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POLAR ICE VARIATIONS OFF THE GREENLAND WESTCOAST 1900 - 1972

by

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Introduction:

It is a well known fact that the drift of pack ice is determined by wind and current. Further, it is obvious that the extent of the ice is determined by ice production, drift and melting.

Much economical interest is involved in the question of predicting ice conditions i.a. for the sake of navigation. While several mathematical models have been developed concerning short - and medium range forecasts very little succes has been gained so far concerning seasonal outlook or - even worse - prediction several years ahead. While temperature conditions most likely are the principal responsible for the ice production and - melting processes, the influence of

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temperature on icedrift, if any, is of much more indirect character and not necessarily in phase with the influence on production and melting. It should, therefore not be expected that a simple relation exists between air temperature and ice conditions. However, if it is true that the air temperature follows a predictable cycle of several years, it is clear that it is warranted to find a possible connection between these climatic cycles and ice conditions. This wish is strengthened if the drilling cores from the Greenland inland ice does provide us with a "thermometer" of historical time since no similar record exists regarding wind and current.

The Danish Meteorological Institute has become involved in this problem in the Greenland waters for several reasons, i.a. navigational, which includes the demand for predicting the severity of coming ice seasons for the sake of better planning the shipbuilding program. Will the next 30 years bring lighter iceseasons, or are the seasons, on the contrary, going to become worse? Is there any periodicity in the degree of severity? Is there any persistency, meaning that severe seasons are likely to occur in groups? Such questions have been raised, and my paper is going to show, that we are still not able to answer these questions with any reasonable degree of probability.

The concept of severe ice seasons:

One of the first problems to run into is how to define the degree of severity. Shall we define it according to information of (I) how the navigational conditions were or (II) according to amount of ice. Even if we could get sufficient information of (I) and in spite of the fact that the effect of the ice is what matters, we may reject (I) because even small ice occurrences may hamper the navigation, if the ice locally is compacting, and because the general judgment of ice conditions varies from shipmaster to shipmaster.

(II) the amount of ice may be defined in several ways:

a) sum of daily products of areal extent x concentration

b) monthly or yearly maximum or mean areal extent x concentration

c) monthly or yearly maximum areal extent

d) the maximum (twodimensional) extent of the ice along the coast ("the northernmost ice edge")

e) the length of period of ice being present within a given area

Several other definitions could be put up, but it is obvious that a) and b) are the only ones which are "exact". However, even the last 10-15 years data which include air reconnaissances and satellite information do not supply us with sufficient information as to enable us to define the season according to a) or b). Even definition c) is demanding more data than are available. The only usable definitions seem therefore to be d) and e) although these may not correctly reflect the degree of severity of the ice seasons.

Basic material:

It is a wellknown fact that polar ice is drifting from the polar basin down along the Greenland eastcoast and that the polar ice, mixed up with thick first year ice formed off northern Eastgreenland, soon or later in the season under the name of "Storis" will pass around Kap Farvel (the southernmost point of Greenland) and drift up into Davis Strait and more or less up along the westcoast of Greenland.

Fig. 1 depicts for the years 1900 - 1971 the approximate date on which the polar ice pass Kap Farvel*.

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* This diagram is, like some of the others, an updating and/or revision of diagrams given by J.S. Fabricius (1959) in "Betænkning Nr. 227" concerning navigation in Greenland.

Fig. 2 illustrate the length of the iceseasons off the Greenland westcoast and refer like all other information in the present paper exclusively to the polar ice of "Storis", not to the Baffin Bay ice or "Vestis" which is entirely excluded from this investigation, although it (extremely rarely) have touched the area in question, i.e. the waters off the ocast between Kap Farvel and a little north of Sukkertoppen.

Fig. 3 is a correlation diagram of length of ice period in the area and date of passage of Kap Farvel. The scale of dates is given in table I.

Table I: Numeric representation of dates.

0	30/9
31	31/10
61	30/11
92	31/12
123	31/1
151	28/2
182	31/3
212	30/4
243	31/5
273	30/6
304	31/7
335	31/8
365	30/9
396	31/10
426	30/11

Table II: Northernmost position of the polar ice edge.

0	Not passed Kap Farvel
2	Kap Farvel
5	Frederiksdal
8	Nanortalik (Nan.)
11	Sydprøven

13 Julianehåb
17 Qagssimiut (Qags.)
20 Nunarssuit
25 Arsuk
30 Narssalik
34 Frederikshåb (Fhb.)
36 Avaigat
38 Frederikshåbs Isblink
41 Ravns Storø
43 Fiskenæsset (Fisken.)
47 Grædefjord
50 Færingehavn
52 Godthåb (Godth.)
57 Atangmik
59 Napassoq
63 Sukkertoppen (Skt.)
68 Kangamiut

As the diagram may show there is a fairly good negative correlation (correlation coefficient -0.86) between passage date (= start of season) and length of season, which seems to indicate that the starting date varies a lot more than the termination date of the season. Further it may allow us to concentrate on comparing length of period with other parameters, while these comparisons may be expected valid for the passage dates too.

Fig. 4 depicts the yearly reported northern ice limit, while fig. 5 gives the frequency distribution of this limit. The figures do not contain any information regarding the duration of the ice. Further, modest quantities of ice may have been present even further to the north without having been reported.

To combine extent and duration the matrix given in the appendix has been set up. The matrix gives the northernmost position of the ice edge month by month through the seasons 1899/1900 to 1971/72. The northernmost position is indicated no matter wether the ice ramained at this position through the whole month or a few hours, only, within the indicated month. The scale of the matrix is given in table II and is nearly proportional to the distance from Kap Farvel along the outer coastline.

It would be desirable to extend the scale as to include information of the southernmost ice edge on the east coast in the period(s) when the ice is not present west of Kap Farvel. However, the date from the eastcoast are far too sparse to enable this extension. Fig. 6 is based upon this matrix and for the sake of clearness the dividing steps of the blockheight has been made logarithmic: No signature means that polar ice has not been reported off the westcoast at all. ½ mm: the ice in the month concerned was present but not reported north of Nunarssuit (table II fig. 2-20); 1 mm: ice present north of Nunarssuit but not of Ravns Storø (table II fig. 21-40). 2 mm: north of Ravns Storø but not of Napassoq (table II fig. 41-60). 4 mm: ice present even north of Napassoq at least once within the given month. All these diagrams may illustrate how varying and obscure the ice conditions seem to be. Is it possible out of this mesh to find any persistency coherence?'

Processing results*:

In fig. 7 the position of northernmost ice edge in January is correlated with its position in February. Although the correlation coefficient is only 0.53 it seems that a northerly position in January may have a tendency to be followed by a northerly position in February, too. However, it appears from fig. 8 that this tendency has vanished already in March. Fig. 9 and 10 gives the same impression for the months May/June and May/August.

How much can be concluded about the extension (NU) of the ice in the following season from data of iceextension in the present season? Very little; the best

* The computer program was set up and the processing executed at RECKU computer center by Mrs. M. Lilholt. In all ab. 3.000 correlation diagrams were plotted.

correlation seem to be NU May (year N)⟷NU April (year N+1) and NU May (year N) ⟷NU May (year N+1) and NU June (year N)⟷NU April (year N+1) with correlation coefficients of 0.39 or lower!

Concludingly may be said, that the tendency of ice extension may persist into the following month, only, i.e.: very little, if anything can be predicted from the present state of the ice concerning the ice conditions several months later in the season.

How much may be concluded from the length of a given ice season concerning the following season? Apparently nothing. Correlation coefficients between length of period (PL) year (N) and length of period year (N+1), (N+2), (N+3) respectively are 0.32, 0.23 and 0.28 and the correlation diagrams show "circular clouds of dots".

Is there any significant coherence between the extent of ice and the length of the current ice period? Very little, if any. The best correlation is found between January extent and length of the ice period (fig. 11). However, since the iceperiod frequently does not start till after January this coherence is not surprising. Fig. 12 and 13 concern the extent in April and May. April extent is apparently not correlated with length of ice period at all, while May may show some correlation with the period length. Ice extents in all other months do not seem correlated with length of ice period in any way.

Is there any coherence between the extent of ice and the length of the following ice season? No significant. May diagram seem to show some correlation (c.c. 0.32), but this may have arizen by chance; diagrams of all other months show no correlation at all.

Is there on the other hand any coherence between length of season and extent of ice the following ice season? No.

Is there any correlation between the date of polar ice passing Kap Farvel, i.e. date of initiation of the ice season and the extent of ice in that season? No.

