CLIMATE CHANGE IN THE SNOW LEOPARD LANDSCAPES OF ASIA'S HIGH MOUNTAINS

MAY 2017

Technical Report

Climate change is already impacting snow leopard habitat across the high mountains of Central Asia. This analysis outlines the specific risks posed to six snow leopard landscapes in the following project areas: Eastern Nepal, Sikkim, Bhutan, South Gobi, Central Tienshan/Sarychat, and the Karakoram-Pamir Range.

Climate Change in the Snow Leopard Landscapes of Asia’s High Mountains

TECHNICAL REPORT

ABOUT THE INSTITUTIONS

Center for Climate Systems Research

The Center for Climate Systems Research (CCSR) is the home of the cooperative relationship between Columbia University and the NASA Goddard Institute for Space Studies (GISS) and is also a research center of The Earth Institute at Columbia University. CCSR was established with the objective of providing enhanced understanding of the Earth’s climate and its impacts on key sectors and systems. CCSR also plays a large role in dissemination of climate change research and information to governments, local and international organizations, educational institutions, and stakeholders.

World Wildlife Fund

For more than 50 years, WWF has been protecting the future of nature. The world’s leading conservation organization, WWF works in 100 countries and is supported by 1.1 million members in the United States and close to 5 million globally. WWF’s unique way of working combines global reach with a foundation in science, involves action at every level from local to global, and ensures the delivery of innovative solutions that meet the needs of both people and nature.

The ADVANCE Partnership

ADVANCE is a partnership between World Wildlife Fund (WWF) and the Columbia University Center for Climate Systems Research (CCSR) at The Earth Institute. Launched in 2015, ADVANCE facilitates adaptation by providing new ways of generating and integrating climate risk information into conservation and development planning, policies and practice. ADVANCE envisions a future where the world is using co-generated climate risk information based on the best available science to guide conservation, development, and disaster risk reduction to benefit both people and nature.

Table of Contents

ABOUT THE INSTITUTIONS 1
Center for Climate Systems Research 1
World Wildlife Fund 1
The ADVANCE Partnership 1

1. INTRODUCTION 3
Interpreting the climate projections 3
Methodology 4

2. EASTERN NEPAL 5

3. SIKKIM 8

4. BHUTAN 11

5. SOUTH GOBI 15

6. CENTRAL TIENSHAN/SARYCHAT 18

7. KARAKORAM-PAMIR 21

8. KEY CONCLUSIONS 25

APPENDIX A: CLIMATE METHODS AND KEY UNCERTAINTIES 27
Methodology 27
Planning for uncertainty in projecting climate change 27

APPENDIX B: FULL MONTHLY SITE RESULTS 29

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Note: Like all projections, climate projections have uncertainty embedded within them. Sources of uncertainty include data and modeling constraints, the random nature of some parts of the climate system, and limited understanding of some physical processes. In this report, the levels of uncertainty are characterized using state-of-the-art climate models, multiple scenarios of future greenhouse gas concentrations, and recent peer-reviewed literature. The projections are not true probabilities, and scenario-planning methods should be used to manage the risks inherent in future climate.

1. INTRODUCTION

Global climate change will have local impacts on snow leopard habitats across the high mountains of Central Asia. Currently, the snow leopard is considered an endangered species, and is already at risk from a variety of threats, including poaching, overgrazing, fragmented range of suitable habitats, and human-wildlife conflicts. Climate change is projected to exacerbate these existing risks, and impose new threats to snow leopards and their prey.

One reason climate change poses a threat to snow leopards is because the current patterns of annual temperature and precipitation cycles govern many elements affecting snow leopard survival, such as water availability, ecosystem health, snow leopard behavior, and human activities. Changes to these cycles, compounded by the potential for more frequent extreme events of many types, will have direct impacts to snow leopards and their prey species and ecosystems upon which they depend.

Climate change will also have indirect impacts by affecting human behavior, with human responses to climate change in turn affecting the snow leopard landscape. Melting glaciers, altered seasonal cycles, increased human-wildlife conflicts, upslope movement of tree-lines, habitat fragmentation, glacial lake outburst floods (GLOFs), and increased pests and disease as a result of changes in climate all pose direct and indirect risks to snow leopards through for example changes in availability of prey species and shifting habitat.

In order to better understand the elements of climate change that affect the snow leopard range across the high mountains of Central Asia, the ADVANCE Partnership developed tailored climate risk information for the USAID project 'Conservation and Adaptation in Asia's High Mountain Communities and Landscapes.' This analysis outlines the specific risks posed to six snow leopard landscapes in the following project areas: Eastern Nepal, Sikkim, Bhutan, South Gobi, Central Tienshan/Sarychat, and the Karakoram-Pamir Range.

This work was informed by the outcomes of a workshop on Climate Smart Snow Leopard Management Planning in Kathmandu, Nepal, conducted in April 2016 (with the managers of snow leopard landscapes from the Global Snow Leopard Ecosystem Protection Program (GSLEP)) to further understand the challenges and to co-generate risk information relevant for the snow leopard context.

Interpreting the climate projections

For each of the six landscapes, an analysis of annual and monthly temperature and precipitation was conducted to compare how climate models suggest changes will occur in the landscape compared to the baseline climate.

Projections are shown as changes relative to the 1980-2005 model baseline for two future time periods:

- Near-term: consisting of the time period from 2011-2040, and
- Mid-century: consisting of the time period from 2041-2070.

Within each of these time periods, a range of possible temperature and precipitation changes are shown spanning from the low estimate to the high estimate. The low estimate reflects the 25th percentile of all climate model outcomes, and the high estimate reflects the 75th percentile of all climate model outcomes (see Appendix A and Methodology below for more explanation on low and high estimates).

Methodology

Outputs from 21 climate models and two scenarios of future changes in greenhouse gases were used to project annual and seasonal temperature and rainfall changes. The NASA Earth Exchange Global Daily Downscaled Projections (NASA NEX GDDP) dataset was used to develop these climate projections and provide the reference baselines values for each of these sites[1]. The data provided for baseline temperature and precipitation reflect bias-corrected model values averaged over a .25 degree (~25km) grid. For a variety of reasons including spatial resolution differences, actual observed station temperatures will differ from the model baselines shown here.

It should be noted that there is uncertainty associated with predicting future climate conditions[2]. Due to these uncertainties, the climate projections in this report are presented as a range of possible future outcomes, rather than a single number for a future time period. The range reflects the 25th and 75th percentile value outputs of 21 climate models under two greenhouse gas emissions scenarios, each of which represents a plausible estimate of future climate. This approach is taken in order to sample a range of future possibilities. In addition, due to rapidly changing topography across the snow leopard landscapes, the model outputs averaged over the continuous 0.25 degree (25km) grid scale, will not reflect true values experienced at the variety of elevations within the grid. Additionally, for each location, climate projections were developed for area averages that contain several grid cells.

More detailed information on methodology and uncertainties in the climate projections can be found in Appendix A.

[1] NASA (2015), NEX Global Daily Downscaled Climate Projections 2015. Available online from: https://nex.nasa.gov/nex/projects/1356/

[2] Horton, R., Bader, D., Kushnir, Y., Little, C., Blake, R. and Rosenzweig, C. (2015), New York City Panel on Climate Change 2015 Report; Chapter 1: Climate Observations and Projections. Ann. N.Y. Acad. Sci., 1336: 18–35. doi:10.1111/nyas.12586

2. EASTERN NEPAL

LANDSCAPE COORDINATES: [E84.75, N29.25 – E90.00, N26.25]

Summary of key findings

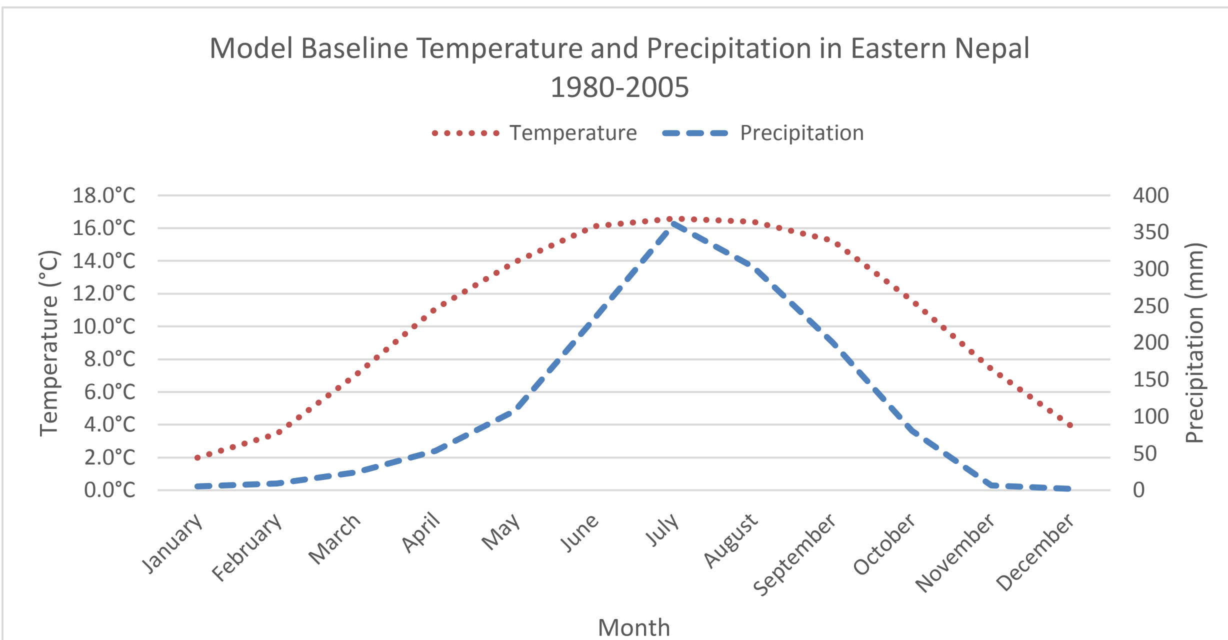

FIGURE 2.1. MODEL BASELINE (1980-2005) MONTHLY TEMPERATURE AND PRECIPITATION IN EASTERN NEPAL.

Temperature: Warmer, especially in winter months

The Eastern Nepal Landscape experiences an average annual model baseline temperature of about 10°C (Figure 2.1.). Under the current climate, the warmest months in Eastern Nepal occur between June and September, and the coldest months occur from December to February. Temperatures begin to rise between March and May, when meltwater becomes available for ecosystems and people.

Annual mean temperature in Eastern Nepal is projected to increase between 0.9°C and 1.3°C above the average baseline temperature in the 2011-2040 time frame (near-term), and between 1.9°C and 2.6°C above the baseline in the 2041 to 2070 time period (mid-century). The greatest projected warming is anticipated during March, where temperatures in the near-term could rise between 1.2°C to 1.7°C, and between 2.3°C to 3.4°C by mid-century (Figure 2.2). Changes in average conditions may lead to an increase in extremes, such as extreme heat events.

While all months of the year show future warming, in general the colder months of the year are projected to have greater magnitudes of warming. These changes may affect the freeze-thaw cycle that governs water availability. Changes in temperature could have implications for snowmelt, with warming temperatures resulting in spring floodwaters arriving earlier than they have historically. Early thaw may trigger premature sprouting of vegetation, which would bring about substantial changes to ecosystem dynamics across the snow leopard range, including herbivory, species migration, and predator-prey interactions. If temperatures remain slightly warmer at the end of summer, the arrival of freezing conditions and snow may occur a few weeks later than previously experienced.

The summary of temperature projections in the mid-century time period is shown in Figure 2.2; see Appendix B for full results.

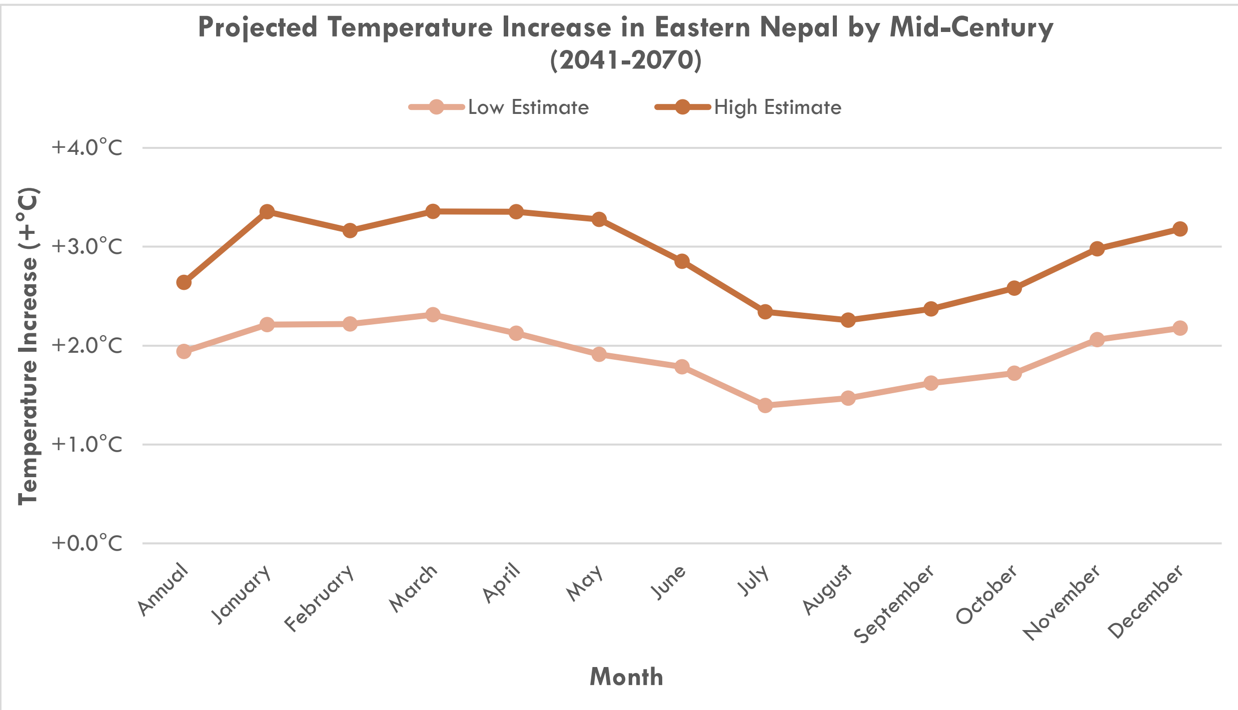

FIGURE 2.2. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY TEMPERATURE INCREASE (°C) IN EASTERN NEPAL BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

Precipitation: More precipitation in the monsoon season

The Eastern Nepal region is a climatically wet zone, experiencing on average approximately 140 cm of precipitation in a year according to the model baseline (Figure 2.1). Most precipitation occurs in Eastern Nepal during the monsoon season, typically lasting between June and September. The driest months of the year occur between November and February, and then wetter conditions begin to arise from March to May.

