Mechanisms of an intensified Hadley Circulation in response to solar forcing in the 20th century

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Ensemble experiments with a global coupled climate model for the 20th century with time evolving solar, greenhouse gas, sulfate aerosol (direct effect), and ozone (tropospheric and stratospheric) forcing are analyzed to show that solar forcing produces coupled dynamical interactions in the tropics that strengthen regional Hadley and Walker circulation regimes over the first half of the 20th century. Solar forcing produces feedbacks involving temperature gradient-driven atmospheric circulations that can alter clouds. Over relatively cloud-free oceanic regions in the subtropics, greater solar forcing in mid-century compared to early century produces greater evaporation, more moisture transport into the precipitation convergence zones, intensified regional Hadley and Walker circulations, less clouds over the subtropical ocean regions, and even more solar input. Coupled dynamical interactions produce upper ocean heat content anomalies in concert with positive SST anomalies that intensify precipitation over the South Indian, South Pacific, and South Atlantic Convergence Zones, as well as the south Asian and west African monsoons. Coupled regional responses are most evident when the solar forcing occurs in concert with increased greenhouse gas forcing of about the same magnitude over the first half of the century. The latter is also altered by interaction with the solar forcing, and the base state tropical SSTs are increased in the relatively cloud-free subtropical regions of low level moisture divergence to fuel the regional feedbacks induced by the spatially differentiated solar forcing. Consequently, the greater solar forcing acting in concert with increased GHGs during the early 20th century produces larger increases of tropical precipitation, calculated as a residual for the solar forcing, than for early century solar-only forcing, even though the size of the solar forcing is the same.