Occurrence of Climate Variability and Change Within the Hydrological Time Series A Statistical Approach

Henryk T. Mitosek
Institute of Geophysics
Polish Academy of Sciences
Warsaw, Poland

CP-92-05
September 1992

IIASA International Institute for Applied Systems Analysis □ A-2361 Laxenburg □ Austria
Telephone: +43 2236 715210 □ Telex: 079 137 iiasa a □ Telefax: +43 2236 71313

Preface

The paper summarizes results of Project A.2 "Analyzing Long-Time Series of Hydrological Data and Indices with Respect to Climate Variability and Change" as one component of the World Climate Program–Water (WCP–WATER). In collaboration with IIASA, an algorithm developed by WMO and the associated program called TIMESER 3 has been set up at the Institute of Geophysics of the Polish Academy of Sciences. The computations used monthly data supplied by the Global Runoff Data Centre. Additionally, even longer time series compiled in Poland were applied. The detailed objective of the study was to test the hypothesis that the analyzed parameters are stationary and ergodic. The rejection of the hypothesis would indicate the occurrence of climate change within the period covered by the hydrological data used.

Foreword

IIASA has an interest in analyzing the impact of a likely climate change on water resources in the scale of a river basin. The Institute was requested by the World Meteorologic Organization (WMO) to assist in implementing the project on "Analyzing Long-Time Series of Hydrological Data and Indices with Respect to Climate Variability and Change" within the World Climate Programme of UNESCO/WMO. A set of more than 150 long-time series was transferred to IIASA from the Global Runoff Data Centre in Koblenz (Germany) for analysis. The Institute of Geophysics of the Polish Academy of Sciences expressed its interest to collaborate with IIASA on the basis of an agreed WMO methodology. The present paper summarizes the results achieved and serves as background material for an international workshop to be organized by WMO on the subject.

László Somlyódy
Leader
Water Resources Project

CONTENTS

SOME INTRODUCTORY REMARKS

Within the framework of the World Climate Program - WATER, i.e. WCP-WATER, the following two research projects have been undertaken:

A.1 - "Analyzing historical hydrological and related information with respect to climate change", and

A.2 - "Analyzing long-time series of hydrological data and indices with respect to climate variability and change".

The International Association of Scientific Hydrology (*IAHS*) and the World Meteorological Organization (*WMO*) have become responsible, respectively, for the two above mentioned projects.

As concerns Project A.2 [*WMO*, 1988] the following definitions have been adopted: climate variability means the variability inherent in the stationary stochastic process approximating the climate on a scale of a few decades. On the other hand, the differences between the stationary stochastic processes being the climate models in successive periods of a few decades can be considered as climate change.

In other words, climate change determines the differences between long-term mean values of a climate characteristic, where the mean is taken over a specified interval of time, usually a number of decades. The climate variability includes the extremes and differences of monthly, seasonal and annual values from the climatically expected values (that is temporal mean). The notion of the climatically expected value involves the assumption of stationarity and ergodicity [e.g., *Fisz*, 1963].

The notion of variability and change of climate can be identified with two different ideas of climatic process, namely that of the climate represented by a stationary process and a nonstationary one. According to such an approach, the climate is analyzed as a nonstationary process that can be approximated by a stationary process on a shorter time scale of a few decades. This stationary approximation is connected with the idea of climate normals considered as measures of the central tendency around which the climate fluctuates.

The climate and the hydrological fluctuations can be analyzed from the point of view of physical and/or statistical criteria as significant or nonsignificant. However, as no physical or economical criteria generally accepted have existed so far which would allow us to determine such changes, it has been accepted that statistical criteria will be the only ones to be analyzed, even if preliminarily only.

Project A.2 (herein after called the Project), the elaboration of which has been undertaken by us, aims at enlarging our knowledge about hydrological fluctuations considered as a certain aspect of such changes in climate.

In the Project we should be aware of the fact that the relation of signal, in the form of possible trend, to noise is very disadvantageous. In all cases, possible trend is masked by noise (compare Fig. 0).

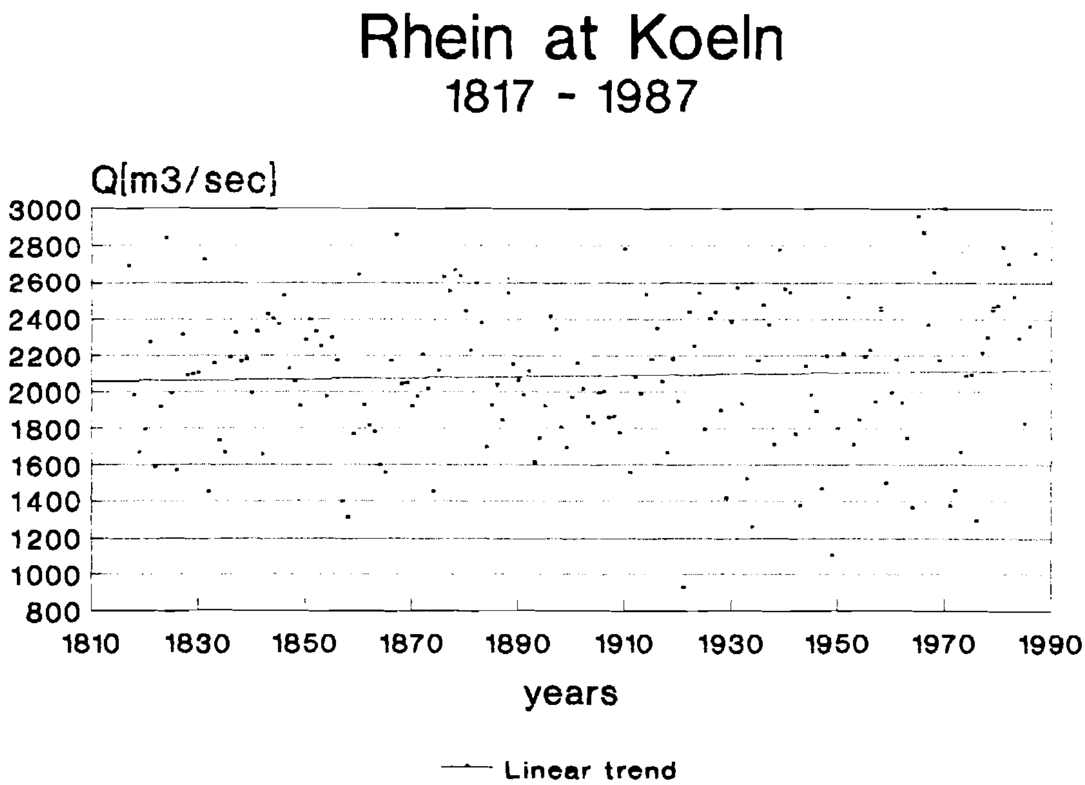

Fig. 0. Runoff at Koeln on Rhein

DATA

The experimental part of the Project will be carried out on the basis of monthly data. It has been accepted that the data of the so-called first priority will be:

(a). water discharge,

(b). lake level,

(c). precipitation,

(d). air temperature,

and those of the second priority will be:

(e). river stage,

(f). fresh water temperature,

(g). ice cover (date of break up),

(h). ice cover (total number of days during season),

(i). groundwater level;

moreover, within each set the order of priority is the order in which the types are listed.

It has been assumed that the data should be consistent and homogeneous. The data are consistent when it can be acknowledged that they have been acquired by the same measurement technique (the same type of device, identical sampling interval, the same manner of data processing, etc.). The homogeneity of data is connected with the constancy of the measurement site and of its environmental conditions as well as with the lack of artificial, and, generally, anthropogenic disturbances in climate and/or in hydrological processes (e.g., because of the forced artificial retention or changes in the cover, or to the use of a basin area). In practice, it is of course difficult to imagine a long time series that would be absolutely consistent and homogeneous. For this reason, those from among the series that had been characterized with a quasi-consistency and a quasi-homogeneity have been accepted for further analyzing. The supplier of the data should assure the postulated quasi-properties by appropriate treatment of the available data.

The time series of data should meet the conditions of qualitative requirements that have been gathered in the Chapters:

4.2.4.4 and 4.3.4. of the *Guide to Hydrological Practice* [*WMO*, 1983]. The supplier of the data who has made them accessible had been obliged to give them an appropriate "certificate" according to the following evaluation scale:

- very good
- good
- acceptable for the purposes of the Project[1].

The assumption has been made that, for the purposes of the Project, the minimum length of data would be: 50 years for precipitations and air temperatures, and up to 30 years for all other data.

A lack of any gaps in the temporal continuity of time series has been of utmost importance. If such gaps happen to occur, their total length in relation to the length of the series should not exceed 5 %. The gaps should be filled in by the data owner using recognized methods.

The Global Runoff Data Centre, established by the Federal Republic of Germany under the auspices of the World Meteorological Organization, has provided the bulk of data that, in general, have been the mean monthly discharges. Moreover, they have provided 21 time series of the monthly precipitation depths, 3 series of the mean monthly lake levels, and one of the mean monthly air temperature.

Additional 4 series of monthly precipitation depths and 5 series of the mean monthly air temperatures have been obtained for Poland.

For the needs of the Project the following quantities of time series have been collected:

Europe (Poland - 11, Commonwealth of Independent States - 10, Norway - 7, Czecho-Slovakia - 6, Germany - 6, Spain - 5, Sweden - 4, Romania - 3, Hungary - 2, Holland - 1, and Ireland - 1),

Canada - 97,

---

[1]N.B. Postulated certificates were prepared for 5 sets data from New Zealand and 1 set from Poland, only.

Argentina -1,
Australia (- 12, New Zealand - 5, and New Caledonia -2),
Africa (Ghana - 15, Nigeria - 3, Benin - 2, Sudan - 2, Egypt - 1, Mali - 1, Niger - 1, Senegal - 1, and Zaire - 1),
Asia (Philippines - 5, Thailand - 4, Malaysia - 1, Sri Lanka - 2).

For appropriate analysis, the data were separated into two sets: of the water discharges and of the other data (the monthly precipitation depths, the mean monthly lake levels, and the mean monthly air temperatures). For the sake of simplicity, the latter set will be called *the others*.

Because of some irregularities (appearance of gaps, some time series were shorter then their required minimum length, etc.), it was necessary to eliminate some time series.

Thus, in total, we have at our disposal, for statistical analyzes, 201 time series which are separated into two sets, and their list is presented in Table 1. Table 2 shows a list of stations (every station is characterized by its number, name, total number of observation years, and first year of observation).

Table 1a. List of the discharge stations

No.	Station	No. of years	First observ. year
	*** Europe ***		
1	LABE AT DECIN	134	1851
2	HRON AT BREZNO	60	1931
3	VAH AT LIPTOVSKY MIKULAS	70	1921
4	KYSUCA AT CADCA	60	1931
5	TOPLA AT HANUSOVCE	60	1931
6	DUNAJ AT BRATISLAVA	90	1901
7	DANUBE AT NAGYMAROS	93	1893
8	DANUBE AT ORSOVA	149	1840
9	WESER AT VLOTHO	163	1823
10	SALZACH AT BURGHAUSEN	161	1827
11	INN AT WASSERBURG	161	1827
12	MAIN AT WUERZBURG	151	1824
13	RHEIN AT KAUB	166	1821
14	RHEIN AT KOELN	171	1817
15	RHINE AT LOBITH	90	1901
16	SAJO AT FELSOZSOLCA	95	1891
17	BROSNA AT FERBANE (STATION NO. 2506)	41	1950

18	410-0, KNAPPOM GLOMMA	72	1917
19	437-0, ETNA DRAMSELV	69	1920
20	586-0, STORDALSVATN ETNEELV	76	1913
21	598-0, BULKEN VOSSA	97	1892
22	714-0, VASSVATN KJERRINGA	72	1917
23	990-0, JUNKERDALSELV SALTELV	51	1938
24	ODRA AT POLECKO	42	1946
25	ODRA AT GOZDOWICE	87	1901
26	WARTA AT GORZOW	87	1901
27	REGA AT TRZEBIATOW	42	1946
28	WISLA AT SZCZUCIN	67	1921
29	WISLA AT TCZEW	87	1901
30	DUNAJEC AT NOWY SACZ	42	1946
31	SAN AT RADOMYSL	67	1921
32	BUG AT WYSZKOW	67	1921
33	MURES AT ARAD	112	1877
34	SOMES AT ATU MARE	64	1925
35	AMUR AT KHABAROVSK	89	1887
36	SHILKA AT SRETENSK	81	1897
37	BIYA AT BIYSK	91	1895
38	TOM AT NOVOKUZNETSK	92	1894
39	TURA AT TIUMEN	90	1896
40	SEVERNAYA DVINA AT UST-PINEGA	104	1882
41	OKA AT KALUGA	104	1882
42	BELAYA AT UFA	108	1878
43	DESNA AT CHERNIGOV	66	1921
44	VINDELAELVEN AT SORSELE	69	1920
45	VISKAN AT ASBRO	62	1927
46	RANEAELV AT MIEMISEL	65	1924
	*** Canada ***		
47	YORK , SUNNY BANK	35	1946
48	KINOJEVIS , EN AVAL DU LAC REISSAC	33	1939
49	PETITE NATION , PRES DE COTE-SAINT-PIE	43	1926
50	MILLE ILES , EN AVAL DU LAC DES DEU	34	1927
51	BEAURIVAGE , SAINTE-ETIENNE	61	1926
52	BECANCOUR , LYSTER	46	1923
53	BELL , SENNETERRE	36	1928
54	HARRICANA , AMOS	54	1933
55	PIGEON , MIDDLE FALLS	64	1924
56	NEEBING , NEAR THUNDER BAY	34	1954
57	NORTH MAGNETAWAN , NEAR BURK'S FALLS	72	1916
58	BLACK , NEAR WASHAGO	72	1916
59	NOTTAWASAGA , NEAR BAXTER	38	1950
60	SAUBLE , SAUBLE FALLS	30	1958
61	SYDENHAM , NEAR OWEN SOUND	39	1949
62	CARRICK CREEK , NEAR CARLSRUHE	34	1954
63	AUSABLE , NEAR SPRINGBANK	40	1948
64	NITH , NEW HAMBURG	37	1951
65	SYDENHAM , NEAR ALVINSTON	39	1949
66	TWENTY MILE CREEK , BALLS FALLS	30	1958
67	EAST HUMBER , NEAR PINR GROVE	34	1954
68	KABINAKAGAMI , HIGHWAY NO. 11	36	1951

69	NAGAGAMI	,HIGHWAY NO.11	37	1951
70	MISSINAIBI	,MATTICE	67	1921
71	STELLAKO	,GLENANNAN	38	1951
72	STUART	,NEAR FORT ST.JAMES	38	1951
73	FRASER	,RED PASS	33	1956
74	MOOSE	,NEAR RED PASS	31	1958
75	FRASER	,SHELLY	38	1951
76	QUESNEL	,NEAR QUESNEL	31	1958
77	CLEARWATER	,OUTLET OF CLEARWATER L	31	1958
78	ADAMS	,NEAR SQUILAX	36	1953
79	SOUTH THOMPSON	,CHASE	41	1915
80	THOMPSON	,NEAR SPENCES BRIDGE	37	1952
81	LILLOOET	,NEAR PEMBERTON	30	1929
82	COLUMBIA	,NEAR FAIRMONT HOT SPRI	43	1946
83	SALMO	,NEAR SALMO	39	1950
84	BARNES CREEK	,NEAR NEEDLES	38	1951
85	KOOTENAY	,WARDNER	35	1937
86	ST.MARY	,NEAR MARYSVILLE	40	1949
87	KOOTENAY	,NEAR SKOOKUMCHUCK	38	1951
88	DUNCAN	,NEAR HOWSER	32	1935
89	LARDEAU	,MARBLEHEAD	43	1946
90	BOUNDARY CREEK	,NEAR PORTHILL	58	1931
91	SLOCAN	,NEAR CRESCENT VALLEY	56	1933
92	ASHNOLA	,NEAR KEREMEOS	32	1948
93	FLATHEAD	,FLATHEAD	37	1952
94	ATLIN	,NEAR ATLIN	38	1951
95	CASTLE	,NEAR BEAVER MINES	38	1951
96	OLDMAN	,NEAR WALDRON'S CORNER	39	1950
97	WATERTON	,NEAR WATERTON PARK	40	1949
98	BOW	,BANFF	78	1911
99	ELBOW	,ABOVE GLENMORE DAM	44	1934
100	BEAVER	,COLD LAKE RESERVE	33	1956
101	MCLEOD	,ABOVE EMBARRAS RIVER	34	1955
102	WOLF CREEK	,HIGHWAY NO.16A	34	1955
103	PEMBINA	,NEAR ENTWISTLE	34	1955
104	LOBSTICK	,NEAR STYAL	31	1956
105	ATHABASCA	,ATHABASCA	37	1952
106	SMOKY	,WATINO	33	1956
107	GODS	,OUTLET OF GODS LAKE	39	1948
108	ISLAND LAKE	,NEAR ISLAND LAKE	31	1934
109	WATERHEN	,NEAR WATERHEN	34	1955
110	SHELL	,NEAR INGLIS	32	1957
111	ROSEAU	,NEAR DOMINION CITY	40	1949
112	SPRAGUE CREEK	,NEAR SPAGUE	41	1941
113	WHITEMOUTH	,NEAR WHITEMOUTH	32	1957
114	GRASS	,WEKUSKO FALLS	31	1958
115	BEAR RIVER EAST BRANC	,BEAR RIVER	34	1917
116	BEAVER	,NEAR KINSAC	67	1922
117	ROSEWAY	,LOWER OHIO	71	1918
118	LA HAVE	,WEST NORTHFIELD	73	1916
119	EAST	,ST.MARGARETS BAY	63	1926
120	ST.MARYS	,STILLWATER	73	1916
121	NORTHEAST MARGAREE	,MARGAREE VALLEY	60	1929
122	SOUTHWEST MARGAREE	,NEAR UPPER MARGARE	70	1919

123	GRAND ,LOCH LOMOND	68	1921
124	SAINT JOHN ,FORT KENT	62	1927
125	ST.FRANCIS ,OUTLET OF GLASIER LAKE	37	1952
126	SHOGOMOC STREAM ,NEAR TRANS CANADA HIG	45	1944
127	LEPREAU ,LEPREAU	70	1919
128	UPSALQUITCH ,UPSALQUITCH	45	1944
129	TETAGOUCHE ,NEAR WEST BATHURST	37	1952
130	LIITLE SOUTHWEST MIRAMICH ,LYTTLETON	37	1952
131	UPPER HUMBER ,NEAR REIDVILLE	36	1953
132	INDIAN BROOK ,INDIAN FALLS	34	1955
133	EXPLOITS ,GRAND FALLS	39	1950
134	GARNISH ,NEAR GARNISH	30	1959
135	PIPERS HOLE ,MOPTHERS BROOK	36	1953
136	ROCKY ,NEAR COLINET	39	1950
137	NORTHEAST POND ,NORTHEAST POND	35	1954
138	BATTLE ,NEAR UNWIN	30	1950
139	TESLIN ,NEAR TESLIN	33	1956
140	NAMAKAN ,OUTLET OF LAC LA CROIX	66	1923
141	TURTLE ,NEAR MINE CENTRE	58	1921
142	ENGLISH ,UMFREVILLE	67	1922
	*** Argentina ***		
143	PARANA AT CORRIENTES	78	1905
	*** Australia ***		
144	O'SHANNASSY RIVER AT O'SHANNASSY WEIR	59	1912
145	SOUTH JOHNSTONE RIVER AT CENTRAL MILL	71	1917
146	PIONEER RIVER AT PLEYSTOWE MILL	52	1917
147	STYX RIVER AT JEOGLA	67	1919
148	CORANG RIVER AT HOCKEYS	62	1925
149	LATROBE RIVER AT WILLOW GROVE	63	1925
150	MITTA MITTA RIVER AT HINNOMUNJIE	56	1926
151	KING RIVER AT CROTTY	46	1925
152	SERPENTINE RIVER AT SERPENTINE FALLS	60	1911
153	AVOCA RIVER AT COONOOER	83	1905
154	TORRENS RIVER AT GORGE WEIR	72	1893
155	KAITUNA AT L ROTOITI OUTL (SITE 14601)	40	1950
156	TARAWERA AT AWAKAPONGA (SITE 15302)	41	1949
157	MOTU AT HOUPOTU	33	1958
158	HURUNUI AT MANDAMUS (SITE 65104)	31	1960
159	BULLER AT LAKE ROTOITI (SITE 93216)	31	1960
	*** Africa ***		
160	OUEME AT PONT DE SAVE	32	1952
161	OKPARA AT KABOUA	33	1952
162	NILE AT ASWAN DAM	114	1871
163	NILE AT DONGOLA	73	1912
164	WHITE NILE AT MALAKAL	71	1912
165	NIGER AT KOULIKORO	82	1907
166	NIGER AT NIAMEY	49	1941
167	RIVER BENUE AT YOLA	30	1960

168	SENEGAL AT BAKEL	81	1904
169	ZAIRE (CONGO) AT KINSHASA	86	1903
	*** Asia ***		
170	MAHAWELI AT PERADENIYA	35	1949
171	GIN GANGA AT AGALIYA	59	1927
172	QUAE YAI AT SRINAGARIND DAM	37	1952
173	NAN AT SIRIKIT DAM	34	1955
174	NAM CHI AT YASOTHON	34	1953
175	MEKONG AT MUKDAHAN	40	1947
176	NAM MUN AT UBON	32	1955

Table 1b. List of other stations (lake levels, precipitations, temperatures):

No.	Station	No. of years	First observ. year
	*** Europe ***		
1	LAKE GORECKIE AT JEZIORY (LAKE LEVEL)	32	1956
2	LAKE WIGRY AT WIGRY (LAKE LEVEL)	40	1948
3	LAKE VAENERN AT SJOETORP (LAKE LEVEL)	182	1807
4	CRACOW (TEMPERATURE)	160	1826
5	POZNAN (TEMPERATURE)	139	1848
6	WARSAW (TEMPERATURE)	200	1786
7	WROCLAW (TEMPERATURE)	106	1881
8	PULAWY (TEMPERATURE)	117	1871
9	CRACOW (PRECIPITATION)	111	1876
10	POZNAN (PRECIPITATION)	139	1848
11	WARSAW (PRECIPITATION)	151	1836
12	WROCLAW (PRECIPITATION)	106	1881
13	MALAGA (PRECIPITATION)	51	1934
14	GUADALAJARA (PRECIPITATION)	72	1912
	*** Africa ***		
15	BOLE (PRECIPITATION)	63	1927
16	WA (PRECIPITATION)	73	1917
17	SUNYANI (PRECIPITATION)	74	1916
18	ACCRA (PRECIPITATION)	89	1901
19	ADA (PRECIPITATION)	75	1915
20	AKUSE (PRECIPITATION)	74	1916
21	AXIM (PRECIPITATION)	75	1915
22	SALTPOND (PRECIPITATION)	64	1926
23	SEFWI-BEKWAI (PRECIPITATION)	64	1926
24	KUMASI (PRECIPITATION)	64	1926
25	TAKORADI (PRECIPITATION)	59	1931

However, Table 2 shows the distribution of the series as a function of their length, N, expressed in terms of years.

Table 2a. Distribution of the number of series of the discharges as a function of their length

Europe:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	46	5	21	11	9

Canada:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	96	78	18	-	-

Argentina:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	1	-	1	-	-

Australia:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	16	9	7	-	-

Africa:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	10	4	5	1	-

Asia:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	7	7	-	-	-

Total:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	176	103	52	12	9

Table 2b. Distribution of the number of series of the others as a function of their length

Europe:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	14	3	1	4	6

Africa:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	11	1	10	-	-

Total:

Length of series N (years)	Total	30÷59	60÷89	90÷119	>120
Number of series	25	4	11	4	6

ALGORITHM

After a series of meetings and discussions, it has been agreed on methodology of the Project. Full particulars of the selected statistics and tests have been presented in [*WMO*, 1988].

In order to assure synchronized results it has been accepted that on December 31, 1980 there ends one of the sub periods of the series of sub periods of the assumed length.

The selection of functions and tests is a key problem of the Project as that is where the decision is made on the possibility and the form of the answer to the questions concerning the way in which the climate variability and change are reflected in the hydrologic data.

Moreover, the stage of creating statistical hypotheses and of their verification is a critical phase of the research procedure. The methods of verification of the hypotheses, both the parametric and nonparametric tests, have an "inborn defect" in their structure that reveals itself in the exclusive capacity of rejecting the advanced hypotheses. The statement that a test does not give - on the assumed level of significance - the ground for rejecting the tested hypothesis is never equivalent to the authorization for its complete acceptance.

The problem of whether two realizations of a stochastic process are the same or, in other words, whether the considered realizations have been derived from the same population is of utmost importance from our point of view. Unfortunately, so far, the theory of statistical testing developed no clear-cut methods that would allow the verification of hypotheses put in this way. In such a situation, the only thing that can be done is to apply the procedures of verification that have been elaborated for random variables. However, the postulated compromise-based solution does not take into consideration - as it is unable to do so - all the questions specific to the hydrological stochastic processes. Moreover, such a type of approach involves serious traps that certain researchers are not willing or - which is more probable - are not able to perceive. Unfortunately, this is also the case of the Program; it concerns any considerations concerning the statistic estimators made on the basis of all the monthly values. In such a case, one does not take into account evident annual cyclicity and the realization of a hydrological process of monthly values is than treated as one which has stationary and ergodic properties; this is a serious malpractice from the point of view of statistic methods and should not occur in the preferred algorithm and in the Fortran computer program TIMESER3 [*WMO*, 1988].

It should be strongly stressed that the idea under consideration [*WMO*, 1988] can be useful for an analysis of hydrological processes of the one year interval time sampling, i.e., processes of annual values and processes of monthly values for each month individually.

The case of hydrological processes of monthly values - the successive values of which belong to the same month - is connected with the hypothesis according to which the hydrological random variables belonging to the round-year time intervals are subject to the same probability distribution [e.g., *Kaczmarek*, 1977].

Most tests require the random variables to be mutually independent. Many hydrologists [e.g. *Buishand*, 1982] are convinced that this is not too great a limitation if provided that the test procedure concerns the sequences of seasonal or annual values. Such sequences are generally considered as mutually independent, though this is not always true [*Yevdjevich*, 1963*b*, *Mitosek*, 1984]. This assumption should be carefully checked in every such case.

The assumption has been adopted for almost all parametric tests that the characteristics under verification belong to the random variables with a normal distribution. However, the assumption on the normality of the distribution would be in almost every case considered as a great idealization.

From our point of view much more practical are nonparametric tests in which no assumption is made on the functional form of the distribution function of random variables. However, much longer samples are required for such tests.

Accepting, at least partially, the algorithm [*WMO*, 1988] and the prepared computer program TIMESER3, we have adopted the hypothesis that hydrological processes of monthly values are the periodical random processes with one year cycle, that is, the 12-dimensional random variables which for the months of the same name have identical moments, up to the second order inclusively. We have adopted the same assumption for the annual hydrological values, that is, for the one-dimensional random variable. In every case, this assumption refers to the identity of the appropriate mean values and variances.

The adopted hypothesis has been then subject to falsification procedure of nonparametric tests (the run test, Kruskal Wallis's test of equality on the means and variances, and Mann's test of trend in the mean and in the variance), the statistics of which have been estimated on the basis of 30-year sub samples and of the whole sample.

However, certain complications have emerged as concerns the autocorrelation coefficients[2]. If evaluated according to the TIMESER3 program, they are the autocorrelation coefficients for the same monthly random variable with a lag of, at least, one year and, generally, they could not be considered as identical for the same lag in a set of all the months. Farther, we will not use estimates of the autocorrelation coefficients for lags exceeding 1 year because this characteristic has, in this context, only an inquiring character. The more so, as when one speaks about the probability distribution of the estimate of autocorrelation coefficients, one uses only its asymptotic Bartlett's approximation [*Bartlett*, 1946].

Taking into consideration the above remarks it seems absolutely necessary to verify the hypothesis according to which the analyzed autocorrelation coefficients are zero [*Box* and *Jenkins*, 1970]. A verification procedure may result in the fact

---

[2]Note that coefficients of the autocorrelation function are calculated when the number of years in the series is greater than or equal to 60 years, only.

that, as concerns the autocorrelation coefficients with one year lag, either the ground is lacking or there is a ground for rejecting the postulated hypothesis. This alternative character of the result may be interpreted within the framework of the correlation theory of random processes [*Bendat* and *Piersol*, 1971], according to which the analyzed realization belongs, appropriately, to the white noise process (the process of independent elements) or to the red noise process (simple Markov's process).

The nonparametric run test [*Fisz*, 1963] allows one to consider the hypothesis concerning the origin of the analyzed realization from the process with independent elements. It is a nonparametric competitor of the parametric test for the autocorrelation coefficients considered above.

However, the results of studies on the interdependence of the successive elements of the analyzed processes, carried out by the run test or the test based on the autocorrelation, have no influence on the considerations about the climate variability and climate change. The rejection of the hypothesis that there is no interdependence between successive elements of the process (including also the hypothesis according to which $H_0(\rho(1) = 0)$) creates additional problems because the time series can be no longer considered as independent and identically distributed random variables.

The Kruskal-Wallis's nonparametric test [*Sneyers*, 1975] of mean values and variances identity is applied for:

(a). 30-year intervals divided into three 10-year subintervals, and

(b). a complete period of observation of N-years divided into 6 subintervals of identical length $[N/6]$-years where [.] denotes the "integer part of".

In case (a), the end of the last 30-year interval falls on December 31, 1980, while for (b), the first year of observation constitutes the beginning of the first subinterval. This test enables us to draw the conclusion on the possible heterogeneity of the mean value or/and of the variance of the analyzed hydrological process. Moreover, one should be aware of the fact that the postulated independence of the samples remains unfulfilled because every subinterval represents a certain part of the observation period. It should be also noted that the limits of 10-year subintervals for case (a) have not much to do with the limits of subintervals that have been singled out in case (b).

Mann's test is a valuable nonparametric test based on Kendall's range correlation statistic [*Sneyers*, 1975] that enables us to check the occurrence of a tendency - including the possibility of determining its direction (increasing versus decreasing) - in the quantities of the mean value and of the variances.

The remaining tests and characteristics are inseparably connected with the assumption that the probability distribution is normal.

TESTS RESULTS

Taking into consideration the earlier remarks, we present only the results of investigations concerning the climate variability and climate change in the time series of the monthly values for each month individually as well for the annual values.

Detailed results of computations in the form of tables and figures will be contained in successive Appendices for monthly values and for annual values.

176 series of discharges have been analyzed, including 46 for Europe, 96 for Canada, 1 for Argentina, 16 for Australia, 10 for Africa and 7 Asia. Their average length was 89.9, 43.0, 78.0, 54.2, 65.1, 38.7, and 38.7 years, respectively, for Europe, Canada, Argentina, Australia, Africa, and Asia.

Moreover, 25 series of *the others* have also been analyzed, including 14 for Europe and 11 for Africa with an average length of 114.7 and 70.4 years, respectively.

Totally, series of discharges and of *the others* have had an average length of 57.6 and 95.2 years, respectively.

All the test studies have been carried out for the significance level α = 5 %. The adopted level of significance is the standard criteria magnitude in the statistical analysis [e.g. *Fisz*, 1963].

The results of verification of the hypotheses showing that (i) run number suggests the independence of random variables, and (ii) the autocorrelation coefficient of one-year lag is equal to zero, $H_0(\rho(1) = 0)$, will be shown in Table *.3[1] separately for the discharges and *the others*. The results will be classified according to particular regions and to the "total", and they illustrate in the numerator the number of cases in which the analyzed hypothesis has been rejected, and in the denominator - their percentage share in the collection of tests. The successive tables showing the results of other tests will be depicted in a similar way.

The results of verification of the hypothesis $H_0(\rho(1) = 0)$ are presented in the third column of Table *.3. They will be not discussed because of their scarcity (*compare* the footnote 2).

Attention should be paid to the fact that the results of test-based investigation connected with the tests of the runs and of the linear independence that are based on the autocorrelation coefficients have no influence upon the deliberations about the climate variation. There exists no appropriate test that would allow for analyzing the identical character of the discussed characteristics in the successive subintervals of the whole observation period.

Next, we will present the results obtained by Kruskal-Wallis's test verifying the identical character of mean values and of variances in (A) six subintervals of equal length, of the complete observation period (presented in Table *.4), and (B) in the successive 30-year intervals (subintervals of the whole observation period), that have been divided, secondarily, into

---

[1]An asterisk in the number of table or figure replaces specific number of the Appendix.

three 10-year sub periods.

Tables *.5 and *.6 show, respectively, the results of Kruskal-Wallis's test - described in the point (B) - for the mean values and for the variances for the 30-year intervals. The first year of every 30-year period has been written down at the top of the tables. As it is shown by the average interval length of observation, only two 30-element intervals could be singled out from the preponderant number of cases. Attention is drawn to the fact that within every from among the singled out 30-year intervals the verification procedure has been carried on independently of the remaining intervals.

As the results of Kruskal-Wallis's test are independent in the 30-year intervals (case (B)), we put together the results from Tables *.5 and Tables *.6 in Table *.7 of the cumulated results.

In case (A) of Kruskal-Wallis's test the obtained results are significantly different from those achieved in case (B) - it is sufficient to compare the results given in Tables *.4 and in Tables *.7. This differentiation is explained by the length of the interval subject to the verification procedure.

In our opinion, from the point of view of the goal, that is, of detecting climate variation and climate change, insofar as Kruskal-Wallis's test is concerned, it would be possible to limit the research to case (B). The practice also supports this view: in climatology, the mean value for at least a 30-year series of mean annual precipitations is considered as the normal annual precipitation [e.g., *Debski*, 1966]. If the time series can be considered as a chronological sequence of independent and identically distributed random variables there are no arguments against generalization of this idea of 30-year normals over *the other* hydrological phenomena.

At the end, we shall discuss the results of the last nonparametric test, that is Mann's test. This test concerns both the run of the mean value and of the variance. It allows for supposing the occurrence of trend in the mean value or in the variance if the analyzed hypothesis of homogeneity is rejected. In the case of rejecting the analyzed hypothesis it is the sign of the test statistic that will decide upon the direction of the supposed trend: being positive or negative it decides on the occurrence of a growing or decreasing trend, respectively.

Figures *.1 and *.2 illustrate the possible occurrence of the trend and its direction, respectively, in the mean value and in the variance for discharge and other phenomena. At the ordinate axis, we have the number with appropriate signs(+) or (-) subject to the stations in which the rejection of the discussed hypothesis occurred. In both cases the values of the mean and of the variance have identical numbers. The time intervals within which the postulated hypothesis was rejected for a certain station have been marked in the figures over the time axis by the segments parallel to it. Moreover, the figure gives the possibility of determining the direction of a possible trend: the signs (+) or (-) are connected with the occurrence of the trend, respectively, growing or decreasing at the station with an appropriate number. The numbers and names of stations are compiled in Table 1.

The regional cases of rejection of the hypotheses in question have been grouped separately in Figure *.1 and Figure *.2.

However, Tables *.8 and *.9 contain the results of Mann's test. Table *.8 shows the distribution of the number of cases of the occurrence of trend and its direction in the mean value and in the variance if the analyzed hypotheses of homogeneity are rejected. In Table *.9, there are the summary results of Mann's test, i.e., the distribution of the number of cases of the occurrence of trend in the mean value and in the variance independently of trend's direction.

CONCLUSIONS

1. Analyzing the initial data with the aim of assuring their quasi-consistence and quasi-homogeneity the researcher must be aware of the fact that even in short time intervals the changes in the régime of the phenomenon may be difficult to detect, because they are frequently small and masked by measurement errors.

2. The idea of algorithm and of the computer program [*WMO*, 1988] is useful when applied to the processes of annual values as well as of monthly values of each month.

3. Because of the obvious annual periodicity of hydrological phenomena, the estimation of the statistics of the process based on its all monthly values is inadmissible.

4. The parametric tests basing on the assumption of the normal probability distribution should not be applied for non-Gaussian processes. For that reason, nonparametric tests are used.

5. The level of significance adopted for the used tests has been 5 %.

6. The results of studies on the interdependence of successive elements of the analyzed processes, carried out by the run test or the test based on the serial correlations, have no influence on the considerations about the climate variability and climate change.

7. The accessible statistical apparatus allows us to draw the conclusion on the climate variability or/and climate change by the temporal run of the mean value and of the variance of the analyzed processes. Both Kruskal-Wallis's test and Mann's test for those characteristics are useful in this respect.

8. Kruskal-Wallis's test suggests that in the 30-year intervals, the hypotheses about the stationarity and ergodicity of the mean value and of the variance should be rejected, respectively:

(a). in 12.3 % and 6.3 % of cases for the monthly discharges, on the average,

(b). in 5.9 % and 4.9 % of cases for the monthly *others*, on the average,

(c). in 14.9 % and 5.8 % of cases for the annual discharges,

(d). in 12.3 % and 6.3 % of cases for the annual *others*.

9. Mann's test allows us to confirm that, on the average, in 32.8 % and 25 % of cases - following the appearance of trends in the mean values and in the variances - there has been rejected the hypothesis about the stationarity and ergodicity of the mean value

and the variance, respectively, for the monthly discharges.

10. In 44.9 % and 20.5 % of cases - because of the appearance of trends in the mean value and in the variance, respectively - the hypothesis of a stationarity and ergodicity of the mean value and of the variance (Mann's test) was rejected for the annual discharges.

11. Mann's test allows us to confirm that, on the average, in 43 % and 32.3 % of cases - following the appearance of trends in the mean values and in the variances - there has been rejected the hypothesis about the stationarity and ergodicity of the mean value and the variance, respectively, for the monthly *others*.

12. When the hypothesis about stationarity and ergodicity of the analyzed characteristic is rejected then one cannot claim that the process together with its fluctuations falls into the category of climate variability. This suggests the ocurrence of climate change within the considered time series.

13. Unfortunately, because of the scarcity of available data we are not authorized to draw any more far-reaching conclusions.

14. Moreover, annual extreme events such as, e.g., maximal or minimal discharge values should be also collected and the same type of statistical analysis should be carried out on them.

LITERATURE

Bartlett M.S., 1946, On the theoretical specification of sampling properties of autocerrelated time series, *J.Roy. Statist. Soc.*, B2, 27.

Bendat J.S., Piersol A.G., 1971, Random Data: Analysis and Measurement Procedures, *John Wiley & Sons, Inc.*, New York.

Box G.E.P, Jenkins G.W., 1970, Time Series Analysis: Forecasting and Control, *Holden Day, Inc.*, San Francisco.

Buishand T.A., 1982, Some methods for testing the homogeneity of rainfall records, *J. Hydrol.*, 58, 11-27.

