A Comparison of Philips RS4 and Väisälä RS80 Radiosonde Data

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ABSTRACT

The paper describes the results of an experiment where, for a series of flights, Philips RS4 and Väisälä RS80 radiosondes were mounted on the same balloon. It is shown that there are both random and systematic differences in the raw and derived data generated from these systems. At all levels above 1000 hPa, solar corrected RS4 temperature soundings are colder than those of the RS80; resulting in a geopotential height difference of the order of 90 m at 50 hPa. The Väisälä RS80 Omega winds are similar to radar-derived wind profiles except in regions of changing vertical shear.

1. Introduction

The New Zealand Meteorological Service recently introduced the first of a number of Väisälä RS80 Digicora thermodynamic and wind sounding systems to its upper-air sounding network. Because all other stations in that network used Philips RS4 or similar radiosondes, a comparison experiment was conducted in order to determine the magnitude and sign of any important biases between data from the two systems. These differences are important since, if uncorrected, they will almost certainly introduce significant noise into an Analysis–Numerical Weather Prediction (NWP) cycle. The accuracy of forecast fields may be reduced simply because of inhomogeneities in the observing system. Further, these differences will tend to increase the magnitude of the "apparent" error in satellite derived thermodynamic profile retrievals.

The thermodynamic measurements were the principal variables of interest, because they are both sensor and radiosonde dependent. As well, in order to evaluate the characteristics of wind information generated from Omega navigation signals, the RS80 Digicora wind speed and direction data were compared with those computed directly from radar returns.

The essential characteristics of the two sounding systems are summarised in Table 1.

Apparently, the Philips RS4 radiosonde has also been used in Australia, Malaysia, Pakistan and Thailand (WMO 1982).

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2. Data and methods

The experimental flight programme was conducted at Christchurch, New Zealand (43°48′S, 172°55′E) from 15 May to 1 June 1986. During the sounding flights, a radar reflector was attached immediately below the balloon, and 30 m below that the radiosondes were suspended from each end of a 2 m long light cane pole. Eighteen pairs of 0000 UTC (local mid-day) thermodynamic, and seven pairs of 0000 UTC wind data were available for analysis. Above 100 hPa the sample sizes were smaller, due to various inflight failures.

The RS4 instrument is a Diamond Hinman type radiosonde, where the temperature and humidity data are reported sequentially as a function of baroswitch position, and pressure is inferred from a calibration chart. The significant levels are determined from inspection of a flight strip chart, and the raw data reduced to meteorological variables using universally standard procedures. Solar radiation corrections, based on a methodology identical to that given in McInturff et al. (1979), were applied to the solar contaminated temperature soundings, so converting the data to equivalent night time values (Uddstrom 1984).

In contrast, the RS80 meteorological data are extracted automatically, and corrected for both solar radiation and infrared emission errors by the ground component 'Digicora' processor (Antikainen and Hyvönen 1983). For both sondes, geopotential heights of the standard levels were computed from the reported significant level pressure, temperature, and dew point data.

Only the standard level wind speed and direction data were analysed. However, to take account of pos-

TABLE 1. Radiosonde characteristics.

Sensor/method	Philips RS4	Väisälä RS80
Pressure	Aneroid capsule with comb commutator baroswitch	Aneroid capsule with capacitive transducer
Temperature	Painted rod type thermistor Time constant†: <5 s	Capacitive thin film sensor encapsulated in aluminium Time constant: 2.3 s
Humidity	Carbon element in duct Time constant‡: <2 s	Humicap thin film capacitor Time constant: 1 s
Wind	Attached radar reflector	Omega system and Digicora
Sampling frequency	1.5–40 s	1.2 s
Radiation correction	Not applied	Applied automatically (Digicora)

† At 1000 hPa and 6 m s^{-1} ventilation speed.
‡ At 1000 hPa and 25°C (from Hooper 1986).

sible dependent errors between wind speed and direction, direction differences were computed from the vector wind components.

