

Temperature, humidity and wind from Estonian and Finnish radiosonde data (1993–2009)

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Abstract. Radiosonde observations of temperature, relative humidity and wind properties are compared at two neighbouring stations – Tallinn-Harku in Estonia and Jokioinen in Finland – with the aim to optimize radiosonde network and measurement times. The comparison is carried out for the period of 1993–2009 when both stations used similar equipment. Midnight and noon soundings are compared separately. It is concluded that the profiles of the temperature and wind speed at these two stations are similar, but those of the relative humidity differ significantly, showing coefficient of correlation over 0.7 only near the tropopause. Wind roses are similar in summer, but somewhat different in winter, especially in the stratosphere during the daytime.

Key words: radiosondes, temperature, humidity, wind, Tallinn-Harku aerological station, Jokioinen observatory.

1. INTRODUCTION

Contemporary weather forecast and climate analysis cannot be imagined without regular radiosoundings that provide the specialists with vertical profiles of meteorological data. Radiosonde observations include the air temperature, pressure, moisture and wind measurements at various levels (up to 35 km). Together with the surface data they form a three-dimensional description of the atmosphere. Radiosondes are launched worldwide at approximately 800 sites simultaneously at main synoptic hours including 00 and 12 UTC. Therefore they give a global picture on the situation of the atmosphere twice a day.

Since 2007, Estonian Meteorological and Hydrological Institute is member of the Network of European Meteorological Services (EUMETNET) which sub-programme EUMETNET Composite Observing System (EUCOS) comprises high-quality observation stations and measurement sites that give initial data for

numerical weather prediction systems and traditional forecast. During the Eyjafjallajökull volcano eruption in April 2010, the measurements from aircrafts were interrupted and radiosonde measurements in Europe were of vital importance.

The history of radiosonde measurements dates back to the 1930s. Due to rapid development of technical possibilities, the earlier data suffer from low quality and inhomogeneity. After application of the quality assessment technique and introduction of necessary corrections, a unique resource for climate studies has been developed [1]. To get a high resolution climatology of vertical profiles of the atmospheric parameters, the Integrated Global Radiosonde Archive has been founded that consists of observations at 1500 globally distributed stations since the 1960s [2]. Based on these raw data, a large amount of quantities for atmospheric analysis has been calculated [3].

Radiosonde observations are expensive. Therefore, optimization of the aerological network is on the agenda all over the world [4,5].

Radiosounding has been performed in Estonia since 1953 [6]. During the period of 1953–1993 several changes have taken place in the observation sites, technique and equipment. Since 1977, soundings are carried out at Harku (59°24'N, 24°36'E) that is situated some kilometres to the west from Tallinn. In 1993 the sondes, manufactured in the USSR, were replaced by Vaisala products. At the same time, the frequency of sounding was reduced from four times a day (00, 06, 12, 18 UTC) to two (00 and 12 UTC). Further reduction of the number of launches took place in 2001 when the noon soundings were terminated.

Expert assessment report for optimizing observational network in Estonia refers to the necessity to establish the second sounding station in South Estonia [7]. As an alternative possibility, moving of the existing aerological station from Harku to inland was proposed. The latter proposal was based on the fact that the next aerological station – Jokioinen Observatory – is situated rather close to Harku. Therefore, radiosonde launching times at these two stations could be combined through asynchronization of the measurements.

Jokioinen Observatory (60°49'N, 23°29'E) is situated in the southwestern part of Finland, approximately 110 km from Helsinki (Fig. 1). It was founded in 1957,



Fig. 1. Location of the measurement sites.

but the data set starts in 1961. During the period of 1993–2009 the soundings were performed twice a day: at 00 and 12 GMT. Only Vaisala equipment has been used, although the types of the sondes have changed. Since 1999 the automatic sounding station is active.

In the present paper, the main atmospheric parameters, measured at these two sites, are compared during 1993–2009. This time period was chosen due to the change of equipment at Tallinn-Harku Aerological station: since 1993 both stations use Vaisala sondes.

2. DATA ANALYSIS

In the present paper, meteorological data at the station level and at the isobaric levels of 850, 500, 250, 100, and 50 hPa are analysed. These levels were chosen due to different reasons. The levels of 850 and 500 hPa permit one to estimate synoptic situation, the 100 and 50 hPa levels are important for the EUCOS quality control system, where the height of the radiosonde is estimated. The station altitude at Harku is 33 m above the sea level and that at Jokioinen 104 m. The following meteorological parameters were compared: air temperature, air humidity, wind speed and direction.

