24 Asia Supplementary Material

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Table SM24-1 | Summary of key observed past and present annual mean temperature trends in Asian countries/territories.

Sub-region	Country/territory	Unit	Change	Period	Reference
Central Asia	Kazakhstan	°C decade^{-1}	+0.31	1936–2005	Kryukova et al. (2009)
	Kyrgyzstan	°C	+1.6	1901–2000	Iliasov et al. (2003)
	Tajikistan	°C decade^{-1}	+0.1 to +0.2	1940–2005	Karimov et al. (2008)
East Asia	Hong Kong	°C decade^{-1}	+0.12	1885–2008	Ginn et al. (2009)
			+0.16	1947–2008	
			+0.27	1979–2008	
	Japan	°C century^{-1}	+1.15	1898–2010	JMA (2011)
	China	°C decade^{-1}	0.09 ± 0.017	1900–2006	Li et al. (2010)
			0.26 ± 0.032	1954–2006	
			0.45 ± 0.13	1979–2006	
		°C decade^{-1}	+0.03 to +0.120	1906–2005	Ren et al. (2012)
			+0.03 to +0.120	1908–2007	
	South Korea	°C	+1.87	1908–2008	Kim et al. (2010)
			+1.37	1954–2008	
			+1.44	1969–2008	
	Taiwan	°C decade^{-1}	+0.14	1911–2009	Hsu et al. (2011)
			+0.19	1959–2009	
			+0.29	1979–2009	
North Asia	Mongolia	°C	+2.14	1940–2005	Dagvadorj et al. (2009)
	Russia	°C	+1.29	1907–2006	Anisimov et al. (2008a)
			+1.33	1976–2006	
South Asia	Afghanistan	°C	+0.6	1960–2008	Savage et al. (2009)
		°C decade^{-1}	+0.13	1960–2008	
	Bangladesh	°C decade^{-1}	+0.097	1958–2007	Shahid (2010)
	India	°C	+0.56	1901–2009	Attri and Tyagi (2010)
		°C century^{-1}	+0.68	1880–2000	Lal (2003)
		°C yr^{-1}	+0.0056	1948–2008	Ganguly (2011)
	Nepal	°C yr^{-1}	+0.06	1977–1994	Shrestha et al. (1999)
	Pakistan	°C	+0.57	1901–2000	Chaudhry et al. (2009)
			+0.47 ± 0.21	1960–2007	
		°C decade^{-1}	+0.099	1960–2007	
	Sri Lanka	°C yr^{-1}	+0.005 to +0.035	1961–2000	Iqbal (2010)
		°C decade^{-1}	+0.3 to +0.93	1869–2007	De Costa (2008)
			+0.75 to +0.94	1910–2007	
Southeast Asia	The Philippines	°C	+0.648	1951–2010	PAGASA (2011)
		°C yr^{-1}	+0.0108	1951–2010	
West Asia	Armenia	°C	+0.85	1935–2007	Gabrielyan et al. (2010)
Tibetan Plateau		°C (°C decade^{-1})	+1.8 (+0.36)	1961–2007	Wang et al. (2008)
		°C decade^{-1}	+0.447	1970–2001	Xu et al. (2008)

Table 24-SM-2 | Summary of key observed past and present annual mean precipitation trends in Asian countries/territories.

Sub-region	Country/territory	Change	Period	Reference
Central Asia	Kazakhstan	No definite national trend	1936–2005	Kryukova et al., 2009
	Kyrgyzstan	+23 mm (+6%)	1901–2000	Iliasov et al., 2003
	Tajikistan (plains region)	+8% (insignificant)	1940–2005	Karimov et al., 2008
	Tajikistan (mountainous region)	–3% (insignificant)		
	Turkmenistan	+12 mm decade^{-1}	1931–1995	MNPT, 2000
East Asia	Hong Kong	+25 mm decade^{-1}	1885–2008	Ginn et al., 2009
	Japan	No clear trend	1898–2008	MEXT et al., 2009
	South Korea	+5.6%	2001–2008	Kim et al., 2010
North Asia	Mongolia	–0.1 to –2.0 mm yr^{-1}	1940–2005	Dagvadorj et al., 2009
	Russia	+7.2 mm decade^{-1}	1976–2006	Anisimov et al., 2008a
South Asia	Afghanistan	–0.5 mm month^{-1}	1960–2008	Savage et al., 2009
		–2% decade^{-1}		
	Bangladesh	+5.53 mm yr^{-1}	1958–2007	Shahid, 2010
	India	No significant national trend	1901–2009	Attri and Tyagi, 2010
	Pakistan	+61 mm	1901–2007	Chaudhry et al., 2009
		–156 mm	1901–1954	
		+35 mm	1955–2007	
	Sri Lanka	–1.55 to –19.06 mm yr^{-1}	1961–2000	Iqbal, 2010
Southeast Asia	Indonesia, Brontas Catchment	–1.23 to –24.25 mm yr^{-1}	1955–2005	Aldrian and Djamil, 2008
West Asia	Armenia	–6%	1935–2007	Gabrielyan et al., 2010
Tibetan Plateau		+0.614 mm yr^{-1}	1961–2001	Xu et al., 2008

Table SM24-3 | Summary of projected changes in temperature (T) and precipitation (P) across sub-regions of Asia.

Sub-region		Projected changes
Central and North Asia (see Section 14.8.8 of WGI AR5)	T	• Central: Similar warming magnitude in winter and summer • Northern: Stronger warming trend than the global mean trend during winter
	P	• Central: *Likely* increase • Northern: *Very likely* increase • Central and Northern: *Likely* increase in extremes
East Asia (see Section 14.8.9 of WGI AR5)	T	*Very likely* longer-duration, more intense, and more frequent heat waves/hot spells in summer and *very likely* decrease in frequency of very cold days
	P	Increase in summer precipitation over East Asia with an intensified East Asian summer monsoon (*medium confidence*) *Likely* increase over East Asia during the Meiyu–Changma–Baiu season in May to July and *very likely* increase in extremes over the eastern Asian continent in all seasons and over Japan in summer under the RCP4.5 scenario (*low confidence*)
West Asia	T	*Very likely* that temperatures will continue to increase
(see Section 14.8.10 of WGI AR5)	P	Overall reduction (*medium confidence*)
South Asia	T	Increase (*high confidence*)
(see Section 14.8.11 of WGI AR5)	P	Increase in summer monsoon precipitation (*medium confidence*)
Southeast Asia	T	*Very likely* increase with substantial subregional variations
(see Section 14.8.12 of WGI AR5)	P	Moderate increase in rainfall, except on Indonesian islands neighboring the southeastern Indian Ocean (*medium confidence*) Strong regional variations because of terrain

Table SM24-4 | Summary of key observed past and present climate change impacts in Asia.

