INFORMATION SOURCES TO SUPPORT ADB CLIMATE RISK ASSESSMENTS AND MANAGEMENT

TECHNICAL NOTE

SEPTEMBER 2018

ADB

ASIAN DEVELOPMENT BANK

INFORMATION SOURCES TO SUPPORT ADB CLIMATE RISK ASSESSMENTS AND MANAGEMENT

TECHNICAL NOTE

SEPTEMBER 2018

ADB

Notes:
In this publication, "$" refers to United States dollars.
Corrigenda to ADB publications may be found at http://www.adb.org/publications/corrigenda
ADB recognizes "Kyrgyzstan" as the Kyrgyz Republic.
This publication may be accessed online at http://dx.doi.org/10.22617/TIM189600-2

Cover Photo: The pitching of Geo bags in progress on the banks of the river Brahmaputra in Gumi, Guwahati, Assam. The project is part of the Integrated Flood and River Bank Erosion Risk Management Investment program funded by ADB. (photo by ADB)

Contents

Tables and Figures

Acknowledgments

Abbreviations

CCKP	Climate Change Knowledge Portal (of the World Bank)
CMIP	Coupled Model Intercomparison Project (number that follows is the phase)
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRA	climate risk assessment
CRMF	Climate Risk Management Framework
EM-DAT	Emergency Events Database
ENSO	El Niño Southern Oscillation
ESRL	Earth System Research Laboratory
GCM	Global Climate Model
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic information system
GSOD	Global Summary of the Day
IPCC	Intergovernmental Panel on Climate Change
km	kilometer
M&E	monitoring and evaluation
NCEP	National Centers for Environmental Prediction
NDC	Nationally Determined Contribution
ND-GAIN	Notre Dame Global Adaptation Initiative
PET	potential evapotranspiration
RCCAP	Regional Climate Consortium for Asia and the Pacific
RCM	Regional Climate Model
SDG	Sustainable Development Goal
SDSM	Statistical Downscaling Model
SST	sea surface temperature
TRMM	Tropical Rainfall Monitoring Mission
USAID	United States Agency for International Development
WASH	water, sanitation, and hygiene
WMO	World Meteorological Organization

Executive Summary

This technical note is intended to support climate risk assessment (CRA) experts, in particular, those undertaking the early stages of project development. Time and resources could be saved by attaching this document to terms of reference issued to CRA consultants. However, there is a limit to which globally accessible, open source data can meet the detailed information needs of local adaptation projects. This note supplements rather than replaces efforts to gather relevant climate information from government agencies and counterparts, especially during the project concept phase.

About 70 sources of public information have been compiled for the Asia and Pacific region, including data on historical and future climate, climate-related disasters, indicators of national vulnerability, and preparedness to adapt. Additional resources produced by ADB are also incorporated. This is a living document—appendixes should be periodically refreshed as new information is located and quality assured. Data sources are collated in four appendixes that broadly map to successive phases of the ADB Climate Risk Management Framework. The appendixes cover:

(i)   national emissions, climate vulnerability, risks, and impacts;
(ii) historic weather, climate, and environmental change;
(iii) multidecadal, regional climate change projections; and
(iv) climate change impacts and adaptation.

Most of the data identified are contextual—they provide high-level information about present and future climate risks at national and/or sector levels. Additional capacity development may be required in specialist "gatekeeping" skills, such as geographic information systems, data homogeneity testing, post-processing research data formats (e.g., NetCDF), regional climate downscaling, and impact assessment. By growing these technical capabilities, more data could be accessed from the same public platforms or combined in ways that add value to the CRA.

As well as strengthening the technical capacities of local consultants and CRA experts, access to existing research-grade data stores should be improved through closer cooperation with scientific programs. For example, new interfaces could be developed to open research archives to a broader user base. In particular, there is an urgent need to widen access to the daily and sub-daily climate information needed for economic analysis, engineering design standards, stress-testing adaptation options, and other aspects of project design.

Large parts of the Asia and Pacific region are scarce in both the climate and socioeconomic information required for robust CRA—in particular, for high-elevation and physically remote locations. Remotely-sensed and reanalysis products certainly improve coverage, but the accuracy of these assets ultimately depends on high-quality observing networks. Therefore, ADB, other multilateral development banks, and partner agencies should continue to invest in programs that strengthen national monitoring systems for climate and environmental change. Open access to such long-term records is invaluable for detecting emergent risks and devising, then implementing, effective adaptation measures.

Introduction

The Asia and Pacific region is vulnerable to temperature extremes, and flooding by heavy rainfall, sea level rise, and tropical cyclones (Asian Development Bank [ADB] 2017). Risks from climate change are further amplified by the pace of population growth and rapid development of urban areas. Both trends are concentrating people and assets in places that are potentially exposed to climate threats. Climate change also has implications for food, water, and energy security; migration; and the stability of trade networks in the region. To counter these risks, ADB has made a commitment to provide $6 billion of climate financing per year by 2020, of which $2 billion will be allocated for adaptation.

Due diligence requires that adaptation finance is invested in projects that deliver intended benefits at the least cost. The Midterm Review of Strategy 2020 (ADB, 2014a) sets out a vision for mainstreaming adaptation and climate resilience in development planning, project design, and implementation. Subsequently, the ADB Strategy, Policy, and Review Department introduced mandatory screening of ADB infrastructure projects to identify those at high or medium risk of being adversely affected by climate change. At-risk projects must be "climate-proofed" to make them resilient to identified climate change impacts.

The process of adapting to climate change can be highly data-intensive (IPCC-TGICA 2007; Weaver et al. 2013; Wilby et al. 2009). Contextual information is needed for preliminary risk screening and to identify socioeconomic factors that define adaptive capacities. Site-level data are required to establish baseline conditions for referencing climate change impacts and avoided damages, as well as for project monitoring and evaluation. Climate change scenarios are used with sector-specific impacts models to quantify expected risks and to evaluate the efficacy of adaptation measures. Alternative adaptation options must be prioritized based on their benefits and costs, as well as other criteria agreed with project partners.

Limited availability of contextual and climate information can present significant obstacles to climate risk assessments (CRAs). This bottleneck is particularly acute in data-sparse regions where even information about past climate trends and impacts may be difficult to obtain. However, improved access to remotely sensed (satellite) products, global climate (gridded) data, reanalysis products, and platforms for accessing country data help to fill some information gaps.

This technical note provides a compendium of open access resources that could assist experts carrying out CRAs. Where feasible, identified resources are mapped to the information needs of specific tasks within the CRA process.

Aims and Overall Approach

Four sector groupings account for the majority of ADB adaptation finance. These are:

    (i)   water and wastewater systems;
    (ii) energy, transport, and other built environment infrastructure;
    (iii) crop and food production; and
    (iv) coastal and riverine infrastructure.

With these sectors in mind, this technical note aims to provide:

    (i) tables of reputable sources of public data on climate, sea level, and
        historical climate-related disasters for the Asia and Pacific region, which
        could be accessed by experts carrying out CRAs (especially those working
        in data-sparse regions); and
    (ii) commentary on the points at which these data might be brought into the
        ADB Climate Risk Management Framework (CRMF) (ADB 2014b) and
        economic analysis (ADB 2015).

The above aims were addressed by systematically appraising the information needs of CRA experts following all 20 steps of the ADB CRMF. Potential sources of data were assigned to one of four categories:

    (i) contextual information about historic greenhouse gas (GHG) emissions,
        climate vulnerability, risks, and impacts;
    (ii) historic information on climate variability and change;
    (iii) projections of multidecadal climate change;
    (iv) information about future climate change impacts and major completed or
        ongoing adaptation projects.

In each case, a brief description is provided along with an outline of the advantages and disadvantages of the information.

This technical note begins with a list of some ADB resources that support CRAs, then an overview of the key entry points for data input within the ADB CRMF. These elements are followed by sections on each of the four categories of information, including example resources and their application. The note closes with a few suggestions for strengthening ADB's capacities in data retrieval and analysis.

ADB Resources to Support Climate Risk Assessments

ADB has developed a range of guidelines to raise awareness of climate hazards and to improve the climate resilience of projects (Table 1). The complete ADB archive is searchable by publication type, country, subject, language, and publication date. Climate-related sector guidelines are available for agriculture, energy, transport, and water. Cross-sector guidance is provided for economic analysis of adaptation options, strengthening resilience through social protection programs, evaluation of natural hazards, and disaster risk assessment.

In addition to the resources listed in Table 1, ADB (ADB 2016a) provides a catalog of other climate-related publications up to 2016. This includes case studies of climate change impacts and options for increasing resilience of water infrastructure (ADB 2011; ADB 2013a); a review of the vulnerability and adaptation options available to the electric power sector (ADB 2012); country and sector studies of the economic costs and benefits of actions on climate change in South Asia (Ahmed and Suphachalasai 2014); a methodology and lessons learned from an assessment of vulnerability and adaptation options in the Greater Mekong Subregion (ADB 2014c); and examples of technologies that can be used to address climate change across six sectors (agriculture, coastal resources, human health, transportation, water resources, and disaster risk management) (ADB 2014d).

ADB technical assistance reports may also provide useful contextual information and examples of economic analysis of climate change adaptation. These documents are also available through the ADB archive.

**Table 1: ADB Guidance Relevant to Climate Risk Assessment
for Project Preparation**

Resource	Description
Strengthening Resilience through Social Protection Programs: Guidance Note. March 2018.	Underscores the importance of strengthening climate change and disaster resilience through social protection programs and proposes a working framework for social protection programs to deliver on resilience outcomes
Disaster Risk Management and Country Partnership Strategies: A Practical Guide. November 2017.	Provides technical advice on the integration of disaster risk management considerations in ADB country partnership strategy preparation
Disaster Risk Assessment for Project Preparation: A Practical Guide. November 2017.	Provides technical advice on disaster risk assessment to facilitate the consideration of disaster risks in the design of development projects
Natural Hazard Data: A Practical Guide. November 2017.	Assists ADB project officers in understanding natural hazards, hazard mapping, disaster risk assessments, and in taking disaster risk into account in project design
Guidelines for Climate Proofing Investment in the Water Sector: Water Supply and Sanitation. December 2016.	Assists project teams in managing climate change risk in the context of water supply and sanitation investment projects
Economic Analysis of Climate-Proofing Investment Projects. September 2015.	Describes the conduct of cost–benefit analysis of climate-proofing investment projects
Climate-Proofing ADB Investment in the Transport Sector: Initial Experience. December 2014.	Describes investments in the transport sector vulnerable to increased sea level and expected changes in the frequency and intensity of extreme weather events
Guidelines for Climate-Proofing Investment in the Energy Sector. May 2013.	Provides a step-by-step methodological approach to help project teams assess climate change adaptation measures to energy investment projects
Guidelines for Climate-Proofing Investment in Agriculture, Rural Development, and Food Security. November 2012.	Provides a methodological approach to assist project teams in assessing and incorporating climate change adaptation measures into investment projects in agriculture, rural development, and food security
Climate-Proofing ADB Investments in the Transport Sector: Road Infrastructure Projects. October 2011.	Provides a step-by-step methodological approach to assist project teams to incorporate climate change adaptation measures into transport sector investment projects

Source: ADB archive.

Data Requirements of the ADB Climate Risk Management Framework

The ADB CRMF helps to identify climate-related risks to investments in the early stages of project development, and to thereby incorporate cost-effective countermeasures in the final project design. This is a top-down, scenario-led, 20-step process with five phases of activity: (i) climate risk screening, (ii) climate risk assessment, (iii) adaptation assessment, (iv) implementation arrangements, and (v) monitoring and evaluation (Figure 1). All phases require data with the exception of implementation arrangements (although even in this case, there may be planned activities to strengthen the information base as an outcome of the project). The following sections outline how the information requirements of these phases may be met (in part) by public data sources (Table 2). More specific examples of resources are given in later sections.

Climate risk screening (steps 1 to 5). For this, there is a need for up-to-date contextual information on existing climate hazards and climate change parameters most relevant to the project development and operational lifetime. International databases on climate-related disasters or hazards, along with national indicators of climate vulnerability and human development, or national plans of action can all set the scene (Appendix 1). Global gridded climate data sets can help to fill gaps in national coverage (Appendix 2). Background data on specific climate-related threats (e.g., floods, fires, drought, and dust) can be gathered too. Time and resources could be saved by attaching lists of approved information sources (e.g., Appendixes 1 to 4 of this technical note) to the terms of reference issued to CRA consultants (step 5).

Figure 1: Steps in the Climate Risk Management of Investment Projects

Project Concept Phase	**CLIMATE RISK SCREENING** STEP 1: Preliminary climate risk screening STEP 2: Detailed climate risk screening STEP 3: Survey existing information and knowledge STEP 4: Identify data needs and required expertise STEP 5: Prepare terms of reference for CRVA	Checklist Screening Report
Project Preparation Phase	**CLIMATE RISK ASSESSMENT** STEP 6: Identify climatic vulnerability of project components STEP 7: Identify biophysical drivers of vulnerability STEP 8: Identify socioeconomic drivers of vulnerability STEP 9: Develop appropriate climate change scenarios STEP 10: Estimate future biophysical impacts STEP 11: Assess impacts on investment project	
	ADAPTATION ASSESSMENT STEP 12: Establish the adaptation objective STEP 13: Identify all potential adaptation options STEP 14: Conduct consultation STEP 15: Conduct economic analysis of adaptation options STEP 16: Prioritize and select adaptation option(s)	CRVA Report
Project Implementation Phase	**IMPLEMENTATION ARRANGEMENTS** STEP 17: Establish arrangements for implementation STEP 18: Identify needs for technical and capacity building	
	MONITORING AND EVALUATION STEP 19: Design monitoring and evaluation plan, including suitable performance indicators STEP 20: Feedback into policy-making and knowledge management processes	

CRVA = climate risk and vulnerability assessment.

Source: ADB. 2015. *Economic Analysis of Climate-Proofing Investment Projects.* Manila, Philippines.

Climate risk assessment (steps 6 to 11). This phase requires project-specific data to determine the vulnerability of project components to changing climate conditions (step 6). However, national indicators (with their constituent scores) can help to situate the project alongside long-term socioeconomic drivers of climate vulnerability and readiness to adapt (e.g., Notre Dame Global Adaptation Initiative [ND-GAIN] Country Index, Appendix 1). Development of appropriate climate change scenarios can be extremely time-consuming and data-intensive depending on the level of detail needed to evaluate potential biophysical impacts and economic costs and benefits. Bespoke scenarios may be created for the project via a range of statistical downscaling techniques fit to available climatic data (Appendix 2). Alternatively, existing high-resolution climate change scenarios can be accessed via online weather generators (e.g., MarkSim), regional (e.g., Coordinated Regional Climate Downscaling Experiment [CORDEX], Regional Climate Consortium for Asia and the Pacific [RCCAP]), or global (e.g., Intergovernmental Panel on Climate Change [IPCC]) model archives (Appendix 3). With all these scenarios, care should always be taken to avoid mistaking increased precision for accuracy.

