CLIMATE CHANGE ASSESSMENT AND MANAGEMENT

I. Basic Project Information

Project Title	Viet Nam: Northern Mountain Provinces Transport Connectivity Project
Project Budget	$200 million
Locations	Lao Cai, Lai Chau and Yen Bai Provinces in the Northwestern region of Viet Nam
Sector **Subsector**	Transport Road Transport (non-urban)
Strategic Agenda **Subcomponents**	Inclusive economic growth (IEG), Regional integration (RCI). Pillar 1: Cross-border infrastructure; Pillar 2: Access to economic opportunities, including jobs, made more inclusive; Pillar 4: Other regional public goods

Brief Description of the Project

The project aims to improve transport connectivity of underdeveloped provinces of Northwestern Viet Nam. This project expands the benefits of Greater Mekong Subregion (GMS) corridors to adjacent provinces with high poverty incidence.[1] The project comprises upgrading of 2 National Highways (NH32 and NH279) and one provincial road (PR175) to enhance connectivity of provinces in the Northwestern Region. These roads are in the northwestern mountains of Viet Nam and provide a connection to the Noi Bai–Lao Cai (NBLC) expressway. The project will also support the Department of Roads Viet Nam (DRVN) of the Ministry of Transport (MOT) in road asset management; and promote traffic safety through traffic safety audits and traffic safety awareness raising campaigns. The project will be financed through a project loan modality.

The project roads will be upgraded to higher class standard. NH279 and NH32 will be upgraded from class IV mountainous roads to class III mountainous roads (with exception of 14km of NH279 which will be retained at class IV or lower to avoid negative impacts on a provincial nature reserve). PR175 will be upgraded from lower than class V mountainous roads to class IV mountainous roads. 182 km of road improvement works (i.e. more than 90%) will be along the existing road alignment and will involve rehabilitation/upgrade works only. However, the project proposes 3 partial road re-alignments, or by-passes in Duong Quy, Minh Luong and Bang Bo-Dong Pao for a total of 15km. These are necessary to avoid congested village centers to improve traffic safety and minimize resettlement. The project will also include rehabilitation of 35 bridges, and the construction of 13 new bridges. All bridge clearances will be designed to account for increased runoff projected from climate change (2050 projections). A more detailed description of the project scope is presented in the environmental impact assessment.[2]

II. Climate Change Trends and Projections

A. Climate Variability (Historic Trends) in Northern Viet Nam

In the period of 1958-2014, temperatures show increasing trends in most areas of Viet Nam. The annual average temperatures increased by about 0.62°C for the whole country, (about 0.10°C/decade). Daily maximum and minimum temperatures show increasing trends with the highest rate of up to 1°C/decade. The number of hot days (days with T ≥35°C) increased in most regions of the country, especially in the Northeast, the Northern Delta and the Central Highlands

[1] The poverty incidence in the Lao Cai, Lai Chau and Yen Bai provinces ranges from 12% to 23%, significantly above the national poverty rate of 6%, and ethnic minorities account for more than 65% of the population.

[2] Accessible through the list of Supplementary Appendixes.

with an increase of about 2-3 days/decade; while the number of hot days decreased in some stations in the Northwest, South Central and the South. Annual rainfall had decreasing trends in the northern regions (5.8%-12.5% over 57 years). Extreme rainfall trends varied between climate zones, decreasing in most stations in the Northwest and Northeast. The number of typhoons and tropical depressions in the East Sea that directly affected or made landfall in Viet Nam show little change in the 57-year period. However, the number of strong typhoons (maximum sustained winds of 33 m/s or higher) had a slight upward trend in recent years.

B. Climate Change Projections in the Project Area

For the climate change scenarios, the period of interest is mid-21st century (2041-2060). Under future climate conditions, monthly total and daily maximum rainfall and maximum/minimum daily temperatures are projected to increase across the region. The projected increases under RCP8.5 are greater than those under RCP4.5.

The results for changes to mean monthly precipitation totals projected by the different GCM/RCMs suggest a high degree of uncertainty (both in the magnitude and direction of change and also in the seasonality of the changes). However, results suggest some consensus that the May/June and November/December (i.e. pre- and post- the traditional July to October wet season months) will be wetter. This is true for both RCP4.5 and RCP8.5, with the magnitude of May precipitation increase possibly up to 59-61%, and the magnitude of December precipitation increase possibly up to 173%-208%. Similarly, results show some consensus that January to April will be drier, with projections suggesting monthly precipitation decreases greater than 60% for some months in the January to April period.

The projected changes to daily precipitation maximums are very uncertain – even more so than changes to mean monthly precipitation totals. However, as with projected changes to mean monthly precipitation totals, results show consensus for the months just before and just after the traditional wet season (July to October) to experience greater daily precipitation maximums. This is true for both RCP4.5 and RCP8.5 and is especially clear for December where projections consistently suggest daily precipitation maximums greater than 1.5-2 times what is experienced historically (refer to Appendix 2 for more details). Potential for such drastic increases to already problematic extreme precipitation is obviously a concern, however, results also show numerous cases where daily precipitation maximums during the rainy season are projected to decrease (sometimes by more than half what they are currently/historically).

The projected increases in temperature are far more certainty than those for rainfall. The CRVA concludes that it is very likely, under both RCP4.5 and RCP8.5, that mean maximum daily temperature will increase across the project area for all months of the year. The range of projected changes in maximum daily temperatures varies from, on average, 0.2-2.7°C for RCP4.5 and 1.1–3.1°C for RCP8.5 (“pessimistic”).

III. Climate Risk, Vulnerability and Impact Assessment (Project Area)

A. Climate risk classification as per AWARE – HIGH

The AWARE tool rated the overall climate-related risk as high. This high-risk rating is mainly because of high risks associated with flooding, landslide/rockfall, and wildfire. Aware has identified medium risks related to projected temperature and precipitation increases. The AWARE risk screening is included in Appendix 1.

B. CRVA methodology

The CRVA was conducted in 5 steps. The first step consisted of collecting and reviewing relevant hydroclimatic data and information. This included historical data as well as downscaled climate change scenario data for Viet Nam, especially the northern mountains region of Viet Nam, which was needed to understand how climate-related hazards, risks and vulnerabilities might change in the future. Sources of historical hydroclimatic data and future hydroclimatic scenarios explored included the Viet Nam Center of Hydro-Met and the Viet Nam Institute of Meteorology, Hydrology and Climate Change (IMHEN). The recently released (January 2017) climate change and sea level rise scenarios for Viet Nam were also used. For the historical data, an analysis of all available hydroclimatic data was conducted to assess existing variability and risks associated with the ~1950-2011 baseline period. For the climate change scenarios, the period of interest is mid-21st century (2041-2060). Uncertainty associated with future climate change projections was accounted for by considering outputs from different climate models and emissions scenarios, referred to as Representative Concentration Pathways (RCPs) for the Intergovernmental Panel on Climate Change's (IPCC's) Fifth Assessment Report (AR5). The two emission scenarios used in this CRVA are RCP4.5 to represent an "optimistic" future and RCP8.5 to represent a "pessimistic" future. This CRVA also needed climate change scenario information to be representative of the different climate patterns that exist across the provinces that contain the NH32/NH279 and PR175 roads. This necessitated some form of downscaling due to the coarse resolution of the original General Circulation Model outputs. Therefore, downscaled climate change scenario data was obtained from CORDEX (Coordinated Regional Climate Downscaling Experiment, http://www.cordex.org/).

