Runoff is a key index of renewable water resources which affect almost all human and natural systems. Any substantial change in runoff therefore has the potential to impact food and freshwater security. We analyze the runoff response to global warming as predicted by climate change experiments generated for the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In contrast to previous work, we estimate the sensitivity of runoff per degree of global mean temperature change, with the rationale that the global average temperature change is indexed to cumulative global emissions, and therefore removes most of the dependence on emissions scenarios. Our results show that the predicted fractional change in runoff per degree warming is relatively stable across emissions scenarios and global mean temperature increments, but varies substantially across models with the exception of the high-latitudes and currently arid or semi-arid areas. Among the 194 large global river basins studied, the number of basins with decreasing runoff increases by about 12% per degree global temperature increase, and the associated fraction of global land area, affected population, and affected Gross Domestic Product (GDP) increases by about 6, 5, and 8%, respectively. The estimated runoff elasticity to precipitation ranges from about one to three. We fit linear models for each basin to analyze the runoff sensitivities to mean annual precipitation change and basin average temperature change, i.e. δR/δP = β δP/δT + α δT, where δR is the relative runoff change, precipitation change, and basin temperature change.

The largest 194 river basins globally (by drainage area) were identified from the Simulated Topological Network (STN-30p). We extracted model output from 23 GCMs from the CMIP3 data base. The global mean temperature and 30-year moving averages were calculated for each model and emissions scenario. The relative change per degree of warming (i.e. runoff sensitivity) was computed as the relative runoff change divided by the given increment (0.5, 1.0, 1.5, 2.0, and 2.5 °C) in the global mean temperature. For each of the above sensitivities, we computed multimodel-ensemble averages from different subsets of the 23 models, 3 emissions scenarios, and 5 global temperature increments to show the effects of emissions scenarios and temperature increment on temperature sensitivity values. We fit linear models for each basin to analyze the runoff sensitivities to mean annual precipitation change and basin average temperature change, i.e. δR/δP = β δP/δT + α δT, where δR is the relative runoff change, precipitation change, and basin temperature change.

Runoff sensitivities (% per degree C global warming) estimated from different subsets of models, emissions scenarios and global mean temperature increments. a) Multimodel ensemble medians for each of the three emissions scenarios (B2, A1B, and A2) plotted against the ensemble median across all emissions scenarios and temperature increments, and b) multimodel ensemble medians at each global mean temperature increment. The shaded area shows the inner quartile range of the ensemble values across all emissions scenarios and temperature increments.

Runoff sensitivities to basin mean annual precipitation change (a) and temperature change (b) for the 194 largest global river basins. The linear model is fitted for each model using data from the (three) emissions scenarios and (five) global mean temperature increments. The multimodel-ensemble median values of β and α were calculated for each river basin.

Our results show that projected runoff sensitivities to global warming are relatively stable across emissions scenarios and global temperature increments. In the 194 largest river basins, the number of river basins with decreasing runoff increases by 12% per °C global temperature increase and the associated fraction of global land area, population, and GDP increases by 6, 5, and 8%, respectively. The estimated runoff sensitivity to mean annual precipitation change generally ranges from 1 to 3. Over most basins in North America, and the middle and high latitudes of Eurasia, runoff sensitivities to local temperature change range from -2 to -6% per degree of local temperature change.

**References**


**Approach**

The largest 194 river basins globally (by drainage area) were identified from the Simulated Topological Network (STN-30p). We extracted model output from 23 GCMs from the CMIP3 data base. The global mean temperature and 30-year moving averages were calculated for each model and emissions scenario. The relative change per degree of warming (i.e. runoff sensitivity) was computed as the relative runoff change divided by the given increment (0.5, 1.0, 1.5, 2.0, and 2.5 °C) in the global mean temperature. For each of the above sensitivities, we computed multimodel-ensemble averages from different subsets of the 23 models, 3 emissions scenarios, and 5 global temperature increments to show the effects of emissions scenarios and temperature increment on temperature sensitivity values. We fit linear models for each basin to analyze the runoff sensitivities to mean annual precipitation change and basin average temperature change, i.e. δR/δP = β δP/δT + α δT, where δR is the relative runoff change, precipitation change, and basin temperature change.

Relative runoff change per degree warming. a) Multimodel-ensemble median value across all emissions scenarios and temperature increments for the 194 global river basins. b) FPN (fraction positive minus fraction negative) for each river basin.

Runoff sensitivities to basin mean annual precipitation change (a) and temperature change (b) for the 194 largest global river basins. The linear model is fitted for each model using data from the (three) emissions scenarios and (five) global mean temperature increments. The multimodel-ensemble median values of β and α were calculated for each river basin.

**Conclusion and Discussion**

Our results show that projected runoff sensitivities to global warming are relatively stable across emissions scenarios and global temperature increments. In the 194 largest river basins, the number of river basins with decreasing runoff increases by 12% per °C global temperature increase and the associated fraction of global land area, population, and GDP increases by 6, 5, and 8%, respectively. The estimated runoff sensitivity to mean annual precipitation change generally ranges from 1 to 3. Over most basins in North America, and the middle and high latitudes of Eurasia, runoff sensitivities to local temperature change range from -2 to -6% per degree of local temperature increase.