Summary of Summaries
The Global Fair and Workshop on Long-Term Observatories on Mountain Social-Ecological Systems

By
Greg Greenwood
Executive Director
Mountain Research Initiative

The Global Fair and Workshop on Long-Term Observatories on Mountain Social-Ecological Systems held on 16-19 July 2014 at the University of Nevada at Reno brought together nearly 200 people to discuss the state of the art of mountain observation: where are we now and where would we like to go in the future. The Fair and Workshop was not designed to produce an output of a specific form but rather to provide a tour de horizon of the issues involved in a proposed global mountain observatory.

The following report crystallizes key messages from the Fair and Workshop in order to frame better the emerging features and challenges of a global mountain observatory. The report draws from the Mountain Observatories blog (http://www.mountainobservatories.net/) to which many but not all session and ateliers chairs posted summaries of their events. Contents of that blog are portrayed below as *bulleted italics* with the main messages shown in **bold** headings and in plain text, numbered or otherwise, beneath headings.

What to monitor?

1. The key features of mountains worthy of monitoring were indicated first of all by the sessions proposed for the Fair and Workshop. Within these broad themes, participants often noted key specific variables, but in general all of the sessions stopped short of lists of master variables.

Theme	Number of Sessions	Session Numbers (from Program)
Climate and the Water Cycle	6	137_1, 137_2, 193_1,193_2, 193_3, 188
Biogeochemistry	2	200,138/216
Species, Ecosystems and Paleo Environments	9	123_1, 123_2, 124_1, 130/162, 1 60_1, 160_2,201/202,198/203, 129/135
Land Use and Tourism	3	145_1,145_2,184
Social System	5	140_1, 140_2, 141_1, 141_2,119/199/204

2. These features of a given mountain social-ecological systems can be bound together in part or in whole through the use of models.

3. These features also exist within both temporal and spatial contexts. Understanding the past history of a system and its connections to large spatial domains is extremely useful for understanding the operation of the system as shown by monitoring data.

Climate and the Water Cycle

1. Sessions and ateliers on climate, meteorology and hydrology emphasized standard climate variables as well as additional variables necessary for understanding energy and water balances.

- *Comprehensive water balance measurements are needed across a variety of climate / geologic regimes to understand the processes controlling the water balance.*
- *Understanding of basin response to changes in climate is limited by a lack of comprehensive measurements across gradients in elevation, latitude, and continentality.*
- *Most platforms monitor temperature, humidity, and wind, while others also measure a wider range of variables: irradiance, snow depth, precipitation, soil moisture, etc. Temperature is the climate variable most studied.*
- *Streams are monitored in terms on how they respond to changes in precipitation regimes*

2. While the sessions did not generate a concise list of basic variables to be monitoring, creating such a list with additional variants for specific problems appeared to be a logical next step.

- *Identifying other key clima/environmental variables (in addition to temperature, i.e., snowpack properties, glacier elevation, water budget variables, wind, precipitation) to add to existing platforms is one area of improvement.*

3. Seasonal snow pack and the ratio of rain to snow were particularly important.

- *Changes in climate and precipitation type (from snow to rain) have unrealized impact to water yield from high elevation catchments*
- *The following parameters seem to be very important with decreasing significance in view of the participants:*
  - *SWE,*
  - *Phase/snowfall,*
  - *snow temperature and snow structure, and finally*
  - *snow height.*

4.Temporal resolution is a concern.

- *While point measurements of these parameters are somehow of high quality, the temporal resolution is insufficient if they are based on manual measurements.*

5. More effective integration of remotely sensed data, ground measurements, and spatial models are needed to address the challenges noted above.

Biogeochemistry

The sessions demonstrated a specific concern with pollutants and nutrient inputs, and less about biogeochemical cycles, with the exceptions of those of carbon and water.

- *Accurate monitoring or measuring elements from atmospheric deposition or other source*
- *More attention on atmospheric deposited pollutants such as heavy metals, POC, etc, not only in mountain lakes but also in mountain soils.*

Species, Ecosystems and Paleo Environments

1. Sessions validated the GLORIA approach and saw promise in expanding such plot and transect based approaches by incorporating additional variables and taxa, and by extending down below the alpine.

