GAPHAZ International Workshop on Glacier, Permafrost and High-Mountain Hazards and Risks – meeting report

On September 14, 2014, the **IACS/IPA[1] Standing Group on Glacier and Permafrost Hazards in Mountains** hold an international meeting to discuss current issues and research progress on the assessment of high-mountain hazards and risks, with respect to glaciers and permafrost. The meeting took place at the Dipartimento di Scienze della Terra, University of Torino (Italy), and brought together about 35 participants from different fields including science and practice (remote sensing, modelling, risk management, social sciences, outreach).

The GAPHAZ Standing Group covers 5 thematic issues that are

A. Glacial lakes and outburst floods
B. Slope instability and upstream/down-stream effects
C. Snow, ice & rock avalanches
D. Debris flows and flash floods
E. Volcano-ice interactions

Important **aims of the workshop** were to

- exchange on recent progress in the field,
- define and prepare the GAPHAZ outreach,
- integrate and strengthen the social and risk component,
- produce a comprehensive publication that demonstrates best practise in dealing with GAPHAZ components, and
- highlight the importance of GAPHAZ topics beyond academic research and in international initiatives.

The workshop was structured in four sessions, each of them with an introductory key note talk and a following moderated discussion. The workshop ended with an extensive discussion round that led to conclusions on needs for future activities and on the way to go. Viewing of the rich poster session was possible during coffee breaks, lunch, and after the sessions. The informal setting enabled a lively exchange between poster presenters, key note speakers, and other experts.

The workshop started with a welcome by Marco Giardino (Local Organizing Committee, University of Torino) and an introductory note by Ken Hewitt (Wilfried Laurier University). Charles Fierz (IACS President) gave a short overview of IACS and IPA activities with relevance to GAPHAZ.

Session 1 was on **observation, monitoring and remote sensing**. In his key note, Andreas Kääb (University of Oslo) presented technical issues and current developments in remote sensing, and thoroughly showed the potential for monitoring of GAPHAZ-related issues, taking into account political issues and limitations regarding data access and handling of the data. A particular focus was given on technical aspects of medium-resolution satellite imagery (Landsat 7&8, Sentinel-2). The issues were illustrated with a recent example from Mt. Kazbek (Caucasus), where a large rock-ice avalanche had occurred in May 2014.
Techniques such as laser scanning, unmanned aerial vehicles (UAVs), Structure from motion (SfM), ground-based laser scanning, automatic GPS, intelligent sensor networks are evolving fast. New satellites, UAVs, and automatic sensor networks give large technical promises and hold a great potential for environmental monitoring, also in view of sustainable mountain development. An important challenge is that glaciers and permafrost hazards (and risks) do not have top priority (cost/benefit), but may have a momentous impact.

[1] International Association of Cryospheric Sciences / International Permafrost Association

In the subsequent discussion (moderated by John Clague, Simon Fraser University), it has come out that the challenge is not much the science, but rather governance or gaps in laws (liability). Here GAPHAZ could act as a signpost to bring together involved stakeholders. GAPHAZ could show the technical potential available to local people/authorities/institutions (e.g. through the organization of workshops). Needs of science (not mountain hazards science, but environmental monitoring science) drive the technical developments. Hence, developments are "application-driven", but not "GAPHAZ-driven". Importance should be given to the prediction of events (failures), taking into account fundamental uncertainties, where GAPHAZ should raise the awareness on uncertainty in data.

In **session 2** on **process analysis, anticipation and modelling**, Duncan Quincey (University of Leeds) gave a key note on glacier lakes and how hydrological systems are changed by advancing (= surging) glaciers. The formation of ponds and supraglacial lakes are highly influenced by open water, insulation by debris, and stagnation at the glacier terminus. Recent advances have been made in understanding processes of failure of glacier- and moraine-dammed lakes and process chains, including different hazards (e.g. avalanches). A sound understanding of processes requires longer term inventories. As a promising evolution, DEM "democratization" can be observed, since nowadays everyone can take photographs to generate a DEM using open-source software.

Retrospective modelling is relatively straightforward, but forward-looking accurate predictive models are still challenging. Further challenges include

- quantifying controls of base-level lake expansion,
- timings of lake formation,
- improved modelling of mass impacts of glacial lakes,
- processes and timings of dam failure,
- model coupling to specific GLOF[2] process changes, and
- temporal evolution of hazards in a time of a changing cryosphere.