Dębski K., 1966, Continental Hydrology, Vol. II: Physics of Water, Atmospheric Precipitation and Evaporation, *U.S. Department of Commerce, National Technical Information Service*, Springfield, Va.

Fisz M., 1963, Probability Theory and Mathematical Statistics, *John Wiley & Sons, Inc.*, New York.

Kaczmerek Z., 1977, Statistical Methods in Hydrology and Meteorology, *U.S. Department of Commerce, National Technical Information Service*, Springfield, Va.

Mitosek H.T., 1984, Stochastyczna struktura przepływu rzecznego, (Stochastic Structure of Discharge), *Wyd. Geologiczne*, Warszawa, (in Polish).

Sneyers R., 1975, Sur l'analyse statistique des séries d'observations, OMM, Genève, *Note Technique No* 143.

WMO, 1983, Guide to hydrological practice, WMO, Geneva.

WMO, 1988, Analyzing long time series of hydrological data with respect to climate variability, Project description, *WCAP Report No*.3, WMO/TD-No.224, WMO.

Yevjevich V.M., 1963b, Fluctuations of wet and dry years, Part 2: Analysis by serial correlations, *Hydrol. Paper* 4, Colorado State Univ., Ft. Collins.

APPENDICES

APPENDIX 1. RESULTS OF JANUARY

It can be stated on the base of the run test that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in ca. 20 % of cases for Europe and Australia, 13.5 % of cases for Canada, ca. 60 % for Africa and Asia, and in 20.5 % for all discharges; (b) of *the others* had to be rejected in 7.1 %, 27.3 %, and 16 % of cases for Europe, Africa, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 1.4) that for about 75 % of all analyzed sequences of the discharges and of *the others*, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Even better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 10.8 % and 4.0 % of cases of the discharges and of *the others*, respectively.

Tables 1.5 and 1.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 1.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 14.4 % and 9.9 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 4.9 % and 1.6 % of cases there occur fluctuations in the mean value and in the variance, respectively.

Mann's test: for the discharges, increasing trends in mean value prevail over decreasing ones, except for Australia (in 18.8 % versus 12.5 % of decreasing and increasing cases, respectively). In ca. 40 % of cases for Europe, Africa, and Asia the increasing trends are observed. Totally, in 23.9 % and 13.1 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, increasing trends in the mean value are observed, except for one case of a decreasing trend in Europe.

For the discharges, decreasing and increasing trends in variance have totally emerged, respectively, in 19.9 % and 9.1 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 19.9 % to 9.1 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Biya at Biysk (station No. 37) and to decrease for the Nile at Aswan Dam (No. 162) and Belaya at Ufa (No. 42); it covers, respectively, 90.1 %, 67.5 %, and 52.8 % of the whole observation periods of 91, 114, and 108 years. The trend in the variance of discharges was the growing one for Niger at Niamey (No. 166) as well as decreasing for Salzach at Burghausen (No. 10) and Knappom Glomma (No. 18), and it lasted 35, 45, and 39 years. However for *the others*, the growing trend in the mean value covered periods of 78 and 76 years for temperatures in Warsaw (No. 6) and Cracow (No. 4).

As it appears from the summarized results of Mann's test (Table 1.9), a trend has emerged in 36.4 % and 29 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 44 % and 24 % of cases in the mean value and in the variance, respectively.

Table 1.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocor. coeffi- cient
Europe	10/21.7	7/17.1
Canada	13/13.5	0/0
Argentina	0/0	0/0
Australia	3/18.8	1/14.3
Africa	6/60.0	6/100
Asia	4/57.1	-
Total	36/20.5	14/19.2

Others:

Region	Run test	Test of autocor. coeffi- cient
Europe	1/ 7.1	1/ 9.1
Africa	3/27.3	0/0
Total	4/16.0	1/ 5.0

Table 1.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	12/26.1	6/13.0
Canada	12/12.5	6/ 6.3
Argentina	1/100	0/0
Australia	5/31.3	3/18.8
Africa	8/80.0	4/40.0
Asia	3/42.9	0/0
Total	41/23.3	19/10.8

Others:

Region	Mean	Variance
Europe	6/42.9	1/ 7.1
Africa	1/ 9.1	0/0
Total	7/28.0	1/ 4.0

Table 1.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	10/71.4	2/ 5.7	2/ 4.7
Canada				0/0	3/ 6.0
Argentina				0/0	1/100
Australia				1/14.3	1/12.5
Africa			1/100	3/50.0	4/57.1
Asia					1/33.3
Total	0/0	0/0	11/73.3	6/ 9.8	12/10.7

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	1/ 7.7
Africa					0/0	2/18.2
Total	0/0	0/0	0/0	0/0	0/0	3/12.5

Table 1.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	1/ 2.9	7/16.3
Canada				0/0	4/ 8.0
Argentina				0/0	0/0
Australia				1/14.3	1/12.5
Africa			1/100	1/16.7	2/28.6
Asia					1/33.3
Total	0/0	0/0	2/13.3	3/ 4.9	15/13.4

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	1/ 7.7
Africa					0/0	0/0
Total	0/0	0/0	0/0	0/0	0/0	1/ 4.2

Table 1.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	14/13.2	9/ 8.5
Canada	3/ 4.8	4/ 6.5
Argentina	1/100	0/0
Australia	2/13.3	2/13.3
Africa	8/57.1	4/28.6
Asia	1/33.3	1/33.3
Total	29/14.4	20/ 9.9

Others:

Region	Mean	Variance
Europa	1/ 2.3	1/ 2.3
Africa	2/11.8	0/0
Total	3/ 4.9	1/ 1.6

Table 1.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	6/13.0	19/41.3	14/30.4	6/13.0
Canada	8/ 8.3	14/14.6	16/16.7	3/ 3.1
Argentina	0/0	0/0	0/0	1/100
Australia	3/18.8	2/12.5	4/25.0	3/18.8
Africa	5/50.0	4/40.0	1/10.0	3/30.0
Asia	1/14.3	3/42.9	0/0	0/0
Total	23/13.1	42/23.9	35/19.9	16/ 9.1

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	1/ 9.1	7/63.6	2/18.2	1/ 9.1
Africa	0/0	3/21.4	0/0	3/21.4
Total	1/ 4.0	10/40.0	2/ 8.0	4/16.0

Table 1.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	24/54.4	20/43.5
Canada	22/22.9	19/19.8
Argentina	0/0	1/100
Australia	5/31.3	7/43.8
Africa	9/90.0	4/40.0
Asia	4/57.1	0/0
Total	65/37.0	51/29.0

Others:

Region	Mean	Variance
Europa	8/72.7	3/27.3
Africa	3/21.4	3/21.4
Total	11/44.0	6/24.0

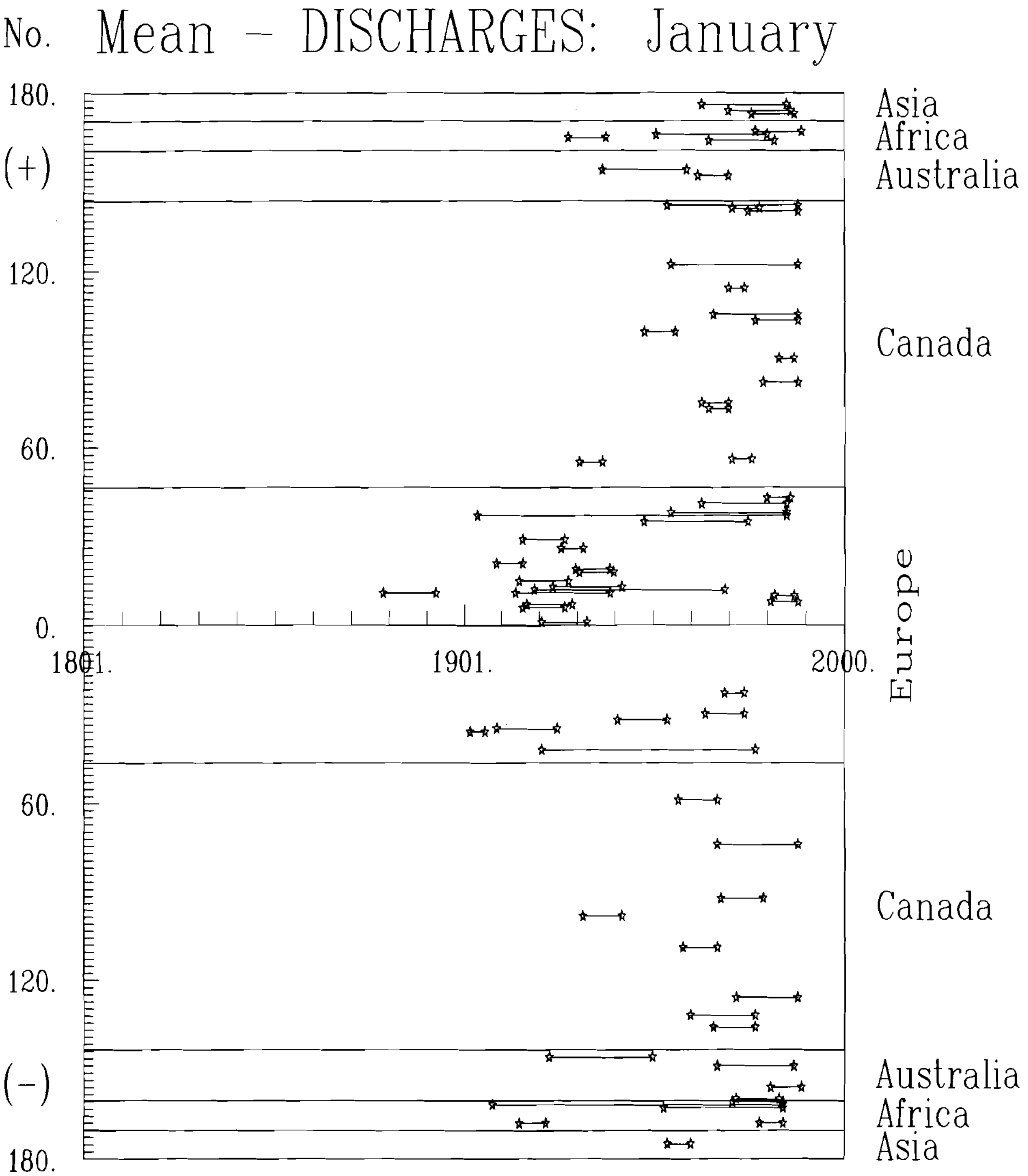

Fig. 1.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

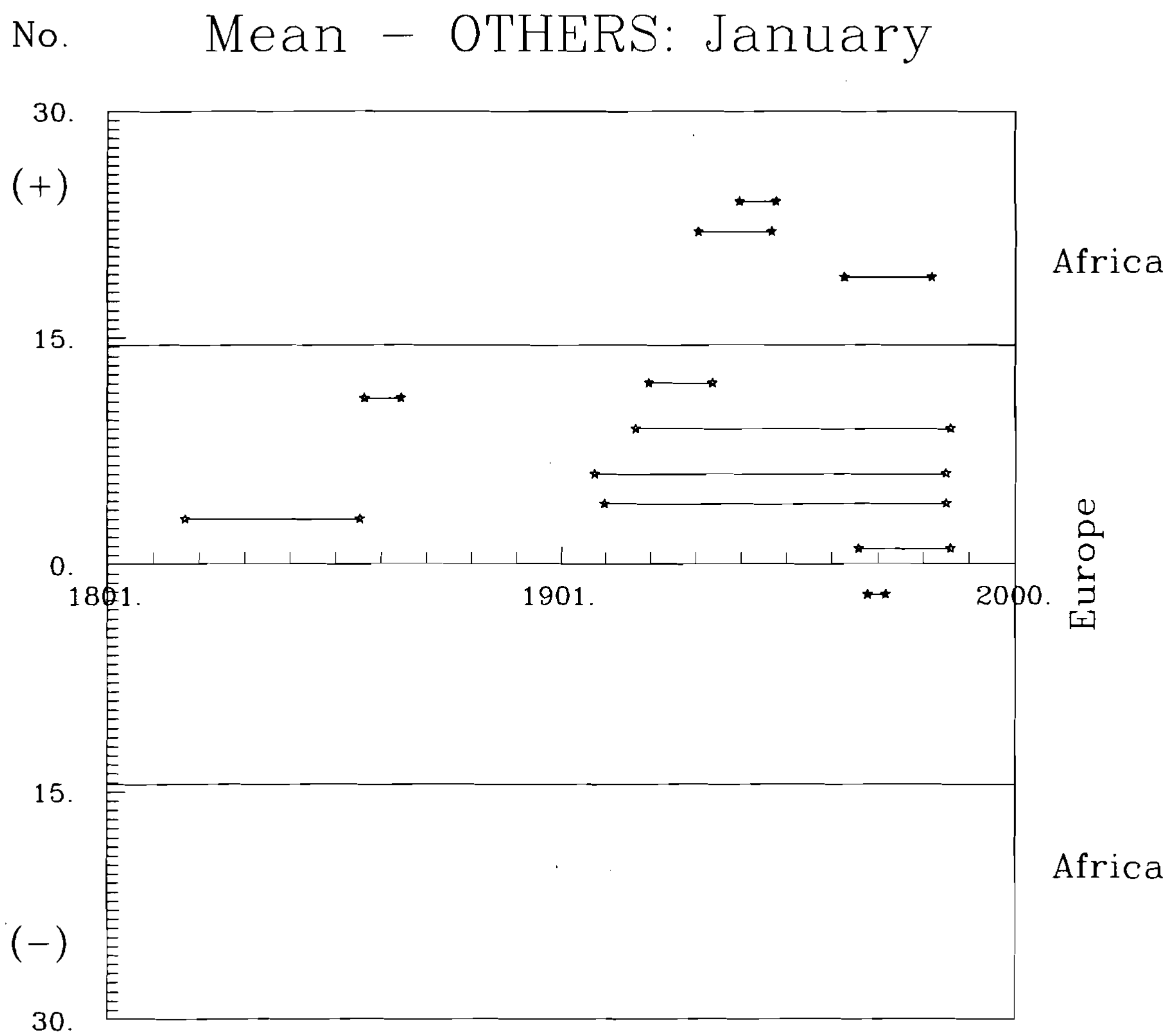

Fig. 1.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

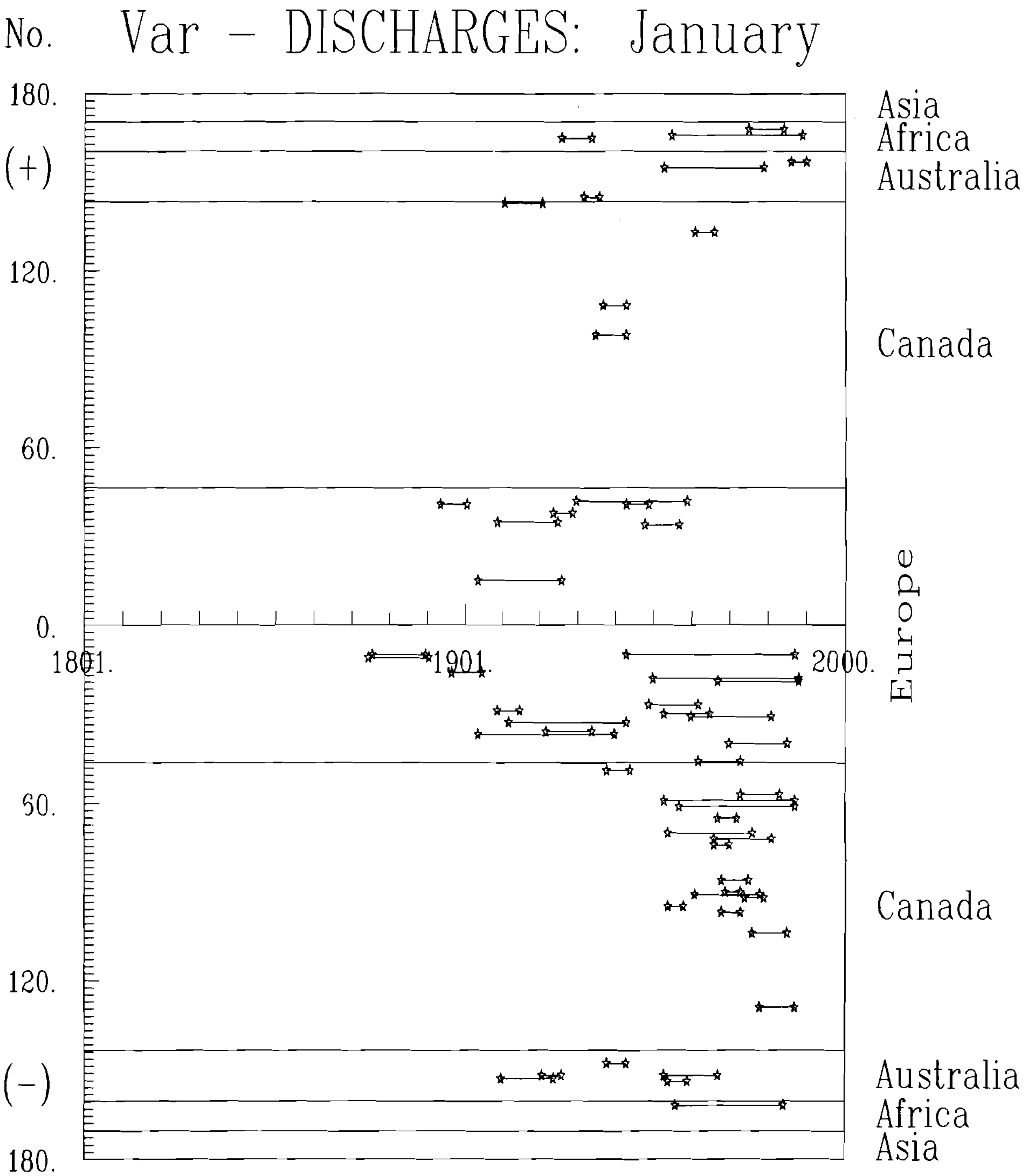

Fig. 1.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

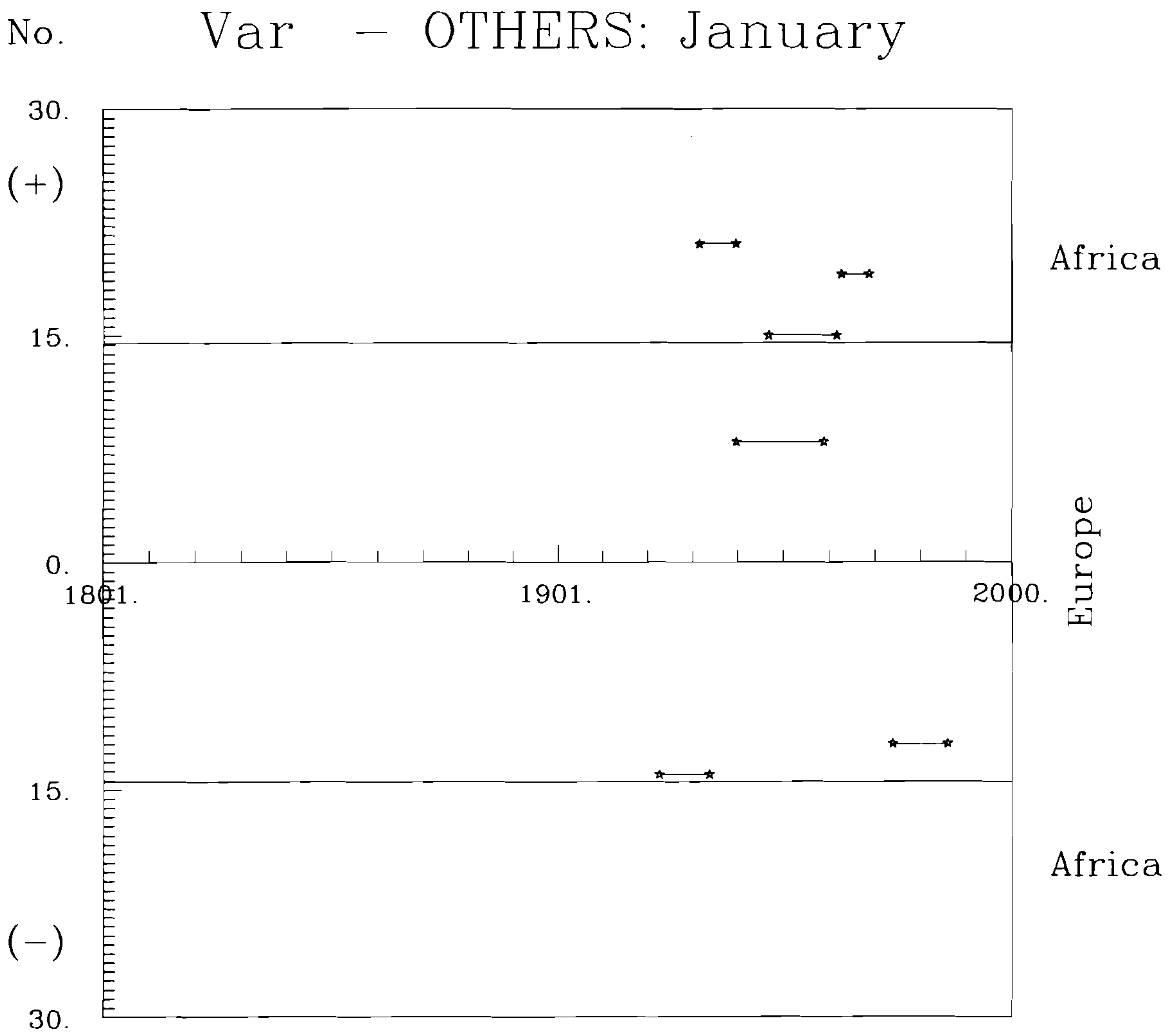

Fig. 1.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 2. RESULTS OF FEBRUARY

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 70 % of cases for Africa, 57.1 % for Asia, 43.8 % for Australia, 17.4 % for Europe, 10.4 for Canada, and in 20.5 % for all discharges; (b) of *the others* had to be rejected in 21.4 %, 9.1 %, and 16 % of cases for Europe, Africa, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 2.4) that for about 80 % of analyzed sequences of the discharges and 90 % of *the others*, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Even better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in ca. 8 % of all analyzed cases.

