growth rate of *T. jerichonana* reported herein (>30 cm $yr^{-1}$) also represents the highest growth rate reported for this species; the single published earlier estimate[5] which was based on a variety of assumptions, was 9.2 cm $yr^{-1}$. The only previous direct measurements of the growth of vestimentiferans were obtained from time-lapse camera studies of three individuals of *Ridgeia piscesae* inhabiting a hydrothermal vent field along the Juan de Fuca Ridge; incremental increases in tube length of the individuals ranged from 3.5 to 5.5 cm over 40 days (approximately 30–50 cm $yr^{-1}$)[3].

Since the discovery of deep-sea, hydrothermal vents in 1977, there has been a growing body of evidence that rates of certain biological processes may proceed relatively rapidly in these unusual environments[1-3,5,8]. The observations reported here provide dramatic, unambiguous evidence that rates of colonization and growth of vestimentiferan tube worms in these hydrothermal systems are extremely rapid. The *R. pachyptila* growth rates, as measured as an increase in length per unit time, are not only the fastest reported to date for any deep-sea organism, but they represent, to the best of our knowledge, the fastest rates of growth documented for any marine invertebrate[9]

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# Pleistocene temperature changes

SIR — Guilderson *et al.*[1] provided geochemical evidence that tropical sea surface temperatures (SSTs) in the western Atlantic may have been 5 ° C colder during the last ice age. This conclusion appears to reconcile a discrepancy between tropical upland changes of 5–6 °C (refs 2, 3) and CLIMAP[4] SST estimates of only a 1–2 °C change. However, if the results in ref. 1 are substantiated by further work, they may create as big a climate problem as they solve, for it would then be necessary to explain why tropical SST changes were so large. To illustrate this point, SST decreases resulting from various changes in forcing can be estimated. For example, glacial–interglacial ice-age trace-gas changes have a radiative forcing of about 2.6 W $m^{-2}$ (ref. 5). If we take the standard Intergovernmental Panel for Climate Change (IPCC) sensitivity estimates[6] for a $CO_2$ doubling (1.5–4.5 °C for a 4.2 W $m^{-2}$ increase) and apply those sensitivities to the ice age case, then the glacial–interglacial SST decrease due to trace gases should be 1.0–2.9 °C. A substantial fraction of this range arises from uncertainties in cloud parameterizations[7].

Model calculations indicate that ice sheets could cause an additional cooling of about 1.5 °C in the tropical Atlantic[8]. If the value for the ice sheet response in this model is scaled to the IPCC range, then cooling from ice sheets would be 1.0–2.9 °C in the tropical Atlantic. Although higher ice age dust loading could conceivably contribute another 2–3 °C decrease[9], the dust effect may have been overestimated by a factor of two to ten.[10] Applying a median overestimate of a factor of five to Harvey's[9] dust calculation yields a revised cooling estimate from dust of about 0.5 °C.

The combined potential SST response to the above changes is 2.5–6.3 °C in the tropical Atlantic. This estimate does not consider additional uncertainties due to the ocean adjustment to changes in Atlantic deep- and intermediate water production[11]. Nor does it consider the possibility of a smaller temperature response to ice sheet changes if high dust levels significantly lowered the albedo of the ice sheets[12]. The potential effects of these changes on the tropical Atlantic is difficult to determine. The most that can be stated at present is that it is not inconceivable that the new geochemical estimates of Atlantic tropical SST changes are out of line with expectations. However, the results would seem to be more in line with sensitivity on the high side of the IPCC range.

Reconciling changes in the western tropical Pacific are more troublesome than for the western Atlantic. Snowline depressions are the same as they are elsewhere in the tropics[2,3] and preliminary geochemical results also suggest large late-glacial depressions in SSTs in this region [13,14]. Yet cooling from ice sheets, dust and ocean circulation changes should have been significantly less than in the western Atlantic. Thus, SST decreases in the western Pacific comparable to the Atlantic should primarily reflect ice age trace gas changes (1.0–2.9 °C). These values may be overestimates of the expected cooling, because tropical sensitivities are less than the global IPCC sensitivities used here. Lapse rate considerations might allow for somewhat larger temperature depressions with height, but it seems unlikely that the snowline data can be reconciled with surface temperature changes less than about 2.5–3.0 °C.

The above reasoning implies that it may be necessary to invoke relatively high climate sensitivities to explain ice age tropical SST changes, especially in regions far removed from the ice sheets. The implied sensitivity could be as high as 4.5 °C for $CO_2$ doubling. Such sensitivities are not necessarily out of line with the observed increase of global temperatures in the last century of only 0.5–0.6 °C (ref. 15), because aerosols may be masking the effect of the $CO_2$ perturbation[16]. But the ice-age data nevertheless suggest that, hidden within the apparent agreement between observed and computed global warming trends, the climate sensitivity may be quite high. If true, such a sensi tivity could be dramatically manifested if aerosol production were to decrease[17].

These calculations assume that the Guilderson *et al.* results are correct. Although some other data support such conclusions[13,14,18], repeated efforts at further validating CLIMAP transfer functions[19,20] continue to reinforce the original CLIMAP conclusions. It now seems that clarification of ice age tropical SST changes is important not only for understanding past climates but also for better constraining predictions for the future.

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