TA 9530-TAJ: CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) Road Project, Tajikistan

Climate Risk and Vulnerability Assessment

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1 Description of the Project

1.1 Background

ADB is providing a technical assistance grant to the government of Tajikistan (the government) for the preparation of the CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) Road Project. The project road, about 72 km long, will replace a section of the existing M41 highway that will be inundated due to the construction of the Rogun Hydropower (HPP) project. The project road passes through mountainous terrain and includes 3 tunnels of total length about 6 km, several substantial bridges, and a high level 700 m long bridge over the future hydropower reservoir. The executing agency for implementing the project is the Ministry of Transport (MOT), represented by its Project Implementation Unit for Roads Rehabilitation (PIURR). The detailed design of the road has been completed by a national design consultant appointed by MOT.

1.2 Scope of work

Since 2014, the Asian Development Bank (ADB) has required that all investment projects consider climate and disaster risk and incorporate adaptation measures in projects at-risk from geo-physical and climate change impacts. This is consistent with the ADB's commitment to scale up support for adaptation and climate resilience in project design and implementation, articulated in the Midterm Review of Strategy 2020: Meeting the Challenges of a Transforming Asia and Pacific (ADB, 2014a), in the Climate Change Operational Framework 2017–2030: Enhancing Actions for Low Greenhouse Gas Emissions and Climate-Resilient Development (ADB, 2017), and in the Climate Risk Management in ADB Projects guidelines (2014b).

The principal objective of a climate risk and vulnerability assessment (CRVA) is to identify those components of the Project that are at risk of failure, damage and/or deterioration from natural hazards, extreme climatic events or significant changes to baseline climate design values (ADB, 2011, 2014 and 2017). This serves to improve the resilience of the infrastructure to the impacts of climate change and geo-physical hazards, to protect communities and provide a safeguard so that infrastructure services are available when they are needed most. As part of this process, the nature and relative levels of risk are evaluated and determined to establish priorities for remedial action.

Working closely with ADB and the project design consultant team (Avtostrada), a (i) climate screening has been carried out and the sensitivity of the project components to climate and/or weather conditions has been assessed, and (ii) climate risks and adequacy of proposed technical solutions have been assessed.

The following tasks are formulated for this CRVA:

I. In coordination with the project design consultant team: review the current design specifications (i.e. explicit and implicit climate-related assumptions), identify key areas of the design's vulnerability to climate, and identify key variables/proxies and location(s) to model so that specifications can be tested/updated for climate-proofing over design life;

II. Develop projections for the key variables/proxies and location(s) to [2050] for mid (RCP 4.5) and high (RCP 8.5) scenarios, presenting outcomes that capture model uncertainty of temperature vs. precipitation rather than just the average of the ensemble.

III. In coordination with the project design consultant team: identify a sub-set of those model runs which appropriately captures a range of feasible outcomes against which the current design specifications can be tested and with which the design specifications can be updated and costed.

1.3 The project road

The Obigarm–Nurobod road section of the existing M41 highway, which carries about 3,000 vehicles per day, will be inundated once the Rogun HPP reservoir has filled to operating levels. The realignment of this road section through the river valley is not part of the Rogun HPP project. A bypass road must be completed and opened to traffic by latest November 2023, the date by which the rising water in the HPP reservoir will have inundated several critical sections of the M41 highway. No other part of Tajikistan's national highway network can provide for this traffic, and the only alternative route would represent a deviation of about 500 km.

The government has requested ADB's assistance to construct a 72 km long road section that will bypass the HPP reservoir through mountainous terrain (Figure 1). It will be constructed to two-lane asphalt surfaced standard, and will include three tunnels with a total length of about 6 km, one high level bridge about 700 m long, and 13 shorter bridges with a total length of about 975 m. The construction of some parts of the project road started in 1988 (mostly earthworks) but was suspended following the abandonment of the Rogun HPP project. The proposed road alignment is largely clear of houses and other assets.

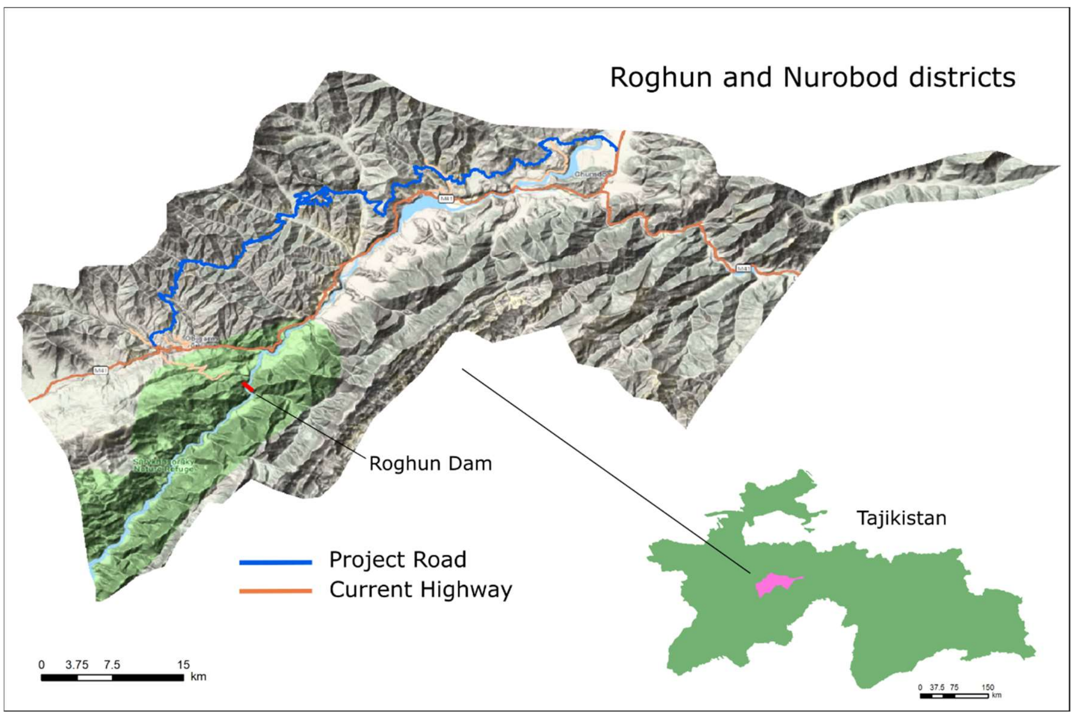


Figure 1. Location of the CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) Road Project


Figure 2: Impression of present road. Photo credits: ADB.

2 Climate Change Projections

2.1 Changes in Climatic Means

Climate change projections for the foreseen location of the CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) Road Project are constructed using the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset. This dataset comprises global downscaled climate scenarios that are derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5) and across two of the four greenhouse gas emissions scenarios known as Representative Concentration Pathways (RCPs). The CMIP5 GCM runs were developed in support of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The NASA-NEX-GDDP dataset includes downscaled projections for RCP 4.5 and RCP 8.5[1] from the 21 models and scenarios for which daily scenarios were produced and distributed under CMIP5. Each of the climate projections includes daily maximum temperature, minimum temperature, and precipitation for the periods from 1950 through 2100. For this climate risk and vulnerability assessment (CRVA), the climate projections for the foreseen location of the project road are evaluated for the intermediate future around 2050 (2035 – 2064) and compared to a reference period (1976 – 2005) covering the same time span. The spatial resolution of the dataset is 0.25 degrees (25 km x 25 km at the equator). The full results are presented in Appendix 1, the most relevant projected changes in climatic means are summarized below. (https://nex.nasa.gov/nex/projects/1356/).

2.1.1 Precipitation trends

The analysis of the NASA NEX-GDDP dataset indicates that for precipitation (annual sum) the range in the climate change projections is large, meaning that there is a large uncertainty in the future precipitation. However, in the ensemble mean (top right panel Figure 3) a trend can be identified for future precipitation compared to the historical reference: under both the RCP 4.5 and RCP 8.5 the annual precipitation sum is expected to increase by about 6 – 7%. In both RCP4.5 and RCP8.5, the spread between the GCMs is equally large for the future period, indicating a large uncertainty in the future precipitation under both RCP's (see also Figure 4).

2.1.2 Temperature trends

The analysis of the NASA NEX-GDDP dataset indicates that the air temperature shows strong increasing trends for all GCMs. Under the RCP 4.5, the annual daily maximum temperature is expected to increase on average by about 2.4 degrees from 13.4 to 15.8 degree Celsius (middle right panel in Figure 3). Similarly, the annual daily minimum temperature is expected to increase on average by about 1.6 degrees from 1.6 to 3.9 degree Celsius (bottom right panel in Figure 3). Under the RCP 8.5, an even stronger increasing trend in air temperatures is projected; the annual daily maximum temperature is expected to increase on average by 3.1 degrees from 13.4 to 16.5 degree Celsius. The annual daily minimum temperature is expected to increase on average by 3.0 degrees from 1.6 to 4.6 degree Celsius. The uncertainty range of future temperature is larger for RCP 8.5 compared to RCP 4.5 (see also Figure 4).

[1] Since the release of Intergovernmental Panel on Climate Change's fifth Assessment Report, four representative concentration pathways (RCPs) have been defined as a basis for long-term and near-term climate modeling experiments in the climate modeling community. The four RCPs together span the range of radiative forcing values for the year 2100 as found in literature, from 2.6 to 8.5 Wm^{-2}. Climate modelers use the time series of future radiative forcing from the four RCPs for their climate modeling experiments to produce climate scenarios. RCP4.5 is a medium stabilization scenario implying a stabilization of greenhouse gas concentrations halfway the 21st century and RCP8.5 is a very high baseline emission scenario (business as usual).

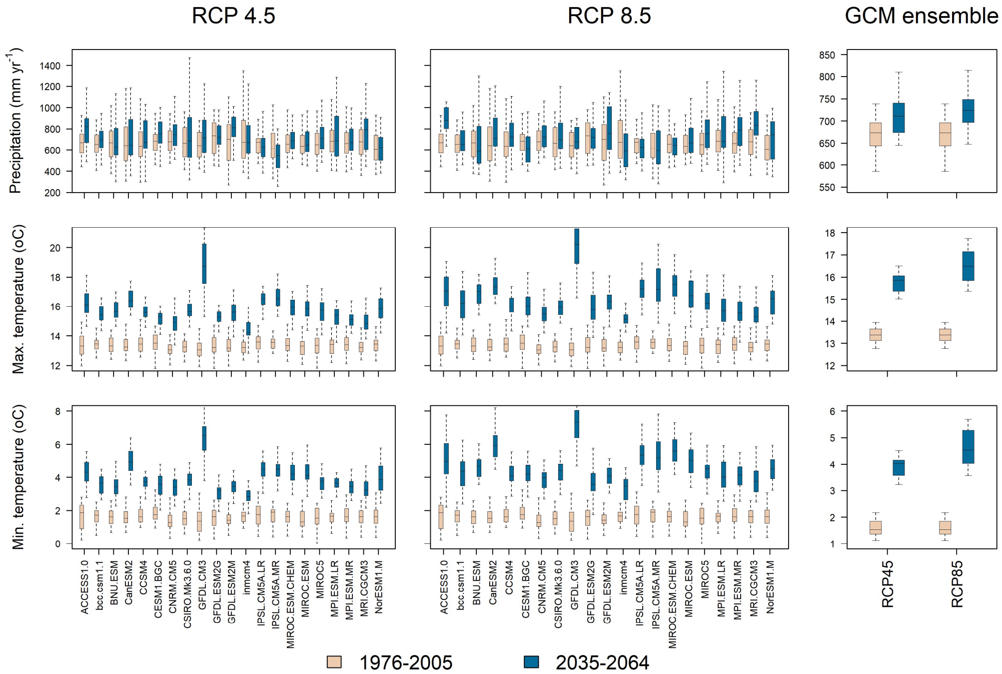


Figure 3. Climate (change) projections for the reference period (1976 – 2005) and intermediate future (2035 – 2064) for the 21 GCMs under RCP 4.5 and RCP 8.5.

Table 1. Climate projections for the intermediate future at different percentiles in the GCM multi-model ensemble under RCP 4.5 and RCP 8.5.

GCM ensemble	RCP 4.5 1976 - 2005			RCP 4.5 2035-2064			RCP 8.5 1976 - 2005			RCP 8.5 2035-2064		
	pr	Tmax	Tmin	pr	Tmax	Tmin	pr	Tmax	Tmin	pr	Tmax	Tmin
Mean	**674.0**	**13.4**	**1.6**	**715.0**	**15.8**	**3.9**	**674.0**	**13.4**	**1.6**	**723.4**	**16.5**	**4.6**
p05	614.3	12.9	1.2	652.6	15.1	3.4	614.3	12.9	1.2	670.9	15.5	3.7
p25	647.7	13.1	1.4	675.6	15.4	3.6	647.7	13.1	1.4	699.4	15.9	4.0
p50	673.2	13.4	1.5	710.9	15.9	4.0	673.2	13.4	1.5	724.3	16.5	4.5
p75	695.6	13.6	1.8	739.6	16.1	4.2	695.6	13.6	1.8	748.2	17.1	5.2
p95	733.1	13.9	2.1	800.0	16.3	4.3	733.1	13.9	2.1	782.6	17.6	5.7

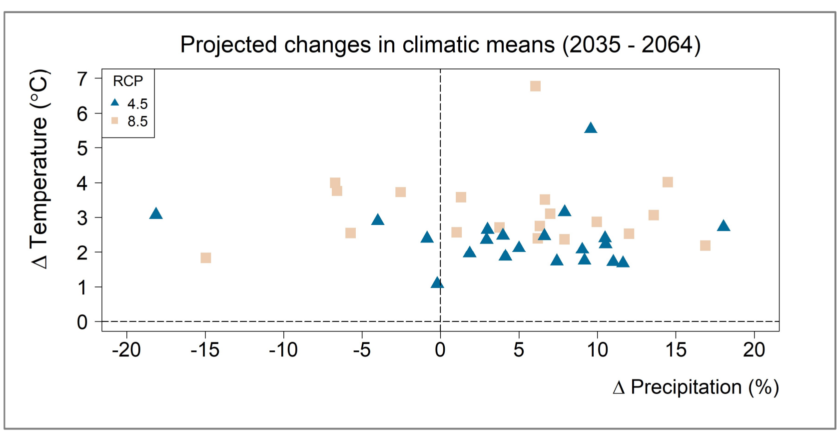


Figure 4. Projected changes in climatic means for the intermediate future (2050) for 21 GCM's under the RCP 4.5 and RCP 8.5.

2.2 Changes in climate extremes

More important to the CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) Road Project are foreseen changes in climatic extremes. Projections for changes in climate extremes have been constructed using the CLIMDEX Climate Extremes Indices (www.climdex.org), which are developed by the Expert Team on Climate Change Detection and Indices (ETCCDI). The 21 downscaled GCMs included in the NASA NEX-GDDP dataset have been used as input to construct the CLIMDEX Climate Extremes Indices. All 27 indices related to precipitation (11) and temperature (16) have been constructed using the GCM ensemble under the RCP 4.5 and RCP 8.5. For both RCPs, one GCM is omitted (ACCESS1-0) because it has projection values far out of the range of all other GCMs. The full results are presented in Annex 1; the most relevant projected changes in climate extremes are summarized below.

2.2.1 Precipitation extremes

The estimation of changes in precipitation extremes is done for events with return periods of 25, 50, and 100 years, where the latter two are used in the project's engineering design. This is done by analyzing the distribution of the percentual change (%) for each downscaled climate model for each of those return periods. Different percentiles of this distribution are considered (5th, 25th, 50th, 75th, 95th), besides the mean of the GCM ensemble, and separately for RCP 4.5 and RCP 8.5.

The analysis indicates that extreme precipitation events in the high tail of the GCM projections are expected to increase in intensity. According to the ensemble mean the annual daily maximum precipitation is expected to remain relatively stable under both the RCP 4.5 and RCP 8.5 at 1:100 years return period, but at the 75th percentile of the GCM ensemble an increase of 7.5 and 22.7% in annual daily maximum precipitation is expected under the RCP 4.5 and RCP 8.5 respectively (see Figure 5 and Table 2). At the 95th percentile, an increase up to 40% is expected. Considering the large uncertainty in climate modeling and large probability that outliers imply unreliable projections, the 75th percentile value is assumed to provide a robust estimate for sensitivity analysis of project components. For events with 1:50 years return period, the 75th percentile value of the ensemble projects an increase in maximum daily precipitation of 7.2% and 19.2% increase respectively. Therefore, it is advised to do sensitivity tests of project components designed to withstand events with return periods up to 1:50 years, with 20% increased daily precipitation input, and for project components designed for return periods up to 1:100 years with 23% increased daily precipitation input.

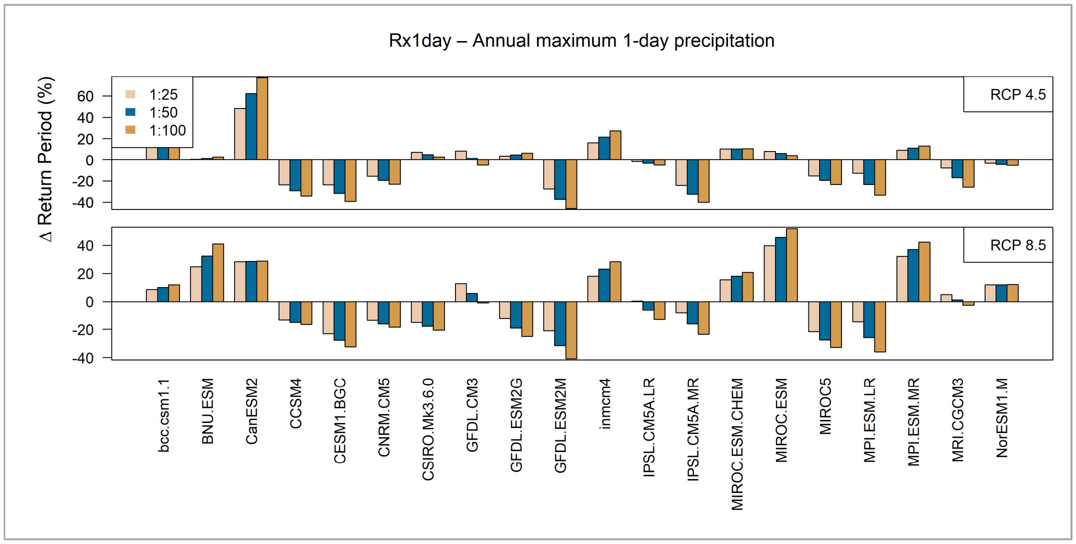


Figure 5. Projected change (%) in return periods of annual maximum 1-day precipitation for the intermediate future (2050) under the RCP 4.5 and RCP 8.5

Table 2. Projected change (%) in different return levels of maximum 1-day precipitation at different percentiles in the GCM model ensemble for RCP 4.5 and RCP 8.5

	Percentile in downscaled GCM ensemble				
RCP 4.5	5th	25th	50th	75th	95th
Δ 1:25 years return level	-24.4	-15.3	-0.6	8.5	22.7
Δ 1:50 years return level	-32.8	-20.5	-1.0	7.2	23.5
Δ 1:100 years return level	-40.5	-27.7	-5.0	7.5	29.9
RCP 8.5					
Δ 1:25 years return level	-22.0	-14.0	2.6	16.1	32.5
Δ 1:50 years return level	-28.0	-18.0	-2.6	19.2	37.4
Δ 1:100 years return level	-36.2	-23.9	-7.8	22.7	42.7

Analysis on annual maximum 5-day consecutive precipitation events show a similar trend (see Figure 6 and Table 3). On average the intensity of annual maximum 5-day consecutive precipitation is projected to remain quite stable under both the RCP 4.5 and RCP 8.5 (about 195 mm/5 days at 1:100 years return level), but in the high tail of the GCM projections the 5-day precipitation extremes are expected to increase in intensity. At the 75th percentile of the GCM ensemble an increase of about 15 – 20% in annual maximum 5-day consecutive precipitation is expected under the RCP 4.5 and RCP 8.5 respectively. At the 95th percentile an increase over 60% is expected at the 1:100 years return level under the RCP 4.5, but as Figure 6 shows this is the outcome of only two downscaled GCM's and therefore probably a less reliable projection.

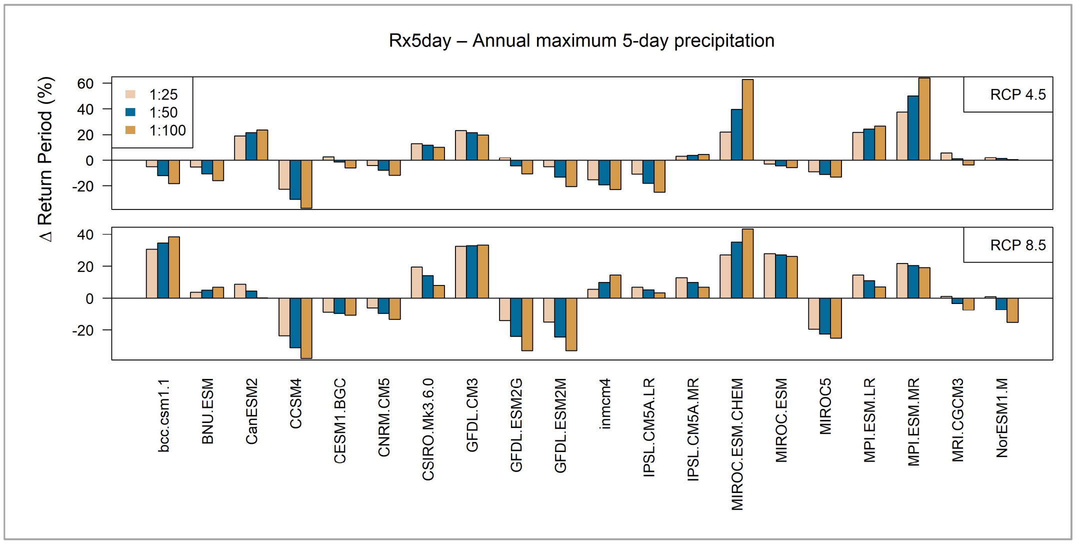


Figure 6. Projected change (%) in return periods of annual maximum 5-day precipitation for the intermediate future (2050) under the RCP 4.5 and RCP 8.5

Table 3. Projected change (%) in different return levels of maximum 5-day precipitation at different percentiles in the GCM model ensemble for RCP 4.5 and RCP 8.5

	Percentile in downscaled GCM ensemble				
RCP 4.5	5th	25th	50th	75th	95th
Δ 1:25 years return level	-15.7	-5.3	2.1	14.7	23.9
Δ 1:50 years return level	-19.8	-11.4	-3.0	14.3	40.1
Δ 1:100 years return level	-25.6	-16.5	-6.1	12.7	63.2
RCP 8.5					
Δ 1:25 years return level	-19.7	-6.7	6.2	20.1	30.7
Δ 1:50 years return level	-24.7	-9.7	5.1	15.7	34.5
Δ 1:100 years return level	-33.1	-13.9	5.2	15.6	38.6

Further, while an increase in extreme precipitation events is expected, the data also indicates that longer dry spells can be expected (see Figure 7 and Table 4). At the 75th percentile of the GCM multi-model ensemble, the number of annual consecutive dry days are projected to increase by about 15% under both the RCP 4.5 and RCP 8.5. At the 1:100 years return level the annual consecutive dry days are therefore expected to increase from 150 days to about 180 days per year. At the same time the number of consecutive wet days (with precipitation > 1 mm per day) are also expected to increase for the intermediate future, by 20% under the RCP 4.5 and 30% under the RCP 8.5 (see Figure 8 and Table 5). This implies that, at the 75th percentile of the 1:100 years return level, the average number of annual wet days are expected to increase from 20 days to 25 - 26 days for the intermediate future. Considering the projected changes in precipitation extremes, this suggest that both the intensity and duration of precipitation events are expected to increase in magnitude for the intermediate future.