The discussion round was moderated by Michael Krautblatter (Technical University of Munich) and was devoted to quantification of uncertainties (e.g. by ensemble modelling, Monte Carlo simulations, rock avalanche modelling). Difficulties are detected in forecasting volumes and frequencies; return periods cannot be calculated due to the very low frequency events (but with high damage potential). Socio-economic aspects must be included when assessing integrated systems.

Session 3 on **hazard and risk analysis** was introduced by a key note by John Reynolds (Reynolds International Ltd.). Risks and their impact are mentioned as emergence of hazard, vulnerability and occurrence/exposure. Thereby, the whole system and its components have to be considered. A multiple-criteria analysis allows for assessing and prioritizing glacial hazards. As illustrative examples, the case of (moraine-dammed) glacial lakes and key locations in Bhutan are discussed, and legal aspects and challenges are mentioned, too.
Daniel Straub (Technical University of Munich) gave a second key note and brought in aspects regarding risks and risk assessment for natural hazards. Here, coherency/consistency of models is crucial; in engineering, decisions must be made and support for decision making is needed. The significant issue thereby is to find best measures to account for optimal total costs, where mitigation costs are steadily increasing, but the risks being reduced (non-linearly). To account for (new) changes, a continuous monitoring is needed.
The subsequent discussion was moderated by Christian Huggel (University of Zurich). The need for continued monitoring (including documentation of past events) and the importance of early warning systems are recognized. Probabilistic risk management should be enhanced.

[2] Glacier Lake Outburst Floods

Additional dimensions were finally brought in by **session 4**, which was on **social dimension, communication and outreach**. In his key note, Ken Hewitt introduced disaster risk reduction from a point of view of social vulnerability. Social factors underpin vulnerability, preparedness, disasters, hazards, and risk. Neglected issues are gender, urbanization, conflict, religion, politics and ethnicity. Disaster risk reduction is increasingly linked to adaptation and climate change, and the urgency is recognized: Since the 1992 Rio Conference, natural disasters have killed 1.3 million people and adversely affected 4.4 billion, with damage estimated at US 3.3 trillion. Main factors behind these statistics are:

- Greater concentrations of vulnerable people in dangerous situations
- Social developments that increase vulnerability by gender, class, occupation
- Processes that multiply risk: rapid urbanization, habitat damage, armed conflicts, enforced migration, unemployment, force labour

Hence, more disasters are caused by smaller geophysical events, greater devastation in less extreme parts of large ones. Climate change aggravates pre-existing risks, with considerable loss of resources such as ecosystem services.

A second key note was given by Christine Jurt (University of Zurich) on different perspectives from inside (perception) and focussing on the concerns of the people. With examples from the eastern Alps, a view on local actions to risks (in the form of action or not) was given. Finally, Christian Huggel gave input on science-policy interaction and joint production experience, and Ken Hewitt moderated the following discussion.

Key questions in science-policy interaction involve:

- Is the assessment relevant to decision makers?
- Are the technical evidence and arguments scientifically adequate?
- Legitimacy – Is knowledge production respectful of stakeholders' divergent views and beliefs?

Emerging lessons are:

- Power relations are important drivers.
- National policies and agendas drive the process and interactions.
- Cultural differences and backgrounds may be an additional challenge and utilized for power/policy purposes.
- Science has limited power and lobbying.
- Scientists need to be aware of power and policy contexts, otherwise misuse of scientific information is a risk and scientific integrity is questioned.
- The definition of a common scope and objectives is essential and may involve compromise.

After the four main sessions, a more general and concluding discussion was hold on GAPHAZ and international standards for high-mountain hazard and risk assessments. Interesting efforts include e.g. Future Earth, a global research platform including social sciences. GAPHAZ has to involve more in those programmes, and communication both to policy makers but also to scientists is important. A key hazard is the loss of benefits (ecosystem services) provided by the cryosphere. An enlargement of GAPHAZ to go beyond hazards would be desirable, as well as an expansion of GAPHAZ towards the risks perspectives (though very few people are available, and they are not specialists in high-mountains). Nevertheless, a consensus agreed upon was to continue focusing on glacier and permafrost and related high-mountain hazards, yet considering, and actively seeking communication with experts on social aspects and risks. Hazard science is not only interdisciplinary, but transdisciplinary.