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A simple explanation for the sensitivity of the hydrologic cycle to global climate change

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The global hydrologic cycle is likely to increase in strength with global warming, although some studies indicate that warming due to solar absorption may result in a different sensitivity than warming due to an elevated greenhouse effect. Here we show that these sensitivities of the hydrologic cycle can be derived analytically from an extremely simple surface energy balance model that is constrained by the assumption that vertical convective exchange within the atmosphere operates at the thermodynamic limit of maximum power. Using current climatic mean conditions, this model predicts a sensitivity of the hydrologic cycle of 2.2 % K^{-1} to greenhouse-induced surface warming which is the sensitivity reported from climate models. The sensitivity to solar-induced warming includes an additional term, which increases the total sensitivity to 3.2 % K^{-1}. These sensitivities are explained by shifts in the turbulent fluxes in the case of greenhouse-induced warming, which is proportional to the change in slope of the saturation vapor pressure, and in terms of an additional increase in turbulent fluxes in the case of solar radiation-induced warming. We illustrate an implication of this explanation for geoengineering, which aims to undo surface temperature differences by solar radiation management. Our results show that when such an intervention compensates surface warming, it cannot simultaneously compensate the changes in hydrologic cycling because of the differences in sensitivities for solar vs. greenhouse-induced surface warming. We conclude that the sensitivity of the hydrologic cycle to surface temperature can be understood and predicted with very simple physical considerations but this needs to reflect on the different roles that solar and terrestrial radiation play in forcing the hydrologic cycle.