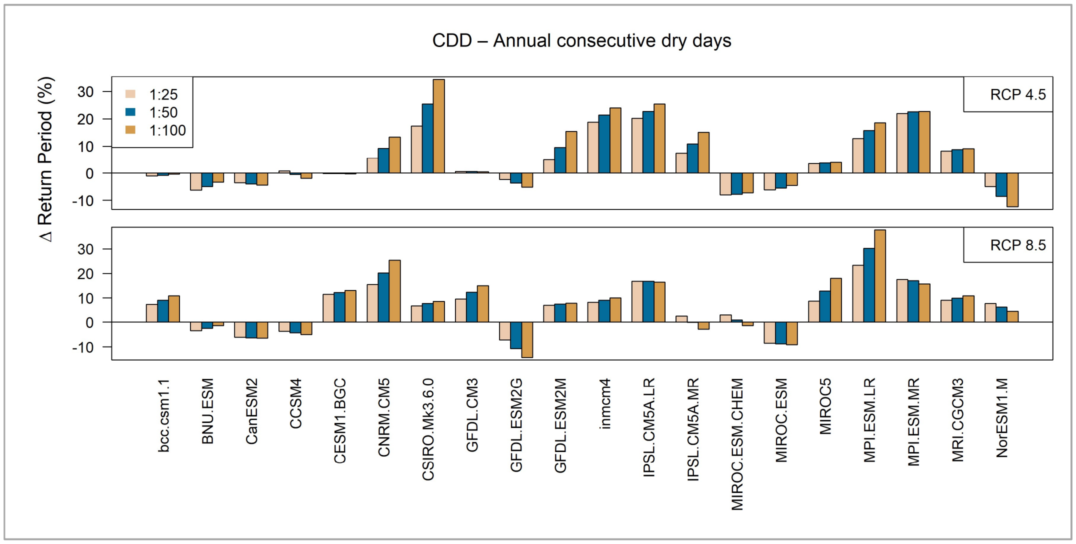


Figure 7. Projected change (%) in return periods of annual consecutive dry days for the intermediate future (2050) under the RCP 4.5 and RCP 8.5

Table 4. Projected change (%) in different return levels of annual consecutive dry days at different percentiles in the GCM model ensemble for RCP 4.5 and RCP 8.5

	Percentile in downscaled GCM ensemble				
RCP 4.5	5th	25th	50th	75th	95th
Δ 1:25 years return level	-6.4	-2.7	2.2	9.3	20.2
Δ 1:50 years return level	-7.8	-3.7	2.2	12.0	22.9
Δ 1:100 years return level	-7.5	-3.6	2.2	16.2	25.9
RCP 8.5					
Δ 1:25 years return level	-7.3	1.0	7.6	10.0	17.8
Δ 1:50 years return level	-8.9	-0.7	8.4	12.5	20.7
Δ 1:100 years return level	-9.3	-1.8	9.3	15.2	26.0

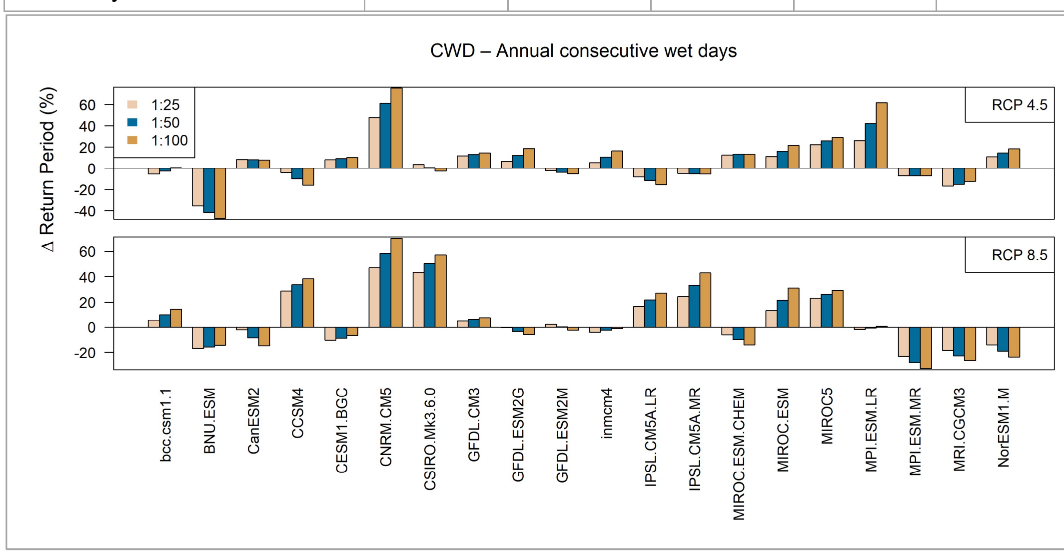


Figure 8. Projected change (%) in return periods of annual consecutive wet days for the intermediate future (2050) under the RCP 4.5 and RCP 8.5

Table 5. Projected change (%) in different return levels of annual consecutive wet days at different percentiles in the GCM model ensemble for RCP 4.5 and RCP 8.5

RCP 4.5	Percentile in downscaled GCM ensemble				
	5th	25th	50th	75th	95th
Δ 1:25 years return level	-17.8	-5.0	6.1	11.3	27.2
Δ 1:50 years return level	-16.4	-5.6	8.8	13.6	43.1
Δ 1:100 years return level	-17.4	-5.8	9.2	18.5	62.4
RCP 8.5					
Δ 1:25 years return level	-18.6	-7.1	1.0	18.2	43.8
Δ 1:50 years return level	-22.9	-8.9	-0.3	22.8	50.8
Δ 1:100 years return level	-26.9	-14.1	-0.3	29.7	57.9

2.2.2 Temperature extremes

Analysis on temperature extremes indicates that minimum and maximum temperatures are both expected to significantly increase under the RCP 4.5 and RCP 8.5. At the 75th percentile of the 1:100 years return level, the annual maximum of daily maximum temperature (i.e. highest yearly temperature) is projected to increase by 2.3 °C under the RCP 4.5 and by 3.9 °C under the RCP 8.5 (see Figure 9 and Table 6). Similarly, the annual minimum of daily minimum temperature (i.e. lowest yearly temperature) is expected to increase at the 75th percentile by 4.6 °C under the RCP 4.5 and by 5.0 °C under the RCP 8.5 (see Figure 10 and Table 7).

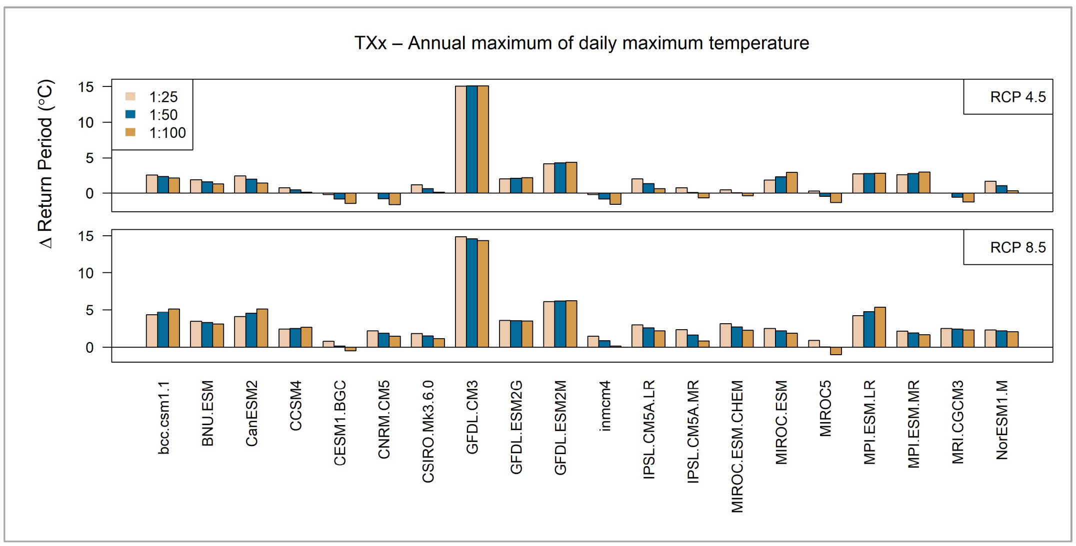


Figure 9. Projected change (°C) in return periods of annual maximum of daily maximum temperature for the intermediate future (2050) under the RCP 4.5 and RCP 8.5

Table 6. Projected change (°C) in return levels of annual maximum of daily maximum temperature at different percentiles in the GCM model ensemble for RCP 4.5 and RCP 8.5

RCP 4.5	Percentile in downscaled GCM ensemble				
	5th	25th	50th	75th	95th
Δ 1:25 years return level	-0.2	0.4	1.7	2.4	4.7
Δ 1:50 years return level	-0.8	-0.1	1.2	2.3	4.8
Δ 1:100 years return level	-1.6	-0.8	0.5	2.3	4.9

RCP 8.5					
Δ 1:25 years return level	0.9	2.1	2.5	3.7	6.6
Δ 1:50 years return level	0.2	1.8	2.4	3.8	6.6
Δ 1:100 years return level	-0.5	1.4	2.2	3.9	6.7

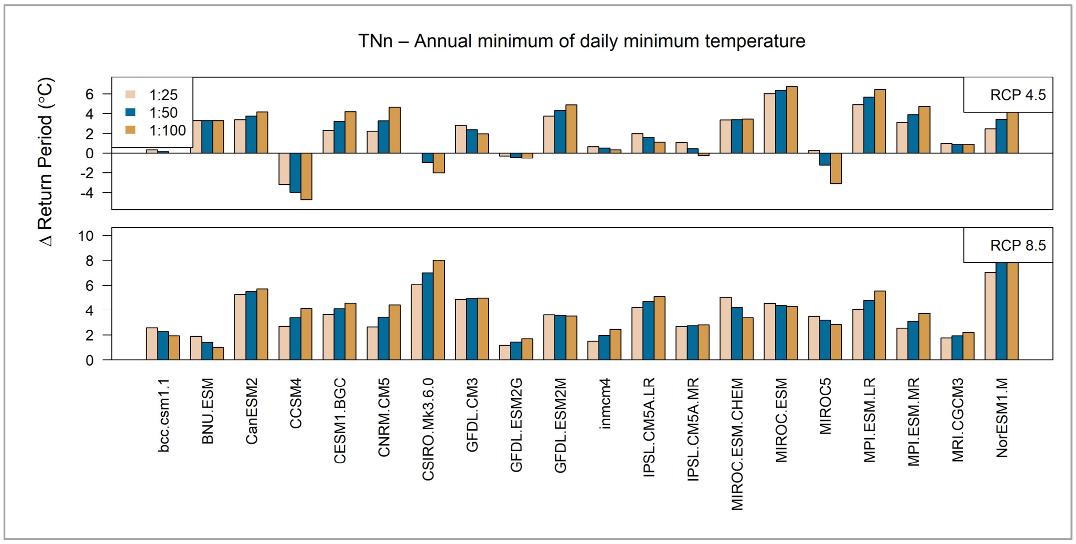


Figure 10. Projected change (°C) in return periods of annual minimum of daily minimum temperature for the intermediate future (2050) under the RCP 4.5 and RCP 8.5.

Table 7. Projected change (°C) in return levels of annual minimum of daily minimum temperature at different percentiles in the GCM model ensemble for RCP 4.5 and RCP 8.5

RCP 4.5	Percentile in downscaled GCM ensemble				
	5th	25th	50th	75th	95th
Δ 1:25 years return level	-0.5	0.6	2.3	3.3	5.0
Δ 1:50 years return level	-1.4	0.4	2.8	3.5	5.7
Δ 1:100 years return level	-3.2	-0.1	2.6	4.6	6.5
RCP 8.5					
Δ 1:25 years return level	1.5	2.6	3.5	4.6	6.1
Δ 1:50 years return level	1.4	2.6	3.5	4.7	7.1
Δ 1:100 years return level	1.7	2.7	3.9	5.0	8.1

Further, while a substantial increase in air temperatures is expected according to the GCM multi-model ensemble, the data also indicates that significant more summer days (daily maximum temperature > 25 °C) and significant fewer icing days (daily maximum temperature < 0 °C) are expected for the intermediate future compared to the reference period. At the 75th percentile of the 1:100 years return level, the number of annual summer days are expected are projected to increase by 30% under the RCP 4.5 and by 45% under the RCP 8.5 (see Figure 11 and Table 8).

Similarly, but conversely, at the 75th percentile of the 1:100 years return level, the average number of annual icing days are expected to decrease also by about 30% to 45%, from about 75 days to 50 days under the RCP 4.5 and 40 days under the RCP 8.5 (Figure 12 and Table 9). In short, analysis on the GCM multi-model ensemble using the CLIMDEX Climate Extremes Indices indicate that all temperature extremes change to the warmer side.

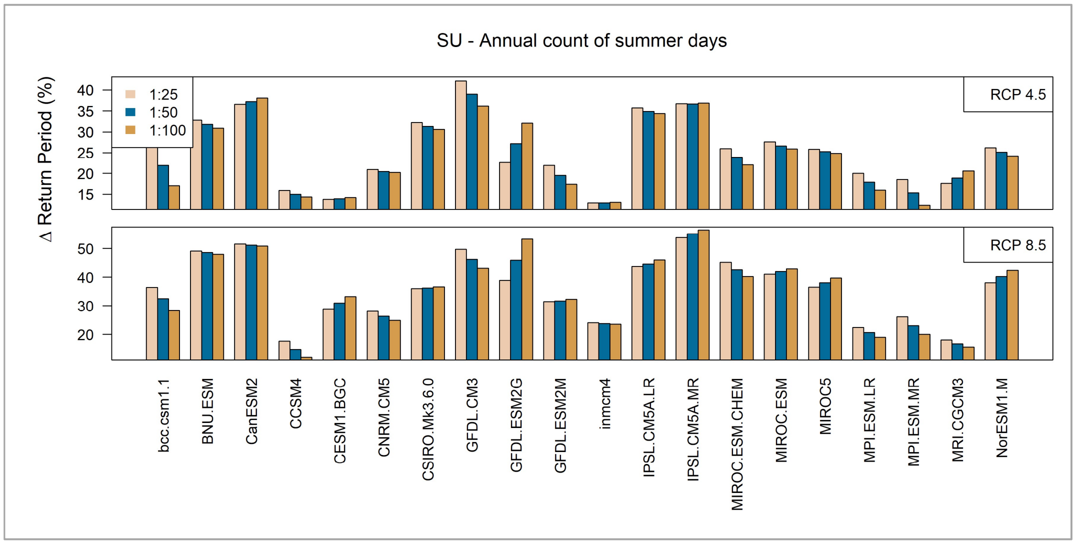


Figure 11. Projected change (%) in return periods of annual count of days where daily maximum temperature exceeds 25 °C (summer days) for the intermediate future (2050) under the RCP 4.5 and RCP 8.5.

Table 8. Projected change (%) in return levels of annual summer days (°C > 25) in the GCM model ensemble for RCP 4.5 and RCP 8.5

RCP 4.5	Percentile in downscaled GCM ensemble				
	5^{th}	25^{th}	50^{th}	75^{th}	95^{th}
Δ 1:25 years return level	13.7	19.7	25.9	32.4	37.0
Δ 1:50 years return level	13.8	18.6	24.5	31.4	37.3
Δ 1:100 years return level	13.0	16.8	23.2	31.2	36.9
RCP 8.5					
Δ 1:25 years return level	18.1	27.6	36.4	44.1	51.7
Δ 1:50 years return level	16.7	25.7	37.1	44.9	51.4
Δ 1:100 years return level	15.4	24.6	38.2	43.9	53.5

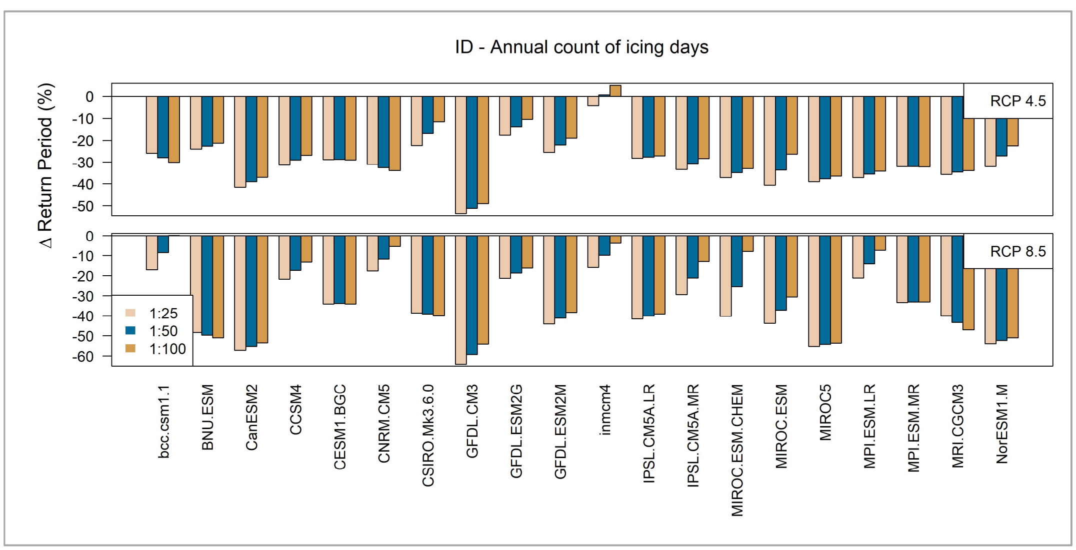


Figure 12. Projected change (%) in return periods of annual count of days where daily maximum temperature is below 0 °C (icing days) for the intermediate future (2050) under the RCP 4.5 and RCP 8.5

Table 9. Projected change (%) in return levels of annual icing days (°C < 0) in the GCM model ensemble for RCP 4.5 and RCP 8.5

RCP 4.5	Percentile in downscaled GCM ensemble				
	5th	25th	50th	75th	95th
Δ 1:25 years return level	-16.9	-25.7	-31.6	-37.1	-42.2
Δ 1:50 years return level	-13.1	-26.0	-29.8	-34.6	-39.6
Δ 1:100 years return level	-9.6	-22.2	-28.7	-33.9	-37.5
RCP 8.5					
Δ 1:25 years return level	-17.0	-21.6	-39.3	-45.2	-57.5
Δ 1:50 years return level	-9.8	-18.3	-35.5	-44.9	-55.4
Δ 1:100 years return level	-3.6	-11.7	-33.5	-48.0	-53.6

3 Climate Risks and Vulnerabilities

The transport infrastructure in Tajikistan is vulnerable to projected changes in climate variables. Foreseen changes in air temperature, precipitation, and associated extreme weather events can result in the following impacts on the project road (ADB 2011):

Table 10. Potential impacts of climate change on road infrastructure (ADB 2011)

Projected climate change	Impacts on Road Transport Infrastructure
Increases in hot days and heat waves	• Deterioration of pavement integrity, such as softening, traffic-related rutting, and migration of liquid asphalt due to increase in temperature • Thermal expansion of bridge expansion joints and paved surfaces
Increases in temperature in very cold areas	• Changes in road subsidence and weakening of bridge supports due to thawing of permafrost • Reduced ice loading on structures such as bridges
Later onset of seasonal freeze and earlier onset of seasonal thaw	• Deterioration of pavement due to increase in freeze–thaw conditions
Increase in intense precipitation events	• Damage to roads, subterranean tunnels, and drainage systems due to flooding • Increase in scouring of roads, bridges, and support structures • Damage to road infrastructure due to landslides • Overloading of drainage systems • Deterioration of structural integrity of roads, bridges, and tunnels due to increase in soil moisture levels
Increases in drought conditions	• Damage to infrastructure due to increased susceptibility to wildfires • Damage to infrastructure from mudslides in areas deforested by wildfires

Figure 13. Examples of damage to infrastructure in Tajikistan. Damaged road and bridge in Varzob District due to flooding and landslides after heavy rainfall. (Adapted from: ADRC country report, 2006)

Tajikistan is prone to many types of natural hazards, including floods, mudflows, landslides (mudslides), droughts (wildfires), earthquakes, snow avalanches, and wind storm. About 93% of the country's area are mountainous, which widely vary in height from several hundred meters to 6000-7000 meters above sea level. The new project road alignment will pass through a severely rugged terrain and crosses numerous water courses, gullies, and erosion cuts. Figure 14 shows the hazard level for (a selection of) natural hazards relevant to the CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) project road.

