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LAKE TANGANYIKA HYDRODYNAMICS AND METEOROLOGY: THE DIEL CYCLE

by
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PREFACE

The Research for the Management of the Fisheries on Lake Tanganyika project (LTR) became fully operational in January 1992. It is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Finnish International Development Agency (FINNIDA) and the Arab Gulf Program for the United Nations Development Organization (AGFUND).

LTR’s objective is the determination of the biological basis for fish production on Lake Tanganyika, in order to permit the formulation of a coherent lake-wide fisheries management policy for the four riparian States (Burundi, Tanzania, Zaïre and Zambia).

Particular attention is given to the reinforcement of the skills and physical facilities of the fisheries research units in all four beneficiary countries as well as to the build-up of effective coordination mechanisms to ensure full collaboration between the Governments concerned.

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Piet Verburg, APO Biologist at LTR/Kigoma.

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SUMMARY

Little is known about the variation of meteorological parameters at Lake Tanganyika over 24 hour periods. Data collections of diel weather patterns were generally incidental. Using several automatic sampling stations around and on the lake, with a high sampling frequency, this report presents diel changes in a number of meteorological parameters at Lake Tanganyika.
Monthly means for each hour over the day were calculated for the east, west, north and south components of the wind vectors, wind speed, wind direction, evaporation, air pressure, air temperature, relative humidity, solar radiation and water temperature at different depths. For this document 280320 measurements were processed and are presented in 432 figures.

Onshore air temperatures were higher than offshore air temperatures during the day, and the gradient was reversed at night. Winds of thermal origin blew from the lake during the day and land winds occurred at night. The air temperature gradient during the day was highest, and lake winds were generally strongest, in the dry season. High evaporation was associated with the south wind at the south and north ends of the lake, since wind speed at both ends of the lake was generally highest from the south. This was partly due to the south-east trade winds during the dry season. Evaporation was therefore, due to the diel pattern of land and lake winds, highest at night in the south and highest during the day in the north.

1. INTRODUCTION

Lake Tanganyika is the second deepest lake in the world (1470 in), the second largest in Africa and is located between 3° and 9° south (Fig. 1) . Lake Tanganyika's wet season is from October to April and the dry season from May to September. Annual rainfall increases from north to south over the lake, although the wet season shortens (Plisnier *et al.,* 1996) . Upwelling occurs at the south end of the lake in the dry season, when air temperatures are relatively low and strong winds occur from the south. The processes of upwelling and mixing of the upper 150 m of the water column during the dry season, and stratification during the wet season, are influenced by meteorological parameters. The Lake Tanganyika Research (LTR) Project has established several automatic high frequency sampling stations on and around the lake. The variation of these parameters over the wet and dry seasons at Lake Tanganyika has been presented by Kotilainen *et al.* (1995) and Verburg *et al.* (1997) . However, little is known about the variation over 24 hour periods. Descriptions of diel weather patterns at Lake Tanganyika are generally anecdotal, based on few observations. This report analyses diel changes in meteorological parameters at Lake Tanganyika.

2. MATERIAL AND METHODS

Data were collected by three stations around the lake and two offshore stations (Huttula *et al.,* 1993; Kotilainen *et al.,* 1995; Verburg *et al.,* 1997), equipped with automatic meteorological and hydrodynamical data recording instruments of Aanderaa Instruments (Fig. 1) . Weather stations were located at the north end (Bujumbura, Burundi) and at the south end of the lake (Mpulungu, Zambia) . A wind station was located at Kigoma (Tanzania), in the north-east, 150 km south of Bujumbura, and two buoys were located off Kigoma and off Mpulungu. Data of wind speed, wind direction, air pressure, air temperature, relative humidity, solar radiation and water temperature at different depths were collected from March 1993 to October 1996. All data were averaged for the same hour each day over one month. The lake level varied between 773.5 and 775.1 m during the sampling period (Verburg, in prep.).

2.1 Wind direction

Wind direction measurements were processed as follows (Equations

1 - 5 and numerical examples are given in Appendix I)

North/south (N/S) and east/west (E/W) wind speed vectors

N/S and E/W wind speed vectors were calculated by multiplying, for each measurement, the north and east components of the wind direction with the wind speed (Equations 1 and 2) . Using this method, a negative N/S wind speed vector indicated wind stress was from the south.

North, south, east and west wind speed vectors

In order to find the relative contribution of each wind direction to the wind stress over averaged periods, the north, south, east and west components of the wind speed vectors were then calculated, for every measurement of wind speed and wind direction. This was done by equaling for instance a negative N/S vector to zero wind from the north, and the absolute value to wind from the south. The north minus the south wind speed vector thus represents the N/S wind speed vector.

Mean wind direction

Mean wind directions were calculated as follows: east and north wind direction vectors were constructed for each measurement, taking the resultant equal to one (Equations 3 and 4, Appendix I). These vectors were averaged over a certain period, and the averages rescaled, so that the resultant was again equal to one. The mean wind direction was then calculated from the rescaled vector averages (Equation 5)

2.2 Evaporation

Evaporation was calculated from wind speed, air temperature, air pressure and relative humidity data, using a simplified form of the Thornthwaite-Holzman equation for vapour transport (Chow *et al.,* 1992; Verburg *et al.,* 1997) . For Bujumbura, values for all 4 variables were recorded at 13 m height on a jetty in the harbour. For Mpulungu, wind speed and air temperature data were collected from a buoy 40 km north-west off Mpulungu at 2.6 m height and humidity and air pressure from the weather station at Mpulungu. This weather station was located about 300 m away from the lake and 40 m above the lake surface. The humidity data were adjusted for the difference found with data collected daily with a clock psychrometer (Citizen IUCHI), between May 1995 and April 1996, at 0800 h on a jetty at the lake shore at Mpulungu, using the relationship:

% Humidity at the shore at 0800 h = 33.890 + 0.465 x % Humidity Weather station at 0800 h

R 0.74, N = 318, P < 0.00001

For humidities below 64 % measured at the weather station, the corresponding humidity at the shore was generally higher, and thus the calculated evaporation lower.

3. RESULTS

The variance within all data sets was generally small. Standard errors are shown in the figures containing the data from the Mpulungu weather station. Seasonal trends of mean daily values were discussed by Verburg et *al.* (1997) and are not treated here.

3.1 Air pressure

Diel changes in air pressure were very similar throughout the year, at Bujumbura and Mpulungu (Figs 2 and 3). The lowest value was usually at 1600 h, and the maximum at 0900 h. Pressure was also high at 2200 - 2300 h, and low pressure was found at 0300 h.

3.2 Air temperature

Daily maxima were higher at Mpulungu than at Bujumbura, 26.9 - 30.0 °C and 25.6 – 27.7 °C respectively. However daily air temperatures for both localities followed a similar pattern, throughout the year (Figs 4 and 5). At Bujumbura and Mpulungu, the air temperature reached a minimum at 0600 h and then increased until to c. 1200 h. At Bujumbura, the air temperature after 1200 h generally remained constant until c. 1700 h, and in April - September slightly increased between 1200 and 1700 h. In Mpulungu, the air temperature fell fast after noon, until about 1900 h, after which a slower decline followed.
At Bujumbura, the range of air temperature over the day was highest in the dry season (maximum in August: 7.6 °C) and lowest in the wet season (4.2 - 5.3 °C) . At Mpulungu, the highest range over the day was found in May (8.3 °C) . Fluctuations decreased after May, with the lowest in December (5.0 °C)

Air and water temperatures at the buoys are discussed below.

3.3 Solar radiation

Throughout the year solar radiation ($W.m^{-2}$) started to rise after 0600 h and returned to c. zero at 1800 h (Figs 6 and 7) . There was no appreciable difference in diel sun duration between ‘summer’ and ‘winter’ seasons, both at Mpulungu and Bujumbura. At both stations the maximum was reached around 1200 h. The daily maxima were at Bujumbura in the dry season and in the wet season 882 and 835 $W.m^{-2}$ respectively, and at Mpulungu 869 and 919 $W.m^{-2}$ respectively.

3.4 Relative humidity

Over the day, humidity at Bujumbura reached a maximum (64 - 84 %) between 0300 and 0600 h, and a minimum between 1000 h and 1700 h (Fig. 8) . From July to September, humidity remained low until c. 2400 h.
At Mpulungu (Fig. 9), a first peak was reached at 0600 h. The

lowest value of the day was then reached between 0900 and 1200 h. The daily maximum was found at 1800 - 2000 h in March - November (55 - 80 %) . The humidity then rapidly decreased until c. 2400 h. In December - February, the humidity was highest at night and similar between 2000 and 0700 h. Thus, with two peaks a day in the dry season, the diel humidity pattern at Mpulungu was different from the one at Bujumbura. Seasonal differences in daily minima and maxima and the range between the daily minima and maxima are given in Table 1.

Table 1. Seasonality of relative humidity at Bujumbura and Mpulungu.

		Bujumbura	%	Mpulungu	%
Daily Range	**Highest** **lowest**	**Jan - May** **Jun - Oct**	**18 - 20%** **11 - 15%**	**Apr - Sept** **Oct - Mar**	**21 -27 %** **14 - 19 %**
Daily minimum	**highest** **lowest**	**Feb** **Aug**	**62%** **51%**	**Feb** **Sept**	**62%** **31%**
Daily maximum	**highest** **lowest**	**Apr** **Aug**	**84%** **64%**	**Jan** **Sept**	**80%** **55%**

At Bujumbura there was more seasonal difference in the daily maxima than in the minima. The seasonal trends of these daily minima and maxima were similar at Mpulungu and Bujumbura, with highest values in the wet season and lowest values in the dry season, but for the range between the minima and maxima this was not the case. The range at Mpulungu was highest when it was lowest at Bujumbura, i.e. at the end of the dry season. Daily fluctuations in humidity were higher at Mpulungu, while the daily maxima were generally higher at Bujumbura.

3.5 Wind speed

Wind speed over the day at Bujumbura showed a similar pattern throughout the year, with a maximum between 1400 and 1700 h (Fig. 10) . This daily maximum was especially high from June to September (7-8 $m.s^{-1}$) and was primarily caused by wind from the south. Wind speed at Bujumbura was about 2 $m.s^{-1}$ between 2000 h and 1000 h from January to July, and between 2000 h and 0900 h from August to December.

At the Kigoma wind station (Fig. 11), in the dry season wind speed reached a maximum at 1400 - 1600 h, as at Bujumbura. This peak was primarily wind from the west (see below) . The daily maximum at the Kigoma wind station reached similar levels as at Bujumbura from July to September (7-9 $m.s^{-1}$) . Differences in wind force between dry and wet season were greater at Kigoma than at Bujumbura. Between 1800 h - 1000 h values remained generally at around 3 $m.s^{-1}$, so a similar period with low wind speeds during the day as at Bujumbura but at a higher level. From November to February there was no clear afternoon peak.

At the Kigoma buoy (Fig. 12) wind speed showed 2 small peaks over the day from April to August. These peaks (wind speeds c. 5 $m.s^{-1}$) occurred at c. 0800 and 1400 h. They represented the southeast and the north-west wind respectively. The daily maximum was highest in May and July (5.5 $m.s^{-1}$), which was lower than at the land station. The wind speed pattern at the buoy differed from the land station where the afternoon peak was relatively high. At the land station the west wind was more important than at the buoy. From November to March the wind speed remained relatively constant (3 $m.s^{-1}$) through the day.

At the Mpulungu buoy wind speed was highest from 0200 - 0500 h from April to October. This daily maximum was in 1993 highest in June (8.8 $m.s^{-1}$, Fig. 13) and in 1995 highest in August (8.3 m.s A small peak (c. 4 $m.s^{-1}$) occurred at about 1500 h, which became the daily maximum from November to March. The former peak was represented mainly by wind from the south-east and the afternoon peak by wind from the north-west. The pattern at the buoy was similar to the pattern at the land station at Mpulungu.

At the Mpulungu weather station (Fig. 14) the maximum was generally reached at 2400 – 0200 h from May to September. Of the five stations, the daily maximum at the Mpulungu weather station was the lowest (highest from June to August, 5 $m.s^{-1}$) . Throughout the year wind speed was lowest at 1800 h (1-2 $m.s^{-1}$) and a second peak was present at 1300 – 1400 h (c. 3 $m.s^{-1}$) . From October to April this peak became the daily maximum. The peak in the night and in the afternoon were represented mainly by wind from the south-east and wind from the north-west respectively. From December to April the wind speed changed to a relatively constant 2 $m.s^{-1}$ through the day, with a reduced peak at 1300 - 1400 h.
At Mpulungu the period of high wind speeds over 24 hours (in the dry season) was longer than at Bujumbura and Kigoma and the seasonal differences were greater at Mpulungu than at Bujumbura.

3.6 Wind direction

The wind regime around Lake Tanganyika is extremely stable. The wind direction patterns over the day did not change significantly from month to month, although wind changed direction during the day.
At Bujumbura (Fig. 15), the night wind blew from the north. In the morning it switched to the south via the west where it continued through the afternoon, and then in the early evening switched back to the north via the east.
At the Kigoma wind station (Fig. 16), the night and morning wind blew from the north-east to east-north-east, and changed to the west to west-south-west in the afternoon. From October to April

the wind changed a few hours earlier from north-east to west. At the Kigoma buoy (Fig. 17) the night and early morning wind blew from south-east. From 1200 to 1800 h the wind blew from north—west.
At the Mpulungu buoy (Fig. 18) the night wind blew from the south-east but was less regular in December to March than in April to November. Between 1200 and 1800 the wind generally blew from the west-north-west to north.
At the Mpulungu weather station (Fig. 19) the diel wind direction pattern was similar to the pattern at the lake station, unlike at Kigoma.

3.7 Wind vector components

East/west and north/south components of the wind vector at the Bujumbura weather station are shown at 10 mm intervals in August 1995 in Fig. 20. The north/south component was usually negative when the east/west component was positive, i.e. the wind blew either from the south—east or from the northwest. The east/west vector component was the smallest. The pattern was very similar from day to day. East/west and north/south components of the wind vector contain less information when averaged, than wind vectors split in 4 components and are not discussed in this report.
Table 2 shows when each wind vector component reached its daily maximum at each station and the daily maximum of each wind vector component in the months when it was highest of the year.

Table 2. Time of daily maxima and magnitude and month(s) of highest daily maxima of wind vector components.

	Station	Afternoon c. 1100-1800 h	Night c. 1800-1000 h	Highest mean monthly daily maxima ($m.s^{-1}$)				Period of highest daily maxima			
				N	S	E	W	N	S	E	W
Bujumbura	**weather**	S + E	N + W	2	7	3	1	Jan-Dec	Jun-Sep	Jun-Sep +Nov-Dec	Jan-Dec
Kigoma	**wind**	S + W	N + E	3	3	5	8	Oct-Nov	Jul-Sep	Jul-Aug	Aug
	buoy	N + W	S + E	4	4	3	3	May-Sep	May-Aug	Sep-Nov	Jun-Oct
Mpulungu	**buoy**	N + W	S + E	4	6	6	2	Sep-Dec	Jun-Aug	Jun-Jul	May-Dec
	weather	N + W	S + E	3	4	3	2	Sep-Dec	Jun-Aug	May-Sep	Jul-Dec

Diel patterns of the wind vector components are shown in Figures 21 - 30. In general wind components from the lake were highest in the afternoon. Diel fluctuations in the south and east wind components were generally highest in the dry season at all stations. At the Kigoma buoy more wind stress came from the south and north and less from the west and east than at the land station (Figs 25 and 26) . At the land station the west wind component was highest of the four wind components. At all other stations the south wind was the strongest.
At the Mpulungu buoy, daily maxima for each wind component usually occurred 1 - 3 hours later than at the land station. For all wind components, speeds were lower at the land station than at the buoy except for the west wind which was similar at the two sites.

3.8 Water and air temperatures at the buoys

Water temperatures at the buoys showed diel changes at 1 and 5 m depth. At 15 m and deeper depths no significant change was observed. At the Mpulungu buoy (Fig. 31), water temperature near the surface increased usually from 0700 to 1500 h. Throughout the year the ranges between the daily minimum and maximum temperatures at 1 m depth were between 0.35 and 0.55 °C and there was no clear seasonal pattern. Decrease and increase occurred usually quite simultaneously for air and water temperature. Only the onset of heat uptake at 1 m in the morning occurred about 2 hours after the air temperature started to rise and in September and October a relatively small peak in air temperature occurred at midnight, but not in water temperature.

The air temperature range at the Mpulungu buoy based on monthly means was from 23.9 to 26.5 °C (March 1994 to December 1995). This was a larger range than at the Kigoma buoy (24.2 to 25.9 °C) during the same period. The minima (19.7 °C at Mpulungu, 19.2 °C at Kigoma) and maxima (30.6 °C at Mpulungu, 30.3 °C at Kigoma) of all measurements at the buoys in the same period differed less. The air temperature daily maximum at the Mpulungu buoy occurred c. 3 hours later than at the Mpulungu weather station. The increase in air temperature between the daily minimum and maximum at the Mpulungu buoy was smallest in October, 1.3 ^{0}C. The range increased up to June when it was 3.2 °C. These daily fluctuations were smaller than at the weather station at Mpulungu (5.0 °C in December and 8.3 °C in May)

Usually the air temperature was K water temperature at 1 m depth. Only from April to October was the air temperature higher. This difference occurred for only a few hours at midday in April to practically the whole 24 hours in October. In November water temperature was higher than in October, the air temperature was lower than in October and throughout the day air temperature was **<** water temperature at 1 m depth from November to March.

At the Kigoma buoy (Fig. 32) water temperatures usually increased from 0700-1600 h from September to February and from c. 0800–1500 h from March to August. The range between the daily minimum and maximum at 1 m depth was smallest in July, 0.21 °C. This range increased up to November, when it was 0.66 °C.

The difference between the daily minimum and maximum air temperature at the Kigoma buoy was between 1.4 °C (November) and 3.4 °C (August) . These ranges were similar to the ranges in air temperature at the Mpulungu buoy.

Maximum and minimum diel heat uptake by the atmosphere took place at different times in the year than that by the water surface. Maximum diel heat uptake by the water, occurred in the wet season, when the increase of the air temperature between the daily minimum and maximum was relatively low. The air temperature at the Kigoma buoy only rose above the water temperature in August and September (from 1000 h to 1900 h) and thus for a much shorter period than in the south.

