Frequently Asked Questions
FAQ 14.2 | How Are Future Projections in Regional Climate Related to Projections of Global Means?

The relationship between regional climate change and global mean change is complex. Regional climates vary strongly with location and so respond differently to changes in global-scale influences. The global mean change is, in effect, a convenient summary of many diverse regional climate responses.

Heat and moisture, and changes in them, are not evenly distributed across the globe for several reasons:

- External forcings vary spatially (e.g., solar radiation depends on latitude, aerosol emissions have local sources, land use changes regionally, etc.).
- Surface conditions vary spatially, for example, land/sea contrast, topography, sea surface temperatures, soil moisture content.
- Weather systems and ocean currents redistribute heat and moisture from one region to another.

Weather systems are associated with regionally important climate phenomena such as monsoons, tropical convergence zones, storm tracks and important modes of climate variability (e.g., El Niño-Southern Oscillation (ENSO), North Atlantic Oscillation (NAO), Southern Annular Mode (SAM), etc.). In addition to modulating regional warming, some climate phenomena are also projected to change in the future, which can lead to further impacts on regional climates (see Table 14.3).

Projections of change in surface temperature and precipitation show large regional variations (FAQ 14.2, Figure 1). Enhanced surface warming is projected to occur over the high-latitude continental regions and the Arctic ocean,

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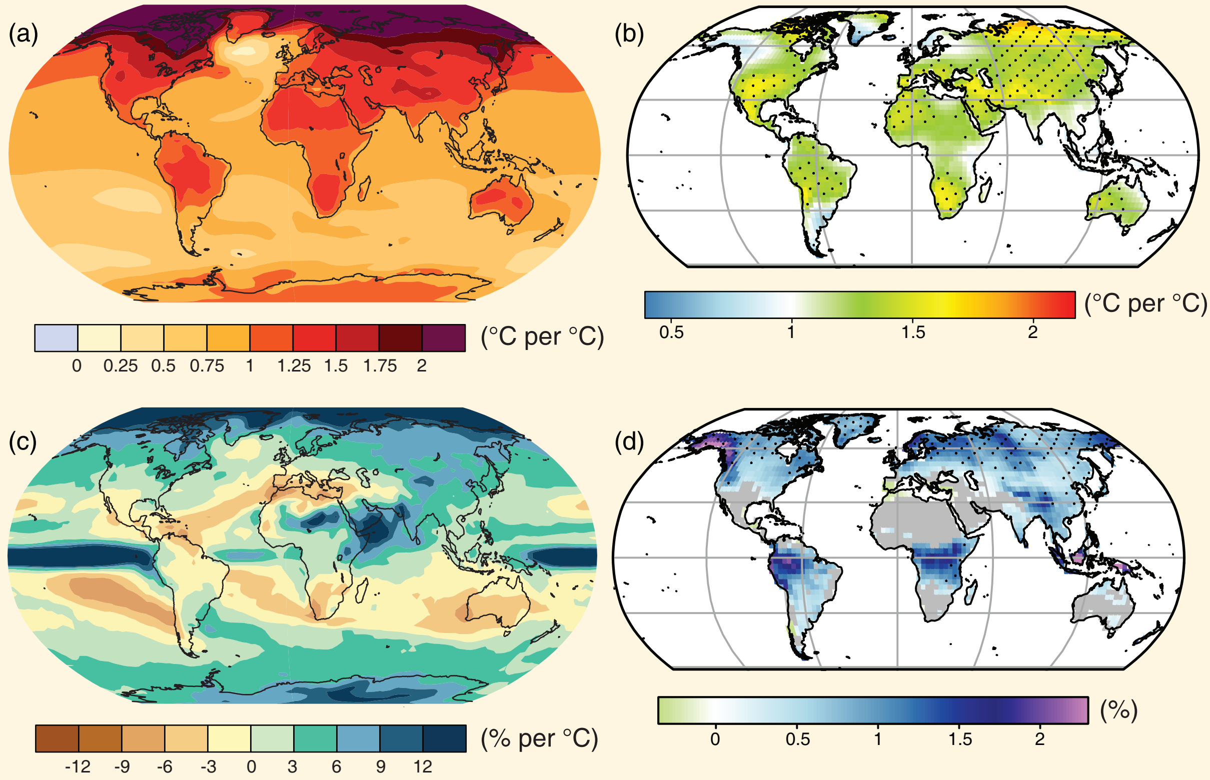

FAQ 14.2, Figure 1 | Projected 21st century changes in annual mean and annual extremes (over land) of surface air temperature and precipitation: (a) mean surface temperature per °C of global mean change, (b) 90th percentile of daily maximum temperature per °C of global average maximum temperature, (c) mean precipitation (in % per °C of global mean temperature change), and (d) fraction of days with precipitation exceeding the 95th percentile. Sources: Panels (a) and (c) projected changes in means between 1986–2005 and 2081–2100 from CMIP5 simulations under RCP4.5 scenario (see Chapter 12, Figure 12.41); Panels (b) and (d) projected changes in extremes over land between 1980–1999 and 2081–2100 (adapted from Figures 7 and 12 of Orlowsky and Seneviratne, 2012).