With climate change, models project that annual precipitation will increase significantly (relative to the model annual baseline of 1980-2005) in Eastern Nepal, rising between 1% and 16% in the near-term. By mid-century, the models project annual precipitation 12% to 27% higher than the yearly baseline mean. However, while annual precipitation is projected to rise, precipitation changes are projected to vary substantially by time of year.

Climate model results suggest that the largest percentage and actual precipitation increases will occur in the `months that already have the greatest amount of rainfall – the monsoon season from May through September. For example, rainfall in May in the near-term is projected to increase 4% to 39%. By mid-century, the increase could be as great as 48% above the baseline average. As the monsoon season progresses, rainfall could increase as high as 32% to 37% between June and September through mid-century.

Months receiving the least amount of precipitation, notably November through January, are about equally likely to receive more or less precipitation in the future. However, because the total precipitation in these months is already so low in comparison with other months (for example, 2 mm baseline average in December, in contrast with 361 mm in July) these absolute changes in precipitation would be small. A combination of early melting snow during summer months with lesser or equal amounts of snow fall during the winter months may affect the overall snow budget of the Eastern Nepal Landscape, resulting in less water storage in snow pack, greater risk of early warm season floods, and a decrease in base flow later in the warm season.

The summary of precipitation projections in the mid-century time period is shown in Figure 2.3; see Appendix B for full results.

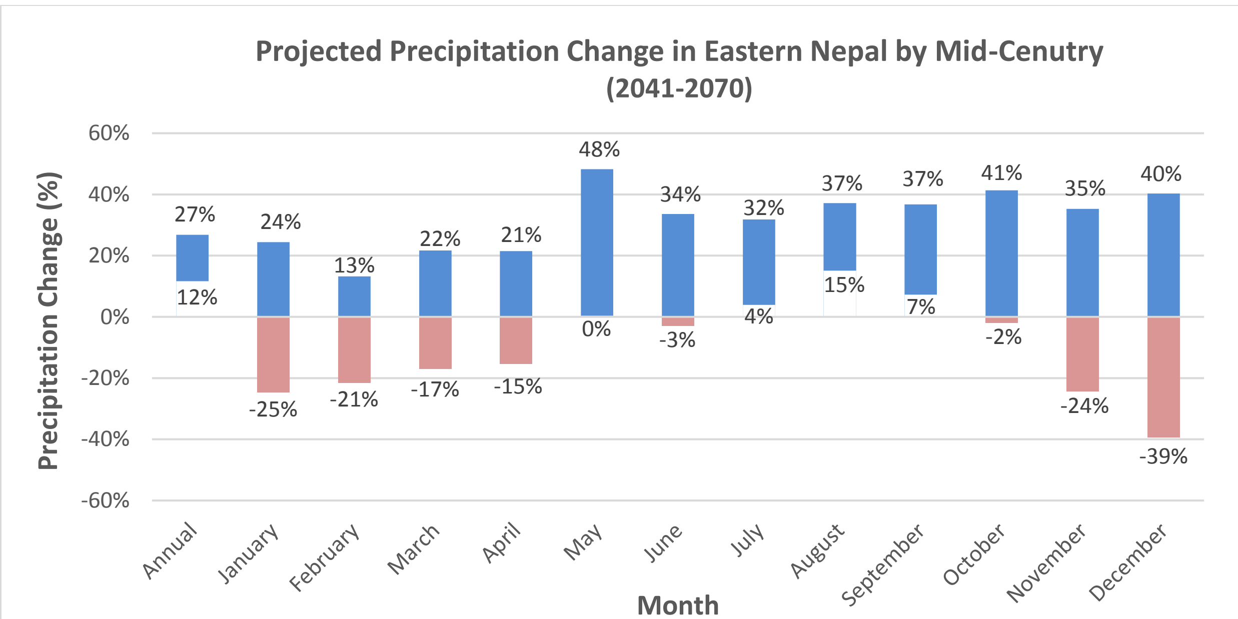

FIGURE 2.3. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY PRECIPITATION CHANGE (%) IN EASTERN NEPAL BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

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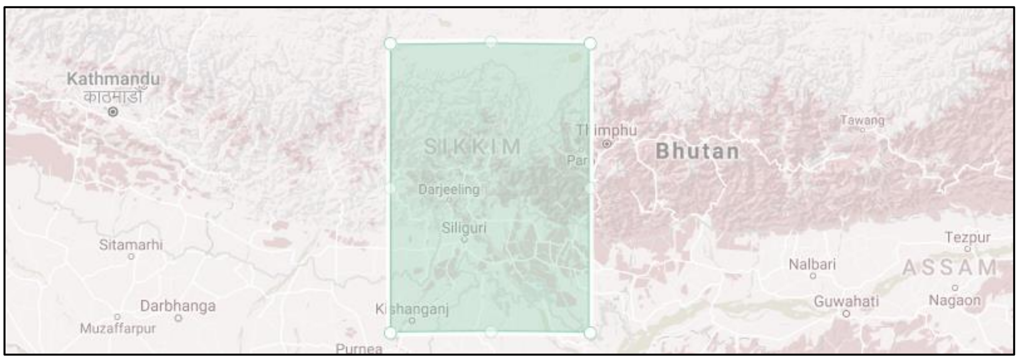
Potential impacts in the snow leopard context

The climate in the Eastern Nepal snow leopard landscape is characterized by a strong seasonal relationship between temperatures and precipitation, with the warmest months of June, July, August, and September receiving the most rainfall. Based on stakeholder feedback provided during the Climate Smart Snow Leopard Management Planning Workshop in April of 2016, the combination of warming throughout the year and a wetter monsoon season could dramatically impact snow leopards, their prey, and the people who live in the region. Impacts could include:

- Changes in vegetation patterns and shifting tree line
- Shifts in seasonal food availability for wildlife
- Increased risk for disease and other health impacts
- Increased flooding and landslide risk
- Encroachment of snow leopard habitats by people
- Increased human-wildlife conflict

The shifts in average climate conditions described here may also lead to changes in the frequency of extreme events like heat waves and flooding that will affect snow leopard ecosystems and people. It is important for ecosystem managers in Eastern Nepal to consider these complex interactions as they plan for climate change.

3. SIKKIM



LANDSCAPE COORDINATES: [E87.75, N28.25 – E89.50, N26.00]

Summary of key findings

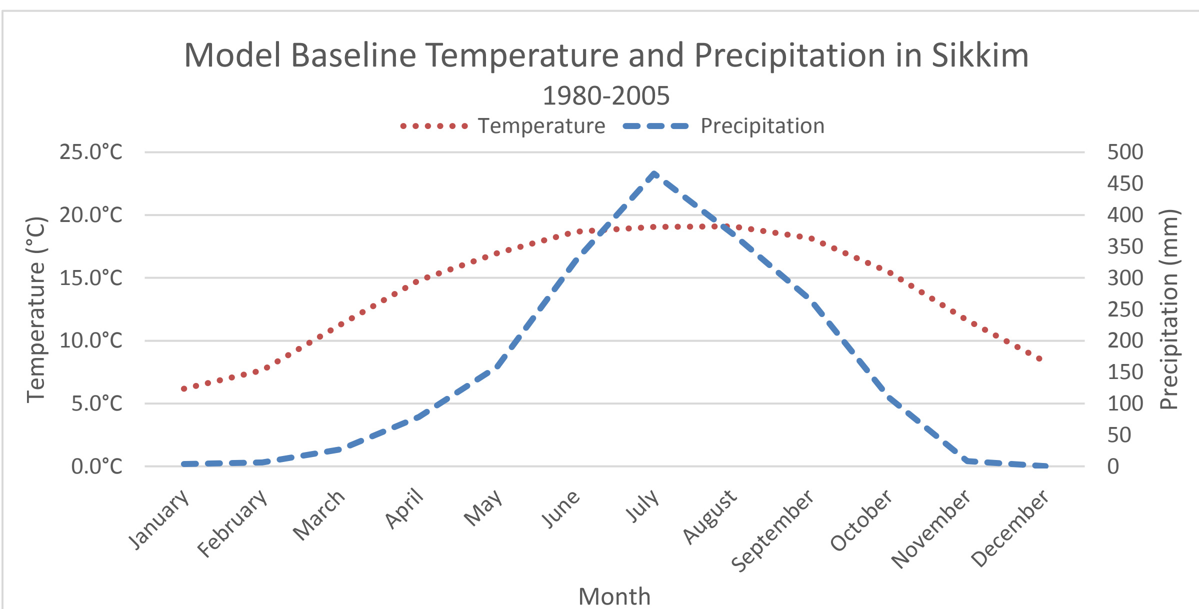


FIGURE 3.1. MODEL BASELINE (1980-2005) MONTHLY TEMPERATURE AND PRECIPITATION IN SIKKIM.

Temperature: Warmer, especially in winter months

Under Sikkim's current climate, annual temperatures average is about 14°C according to the model baseline (Figure 3.1). The coldest months of the year occur between December and February. Temperatures warm between March and May, and spring snow melt provides water for ecosystems and people. June to September are the warmest months of the year.

As a result of climate change, annual temperatures are projected to increase over the course of the coming decades. In the time period from 2011-2040 (near-term), annual average temperatures may reach between 0.8°C and 1.2°C above the baseline, and during 2041-2070 (mid-century) the average may increase between 1.7°C and 2.5°C.

While all months are projected to see increases in average temperatures throughout the year, projections indicate that the colder months between December and March could see a slightly greater magnitude of warming than in the warmer months. The months of January and March have the highest projected warming trend. In March a 1.1°C to 1.5°C increase above historical is projected in the near-term, and a 2.2°C to 3.0°C increase by mid-century. January is projected to increase monthly baseline temperature between 0.9°C to 1.6°C above historical temperatures in the near-term, and between 2.1°C and 3.1°C by mid-century. Warmer temperatures may result in changes to the freeze-thaw cycle, and thus the overall snow budget, with spring melt potentially occurring earlier in the year and snow accumulation after the summer occurring a few weeks later than historical patterns.

The summary of temperature projections in the mid-century time period is shown in Figure 3.2; see Appendix B for full results.

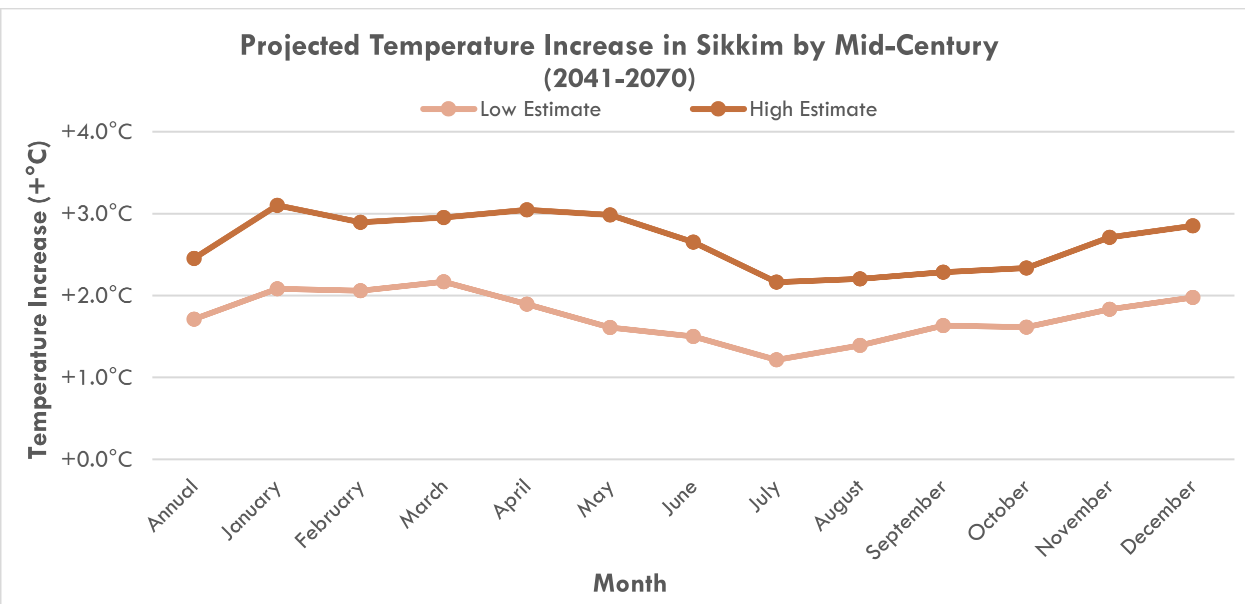


FIGURE 3.2. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY TEMPERATURE INCREASE (°C) IN SIKKIM BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

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Precipitation: More precipitation, mostly in the monsoon season

Historically, the model baseline shows that the Sikkim region receives about 180cm of precipitation per year, and the majority of which occurs between the months of April and October (Figure 3.1). November to February are the driest months, and March and April typically experience small amounts of precipitation.