The second step involved the preparation and interpretation of the historical and future hydroclimatic data collected in Task 1 such that it is relevant to the purposes of this CRVA. The focus here was on preparing data, and associated maps, for variables required to quantify and better understand the hazards and "high climate-related risks" identified by the AWARE rapid climate screening (i.e. flooding, landslide/rockfall and wild fire). Thematic layers of topography, slope aspect, slope angle, stream density, land use/land cover (LULC), lineament density, and soil were used. Elevation, slope aspect and slope angle were derived from a DEM with 50 m x 50 m horizontal spatial resolution. LULC was derived from the official land use map made by provincial authorities in 2015. Stream density was captured from the provincial topographic map. The scale of thematic maps was designed at 1:100,000. All collected data was converted to a raster grid with 30 m x 30 m cell.

In step 3, an assessment of existing climate-related hazards, risks and vulnerabilities along the project roads was conducted. The assessment followed the World Bank guidelines on Climate and Disaster Risk Screening (http://climatescreeningtools.worldbank.org/) and involved: (i) identification of where/when climate-related hazards exist for the upgrade of NH32/NH279 and PR175. A multi-criteria decision analysis (MCDA) based geospatial approach was applied to prepare thematic hazard maps (i.e. flood, landslide/rockfall, wild fire) – see Appendix 2 for details; (ii) using information gained from site visits, literature review, statistical analysis, and consultation with PPTA consultants and other stakeholders, classification of likelihood and severity of impacts on the project from the climate-related hazards ; (iii) classification of level of existing risk associated with each climate-related hazard; (iv) estimation of existing vulnerability, using the risk assessments and information about the capacity to adapt to the identified climate-related risks.

In step 4, an assessment of future climate-related hazards, risks and vulnerabilities for the project was conducted. The hazard, risk and vulnerability mapping process developed in step 3 were applied under climate conditions for RCP4.5 and RCP8.5 for 2041-2060. The outputs were then

compared with the outputs from step 3 to quantify if/how/where/when the climate-related hazards, risks and vulnerabilities could change in the future.

The aim of step 5 was to identify adaptation options that potentially could mitigate the existing or future vulnerabilities identified in steps 3 and 4. The identification of structural and non-structural adaptation options was informed by the results emerging from steps 1-4 and via ongoing stakeholder consultation. The identified adaptation options were weighed against each other in a qualitative sense to assist in identifying and prioritizing the most appropriate adaptation measures. The likelihood of different climate change impacts, based on current conditions and projected future trends, was also considered when assessing the most appropriate adaptation options. A second site visit was conducted (30-31 October 2017) to verify and provide further on-the-ground information about, the risks, vulnerabilities and adaptation options identified in steps 1-5.

C. Climate Risk Classification as per detailed assessment – HIGH

The implications of the projected changes in monthly precipitation totals and daily precipitation maximums for the project roads (NH32, NH279 and PR175) are similar. That is, for the climate-related hazards, there is an increased risk (likelihood and magnitude of impacts) of flooding, landslides and rockfalls in the July to October wet season and an increased risk of wildfire from January to April. The implication of the projected increases in maximum daily temperatures is an increased risk of wildfire in the dry/hot months between December to April.

High flood risk. The CRVA concludes that NH32 and NH279 contain three zones with a High-Risk rating for flood hazards. These flood prone zones are the low elevation areas near the Nam Chan River and a high density of smaller streams in Tan Thuong, Son Thuy, and Phuc Than communes (Van Ban district); Tan Uyen Town; Pac Ta and Phuc Khoa communes (Tan Uyen district); and the Ban Bo and Binh Lu communes (Tam Duong district). PR175 contains two zones with a High-Risk rating for flood hazards. These are the An Thinh and Mo Vang communes in the Van Yen District.

High landslide risk. For NH32 and NH279, a High-Landslide-Risk rating was found for Tan Thuong, Son Thuy, Hoa Mac communes (Van Ban district); Tam Duong district; and Tan Uyen district. PR175 was found to have High-Landslide-Risk rating in Suoi Quyen and An Luong communes. In these locations, landslides are triggered by the steep, thinly vegetated slopes and regular heavy precipitation events.

High rockfall risk. For PR175 the stretch of road between Km40 to Km41 is associated with a High-Risk rating for rockfall hazards. For NH32 and NH279, a High-Risk of rockfall is identified for the area mainly located in Son Thuy commune (Van Ban district).

High wildfire risk. For NH279, a High-Risk rating for wildfire hazard is found in the northeast of Van Ban district. For PR175, the risk of wildfire hazard is rated as High along most of the road.

IV. Climate Risk Management Response (Adaptation Measures) within the Project

A. Contribution of the project to National Climate Resilience Plans

In October 2016, Viet Nam published its Plan for Implementation of the Paris Agreement, articulating its NDC. Covering the period 2016-2030, this Plan highlights Viet Nam's NDC as comprising two main objectives: mitigation of greenhouse gas (GHG) emissions, and strengthening the countries adaptation to climate change impacts. In terms of adaptation to climate change, Viet Nam committed to continue implementing programs and projects to adapt

to climate change within the scope of the National Climate Change Strategy (2011), aimed at improving resilience and protecting citizens' lives and livelihoods.

The project will directly contribute to the following targets of the National Climate Change Strategy: (i) to modernize the nationwide transport network; and (ii) to take measures to prevent and cope with natural disasters, flash floods and landslides in mountain areas.

B. Contribution of the project to enhanced climate resilience

Through detailed site surveys, the CRVA team identified a total of 30 sites most vulnerable to the identified climate-related risks (so-called "hot spots"). Flood and landslides were the most common hazard types. For NH32 and NH279, 11 climate-related vulnerability "hot spots" were identified. Most of this vulnerability is associated with flooding due to the low elevation of the roads and frequent high-water levels experienced in the nearby Nam Chan River. For PR175, 19 climate-related vulnerability "hot spots" were identified. The biggest concern is about landslides and floods associated with high water levels in the Ngoi Thia River. The list of "hot spots" is presented in Appendix 3.

