HONG KONG OBSERVATORY

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Comparison between RS92 and RS80 Series Radiosondes

in Upper-air Weather Measurements in Hong Kong

by

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Abstract

The Hong Kong Observatory (HKO) has a long history of carrying out upper-air sounding operation using radiosondes since 1949. In 1984, HKO began using the RS80 series radiosondes. From mid-2006 onwards, they were replaced by RS92 series radiosondes which were of an all-digital design.

The reliability of the two types of radiosondes was assessed based on their respective number of repeat ascents in operational use. A comparison exercise was also carried out during the period from June 2006 to July 2007 to compare the upper-air data recorded by the RS92 and RS80 radiosondes. During the exercise, a total of 16 comparison ascents were made. The results showed that the performance of RS92 radiosonde was more reliable than its predecessor, RS80 radiosonde. The temperature and wind data obtained by both types of radiosondes were also comparable to each other. In respect of humidity, RS92 showed a small but persistent dry bias against RS80.

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1. Introduction

The HKO has been conducting measurement of upper-air meteorological data since 1921. In the early years, pilot balloons were used to measure upper-air winds only. In 1949, the first upper-air sounding system using a radiosonde carried by a balloon was installed at the headquarters of HKO. A permanent site was established in 1951 at King's Park providing a better venue for release of radiosondes (Dyson, 1983; Ho, 2003). Since then, radiosonde operation has been carried out at King's Park meteorological station (station code: 45004, location: 22.31 N, 114.17 E). Throughout the years, there have been changes in the sounding systems as well as the types of radiosonde used for upper-air sounding operation (Apps, 1971; Wong KP, 1998).

In May 2004, an automatic upper-air sounding system, Vaisala Autosonde (see Figure 1), was put into operation. The then radiosonde type used was the Vaisala RS80 series, which had been used for upper-air measurement by HKO since 1984 (Wong NY, 1988). After 2005, the RS80 series was no longer in production and was substituted by a new RS92 series, which has an all-digital design. The manufacturer claimed that it would offer improved data availability and accuracy in its measurements over the RS80. The HKO subsequently began using the RS92 series from July 2006.

To assess the reliability of both types of radiosondes, the statistics of repeat ascents during routine daily operations in the few years prior to and following the changeover from RS80 to RS92 was compiled. The number of repeat ascents is an important indicator of upper-air operations. A large number of repeat ascents means higher operation costs and most importantly, a reduced punctuality in the timely dissemination of upper-air data to the international meteorological community.

Furthermore, during the period between June 2006 and July 2007, the HKO carried out a comparison exercise to assess the difference in measurements recorded by the RS92 and RS80 radiosondes. A total of 16 comparison ascents were made. During the comparison ascents, RS80 and RS92 radiosondes were launched one shortly after the other with a time difference of around 2 to 3 seconds. The results of the comparison are presented in this report.

2. Technical Information of RS92 and RS80 radiosondes

A major difference between the new series of RS92 radiosonde and its RS80 predecessor lies in the GPS windfinding technology. The RS92 GPS radiosonde uses a code-correlating GPS receiver to track the GPS satellites in view rather than a codeless receiver, which was used in the RS80. The manufacturer claims that the code-correlating GPS receiver offers more reliable tracking of GPS satellites than its codeless counterpart resulting in better spatial positioning of the radiosonde as it ascends through the atmosphere.

According to the manufacturer, other areas of improvement for the RS92 radiosonde include better immunity to RF interference, digital transmission between the radiosonde and the ground reception system, improved silicon-based pressure sensor, heated twin humidity sensors that prevent ice formation during freezing condition, and a small but faster temperature sensor. Table 1 shows the technical information of RS92 (Vaisala, 2006) and RS80 (Vaisala, 2003) radiosondes indicating their similarities and differences. It should be mentioned that apart from GPS techniques, both radiosondes also use LORAN-C windfinding technology.

3. Data sets and their acquisition

Statistical information on the number of repeat ascents was obtained through operational logs prior to and following the changeover from RS80 to RS92 radiosondes. The information was used to determine the reliability of the new RS92 radiosondes relative to the RS80.

A total of 16 comparison ascents were made between June 2006 and July 2007, of which 10 ascents utilized GPS windfinding technique and 6 ascents utilized Loran-C windfinding technique. The difference in windfinding techniques is not expected to affect the measurement of temperature and relative humidity but is likely to make a difference in the inferred wind readings. More details of the comparison ascents are summarized in Table 2.

During each comparison ascent, RS80 and RS92 radiosondes were launched almost simultaneously at King's Park meteorological station. RS80 was first launched manually and RS92 was then launched 2 to 3 seconds shortly afterwards manually or by the Autosonde system (see Figure 2). Each radiosonde was carried aloft by a TOTEX 500 gram balloon at an ascent rate of around 350 metres per minute up to an altitude of more than 17 km (roughly corresponding to a pressure level of 100 hPa or higher). Data from the RS80 and RS92 radiosondes were received and processed by the Vaisala DigiCORA system and Autosonde system respectively.