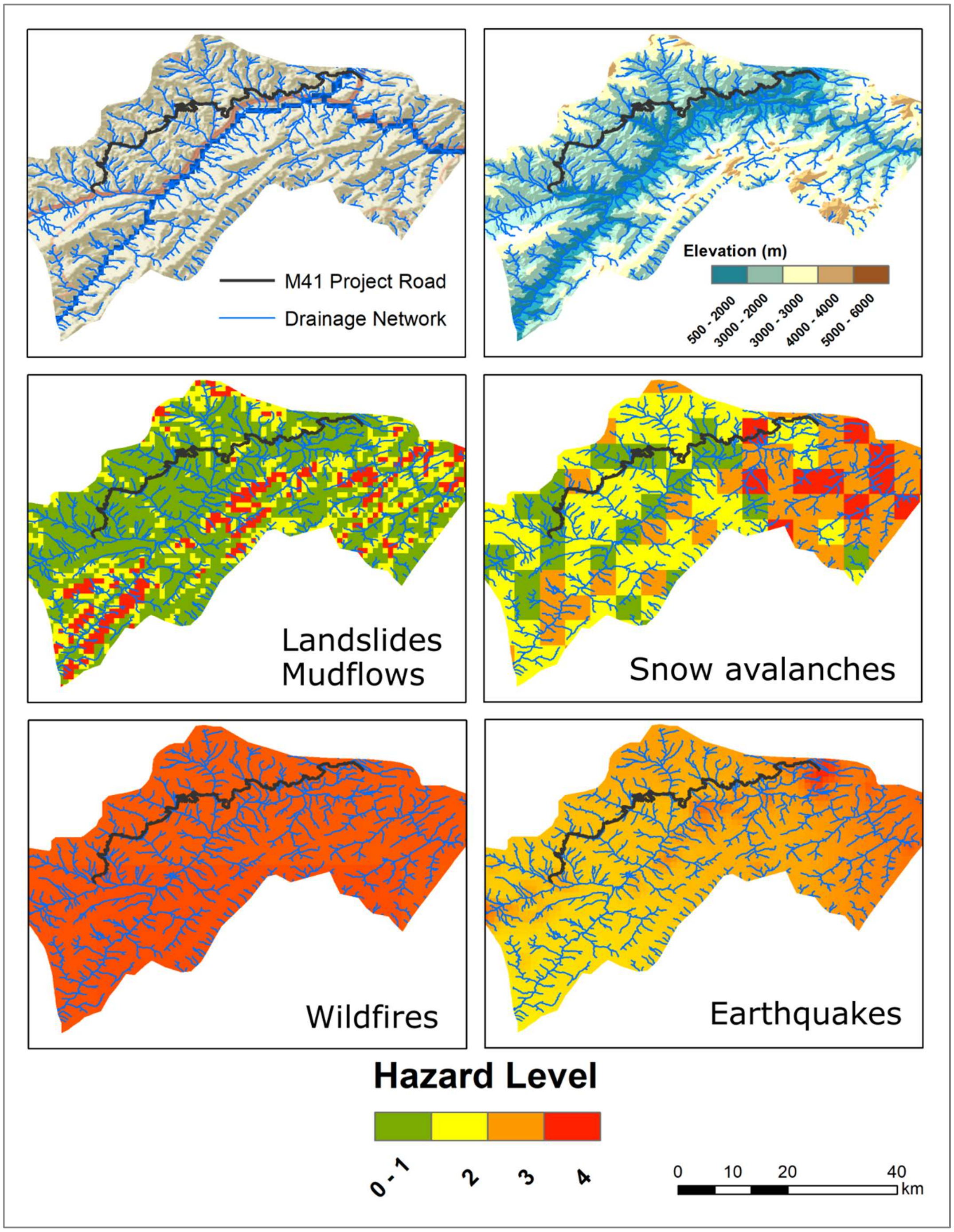


Figure 14. Current natural hazard risks in the project area (source: https://www.geonode-gfdrrlab.org/)

3.1 Flooding and Inundation

Considering the dynamics of the water courses relevant to the project road, two periods are clearly distinguished in the annual water flow: spring-summer high water and autumn-winter low water. The difference in the regime of the rivers is in the predominance of the feed source. The water courses intersected by the road, according to the type of feed, belong to the snow-rain type, characteristic of low-mountain peripheral regions (Avtostrada 2017, 2018). The projected increase in extreme precipitation events increases the potential risk of flooding or inundation of road infrastructure, e.g. due to overloading of drainage systems. The projected increase in intensity of extreme precipitation events implies that this risk increases in the future.

3.2 Mudflow and Landslide

In the mountainous and foothill regions of the project road, mudflows are widespread and dangerous for their unpredictability and lack of methods for calculating glacial mudflows that are formed during the melting of glaciers. Active physical weathering, sparse vegetation, intense rainfall activity and significant snow reserves contribute to the formation of high flow maxima with solid content, causing a descent of mudflows. The highest annual discharges of water courses intersected by the road are in April-May due to heavy rainfall which, as a rule, are characterized by frequent short-term destructive mudflows (Avtostrada 2017, 2018). Since the new project road alignment passes through similar land form and geological characteristics as the existing road, it can reasonably be assumed that the projected increase in extreme precipitation events may increase the risk of mudflows. Potential later onset of seasonal freeze and earlier onset of seasonal thaw may lead to an increase in freeze–thaw conditions which could increase the risk and of slope instability and occurrence of landslides and/or rockfall due to weathering effects.

3.3 Snow avalanche

The major reason of avalanches in Tajikistan is fresh snow formation. Large amounts of fresh snow not yet consolidated, are likely to be set in motion. In addition, the interface between fresh and old snow is rather unstable and tends to create sliding planes. Most avalanches in Tajikistan are observed in February and March (ADRC, 2006). Projected increases in extreme precipitation events during cold weather conditions could result in extreme snowfall events which may lead to avalanching, especially if combined with warm spells, which are likely to increase under the projected climate change scenarios. The occurrence of heavy snow and avalanches will likely increase considering the projections of increases in extreme precipitation and higher minimum daily temperatures.

3.4 Heatwave, Drought, Wildfire

The substantial projected increase in air temperatures as well as annual number of days where daily maximum temperature exceeds 25 °C, indicates that heat waves are more likely to occur and may last longer. This poses potential increased risks related to asphalt pavement integrity and thermal expansion of bridge expansion joints and paved surfaces. The current hazard level for wildfire in the project area is medium to high, but since the project road passes largely through locations that are not heavily forested the risk to the project road is relatively minor. Nonetheless, wildfires may occur in the project area more frequently due to the projected increase in annual consecutive dry days. This may lead to increased drought conditions which could result in an increased risk for wildfires. The risk of mudflows may also increase as their occurrence can be linked to deforestation by wildfire and increasing precipitation extremes.

3.5 Mountain permafrost

Thawing of mountain permafrost and glacial melt does not pose direct risks to the project road for the intermediate future, as permafrost is not very likely to be present in the subsoil in close proximity to the new project road alignment (see Figure 15).

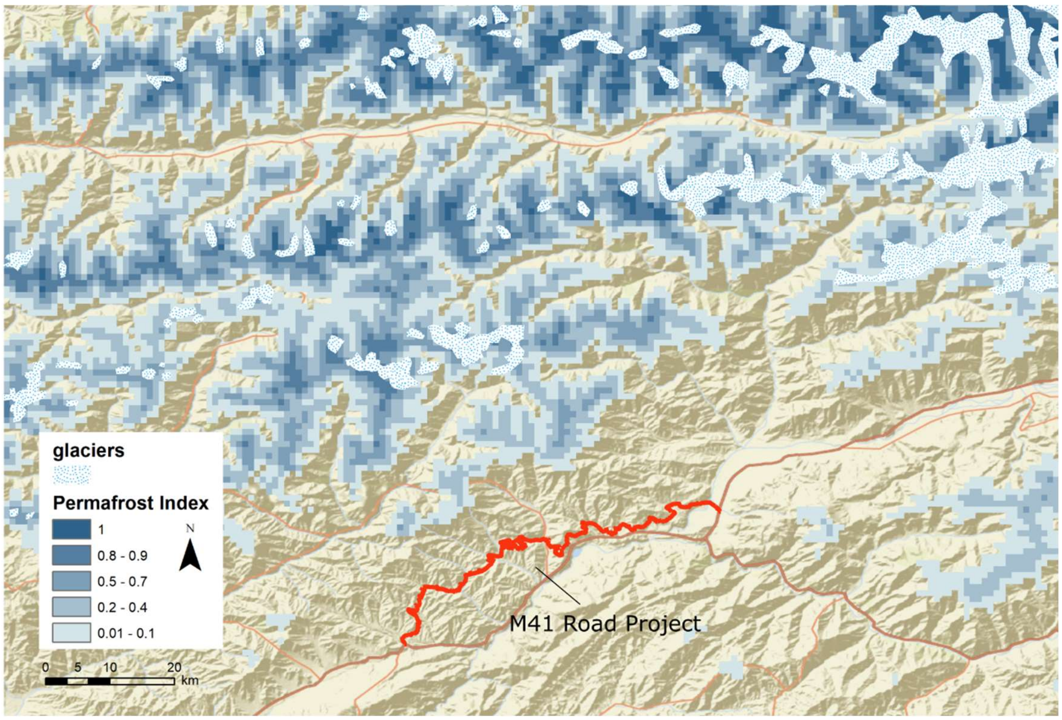


Figure 15. Permafrost Zonation Index (PZI) indicating to what degree permafrost is likely present in the project area (Gruber (2012).

3.6 Vulnerable components in the design

Considering the type of climate hazards and risks in the project area, and the area-specific climate change projections, the most serious threat comes from the expected increase in extreme precipitation events. This may not only lead to higher extreme discharges (i.e. flash floods) but can also lead to more frequent and more powerful mudflows, landslides, and avalanches. These may pose additional risk for bridge foundations and drainage systems (i.e. culverts) by discharge levels and solid loads exceeding the systems' design capacity. Similarly, an increase in extreme snowfall events may lead to an increase in the frequency of avalanches. Increases in precipitation extremes is also likely to increase the frequency of landslides and rockfall, making any road stretches close to steep terrain vulnerable.

4 Current Design under Climate Change

4.1 Bridges

4.1.1 Precipitation extremes

For bridges generally, the projected increases in intensity of extreme precipitation events poses the most serious risk. In the current engineering design (Avtostrada 2017, 2018), the design specifications of bridges are based on discharge events with 1:100 year return periods, which are calculated using empirical formulas. These formulas are based on historical discharge records on the daily maximum precipitation records over many years, taken from local metrological stations in the project area.

Based on the climate model analysis, the increase in annual maximum daily precipitation would likely be around 20% (section 2.2.1). To assess the exact changes in projected discharge levels at this return period, hydrological modelling is required. Taking into account a long-term increase of 20% in the daily maximum of liquid precipitation, a recalculation was done by the project design consultant team for 1:100 years discharge events that are expected for bridges included in the project road design. Table 11 shows the expected changes in liquid runoff ($Q_{1\%}$), design high water level ($DHWL_{1\%}$) and average flow velocity (V_{cp}) of such discharge events at the bridge sections due to increased precipitation by 20%.

Table 11. Comparison of discharge flow characteristics at the bridge sections due to increased precipitation by 20%

№ of bridge	ПК	$Q_{1\%}$, м³/с		$DHWL_{1\%}$		$V_{cp.}$, м/с	
		Current	20% increase	Current	20% increase	Current	20% increase
1	77+60	106	131	1737,05	1736,26	3,70	3,99
2	130+97	173	204	1823,28	1823,44	3,70	3,93
3	135+50	74,3	92,2	1804,13	1804,33	3,55	3,82
4	209+04	121	148	1697,77	1697,98	3,99	4,27
5	266+93	251	283	1414,46	1414,69	4,22	4,38
6	283+62	284	341	bottom+3,06	bottom+3,39	4,72	5,01
7*	331+17	58,6	72,6	1535,28	1535,44	2,88	3,10
8*	360+00	422	453	1330,13	1330,21	2,75	2,82

*Note: Bridge 7 and 8 are not included in the ADB Contract.

Most importantly, the recalculations of Table 11 shows that flow rates of extreme discharge events can increase up to 30% because of increases in precipitation extremes. However, since the bridges are designed to have a deep pile foundation and will be elevated high above the stream bed (due to the rugged terrain characteristics), it is reasonable to assume that the bridges will be able to accommodate the projected increase in liquid flow rates of 1:100 years extreme discharge events.

Further, the project design consultant team also reports that the bridges are not expected to be affected by potential greater solid discharge loads (i.e. mudflows) that could occur due to an increase in extreme precipitation events. The channels and/or streambeds under the bridges are designed to withstand intense scouring by both liquid and solid flow, using large-sized stone and concrete filling of voids. Bridge abutments are protected by stone pitching from abutment walls to stream slopes. Potential negative impact of higher flows is also avoided by the absence of bridge support structures (i.e. intermediate piers) in the river channel

It is concluded that current bridge design can handle the foreseen increase in extreme precipitation events, but the bridge components most vulnerable to higher extreme discharges and increases in solid loads are the riverbed near bridges and bridge foundation pile caps. Regular inspection to check their condition is strongly recommended as is their maintenance when required. Heavier scour protection works (larger size boulders and/or thicker rock mortar layer) may potentially be required if structural deterioration of these bridge components is observed.

4.1.2 Temperature extremes

The projected increases in temperature extremes poses additional risks to the design of bridge components and requires examining its design specifications.

4.1.2.1 Bridge expansion joints

Higher temperature extremes are foreseen for the project area which may require a greater range of movement to be built into the bridge expansion joints. However, this is not considered necessary by project design consultant team as (i) the current operating temperatures of the expansion joints at the project site are well within the normal operating limits of the proposed expansion joint material specified and (ii) the design of the bridge expansion joints allows for movement well in excess of what has been calculated. Hence the margin allowed is considered sufficient to cover any anticipated increases in air temperature. In short, increasing temperature extremes are not considered to be an issue within the normal functional life of the bridge expansion joints. Potential risks can be mitigated by adequate and timely maintenance to replace expansion joints at an appropriate time.

4.1.2.2 Bridge bearings

The project design consultant team indicates that the bearings specified for the project road have enough margin for the anticipated increase in temperature extremes. It should be noted that the current existing temperatures near the project site are well within the performance specifications of the proposed bearings even considering possible increase in air temperature, and hence no change is required. Therefore, it is expected that there are no additional costs needed to account for climate change impacts. However, it is important that towards the end of the lifetime of the bearings, procedures and funds need to be in place to replace these bearings.

4.2 Drainage systems

Similarly to bridges, the projected increases in intensity of extreme precipitation events poses the most serious risk to the drainage systems, which need to have sufficient capacity to cope with increased amounts of water.

4.2.1 Culverts

For culverts the current design criteria are based on extreme discharge events with a return period of 1:50 years. As is the case for bridges, the 1:50 years return levels are based on historical data and do therefore not consider the possibility of future changes in the severity of 1:50 years events (or the higher frequency of events with 1:50 years return period under the present climate). Based on the climate model analysis, the increase in the annual maximum daily precipitation would likely be about 20% (section 2.2.1).

The project design consultant team recalculated the flow characteristics of 1:50 years discharge events for drainage culverts under the assumption of an 20% increase in daily maximum precipitation (see Table 38, appendix 2). The recalculation indicates that the capacity of the culverts is well in excess of any potential climate change induced increased flow, whether it be precipitation, mudflows, or avalanche. For example, at the median for all culverts the reserve in drainage capacity is over 2000%, meaning that the culverts included in the project road design can typically handle extreme discharge events that are 20 times larger than currently foreseen by the 20% increase in daily maximum precipitation. The culverts have been designed to cater for mudflows and for medium to large boulders to be carried down the streams.

The recalculation shows that a 20% precipitation increase can lead up to a 40% increase of liquid flow rate of 1:50 years discharge event in the culverts. What poses the most serious risk to the structural integrity of the culverts is the subsequent increase in flow velocity, which increases the risk of erosion at the outlet apron and outlet channel. If the culvert outlet protection works fails and the channel starts to erode, the culvert may fail. Regular inspections and careful maintenance of these structures are therefore recommended but a reconsideration of the type of material used for the construction of inlet and outlet works may also be required. The current stone mortar slabs or channel protection works may need to be replaced by reinforced concrete and downstream channel protection works may need to be increased in both size and length.

4.2.2 Roadside ditches

Roadside drains are generally designed for a 1:10 year return period. An increase in maximum daily precipitation and possible rainfall intensity may have an impact on the capacity of the side drains to handle the increased volume. This will depend on the slopes (grades) of the road, the surface runoff from adjacent land and the length of drain. The project design consultant team recalculated the capacity of the roadside ditches based on a 20% flow rate increase (see Table 39, appendix 2). The recalculations show that for 3 out of the nearly 100 considered roadside ditches the capacity may be exceeded if daily extreme precipitation levels increase by 20% (These sections are highlighted in brown in Table 39). Further, there are four drains that are reaching capacity under these conditions. These sections are highlighted in yellow in Table 39.

Based on the design assessment provided above, project design consultant team proposes to not make any modifications to the side drainage design at this stage. It is recommended to review the mentioned sections of roadside ditches and estimate the cost-effectiveness of upgrading these to higher capacity.

4.3 Mass movement protection and retaining walls

Most of the new project road alignment keeps some distance from the steeper slopes and mountains and there are only a few areas along the alignment that have been subject to mudslides or large landslides in the past. The design of the bridges has considered historical maximum landslides, and associated debris. Given the height of the bridge decking above the stream bed and a clear passage under the bridges, the foreseen increases in the frequency and magnitude of the mudflows are not expected to exceed the system’s design capacity.

It is reported by the project design consultant team that the reserve capacity of the culverts to handle increased flow, including mudflows, ensures that this type of hazard will not pose a risk to the culverts. The stability of the slopes has been investigated in an extensive geotechnical study and the new road alignment avoids the most vulnerable sites and otherwise proposes retaining structures in the design. Due to a potential increase in frequency of rockfall and slides, these structures may require higher maintenance than currently anticipated. The project design consultant team indicates that adequate measures have been included in the project design to protect avalanche-, landslide- and mudflow-prone areas along the new road alignment to these events. Based on the mentioned geotechnical study, batter slopes were designed accordingly to remove the risk of landslides at the most vulnerable sites and appropriate retaining structures were included in the design. While potential increased weathering of slopes may increase the risk of slope instability, the design of retaining structures (taking also into account seismic loading) are appropriately dimensioned to provide safety to avalanche-, landslide- and mudflow-prone areas. Risk mitigation against these natural hazards, however, may require more focus on routine inspections and timely road maintenance.

4.4 Road pavement

Deterioration of pavement integrity, such as softening, and traffic-related rutting could accelerate due to foreseen increases in air temperature in the region. These projected increases are being flagged where maximum daily temperature exceeds 25 °C and the project area would meet this criterion albeit only for short periods through the year. However, it is reported by the project design consultant team that the foreseen temperature increases are still well within the range of the operational temperature range of the asphalt. The potential impact of temperature increases on the asphalt (if any) is that the life of the pavement surfacing could be shorter and overlay work would possibly need to be planned at a shorter interval (periodic maintenance). More routine maintenance may also be required.

The project road plans to use stone mastic asphalt (SMA) as the wearing course and its operational range will not be exceeded by the foreseen increase of air temperatures. SMA is more thermo-stable than classic asphalt mixtures due to use of polymer-modified bitumen (increased resistance to permanent deformation), presence of cellulose and mineralized fibers (creating a bituminous gel which does not bleed) and discontinuous grading curve (resulting in better locking of the aggregate). SMA was created as alternative to classic asphalt mixtures exactly to prevent deformations due to exposure to higher temperatures. Therefore, it is considered that the stone mastic asphalt used for the wearing course on the project road will be as resilient to the increased temperatures likely to be experienced. No adjustment is required, but as indicated above, routine maintenance must be implemented. The climate change risk will need to be addressed by adequate scheduled routine maintenance, and timely periodic maintenance. As stated by the designers, the critical issue is the allocation of adequate funds for the maintenance, and not amendments to the design.

5 Conclusions and Recommendations

The present Climate Risk and Vulnerability Assessment (CRVA) reviewed the current project design documents under the proposed CAREC corridors 2, 3, and 5 (Obigarm–Nurobod) Road Project in Tajikistan, in the context of expected climate change for the area around 2050. The analysis was done based on the NASA-NEX ensemble of downscaled General Circulation Models (GCMs). The consideration based on the full ensemble for a medium stabilization scenario (RCP4.5) and a business as usual scenario (RCP8.5) allows for inclusion of the uncertainty in future climate in the assessment. The climate model analysis yields following conclusions for the project area:

- Temperature increases by about 2.4 °C (RCP4.5) to 3.1 °C (RCP8.5) are to be expected.
- Minimum and maximum temperature are likely to change inconsistently, with maximum air temperatures increasing more than minimum air temperatures.
- Extremes related to temperatures (e.g. warm spells, extremely warm days) are likely to increase in frequency and intensity.
- Precipitation totals are likely to increase slightly but a large spread in precipitation projections has to be noted.
- Precipitation extremes are likely to increase in frequency and intensity. For example, maximum 1-day precipitation volumes with return periods of 50 and 100 years are expected to increase by about 20% according to the 75th percentile values in the distribution of change projections of the entire climate model ensemble.

The increase in extreme precipitation events is considered as the most important climate risk for the project road. This not only leads to higher extreme discharge events but can also lead to more frequent and more powerful mudflows, landslides, and/or avalanches. The increase in temperature can pose additional loadings from thermal expansion to bridge joints and bearings as well as the road pavement asphalt, but it is unlikely that these would be significant.

The project design consultant team recalculated the expected flow characteristics for bridge sections for 1:100 years discharge events using a foreseen 20% increase in daily maximum precipitation. The recalculations reveal that bridges have sufficient capacity in the current design to cope with higher discharge levels in the future, although it would be prudent to check the bridge substructure designs to withstand higher flow velocities and increased debris content in the flow. Heavier scour protection works may be required if structural deterioration of bridge components is observed.

The project design consultant team similarly recalculated the expected flow characteristics for culvert and roadside drains, but now for 1:50 years discharge events considering a 20% precipitation increase. The recalculations reveal that the drainage capacity of the culverts is well in excess of foreseen increases in flow, whether it be precipitation, mudflow, or avalanche. However, the structural integrity of the culverts may be at risk due to subsequent increases in the flow velocity, which increases the risk of erosion at the outlet apron and outlet channel. Regular inspections and careful maintenance of these structures are therefore recommended, which may include a reconsideration of the material used for its construction.

The recalculations show that for 3 out of the nearly 100 considered roadside ditches the capacity may be exceeded if daily extreme precipitation levels increase by 20, and there are four drains that are reaching capacity under these conditions. It is recommended to review the design of these sections and check the cost-effectiveness of upgrading these sections to higher capacity.

For areas that may be subject to landslides, rockfalls and avalanches (which are likely to increase under climate change), it is recommended to revisit and confirm where appropriate the adequacy of retaining walls and protection structures for road sections near steep terrain or terrain that is already prone to these hazards.

This CRVA relies on climate model projections and therefore is prone to uncertainties. The downscaled climate models used in this study have a spatial resolution of about 25 km, whereas climate change signals may vary strongly over short distances, in particular in mountainous terrain. There is often also a large spread in the climate model projections. Therefore the full ensemble of models has been analyzed and the uncertainty range is displayed in all figures in this report.

