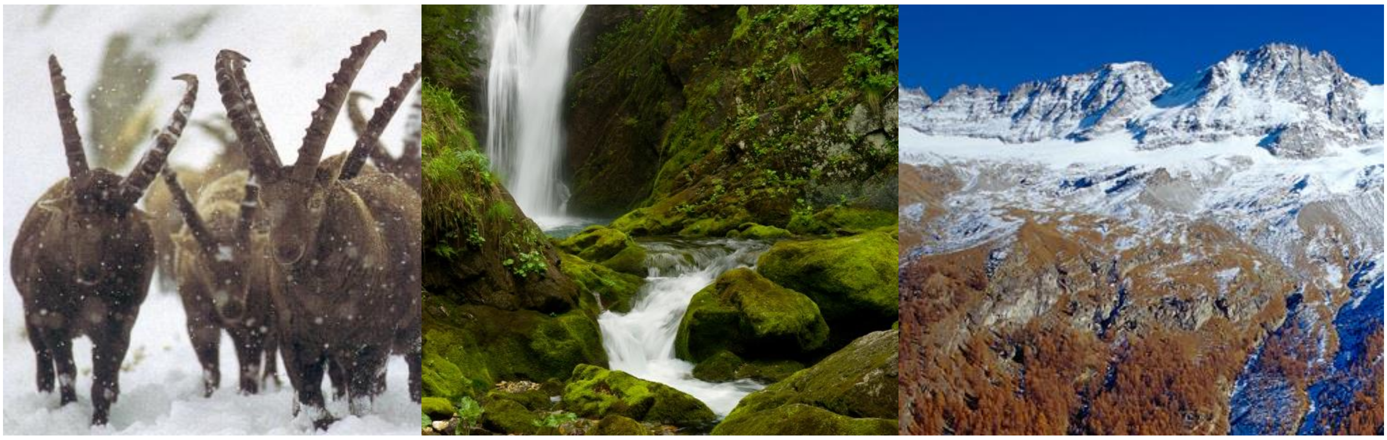
Changes in the Hydrological Cycle

Briefing Document



Contact:
European Climate Research Alliance
Rue du Trône 98
1050 Brussels
www.ecra-climate.eu

Purpose

The global hydrological cycle is composed of many different elements, which include evaporation from water surfaces and bare soil, evapotranspiration from vegetated land, transport of water vapour in the atmosphere, cloud droplet formation and cloud dynamics, the mechanisms leading to liquid and solid precipitation, glaciers and snow cover dynamics, surface and river runoff, and subsurface processes such as root dynamics in vegetation and groundwater flow. All these components react in a different way to climate change, sometimes amplifying each other's action, sometimes giving rise to negative feedbacks. In addition, variations in the hydrological cycle often take place at regional or even local scale (such as variations in ecosystem composition or runoff processes) but can trigger modifications that have an upscale effect possibly leading to regional or even global changes in the water cycle.
Precipitation is an especially difficult variable, as it is characterized by strong intermittency at all scales, which makes it often hard to model, and strong orographic dependence. The measurement of precipitation itself, either by ground stations, radars or satellites, is still a challenging task, which becomes especially hard for solid precipitation at high latitudes or altitudes. These difficulties could hamper efforts to understand and model the hydrological cycle and its variability.
In this Collaborative Programme, developed in the framework of ECRA, we intend to foster the study of the changes of the hydrological cycle at global and regional scale, with special emphasis on the following set of research tasks (which have clear cross-links):

- Global precipitation change and its effects on runoff
- Interaction between climate and hydrological/land surface processes
- Changes in the hydrological cycle in the Mediterranean region
- Changes in the hydrological cycle in mountain areas

The research tasks illustrated above will be pursued by the research groups and Institutions involved in ECRA who participate in this specific CP, in collaboration with other European and international scientific initiatives devoted to the study of the hydrological cycle. Collaborations are envisaged with existing EU Projects and new proposals will be developed during the research activities.

Global precipitation changes and runoff

At global level, precipitation displays a complex pattern of changes, without a clear-cut average trend in the last century but with an apparent tendency to the intensification of the hydrological cycle in many areas of the world. Global climate models indicate the possibility of global precipitation changes before the end of the current century, with an intensity and pattern that depend on the specific climate scenario and which are not always consistent between the different models. In this task, it is intended to study current and expected changes of precipitation at global and European scale, with a specific focus on extreme episodes and their effects on mean runoff and intense flooding and drought events, using data analysis approaches and a host of different modelling methods. Data-wise, the focus will be mainly on satellite data and their interpretation, including the problem of precipitation and snow cover retrieval and analysis, and on the study of long historical climatic time series from ground station networks. In particular, satellite data will be instrumental for the definition of water scarcity and drought conditions in connection with global and regional hydrological models in the relatively data sparse areas of the globe. At the modelling level, global and regional climate models, mesoscale convective models and stochastic/statistical downscaling procedures, coupled with hydrological models of varying complexity and sub-surface water dynamics will be used and developed. A huge numerical initiative based on the use of high-resolution climate models coupled with global runoff and subsurface flow models will provide new and crucial information on how the global hydrological cycle is changing. Regional climate models nested into the global simulations will allow for focusing on specific climatic hotspots.