Tables 1.5 and 1.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 1.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 14.4 % and 6.4 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 3.3 % and 6.6 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean value prevail over decreasing ones. In ca. 40 % of cases for Australia, Africa, and Asia as well as in ca. 30 % for Europe and Canada the increasing trends are observed. Totally, in 33.5 % and 10.8 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, increasing trends in the mean value are observed, except for two cases of decreasing trends in Europe.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 19.3 % and 11.9 % of cases. However, for *the others* decreasing and increasing trends in variance are totally in proportion 16 % to 20 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Biya at Biysk (station No. 37) and Lepreau, Lepreau (No. 127) and to decrease for the Nile at Aswan Dam (No. 162) and Weser at Vlotho (No. 9) covering, respectively, 96.7 %, 70 %, 50 %, and 41.1 % of the whole observation periods of 91, 70, 114, and 163 years. The trend in the variance of discharges was the growing one for Dunaj at Bratislava (No. 6) and Belaya at Ufa (No. 42) as well as decreasing for Mures at Arad (No. 33), and it lasted 62, 58, and 49 years, respectively. However for *the others*, the trend in the mean value grows for temperatures in Warsaw (No. 6) covering period of 83 years and decreases for precipitations in Poznan (No. 10) during 46 years. Decreasing trend in the variance was observed during 50 years in Accra's precipitations (No. 18).

As it appears from the summarized results of Mann's test (Table 1.9), a trend has emerged in 44.3 % and 31.3 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 40 % and 36 % of cases in the mean value and in the variance, respectively.

Table 2.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocor. coefficient
Europe	8/17.4	6/14.6
Canada	10/10.4	2/11.1
Argentina	0/0	0/0
Australia	7/43.8	2/28.6
Africa	7/70.0	6/100
Asia	4/57.1	-
Total	36/20.5	16/21.9

Others:

Region	Run test	Test of autocor. coefficient
Europe	3/21.4	1/ 9.1
Africa	1/ 9.1	0/0
Total	4/16.0	1/ 5.0

Table 2.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	9/19.6	3/ 6.5
Canada	12/12.5	5/ 5.2
Argentina	0/0	0/0
Australia	6/37.5	2/12.5
Africa	9/90.0	3/30.0
Asia	2/28.6	0/0
Total	38/21.6	13/ 7.4

Others:

Region	Mean	Variance
Europe	2/14.3	0/0
Africa	0/0	2/18.2
Total	2/ 8.0	2/ 8.0

Table 2.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	2/14.3	2/ 5.7	1/ 2.3
Canada				0/0	9/18.0
Argentina				0/0	0/0
Australia				1/14.3	2/25.0
Africa			1/100	3/50.0	7/100
Asia					1/33.3
Total	0/0	0/0	3/20.0	6/ 9.8	20/17.9

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	2/15.4
Africa					0/0	0/0
Total	0/0	0/0	0/0	0/0	0/0	2/ 8.3

Table 2.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	1/16.7	1/12.5	2/14.3	1/ 2.9	1/ 2.3
Canada				1/ 8.3	3/ 6.0
Argentina				0/0	0/0
Australia				0/0	1/12.5
Africa			0/0	0/0	2/28.6
Asia					0/0
Total	1/16.7	1/12.5	2/13.3	2/ 3.3	7/ 6.3

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	2/33.3	1/10.0	0/0	0/0
Africa					1/16.7	0/0
Total	0/0	0/0	2/33.3	1/10.0	1/ 5.9	0/0

Table 2.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	5/ 4.7	6/ 5.7
Canada	9/14.5	4/ 6.5
Argentina	0/0	0/0
Australia	3/20.0	1/ 6.7
Africa	11/78.6	2/14.3
Asia	1/33.3	0/0
Total	29/14.4	13/ 6.4

Others:

Region	Mean	Variance
Europa	2/ 4.5	3/ 6.8
Africa	0/0	1/ 5.9
Total	2/ 3.3	4/ 6.6

Table 2.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	6/13.0	13/28.3	11/23.9	11/23.9
Canada	5/ 5.2	33/34.4	16/16.7	4/ 4.2
Argentina	0/0	0/0	0/0	0/0
Australia	3/18.8	6/37.5	3/18.8	3/18.8
Africa	4/40.0	4/40.0	3/30.0	3/30.0
Asia	1/14.3	3/42.9	1/14.3	0/0
Total	19/10.8	59/33.5	34/19.3	21/11.9

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	2/18.2	8/72.7	3/27.3	1/ 9.1
Africa	0/0	0/0	1/ 7.1	4/28.6
Total	2/ 8.0	8/32.0	4/16.0	5/20.0

Table 2.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	17/37.0	22/47.9
Canada	38/39.6	20/20.8
Argentina	0/0	0/0
Australia	9/56.3	6/37.5
Africa	8/80.0	6/60.0
Asia	4/57.1	1/14.3
Total	78/44.3	55/31.3

Others:

Region	Mean	Variance
Europa	10/90.9	4/36.4
Africa	0/0	5/35.7
Total	10/40.0	9/36.0

