data sets, with levels over the North Pacific substantially elevated relative to the south Indian Ocean. It is not clear, however, just how far two experiments of only about two-weeks duration each can be extrapolated, and how much the aerosol at these altitudes contributes to cloud formation.

Finally, we note that Schwartz[2] did not attempt to test the hypothesis that most natural marine CCN are produced from dimethylsulphide. Regardless of any climate role of CCN, understanding their sources, properties, distribution and variability are important objectives.

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SIR—Schwartz[1] proposes that because aerosol sulphate concentrations are considerably higher in the industrialized Northern Hemisphere (NH) than in the Southern Hemisphere (SH), the climatic effect should be observed in the difference between the hemispheric temperature trends. Based on data presented by Jones *et al.*[2-4], he reports that there is no difference in the temperature trends of the two hemispheres over about the past century and therefore no supporting evidence for the role of SO_2 in climate.

We do not think that such a conclusion is justified given the sparsity of temperature data, particularly for the SH, earlier this century. A recent analysis of the spatial patterns in temperature trends for 1947–86 in the NH and in the SH (data for the Antarctic were not available until the late 1950s) points to almost uniform warming in the SH and large regions of both cooling and warming trends in the NH[5]. Earlier studies also indicate regions of positive and negative temperature anomalies in the NH[6-8]. Given the large geographic variability of sulphate concentrations, one could expect its impact to be regional. Among the areas which exhibit cooling are eastern North America and Europe, both known to be regions of exceptionally high SO_2 emissions that have increased substantially over the past century. Large regions of cooling are also observed over the North Atlantic and North Pacific oceans[5]. Qualitatively, the observations are not inconsistent with the idea of regional compensation of CO_2 warming by aerosols. Therefore, given the complexity of the climate system, the question of the influence of sulphates on climate remains open.

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SIR—For a link to exist between changes in gaseous sulphur emissions and changes in planetary albedo several conditions must be met. The conditions associated with air masses containing anthropogenic SO_2 emissions may not be conducive to changing cloud albedos. First, increases in concentrations of cloud condensation nuclei (CCN) must necessarily lead to increases in typical cloud-drop concentrations and decreases in drop size. Such an assumption is consistent with observation when CCN concentrations are low — as expected over cleaner areas in both the Northern hemisphere (NH) and the Southern Hemisphere (SH). But in areas where the CCN concentration exceeds 1,000 cm^{-3} and where sulphate concentrations exceed 2,000 ng cm^{-3}, this relationship is not observed[2]. Such a lack of correlation is expected because as CCN concentrations increase, supersaturation levels in clouds become depressed, causing a smaller fraction of aerosol particles to act as CCN[3]. Because continental air masses typically contain plenty of CCN, addition of anthropogenic sulphur is not expected to affect the cloud-drop number density in these air masses.

Second, the measurements of sulphate concentration given by Schwartz[1] are in terms of total mass per unit volume; no measurements for number density of sulphate particles are provided. Schwartz assumes that sulphate concentrations would be proportional to CCN concentrations and that the increased sulphate concentrations observed in the NH would imply increased numbers of CCN. This would only be expected if the conversion of anthropogenic SO_2 to sulphate were dominated by gas-phase processes followed by homogenous nucleation of SO_4^{2-} to the aerosol. In fact, a significant proportion of SO_2 is converted to sulphate via aqueous reactions which take place in cloud drops. These reactions would increase the size of existing aerosol and CCN particles but not their number. An increase in size is observed in air masses which originate over continents and move offshore[4].

Satellite observations presented by Schwartz[1] indicate that the cloud component of the planetary albedo is larger in the SH than in the NH, which he says is opposite to the difference expected if sulphate controls the number of cloud droplets. However, he implicitly assumes that the cloud fraction is the same for each hemisphere, which is not the case. The fractional cloudiness of the SH is generally larger than that of the NH[5], so that the cloud albedos are not necessarily greater in the SH. An additional shortcoming is the lack of distinction between marine and continental clouds, whose albedos are influenced by the difference between the albedos of the underlying surface. Moreover, the liquid water content of clouds varies widely with latitude and altitude. If satellite measurements of planetary albedo are to be used to evaluate the influence of sulphate aerosols on cloud albedo, comparisons between marine clouds of comparable liquid-water content must be performed.

Finally, the observed albedos of optically thick clouds are significantly lower than expected from a straightforward theoretical analysis. One explanation for the discrepancy is the absorption by graphitic carbon particles that have been scavenged by the cloud drops[6]. This requires the carbon to be at the surface of the drop in order to substantially increase its absorption, but this has been observed in laboratory experiments[7]. The carbon, of course, is associated with urban pollution and would originate in the same continental regions as the anthropogenic sulphur discussed by Schwartz[1]. For clouds of intermediate optical depth the effect of carbon on cloud albedo is much less significant, but the lowered albedo of optically thick clouds would still tend to obscure the analysis by Schwartz because he does not distinguish between optically thick and thinner clouds.

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