Earth Sciences

Advice on global change studies

In a report released last month, a panel of prominent earth scientists largely gives thumbs up to the Bush administration's research program on global change. But the report also highlights some problem areas that could hamper future efforts to understand and predict global warming, stratospheric ozone depletion and other environmental threats.

In general, the report concludes that the program is heading in the right direction, says panel member D. James Baker Jr. of the Joint Oceanographic Institutions, Inc., in Washington, D.C.

The panel of outside experts, assembled by the National Research Council, focuses many of its recommendations on NASA's proposed Earth Observing System (EOS), a group of satellite-borne instruments designed to monitor Earth's vital signs for 15 years starting in 1998. NASA plans to launch two large orbiting platforms that would hold about a dozen instruments each. Platforms and instruments would be replaced with identical models every five years.

The panelists recommend that NASA rethink its EOS plans. They agree that one of the platforms is necessary because several EOS instruments must observe Earth simultaneously from the same point in orbit. But they suggest that the remaining instruments could fly separately on a sequence of smaller satellites. This might allow NASA to launch some of the instruments sooner than would be possible with one large platform, they say. Moreover, putting these "eggs" in several different "baskets" would safeguard against losing them all in the event of some mishap — a concern that seems all the more real after NASA's mechanical problems this summer.

The report also stresses that EOS should not take precedence over some smaller but critical instruments planned for launch in the next few years to make important global measurements. "If budgetary constraints arise, it would be more desirable to delay the launch of EOS spacecraft than to forego or diminish the effectiveness of near-term missions," the report states.

Volcanic warming during dinosaur days

While many geoscientists think a meteorite impact caused the mass extinctions at the end of the Cretaceous period some 65 million years ago, some argue that an extraordinary set of volcanic eruptions in India did the dirty deed. According to one theory, the volcanoes belched out enough carbon dioxide to raise the planet's temperature significantly via the greenhouse effect. But two researchers who tested this hypothesis now conclude that the ancient eruptions would have warmed Earth only weakly.

Computer simulations of Earth's carbon cycle suggest the eruptions slowly raised global mean temperatures by a maximum of about 0.8°C over several hundred thousand years, report Ken Caldeira and Michael R. Rampino of New York University in the August Geophysical Research Letters. In contrast, the world now faces the threat of a 3°C warming by the end of the next century due to fossil-fuel burning and deforestation, according to a recent report by an international panel of scientists (SN: 6/23/90, p.391).

Caldeira and Rampino's simulations suggest that over thousands of years, Earth's climate system limited carbon dioxide buildup in the atmosphere. At first, the rising levels of the gas elevated temperatures and rainfall rates, stimulating the growth of land plants. Eventually, these effects forced the oceans to absorb much of the carbon dioxide from the eruptions, keeping temperatures down.

The researchers conclude that the species extinctions at the end of the Cretaceous did not stem from a greenhouse warming caused by volcanic eruptions. But that doesn't absolve the eruptions entirely. Other scientists have proposed that sulfur from the volcanoes could have dramatically *cooled* the planet.

Physics

Time travel, quantum-style

The boundary between science fiction and theoretical physics sometimes gets fuzzy, especially when quantum theory is invoked. The latest apparent border-crossing offers the prospect of a "quantum time-translation machine" — a device capable of moving an event to a different position in time.

The secret of the machine's operation lies in a novel interpretation of the equations governing quantum mechanics. Physicist Yakir Aharonov of the University of South Carolina in Columbia and his collaborators start with a fundamental quantum-mechanical feature called superposition, which expresses the idea of combining a suitable set of "elementary" physical situations to describe a quantum system's physical state — somewhat analogous to overlapping photographic images to create a composite picture. Such superpositions, when applied to the way a quantum system evolves over time, "may lead to unusual consequences," the researchers state in the June 18 Physical Review Letters.

Aharonov and his colleagues initially apply the superposition principle to physical forces, described by mathematical constructs known as hamiltonians. In a system in which an external control sets the force, they arrange for a superposition of all the situations arising from different force settings. That's equivalent to taking a weighted average of all the possible forces. Because of the way this quantum-mechanical averaging works, the resulting average may occasionally be far larger than the individual forces involved. In that situation, the action of a number of weak forces would correspond to the action of a single, strong force, furnishing a new, quantum-mechanical route for amplifying forces.

Time enters the picture because the strength of a force, as expressed in a hamiltonian, is directly related to the time it takes to produce a given effect. In other words, doubling the hamiltonian has the same net effect as doubling the period of time for which it operates. Thus, the superposition concept used for forces also applies to time. By superposing a number of situations in which different periods of time have elapsed, one could obtain the effect of a passage of time longer than in any of the original situations — in effect, taking the system into the future. Or, if the superposition produces a negative time, one could move into the past.

To achieve such an effect, one needs to produce a number of coexisting situations in which a given force is allowed to operate for different times. Aharonov's group solves the problem by appealing to the general theory of relativity, in which the time elapsed for an observer in a particular place depends on the strength of the local gravitational field. One can control the passage of time by controlling the gravitational potential, perhaps by enclosing the system in a massive spherical shell and then altering the shell's radius.

Could one construct such a time-translation machine? Aharonov and his colleagues concede that their machine would work only rarely because it relies on the random processes of quantum mechanics to produce the required superposition state. Furthermore, such a superposition state has never been produced on the scale required for a time-translation machine.

In the Aug. 23 Nature, mathematician Tony Sudbery of the University of York in England notes that quantum systems develop over time in two distinct ways. "There is the natural development which happens if the system is left undisturbed, and there are the quantum jumps which occur at a measurement, representing the inevitable disturbance caused by observation," he writes. "The proposed machine takes the system into what would be the future (or the past) if only the first of these [evolutionary paths] was operating." That would put a time traveler in a time frame quite different from the actual future or past we experience.