A preliminary assessment of various potential adaptation options unique to this project setting (including those already in practice) was made. This preliminary list of potential adaptation options was then verified and further informed by site visits and discussions with PPTA consultants and local stakeholders. The final list of potential adaptation options identified against the relevant climate vulnerabilities for all identified hot spots, including structural and non-structural measures, have been shared with the PPTA consultants. These are presented in Appendix 3, and principally include:

For landslide and flood risks: (i) cross-section design adjustments (including slope gradient reduction, step cuts); (ii) various slope protection approaches; (iii) increase of road centerline elevation; (iv) construction of new bridges over flood-prone areas; (v) capacity increase of drainage structures and culverts; (vi) maintaining or strengthening vegetation cover along steep slopes; and (vii) partial horizontal re-alignment of road.

For wildfire risk: (i) strengthening of fire monitoring and alert system; and (ii) fire protection by provision of separation bands.

In addition, the CRVA team reviewed the daily rainfall data that was used to establish design specifications (e.g. IFD curves, peak flow height/volume, bridge heights, drainage systems, size of culverts etc.). The daily rainfall data and associated IFD curves were adjusted to factor in the climate change scenario information presented in the CRVA report. The adjusted (climate proofed) IFD curves and design rainfalls will be used by the detailed design consultant (DD consultant) to re-evaluate road engineering and design specifications and subsequently determine what changes to the road design or route, or what extra or alternative adaptation strategies, are required.

V. Adaptation Finance

Per Viet Nam design codes, transport infrastructure must be designed at the outset to be resilient to the impacts of present-day climate extremes. Adaptation financing thus covers the incremental investment to ensure that project infrastructure is resilient to projected climate conditions, rather than present-day climate variability.

Exact cost estimates of climate-proofing of the project roads could not be established at preliminary design stage given the lack of accurate information on proposed road elevation, slope protection works, bridges locations and apertures, lateral drainage and culverts, among others.

To avoid over-reporting of climate finance, a conservative approach was applied. Climate adaptation costs for climate adaptation of the project are estimated to amount to $10 million. Incremental costs for climate-proofing will result from adjustments to bridge design and aperture (5% of total bridge construction costs, or $1 million); increase of cross drainage density and capacity (25% of total drainage costs, or $1 million); and adoption of more resilient slope protection approaches (50% of total slope stabilization costs, or $8 million). [3] These costs will be covered through the project loan. Exact cost estimates will be established at detailed design stage.

VI. GHG Emissions and Reduction Benefit Assessment

A. Approach for Computing GHG emissions

GHG emissions of the project were estimated for both the construction phase and the operation phase. GHG emissions during construction were estimated based on the Transport Emissions Evaluation Model for Projects (TEEMP) tool developed by CleanAir Asia, and average values for highways and provincial roads recommended by ADB and the World Bank.

The project's total incremental GHG emissions during operation were assessed based on the traffic forecast prepared in the framework of the project's economic analysis (which differentiates traffic forecasts by road section, and by vehicle type), and as the difference between the no-project and the project-alternatives (i.e. total traffic minus normal traffic) using HDM-4 Version 2.

B. GHG Emissions during Construction

The construction and improvements of the roads will generate significant amounts of Greenhouse Gas (GHG) emissions through (i) the extraction/production of construction materials, (ii) their transport and (iii) the consumption of engines used for their laying.

Based on the references mentioned above, total GHG gas emissions during construction are projected to be in the lower range of 207-794 tons of CO2eq per kilometer of road construction. With a total length of 197 km, the construction/upgrade of the proposed roads is expected to generate 40,000 to 156,000 tons of CO2eq during the entire construction period, or some 13,600 to 52,200 tons of CO2eq per year (assuming a construction period of 3 years).

Earthwork/material extraction and pavement are the biggest contributors to GHG emissions (50-70%). Material transport is also a significant GHG producer, with around 25% for highways. Culverts, structures and other auxiliary facilities contribute some 10-15% of the total GHG emissions.

C. GHG Emissions during Operation

Absolute CO2eq emissions for the baseline year (2018) were estimated based on actual traffic counts and amount to 41,323 tons per year. These absolute CO2eq emissions are anticipated to increase to 69,678.5 tons per year (2031) and 104,252.7 tons per year (2041). These figures represent the sum of normal traffic (i.e. traffic that would use the project roads even if no improvements were made); diverted traffic (i.e. traffic that changes from an original route to the project road because of the road improvement); and generated traffic (i.e. traffic that occurs only because of the improvement to the roads, due to the reduction in perceived costs).

[3] Slope protection works in Viet Nam are traditionally very rudimentary (minor stabilization of slopes). The project will support state-of-the-art slope stabilization works to address the high risk of landslides and embankment collapses identified in the CRVA.

The sum of diverted plus generated traffic thus represents the relative or net CO_2eq emissions, i.e. the net increase in CO_2eq emissions generated by the project as compared to “business as usual” or “without project”. For the period 2021-2041 (20 years), the cumulative net CO_2eq emissions are estimated at -35,400 tons, representing an average annual emission reduction of approximately 2,000 tons as compared with the no-project alternative. This (very modest) net decrease in CO_2eq emissions, despite a net increase in total traffic, is considered plausible given the improved road standard and smoothness, reduced travel distances (from improved connectivity), and reduced travel durations.

VII. GHG Emissions and Reduction Benefit Assessment

The project does not contribute to GHG mitigation finance.

RESULTS OF AWARE RAPID CLIMATE RISK SCREENING (EXCERPT)

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Aware for Projects

01 Introduction

This report summarizes results from a climate risk screening exercise. The project information and location(s) are detailed in Section 02 of this report.

The screening is based on the Aware™ geographic data set, compiled from the latest scientific information on current climate and related hazards together with projected changes for the future where available. These data are combined with the project's sensitivities to climate variables, returning information on the current and potential future risks that could influence its design and planning.

Project Information

PROJECT NAME:	GMS Corridor Connectivity Enhancement Project
SUB PROJECT:	Mountainous road (NH32/NH279 and PR175) upgrading
REFERENCE:	50098
SECTOR:	Rural transport infrastructure
SUB SECTOR:	Road/ highway/ runway surface

DESCRIPTION: The indicative Project roads include: (1) Upgrading of National Highway (NH) NH14D in Quang Nam province (75 km) - mountainous road class III; (2) upgrading of NH32 and NH279 connecting Lai Chau province to NBLC (137 km) - mountainous road class III, including 1.9 km tunnel; and (3) upgrading PR175 enhancing connectivity of Yen Bai province to NBLC (52 km) - mountainous road class IV.

