QUESTIONS ABOUT THE ITCZ MIGRATION OVER THE TROPICAL ATLANTIC SEA SURFACE TEMPERATURE IN THE GULF OF GUINEA AND THE RUNOFF OF SENEGAL RIVER

par

CITEAU J.*, FINAUD L.**, CAMMAS J.P.*[(1)] and GOURIOU Y.*[(2)]

A B S T R A C T

The seasonal displacement of the Atlantic Intertropical Convergence Zone (ITCZ - maximum of cloudiness)has been followed over fifteen years (1971-1985) with meteorological satellites imagery.

Additional data used were : wind field data from UBO (PICAUT et al., 1985) and ECMWF (Reading) analysis ; sea surface temperature on a monthly basis were provided by UBO analysis ; and the Senegal river runoff , as expected to be a good indicator of Sahelian drought, has been followed for the same period (1964 - 1985) by the ORSTOM Hydrological Service.

If the seasonal northwards displacement of the ITCZ is well correlated with the intensification of the wind stress, the relation between the anomalies of ITCZ position, SST anomalies in the Gulf of Guinea and the intensity of rainy season over sahelian countries is not always as evident as related by former works.

Moreover ITCZ and SST departures are not sufficient to support the continuous and alarming decrease of Senegal river runoff.

As dynamical processes in the upper air wind field are often mentionned about the sahelian rainy season, we have analyzed the vertical structure of wind over Niamey for recent years for which classical argumentations with ITCZ or SST gave no answer to observed climatic anomalies.

* ORSTOM/CRODT BP 2241 Dakar, Sénégal.
** ASECNA BP 3144 Dakar, Sénégal.
(1) Present adress : Université de Clermon Ferrand - France.
(2) Present adress : ORSTOM BREST - France.

The unexplained situations brought by the flow pattern suggested that, besides the components of african easterly jet, the timing of the change from dry to wet season affecting the whole system may be important in terms of mass and energy transfer between the two hemispheres.

In that idea we introduced a new parameter, the velocity of northwards ITCZ migration as a descriptor (more or less qualitative) of theses energetic seasonal changes at the onset of the rainy season.

The results obtained for the whole period 1971-1985 give more satisfactory results when analyzed versus sahelian rainfall anomalies and are able to give also , some informations about the coming rainy season in case of pessimistic configurations.

INTRODUCTION

The past fifteen years of African drought had led several authors to suggest interpretation and possible mechanisms supported by different time series of different parameters.

All of these works refer to the position of the Intertropical Zone of Convergence (ITCZ), although they differ often in its definition.

As satellite imagery now available represents a longer time serie for a continuous watch of the ITCZ, we intended in this note to check if its location followed in this way, on a daily basis over the tropical Atlantic ocean, is consistent with the general ideas referred by previous studies.

MATERIALS AND METHODS

The ITCZ (Intertropical Convergence Zone) is a wide feature of the general circulation which can be either easy to determine when narrow and unique or more difficult to locate when double, triple or broad convergence zone appears.

In order to minimize the role of our subjective analysis, we choose as FRANK (1983) to define ITCZ as the "prevailling east-west line of maximum convection" determined from satellite imagery.

The data used are NOAA (and ESSA) composite images displayer on Mercator projection. Two images per day (on visible and one night infra-red) were generally available. In case of double convergence zone, the two locations habe been distinguished, and the northern one has been chosen.

In order to avoid continental influence which induce very large north-south migrations of ITCZ, we choose to determine its location in the Atlantic equatorial zone around 28°W, in other terms in the central area between Western Africa and South America coast. The idea in this choice is to follow the limit between the northern and southern Atlantic anticyclones or in other terms their relative influences in this area.

Another reason of this choice is the fact that theories of "remote forcing" (PICAUT et al., 1985) link the intensification of the zonal component of the wind in this area to eastward propagation of Kelvin wave and later on, to the decrease of the homogeneous layer thickness and upwelling process in the Gulf of Guinea.

Mean values (over a week) of ITCZ positions have been computed from daily estimates. For recent years for which numerical data of Meteosat were available and processed on a routinely basis by ORSTOM/CMS team in Lannion, the ITCZ position has been extracted from composite images ; in retaining the "warmest value" (CITEAU, 1984) or the mean value (BELLEC, 1984).

It is clear that even if the two approaches (photographs analysis or computation) give similar results, the last one must be preferred (when numerical data are available) because it minimizes the role of subjective analysis when north-south ITCZ migration occurs at short time scale. But it is often very heavy and sometimes quite impossible in satellite data processing to go backward. The period of our analysis covers the years 1971 to 1985. Unfortunately, the period 1967-1970 delivered by NOAA was only available as a mean monthly cloud climatology atlas for the whole period, and unusable for our intent.

- Other sources of data used here were the monthly wind field and SST field from SERVAIN (UBO), covering the period of our study.
- Wind field issued from ECMWF (*) (Reading) analysis at standart levels between 100 mb and 1000 mb for recent period (1980-1984).
- SST ship of opportunity data delivered by French Meteorology.
- At last, the runoff record of Senegal river has been used as a drought indicator : in spite of the fact that this river originates in Guinea mounts different authors obtained a fairly good correlation (0,76) between its flow (in module) and annual normalized rainfall over Sahel (PALUTIKOF et al., 1981 and SIRCOULON, 1976).

R E S U L T S

In figure 1 is given the representation of ITCZ location versus time for years 1971 to 1985, along the meridian 28°W.