Sub-region	Country or territory	Area	Parameters	Observed changes	Period	References
Central Asia	Kazakhstan	Steppe region in north	Normalized Difference Vegetation Index	Decline (browning)	1982–2008	De Jong et al. (2012)
		Northern Tien Shan Mountains	Permafrost temperature at depths of 14–25 m	+0.3°C to +0.6°C	1974–2004	Marchenko et al. (2007); Zhao et al. (2010)
			Active layer thickness	+23%		
	Uzbekistan	Zerafshan River Basin	Monthly water discharge	Significant increases in spring and decreases in summer	1923–2006	Olsson et al. (2010)
	Kazakhstan, Uzbekistan, Kyrgyzstan	Main lakes	Surface area	• –75.70% (Aral Sea) • –2.61% (Balkhash) • –8.37% (Ebinur) • +0.66% (Issyk-Kul) • +5.85% (Zaysan) • –9.18% (Bosten)	1975–2007	Bai et al. (2012)
East Asia	East Asia north of 23°N		Tree growth	Tree-ring data suggests recent summer temperatures have exceeded those for warm periods of similar length over the past 1210 years.	800–2009	Cook et al. (2013)
	Japan	Multiple sites	Spring leafing and flowering	Earlier by <3 days per decade	Last 60 years	Ogawa-Onishi and Berry (2013)
			Species distributions	Northward by <126 km per decade	Last 50–70 years	
		Seas around Japan	Species distributions	Northward expansion of fish, corals, and algae	Recent decades	Nagai et al. (2011); Yamano et al. (2011); Tian et al. (2012)
	China	Shiyang River Basin	Streamflow	Five of eight catchments showing significant decreasing trends	1950–2005	Ma et al. (2008)
		Dongjiang River	Runoff	No significant change. Clear increasing trend at two of three stations in low-flow period	1956–2000	Liu, D. et al. (2010)
		Tarim River Basin	Streamflow	Three of four rivers with increasing streamflow except Aksu River	1960–2005	Zhang, Q. et al. (2010)
			Mainstreams' runoff	Decreased by 41.59% (1970s), 63.77% (1980s), 75.15% (1990s)	1957–2003	Hao et al. (2008)
			Runoff	In 1990s, runoff from headwaters of Aksu and Yarkand Rivers increased by 10.9%.	1955–2000	Chen et al. (2007)
		Baimasi Basin	Runoff	Decreased by 1.88% per year, decreasing from 1960s	1950–2000	Wang et al. (2010)
		Upper reaches of Tarim River Basin	Runoff	Aksu River showed a significant increasing trend by 10.9%. Three of four rivers showed an increasing trend with one showing a subtle reduction.	1958–2004	Chen et al. (2009)
		Laohahe River Basin	Runoff	Runoff in 1980–2008 decreased by 36% compared with 1964–1979	1964–2008	Jiang et al. (2011)
		Hun-Tai River Basin	Streamflow	Downward trends	1961–2006	Zhang et al. (2011)
		Kaidu River Basin	Runoff	Increasing with rate of 8.4 mm decade^{-1}; 1994–2009 increased 26.4% compared to 1960–1993	1960–2009	Chen et al. (2013)
		Haihe River Basin	Runoff	Significant downward trends	1957–2000	Wang et al. (2011)
		Pearl River, Yangtze River, Yellow River, Liao River, Songhua River	Runoff	• Increased by 10% (Pearl River) • Little change (Yangtze River) • Decreased by 80% (Yellow River) • Decreased by 54% (Liao River) • Decreased by 14% (Songhua River)	1951–2000	Xu et al. (2010)
		Qinghai–Tibetan Plateau	Active layer thickness along Qinghai–Tibetan Highway	Mean rate of +7.5 cm yr^{-1}	1995–2007	Wu and Zhang (2010)
			Position of lower altitudinal limit of permafrost in north	Moved up by 25 m	Last 30 years	Cheng and Wu (2007); Li et al. (2008)
			Position of lower altitudinal limit of permafrost in south	Moved up by 50–80 m	Last 20 years	
			Total area of glaciers of Qinghai–Tibetan Plateau and surrounding areas	Decreased by c. 9%, from 13363 ± 668 km^2 to 1213 ± 607 km^2	1970s–2000s	Yao et al. (2012)
		Whole country	Start of plant growth in spring	Earlier start by c. 2 days per decade	Last 30 years	Table SM24-6
		Most rice production areas	Rice yield	Positive correlation to temperature	1981–2005	Zhang, T. et al. (2010)
	Taiwan	Mountains	Plant distributions	Upper limits shifted upwards by 3.6 m per year	1906–2006	Jump et al. (2012)

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Table SM24-4 (continued)

