

MOUNTAINS UNCOVERED

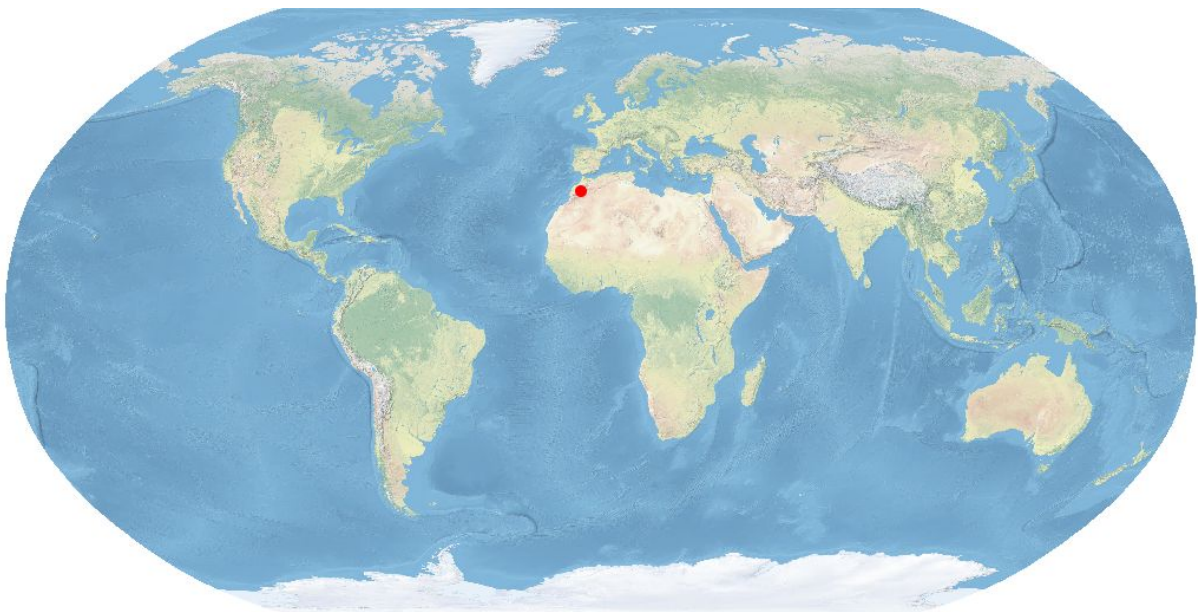
Intercomparable Maps and Statistics for 100 Selected Global Mountain Ranges

High Atlas Range

#7

High Atlas Range

The *Mountains Uncovered* series has been developed by GEO Mountains to provide a set of easily understandable and inter-comparable maps, tables, and figures spanning a range of thematic areas for 100 selected global mountain ranges. This is the report for the **High Atlas Range** mountain range. The [index page](#) shows an overview of all mountain ranges in the series.



Location of the High Atlas Range mountain range [1][2].

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1. General Information

1.1. Administrative

The mountain range is fully within **Morocco**, as shown in Figure 1.1. The overview is based on the GADM dataset [3] of administrative divisions at Level 0.

Figure 1.1. Administrative Overview



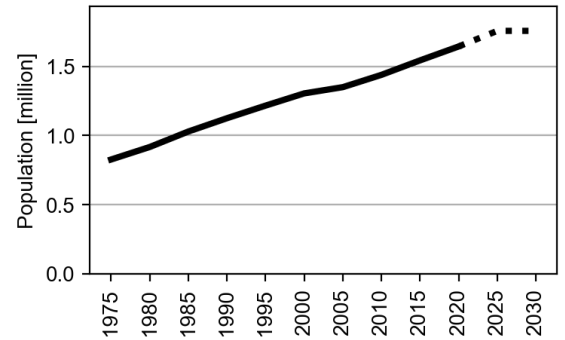
● Morocco: 46,311 km² 100%

1.2. Demographics

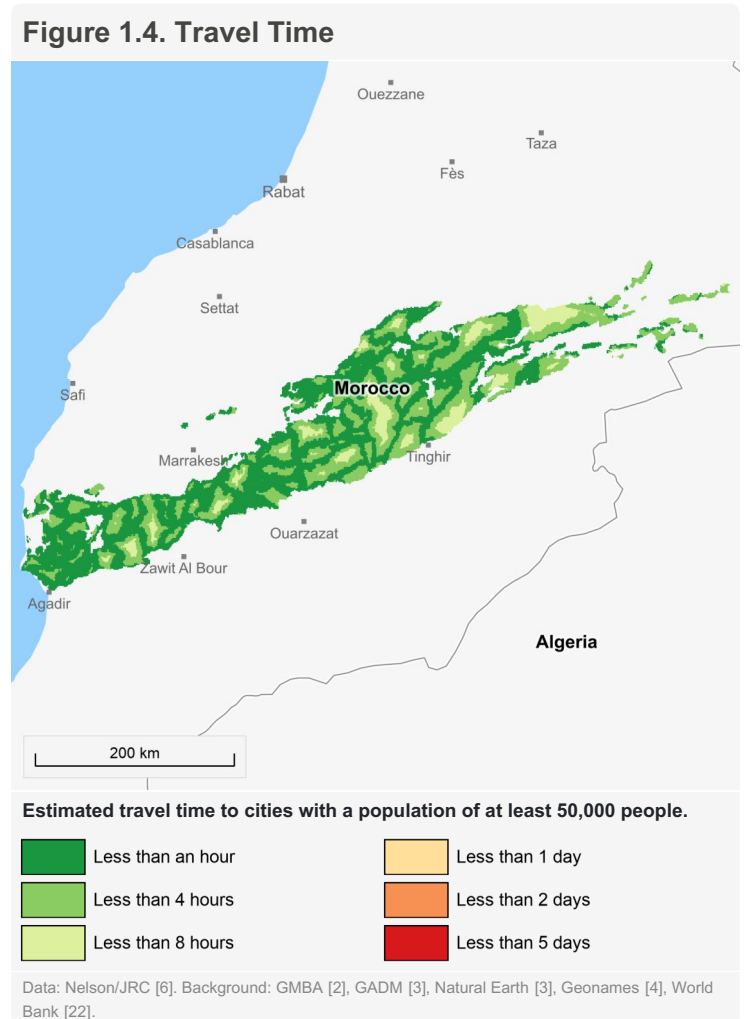
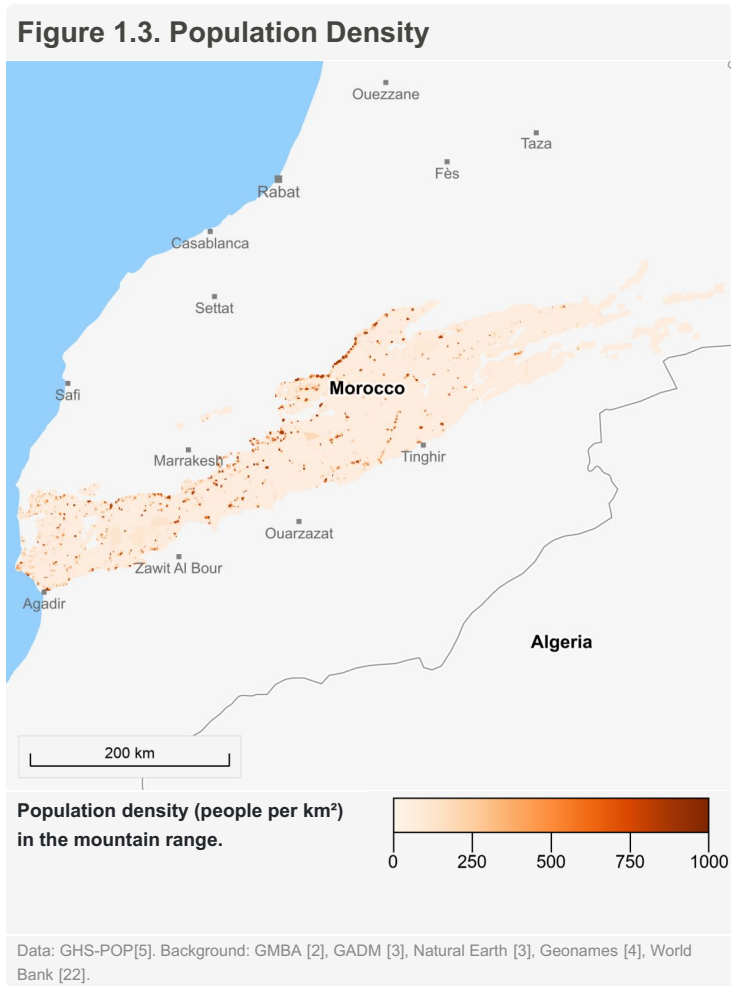
Data on the mountain range's human population are sourced from the European Commission's GHS-POP dataset [5]. According to this source, it is estimated that **2 million** people lived in the area in 2020. This is expected to **increase to 2 million** by 2030. There are **no large settlements** listed in the populated places database.

