Estimates of Near-Infrared Atmospheric Window Absorption

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Increased understanding of low-level atmospheric absorption is essential to propagation model predictions of thermal blooming for high-energy laser performance studies. Atmospheric absorption is classified into two general types, gas-phase local line and continuum.

Local line absorption within the near-infrared (NIR) atmospheric windows is reasonably well characterized by the HITRAN (HIgh-resolution TRANsmission molecular absorption) database. Often, lasers are selected or tuned so that local line absorption is avoided. Thus, the microwindows between these lines represent the lowest absorption that can be realized. Such microwindows are dominated by continuum-type absorption. Molecules and aerosols contribute to continuum absorption. A good estimate of aerosol absorption can be obtained from knowledge of the bulk complex index of refraction of the media composing the aerosol and the size distribution function as input to standard computer codes (e.g., Mie theory).

APPROACH

The molecular species contributing to NIR continuum absorption are water vapor and molecular oxygen. Unfortunately, a very limited set of experimental data exists to directly determine the absorption levels, frequency dependence, temperature dependence, and pressure dependence within the NIR. A combination of theory and indirect experimental data (from the mid-wavelength and long-wavelength infrared) is used to estimate the NIR continuum absorption. The contributions from oxygen are caused by collision-induced absorption (CIA) bands located at 1.27 and 1.06 μm. The water vapor continuum is represented as far wings of the main monomer fundamental bands defining the atmospheric windows and CIA bands underlying each fundamental band. The resulting models are compared to a limited set of laser-based experimental data that show good agreement at these spectral points. A calculation of a water-based aerosol absorption (e.g., light fog) shows that the molecular absorption dominates (Fig. 1).

ACCOMPLISHMENTS AND FUTURE PLANS

A semi-empirical model of NIR atmospheric window absorption attributable to molecular water and oxygen is now in place at APL; the model needs experimental data for completion and verification. Preliminary field experiments with a tunable fiber laser amplified to 1 kW covering the wavelength region from 1030 to 1083 nm are planned for the near future. Also, preliminary cavity ring-down spectroscopic measurements to identify the contribution of CIA O_2 to the optical absorption of laser light in the atmosphere at ~1050 nm have begun.

Extensive measurements are planned on oxygen and water vapor that are needed to accurately characterize the NIR molecular continuum absorption, which

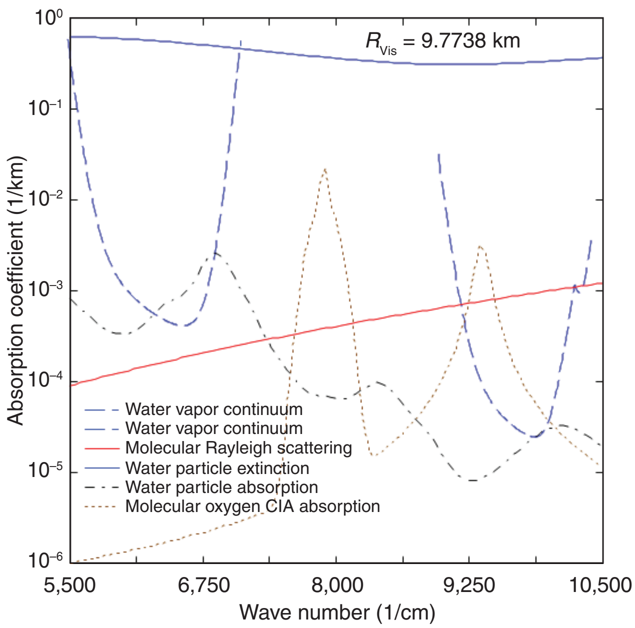

Figure 1. Calculation of a water-based aerosol absorption (e.g., light fog) showing that aerosol scatter is the dominant loss mechanism and that, in this case, aerosol absorption is less than molecular continuum absorption.

will require investigating the frequency, pressure, and temperature dependence (challenging because of low absorption levels). This is planned to be accomplished in collaboration with the National Institute of Standards and Technology cavity ring-down facility, with APL and the Department of Electrical and Computer Engineering developing tunable fiber lasers and matching the lasers to a power amplifier for field experiments. CIA and far wings will be used to interpret the data. Aerosol absorption also needs to be better understood, especially because carbon-based aerosols are a concern as countermeasures against high-energy lasers. Field testing will be conducted with a kilowatt-class tunable Yb:fiber laser (Fig. 2).

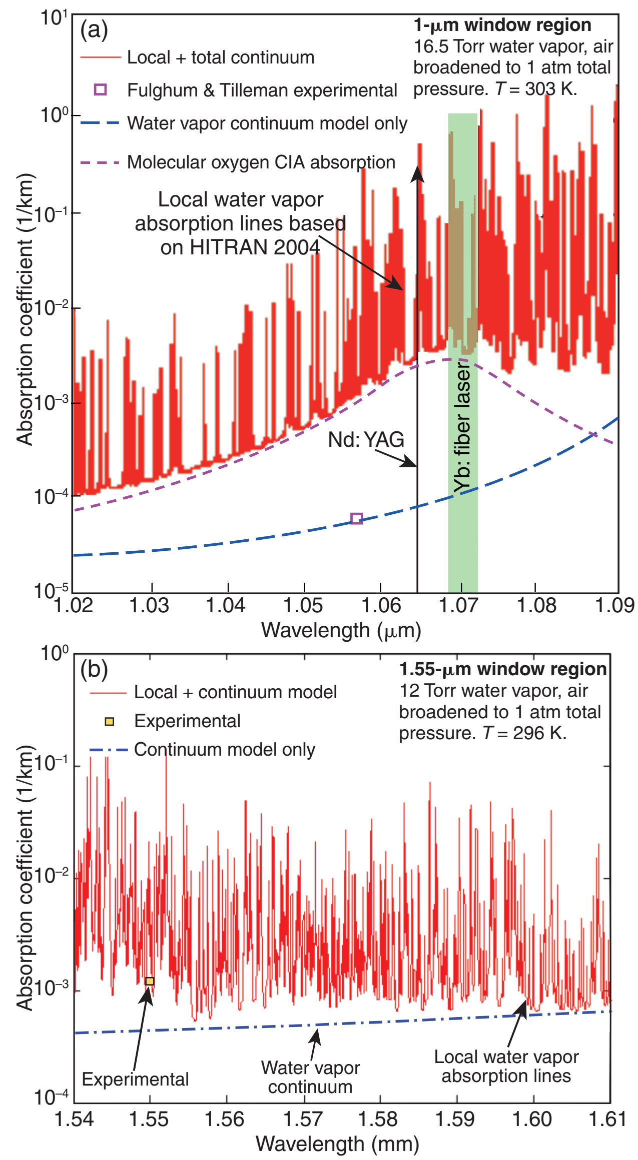

Figure 2. Extrapolation to NIR. (a) Note that 10^{-4} km^{-1} range is possible at 1.045 μm, which is within the tuning range of Yb:fiber laser. (b) Absorption levels are above 10^{-4} km^{-1}.

For further information on the work reported here, see the references below or contact mike.thomas@jhuapl.edu.

[1]Fulghum, S. F., and Tilleman, M. M., "Interferometric Calorimeter for the Measurement of Water-Vapor Absorption," *J. Opt. Soc. Am. B* 8, 2401–2413 (1991).

[2]Thomas, M. E., *Optical Propagation in Linear Media: Atmospheric Gases and Particles, Solid-State Components, and Water*, Oxford University Press, New York (2006).