**Marginal Snowpacks:**

**Characterizing and developing techniques for monitoring and modelling their hydrological and ecological importance and evolution under climate warming**

Consortium Team:

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Snow was recently listed as one of the essential climate variables to be monitored to support the work of the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change. Much of the traditional snow science has focused on cold, continental areas with well-developed and persistent snowpacks. In the last few years there has been growing recognition to understand and properly monitor marginal snow environments. Marginal snowpacks are found in areas lying close to the 0ºC winter isotherm, and often present a patchy distribution over the terrain and experience several cycles of melting an accumulation during a single snow season. Marginal snowpacks are found throughout the world at moderate altitudes and in mountain environments influenced by warmer more equatorial mid-latitude climate and more by maritime influences.

The importance of marginal snowpacks to montane and downstream communities is significant; and makes them acutely vulnerable to climate change due to the warm temperatures and isothermal snowpack characteristics. The common location in the mid-latitudes and intertropical zone makes these areas prone to receive atmospheric aerosols (dust) reducing albedo and increasing energy inputs. However, our current understanding of this and other hypotheses needs further research as most of our understanding comes from cold continental regions, and melting rates of marginal snowpacks during the coldest months with low radiation that may be significantly different. Marginal snowpacks are of critical importance as under a warmer climate, large areas occupied now by well-developed cold snowpacks will become marginal snowpacks, and this research can underpin how we more completely understand the best way to use science to manage, plan, and adapt to the impacts of climate change.

Studying, monitoring and modelling marginal snowpacks is definitively more complicated than well-developed snowpacks. First, it remains to provide a definitive and accurate definition to classify marginal snowpacks to be used in a consistent way globally. Second, their ephemeral and patchy nature force to work to be conducted at very detailed resolution, in such a way that conventional remote sensing, manual measurement protocols and modelling approaches fail to capture the spatial complexity of marginal snowpacks, or to reproduce specific physical processes affecting them (interactions with vegetation, advection of heat from surrounding bare ground). In addition, they need more accuracy than those applied to well-developed snowpacks since small errors are translated into large deviations in the estimation of the total resource. However, in recent years, new remote sensing techniques have emerged (terrestrial LIDAR, UAV photogrammetry, high resolution satellites, time lapse photography, etc.) and new downscaling techniques for atmospheric models than can be linked to snow energy balance models may successfully address the mentioned challenges.

Objectives

The main objective of this consortium is to set the basis to improve the scientific capabilities to monitor and to model marginal snowpacks, creating appropriate tools and protocols useful to assess their environmental relevance, to map them under current climate and identify the marginal snowpacks vulnerable to disappear, and the snow regions that will turn into marginal snowpacks under available scenarios of climate change. The specific objectives are:

1. Discuss and set an accurate definition of marginal snowpack to be accepted by the international community working on snow sciences.

2. Explore the use of LIDAR, unmanned aerial vehicles and emerging high-resolution remote sensing products (i.e. Sentinel-2, PlanetScope images) not only to map and monitor the evolution of marginal snowpacks, but also to downscale already existing products at coarser resolution but covering longer periods (i.e. MODIS). We will then use this information to set protocols to measure meteorological variables and snowpack in these environments.

3. Explore the optimal methodologies to reproduce atmospheric fields at very high resolution to be used as inputs of reliable snow energy and mass snow models.

4. Use previously defined methodologies to test the sensitivity of marginal snowpacks to changing climate, presence of impurities on snow surface, thermal advection in patchy snowpacks and complex interactions between vegetation and marginal snowpacks.

5. Begin study cases for detecting vulnerable areas of marginal snowpacks to disappear, and well developed ones that may become marginal. This can be the base of regional or global studies.