Interaction between climate and hydrological/land surface processes

Climate and the hydrological cycle are strongly coupled with land surface and ecosystem processes, both in the sense that modifications of the water cycle significantly affect land surface properties and ecosystem functioning, and because vegetation and land surface changes can lead to important effects on the whole hydrological cycle and on climate. In this framework, a crucial problem is the scale mismatch between climatic variability, usually resolved at rather large spatial scales, and the much smaller scales of land surface processes. Open questions concern the upscaling of small-scale ecosystem and land surface changes and how to incorporate them into climate models, and the downscaling of climate information to properly drive land surface and ecosystem responses. Another question concerns the impact of small-scale heterogeneities on climate variability. Here, one can ask up to which scale variations in the small-scale surface processes (eg, evapotranspiration) affect climate dynamics, or what effect land surface heterogeneities can have on the statistics of extreme events. An open question is whether changes in vegetation properties (such as vegetation patterning) and ecosystem transitions can trigger regional or global changes in climate dynamics. These issues will be addressed using conceptual approaches, intermediate complexity models, fully coupled, scale-crossing climate and land surface models, global and regional climate models and the analysis of available data.

Changes in the hydrological cycle in the Mediterranean region

The Mediterranean basin is considered as a “hot spot” of climate change, and it displays an ongoing tendency towards drier conditions which is expected to continue and possibly worsen in the coming decades. At the same time, individual events of extreme rainfall continue to cause human losses and severe economic damage. This task will be devoted to the analysis of current data on the hydrologic cycle in the Mediterranean basin and to the use and development of regional climate models specifically tuned for the Mediterranean area, to obtain reliable information on water availability and distribution in the next decades and to develop appropriate adaptation measures. Several modelling groups are taking part to the MedCORDEX (www.medcordex.eu) international effort in order to better simulate the Mediterranean hydrological cycle, to improve the modelling tools and to produce new climate scenarios. MedCORDEX is collaborating with Hymex in order to improve the modelling components through the use of the new data gathered during dedicated field campaigns. Attention will also be paid to the reconstruction of the Mediterranean hydrological cycle in the last centuries through the analysis of paleo-data and modelling efforts. Hydrological model schemes must be improved to meet the specific requirements of semi-arid climates, accounting for the related seasonal soil water dynamics and the complex surface-subsurface interactions in such regions.

Changes in the hydrological cycle in mountain areas

Often called the “water towers” of our planet, owing to their role in providing water to the surrounding lowland areas, mountain regions are heavily impacted by climate change. Here, measurements are more difficult owing to the remoteness and harsh environmental conditions of most mountain regions and to the fact that a large fraction of precipitation falls as snow. Modelling of precipitation in mountain regions is also quite demanding, owing to the steep orography and complex atmospheric circulations which put severe constraints on regional and mesoscale numerical models. In this task, attention will be given to all aspects of the hydrological cycle in the mountains, from precipitation to runoff, from snow cover changes to glacier and permafrost dynamics. The activities of this task will consider both data analysis and modelling, and will focus on specific mountain areas of the world such as the Alpine and Apennine regions in Europe and the Hindu-Kush - Karakoram – Himalaya (HKKH) area, currently subject to intense investigation by several European research groups. The data analysis activities will be conducted in collaboration with national and international programs such as Ev-K2-CNR SHARE and GEO/GEOSS, and benefitting from the data provided by the global and regional GAW-WMO stations managed by participant Institutions in ECRA.

Special Focus:
The changing mountains of Europe - Water Resources and Ecosystems at Risk

Mountain regions host 12% of the world's population and are home to about half of the global biodiversity hotspots. Besides providing crucial ecosystem services they are not only economically relevant (e.g. tourism, hydropower, specialized agriculture) but also conserve a rich and diversified cultural heritage. As they provide water to the surrounding lowland areas, they are often called the "water towers" of our planet.
However, mountain environments are particularly fragile and sensitive to human impact such as land use change, water and air pollution or the invasion of alien species, and are thus frequently referred to as 'sentinels of change'. Furthermore, climate change impacts all aspects of the hydrological cycle: Precipitation, runoff, snow cover changes and glacier and permafrost dynamics. Glaciers in the European Alps have lost about two thirds of their volume since 1850 with a clear recent acceleration, making them one of the regions with the greatest mass loss globally. This retreat is expected to continue in the future and will affect important water related services such as river navigation, irrigation and power generation. With regard to snowfall and snow cover, a reduced retention, earlier snowmelt and reduced summer precipitation is projected to modify seasonality in river discharge, imposing stress on aquatic ecosystems. Increasing temperatures and extended photoperiods accelerate phenological change and foster migration within terrestrial habitats.
Gaps in our scientific understanding and predictive capabilities are still hampering stakeholders' evidence-based decision-making processes. In alpine regions, measurements are difficult owing to the remoteness and harsh environmental conditions and to the fact that a large fraction of precipitation falls as snow. Also, the complex orographic and atmospheric conditions put severe constraints on regional and mesoscale numerical models.