02 Chosen Locations

1) Vietnam
2) Vietnam
3) Vietnam
4) Vietnam
5) Vietnam
6) Vietnam
7) Vietnam
8) Vietnam

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Aware for Projects

03 Project Risk Ratings

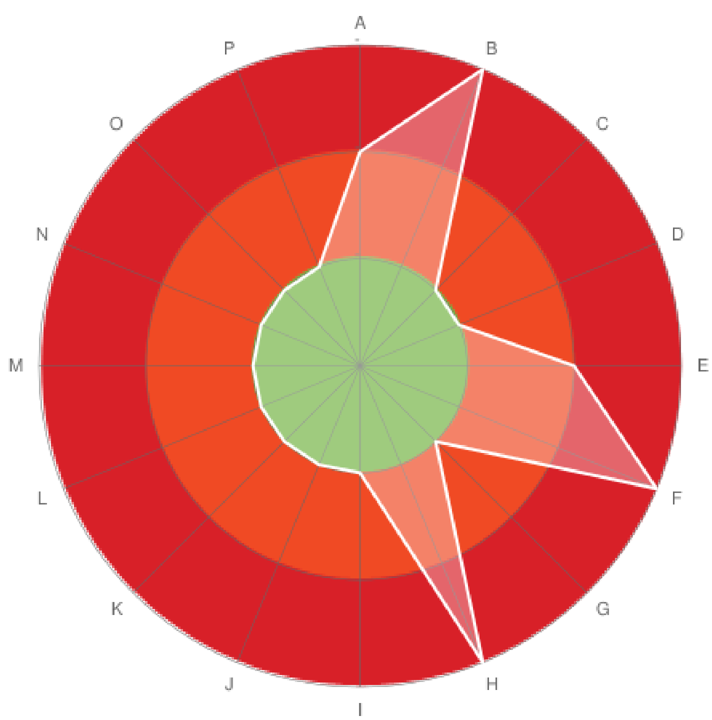
Below you will find the overall risk level for the project together with a radar chart presenting the level of risk associated with each individual risk topic analyzed in Aware™. Projects with a final "High risk" rating are always recommended for further more detailed climate risk analyses.

The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing and possible future climate conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage current and future climate change risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project risk ratings

High Risk



A) Temperature increase
B) Wild fire
C) Permafrost
D) Sea ice
E) Precipitation increase
F) Flood
G) Snow loading
H) Landslide
I) Precipitation decrease
J) Water availability
K) Wind speed increase
L) Onshore Category 1 storms
M) Offshore Category 1 storms
N) Wind speed decrease
O) Sea level rise
P) Solar radiation change

DIFFERENCE BETWEEN CURRENT (1986-2005) AND FUTURE (2041-2060) CLIMATE VARIABLES

Figure A2.1: Difference between current (1986-2005) and future (2041-2060) mean monthly precipitation totals under the RCP4.5 ("optimistic") climate change scenario (projections from GFDL-CM3 downscaled using CSIRO-CCAM)

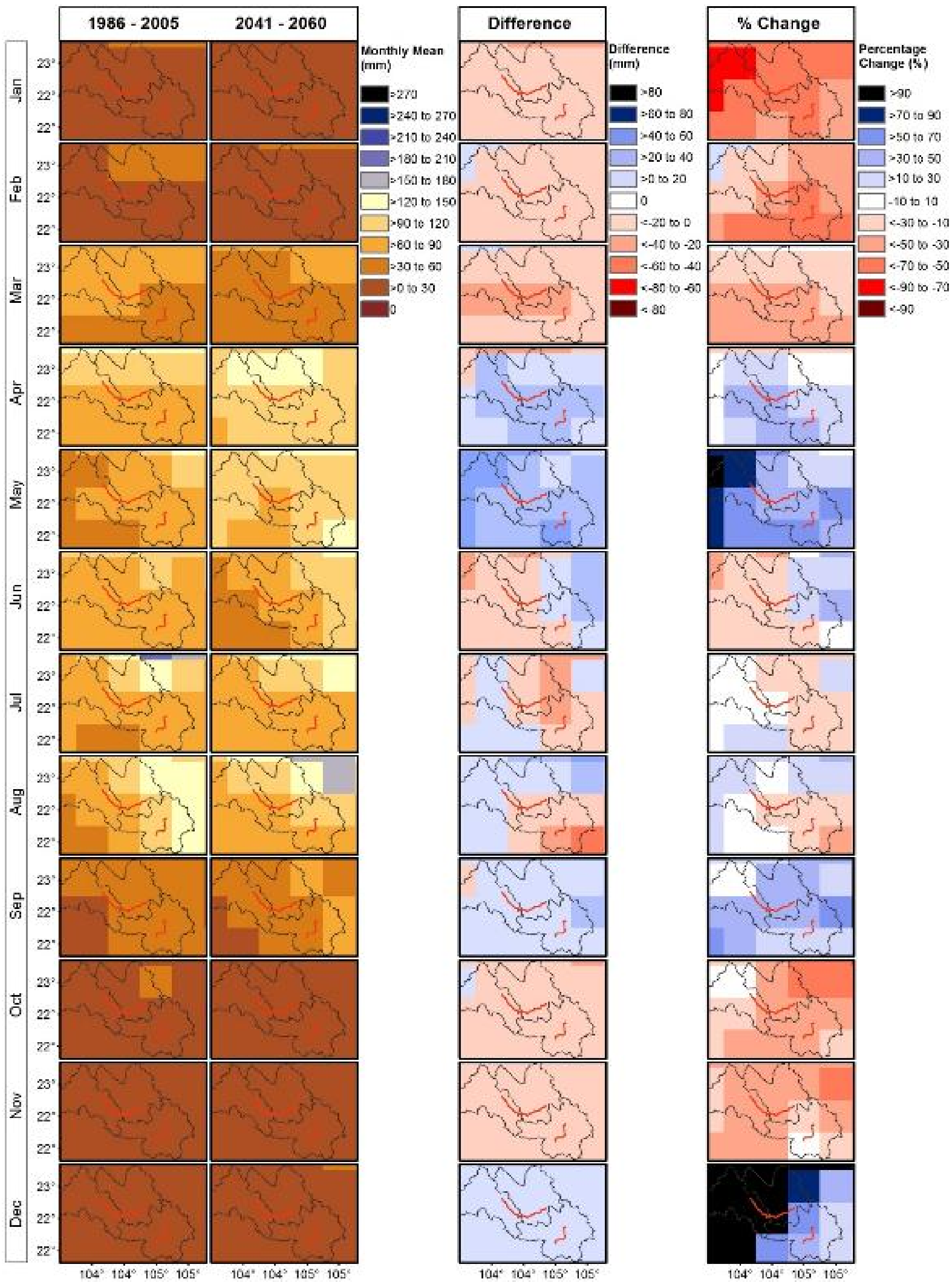


Figure A2.2: Difference between current (1986-2005) and future (2041-2060) <u>mean monthly precipitation totals</u> under the RCP8.5 ("pessimistic") climate change scenario (projections from GFDL-CM3 downscaled using CSIRO-CCAM)