This means that nothing can be predicted from the initiation date about the severity of the season with respect to the (twodimensional) extent of the ice.

Correlation with air temperatures:

For the sake of elucidating possible connexions between air temperatures and sea ice conditions the preceding ice data have been correlated with air temperature data. Unfortunately only very few stations in or near the area have continous or homogenised records through the whole period 1900-1971. The 4 stations Pt. Barrow, Jan Mayen, Godthåb and Upernavik fulfil the requirements and were chosen and their data correlated with length of ice period (PL) and ice extent off the Greenland west coast (i.e. the northernmost ice edge (NU)) 0, 1, 2 and 3 year later. No correlation at all was found between air temperatures at resp. Pt. Barrow, Godthåb, Upernavik and the ice data.

Jan Mayen air temperatures (JT) seem to be correlated with the ice conditions to some extent. Below is given the correlations which on the diagrams seem to be best (and which with one exception had the highest correlation coefficients (c.c.)):

JT ⟷ NU:

JT Nov.$_{(year\ N)}$ ⟷ NU January$_{(year\ N+2)}$;	c.c.:	-0.55
JT Jan.$_N$ ⟷ NU Jan.$_{(N+1)}$;	c.c.:	-0.53*
- ⟷ NU Febr$_{(N+1)}$;	c.c.:	-0.43
JT May$_N$ ⟷ NU Jan.$_{(N+1)}$;	c.c.:	-0.60*
JT July$_N$ ⟷ NU Febr$_{(N+1)}$;	c.c.:	-0.41
- ⟷ NU Febr$_{(N+2)}$;	c.c.:	-0.49

* The frequency distribution of NU Jan. is very skew whence the relatively heigh c.c. may be meaningless.

	JT Sept.$_N$ ⟶ NU May $_{(N+1)}$;	c.c.:	-0.29
	- ⟶ NU May $_{(N+2)}$;	c.c.:	-0.33
	- ⟶ NU June$_{(N+1)}$;	c.c.:	-0.29
	- ⟶ NU June$_{(N+2)}$;	c.c.:	-0.34
	- ⟶ NU June$_{(N+3)}$;	c.c.:	-0.44
	JT Oct.$_N$ ⟶ NU April$_N$;	c.c.:	+0.3
	- ⟶ NU April$_{(N+3)}$;	c.c.:	-0.38
	- ⟶ NU May$_N$;	c.c.:	+0.19
	- ⟶ NU May $_{(N+3)}$;	c.c.:	-0.43
JT ⟶ PL:	JT Sept.$_N$ ⟶ PL $_{(N+1)}$;	c.c.:	-0.39
	JT Nov. $_N$ ⟶ PL$_{(N+1)}$;	c.c.:	-0.60
	JT Sept.$_N$ ⟶ PL$_{(N+2)}$;	c.c.:	-0.35

Three of the corresponding diagrams are shown: Fig. 14 shows a relatively good correlation between JT Jan.$_N$ and NU Jan.$_{(N+1)}$ which might indicate that the air temperature at Jan Mayen is reflected in the ice conditions off southern Westgreenland one year later, which is a rather long delay compared with the generally assumed pack ice travelling time of ab. 6 months from Jan Mayen latitude to Kap Farvel.

On the other hand fig. 15 seem to show some, apparently weaker correlation between JT May and ice extend 8 month later. Finally, fig. 16 may show some, however extremely faint correlation between JT Sept. and the length of following ice season in southern Westgreenland.

Concludingly may be said, that the temperature data do not seem to be of much help in predicting the severity of the ice seasons (as severity is defined in the present paper).

This rather discouraging conclusion corresponds well with the observed fact that the presence of atmospheric lows in Davis Strait frequently accelerates the penetration of the pack ice to the north, whence shortlasting "out breaks" of the ice are frequent.

Dato for storisens passage af Kap Farvel

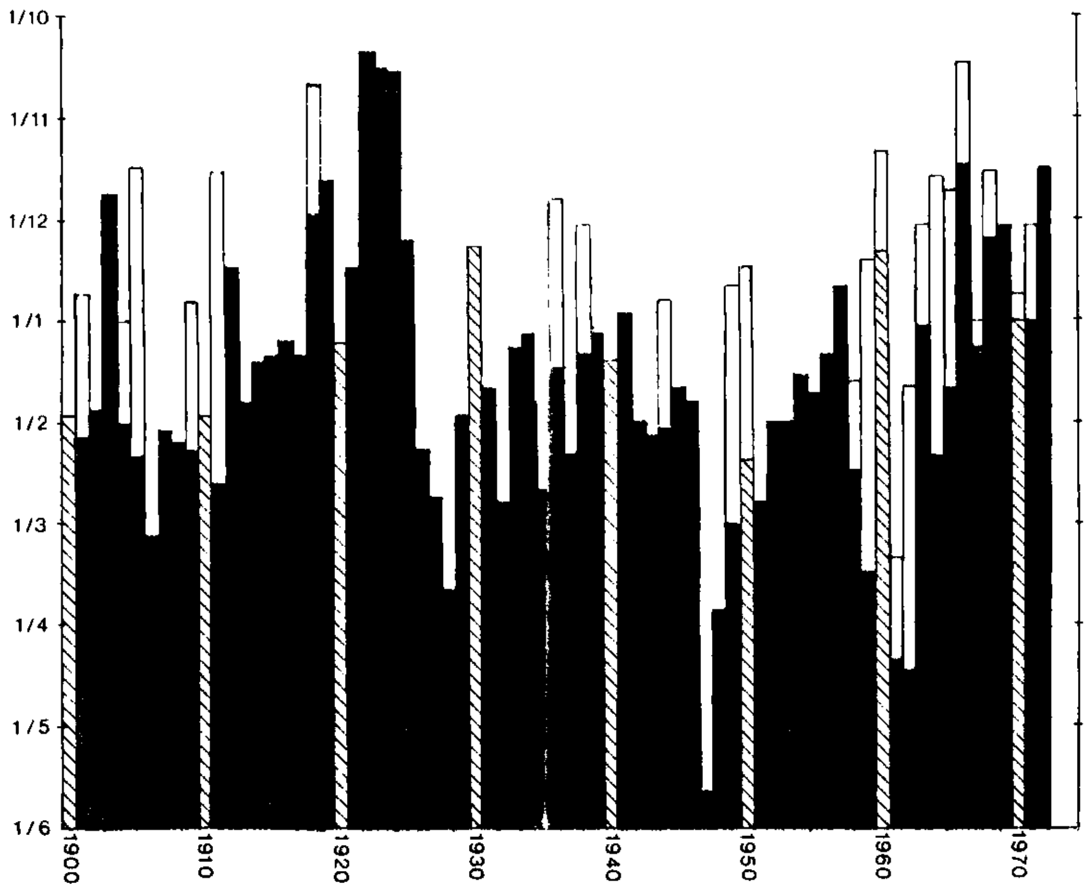


FIG. 1 DATE OF POLAR ICE PASSAGE OF KAP FARVEL, 1900 - 1972.

Top of white section of columns indicate date of first reported "forerunners", while top of black section indicate date of arrival of polar ice of more than 2 weeks duration.

