Climate risk report for the Central & South Asia region: Technical Reference Document

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A: Methods and Data

Methodological approach

This report presents an analysis of climate risk in the Central and South Asia region, combining climate with social and economic analysis to identify key challenges to production systems, resources, economies, services, and livelihoods. The report aims to guide development planners to areas requiring attention, providing an overview of key risks and uncertainties, highlighting prominent regional risks.

Climate has been analysed for distinct geographical regions which were determined using the following criteria:

- Similar climate characteristics e.g., timing of rainy seasons or similar seasonal temperatures (please see TRD Section E for more detail on Köppen-Geiger climate classifications).
- Zone size was tailored to the resolution of the climate data and to capture large regional features such as e.g., mountain ranges.
- Zone boundary selection was balanced between Köppen-Geiger climate zones, river basins, and elevation changes.

This tailored zonal climate analysis is combined with regional socio-economic information to assess potential impacts of future regional climate change on the following:

- Agriculture and food security
- Water resources and water-dependent services
- Health
- Infrastructure and settlements
- Energy
- Environment
- Blue economy and the marine environment

Further information regarding the data used and detailed methodology can be found in Section A of the Technical Reference Document and on the Met Office website[1]. Focus Box A1 explains why it is necessary to consider both exposure and vulnerability to climate hazards, and the need for an interdisciplinary approach when interpreting compound risks associated with, or exacerbated by, climate change.

[1] https://www.metoffice.gov.uk/services/government/international-development/climate-risk-reports

Climate in context methodological approach

The key stages in the methodology and division of responsibilities across the project team are presented in a schematic in Figure A1 and described in more detail below.

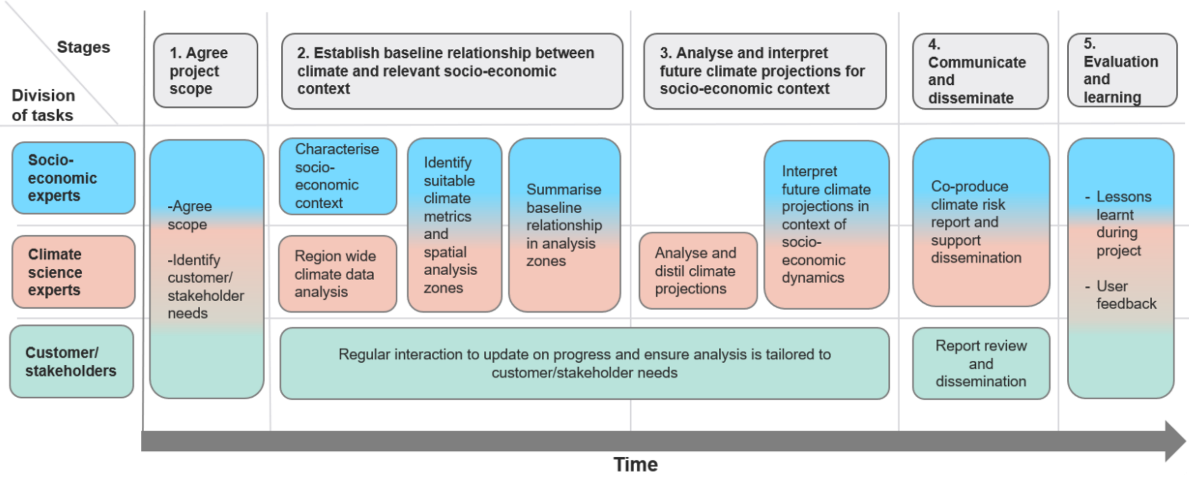

Figure A1: Schematic diagram of the key stages of the methodology and division of tasks between the socio-economic experts (ODI), climate science experts (Met Office) and customer (FCDO) roles of the project team (Richardson et al., 2022)

Stage 1 involves agreement on the scope of the work and the format of the outputs through iterative discussions across the project team. Consultations with the customer (FCDO) are conducted to identify the socio-economic themes relevant to their decision context.

Stage 2 involves establishing the baseline relationship between climate and the key socioeconomic themes identified in Stage 1. This includes:

- Preliminary analysis is conducted to characterise the regional socio-economic context and regional climate through a combination of literature review and processing climate reanalysis data by the relevant experts.
- Identification of suitable climate metrics and spatial analysis zones via an iterative process between the experts, drawing on the outcomes of the preliminary analysis.
- Characterisation of the baseline climate, the key climate-related vulnerabilities and exposure to climate-related hazards in each of the spatial analysis zones.

Stage 3 involves analysis of future climate projections and interpretation in the context of the key vulnerabilities and baseline assessments developed in Stage 2. This includes:

- Selection of appropriate climate model simulations for the region and quantitative analysis of projected changes in relevant climate variables in each of the spatial analysis zones.
- Distillation of the future climate projections into narrative summaries for the relevant climate metrics in each spatial analysis zone.
- Translation of the future climate summaries into climate risk impacts with a focus on the key socio-economic themes.

Stage 4 involves the co-production of a report summarising the analysis and outcomes, tailored to the needs of the customer.

Stage 5 involves evaluation and learning of the process to support future applications of the methodology.

Climate data and analysis methods

This report uses spatial analysis zones (which were selected using criteria, as mentioned on TRD page 1, to process ERA5 reanalysis[2,3] data; Hersbach et al., 2020) to characterise the current climate over the 1981-2010 baseline period. Global and regional climate model simulations were used to assess the projected change in temperature and precipitation for the 2050s (2041-2070- consistent with IPCC AR6).

To model and predict future climate it is necessary to make assumptions about the economic, social and physical changes to our environment that will influence climate change. Representative Concentration Pathways (RCPs) used in IPCC AR5, and Shared Socio-Economic Pathways (SSPs) used in IPCC AR6 are both methods for capturing those assumptions within a set of scenarios. The conditions of each scenario are used in the process of modelling possible future climate evolution.

In this study, we use RCP8.5[4,5] (radiative forcing of 8.5 Watts m^{-2} by 2100)- a pathway where greenhouse gas emissions are not substantially reduced, and SSP5-8.5, a fossil-fuel driven development scenario. RCP4.5 (a stabilisation pathway where greenhouse gas emissions are limited to 4.5 Watts m^{-2} by 2100) has also been analysed but only mentioned where it differs substantially from RCP8.5. Both RCP8.5 and SSP5-8.5 represent an increase in global average temperature of around 2.5˚C compared to pre-industrial levels, (van Vurren et al. 2011), which is higher than the target of limiting warming to well below 2˚C set by the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement. The baseline period of 1981-2010 considered in this report represents an observed increase of around 1°C in global average temperature compared to pre-industrial levels.

The climate projections in this report comprise of up to a 73-member ensemble made up of; 30 World Climate Research Project (WCRP) Coupled Model Intercomparison Project Phase

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[2] A gridded dataset that blends climate observations and model data to present the current climate for use as a baseline in future climate assessments.

[3] All observational and reanalysis datasets have associated uncertainties and limitations. For example, reanalysis datasets may underestimate observed extremes, and cannot fully represent localised features such as intense precipitation caused by complex topography, partly due to their limited resolution in space and time. Additionally, ERA5 precipitation fields are derived from 'forecast' output and are therefore more affected by imperfections within the underlying model. The benefit, however, of using reanalyses is that they provide a systematic approach to producing gridded, dynamically consistent datasets for climate monitoring, particularly over data-scarce regions. However, the use of these data to characterise climatological means for the purpose of this analysis is largely uninfluenced by these biases, and the benefits of using a dataset that is globally consistent and consistent with other climate information products outweighs this.

[4] The RCP8.5 Representative Concentration Pathway represents the highest emission scenario/future pathway of ongoing and substantial increases in future global greenhouse gas concentrations. Other pathways represent stabilisation or eventual reduction of greenhouse gas concentrations with the lowest projecting less additional climate change in the 2050s compared to RCP8.5. Analysis of the RCP4.5 scenario was also conducted, and results were broadly consistent with those presented here for RCP8.5.

[5] The SSP5-8.5 scenario was used for the CMIP6 generation of climate models.

5 (CMIP5; Taylor et al., 2012) global climate model simulations (Table A1), 20 WCRP CMIP Phase 6 (CMIP6; Eyring et al., 2016; Table A2) global climate model simulations, and up to 23 regional climate model simulations[6] from the WCRP CoOrdinated Regional climate modelling Downscaling EXperiment (CORDEX; Giorgi and Gutowski, 2015) project (Table A3).

CMIP5 models were used to inform the Intergovernmental Panel on Climate Change (IPCC) 5 the Assessment Report (AR5; IPCC, 2013), with horizontal model resolution ranging from 100- 300 km. CMIP6 models informed the latest Assessment Report (AR6; IPCC, 2021). Like CMIP5, the horizontal resolution of the CMIP6 models varies by model with some at a higher resolution than CMIP5 and some unchanged. The regional climate models are downscaled CMIP5 simulations over the CORDEX South Asia (WAS-44) and Central Asia domains (CAS-22) at resolutions of 50km and 25km respectively.

The models selected are those that were available to access at the time of analysis. The CORDEX South Asia domain did not extend to the northern part of Zone 1, northern Central Asia. Although the Central Asia CORDEX simulations do cover the northern parts of Zone 1, there were not enough RCMs to comprise a sufficient sample, so only CMIP5 and CMIP6 data were used for this Zone. Central Asian CORDEX simulations were not included in the recent IPCC Interactive Atlas (Gutiérrez et al., 2021) or CORDEX core exercise due to lack of sufficient simulations.

Model suitability was evaluated by comparing baseline periods from model simulations with reanalysis data. This model evaluation was taken into consideration when interpreting the future model projections. More detail on evaluation of these model simulations and known biases is available in IPCC (2021).

The climate data analysis focuses on quantifying projected changes in annual, and seasonal means in temperature and precipitation in the spatial analysis zones. This is supplemented with information from literature and analysis contained within the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Report (AR6) and the IPCC Interactive Atlas (Gutiérrez et al., 2021). Information on the projected changes in other relevant climate variables and indicators – such as sea surface temperatures, sea level rise and relevant climate extremes – is drawn from appropriate scientific literature and from the IPCC Interactive Atlas (Gutiérrez et al., 2021).

Table A1: GCM simulations from CMIP5 used in the climate data analysis, from https://pcmdi.llnl.gov/mips/cmip5/availability.html.

Modelling Centre	Model	Institution
BCC	BCC-CSM1-1	Beijing Climate Center, China Meteorological Administration
	BCC-CSM1-1-m	
CSIRO-BOM	ACCESS1-0	

[6] There were too few CORDEX Central Asia runs for reliable climate interpretation of Zone 1, northern Central Asia so only CMIP5 and CMIP6 were analysed for this region

	ACCESS1-3	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)
GCESS	BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University
CCCma	CanESM2	Canadian Centre for Climate Modelling and Analysis
NCAR	CCSM4	National Center for Atmospheric Research
NSF-DOE-NCAR	CESM1-CAM5	National Science Foundation, Department of Energy, National Center for Atmospheric Research
CMCC	CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici
CNRM-CERFACS	CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
CSIRO-QCCCE	CSIRO-Mk3-6-0	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence
EC-EARTH	EC-EARTH	EC-EARTH consortium
NOAA-GFDL	GFDL-CM3	NASA Goddard Institute for Space Studies
	GFDL-ESM2G	
	GFDL-ESM2M	
MOHC	HadGEM2-AO	Met Office Hadley Centre
	HadGEM2-CC	
	HadGEM2-ES	
INM	INMCM4	Institute for Numerical Mathematics
IPSL	IPSL-CM5A-LR	Institut Pierre-Simon Laplace
	IPSL-CM5A-MR	
	IPSL-CM5B-LR	
MIROC	MIROC5	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
	MIROC-ESM	
	MIROC-ESM-CHEM	
MPI-M	MPI-ESM-LR	Max Planck Institute for Meteorology
	MPI-ESM-MR	
MRI	MRI-CGCM3	Meteorological Research Institute
NCC	NorESM1-M	Norwegian Climate Centre

Table A2: GCM simulations from CMIP6 used in the climate data analysis, from https://pcmdi.llnl.gov/CMIP6/ArchiveStatistics/esgf_data_holdings/

Modelling Centre	**Model**	**Institution**
BCC	BCC-CSM2-MR	Beijing Climate Center, China Meteorological Administration

CCCma	CanESM5	Canadian Centre for Climate Modelling and Analysis
CNRM-CERFACS	CNRM-CM6-1	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique
	CNRM-CM6-1-HR	
	CNRM-ESM2-1	
CSIRO	ACCESS-ESM1-5	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia)
EC-EARTH Consortium	EC-Earth3	EC-EARTH consortium
	EC-Earth-Veg	
INM	INM-CM4-8	Institute for Numerical Mathematics
	INM-CM5-0	
IPSL	IPSL-CM6A-LR	Institut Pierre-Simon Laplace
MIROC	MIROC6	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies
MOHC	HadGEM3-GC31-LL	Met Office Hadley Centre
	UKESM1-0-LL	
MPI-M	MPI-ESM1-2-LR	Max Planck Institute for Meteorology
MRI	MRI-ESM2-0	Meteorological Research Institute
NCC	NorESM2-MM	Norwegian Climate Centre
NOAA-GFDL	GFDL-ESM4	NASA Goddard Institute for Space Studies
	GFDL-CM4	
NUIST	NESM3	Nanjing University of Information Science and Technology

Table A3: Regional Climate Model (RCM) simulations from CORDEX WAS-44 and CAS-22 used in the climate data analysis. These are downscaled simulations of a subset of the Global Climate Model (GCM) CMIP5 models in Table A1 at ~50km resolution for WAS-44 and ~25km for CAS-22.

Modelling Centre	**RCM**	**Driving GCM**	**Institution**
SMHI	RCA4	CanESM2	Swedish Meteorological and Hydrological Institute
		CNRM-CM5	
		CSIRO-Mk3-6-0	
		EC-EARTH	
		IPSL-CM5A-MR	
		MIROC5	
		HadGEM2-ES	
		MPI-ESM-LR	
		NorESM1-M	
		GFDL-ESM2M	
MPI-CSC	REMO2009	MPI-ESM-LR	Helmholtz-Zentrum Geesthacht, Climate Service Center, Max Planck Institute for Meteorology
IITM	RegCM4-4	CanESM2	Indian Institute of Tropical Meteorology
		CNRM-CM5	
		CSIRO-Mk3-6-0	
		IPSL-CM5A-LR	
		MPI-ESM-MR	
		GFDL-ESM2M	

GERICS	REMO2015	HadGEM2-ES MPI-ESM-LR NorESM1-M	Helmholtz-Zentrum Geesthacht, Climate Service Center Germany
CLMcom	ETH-COSMO-CrCLIM-v1-1	EC-EARTH MPI-ESM-LR NorESM1-M	Climate Limited-area Modelling Community (CLM-Community)

B: Climate risk in Central and South Asia

Focus Box B1: Risk-informed development

There is an increasing recognition that development objectives face multiple, intersecting threats, beyond just the risks associated with environmental and climate factors. The full implications for development programming will not be captured by traditional single threat analysis. In order to be risk-informed, programme decision making must undertake multi-threat analysis that considers how different threats merge with existing and changing socioeconomic contexts to create complex risk. In practice, this means that climate-resilient development must not only consider threats to programme outcomes from climate and environmental degradation, but also political, economic and financial instability, cyber and technology, transboundary crime and terrorism, geopolitical volatility, conflict and global health pandemics.

Risk-informed development requires us to think about risks to development as well as risks from development. Development outcomes are uneven, creating opportunities for some and risks for others. Risk-informed development must account for trade-offs inherent in development choices, including climate adaptation and mitigation. Such decisions are inherently political, involving the redistribution of resources and navigating unequal power structures.

Source: Opitz-Stapleton et al. (2019); Eriksen et al. (2015).

Climate risk rankings and comparisons

Figure B1 presents a snapshot of climate risk across the region using widely used ND-GAIN[7] country rankings for 2021 – the most recent year for which data are available. The ND-GAIN country index uses a range of metrics to assess both a country's vulnerability to climate change and other global challenges and its readiness to build resilience. Vulnerability is measured by assessing a country's exposure, sensitivity, and capacity to adapt to the negative effects of climate change, looking at seven sectoral themes: agriculture and food security, water resources and water-dependent services, health, infrastructure and settlements, energy, environment, and blue economy and the marine environment. Readiness is measured by assessing a country's ability to leverage investments and convert them into adaptation actions, looking at three components: economic readiness, governance readiness, and social readiness. Figure B1 presents a snapshot of climate risk across the region using widely used ND-GAIN[8] country rankings for 2021 – the most recent year for which data are available. The

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[7] Notre Dame Global Adaptation Initiative: https://gain.nd.edu/ ND-GAIN country scores and rankings are used by, amongst others, the World Bank in their climate risk country profiles – see https://climateknowledgeportal.worldbank.org/. Scores are available for a total of 182 countries based on data for 2021.

[8] Notre Dame Global Adaptation Initiative: https://gain.nd.edu/ ND-GAIN country scores and rankings are used by, amongst others, the World Bank in their climate risk country profiles – see https://climateknowledgeportal.worldbank.org/. Scores are available for a total of 182 countries based on data for 2021.

ND-GAIN country index uses a range of metrics to assess both a country's vulnerability to climate change and other global challenges and its readiness to build resilience.

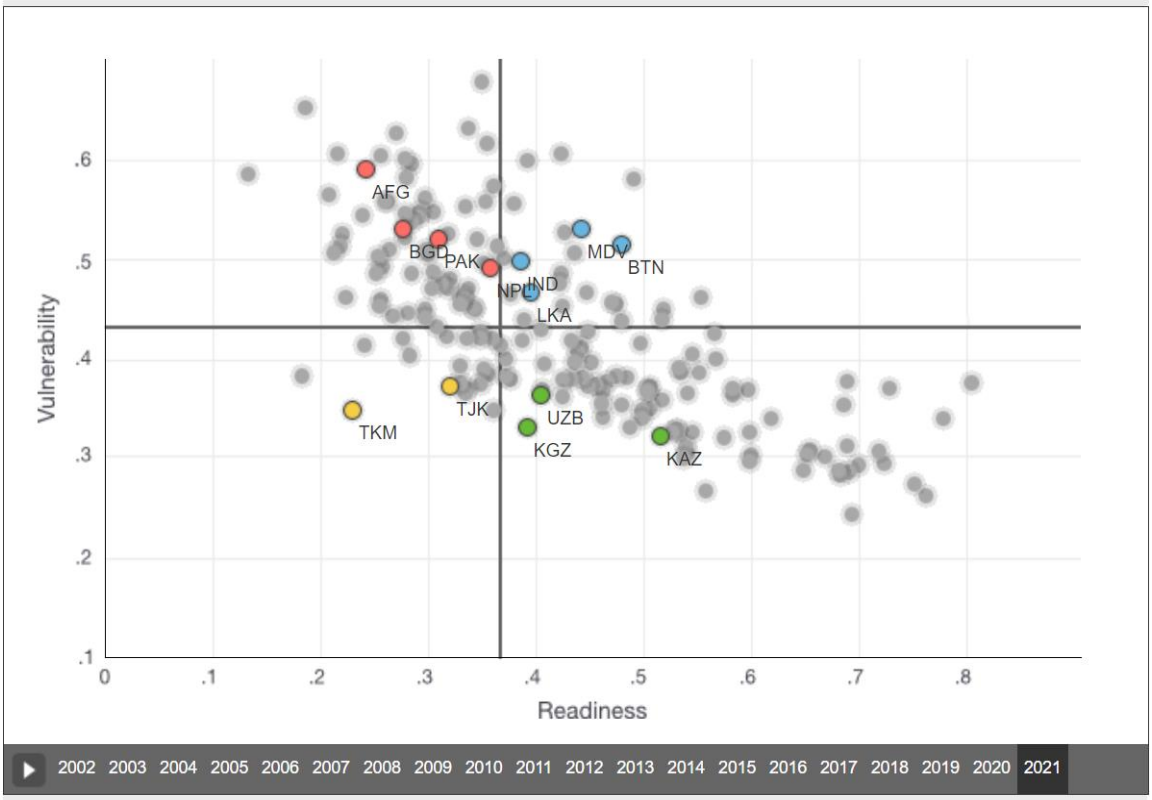

Figure B1: ND-GAIN country scores for the Central and South Asia region. Red denotes high vulnerability and low readiness (Afghanistan as AFG, Bangladesh as BGD, Pakistan as PAK, and Nepal as NPL). Yellow denotes low vulnerability and low readiness (Turkmenistan as TKM and Tajikistan as TJK). Blue denotes high vulnerability and high readiness (Maldives as MDV, Bhutan as BTN, India as IND, and Sri Lanka as LKA). Green denotes low vulnerability and high readiness (Kyrgyzstan as KGZ, Uzbekistan as UZB, and Kazakhstan as KAZ). Source: https://gain.nd.edu/.

