Climate Impact Profiles Supplemental Information

Weathering Risk| Climatepedia

The Weathering Risk initiative, led by adelphi, is a multilateral initiative that offers tailored analysis and tools to understand climate and environmental security risks to human security and build sustainable peace. In support of this mission, adelphi and its partners produced a series of Climate Risk Profiles (now renamed Climate Impact Profiles) between 2022 and 2023 for use by policymakers and interdisciplinary practitioners in activities such as assessments, studies and roadmaps. These profiles provide forward-looking data on a region's climate – including projected parameters under various emission scenarios across key sectors – with the goal of supporting resilience-oriented short and long-term planning.

The following resource serves to elaborate upon the data sources and methods mentioned in Climate Impact Profiles for technical users starting in 2024. Each subsection below describes data specifications and limitations for the corresponding section listed in each profile. For further inquiries regarding information presented in the profiles, please contact steinkraus@adelphi.de.

Observed Climate

Two primary data sources inform analysis of countries' historical observed climate, both accessed through the World Bank's Climate Change Knowledge Portal (CCKP), which provides freely and publicly available data and visualisations for download under CC-BY 4.0.[1]

1. The Climatic Research Unit of the University of East Anglia (CRU) collects observational time series (TS) records of temperature and precipitation from thousands of weather stations globally. CCKP uses CRU TS version 4.07, which presents data (1901-2022) on a 0.5º x 0.5º resolution grid – an area of approximately 3,080 km^2 at the equator – by employing interpolation methods (i.e., spatial averaging).[2] CRU data allows the Climate Impact Profiles to assess temperature and precipitation trends over the most recent climatological period (1991-2020).

2. The European Centre for Medium-Range Weather Forecasts (ECMWF) operates the European Union's Copernicus Climate Change Service (C3S) Data Store (CDS), which provides hourly gridded data on atmosphere, ocean, and land-based components. CCKP uses ERA5, the fifth version of ECMWF

[1] Descriptions of data sources and methods in this document draw from CCKP's 'Metadata' guide. For more information, see World Bank (2024). Metadata: Climate Change Knowledge Portal. CCKP. URL: https://climateknowledgeportal.worldbank.org/media/document/metatag.pdf

[2] World Bank Group Climate Change Knowledge Portal: Observed Climate Data, CRU TS4.07, DOI: https://doi.org/10.57966/tw2k-9h36; Source dataset: Harris, I., Osborn, T. J., Jones, P., and Lister, D. (2020). Version 4 of the CRU TS monthly high-resolution gridded multivariate climate dataset. *Scientific Data*, *7*(1), 109. DOI: https://doi.org/10.1038/s41597-020-0453-3, Access via URL: https://crudata.uea.ac.uk/cru/data/hrg/

Copernicus climate reanalysis data (1950-2022) at 0.25º x 0.25º resolution – an area of approximately 770 km^2 at the equator – for studying trends and variability in historical observational records.[3] The technique of climate reanalysis produces comprehensive time series by combining past instrumental data (e.g., from weather stations, airplanes, weather balloons, ships and buoys), satellite observational systems and climate modelling according to variational data assimilation methods.[4] ERA5 data allows the Climate Impact Profiles to assess significant patterns in underlying modes of climate variability (i.e., temperature and precipitation change per decade) from 1971-2020 and other climatological timescales since 1950.

In addition, CCKP illustrates current climate conditions spatially by presenting CRU calculations according to a Köppen-Geiger classification method at a 0.5º x 0.5º resolution (~3,080 km^2 at the equator).[5] However, the Climate Impact Profiles supplement this analysis by assessing the extents of eighteen climate zones across subnational units using the World Climate Regions global dataset.[6] This dataset, developed using IPCC and FAO-endorsed criteria, offers a granular, modified update to conventional Köppen-Geiger classifications by systematically accounting for landforms, subtropical variations, and potential evapotranspiration.

Projected Climate

Projected CCKP data analysed by Climate Impact Profiles originate from the World Climate Research Programme's CMIP6, the Coupled Model Intercomparison Project Phase 6.[7] CCKP's CMIP6 collection comprises 30 models.[8] Historical simulations for each model formed reference periods (1961-2014) using the

[3] World Bank Group Climate Change Knowledge Portal: Observed Climate Data, ERA5 0.25-Degree, DOI: https://doi.org/10.57966/128g-6s70; Source dataset: Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., ... and Thépaut, J. N. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, *146*(730), 1999-2049. DOI: https://doi.org/10.1002/qj.3803; Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., ... and Thépaut, J. N. (2017). Complete ERA5 from 1940: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service (C3S) Data Store (CDS). DOI: https://doi.org/10.24381/cds.143582cf; Access via URL: https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-complete

[4] Rabier, F., and Liu, Z. (2003). Variational data assimilation: theory and overview. In *Proc. ECMWF Seminar on Recent Developments in Data Assimilation for Atmosphere and Ocean, Reading, UK, September 8–12* (pp. 29-43). URL: https://www.ecmwf.int/sites/default/files/elibrary/2003/11805-variational-data-assimiltion-theory-and-overview.pdf

[5] The Köppen-Geiger classification system is a widely adopted taxonomy that subdivides the world into more than twenty climate types according to generalisable temperature and precipitation criteria. Contemporary scholars continue to make revisions to the originally proposed classification categories. For further background, criteria specifications, and global distribution, see Arnfield, A. John. 2024. Köppen Climate Classification. *Encyclopedia Britannica*. May 28, 2024. URL: https://www.britannica.com/science/Koppen-climate-classification/World-distribution-of-major-climatic-types; NOAA (2023). Köppen-Geiger Climate Subdivisions. U.S. National Oceanic and Atmospheric Administration. April 14, 2023. URL: https://www.noaa.gov/jetstream/global/climate-zones/jetstream-max-addition-k-ppen-geiger-climate-subdivisions

[6] Sayre, Roger, Deniz Karagulle, Charlie Frye, Timothy Boucher, Nicholas H. Wolff, Sean Breyer, Dawn Wright et al. An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. *Global Ecology and Conservation* 21 (2020): e00860. DOI: https://doi.org/10.1016/j.gecco.2019.e00860, Access via URL: https://storymaps.arcgis.com/stories/61a5d4e9494f46c2b520a984b2398f3b

[7] 'Coupled' climate models include atmospheric and oceanic components. A 'Model Intercomparison Project' or MIP coordinates simulation runs across models with designated inputs and configurations. IPCC's 6th *Assessment Report* heavily draws on CMIP6 results. See World Bank Group Climate Change Knowledge Portal: Projected Climate Data, CMIP6 0.25-Degree. DOI: https://doi.org/10.57966/b54h-7s87; Source dataset: Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E. (2016). Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organisation. *Geoscientific Model Development*, *9*(5), 1937-1958. DOI: https://doi.org/10.5194/gmd-9-1937-2016; Access via URL: https://www.wcrp-climate.org/wgcm-cmip/wgcm-cmip6; https://pcmdi.llnl.gov/CMIP6/

[8] For list, see World Bank (2024). Metadata: Climate Change Knowledge Portal. CCKP. URL: https://climateknowledgeportal.worldbank.org/media/document/metatag.pdf

