ROYAL METEOROLOGICAL SOCIETY: AUSTRALIAN BRANCH MEETING

28 August 1980

Thermodynamic Dissipation and the Global Climate System

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As every on-the-bench forecaster and every atmospheric modeller knows, the atmosphere is not a linear system; the whole earth-atmosphere-ocean system is in fact highly non-linear, and we do not even have fixed boundary conditions to help us deal with that system or any part of it. Dr Paltridge emphasised these forbidding facts at the start of his address, in pointing out that the thermodynamics of linear systems are inapplicable to the earth. In marked contrast to what might be expected from linear theory, the climate of the earth seems to have adopted a format of maximum thermodynamic dissipation.

Dr Paltridge has formulated a new type of energy balance model that constructs a steady state thermal distribution for the globe's oceans and atmosphere for which thermodynamic dissipation is a maximum (i.e. minimum entropy exchange). The 'predicted' temperature distribution from the model is close to the observed climatic mean. Of course, the steady state attained is an annual mean from an energy input corresponding to perpetual annual mean conditions. However, the atmosphere is not in true steady state (only in a statistical sense), because of the large seasonal variations that contribute to the annual mean.

The seasonal extremes may be investigated by applying perpetual January or perpetual July boundary conditions to the model. When this is done, the latitudinal temperature distributions that result are very different from the observed seasonal states. In fact, the winter hemisphere is much colder and the summer hemisphere much warmer than observed. Why? Because the seasonal forcing occurs more rapidly than the time constants associated with the thermal inertia of the various regions of the earth. Using the observed annual temperature range for each latitude, and the difference between observed seasonal climatic temperatures and model-derived 'perpetual season' temperatures, a time constant for each latitude zone can be derived. This time constant applies to seasonal change and Dr Paltridge calculates values of about 9 months in the northern hemisphere (30°N) to a maximum of about 5 years at 50°S*.

An interpretation of these results would be: if extreme seasonal radiation conditions were to apply continuously to the real atmosphere for 5 years or longer, then the real atmosphere would have temperatures close to Dr Paltridge's model at 50°S. The results also imply that the northern hemisphere responds about 6 to 7 times more rapidly than the southern

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* These values represent the seasonal thermal inertia of the atmosphere, but do not include a component for melting winter snow since albedos are fixed.

hemisphere to seasonal forcing, presumably refelecting to a large extent its far greater continentality.

Question time, following Dr Paltridge's talk, was lively and directed mainly towards the model details, its applicability, and the problem of uniqueness of the model's derived steady state. Several questions centred around the selection of an extremum principle appropriate to the broad format of global climate. Dr Paltridge has tried many others without success, and while the chosen principle has not been proved unique, it fits closely with the ideas of Dutton and Lorensz, and has shown success in predicting the mean climate state, so perhaps another equally successful extremum principle would be difficult to find. One member of the audience suggested that the theory should be tested for Mars where difference geometrical constraints apply.

Could the model be used to simulate or predict an ice age? Dr Paltridge pointed out that in general, if the model climate is forced away from its steady state, it will usually revert back to that steady state. If the surface of the model earth is completely iced over, to test an extreme ice age position, the model reverts to present steady state, unless the energy input from the sun is reduced by 20 per cent. This is unlike the Sellers-type climate models that can maintain a completely iced-over earth steady state via strong albedo feedback.

M.E.V.