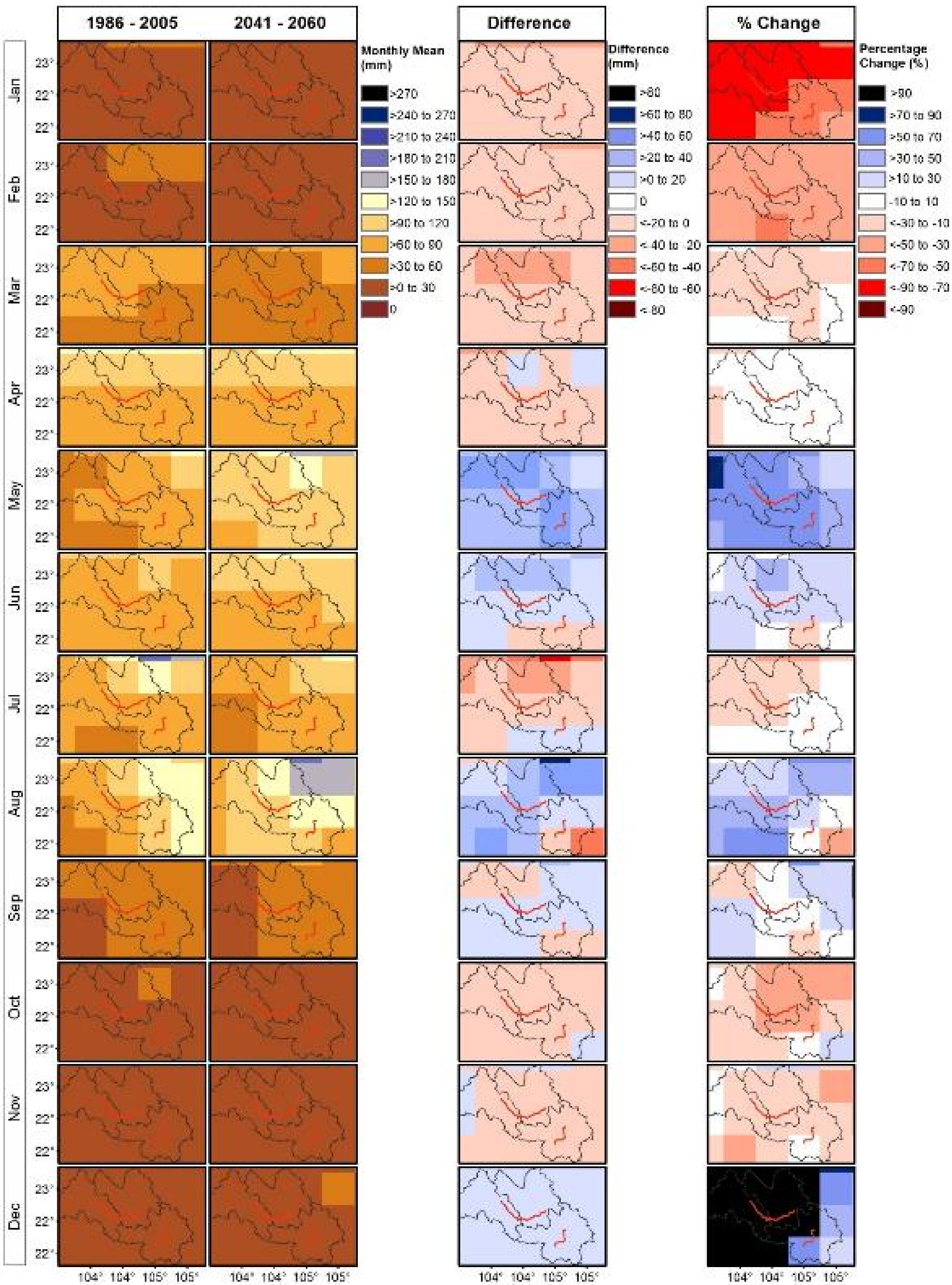


Figure A2.3: Difference between current (1986-2005) and future (2041-2060) <u>daily precipitation maximums</u> within each month under the RCP4.5 (“optimistic”) climate change scenario (projections from GFDL-CM3 downscaled using CSIRO-CCAM)