Table 2: Tasks and Resources Required to Complete Each Step in the ADB Climate Risk Management Framework

Step	Tasks	Requirements	Resources
1	Preliminary risk screening	"…expert opinion and judgment, based on awareness and knowledge of climate change and hazards" (p. 17)	Appendix 1
2	Detailed risk screening	"Projects identified to be at medium or high risk undergo a further and more detailed screening" (p. 20)	AWARE™ for projects
3	Survey existing information and knowledge	"Identifying existing available information can help to avoid duplication and ensure that coordination efforts within countries and between donors are being supported" (p. 23)	NAPAs, NDCs, Appendix 1
4	Identify data needs and required expertise	"A preliminary identification of all climate change parameters most relevant to the project should be initiated during the project concept phase" (p. 25)	Appendix 2
5	Prepare terms of reference for the CRA	"Collect all relevant climate change data from government ministries and international and community organizations… [and analyze] raw and observational data of current practices to compensate for vulnerability" (pp. 95–98)	Attach Appendixes 1 to 4
6	Identify vulnerability of project components	"…information gathered during a vulnerability assessment may include local experiences related to shifting precipitation patterns and water availability, effects of warming on vegetative health, incidence of extreme climate events, such as floods, and melting of permafrost" (p. 33)	Project-specific data

Table 2   *continued*

Step	Tasks	Requirements	Resources
7	Identify biophysical drivers of vulnerability	"Using geographic information system (GIS), it is possible to map areas that are particularly vulnerable to a combination of local conditions and climate variability" (p. 34)	Remotely sensed data
8	Identify socioeconomic drivers of vulnerability	"It is useful at this stage to identify those socioeconomic factors that influence adaptive capacities" (p. 34)	Appendix 1
9	Develop appropriate climate change scenarios	"The construction of climate change scenarios begins with an understanding of which climate variables are likely to affect the project, including both the integrity of project components and project outputs" (p. 36)	Appendix 2
		"...analysis of historical data helps to identify trends in the main climate variables and also allows for the ground-truthing of the simulation results from climate models" (p. 38)	Appendix 3
10	Estimate future biophysical impacts	"Once climate change scenarios have been constructed, key relationships between changes in climate parameters—such as average temperature, average precipitation, temperature and precipitation extremes, sea-level rise, and storm surges—and impacts... must be quantified" (p. 48)	Impact models Appendix 4
11	Assess impacts on investment projects	"Provide information on the impacts of projected climate change on the project's performance and outputs, and, where appropriate, to transform the quantification of these impacts into economic costs and/or benefits" (p. 49)	Project-specific economic data Appendix 3
12	Establish the adaptation objective	"The adaptation-related activities should seek to minimize the potential negative effects" (p. 51)	Partner consultations
13	Identify all potential adaptation options	"Based on an understanding of the project's vulnerability to climate change, the project team will have to identify a range of technically feasible adaptation options to reduce climate risk to the project" (p. 51)	Partner consultations Appendix 4

Table 2   *continued*

Step	Tasks	Requirements	Resources
14	Conduct consultations	"Conducting roundtable consultations provides useful input for identifying and appraising the whole range of adaptation options... Options must be scientifically sound, socially beneficial, and economically viable" (p. 52)	Partner consultations Appendix 4
15	Conduct economic analysis	"...the costs and benefits of the climate-proofing options must be assessed by identifying and quantifying the climate change impacts along two scenarios: Scenario without climate proofing... Scenario with climate proofing" (p. 53)	Discount rate Incremental costs of adaptation options Appendix 3
16	Prioritize and select adaptation options	"...prioritization can be based on an assessment of their technical feasibility, their benefits and costs, their social acceptability, and the opportunities they may offer for synergies with national priorities" (p. 60)	Partner consultations Multicriteria analysis
17	Establishing arrangements for implementation	"A lead organization should be selected to implement the adaptation measures" (p. 64)	M&E framework
18	Identify needs for technical support and capacity building	"Provisions for training and capacity building will likely be needed for executing agencies, partner institutes, local communities, project management units, and contractors" (p. 65)	Needs assessment
19	Design monitoring and evaluation plan including suitable performance indicators	"There are some challenges in developing M&E indicators, including the long-term nature of actual climate change, the need to acquire appropriate baseline data and metrics for measuring vulnerability, and isolating vulnerability to climate change from other sources of pressure" (p. 67)	Indicators of project impacts, outcomes, and outputs Appendix 1 Appendix 2
20	Feedback into policy-making and knowledge management processes	"Lessons from adaptation measures undertaken at a project level should inform policy makers about appropriate approaches at the sector and/or national levels" (p. 68)	Institutional frameworks and processes

M&E = monitoring and evaluation, NAPA = National Adaptation Programme of Action, NDC = Nationally Determined Contribution.

Source: ADB. 2016. *Guidelines for Climate-Proofing Investment in the Water Sector: Water Supply and Sanitation.* Manila, Philippines.

Adaptation assessment (steps 12 to 16). The value added by this phase of activity largely rests on the quality of consultation and level of engagement with project partners when identifying potential adaptation options. Lessons about "successful adaptation" processes can be exchanged through knowledge sharing platforms, regional networks, and case study catalogs (e.g., Asia-Pacific Network for Global Change Research, Appendix 4). However, adaptation outcomes may not be realized for decades and, even then, reliable counterfactuals may be hard to find (Moser and Boykoff, 2013). Nonetheless, the ADB CRMF requires that incremental benefits and costs of various adaptation options are established through economic analysis (step 15). Hence, climate scenarios are needed to assess the economic consequences of the project with or without climate change and with or without adaptations.

Monitoring and evaluation (steps 19 to 20). Reliable baseline data and long-term, post-project monitoring are needed to evaluate investment impacts, outcomes, and outputs. Scope for developing meaningful performance indicators is partly constrained by available baseline socioeconomic and climate information (Appendixes 1 and 2). The recurrent costs of long-term data collection must also be considered when setting up monitoring and evaluation frameworks. Ultimately, the intention is to use such evidence to share learning about what mix of adaptation measures work best, where, and when. Monitoring may also be needed to trigger measures at various points along planned adaptation pathways (e.g., rising sea levels as a stimulus for progressive raising and/or relocating of port infrastructure). Haasnoot et al. (2013) and Ranger et al. (2013) have other examples of adaptation pathways.

Historic Greenhouse Gas Emissions, Climate Vulnerability, Risks, and Impacts

Appendix 1 provides various sources of contextual information, including for existing climate-related hazards, disaster impacts, development indicators, socioeconomic vulnerability, and readiness to adapt to climate change.

Many of the global databases listed provide national annual statistics; hence, any regional and/or sub-annual variations can be obscured. For example, the Emergency Events Database (EM-DAT) is a global archive of mass disasters since 1900, searchable by country, cause, and impact (Figure 2). National summary sheets and dashboards of climate risks are also widely available (e.g., World Bank Climate Change Knowledge Portal), but generic outputs should always be sanity-checked using local knowledge. In Figure 3, Tajikistan is entirely landlocked, so cannot be at a "very low" risk of coastal flooding, whereas Metropolitan Manila has more than a "very low" risk of coastal flooding. Other sources give data on individual disaster losses and areas affected (e.g., DesInventar Sedai, or Dartmouth Flood Observatory), but the precise definition of events may not always be clear. Aqua Monitor gives a global view of land-to-water and water-to-land conversions over the period 1985–2016 (Donchyts et al. 2016).

**Figure 2: National Exposures to Drought and Extreme Temperatures
1986–2015**
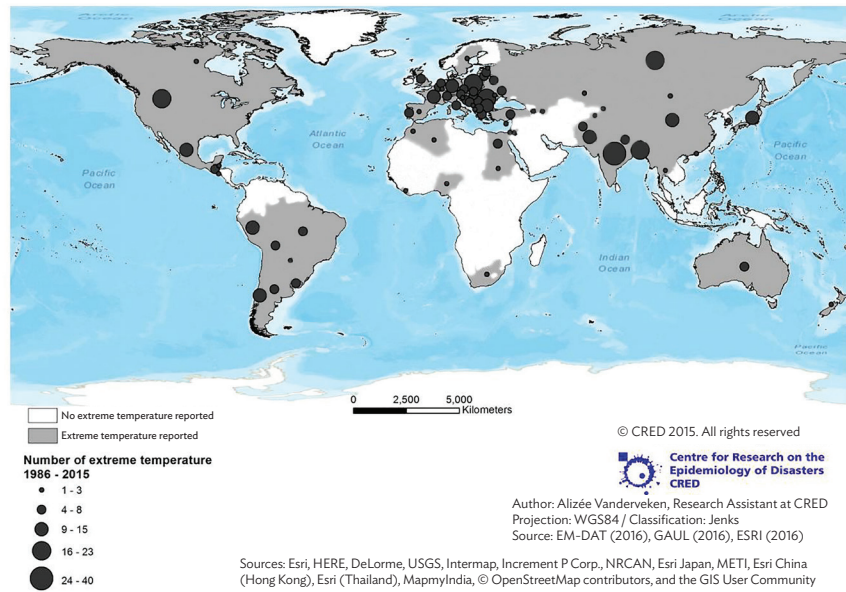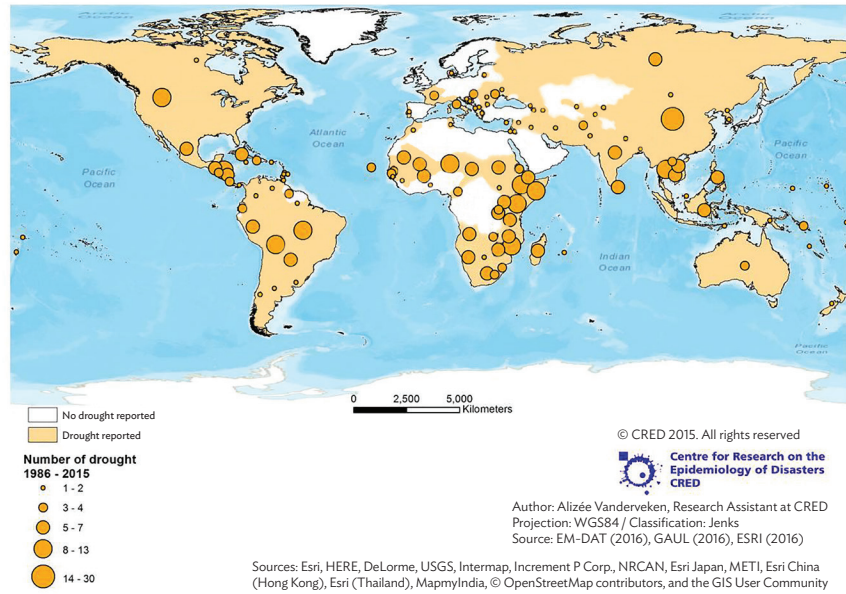
Source: Centre for Research on the Epidemiology of Disasters. Emergency Events Database.

Figure 3: Need for Careful Use of Hazards Dashboards Shown by Outputs for Tajikistan and Metropolitan Manila, Philippines

Tajikistan

Hazard	Hazard Level
River flood	High
Urban flood	High
Earthquake	High
Landslide	High
Wildfire	High
Water scarcity	Medium
Extreme heat	Medium
Coastal flood	Very low
Cyclone	Very low
Tsunami	no data
Volcano	no data

Metropolitan Manila

Hazard	Hazard Level
Earthquake	High
Volcano	High
Cyclone	High
Wildfire	High
Urban flood	Medium
Tsunami	Medium
Extreme heat	Medium
River flood	Low
Water scarcity	Low
Coastal flood	Very low
Landslide	Very low

Source: ThinkHazard.

National socioeconomic and composite vulnerability indicators are widely available as raw annual statistics that can be downloaded for post-processing and analysis (Figure 4). Much information is collected and distributed via the agencies of the United Nations, including for reporting against Sustainable Development Goals (e.g., Joint Monitoring Programme) or emissions targets (e.g., ClimateWatch). Some indicators give useful contextual information on underlying drivers of climate risk, such as high dependency on imported food (Figure 4) (d'Amour et al., 2016). Project-level information on low-carbon development and monitoring is available through the database of the Clean Development Mechanism.

Figure 4: Changing National Economic Indicator of Readiness to Adapt to Climate Change and Proportion of Cereal Consumption Obtained from Outside the Country as an Indicator of Climate Vulnerability

Changing National Economic Indicator of Readiness to Adapt to Climate Change

Time-series plot of Economic
Notre Dame Global Adaptation Index. Data release Nov. 2015

Proportion of Cereal Consumption Obtained from Outside the Country as an Indicator of Climate Vulnerability

Time-series plot of Food Import Dependency
Notre Dame Global Adaptation Index. Data release Nov. 2015
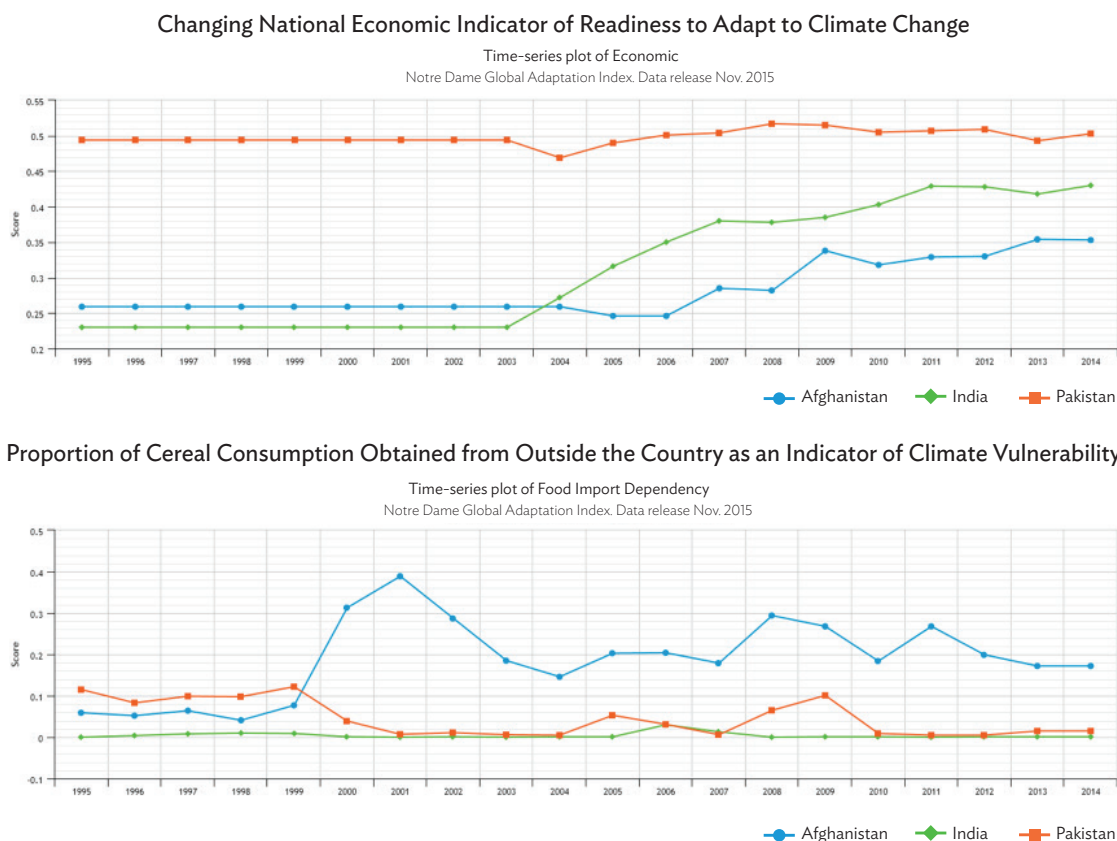
Source: ND-GAIN. Raw data are available up to 2016.

