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METEOROLOGY FOR LOCUST CONTROL

LA METEOROLOGIE AU SERVICE DE LA LUTTE ANTI-ACRIDIENNE

Contributions by National Meteorological Services

Contributions des Services météorologiques nationaux

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(each contribution is given in the original language of presentation / chaque contribution est donnée dans sa langue d'origine)

INTRODUCTION

Participants in the Workshop on Meteorological Support for Locust Control held in Tunis in July 1988 agreed to send accounts of the use of meteorological information for locust control practices to the WMO Secretariat for publication as a collection of case studies.

We are pleased to present herewith the contributions provided by staff of the Meteorological Services and Locust Control Services from Algeria, Ethiopia, India, Morocco, Pakistan, Senegal and Sudan.

As a follow up action to the workshop, Mr. A. Kassar, President of the Commission for Agricultural Meteorology of WMO, formulated an outline on the organization and working procedures for locust control campaign, a copy of which we are pleased to include as a conclusion to this report.

If staff from National Services in other countries have further contributions to make on this subject, the WMO Secretariat will issue a supplement to this report at a later date.

INTRODUCTION

Les participants à la réunion technique sur la contribution de la météorologie à la lutte anti-acridienne, qui a eu lieu à Tunis en juillet 1988, ont accepté de faire parvenir au Secrétariat de l'OMM, afin qu'ils soient publiés, des résumés sur l'utilisation des informations météorologiques pour la lutte anti-acridienne dans leur pays.

Nous avons le plaisir de présenter dans le présent rapport les contributions fournies par le personnel des Services météorologiques et de lutte anti-acridienne d'Algérie, d'Ethiopie, de l'Inde, du Maroc, du Pakistan, du Sénégal et du Soudan.

Suite à cette réunion technique, Monsieur A. Kassar, Président de la Commission de météorologie agricole de l'OMM, a indiqué les grandes lignes à suivre pour l'organisation d'une campagne de lutte anti-acridienne, ainsi que ses modalités de fonctionnement; ces directives sont données à la fin de ce rapport.

Si du personnel des Services nationaux d'autres pays désirent faire parvenir leurs contributions sur ce sujet, le Secrétariat de l'OMM préparera à une date ultérieure un supplément au présent rapport.

APPLICATION OF METEOROLOGY FOR THE EFFECTIVE CONTROL OF THE DESERT LOCUST

(R.C. Dubey, India Meteorological Department,
and
Satish Chandra, Directorate of Plant Protection (Locust Control))

1. Introduction:

The potential importance of meteorology in breeding and migration of desert locust is well recognised. The migration and distribution of locusts are mainly controlled by wind field, on the macro and also micro scales. The downwind displacement of flying locust population, implies a corresponding association of lower level convergance with concentration and divergence with dispersal of populations. These wind patterns are indirectly related with the distribution of precipitation too, which is essential for successful locust breeding. Thus the current synoptic charts and micro scale meteorological observations in all countries lying in the locust belt are very useful in short-term forecasting of locust movement and invasion. These informations are necessary in current developments in the technique of locust mitigation particulary while using aircraft and organising control operations on national, regional and international level.

As for an efficient aviation forecaster it is necessary to have some acquaintance with the operating characteristics of the aircraft, for an effective use of meteorological information in anti-locust operations the acquaintance with the relevant meteorological aspects of the biology of locust is essential. This takes into account not only of the flight performance and behaviour of the individual locust but also of other aspects of its biology. The availability of locusts in any distinct stage of their life cycle, successively from eggs of wingless hoppers, to newly fledged, to immature, and finally to mature egg-laying adults again, implies the previous presence of the corresponding earlier stage, within limits of time and distance.

The increased understanding and application of the effect of meteorological factors on the movement and behaviour of locusts has made the use of new technique of improved application machinery and insecticides very effective. A considerable change has come about by taking advantage of the meteorological environment and exploiting it to the disadvantage of the locust. It has also been shown that under the climatic conditions normally associated with desert locust habitates, the evaporation of the diluents from the liquid spray droplets results in a loss of deposition of the insecticides. The droplets assume their terminal velocities within a metre of the point of emission. Hence the trajectories of the droplets are the resultants of the terminal velocities and of the wind. The application of dry dusting from the ground as well as aerial spraying may be made more effective under suitable wind and humidity conditions.

The wind is very useful in both the spray barrier techniques for hoppers and air to ground aerial spray technique for adults. The egg laying, development, hatching, hopper development, mortality and adult maturation is well controlled by micrometeorological factors. The historical analysis has shown that during recessions both the swarming and non-swarming scattered populations occured over, about half as large as the invasion area. Weather condusive to predators and parasites of locust play an indirect role in reducing the alarming threat of locust.

Thus the influence of meteorological factors on the life cycle, invasion and control of locust must be fully understood by the operational anti-locust staff for a successful application of meteorological information in effective control measures. These are discussed below with some past cases described by earlier workers. (WMO, Tech.Note No. 54,69, Antilocust memoirs, Antilocust bulletins, FAO Bulletins etc.)

2. LIFE CYCLE - In view of meteorological significance:

2.1 EGG LAYING

The adult locust with a wing-span of 10-15 cm and a weight of 1-3 gms lays eggs within hours of copulation preferably in warmer, open sites with soft sandy, moist soil at a depth of 10-15 cm. If no suitable site is found, eggs can be retained for about 3 days without laying by female. This may happen because of deficient rain or inadequate vegetation to sustain the hoppers, or swarms flying over sea. The egg first laid contains less than half the water present in the young hatchlings. It minimizes the demands made by egg-laying on the water resources of female locust as compared with most other egg-laying land animals, of which the egg is laid with an initial water content sufficient for the whole embryonic stage development (Needham,1942). Therefore, the presence of free soil water is necessary at the place of egg laying to be absorbed by egg for further development and to promote the growth of vegetation to make food available to young hatchlings. Soil moisture produced by 15-20 mm rainfall within past 24-48 hours may create suitable site. Eggs can remain dormant up to 60 days if no moisture is available within soil.

The major breeding areas are characterised by a scanty and erratic rainfall averaging between 80 to 400 mm per annum. It implies a very considerable degree of coincidence of parent locusts with rainfall both in time and space. It is found that maturation is commonly delayed even up to six months until the locusts have encountered the onset of seasonal rainfall. The pysiological mechanism of this effect is still not known. Optimum air temperature for egg laying is between 22–34° C.

Soil temperature also plays vital role in the development of egg-pods. Egg development period depends upon soil temperature. The duration decreases as the temperature increases. It means the rate of egg development increases as temperature increases. Based on the work of Pradhan (1945) (Fig.1), Draper proposed a relationship between daily percentage development and mean daily air temperature expressed by the following equation.

$$Y = 9.416 \; e^{-0.00357\,(35.019 - t)^2}$$

where Y is the percentage development, t (°C) is the mean daily temperature of air.

Egg stage may continue for ten weeks at a soil temperature of 19°c at 10 cm. depth and two weeks at 34°c (Ramchandra Rao, 1942) with a threshold temperature of 14.6°c. At temperature higher than 35°c high mortality of eggs may result. Such informations are useful in operational forecasting to provide approximate dates of hatching and subsequent appearance of swarms for planning appropriate control operations.

2.2 Hopper development.

Soon after hatching, the young hoppers emerge from the soil, feed actively, grow and moult five to six times depending upon their gregarious or solitarious phase respectively. They begin to react gregariously to each other, to assemble into dense groups and march together as coherent bands covering distances from 3 to 25 kms. during this stage. Temperature and relative humidity are the main factors controlling the duration of the hoppers stage. In the field, however, hoppers are able to regulate their body temperature, by moving about in response to changes in the microclimate. As a result there is lesser variation in the duration of this stage than in the egg stage. Field studies by Wardhaugh et al (1969) showed a linear relationship between temperature and the rate of hopper development(Fig.2)

Symmons et al (1974) found that the relationship could be expressed as follows: $Y = 0.222\,t - 3.166$

where Y is the percentage development per day and t (°C) is the mean air temperature.

Based on the studies made at different places in the major breeding areas, it is concluded that:

- In summer breeding belt, most hopper development periods lie in the range 30-39 days (Wardhaugh, 1964).
- In winter-spring breeding areas the duration may vary from 25 days (mean air temperature 37°c) to two months (mean air temperature around 22°c).

In Indian situation the total heat needed by hoppers to complete full development was found to be about 8640 degree hours above 17.2°c (Venkatesh et al 1972).

Although the rainfall may be adequate to allow egg laying but inadequate to promote sufficient vegetation growth to provide food and shelter to hoppers. Ashall and Ellis (1962) recorded hoppers dying beneath the shrubs where they sought shelter during heat of the day. Inadequate reserves of food and water at hatching cause very large number of hoppers in first instance to die (Albrecht, 1962). Thus the knowledge of temperature effects will help in forecasting fledging dates of locusts.

2.3 Swarming Locust and its migrations

Environmental factors may either disperse the hopper band or may bring scattered hopper within range of mutual perception, to give rise to adult having morphometric and colour pattern characteristics of solitarious or gregarious phase respectively. Temperature determines the flying activity of locusts. At first, fledglings bask, march and feed like hoppers, till their integument hardens and flight muscles develop. Then they start to make short flights. Swarms generally take off from their night roosting sites after basking in the morning sun, when their flight muscle get sufficiently warmed. It has been shown (Gunn et al, 1948) that in continuous bright sunshine thoracic temperature may exceed those of air by 10°C within one hour of sunrise. The lowest air temperature in the absence of sun at which sustained flight has been seen to begin in immature swarms is 23-24°C while with mature swarms the air temperature may have to rise to 26°C (Gunn et al, 1948, Waloff and Rainey, 1951). In sunshine sustained flight may occur even when air temperature is 15°C but threshold temperature is 23°C in cloudy weather. Flight activity is diminished when air temperature exceeds 40°C. Metabolic heat may raise thoracic temperature of steadily flying locusts by 6°C above air temperature. As a result of the combined effects of sunshine and metabolic heat, immature swarms have been seen to leave their resting sites at lower temperature (17°C) in clear weather than in overcast weather (23°C).

The relation between temperature (T) suitable for mass departure on a particular day and the previous day temperature(P) were found to be:

T = 0.51P + 6.2 for Kenya (Gunn et al, 1948).

Other factors affecting the mass departure are strong winds, rain and fatigue. Thus in brief we can say that swarms leave their resting sites and begin to migrate about two to three hours after sunrise during warmer months of the year. But in areas having strong winds, or cool seasons, mass departure may be delayed by four to six hours after sunrise or it may be totally inhibited by low temperatures, the absence of sunshine or rain. These temperature effects provide valuable clues in predicting movements of locusts.

Swarm structure and so the flight level of locusts are controlled by state of the atmosphere. When there is a little or no convective turbulance, swarms are stratiform or low flying, where as in moderate or intense turbulence condition the high flying cummiliform swarms upto 1500-2000 metres height are characteristic features of locust migration (Rainey, 1958). There is now overwhelming evidence (Rainey, 1963) that major long range swarm migrations are down wind within 10 degrees mostly to the right due to frictional drag on the wind near ground and take place towards and with zones of low level mild convergence which are more likely to receive rain, necessary for survival. Sometimes low-flying mature swarms are found to move short distances opposite to light winds also. Thus, downwind displacement theory of locust was contradicted by Baker (1978) saying that swarm displacement is towards (i) a preferred compass direction (ii) rain in-sight (iii) high ground. Draper (1980) did not support Baker's hypothesis and showed that downwind displacement is still an adequate theory of locust movement. Wind direction should be taken as mean wind direction from surface up to the top of swarm. Relative speed and direction of swarms with wind are given in Fig.3. This finding is extremely useful in forecasting locust movement and in knowing the areas at risk of locust invasion and arranging for their prompt control. The data of fig.3 are presented in fig.4 in a different manner. It may be seen that swarms travelled at ground speeds of 1.5 to 16 km/hour, with the highest ground speeds occurring at wind speeds of about 12-24 km per hours. Using Rainey's (1963) data, Draper showed that ground speed of swarm (D km/hr) can be expressed in terms of wind speed (W km/hr) and the maximum height of flight (H metres) by the following equation:

$$D = .09071\ W - 0.0199W^2 + 0.0049\ H - 3.7373$$

The reason why large and high flying swarms have higher speeds of displacement than small low-flying ones in the same environment are not fully understood. When swarms are usually low flying, the passing of a cloud across the sun causes rapid settling. At night, air temperature in the middle of day, and heavy rain also cause locusts to settle. Migration of immature swarms normally ends when they reach areas having rain fall and mature, copulate and start laying. Mature swarms frequently resume their migration after first laying so that second and third waves of laying may take place several hundred kilometres downwind of previous laying.

3. **Synoptic features associated with locust activities and its control:**

The meteorological guidance in forecasting of locust breeding and swarm movements are essential for effective control operations. This may be divided in two categories. First is a long term strategic forecast useful for plannig the procurement and distribution of stores and equipment for coming season. Second is the short-period detailed tactical forecast useful for movement of personnel and mobile control units acording to weekly, daily or hour to hour movement of swarms. Long term forecasts are based on the regularity of seasonal migration of swarms and breeding zones to be prepared from past records. One such map described in a series of papers (Davies, 1952, Donnelly, 1947, Fortescue-Foulkes, 1953, Waloff, 1946, 1966) is shown in Fig.5.

Synoptic features and their future development are found to be associated with the distribution and movement of desert locusts. The Inter-Tropical Convergence Zone (ITCZ) clearly dominates the movements and distribution of locusts throughout almost the whole area infested. Extreme position of ITCZ in July and January are shown in fig.6 for most of the year. Any departure from the regular seasonal movements of ITCZ can also be of major significance in relation to locusts.

Detailed analysis have shown that the air brought into circulation of cyclones from the surrounding countries may collect locusts from any scattered solitary living population as well as survivors from several swarming populations. The associated widespread and scattered rains may provide conditions suitable for rapid multiplication of all such immigrants causing outbreak. Locust movements are also associated with extra tropical disturbances like depressios and trough of low pressures travelling in generally eastward direction along the Mediterranian and Persian Gulf and across north-western Indo-Pakistan and also induced lows at lower latitudes over Rajasthan and Gujarat in India. These synptic features arise from corrsponding changes not only in wind field but also in air temperatures. The Eddies always have the effect of aggregating, not dispersing, swarms of locust. Air reconnaissance is capable of tracking the movement of swarms and provide informations on the number and size of swarm in invasion. Meteorological guidance is necessary for appropriate planning of flying height and direction in aerial operations. Long range movement and redistribution of swarms are related to the wind fields which may be quasi-uniform or show day to day variation for which pilot balloon ascents are needed.

In addition, weather radars located in infested areas may also be used for locust tracking. Ships used for marine meteorological services and full network of densely situated observatories may provide locust sighting data during locust season.

4. General patterns of swarm movement and breeding in India

The general sequence of events during year of locust swarm activity in India may be classified under (i) over wintering (ii) spring breeding and (iii) summer breeding.

During winter months (December-February) swarms are inactive, pass the cold weather scattered among vegetation and may make short migration flight during any warm spells occurrences. If good rainfall occurs due to western disturbance passing over in January/February, locusts attain early maturity and may begin laying eggs.

The adults of winter-spring brood from complimentary areas in Pakistan, Iran, Arabian Peninsula etc. are ready for flying by April/May and carried by prevailing westerlies towards India. During this time the desert areas of Rajsthan, Gujarat and Haryana are hot and dry and as such the swarms may rapidly migrate eastwards upto Assam, or southwards if northerly wind prevails. Extreme positions reached so far are shown in figure 7. Further waves of migrant swarms mostly invade India during July. With the occurrence of good monsoon rain by this time, they start laying eggs. Swarms earlier migrated eastwards also return to desert area because of easterly winds in Indo-Gangetic belt. If August and September have good rains the swarms may lay second and third batch of eggs. By middle of October due to sudden rise in temperature, fall in humidity and change in wind direction to north-easterlies (fig.8) the swarms are carried towards south-west and start breeding in winter-spring rainfall zone of Baluchistan and Iran (Ramchandra Rao, 1941).

With such knowledge of wind pattern controlling migration routes, it is possible to prognosticate with the fair degree of accuracy, where attacks of swarms might be expected. So the countries concerned may be prepared for the invasion beforehand. Seasonal distribution of swarms over India were studied by Dubey et al (1987) based on data from 1945 to 1980. Peak activity was found in August.

5. **Satellite application in locust control:**

The erratic distribution of rain in the vast locust belt makes it difficult to detect potential breeding sites by manual survey in short time. Using the extensive knowledge of the bio-geography of desert locust, satellite can help to delimit the most likely breeding pockets. It may lead to an improvement in the forecastig of population changes and a consequent improvement in control strategy by detailed plannig of survey and control meaures. Tonal variation in the imagery caused by recent rains or renewed growth of vegetation makes it possible to locate the suitable breeding areas. The temporal monitoring of desert vegetation in western Rajasthan through Satellite imageries attempted by Sinha and Satish Chandra (1987) are shown in Fig.9. Thus an efficient survey and control programme can be mounted to check the locust population from building up and averting serious upsurge and plague conditions.

6. **Case studies:**

6.1 Radar study of locust swarm over Delhi:

On 26th July 1962 large swarms invaded over Delhi and infestation continued until 29th July (Mazumdar et al,1965) (fig.12). They were observed on storm detection radar. A photograph of the echo out of several photographs taken by National Physical Laboratory, New Delhi is reproduced in Fig.13a. It contains prominent echoes on the plan position indicator (PPI) display in the third quadrant which indicates the dense concentration of locust there. Their vertical extent reached upto at least 1.5 Kms. (fig.13b.). The stream line chart shows winds from the western sector, of speeds ranging between 15 and 25 Kms over Delhi.

This feature could be associated with a flow of swarms from Rajasthan into the areas surrounding Delhi, along with Westerly wind flow shown in fig. 14.

6.2 Swarm migration and formation during the passage of cyclonic storm:

There was heavy infestation of swarms in India and Pakistan (Pedgley, 1969) during September 1961 (Fig.15a). A depression formed over the head Bay of Bengal on 5 September moved upto north Arabian sea turning into cyclonic storm by 15 September following the track shown in fig.15b. The corresponding change in wind direction over the infested areas brought several swarm over Kutch and Gujarat region under the influence of north-westerly wind on 9 September (fig.15c). The depression passed out to sea on 14th and the swarms were dragged off-shore into the Arabian sea by easterly to north-easterly winds over Mekran coast (fig.15d). This westward movement of swarm was exceptionally early due to special track followed by the storm. This helped in issuing timely warning to the countries concerned. This case was an example of how an appreciation of the local current weather information could help the locust control departments. It may be possible for the meteorological departments of the countries to provide accurately timely warning of such developments at an earlier stage if there is good co-ordination with locust department.

In September 1962, a severe cyclonic storm passing through southern part of Pakistan influenced a number of swarms widely dispersed around the area into a focal point and the associated rains made the area suitable for breeding and the swarms could stay there for a long time (Venkatesh, 1979). The anti-locust forces could launch a very economical, successful and speedy compaign. This shows the importance of an intelligent and prompt appreciation of weather factors in creating a locust population explosion. A sudden appearance of a swarm in June 1964, over Rajasthan, when the country was in midst of a locust recession was due to a cyclone developed off the Saurastra coast and moved in land (Venkatesh, 1971).

6.3 Meteorological aspects of some recent swarms and anti-locust compaign in India.

Heavy and widespread rains caused by some cyclonic disturbances created favourable breeding conditions in the 'Horn of Africa ' during October 1977 (Paharia et al, 1981). Due to lack of control operations swarms invaded coastal areas of Red Sea and Saudi Arabia. A huge chunk of swarms were lifted and dumped on the coasts of Karachi and Saurashtra on 8th June 1978 by a storm which developed in Arabian sea, deviating from their normal migration route throughout Afganistan and Pakistan. The locust warning organisation (LWO) of India sprang into action from the first day of incursion. No swarm was allowed to breed or do any damage in Gujarat because of timely successful operation. But some swarms flew over the Rajasthan and due to strong and erratic winds they split up and got widely dispersed and then controlled. Another incursion of swarms started on 4th August 1978 in

Jaisalmer and Barmer districts of Rajasthan, which was also controlled. Third wave started on 20th September when 14 districts of Rajasthan were affected. The winds continued to be south-westerly during September to mid October and later the pattern became erratic. Hence the possibility arose that the swarms would exist and re-enter India from the west. But they were timely controlled.

Western Rajasthan received heavy and wide spread rainfall during July 1983, creating highly favourable condition for the breedidng of widely scattered locusts already present there. Similar favourable conditions continued up to August. A swarm entered India on 31st August from west under the influence of north-westerly wind during this month. All these swarms were promptly controlled by ground operations (Satish Chandra, 1985). There was a sudden influx of considerable, low density scattered population in July 1986 from across western border harbouring widespread locust population during earlier months. This coincided with heavy and widespread rainfall in the Indian desert and triggered the development of the seasonal upsurge from August onward (Satis Chandra, 1988). These were controlled both by ground and aerial operations. Due to monsoon withdrawal from September ecological conditions for breeding deteriorated and scattered adults undertook their usual west-ward migration with wind during autumn (fig.8).

7. **Applications of meteorology in anti-locust operations:**

Locust forecast depends upon a proper assesement of continually changing locust situation in the light of known locust biology and ecology which is already described in detail. An ideal report should contain as much information as possible about locust. The forecast should consist the guideline on the scale, timing and location of likely changes in the locust distribution, for survey and control teams in the field on where best to look for locust on a monthly, weekly, daily or even hourly basis.

Detection of solitary locust population is difficult in desert areas unless locust surveys are conducted during suitable hours. The solitarious locusts are most active when the soil temperaure ranges between 25°c to 30°c after their morning basking in the open patches between bushes. This information helps in formulating survey schedules for Locust Warning Organisation to get the best results in surveys. As such timings of locust surveys during summer months have been fixed between 0800-1100 hrs. and 1600-1900 hrs.IST, while in winter season the timing are between 1000-1500 hrs. IST.

Wind helps to know the spatial distribution of direction and speed of swarm movements which generally fly with a speed slightly less than wind speed. This requires the wind field analysis by plotting stream lines, isotach and isogons. A sample of these isopleths are depicted in figures 10 and 11. The isogones are the lines joining places having same wind directions.

The rainfall distribution in a particular area controls the maturity period, population density and the plague upsurge of locust. Once the breeding has started, the approximate period of hatchlings coming out from the ground can be estimated if the soil temperature and moisture availability is known. Therefore, meteorologist should supply informations about winds convergence or divergence, convection and turbulance in the lower atmosphere upto 1.5 kms., temperature and moisture upto the upper 10 cm. depth of soil, sunshine and cloud.

8. **Existing set up of Locust Control Organisation in India:**

Following the Desert Locust plague of 1926-31, a scheme of research on Desert Locust was sponsored by Indian (then Imperial) Concil of Agricultural Research in 1931. The scheme made good contribution to the understanding of locust problem in general and so the Government of India established a permanent Locust Warning Organization (LWO) in 1939. It was merged with the Plant Protection, Quarantine and Storage Directorate under the Ministry of Agriculture, Govt. of India in 1946. At present it maintains a permanent Locust Warning Organisation for survey and control of locusts in 200,000 sq.kms. of the scheduled desert area of India comprising parts of Rajasthan, Gujarat and Haryana. Whole area is divided into four circles which are further divided into 9 zones maintaining 34 outposts well equipped with vehicles, wireless set, locust control equipment and insecticides. Aircraft meant for locust reconnaissance and control is maintained by an autonomous body under the Government of India. During emergency its services can be utilised at short notices. The Central Field Headquarter at Jodhpur Co-ordinates the work of all circles and also maintains a direct link with the Director of Locust Control located at Faridabad (fig.16).

8.1 Functions

LWO studies the fluctuation in locust population in the scheduled desert area to detect tendencies, if any, for its transformation into gregarious phase and warns all concerned and prevents swarm formation by destroying incipient hopper population. It also collects and collates information on locust incidence from various parts of India and other countries and disseminates it to all concerned and renders technical assistance to all states in locust control. Training courses in locust biology and control are also held periodically for the benefit of agricultural staff of various states.

Locust outpost staff conduct field surveys 5 days a week in a radius of 5 to 15 kms of each location as per the survey schedule prepared in advance in the begining of a year. The surveys are conducted on foot by beating the bushes with a stick and counting the number of locusts in one or more transects of 1 km each. This information is passed on to zonal office as a matter of routine. The locust activities are daily transmitted through wireless. Information is also collected by outpost staff by making personal enquiries from local people. The police, custom, postal, railway, observatories, school staff etc. also transmit locust information to the nearest locust office. The zonal offices pass on the information to the circle office which in its turn to field headquarters, Jodhpur and Central Office at Faridabad. The information is further processed and forecast is prepared on the likely developments in the desert locust activities at Faridabad. A fortnightly locust situation bulletin is issued for use by a large number of functionaries in India and other locust prone countries. India also receives locust information from FAO and several other countries at periodical intervals.

8.2 Meteorological services in anti-locust operations

Based on the recommendations in the WMO/FAO regional training seminar on the relation between meteorology and the desert locust held in Tehran from 25 November to 11 December 1963, India Meteorological Department established a Locust Meteorology Unit at Pune in 1971. Under this scheme, 7 Pilot Balloon cum-micrometeorological observatories are functioning in north-west part of India. For reporting locust sighting data during locust season, 130 meteorological observatories have been earmarked. These are depicted in fig.7 where boundaries of locust invasion indicate the earlier extreme cases reported so far.

India Meteorological Department keeps liaison with Indian Locust Control Organisation and provides concerned upper wind and rainfall data throughout the year. In locust invasion period, special rainfall forecasts are issued and special pilot balloon ascents are taken for antilocust operations. Because of the alertness, good co-ordination and effective control measures, hardly any plague upsurge is noticed after 1970. The locust infestation area is also very much reduced and centred around Rajasthan desert only.

9. **Benefits through meteorological information:**

Availability of timely meteorological information has proved very useful in locust forecasting work which facilitates in making advance preparation for locust campaign. Efficiency of control operation is determined to a large extent on judicious use of various meteorological information like rainfall, temperature, wind etc. as enumerated in the foregoing paragraphs. In addition, weather parameters are indispensable in assessing and analysing locust situation on national or regional basis. Detection of locust population in the early hopper stages has been possible because of weather based forecasting. During this stage locust is most vulnerable and control operations are most effective and economical in terms of consumption of pesticides and speed of control operations. Consequently pollution of environment is reduced. In addition meteorological data are frequently required for research oriented case studies with a view to improve locust forecasting both on short and long term basis.

10. **Need for further strengthening of coordination between Met.Dept.& LWO**

In view of the foregoing discussions, it can be mentioned that the displacement of both day flying gregarious and night flying solitarious locusts is downwind and is strongly affected by temperature. It is therefore of great use to a locust forecaster to know what wind and temperature might have been or likely to be met by the flying locusts. The places of wind convergences can be recognised on synoptic weather maps, which can be used to find out locations of locust outbreaks. Because winds and temperature are also continuously varying with height, time and space, locust forecasters need a way of depicting the variations over the area, and for the period of movement. Therefore, availability of synoptic weather maps and upper air charts upto 3 km height of the high frequency breeding area of Rajasthan are needed on daily basis. There is active cooperation between meteorologists and locust entomologists in the country and this should continue.

