

Remote Sensing Information for Disaster Management

By

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Abstract

Climate plays an important role in the economy of many countries in the tropics. It determines the performance of the planted crops, forestry and livestock particularly in the arid and semi-arid tropics. The climate of these countries varies from dry desert through a belt of seasonal rains of varying duration and intensity to wet conditions at times. Frequent drought and flood incidences may occur causing massive damage in property and loss of lives. They usually cause shortage in stable food, loss of livestock and serious human suffering. Contribution of research in agriculture is, therefore, to reduce the negative impacts of climate variability or the foreseen climate change. The need to properly assess and predict the rainy season is important in monitoring and prediction of crop performance. In the Sudan, in the last two decades, a major drought incident occurred in 1984 affecting the whole country. Serious shortage in rainfall has occurred in several areas in the country leaving acute shortage in food production. Other localized incidences occurred during 1987, 89, 90, 91 and 1993. An exceptional case of severe drought occurred in the west in 1996 at a time when the rest of the country received normal rainfall. Several major severe flood incidences were recorded during the last two decades for the River Nile and tributaries in 1988, 94 and 1998 besides frequent wide spread flash floods. The suffering that follows an extreme weather event, such as sever drought or floods, could be alleviated through tangible advance warning systems and planning strategies based on reliable weather forecast and information. Timely available information on the nature of the forthcoming weather event would assist contingency plans to mitigate disaster and secure food needs. Remote sensing applications, therefore, may provide useful information for monitoring the environment and manage disasters.

Introduction

Climate variability is the major cause of disaster and unrest in a number of locations in the globe. Varying intensities of annual rainfall has affected many people and caused serious problems in recent years in the Sudan, as well as in many other countries. Floods usually damage the infrastructure and drought may destroy human health and life.

It is strongly believed that provision of satellite information on weather and climate shall help reducing human suffering and enable precaution measures to be undertaken in reasonable earlier time to avoid catastrophe. The study considers the role of remote sensing information on disaster management with particular reference to floods and drought. The climate dynamic models are discussed and tools and equipments for acquisition of digital information on weather and climate are highlighted.

Atmospheric processes

The atmosphere is in continuous random motion. The motion causes continuous air deformation affecting the composition and structure of the atmosphere. Being a sink and a source, the behaviour (motion and deformation) of the atmosphere enhances changes in the living environment that are mostly undesirable.

Observing the changing atmosphere provides the necessary information needed to identify the behaviour of the atmospheric systems. The interaction between the minute particles of the system may cause unfavourable random variations. Such variations are likely to cause disaster and reduce the chances for easy recover.

Being living on the earth surface, upper air observations can only be conducted remotely with high resolution and accuracy. An efficient system to sense the changing weather and climate elements in the atmosphere provides the required mechanisms for provision of information regarding the behaviour of the changing atmosphere. A sensor in a complex traveling in the atmosphere would assist to measure the instantaneous condition of the atmosphere, such as wind, temperature and humidity, at different structural levels and transmits the results to a ground detector. Such information can be easily used to monitor the living environment and help monitor disaster and manage the natural environment. The ability to carefully read the remotely sensed observations is, therefore, an ideal way of identifying the chances for survival in the living environment.

Atmospheric convergence

Convergence is a state of the atmosphere where rising - convective - air transports particles, including water vapour and aerosols, in a turbulent vertical depth. The degree of convection is determined by the vertical extent of the vertical depth. It is explained by a parcel of air traveling in wind field against the forces of attraction

of the earth's gravity. Mathematically (Gordon, 1962), the losses of mass in a sphere or a region in the atmosphere is expressed as:

$$\text{div}(p\mathbf{V}) = \frac{d(pu)}{dx} + \frac{d(pv)}{dy} + \frac{d(pw)}{dz}$$

where $\text{div}(p\mathbf{V})$ is the divergent wind field at selected level relative to the resolved 3-dimensional horizontal (u & v) and vertical (w) wind components. The letter (p) represents air density and if the density does not change appreciably then:

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0$$

and the horizontal divergence is, therefore, given as:

$$\text{div } \mathbf{V} = - \frac{dw}{dz}$$

Convergence of the atmospheric currents, which usually lead to convection in the atmosphere, is the condition necessary for active weather and associated precipitation in addition to other changes. The configuration of the wind field initiating convection is shown in Fig. 1.