The ITCZ migrations has been analyzed versus different parameters as follows :

- <u>Relation between ITCZ and local sea level wind</u> :

As different existing works (HASTENRATH et al., 1977 ; Documentation AIR FRANCE, 1963) assess the relation between ITCZ location and minimum of wind in the same area at sea level, we have examined more precisely the connection between the date of the zonal wind component intensification at sea level, and the date of the northwards ITCZ motion.

The result is displayed in figure 2. As expected, a good correlation (r = 0,84) exists between the two dates and moreover, it appears that the northwards motion of ITCZ precedes broadly the zonal wind intensification (at sea level) by 25 days approximately (slope 0,99 ; intercept = 24,8).

(*) ECMWF : European Center for Medium Range Weather Forecast.

- ITCZ migration characteristics :

Another observation issued from the same figure 2, is the time delay existing between years (as 76, 82, 83) characterized by an early date of northwards migration and years (as 71, 74, 77...) for which the same signal occurs later.

This signal can be related to the global displacement of the two anti-cyclonic centers (Azores and St. Helena over the Atlantic).

The northernmost position reached by the ITCZ is the most frequent characteristic used to compare different years and to relate these to dry or wet years ... ans that point will be discussed later. A qualitative comparison for ITCZ motion along 28°W, is given on figure 1 for which a limit at 8°N has been drawn.

Discarding the cyclones phenomena which generally begin at the end of september,and draw ITCZ northwards, its northernmost position has been actually observed between 8 and 10° N during 1971, 1974 to 1976, 1978, 1982, 1983 and 1985.

The remaining years indicate during summertime a northern position roughly equal to or lesser than 8°N.

- Relations between ITCZ and sea surface temperature :

Remote forcing theories (PICAUT, 1983) linked the (eastern) equatorial Atlantic upwelling which occurs in summertime to wind intensification in the western Atlantic area.

In the same idea of wind-driven upwelling, the intensity of equatorial upwelling has been related to the position of ITCZ during summertime.

Keeping in mind the 1968 event related by HISARD (1980) for which ITCZ was at a more southern position than usual during summertime (LAMB, 1978), and for which sea surface temperature show positive anomalies in the Gulf of Guinea, we tried to check this scheme with our series.

In focusing attention to the sea surface temperature anomaly in the area bounded by 2°N-2°S and 12°W-8°W during the period July-August, it appears that (fig. 3).

Roughly and in qualitative terms, years showing a northernmost ITCZ location (north of 8°N), show also negative temperature anomalies in summertime except for :

- 1982 and 1983, for which the equatorial upwelling is close to the mean signal (the characteristic of these years being rather an early equatorial upwelling).
- for 1985 for which the SST anomalies of the period June to August were positive or close to the mean.

These three cases apart, 1971, 74, 75, 76 and 78 are actually relevant of the previously so defined group of years.

On the other side, years showing a weaker northward location in summertime show a weak equatorial upwelling or position anomalies and that is the case of 1973, 77, 79, 81, 84, except for :

- 1972 for which the observed cooling along the equator was close to the mean in spite of an ITCZ location near of 8°N.

This year was the well-reported drought year on both sides of the Atlantic, either on Brazil or the western Africa. It is the only year showing a short amplitude of ITCZ locations between January and September : the ITCZ location remains between 2N and 8N (except during a week in July) (The drought ober Brazil was in fact concerned by the October 71 to May 72 period for which ITCZ was at northern position than usual. The 1972 African drought was concerned by May to September period).

In order to test the consistency of these observations, a correlation has been attempted in introducing a time delay between ITCZ positions anomalies along 28°W and SST anomalies in the Gulf of Guinea: the result displayed (in figure 4) a poor correlation between the two parameters. The maximum value (0.4) being obtained with a time lag of 1 month.

- Relation of ITCZ and SST with the flow of Senegal river :

As previously mentionned, the work of PALUTIKOFF (1984) allows to consider in a first step, the flow of Senegal river as representative of the Sahelian drought.

Notwithstanding that Senegal river originates in Guinea mounts, it can be observed (NICHOLSON, 1980, 1981 ; MOTHA et al., 1980) that the African drought has extended simultaneously over a large area of intertropical Africa, and the fact that the flow of Senegal river(in normalized departure) is globally similar to rainfall index of LAMB (1982) or others, is not a pure coincidence.

The data kindly provided by the Service Hydrologique of ORSTOM-DAKAR (OLIVRY, 1983; GAC, 1985) are represented in figure 5 in term of normalized departure of the flow in module.

The main feature evidenced is a general decrease of the flow and, for 80 % the module is representative of the amount of rain during the hydrological year (GAC, pers. comm).

This general decrease, consistent with the linear downward trend observed in Agades (Niger) and Abeche (Tchad), (HARE,1983), cannot be explained only by ITCZ or SST departures.

But, in counterpart, potential mechanism given by SCHUPELIUS (1975) and HASTENRATH (1984), may explain a part of these year to year variations.

Before 1971 :

We must remind that,(reported by aforementionned references) in 1968, ITCZ location was observed at markedly southern positions, and northern ones in 1967 and 1969.

For the same time in the Gulf of Guinea SST anomalies were positive in 1968 and negative in 1967 and 1969. Senegal river departure is negative in 1968, positive in 1967 and 1969. Rainfall variations over sahelian countries reported negative anomalies in 1968 and positive in 1967 and 1969 (JANICOT, 1985). Furthermore, the same author evidence the opposite rainy regime existing in west Africa, between sahelian area and coastal countries of Gulf of Guinea (raifall over 1941-1973 period).

After 1971 :

If we admit that a northern position of ITCZ and a marked equatorial upwelling meet with wet years over Sahelian countries, our series till 1979 in ITCZ, SST and Senegal flow agrees more or less with this scheme.