In 2020, the human population in this mountain range was estimated to be 2 million.

Figure 1.2. Population estimates in the mountain range from 1975-2030. The data after 2020 are projections.



The maps show the population density in the mountain range (Figure 1.3), and estimated travel time to the nearest population centre with more than 50,000 inhabitants (Figure 1.4). Estimated travel time can be useful for evaluating accessibility to services and markets.



1.3. Development and Economic Indicators

The Human Development Index (HDI) is determined by a combination of indicators such as life expectancy, literacy rate, access to electricity, Gross Domestic Product (GDP), and others. In 2015, the average HDI in this mountain range was estimated to be **0.65**. This is considered to be a **medium level of development**.

The total GDP within this mountain range in 2015 was estimated to be **\$13 billion**, an **increase of \$6 billion since 2000**. Table 1.2. shows an overview of the HDI and GDP indicators over time.

Table 1.2. GDP and HDI Indicators over Time

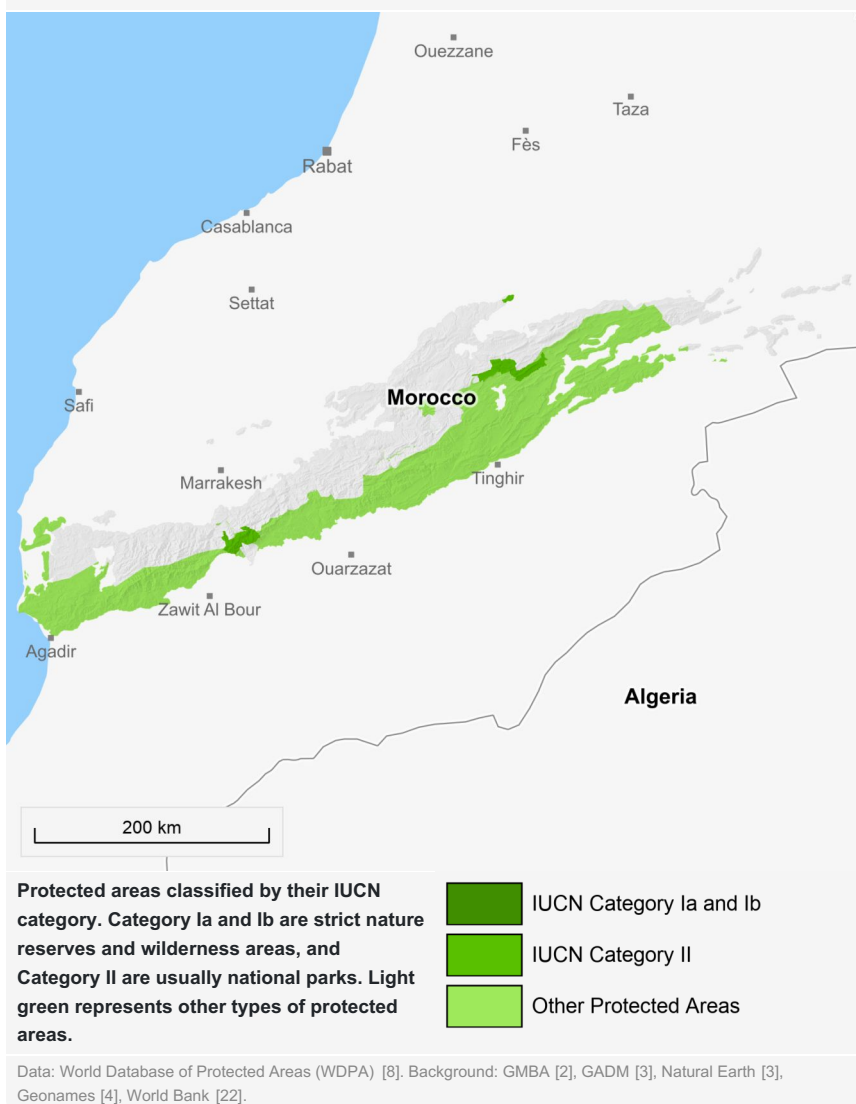
	1990	2000	2015
Gross Domestic Product	\$6 bn	\$7 bn	\$13 bn
Human Development Index	0.46	0.53	0.65

Source: Kummu et al. [7]

1.4. Protected Areas

Figure 1.3 shows the spatial coverage of protected areas in the mountain range according to the World Database of Protected Areas (WDPA) [8]. A total of **49%** of the mountain range is covered by a protected area. The establishment of protected areas represents a key measure to protect and conserve valuable mountain biodiversity and ecosystems. These areas vary broadly in their aims, regulations, and effectiveness, however.

Figure 1.3. Protected Areas



A total of 49% of the mountain range is classified as protected in the World Database of Protected Areas.

