1. Introduction: Why a focus on mountain regions?

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1.1 Specificity of mountain regions

Mountains are important environments, which extend their influence well into the surrounding lowlands and are rich with natural resources and raw materials. About 20% of the Earth's land surface is mountainous (Kapos 2000) and more than 40% of the world's population relies on water that originates from mountain regions (Barnett et al., 2005, Beniston 2006). The seasonal glacier and snow melt, in particular, nurtures streams and rivers during summer, when rainfall is often scarce or absent, allowing for the presence of running waters also in a meteorologically dry season. Mountains host complex and often special ecosystems with a wide range of ecological habitats, extremely rich biodiversity and many rare and/or endangered species concentrated in small geographical areas. Finally, mountains are historical and natural heritage sites, forged by millennia of coexistence between human societies and the natural environment, and they are among the few places where we can still feel the power of nature in the current hyper-anthropized world.

On the other hand, mountain regions are especially exposed to the impact of climate change. The mosaic of contrasting environments present in mountain areas makes it easy for environmental and ecosystem changes to occur relatively rapidly, as a result of variations in the climate forcing. Temperature rise, upward displacement of the snowline and of the tree-line (Harsch et al., 2009), larger liquid-to-solid precipitation ratio, reduced duration and depth of the seasonal snow cover (Mote et al., 2005), permafrost and glacier melt (Meier et al., 2003), changes in local ecosystems as a result of temperature rise (Pauli et al., 2012), have been more and more evident in the last decades and they are expected to become even more severe in the near future (for a recent review on cryosphere changes, see Beniston et al., 2018). Because the mountain environment is complex, extreme and often exposed to drastic modifications generated by the effect of many factors, even small temperature changes could have an enhanced influence on it compared with lowland areas.

Climate change is not the only stressor that is currently impacting Italian mountains. Other effects such as land use change, pollution, invasive species, unsustainable exploitation of natural resources, and loss of ecosystem services and biodiversity combine with and sometimes amplify the effects of climate change, generating an ensemble of multiple anthropogenic impacts.

Land use change and the abandonment of high-altitude pastures is one important example. The upward displacement of the tree line, currently observed in many Alpine areas, is generated by both the temperature rise and the abandonment of pastures (see e.g. Gehrig-Fasel et al., 2007). Most of the high-elevation open areas are in fact the product of grazing and browsing that cleared the Alpine prairies, turning wooden areas into grasslands. The recent absence of grazing and browsing animals combines with the temperature rise, leading to a return of the trees in previously cleared areas. This in turn leads to a change of the environment, with a loss of ecotones and of the biodiversity associated with them.

Another example of direct human influence comes from the effect of an invasive fish species in the high-altitude, highly oligotrophic lakes in the Gran Paradiso National Park. Around 1960, several naturally fishless lakes in the park were stocked with brook trout by the park management and presumably also by individual fishermen. The brook trout (*Salvelinus fontinalis*) is native to North America and prefers waters with low temperatures and high oxygen content. In Gran Paradiso, stable fish populations did not survive in all stocked lakes; reproductive stable populations survived at depressed growth rates only in some of the lakes. The introduction of *S. fontinalis* in different lakes has been shown to result in changes in the average body size of zooplankton and in the whole plankton community structure (Boavida and Gliwicz, 1996; Knapp et al., 2001). For GPNP lakes, there is an indication of smaller sizes of *Daphnia* gr. *longispina* and *Cyclops abyssorum* where brook trout is present (Tiberti and Iacobuzio, 2012). In addition, the introduction of the brook trout in previously fishless lakes is known to be the cause of a dramatic reduction of many threatened and endangered amphibian populations [Global invasive species database http://www.issg.org/database], and this has been observed also in Gran Paradiso. Similarly, very few invertebrates are found in parkse lakes with fish populations (Tiberti, 2012).

A lake ecosystem model developed to understand the role of introduced fish agrees with the observations, indicating that, owing to the highly oligotrophic nature of the lakes, the introduction of *S. fontinalis* does not lead to phytoplankton bloom but, rather, to the reduction of the size of both phyto- and zooplankton and strong reduction of the Cladoceran populations. Recently, an European Interreg project was devoted to the eradication of the *S. fontinalis* populations from three lakes in the park. The project was successful and very rapidly the lake ecosystem recovered a state close to that of fishless lakes, indicating that active ecosystem management, if carefully planned and implemented, can help recovering from the presence of invasive species.