3.9 Spatial gradients in air temperature

Air temperature at the Mpulungu weather station was higher than at the Mpulungu buoy between 0008 - 1800 h (Fig. 33). At night the air temperature was higher at the buoy. The differences in air temperature are shown in Table 3. The difference during the day was highest in the dry season. The difference during the day was larger than the difference at night from May to November (section C in Table 3) . The difference at night was highest from January to July, but was higher than the difference during the day from December to April (section C in Table 3)

Table 3. Seasonality of the differences in air temperature. Air temperature at the Mpulungu buoy was subtracted from air temperature at the land weather station (cf. Fig. 33).

	period	lowest	highest
A. positive difference (i.e., T at land station higher than at the lake)	**Day**	**Dec - Mar: +1.5 - +1.7°C**	**Jul - Aug; +3.5 - +3.6°C**
B. negative difference (i.e., T at lake station higher than on land)	**Night**	**Aug - Dec; -1.9 - -2.1°C**	**Jan - Jul; -2.5 - -3.2°C**
C. A - B (i.e., the difference between A and B)		**Jan - Mar; -1.0 - -1.6°C**	**Jul - Sep; +1.1 - +1.4°C**

Air temperature at the buoy was only during the afternoon from May to September higher than the water temperature at 1 m depth (Fig. 33)

3.10 Evaporation

In 1995 at Bujumbura 25 % of the evaporation occurred at night (1800 h - 0600 h) . This varied little from month to month, and was on average the same from March 1993 - April 1994. Monthly percentages for evaporation at night ranged from 22 - 30 % of the daily total. Daily maxima in evaporation occurred at 1400 - 1700 h (Fig. 34) . The daily maximum was highest in the dry season (0.5 $mm.h^{-1}$) and lowest in January (0.2 $mm.h^{-1}$).
Evaporation calculated for the Mpulungu buoy was highest in the night in April to September (53 to 59 %) . Evaporation during the night was 45 to 50 % from October to March, and

the annual mean 52 % (Fig. 35) . There were two peaks, one between 0000 – 0400 h, and one at c. 1400 h. The first peak disappeared after October and reappeared in April. The diel evaporation pattern at the Mpulungu buoy was thus different from Bujumbura. The midday peak was c. 0.3 $mm.h^{-1}$. In the night in the dry season evaporation at Mpulungu reached 0.7 $mm.h^{-1}$. Monthly mean vaporation at night at Mpulungu was between x 2 and x 12 the evaporation at night at Bujumbura. Evaporation calculated for the weather station at Mpulungu was during the night from May to September only 43 to 52 % (mean 49 %) of the daily evaporation. At the Mpulungu weather station the wind speed and air temperature at night were lower than at the buoy.

4. DISCUSSION AND CONCLUSIONS

Among the more important aspects of the data presented here are the higher air temperatures at land, compared with those at the lake during the day, and a reversed gradient at night. Winds of thermal origin blew from the lake during the day and land winds occurred at night. In the dry season the air temperature gradient was highest during the day, and lake winds were generally strongest then.

During the dry season there are few clouds, so land and water are exposed to the full heat of the sun. The nights are also clear, so loss of heat by radiation is rapid. During the wet season, clouds reduce the effect of the sun’s heat and lower the rate of cooling at night. As a consequence the on and off shore winds are lighter during the wet season than they are during the dry season (Beauchamp, 1939; Savijärvi, 1997)

High evaporation was associated with the south wind at the south and north ends of the lake, since wind speed at both ends of the lake was generally highest from the south. This was partly due to the south-east trade winds during the dry season (Asnani, 1993; Podsetchine *et al.,* 1996) . Evaporation was therefore, due to the diel pattern of land and lake winds, highest at night in the south and highest during the day in the north.

Bultot (1965; 1993) calculated lake wide evaporation at night at Lake Tanganyika at 42 % of the daily evaporation, with the energy balance method. This was in between the values calculated for the Mpulungu buoy (52 %) and the Bujumbura weather station (25 %)

5. ACKNOWLEDGEMENTS

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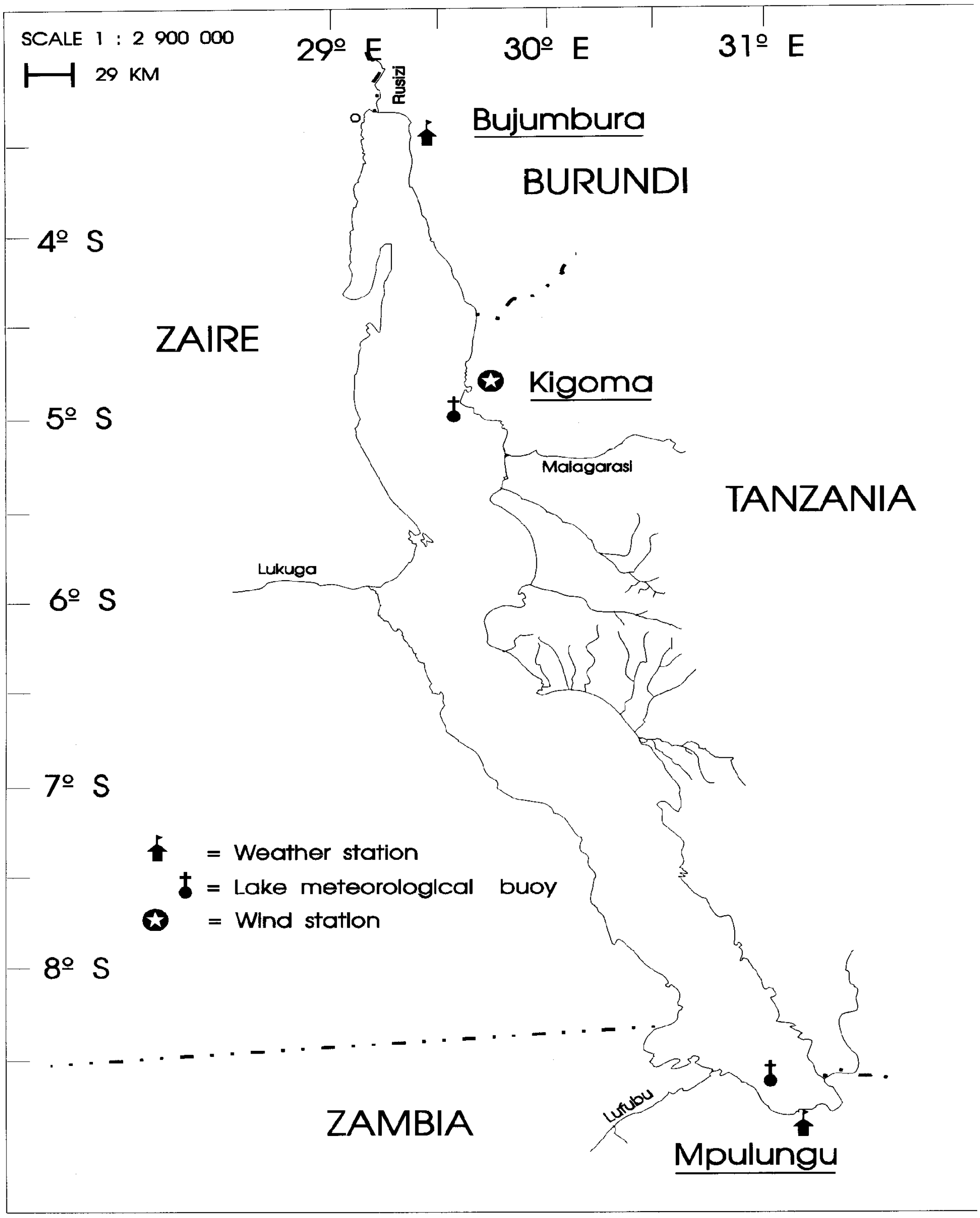

Figure 1. The positions of the meteorological instruments at Lake Tanganyika.

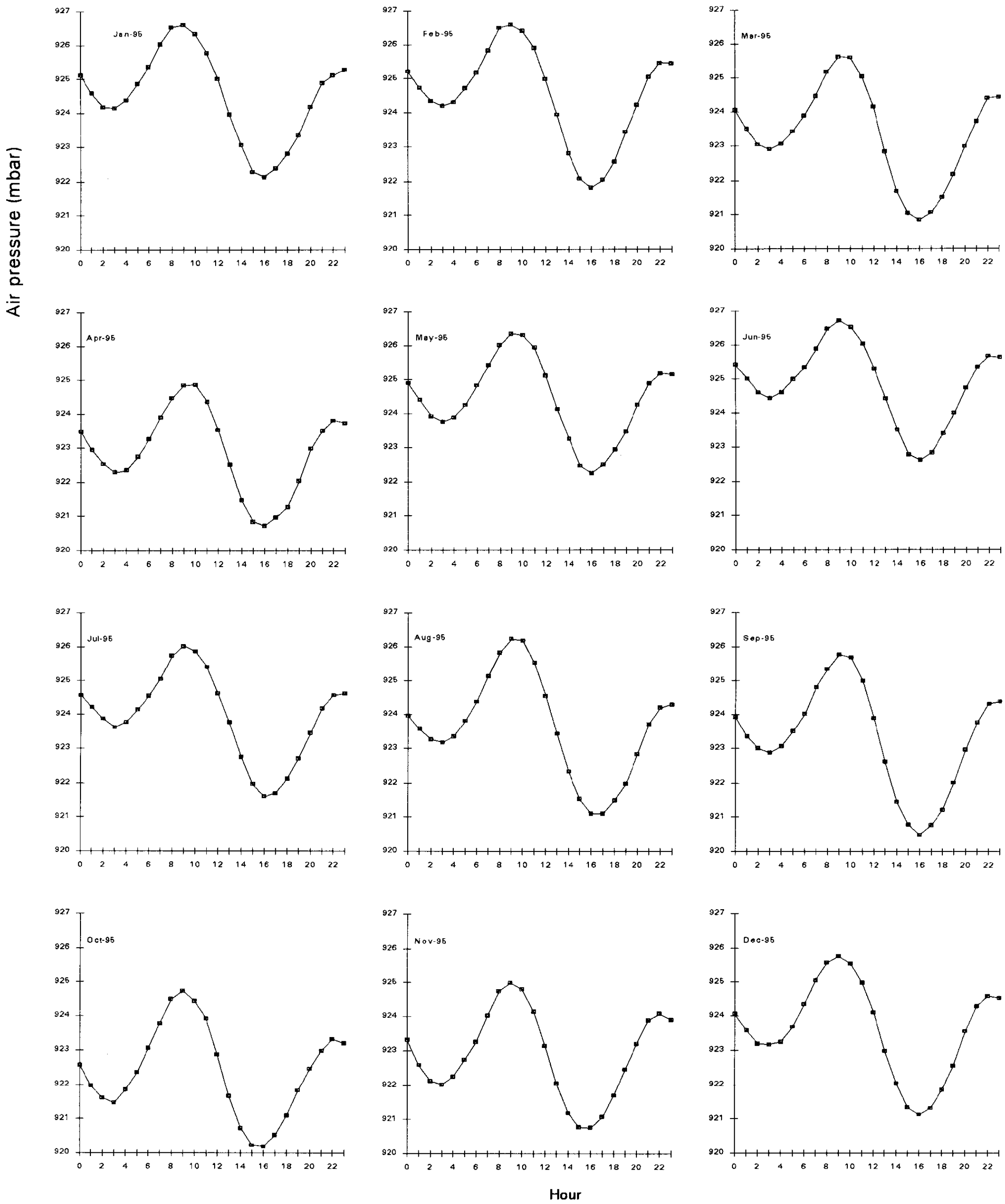

Figure 2. Mean monthly air pressure over the day at the Bujumbura weather station.

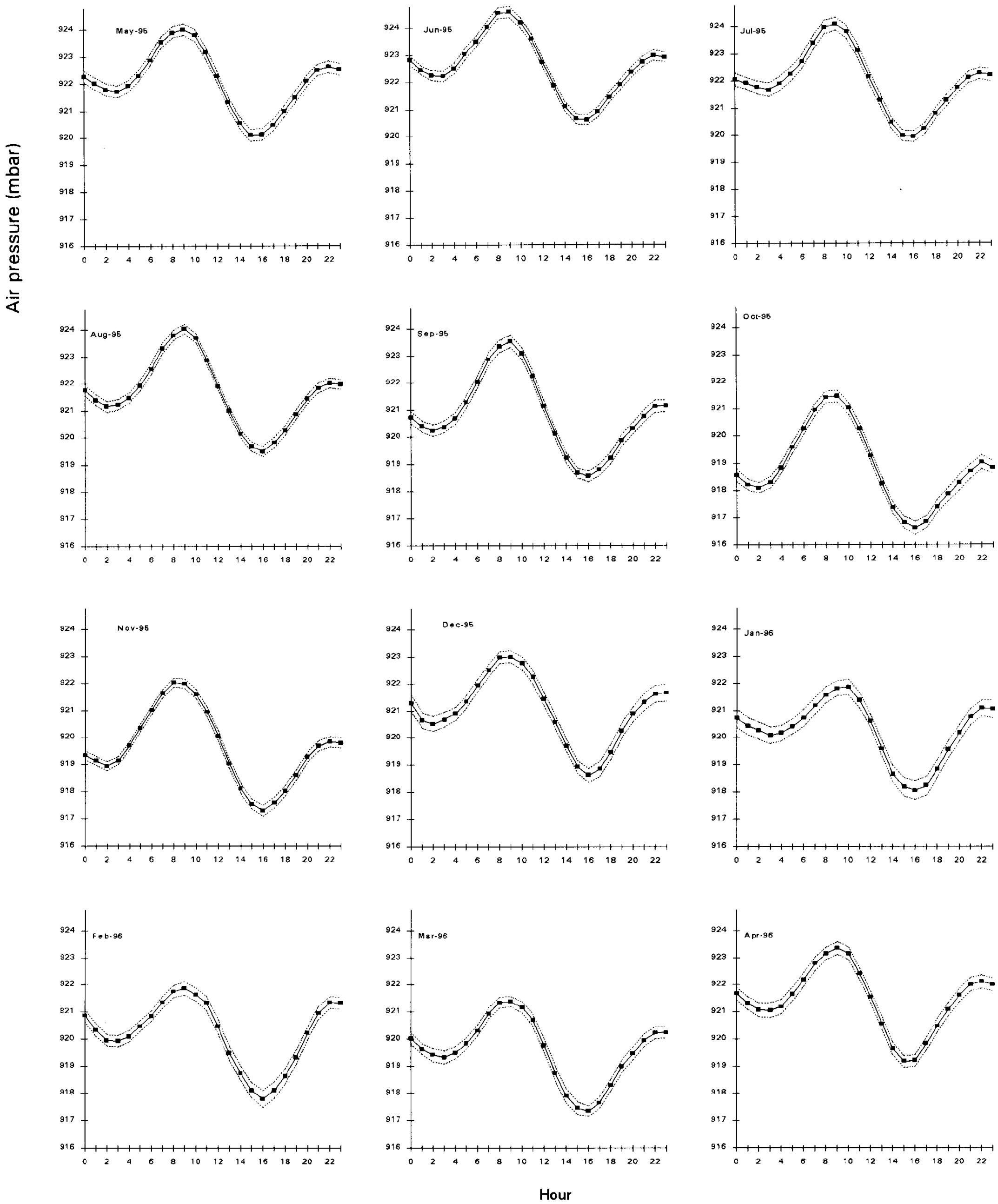

Figure 3. Mean monthly air pressure over the day, at the Mpulungu weather station. Dotted lines indicate plus or minus 1 standard error.

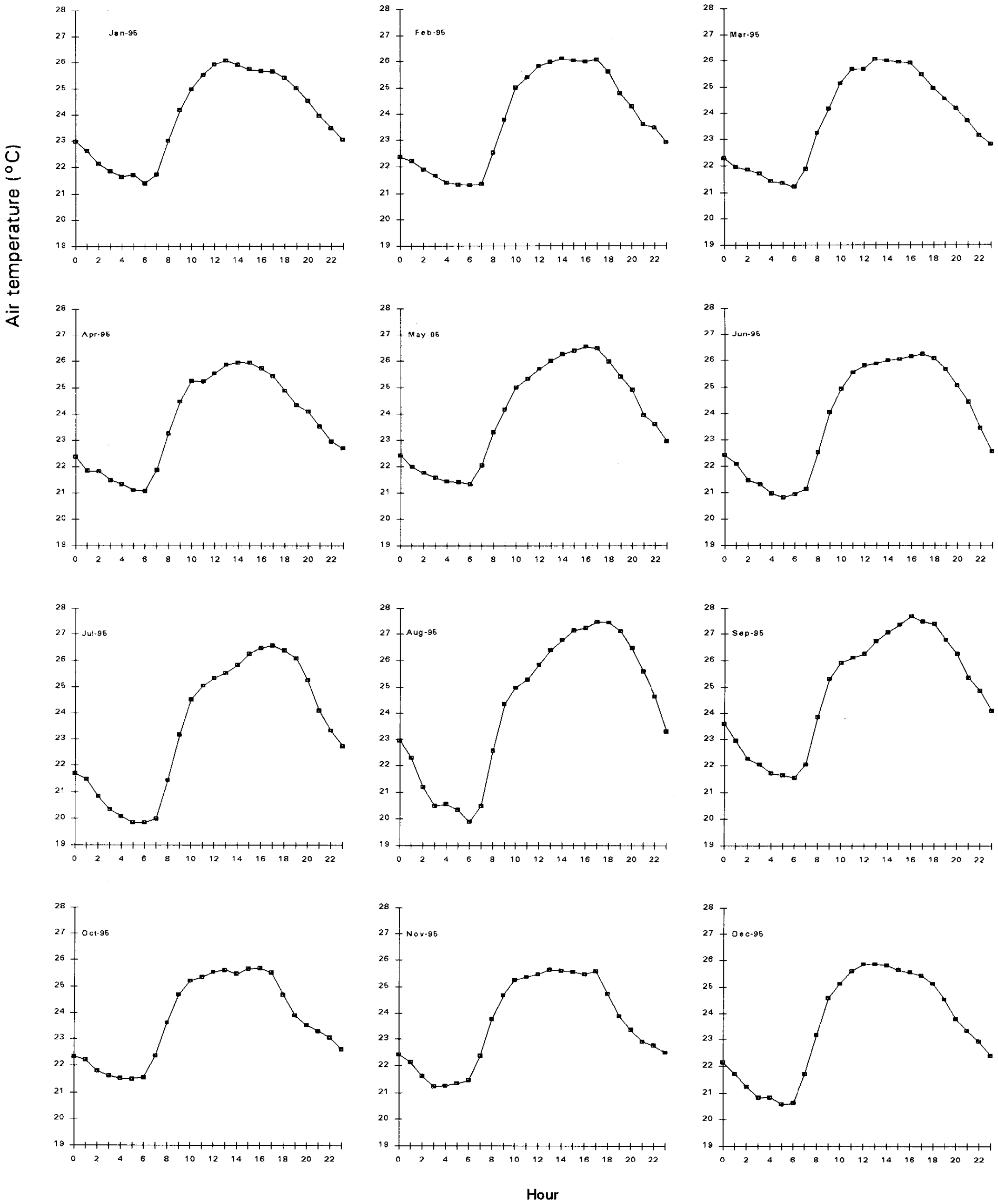

Figure 4. Mean monthly air temperature over the day, at the Bujumbura weather station.