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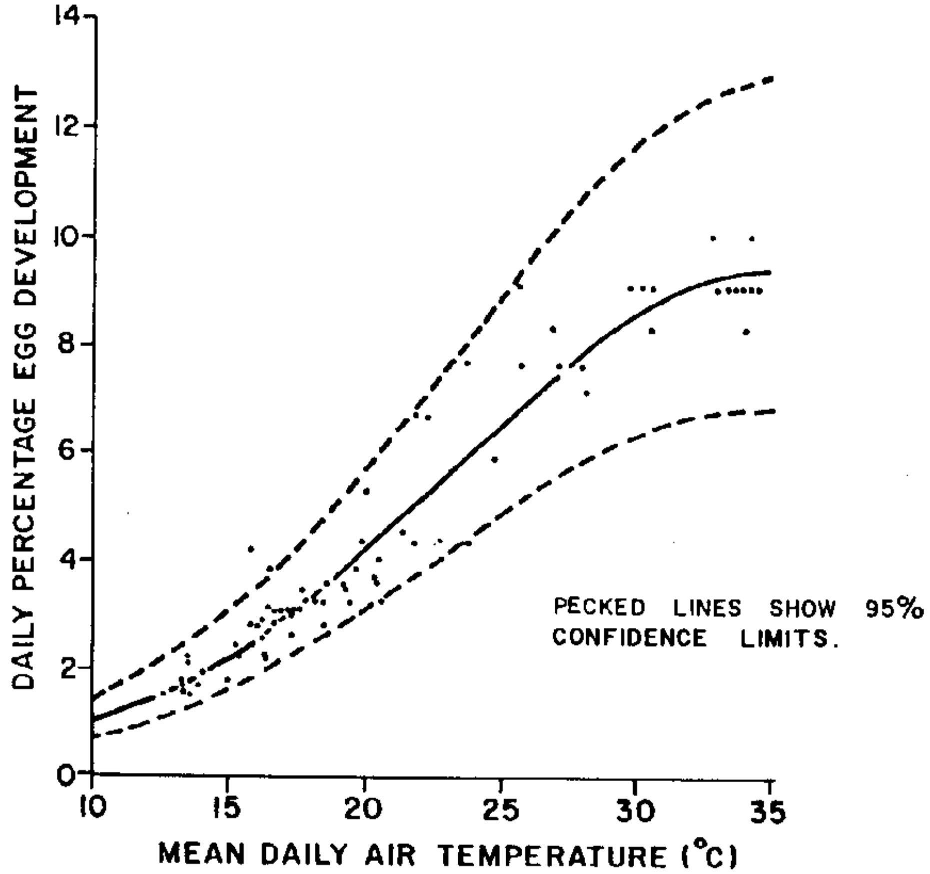


FIG. 1: VARIATION OF DAILY PERCENTAGE EGG DEVELOPMENT WITH MEAN DAILY AIR TEMPERATURE.

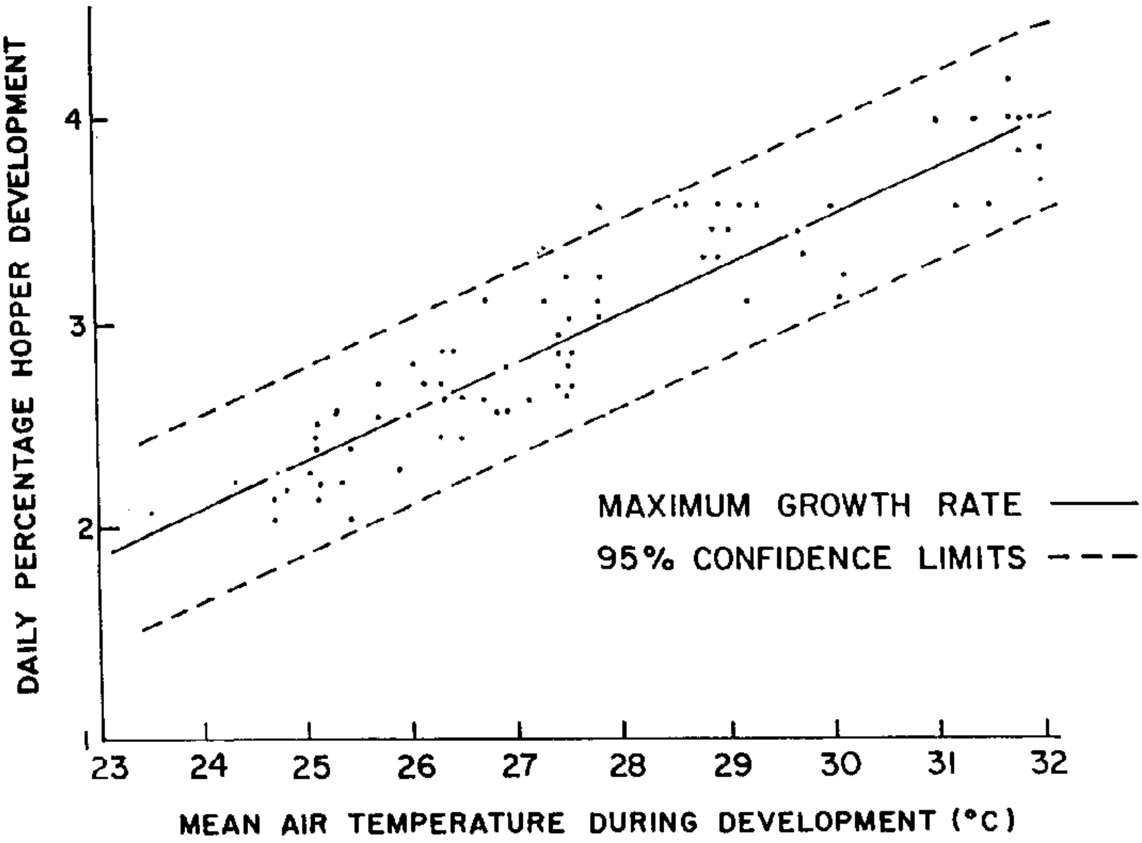


FIG. 2 : VARIATION OF DAILY PERCENTAGE HOPPER DEVELOPMENT WITH MEAN DAILY AIR TEMPERATURE

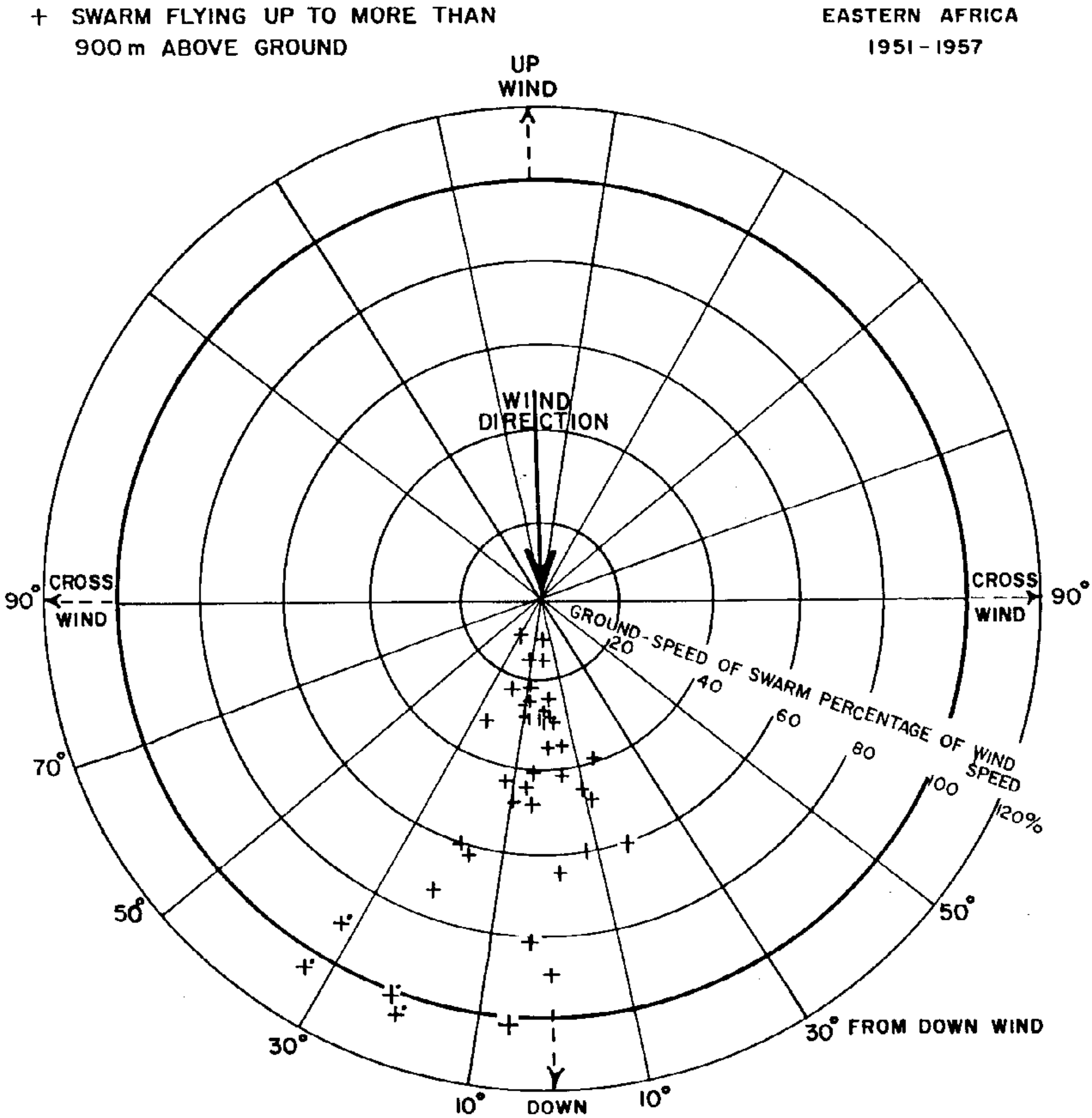


FIG.3 : DIRECTION AND SPEED OF DISPLACEMENT OF INDIVIDUAL SWARMS IN RELATION TO WIND.

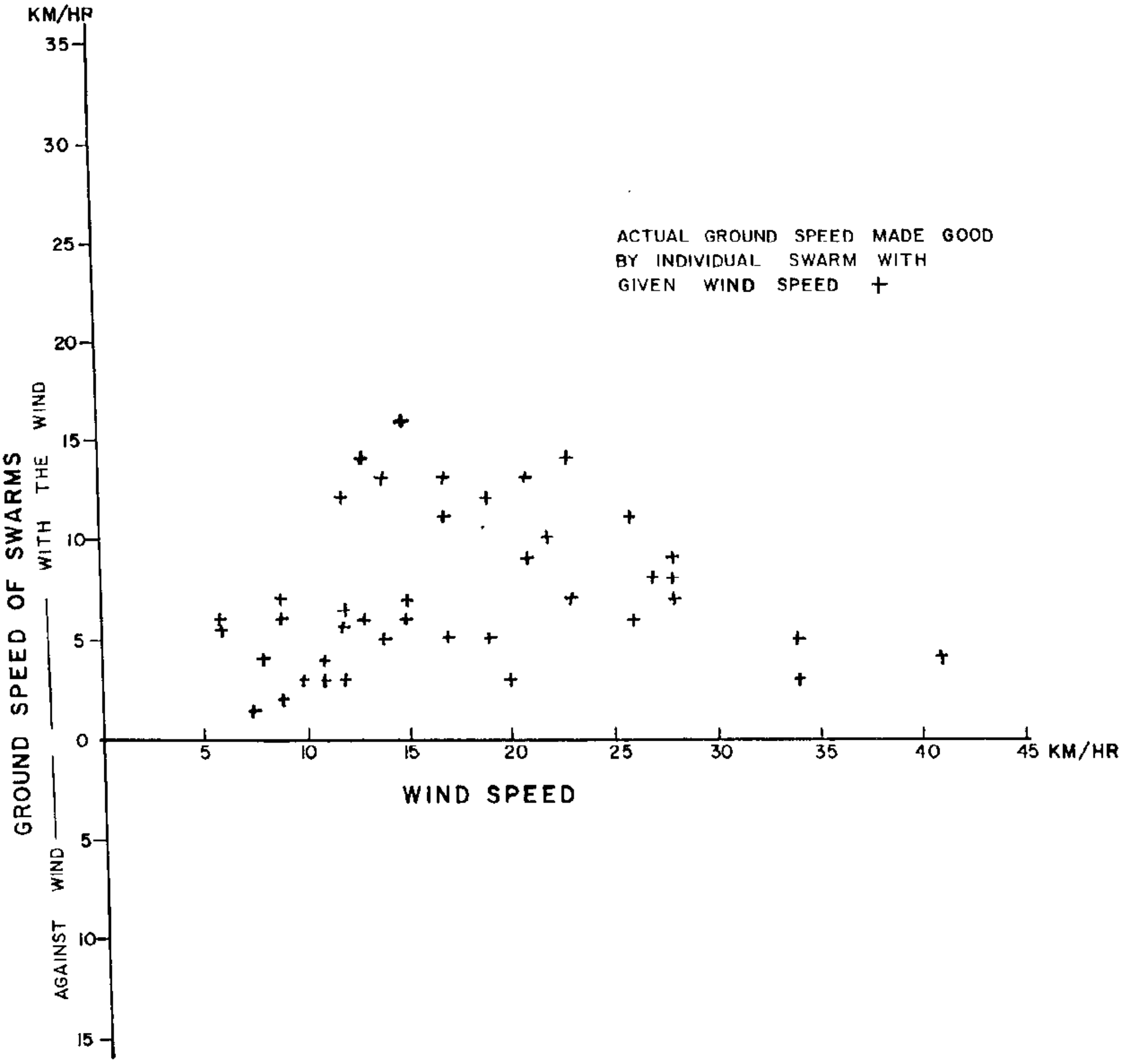


FIG.4: GROUND SPEED OF INDIVIDUAL SWARMS IN RELATION TO WIND SPEED.

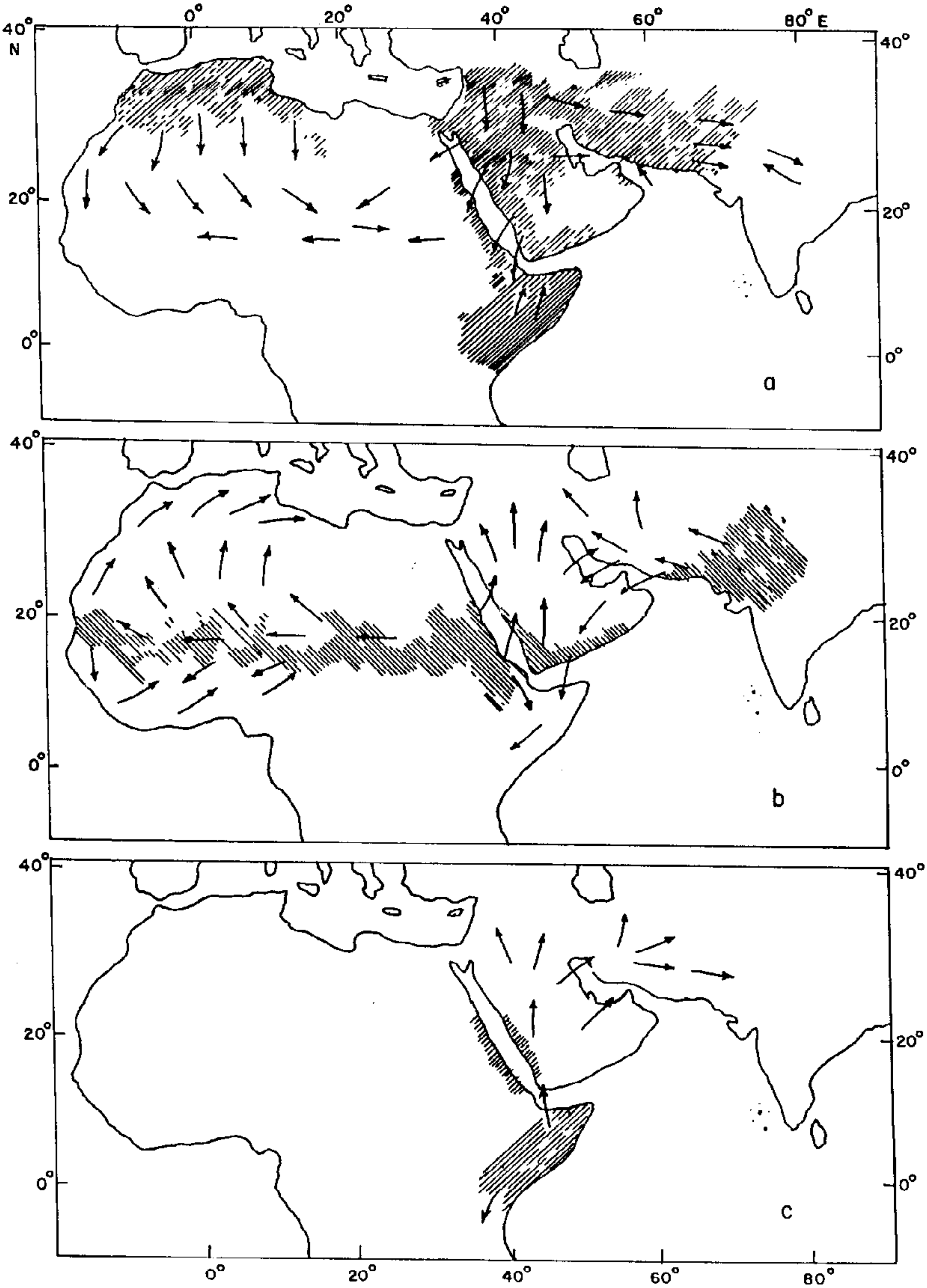


FIG. 5: SEASONAL BREEDING AREAS AND MAJOR MOVEMENTS OF DESERT LOCUST SWARMS. a, SPRING (MAR.-JUN.); b, SUMMER (AUG.-SEPT.); c, WINTER (OCT.-JAN.).

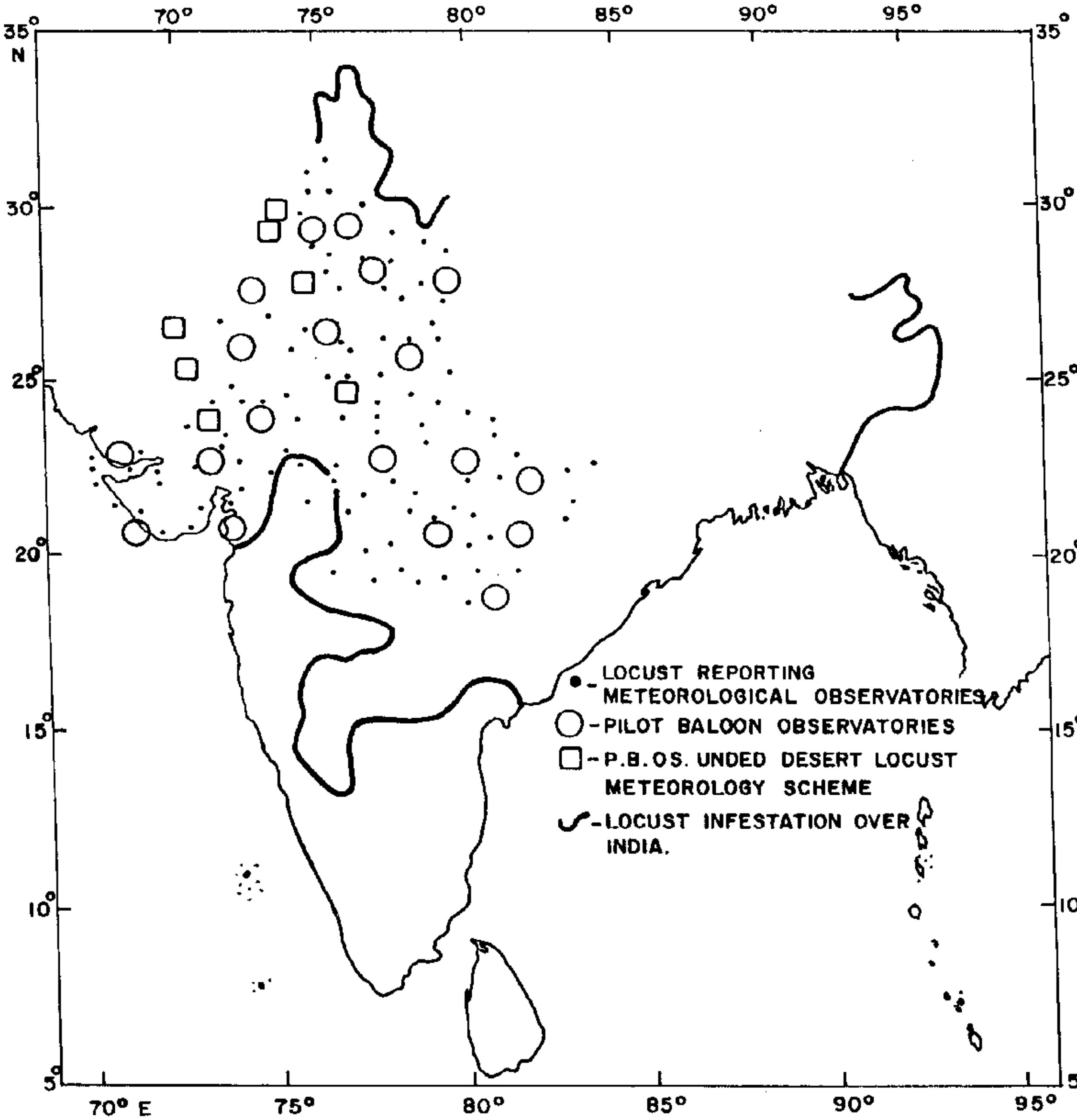
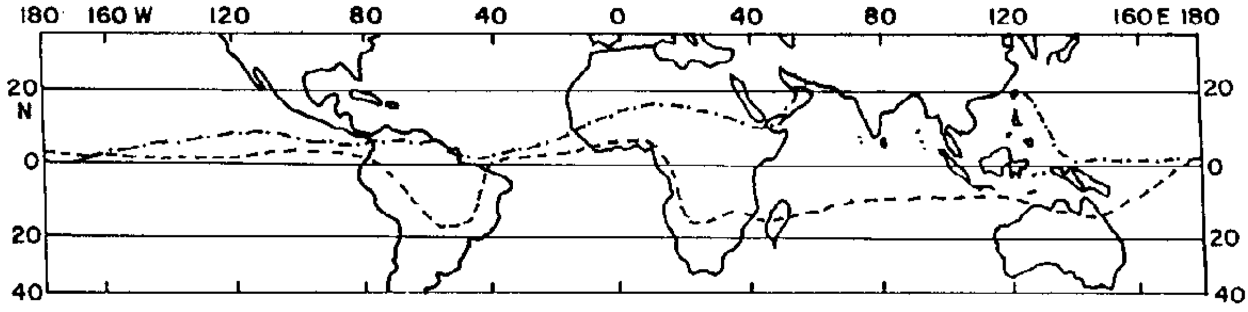


FIG.7.

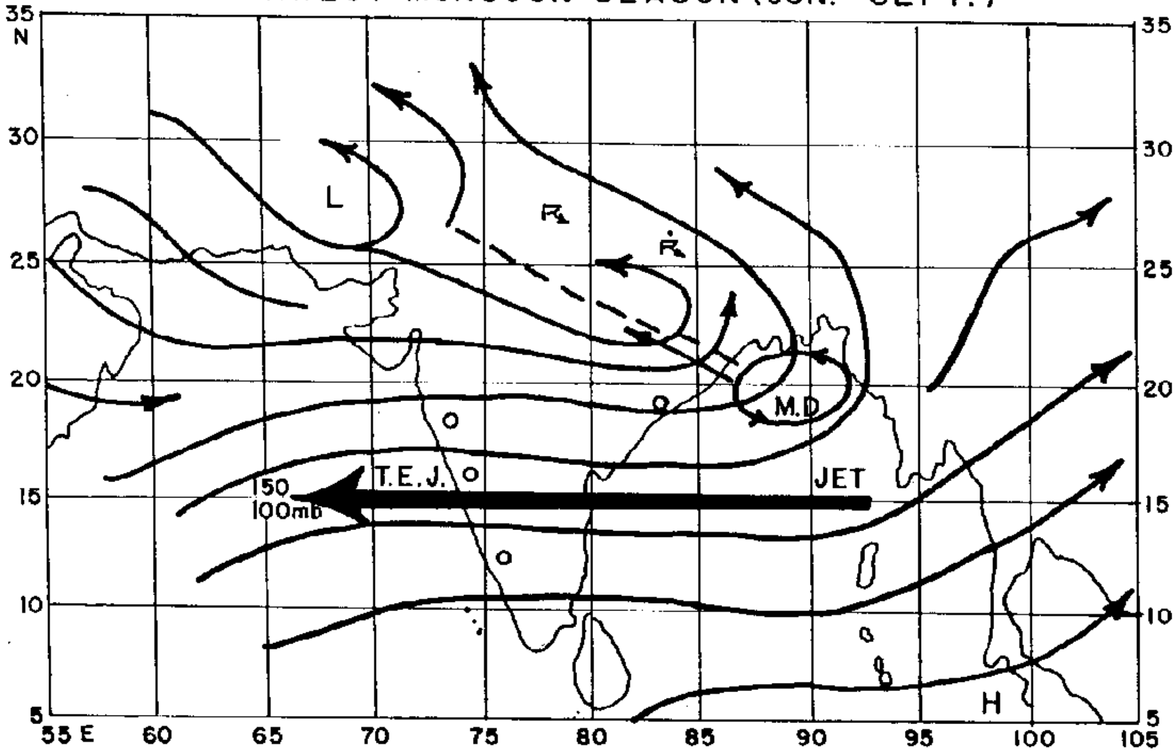
I.T.C.Z IN JANUARY ----



I.T.C.Z. IN JULY —·—·—

FIG.6.

SOUTHWEST MONSOON SEASON (JUN.- SEPT.)



RETREATING MONSOON SEASON (OCT. & NOV.)