4. Treatment of data obtained in the comparison exercise

Pressure, temperature, relative humidity, wind direction and wind speed were obtained separately from RS92 and RS80 radiosondes in each comparison ascent. For operational reasons, a majority of the comparison ascents was carried out at 06UTC (daytime) while several ascents were carried out at 12UTC (nighttime). The data set in the exercise in general covers both hot and cold seasons as well as different weather conditions.

The following weather elements measured by the two types of radiosonde at the 12 standard levels, i.e. 925, 850, 700, 500, 400, 300, 200, 150, 100, 70, 50, and 30 hPa, are compared and presented in the respective tables indicated below:

(i) Temperature (Table 3),
(ii) Relative humidity (RH) (Table 3),
(iii) Wind direction (Table 4),
(iv) Wind speed (Table 4),
(v) E-W components of wind (Table 5), and
(vi) N-S components of wind (Table 5).

The differences for all elements in the tables were obtained by subtracting the readings of the RS80 radiosonde from those of the RS92 radiosonde. Standard deviation (SD) and root mean square difference (RMSD) were also calculated with respect to RS80 data.

5. Results and Discussions

5.1 Percentage of repeat ascents

In upper-air sounding operations, ascents were sometimes not successful mostly because of poor signal transmission/reception or, to a lesser extent, premature balloon failure. In these cases, a repeat ascent would then be required if the scheduled ascent did not produce enough weather data for the upper air.

The percentage of routine upper-air ascents that required repeat ascents for the period June 2004 – December 2007 is presented in Figure 3. From June 2004 to June 2006, RS80 radiosonde was used, while from July 2006 to December 2007, RS92 radiosonde was used. All of the above ascents were carried out by the Autosonde system. The average percentages of repeat ascents for RS80 and RS92 were 8% and 4% respectively showing a significant reduction of repeat ascents when using the RS92 radiosondes.

Among the two causes for a repeat ascent, premature balloon failure could be easily identified by the detection of a rise in the measured air pressure, which signifies a falling, instead of rising, radiosonde. On this basis, about 92% of the repeat ascents involving RS80 radiosondes were found to be due to communication loss. The corresponding figure for RS92 radiosondes was 83%. This indicated fewer occurrences of communication loss with the RS92 radiosondes, suggesting their better immunity to radiofrequency interference as a result of the digital communication between the radiosonde and the ground station. The results corroborate those obtained by Åkerberg (2004).

5.2 Temperature

A comparison of the temperature readings obtained at each standard pressure level by RS92 and RS80 is given in Table 3 and illustrated in Figure 4.

Throughout the atmosphere, i.e. from 925hPa up to 30hPa, the magnitude of the mean temperature difference at all levels was less than 0.3°C, well within the claimed instrumental uncertainty of 0.5°C (Vaisala, 2006). However, at the three highest levels, the standard deviation values exceeded 0.5°C. The close agreement in temperature data of the RS80 and

RS92 radiosondes, at least for the levels at or below 100hPa, is not unexpected as both types of radiosondes use essentially the same kind of temperature sensor.

5.3 Relative Humidity

A comparison of the relative humidity (RH) readings obtained at each standard pressure level by RS92 and RS80 is given in Table 3 and illustrated in Figure 5. There was a significant difference in the RH data between RS92 and RS80, ranging from -5% to -16% in the atmosphere from 925hPa to 70hPa. Above 70hPa, the RH measurements were generally consistent with each other.

Both the RS92 and the RS80 use the Humicap sensor which is a thin-film capacitive sensor that changes in capacitance depending upon the air temperature and amount of water vapour. The RS80 use a single sensor whereas the RS92 uses two sensors, which are alternately heated to discourage water and ice buildup onto the sensor. This new de-icing method is claimed by the manufacturer to minimize contamination errors from water or ice buildup when the sensor passes through layers of moisture or ice.

The significant dry bias of the RS92 was consistent with observations made by Vomel et al (2007) and Yoneyama et al (2008) that the RS92 humidity sensors were prone to the effects of solar heating due to the lack of radiation shielding. This was especially significant as the ascents were conducted during the day and in fine weather. Vaisala made modifications to improve the shielding of the RS92 Humidicap sensors from the effects of solar heating to reduce the dry bias. The RS92 now operationally in use by the Observatory has incorporated the improved shielding.

5.4 Wind Direction and Wind Speed

Both types of radiosondes use windfinding technology based upon the signals from the Global Positioning System (GPS) or the Long Range Aids to Navigation (LORAN-C) network (Skrivankova P *et al*, 2004). Previous comparison of the two windfinding techniques showed that they were in very good agreement with each other (Poon *et al*, 2000). Of the 16 comparison ascents made in the present exercise, 10 ascents utilized GPS windfinding technique and 6 ascents utilized Loran-C windfinding technique. The present results (not shown) also indicated that the two windfinding techniques were comparable. Hence, the discussions that follow will only compare the two types of radiosondes, but will not distinguish between the two different windfinding techniques.

