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# Performance Modeling of Ultraviolet Raman Lidar Systems for Daytime Profiling of Atmospheric Water Vapor


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MASTER


## Abstract

We describe preliminary results from a comprehensive computer model developed to guide optimization of a Raman lidar system for measuring *daytime* profiles of atmospheric water vapor, emphasizing an ultraviolet, solar-blind approach.

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Summary

We describe preliminary results from a comprehensive computer model under development to guide optimization of an ultraviolet Raman lidar system for measuring *daytime* profiles of atmospheric water vapor. The Raman lidar technique is a leading candidate for providing the high-resolution, day/night profiling of water vapor that is critical to research in global climate change. While Raman lidar is used currently to perform meteorologically important, sustained, reliable nighttime profiling of water vapor, daytime measurements present added challenges because of the difficulties inherent in detecting Raman signals against solar backgrounds.

Raman lidar systems detect selected molecular species by monitoring their corresponding wavelength-shifted backscattered Raman return signals. Solar-blind

operation is based on choosing an excitation wavelength such that the return signal is in the solar-blind region of the spectrum ($\lambda \lesssim 300$ nm). Background daytime radiance drops off extremely rapidly below 300 nm (see Fig 1), because atmospheric ozone (as well as other gases for the shorter wavelengths) absorb practically all of the incoming solar radiation in this region of the spectrum, providing a "black background" for detection of the Raman signal. However, tropospheric ozone (see Fig. 1 for absorption cross-section) also absorbs the transmitted laser beam and the wavelength-shifted, backscattered Raman signal, reducing the range to which signals can be detected even in the absence of any background. Thus, the optimum excitation wavelength must be short enough to result in only a small level of background radiation, but long enough to result in sufficient atmospheric penetration.

We are developing a detailed Raman lidar instrument performance model, more comprehensive than those reported previously,[1,2] that will provide this optimum excitation wavelength as a function of a variety of operational parameters. The model simulates key characteristics of the lidar system, using realistic atmospheric profiles, estimated background sky radiance, and experimentally determined values for the lidar system parameters; model results demonstrate the tradeoffs among range, measurement precision, and data acquisition time during daytime operation. Figure 2 displays the calculated range obtained versus wavelength in relatively clear air for a Raman lidar system based on a high-average-power excimer laser, such as the instrument developed at the NASA Goddard Space Flight Center and fielded by the NASA/Sandia authors at the SPECTRE (Spectral Radiance Experiment) campaign in Coffeyville, Kansas during late 1991. Measurements performed at SPECTRE using 248-nm excitation will be compared to our model calculations to guide further development of the model, which will in turn be used to guide our development of wavelength-shifting capabilities for providing the optimum wavelength.

The preliminary results shown in Fig. 2 indicate that the optimum laser excitation wavelength is in the range of 255-265 nm. One factor that requires significant further investigation is the influence of attenuation by the weak ("forbidden") Herzberg I molecular oxygen uv absorption bands, which could influence signals over the several-kilometer atmospheric paths probed by the Raman lidar system. In addition, the calculation shown in Fig. 2 represents only a signal-to-noise calculation, and does not take into account *systematic* effects, such as those introduced by the strong wavelength dependence of the ozone absorption cross section. These and other potential effects on optimum wavelength selection for solar-blind operation are being addressed currently in model, laboratory, and field-based lidar studies. We are also investigating the merits of a different approach for daytime operation based on a narrow spectral bandpass, narrow field-of-view system.