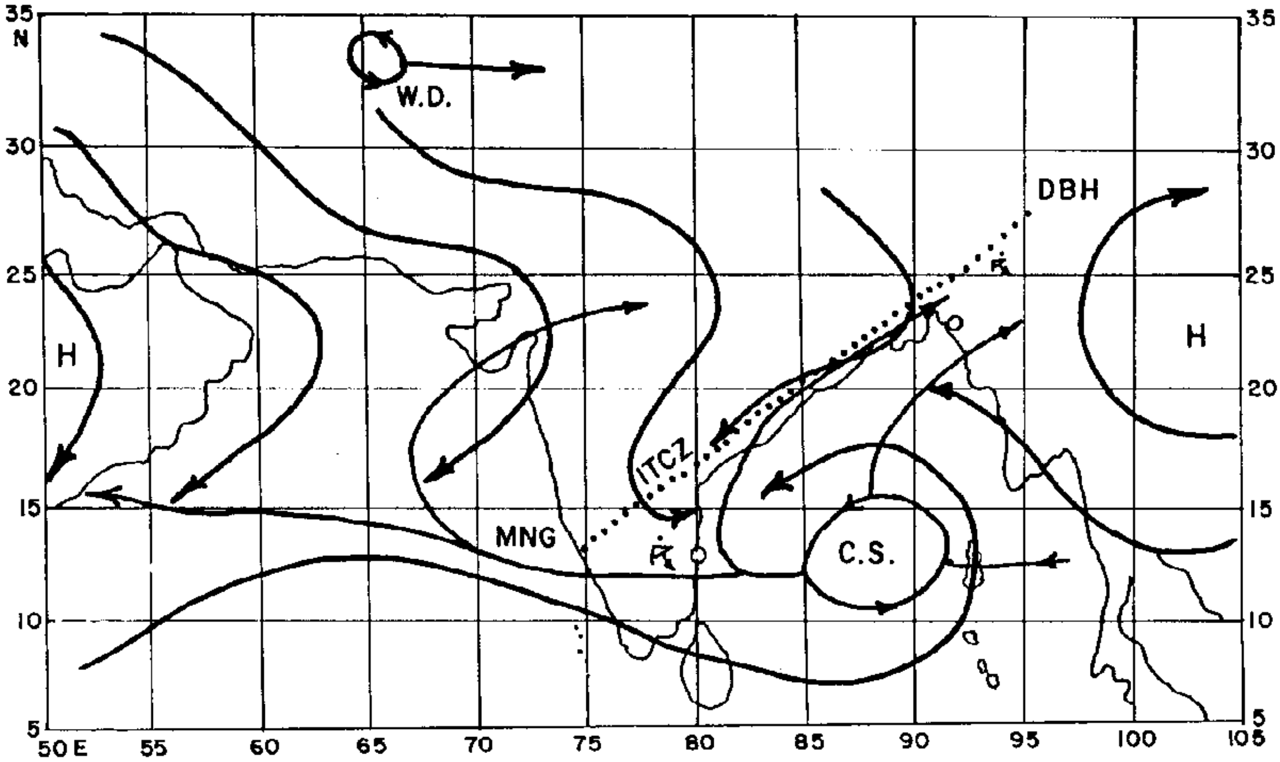
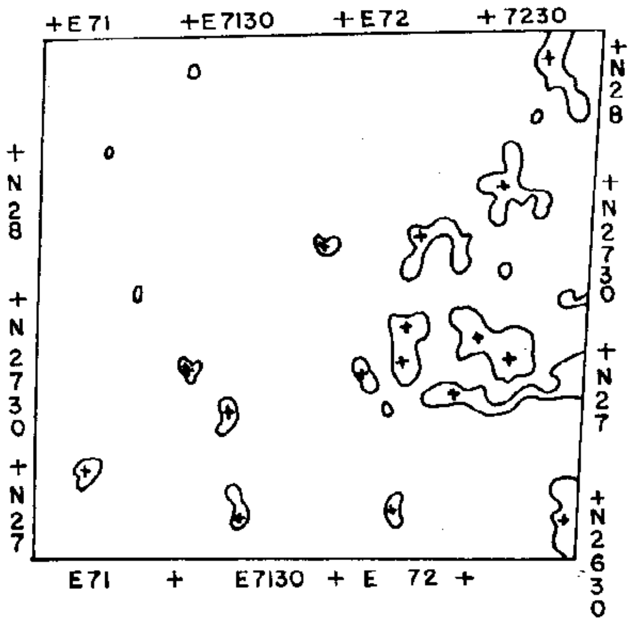
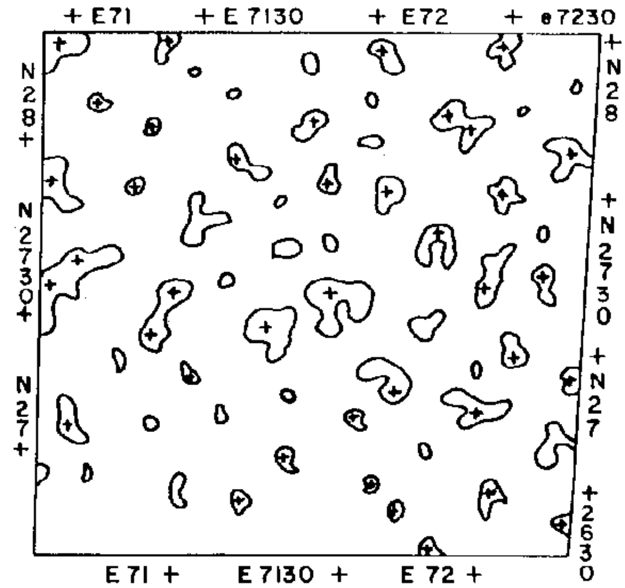


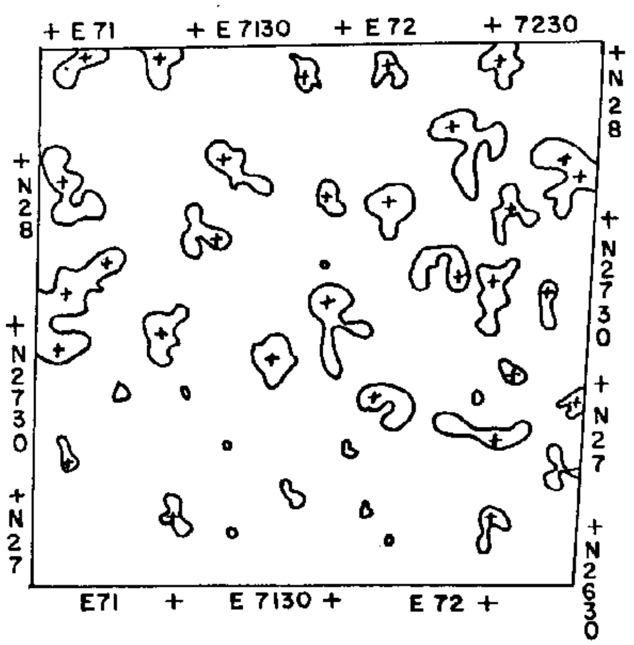
FIG. 8: STREAMLINES AT 850 MB LEVEL

VEGETATIVE CONDITIONS ON 20·5·81.
GREEN PATCHES DUE TO PERENNIAL VEGETATION. VERY LOW POTENTIAL FOR BREEDING.

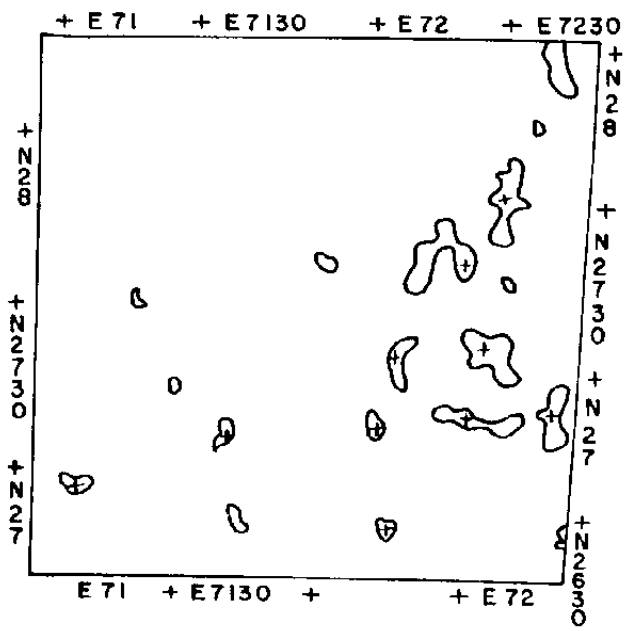


VEGETATION CONDITIONS ON 31·7·81.
MAXIMUM GREEN VEGETATION DEVELOPMENT DUE TO GOOD RAINFALL. HIGH POTENTIAL FOR LOCUST BREEDING.





VEGETATION CONDITIONS ON 13·7·81
GREEN VEGETATION AREA INCREASED DUE TO SCATTERED RAINFALL. DEVELOPMENT OF EPHEMERAL VEGETATION. LOW POTENTIAL FOR LOCUST DEVELOPMENT.



VEGETATION CONDITIONS ON 11·10·81
RAPID DECLINE OF BIOMASS. DRY VEGETATION THROUGHOUT AREA. UNSUITABLE FOR LOCUST BREEDING.

 → INDICATES VEGETATION COVERAGE.

FIG. 9.

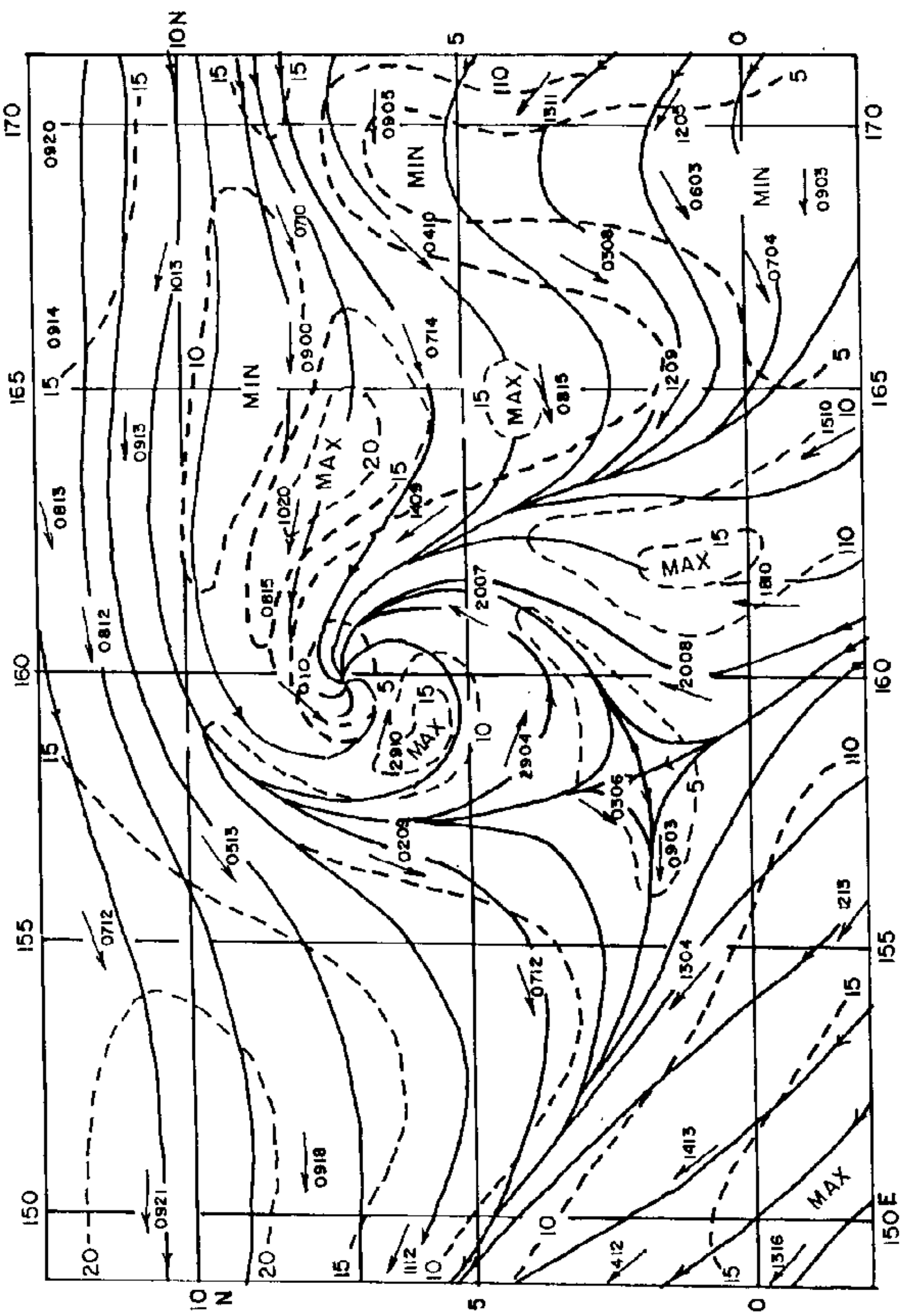


FIG. 10: A COMPLETE STREAMLINE-ISOTACH ANALYSIS

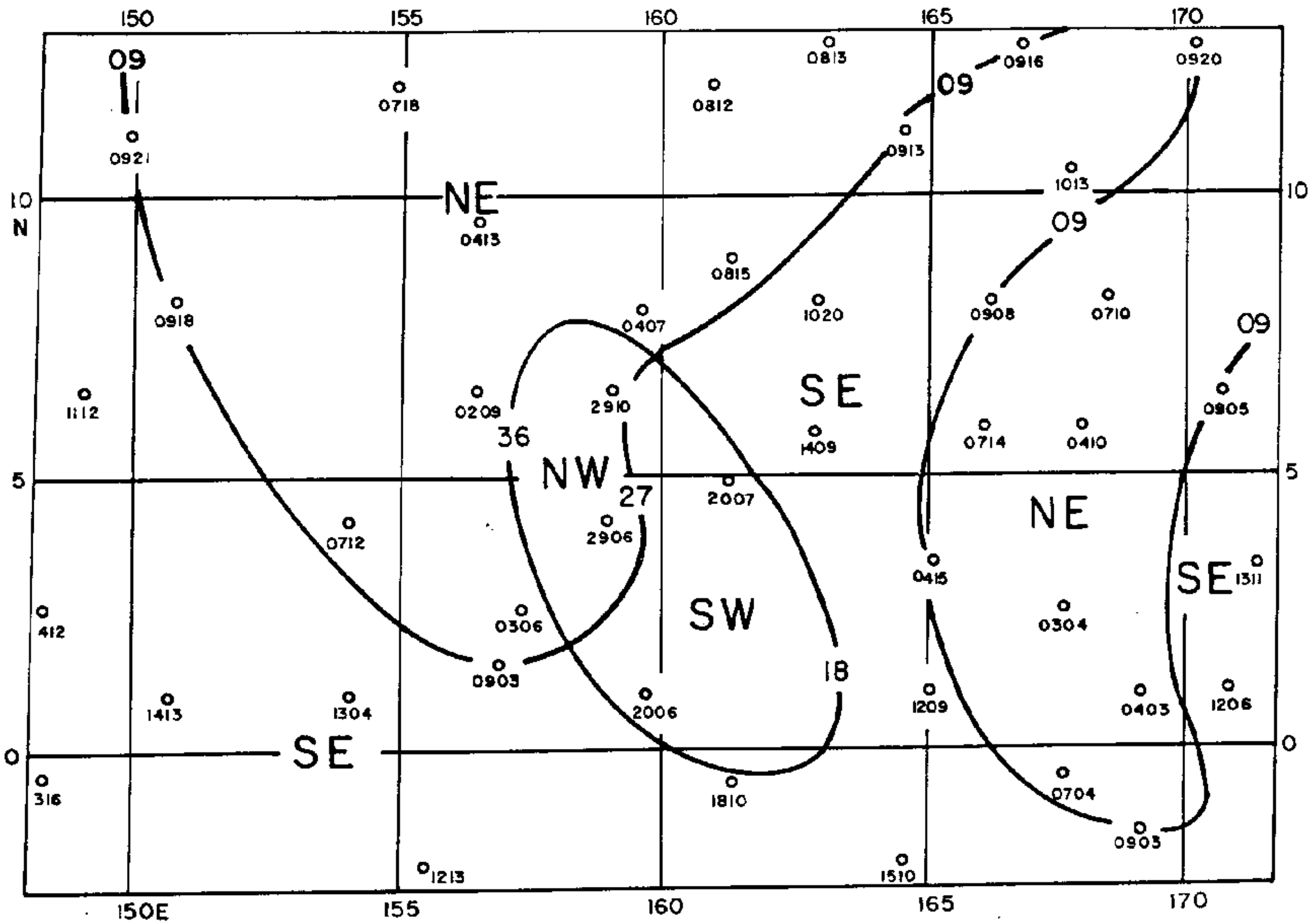


FIG. 11: A PRELIMINARY SKETCH OF THE CARDINAL ISOGONS

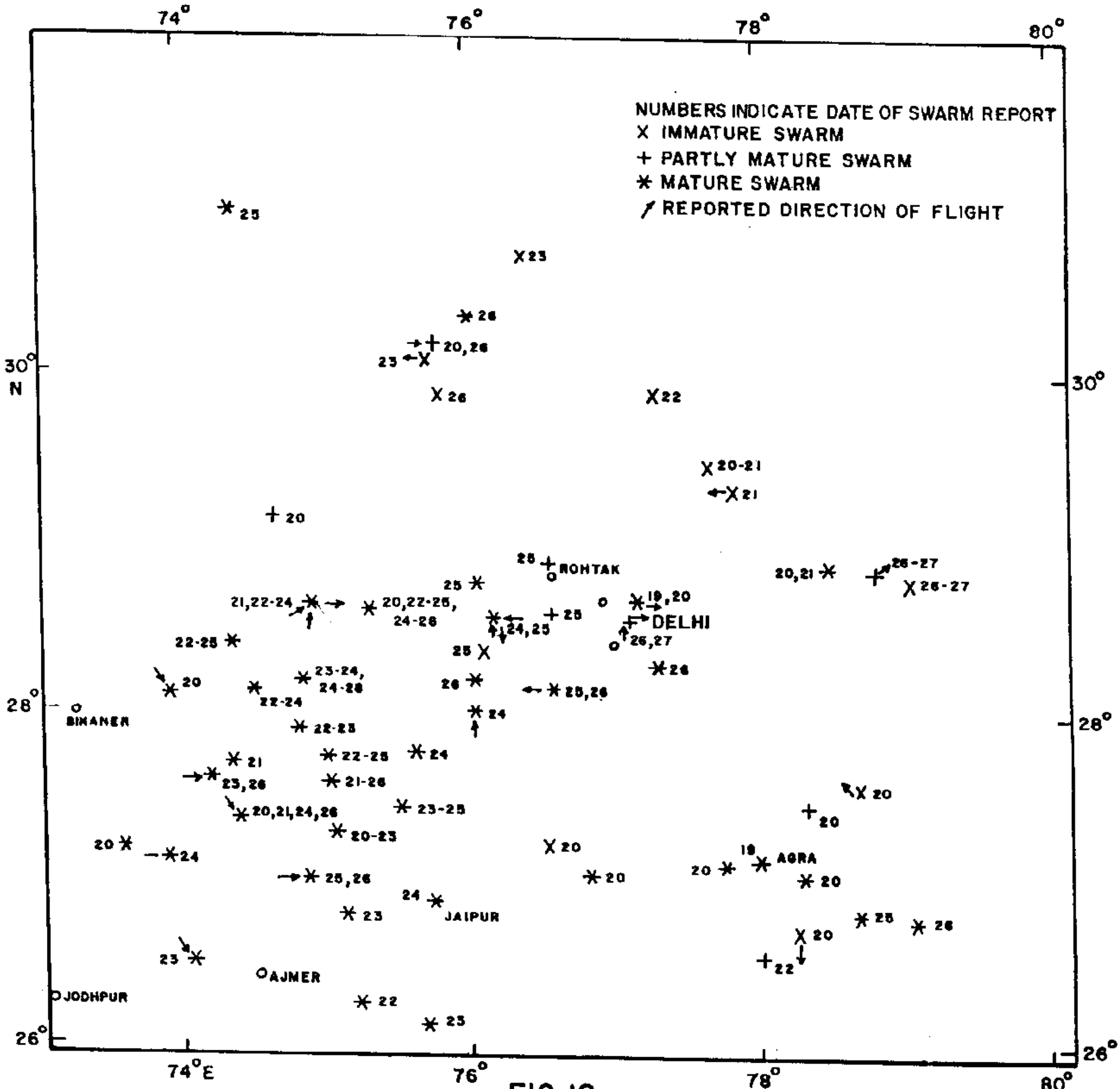

NUMBERS INDICATE DATE OF SWARM REPORT
X IMMATURE SWARM
+ PARTLY MATURE SWARM
* MATURE SWARM
/ REPORTED DIRECTION OF FLIGHT
ROHTAK
DELHI
BIKANER
AGRA
JAIPUR
AJMER
JODHPUR
74°
76°
78°
80°
30° N
28°
26°
74°E

FIG.12.

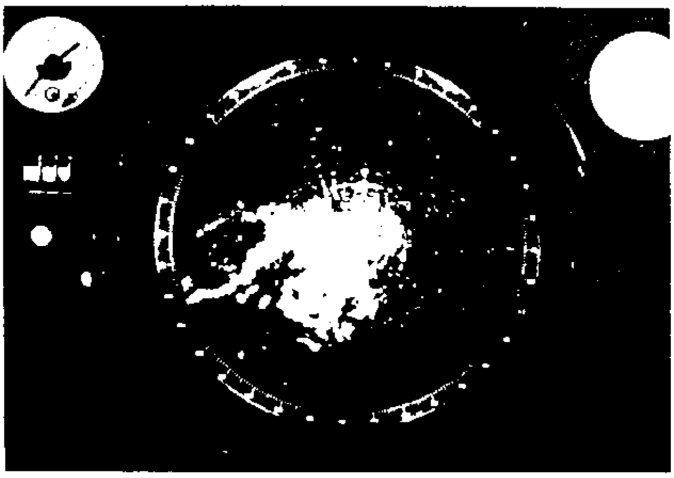


FIG. 13. (a).

INDICATION - PPI
TIME - 1336 IST (0806 GMT)
ELEVATION - 3 DEGREES
RANGE - 20 Km.

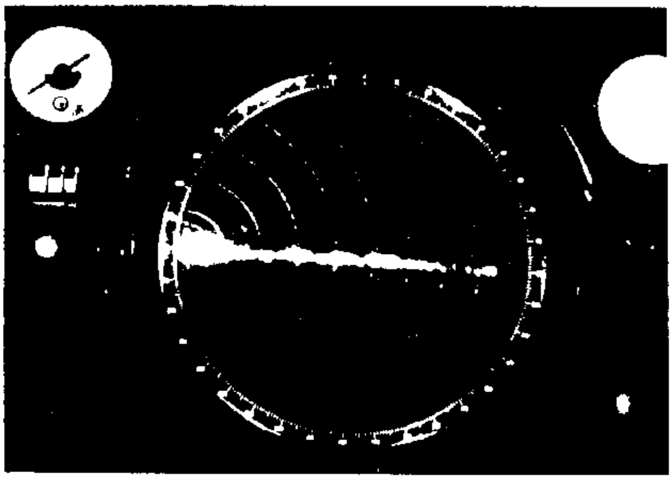


FIG. 13. (b)

INDICATION - REI
TIME - 1339 IST (0809 GMT)
AZIMUTH - 252 DEGREES
RANGE - MARKERS 5 Km APART.

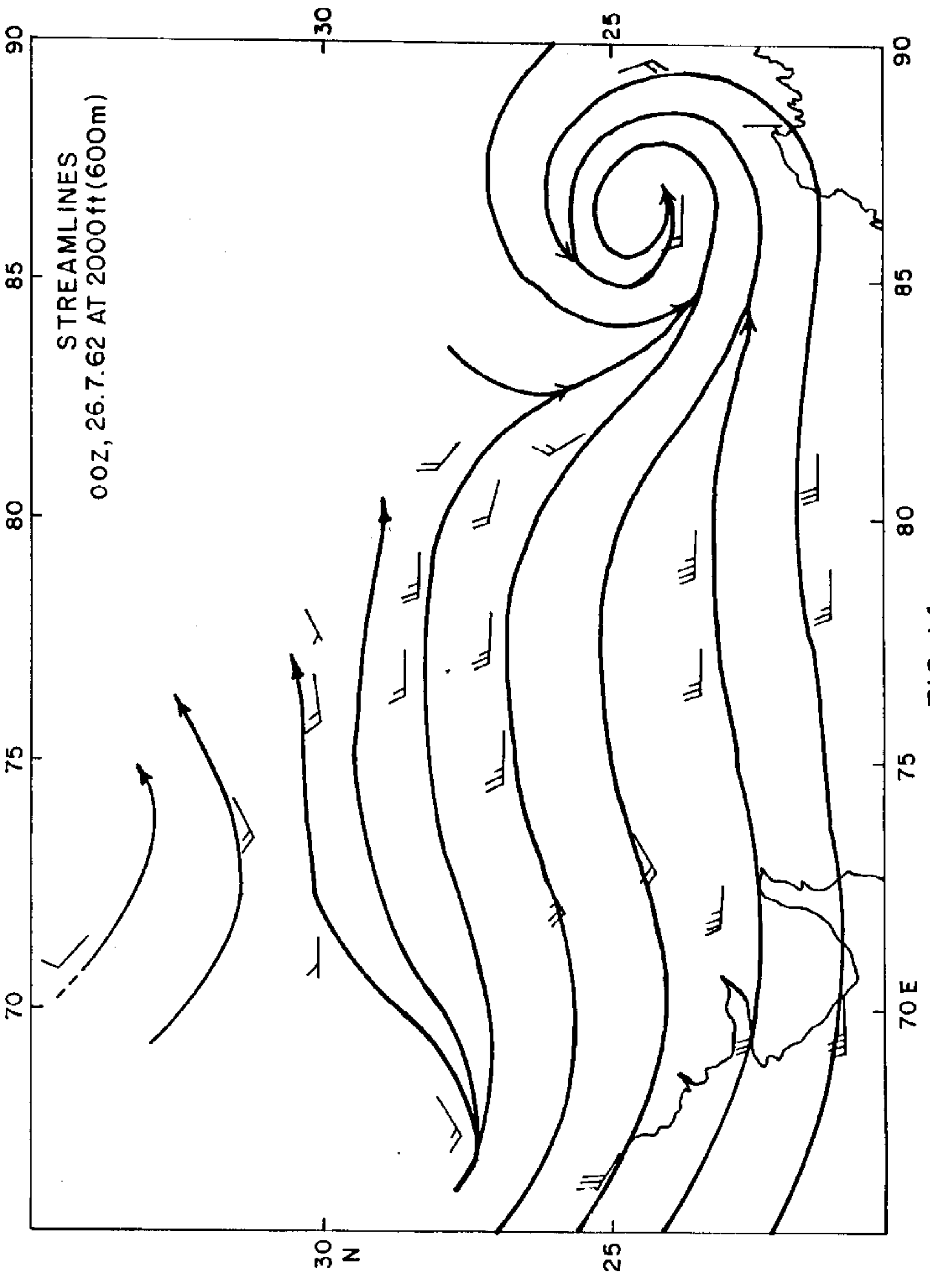

STREAMLINES
00Z, 26.7.62 AT 2000ft (600m)
90
85
80
75
70
70E
30
25
30 N
25

FIG. 14

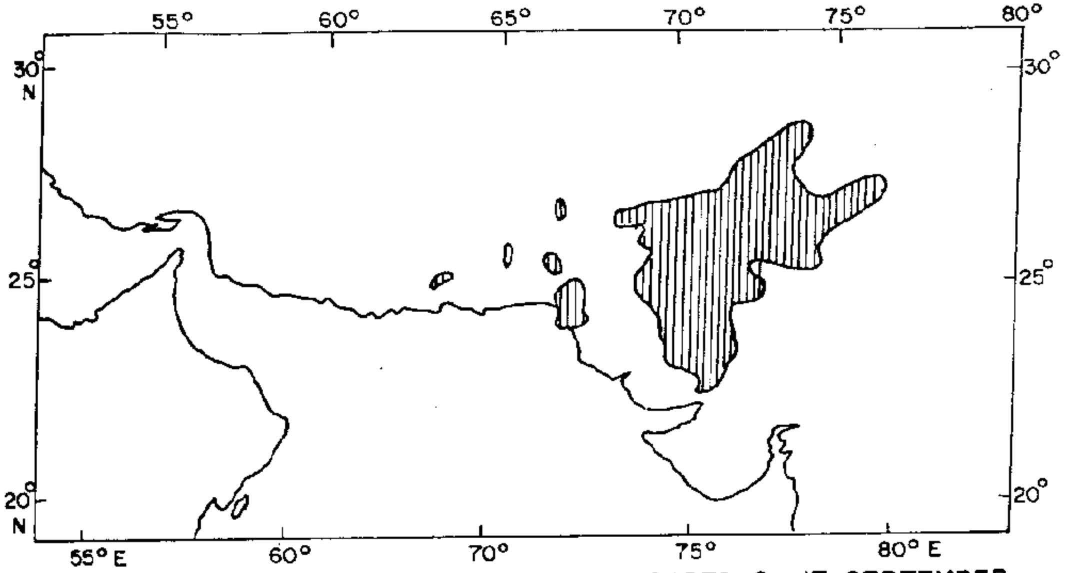


FIG. 15 a. DATES AND POSITIONS OF SWARM REPORTS 9 - 17 SEPTEMBER 1961. SHEDING INDICATES AREAS INFESTED BY SWARMS 1 - 8 SEPT. 1961.