A comparison of the wind direction and wind speed obtained by RS92 and RS80 is given in Table 4 and illustrated in Figures 6 and 7 respectively. In light wind conditions, large differences in wind direction were possible, which could lead to misleading conclusions. As such, only readings with wind speed greater than 3.0 m s^{-1} were used in the comparison. Table 5 and Figures 8 and 9 show the comparison of the E-W and N-S components of wind data of the two types of radiosondes. The scatter diagrams of the E-W component and the N-S component between the two types of radiosondes are presented in Figures 10 and 11 respectively.

Fron Table 4, it can be seen that the mean difference in wind speed between RS92 and RS80 ranged from -1.34 to 0.45 m s^{-1} while the mean difference in wind direction ranged from -6.4 to 6.9 deg. It was previously noted that the differences in wind speed between the two types of radiosondes were well within the random errors of the two windfinding systems (for GPS windfinding system: 0.4 to 2 m s^{-1}, and for LORAN-C windfinding system: 0.6 to 3.0 m s^{-1} (World Meteorological Organization, 2008)). The differences in wind direction were also small, less than 10 degrees in general. These results suggested that upper-air wind measurements between the two types of radiosondes were comparable and consistent with each other.

Figures 10 and 11 show that the correlation coefficients for both E-W and N-S components are close to 1, with intercepts close to 0, indicating no significant systematic difference between the two types of radiosondes. The slightly lower correlation in the N-S component is likely to be the result of the larger differences in this component for the Loran-C radiosondes, which is a manifestation of the geometry of the locations of the Loran-C stations in the southern China region (Poon *et al*, 2000).

6. Conclusion

Operational statistics reflected a higher reliability of the RS92 with fewer percentages of repeat ascents being made following operation using RS92, demonstrating it to be more reliable than the RS80 radiosondes used in the past. This may be attributed to the code correlating GPS receivers used by the RS92 radiosonde and the digital communication between the radiosonde and the ground control unit.

A comparison on the performance between the new RS92 radiosondes with the now discontinued RS80 radiosondes was made between June 2006 and July 2007. Weather elements comprising the temperature, humidity, wind speed, and wind direction were compared for 16 simultaneous ascents. Close agreement was found with the temperature (at least for levels up to 100hPa), wind speed, and wind direction measurements. With temperature, this is not unexpected since both radiosondes use the same model temperature sensors. With humidity, the RS92 showed a slight but persistent dry bias against the RS80. Also, wind speed and direction were found to be comparable between the two types of radiosondes after excluding those data from light wind conditions.

7. Acknowledgements

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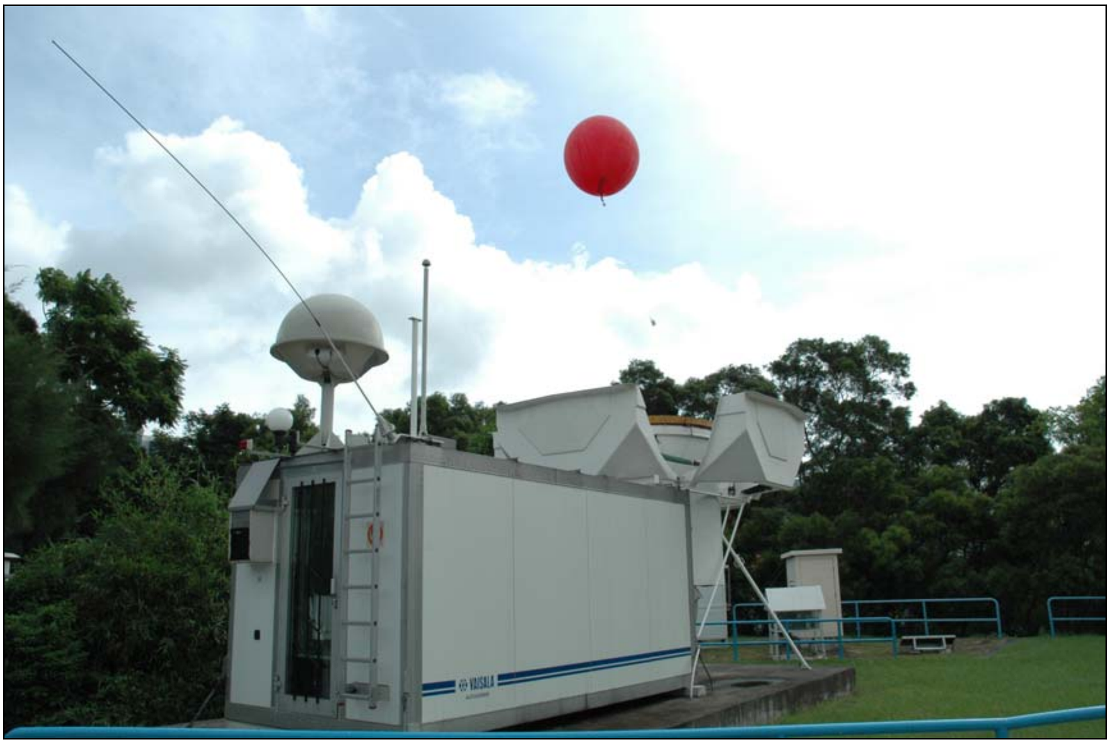

Figure 1. The Automatic Upper-air Sounding System at King's Park Meteorological Station

Figure 2. Simultaneous launching of RS80 and RS92 radiosondes at the King's Park Meteorological Station on 8 June 2006.

