CHAPTER 6

The Use of Meteorological Observations for Studies of the Mobilization, Transport, and Deposition of Saharan Soil Dust

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ABSTRACT

SYNOP reports (weather reports from the meteorological network of so-called SYNOP stations) contain much valuable information in relation to studies of the mobilization, air-borne transport and deposition of desert soil dust. Details of this information are presented in the paper. Further two examples are given on how to make use of the SYNOP reports, one showing the migration of a duststorm over the Sudan area on a series of synoptic weather maps, the other for a study on the threshold wind velocity for raising desert soil dust.

6.1 INTRODUCTION

The object of the Saharan Dust Project is to describe and explain as far as possible the three phases of Saharan dust and sand transport within the Sahara and its pre-Saharan margins, where desertification occurs. These three phases are the mobilization phase, the air-borne transport phase, and the deposition phase. In all three phases meteorological factors play an important part. The object of this paper is to demonstrate the usefulness of meteorological synoptic observations for investigations in relation to the Saharan Dust Project.

To which questions can we hope to get an answer by means of meteorological investigations concerning the desertification process, and what resources do we have to help us in answering these questions?

In this relation the following questions are of importance:

1. Which types of weather mechanisms are responsible for raising and transporting desert soil dust? In this respect a distinction should be made between different intensities of dust transport, i.e. from low dust density with good visibility conditions and weak or moderate winds to high dust density and very poor visibility in connexion with strong winds (duststorm conditions).

2. How are these weather mechanisms linked to the actual broad-scale weather situation?

3. What is the frequency distribution over the Saharan area of dust observations as contained in the meteorological SYNOP reports from meteorological stations?

4. Does this frequency distribution have seasonal changes, and, if so, in what manner?

5. Is this frequency distribution related to the topography of the Saharan area as well as to its vegetational and land use pattern and ground conditions?

6. Which is the critical wind speed for initiating the raising of dust into the air? Does this speed change from place to place? Is it depending on other factors like moisture in the air and soil, etc.?

7. Is it possible to visualize duststorms on synoptic weather maps and to follow their migrations and developments?

8. Is it possible to use synoptic weather observations as contained in SYNOP reports as a substitute for direct measurements of air-borne dust?

In this paper efforts have been made to give an answer to at least two of these questions namely No. 6 and 7.

6.2 SYNOP REPORTS AND DESERT DUST STUDIES

The meteorological observations as reported in the SYNOP code [code form WMO FM-11-V-SYNOP in WMO's Manual on Codes (WMO, 1974)] provide much useful material for investigations of air-borne soil dust, in particular

wind direction	(dd in the SYNOP code)
wind speed	(ff in the SYNOP code)
visibility	(VV in the SYNOP code)
present weather	(ww in the SYNOP code)
past weather	(W in the SYNOP code)

The two digits for VV in the SYNOP code permit a very accurate reporting of the visibility, with intervals of 100 m from 0.0 km up to 5.0 km, and with intervals of 1 km from 5 km up to 30 km.

The 'present weather' [code 4677 in WMO's Manual on Codes (WMO, 1974) for ww – Present weather], gives a lot of information in relation to air-borne dust as demonstrated in Table 6.1.

The information which can be obtained from W (past weather) is much less, but anyhow important. Only one digit, i.e. $W = 3$, provides information on dust: sandstorm or duststorm has occurred during the last three hours or six hours prior to the actual observation (depending on the time of the observation).

Some indirect information about the state of the ground (dry or wet) can be drawn from those figures in the ww code, which indicate rain, drizzle, or showers at the time of observation or during the hour prior to the observation. These code figures should be studied together with the code figure giving the amount of

TABLE 6.1 Data on Air-borne Dust

Code figure ww	Symbol	Text en clair
00, 01, 02, 03		The characteristic change of the state of sky is described, but no hydrometeors (precipitation, fog, hoarfrost, etc.), lithometeors (haze, smoke, drifting dust, etc.) or electrometeors (lightning, thunderstorms, etc.) are present
04		Visibility reduced by smoke, e.g. veldt or forest fires, industrial smoke or volcanic ashes
05		Haze
06		Widespread dust in suspension in the air, not raised by wind at or near the station at the time of observation
07		Dust or sand raised by wind at or near the station at the time of observation, but no well-developed dust whirl(s) and no duststorm or sandstorm seen
08		Well-developed dust whirl(s) or sand whirl(s) seen at or near the station during the preceding hour or at the time of observation, but no duststorm or sandstorm
09		Duststorm or sandstorm within sight at the time of observation or at the station during the preceding hour
30		Slight or moderate duststorm or sandstorm – has decreased during the preceding hour
31		Slight or moderate duststorm or sandstorm – no appreciable change during the preceding hour
32		Slight or moderate duststorm or sandstorm – has begun or has increased during the preceding hour
33		Severe dust-storm or sandstorm – has decreased during the preceding hour
34		Severe dust-storm or sandstorm – no appreciable change during the preceding hour
35		Severe dust-storm or sandstorm – has begun or has increased during the preceding hour
98		Thunderstorm combined with duststorm or sandstorm at time of observation

precipitation during the previous 6, 12, or 24 hours (depending on the time of the observation).