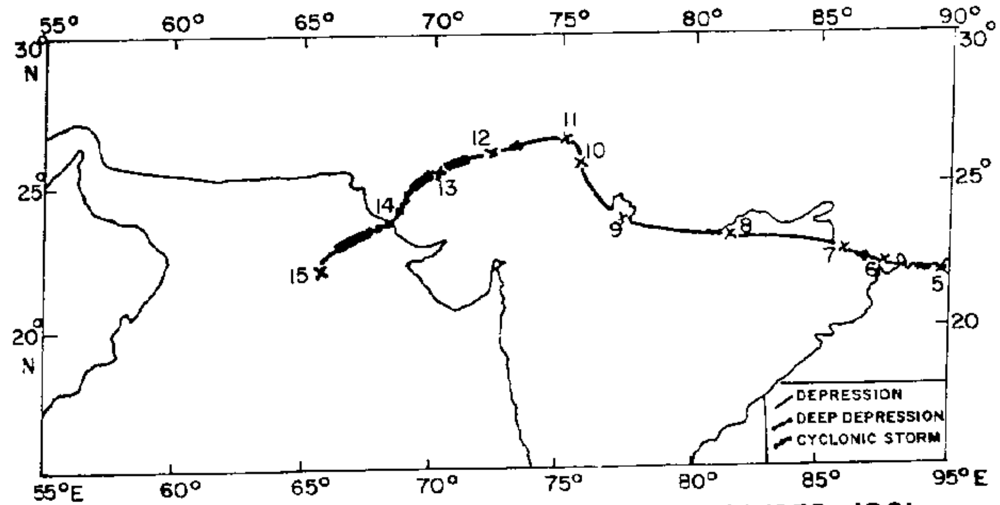


FIG. 15 b. TRACK OF DEPRESSION 5 - 15 SEPTEMBER 1961 POSITIONS OF CENTRE OF DEPRESSION AT 0300 GMT EACH DAY.

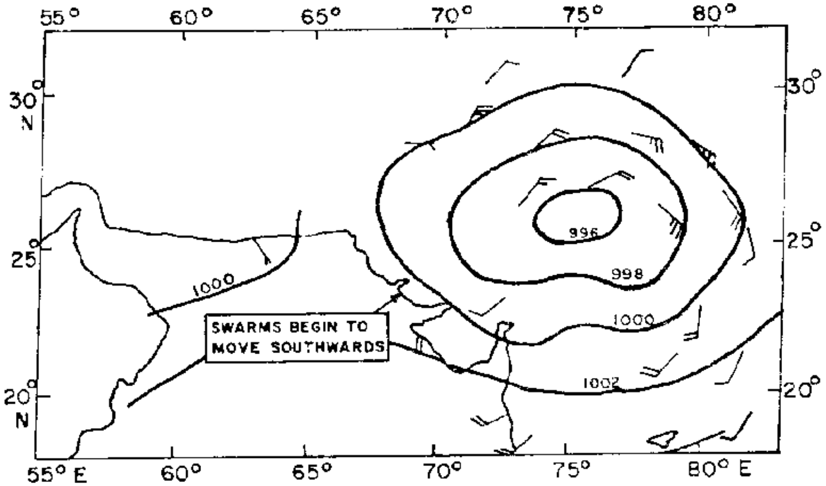


FIG. 15 c. SURFACE CHART FOR 1200 GMT, 9th SEPTEMBER 1961 (WINDS AT 2000 FT ASL)

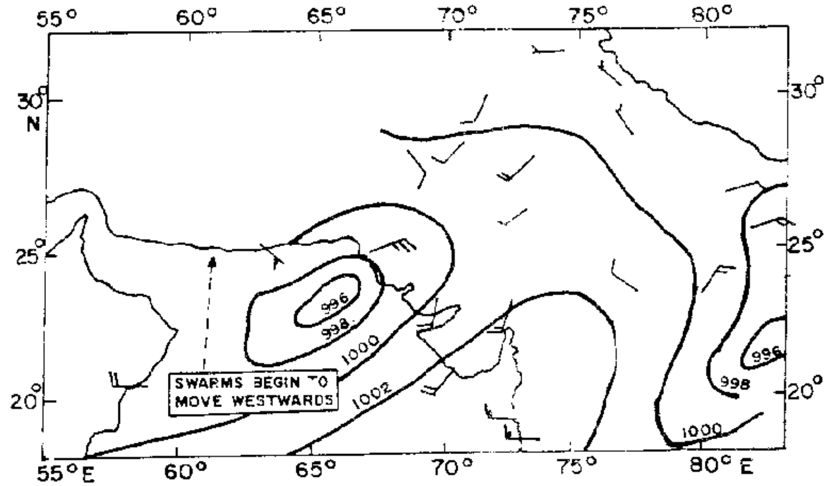


FIG. 15 d. SURFACE CHART FOR 1200 GMT 14th SEPTEMBER 1961 (WINDS AT 2000 FT ASL)

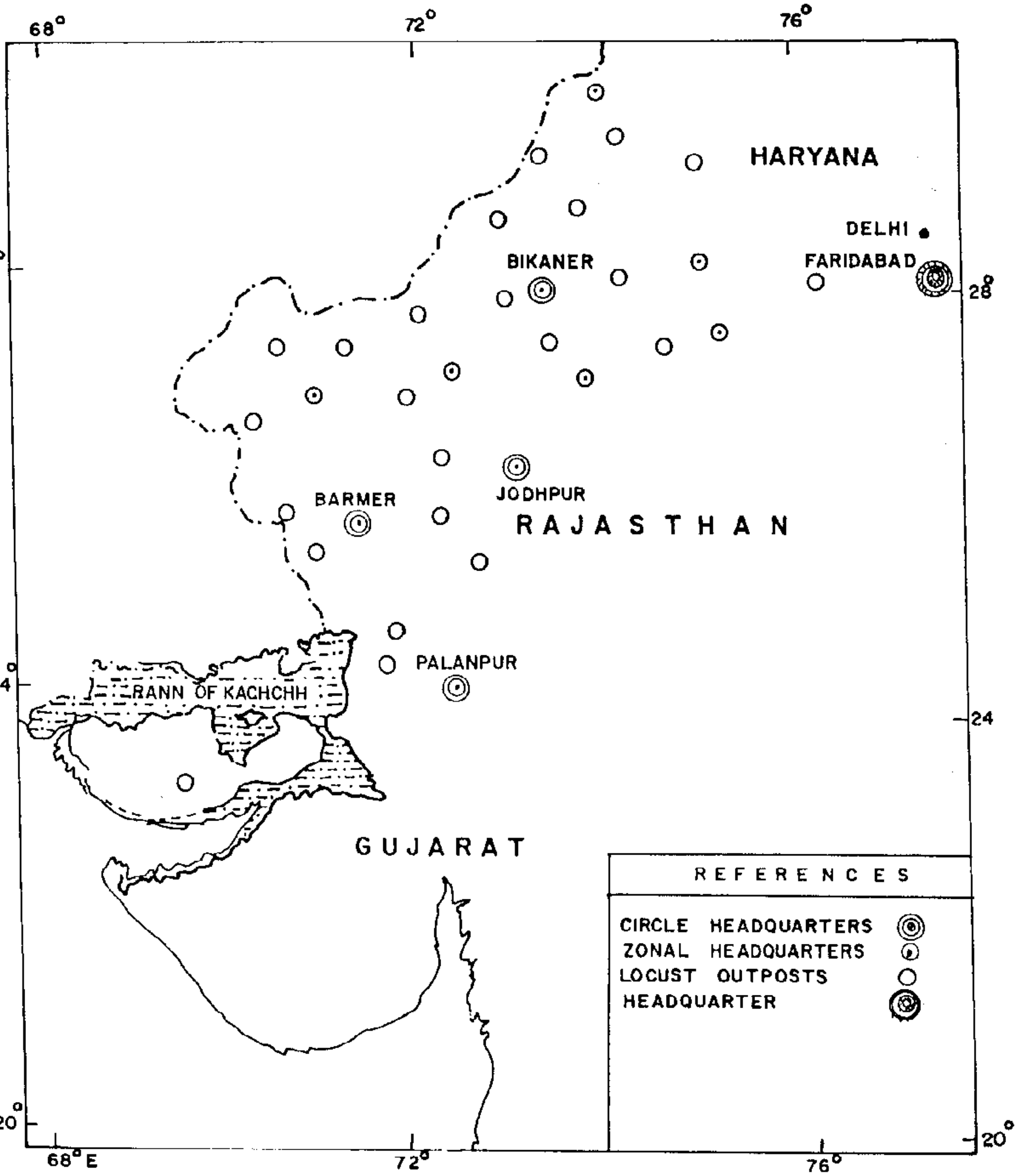


FIG. 16 MAP SHOWING LOCUST OUTPOSTS IN SCHEDULED DESERT AREA OF INDIA

METEOROLOGY AND THE DESERT LOCUST

(Syed Khurshid Anwar, Entomologist (locust),
Dept. Plant Protection, Karachi, Pakistan)

The problem of desert locust migrations is a complex one, because meteorological conditions must be taken into account in addition to biological facts. Because the range of occurrence of desert locust is immense and its period of activity unlimited, the impact of climatological facts on the desert locust can be described as below.

Climate

There is great variation in the weather of any place in the locust area, but also much repetition. Repetition both in the weather of days following each other, and in the weather at a given date or during a given period, year after year.

Climate is accumulated weather and, therefore, tends to show up those characteristics which are repeated. Climate also provides a useful background against which to assess important departures from average conditions.

Locust climatology

The aims of locust climatology are to identify the meteorological elements which, by themselves or in combination, affect the movement, growth and development of the desert locust, and to define the occurrence and seasonal variation of these elements.

Uses of climatology in anti-locust action

Climate information is most important in strategic planning, in advance of operations, since it indicates the weather most likely to be encountered or the absence of prevailing weather. For more immediate action, such as tactical actions during actual control operations, observations of actual weather and weather forecasts are needed. In their absence, climate date will still be of some use. Ideally the three types of information should be available: climate, actual weather and forecasts.

Important elements

The main meteorological elements affecting locusts are winds, temperatures and rainfall, and the locust climatology of these elements is discussed in the following paragraphs.

Winds

The winds act as conveyors of locusts and also concentrate them by convergence. In certain parts of the locust area, at certain seasons, winds are very regular in speed and direction. One of the tasks of locust climatology is to recognize these areas and define these winds. Winds are vector quantities. They have speed and direction. To add and average them is more complicated than with scalar quantities.

There are methods for representing wind climate summaries which avoid actual vector adding and averaging, and quote instead the frequency of occurrence of specific speeds and directions, either in the form of wind roses, or as tables of frequencies of concurrent directions and speeds, such as are recommended by WMO for the needs of aviation.

Vector mean wind

For actual vector adding and averaging, it is necessary to split the vector into northerly and easterly components, add these components separately, with due regard to sign, and recombine, obtaining a vector mean wind. Vector mean winds may also be obtained graphically by drawing a polygon of vectors.

Constancy

It is important to know how frequently conditions approach those represented by the vector mean wind. An indication is given by the ratio of the speed of the vector mean wind to the mean speed of the wind irrespective of direction. This is known as constancy.

A representation of monthly vector mean winds in West Africa is shown in FAO report UNSF/DL/RFS/7.A.1 and 2; more examples will be found in this text. With very high constancy values, streamlines based on vector mean winds give useful information. With low constancy, streamlines would be misleading. In certain areas low constancy can be taken as an indication of convergence. The variability of conditions denoted by low constancy is in itself useful information.

Wind convergence

Average convergence relative to the ground over the locust area on a monthly basis should be very useful for an understanding of locust distribution, and for anti-locust strategy, as it might single out areas where plagues are likely to develop.

A relatively simple method for describing convergence relative to the ground is that of Bellamy using triangular areas. An example of this work is given at Fig. 7 in WMO Technical Note N° 54. Details of its working, together with those of a more laborious method, are given in WMO Technical Note N° 69, pp. 23-41.

Convergence relative to the main wind stream is more difficult to represent at the climatic scale. It is more suited to the study of specific cases.

Temperatures

The distribution of screen temperatures, extremes or averages by day and by night, is important since it affects the probability of flight. Working approximations to daytime and nighttime temperatures can be obtained by choosing values half way between the daily mean and the extremes, known as effective day and night temperatures respectively.

Examples will be found in FAO Reports UNSF/DL/RFS/7.B1 and 2. In addition to screen temperature, temperatures of the air close to the ground are informative in as far as they are part of the immediate environment of the insect on the ground. Soil temperatures are also important since they affect egg laying and development. All these temperatures are subject to variations, of which it is essential to try and determine the amplitude. Often the temperatures are normally distributed.

Rainfall

Rainfall is important in connection with egg development and production of food at hatching time. Rainfall is a climate characteristic which is receiving much attention from different quarters because its uses are numerous, and much of the analysis required for anti-locust work is already available, unlike other parameters of less universal interest.

With rainfall it is specially important to take variability into consideration in order to assess probabilities of receiving specified amounts. When trying to assess these probabilities two methods are possible:

(a) To consider that variations in the past will be similar in the future. With this empirical approach, values available are arranged in order of magnitude, subdivided in classes, and probabilities derived directly;

(b) To consider that available data are part of a series of an infinite number of measurements distributed according to certain well known mathematical laws. With this theoretical approach it is possible to obtain the probability of occurrence of any rainfall amount.

Normal distribution

The most common distribution law used with rainfall is the Gaussian or normal distribution. There are several simple tests to check whether a given sample approximates closely enough to this law to warrant its use. The distribution is defined by two parameters, the mean and the standard deviation. Using 30 years of annual rainfall at Asmara, the two methods were compared. The errors to be expected in the fit to a normal distribution of a sample of a given number of years can also be calculated.

Variability of shorter periods

The same analysis can be carried out with shorter intervals such as months or even less. The variability tends to increase as the intervals become shorter and the amounts of rain smaller. As the length of the intervals approaches the duration of a rainstorm, the risk of the average being not truly representative increases, because it can be influenced by one heavy fall. It is not advisable to analyse periods shorter than 10 days.

Specific parameters

Rainfall characteristics more specifically applicable to locusts should be sought. One example is the frequency of occurrence of rainfall amounts that one sufficient to make hatching possible. This amount must be ascertained in terms of local conditions of drainage and evaporation. If, for instance, it were decided that a fall of 200 mm is necessary, then the average number of occasions per month, or fortnight, when this amount is obtained, would be a parameter more specifically adapted to locusts than mere amounts of rainfall in millimeters.

Synoptic climatology

Synoptic climatology is a very important part of anti-locust meteorology. It is concerned with the definition and estimation of the frequency of occurrence of synoptic features which significantly affect the growth, development and transport of the desert locusts.

Meteorological principles for planning locust surveys

To summarize, desert locust populations possess a sufficiently high probability of becoming of actual economic importance to warrant the expense of destruction only when they occur in adequate density. Moreover, only under conditions of such density it is economic to consider killing them. Airborne populations can achieve such densities only under conditions of low-level wind convergence. It is therefore by identifying and searching such areas that economically significant desert locust populations can be discovered. Therefore, in planning locust surveys the following principles must be borne in mind:

1. Locust populations move downwind.

2. The hotter the wind the greater the distance travelled per day.

3. Highly turbulent (and correspondingly hot) winds disperse populations (reduce their area density).

4. Downwind movement eventually brings locusts into zones of wind convergence where they accumulate as particles in a filter.

5. As opposed to steady wind conditions, where turbulence disperses populations, convergent winds have been shown to concentrate populations at least to the order of 10^3.

6. Locusts populations are trapped in zones of wind convergence and participate in the diurnal and daily cycle of movement of such zones. In some places and seasons these movements are relatively small and the locust population is correspondingly relatively stationary.

7. For efficient and economic control of locusts high density of populations is the most important factor, so that the concentrating effect of zones of convergence must be utilised in control techniques;

8. In solstitial periods the convergence zones which develop in the Equatorial Trough are relatively stationary in both northerly and southerly positions. Attacking locusts at the solstitial period is probably the most effective way of controlling locusts.

Meteorology in planning of control

While strategic control of desert locusts is probably achieved most economically by taking maximum advantage of the concentration of locusts which occur in areas of persistent low-level wind convergence, reduction of populations of a past season which can continue to breed 2-3 times a year and multiply in numbers by 0-20 times on each occasion, requires a sustained attack against all stages and all generations. Moreover when swarm movement towards crop areas are imminent such swarms must be destroyed whether or not they present themselves as ideal targets. Thus, a major effort directed against swarms in the summer solstice must be followed by control of the subsequent hopper progeny of survivors and by attacking any swarms derived from such breeding.

Though the extent and success of breeding is a function of rainfall, meteorological departments cannot provide much assistance in hopper control except on the basis of climatological data. Regarding the progeny of such breeding, fledglings will at first be scattered over areas at least 2-5 times that which the population occupied as hoppers. Swarm formation may or may not occur in the source area depending on the disruptive or concentrating influences imposed by the winds. For example, after summer breeding in Sudan, vast areas are occupied by low density scattered populations which may, moreover, be in the solitary form despite having bred under conditions of high density.

Few swarm reports emanate from the breeding areas, because swarms do not exist there, but such areas are nevertheless the sources of swarms which are later reported in west or north Africa, Ethiopia and Arabia following processes of concentration brought about by meteorological factors. The study of individual cases would be highly rewarding. An example is the invasion in September 1958 of the western districts of Eastern Province of Ethiopia by some 300 square miles of locusts in swarms not reported in Sudan during a period of a Westerly wind in Eastern Sudan and Northeasterly wind in Eritrea.

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Algerian case study and the need for permanent Desert Locust monitoring

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Through the experience gained by Algeria and the Maghreb Commission for Desert Locust control during the past recession and the present plague (1987, 1989), especially in the use of operational meteorological products of the World Weather Watch of the World Meteorological Organization for improved forecasts of swarm movement, an integrated acridometeorological watch system is suggested for the whole Saharan breeding area to avoid any surprise in the future. This permanent monitoring system should be built and operated jointly by the meteorological and the plant protection services at the national level. The regional and international coordination by the Food and Agriculture Organization of this Desert Locust monitoring could make use of the now experienced and integrated system of the World Weather Watch. The system proposed is not only useful for Desert Locust survey and control, but for the realistic use of the Saharan environment for a better life for nomads and the newly settled peasants.

1. Introduction

In October 1987, the Food and Agriculture Organization (FAO) stated in its Desert Locust Situation Summary and Forecast: 'Swarms produced south of the Sahara invaded Algeria and Morocco on a broad front in the second half of October... Summer breeding has probably terminated in western Sudan, Chad and Niger, but continues in Mali where it may become more widespread, and is probably starting in Mauritania'. The next FAO bulletin of November 1987 stressed that 'The scale of summer breeding south of the Sahara has been far greater than anticipated. Mali was invaded by swarms in early October, and Mauritania in late October. Breeding continues in both countries and is widespread in Mauritania...' In spite of these two warnings, no general mobilization was declared in the Maghreb and for good reason: the financially important decisions that had to be taken needed more precise field information than was available at that moment. In fact, the war against the Desert Locust would be declared only in February 1988, after the first big swarms coming from Mauritania and the Western Sahara had crossed the border of Algeria and Morocco, in association with a series of exceptional weather situations during 21–28 February 1988. These weather situations brought exceptional rain in the southwest of Algeria and Morocco and well-organized warm and strong winds, which provided a transport system of 10 days duration in Western Sahara.

In September 1988, all the national and international specialized authorities (FAO, Overseas Development Natural Resources Institute (ODNRI), National Desert Locust Services) were unanimous in predicting a severe Desert Locust invasion for the north African countries, starting from October 1988. The reason was the heavy rainfall in the Sudan and Sahel, which enhanced an unprecedentedly successful breeding season in the whole of the summer breeding area from the Red Sea to the Atlantic. Year one of the worst plague in this century was announced. In fact, Dr R. C. Rainey (personal communication), in preparing this discussion meeting, was urging the Algerian Desert Locust control team to follow closely this special situation and wrote: 'Algeria's forthcoming Desert Locust invasion of 1988/1989 could well be the most damaging the country has ever had, by reason not only of the scale of the parent generation in the Sahel, but also from the extent of agricultural development in Algeria, since the last comparable invasion of 1954–1958'.

Following these unanimous and pessimistic forecasts, Algeria, the Maghreb countries and the FAO mobilized huge and costly resources, but apart from Morocco, the scourge did not materialize because the majority of swarms had boarded the Atlantic cyclones. These cyclones, taking their origin from the heart of the Sahara and Sahel area, transported the Desert Locust swarms to the Caribbean Islands in a spectacular and apparently unpredictable way. The mechanism was explained, however, once we had the time to use the World Weather Watch (WWW) products prepared and disseminated by world forecasting centres such as European Centre for Medium-range Weather Forecasting (ECMWF) (Reading) or U.K. Meteorological Office (Bracknell).

In September 1989, the FAO Emergency Centre for Locust Operations (ECLO) Desert Locust Summary disseminated the following information: 'The continuing heavy rains in several parts of West Africa... have created excellent conditions for continued summer breeding. This could constitute the beginning of another upsurge, so every effort should be made to detect and destroy any infestations which may result.'

One month later, the FAO/ECLO Summary stated that: 'The general Desert Locust situation remained unexpectedly calm during the past month. Despite adequate rainfall and good ecological conditions in many areas, there is no evidence suggesting an upsurge in Western Africa as previously forecast'. In fact, in Algeria the Desert Locust control system had been fully mobilized during the whole 1989 season and no definite decision had been taken as of November 1989. This created an unbearable situation of 'no war, no peace', the main reason being the lack of adequate and reliable Desert Locust information in the vast breeding area in the Sahara.

Any decision-maker involved in the Desert Locust operations was therefore asking and being asked the same questions: 'Should we demobilize the whole system or should we maintain the current capability; or should we perhaps reorganize the resources of preventive control operations and set up a permanent Desert Locust Watch?'

As a matter of fact, the Desert Locust is feared not only for its destructive capacity of the food crops but also for the permanent threat that the 60 countries concerned have to bear. During these past years, we have experienced a true psychosis of the Desert Locust invasion in many African countries of the Sahara and Sahel regions. To protect the threatened countries from invasions that may not occur, the expenditures incurred are as heavy as those involved during a real Desert Locust plague. Nevertheless, the progress made in the scientific knowledge of this migrant pest should have changed this situation.

Some specialized authorities assure the public and the governments that it is now possible to answer positively the questions on *where*, *when* and *how* the desert plague develops and even *what are the means* and *methods* required to control rationally any scourge.

In our opinion, the solution to the Desert Locust problem is not only technical, but also organizational. It depends mainly on the willingness of all countries concerned, the donors and the interested international agencies, to unify their efforts to build an integrated system for a permanent World Locust Watch (WLW of FAO) complementary to the World Weather Watch system of the World Meteorological Organization (WMO). An invasion of the Desert Locust in its gregarious phase presents many similarities with meteorological phenomena: it knows no frontiers, concerns large areas, has great mobility, develops in areas difficult to reach and monitor, can take man by surprise, and is unpredictable in the long term.

After this review of the status of the actual Desert Locust information system and control organization (and before suggesting a realistic contribution to the strengthening of the organizational scheme and information network for a better plague forecast), let us look at the expenses incurred by Algeria and the lessons drawn from the recent Desert Locust campaign, which is not yet over because of the lack of information on the Desert Locust in its large breeding and development areas.

2. Algerian case study: the 1987 1989 Desert Locust control campaign

Because of its importance and suddenness, the Desert Locust plague of 1987–1989, which occurred in West and northwest Africa, forced Algeria and Morocco into an unprecedented campaign covering more than 5 million ha† and requiring more than U.S. $100 million.

(*a*) *The invasion, as seen from Algeria*

In 1985, intensive breeding by the Desert Locust on the western edges of the Red Sea, though limited in space, started the formation of swarms that invaded Saudi Arabia in 1986 and left an important breeding potential in Sudan and Ethiopia. Insufficient control operations and favourable winds allowed the new swarms to reach the Sahel in July and August 1987. From September to October 1987 onwards the swarms settled in the northeast of Mauritania and in the Western Sahara where breeding was intense because of extremely favourable ecological conditions. This gave rise to winter-spring generations. These swarms invaded southwest Algeria during the first quarter of 1988 from February onwards. After that the monsoon rain, which fell in the Sahel from June to August 1988, led to the production of two locust generations that were expected to move to the north and the northwest from September 1988 in a massive invasion of the Maghreb countries. This scourge did not occur and many swarms ended in the Atlantic, with some reaching the Caribbean, forced by unusual westward winds. However, some swarms managed to reach western Algeria and southern Morocco.

This exceptional mass-cleaning phenomenon seems to have considerably reduced the locust potential in the west African and Sahel zone, enabling us to enjoy, since the end of 1988, a quiet period as regards acridian activity, despite the presence of a few populations in traditional breeding sites.

† 1 hectare = 10^4 m^2.

(b) The organization of the locust control system: efforts and means

Algeria has responded to the 1987–1989 locust invasion on more than 2 million ha representing more than 30% of the treated area in the Maghreb (7 500 000 ha).

The dangerous evolution of the locust situation from October 1987 onwards had led the Algerian government to adopt exceptional procedures to face this plague so that minimum damage to agricultural production and the environment would result. The tasks of Desert Locust prevention and control are led by the National Plant Protection Institute (INPV), a specialized Public Service of the Ministry of Agriculture. During plague periods there is a strengthening of the preventive measures to ensure: (i) Government control; at the state's expense and conducted by the specialized public services in areas, such as in the Sahara and the Highlands, where swarms cannot be controlled by peasants. (ii) Collective control; to complement the public effort and locally conducted in the agricultural areas by peasants with coordination by professional associations.

The legal framework for this organization of locust control is provided by different laws, decrees and instructions:

(i) Decree No 67-177 dated August 8, 1967, appointing an interministerial committee responsible for the organization, coordination and evaluation of the Desert Locust control campaign.

(ii) Decree No 85-231 and 85-232 dated August 25 1985, related to the emergency organization and action at local level to prevent or face natural disasters, of which a Desert Locust plague is one.

