

NOTES AND CORRESPONDENCE

A Newly Found Jet in North Kenya (Turkana Channel)

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ABSTRACT

On the basis of recent pilot balloon observations which have become available in northern Kenya, it is shown that there exists a strong southeasterly low-level jet in the Turkana Channel which separates the Ethiopian Highlands and the East African Highlands. The jet exists throughout the year, with speeds exceeding 30 m s^{-1} (60 kt) on a number of occasions and sometimes exceeding 50 m s^{-1} (100 kt). During February and March, the mean monthly winds based on the morning observations exceed 25 m s^{-1} (50 kt). The morning winds are stronger than afternoon winds, presumably due to stronger vertical mixing and dilution of the jet maximum in the afternoon. The hodograph turns in a counterclockwise direction from the lowest levels up to 0.75 km (2500 ft) above ground level and sometimes even aloft. Up to 0.45 km (1500 ft) above ground level, the hodograph manifests some of the characteristics of the Southern Hemisphere Ekman layer.

This jet is different from the now well-known East African low-level jet (Findlater 1966, 1977). Earlier climatological charts give no indication of the existence of this jet stream throughout the year. Orographic channeling of flow seems to be responsible for this jet.

1. Introduction

The East African low-level jet near the East African coast which was first observed by Bunker (1965) and Findlater (1966) is now a well-recognized system which has been studied through observational and theoretical models (Anderson, 1976; Krishnamurti *et al.*, 1976; Findlater, 1977; Hart *et al.*, 1978; Bannon, 1979a,b). It crosses the equator approximately from south to north and is most pronounced during the Northern Hemisphere summer (June to August). It builds in April and May and decays in September and October. During the northern winter (December to February), the low-level flow near the coast of East Africa is mainly northeasterly. Recent observations described in this paper suggest that, quite distinct from the above-mentioned low level jet, there is another jet stream over northern Kenya which persists throughout the year. The direction of its flow is southeasterly. We shall refer to it as the Turkana Channel Jet.

The existence of this jet is established from pilot balloon observations taken since 1979 at Marsabit, Kenya. (This is the region where the remains of primitive man were discovered by Dr. Leakey; due to archaeological and historical interest, there have been many expeditions in this region; aircraft pilots have generally complained of very strong winds and severe turbulence experienced during landing and take off.)

2. Observations

Marsabit is located at $02^{\circ}18'N$, $37^{\circ}54'E$. Pilot balloon observations were started there in November 1977, but they were very irregular. Records made available by the Kenya Meteorological Department show that the observations were more regular from approximately mid-1979. We have analyzed observations for the 12-month period July 1979 to June 1980. The observations at 0600 GMT [0900 EAST (East African Standard Time)] and 1200 GMT were used for the study. In general, there are fewer observations available for the morning ascent. For each of the twelve months, we have more than twenty observations in the afternoon, but fewer (~ 10) observations in the morning. The availability of observations for the entire 12-month period is shown in Table 1, which gives the monthly mean values of Marsabit winds at various levels, separately for morning and afternoon ascents. The observations were almost evenly distributed among the twelve months. The original pilot balloon registers had tabulations at height intervals of 500 ft (152 m). The station height itself is 1345 m (4413 ft) above MSL. The first reporting level for upper air winds is 1497 m (4913 ft). Hence, Table 1 shows height values at intervals of $\sim 152 \text{ m}$.

Hodographs have been examined separately for each of the twelve months for 0600 and 1200 GMT,

TABLE 1a. Monthly and annual mean vector winds (deg, kt)* at Marsabit, 0600 GMT, July 1979–June 1988. Strongest winds are underlined.

