pursuit of expanding the frontiers of knowledge.

Nick Tufillaro
(nick@gybe.eco)
Gybe
Portland, Oregon

Earth's radiative balance

In the July 2022 issue of Physics Today, Martin Singh and Morgan O'Neill address the thermodynamics of Earth's climate system (page 30). Their statement that "the climate system is close to an energy balance at all times" is true, but only if energy has been redistributed by Earth's fluid systems, oceans, and atmosphere. Their following sentence, which states that "terrestrial radiation is emitted to space at approximately the same rate at which solar energy is absorbed," is ambiguous and does not apply locally or instantaneously.

The radiant heat balance of the atmosphere, oceans, and surface of the planet depends on Earth's absorption of short-wave radiation from the Sun, long-wave emissions into space, and reflections of short-wave radiation from Earth's surface and atmosphere.

The atmosphere absorbs less than 20% of incident solar beams. Reflection and scattering from the atmosphere and Earth's surface cause 30% of the solar beams to be lost to space. The remaining 50% of the Sun's energy is unequally distributed across the planet's surface. Between the latitudes of 40° N and 40° S, more energy is received annually from the Sun than is lost to space. Poleward of those latitudes, more energy is lost to space than received from the Sun. If that imbalance were not redressed by heat transported by the atmosphere and oceans, the high latitudes would turn into a block of ice and the tropical latitudes would become unsustainably hot.[1]

For the polar regions of heat deficit to be redressed, they must draw on the tropical regions of excess heat. Approximately 30% of the excess is transferred from the tropics to the polar regions by the oceans.[2] The remaining 70% must be transferred to the poles by the atmosphere to achieve the climatic equilibriums of Earth's temperatures. Surface winds in the tropical regions of excess heat, however, are directed toward the regions of excess. Heat transport from the "warm" tropics must therefore occur at altitude rather than at the surface.

In considering the vertical motion of hot, moist tropical air, a useful, adiabatically conserved quantity is the equivalent potential temperature, which can be defined as the temperature that a parcel of air would have if all water were condensed at constant pressure and the entropy released from the sample to heat the atmosphere.[3]

A midtropospheric minimum in the vertical profile of the equivalent potential temperature prevents simple mixing from transferring surface heat to the upper levels of the troposphere. To affect that transport, protected vertical transport channels, referred to as hot towers,[2] penetrate the midtropospheric temperature minimum, and the various components of the atmospheric general circulation allow energy to reach the polar region's upper troposphere.[4]

The set of thermodynamic interactions between Earth and the Sun can be explained in quantitative detail. In fact, the complex of scales of motion that governs the radiative relationships is manifested in Earth's climate. Besides climate issues, researchers have only recently begun studying those various scales for their use by birds and perhaps other animals.[5] Cause and effect of such factors challenge predictability.

References

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Michael Garstang
(mxg@swa.com)
University of Virginia
Charlottesville
Robert G. Ellingson
(rellingson@admin.fsu.edu)
Florida State University
Tallahassee PT