

Section 5

KENYA AND TANZANIA

5.1 TOPOGRAPHY

The most significant topographical features are the mountainous highlands of western Kenya and northeastern Tanzania (Figs. 1.1, 1.2 and 5.1). The interior mountains ascend to 6000 m (Griffiths, 1972). The mountains extend almost to the ocean at the Kenya-Tanzania border. The eastern portions of Kenya and southeastern Tanzania are mostly lowlands and plains with elevations between sea level and 500 m. The western interior of Tanzania is mostly plateau (1000 m) ascending toward the west, northwest and toward the mountainous northeast (over 2000 m) (Editions Jenne Afrique, 1973). Lake Victoria extends over a large portion of northern Tanzania and also into western Kenya.

Kenya and Tanzania are positioned geographically such that weather is dominated year round by monsoonal flow. Northeast monsoons dominate from December through March (Northern Hemisphere winter monsoon) and the southeast/southwest monsoon dominates from June through September (Northern Hemisphere summer monsoon). Both monsoon flows are shallow, averaging only 2 km in depth, and are capped by inversion and dry subsiding air. Stratus/stratocumulus overcasts occur frequently over Nairobi and the surrounding region in association with this inversion. Additionally, flow in both of the monsoons is divergent over the eastern portions of Kenya and northern Tanzania. The associated rainfall over these regions is light or insignificant except during the transition periods. A semipermanent heat low over southwestern Kenya is a cause for intense thunderstorm activity over the Rift Valley region and the surrounding west Kenyan highlands during the winter and summer monsoons. Other significant synoptic features include the low-level jet which develops over the Kenya/Somali coast during the austral (southern) winter months, and the strong low-level southeasterly jet present year round between the Kenyan and Ethiopian highlands.



Fig. 5.1. Station Locations of Kenya and Tanzania (After Griffiths, 1972)

5.2 SURFACE WINDS

5.2.1 Kenya

The mean surface wind is less than 10 kt over most of Kenya and calms occur frequently at night. An exception to this rule is in Equator, Kenya (Fig. 5.1) where the mean wind is 16-17 kt during the austral summer. The strongest winds occur in association with thunderstorm activity which occurs mostly over the western plateau throughout the year. Convection and thunderstorm activity occur over the eastern plains in March and April. Strong winds also occur frequently over the coastal region. Diurnal variation of the winds is greatest over the coastal region and in the vicinity of Lake Victoria. On the coast at Mombasa (Fig. 5.1) the annual mean wind varies from 5 kt at 0600 to 13 kt at 1200 (LST). There is little seasonal change in the diurnal variation. Over most of the western plateau there is no diurnal variation in surface wind velocities.

5.2.2 Tanzania

Surface winds over Tanzania vary little from one location to another and are generally weak (mean winds less than 10 kt over most of the country) during the entire year. As in Kenya, the strongest winds occur in association with convection and thunderstorm activity, which is most prevalent in the vicinity of the western lakes. The weakest winds occur over the northeast interior. The monthly mean maximum winds at Morogoro, Tanzania (Fig. 5.1) do not exceed 6 kt. Over the coastal region south of 5°S, southeasterlies during the month of June are often 10-20 kt and occasionally strengthen to 25 to 35 kt (United States Naval Weather Service Command, 1974). The extreme south coast is likely to experience strong (greater than 20 kt) southeasterly winds in January and February in association with tropical cyclones to the south. From June to September occasionally strong (greater than 20 kt) winds may occur in association with frontal passages to the south and east. The strongest winds over most of Tanzania occur from July through September, although seasonal variation is small. Diurnal variation of the wind is strongest over the coastal regions and in the vicinity of the lakes. The annual mean wind on the coast at Dar es Salaam (Fig. 5.1) varies from 2.5 kt at 0600 to 5 kt at 1200 (LST). Over the central interior there is virtually no diurnal wind variation (Griffiths, 1972).

5.3 TEMPERATURE

The annual temperature variation over Kenya and Tanzania is six degrees Celsius or less. The annual mean maximum temperature in Mombasa and Dar es Salaam is 30°C (86°F), and monthly mean maximum temperatures fluctuate within three degrees (Mombasa) and within one degree (Dar es Salaam) of this value. Spatial variation of temperature over the region is small and is due almost entirely to changes in elevation. The western highlands are five to ten degrees cooler than the coastal region. The hottest portion of the region is the interior lowlands where temperatures often climb above 32°C (90°F). The coldest period of the year is in July-August. The warmest period is in March over most of Kenya and northern Tanzania. In south and central Tanzania, November and December are the warmest months. The diurnal temperature variation is 10 to 13°C over most of the region. The exceptions to this are the coastal region and in the vicinity of the lakes where the diurnal temperature variation is seven to nine degrees Celsius. Diurnal temperature ranges do not vary significantly from summer to winter (Griffiths, 1972).

5.4 SIGNIFICANT WEATHER SYSTEMS

5.4.1 Austral Summer

a. Kenya

Northeasterly flow is present over Kenya in austral summer months (Fig. 5.2) due to the influence of the Arabian anticyclone. The low-level large scale flow diverges over the east Kenyan plains. Part of the flow continues south, drawn by the heat low over Mozambique and the other portion branches westward toward the heat low over the Rift Valley. The large scale flow is strongest in January. The flow is warm moist and unstable but also shallow and meridional. The northeasterly monsoon is associated with frequent rains over the western highlands. Surges of tropical westerly flow over western Kenya are associated with occasionally intense rainfall. The east Kenyan plains are hot and dry in winter due to the effect of low-level diverging winds (Trewartha, 1981).

b. Tanzania

Shallow (low-level) northeast monsoonal flow dominates weather over Tanzania in summer (Fig 5.2). The shallow monsoonal flow diverges over the northeastern portion of the country and is associated with hot rainless weather over the region. The flow over the south travels a greater distance over water than the flow over northern Tanzania and is more moist. The low-level flow converges over the south and southwest portions of the country as it flows toward the southwest African low. Rain shower activity over south and southwestern Tanzania is greatest in the summer period. This is also the rainy season over north central Tanzania east of Lake Victoria (Griffiths, 1972). Much convection occurs over the western interior and mountains in association with convergence of highly unstable westerly flow with the tropical northeasterlies.

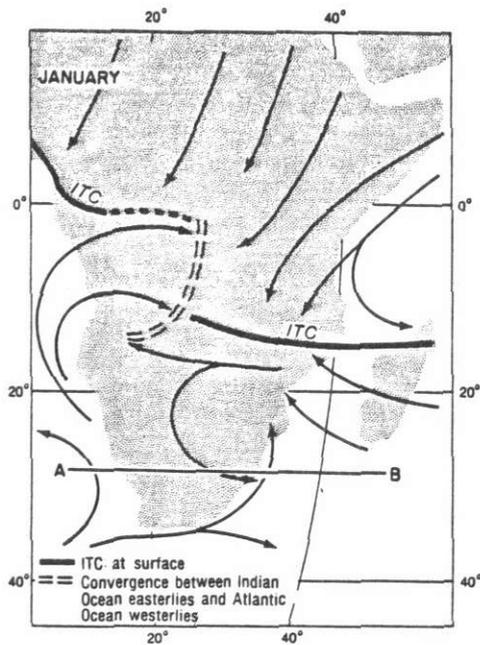


Fig. 5.2. Mean Northeasterly Monsoon Flow at lower levels over eastern and southern Africa: January (Trewartha, 1981)

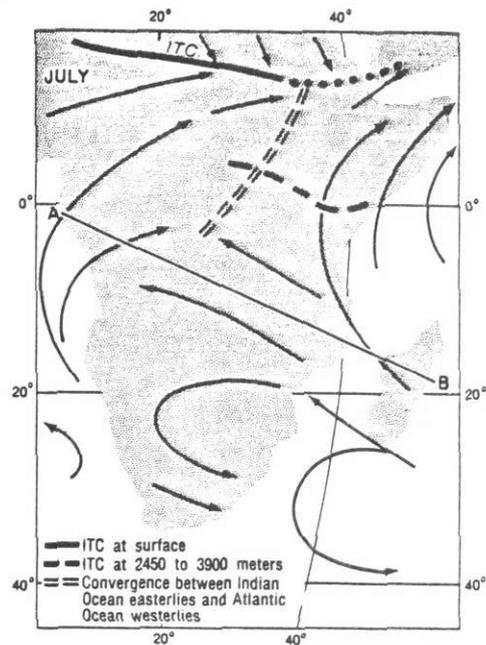


Fig. 5.3. Mean Southwesterly or Southeasterly Monsoon Flow at lower levels over eastern and southern Africa: July (Trewartha, 1981)

5.4.2 Austral Winter

a. Kenya

Southeasterly/southwesterly flow dominates weather over Kenya in the winter months (Fig. 5.3). This flow is shallow but increases in depth to 2400 m to 3600 m (above sea level) near the equator. The flow is strongest in May and June. In June the winds over the Kenya coastal waters generally exceed 16 kt and sometimes strengthen to 25-35 kt (Naval Environmental Prediction Research Facility, 1980b). The anticyclone over the southwest Indian Ocean has made its farthest penetration northward. Additionally, the semipermanent low center over southwest Asia is at its northernmost position. The southerly flow over eastern Kenya is divergent. The major flow continues northward towards the low over southwest Asia while a minor flow branches westward into the heat low over the Rift Valley. Divergent flow over eastern Kenya is associated with hot, dry weather during the winter months. However, the west Kenyan highlands experience frequent heavy rainfalls during the winter months. The southerly monsoon flow is more unstable and less meridional than the northeasterly (summer) monsoon. The associated rainfalls over the western highlands are frequent and occasionally heavy.

Occasionally, in the winter months, belts of rain shower activity develop over the coastal ocean waters. The belts are oriented from north-northeast to south-southwest and advance toward the coast after formation. A possible cause for such a development is surging in the southeast monsoonal flow. The likelihood of this kind of rain shower activity increases in September (Trewartha, 1981). Fog (associated with upwelling) is likely when strong southeasterlies develop over the coastal waters.

b. Tanzania

The winter southeast monsoon flow divides over Tanzania, one major flow continuing northward and the other flowing northwestward (Fig. 5.3). The southeasterly flow is strongest in June when winds are often 10-20 kt (sometimes up to 35 kt) over the Tanzania coastal water (Naval Weather Service, 1974). The flow is also shallow (less than 2 km deep) (Trewartha, 1981). Weather over most of Tanzania is hot and rainless in winter in association with the low-level divergence. The southwest African low, present during the summer period, is replaced by a low-level anticyclone in winter. Aloft (500 mb), strong convergence and subsidence is present over much of Tanzania (Anyamba and Kiangi, 1983). Rain shower activity is infrequent over most of the country. Even in the vicinity of the western lakes thunderstorm activity is reduced significantly. Over the coastal region fog is likely when the southerly flow is strong. The fog occurs in association with upwelling of the coastal waters.

5.4.3 Transition Periods (April-May and October-November)

a. Kenya

During the transition periods wind flow is weaker and easterly. This is the most unstable flow occurring over Kenya and is associated with increased rain shower activity over the eastern lowlands. Converging easterlies and rain shower activity are most likely when an equatorial duct develops over the country. The duct develops when anticyclones are present on both sides of the equator, positioned on a north-south axis (Fig. 5.4) (Trewartha, 1981). Cross contour flow and convergence occurs at the entry point on the east side of the duct. Extensive cloud development and rain shower activity is likely to develop in this region. At the exit on the west side of the duct the flow is decelerating and diverging (World Meteorological Organization, 1964). The likelihood of rain shower activity increases over eastern Kenya if either or both of the anticyclones intensify. The equatorial duct is occasionally displaced four to five degrees of latitude away from the equator. The rains which occur in October - November are much less significant than those in April - May over the eastern lowlands. Occurrence of the duct is critical to the development of rains in the October - November period. If the Southern Hemisphere subtropical high recedes southward early in the transition period or if the anticyclone north of the equator is slow in establishing itself, rains in October and November will be light or insignificant over the east.