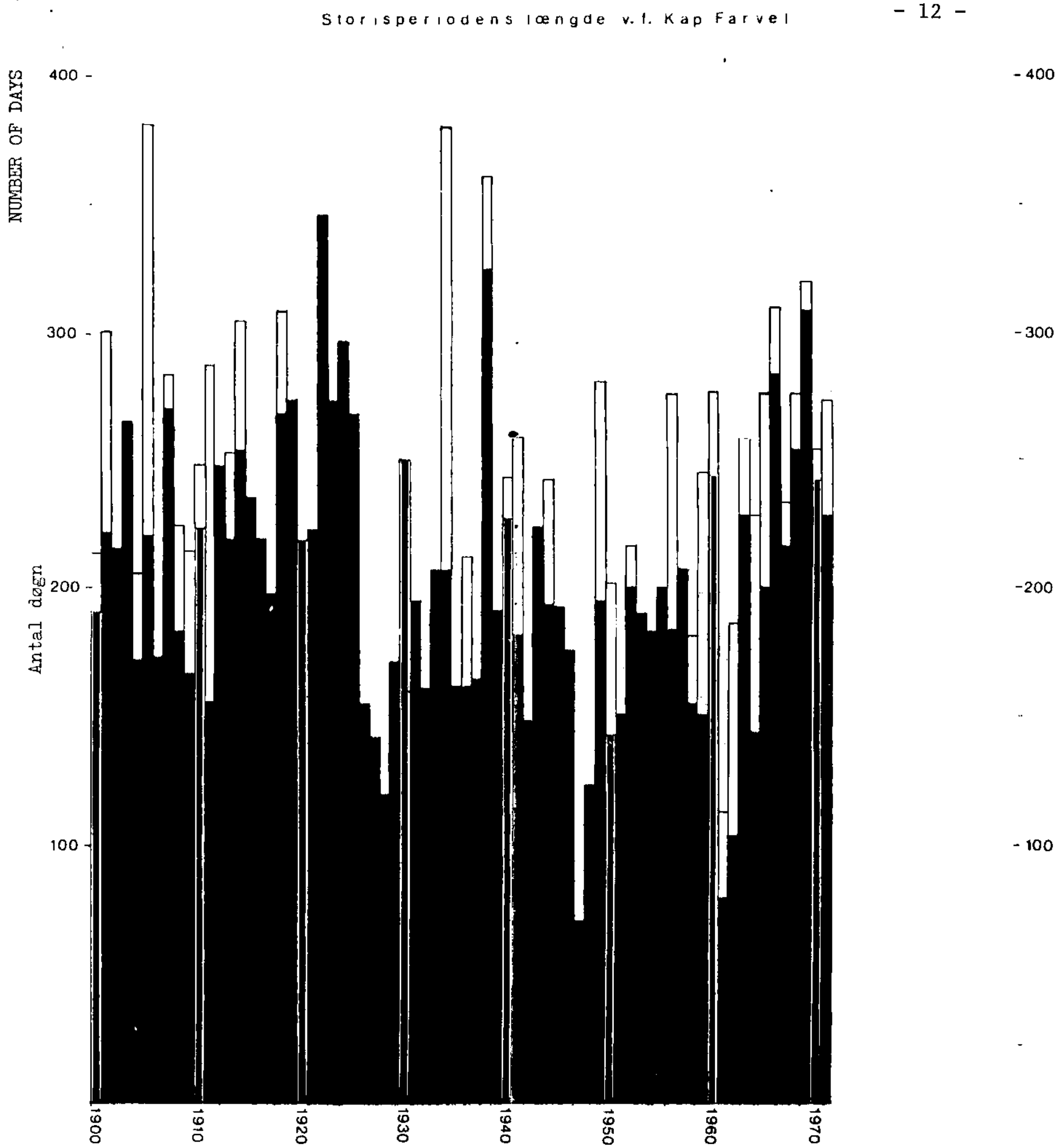


FIG. 2 LENGTH OF ICE PERIOD , 1900 - 1971.

White section of columns indicate sporadic occurrences before and after the season.

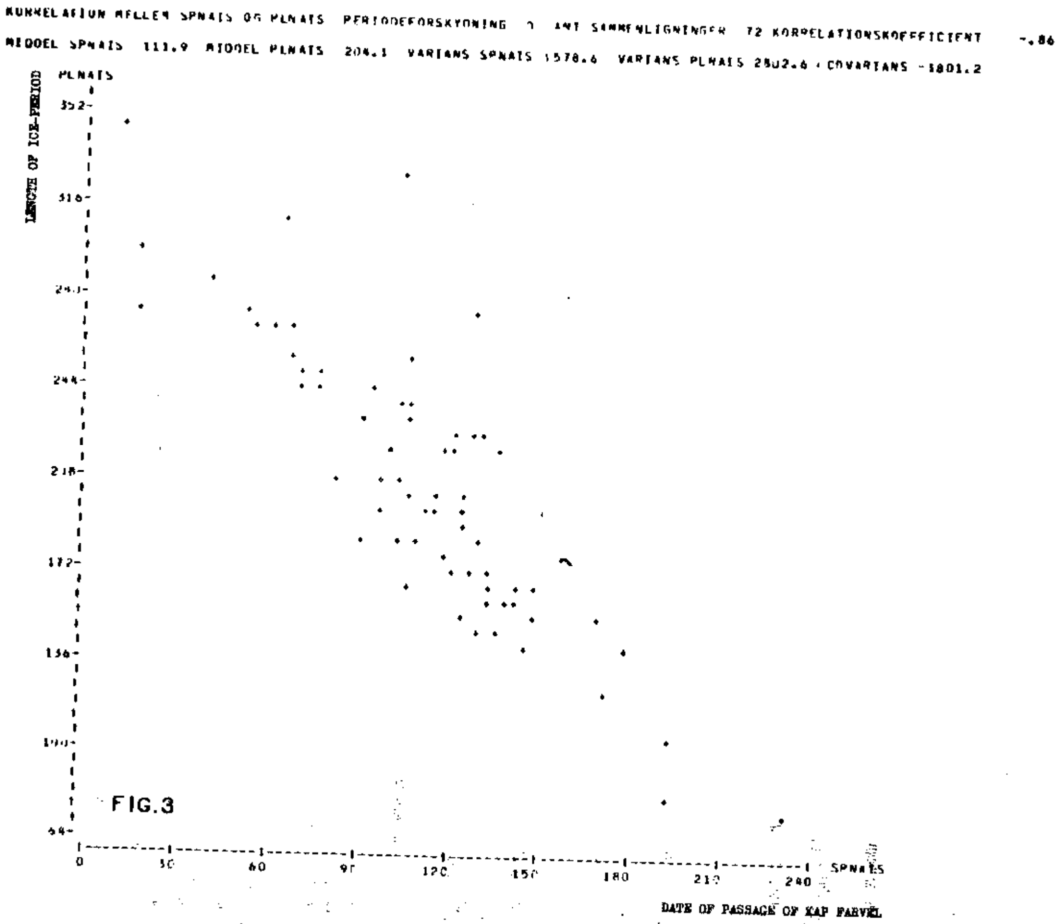


FIG.3

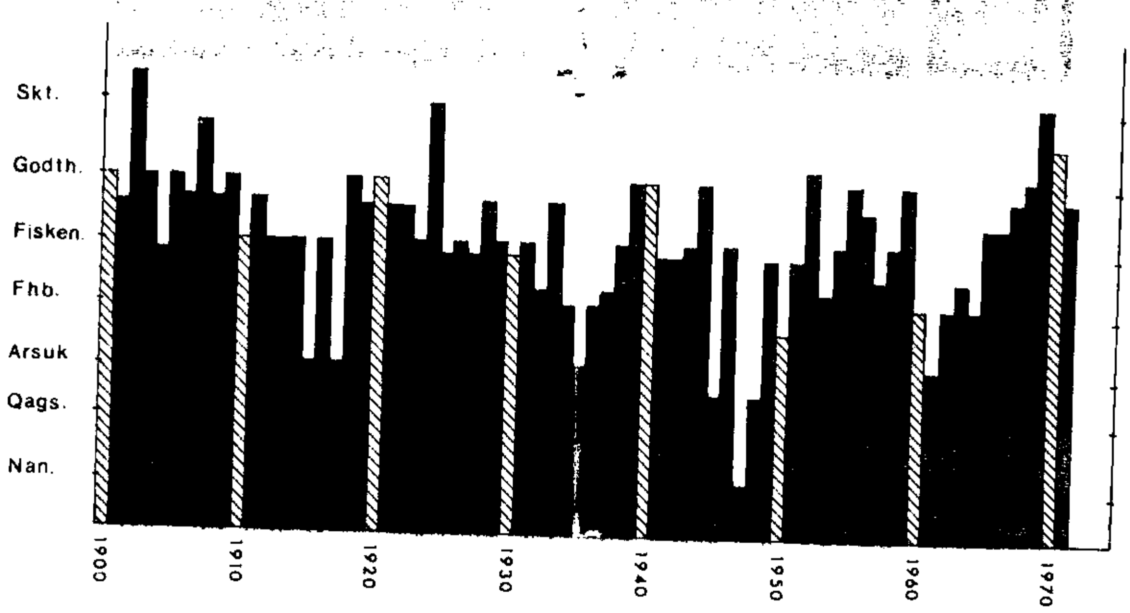


FIG. 4

POLAR ICE, NORTHERNMOST ICE EDGE, 1900 - 1971

The histogram indicate the northernmost position year by year of the polar ice edge off the Greenland westcoast.

