CHARACTERISTICS OF WATER VAPOR OVER KITT PEAK AS DETERMINED FROM FTS DATA

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Spectra of three water vapor lines obtained with the Fourier transform spectrometer at the McMath telescope have been analyzed to obtain the atmospheric water-vapor content. The results for 52 days between 1978 and 1983 show a maximum of between 20 and 25 mm precipitable water vapor in July and August and minima between February and June and between October and December. Outside of a secondary maximum due to two days in January 1983 the results are in generally good agreement with those obtained with a grating spectograph.

The pressure-broadened linewidths have been used to make corrections not exceeding 11% to the results obtained with the spectograph.

Key words: atmospheric water vapor—observatory sites

I. Introduction

A previous report contained data on atmospheric water vapor obtained with the 13.5-m grating spectograph at the McMath telescope (Wallace and Livingston 1984); the present report contains parallel data obtained with the Fourier transform spectrometer at the same telescope but on different dates. The FTS data reported here are more sparse than the spectrograph data, representing only 52 days as opposed to 179. They also extend from 1978 to 1983 as opposed to from 1977 to 1983. They are, however, of sufficiently high spectral resolution that the line shapes are revealed and the water-vapor amounts can be determined without recourse to a curve of growth. Secondary, the pressure-broadened widths, γ, allow an approximate correction for the amount of water-vapor absorption inside the telescope.

II. FTS Results

Since the line analyzed in the spectrograph data, at 1.0832 μm, was infrequently observed with the FTS, three other lines near 2.2 μm were chosen for analysis. These lines, at 4556.56, 4565.12, and 4569.88 cm⁻¹, are relatively free of blends and their absorption coefficients have been measured (Brault, Fender, and Hall 1975). The spectrum chosen from each day’s observations was that corresponding to minimum air mass.

The spectral region containing the three water lines was modeled as a number of overlapping Voigt profiles. The parameters defining each Voigt profile were adjusted and additional Voigt profiles were added until the difference between the observed spectrum and the model was noise. The parameters for the Voigt profiles were then taken to represent the observed lines. The adopted absorption coefficients, averaged from Brault et al. (1975) were S(4556.56) = 0.109, S(4565.12) = 0.108, and S(4569.88) = 0.081 cm⁻¹/gram cm⁻². The first two are in excellent agreement with the values of 0.105 and 0.106 cm⁻¹/gram cm⁻² obtained by Flaud et al. (1977); no measurement was reported for the third line.

The mean of the water-vapor amounts determined from the three lines for each day given in units of millimeters of precipitable water vapor (mm pwv) and corrected to the vertical are given in Figure 1. The standard deviations of the daily means are not dependent on water-vapor amount and are generally 0.1 or 0.2 mm pwv.

The agreement between the FTS results and the monthly means from the spectrograph (Wallace and Livingston 1984), also given in the figure, is reasonable enough considering that the two data sets have no dates in common. The outstanding difference is the two FTS points for 1983 January 12 and 13. We have checked these particular results and there is no mistake. The largest amount observed in January with the spectrograph was 8 mm pwv; 1983 January 12 and 13 were extraordinarily wet and the atmosphere must have been abnormally warm.

In order to obtain information on the vertical distribu-
The real day-to-day variation in $\gamma_{obs}/\gamma_0$ is a reflection of the variability in the vertical distribution and is not correlated with water-vapor amount. No convincing seasonal variation in $\gamma_{obs}/\gamma_0$ is apparent. The extremes of the bimonthly means are 0.80 and 0.84 and the mean of all the data is 0.81.

III. Corrections of the Spectrograph Data for Absorption in the Telescope

These data on $\gamma_{obs}/\gamma_0$ have allowed us to clarify the two major uncertainties in the reduction of the spectrograph data of Wallace and Livingston. It is clear from Figure 2 that while their assumption of a single $\gamma_{obs}/\gamma_0$ for all the observations was not strictly correct, the seasonal variation of $\gamma_{obs}$ is too small to have any significant effect on their monthly mean water-vapor amounts.

The second problem is that of correcting the water-vapor amounts for absorption within the telescope. The path length in the telescope, $l$, is 1/4 km. Then, if the water-vapor density falls off strictly exponentially with altitude with a scale height $h$ and if it is the same inside the telescope and outside and $A$ is the air mass factor, the amount of water vapor corrected for absorption in the telescope and to unit air mass is

$$a_{corr} = a_{obs} \frac{h}{A}$$

(1)

instead of the usual $a_{obs}/A$. At any given time the Rawinsonde data taken at the Tucson Airport indicate very substantial departures from an exponential falloff in water-vapor density but the monthly means of that data taken from the NOAO publication “Climatological Data, National Summary” show smooth distributions with a mean scale height of 1.9 km. With $A = 1$, $l = \frac{h}{A}$. 

FIG. 2—Variation of the observed pressure-broadened line widths, $\gamma_{obs}$, referred to the line widths at Kitt Peak pressure, $\gamma_0$. 

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$1/4 \text{ km, and } h = 2 \text{ km, equation (1) indicates an 11\% correction.}$

We have reduced the data in Figure 2 to obtain $h$ appropriate to Kitt Peak, invoking the two assumptions necessary to obtain equation (1). Additionally, we have taken the pressure and temperature dependence of $\gamma$ to be that cited by Giver et al. (1982) and assumed that $\gamma_{\text{obs}}$ can be taken as the mean $\gamma$ weighted according to water-vapor density. That is,

$$\gamma_{\text{obs}} = \frac{\int \gamma n ds}{\int n ds}$$  (2)

where $n$ is the water vapor density and $ds$ is an element of path. Evaluation of the integrals gives an expression for $\gamma_{\text{obs}}/\gamma_0$ in which $h$ is the only unknown.

The individual values of $h$ derived in this way are given in Figure 3. With the bimonthly means of $h$ the spectrograph data were corrected for absorption in the telescope using equation (1). The derived corrected monthly mean amounts are indicated in Figure 1. Since the variation in the bimonthly mean values of $h$ is small the corrections can be represented to 1% accuracy using equation (1) with the mean value of $h$ (2.2 km) and the monthly mean air-mass factors which range from 2.1 in January to 1.1 in the interval May through August. These changes are small enough that no changes in the discussion by Wallace and Livingston are required.

REFERENCES