1.2 Mountains as natural thermometers and sentinels of changes

Mountains are often referred to as sentinels of climate and environmental changes, since they are being affected at a faster rate than other ecosystems and their response to external perturbations is amplified or just comes in advance with respect to other regions.

In spite of the limitations in our understanding of mountain climate and climate changes, owing to observational and modelling issues when studying high-elevation environments, the analysis of the available measurements and of climate model simulations point toward an amplification of warming rates in mountain areas, similar to the Arctic Amplification, a phenomenon which has been often referred to as “Elevation-Dependent Warming” (EDW). This means that high-mountain environments experience more rapid changes in temperature than their counterparts at lower elevations, or compared to globally-averaged temperature increase (Pepin et al., 2015 for a review on EDW).

We also refer to mountains as “natural thermometers" because they are clear indicators of the (lack of) health of our planet. Mountains also provide several indicators of climate change, such as retreating glaciers, permafrost thawing, decrease in the extent, thickness and duration of snowpack, biodiversity loss, mismatch in high-altitude ecosystems. All these factors can affect the provision and quality of the many ecosystem services which mountains provide to lowland communities and societies. In fact, climate impacts constitute an important threat to mountain ecosystem services and the populations depending on them, and have considerable effects on the present and future availability of water resources.

Understanding how climate change is already affecting and is expected to affect mountains is of utmost importance to elaborate mitigation and adaptation strategies, particularly engaging local communities, and build climate change resilience in mountain regions.

1.3 Observing and modelling mountain environments

Understanding climate and environmental changes and their effects in mountain environments requires the availability of accurate and high-resolution observations, especially by in situ stations. However, the existing number of climate and meteorological stations is still low in mountain tops (Pepin et al., 2015) while most of the stations are located in valley floors, and thus measurements of several key variables are biased by elevation. Regions above 5 km still remain largely unexplored in fact, mainly for technical and instrumental issues (e.g. Winiger et al., 2005).

To overcome the limitations arising from the lack and sparseness of in situ stations, remote sensing from satellite can be used. Satellite data provide a spatially complete and homogeneous coverage, but do not extend back beyond the 1970s. The shortcomings of satellite data and of surface station data have stimulated the development of combined or merged climatologies, in order to maximize the benefits and minimize the disadvantages of the in-situ and remote sensing approaches.

Parallel to observations, also correctly simulating the spatial and temporal variability of temperature, precipitation and other key variables in mountain regions using global and regional climate models (GCMs, RCMs) has proven to be a very difficult task (e.g. Palazzi et al., 2015, 2019). One issue is that appropriate simplifications and parameterizations are required for processes that occur at scales smaller than the model resolution (“sub-grid” processes). The commonly parameterized processes include, among others, radiation, heat transfer, cloud microphysics, and convection. For example, several schemes that differ in complexity and physical assumptions have been implemented in the models to parameterize convection (e.g., Kuo, 1965; Manabe and Strickler, 1964; Betts, 1986; Arakawa and Schubert, 1974; Emanuel, 1994; Tiedtke, 1989; Kain and Fritsch, 1990) and the use of either one or another method can introduce uncertainties in model simulations of precipitation and, by consequence, of the mountain hydrological cycle.

In complex areas like mountains, where processes are complicated by topographic effects, downscaling of climate model projections is a necessary step for generating high-resolution input data to force smaller scale models designed to provide the “answer” of a given resource to a climate forcing: land-surface, eco-hydrological, snow, glacier, hazard or, more generally, impact models (e.g. Lutz et al., 2016). This calls for the implementation of a modelling chain connecting the large-scale GCMs (average resolution of 100 km) to local-scale models. Through dynamical downscaling, RCMs allow climate simulations over limited domains at higher spatial resolution than that achieved by GCMs. For hydrostatic RCMs these resolutions are typically in the range of 10 to 50 km, and cover domains encompassing entire continents or parts of them. Climate change impact or assessment studies, however, require climate information at a much higher spatial resolution than that achieved by these RCMs. To fill this scale gaps, various statistical and stochastic downscaling methods are applied (e.g., Maraun et al., 2010) to the output of RCMs or even GCMs.