Sub-region	Country or territory	Area	Parameters	Observed changes	Period	References
North Asia	Mongolia	Kherlen River Basin	Underground water storage	No evidence for long-term storage change	1947–2006	Brutsaert et al. (2008)
		Khentey Mountains	Growth of Siberian larch forest in forest-steppe ecotone	• Tree-ring analysis shows a decreasing annual increment. • Regeneration of larch decreased.	1940s–2010	Dulamsuren et al. (2010a,b)
		Hovsgol mountain region	Mean annual permafrost temperature at 10 m depth	Increased on average by 0.02–0.03°C $year^{-1}$	Last 10–40 years	Sharkhuu et al. (2008); Zhao et al. (2010)
		Hangai and Khentey mountain regions	Mean annual permafrost temperature at 10 m depth	Increased on average by 0.01–0.02°C $year^{-1}$		
	Russia, east of Urals	Siberia	Forest-tundra ecotone	• Larch stands crown closure, and larch invasion into tundra at a rate of 3–10 m $year^{-1}$ • Shrub expansion in arctic tundra as result of an increase in shrub growth	1970–2000	Kharuk et al. (2006); Myers-Smith et al. (2011); Blok et al. (2011)
			Distribution of dark needle conifers, Siberian pine, spruce, and fir	Invasion of dark needle conifers and birch into larch habitat	1980–2010	Kharuk et al. (2010a,b); Osawa et al. (2010); Lloyd et al. (2011)
			Permafrost temperature at zero annual amplitude	Warming of permafrost in most permafrost observatories in Asian Russia by 0.5–2°C	1970s–1990s	Romanovsky et al. (2008), with supplement; Romanovsky et al. (2010)
				No significant warming	2000–2007	
				Warming of permafrost resumed at many locations, predominantly near Arctic coasts	2007–2008	
		Asian Arctic	Average erosion rate of coastline	0.27–0.87 m $year^{-1}$	Second half of 20th century	Lantuit et al. (2012)
		Ural Mountains	Area of glaciers	Decreased by 20–30% in total	1953–1981	Anisimov et al. (2008b)
		Kodar Mountains	Area of glaciers	Exposed ice area declined by c. 44%.	ca. 1963–2010	Stokes et al. (2013)
				Exposed ice area declined by c. 40%, from 11.72 ± 0.72 km^2 to 7.01 ± 0.23 km^2.	1995–2010	
		Suntar–Khayata Range	Area of glaciers	Decreased by 19.3%	Mid-20th century–2003	Ananicheva et al. (2005, 2006)
		Chersky Range	Area of glaciers	Decreased by 28%	1970–2003	Anisimov et al. (2008b)
		Kamchatka	Area of glaciers	Decreased for some glaciers, increased for others	Since mid-19th century	
South Asia	India	Upper Indus Basin	Water stress	No strong evidence for marked reduction in water resources	1961–2004	Archer et al. (2010)
		Headwater of Kosi River	Water resources	Reduction in groundwater recharge, 36% of springs have dried, heads of perennial streams have dried, and water discharge in springs and streams has decreased considerably.	1990–2010	Tiwari and Joshi (2012)
		Andaman Islands	Coral health	Mass bleaching	2010	Krishnan et al. (2011)
	Nepal	Himalayan region	Water resources	Significantly moving snowline	1961–1998	Karki et al. (2009)
		Shorong, Khumbu, Langtang, Dhaulagiri, Kanchenjunga	River discharge	Decreasing trend in Karnali and Sapta Koshi; increasing trend in Narayani. No trend in southern rivers	1970s–2000s	Shrestha and Aryal (2011)
	Pakistan, India, Nepal, Bhutan	Himalayas	Start of plant growth in spring	Earlier start by 1.9 days per decade	1982–2006	Shrestha et al. (2012)
	All countries	Whole area	Livelihoods	Leave farming due to repeated droughts	Last few decades	Kulkarni and Rao (2008)

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Table SM24-4 (continued)

Sub-region	Country or territory	Area	Parameters	Observed changes	Period	References
Southeast Asia	Indonesia	Province of Papua	Area of mountain glaciers Puncak Jaya, Central Cordillera, New Guinea Island	Reduced from 19.3 km^2 to 7.3 km^2 (mid-19th century–1972), reduced from 7.3 km^2 to 2.1 km^2 (1972–2002)	Mid-19th century–2002	Prentice and Glidden (2010); Allison (2011)
	Malaysia	Mount Kinabalu, Sabah	Altitudinal distributions of moth species	Uphill shifts by average 83 m (upper) and 86 m (lower)	1965–2007	Chen et al. (2011)
	Indonesia, Malaysia, Singapore		Coral health	Mass bleaching and subsequent mortality	2010	Guest et al. (2012)
West Asia	Jordan		Wheat and barley yield	In 1999, total production and average yield for wheat and barley were lowest among years due low rainfall, which was 30% of average.	1996–2006	Al-Bakri et al. (2010)
	Azerbaijan, Georgia	Southern flank of Greater Caucasus Range	Area of glaciers	Decreased by 31.2% in total	1895–2000	Anisimov et al. (2008b)
	Iran, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Emirates		Coral health	Mass bleaching and subsequent mortality	1996–2012	Coles and Riegl (2013)
Kazakhstan, Kyrgyzstan, Tajikistan, China, Mongolia, Russia (east of Urals), Afghanistan		Altai–Sayan, Pamir, and Tien Shan Mountains	Area of glaciers	Decreased on average by 10%	1960–2009	Aizen (2011); Aizen et al. (2006, 2007)
			Ice volume of glaciers	Decreased on average by 15%		
East and South Asia			Poverty	Disproportionately impacted by climate-related hazards	1970s–2000s	Kim (2012)
East and Southeast Asia		Mekong region	Livelihoods	Increased migration due to environmental (e.g. rapid-onset disasters), social, and economic reasons	Over past four decades	Warner (2010); Black et al. (2011)

Table SM24-5 | Summary of key projected climate change impacts in Asia.