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## References

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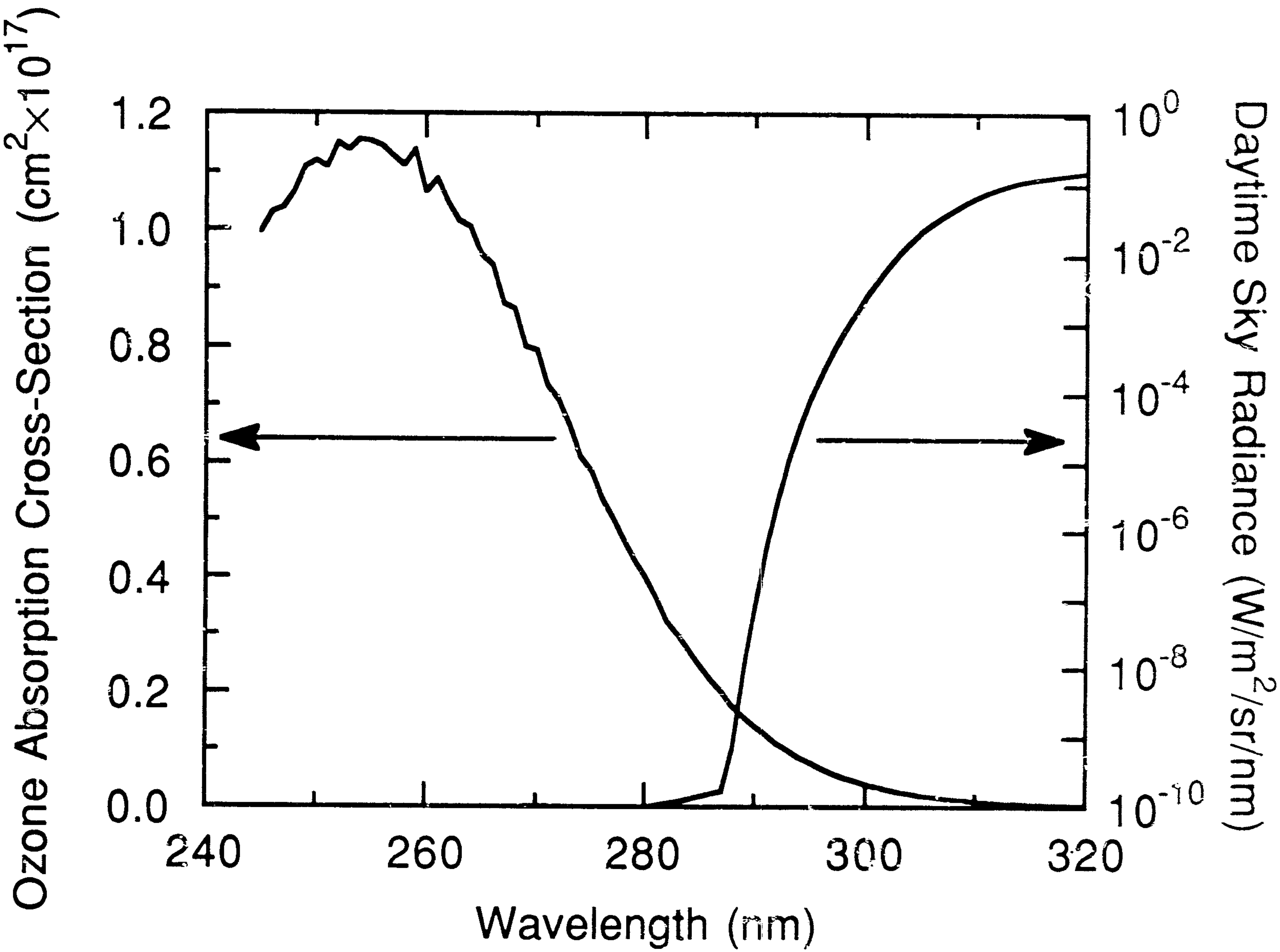
2. D. Renaut and R. Capitini, "Boundary-Layer Water Vapor Probing with a Solar-Blind Raman Lidar: Validations, Meteorological Observations and Prospects," J. Atmos. Oceanic Technol. **5**, 585-601 (1988).

