Tropical SST controversy:

The CLIMAP group put together a picture of the Ice-age earth back in the 1970's (CLIMAP, 1976, 1981). One of the interesting features of this map was the SST in the tropics. In my book(Hartmann, 1994; Fig. 8.8, page 218). I show this SST difference superimposed on CLIMAP inferred land changes between August 20Kbp and August today. Big differences in SST appear at high latitudes, but small differences appear in the tropics and subtropics, and large regions are even shown with temperature increases during the ice age. Hawaii, in particular, sits in a region where SST is inferred to have increased. Prof. Steve Porter of Geological Sciences at UW has investigated the Hawaiian peaks (Mauna Kea) and inferred that snow lines were about 900 meters lower then than now(Porter 1979). Other information of this type is summarized in Rind and Peteet(1985, Rind 1990) and Broecker(1996), which indicates that snow lines were lower by the same amount over much of the tropics. Lowering snow lines seems inconsistent with rising SST because it requires big stability changes or big precipitation changes. With a fixed lapse rate, a 1km depression of the snowline implies about a 5˚C decrease in SST. Sun and Lindzen(1993) took these observations of small SST change and big upper tropospheric cooling and argued that the relative humidity of the tropical troposphere during the ice age should have been higher than at present, and offered this as evidence against positive water vapor feedback. Other evidence, of course, suggests that the tropics were drier during the glacial advances.

CLIMAP SST estimates are based on projecting modern plankton species/SST relationships onto the record of relative species abundances recorded in ocean sediment cores. It is asserted, but not proven, that the relationship between tropical species and SST remains constant over glacial time scales. An alternative is that the tropical species are more tolerant of SST variations than we think and that their abundances respond to other stimuli, such as the nutrient or trace metal content of the water, which currently is highly correlated with SST.

The first people on the block with an alternative to the fixed SST of the CLIMAP people were perhaps the Coral head people. They drill coral heads that are quite old and measure the Strontium/Calcium ratios over time. The Sr/Ca ratio is related to temperature empirically. With this methodology they inferred that tropical SST was 4-6C colder during the last ice age (Beck, et al. 1992, Guilderson, et al. 1994, Beck, et al. 1997, Guilderson and Schrag 1998, Guilderson and Schrag 1999). Some people from the UW (de Villiers, et al. 1995) show that these Sr/Ca paleotemperatures are uncertain by 2-3˚C, about half of the signal. Here's how they did it. When making the Sr/Ca paleotemperature estimates one must assume that:

1) The temperature affect on Sr/Ca dominates over biological controls on this time scale
2) the Sr/Ca content of sea water remained constant (recently it has been shown that the Sr/Ca content in the Pacific varies by 2% between 10N and 30S. This amounts to an uncertainty of 2-3C).

What de Villiers et al. did was to drill two cores in the same coral, one along a fast-growing radius and one along a slower growing radius. They showed that the uptake of Sr/Ca along these two transects was different. The slower-growing transects had higher Sr/Ca. The temperature difference would be 2-4C. They also found that the $\delta^{18}0$ along the slower-growing transect was enriched, calling into question whether $\delta^{18}0$ in shells also has a biological component unrelated to temperature or ocean water concentration. They went on to compare some coral heads from Hawaii with similar extension rates to see if the problem could be gotten around by sampling corals with similar extension rates. Again and uncertainty of 2-3˚C in the Sr/Ca-inferred temperatures was uncovered. A review of the coral work has recently been published (Gagan, et al. 2000).

Stute et al.(1995) looked at noble gases in ^{14}C-dated ground water in lowland Brazil and inferred a 5.4˚C cooling for the last ice age. The idea is that the solubility of noble gases in water is temperature-dependent and that once below ground their noble gas content remains fixed. So what is measured is the temperature when the water was last in equilibrium with air. The 5˚C difference inferred is consistent with the snowlines, pollen data and a lot of other records. This would mean that the tropical continents cooled by about the same amount as the midlatitudes up to 40N.

Thompson, et al.(1995) looked at oxygen isotope data from an ice core from a high altitude col in the Peruvian Andes. On the basis of $\delta^{18}O$ they concluded that the previous ice age was 5-6˚C colder than present, at least at the altitude of the glacier. They also inferred that it was warmer 8,400 to 5,200 years ago than at present. They see the Little Ice Age and a rapid warming for the last 200 years. The Thompson et al and Stute et al data, taken together, suggest that at least the tropical Atlantic region was about 5˚C colder during the last glacial maximum. This is much more consistent with dynamical reasoning, since current climate models have a hard time keeping the tropics warm while the rest of the planet cools by more than 5˚C. Models usually have the tropics and the midlatitudes changing by about the same amount, although polar regions can change a lot more at the surface than the tropics. A recent review of the tropical ice core work can be found in Thompson(2000). In a recent paper, Thompson, et al.(2000) review several long ice cores from the tropics spanning the last 25,000 years. They indicate that the tropics were cooler, but are somewhat fuzzy on the exact temperature difference because their records are not consistent. They suggest that the tropics were drier than present in the tropics, but wetter in the subtropics, indicating some kind of significant change in the circulation patterns. Nitrate in the cores suggest that the Amazon basis was less biologically productive during the ice ages.

Broecker(1997) has taken this more recent evidence and argued that the water vapor content of the tropical atmosphere had to be much less during glacial time. This would also be consistent with conventional climate theory. On the other hand, Crowley(2000) argues for smaller tropical SST changes on the order of a 2.5 degree cooling in the tropics, saying that a change of this order is consistent with climate model behavior and polar paleoclimate records.

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