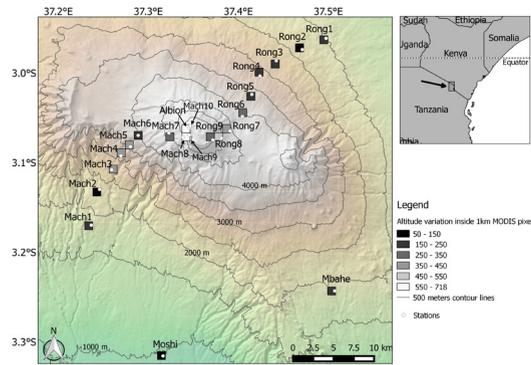


These transects will not only provide the data needed to assess EDW and elevation-dependent precipitation changes, but will also provide energy balance data to understand the mechanisms of EDW and to validate remotely sensed land surface temperature and precipitation products. Finally, they will provide data needed to assess the performance of climate simulation models, which currently perform quite poorly in complex mountain terrain.



(Fig. 4) An example UHOP observing sites along elevational gradients on two different aspects of Kilimanjaro. Circles show the location of sensors. The ANCHOR station (see fig. 2) is located at Mach10 at Kilimanjaro Northern Ice Field. All other stations are FLOAT stations.

The first stage of development of the global UHOP is to collate information on current transects and to add new transects to those already within the platform.



(Fig. 5) UHOP Map: Functional UHOP transect (yellow), Anchor station only UHOP transect requires satellite stations (orange), Proposed UHOP transect (brown), Desired future UHOP transect (grey)

Next steps will focus on protocols concerning data quality, calibration, upgrading, maintenance and screening of current instruments etc., but it is critical to ensure to that the UHOP is composed of enough stations to build a representative overview of warming at high elevations at a global scale.

To register your current mountain stations, potential UHOP anchor or float stations, or for more information, please contact Dr Nick Pepin (nicholas.pepin@port.ac.uk).

Pepin, N.C., Maeda, E.E. & Williams, R. (2016). Use of remotely-sensed land surface temperature as a proxy for air temperatures at high elevations: Findings from a 5000 metre elevational transect across Kilimanjaro, submitted to *Jnl / Geophysical Research Atmospheres*, In press

Pepin, N. and MRI Elevational Dependent Warming Working Group. 2015. Elevation-dependent warming in mountain regions of the world. *Nature Climate Change* 5(5): 424 -43



UNIFORM HIGH-ELEVATION OBSERVING PLATFORM (UHOP)

Needed to Detect and Understand Global Warming
in Mountains.

The UHOP network is coordinated by:
Dr Nick Pepin and Professor Raymond Bradley
Elevation Dependent Warming Group
Mountain Research Initiative, Bern, Switzerland
e-mail: nicholas.pepin@port.ac.uk



Department of earth System Science
and Environmental Technologies
of CNR



Institute of Atmospheric
Sciences and Climate
of CNR



Mountain Research Initiative



(Fig. 1) Chacaltaya Bolivia – formerly the world's highest ski resort (1998, 2003, 2005)
Note the decreasing glacier extent.

From rapidly retreating alpine glaciers to increasingly frequent landslides and rockfalls, there are indications that climate warming is proceeding more rapidly at higher elevations (Pepin et al. 2015). Elevation dependent warming (EDW) is similar to the recognized phenomenon of accelerated Arctic warming and may lead to similar environmental changes (e.g. reduced snow cover and increased glacier melt, stresses on mountain biodiversity, changes in mountain water resources).

As mountains and their downstream environments are often densely populated, however, the human consequences of accelerated warming in mountains are particularly important.

Unfortunately, our current climate data networks are biased towards lower elevations, where data are easier to collect and topographies less complex. In order to gain critical information on climate change in mountains, we need to expand our capabilities in mountain regions by establishing data-rich observing sites.

The International Group on Earth Observations GEO has begun to tackle this challenge by establishing a Global Network for Observations and information in Mountain Environments, or GEO-GNOME. GEO-GNOME is a campaign to detect high elevation climate change and to understand the responsible physical processes, which will allow for better predictions of future climate change in mountains and its consequences.

The backbone of GEO-GNOME is the creation of a Unified High Elevation Observing Platform (UHOP). This unified high elevation platform will consist of observational elevational transects in mountain ranges representative of the global variation in latitude, elevational extent, continentality, and orientation. On some mountain ranges, it may be important for the transects to extend over the whole range to include both windward/lee slope effects. The exact number and location of sites will be decided in consultation with national agencies and research organization, but an indicative distribution is shown on the map (page 4, fig. 5).

Each transect will consist of:

1. At least two (on-grid/power) weather stations (ANCHOR stations) in a tower configuration with automatic data-logging, full energy balance instrumentation and ventilated radiation shields for temperature and humidity measurements.

At a minimum, measured variables will include air temperature, relative humidity, upward and downward shortwave and longwave energy fluxes, wind speed and direction, and pressure, but may also include much more (e.g. full flux and air quality measurements). Stations will be equipped to measure precipitation in both solid and liquid form, as well as snow pack/depth where climate conditions are appropriate. Corroborating data can be supplied by a webcam/time-lapse camera for verification of snow presence/absence for data clearing/cleaning purposes.



(Fig. 2) Anchor station providing high quality data at Kilimanjaro Northern Ice Field (5803 m asl). The anchor station is equipped to measure energy balance components and snow depth as well as standard variables.

2. Multiple sites (at least 5 and maybe as many as 20) located between the two anchor sites along a mesoscale transect.

Using inexpensive battery-powered sensors, these FLOAT stations will measure limited variables (near surface air temperature, relative humidity and if possible land surface temperature/upward and downward short wave radiation or proxy) with hourly data logging to enable detailed characterization of the diurnal cycle.



(Fig. 3) Examples of FLOAT stations in tropical (Kilimanjaro) and polar (Lapland) environments. It is recognised that local solutions may be required for screening of multiple FLOAT stations, and different screens may be practical in different environments. Calibration against ANCHOR stations (with standard screening) is therefore essential.

Located at or near the extremities of the observational transects, the two ANCHOR stations are essential for the calibration of FLOAT sensors along the transect. Wherever possible, additional ANCHOR stations will be located at intermediate points along the transect, filling essential information gaps about high elevation climate changes in these complex topographies. In order to reduce costs, facilitate site selection, and encourage the participation of relevant meteorological agencies, elevational transects will be anchored by existing, well-established mountain weather stations.