The coverage of time series for day (12 GMT) and night (00 GMT) observations is different at these two stations. Therefore, the time periods were chosen, where both stations have performed observations simultaneously: from 25 May 1993 to 31 December 2009 for midnight data and from 1 January 1993 to 14 September 2001 for noon data.

The gaps in both time series stem from three types of sources:

- 1) the sounding did not take place and all data are missing,
- 2) radiosonde did not reach high altitudes and upper-level data are missing,
- 3) wind or humidity sensor did not work.

The cases when a sounding at one of the stations under consideration is missing were left out.

2.1. Temperature

Temperature profiles in the troposphere are important as input data for initialization of numerical weather prediction models, but also as a suitable material for the analysis of warming or cooling trends [8,9]. The period under observation is too short for climatological analysis, but nevertheless, it could be said that temperature values at all isobaric levels at both measurement sites do not show any trends. The average values of temperature are nearly the same at the two measurement sites being slightly lower in the northernmost station – Jokioinen. Annual average midnight temperatures for six isobaric levels are given in Table 1.

Table 1. Average midnight temperature profiles at both measurement sites

Level, hPa	Temperature, °C	
	Harku	Jokioinen
Surface	4.5	2.8
850	-0.4	-0.8
500	-24.3	-24.7
250	-54.7	-54.7
100	-56.1	-56.1
50	-57.9	-58.5

The relationships between temperature observations at these two sites are analysed on the basis of correlation coefficients and linear regressions. Regression gives the prescription for deriving Harku temperature data from those at Jokioinen. The respective correlation coefficients and regression parameters are shown in Table 2.

The relationships between temperature observations at these two sites are visualized as scatter-plots in Fig. 2 for the 250 hPa level, where correlation between measurement results at the two stations is the weakest.

It can be said that the air temperature is well correlated at all levels and from the point of view of temperature soundings, observations at one station represent well also the situation at the other site.

Table 2. Correlation coefficients between air temperature at Harku and Jokioinen and regression parameters to get Harku temperature from that at Jokioinen

Level, hPa	Observation time, GMT	Correlation coefficient	Regression slope	Regression intercept
Surface	00	0.94	0.89	1.96
	12	0.97	0.91	1.45
850	00	0.97	0.98	0.31
	12	0.97	0.99	0.45
500	00	0.97	0.97	-0.31
	12	0.98	0.97	-0.38
250	00	0.93	0.91	-5.01
	12	0.94	0.93	-4.00
100	00	0.98	0.93	-4.00
	12	0.98	0.94	-3.74
50	00	0.99	0.94	-3.77
	12	0.99	0.94	-3.53

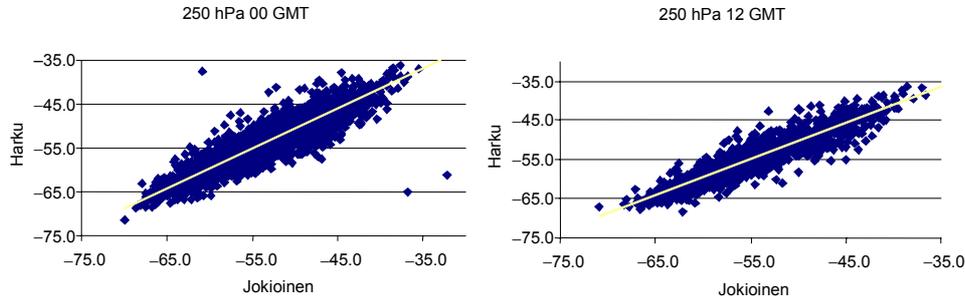


Fig. 2. Air temperature (°C) at Harku versus air temperature at Jokioinen near the tropopause. The line shows linear regression between the temperature measurements at these two sites.

2.2. Humidity

Water vapour is the main greenhouse gas in the atmosphere and its importance in the climate change studies cannot be overestimated. The water cycle is driven by the general circulation of the atmosphere and, on the other hand, influences it. Radiosonde observations contribute much to the knowledge of the three-dimensional humidity distribution in the troposphere, but similarly to the temperature soundings, the humidity data need critical assessment and homogenization [10]. Fortunately, this is not the case by our comparison, as the time series is rather short and the measurement equipment similar.

