RELEVANT INFORMATION ON CLIMATE CHANGE IN MOUNTAINS

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An informal summary based on the Report of the Intergovernmental Panel on Climate Change 6th Assessment

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1. MOUNTAIN AREAS

In 2015, a total of 1.28 billion people resided in mountain regions (IPCC, 2022c).

They are regions of high biological and cultural diversity and provide vital goods and services to people living in and around mountain regions and in downstream areas (Adler *et al.*, 2022).

Mountains are highly significant regions in the context of climate change and sustainable development. They lie at the intersection of accelerated warming and large populations that depend directly or indirectly on them (Adler *et al.*, 2022).

Mountains are an essential source of freshwater for large and growing populations; the number of people largely or fully dependent on water from mountains has increased worldwide from approximately 0.6 billion in the 1960s to approximately 2 billion in the past decade, and globally two-thirds of irrigated agriculture depends on essential runoff contributions from mountains (Adler *et al.*, 2022).

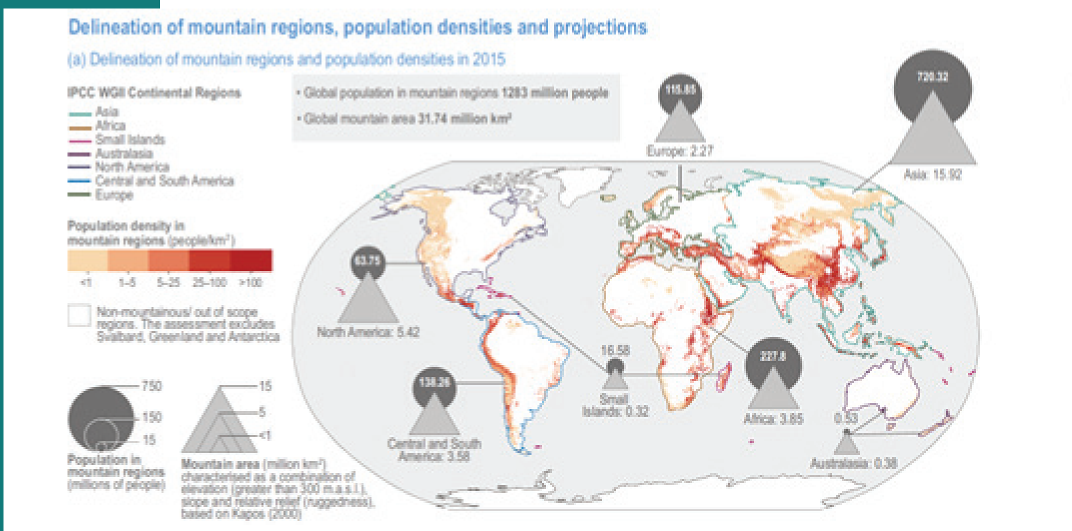

Figure 1: CCP5.1 Delineation of mountain regions in CCP Mountains, population numbers and densities in 2015 and their projections to 2100 (p. 2278), (Adler *et al.*, 2022).

2. MAIN CHANGES

2.1 CRYOSPHERE

Observed changes include increasing temperatures, changing seasonal weather patterns, reductions in snow cover extent and duration at low elevation, loss of glacier mass, increased permafrost thaw and an increase in the number and size of glacier lakes (high confidence) (Adler *et al*., 2022).

Over the last two decades, the global glacier mass loss rate has been the highest since the glacier mass balance measurements began a century ago (high confidence) (Pörtner *et al*., 2022).

Warming has occurred in the Himalayas, the Swiss Alps, and the central Andes and has increased with altitude. Such elevation-dependent warming could lead to faster changes in the snowline, the glacier equilibrium-line altitude and the snow/rain transition height (high confidence) (IPCC, 2022b).

2.2 WATER CYCLE

Climate and cryosphere change have negatively impacted the water cycle in mountains, including variable timing of glacier melt and snowmelt stream discharge (high confidence). These changes have variable impacts on water availability for people and economies, contributing to increasing tensions or conflicts over water resources, especially in seasonally dry regions (medium confidence) (Adler *et al*., 2022; IPCC, 2022c).

Climate change has intensified the global hydrological cycle, causing several societal impacts, which are felt disproportionately by vulnerable people (high confidence). Water insecurity disproportionately impacts the poor, women, children, Indigenous Peoples and the elderly in low-income countries (high confidence) and specific marginal geographies (e.g., small island states and mountain regions), (medium confidence) (Pörtner *et al*., 2022).