3. The results

The comparison data—temperature and dewpoint temperature, together with the wind speed and direction—were individually examined for systematic and random differences. Also, bulk statistics of the measurements, derived parameters and between sonde differences were computed.

a. From inspection

Because the thermodynamic data were expressed in terms of significant-level pressures rather than time, pressure height differences between the two sondes were detectable from consideration of the reported pressures for sharp significant level features and tropopause turning points. Two characteristic sounding pairs are shown in Fig. 1. Evidently, there are on occasions important differences in the reported pressures of some features. The differences in Fig. 1b for some of the stratospheric levels are as large as 7 hPa. When differences do occur, as was the case in 12 out of the 18 comparisons, the RS4 features are always biased towards higher pressure. Further, the sign of these differences is opposite to that which would be inferred from the relative response times of the two sensors (Table 1), and therefore is not the source of the error.

Laboratory tests of the RS80 pressure sensor indicate that this device can be used to measure pressure with high precision. These tests, reported in Antikainen and Hyvönen, 1983, suggest the sensor has a standard deviation (precision) error of between 0.14 hPa at 1000 hPa and 0.03 hPa at 5 hPa. The absolute accuracy of the sensor, would be expected to be poorer, especially under field conditions. Consequently, it would appear that either the RS4 pressure cells are not uniformly well calibrated, or the comb commutator baroswitch is in some cases not sufficiently well polished so as to present no frictional force to the moving contact. Recent results, published in the Final Report of the WMO International Radiosonde Comparison (Nash and Schmidlin 1987) indicate that the RS4 pressure sensor errors probably arise from imperfections in the manufacturer's calibration procedures.

With regard to the measured temperatures, the RS4 soundings are noticeably colder than the RS80 values, except below approximately 700 hPa. The dewpoint temperature data are more difficult to interpret. At high relative humidities, and near the surface, there is little difference between the measurements of the two sensors. Above strong subsidence inversions the RS80 data tend to indicate drier atmospheres than do the RS4 measurements.

b. Statistics

Two sets of standard level thermodynamic difference statistics have been compiled. In the first, no solar corrections were applied to the RS4 data, thereby simulating the characteristics of data inserted into the World Meteorological Organisation's Global Telecommunications System. In the second, the RS4 data were corrected for solar errors. The temperature, relative humidity, and geopotential height mean and difference profiles (RS4 minus RS80) for both solar corrected and non solar corrected RS4 data are given in Fig. 2. Also, the standard errors for the solar corrected difference profiles are indicated. (The standard errors for the non solar corrected data are identical.)

Considering the temperature measurements first, it is clear that the two sounding systems yield rather different results. At all levels except 30 hPa, and above, where the statistics are rather noisy due to small sample size, even the uncorrected RS4 data are cooler than the (solar corrected) RS80 data. In the stratosphere, the corrected RS4 values are much colder than the RS80 measurements, with the result that the geopotential heights of standard levels above 300 hPa are significantly different. Mid-day uncorrected RS4 soundings would produce stratospheric heights approximately 20 to 30 m lower than equivalent (solar corrected) RS80 derived values, but night time RS4 heights would be significantly lower (see Fig. 2 and Table 2).