Remotely sensed physical features and hazards are increasingly available, both historically and in near real-time at subnational scales. For instance, the World Glacier Monitoring Service issues periodic bulletins on changing ice thickness, area, length and mass balance (Figure 5). Terra/MODIS satellite imagery shows distributions of wildfires (Figure 6, left, at 1-kilometer [km] resolution) and dust storms (Figure 6, right, at 2 km resolution). In Figure 6, Terra/MODIS thermal imagery shows extensive forest fires across Borneo and Indonesia on 23 October 2015 at 15:05–15:10 UTC (left). The path of the satellite and central points of tiles are also shown. Terra/MODIS aerosol optical depth reveals the severe dust storms that impacted Beijing and northern People's Republic of China on 4 May 2017 (right). Satellite

data are available in a range of formats that can be interrogated by GIS to extract local information relevant to the project. Historic data—whether on the properties of glaciers or climate-related hazards (such as fires and dust storms)—provide baselines for evaluating future threats to a project.

**Figure 5: Changes in the Front and Mass Balance
of the Abramov Glacier, Kyrgyz Republic**
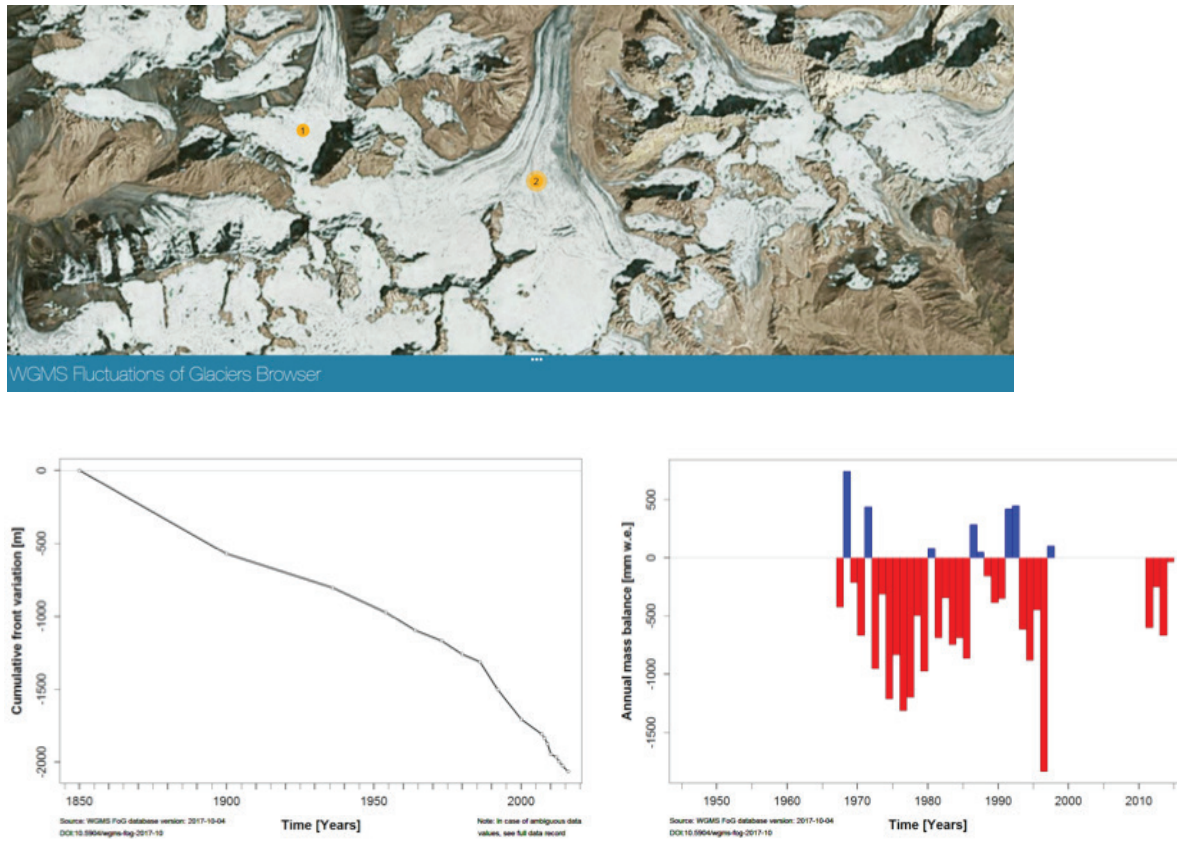
Source: World Glacier Monitoring Service.

**Figure 6: Terra/MODIS Satellite Imagery Showing Distributions
of Wildfires and Dust Storms**
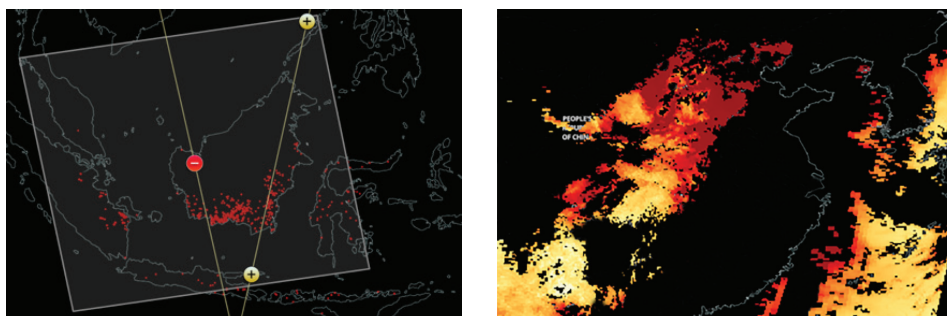
Source: Terra/MODIS.

Historic Weather and Climate Information

Appendix 2 lists sources of historic climate information for standard meteorological variables (such as temperature and precipitation over land areas), seasonal teleconnection patterns (such as for El Niño Southern Oscillation [ENSO]), remotely sensed variables (such as snow and ice cover), derived products (such as gridded weather data or reanalysis variables), and climate effects (on drought, food security, fire, and human health indicators). In each case, users should consider the temporal and spatial resolution of the various data sources in relation to the accuracy and precision required for the intended application.

Historic weather and climate data can be expensive to acquire or may be subject to strict licensing conditions. Sub-daily and daily hydrometeorological data are especially difficult to obtain from open sources and options may be particularly limited in data-sparse regions. The Global Summary of the Day (GSOD) is a searchable archive that provides access to daily variables for World Meteorological Organization (WMO) stations. However, records may be incomplete or contain unresolved quality issues so should always be checked carefully (Wilby et al. 2017). Sources of sub-daily weather data for selected sites in the Asia and Pacific region include RCCAP, Planet OS, and Weather Underground.

Other sub-daily and daily precipitation estimates can be obtained via the Giovanni portal for instruments, such as the Tropical Rainfall Monitoring Mission (TRMM). However, TRMM and other satellite-based precipitation estimates may be unreliable in mountainous, snow-covered regions, or near large water bodies, and where there are few land-based data for calibration (Karaseva et al. 2012; Yong et al. 2012; Dixon and Wilby 2016). A comprehensive evaluation of 30 global precipitation products showed that satellites tend to underestimate monsoon precipitation at high elevations in South Asia, and struggle to replicate observed frequencies of light and heavy rainfall in East Asia (Sun et al. 2018). Maps from the study show regional variations in systematic and random errors for satellite data.

Proxy daily weather variables can also be sourced from global reanalysis products, such as National Centers for Environmental Prediction (NCEP). These are essentially observed data from land, ocean, and satellite observations that have been assimilated by a climate model to create global coverage on a regular grid. Raw data are typically in NetCDF format, but some portals issue selected variables as TXT files from 1940s onward (e.g., SDSM).

Monthly precipitation and temperature series are readily available from several sources (e.g., Earth System Research Laboratory [ESRL], and The Royal Netherlands Meteorological Institute [KNMI] Climate Explorer). The CRU Google Earth Interface is an interactive tool for locating nearest weather stations or interpolated data at 0.5° grid resolution for the period 1901–2014 (as in Figure 7). Although the underlying station data have been quality assured, reliability of the interpolated estimates decreases in data-sparse and complex terrain (Harris et al. 2014). Accuracy and coverage also diminishes for earlier decades, with much lower station densities before the 1950s (Figure 8). More recent political instability and conflict can lead to gaps in data too (e.g., Aich et al. 2017).

Figure 7: Annual Mean Temperature and Annual Precipitation Totals for the 0.5° Grid Nearest Bandar Seri Begawan, Brunei Darussalam
(4.75°N, 114.75°E)
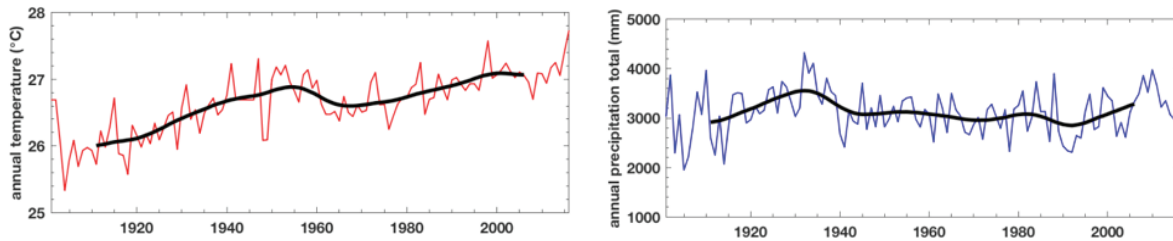
Source: I. Harris et al. 2014. Updated High-Resolution Grids of Monthly Climatic Observations – the CRU TS3.10 Dataset. *International Journal of Climatology*. 34.

Figure 8: Density of Active Weather Stations in June 1921
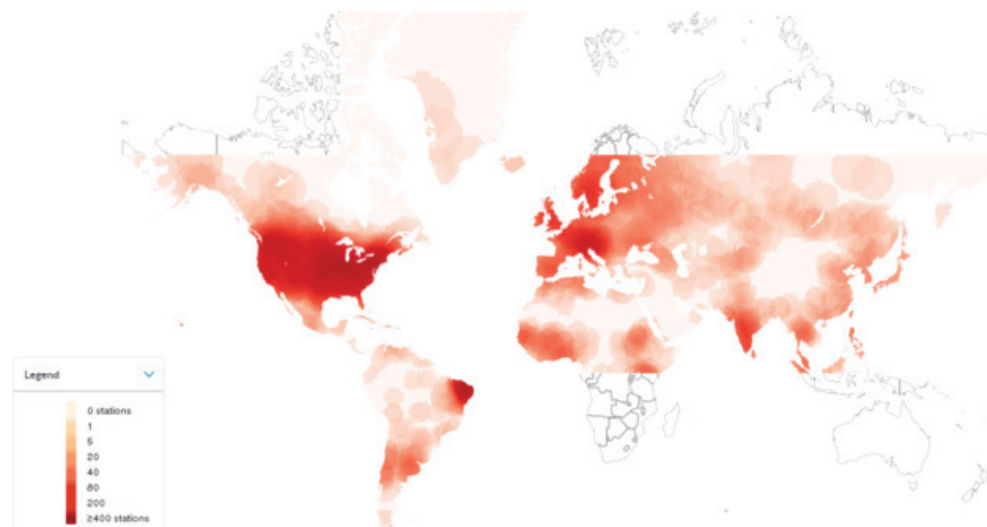
Source: Global Climate Monitor.

The KNMI Climate Explorer gives access to a variety of gridded, monthly weather variables from land-based observations and reanalysis products (Table 3). The portal can aggregate data by country, point location, or user-specified domain and season. Output is available as TXT files, time-series plots, or maps (showing change between chosen periods, or as anomalies and averages over time, Figure 9). When selecting data, one product might be preferred over another depending on the amount of interpolation applied, spatial resolution or period covered.

Table 3: Monthly Variables Available through the KNMI Climate Explorer

Variable	Description
GISTEMP 1200	Relatively low-resolution (1,200 km interpolated) temperature data set, more accurate over large spatial (more than 1,000 km) and temporal (annual and longer) scales
NCDC MOST	Less interpolated temperature data set with other homogeneities, 5° resolution
HadCRUT4.2.0.0	Temperature data set with most gaps, but with advanced sea surface temperature (SST) corrections; area averages are less accurate due to the missing data
CRU TS 4.00	Fully interpolated temperature and precipitation data set with high resolution (0.5°); in areas without observations it gives climatology
GPCCV7	High-resolution reconstruction of precipitation; in areas without observations it gives climatology
NCDC anomalies	Low-resolution (5°) analysis with missing data
UCAR ds010	Subjective reconstruction of mean sea level pressure based on old weather maps, Northern Hemisphere only
HadSLP2r	Low-resolution (5°) reconstruction of mean sea level pressure
ERA-Interim	Reanalysis of the state of the atmosphere over the satellite era, from 1979 to the present; uses all information available to reconstruct the weather and propagates this information using a high-resolution (~0.7°) weather model
ERA-20C	Reanalysis of the state of the atmosphere over the period 1900–2010 at 125 km resolution; based only on SST and air pressure observations to make it as homogeneous as possible; fidelity to the historical weather depends on the number of observations in an area
20C reanalysis	As above but for the period 1871–2012 at 200 km resolution

km = kilometer, KNMI = The Royal Netherlands Meteorological Institute.
Source: KNMI Climate Explorer.