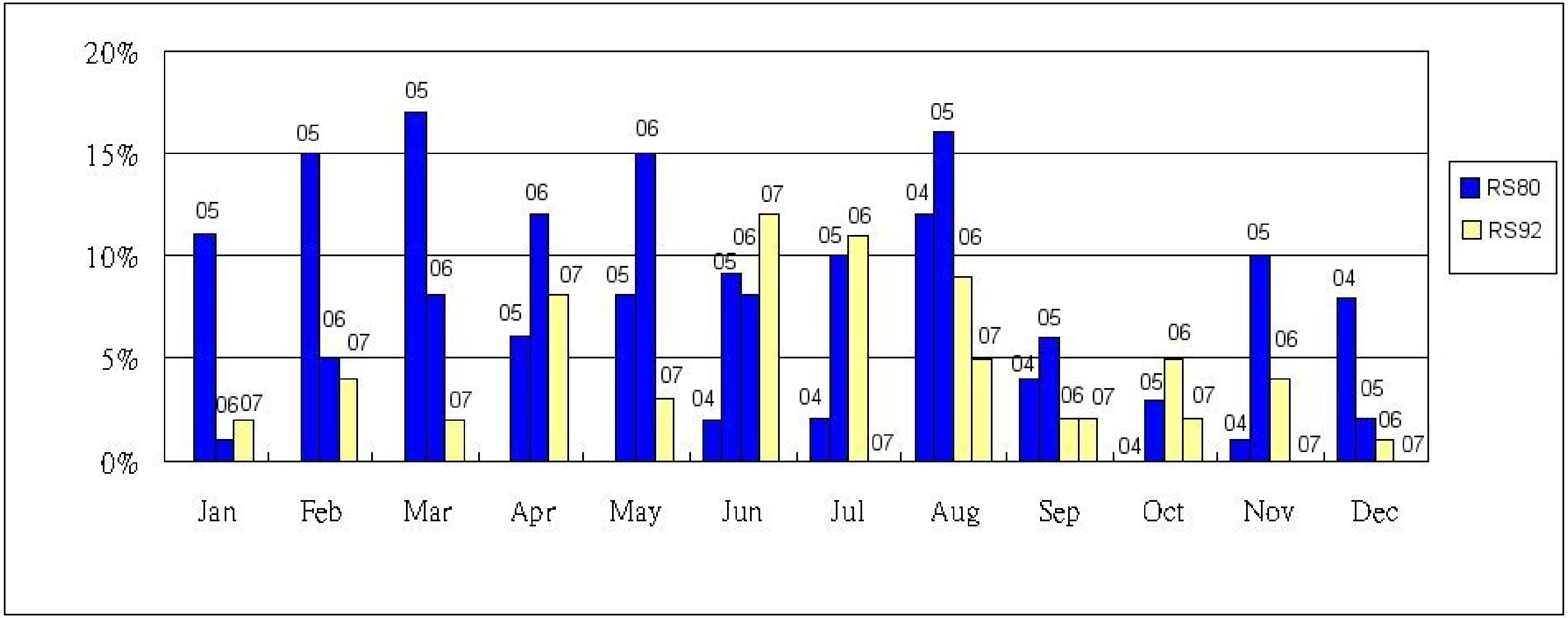

Figure 3.   Percentage of repeat ascents for RS80 radiosondes (Jun 2004 to Jun 2006) and RS92 radiosondes (July 2006 to December 2007) (Remark: 04, 05, 06 and 07 shown on the chart represented year 2004, 2005, 2006 and 2007 respectively.)

Table 1 Technical data of RS80 and RS92 series radiosondes

Radiosondes	**RS80**		**RS92**	
Sonde type	GPS (RS80-15G)	Loran-C (RS80-15L)	GPS (RS92-SGP)	Loran-C (RS92-KL)
Sonde shape				
Dimensions excluding antenna	55 x 155 x 125 mm	55 x 147 x 90 mm	220 x 80x 75 mm	220 x 80 x 75 mm
Weight with battery activated	Approx. 330 g	Approx. 220 g	Approx. 250 g	Approx. 240 g
Length of string	60 m connected between balloon and radiosondes		30 m connected between balloon and radiosondes	
Pressure sensor	Sensor type using capacitive aneroid		Sensor type using silicon	
Temperature sensor	Sensor type using capacitor wire same as RS92		Sensor type using capacitor wire same as RS80	
Humidity sensor	Using thin film capacitor with small silver cap		Using thin-film capacitor with heated twin sensor	
DigiCora Sounding System	MW11		MW15	
Tuning range	403 MHz in normal frequency band		403 MHz in normal frequency band	
Frequency stability (max. drift)	±300 kHz	±2 kHz	±300 kHz	
Code correlating GPS receiver	8 channels	---	12 channels	---
Wind finding technology	Using codeless GPS receiver for wind finding	Using LoranC wind finding by LoranC network	Using code-correlating GPS receiver for wind finding	Using LoranC wind finding by LoranC network