1.4 The mountain cryosphere

One of the most evident changes that are currently taking place in the mountain environment, including the Italian mountains, is the significant and rapid reduction of cryospheric resources. The recent review of Beniston et al. (2018) illustrates how the mountain cryosphere is affected by climate change and temperature rise. Glaciers are now retreating almost everywhere in the Alps, with the disappearance of many smaller glaciers and the fragmentation of several larger glaciers. Figure 1, from Bonanno et al. (2013), shows on the left the average standardized snout fluctuations for 14 large glaciers in the northwestern Italian Alps for the period 1958-2009, from the data of the Italian Glaciological Committee (CGI), (black lines with white uncertainty bounds) together with the projections from 2010 to 2100 for the RCP4.5 scenario provided by the EC-Earth global climate model (curves in color and green uncertainty bounds). On the right, we show the average snout position with respect to the position in 1968. For all scenarios, the data and the projections indicate continued retreat of the glaciers.

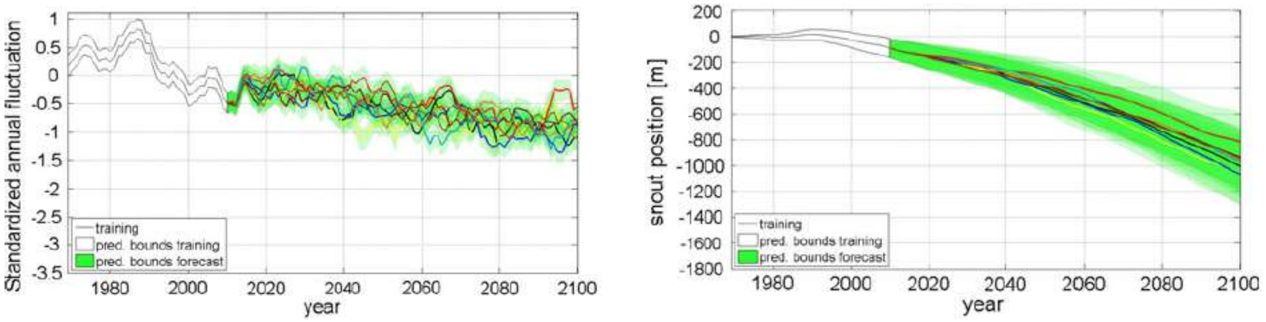

Figure 1. *Left: Average standardized snout fluctuations for 14 large glaciers in the northwestern Italian Alps from the data of the Italian Glaciological Committee (1958-2009) and from the projections for the RCP4.5 scenario from 2010 to 2100. Right: The same for the average snout position with respect to the positions measured in 1968.*

During the NextData project, a large-scale data inventory on Alpine glaciers has been compiled and made available, including time series of glacier snout positions, time series of mass balances, and ensembles of aerial surveys on the extent and shape of a large number of Alpine glaciers. This large dataset will be the basis for future statistical analysis and dynamical studies on the response of glaciers to temperature and precipitation changes.

The other components of the mountain cryosphere are changing as well. Permafrost temperature is increasing, with the danger of rock falls as observed many times in recent years. Similarly, the snow amount is reduced both in average depth and duration, owing to a modified snow-to-rain ratio and higher temperatures that induce a more rapid melt of the snow on the ground (Terzago et al., 2017). As an example, Figure 2 shows the average winter snow depth recorded at the Lake Serrù meteorological station (data by courtesy of IREN) in the Gran Paradiso National Park. Most of these aspects will be discussed further in the following chapters.

