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Comparison and Calibration of NCAR Electra Instruments: July 5 and July 7, 1987

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Measurements of temperature, water vapor, cloud liquid water, and lidar cloud height taken by the NCAR Electra are analyzed for two days of the FIRE stratocumulus field program. Examination of instrument time series, correlations between sensors, soundings through the layer and lidar measurements of cloud base height are used to correct sensor offset problems, check for probe wetting, and choose the most accurate measurements of temperature, humidity, and cloud liquid water.

1) Temperature and Humidity

Three instruments measured water vapor concentration: the top and bottom Cambridge dewpoint thermometers (DPTC and DPBC) and the Lyman-α hygrometer.(RHOLA). Both of the Cambridge mirrored dewpoint instruments displayed the 0.33 Hz oscillations and lagged response typical of these sensors (Boers and Betts, 1988). We applied a simple three point running mean filter to the measurements and introduced a 2 second delay, which brings both dewpoint probes into qualitative agreement with the Lyman-α hygrometer.

A grouped comparison of the two dewpoint thermometers, the Lyman-α hygrometer and the four temperature sensors (fast response (ATKP), reverse flow (ATRF), Rosemount (ATB), and radiometric (PRT6)) can be done when the aircraft is in solid cloud. Cloud penetrations were examined for both July 5 and July 7, and a typical segment is shown in Figure 1. The 10 Hz measurement of droplet number concentration given by the Forward Scattering Spectrometer Probe (FSSP) is > 10 cm^{-3} throughout this section, indicating that the air is close to saturation on 10 meter length scales. The range of readings from the different thermometers, their relative values with respect to one another, and the tendency of the each of the dew point sensors to pair with a different thermometer (DPTC with ATKP and DPBC with ATRF) are typical of cloud penetrations on both July 5 and July 7. The fast response and top dewpoint thermometers are 1 K warmer than the reverse flow and bottom dewpoint thermometers, with the Rosemount probe in between the two extremes. Out of cloud the temperature measured by the reverse flow sensor warms relative to the other instruments, indicating wetting problems. On some cloud penetrations the temperature of the fast response probe also appears to be affected by wetting, as is the output of the Lyman-α hygrometer. The radiometric thermometer (PRT6) gives a 1 K higher temperature reading and is not affected by cloud water, but the air volume measured by the PRT6 depends on the optical thickness of the surrounding cloud.

For purposes of comparison in Figure 1 the Lyman-α absolute humidity measurement is converted into a saturation vapor pressure using the fast response temperature. The vapor pressure is then inverted to find the dewpoint using an approximation from Bolton (1980). As Figure 1 shows, the humidity value given by the Lyman-α instrument is consistently 1 K higher than that given by either dewpoint thermometer. The difference is equivalent to an approximately 1 g m^{-3} offset in the water vapor measurement between the Lyman-α and the dewpoint temperature probes.

An independent check on the absolute accuracy of these divergent temperature measurements can be made using the lidar measurement of cloud base height. The lifting condensation level of sub-cloud air was computed for all pairs of vapor and temperature measurements for the sub-cloud flight legs on the July 5 case, which had a well-mixed boundary layer. Figure 2 shows the cloud base heights above the aircraft determined in this way for three of the instrument pairs as well as the lidar measurement of cloud base height. The best agreement with the lidar-determined cloud base is consistently given by the fast response thermometer (ATKP) and the top dewpoint sensor (DPTC), indicating that the bottom dewpoint sensor, the Rosemount thermometer, the reverse flow thermometer and the Lyman-α hygrometer have offset problems that will have to corrected before use.

2) Liquid water

Vertical profiles of the two analog liquid water probes, the King and the Johnson-Williams (JW), show pressure dependent zero offsets on both July 5 and July 7. At cloud level the zero offsets range from 0.04 - 0.08 g kg^{-1} (JW) and 0.05 - 0.10 g kg^{-1} (King). When these offsets are removed the maximum cloud liquid water content measured by the two sensors agrees within 20% on 10 of the 15 penetrations examined on the two days. On July 7 the liquid water content measured by the FSSP agrees to within 20% with the measurements of both the JW and King probes, but on July 5 it underestimates the cloud liquid water by a factor of 3-5.

3) Work in progress

Further studies are underway to determine the sensitivity of the temperature and water probes to the rapid ascents and descents through the cloud layer ("dolphin" flight legs), to compare conditional sampling of updrafts and downdrafts using cloud droplet concentrations, parcel temperature, and ozone content, and to calculate boundary layer mixing lines using ozone concentration as well as conservative thermodynamic tracers.

References:

Bolton, David, 1980: 'The computation of equivalent potential temperature'. Mon. Wea. Rev., 108, 1046-1053.

Boers, R. and A.K. Betts, 1988: 'Saturation point structure of marine stratocumulus clouds'. J. Atmos. Sci., 45, 1156-1175.