The largest protected areas are:

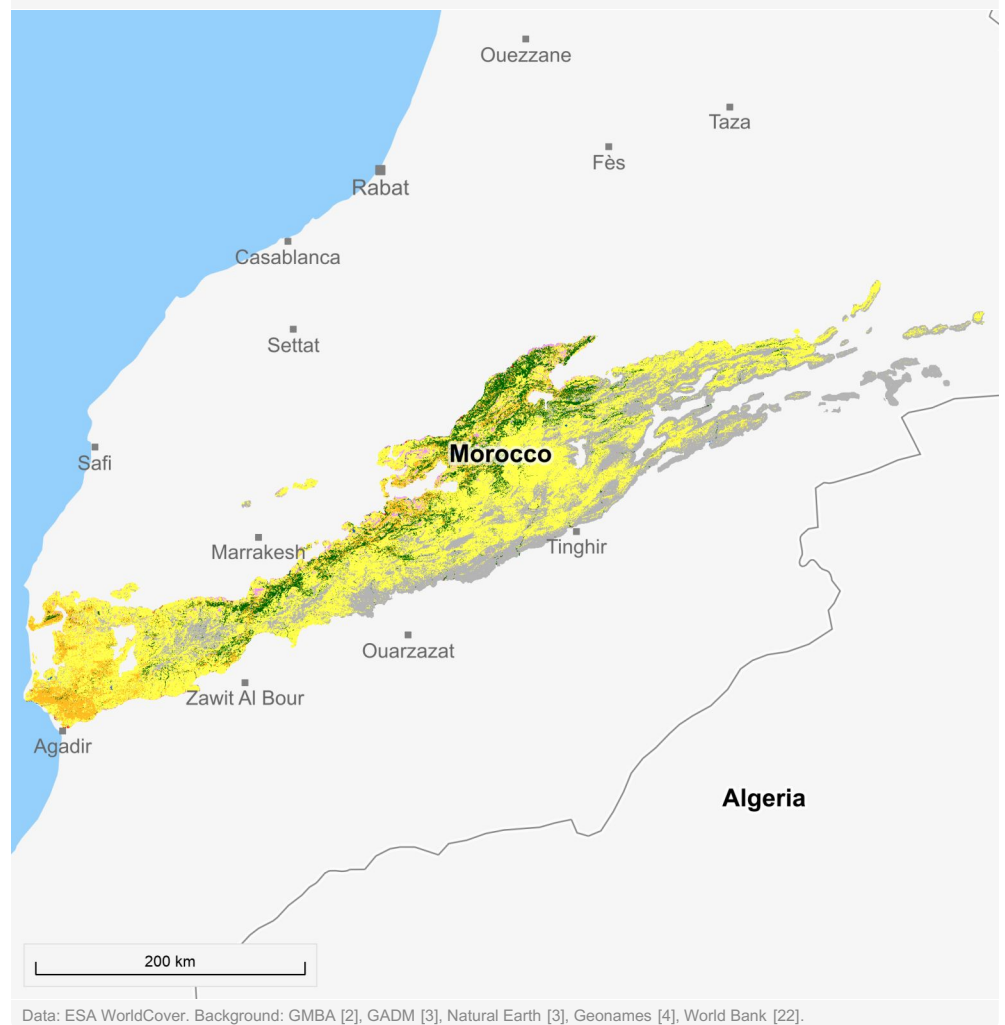
1. Réserve de Biosphère des Oasis du Sud Marocain (RBOSM) UNESCO-MAB Biosphere Reserve	80,158 km ²
2. Réserve de Biosphère de l'Arganeraie (RBA) UNESCO-MAB Biosphere Reserve	23,721 km ²
3. Khānifra National Park National Park	845 km ²
4. Haut-Atlas-Oriental National Park National Park	558 km ²
5. Toubkal National Park National Park	394 km ²

2. Land cover

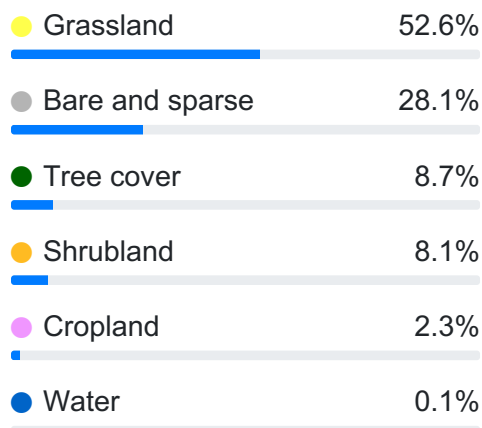
2.1. Land Cover

According to the ESA WorldCover dataset [9], the most dominant land cover types in 2021 were **grassland (52.6%)** and **bare and sparse (28.1%)**.

Figure 2.1. Land Cover



Land cover percentages from 2021 for the largest land cover classes in the mountain range.



The European Commission's Global Human Settlement Layer (GHSL) [10] classifies **0.0%** of the mountain range's area as urban centre, **0.9%** as urban cluster, and **99.1% as rural**.

3. Topography

The land surface elevation ranges from a **minimum of zero m** to a **maximum of 4,167 m** at **Jbel Toubkal**. The **mean elevation is 1,737 m**. **50%** of the area lies is between **1,296 m and 2,170 m**, and **90%** of the area lies between **634 m and 2,598 m**. Figure 3.1 shows a shaded relief elevation map based on the MERIT DEM [11] and a selection of peaks from the Geonames dataset [4]. The distribution of land surface elevation strongly affects local climatic and living conditions in mountains.

Figure 3.1. Elevation and Peaks

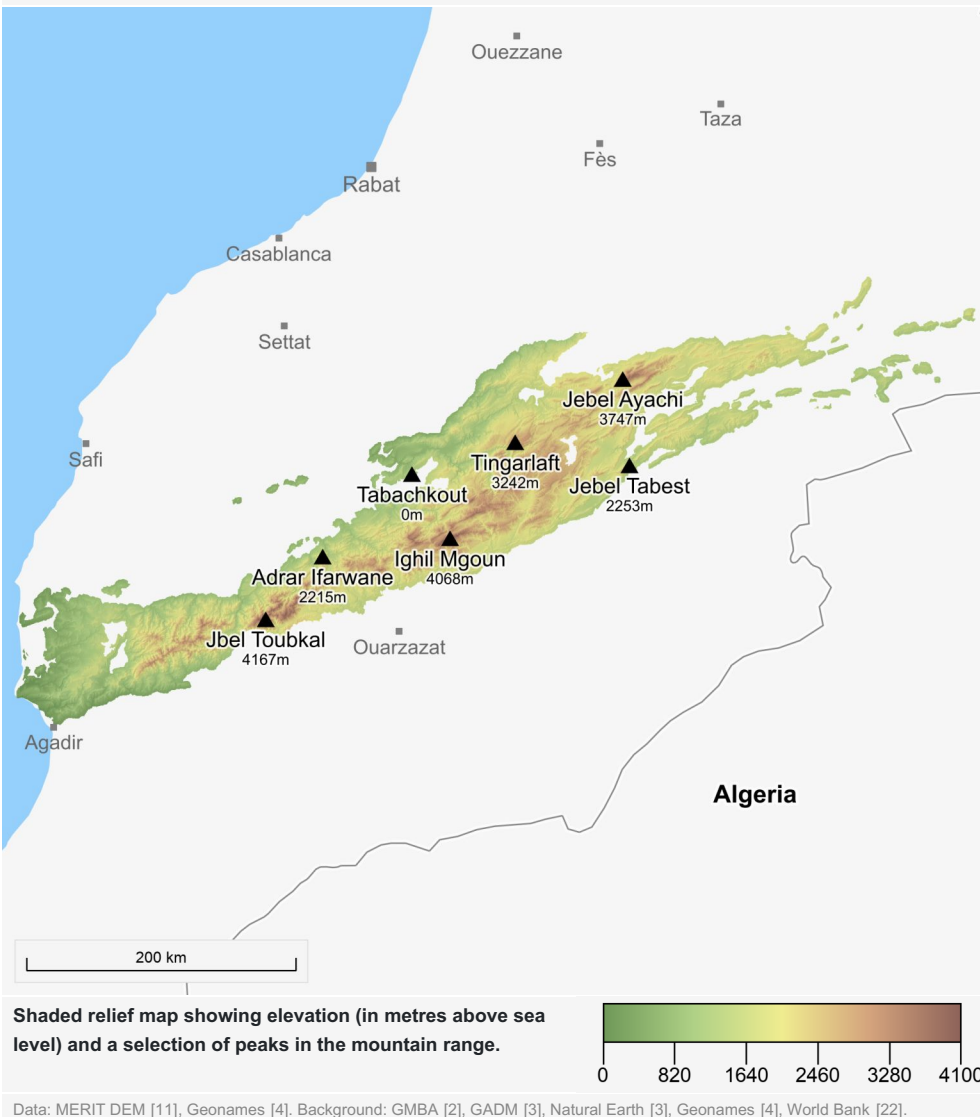


Figure 3.2. Distribution of elevation within in the mountain range [11].

