Climate change challenges for management of natural resources in the Panama Canal watershed

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Abstract: What climate conditions can the Panama Canal Authority (ACP) expect in the coming decades? What are the extremes of droughts and floods that we may experience? How might climate change affect El Niño frequency and intensity (figure 1), and the droughts associated with strong El Niño periods in Panamá? According to reports from NASA and the U.S. National Oceanic and Atmospheric Administration, "Earth's 2016 surface temperatures were the warmest since modern recordkeeping began in 1880", with 16 of the 17 warmest years recorded since 2001. A warmer atmosphere contributes to more evaporation and convective storms, to deeper and more prolonged droughts and, when associated with increased ocean surface temperature, it can also generate higher-intensity tropical storms such as those witnessed during the remarkable 2017 Atlantic-Caribbean hurricane season.

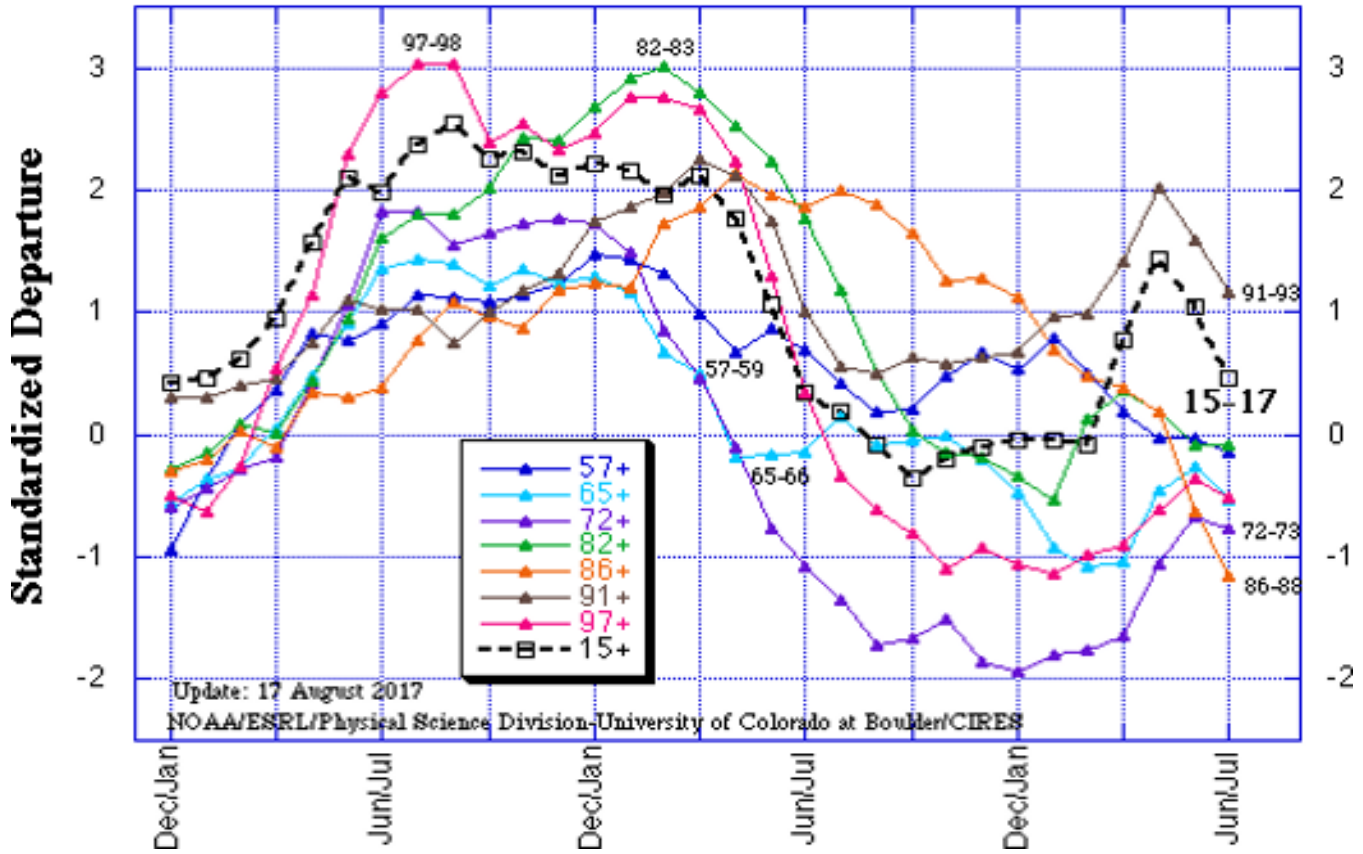

Figure 1. Graph of ENSO index for the eight strongest El Niño events from 1950 to 2015. [U.S. Department of Commerce. ENSO data. National Oceanic and Atmospheric Administration, Earth System Research Laboratory, Physical Sciences Division, http://www.esrl.noaa.gov/psd/enso/past_events.html; 2017].

We live in an age of increasing uncertainty with respect to air temperature and precipitation distribution and accumulation. Past norms for seasonality and annual variability of these fundamental climate variables have become unreliable. In a landmark 2008 paper in the journal *Science*, hydrologists declared that "stationarity is dead". During the 20th century in most watersheds where a 30-year hydrologic record had been acquired, scientists were able to reasonably predict future key variables such as average and maximum precipitation amounts (both temporally and spatially), minimum and maximum stream flow, and flood peaks. Climate and land use change have degraded our ability to make these predictions.