6 References

ADB (2011). Guidelines for climate proofing investment in the transport sector: Road infrastructure projects

ADB (2014a). Midterm Review of Strategy 2020: Meeting the Challenges of a Transforming Asia and Pacific

ADB (2014b). Climate Risk Management in ADB Projects

ADB (2017a). Climate Change Operational Framework 2017-2030 - Enhanced Actions for Low Greenhouse Gas Emissions and Climate-resilient Development

ADRC. (2006). Tajikistan. Country Report. Asian Disaster Reduction Center.

Avtostrada (2017). Vahdat-Rasht-Jirgatal Kyrgyzstan Border Road (From km 72 to km 158). Stage I Hydrological Report 16-16-EGE. Dushanbe.

Avtostrada (2018). Vahdat-Rasht-Jirgatal Kyrgyzstan Border Road (From km 72 to km 158). Stage II Hydrological Report 16-16-EGE. Dushanbe

Gruber, S. (2012). Derivation and analysis of a high-resolution estimate of global permafrost zonation, *The Cryosphere*, 6, 221-233.

OSCE Technical Report. Natural Hazards in Tajikistan

UNDP (2018) Flood disaster risk reduction manual for Tajikistan. Part 1: Flood Management Guideline

Appendix 1: Climate Model Analyses

6.1 NASA-NEX-GDDP Projections of Future Climate

Table 12. GCMs included in the NASA-NEX-GDDP dataset

Model	Research centre	Country	Resolution (Original)		Resolution (NASA-NEX)	
			Lat (°)	Lon (°)	Lat (°)	Lon (°)
ACCESS1-0	BCC	Australia	1.25	1.88	0.25	0.25
BCC-CSM1-1	GCESS	China	2.79	2.81	0.25	0.25
BNU-ESM	NSF-DOE-NCAR	China	2.79	2.81	0.25	0.25
CanESM2	LASG-CESS	Canada	2.79	2.81	0.25	0.25
CCSM4	NSF-DOE-NCAR	USA	0.94	1.25	0.25	0.25
CESM1-BGC	NSF-DOE-NCAR	USA	0.94	1.25	0.25	0.25
CNRM-CM5	CSIRO-QCCCE	France	1.40	1.41	0.25	0.25
CSIRO-MK3-6-0	CCCma	Australia	1.87	1.88	0.25	0.25
GFDL-CM3	NOAAGFDL	USA	2.00	2.50	0.25	0.25
GFDL-ESM2G	NOAAGFDL	USA	2.02	2.00	0.25	0.25
GFDL-ESM2M	NOAAGFDL	USA	2.02	2.50	0.25	0.25
INMCM4	IPSL	Russia	1.50	2.00	0.25	0.25
IPSL-CM5A-LR	IPSL	France	1.89	3.75	0.25	0.25
IPSL-CM5A-MR	MIROC	France	1.27	2.50	0.25	0.25
MIROC5	MPI-M	Japan	1.40	1.41	0.25	0.25
MIROC-ESM	MIROC	Japan	2.79	2.81	0.25	0.25
MIROC-ESM-CHEM	MIROC	Japan	2.79	2.81	0.25	0.25
MPI-ESM-LR	MPI-M	Germany	1.87	1.88	0.25	0.25
MPI-ESM-MR	MRI	Germany	1.87	1.88	0.25	0.25
MRI-CGCM3	NICAM	Japan	1.12	1.13	0.25	0.25
NorESM1-M	NorESM1-M	Norway	1.89	2.50	0.25	0.25

The NASA-NEX-GDDP Projections are evaluated at the following time horizons:

- Reference period : 1976 – 2005
- Intermediate future (2050) : 2035 – 2064

Table 13. Average and range of climate projections for the intermediate future for the ensemble of 21 GCM under RCP 4.5 and RCP 8.5.

GCM ensemble	RCP 4.5 1976 - 2005			RCP 4.5 2035-2064			RCP 8.5 1976 - 2005			RCP 8.5 2035-2064		
	pr	Tmax	Tmin	pr	Tmax	Tmin	pr	Tmax	Tmin	pr	Tmax	Tmin
Mean	674.0	13.4	1.6	715.0	15.8	3.9	674.0	13.4	1.6	723.4	16.5	4.6
p05	614.3	12.9	1.2	652.6	15.1	3.4	614.3	12.9	1.2	670.9	15.5	3.7
p25	647.7	13.1	1.4	675.6	15.4	3.6	647.7	13.1	1.4	699.4	15.9	4.0
p50	673.2	13.4	1.5	710.9	15.9	4.0	673.2	13.4	1.5	724.3	16.5	4.5
p75	695.6	13.6	1.8	739.6	16.1	4.2	695.6	13.6	1.8	748.2	17.1	5.2
p95	733.1	13.9	2.1	800.0	16.3	4.3	733.1	13.9	2.1	782.6	17.6	5.7

6.2 CLIMDEX Climate Extremes Indices

Table 14. CLIMDEX precipitation indices

Index name	Description	Unit
1. PRCPTOT	Annual total wet-day precipitation; annual sum of precipitation in days where precipitation is at least 1mm	mm
2. SDII	Simple precipitation intensity index; sum of precipitation in wet days during the year divided by the number of wet days in the year	mm
3. Rx1day	Annual maximum 1-day precipitation	mm
4. Rx5day	Annual maximum 5-day consecutive precipitation	mm
5. R95pTOT	Annual total precipitation exceeding 95th percentile threshold (very wet days); annual sum of precipitation in days where daily precipitation exceeds the 95th percentile of daily precipitation in the reference period	mm
6. R99pTOT	Annual total precipitation exceeding 99th percentile threshold (extremely wet days); annual sum of precipitation in days where daily precipitation exceeds the 99th percentile of daily precipitation in the reference period	mm
7. R1mm	Annual count of days where daily precipitation exceeds 1mm per day; number of wet days	days
8. R10mm	Annual count of days where daily precipitation exceeds 10mm per day; number of heavy precipitation days	days
9. R20mm	Annual count of days where daily precipitation exceeds 20mm per day; number of very heavy precipitation days	days
10. CCD	Annual maximum consecutive dry days; annual maximum length of dry spells, sequences of days where daily precipitation is less than 1mm per day.	days
11. CWD	Annual maximum consecutive wet days; annual maximum length of wet spells, sequences of days where daily precipitation is at least 1mm per day	days

Table 15. CLIMDEX temperature indices

Index name	Description	Unit
12. TXx	Annual maximum of daily maximum temperature	Celsius
13. TXn	Annual minimum of daily maximum temperature	Celsius
14. TNx	Annual maximum of daily minimum temperature	Celsius
15. TNn	Annual minimum of daily minimum temperature	Celsius
16. DTR	Mean annual diurnal temperature range; annual mean difference between daily maximum and daily minimum temperature	Celsius
17. SU	Summer days; annual count of days where daily maximum temperature exceeds 25 degrees Celsius	days
18. TR	Tropical nights; annual count of days where daily minimum temperature exceeds 20 degrees Celsius	days
19. FD	Frost days; annual count of days where daily minimum temperature drops below 0 degrees Celsius	days
20. ID	Icing days; annual count of days where daily maximum temperature is below 0 degrees Celsius	days
21. WSDI	Warm spell duration index; annual count of days which are part of a warm spell, defined as at least 6 consecutive days where the daily maximum temperature exceeds the 90th percentile of daily maximum temperature for a 5-day running window surrounding this day during a reference period.	days
22. CSDI	Cold spell duration index; annual count of days which are part of a cold spell, defined as at least 6 consecutive days where the daily minimum temperature is below the 10th percentile of daily minimum temperature for a 5-day running window surrounding this day during a reference period.	days

23. GSL	Growing season length; annual count of days between the start of the first spell of warm days in the first half of the year, and the start of the first spell of cold days in the second half of the year. Spells of warm days are defined as six or more days with mean temperature above 5 degrees Celsius; spells of cold days are defined as six or more days with a mean temperature below 5 degrees Celsius.	days
24. TX90p	Warm days; annual percentage of days above the 90th percentile of reference daily maximum temperature	%
25. TN90p	Warm nights; annual percentage of days above the 90th percentile of reference daily minimum temperature	%
26. TX10p	Cold days; annual percentage of days below the 10th percentile of reference daily maximum temperature	%
27. TN10p	Cold nights; annual percentage of days below the 10th percentile of reference daily minimum temperature	%

6.2.1 Climdex indices RCP 4.5

Listed here are the Climdex indicator values under the RCP 4.5 for the reference period (1981 - 2010) and intermediate future (2035 – 2064). For each CLIMDEX index the annual mean of the 21 GCMs and the range (5^{th} – 95^{th} percentile) between them is given.

Table 16. Climdex indicator values RCP 4.5

Pr. index	**Ref_{mean}**	**Ref_{p05}**	**Ref_{p95}**	**2050_{mean}**	**2050_{p05}**	**2050_{p95}**
climdex.prcptot	657.4	434.3	903.9	691.5	442.7	982.3
climdex.sdii	6.9	5.1	8.8	7.4	5.5	9.8
climdex.rx1day	48.7	26.6	75.9	52.1	30.3	80.4
climdex.rx5day	88.5	51.5	141.3	96.1	55.9	148.8
climdex.r95ptot	166.6	44.7	317.9	207.2	62.3	399.0
climdex.r99ptot	52.2	0.0	144.1	71.4	0.0	193.4
climdex.rnnmm	96.1	71.5	122.6	93.1	70.4	119.8
climdex.r10mm	18.7	10.7	27.7	20.1	11.2	30.0
climdex.r20mm	6.3	2.2	11.4	7.5	2.7	13.6
climdex.cdd	110.5	92.2	133.5	112.8	94.3	138.2
climdex.cwd	9.1	5.6	14.1	9.1	5.6	14.2
Temp. index	**Ref_{mean}**	**Ref_{p05}**	**Ref_{p95}**	**2050_{mean}**	**2050_{p05}**	**2050_{p95}**
climdex.txx	32.3	30.5	34.6	34.8	32.4	37.3
climdex.txn	-8.3	-11.5	-5.5	-6.7	-10.3	-3.5
climdex.tnx	16.2	14.5	18.6	18.5	16.4	20.8
climdex.tnn	-19.5	-23.9	-15.9	-17.3	-22.5	-12.9
climdex.dtr	11.7	11.3	12.2	11.9	11.2	12.5
climdex.su	76.8	60.9	92.0	100.8	82.8	120.7
climdex.tr	0.0	0.0	0.0	2.1	0.0	2.9
climdex.fd	148.8	131.7	164.4	124.8	104.3	144.5
climdex.id	46.7	29.6	63.7	27.2	10.9	44.9
climdex.wsdi	7.8	0.0	22.4	65.1	15.8	122.4
climdex.csdi	7.0	0.0	18.5	1.7	0.0	8.2
climdex.gsl	216.7	196.4	236.6	236.4	213.8	259.7
climdex.tx90p	10.6	4.8	18.0	32.7	17.4	49.1

climdex.tn90p	10.6	5.4	16.6	34.5	19.3	49.9
climdex.tx10p	10.6	5.9	16.1	3.6	1.0	7.6
climdex.tn10p	10.6	5.7	16.1	3.2	0.5	6.9

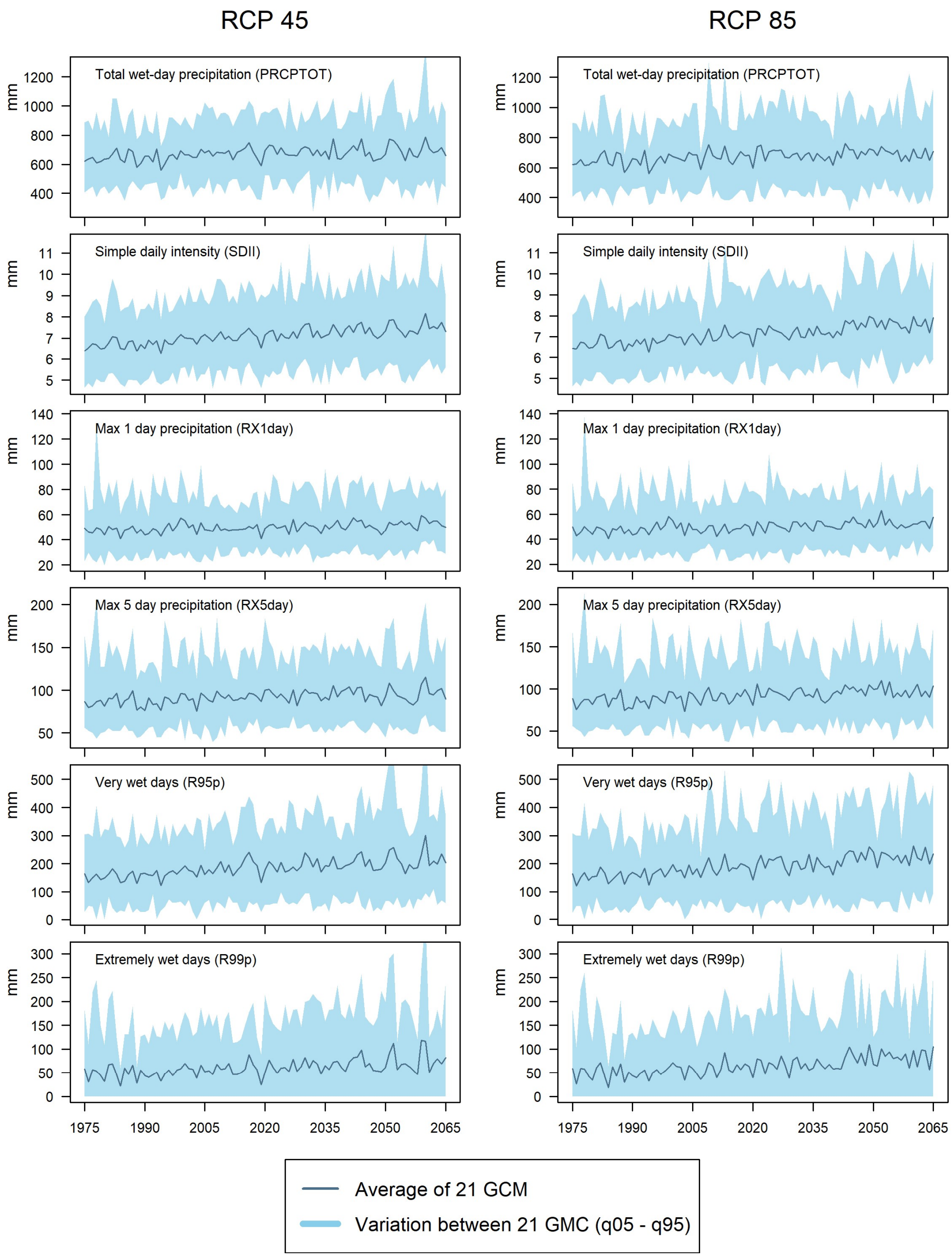
6.2.2 Climdex indices RCP 8.5

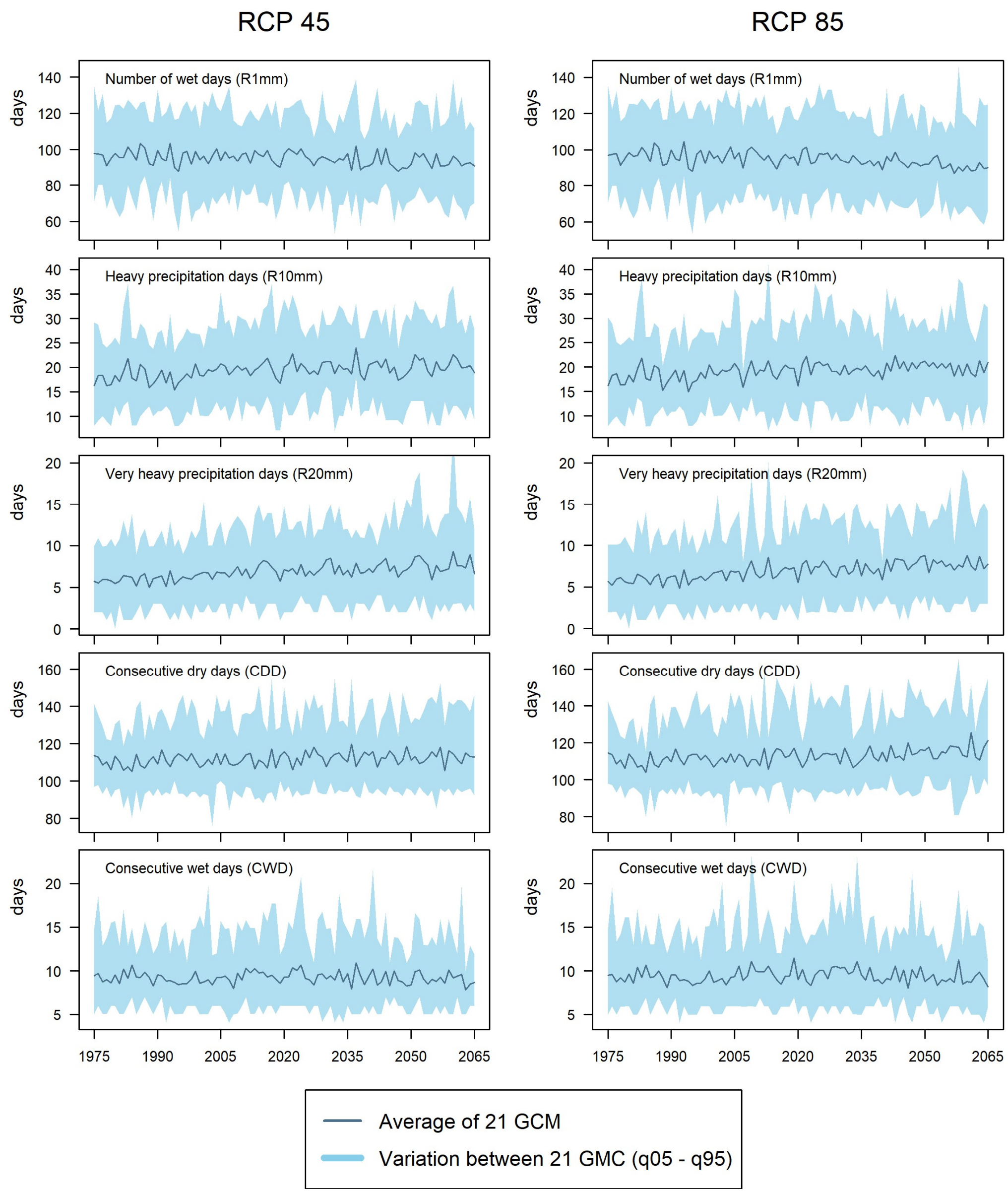
Listed here are the Climdex indicator values under the RCP 8.5 for the reference period (1981 - 2010) and intermediate future (2035 – 2064). For each CLIMDEX index the annual mean of the 21 GCMs is given and the range (5th – 95th percentile) between them.

Table 17. Climdex indicator values RCP 8.5

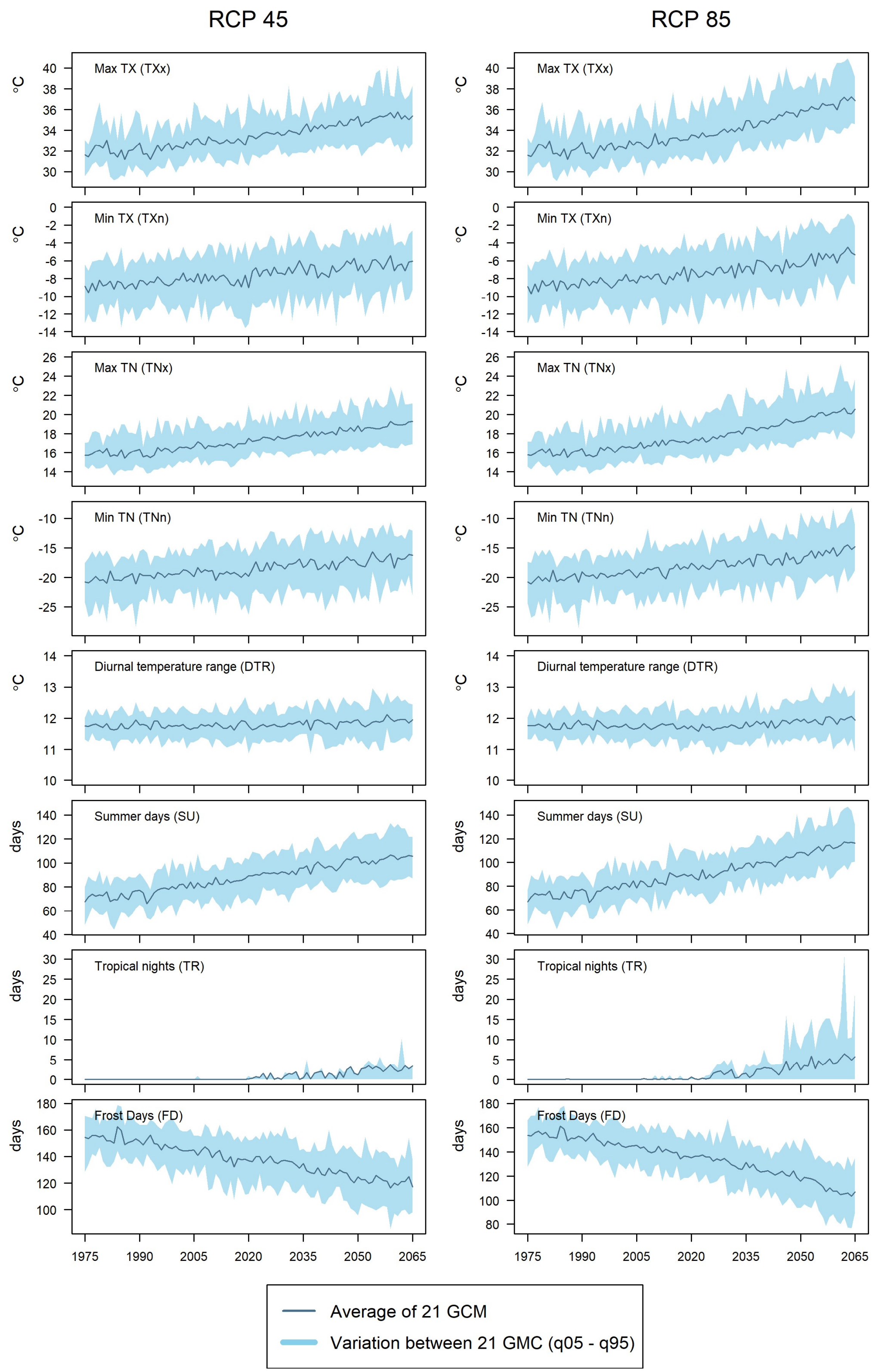
Pr. index	**Ref$_{mean}$**	**Ref$_{p05}$**	**Ref$_{p95}$**	**2050$_{mean}$**	**2050$_{p05}$**	**2050$_{p95}$**
climdex.prcptot	657.3	434.2	914.0	688.4	427.8	983.8
climdex.sdii	6.8	5.1	8.8	7.5	5.5	9.9
climdex.rx1day	48.6	27.5	76.4	52.3	30.8	79.4
climdex.rx5day	88.2	52.3	141.2	96.5	56.1	145.8
climdex.r95ptot	166.6	47.1	327.4	217.1	57.6	414.3
climdex.r99ptot	52.3	0.0	145.4	77.9	0.0	197.5
climdex.rnnmm	96.7	71.3	124.1	91.7	67.8	118.7
climdex.r10mm	18.5	10.6	27.7	19.8	10.8	29.9
climdex.r20mm	6.2	2.1	11.6	7.6	2.8	13.7
climdex.cdd	110.7	92.5	134.5	114.6	94.4	140.5
climdex.cwd	9.3	5.7	14.9	9.3	5.5	14.7
Temp. index	**Ref$_{mean}$**	**Ref$_{p05}$**	**Ref$_{p95}$**	**2050$_{mean}$**	**2050$_{p05}$**	**2050$_{p95}$**
climdex.txx	32.3	30.3	34.7	35.8	33.1	38.8
climdex.txn	-8.4	-11.4	-5.5	-6.1	-9.5	-2.6
climdex.tnx	16.3	14.6	18.7	19.4	17.3	22.4
climdex.tnn	-19.6	-24.1	-15.9	-16.4	-21.1	-11.3
climdex.dtr	11.7	11.3	12.2	11.9	11.3	12.6
climdex.su	77.0	60.8	92.6	106.7	87.6	128.2
climdex.tr	0.0	0.0	0.1	3.5	0.0	9.7
climdex.fd	148.5	131.4	164.9	117.6	95.8	139.5
climdex.id	46.7	29.8	64.1	22.9	7.5	42.0
climdex.wsdi	7.6	0.0	23.1	94.1	35.5	164.2
climdex.csdi	6.9	0.0	19.3	1.3	0.0	6.5
climdex.gsl	217.3	196.6	238.4	242.1	215.0	269.5
climdex.tx90p	10.6	4.8	18.4	41.1	24.3	59.0
climdex.tn90p	10.6	5.5	16.8	43.8	27.0	60.7
climdex.tx10p	10.6	5.8	16.1	2.7	0.5	5.9
climdex.tn10p	10.6	5.5	16.4	2.5	0.3	5.8