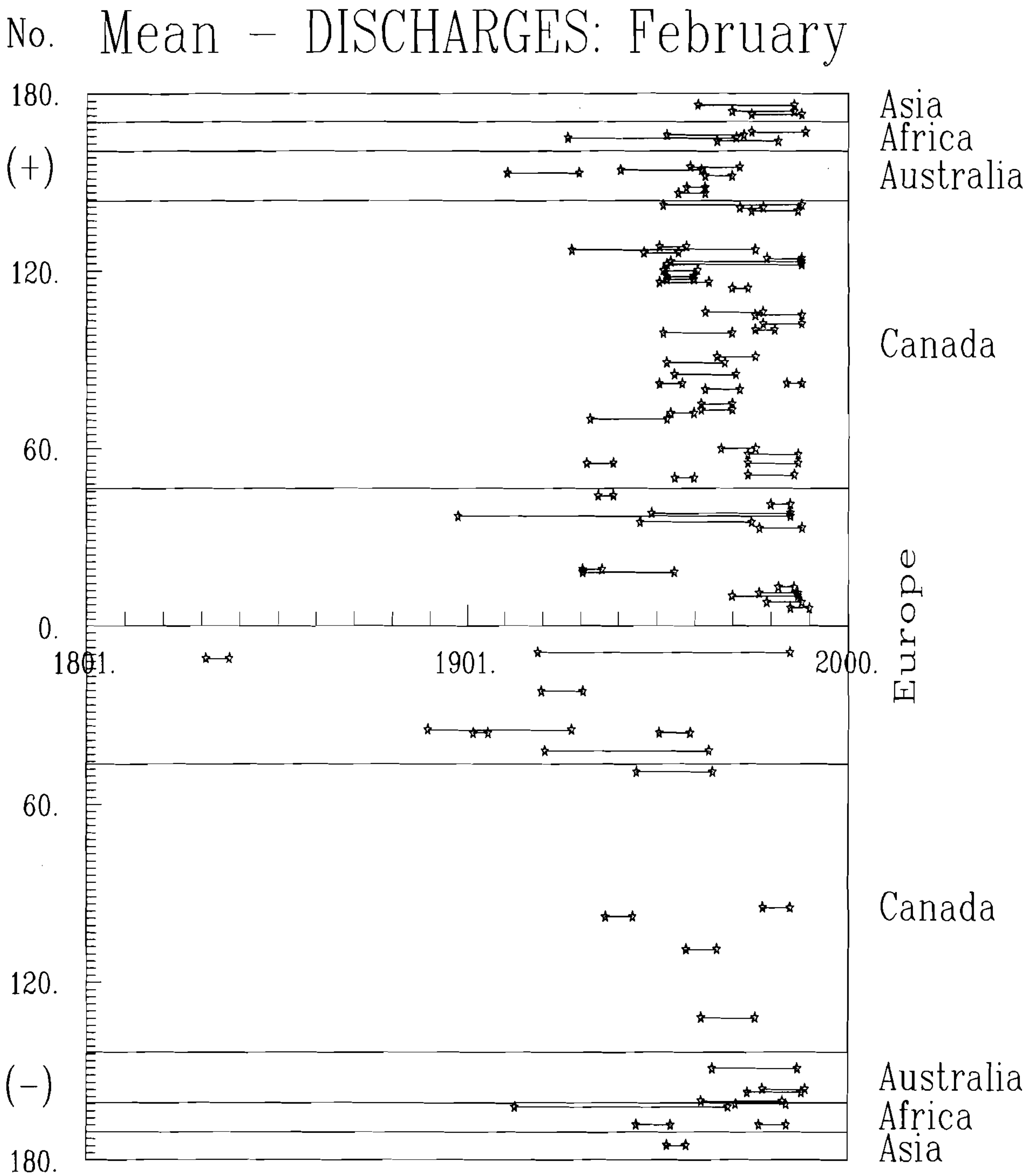

Fig. 2.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

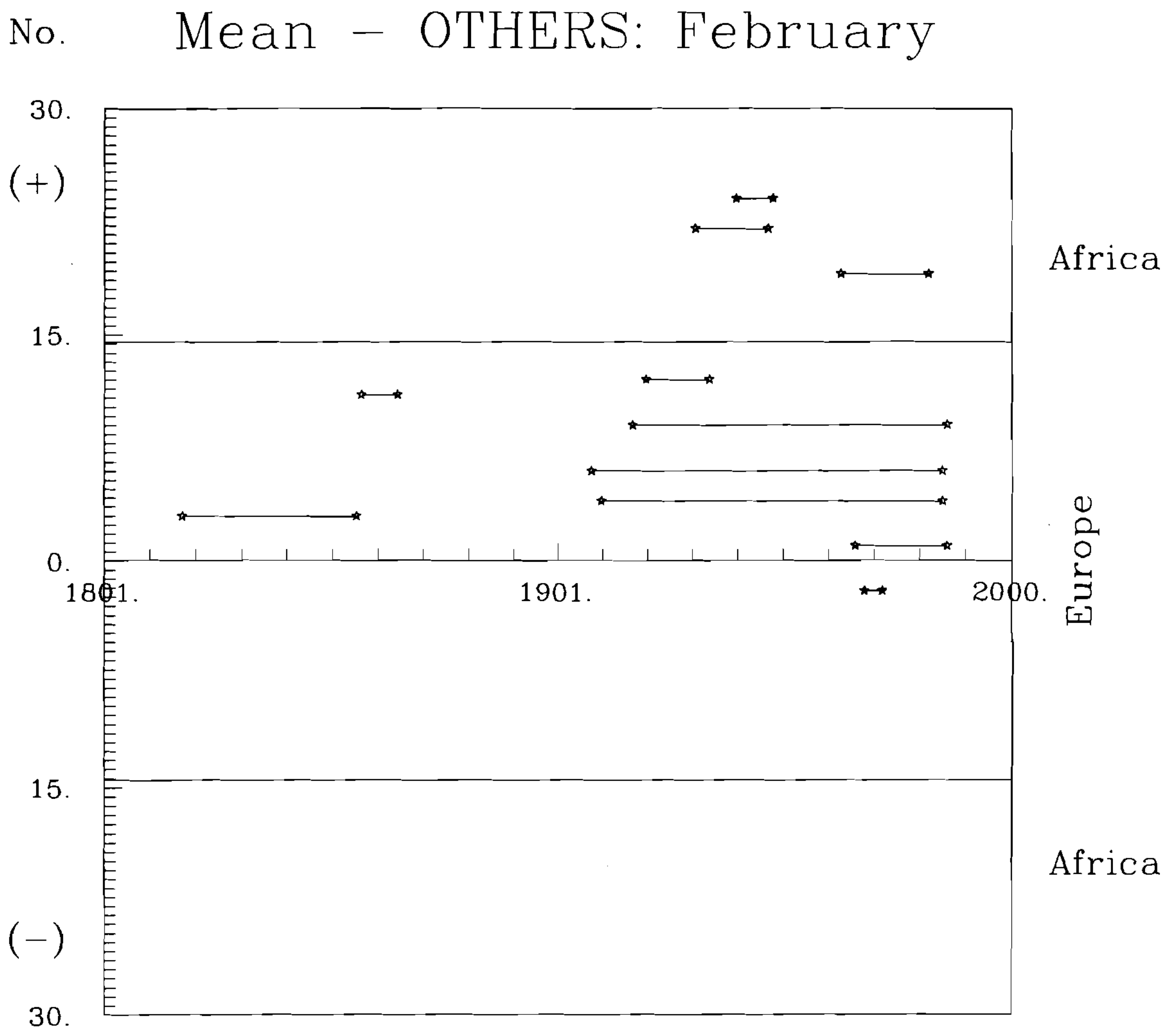

Fig. 2.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

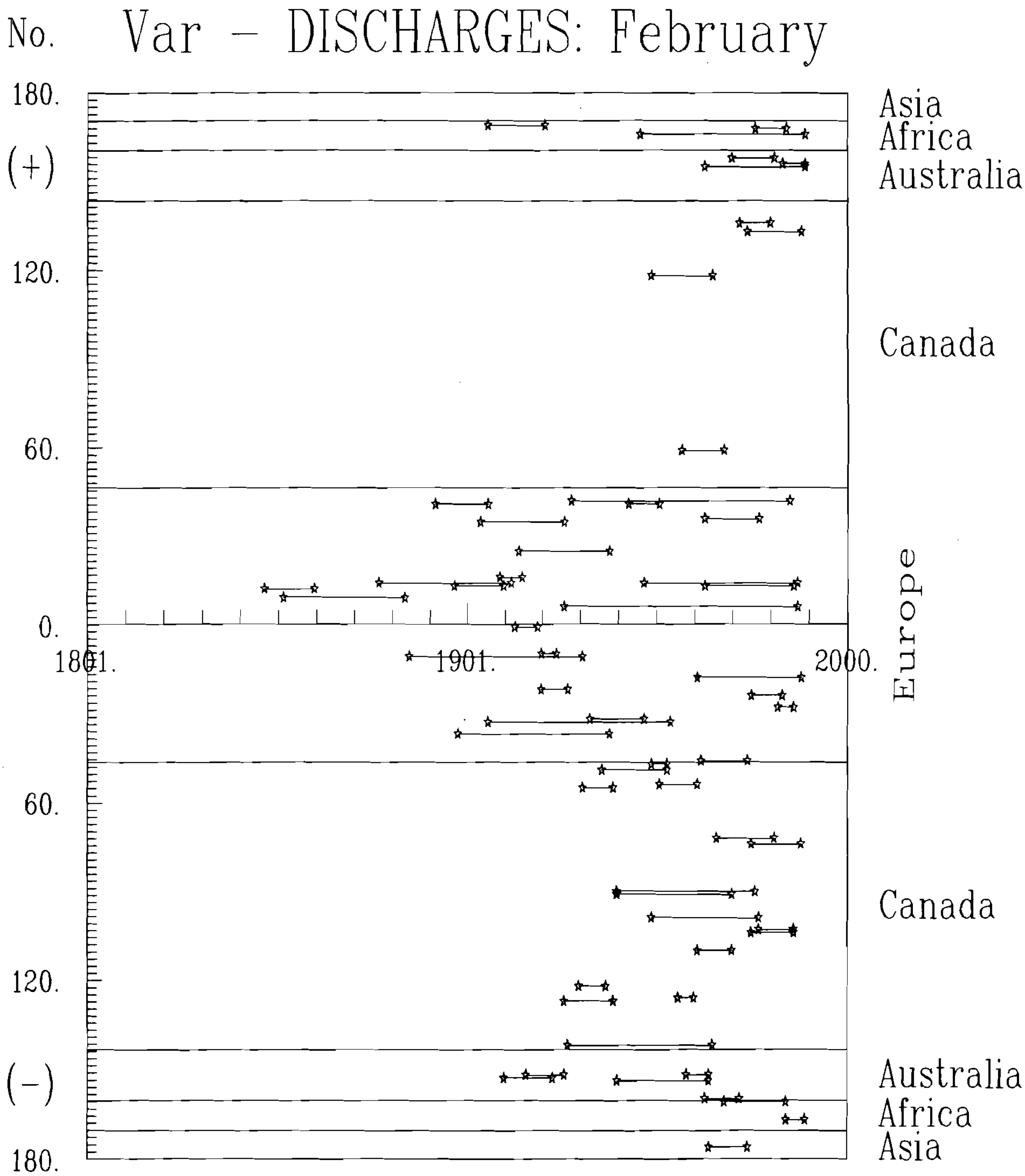

Fig. 2.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

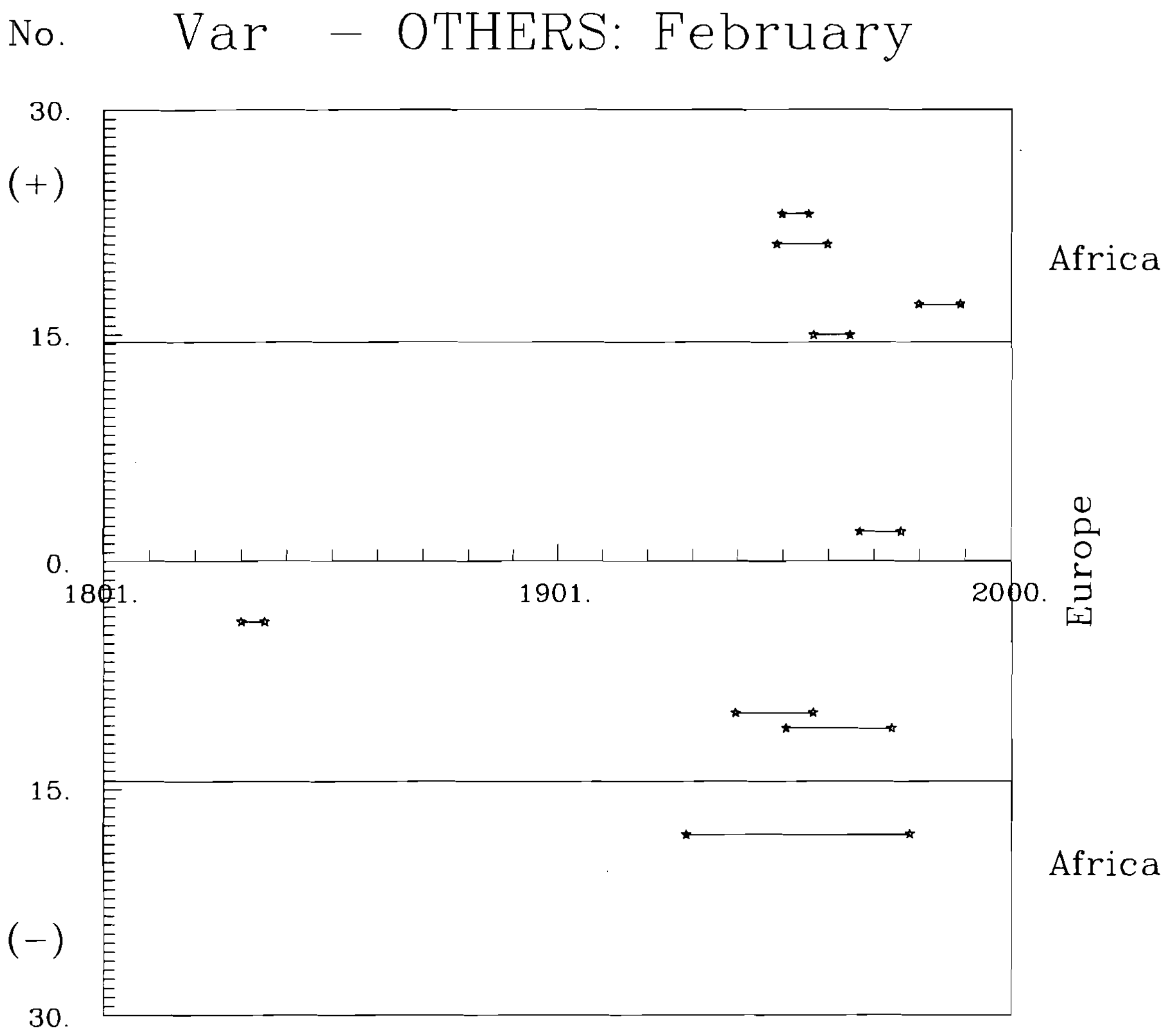

Fig. 2.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 3. RESULTS OF MARCH

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 80 % of cases for Africa, 42.9 % for Asia, 25 % for Australia, 23.9 % for Europe, 10.4 for Canada, and in 21 % for all discharges; (b) of *the others* had to be rejected in 7.1 %, and 4 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 3.4) that for about 80 % of analyzed sequences of the discharges and 85 % of *the others*, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Even better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 9.1 % and 4 % of cases of the discharges and of *the others*, respectively.

Tables 3.5 and 3.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 3.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 15.3 % and 6.9 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 4.9 % of cases there occur fluctuations in the mean value and in the variance. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean value prevail over decreasing ones. In 60 % of cases for Africa, in 42.9 % for Asia, 25 % for Australia as well as in ca. 15 % for Europe and Canada the increasing trends are observed. Totally, in 21 % and 12.5 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, increasing trends in the mean value are observed, except for one case of a decreasing trend in Europe.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 20.5 % and 9.1 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 20 % to 16 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Biya at Biysk (station No. 37) and the Nile at Dongola (No. 163) and to decrease for Belaya at Ufa (No. 42) and Weser at Vlotho (No. 9) covering, respectively, 96.7 %, 57.5 %, 47.2 %, and 34.4 % of the whole observation periods of 91, 73, 108, and 163 years. The trend in the variance of discharges was the growing one for Belaya at Ufa (No. 42) and decreasing for Salzach at Burghagen (No. 10) and for Inn at Wasserburg (No. 11); it lasted 65, 145, and 72 years, respectively. However for *the others*, the trend in the mean value grows for temperatures in Warsaw (No. 6) and in Cracow (No. 4) covering periods of 92 and 72 years, respectively. Decreasing trend in the variance was observed during 38 years in Warsaw's precipitations (No. 11).

As it appears from the summarized results of Mann's test (Table 1.9), a trend has emerged in 33.5 % and 29.5 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 40 % and 36 % of cases in the mean value and in the variance, respectively.

Table 3.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocor. coeffi-cient
Europe	11/23.9	9/22.0
Canada	10/10.4	3/16.7
Argentina	1/100	1/100
Australia	4/25.0	1/14.3
Africa	8/80.0	6/100
Asia	3/42.9	-
Total	37/21.0	20/27.4

Others:

Region	Run test	Test of autocor. coeffi-cient
Europe	1/ 7.1	1/ 9.1
Africa	0/0	1/11.1
Total	1/ 4.0	2/10.0

Table 3.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	9/19.6	4/ 8.7
Canada	14/14.6	3/ 3.1
Argentina	0/0	0/0
Australia	5/31.3	2/12.5
Africa	9/90.0	6/60.0
Asia	3/42.9	1/14.3
Total	40/22.7	16/ 9.1

Others:

Region	Mean	Variance
Europe	3/21.4	1/ 7.1
Africa	1/ 9.1	0/0
Total	4/16.0	1/ 4.0

Table 3.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	3/ 8.6	2/ 4.7
Canada				0/0	11/22.0
Argentina				0/0	0/0
Australia				1/14.3	2/25.0
Africa			1/100	5/83.3	7/100
Asia					0/0
Total	0/0	0/0	2/13.3	9/14.8	22/19.6

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	1/ 7.7
Africa					1/16.7	1/ 9.1
Total	0/0	0/0	0/0	0/0	1/ 5.9	2/ 8.3

Table 3.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	5/11.6
Canada				0/0	2/ 4.0
Argentina				0/0	0/0
Australia				1/14.3	0/0
Africa			0/0	2/33.3	4/57.1
Asia					0/0
Total	0/0	0/0	0.0	3/ 4.9	11/ 9.8

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	2/20.0	0/0	1/ 7.7
Africa					0/0	0/0
Total	0/0	0/0	0/0	2/20.0	0/0	1/ 4.2

Table 3.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	6/ 5.7	5/ 4.7
Canada	11/17.7	2/ 3.2
Argentina	0/0	0/0
Australia	3/20.0	1/ 6.7
Africa	13/92.9	6/42.9
Asia	0/0	0/0
Total	33/16.3	14/ 6.9

Others:

Region	Mean	Variance
Europa	1/ 2.3	3/ 6.8
Africa	2/11.8	0/0
Total	3/ 4.9	3/ 4.9

Table 3.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	7/15.2	7/15.2	13/28.3	8/17.4
Canada	7/ 7.3	17/17.7	15/15.6	1/ 1.0
Argentina	1/100	0/0	0/0	0/0
Australia	2/12.5	4/25.0	4/25.0	2/12.5
Africa	5/50.0	6/60.0	3/30.0	5/50.0
Asia	0/0	3/42.9	1/14.3	0/0
Total	22/12.5	37/21.0	36/20.5	16/ 9.1

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	1/ 9.1	7/63.6	5/45.5	0/0
Africa	0/0	2/14.3	0/0	4/28.6
Total	1/ 4.0	9/36.0	5/20.0	4/16.0

Table 3.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	12/26.1	20/43.5
Canada	24/25.0	16/16.7
Argentina	1/100	0/0
Australia	6/37.5	6/37.5
Africa	9/90.0	7/70.0
Asia	3/42.9	1/14.3
Total	59/33.5	52/29.5

Others:

Region	Mean	Variance
Europa	8/72.7	5/45.5
Africa	2/14.3	4/28.6
Total	10/40.0	9/36.0

