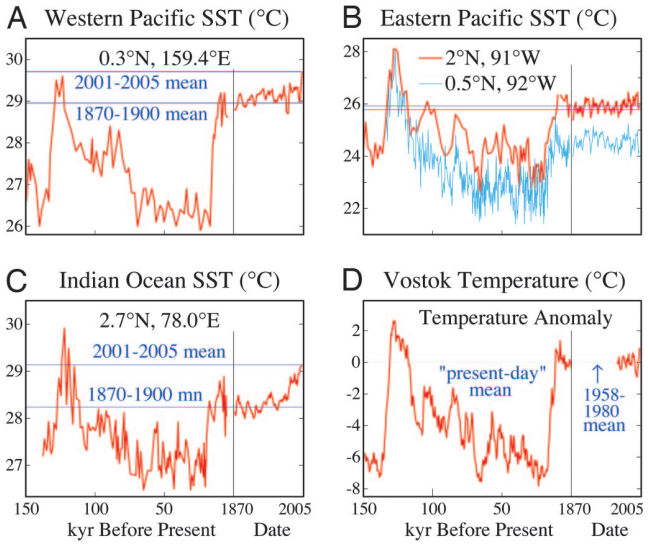

Fig. 4. Comparison of modern surface temperature measurements with paleoclimate proxy data in the WEP (28) (*A*), EEP (3, 30, 31) (*B*), Indian Ocean (40) (*C*), and Vostok Antarctica (41) (*D*).

contrast between WEP and EEP may remain large or increase in coming decades.

Thus, we suggest that the global warming effect on El Niños is analogous to an inferred global warming effect on tropical storms (27). The effect on frequency of either phenomenon is unclear, depending on many factors, but the intensity of the most powerful events is likely to increase as GHGs increase. In this case, slowing the growth rate of GHGs should diminish the probability of both super El Niños and the most intense tropical storms.

Estimating Dangerous Climate Change

Modern vs. Paleo Temperatures. Modern SST measurements (5, 6) are compared with proxy paleoclimate temperature (28) in the WEP (Ocean Drilling Program Hole 806B, 0°19′ N, 159°22′ E; site circled in Fig. 3*A*) in Fig. 4*A*. Modern data are from ships and buoys for 1870–1981 (6) and later from satellites (5). In concatenation of satellite and ship data, as shown in Fig. 8*A*, the satellite data are adjusted down slightly so that the 1982–1992 mean matches the mean ship data for that period.

The paleoclimate SST, based on Mg content of foraminifera shells, provides accuracy to ≈1°C (29). Thus we cannot be sure that we have precisely aligned the paleo and modern temperature scales. Accepting paleo and modern temperatures at face value implies a WEP 1870 SST in the middle of its Holocene range. Shifting the scale to align the 1870 SST with the lowest Holocene value raises the paleo curve by ≈0.5°C. Even in that case, the 2001–2005 WEP SST is at least as great as any Holocene proxy temperature at that location. Coarse temporal resolution of the Holocene data, ≈1,000 years, may mask brief warmer excursions, but cores with higher resolution (29) suggest that peak Holocene WEP SSTs were not more than ≈1°C warmer than in the late Holocene, before modern warming. It seems safe to assume that the SST will not decline this century, given continued increases of GHGs, so in a practical sense the WEP temperature is at or near its highest level in the Holocene. Fig. 5, including WEP data for the past 1.35 million years, shows that the current WEP SST is within ≈1°C of the warmest interglacials in that period.

The Tropical Pacific is a primary driver of the global atmosphere and ocean. The tropical Pacific atmosphere–ocean system is the main source of heat transported by both the Pacific and Atlantic Oceans (2). Heat and water vapor fluxes to the atmosphere in the Pacific also have a profound effect on the global atmosphere, as demonstrated by El Niño Southern Oscillation climate variations. As a result, warming of the Pacific has worldwide repercussions. Even distant local effects, such as thinning of ice shelves, are affected on decade-to-century time scales by subtropical Pacific waters that are subducted and mixed with Antarctic Intermediate Water and thus with the Antarctic Circumpolar Current.

The WEP exhibits little seasonal or interannual variability of SST, typically <1°C, so its temperature changes are likely to reflect large scale processes, such as GHG warming, as opposed to small scale processes, such as local upwelling. Thus, record Holocene WEP temperature suggests that global temperature may also be at its highest level. Correlation of local and global temperature change for 1880–2005 (Fig. 9, which is published as supporting information on the PNAS web site) confirms strong positive correlation of global and WEP temperatures, and an even stronger correlation of global and Indian Ocean temperatures.

The Indian Ocean, due to rapid warming in the past 3–4 decades, is now warmer than at any time in the Holocene, independent of any plausible shift of the modern temperature scale relative to the paleoclimate data (Fig. 4*C*). In contrast, the EEP (Fig. 4*B*) and perhaps Central Antarctica (Vostok, Fig. 4*D*) warmed less in the past century and are probably cooler than their Holocene peak values. However, as shown in Figs. 1*B* and 3*A*, those are exceptional regions. Most of the world and the global mean have warmed as much as the WEP and Indian Oceans. We infer that global temperature today is probably at or near its highest level in the Holocene.

Fig. 5 shows that recent warming of the WEP has brought its temperature within <1°C of its maximum in the past million years. There is strong evidence that the WEP SST during the penultimate interglacial period, marine isotope stage (MIS) 5e, exceeded the WEP SST in the Holocene by 1–2°C (30, 31). This evidence is consistent with data in Figs. 4 and 5 and with our conclusion that the Earth is now within ≈1°C of its maximum temperature in the past million years, because recent warming has lifted the current temperature out of the prior Holocene range.

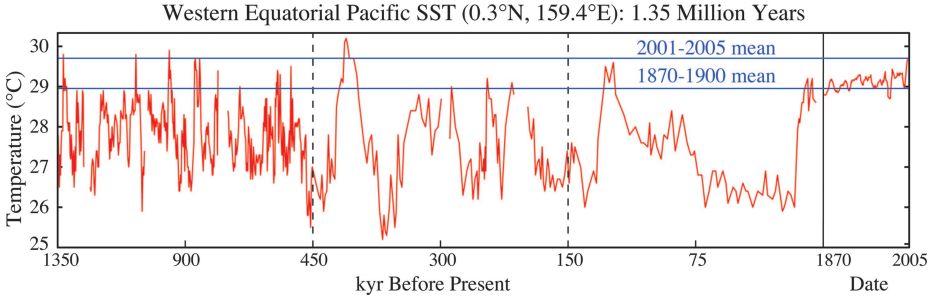

Fig. 5. Modern sea surface temperatures (5, 6) in the WEP compared with paleoclimate proxy data (28). Modern data are the 5-year running mean, while the paleoclimate data has a resolution of the order of 1,000 years.