Height above ground (m)	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Year	Number of observations during year
152	161 23.6	168 24.2	160 23.0	165 25.6	155 19.8	153 20.6	153 19.6	158 25.4	161 23.2	151 16.6	168 18.8	161 22.4	169 20.0	142
305	162 <u>37.8</u>	163 35.7	157 30.4	162 44.0	145 28.2	128 21.6	148 30.8	154 36.8	153 42.9	148 22.0	167 31.2	161 37.1	153 30.0	142
457	160 <u>37.8</u>	154 <u>38.1</u>	160 30.2	156 <u>51.3</u>	135 <u>31.8</u>	134 29.2	139 35.2	150 45.6	152 56.8	144 22.6	162 <u>31.2</u>	156 <u>40.0</u>	148 <u>34.0</u>	142
610	154 24.0	142 30.8	156 <u>31.0</u>	132 27.4	126 24.4	122 31.0	128 40.8	143 <u>56.1</u>	148 <u>57.6</u>	140 <u>25.0</u>	155 21.6	150 26.8	141 32.4	142
762	153 8.9	166 1.6	151 18.8	125 21.7	113 20.2	114 <u>31.8</u>	121 <u>46.8</u>	127 30.6	133 53.6	132 24.6	149 14.8	022 3.7	120 19.9	142
914	337 9.8	045 6.5	154 6.9	121 17.1	078 14.9	094 27.6	111 37.6	079 13.8	113 32.8	107 18.4	349 3.1	015 3.9	098 21.8	141
1067	327 8.5	332 8.9	171 11.1	004 15.2	043 12.0	062 22.6	087 22.4	076 15.2	074 26.2	083 12.9	353 3.4	015 3.9	072 8.4	140
1219	340 8.1	335 13.2	151 5.7	008 4.2	023 10.2	031 17.3	043 14.9	043 16.1	038 21.4	075 20.7	007 5.2	360 1.3	027 9.8	139
1372	345 7.0	333 11.0	156 4.4	039 3.8	042 9.6	019 16.9	032 17.6	019 17.4	022 19.8	054 12.2	020 4.0	345 4.8	023 9.1	138
1524	312 5.7	318 7.8	128 4.8	044 19.2	037 9.6	032 16.0	015 18.2	046 13.7	012 14.8	065 11.9	075 10.8	333 7.0	024 10.0	135

* Top number on each pair is degrees, the bottom number is knots.

TABLE 1b. As in Table 1a, but for 1200 GMT.

Height above ground (m)	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Year	Number of observations during year
152	151 16.0	153 18.4	149 18.1	149 22.8	143 15.0	146 14.3	144 18.2	151 19.6	154 20.0	155 17.4	149 11.7	150 14.8	150 17.1	311
305	146 22.2	156 24.0	148 25.6	145 14.2	140 18.2	139 19.1	138 25.8	148 25.6	155 <u>31.6</u>	144 26.0	149 13.1	149 <u>16.3</u>	145 21.0	311
457	151 <u>32.4</u>	144 23.2	148 30.6	144 15.6	132 <u>21.1</u>	134 21.8	139 24.4	145 30.2	145 23.4	138 23.2	154 <u>13.3</u>	145 15.8	141 25.0	311
610	149 28.6	150 <u>26.6</u>	148 <u>36.4</u>	146 17.9	125 19.5	122 21.5	129 24.3	139 <u>35.4</u>	144 24.4	141 <u>33.8</u>	152 12.3	149 12.7	142 <u>26.0</u>	310
762	145 21.6	150 16.7	145 29.4	141 <u>30.4</u>	134 11.7	113 <u>23.2</u>	113 <u>34.2</u>	096 26.6	134 26.6	139 29.0	139 7.9	156 10.3	130 21.9	310
914	151 15.0	144 5.7	150 12.5	130 14.9	071 18.2	111 21.0	102 16.9	062 17.6	117 21.5	131 23.0	150 7.6	090 1.6	108 12.2	307
1067	149 7.9	014 2.5	170 6.7	108 8.4	049 4.5	099 15.0	046 12.3	078 14.9	103 18.4	100 9.1	121 1.2	265 2.4	095 6.8	306
1219	204 1.9	332 3.0	207 2.2	101 6.3	078 11.3	060 11.6	034 13.3	091 15.8	073 13.4	107 13.4	115 2.9	245 2.9	079 6.1	306
1372	289 4.9	335 3.3	063 3.1	080 7.3	058 11.5	048 12.0	029 12.8	049 19.3	067 13.1	108 12.4	072 3.2	257 2.7	052 6.6	305
1524	329 8.2	318 2.7	045 3.4	078 4.9	047 10.3	042 11.5	034 14.0	048 13.7	057 13.8	111 13.9	051 2.8	234 1.7	046 7.0	299

* See Table 1a footnote.

