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APPLICATION OF TETHERED BALLOON AND KITE MEASUREMENTS USING CHILLED MIRROR HYGROMETERS DURING THE ARM WVIOP IN THE FALL OF 1996 IN OKLAHOMA

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1. INTRODUCTION

Water vapor is the most important "greenhouse gas", and it's measurement is currently so imprecise that long term trends are difficult to document. This problem was the focus a Water Vapor Intensive Operations Period (WVIOP) at the Atmospheric Radiation Measurement (ARM) Southern Great Plains (SGP) site near Billings, OK in September 1996. Our part of this comparison involved tethered-balloon and kite profiling of meteorological parameters and dew-point measurements using a light-weight chilled-mirror system. The tethered balloon system was used when the winds were less than about 12 m/s. The kite system was used when winds were in the 12-15 m/s range. In this abstract, we will focus on comparisons on boundary-layer profiles using the tethered systems and conventional rawinsonde measurements at ARM SGP. The tethered systems were limited to profiles up to 1 km above ground level. Of particular interest, is the representativity of the rapid-ascent measurements associated with rawinsonde launches and the longer-term profiling associated with the tethered system in the boundary layer. Comparisons show that profiles differed significantly in both temperature (1 to 2 °C) and water vapor (5 to 10 %). Both calibration and representativity contribute to these differences.

2. EXPERIMENT DESCRIPTION

Vertical profiles were made of water vapor mixing ratios using a chilled-mirror dew-point hygrometer. The chilled-mirror systems are commercial instruments from Meteor AG™ and flown on a tethered balloon with the tethersonde® meteorological profiling system from AIR Inc. The chilled-mirror systems are designed to fly on tethered balloons (Richner et al. 1991). Two tethersonde® systems were used at two different frequencies (403.5 and 404.7 MHz). Possible interference related problems occurred with the 404.7 MHz system. This frequency is close to the 404.5 MHz Lamont Profiling System frequency. The noise problems resulted in high noise on the chilled-mirror reference temperature measurement.

The tethersonde® systems and the chilled-mirror systems were calibrated after the experiment at the University of Wisconsin and the University of Oklahoma and showed that the tethersonde® systems measured temperatures to an accuracy of about +/- 0.1 °C and the chilled mirror systems agreed with a standard to within +/- 0.25 °C (Fig. 1). However, field comparisons with a ground station temperature/relative humidity

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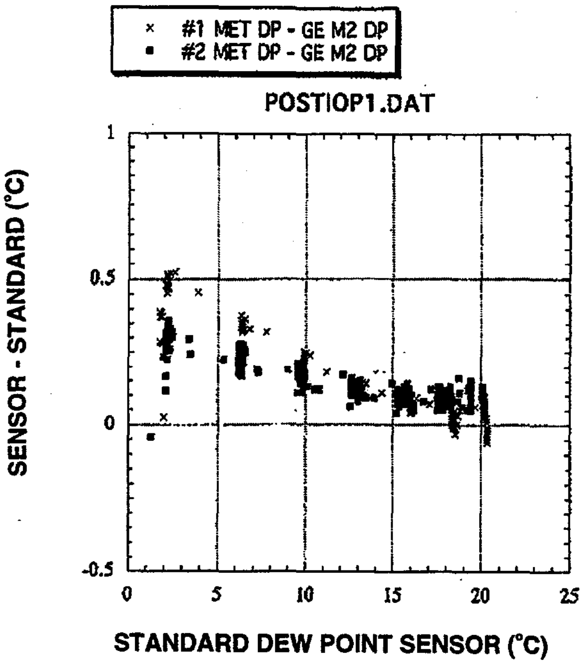

Fig. 1 Calibration comparison of dew point differences from two chilled-mirror sensors with a standard sensor during post calibration.

(T/RH) ground station probe (GS) used for comparison with the rawinsonde showed much greater differences.

