Unifying Physics Theory Predicts Global Climate Patterns In Simple Way

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A unifying physics principle that describes design in nature predicts, in surprisingly straightforward fashion, the basic features of global circulation and climate, according to researchers at Duke University's Pratt School of Engineering and the University of Evora in Portugal. They said the new approach to climate may have important implications for forecasting environmental change.

The researchers found that the "constructal theory" can predict the global circulation that determines the boundaries between desert and tropical forests as well as between temperate zones and the poles. Based only on the optimal flow of heat from the sun, the theory also predicts other climate characteristics, such as average wind speed and the average temperature difference between night and day.

The findings may lead to a new understanding of the factors that drive global circulation patterns of the atmosphere and ocean, the researchers said. The theory might also prove useful for predicting the consequences of environmental change -- such as shifts in the atmospheric concentrations of greenhouse gases -- for broad weather patterns, they said.

The team, including Professor Adrian Bejan, of Duke's Pratt School, who first developed constructal theory, reports its findings in a forthcoming issue of the *International Journal of Heat and Mass Transfer* (available online Jan. 19, 2006).

Constructal theory is founded on the principle that configurations evolve in time so as to optimize the flow of matter or energy. The theory has been applied previously in many arenas, including the internal structure of the lungs, river currents, and animal locomotion.

“We now demonstrate that the constructal theory of organization in nature predicts many characteristics of global circulation -- the grandest of all flow systems on Earth,” said Bejan.

“While other very complicated empirical models predict the same basic features, constructal theory does this in a much simpler way,” said geophysicist A. Heitor Reis of the University of Evora. “This is an entirely new kind of approach to climate.”

Atmospheric circulation is the large-scale movement of air that distributes heat on the surface of the Earth, the researchers explained. These flows develop as air and water moves from hot to cold regions, a result of variation in the heating of the Earth’s surface by the sun.

Atmospheric circulation is characterized by three distinct bands, or convection cells, known as the equatorial Hadley cell, the Ferrel cell and the Polar cell, which drive wind and other air currents.

Despite annual and daily variation in weather patterns, the basic climate conditions in a particular region remain fairly constant over periods on the order of 30 years, Reis said. It is the boundaries between the planet’s three-tiered global circulation that determines climate patterns and the location of biotic communities, such as deserts, forests and grasslands.

To apply the constructal theory to global climate, the researchers treated Earth as if it were a heat engine that, rather than doing work, dissipates all the power it produces through air and water currents.

“The Earth with its solar heat input, heat rejection, and wheels of atmospheric and oceanic circulation, is a heat engine without shaft,” Bejan said. “Its maximized mechanical power cannot be delivered, but is instead destined to dissipate through air and water friction and other forms of heat loss. It produces maximum power, which it then dissipates at a maximum rate.”

By applying this analogy, the researchers predicted the main characteristics of global circulation and climate based on very few inputs – namely the temperature of the sun, the solar constant, cloud cover and the Earth’s greenhouse factor. The solar constant refers to the amount of incoming solar radiation measured on the outer surface of Earth's atmosphere. The greenhouse factor takes into account the concentrations of aerosols and greenhouse gases to determine the amount of heat energy trapped by the atmosphere.

“To my surprise, a simple theory anticipates the latitudinal boundaries of the three zones – the Hadley, Ferrel and Polar cells – which comprise the main global circulation on Earth,” Reis said. The theory also predicted the average speed of atmospheric and oceanic flow and the average temperature on Earth, among other climate features, they reported.

A second version of the theory on the daily scale, which included the speed of Earth’s rotation, also predicted the average difference in temperatures between night and day.

The findings may change the understanding of the factors that drive climate patterns. For example, scientists have thought that the circulation zones arise due in part to the rotation of Earth, the researchers said.

“We cast doubt on this idea by showing that the circulation patterns can arise based solely on the optimal structure of global heat flow,” Reis said.

The new climate theory may also aid in predicting the consequences of global change, the researchers said.

“If the properties of the atmosphere change as people say they will, we could anticipate what that might mean for global climate,” Bejan said.

“By playing with the Earth’s greenhouse factor, we could determine what it would take to get another result,” Reis added.

The findings, along with earlier applications of constructal theory, also add support for the theory’s general relevance to natural phenomena. “The accumulation of coincidences between theoretical predictions and natural facts adds weight to the claim that the constructal law is a law of nature,” Bejan said.

Source: Duke University