Sub-region	Country or territory	Area	Parameters	Projected impacts	Scenario	GCM (RCM)	Period	Base year	Reference
Central Asia	North and east Kazakhstan		Crop yield (cereal)	Benefit from longer growing season, warmer winters and slight increase in winter precipitation					Lioubimtseva and Henebry (2009)
	West Turkmenistan and Uzbekistan		Crop yield (cotton)	Negative impacts from frequent droughts					
East Asia	Japan	Tohoku and Hokuriku	River discharge	200% higher in February, 50 to 60% lower in May	A1B	AGCM	2080–2099	1980–1999	Sato, Y. et al. (2012)
			Rice transplanting date	Northward shift of isochrones of safe transplanting dates for rice seedlings	A2	MRI-CGCM2 (RCM20)	2081–2100	1971–2000	Ohta and Kimura (2007)
	China	Tarim River Basin	Flow	Positive change of 1.3 to 12.8% in BYBLK and 17.7 to 29.7% in DSK	A2, A1B, B1	18GCMs	2046–2065	1979–1998	Liu et al. (2011)
		Poyang Lake	Annual catchment inflow	Increased by 2.9% (A1B) and 6.5% (B1), decreased by 5.2% (A2).	A1B, B1, A2	ECHAM5	2011–2050	1961–2000	Ye et al. (2011)
		Qinghai–Tibet Plateau	Permafrost area	Decrease by <19% (20–50 years since 1996), decrease by 58% (2099)	+1°C in air temp. in 30 years since 1996	HADCM2	20–50 years since 1996, 2099	1996	Results of Li and Cheng (1999) after Cheng and Wu (2007)
		Tibetan Plateau	Alpine vegetation	Most replaced by forest and shrubland	A1B	Pattern-scaled output of multiple models	2070–2099	1931–1960	Liang et al. (2012); Wang (2014)
		Eastern China	Rice production	Yield would change on average by 7.5% to 17.5% (–10.4% to 3.0%), 0.0% to 25.0% (–26.7% to 2.1%), and –10.0% to 25.0% (–39.2% to –6.4%) during the 2020s, 2050s, and 2080s, respectively, in response to climate change, with (without) consideration of CO_2 fertilization effects.	10 climate scenarios, relative to 1961–1990 levels				Tao and Zhang (2013)
		Huang-Hai Plain in northeast China	Winter wheat yield	Increase by 0.2 Mg/ha (2015–45), increase by 0.8 Mg/ha (2070–2099)	A2, B2	HadCM3	2015–2045, 2070–2099	1961–1990	Thomson et al. (2006)
		Huang-Huai-Hai (3H) Plain	Wheat-maize relative yield change (RYC)	• +2°C & +5°C in temperature, +15 & –30% in precipitation, 500 & 700 ppmv CO_2: decreased on average by –10.33% • As above, with CO_2 fertilization: +4.46 ± 14.83% (2°C), –5.78 ± 25.82% (5°C)				1996–2004	Liu, S. et al. (2010)
	South Korea		Paddy irrigation requirements	Decrease by 1–8%	A2, B2	HadCM3 (RCMs)	2010–2039, 2040–2069, 2070–2099	1961–1990	Chung et al. (2011)
			Volumetric irrigation demand	Decrease by 4–10%					
		Yongdam basin	Annual mean streamflow	Reduced by 7.6%	2×CO_2	YONU GCM (WGEN)	2031–2050	1961–1980	Kim et al. (2007)
	China, Taiwan province	Upstream catchment of Shihmen reservoir	Runoff	Future runoff may be higher during wet season and lower during dry season.	A2, B2	CCSR, CGCM2, CSIRO, ECHAM4, GFDL, HADCM3	2010–2039; 2040–2069; 2070–2099	1973–2000	Yu and Wang (2009)
			Annual renewable water resource	Drop by 12.3%	A1B	JAM/MRI TL 959L60	2080–2099	1949–2000	Tsai and Huang (2012)
			Water resource condition for five levels	Good (L1), good (L2), fair (L3), poor (L4), very poor (L5): No change in northern and eastern parts with L2; visibly deteriorate in southern part with L3 to L4; central part will be L4	A1B	JAM/MRI TL 959L60	2080–2099	1979–1998	Tsai and Huang (2011)

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Table SM24-5 (continued)

Sub-region	Country or territory	Area	Parameters	Projected impacts	Scenario	GCM (RCM)	Period	Base year	Reference
North Asia	Russia, East of Urals	Siberia	Tundra area	Decrease by 93% as result of boreal forest expansion	+1% GHG per year	HADCM3 (GGa1)	2090–2100	1965–2000	Tchebakova et al. (2010)
			Steppe area	Increase by 27%					
			Tundra area	Decrease by 3% as result of boreal forest expansion	+1°C in annual mean global surface temp.	ECHAM4/OPYC3, HadCM3, IAP RAS CM	Late 2030s to early 2050s	1961–1990	Golubyatnikov and Denisenko (2007)
			Steppe area	Decrease by <65%					
		Arctic	Ice-dependent mammals	Population declines in some species	Various	Various	21st century		Post et al. (2013); Kovacs et al. (2011)
	Russia	Pechora Sea	Coast recession rate	1.5- to 2.6-fold increase	+2°C in annual mean global surface temp. over 21st century		2100	c. 2000	Pavlidis et al. (2007)
		East of Urals	Frequency of food production shortfalls	+3 to 4 (A2) and +2 to 3 (B2) years/decade in 2070s	A2, B2	ECHAM, HadCM3	2070s	1961–1990	Alcamo et al. (2007)
South Asia	India	All	Forests	34 to 39% of forests to change forest type	A2, B2	HadRM3	2085	1961–1991	Chaturvedi et al. (2011)
		Indo-Gangetic Plains, Indore, Hyderabad, Dharwad	Sorghum winter grain yield	Reduced by up to 7% by 2020, up to 11% by 2050, and up to 32% by 2080	A2a	HadCM3	2020, 2050, 2080	1970–1995	Srivastava et al. (2010)
	Pakistan	Swat & Chitral districts	Wheat yield	–7% & –24% (Swat district), +14% & 23% (Chitral district)	1.5 & 3°C in temperature			1976–2000	Hussain and Mudasser (2007)
Southeast Asia	Thailand	Chao Phraya River basin	River discharge	Decreased 60% in January, no significant change in September	A1B	MRI-AGCM+TRIP	2075–2099	1979–2003	Champathong et al. (2013)
	Vietnam	Mekong River delta	Agricultural land	About 7% of Vietnam's agricultural land may be submerged by 1 m sea level rise	1 meter sea level rise scenario	no GCMs used			Dasgupta et al. (2009)
West Asia	Iran	All	Deep aquifer recharge	Decreases by 50 to 100% in groundwater recharge in eastern region	A1B; B1; A2	CGCM 3.1	2010–2040, 2070–2100	1980–2002	Abbaspour et al. (2009)
	Jordan	Upper Jordan; Wadi Faynan	Stream flows, flood flow and numbers	Decrease by 12%	A2	(HadRM3)	2071–2100	1961–1990	Wade et al. (2010)
Eastern Mediterranean and Middle East region			Internal water resource	Decreases from 464 to 419 and 412 km^3	A1B	HadCM3 (PRECIS)	2040–2069, 2070–2099	1961–1990	Chenoweth et al. (2011)
			Runoff	–9.5% & –10% (Tigris–Euphrates River), –22% & –30% (Jordan River)					
North, East, Central Asia	Asian Russia, China, Mongolia, Kazakhstan	Permafrost area in Asia	Permafrost degradation	Spread from southern and low-altitude margins, advancing northwards and upwards	Multiple scenarios	Multiple GCMs	21st century		Multiple references, see section 24.4.2.3.
North, East Asia	Asian Russia, China	Siberia and Tibet	Permafrost distribution	Permafrost will remain only in Central and Eastern Siberia and in part of Tibet	A1B, A2	IAP RAS CM	Late 21st century		Eliseev et al. (2009)
West, South, Southeast Asia		All countries with tropical coasts	Coral health	Large declines in structure and diversity	Several	Several	2050		Hoegh-Guldberg (2011); Burke et al. (2011)
Asia			Poverty	Negative impact on rice crop, increase in food price and cost of living, increased poverty, projections for 2030 by GTAP Model under three scenarios resulting low, medium and high productivity					Hertel et al. (2010)
Central, East, South, Southeast Asia		Tibet/Himalayas	Livelihoods	Loss of livelihoods of indigenous people from declining alpine biodiversity					Salick and Ross (2009); Xu et al. (2009)

Table SM24-6 | Summary of recent literature from East Asia (China and Japan) reporting phenological observations in relation to recent climate change. Studies differ in objectives, methods, locations, and study periods. The source publications should be consulted for details. Phenological responses are given in days per decade, unless otherwise indicated, with negative values indicating an earlier occurrence of the event (i.e., an advance), and positive values a later occurrence (i.e., a delay). The "major influence" column shows the environmental variable that the authors of the study considered most important.