3. RESULTS

Figure 2 shows examples of surface comparisons with a Vaisala™ T/RH probe near the rawinsonde launch location. The comparison on 13 Sept. was relatively close in mixing ratio. However, the comparison on 16 Sept. using a different tethersonde® showed an offset with the Vaisala™ sensor value elevated by about 0.5g kg^{-1}. At times during wet periods the Vaisala™ sensor read over 100% relative humidity.

Temperature comparisons between a tethersonde® dry-bulb sensor and the Vaisala™ probe temperature are also shown in Fig. 2. The tethersonde® temperatures were used to derive relative humidities from the chilled-mirror sensor. It is important to remember that water vapor mixing ratio is directly determined from the dew-point temperature and pressure without the need to know the air temperature.

$$W = 621.97 * P_{sat}(T_d) / (P - P_{sat}(T_d)) \quad (1)$$

where W is the mixing ratio in g kg^{-1}, $P_{sat}(T_d)$ is the saturation vapor pressure at the dew-point temperature (T_d), and P is the pressure in kPascals.

Figure 3 shows a comparison of water vapor mixing ratio and temperature profiles between the tethered systems (all these profiles were made with the tethered balloon system) and the rawinsonde. Launches on Sept. 10 and 11 show the noise problem from sonde #1907 but are in closer agreement than the later sonde launches. Sonde launches on Sept. 24 and 27 show that both the mixing ratios and the temperatures disagree. The rawinsonde is warmer and drier. The temperature difference would be corrected if tethersonde #1210 (403.5 Hz) temperatures were cold by about 2 degrees. This wouldn't change the mixing ratios. If the rawinsonde were warm by the same amount, both the temperatures and the mixing ratios would agree more closely. The ground station was 2.2 ^{o}C colder than the rawinsonde on 24 Sept., but was 0.1 ^{o}C warmer on 27 Sept. The tethersonde #1907 dry bulb and the chilled-mirror temperatures agreed closely. Though calibration may have played a role on 24 Sept., the differences on 27 Sept. seem to be more associated with the ability of the rawinsonde to adjust quickly to a shallow temperature inversion.

The comparison in Fig. 3 shows that the nocturnal boundary layer jet is drier than air above and below. This is of interest as the mid-west synoptic nocturnal jet is usually thought of as a mechanism for transporting water vapor northward over Oklahoma (e.g. Arritt et al. 1996). It is possible that the wind jet associated with the inversion pulls dry air down from above. However, since the air is relatively more moist above as well as below, a three dimensional effect seems likely. Advection of relatively dry air from the southwest is possible, but at least at the SGP site for 11 and 24 Sept. the jet was almost directly from the south. The