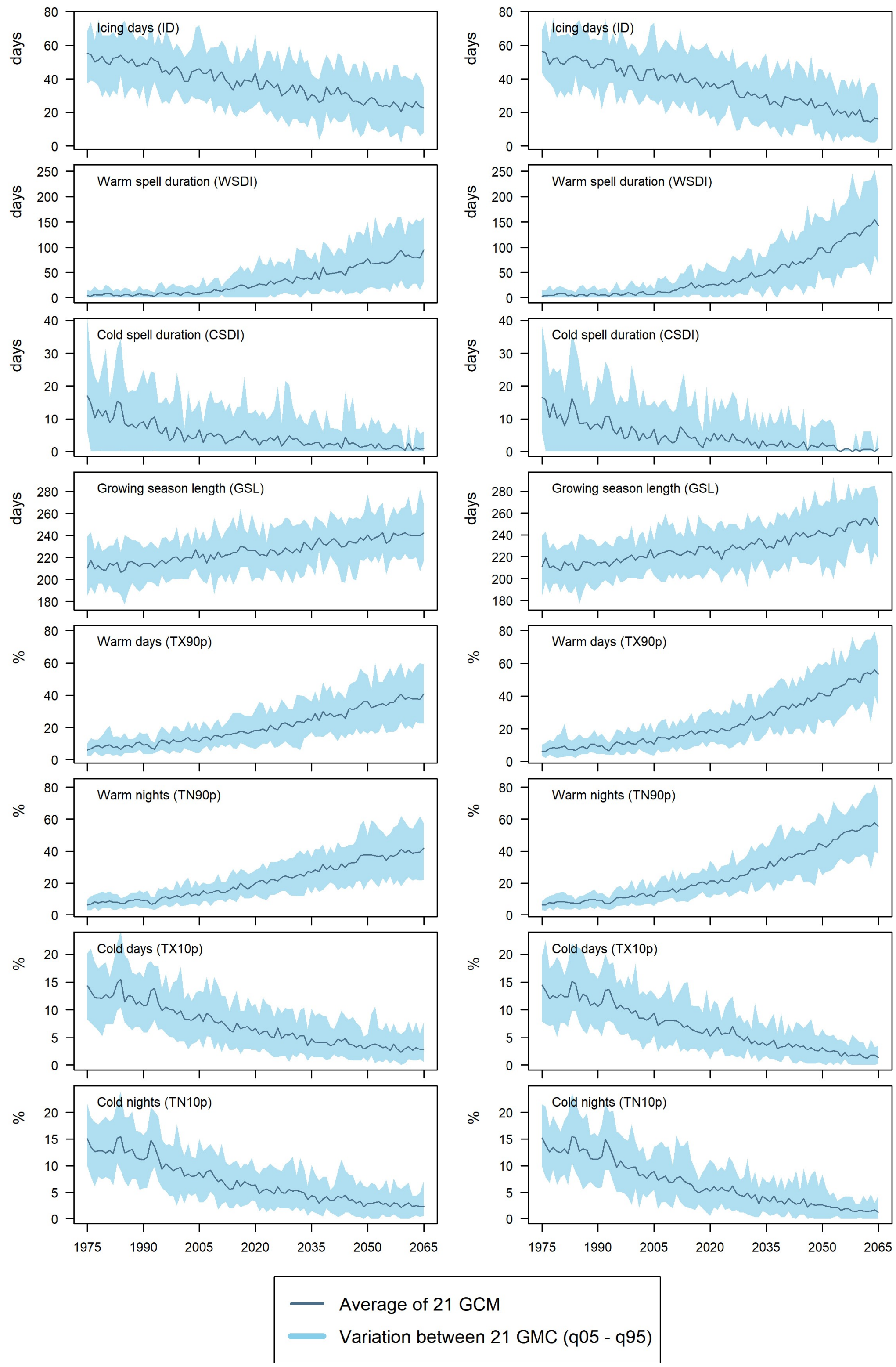
6.2.3 *CLIMDEX Precipitation indices*




RCP 45
RCP 85
Number of wet days (R1mm)
Heavy precipitation days (R10mm)
Very heavy precipitation days (R20mm)
Consecutive dry days (CDD)
Consecutive wet days (CWD)
days
1975
1990
2005
2020
2035
2050
2065
Average of 21 GCM
Variation between 21 GMC (q05 - q95)

6.2.4 CLIMDEX Temperature indices




Icing days (ID)
Warm spell duration (WSDI)
Cold spell duration (CSDI)
Growing season length (GSL)
Warm days (TX90p)
Warm nights (TN90p)
Cold days (TX10p)
Cold nights (TN10p)
days
%
1975 1990 2005 2020 2035 2050 2065
Average of 21 GCM
Variation between 21 GMC (q05 - q95)

6.2.5 *CLIMDEX Return periods Precipitation*

The estimation of changes in precipitation extremes is done for the return periods of 25, 50, and 100 years. This is done by analyzing the distribution of the percentual change (%) for each downscaled climate model for each of those return periods.

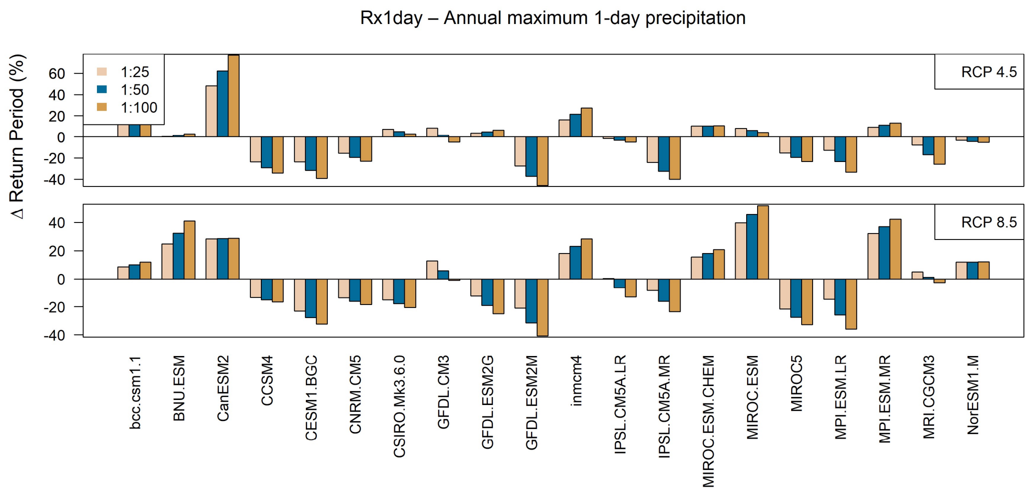


Table 18. CLIMDEX Rx1day – Annual maximum 1-day precipitation (RCP 4.5)

Rx1day	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	64.4	71.2	77.8	78.1	86.1	93.8	21.3	21.0	20.6
BNU.ESM	71.4	77.5	83.0	71.7	78.6	85.3	0.4	1.5	2.8
CanESM2	56.6	61.5	66.0	84.0	99.7	117.2	48.3	62.1	77.5
CCSM4	116.8	134.2	152.3	89.2	94.9	100.0	-23.6	-29.3	-34.4
CESM1.BGC	110.9	129.5	150.7	84.6	88.4	91.6	-23.7	-31.7	-39.2
CNRM.CM5	97.8	108.6	119.1	82.5	87.4	91.7	-15.6	-19.4	-23.0
CSIRO.Mk3.6.0	89.6	99.7	109.7	96.2	104.8	112.8	7.3	5.0	2.8
GFDL.CM3	85.1	95.4	105.9	92.2	96.9	100.7	8.3	1.6	-4.9
GFDL.ESM2G	87.7	97.8	107.7	90.8	102.3	114.6	3.5	4.7	6.4
GFDL.ESM2M	107.1	130.2	157.0	77.4	81.5	84.9	-27.7	-37.4	-45.9
inmcm4	80.7	86.4	91.3	93.8	105.0	116.4	16.2	21.5	27.4
IPSL.CM5A.LR	77.5	90.3	104.7	76.3	87.3	99.3	-1.5	-3.4	-5.1
IPSL.CM5A.MR	84.3	101.0	120.0	63.9	68.1	71.8	-24.2	-32.5	-40.2
MIROC.ESM.CHEM	64.8	70.7	76.3	71.4	78.0	84.4	10.2	10.3	10.6
MIROC.ESM	62.4	70.1	78.0	67.4	74.4	81.2	8.1	6.2	4.1
MIROC5	99.4	113.0	127.0	84.3	91.0	97.2	-15.2	-19.5	-23.5
MPI.ESM.LR	97.9	119.9	146.4	85.5	91.8	97.3	-12.7	-23.5	-33.5
MPI.ESM.MR	74.5	79.5	83.8	81.4	88.3	94.8	9.2	11.1	13.1
MRI.CGCM3	108.6	128.9	152.4	100.3	107.0	113.1	-7.7	-17.0	-25.8
NorESM1.M	81.0	88.8	96.3	78.4	85.0	91.1	-3.2	-4.3	-5.3

Table 19. CLIMDEX Rx1day – Annual maximum 1-day precipitation (RCP 8.5)

Rx1day	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	64.4	71.2	77.81	69.8	78.3	87.15	8.46	10.1	12
BNU.ESM	71.4	77.5	83.05	89.1	103	117.1	24.7	32.4	41.04
CanESM2	56.6	61.5	66.03	72.7	79.1	85.01	28.4	28.6	28.74
CCSM4	117	134	152.3	101	114	127	-13	-15	-16.6
CESM1.BGC	111	130	150.7	85.2	93.7	101.8	-23	-28	-32.4
CNRM.CM5	97.8	109	119.1	84.4	91.1	97.19	-14	-16	-18.4
CSIRO.Mk3.6.0	89.6	99.7	109.7	76	81.9	87.15	-15	-18	-20.6
GFDL.CM3	85.1	95.4	105.9	96	101	104.9	12.7	5.74	-0.99
GFDL.ESM2G	87.7	97.8	107.7	76.9	79.2	80.82	-12	-19	-24.9
GFDL.ESM2M	107	130	157	84.7	89.3	93.07	-21	-31	-40.7
inmcm4	80.7	86.4	91.34	95.1	106	117.3	17.9	23.1	28.44
IPSL.CM5A.LR	77.5	90.3	104.7	77.7	84.5	91.03	0.31	-6.4	-13
IPSL.CM5A.MR	84.3	101	120	77.3	84.7	91.77	-8.3	-16	-23.6
MIROC.ESM.CHEM	64.8	70.7	76.31	74.8	83.4	92.17	15.5	17.9	20.77
MIROC.ESM	62.4	70.1	77.95	87.2	102	118.6	39.8	45.7	52.11
MIROC5	99.4	113	127	77.9	82	85.47	-22	-27	-32.7
MPI.ESM.LR	97.9	120	146.4	83.6	89	93.72	-15	-26	-36
MPI.ESM.MR	74.5	79.5	83.82	98.4	109	119.2	32.1	36.9	42.16
MRI.CGCM3	109	129	152.4	114	130	148.5	4.86	1.19	-2.57
NorESM1.M	81	88.8	96.27	90.7	99.4	107.8	12	11.9	12.02

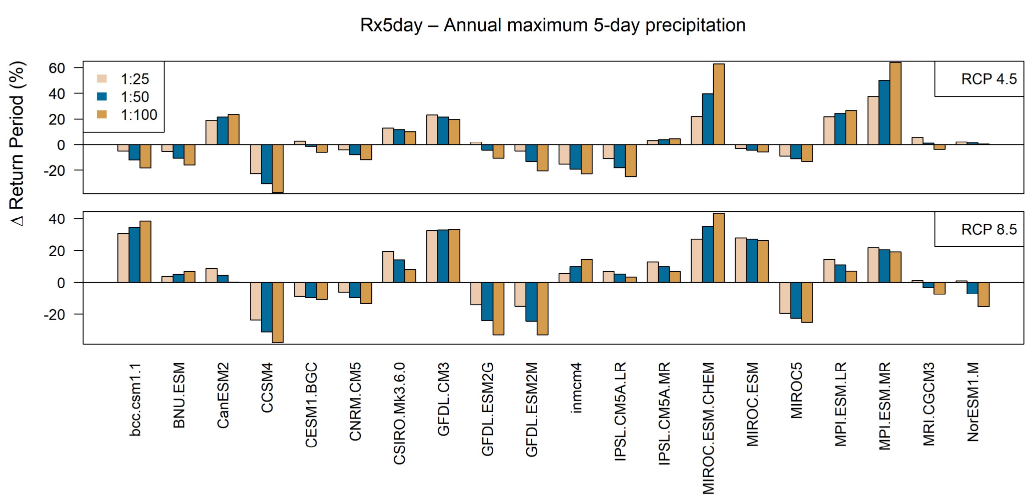


Table 20. CLIMDEX Rx5day – Annual maximum 5-day precipitation (RCP 4.5)

Rx5day	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	114.1	126.1	138.2	108.1	110.9	113.1	-5.3	-12.0	-18.2
BNU.ESM	148.6	174.8	204.6	140.7	156.3	172.0	-5.3	-10.6	-15.9

CanESM2	120.1	133.9	147.7	143.2	162.7	182.8	19.2	21.5	23.8
CCSM4	196.3	231.2	269.3	151.8	160.8	168.4	-22.7	-30.5	-37.5
CESM1.BGC	163.0	185.5	209.8	167.8	182.6	196.9	2.9	-1.5	-6.2
CNRM.CM5	158.2	176.5	195.2	151.5	162.4	172.2	-4.3	-8.0	-11.8
CSIRO.Mk3.6.0	156.2	180.1	206.7	176.7	201.6	228.0	13.2	11.9	10.3
GFDL.CM3	150.0	167.2	184.5	184.8	203.2	221.0	23.2	21.6	19.8
GFDL.ESM2G	162.8	190.2	220.7	165.9	181.6	197.1	1.9	-4.5	-10.7
GFDL.ESM2M	187.8	225.4	268.1	178.0	195.7	212.6	-5.2	-13.2	-20.7
inmcm4	186.4	209.3	231.7	157.9	168.9	178.6	-15.3	-19.3	-22.9
IPSL.CM5A.LR	145.0	166.9	190.9	129.2	136.8	143.3	-10.9	-18.0	-25.0
IPSL.CM5A.MR	145.4	162.0	178.0	150.4	168.5	186.5	3.5	4.0	4.8
MIROC.ESM.CHEM	112.4	120.4	127.5	137.2	168.0	208.1	22.0	39.6	63.2
MIROC.ESM	114.7	126.4	138.1	111.2	120.7	129.9	-3.0	-4.5	-5.9
MIROC5	176.3	196.1	215.7	160.4	174.2	187.0	-9.0	-11.2	-13.3
MPI.ESM.LR	157.4	177.1	197.5	191.7	220.3	250.4	21.8	24.4	26.7
MPI.ESM.MR	146.0	160.7	175.1	200.7	241.2	287.7	37.4	50.1	64.3
MRI.CGCM3	185.4	215.5	248.3	196.4	217.9	239.1	6.0	1.1	-3.7
NorESM1.M	151.6	173.6	197.2	155.0	175.9	198.2	2.3	1.3	0.5

Table 21. CLIMDEX Rx5day – Annual maximum 5-day precipitation (RCP 8.5)

Rx5day	**RCP 8.5 1976 - 2005**			**RCP 8.5 2035 - 2064**			**Δ RCP 8.5 (%)**		
GCM	**Return Period**			**Return Period**			**Return Period**		
	25 yr	**50 yr**	**100 yr**	**25 yr**	**50 yr**	**100 yr**	**25 yr**	**50 yr**	**100 yr**
bcc.csm1.1	114.1	126.1	138.2	149.0	169.6	191.2	30.6	34.5	38.3
BNU.ESM	148.6	174.8	204.6	154.1	183.6	218.9	3.7	5.0	7.0
CanESM2	120.1	133.9	147.7	130.7	139.9	148.1	8.8	4.5	0.3
CCSM4	196.3	231.2	269.3	149.9	159.4	167.8	-23.6	-31.1	-37.7
CESM1.BGC	163.0	185.5	209.8	148.4	167.4	187.0	-9.0	-9.7	-10.9
CNRM.CM5	158.2	176.5	195.2	148.7	159.3	168.9	-6.0	-9.7	-13.5
CSIRO.Mk3.6.0	156.2	180.1	206.7	186.7	205.6	223.4	19.5	14.2	8.1
GFDL.CM3	150.0	167.2	184.5	198.6	222.1	245.6	32.3	32.8	33.1
GFDL.ESM2G	162.8	190.2	220.7	139.6	144.4	148.1	-14.3	-24.1	-32.9
GFDL.ESM2M	187.8	225.4	268.1	159.2	170.4	180.2	-15.2	-24.4	-32.8
inmcm4	186.4	209.3	231.7	196.9	229.8	265.3	5.7	9.8	14.5
IPSL.CM5A.LR	145.0	166.9	190.9	154.9	175.6	197.5	6.8	5.2	3.4
IPSL.CM5A.MR	145.4	162.0	178.0	164.0	177.8	190.3	12.8	9.8	6.9
MIROC.ESM.CHEM	112.4	120.4	127.5	142.9	162.4	183.0	27.1	34.9	43.5
MIROC.ESM	114.7	126.4	138.1	146.5	160.7	174.2	27.7	27.1	26.1
MIROC5	176.3	196.1	215.7	141.8	152.1	161.6	-19.5	-22.5	-25.1
MPI.ESM.LR	157.4	177.1	197.5	180.3	196.4	211.4	14.5	10.9	7.0
MPI.ESM.MR	146.0	160.7	175.1	177.8	193.5	208.4	21.8	20.4	19.0
MRI.CGCM3	185.4	215.5	248.3	187.4	208.4	229.5	1.1	-3.3	-7.6
NorESM1.M	151.6	173.6	197.2	153.2	160.8	167.0	1.0	-7.4	-15.3

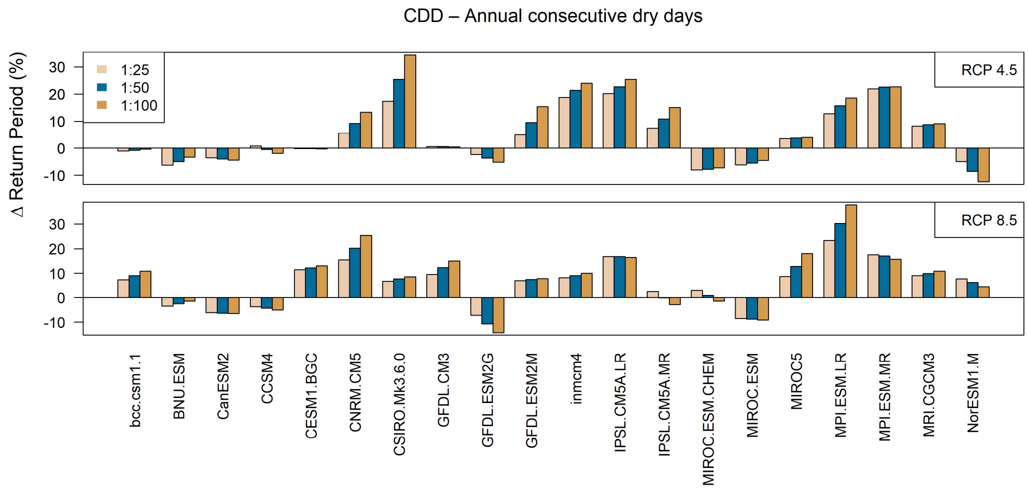


Table 22. CLIMDEX CDD – Annual consecutive dry days (RCP 4.5)