ERA5 0.25º x 0.25º dataset.[9] Four prioritised Shared Socioeconomic Pathways or SSP scenarios – also used in the IPCC's *Sixth Assessment Report* – compare different global development storylines, which present a range of outcomes through 2100.[10] CCKP downscaled model outputs of four priority-tier SSP scenarios over the period 1950-2100 to 0.25º x 0.25º resolution (~770 km^2 at the equator), using bias correction and spatial disaggregation (BCSD) methods.[11] The Climate Impact Profiles prioritise analysis of two climate scenarios, the SSP3-7.0 scenario and SSP1-2.6 scenario, detailed below under the section 'How to Interpret Future Climate Scenarios.' The SSP3-7.0 scenario explores the effects of high-adaptation challenges under a pessimistic warming scenario and regional conflicts, whereas the SSP1-2.6 scenario explores the effects of low-adaptation challenges under more optimistic warming and greater international collaboration. Where possible, analysis notes deviations compared to other scenarios (see below) in the short-term (2020-2039) and medium-term (2040-2059) to serve stakeholder needs, while considering long-term implications (2060-2079, 2080-2099), as relevant.

Indicators

CCKP processed CMIP6 model simulations individually to produce daily outputs for essential climate variables (mean, minimum, and maximum temperature, and precipitation) and then calculated the following indicators listed according to each available SSP for both a present-day reference period (1995-2014) and 20-year future time periods (2020-2039, 2040-2059, 2060-2079, 2080-2099). Bias-corrected and downscaled (0.25º x 0.25º resolution) data from 30 total models generated ensemble collections of median (50th percentile), 10th percentile, and 90th percentile model values for different indicator parameters.[12] A percentile indicates the percentage of a dataset at or below a specified quantity. For example, the 50th percentile or median divides a dataset in half, the 10th percentile marks the point at or above the lowest 10% of data values, and the 90th percentile marks the point at or above the lowest 90% of data values. The 10th and 90th percentiles typically demarcate the most extreme values of a dataset, such as the most extreme temperature or precipitation amounts of a given record (see section below on 'How to Interpret Scientific Data'). Multi-model ensemble results produce ranges of uncertainty associated with different models, particular scenario conditions, and naturally inherent variability (see section below on 'How to Interpret Uncertainty in Climate Change Projections').[13] For quality control, CCKP ran an algorithm to spot outliers and other errors.

Climate Impact Profiles employ the following subset of CCKP's sample of data indicators to analyse climate-related trends for each key sector.[14] These temperature and precipitation indicators, in addition to proxies for

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[9] See CCKP's 'Metadata' guide for further details on data processing and formatting using Open Geospatial Consortium. See World Bank (2024). Metadata: Climate Change Knowledge Portal. CCKP. URL: https://climateknowledgeportal.worldbank.org/media/document/metatag.pdf

[10] Integrated Assessment Models (IAMs) produced SSP scenarios using a range of socioeconomic (e.g., population, economic development, technological, and governance) assumptions and associated emissions trajectories. SSPs not only feature updated data and models but are different from Representative Concentration Pathways (RCPs) used in the IPCC's *Fifth Assessment Report*. For Tier 1 priority scenarios, see O'Neill, B. C., Tebaldi, C., van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R. et al. 2016. The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. *Geosci. Model Dev.*, 9, 3461–3482. DOI: https://doi.org/10.5194/gmd-9-3461-2016

[11] Thrasher, B., Maurer, E. P., McKellar, C., and Duffy, P. B. (2012). Bias correcting climate model simulated daily temperature extremes with quantile mapping. *Hydrology and Earth System Sciences*, *16*(9), 3309-3314. DOI: https://doi.org/10.5194/hess-16-3309-2012

[12] However, the number of models applied to each indicator vary.

[13] Möller, V., R. van Diemen, J.B.R. Matthews, C. Méndez, S. Semenov, J.S. Fuglestvedt, and A. Reisinger (eds.) (2022). Annex II: Glossary. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. New York: Cambridge University Press, 2897–2930. DOI:10.1017/9781009325844.029.

[14] For the latest updates on existing datasets and newly available indicators, refer to CCKP website and 'Metadata' guide. Temperature and precipitation indicator definitions paraphrased from those of the Expert Team on Climate Change Detection and Indices (ETCCDI) Consortium, used by CCKP. See Climdex. 2024. Indices. University of New South Wales. URL: https://www.climdex.org/learn/indices/

various types of hazard exposure, inform analysis of findings from context and sector-specific research. For example, one can analyse whether projected climate and hazard conditions under SSP1-2.6 and SSP3-7.0 scenarios surpass critical sector-specific thresholds obtained from academic and grey literature, or if certain conditions extend to geographic locations of sectoral interest. Relevant findings from academic and grey literature may supplement or supplant applicable data from indicators below, if available.

Temperature Indicators

- **Mean, Minimum, and Maximum Temperature (ºC)** refer to average daily surface air temperatures over a chosen timeframe.
- **Number of Hot Days** counts days with daily maximum temperature over a chosen timeframe at or above the indicated threshold (**30ºC, 35ºC, 40ºC, 42ºC, 45ºC)**, while **Number of Summer Days** counts days over a chosen timeframe with daily maximum temperature at or above **25ºC**.
- **Maximum of Daily Max Temperature (ºC)** refers to the single-day maximum of daily maximum temperatures, and **Minimum of Daily Min Temperature (ºC)** refers to the single-day minimum of daily minimum temperatures, respectively, over a chosen timeframe.
- **Number of Tropical Nights** counts nights with daily minimum temperature at or above the indicated threshold **(20ºC, 23ºC, 26ºC, 29ºC)** over a chosen timeframe.
- **Number of Heat Index Days** counts days with temperature at or above the indicated threshold **(35ºC, 37ºC, 39ºC, 41ºC)** on the Heat Index, which combines air temperature and relative humidity, over a chosen timeframe.
- **Warm Spell Duration Index** counts consecutive days (minimum six) with daily maximum temperature above the 90th percentile of daily maximum temperature. **Cold Spell Duration Index** counts consecutive days (minimum six) with daily minimum temperature below the 10th percentile of daily minimum temperature.
- **Number of Frost Days** counts days with daily minimum temperature below freezing point **(0ºC)** over a chosen timeframe. **Number of Ice Days** counts days with daily maximum temperature below freezing point **(0ºC)** over a chosen timeframe.

Precipitation Indicators

- **Precipitation (mm)** refers to the amount of liquid or frozen water accumulated over a chosen timeframe.
- **Precipitation Percent Change (%)** refers to the change in total precipitation compared to the historical reference period for a chosen timeframe.
- **Max Number of Consecutive Wet Days** counts consecutive days over a chosen timeframe with total precipitation greater or equal to **1mm**.
- **Number of Consecutive Dry Days** counts consecutive days over a chosen timeframe with total precipitation less than or equal to **1mm**.
- **Average Largest 1-Day and 5-Day Precipitation (mm)** refer to the average largest precipitation quantity over a 1-day or 5-day span for each month of a chosen timeframe.
- **Future Return Period (years)** estimates the time between two extreme event occurrences at a certain threshold of intensity (**1-Day or 5-Day precipitation event, measured in mm)**, calculated using monthly or annual maximum values over at least a 30-year period and fitting data to a Generalised Extreme Value (GEV) distribution.[15]
- **Precipitation Amount During Wettest Days (mm)** refers to the precipitation quantity received during the 5% wettest days over a chosen timeframe.
- **Annual SPEI Drought Index** refers to the Standardised Precipitation Evapotranspiration Index, which calculates droughts by accounting for both precipitation and temperature records over a 12-month period.