In the near-term, Sikkim is expected to see an annual precipitation increase ranging from 5% to 17% above the annual baseline. By mid-century the change in precipitation may increase between 9% and 29% above historical levels. While climate change is projected to increase the total amount of for the year, seasonal changes in precipitation are not expected to be so uniform. Precipitation is projected to increase during the wettest parts of the year, but climate models disagree about how precipitation may change in the drier months.

In the wettest months of May through October, projections show that precipitation will increase overall. The greatest future percentage increase is projected to occur in May, up to 47% above the baseline in the near-term, and up to 57% through mid-century. The second rainiest month, August, is also projected to see an increase in precipitation.

Months that historically receive less precipitation are, in general, equally likely to see an increase or decrease in rainfall over the next few decades. By mid-century, models show that the dry months are slightly more likely to receive more precipitation than they are to see a decrease, but the low baseline values in these months mean that actual rainfall change would be small.

The summary of precipitation projections in the mid-century time period is shown in Figure 3.3; see Appendix B for full results.

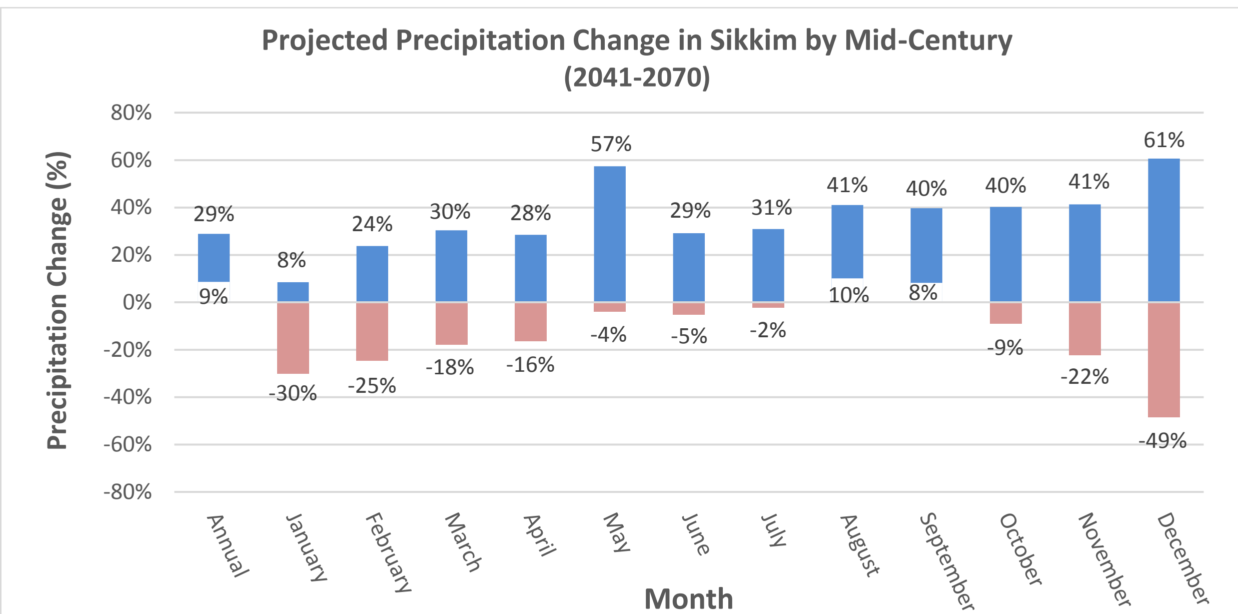

FIGURE 3.3. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY PRECIPITATION CHANGE (%) IN SIKKIM BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

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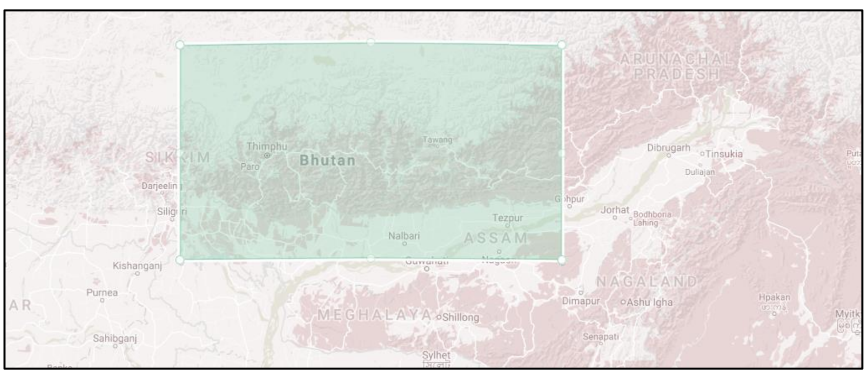
Potential impacts in the snow leopard context

The Sikkim landscape is characterized by a strong seasonal relationship between temperatures and precipitation, with the warmest months of June, July, August, and September receiving the most precipitation. Based on stakeholder feedback provided during the Climate Smart Snow Leopard Management Planning Workshop in April of 2016, the combination of increased temperatures, particularly in winter months, and a wetter and warmer monsoon season has the capacity to dramatically impact the interactions between snow leopards, their prey, and local human populations. Impacts could include:

- Changes in vegetation patterns in the short-term
- Shifting tree line in the long-term
- Changes in seasonal food availability
- Early thaw and Spring snowmelt
- Extended time of the year for livestock grazing
- Increased flooding and landslide risk
- Disruptions to traditional patterns of rotational grazing
- Increased human-wildlife conflict

The shifts in average climate conditions described here may also lead to changes in the frequency of extreme events like heat waves, flooding, and drought that will affect snow leopard ecosystems and people. It is essential that ecosystem managers and wildlife experts in Sikkim consider these complex interactions among snow leopards, ecosystems, and humans as they plan for climate change.

4. BHUTAN



LANDSCAPE COORDINATES: [E88.50, N28.75 – E93.50, N26.25]

Summary of key findings

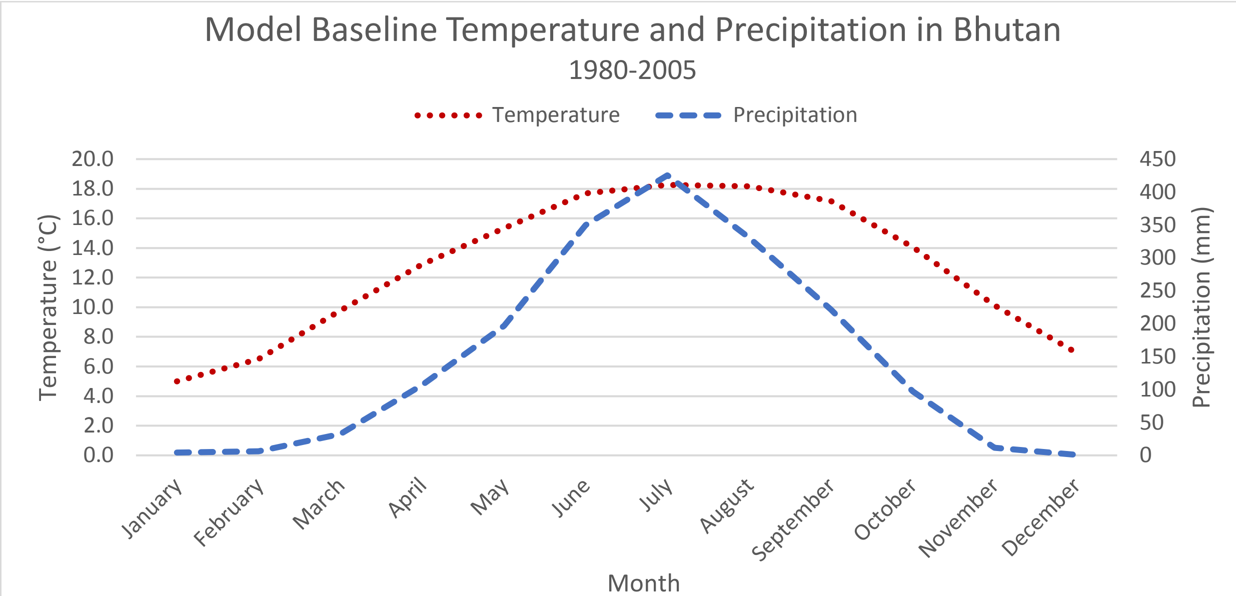


FIGURE 4.1. MODEL BASELINE (1980-2005) MONTHLY TEMPERATURE AND PRECIPITATION IN BHUTAN.

Temperature: Warmer, especially in winter months

Historically, the snow leopard landscape in Bhutan averages an annual temperature of about 13.0°C according to the model baseline (Figure 4.1). The warmest temperatures currently occur between June and September, and the coldest months of the year are December through February. These annual temperature cycles govern water availability, ecosystems, and human activities.

In the time period from 2011 to 2040 (near-term), climate models project that annual average temperature could be between 0.9°C and 1.2°C warmer than the current climate, and by 2041-2070 (mid-century) the warming trend is expected to reach between 1.8°C and 2.5°C above the baseline. The colder months of the year are projected to experience the greatest degree of warming, and warmer temperatures between January and April can mean earlier spring snowmelt, affecting water flows and the communities and ecosystems that depend on it for spring water availability.

The degree of warming is projected to be highest in the colder months of the year. July is projected to see the least increase in average temperature, ranging from 1.4°C to 2.2°C through mid-century, while February is projected to experience the greatest magnitude of warming ranging from an increase of 2.2°C to 3.0°C in average temperatures in the same time frame. These changes in average conditions can lead to greater frequency and intensity of extremes, such as heat waves, which can affect health and the ecosystem landscape.

The summary of temperature projections in the mid-century time period is shown in Figure 4.2; see Appendix B for full results.

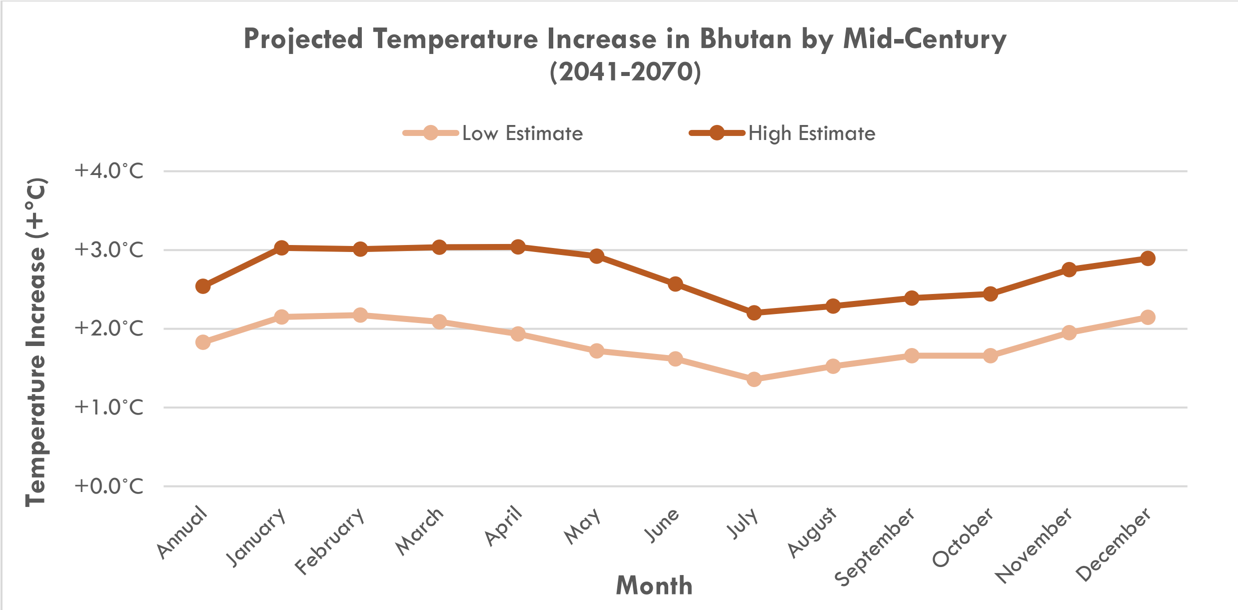


FIGURE 4.2. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY TEMPERATURE INCREASE (°C) IN BHUTAN BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

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Precipitation: Wetter monsoon

The landscape in Bhutan historically receives about 180cm of precipitation on an average annual basis, according to the model baseline (Figure 4.1). Under the current climate, the area typically receives the majority of this between the months of April and October, with minimal precipitation occurring November to March. With climate change, annual precipitation is expected to increase between 2% and 17% above the historical average in the near-term, and between 10% and 30% through mid-century. However, this change in rainfall is projected to vary widely throughout the year.