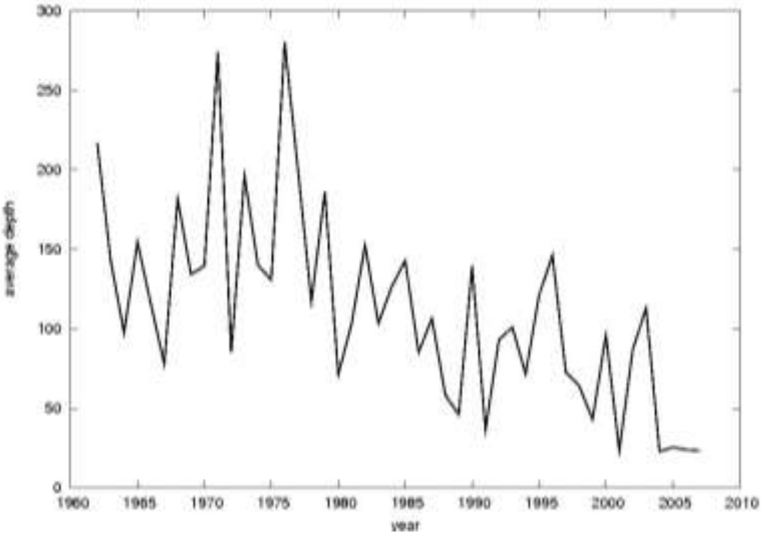

Figure 2. *Average winter snow depth (November to May) from 1962 to 2007 recorded at the Lake Serrù meteorological station (data by courtesy of IREN) in the Gran Paradiso National Park.*

1.5 Mountains as water towers

In many areas of the world, such as the Himalayas, the western Italian Alps and the Apennines, mountains play an essential role in providing water resources to the surrounding lowlands (Viviroli et al., 2011). In the Alps, water is stored into glaciers and seasonal snow cover during winter and it is released later in the warm season to lowland areas. In addition, the recharge of groundwater reservoirs usually happens at the interface between the scarcely permeable mountain rock strata and the alluvial sediments of the lowlands. Changes in the precipitation regime, in the amount and timing of water storage and release of glaciers and snow, and in the amount and seasonal distribution of aquifer recharge can impact on the water cycle in large lowland areas surrounding the mountains.

During the NextData project, two aspects of the dynamics of mountain water resources received particular attention:

(1) The changes in snowmelt timing in the Alps. Earlier snowmelt implies a potential surplus of water in spring, when there are already precipitations, and a deficit of seasonal snowmelt in the late spring – summer season when precipitation is usually scarce. Even though the total amount of annual precipitation can be the same, the seasonal distribution of the runoff can be changing, with a lower water availability in the lowlands during the warm months and the periods of higher demand.

(2) The role of mountains in feeding groundwater resources in the alluvial areas just where mountains meet the plain. Analysis of ongoing and expected changes in the quantity and quality of groundwater resources is crucial and still scarcely explored. On the other hand, aquifers are the main source of water for drinking purposes and an important source for irrigation.

1.6 Mountain ecosystems

This geodiversity of mountain landscapes is associated with high levels of biodiversity, usually higher than those recorded in adjacent lowland areas (Körner, 2000; Theurillat et al., 2003). In addition, mountains host some of the world's most rare and fragile ecosystems (Pauchard et al., 2009). Populations at high elevations are typically small, isolated and prone to local extinction, are often poor dispersers and are characterised by high levels of endemism (McNeely 1990, Boggs and Murphy 1997).

Overall, mountain ecosystems are very sensitive to environmental changes and to global warming. Some of the effects that are already observed and visible include the tendency of natural populations to move to higher elevation (e.g. Pauchard et al., 2016), and a tendency to homogenisation of natural communities of plants and animals.

1.7 Conclusions

The chapters of this volume are in large part devoted to explore and summarise the results of the NextData project, that provided new and more refined quantitative information on many of the aspects and effects mentioned in the sections above. The Volume is structured as follows.

Chapter 2 focuses on the phenomenon of elevation-dependent warming, i.e., the dependence of warming rates on elevation, describing its characteristics and driving mechanisms as well as main uncertainties and issues in its detection and attribution, and focusing in particular on the Alpine region, compared to other mountain areas of the northern hemisphere mid-latitudes.

Chapter 3 deals with the Italian high-altitude network of atmospheric composition measurements and its connections with the WMO Global Atmospheric Watch programme, illustrating the results of high-altitude data analysis and the underlying research questions.