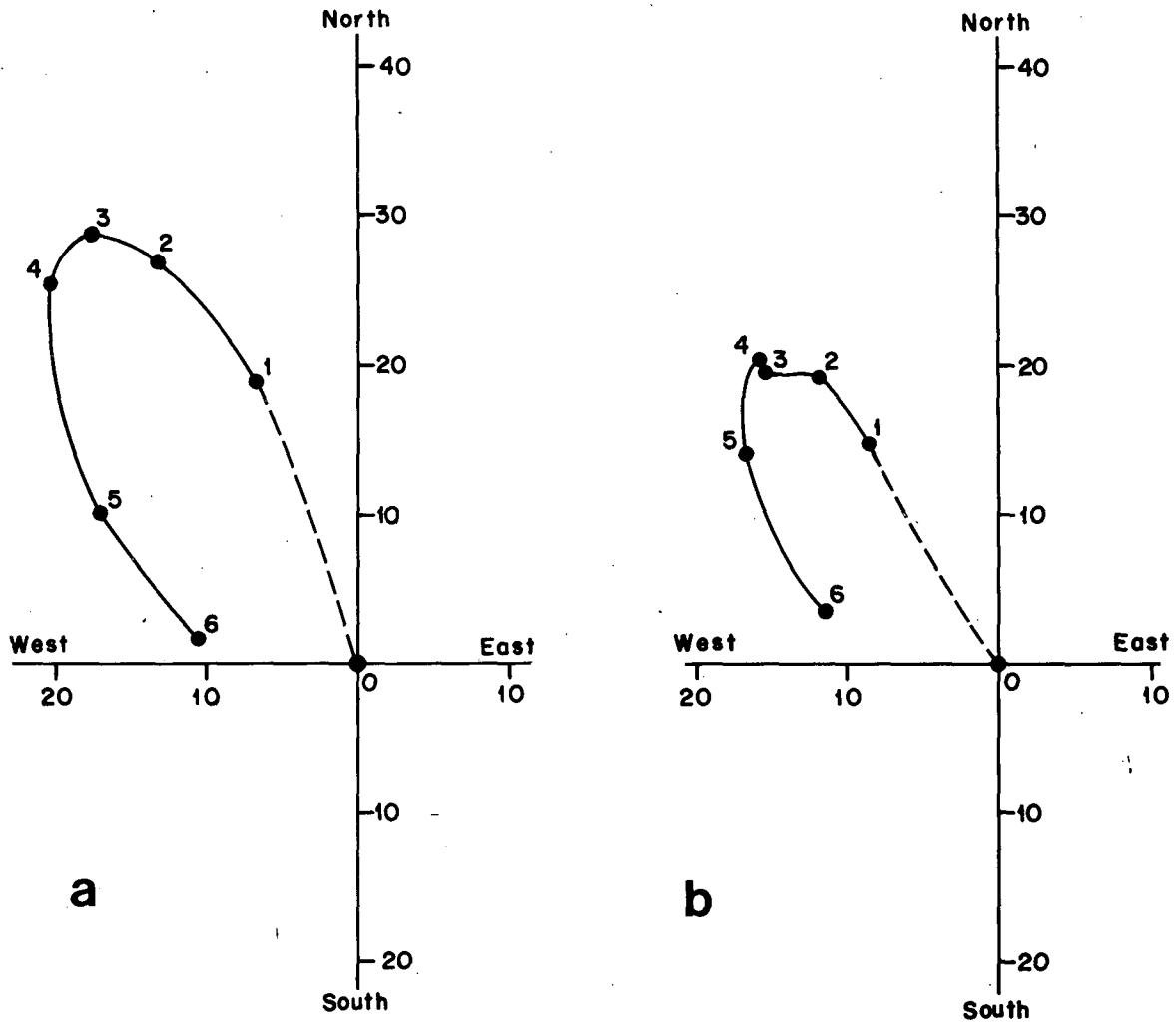


FIG. 1. Annual hodograph of winds (knots) at Marsabit: (a) 0600 GMT, (b) 1200 GMT.

and they show similar features. For illustration, we present only the annual mean wind hodographs (Fig. 1) for 0600 and 1200 GMT. Ground level is referred

to as level "0" and subsequent levels at intervals of 152 m as levels 1, 2, 3, 4, etc.