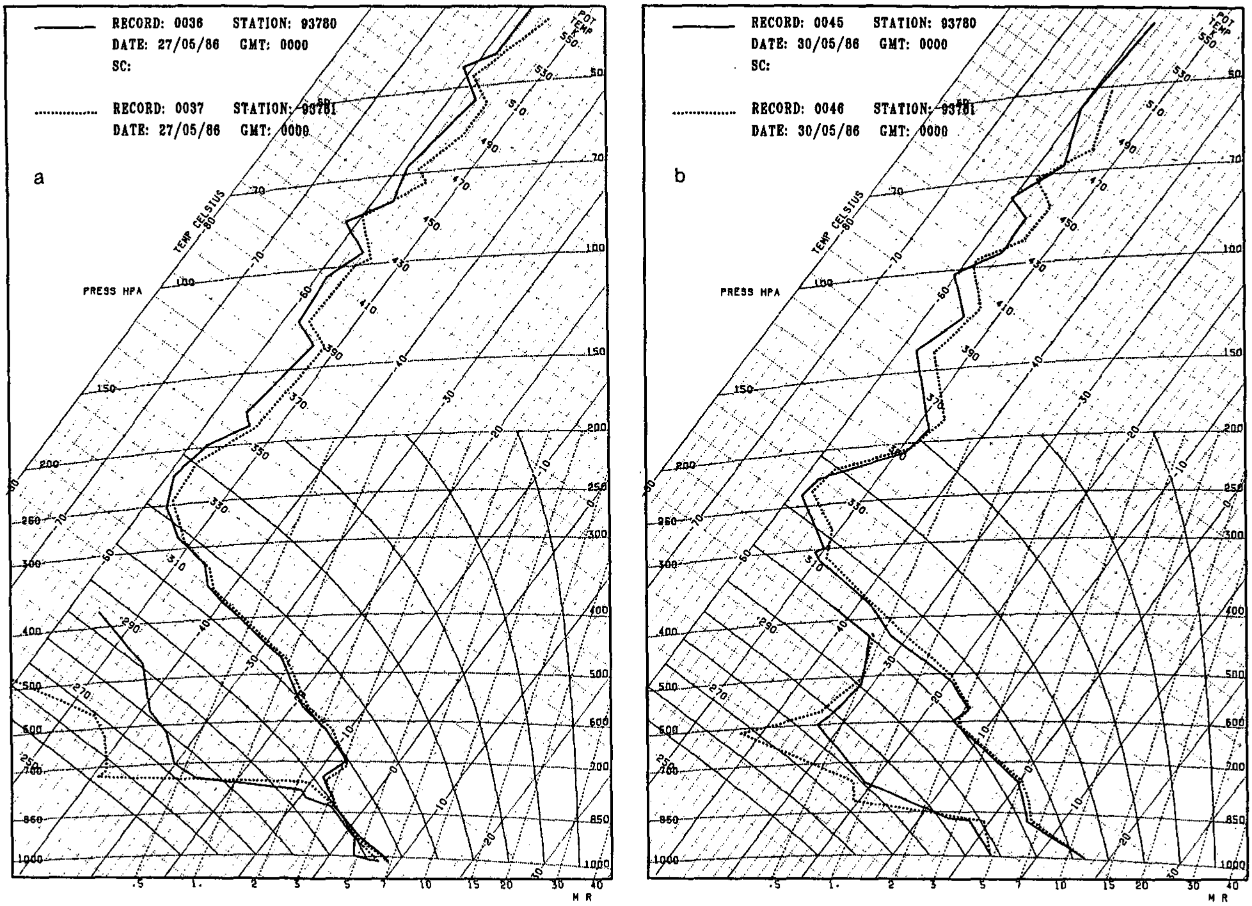

FIG. 1. Example dual soundings for (a) 27 May and (b) 30 May 1986. Station 93780 refers to the RS4 data, and station 93781 to the RS80 data. Both sets of soundings have been corrected for solar errors.

The contribution to these differences arising from the RS4 pressure sensor errors is not significant, because for an essentially isothermal stratosphere the significant layer mean virtual temperatures used in the hypsometer equation would differ only slightly from those calculated from the RS80 data. Accordingly, the pressure differences have not been accounted for in the results of Table 2. Likewise the component in these differences due to the different response times of the temperature sensors would be negligible.

The relative humidity mean and difference profiles suggest that at low humidities the RS4 sensor appears to over-estimate the atmospheric water vapour relative to the RS80 measurements, although the difference is only significant at 700 hPa. At 850 hPa and below, there is little difference between the two sets of measurements. Solar correction of the RS4 temperature data has essentially no effect on the relative humidity result, if temperature sensor thermal lag effects are ignored in both the uncorrected and corrected data.