Chapter 4 describes the methodology employed to reconstruct the monthly temperature and precipitation high-resolution climatology (1951-2012) for three Italian National Parks located in the Alpine region: Gran Paradiso, Stelvio and Paneveggio - Pale di San Martino. Episodes characterized by very low or high temperature or by intense rainfall are also discussed.

Chapter 5 deals with geochemistry and isotopes research in mountain environments and especially in water applications taking advantage of recent instrumental and technological innovations acquired in the framework of the NextData project.

Chapter 6 focuses on snowfall and snow depth detection, characteristics and simulations, highlighting strengths and limitations of observational (in-situ and remote sensing) and modelling approaches. Examples and applications are discussed focusing on the Italian mountains.

Chapter 7 described a new database - "Database Idrologico Bacini Appenninici" (DIBA) - developed within NextData, which provides data useful for analyses on climate and hydrological processes in catchments using ground-based and satellite-based observations

Chapter 8 is devoted to present the state of Italian glaciers comparing the years 1988-89, 2006-07, and 2014-15, and discusses glacier snout fluctuations and the database of annual mass balance measurements.

Chapter 9 describes the contribution of NextData to the Long Term Ecological Research (LTER) Network.

Chapter 10 deals with mountain biodiversity, reporting the results of a long-term study of biodiversity of multiple taxa monitoring in the Italian Alps, and in particular along altitudinal transects encompassing three vegetation belts in three protected areas.

Along these lines, Chapter 11 presents the results of a long-term study of rodent population dynamics in the Apennines.

Chapter 12 deals with the network of ground measurement stations in the Italian mountains devoted to the estimate of carbon fluxes and to the study of the mountain Critical Zone, and discusses some of the results of the measurement campaigns performed within NextData.

Chapter 13 presents the climate change scenarios for the Italian mountains obtained from the numerous simulations collected and conducted within NextData, from global and regional, coupled ocean–atmosphere and atmospheric only models, at different spatial resolutions.

Finally, Chapter 14 describes the archive of databases from the mountain monitoring networks of the project.

References

Arakawa A., Schubert W. H., 1974. Interaction of a cumulus cloud ensemble with the large-scale environment, Part I. J. Atmos. Sci. 31:674–701. doi:10.1175/1520-0469(1974)031<0674:IOACCE> 2.0.CO;2.

Barnett T. P., Adam J. C., Lettenmaier D. P., 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438:303–309.

Beniston M., 2006. Climatic Change: Implications for the Hydrological Cycle and for Water Management. Volume 10 of Advances in Global Change Research, Springer Science & Business Media.

Beniston M., Farinotti D., Stoffel M., Andreassen L. M., Coppola E., Eckert N., Fantini A., Giacona F., Hauck C., Huss M., Huwald H., Lehning M., López-Moreno J., Magnusson J., Marty C., Morán-Tejéda E., Morin S., Naaim M., Provenzale A., Rabatel A., Six D., Stötter J., Strasser U., Terzago S., Vincent C., 2018. The European mountain cryosphere: a review of its current state, trends, and future challenges. The Cryosphere, 12:759–794.

Betts A. K., 1986. A new convective adjustment scheme. Part I: obser- vational and theoretical basis. Q. J. R. Meteorol. Soc., 112:677–691. doi:10.1002/qj.49711247307.

Boavida M., Gliwicz Z.M., 1996. Limnological and biological characteristics of the Alpine lakes of Portugal. Limnetica, 12:39–45.

Boggs C. L., Murphy D. D., 1997. Community composition in mountain ecosystems: climatic determinants of montane butterfly distributions. Global. Ecol. Biogeogr. Lett., 6:39–48.

Bonanno R., Ronchi C., Cagnazzi B., Provenzale A., 2013. Glacier response to current climate change and future scenarios in the northwestern Italian Alps. Regional Environmental Change, doi: 10.1007/s10113-013-0523-6.

Diaz S., Symstad A. J., Chapin F. S., Wardle D. A., Huenneke L. F., 2003. Functional diversity revealed by removal experiments. Trends Ecol. Evol., 18:140–46.

Emanuel K., 1994. Atmospheric convection. Oxford University Press, Oxford, p. 580.

Gehrig-Fasel J., Guisan A., Zimmermann N.E., 2007. Tree line shifts in the Swiss Alps: Climate change or land abandonment? J. Vegetation Science, 18:571-582.

