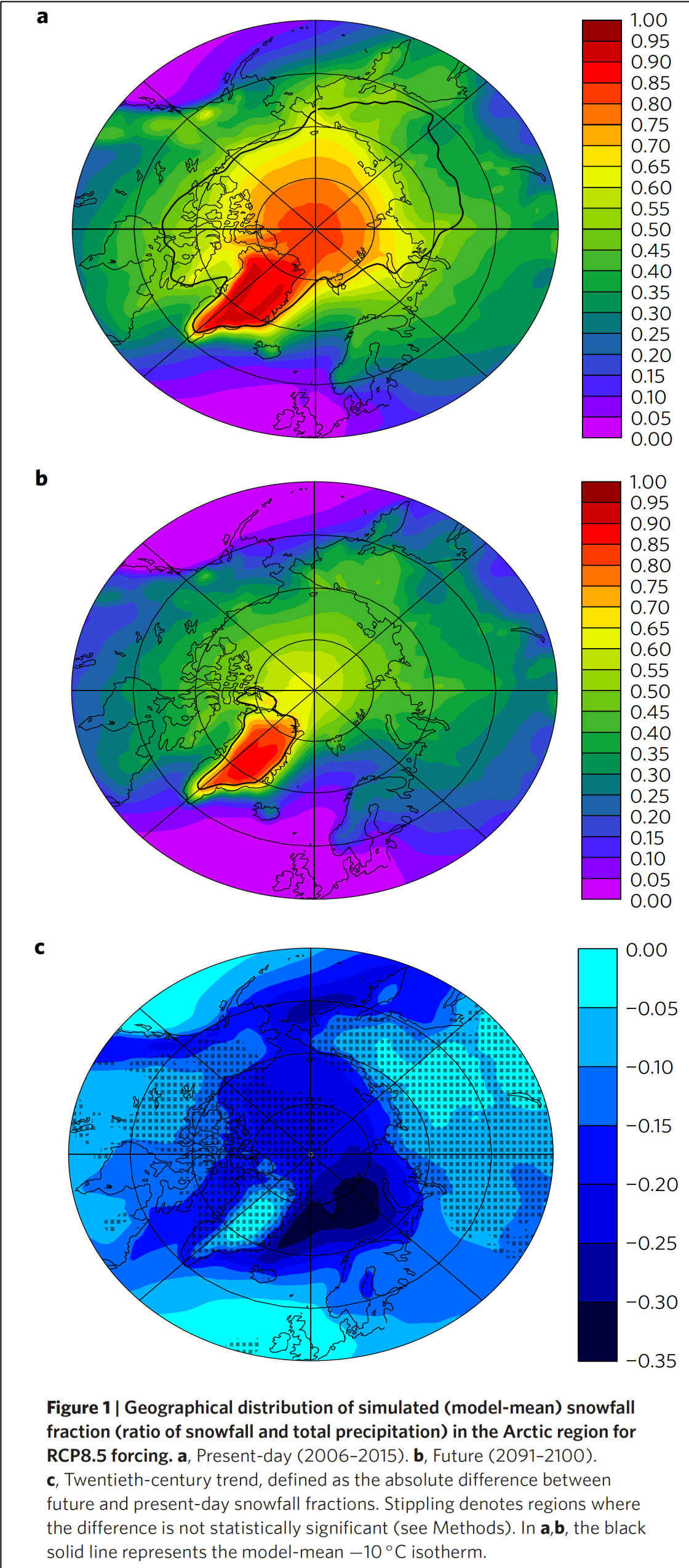




# Towards a rain-dominated