CLIMATE MODELLING

Climate modelling uses mathematics and principles of physics to produce numerical expressions and solutions for energy, mass, and momentum processes and characterizations for the atmosphere, oceans, land surface, and the cryosphere (snow/ice sheets/glaciers). These solutions are formed for global and regional scales to depict climate processes and typically solve the full equations for fluid motion on a spherical Earth. Models range from treating the Earth as a point to detailed Earth–atmospheric three-dimensional representation (see GENERAL CIRCULATION MODELS). A point model of Earth's radiation budget, for example, may involve using the well-known Stefan–Boltzmann law to calculate the radiative temperature, *T*, of Earth, by assuming *S* (the solar constant – the incoming solar radiation per unit area – about 1367 $W\,m^{-2}$), α (the Earth's average albedo, approximately 0.37 to 0.39), *r* is the radius of the Earth, and σ is the Stefan–Boltzmann constant – approximately 5.67×10^{-8} $J\,K^{-4}\,m^{-2}\,s^{-1}$ (J = Joule, K = degrees Kelvin, m = meter, s = second). This modelling relies on the principle of conservation of energy between incoming solar radiation and energy emission from the Earth by this simple equation:

$$(1\text{-}\alpha)S\pi r^2 = 4\pi r^2\sigma T^4$$

S shines to the cross-sectional area of Earth represented by πr^2; the spherical area of the entire Earth, $4\pi r^2$, emits at *T* – note in the equation both sides contain πr^2 and thus cancel out.

This yields a value of 246 – 248 °K or about -27 to –25 °C — for the Earth's average radiative temperature *T*. This is approximately 35 °K colder than the average observed surface temperature of 282 °K. This is because the above model represents the radiative temperature of the Earth with no blanketing atmosphere. The difference between this cold radiative temperature and the warmer surface temperature is the existence of the atmosphere's natural greenhouse warming effect. A radiative-convective model (RCM) simplifies the atmosphere by two energy transfer processes – up and down radiative transfer through atmospheric layers as well as vertical transport of heat by convection (especially important in the lower troposphere). The RCMs have advantages over the simple model above – they can resolve the radiative exchanges that impact the surface temperature, and the effects of varying greenhouse gas concentrations on the surface temperature. A zero-dimensional model may be expanded to estimate energy transported horizontally in the atmosphere. This kind of model typically is zonally averaged. The model also has the advantage of allowing a dependence of albedo on temperature – the poles can be allowed to be frozen and the equator warm. Depending on the nature of questions asked and the associated time scales, there are conceptual, more inductive models; and, general circulation models operating at the highest spatial and temporal resolution currently possible.

See also: ATMOSPHERIC SCIENCES, ENERGY FLUX, ENERGY AND MASS BALANCE

Further reading

IPPC Climate Change, 2001. *Working Group I: The Scientific Basis 8. Model Evaluation*. IPCC Secretariat, Geneva.

Hanse, *et al.* at http://pubs.giss.nasa.gov/abstracts/submitted/Hansen_etal_2.html

Intergovernmental Panel on Climate Change, WMO/UNEP at http://www.ipcc.ch/

Rennó, N.O., Emanuel, K.A. and Stone. P.H., 1994. Radiative–convective model with an explicit hydrologic cycle. 1. Formulation and sensitivity to model parameters. *Journal of Geophysical Research,* 99, No. D7, 14429–14442.

COST-BENEFIT ANALYSIS (CBA)

Most human actions involve an intuitive calculation, often unconscious, of the costs and benefits of a particular activity. Shall I kill this small animal, with a lot of noise, or shall I wait in case a bigger meal comes along, albeit without any certainty? With the coming of industrialization and the chance to commit large amounts of private or public finance, and the very real likelihood of causing environmental damage, a method of systematizing the likely cost of a project and the return from it was needed. The result was CBA. The process involves monetary value of initial and ongoing expenses versus expected return. Constructing credible measures of the costs and benefits of specific actions is often very difficult. In practice, analysts try to estimate costs and benefits either by using survey methods or by drawing inferences from market behaviour. because of the timescale over which a project is expected to last, all the costs must be put on a single time-horizon. Cost-benefit analysis attempts to put all relevant costs and benefits on a common temporal footing. A discount rate is chosen, which is then used to compute all relevant future costs and benefits in present-value terms. This is all much more difficult where the environment is concerned. Putting a monetary value on the return of a commercial crop is possible, but on a much-loved view, or the amenity value of a stand of trees, is very difficult and subject to many controversies. The flow of future benefits is also difficult to deal with; in an era of rapid technological change any development may be rendered obsolete well before its expected expiry date in the CBA. In general, CBA is best used as one of a number of tools in a decision-making process but not allowed to determine the outcome by itself. Like computers, it is susceptible to the GIGO principle.

See also: CULTURES, ENVIRONMENTAL VALUES, ENVIRONMENTAL LAW