A 14

FREQUENCY FOR NORTHERNMOST YEARLY LIMIT OF POLAR ICE

ON THE GREENLAND WESTCOAST (1900 - 1971)

FIG. 5

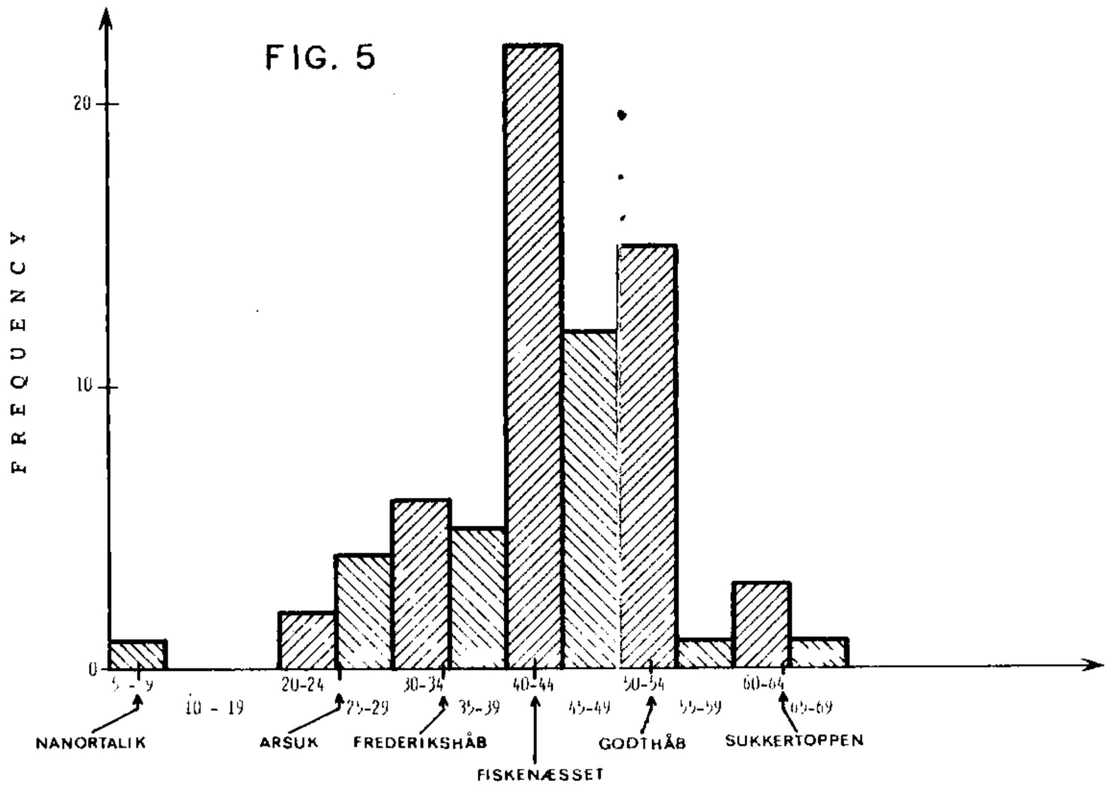
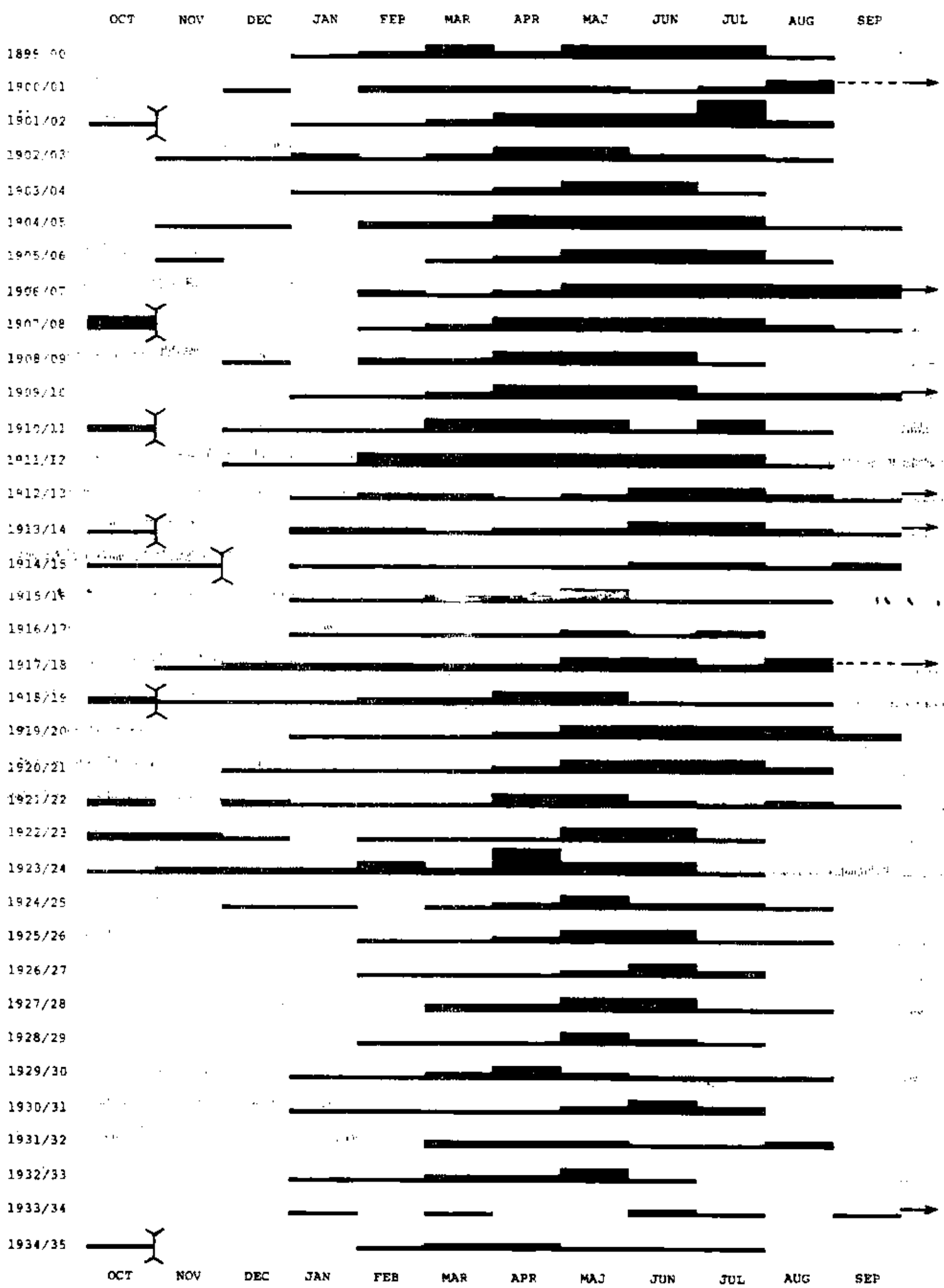
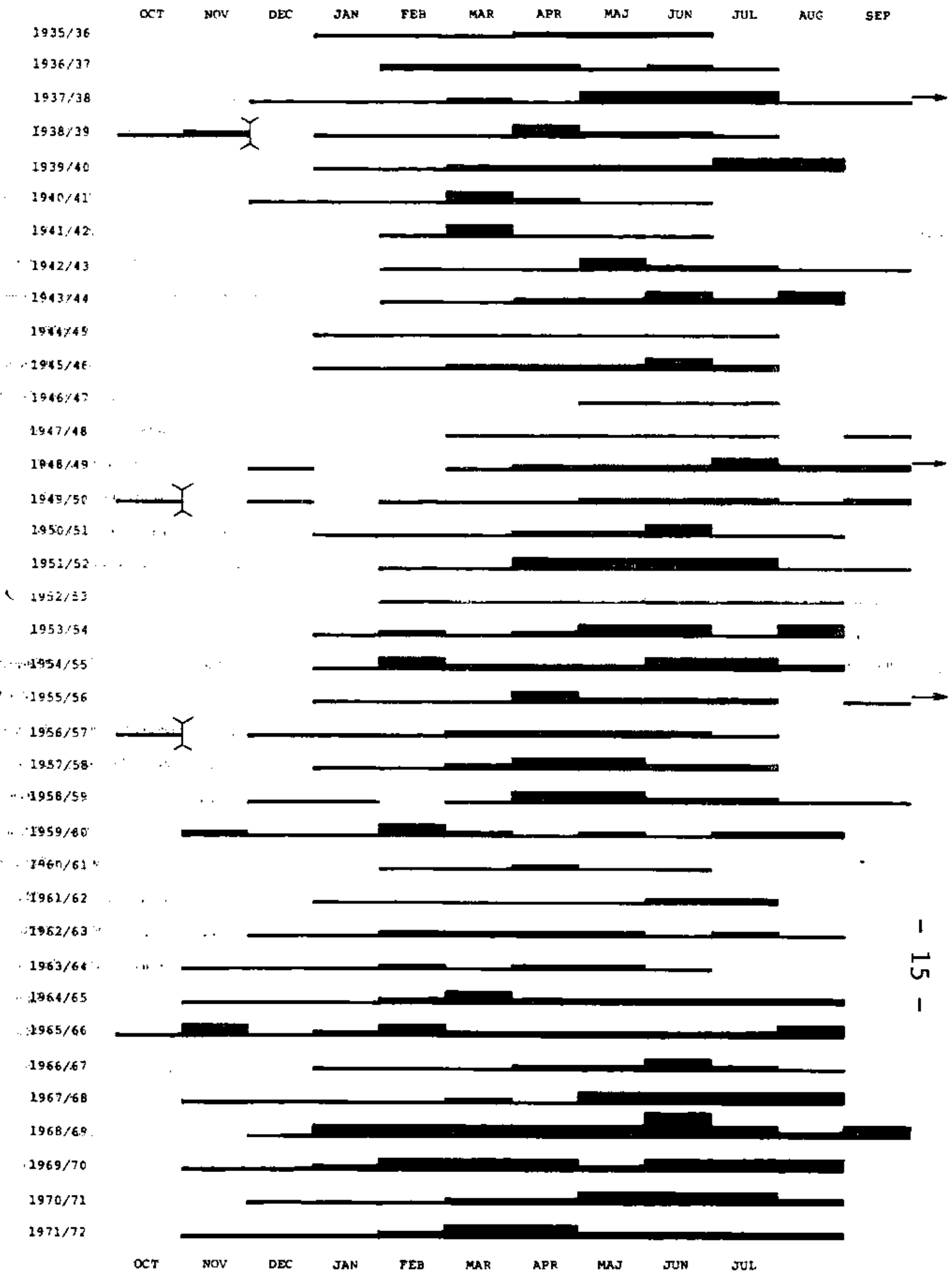