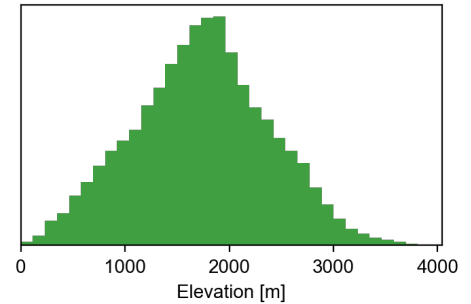


Figure 3.3. Distribution of slope steepness within in the mountain range [21].

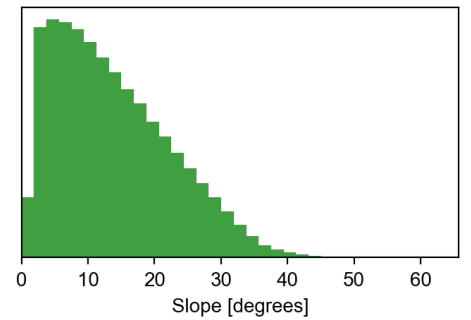


Figure 3.4. Highest peaks in the mountain range according to the Geonames [4] dataset.

1. Jbel Toubkal	▲ 4,167 m
2. Timesguida n'Ouanoukrim	▲ 4,089 m
3. Adrar n' Ouanoukrim	▲ 4,080 m
4. Ighil Mgoun	▲ 4,068 m
5. Jbel n' Nig Oumassine	▲ 3,883 m
6. Aksoual	▲ 3,842 m
7. Taska n'Zat	▲ 3,805 m
8. Rjoute	▲ 3,757 m
9. Jebel Ayachi	▲ 3,747 m
10. Jbel Ouzourki	▲ 3,677 m

4. Climate

4.1. Temperature and Precipitation

Precipitation and temperature combine to control local weather and climate, with implications for water availability, vegetation growing conditions, snow and ice accumulation, and extreme events such as floods and droughts.

The mean annual temperature across the mountain range is shown in Figure 4.1. The **mean annual temperature for the entire mountain range is 13.6°C**, but it varies geographically from a **minimum of 0.9°C** to a **maximum of 22.0°C**. The temperature data are extracted from the CHELSA climatology dataset [13].

The mean annual precipitation shown in Figure 4.2. The **mean annual precipitation for the entire mountain range is 444 mm**, but it varies geographically from a **minimum of 129 mm** to a **maximum of 1,023 mm**. Precipitation data are bias-corrected for use in mountain environments, and are extracted from CHELSA data in the Precipitation Bias CORrection (PBCOR) dataset [12].

Figure 4.1. Mean Annual Temperature

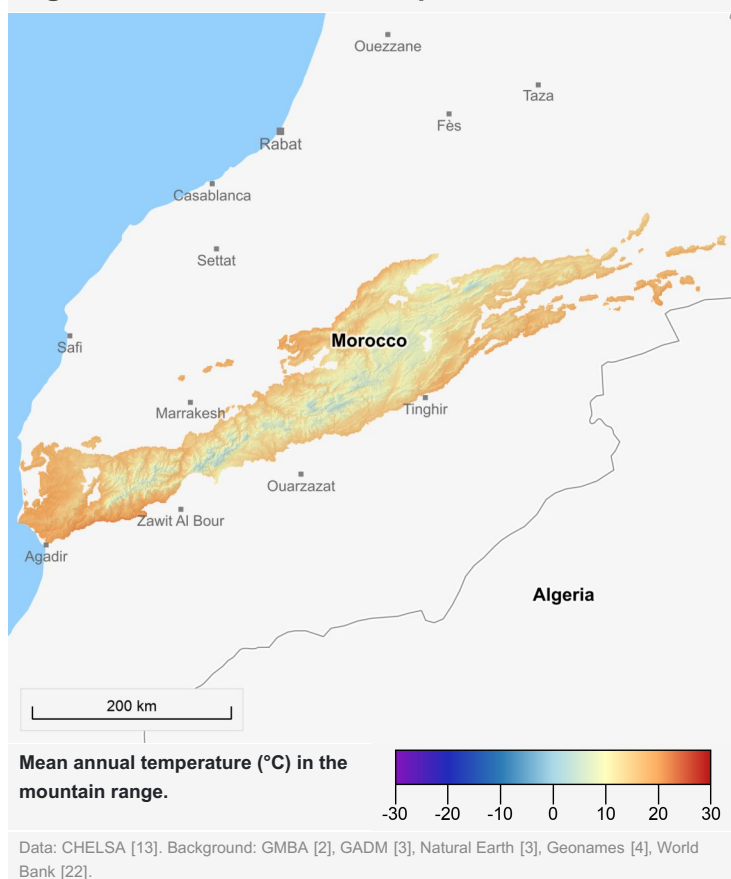
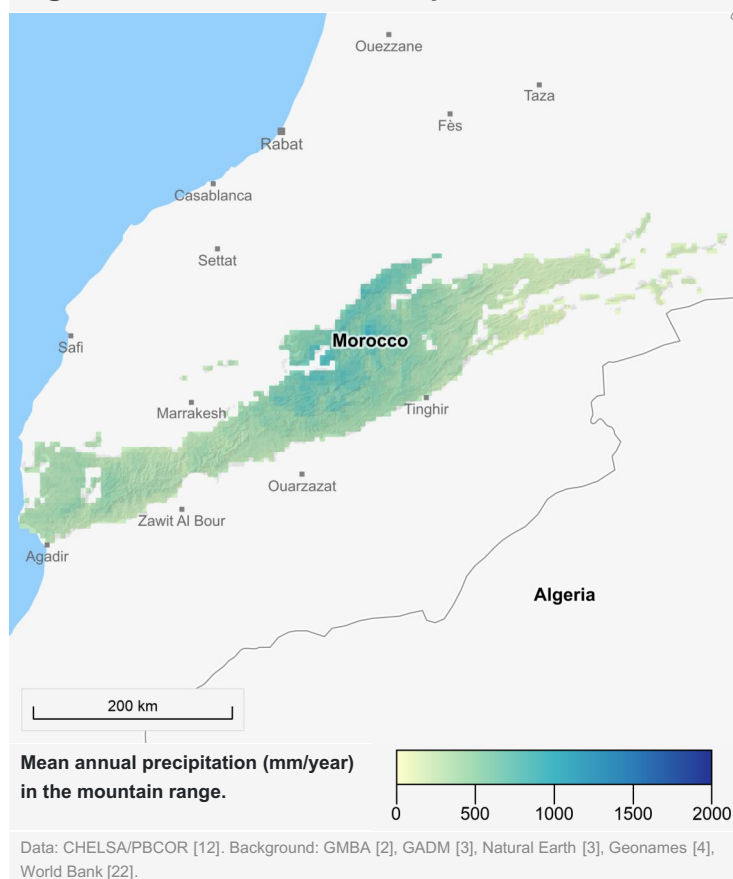
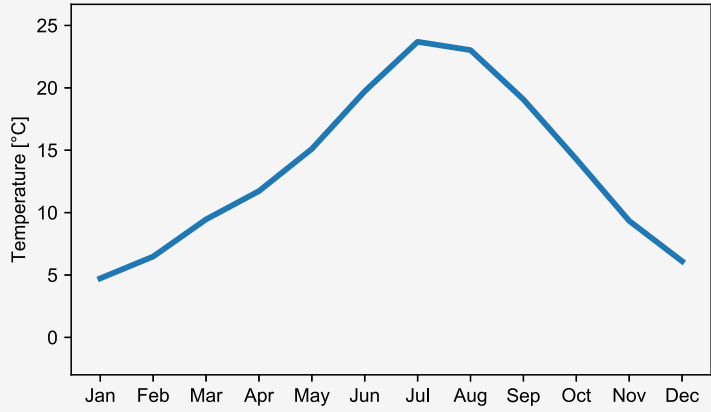