The wind speed, direction, and u (eastward) and v (northward) component mean and difference profiles are presented in Fig. 3. The wind speed difference curve demonstrates the effect of the four minute vertical smoothing applied in the RS80 data processing. Wind speed maxima and minima are smoothed over, although the differences, none of which are significant, are generally less than 1 m s^{-1}, except in the low wind region above 70 hPa. Likewise, the direction differences are not significant. The u and v component means and differences are presented for completeness. For clarity, standard errors have not been plotted, but the differences are not significant.

4. Other intercomparison results

In the literature, two intercomparison experiments have been reported where a Väisälä RS80 and a sonde like a Philips RS4 have been compared. The first is the SONDEX experiment run in support of the ALPEX programme and reported by Richner and Phillips (1982), and the second, the first phase of the WMO International Radiosonde Comparison (Hooper 1986). In both of these experiments VIZ sondes were flown,

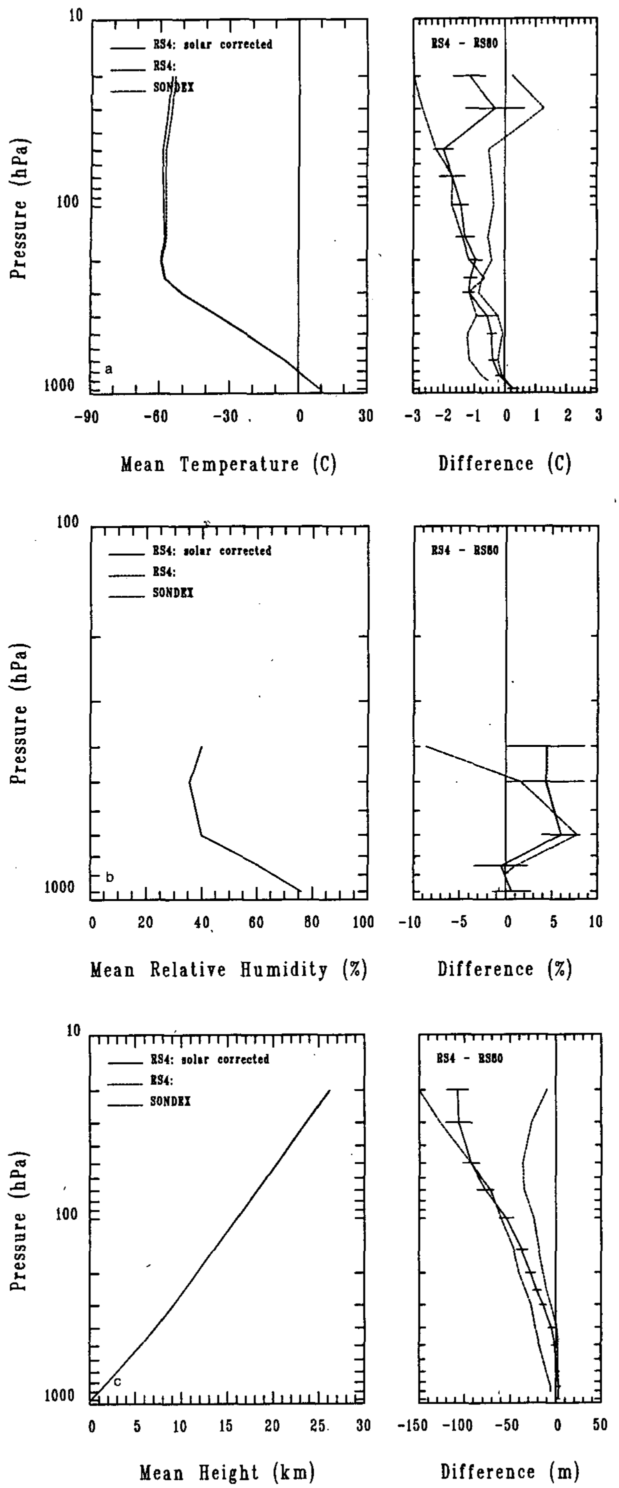

FIG. 2. Mean (RS4) and difference (RS4 minus RS80) profiles for (a) temperature, (b) relative humidity and (c) geopotential height profiles, for both solar and non-solar corrected RS4 data and 0000 UTC soundings. The error bars indicate the standard errors of the solar corrected RS4 difference profile. Equivalent difference (VIZ minus RS80) profiles from SONDEX are also given (after Richner and Phillips 1982).