Afghanistan, Bangladesh, Pakistan and Nepal occupy the top left quadrant of the ND-GAIN matrix (Figure B1; red dots), therefore are considered to be highly vulnerable combined with a low level of readiness, indicating an urgent need for adaptation action. All four countries are classified as lower-middle income in the latest World Bank ranking[9] with the exception of low-income Afghanistan. Collectively, these 'high risk' countries account for 24.1% (478.5 million people) of the whole region's population (1.9 billion people)[10].

Turkmenistan (upper-middle income) and Tajikistan (lower-middle income)9 occupy the solitary bottom-left box (yellow dots; low vulnerability, low readiness). Turkmenistan and

[9] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups
[10] https://data.worldbank.org/indicator/SP.POP.TOTL?view=map

Tajikistan collectively account for 0.8% (16.3 million people) of the whole region's population (1.9 billion)10.

Lower-middle income Bhutan, India, and Sri Lanka (blue dots) occupy the high vulnerability and high readiness quadrant as does the Maldives – an upper-middle income country9. These are countries with exposed populations and assets, but demonstrable capacity to act and adapt. Collectively, these three countries account for 71.9% (1.4 billion people, with India accounting for 99.7% of that number) of the whole region's population (1.9 billion people, with India alone accounting for 73.6% of that number)10.

The three countries indicated by green dots, i.e., in the low vulnerability and high readiness quadrant, are Kyrgyzstan (lower-middle income), Uzbekistan (lower-middle income), and Kazakhstan (upper-middle income)9. These countries collectively account for 3.1% (62.1 million people) of the whole region's population (1.9 billion)10.

C: Climate projections and drivers of climate variability

Climate stripes

The following Figures C1 and C2 show climate stripes for temperature and precipitation for all 6 different IPCC regions which form Central and South Asia for the period 1950-2100 (centred around a 1981-2010 baseline). This gives an indication of the inter-model agreement, an important factor in establishing confidence in the projections. There is more consistency (although, still variation between models) in the projected magnitude and rate of warming by the end of the century, compared to less confidence in magnitude and rate of precipitation changes.

The climate stripes were produced using the IPCC interactive atlas (https://interactive-atlas.ipcc.ch/) and summarise temperature and precipitation changes over a broader geographical area so they are not directly comparable with the bespoke zonal climate analysis conducted in this report. Additionally, the climate stripes were made with a larger global model selection (CMIP5; 29 models, CMIP6; 34 models) and regional climate model (CORDEX South Asia; 26 models) whereas the zonal analysis in this report uses a sub-selection of these models as seen in Tables A1-A3 (CMIP5; 20 models, CMIP6; 30 models, CORDEX South Asia; 23 models). This sub-selection of models used in this report is based on model data which was available at the time of analysis. The number of models used in the bespoke zonal climate analysis in this report are considered representative of the range of climate outcomes. Climate stripes are a useful tool for visualising broader regional trends and associated inter-model variability.

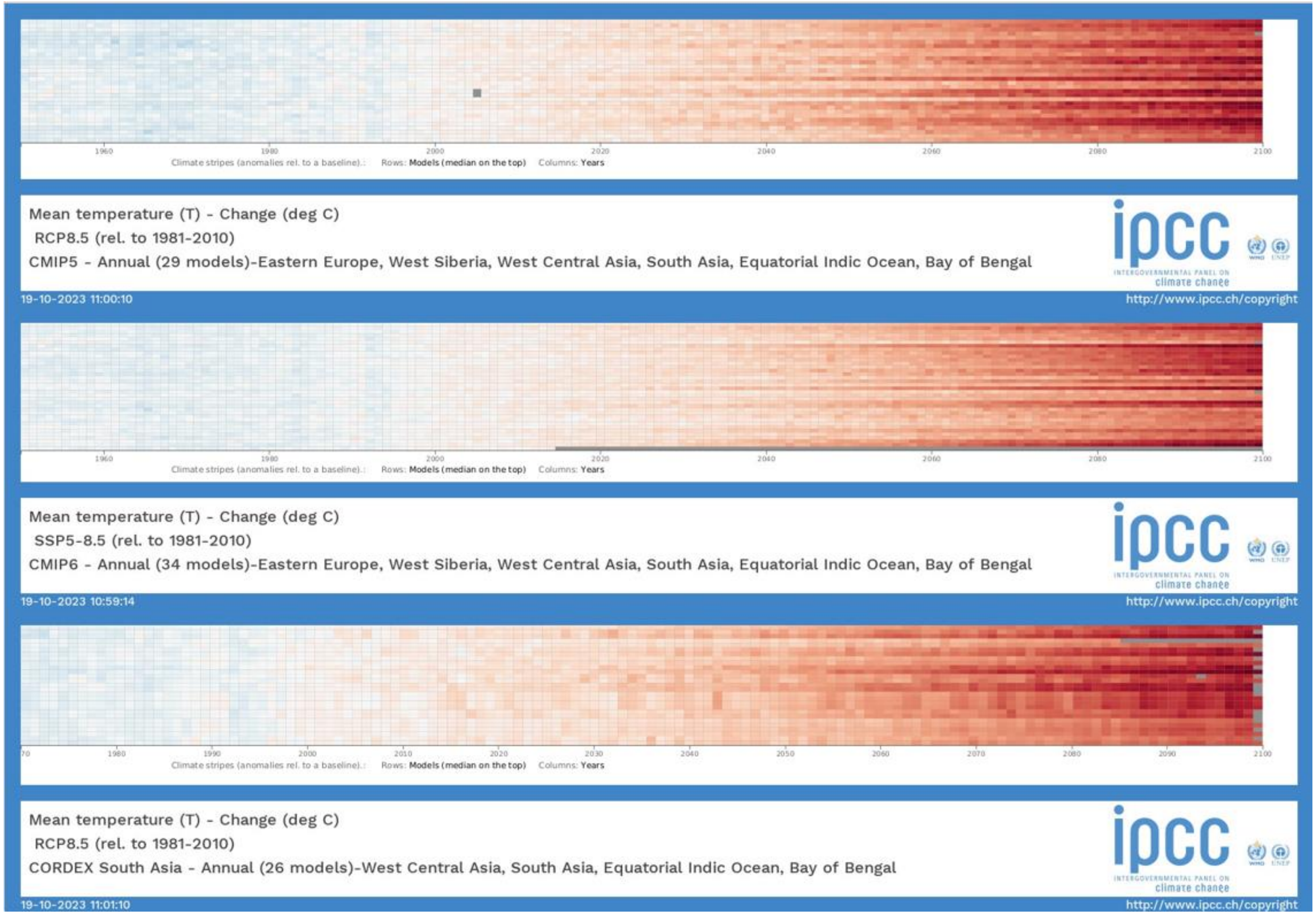

Figure C1: Mean near-surface air temperature anomaly projections for RCP8.5 CMIP5 (top) and CORDEX (bottom), ssp5-8.5 CMIP6 (middle) encompassing 6 different IPCC regions which form Central and South Asia for the period 1950-2100 (centred around a 1981-2010 baseline). CORDEX South Asia domain only covers 4 IPCC regions so may not be directly comparable. Each box represents the average projected temperature for a single year, relative to the average temperature over the period. Each stripe running left to right represents an individual model run, and therefore a plausible outcome. Shades of blue indicate cooler-than-average years, while red shows years that were hotter than average. The stark band of deep red stripes on the right-hand side of the graphic show the rapid warming that is projected. Grey squares represent areas of missing data.

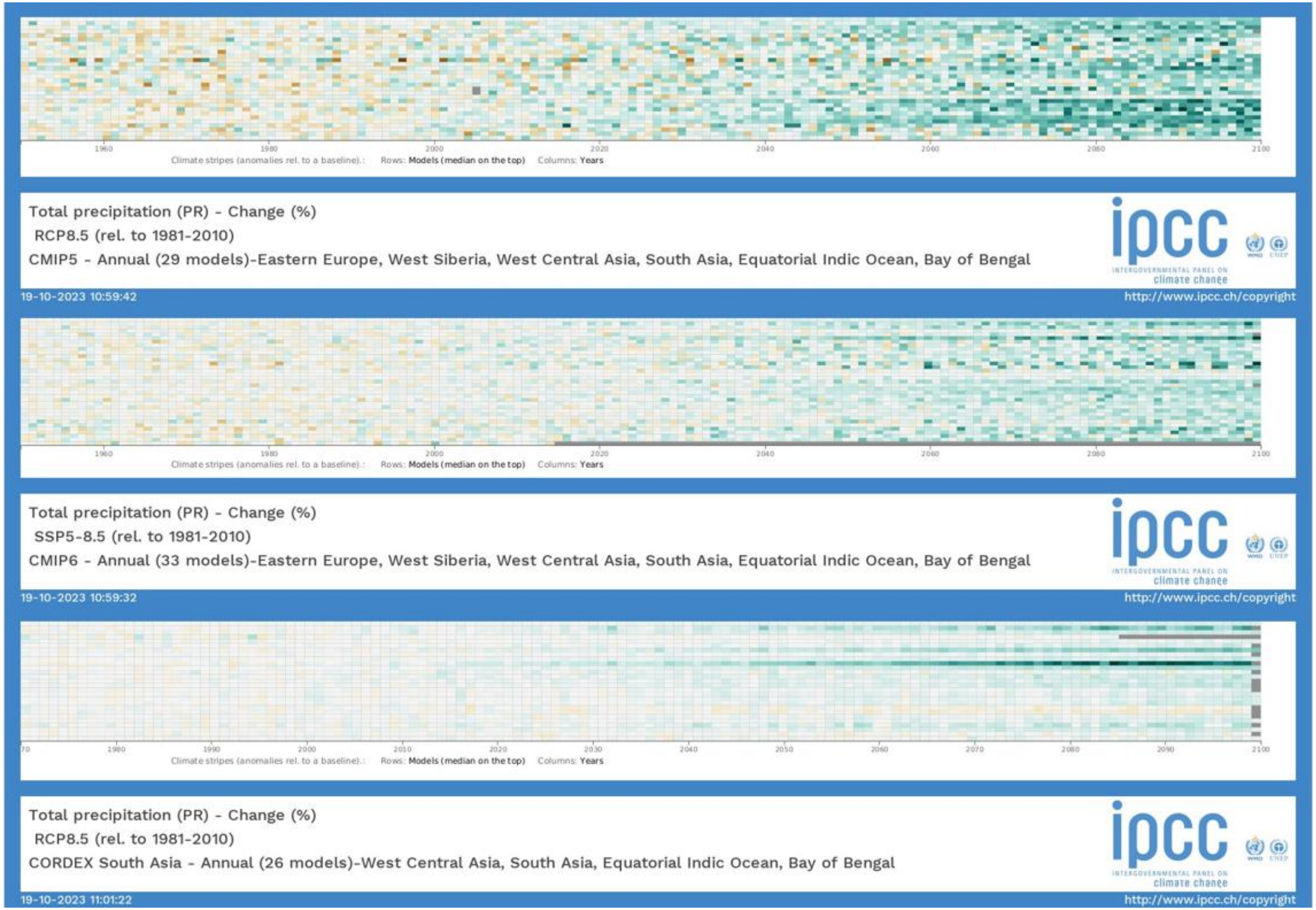

Figure C2: Near-surface total precipitation anomaly projections for RCP8.5 CMIP5 (top) and CORDEX (bottom), SSP5-8.5 CMIP6 (middle) encompassing 6 different IPCC regions which form Central and South Asia for the period 1950-2100 (centred around a 1981-2010 baseline). CORDEX South Asia domain only covers 4 IPCC regions so may not be directly comparable. Each box represents the average projected precipitation for a single year, relative to the average precipitation over the period. Each stripe running left to right represents an individual model run, and therefore a plausible outcome. Shades of brown indicate drier-than-average years, while blue shows years that were wetter than average. Grey squares represent areas of missing data.

Climate, climate change and drivers of climate variability

What is weather? The weather varies from day to day and season to season, with the long-term average trends in weather typically defining a region's climate. These statistics are typically defined over a 30- year period. Climate change can then be characterised as the difference in these statistics between two 30-year climate periods. This will include the annual climate range through the year, from one period to another, as well as changes in the frequency, intensity, and duration of extreme events, such as heavy rainfall and high temperatures.

Climate varies naturally over shorter periods of several years, and this natural variability can accentuate or dampen longer-term climate change signals. Both average conditions and the variability around that average can change and can result in increase in events that in the past were rare or extreme. It can also lead to situations where climate change increases the frequency of both heavy rainfall events and the occurrence of very dry conditions (IPCC, 2021).

The actual annual and seasonal rainfall and temperature values vary from year to year, resulting in hotter, drier, cooler, and wetter periods in relation to the climatological mean. This happens because the local weather is influenced by larger scale processes in the climate, known as climate drivers, which influence regional and local climate over different timescales.

The main climate drives in Central and South Asia include:

- El Niño-Southern Oscillation (ENSO)
- Indian Ocean Dipole (IOD)
- North Atlantic Oscillation (NAO)

In South Asia, the main drivers of climate variability are the South West monsoon (heavy rainfall occurring every year between June and September), ENSO (every 3-5 years) and IOD (phases last 2-5 months) which refer to oscillations of sea surface temperatures and lead to variations in associated atmosphere and ocean circulations. A negative phase of ENSO (known as El Niño) leads to warmer, drier conditions and is associated with lower-than-average South West monsoon precipitation (see Table C1 for definition), in contrast to La Niña which generally leads to an enhanced South West monsoon. ENSO interacts with the variability and intensity of IOD on an interannual timescale, with positive phases of IOD correlating with warmer seasonal temperatures and above average precipitation (Wang et al., 2016). Tropical cyclones also impact countries surrounding the Bay of Bengal and the Arabian Sea.

In Central Asia, the NAO and ENSO are the main drivers of climate variability. The NAO varies interannually and is driven by atmospheric pressure differences between the Azores High and Icelandic low in the Atlantic. When NAO is positive, it leads to warmer temperatures and wetter and stormier winters (Hunt and Zaz, 2023). When ENSO is positive, it leads to wetter than average winter in Central Asia (Chen et al., 2018). A summary of drivers of climate variability and their regional relevance for Central and South Asia is provided in Table C1.

Table C1: Summary of the drivers of rainfall and temperature variability in Central and South Asia and their regional relevance. Definitions of the drivers of variability are provided in the glossary in TRD Section G.

Drivers of variability	Influence on seasonal climate	Regional relevance
South West monsoon	A monsoon climate is characterised by a dramatic seasonal change in direction of the prevailing winds of a region which brings a marked change in rainfall. SW monsoon is associated with heavy seasonal rainfall occurring between June-September.	Predominantly affecting South Asia, Southern and Eastern areas of Central Asia.
El Niño Southern Oscillation (ENSO)	ENSO involves recurrent changes in sea surface temperatures and atmospheric surface pressure across central and eastern tropical Pacific. ENSO has three phases: El Niño, La Niña, and neutral. El Niño generally suppresses monsoon rainfall while La Niña generally increases it. From June to September, India receives most of its annual rainfall due to the monsoon. An El Niño event could result in, or contribute to, a poor Indian Monsoon.	South and Central Asia (predominantly summer SW monsoon season)
Indian Ocean Dipole (IOD)	The IOD describes the difference in sea surface temperature between the western and eastern ends of the Indian Ocean. IOD affects the southern coastline of South Asia (India, Pakistan). Positive events are associated with warmer than normal conditions with increased chance of precipitation while negative events are associated with cooler than normal conditions with reduced chance of precipitation. Positive events can cause flooding, landslides, and marine heatwaves while negative events can cause drought.	South Asia
North Atlantic Oscillation (NAO)	The NAO is a large-scale atmospheric pressure see-saw in the North Atlantic region. The summer NAO can extend its influences farther eastward, influencing precipitation and temperature anomalies over South Asia.	Central Asia (predominantly winter)
Tropical Cyclones	TCs are deep areas of low pressure, bringing catastrophic impacts to an area through wind, rain and storm surges. Strong winds cause damage to infrastructure and the environment and danger to life. Heavy rain causes flooding, landslide risk, and increased disease prevalence due to flooding. Storm surges cause coastal inundation, danger to life and infrastructure, and coastal erosion.	Bay of Bengal, Arabian Sea

D: Attribution of weather and climate-related events in Central and South Asia

Climate attribution can tell us how changes to the physical climate system from human-caused greenhouse gas emissions are influencing weather and climate. This is physics based and typically uses observations of physical climate metrics (rainfall, temperature, etc) and compares these against events in climate models. Where observations are deficient this is more difficult. Modelled worlds with and without human greenhouse gas emissions are compared to quantify the influence of human-caused climate change on individual extreme weather and climate events **(Extreme Event Attribution (EEA)**, as well as on slower onset changes e.g. sea level rise (**Trend Attribution**)**.** EEA can be performed rapidly in the days following an event by research groups such as the World Weather Attribution collaboration. The UK also has capability to perform EEA assessments. These climate attribution studies aim to quantify the extent to which human-induced climate change has altered the likelihood or intensity of a specific event, such as a heatwave, a flood, or a drought.

Impact attribution takes into consideration the economic and social impacts arising from an individual climate event (loss of life, damage to property, etc). So, this includes aspects of exposure and vulnerability. This is more complicated as it requires socioeconomic information (in addition to the assessment of the physical climate event attribution). So, the science can tell us about whether an individual event was made more likely or more intense due to human-caused climate change. The quantification of any impacts from an individual event requires additional information.

The following paragraphs and table provide a summary of the main findings and limitations of attribution studies of weather and climate-related events in Central and South Asia, based on the literature review conducted for this report.