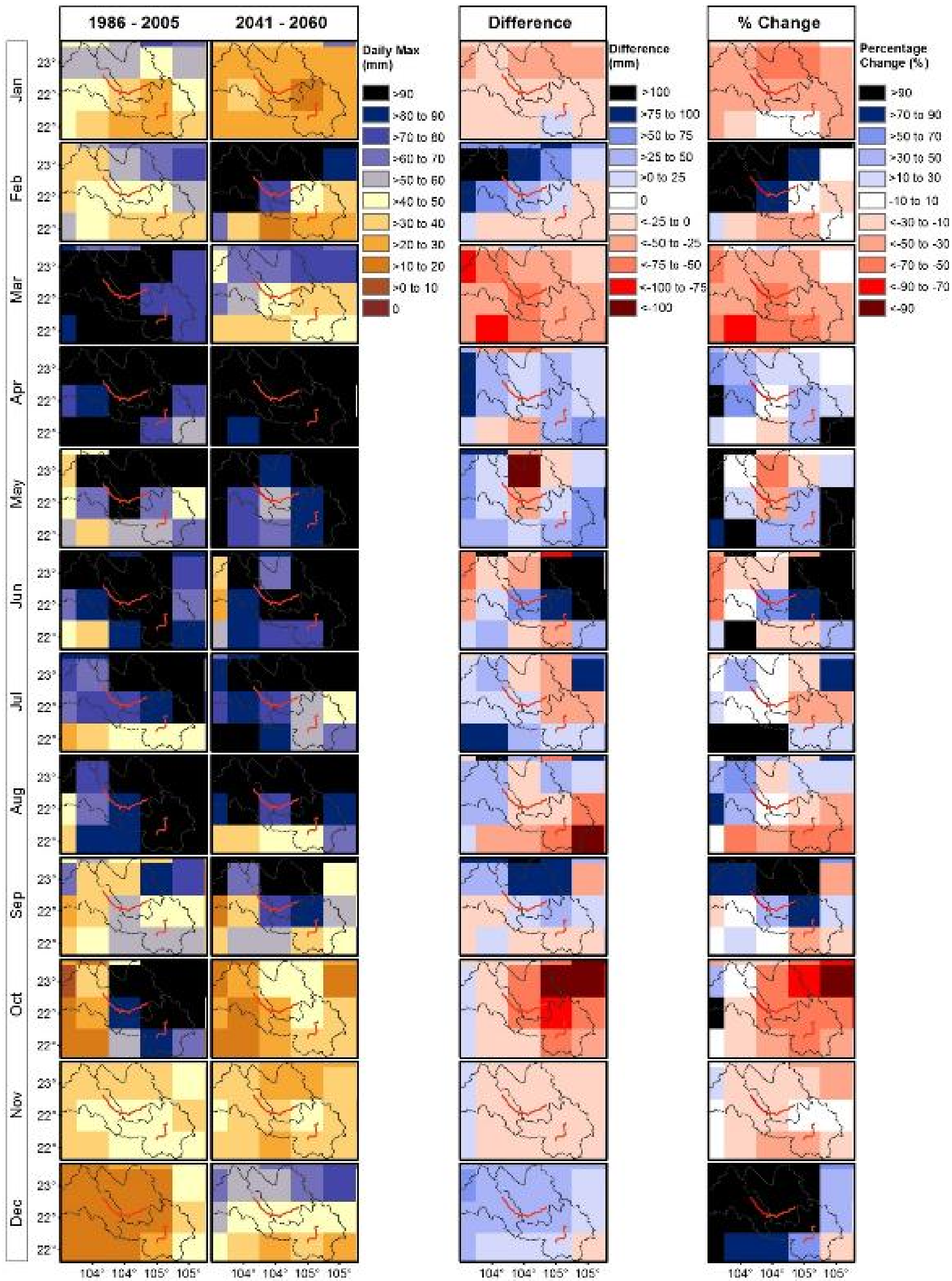


Figure A2.4: Difference between current (1986-2005) and future (2041-2060) <u>daily precipitation maximums</u> within each month under the RCP8.5 ("pessimistic") climate change scenario (projections from GFDL-CM3 downscaled using CSIRO-CCAM)

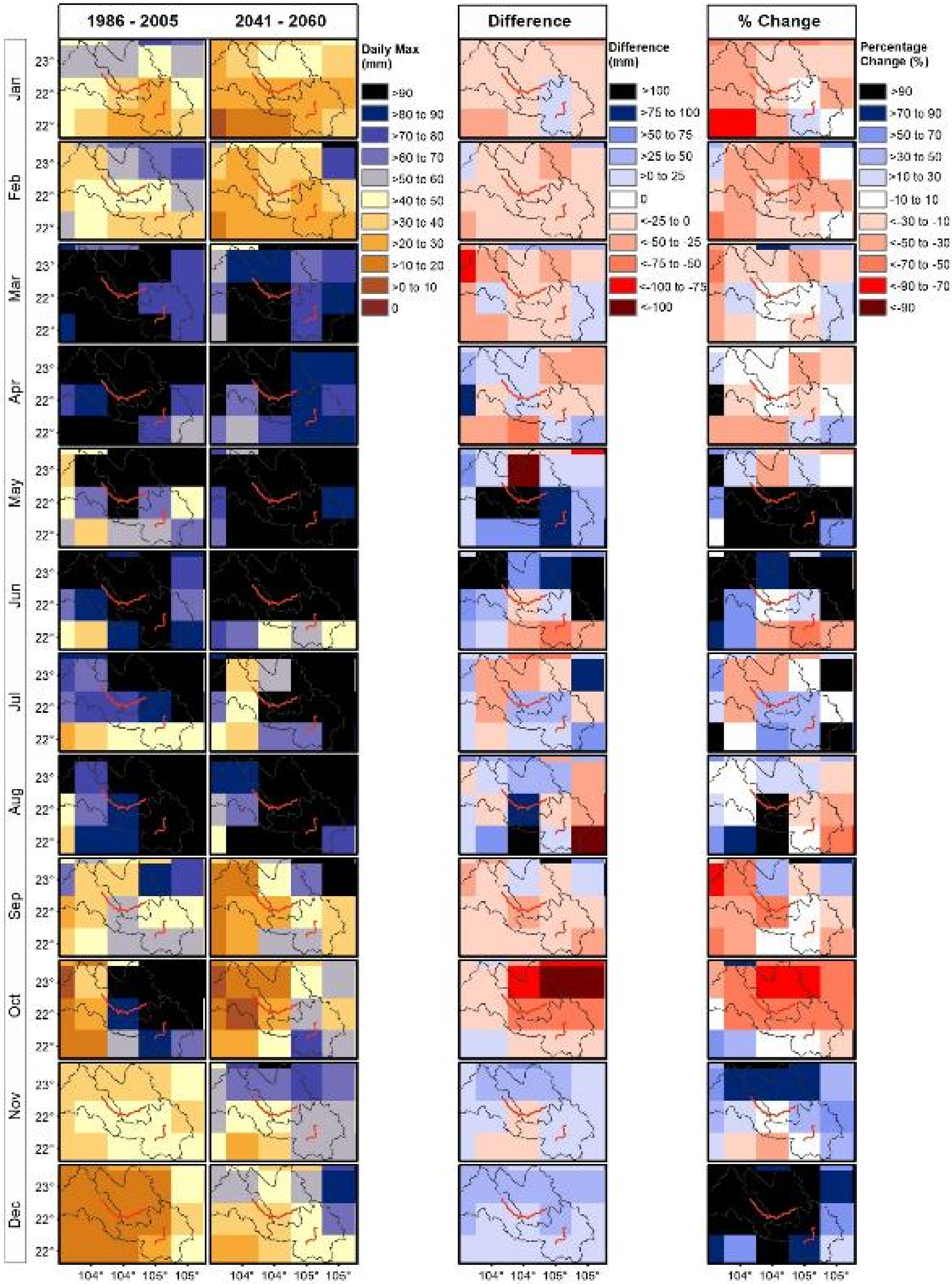


Figure A2.5: Difference between current (1986-2005) and future (2041-2060) <u>mean maximum daily temperature</u> within each month the RCP4.5 (“optimistic”) climate change scenario (projections from GFDL-CM3 downscaled using CSIRO-CCAM)