Table 2 Operational details of the comparison ascents

Ascent Number	Launch Time		Sonde Type	Highest Standard Level reached	
	Date	Hour		hPa	Altitude in km
1	8-Jun-06	02 UTC	Loran-C	30	24
2	16-Jun-06	06 UTC	GPS	40	22
3	19-Jun-06	06 UTC	GPS	50	21
4	24-Jul-06	06 UTC	Loran-C	60	20
5	24-Jul-06	12 UTC	Loran-C	40	21
6	24-Aug-06	06 UTC	GPS	30	24
7	31-Aug-06	06 UTC	GPS	30	24
8	31-Aug-06	12 UTC	GPS	80	18
9	14-Sep-06	06 UTC	Loran-C	30	24
10	14-Sep-06	12 UTC	Loran-C	25	25
11	27-Sep-06	06 UTC	GPS	30	24
12	11-Oct-06	06 UTC	GPS	100	17
13	18-Oct-06	06 UTC	GPS	30	24
14	19-Oct-06	06 UTC	Loran-C	25	25
15	7-Feb-07	06 UTC	GPS	70	19
16	14-Mar-07	06 UTC	GPS	30	24

Table 3 Differences in mean temperature and relative humidity between RS92 and RS80 radiosondes

Pressure Level (hPa)	Temperature			Relative Humidity			N
	ΔT(°C)	SD	RMSD	ΔRH(%)	SD	RMSD	Data count
925	0.08	0.18	0.19	-15.81	6.67	17.08	16
850	0.01	0.18	0.18	-12.69	3.07	13.03	16
700	-0.06	0.20	0.20	-8.06	4.68	9.25	16
500	-0.07	0.20	0.20	-6.25	3.53	7.12	16
400	0.04	0.28	0.28	-5.06	5.05	7.04	16
300	0.04	0.27	0.26	-4.81	6.11	7.63	16
200	0.17	0.36	0.39	-8.19	7.23	10.77	16
150	0.16	0.44	0.45	-12.81	5.78	13.98	16
100	0.23	0.49	0.52	-15.38	8.27	17.33	16
70	-0.15	1.87	0.87	-6.93	4.07	10.53	14
50	-0.12	1.19	0.99	-0.69	2.18	2.72	12
30	0.25	1.42	1.76	0.10	3.57	4.38	10

ΔT, ΔRH : Mean differences in Temperature and Relative Humidity respectively are with respect to RS80 at each standard pressure level.
SD : Standard deviation
RMSD : Root mean squared difference

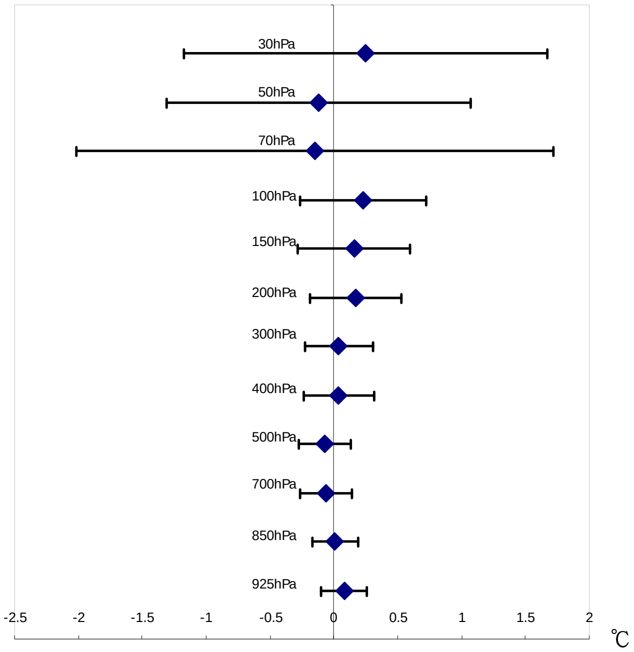

Figure 4 Vertical profile of the mean temperature difference with error bars representing one standard deviation from the mean difference with respect to RS80

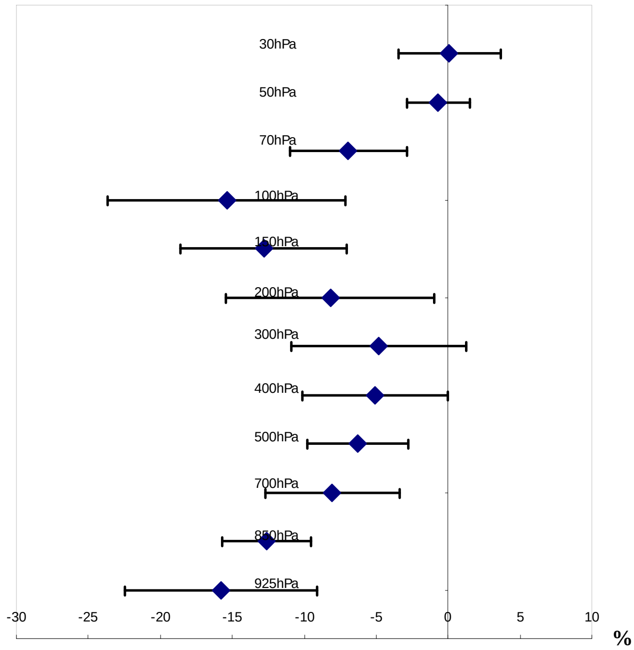

Figure 5 Vertical profile of the mean humidity difference with error bars representing one standard deviation from the mean difference with respect to RS80