CDD	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	133.6	138.9	143.6	132.2	137.8	143.1	-1.0	-0.8	-0.4
BNU.ESM	145.8	150.7	154.6	136.6	143.2	149.5	-6.3	-5.0	-3.3
CanESM2	128.0	132.2	135.9	123.5	127.0	129.9	-3.5	-4.0	-4.4
CCSM4	153.1	162.2	170.9	154.3	161.4	167.6	0.8	-0.5	-1.9
CESM1.BGC	142.6	148.4	153.6	142.4	148.1	153.2	-0.2	-0.2	-0.3
CNRM.CM5	132.9	136.8	140.1	140.3	149.4	158.8	5.6	9.2	13.4
CSIRO.Mk3.6.0	133.1	135.1	136.5	156.2	169.4	183.7	17.4	25.4	34.6
GFDL.CM3	132.5	135.1	137.1	133.3	135.9	137.8	0.6	0.6	0.5
GFDL.ESM2G	143.6	152.5	161.6	140.2	146.9	153.3	-2.4	-3.7	-5.1
GFDL.ESM2M	146.2	154.7	163.1	153.4	169.4	188.2	4.9	9.5	15.4
inmcm4	135.4	141.0	146.3	160.9	171.2	181.3	18.8	21.4	24.0
IPSL.CM5A.LR	131.8	137.4	142.7	158.4	168.6	179.0	20.2	22.7	25.4
IPSL.CM5A.MR	138.6	146.3	154.1	148.9	162.2	177.3	7.4	10.8	15.0
MIROC.ESM.CHEM	131.7	138.5	145.3	121.1	127.7	134.8	-8.1	-7.8	-7.2
MIROC.ESM	133.4	137.2	140.3	125.1	129.7	134.0	-6.2	-5.5	-4.5
MIROC5	136.5	142.7	148.3	141.3	148.0	154.2	3.6	3.8	4.0
MPI.ESM.LR	137.0	141.7	145.9	154.5	163.9	173.0	12.8	15.7	18.5
MPI.ESM.MR	137.0	145.4	154.1	167.1	178.2	189.0	21.9	22.6	22.6
MRI.CGCM3	131.0	135.9	140.5	141.7	147.8	153.3	8.2	8.7	9.1
NorESM1.M	151.0	162.4	174.5	143.6	148.5	152.8	-4.9	-8.5	-12.4

Table 23. CLIMDEX CDD – Annual consecutive dry days (RCP 8.5)

CDD	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	133.6	138.9	143.6	143.6	151.6	159.2	7.4	9.1	10.9
BNU.ESM	145.8	150.7	154.6	140.8	146.9	152.4	-3.4	-2.5	-1.5

CanESM2	128.0	132.2	135.9	120.2	123.9	127.1	-6.1	-6.3	-6.5
CCSM4	153.1	162.2	170.9	147.4	155.2	162.4	-3.7	-4.3	-5.0
CESM1.BGC	142.6	148.4	153.6	158.9	166.6	173.6	11.5	12.3	13.0
CNRM.CM5	132.9	136.8	140.1	153.6	164.5	175.6	15.5	20.2	25.3
CSIRO.Mk3.6.0	133.1	135.1	136.5	142.2	145.5	148.3	6.8	7.7	8.6
GFDL.CM3	132.5	135.1	137.1	145.1	151.8	157.7	9.6	12.3	15.0
GFDL.ESM2G	143.6	152.5	161.6	133.2	136.1	138.4	-7.2	-10.7	-14.3
GFDL.ESM2M	146.2	154.7	163.1	156.5	166.3	175.9	7.1	7.5	7.8
inmcm4	135.4	141.0	146.3	146.6	153.9	161.0	8.3	9.1	10.1
IPSL.CM5A.LR	131.8	137.4	142.7	154.0	160.4	166.3	16.8	16.8	16.5
IPSL.CM5A.MR	138.6	146.3	154.1	142.1	146.2	149.7	2.5	-0.1	-2.9
MIROC.ESM.CHEM	131.7	138.5	145.3	135.6	139.7	143.3	2.9	0.9	-1.4
MIROC.ESM	133.4	137.2	140.3	122.1	125.2	127.6	-8.5	-8.8	-9.1
MIROC5	136.5	142.7	148.3	148.3	161.0	175.0	8.7	12.9	18.0
MPI.ESM.LR	137.0	141.7	145.9	168.9	184.5	201.3	23.3	30.2	37.9
MPI.ESM.MR	137.0	145.4	154.1	161.0	170.1	178.4	17.6	17.0	15.8
MRI.CGCM3	131.0	135.9	140.5	142.8	149.5	155.8	9.1	10.0	10.9
NorESM1.M	151.0	162.4	174.5	162.7	172.6	182.1	7.7	6.3	4.4

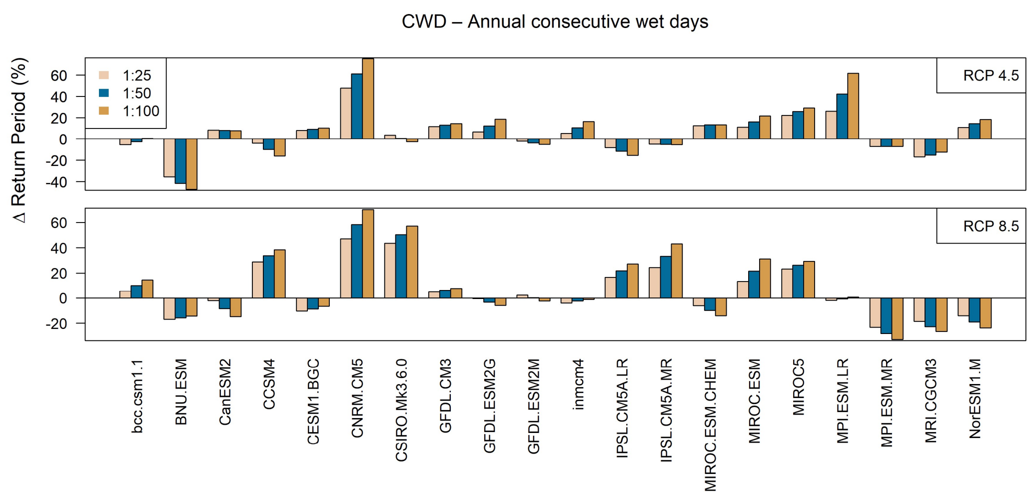


Table 24. CLIMDEX CWD – Annual consecutive wet days (RCP 4.5)

CWD	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (%)		
GCM	**Return Period**			**Return Period**			**Return Period**		
	25 yr	**50 yr**	**100 yr**	**25 yr**	**50 yr**	**100 yr**	**25 yr**	**50 yr**	**100 yr**
bcc.csm1.1	16.2	17.5	18.6	15.3	17.0	18.7	-5.6	-2.6	0.5
BNU.ESM	27.4	33.9	41.6	17.7	19.8	22.0	-35.4	-41.4	-47.1
CanESM2	22.8	27.9	34.1	24.7	30.2	36.8	8.4	8.3	8.0
CCSM4	12.5	14.3	16.2	12.0	12.9	13.7	-4.1	-10.0	-15.9
CESM1.BGC	13.1	14.6	16.1	14.1	15.9	17.8	8.1	9.2	10.5
CNRM.CM5	11.6	12.3	12.8	17.1	19.7	22.6	47.9	61.1	75.9
CSIRO.Mk3.6.0	14.8	16.6	18.6	15.3	16.7	18.1	3.7	0.6	-2.8
GFDL.CM3	11.7	12.5	13.3	13.1	14.2	15.2	11.8	13.1	14.5

GFDL.ESM2G	15.7	17.1	18.4	16.7	19.2	21.9	6.8	12.2	18.7
GFDL.ESM2M	19.6	23.1	27.1	19.2	22.3	25.7	-2.1	-3.7	-5.1
inmcm4	14.3	16.0	17.7	15.1	17.7	20.6	5.4	10.7	16.5
IPSL.CM5A.LR	15.1	17.3	19.7	13.8	15.2	16.7	-8.2	-11.7	-15.4
IPSL.CM5A.MR	12.4	13.2	13.9	11.8	12.5	13.1	-4.8	-5.1	-5.3
MIROC.ESM.CHEM	16.0	18.4	21.1	18.0	20.8	23.9	12.6	13.4	13.5
MIROC.ESM	15.1	16.5	17.8	16.8	19.1	21.6	11.1	16.2	21.7
MIROC5	9.5	10.2	10.9	11.6	12.8	14.0	22.4	25.8	29.2
MPI.ESM.LR	15.7	17.2	18.6	19.8	24.4	30.0	26.1	42.2	61.7
MPI.ESM.MR	16.2	18.2	20.3	15.1	16.9	18.9	-7.2	-7.2	-7.0
MRI.CGCM3	12.7	14.4	16.1	10.5	12.2	14.1	-16.8	-15.1	-12.5
NorESM1.M	17.8	20.4	23.2	19.7	23.4	27.5	10.8	14.5	18.4

Table 25. CLIMDEX CWD – Annual consecutive wet days (RCP 8.5)

CWD	**RCP 8.5 1976 - 2005**			**RCP 8.5 2035 - 2064**			**Δ RCP 8.5 (%)**		
GCM	**Return Period**			**Return Period**			**Return Period**		
	25 yr	**50 yr**	**100 yr**	**25 yr**	**50 yr**	**100 yr**	**25 yr**	**50 yr**	**100 yr**
bcc.csm1.1	16.2	17.5	18.6	17.2	19.2	21.3	5.7	10.1	14.5
BNU.ESM	27.4	33.9	41.6	22.8	28.5	35.7	-16.8	-15.7	-14.2
CanESM2	22.8	27.9	34.1	22.3	25.6	29.0	-2.0	-8.4	-14.9
CCSM4	12.5	14.3	16.2	16.1	19.1	22.5	28.9	33.6	38.5
CESM1.BGC	13.1	14.6	16.1	11.7	13.3	15.0	-10.2	-8.6	-6.6
CNRM.CM5	11.6	12.3	12.8	17.0	19.4	21.9	47.0	58.3	70.6
CSIRO.Mk3.6.0	14.8	16.6	18.6	21.2	25.0	29.2	43.7	50.4	57.2
GFDL.CM3	11.7	12.5	13.3	12.3	13.3	14.4	4.9	6.4	7.8
GFDL.ESM2G	15.7	17.1	18.4	15.6	16.5	17.4	-0.4	-3.2	-5.9
GFDL.ESM2M	19.6	23.1	27.1	20.1	23.2	26.5	2.3	0.1	-2.3
inmcm4	14.3	16.0	17.7	13.8	15.6	17.5	-4.0	-2.4	-1.2
IPSL.CM5A.LR	15.1	17.3	19.7	17.6	21.0	25.1	16.6	21.7	27.2
IPSL.CM5A.MR	12.4	13.2	13.9	15.5	17.6	19.8	24.3	33.3	43.0
MIROC.ESM.CHEM	16.0	18.4	21.1	15.0	16.6	18.1	-6.0	-9.8	-14.1
MIROC.ESM	15.1	16.5	17.8	17.1	20.0	23.3	13.3	21.6	31.2
MIROC5	9.5	10.2	10.9	11.7	12.8	14.0	23.1	26.2	29.2
MPI.ESM.LR	15.7	17.2	18.6	15.4	17.0	18.7	-2.0	-0.7	0.7
MPI.ESM.MR	16.2	18.2	20.3	12.5	13.1	13.6	-23.1	-28.1	-32.9
MRI.CGCM3	12.7	14.4	16.1	10.3	11.1	11.9	-18.4	-22.6	-26.6
NorESM1.M	17.8	20.4	23.2	15.3	16.6	17.7	-13.9	-19.0	-23.7

6.2.6 CLIMDEX Return periods Temperature

The estimation of changes in temperature extremes is done for the return periods of 25, 50, and 100 years. This is done by analyzing the distribution of the change (in °C) for each downscaled climate model for each of those return periods.

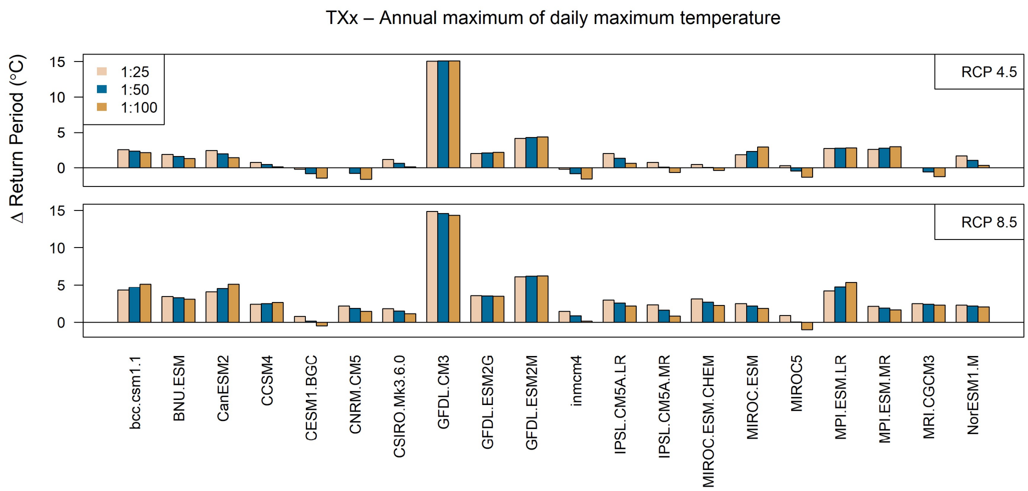


Table 26. CLIMDEX TXx – Annual maximum of daily maximum temperature (RCP 4.5)

TXx	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	34.9	35.4	35.9	37.4	37.8	38.0	2.5	2.3	2.1
BNU.ESM	35.6	36.4	37.1	37.5	38.0	38.4	1.9	1.6	1.3
CanESM2	35.5	36.5	37.5	37.9	38.5	38.9	2.4	2.0	1.4
CCSM4	36.1	36.9	37.6	36.9	37.3	37.7	0.8	0.4	0.1
CESM1.BGC	35.9	36.7	37.5	35.7	35.9	36.1	-0.2	-0.8	-1.5
CNRM.CM5	35.2	36.1	37.1	35.2	35.4	35.5	0.0	-0.8	-1.6
CSIRO.Mk3.6.0	35.6	36.3	37.0	36.7	37.0	37.1	1.2	0.6	0.1
GFDL.CM3	34.5	34.9	35.3	49.5	50.0	50.3	15.0	15.1	15.1
GFDL.ESM2G	34.2	34.5	34.8	36.2	36.6	36.9	2.0	2.1	2.2
GFDL.ESM2M	33.9	34.3	34.7	38.1	38.6	39.0	4.1	4.2	4.3
inmcm4	36.3	37.3	38.3	36.1	36.4	36.7	-0.2	-0.9	-1.6
IPSL.CM5A.LR	35.2	36.1	37.0	37.2	37.4	37.6	2.0	1.3	0.6
IPSL.CM5A.MR	35.7	36.7	37.7	36.4	36.8	37.0	0.7	0.1	-0.7
MIROC.ESM.CHEM	35.1	35.7	36.3	35.6	35.8	36.0	0.5	0.1	-0.4
MIROC.ESM	35.1	35.7	36.2	36.9	38.0	39.1	1.8	2.3	2.9
MIROC5	35.7	37.0	38.5	36.0	36.6	37.1	0.3	-0.4	-1.3
MPI.ESM.LR	34.6	34.9	35.1	37.3	37.7	38.0	2.7	2.8	2.8
MPI.ESM.MR	35.7	36.4	37.1	38.3	39.2	40.0	2.6	2.8	3.0
MRI.CGCM3	35.4	36.2	37.0	35.4	35.6	35.7	0.0	-0.6	-1.3
NorESM1.M	35.5	36.6	37.7	37.2	37.6	38.1	1.7	1.1	0.3

Table 27. CLIMDEX TXx – Annual maximum of daily maximum temperature (RCP 8.5)

TXx	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	34.9	35.4	35.9	39.2	40.1	41.0	4.3	4.7	5.1
BNU.ESM	35.6	36.4	37.1	39.1	39.6	40.1	3.4	3.3	3.1
CanESM2	35.5	36.5	37.5	39.6	41.0	42.7	4.0	4.5	5.2
CCSM4	36.1	36.9	37.6	38.5	39.4	40.2	2.4	2.5	2.6
CESM1.BGC	35.9	36.7	37.5	36.7	36.9	37.1	0.8	0.2	-0.5
CNRM.CM5	35.2	36.1	37.1	37.4	38.0	38.5	2.1	1.8	1.4
CSIRO.Mk3.6.0	35.6	36.3	37.0	37.4	37.8	38.1	1.8	1.5	1.1
GFDL.CM3	34.5	34.9	35.3	49.3	49.5	49.5	14.8	14.5	14.3
GFDL.ESM2G	34.2	34.5	34.8	37.8	38.0	38.2	3.6	3.5	3.5
GFDL.ESM2M	33.9	34.3	34.7	40.1	40.6	41.0	6.1	6.2	6.3
inmcm4	36.3	37.3	38.3	37.8	38.1	38.4	1.5	0.8	0.1
IPSL.CM5A.LR	35.2	36.1	37.0	38.1	38.7	39.1	2.9	2.6	2.2
IPSL.CM5A.MR	35.7	36.7	37.7	38.0	38.3	38.5	2.3	1.6	0.8
MIROC.ESM.CHEM	35.1	35.7	36.3	38.2	38.4	38.6	3.1	2.7	2.2
MIROC.ESM	35.1	35.7	36.2	37.5	37.8	38.0	2.5	2.2	1.8
MIROC5	35.7	37.0	38.5	36.6	37.1	37.5	0.9	0.0	-1.0
MPI.ESM.LR	34.6	34.9	35.1	38.8	39.7	40.5	4.2	4.8	5.4
MPI.ESM.MR	35.7	36.4	37.1	37.8	38.3	38.7	2.1	1.9	1.6
MRI.CGCM3	35.4	36.2	37.0	37.8	38.6	39.2	2.5	2.4	2.3
NorESM1.M	35.5	36.6	37.7	37.8	38.8	39.8	2.3	2.2	2.1

TXn – Annual minimum of daily maximum temperature

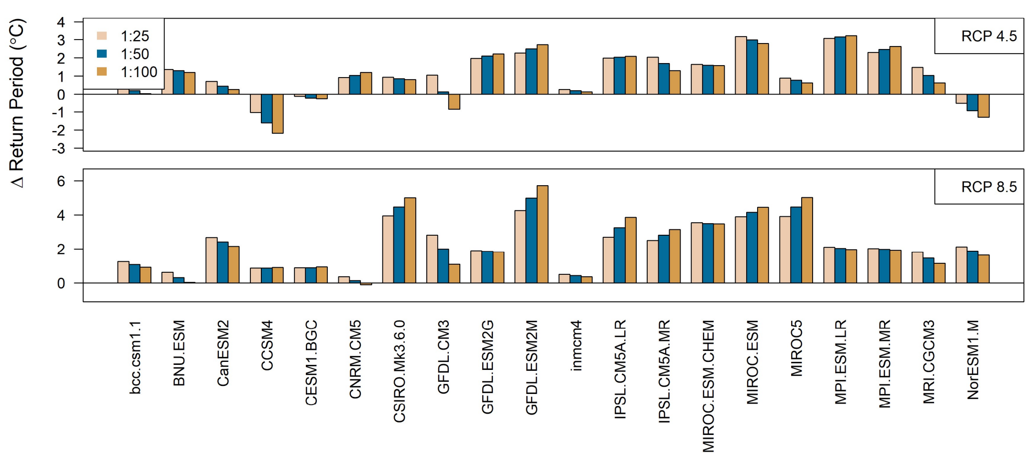


Table 28. CLIMDEX TXn – Annual minimum of daily maximum temperature (RCP 4.5)

TXn	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	-12.3	-13.0	-13.6	-11.9	-12.8	-13.5	0.4	0.2	0.0
BNU.ESM	-12.5	-13.0	-13.4	-11.1	-11.7	-12.2	1.4	1.3	1.2

CanESM2	-11.3	-11.9	-12.3	-10.6	-11.4	-12.1	0.7	0.4	0.3
CCSM4	-12.2	-12.8	-13.4	-13.2	-14.5	-15.6	-1.0	-1.6	-2.2
CESM1.BGC	-12.9	-14.0	-15.0	-13.0	-14.2	-15.3	-0.1	-0.2	-0.2
CNRM.CM5	-11.4	-12.0	-12.5	-10.5	-10.9	-11.3	0.9	1.0	1.2
CSIRO.Mk3.6.0	-13.5	-14.5	-15.3	-12.6	-13.6	-14.5	0.9	0.9	0.8
GFDL.CM3	-12.0	-12.5	-13.0	-10.9	-12.4	-13.8	1.0	0.1	-0.8
GFDL.ESM2G	-13.3	-13.9	-14.4	-11.3	-11.8	-12.2	2.0	2.1	2.2
GFDL.ESM2M	-12.6	-13.5	-14.3	-10.3	-11.0	-11.6	2.3	2.5	2.7
inmcm4	-11.8	-12.4	-13.0	-11.6	-12.3	-12.9	0.3	0.2	0.1
IPSL.CM5A.LR	-13.2	-14.2	-15.1	-11.2	-12.1	-13.0	2.0	2.0	2.1
IPSL.CM5A.MR	-12.7	-13.4	-14.0	-10.7	-11.7	-12.7	2.0	1.7	1.3
MIROC.ESM.CHEM	-12.9	-14.0	-15.0	-11.2	-12.4	-13.5	1.6	1.6	1.6
MIROC.ESM	-12.5	-13.2	-13.9	-9.3	-10.2	-11.1	3.2	3.0	2.8
MIROC5	-12.5	-13.5	-14.3	-11.6	-12.7	-13.7	0.9	0.8	0.6
MPI.ESM.LR	-12.4	-12.9	-13.3	-9.4	-9.8	-10.1	3.1	3.2	3.2
MPI.ESM.MR	-12.7	-13.4	-14.0	-10.4	-10.9	-11.4	2.3	2.5	2.6
MRI.CGCM3	-12.3	-12.5	-12.6	-10.8	-11.5	-12.0	1.5	1.0	0.6
NorESM1.M	-11.7	-12.1	-12.4	-12.2	-13.0	-13.7	-0.5	-0.9	-1.3

Table 29. CLIMDEX TXn – Annual minimum of daily maximum temperature (RCP 8.5)