Models project that the wettest months of the year will become wetter. By mid-century, precipitation is projected to increase between 35-40% over the wettest months of June to September. With already high amounts of precipitation occurring at this time of the year, such large percentage increases could result in a much wetter monsoon season in the Bhutan landscape. These changes could result in larger amounts of flooding and consequential landslides, affecting the landscape for snow leopards and people.

Models disagree about how precipitation may change during the dry months of the year, with some results suggesting decreases in precipitation while others suggest an increase in the same time period. However, it should be noted that due to such low baseline precipitation during these months, any percentage changes in monthly precipitation projected by the models would result in small future totals.

The summary of precipitation projections in the mid-century time period is shown in Figure 4.3; see Appendix B for full results.

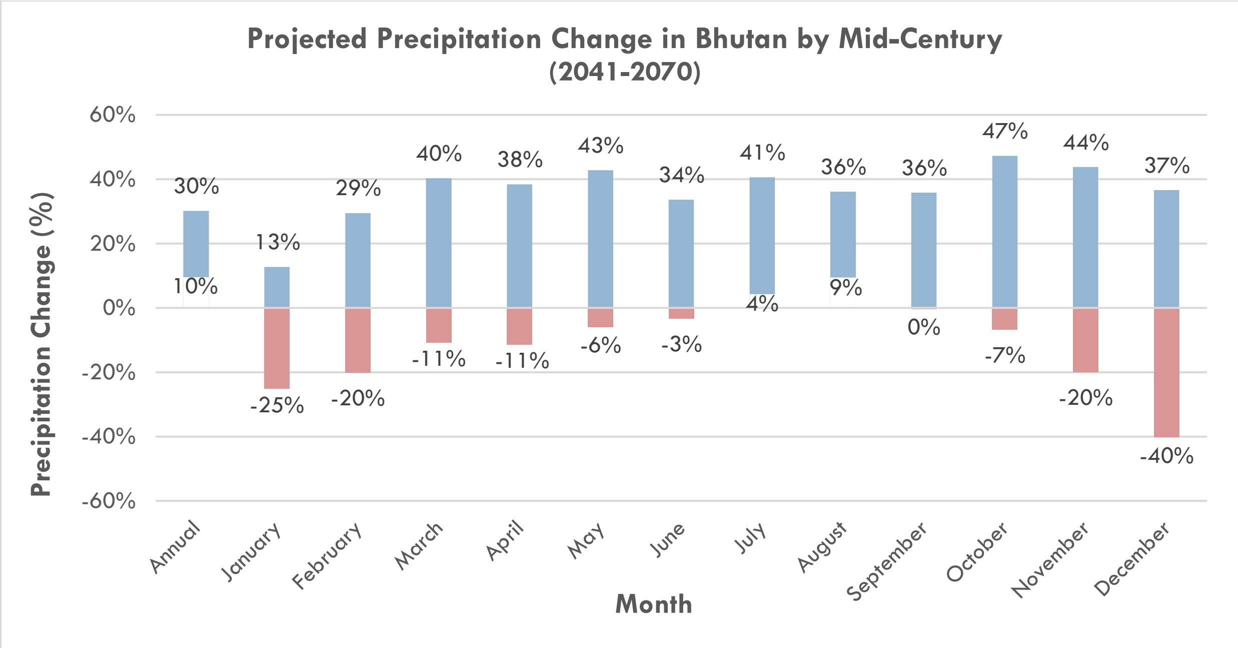

FIGURE 4.3. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY PRECIPITATION CHANGE (%) IN BHUTAN BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

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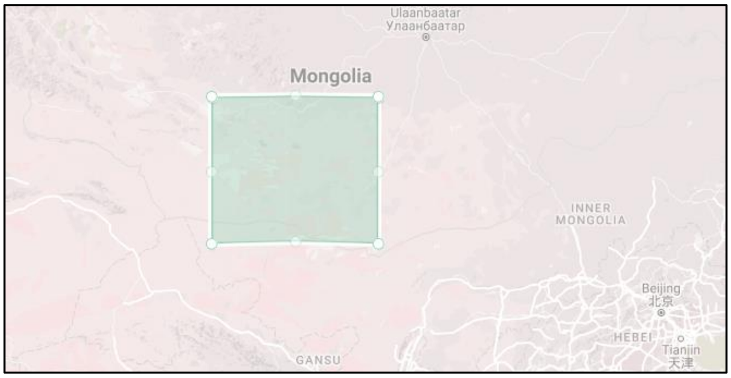
Potential impacts in the snow leopard context

The snow leopard landscape in Bhutan is characterized by a strong seasonal relationship between temperatures and precipitation, with the warmest months of June, July, and August receiving the most rainfall. Based on stakeholder feedback provided during the Climate Smart Snow Leopard Management Planning Workshop in April of 2016, the combination of warmer temperatures and wetter months, particularly during the monsoon season, can have major impacts on snow leopards and the human populations that live near them. Impacts could include:

- Increased risk for landslides, flooding, and avalanches
- Shifting seasonal vegetation patterns
- Changes in seasonal food availability
- More frequent human-wildlife interaction and conflict
- Habitat encroachment
- Early Spring snowmelt

The shifts in average climate conditions described here may also lead to changes in the frequency of extreme events like heat waves, flooding, and drought that will affect snow leopard ecosystems and people. Climate changes in Bhutan will influence not only the immediate habitat of the snow leopard but also interactions with other sympatric species. It is important for ecosystem managers and wildlife experts in this landscape to consider these how these interactions between humans, snow leopards, and their habitats may lead to cascading risks as they plan for climate change.

5. SOUTH GOBI



LANDSCAPE COORDINATES: [E98.25, N46.25 – E105.00, N42.00]

Summary of key findings

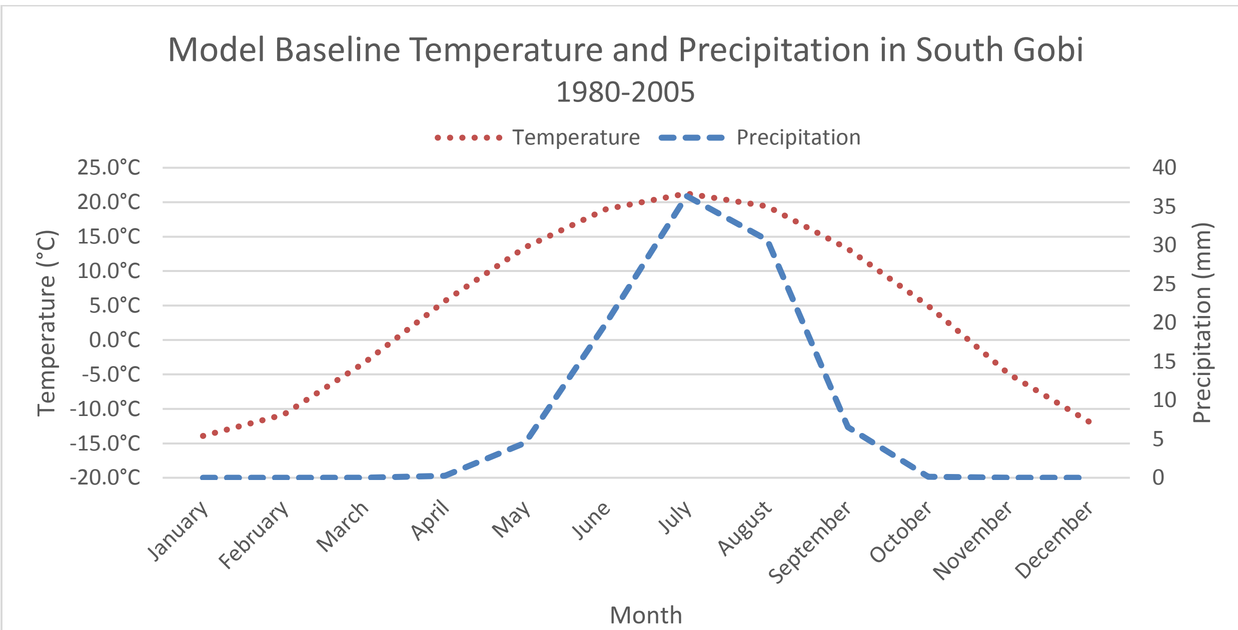


FIGURE 5.1. MODEL BASELINE (1980-2005) MONTHLY TEMPERATURE AND PRECIPITATION IN SOUTH GOBI.

Temperature: Warmer, especially in summer

The snow leopard landscape in the South Gobi region experiences an annual average temperature of just around 4.0°C in the model baseline. In the coldest months of the year, monthly temperatures average below freezing from November to March (Figure 5.1). The warmest months occur between June and August.

With climate change, average annual mean temperatures are projected to rise between 0.9°C and 1.8°C during the 2011 to 2040 (near-term) time period compared to the baseline. Temperatures up to 2.0°C to 3.3°C warmer than the baseline are expected in the 2041 to 2070 (mid-century) time frame.

All months of the year are projected to warm as a result of climate change. However, the projections indicate that the warmest months of the year may experience more warming than the cold months. For example, average mean temperature in the coldest month, January, is projected to increase between 0.6°C and 1.8°C above the monthly baseline average in the near-term, and between 1.4°C and 3.1°C by mid-century. In contrast, August is projected to see near-term average temperatures increase between 1.3°C and 2.1°C above the baseline, and between 2.7°C and 3.8°C above the monthly baseline in mid-century. Warming is projected to yield a longer growing season and a changing freeze-thaw cycle, resulting in slope instability of permafrost areas no longer above the frost line and potential changes to the productivity of grassland systems.

The summary of temperature projections in the mid-century time period is shown in Figure 5.2; see Appendix B for full results.

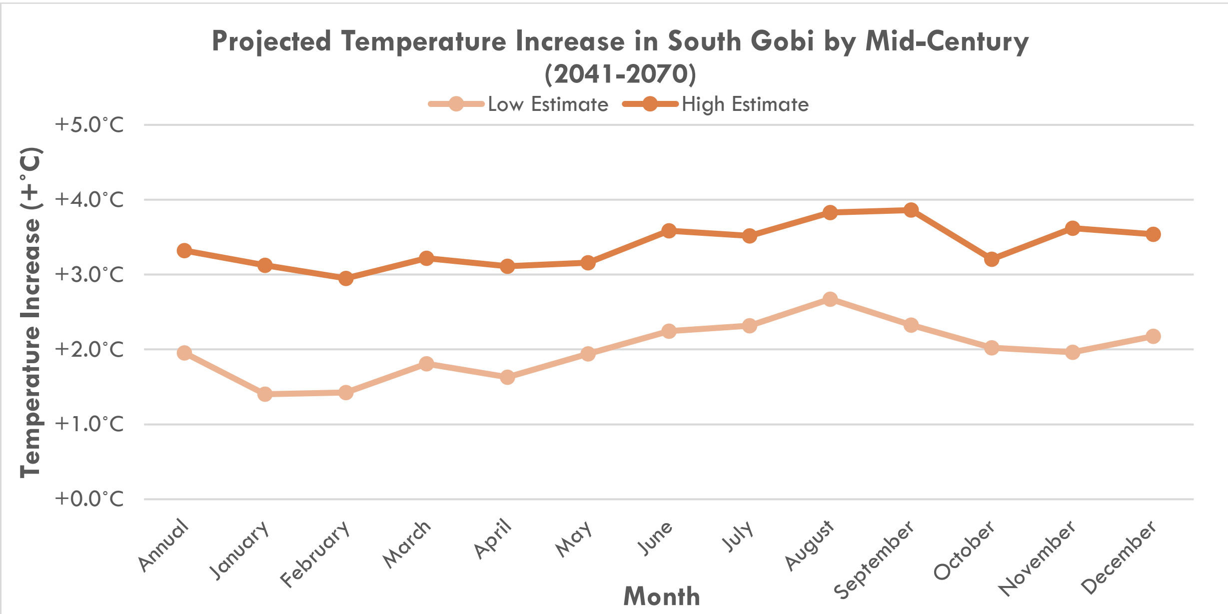


FIGURE 5.2. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY TEMPERATURE INCREASE (°C) IN SOUTH GOBI BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

Precipitation: Minimal increase in annual rainfall in a climatically dry zone

The Southern Gobi landscape is a climatically dry region, and precipitation in the model baseline is very low, averaging roughly 10cm per year. The area receives almost all its annual rainfall in June, July, and August, with minimal rainfall occurring in the months of May and September. The remainder of the year receives almost no precipitation between the months of October and April. Therefore, it is important to note that due to such low baseline values in the cold season, even large percentage changes in precipitation would not result in large absolute precipitation changes in the future.

Annually, precipitation is projected to increase slightly, up to 12% above the baseline in the near-term, and up to 18% by mid-century. These changes are not projected to be experienced uniformly throughout the year. The already wettest months of the year are more likely than not going to see slight increases in precipitation – by mid-century models project a range in June precipitation to change between -4% and +18%, July precipitation to change between -5% and +21%, and August to change between +1% and +13%. While June, July, and August currently receive the most precipitation throughout the year, these months still currently experience relatively low baseline precipitation values, and therefore the projected changes will not be large in absolute terms.

The summary of precipitation projections in the mid-century time period is shown in Figure 5.3; see Appendix B for full results.