Figure 4.2. Mean Annual Precipitation



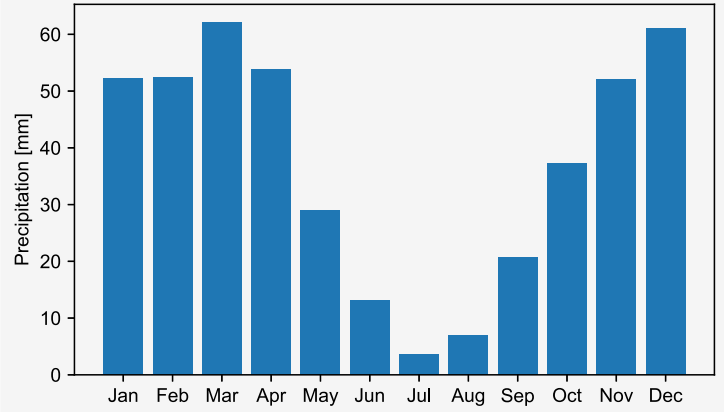
The mean monthly temperature across the entire mountain range shown in Figure 4.3, and varies from a **maximum of 23.7°C in July** to a **minimum of 4.7°C in January**. Equivalent statistics for precipitation are shown in Figure 4.4, which vary from a **maximum of 62 mm in March** to a **minimum of 4 mm in July**.

Figure 4.3. Mean Monthly Temperature



Data: CHELSA [13].

Figure 4.4. Mean Monthly Precipitation

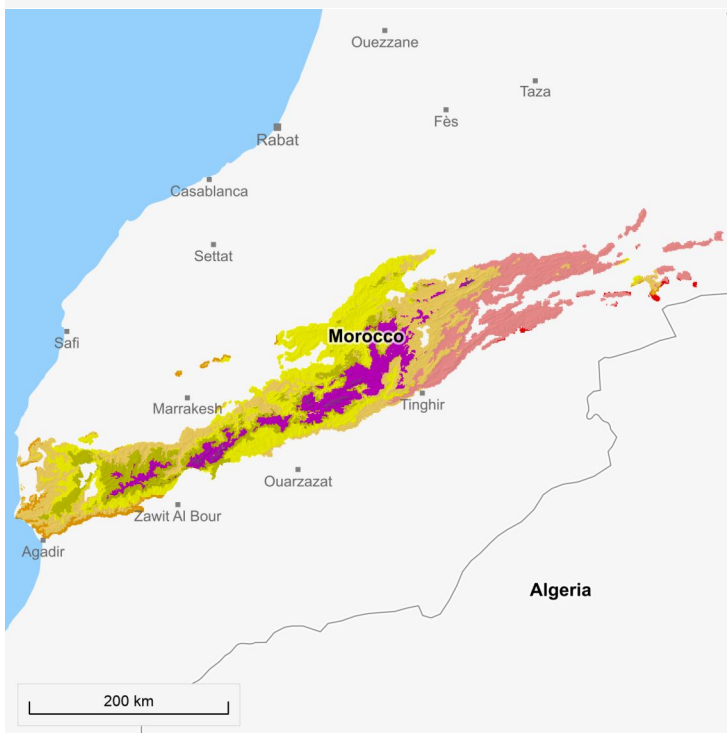


Data: CHELSA/PBCOR [12].

4.2. Climate Classifications

Figures 4.5 and Figure 4.6 show Köppen-Geiger climate classifications for the present day (1980-2016) and for projected future conditions (2071-2100), respectively. Future conditions are derived from an ensemble of 32 climate model projections under the RCP 8.5 "business-as-usual" scenario [14].

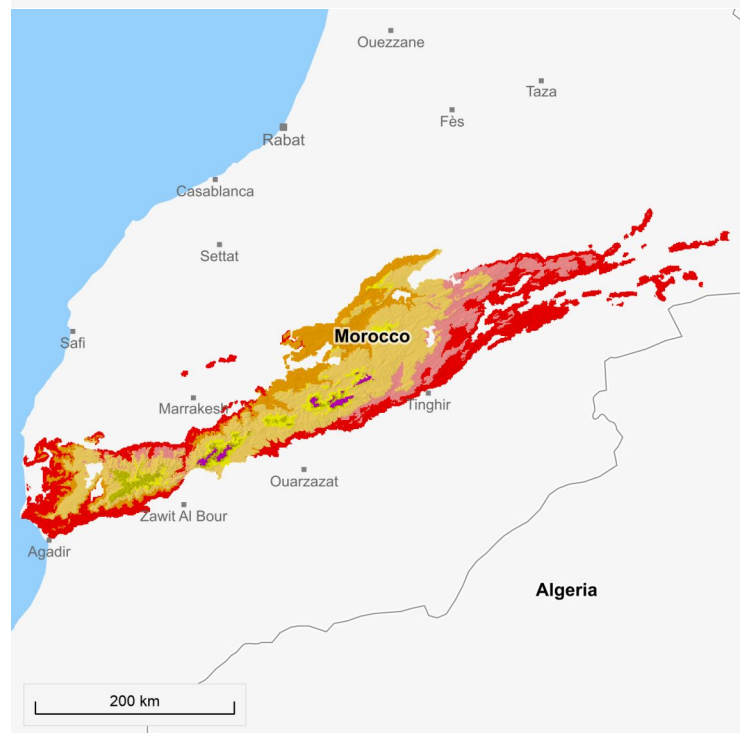
Figure 4.5. Current Climate Classifications



Köppen-Geiger climate classification for the present day (1980-2016).

Data: GloH2O [14]. Background: GMBA [2], GADM [3], Natural Earth [3], Geonames [4], World Bank [22].









Figure 4.6. Future Climate Classifications



Köppen-Geiger climate classification for ensemble mean projected future conditions (2071-2100) under the RCP 8.5 scenario.

Data: GloH2O [14]. Background: GMBA [2], GADM [3], Natural Earth [3], Geonames [4], World Bank [22].