Relevant studies to Central and South Asia

In general, both Central Asia and South Asia have a distinct lack of climate attribution studies compared to e.g., Europe or China. Available EEA studies are concentrated in the northern region of South Asia, with very few in Central Asia. A synthesis of available climate attribution studies and gaps can be found below:

Across South Asia, anthropogenic aerosols currently mask the climate warming caused by greenhouse gases (GHG) equivalent to nearly 75% of CO_2 induced radiative forcing over South Asia (Nair et al., 2023). As countries strive to reduce their GHG emissions in line with the Paris Agreement's warming target of 1.5°C by 2100, co-emitted atmospheric aerosols will also decline. This future atmospheric aerosol reduction is projected to increase the incidence of extreme precipitation and heat wave events attributable to anthropogenic climate change (Wang et al., 2023; Zhao et al., 2019). Intensification of pre-monsoon (May) cyclones over the Bay of Bengal since 1979 has been linked to rising Bay of Bengal temperatures due to an increase in aerosol loading and anthropogenic warming of land from increased greenhouse gases (Wang et al., 2013).

Across Central Asia, Central Asia region has a distinct lack of trend attribution and especially specific EEA studies due to lack of reliable observation records (Fallah et al., 2023). Central Asian countries such as Kyrgyzstan and Tajikistan have very complex topography which requires high resolution climate data (~30km) for regional trend attribution studies (Fallah et al., 2023). Central Asian trend attribution studies are focused on assessing trends in drought and extreme precipitation indices in (predominantly northern) Kazakhstan which suggest extreme heat, drought and extreme precipitation has increased since 1960s.

The tables below provide summaries of **extreme event** and **trend attribution** studies of weather and climate-related events in South Asia (Table D1) and Central Asia (Table D2).

*Table D1: Cases of event attribution for **South Asia**. This list is non-exhaustive. Red rows represent events that are attributed to anthropogenic climate change. Blue rows represent events that are not attributed to anthropogenic climate change. Blank rows (white) represent studies that are inconclusive or lacking in data.*

Month / Year	Country	Variable	Study statement	Attribution	Study reference
April 2023	Bangladesh, India, Thailand, Lao	Extreme heat	"The combined results give an increase in the likelihood of such an event to occur of at least a factor of 30 over India and Bangladesh due to human-induced climate change. At the same time, a heatwave with a chance of occurrence of 20% (1 in 5 years) in any given year over India and Bangladesh is now about 2°C hotter in heat index than it would be in a climate not warmed by human activities"	Attributed to anthropogenic climate change	World Weather Attribution (2023)
May 2022	Pakistan, Northern India	Extreme heat	"The analysis suggests that human influence has increased the likelihood of extreme April-May temperature anomalies by a factor of about 100."	Attributed to anthropogenic climate change	Christidis et al. (2022)
March-May 2022	India and Pakistan	Extreme heat	"Because of climate change, the probability of an event such as that in 2022 has increased by a factor of about 30."	Attributed to anthropogenic climate change	World Weather Attribution (2022)
August 2017	Bangladesh	Extreme rainfall, river flooding	"The change in risk of high precipitation that has occurred since pre-industrial times is therefore uncertain…The attribution of the change in discharge is therefore somewhat less uncertain than for precipitation, but the 95 % CI still encompasses no change in risk… it highlights the importance of using multiple models in attribution studies, particularly where the climate change signal is not strong relative to natural variability or is confounded by other factors such as aerosols"	Inconclusive	Philips et al. (2019)

March 2017	NE Bangladesh	Extreme rainfall	"Anthropogenic climate change doubled the likelihood of the 2017 pre-monsoon extreme 6-day rainfall event at northeast Bangladesh. The magnitude of this contribution is sensitive to the climatological period in use."	Attributed to anthropogenic climate change	Rimi et al. (2018)
May 2016	India	Extreme heat	"The analysis did not find a significant trend for these individual heat waves…The lack of a detectable trend may be due to the masking effect of aerosols on global warming and increased use of irrigation."	Not attributed to anthropogenic climate change	World Weather Attribution (2016)
2015	Southern India Sri Lanka	Extreme heat. Annual mean surface temperature for 2015	"In 2015, record warm surface temperatures were observed for the global mean, India, and the equatorial central Pacific. CMIP5 simulations suggest that for the globe and India, anthropogenic warming was largely to blame."	Attributed to anthropogenic climate change	Kam et al. (2016)
December 2015	India	Extreme rainfall. Heavy rainfall event in Chennai, 2015	"Extreme one-day rainfall caused widespread flooding in Chennai, India, in December 2015. No effect of global warming was detected, likely caused by aerosols counteracting greenhouse gases up to now."	Not attributed to anthropogenic climate change	van Oldenborgh et al. (2016)
May-July 2015	India and Pakistan	Extreme heat and humidity	"We find that the deadly heat waves in India and Pakistan in 2015 were exacerbated by anthropogenic climate change. Although the impacts of both events were severe, the events themselves were not connected to each other."	Attributed to anthropogenic climate change	Wehner et al. (2016)

October 2014	Nepal	Extreme snowstorm	"The Himalayan snowstorm of October 2014 resulted from the unusual merger of a tropical cyclone with an upper trough, and their collective changes under climate warming have increased the odds for similar events."	Attributed to anthropogenic climate change	Wang et al. (2015)
June 2013	Northern India	Extreme rainfall	"Cumulative precipitation in northern India in June 2013 was a century-scale event, and evidence for increased probability in the present climate compared to the preindustrial climate is equivocal."	Attributed to anthropogenic climate change	Singh et al. (2014)
1951-2010	Series of river flooding events in South Asia	River flooding	"The results indicate that human-induced climate change altered the probabilities of 20 of the 52 analyzed flood events. Fourteen of these 20 flood events, which occurred mainly in Asia and South America, were very likely to have been enhanced by human-induced climate change due to an increase in heavy precipitation"	Attributed to anthropogenic climate change	Alifu et al. (2022)
2010	Northern India	River flooding	"[T]he cause of five flood events (Magdalena in 2011, Amazon in 2012, Amur in 2013, Songhua in 2013, and Indus in 2010) was heavy rainfall, corresponding to the observed significant increases in heavy precipitation on a global scale, which has been shown to be the result of anthropogenic changes."	Attributed to anthropogenic climate change	Hirabayashi et al. (2021)
April-May 2010	India	Extreme heat. Hottest summer in India, 2010	"Overall, the observed hottest summer in 2010 can be attributed to anthropogenic warming with high confidence"	Attributed to anthropogenic climate change	Nanditha et al. (2020)

*Table D2: Cases of event attribution for **Central Asia**. This list is non-exhaustive. Red rows represent events that are attributed to anthropogenic climate change. Blue rows represent events that are not attributed to anthropogenic climate change (there are no blue rows in this case). Attribution status is also given in the 'Attribution' column.*

Month / Year	Country	Variable	Study statement	Attribution	Study reference
1961-2014	Central Asia region	Extreme heat	'higher risk of extreme heat events over large parts of CA due to anthropogenic influence. a higher likelihood of extreme precipitation over CA, especially over Kyrgyzstan and Tajikistan, can be attributed to anthropogenic forcing (over 100% changes in intensity and 20% in frequency)'	Attributed to anthropogenic climate change	Fallah et al. (2023)
1961-2005	Central Asia region	Extreme precipitation events	"Results indicate that radiative forcing changes, mainly driven by human activities, have significantly augmented the extreme precipitation indices in Central Asia."	Attributed to anthropogenic climate change	Zou et al. (2021)
1958-2014	Northern Central Asia	Drought	"[W]e show evidence that the drying trend is dominated by anthropogenic change of the atmospheric circulation evinced in the southward shift and weakening of the subtropical westerly jet (SWJ)."	Attributed to anthropogenic climate change	Jiang and Zhou (2021)

Gaps

- Currently, extreme precipitation is more difficult to attribute than extreme temperature due to poor parametrization of precipitation in GCMs.
- Both Central and South Asia lack any (trend or EEA) attribution studies on snow (important over the Himalayas, Karakorum, Tien Shen ranges) related to spring melt and extreme events such as Glacial Lake Outburst Flooding.
- Both Central and South Asia lack impacts attribution studies on river and coastal flooding which would be beneficial in this region, especially in downstream countries (prone to flooding e.g., Bangladesh and drought e.g., Kazakhstan), although results of these are more likely to deliver uncertain results e.g., Philips et al. (2019) due to the additional complexity of hydrological modelling.
- Both Central and South Asia would benefit from additional impacts attribution studies on: ecosystem functioning (e.g., seasonality of crops), and health (attribution to e.g., heat related deaths dependent on health records), which requires combining climate data with socio-economic and ecological data.

E: Climate analysis in the zones

Selection of spatial analysis zones

To assess the magnitude and direction of projected climate trends at a sub-regional scale it is useful to spatially aggregate gridded climate data over climatologically similar regions. As the Central and South Asia region represents a large, climatologically diverse area, it is also important to reflect this. Averaging the climate data by country borders is often not useful, as these do not reflect the climate and some countries may experience a range of climate types. Therefore, the region is divided into seven spatial analysis zones that reflect the different climate types.

As mentioned in TRD Section A, the climate analysis was conducted at a sub-regional scale using seven zones displayed in Figure E3. The IPCC AR6 WG I sub-continental analysis boxes for comparison are provided in Figure E2. This zonal approach uses a multidisciplinary integrated analysis which allows for transboundary climate-related risks to be examined at a sub-regional and regional scale within consideration of pre-existing socio-economic and environmental stressors which may act to amplify future climate risks. In this way, additional and new insights on climate-related risks for the region are described, beyond the information available from using the IPCC AR6 WGI reference regions. The following criteria were considered during selection of the zones:

1. **Political borders:** By considering political borders we can pair climatological data with socio-economic data for each country for the integrated analysis. However, where political boundaries traverse multiple geographical or climate features, the risk report zone boundary is informed by other criteria.
2. **Köppen-Geiger climate zones (Figure E1):** Ensures the climatological analysis is consistent across the zone and not averaged over many different climatological zones. For instance, the IPCC region 'Western Central Asia (WCA)' encompasses hot desert climates (as seen in Iran) as well as warm, semi-arid (as seen in eastern Uzbekistan, Tajikistan, Kyrgyzstan, northern Afghanistan), as well as cold steppe and desert (as seen in Kazakhstan). The Risk Report zone selection distinguishes between these in order to provide more tailored climate information for specific climate zones.
3. **Major river basins and catchment areas:** Given the critical interest in water resources in this region, it is essential to account for changing climate to the entirety of the river basin. The zonal analysis allows for this by extending zones outside of political borders where necessary (e.g., Zone 3 extends beyond Nepal into China to capture the Indus and Ganges-Brahmaputra river source). Equally, river basins are considered during the socio-economic analysis e.g., the source of the Amu Darya and Syr Darya rivers lies in Zone 2 (a climatologically distinct mountainous zone) whereas the discharge of these rivers is in Zone 1 (an arid desert climatological zone). In this case, it makes sense to conduct an upstream climatological analysis in Zone 2 and separate downstream analysis in Zone 1. For more detailed risk analysis, climatological trends in Zone 2 will be considered when looking at socio-economic impacts in Zone 1. This allows for the risks to be considered in context e.g., upstream risks vs downstream.

4. **Elevation:** Elevation is not captured in detail in the IPCC regions. For instance, the IPCC region WCA encompasses the mountainous Hindu Kush region (7000-7500m elevation) as well as the flatter plains of Kazakhstan, Uzbekistan, and Turkmenistan (the Caspian Sea is -28m elevation). These significant differences in elevation are separated into Zones 1 and 2 in the Risk Report analysis, to allow for more detailed understanding in different risks associated with regional topography.

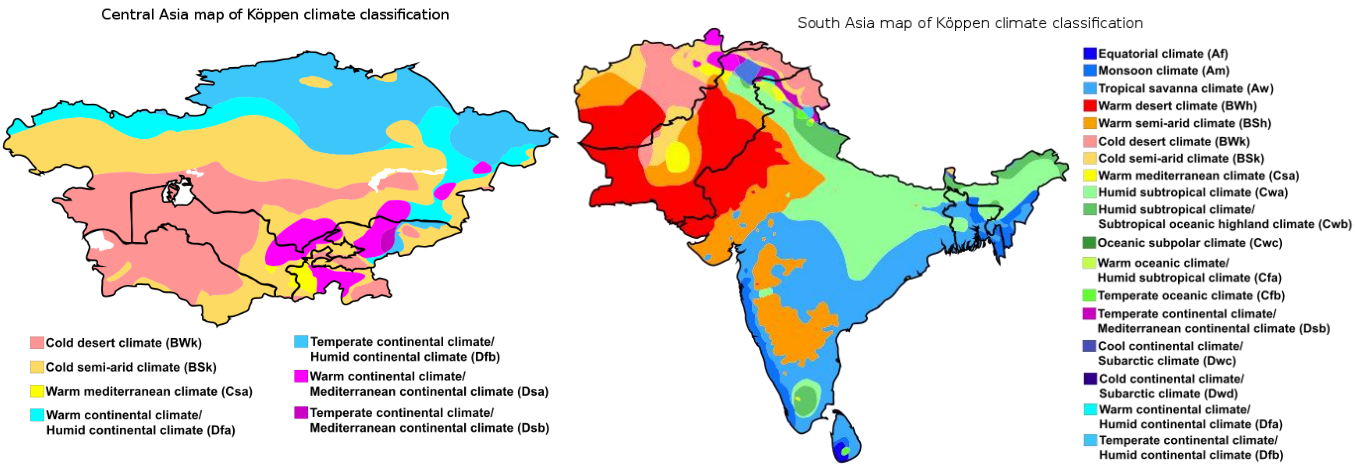

Figure E1: Köppen-Geiger climate classification map for the Central and South Asia region, adapted from Beck et al. (2018). Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

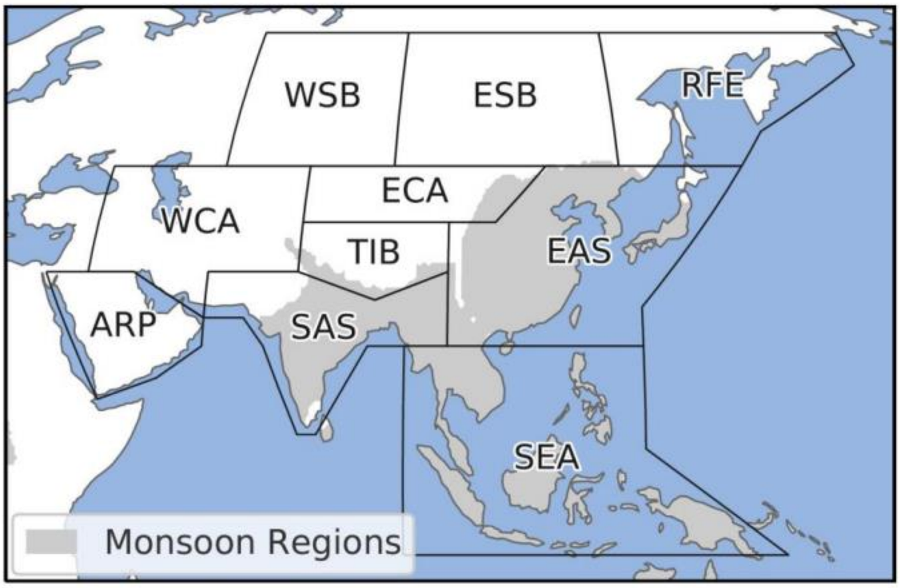

Figure E2: IPCC AR6 reference regions, as defined by WGI. Source: IPCC AR6 Regional Factsheet – Asia[11]. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

[11] https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Asia.pdf

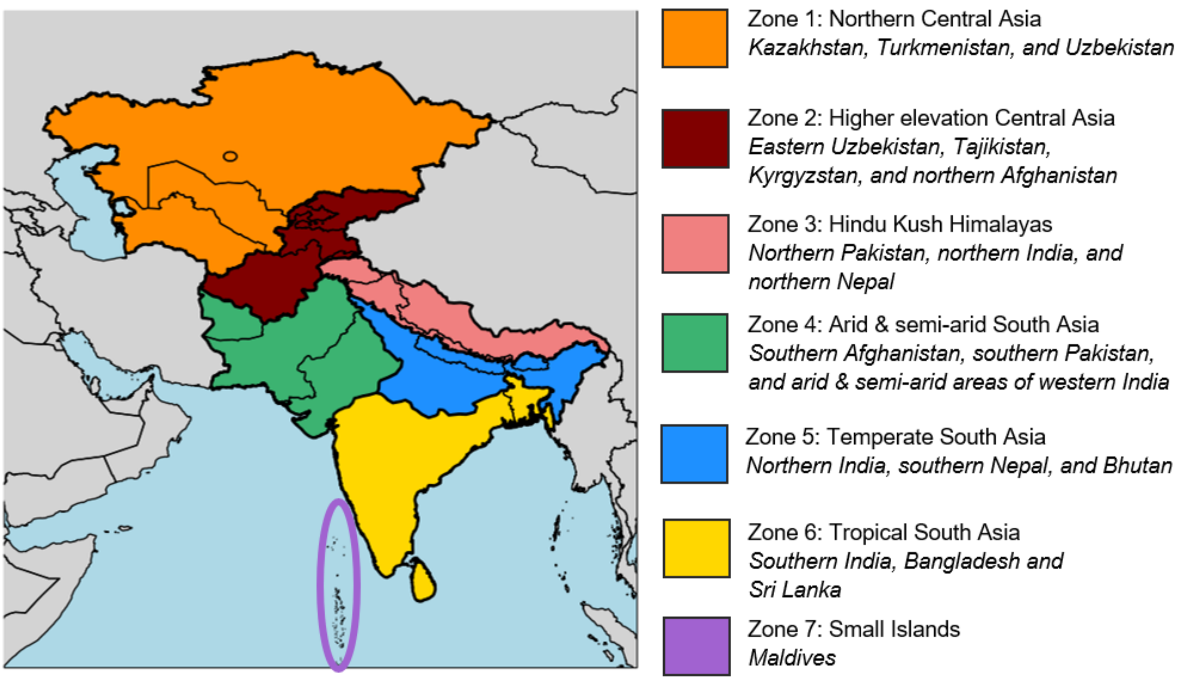

Figure E3: The seven spatial analysis zones across the Central and South Asia region. Zone 1 relates to the Western Siberia (WSB) and West Central Asia (WCA) boxes, Zone 2 relates to the West Central Asia (WCA) box, Zone 3 relates to the Tibetan Plateau (TIB) box, Zone 4 relates to the Tibetan Plateau (TIB) and South Asia (SAS) boxes, and Zones 6-7 relate to the South Asia (SAS) box. Table D1 relates the countries to the spatial analysis zones for reference. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Table E1: Countries in the Central and South Asia region and the relevant spatial analysis zones.

Country	**Climate analysis zones that cover that country**
Afghanistan	Zones 3 and 4
Bhutan	Zone 5
India	Zones 4, 5 and 6
Kazakhstan	Zone 1
Kyrgyzstan	Zone 2
Maldives	Zone 7
Nepal	Zones 3 and 5
Pakistan	Zones 3 and 4
Sri Lanka	Zone 6
Tajikistan	Zone 2
Turkmenistan	Zone 1
Uzbekistan	Zones 1 and 2

Results from the zonal analysis

The bespoke climate data analysis conducted in the spatial analysis zones (Figure E3) focuses only on characterising the baseline climate of each zone and assessing the projected trends in annual and seasonal mean temperature and precipitation for the 2050s relative to the baseline period (1981-2010; see TRD Section A for detail on the data and methods). The current climate is represented by a baseline climatology for the period 1981 – 2010 (hereafter referred to as the 'baseline climate').

Maps of the baseline climatology with the zones overlaid are shown in Figure E4 below.