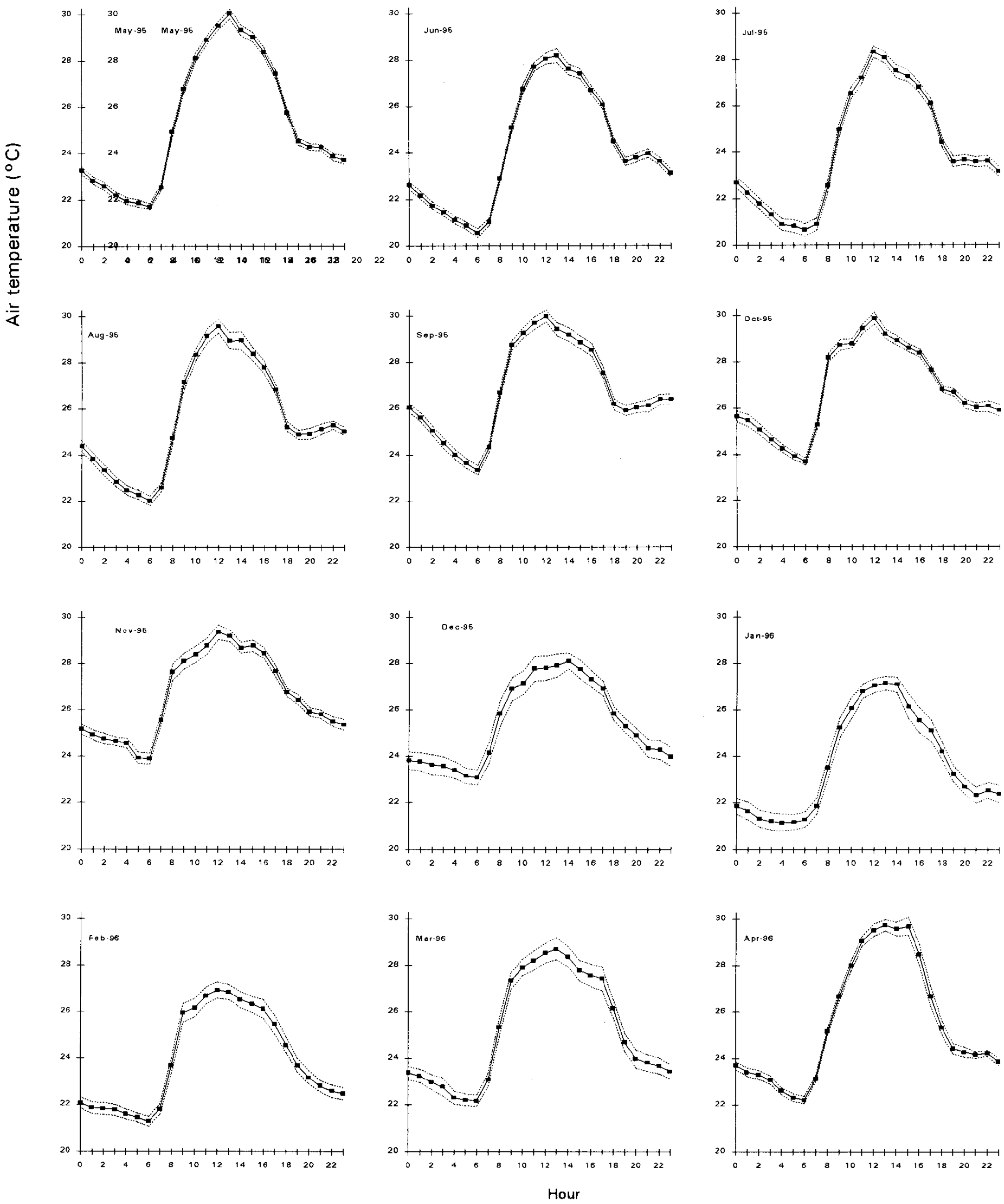

Figure 5. Mean monthly air temperature over the day, at the Mpulungu weather station. Dotted lines indicate plus or minus 1 standard error.

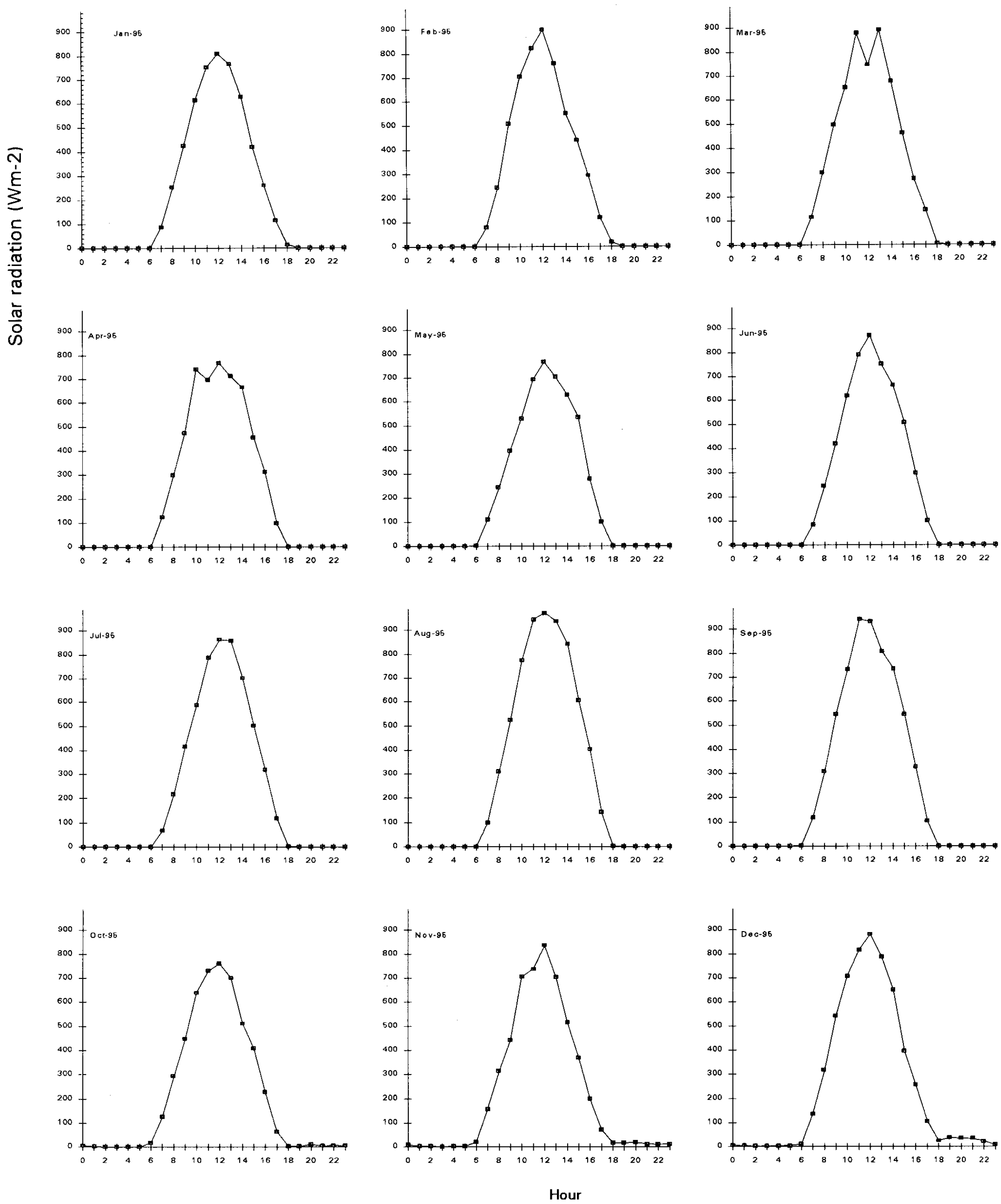

Figure 6. Mean monthly solar radiation over the day, at the Bujumbura weather station.

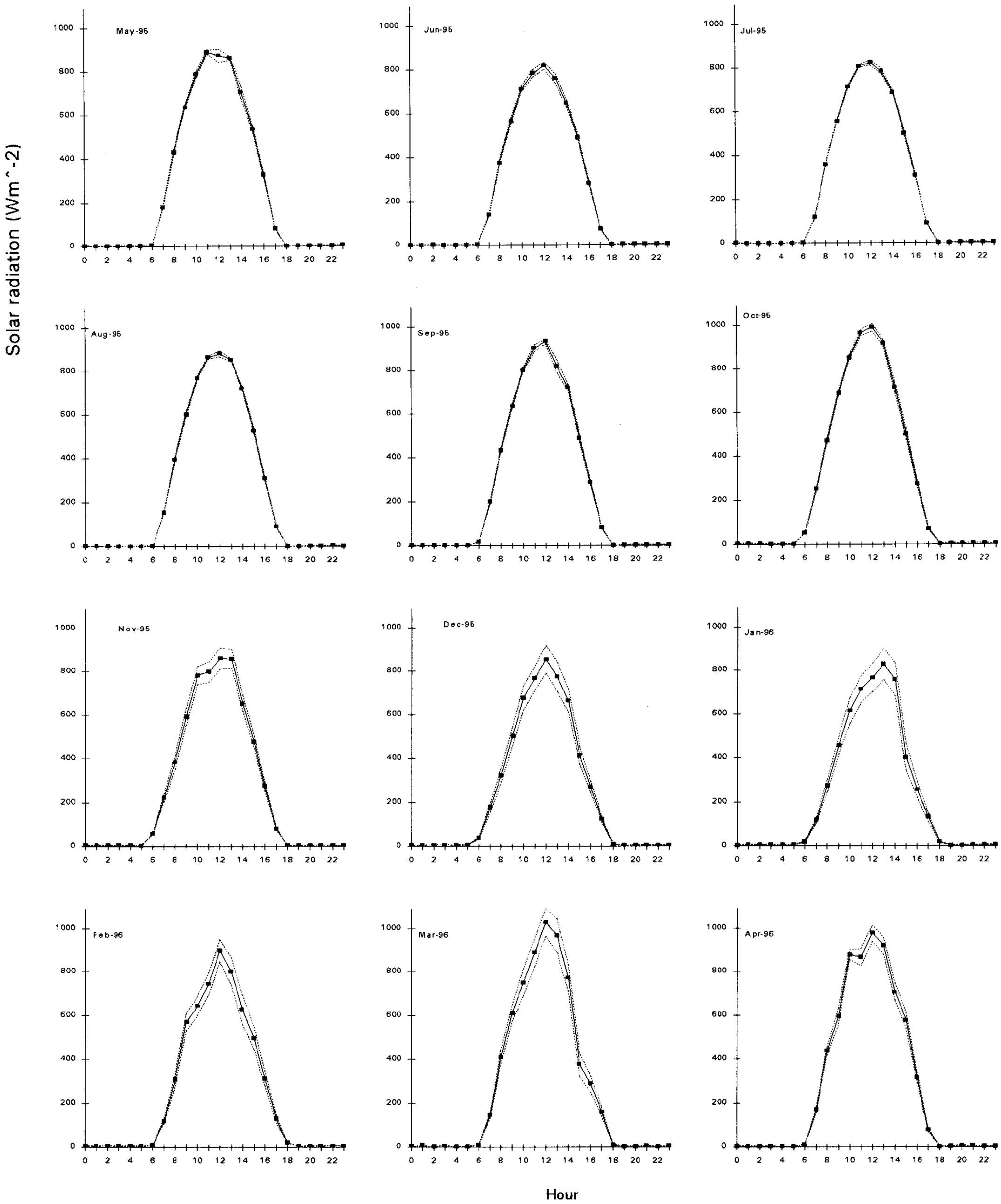

Figure 7. Mean monthly solar radiation over the day, at the Mpulungu weather station. Dotted lines indicate plus or minus 1 standard error.

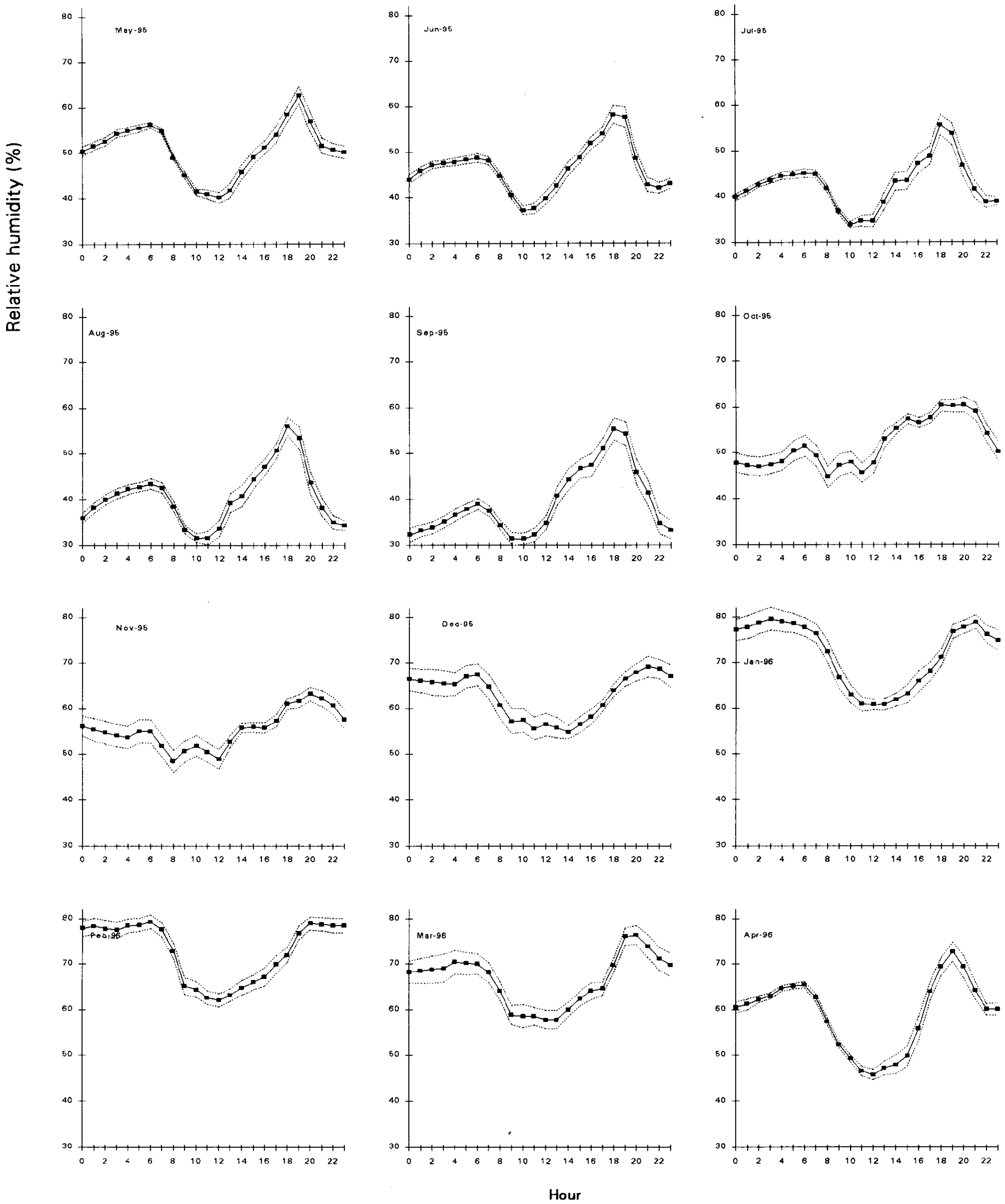

Figure 9. Mean monthly relative humidity over the day, at the Mpulungu weather station. Dotted lines indicate plus or minus 1 standard error.

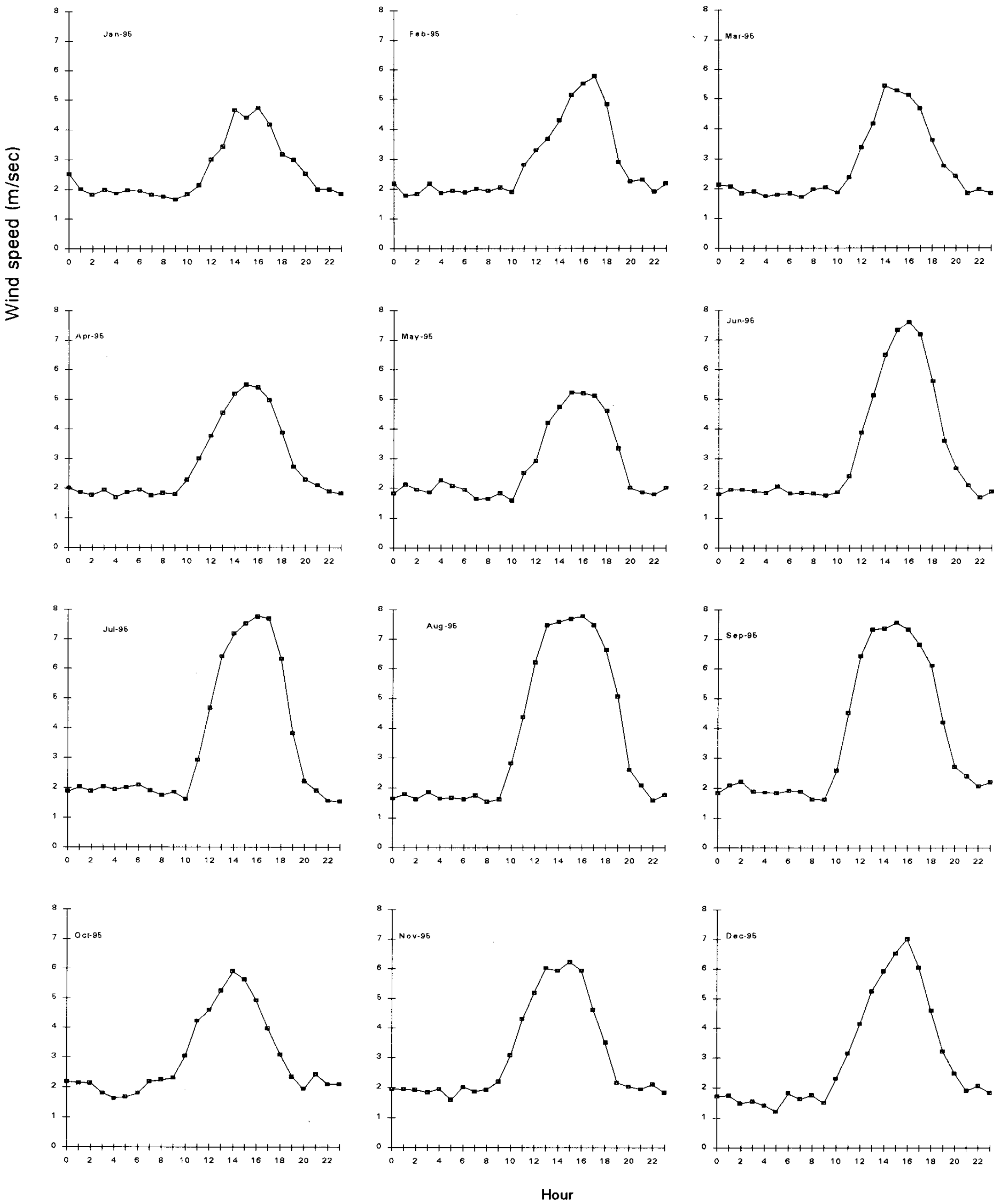

Figure 10. Mean monthly wind speed over the day at the Bujumbura weather station.