The investigations presented in this paper are based on SYNOP reports from the Sudan as contained in Synoptic Bulletins issued by the Sudan Meteorological

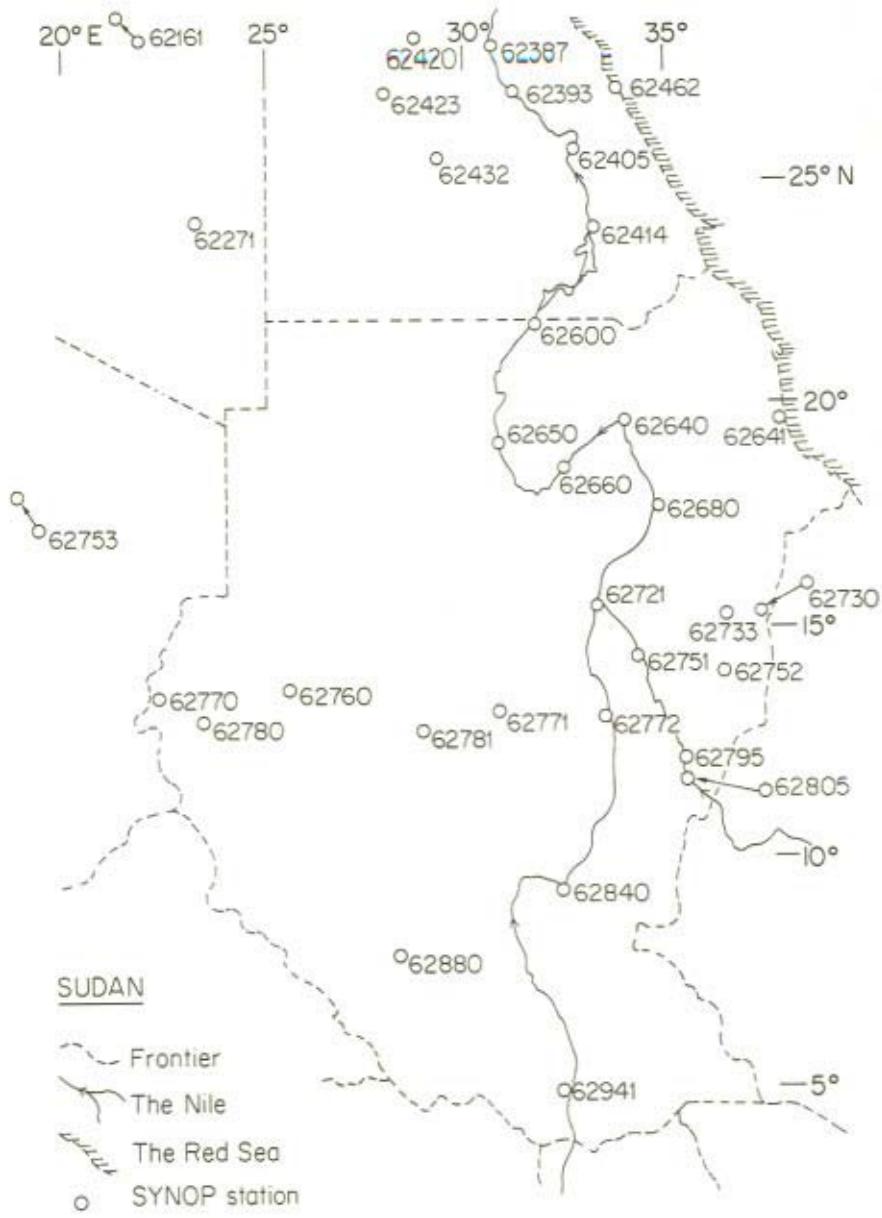

Figure 6.1 The network of meteorological SYNOP stations in the Sudan area. The station numbers are plotted quite close to the station (the small circle). In the weather charts (Figures 6.4 to 6.7) four stations, namely 62161, 62730, 62753, and 62805 have been plotted at a small distance from the true position owing to insufficient plotting space. The true position of these stations is the circle where the arrows end.

