SPATIAL AND SEASONAL DISTRIBUTION OF THE MOLECULAR ABSORPTION OF LONG–WAVE OPTICAL RADIATION IN THE ATMOSPHERE OVER NORTHERN PART OF THE WORLD'S OCEAN

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Based on mathematical processing of statistical array of data on climatic factors obtained over a period of many years we have investigated the spatial and seasonal distribution of the optical radiation molecular absorption in the atmosphere over macroclimatic regions of the globe. We have calculated the average value of the optical radiation molecular absorption and its geographic and seasonal variations over northern regions of the world's ocean.

1. INTRODUCTION

Spatial and seasonal variations of atmospheric transmission in different sections of optical radiation spectrum are of interest for applied problems of atmospheric optics. In Refs. 1 and 2 spatiotemporal statistical parameters of transmission of the atmospheric column in the visible range of optical radiation wavelength (0.34–0.63 μm) were considered only over the territory of the former Soviet Union. In Ref. 3, results are presented of the molecular absorption index (MAI) calculation for a great deal of wavelengths in the 2.9–10.8 μm range for several atmospheric models: tropics, mid-latitudes in winter, and Arctic latitudes in winter.

This paper describes results of investigation of spatial and temporal variations of MAI of long-wave optical radiation (near 10.6 μm) performed on the basis of processing of statistical array of data on climatic factors obtained over northern part of the world's ocean. Pressure, temperature, and air absolute humidity in lower atmospheric layer were used as main climatic factors determining MAI value.

2. TECHNIQUE FOR PROCESSING OF STATISTICAL ARRAY OF DATA ON CLIMATIC FACTORS

Under standard weather conditions (in the absence of peculiar meteorological phenomena – fogs, precipitation, and so on) the basic component of the long-wave (near 10.6 μm) optical radiation extinction in the atmosphere is the water vapor and CO_2 molecular absorption. The water vapor and CO_2 content in the atmosphere depends on the following climatic factors: pressure, absolute humidity, and temperature of air.

The above-mentioned climatic factors are continually observed. Results of these observations can be used as initial data for statistical estimates of the radiation molecular absorption in the atmosphere.

As the first source of initial data, we used generalized results of observations of nine weather ships over the period between 1951 and 1960 (Ref. 4). Over this period, each of the ships was at a definite point in the Atlantic Ocean in the 35°–66°N latitude belt and performed four observations of the atmosphere and ocean a day. The data obtained were averaged over observation time and months for each ship.

As the second source of initial data, the All-Union State Standard 24482-80 "Macroclimatic Regions of the Earth with Tropical Climate. Regionalization and Statistical Parameters of Climatic Factors for Technical Purposes" was used, in which the data of twenty-year meteorological observations were summarized. Of all the variety of statistical values of climatic factors given in the above All-Union State Standard (AUSS) 24482-80 we used the material of a group of stations located in the tropical humid region. Stations of this region encompass southern part of the Atlantic Ocean, Indian Ocean, and southern part of the Pacific Ocean.

As the basis of MAI calculations from meteorological data, the following two formulas were used:

1) empirical formula for MAI in the water vapor continuum borrowed from Ref. 5 and transformed for λ = 10.6 μm and γ = 0.00366 to the form

$$\alpha_{H_2O} = 3.14 \cdot 10^{-6} \exp\left[1800\left(\frac{1}{T} - \frac{1}{296}\right)\right] \times$$

$$\times (P + 272\, P_{H_2O})\, P_{H_2O}\,,$$

where α_{H_2O} is MAI in water vapor, km^{-1}; T is the air temperature, K; P is the air pressure, Torr; and, P_{H_2O} is the partial pressure of water vapor, Torr;

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2) empirical formula for MAI for CO_2 at $\lambda = 10.6$ μm (Ref. 6):

$$\alpha_{CO_2} = 7.57\cdot10^{-2}\left(\frac{296}{T}\right)^{3/2} \exp\left[2233\left(\frac{1}{296}-\frac{1}{T}\right)\right],$$

where α_{CO_2} is MAI in CO_2, km^{-1}.

The radiation MAI in the atmosphere is the sum $\alpha_{H_2O} + \alpha_{CO_2}$. When calculating α_{H_2O} and α_{CO_2} from the meteorological data of weather ships, the values of the air pressure and temperature as well as partial pressure of water vapor were selected from the statistical material on meteorological observations. When processing the data of AUSS 24482-80, the air pressure was taken equal to its mean value of 760 Torr.

3. STATISTICAL PARAMETERS OF MOLECULAR ABSORPTION VARIABILITY

Figure 1 shows the most general results of the estimate of the long-wave radiation MAI in northern part of the world's ocean, with the average-annual MAI values (with minimum and maximum monthly standard deviations) as functions of latitude. Figure 2 shows the data on the MAI annual behavior. In Figs. 1 and 2, the letters *A*, *B*, *C*, *D*, *E*, *I*, *J*, *K*, and *M* denote weather ships (international notation). Ground-based stations Bitam, Calcutta, Havana, and Manaus are denoted by letters *B*, *C*, *H*, and *M* enclosed in circles.

