OBSERVATIONS OF ATMOSPHERIC WATER VAPOR WITH THE SAGE II INSTRUMENT

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1. Introduction

The Stratospheric Aerosol and Gas Experiment II (SAGE II) is a multiwavelength spectrometer which infers the vertical distribution of stratospheric aerosols, ozone, nitrogen dioxide and water vapor from the extinction of solar radiation measured during spacecraft sunrise/sunset. The water vapor channel is centered at 935.5 nm with a bandwidth of 20 nm. The instantaneous field-of-view is rectangular in shape, 0.5 arc minutes in elevation by 2.5 arc minutes in azimuth which corresponds to 0.5 km by 2.5 km at the tangent layer. Each day, 15 sunrise and 15 sunset profiles are obtained with successive measurements separated by 24^{o} in longitude at similar latitudes. Global coverage ranges from 80^{o}N to 80^{o}S at altitudes from 45 km down to cloud tops or 2 km in cloud free regions. SAGE II was launched in October, 1984 and remains operational today. Further details of the instrument and measurement technique may be found in (1, 2). The procedure for converting the solar radiance data to atmospheric slant path transmission and inversion to gas concentration may be found in (3). Since this is the first measurement of water vapor with the SAGE observational technique and the first use of the ρ water vapor band to infer H_2O from space, an extensive validation program has been undertaken that incorporates correlative measurements and comparisons to other global data sets. In this paper, we will present preliminary zonal means for November 1985 and compare them to tropospheric water vapor (4) and the LIMS stratospheric water vapor (5, 6). Correlative measurements from a frost-point hygrometer will also be compared to individual SAGE II profiles.

2. Correlative Measurements

To validate the SAGE II water vapor measurements a balloon-borne frost-point hygrometer (7) was flown several times in the northern hemisphere at low, middle and high latitudes. The flights were planned to coincide as close as possible in space and time with the SAGE II overpasses. Results from two mid-latitude flights are shown in Figure 1 along with the corresponding SAGE II profiles for comparison. The error bars indicate the estimated one standard deviation uncertainties in the SAGE II water vapor retrievals. The time separation between the frost-point hygrometer and SAGE II is less than an hour for the November 30 measurements and less than 2 hours on May 18. The November 30 measurement location is also closer to the SAGE II observations than for May 18. On both days, excellent agreement is apparent above 15 km, below this altitude some discrepancies are evident. Some of the differences at these altitudes are likely a result of comparing point measurements (the hygrometer) to long path occultation measurements (SAGE II) of an atmospheric species with rapid vertical and horizontal variations. Of some interest is the enhancement in water vapor at 10 km measured by the frost-point hygrometer on November 30. Inspection of the SAGE II slant path transmission (not shown) and the 1.0 μm aerosol extinction profile indicates a layer of clouds at the tropopause which the balloonsonde passed through and which terminated the aerosol and water vapor inversion. A hint of cloud also appears in the May 18 data at 11 and 12 km in the aerosol extinction and hygrometer profiles.