For all the above reasons, there is an urgent need to accelerate progress in building a reliable knowledge base to better characterise, understand and predict the changing mountain environment for sustainable development, environmental preservation and the development of adaptation strategies. Best use of available ground and satellite data, new measurement networks, models specifically suited for mountain areas and a stronger link between scientific communities and stakeholders are needed. It is thus recommended that the EU funds collaborative research that aims to provide answers to the following four research questions:

- What are the observed and expected impacts of climate change on European mountain regions?
- How do mountain ecosystems respond to changes in climate and the hydrological cycle?
- What are the socio-economic impacts of climate and ecosystem changes in European mountains?
- What are the effects of mountain water cycle changes in fore- and lowland areas?

This "Special Focus" is based on a Science Briefing for Policy Makers, hosted by MEP Patrizia Toia, Italian Socialists and Democrats, on Tuesday, 15 October 2013, at the European Parliament, Brussels, and is built around four interventions of distinguished scientists in the field, referring to the above mentioned research topics:

Dr. Margot Hill & Prof. Dr. Martin Beniston, University of Geneva, Switzerland
"Climate change in the European mountains"

The authors highlight results from the EU-FP7-project ACQWA (www.acqwa.ch). Alpine snow cover will decline, particularly in mid-latitudes between 1000-2000m. Glacier retreat will be highly variable, while glaciers without debris reach a negative mass balance faster than those with. This variability affects hydropower management due to reductions in surface water flows and seasonal shifts in water availability. Yet, technological, economic and behavioural changes in the electricity system will for now likely impact hydropower more strongly than climate change. To improve water governance, possible conflicts between economic actors (hydropower; agriculture; tourism; industry) facing potential water shortfalls must be identified. An integrated modelling approach is essential to refine projections of climate change impacts on rivers originating in mountains.

Prof. Dr. Maria del Carmen Llasat, University of Barcelona, Spain

"The Pyrenees: a water resource in danger?"

The presentation focuses on climate change impacts in the Pyrenees and related scientific challenges. Research indicates an increasing water demand by cities, environmental services and socioeconomic activities but a decreasing supply. Climatic change and an increasing vulnerability can lead to higher frequency and impact of flash-floods and mass movements. However, the full extent of impacts and their cost is still uncertain. A holistic approach is necessary to develop sustainable adaptation and mitigation strategies, with an emphasis on population awareness. In order to strengthen the stakeholders' relationship (scientists, policymakers, society, economic public and private sector) and the cross-border collaboration, mountain problems should be addressed in a unified European perspective and must take a prominent position in Horizon 2020.

Dr. Elisa Vuillermoz, Ev-K2-CNR, Italy

"Monitoring of the mountain environment and changes in mountain ecosystems"

The author presents findings from two Italian projects: NextData (www.nextdataproject.it) and SHARE (www.evk2cnr.org). She explains the crucial role of short-lived climate forcers, black carbon and ozone, in mountain environments. There, changes occur in species range, distribution and biodiversity, with larger risk for endangered and endemic species. The case of Alpine ibex in an Italian National Park illustrates the important role of snow cover change and its interaction with resource competition. In conclusion, the anthropogenic pollutants BC and O_3, emitted at regional scales and transported to the mountains, can have systematic effects. Mountain research needs continuous observations and measurements that provide estimates of the possible impact of climate and environmental change and air pollution on ecosystems and ecosystem services.

Prof Dr Wolfram Mauser, LMU Munich, Germany

"Water from the Alps - Future Needs and Perspectives"

The presentation connects the Alps with its adjacent low-lands, exemplified by the Upper Danube river, the water tower to 14 downstream countries. It has transregional water export, hydropower production, navigation and food production. The GLOWA-Danube project (www.glowa-danube.de) finds a future river regime change with a diminishing role of the Alps as a water tower for the lowlands. The required multi-sectoral adaptation for e.g. hydropower generation includes either a gain in efficiency, new hydropower plants or new storage reservoirs, compensating the snow and ice storage loss. Climate change will likely reduce navigation and winter tourism, improve agriculture and cause rivalries around Danube water. A European strategy is needed to identify the Alps' future role, efficient trans-boundary water management and sustainable adaptation solutions.

Conclusions

The authors conclude that climate change will make a difference for European mountains, ecologically and economically. It is by now well understood that impacts can be severe, highly variable in time and space and far reaching!

Adaptation must be based on sound scientific analysis and should include improved water governance structures. Yet, strategies are costly, require strong commitments and can likely not offset all negative impacts.
Ultimately, it is strongly recommended that research on climate change and the water cycle in mountain areas considers specific approaches for unique conditions and is tailored to reduce existing uncertainties in climate change impact assessment. Research must be coordinated, interdisciplinary, integrative and transboundary. Innovative monitoring techniques will help further improve process knowledge, which is also needed to include a new focus on seasonal and decadal prediction. These issues should be specifically addressed in Horizon 2020.

Current ECRA members: