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Synoptic disturbances over the Nile valley north of the intertropical convergence zone

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ABSTRACT

The synoptic climatology of disturbances crossing the Nile valley of Egypt and Sudan during 1967 was studied using 1200 GMT horizontal time sections, at surface and upper levels, for thirteen stations roughly along a north–south line from Nicosia (35° N) to Juba (5° N). Disturbances were defined as prescribed departures from dominant surface wind direction or speed at two or more adjacent stations. There were 43 disturbances during the year, most frequent in winter and spring. Almost all were windshift lines associated either with cyclonic centres over or north of the Mediterranean, or with desert depressions. The lines were accompanied by changes in temperature tendency and were therefore advection discontinuities. Because they were followed by falling temperatures they were also cold fronts. In winter, cool air at the rear of the disturbances penetrated deep into Sudan while in late spring, khamsin weather with southerly winds and interdiurnal temperature rises of up to 13° C preceded fronts over northern Egypt. Most disturbances were associated with troughs in the upper tropospheric westerlies.

1. Introduction

In all months of the year surface winds over the Nile valley of Egypt are mostly from the north (see e.g. Thompson, 1965). In Sudan, northerlies predominate from November to March; then southerlies spread progressively northwards behind the intertropical convergence zone (ITCZ), which reaches its highest latitude of about 20° N in July and August. The northerly winds vary in speed from day to day as a result of the passing of synoptic disturbances, and they are occasionally replaced by southerlies. There have been many synoptic studies of individual disturbances (e.g. El Fandy, 1940; Lunson, 1950; Tantawy, 1969). All these studies were of spring disturbances accompanying "desert depressions" that form over north Africa and move eastwards either just south of the north coast of Africa or later over the Mediterranean Sea. The southerly winds ahead of these depressions produce the well-known warm, dry, and dusty "khamsin" weather of Egypt. Hassan (1972) distinguished two types of khamsin weather: strong winds and dust-storms without large temperature rises in early spring; and hot but often not dusty weather accompanying southerly winds in late spring.

Lunson (1950) described a desert depression with a warm front within the southerly winds, and a cold front ahead of returning northerly winds. Subsequently (e.g. Pedgley, 1972), synoptic-scale warm fronts have not been found but the presence of cold fronts has been confirmed. Cold fronts also cross the Nile valley in the absence of desert depressions, and Pedgley identified nine such fronts as well as 14 desert depressions in the period January to June 1962. The occurrence of cold fronts over north Africa is generally accepted, but Kirk (1964) argued that the term "front" was not very useful in this area where temperature changes accompanying wind direction changes are often small and are superimposed on a strong pre-existing north–south temperature gradient. He used the term "advection discontinuity", emphasizing that changes with time at a given place are caused by changes in horizontal advection rather than the replacement of one "air-mass" by another. Pedgley (1972), however, considered the cold front to be a particular form of "advection discontinuity".

These studies have shown that some synoptic disturbances affecting the Nile valley of Egypt and Sudan have "cold fronts" or "advection discontinuities" associated with eastward-moving desert depressions or Mediterranean cyclones. There is, however, no published synoptic climatology of the frequency and possible variety of disturbances throughout the year over the Nile valley. This paper discusses the synoptic climatology of disturbances based on data for one year, 1967; this year was chosen as it is the last for which detailed 1200 GMT synoptic data from Egypt have been published.

2. Data and analysis

Because previous work has shown that many synoptic disturbances over the Nile valley move from west to east, time sections along a north–south line were considered suitable for studying such disturbances. A time section can be constructed much more easily than a series of synoptic charts, and it readily shows up many of the properties of disturbances. Sections were constructed from daily 1200 GMT data for 13 synoptic stations near a north–south line at 32° E (Fig. 1), between Nicosia (35° N) and Juba (5° N). Data for 1200 GMT were used because, of the four main synoptic hours each day, it is the time when observations are most likely to be representative of broad areas and not greatly influenced by local effects such as the channelling of winds or the stagnation of cold air in the presence of nocturnal temperature inversions.

Data were obtained from three published sources: the *Egyptian Daily Weather Report*, the *Synoptic Bulletin* of the Sudan Meteorological Service and the *Daily Weather Report* (*Overseas Supplement*) of the British Meteorological Office.