Figure 1 shows a clearly defined latitude variation of MAI. In polar latitudes, the average-annual MAI values are close to 0.1 km^{-1}. In mid-latitudes, MAI varies within 0.15–0.20 km^{-1}. In low latitudes and at the equator, the average-annual values of MAI increase up to 0.35–0.50 km^{-1}. As one can see from Figs. 1 and 2, the annual variation of MAI has especially large amplitude within 40°–20°N, where maximum average monthly values (July–September) exceed minimum ones (January–March) by a factor of 2–2.5. The results obtained are in good agreement with the results of Ref. 3 according to which the MAI values were the following: 0.05 km^{-1} for winter in Arctic latitudes, 0.1 km^{-1} for winter in mid-latitudes, and 0.6 km^{-1} for tropics.

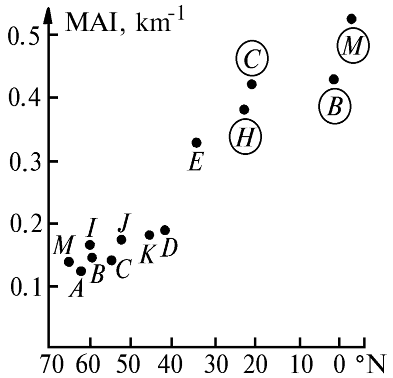

FIG. 1.

In AUSS 24482-80, the data are compiled so that it is possible to estimate not only the average monthly and average-annual MAI values, but also the recurrence (relative frequency of repetition) of MAI specific values. As an example, Fig. 3 shows recurrence (q) of MAI for three points, namely, Bitam (*B*), Calcutta (*C*), and Havana (*H*). Figure 3 shows that although the MAI recurrence curves for Calcutta and Havana have two maxima, all three curves indicate the highest recurrence of MAI values more than 0.4 km^{-1}. From a comparison of Figs. 1 and 3, it is clear that the average-annual MAI values for Havana are 0.38 km^{-1} (0.30–0.46 km^{-1}) but most often (in 25 percent of cases) the MAI values are equal to 0.45 km^{-1}.

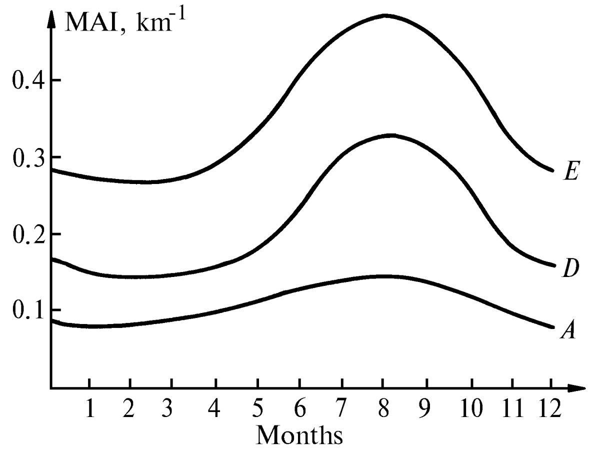

FIG. 2.

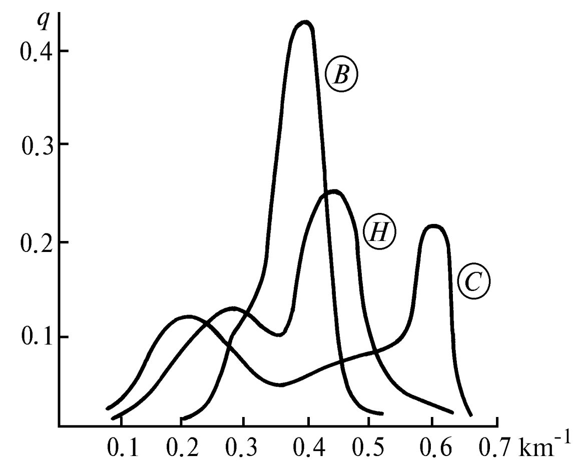

FIG. 3.

The above-presented MAI estimates obtained for northern part of the world's ocean indicate that the MAI average-annual value increases from the north to the south from 0.1 to 0.2 km^{-1} in mid-latitudes and reaches 0.4–0.5 km^{-1} in tropics and at the equator. In southern latitudes, the most probable MAI values are 0.4 km^{-1}.

4. CONCLUSION

In this paper, the estimate has been given of spatial and seasonal distribution of molecular absorption of long-wave (near 10.6 μm) optical radiation in the atmosphere over the northern part of the world's ocean. The average-annual MAI value, its latitude variation and recurrence for several typical observation points have been estimated. The results obtained have made it possible to evaluate numerically the regional and seasonal conditions of the 10.6 μm radiation propagation in the atmosphere over northern part of the world's ocean.

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