[15] Precipitation return intervals calculated based on the algorithm described in Naveau, P., Huser, R., Ribereau, P., and Hannart, A. (2016). Modelling jointly low, moderate, and heavy rainfall intensities without a threshold selection. *Water Resources Research*, *52*(4), 2753-2769. DOI: https://doi.org/10.1002/2015WR018552

Hazard Exposure Indicators

- **Future Changes in Hazard Exposure** are identified by investigating subnational impacts of hazards reported in the national-level historical record,[16] then analysing projected spatial overlays of CCKP-projected population density and income level distributions with hazard-specific data layers detailed below. Supplementary data from academic and grey literature is identified and included, when available.
- **Projected Population and Density (people per km²)** bases projections off of the historical reference period (1995-2014),[17] and CCKP displays gridded data spatially using thresholds for population count (1,000; 10,000; 100,000; 1,000,000) and for density (1, 10, 100, 1,000). **Poverty as Percentage of Population (%)** is calculated according to income per day below the thresholds **$1.90, $3.20, and $5.50**, in association with CMIP6 Shared Socioeconomic Pathways (SSPs).[18]
- **Heat Risk:** Subnational-level exposure is calculated using CCKP 'Heat Risk' tool (see 'Human Health' section).
- **Flood Risk:** Watershed-level hydrological and coastal flood exposure is determined using Aqueduct 4.0 tool (see 'Floods and Droughts' section). Meteorological flood risk is detailed as part of the 'Precipitation' section in Climate Impact Profile projections.
- **Drought Risk:** Watershed-level baseline drought exposure is determined using Aqueduct 4.0 tool (see 'Floods and Droughts' section). Future meteorological drought risk is detailed as part of the 'Precipitation' section in Climate Impact Profile projections, while future agricultural and socioeconomic drought risk is represented by watershed-level water stress (see 'Floods and Droughts' and 'Food and Agriculture' sections).
- **Tropical Cyclone Risk:** Subnational-level exposure is based solely on projected trends in academic and grey literature for local geography (see 'Floods and Droughts' section).
- **Seismic Risk:** Subnational-level seismic risk is determined according to the Global Earthquake Model (GEM) Foundation's Global Seismic Hazard Map (version 2023.1), based on peak ground acceleration (PGA) with a 10% probability of being exceeded in 50 years.[19] GEM's Global Seismic Risk Map (version 2023.1) represents average annual loss due to ground shaking, combining layers for built-up area loss and economic, human, and building losses.[20]

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[16] Country-specific data sourced from the Centre for Research on the Epidemiology of Disasters (CRED). Hazard types distinguish between geophysical (e.g., earthquake), hydrological (e.g., flood, precipitation-induced landslide), meteorological (e.g., storm, extreme temperature), climatological (e.g., drought, wildfire), and biological (e.g., epidemic, infestation). See CRED (2024). EM-DAT (Emergency Events Database). Brussels: UCLouvain, Access via URL: www.emdat.be

[17] World Bank Group Climate Change Knowledge Portal: Projected Population and Poverty, 0.25-Degree. DOI: https://doi.org/10.57966/7r80-cc19; Source dataset: Center for International Earth Science Information Network, Columbia University. 2018. Gridded Population of the World, Version 4 (GPWv4): Population Density, Revision 11. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). Access via URL: https://sedac.ciesin.columbia.edu/data/collection/gpw-v4; World Bank Group Climate Change Knowledge Portal: Projected Population and Poverty, 0.25-Degree. DOI: https://doi.org/10.57966/7r80-cc19; Source dataset: Jones, B., and B. C. O'Neill. 2020. Global One-Eighth Degree Population Base Year and Projection Grids Based on the Shared Socioeconomic Pathways, Revision 01. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). DOI: https://doi.org/10.7927/m30p-j498

[18] World Bank Group Climate Change Knowledge Portal: Projected Population and Poverty, 0.25-Degree. DOI: https://doi.org/10.57966/7r80-cc19; Source dataset: World Bank Data Catalog: International Poverty Line - Global Subnational Poverty Atlas GSPA. Access via URL: https://datacatalog.worldbank.org/search/dataset/0042041; Rao, N. D., Sauer, P., Gidden, M., and Riahi, K. (2019). Income inequality projections for the shared socioeconomic pathways (SSPs). *Futures*, *105*, 27-39. DOI: https://doi.org/10.1016/j.futures.2018.07.001

[19] Spatial resolution represents interpolation of values calculated at points with ~6 km spacing using inverse distance weighting of nearest neighbors. For details, see Johnson, K., M. Villani, K. Bayliss, C. Brooks, S. Chandrasekhar, T. Chartier, Y. Chen, J. Garcia-Pelaez, R. Gee, R. Styron, A. Rood, M. Simionato, and M. Pagani (2023). Global Earthquake Model (GEM) Seismic Hazard Map (version 2023.1 - June 2023). DOI: https://doi.org/10.5281/zenodo.8409647; Access via URL: https://www.globalquakemodel.org/product/global-seismic-hazard-map

[20] Spatial resolution presented on a hexagonal grid of 0.30-Degree x 0.34-Degree spacing (approximately 1,000 km² at the equator). For details, see Silva, V., A. Calderon, M. Caruso, C. Costa, J. Dabbeek, M.C. Hoyos, Z. Karimzadeh, L. Martins, N. Paul, A. Rao, M. Simionato, C. Yepes-Estrada, H. Crowley, and K. Jaiswal (2023). Global Earthquake Model (GEM) Seismic Risk Map (version 2023.1). DOI: https://doi.org/10.5281/zenodo.8409623; Access via URL: https://www.globalquakemodel.org/product/global-seismic-risk-map

- **Landslide Risk:** Subnational-level exposure is approximated by overlaying seismic hazard risk layer with CCKP-projected 'average largest 1-day or 5-day precipitation' (see 'Floods and Droughts' section).