but it is understood that the temperature and moisture sensors on VIZ and Philips radiosondes are identical (Falconer, personal communication). The baroswitches are not.

a. SONDEX

At the time of SONDEX, the Väisälä RS80 radiosonde was still undergoing development, with the result that only eight comparison flights occurred. Accordingly, the reported statistics must be regarded as tentative (Richner and Phillips 1982). Notwithstanding this proviso, the daytime temperature, geopotential and relative humidity differences for the VIZ minus RS80 comparison results have been appended to Fig. 2. Considering the temperature measurements, it is apparent that the (solar corrected) VIZ sonde also reports temperatures lower than those of the RS80, and consistent with the RS4 results. At 50 hPa this difference is approximately 2.3°C, and the corresponding height difference is 93 m, results which are in agreement with those calculated from the Christchurch comparison. Likewise, the relative humidity results are identical to those from the Christchurch comparison except at 400 hPa.

The Christchurch wind speed and direction results are essentially identical to those computed from the SONDEX experiment, where no significant differences between radar and RS80 winds were detected.

b. WMO intercomparison (Phase I)

The equivalent temperature and geopotential difference curves for this intercomparison are shown in Fig. 4. Again the comparison of interest is between the VIZ and Väisälä RS80 instruments. In this case, however, the VIZ data have not been corrected for solar

TABLE 2. RS4 minus RS80 differences for solar corrected data.

Pressure (hPa)	Temperature (°C)	Relative Humidity (%)	Geopotential (m)
20	−1.19		−107
30	−0.33		−106
50	−2.03		−93
70	−1.73		−77
100	−1.45		−54
150	−1.33		−37
200	−0.95		−28
250	−1.13		−20
300	−1.19		−14
400	−0.59	4.4	−5
500	−0.44	4.4	−1
700	−0.39	6.0	2
850	−0.18	−0.5	3
1000	0.27	0.7	2