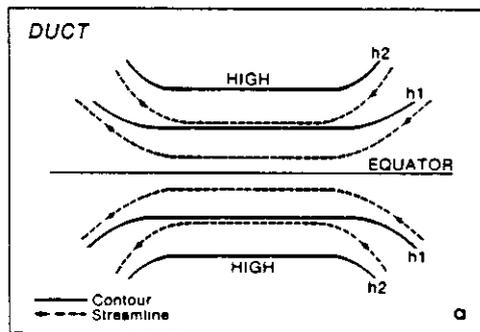


Fig. 5.4. Equatorial Duct (Trewartha, 1981)

b. Tanzania

During the transition periods the flow over Tanzania is weak and easterly. This flow is similar to the warm, moist and highly unstable air present over Kenya during the same period. Rain shower activity is maximum in the northeast portion of the country in March and April. In Dar es Salaam and Morogoro, between 50 and 60% of the mean annual rain falls from March through May. Rain shower activity does occur, though much less frequently, in the other (October-November) transition period. Frequent and occasionally heavy rain shower activity is likely over northeast and north central Tanzania when the equatorial duct develops. Intensification of either anticyclone (north or south of the duct) in such a situation increases the likelihood of heavy rain shower activity.

5.4.4 Thunderstorms

a. Kenya

Thunderstorms occur during summer and winter months with high frequency over the western Kenyan highlands. The eastern lowlands experience little thunderstorm activity except in March and April because flow at low-levels in this region is generally divergent. During the austral summer months showers develop frequently when unstable tropical westerly flow frequently penetrates over the Kenyan highlands, converging with the northeasterly flow (Trewartha, 1981). Convective cloudiness occurs mostly over the western slopes of the mountains. The probability of penetrating westerlies is increased if the subtropical anticyclone over northwest Southern Africa is intense or building.

The austral winter southeast monsoon has greater heat, moisture and instability than the northeast monsoon (United States Air Force Air

Weather Service, 1980), and is associated with frequent convective and thunderstorm activity over the western highlands. Thunderstorm activity is likely to increase, especially over the southwest highlands, with intensification of the heat low over the Rift Valley region.

During the transition months highly unstable easterly flow dominates. The air has a long trajectory over warm tropical waters before passing over eastern Kenya. Over the eastern lowlands this flow is associated with convective rain shower and thunderstorm activity. In Nairobi thunderstorm activity is highest in April (mean of five thunderstorm days). Enhanced convection and thunderstorm activity over eastern Kenya is likely when the easterly flow is strong and increasing.

b. Tanzania

Convection and thunderstorm activity occur with highest frequency over the western and southwestern portions of Tanzania, during the summer months (December - March). The summer maximum over the extreme western portions of the country is associated with surges in the tropical westerlies penetrating over the western mountains. As in Kenya, most of the convective activity occurs over the western facing slopes as the unstable westerly flow converges with the northeast monsoon (Trewartha, 1981).

Thunderstorm activity, though significant during the transition months, occurs with much lower frequency than in summer. Convective activity over most of Tanzania during the winter is minimal. Thunderstorm activity is almost nonexistent over the west and southwest portions of the country. Even over the western mountains and lakes the frequency of convective activity is low. Divergent southeasterly flow at the surface and convergent flow at 500 mb are associated with reduced convective activity over most of the country in the austral winter (Anyamba and Kiangi, 1983). Additionally, the semipermanent low over southwest Africa is replaced with an anticyclone from June through September. The associated low-level subsidence is an additional factor in the suppression of convection.

5.5 UPPER-AIR WINDS AND TURBULENCE

5.5.1 Kenya

The significant features in the flow aloft are the Somali (low-level) Jet and a low-level southeasterly jet present year round between the Kenyan and Ethiopian highlands. The Somali Jet is present during the winter months at elevations up to 1-1.5 km off the Kenya-Somali coast. The jet migrates northwest from south of the equator during the months of February to June and then remains stationary from June through August (see Fig. 3.14). In September the jet axis begins migration back to the southeast. Fig. 3.15 (Krishnamurti, 1979) shows the mean position of the wind speed maxima in August. The mean wind maxima occur northeast and southeast of Kenya, however strong (mean 15-25 kt) winds are still observed over the Kenyan coast. Stronger wind velocities occur when the jet is intensified. The Somali Jet develops on

