tion that anthropogenic aerosols will, in fact, cause a global heating. We cannot pass judgment on that. The point of our note was to show that an anthropogenic increase in CCN, one component of the aerosol which is not even well monitored on a global basis at present, could cause a global cooling. It is possible for the (non CCN) aerosol to cause a net surface heating if the ratio of aerosol absorption to extinction is high enough. But a recent determination with spectrophone techniques (Foot, 1979) indicates that this ratio may be sufficiently small (0.8–2.5%), even for aerosol in which smoke was a major contribution, for cloudless aerosol cooling (scattering) effects to dominate heating (absorption) effects. Present uncertainties regarding both the imaginary indices of refraction and shape effects of atmospheric aerosols makes it difficult to judge whether aerosols cause a net cooling or heating of the globe (Pollack and Cuzzi, 1980).

While aerosol effects on climate are complex, we feel that Charlock and Sellers (1980a) clearly point to the importance of one aspect of the problem, that of CCN effects on radiation, with a quantitative estimate. CCN are a small fraction of the total aerosol mass, but their optical effects are fairly large. Before the last word on the climatic effect of aerosols is given, there must be a global monitoring of CCN.

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Comments on "Seasonal Simulation as a Test for Uncertainties in the Parameterization of a Budyko-Sellers Zonal Climate Model."

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The lively exchange of ideas concerning heat-transport parameterizations in energy balance models (EBM's) has been with us since the pioneering papers of Budyko (1969) and Sellers (1969). It was recently rekindled by Warren and Schneider (1979, 1980) and by Lindzen and Farrell (1977, 1980).

One of the issues central to the exchange, at least as reflected in these four recent contributions, is how well do linear parameterizations of meridional heat transport, diffusive (Sellers) or of the Newtonian-cooling type (Budyko), simulate observed, zonally averaged climatic features—surface air temperatures and meridional fluxes. I would like to submit that mean annual meridional profiles of temperature can be simulated perfectly (Fig. 1, after Ghil, 1976), and heat fluxes reasonably well (Ghil, 1976, Fig. 3b) by eddy diffusive EBM's; this simulation is, if at all, rather better than the one with Newtonian-cooling EBM's (Warren and Schneider, 1979).

Good simulations of observed mean quantities can be easily achieved with EBM's when allowing for latitude-dependent meridional transport coefficients, as suggested by Lindzen and Farrell (1977, 1980), and for latitude-dependent albedo parameterization, as suggested by Warren and Schneider (1979, 1980). Both latitude dependences were already present in the Sellers (1969) model, although not in Budyko's (1969). Good simulation, however, is in my opinion somewhat beside the point.

The simplicity of EBM's makes them ideally suited for studying *qualitatively* physical mechanisms affecting long-term climate changes (Schneider and Dickinson, 1974; Ghil, 1981a,b) and the interaction of these mechanisms. It also precludes EBM's, in general, from being very accurate or reliable in simulating *quantitatively* observed climate or climate changes (Gates, 1979). Specifically, the eddy diffusive approximation is quite adequate for the physical description and numerical simulation of the largest, planetary space scales and for very long,

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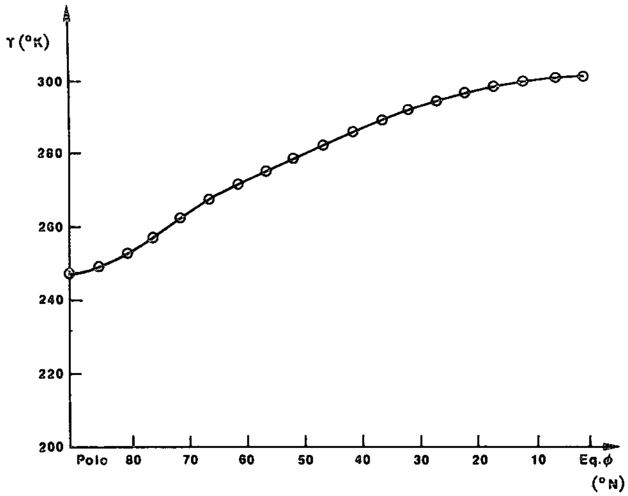

FIG. 1. Comparison of observed annual mean sea-level temperatures (open circles) with equilibrium values for present insolation conditions (solid line) produced by the model of Ghil (1976). Both data and model values have been symmetrized around the equator, i.e., the Northern and the Southern Hemispheres have been averaged together.

yearly time scales (North and Coakley, 1979; Ghil, 1981a); it is clearly not so good for either the description or simulation of smaller space scales and shorter time scales (Lorenz, 1979; Ghil, 1981b). In particular, dynamic phenomena active on monthly time scales might be accounted for only marginally well in seasonal simulations with eddy diffusive EBM's. The partial fit to the data of the Newtonian-cooling parameterization (Warren and Schneider, 1979) does not appear at present to be founded in any physics or dynamics relevant to the phenomena of interest.

It would seem that the effort to formulate better parameterizations of meridional heat transports (Lindzen and Farrell, 1977), in terms of latitude-specific dynamics is an interesting direction in the development of the theory and applications of EBM's. In particular, it would be worthwhile addressing by physical reasoning the problem of parameterizing *seasonal* fluxes in the tropics, apparent in both eddy diffusive (Thompson and Schneider, 1979) and Newtonian-cooling (Warren and Schneider, 1979) EBM's. The validation of such parameterizations clearly requires rigorous logical and numerical tests (North and Coakley, 1979; Warren and Schneider, 1979, 1980).

More generally, I am afraid that undue stress on the detailed simulation requirement detracts from the major purpose of EBM work, which is to contribute to the understanding of the macrophysics of climate change. The crude understanding derived from these simple models can and should be verified by more realistic, complex models and be further combined with the more detailed understanding the latter can and will provide. Quantitative prediction of climate change will hopefully follow such understanding. It is hard to see how it might precede it.

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