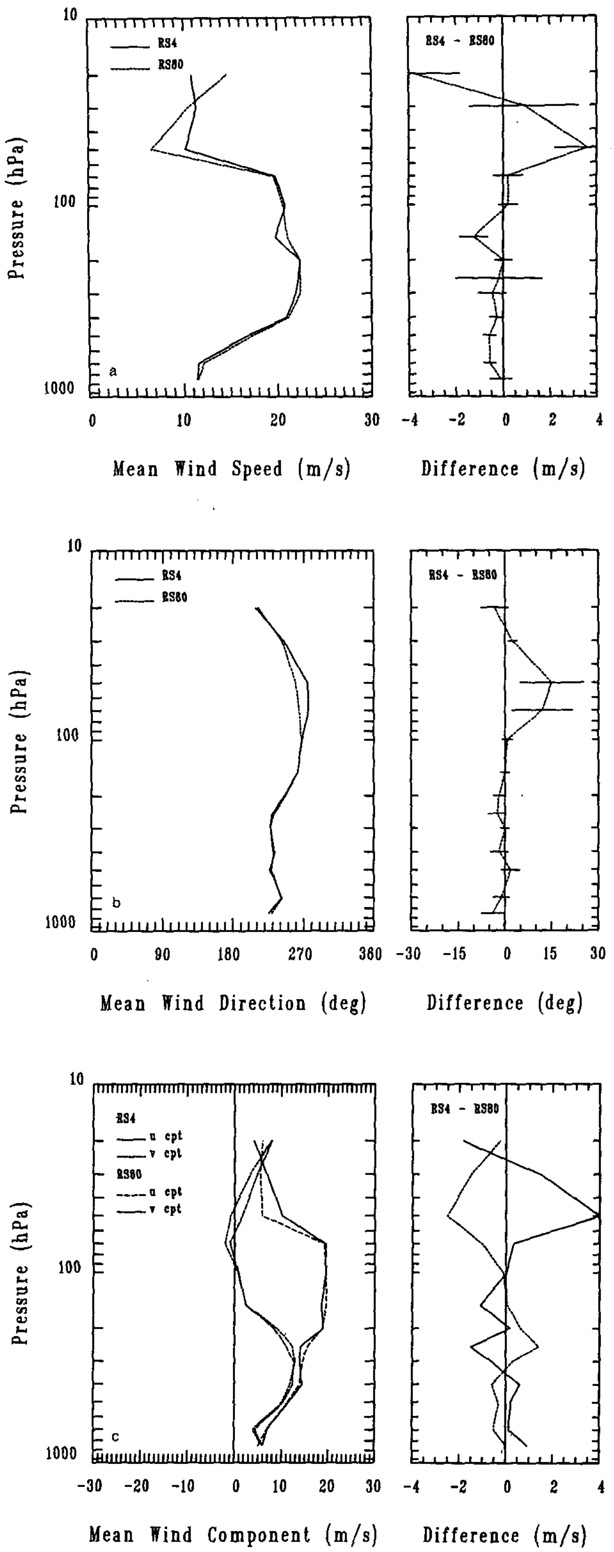

FIG. 3. (a) Wind speed, (b) direction, and (c) u (eastward) and v (northward) component mean and difference profiles (RS4 minus RS80) for 0000 UTC soundings. Standard errors are indicated for the direction and difference results.

errors, but the RS80 data have. At 50 hPa, the VIZ sonde reports temperatures approximately 0.8°C higher than those of the RS80, with the result that the VIZ derived geopotential height of the 50 hPa level is of the order of 40 m greater than that derived from the RS80 data. The expected 50 hPa mid-day sounding height correction (to correct the height to an effective night time value) for a VIZ type radiosonde for Beaufort Park, UK, and June is approximately 70 m (Uddstrom 1984). Accordingly, correcting the VIZ data at 50 hPa for solar radiation errors would result in a reported height 30 m lower than that estimated from the RS80 data. This result is not consistent with that derived from either the SONDEX or Christchurch comparisons.

Although the reason for this discrepancy is unknown, it is possible that a component of the difference arises from longwave radiation errors. McMillin et al. (1987) have demonstrated that radiosonde longwave errors, which may be as large as 1 to 2°K, are both a function of the radiosonde sensor emissivity (Schmidlin et al. 1986) and the atmosphere through which the sondes are flown. The latter is important, because the magnitude and sign of the infrared errors is strongly dependent upon the radiational environment during a sounding flight.

Hooper does not indicate wind data differences as a function of pressure, so no comparison can be drawn from this experiment.

5. Conclusions

From this analysis of data from the Christchurch comparison of the Philips RS4 and Väisälä RS80 radiosondes, the following conclusions may be drawn:

- The precision of the pressure derived from the Philips RS4 aneroid cell is rather poor relative to that reported by the RS80 aneroid cell. When reported level pressures differ, the RS4 sonde indicates a pressure greater than that from the RS80 instrument.
- At all levels above 1000 hPa, the solar corrected (i.e. data reduced to effective night time values) RS4 radiosonde temperature data are cooler than those reported by the RS80. As a result, derived geopotential heights are different by 30 m at 200 hPa and 110 m at 30 hPa.
- The Christchurch difference statistics are in agreement with those determined from nearly identical sounding systems during SONDEX, but are not consistent with those generated from Phase I of the WMO International Radiosonde Comparison at Beaufort Park, UK.
- Omega navigation signal derived standard level wind data are in agreement with those derived from radar methods, except that sharp features are smoothed in the vertical.