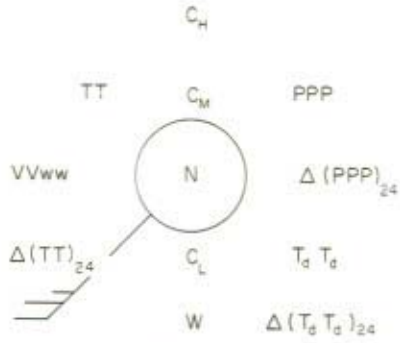

Figure 6.2

Department. SYNOP reports have also been taken from U.S. Northern Hemisphere Data Tabulations issued by the U.S. National Oceanic and Atmospheric Administration (NOAA). In this paper the SYNOP reports have been used for demonstrating their fitness for use in relation to two types of studies, namely

- for a case study of duststorms by means of synoptic weather charts
- for a statistical study in relation to the critical wind speed for initiating the raising of desert soil dust into the air.

Figure 6.1 gives the chart form for the Sudan area in which the SYNOP stations have been plotted together with the relevant station number according to WMO's publication: Weather Reporting, Volume A, observing stations (WMO, 1975).

For the plotting of the SYNOP reports the following station model was used (Figure 6.2).

In the station model below the code letters are explained (Figure 6.3).

The wind direction is plotted as a line from the station circle towards the direction, from which the wind is blowing, and the wind speed as slanting bars on

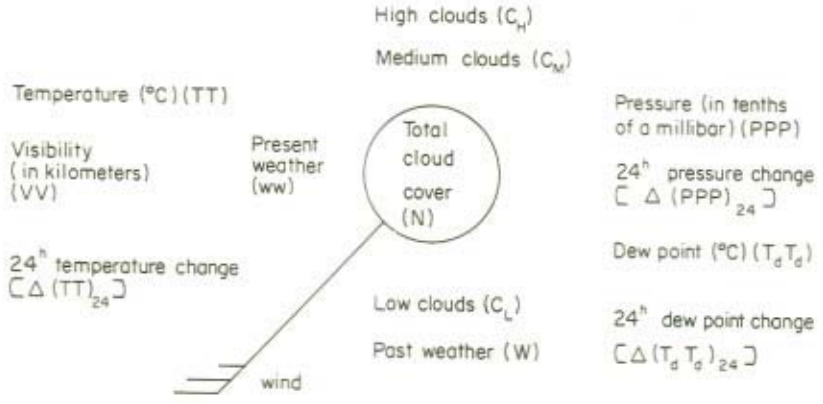

Figure 6.3

that line. One full bar denotes 8 to 12 knots, and a half bar 3 to 7 knots. No bar is plotted for wind speeds below 3 knots. Thus, if the wind is blowing from 230° with a speed of 26 knots this wind is plotted as 

6.3 THE SUDANESE DUSTSTORM FROM 16th TO 19th MARCH, 1974, A CASE STUDY

In Figures 6.4 to 6.7 are reproduced synoptic weather analyses for the Sudan area during a period when a duststorm passed this area. In order to avoid over-burdening of the analyses presented in this paper only isopleths for visibility (in a quasi-logarithmic scale) have been drawn. On account of the sparse SYNOP station network, particularly in the western part of the area, the isopleths for visibility give only an approximate idea of the true visibility pattern.

On the 15th March, 1974, at 00^h GMT, the visibility was above 20 km at all Sudan SYNOP stations but for station No 62640 (Abu Hamed) (Figure 6.4). One day later (Figure 6.5) the wind speed started to increase at the northernmost station, No 62650 (Dongola), which reported dust raised by the wind (ww = 07) and wind speed 17 knots, while the neighbouring station No 62660 (Karima) still had good visibility though the wind speed also had increased to 17 knots.

The weather had deteriorated substantially 18 hours later at both stations: Abu Hamed reported severe duststorm with wind speed 30 knots (gale) and visibility between 100 and 200 m, and Karima dust raised by the wind with wind speed 23 knots and visibility 2 km. The duststorm seems to have been connected with a cold front passage (in fact the temperature dropped 8°C in Abu Hamed as compared with 24 hours earlier). On the 17th March at 00^h GMT the duststorm had reached Khartoum (station No 62721) (Figure 6.6). The duststorm continued to move south-south-eastwards [see the weather chart for 18th March 12^h GMT (Figure 6.7)] and had disappeared from the weather chart 18 hours later.

In the diagram, Figure 6.8, a number of meteorological variables, taken from the SYNOP reports from Khartoum during the actual period (14th March, 12^h GMT – 19th March, 00^h GMT) are plotted. The variables are wind direction and speed, present weather, visibility, temperature, dew-point and pressure. The diagram supports the assumption that this duststorm was connected with the passage of a cold front. After the arrival of the duststorm (17th March, 00^h GMT) both the temperature and the dew-point dropped appreciably while the pressure rose.