The annual average values of relative humidity at Harku and Jokioinen are shown in Table 3, where differences do not exceed 3% (near the tropopause). Unfortunately, the scattering of the relative humidity data at Harku and Jokioinen is large (Table 4 and Fig. 3).

According to Table 4, one could divide the atmosphere into three layers. In the troposphere the correlation coefficient is from 0.51 to 0.72, i.e., only 25%–50% of the variability of the relative humidity at Harku can be described by the variability at Jokioinen. In dry conditions, Harku tends to show larger values of relative humidity and in the more humid conditions smaller values than those at Jokioinen. The best is the correlation at the level of the tropopause, but differences between the measurements in the stratosphere are large. Although the

Table 3. Average midnight relative humidity profiles at both measurement sites

Level, hPa	Relative humidity, %	
	Harku	Jokioinen
Surface	87	89
850	69	68
500	46	45
250	29	26
100	3	3
50	2	3

Table 4. Correlation coefficients between relative humidity at Harku and Jokioinen and regression parameters to get Harku relative humidity from that at Jokioinen

Level, hPa	Observation time, GMT	Correlation coefficient	Regression slope	Regression intercept
Surface	00	0.55	0.62	32.25
	12	0.72	0.62	29.32
850	00	0.60	0.62	27.35
	12	0.59	0.64	23.24
500	00	0.53	0.56	20.44
	12	0.51	0.52	20.69
250	00	0.73	0.84	6.93
	12	0.73	0.81	4.87
100	00	0.33	0.31	1.78
	12	0.22	0.21	2.26
50	00	0.22	0.19	1.81
	12	0.17	0.15	2.26

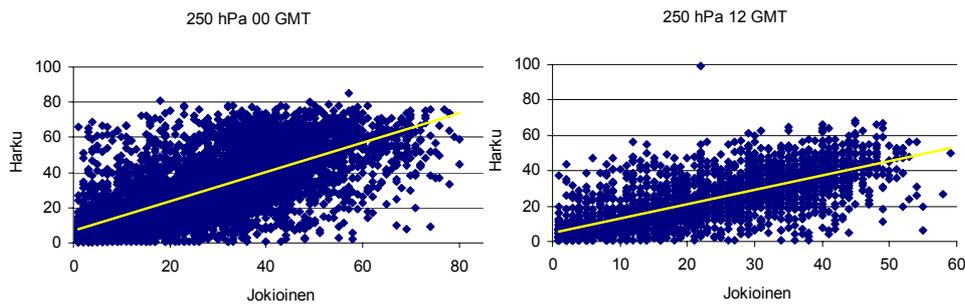


Fig. 3. Relative humidity (%) at Harku versus relative humidity at Jokioinen near the tropopause. The line shows linear regression between the humidity measurements at these two sites.

amount of the water vapour in stratosphere is small, one cannot ignore it, as its variations affect seriously the temperature regime of our planet [11].

It has been shown that there may exist differences between different Vaisala radiosonde systems [12]. Jokioinen has used the same equipment (RS92-SGPW) during the whole period. At Harku, several changes have taken place during the period under consideration. The most serious change took place in 1999 when RS80-15L was replaced by RS90-AL. The humidity sensor RS80-15L was somewhat different from later sensors that were similar to those used at Jokioinen (thin film capacitor, heated twin-sensor design). To test the influence of the change, the period of 1993–1999 was left out by the comparison of relative humidity data at the two sites. The test shows that low correlation of the humidity data in the stratosphere is not caused by differences in the measurement devices. On the other hand, the resolution of the humidity sensors is 1% and the total

uncertainty in sounding is 5%. As the values of the relative humidity in the stratosphere are often around 1%, the low correlation of the data may be attributed to the sounding errors.

Figure 3 presents the scatter plot of synchronous measurements at Harku and Jokioinen at the 250 hPa level, where the correlation is the best.

2.3. Wind speed

Wind velocity vector in the free atmosphere can be used to calculate the average air flow and its vertical profile permits one to detect temperature advection in a certain layer [13]. Such an analysis for the wind data, recorded at Tallinn Aerological Observatory, reveals a significant turning of the average airflow in March during 1955–1995 [14]. Radiosondes measure wind speed and direction separately, but from these measurements it is easy to get wind velocity components [3].

Annual average values of the wind speed at both measurement sites are practically equal, showing a difference of 0.8 m/s only on the 50 hPa level (Table 5).