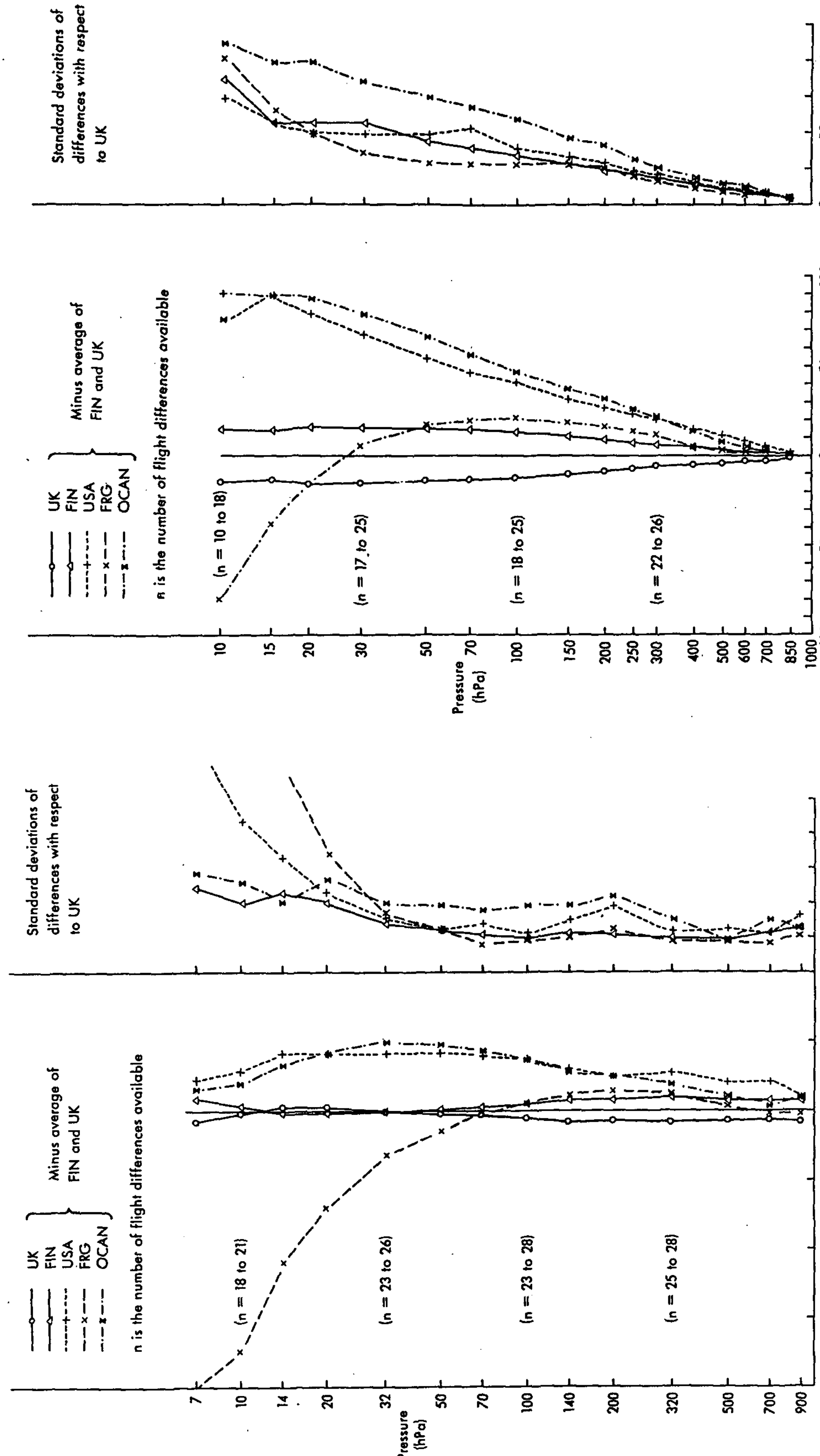

FIG. 4. WMO Intercomparison Radiosonde Phase I intercomparison results for (a) temperature and (b) geopotential, and local mid-day, taken from Hooper (1986). Where "FIN" refers to the RS80 radiosonde and "USA" to the VIZ radiosonde.

Although these differences will most directly affect NWP data assimilation schemes, they will also have some effect on the error statistics of satellite derived thermodynamic profiles. For example, a proportion of the error attributed to the satellite retrieval algorithm will arise from inhomogeneities in the "ground truth" radiosonde network.

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