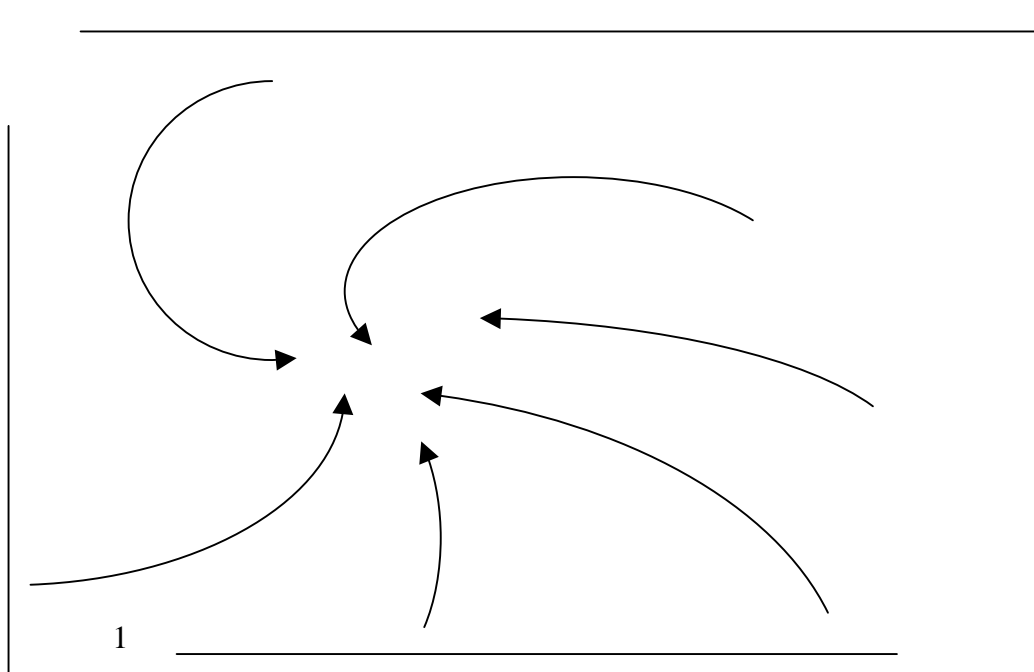


Fig. (1): Wind convergence at 850 hPa, 1200Z on 4 August 1988 over Central Sudan.

For a succession of layers in the lower depth of the atmosphere, determination of a vertical wind currents determine the established atmospheric convergence. The orientation of the 3-dimensional overlays given in Fig. 2 corresponds to active weather situation which would be responsible for localized floods. This is achieved through regular remote sensing observations.

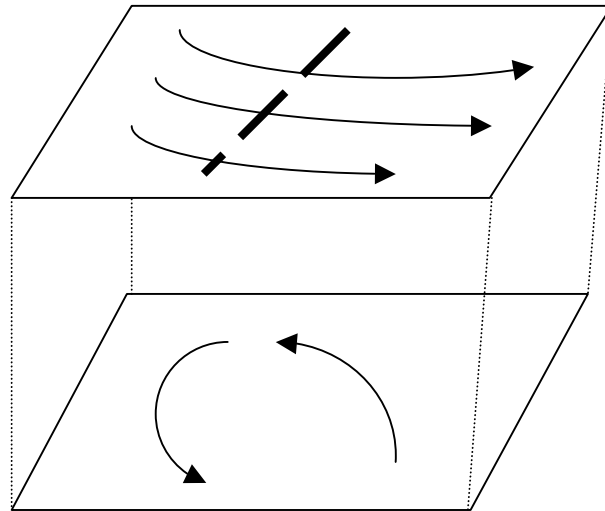


Fig. (2): Wind flow at 850 hPa and 500 hPa, 1200Z on 14 August 1994 over Western Sudan.