Table 4 Difference in mean wind direction and wind speed between RS92 and RS80 Radiosondes

Pressure Level (hPa)	Wind Direction			Wind Speed			N
	ΔDir(deg)	SD	RMSD	ΔWS($m\ s^{-1}$)	SD	RMSD	Data Count
925	-6.4	13.1	14.2	0.45	0.73	0.84	16
850	1.3	7.7	7.5	-0.30	0.61	0.66	16
700	6.9	14.4	15.6	0.06	1.02	0.99	16
500	-1.0	6.5	6.3	-0.22	0.98	0.97	14
400	4.7	28.9	28.3	0.19	0.86	0.86	16
300	2.6	10.8	10.8	-0.09	0.74	0.72	16
200	-2.3	5.2	5.5	-0.26	1.02	1.02	14
150	1.4	6.9	6.8	0.14	0.60	0.59	14
100	-1.9	7.7	7.7	-0.03	1.22	1.18	15
70	-3.4	9.4	9.7	0.03	1.06	1.03	14
50	-3.5	7.9	8.4	-1.34	1.21	1.76	11
30	0.0	7.8	7.3	-0.01	0.94	0.88	8

ΔDir, ΔWS : Mean differences in wind direction and wind speed respectively are with respect to RS80 at each standard pressure level.
SD : Standard deviation.
RMSD : Root mean squared difference

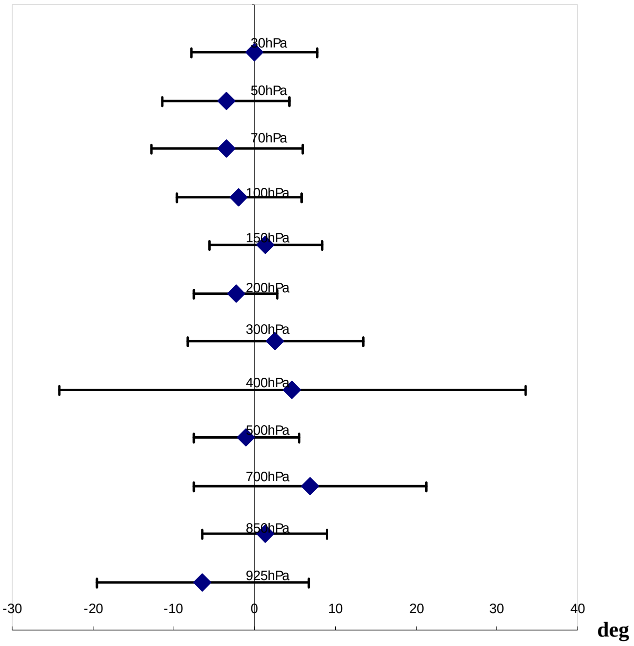

Figure 6 **Vertical profile of the mean wind direction difference with error bars representing one standard deviation from the mean difference with respect to RS80**

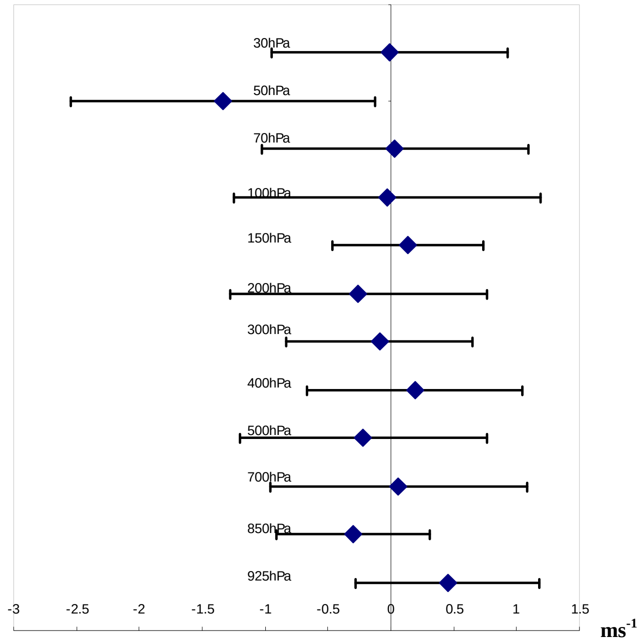

Figure 7 **Vertical profile of the mean wind speed difference with error bars representing one standard deviation from the mean difference with respect to RS80**