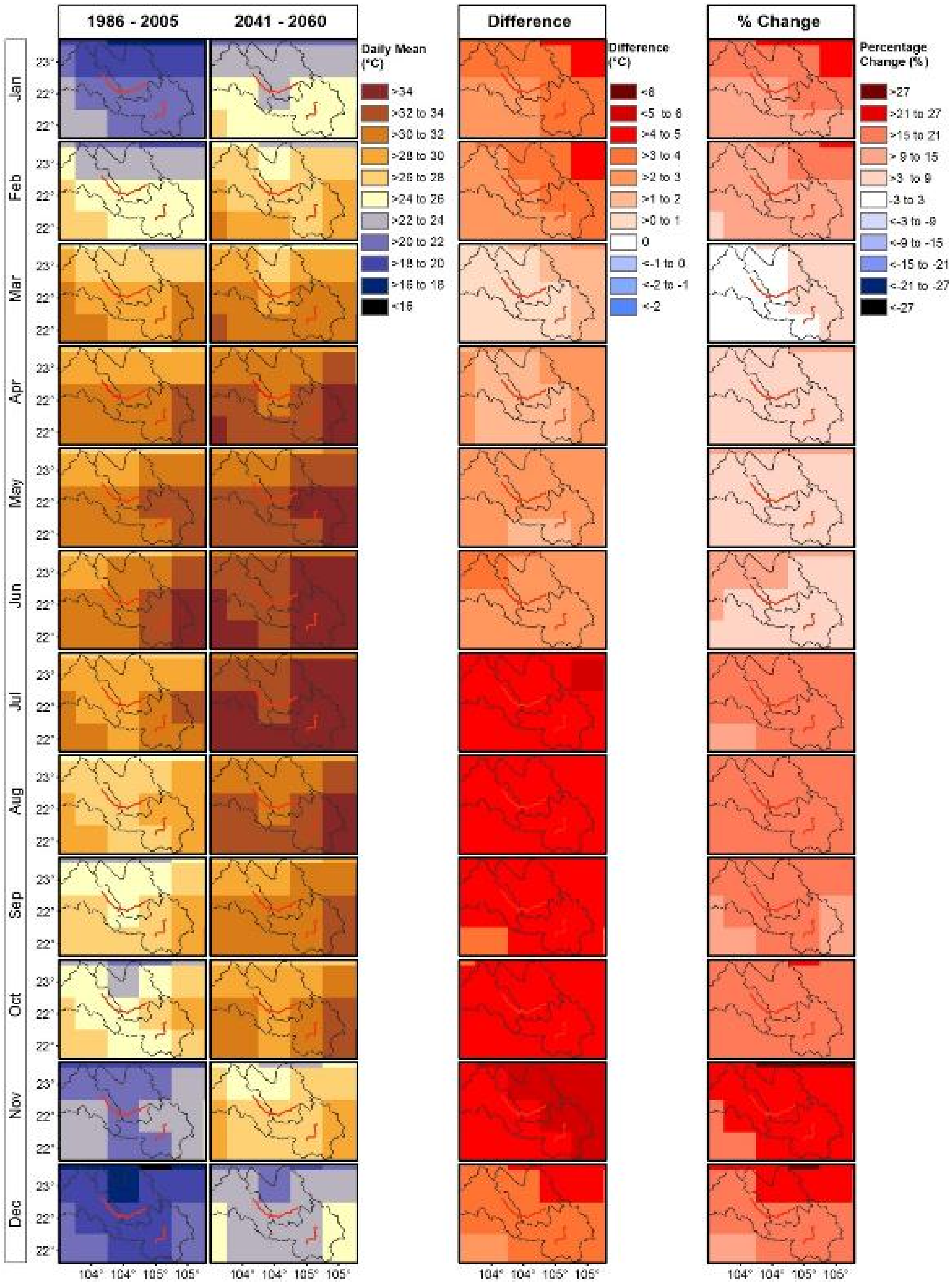
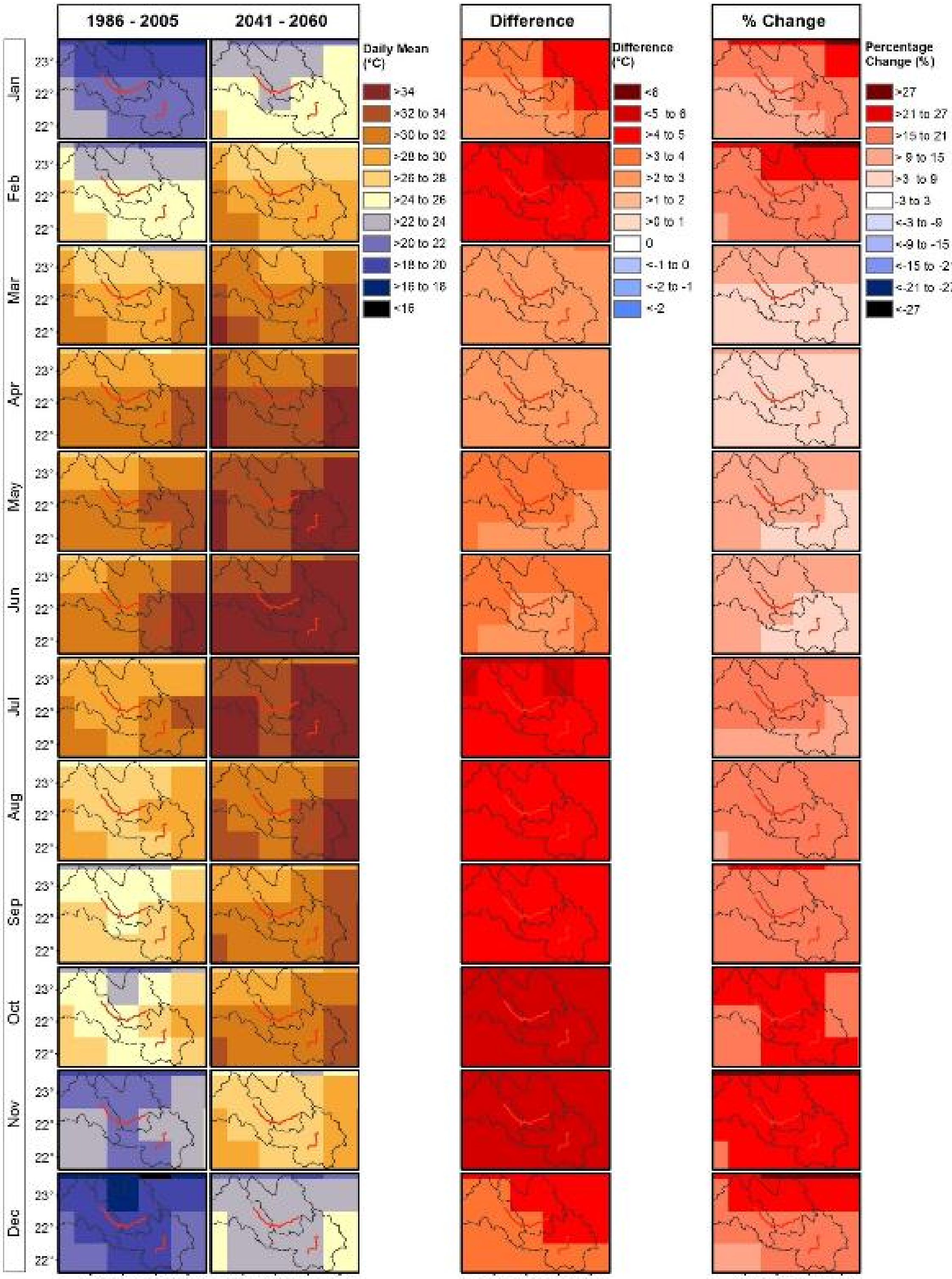


Figure A2.6: Difference between current (1986-2005) and future (2041-2060) <u>mean maximum daily temperature</u> within each month under the RCP8.5 ("pessimistic") climate change scenario (projections from GFDL-CM3 downscaled using CSIRO-CCAM)



CLIMATE-RELATED HOT SPOTS ALONG PROJECT ROADS, ADAPTATION OPTIONS

The CRVA identified a total of 30 “hot spot” sites. Flood and landslides were the most common hazard types.