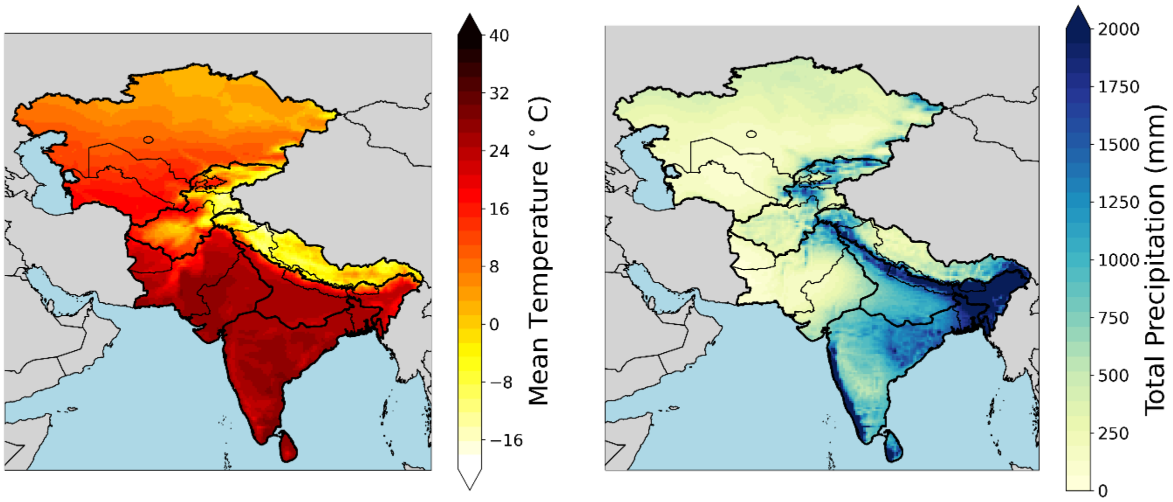

Figure E4: Baseline climate for the Central and South Asia region for the period 1981-2010 with the spatial analysis zones overlaid. Maps show climatological average values of annual mean total precipitation (mm/year; right panel) and annual mean temperature (°C; left panel). Temperature and precipitation data come from the ERA5 reanalysis dataset. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Other outputs from the bespoke zonal data analysis are presented in the following zone-specific sections. This includes time series plots for the baseline climate and scatter plots of the future climate model projections for the 2050s under RCP8.5 (see TRD Section A for detail on the data and methods).

The climate in context assessment (main report, Section 3) at the zone scale includes this bespoke zonal data analysis, supplemented by regional findings from IPCC (2021) and the IPCC Interactive Atlas (as presented in the main report), and the socio-economic and geographic context to identify relevant impacts in each of the zones. Summaries of this assessment are provided in Tables E2-E8 in the following sections.

Climate analysis by zone

To assess the magnitude and direction of projected climate trends at a sub-regional scale the region has been divided into seven sub-regional spatial analysis zones that reflect the different climate types, as shown in Figure E3. The projected trends in these zones are summarised in Table E2. Further detail on the selection of zones and the zonal climate analysis is provided in Section E of the Technical Reference Document.

Table E2: Summary of the zonal analysis for Central and South Asia. More detail is provided in Section E of the TRD. Climate types are defined in the TRD Section G – Technical Terms.

Zone	Countries included	Climate type	Future projections for the 2050s (under a High Emissions Scenario) Headline Messages
Zone 1	Kazakhstan, Turkmenistan and Uzbekistan	Arid climate	• This region will become warmer across all seasons (annual average increase ~2-6°C), particularly in the winter (Dec-Feb). • It is unlikely to become significantly wetter. • Droughts likely to be more frequent and intense. • Earlier spring melt leading to increased downstream river flow until 2050.
Zone 2	Eastern Uzbekistan, Tajikistan, Kyrgyzstan, and northern Afghanistan	Mixed with cold, temperate and tundra climates	• This region will become warmer across all seasons (annual average increase ~2-6°C) • Wetter conditions throughout the year, particularly in Oct-Nov and Mar-May (0-100mm/season). • More rainfall instead of snowfall in winter. • Greater uncertainty in extent of warming/wetting over mountainous regions. • Earlier spring melt leading to increased downstream flow until 2050.
Zone 3	Northern Pakistan, Himalayan areas of NW India, and northern Nepal	Tundra climate	• This region will become warmer across all seasons (annual average increase ~2-6°C), particularly in the winter (Dec-Feb). • Likely to become significantly wetter in the Jun-Sep monsoon season (~0-200mm/season). • Drier winters in eastern Himalayas and wetter in western Himalayas. • More extreme rainfall over the mountains esp. eastern Himalayas.

			• Earlier spring melt leading to increased downstream flow until 2050. • Greater uncertainty in extent of warming/wetting over mountainous regions.
Zone 4	Southern Afghanistan, southern Pakistan and arid and semi-arid areas of western India	Arid climate	• This region will become warmer across all seasons (annual average increase ~2-6°C) but potentially less warming during the monsoon season (Jun-Sep). • It is likely to become wetter especially in the Jun-Sep monsoon season (~0-100mm/season). • Earlier spring melt leading to increased downstream flow until 2050. • Greater uncertainty in extent of warming/wetting over mountainous regions.
Zone 5	Northern India, southern Nepal, and Bhutan	Temperate climate	• This region will become warmer across all seasons (annual average increase ~1.5-3.5°C). • Likely to become significantly wetter in the Jun-Sep monsoon season (~0-400mm/season) but greater model spread indicates uncertainty in the magnitude of wetting. • Earlier spring melt leading to increased downstream flow until 2050. • Models may underestimate warmer but overestimate wetter trends • Greater uncertainty in monsoon onset and extreme precipitation.
Zone 6	Southern India, Bangladesh and Sri Lanka	Mostly tropical climate with small area of arid climate to southwest of India	• Warmer across all seasons (annual average increase ~1-3.5°C), especially warmest season pre-monsoon (Mar-May) (~1-4°C). • Likely to become significantly wetter in the Jun-Sep monsoon season (~0-300mm/season). • Models may underestimate trend for wetter conditions.

			• Sea levels, sea surface temperatures, marine heatwaves (frequency/intensity) and ocean acidity will increase. • Tropical cyclones will, on average, decrease in frequency and increase in overall intensity.
Zone 7	Maldives	Tropical climate	• Annual mean temperatures will rise more slowly than global average. • Generally a trend for wetter conditions over North Indian Ocean. • Sea levels, sea surface temperatures, marine heatwaves (frequency/intensity) and ocean acidity will increase. • Tropical cyclones will, on average, decrease in frequency and increase in overall intensity.

Zone 1: Northern Central Asia

Zone 1 includes Kazakhstan, Turkmenistan, and Uzbekistan (Figure E5) and experiences an arid climate.

Figure E5: Zone 1. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Plots of the baseline climate are shown in Figures E3 and E6. Scatter plots of the future projections are shown in Figure E7. The climate in context assessment for Zone 1 is summarised in Table E3.

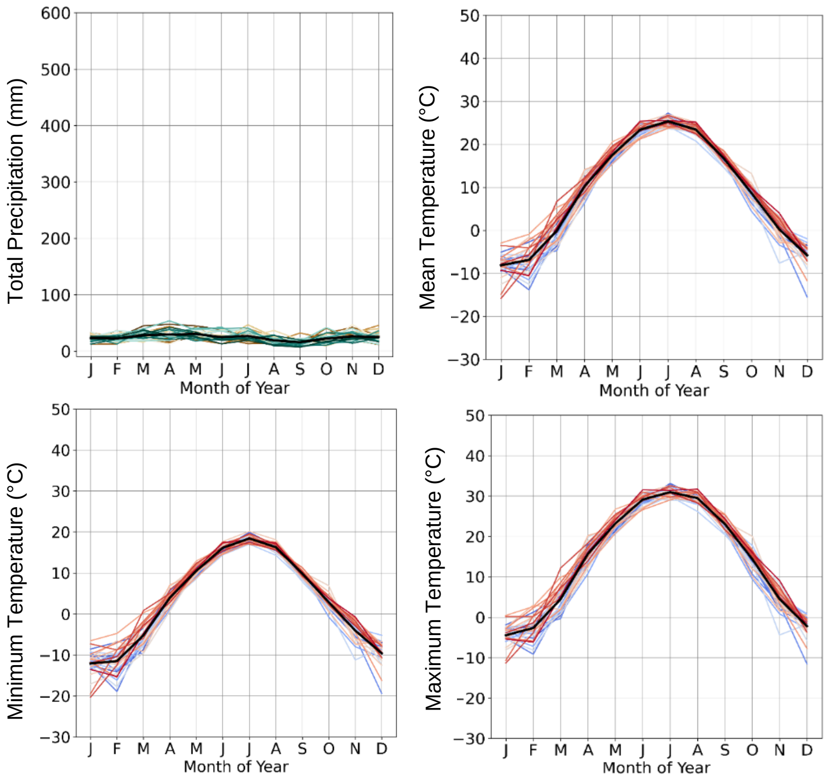

Figure E6: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline climate (1981-2010) for Zone 1. Each line is one individual year. Colours show the ordering of years from brown-green (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

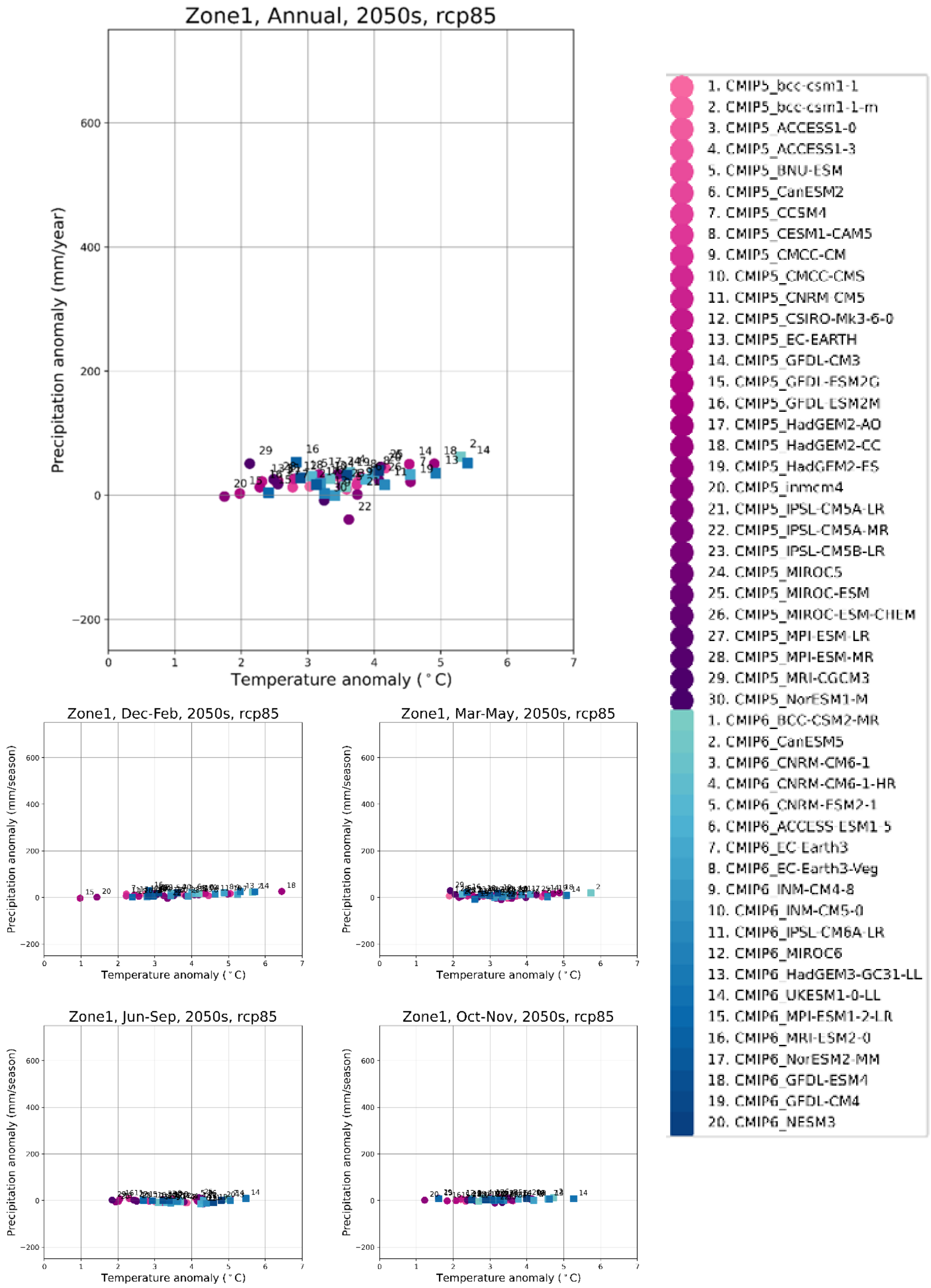

Figure E7: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 1. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend. Only CMIP5 and CMIP6 model simulations have been analysed for Zone 1 because the CORDEX South Asia domain does not sufficiently cover this region.

Table E3: Climate in context analysis for Zone 1		
Baseline (1981-2010)	Current climate	• Daily mean temperatures typically range from -15°C in the winter to 25°C in the summer. Daily maximums exceed 30°C during the hottest months (July to August). • Zone 1 receives very low precipitation (less than 50mm) throughout the year with slightly more precipitation falling over mountainous areas in the southeast of the zone. • Zone 1 has experienced a warming and a wetting trend in recent decades.
	Context	• Zone 1 includes the Caspian Sea to the west of the zone and several large lakes throughout. The Amu Darya river runs through the zone. Other notable features include the Aral Sea, Lake Balkhash, and Altai mountains. • Key climate sensitivities include rising temperatures impacting crops, irrigation, and the environment; rising temperatures and increased frequency, and intensity of droughts significantly increasing water stress; and intensified droughts also contributing to wildfires, deforestation and sand and dust storms worsening air quality and posing significant risks to the environment and human health.
In the 2050s Zone 1 is projected to be warmer and wetter on average		
Future projections (2050s)	Climate trends	• Zone 1 will become warmer across all seasons, particularly in the winter months December to February. • This zone is unlikely to become significantly wetter, and droughts are likely to be more frequent and intense. • Heavy rainfall events will become more intense and frequent.
	Relevant impacts	• Increased risk to river flows due to rising summer temperatures due to evapo-transpiration potentially outstripping rainfall contributions to river flows by 2030. • Increased risk to air quality and health through air pollution due to increasing sand and dust storms and wildfires. Intensified droughts and heatwaves will exacerbate these risks. • Increased risk of desertification due to compounded risks from human activities and increasing droughts. • Increased risk to wetland territories from droughts. • Increased risk of water stress due to a heavy reliance on upstream flows for intensive irrigation (e.g., cotton) which are expected to be impacted by increasing droughts and higher temperatures. Uzbekistan is the most water stressed country in Central Asia. • Increased risk to imported irrigated crops in Uzbekistan due to heat and water stress. • Increased risk of heat extremes on de-rating (lower performance) of power lines (Uzbekistan). This could lead to power cuts and outages as demand for cooling and irrigation increases.

Zone 2: Higher elevation Central Asia

Zone 2 includes eastern Uzbekistan, Tajikistan, and Kyrgyzstan and northern Afghanistan (Figure E8) and experiences a mixed climate with some cold, temperate, and tundra climates.

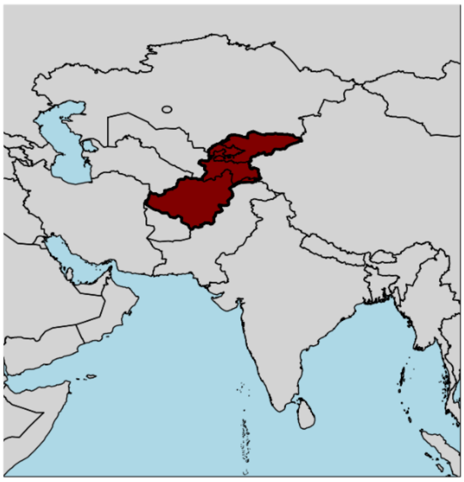

Figure E8: Zone 2. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Plots of the baseline climate are shown in Figures E3 and E9. Scatter plots of the future projections are shown in Figure E10. The climate in context assessment for Zone 2 is summarised in Table E4.

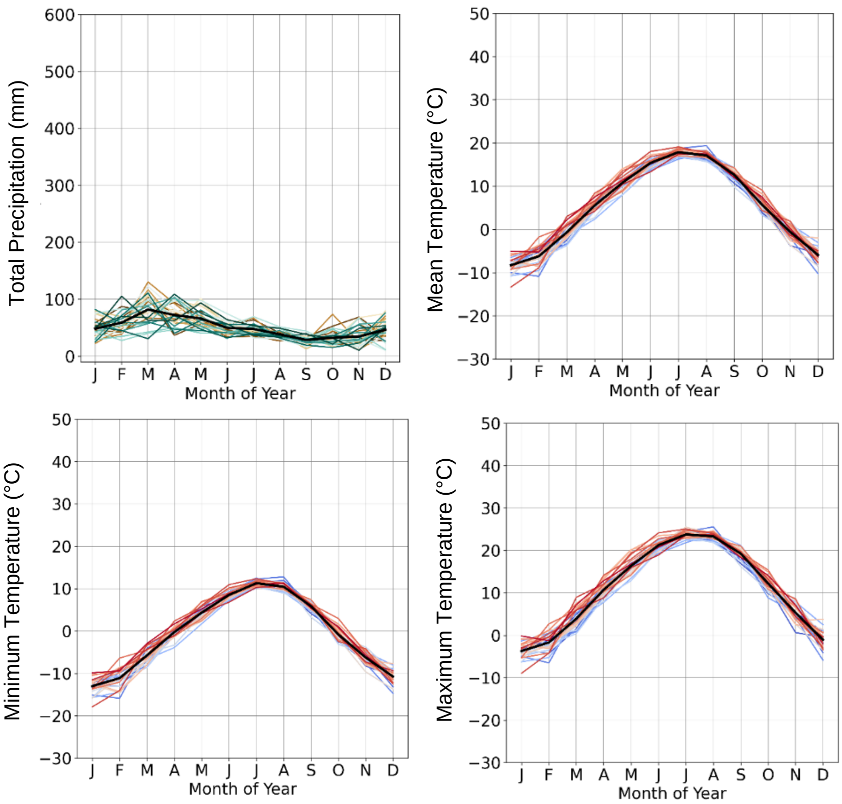

Figure E9: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline climate (1981-2010) for Zone 2. Each line is one individual year. Colours show the ordering of years from brown-green (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