2.3 BIOLOGICAL COMMUNITIES

Impacts on biological communities and animal species are also increasingly being reported, with species of lower elevations increasing in mountain regions, creating more homogeneous vegetation and increasing risks to mountain-top species (medium confidence) (Adler *et al*., 2022).

Many mountain-top species have suffered population losses along lower elevations, leaving them increasingly restricted to a smaller area and at higher risk of extinction (medium confidence) (Pörtner *et al*., 2022).

Invasive species effects are most prominent in geographically constrained areas, including islands, semi-enclosed seas and mountains, and they increase vulnerability in these systems (high confidence) (Pörtner *et al*., 2022).

3. MAIN IMPACTS

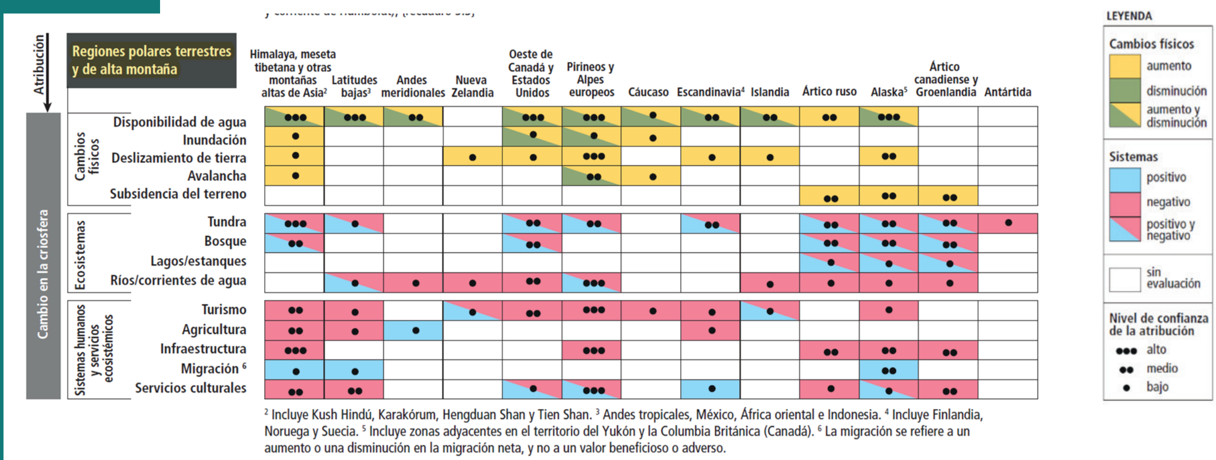

Figure 2: RRP.2 Observed regional impacts derived from changes in the oceans and the cryosphere (p. 12), (6).

3.1 BIOLOGICAL COMMUNITIES

There is an increasing risk of local and global species extinctions where species are not able to move to higher elevations or other cooler locations (high confidence). Mountain regions may act as refugia for some species from lower elevations if they can move into them (Adler *et al*., 2022).

Ecosystem change has led to the loss of specialized ecosystems where warming has reduced thermal habitat, as at the poles, at the tops of mountains and at the equator, with the hottest ecosystems becoming intolerable for many species (Pörtner *et al*., 2022).

The median values for percentage of species at very high risk of extinction are 9% to 15%. Extinction risks are higher for species in biodiversity hotspots (medium confidence), reaching 24% of species at very high extinction risk above 1.5°C, with yet higher proportions for endemic species of 84% in mountains (medium confidence) and 100% on islands (medium confidence) (Pörtner *et al*., 2022).

3.3 ENERGY AND TOURISM

Climate-change-driven changes in precipitation, river flow regimes and landslides affect the production and use of energy in mountain regions, in particular hydropower (high confidence) (Adler *et al*., 2022).

Drought years have reduced thermoelectric and hydropower production by around 4-5% compared to log-term average production since the 1980s (medium confidence) (Pörtner *et al*., 2022).

Observed changes in seasonality (timing and extent) are negatively affecting mountain winter tourism and recreation (high confidence) and variably affect tourism and recreation activities in other seasons (medium confidence) (Adler *et al*., 2022).

Climate change is projected to lead to profound changes and irreversible losses in mountain regions with negative consequences for ways of life and cultural identity (medium confidence). However, there is limited evidence on the magnitude of the consequences (Adler *et al*., 2022).

3.4 CRYOSPHERE – WATER CYCLE

Many low-elevation and small glaciers around the world will lose most of their total mass at a 1.5°C global warming level (GWL) (high confidence) (Adler *et al*., 2022).

Extreme precipitation is projected to increase in major mountainous regions (medium to high confidence, depending on location), with potential cascading consequences of floods, landslides and lake outbursts in all scenarios (medium confidence) (IPCC, 2022b).