For NH32/NH279, 11 climate-related vulnerability “hot spots” were identified. Most of this vulnerability is associated with flooding due to the low elevation of the road and frequent high-water levels experienced in the nearby Nam Chan River. For PR175, 19 climate-related vulnerability “hot spots” identified. The biggest concern is the risk of landslides and floods associated with high water levels in the Ngoi Thia River.

Recommended adaptation measures for these hot spots, including structural and non-structural adaptation measures, are presented in Table A3-1 below.

Table A3-1: Proposed adaptation options for identified climate hot spots

NH32/NH279-	Climate hazard	Structural adaptation options	Non-structural adaptation options
1	Landslide	– Cross-section design: Reduce slope gradient; Step cut (AOS08). – Slope protection by cement concrete: shotcrete (with and without reinforcement) (AOS04).	– Maintain and strengthen vegetation coverage along the road alignment to enhance resilience to flooding or slope slump (AON02).
2	Landslide, Wildfire	– Slope protection by grass and tree planting (AOS02). – Slope protection by gabions and cemented ashlar retaining wall (AOS03).	– Maintain and strengthen vegetation coverage along the road alignment to enhance resilience to flooding or slope slump (AON02). – Fire monitoring and alert system; fire protection by separation band (AON04).
3	Flood, Wildfire	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Flood protection by constructing bridges over flood-prone sites (AOS15). – Slope protection by gabions and cemented ashlar retaining wall (AOS03).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02). – Fire monitoring and alert system; fire protection by separation band (AON04).
4	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culvert) (AOS13). – Flood protection by increasing the aperture of drainage works (AOS14). – Flood protection by constructing bridges over flood-prone sites (AOS15). – Erosion protection by cement concrete retaining wall (AOS11).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
5	Landslide, Rockfall	– Slope protection by cement concrete: concrete slabs, shotcrete (with and without reinforcement) covers slopes (AOS04). – Cross-section design: Reduce slope gradient; Step cut (AOS08).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02). – Partial realignment of road (AON03).
6	Flood, Landslide	– Flood protection by rising design elevation of center line and structure (bridges, culvert) (AOS13).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).

		– Cross-section design: Reduce slope gradient; Step cut (AOS08). – Slope protection by cement concrete: concrete slabs, shotcrete (with and without reinforcement) covers slopes (AOS04). – Erosion protection by cemented ashlar (AOS12).	
7	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13).	
8	Landslide	– Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Reinforced concrete retaining wall (AOS06). – Cross-section design: Reduce slope gradient; Step cut (AOS08).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
9	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13).	– Partial realignment of road (AON03).
10	Flood	– Flood protection by increasing the aperture of drainage works (AOS14). – Flood protection by constructing bridges/tunnels over/under flood-prone sites (AOS15). – Flooding protection by rising design elevation of center line and structure (bridges, culverts) (AOS13).	– Partial realignment of road (AON03).
11	Rockfall	– Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Reinforced concrete retaining wall (AOS06).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
PR175-	**Climate hazard**	**Structural adaptation options**	**Non-structural adaptation options**
1	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culvert) (AOS13). – Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Erosion protection by cemented ashlar (AOS12).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02). – Partial realignment of road (AON03).
2	Landslide	– Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Erosion protection by cemented ashlar (AOS12).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
3	Landslide	– Reinforced concrete retaining wall (AOS06). – Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Embankment slope protection by cemented ashlar (AOS12).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
4	Flood	– Flood protection by rising design elevation of center line and	– Partial realignment of road (AON03).

		structure (bridges, culverts) (AOS13). – Flood protection by increasing the aperture of drainage works (AOS14). – Flood protection by constructing bridges/tunnels over/under flood-prone sites (AOS15).	
5	Flood, Landslide	– Flooding protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Flood protection by increasing the aperture of drainage works (AOS14)	– Partial realignment of road (AON03).
6	Landslide	– Reinforced concrete retaining wall (AOS06). – Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Embankment slope protection by cemented ashlar (AOS12).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
7	Landslide, Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Reinforced concrete retaining wall (AOS06). – Slope protection by gabions and cemented ashlar retaining wall (AOS03). – Erosion protection by cement concrete retaining wall (AOS11).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
8	Landslide	– Reinforced concrete retaining wall (AOS06). – Slope protection by gabions and cemented ashlar retaining wall (AOS03).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
9	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Flood protection by constructing bridges/tunnels over/under flood-prone sites (AOS15)	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
10	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Flood protection by increasing the aperture of drainage works (AOS14) – Flooding protection by constructing bridges/tunnels over/under flood-prone sites (AOS15). – Reinforced concrete retaining wall (AOS06). – Erosion protection by cement concrete retaining wall (AOS11).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
11	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road

		– Flood protection by increasing the aperture of drainage works (AOS14). – Flood protection by constructing bridges/tunnels over/under flood-prone sites (AOS15). – Reinforced concrete retaining wall (AOS06). – Erosion protection by cement concrete retaining wall (AOS11).	alignment to enhance resilience to flooding or slope slump (AON02).
12	Landslide	– Reinforced concrete retaining wall (AOS06). – Slope protection by gabions and cemented ashlar retaining wall (AOS03).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
13	Landslide	– Cross-section design: Reduce slope gradient; Step cut (AOS08). – Slope protection by gabions and cemented ashlar retaining wall (AOS03).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
14	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culvert) (AOS13). – Flood protection by constructing bridges/tunnels over/under flood-prone sites (AOS15). – Reinforced concrete retaining wall (AOS06). – Erosion protection by cement concrete retaining wall (AOS11).	– Partial realignment of road (AON03). – Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02).
15	Landslide	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Erosion protection by cement concrete retaining wall (AOS11).	– Partial realignment of road (AON03).
16	Flood	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Erosion protection by cemented ashlar (AOS12).	– Partial realignment of road (AON03).
17	Landslide	– Erosion protection by cement concrete retaining wall (AOS11).	– Partial realignment of road (AON03).
18	Landslide	– Slope protection by grass and tree planting (AOS02). – Slope protection by gabions and cemented ashlar retaining wall (AOS03).	– Maintain and strengthen vegetation cover along the road alignment to enhance resilience to flooding or slope slump (AON02). – Partial realignment of road (AON03).
19	Flood - Erosion	– Flood protection by rising design elevation of center line and structure (bridges, culverts) (AOS13). – Erosion protection by cement concrete retaining wall (AOS11). – Slope protection and erosion control by cemented ashlar retaining wall (AOS10).	