Atmospheric divergence

Divergence is a state of stable atmosphere. Lower diverging wind subsiding towards a lower surface (earth's surface) eliminates particles from the column of the atmosphere through which it is descending. The sky is then virtually clear. The configuration most representative for this situation is shown in Fig. 3. The

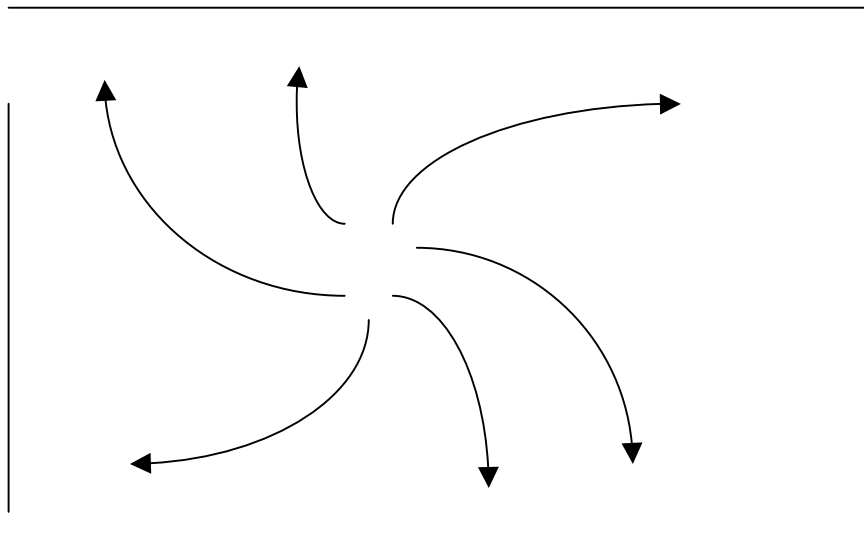


Fig. (3): Wind divergence at 850 hPa, 1200Z on 18 August 1984 over Western Sudan.

flow suppresses lower layer convergence and, because of the denser air in the lower surface, it could lead to temperature inversion overlying the stable spectrum as shown in Fig. 4. Prolonged divergence in the rain season brings about conditions favourable for drought. The dry subsiding air limits moisture availability, disturbs convection and prohibits cloud formation that might cause precipitation.

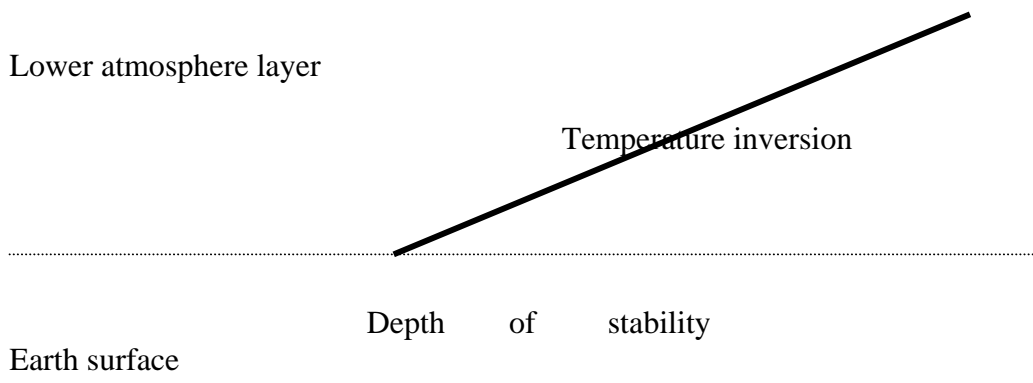


Fig. (4): Conditions favouring temperature inversion in lower atmosphere

Advection

Monsoon air flow near the earth's surface and about the lower atmosphere is transported from distant sources. Such advected air mixes with the overlying air and increases atmospheric instability. It affects moisture status of the surrounding and overlying atmosphere. When the air is induced thermally convection currents cause cloudiness which may cause precipitation. The southwesterly monsoon in the Sudan advects moisture, which, under favourable weather conditions, initiates seasonal prolonged precipitation. The schematic diagram given in Fig. 5 shows the advances of the rain season in the Sudan.

Advection of moisture continues under favourable atmospheric general circulation and the apparent location of the Inter Tropical Convergence Zone (ITCZ). Identification of the southwesterly flow, the ITCZ, the maximum wind core (Jet Stream), and the regeneration of the Mediterranean depressions and associated southerly flow indicates chances for localized and/or widespread torrential rains.

