources is one of the most pressing problems faced by decision-makers today. We need to integrate across disciplines and systems to understand how physical, environmental, and socio-economic processes feedback on each other (negatively and positively) and affect fresh water resources.