COMPUTED SURVEY SPECTRA OF 2-5 MICRON ATMOSPHERIC ABSORPTION (U) NAVAL RESEARCH LAB WASHINGTON DC
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Computed Survey Spectra of 2-5μ Atmospheric Absorption

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# Computed Survey Spectra of 2-5 μm Atmospheric Absorption

## Abstract

Computed high resolution survey spectra of atmospheric absorption coefficient vs wavenumber are presented covering the wavelength region 2-5 μm. The 1980 AFGL atmospheric absorption parameter compilation was employed with a mid-latitude, sea-level atmospheric model.

## Key Words

- Atmospheric propagation
- HITRAN
- Infrared
- Micrometers
COMPUTED SURVEY SPECTRA OF 2-5\( \mu \) ATMOSPHERIC ABSORPTION

This report presents computed spectra of atmospheric absorption in the 2-5 \( \mu \)m region. The spectra collected here followed from a request for detailed information on narrow transmission windows. The recent availability of tunable laser sources at 2-5 \( \mu \)m, including F-center lasers and downshifted Raman devices, has renewed interest in narrow atmospheric transmission windows.

The spectra in Figs. 3-77 present molecular absorption coefficient (km\(^{-1}\)) vs wavenumber (cm\(^{-1}\)), where \( \nu \) (cm\(^{-1}\)) = \( 10^4 \times \lambda^{-1}(\mu m) \). Aerosol scattering and absorption are not considered here. The standard midlatitude-summer sea-level atmosphere is assumed, and described in Table 1. The water vapor standard isotopic ratio HDO/H\(_2\)O = 0.030% is assumed.

Table 1 — MidLatitude Summer Sea-Level Atmospheric Parameters

<table>
<thead>
<tr>
<th>Molecular</th>
<th>Pressure (torr)</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H(_2)O</td>
<td>14.26</td>
<td>1.88 ( \times ) 10(^4)</td>
</tr>
<tr>
<td>CO(_2)</td>
<td>0.251</td>
<td>330</td>
</tr>
<tr>
<td>O(_2)</td>
<td>2.3 ( \times ) 10(^{-5})</td>
<td>0.030</td>
</tr>
<tr>
<td>N(_2)O</td>
<td>2.1 ( \times ) 10(^{-4})</td>
<td>0.276</td>
</tr>
<tr>
<td>CO</td>
<td>5.7 ( \times ) 10(^{-5})</td>
<td>0.075</td>
</tr>
<tr>
<td>CH(_4)</td>
<td>1.2 ( \times ) 10(^{-3})</td>
<td>1.58</td>
</tr>
<tr>
<td>O(_3)</td>
<td>159.6</td>
<td>2.10 ( \times ) 10(^5)</td>
</tr>
<tr>
<td>N(_2)</td>
<td>585.9</td>
<td>7.7 ( \times ) 10(^5)</td>
</tr>
</tbody>
</table>

NOTE: Temperature = 22.9°C

The calculations were performed using our HITRAN code with the 1980 AFGL line compilation.\(^{1,2}\) The plots were made on a Versatek plotter at 100 points per inch resolution. Since each plot is 40 cm\(^{-1}\) long across 7 inches, the effective wavenumber resolution is approximately 0.057 cm\(^{-1}\) per point. At sea level almost all absorption lines are pressure broadened to a HWHM greater than 0.05 cm\(^{-1}\). The plot parameters were chosen to maximize the number of wavenumbers per plot panel, without undersampling the true spectrum. The user of these survey spectra is cautioned to pay atten-
tion to the vertical scale: each panel is self-scaling so some plots cover 2 decades where others cover as much as 6 decades of absorption coefficient.

The 1982 AFGL listing has recently been released, but no significant changes have been made in the 2-5 μm region for the molecules considered here. Areas of uncertainty remain in the specific correction needed for the sub-Lorentz CO₂ lineshape, and the Burch vs White water continuum absorption model.