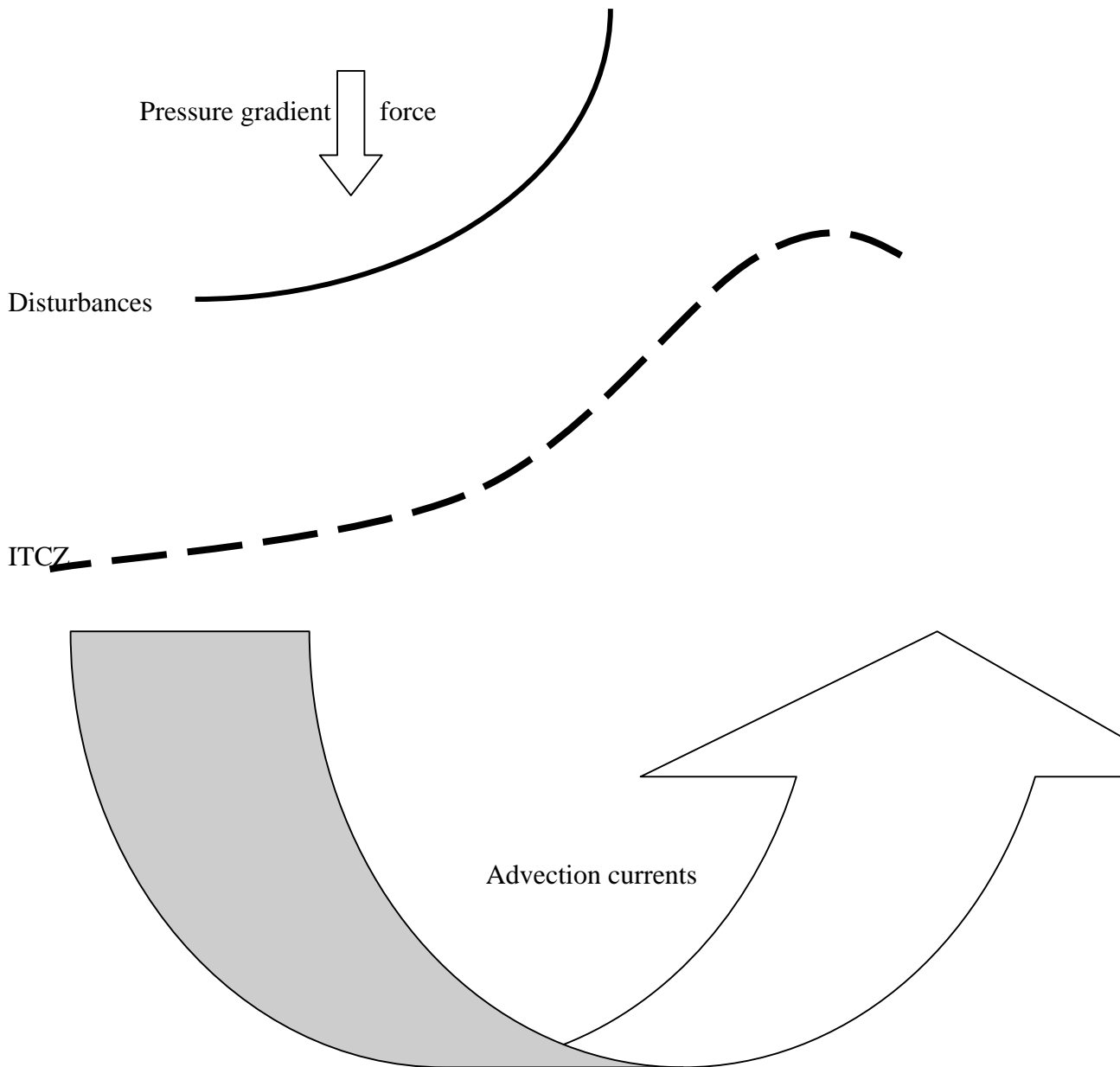


Fig. (5): Conditions initiating torrential rains in the Sudan.

Remote sensing information

Upper air information

Upper air information is crucial for monitoring disaster and managing the environment. The information is reached through meteorological radiosonde and optical theodolite observations. Upper air observation allows measurement of four key elements including wind field, which is indispensable. Best results are obtained when the network is dense and evenly distributed. Such conditions are

favourable for monitoring disaster (floods or drought) through improving and developing techniques for prediction of the onset of a disastrous phenomenon.