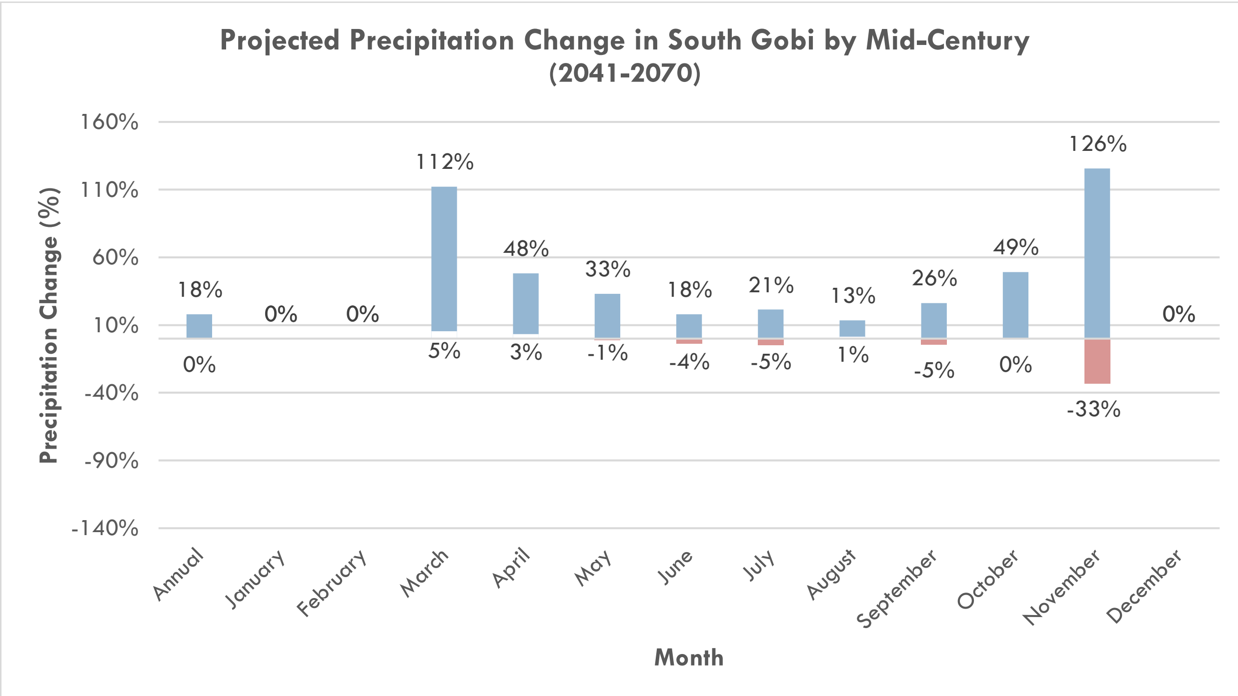


FIGURE 5.3. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY PRECIPITATION CHANGE (%) IN SOUTH GOBI BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

Potential impacts in the snow leopard context

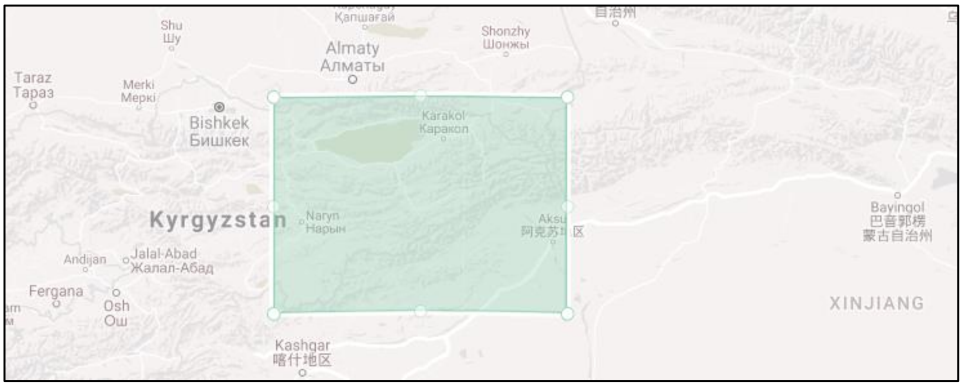
In general, South Gobi, while very dry throughout most of the year, receives the majority of its precipitation in the warmest months of the year during June, July, and August. Based on stakeholder feedback provided during the Climate Smart Snow Leopard Management Planning Workshop in April of 2016, the combination of increasing temperatures with the additional possibility of minor increases in rainfall may lead to impacts on snow leopards, their prey, and surrounding communities. Impacts could include:

- Increased heat stress
- Changes in water availability
- Shifts in patterns of rotational grazing
- Shifting seasonal vegetation patterns
- Habitat encroachment
- Increased human-wildlife conflict

- Changes in the intensity of winter Dzud[3] storms

The shifts in mean climate conditions described here may also lead to changes in the frequency of extreme events like heat waves, flooding, and drought that will affect snow leopard ecosystems and people. Climate changes in South Gobi will influence not only the immediate habitat of the snow leopard but also interactions with other species. It is important for ecosystem managers and wildlife experts in the region to consider the complex relationships between snow leopards, ecosystems, and people as they plan for climate change.

6. CENTRAL TIENSHAN/SARYCHAT



LANDSCAPE COORDINATES: [E75.50, N43.00 – E80.50, N40.25]

Summary of key findings

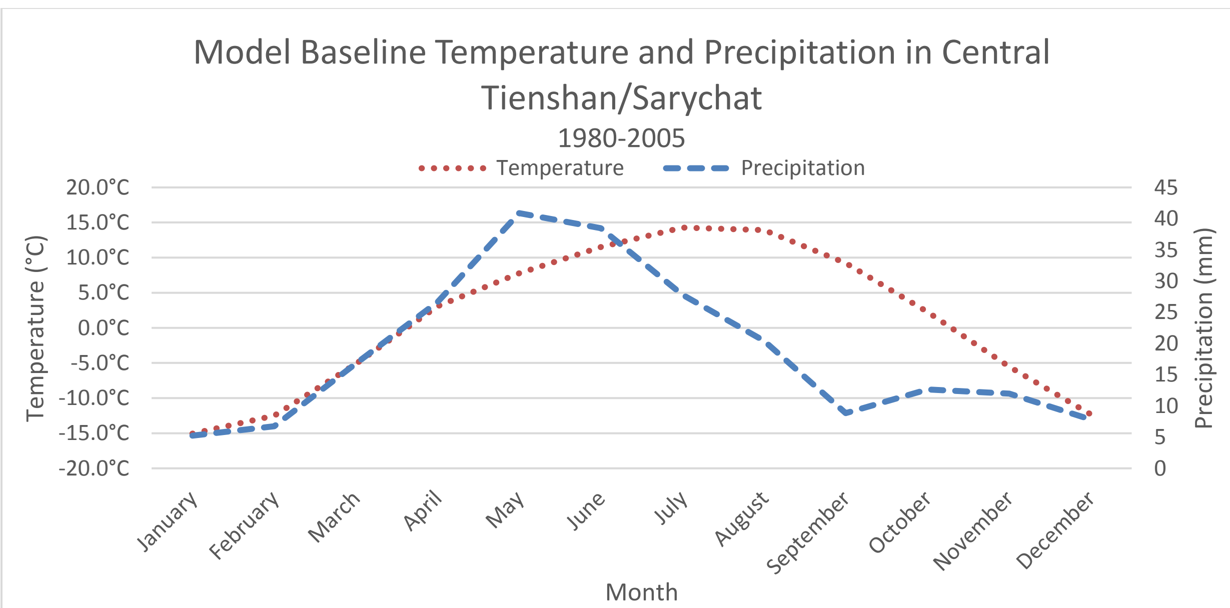


FIGURE 6.1. MODEL BASELINE (1980-2005) MONTHLY TEMPERATURE AND PRECIPITATION IN CENTRAL TIENSHAN/SARYCHAT.

[3] "Dzud is the Mongolian term for a winter weather disaster in which deep snow, severe cold, or other conditions render forage unavailable or inaccessible and lead to high livestock mortality. Dzud is a regular occurrence in Mongolia, and plays an important role in regulating livestock populations." Source: Work Bank, 2012 - http://www.worldbank.org/en/news/feature/2012/11/06/lessons-from-dzud

Temperature: Warmer, especially in summer

Historically, Central Tienshan/Sarychat experiences a very cold climate, averaging just about 1.0°C on an annual basis in the model baseline (Figure 6.1). Average monthly temperature remain below freezing from November to March, with the coldest temperatures felt in December, January, and February. The warmest months of the year occur between June and August. Typically, July is the hottest month of the year, and January is the coldest.

With climate change, annual average temperature in the region is projected to rise between 0.9°C and 1.5°C above the baseline temperature during the 2011 to 2040 (near-term) time period. By the 2041 to 2070 (mid-century) time frame, models show that annual mean temperatures could range 1.9°C to 3.2°C warmer than the historical average.

Trends in increasing temperature are fairly consistent across the months of the year. However, in general the warmer months of the year are projected to see temperatures rise slightly more than the colder months. The greatest change is projected to occur in August, raising the average monthly temperature between 1.1°C and 2.1°C in the near-term above the historical baseline, and between 2.3°C and 4.1°C by mid-century. Warmer temperatures may extend the growing season and alter the length of the freeze-thaw cycle.

The summary of temperature projections in the mid-century time period is shown in Figure 6.2; see Appendix B for full results.

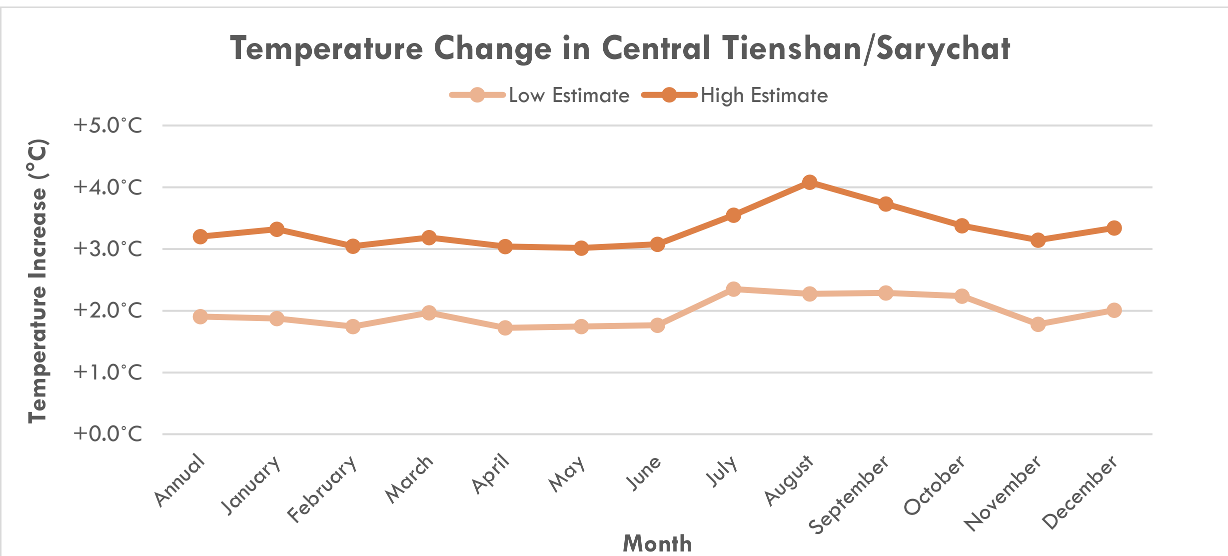


FIGURE 6.2. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY TEMPERATURE INCREASE (°C) IN CENTRAL TIENSHAN/SARYCHAT BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

Precipitation: Small increase in annual precipitation, though uncertain change in some rainy months

The Central Tienshan/Sarychat area has a relatively dry baseline climate, with the models showing that the area receives about 20cm of precipitation on an annual basis in the 1980-2005 baseline period (Figure 6.1). While all months receive some amount of rainfall, on average the months between April and August experience more precipitation, with the greatest amounts of precipitation falling in May and June. The drier months tend to occur between September and March, with December to January being the driest of the year.

In the near-term, the average annual precipitation in the region is projected to increase up to 17% above historical levels. By mid-century, models show that annual average precipitation will range between +6% to +23% above the baseline. However, these precipitation changes are not projected to occur uniformly throughout the year.

The historically dry months of the year are projected to experience more precipitation in the future. However, due to the low baseline values, these larger positive percentage shifts in dry months from December to February – ranging between a +15% and + 59% increase by mid-century – will not result in large absolute precipitation totals in the future. In months such as April that receive more precipitation, an increase between +19% and +46% above the baseline could notably affect total annual precipitation for the area.

Models disagree in the direction of precipitation change between the months of June and September in the future. For example, in the month of July the model results range from a -14% decrease in monthly rainfall while others suggest up to a 9% increase by mid-century. At this point the models do not share enough agreement to determine which scenario to plan for during this time of the year.

The summary of precipitation projections in the mid-century time period is shown in Figure 6.3; see Appendix B for full results.