Tables 1a and b, hodographs and higher-level data,

TABLE 2. Frequency distribution of wind speed (kt) for the entire year, 0600 and 1200 GMT. Heights above ground are given at intervals of 152.4 m.

Height above ground (m)	<10	>10 ≤20	>20 ≤30	>30 ≤40	>40 ≤50	>50 ≤60	>60 ≤70	>70 ≤80	>80 ≤90	>90 ≤100	>100	Total number of observations
<i>0600 GMT</i>												
152	3	48	74	13	4	—	—	—	—	—	—	142
305	2	16	30	46	36	8	3	—	—	1	—	142
457	12	12	27	31	26	16	10	1	5	—	2	142
610	32	17	19	19	16	13	6	4	8	1	7	142
762	50	27	13	12	12	9	6	3	3	—	7	142
914	56	31	15	14	6	7	1	6	2	2	1	141
<i>1200 GMT</i>												
152	52	164	68	23	4	—	—	—	—	—	—	311
305	53	104	79	33	23	11	2	3	2	—	1	311
457	45	96	90	35	20	7	8	4	2	—	4	311
610	69	86	54	43	16	19	6	6	4	1	6	310
762	95	85	50	21	17	13	12	4	3	2	8	310
914	135	72	37	32	11	4	4	4	3	2	3	307