- *Extend vegetation monitoring efforts downslope of the summits in an effort to enhance our capability for early detection of elevational shifts by taxa.*
- *Plant functional traits along an elevational gradient.*
- *Vegetation structure in addition to species comp*
- *Preliminary evidence of rapid arthropod response to alpine environmental change. Arthropod sampling can be done rapidly.*

2. Particular plant and animal species of economic importance could also be included.

- *Invasives and plants useful to traditional cultures are two classes, perhaps occasionally overlapping, of economically and cultural important plant species.*
- *Changing environmental conditions may also disrupt interactions between pest taxa and their natural predators, thus exacerbating pest spread.*

3. Montane forests are important features and often require different levels of monitoring.

- *Field methods for monitoring montane forest structure and functioning, the methods emphasize measuring tree and basal area turnover, forest dynamics, precipitation and temperature.*
- *Remote sensing methods include sensors that utilize the NIR and IR bands, and historical black and white and recent panchromatic aerial photography.*

4. Aquatic habitats were mentioned but less frequently than terrestrial habitats and with few specifics.

- *Lakes in mountain regions are monitored in terms of water quality, biochemistry*, *biodiversity, physic chemical and "lake-uses" in terms of tourism, fishing, etc.*
- *Streams are monitored in terms on how they respond to changes in precipitation regimes*

5. Trophic levels are of interest as are exchanges between trophic and physical levels.

- *Inclusion of decomposers and consumers in addition to primary producers.*
- *Vertical and reciprocal exchanges.*

6. Paleo ecology and refugia, while not strictly subjects of monitoring, are nonetheless important to understand current distribution.

- *Paleo ecology and refugia.*
- *Presence and location of habitat refugia may be key*.

Land Cover and Tourism

1. Land cover emerged as a key point of contact between social and ecological systems.

- *Do we need to aim for a consistent land cover change product, or does one already exist? If one already exists (I suspect that this is true) should we consider a project to verify the product against ground data for mountain regions?*
- *What is the current state-of-the-art regarding the translation of land cover change into impacts in ecosystem services?*
- *Urban growth in high mountain areas*

2. Tourism was called out as a particularly important feature in mountains.

- *Numbers, types, and (environmental) impacts of tourists, to be used to design management strategies (e.g., based on evaluation of carrying capacities, behaviours)*
- *A need to monitor tourists' perceptions, to understand what they appreciate.*

Social System

1. Barriers impede the development of common approaches across social science.
    - *Tensions in qualitative and quantitative research*
    - *The use of the scientific method against more interpretive and critical approaches*
    - *The need for a broad enough framework to be inclusive, yet allow for cross-site comparisons.*

2. Several central theoretical questions emerged from conversations among participants.

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- *Both structure and agency are important. All agree that institutions are important channels for human behavior, but most (all?) would also agree that humans are not automata but can act with intention, within or around existing institutions, even to the point of altering those institutions.*
- *Are we attempting to find critical point of agency [e.g. individual, households, etc.] and link to structure [e.g. rural-urban linkages in mountain areas])*
- *The complexity of mountain systems, including the challenge of managing resources according to multiple criteria both by bureaucratic managers and local resource users.*
- *A focus on community well-being was also identified a guiding concept for research.*

3. Participants identified the following kinds of data as important (in no particular order).

- *Well-being*
- *Adaptive capacity*
- *Resilience*
- *Institutional arrangements*
- *Values*
- *Trust/legitimacy*
- *Ecosystem services (including cultural services)*
- *Government*

- *Economy*
- *Prices as drivers*
- *Demography, population movements*
- *Identity*
- *Perception*
- *Land use*
- *New technologies, leadership in the resources governance, social linkages etc. that are key drivers of changes in communities socio economic perspectives and ecosystems.*
- *The community perception on natural resources as commodities and commons, governance mechanism and management regimes, policies and externalities in terms of new and innovative entrepreneurships (orchards, tourism in protected areas etc.)*
- *Central to the discussion was the idea of economic driver to local economies and identifying those that are central drivers of change within and across systems.*
- *A side discussion emerged on how to capture policies that impact change and stability in mountain systems – as incentive, rules, and/or governance structures?*
- *All data had a need to be scale-relevant and pragmatically requires a heavy reliance on existing secondary sources not just primary data collection.*

4. These "common core data" should be complemented by contextual information (e.g. histories), stretched as needed over space and time and open to elaboration by participants in the social ecological system.