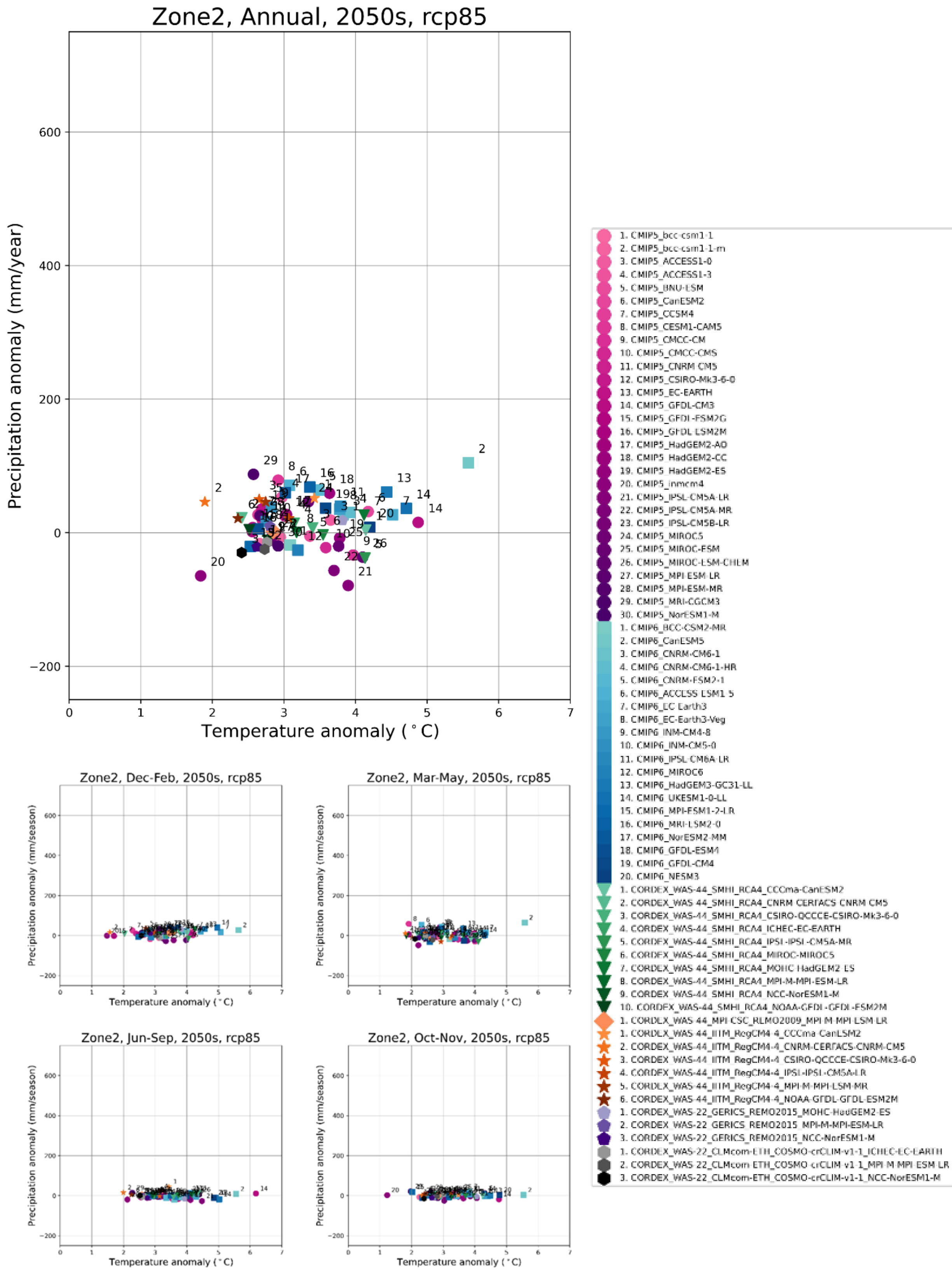

Figure E10: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 2. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Table E4: Climate in context analysis for Zone 2		
Baseline (1981-2010)	Current climate	• Daily mean temperatures typically range from -10°C to 19°C throughout the year, with daily maximums exceeding 22-24°C during the hottest months of July to August. • Zone 2 receives low precipitation throughout the year with a maximum of 50-80mm per month during February to April. • Zone 2 has experienced a warming trend in recent decades. There has been a wetting trend during winter, including both rainfall and snowfall.
	Context	• Zone 2 is a land-locked zone mostly dominated by mountainous terrain with glaciers. Rivers flow from the mountains (such as Al-Say, Chu, Kara Darya, and Naryn). Zone 2 contains many lakes, such as Issyk-Kul which is the world's second largest alpine lake. • Key climate sensitivities include rising temperatures increasing water stress from increasing droughts, earlier melting of glacier snow changing seasonality of river flows, more precipitation falling as rain rather than snow impacting seasonality of river flows (lower summer flows) and subsequent hydropower insecurity; higher temperatures impacting species and the environment; and rising temperatures, droughts and changes to water supply impacting agriculture and irrigation.
In the 2050s Zone 2 is projected to be warmer and wetter on average		
Future projections (2050s)	Climate trends	• This zone will become warmer in the future throughout the year. • This zone will experience wetter conditions throughout the year, particularly from October to November and also March to May. It is expected that there will be more rainfall instead of snowfall in future winters. • Heavy rainfall and drought events will become more intense and frequent.
	Relevant impacts	• Increased risk of worsening water stress due to a heavy reliance on upstream flows for intensive irrigation (e.g., cotton) which are expected to be impacted by increasing droughts and higher temperatures. Uzbekistan is the most water stressed country in Central Asia. • Increased risk to imported irrigated crops in Uzbekistan due to heat and water stress. • Increased risk of heat extremes on de-rating (lower performance) of power lines (Uzbekistan). This could lead to power cuts and outages as demand for cooling and irrigation increases. • Increased vulnerability to changes to glacial-snowmelt causing reduced and/or variable river flow, increasing water stress, as a result of rising temperatures. • Increased economic and social risk from climate-related hydropower insecurity. Kyrgyzstan and Tajikistan are vulnerable to seasonal variations in water supply which is at risk from rising temperatures and changes to glacial snow melt. • Higher average temperatures and changing precipitation will impact species distribution, impacting their ranges, ecological interactions and behaviour patterns. (e.g., the range of Kashmir musk deer will likely expand from central Nepal and northeast Afghanistan to parts of India, Nepal, and China). • Increased risk to undernutrition levels, especially children under five years old, in Afghanistan. Successive droughts and food price inflation have contributed to food insecurity and undernutrition in Afghanistan.

Zone 3: Hindu Kush Himalayas

Zone 3 includes northern Pakistan, Himalayan areas of NW India, and northern Nepal (Figure E11) and experiences a tundra climate.

Figure E11: Zone 3. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Plots of the baseline climate are shown in Figures E3 and E12. Scatter plots of the future projections are shown in Figure E13. The climate in context assessment for Zone 3 is summarised in Table E5.

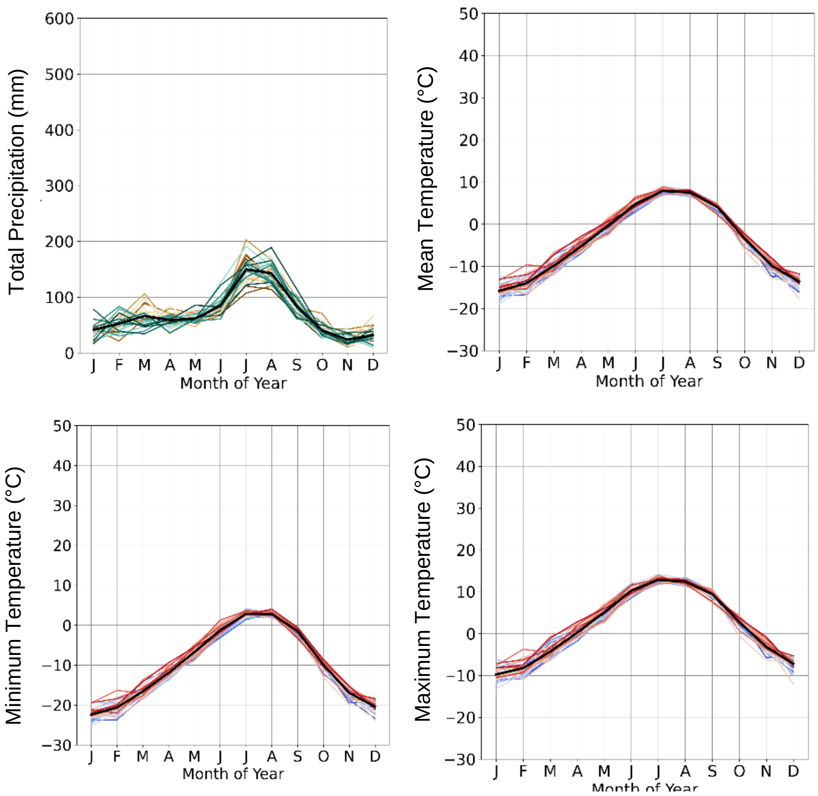

Figure E12: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline climate (1981-2010) for Zone 3. Each line is one individual year. Colours show the ordering of years from brown-green (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

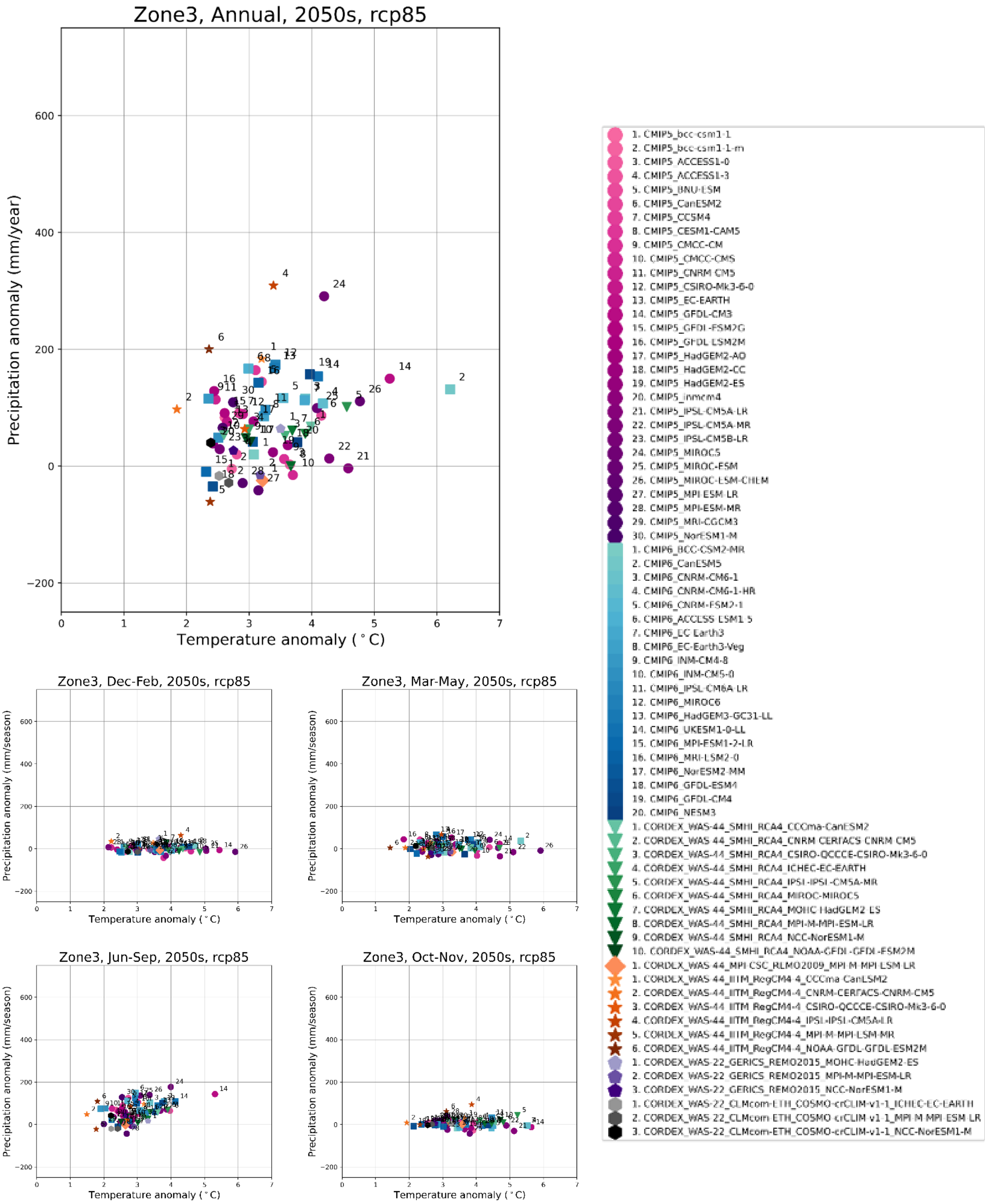

Figure E13: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 3. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Table E5: Climate in context analysis for Zone 3		
Baseline (1981-2010)	Current climate	• Daily mean temperatures typically range from -15°C to 10°C throughout the year, with daily maximums reaching around 12-15°C during the hottest months of July and August. • Zone 3 receives around 120-220mm of precipitation per month between June and August. • Zone 3 has experienced a warming trend in recent decades. There has been a wetting trend during winter and more precipitation has increasingly fallen as rain instead of snow.
	Context	• Zone 3 is a land-locked zone hosting the Himalaya Mountains as well as glaciers and lakes. Major rivers include the Narayani, Kosi, Karnali, and Indus rivers. • Key climate sensitivities include heat-related impacts to health, species distribution, agriculture, livestock; changes to glacial snowmelt increasing water stress; droughts and food prices impacting food insecurity and undernutrition; and heavy rainfall events and potential glacial lake outburst flooding impacting water-related disease prevalence, mudflows, and landslides.
In the 2050s Zone 3 is projected to be wetter during the monsoon and warmer on average		
Future projections (2050s)	Climate trends	• This zone will become warmer across all seasons, particularly in the winter months between December to February. • It is likely that this zone will become significantly wetter on average over the June to September monsoon season. Drier winters are expected over the eastern Himalayas and wetter winters are expected over the western Himalayas. • More extreme rainfall is expected over the mountain areas, especially over the eastern Himalayas. • Heavy rainfall and drought events will become more intense and frequent.
	Relevant impacts	• Increased risk to rice-wheat cropping systems (Pakistan, Nepal) where increased heat, water stress, drought and flooding, may affect yields. • Rising temperatures and heat extremes pose risks to livestock production and productivity, though non-climate drivers (overstocking and loss of traditional rangelands) probably contribute the most to these risks (Pakistan). • Increased risk of flood, mudflow, landslides and glacial lake outburst flooding, leading to variable river flows, lake expansion and landscape instability in mountain areas. • Increased risk of water-borne diseases from flooding due to rising temperatures and more frequent and/or intense heavy rainfall events. • Informal settlements increasing in number, climate risks, and poverty, will increasingly overlap in urban areas. Impacts will be compounded by climate hazards (droughts, floods). • Increased vulnerability to changes to glacial-snowmelt causing reduced and/or variable river flow, increasing water stress, as a result of rising temperatures (Nepal). • Increased risk to rice production and yields due to heat stress affecting susceptible plant growth stages (northern India). • Risk of more sporadic springtime and lower summer river flows driven by accelerated glacial snowmelt due to rising temperatures (northern India). • Increased and more intense monsoon rainfall may buffer the loss of spring river flows but will lead to increased flood and landslide risks particularly in the Hindu Kush-Karakorum-Himalayas, such as northern India. • Increased risk of periodic heat stress conditions approaching the upper limits of labour productivity and human survivability (north-western India).

Zone 4: Arid and semi-arid South Asia

Zone 4 includes southern Afghanistan, southern Pakistan, and arid and semi-arid areas of western India (Figure E14) and experiences an arid climate.

Figure E14: Zone 4. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Plots of the baseline climate are shown in Figures E3 and E15. Scatter plots of the future projections are shown in Figure E16. The climate in context assessment for Zone 4 is summarised in Table E6.

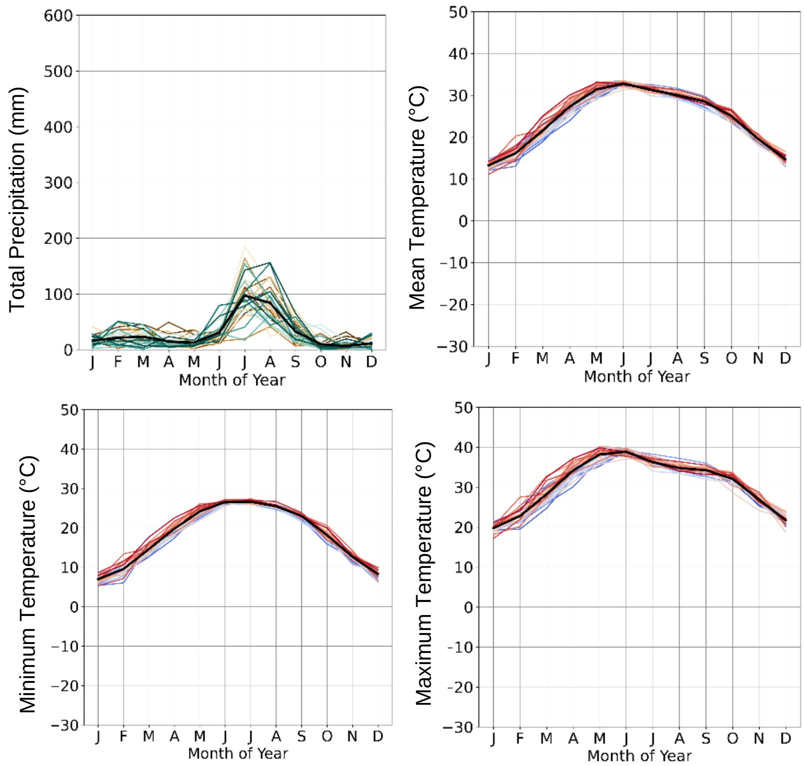

Figure E15: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline climate (1981-2010) for Zone 4. Each line is one individual year. Colours show the ordering of years from brown-green (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

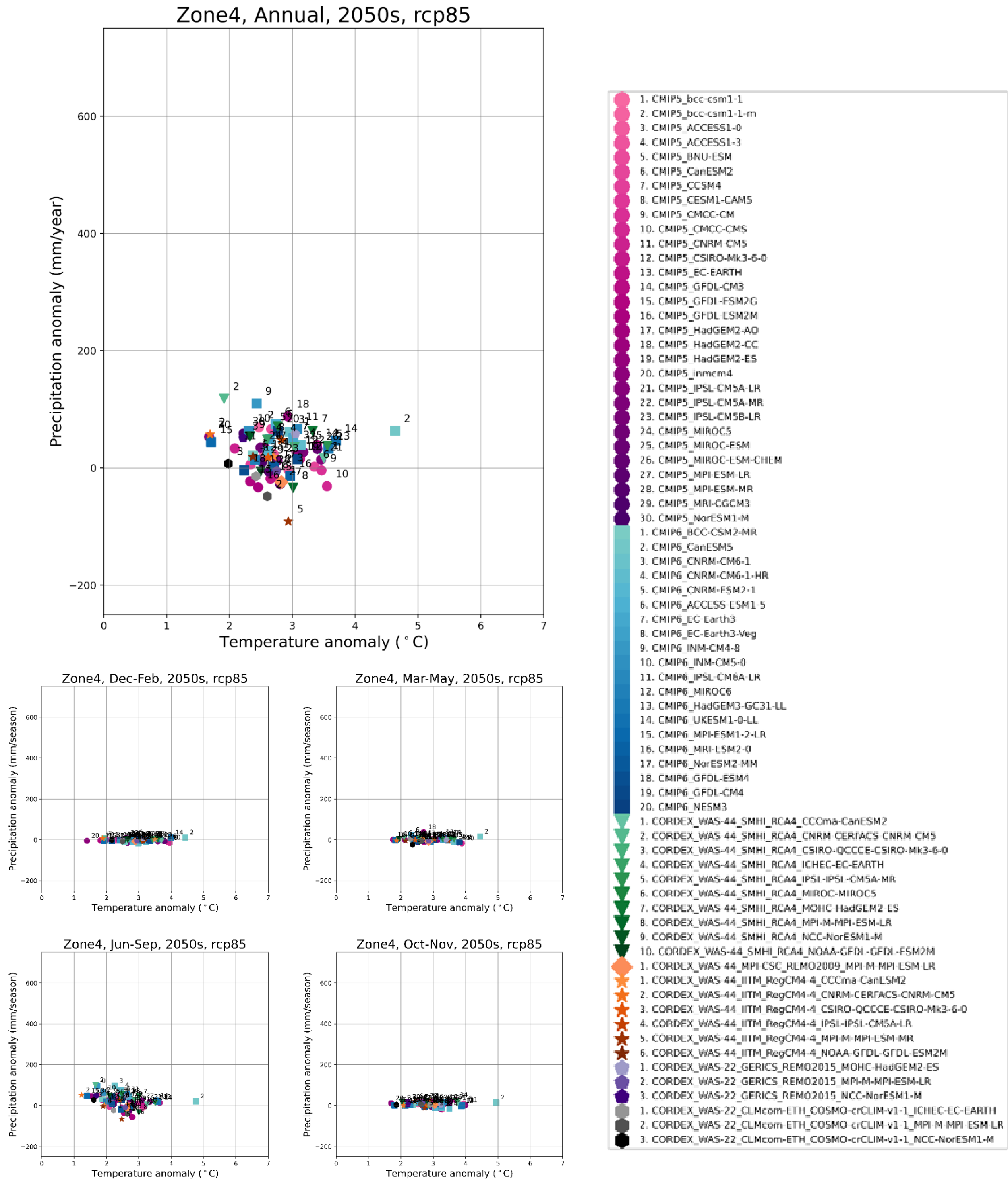

Figure E16: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 4. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