Sector-Specific Indicators

Human Health

- **Exposure to Heat Risk** linked to heat-related illness and mortality, is determined using CCKP's categorical-based compound 'Heat Risk' tool which overlays projected metrics for 'Hot Days', 'Tropical Nights', and 'Heat Index Days' with layers for population density and percentage of population in poverty (cited under 'Hazard Exposure Indicators').[21]
- Past and projected **Exposure to Vector-Borne** (e.g., mosquito-borne malaria, dengue, zika) and **Food and Water-Borne Diseases** (e.g., cholera, typhoid) is derived from national and subnational-level academic and grey literature. CCKP temperature and precipitation indicators, as well as metrics from 'Food and Agriculture' and 'Floods and Droughts' sections, are analysed with case incident records or suitable vector transmission ranges, when possible. For indicator details on **projected population at risk of malnutrition**, see 'Food and Agriculture' section.
- **Total Number of Fatalities and People Affected from Hazard Events** are derived from CRED's country-specific historical record. The total number of people affected includes those injured, homeless, and requiring immediate assistance.[22]

Floods and Droughts

- **Riverine and Coastal Flood Risk** offered as part of the World Resources Institute's (WRI) Aqueduct 4.0 tool and available for use under CC-BY 4.0, measure the percentage of the population exposed annually on average by riverine and coastal inundation (in cm/year), respectively, at the hydrological sub-basin level (0.5º x 0.5º spatial resolution, or 55 km x 55 km at the equator) according to various (e.g., 100-year) return periods.[23]
- Baseline **Drought Risk,** averaged for each sub-basin by Aqueduct 4.0, combines meteorological, agricultural, and socioeconomic (not hydrological) measures of drought hazard, exposure, and vulnerability (10 km x 10 km pixel spatial resolution at the equator) for the period 2000-2014.
- **Water Stress Risk** (ratio percentage of total water demand for domestic, industrial, irrigation, and livestock uses to available renewable surface and groundwater sources), and
- **Average Seasonal and Interannual Water Variability** (standard deviation of available water divided by mean per basin per month, measured by percentage) are also mapped by Aqueduct 4.0 tool for baseline and future periods,[24] Metrics are obtained for each major hydrological sub-basin using a global gridded hydrological model (PCR-GLOBWB 2) with 10 km x 10 km pixel spatial resolution.

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[21] The level of highest heat risk (ranked on a relative numerical scale) applies when a subnational unit's median projected conditions surpass any of the following heat metrics in order of moderate, high, very high, and extreme risks, respectively: daily maximum (30°C, 35°C, 40°C, 45°C), nighttime minimum (20°C, 23°C, 26°C, 29°C), and Heat Index (35°C, 37°C, 39°C, 41°C). See 'Indicators' section of this document for CCKP spatial resolution, projected time periods, and available scenarios.

[22] For further information about source reporting, see CRED (2024). EM-DAT (Emergency Events Database). Brussels: UCLouvain, Access via URL: www.emdat.be

[23] Aqueduct's modeling accounts for current levels of flood protection but not combined or interacting risks between riverine and coastal flooding. For details, see Kuzma, S., M.F.P. Bierkens, S. Lakshman, T. Luo, L. Saccoccia, E. H. Sutanudjaja, and R. Van Beek (2023). Aqueduct 4.0 Technical Note: Updated decision-relevant global water risk indicators. Washington, DC: World Resources Institute. DOI: https://doi.org/10.46830/writn.23.00061

[24] Aqueduct's future projections are made using a representative sample of five General Circulation Models with bias-corrected inputs from IPCC's CMIP6 SSP1-2.6, SSP3-7.0, and SSP5-8.5 scenarios for near-term (2015-2045, centred on 2030), medium-term (2035-2065, centred on 2050), and long-term (2065-2095, centred on 2080) periods (historical reference 1960-2014). For details on data processing methodology, parameters, and indicators, see Kuzma, S., M.F.P. Bierkens, S. Lakshman, T. Luo, L. Saccoccia, E. H. Sutanudjaja, and R. Van Beek (2023). Aqueduct 4.0 Technical Note: Updated decision-relevant global water risk indicators. Washington, DC: World Resources Institute. DOI: https://doi.org/10.46830/writn.23.00061

Food and Agriculture

- **Percentage Change Nationally in Irrigated and Rainfed Crop Production Areas Under Water Stress, Percentage Change Nationally Due to Seasonal Variability,** and **Percentage Nationally of Crop Production Areas Under Drought Risk** are mapped on WRI's Aqueduct Food tool. These indicators use WRI's Aqueduct 4.0 baseline and future water risk metrics (see 'Floods and Droughts' section), as well as subnational crop-specific spatial data from MapSPAM 2020 (baseline year). This latest version includes 46 major crop types divided into irrigated and rainfed classifications at 10 km x 10 km per pixel.[25]
- **Change in Net Trade Nationally for Highest-Demand Crops** (projected import-export balance, which considers trade **share** of annual domestic production demand for food) and **Population Percentage Nationally at Risk of Malnutrition** (population consuming below minimum caloric intake, based on projected mean per capita caloric intake and population density) are also mapped on WRI's Aqueduct Food tool. National-level projections use the International Food Policy Research Institute's (IFPRI) IMPACT Model 3.6, an integrated system of models that combines climate, crop simulation, water, and agro-economic modelling components.[26] While these projections are tied to IPCC's SSP2 'Middle-of-the-Road' scenario, Climate Impact Profiles indicate likely deviations under SSP1-2.6 and SSP3-7.0 scenarios.
- Subnational-level **exposure of livestock** (cattle, goat, sheep, pig, chicken) **to projected hazard impacts** combine data overlays from 'Hazard Exposure Indicators' **with** those of the Food and Agriculture Organisation of the U.N. (FAO) Global Livestock of the World (GLW version 4) represented at ~10 km x 10 km spatial resolution at the equator.[27]

Human Displacement

- **Disaster** (i.e., sudden-onset hazard) **and Conflict-Induced** (i.e., generalised violence-driven) **Internal Displacement** figures at the national-level (2008-2022) are obtained annually from the Internal Displacement Monitoring **Centre's** (IDMC) Global Internal Displacement Database (GIDD).[28] Subnational-level details are noted when available in the database.

Ecosystems

- **High-Priority Conservation Areas** (intact ecosystems with <10% of area classified as human-modified and high **importance** to reduce species extinction) are mapped and classified by the Nature Conservancy using the World Climate Regions global dataset (the same source referenced under the 'Observed Climate' section), and analysed at the subnational level.[29]

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[25] International Food Policy Research Institute (2024). Global Spatially-Disaggregated Crop Production Statistics Data for 2020 Version 1.0.0, DOI: https://doi.org/10.7910/DVN/SWPENT, Harvard Dataverse, V1; Access via URL: https://www.wri.org/applications/aqueduct/food/#/

[26] For definitions, data sources, and methodology, see Robinson, S., Dunston, S., Mishra, A., Sulser, T.B., Mason-D'Croz, D., Robertson, R., Cenacchi, N., Thomas, T.S., Zhu, T., Gueneau, A., Pitois, G., Wiebe, K., and Rosegrant, M.W. (2024). The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT): Model documentation for version 3.6. Modelling Systems Technical Paper 1. Washington, DC: International Food Policy Research Institute (IFPRI). URL: https://hdl.handle.net/10568/148953; Access via URL: https://www.wri.org/applications/aqueduct/food/#/