Table 2 — Spectral Plot Parameters

<table>
<thead>
<tr>
<th>Lineshape: Lorentz with ±20 cm⁻¹ bound</th>
<th>Self-to-Foreign Broadening: (1)</th>
<th>Temperature Coefficient γ ~ T³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ratio: γ_L/γ_F</td>
<td>Temperature Coefficient γ ~ T³</td>
</tr>
<tr>
<td>H₂O</td>
<td>5.0</td>
<td>0.62</td>
</tr>
<tr>
<td>CO₂</td>
<td>1.3</td>
<td>0.58</td>
</tr>
<tr>
<td>O₃</td>
<td>1.0</td>
<td>0.50</td>
</tr>
<tr>
<td>N₂O</td>
<td>1.24</td>
<td>0.50</td>
</tr>
<tr>
<td>CO</td>
<td>1.02</td>
<td>0.50</td>
</tr>
<tr>
<td>CH₄</td>
<td>1.3</td>
<td>0.50</td>
</tr>
<tr>
<td>O₂</td>
<td>1.0</td>
<td>0.50</td>
</tr>
</tbody>
</table>

NOTE: Water Vapor Continuum 2350 – 2800 cm⁻¹(5,6)  
Nitrogen continuum 2080 – 2740 cm⁻¹(5,8)  
CO₂ sub-Lorentz lineshape (4)

The spectral plot parameters are summarized in Table 2. The two continuum absorption contributions are well documented in the literature. The line-by-line summation was carried out to ±20 cm⁻¹ from the plotted frequency. The correction to the CO₂ spectra to account for the sub-Lorentz lineshape is described in Fig. 1 and Eq. (1) below:

\[ k(ν₀) = \chi(ν - ν₀) \cdot k_L(ν₀) \] (1)

where

\[ k_L(ν₀) = \frac{1}{π} \frac{γ S}{(ν - ν₀)^2 + γ^2} \]

and \( \chi(ν - ν₀) \) is given in Fig. 1.

A broad-band transmittance plot for a 1 km path was produced using LOWTRAN-5b with the above atmosphere and no aerosols (9). This is given in Fig. 2 and is useful for a quick glance at the
same region covered by the 75 high-resolution absorbance plots. The effective spectral resolution of Fig. 2 is 20 cm\(^{-1}\).

| \(|x - \nu_0| \) cm\(^{-1}\) |
|-----------------|
| 0.0             |
| 0.2             |
| 0.4             |
| 0.6             |
| 0.8             |
| 1.0             |

Fig. 1 – \(x\) function in Eq. (1) used for CO\(_2\) sub-Lorentz lineshape

Fig. 2 – LOWTRAN-5 1 km mid-latitude summer sea-level transmittance 5-2 \(\mu\)m
REFERENCES


Fig. 3 - 2000-2040 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 10 — 2280-2320 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 15 — 2480-2520 cm$^{-1}$ atmospheric absorption coefficient (km$^{-1}$)
Fig. 19 - 240-2660 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 20 — 2680-2720 cm$^{-1}$ atmospheric absorption coefficient (km$^{-1}$)
Fig 22 - 2700-2800 cm⁻¹ zero-sphere absorption coefficient (cm⁻¹)
Fig. 24 — 2840-2880 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 25 — 2880-2920 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 26 — 2920-2960 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 27 - 2960-3000 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 28 — 3000-3040 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 30 – 3080-3120 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 32 — 3160-3200 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 34 — 3240-3280 cm$^{-1}$ atmospheric absorption coefficient ($km^{-1}$)
Fig. 37 – 3360-3400 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 42 - 3560-3600 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 44 - 3840-3880 cm⁻¹ atmospheric absorption coefficient (cm⁻¹)
Fig. 45 - 3000-3700 cm⁻¹ atmospheric absorption coefficient (λm⁻¹)
Fig. 47 — 3760-3800 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. S.1 - 3800-4000 cm⁻¹ atmospheric absorption coefficient (cm⁻¹)
Fig. 50 — 4120-4100 cm⁻¹ atmospheric absorption coefficient (cm⁻¹)
Fig. 57 — 4160-4200 cm$^{-1}$ atmospheric absorption coefficient (km$^{-1}$)
Fig. 58 — 4200-4240 cm\(^{-1}\) atmospheric absorption coefficient (km\(^{-1}\))
Fig. 60 — 4280-4320 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 62 - 4300-4400 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 66 – 4520-4560 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 68 - 4600-4640 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 70 - 4680-4720 cm⁻¹ atmospheric absorption coefficient (km⁻¹)
Fig. 75 — 4880-4920 cm$^{-1}$ atmospheric absorption coefficient (km$^{-1}$)
Fig. 77 - 4960-5000 cm$^{-1}$ atmospheric absorption coefficient (km$^{-1}$)