FIG. 6

POLAR ICE, GREENLAND WESTCOAST, NORTHERN LIMIT



POLAR ICE, GREENLAND WESTCOAST, NORTHERN LIMIT



B 2

KORRELATION MELLEM NUJAN OG NUFEB PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 45 KORRELATIONSKOEFFICIENT .53

MIDDEL NUJAN 14.4 MIDDEL NUFEB 21.7 VARIANS NUJAN 89.4 VARIANS NUFEB 141.5 COVARIANS 60.2

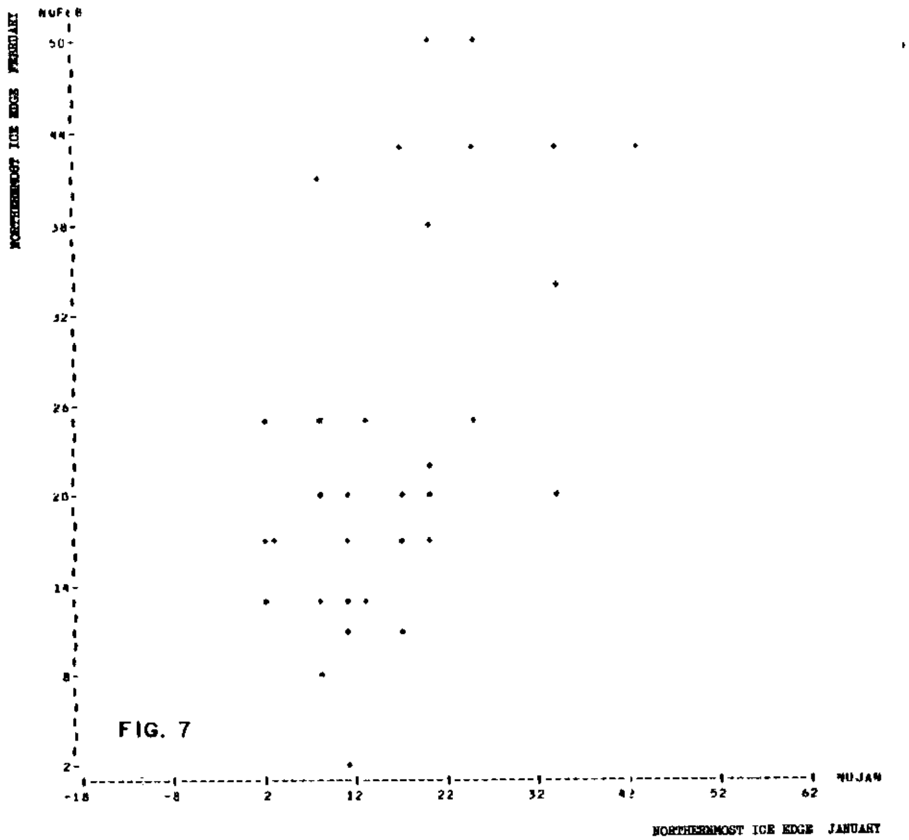


FIG. 7

KORRELATION MELLEM NUJAN OG NUMAR PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 48 KORRELATIONSKOEFFICIENT .24

MIDDEL NUJAN 14.1 MIDDEL NUMAR 24.9 VARIANS NUJAN 84.9 VARIANS NUMAR 158.1 COVARIANS 27.4

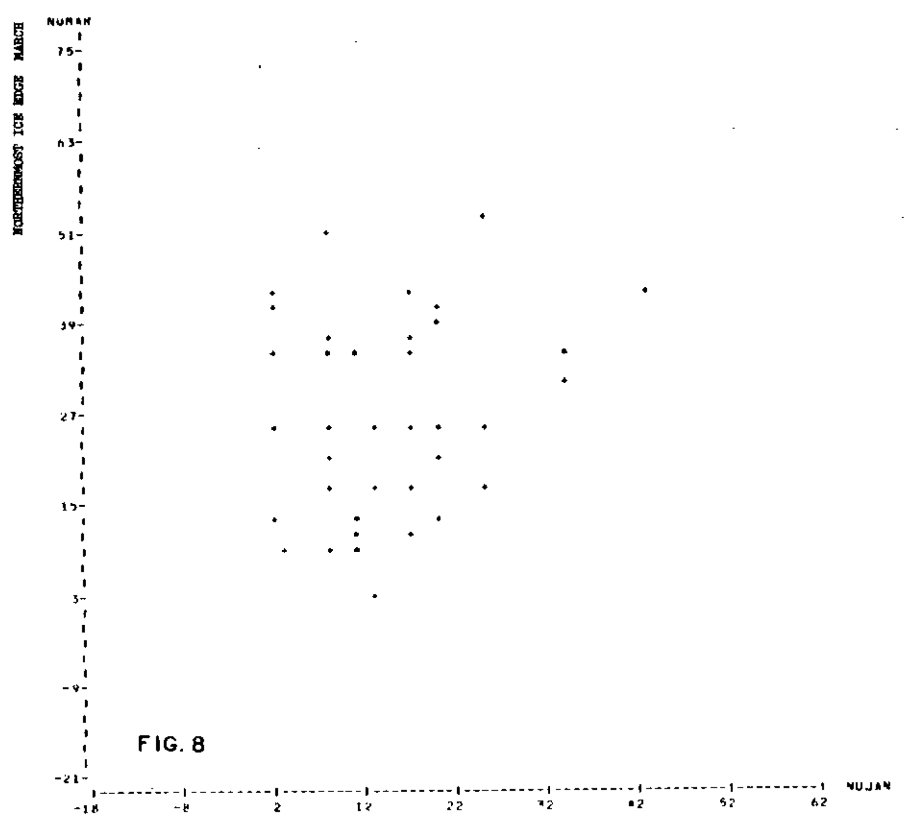


FIG. 8

B 3

KORRELATION MELLEM NUMAJ OG NUJUNI PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 31 KORRELATIONSKOEFFICIENT .55

MIDDEL NUMAJ 36.3 MIDDEL NUJUNI 34.3 VARIANS NUMAJ 146.1 VARIANS NUJUNI 170.7 COVARIANS 86.2