[27] Gilbert, M., Cinardi, G., Da Re, D., Wint, W.G.R., Wisser, D., Robinson, and Timothy, P. (2022). Global chickens distribution in 2015 (5 minutes of arc), DOI: https://doi.org/10.7910/DVN/SXHLF3, Global sheep distribution in 2015 (5 minutes of arc), DOI: https://doi.org/10.7910/DVN/VZOYHM, Global pigs distribution in 2015 (5 minutes of arc), https://doi.org/10.7910/DVN/CIVCPB, Global goats distribution in 2015 (5 minutes of arc), DOI: https://doi.org/10.7910/DVN/YYG6ET, Global cattle distribution in 2015 (5 minutes of arc), https://doi.org/10.7910/DVN/LHBICE, Harvard Dataverse, V1; Access via URL: https://dataverse.harvard.edu/dataverse/glw_4

[28] For methodology, see Internal Displacement Monitoring Centre (2023). Global Internal Displacement Database. IDMC. URL: https://www.internal-displacement.org/database/displacement-data/

[29] Ecosystem regions are classified as 'vulnerable' (< 30% protected, > 30% converted), 'endangered' (< 17% protected, > 50% converted), 'critical' (< 10% protected, > 80% converted), or intact 'last chance' conservation areas (< 10% converted) with disproportionate importance to reduce species extinction. The Nature Conservancy (2023). Last Chance Ecosystems. TNC. URL: https://geospatial.tnc.org/apps/TNC::last-chance-ecosystems-1/about

- **Mean Projected Magnitude of Species Change (Mild, Moderate, High, Very High)** at various global warming thresholds (including SSP1-2.6 and SSP3-7.0 scenarios) is obtained through a systematic statistical analysis study of climate change studies on native and endemic species located in global biodiversity hotspots.[30] Species level impacts in available literature included: population abundance, physiology, spatial range, taxonomic richness, and habitat changes at various global warming thresholds.

Critical Infrastructure and Economy

- **Cooling Degree Days** approximate the energy required to cool a building, counting the number of degrees that the daily average temperature is above **18.3ºC** over a chosen timeframe**. Heating Degree Days** approximate the energy required to warm a building, counting the number of degrees that the daily average temperature is below **18.3ºC** over a chosen timeframe. Both are sourced from CCKP with parameters described above.
- **Monetary Damages, Casualties, and Network Service Access Interruptions** observed in the recent historical record are based on academic and grey literature. Future possible gaps, vulnerabilities, and impacts are identified by overlaying projected temperature and precipitation indicators (according to CMIP6 scenarios) with major open-source transportation, energy, water and sanitation, and built environment networks.
- **GDP (Gross Domestic Product) Exposure (%)** lost annually to various climate impacts at the national level is sourced from S&P Global, which explores the mid-century economic effects of the SSP3-7.0 scenario from precipitation and riverine flooding, sea level rise, water stress, severe storms, extreme heat, wildfires, and combined hazard risks.[31]

Coastal Zone Sector

- **Sea Level Rise (m)** projections, according to the IPCC 6^{th} *Assessment Report's* Shared Socioeconomic Pathways (SSPs), are displayed by NASA. For specific parameters, see footnote.[32]
- **Sea Surface Temperature Change (ºC)** is projected monthly and annually according to CMIP6 scenarios for short-term, medium-term, and long-term periods (from the 1995-2014 baseline) using the Copernicus Interactive Climate Atlas (at a spatial resolution of 1º x 1º spatial resolution, or 111 km x 111 km at the equator).[33] Relevant temperature thresholds for local marine ecosystems sourced from academic and grey literature. See footnote for details on multi-model ensemble and processing.
- **Global Warming Level (ºC) Preventing Marine Biomass Rebuilding** is estimated by linear mixed-modelling marine biomass for 121 global ecoregions under a 'conservation', 'sustainability', and 'catch maximisation' scenarios, and examining five reference global warming levels (including SSP1-2.6 and SSP5-8.5 scenarios) according to three CMIP6 earth system models.[34]

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[30] Manes, S., Costello, M.J., Beckett, H., Debnath, A., Devenish-Nelson, E., Grey, K.A., Jenkins, R., Khan, T.M., Kiessling, W., Krause, C. and Maharaj, S.S. (2021). Endemism increases species' climate change risk in areas of global biodiversity importance. *Biological Conservation*, *257*, 109070. DOI: https://doi.org/10.1016/j.biocon.2021.109070

[31] Munday, P., Amiot, M., and Sifon-Arevalo, R. (2023). Lost GDP: Potential Impacts of Physical Climate Risks. S&P Global. URL: https://www.spglobal.com/_assets/documents/ratings/research/101590033.pdf

[32] NASA. 2024. Sea Level Rise Projection Tool. Earth Science Data Systems Program. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

[33] Copernicus Climate Change Service (2023). Gridded monthly climate projection dataset underpinning the IPCC AR6 Interactive Atlas. C3S Climate Data Store. DOI: https://doi.org/10.24381/cds.5292a2b0; Source dataset: Intergovernmental Panel on Climate Change (2023): Atlas. In *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 1927-2058. DOI: 10.1017/9781009157896.021; Access via URL: http://interactive-atlas.ipcc.ch and https://atlas.climate.copernicus.eu/atlas

[34] Cheung, W.W., Palacios-Abrantes, J., Frölicher, T.L., Palomares, M.L., Clarke, T., Lam, V.W., Oyinlola, M.A., Pauly, D., Reygondeau, G., Sumaila, U.R. and Teh, L.C. (2022). Rebuilding fish biomass for the world's marine ecoregions under climate change. *Global change biology*, *28*(21), 6254-6267. DOI: 10.1111/gcb.16368

How to Interpret Future Climate Scenarios

A scenario describes a trajectory of future conditions based on key assumptions, serving as an important tool for both climate scientists and social scientists to understand and plan for the effects of complex, unpredictable, human-non-human interactions across various timeframes. The Intergovernmental Panel on Climate Change's (IPCC's) *Sixth Assessment Report* draws upon a handful of hypothetical future scenarios (Shared Socioeconomic Pathways or SSPs) simulated by a large collection of computer models to gain insight into future societal and climate conditions. These scenarios possess a range of socioeconomic (e.g., population, economic development, technological, and governance) assumptions and associated emissions trajectories.

The Climate Impact Profiles prioritise analysis of (1) the SSP3-7.0 scenario, as it explores the effects of high-adaptation challenges under a pessimistic warming scenario and regional conflicts; and (2) the SSP1-2.6 scenario, as it explores the effects of low-adaptation challenges under an optimistic warming scenario and greater international collaboration. Where possible, analysis notes deviations compared to other scenarios in the short and medium-term. See section below on 'How to Interpret Uncertainty in Climate Change Projections' for details on the relationship between model scenarios and probability.

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Table 1 details each scenario's narrative storyline, factors influencing climate mitigation and adaptation plotted in **Figure 1**, and expected carbon dioxide concentrations and global temperature increase by end-of-century.