Arctic

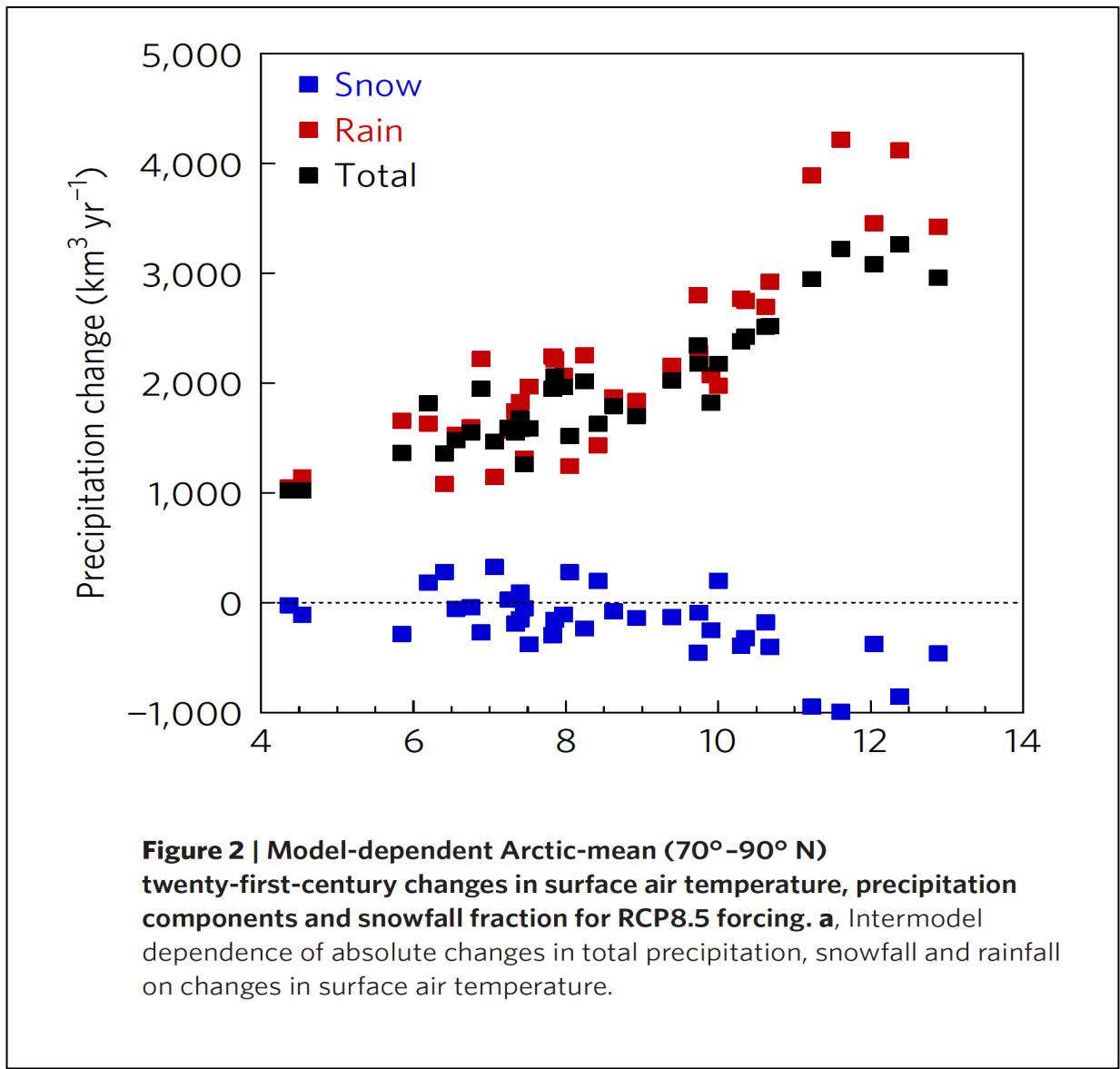