Correlation between the wind speed data at Harku and Jokioinen is perfect in the stratosphere and good in the upper troposphere (Table 6 and Fig. 4). At the station level the correlation is rather weak, most probably due to the orographic

Table 5. Average midnight wind speed profiles at the two measurement sites

Level, hPa	Wind speed, m/s	
	Harku	Jokioinen
Surface	2.9	3.0
850	9.8	9.8
500	15.6	15.5
250	22.8	22.9
100	13.3	13.4
50	12.7	13.5

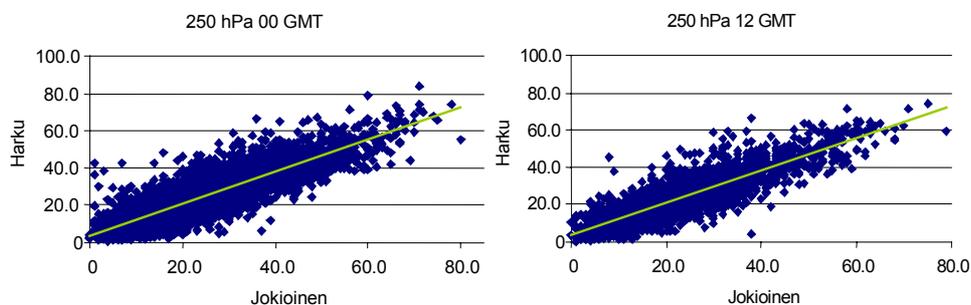


Fig. 4. Wind speed (m/s) near the tropopause at Jokioinen and Harku.

Table 6. Correlation coefficients between wind speeds at Harku and Jokioinen and regression parameters to get Harku wind speed from that at Jokioinen

Level, hPa	Observation time, GMT	Correlation coefficient	Regression slope	Regression intercept
Surface	00	0.61	0.61	1.02
	12	0.52	0.46	2.24
850	00	0.75	0.74	2.55
	12	0.77	0.77	2.40
500	00	0.82	0.82	2.93
	12	0.83	0.84	2.75
250	00	0.88	0.87	3.19
	12	0.87	0.87	3.23
100	00	0.94	0.93	0.94
	12	0.96	0.95	0.85
50	00	0.96	0.95	0.49
	12	0.97	0.96	0.55

differences. Fortunately, radiosoundings are not focused on the near-surface measurements and from the point of view of the wind speed measurements the Jokioinen data can be used instead of the Harku observations.

2.4. Wind direction

Wind direction comparison was carried out on the basis of directional frequency distributions – wind roses. Radiosondes measure wind direction in degrees. In order to remove unnecessary details, the wind roses are drawn on the 8-rhumb basis [15].

Annual average wind roses practically coincide at these two measurement sites at all levels, except near the surface where wind direction is very sensitive to the properties of the landscape. To get a closer view, wind roses were drawn separately for January and July that represent winter and summer conditions, respectively. For these wind roses the period from May 1993 to September 2001 was used to ensure that the time span for midnight and noon data was similar. As this data set contains only 8 Januaries and 9 Julies, the wind roses expose significant differences (Figs 5 and 6).

In January the wind roses near the surface differ at Jokioinen and Harku, but the directional distribution is similar at midnight and noon. The difference between wind roses of the two measurement sites gradually disappear at higher levels of the troposphere and reappear at noon in the stratosphere where the fraction of the NW winds at Jokioinen is twice as large as at Harku.

In July the wind roses at the surface are different at Harku and Jokioinen for both noon and midnight data. Such differences can be explained mainly by the breeze wind system that is well developed at Harku due to the vicinity of the sea. In the free atmosphere the wind roses at Harku and Jokioinen practically coincide.

Therefore, in case we leave out measurements near the surface, wind direction recordings in summer at Jokioinen represent well wind direction at Harku. In winter there are slight differences between wind roses in the troposphere and serious differences during the daytime in the stratosphere.