- *Oral histories (Mountain Voices Project); Media revisiting; Survey data; etc*.

The Role of Modeling

Modeling can serve as a focal point to organize monitoring.

- *Simulation of water and carbon distribution in mountain region using suitable data should be verified, calibrated and widely used to figure out other elements distribution.*
- *Should every mountain monitoring station attempt "data assimilation" (meaning an on-going mixture of monitoring and modeling) of water and carbon?*
- *Can we develop coupled (SES) models?*

Historical and Paleo Reconstructions

Reconstructions of the recent and distant past provide a context for current and future monitoring.

- *(T)he qualitative narrative of a place provides important information. And, interpretation of quantitative or qualitative data at any point in time may be completely inaccurate if not placed in historical (and spatial) context. This recognition allows history and humanities to contribute data for a given place.*
- *As part of a proposed template for a proposed mountain monitoring program, should we emphasize the development of a history of observation for each site (i.e., to identify early organized observations) and a commitment at least to consider revisiting and remeasuring*
- *Lakes can preserve also paleo information on past relationships between mountain environments, natural hazards (i.e. earthquakes, landslides) and human pressures (pollution, deforestation..).*
- *Time series of discharge, or at least, a time series of floods, however defined?*
- *Describe the statistical population of floods*
- *Temporal and spatial distribution of extreme floods as well as the triggering processes.*
- *A more general call for paleo information on mountain sites*
- *Uncertainty about the relative importance of extreme events versus gradual change(forests)*
- *The understanding of the past land use changes allows us to model the future landscapes.*
- *Can revisiting studies fill data gaps in monitoring programmes?*

Spatial Context

As site are embedded in the past, so too are they embedded in larger spatial domains, data on which provide additional context.

- *The connection of surface-based stations to upper air (i.e., free tropospheric) atmospheric data and larger-scale atmospheric circulation patterns is rarely considered.*
- *Remote sensing methods include sensors that utilize the NIR and IR bands, and historical black and white and recent panchromatic aerial photography.*
- *What kinds of global data should we collect to understand the drivers and constraints on land cover/land use change? Should we be thinking of, for instance, a global land tenure coverage?*
- *-Basic hydrographic datasets for mountain areas (e.g. HydroSHEDS)*
- *Other global datasets that could be valuable additions to SES studies in mountains include:*
  - *Protected areas*
  - *Indigenous territories*
  - *Demographic variables (e.g.http://sedac.ciesin.columbia.edu/),*

- *Additional key socioeconomic variables summarized per political – administrative units at the sub-national level. The challenge is to build regional / global datasets from national sources, but precedents of this approach exist (e.g. in the Andean region).*

Issues and Challenges in Monitoring

The success of a global mountain observatory depends on dealing with a number of key issues and challenges .

Improvements in Sensor Design

A global mountain observatory would benefit greatly from improved sensors.

- *More robust instrument technology and energy solutions should be developed.*
- *Expert knowledge about the specific sensor set up to be used as well as basic information about the to be investigated process or phenomenon is essential.*
- *Are there references that might be useful for helping researchers address this issue?*
- *Appropriate maintenance of the hardware and accuracy assessment/recalibration is mandatory to get reliable datasets.*
- *Are there standards for these actions?*

Data Management and Information Technology

1. A global mountain observatory needs a well developed data management plan.

- *Basic QA/QC checks (lower level data products) then published through NEON's data portal rapidly after collection*.
- *Develop document of montane environmental observing and metadata standards, perform data and metadata QC, and build website to host metadata and data source links*

2. A global mountain observatory needs to take advantage of current information technology

- *E-infrastructures are beginning to achieve their potential*
- *Many projects … don't have a dedicated data manager*
- *Access to high-performance computing through cloud services promises a simpler approach.*

- *Best approached by organizing some kind of summer course for mountain researchers and site managers? (e-infrastructures)*

3.Sharing of data may require multiple methodologies.