Figure 9: Area Average Annual Mean Maximum Air Temperature Anomalies for Indonesia since 1901 and Change in Annual Mean Maximum Air Temperature over 2001–2017 versus 1971–2000
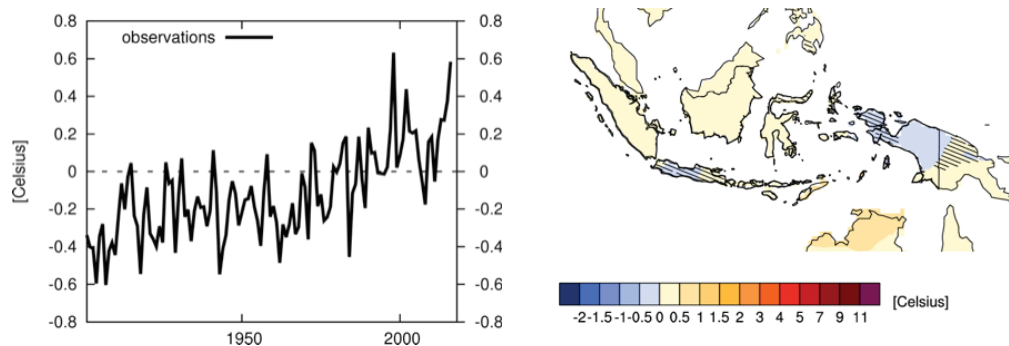
Source: KNMI Climate Explorer.

Other sources of monthly climate and environmental series include river flow, drought, and water balance indexes (e.g., CAWater-Info, Global Climate Monitor, Palmer Drought Severity Index, Gravity Recovery and Climate Experiment); snow, ice, and glacier properties (e.g., National Snow and Ice Data Center); long-term sea levels (e.g., Permanent Service for Mean Sea Level); wind and sea surface temperature (SST) indexes (e.g., NOAA Climate Prediction Center). Global layers of monthly climate and bioclimatic 30-year means are available via WorldClim.

The ESRL correlation portal is a versatile tool for identifying significant teleconnections between various SST and atmospheric indexes, and remote responses in regional climate variables—the basis for seasonal forecasting. The tool is also useful for extracting and interpreting signatures of seasonal climate variability in long-term climate records. For example, Figure 10 shows the well-known teleconnection between Pacific SSTs in autumn and precipitation in winter across Southeast Asia. When the Niño3.4 index is strongly positive, there is increased likelihood of drought in the region. Some assert that developing a seasonal forecasting capability is one way of strengthening capacity to adapt to extreme weather both now and in the future (e.g., Washington et al. 2006).

The IRI Climate and Society Map Room is a library of graphics and data that monitors climate conditions at global and regional scales, along with metrics of climate effects on society (including food and water security, or human health). Many records are updated in near real-time and provide historic information, including trends and analysis of climate extremes. For example, Figure 11 shows the distribution of the 3-month Standardized Precipitation Index across Asia at the start of 2018 and the monthly time-series of this drought index for a site in India. Such information could be helpful as part of the preliminary evaluation of climate risks and in benchmarking climate change scenarios.

Figure 10: Spatial Variations in the Correlation between ENSO (Niño3.4 Index) in Autumn (September–November) and Precipitation the Following Winter (December–February)
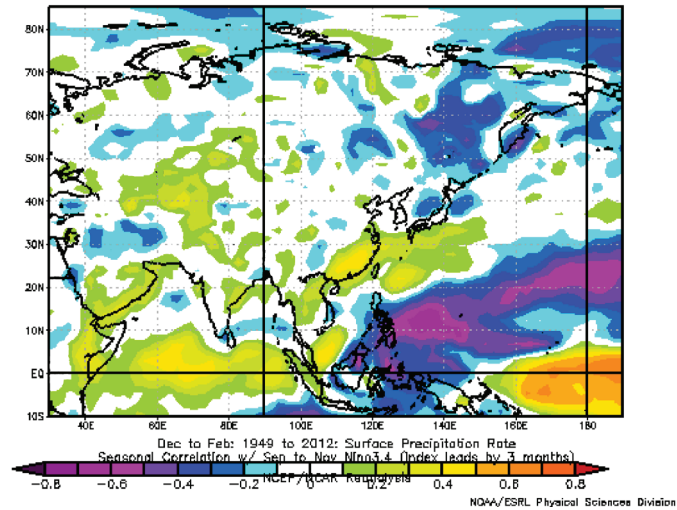
ESRL = Earth System Research Laboratory, ENSO = El Niño–Southern Oscillation
Source: ESRL Teleconnection Tool.

Figure 11: Three-Month Standardized Precipitation Index for Asia in January 2018 and for the Indian State of Madhya Pradesh since 2008
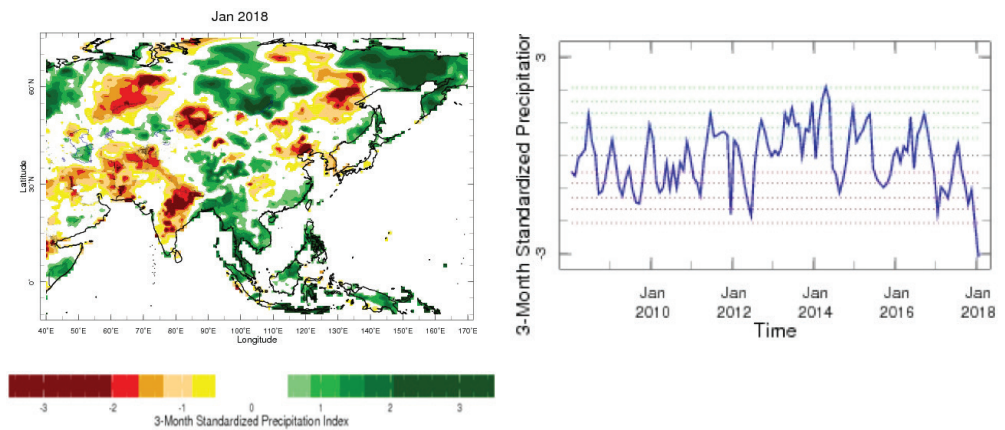
Source: IRI Global Drought Analysis Tool.

Multidecadal Climate Change Projections

Appendix 3 provides sources of information about future climate based on Global Climate Model (GCM) and downscaled regional climate scenarios. Even in an era of rapidly expanding climate services, access to high-resolution scenarios is more limited than might be expected. For instance, most portals offering daily climate model information (e.g., CORDEX, IPCC) are intended for use by the research community—with assumed expertise in handling NetCDF files or ability to assemble complex command sequences to access subsets of data from large archives.

The KNMI Climate Explorer and World Bank Climate Change Knowledge Portal (CCKP) are more user-friendly. They give access to climate change projections from the Coupled Model Intercomparison Project Phase 3 (CMIP3) and Phase 5 (CMIP5). Example output is provided for each in Figures 12 (KNMI) and 13 (CCKP). Both portals are highly versatile in terms of the domain, time period, key sector indicators, and outputs that can be retrieved. However, the most accessible data are only available as monthly, annual, or multidecadal means at the native grid-resolution of the GCM; downscaled and daily data are available, but in NetCDF format (CCKP) or only for Europe (KNMI). In Figure 12, changes in precipitation for Thailand by 2080–2099 are compared with 1986–2005. On the left of the figure is the 97.5 percentile of CMIP5 (Representative Concentration Pathways [RCP]8.5) ensemble annual mean; on the right is the annual ensemble mean of CMIP5 (RCP2.6 and RCP8.5) during 1900–2100. Figure 13 shows the change in the number of days with rainfall exceeding 50 millimeters per day in Thailand by 2080–2099, compared with 1986–2005 (based on the CMIP5 ensemble and a projection by HadGEM2_CC under RCP8.5).

Figure 12: Projected Changes in Precipitation for Thailand
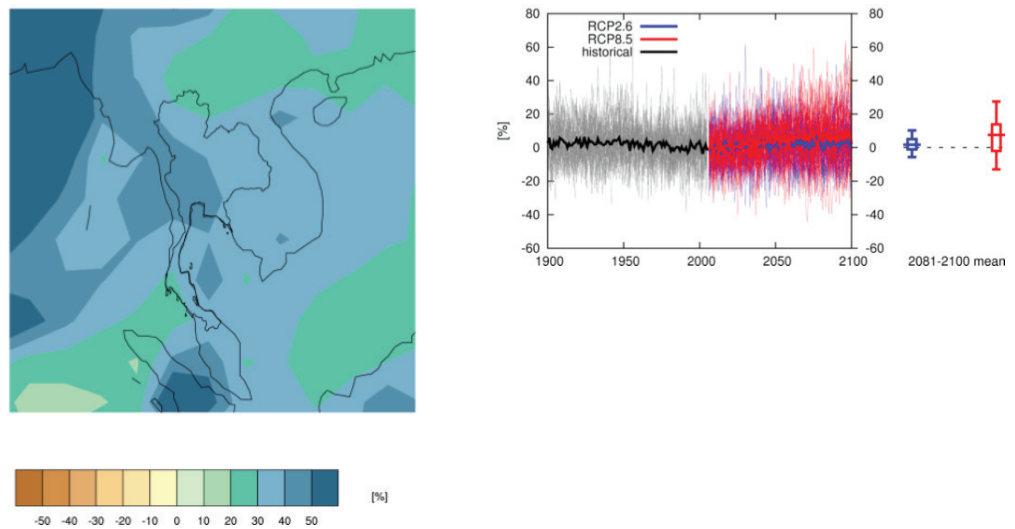
Source: KNMI Climate Explorer.

Figure 13: Change in Number of Days with Rainfall Exceeding 50 mm/day in Thailand by 2080–2099 versus 1986–2005
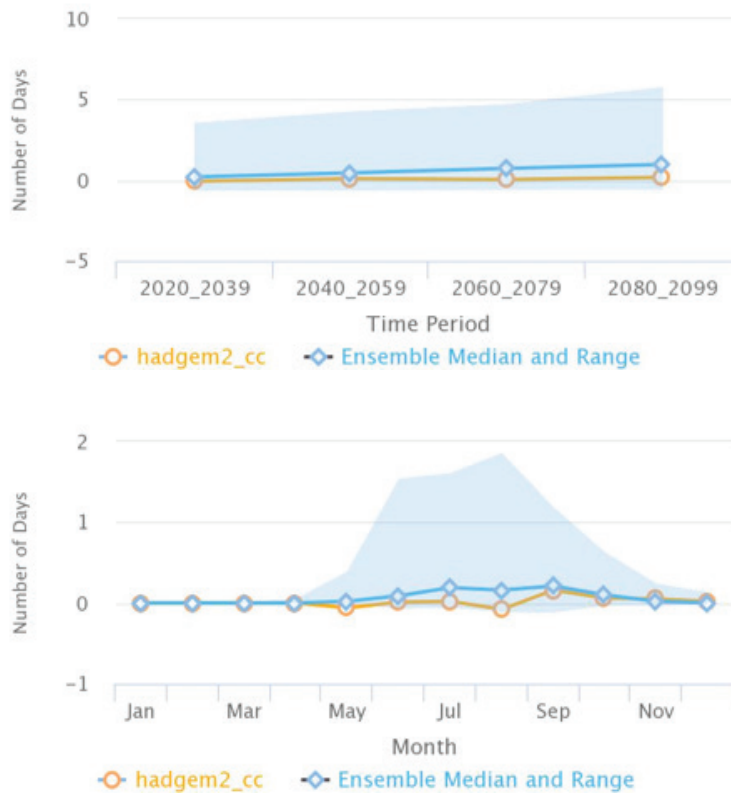
mm/day = millimeter per day, CMIP = Coupled Model Intercomparison Project , SRES = Special Report on Emissions Scenarios

Source: World Bank Climate Change Knowledge Portal.

The World Bank Water Anchor also produced scenarios (including mean air temperature, annual precipitation, a flood and a drought indicator) for major river basins. For example, Figure 14 shows climate changes (%) in the Chao Phraya river basin, Thailand by the 2050s based on CMIP3 output under SRES A2, A1b, and B1 emissions. However, the CCKP makes it clear that these data are not intended for use in any design study.

Figure 14: Climate Changes in the Chao Phraya River Basin, Thailand by the 2050s based on Coupled Model Intercomparison Project 3; SRES = Special Report Emissions Scenario3 Output under Special Report Emissions Scenario A2, A1b, and B1 Emissions (%)
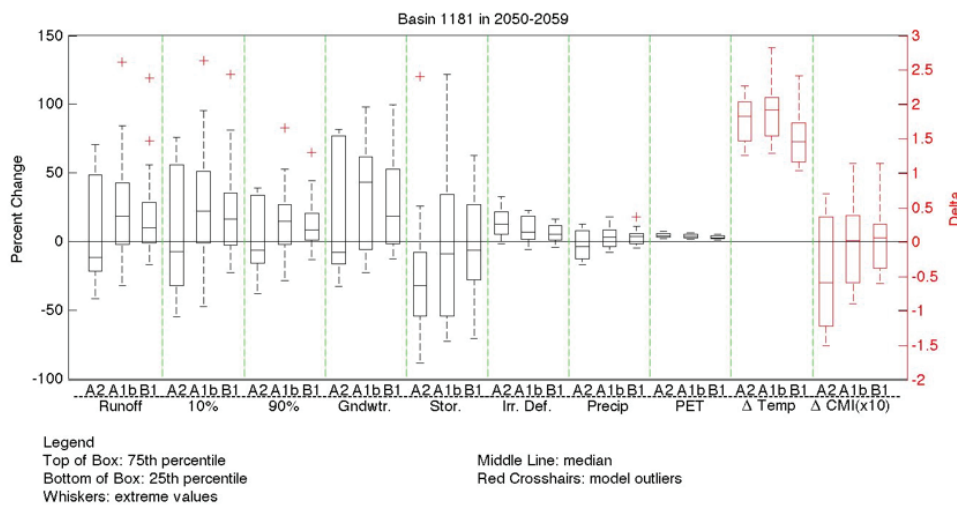
Note:

The bars are mean annual water runoff; annual high flow (10%); annual low flow (90%); groundwater (Gndwtr); basin yield/water availability (Stor); crop water deficit (Irr. Def); mean annual precipitation (Precip); annual potential evapotranspiration (PET); average change of mean temperature (Δ Temp); and climate moisture index (Δ CMIX(x10)).