Melting of glaciers, snow decline and thawing of permafrost have threatened the water and livelihood security of local and downstream communities through changes in hydrological regimes and increases in the potential of landslides and glacier lake outburst floods (Pörtner *et al*., 2022).

Cryosphere related changes in floods, landslides and water availability have the potential to lead to severe consequences for people, infrastructure and the economy in most mountain regions (high confidence). Cryosphere change has affected ecosystems, water resources, livelihoods and cultural uses of water in all cryosphere-dependent regions across the world (very high confidence) (Pörtner *et al*., 2022).

4. RISKS

4.1 REASONS FOR CONCERN

The Reasons for Concern (RFC) framework communicates scientific understanding about accrual of risk for five broad categories assuming low to no adaptation. RFC1: Unique and threatened systems: ecological and human systems that have restricted geographic ranges constrained by climate-related conditions and have high endemism or other distinctive properties. Examples include coral reefs, the Arctic and its Indigenous Peoples, mountain glaciers and biodiversity hotspots. [Fig. TS4 – p.59] (Pörtner *et al*., 2022)

Levels of concerns at a given level of warming remain higher for RFC1 than others. Limiting global warming to 1.5°C would ensure risk levels remain moderate for RFC3, RFC4 and RFC5 (medium confidence), but risk for RFC2 would have transitioned to a high risk at 1.5°C and RFC1 would be well into the transition to very high risk (high confidence). RFC1, RFC2 and RFC5 include risks that are irreversible, such as species extinction, loss of cultural heritage (Pörtner *et al*., 2022).

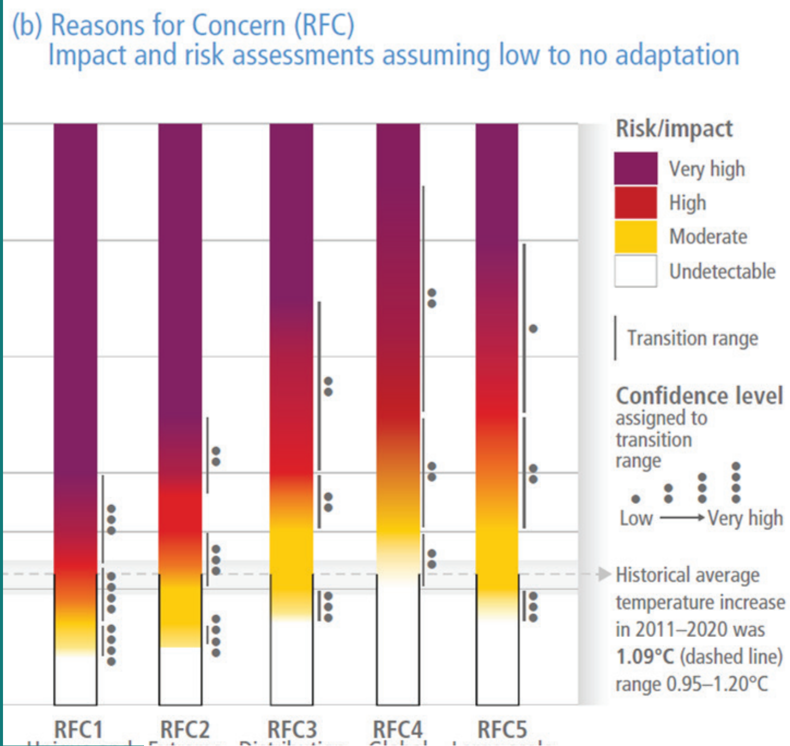

Figure 3: Impact and risk assessments assuming low to no adaptation (Pörtner *et al*., 2022).

4.2 CASCADING EFFECTS

Climate-related hazards, such as flash floods and landslides, have contributed to an increase in disasters affecting a growing number of people in mountain regions and areas further downstream (high confidence) (Adler *et al*., 2022, 5). Projected changes in hazards, such as floods and landslides, as well as changes in the water cycle, will lead to severe risk consequences for people, infrastructure and the economy in many mountain regions (high confidence) (Adler *et al*., 2022, 5).

Adverse impacts from climate hazards and resulting risks are cascading across sectors and regions (high confidence), propagating impacts along coasts and urban centres (medium confidence) and in mountain regions (high confidence). These hazards and cascading risks also trigger tipping points in sensitive ecosystems and in significantly and rapidly changing social-ecological systems impacted by ice melt, permafrost thaw and changing hydrology in polar regions (high confidence). In Amazonia, and in some mountain regions, cascading impacts from climatic (e.g., heat) and non-climatic stressors (e.g., land use change) will result in irreversible and severe losses of ecosystem services and biodiversity at 2°C global warming level and beyond (medium confidence) (IPCC, 2022a).