1972, 1973, 1977, 1979 and 1984 have low ITCZ position, weak upwelling and a relative deficit in Senegal river flow.

On the other side, years 1971, 1974, 1975 and 1978 show opposite observations. Exceptions to this scheme are the following :

- the year 1976 for which ITCZ at northern positions and an intense equatorial upwelling are opposite to a flow decrease.

The series 1980-1983 has no more issue in that direction :

- 1980 and 1981 are very close in terms of Senegal river flow or ITCZ motions but their respective upwellings are different (positive anomalies in 1981)

- in 1982 and 1983 very similar motions were observed for ITCZ but (as aforementionned), the observed upwellings are quite normal in spite of northern position of ITCZ (10°N).

As well reported by the flow of Senegal river, these years have known severe droughts.

While the year 1984, relative to its ITCZ and SST signals, support a "normal dryness", the year 1985, which was wetter, leads to unexplained SST positive anomalies.

The conclusion is that if ITCZ and SST, choosen here, have any significance in terms of drought, and if this one can be followed by the module of Senegal river, it is clear that ITCZ and SST may appear as components or descriptors of drought but are not the only ones.

As rain over sahelian area is frequently referred to "squall lines" and atmospheric circulation,we have searched in other directions explanations of the interannual drought anomalies for the "eighties", years for which precedent scheme fails.

DHONNEUR (1985), LAMBERGEON (1981), LE ROUX (1983) among other tropical meteorologists admit that the rainy season in Western Africa is the result of :

- a monsoon flux over the Atlantic ocean governed by the S.E. trades (trajectories) and the sea surface temperature over the tropical area (heat and vapor content),
- the transport of this monsoon flux over the continent governed by the relative action of St Helena and Azores anticyclones with the saharian trough,
- the effective use of the vapor content of the ITCZ and its precipitation.

In this latter step, the role of African and tropical easterly jet (AEJ and TEJ) has been investigated.

"These jets have seasonal migrations and follow the migration of anticyclonic area in altitude and consequently... are associated to the meteorological equator and the raining belt".

From several studies, DHONNEUR (1985), TOURRE (1979) and FINAUD (1976), it is suggested that a dry year over sahelian countries may be linked to :

- a late northward migration of the AEJ,
- a positive velocity anomaly of the AEJ,
- a weak TEJ.

The opposite observations prevail in wet years.

Taking in reference the data acquired over NIAMEY in 1969 (wet year) and 1972 (dry year),we tried to analyse the serie 1980-1984 in terms of atmospheric circulation over NIAMEY (fig. 6) :

- 1980 displays a late northwards AEJ migration (day 170) (but the velocity is similar to the 1969 wet year),
- 1981 displays an early northwards AEJ migration (day 135) and the velocity is weak : the year 1981 should have been wet,
- in 1982 the S-N and N-S migration cannot be isolated (as in 1972) and occurs at the 195th day but the velocity is weak,
- in 1983 the S-N migration occurs late at day 180 : the AEJ velocity anomaly is positive and the observed drought was "normal" according to last scheme,
- in 1984 the S-N migration occurs at day 150 but the AEJ velocity shows a positive anomaly.

In short, it appears that :

- years 80, 82, 83 belong to the last scheme,
- the 1981 year raises a question in interpretation of the AEJ northwards migration,
- in 1984 in spite of an early northward AEJ migration, the drought over sahelian area was as severe as precedent year, and it is more its positive velocity anomaly which may explain the weakness of the rainy season.

From this short review, and with the two proposed parameters, it is difficult to make clear difference between a weak or a strong African easterly jet. Conversely, the onset of this flow could be probably the better index.

As the timing of all these events (SST, ITCZ, AEJ and TEJ) is documented, and as the limits governing a wet or a dry year are globally known (even if questions remain), it may be interesting to determine whether the velocity of the seasonnal changes has an effect.

We have used once more the ITCZ representation displayed in figure 1, and computed the velocity of the northward migration.

The result is displayed in figure 7 which recapitulates SST (a) and ITCZ (b) anomalies, velocity of northward migration (c), and normalized departure of Senegal river flow (d).

In this figure years showing a slow northward migration (1972, 1982, 1983) are also years of important rain deficit.

On the other side, a rapid migration as for 1974 and 1985 is associated with wetter years.

This figure showing parallel evolutions of Senegal river departure and velocity of the ITCZ northward migration, has the advantage to take into account our whole serie 1971-1985, when admitted that at rainy season, ITCZ and SST must reach their "normal" values.

Nevertheless one exception appears for 1984, for which our drought indicator (Senegal river) may be affected by repeated drought and the need of feeding underground water (GAC, com. pers.).

Moreover certain situations showing an early northward migration (76, 82, 83), inducing a slow ITCZ northward movement, can be indicator for a bad coming rainy season.

C O N C L U S I O N

In this work, the intent was to take advantage of the availability of NOAA imagery to follow ITCZ over a longer time period.

The link between ITCZ and rainy season over western Africa (Sahelian regime or Gulf of Guinea regime) has been widely studied in term of scalar parameters (cloudiness, position, temperature).

The addition of a dynamic component (or similar to momentum transfer) is an help for recent unexplained drought situations.

As the satellite imagery, available daily, contains a lot of information, a regular and normalized watch can be suggested, especially in regard of TOGA programme.

Moreover the onset of the rainy season over western Africa can be followed and in some case its quality expected.

A C K N O W L E D G E M E N T S

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CAPTIONS OF FIGURES

Figure 1 - ITCZ positions along 28°W.

