ATMOSPHERIC OZONE OVER THE TROPICAL BELT OF THE ATLANTIC OCEAN

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Abstract

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ATMOSPHERIC OZONE OVER THE TROPICAL BELT OF THE ATLANTIC OCEAN

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The study of variations in ozone content as a minor admixture to stratospheric air and as a natural tracer makes it possible to follow large-scale motions of the atmosphere and air exchange between polar and tropical latitudes. In photochemical processes over tropical latitudes more ozone is formed than over the less illuminated polar latitudes, but theoretically in the latter the winter descent of air with ozone into the lower stratosphere (and the subsequent recovery of ozone in the middle stratosphere) should promote the progressive accumulation of O_3 and an increase in its total amount X in the atmospheric column (under stationary conditions), while in equatorial latitudes the ascending motion should lead to the opposite effect ([1–3]).

The features of the ozone distribution, in parallel with observations of air currents and temperatures in the free atmosphere up to heights of more than 20 km above the tropical part of the Atlantic Ocean between 25° N and 25° S, were studied during the fourteenth cruise of the research vessel *Mikhail Lomonosov* in August-November 1963. They showed that the theoretical scheme must be substantially supplemented in order to describe phenomena in the tropical zone. The observations showed that near sea level in the tropics the interdiurnal variations of temperature (2–3°) and pressure (1–2 mb) were insignificant and the weather very steady, whereas in the free atmosphere there occurred abrupt changes of temperature and pressure, a change of strong air currents, together with sharp changes in the amount of ozone X.

A clearly expressed maximum of X (Fig. 1) was found directly over the equatorial zone between 6° N and 4° S (where on the average $X = 0.293$), undoubtedly of photochemical origin. Somewhat farther north, between 16° and 6° N, the local minimum of X (0.260–0.270 cm) is explained by the convergence of the trade winds of the Northern and Southern Hemispheres and by a powerful ascending motion of air, filling the stratosphere with ozone-poor air from the lower layers. The minimum zone is also traceable over the nearest part of Africa, where, for example, the Tamanrasset observatory (22° N) recorded during the IGY a very low ozone content and where, as recent satellite observations have shown,

Fig. 1

Figure 1: Fig. 1

convergence of the trade winds promotes the formation of hurricanes that subsequently move out over the Atlantic Ocean. We note that the only case we recorded of a breakthrough of this convergence zone into the Southern Hemisphere, on October 30-31, 1965 (followed by an intrusion of the northeastern trade wind), was also accompanied by a noticeable decrease of X (to 0.267 cm).

Against the background of the above-described mean latitudinal dependence of the ozone content, separate large fluctuations of it were observed, which, as became clear, were associated with abrupt changes in the circulation of the upper atmosphere. Thus, between September 13 and 15, at 13-14° S, X increased from 0.260 to 0.332 cm; moreover, although below the usual southeastern trade wind was observed, at heights a strong southwesterly flow appeared (up to 37 m/sec at the 14 km level),

spread gradually downward. It created a noticeable cooling aloft (to $-8°$ at an altitude of 17 km) and carried (in the rear of a deep cyclone located near Cape Town) air from the high latitudes of the Southern Hemisphere. As is known, under 60—65° S lat. in the spring season a high maximum of X is observed (on average up to 0.540 cm), and the inflow of air from there can easily explain the increase in X that we observed.

An even sharper increase in ozone content—to 0.398 cm—was brought by two waves of cold air that followed rapidly one after the other on 25 and 28 IX (at 15° S lat.). During the first of them the velocity of the southwesterly wind at an altitude of 13 km reached the enormous value of 44 m/sec. The second wave was weak at this altitude, but below, the cyclone "driving" it was much more intense, and it spread down to sea level, accompanied by a sharp deterioration of the weather and by the above-mentioned record increase of X for the tropics.

Fig. 1

The incursion of an air flow from the Northern Hemisphere, which penetrated on 18–19 X across the equator and, owing to the change in sign of the Coriolis force, turned from northeasterly into northwesterly, was accompanied by only an insignificant increase in X. This is easily explained, since in the Northern Hemisphere at that time it was autumn, and X in the high latitudes was insignificant. This difference, consequently, indirectly confirms that the ozone "waves" originate from high latitudes. Conversely, on 31 X–2 XI, when a strong flow which at an altitude of 16 km had a velocity of up to 35 km/sec was directed across the equator from south to north, extending at least to 4° N lat., a much more noticeable increase in X was observed, from 0.267 cm on 31 X to 0.326 cm on 2 XI.

From an analysis of the ozonometric and radiosonde observations during the

XIV voyage of the *Mikhail Lomonosov*, the general conclusion may be drawn that a sharp increase in the amount of ozone in the tropics of the Atlantic is always associated with the appearance of well-defined strong flows beneath the tropopause, with a meridional component on the axis of the flow of more than 20 m/sec. In this case the easterly component, usual for the tropics, is abruptly replaced by a westerly component in the 700–150 mb layer or even higher. During sharp increases in the amount of ozone, its maximum is observed at the time when a well-defined axis of a low-pressure trough is passing. At the same time, cooling is observed in the troposphere and warming in the stratosphere (it is known that poleward of 40° latitude in the temperate belt the stratosphere is generally warmer than over the equator). The corresponding inflow from high latitudes is also detected from the lowering of the tropopause.

Thus, our observations revealed in the tropical zone, together with strong meridional currents resembling jet streams, significant changes in the amount of ozone in the atmosphere, indicating the inflow of air at times from high southern or, sometimes, northern latitudes. These changes in the upper atmosphere over the tropics contrast with the generally smooth course of weather in the surface layer over the ocean. The ozone changes in this case go far beyond the limits predicted by the theoretical scheme based on the assumption of stationary general circulation (2). They likewise point to substantial meridional exchange of air across the equator.

The same conclusion concerning the presence of active exchange of air between the hemispheres in equatorial latitudes, especially noticeable in the upper troposphere, has recently been drawn in (4). The ozonometric observations of the XIV voyage of the R/V *Mikhail Lomonosov* showed that the penetration of upper-level baric troughs into the tropics is distinctly recorded by an increase in the quanti-

ozone amounts. At the same time, clearly pronounced relationships appear between ozone content and the temperature, pressure, and height of the tropopause, similar to those that have been well studied at higher latitudes. All this gives reason to hope that ozonometric observations in the tropics will be very useful in studying the important problem of the circulation of the tropical belt and its interaction with temperate latitudes.

In conclusion, the author expresses gratitude to the administration of the Marine Hydrophysical Institute of the Academy of Sciences of the Ukrainian SSR for providing the opportunity to participate in the XIV cruise of the research vessel *Mikhail Lomonosov* and to use the radiosonde data from this cruise.

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Note: Figure translations are in progress. See original paper for figures.