Time sections were constructed for winds, temperatures and dew points at the surface; for clouds and weather; and for winds and temperatures at 850, 700, 500 and 200 mbar. Radio-sonde observations were regularly available from only three places: Nicosia, Helwan and Khartoum. Potential temperatures were calculated from surface data so that comparisons could be made between stations at different altitudes (all less than 500 m above sea level). Six-hourly data were used for more detailed analysis of four disturbances, but to reduce the effect of diurnal variations only 24-hour changes between observations at the same time on successive days were considered. Hourly data would have been useful in the analysis of these disturbances but they were not available in published form.

The passage of a disturbance causes a deviation from the "dominant wind", which in this paper is defined in the following way. Frequencies of occurrence of 1200 GMT surface winds were tabulated by direction (on an 8-point compass) and by speed (at 5-kt intervals). It was found that, at a given station in a given month, winds were mostly in one or two direction intervals and in one or two speed intervals. These directions and speeds were taken as the "dominant wind". Deviations from this "dominant wind" by one or more intervals in either wind speed or wind direction (or both) were taken as a "station disturbance". A synoptic disturbance was considered to be present on a given day when "station disturbances" occurred at two or more key stations. The key stations used were Helwan, Asyout, Aswan, Abu Hamad and Khartoum.

To illustrate the properties of disturbances and to demonstrate the usefulness of time sections as a method of analysis we first consider two examples. Section 4 then gives the general properties of all disturbances during 1967.

3. Two disturbances

Fig. 2 shows a cyclonic centre that crossed the Nile valley near 28° N on 20 May. It lay beneath a deep mid-tropospheric trough, and was notable for:

(i) a trailing windshift line, passing Aswan on the 22nd and just reaching northern Sudan on the 23rd, with a brief northward movement of the ITCZ by about five degrees of latitude;
(ii) a stationary coastal front, with a temperature contrast of 9° C between Helwan (with a light southerly wind) and Alexandria (with a 15 kt northerly wind);
(iii) a wave-like pattern in the isotherms, with an axis of maximum temperature along the windshift line;
(iv) khamsin weather ahead of the windshift, with temperature rises reaching 14° C.

Fig. 3 shows a cyclonic centre that crossed the section line between Egypt and Cyprus on 13