<table>
<tr><th colspan="3">Table E6: Climate in context analysis for Zone 4</th></tr>
<tr><td rowspan="2">Baseline (1981-2010)</td><td>Current climate</td><td>• Daily mean temperatures typically range from 12°C to 33°C through the year, with daily maximums exceeding 40°C during the hottest months from May to June.
• Zone 4 receives around 100-150mm of precipitation per month between June and August.
• Zone 4 has experienced a warming trend in recent decades, with an exacerbation in heatwaves especially in the pre-monsoon season. There has been a wetting trend in the central monsoon belt of Pakistan.</td></tr>
<tr><td>Context</td><td>• Zone 4 is bound by the Arabian Sea to the south and the Thar Desert to the east. This zone hosts mountainous areas with high peaks of the Hindu Kush with extensions of Pamir, Karakorum, and the Himalayan Mountains. Major rivers include the Kabul and Indus while the zone also contains deep lakes in the Hindu Kush Mountains national park.
• Key climate sensitivities include increasing average temperature impacting disease transmission, health and mortality, air pollution, agriculture, water stress, drought, livestock, and undernutrition; heat extremes impacting health and mortality, heat stress, agriculture, and livestock; sea level rise impacting ingress of salty water into coastal aquifers, coastal infrastructure, and economic activities and livelihoods; rising sea surface temperatures and marine heatwaves impacting marine species; and rising aridity alongside heat impacting air quality.</td></tr>
<tr><th colspan="3">In the 2050s Zone 4 is projected to be warmer and wetter on average</th></tr>
<tr><td rowspan="2">Future projections (2050s)</td><td>Climate trends</td><td>• This zone will become warmer across all seasons of the year but potentially less warming will occur during the monsoon season from June to September.
• It is likely that this zone will become wetter in the future, especially during the monsoon season from June to September.
• Heavy rainfall and drought events will become more intense and frequent.
• Sea levels, sea surface temperatures, marine heatwaves (frequency and intensity) and ocean acidity will increase in the future.
• Tropical cyclones will, on average, decrease in frequency and increase in overall intensity in the future.</td></tr>
<tr><td>Relevant impacts</td><td>• Increased disease transmission risk (malaria) in some areas of northern and western India as average temperatures increase in all seasons resulting in extended transmission months.
• Increased risk of periodic heat stress conditions approaching the upper limits of labour productivity and human survivability (north-western India).
• Increased risk to marine species from rising sea surface temperatures.
• Increased risk to air quality from high heat and aridity causing air pollution, impacting health.
• Increased risk to rice-wheat cropping systems (Pakistan) where increased heat, water stress, drought and flooding, may affect yields.
• Rising temperatures and heat extremes pose risks to livestock production and productivity.
• Increased risk of undernutrition levels, especially of children under five years old (India).
• Increased risk of heatwave events and humid heat-related mortality, especially in arid and tropical regions (southern Afghanistan, southern Pakistan, and India), and especially in summer, due to the combination of increasing summer heat and humidity levels and rapidly growing population and urbanisation such as in India.
• Increased risk to coastal infrastructure, economic activities and livelihoods of coastal populations from sea level rise (and related coastal flooding) compounded with land subsidence.
• Increased risk of ingress of salty water into coastal aquifers (India) driven by sea level rise and groundwater pumping.
• Increased risk of informal settlements and poverty as these compound with climate risks and increasingly overlap in urban areas. India is particularly at risk due to a large proportion of low-income populations.</td></tr>
</table>

Zone 5: Temperate South Asia

Zone 5 includes northern India, southern Nepal, and Bhutan (Figure E17) and experiences a temperate climate. Plots of the baseline climate are shown in Figures E3 and E18. Scatter plots of the future projections are shown in Figure E19. The climate in context assessment for Zone 5 is summarised in Table E7.

Figure E17: Zone 5. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

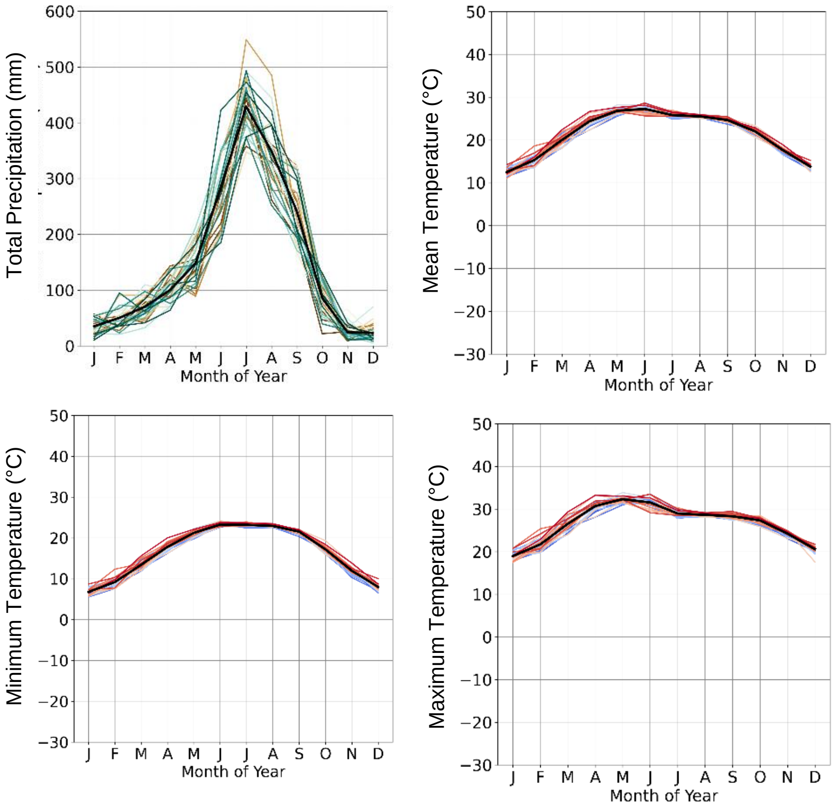

Figure E18: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline climate (1981-2010) for Zone 5. Each line is one individual year. Colours show the ordering of years from brown-green (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

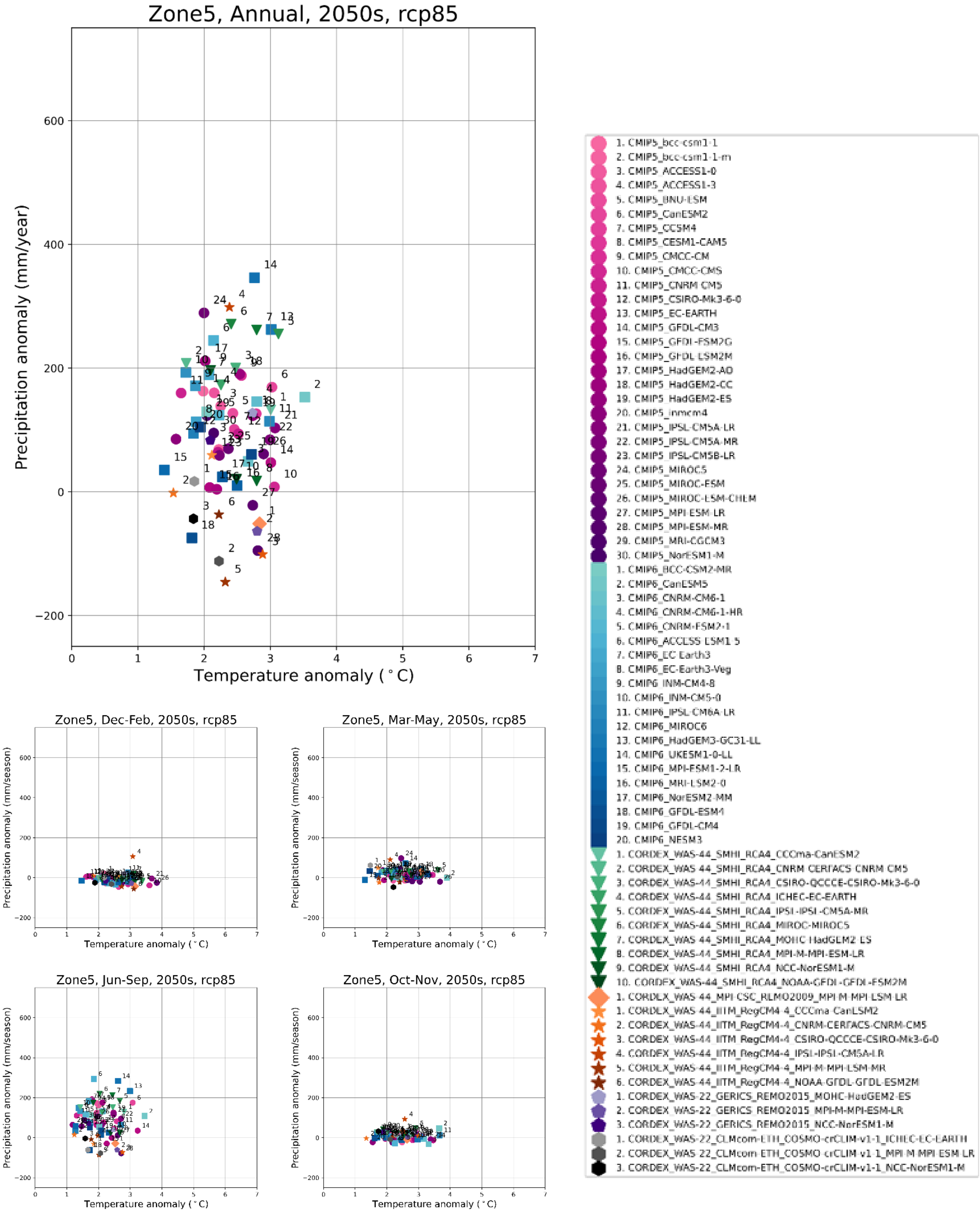

Figure E19: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 5. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Table E7: Climate in context analysis for Zone 5		
Baseline (1981-2010)	Current climate	• Daily mean temperatures typically range from 12°C to 28°C through the year, with daily maximums exceeding 30°C during the hottest months from April to June. • Zone 5 receives around 400-500mm of precipitation per month between June to August with relatively lower amounts of precipitation during the coldest months. • Zone 5 has experienced a warming trend in recent decades. There has been a drying trend with a decrease in overall rainfall, however extreme rainfall events are expected to increase in intensity and frequency.
	Context	• Zone 5 includes the Ganges, Yamuna, and Brahmaputra rivers. The zone has mostly low elevation and is bounded by mountainous areas to the east through which the Brahmaputra River runs. • Key climate sensitivities include heat stress on agriculture (rice); increasing levels of undernutrition; high overnight temperatures and extreme heat events impacting health and overall higher temperatures on species distribution and glacier snowmelt; heavy rainfall events impacting flooding and landslides; droughts impacting hydropower generation and river flows and associated water security.
In the 2050s Zone 5 is projected to be wetter during the monsoon and warmer on average		
Future projections (2050s)	Climate trends	• This zone will become consistently warmer across all seasons in the future. • It is likely that this zone will become significantly wetter on average in the monsoon season from June to September, and likely to be a decrease in winter precipitation (December to February). • Heavy rainfall and drought events will become more intense and frequent.
	Relevant impacts	• Increased risk to rice production and yields due to heat stress affecting susceptible plant growth stages (northern India). • Increased risk of undernutrition levels, especially of children under five years old (India, Bhutan). • Increased health risks from increasingly high overnight temperatures. • Increased risk of heatwave event exposure and heat-related mortality due to the combination of high summer heat and humidity and rapidly growing population and urbanisation. • Increased risk of floods and landslides from heavy rainfall events (Nepal). • Increased risk to run-of-river hydropower generation with limited storage capacity (Nepal) which are dependent on seasonal (monsoon) rainfall and vulnerable to rainfall variability and increased droughts. • Increased risk to river flows driven by glacial snowmelt due to rising temperatures (northern India and Nepal). • Increased and more intense monsoon rainfall may buffer the reduction of spring river flows but will lead to increased flood and landslide risks particularly in the Hindu Kush-Karakorum-Himalayas, such as northern India. • Increased risk to species distribution due to warmer temperatures, potentially increasing risk to ecosystem health (e.g., endangered Kashmir musk deer will likely expand from central Nepal and northeast Afghanistan to parts of India, Nepal and China). • Increased risk of periodic heat stress conditions approaching the upper limits of labour productivity and human survivability (north-western India).

Zone 6: Tropical South Asia

Zone 6 includes southern India, Bangladesh and Sri Lanka (Figure E20) and experiences a tropical climate with a smaller area of arid climate to the southeast of India.

Figure E20: Zone 6. Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Plots of the baseline climate are shown in Figures E3 and E21. Scatter plots of the future projections are shown in Figure E22. The climate in context assessment for Zone 6 is summarised in Table E8.

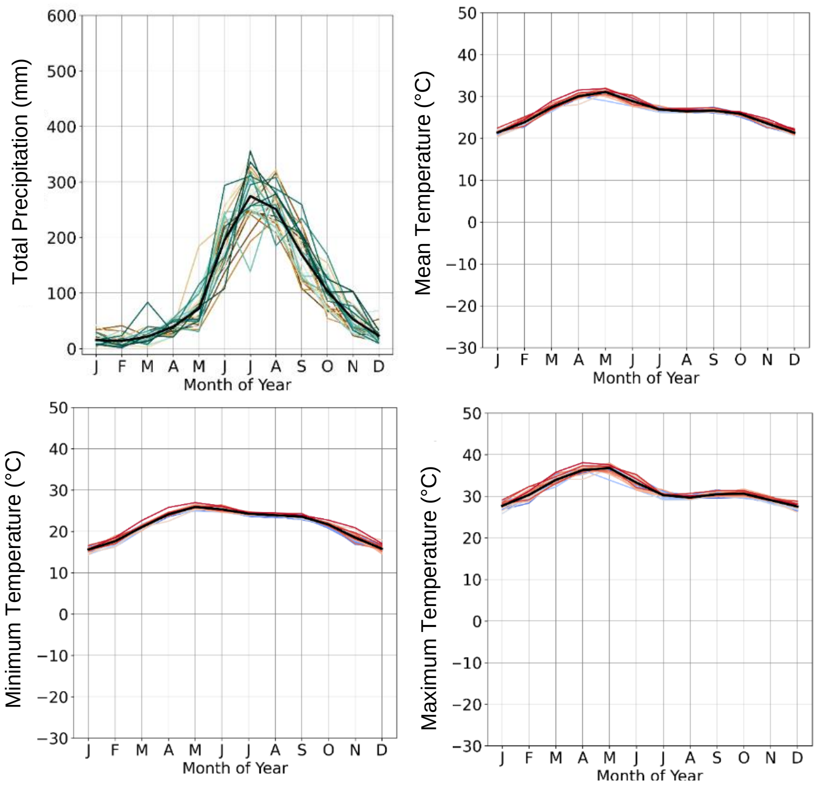

Figure E21: Observations of total monthly precipitation (a) and average daily mean (b), minimum (c) and maximum (d) temperature over the baseline climate (1981-2010) for Zone 6. Each line is one individual year. Colours show the ordering of years from brown-green (total precipitation) and blue-red (mean temperature) – this highlights the presence, or lack of, a trend over the baseline period. The bold black line indicates the average of the 30-year period.

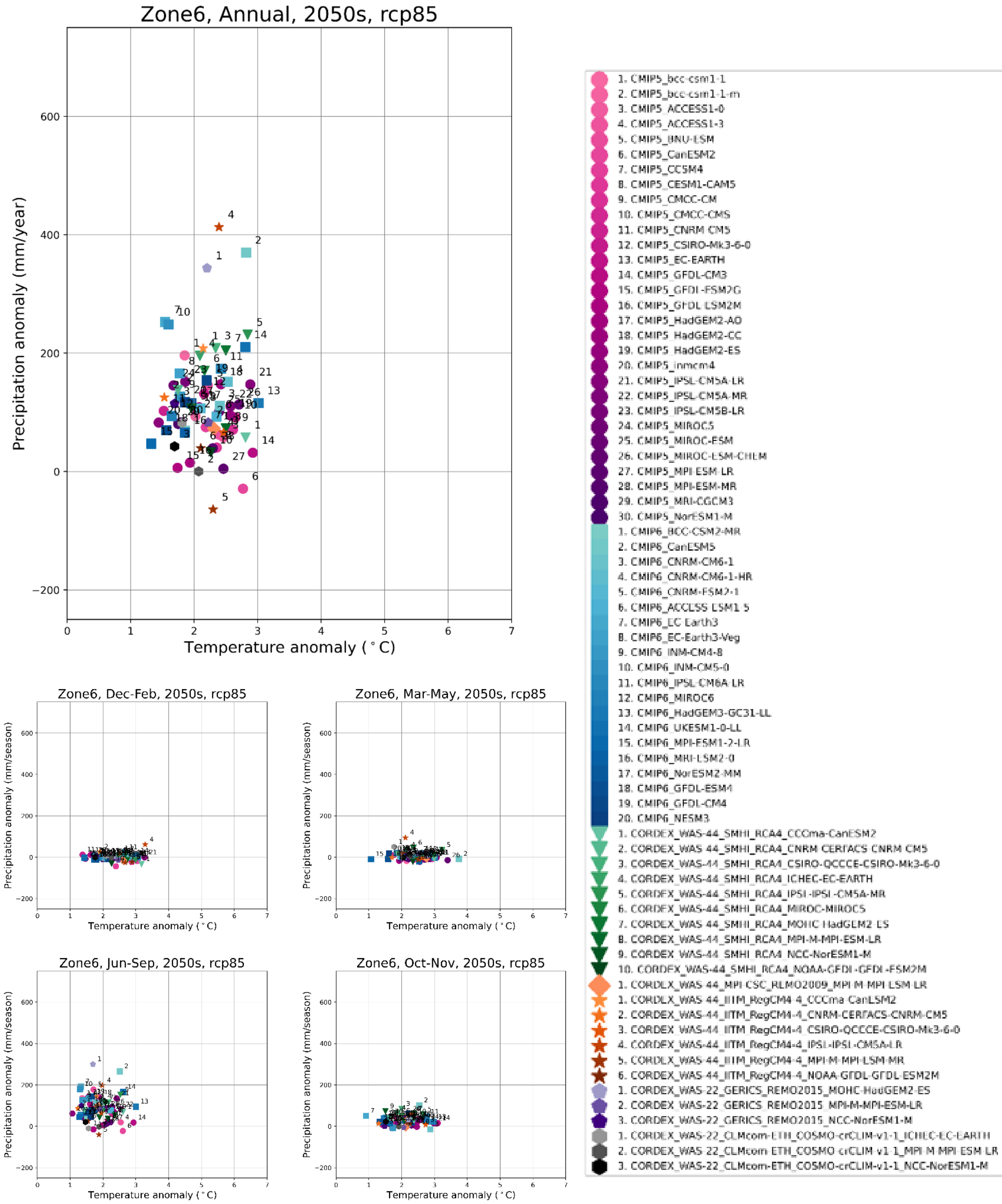

Figure E22: Projected change in average annual (top panel) and seasonal (bottom panels) precipitation and temperature in Zone 6. Each dot shows the difference between the average projected values in the 2050s and the average values in the current climate, for each climate model. Individual models are identified by the icon and number in the legend.