(iii) Law No 87-17 dated August 1 1987, organizing the phytosanitary protection and prevention measures against pests and plant diseases, of which the Desert Locust is given top priority because of its potential damage to agriculture in both crops and pastures.

(iv) Instruction No 1 of July 13 1988, defining the tasks, organization and the creation of control groups during the invasion period.

(v) Instruction No 2 of October 16 1988, coordinating the collection and dissemination of Desert Locust monitoring and movement forecasts.

(vi) Instruction No 3 of March 1989, related to the protection of man and his environment.

Besides the legal form and organizational scheme at a high level, necessary to effectively control this plague over a vast territory, the following means have been progressively and rapidly deployed, beginning from February 1988: 50 light vehicles (4-wheel drive) for finding and monitoring the swarms; 60 heavy treatment vehicles fitted with exhaust nozzle sprayers; 200 heavy logistic transport vehicles; 1600 back sprayers (individual control in the oases); 60 airplanes (fixed wing and helicopters fitted with rotary atomizers); 5 million l of pesticides of which 3 million l have been sprayed; 500 plant protection technicians, and 1500 general workers (drivers, guides operators).

On the financial side, the control operations needed more than U.S. $36 million to meet the cost of pesticides and hired airplanes.

(c) The results and the weaknesses of the general mobilization

In tackling a national disaster such as a locust plague, it is difficult to quantify or even estimate all the positive results, therefore we concentrate on two main apparent effects. The first and most spectacular one was the successful protection of the major productive agricultural lands that cover the northern zone, and the range lands and main irrigated areas of the central and eastern Sahara. Some damage has been noticed in the natural pasture lands of the western Sahara, in irrigated agricultural land of the Imperial Valley in the Saoura region (southwest Algeria), and in the bee-keeping farms that have not been protected against the aerial spraying. The second and more indirect effect is the considerable decrease of the locust potential, which could have reestablished in the Sahelian summer breeding zones if the Maghreb countries, mainly Algeria, had not made a major effort particularly in hopper control. Indeed, in Algeria alone, more than 700000 ha of hopper bands were treated during June and July 1988. Thereby the life cycle of the gregarious Desert Locust has been disturbed and even cut.

Even though the actions were successful, the field operations against the Desert Locust have been hampered by the lack of bio-ecological real time information on the migrant pest and of real time and precise observations on the prevailing meteorological conditions over the vast source and target areas. This hindered the making of medium term forecasts of swarm movements, the strategic deployment of control equipment and the most efficient use of chemical spraying. In fact, the protection of the agricultural potential led the organization in charge of control of this plague to set up some techniques, means and procedures that were certainly efficient, but that left some negative effects on the environment by accumulating some pesticide residues in the water and food chain.

Although the efforts made by the countries of the Maghreb and of West Africa have been considerable and costly, better control of the locust phenomenon should in future be obtained through a strict coordination of the general prevention programmes, not only between these two subregions of Africa, but also between them and the central regions of East Africa and the Middle East. In this respect, the role of the international (FAO, ECLO, Organization for African Unity (OAU)) and regional organizations (CLCPANO, OCLALAV, DLCO-EA) appears predominant in locust information collection and its transmission and treatment. This is in addition to the training of specialists in control techniques and the coordination of the necessary field research.

3. The coordination at the regional and bilateral level

To be able to take charge of the prevention and the control of Desert Locust plagues, the four Maghreb countries created in 1972, under the aegis of FAO, a regional specialized commission named CLCPANO (Desert Locust Control Commission for northwest Africa). In 1988 Mauritania joined the commission. Its members are the Agriculture Ministries in charge of Desert Locust prevention and control. An executive committee composed of experts from each country meets every year in recession periods and as often as necessary during invasion situations. The secretary of the commission installed in Algiers is in charge of the coordination with FAO, and the collection and regular dissemination of locust and meteorological information.

This commission has been very active in the training of locust specialists, the organization of workshops on locust control and on meteorological needs for better preventive control. It has been prominent in the conception of guides and manuals, and the conduct of locust prospection campaigns in summer breeding areas such as southern Algeria, northern Niger, Mali and Mauritania.

During the invasion period of 1987-1989, the Maghreb commission organized or contributed to meetings or seminars in:

(i) Tunis (Tunisia), March 1988; a common strategy for the control of Desert Locust.

(ii) Rabat (Morocco), April 1988; adoption of a strategy for the period May-September 1988.

(iii) Tamanrasset (Algeria), May 1988; coordination of the financial means for a common preventive strategy. During this meeting the creation of a Maghreb task force was agreed together with the strengthening of the meteorological observing network over all the summer breeding Saharan area with a focal point at Tamanrasset Regional Meteorological Centre.

(iv) Nouakchott (Mauritania), June 1988: a common Maghreb strategy was adopted at the ministerial level and presented by the Ministry of Agriculture of Mauritania to the Desert Locust Control Committee of FAO.

(v) Rabat (Morocco), September 1988.

These meetings have permitted the establishment of a Maghreb fund and a Maghreb prevention task force, which started working in association with neighbouring countries (Niger, Mali, Mauritania).

On the other hand, the CLCPANO commission has contributed to the conception of an inter-regional project for Desert Locust control, which aims to strengthen the plant protection services of eight countries from the Sahel and the Maghreb, which may be financed by FIDA (International Fund for Agricultural Development) and executed by FAO.

In addition to this regional system of coordination many bilateral agreements have been elaborated by Algeria and signed with Morocco, Tunisia, Libya, Niger, Mali and Mauritania. This was done, to coordinate the control effort, to normalize the observing system, to exchange locust forecasts and also to make rational use of mobile equipment, mainly in the border regions.

4. Meteorological assistance to the Desert Locust control

In addition to a seminar on hydrological resources in the Sahara, a conference held in Tamanrasset in May 1980 on the need for meteorological data for Desert Locust Survey helped identify the necessity for reinforcement of the meteorological network in the border zones. A programme to install eight meteorological stations was made for data collection in central Sahara with the assistance of the National Plant Protection Institute.

Many seminars on acrido-meteorology have been organized and financed by the CLCPANO. These seminars have allowed preparations to progress for meteorological assistance in locust prospection and control.

Moreover, at the beginning of the first Desert Locust warning in August 1986, a new call for the reinforcement of the meteorological watch system in the summer breeding zones was made. Following an Algerian proposal, the African Regional Association of WMO adopted a resolution appointing a rapporteur for acrido-meteorological questions (Harare, December 1986) to suggest a pilot project to WMO/FAO to finalize these proposals for meteorological assistance to Desert Locust prevention and control.

This first alert has allowed the Algerian meteorological service to request and obtain a telecommunication line between Algiers, Dakar and Cairo (October 1986, December 1986). This is in addition to the existing links with Niamey (Niger) and Jeddah (Saudi Arabia).

Thus the Algerian meteorological service was linked to all centres of the regions concerned with Desert Locust problems. The first forecast of Desert Locust movement was made for the October 1987 invasion. On that occasion, the regional meteorological centres (Tamanrasset and the border stations of Tindouf. In Guezzam and Bordj Bordji Mokhtar), played a major role, but in spite of all the means involved, two main deficiencies were identified which are:

(i) The very low density of the meteorological network in the Saharan zone situated between the 15° and 25° north and between the Atlantic and the Red Sea. This is the main breeding and development area for the Desert Locust swarms before their invasion of the Maghreb region.

(ii) The lack of knowledge of the meteorological phenomena in the dry tropical zone and the difficulty to make a reliable medium range numerical weather forecasts (5–10 days) even by the most advanced meteorological centres.

From November 1987 onwards, information from the ECMWF was requested for humanitarian and emergency purposes, and this arrived three months later (February 1988). From the beginning of March and thanks to a link by telefax with ECMWF, the five-day forecasts of wind fields and rainfall at ground level and 850 hpa over the Maghreb area have been used for Desert Locust control. This was organized at the level of the central headquarters, bringing together all the services concerned (plant protection, aviation, meteorology, telecommunication, logistics). Later on, the importance of the plague on the regional side gave rise to a request for the numerical products of the U.K. Meteorological Office. These products covered the gregarious zone from India to the Atlantic via the Red Sea, which allowed a better understanding of the general situation and a better forecast for successive invasion five days in advance. These products, together with the experience gained in the field, have been used by members of the same team of meteorological forecasters from September 1988 onwards successively to reinforce the specialized services of FAO/ECLO. This action has been running now for 18 months and has been considered as advantageous by the Plant Protection Direction of FAO.

This experience, which has been going on intensively for two years, has proved that the meteorological products available at the local and especially at the European level, have contributed significantly to the organization of the Desert Locust prevention and control effort. The meteorological phenomena at the synoptic scale proved to be the major factors in the Desert Locust tragedy. The quick availability of these meteorological products by telefax transmission from the European meteorological centres to the national meteorological centre and then to the local control centres has been decisive in that a wind map is more expressive than a long telex. This technique of meteorological dissemination gave help in real time and enabled specification of some relations between the meteorological conditions and movement of the swarms.

However, some shortcomings have been felt and they concern mainly the meteorological conditions, which affect the locust reproduction in Sahara regions, and the effect of mesoscale meteorological phenomena on the aerial spraying of locust swarms. In view of those deficiencies, the need for a Desert Locust strategy was discussed at the regional seminar at Tamanrasset (May 1988), and later, at the international workshop on acrido-meteorology in Tunis (WMO/FAO, July 1988), it was decided to develop a permanent integrated meteorological and Desert Locust monitoring system to provide the necessary assistance for plant protection survey teams. This system, which will strengthen the World Weather Watch network, should be fully integrated into the actual monitoring network of each country and may be structured as:

(i) A regional meteorological centre for the Saharan area built on the strategic site of Tamanrasset which is in the heart of the Desert Locust breeding area common to Algeria, Niger and Mali and which hosts an old locust research base.

(ii) A national climatic network to complement the actual network in central Sahara, limited in the north by the Saharan Atlas, and which will help to improve the aerial assessment of the rainfall and of air corridors necessary for the development and progression of the Desert Locust.

(iii) A regional synoptic network consisting of 50 automatic weather stations fitted with data collection platforms for transmission via Meteosat and covering the whole area of Desert Locust activity from the north and central Sahara to the Atlantic and the Red Sea (the north of Chad, Niger, Mali, Mauritania, southern Algeria and Libya).

(iv) Five mobile meteorological 'centres', which will complement the basic network in areas where the access is extremely difficult, but which represent important sources during the invasion or remission periods.

This regional and national meteorological monitoring network will rely on and also strengthen the integrated system of the World Weather Watch. In parallel, the Desert Locust control plan should allow for the following actions:

(i) Establish a permanent locust watch (monitoring) system as a main component of the plan of action to strengthen and reorganize the preventive control of the Desert Locust plague at the national, regional and international scale. As a matter of fact, the Desert Locust research base of Tamanrasset could well present an important focal point because of its strategic position in the main Saharan breeding zone.

(ii) Maintain permanently the prospection teams in the field, to allow them, supported by the past, present and forecast meteorological information, to go through all the potential breeding areas where the ecological conditions might be favourable to Desert Locust development. When searching the large desert areas, contact could be made with the nomads or travellers, and even the newly settled peasants, to complete the survey and to cover wider areas.

(iii) Develop plans to train observers and scouts, plant protection inspectors, meteorologists, peasants and even local administrative authorities to build a unified team for locust control. Because of the wide development of agricultural production in the Sahara, all of these have a vested interest in such control.

(iv) Finally, the plant protection services of the different countries should develop a permanent system for the free exchange and dissemination in real time of locust observations and forecasts of their movement. Such exchange should be modelled after the World Weather Watch, which is coordinated by WMO and has already proven its efficacy as an example of international cooperation. This coordination, for instance between the national Maghreb services, should be done by the Regional Desert Locust Commission (CLCPANO) and may take advantage of the FAO regional Desert Locust control project, which is planned to cover eight neighbouring countries of the Maghreb and the Sahel. An exchange of basic locust information could be done directly between the regional centres of north Africa, the Sahel and the Red Sea, the international coordination being left to FAO/ECLO in Rome.

In conclusion, and having in mind the recent field experience of the 1987/1989 Desert

Locust plague, it is extremely urgent to consolidate and perpetuate an integrated monitoring system for locusts and meteorology (acrido-meteorology), knowing that the Desert Locust is a permanent calamity and a constant threat over a long time. This integrated system should allow a minimal use of pesticide, which used in large quantities represents another threat to the environment. Besides this important objective, the meteorological network covering those Saharan areas will also enable better use of the water resources, the range land and the development of agriculture for a better life for the local population.

Discussion

K. A. BROWNING, F.R.S. (*Meteorological Office, Bracknell, U.K.*). Most of the meteorological data that Mr Boulahya was using were synoptic data. There wasn't much said about mesoscale or local scale data, or about the smaller scale information obtainable from satellites. Is this kind of information used?

M. S. BOULAHYA. I started at the regional scale only because it is very important. On the local scale, satellite data are used to follow rainfall events. We were grateful in September 1988 to receive a satellite receiving system from the U.K. Government, which has been installed at Tamanrasset. There, it is being used to monitor probable rainfall distribution, with ground teams scouting to verify the information. Secondly, an automatic station transmitting through Meteosat (Data Collection Platform, DCP) was installed at In Guezzam, 400 km south of Tamanrasset at about 20° N, so ground proof of this rainfall information via satellite is also received. This local scale information is used mainly for rainfall distribution and for directing aircraft operations, forecasting low-level winds, etc., for where and when the planes should fly. But forecasting for general aviation was not new in Algeria, only its application to the anti-Desert Locust campaign.

D. E. PEDGLEY (*ODNRI, Chatham, U.K.*). We cannot fail to be impressed by the energy with which Mr Boulahya has tackled the severe and sudden problems faced by Algeria during the swarm invasions of 1988. He has made use of forecast wind fields, temperature and rainfall, derived from global numerical models, but I wonder to what extent he has found them to be realistic? I ask this because there is a pressing need to validate these forecasts in some parts of the world, not least over Africa.

K. A. BROWNING, F.R.S. As Mr Boulahya answers Mr Pedgley's point, could he also perhaps comment on the accuracy of the rainfall forecasts, which may be even more vulnerable to errors.

M. S. BOULAHYA. For winds, pressures and temperatures, the numerical forecasts were alright for our needs up to five days ahead, by using the products of Bracknell and Reading. The rainfall forecasts are not sensitive enough for the locust work, it is necessary to know where grass is going to grow and where the soil is wet enough for egg laying.

W. H. LYNE (*Meteorological Office, Bracknell, U.K.*). The Meteorological Office is a supplier of some of the products used by the Algerian Meteorological Service for locust and weather monitoring, and it was gratifying to learn of the good use to which they are being put by

Mr Boulahya and his colleagues. These products are sent only to Algeria at present, communications being a major problem in the supply of numerical weather prediction products to the African continent.

The Meteosat Meteorological Data Distribution (MDD) mission, now entering its demonstration phase, should provide a means of making such products more readily available to meteorological services within Africa and the Middle East. As well as the standard meteorological products, specialized products more directly related to the locust problem could be transmitted. Examples might include vertical velocity and convergence or divergence. The allied DCP mission should also enable more observational data from Africa both to reach the Numerical Weather Prediction (NWP) centres and to be redistributed back to the continent by MDD.

One of the more specialized products the Meteorological Office supplies is trajectory data, and these have recently been utilized by Mr Thomas of the Food and Agriculture Organization in an investigation into the arrival of locusts in the West Indies in the autumn of 1988. These trajectories were calculated from analysed data archived routinely at Bracknell from the numerical forecast model.

Numerical forecast models are under continuous development, with the present version to be replaced later in 1990. This will have a higher resolution, improved parameterization of physical processes, and should lead to improvements in the quality as well as the range of products.

M. S. Boulahya. We are working with Bracknell and the European Centre on the existing trajectory models for following air pollution and nuclear fallout, to refine them for use on the Desert Locust. They need to be more precise because the Desert Locust is an active element and not a passive one. We plan to do this work with colleagues from biological backgrounds. The existing model gives some idea, but not the right one, because it doesn't assume that the locusts stop flying at night, for instance, so we have to stop it at a certain time and then start it again at another time; we don't know how to do this within the present model.

The locust watch system started during the plague years and we hope to continue with it, as it is the best way to assist preventative control.

D. Rijks (*World Meteorological Organization, Geneva, Switzerland*). On behalf of Professor Obasi, Secretary-General of WMO, I thank the organizers of the meeting for the invitation to participate in the discussions. Mr Boulahya has mentioned the role of weather information in the preparation of forecasts for the development and movement of Desert Locusts, and proposed arrangements to enhance this role. Such use of weather information is one of the public services that is being promoted under the Application of Meteorology Programme of WMO, that can show the economic and social benefits of the use of meteorological information. These economic benefits include not only the timely mobilization of resources for locust control, but also the timely demobilization. A demobilization coming too late can be quite costly. Meteorological information is used to increase the efficiency of the tactical movements of intervention forces. Spray pilots estimate that during the past campaign they spent about two thirds of their flying time in conveyance and one third on actual spraying. The total amount paid for flying time was about $100 million. Therefore, even a modest increase in efficiency of conveyance, through the use of trajectory estimates of expected locust movements, could mean a decrease of millions of dollars in spraying costs. Use of such trajectory estimates would also increase the number of hours of possible treatment of swarms, before flight. Other benefits of a social or environmental nature are more difficult to quantify in monetary terms, but they are recognized by national decision makers as important.

Although improvements in the forecasting of development and movement of Desert Locusts certainly need to be and will be made, the present capabilities have credibility. Therefore the step from a curative to a more permanent preventive locust observing and warning system seems feasible.

Mr Boulahya has stressed the need for a regional approach, which appears to be the only one practicable. To facilitate this, a coding of acrido-meteorological information on the meteorological communication system has been proposed, and will probably soon become operational. This would help to achieve a 'global Desert Locust watch' analogous to the world weather watch of WMO. In addition to this international cooperation, there is need for interdisciplinary cooperation (such as shown by the participants in the meeting in Tunis in July 1988, organized jointly by FAO and WMO), and increased cooperation between European and African scientists and technicians (as witnessed by Mr Boulahya's presence at this meeting). The results of actions on the recommendations of the Tunis workshop have been described in a circular letter from the Secretary-General of WMO, dated 13 October 1989, ref. WMO 36.229/M/AGDL.

The implementation of the 'Desert Locust Watch' does need the installation of about 50 automatic weather stations, transmitting via satellite links, to complement the existing synoptic network and to provide the ground-based information that enhances the value of remotely sensed information and vice versa. A start on the installation of this network has been made in cooperation with bilateral donor agencies. The payoff of such a network will not only be in Desert Locust control, but also in many other fields, including Climate System Monitoring and studies on climatic change.

WMO fully supports the training proposals made by Mr Boulahya. Perhaps, in addition, spray-pilots could be helped to understand better the physiology and habits of Desert Locusts, to help them achieve the highest possible efficiency in control operations. Such type of 'training' for agricultural aviation operators is generally provided and required for operation in the U.S.A.

The most important lesson from a locust control operation that cost about $300 million in the past few years, is that a permanent locust watch, capable of preventive control, at the cost of 1 % or less of the curative operation, is a sensible proposition, to be implemented as rapidly as possible. It should, and can use the existing meteorological infrastructure, and provide for complementary infrastructure, if and where requested.

P. M. SYMMONS (*FAO, Rome, Italy*). FAO is obtaining a trajectory model; which will push swarms around by using the winds at varying heights. The work that will be done on our model will be primarily to explain past events. If the present location of the locusts is known, one can usually tell where they've come from, but that's very different from saying where they are going to go. Work on solitary locusts is even more problematic. We know very little about the controlling mechanisms that will cause non-swarming locusts to take off into the night sky. Predictions of the type Mr Boulahya has been talking about are certainly useful for the direct deployment of aircraft for swarm control, but then it is necessary to predict, to a scale of tens of kilometres in space. I would emphasize that one can go a long way if the reporting and reporting-back system for the control is working well.

ASSISTANCE METEOROLOGIQUE A LA LUTTE ANTIACRIDIENNE

(par le Service météorologique du Maroc)

I-PREAMBULE

La dernière invasion du criquet pèlerin était celle de 1987-88 au cours de la quelle la moitié sud du pays a été touchée. L'action de l'homme, le retour de facteurs climatiques défavorables aux criquets et le nombre très important d'essaims qui se sont perdus en mer lors de leurs migrations du Sahara vers l'ouest, sont les principales causes de la période de rémission.

Les criquets pèlerins se développent en fonction de 4 facteurs principaux:
- L'environnement désertique sec et chaud.
- Le type du sol sablonneux ou limoneux pour la pondaison des oeufs.
- L'humidité suffisante du sol dans la couche supérieure du profil humide pour l'éclosion des oeufs.
- La verte végétation pour la nourriture durant les différents stades de développement.

L'assistance fournie par la Direction de la Météorologie Nationale, s'est étalée sur plus d'une décennie:

* pendant la période d'accalmie, par l'échange d'informations périodiques avec l'organisme national de la protection des végétaux (DPV).
* avec la commission de la lutte antiacridienne en Afrique de Nord-ouest, par l'échange d'information au niveau de la région.
* par la participation à la planification du travail et de la prospection des sites en vue d'installation d'équipements adéquats.
* par le renforcement du réseau dans les zones arrêtées conjointement dans l'est et le sud du pays.
* par l'organisation des séminaires de météorologie au profit des acridologues et d'acridologie au profit des météorologistes.
* par l'encadrement des chercheurs de la DPV pour le volet météorologique en donnant les sujets et les moyens matériels pour mener ces études sur les lieux.
* par l'étude des situations météorologiques ayant favorisées par le passé l'apparition des criquets.

C'est à partir de là, que lors de l'invasion, la météorologie nationale était déjà préparée pour cette assistance.

II-EXPERIENCE DU MAROC

Les spécialistes nationaux ont pu confronter leurs expériences dans les domaines biologiques, écologiques et tenter de comprendre les raisons de cette gigantesque invasion des criquets pèlerins. La mise en place du système de lutte a donné entière satisfaction dans la mesure où le patrimoine agro-pastoral a été préservé. La fiabilité du système réside principalement dans:

* la décentralisation de la mise en oeuvre des moyens.
* le renforcement du pouvoir de décision des chefs des postes de commandement régionaux (PCR).
* la coordination au double niveau central et régional.
* la protection de la santé des personnes.
* l'importance des moyens engagés notamment le recours aux avions gros-porteurs.
* l'adoption d'une stratégie basée sur l'efficacité de la signalisation et la circulation rapide de l'information et consistant à intercepter les essaims au plus loin.

a-Rôle du poste de commandement central (PCC)

Le Poste de Commandement Central (PCC), dirigé par la Gendarmerie Royale, est mis en place pour coordonner entre les différents secteurs engagés dans la lutte antiacridienne (Agriculture, Protection civile, Armée, Santé, Météorologie, etc...).

Il est directement lié aux Postes de Commandement régionaux (PCR) qui orientent les équipes d'intervention sur terrain chargées de traitement des zones infestées par les criquets. La connaissance des données météorologiques de chacune de ces zones influant sur le comportement du criquet leur permet de connaître les particularités climatiques, afin d'augmenter l'efficacité des traitements aussi bien par voie terrestre qu'aérienne.

La représentation de la Météorologie Nationale au sein du PCC nous a permis de suivre en temps réel les différentes phases d'organisation de l'opération de lutte et la définition des moyens à mettre en oeuvre pour subvenir au mieux aux besoins en information météorologique.

Notre présence a eu l'avantage d'exposer nos idées en temps voulu sans quoi la Météorologie serait restée un secteur fournissant des renseignements sans savoir leur portée ni avoir l'échos de leur impact.

III-CONTRIBUTION DE LA METEOROLOGIE NATIONALE

Les acridiens relèvent donc des facteurs météorologiques dans leur vie quotidienne. Leurs fonctions de relation, de nutrition et de reproduction sont fortement influencées par les composantes dynamiques de leurs environnements. Cependant l'assistance fournie par la Météorologie nationale aux équipes du réseau de surveillance est engagée pour satisfaire le besoin en information météorologique. Ces équipes, responsables de traitements des endroits infestés par les criquets, interviennent aussi bien par avion que par véhicules au sol. De ce fait leur besoin en information météorologique dans les basses couches de l'atmosphère est primordial.

Cette assistance joue un rôle essentiel pour le renforcement de la collecte, de traitement, et de diffusion à tous les niveaux, de l'information sur les conditions favorables à l'invasion acridienne et l'avertissement agricole antiacridien pour une meilleure prévision et une mise en application plus efficace des moyens de lutte.

a-Structure générale

Depuis l'avènement de l'invasion des criquets, une cellule d'information et de prévision a été mise en place au Poste de Commandement Central (PCC) de lutte antiacridienne par la Direction de la Météorologie Nationale. Parallélement, au sein du Centre National de l'Exploitation Météorologique (CNEM), une autre cellule spécialisée dans les prévisions pour la lutte antiacridienne a été mise en place et a fonctionné en permanence. D'autre part le réseau de stations météorologiques sur les zones infestées a été chargé de l'acheminement des données aux différents usagers qui s'occupent de la lutte antiacridienne au niveau local.

Pour les études et les statistiques nationales et autres, la division de la climatologie générale et appliquée a contribué à l'élaboration des documents necessaires.

b-Réseau d'exploitation

- Station de RABAT/SALE

En raison de la proximité de cette station du PCC, elle lui est revenu la tache d'exposer quotidiennement l'information météorologique.

Elle fourni tous les matins au PCC:
* La situation météorologique à 00 h UTC sur les cartes 200 MGZ domaine Europe-Afrique.
* Les prévisions de vent en basse couche 700 hPa et 850 hPa valable à 12h00 UTC.
* Les prévisions sur le temps significatif valable à 12h00 UTC sur carte MAR et sur demande du PCC, la fourniture de toutes les données de base ou de prévision émanant du CNEM et des stations du réseau.

- <u>Cellule météorologique sur PCC</u>

Elle a accompli les tâches suivantes:
* Contrôle et analyse des données météorologiques disponibles au PCC (cartes, bulletins et images satellitaires).
* Elaboration du Breifing au profit du Haut commandement de la Gendarmerie Royale, ses collaborateurs et autres usagers.
* Collecte directe des données non disponibles par les moyens classiques mis en place, et leur exploitation.
* Assistance directe à la cellule aéronautique du PCC.
* Représentation de notre direction à tous travaux effectuées au PCC ou notre présence est requise.
* Elaboration de certaines études demandées par le PCC.
* Analyse et prévision sur les domaines MAROC, SAHEL, EUROPE, MEDITERANNEE OCCIDENTALE et ATLANTIQUE DU NORD.
* Liaison avec tous les services représentés au PCC (Intérieur, Agriculture, Gendarmerie Royale, etc..).
* Information journalière sur la situation acridienne dans notre pays et occasionnellement sur les pays limitrophes.