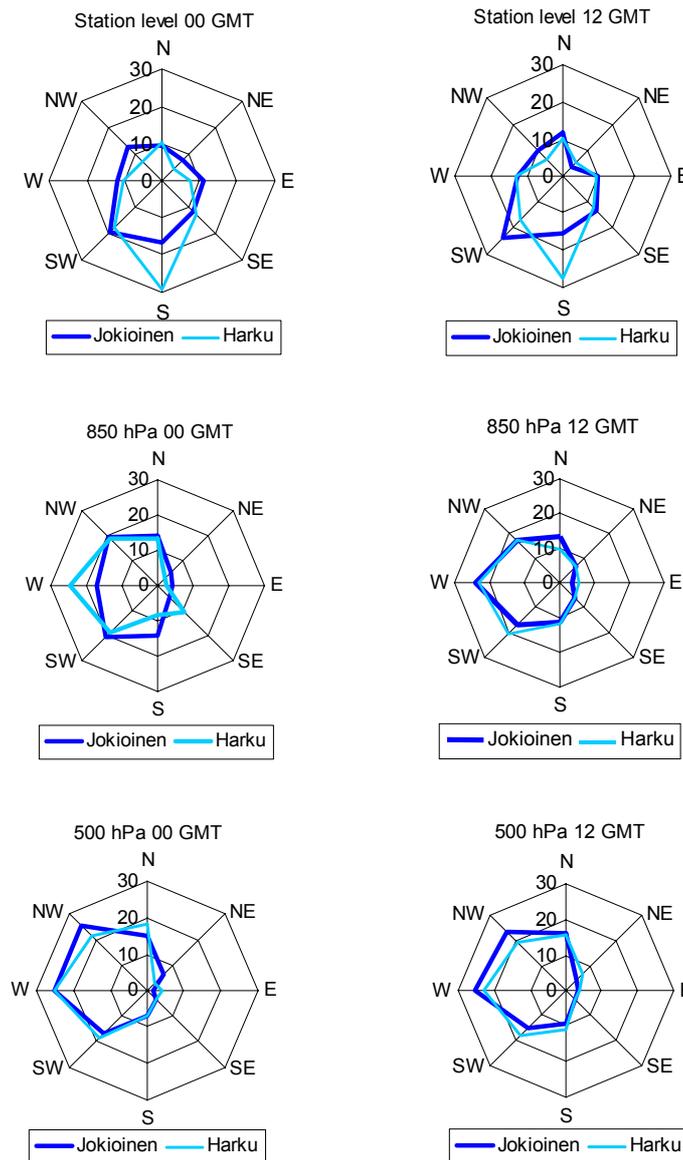


Fig. 5. Wind roses in January at Jokioinen and Harku. The frequency is given in percents.

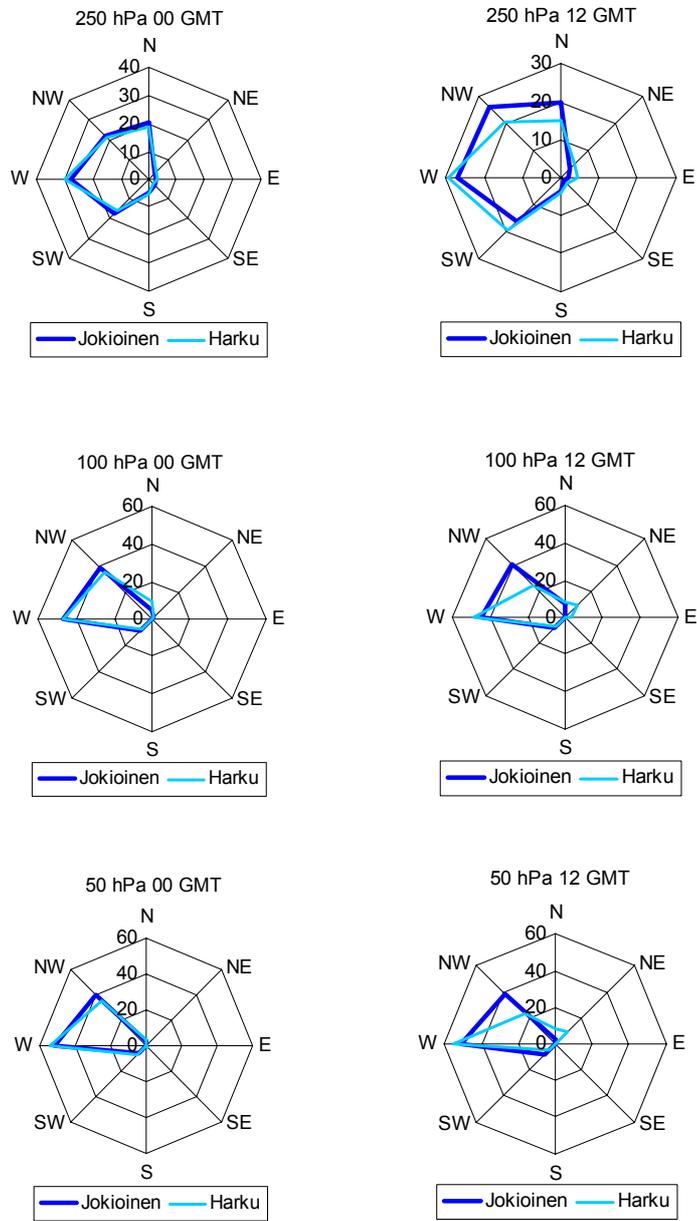


Fig. 5. Continued.

