PARTICULAR POINTS IN TEMPERATURE DEPENDENCE OF ABSORPTION COEFFICIENT IN THE 4.3 μm CO_2 BAND

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The absorption coefficient in the R–branch of the 4.3 μm CO_2 *band at temperatures and pressures typical of atmospheric conditions was calculated on the basis of the spectral line wing theory. The results obtained are presented. At some frequencies of interest for remote sensing there is inversion of the temperature dependence which is more pronounced in the case of self–broadening. It is pointed out that the transformed integrand for the spectral intensity of outgoing radiation with an unconventional form of the weighting function associated with dT/dz may be used for temperature retrieval.*

Passive IR remote sensing of vertical profiles of the atmospheric temperature and that of the underlying surface employs, among other things, a set of channels in the high–frequency part of the R–branch of the 4.3 μm CO_2 band and beyond the band–head.[1,2] Clearly, the temperature dependence of the atmospheric transmission is essential here.

In this spectral region the temperature behavior of the CO_2 absorption coefficient exhibits a number of peculiar features due to different patterns of the temperature dependence of the absorption coefficient in the spectral line center and wings. These peculiarities reveal themselves in the fact that the spectral curves recorded at different temperatures have intersection points (see Fig. 1, its general discussion,[3] and the discussion of the consequences for the sensing problem[4]). It is worth noting that the spectral line wing theory[5] allows one to interpret these subtleties in the behavior of the absorption coefficient vs. frequency, temperature, and pressure (see Fig. 1).

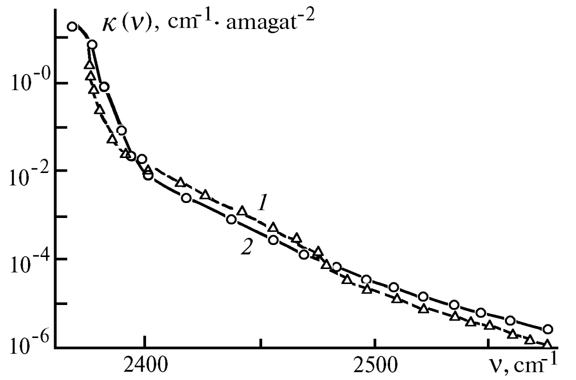

FIG. 1. The CO_2 *absorption coefficient in the* 4.3 μm *band wing at T* = 193 K *(curve 1) and at T* = 296 K *(curve 2) calculated on the basis of the line wing theory. Experimental data are taken from Ref. 6:* o – 296 K *and* Δ – 193 K.

This paper presents the results of calculations of the CO_2 absorption coefficient at various temperatures and pressures in the spectral region in question using the spectral line wing theory. The object of the exercise was to identify frequencies for which the change in the sign of the temperature dependence can affect the results of the temperature sensing.

In Fig. 2 the temperature behavior of the CO_2 absorption coefficient is depicted for self–broadening and N_2–broadening at several frequencies within the band and beyond the band–head. The temperature dependence of the

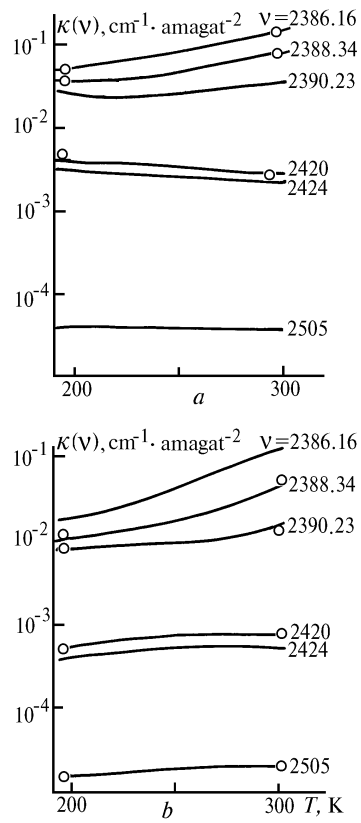

FIG. 2. Temperature dependence of the CO_2–CO_2 *(a) and* CO_2–N_2 *(b) absorption coefficients in the* 4.3 μm *band at several frequencies given to the right of the curves.*

absorption coefficient at frequencies in the vicinity of several sensing channels is shown in some detail in Fig. 3. The inversion of the temperature dependence is clearly pronounced in the case of self–broadening.