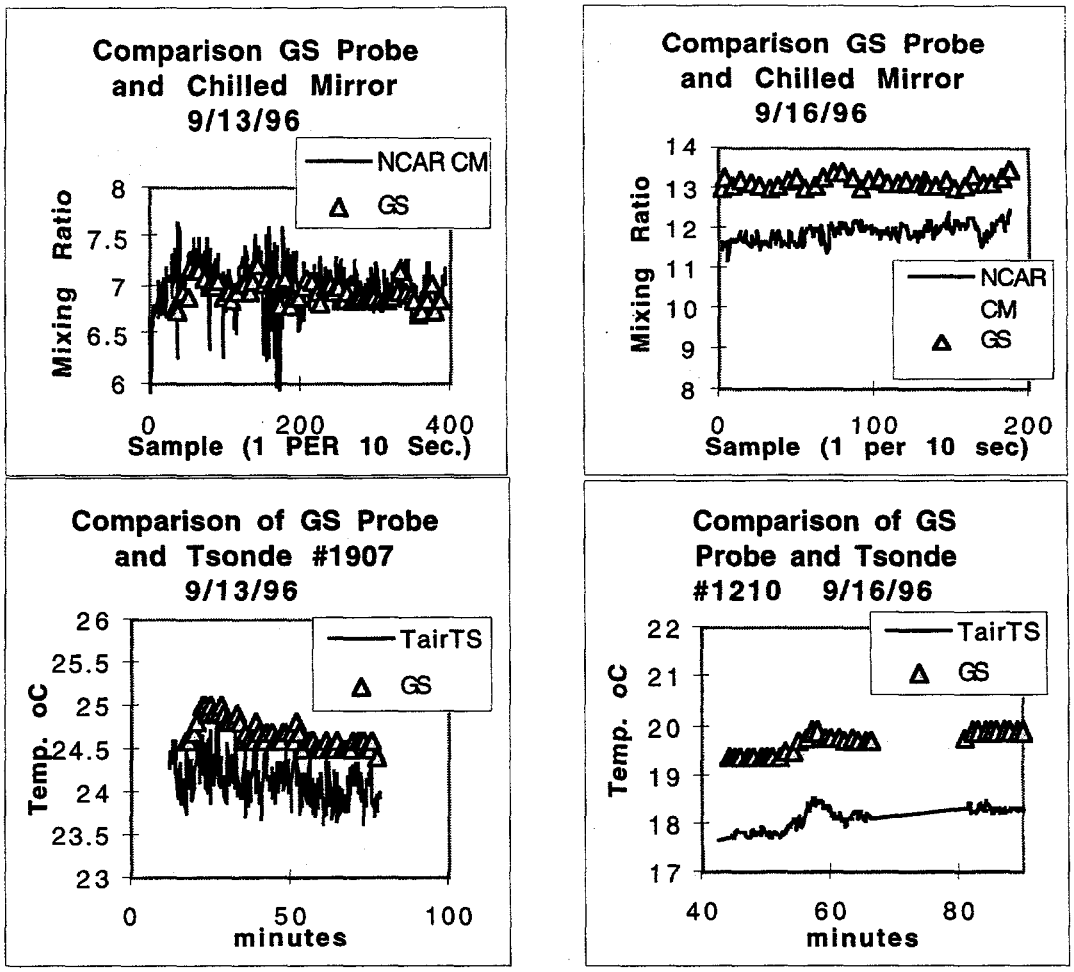

Fig. 2 Comparisons of water vapor mixing ratios (CM chilled-mirror) and temperatures (TairTS tethersonde dry bulb) at a location (GS ground staion) near the lauch of the SGP rawinsonde.

profile on 27 Sept. shows a wind feature from the west with little or no change in water vapor mixing ratio.

The ability of the rawinsonde to profile wind speeds associated with the very low boundary-layer jet at SGP is tested by comparisons of wind speeds associated with the profiles shown in Fig. 3. Figure 4 shows the wind speeds from the tethered systems and the rawinsonde. The rawinsonde tends to show lower wind speeds and overestimate the height of the jet on nights when the jet is strong and shallow.

Figure 5 shows a comparison of mixing ratio determined from two chilled-mirror sensors (NCAR and Swiss1) flown with two separate tethersonde® systems (at 403.5 MHz and 404.7 MHz) on the same tethered balloon. This figure shows that the sensors were relatively consistent with each other.

Improvements in experiment design are planned for a follow-on WVIOP experiment in September 1997 to better isolate calibration and environmental differences associated with differences in aspiration and the ability of the rawinsonde to quickly respond to changing boundary-layer temperature, humidity and winds associated with the nocturnal boundary layer.