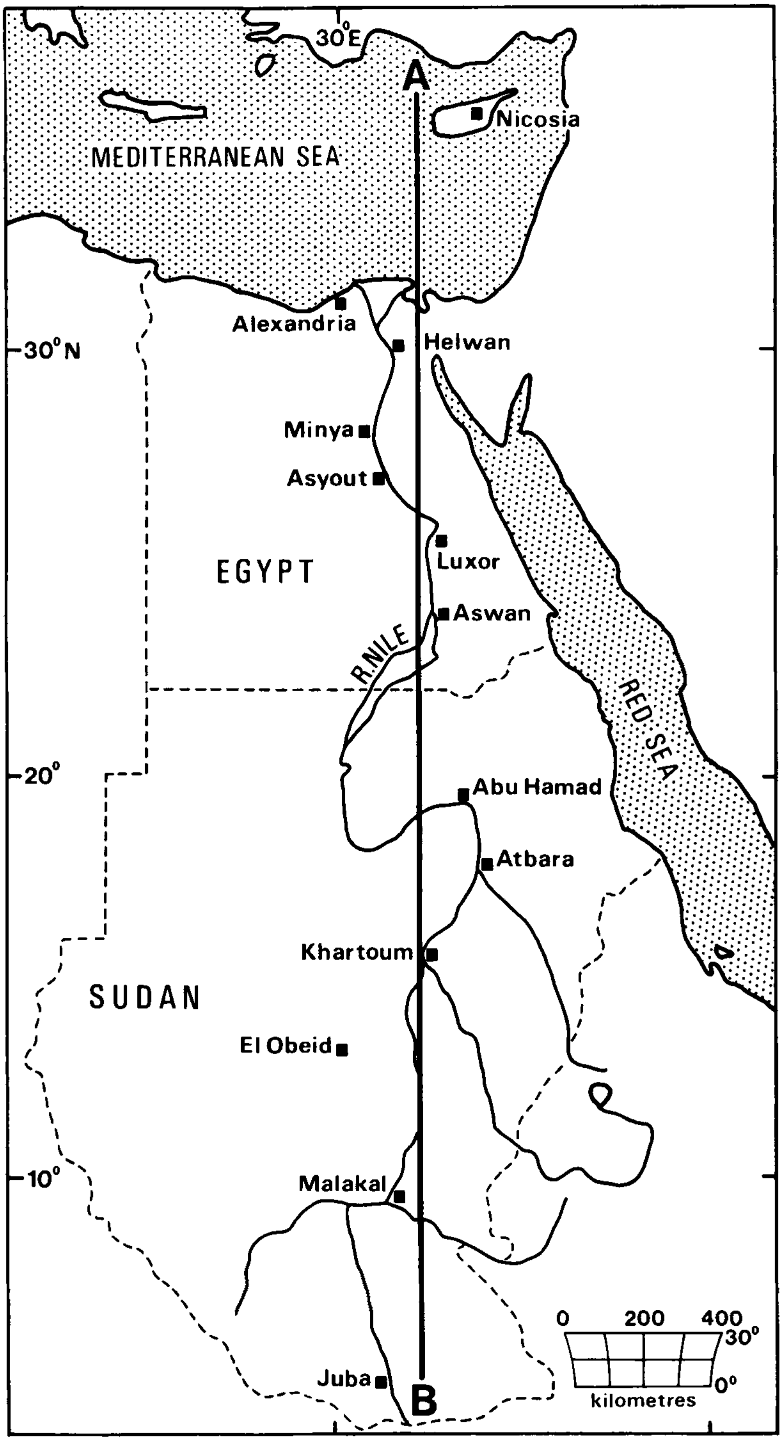

Fig. 1. Meteorological stations used in time sections and approximate line of the section.

