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Dust-climate interactions in the Sahel-Sahara zone of northern Africa, with particular reference to late twentieth century Sahelian drought.

PhD Thesis

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Abstract

Since the 1950s, the Sahel region of Africa has experienced a decline in rainfall, while levels of atmospheric dust in the region have increased. The rainfall regime changed dramatically around 1950, after which time interannual variability of rainfall decreased. The corresponding high degree of persistence in annual rainfall is not reproduced by the GFDL or HADCM2 climate simulations, in which certain land-atmosphere interactions are not parameterised. The potential of atmospheric dust to modify the radiative structure of the atmosphere, and its absence from these and other GCM simulations, suggests that an investigation of the role of mineral aerosols in regional climate modification in the Sahel is appropriate.

The Infra-red Difference Dust Index (IDDI), a new satellite-derived proxy dust-loading climatology for 1984-1993, is used to examine variability of dust production on monthly, seasonal and interannual timescales within the context of climate variability over northern African. Lagged relationships between rainfall and dust production in the Sahel are investigated, and the relative importance of atmospheric and land-surface processes in dust mobilisation is discussed. Influences of the regional-scale circulation on dust production are examined through comparisons of IDDI and climatological fields.

The impact of atmospheric dust on climate is inferred by examining changes in fields of temperature and vertical velocity at different levels of the atmosphere which are associated with high dust loadings on timescales of months and days. The extent to which dust modifies the vertical temperature structure of the atmosphere, and modulates convective activity, is assessed. The translation of such atmospheric modifications into changes in the regional circulation which are important for rainfall generation is analysed by correlating IDDI indices with zonally averaged meridional wind indices over the Gulf of Guinea and Sahel-Sudan regions.

The distribution of dust sources and the relationship of atmospheric dust concentrations to the atmospheric circulation indicates that increased dustiness in the region is not necessarily associated with anthropogenic land degradation. In particular, summer dust production appears to be strongly related to easterly wave activity. There is a discernible influence of rainfall on dry season dust production, although the impact of rainfall is complex, and acts in conjunction with the synoptic climatology to determine deflation. Widespread significant correlations between dust concentrations and temperatures at different atmospheric levels indicate that airborne dust has a large potential for regional-scale atmospheric modification. This modification generally takes the form of cooling below about 4 km, and warming above 4 km, with the lower-altitude cooling being dominant. The cooling is widespread throughout much of the Sahel and southern Sahara throughout the year, particularly at and below 1.5 km. There is evidence that large dust loadings may delay the onset of the West African monsoon.

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