Source: World Bank Water Anchor.

Climate model outputs are most readily available as monthly scenarios. This implies that their likely use within CRAs will be as change factors applied to higher resolution baseline data (IPCC-TGICA 2007). For example, the upper bound (97.5 percentile) ensemble projection for annual precipitation changes in the vicinity of Bangkok is 40%–50% (Figure 12). In this case, a multiplier (change factor) of 1.4 to 1.5 would be applied to observed daily or sub-daily precipitation series for the city during the baseline period (1986–2005). Sensitivity testing of options within the economic analysis might scale across the ensemble range (0.9 to 1.5 for Bangkok) to represent the climate scenario uncertainty. Return period estimates can also be recomputed from the scaled series. However, in these types of application, a questionable assumption is typically made that all time-intervals (whether sub-daily, daily, monthly, or annual) scale by the same factor.

A limited amount of daily CMIP5 Regional Climate Model (RCM) output is available for Asia and the Pacific through the RCCAP portal. For example, the CSIRO RCM was used to downscale output from six CMIP5 GCMs (ACCESS1-0, CCSM4, CNRM-CM5, GFDL-CM3, MPI-ESM-LR, and NorESM1-M) to 10 km resolution for Thailand. Some of these scenarios were used to quantify crop water demand and rice yields in the Nam Oon Irrigation Project (Shrestha et al. 2017). Other RCMs, such as the PRECIS system, have been applied in the lower Mekong Basin (e.g., Mainuddin et al. 2013). A limited selection of outputs may be accessed via the Southeast Asia START Regional Center (SEA START RC) Data Distribution System and Analysis Tool (Figure 15).

Figure 15: Changes in Precipitation Projected for the 2070s by the PRECIS System under SRES A2 Emissions, (mm)
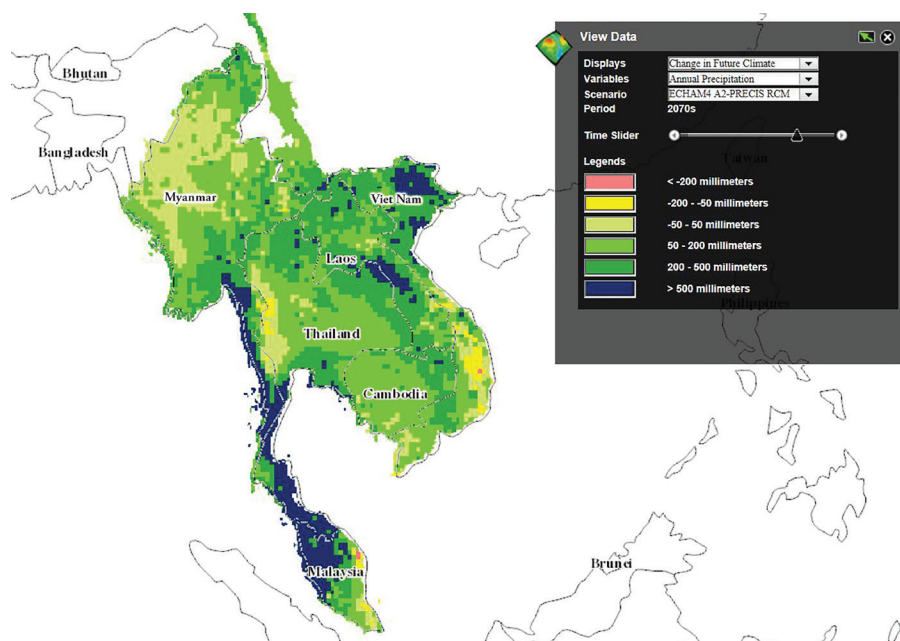
mm = millimeter, PRECIS = Providing Regional Climates for Impacts Studies, SRES = Special Report on Emissions Scenarios.
Source: SEA START RC.

Site-specific and bespoke climate change scenarios can be created by weather generators and statistical downscaling tools (IPCC-TGICA 2004). The latter may be calibrated using daily meteorological data from open sources, such as GSOD combined with reanalysis products from various portals. For example, the Statistical Downscaling Model (SDSM) has been applied in about 500 studies covering at least 25 countries in Asia and the Pacific region. The bibliography of SDSM research provides a starting point for developing high-resolution climate change scenarios for a range of sectors. Although the majority of studies focus on scenario creation for impact assessment, the latest version of the tool was intentionally designed to stress-test adaptation options (Wilby et al. 2014). The tool

can also be used to reconstruct missing meteorological data within the period 1948–2017 (Figure 16).

Figure 16: Reconstructed Wet-Day Frequencies and Annual Precipitation Totals for Changwu, People's Republic of China
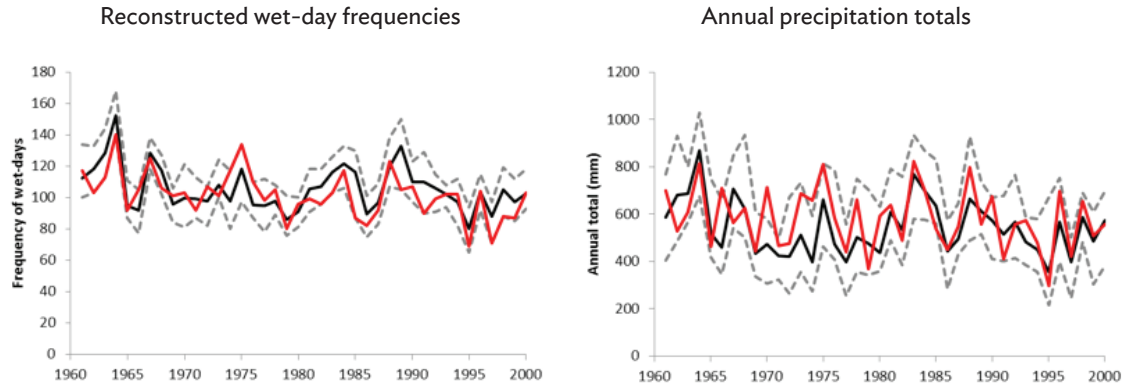
Note:

Black lines are reconstructed, grey dashed lines are model confidence intervals, red lines are observations.

Source: Wilby et al. 2014. The Statistical Downscaling Model–Decision Centric (SDSM–DC): Conceptual Basis and Applications. *Climate Research*, 61. pp. 259–276.

mm = millimeter.

Online weather generators (e.g., MarkClim) may deliver site-specific simulations of daily variables, intended for agricultural and hydrological impact assessments. Both types of downscaled product offer high-resolution scenarios conditional on coarser resolution climate model experiments and choice of emissions scenario. However, when applying such climate change information, care should always be taken to avoid mistaking increased precision for accuracy. Just because a particular tool or data set offers daily (or even sub-daily) climate scenarios at a point does not necessarily mean that the projected changes are credible (Racherla et al. 2012). Ideally, indicators of climate model skill—that are relevant to the intended application—are evaluated as part of the scenario development process (e.g., Ekström et al. 2018; Wilby 2010).

Climate Change Impacts and Adaptation Projects

Appendix 4 lists sources of information on climate change impacts (mainly for the water sector), programs of research and development with an adaptation dimension, as well as several knowledge platforms for exchanging intelligence and insights on adaptation (using case studies, project archives, and technical materials).

Some portals provide global risk assessments based on climate model scenarios and impact models. Archives of preformulated results are typically interrogated via mapping and visualization tools. For example, the Aqueduct Water Risk Atlas plots indicators of future water supply and demand under contrasting emissions scenarios (Figure 17). Likewise, the DARA Climate Vulnerability Monitor (2012) gives national indicators of climate impacts and economic costs for 2030 compared with 2010 (Figure 18). Care must be taken when interpreting such output because much is based on macro impact models applied at coarse scales with unspecified uncertainties. The information may be helpful for rapid appraisal of key climate threats and policy development, but unsuitable for detailed project design.

Figure 17: Projected Changes in Global Water Supply by 2040 Assuming a Business as Usual (RCP8.5) Climate Change Scenario
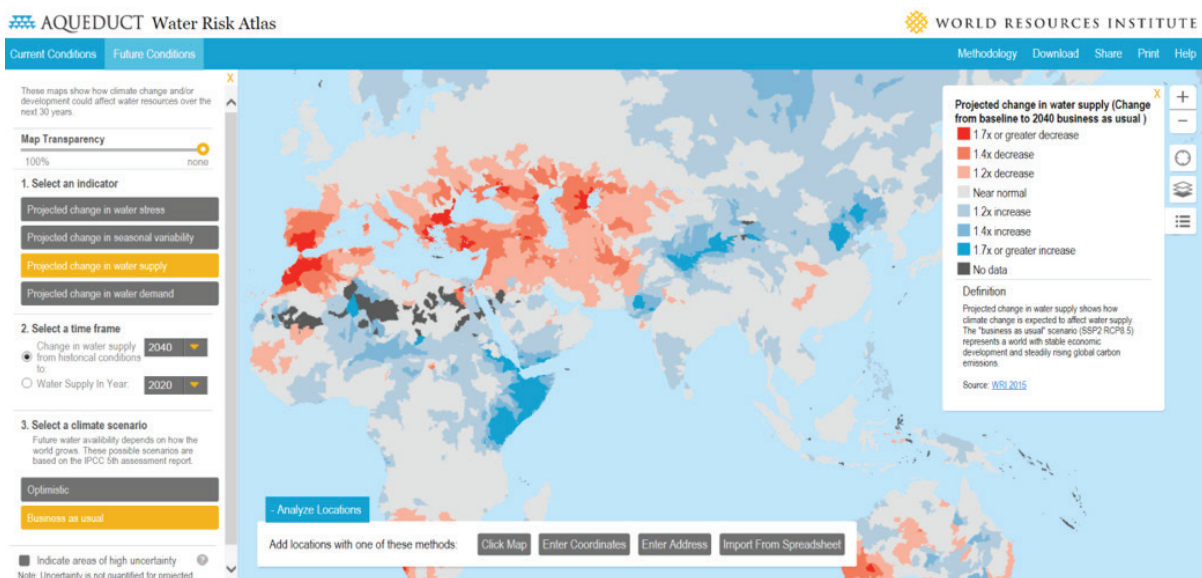
RCP = Representative Concentration Pathways
Source: Aqueduct Water Risk Atlas.

Figure 18: Example Climate Indicator Report: Drought
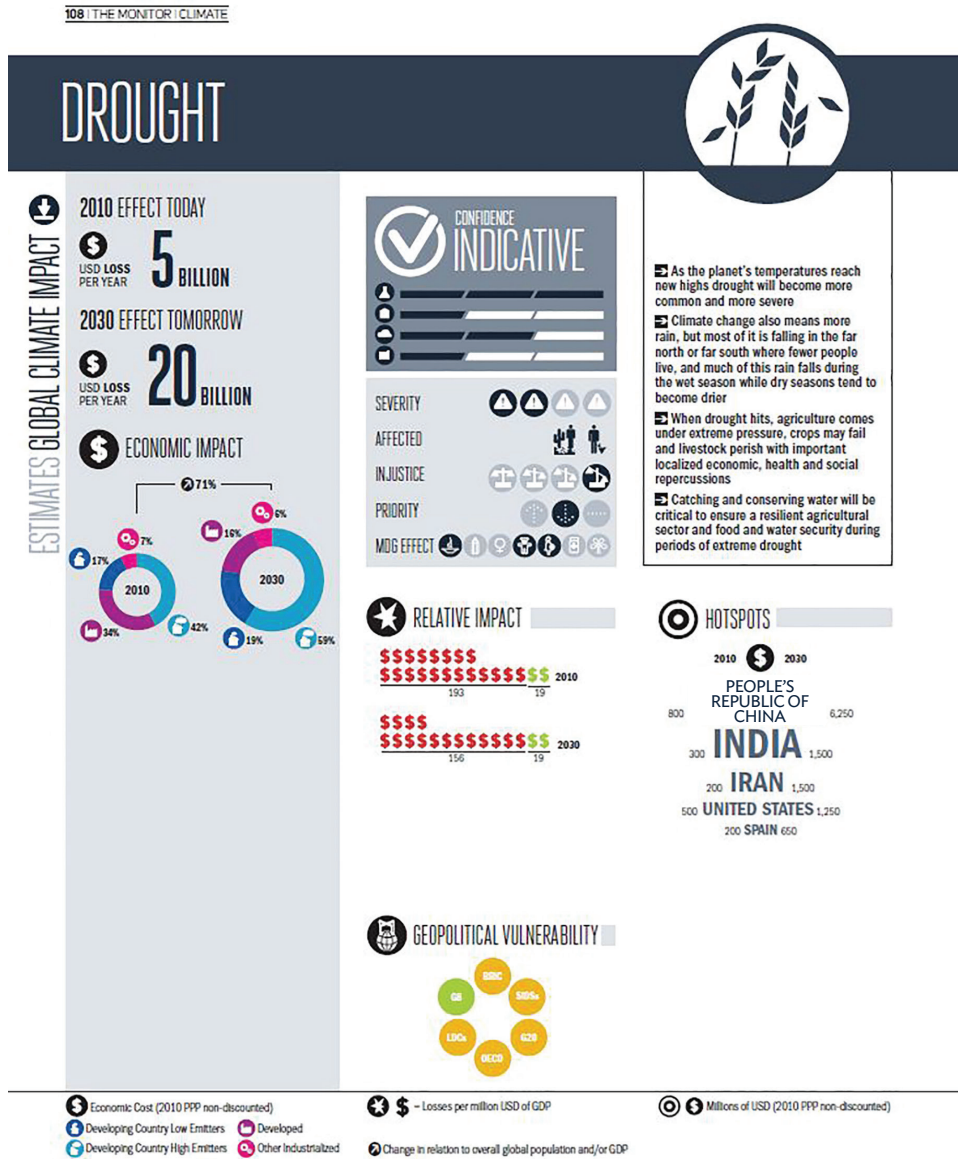
Source: DARA Climate Monitor.

The DARA Climate Vulnerability Monitor and other agencies (e.g., Climate Service Center Germany [GERICS], United States Agency for International Development [USAID], World Health Organization [WHO], World Bank CCKP) offer national "fact sheets," "dashboards," or "country profiles" of sector-specific climate vulnerabilities and impacts. For example, the country profile in Figure 19 shows sector-level vulnerability levels, climate-related economic costs, and mortality, as well as the size of the affected population for Tajikistan in 2010 and 2030. This highlights acute vulnerability of the country to drought, flood, and landslides. Loss of hydro-energy is evidently the most significant economic vulnerability.