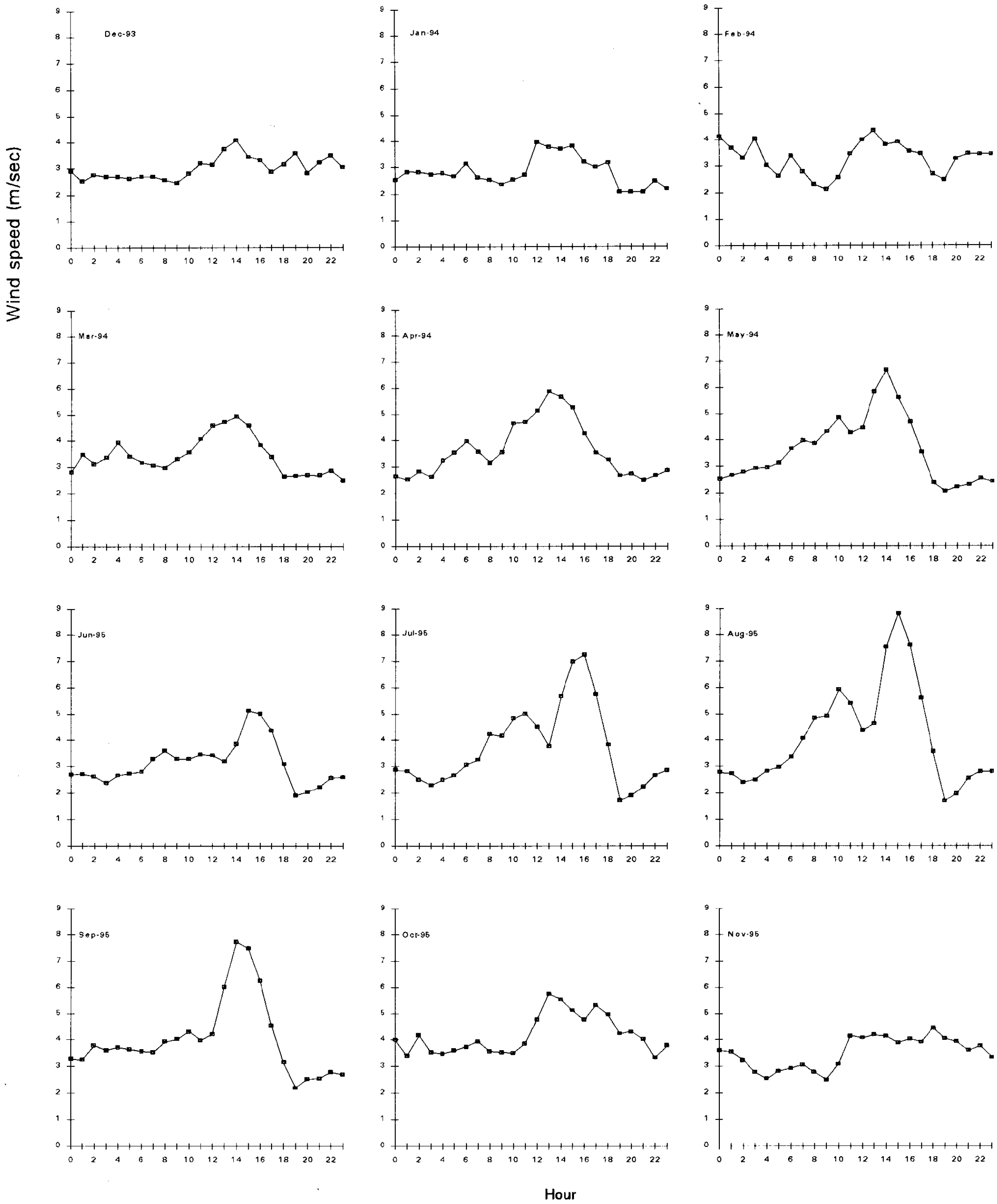

Figure 11. Mean monthly wind speed over the day, at the Kigoma wind station.

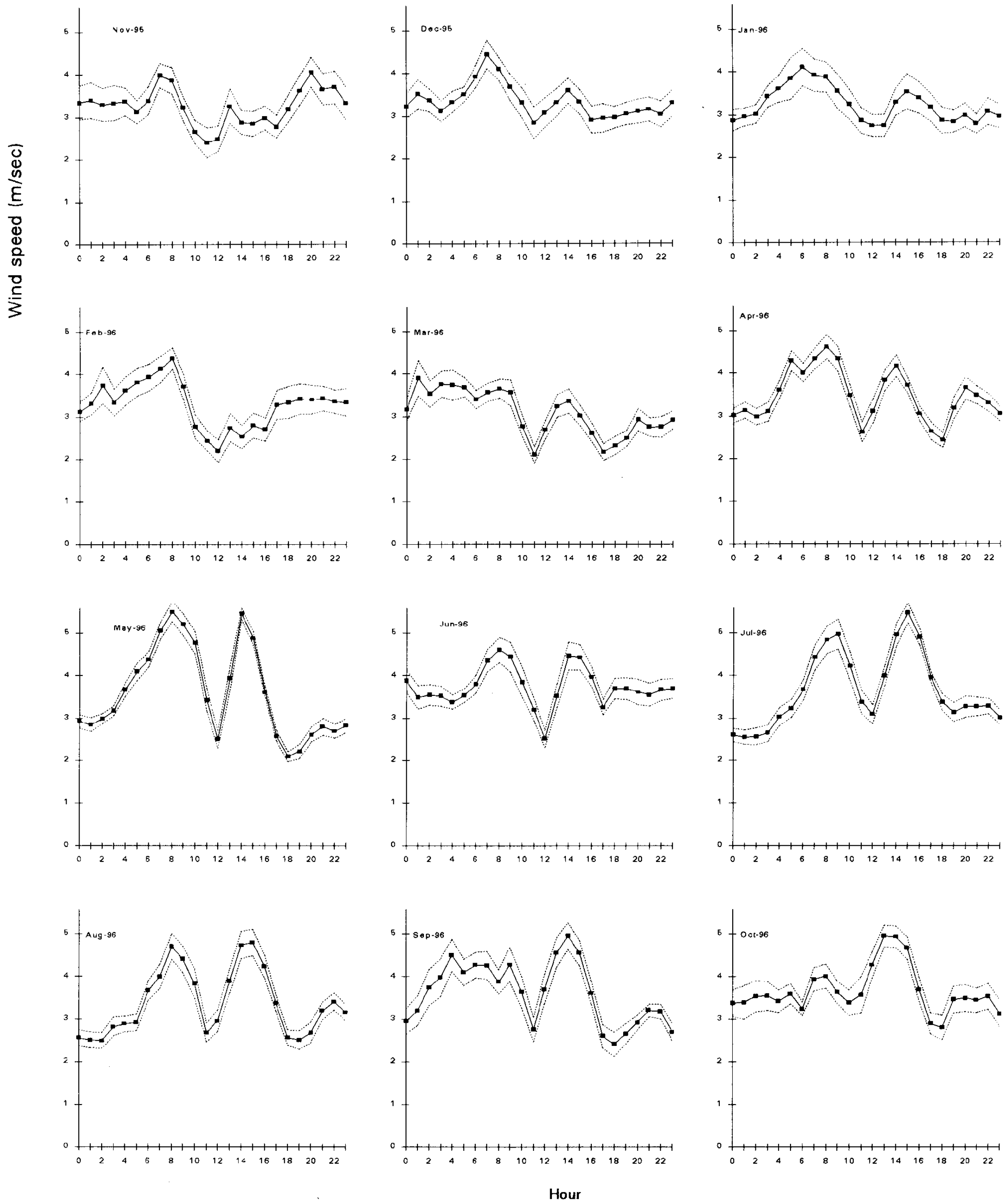

Figure 12. Mean monthly wind speed over the day, at the Kigoma buoy. Dotted lines indicate plus or minus 1 standard error.

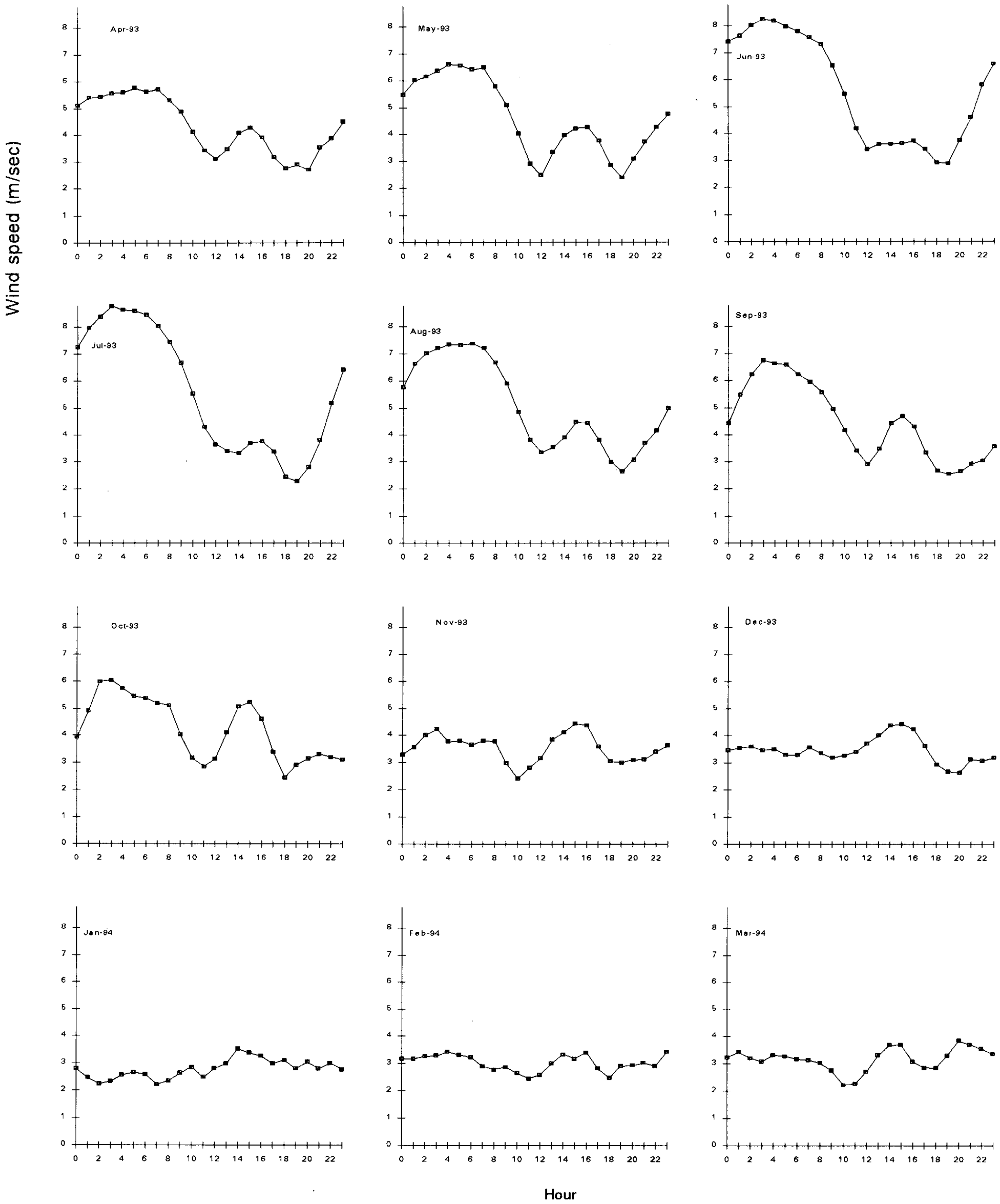

Figure 13. Mean monthly wind speed over the day, at the Mpulungu buoy.

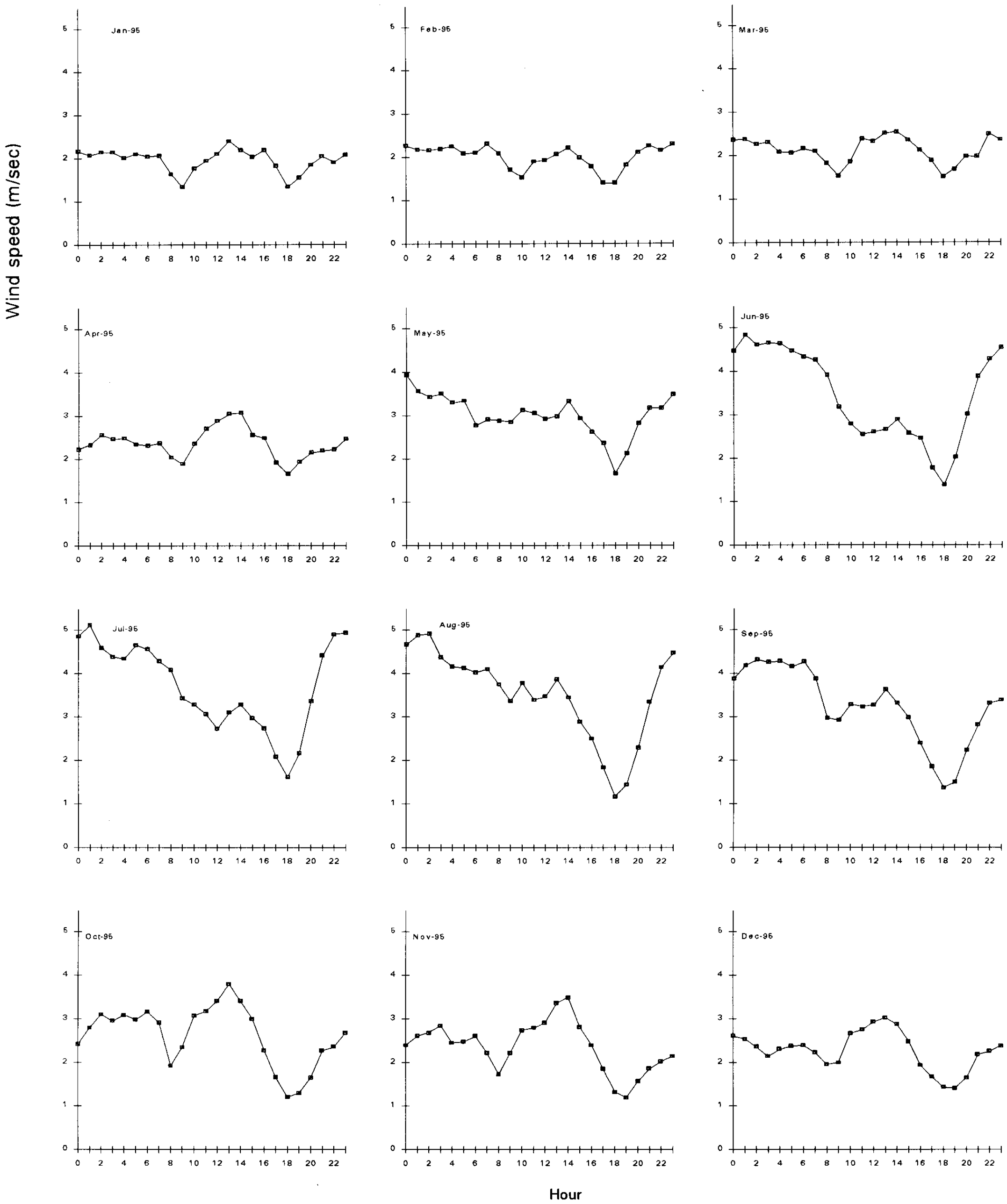

Figure 14. Mean monthly wind speed over the day, at the Mpulungu weather station.

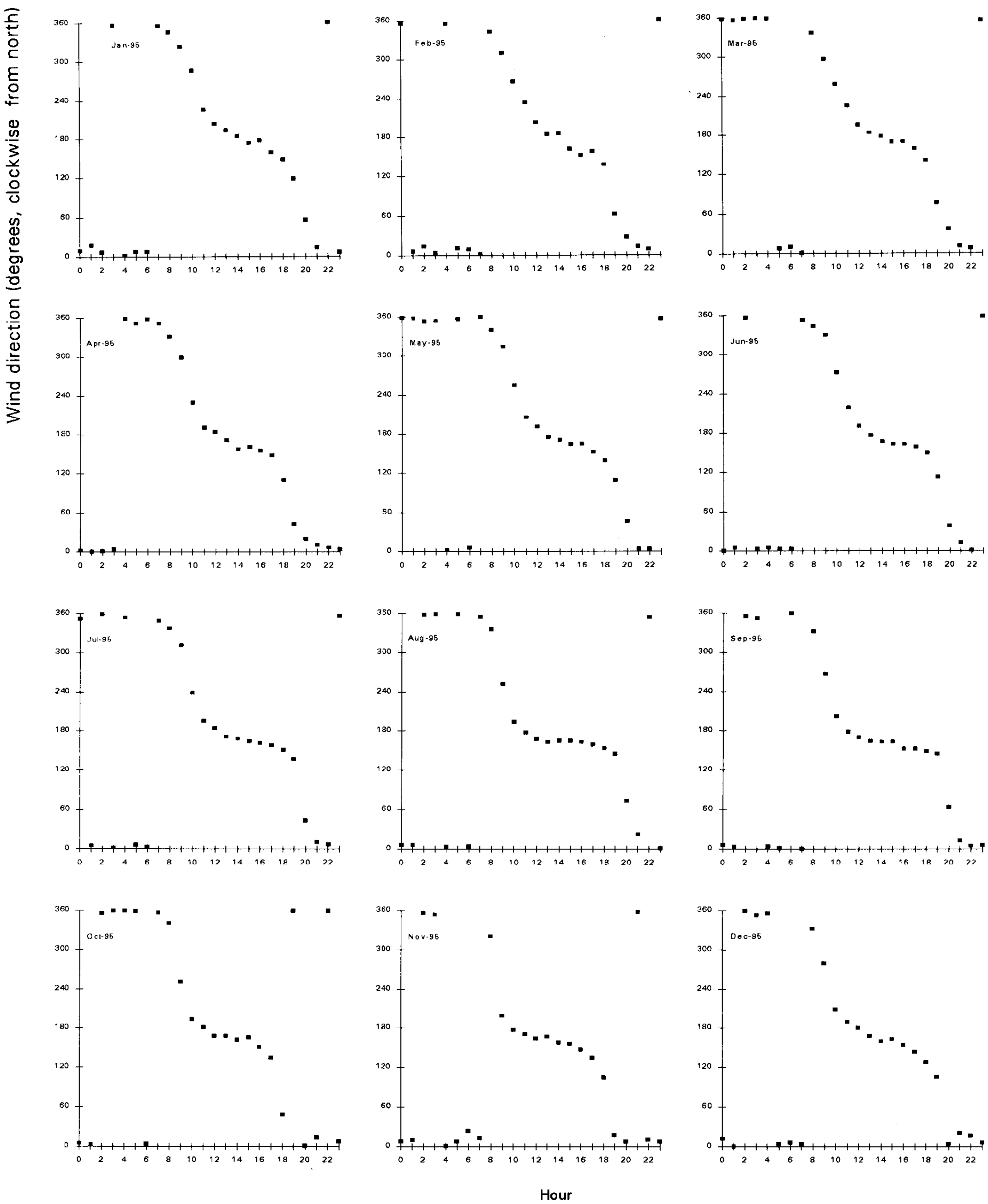

Figure 15. Mean monthly wind direction over the day, at the Bujumbura weather station.