Location	Latitude	Period	Type of data	Variable	Species	Response (timing)	Major influence	Source
China	All	1982–2006	Observations and NDVI	Spring green-up		–2.9 ± 2.3 days dec^{-1}	Temperature	Ma and Zhou (2012)
	Most	1952–2007	Observations	First leaf date	20 spp. broadleaved deciduous	–1.1 days dec^{-1}	Temperature	Ge et al. (2013a)
		1960–2009	Observations	First leaf date	4 tree spp.	–1.1 days dec^{-1}	Temperature	Dai et al. (2013a)
				Leaf coloring date	4 tree spp.	+0.9 days dec^{-1}		
	>35°N and <35°N	1951–2007	Meteorological data	Thermal growing season length		• N: +2.3 days dec^{-1} • S: +1.3 days dec^{-1}	Temperature	Song et al. (2010)
				Start of thermal growing season		• N: –1.7 days dec^{-1} • S: –0.6 days dec^{-1}		
Eastern China	18–54°N	1982–2006	GIMMS-NDVI	Spring green-up	All	Advance in most areas except northeast China plain	Temperature	Yu et al. (2013a)
Xishuangbanna, China	21°N	1973–1999	Observations	Leaf budburst	21 species	+14 days (7 spp.)	Temperature	Zhao et al. (2013)
				Growing season length	21 species	+35 days (4 spp.)		
				First flowering	21 species	Varied	Temperature, rainfall	
China	23–46°N	1952–2007	Observations	First leafing	*Fraxinus chinensis*	• NE: –1.5 days dec^{-1} • N: –2.0 days dec^{-1} • NW: –1.4 days dec^{-1} • E: –0.9 days dec^{-1} • C: –1.1 days dec^{-1} • S: –0.3 days dec^{-1} • SW: –0.6 days dec^{-1}	Temperature	Wang et al. (2012)
Yangtze River delta, China	28–32°N	1834–2010	Observations	Flowering	14 ornamental species	Delayed 1843–1893, advanced 1893–1905, 1990–2010.	Temperature	Zheng et al. (2013)
Temperate China	28–54°N	1982–2006	GIMMS-NDVI	Spring green-up	All biomes	Advanced to mid-late 1990s, then delayed to 2006	Temperature	Wu and Liu (2013)
Temperate China (incl. Tibet)	c. 28–54°N	1982–1998	GIMMS NDVI	Start of growing season	All	–6.8 days dec^{-1} 1982–1998, +21.3 days dec^{-1} 1998–2005	Temperature, snow depth	Yu et al.. (2013b)
China	>30°N	1986–2005	Observations	Leaf unfolding	*Ulmus pumila*	–4.0 days dec^{-1}	Temperature	Chen and Xu (2012)
				Leaf fall	*Ulmus pumila*	+2.2 days dec^{-1}		
		1982–2010	GIMMS-NDVI3g	Spring green-up	All	–1.3 ± 0.6 days dec^{-1}	Temperature	Cong et al. (2013)
North China	33–53°N	1960–2009	Observations and modeling	First leaf unfolding	4 deciduous tree spp.	–1.4 to –1.6 days dec^{-1}	Temperature	Xu and Chen (2013)
Xi'an, China	34°N	1963–1996 vs. 2003–2011	Observations	First leafing	42 woody species	–5.5 days between periods	Temperature	Dai et al. (2013b)
				Leaf coloring	42 woody species	+16.1 days between periods		
				First flowering	42 woody species	–10.2 days between periods		
Beijing and Xi'an	34–40°N	1963–2010	Observations	Leaf coloring	*Acer mono*	+4 to 5 days dec^{-1}	Temperature	Ge et al. (2013b)
Temperate China	34–47°N	1963–2009	Observations	First flowering	210 species	• NE: –1.5 days dec^{-1} • N: –2.2 days dec^{-1}	Temperature	Dai et al. (2013c)
Inner Mongolia, China	37–53°N	1982–2006	Observations	First flowers	*Populus tomentosa*	–2.9 (–6.5 to +1.5) days dec^{-1}	Temperature	Wu et al. (2009)
				Leaf fall	*Populus tomentosa*	+3.1 (–5.8 to +9.5) days dec^{-1}		
Beijing, China	40°N	1963–2008	Observations	Growing season length	*Castanea mollissima*	+4.3 days dec^{-1}	Temperature	Guo et al. (2013)
				Leaf coloring	*Castanea mollissima*	Not significant		
				First flowers	*Castanea mollissima*	–1.6 days dec^{-1}		
		1963–1989, 1990–2007	Observations	First flowers	48 woody species	–5.4 days between periods	Temperature	Bai et al. (2011)

Continued next page →

Table SM24-6 (continued)