6.4 A STATISTICAL STUDY BASED ON SYNOP OBSERVATIONS

The results of a preliminary investigation concerning critical wind speed for initiating the raising of desert soil dust into the air for one SYNOP station in the Sudan [Dongola (62650)] during April 1973 is presented in Figure 6.9. The three

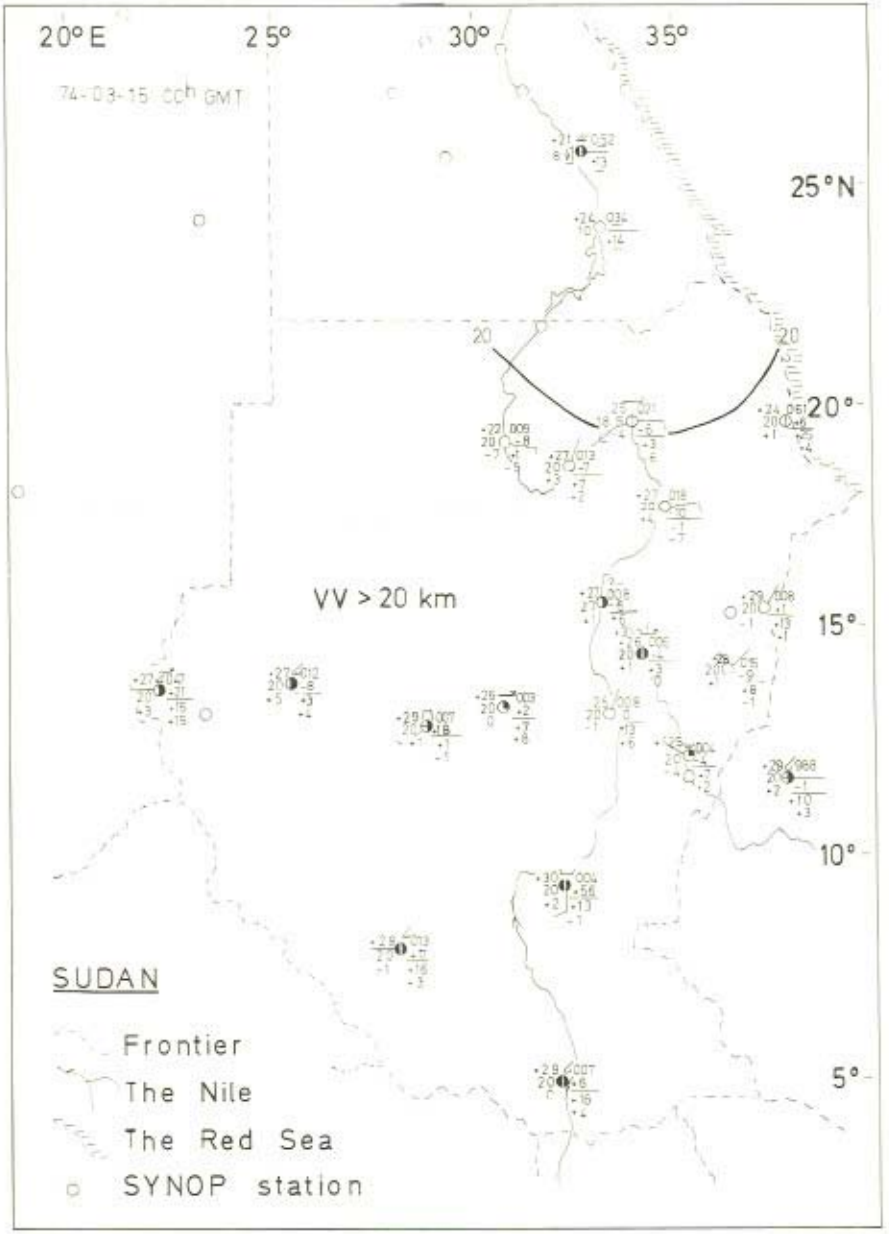

Figure 6.4 Weather charts based on SYNOP observations for the observation time 15th March, 1974, 00^h GMT. Only the analysis of the visibility pattern has been introduced in the charts. The isopleths for visibility (VV) have been drawn for the values 20 km, 10 km, 5 km, 2 km, 1 km, 0.5 km, 0.2 km and 0.1 km. The dotted isopleths only give a general indication of the visibility pattern. An area with very low visibility (< 500 m) in connexion with reports of air-borne dust can be followed on the weather charts during its movement sout-south-east.

