The Walker circulation determines much of the tropical Indo-Pacific climate and has global impact as seen in the floods and droughts spawned by the El Niño-Southern Oscillation. Climate scientists, however, have been uncertain about the recent long-term trends of this important circulation, and projections of how it will respond to global warming have, therefore, remained unclear.

In the last IPRC Climate issue, IPRC’s Assistant Researcher Hiroki Tokinaga and his colleagues Shang-Ping Xie and Axel Timmermann at the IPRC and elsewhere provided firm evidence that the Walker circulation had slowed from 1950 to 2010, the trade winds weakening and rainfall shifting eastward toward the central Pacific. Their results were based on analyses of several data sets bias-corrected by Tokinaga.

The immediate cause of this slowdown, however, continued to puzzle climate scientists. They could not reproduce the weakening consistently in global atmospheric models, questioning the ability of climate models to simulate the observed gradual climate change.

At the root of the models’ failure, Tokinaga suspected, was the lack of precise sea surface temperature (SST) data used to drive the models. Such observations must show small east-west differences across the tropical Pacific. Differences in the order of 0.1°C can greatly affect wind and rainfall.

Over the 60-year period, the methods used to measure ocean temperature have evolved enormously. Until routine satellite monitoring of SST began in the 1980s, the observational record relied heavily on measurements taken from ships. Such ship records themselves were subject to spurious effects introduced by changing observational techniques. This makes it nearly impossible to have one continuous, unbiased record that goes back for so long.

Tokinaga, who is an expert in analyzing old, archived data sets and at

**Warming Sea Surface Couples with Weaker Walker Circulation**

Historical sampling devices from Folland and Parker (1995).

Polar Operational Environmental Satellite. Courtesy of NOAA.
correcting their biases, found two measures that have been taken from ships over the whole period: the bucket technique, in which the temperature is taken of sea water scooped up in a bucket lowered from a ship, and night-time marine air-temperature.

“Removing observational biases from these measurements was still challenging, but we saw that these quite different ways of measuring sea surface temperature turned out to agree very well over the 60-year span from 1950 to the end of 2009. The results were supported by subsurface ocean temperature observations,” explains Tokinaga.

Somewhat unexpected was that the two very different measurements revealed that SST did not rise evenly with global warming across the Indo-Pacific, but rather that the east-west temperature contrast has actually decreased by 0.3–0.4°C, a change similar to what happens during an El Niño.

For the experiments that follow, the bucket and the night-time air-temperature data sets were merged (MST).

Figure 1 shows SST changes from 1950 to 2009 across the Pacific in Tokinaga’s MST product and in two SST products (HadISST1 and ERSST3b) frequently used in climate change studies, as well as a spatially uniform SST increase (SUSI) of ~0.5°C over the 60 years.

Tokinaga’s team used these four SST products then to drive four widely used atmospheric models. The four-model ensemble-mean results are shown in the right panels of Figure 1. It can be seen that the unbiased, reconstructed surface temperature data set reproduces quite closely the observed patterns of climate change seen over the 60-year period in the tropical Indo-Pacific, including the slowdown of the Walker circulation (compare panels e and f). When HadISST1 was used, the Walker Circulation actually strengthened (Figure 1, right panel g), whereas when ERSST3b or a uniform rise in SST was used, there was virtually no change. (Figure 1, right panel h and i).

Consistent with the changes in surface wind convergence, observations show that precipitation and cloudiness...
have shifted from the Maritime Continent to the central tropical Pacific (Figures 2a-b). The MST-forced experiments simulate these patterns of cloud, precipitation, and surface wind changes quite well, albeit at reduced magnitudes (Figs. 2c-d). The simulated convection changes closely follow the spatial patterns of SST warming, consistent with the “warmer-get-wetter” mechanism and agree with climate model projections and satellite observations for the past three decades. The SUSI experiments (not shown), on the other hand, simulated increasing precipitation/cloudiness over the Maritime Continent, differing from observations.

“Our experiments show that the main driver of the change in the Walker circulation over the last six decades is the gradual change that has taken place in the surface temperature pattern toward a more El Niño-like state rather than the hydrological cycle response to uniform warming. We don’t have enough data yet to say to what degree the slowdown over the last 60 years is due to a rise in man-made greenhouse gases or to natural cycles in the climate,” explains Tokinaga.

“Short-term fluctuations in the strength of the Walker circulation happen every few years: during La Niña the circulation strengthens, during El Niño it weakens,” adds co-author Shang-Ping Xie. “The Walker circulation affects tropical convection, and the global impacts of a temporary slowdown during an El Niño are well known, resulting in extreme floods or droughts in North America and other regions of the world. How the gradual slowdown observed in this study impacts global climate still needs to be investigated.”

This story is based on

Figure 2. Changes over 60 years: in observed (a) cloudiness, surface wind (m/s per 60 years), and (b) in precipitation from ICOADS, WAS-Wind, and rain-gauges; in (c) and (d) MST-forced experiment. Stippling in (c) and (d) indicates regions of the MST warming trend above the tropical mean.