- *The sharing of the data is the good idea, but if it may work well only for quantitative data gathered through mechanical/technical data gathering solutions. The exchange of the direct observation qualitative data is a quite greater challenge.*
- *Knowledge repositories and facilitating data sharing*
- *The need to continue to share experiences from seemingly very different contexts*
- *Core data and principles with flexibility for context sensitivity;*
- *Creating a loose structure to incorporate various social science research project and activities into a central repository of data and tracking of methods.*

Social-Ecological Sysem (SES) Framework

To make sense of the various data types, we need the overarching framework of SES with particular attention to the links between social and ecological systems.

- *A common conceptual framework is needed that guides research questions and provides shared goals, and methods. In this context is important to have a common language (definitions and concepts).*
- *Approaches used to link the social and ecological components of the studied systems are less structured and vary from case to case.*
- *A combination of qualitative and quantitative methods is applied but this is not necessarily translated into a clear integration of social and environmental processes.*
- *A true SES monitoring approach should focus on the linkages between the ecological and social components of a system. An ecosystem good & services (E-G&S) approach may offer a starting point, but not all services are relevant under different contexts.*

Scaling

A global mountain observatory must address scaling issues if site-based data is to inform larger or adjacent domains.

- *Most everything is embedded in a web of relationships from the individual to the family to local to regional to national to international. For example, understanding the behavior of a given actor at point X may*

require data pertaining to political arrangements in the capital or to commodity markets in Chicago or London.

- *A robust approach to monitoring SES in the long term has to incorporate the effects of local and extra-local processes that operate at different scales*
- *Scaling up from specific observatory sites to broader regions is challenging.*
- *Extrapolating point data to an area was identified as an ongoing main issue. Therefore a combination of in situ observations as "ground truth" and remote sensing techniques or reanalysis data for the second and third dimension was suggested*
- *Uneven spatial distribution of point data.*
- *The approach of representative basins*
- *A huge problem is the regionalization of these point measurements in space*
- *What form would these take (e.g. a daily? weekly? or monthy? time series for SWE)?*

Engagement and Commitment

A successful observatory requires engagement and commitment among researchers for an extended period of time.

- *For those in the developing world (South/East) an obligation to make their data available to the global community. Way too much information lies in cupboards or on personal computers.*
- *North/West should have a strong commitment to facilitate collaboration with the South/East in order to obtain a truly global data set upon which responsible decision-making can be based*
- *Coordination without centralization*

Transdisciplinarity

A sustainable observatory that informs social change requires engagement with stakeholders and policy makers.

- *Our knowledge of mountain SES will improve to the degree that we engage participants in the SES in the very creation of knowledge, knowing full well that we and they are not involved in a strictly epistemological exercise.*
- *Likely require engaging actors inside and outside the academy (e.g. local governments, advocacy groups)*
- *Better involvement of stakeholders, better knowledge of reason of decisions of local population about land use (e.g. South America, Himalaya region)*

- *An important challenge is to generate and maintain relationships based on trust. In many cases, barriers persist to share information, methods and expertise in a more open way.*
- *To strengthen the links between the scientific knowledge and tools that are being generated, and the relevant decision making processes*

Useful Next Steps

The next steps in creating a global mountain observatory include the following.

Due Diligence on What's Already Been Done

1. A global mountain observatory should identify and engage other pertinent observational activities.

- *Consult with NEON, NPS I&M, GEOSS and others regarding the implementation of principles*
- *Review WMO, GIVD, IPCC, and other guides of observation*
- *Talk with WMO and other organizations for guidance on a protocol for establishing new mountain observing standards.*
- *If such a minimum set has been defined, are there extant data portals for such data? And if those exist, what would help increase their use (i.e., increase the deposition of data on such portals)?*
- *Publish review paper about problem and vision of action*
- *New satellite missions will bring opportunities for better monitoring of land use*
- *Extracting lessons from earlier efforts at integrative cross-site research in developing long-term observatories of socio-ecological systems in mountain regions.*
- *Reviewing past approaches to cross-site research (ex: IFRI)*

2. A global mountain observatory should identify relevant existing data.

- *Should we have a project that clips land cover change projects to specific mountain regions (for instance, the GMBA mountain range polygon coverage) and then delivers them, for discussion and refinement, to stakeholders in those mountain regions?*
- *Two strategies could render important information:*
  - *1) identify and systematically compare continental / global LUC datasets to assess their potential uses in mountain areas and*
  - *2) for key land cover datasets, quantify their thematic accuracy. This last activity could be done with a crowdsourcing approach in which regional / local experts feed a centralized validation dataset.*

Networking

Information exchange and the development of a global mountain observatory community will be required.