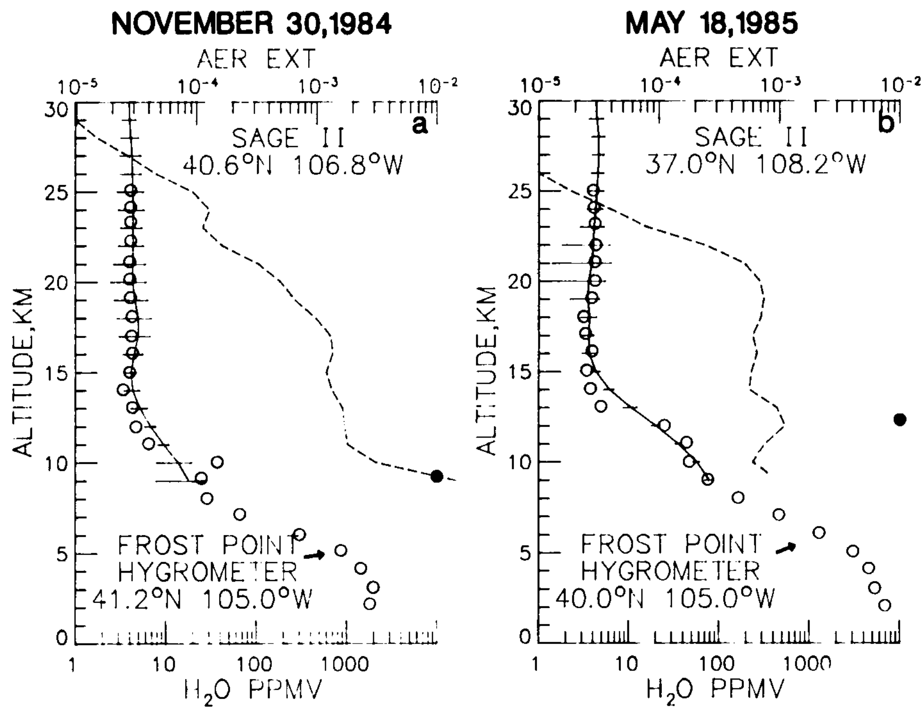

Figure 1. Water vapor correlative measurements for November 30, 1984(a) and May 18, 1985(b). Open circles correspond to frost-point hygrometer measurements, solid curve SAGE II. Error bars indicate estimated one standard deviation uncertainty in SAGE II retrieved H_2O. Dashed line gives the simultaneous SAGE II 1.0 μm aerosol extinction profile. Solid circle indicates altitude of NMC defined tropopause.

3. Global Water Vapor Compilations

Another approach one can take to validate a large body of data, such as the SAGE II water vapor data, is to calculate and compare monthly zonal means with other published climatologies. In this section we present monthly zonal means for November, 1985 and compare them to two global water vapor compilations, the November 1978 LIMS measurements (5, 6) and the Global Atmospheric Circulation Statistics (GACS), 1958-1973, developed by Oort (4). The LIMS experiment on Nimbus 7 used the 6.9 μm water vapor band to measure the vertical profile of water vapor from 100 to 1 mb. Near global coverage was obtained (64°S to 84°N) from October 24, 1978 to May 28, 1979. The GACS water vapor climatology has been developed from several data sets composed primarily of rawinsonde observations. Southern hemisphere climatology covers the 1963 to 1973 time period while the northern hemisphere covers an additional 5 years, from 1958 to 1973. Uniform longitudinal coverage is obtained with LIMS in both hemispheres, while most GACS rawinsonde data are taken over land at fixed locations. Altitude coverage of the GACS data ranges from 1000 to 300 mb. Global information covering the intermediate levels from 300 to 100 mb is non-existent to our knowledge.