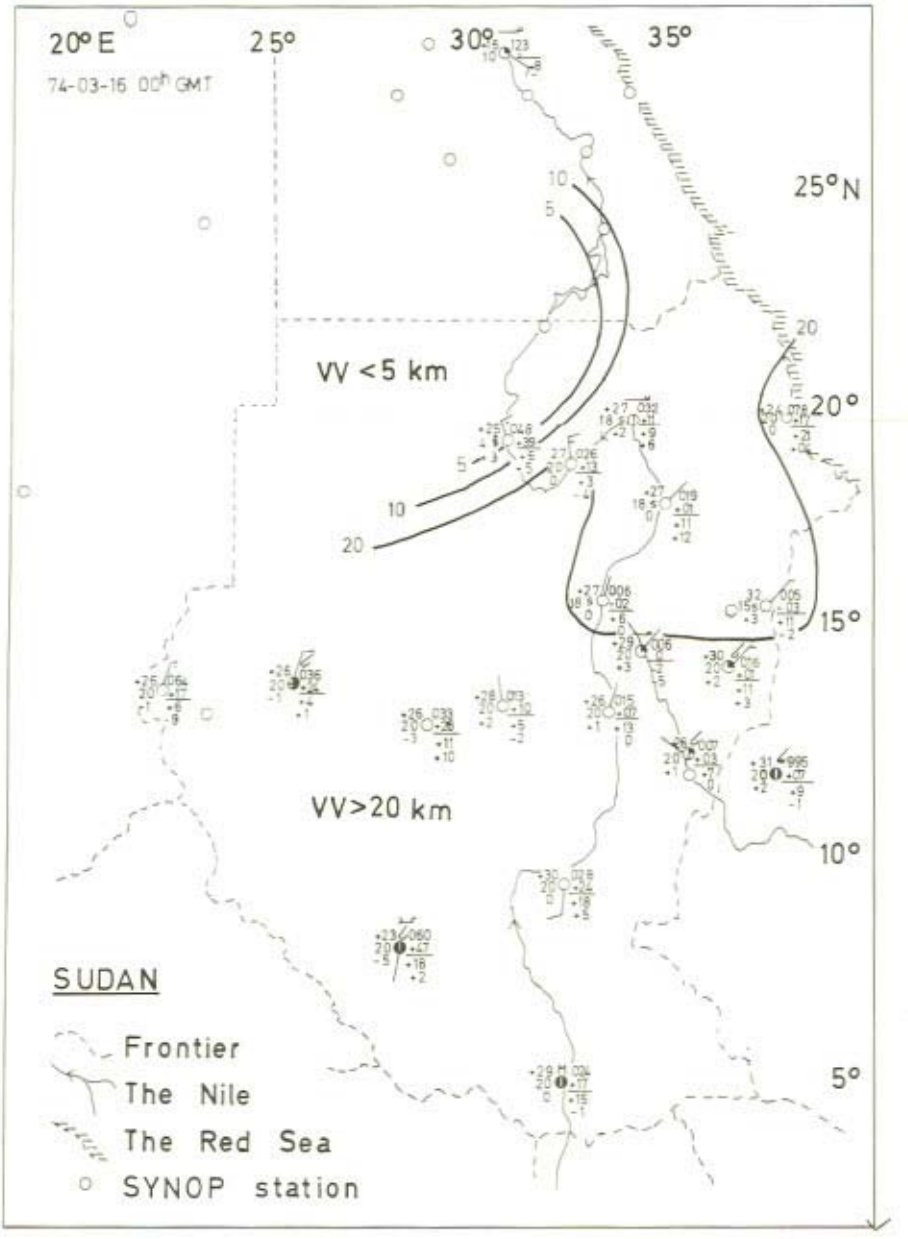

Figure 6.5 As Figure 6.4, for observation time 16th March, 1974, 00^h GMT

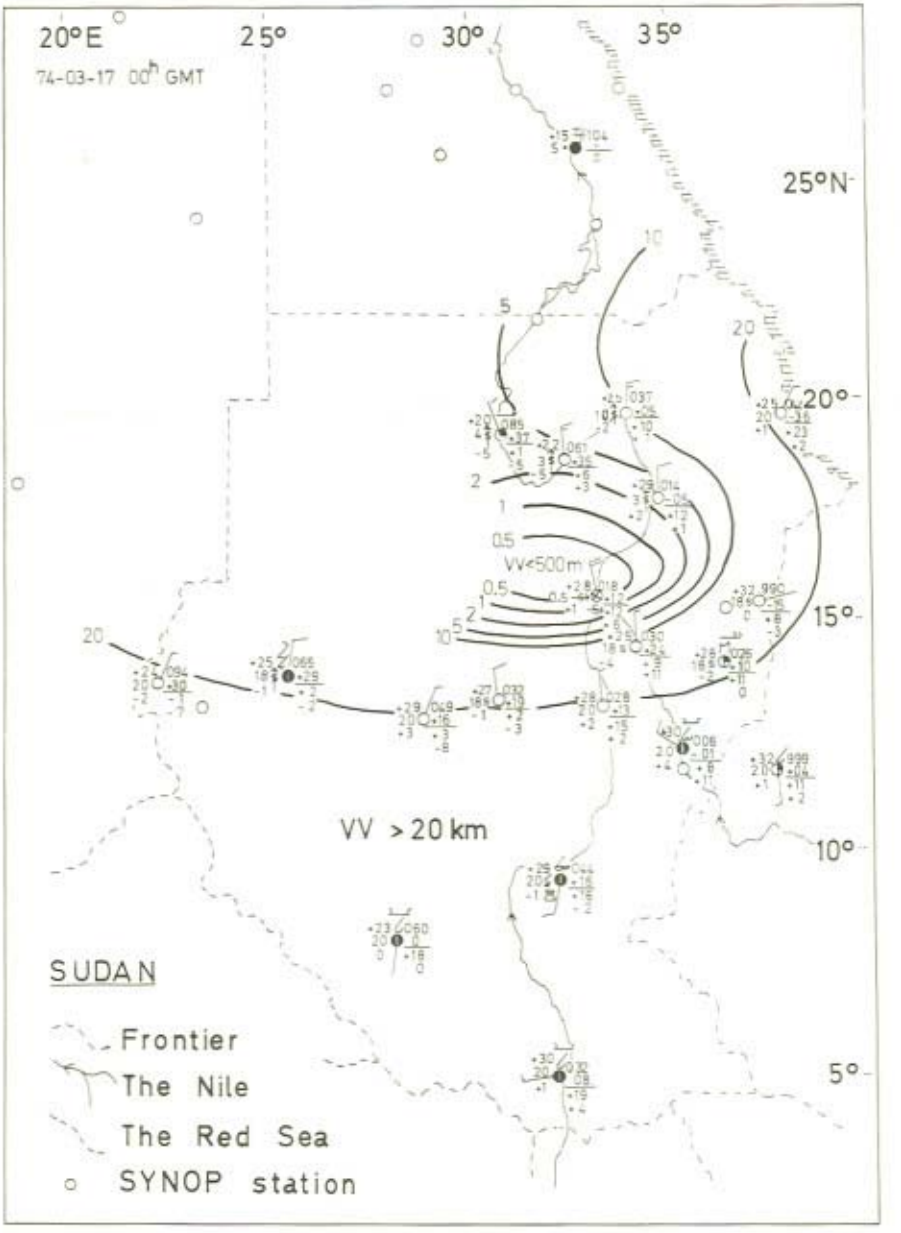

Figure 6.6 As Figure 6.4, for observation time 17th March, 1974, 00^h GMT

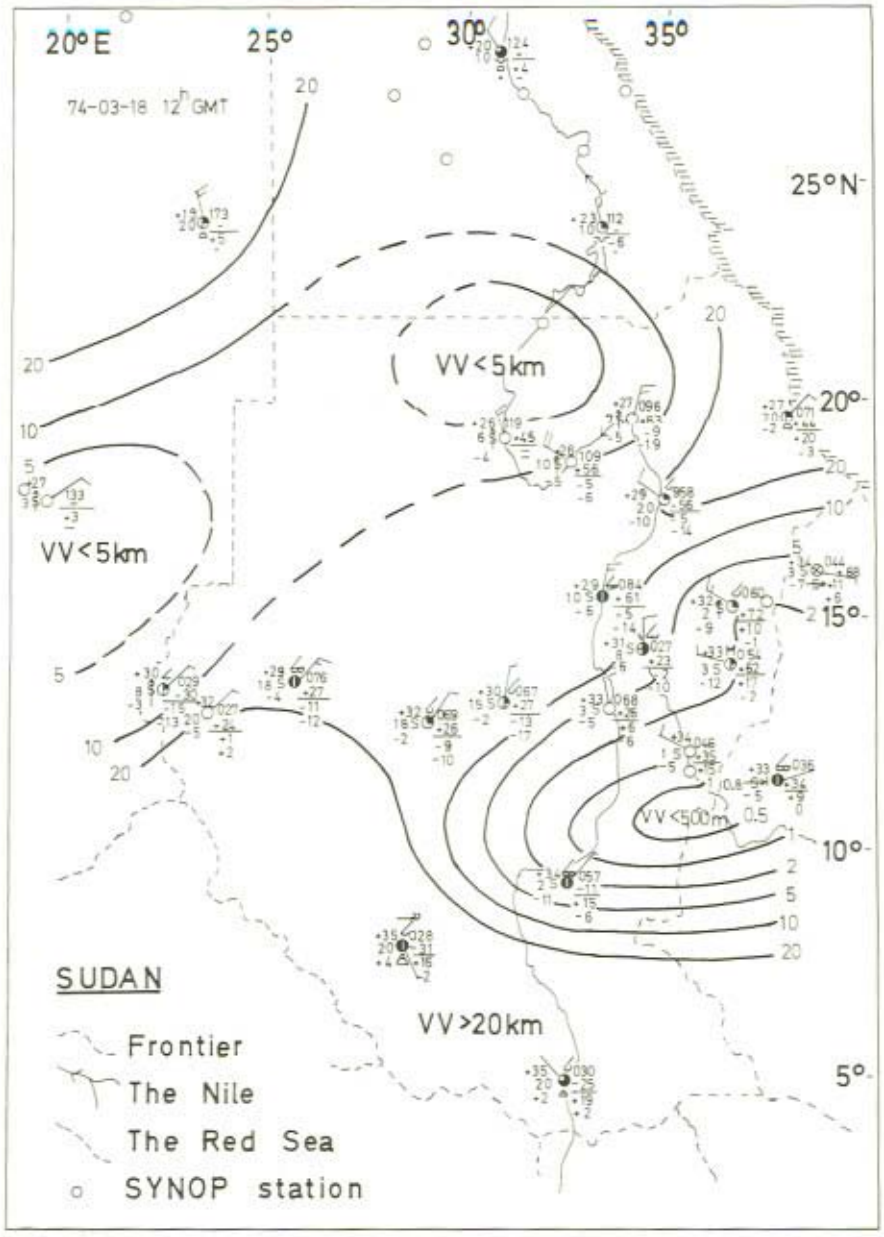

Figure 6.7 As Figure 6.4, for observation time 18th March, 1974, 12^h GMT

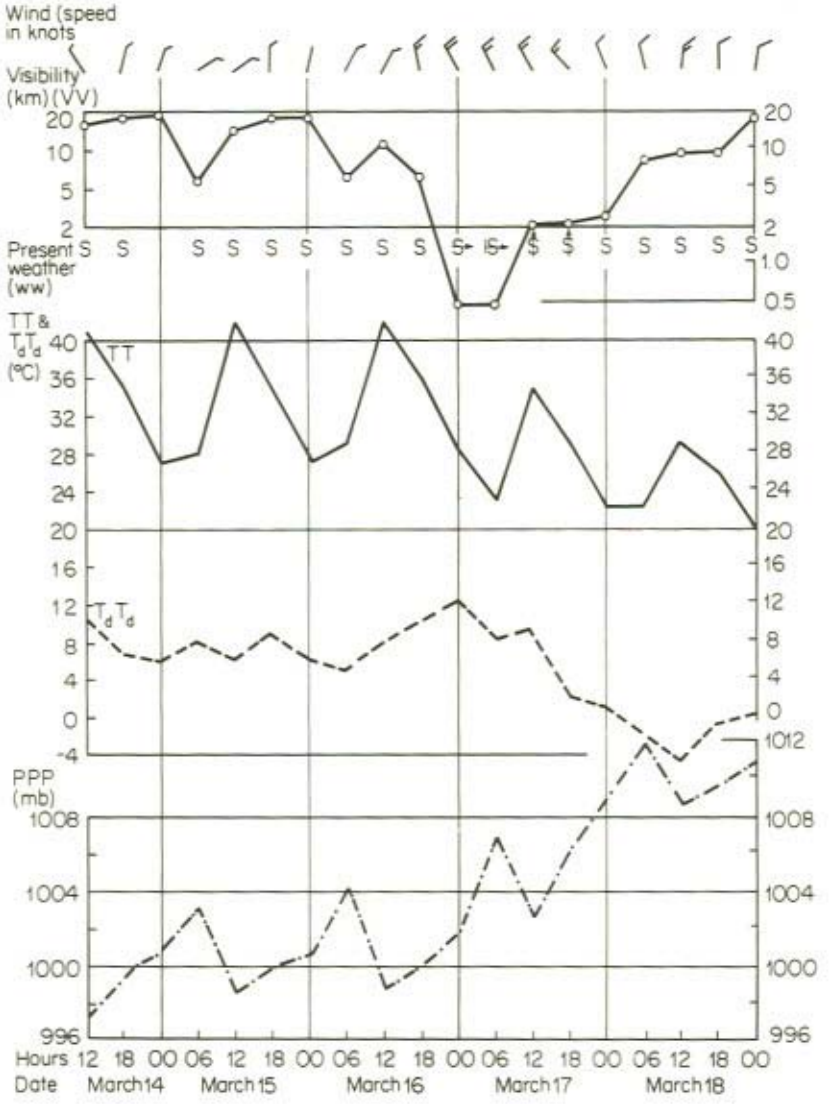

Figure 6.8 Diagram showing the variations in wind, weather, visibility, temperature (TT), dewpoint (T_dT_d), and pressure (PPP) at station 62721 (Khartoum) in Sudan, from 14th to 18th March 1974, when a duststorm moved across the Sudan. The duststorm hit Khartoum at about midnight the 17th March. The storm was connected with the invasion of a colder and drier airmass.

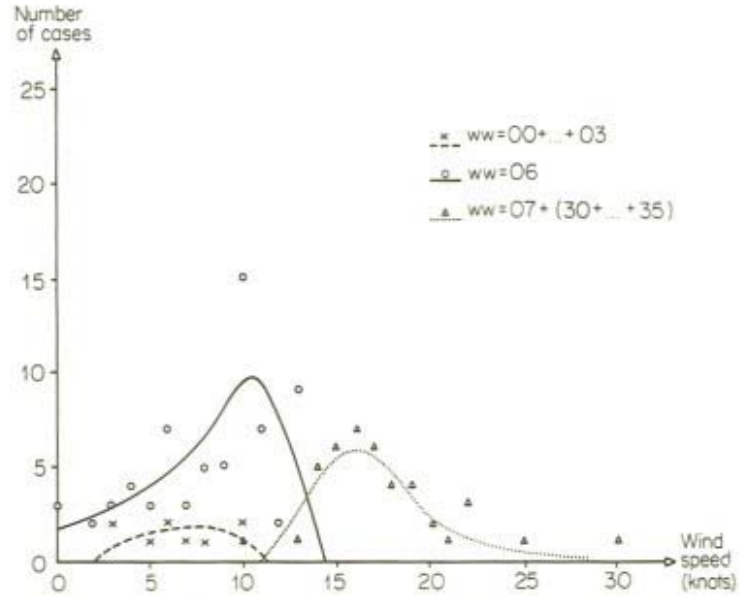