Figure 19: Sample Country Profile of Tajikistan

		LEVEL		(MILLION USD PPP)		MORTALITY		POPULATION (1000s)		VALUE 1*		VALUE 2*	
		2010	2030	2010	2030	2010	2030	2010	2030	2010	2030	2010	2030
ENVIRONMENTAL DISASTERS													
DROUGHT				5	20								
FLOODS AND LANDSLIDES				40	300	5	5	30	45				
STORMS				1	15								
WILDFIRES													
TOTAL				46	335	5	5	30	45				
HABITAT CHANGE													
BIODIVERSITY				45	300					-450	-850	80	250
DESERTIFICATION													
HEATING AND COOLING				-5	-15					-95	-90	-1	-1
LABOUR PRODUCTIVITY				5	25					35	26		
PERMAFROST				100	500			150	250				
SEA-LEVEL RISE													
WATER				45	300					1	1		
TOTAL				190	1,110			150	250				
HEALTH IMPACT													
DIARRHEAL INFECTIONS						45	25	0					
HEAT AND COLD ILLNESSES						45	20						
HUNGER													
MALARIA AND VECTOR-BORNE													
MENINGITIS						55	80	0	0				
TOTAL						145	125	0	0				
INDUSTRY STRESS													
AGRICULTURE				15	100								
FISHERIES					1								
FORESTRY					1								
HYDRO ENERGY				-45	-250								
TOURISM													
TRANSPORT													
TOTAL				-30	-148								
CLIMATE TOTAL				206	1,297	150	130	180	295				
ENVIRONMENTAL DISASTERS													
OIL SANDS													
OIL SPILLS													
TOTAL				0	0								
HABITAT CHANGE													
BIODIVERSITY				10	70					20	55		
CORROSION													
WATER													
TOTAL				10	70								
HEALTH IMPACT													
AIR POLLUTION						300	450	4	10				
INDOOR SMOKE						5,500	6,250	250	250				
OCCUPATIONAL HAZARDS						5	5	0	0				
SKIN CANCER						5	10	0	0				
TOTAL						5810	6715	254	260				
INDUSTRY STRESS													
AGRICULTURE				-1	-250								
FISHERIES													
FORESTRY													
TOTAL				-1	-250								
CARBON TOTAL				9	-180	5,810	6,715	254	260				

VULNERABILITY LEVELS:
Acute+ / High+ / Acute- / High- / Severe+ / Moderate / Severe- / Low

+ = Upper tier of vulnerability level
- = Lower tier of vulnerability level

Environmental disasters
Habitat change
Health impact
Industry stress

CLIMATE = Impact/Vulnerability to Climate Change
CARBON = Impact/Vulnerability to Carbon Intensiveness

	OTHER VALUE 1	OTHER VALUE 2
BIODIVERSITY	Contraction of biological zones (km²) (cumulative)	Decline in biological richness
DESERTIFICATION	Additional land degraded (km²) (cumulative)	
HEATING & COOLING	Change in energy load (GWh)	
LABOUR PRODUCTIVITY	Share of workforce particularly affected (%)	
SEA-LEVEL RISE	Net loss of land (km²) (cumulative)	
WATER	Loss in water runoff 2030 (km²)	
OIL SANDS	Tonnes toxic waste (1000s)	
OIL SPILLS	Gallons oil spill (1000s)	
BIODIVERSITY	Decline in biological richness	
WATER	Volume of water to treat (millions m³)	

Source: DARA Climate Vulnerability Monitor.

Fact sheets are intended to raise awareness within government and civil society of the underlying risk factors that increase vulnerability to emergent climate threats. They also enable risk screening and comparative analysis between different countries to inform investment decisions or resource allocation at programmatic levels. Indicative social and economic costs of climate impacts can demonstrate scope for avoided damages through adaptation investments. Some resources like the USAID Fact Sheets provide helpful links to documents on national strategies and plans, as well as tables of donor funded programs related to climate adaptation.

Knowledge platforms with searchable archives can widen access to information about adaptation projects across the Asia and Pacific region. Some specialize in key sectors (e.g., Asian Cities Climate Change Resilience Network) or regions (e.g., Climate Himalaya). However, web-based content can sometimes be dated or have broken links. Nonetheless, libraries enable shared learning from established impact case studies and adaptation projects. Such knowledge can inform the design, monitoring, and evaluation process of the ADB project implementation phase.

Peer-reviewed scientific articles on regional climate change, impacts, and adaptation can also yield useful links to open access data. Increasingly, publishers are requiring that research teams place their data and algorithms in the public domain, with unique identifiers (e.g., Pritchard 2017, Huss and Hock 2018).

Concluding Remarks

This technical note is intended to support CRA experts, particularly those involved in the early stages of project development. Time and resources could be saved by attaching this document to terms of reference issued to CRA consultants. However, there is a limit to which globally accessible, open source data can meet the specific information needs of local adaptation projects. Hence, this note supplements rather than replaces efforts to gather relevant climate information from government agencies and counterparts, especially during the project concept phase.

This technical note compiles about 70 sources of public information for the Asia and Pacific region, including data on historical and future climate, climate-related disasters, indicators of national vulnerability, and preparedness to adapt. Additional sources will no doubt come to light so this is a living document—appendixes should be periodically refreshed as new information is located and quality assessed.

Most of the public data identified are contextual—providing high-level information about present and future climate risks at national and/or sector levels. Additional capacity development may be required in specialist "gatekeeping" skills, such as GIS, data homogeneity testing, post-processing research data formats (e.g., NetCDF), regional climate downscaling, and impact assessment. By growing these technical capabilities, more data could be accessed from the same public platforms or combined in ways that add value to the CRA.

As well as strengthening the technical capacities of local consultants and CRA experts, access to existing research-grade data stores should be improved through closer cooperation with scientific programs. For example, new interfaces could be developed to open research archives (e.g., CORDEX) to a broader user base. In particular, there is an urgent need to widen access to the daily and sub-daily climate information needed for economic analysis, engineering design standards, stress-testing adaptation options, and other aspects of project design.

Parts of the Asia and Pacific region are scarce of both the climate and socioeconomic information required for robust CRA. High elevation and remote environments are particularly problematic for data gathering, yet these locations have some of the most climate vulnerable communities and resources. Remotely-sensed and reanalysis products certainly improve coverage, but the accuracy of these assets ultimately depends on high-quality observing networks. Therefore, ADB, other multilateral development banks, and partner agencies should continue to invest in programs that strengthen national monitoring systems for climate and environmental change. Open access to such long-term records is invaluable for detecting emergent risks and devising, then implementing, effective adaptation measures.

References

Asian Development Bank (ADB). 2011. *Adapting to Climate Change: Strengthening the Climate Resilience of Water Sector Infrastructure in Khulna, Bangladesh*. Manila.

————————. 2012. *Climate Risk and Adaptation in the Electric Power Sector.* Manila.

————————. 2013. *Guidebook: Increasing Climate Change Resilience of Urban Water Infrastructure—Based on a Case Study from Wuhan City, People's Republic of China.* Manila.

————————. 2014a. *Midterm Review of Strategy 2020: Meeting the Challenges of a Transforming Asia and Pacific. Policy Paper.* Manila.

————————. 2014b. *Climate Risk Management in ADB Projects.* Manila.

————————. 2014c. *Climate Change and Rural Communities in the Greater Mekong Subregion: A Framework for Assessing Vulnerability and Adaptation Options.* Manila.

————————. 2014d. *Technologies to Support Climate Change Adaptation.* Manila.

————————. 2015. *Economic Analysis of Climate-Proofing Investment Projects.* Manila.

————————. 2016a. *ADB Climate Change Publications Catalogue 2016.* Manila.

————————. 2016b. *Guidelines for Climate-Proofing Investment in the Water Sector: Water Supply and Sanitation.* Manila.

————————. 2017. A Region at Risk: The Human Dimensions of Climate Change in Asia and the Pacific. Manila.

Ahmed, M. and S. Suphachalasai. 2014. *Assessing the Costs of Climate Change and Adaptation in South Asia*. Manila. ADB.

Aich, V. et al. 2017. Climate Change in Afghanistan Deduced from Reanalysis and Coordinated Regional Climate Downscaling Experiment (CORDEX)—South Asia Simulations. *Climate*. 5. p. 38.

d'Amour, C. B. et al. 2016. Teleconnected Food Supply Shocks. *Environmental Research Letters*. 11, 035007.

DARA and the Climate Vulnerable Forum. 2012. *A Guide to the Cold Calculus of a Hot Planet. Climate Vulnerability Monitor, Second Edition.* Madrid, Spain.

Dixon, S. G. and R. L. Wilby. 2016. Forecasting Reservoir Inflows Using Tropical Rainfall Measuring Mission (TRMM) Precipitation Estimates. *Hydrological Sciences Journal.* 61. pp. 107–122.

Donchyts, G. et al. 2016. Earth's Surface Water Change Over the Past 30 years. *Nature Climate Change.* 6. pp. 810–813.

Ekström, M. et al. 2018. Robustness of Hydroclimate Metrics for Climate Change Impact Research. *WIRES Water.* doi.org/10.1002/wat2.1288.

Haasnoot, M. et al. 2013. Dynamic Adaptive Policy Pathways: A Method for Crafting Robust Decisions for a Deeply Uncertain World. *Global Environmental Change.* 23. pp. 485–498.

Harris, I. et al. 2014. Updated High-Resolution Grids of Monthly Climatic Observations – the CRU TS3.10 Dataset. International Journal of Climatology. 34. pp. 623–642.

Huss, M. and R. Hock. 2018. Global-Scale Hydrological Response to Future Glacier Mass Loss. *Nature Climate Change.* 8. pp. 135–140.

Intergovernmental Panel on Climate Change, Task Group on Data and Scenario Support for Impact and Climate Analysis (IPCC-TGICA). 2004. *Guidelines for Use of Climate Scenarios Developed from Statistical Downscaling Methods.* Prepared by R.L. Wilby et al. on behalf of IPCC-TGICA.

_____. 2007. *General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment.* Version 2. Prepared by T.R. Carter on behalf of IPCC-TGICA.

Karaseva, M. O., S. Prakash, and R. M. Gairola. 2012. Validation of High-Resolution TRMM-3B43 Precipitation Product Using Rain Gauge Measurements over Kyrgyzstan. *Theoretical and Applied Climatology.* 108. pp. 147–157.

Mainuddin, M., M. Kirby, and C.T. Hoanh. 2013. Impact of Climate Change on Rainfed Rice and Options for Adaptation in the Lower Mekong Basin. *Natural Hazards.* 66. pp. 905–938.

Moser, S. C. and M. T. Boykoff. 2013. *Successful Adaptation to Climate Change.* London and New York: Routledge.

Pritchard, H. D. 2017. Asia's Glaciers are a Regionally Important Buffer against Drought. *Nature.* 545. pp. 169–174.

Racherla, P. N., D.T. Schindell, and G.S. Faluvegi. 2012. The Added Value to Global Model Projections of Climate Change by Dynamical Downscaling: A Case Study Over the Continental US Using the GISS-ModelIE2 and WRF models. *Journal of Geophysical Research-Atmospheres.*

Ranger, N., T. Reeder, and J. Lowe. 2013. Addressing 'Deep' Uncertainty Over Long-Term Climate in Major Infrastructure Projects: Four Innovations of the Thames Estuary 2100 Project. *EURO Journal on Decision Processes.* 1. pp. 233–262.

Shrestha, S., R. Chapagain, and M. S. Babel. 2017. Quantifying the Impact of Climate Change on Crop Yield and Water Footprint of Rice in the Nam Oon Irrigation Project, Thailand. *Science of the Total Environment.* 599. pp. 689–699.

Sun, Q. et al. 2018. A Review of Global Precipitation Data Sets: Data Sources, Estimation, and Intercomparisons. *Reviews of Geophysics.* 56. pp. 79–107.

Vaughan, C. and S. Dessai. 2014. Climate Services for Society: Origins, Institutional Arrangements, and Design Elements for an Evaluation Framework. *WIREs Climate Change.* 5. pp. 587–603.

Washington, R. et al. 2006. African Climate Change: Taking the Shorter Route. *Bulletin of the American Meteorological Society.* 87. pp. 1,355–1,366.

Weaver, C. P. et al. 2013. Improving the Contribution of Climate Model Information to Decision Making: the Value and Demands of Robust Decision Frameworks. *WIREs Climate Change.* 4. pp. 39–60.

Wilby, R. L.. 2010. Evaluating Climate Model Outputs for Hydrological Applications – Opinion. *Hydrological Sciences Journal.* 55. pp. 1,090–1,093.

Wilby, R. L. et al. 2009. A Review of Climate Risk Information for Adaptation and Development Planning. *International Journal of Climatology.* 29. pp. 1,193–1,215.

Wilby, R. L. et al. 2014. The Statistical Downscaling Model–Decision Centric (SDSM–DC): Conceptual Basis and Applications. *Climate Research.* 61. pp. 259–276.

Wilby, R. L. et al. 2017. The "Dirty Dozen" of Freshwater Science: Detecting then Reconciling Hydrological Data Biases and Errors. *WIREs Water.* 4. p. 1,209.

Yong, B. 2012. Assessment of Evolving TRMM-Based Multisatellite Real-Time Precipitation Estimation Methods and their Impacts on Hydrologic Prediction in a High Latitude Basin. *Journal of Geophysical Research.* 117. pp. 1–21.