Figure 2 - Date of zonal wind intensification versus date of ITCZ northward migration.

Figure 3 - Sea surface temperature anomalies in 2N-2S, 8W-12W area.

Figure 4 - Correlation between ITCZ position anomalies and SST anomalies.

Figure 5 - Standardized departure of Senegal river runoff.

Figure 6 - Zonal component of wind over Niamey.

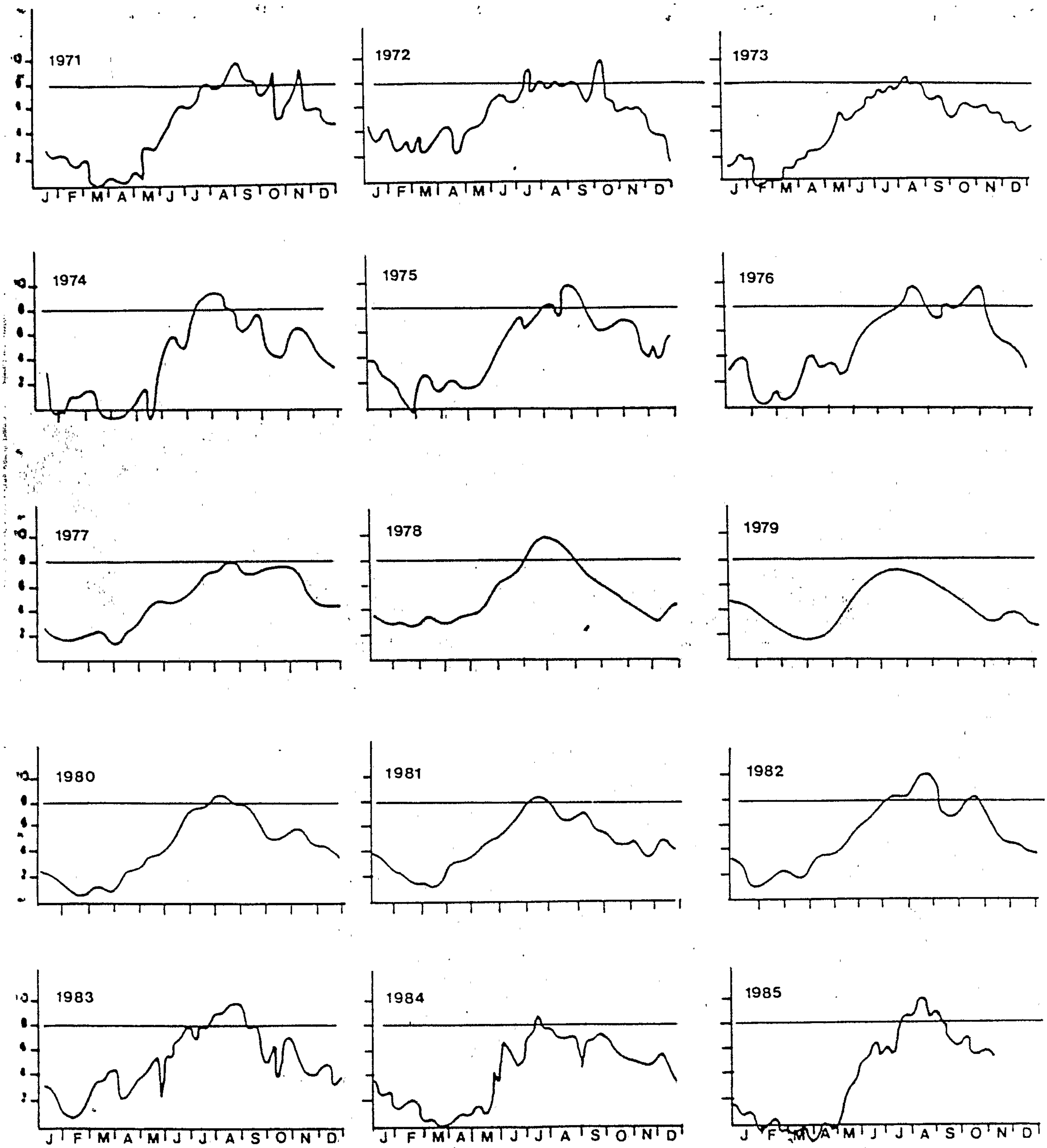
Figure 7 - Time series of

a) SST anomalies in 2N-2S, 8W-12W area

b) ITCZ positions anomalies along 28°W

c) mean velocity of northwards ITCZ migration

d) standardized departure of Senegal river runoff.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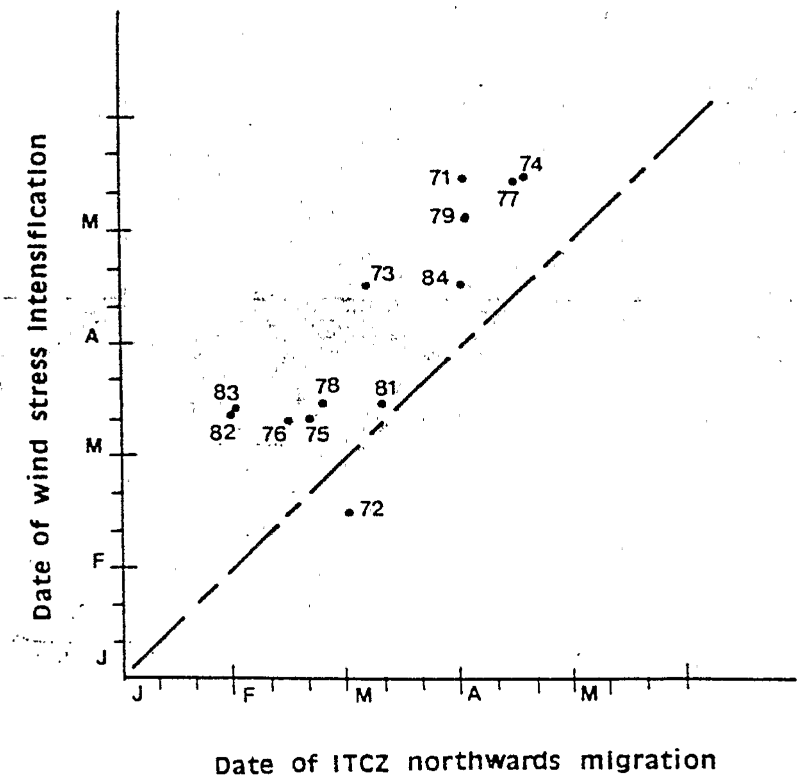