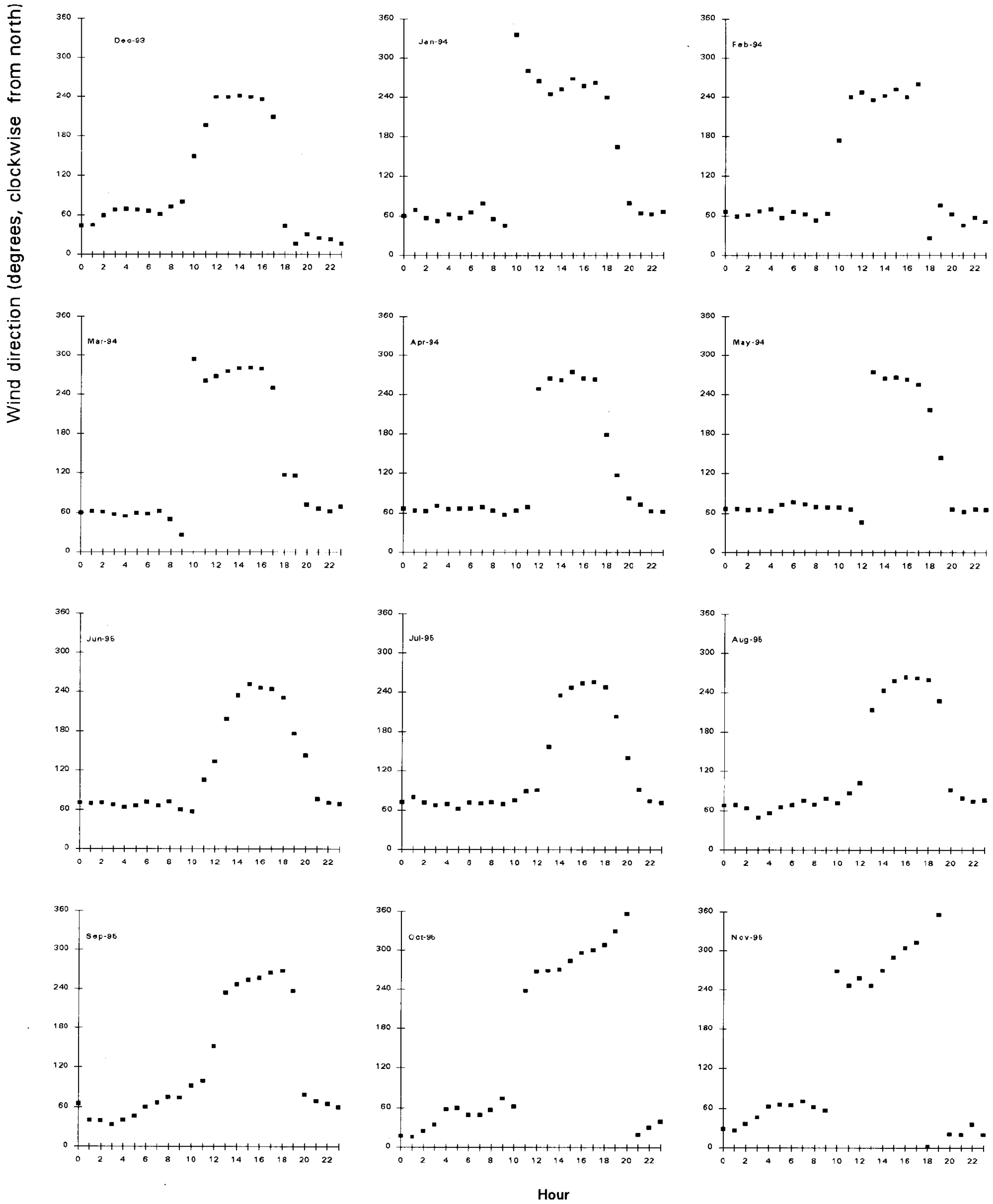

Figure 16. Mean monthly wind direction over the day at the Kigoma wind station.

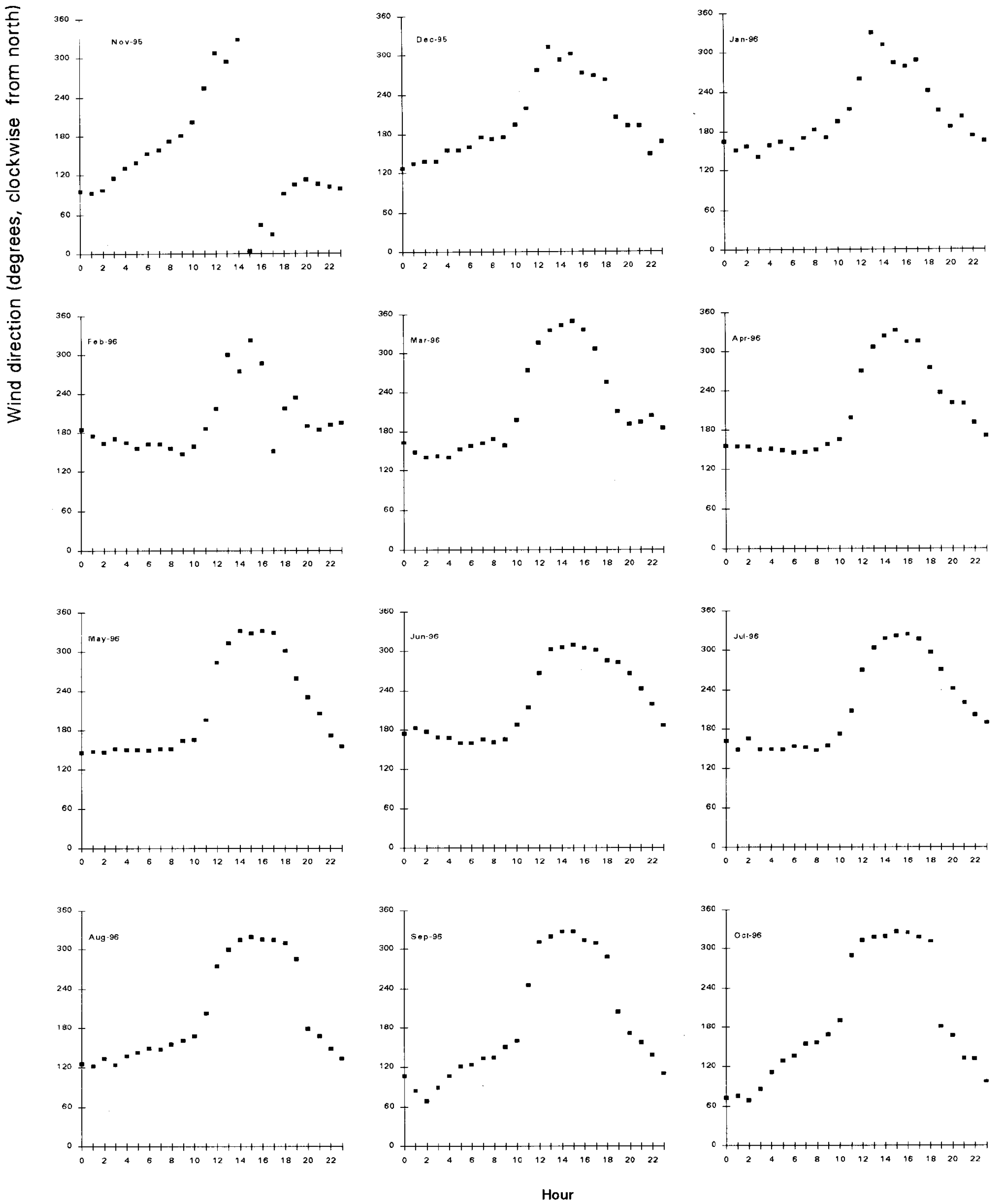

Figure 17. Mean monthly wind direction over the day, at the Kigoma buoy.

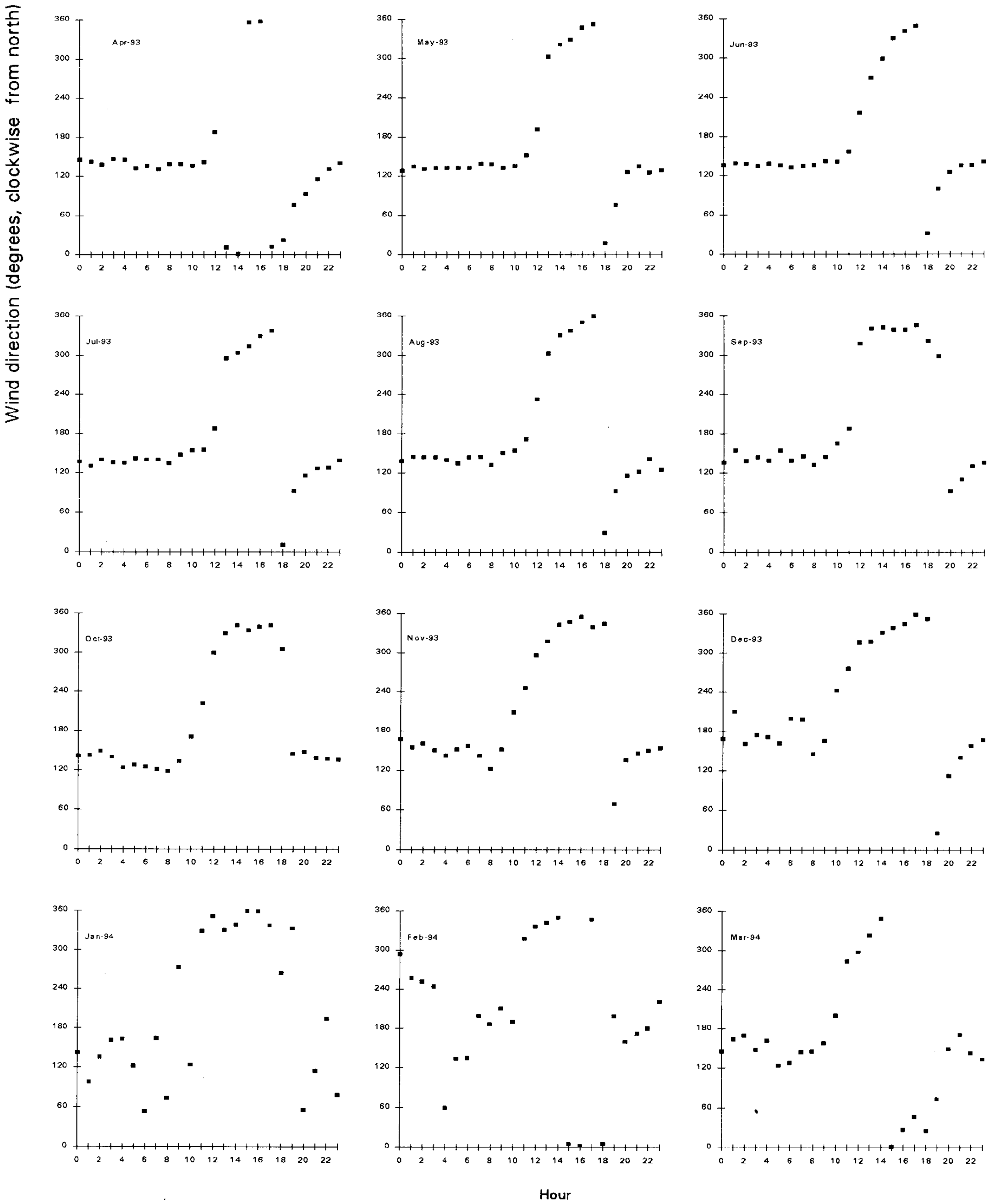

Figure 18. Mean monthly wind direction over the day at the Mpulungu buoy.

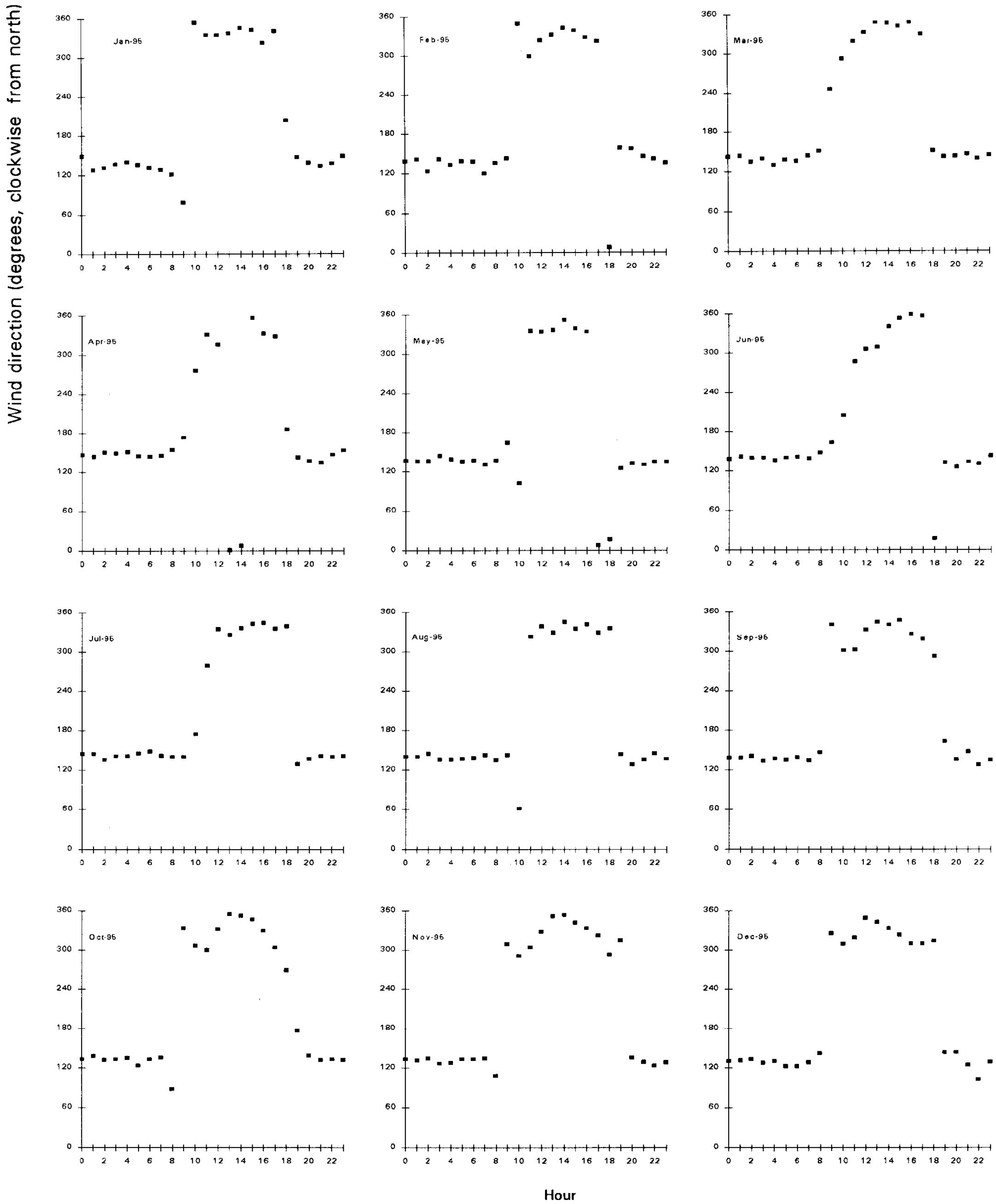

Figure 19. Mean monthly wind direction over the day at the Mpulungu weather station.

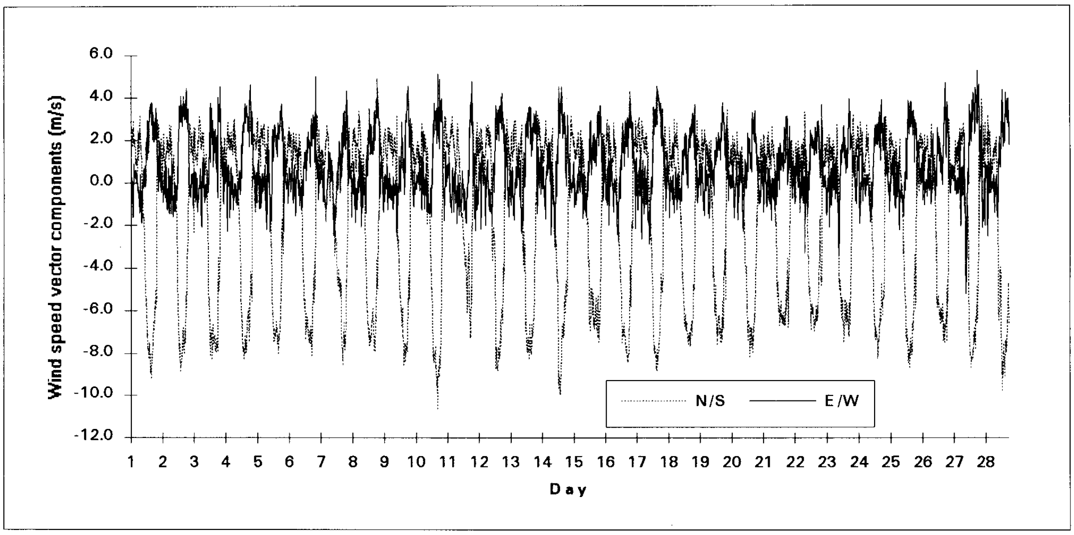

Figure 20. North-south and east-west components of the wind vector at the Bujumbura weather station on 10 min basis in August 1995.

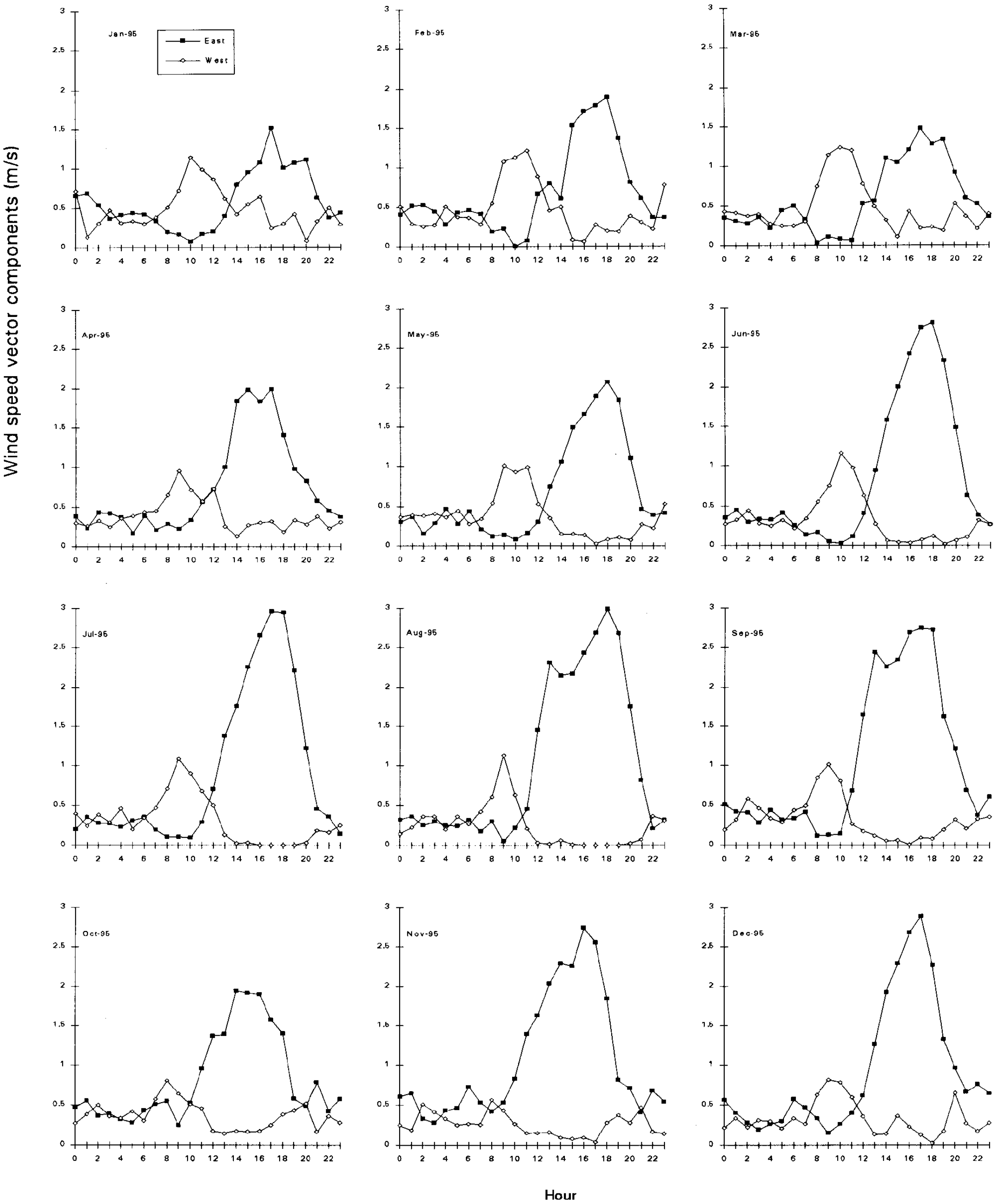

Figure 21. Mean monthly east and west wind vector components at the Bujumbura weather station.