Location	Latitude	Period	Type of data	Variable	Species	Response (timing)	Major influence	Source
Northeast China	40–52°N	1980–2005	Observations	Leafing	11 woody species	–2.3 days dec^{-1}	Temperature	Li and Zhou (2010)
				Leaf yellowing	11 woody species	+1.9 days dec^{-1}		
Inner Mongolia, China	42°N	2006–2009	Experimental warming (day and night)	Flowering and fruiting	8 species in temperate steppe	–0.8 days (flowering), –0.7 days (fruiting) with night warming	Temperature	Xia and Wan (2013)
Northeast China	45–53°N	2001–2009	MODIS EVI	Start of season	Broadleaved deciduous forest	Advance	Temperature	Cai et al.. (2012)
Tibet, China		1961–2000	Herbarium collections	Flowering	41 species	–5.0 days dec^{-1}	Temperature	Li et al. (2013)
		1982–2006	GIMMS-NDVI	Spring green-up	All	Advance to 1999, then delay	Temperature	Piao et al. (2011)
		1982–2006	GIMMS-NDVI	Spring green-up	Grassland	Advance to 1990s, then delay	Temperature	Yu et al. (2012)
				Senescence and end of growing season	Grassland	Mostly earlier		
		1999–2009	SPOT-VGT NDVI	Start of growth season	Grassland	–6 days dec^{-1}		Ding et al. (2013)
				End of growing season	Grassland	+2 days dec^{-1}		
		1982–2011	GIMMS and SPOT-VGT NDVI	Spring green-up		–10.4 days dec^{-1}	Temperature	Zhang et al. (2013a)
		1982–2006	GIMMS-NDVI	Spring green-up	All	Earlier in most areas	Temperature	Panday and Ghimire (2012)
		1994–2005	Observations	Growing season	*Festuca rubra, Kobresia pygmaea, Poa pratensis*	Longer	Precipitation	Zhang et al. (2013b)
Japan	31–44°N	1969–1989, 1990–2005	Observations	First flowers	*Prunus mume*	–7.0 (–22.8 to +8.0) days between periods	Temperature	Doi (2007)
		1953–2005	Observations	Leaf budburst	*Morus bombycis*	–1.3 days dec^{-1}	Temperature	Doi (2012)
				Leaf fall	*Morus bombycis*	+2.4 days dec^{-1}		
	33–38°N	1953–2005	Observations	Leaf budburst	*Ginkgo biloba, Morus bombycis, Salix babylonica, Camellia sinensis*	–2.7 days dec^{-1}	Temperature	Doi and Katano (2008)
Kyoto, Japan	35°N	812–2005	Observations	Peak flowering	*Prunus jamasakura*	General advance after 1820s	Temperature	Aono and Kazui (2008)
Japan	36–41°N	1977–2004	Observations	Budburst	*Malus pumila* var. *domestica*	–1.8 to –3.6 days dec^{-1}	Temperature	Fujisawa and Kobayashi (2010)
				Flowering	*Malus pumila* var. *domestica*	–2.1 to –3.5 days dec^{-1}		
	42°N	3 years	Experimental soil warming	Leaf phenology	7 understory species	Variable between species	Temperature	Ishioka et al. (2013)

Table SM24-7 | Examples of adaptation options for agriculture in Asia.

Crop	Country/region	Potential adaptation strategies	Benefits/co-benefits	References
Wheat	General	Conservation agriculture (reductions in tillage, surface retention of adequate crop residues, and diversified, economically viable crop rotations)	Improve rural incomes and livelihoods by reducing production costs, managing agroecosystem productivity and diversity more sustainably, and minimizing unfavorable environmental impacts	Ortiz et al. (2008)
	Pakistan	Development of short duration and high yield varieties of wheat	Can withstand climatic anomalies expected in future	Hussain and Mudasser (2007)
	Indo-Gangetic Plains, India	Development of heat-tolerant wheat germplasm, as well as cultivars	Better adapted to heat and conservation agriculture	Ortiz et al. (2008)
Barley; wheat	Jordan	Soil water conservation. Selection of drought tolerant genotypes with shorter growing seasons	Increase available water to crop	Al-Bakri et al. (2010)
Sorghum	India	Changing variety and sowing date	Reduce impacts on monsoon sorghum to about 10%, 2% and 3% in 2020 scenario. Reduce impacts on winter crop to 1–2% in 2020, 3–8% in 2050 and 4–9% in 2080.	Srivastava et al. (2010)
Rice	Sri Lanka	Traditional approaches for resolving water stress, such as increasing water use efficiency, water harvesting and/or reducing cropped areas. Earlier planting and shorter duration varieties to avoid impacts of less rainfall in January and February		De Silva et al. (2007)
	China	Shifts in planting dates and automatic application of irrigation and fertilization. Selection for more temperature-tolerant cultivars and later-maturing cultivars to take advantage of longer growing seasons		Tao et al. (2008)
Corn	China	Using high-temperature sensitive varieties. Early planting, fixing variety growing duration, and late planting	Using high-temperature sensitive varieties, maize yield could increase on average by 1.0–6.0%, 9.9–15.2%, and 4.1–5.6% by adopting adaptation options of early planting, fixing variety growing duration, and late planting, respectively	Tao and Zhang (2010)
General	India	Water harvesting		Kelkar et al. (2008)
	South Asia	Increasing livestock production relative to crops. Selection of crop varieties. Livelihood diversification		Morton (2007)
	Central Asia	Replacement of existing network of open irrigation canals by more efficient drip irrigation systems Development of early warning systems, such as drought forecast, pest and epidemic disease forecasts, and water quality monitoring systems	Could significantly reduce evaporative water loss, while simultaneously improving crop productivity, reducing soil salinization, and decreasing risks of water contamination and transmission of vector-borne and waterborne diseases	Lioubimtseva and Henebry (2009)
	Central and West Asia	Changing of cropping systems and patterns, switching from cereal-based systems to cereal–legumes and diversifying production systems into higher value and greater water use efficient options. Using supplementary irrigation systems, more efficient irrigation practices and adaptation and adoption of existing and new water harvesting technologies. Development of more drought and heat tolerant germplasm using traditional and participatory plant breeding methodologies and better predictions of extreme climatic events		Thomas (2008)
	Russia	Crop substitution, diversification of crops, expanding irrigated agricultural areas, strategic food reserves, improving management, monitoring and early warning systems, food imports from abroad		Alcamo et al. (2007)
	Philippines	Crop diversification; change of crop varieties, use of water conservation practices		Peras et al. (2008); Lasco et al. (2011)
	General	Cultivars with multiple resistance to insects and diseases		Sharma et al. (2010)

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Table SM24-8 | Examples of adaptation options for securing livelihoods in Asia.

Aspect/issues	Country/region	Potential adaptation strategies	Benefits/co-benefits	References
Delay and shortfall in rainfall	Indonesia	Access to credit and public works project	Able to protect food expenditure in the face of weather shocks	Skoufias et al. (2011)
General (droughts, floods etc.)	General	Weather index insurance, cattle insurance, seed banks, credit facilities, assisted migration, cash for work	Poverty-centered adaptation, creation of assets and access to resources	Barrett et al. (2007); Tanner and Mitchel (2008); Jarvis et al. (2011)
		Assisted migration	Build financial, social, and human capital	Barnett and Webber (2010)
	Vietnam	Yield growth and improving agriculture labor productivity	Rural poverty reduction, livelihood diversification	Janvry and Sadoulet (2010)
Droughts and floods	Philippines	Bundling of improved varieties and agronomic practices and combination of production and market support	Economic benefits and social learning	Acosta-Michlik and Espaldon (2008)
General	Asia	Community based adaptation	Capture information at the grassroots, help integrating disaster risk reduction, development, and climate change adaptation, connect local communities and outsiders, and address the location-specific nature of adaptation	van Aalst et al. (2008); Heltberg et al. (2010); Rosegrant (2011)
		Forest management	Resilient livelihoods, buffer from shocks	Chhatre and Agrawal (2009)
		Securing rights to resources, community forest tenure rights	Resilient livelihood benefits to the poor indigenous and traditional people	Macchi et al. (2008); Angelsen (2009)
Biodiversity loss	Tibet	Greater involvement of traditional and indigenous people in climate change adaptation decision making	Indigenous knowledge from the years of living in close harmony with nature	Byg and Salick (2009); Salick and Ross (2009)

Table SM24-9 | Recent publications on changes in Central Asian glaciers.