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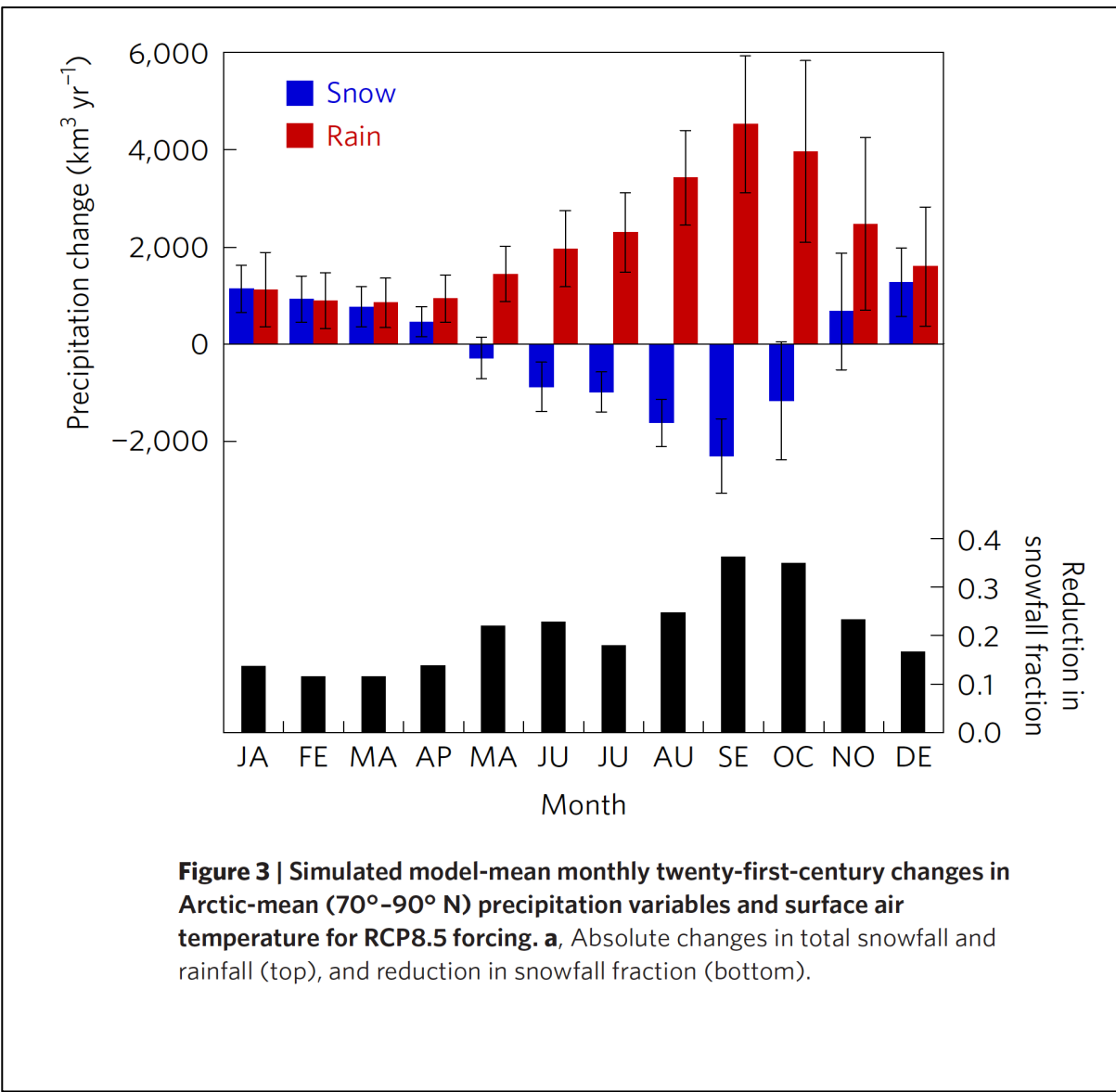