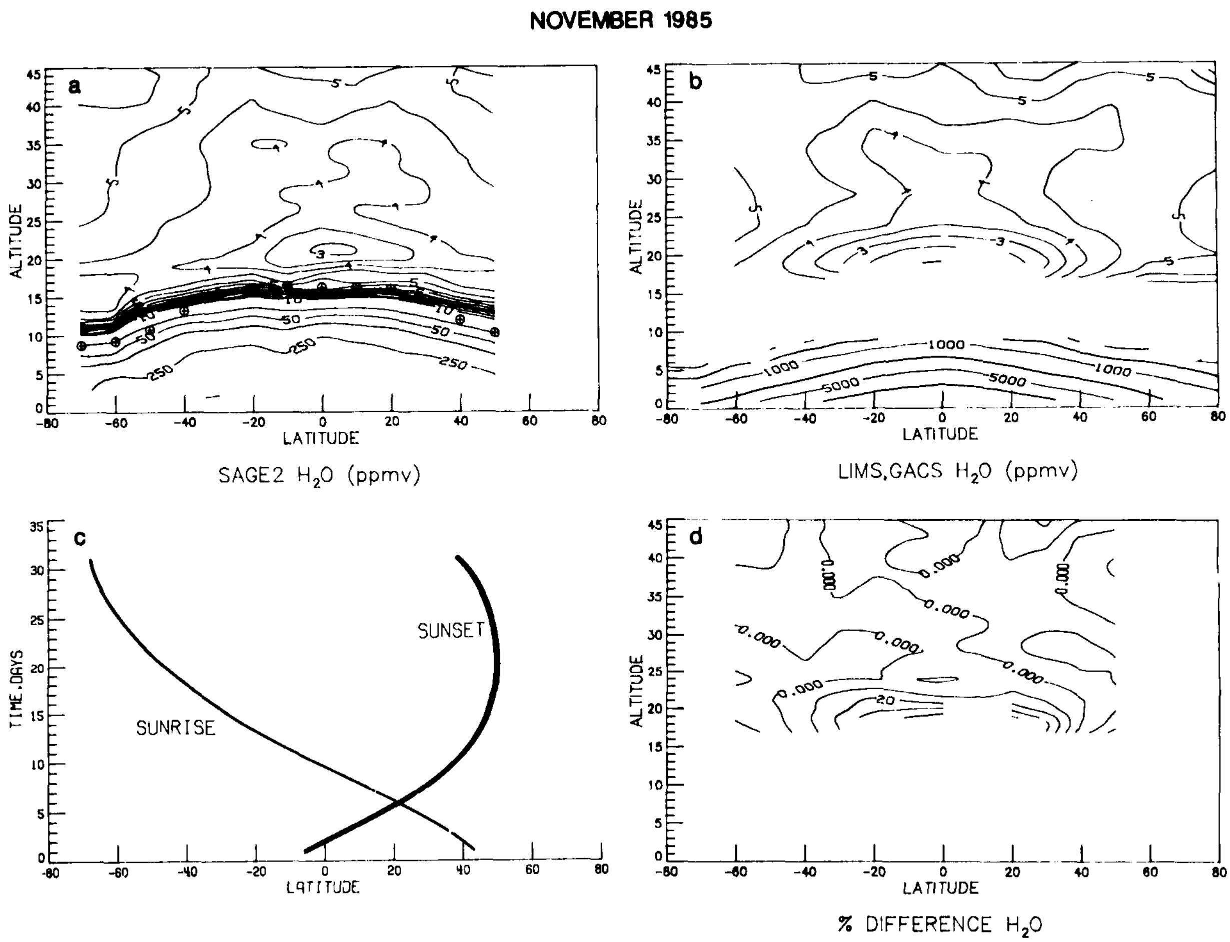

Figure 2. a) SAGE II monthly zonal means for November, 1985. Circles with pluses indicate monthly averaged NMC tropopause altitude. b) Stratospheric LIMS monthly zonal means for November, 1978 and tropospheric GACS monthly zonal means. c) SAGE II latitudinal coverage for November, 1985. d) Percent difference between SAGE II and LIMS monthly zonal means in the stratosphere.

Figure 2a shows the November 1985 monthly zonal means obtained with SAGE II. The SAGE II profiles have been screened for cloud and aerosol contamination as discussed in (8). The screening has the greatest effect in the equatorial lower stratosphere where the most clouds and highest levels of aerosol are found. The screening process tends to bias the data set in the troposphere to cloud free air masses and thus presumably dry conditions.

Mixing ratios of 3 ppmv are found at the hygropause and increase to 5 ppmv at higher altitudes and latitudes. The transition from the stratospheric to tropospheric regime is delineated by the 5 to 10 ppmv contours. At low latitudes this transition region corresponds closely to the average NMC defined tropopause height (circles with pluses) but at high latitudes the water transition region lies above the average tropopause. Figure 2b shows the corresponding November zonal means for the LIMS and GACS water vapor compilations. The SAGE II zonal means were calculated with 10^{o} latitude bins, LIMS with 4^{o} bins and GACS with 5^{o} bins. In the stratosphere, SAGE II and LIMS agree quite well even though the measurements were taken 6 years apart.

The percent difference in mixing ratio, shown in Figure 2d, is better than 20% outside of the hygropause region. Within the hygropause region, the differences reach 40%. Some of this may be due to differences in the instantaneous field-of-view, 3.6 km (FWHM) for LIMS versus 0.5 km for SAGE II, but it may also result from the fact that SAGE II obtains all of its equatorial data in the first third of the month as indicated in Figure 2c, thus the SAGE II monthly zonal mean is more representative of the early part of the month. The SAGE II tropospheric water is considerably lower than the radiosonde GACS water data. This difference may be indicative of the level of bias caused by the cloud screening process.