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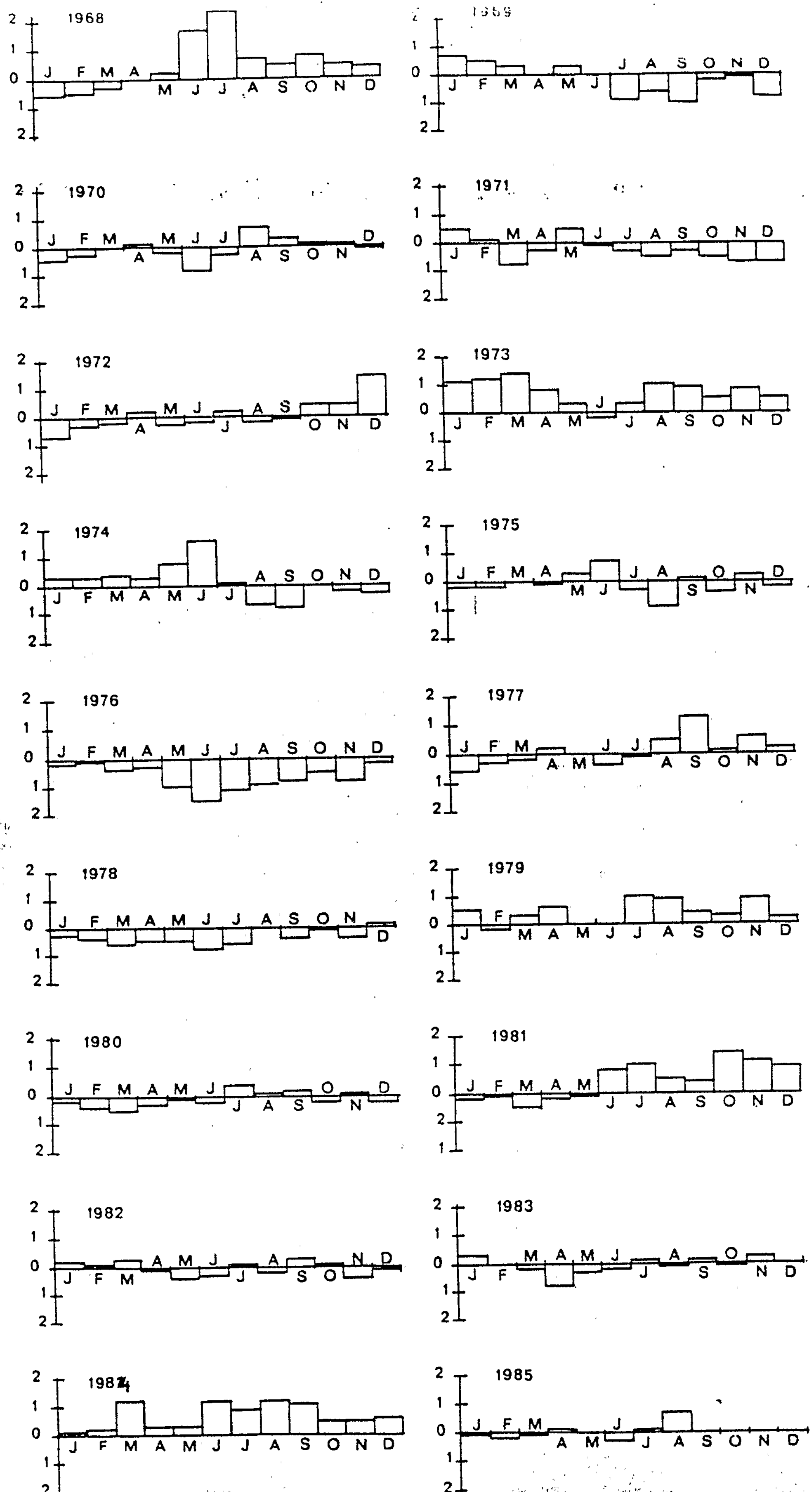
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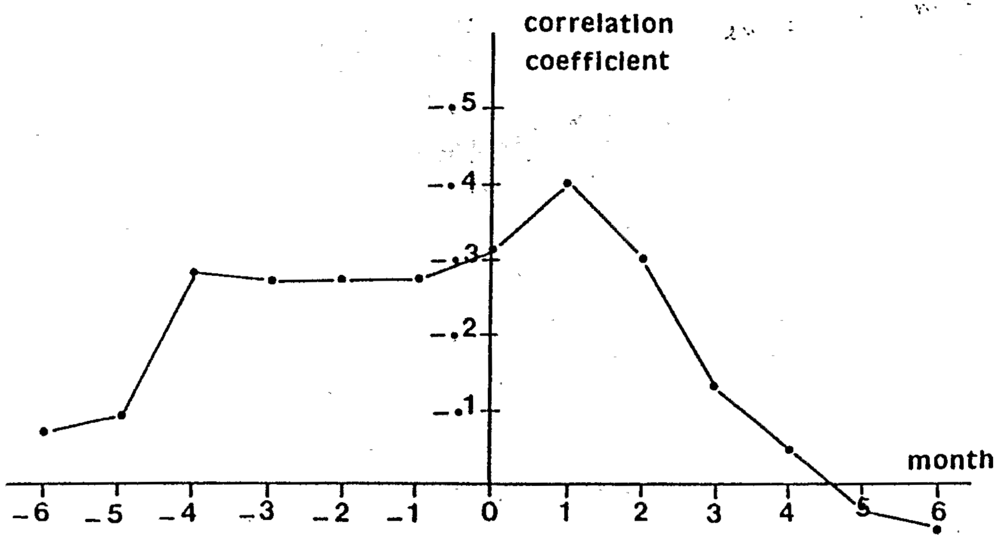
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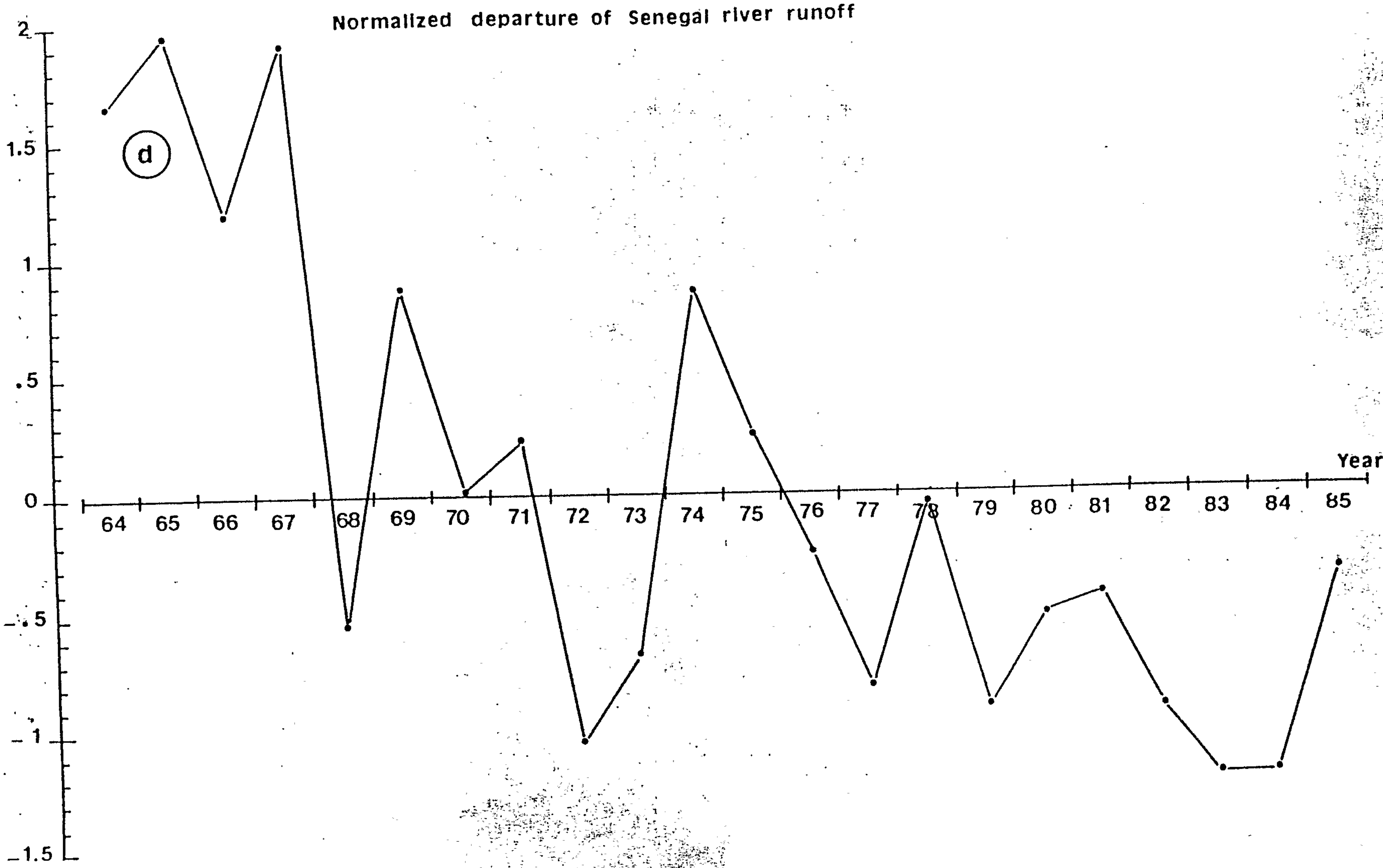