Figure 6.9 The three sets of curves give the frequencies of present weather ww = 00 + . . . + 03 (no air-borne dust, cf. Table 6.1) ww = 06 (dust suspended in the air) and ww = 07 + (30 + . . . + 35) (dust raised by the wind including duststorms) with respect to the wind speed observed at the same observation time. The observations are taken from the SYNOP station Dongola in the Sudan (station number 62650) during April 1973 (observation times 00^h, 06^h, 12^h, and 18^h GMT). The threshold wind speed for raising soil dust into the air is about 12 knots (no reports of ww = 06 above 14 knots and no reports of ww = 07 + (30 + . . . + 35) below 10 knots)

sets of curves give the frequencies of ww = 00 + − − − + 03, ww = 06 and ww = 07 + (30 + − − − + 35) respectively (for explanation of ww *cf.* Table 6.1 above), with respect to the wind speed observed at the same observation time. The mode for ww = 00 + − − − + 03 is about 7 knots, for ww = 06 about 10 knots and for ww = 07 + (30 + − − − + 35) at about 16 knots. The threshold value for dust-raising wind speeds seems to be about 12 knots [no reports of ww = 06 above 14 knots and no reports of ww = 07 + (30 + − − − + 35) below 10 knots].

Since this investigation comprises only one month and one SYNOP station the results should be regarded as preliminary.

6.5 CONCLUSIONS

The mobilization, the air-borne transport and the deposition of desert soil dust are phenomena where meteorological factors are decisive. Since many variables of

importance for studying these phenomena are available in the meteorological observations as reported from SYNOP stations these SYNOP reports can be used for such studies. This is demonstrated with two examples. In the first example a duststorm over the Sudan area is visualized by means of isophleths for visibility on synoptic weather charts. It is possible to follow on the charts the movement of the duststorm in a south-south-east direction over the Sudan area during a four day period.

In the second example the SYNOP reports have been used in a statistical study regarding the threshold wind velocity for raising desert soil dust into the air. According to this study the threshold value for dust raising wind speeds seems to be about 12 knots. This result should, however, be regarded as preliminary since the study only comprises one month and one SYNOP station.

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