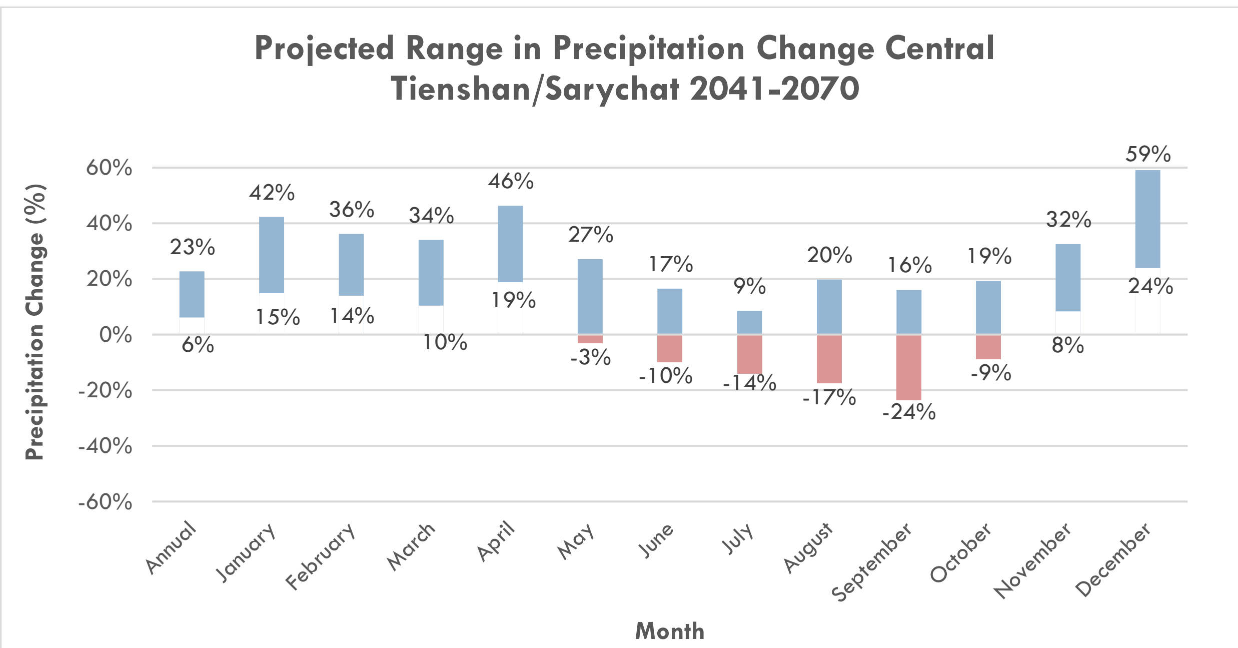


FIGURE 6.3. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY PRECIPITATION CHANGE (%) IN CENTRAL TIENSHAN/SARYCHAT BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

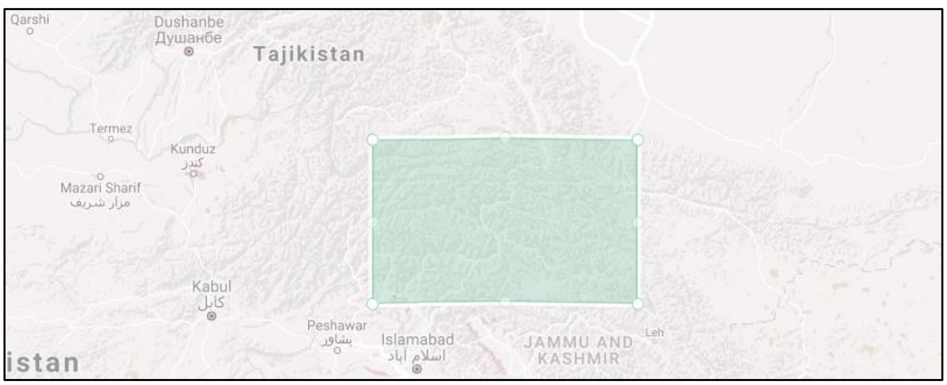
Potential impacts in the snow leopard context

The Central Tienshan/Sarychat region is a typically cold and dry climate that experiences the greatest amounts of precipitation between April and June, just prior to the warmest months of the year between June and September. Based on stakeholder feedback provided during the Climate Smart Snow Leopard Management Planning Workshop in April of 2016, the projected changes in climate may lead to impacts on snow leopards, their prey, and surrounding communities. Impacts could include:

- Early snow melt
- Changes in seasonal vegetation patterns
- Increased human-wildlife conflicts
- Increased risk for flooding and landslides
- Habitat shifts
- Changes in food availability

The shifts in average climate conditions described here may also lead to changes in the frequency of extreme events like heat waves, flooding, and drought that will affect snow leopard ecosystems and people. Climate changes in the Central Tien Shan will influence not only the immediate habitat of the snow leopard but interactions with other species. It is important for ecosystem managers and wildlife experts in the Central Tienshan/Sarychat region to consider these complex relationships among people, snow leopards, and ecosystems as they prepare for a changing climate.

7. KARAKORAM-PAMIR



LANDSCAPE COORDINATES: [E72.25, N37.25 – E77.25, N34.75]

Summary of key findings

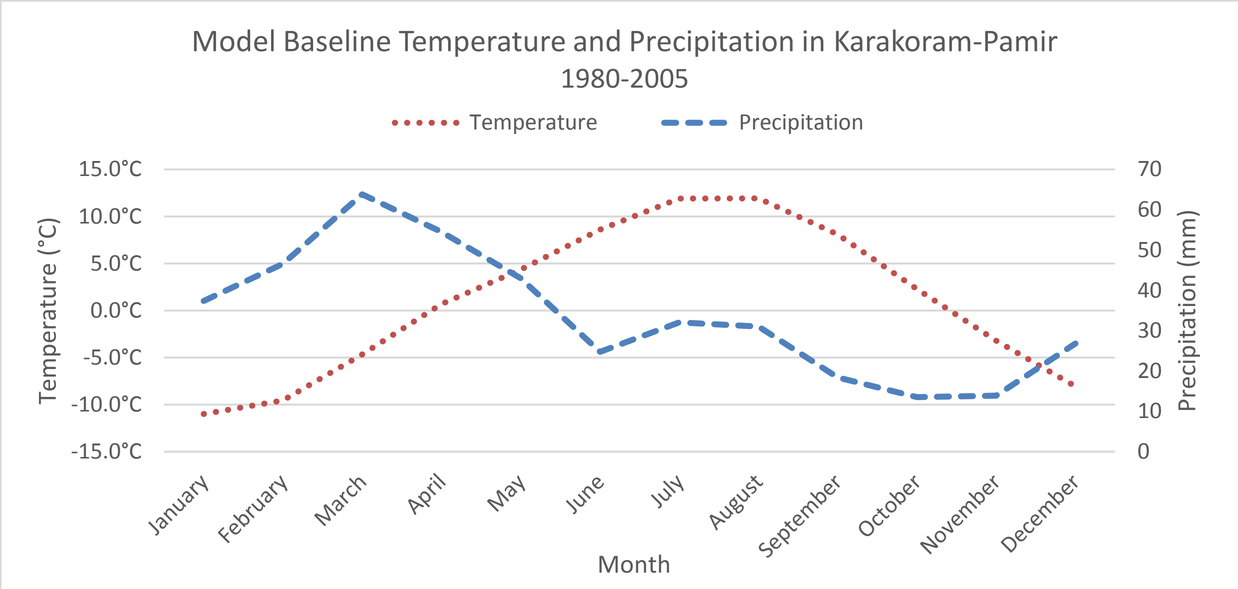


FIGURE 7.1. MODEL BASELINE (1980-2005) MONTHLY TEMPERATURE AND PRECIPITATION IN KARAKORAM-PAMIR

Temperature: Fairly consistent warming across all months

Historically, the average annual temperature in the Karakoram-Pamir Range is just about 1.0°C according to the model baseline (Figure 7.1). The area experiences below freezing monthly average temperatures between November and March, with January being the coldest month in the region. From April to June, average temperatures rise above freezing, and the warmest months of the year occur in July and August. Temperatures cool again in September and October, before reaching below freezing averages again in November.

By 2011 to 2040 (near-term), climate change may result in average annual temperatures increasing between 1.0˚C and 1.6˚C above the baseline in the Karakoram-Pamir Range. By the 2041-2070 (mid-century) time frame, annual average temperatures may rise between 2.2˚C and 3.6˚C above the baseline. From month-to-month, the rising temperature trends fairly consistent. Shifts in average temperature conditions in the future may result in greater frequency and intensity of extreme heat events in the region.

The largest increases are projected in the months of September – between 2.4°C to 3.9°C – and October – 2.5°C to 3.9°C – above baseline monthly temperatures by mid-century. This temperature increase may delay the onset of freezing and snow conditions to later in the year. Additionally, projected temperature increases in March and November may bring the average monthly temperatures to near or above 0˚C, which could have consequences for snow melt, potentially shrinking the length of the freeze-thaw cycle.

The summary of temperature projections in the mid-century time period is shown in Figure 7.2; see Appendix B for full results.

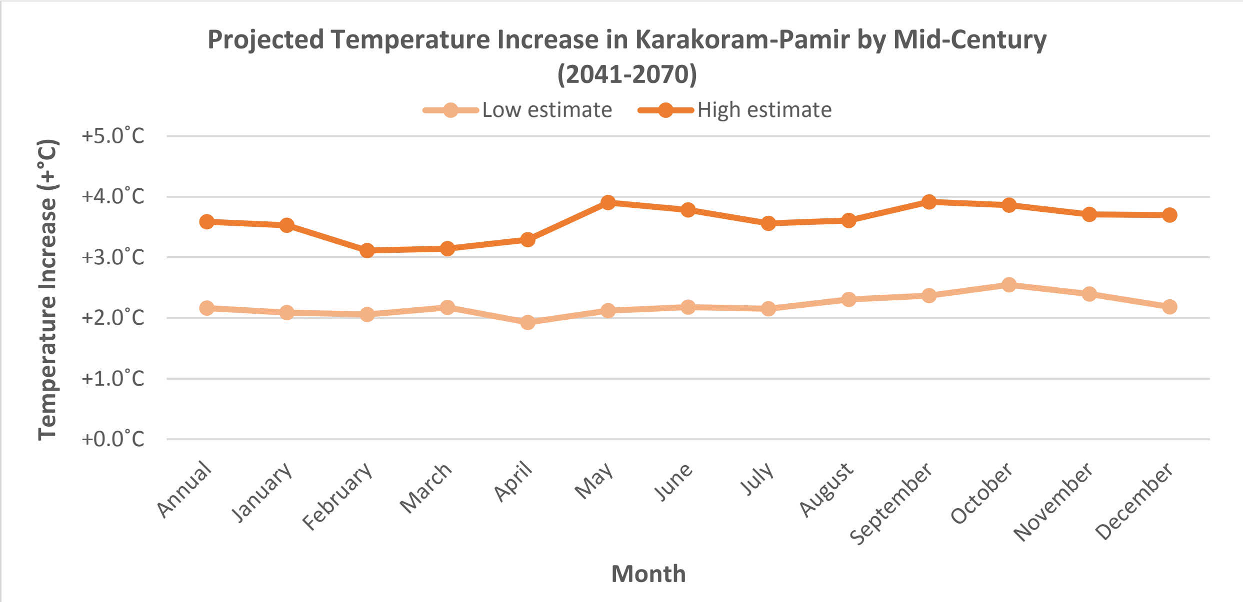


FIGURE 7.2. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY TEMPERATURE INCREASE (°C) IN KARAKORAM-PAMIR BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

Precipitation: Precipitation increases in winter

The Karakoram-Pamir Range climatologically receives little precipitation, averaging roughly 40cm per year on an annual basis in the model baseline (Figure 7.1). The wettest months of the year occurs in March, and the driest months in October and November. In general, precipitation falls fairly consistently throughout the year.

Based on climate model projections, precipitation in this region may increase slightly in the future. The annual total precipitation is expected to increase between 2% and 13% above historical levels in the near-term, and between 6% and 18% by mid-century. While some months show a wider range in uncertainty in the direction of rainfall change, projections show that nearly all months lean towards increasing precipitation.

Between October and January, in particular, the projected percentage increases in precipitation are higher. In the near-term, January may see an average precipitation increase ranging from 0% to 30%, and extending to an increase ranging from 4% to 46% by mid-century. November and December may see precipitation increase up to 51% and 50%, respectively, by mid-century.

It is important to note that the Karakoram-Pamir region has rapidly changing topography. Dramatic elevation shifts over short distances result in microclimates that are difficult to capture in climate models, and this should be considered when interpreting climate projections in this area.

The summary of precipitation projections in the mid-century time period is shown in Figure 7.3; see Appendix B for full results.