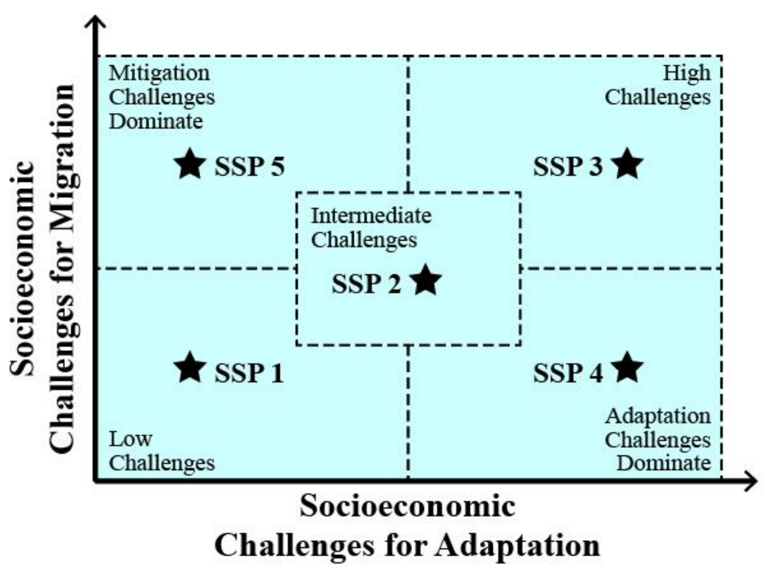

Figure 1. Shared Socioeconomic Pathway (SSP) Scenarios Plotted According to Their Component Factors Influencing Climate Mitigation and Adaptation Possibilities.[35]

[35] Modified from O'Neill, B.C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T.R., Mathur, R., and D. P. van Vuuren. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Climatic Change* **122**, 387–400 (2014). DOI: https://doi.org/10.1007/s10584-013-0905-2

Mitigation Challenges (MC) / **Adaptation Challenges** (AC)	**SSP (Shared Socioeconomic Pathway) Storyline**	**SSP Scenarios**[36]: CO_2 Emission Concentrations and Global Average Surface Temperature (ºC)
Low MC Low AC	**SSP1: Sustainability "Taking the Green Road"** *The world shifts gradually, but pervasively, toward a more sustainable path, emphasising more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.*	SSP1-1.9: Net-zero CO_2 emissions achieved around 2050, with 1.5ºC warming by 2100.[37] **SSP1-2.6:** Net-zero CO_2 emissions achieved after 2050, with up to 2ºC warming by 2100.
Medium MC Medium AC	**SSP2: Middle-of-the-Road** *The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall, the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.*	**SSP2-4.5:** Current CO_2 emission levels maintained by 2050 and net-zero CO_2 emissions achieved after 2100, with a best estimate of 2.7ºC warming by 2100.
High MC	**SSP3: Regional Rivalry "A Rocky Road"** *A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to*	**SSP3-7.0:** CO_2 emissions double by 2100, with simultaneously high non-CO_2 emissions

[36] Text in black reference scenarios used in Weathering Risk Climate Impact Profiles. Scenario text in grey were not prioritised for profile analysis.
[37] CMIP6 later added the SSP1-1.9 scenario to align with Paris Agreement target of 1.5ºC, but Adelphi's Climate Impact Profiles interpret the prioritised SSP1-2.6 scenario instead, given current emission trends.

High AC	*become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialised and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.*	and best-estimate warming above 3ºC by 2100.
Low MC High AC	**SSP4: Inequality "A Road Divided"** *Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labour intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle- and high-income areas.*	SSP4-6.0 and SSP4-3.4: Best-estimate warming by 2100 does not extend below 2ºC.[38]
High MC	**SSP5: Fossil Fuel Development "Taking the Highway"** *This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are*	**SSP5-8.5:** CO_2 emissions double by 2050, with best-estimate warming above 3.3ºC by 2100.[39]

[38] Climate modelling groups did not include SSP4 scenarios in the first prioritised phase of model runs and is not reflected in CCKP platform. See O'Neill, B. C., Tebaldi, C., van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R. et al. 2016. The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. *Geosci. Model Dev*., 9, 3461–3482. DOI: https://doi.org/10.5194/gmd-9-3461-2016

[39] IPCC's *Sixth Assessment Report* notes that the high emissions in the SSP5-8.5 scenario cannot be ruled out but drew scientific scepticism, so it is therefore not prioritised by the Climate Impact Profiles. See Chen, D., M. Rojas, B.H. Samset, K. Cobb, A. Diongue Niang, P. Edwards, S. Emori et al. 2021. Framing, Context, and Methods. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 147–286. New York: Cambridge University Press, DOI:10.1017/9781009157896.003.

Low AC	*also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.*	

Table 1. SSP Scenario Narratives for Climate Impact Analysis.[40] Red indicates pessimistic conditions. Green indicates optimistic conditions. Yellow indicates intermediate, uneven, or opposing conditions. The far-left column denotes challenges plotted in Figure 1, while the far-right column denotes future CO_2 emissions and global average surface temperature compared to the preindustrial reference period (1850-1900).[41] Scenario text in grey were not prioritised for profile analysis.

How to Interpret Scientific Data

Bar graphs present observed precipitation data averaged nationwide or at subnational levels, and **line plots** present observed temperature data averaged nationwide or at subnational levels, as indicated. 'Observed' data is collected from weather monitoring instruments and satellite imagery over the most recent 30-year historical period (1991-2020, ~55 km x 55 km spatial resolution at the equator) and reanalysed 50-year historical period (1971-2020, ~ 28 km x 28 km resolution at the equator).

Line plots also depict future temperature and precipitation projections, averaged nationally or across individual subnational units at ~28 km x 28 km spatial resolution at the equator. Higher and lower-emission climate scenarios (i.e., SSP3-7.0 and SSP1-2.6, respectively) are plotted in designated colours by calculating a present-day baseline period (1995-2014) and future 20-year timeframes that account for the rapid pace of expected change relative to historical levels. One type of data presentation plots historical and projected indicator results from 1950-2100 (see **Figure A**) and another type plots projected results for every month averaged over a 20-year climatological time period (2020-2039 or 2040-2059, see **Figure B**).

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[40] Scenario storylines listed verbatim from IPCC-supporting literature but modified with colour shading to enhance legibility. See Riahi, K., Van Vuuren, D. P., Kriegler, E., Edmonds, J., O'Neill, B. C., Fujimori, S. et al. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global environmental change*, *42*, 153-168. DOI: https://doi.org/10.1016/j.gloenvcha.2016.05.009

[41] See Chen, D., M. Rojas, B.H. Samset, K. Cobb, A. Diongue Niang, P. Edwards, S. Emori et al. 2021. Framing, Context, and Methods. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 147–286. New York: Cambridge University Press, DOI:10.1017/9781009157896.003.