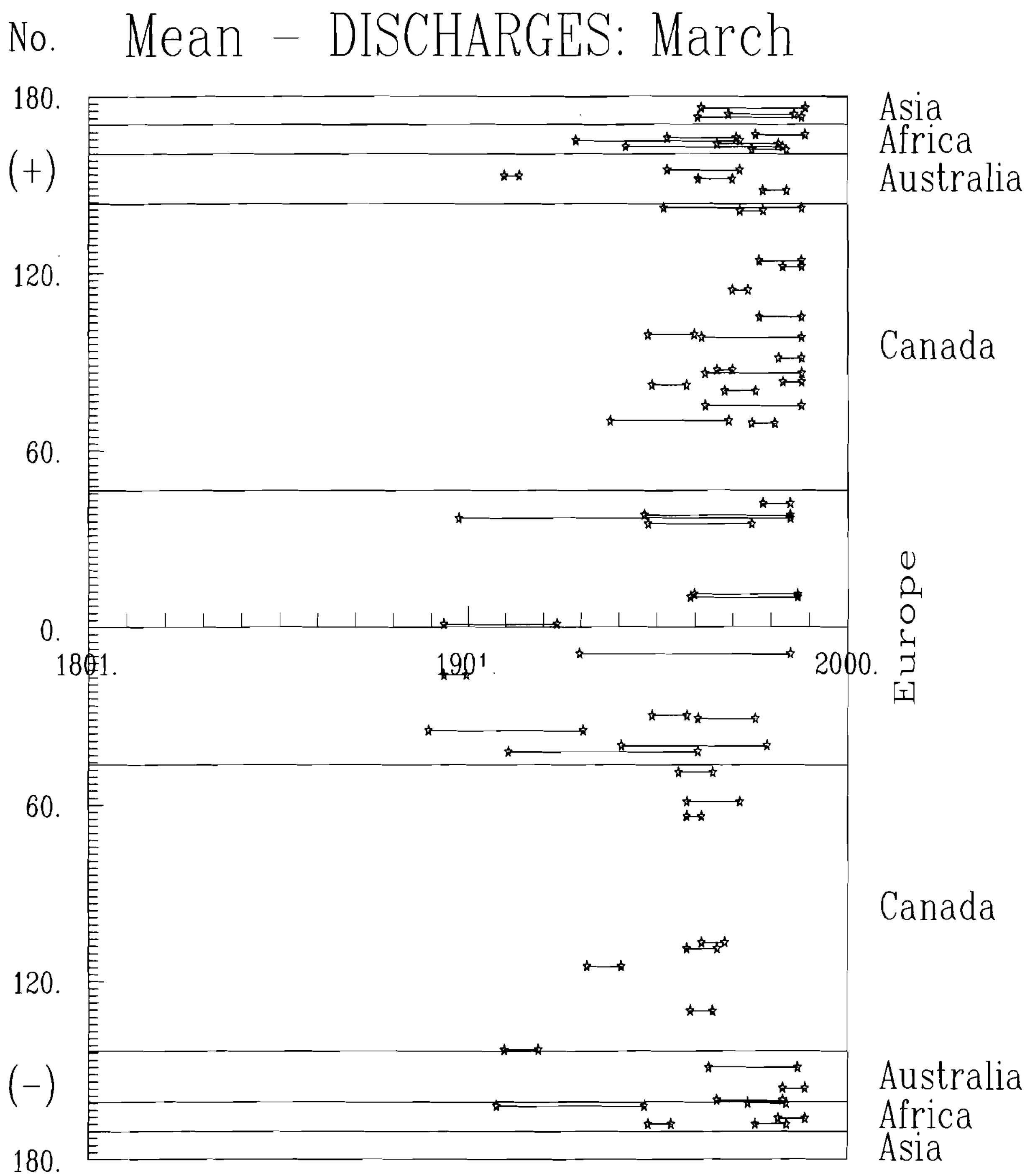

Fig. 3.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

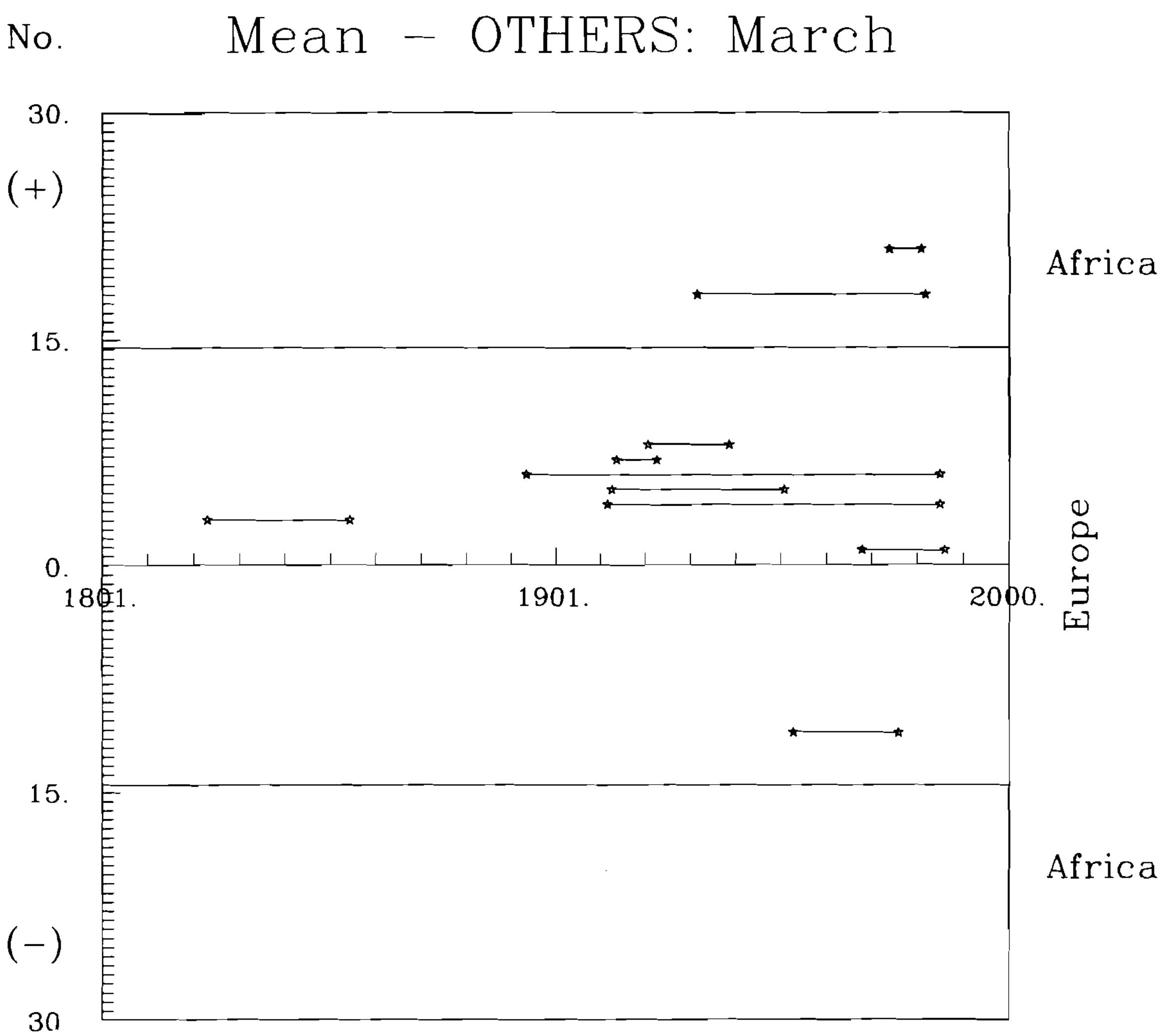

Fig. 3.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

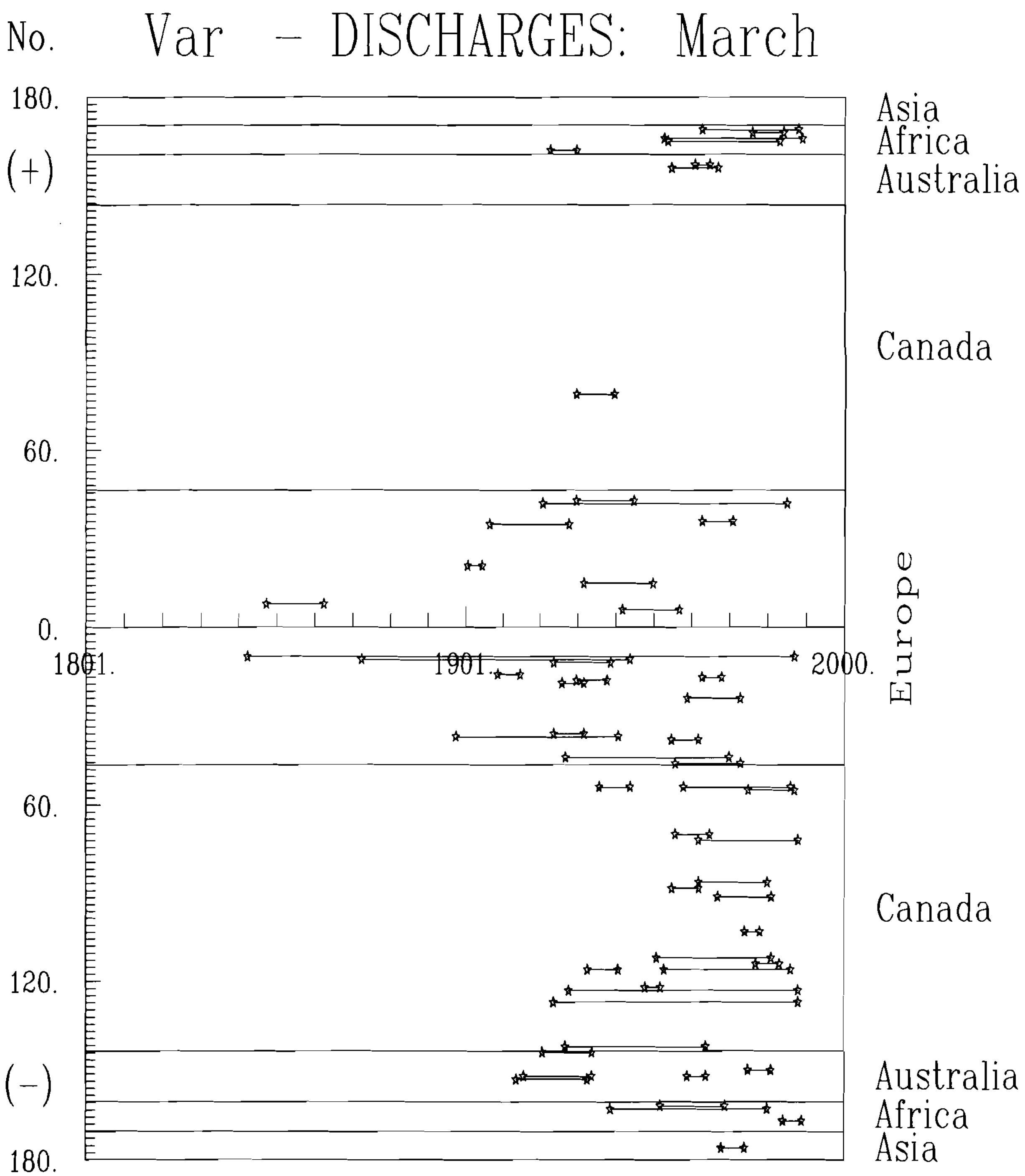

Fig. 3.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

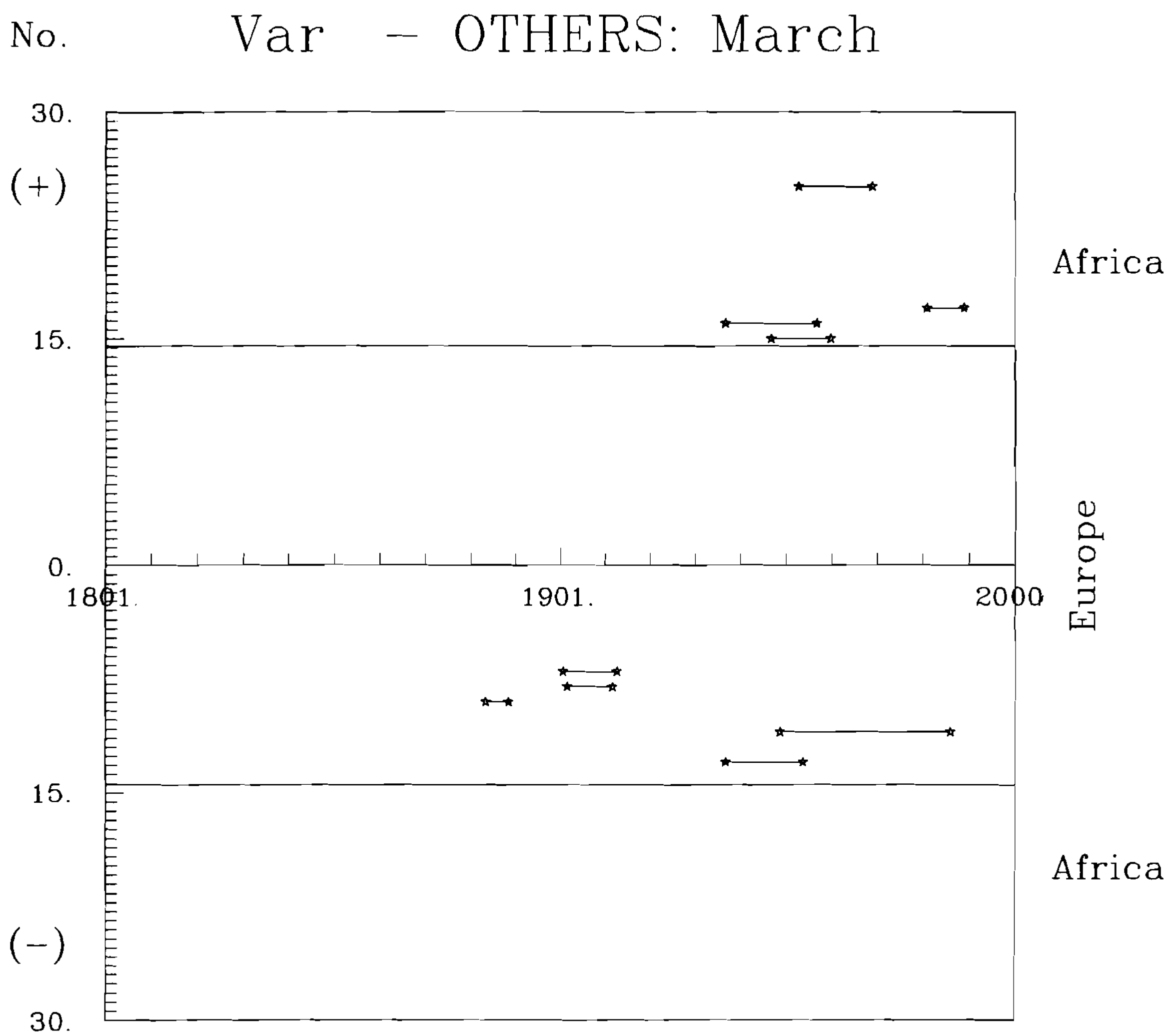

Fig. 3.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 4. RESULTS OF APRIL

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 80 % of cases for Africa, 57.1 % for Asia, 12.5 % for Australia, 6.5 % for Europe, 5.2 % for Canada, and in 12.5 % for all discharges; (b) of *the others* had to be rejected in 7.1 %, 0 %, and 4 % of cases for Europe, Africa, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 4.4) that for about 85 % of all analyzed sequences, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Even better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 6.3 % of analyzed cases of discharges only.

Tables 4.5 and 4.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 4.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 14.4 % and 7.4 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 1.6 % and 9.8 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean value prevail over decreasing ones. In 80 % of cases for Africa, in ca. 28 % for Europe and Asia as well as in ca. 10 % for Canada and Australia the increasing trends are observed. Totally, in 19.3 % and 11.9 % of cases occur growing and decreasing trends in the mean value, respectively. For *the others*, increasing trends in the mean value are observed, except for two cases of decreasing trends in Europe and one case in Africa.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 17.6 % and 10.2 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 16 % to 12 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Biya at Biysk (station No. 37) and Inn at Wasserburg (No. 11) and to decrease for Weser at Vlotho (No. 9) covering, respectively, 69.2 %, 50 %, and 68.1 % of the whole observation periods of 63, 81, and 111 years. The trend in the variance of discharges was the growing one for St. Mary (No. 120) and Vah at Liptovsky Mikulas (No. 3) as well as decreasing for the Nile at Dongola (No. 163), and it lasted 46, 35, and 46 years, respectively. However for *the others*, trend in the mean value grows for temperatures in Warsaw (No. 6) and the levels of Lake Vaenern at Sjoetorp (No. 3) covering periods of 70 and 39 years. Decreasing trend in the variance was observed during 31 years in Pulawy's temperatures (No. 8).

As it appears from the summarized results of Mann's test (Table 4.9), a trend has emerged in 31.3 % and 27.8 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 48 % and 28 % of cases in the mean value and in the variance, respectively.

Table 4.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocor. coeffi-cient
Europe	3/ 6.5	5/12.2
Canada	5/ 5.2	1/ 5.6
Argentina	0/0	1/100
Australia	2/12.5	1/14.3
Africa	8/80.0	6/100
Asia	4/57.1	-
Total	22/12.5	14/19.2

Others:

Region	Run test	Test of autocor. coeffi-cient
Europe	1/ 7.1	1/ 9.1
Africa	0/0	0/0
Total	1/ 4.0	1/ 5.0

Table 4.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	5/10.9	2/ 4.3
Canada	7/ 7.3	2/ 2.1
Argentina	0/0	0/0
Australia	4/25.0	0/0
Africa	9/90.0	5/50.0
Asia	4/57.1	2/28.6
Total	29/16.5	11/ 6.3

Others:

Region	Mean	Variance
Europe	2/14.3	0/0
Africa	1/ 9.1	0/0
Total	3/12.0	0/0

Table 4.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	3/50.0	0/0	1/ 7.1	2/ 5.7	8/18.6
Canada				0/0	3/ 6.0
Argentina				0/0	0/0
Australia				0/0	0/0
Africa			0/0	5/83.3	7/100
Asia					0/0
Total	3/50.0	0/0	1/ 6.7	7/11.5	18/16.1

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	1/ 7.7
Africa					0/0	0/0
Total	0/0	0/0	0/0	0/0	0/0	1/ 4.2

Table 4.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	1/12.5	0/0	2/ 5.7	0/0
Canada				1/ 8.3	4/ 8.0
Argentina				0/0	0/0
Australia				1/14.3	0/0
Africa			0/0	2/33.3	4/57.1
Asia					0/0
Total	0/0	1/12.5	0.0	6/ 9.8	8/ 7.1

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	4/30.8
Africa					0/0	2/18.2
Total	0/0	0/0	0/0	0/0	0/0	6/25.0

Table 4.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	14/13.2	3/ 2.8
Canada	3/ 4.8	5/ 8.1
Argentina	0/0	0/0
Australia	0/0	1/ 6.7
Africa	12/85.7	6/42.9
Asia	0/0	0/0
Total	29/14.4	15/ 7.4

Others:

Region	Mean	Variance
Europa	1/ 2.3	4/ 9.1
Africa	0/0	2/11.8
Total	1/ 1.6	6/ 9.8

Table 4.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	−	+	−	+
Europe	5/10.9	13/28.3	8/17.4	8/17.4
Canada	5/ 5.2	8/ 8.3	15/15.6	5/ 5.2
Argentina	0/0	0/0	0/0	0/0
Australia	4/25.0	2/12.5	4/25.0	2/12.5
Africa	5/50.0	8/80.0	2/20.0	3/30.0
Asia	2/28.6	7/28.6	2/28.6	0/0
Total	21/11.9	34/19.3	31/17.6	18/10.2

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	2/18.2	6/54.5	4/36.4	0/0
Africa	1/ 7.1	3/21.4	0/0	3/21.4
Total	3/12.0	9/36.0	4/16.0	3/12.0

Table 4.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	16/34.8	16/34.8
Canada	13/13.5	20/20.8
Argentina	0/0	0/0
Australia	6/37.5	6/37.5
Africa	9/90.0	5/50.0
Asia	5/71.4	2/28.6
Total	55/31.3	49/27.8

Others:

Region	Mean	Variance
Europa	8/72.7	4/36.4
Africa	4/28.6	3/21.4
Total	12/48.0	7/28.0