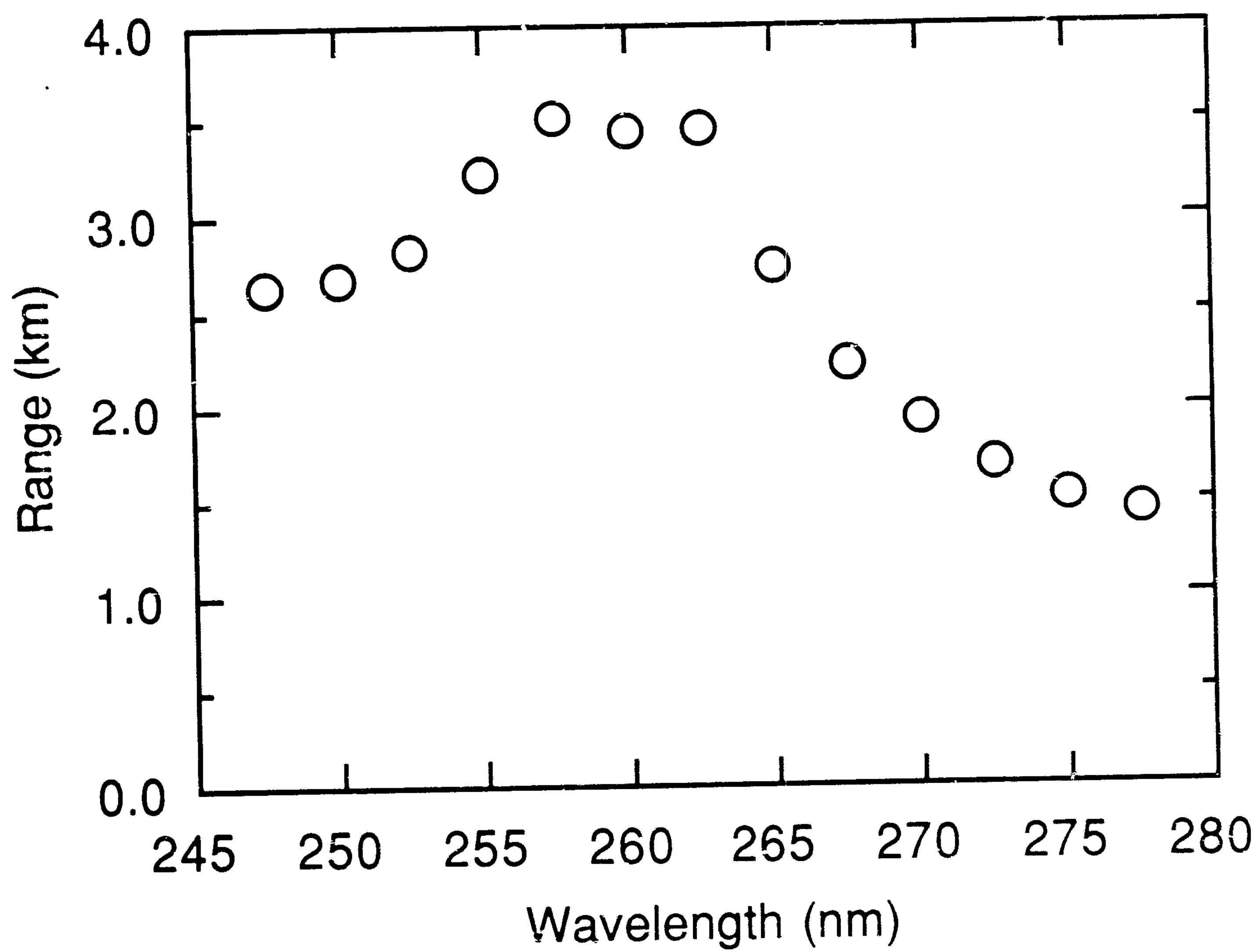
Figure Captions

1. Ozone absorption cross-section and daytime sky radiance in the spectral region 240-320 nm.

2. Observation range as a function of laser wavelength computed from the model. This maximum range corresponds to a signal-to-noise ratio of 10 (based on Poisson statistics) in the Raman water vapor channel. The laser output power and lidar system parameters are assumed constant over the indicated spectral region.



Ozone Absorption Cross-Section (cm²×10¹⁷)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
240
260
280
300
320
Wavelength (nm)
Daytime Sky Radiance (W/m²/sr/nm)
10⁰
10⁻²
10⁻⁴
10⁻⁶
10⁻⁸
10⁻¹⁰


4.0
3.0
2.0
1.0
0.0
Range (km)
245
250
255
260
265
270
275
280
Wavelength (nm)