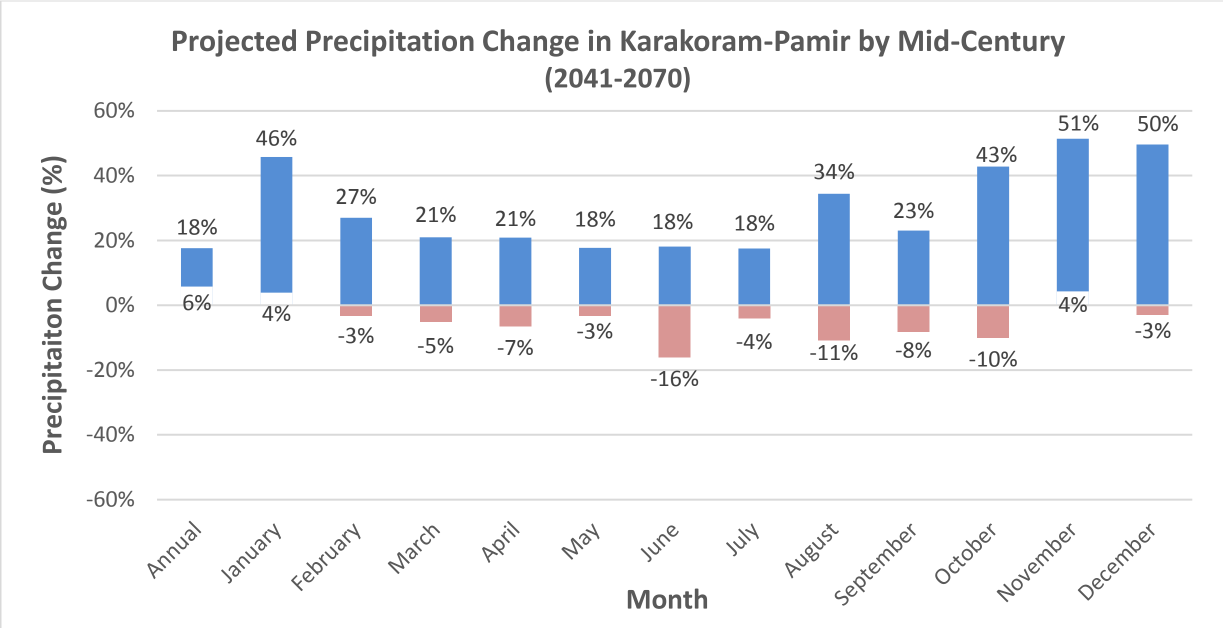


FIGURE 7.3. PROJECTED RANGE (LOW TO HIGH ESTIMATE*) IN ANNUAL AND MONTHLY PRECIPITATION CHANGE (%) IN KARAKORAM-PAMIR BY MID-CENTURY IN REFERENCE TO THE 1980-2005 BASELINE. SEE APPENDIX B FOR FULL RESULTS.

*THE LOW ESTIMATE REFERS TO THE 25TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP8.5 GREENHOUSE GAS EMISSIONS SCENARIOS. THE HIGH ESTIMATE REFERS TO THE 75TH PERCENTILE OF THE 42 MODEL OUTCOMES UNDER THE RCP4.5 AND RCP 8.5 GREENHOUSE GAS EMISSIONS SCENARIOS.

Potential impacts in the snow leopard context

The Karakoram-Pamir region is characterized by low monthly baseline temperatures, where the warmest months of the year – June to September – are preceded by the wettest months of the year – February to April. Based on stakeholder feedback provided during the Climate Smart Snow Leopard Management Planning Workshop in April of 2016, the projected changes in climate may lead to impacts on snow leopards, their prey, and surrounding communities. Impacts could include:

- Potential shifts in winter storms
- Impacts on livestock health
- Early Spring snowmelt
- Increased risk for flooding and landslides
- Shifts in rotational grazing patterns
- Changes in seasonal food availability
- Increased human-wildlife conflict
- More frequent extreme heat and rainfall events

The shifts in average climate conditions described here may also lead to changes in the frequency of extreme events like heat waves, flooding, and drought that will affect snow leopard ecosystems and people. Climate changes in the Karakoram-Pamir region will influence not only snow leopard habitat, but also the prey base and interactions with surrounding communities. As they prepare for climate change, it is important for ecosystem managers and wildlife experts in the region to consider these complex relationships among snow leopards, ecosystems, and people that will increasingly lead to cascading impacts as temperatures increase.

8. KEY CONCLUSIONS

Across all six snow leopard landscapes examined, all of the regions are projected to see warming as the century progresses. Eastern Nepal, Sikkim, and Bhutan are projected to see greater warming in winter months while South Gobi and Central Tienshan/Sarychat are projected to see more warming in the summer. In the Karakoram-Pamir region, warming is fairly consistent across all months. Eastern Nepal, Sikkim, and Bhutan are projected to have a wetter monsoon, while the Karakoram-Pamir region may see an increase in winter precipitation. South Gobi, a climatically dry zone, is projected to see a minimal increase in annual precipitation, and the dry Central Tienshan/Sarychat region also sees a small increase in annual precipitation.

A summary of projected changes for each of the six snow leopard landscapes is presented in Table 8.1.

Project Site	**Temperature**	**Precipitation**
Eastern Nepal	*Warmer, especially in winter months*	*Wetter, especially in the summer monsoon season*
Sikkim	*Warmer, especially in winter months*	*Wetter, especially in the summer monsoon season*
Bhutan	*Warmer, especially in winter months*	*Wetter, especially in the summer monsoon season*
South Gobi	*Warmer, especially in summer monsoon season*	*Minimal increase in annual rainfall in a climatically dry zone*
Central Tienshan/Sarychat	*Warmer, especially in summer monsoon season*	*Small increase in annual precipitation.*
Karakoram-Pamir	*Consistent warming across all months*	*Precipitation increases in winter*

TABLE 8.1. PROJECTED CHANGES IN TEMPERATURE AND PRECIPITATION ACROSS ALL SIX PROJECT SITES.

Shifts in average temperature and precipitation conditions have the possibility to lead to an increase in extreme events. As average temperatures shift upwards in already hot and humid seasons, heat waves may increase in duration and intensity, leading to health effects on snow leopards and their prey, as well as the human systems and ecosystems with which they interact. While many of the sites currently experience measurable precipitation throughout the year, increases in rainfall, especially during peak summer months, intensify the risk for flooding and landslides. In some relatively low and warm areas, however, extra rainfall in the future may be outstripped by evapotranspiration due to warming temperatures.

A few additional concluding points are important to note from this analysis. Changes in precipitation need to be interpreted carefully, as some of the projections across all of the project sites show large percentage changes in months with historically low baseline precipitation. Any projected percentage changes during these dry months will therefore likely not reflect any meaningful precipitation totals, and these changes should not be emphasized.

It is also important to note that as the century progresses, projected changes in both precipitation and temperature tend to become larger, as does the model-based range of possible future outcomes. The amount of projected change depends, among other things, on greenhouse gas concentrations and how sensitive climate models are to those changes. Additionally, the rapidly changing topography across much of the snow leopard landscape creates a myriad of micro-climates and will lead to more complexity than can be captured here. For example, some locations have such a high altitude that even in summer they will remain snow-dominated, and could accumulate more snow in a moister environment.

Finally, many factors not captured here will impact the human-wildlife system in these regions. Even without climate change, snow leopards face environmental and human threats that impact their livelihoods. With climate change, many of these risks will be exacerbated. The information presented in this report may be used as a starting point in preparing for these complex and often cascading impacts of climate change in the snow leopard landscape.

APPENDIX A: CLIMATE METHODS AND KEY UNCERTAINTIES

Methodology

Temperature and precipitation projections were developed using the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset released in 2015[4]. It is comprised of downscaled climate scenarios for the globe that are derived from the General Circulation Model (GCM) simulations conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5) and across two greenhouse gas emissions scenarios known as Representative Concentration Pathways (RCPs). The two RCPs in the dataset are RCP 4.5 and RCP 8.5. The CMIP5 GCM simulations were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The NEX-GDDP dataset includes downscaled projections from the 21 models and scenarios for which daily scenarios were produced and distributed under CMIP5. Each of the climate projections includes monthly mean temperature and monthly mean precipitation for the periods from 1950 through 2100. The spatial resolution of the dataset is 0.25 degrees (approximately 25 km x 25 km).

For the analysis carried out for the six sites in this report, two time slices were developed to represent 30-year averages – 2020s (2011-2040) and 2050s (2041-2070). Temperature change factors reflect changes in monthly and annual averages of daily mean temperature in reference to the base period. Precipitation change factors reflect percent changes in total monthly and annual precipitation in reference to the base period. All change factors are relative to the 1980-2005 same-model base period.

In this report, projections are presented as ranges. The low and high estimates were computed to capture a range of possible future outcomes generated from the 21 model projections run under the two greenhouse gas emissions scenarios (RCP4.5 and RCP8.5), reflecting 42 different possible outcomes. These estimates are based on a ranking (from most to least) of the 42 model outcomes. The low estimate value reflects the 25th percentile, defined as the value that 25 percent of model outcomes (roughly 10 out of the 42 values) are the same or lower than, and 75 percent of the model outcomes (roughly 31 out of the 42 values) are the same or higher than. This 25th percentile value is the model outcome for which 75 percent of the model results reflect a larger increase (or, if the value is negative, a smaller decrease), and thus is considered the low estimate. The high estimate value reflects the 75th percentile, defined as the value that 75 percent of the model outcomes (roughly 31 out of the 42 values) are the same or lower than, and 25 percent of the model outcomes (roughly 10 out of the 42 values) are the same or higher than. This 75th percentile value is the model outcome for which 25 percent of the model results reflect a larger increase (or, if the value is negative, a smaller decrease), and thus is considered the high estimate.

Presenting the projections as a range can assist decision-makers and planners applying risk-based approaches to climate change adaptation and resiliency.

Planning for uncertainty in projecting climate change

Climate projections, like all projections are characterized by uncertainty[5]. One of the reasons for this uncertainty is that natural variability of the climate system is largely unpredictable. This includes randomness

[4] NASA (2015), NEX Global Daily Downscaled Climate Projections 2015. Available online from: https://nex.nasa.gov/nex/projects/1356/

[5] Horton, R., Bader, D., Kushnir, Y., Little, C., Blake, R. and Rosenzweig, C. (2015), New York City Panel on Climate Change 2015 Report; Chapter 1: Climate Observations and Projections. Ann. N.Y. Acad. Sci., 1336: 18–35. doi:10.1111/nyas.12586

in ocean dynamics, storm events, solar cycles, and atmospheric patterns that shift in an erratic manner over time.

The second source of uncertainty is human behavior, which is directly related to the magnitude of climate changes. The effectiveness of international climate agreements, the development of new technologies, and cultural and behavior patterns will direct the trajectory of emissions of greenhouse gases and other radiatively important agents like aerosol particles over time.

A third source of uncertainty is in the global climate models that project future climate patterns. Each of these mathematical models simulates the climate system and how that system will respond to increased greenhouse gas concentrations and feedback loops from the interconnected systems that govern weather and climate. These models incorporate these various aspects in slightly different ways, resulting in different outputs for temperature, precipitation, sea level rise, and other variables.

Due to these uncertainties, the climate projections in this report are presented as a range of possible outcomes, rather than a single number for a time period. The analysis uses outputs of 21 climate models, so one single number cannot capture the full range of future modeled possibilities. Projections indicate that temperature will increase in both the 2011-2040 and the 2041-2070 timeslices. The magnitude and range of possible outcomes generally widens as the century progresses, as uncertainties about greenhouse gas concentrations and system response grow.

While temperature is projected to increase in all these regions, the direction of projected seasonal precipitation change is less defined, with some models projecting decreases in total rainfall and others suggesting an increase. It is vital to note that these are projections averaged across 30-year timeslices; there will still be year-to-year variability. For example, even if the monsoon season is expected to become wetter as the century progresses, there will be years with low precipitation and potentially even drought conditions during that time of the year. The risk-based approach to decision making presented in this report can help to manage uncertainty and support adaptation planning across a range of sectors and applications.

APPENDIX B: FULL MONTHLY SITE RESULTS

Eastern Nepal

Month	Average Baseline Temperature 1980-2005 (°C)	Projected Average Temperature in 2011-2040 (+°C in relation to baseline)	Projected Average Temperature in 2041-2070 (+°C in relation to baseline)
Annual	*10.4*	*+0.9 to +1.3*	*+1.9 to +2.6*
January	*2.0*	*+1.0 to +1.7*	*+2.2 to +3.4*
February	*3.4*	*+1.0 to +1.6*	*+2.2 to +3.2*
March	*7.1*	*+1.2 to +1.7*	*+2.3 to +3.4*
April	*11.1*	*+1.0 to +1.7*	*+2.1 to +3.4*
May	*13.9*	*+1.0 to +1.8*	*+1.9 to +3.3*
June	*16.1°C*	*+0.7°C to +1.5°C*	*+1.8°C to +2.9°C*
July	*16.6°C*	*+0.5°C to +1.3°C*	*+1.4°C to +2.3°C*
August	*16.4°C*	*+0.7°C to +1.1°C*	*+1.5°C to +2.3°C*
September	*15.2°C*	*+0.6°C to +1.1°C*	*+1.6°C to +2.4°C*
October	*11.6°C*	*+0.8°C to +1.2°C*	*+1.7°C to +2.6°C*
November	*7.4°C*	*+1.0°C to +1.4°C*	*+2.1°C to +3.0°C*
December	*3.9 °C*	*+1.0°C to +1.6°C*	*+2.2°C to +3.2°C*

TABLE B.2.1. MONTHLY AVERAGE MODEL BASELINE TEMPERATURE (°C) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE TEMPERATURE (°C) IN EASTERN NEPAL IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Month	Average Baseline Precipitation 1980-2005 (mm)	Projected Average Precipitation in 2011-2040 (% change in relation to baseline)	Projected Average Precipitation in 2041-2070 (% change in relation to baseline)
Annual	*1386*	*+1 to +16*	*+12 to +27*
January	*5*	*-25 to +19*	*-25 to +24*
February	*9*	*-18 to +5*	*-21 to +13*
March	*24*	*-13 to +18*	*-17 to +22*
April	*53*	*-22 to +15*	*-15 to +21*
May	*108*	*+4 to +39*	*0 to +48*