Table E8: Climate in context analysis for Zone 6		
Baseline (1981-2010)	Current climate	• Daily mean temperatures typically range from 20°C to 31°C through the year, with daily maximums reaching around 35°C to 38°C during the hottest months from March to May. • Zone 6 receives around 250-300mm of precipitation per month between June to September (monsoon season) with very low rainfall during the coldest months. • Zone 6 has experienced a warming trend in recent decades. There have been no significant trends in precipitation over this zone but there has been increasing frequency of extreme rainfall events in the pre-monsoon season in NE Bangladesh. .
	Context	• Zone 6 includes the Indian Ocean and Gulf of Mannar to the south and the Arabian Sea to the west. This zone is host to many rivers and deltas such as the Ganges, Brahmaputra, and Meghna. • Key climate sensitivities include extreme heat events impacting health and mortality; rising average temperatures impacting health, wetlands, agriculture, and disease prevalence; rising sea levels, intensifying tropical cyclones, storm surges and flooding impacting coastal cities' infrastructure, economics, and livelihoods, shoreline retreat, saltmarshes, tourism, and ingress of salty water into coastal aquifers; and rising sea surface temperatures and marine heatwaves impacting marine species, especially corals, seagrasses, and tourism.
In the 2050s Zone 6 is projected to be wetter during the monsoon and warmer on average		
Future projections (2050s)	Climate trends	• This zone will become warmer in the future across all seasons, especially during the pre-monsoon warm months March to May. • It is likely that this zone will become significantly wetter on average during the monsoon season from June to September. • Heavy rainfall and drought events will become more intense and frequent. • Sea levels, sea surface temperatures, marine heatwaves (frequency and intensity) and ocean acidity will increase in the future. • Tropical cyclones will, on average, decrease in frequency and increase in overall intensity.
	Relevant impacts	• Increased risk of heat-related mortality due to rising temperatures and heat extremes. • Increased risk of heatwave events and humid/heat-related mortality due to increasing summer heat and humidity levels and India and Sri Lanka's rapidly growing population and urbanisation. • Increased risks to coastal infrastructure, particularly cities, from tropical cyclones, storm surges and floodings. • Increased risk of sea level rise (and related coastal floods) compounded with land subsidence. Sri Lanka and southern India will especially experience shoreline retreat. • Increasing sea surface temperatures and marine heatwaves impacting marine species, especially corals. • Increased risk to seagrass habitats and their survival due to rising sea levels, warmer temperatures and ocean acidification. • Increased risk to tourism in coastal zones and coral reefs due negative impacts associated with sea level rise and marine heatwaves. • Increased risk to wetlands driven by higher temperatures, sea level rise and droughts. • Increased risk of ingress of salty water into coastal aquifers (India, Bangladesh) driven by sea level rise and groundwater pumping. • Increased risk of diarrhoeal disease driven by warmer and wetter conditions leading to reduced water quality and increased mortality (Bangladesh, India). • Coastal cities will become increasingly exposed to impacts from tropical cyclones, storm surges and flooding leading to large-scale human and economic losses. • Increased risk of periodic heat stress conditions approaching the upper limits of labour productivity and human survivability (eastern coastal India).

Zone 7: Small Islands

Zone 7 includes the Maldives (Figure E23) and experiences a tropical climate.

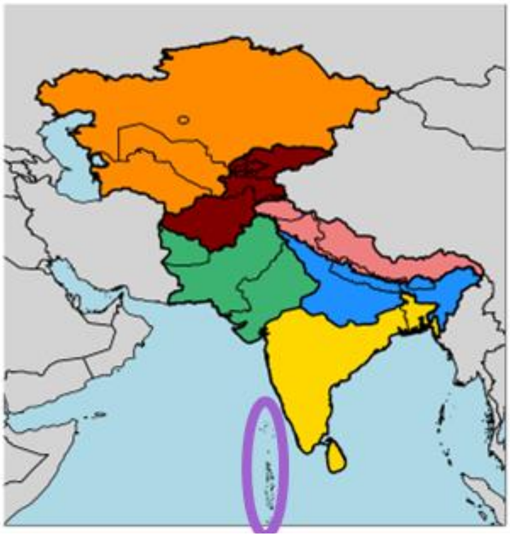

Figure E23: Zone 7 (circled in purple). Maps are used in this report for representational purposes. The Government of the UK does not necessarily endorse the political boundaries depicted in the maps.

Zone 7 is solely based on analysis of available literature. Average monthly temperature and rainfall in the Maldives is shown in Figure E24 (1991-2020; World Bank, 2021).

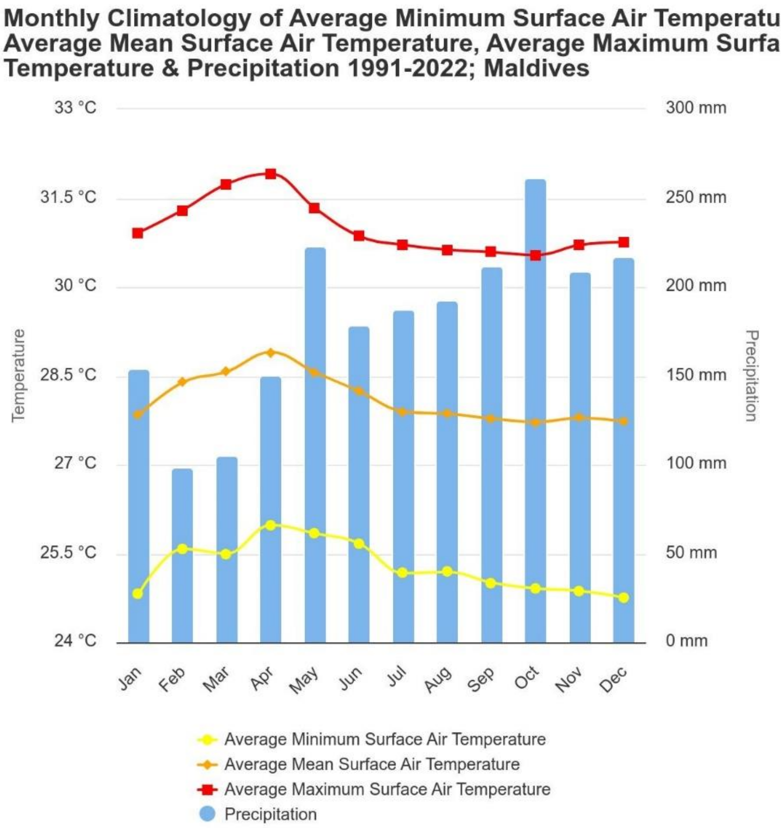

Figure E24: Monthly climatology of average minimum, mean, and maximum surface air temperature, as well as precipitation 1991-2022 for the Maldives. Source: World Bank, accessed 16th January 2024, available at https://climateknowledgeportal.worldbank.org/country/maldives

Projected average temperature (anomaly) and annual rainfall (anomaly) in the Maldives is shown in Figure E25. The climate in context assessment for Zone 7 is summarised in Table E9.

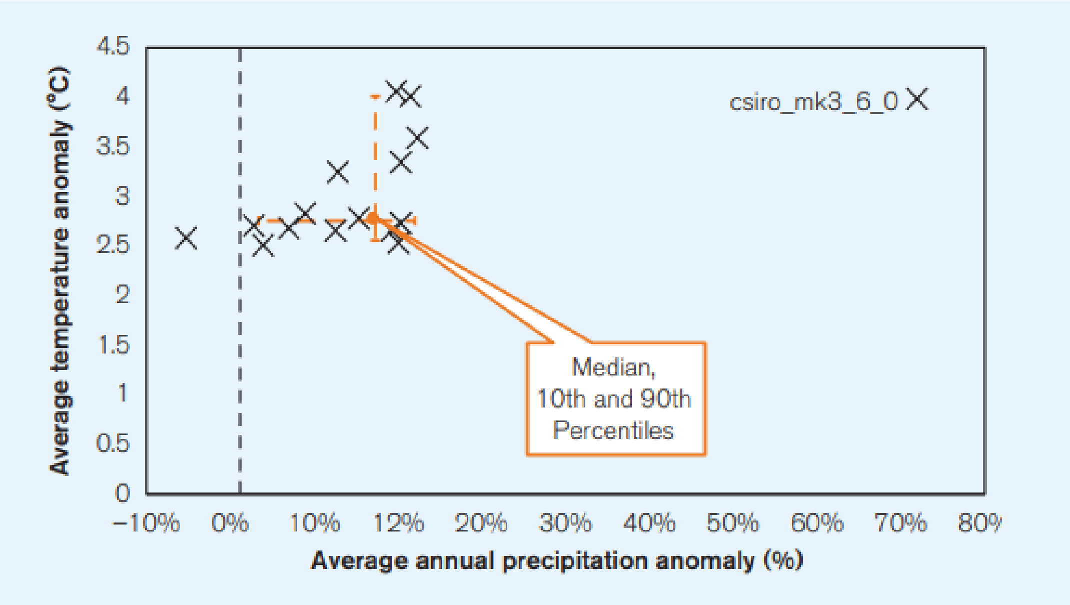

Figure E25: Projected average temperature anomaly and projected annual rainfall anomaly in the Maldives. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080-2099. Models shown represent the subset of models within the ensemble which provide projections across all RCPs and therefore are most robust for comparison. One model is labelled. Source: World Bank (2021), accessed 16th January 2024, available at https://climateknowledgeportal.worldbank.org/sites/default/files/2021-08/15649-WB_Maldives%20Country%20Profile-WEB.pdf

Table E9: Climate in context analysis for Zone 7		
Baseline (1981-2010)	Current climate	• Zone 7 experiences average annual temperatures of 27.8°C and temperatures generally range from 25 to 31°C over the year with higher temperatures in the north. There are seasonal fluctuations in temperature due to the monsoon. • Zone 7 receives an average annual precipitation of 2365mm per year (averaging just under 200mm per month). Usually there is more rainfall during the southwest monsoon. Southern islands tend to receive more rainfall than the northern. • Zone 7 has experienced a warming trend in recent decades. • Zone 7 has experienced sea surface temperature increases and sea level rise.
	Context	• Zone 7 is the archipelagic nation of the Maldives in the Indian Ocean and is Asia's smallest country. The archipelago contains 1110 islands surrounded by coral reefs. The Maldives includes some marsh wetlands and is overall extremely low-lying with the highest point being only 2.4m above sea level (Wilingili Island). • Key climate sensitivities include sea level rise on coastal infrastructure and livelihoods, which is also compounded with land subsidence, sea surface temperatures, ocean acidification and sea level rise impact marine species (especially corals and seagrasses), and overarching impacts on tourism as a major economic sector in the Maldives.
In the 2050s Zone 7 is projected to be warmer and wetter on average		
Future projections (2050s)	Climate trends	• This zone will become warmer in the future. • There is a general wetting trend over the North Indian Ocean. • Heavy rainfall and drought events will become more intense and frequent. • Sea levels, sea surface temperatures, marine heatwaves (frequency and intensity) and ocean acidity will increase in the future. • Tropical cyclones will, on average, decrease in frequency and increase in overall intensity in the future.
	Relevant impacts	• Increased risk from sea level rise, affecting a large proportion of the total population of the Maldives which lives in very low-lying areas. This population faces risks to housing infrastructure and livelihoods due to sea level rise and related coastal flooding. • Sea level rise (and related coastal floods) and land subsidence compounds risks to coastal infrastructure, economic activities, and livelihoods of coastal populations. The Maldives especially will experience shoreline retreat. • Increased risk to marine species, especially corals, from rising sea surface temperatures. • Increased risk to economic and social benefits from coral reefs, mainly tourism. Sea level rise, extreme weather conditions and changes in the marine environment will play an important role in the sustainability of tourism as a key economic sector in the Maldives. • Increased risk to seagrass habitats and their survival due to elevated sea levels, warmer waters and ocean acidification. Dredging degrades seagrass habitat and adds additional stress, further threatening habitat survival. • Increased risk to the Maldives' economy from fish catch.

F: Socio-economic data

Table F1: Demographic, economic and food security data. Data sources and notes outlined below table. Instances of "pop" refer to population; "agric" to agriculture; and "insec" to insecurity.

	Demographics				Economics					Food security	
Country	**Total pop (M)**	**Pop growth/yr (%)**	**Rural pop (%)**	**Urban slum (%)**	**GDP/capita (USD)**	**Annual GDP growth (%)**	**Agric GDP (%)**	**Below USD3.65 (%)**	**Below USD2.15 (%)**	**Food insec (%)**	**Food insec trend**
Kazakhstan	19.7	3.2	42	1	11244	3.2	5	0.5	0.0	2.4	Falling
Uzbekistan	35.6	2.1	50	ND	2255	5.7	24	NA	NA	26.1	Rising
Kyrgyzstan	6.8	1.6	63	2	1607	7	12	18.7	1.3	6.9	Rising
Turkmenistan	6.4	1.4	47	9	7297	NA	11	NA	NA	NA	NA
Tajikistan	9.9	2.1	72	17	1054	8	22	25.7	6.1	NA	NA
Total	*78.4*	-	-	-	-	-	-	-	-	-	-
Regional %	*38*	-	*52*	-	-	-	-	-	-	-	-
Afghanistan	41.1	2.5	73	73	364	-20	33	NA	NA	79.1	Rising
Pakistan	235.8	1.9	62	56	1597	6.2	22	39.8	4.9	42.3	Rising
Nepal	30.5	1.7	79	40	1337	5.6	21	NA	NA	37.4	Rising
Bhutan	0.8	0.6	56	NA	3266	4.1	19	9.4	0.9	NA	NA
Bangladesh	171.2	1.1	60	52	2688	7.1	11	51.6	13.5	31.1	Level
India	1471	0.7	64	49	2389	7	17	44.8	10.0	NA	NA
Sri Lanka	22.2	0.1	81	NA	3354	-7.8	9	11.3	1.0	10.9	Rising
Maldives	0.5	0.4	58	35	11,817	12.3	5	0.0	0.0	13.4	Level
Total	*1973.1*	-	-	-	-	-	-	-	-	-	-

Regional %	*62*	-	*64*	-	-	-	-	-	-	-	-

Data sources and notes:

Demographics

- *Total population, rural population, population growth rate: UN World Population Prospects, 2022 data (World Bank, 2022).*
- *Slum population: UN-HABITAT 2020 data (World Bank, 2022; Note: represents proportion of urban population living in slum households, defined as households lacking >1 basic conditions (improved water and sanitation, sufficient living area, housing durability, secure tenure).*

Economics, poverty

- *GDP/capita, growth and agric as a % GDP: (World Bank, 2022) (except Afghanistan, Bhutan, Kyrgyzstan 2021; Turkmenistan 2020). Note: countries shaded red defined as low income (GDP/cap <USD1085), orange lower-middle income (GDP/cap USD1086 – USD4255) and yellow upper-middle income (USD4256 – USD13,205) (World Bank, 2022).*
- *Poverty: World Bank data for 2019 except Tajikistan (2015), Bangladesh (2016), Bhutan (2017), Pakistan, Kazakhstan (2018) and Kyrgyzstan (2020) (Aquilar et al., 2023). Note: % population living below USD2.15 (extreme) and USD3.65 poverty line, measured in 2017 USD.*

Food security

- *Food insecure % population: FAO 2020-2022 3-year average data (FAO, 2023). Note: Prevalence of moderate or severe food insecurity in the population. Data used to monitor SDG Indicator 2.1.2 under Target 2.1: 'By 2030 end hunger and ensure access by all people…to safe, nutritious and sufficient food year-round'. NA not available – data not collected or not reported.*
- *Food insecurity trend: comparison between FAO 2017 – 2019 and 2020-2023 3-year average data (FAO, 2023).*

Total, regional %

- *Note: % calculations account for different country populations.*

Table F2: Water resources, water withdrawals, access to basic services. Data sources and notes outlined below table. Instances of "irrig" refer to irrigation; "agri" to agricultural; "ind" to industrial; "mun" to municipal; and "san" to sanitation.

	Water resources, water withdrawals						**Access to basic services**					
	Water stress (%)	**Depend ratio (%)**	**Irrig area (%)**	**Agric use (%)**	**Ind use (%)**	**Mun use (%)**	**Basic water all (%)**	**Safely manage water all (%)**	**Rural water basic (%)**	**Basic san all (%)**	**Safely manage san all (%)**	**Rural san basic (%)**
Kazakhstan	34	41	4	63	18	19	95	86	91	98	NA	99
Uzbekistan	169	80	97	92	4	4	97	80	95	100	75	100
Kyrgyzstan	50	1	75	93	4	3	91	76	87	98	93	100
Turkmenistan	135	97	90	95	3	2	100	95	100	99	NA	100
Tajikistan	70	17	71	75	16	9	82	55	77	97	NA	97
Regional %	-	-	-	-	-	-	*94*	*79*	*71*	*99*	-	*99*
Afghanistan	55	29	40	98	1	1	82	30	76	56	NA	51
Pakistan	116	78	63	94	1	5	91	51	89	71	NA	63
Nepal	8	6	49	98	0	2	91	16	92	80	51	81
Bhutan	1	0	28	94	1	5	100	73	99	78	51	79
Bangladesh	6	91	54	88	2	10	98	59	98	59	31	62
India	66	31	42	90	3	7	93	NA	92	78	52	75
Sri Lanka	91	0	24	87	7	6	89	39	87	95	NA	95
Maldives	16	0	0	0	5	95	100	NA	100	100	NA	100
Regional %	-	-	-	-	-	-	*93*	-	*92*	*75*	-	*72*

Data sources and notes:

Water resources, withdrawals

- *Water stress %: SDG 6.4.2 water withdrawals as a percentage of renewable freshwater, FAO data for 2020 (FAO AQUASTAT, 2023). Note: countries where this % falls in the 0-25% bracket classified as 'no stress' (blue); >25-50% 'low stress' (yellow), >50-75% 'medium stress' (orange); >75-100% 'high stress' (light red); >100% 'critical stress' (dark red) in the SDG 6.4.2 monitoring framework.*
- *Dependency ratio %: percentage of renewable water originating outside country, FAO 2020 estimates (FAO AQUASTAT, 2023).*
- *Irrigated area %: percentage of cultivated land equipped for irrigation. FAO data for 2020 (FAO AQUASTAT, 2023).*
- *Agric, Ind and Mun use %: water withdrawals (use) by sector as a % of total withdrawals (agriculture, industrial, municipal), FAO data for 2020 (FAO AQUASTAT, 2023).*

Access to basic services: water, sanitation

- *Basic water all: % of total population with access to at least basic water services. (United Nations, 2023). Note: basic means from an improved source, collection time <30 mins.*
- *Safely managed water all: % of total population with access to safely managed water. (United Nations, 2023). Note: safely managed means accessible on premises, available when needed and free from contamination.*
- *Basic water rural: as above, rural only. (United Nations, 2023)*
- *Basic sanitation all: % of population with access to at least basic sanitation. (United Nations, 2023). Note: improved facilities i.e., not shared with other households.*
- *Safely managed sanitation all: % of total population with access to safely sanitation. (United Nations, 2023). Note: safely managed means improved facilities not shared with other households, with excreta safely disposed of in situ or treated off site.*
- *Basic san rural: as above, rural only. (United Nations, 2023)*

Regional (Reg) %

- *Excl UMI: excluding upper-middle income countries, i.e., low and lower-middle income countries only (see Economics above for definitions). Note: % calculations account for different country populations.*

Table F3: Potential direct impact of climate events on information and communication technology (ICT) infrastructure. Source: Sandhu and Raja (2019).