Appendixes

Appendix 1: Sources of Information on Historic Greenhouse Gas Emissions, Climate Vulnerability, Risks, and Impacts

Description	Advantages	Disadvantages	Source
Surface water changes	Global-scale analysis at 30 m resolution of water-to-land and land-to-water conversions in 1985-2016 based on satellite imagery from multiple Landsat missions; reveals documented and undocumented conversions due to natural variability, human interventions and climate change	Only shows compound effects of natural variability, human interventions and climate change so more local information is needed to attribute changes; processed data behind the maps are not openly available	Aqua Monitor
Emission-reduction projects in developing countries	Archive of CDM projects searchable by sector scope, scale of emission reductions, host country	Marginal relevance of CDM project design and monitoring documentation to the specific information needs of CRA	Clean Development Mechanism
Greenhouse gas (GHG) emissions, nationally determined contributions (NDCs), emissions pathways	Platform to visualize and compare national emissions, climate commitments, and performance; national summaries of climate vulnerability and readiness, climate risk index (Germanwatch), and associations between NDCs and Sustainable Development Goals (SDGs)	Some features are still under development (e.g., sector-level analysis, emission pathways); data begin in 1990	ClimateWatch
Large flood events	Global near real-time archive of large flood events based on news, government, surface, and satellite sources; available as online table or downloaded as a spreadsheet file; each entry includes country or area affected, main causes, number of fatalities and/or displaced, and severity score	No data prior to 1985; unclear what criteria are applied for inclusion or rating of flood severity	Dartmouth Flood Observatory

Appendix 1   *continued*

Description	Advantages	Disadvantages	Source
Disaster loss data for 89 countries	Covers all disaster types (including non-climatic) occurring in the period 1970–2013; raw data are accessible in a spreadsheet file; searchable archives	Incomplete coverage of the Asia and Pacific region	DesInventar Sedai
International disaster database for vulnerability assessment and priority setting	Core data on the occurrence and impacts of more than 22,000 mass disasters since 1900; archive searchable by period, country, disaster type, and impact; climate-related disasters include wildfire, drought, mass movement, landslide, flood, fog, extreme temperature, storm; output as reference maps, CSV files, time series plots	Registration required; country-level and continental-scale data base; priority given to United Nations and government data, but quality of entries reflects sources	Emergency Events Database (EM-DAT)
Fires and thermal anomalies	Thermal anomalies (day and night) at 1-kilometer (km) resolution, approximately twice daily; global coverage	Data format HDF; registration required; data begin in 2012; image time and location depends on path of satellite orbit; other sources of thermal anomalies include volcanic eruptions and gas flares	EOSDIS Worldview
Atmospheric aerosols	Aerosol optical depths at 2 km resolution, approximately daily; global coverage	Data format HDF; registration required; data begin in 2000; image time and location depends on path of satellite orbit; algorithm is not applied over sun glint ocean or bright desert; sources of aerosols include industrial emissions, fire smoke, dust storms, sea salt, volcanic ash, and smog	EOSDIS Worldview
Storm surface runoff and groundwater– baseflow	Gridded products based on satellite observations and land surface modeling; available at 0.25° (2000 onward) and 1° (1948 onward) resolution, 3-hourly or monthly	Requires offline routing algorithm to aggregate and pass river flow between neighboring cells; large uncertainty in precipitation inputs to model	Global Land Data Assimilation System (GLDAS)

Appendix 1   *continued*

Description	Advantages	Disadvantages	Source
Global data on risk from natural hazards, including floods, droughts, storm surges, fires, and landslides	Based on spatial hazard data from the Global Assessment Report on Disaster Risk Reduction versions 2009, 2011, and 2013; zoom, pan, and layering capabilities to create bespoke maps; various backgrounds to highlight vulnerability, such as population distribution, gross domestic product (GDP) per capita, elevation, land cover; online visualization, data and map downloads; various data formats, including shape files and text	Contextual layers have missing features (such as some major rivers); pixelated output depends on the grid-resolution of the data used for hazard modeling	Global Risk Data Platform
Global data on drinking water, sanitation, and hygiene (WASH)	Annual country-level indicators showing status and trends toward SDGs on WASH; standard classification and estimation methods applied across countries; downloadable country files with graphics and raw data; searchable by rural or urban, socioeconomic and service level	National statistics may conceal regional variations in WASH; data cover 2000–2015	Joint Monitoring Programme (JMP)
National indexes of climate vulnerability and readiness to adapt	45 indicators of climate change related vulnerability and readiness for 192 UN countries since 1995; vulnerability scores for water, agriculture, health, infrastructure, food and ecosystems; component scores for climate exposure, sensitivity and adaptive capacity; readiness scores based on economic, governance and social indicators; GDP adjusted scores for ND-GAIN index	Some interpolation used to fill in missing values; national indicators may conceal marked regional variations; international climate threats to local economies are not considered	Notre Dame Global Adaptation Initiative (ND-GAIN) Country Index
Glacier outlines	A global inventory of glacier outlines (ice covered areas) at the beginning of the 21st century; includes topographic and hypsometric attributes for most glaciers; data available as ESRI shapefile or KML	A "snapshot" of outlines not intended for measurement of glacier-specific rates of area change; substantial range of survey dates as priority was completeness of coverage	Randolph Glacier Inventory (RGI)

Appendix 1   *continued*

Description	Advantages	Disadvantages	Source
Inventories of river and urban flooding, earthquake, landslide, wildfire, water scarcity, extreme heat, coastal flood, cyclone, tsunami, volcano	General view of hazards, for a given location, intended for project design and implementation to promote disaster and climate resilience; national summary sheets with links to supporting materials on each hazard type	Some rated hazards are nonsensical (e.g., very low risk of coastal flood in Tajikistan and Manila); qualitative assessment of how each hazard could change in the future due to climate change	ThinkHazard
National disaster risk profiles and loss estimates	Country statistics alongside nationally and internationally reported losses (mortality, economic); probable maximum loss estimates by hazard for return periods of 20 to 1,500 years; overall national INFORM risk index (based on hazard, vulnerability and coping capacity); draws on EM-DAT, UNISDR, and DesInventar	Contains some spurious information (e.g., three volcanoes identified for the United Kingdom, whereas probable maximum losses from wind and storm surge are allegedly zero); methods of risk estimation could be more transparent	UNISDR PreventionWeb
GHG and socioeconomic data (various)	Portal providing links to 20 external sources of primary data covering emissions, development indicators, energy production and prices, sector and environmental indicators	National statistics may conceal regional variations	United Nations Climate Change portal
Human Development Indicators (HDIs)	Archive searchable by dimension (health, education, income, inequality, gender, poverty, work, human security, trade and finance, mobility and communication, environmental sustainability, and demography), indicator, year and country; visualize data as bar charts, trends and maps; download as spreadsheet files	Data cover period 1990–2015; national statistics may conceal significant regional variations	United Nations Development Programme (UNDP)

Appendix 1   *continued*

Description	Advantages	Disadvantages	Source
Global international trade, national accounts, energy, industry, environment, demographic, and social statistics	Includes annual country and regional indicators of SDGs, monthly bulletin of statistics online (from 2000 onward), gender and disability statistics	National statistics may conceal regional variations; some data begin in 1990s, most in 2000; incomplete data for some indicators and countries	United Nations Statistics Division (UNSD)
National sector-level indicators of climate impacts and vulnerabilities since 2000	38 climate impact indicators for agricultural, natural hazards, water and coastal zone; range of socioeconomic and demographic vulnerability metrics	Country- and sector-level statistics may conceal regional variations; future downscaled scenarios are only available for SRES emissions in NetCDF format	World Bank Climate Change Knowledge Portal
Glacier locations and properties	Basic information about 130,000 glaciers, including location, area, length, orientation, elevation, and classification; data available in TXT and CSV format	Snapshot of glacier distribution in the second half of the 20th century mainly based on aerial photographs	World Glacier Inventory
Glacier fluctuations and events	Standardized observations of changes in glacier mass, volume, snout position, area, and length; statistical information on the distribution of perennial surface ice in space (World Glacier Inventory); data on events, such as surges, calving, rock falls, lake outbursts, ice avalanches, eruptions of glacier-covered volcanoes; global glacier change bulletin now published every 2 years, 5-yearly reports since 1959	Some records are short or broken; some regions are underrepresented or require integration of onsite measurements with remote sensing and modeling	World Glacier Monitoring Service Fluctuations of Glaciers (FOG) database

CDM = Clean Development Mechanism, CRA = Climate Risk Analysis, CSV = comma separated values, HDF = Hierarchal Data Format, EOSDIS = Earth Observing System Data and Information System, ESRI = Environmental Systems Research Institute, INFORM = Index For Risk Management, KML = Keyhole Markup Language, m = meter, NetCDF = Network Common Data Form, SRES = Special Report on Emissions Scenarios, UN = United Nations, UNISDR = United Nations International Strategy for Disaster Reduction.

Sources: ADB and other sources in the rightmost column.

Appendix 2: Sources of Information on Historic Weather, Climate Variability, and Change (by timescale)

Description	Advantages	Disadvantages	Source
Sub-daily, daily, monthly, and annual precipitation estimates	Various remotely-sensed precipitation products with spatial resolutions of 0.04° (2003–present) and 0.25° (1983–2017) for the domain 60°S to 60°N; online data visualization tool and FTP download	Daily version may not record some intense, short-lived events; based on complex algorithms to convert infrared measurements into precipitation rates; not quite global coverage; partly dependent on other precipitation products, such as GPCP	Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)
Sub-daily, daily, monthly, and annual precipitation and temperature data	Searchable repository for the Asia-Pacific region providing links to resources (e.g., APHRODITE, SACA&D, PERSIANN); data accessible for points and areas; easily downloaded	Registration required to access data; some data held as NetCDF or BIN format; some links pass to other portals (e.g., reanalysis, TRMM, CRU); filters sort by the number of data sets (not alphabetically)	Regional Climate Consortium for Asia and the Pacific (RCCAP)
Sub-daily, daily and monthly precipitation for the tropics	Searchable archive by domain, date range, spatial, and temporal resolution; output as maps, time series, and other formats	Finest grid resolution is 0.25°; earliest data from 1998 onward; registration required to download some output	Tropical Rainfall Monitoring Mission (TRMM)
Sub-daily and daily weather variables in point and grid format	User interface with searchable map providing access to forecast, model, radar, reanalysis, and station weather variables	Registration required to access data; easier to search by country and date range to identify available open and commercial data sets first (rather specify variable[s] of interest)	Planet OS
Sub-daily, daily, weekly, and monthly summaries of standard weather variables	Searchable archive by city, state, zip code, or airport; coverage tends to be post-2000; variables include maximum, minimum, and mean daily air temperature, dew point temperature, relative humidity, air pressure, visibility and wind speed, precipitation, cloud cover, and wind direction; data up to date	Bias toward WMO-reporting stations; time-consuming to build a complete multivariate series from screen output; data interspersed with advertising	Weather Underground

Appendix 2 *continued*

Description	Advantages	Disadvantages	Source
Daily precipitation for Asia	High density and quality rain gauge network covering the period 1950–2011	Station network changes with time and season; no homogenization of data so potentially susceptible to discontinuities; limited coverage for India, Indonesia, and Papua New Guinea; record discontinued and data download links broken (RCCAP)	Asian Precipitation – Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE)
Daily, monthly, and seasonal reanalysis products (including precipitation rate, air temperature, zonal wind, sea level pressure)	Versatile tools to extract raw data, monthly or seasonal series and maps from global reanalysis fields; nearly 30 products available; downloadable as TXT, CSV, or NetCDF	NCEP/NCAR reanalysis and derived variables (i.e., these are quasi-data, not actual observations); earliest output is from 1979 onward	Earth System Research Laboratory (ESRL)
Daily data for standard meteorological variables	Global archive searchable by country, station, date; data downloadable as TXT file	Incomplete records and quality issues must be resolved on a site by site basis; missing dates are not shown, so post-processing of files is required to fill blocks with these missing values; all units are US imperial	Global Summary of the Day (GSOD)
Daily and monthly weather variables (including maximum and minimum temperature, total precipitation, snowfall, and snow depth) for land surface stations	Searchable archive of 100,000 stations in 180 countries; data subjected to a standard set of quality checks; observations can be selected by data set, date range, station name, and/or user defined search terms; supplied in various formats, including CSV	The total number of stations and spatial coverage varies with time; missing dates are not shown, so post-processing of files is required to fill blocks with these missing values	Global Historical Climate Network (GHCN)

Appendix 2   *continued*

Description	Advantages	Disadvantages	Source
Daily and monthly teleconnection indexes	Various indexes describing historic and current teleconnections, including ENSO, AAO, AO, NAO, and PNA; diagnostic and attribution tools to interrogate El Niño indexes; forecasts and bulletins for each index in real time	Bias toward Northern Hemisphere teleconnection patterns; some maps will not display in Internet Explorer10 (use Chrome instead); earliest data available for some indexes is from 1979 onward	NOAA Climate Prediction Center
Daily atmospheric predictor variables (for downscaling)	Archive holds more than 30 predictor variables describing atmospheric stability, airflow strength, pressure, vorticity, wind direction, humidity, temperature, and precipitation; interface locates nearest NCEP reanalysis data based on latitude and longitude; available as TXT format	Coarse grid resolution 2.5,° only available from 1948 onward; most predictors are normalized (i.e., z-values); records end in 2017; vorticity and airflow indexes cannot be derived for equatorial regions	SDSM portal
Weekly and monthly water and environmental data for Central Asia	Various data sets for accounting land and water resources in the Aral Sea basin	Earliest data begin in 1980; registration required for some data sets	CAWater-Info
Monthly mean temperature and precipitation	Interactive Google Earth interface to locate monthly or annual mean precipitation and temperature series for the period 1901–2016; graphical and TXT output of gridded data at 0.5° resolution	Based on gridded (i.e., area-average) rather station (i.e., point) meteorological information interpolated from nearest stations; larger uncertainty in estimated values for data-sparse regions	CRU TS Version 4.01 Google Earth Interface
Monthly Palmer Drought Severity Index for global land areas	Gridded Palmer Drought Severity Index from 1850 to 2012 at 2.5° resolution for the domain 58.75°S to 76.25°N	Data are provided for all global land areas by month (in NetCDF and TXT); sub-sets of the data have to be extracted from global fields offline	Earth System Research Laboratory (ESRL)
Monthly rainfall, temperature, and potential evapotranspiration (PET)	Map interface for interrogating monthly or annual climate series since 1901; options include climate anomaly and trend analysis for points and areas; enables comparison of annual temperatures at two points	Site under development; charting option only gives temperature series; trends are for three fixed periods; PET data are not available beyond 2012	Global Climate Monitor

Appendix 2   *continued*

Description	Advantages	Disadvantages	Source
Monthly ocean, ice, and hydrology equivalent water height	Global water storage anomalies relative to time-mean of monthly mass, applicable to ocean, ice and hydrology; expressed as equivalent water thickness (centimeter); 0.25° grid resolution	Data begin in 2002; individual ASCII files must be downloaded for each month (but also available as NetCDF)	Gravity Recovery and Climate Experiment
Monthly precipitation, temperature, and air pressure	Global archive searchable by domain, country or point for specified seasons from various sources (e.g., CRU, GIS, GPCC, Hadley Centre, NCDC, UCAR); raw data available in TXT format; versatile and downloadable maps and time series	Finest temporal resolution is monthly	KNMI Climate Explorer
Monthly wind and sea surface temperature (SST) indexes	Standard teleconnection and pressure indexes available from the 1880s onward; weekly and monthly SST series available from the 1980s and 1950s, respectively, upper atmosphere temperature and radiation fields from the 1980s; graphical and TXT data formats	Earliest wind indexes available from 1979	NOAA Climate Prediction Center
Monthly and annual sea levels	Stations sortable by name, ID, latitude and longitude, and country code; detailed station meta information on known quality issues (e.g., sedimentation, subsidence); shows nearest neighbor stations; graphical and TXT formats	Station data are presented as a single table not easily searched; some records end as early as 1980	Permanent Service for Mean Sea Level
Mean monthly climate and bioclimatic data	Global layers at 1 square kilometer (km^2) to 340 km^2 resolution for the period 1970–2000; downloaded as a "zip" file containing GeoTiff (.tif) files	Fixed period, mean monthly values	WorldClim Version2