Table 5 Difference in the East-West and North-South components of wind data between RS92 and RS80 radiosondes

Pressure	East-West Component		North-South Component		N
(hPa)	ΔEW(m s^{-1})	SD	ΔNS(m s^{-1})	SD	Data count
925	-0.34	0.83	0.18	1.17	16
850	0.35	0.82	-0.08	0.71	16
700	-0.01	0.61	-0.23	1.20	16
500	0.04	0.40	0.00	1.20	14
400	-0.32	0.91	0.38	0.93	16
300	-0.04	0.78	0.43	1.16	16
200	0.47	0.89	0.07	0.91	14
150	-0.12	0.77	0.05	1.13	14
100	-0.54	1.08	-0.10	0.89	15
70	-0.28	1.12	-0.30	1.49	14
50	0.95	0.91	-1.16	2.08	11
30	-0.27	1.39	0.36	1.72	8

ΔEW, ΔNS : Mean difference in the East-west and North-south components if the wind data with respect to RS80 at each standard pressure level
SD : Standard deviation.
RMSD : Root mean squared difference.

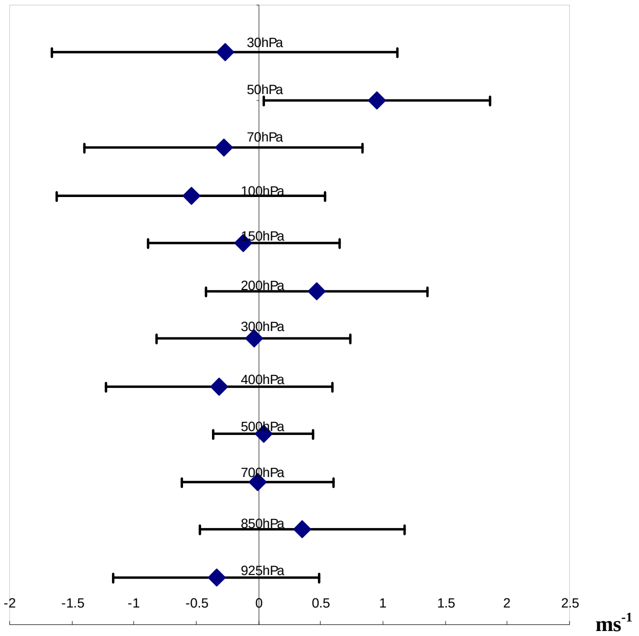

Figure 8 **Vertical profile of the mean wind speed difference in the E-W components with error bars representing one standard deviation from the mean difference with respect to RS80**

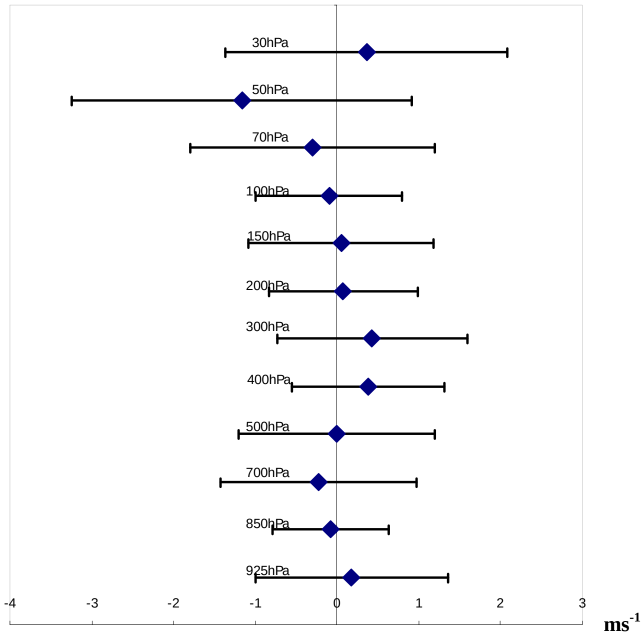

Figure 9 **Vertical profile of the mean wind speed difference in the N-S components with error bars representing one standard deviation from the mean difference with respect to RS80**