In our 21st century “non-stationary” world, managers of natural resources must be increasingly adaptive in administering these assets. For water availability and quality, this means constantly searching for ways to be more efficient with our use. For land resources, it means minimizing human-caused disruption of natural systems, by planting and maintaining endemic tree species that are adapted to local environmental conditions (soil, precipitation), and natural disturbances such as storms, pests, and fire. It also requires collaborating with economists and social scientists to find ways that incentivize effective stewardship by private and public land owners.

Good stewardship assures that the benefits we receive from natural systems, known as ecosystem services, continue to accrue into the future in spite of the vagaries of climate change. Well managed watersheds provide numerous ecosystem services, such as high quality water, reduced peak river flow during storms, increased availability of groundwater and base flow in streams during seasonal dry periods and droughts, reduced soil erosion and landslide probability, enhanced resilience to wildfire, pathogens and invasive species, biodiversity, genetic resources, and recreation.

Challenges ahead: Effective operation of the Panama Canal is dependent on abundant annual rainfall in the 3,313 km^2 Canal watershed. During below average years for rainfall, the ACP has had to notify shipping companies to reduce vessels drafts in order to use the Canal (figure 2). This affects global shipping interests and reduces income for the ACP and for the nation. With changing climate, the frequency and intensity of drought has increased around the world, including in Central America. This creates new and more complex challenges following the successful completion in 2016 of the second set of locks, which increases the freshwater operational needs for the Canal.
The ACP currently uses more than 4 cubic kilometers of freshwater per year for lockages, hydroelectric power generation, and potable water supply. As climate change continues to intensify in the coming decades, it is incumbent on the ACP and the nation to optimize land and water management so that we can guarantee an economically and environmentally stable future.

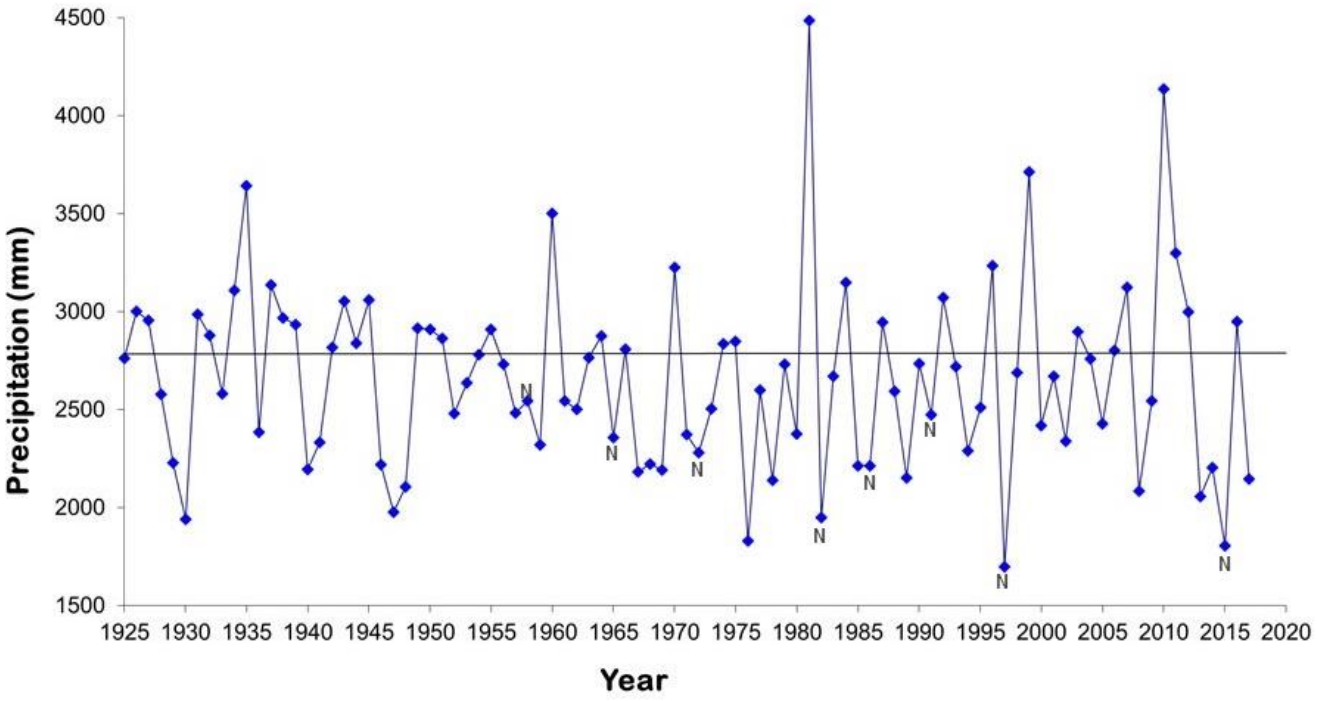

Figure 2. Annual rainfall totals, 1925 to 2017, Barro Colorado Island, located in the Canal watershed. Note the low rainfall years associated with the eight strongest El Niño events (marked with N) in from 1950 to 2015. [S. Paton, written communication, Smithsonian Tropical Research Institute]