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Impacts of Irrigation on Daily Extremes in the Coupled Climate System

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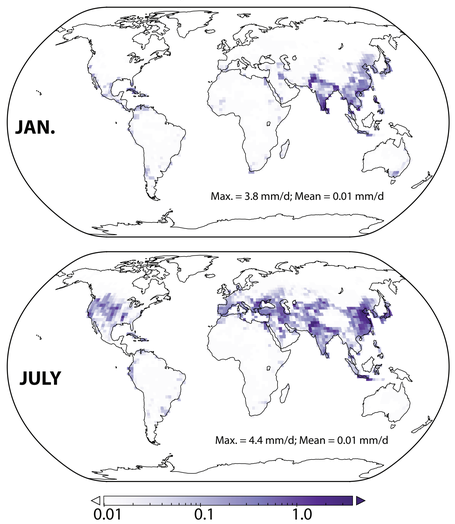
1. ABSTRACT

Widespread irrigation alters regional climate through changes to the energy and water budgets of the land surface. Within general circulation models, simulation studies have revealed significant changes in temperature, precipitation, and other climate variables. Here we investigate the feedbacks of irrigation with a focus on daily extremes at the global scale. We simulate global climate for the year 2000 with and without irrigation to understand irrigation-induced changes. Our simulations reveal shifts in key climate-extreme metrics. These findings indicate that land cover and land use change may be an important contributor to climate extremes both locally and in remote regions including the low-latitudes.

2. METHODS

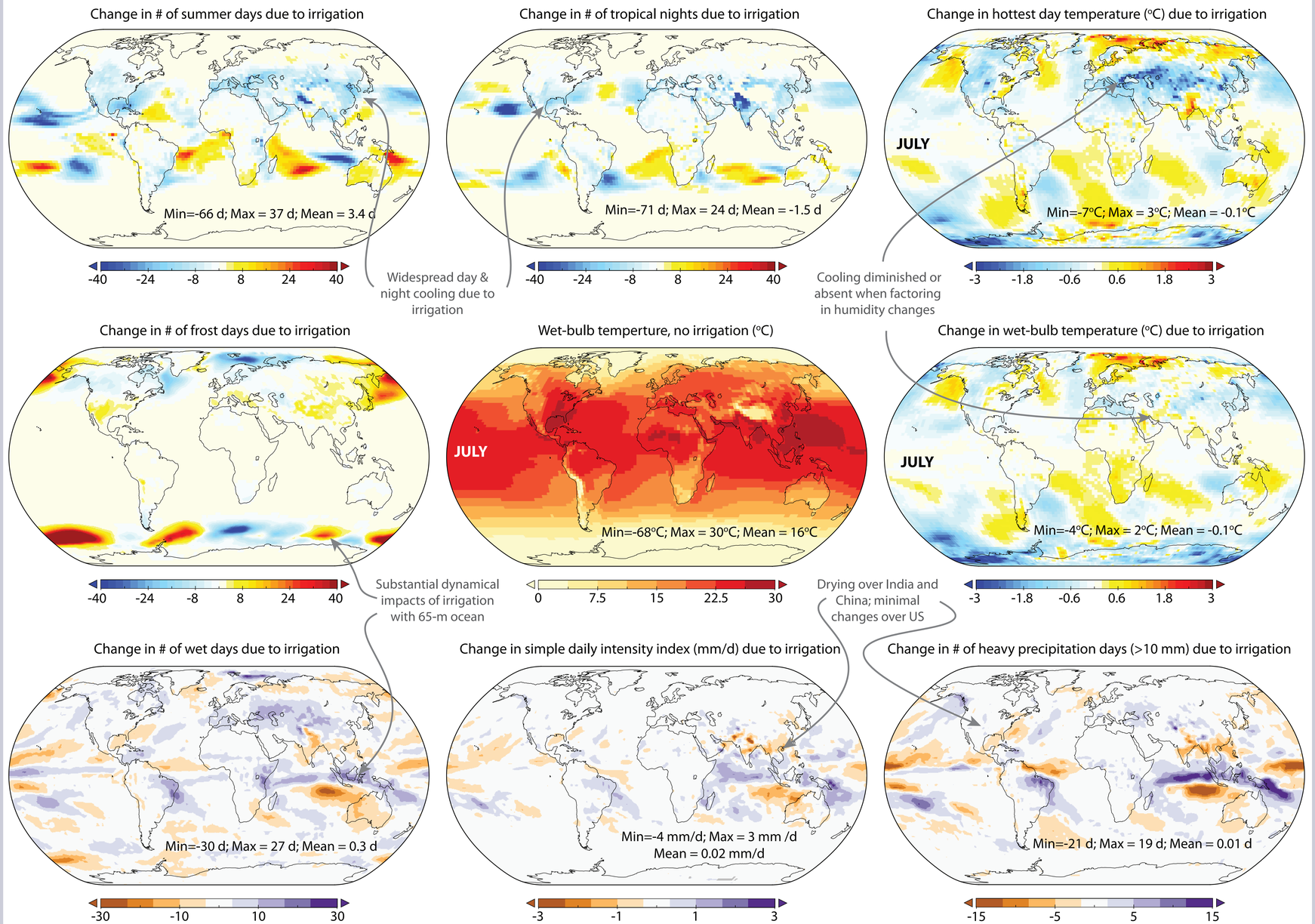
We use the Goddard Institute for Space Studies ModelE, a state-of-the-art general circulation model with 40 vertical layers in the atmosphere. The ocean is represented as a 65-m deep mixed layer ("q-flux" mode), so sea-surface temperatures vary from year-to-year. We ran ModelE for 60 years using year 2000 forcings both with and without irrigation. The "q-flux" ModelE takes about 10 years to reach equilibrium when driven by constant forcings, so we exclude the first 10 years of each simulation from our analyses.



January (top) and July (bottom) irrigation for the year 2000 used in ModelE. During boreal winter, irrigation occurs primarily in Asia. By boreal summer, irrigated areas expand throughout North America, Europe, and western Asia.

Irrigation rates are taken from a global gridded reconstruction of twentieth century hydrography (Wisser et al. 2010). Irrigation water is added to the vegetated fraction of the grid cell at the top of the soil column, beneath the vegetation canopy. Water for irrigation is initially withdrawn from rivers and lakes in the same grid cell. If irrigation demand is not satisfied by these surface sources, water is added under the assumption that it is taken from groundwater sources that are not represented in the model (i.e. "fossil" groundwater).

3. IRRIGATION IMPACTS ON EXTREME TEMPERATURE AND PRECIPITATION INDICES



4. DISCUSSION

In our experiments, we assess the impacts of irrigation on extreme temperatures and precipitation. In line with previous global studies that found cooling at monthly timescales, irrigation leads to substantial reductions in the number of summer days and tropical nights for many irrigated areas. We also find reductions in the hottest-day temperatures, along with increases in the number of frost days over parts of North America. Importantly, cooling is diminished or absent for the wet-bulb temperature, which factors in humidity changes. The dynamical impacts of irrigation are particularly striking, with shifts in precipitation throughout the tropics and mid-latitudes. For temperature, dynamical shifts are found in the mid- and low-latitudes. Acknowledgments: M.J. Puma gratefully acknowledges support from the Interdisciplinary Global Change Research under NASA cooperative agreement NNX08AJ75A supported by the NASA Climate and Earth Observing Program. Reference: Wisser, D., et al. "Reconstructing 20th century global hydrography: a contribution to the Global Terrestrial Network-Hydrology (GTN-H)." Hydrology and Earth System Sciences 14.1 (2010): 1-24.