Radar information

Radar detection provides information that can be used for short-term disaster monitoring and early warning. The detected state of the atmosphere and the instantaneous short term monitoring of the generating cloud cells and moving cloud bands shall provide information on the likelihood of localized or wide spread storm. Frequent absence of such generating mechanisms may encourage conditions favourable for water shortage.

Complementary information

Strong winds in the upper atmosphere usually enhance instability. The extreme north location (about 16°N) of the core of the Easterly Jet stream (EJ) in the Sudan or the neighbouring countries affects the stability of the atmosphere and enhances heavy rain showers, which may cause disastrous floods. Failure to detect the EJ or the retreat of the EJ from its normal northerly location to a southerly location (about 10°N) in the rain season in the Sudan may result in drought symptoms. The determinant factor here is, therefore, the seasonal location of the jet core and, apparently, the strength of the core. Fig. 6 shows the relative location of the seasonal EJ in the Sudan. With the progress of the rain season the jet acquires the ability to progress northwards and strongly propagates westwards with the advances of the regenerated cloud bands traveling in squall line. This causes heavy and widespread rain showers, which is most likely to trigger floods.

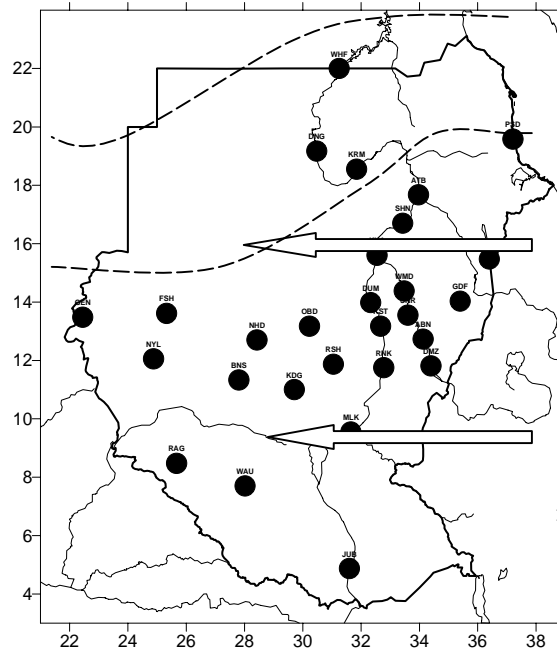


Fig. (6): Relative location of the Easterly Jet stream (in arrows) and the ITCZ (dashed lines).

The horizontal convergence of the wind field covers a larger area when the jet core is in its most northwards position.

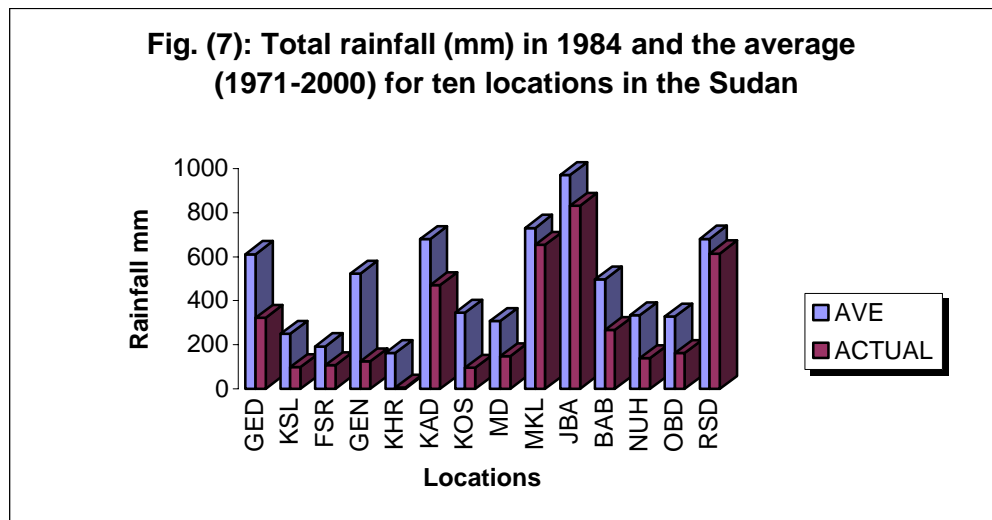
The geostationary satellites (and the orbiting satellites) detect target meteorological elements and record observed data efficiently. The results on Cold Cloud Duration (CCD), Rainfall Estimates (REF) and cloud cover support studies to identify the probability for a disaster. Prevention measures can then be considered at early stage and coordinated. The effect of disaster, therefore, can be highly reduced and the environment properly sustained.