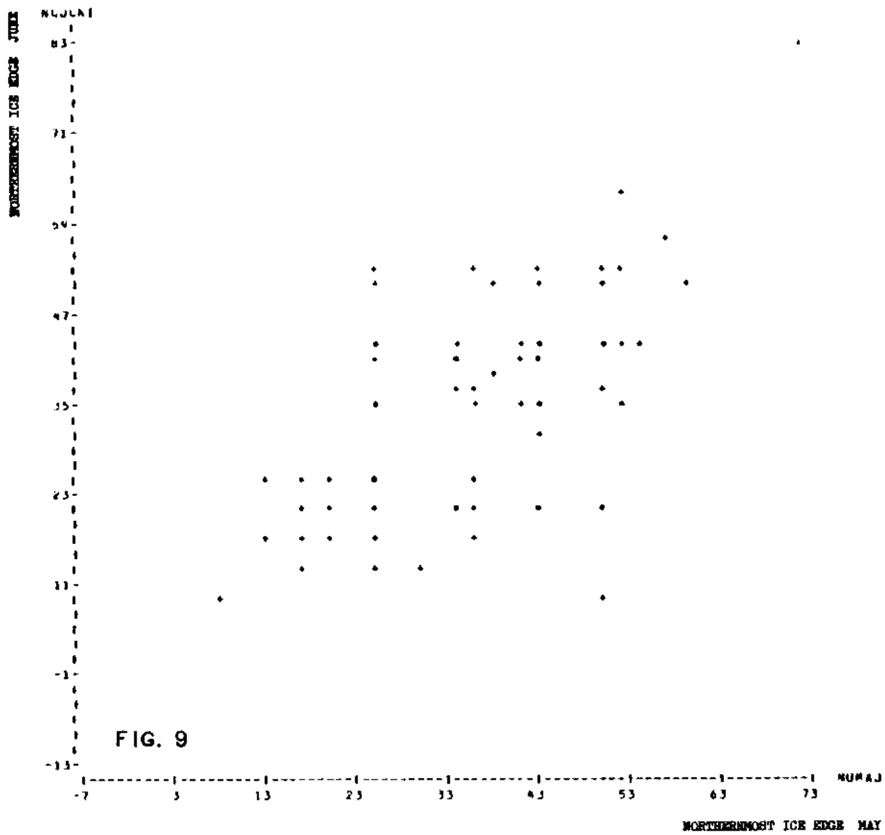


FIG. 9

KORRELATION MELLEM NUMAJ OG NUAUG PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 46 KORRELATIONSKOEFFICIENT -.10

MIDDEL NUMAJ 39.8 MIDDEL NUAUG 26.0 VARIANS NUMAJ 92.6 VARIANS NUAUG 214.0 COVARIANS -14.1

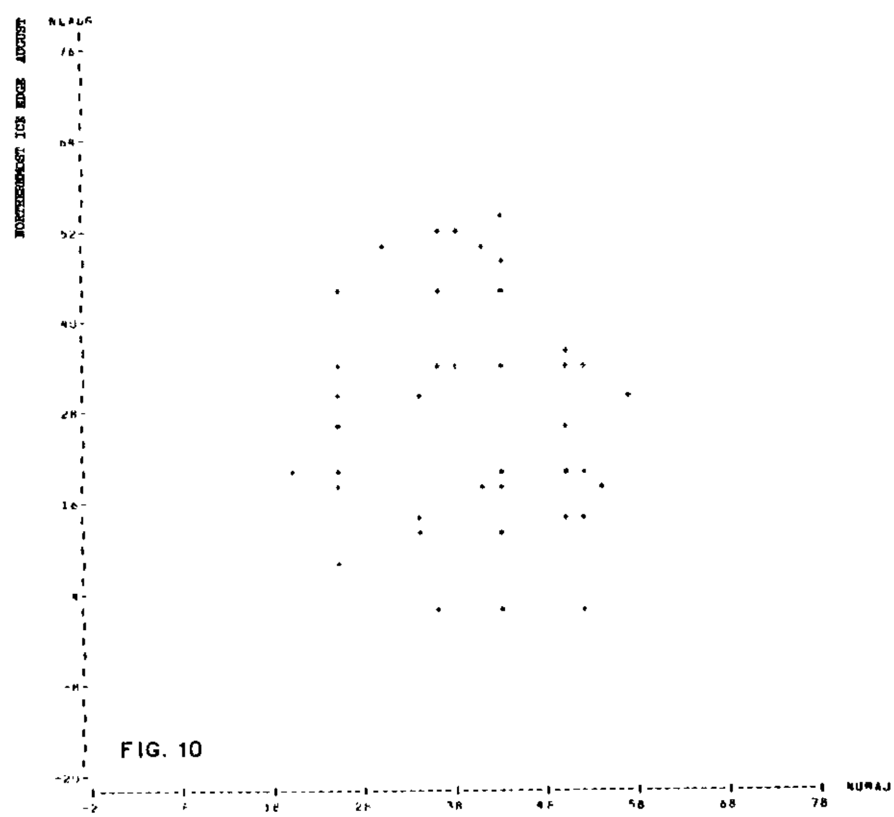


FIG. 10

B 4

KORRELATION MELLEM PLNAIS OG NUJAN PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 48 KORRELATIONSKOEFFICIENT .56
MIDDEL PLNAIS 219.3 MIDDEL NUJAN 14.1 VARIANS PLNAIS 237[illegible].1 VARIANS NUJAN 64.9 COVARIANS 206.0

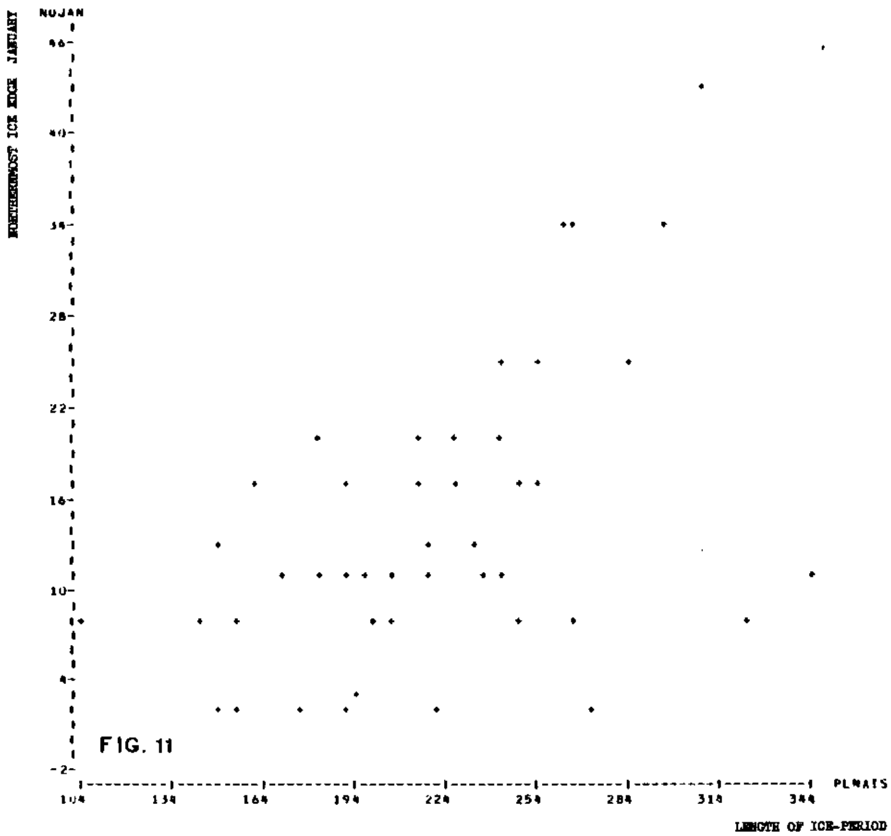


FIG. 11

KORRELATION MELLEM PLNAIS OG NUAPR PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 70 KORRELATIONSKOEFFICIENT .24
MIDDEL PLNAIS 256.0 MIDDEL NUAPR 32.8 VARIANS PLNAIS 26[illegible]6.0 VARIANS NUAPR 136.3 COVARIANS 145.7