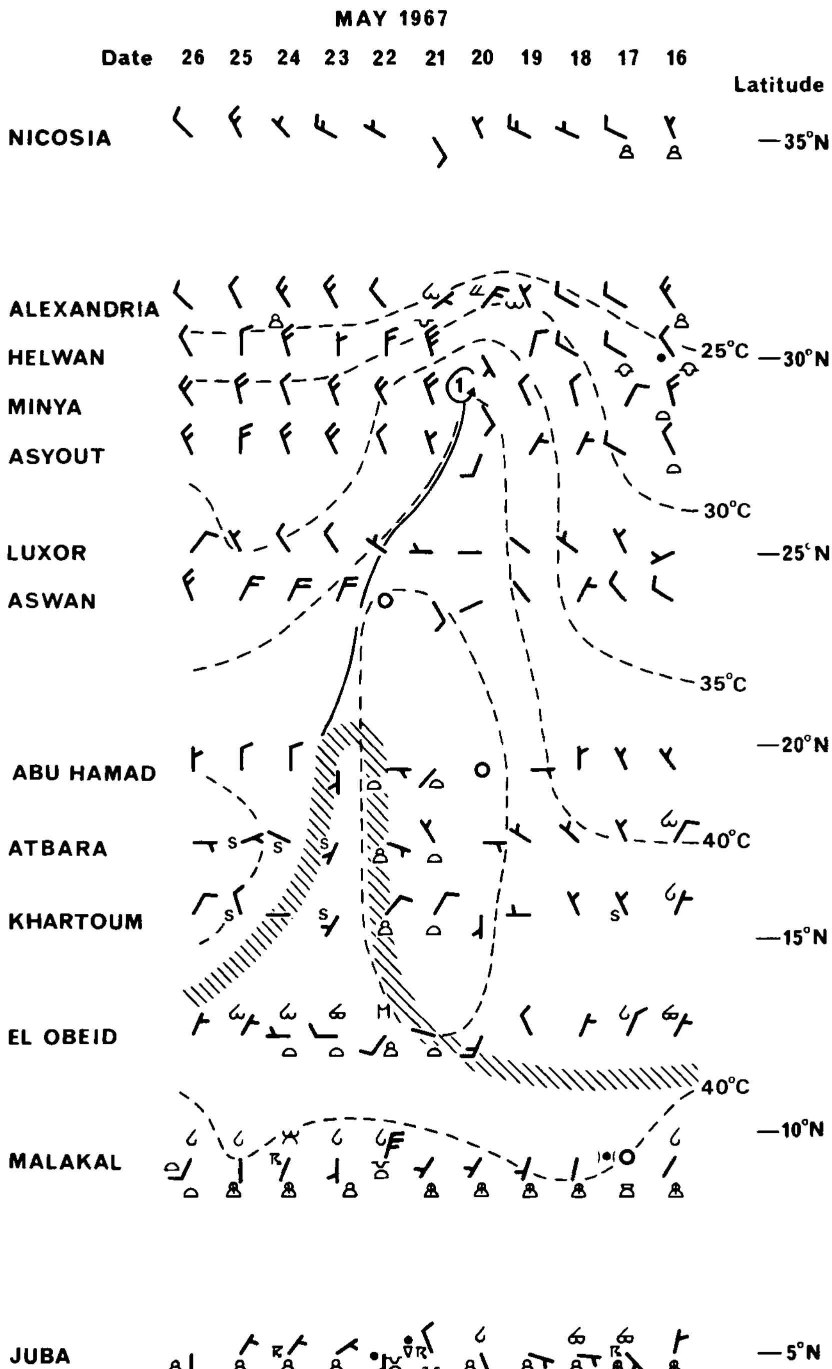

Fig. 2. Horizontal time section along line AB of Fig. 1, showing 1200 GMT observations for the period 16–26 May 1967. Winds, low and middle level clouds, and weather are shown in conventional symbols. Disturbances are shown by continuous lines and potential isotherms by broken lines. Approximate position of the intertropical convergence zone is shown by a band of hatching.

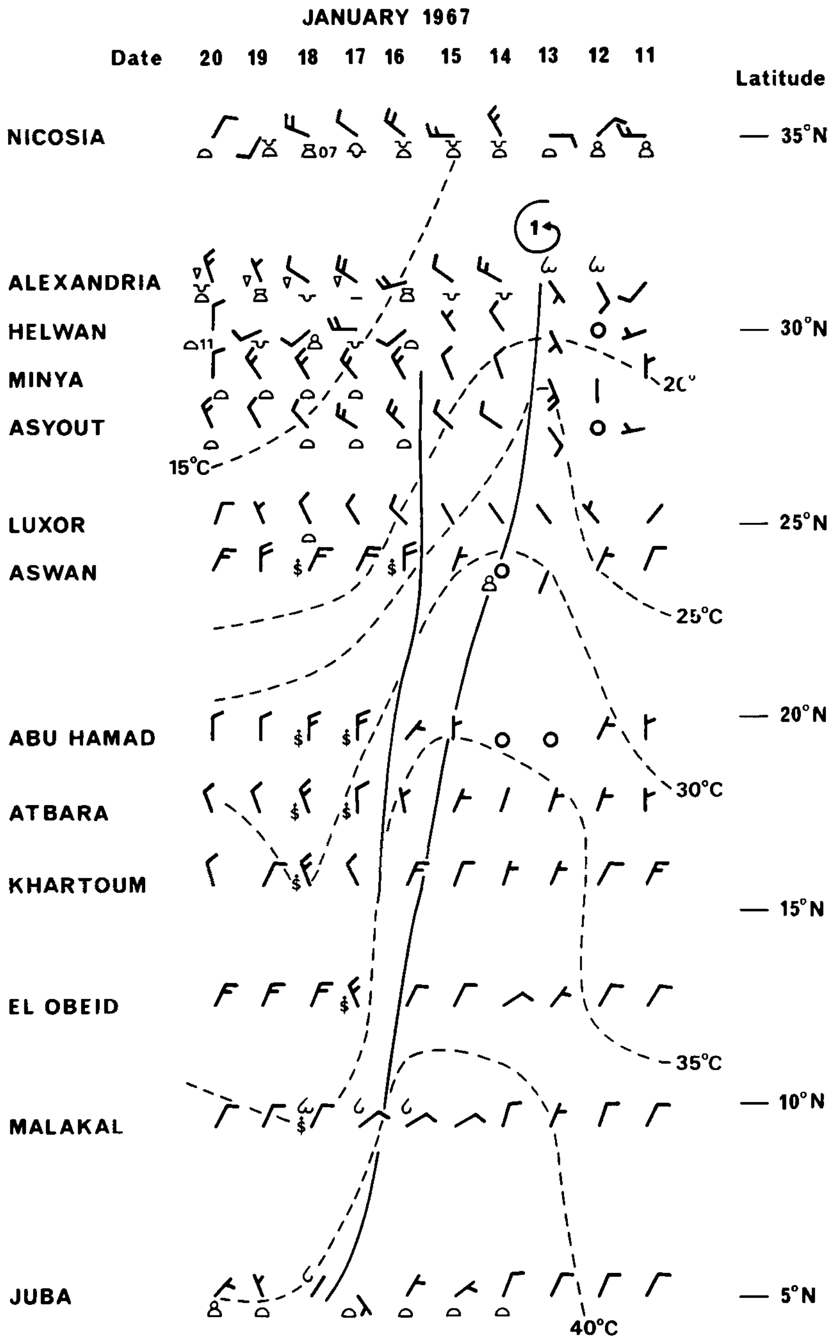

Fig. 3. Similar to Fig. 2, but for 11–20 January 1967.