Region	Period	Initial area (km^2)	Area change, km^2 (%)	References
Akshiirak (Inner Tien Shan)	1977–2001	406.8	–93.6 (–23)	Khromova et al. (2003)
	1977–2003	406.8	–35.15 (–8.6)	Aizen et al. (2006)
Zailiyskiy Alatau (Northern Tien Shan)	1955–1990	287.3	–81.8 (–29)	Vilesov and Uvarov (2001)
Sokoluk river basin, Kirgizkiy range (Northern Tien Shan)	1963–1986	31.7	–4.2 (–13.3)	Niederer et al. (2008)
	1986–2000	27.5	–4.7 (–17.1)	
Glacier No. 1, Urumqi (Eastern Tien Shan)	1962–2003	1.94	–0.24 (–12.4)	Ye et al. (2005)
Terskey–Alatoo (Issyk-Kul Lake Basin, Northern Tien Shan)	1971–2002	245	–18 (–8)	Narama et al. (2006)
Akesu river basin (Tarim river Basin, Central Tien Shan)	1963–1999	1760	–58.6 (–3.3)	Liu et al. (2006)
Kaidu river basin (Tarim river Basin, Central Tien Shan)	1963–2000	333	–38.5 (–11.6)	
Southern Tien Shan, Chinese territory	1960s–1999	2093.8	–96.3 (–4.6)	Ding et al. (2006)
Tien Shan (all mountain systems)	1970s–2008	13,271	–1,128 (8.5%)	Aizen (2011)
Altai–Sayan (all mountain systems)	1950–2000	42,565	–5959 (14%)	

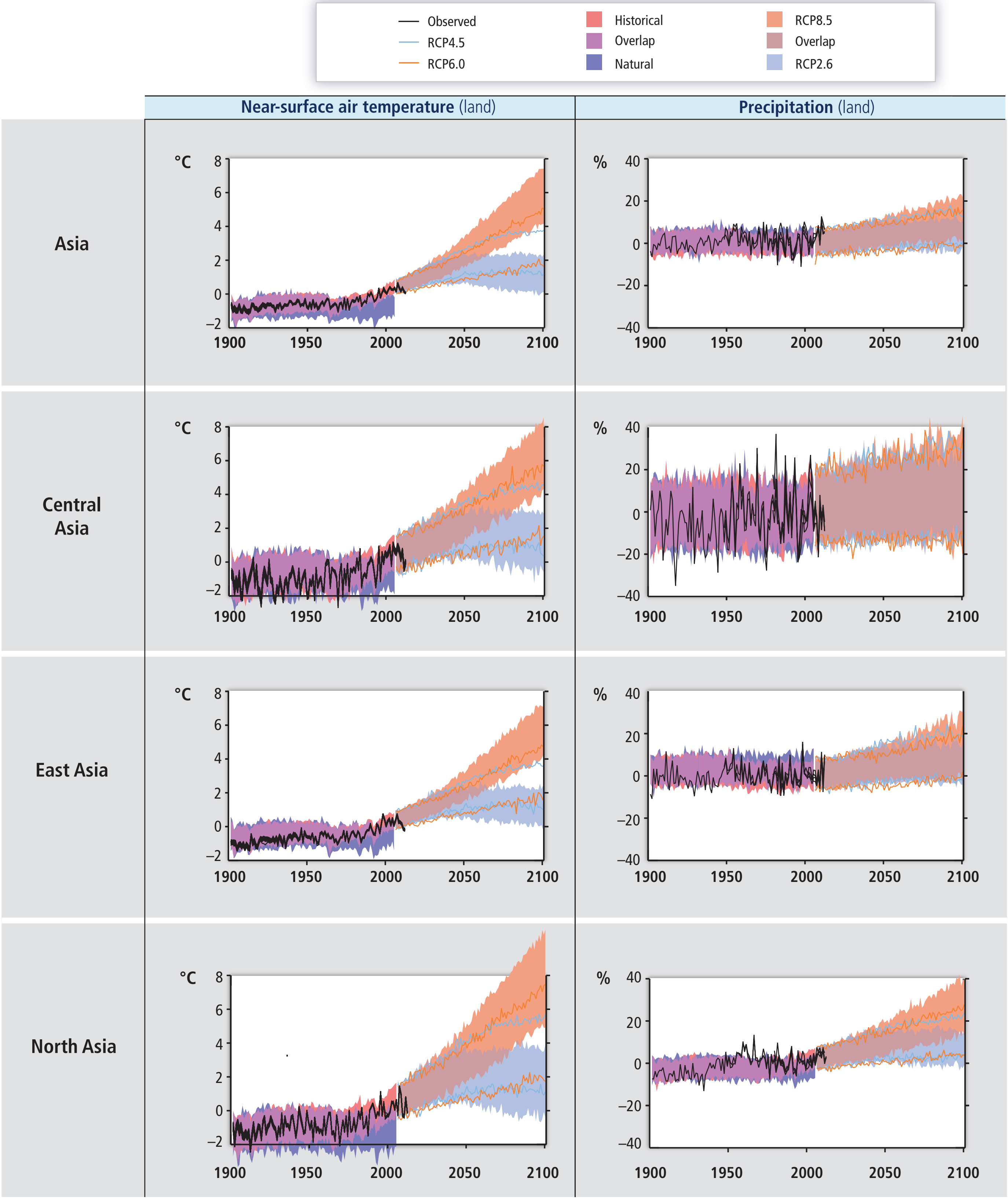
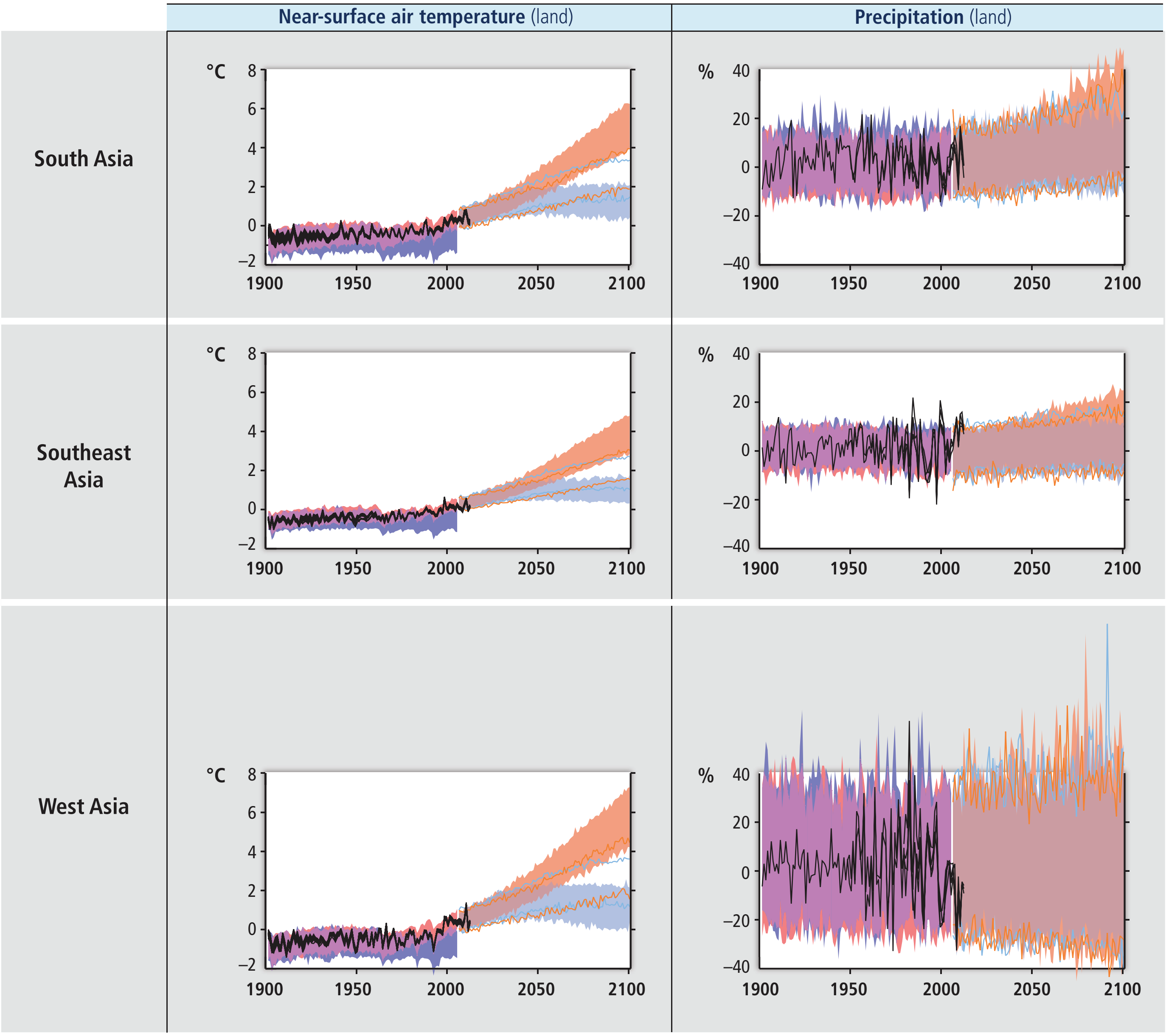