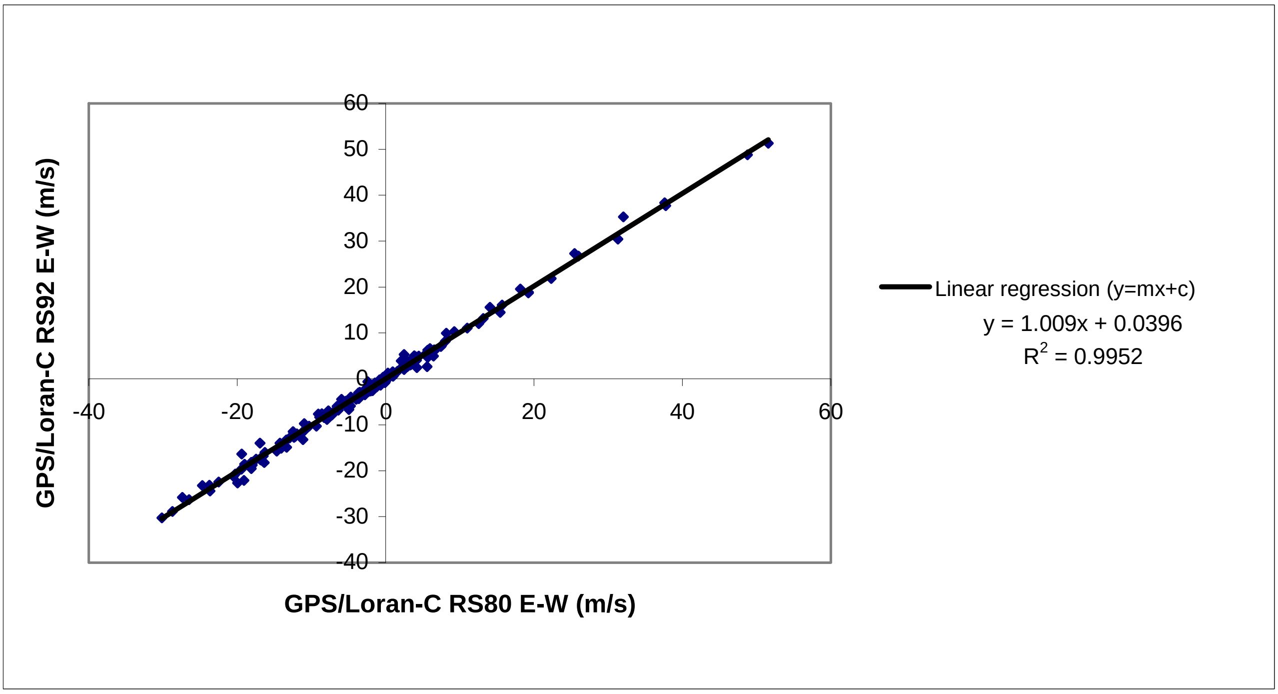

Figure 10 **Scatter diagram of RS92 and RS80 east-west components measured by the GPS/Loran-C wind-finding system**

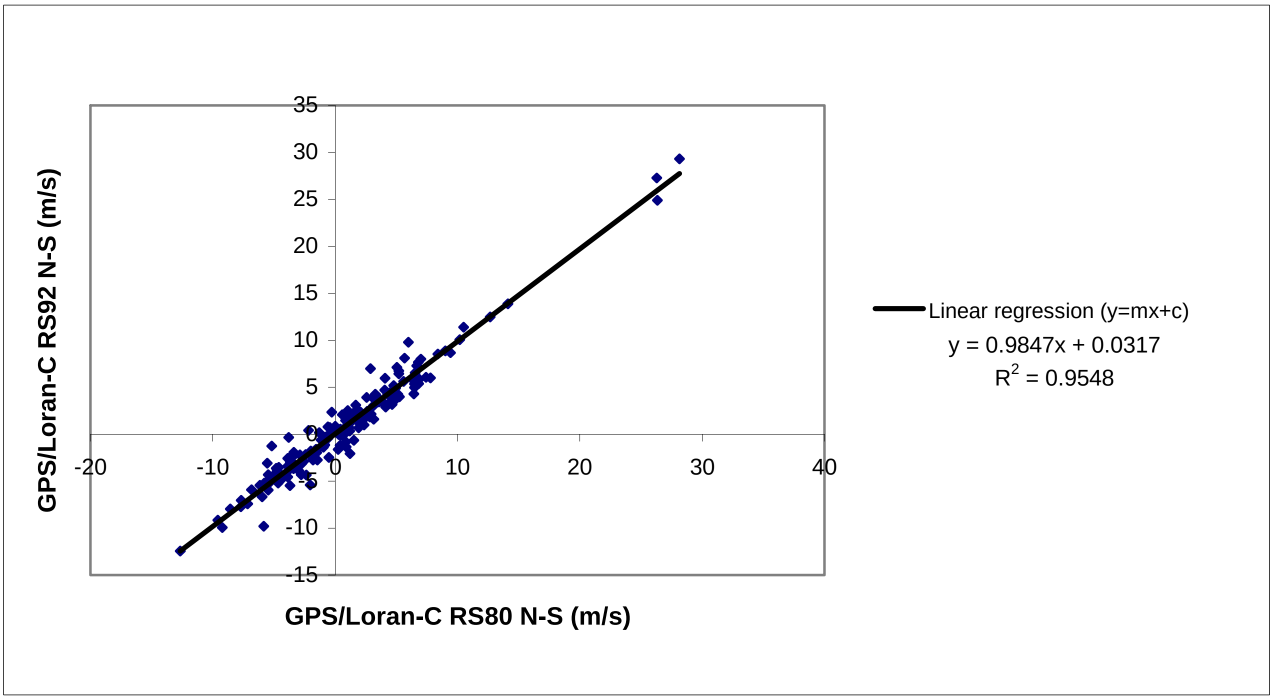

Figure 11 **Scatter diagram of RS92 and RS80 north-south components measured by the GPS/Loran-C wind-finding system**