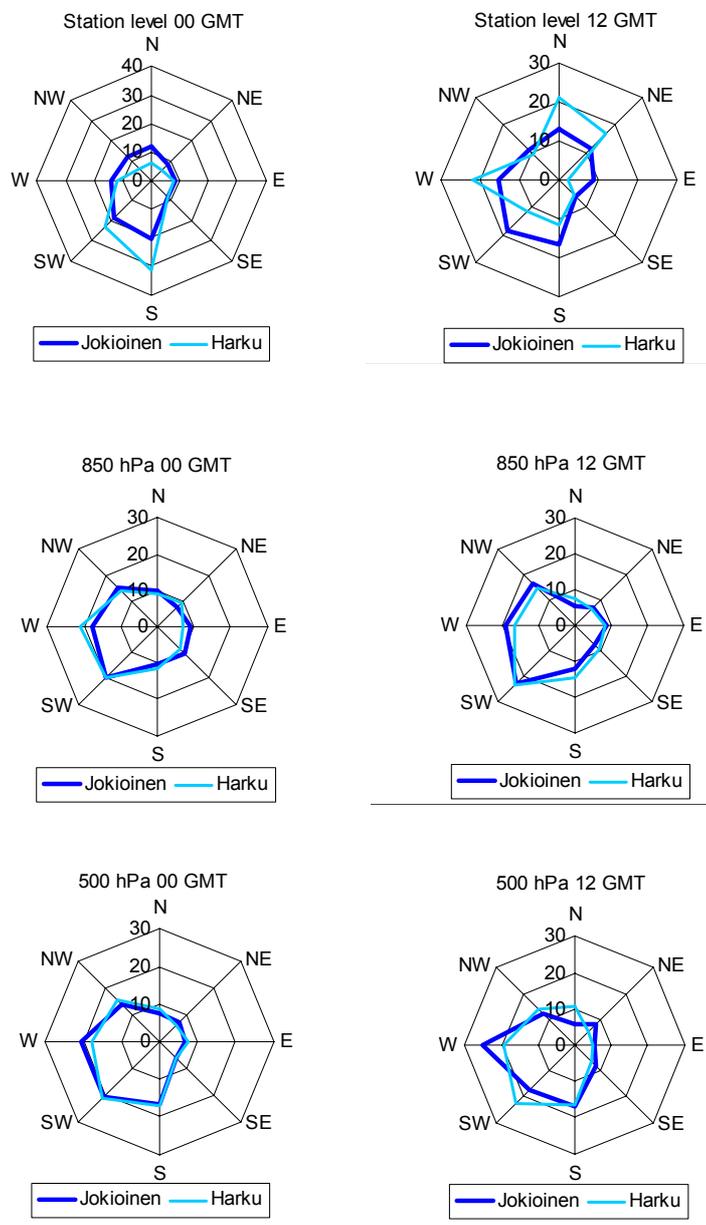


Fig. 6. Wind roses in July at the two measurement sites.