Normalized departure of Senegal river runoff
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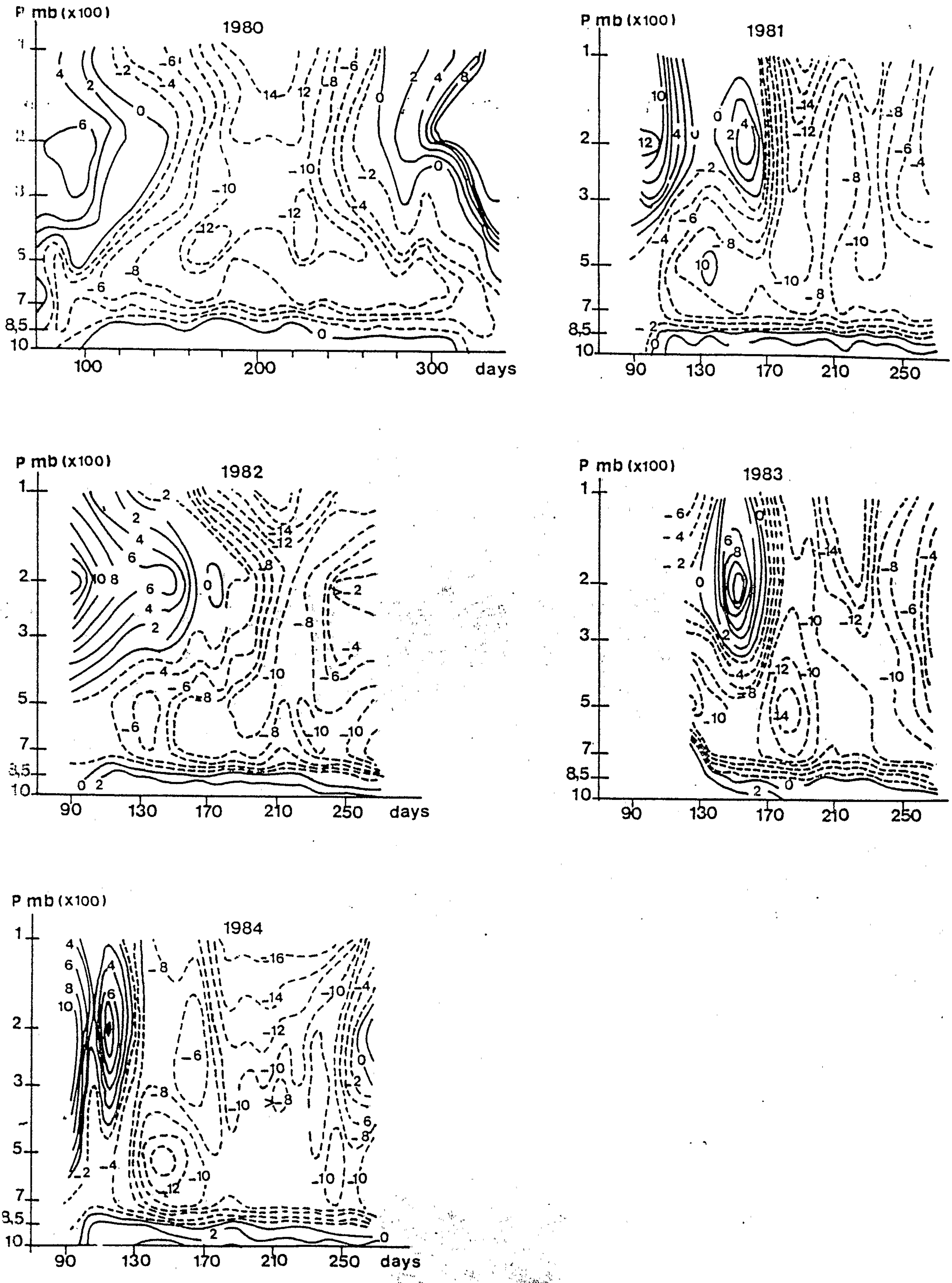
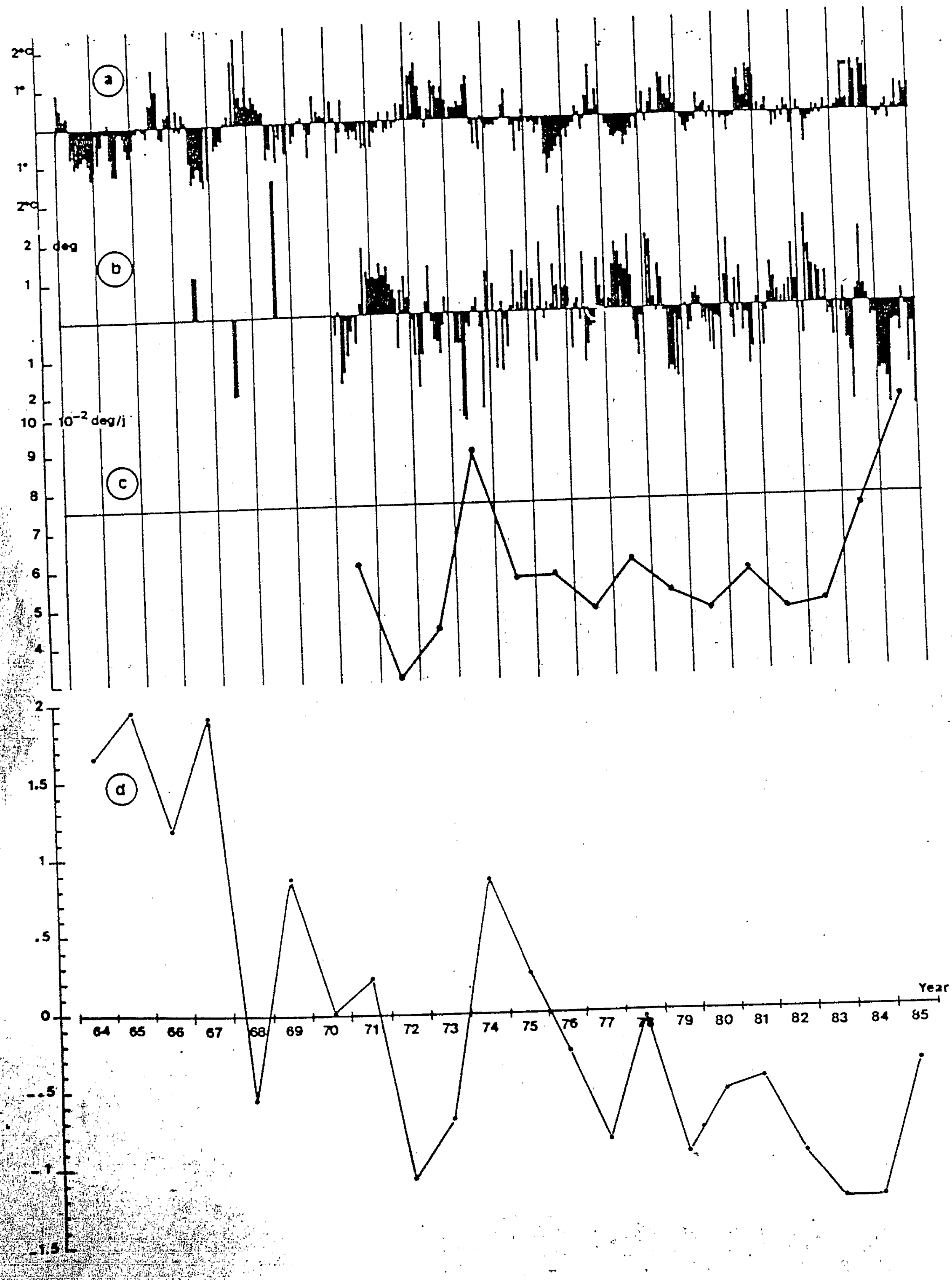