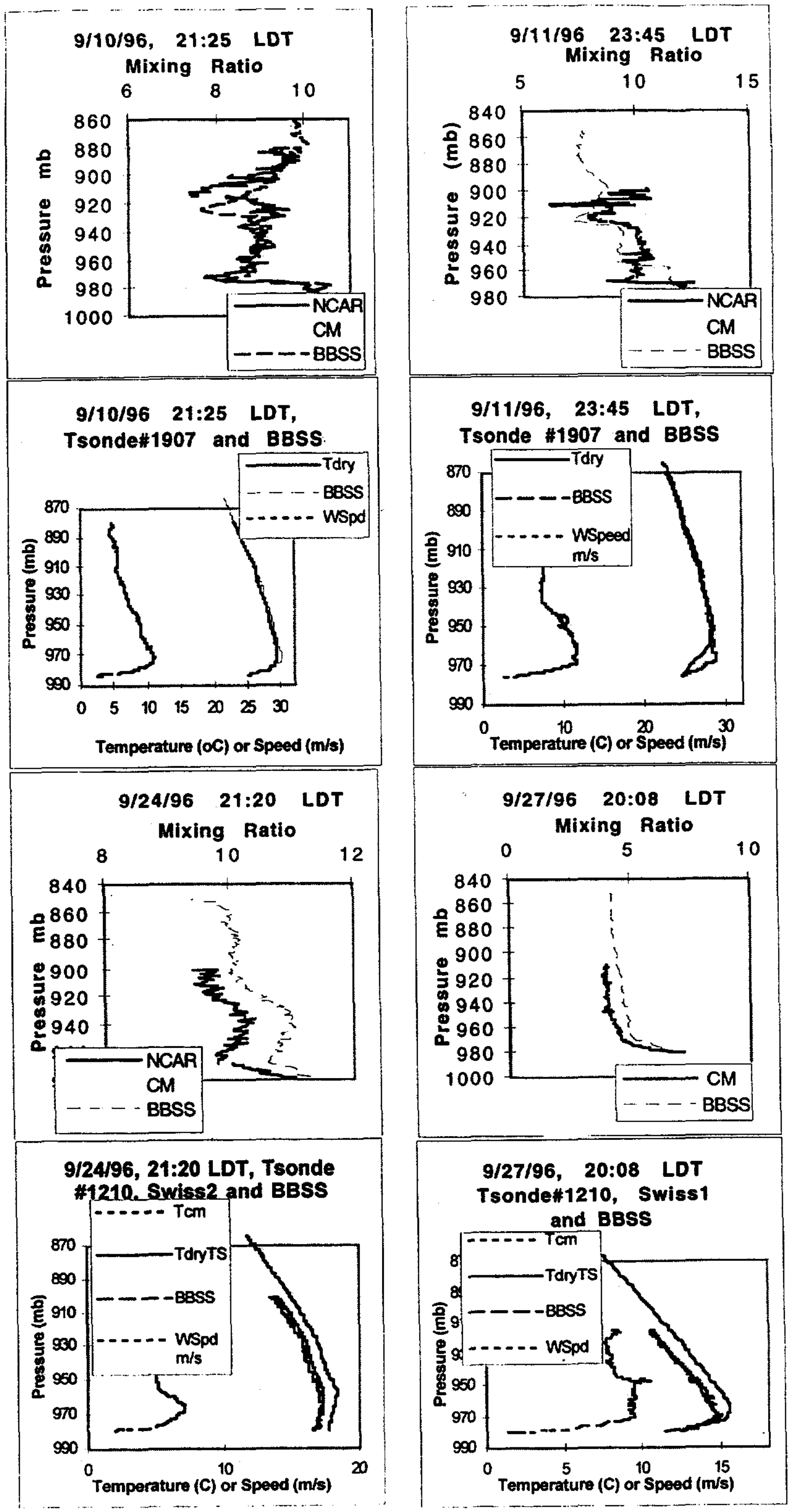

Fig. 3 Profile comparisons of water vapor mixing ratios (CM chilled-mirror) and temperatures (Tcm chilled-mirror, TdryTS dry bulb) from the tethered systems and the rawinsondes (BBSS). The times listed correspond to the launch times of the tethersonde. The rawinsonde launch dates and times were 9/10 20:29 LDT, 9/11 23:30 LDT, 9/24 20:31 LDT and 9/27 20:00 LDT.