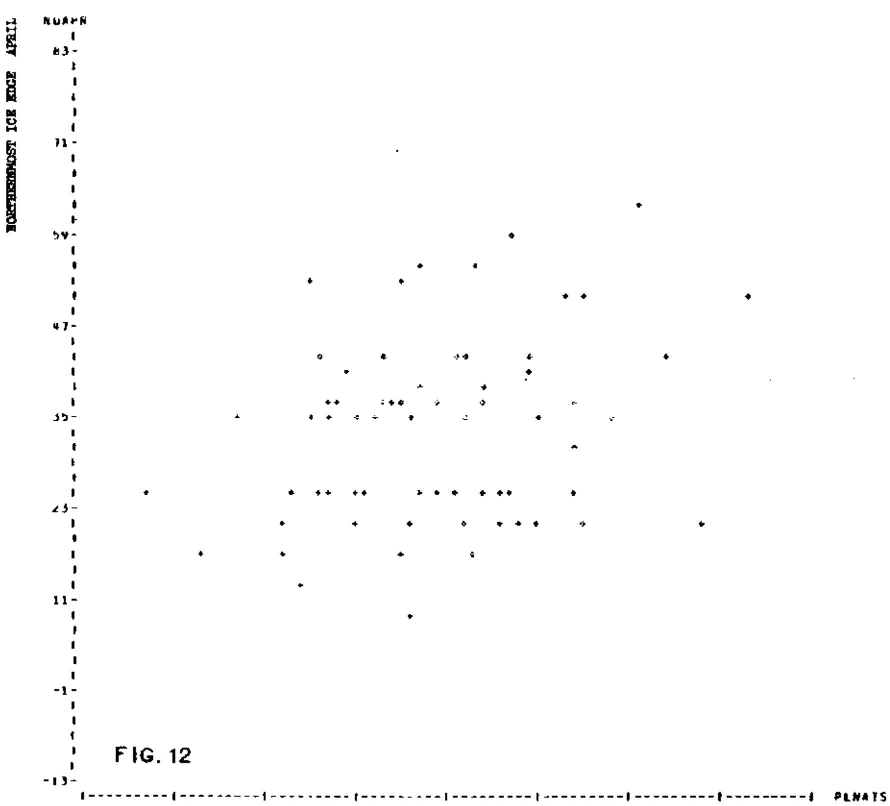


FIG. 12

B 5

KORRELATION MELLEM PLNAIS OG NUMAJ PERIODEFORSKYDNING 0 ANT SAMMENLIGNINGER 71 KORRELATIONSKOEFFICIENT .42

MIDDEL PLNAIS 234.1 MIDDEL NUMAJ 36.3 VARIANS PLNAIS 2842.0 VARIANS NUMAJ 146.1 COVARIANS 273.8

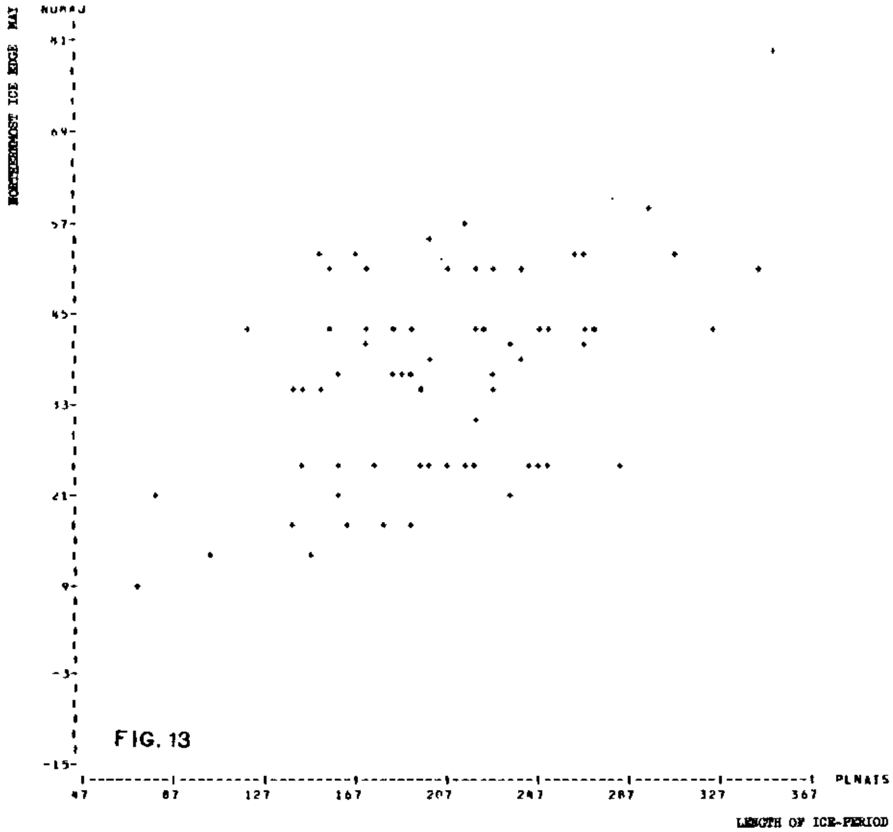


FIG. 13

KORRELATION MELLEM JTJAN OG NUJAN PERIODEFORSKYDNING 1 ANT SAMMENLIGNINGER 29 KORRELATIONSKOEFFICIENT -.53

MIDDEL JTJAN -44.1 MIDDEL NUJAN 14.0 VARIANS JTJAN 700.2 VARIANS NUJAN 81.0 COVARIANS -125.7

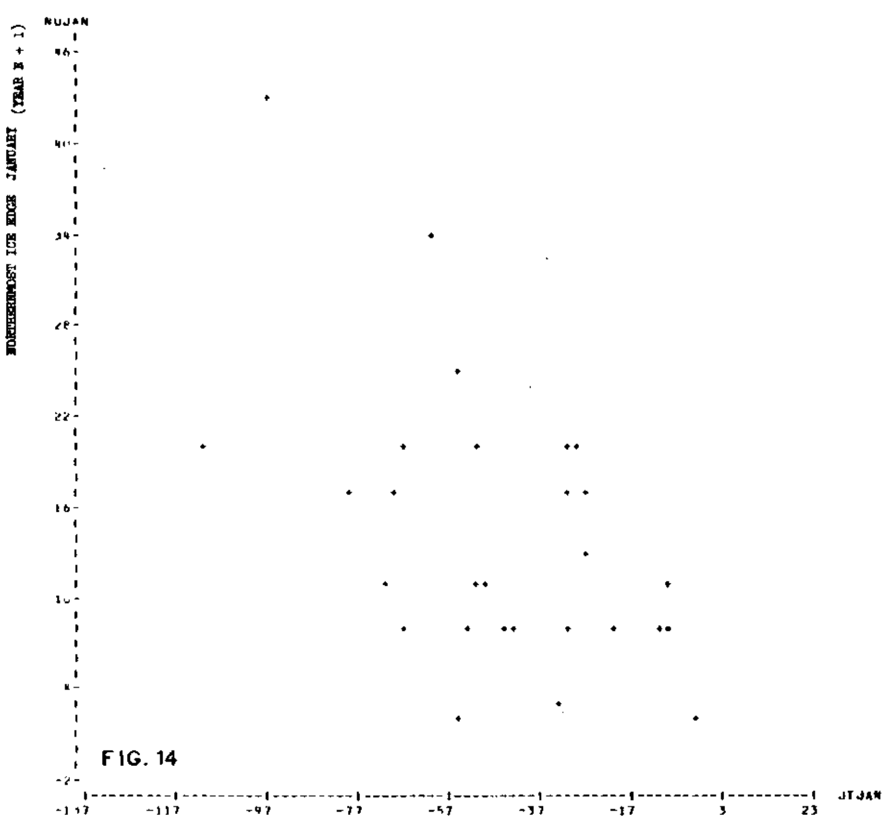


FIG. 14

KORRELATION MELLEM JTMAJ OG NUJAN PERIODEFORSKYDNING 1 ANT SAMMENLIGNINGER 29 KORRELATIONSKOEFFICIENT -.60

MIDDEL JTMAJ -4.5 MIDDEL NUJAN 14.1 VARIANS JTMAJ 135.7 VARIANS NUJAN 81.0 COVARIANS -55.5

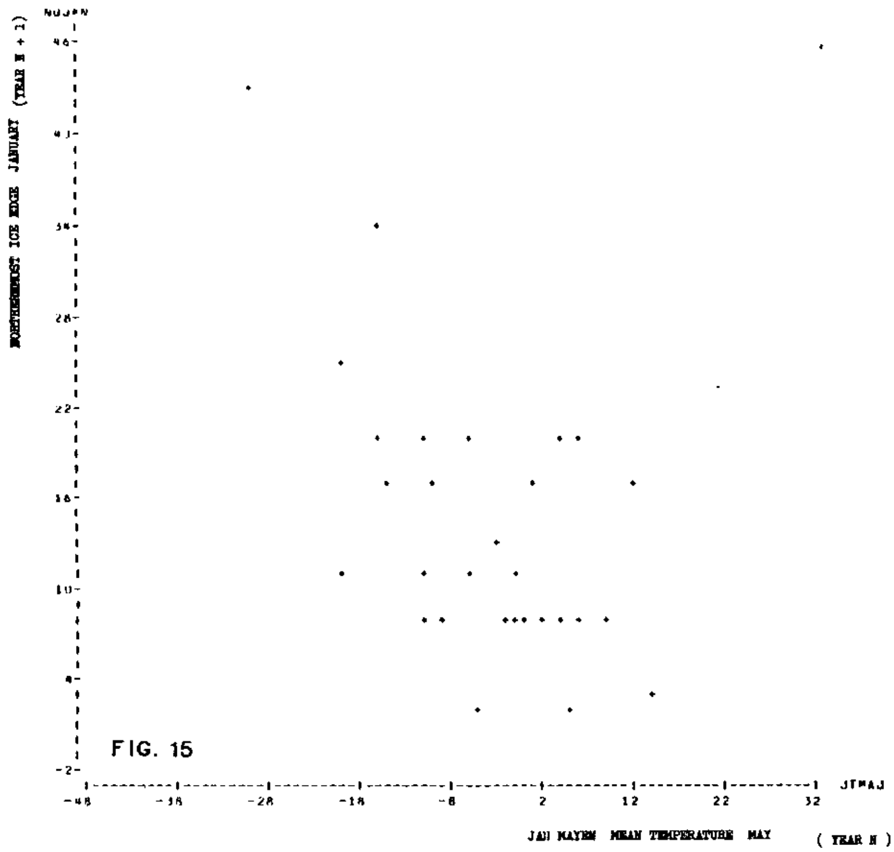


FIG. 15

KORRELATION MELLEM JTSEP OG PLNAIS PERIODEFORSKYDNING 1 ANT SAMMENLIGNINGER 46 KORRELATIONSKOEFFICIENT -.39

MIDDEL JTSEP 35.5 MIDDEL PLNAIS 197.5 VARIANS JTSEP 154.9 VARIANS PLNAIS 3047.0 COVARIANS -266.9

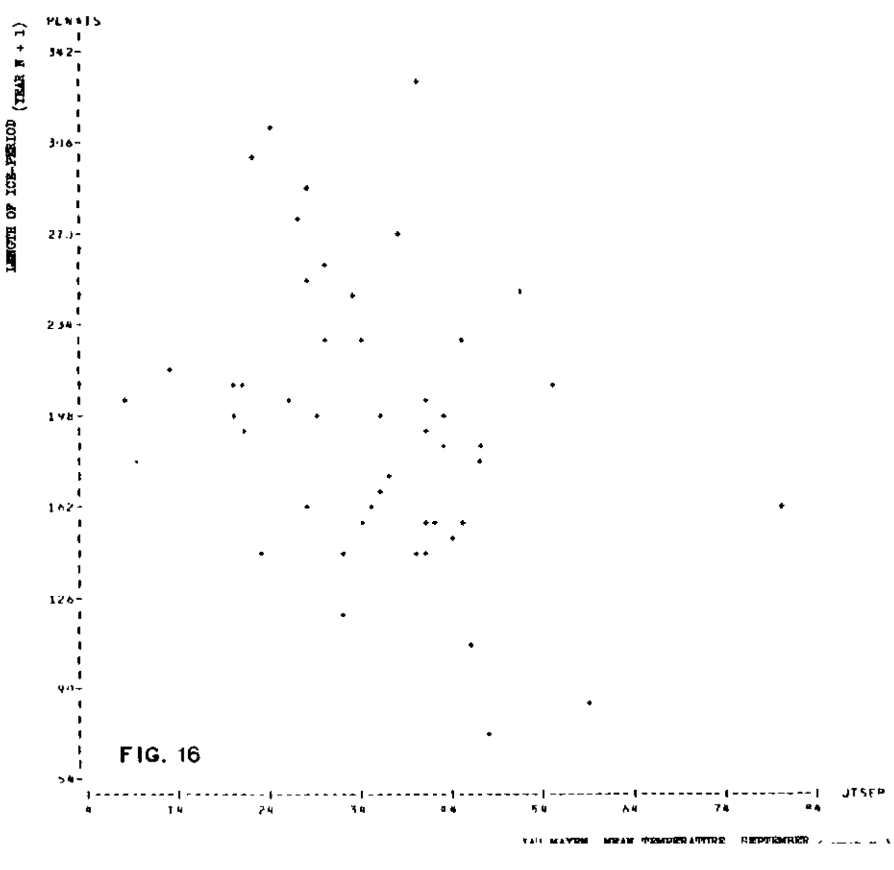


FIG. 16

POLAR ICE, GREENLAND WESTCOAST, NORTHERN LIMIT. (ref.: Table II)

	O	N	D	J	F	M	A	M	J	J	A	S
1899/1900				2	25	41	36	43	41	52	20	
1900/1901			8		34	34	34	30	13	34	50	
1902	8			17	11	25	43	57	57	68	30	
1903		8	2	34	20	(30)	50	52	34	36	20	
1904				11	20	11	25	41	41	20		
1905		13	13		30	25	43	50	50	52	20	13
1906		13				11	35	50	43	41	20	
1907					25	13	30	43	52	59	43	54
1908	46				13	25	43	43	41	50	34	8
1909			11		25	25	41	52	43	20		
1910				2	13	25	54	43	43	34	34	25
1911	25		2	2	13	43	43	50	20	43	13	
1912			17	17	43	43	43	43	43	43	20	
1913				13	25	25	20	25	43	41	30	20
1914	2			25	25	17	34	25	41	43	34	8
1915	11	11		13	13	17	20	20	25	25	20	25
1916				11	2	34	34	43	20	17	2	
1917				11	11	11	20	25	17	25		