Harsch M. A., Hulme P. E., McGlone M. S., Duncan R. P., 2009. Are treelines advancing? A global meta-analysis of treeline response to climate warming. Ecol. Lett., 12(10):1040-9. doi: 10.1111/j.1461-0248.2009.01355.x.

Kapos V., Rhind J., Edwards M., Price M., Ravilious C., 2000. Developing a map of the world's mountain forests. In: Price M, Butt N, editors. Forests in Sustainable Mountain Development: A State of Knowledge Report for 2000. IUFRO [International Union of Forest Research Organizations] Research Series 5. Oxon, NY: CAB International Publishing, pp 4–9. http://dx.doi.org/10.1007/1-4020-3508-X_52.

Kain J. S., Fritsch J. M., 1990. A one-dimensional entrain- ing/ detraining plume model and its application in con- vective parameterization. J. Atmos. Sci., 47:2784–2802. doi:10.1175/1520-0469(1990)047<2784:AODEPM>2.0.CO;2.

Knapp R. A., Matthews K. R., Sarnelle O., 2001. Resistance and resilience of Alpine lake fauna to fish introductions. Ecological Monographs, 71:401–421.

Körner C., 2000. Why are there global gradients in species richness? Mountains might hold the answer. Trends Ecol. Evol., 15:513–514. doi: 10.1016/S0169-5347(00)02004-8.

Kuo H. L., 1965. On formation and intensification of tropical cyclones through latent heat release by cumulus convection. J. Atmos. Sci. 22:40–63. doi:10.1175/1520-0469(1965)022<0040:OFAIOT>2.0 .CO;2.

Lal M., Meehl G. A., Arblaster J. M., 2000. Simulation of Indian sum- mer monsoon rainfall and its intraseasonal variability in the NCAR climate system model. Reg. Environ. Change 1:163–179. doi:10.1007/s101130000017.

Lutz A. F., Immerzeel W. W., Kraaijenbrink P. D. A., Shrestha A. B., Bierkens M. F. P., 2016. Climate Change Impacts on the Upper Indus Hydrology: Sources, Shifts and Extremes. PLoS ONE 11(11): e0165630. https://doi.org/10.1371/journal.pone.0165630.

Magnea U., Sciascia R., Paparella F., TibertimR., Provenzale A., 2013. A model for high-altitude alpine lake ecosystems and the effect of introduced fish. Ecological Modelling, 251:211-220.

Manabe S., Strickler R. F., 1964. Thermal equilibrium of the atmos- phere with a convective adjustment. J. Atmos. Sci. 21:361–385. doi:10.1175/1520-0469(1964)021<0361:TEOTAW>2.0.CO;2.

Maraun D., Wetterhall F., Ireson A. M., Chandler R. E., Kendon E. J., Widmann M., Brienen S., Rust H. W., Sauter T., Themeßl M., Venema V. K. C., Chun K. P., Goodess C. M., Jones R. G., Onof C., Vrac M., Thiele-Eichet I., 2010. Precipitation downscaling under climate change: Recent developments to bridge the gap between dynamical models and the end user. Rev. Geophys., 48, RG3003.

McNeely J. A., 1990. Climate change and biological diversity: policy implications. In Landscape - ecological impact of climatic change, Boer, M.M., Groot, R.S.de (eds), 406-429.

Meier M. F., Dyurgerov M.B., McCabe G. J., 2003. Thehealth of glaciers: recent changes in glacier regime. Climatic Change, 59:123–135.

Mote P. W., Hamlet A. F., Clark M. P., Lettenmaier D. P., 2005. Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society, 1:39–49.

Palazzi E., von Hardenberg J., Terzago S., Provenzale A., 2015. Precipitation in the Karakoram-Himalaya: a CMIP5 view. Clim. Dyn. 45:21. https://doi.org/10.1007/s00382-014-2341-z, 2015.

Palazzi E., Mortarini L., Terzago S., von Hardenberg J., 2019. Elevation-dependent warming in global climate model simulations at high spatial resolution. Clim. Dyn. 52:2685. https://doi.org/10.1007/s00382-018-4287-z, 2019.