June	*233*	*-4 to +18*	*-3 to +34*
July	*361*	*+2 to +21*	*+4 to +32*
August	*303*	*+1 to +22*	*+15 to +37*
September	*200*	*-1 to +26*	*+7 to +37*
October	*81*	*-9 to +19*	*-2 to +41*
November	*6*	*-22 to +39*	*-24 to +35*
December	*2*	*-40 to +20*	*-39 to +40*

TABLE B.2.2. MONTHLY AVERAGE MODEL BASELINE PRECIPITATION (MM) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE PRECIPITATION (%) IN EASTERN NEPAL IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Sikkim

Month	**Average Baseline Temperature 1980-2005** (°C)	**Projected Average Temperature in 2011-2040** (+°C in relation to baseline)	**Projected Average Temperature in 2041-2070** (+°C in relation to baseline)
Annual	*13.9*	*+0.8 to +1.2*	*+1.7 to +2.5*
January	*6.2*	*+0.9 to +1.6*	*+2.1 to +3.1*
February	*7.7*	*+0.9 to +1.4*	*+2.1 to +2.9*
March	*11.3*	*+1.1 to +1.5*	*+2.2 to +3.0*
April	*14.8*	*+0.9 to +1.5*	*+1.9 to +3.0*
May	*17.0*	*+0.8 to +1.5*	*+1.6 to +3.0*
June	*18.7*	*+0.6 to +1.4*	*+1.5 to +2.7*
July	*19.1*	*+0.5 to +1.1*	*+1.2 to +2.2*
August	*19.1*	*+0.6 to +1.1*	*+1.4 to +2.2*
September	*18.2*	*+0.6 to +1.1*	*+1.6 to +2.3*
October	*15.5*	*+0.7 to +1.1*	*+1.6 to +2.3*
November	*11.6*	*+0.8 to +1.4*	*+1.8 to +2.7*
December	8.3°C	*+0.8°C to +1.5°C*	+2.0°C to +2.9°C

TABLE B.3.1. MONTHLY AVERAGE MODEL BASELINE TEMPERATURE (°C) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE TEMPERATURE (°C) IN SIKKIM IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Month	Average Baseline Precipitation 1980-2005 (mm)	Projected Average Precipitation in 2011-2040 (% change in relation to baseline)	Projected Average Precipitation in 2041-2070 (% change in relation to baseline)
Annual	*1820*	*+5 to +17*	*+9 to +29*
January	*4*	*-27 to +18*	*-30 to +8*
February	*6*	*-19 to +16*	*-25 to +24*
March	*27*	*-18 to +19*	*-18 to +30*
April	*78*	*-23 to +21*	*-15 to +28*
May	*158*	*+2 to +47*	*-4 to +57*
June	*327*	*-5 to +18*	*-5 to +29*
July	*466*	*-1 to +24*	*-2 to +31*
August	*370*	*+1 to +21*	*+10 to +41*
September	*265*	*-7 to +24*	*+8 to +40*
October	*110*	*-6 to +17*	*-9 to +40*
November	*8*	*-25 to +54*	*-22 to +41*
December	*0*	*-54 to +46*	*-49 to +61*

TABLE B.3.2. MONTHLY AVERAGE MODEL BASELINE PRECIPITATION (MM) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE PRECIPITATION (%) IN SIKKIM IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Bhutan

Month	Average Baseline Temperature 1980-2005 (°C)	Projected Average Temperature in 2011-2040 (+°C in relation to baseline)	Projected Average Temperature in 2041-2070 (+°C in relation to baseline)
Annual	*12.7*	*+0.9 to +1.2*	*+1.8 to +2.5*
January	*5.0*	*+1.0 to +1.6*	*+2.1 to +3.0*
February	*6.5*	*+0.9 to +1.5*	*+2.2°C to +3.0*
March	*9.8*	*+1.1 to +1.5*	*+2.1°to +3.0*
April	*12.9*	*+0.8 to +1.5*	*+1.9 to +3.0*
May	*15.3*	*+0.9 to +1.6*	*+1.7 to +2.9*
June	*17.7*	*+0.7 to +1.3*	*+1.6 to +2.6*
July	*18.3*	*+0.5 to +1.1*	*+1.4 to +2.2*

August	18.2	+0.7 to +1.1	+1.5 to +2.3
September	17.2	+0.6 to +1.2	+1.7 to +2.4
October	14.1	+0.7 to +1.1	+1.7 to +2.4
November	10.1	+0.9 to +1.4	+2.0 to +2.8
December	6.9	+0.9 to +1.6	+2.1 to +2.9

TABLE B.4.1. MONTHLY AVERAGE MODEL BASELINE TEMPERATURE (°C) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE TEMPERATURE (°C) IN BHUTAN IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Month	**Average Baseline Precipitation 1980-2005** (mm)	**Projected Average Precipitation in 2011-2040** (% change in relation to baseline)	**Projected Average Precipitation in 2041-2070** (% change in relation to baseline)
Annual	1783	+2 to +17	+10 to +30
January	4	-33 to +22	-25 to +13
February	6	-20 to +20	-20 to +29
March	32	-10 to +20	-11 to +40
April	107	-24 to +23	-11 to +38
May	197	-5 to +28	-6 to +43
June	350	-2 to +23	-3 to +34
July	425	+2 to +20	+4 to +41
August	330	+2 to +22	+9 to +36
September	221	-9 to +20	0 to +36
October	97	-7 to +19	-7 to +47
November	11	-13 to +42	-20 to +44
December	1	-48 to +18	-40 to +37

TABLE B.4.2. MONTHLY AVERAGE MODEL BASELINE PRECIPITATION (MM) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE PRECIPITATION (%) IN BHUTAN IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

South Gobi

Month	**Average Baseline Temperature 1980-2005** (°C)	**Projected Average Temperature in 2011-2040** (+°C in relation to baseline)	**Projected Average Temperature in 2041-2070** (+°C in relation to baseline)

Annual	*4.3*	*+0.9 to +1.8*	*+2.0 to +3.3*
January	*-13.9*	*+0.6 to +1.8*	*+1.4 to +3.1*
February	*-10.8*	*+0.7 to +1.6*	*+1.4 to +3.0*
March	*-3.3*	*+0.8 to +1.6*	*+1.8 to +3.2*
April	*5.7*	*+0.6 to +1.8*	*+1.6 to +3.1*
May	*13.4*	*+0.9 to +1.7*	*+1.9 to +3.2*
June	*19.0*	*+1.1 to +1.7*	*+2.2 to +3.6*
July	*21.3*	*+1.1 to +1.8*	*+2.3 to +3.5*
August	*19.4*	*+1.3 to +2.1*	*+2.7 to +3.8*
September	*13.2*	*+1.2 to +2.0*	*+2.3 to +3.9*
October	*5.0*	*+0.9 to +1.9*	*+2.0 to +3.2*
November	*-4.9*	*+1.0 to +1.8*	*+2.0 to +3.6*
December	*-11.9*	*+1.1 to +1.7*	*+2.2 to +3.5*

TABLE B.5.1. MONTHLY AVERAGE MODEL BASELINE TEMPERATURE (°C) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE TEMPERATURE (°C) IN SOUTH GOBI IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Month	**Average Baseline Precipitation 1980-2005** (mm)	**Projected Average Precipitation in 2011-2040** (% change in relation to baseline)	**Projected Average Precipitation in 2041-2070** (% change in relation to baseline)
Annual	*98*	*-2 to +12*	*0 to +18*
January	*0*	*0 to 0*	*0 to 0*
February	*0*	*0 to 0*	*0% to 0*
March	*0*	*-8 to +139*	*+5 to +112*
April	*0*	*-1 to +37*	*+3 to +48*
May	*5*	*-11 to +28*	*-1 to +33*
June	*20*	*-6 to +15*	*-4 to +18*
July	*36*	*-4 to +15*	*-5 to +21*
August	*31*	*-5 to +12*	*+1 to +13*

September	7	-4 to +15	-5 to +26
October	0	-18 to +46	0 to +49
November	0	-44 to +57	-33 to +126
December	0	0 to 0	0 to 0

TABLE B.5.2. MONTHLY AVERAGE MODEL BASELINE PRECIPITATION (MM) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE PRECIPITATION (%) IN SOUTH GOBI IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Central Tienshan/Sarychat

Month	**Average Baseline Temperature 1980-2005** (°C)	**Projected Average Temperature in 2011-2040** (+°C in relation to baseline)	**Projected Average Temperature in 2041-2070** (+°C in relation to baseline)
Annual	1.0	+0.9 to +1.5	+1.9 to +3.2
January	-15.1	+0.7 to +1.6	+1.9 to +3.3
February	-12.5	+0.6 to +1.5	+1.7 to +3.0
March	-5.1	+1.1 to +1.5	+2.0 to +3.2
April	3.1	+0.5 to +1.6	+1.7 to +3.0
May	7.8	+0.9 to +1.7	+1.7 to +3.0
June	11.5	+0.8 to +1.7	+1.8 to +3.1
July	14.3	+1.0 to +1.8	+2.3 to +3.6
August	13.9	+1.1 to +2.1	+2.3 to +4.1
September	9.2	+1.1 to +2.0	+2.3 to +3.7
October	2.3	+1.0 to +1.8	+2.2 to +3.4
November	-5.5	+0.9 to +1.5	+1.8 to +3.1
December	-12.3	+0.8 to +1.8	+2.0 to +3.3

TABLE B.6.1. MONTHLY AVERAGE MODEL BASELINE TEMPERATURE (°C) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE TEMPERATURE (°C) IN CENTRAL TIENSHAN/SARYCHAT IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Month	**Average Baseline Precipitation 1980-2005** (mm)	**Projected Average Precipitation in 2011-2040** (% change in relation to baseline)	**Projected Average Precipitation in 2041-2070** (% change in relation to baseline)

Annual	*224*	*0 to +17*	*+6 to +23*
January	*5*	*+2 to +22*	*+15 to +42*
February	*7*	*+2 to +23*	*+14 to +36*
March	*17*	*+4 to +23*	*+10 to +34*
April	*27*	*+3 to +29*	*+19 to +46*
May	*41*	*-6 to +20*	*-3 to +27*
June	*38*	*-12 to +18*	*-10 to +17*
July	*28*	*-14 to +17*	*-14 to +9*
August	*20*	*-6 to +17*	*-17 to +20*
September	*9*	*-13 to +19*	*-24 to +16*
October	*13*	*-13 to +11*	*-9 to +19*
November	*12*	*-3 to +16*	*+8 to +32*
December	*8*	*+5 to +31*	*+24 to +59*

TABLE B.6.2. MONTHLY AVERAGE MODEL BASELINE PRECIPITATION (MM) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE PRECIPITATION (%) IN CENTRAL TIENSHAN/SARYCHAT IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Karakoram-Pamir

Month	**Average Baseline Temperature 1980-2005** (°C)	**Projected Average Temperature in 2011-2040** (+°C in relation to baseline)	**Projected Average Temperature in 2041-2070** (+°C in relation to baseline)
Annual	*0.9*	*+1.0 to +1.6*	*+2.2 to +3.6*
January	*-11.0*	*+0.9 to +1.8*	*+2.1 to +3.5*
February	*-9.5*	*+0.8 to +1.6*	*+2.1 to +3.1*
March	*-4.7*	*+1.0 to +1.6*	*+2.2 to +3.1*
April	*0.7*	*+0.9 to +1.5*	*+1.9 to +3.3*
May	*4.3*	*+0.7 to +1.9*	*+2.1 to +3.9*
June	*8.6*	*+1.0 to +1.9*	*+2.2 to +3.8*
July	*11.9*	*+0.8 to +1.8*	*+2.2 to +3.6*
August	*11.9*	*+1.0 to +1.6*	*+2.3 to +3.6*

September	8.1	+1.2 to +1.8	+2.4 to +3.9
October	2.3	+1.0 to +2.0	+2.5 to +3.9
November	-3.2	+1.1 to +1.8	+2.4 to +3.7
December	-8.0	+0.9 to +1.9	+2.2 to +3.7

TABLE B.7.1. MONTHLY AVERAGE MODEL BASELINE TEMPERATURE (°C) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE TEMPERATURE (°C) IN KARAKORAM-PAMIR IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.

Month	**Average Baseline Precipitation 1980-2005** (mm)	**Projected Average Precipitation in 2011-2040** (% change in relation to baseline)	**Projected Average Precipitation in 2041-2070** (% change in relation to baseline)
Annual	406	+2 to +13	+6 to +18
January	37	0 to +30	+4 to +46
February	47	-8 to +8	-3 to +27
March	64	-14 to +23	-5 to +21
April	55	-11 to +19	-7 to +21
May	43	-9 to +20	-3 to +18
June	25	-15 to +25	-16 to +18
July	32	-3 to +22	-4 to +18
August	31	-10 to +22	-11 to +34
September	18	-14 to +35	-8 to +23
October	14	-14 to +27	-10 to +43
November	14	-4 to +24	+4 to +51
December	27	-5 to +32	-3 to +50

TABLE B.7.2. MONTHLY AVERAGE MODEL BASELINE PRECIPITATION (MM) IN 1980-2005 AND PROJECTED CHANGE IN MONTHLY AVERAGE PRECIPITATION (%) IN KARAKORAM-PAMIR IN THE 2011-2040 AND 2041-2070 TIME PERIODS COMPARED TO THE BASELINE.