FAQ 14.2 (continued)

while over other oceans and lower latitudes changes are closer to the global mean (FAQ 14.2, Figure 1a). For example, warming near the Great Lakes area of North America is projected to be about 50% greater than that of the global mean warming. Similar large regional variations are also seen in the projected changes of more extreme temperatures (FAQ 14.2, Figure 1b). Projected changes in precipitation are even more regionally variable than changes in temperature (FAQ 14.2, Figure 1c, d), caused by modulation from climate phenomena such as the monsoons and tropical convergence zones. Near-equatorial latitudes are projected to have increased mean precipitation, while regions on the poleward edges of the subtropics are projected to have reduced mean precipitation. Higher latitude regions are projected to have increased mean precipitation and in particular more extreme precipitation from extratropical cyclones.

Polar regions illustrate the complexity of processes involved in regional climate change. Arctic warming is projected to increase more than the global mean, mostly because the melting of ice and snow produces a regional feedback by allowing more heat from the Sun to be absorbed. This gives rise to further warming, which encourages more melting of ice and snow. However, the projected warming over the Antarctic continent and surrounding oceans is less marked in part due to a stronger positive trend in the Southern Annular Mode. Westerly winds over the mid-latitude southern oceans have increased over recent decades, driven by the combined effect of loss of stratospheric ozone over Antarctica, and changes in the atmosphere's temperature structure related to increased greenhouse gas concentrations. This change in the Southern Annular Mode is well captured by climate models and has the effect of reducing atmospheric heat transport to the Antarctic continent. Nevertheless, the Antarctic Peninsula is still warming rapidly, because it extends far enough northwards to be influenced by the warm air masses of the westerly wind belt.

14.8.2 Arctic

This section is concerned with temperature and precipitation dimensions of Arctic climate change, and their links to climate phenomena. The reader is referred elsewhere for information on sea ice loss (Sections 4.2.2, 5.5.2 and Chapter 10), and projections of sea ice change (Sections 9.4.3, 9.8.3 and Chapters 11 and 12).

Arctic climate is affected by three modes of variability: NAO (Section 14.5.1), PDO (Section 14.7.3) and AMO (Section 14.7.6). The NAO index correlates positively with temperatures in the northeastern Eurasian sector, and correlates negatively with temperatures in the Baffin Bay and Canadian Archipelago, but exhibits little relationship with central Arctic temperatures (Polyakov et al., 2003). The PDO plays a role in temperature variability of Alaska and the Yukon (Hartmann and Wendler, 2005). The AMO is positively associated with SST throughout the Arctic (Chylek et al., 2009; Levitus et al., 2009; Chylek et al., 2010) (Mahajan et al., 2011). ETCs are also mainly responsible for winter precipitation in the region (see Table 14.3).

The surface and lower troposphere in the Arctic and surrounding land areas show regional warming over the past three decades of about 1°C per decade—significantly greater than the global mean trend (Figures 2.22 and 2.25). According to temperature reconstructions, this signal is highly unusual: Temperatures averaged over the Arctic over the past few decades are significantly higher than any seen over the past 2000 years (Kaufman et al., 2009). Temperatures 11 ka were greater than the 20th century mean, but this is probably a strongly forced signal, since summer solar radiation was 9% greater than present (Miller et al., 2010). Finally, warmer temperatures have been sustained in pan-Arctic land areas where a declining NAO over the past decade ought to have caused cooling (Semenov, 2007; Turner et al., 2007b). Since AR4, evidence has also emerged that precipitation has trended upward in most pan-Arctic land areas over the past few decades (e.g., Pavelsky and Smith, 2006; Rawlins et al., 2010), though the evidence remains mixed (e.g., Dai et al., 2009). Increasing ETC activity over the Canadian Arctic has also been observed (Section 2.6.4).

Since AR4, there has been progress in adapting RCMs for polar applications (Wilson et al., 2012). These models have been evaluated with regard to their ability to simulate Arctic clouds, surface heat fluxes, and boundary layer processes (Tjernstrom et al., 2004; Inoue et al., 2006; Rinke et al., 2006). They have been used to improve simulations of Arctic-specific climate processes, such as glacial mass balance (Zhang et al., 2007). A few regional models have been used for Arctic climate change projections (e.g., Zahn and von Storch, 2010; Koenigk et al., 2011; Döscher and Koenigk, 2012). For information on GCM quality in the Arctic, see Chapter 9 and the brief summary of assessed confidence in the CMIP5 models in Table 14.2.

The CMIP5 model simulations exhibit an ensemble-mean polar amplified warming, especially in winter, similar to CMIP3 model simulations (Bracegirdle and Stephenson, 2012; see also Box 5.1). For RCP4.5, ensemble-mean winter warming rises to 5.0°C over pan-Arctic land areas by the end of the 21st century (2081–2100), and about 7.0°C over the Arctic Sea (Table14.1). Throughout the century, the warming exceeds simulated estimates of internal variability (Figure AI.8). The RCP4.5 ensemble-mean warming is more modest in JJA (Table 14.1),