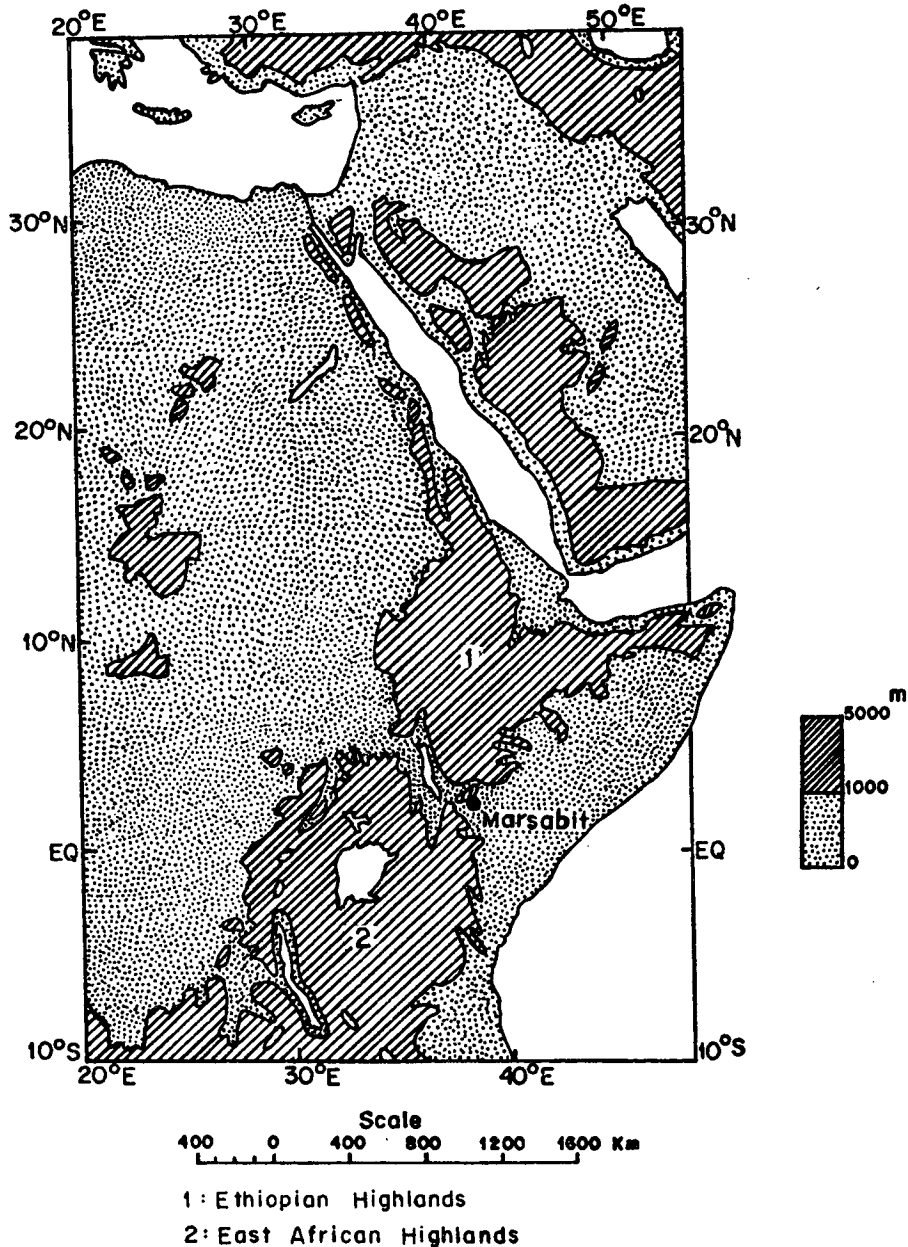


FIG. 2. Large-scale topography of northeast Africa with location of MARSABIT pilot balloon station. 1: Ethiopian Highlands. 2: East African Highlands.

not given here, reveal the following characteristics of the monthly and annual mean winds:

1) Throughout the year, the winds in the lowest 0.75 km (2500 ft) are from the southeast. At levels above 1.5 km (5000 ft), the winds are generally from northwest to northeast during northern summer (June–September) and from northeast during the rest of the year.

2) The southeasterlies increase in intensity from the ground to 0.5–0.8 km and then decrease aloft. The intensity of mean monthly winds exceeds 50 knots during February and March in the morning.

3) The hodograph turns in a counterclockwise direction from the lowest levels up to 0.75 km (2500 ft) and sometimes even aloft. Up to 450 m (1500 ft), the hodograph manifests some of the usual characteristics of the Southern Hemisphere Ekman layer.

4) Morning maximum winds are stronger than afternoon maximum winds. This may be due to stronger vertical mixing and the consequent dilution of the jet maximum in the afternoon.

Table 2, based on combined data for all months, shows that on a significant number of occasions, the wind speeds exceed 30 m s^{-1} (60 kt) and sometimes