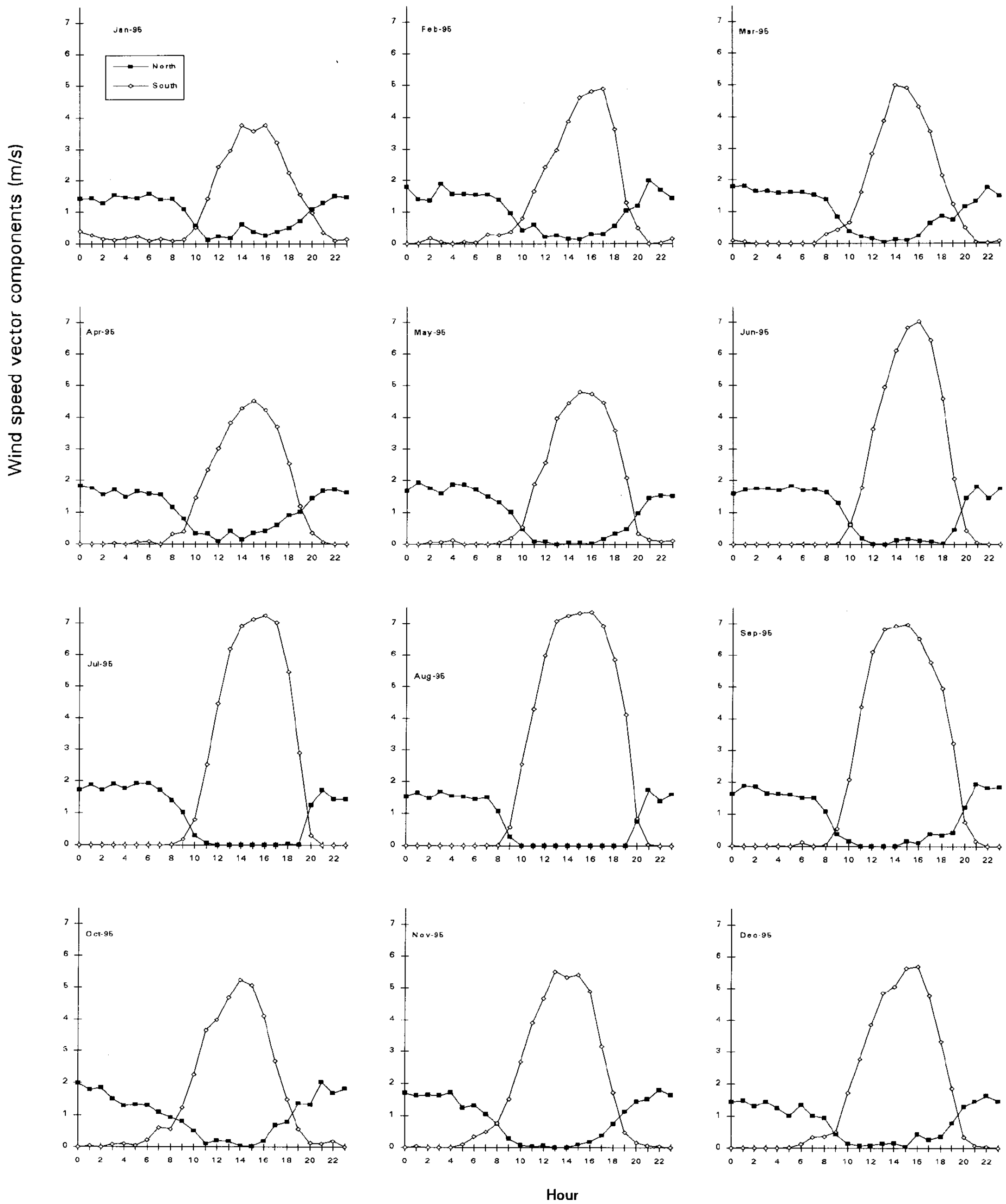

Figure 22. Mean monthly north and south wind speed components at the Bujumbura weather station.

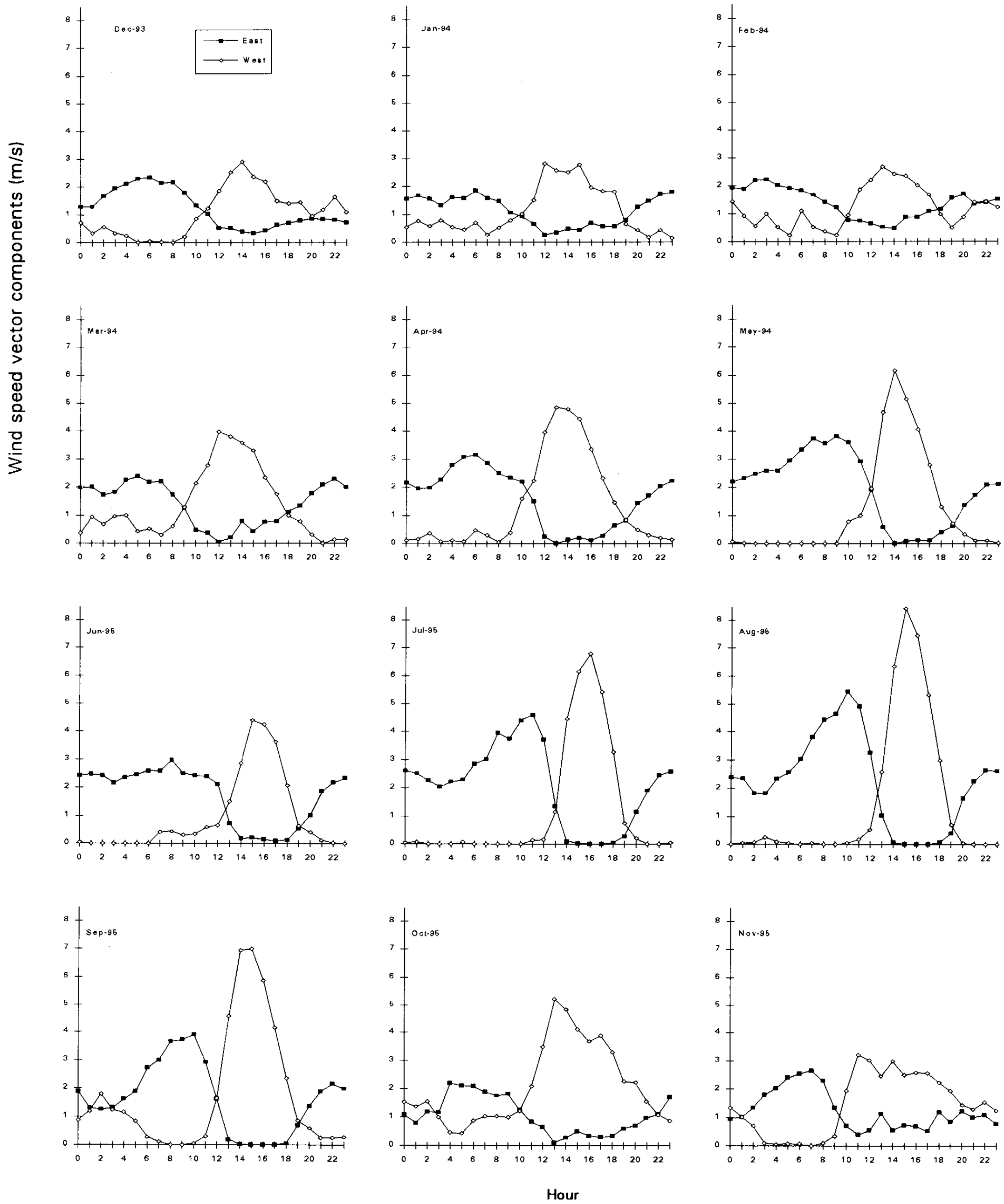

Figure 23. Mean monthly east and west wind vector components at the Kigoma wind station.

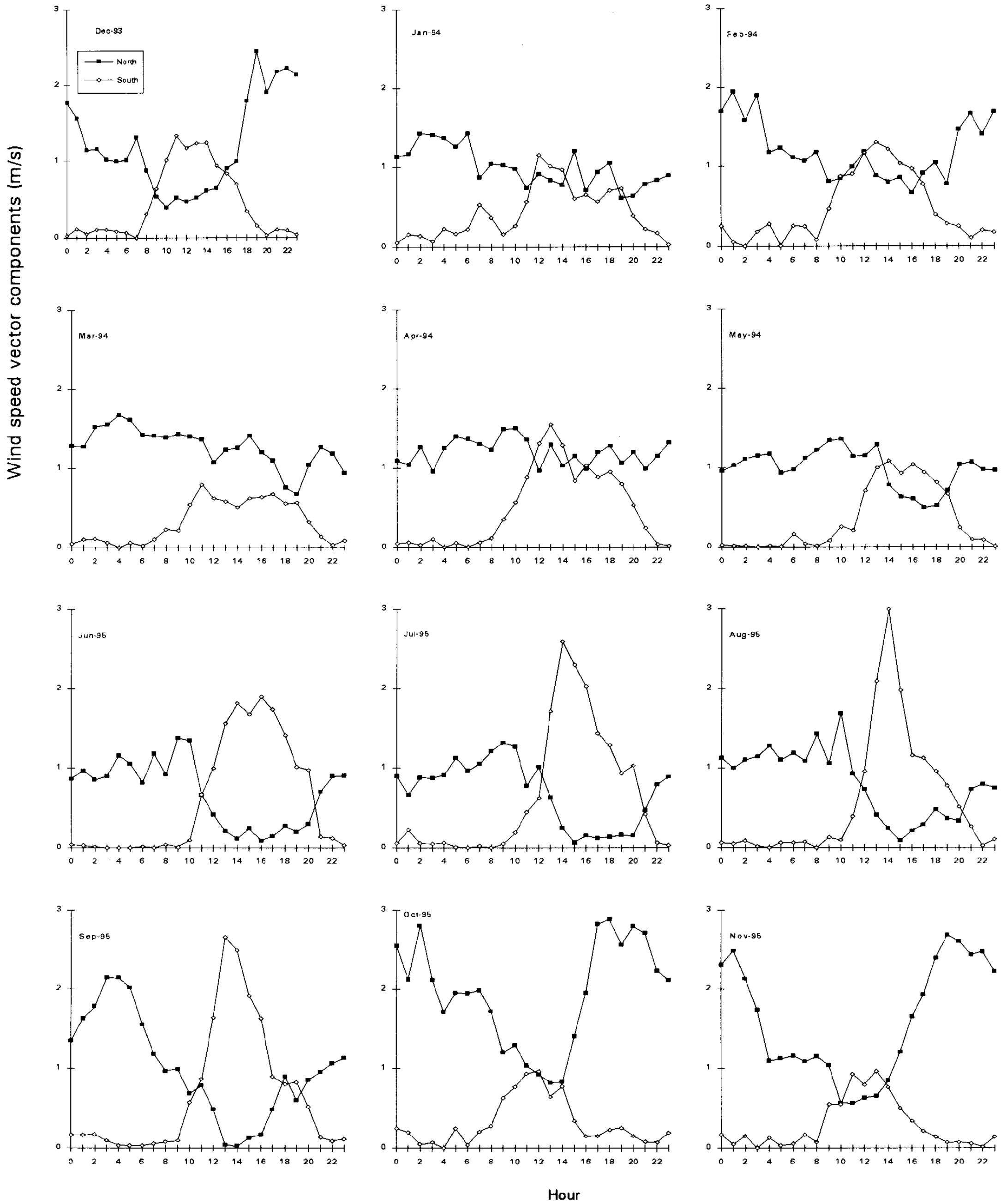

Figure 24. Mean monthly north and south wind vector components at the Kigoma wind station.

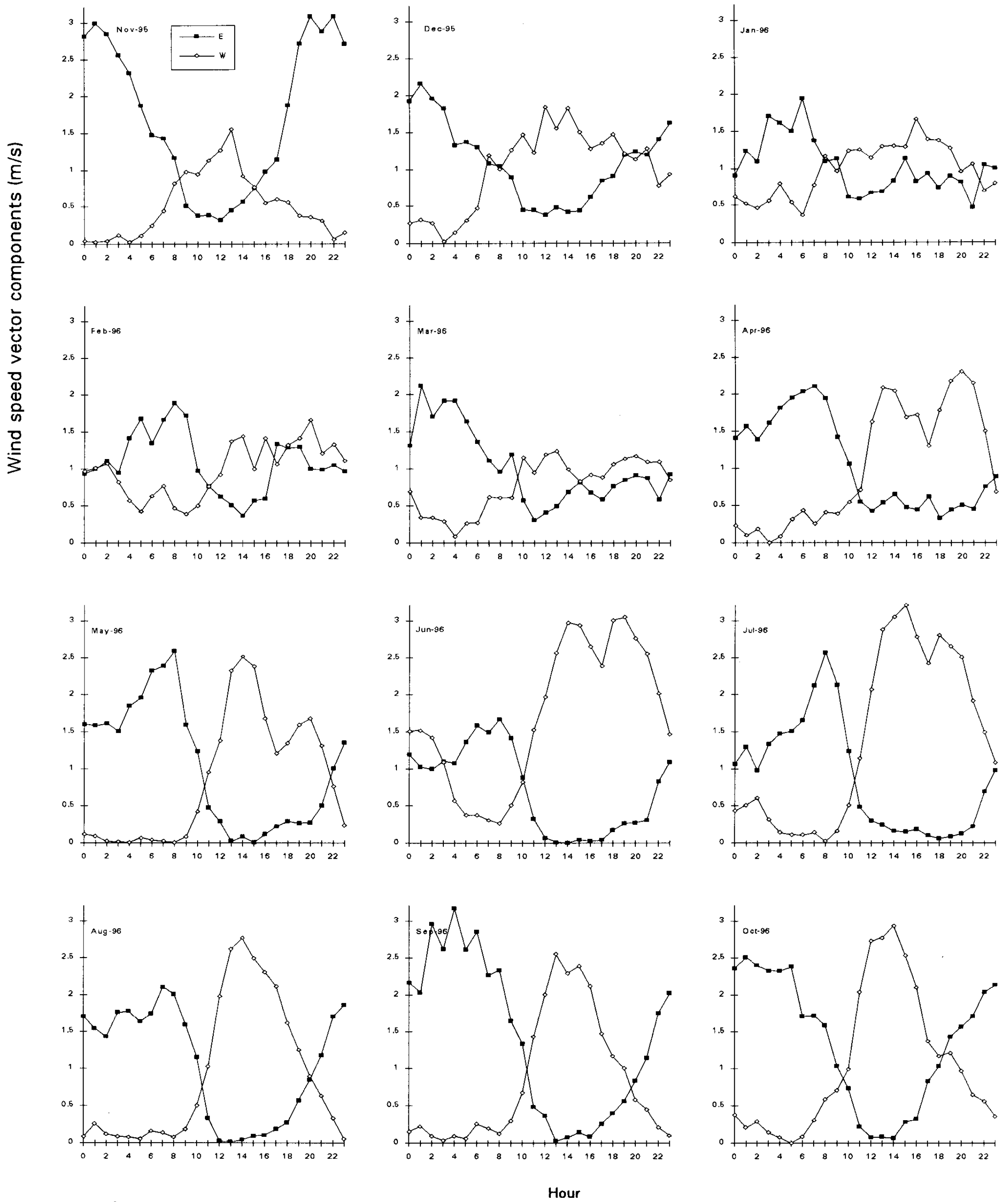

Figure 25. Mean monthly east and west wind vector components at the Kigoma buoy

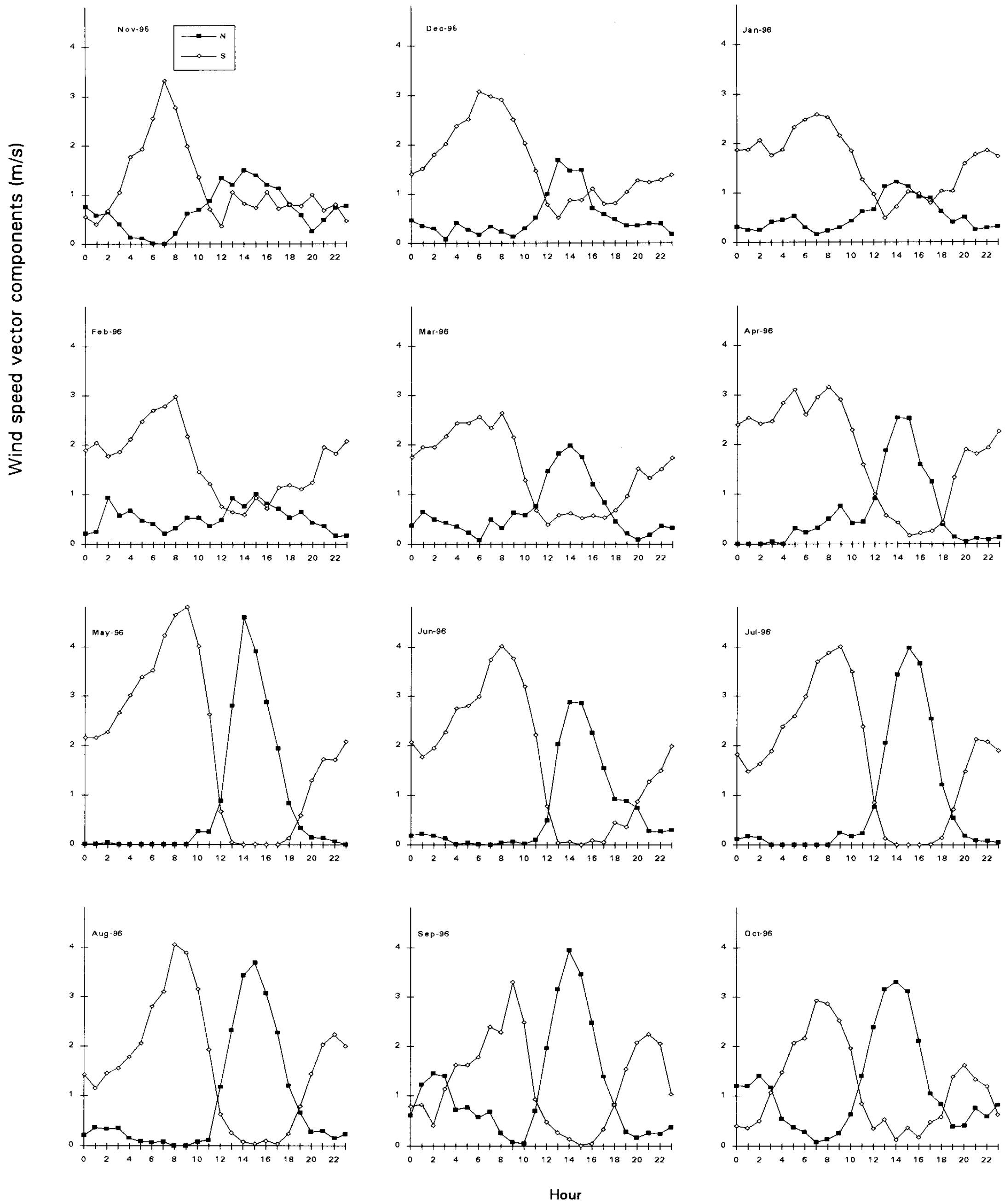

Figure 26. Mean monthly north and south wind vector components at the Kigoma buoy