Pauchard A., Kueffer C., Dietz H., Daehler C. C., Alexander J., Edwards P. J., Arévalo J. R., Cavieres L. A., Guisan A., Haider S., Jakobs G., McDougall K., Millar C. I., Naylor B. J., Parks C. G., Rew L. J., Seipel T., 2009. Ain't no mountain high enough: plant invasions reaching new elevations. Frontiers in Ecology and the Environment, 7:479-486. doi:10.1890/080072.

Pauchard A., Milbau A., Albihn A., Alexander J., Burgess T., Daehler C., Englund G., Essl F., Evengard B., Greenwood G. B., Haider S., Lenoir J., McDougall K., Muths E., Nunez M. A., Olofsson J., Pellissier L., Rabitsch W., Rew L. J., Robertson M., Sanders N., Kueffer C., 2016. Non-native and native organisms moving into high elevation and high latitude ecosystems in an era of climate change: new challenges for ecology and conservation. Biol. Invasions, 18:345-353. https://doi.org/10.1007/s10530-015-1025-x.

Pauli H., Gottfried M., Dullinger S., Abdaladze O., Akhalkatsi M., Alonso J. L. B., Coldea G., Dick J., Erschbamer B., Calzado R. F., Ghosn D., Holten J. I., Kanka R., Kazakis G., Kollar J., Larsson P., Moiseev P., Moiseev D., Molau U., Mesa J. M., Nagy L., Pelino G., Puscas M., Rossi G., Stanisci A., Syverhuset A. O., Theurillat J. –P., Tomaselli M., Unterluggauer P., Villar L., Vittoz P., Grabherr G., 2012. Recent plant diversity changes on Europe's mountain summits. Science, 336:353–355. 10.1126/science.1219033.

Pepin N., Bradley R. S., Diaz H. F., Baraer M., Caceres E. B., Forsythe N., Fowler H., Greenwood G., Hashmi M. Z., Liu X. D., Miller J. R., Ning L., Ohmura A., Palazzi E., Rangwala I., Schöner W., Severskiy I., Shahgedanova M., Wang M. B., Williamson S. N., Yang D. Q., 2015. Elevation-dependent warming in mountain regions of the world, Nature Climate Change, 5:424-430, https://doi.org/10.1038/nclimate2563, 2015.

Terzago S., von Hardenberg J., Palazzi E., Provenzale A., 2017. Snow water equivalent in the Alps as seen by dridded data sets, CMIP5 and CORDEX climate models. The Cryosphere, 11:1625-1645.

Theurillat J. P., Schlüssel A., Geissler P., Guisan A., Velluti C., Wiget L., 2003. Vascular Plant and Bryophyte Diversity along Elevation Gradients in the Alps. In: Nagy L., Grabherr G., Körner C., Thompson D.B.A. (eds) Alpine Biodiversity in Europe. Ecological Studies (Analysis and Synthesis), vol 167. Springer, Berlin, Heidelberg.

Tiberti R., 2012. Ecology of Alpine lakes in Gran Paradiso National Park. Ph.D. thesis. University of Pavia.

Tiberti R., Iacobuzio R., 2012. Does fish predation influence the vertical distribution of zooplankton in high transparency, shallow lakes? Hydrobiologia, http://dx.doi.org/10.1007/s10750-012-1405-5.

Tiedtke M., 1989. A comprehensive mass flux scheme for cumu-lus parameterization in large-scale models. Mon. Weather. Rev., 117:1779–1800. doi:10.1175/1520-0493(1989)117<1779:ACMFSF>2.0.CO;2.

Viviroli D., Archer D. R., Buytaert W., Fowler H. J., Greenwood G. B., Hamlet A. F., Huang Y., Koboltschnig G., Litaor M. I., López-Moreno J. I., Lorentz S., Schädler B., Schreier H., Schwaiger K., Vuille M., Woods R., 2011. Climate change and mountain water resources: overview and recommendations for research, management and policy. Hydrol. Earth Syst. Sci., 15:471–504.

Winiger M., Gumpert M. Yamout H., 2005. Karakorum-Hindukush- western Himalaya: assessing high altitude water resources. Hydrol. Process., 19:2329–2338, doi:10.1002/hyp.5887.