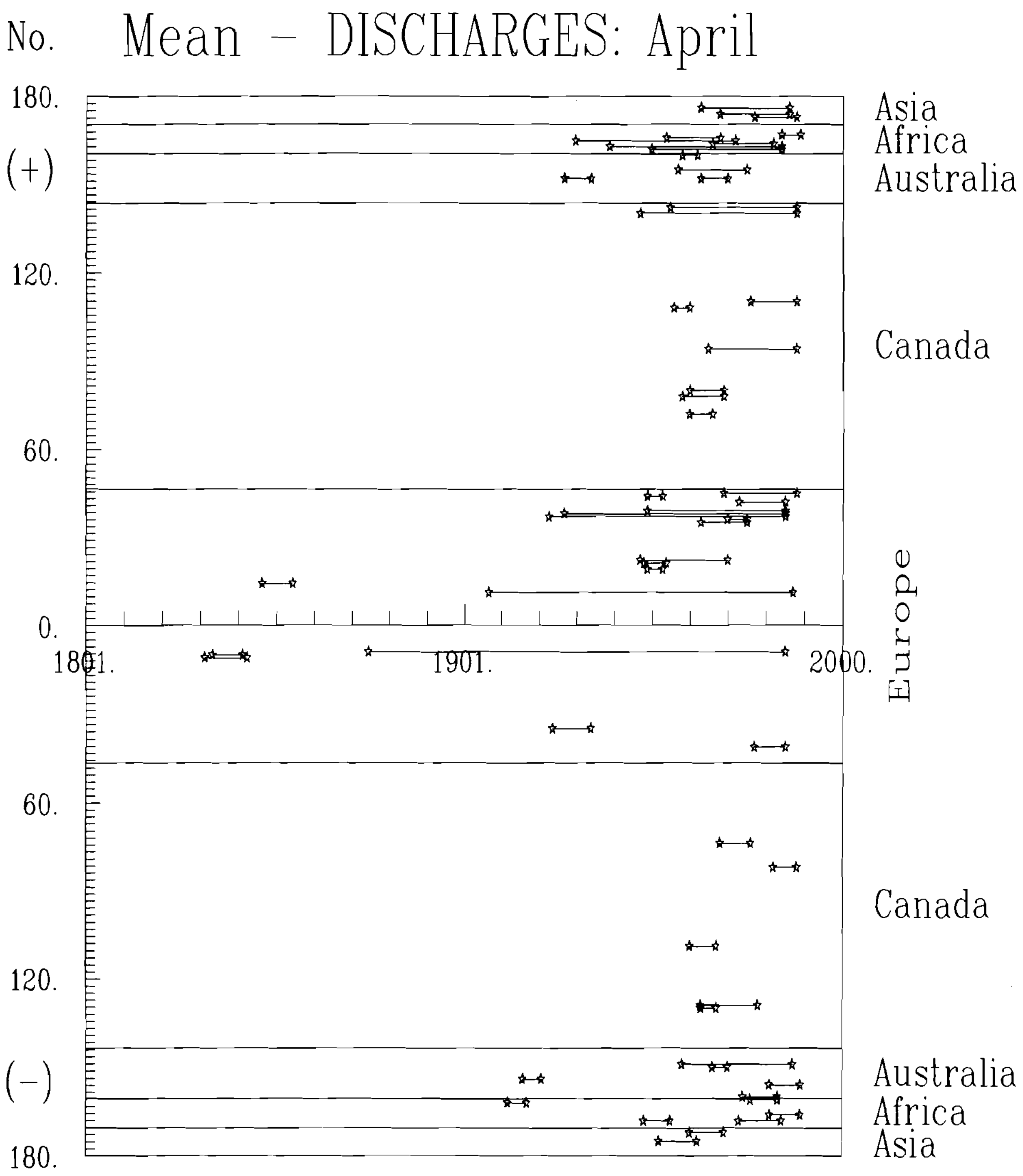

Fig. 4.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

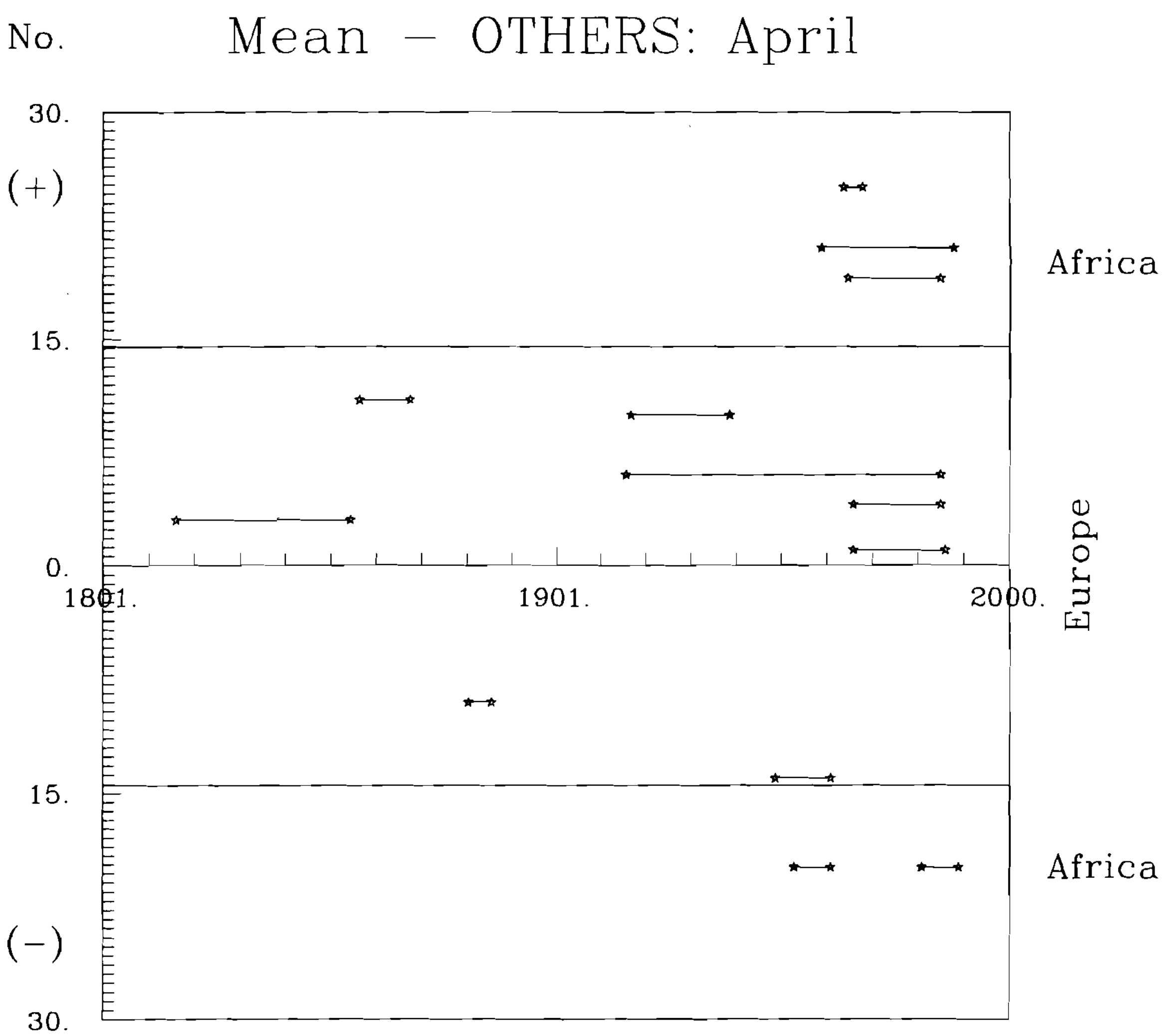

Fig. 4.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

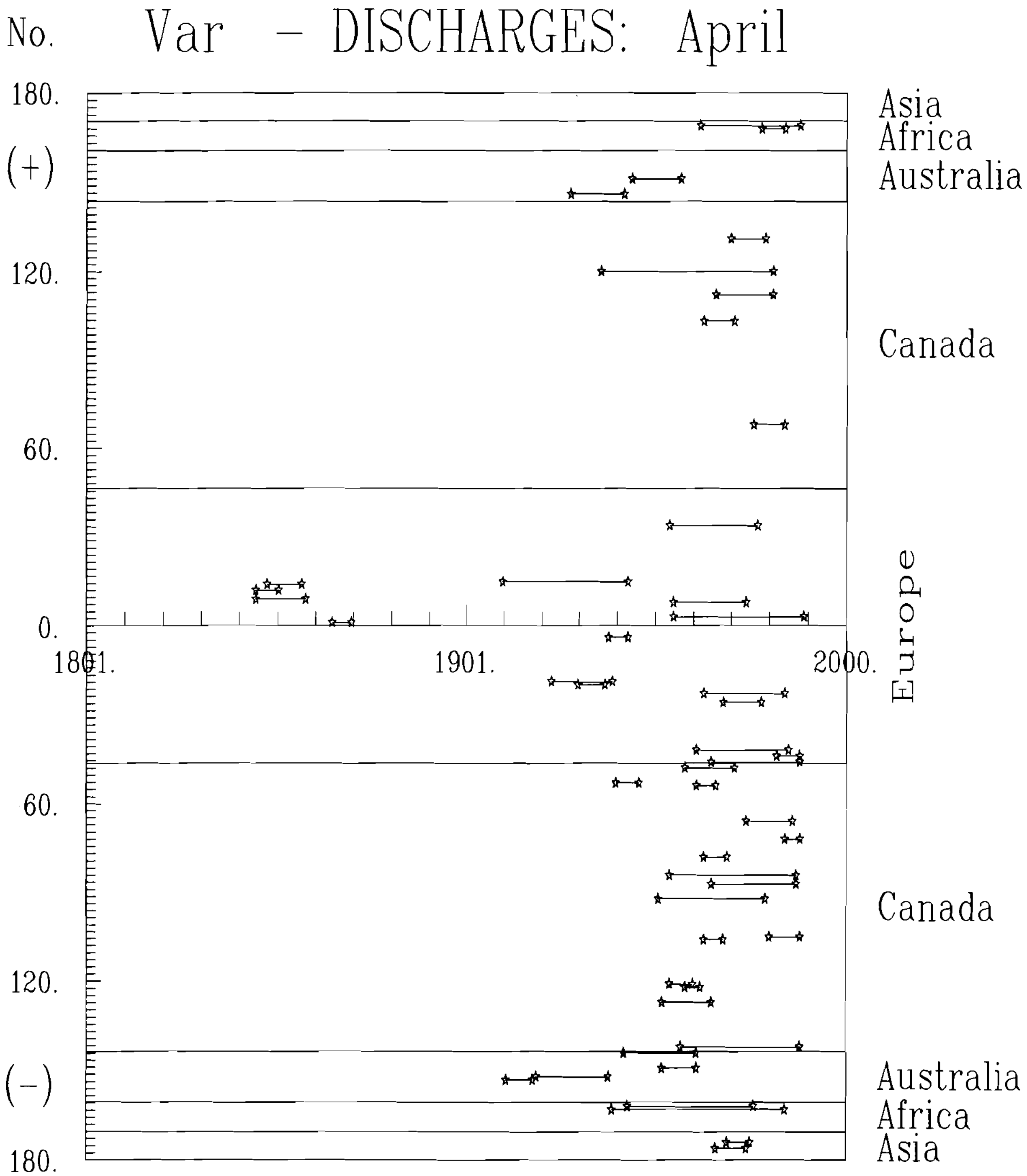

Fig. 4.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

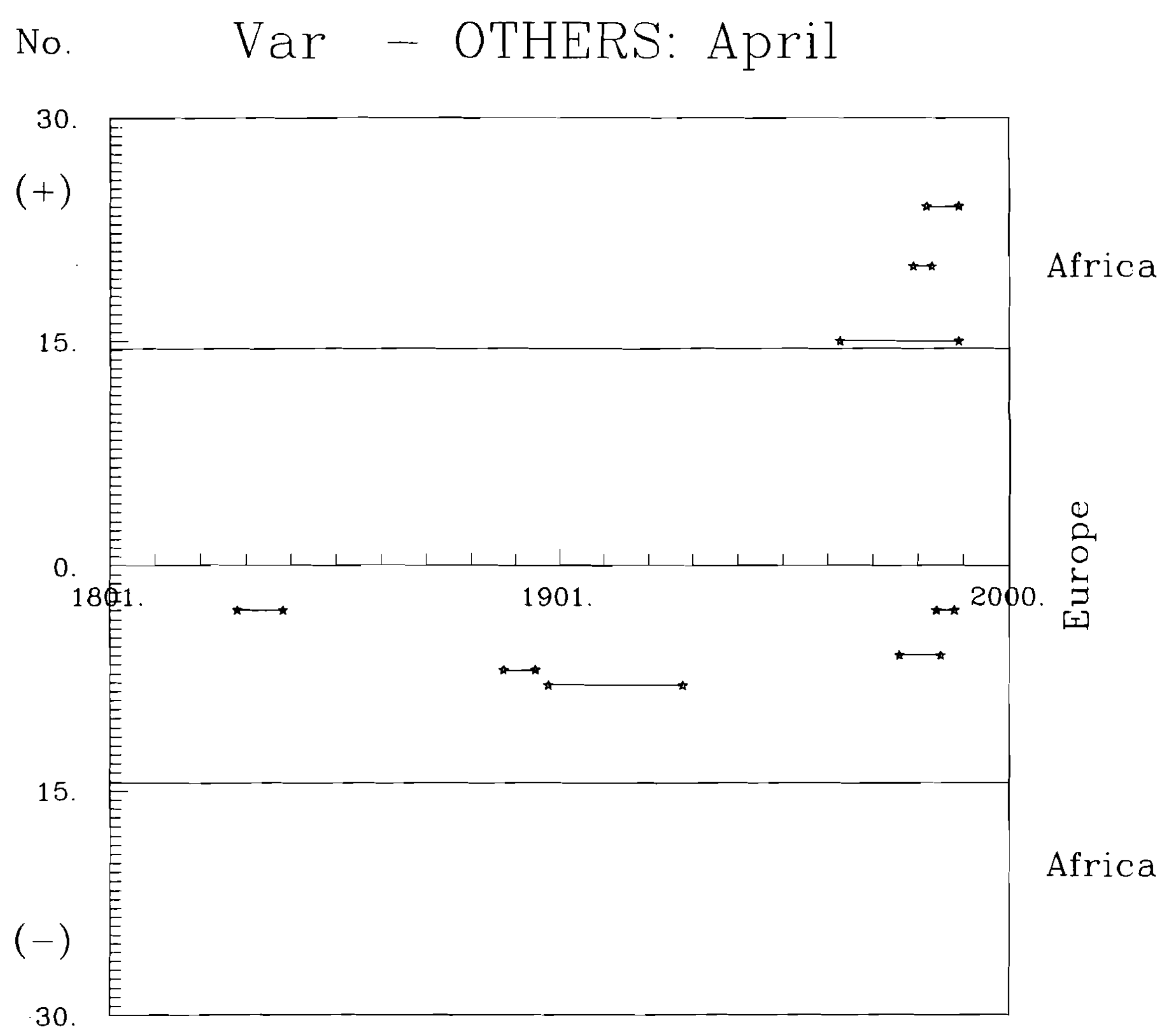

Fig. 4.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPPENDIX 5. RESULTS OF MAY

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 60 % of cases for Africa, in ca. 15 % for Australia, Europe, and Asia, in 9.4 % for Canada, and in 14.8 % for all discharges; (b) of *the others* had to be rejected in 21.4 %, and 12 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 5.4) that for about 85 % of analyzed sequences of the discharges and 90 % of *the others*, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 8.5 % and 4 % of cases of the discharges and of *the others*, respectively.

Tables 5.5 and 5.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from the Table 5.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 11.9 % and 6.9 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 6.6 % and 1.6 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, it was equilibrium between increasing and decreasing trends in mean values. Totally, in 12.5 % and 13.1 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others* no increasing trend in the mean value is observed.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 10.8 % and 11.4 % of

cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 20 % to 16 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Inn at Wasserburg (station No. 11) and the Nile at Aswan Dam (No. 162) and to decrease for Weser at Vlotho (No. 9) covering, respectively, 44.1 %, 49.1 %, and 76.7 % of the whole observation periods of 71, 56, and 125 years. The trend in the variance of discharges was the growing one for Parana at Corrientes (No. 143) and decreasing for the Nile at Aswan Dam (No. 162); it lasted 66 and 45 years, respectively. However, for *the others*, the trend in the mean value grows for temperatures in Pulawy (No. 8) and in Warsaw (No. 6) covering periods of 103 and 54 years, respectively. Decreasing trend in the variance was observed during 73 and 25 years, respectively, in Warsaw's precipitations (No. 11) and Pulawy's temperatures (No. 8).

As it appears from the summarized results of Mann's test (Table 5.9), a trend has emerged in 25.6 % and 22.2 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 32 % and 36 % of cases in the mean value and in the variance, respectively.

Table 5.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocor. coeffi-cient
Europe	7/15.2	4/ 9.8
Canada	9/ 9.4	0/0
Argentina	0/0	0/0
Australia	3/18.8	0/0
Africa	6/60.0	5/83.3
Asia	1/14.3	-
Total	26/14.8	9/12.3

Others:

Region	Run test	Test of autocor. coeffi-cient
Europe	3/21.4	1/ 9.1
Africa	0/0	0/0
Total	3/12.0	1/ 5.0

Table 5.4. The results of Kruskal-Wallis's test
(case (A))

Discharges:

Region	Mean	Variance
Europe	6/13.0	3/ 6.5
Canada	5/ 5.2	6/ 6.3
Argentina	0/0	0/0
Australia	3/18.8	1/ 6.3
Africa	8/80.0	5/50.0
Asia	2/28.6	0/0
Total	24/13.6	15/ 8.5

Others:

Region	Mean	Variance
Europe	2/14.3	0/0
Africa	0/0	1/ 9.1
Total	2/ 8.0	1/ 4.0

Table 5.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	1/12.5	1/ 7.1	3/ 8.6	7/16.3
Canada				0/0	0/0
Argentina				0/0	0/0
Australia				0/0	2/25.0
Africa			0/0	3/50.0	7/100
Asia					0/0
Total	0/0	1/12.5	1/ 6.7	6/ 9.8	16/14.3

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	4/30.8
Africa					0/0	0/0
Total	0/0	0/0	0/0	0/0	0/0	4/16.7

Table 5.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	1/12.5	0/0	3/ 8.6	1/ 2.3
Canada				3/25.0	2/ 4.0
Argentina				0/0	0/0
Australia				1/14.3	0/0
Africa			0/0	0/0	3/42.9
Asia					0/0
Total	0/0	1/12.5	0.0	7/11.5	6/ 5.4

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	0/0	0/0	0/0	0/0
Africa					0/0	0/0
Total	0/0	1/33.3	0/0	0/0	0/0	0/0

Table 5.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	12/11.3	5/ 4.7
Canada	0/0	5/ 8.1
Argentina	0/0	0/0
Australia	2/13.3	1/ 6.7
Africa	10/71.4	3/21.4
Asia	0/0	0/0
Total	24/11.9	14/ 6.9

Others:

Region	Mean	Variance
Europa	4/ 9.1	1/ 2.3
Africa	0/0	0/0
Total	4/ 6.6	1/ 1.6

Table 5.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	7/15.2	6/13.0	4/ 8.7	6/13.0
Canada	8/ 8.3	5/ 5.2	11/11.5	8/ 8.3
Argentina	0/0	0/0	0/0	1/100
Australia	5/31.3	2/12.5	2/12.5	1/ 6.3
Africa	2/20.0	6/60.0	2/20.0	3/30.0
Asia	1/14.3	3/42.9	0/0	1/14.3
Total	23/13.1	22/12.5	19/10.8	20/11.4

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	0/0	8/72.7	5/45.5	1/ 9.1
Africa	0/0	0/0	0/0	3/21.4
Total	0/0	8/32.0	5/20.0	4/16.0

Table 5.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	13/28.3	10/21.7
Canada	13/13.5	19/19.8
Argentina	0/0	1/100
Australia	7/43.8	3/18.8
Africa	7/70.0	5/50.0
Asia	4/57.1	1/14.3
Total	45/25.6	39/22.2

Others:

