The Large-Scale Movement of Saharan Air Outbreaks over the Northern Equatorial Atlantic

TOBY N. CARLSON
National Hurricane Research Laboratory, NOAA, Miami, Fla. 33124

AND JOSEPH M. PROSPERO
University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, Fla. 33149

(Manuscript received 20 July 1971)

ABSTRACT

The intense and prolonged heating of air passing over the Sahara during the summer and early fall months forms a deep mixed layer which extends up to 15-20,000 ft during July, the warmest month. The dust-laden heated air emerges from West Africa as a series of large-scale anticyclonic eddies which move westward over the tropical Atlantic above the trade-wind moist layer, principally in the layer between 5000 and 15,000 ft (600-800 mb). Measurements made during BOMEX show that this Saharan air is characterized by high values of potential temperature, dust and radon-222 which confirm a desert origin. As the parcels of air within the layer proceed across the Atlantic the continuous fallout of particulate matter and the mixing at the base of the layer cause dust to be transferred to the lower levels where its concentration may become sufficiently great to produce dense haze at the surface over wide areas over the Atlantic and Caribbean in the latitude belt 10-25N. Nevertheless, measurements indicate that the dust concentration and associated haziness are greater at 10,000 ft than at the surface.

The presence of Saharan air over the Caribbean can be recognized on conventional meteorological soundings as a virtually isentropic layer within which the potential temperature is about 40C; the mixing ratio within this layer generally remains fairly constant with height with typical mean values of 2-4 gm kg\(^{-1}\). The upper surface of the Saharan air layer, clearly visible from above as a sharply defined haze top, coincides with an inversion, above which the mixing ratio decreases rapidly with height. The lower portion of the isentropic Saharan air layer may be as much as 5-6C warmer than the normal tropical atmosphere; consequently, there is a strong suppressive inversion above the moist trade-wind layer. There is also a sharp horizontal temperature gradient between the Saharan dust plume and the normal tropical air mass; air craft penetrations into Saharan air at heights of 700-800 mb show that the discontinuity between Saharan and non-Saharan air is front-like in character inasmuch as the potential temperature and mixing ratio may change by several degrees Celsius and several grams per kilogram, respectively, over a distance of just a few kilometers. Because of the steep (adiabatic) lapse rate in the Saharan air, the positive temperature anomaly diminishes rapidly with height and tends to vanish near 650 mb, above which the dusty air may be slightly cooler than the normal tropical environment. Associated with this large-scale temperature contrast is a wind maximum of up to 40-50 kt in the Saharan air layer, usually between 600 and 700 mb.

The westward speed of the Saharan air mass is usually about 15 kt, requiring about 5-6 days to cross the Atlantic. The leading edge of the Saharan air is often found immediately to the rear (east) of a large-amplitude African disturbance which also migrates from Africa, to the Caribbean during the summer months at about the same forward speed. Normally the strongest winds and highest dust concentrations in the Saharan air are found in the southeasterly winds behind the disturbance and are therefore associated with the so-called "surges in the trades" which are often observed in the tropical Atlantic.

Saharan air pulses tend to leave the continent of Africa with a potential temperature of 43-44C, about 3-4C higher than that found in the Saharan layer over the Caribbean. This apparent cooling is due to net radiation losses within the Saharan air which amount to about 0.7C per day. At the same time the Saharan air sinks by 50-100 mb (a mean descending motion of 1-2 mm sec\(^{-1}\)) between Africa and the Caribbean.

A model is proposed which depicts the movement of Saharan air from Africa to the Caribbean and its interaction with African disturbances. Although it is not known what effect, if any, the dust plume has upon the growth or suppression of disturbances, it is clear that the warmth of the Saharan air has a strong suppressive influence on cumulus convection and that, as a result, the advancing dust pulse is often marked by rapid clearing behind the disturbances.