the west side of the southerly/southwesterly monsoon flow. The Somali Jet has a diurnal variation in its elevation and intensity. The jet is at its highest elevation (1-1.5 km) during the night-time hours between midnight and dawn. After sunrise the wind velocities aloft begin weakening and the jet builds toward the surface. The jet descends to elevations as low as 250 m during daylight hours. At dusk the low-level winds begin to decrease and the jet begins its evening ascent. Strongest winds at night occur near the 750 m level (United States Air Force Air Weather Service, 1980). The strength of the Somali Jet is also affected by synoptic disturbances to the south in the Southern Hemisphere westerlies. Clear air turbulence is likely near the surface during daylight hours and at elevations near one kilometer at night in the vicinity of the jet. Low-level turbulence is most likely and most severe in the afternoon, while upper-level (one kilometer) turbulence is most likely in the morning hours.

The strong low-level southeasterly flow between the Kenyan and Ethiopian highlands (referred to as the Turkana Channel Jet, see Fig. 3.15) is present throughout the year. The jet occurs at and below an elevation of 0.75 km (above ground) and is strongest near the 0.6 km level. The flow increases in intensity from the ground to 0.5 km and weakens above 0.8 km. Wind velocities in the jet often exceed 60 kt and occasionally exceed 100 kt. There is a diurnal variation in the jet intensity with the strongest winds occurring in the morning hours. Clear air turbulence, occasionally severe, is likely in the vicinity of the jet flow (Kinuthia and Asnani, 1983).

Wind⁹ at high elevations (e.g., 300 mb, 200 mb) over Kenya is weak throughout the year. The mean flow is south-southeasterly (10-20 kt) over northern Kenya and southeasterly over southern Kenya in the austral summer becoming east-northeasterly (5-20 kt) during the winter months (see Figs. 2.27, 2.28). At 500 mb, weak (5-15 kt) east-northeasterly flow dominates over Kenya throughout the year (see Figs. 2.29, 2.30). Northeasterly (5-15 kt) flow is present at low level (700 mb) in summer, and in the winter months weak (5-15 kt) south-southwesterly winds dominate (see Figs. 2.31, 2.32) (Dean, 1972).

Clear air turbulence is associated with the low-level jets mentioned earlier. Areas affected are limited to northeastern and coastal Kenya, and the Kenyan-Ethiopian Highlands. Additionally, turbulence occurs in association with thunderstorm and convective activity over the western highlands in winter and summer, and over the eastern lowlands in March and April. Turbulence associated with these thunderstorms occurs at all levels and can be severe.

⁹ See footnote 4 on page 2-24 regarding upper-air wind analyses.

5.5.2 Tanzania

The significant low-level feature over Tanzania is the low-level jet, found often in close proximity to the eastern coast. This low-level jet migrates northwest from February to June (see Fig. 3.14). The jet remains quasi-stationary from June through August and is most likely to affect the Tanzanian coast starting in May. Fig. 3.15 shows the mean low-level jet flow for the month of August. Although the speed maxima are not close to the Tanzanian coast, strong (15-25 kt) wind occurs frequently. Stronger winds occur over the northern coast when the jet and surrounding wind field are intensified. This strong flow is part of a larger scale low-level flow which includes the Somali Jet described earlier in this section. Turbulence is likely in the vicinity of the jet at low-levels in the afternoon and near the one kilometer elevation before sunrise.

At the upper levels (200 mb) the summer mean winds are southeasterly (15-25 kt) over Tanzania while during the winter mean winds are primarily easterly (Figs. 2.27, 2.28). The 500 mb flow is light (5-15 kt) and variable in summer and light southeasterly in winter (see Figs. 2.29, 2.30). At 700 mb the mean flow is weak northeasterly during the summer months and 5-15 kt southerly/southeasterly in the winter (see Figs. 2.31, 2.32).

Turbulence, occasionally severe, is also likely in the vicinity of intense convection and thunderstorm activity in western and southwestern Tanzania. Such weather is most likely in winter and during the transition periods.