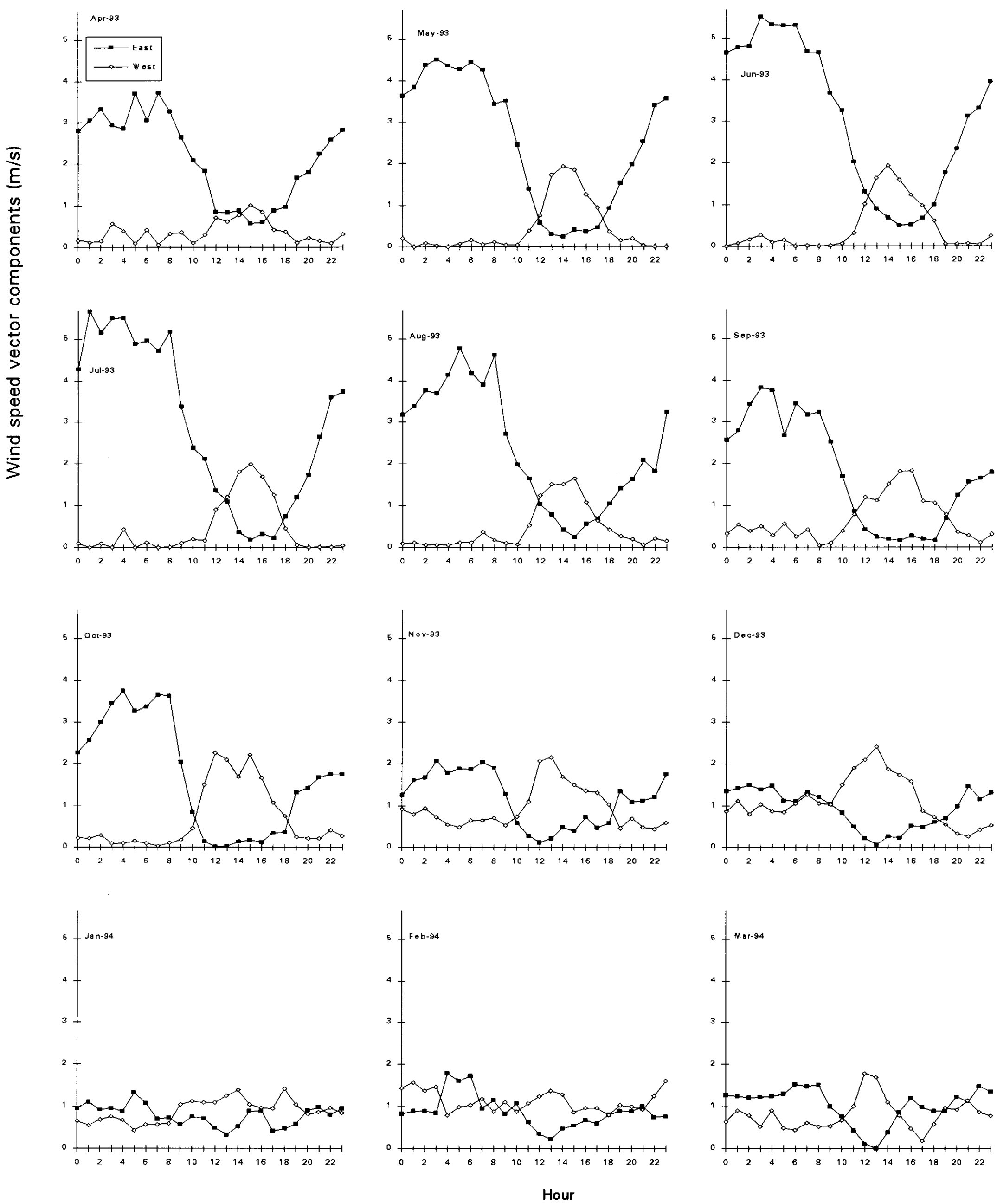

Figure 27. Mean monthly east and west wind vector components at the Mpulungu buoy.

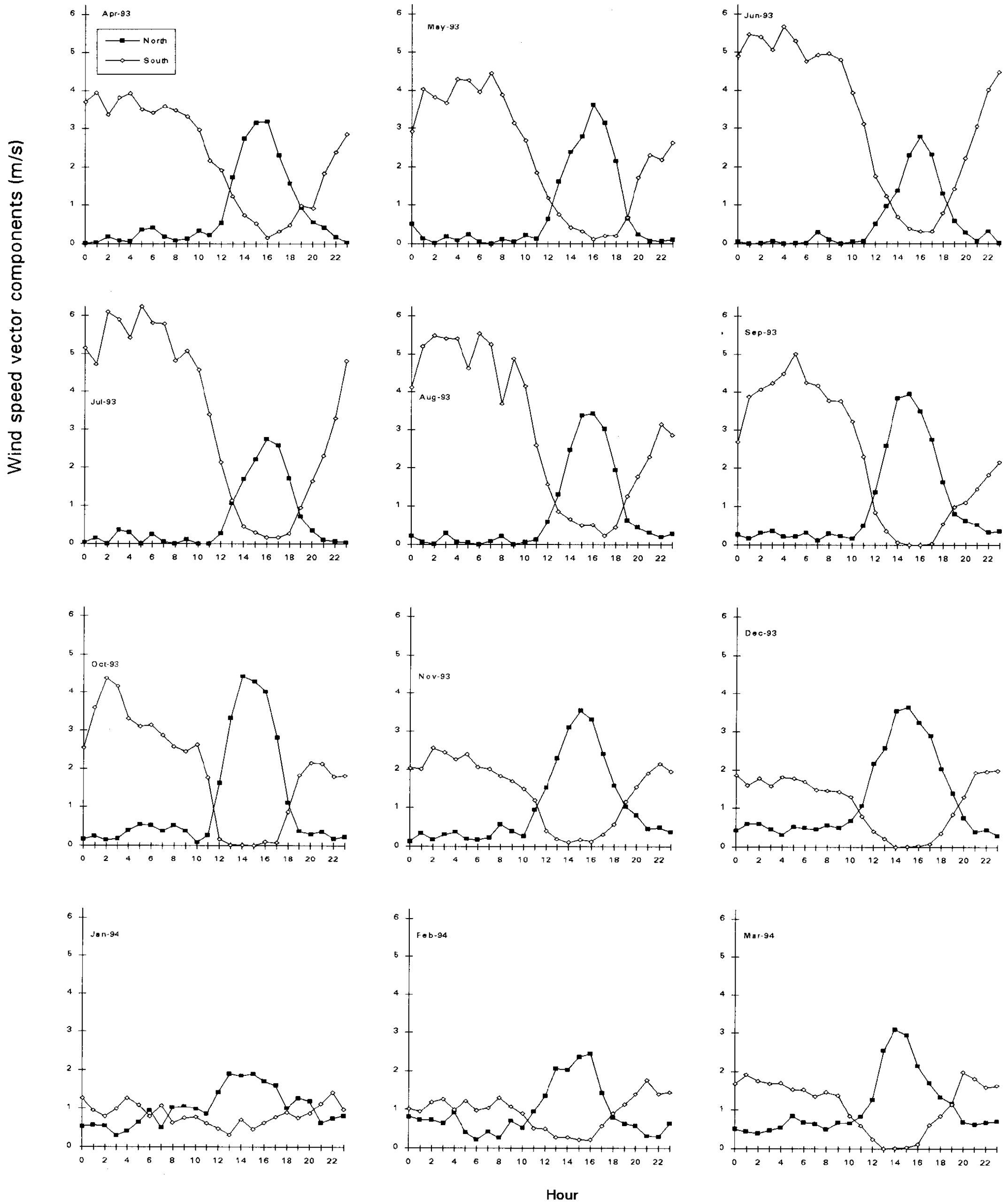

Figure 28. Mean monthly north and south wind speed components at the Mpulungu buoy.

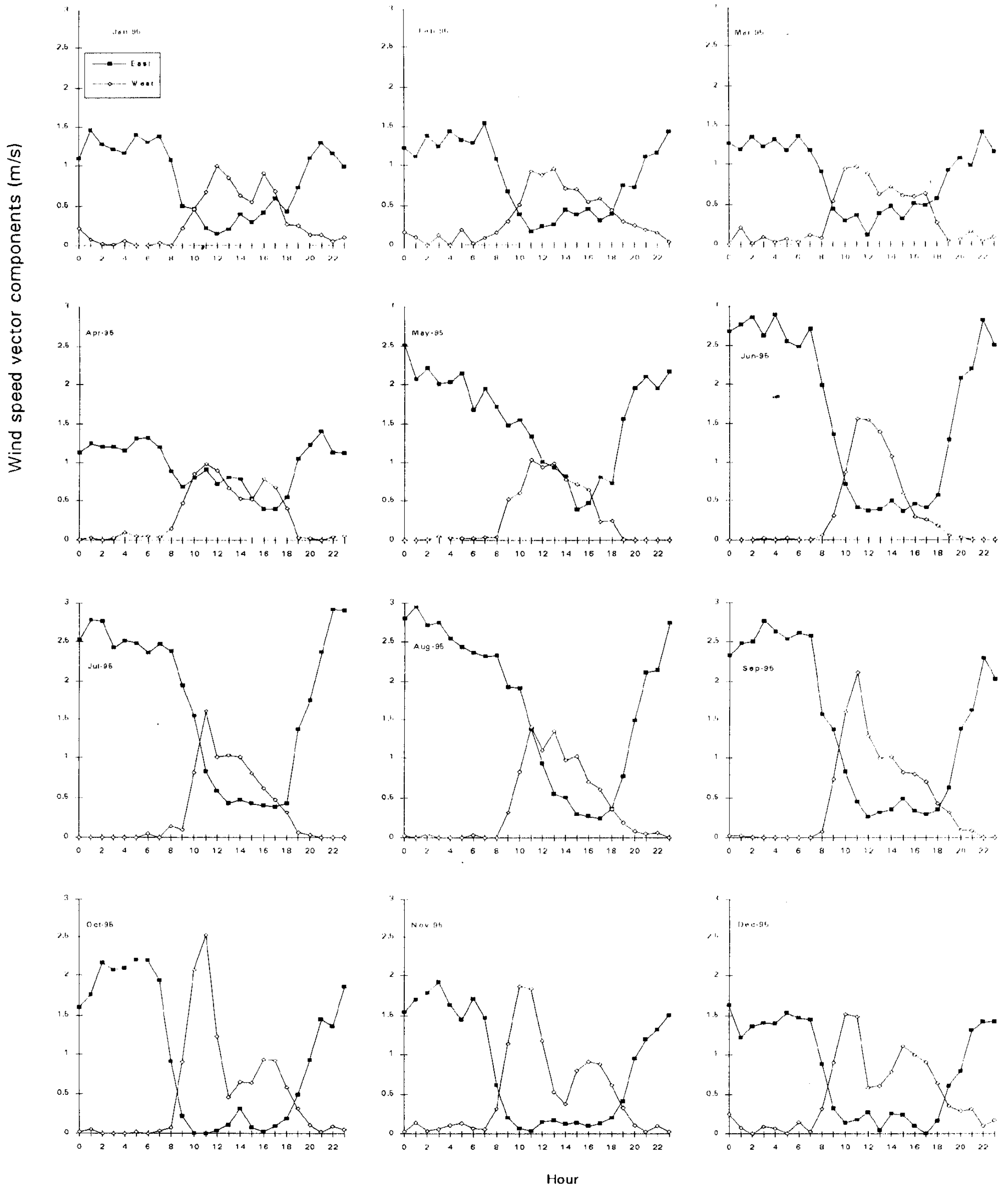

Figure 29. Mean monthly east and west wind speed vector components at the Mpulungu weather station.

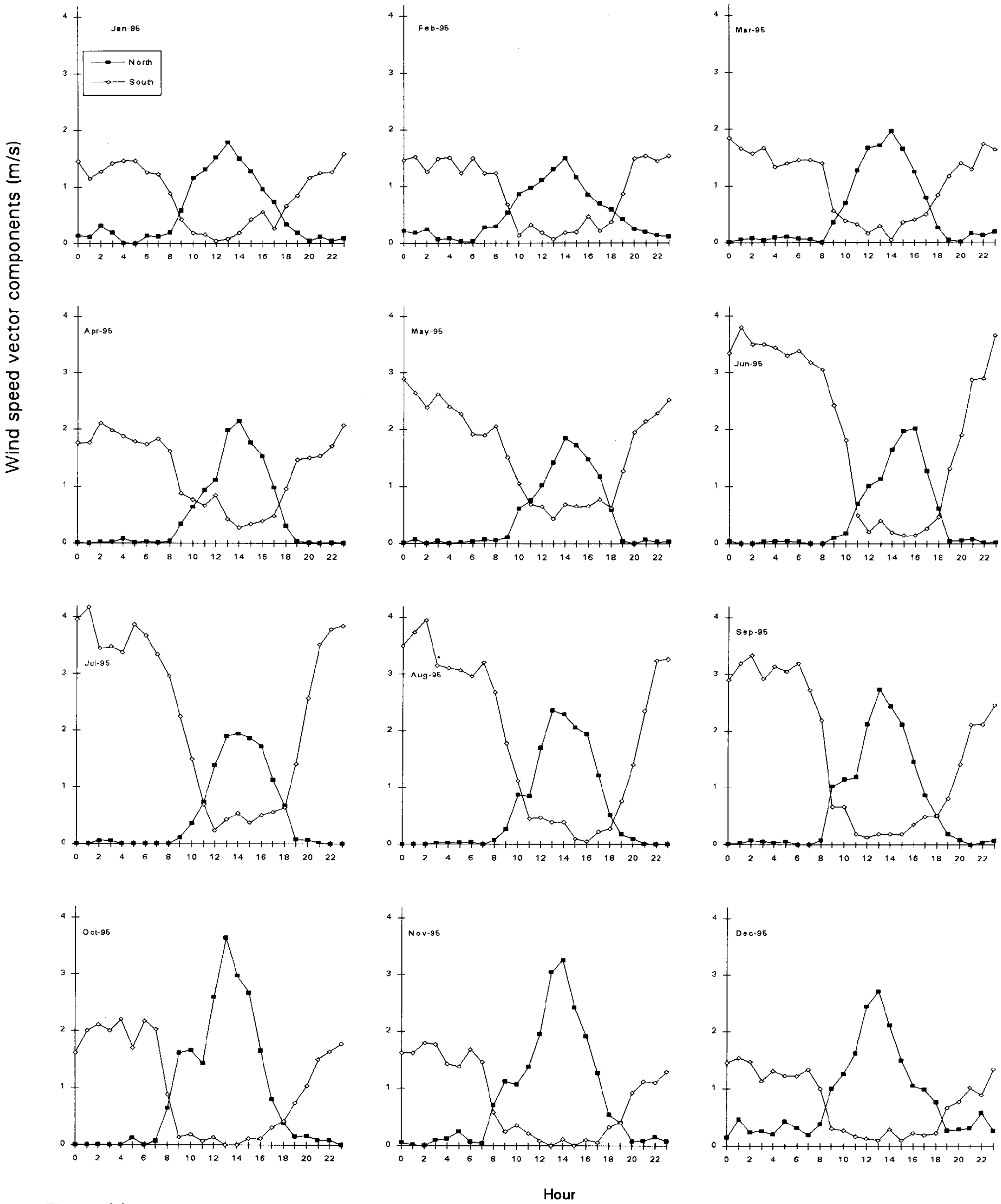

Figure 30. Mean monthly north and south wind speed vector components at the Mpulungu weather station.

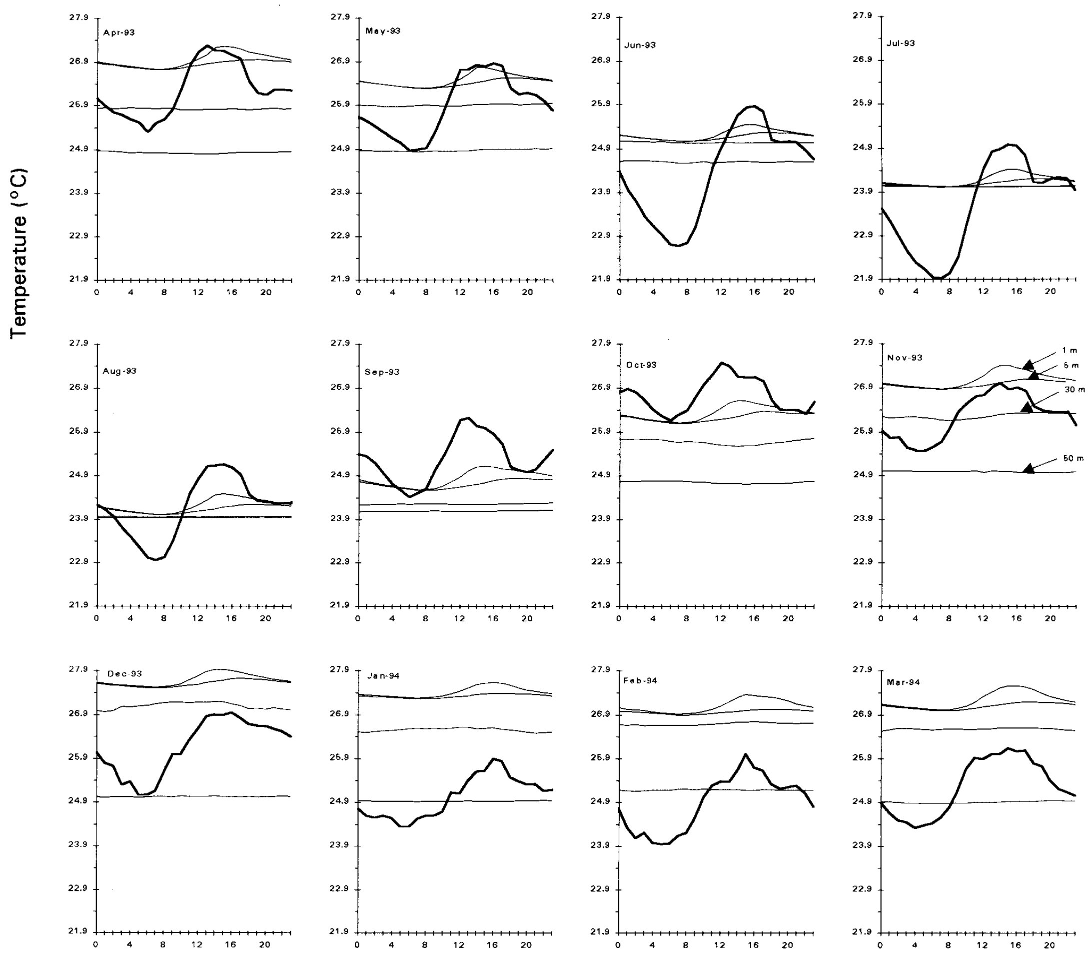

Figure 31. Water temperatures (thin lines) and air temperature (thick line) over the day, at the Mpulungu buoy.
Water temperatures is shown at 1, 5, 30 and 50 m depth. Water temperature decreases from the surface downwards.