Infrastructure/climate event	Inland/coastal floods	Sea-level rise	High temperature	Water scarcity	Storms/high winds
Deep sea submarine cables	Low	Low	Low	Low	Low
Near Shore submarine cables	Low	Low	Low	Low	Medium
Underground terrestrial cables	Medium	Low	Low	Low	Low
Overland terrestrial cables	Low	Low	Low	Low	Medium
Landing stations	High	High	Low	Low	Low
Data centres	High	Low	Medium	Medium	Low
Antennas/towers	Low	Low	Low	Low	High

G: Glossary

A list of acronyms and definitions for technical terms used throughout the report are provided below.

Acronyms

AC	Air conditioning
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
AWT	Asian Water Tower
BCR	Benefit-cost ratio
CAPS	Central Asia Power System
CAREC	South Asian Subregional Economic Cooperation
CASA	South Asia Transmission Interconnection Project
CDD	Cooling Degree Days
CMIP	Coupled Model Intercomparison Project
CO_2	Carbon dioxide
CORDEX	Coordinated Regional Climate Downscaling Experiment
COVID-19	Coronavirus Disease 2019
CSA	Central and South Asia
DALY	Disability Adjusted Life Years
EAD	Expected annual damage
ENSO	El Niño Southern Oscillation
ERA5	See technical terms
FAO	Food and Agriculture Organization
FCDO	Foreign, Commonwealth & Development Office
GBD	Global Burden of Disease
GCM	Global climate model
GDP	Gross Domestic Product
GHG	Greenhouse gas
GW	Groundwater
HWFI	Heat Wave Frequency Index
ICT	Information and communication technology
ICWC	Interstate Coordination Water Commission
IGB	Indo-Gangetic Basin
IGP	Indo-Gangetic Plain
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change

IPO	Interdecadal Pacific Oscillation
LCOE	Levelized Cost of Energy
MHW	Marine heatwave
NAO	North Atlantic Oscillation
NbS	Nature-based solutions
NCDs	Non-communicable diseases
NDCs	Nationally Determined Contributions
OECD	Organisation for Economic Co-operation and Development
PDNA	Post-disaster needs assessment
PESCO	Peshawar Electric Supply Company
PV	Solar photovoltaic
RCM	Regional climate model
RCP	Representative Concentration Pathway
SAARC	South Asian Association for Regional Cooperation
SAREC	South Asian Subregional Economic Cooperation
SDG	Sustainable Development Goal
SEA	Southeast Asia
SLR	Sea level rise
SRES	Special Report Emissions Scenarios
SSP	Shared Socioeconomic Pathways
SST	Sea surface temperatures
TC	Tropical Cyclones
TRD	Technical Reference Document
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
USD	United States Dollar
WASH	Water, Sanitation, and Hygiene
WFP	World Food Programme
WHO	World Health Organization

Technical Terms

Term	Definition
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.
Aerosols	A suspension of airborne solid or liquid particles, with a typical size between a few nanometres and 10 μm that reside in the atmosphere for at least several hours. Aerosols may be of either natural or anthropogenic origin. Aerosols may influence climate in several ways: through both interactions that scatter and/or absorb radiation and through interactions with cloud microphysics and other cloud properties, or upon deposition on snow- or ice-covered surfaces thereby altering their albedo and contributing to climate feedback.
Agro-ecological	The process applied to agricultural production systems, bringing ecological principles to suggest new management approaches.
Agricultural Drought	Agricultural drought happens when there is lack of rainfall or dry soil affects farming and crop growth.
Anomaly	The deviation of a variable from its value averaged over a reference period.
Anthropogenic	Resulting from or produced by human activities.
Aquaculture	The breeding, rearing, and harvesting of fish, shellfish, algae, and other organisms in all types of water environments.
Archipelago	An extensive group of islands.
Arid	(Of land or a climate) having little or no rain
Asian Water Tower	The Hindu Kush Himalaya Region is the source of the 10 major river basins in Asia and is therefore widely regarded as the 'water tower' of Asia. It is also the largest global store of frozen water after the polar regions (thus also named the Third Pole) provides a reliable water supply to almost two billion people.
Atmosphere	The gaseous envelope surrounding the earth, divided into five layers – the troposphere which contains half of the Earth's atmosphere, the stratosphere, the mesosphere, the thermosphere, and the exosphere, which is the outer limit of the atmosphere.
Attribution	The action of regarding something as being caused by a person or thing. Climate attribution refers to the process of establishing the most likely causes for the detected climatic change with some level of confidence.
Baseline	The state against which change is measured. It might be a 'current baseline,' in which case it represents observable, present-day conditions. It might also be a 'future baseline,' which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.

Biodiversity	The variability among living organisms from terrestrial, marine, and other ecosystems. Biodiversity includes variability at the genetic, species, and ecosystem levels.
Biodiversity	The variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable.
Blue Economy	A term in economics relating to the exploitation, preservation, and regeneration of the marine environment.
Carbon Dioxide (CO_2)	A naturally occurring gas, CO_2 is also a by-product of burning fossil fuels (such as oil, gas, and coal), of burning biomass, of land-use changes (LUC) and of industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance.
Catchment	An area that collects and drains precipitation.
Climate	In a narrow sense, climate is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization.
Climate Change	A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer.
Climate Feedback	An interaction in which a perturbation in one climate quantity causes a change in a second and the change in the second quantity ultimately leads to an additional change in the first. A negative feedback is one in which the initial perturbation is weakened by the changes it causes; a positive feedback is one in which the initial perturbation is enhanced.
Climate Impacts	Impacts describe the consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability.
Climate Indicator	Measures of the climate system including large-scale variables and climate proxies.
Climate Information	Information about the past, current state, or future of the climate system that is relevant for mitigation, adaptation, and risk management. It may be tailored or "co-produced" for specific contexts, considering users' needs and values.
Climate Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Climate Model	A numerical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties.
Climate Projection	The simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHG) and aerosols, generally derived using climate models. Climate projections are distinguished from climate

	predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized.
Climate Risk	The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence.
Climate System	The highly complex system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere and the interactions between them.
Climate Variability	Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events.
Communicable Disease	Refers to an illness caused by an infectious agent or its toxins that occurs through the direct or indirect transmission of the infectious agent or its products from an infected individual or via an animal, vector or the inanimate environment to a susceptible animal or human host (CDC, 2012).
Confidence	The robustness of a finding based on the type, amount, quality, and consistency of evidence (e.g., mechanistic understanding, theory, data, 51 models, expert judgment) and on the degree of agreement across multiple lines of evidence.
Coral Bleaching	The process when corals become white due to various stressors, such as changes in temperature, light or nutrients. Ocean acidification reduces the availability of calcium minerals for coral skeleton building and repair. Rising temperatures and ocean acidification work together to increase coral bleaching.
Crop Water Deficit	A water deficit occurs whenever water loss exceeds absorption. The use of total water potential as the best single indicator of plant water status has its limitations while attempting to understand the effect of water deficits on the various physiological processes involved in plant growth. Water deficits reduce photosynthesis by closing stomata, decreasing the efficiency of the carbon fixation process, suppressing leaf formation and expansion, and inducing shedding of leaves.
Dam	A barrier constructed to hold back water and raise its level, forming a reservoir of water used to generate electricity or as a water supply.
Deltaic	Of or pertaining to a river delta.
Disaster	A ‘serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability,

	and capacity, leading to one or more of the following: human, material, economic and environmental losses, and impacts' (UNDRR, 'Disaster').
Downscaling	A method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses.
Drought	A prolonged period of abnormally low rainfall, leading to a shortage of water.
El Niño Southern Oscillation (ENSO)	The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere–ocean phenomenon, with preferred time scales of two to about seven years, is known as the El Niño-Southern Oscillation (ENSO). The cold phase of ENSO is called La Niña.
Emissions Scenario	A plausible representation of the future development of emissions of substances that are radiatively active (e.g., greenhouse gases (GHGs), aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy, and land use) and their key relationships.
Enhanced Greenhouse Effect	The process in which human activities have added additional greenhouse gases into the atmosphere, this has resulted in a 'stronger' greenhouse gas effect as there are more gases available to trap outgoing radiation.
ERA5	Fifth generation ECMWF atmospheric reanalysis of the global climate covering January 1940-present. ERA5 is produced by the Copernicus Climate Change Service (C3S) at ECMWF.
Evaporation	The physical process by which a liquid (e.g., water) becomes a gas (e.g., water vapour).
Evapotranspiration	The process in which water moves from the earth to the air from evaporation (= water changing to a gas) and from transpiration (= water lost from plants).
Exposure	Exposure describes the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.
Extreme/Heavy Precipitation Event	An extreme/heavy precipitation event is an event that is of very high magnitude with a very rare occurrence at a particular place. Types of extreme precipitation may vary depending on its duration, hourly, daily or multi-days (e.g., 5 days), though all of them qualitatively represent high magnitude. The intensity of such events may be defined with block maxima approach such as annual maxima or with peak over threshold approach, such as rainfall above 95th or 99th percentile at a particular space.
Fifth Assessment Report (AR5)	A series of IPCC reports published in 2013-2014, reports are divided into publications by three working groups.
Food security	The state of having reliable access to a sufficient quantity of affordable, nutritious food.

Fossil Fuels	Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.
Global Breadbasket	The term "breadbasket" is used to refer to an area with highly arable land. The breadbaskets of the world are the regions in the world that produce food, particularly grains to feed their people as well as for export to other places.
Global Warming	The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centred on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue.
Green Revolution	A period of technology transfer initiatives that saw greatly increased crop yields. These changes in agriculture began in developed countries in the early 20th century and spread globally until the late 1980s.
Greenhouse Effect	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect.
Greenhouse Gas (GHG) Concentrations	Lead to an increased infrared opacity of the atmosphere and therefore to an effective radiation into space from a higher altitude at a lower temperature. This causes a radiative forcing that leads to an enhancement of the greenhouse effect, the so-called enhanced greenhouse effect.
Greenhouse Gases (GHGs)	The gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO2, N2O and CH4, the Kyoto Protocol deals with the GHGs sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). (IPCC, 2018).
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
Heat Stress	A range of conditions in, e.g., terrestrial, or aquatic organisms when the body absorbs heat during overexposure to high air or water temperatures or thermal radiation. In aquatic water breathing animals, hypoxia and acidification can exacerbate vulnerability to heat. Heat stress in mammals (including humans) and birds, both in air, is exacerbated by a detrimental combination of ambient heat, high humidity, and low wind-speeds, causing regulation of body temperature to fail.

Heatwave	A period of abnormally hot weather often defined with reference to a relative temperature threshold, lasting from two days to months. Heatwaves and warm spells have various and, in some cases, overlapping definitions.
Himalaya Mountains	The Himalayas, or Himalaya, is a mountain range in Asia, separating the plains of the Indian subcontinent from the Tibetan Plateau. The range has some of the Earth's highest peaks, including the highest in the world, Mount Everest.
Hydrological Drought	Hydrological drought occurs when low water supply becomes evident, especially in streams, reservoirs, and groundwater levels, usually after many months of meteorological drought.
Ice Sheet	An ice body originating on land that covers an area of continental size, generally defined as covering >50,000km2 , and that has formed over thousands of years through accumulation and compaction of snow. (IPCC, 2019).
Impacts	Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system.
Indian Ocean Dipole (IOD)	The Indian Ocean Dipole (IOD) is an irregular oscillation of sea surface temperatures in which the western Indian Ocean becomes alternately warmer (positive phase) and then colder (negative phase) than the eastern part of the ocean. The Subtropical Indian Ocean Dipole (SIOD) is featured by the oscillation of sea surface temperatures.
Indo-Gangetic Plain / Basin	A 700,000 km^2 fertile plain encompassing northern regions of the Indian subcontinent, including most of modern-day northern and eastern India, most of eastern-Pakistan, virtually all of Bangladesh and southern plains of Nepal.
Influx	An arrival or entry of large numbers of people or things.
Intergovernmental Panel on Climate Change (IPCC)	The leading international body for the assessment of climate change. Scientists come together approximately every six years, to assess peer reviewed research in working groups to generate three reports including the Physical Science Basis, impact adaptation and vulnerability, and Mitigation of Climate Change.
Intertropical Convergence Zone (ITCZ)	The Intertropical Convergence Zone (ITCZ) is a band of low pressure around the Earth which generally lies near to the equator. The trade winds of the northern and southern hemispheres come together here, which leads to the development of frequent thunderstorms and heavy rain.
Macro-economic (Factors)	A phenomenon, pattern, or condition that emanates from, or relates to, a large aspects of an economy rather than to a particular population. Inflation, GDP, and national income are examples of macroeconomic factors.
Marine Heatwave	A period during which water temperature is abnormally warm for the time of the year relative to historical temperatures with that extreme warmth persisting for days to months. The phenomenon can manifest in any place in the ocean and at scales of up to thousands of kilometres.

Meteorological drought	When rainfall in an area is below average for the region.
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Monsoon	A seasonal prevailing wind in the region of south and southeast Asia, blowing from the south-west between May and September and bringing rain (the wet monsoon), or from the north-east between October and April (the dry monsoon).
NbS	Nature-based solutions (NbS) refers to the sustainable management and use of nature for tackling socio-environmental challenges. The challenges include issues such as climate change, water security, water pollution, food security, human health, biodiversity loss and disaster risk management.
Ocean Acidification	A reduction in the pH of the ocean, accompanied by other chemical changes (primarily in the levels of carbonate and bicarbonate ions), over an extended period, typically decades or longer, which is caused primarily by uptake of carbon dioxide (CO2) from the atmosphere, but can also be caused by other chemical additions or subtractions from the ocean. Anthropogenic ocean acidification refers to the component of pH reduction that is caused by human activity.
Overharvested	Refers to harvesting a renewable resource to the point of diminishing returns.
Paris Agreement	The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is 'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels', recognising that this would significantly reduce the risks and impacts of climate change. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts of climate change.
pH	pH is a measure of how acidic/basic water is. The range goes from 0 to 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base.
Projection/Projected	A projection is a potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.
Radiative Forcing	The change in the net, downward minus upward, radiative flux (expressed in W m-2) at the tropopause or top of atmosphere due to a change in a driver of climate change, such as a change in the concentration of carbon dioxide (CO_2) or the output of the sun.
Reanalysis	Atmospheric and oceanic analyses of temperature, wind, current and other meteorological and oceanographic quantities, created by processing past meteorological and oceanographic data using fixed state-of-the-art weather forecasting models and data assimilation techniques.

Representative Concentration Pathways (RCPs)	Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover.
Research Gap	A question or problem that has not been answered by any of the existing studies or research.
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning and transformation.
Resolution	In climate models, this term refers to the physical distance (metres or degrees) between each point on the grid used to compute the equations. Temporal resolution refers to the time step or time elapsed between each model computation of the equations.
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.
Runoff	The flow of water over the surface or through the subsurface, which typically originates from the part of liquid precipitation and/or snow/ice melt that does not evaporate or refreeze and is not transpired.
Saline Intrusion	The movement of saline water into freshwater aquifers, which can lead to groundwater quality degradation, including drinking water.
Scenario	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts but are used to provide a view of the implications of developments and actions.
Signal	Climate signals are long-term trends and projections that carry the fingerprint of climate change.
Sixth Assessment Report (AR6)	The latest series of IPCC reports published in 2021-2022, reports are divided into publications by three working groups. At the time of writing this report only the Working Group I contribution to the Sixth Assessment Report published in 2021 was available to use.
Soil Moisture	Water stored in the soil in liquid or frozen form. Root-zone soil moisture is of most relevance for plant activity.
Special Report on Emissions Scenarios (SRES)	A report by the Intergovernmental Panel on Climate Change (IPCC) that was published in 2000. The SRES scenarios, as they are often called, were used in the IPCC Third Assessment Report (TAR), published in 2001, and in the IPCC Fourth Assessment Report (AR4), published in 2007.
Storm Surge	The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong

	winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place. (IPCC, 2019).
Stream Flow	Water flow within a river channel, for example, expressed in m3s1 . A synonym for river discharge.
Teleconnection	Association between climate variables at widely separated, geographically fixed locations related to each other through physical processes and oceanic and/or atmospheric dynamical pathways. Teleconnections can be 58 caused by several climate phenomena, such as Rossby wave-trains, midlatitude jet and storm track displacements, fluctuations of the Atlantic Meridional Overturning Circulation, fluctuations of the Walker circulation, etc. They can be initiated by modes of climate variability thus providing the development of remote climate anomalies at various temporal lags.
Temperate	Relating to or denoting a region or climate characterised by mild temperatures.
Tourism	The commercial organisation and operation of holidays and visits to places of interest. A social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes.
Tropical	A climatic zone typically found in the equatorial zone and characterised by high temperatures throughout the year, generally high humidity, and high precipitation, although the latter may occur in a distinct rainy season.
Tropical Cyclone / Typhoon	A rapidly rotating storm system characterised by a low-pressure center, a closed low-level atmospheric circulation, strong winds, and a spiral arrangement of thunderstorms that produce heavy rains and strong winds.
Tundra	A type of biome where tree growth is hindered by frigid temperatures and short growing seasons. There are three types of tundra: Arctic, alpine, and Antarctic.
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. In climate change analysis, it may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour.
United Nations Framework Convention on Climate Change (UNFCCC)	The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement. (IPCC, 2018).
Urban Heat Island	The relative warmth of a city compared with surrounding rural areas, associated with changes in runoff, effects on heat retention, and changes in surface albedo.
Urbanisation	The process of making an area more urban.

Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm, and lack of capacity to cope and adapt.
Weather	The conditions in the air above the earth such as wind, rain, or temperature, especially at a particular time over a particular area.

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Image location: Eastern mountains near Trashigang, Bhutan

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