Additional warming, e.g. above 1.5°C during an overshoot period this century, will result in irreversible impacts on certain ecosystems with low resilience, such as polar, mountain, and coastal ecosystems, impacted by ice-sheet, glacier melt, or by accelerating and higher committed sea level rise (high confidence) (IPCC, 2022a).

4.3 VULNERABILITY

Regions heavily relying on glacier melt and snowmelt for irrigation will face erratic water supply and increased food insecurity (Adler *et al*., 2022). The difference in impacts will be particularly strong in regions that greatly depend on glacier and snow melt and, in pronounced dry seasons (high confidence) (IPCC, 2022c).

Vulnerability will also rapidly rise in low-lying Small Island Developing States and atolls in the context of sea level rise and in some mountain regions, already characterised by high vulnerability due to high dependence on climate-sensitive livelihoods, rising population displacement, the accelerating loss of ecosystem services and limited adaptive capacities (high confidence). Future exposure to climatic hazards is also increasing globally due to socioeconomic development trends including migration, growing inequality and urbanization (high confidence) (IPCC, 2022a).

Cities and settlements (particularly unplanned and informal settlements and in coastal and mountain regions) have continued to grow at rapid rates and remain crucial both as concentrated sites of increased exposure to risk and increasing vulnerability and as sites of action on climate change (high confidence). The most rapid growth in urban vulnerability and exposure has been in cities and settlements where adaptive capacity is limited, including informal settlements in low- and middle-income communities and in smaller and medium-sized urban communities (high confidence) (Pörtner *et al*., 2022).

Unplanned rapid urbanisation is a major driver of risk, particularly where increasing climate-driven risks affect key infrastructure and potentially result in compounding and cascading risks as cities expand into coastal and mountain regions prone to flooding or landslides that disrupt transportation networks, or where water and energy resources are inadequate to meet the needs of growing settlements (high confidence) (Pörtner *et al*., 2022).

4.4 ADAPTATION

The current pace, depth and scope of adaptation are insufficient to address future risks in mountain regions, particularly at higher warming levels (high confidence). With warming above 1.5°C, the need for adaptation to address key risks in mountains becomes increasingly urgent (high confidence) (IPCC, 2022c). Climate-resilient development is most constrained in regions/subregions in which climate impacts and risks are already advanced, including low-lying coastal cities and settlements, small islands, deserts, mountains and polar regions (high confidence) (IPCC, 2022a).

Observed adaptation responses in mountains are largely incremental and mainly focus on early warning systems and the diversification of livelihood strategies in smallholder agriculture, pastoralism and tourism. However, there is limited evidence of the feasibility and long-term effectiveness of these measures in addressing climate-related impacts and related losses and damages, including in cities and settlements experiencing changing demographics (Adler *et al.*, 2022).

While contributing to poverty reduction in some mountain regions, there is limited evidence of adaptations effectively contributing to the remediation of underlying social determinants of vulnerability, such as gender and ethnicity (medium confidence) (Adler *et al.*, 2022). Reducing climate risks will depend on addressing the root causes of vulnerability, which include poverty, marginalisation and inequitable gender dynamics (high confidence) (Adler *et al.*, 2022).

There is high confidence that water conservation efforts, including restoration and protection of particularly vulnerable areas (e.g., wetlands) and increase inefficiency in water use, are robust, low-regret adaptation measures (IPCC, 2022c).

Regional cooperation and transboundary governance in mountain regions, supported by multi-scale knowledge networks and monitoring programmes, enable long-term adaptation actions where risks transcend boundaries and jurisdictions (medium confidence) (Adler *et al.*, 2022).

Limits to adaptation have been observed for terrestrial and aquatic species and ecosystems and for some human and managed systems in specific geographies such as small island states and mountain regions (high confidence) (Pörtner *et al.*, 2022). Many natural systems are near the hard limits of their natural adaptation capacity and additional systems will reach limits with increasing global warming (high confidence). Ecosystems already reaching or surpassing hard adaptation limits include some warm-water coral reefs, some coastal wetlands, some rainforests, and some polar and mountain ecosystems (high confidence) (IPCC, 2022a).

Opportunities for climate resilient development are not equitably distributed around the world (very high confidence). Climate impacts and risks exacerbate vulnerability and social and economic inequities and consequently increase persistent and acute development challenges, especially in developing regions and sub-regions, and in particularly exposed sites, including coasts, small islands, deserts, mountains and polar regions. This in turn undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities (very high confidence) (IPCC, 2022a).

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