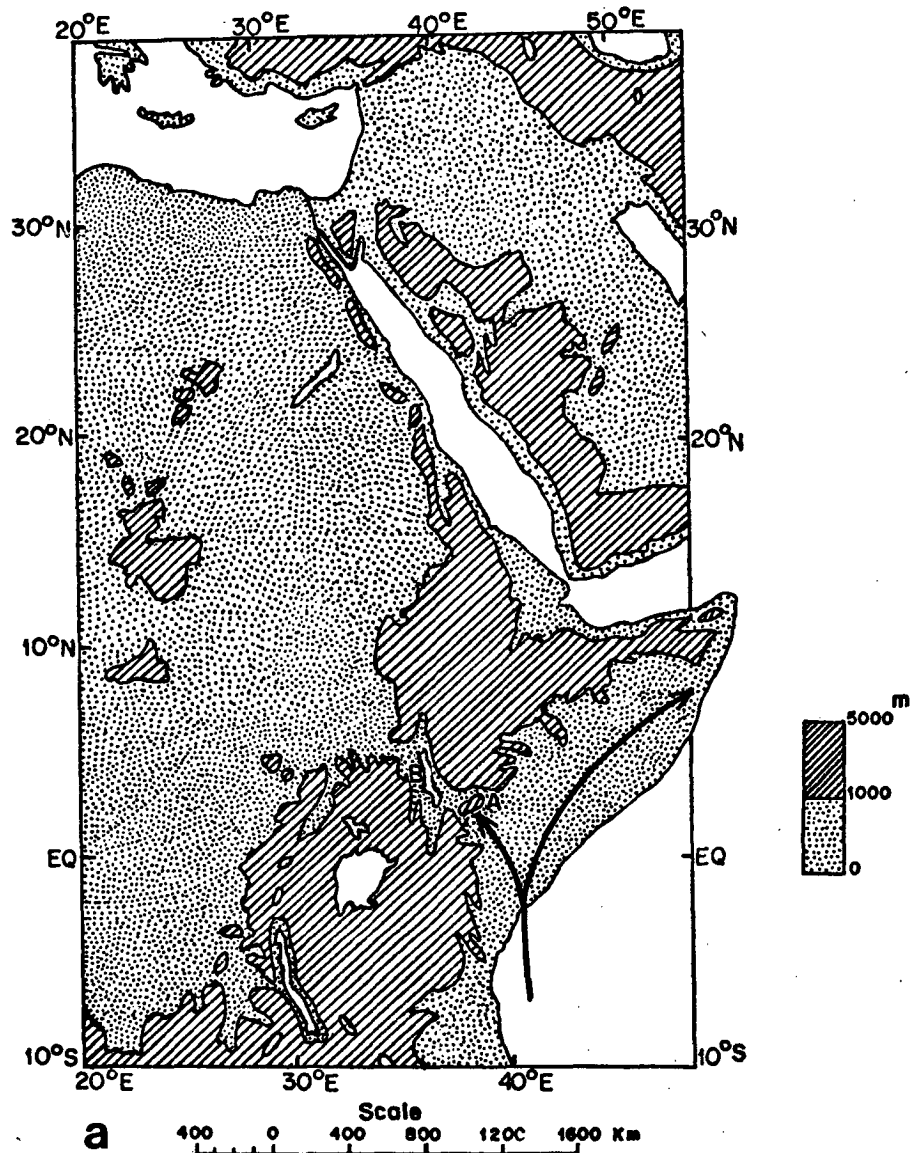


FIG. 3. Simplified model of flow near Marsabit, entrance into Lake Turkana Channel: (a) during northern summer, (b) during northern winter.

exceed 50 m s^{-1} (100 kt). At 0.6 km (2000 ft) above the ground, on more than 15% of the occasions in the morning, the speeds exceeded 30 m s^{-1} (60 kt). About 5% of the time, the wind speed exceeded 50 m s^{-1} (100 kt).

Examination of individual flights showed that on some rare occasions the speeds exceeded 75 m s^{-1} (150 kt). However, with extremely strong low-level winds, the angles of elevation become low and slight errors in the reading of angles with the theodolite could cause considerable errors in the computation of horizontal wind speeds. One should therefore treat with caution reports of extremely strong winds in Marsabit reports. In spite of this, the body of observations leaves us in no doubt that wind speeds of 50 m s^{-1} (100 kt) and more do occur in this region.

3. Conclusion

Fig. 2 shows the large-scale orographic features of northeast Africa. Lake Turkana lies in the relatively low-level region separating the Ethiopian Highlands and the East African Highlands. Marsabit is near the eastern side of this low level region. In a simplified form, we can look at the flow in this region as shown in Fig. 3. Fig. 3a shows the situation during the northern summer, characterized by the well-known East African low-level jet. Some air near the equator branches off from the coast and enters the Turkana Channel. Near Marsabit (A) there is a narrowing of the channel and near B there is a broadening. A small hill near Marsabit may have its own local effect, but we believe that the strong winds observed at Marsabit