Table 4.1. Changes in climate classifications between current (1980-2016) and future (2071-2100) conditions

Classification	Current	Future	Change
 BSk Arid, steppe, cold	27.4%	34.3%	▲ 6.9%
 Csa Temperate, dry summer, hot summer	26.5%	4.2%	▼ 22.3%
 BWk Arid, desert, cold	19.4%	11.7%	▼ 7.7%
 Csb Temperate, dry summer, warm summer	12.8%	2.6%	▼ 10.2%
 Dsb Cold, dry summer, warm summer	10.4%	0.9%	▼ 9.5%
 BSh Arid, steppe, hot	2.5%	15.3%	▲ 12.9%
 Dsc Cold, dry summer, cold summer	0.7%	0.0%	▼ 0.7%
 BWh Arid, desert, hot	0.4%	31.1%	▲ 30.7%

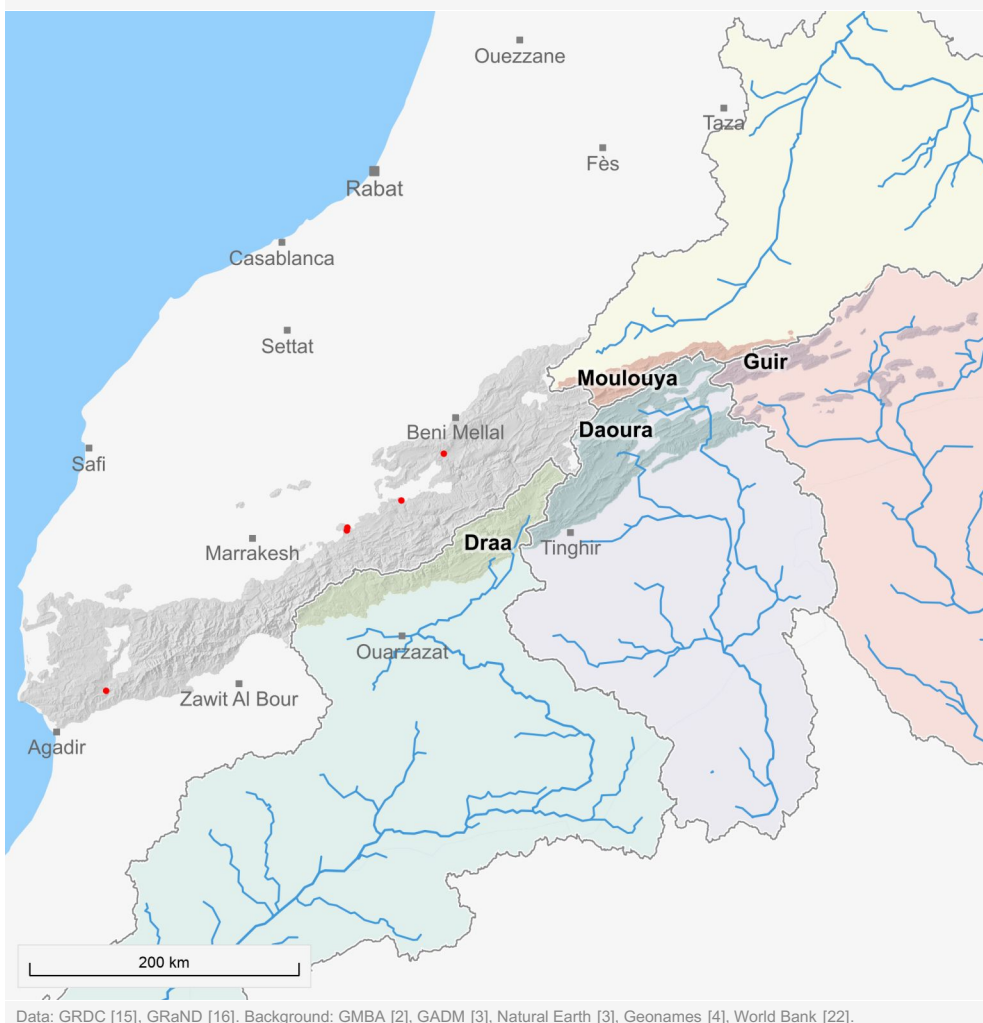
Source: GloH2O [14].

5. Hydrology

According to the GRDC Major River Basins dataset, **four major basins** intersect the mountain range [15]. The **Daoura** has the most overlap with 17%.

Within the mountain range, there are a total of **five dams** listed in the Global Reservoirs and Dams (GRaND) database [16]. The main usages of these dams are **irrigation (3)**, **hydroelectricity (1)**, and **none (1)**. The total capacity of these dams is estimated to be **1,909 million m³**. Figure 5.1 shows major rivers, basins, and dams (red points) that intersect with this mountain range.

Figure 5.1. Major Rivers, Basins, and Dams.



Daoura	17.0%
Draa → North Atlantic	12.0%
Guir	7.0%
Moulouya → Mediterranean Sea	5.0%

Dams in this mountain range with the most capacity [16].

Bin el Ouidane	1,484 Mm ³
Sidi Driss	seven Mm ³
Abdelmoumen	216 Mm ³

6. Cryosphere

6.1. Glaciers and Permafrost

According to the Randolph Glacier Inventory dataset there are **no glaciers** in this mountain range [17].

6.2. Snow Cover

The proportion of the mountain range's area that is covered by snow each month on average (according to monthly snow cover data between 2000-2020 by ESA's Climate Change Initiative [18]) is shown in Figure 6.2.

The average snow covered area varies between a **minimum in August of 0 km² (0.0%)** (Figure 6.3) and a **maximum in February of 2,799 km² (6.0%)** (Figure 6.4). Snow cover extent acts as an indicator of seasonal downstream water availability, is a crucial factor in winter tourism, and is a key determinant of vegetation growing conditions.

Figure 6.2. Monthly mean snow covered area percentage (2000-2020) [18].

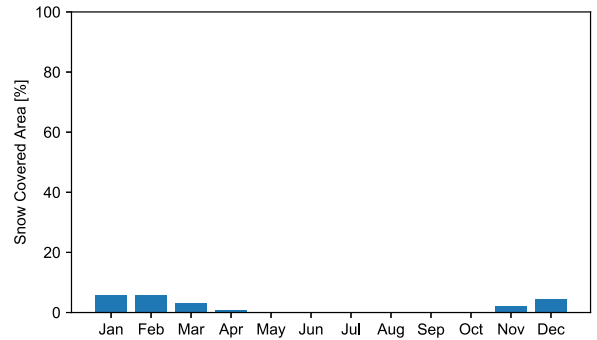
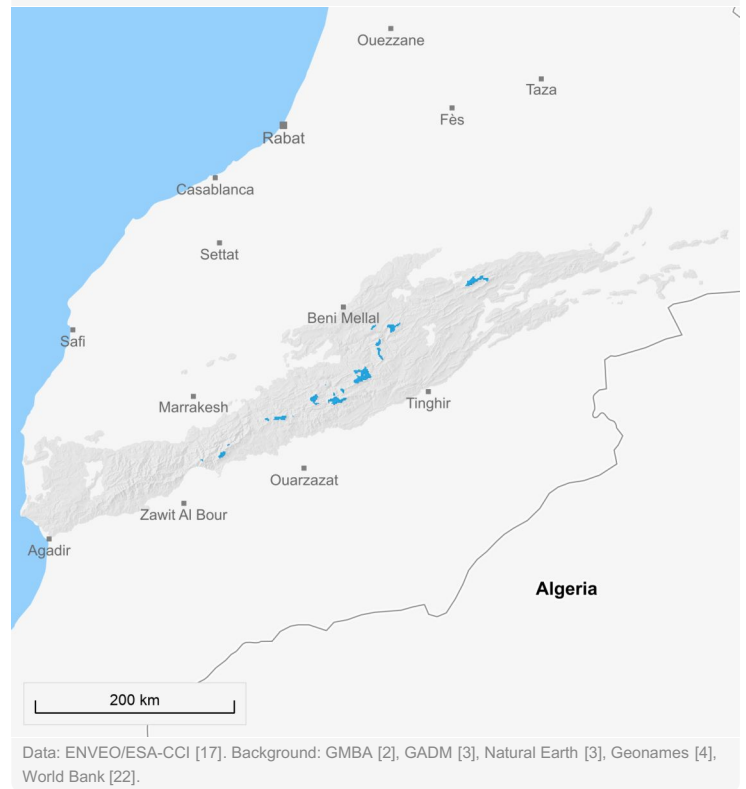