January. It was notable for:

(i) two windshift lines (more clearly shown by using 6-hourly data), the first being traceable (with the help of onset of falling temperatures) as far south as Juba (5° N) by the 16th;

(ii) small wind changes across the first windshift line south of about 26° N, but marked increases in northerly winds behind the second line;

(iii) a wave-like pattern of isotherms similar to that in Fig. 2;

(iv) a 14 °C temperature fall in four days at Aswan, but smaller falls progressively further south;

(v) small cumulus clouds behind the second windshift line as far south as Luxor on the 18th;

(vi) large cumulus at Aswan on the 14th, with a dew point rise of 24 °C over two days and strong south-easterly flow at 850 mbar (despite light surface winds).

4. General properties of disturbances in 1967

During 1967 there were 43 disturbances defined as in Section 2. They occurred in all months (Table 1), but were most frequent in winter and spring. Their most notable properties were as follows.

Winds

Surface northerly winds became variable or southerly, and were followed by northerlies again after 1–3 days, often strong enough to give blowing dust over Sudan. The onset of southerlies was either on the same day at all latitudes or in the north at first. Southerlies were most frequent in northern Egypt, but in one February disturbance they were present as far south as Khartoum. The change to northerly winds was almost always at a windshift line moving east or south-east, 13 of which reached Sudan (mostly January–March and November–December).

With 26 of the 43 disturbances, cyclones crossed the section line, including seven desert depressions crossing Egypt at about 30° N (four in April–May and three in September–November) and three former desert depressions that had moved just north of the Egyptian coast. Almost all disturbances (37 of 43) lay beneath or just ahead of the axes of mid-tropospheric troughs. Desert depressions were usually shallow, with only weak troughs or straight flow aloft, even as low as 700 mbar. The three July and August disturbances (two being confined to southern Egypt), although weak at the surface, were associated with well-developed mid-tropospheric troughs.

The ITCZ, where northerly winds meet south-westerlies from low latitudes (and often marked by the latitude of greatest temperature), sometimes moved north by up to 10° of latitude over several days ahead of a windshift line, entering southern Egypt three times in July and August, once reaching just north of Luxor.

Temperatures

In all disturbances but two weak ones, 1200 GMT temperatures rose ahead of, and fell behind, each windshift line. Inter-diurnal changes were mostly 3–4 °C, with a range 1–13 °C. Rises and falls had similar sizes. Rises of 7 °C were most fre-

Table 1. *Monthly frequencies of the three types of disturbances over the Nile valley north of the ITCZ during 1967*

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Disturbances associated with cyclonic centres over the Mediterranean or further north.	5	7	4	3	2	–	–	1	–	1	3	3	29
Desert depressions (*Centres north of the Egyptian coast at 32° E)	–	–	1*	3	1	1*	–	–	1	1	1	1*	10
Weak disturbances confined to southern Egypt.	–	–	–	–	2	–	1	1	–	–	–	–	4
TOTAL	5	7	5	6	5	1	1	2	1	2	4	4	43

quent in April–June, the greatest being 14 °C over three days at Asyout ahead of a desert depression. The highest 1200 GMT potential temperature in Egypt was 47 °C. Potential temperatures fell below 20 °C as far south as Aswan following three windshift lines in January, February and December. Maximum 1200 GMT temperatures were on the windshift lines, although the greatest inter-diurnal falls were sometimes 1–2 days later, with strengthening northerly winds.

Clouds and Rain

At Helwan, dew points usually fell with southerly surface winds and rose with strong northerlies, but south of Minya the reverse was often true. During January–March and October–December, small cumulus clouds were common after windshift lines north of 25° N; on one day they formed as far south as Aswan in northerly winds east of strong anticyclones over Libya and central Europe. Cumulus clouds sometimes gave showers north of 30° N. There were seldom any low clouds ahead of a windshift line, but on two days (in January and in June) there were large cumulus clouds at Aswan when the lower tropospheric flow was from the south-east and presumably bringing moisture from the Red Sea.