Appendix 2   *continued*

Description	Advantages	Disadvantages	Source
Seasonal teleconnection patterns	Tool for analyzing seasonal mean correlation fields for NCEP reanalysis variables versus specified teleconnection and ocean indexes; enables exploration of coincident and lagged relationships; possible to import user-created time series; versatile plotting options	Earliest records begin in 1948	Earth System Research Laboratory (ESRL)
Various time scales of remotely sensed Earth observations for aerosols, atmospheric chemistry, atmospheric dynamics, cryosphere, hydrosphere, ocean biology, oceanography, water and energy cycles	Global archive searchable by domain, date range, scientific discipline, instrument, spatial and temporal resolution, wavelengths, depths; nearly 2000 data sets available; output as maps, time series, and other formats	Remote processing times for data can be long depending on domain, sampling interval and output type; earliest output available from 1948	Giovanni
Various timescales for map collections of present and recent past climate and societal impacts	Maps covering wide range of climate variables, indicators of food security, agriculture, teleconnection indexes, human health, fire risk, water management; data can be downloaded for user-specified domains, time periods, and formats; interactive maps to plot time series of indexes at selected locations	Not all raw data can be downloaded; large volume and variety of resources can be difficult to navigate	IRI Climate and Society Map Room
Various timescales for snow and ice cover, glacier, permafrost, sea ice and soil moisture	Global archive searchable by domain, date range, parameter, sensor, spatial and temporal resolution, data format, scientific program; more than 400 data sets available; output as maps, time series, and other formats	Only seven data sets pertain to Asia: two precipitation, three DEMs, one short permafrost record for Central Asia and Mongolia, one snow survey for Central Asia	National Snow and Ice Data Center

Appendix 2   *continued*

Description	Advantages	Disadvantages	Source
Global weather and climate extremes archive	Record weather extremes with dates and locations for global, hemispheric, and WMO regions; background notes and supporting information (e.g., on instrumentation issues)	Records are not searchable by country	World Meteorological Organization (WMO)

AAO = Antarctic oscillation, AO = Arctic Oscillation, ASCII = Annual climate indices, BIN = non-text binary file format, CAWater = Portal of Knowledge for Water and Environmental Issues in Central Asia, CRU = Climatic Research Unit, CSV = comma separated values, DEM = Digital Elevation Model, ENSO = El Niño Southern Oscillation, FTP = File Transfer Protocol, GIS = geographic information system, GPCC = Global Precipitation Climatology Centre, GPCP = Global Precipitation Climatology Project, IRI = International Research Institute for Climate and Society, KNMI = Royal Netherlands Meteorological Institute, NAO = North Atlantic oscillation, NCDC = National Climatic Data Center, NCEP = National Centers for Environmental Prediction, NetCDF = Network Common Data Form , NOAA = National Oceanic and Atmospheric Administration, PNA = Pacific/North American teleconnection pattern, SACA&D = Southeast Asian Climate Assessment & Dataset, SDSM = Statistical DownScaling Model, TRMM = Tropical Rainfall Measuring Mission, TXT = text file, UCAR = University Corporation for Atmospheric Research, WMO = World Meteorological Organization.

Sources: ADB and other sources in the rightmost column.

Appendix 3: Sources of Information on Multidecadal Climate Change Projections (by timescale)

Description	Advantages	Disadvantages	Source
Hourly to seasonal regional climate model output (14 domains)	Historical runs available for South Asia (SAS); East Asia (EAS); Central Asia; Southeast Asia (SEA); and Australasia (AUS); large number of meteorological variables at multiple atmospheric levels; hourly to seasonal output	Registration required to access data; NetCDF format; limited number of RCP runs to 2050s only for AUS, EAS, and SEA	Coordinated Regional Climate Downscaling Experiment (CORDEX)
Daily bioclimatic, precipitation, solar radiation, and temperature variables	Bias-corrected and spatially downscaled data derived from CMIP3 and CMIP5 output, available at spatial resolutions of 30 seconds to 20 minutes; intended for agricultural applications, but may have wider utility	Data download in ASCII format, but for large regions and monthly time-slices; unsuitable for transient climate change analysis	Climate Change, Agriculture and Food Security (CCAFS)
Daily weather generator of precipitation, solar radiation, maximum and minimum temperature	Site specific synthetic data obtained by entering location name or coordinates; simulations are conditioned by CMIP5 model(s) and RCPs for target years in the period 2010–2095; variables are intended for agricultural applications, but may have wider utility; outputs provided as text file, histogram, or polar charts	The model outputs data for 1 year per simulation and Global Climate Model (GCM) ensemble, so analysis of transient changes would be time-consuming; the weather-typing algorithm and attendant regression equations are assumed to be valid for hitherto unseen climate states	MarkSim Weather Generator
Daily bias corrected precipitation, maximum and minimum temperature	High-resolution (~25 km) global historic and climate change scenarios for 21 GCMs, RCP4.5 and RCP8.5 for the period 1950–2100	NetCDF format; files accessed from THREDDS catalog via URL	NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP)
Daily meteorological variables (rainfall, temperature, humidity, solar radiation, wind)	Searchable repository for the Asia-Pacific region providing links to Regional Climate Model output for historical, RCP4.5 and RCP8.5 (e.g., CCAM, CORDEX); data accessible for points, areas and individual Regional Climate Models (RCMs); easily downloaded; supporting guidance on climate model information	Registration required to access data; some data only as NetCDF format; CMIP5 GCM output only available for the Philippines and Thailand; filters sort by number of data sets (not alphabet)	Regional Climate Consortium for Asia and the Pacific (RCCAP)

continued on next page

Appendix 3   *continued*

Description	Advantages	Disadvantages	Source
Daily weather as well as exotic variables (such as storm surge, air quality and heat island indexes)	Globally applicable statistical downscaling model that can reconstruct and synthesize site specific weather series and exotic variables based on reanalysis predictors covering the period 1948–present; useful for infilling missing data or generating synthetic scenarios for stress-testing impact models and adaptation options	Future downscaled scenarios are not explicitly tied to any given GCM; depends on sufficient daily data (for the required variable[s]) for model calibration; multisite and multivariate applications can be time-consuming to undertake; some training or expertise in downscaling is recommended prior to calibrating the model and applying outputs	Statistical DownScaling Model – Decision Centric (SDSM-DC)
Monthly global climate model output (various)	Historic and CMIP experiments; produces maps and time series; searchable by domain, country, point; output for standard climate variables; raw data available in TXT format	Finest temporal resolution is monthly	KNMI Climate Explorer
Decadal precipitation, maximum and minimum temperature	Decadal mean projections and changes in precipitation, maximum and minimum temperature for Southeast Asia from 2010s to 2090s	Outputs are only for one GCM (ECHAM4) and one RCM (PRECIS) under two SRES emissions scenarios (A2 and B2)	SEA START RC Data Distribution System
Global climate model output (CMIP3 and CMIP5)	Snap-shots of the Coupled Model Intercomparison Projects that underpinned IPCC AR5; archive of 952 simulations provided by 58 models from 24 institutes	NetCDF format; data intended for use by the research community	IPCC Data Distribution Centre

Appendix 3   *continued*

Description	Advantages	Disadvantages	Source
Global climate model projections (CMIP5)	An atlas of global and regional climate projections from the IPCC Fifth Assessment Report; a point of reference for projected seasonal and annual precipitation and temperature changes relative to 1986–2005; maps show the 25th, 50th, and 75th percentiles of the ensemble for 2016–2035, 2046–2065, and 2081–2100; maps cover SREX regions as well as the Caribbean, Indian Ocean, and Pacific island states and land and sea areas of the two polar areas; hatching denotes areas with weak signals relative to model variability	Seasonal and annual climate changes are based on the unweighted ensemble, averaged across large regions (i.e., regional climate change signals may be obscured); note that the underlying climate model output can be accessed by the KNMI Climate Explorer (see above)	IPCC AR5 Annex 1
Global climate model change factors (CMIP3, CMIP5) and downscaled scenarios (CMIP3)	CMIP3 (SRES A2, B1) and CMIP5 (RCP 2.6, 4.5, 6, 8.5) projections for standard and sector specific climate indicators (e.g., days with heavy rain, hot and cold days, days below freezing) for 2020–2039, 2040–2059, 2060–2079, and 2080–2099; change factors available as spreadsheet files; downscaled global daily scenarios for some CMIP3 models and climate indexes	Country-level, change factors based on 20-year blocks (i.e., not time-series output); downscaled data only for SRES and subset of CMIP3 models in NetCDF format	World Bank Climate Change Knowledge Portal

ASCII = Annual climate indices , CMIP = Coupled Model Intercomparison Project, ECHAM4 = An atmospheric general circulation model developed at the Max Planck Institute for Meteorology, IPCC AR5 = Intergovernmental Panel on Climate Change Fifth Assessment Report, km = kilometer, KNMI = Royal Netherlands Meteorological Institute, NetCDF = Network Common Data Form, PRECIS = Providing Regional Climates for Impacts Studies, RCP = Representative Concentration Pathway, SRES = Special Report on Emissions Scenarios , SREX = Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, THREDDS = Thematic Real-time Environmental Distributed Data Service, TXT = text file, URL = Uniform Resource Locator.

Sources: ADB and other sources in the rightmost column.

Appendix 4: Sources of Information on Future Climate Change Impacts and Adaptation Projects

Description	Advantages	Disadvantages	Source
Flood risk under current and future climate	Assesses flood risks by country, river basin scale, state or city (120) by population, GDP or urban damage; evaluates risks for 2010 and 2030 under three scenarios (RCP 4.5 with SSP2, RCP8.5 with SSP2 and RCP 8.5 with SSP3)	Only simulates large-scale river flooding (does not include coastal, pluvial or flash flooding); hazard maps show situations with no flood protection); assumes a globally applicable flood depth-damage relationships; projections are based on five unspecified climate models	Aqueduct Global Flood Analyzer
Maps of water-related risk	Global to local coverage for current and future (next 30 years) climate conditions under three emissions scenarios; indicators cover water stress, seasonal variability, water supply and demand	Download via ESRI Geodatabase files; decadal and annual means conceal sub-annual variations in risk and opportunities	Aqueduct Water Risk Atlas
Regional network connecting professionals and communities to build urban climate resilience	Searchable archives of news stories, case studies, technical reports, policy briefs, media	Some search fields are not populated	Asian Cities Climate Change Resilience Network
Knowledge platform for enhancing institutional capacity and implementing adaptation	Searchable archive by theme, country, project status	Some content quite dated or project details missing	Asia-Pacific Adaptation Network
E-library of sector- and country-level impact case studies	Searchable archive by theme, country, program, framework, key terms, technical reports	No access to underpinning data	Asia-Pacific Network for Global Change Research

continued on next page

Appendix 4   *continued*

Description	Advantages	Disadvantages	Source
Knowledge platform for information and networking on climate impacts on the Himalayan Mountains	Searchable archive of news stories, case studies and opinions covering 2010–2015	Content now dated	Climate Himalaya
National indicators of climate impacts and vulnerability	National vulnerability levels shown for 2010 and 2030 with indicative economic costs; results in tabular and map format	Weblinks to national summaries broken; national means conceal regional variations and sub-annual differences in risk and opportunities	DARA Climate Vulnerability Monitor
Knowledge platform for sharing information and networking on climate change in Nepal	Searchable archives of maps, data bases, journal articles	Some content quite dated or irrelevant	Nepal Climate Change and Development Portal
Global explorer on climate change adaptation projects	Searchable by country, hazard type, thematic area, level of intervention; detailed project-level information	Some content now dated	United Nations Development Programme
Regional and country-specific climate risk profiles	High-level summaries of expected sector impacts for agriculture, water energy, coastal ecosystems, infrastructure and human health; useful links to supporting information on institutional context, national strategies, key reports, and donor programs; annexes contain forms of language for sector contracts	Historical and future climate summaries are very high-level, rather qualitative and unattributed; some Asian countries are not covered	United States Agency for International Development (USAID) Fact Sheets

Appendix 4   *continued*

Description	Advantages	Disadvantages	Source
Portal for accessing agriculture, water, energy, and health sector climate indexes	38 climate variables accessed by the Climate for Sectors Dashboard; available in graphical and Excel formats, by Global Climate Model (GCM) and emissions scenario, for CMIP3 and CMIP5; some future downscaled scenarios	Most output provided as national, multidecadal mean changes for specified time periods (2020–2039, 2040–2059, 2060–2079, 2080–2099); downscaled output only available for SRES emissions; some links broken	World Bank Climate Change Knowledge Portal
Country-specific evaluations of present and future climate impacts on human health	First round (2015) profiles cover 40 countries, second set (2019) will expand to ~80 countries; each shows burden of climate change on human health, with opportunities for health co-benefits from climate mitigation actions, and analysis of policy responses at national level	National statistics conceal significant variations in group exposure, sensitivity, and ability to adapt to climate hazards; some of the global opportunities for health co-benefits from mitigation policies may not be priorities at national scales	World Health Organization Climate and Health Country Profiles

ESRI = Environmental Systems Research Institute, GDP = gross domestic product , RCP = Representative Concentration Pathway, SRES = Special Report on Emissions Scenarios , SSP = Shared Socioeconomic Pathway.

Sources: ADB and other sources in the rightmost column.

Information Sources to Support ADB Climate Risk Assessments and Management
Technical Note

The Asia and Pacific region is vulnerable to extreme temperatures, flooding by heavy rainfall, sea level rise, coastal erosion, and damage by tropical cyclones. This technical note provides information that supports climate risk assessment experts undertaking early stages of project development in the region. The information is grouped into four major categories: inventories of national emissions, climate risks, vulnerability, and impacts; historic weather, climate, and environmental change; regional climate change projections; and climate change impacts and adaptation. The note also identifies opportunities for capacity development in key skills such as geospatial analysis, data testing and post-processing, regional climate downscaling, and impact assessment.

About the Asian Development Bank

ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 67 members—48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.