Figure 6.3. Mean Snow Covered Area (August)



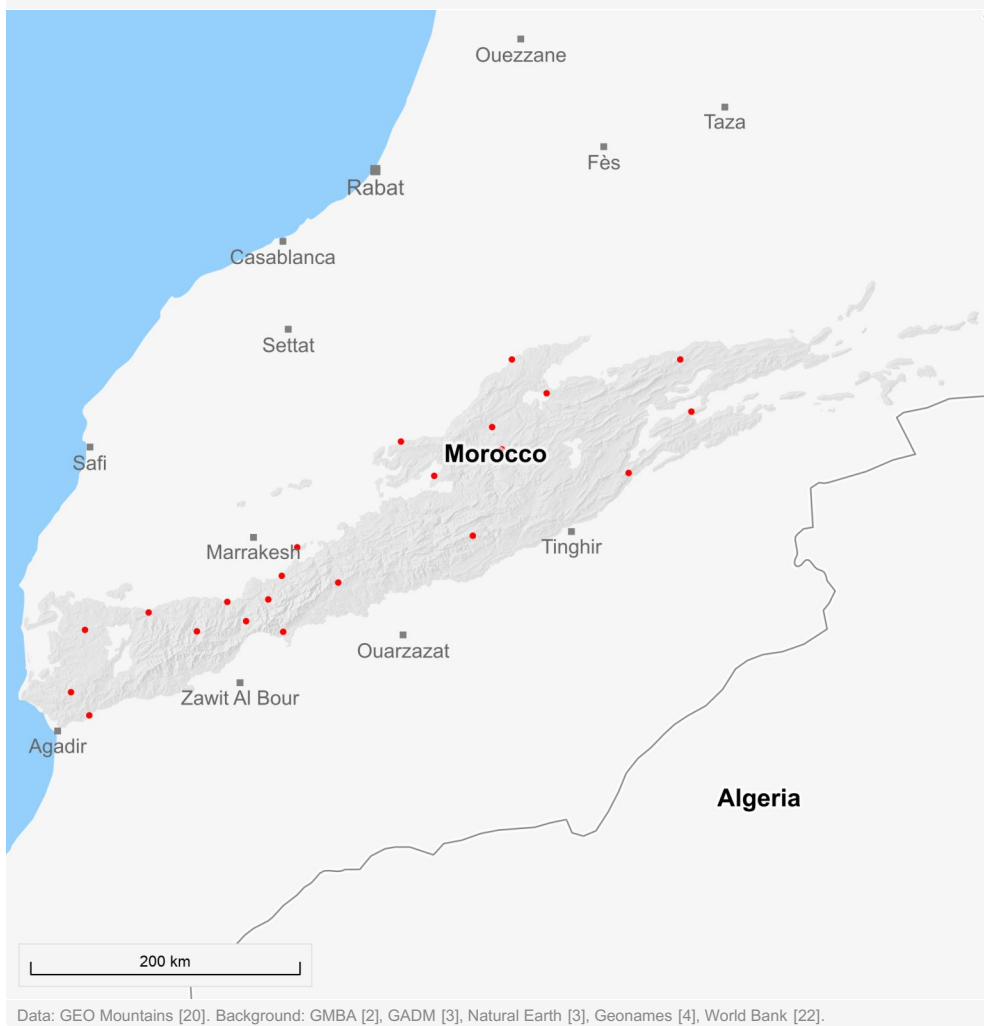
Figure 6.4. Mean Snow Covered Area (February)



7. Measurement Locations

The GEO Mountains Inventory of In Situ Observational Infrastructure (v2.0) lists a total of **22 measurement sites** in this mountain range [20]. Their locations are shown as red dots in Figure 7.1. In situ measurements are crucial for a range of scientific and practical application in mountains, yet the locations of measurement sites are often difficult to gain an appreciation of. Measurement sites include weather and climate stations, river gauging stations, networks of stations, experimental basins, and others.

Figure 7.1. Locations of Measurement Sites



Data: GEO Mountains [20]. Background: GMBA [2], GADM [3], Natural Earth [3], Geonames [4], World Bank [22].

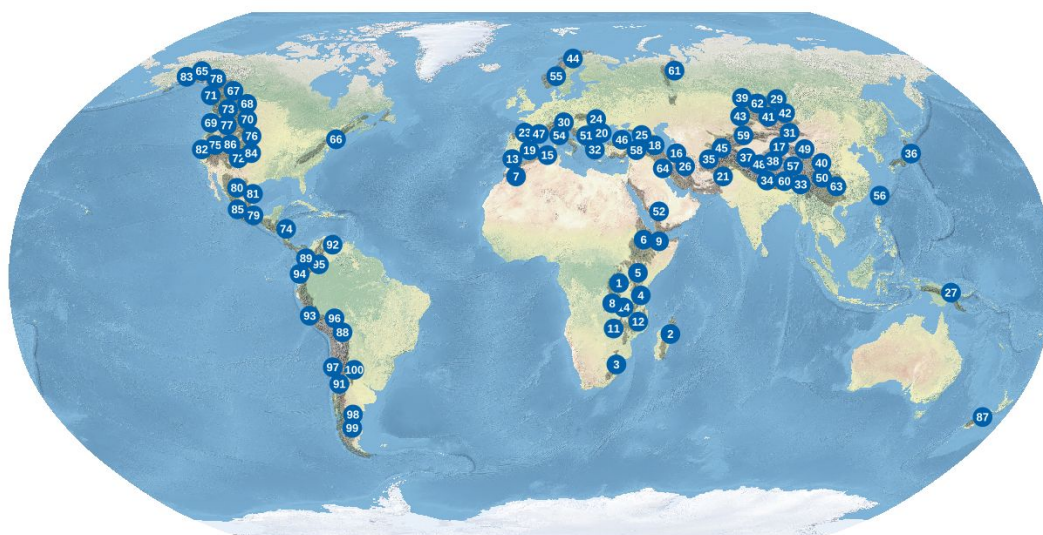
According to the GEO Mountains Inventory of In Situ Observational Infrastructure, there are 22 measurement sites in this mountain range

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Index

The index shows an overview of the 100 mountain ranges in version v1.0 of the *Mountains Uncovered* series.