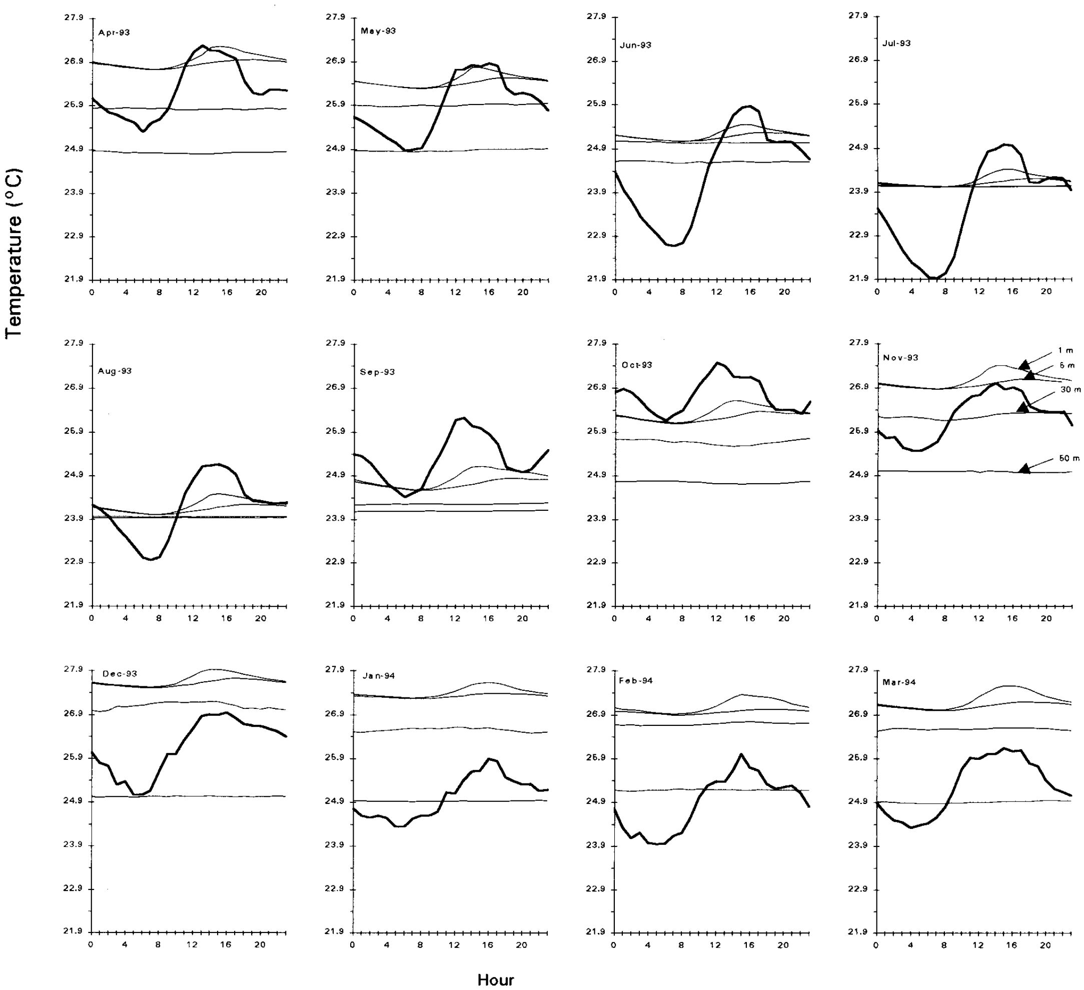

Figure 31. Water temperatures (thin lines) and air temperature (thick line) over the day, at the Mpulungu buoy.
Water temperatures is shown at 1, 5, 30 and 50 m depth. Water temperature decreases from the surface downwards.

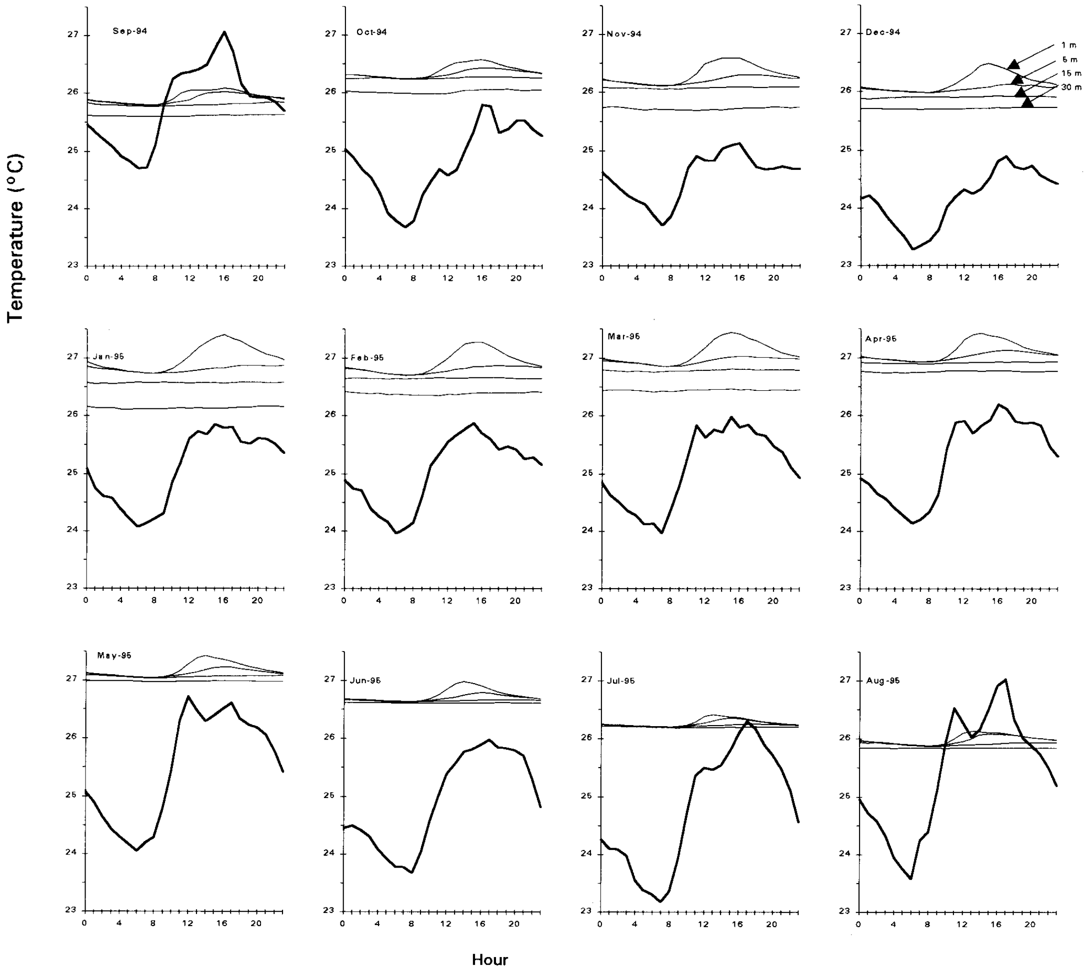

Figure 32. Water temperatures (thin lines) and air temperature (thick line) during the day, at the Kigoma buoy.
Water temperatures are shown at 1, 5, 15 and 30 m depth. Water temperature decreases from the surface downwards.

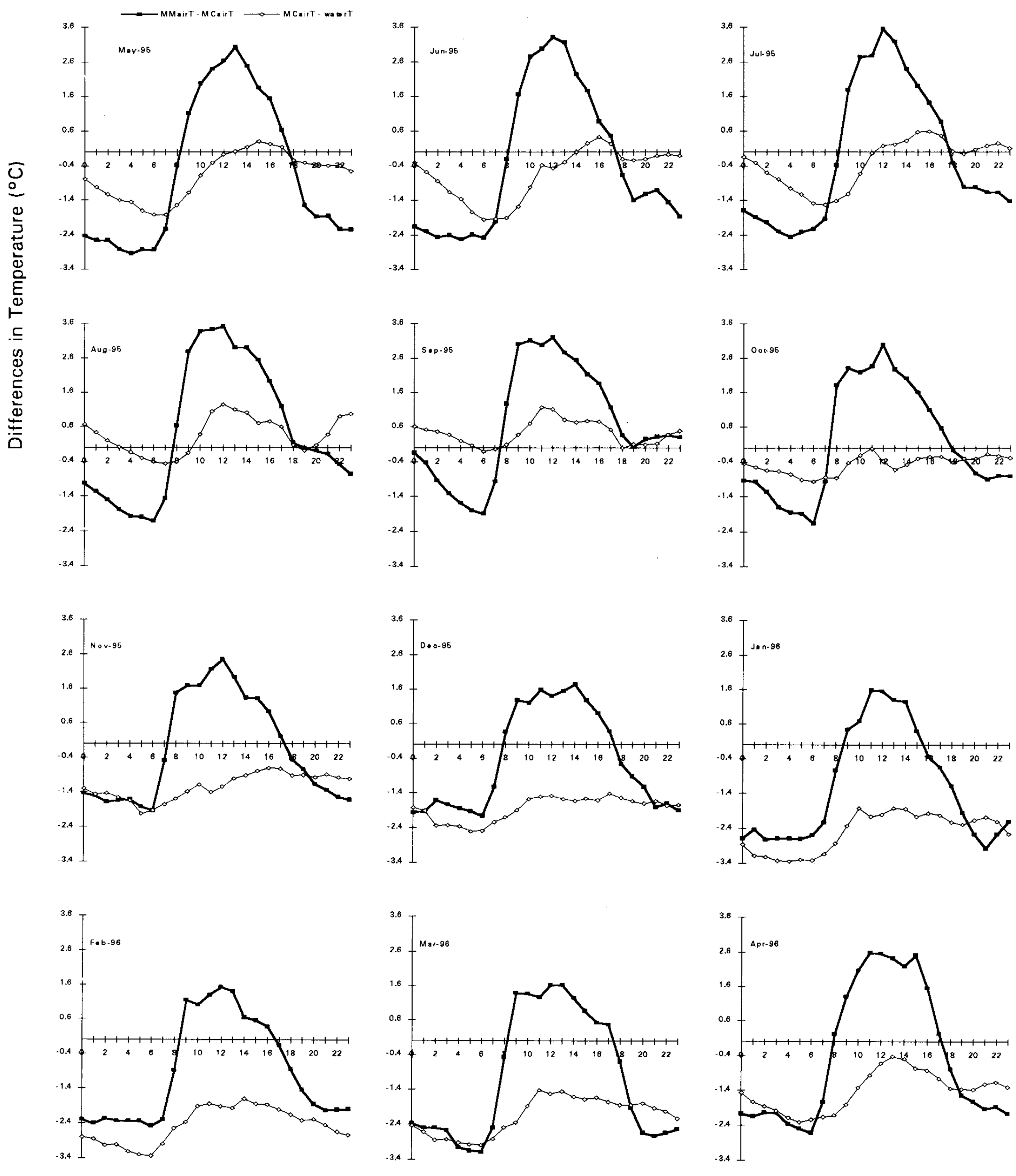

Figure 33. Differences over the day, between air temperature at the Mpulungu weather station (MMairT) and at the Mpulungu buoy (MCairT) and between air temperature and water temperature (1 m depth) at the Mpulungu buoy (MCairT - MCwater T).

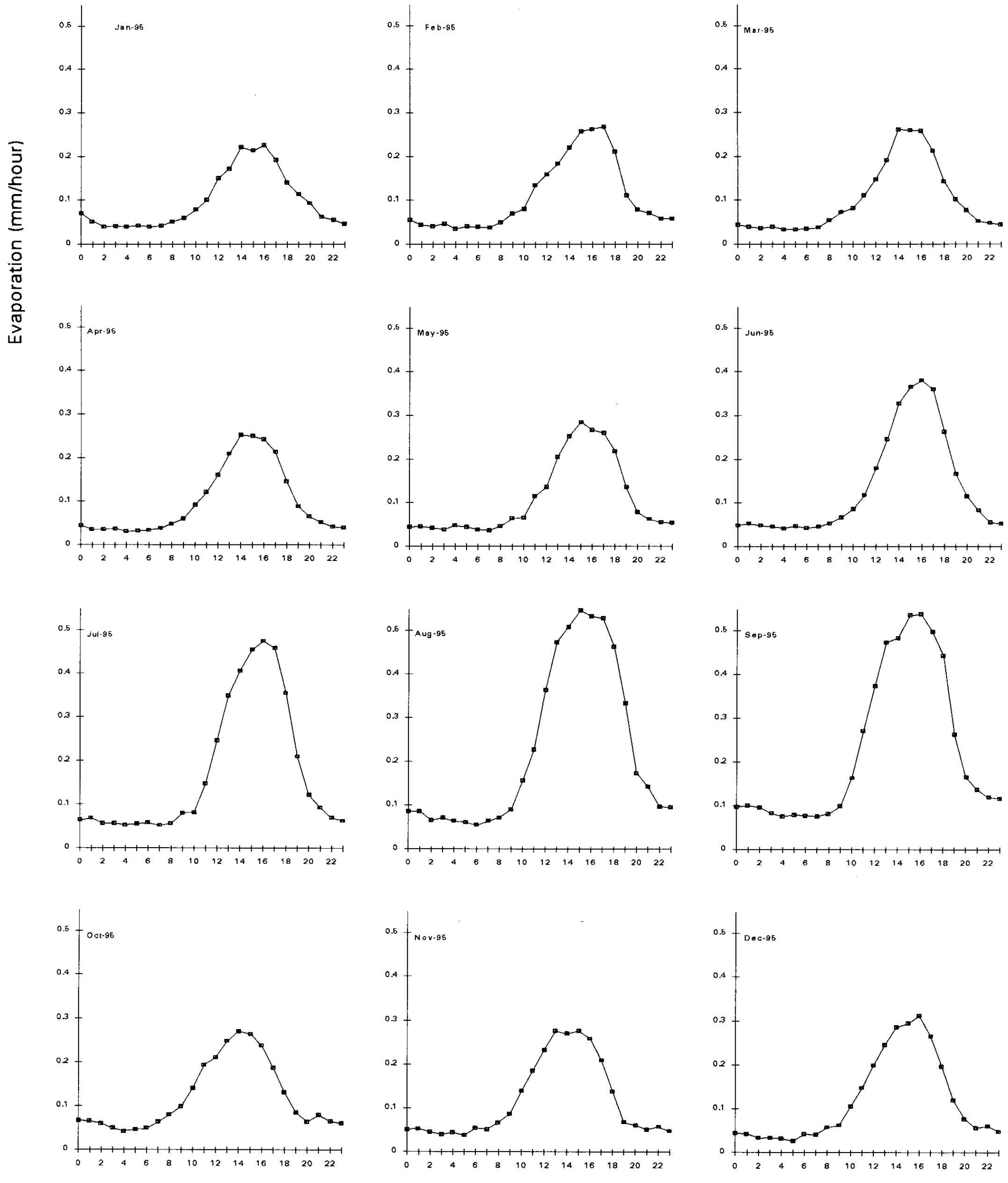

Figure 34. Evaporation over the day at the Bujumbura weather station.

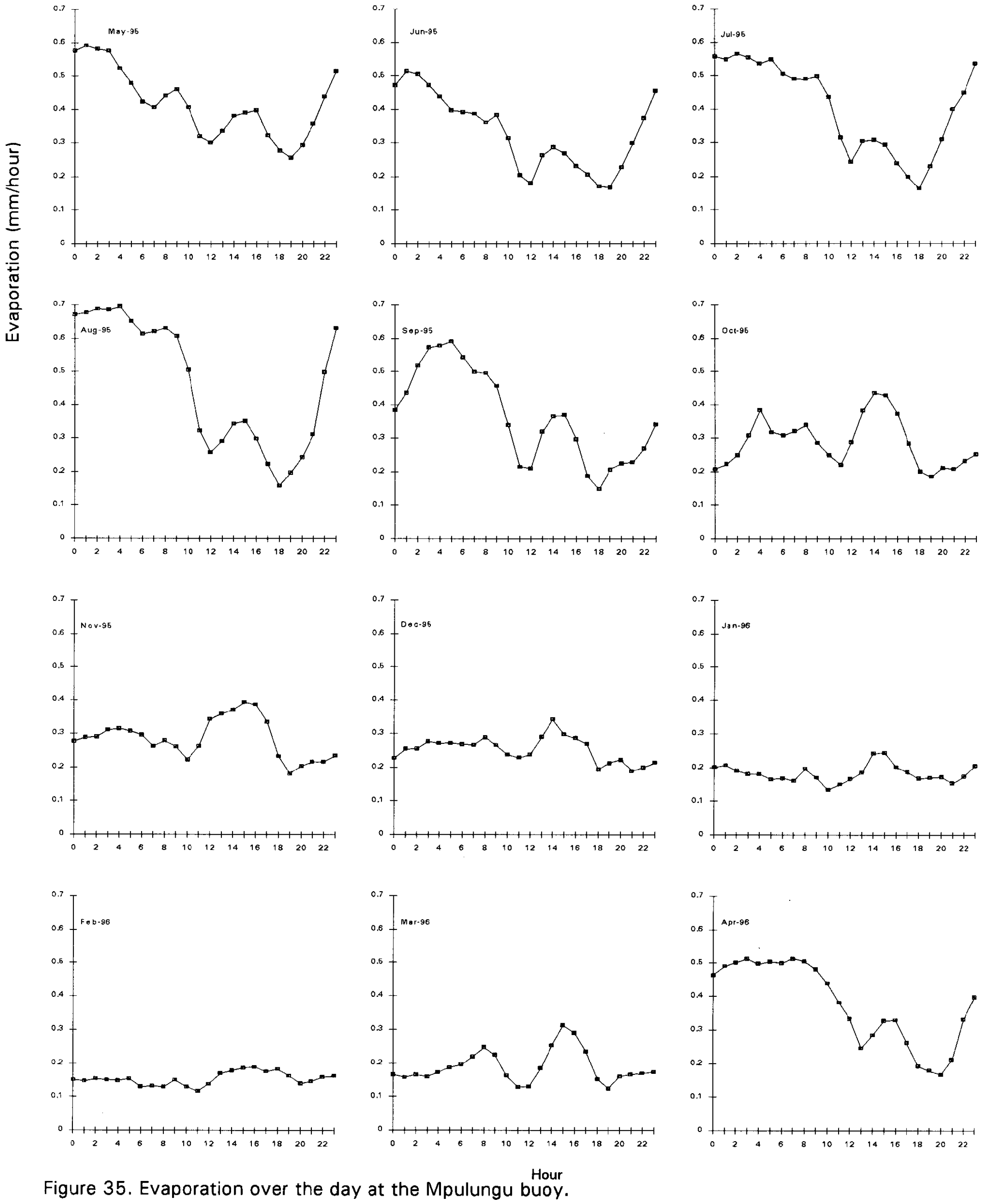

Figure 35. Evaporation over the day at the Mpulungu buoy.