**Figure 1** | Geographical distribution of simulated (model-mean) snowfall fraction (ratio of snowfall and total precipitation) in the Arctic region for RCP8.5 forcing. **a**, Present-day (2006-2015). **b**, Future (2091-2100). **c**, Twentieth-century trend, defined as the absolute difference between future and present-day snowfall fractions. Stippling denotes regions where the difference is not statistically significant (see Methods). In **a**, **b**, the black solid line represents the model-mean  $-10^{\circ}\text{C}$  isotherm.

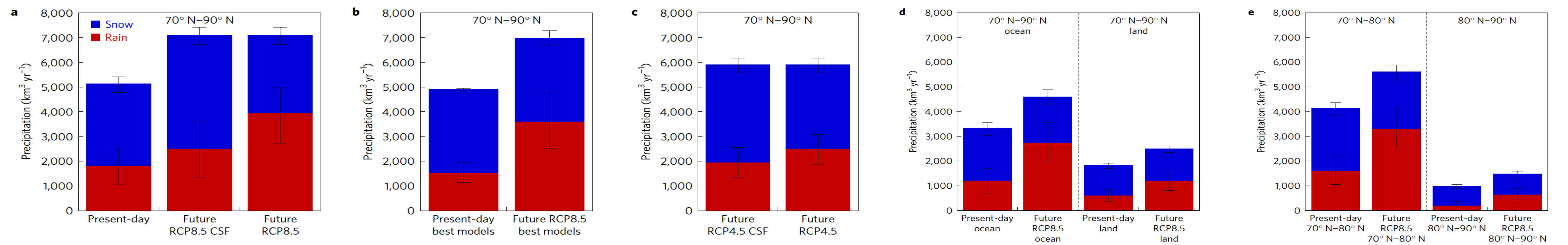
Climate models project a strong increase in Arctic precipitation over the coming century<sup>1</sup>, which has been attributed primarily to enhanced surface evaporation associated with sea-ice retreat<sup>2</sup>. Since the Arctic is still quite cold, especially in winter, it is often (implicitly) assumed that the additional precipitation will fall mostly as snow<sup>3</sup>. However, little is known about future changes in the distributions of rainfall and snowfall in the Arctic. Here we use 37 state-of-the-art climate models in standardized twenty-first-century (2006-2100) simulations<sup>4</sup> to show a decrease in average annual Arctic snowfall ( $70^{\circ}$ - $90^{\circ}$  N), despite the strong precipitation increase. Rain is projected to become the dominant form of precipitation in the Arctic region (2091-2100), as atmospheric warming causes a greater fraction of snowfall to melt before it reaches the surface, in particular over the North Atlantic and the Barents Sea. The reduction in Arctic snowfall is most pronounced during summer and autumn when temperatures are close to the melting point, but also winter rainfall is found to intensify considerably. Projected (seasonal) trends in rainfall and snowfall will heavily impact Arctic hydrology (for example, river discharge, permafrost melt)<sup>5-7</sup>, climatology (for example, snow, sea-ice albedo and melt)<sup>8,9</sup> and ecology (for example, water and food availability)<sup>5,10</sup>.



**Figure 2** | Model-dependent Arctic-mean ( $70^{\circ}$ - $90^{\circ}$  N) twenty-first-century changes in surface air temperature, precipitation components and snowfall fraction for RCP8.5 forcing. **a**, Intermodel dependence of absolute changes in total precipitation, snowfall and rainfall on changes in surface air temperature.



**Figure 3** | Simulated model-mean monthly twenty-first-century changes in Arctic-mean ( $70^{\circ}$ - $90^{\circ}$  N) precipitation variables and surface air temperature for RCP8.5 forcing. **a**, Absolute changes in total snowfall and rainfall (top), and reduction in snowfall fraction (bottom).



**Figure 4** | Simulated model-mean Arctic total snowfall and rainfall. **a**, Present-day and future (left and right bars, respectively) total ( $70^{\circ}$ - $90^{\circ}$  N) snowfall and rainfall for the strong forcing scenario (RCP8.5), as well as the future situation in which it is hypothetically assumed that the current snowfall fraction remains constant (constant snowfall fraction, CSF). **b**, Present-day and future snowfall and rainfall (RCP8.5) for the 'best' five models (see Supplementary Information). **c**, Future snowfall and rainfall for the intermediate forcing scenario RCP4.5 (actual and assuming CSF). **d**, Present-day and future snowfall and rainfall (RCP8.5) averaged over ocean (left) and land (right) regions within the Arctic ( $70^{\circ}$ - $90^{\circ}$  N). **e**, Present-day and future snowfall and rainfall (RCP8.5) over the regions  $70^{\circ}$ - $80^{\circ}$  N (left) and  $80^{\circ}$ - $90^{\circ}$  N (right). Error bars represent the multi-model standard deviation and indicate model uncertainty.