PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Preface to Vegetation–climate–atmosphere interactions: past, present and future, the proceedings of a Discussion Meeting held at the Royal Society

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Preface

The global distribution of plants is largely controlled by climate, but the vegetation cover changes the albedo of the Earth's surface, and exchanges carbon dioxide, oxygen and water vapour with the atmosphere, so influencing climate. This interaction between climate and vegetation has been a significant feature of the geosphere–biosphere system since the land surface was colonized by vascular plants, some 400 million years ago. Even before this 'greening of the land', various feedback pathways existed allowing biotic systems to influence their abiotic environment. The gas and water vapour exchange is regulated primarily by the stomatal pores on leaf surfaces and their response to the boundary layer meteorological conditions. But the growth habit of the plant and the spatial and seasonal distribution of leaf cover also have an effect on the character of the exchange of materials between plants and the environment, and hence on the energy balance between the land surface and the atmosphere.

The realization that the atmospheric CO_2 concentration is rising and the recognition of its influence on global climate has heightened interest in vegetation–climate–atmosphere interactions. Much laboratory and field work has focused on plant–atmosphere interactions at the single plant and community level. The need to understand the impact of these processes at the global scale has in turn stimulated the construction of computer models, simulating the functioning of the Earth's climate, oceans and terrestrial biosphere. The nature of this research requires an interdisciplinary approach, and one of the aims of this meeting was to bring scientists from these different disciplines together for informed debate. One ultimate goal of this research is to integrate climate, ocean and vegetation models to arrive at a so called 'Earth system' model. This would not only effectively simulate the complete range of atmospheric, climatic and biogeochemical processes, but would offer a basis for predicting the impact of anthropogenic perturbations.

There is ample evidence that the proportion of atmospheric oxygen and CO_2 has undergone major changes through the course of geological history, as has the pattern of global climate. Although the details of these changes are still the subject of lively debate, the past record of the vegetation–climate–atmosphere feedback system is still an important means of testing the validity of the ocean, climate and biosphere models. This is not to say that ancient climates can be invoked as analogues for a future 'greenhouse' world since a future climate response will have a significant non-equilibrium component very different from the long-term average picture of past warm periods.

The contributions in this volume deal with several key aspects of the vegetation–climate–atmosphere interaction on different time scales and from different standpoints. The opening paper by Hayden reviews the problems in trying to scale up from the community to the global processes of ecosystem feedbacks. Raven considers the interaction of biotic and abiotic systems over some 3.4 billion years, and this theme is continued into the impact of terrestrial vegetation in Palaeozoic time by Edwards. The weathering of silicates in terrestrial soil profiles is an important route carrying atmospheric CO_2 as bicarbonate into the oceans. When it is then precipitated as biogenic carbonate sediment on the ocean floor, this effectively removes the carbon from the year-to-year carbon cycle, until it is recycled into the atmosphere by volcanic activity, on a time scale of tens of millions of years, following subduction of the ocean plate on which it was deposited. Living organisms are involved in two stages even in this process, since terrestrial vegetation plays a key role in the depth of weathering. Different aspects of this weathering pathway of carbon are described by Algeo & Scheckler, who consider how this mechanism has changed through the course of land-plant evolution. Berner uses a global carbon-cycle model in combination with various physical and biological records through the Phanerozoic to quantify the changes in atmospheric CO_2 through time. The other half of the equation, consisting of the role of marine biota in ocean–atmosphere feedbacks, is covered in the papers by Watson & Liss and Claussen; the latter suggests from a modelling standpoint that the climate in the present Sahel region of Africa could have flipped between distinct and very different states within the Holocene. The possible role of historical changes in atmospheric CO_2 in mediating changes in vegetation communities is investigated by Cerling using variations in the isotopic composition of fossil herbivore teeth over the past ten million years.

Berner's quantitative record is tested by the work of McElwain on fossil leaves, in which the stomatal density gives a proxy record of atmospheric CO_2 levels. This stomatal record shows remarkable agreement in tracking the major excursions of CO_2 levels shown in Berner's model. A different proxy record is contained in the growth rings of trees, which constitute a 'natural database' of past climate. Briffa reviews the problematic story represented by the thousands of years of overlapping tree-ring chronologies. There appears to be a significant increase in tree growth over recent centuries, but there are still problems in separating the effect of climate, rising CO_2 and nitrogen fertilization from atmospheric 'pollution'. The use of climate and vegetation models to predict how vegetation will respond to future increases in atmospheric CO_2 concentrations is considered by Woodward *et al.*, who go on to deal with the possible influence that this may have on the rate at which CO_2 continues to accumulate in the atmosphere. The bringing together of climate and vegetation models, past climates and the fossil record is considered in two papers. One, by Upchurch *et al.*, considers the ability of models to simulate climates in the 'greenhouse world' of the Cretaceous and the other, by Beerling *et al.*, who investigate the effect of high O_2 concentrations in the late Carboniferous on vegetation function.

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