- <u>Centre national de l'exploitation météorologique (CNEM)</u>

Durant la campagne des périodes d'invasions, le CNEM prend en charge quotidiennement l'élaboration des bulletins de prévisions météorologiques. Une équipe spéciale de prévisionnistes est engagée pour accomplir cette tache. Le CNEM dispose de données brutes reçues par l'intermédiaire des moyens de télécommunication du réseau du Système Mondial de Télécommunications (SMT). Ces données sont nécessaires pour le tracé des cartes d'analyse en surface et en altitude. L'analyse de la situation météorologique nous permet d'identifier les types de masses d'air intéressant les zones infestées par les criquets afin de determiner l'état de paramètres concernés et leurs caractères d'évolution. Les cartes prévues (surface et altitude) du Centre Européen de Prévision (CEP) nous permettent de savoir le champ de pression prévu sur nos régions à une échéance qui peut s'étaler jusqu'à 6 jours.

Avant l'élaboration des bulletins, chaque jour l'équipe des prévisionnistes discute de la situation météorologique prévue au cours du Breifing pour se mettre d'accord enfin, d'une prévision représentative de chaque zone d'assistance.

En somme, le CNEM s'occupe des travaux suivants:
* Deux bulletins de prévision lutte antiacridienne à 10h00 et 15h00 UTC.
* Renseignements des stations de réseau sous forme de METAR à 08h00, 11h00 et 15h00 UTC.
* Deux bulletins de prévision sur l'ensemble du MAROC à 10h00 et 15h00 UTC.
* Prévisions moyenne échéance deux fois par semaine (lundi et jeudi).
* Essais de poursuite de prévision de la trajectoire des essaims signalés à l'aide d'un modèle de prévision de la météorologie française.
* Surveillance des zones infestées à l'aide de la station PDUS (station automatique de réception satellitaire METOSAT).

<u>c-Assistance régionale</u>

Afin de faciliter l'assistance météorologique, on a subdivisé les régions menacées par les criquets pèlerins en zones plus ou moins homogènes en tenant compte du caractère climatique et géographique de chaque région.

Ces zones sont mentionnées ci-après (voir fig.1):
- Nord de l'oriental et hauts plateaux.
- Sud de l'oriental: LAHMADA du GUIR.
- Versant Sud-est et Sud des hauts plateaux.
- Plaine du Souss Massa.
- Anti Atlas et versants Sud-est et Sud.
- LAHMADA du Draa et LAHMADA du TINDOUF.
- Nord provinces sahariennes.
- Sud provinces sahariennes.

Certaines stations appartenant à ces zones sont considérées au début comme étant des stations directement concernées par la lutte antiacridienne (voir fig.2 : NADOR, TAZA, OUJDA, BOUARFA, ERRACHIDIA, OUARZAZATE, GUELMIME, TANTAN, AGADIR, TIZNIT, SIDI IFNI, SEMARA, LAAYOUNE, EDAKHLA). Cependant, au cours de la campagne de 1987, ce réseau s'est avéré insuffisant en raison des distances entre chaque station, en particulier au Sud-est de l'Anti-atlas. C'est pourquoi au début de la campagne 1988-89 un réseau supplémentaire de stations météorologiques équipées par le programme de lutte antiacridienne a été mis en place à TENDRARA, ALNIF, ZAGORA, BOUMALEN, TATA, FOUM ZGUIDE et AKKA. Ce réseau supplémentaire est relié directement aux stations régionales et au PCC par l'intermédiaire des postes de commandements régionaux de lutte antiacridienne. L'équipement fourni aux agents mis en place leur permet de se déplacer si besoin sur les aires d'infestation massive des criquets.

d-Travaux et études

Plusieurs travaux ont été effectués par la météorologie nationale, citons à titre d'exemple:
* Etude comparative pour la station de GUELMIME entre l'infestation des criquets et les variations de température et du vent.
* Etude de fréquence des vents sur tableaux pour les dix stations météorologiques de la zone de lutte pour les périodes de Janvier, Mars, Avril 1988 et du 25 octobre au 5 décembre 1987.
* Etudes sur graphique des variations des températures extrêmes et des humidités extrêmes pour les stations de GUELMIME, ERRACHIDIA, OUARZAZATE et BOUARFA.
* Analyse de la situation météorologique qui a prévalu sur l'afrique du nord pendant les mois de Novembre et Décembre 1987 élaborée par le CNEM.
* Prévision sur nos régions des trajectoires des essaims observés.

Préparation des cartes moyennes sur le domaine des pays du SAHEL:
* Répartition climatique.
* Circulation moyenne atmosphérique (Octobre, Novembre et Décembre).
* Humidité relative moyenne (Octobre, Novembre et Décembre).
* Pluviométrie moyenne (Octobre, Novembre et Décembre).
* Pression moyenne (Octobre, Novembre et Décembre).
* Lever et coucher de soleil sous forme de tableau et de graphique de 16 stations météorologiques sur la zone de lutte.

IV-LES CONDITIONS METEOROLOGIQUES ASSOCIEES AUX INVASIONS DES CRIQUETS (CAMPAGNE 1987-1988)

Le début de l'année agricole 1987-1988 était marqué par un régime pluviométrique très appréciable en raison du passage des perturbations pluvio-orageuses sur l'afrique du nord (fig-3 :Nombre de jours de pluie - Année agricole 1987-1988).

Ces perturbations, qui sont généralement d'origine polaire, associées parfois aux systèmes nuageux d'origine tropicale, ont provoqué suffisamment de pluie favorable à l'éclosion des oeufs des criquets et au maintien du couvert végétal. Ces perturbations ont influé aussi bien sur le régime du vent que sur la quantité de pluie recueillie.

Ainsi, au mois de septembre 1987, presque toutes les hauteurs de précipitations enregistrées au MAROC, ont été proches des normales ou supérieures à la normale, sauf sur l'oriental. Il faut signaler les hauteurs exceptionnelles pour septembre enregistrées à LAAYOUNE (10.4 mm), TANTAN (11.5 mm), SIDI IFNI (15.7 mm), OUARZAZATE (30.3 mm) et ADDAKHLA (57.3 mm). (voir fig-4 Tableau climatique pour septembre 1987).

Les précipitations ont touché également la majeure partie des zones de reproduction des criquets dans les pays limitrophes; ce qui a assuré le développement de la végétation nécessaire aux différents stades de l'activité acridienne.

Sachant que le SAHEL constitue une des sources principales d'activité acridienne, les populations ont transité à l'ouest pour progresser au cours du deuxième semestre de l'année 1987 vers l'afrique du nord. Au SAHEL, les larves acridiennes ont pu profiter du front intertropical (FIT) pour assurer leur maturation, bien que les pluies aient été irrégulières. Ainsi en novembre 1987, les criquets ont pu rejoindre le Maroc en suivant les reliefs du HOGGAR (Algérie). Certes, les pluies ont permis l'émergence de pâturages dont le criquet pèlerin s'est servi comme plate-forme de relais et de multiplication.

La première décade de novembre 1987 est caractérisé par la présence, dans la baie océanique ibéro-marocaine, d'une dépression qui a donné des précipitations abondantes sur tout le pays.

La deuxième décade, au contraire, a vu des conditions anticycloniques prédominer sur le Maroc (voir fig.5 :situation en surface du 17-11-87 à 1200 UTC). Cette décade se caractérise par une circulation atmosphérique de Sud à Sud-est (vent chaud et sec soufflant du sud algérien vers la chaîne d'atlas), qui a duré jusqu'au 22 novembre. Cette situation se caractérise par d'importantes pénétrations d'essaims par le Sud marocain. Les essaims ont progressé très rapidement vers les versants Sud et Sud-est de la chaîne de l'atlas infestant toute la région.

La troisième décade a, de nouveau, été perturbée. Les perturbations venaient du Nord du 23 au 27 et du Sud-Sud-Ouest à partir du 28. Alors le fait marquant de ce mois est le nombre important de jours de précipitation (voir fig-3 :Nombre de jours de pluie - Année agricole 1987-1988). L'établissement du vent de Sud-sud-ouest à partir du 28 (voir fig-6 :situation en surface du 29 novembre 1987 à 1200 UTC), a favorisé le déplacement des essaims vers l'est de l'atlas et les régions frontalières algéro-marocaines (voir fig.7 :localisation des criquets du novembre 1987 au mars 1988).

Cependant, les pluies exceptionnelles aux confins de l'ensemble: provinces sahariennes, Algérie et Mauritanie avec des températures plus élevées que la normale, ont favorisé une bonne reproduction en décembre 1987 et janvier-février 1988. Les moyennes des températures, pendant cette période, ont généralement été plus chaudes que la normale. L'écart est faible sur le GHARB, le SAISS et les régions voisines. Il est, par contre, plus important sur le Haut Atlas et les régions proches, particulièrement sur son versant Sud-est où les normales ont été dépassées de 3 à 4°C (OUARZAZATE, ERRACHIDIA) (voir fig.8, 9 et 10 :Les tableaux climatiques de décembre 1987, janvier 1988 et février 1988).

Les précipitations ont été recueillies sur tout le littoral atlantique et le Sud-ouest du Haut-Atlas, parfois exceptionnelles, à titre d'exemple, ESSAOUIRA et OUARZAZATE correspondent à 4 fois la normale locale (voir fig.9 :Tableau climatique pour janvier 1988). Aussi, les provinces sahariennes ont reçu des précipitations très importantes, surtout entre AGADIR et ADDAKHLA (fig.11 :précipitation de l'année agricole 1987-1988).

Les pullulations qui existaient de décembre 1987 à février 1988, ont donné des ailés disponibles en mars et avril 1988, qui se sont observés successivement au Maroc, l'Algérie et la Tunisie.

Cependant, on avait signalé en fin de janvier 1988 des pullulations grégaires dans la région s'étendant du nord de la Mauritanie aux provinces sahariennes marocaines. En conséquence, une invasion de grande ampleur vers le nord était probable, dès l'établissement des conditions météorologiques favorables aux déplacements des criquets pèlerins.

Toutefois, il était très difficile d'évaluer les superficies infestées en raison de la disperssion des zones potentielles sur de très grandes étendues, l'impossibilité de prospecter certaines régions et la pénétration régulière de population acridienne qui se trouvaient sur les régions limitrophes.

Le criquet pèlerin se développe initialement dans les zones désertiques, donc des régions réputées d'accès difficile, peu habitées et difficiles à surveiller; il en résulte que la prospection de ces zones reste rare, d'ou une ignorance complète des événements acridiennes les plus importants, ainsi que des paramètres météorologiques.

En somme, les causes de grégarisation initiale du criquet pèlerin sont d'ordre naturel ainsi que le sens de déplacement des essaims. On aurait pu contrarier l'expansion démographique de cette espèce prolifique si on avait pu accéder à l'ensemble de l'aire d'infestation.

V-METHODE D'ASSISTANCE

Devant un fléau dont on a beaucoup de raisons de croire que l'homme, même moderne, est incapable de gérer en période d'expansion, il faut absolument développer un système de lutte préventive efficace. La connaissance du problème, la stratégie globale à développer, ainsi que les moyens matériels à mobiliser sont connus dans leur ensemble. Il faut aussi se préoccuper de la pérennité du fonctionnement des structures en préservant les possibilités d'évolution adaptative aux technologies nouvelles d'observation et d'évaluation des milieux terrestres en tenant compte de l'expérience déjà acquise.

L'application des techniques nouvelles dans le domaine de la lutte antiacridienne est extrêmement utile. Ces techniques permettent elles aussi, aux équipes d'intervention dans les zones infestées de prendre des décisions pratiques pour l'organisation des prospections, la surveillance, la logistique et la stratégie de la lutte.

Certaines méthodes sont utilisées, dans la lutte antiacridienne, surtout par la direction de protection des végétaux, telles que le calcul de l'indice de la végétation ou encore, l'utilisation des biomodèles.

a-Bulletin de prévision météorologique

Les prévisions pour une échéance de 48 heures sont quotidiennement transmises aux postes de commandements de lutte antiacridienne. Cette prévision se rapporte à la situation météorologique aussi bien en altitude (500,700,850 hPa) qu'en surface (l'état du ciel, phénomènes météorologiques importants, vent, températures extrêmes, humidité et visibilité).

La station de réception spatiale (PDUS) nous permet de compléter les données dont on dispose pour une meilleure analyse des situations météorologiques en temps réel en fournissant des données sur la couverture nuageuse, la température en surface et aux sommets des nuages ainsi que la trajectoire des systèmes nuageux. Elle est en mesure aussi de collecter et traiter en temps réel et différé les données en provenance de plates formes de collectes de données (DCP) qui consistent en des stations automatiques placées généralement dans des régions d'accès difficile et mesurant des paramètres tels que le vent, la pression, la température et l'humidité.

La station PDUS permet entre autres une élaboration de coloration en fonction de température, une estimation des précipitations en suivant les nuages froids dans le temps, des calculs statistiques comme l'histogramme de température pour une image donnée et l'utilisation de l'artifice des fenêtres et zooms pour agrandir les zones qui présentent plus d'intérêt avec la sortie des images sur imprimantes avec contours.

L'estimation des précipitations nous permet en définitive de localiser les endroits recevant plus de 20 mm de pluie au cours d'une décade. Les zones ayant reçu plus de 20 mm sont considérées comme des zones favorables aux criquets.

De même, on peut dresser une carte d'analyse de pluie décadaire pour identifier ces zones par l'intermédiaire des relevées pluviomètriques.

b-Modèle français de prévision de trajectoire des essaims

Le centre de Paris a développé des procédures expérimentales pour prévoir les trajectoires suivies par les essaims de sauterelles. Ces trajectoires sont calculées à partir des vents prévues par le modèle numérique EMERAUDE. Pour déclencher ces prévisions, il faut fournir au centre de Paris la position observée des essaims, et en quelques minutes, les trajectoires sont calculées et dessinées sur une carte. Cette méthode expérimentale de prévision de trajectoires suivies par les essaims de criquets nécessite de connaître à une heure fixe de la journée (10 H par exemple) la position observée des essaims. Ce modèle n'a pas donné de satisfaction et reste encore un outil expérimental.

VI-CONCLUSION

Les météorologistes, par leur contribution, à la surveillance des masses d'air, l'évaluation de leurs impacts sur les zones infestées ainsi qu'au contrôle suivi de l'évolution atmosphérique, jouent un rôle primordial dans la campagne de la lutte antiacridienne.

En outre la coopération multidisciplinaire est tellement bénéfique pour un tel pays touché par les criquets ravageurs; cette coopération devient plus efficace, si elle est dirigé par un seul commandement (exemple: PCC). Sur le plan strictement technique, les agents du terrain d'opération contribuent pleinement à l'organisation logistique des campagnes de lutte par leur connaissance du terrain et leur savoir faire en matière de communication d'intendance.

Cependant certains aspects de la lutte restent à améliorer. A ce titre, il y a lieu de retenir les recommandations suivantes:

* amélioration des moyens de surveillance et d'observation.
* renforcement des moyens techniques appropriés.
* soutient des cellules techniques météorologiques et autres par des stages de formation spécialisée.
* renforcement des échanges entre météorologistes et acridologues.

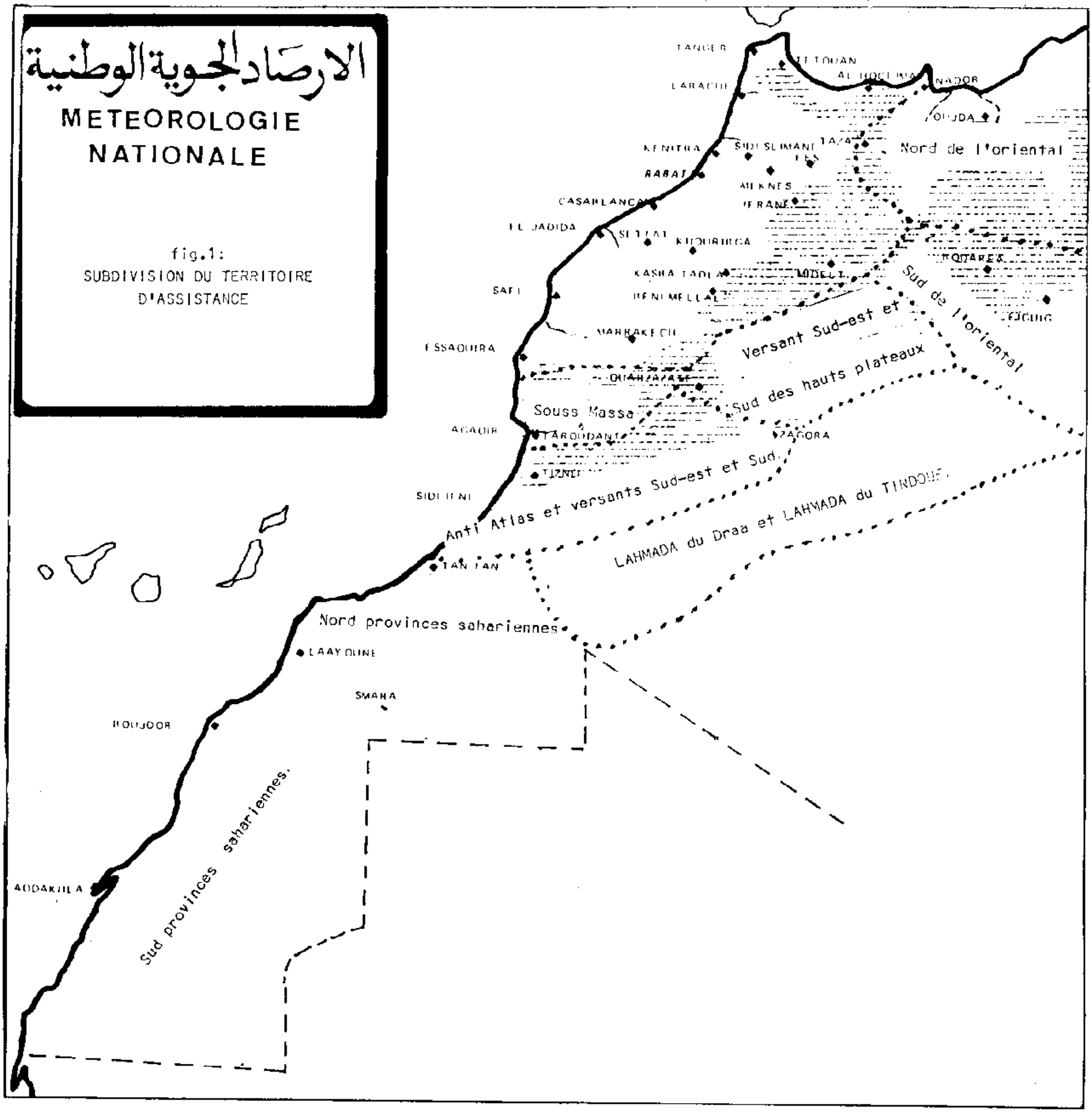
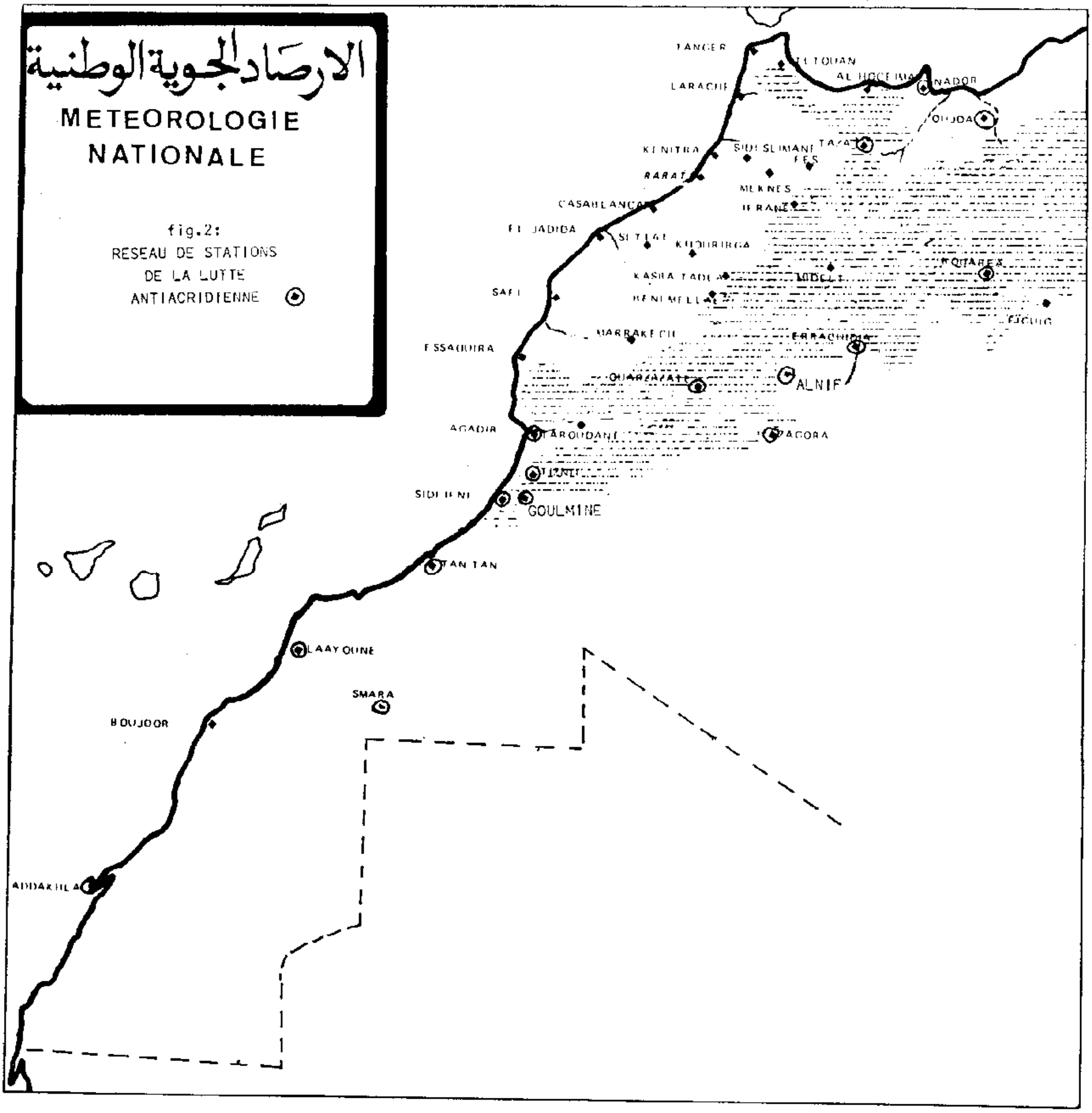


fig.1:
SUBDIVISION DU TERRITOIRE
D'ASSISTANCE


الارصاد الجوية الوطنية
METEOROLOGIE NATIONALE
fig.2:
RESEAU DE STATIONS
DE LA LUTTE
ANTIACRIDIENNE
TANGER
TETOUAN
AL HOCEIMA
NADOR
LARACHE
OUJDA
KENITRA
SIDI SLIMANE
TAZA
FES
RABAT
MEKNES
CASABLANCA
IFRANE
EL JADIDA
SETTAT
KHOURIBGA
BOUARFA
KASBA TADLA
MIDELT
SAFI
BENI MELLAL
FIGUIG
MARRAKECH
ERRACHIDIA
ESSAOUIRA
OUARZAZATE
ALNIF
AGADIR
TAROUDANT
ZAGORA
TIZNIT
SIDI IFNI
GOULMINE
TAN TAN
LAAYOUNE
SMARA
BOUJDOR
ADDAKHLA

NOMBRE DE JOURS DE PLUIE
(supérieure à 0,1mm)
Année agricole 1987 - 1988

STATIONS	SEP	OCT	NOV	DEC	JAN	FEV	MAR	AVR	MAI	JUI	JUL	AOU	Année
OUJDA	4	6	6	6	11	6	4	5	8	6	1	0	63
NADOR	3	6	10	7	7	9	5	8	10	6	0	1	72
AL HOCEIMA	4	7	7	8	8	8	2	5	6	5	0	0	60
TETOUAN	2	12	13	14	12	11	6	8	5	3	1	1	88
TANGER	4	13	12	18	16	11	7	8	5	12	2	0	108
LARACHE	3	14	13	17	16	8	7	8	7	12	1	0	106
SIDI SLIMANE	2	8	15	14	10	9	5	7	6	4	0	0	80
KENITRA	3	13	18	14	15	10	6	6	7	7	0	0	99
RABAT	2	9	17	14	14	9	6	6	7	3	0	0	87
CASABLANCA	3	8	15	12	11	11	5	7	7	6	0	0	85
CASA Med V	3	9	14	10	11	10	5	4	7	3	0	0	76
EL JADIDA	1	10	14	12	11	11	4	4	6	6	1	0	80
KHOURIBGA	7	7	10	11	10	12	5	3	6	3	1	0	75
MEKNES	4	6	14	13	10	11	4	8	6	1	0	1	78
FES	3	6	15	9	12	13	4	7	9	2	0	0	80
IFRANE	6	7	13	12	9	13	5	7	9	4	0	1	86
TAZA	4	6	13	10	11	12	6	10	9	2	2	0	85
SAFI	3	7	11	12	9	10	5	2	4	4	0	0	67
ESSAOUIRA	2	6	9	10	8	11	4	1	5	2	0	0	57
MARRAKECH	5	5	7	8	8	11	5	3	2	1	1	1	57
KASBA TADLA	4	7	11	10	8	12	5	3	6	2	1	1	70
BENI MELLAL	3	6	9	9	8	11	5	3	7	0	1	1	63
MIDELT	9	6	10	5	6	9	3	1	7	2	1	1	60
BOUARFA	3	3	4	5	7	10	3	0	2	2	1	0	40
ERRACHIDIA	2	1	5	4	2	9	1	1	3	2	0	0	30
OUARZAZATE	6	2	2	4	4	9	3	1	1	0	1	2	35
AGADIR	4	6	4	9	8	11	4	0	3	2	1	0	52
SIDI IFNI	2	5	2	10	8	9	5	0	2	3	5	4	55
TAN TAN	4	4	5	9	10	5	3	2	2	2	1	1	48
LAAYOUNE	3	5	2	6	7	6	3	0	1	1	0	0	34
DAKHLA	2	0	2	4	1	8	3	0	0	0	0	2	22