Analytic information

Drought infliction

Analysis has indicated that a combination of incidences contributes to drought infliction. Model type results are, therefore, investigated. In dry seasons in the Sudan the ITCZ reaches 17°N in August during its seasonal northward migration. This is the furthest northern position which can be reached in dry years while the average location is about 19-20°N. The depth of advected moisture in dry years is rather shallow and trigger mechanisms remain at low profile. The absence or weakness of the EJ stream is indicative of the conditions favourable for drought symptoms or drought persistence.

A famous drought incident occurred in the Sudan during 1984. Rainfall amounts were far below average (Fig. 7). The disaster was so tragic that migration, loss

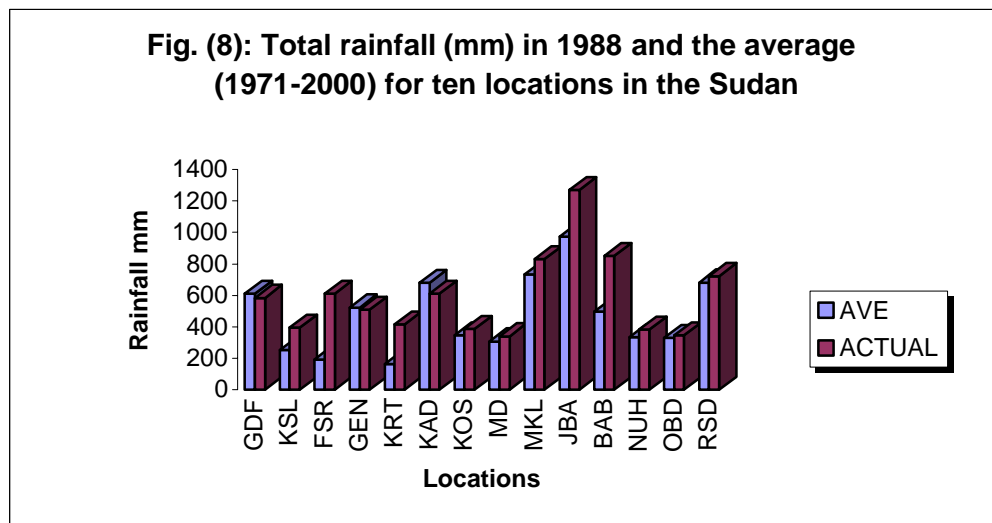


of property and even death occurred as a direct result to the severe drought. The synoptic situation was one of a unique general circulation pattern lying over and above the country as shown in Fig. 6 when the core of the EJ was about 10°N and the ITCZ was around 17°N during the peak of the rain season. The weak Mediterranean depressions failed to cause break through and the permanent undesirable synoptic situation persisted for the major part of the season. The

advection term was considerably weak. Heat generating mechanisms were relatively inactive and the established thermal factor could not provide break through.

Flood incidences

The frequency of floods in the Sudan has increased in the last two decades. The years 1994 and 1998 witnessed flood incidences of relatively high intensities. A major one occurred during 1988 and affected nearly the entire country. The amounts of rainfall in the flood years were much higher than the average (Fig. 8). Remote sensing information showed organized cloud clusters traveling,



frequently, from east to west. The advected southwesterly moist flow forced convective clouds on the edges of the Ethiopian Plateau. The clouds continued to travel in the EJ wave giving rise to continuous heavy rain showers during the rain season in that year. A huge semi-stationary cloud band (Fig. 9) was observed to cover Khartoum boundary area causing large damage to the infrastructure and properties. Few people lost their lives and many others were made homeless. Early detection of such weather situation using remote sensing techniques could have alerted the authorities to take early measures to reduce the damage and protect lives.