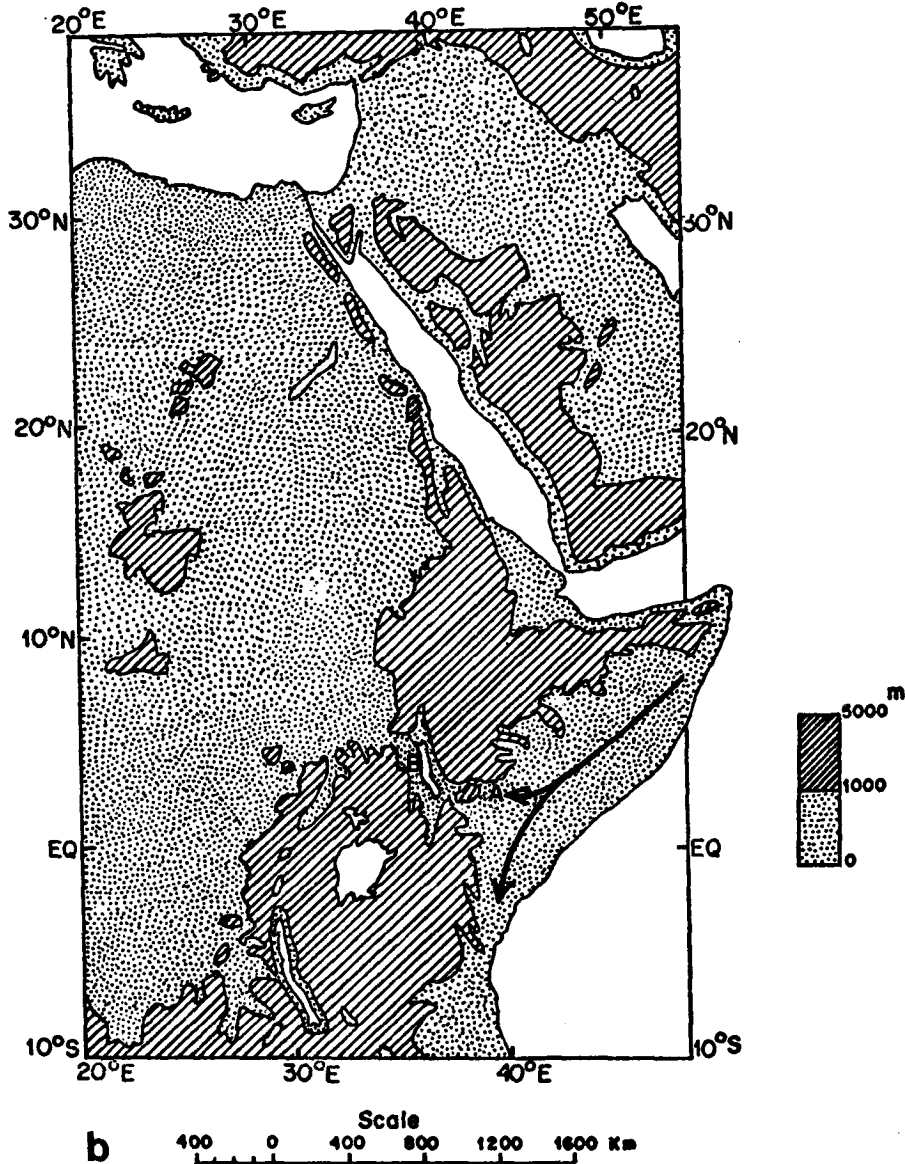


FIG. 3. (Continued)

are not the result of this hill, but of the large-scale orography of the Ethiopian and East African highlands. The winds strengthen due to the narrowing of the channel entrance at A.

Similarly, during the northern winter (Fig. 3b) the northeasterlies enter into the gap at A and intensify. Therefore, the orography is such that throughout the year the winds strengthen at A.

Because observations from Marsabit have only recently become available, earlier climatological charts did not indicate a strong low-level southeasterly jet in this area throughout the year.

While the data presented are based on pilot balloon observations from one station (Marsabit) for one year only, these observations have shown a great deal of

consistency. They are also consistent with the well-known principles of orographic channeling. Further analysis of the continuing observations from Marsabit will undoubtedly lead to a greater understanding of the structure of the Turkana Channel Jet and its orographic forcing.

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