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5. Eastern Rift mountains
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7. High Atlas Range
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15. Tell Atlas

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90. Cordillera Central (Central Andes)
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99. Patagonian Andes
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About the Series

Aims

The *Mountains Uncovered* series (v1.0) aims to provide an easily understandable overview of the key characteristics of 100 selected mountain ranges around the world. Comparisons between mountain ranges can also readily be made. The series was developed by collating and visualising a variety of current global scale data products. We hope that the series will be a useful resource for researchers, policy-makers, environmental managers, educators, and others seeking to better understand the Earth's major mountain regions, and that over time it will inspire the generation of additional datasets, analyses, and products.

Citation and Sharing

The *Mountains Uncovered* series (v1.0) has been developed on the basis of exclusively open global spatial datasets. In turn, all visualisations, statistics, and code generated are shared under the [Creative Commons BY 4.0](#) license. You may use, distribute, and reproduce the product in any medium, provided appropriate acknowledgement is given. Please cite the series as:

GEO Mountains (2023). The Mountains Uncovered Series: Intercomparable Maps and Statistics for 100 Selected Global Mountain Ranges (v1.0). doi: [10.5281/zenodo.8010166](https://doi.org/10.5281/zenodo.8010166)

Before the reuse of the products, the licence terms associated with the underlying third-party datasets should be carefully checked, and those datasets should also be appropriately cited; please see the reference list provided for further details and links.

GEO Mountains assumes no responsibility and accepts no liability for the product's use, and remains neutral with respect to the locations of any borders and the place names shown in the third-party datasets employed.

Limitations

Users should note that data and information are limited in many mountain regions around the world. As a result, the figures, maps, and graphs presented in this series are associated with uncertainties, and these uncertainties must be taken into account when interpreting the information given.

To ensure that any comparisons made between individual mountain ranges are as fair as possible, global-scale datasets were used (without any additional modification). Consequently, the series does not necessarily represent a compendium of the "best" data available in any given mountain range or local area, but rather a common, generally intercomparable set. For applications at local and regional scales, alternative datasets to those shown may be more suitable.

Indeed, in parallel to the ongoing development of the global series, more local and regional "bottom-up" engagements and activities to improve the quality and availability of data should also be undertaken, since data on these scales also play a crucial role in supporting decision-making for the benefit of mountain people and ecosystems.

Get Involved

While many global mountain regions remain notoriously data-scarce, new datasets are being released regularly. If you are aware of any datasets you would like us to consider including in a potential future release, please provide the necessary details via [this form](#). Likewise, if you become aware of any errors, omissions, or other potential modifications that could be made in a future version, please let us know via the same form. By taking these actions, you will help us expand the scope and improve the impact of the *Mountains Uncovered* series. Feedback concerning the underlying datasets will be collated and shared with the relevant organisations or data providers.

Contact

For any general queries or comments, please contact: geomountains@mountainresearchinitiative.org

Many thanks for your interest, support, and contributions to global mountain data, policy, and education!

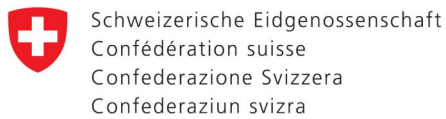
Developed with:



A contribution from:



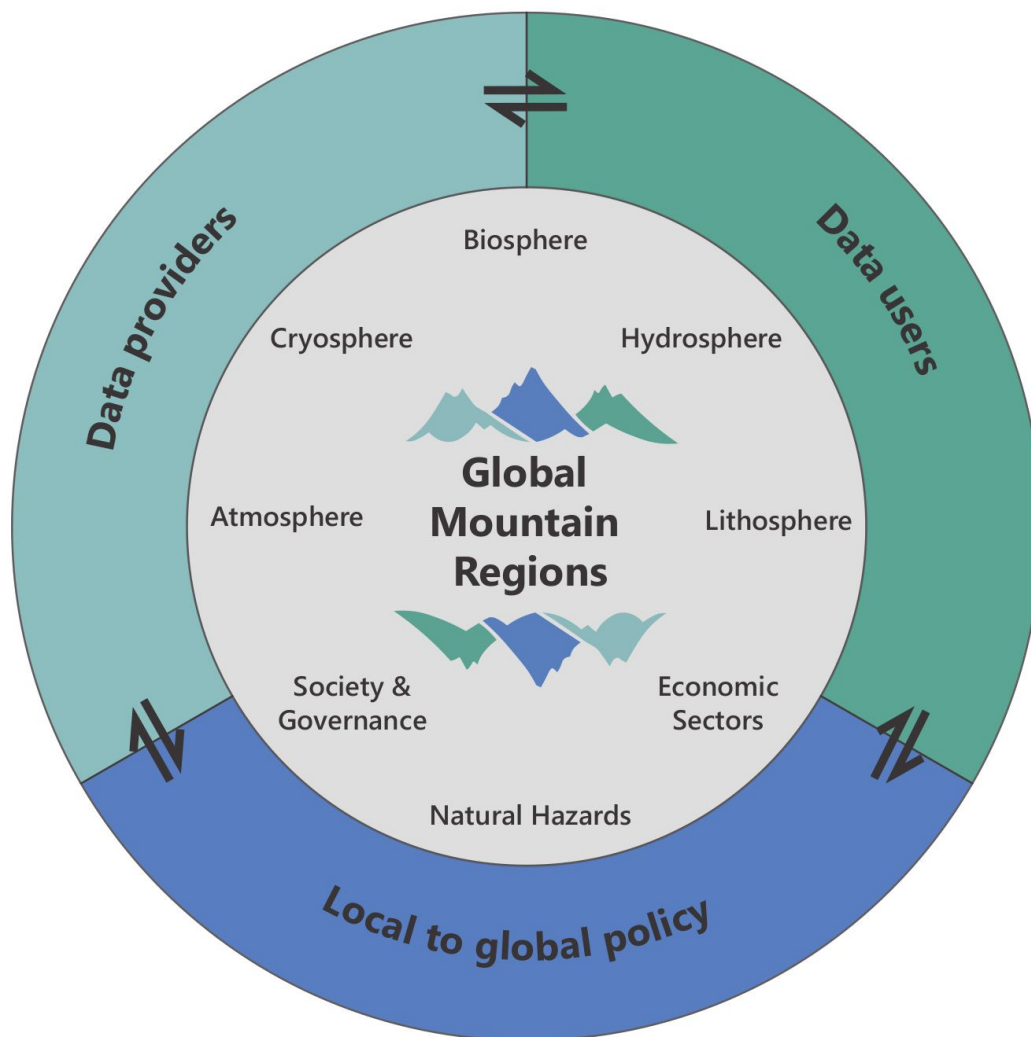
Supported by:



**Swiss Agency for Development
and Cooperation SDC**

About GEO Mountains

GEO Mountains is an Initiative of the Group on Earth Observations (GEO). It aims to bring together research institutions and mountain observation networks to enhance the discoverability, accessibility, and use of a wide range of relevant data and information pertaining to environmental and socio-economic systems – both in situ and remotely sensed – across global mountain regions. In doing so, we hope to help facilitate scientific advancements and support decision makers at local, national, and regional levels. The figure below illustrates the scope of the Initiative.



GEO Mountains is an open and inclusive network. We aspire to follow the principles of open data and open science wherever possible.