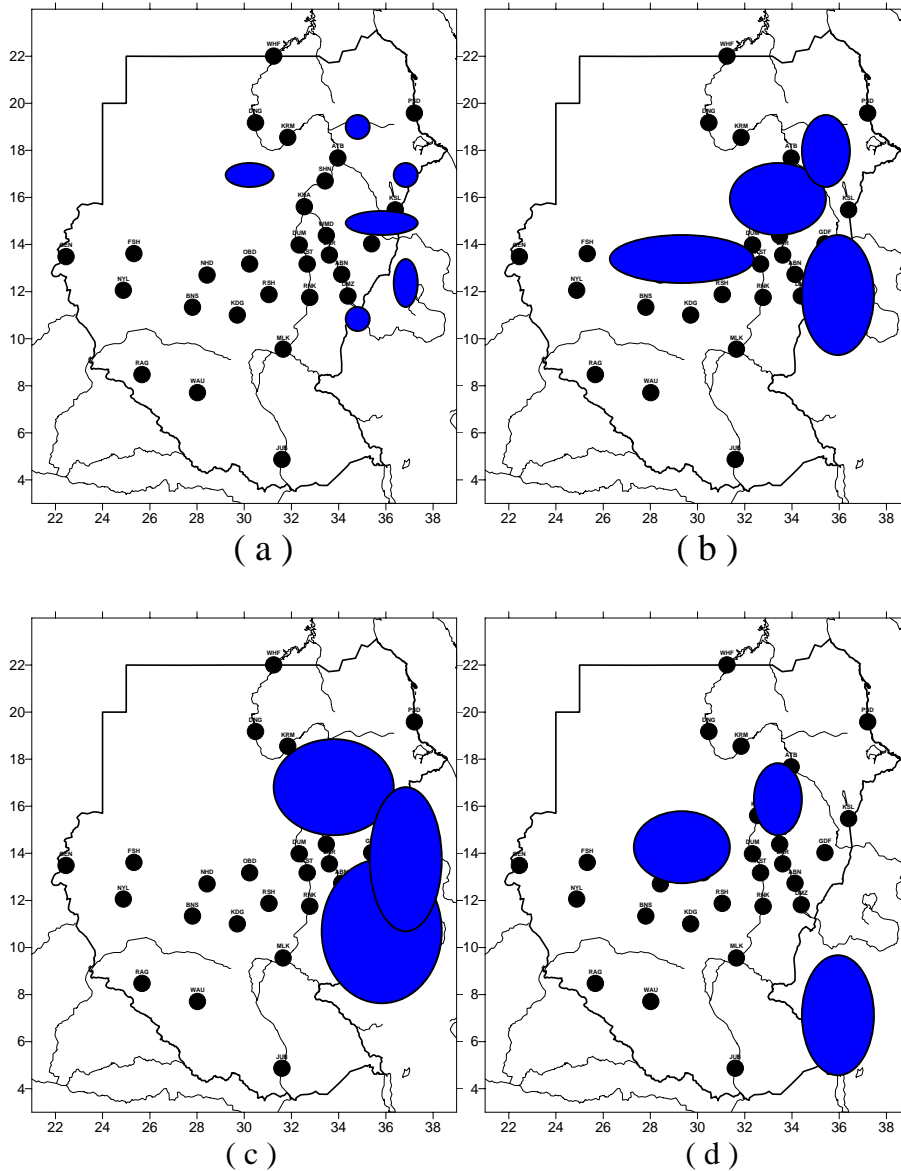


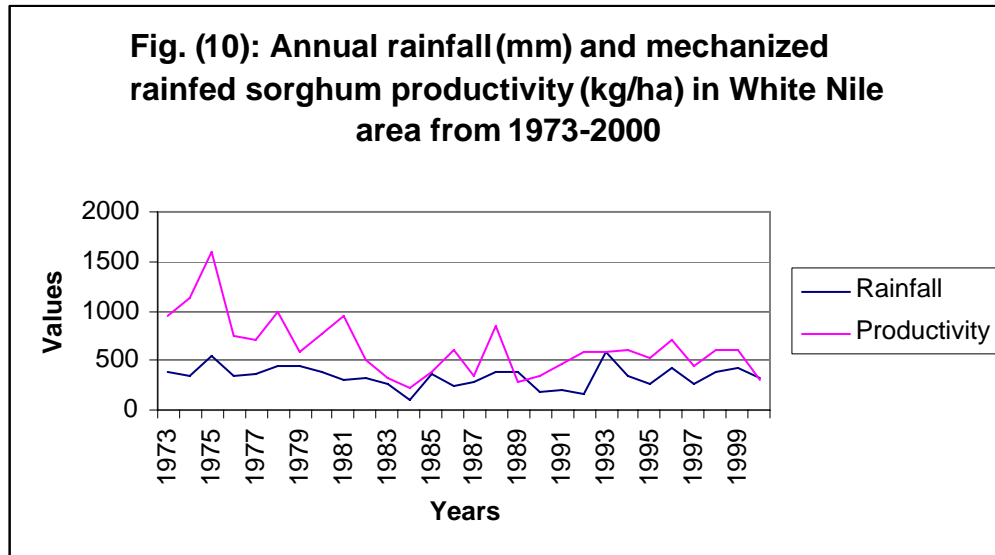
Fig. (9): Cloud cover on 4/5 August 1988 over Khartoum area (a) Development of storm clouds at 1218Z (b) Developed storm clouds at 1718Z (c) Storm cloud at 2218Z (d)Decaying clouds at 0418Z (After Ali, 1989).

Agriculture production

Agricultural production is invariably influenced by availability of soil moisture. The status of moisture is determined by the amount of rainfall, which is highly variable in space and time. Rainfall estimates produced by remote sensing techniques provide guidance and allow follow up in order to secure food needs and alleviate disaster which otherwise would result in limited agricultural production.

Attempts are still underway to increase agricultural production and improve productivity of food and cash crops in the country. In good years sorghum

productivity under mechanized rainfed practice could be as high as 1600 kg/ha (Fig. 10). Alternatively, the productivity could be as low as 225 kg/ha in bad years. The figure shows how sorghum productivity varies with rainfall in the central parts of the country.



Future perspectives

Awareness for disaster management in recent years has increased. Remotely sensed information is, therefore, becoming vital for prosperous life with less danger inflicted by disaster. Tools and equipments for developing remote sensing techniques are renewed or replaced after high technical improvements. More money is devoted for installation of space stations and calibration of data to ensure accuracy and consistency. For instance, a programme is underway to replace the old European Meteorological Satellite (METEOSAT) by a new second generation geostationary satellite. Once it is launched, the continuous flow of high quality data and information at wider spectrum of cluster information shall encourage better disaster monitoring and sustainable environmental management.