TXn	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	-12.3	-13.0	-13.6	-11.1	-11.9	-12.7	1.2	1.1	0.9
BNU.ESM	-12.5	-13.0	-13.4	-11.9	-12.7	-13.4	0.6	0.3	0.0
CanESM2	-11.3	-11.9	-12.3	-8.6	-9.4	-10.2	2.7	2.4	2.1
CCSM4	-12.2	-12.8	-13.4	-11.3	-12.0	-12.5	0.9	0.9	0.9
CESM1.BGC	-12.9	-14.0	-15.0	-12.0	-13.1	-14.1	0.9	0.9	0.9
CNRM.CM5	-11.4	-12.0	-12.5	-11.0	-11.8	-12.6	0.4	0.1	-0.1
CSIRO.Mk3.6.0	-13.5	-14.5	-15.3	-9.6	-10.0	-10.3	3.9	4.5	5.0
GFDL.CM3	-12.0	-12.5	-13.0	-9.2	-10.6	-11.9	2.8	2.0	1.1
GFDL.ESM2G	-13.3	-13.9	-14.4	-11.4	-12.0	-12.6	1.9	1.9	1.8
GFDL.ESM2M	-12.6	-13.5	-14.3	-8.3	-8.5	-8.6	4.2	5.0	5.7
inmcm4	-11.8	-12.4	-13.0	-11.3	-12.0	-12.6	0.5	0.4	0.4
IPSL.CM5A.LR	-13.2	-14.2	-15.1	-10.5	-10.9	-11.2	2.7	3.2	3.9
IPSL.CM5A.MR	-12.7	-13.4	-14.0	-10.2	-10.6	-10.9	2.5	2.8	3.1
MIROC.ESM.CHEM	-12.9	-14.0	-15.0	-9.3	-10.5	-11.6	3.5	3.5	3.5
MIROC.ESM	-12.5	-13.2	-13.9	-8.6	-9.1	-9.4	3.9	4.2	4.5
MIROC5	-12.5	-13.5	-14.3	-8.6	-9.0	-9.3	3.9	4.5	5.0
MPI.ESM.LR	-12.4	-12.9	-13.3	-10.3	-10.9	-11.4	2.1	2.0	1.9
MPI.ESM.MR	-12.7	-13.4	-14.0	-10.7	-11.4	-12.1	2.0	2.0	1.9
MRI.CGCM3	-12.3	-12.5	-12.6	-10.5	-11.0	-11.5	1.8	1.5	1.1
NorESM1.M	-11.7	-12.1	-12.4	-9.6	-10.2	-10.8	2.1	1.9	1.6

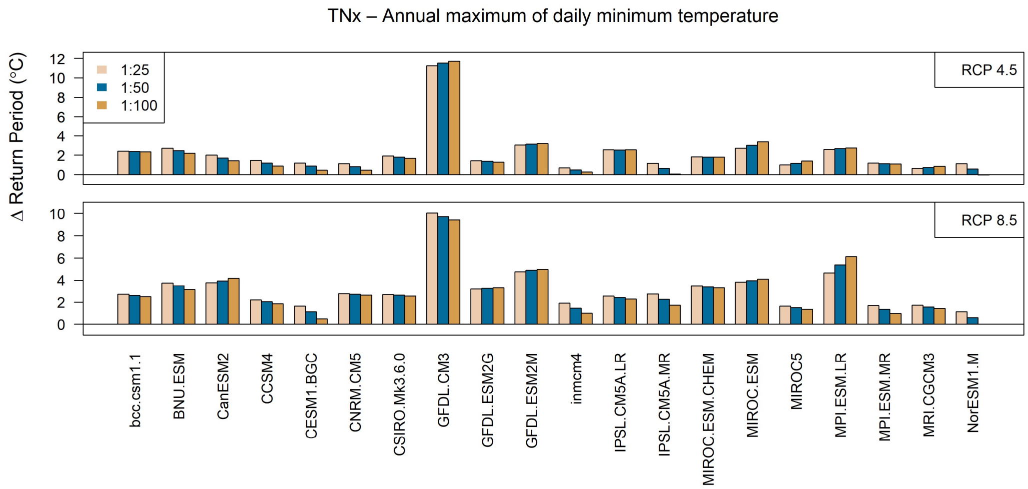


Table 30. CLIMDEX TNx – Annual maximum of daily minimum temperature (RCP 4.5)

TNx	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	17.6	18.0	18.3	20.0	20.3	20.6	2.4	2.4	2.3
BNU.ESM	18.6	19.2	19.7	21.3	21.7	21.9	2.7	2.5	2.2
CanESM2	20.5	21.2	21.8	22.5	22.9	23.2	2.0	1.7	1.4
CCSM4	18.1	18.6	19.0	19.6	19.8	19.9	1.5	1.2	0.9
CESM1.BGC	18.8	19.7	20.6	20.0	20.6	21.1	1.2	0.9	0.5
CNRM.CM5	17.0	17.5	18.0	18.2	18.3	18.4	1.1	0.8	0.5
CSIRO.Mk3.6.0	18.8	19.3	19.8	20.7	21.1	21.5	1.9	1.8	1.7
GFDL.CM3	19.9	20.4	20.8	31.1	31.9	32.5	11.2	11.5	11.7
GFDL.ESM2G	18.3	18.6	18.8	19.7	19.9	20.1	1.4	1.4	1.3
GFDL.ESM2M	17.8	18.2	18.4	20.9	21.3	21.6	3.1	3.1	3.2
inmcm4	21.1	21.7	22.4	21.8	22.2	22.6	0.7	0.5	0.3
IPSL.CM5A.LR	18.1	18.6	19.0	20.7	21.1	21.5	2.6	2.5	2.6
IPSL.CM5A.MR	19.1	19.9	20.8	20.3	20.6	20.8	1.2	0.6	0.1
MIROC.ESM.CHEM	17.0	17.2	17.5	18.8	19.0	19.2	1.8	1.8	1.8
MIROC.ESM	16.9	17.2	17.4	19.6	20.2	20.8	2.7	3.0	3.4
MIROC5	18.0	18.4	18.9	19.0	19.6	20.3	1.0	1.2	1.4
MPI.ESM.LR	17.9	18.1	18.2	20.5	20.8	21.0	2.6	2.7	2.7
MPI.ESM.MR	19.1	19.7	20.3	20.3	20.8	21.4	1.2	1.1	1.1
MRI.CGCM3	20.2	20.9	21.5	20.9	21.6	22.4	0.6	0.7	0.9
NorESM1.M	18.4	19.2	20.0	19.5	19.8	20.0	1.1	0.6	0.0

Table 31. CLIMDEX TNx – Annual maximum of daily minimum temperature (RCP 8.5)

TNx	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	17.6	18.0	18.3	20.3	20.6	20.8	2.7	2.6	2.5
BNU.ESM	18.6	19.2	19.7	22.4	22.7	22.9	3.8	3.5	3.2

CanESM2	20.5	21.2	21.8	24.3	25.1	25.9	3.8	4.0	4.2
CCSM4	18.1	18.6	19.0	20.3	20.6	20.8	2.2	2.0	1.9
CESM1.BGC	18.8	19.7	20.6	20.5	20.8	21.1	1.7	1.1	0.5
CNRM.CM5	17.0	17.5	18.0	19.8	20.2	20.6	2.8	2.7	2.6
CSIRO.Mk3.6.0	18.8	19.3	19.8	21.4	21.9	22.4	2.7	2.6	2.6
GFDL.CM3	19.9	20.4	20.8	29.9	30.1	30.2	10.0	9.7	9.4
GFDL.ESM2G	18.3	18.6	18.8	21.5	21.8	22.1	3.2	3.2	3.3
GFDL.ESM2M	17.8	18.2	18.4	22.6	23.1	23.4	4.8	4.9	5.0
inmcm4	21.1	21.7	22.4	23.0	23.2	23.3	1.9	1.5	1.0
IPSL.CM5A.LR	18.1	18.6	19.0	20.7	21.0	21.3	2.6	2.4	2.3
IPSL.CM5A.MR	19.1	19.9	20.8	21.9	22.2	22.5	2.7	2.3	1.7
MIROC.ESM.CHEM	17.0	17.2	17.5	20.4	20.6	20.8	3.5	3.4	3.3
MIROC.ESM	16.9	17.2	17.4	20.7	21.1	21.5	3.8	4.0	4.1
MIROC5	18.0	18.4	18.9	19.6	19.9	20.2	1.6	1.5	1.3
MPI.ESM.LR	17.9	18.1	18.2	22.5	23.5	24.4	4.7	5.4	6.1
MPI.ESM.MR	19.1	19.7	20.3	20.8	21.0	21.2	1.7	1.3	1.0
MRI.CGCM3	20.2	20.9	21.5	21.9	22.5	23.0	1.7	1.6	1.4
NorESM1.M	18.4	19.2	20.0	19.5	19.8	20.0	1.1	0.6	0.0

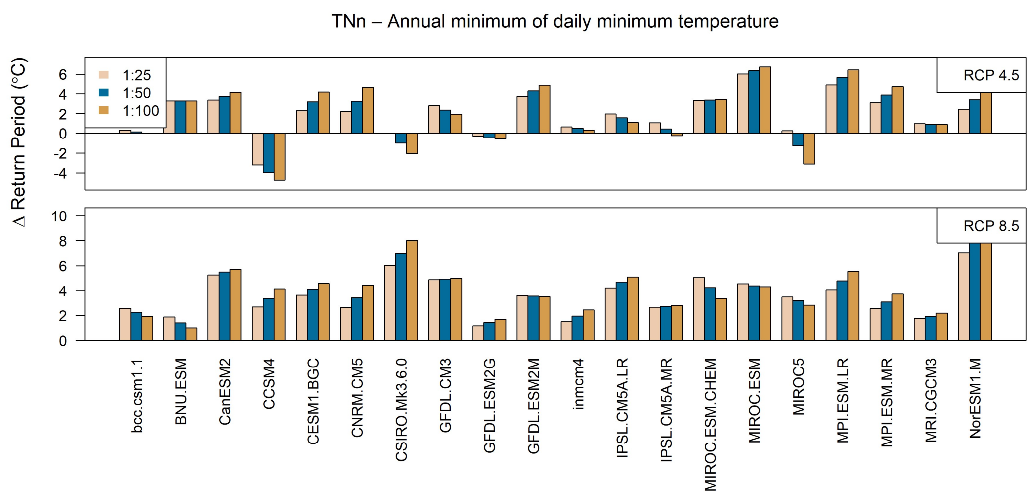


Table 32. CLIMDEX TNn – Annual minimum of daily minimum temperature (RCP 4.5)

TNn	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	-25.2	-26.4	-27.5	-24.9	-26.2	-27.5	0.3	0.2	0.0
BNU.ESM	-26.4	-27.1	-27.6	-23.1	-23.8	-24.3	3.3	3.3	3.3
CanESM2	-24.2	-25.1	-26.0	-20.8	-21.4	-21.8	3.4	3.8	4.2
CCSM4	-27.0	-28.4	-29.8	-30.2	-32.4	-34.5	-3.2	-4.0	-4.7
CESM1.BGC	-29.1	-30.9	-32.5	-26.8	-27.7	-28.3	2.3	3.2	4.2
CNRM.CM5	-25.0	-26.7	-28.6	-22.8	-23.5	-24.0	2.2	3.3	4.6
CSIRO.Mk3.6.0	-25.7	-27.0	-28.3	-25.7	-28.0	-30.4	0.0	-1.0	-2.0
GFDL.CM3	-23.8	-24.3	-24.7	-21.0	-21.9	-22.7	2.8	2.4	2.0

GFDL.ESM2G	-22.3	-22.9	-23.4	-22.6	-23.3	-23.9	-0.3	-0.4	-0.5
GFDL.ESM2M	-23.2	-24.2	-25.2	-19.4	-19.9	-20.3	3.8	4.3	4.9
inmcm4	-24.1	-25.2	-26.2	-23.4	-24.7	-25.8	0.7	0.5	0.3
IPSL.CM5A.LR	-24.9	-25.6	-26.2	-22.9	-24.0	-25.1	2.0	1.6	1.1
IPSL.CM5A.MR	-24.0	-24.4	-24.8	-22.9	-24.0	-25.0	1.1	0.4	-0.2
MIROC.ESM.CHEM	-25.1	-26.5	-27.8	-21.8	-23.1	-24.3	3.4	3.4	3.5
MIROC.ESM	-26.5	-28.2	-30.0	-20.4	-21.9	-23.2	6.0	6.3	6.7
MIROC5	-25.8	-26.8	-27.8	-25.5	-28.1	-30.9	0.3	-1.2	-3.1
MPI.ESM.LR	-25.0	-26.4	-27.7	-20.1	-20.7	-21.2	4.9	5.7	6.4
MPI.ESM.MR	-23.3	-24.4	-25.5	-20.1	-20.5	-20.8	3.1	3.9	4.7
MRI.CGCM3	-23.8	-24.7	-25.5	-22.8	-23.8	-24.6	1.0	0.9	0.9
NorESM1.M	-29.7	-31.8	-33.7	-27.3	-28.3	-29.2	2.4	3.4	4.6

Table 33. CLIMDEX TNn – Annual minimum of daily minimum temperature (RCP 8.5)

TNn	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (°C)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	-25.2	-26.4	-27.5	-22.6	-24.1	-25.6	2.6	2.3	1.9
BNU.ESM	-26.4	-27.1	-27.6	-24.6	-25.7	-26.6	1.9	1.4	1.0
CanESM2	-24.2	-25.1	-26.0	-18.9	-19.6	-20.3	5.3	5.5	5.7
CCSM4	-27.0	-28.4	-29.8	-24.3	-25.0	-25.6	2.7	3.4	4.1
CESM1.BGC	-29.1	-30.9	-32.5	-25.5	-26.8	-27.9	3.6	4.1	4.6
CNRM.CM5	-25.0	-26.7	-28.6	-22.4	-23.3	-24.2	2.6	3.4	4.4
CSIRO.Mk3.6.0	-25.7	-27.0	-28.3	-19.6	-20.0	-20.3	6.0	7.0	8.0
GFDL.CM3	-23.8	-24.3	-24.7	-18.9	-19.4	-19.7	4.9	4.9	5.0
GFDL.ESM2G	-22.3	-22.9	-23.4	-21.2	-21.5	-21.7	1.2	1.4	1.7
GFDL.ESM2M	-23.2	-24.2	-25.2	-19.6	-20.6	-21.7	3.6	3.6	3.5
inmcm4	-24.1	-25.2	-26.2	-22.6	-23.2	-23.7	1.5	1.9	2.4
IPSL.CM5A.LR	-24.9	-25.6	-26.2	-20.6	-20.9	-21.1	4.2	4.7	5.1
IPSL.CM5A.MR	-24.0	-24.4	-24.8	-21.3	-21.7	-22.0	2.7	2.7	2.8
MIROC.ESM.CHEM	-25.1	-26.5	-27.8	-20.1	-22.2	-24.4	5.1	4.3	3.4
MIROC.ESM	-26.5	-28.2	-30.0	-21.9	-23.9	-25.7	4.5	4.4	4.3
MIROC5	-25.8	-26.8	-27.8	-22.3	-23.7	-25.0	3.5	3.2	2.8
MPI.ESM.LR	-25.0	-26.4	-27.7	-21.0	-21.6	-22.1	4.1	4.8	5.5
MPI.ESM.MR	-23.3	-24.4	-25.5	-20.7	-21.3	-21.8	2.5	3.1	3.7
MRI.CGCM3	-23.8	-24.7	-25.5	-22.0	-22.7	-23.3	1.8	1.9	2.2
NorESM1.M	-29.7	-31.8	-33.7	-22.7	-23.5	-24.1	7.0	8.3	9.6

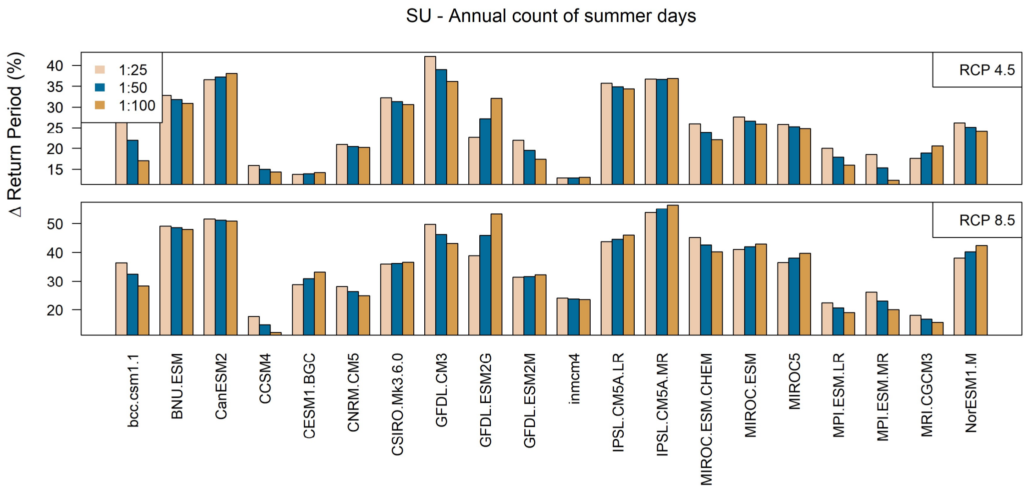


Table 34. CLIMDEX SU – Annual count of days where daily maximum temperature exceeds 25 °C (RCP 4.5)

SU	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	93.8	99.4	105.2	118.9	121.2	123.1	26.7	21.9	17.0
BNU.ESM	89.2	91.6	93.6	118.4	120.7	122.5	32.8	31.8	30.9
CanESM2	90.0	91.8	93.2	122.9	126.0	128.6	36.6	37.2	38.0
CCSM4	100.5	104.3	107.7	116.4	120.0	123.2	15.9	15.0	14.4
CESM1.BGC	97.3	99.5	101.1	110.7	113.3	115.4	13.8	13.9	14.2
CNRM.CM5	97.2	101.6	105.3	117.6	122.3	126.6	20.9	20.5	20.3
CSIRO.Mk3.6.0	91.9	94.8	97.3	121.6	124.5	127.0	32.2	31.3	30.6
GFDL.CM3	102.5	106.8	110.4	145.9	148.5	150.4	42.3	39.0	36.2
GFDL.ESM2G	92.8	94.0	94.8	113.9	119.6	125.1	22.6	27.2	32.1
GFDL.ESM2M	99.7	104.5	108.6	121.5	124.9	127.5	21.9	19.5	17.4
inmcm4	90.7	92.6	93.9	102.4	104.5	106.2	12.9	12.9	13.1
IPSL.CM5A.LR	99.0	102.5	105.4	134.3	138.2	141.7	35.8	34.9	34.4
IPSL.CM5A.MR	99.0	101.0	102.4	135.4	138.0	140.1	36.7	36.6	36.9
MIROC.ESM.CHEM	91.6	95.3	98.5	115.4	118.1	120.2	26.0	23.9	22.1
MIROC.ESM	92.0	94.3	96.0	117.5	119.4	120.8	27.6	26.6	25.9
MIROC5	91.5	93.9	95.8	115.2	117.7	119.7	25.9	25.3	24.9
MPI.ESM.LR	93.6	96.1	98.2	112.3	113.3	113.9	20.0	17.9	16.0
MPI.ESM.MR	99.2	104.2	108.7	117.6	120.1	122.1	18.6	15.3	12.3
MRI.CGCM3	96.5	99.5	101.9	113.4	118.2	122.8	17.6	18.9	20.6
NorESM1.M	91.6	93.4	94.7	115.6	116.8	117.7	26.2	25.1	24.2
Mean	95.0	98.0	100.6	119.3	122.3	124.7	25.7	24.7	24.1

Table 35. CLIMDEX SU – Annual count of days where daily maximum temperature exceeds 25 °C (RCP 8.5)

TNn	RCP 8.5 1976 - 2005	RCP 8.5 2035 - 2064	Δ RCP 8.5 (%)
GCM	Return Period	Return Period	Return Period

	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	93.8	99.4	105.2	127.9	131.7	134.9	36.4	32.5	28.3
BNU.ESM	89.2	91.6	93.6	133.0	136.0	138.5	49.1	48.5	47.9
CanESM2	90.0	91.8	93.2	136.5	138.8	140.5	51.6	51.2	50.8
CCSM4	100.5	104.3	107.7	118.2	119.7	120.8	17.7	14.7	12.1
CESM1.BGC	97.3	99.5	101.1	125.5	130.3	134.7	28.9	30.9	33.2
CNRM.CM5	97.2	101.6	105.3	124.5	128.3	131.5	28.1	26.3	24.9
CSIRO.Mk3.6.0	91.9	94.8	97.3	125.0	129.2	132.9	36.0	36.2	36.7
GFDL.CM3	102.5	106.8	110.4	153.5	156.1	158.1	49.7	46.2	43.2
GFDL.ESM2G	92.8	94.0	94.8	129.0	137.2	145.3	38.9	45.9	53.3
GFDL.ESM2M	99.7	104.5	108.6	131.1	137.6	143.8	31.5	31.7	32.3
inmcm4	90.7	92.6	93.9	112.5	114.5	116.1	24.1	23.7	23.6
IPSL.CM5A.LR	99.0	102.5	105.4	142.3	148.1	153.9	43.8	44.6	46.0
IPSL.CM5A.MR	99.0	101.0	102.4	152.3	156.7	160.2	53.9	55.1	56.5
MIROC.ESM.CHEM	91.6	95.3	98.5	133.0	135.9	138.1	45.2	42.6	40.2
MIROC.ESM	92.0	94.3	96.0	129.8	133.8	137.2	41.1	42.0	43.0
MIROC5	91.5	93.9	95.8	124.9	129.7	133.9	36.5	38.0	39.7
MPI.ESM.LR	93.6	96.1	98.2	114.5	115.9	116.8	22.4	20.6	19.0
MPI.ESM.MR	99.2	104.2	108.7	125.1	128.2	130.6	26.1	23.0	20.1
MRI.CGCM3	96.5	99.5	101.9	113.9	116.1	117.8	18.1	16.8	15.6
NorESM1.M	91.6	93.4	94.7	126.5	130.9	134.9	38.1	40.2	42.4

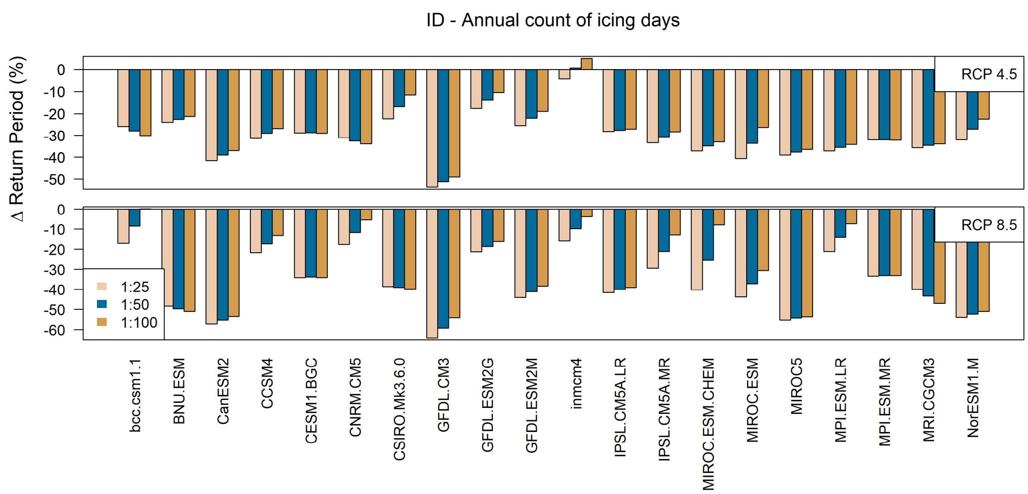


Table 36. CLIMDEX ID – Annual count of days where daily maximum temperature is below 0 °C (RCP 4.5)