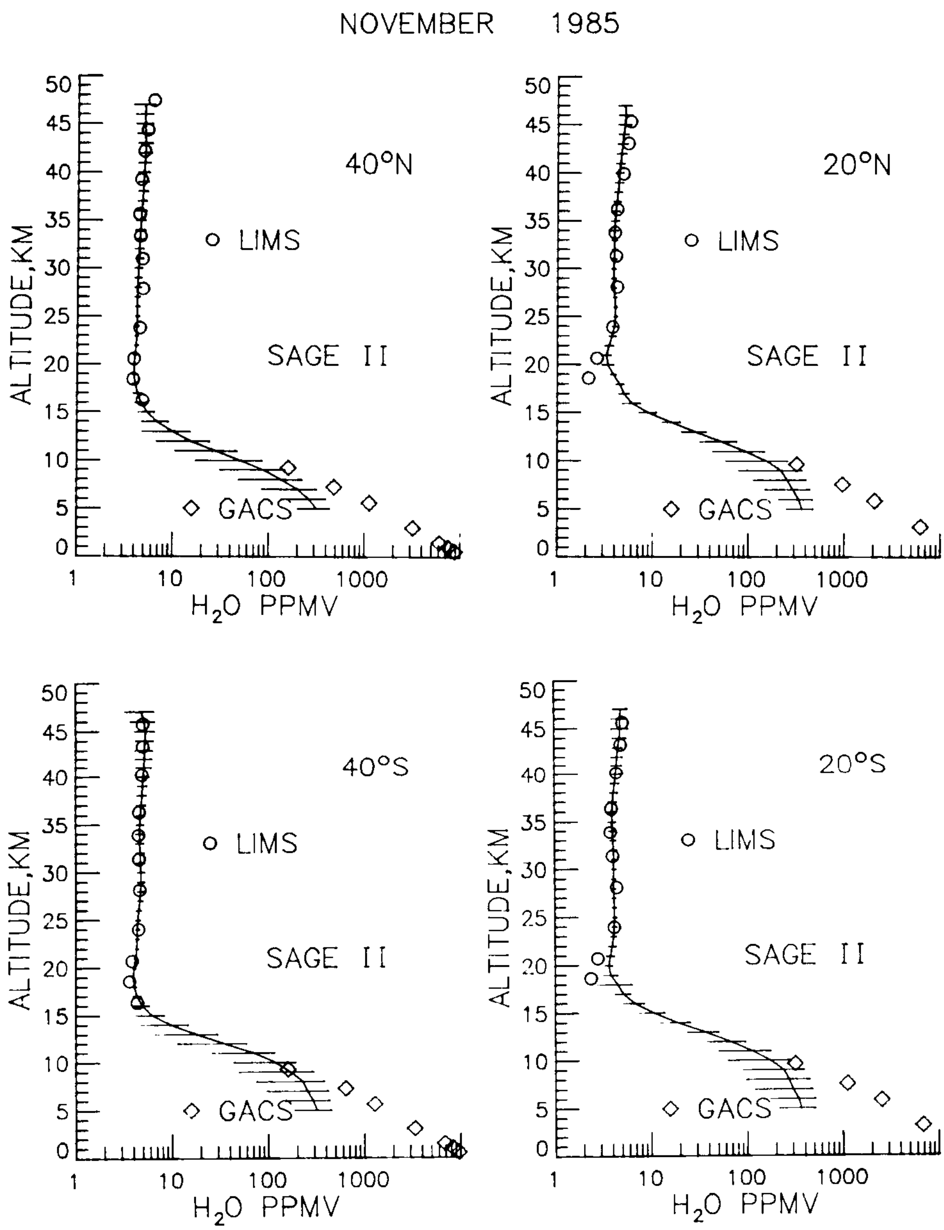

Figure 3. Comparison of selected SAGE II, LIMS and GACS monthly zonal means for November. The SAGE II error bars represent the standard deviation of the mean mixing ratio.

Figure 3 highlights the monthly zonal near vertical profiles for selected latitude bins corresponding to Figure 2. The error bars in this figure represent the standard deviation of the mean SAGE II mixing ratio. The error bars are small in the stratosphere where little variability is expected and large in the troposphere where dynamics determines the distribution to a large extent.

4. Discussion

Given the many differences (measurement techniques, sampling biases and observational periods) between SAGE II, LIMS, and GACS; the agreement between SAGE II and the comparison data sets is quite good. Some of the remaining differences may never be fully explained. The quality of the comparison to LIMS data in the stratosphere shown here for November is representative of that found in other months for which LIMS obtained data. The SAGE II data indicates a smooth transition from the LIMS data at 100 mb to the GACS data at 300 mb. The quality and consistency of the SAGE II water vapor will lead to improved understanding of the global water vapor climatology, aerosol formation mechanisms, and tropospheric/stratospheric exchange processes.

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