- *It is important for the general community to come together and share solutions. Compiling best practices and systems used in successful deployment at a variety of funding scales is important.*
- *One such emerging community is the EnviroSensing Cluster (http://wiki.esipfed.org/index.php/EnviroSensing_Cluster) within the Federation for Earth Science Information Partners (ESIP, http://www.esipfed.org/), mostly populated by LTER scientists: would it be useful to try to convene potential members of the observatory network at the next ESIP meeting?*
- *Paul Campbell's company must have some kind of client network to it uses to improve its products. Could we call on him?*
- *Where might (a forum to prioritize) happen? The mountain community has its own meeting in Perth Scotland 4-8 Oct 2015*
- *There is OBFS meeting in Woods Hole in September.*
- *There is the AGU where MRI could set up a side event to work on this topic.*
- *What are the existing fora via which we could pursue these topics: FRIEND, PUB, CUASHI, CZO,IAHS? Should we be proposing sessions at the AGU, EGU?*
- *A network of climate scientists and instrumentation technicians is needed for the purpose of sharing expertise in the design, installation, and maintenance of environmental monitoring stations*
- *Create a network of scientists working in BRs, to complement the existing networks of the MAB programme and also to create opportunities for collaborative projects.*

Protocol Compilation and Development

The compilation of protocols for the measurement of variables is a key next technical step.

- *Reference to key paleo reconstruction methods.*
- *Catalog the methods that one could use to generate such a flood time series*
- *What are the standard methodologies? Can we create a comprehensive but finite list of methodologies that generate different kinds of information (e.g., biomass standing crop vs. demography) for different life forms (e.g. alpine tundra, treeline, montane forest)?*
- *Maintain raw data collected with accurate meta data*

- *Are there standard approaches to analyzing the diversity and evolution of local institutions? How can these methods be incorporated into a monitoring strategy?*
- *Calling the conferences and congresses on the terms and definitions; translation of the key books which was instrumental in the forming of the existed systems of monitoring, preparation and publication of manuals for the different methods to make the methods of one side more apprehensible to the other side.*
- *Organizational: creating of workgroup on the development of the method integration.*
- *It is possible the term of existence of workgroup must be enough to turn from intention to actual results, like publishing of a solid book with description of priority methods, a kind of a set of manuals on data gathering and processing or something else.*
- *Conducting literature reviews on core concepts (ex: community well-being) before tackling questions of data and methods*

Model Sites

The engagement of existing observing sites is central to a bottom-up approach to a global mountain observatory.

- *Experimental: test bed solution: creating of the test beds in the developing countries (to determine how well the eastern system may work in the different conditions and how it can improve quality of the monitoring there) and the unified (e.g. USA-Russia) test bed for testing of the integration solutions at the relatively close conditions (e.g. Altai-Alaska)*
- *A workgroup is a fine idea but it must be constituted by people who agree at the outset to apply the methods at their respective sites.*
- *A forum to prioritize these key climate/environmental variables would be a beneficial method to engage mountain observatories in the decision-making process and identify collaborative methods for funding and standardizing such instrumentation.*
- *It is through the test bed idea that the methodology can be created*.

Framing

A global mountain observatory can be advanced via linkages to other activities.

- *Global: appealing to the government for the International Ecology Year– an initiative similar to the International Geophysical Year, International Polar Year or International Mountain Year.*
- *it is anticipated that the new strategy and action plan for the MAB programme (2015-2021) will have an increased emphasis on research,*

probably as a contribution to Future Earth. Does this represent an opportunity for the development of a coordinated programme of monitoring in mountain BRs?