Figure SM24-1 | Observed and simulated variations in past and projected future annual average temperature (left) and precipitation (right) over land areas of the regions shown in Figure 24-1. Black lines show various estimates from observational measurements. Shading denotes the 5-95 percentile range of climate model simulations driven with "historical" changes in anthropogenic and natural drivers (63 simulations), historical changes in "natural" drivers only (34), the "RCP2.6", "RCP4.5", and "RCP8.5" emissions scenarios (63 each), and the "RCP6.0" scenario (45). Data are anomalies from the 1986–2005 average of the individual observational data (for the observational time series) or of the corresponding historical all-forcing simulations. Further details are given in Table SM21-5.

Continued next page →

Figure SM24-1 (continued)



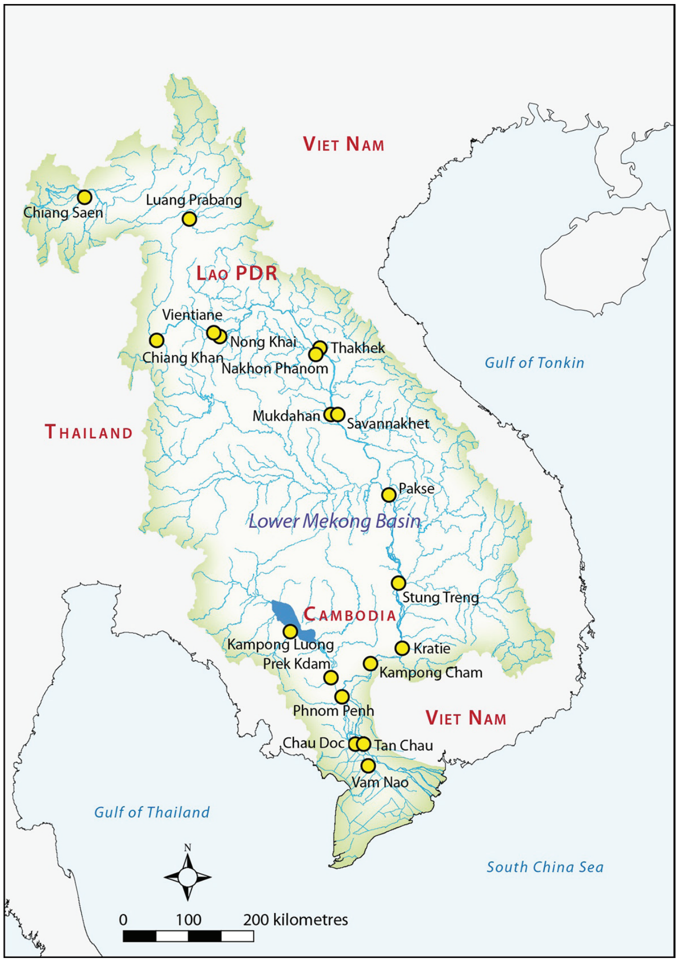


Figure SM24-2 | Geographical boundary and major cities of the Lower Mekong Basin (MRC, 2009).

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