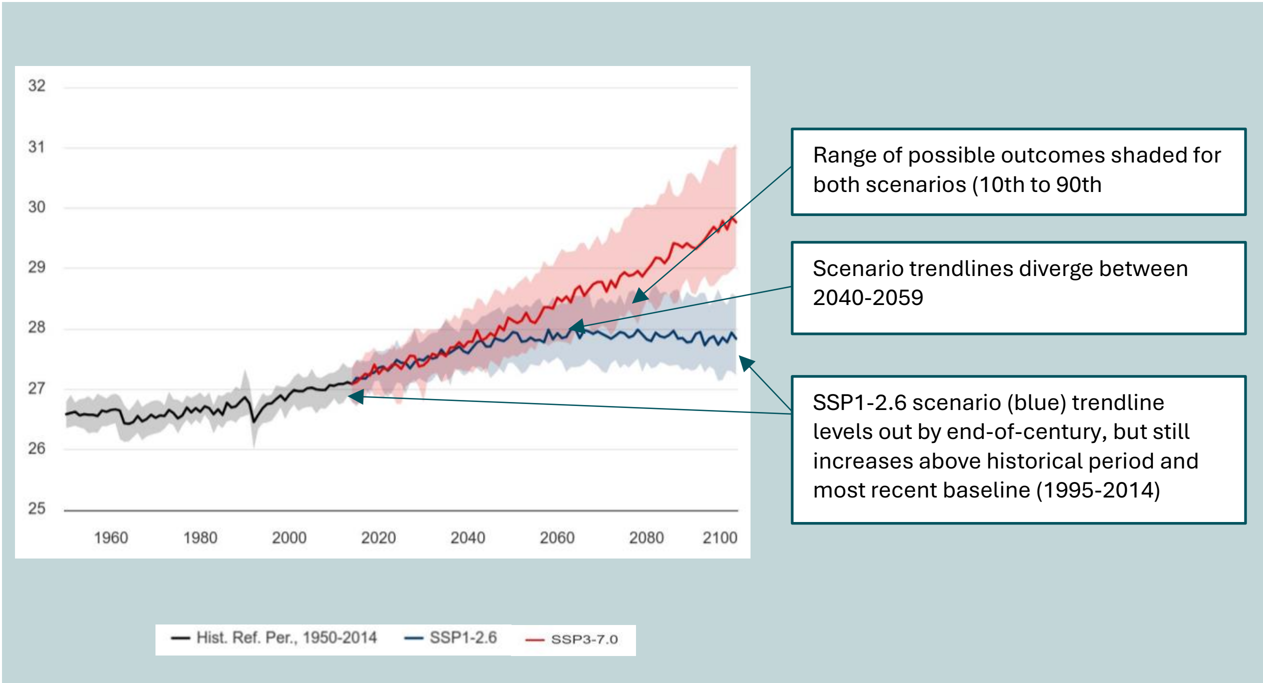

Figure A. **Average Nationally Projected Mean Temperature in Degrees Celsius Under SSP1-2.6 (Blue) and SSP3-7.0 (Red) Scenarios.**

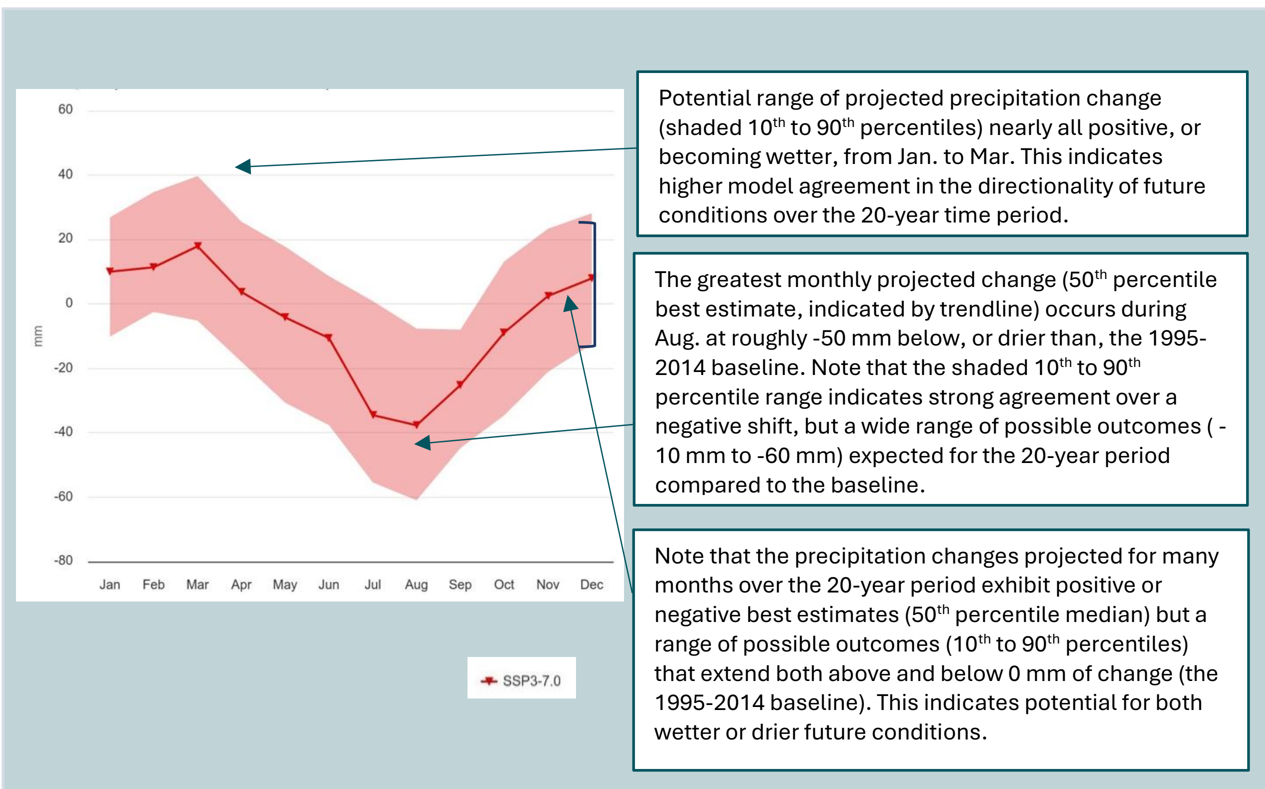

Figure B. **Projected Precipitation Change Over Future 20-Year Period (in mm) from 1995-2014 Reference Period Under SSP3-7.0 Scenario (Red).**

As noted, plots present indicator data either as mean (average) values, like Figure A, or anomalies (change from a baseline reference), like Figure B. A charted indicator line represents the best-estimate median (50th percentile, or midway point) results of 30 climate models. Shaded areas surrounding a median line indicate the range of model results between 10th percentile and 90th percentile values; in other words, model results at or above the lowest 10% of data values and below the highest 90% of data values, respectively, represent the range of potential indicator outcomes under a certain climate scenario. **Note that a narrower range of 10th and 90th percentile data outcomes indicate stronger model agreement under a given scenario and timeframe** (see narrow, overlapping ranges in Figure A). Meanwhile, **a wider range of data outcomes – especially those with diverging directions from baseline conditions** (see Figure B) **– indicate generally lower levels of model agreement under a given scenario and timeframe.** All projected model results possess some level of uncertainty, but **policymakers should proceed with caution and note additional instructions when interpreting results with higher uncertainty.** Under these conditions especially, policymakers should consider planning for multiple potential outcomes. See section below on 'How to Interpret Uncertainty in Climate Change Projections' for more details.