fig-3 :Tableau de nombre de jours de pluie durant l'année agricole 1987-88

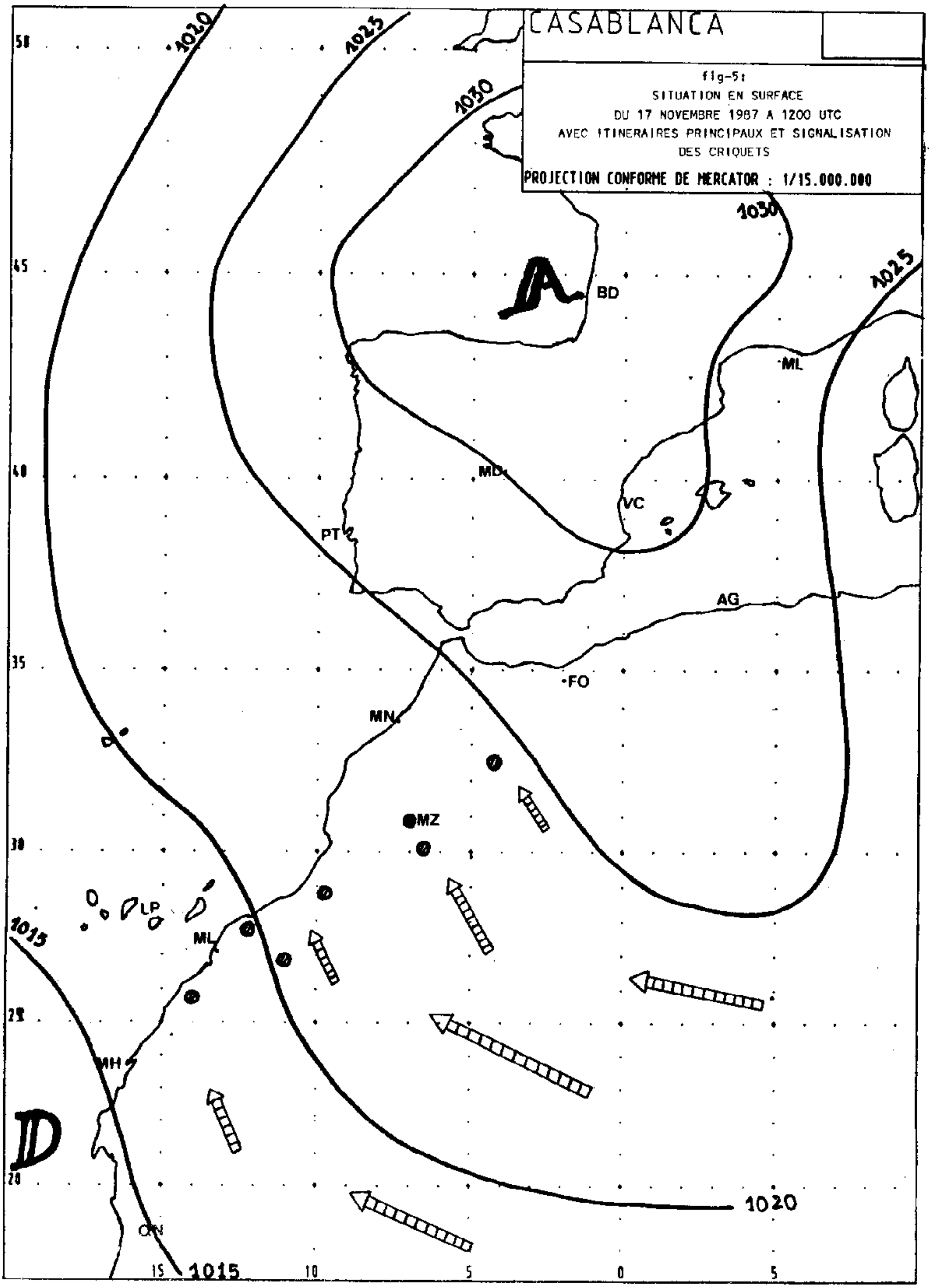
SEPTEMBRE 1987

STATIONS	Température moy en °C	Température max absolu	Température min absolu	Pluies totaux en mm	Insol totaux en heures	Humidité relative moy en %	E.T.P total en mm
OUJDA	24.7	39.0	13.5	6.4	210	66	151
NADOR	24.6	32.6	18.0	0.4	216	81	99
AL HOCEIMA	23.8	31.2	18.5	28.4	215	84	97
TETOUAN	24.1	30.4	17.5	55.9	230	77	138
TANGER	25.0	36.1	15.7	17.2	252	68	190
LARACHE	24.2	38.6	16.2	30.2	258	77	120
SIDI SLIMANE	27.2	43.7	17.0	4.9	251	64	119
KENITRA	24.3	40.5	16.4	5.9	259	79	125
RABAT	23.9	40.7	17.1	11.8	265	81	138
CASABLANCA	24.3	38.5	19.0	5.5	242	87	108
CASA M^ed^ V	25.2	41.6	14.4	6.5	250	66	133
EL JADIDA	23.5	36.4	17.0	4.6	252	82	120
KHOURIBGA	26.5	41.2	14.9	17.3	240	41	180
MEKNES	25.9	40.5	14.8	11.6	228	57	130
FES	25.4	39.5	14.5	39.7	248	49	151
IFRANE	20.4	33.3*	7.3	27.3	225	49	123
TAZA	26.0	37.0	16.2	15.6	247	57	128
SAFI	25.6	40.6	17.6	3.7	239	73	170
ESSAOUIRA	21.9	33.8	16.2	1.6	206	85	103
MARRAKECH	28.5	43.3	15.6	8.5	232	39	165
KASBA TADLA	28.2	43.6	16.3	10.6	250	40	73
BENI MELLAL	27.4	43.0*	15.0	11.8	250	43	147
MIDELT	21.9	34.8	11.7	28.2	199	45	281
BOUARFA	25.8	36.5	14.7	2.7	187	50	153
ERRACHIDIA	26.6	37.5	12.5	6.5	247	38	174
OUARZAZATE	26.0	37.8	13.2	30.3	238	34	201
AGADIR	26.2	43.8	15.4	3.3	207	67	160
SIDI IFNI	24.6	42.1*	19.0	15.7	164	83	150
TAN TAN	25.9	42.1	17.9	11.5*	186	70	251
LAAYOUNE	27.2	43.8	18.8	10.4	188	73	170
DAKHLA	24.4	34.0	18.7	57.3	169	81	136

fig-4 :Tableau climatique pour septembre 1987

Ce tableau présente les données mensuelles de température, de quantité de précipitations recueillies; de durée d'insolation, d'humidité relative et d'évapotranspiration potentielle (ETP) pour chacune des stations synoptiques du Maroc.

L'astérisque (*) indique qu'il s'agit d'une valeur record; N signifie pas de précipitation, T que les précipitations enregistrées sont inférieures à 0,1 mm.


CASABLANCA
fig-5:
SITUATION EN SURFACE
DU 17 NOVEMBRE 1987 A 1200 UTC
AVEC ITINERAIRES PRINCIPAUX ET SIGNALISATION
DES CRIQUETS
PROJECTION CONFORME DE MERCATOR : 1/15.000.000
1020
1025
1030
1030
1025
1015
1020
1015
A
D
BD
ML
MD
VC
PT
AG
FO
MN
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LP
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ON
15
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5
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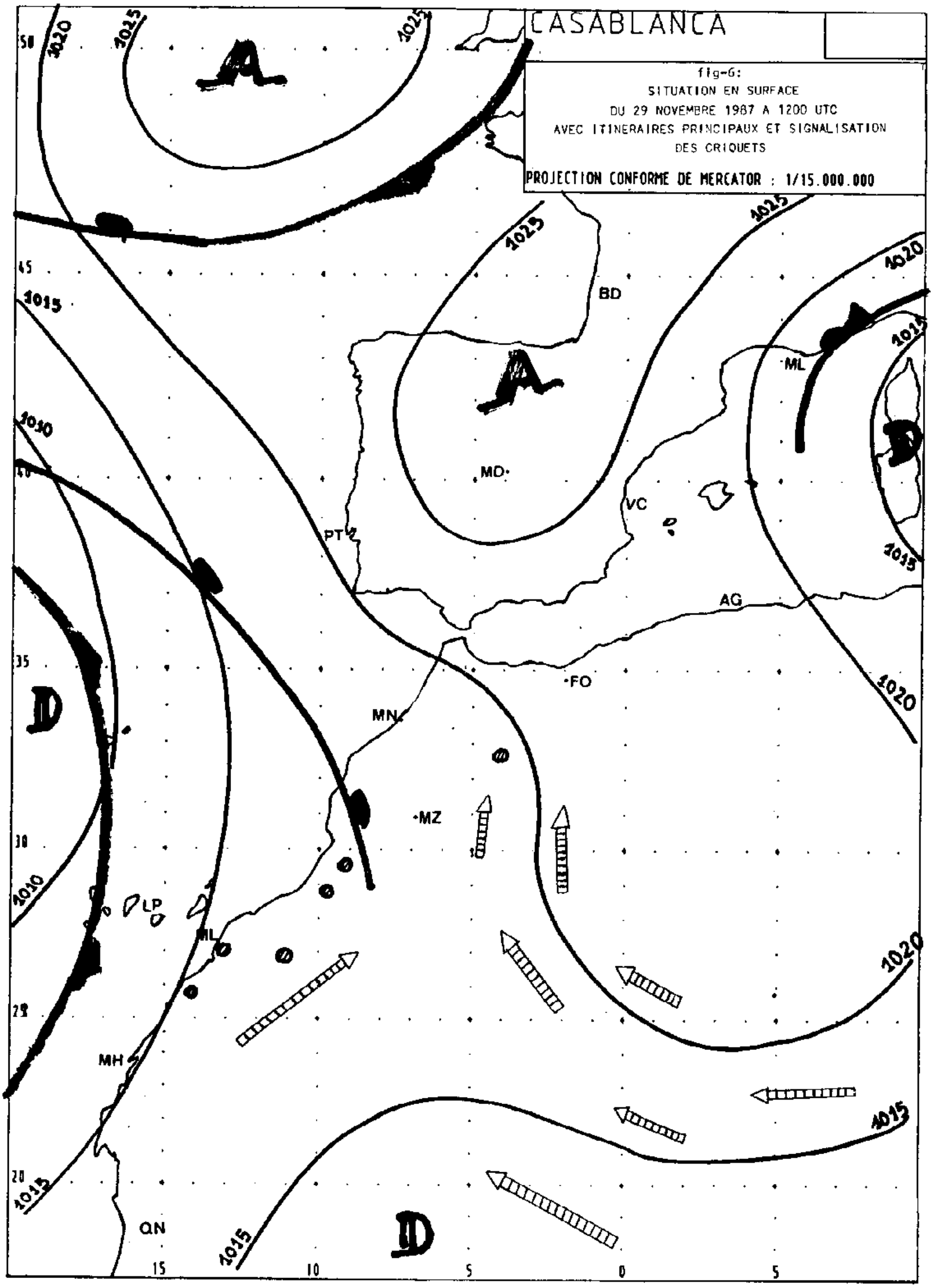
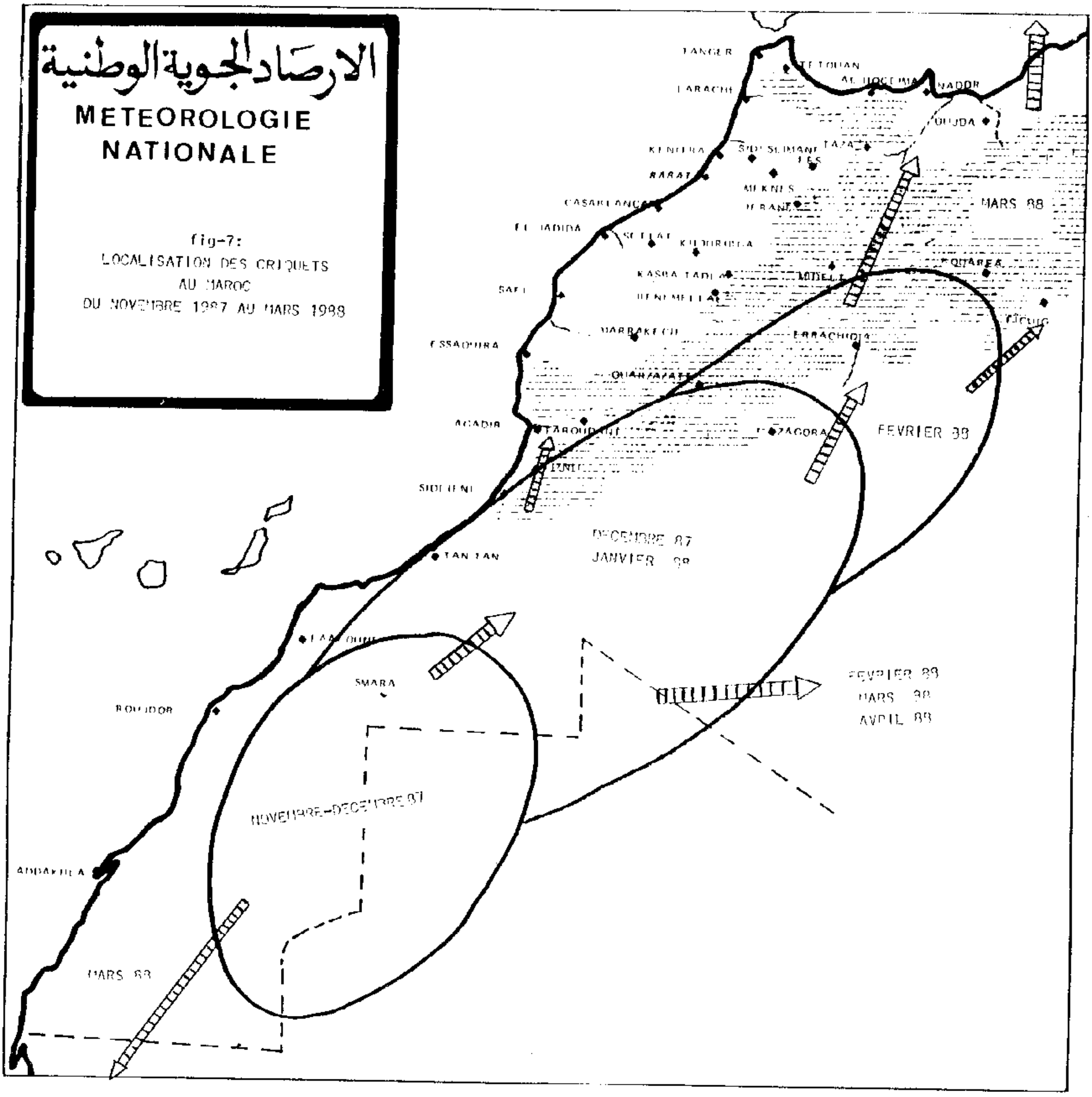
40
35
30
20


CASABLANCA
fig-6:
SITUATION EN SURFACE
DU 29 NOVEMBRE 1987 A 1200 UTC
AVEC ITINERAIRES PRINCIPAUX ET SIGNALISATION
DES CRIQUETS
PROJECTION CONFORME DE MERCATOR : 1/15.000.000
1020
1015
1025
A
D
BD
ML
MD
VC
PT
AG
FO
MN
MZ
LP
MH
QN
1010
50
45
40
35
30
25
20
15
10
5
0
5


الارصاد الجوية الوطنية
METEOROLOGIE
NATIONALE
fig-7:
LOCALISATION DES CRIQUETS
AU MAROC
DU NOVEMBRE 1987 AU MARS 1988
TANGER
TETOUAN
LARACHE
AL HOCEIMA
NADOR
OUJDA
KENITRA
SIDI SLIMANE
TAZA
FES
RABAT
MEKNES
CASABLANCA
IFRANE
MARS 88
EL JADIDA
SETTAT
KHOURIBGA
KASBA TADLA
MIDELT
BOUARFA
SAFI
BENI MELLAL
FIGUIG
MARRAKECH
ERRACHIDIA
ESSAOUIRA
OUARZAZATE
AGADIR
TAROUDANT
ZAGORA
FEVRIER 88
TIZNIT
SIDI IFNI
DECEMBRE 87
JANVIER 88
TAN TAN
LAAYOUNE
SMARA
FEVRIER 88
MARS 88
AVRIL 88
BOUJDOR
NOVEMBRE-DECEMBRE 87
DAKHLA
MARS 88

DECEMBRE 1987

STATIONS	Température moy en °C	Température max absolu	Température min absolu	Pluies totaux en mm	Insol totaux en heures	Humidité relative moy en %	E.T.P total en mm
OUJDA	12.7	24.9	0.1	20.1	189	74	39
NADOR	14.7	24.5	3.4	16.8	169	80	28
AL HOCEIMA	15.0	22.4	6.2	14.8	160	79	29
TETOUAN	15.2	22.1	6.6	88.5	142	78	55
TANGER	14.8	23.3	4.8	151.2	141	83	34
LARACHE	15.1	23.7	6.4	84.2	144	88	27
SIDI SLIMANE	15.0	26.5	5.0	73.4	173	77	32
KENITRA	14.7	22.6	4.8	107.8	171	82	24
RABAT	15.1	24.0	5.7	104.4	190	87	26
CASABLANCA	15.0	24.4	6.0	73.0	187	88	29
CASA M[ed] V	13.6	24.6	3.0	82.3	181	83	23
EL JADIDA	14.8	22.7	6.5	78.0	176	84	60
KHOURIBGA	11.6	25.4	3.1	211.0	198	83	27
MEKNES	12.4	24.6	2.8	89.3	152	81	29
FES	11.4	23.6	0.1	56.2	205	78	33
IFRANE	6.0	19.1	- 4.6	120.5	185	77	23
TAZA	12.1	23.2	2.3	41.5	179	80	23
SAFI	15.3	24.3	6.4	191.2	196	89	38
ESSAOUIRA	16.7	24.2	10.5	158.5	179	80	46
MARRAKECH	13.6	24.3	3.8	48.1	215	75	35
KASBA TADLA	12.4	24.4	2.2	77.0	207	79	28
BENI MELLAL	12.3	24.4	1.5	64.3	198	78	29
MIDELT	8.1	19.4	- 3.3	12.8	225	67	48
BOUARFA	10.3	21.1	0.0	9.3	193	65	43
ERRACHIDIA	10.6	21.7	- 1.7	19.3	239	69	31
OUARZAZATE	11.1	20.7	0.5	16.1	248	62	38
AGADIR	15.8	29.5	6.8	206.2	197	79	36
SIDI IFNI	18.1	31.0	12.0	44.2	201	81	70
TAN TAN	17.1	28.2	10.0	42.8	232	74	70
LAAYOUNE	18.0	30.2	9.9	21.1	235	72	66
DAKHLA	20.2	32.5	13.6	5.3	245	78	75

fig-8 :Tableau climatique pour décembre 1987

Ce tableau présente les données mensuelles de température, de quantité de précipitations recueillies; de durée d'insolation, d'humidité relative et d'évapotranspiration potentielle (ETP) pour chacune des stations synoptiques du Maroc.

L'astérisque (*) indique qu'il s'agit d'une valeur record; N signifie pas de précipitation, T que les précipitations enregistrées sont inférieures à 0,1 mm.

JANVIER 1988

STATIONS	Température moy en °C	Température max absolu	Température min absolu	Pluies totaux en mm	Insol totaux en heures	Humidité relative moy en %	E.T.P total en mm
OUJDA	11.4	22.5	0.2	7.7	192	69	49
NADOR	13.4	21.3	2.2	23.4	196	79	36
AL HOCEIMA	13.5	21.4	6.6	24.2	183	82	29
TETOUAN	13.6	20.3	3.0	64.4	183	72	70
TANGER	12.2	18.5	2.6	105.3	149	84	27
LARACHE	12.9	19.5	4.8	122.1	135	86	30
SIDI SLIMANE	12.6	21.3	2.0	98.8	145	70	31
KENITRA	12.6	19.9	2.5	122.3	148	87	24
RABAT	12.7	20.7	4.6	107.3	166	89	25
CASABLANCA	13.1	22.6	5.5	121.2	174	84	31
CASA M^ed V	11.2	22.0	1.0	65.8	177	82	25
EL JADIDA	12.8	20.7	3.8	129.9	177	81	44
KHOURIBGA	9.1	21.4	2.2	52.6	181	84	27
MEKNES	10.2	21.4	0.8	104.8	124	81	29
FES	9.5	19.6	- 1.3	69.4	161	80	31
IFRANE	4.0	18.1	- 6.4	175.4	167	75	24
TAZA	10.4	21.2	1.8	104.1	178	81	25
SAFI	13.1	21.4	3.3	131.1	203	83	44
ESSAOUIRA	14.5	20.4	7.7	175.2	199	81	47
MARRAKECH	11.5	22.6	3.2	62.9	195	72	35
KASBA TADLA	10.3	20.8	1.3	85.1	186	74	30
BENI MELLAL	10.0	21.2	- 1.0	80.4	176	76	32
MIDELT	7.4	18.5	- 2.4	10.7	245	57	56
BOUARFA	9.0	19.8	- 0.8	14.5	202	58	46
ERRACHIDIA	9.6	22.9	- 0.4	9.6	247	55	42
OUARZAZATE	10.2	24.7	0.7	36.9	254	50	54
AGADIR	13.3	24.2	4.6	70.4	214	76	35
SIDI IFNI	15.8	25.6	9.8	99.8	200	85	55
TAN TAN	15.2	23.0	8.3	57.9	218	72	95
LAAYOUNE	16.6	24.9	9.1	14.1	215	63	84
DAKHLA	18.0	25.0	13.0	0.1	220	77	79

fig-9 :Tableau climatique pour janvier 1988

Ce tableau présente les données mensuelles de température, de quantité de précipitations recueillies; de durée d'insolation, d'humidité relative et d'évapotranspiration potentielle (ETP) pour chacune des stations synoptiques du Maroc.

L'astérisque (*) indique qu'il s'agit d'une valeur record; N signifie pas de précipitation, T que les précipitations enregistrées sont inférieures à 0,1 mm.

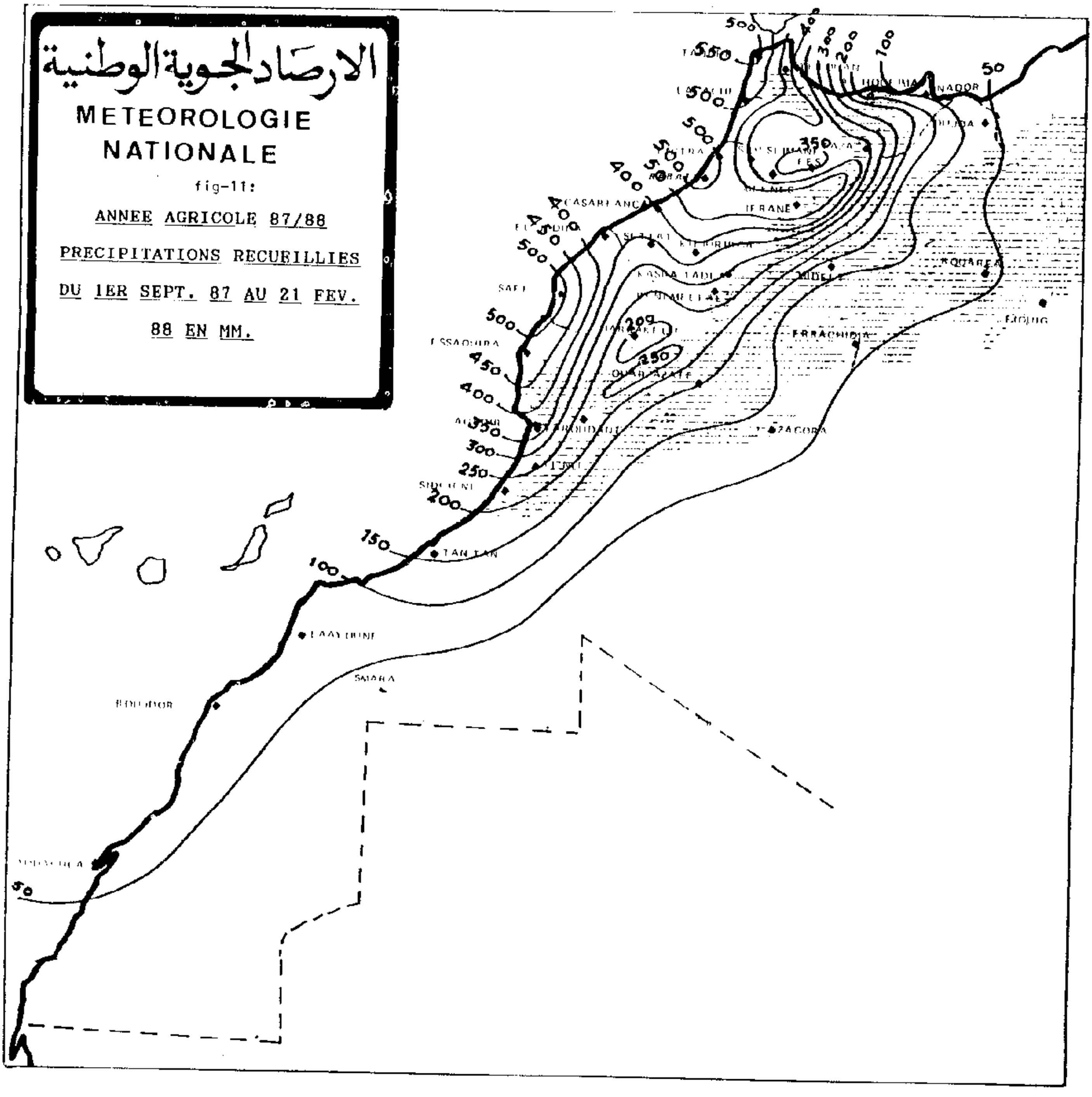
FEVRIER 1988

STATIONS	Température moy en °C	Température max absolu	Température min absolu	Pluies totaux en mm	Insol totaux en heures	Humidité relative moy en %	E.T.P total en mm
OUJDA	10.7	23.5	- 2.6	19.7	181	74	47
NADOR	12.9	21.6	4.6	24.9	187	77	47
AL HOCEIMA	13.4	21.4	6.4	20.5	177	75	49
TETOUAN	13.1	20.4	4.2	86.1	165	76	72
TANGER	12.2	20.5	2.9	41.3	194	84	57
LARACHE	13.4	23.2	4.7	42.1	191	80	46
SIDI SLIMANE	13.3	24.0	4.4	39.3	184	69	44
KENITRA	13.1	23.8	4.5	59.0	192	86	37
RABAT	13.1	25.4	3.8	51.3	192	86	37
CASABLANCA	13.4	26.6	4.2	63.7	181	81	46
CASA M^ed^ V	11.9	25.2	0.3	67.7	172	78	38
EL JADIDA	13.3	25.8	3.6	44.4	184	76	58
KHOURIBGA	10.7	21.7	- 1.0	65.9	218	79	42
MEKNES	10.9	22.5	0.0	71.6	139	80	38
FES	10.2	20.7	0.3	63.2	188	78	43
IFRANE	5.3	16.0	-10.0	151.7	188	74	36
TAZA	11.1	22.2	2.6	51.3	181	76	41
SAFI	13.8	25.5	2.5	42.9	198	80	59
ESSAOUIRA	15.2	25.4	6.7	38.9	182	79	66
MARRAKECH	12.9	25.0	2.6	51.5	185	71	53
KASBA TADLA	11.8	23.0	0.9	72.4	193	78	43
BENI MELLAL	11.7	23.2	- 0.5	82.8	178	74	44
MIDELT	8.2	20.6	- 2.2	22.9	207	61	63
BOUARFA	9.8	20.6	- 1.0	64.9	171	57	62
ERRACHIDIA	11.5	22.5	2.8	34.0	205	60	58
OUARZAZATE	12.2	22.9	0.1	66.7	222	52	76
AGADIR	15.5	27.6	2.9	47.0	183	71	56
SIDI IFNI	16.4	27.5	10.0	35.1	146	77	81
TAN TAN	16.0	26.7	8.0	43.5	165	74	113
LAAYOUNE	17.5	29.0	9.9	25.2	192	73	81
DAKHLA	18.0	30.2	11.3	48.8	193	82	82

fig-10 :Tableau climatique pour février 1988

Ce tableau présente les données mensuelles de température, de quantité de précipitations recueillies; de durée d'insolation, d'humidité relative et d'évapotranspiration potentielle (ETP) pour chacune des stations synoptiques du Maroc.

L'astérisque (*) indique qu'il s'agit d'une valeur record; N signifie pas de précipitation, T que les précipitations enregistrées sont inférieures à 0,1 mm.


