tions menu item, pages titled "Basic Research Remains Vital" and "The Development of Lasers and Fiber-Optics—A Chronology of Selected Events." Those state that Southampton University and Bell Labs discovered and developed "practical and effective" EDFAs.

Reference

1. N. Savage, *IEEE Spectrum* **38** (June 2001), p. 43.

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More Heat Over Greenhouse Gases

The article "Warming Oceans Appear Linked to Atmospheric Greenhouse Gases" (PHYSICS TODAY, June 2001, page 19) prompted a comment from Robert C. Whitten (PHYSICS TODAY, December 2001, page 12). He stated "how the mean atmospheric temperature can remain essentially constant while warming the oceans is never explained." In her response to Whitten, Barbara Goss Levi tells us that "additional greenhouse gases added to Earth's atmosphere absorb infrared radiation emitted by Earth's surface and reradiate part of it to the surface. This radiation can warm the surface directly without warming the atmosphere first." This reasoning is flawed for two reasons.

First, that the additional greenhouse gases absorb additional radiation from Earth's surface implies that warming will obviously occur where the additional gases are located, assuming they are at a lower temperature than Earth's surface. This assumption will normally be satisfied. Indeed, the original article by Levi states, "If the trapped infrared radiation is heating the atmosphere, we might expect it to be warming the world's oceans as well." While this statement is correct, the response to Whitten contradicts it.

Second, if we were to accept the erroneous explanation that reradiation from the greenhouse gases warmed only the ocean surface, then we would have difficulty explaining why this warmer ocean did not transfer some of the added heat to the surface air layer in contact with the ocean, thereby warming the atmosphere. It is well known that air passing over the ocean rapidly reaches thermal equilibrium with the water surface, and surface air temperatures normally maintain a value very nearly that of the ocean surface. This warming of the surface air would, in turn, be distributed upward, probably in a period of days, certainly not years, resulting in a mean temperature above what it would be without the greenhouse gases. Thus, in either scenario, a net warming of the troposphere would result. We thus conclude that there is no way that the ocean surface can warm without a resulting warming of the overlying atmosphere.

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In the December issue of PHYSICS TODAY (page 12), Robert Whitten takes Barbara Goss Levi to task concerning her article about greenhouse gases. However, I am not convinced that Levi's response gets to the nub of the problem. Whitten's question about "how the mean atmospheric temperature can remain essentially constant while warming the oceans," touches on some very basic physics. The question can best be addressed in the context of a simplified, globally-averaged model of Earth's atmosphere that one finds in texts on meteorology and climate. See, for example, chapter 1 of J. T. Houghton's *The Physics of Atmospheres* (Cambridge U. Press, 1986), in which Earth is treated as a "gray" spherical body with uniform radiant properties, immersed in a beam of solar plane waves.

First, the mean planetary radiant temperature of about 255 K must remain approximately constant, independent of any altered greenhouse emissions, if one assumes that the planetary reflection coefficient, emissivity coefficient, and solar constant all remain unchanged. (These assumptions can be relaxed, but that would only cloud the issue). This model reflects the steady state achieved in the power balance between the constant incoming short-wave radiation from the Sun and the constant outgoing long-wave infrared terrestrial radiation. A temperature of 255 K corresponds to a height of some 5 km in the atmosphere; but