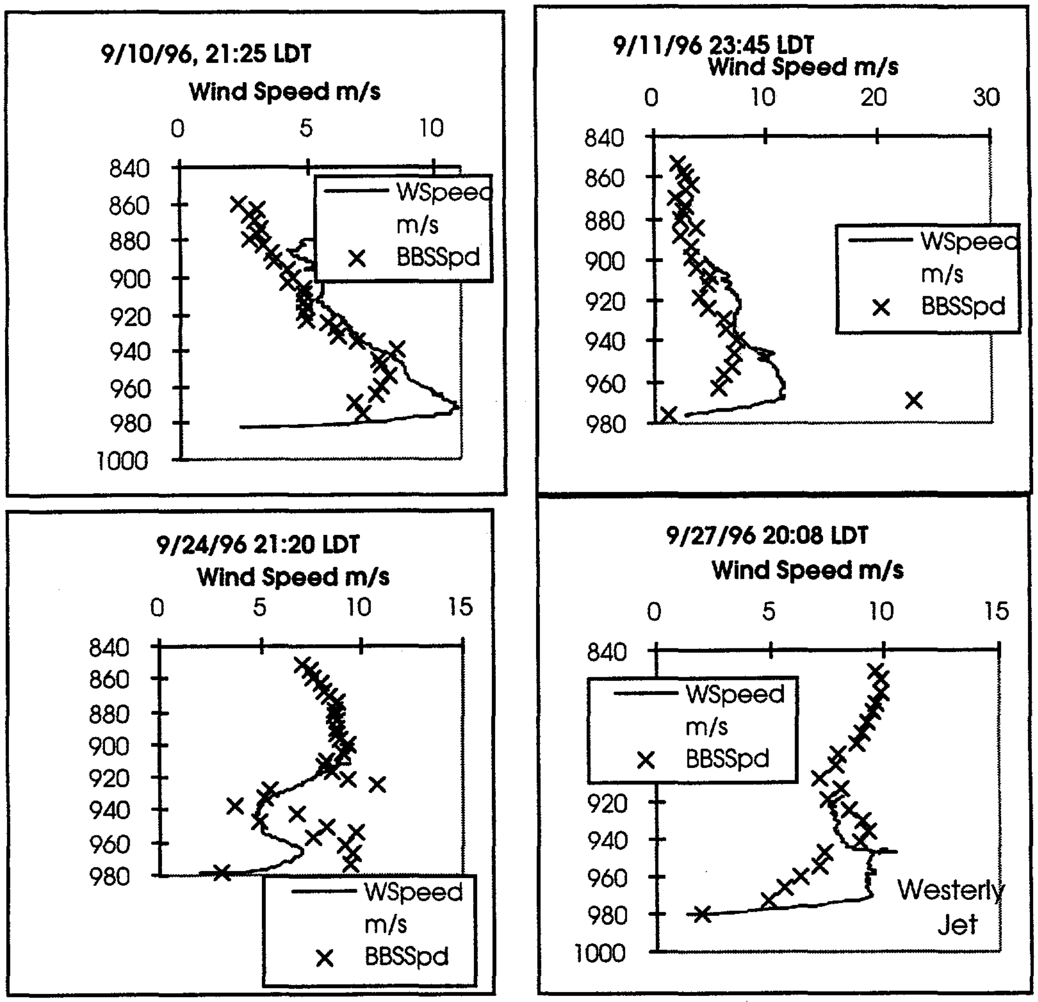

Fig. 4 Comparisons of wind speed profiles from tethered systems and rawinsondes (BBSS) for nights and times shown in Fig. 2. The wind directions were from the south on all nights except 9/27 which had a westerly jet.

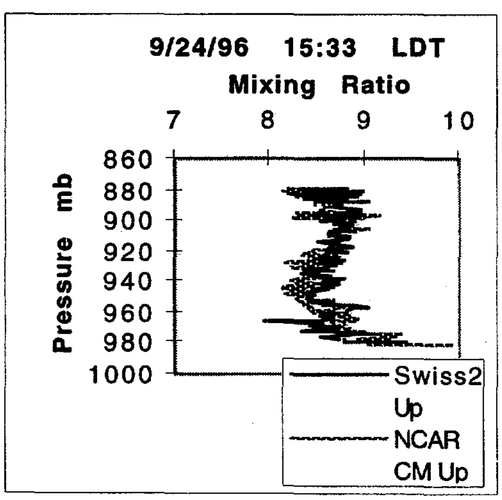

Fig. 5 Comparison of profiles from two chilled-mirror dew point sensors on a dual tethered system flight.

4. ACKNOWLEDGMENT

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