Archived data and information shall gain momentum in near future. Studies to investigate conditions favourable for disaster or extreme weather events shall require long series of historical archived data and information. In the developing countries high quality archived satellite data is of increasing importance to initiate applied research work. This shall help to bridge or narrow the existing gap between knowledge and information.

Field monitoring and experimentation is an efficient methodology for monitoring the progress of field greenness to ensure food security. Several countries in southern Africa attempted testing the value of the so called Vegetation Production Index (VPI) using remote sensing information and satellite imagery. The outcome was convincing and the VPI is now routinely applied to predict the progress of the rain season and the prospects of the crop harvest. Further attempts to implementing the VPI are encourage for the purpose of awareness and to secure

national food security. Sudan provides good opportunity for testing the viability of the VPI for a country extending, climatically, from a very dry desert in the north to the humid regions in the equatorial belt. Driven methodologies from such a test shall enable the country to reduce drastically the effect of natural disasters including wild fires.

Conclusion

Remote sensing information is useful for disaster prediction and control. When the available data and information cover long periods for extensive sensing network then more accurate results can be drawn.

Work has been done to improve prediction of extreme weather events in order to avoid disaster or to reduce the effect of disaster. Equipments are improving and becoming available. Restrictions on data and information are easing and new methodologies (VPI inclusive) to investigate the chances for disaster are introduced. However, projects for implementing the VPI are encouraged especially under the encouraging characteristics of the climate of the Sudan. Other African countries could benefit as well through implementation of tangible funded projects. Donor community is therefore highly encourage to consider improvements in data and information acquiring system in the Sudan and other African countries and to endorse genuine projects.

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