To depict sectoral impacts with overlaid climate projections, some Climate Impact Profiles employ **maps** produced using MapChart under CC BY-SA 4.0. Unless otherwise indicated, maps depict trends and impacts across subnational levels according to a relative categorical scale with key thresholds noted. For example, heat risk maps display whether an area surpasses one or more of three temperature metrics (daily maximum, nighttime minimum, and Heat Index which combines temperature and humidity) at four threshold levels (0-4) that signify low, moderate, high, or extreme heat risk, respectively. Since data for indicated metrics are averaged or totalled across subnational areas, maps that display large contrasts between adjacent areas do not necessarily entail sharp distinctions at borderlines. Refer to captions and footnotes for information regarding spatial resolution, timeframes, data scales, data sources, and levels of uncertainty for each mapped metric.

How to Interpret Uncertainty in Climate Change Projections

The IPCC's climate scenarios represent the various global trajectories that scientists have explored so far under strategic input conditions, but **in theory, could all possibly occur.** Since scenario modeling activities do not produce a statistically complete sample by design, **data distributions of multi-model ensemble ouputs cannot conclusively predict the probability of a specific outcome.**[42] That does not mean that climate model outputs are not useful. Instead, scientists and decision-makers can **analyse** multi-model ensembles by considering the **extent to which participating models statistically agree** on a climate indicator's direction, magnitude, timing, and duration, among other factors. Supplemental observations and evidence may then increase confidence in a particular outcome or a wide range of potential outcomes.

Uncertainty is indicated with an ( ) throughout the Climate Impact Profiles. Additional details are specified in the corresponding text.

[42] Guivarch, C., E. Kriegler, J. Portugal-Pereira, V. Bosetti, J. Edmonds, M. Fischedick, P. Havlík, P. Jaramillo, V. Krey, F. Lecocq, A. Lucena, M. Meinshausen, S. Mirasgedis, B. O'Neill, G.P. Peters, J. Rogelj, S. Rose, Y. Saheb, G. Strbac, A. Hammer Strømman, D.P. van Vuuren, and N. Zhou (2022). Annex III: Scenarios and Modelling Methods. *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change,* pp. 1841-1908. New York: Cambridge University Press. DOI: 10.1017/9781009157926.022

The three sources of uncertainty for climate change projections are described below.[43]

Model Uncertainty: Global climate models consider different assumptions and factors when simulating future climate conditions, resulting in variegated levels of sensitivity to greenhouse gas-driven warming. Analysing multi-model ensembles (e.g., 30 model results) helps broaden potential outcomes beyond those produced by one individual model. However, there are trade-offs. For example, a trade-off exists between representing larger-scale climate phenomena (e.g., El Niño) and smaller-scale phenomena (e.g., localised, reflective cloud cover) at a given resolution. More simulation runs and larger model ensembles provide greater volumes of information, but do not eliminate model uncertainty associated with current scientific understanding of cloud cover formation, which affect simulated climate responses and take place across different geographies and scales of resolution. While all climate projections possess some level of model uncertainty, model uncertainty for **precipitation projections tends to exceed that of temperature projections** because of the complex processes involved. The Climate Impact Profiles specify projections with greater levels of model uncertainty relative to other forms of uncertainty, climate indicators, or geographies. Under these conditions, **decision-makers should consider options that account for the magnitude and direction of precipitation change across the full range of multi-model ensembles**.

> **Example A:** A wider range of projected estimates for future precipitation change annually – compared to a location's baseline period – indicates higher model uncertainty. Model results could range from wetter conditions (+100 mm as 90th percentile value), to slightly wetter conditions (+10 mm as 50th percentile median), to much drier conditions (-100 mm as 10th percentile value). **The direction of future precipitation change over a given time period could thus reasonably increase, vary minimally, or decrease, respectively.**

A predominant source of model uncertainty across many tropical and subtropical Pacific regions reflects incomplete scientific understanding of future El Niño-Southern Oscillation (ENSO) patterns. Different ENSO phases (El Niño and La Niña) cyclically produce extreme wet and dry years in many locations across the region but could deviate in frequency and intensity compared to past observations when considering future emission scenarios. Given the uncertain range of magnitude and direction of change (and unless other locally specific factors, indicators, or literature suggest otherwise), decision-makers should prepare for more extreme wet years *and* more extreme dry years to occur over the assessed timeframe.

Scenario Uncertainty: Scientists are relatively confident that **mean temperature** projections for various scenarios will increase, in part because of the influence of and lag time of greenhouse gas emissions released in recent years. However, scenario projections available for analysis diverge significantly **starting around mid-century**, in part because of uncertainties surrounding future greenhouse gas emissions, population growth, land use, and other drivers of human development worldwide. The Climate Impact Profiles indicate projections with the potential for divergent trajectories by mid-century, depending on scenario assumptions. **Under such scenario uncertainty, decision-makers should consider options that account for outcomes across the full range of scenario projections (SSP1-2.6, SSP3-7.0, and possibly other representative scenarios).** Users should note that while scenario uncertainty remains an important consideration for many longer-term temperature projections, longer-term precipitation projections generally tend to exhibit different sources of relative uncertainty.

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[43] Sources of projection uncertainty are summarised, among other sources in: Chen, D., M. Rojas, B.H. Samset, K. Cobb, A. Diongue Niang, P. Edwards, S. Emori et al. (2021). Framing, Context, and Methods. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 147–286. New York: Cambridge University Press, DOI:10.1017/9781009157896.003; Sauchyn, D., J. Belanger, M. R. Anis, S. Basu, and S. Stewart (2022). Understanding and Accommodating Uncertainty in Climate Change Data: A ClimateWest Primer. *ClimateWest.* URL: https://climatewest.ca/wp-content/uploads/2022/09/ClimateWest-Plain-Language-Uncertainty-Primer-2022.pdf

Example B: Average annual temperature increases projected for one location under a higher-emission scenario (SSP3-7.0) may significantly outpace best-estimate increases projected under lower-emission scenario (SSP1-2.6), but only starting around midcentury. Due to the unpredictability of future global greenhouse gas emissions (e.g., some countries may adopt policies or technologies to effectively reduce net emissions, while others may increase emissions from fossil fuel-driven development), annual mean temperatures may rise moderately (+1.5ºC on average) or dramatically (+3ºC on average) by end-of-century. This range of possibilities results from scenario uncertainty (e.g., which global emission pathway transpires). In effect, decision-makers should prepare for moderately warmer temperatures *and* significantly warmer temperatures to occur by midcentury, on average.

Inherent variability is an additional source of uncertainty that can never be entirely eliminated from future projections. The global climate system features interactions and feedback processes that produce random variation ('internal variability'). For instance, **near-term precipitation projections** for a specific season may reflect uncertainty not because of the scenario (e.g., future emission trajectories) or modelling assumptions (e.g., predicting how ENSO variability may deviate under enhanced warming), but because of the timing and magnitude of naturally dynamic ENSO cycles (e.g., wet and dry years will periodically vary, even if emission levels and future ENSO behaviour do not change from observed baseline conditions). By contrast, longer-term projections on average often better account for uncertainty due to the inherent variability of the climate system. The Climate Impact Profiles identify projections where inherent variability plays a relatively prominent role in the near-term. Under such conditions, **decision-makers should consider options informed by trends of recent or longer-term climatological observations (e.g., described in the 'Observed Climate' section of Climate Impact Profiles**).