SU	RCP 4.5 1976 - 2005			RCP 4.5 2035 - 2064			Δ RCP 4.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	68.0	73.1	77.9	50.4	52.7	54.4	-25.8	-27.9	-30.1
BNU.ESM	73.0	77.3	81.1	55.5	59.9	63.8	-24.0	-22.6	-21.3
CanESM2	65.1	67.0	68.4	38.0	40.8	43.2	-41.6	-39.0	-36.9
CCSM4	64.3	66.1	67.4	44.1	46.9	49.3	-31.3	-29.0	-26.9
CESM1.BGC	71.3	78.0	84.6	50.7	55.6	60.0	-28.8	-28.7	-29.0

CNRM.CM5	78.0	81.6	84.6	53.8	55.1	56.0	-31.0	-32.5	-33.9
CSIRO.Mk3.6.0	71.4	75.9	79.9	55.4	63.1	70.7	-22.3	-16.9	-11.5
GFDL.CM3	74.8	78.0	80.6	34.7	38.1	41.1	-53.6	-51.2	-49.0
GFDL.ESM2G	66.1	67.7	68.8	54.5	58.3	61.7	-17.6	-13.9	-10.4
GFDL.ESM2M	69.0	71.0	72.5	51.4	55.4	58.8	-25.5	-22.0	-18.9
inmcm4	62.5	64.0	65.0	59.9	64.4	68.5	-4.2	0.7	5.3
IPSL.CM5A.LR	67.0	68.9	70.3	48.1	49.9	51.3	-28.2	-27.6	-27.0
IPSL.CM5A.MR	62.9	64.7	66.0	42.0	44.8	47.3	-33.3	-30.7	-28.3
MIROC.ESM.CHEM	66.1	67.9	69.2	41.5	44.2	46.4	-37.2	-34.9	-32.9
MIROC.ESM	71.0	73.2	74.8	42.2	48.6	55.1	-40.6	-33.5	-26.3
MIROC5	77.7	82.3	86.0	47.4	51.3	54.6	-39.0	-37.7	-36.5
MPI.ESM.LR	67.7	69.1	70.1	42.6	44.6	46.2	-37.1	-35.4	-34.1
MPI.ESM.MR	73.9	78.6	82.6	50.3	53.4	56.2	-32.0	-32.0	-32.0
MRI.CGCM3	73.2	80.9	89.2	47.1	53.0	58.9	-35.6	-34.5	-33.9
NorESM1.M	72.5	76.4	79.6	49.3	55.7	61.7	-32.0	-27.1	-22.5

Table 37. CLIMDEX ID – Annual count of days where daily maximum temperature is below 0 °C (RCP 8.5)

TNn	RCP 8.5 1976 - 2005			RCP 8.5 2035 - 2064			Δ RCP 8.5 (%)		
GCM	Return Period			Return Period			Return Period		
	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr	25 yr	50 yr	100 yr
bcc.csm1.1	68.0	73.1	77.9	56.4	66.9	78.0	-17.1	-8.5	0.1
BNU.ESM	73.0	77.3	81.1	37.8	39.0	39.8	-48.3	-49.6	-50.9
CanESM2	65.1	67.0	68.4	27.9	30.0	31.8	-57.2	-55.2	-53.5
CCSM4	64.3	66.1	67.4	50.3	54.7	58.5	-21.7	-17.2	-13.1
CESM1.BGC	71.3	78.0	84.6	47.0	51.6	55.9	-34.1	-33.8	-34.0
CNRM.CM5	78.0	81.6	84.6	64.2	72.1	80.0	-17.6	-11.7	-5.4
CSIRO.Mk3.6.0	71.4	75.9	79.9	43.8	46.3	48.2	-38.6	-39.0	-39.7
GFDL.CM3	74.8	78.0	80.6	26.9	31.9	37.0	-64.0	-59.1	-54.1
GFDL.ESM2G	66.1	67.7	68.8	52.0	55.1	57.7	-21.3	-18.6	-16.2
GFDL.ESM2M	69.0	71.0	72.5	38.6	41.8	44.7	-44.1	-41.1	-38.3
inmcm4	62.5	64.0	65.0	52.6	57.7	62.6	-15.8	-9.8	-3.8
IPSL.CM5A.LR	67.0	68.9	70.3	39.2	41.2	42.9	-41.5	-40.2	-39.0
IPSL.CM5A.MR	62.9	64.7	66.0	44.4	51.0	57.4	-29.4	-21.1	-12.9
MIROC.ESM.CHEM	66.1	67.9	69.2	39.5	50.6	63.7	-40.3	-25.4	-7.9
MIROC.ESM	71.0	73.2	74.8	39.9	46.0	52.0	-43.8	-37.1	-30.5
MIROC5	77.7	82.3	86.0	34.9	37.6	40.0	-55.2	-54.3	-53.6
MPI.ESM.LR	67.7	69.1	70.1	53.4	59.4	65.0	-21.1	-14.1	-7.3
MPI.ESM.MR	73.9	78.6	82.6	49.3	52.6	55.4	-33.3	-33.1	-33.0
MRI.CGCM3	73.2	80.9	89.2	44.0	45.9	47.3	-39.9	-43.3	-47.0
NorESM1.M	72.5	76.4	79.6	33.5	36.4	39.0	-53.8	-52.3	-51.0

Appendix 2 – Drainage design flow rate recalculations

Table 38. Recalculation of culvert design water flow due to 20% increase in daily maximum precipitation

№ as per scheme	Location	Hydrographic characteristics			Previously calculated flow		Magnification factor	Estimated flow with an increase in precipitation		Pipe cross section, m	Longitudinal pipe slope,%	Pipe capacity with free-	Reserve capacity in%
		F км²	L км	I°/ₒₒ	1%	2%		1%	2%				
1	0+34,14	0,166	0,82	139	1,51	1,32	1,22	1,84	1,61	2,0x2,0	6	17,8	1105%
2	5+38,13	0,133	0,7	130	1,25	1,1	1,22	1,53	1,34	1,5x1,5	4	15,5	1155%
3	17+92,73	1,45	2,62	157	7,53	6,59	1,22	9,16	8,02	4,0x2,5	11	41	511%
4	20+63,18	0,35	1,36	262	3,00	2,62	1,26	3,78	3,30	4,0x2,5	17	41	1243%
5	25+08,11	0,14	0,93	329	1,37	1,20	1,24	1,70	1,49	2,0x2,0	25	17,8	1195%
6	27+58,13	0,10	0,54	339	1,17	1,02	1,20	1,40	1,22	1,5x1,5	19	15,5	1266%
7	29+30,02	0,34	1,26	271	3,32	2,89	1,15	3,81	3,32	2,0x2,0	5	17,8	536%
8	34+01,22	0,040	0,47	274	0,46	0,4	1,86	0,86	0,75	1,5x1,5	8	15,5	2079%
9	39+80,07	0,06	0,48	454	0,82	0,7	1,20	0,98	0,84	1,5x1,5	25	15,5	1845%
10	42+45,46	0,17	0,65	365	2,14	1,84	1,20	2,57	2,21	1,5x1,5	15	15,5	702%
11	43+95,95	0,10	0,49	404	1,32	1,13	1,20	1,58	1,36	1,5x1,5	22	15,5	1143%
12	47+46,86	0,50	1,12	203	4,83	4,22	1,20	5,80	5,06	1,5x1,5	12	15,5	306%
13	54+88,90	0,259	0,86	276	2,75	2,4	1,20	3,30	2,88	2,0x2,0	9	17,8	618%
14	59+94,54	0,116	0,50	458	1,53	1,32	1,25	1,91	1,65	1,5x1,5	10	15,5	939%
15	66+02,73	0,24	0,80	500	3,05	2,62	1,20	3,66	3,14	2,0x2,0	25	17,8	566%
16	74+34,76	0,053	0,35	743	0,76	0,66	1,20	0,91	0,79	2,0x2,0	25	17,8	2247%
17	76+42,67	0,021	0,20	650	0,35	0,30	1,20	0,42	0,36	1,5x1,5	8	15,5	4306%
18	81+79,22	0,26	0,97	305	2,63	2,30	1,20	3,16	2,76	1,5x1,5	12	15,5	562%
19	83+97,18	0,125	0,580	367	1,46	1,27	1,25	1,83	1,59	1,5x1,5	10	15,5	975%
20	85+73,24	0,025	0,30	466	1,05	0,82	1,30	1,36	1,06	1,5x1,5	19	15,5	1459%
21	88+62,57	0,040	0,31	413	0,53	0,46	1,30	0,69	0,60	1,5x1,5	14	15,5	2600%
22	99+68,05	0,350	0,87	346	4,29	3,63	1,86	7,99	6,76	1,5x1,5	21	15,5	229%
23	103+47,84	0,026	0,20	650	0,40	0,35	1,20	0,48	0,42	1,5x1,5	20	15,5	3690%
24	108+00,50	0,25	0,79	386	3,02	2,59	1,95	5,88	5,05	1,5x1,5	9	15,5	307%
25	112+40,66	0,557	1,35	313	5,86	5,05	1,20	7,03	6,06	2,0x2,0	15	17,8	294%
26	113+13,55	0,706	1,12	384	8,93	7,67	1,86	16,6	14,29	2,0x2,0	17	17,8	125%
27	115+92,82	0,266	0,850	447	3,21	2,78	1,95	6,25	5,42	2,0x2,0	1,6	17,8	329%
28	138+57,01	0,051	0,40	500	0,97	0,59	1,20	1,16	0,71	1,5x1,5	7	15,5	2189%
29	141+76,73	0,390	1,31	325	4,96	4,13	1,25	6,22	5,18	1,5x1,5	8	15,5	299%
30	142+96,95 Degizarango	1,95	2,98	281	12,00	10,3	1,26	15,2	13,0	2,0x2,0	10	17,8	137%
31	146+23,81	0,045	0,30	475	0,64	0,56	1,20	0,77	0,67	2,0x2,0	10	17,8	2649%
32	148+63,99	0,11	0,70	457	0,80	0,69	1,95	1,56	1,34	1,5x1,5	18	15,5	1153%
33	151+02,74	0,035	0,35	400	0,46	0,40	1,20	0,55	0,48	1,5x1,5	20	15,5	3229%
34	154+25	0,27	1,1	390	2,75	2,40	1,20	3,30	2,88	2,0x2,0	10	17,8	618%
35	156+41,69	0,024	0,20	300	0,34	0,30	1,20	0,41	0,36	2,0x2,0	9	17,8	4944%

36	160+61,56	0,23	0,9	360	4,79	3,79	1,20	5,75	4,55	2,0x2,0	7	17,8	391%
37	164+27,93	0,038	0,35	400	0,50	0,43	1,20	0,60	0,52	1,5x1,5	8	15,5	3004%
38	167+71,72	0,050	0,50	480	0,61	0,53	1,25	0,76	0,66	1,5x1,5	8	15,5	2336%
39	170+85,95	4,40	4,06	265	31,80	26,5	1,23	39,22	32,68	4,0x2,5	10	41	125%
40	176+78,21	0,085	0,55	473	1,08	0,94	1,20	1,30	1,13	2,0x2,0	20	17,8	1578%
41	181+61,79	0,090	0,50	520,0	1,14	0,99	1,25	1,43	1,24	1,5x1,5	8	15,5	1253%
42	183+22,59	0,086	0,60	467	1,04	0,91	1,20	1,25	1,09	1,5x1,5	16	15,5	1419%
43	185+14,75	0,024	0,25	560	0,34	0,30	1,20	0,41	0,36	1,5x1,5	16	15,5	4306%
44	188+94,49	0,55	1,43	357	5,17	4,50	1,25	6,48	5,64	2,0x2,0	8	17,8	315%
45	193+39,12	0,20	0,98	362	2,20	1,91	1,20	2,64	2,29	1,5x1,5	16	15,5	676%
46	197+30,27	0,411	1,22	394	4,51	3,88	1,20	5,41	4,66	2,0x2,0	10	17,8	382%
47	201+51,92	0,054	0,40	500	0,71	0,62	1,20	0,85	0,74	1,5x1,5	20	15,5	2083%
48	203+88,45	0,024	0,35	571	0,32	0,28	1,20	0,38	0,34	1,5x1,5	16	15,5	4613%
49	207+84,09	0,411	1,10	490	5,49	4,55	1,39	7,63	6,32	2,0x2,0	8	17,8	282%
50	232+78,45	0,10	0,59	346	1,17	1,02	1,20	1,40	1,22	1,5x1,5	20	15,5	1266%
51	235+92,74	0,130	0,51	445	1,59	1,39	1,25	1,99	1,74	2,0x2,0	20	17,8	1024%
52	237+83,85	0,050	0,32	394	1,23	0,98	1,30	1,59	1,27	1,5x1,5	10	15,5	1220%
53	239+54,78	0,040	0,30	450	0,93	0,74	1,20	1,12	0,89	1,5x1,5	20	15,5	1745%
54	242+00,97	0,050	0,38	550	1,17	0,94	1,20	1,40	1,13	1,5x1,5	8	15,5	1374%
55	243+90,11	0,029	0,25	533	0,66	0,53	1,20	0,79	0,64	1,5x1,5	20	15,5	2437%
56	249+68,79	0,01	0,10	500	0,16	0,14	1,21	0,19	0,17	1,5x1,5	15	15,5	9177%
57	251+26,44	0,023	0,13	800	0,38	0,33	1,21	0,46	0,40	1,5x1,5	10	15,5	3893%
58	261+57,16	2,10	2,35	290	37,90	29,8	1,20	45,5	35,8	(4.0x2.5)x2	5	65,6	183%
59	267+40,96	0,025	0,20	850	0,62	0,5	1,20	0,74	0,60	1,5x1,5	8	15,5	2583%
60	268+94,67	0,059	0,40	500	1,24	0,99	1,20	1,49	1,19	1,5x1,5	8	15,5	1305%
61	271+74,10	0,031	0,30	535	0,66	0,52	1,30	0,86	0,67	1,5x1,5	5	15,5	2300%
62	272+30,08	0,025	0,23	620	0,62	0,49	1,20	0,74	0,59	1,5x1,5	3	15,5	2636%
63	272+98,36	0,044	0,25	720	0,68	0,59	1,20	0,82	0,71	1,5x1,5	1,5	15,5	2189%
64	276+23,35	0,31	1,28	336	5,41	4,29	1,20	6,49	5,15	4,0x2,5	10	41	796%
65	279+71,26	0,10	0,61	367	2,09	1,66	1,25	2,62	2,08	2,0x2,0	5	17,8	855%
66	281+82,22	0,10	0,56	355	2,18	1,72	1,20	2,62	2,06	1,5x1,5	8	15,5	751%
67	284+16,09	0,27	0,91	377	7,51	5,88	1,26	9,44	7,39	1,5x1,5	8	15,5	210%
68	285+51,13	0,26	1,11	378	6,65	5,22	1,24	8,26	6,48	1,5x1,5	10	15,5	239%
69	290+23,46	0,10	0,75	348	4,36	3,13	1,20	5,23	3,76	1,5x1,5	7	15,5	413%
70	294+03,54	0,10	0,68	847	5,45	3,83	1,20	6,54	4,60	1,5x1,5	5	15,5	337%
71	299+48,47	0,12	0,97	589	5,36	3,79	1,26	6,75	4,78	2,0x2,0	10	17,8	373%
72	300+23,56	0,58	1,08	537	18,3	12,9	1,95	35,65	25,13	4,0x2,5	10	41	163%

Table 39. Recalculation of roadside ditches water flow design due to 20% increase in daily maximum precipitation

Comparison of the design water flow due to an increase in precipitation by 20%, open cut drainage (section - 1)

№ п.п	Drainage locations (ПК)		Section length, m	Design flow, м3/с	Calculation with the increase in flow rate by 20%, м3/с	Drainage carrying capacity, м3/с	Capacity benefit, %
	from the left	from the right					
1	0+50,00 - 1+79,87		173	0.13	0.16	0.62	397%
2		1+94,94 - 5+39,98	344	0.25	0.3	1	333%
3		5+39,98 - 17+00,00	1048	0.76	0.91	4.09	448%
4	10+60,05 - 17+35,10		632	0.84	1.01	4.5	446%
5	17+89,98 - 20+35,07		246	0.18	0.22	0.96	444%
6		18+60,00 - 20+50,00	188	0.14	0.17	0.96	571%
7	20+81,98 - 21+95,11		120	0.17	0.2	3.32	1627%
8	26+32,37 - 27+62,78		124	0.18	0.22	1.84	852%
9	27+62,78 - 29+36,52		176	0.25	0.3	4.28	1427%
10	29+36,52 - 33+69,98		356	0.51	0.61	2.03	332%
11	34+35,18 - 39+79,94		544	0.78	0.94	1.66	177%
12	39+79,94 - 42+47,06		242	0.26	0.31	5.7	1827%
13	42+47,06 - 43+85,01		147	0.21	0.25	8.12	3222%
14	44+19,98 - 47+60,05		350	0.38	0.46	0.96	211%
15	47+70,05 - 54+54,97		672	0.49	0.59	4.32	735%
16	55+44,98 - 59+74,97		430	0.31	0.372	0.72	194%
17	60+19,97 - 65+99,32		536	0.39	0.468	0.81	173%
18	65+99,32 - 74+29,90		838	0.91	1.09	1.12	103%
19	74+54,50 - 76+41,48		191	0.28	0.34	1.67	497%
20	78+26,50 - 81+79,09		315	0.34	0.41	0.43	105%
21	81+79,09 - 84+15,34		234	0.34	0.41	0.57	140%
22	84+15,34 - 85+74,90		180	0.26	0.31	0.65	208%
23	85+74,90 - 88+61,93		288	0.42	0.5	0.82	163%
24	88+61,93 - 99+20,00		1040	0.75	0.9	1.37	152%
25	99+89,98 - 103+47,21		343	0.5	0.6	1.41	235%
26	103+47,21 - 107+98,59		444	0.32	0.38	0.73	190%
27	107+98,59 - 112+41,25		452	0.33	0.4	0.73	184%
28		114+72,48 - 115+89,10	160	0.69	0.83	0.96	116%

Comparison of the design water flow due to an increase in precipitation by 20%, open cut drainage (section - 2)							
№ п.п	Drainage locations (ПК)		Section length, m	Design flow, м3/c	Calculation with the increase in flow rate by 20%, м3/c	Drainage carrying capacity, м3/c	Capacity benefit, %
	from the left	from the right					
1	131+95,27 - 134+89,63		302	0.65	0.78	1.02	131%
2	136+10,40 - 138+56,99		249	0.72	0.86	2.3	266%
3	138+56,99 - 141+77,49		319	0.46	0.55	0.91	165%
4	141+77,49 - 142+75,04		100	0.14	0.17	1.14	679%
5	143+27,81 - 145+11,73		260	0.75	0.9	0.86	96%
6	146+21,92 - 148+61,17		251	0.72	0.86	0.93	108%
7	148+61,17 - 151+3,05		230	0.66	0.79	1.22	154%
8	151+3,05 - 154+24,55		338	0.49	0.59	1.17	199%
9	154+24,55 - 156+4,93		184	0.53	0.64	1	157%
10	156+75,93 - 160+29,93		351	0.51	0.61	1.34	219%
11	160+84,92 - 164+26,45		343	0.5	0.6	1.34	223%
12	164+26,45 - 167+68,41		338	0.98	1.18	6.16	524%
13	167+68,41 - 170+29,90		264	0.76	0.91	1.17	128%
14	170+89,90 - 176+78,55		582	2.52	3.02	5.6	185%
15	176+78,55 - 181+61,85		470	1.01	1.21	2.94	243%
16	181+61,85 - 183+23,45		165	0.71	0.85	1.05	123%
17	183+23,45 - 185+22,23		200	0.87	1.04	2.85	273%
18	185+22,23 - 188+94,58		371	1.6	1.92	2.23	116%
19	188+94,58 - 193+42,48		450	1.94	2.33	4.8	206%
20	193+42,48 - 197+24,80		382	1.65	1.98	2.01	102%
21	197+34,80 - 201+52,24		408	1.77	2.12	4.17	196%
22	201+52,24 - 203+86,85		233	1.01	1.21	2.1	173%
23	203+86,85 - 207+84,79		414	0.45	0.54	0.4	74%
24		209+89,78 - 212+7,25	224	0.97	1.16	3.61	310%

Comparison of the design water flow due to an increase in precipitation by 20%, open cut drainage (section - 3)

№ п.п	Drainage locations (ПК)		Section length, m	Design flow, м3/с	Calculation with the increase in flow rate by 20%, м3/с	Drainage carrying capacity, м3/с	Capacity benefit, %
	from the left	from the right					
1	232+51,17 - 235+79,98		318	1.38	1.66	6.58	397%
2	235+85,30 - 237+93,05		205	0.89	1.07	2.8	262%
3	237+93,05 - 239+59,96		170	0.74	0.89	8.8	991%
4	239+59,96 - 242+1,30		244	1.06	1.27	2.9	228%
5	242+1,30 - 243+89,82		194	0.84	1.01	3.07	305%
6	243+89,82 - 249+69,03		566	2.04	2.45	2.9	118%
7	249+69,03 - 251+27,40		167	0.72	0.86	3.07	355%
8	251+27,40 - 261+19,91		961	2.08	2.5	2.13	85%
9	261+84,90 - 267+41,97		553	2.4	2.88	4.9	170%
10	267+41,97 - 268+94,84		143	0.62	0.74	2.85	383%
11	268+94,84 - 270+14,87		122	0.53	0.64	2.85	448%
12	276+20,99 - 279+49,85		368	1.59	1.91	2.52	132%
13	279+69,81 - 281+82,06		206	0.89	1.07	4.18	391%
14	281+82,06 - 284+15,93		206	0.89	1.07	2.96	277%
15		289+65,43 - 299+0,08	904	3.9	4.68	7.46	159%
16	297+14,75 - 299+9,83		204	0.88	1.06	3.87	366%
17		300+84,83 - 302+16,59	132	0.57	0.68	3.05	446%