1918		2	25	34	34	34	36	52	52	34	43	
1919	30	2	13	2	25	34	50	43	20	11	2	
1920				11	13	8	25	41	43	52	50	34
1921			11	11	13	13	25	50	43	43	25	
1922	25		25	11	11	13	50	50	36	17	36	11
1923	25	34	8		2	17	20	43	43	13		
1924	8	25	30	34	43	34	63	59	50	20		

	O	N	D	J	F	M	A	M	J	J	A	S
1924/1925			11	8		17	25	41	34	25	17	
1926					8	8	25	43	41	8	11	
1927					8	11	20	34	41	36		
1928						25	34	43	50	11	11	
1929					8	13	20	43	34	20		
1930				8	8	25	41	25	20	17	17	
1931				13	17	8	8	34	43	34		
1932						36	36	36	17	8	34	
1933				8	20	34	36	50	8			
1934				11		8			34	17		11
1935	2				8	25	25	20	20	13		
1936				17	11	11	34	25	25			
1937					25	36	36	17	25	17		
1938			2	8	13	25	20	43	43	43	20	17
1939	11	25		11	17	17	52	36	34	17		
1940				17	17	36	36	36	36	52	52	
1941			8	20	17	41	34	17	17			
1942					17	41	13	13	17			
1943					8	8	17	43	30	25	17	8
1944					20	8	36	36	52	36	43	
1945				17	17	17	17	17	20	20		
1946				2	17	25	25	25	43	34		
1947								8	8	8		
1948						2	2	17	13	20		2
1949			8			17	25	34	36	41	30	36
1950	(2)		2		8	20	20	25	25	30	8	34

	O	N	D	J	F	M	A	M	J	J	A	S
1950/1951				2	13	13	25	34	41	17	11	
1952					8	20	41	54	43	43	17	13
1953					2	13	20	36	20	8	2	
1954				20	22	20	25	43	41	20	43	
1955				8	41	36	34	25	52	52	25	
1956				11	13	8	50	36	25	34		5
1957	11		2	11	11	34	25	25	34	17		
1958				8	20	34	43	43	34	25		
1959			5	13		2	52	52	34	34	2	2
1960		25	20	20	50	25	20	25	13	25	25	
1961					17	17	25	20	17			
1962				8	8	8	17	13	25	34		
1963			2	20	38	25	25	34	20	25	13	
1964		17	13	8	25	20	25	34	20			
1965		8	8	8	25	50	38	38	38	34	34	
1966	2	50	20	25	43	25	34	25	34	34	43	
1967				20	20	13	25	25	50	25	20	
1968		2	13	17	20	34	20	43	43	52	47	
1969			13	43	43	43	43	52	63	60	34	43
1970		8	13	25	50	52	58	38	50	52	52	
1970/1971			13	20	20	38	38	50	52	52	34	
1971/1972		20	13	17	25	43	41	34	34	22	34	