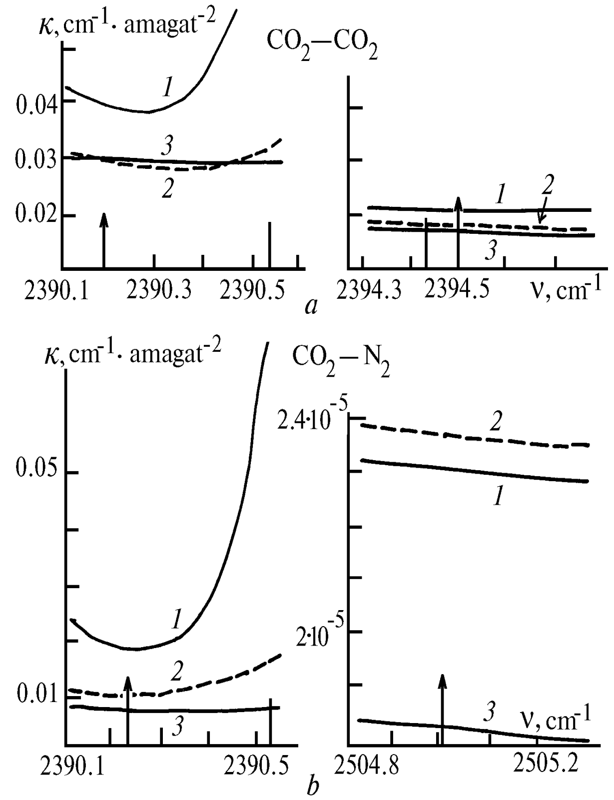

FIG. 3. Change in the character of the temperature dependence of the CO_2–CO_2 *(a) and* CO_2–N_2 *(b) absorption coefficients in the vicinity of several sensing channels (marked by arrows). The curves correspond to temperatures of* 300 *(1),* 250 *(2), and* 190 K *(3).*

The spectral intensity I of outgoing terrestrial radiation, i.e., the solution of the radiative transfer equation for the molecular atmosphere under standard assumptions for the emissivity of the underlying surface may be written as

$$I = -\int_{y^*}^{1} \mathrm{d}y \left(\frac{dB}{dT}\frac{dT}{dz}\kappa^{-1}(z)\right)_{z=z(y)}, \qquad (1)$$

where B is the Planck function, $y = \mathrm{e}^{-\varepsilon}$, $\varepsilon(z) = \int_z^{\infty} \kappa(z')\,\mathrm{d}z'$, $z = H\sec\Theta$, H is the altitude above the Earth's surface, Θ is the zenith angle, and T is the temperature. The z–dependence of the absorption coefficient k is the result of altitude–dependent changes in the thermodynamic characteristics of the atmosphere.

The results of calculations of the weighting function at dT/dz are given in Fig. 4. In the case of the CO_2–N_2 mixture, a consideration of the temperature dependence of the absorption coefficient has practically no effect on the value of the weighting function. The case of self–broadening may be different, however.

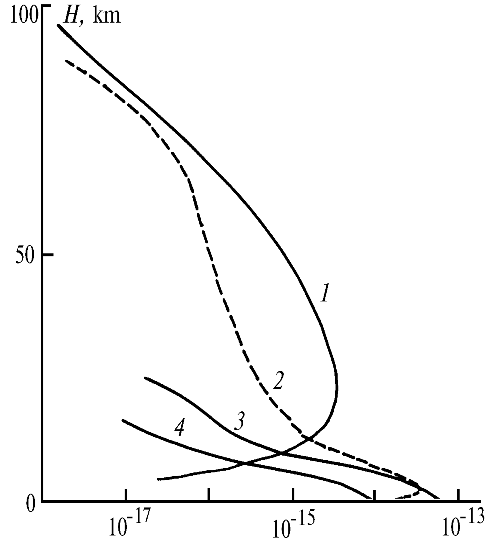

FIG. 4. Altitude dependence of the weighting function at dT/dz for several frequencies: ν = 2360.8 *(1),* 2379.27 *(2),* 2392.35 *(3), and* 2424 cm^{-1} *(4).*

A subtle feature should be noted at this point. Although Eq. (1) is formally equivalent to the commonly used expression

$$I = -\int_{p_i}^{0} B(T(p))\,\frac{d\,\tau(p,0)}{d\ln p}\,\mathrm{d}\ln p, \qquad (2)$$

where τ is the transmittance and p is the pressure, the maxima in the weighting functions of Eqs. (1) and (2) are shifted relative to each other. It is hardly surprising, because we actually deal with the weighting functions associated with the integration variables that have different meaning. This fact may be properly accounted for in the satellite data processing.

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