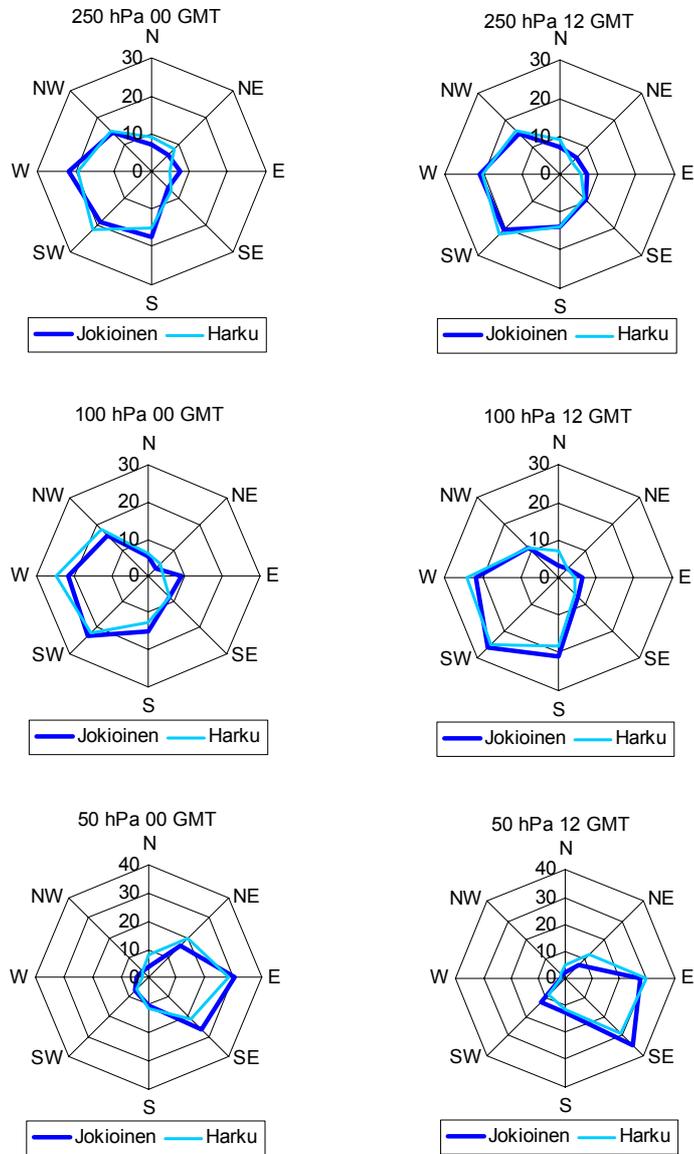


Fig. 6. Continued.

3. CONCLUSIONS

Leaving surface measurements aside, one may confirm that temperature patterns at Harku are properly represented by measurements at Jokioinen as the correlation coefficient is between 0.93 and 0.97. This means that measurement times may be asynchronized. On the other hand, correlation coefficient between relative humidity data at these two stations has a reasonable value of 0.73 only

near the tropopause. In the stratosphere it is not more than 0.3. Consequently, humidity profile measured at one station does not describe the situation at the other one. Correlation of wind speed data increases with the altitude, showing a coefficient of correlation 0.75–0.77 at the 850 hPa level and 0.96–0.97 at the 50 hPa level. The distributions of wind direction, described by means of wind roses, are similar at both stations in July, but differ somewhat in January when the difference is the largest in the stratosphere during daytime.

In case optimization of the observation routine is in question, it can be concluded that from the point of view of temperature and wind speed, soundings at Harku may be replaced by soundings at Jokioinen. Such replacing may be undertaken in the case if not very high precision is required for wind direction. From the point of view of the relative humidity, replacing soundings at one site with soundings at the other is not recommended.

On the other hand, the expert assessment report [7] stresses the value of homogeneous time series of observations. Radiosonde measurements have been carried out in Estonia since 1953. Although several changes have taken place in observation sites and measurement routine, the long time series is a valuable material for trend analysis. Therefore, changing the routine of aerological observations at Tallinn-Harku station should be carefully considered before the decision is made.

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Temperatuur, õhuniiskus ja tuul raadiosondi andmetel Eestis ning Soomes (1993–2009)

Sirje Keevallik ja Miina Krabbi

Eesmärgiga optimeerida raadiosondide võrgustikku ja sondeerimise aegu võrreldi kahes naaberjaamas – Harkus ning Jokioises – registreeritud õhutemperatuuri, suhtelise niiskuse ja tuule parameetrite profile. Võrdlus viidi läbi perioodi 1993–2009 kohta, mil mõlemas jaamas olid kasutusel Väisälä sondid. Eraldi võrreldi südaõiseid ja keskpäevaseid mõõtmisi. Leiti, et temperatuuri ja tuule kiiruse profiilid on mõlemas vaatluskohas ühesugused, aga suhtelise niiskuse andmed erinevad oluliselt, näidates rahuldavat korrelatsiooni (korrelatsioonikoefitsient üle 0,7) vaid tropopausi lähedal. Tuuleroosid on suvel üsna sarnased, aga talvel mõnevõrra erinevad, iseäranis päeval ajal stratosfääris.