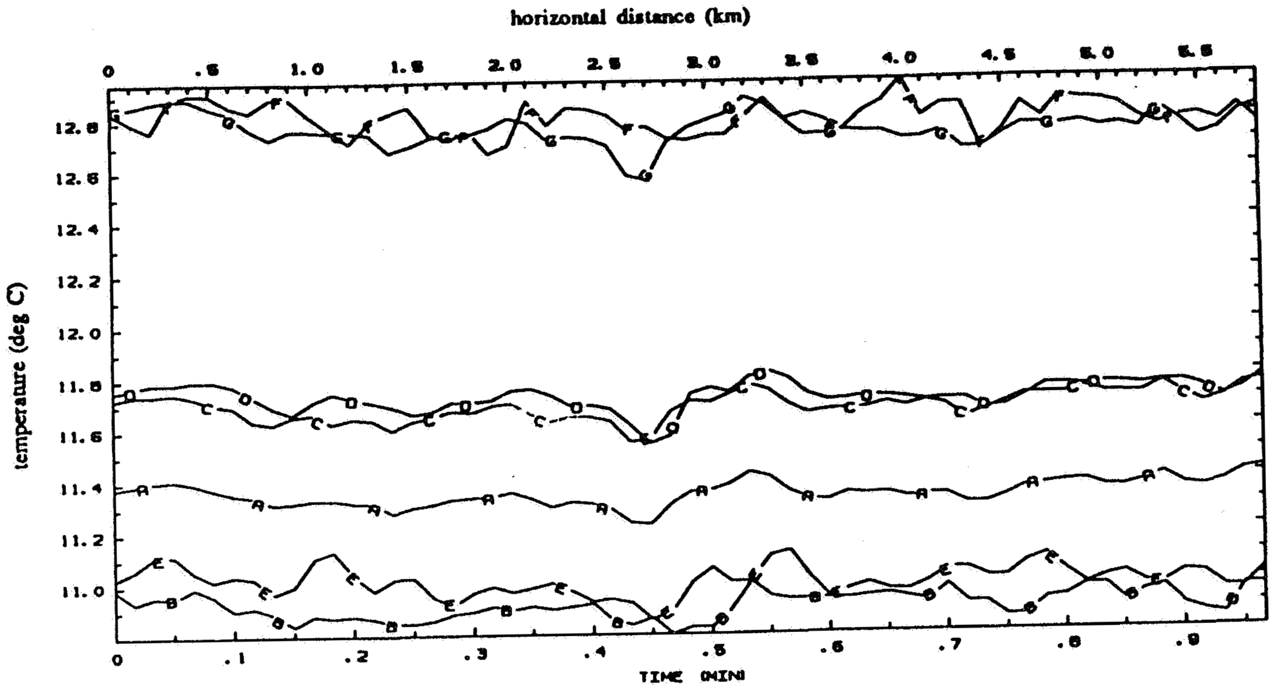

Figure 1: One miniute of in-cloud data (July 7, beginning at 20:16 Z) showing temperature measurements from (a) Rosemount, (b) reverse flow, (c) fast response, (d) top Cambridge dewpoint, (e) bottom Cambridge dewpoint, (f) Barnes PRT-6, (g) Lyman-a hygrometer (see text)

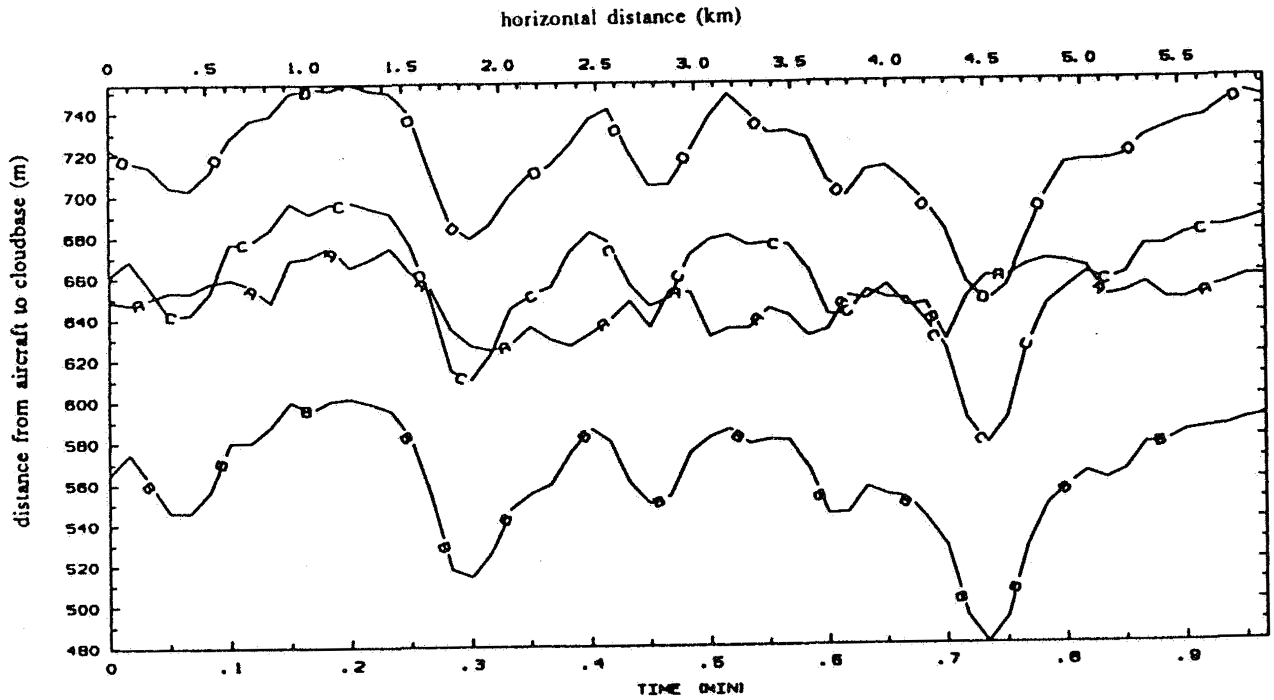

Figure 2: One minute of sub-cloud data (July 5, beginning at 18:11 Z) showing distance from aircraft to cloud base measured by (a) lidar, and computed assuming a well-mixed layer using measurements from (b) Rosemount and top Cambridge dewpoint thermometer, (c) fast response and top Cambridge dewpoint thermometer, (d) fast response and bottom Cambridge dewpoint thermometer.