Figure 5 _Zonal component of wind at Niamey (ECMWF data)



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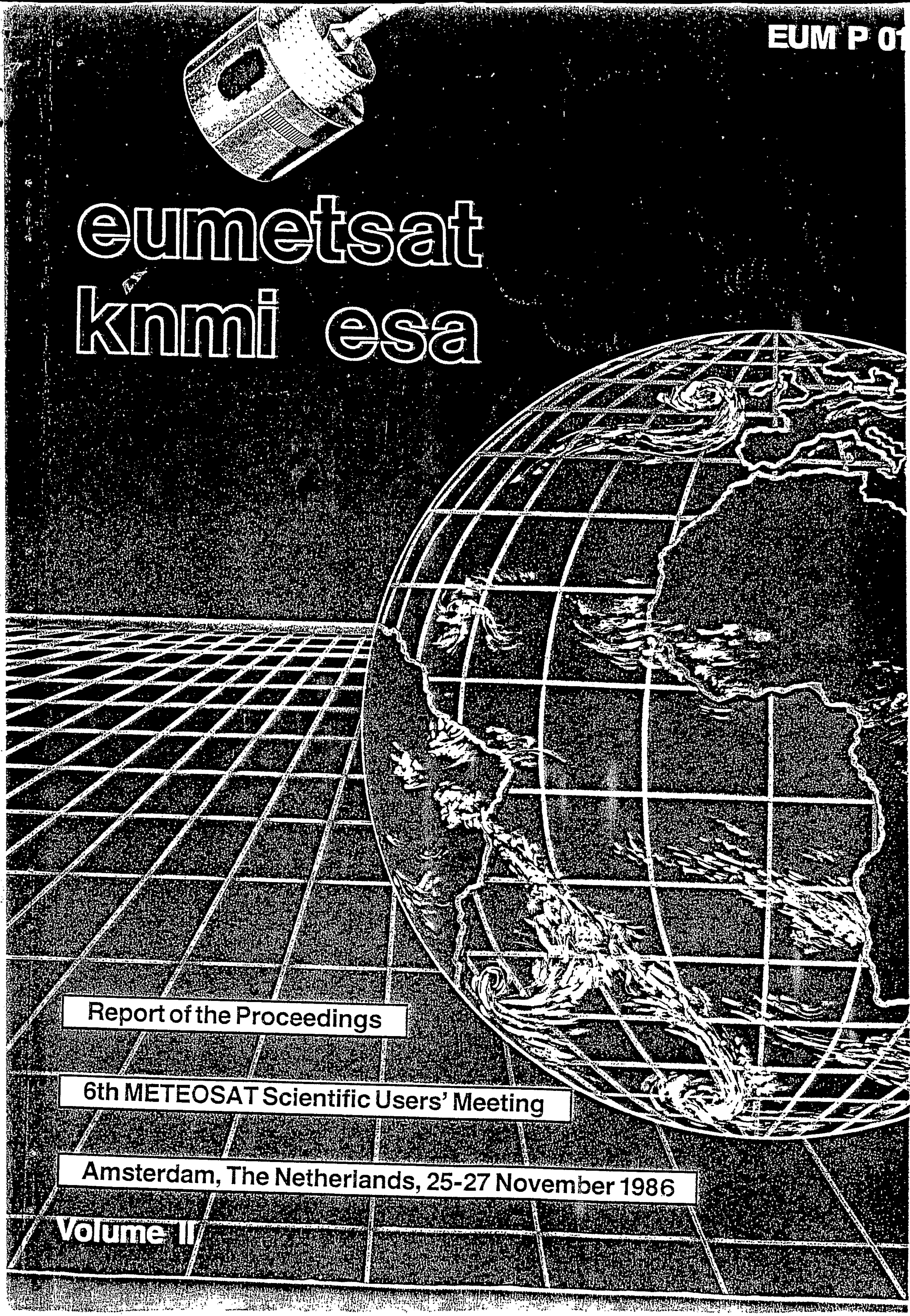
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