الارصاد الجوية الوطنية
METEOROLOGIE
NATIONALE
fig-11:
ANNEE AGRICOLE 87/88
PRECIPITATIONS RECUEILLIES
DU 1ER SEPT. 87 AU 21 FEV.
88 EN MM.
NADOR
OUJDA
FES
IFRANE
MIDELT
BOUARFA
FIGUIG
ERRACHIDIA
ESSAOUIRA
OUARZAZATE
ZAGORA
TAN TAN
LAAYOUNE
SMARA
SAFI

CONTRIBUTION DE LA METEOROLOGIE A LA LUTTE ANTI-ACRIDIENNE

(Rawane Diop, Service météorologique, Dakar, Sénégal)

I. Généralités

Le criquet pélerin (Schistocerca Grégaria Forskal, 1 775) désigné par le nom code SGR est en phase solitaire un criquet des zones arides, dispersé sur de vastes étendues désertiques.

L'Afrique, où l'espèce vit de façon endémique, abrite 3 principales zones de reproduction :

- la corne de l'Afrique
- le sud du Sahara
- l'Afrique du Nord

Dans la corne de l'Afrique, la reproduction a lieu de juillet à octobre, puis de février à juin. Les essaims qui se forment migrent d'une part vers l'Arabie et d'autre part vers l'Afrique de l'Ouest à travers le Soudan et le Tchad.

En Afrique de l'Ouest, du Centre et de l'Est, cinq pays abritent des zones de reproduction du SGR : le Soudan, le Tchad, le Niger, le Mali et la Mauritanie, avec une période de reproduction se situant entre juillet et décembre.

La zone de reproduction de l'Afrique du Nord regroupe le Maroc, l'Algérie, la Tunisie et la Lybie. Cette zone constitue l'aire de reproduction printanière et est active de février à mai.

En phase grégaire, le SGR devient très actif sur le plan métabolique, écologiquement beaucoup moins exigeant et capable de parcourir en vol de grandes distances. Il saisit toutes les opportunités que lui offre la nature pour proliférer et gagner les zones favorables.

Pendant l'hivernage 1986 les premières populations grégarisantes furent signalées en Afrique de l'Ouest dans l'Air (Niger) et au Timetrime (Mali et Mauritanie). Plusieurs milliers d'hectares seront traités mais les populations venant régulièrement de l'Est ont continué à renouveler les effectifs.

C'est ainsi que l'année 1987 vit le démarrage incontrolable de l'invasion dont le cheminement fut le suivant dans le continent africain :

- de mai à juin 1987 : Ethiopie - Soudan
- de juillet à octobre 1987 : Tchad - Niger
- de novembre 1987 à mars 1988 : Mali, Mauritanie, Maroc, Algérie
- d'avril 1988 à février 1989 : Sénégal, et des migrations vers la Gambie, la Guinée-Bissau, la Guinée.

II. L'INVASION AU SENEGAL : CONTRIBUTION DE LA METEOROLOGIE

Le Sénégal est donc un point de passage et de stationnement des essaims grégaires. Face à cette situation, le service météorologique, en collaboration avec la Direction de la Protection des Végétaux (D.P.V.) et compte tenu des directives qui ont été dégagées à Tunis, a mis au point une stratégie d'assistance dont le principe est le suivant :

- étude du régime des vents dans les 1500 premiers mètres et établissement chaque jour de deux cartes prévues aux niveaux 600 mètres, 1000 mètres et 1500 mètres à 09 HTU et 18 HTU;

- relevé des données pluviométriques de la veille;

- établissement chaque jour de deux cartes de températures prévues à 09 HTU et 18 HTU;

- temps prévu pour le lendemain.

Le dossier ainsi préparé et analysé en rapport avec la position des essaims a permis de prévoir la trajectoire des criquets.

C'est ainsi qu'en avril, mai et juin, des essaims de dimensions relativement modestes en cours de maturation sexuelle sont passés de la Mauritanie au Sénégal où ils n'ont pas trouvé le milieu favorable (vent d'Est dominant; temps chaud et sec).

En septembre et octobre, des essaims sont revenus au Sénégal en nombre plus important. Le Sénégal offrait à cette époque un milieu très favorable, tant du point de vue alimentaire que pour la ponte.

Et c'est précisément le 21 septembre qu'à la faveur de vents forts soufflant du Nord des essaims sont entrés au Sénégal au niveau de la Cuvette de Savoigne (arrondissement de Rosso-Béthio). Cette première vague d'essaims jaunes (murs sexuellement) a rapidement longé le littoral, atteignant Tivaouane le 26 septembre (fig. 1A, 1B, 1C).

Une deuxième vague d'essaims jaunes, plus importante encore, est entrée au Sénégal les 27 et 28 septembre au niveau de Podor et Dagana (fig. 2A). Elle sera suivie de façon quasi-quotidienne par d'autres infiltrations jusqu'au 12 octobre, date à partir de laquelle ce sont des essaims à 90% roses (immatures sexuellement) que le Sénégal a reçu et de manière irrégulière jusqu'en décembre 1988.

A l'intérieur du pays, une partie des essaims jaunes a continué, à partir de Tivaouane, à suivre le littoral pour descendre vers le Sud, atteignant la Gambie le 4 octobre et Ziguinchor le 10 (fig. 3A, 3B).

L'autre partie s'est propagée à partir de Kébémer et Tivaouane vers l'intérieur, infestant le Centre Ouest (Bambey, Diourbel, Gossas), atteignant l'Est du pays (Koupentoum, Maleine) vers le 10 octobre également. Sur tout leur parcours les essaims jaunes ont déposé des quantités énormes d'oeufs dont les premières éclosions sont intervenues dans l'arrondissement de Rao le 5 octobre, multipliant ainsi les bandes larvaires au Nord et au Centre surtout.

Les cartes de vent ont permis, en plus des critères énoncés plus haut, de mettre en évidence la présence ou non d'une circulation cyclonique. Ce dernier facteur semble d'ailleurs être essentiel au regroupement des criquets.

En tout cas, tout au long de cette campagne, à chaque fois que des vents favorables ont été associés à une humidité suffisante et à la présence d'une circulation cyclonique, les essaims se sont déplacés vers ce secteur de basses pressions.

III. TRAITEMENT DES ESSAIMS

La connaissance du milieu a donc permis aux agents chargés de mener la lutte active de se diriger vers le bon endroit au bon moment.

Ainsi, sur trois millions d'hectare (3.000.000 ha) intéressés par l'invasion du criquet pèlerin, 5% ont subi des dégâts de l'ordre de 3% des récoltes. Environ 2.600.000 ha ont été traités par les équipes de la D.P.V., les aéronefs et les comités de lutte des villageois.

Ces résultats encourageants ne sont dus qu'à la collaboration entre les agents du service météorologique et les agents de la protection des végétaux chargés des opérations de lutte.

APPLICATION OF METEOROLOGICAL INFORMATION FOR LOCUST CONTROL IN ETHIOPIA

(Asgedom Asfaha, National Meteorological Service Agency, Addis Ababa, Ethiopia)

In Ethiopia there are locust recession and invasion areas which are also one of the major seasonal breeding areas of the desert locust during plagues in Africa.

The Ethiopian National Meteorological Services Agency and the Desert Locust Steering Committee work in co-operation for locust control purposes. During the three Ethiopian seasons (dry period, small rainy season and high rainy season) the synoptic features which may be responsible for the survival, reproduction, maturation, take-off, flight, landing, daily displacemnt and seasonal displacement of swarms are assessed and accordingly reported locusts are back-tracked to known or likely sources, forward-tracked from those sources in order to estimate the chance of as yet unreported invasions, and the areas of wind convergence where flying locusts can be brought closer together are located.

At present in Ethiopia there are 7 main and secondary operational points.

In 1988 in the months September-October inclusive 18, 281-HA was sprayed, 9,613.5 litres of Fenetrothion was used in 246.2 flight hours in the northern Ethiopian regions.

PRACTICES USED IN THE SUDAN FOR THE CONTROL OF LOCUSTS

Collaboration between the Meteorological Department and the Plant Protection Directorate in the Ministry of Agriculture and Natural Resources

(Sabir Ali Taha, Meteorologist, Meteorological Department, Khartoum, Sudan)

Two important meteorological phenomena are related to locust control in the Sudan. These are:

1. The Movement of the Intertropical Convergence Zone (ITCZ);

2. The Red Sea Coastal Convergence Zone (RSCZ).

Each of the above phenomena is dealt with as elaborated below:

The Movement of the Intertropical Convergence zone (ITCZ)

During the period from about April to September each year, the ITZC can be found somewhere between 10°N and 22°N in the Sudan. Starting at around 10°N in April, the ITCZ moves northward to arrive at its northern-most position at 20°-22°N in July or August after which it begins its southward retreat. During this period (April to September) the rainy season is predominant in both Central and Northern Sudan; many parts of this zone come under the influence of moist surface and low-level southwesterly rain-bearing winds.

Several episodes of locusts have been observed in the southwestern parts of the central zone of the Sudan in both the Kordofan and Darfur Regions and the locusts were aided in their northeastward movement by such low-level southwesterlies.

A close co-operation in the fight against locusts exists between the Locust Control Centre of the Plant Protection Department (PPD) and the Meteorological Department through its Forecasting Division located at Khartoum International Airport. The Forecasting Division provides the PPD with the following meteorological information:

(i) The actual and forecast position of the ITCZ;

(ii) The actual and forecast surface and low-level winds over both Central and Northern Sudan;

(iii) Mean actual and forecast air temperatures;

(iv) Rainfall amounts.

The Red Sea convergence zone (RSCZ)

There is a convergence zone in the Red Sea and its coastal areas during the period October to about May each year. The position of this zone is not steady but oscillates to the North and South. This RSCZ enhances rainfall on the western coasts of the Red Sea in the Sudan, particularly during times when extratropical depressions with their associated cold fronts (4 to 5 on average each month) move eastwards along the Mediterranean Sea or parallel to the North African Coast to the Middle East and the Near East.

For the fight against locusts in this coastal area of the Sudan, the Forecasting Division again provides daily forecasts of the following weather elements:

(i) Wind fields to determine the areas of convergence;

(ii) Air and dew-point temperatures;

(iii) Rainfall distribution;

(iv) Pressure distribution to depict, if any, the existence of a cold front intrusion associated with the eastward-moving depressions.

LA METEOROLOGIE ET LA LUTTE ANTI-ACRIDIENNE

(Office National de la Météorologie, Alger, Algérie)

I. OBJECTIF A LONG TERME DE LA LUTTE ANTI-ACRIDIENNE

Il s'agit de dégager une organisation à l'échelon national et à l'échelon régional à même d'assurer une veille permanente anti-acridienne et d'intervenir efficacement dans l'espace et le temps pour détruire les populations acridiennes.

II. OBJECTIFS A COURT TERME

Il s'agit d'utiliser de façon efficace et optimale les moyens nationaux actuels pour neutraliser les populations acridiennes. Ces moyens se trouvent à trois niveaux : local et national. Ces moyens relevant de plusieurs organismes doivent être organisés de façon à répondre opérationnellement aux besoins de la lutte anti-acridienne.

Au niveau régional, il s'agit de coordonner les moyens pour agir sur les zones prioritaires définies à partir de critères objectifs préalablement établis d'un commun accord et éventuellement sous l'égide de la FAO.

III. DEFINITION DU PROBLEME

La lutte anti-acridienne, de par sa nature, nécessite l'apport de plusieurs organismes dont les tâches sont spécifiques :

- les services de l'agriculture;
- le service météorologique;
- la société des transports aériens;
- la protection civile;
- les services de soutien (PTT, pétrole, ...)
- les organismes de recherches et de formation.

Le problème qui se pose est de définir dans un cadre approprié les prérogatives, obligations et les liens de coordination requis.

En Algérie, il y a un organe de coordination en vue d'assurer cette coordination qui est présidé par le Département de l'Agriculture.

Des objectifs spécifiques sont assignés à chaque organisme.

IV. OBJECTIF SPECIFIQUE PROPRE AU SERVICE METEOROLOGIQUE

Les conditions météorologiques interviennent à tous les stades d'évolution des acridiens : fécondation, incubation, éclosion, développement postembryonnaire, genèse des invasions.

On peut distinguer deux formes distinctes d'intervention de la météorologie :

- informations météorologiques nécessaires à la lutte durant la phase de reproduction des criquets;
- informations météorologiques nécessaires à la lutte durant la phase migratoire et de déplacement des essaims de criquets.

Chacune de ces phases fait appel à une méthodologie d'action appropriée. Si la première phase est surtout climatologique, utilisant les paramètres mesurés à la surface du sol, la seconde phase est plutôt d'ordre dynamique et fait intervenir les courants, principalement dans les basses couches de l'atmosphère.

V. METHODOLOGIE DURANT LA PHASE DE "REPRODUCTION"

L'assistance météorologique va consister à :

- élaborer des mesures au sol;
- délimiter les zones favorables à la reproduction des criquets pour permettre une intervention efficace des services chargés de la destruction des oeufs, larves et embryons.

VI. METHODOLOGIE DURANT LA PHASE "MIGRATION"

L'assistance météorologique va consister à :

- élaborer les mesures au sol;
- élaborer les mesures en altitude (profil thermique, profil d'humidité, profil du vent en vitesse et direction);
- utiliser les photos satellites;
- élaborer une prévision de déplacement des criquets.

VII. PROGRAMME DE RECHERCHE

Il consistera à :

- étudier les aspects de la météorologie synoptique par rapport à la répartition et au déplacement des insectes.

Une meilleure connaissance de la climatologie saharienne et de la météorologie tropicale (WAMEX) est nécessaire, puisque le déplacement en masse des criquets dépend des conditions atmosphériques propres.

VIII. MOYENS ET RESSOURCES

Le nombre de stations de mesure au sol doit permettre de disposer de l'information météorologique, même dans les régions difficilement accessibles.

Ces postes climatologiques feront des mesures de température, de vent et d'humidité. D'autre part, le déplacement des acridiens est lié au profil thermique et au vent en altitude, d'où la nécessité d'avoir plusieurs stations de mesure en altitude.

Une coordination entre stations et services centraux est nécessaire pour une meilleure élaboration de la prévision en temps réel.

La télédétection doit être développée pour permettre la meilleure assistance possible à la prévision.

IX. ORGANISATION

Les moyens météorologiques doivent être organisés de façon à assurer l'observation, l'exploitation de ces observations et la communication de l'information météorologique aux services chargés de l'information dans le cadre de la lutte anti-acridienne.

X. ORGANISATION DE LA PREVENTION ET DE LA LUTTE

1. Organisation

L'évolution dangereuse de la situation acridienne a conduit les autorités algériennes, dès octobre 1987, à convoquer le Comité Interministériel de Lutte Anti-acridienne (CILA - décret N°66-177 du 21 août 1966) qui a examiné et approuvé le programme d'actions de première urgence.

Dans ce cadre, un dispositif de prévention et de lutte a immédiatement été déployé à travers quatre zones opérationnelles, regroupant les principales wilaya concernées au sein desquelles ont été installés des postes de commandement de wilaya placés sous la présidence du Wali.

Les postes de commandement de wilaya, pour des besoins de coordination et d'orientation des moyens mobilisés par l'Institut National de la Protection des Végétaux (avions, camions de traitement, produits), ont été reliés à un poste de commandement central placé auprès de cet Institut.

L'instruction interministérielle N 1 du 13 juillet 1988 relative à "la prévention et la lutte contre le criquet pélerin" apporte toutes les précisions utiles quant aux missions et prérogatives de chacun de ces organes opérationnels.

1.1 Transmission de l'information

La circulation de l'information acridienne des zones opérationnelles au poste de commandement central, acheminée par un réseau spécialisé radiophonique, téléphonique et de télex, a fait l'objet d'une instruction interministérielle N 2, relative à "la transmission de l'information acridienne".

En outre, dans le cadre des comptes-rendus hebdomadaires et de la circulation de l'information, le poste de commandement central élabore et transmet :

- un flash quotidien sur la situation acridienne adressée aux Ministères de l'Agriculture, de l'Intérieur, des Finances et des Transports;

- un bulletin hebdomadaire relatif à l'évolution de la situation acridienne, aux mesures prises et aux recommandations particulières, adressé à toutes les wilaya.

1.2 Moyens mis en oeuvre

L'importance et la rapidité des moyens d'intervention mobilisés ont été à la mesure de l'intensité du fléau acridien. Le potentiel du dispositif national de l'Institut National de la Protection des Végétaux a été renforcé par les moyens réquisitionés au niveau des wilaya pour les campagnes hiverno-printanière et automno-hivernale.

XI. EFFETS SUR L'ENVIRONNEMENT ET MESURES PRISES

La lutte contre le fléau acridien fait appel à l'utilisation de pesticides en grandes quantités et sur de larges superficies.

Le choix du pesticide, la technique d'utilisation et les mesures de protection des utilisateurs ont constitué une préoccupation permanente des opérateurs.

Ainsi, dans la gamme de pesticides recommandés par la FAO ont été retenus les produits présentant une faible toxicité pour les humains et animaux et une rémanence limitée dans le temps.

Dans ce cadre, les services du Ministère de l'Agriculture, en collaboration avec ceux de la Santé Publique, de l'Intérieur, de l'Environnement, et le Haut Commissariat à la Recherche a mis en oeuvre un programme d'intervention, qu'il y a lieu de renforcer, visant :

- la couverture sanitaire des personnes intervenant dans les opérations de lutte et des populations qui y sont exposées;

- la recherche de résidus de pesticides dans les cadavres de criquets, dans le sol, les plantes et les eaux;

- la conception et l'élaboration par l'Agence Nationale de la Protection de l'Environnement d'une carte à hauts risques, prenant en considération les dangers potentiels de pollution.

XII. MESURES A PRENDRE

Les efforts à entreprendre, notamment dans le cadre de la coopération régionale et internationale, devront converger vers la mise en oeuvre d'un programme de lutte chargé d'atteindre les objectifs suivants :

1) Définition des informations requises par les services de lutte contre les criquets et sauteriaux;

2) Elaboration d'études statistiques à partir de longues séries météorologiques et de fichiers concernant les acridiens, car ce type d'études s'avère fondamental pour mener la lutte sur le plan opérationnel;

3) Echange des informations sur les techniques d'analyses des données météorologiques utilisées dans la lutte anti-acridienne;

4) Mise en oeuvre d'un Centre spécialisé en météorologie pour la lutte anti-acridienne;

5) Distribution des tâches entre les différentes parties en vue de l'élaboration de l'ensemble des informations requises;

6) Diffusion des informations aux services utilisateurs;

7) Assurer la formation des personnels spécialisés; pour celà, il s'avère nécessaire d'intensifier la coopération avec le Centre européen et les organismes spécialisés tels que la FAO. Les aspects de formation peuvent être pris en charge dans le cadre de PCV à identifier. Parmi les moyens à mettre en oeuvre à court terme on citera :

   a) le renforcement de la couverture d'observation météorologique des zones sahariennes et subsahariennes, tant dans le cadre de la VMM qu'à l'échelon régional;

   b) le renforcement des moyens des télécommunications et notamment l'accès aux données satellitaires;

   c) l'élaboration d'un modèle de prévision adapté à la région concernée par le fléau;

   d) la mise en oeuvre d'un centre opérationnel à vocation régionale, chargé de l'assistance tant sur le plan des études qu'au niveau opérationnel.

En conclusion, et compte tenu de la dimension d'un problème dépassant le cadre d'un seul pays, ce programme ne pourra se concrétiser que dans le contexte de la coopération internationale, notamment avec l'OMM qui, disposant du cadre et des moyens appropriés (VMM, PCM, PCV), est à même d'assurer d'une part l'expertise nécessaire et de contribuer d'autre part à identifier des sources de financement pour un tel projet, en coordination avec d'autres institutions telles que la FAO, le PNUE, l'UNDRO.

ORGANISATION ET MODALITES DE FONCTIONNEMENT D'UNE CAMPAGNE DE LUTTE ANTI-ACRIDIENNE

(A. Kassar, Président de la Commission de météorologie agricole)

Il peut être créé, au Première Ministère, un Conseil supérieur de lutte acridienne, présidé par le Premier Ministre ou son représentant, et groupant les Ministres, ou leurs représentants, de l'Intérieur, des Affaires étrangères, de la Défense nationale, du Plan, des Finances, de l'Equipement (ou Travaux Publics), de la Santé publique, de l'Agriculture, des Communications et de l'Information, y compris le ministère de tutelle de la météorologie nationale.

Son rôle serait d'élaborer et d'arrêter la stratégie et la politique générale en matière de lutte anti-acridienne. Pour ce faire, il devrait disposer d'un Comité national de vigilance et de lutte anti-acridienne et de Comités régionaux de vigilance et de lutte anti-acridienne créés à cet effet.

Le Comité national de vigilance et de lutte anti-acridienne devrait être présidé par un très haut responsable du Ministère de l'Agriculture et devrait veiller à l'exécution de la stratégie générale arrêtée par le Conseil supérieur de lutte anti-acridienne.

Le Comité national de vigilance et de lutte anti-acridienne serait chargé :

- de centraliser toutes les informations utiles concernant les opérations de prospection, de dépistage et d'infestation dans les régions concernées;
- de coordonner les différents programmes d'actions;
- d'organiser et d'assurer l'approvisionnement en moyens et des produits;
- de contrôler les modalités et techniques d'utilisation des moyens et produits et d'effectuer les inspections concernant le déroulement des opérations d'intervention;
- d'établir des liaisons avec les différents départements et organismes nationaux et internationaux concernés par la lutte anti-acridienne;
- d'effectuer toute autre mission que lui confierait le Conseil supérieur de lutte anti-acridienne;
- de tenir informé le Conseil supérieur de lutte anti-acridienne de l'évolution de la situation acridienne.

Le Président du Comité national de vigilance et de lutte anti-acridienne devrait disposer et gérer les crédits alloués à la campagne de lutte anti-acridienne.

La composition du Comité national de vigilance et de lutte anti-acridienne pourrait être la suivante :

- le très haut responsable du Ministère de l'Agriculture : Président;

- un représentant du Premier Ministre : membre;

- des représentants des différents ministères et organismes concernés, y compris un représentant de la météorologie nationale : membres.

Le Comité national de vigilance et de lutte anti-acridienne pourrait faire appel à toute autre personne compétente.

Les membres du Comité national de vigilance et de lutte anti-acridienne devraient être désignés par décision du Premier Ministre sur proposition des ministres concernés.

Pour l'accomplissement de sa mission, le Comité national de vigilance et de lutte anti-acridienne devrait disposer, outre les locaux administratifs éventuels, d'une salle d'opérations constituant son poste de commandement central.

Outre le secrétariat, le Comité national de vigilance et de lutte anti-acridienne pourrait comprendre les sections suivantes :

- section acrido-météorologie;
- section budget et finances;
- section logistique, matériels et approvisionnement;
- section informatique et transmissions;
- section contrôle et suivi.

Un Comité régional de vigilance et de lutte anti-acridienne devrait être créé au niveau de chaque division administrative régionale. Chaque Comité régional de vigilance et de lutte anti-acridienne serait chargé :

- de veiller à l'application des directives du Comité national de vigilance et de lutte anti-acridienne;

- de prospecter chaque zone de sa division administrative régionale, de localiser les lieux infestés et de les délimiter;

- de collecter régulièrement les informations se rapportant à la situation acridienne et de les communiquer au Comité national de vigilance et de lutte anti-acridienne aux dates et heures fixées;

- de tenir un inventaire des moyens mobilisables de la région;

- de coordonner au niveau régional toutes les actions relatives à la campagne anti-acridienne et d'en suivre l'exécution;

- de veiller à la bonne utilisation des moyens et des produits, ainsi qu'à la bonne maintenance du matériel;

- de réquisitionner, en cas de nécessité, tout moyen de la région nécessaire à la lutte.

Chaque Comité régional de vigilance et de lutte anti-acridienne devrait être présidé par le responsable politique de la division administrative régionale considérée et devrait comprendre tous les représentants des ministères et organismes concernés au niveau de la région.

Chaque Comité régional de vigilance et de lutte anti-acridienne pourrait également faire appel à toute autre personne compétente.

De même que le Comité national, les Comités régionaux de vigilance et de lutte anti-acridienne devraient pouvoir disposer de crédits pour faire face à toute dépense occasionnée par la campagne de lutte anti-acridienne.

ORGANIZATION AND WORKING PROCEDURES FOR A LOCUST CONTROL CAMPAIGN

(A. Kassar, President of the Commission for Agricultural Meteorology)

A Supreme Council for Locust Control could be created which would be presided over by the Prime Minister or his representative, and include Ministers, or their representatives, of the Interior, Foreign Affairs, National Defence, the Plan, Finance, Equipment and Housing, Public Health, Agriculture, Communications and Information, including the ministry in charge of the national Meteorological Service.

The role of this Council would be to formulate locust control strategy and policies. To do this, a National Committee as well as Regional Committees for Locust Monitoring and Control would need to be created.

The National Committee for Locust Monitoring and Control would be presided over by a senior official from the Ministry of Agriculture. It ensure the application of the overall strategy laid down by the Supreme Council for Locust Control.

The responsibilities of the National Committee for Locust Monitoring and Control would be:

- To centralize all information pertaining to quantitataive surveys, locust tracking and infestation in the regions involved;
- To co-ordinate the different plans of action;
- To organize and guarantee the supply of resources and products;
- To monitor the way in which resources and products are used and to inspect progress made in operations;
- To establish links with different departments and national and international bodies involved in locust control;
- To carry out any other task entrusted to it by the Supreme Council for Locust Control;
- To keep the Council informed of developments in the locust situation.

The President of the National Committee for Locust Monitoring and Control should hold and manage the credit allocated to the locust control campaign.

The composition of the National Committee should be as follows:

- The senior official from the Ministry of Agriculture: President;
- The Prime Minister's representative: member;
- Representatives from the different ministries and bodies involved, including a representative from the national Meteorological Service: members.

The National Committee for Locust Monitoring and Control may call upon the services of any other competent person.

The members of the National Committee for Locust Monitoring and Control are appointed by the Prime Minister on proposition of relevant ministers.

The Committee should, in addition to its administrative offices, have an operations room at its disposal which can serve as its headquarters.

In addition to the secretariat, the Committee should also include the following sections:

- locust meteorology;
- budget and finances;
- equipment and supplies;
- data processing and transmissions;
- monitoring and control.

A Regional Committee for Locust Monitoring and Control should be created in each regional administrative division. The responsibilities of each Regional Committee should be:

- To see that directives from the National Committee for Locust Monitoring and Control are applied;

- To carry out quantitative surveys of each area within its division, pin-point and demarcate infected areas;

- To collect information concerning the locust situation on a regular basis which should then be conveyed to the National Committee for Locust Monitoring and Control at specified times;

- To keep an inventory of available resources within the region;

- To co-ordinate locust control activities at regional level and to monitor implementation;

- To see that resources and products are put to good use and that equipment is well maintained;

- To commandeer, if necessary, resources in the region needed for control purposes.

Each Regional Committee for Locust Monitoring and Control should be presided over by the official in charge of the regional administrative division in question and include all representatives of relevant ministries and bodies within the region.

The Regional Committee for Locust Monitoring and Control may also call upon the services of any other competent person.

As for the National Committee, the Regional Committees for Locust Monitoring and Control should be provided with credits to cover any expense incurred in relation to the locust control campaign.