Middle-level clouds accompanied some windshift lines (but never south of 20° N), either on the day of passage or one day before or after, and almost always ahead of a mid-tropospheric trough. Rain fell south of 30° N on 10 days (all but one between February and May)—on all but two from middle-level clouds—but falls were < 1 mm.

5. Discussion

Of the 43 synoptic disturbances during 1967 in the dominantly northerly surface winds over the Nile valley, 39 were eastward-moving windshift lines, separating southerly winds (or weakening northerlies) with rising temperatures from strengthening northerlies with falling temperatures. The windshift lines can be taken to be either cold fronts or "advection discontinuities" in the sense used by Kirk (1964), each line marking a change from warm advection to cold advection. There was no evidence for warm fronts nor for advection discontinuities in which cold advection was followed by warm, but sometimes there were coastal fronts where warm southerly winds over land met cool winds over the sea. The classical frontal structures of some earlier studies (e.g. El Fandy, 1940; Lunson, 1950) could not be supported. The disturbances were similar in structure to those over Saudi Arabia (Pedgley, 1974).

Each windshift line lay beneath or ahead of the axis of a trough in the middle and upper tropospheric westerlies, and moved eastwards at about weekly intervals. Judging by the known behaviour of such troughs elsewhere (see, e.g., Palmén & Newton, 1969), and the formation of middle-level clouds in some Nile disturbances, the windshift lines were presumably maintained (and even formed) by upper divergence acting on the surface windfield in the presence of a north–south temperature gradient. Where that gradient was strengthened in the lower troposphere by seasonal contrasts across the southern coast of the Mediterranean, desert depressions could form (in spring, and less so in autumn), sometimes even in the absence of an upper trough. The characteristic wavelike pattern on the dominantly east–west surface isotherms was presumably a result of interaction between advection (both horizontal and vertical) and surface heating. There is a need for dynamical studies to examine the relative importance of these processes.

The disturbances described here bear a strong likeness to disturbances elsewhere in the tropics, notably in southern Africa (e.g. Taljaard et al., 1961; Hattle, 1970) and in Australia (e.g. Berson et al., 1957, 1959; Hill, 1969), where spells of cool southerly winds are ushered in by windshift lines beneath upper troughs and between successive eastward-moving surface anticyclones. Their likeness is matched by their dominance, to the almost complete exclusion of other types of synoptic disturbances, between 30° latitude and the ITCZ. The other main kind of disturbance occurs where coastal temperature contrasts seem to allow the formation of desert depressions—matched by the "coastal lows" of South Africa (e.g. Tyson, 1965) and southern Western Australia (e.g. Gaffney, 1955).

Although time sections cannot show the origin or growth of disturbances, and some disturbances may approach but not cross a section line, nevertheless the time section is a useful analysis tool for describing the structures of a succession of disturbances without the need for much time to be spent in preparing synoptic charts. The tool is particularly useful where disturbances are known or suspected to cross the section line quickly and without much change. It is a method of analysis that could be used more widely in areas with few synoptic stations, so long as several lie on a line more or less normal to the direction of movement of disturbances.

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СИНОПТИЧЕСКИЕ ВОЗМУЩЕНИЯ НАД ДОЛИНОЙ НИЛА К СЕВЕРУ ОТ ВНУТРИТРОПИУЕСКОЙ ЗОНЫ КОНВЕРГЕНЦИИ

Изучается синоптическая климатология возмумений, пересекавших долину Нила в Египте и Судане в течение 1967 г. с использованием горизонтальных временных разрезов за 12·00 ГМТ у поверхности и на высотах для тринадцати станций, расположенных приблизительно в направлении с северана юг от Никозии (35°N) до Джубы (5°N). Возмущения определялись как отклонения пресбладающего направления или скорости ветра на двух или более соседних станциях. В течение года наблюдались 43 Возмущения, причем зимой и весной более часто. Почти все они были линиями сдвига ветра, связанными или с циклоническими центрами над Средиземным морем (или севернее) или с депрессиями над пустыней. Эти линии сопровождались изменениями в тенденции температуры и иоэтому были разрывами в поле адвекции. Так как они сопровождались падением температуры, они являлись также холодными фронтами, Зимою холодный воздух в тылу возмущений проникает в глубь Судана, тогда как поздней весной наблюдаются южные ветры, и межсуточные изменения температуры, достигая 13°C, предшествуют фронтам над северным Египтом. Большинство было связано с ложбинами в западном потоке в верхней тропосфере.