Region	Mean	Variance
Europa	8/72.7	6/54.5
Africa	0/0	3/21.4
Total	8/32.0	9/36.0

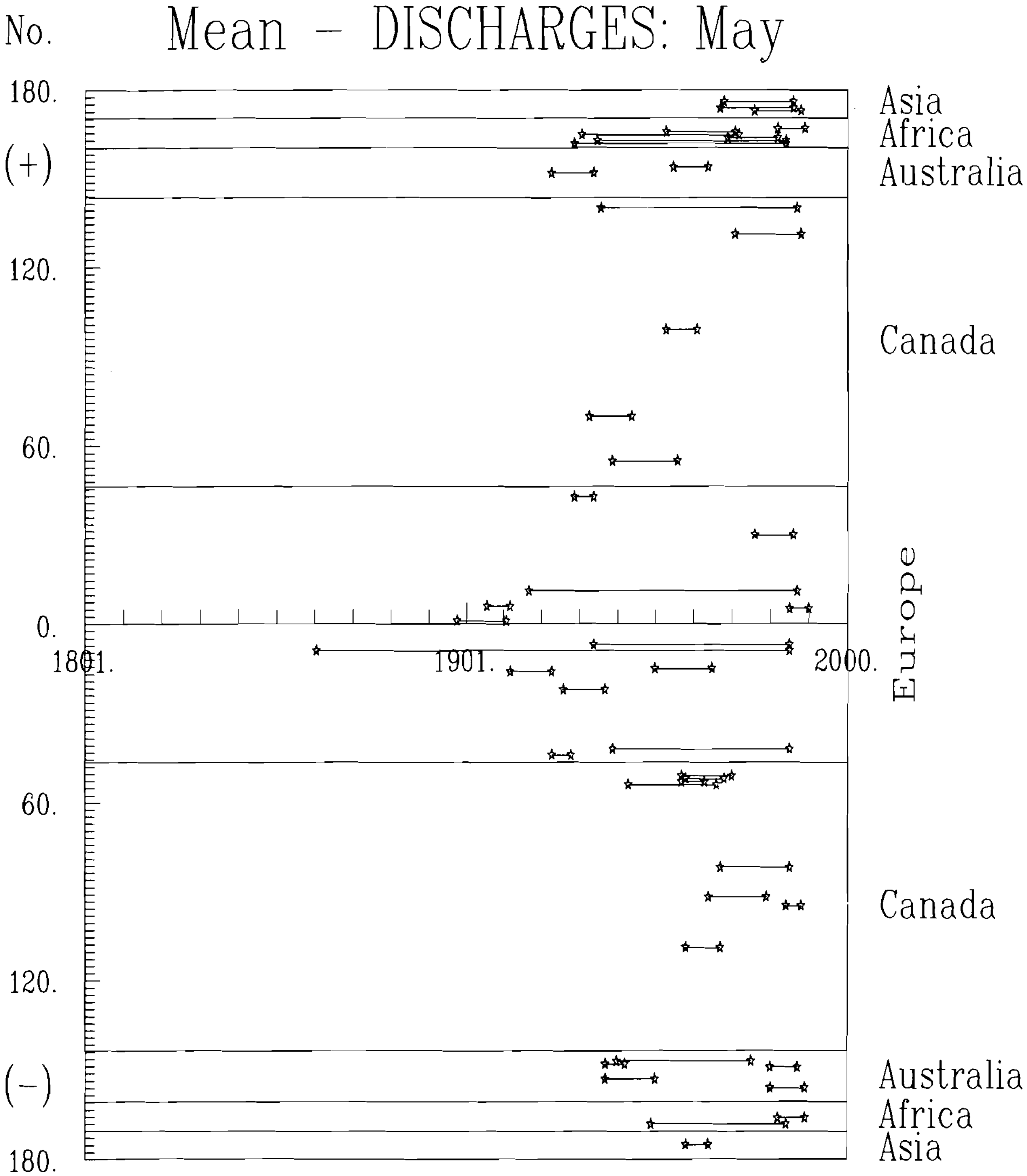

Fig. 5.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

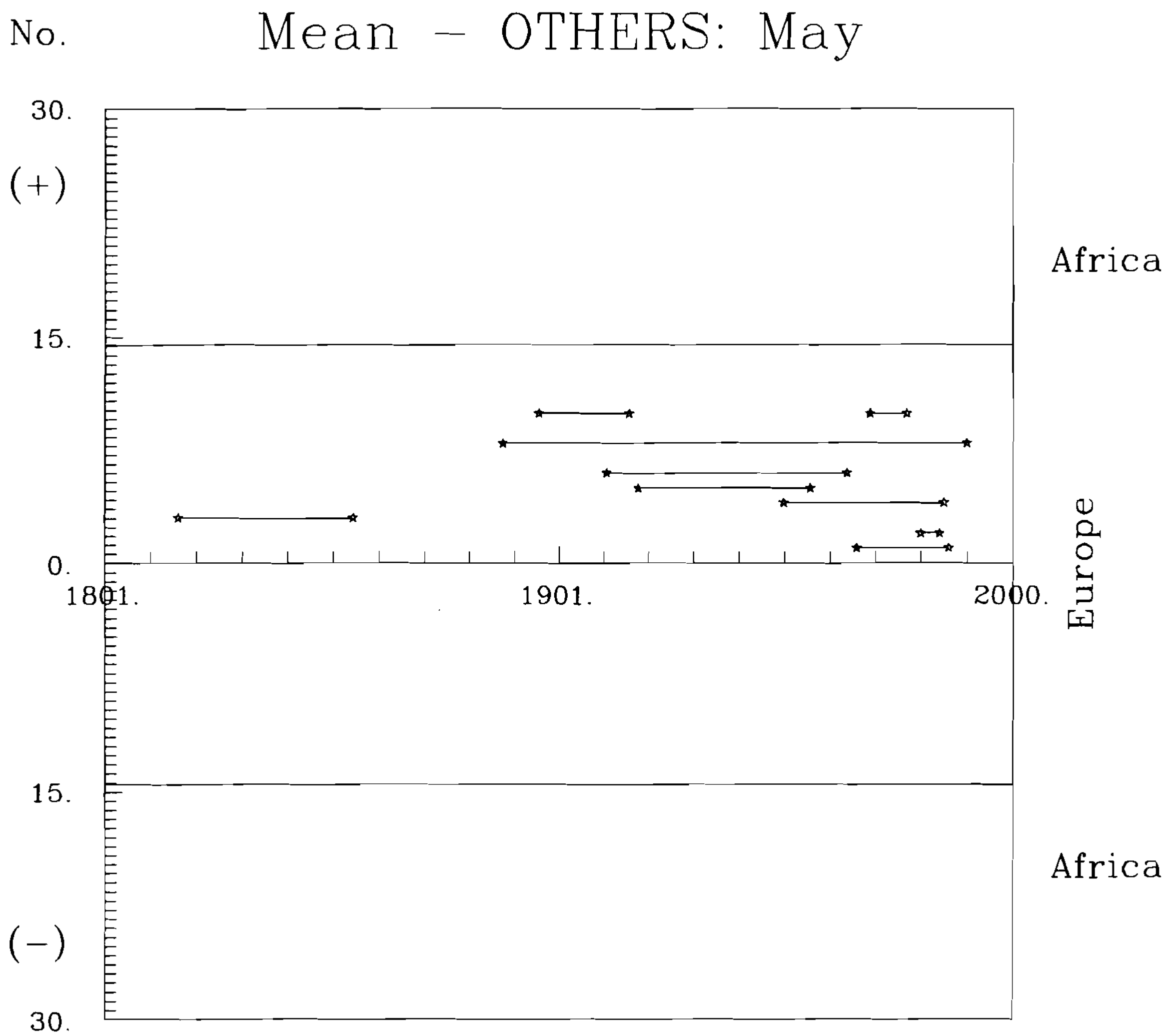

Fig. 5.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

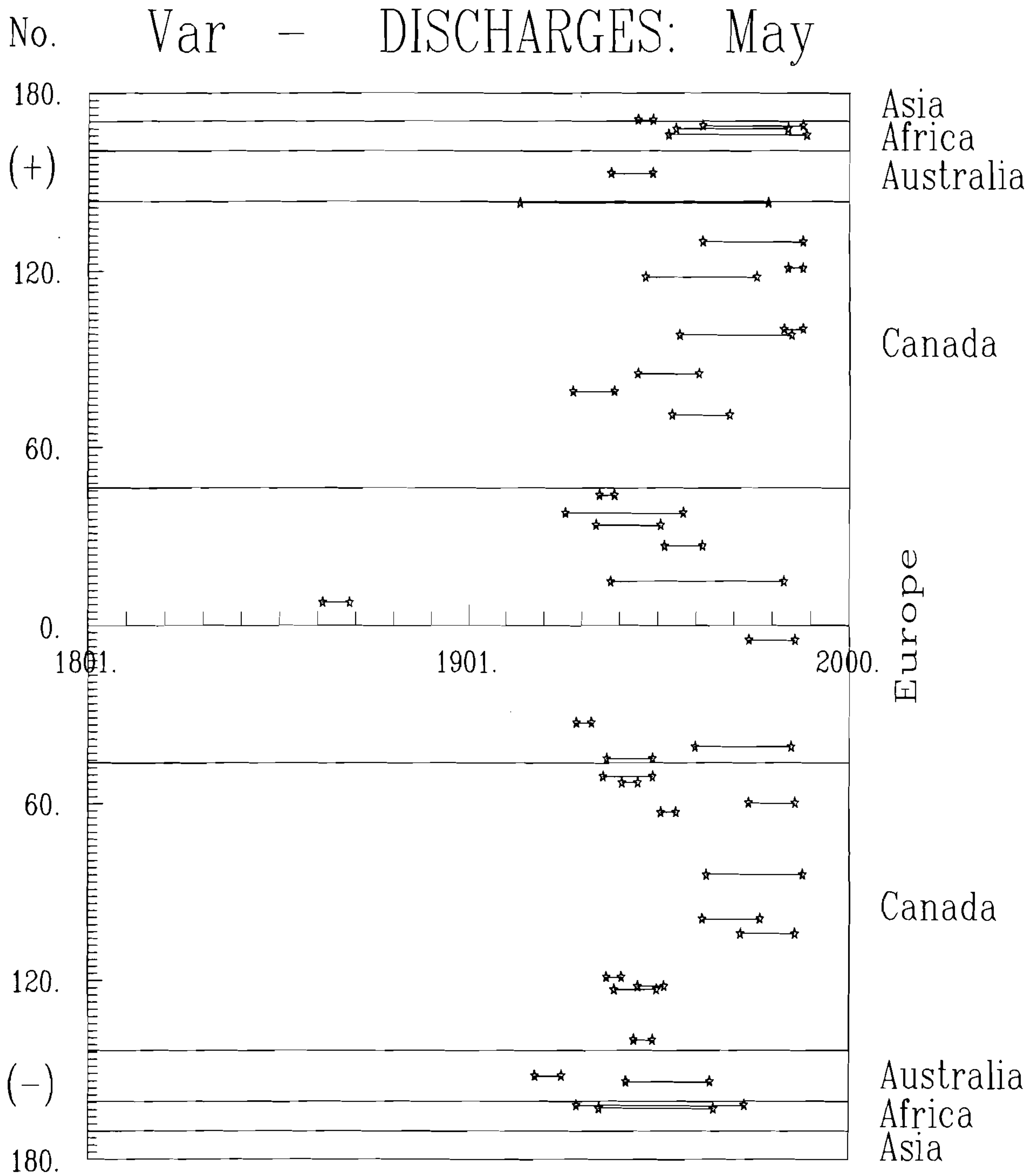

Fig. 5.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

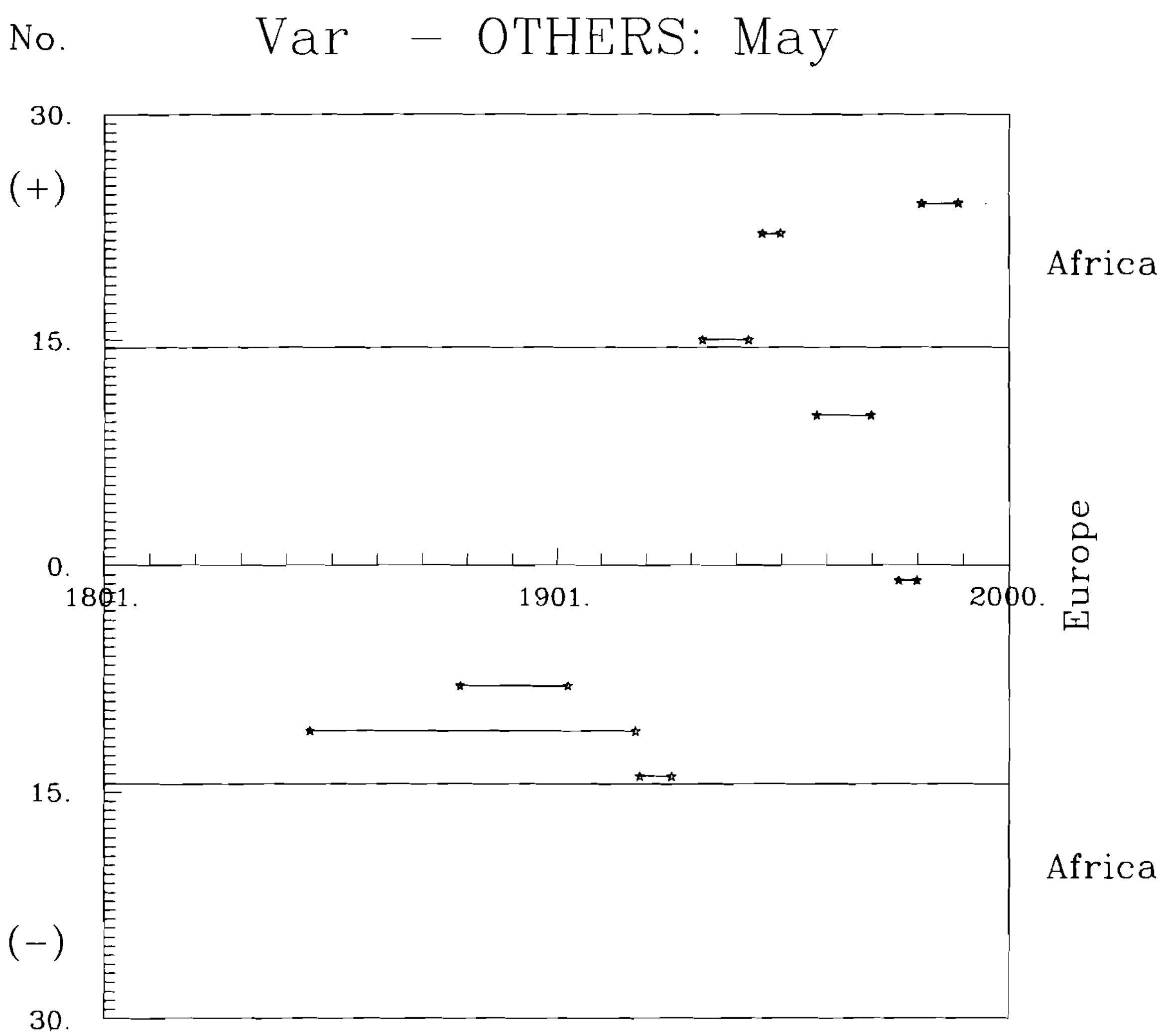

Fig. 5.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 6. RESULTS OF JUNE

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 50 % of cases for Africa, in ca. 15 % for Europe and Asia, in 10.4 % for Canada, in 6.3 % for Australia and in 13.6 % for all discharges; (b) of *the others* had to be rejected in 14.3 %, and 8 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 6.4) that for about 85 % of all analyzed sequences, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 9.1 % and 8 % of cases of the discharges and of *the others*, respectively.

Tables 6.5 and 6.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 6.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 11.4 % and 9.4 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 11.5 % and 1.6 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean values slightly prevail over decreasing ones. Totally, in 19.9 % and 11.4 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, in 36 % of cases, increasing trends in mean value are observed, except for three cases of decreasing trends in Europe.

Decreasing and increasing trends in variance have totally

emerged for the discharges, respectively, in 14.8 % and 6.8 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 20 % to 12 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for the Nile at Aswan Dam (No. 162) and to decrease for Salzach at Burghausen (No. 10) and Weser at Vlotho (No. 9) covering, respectively, 49.1 %, 63.4 %, and 60.1 % of the whole observation periods of 56, 102, and 98 years. The trend in the variance of discharges was the growing one for Parana at Corrientes (No. 143) and decreasing for Main at Wuerzburg (No. 12); it lasted 38 and 46 years, respectively. However, for *the others*, the trend in the mean value grows for temperatures in Warsaw (No. 6) and levels of Lake Vaenern at Sjoetorp (No. 3) during periods of 64 and 38 years, respectively. Increasing trend in the variance was observed during 58 years in Wa's precipitations (No. 16).

As it appears from the summarized results of Mann's test (Table 6.9), a trend has emerged in 31.3 % and 21.6 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 48 % and 32 % of cases in the mean value and in the variance, respectively.

Table 6.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocor. coeffi- cient
Europe	7/15.2	1/ 2.4
Canada	10/10.4	0/0
Argentina	0/0	0/0
Australia	1/ 6.3	1/14.3
Africa	5/50.0	6/100
Asia	1/14.3	-
Total	24/13.6	8/11.0

Others:

Region	Run test	Test of autocor. coeffi- cient
Europe	2/14.3	1/ 9.1
Africa	0/0	0/0
Total	2/ 8.0	1/ 5.0

Table 6.4. The results of Kruskal-Wallis's test
(case (A))

Discharges:

Region	Mean	Variance
Europe	5/10.9	6/13.0
Canada	8/ 8.3	5/ 5.2
Argentina	0/0	0/0
Australia	4/25.0	4/25.0
Africa	5/50.0	1/10.0
Asia	0/0	0/0
Total	22/12.5	16/ 9.1

Others:

Region	Mean	Variance
Europe	3/21.4	1/ 7.1
Africa	1/ 9.1	1/ 9.1
Total	4/16.0	2/ 8.0

Table 6.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	1/12.5	2/14.3	2/ 5.7	8/18.6
Canada				1/ 8.3	1/ 2.0
Argentina				0/0	0/0
Australia				0/0	0/0
Africa			0/0	1/16.7	6/85.7
Asia					1/33.3
Total	0/0	1/12.5	2/13.3	4/ 6.6	16/14.3

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	1/10.0	2/18.2	1/ 7.7
Africa					0/0	3/27.3
Total	0/0	0/0	0/0	1/10.0	2/11.8	4/16.7

Table 6.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	2/ 5.7	4/ 9.3
Canada				0/0	5/10.0
Argentina				0/0	0/0
Australia				1/14.3	1/12.5
Africa			0/0	1/16.7	4/57.1
Asia					0/0
Total	0/0	0/0	1/ 6.7	4/ 6.6	14/12.5

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	0/0	0/0	0/0	0/0
Africa					0/0	0/0
Total	0/0	1/33.3	0/0	0/0	0/0	0/0

Table 6.7. The cumulated results of Kruskal-Wallis's test for mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	13/12.3	7/ 6.6
Canada	2/ 3.2	5/ 8.1
Argentina	0/0	0/0
Australia	0/0	2/13.3
Africa	7/50.0	5/35.7
Asia	1/33.3	0/0
Total	23/11.4	19/ 9.4

Others:

Region	Mean	Variance
Europa	4/ 9.1	1/ 2.3
Africa	3/17.6	0/0
Total	7/11.5	1/ 1.6

Table 6.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	–	+	–	+
Europe	8/17.4	9/19.6	8/17.4	6/13.0
Canada	6/ 6.3	18/18.8	14/14.6	3/ 3.1
Argentina	0/0	0/0	0/0	1/100
Australia	4/25.0	3/18.8	3/18.8	1/ 6.3
Africa	2/20.0	4/40.0	1/10.0	1/10.0
Asia	0/0	1/14.3	0/0	0/0
Total	20/11.4	35/19.9	26/14.8	12/ 6.8

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	3/27.3	4/36.4	5/45.5	1/ 9.1
Africa	0/0	5/35.7	0/0	2/14.3
Total	3/12.0	9/36.0	5/20.0	3/12.0

Table 6.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	16/34.8	14/30.4
Canada	23/24.0	17/17.7
Argentina	0/0	1/100
Australia	7/43.8	4/25.0
Africa	5/50.0	1/10.0
Asia	1/14.3	0/0
Total	55/31.3	38/21.6

Others:

Region	Mean	Variance
Europa	6/54.5	6/54.5
Africa	5/35.7	2/14.3
Total	12/48.0	8/32.0

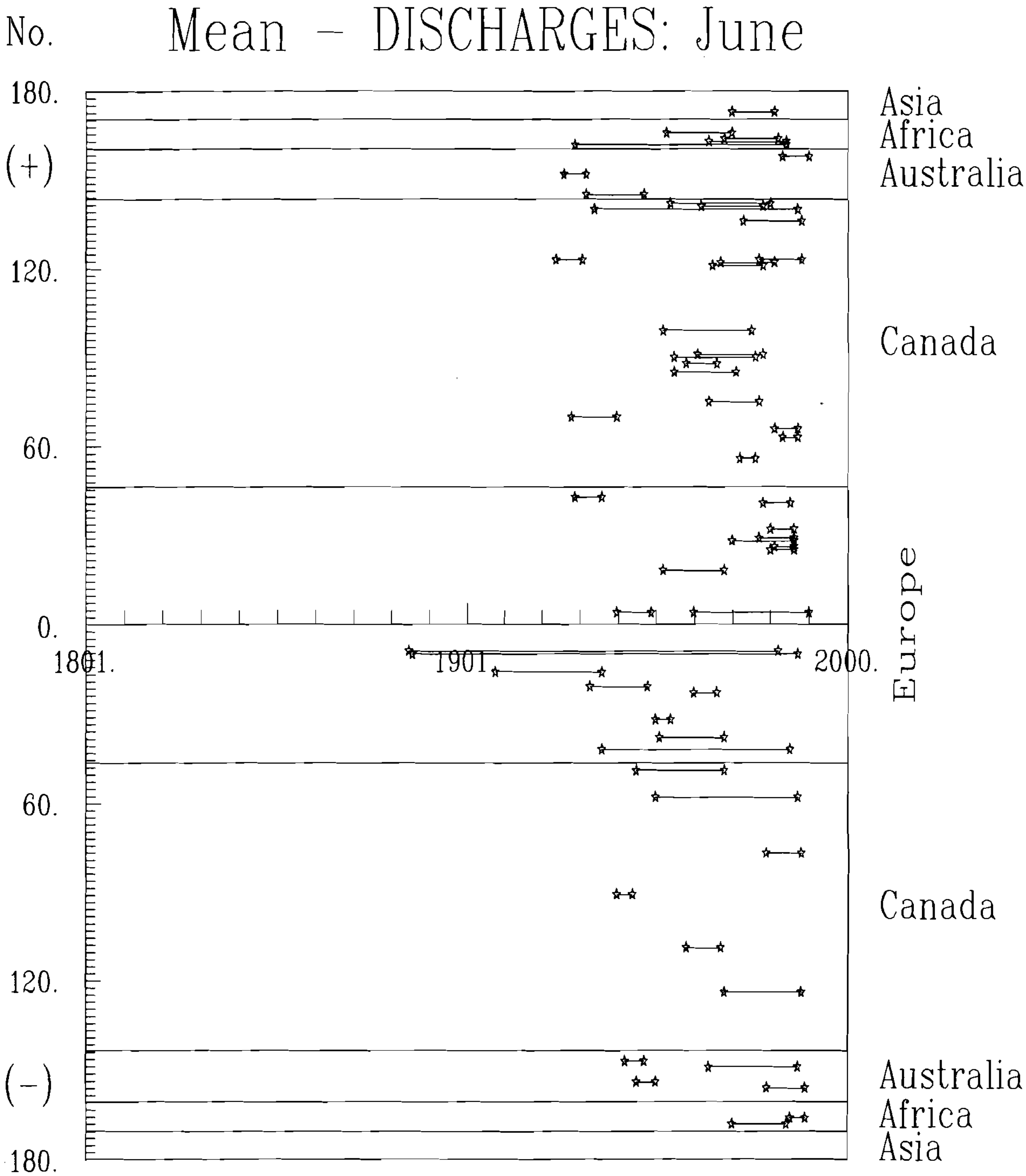

Fig. 6.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

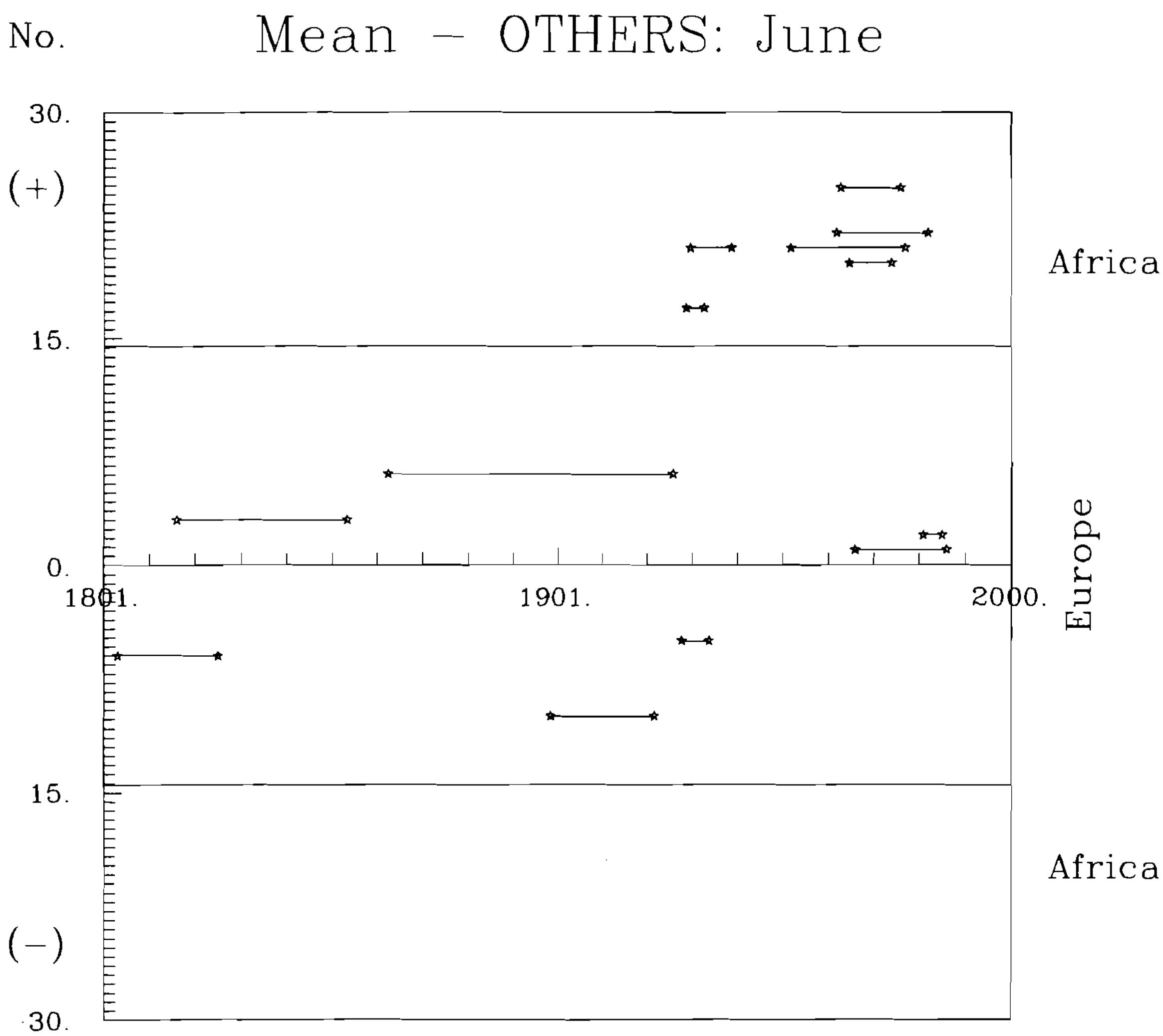

Fig. 6.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

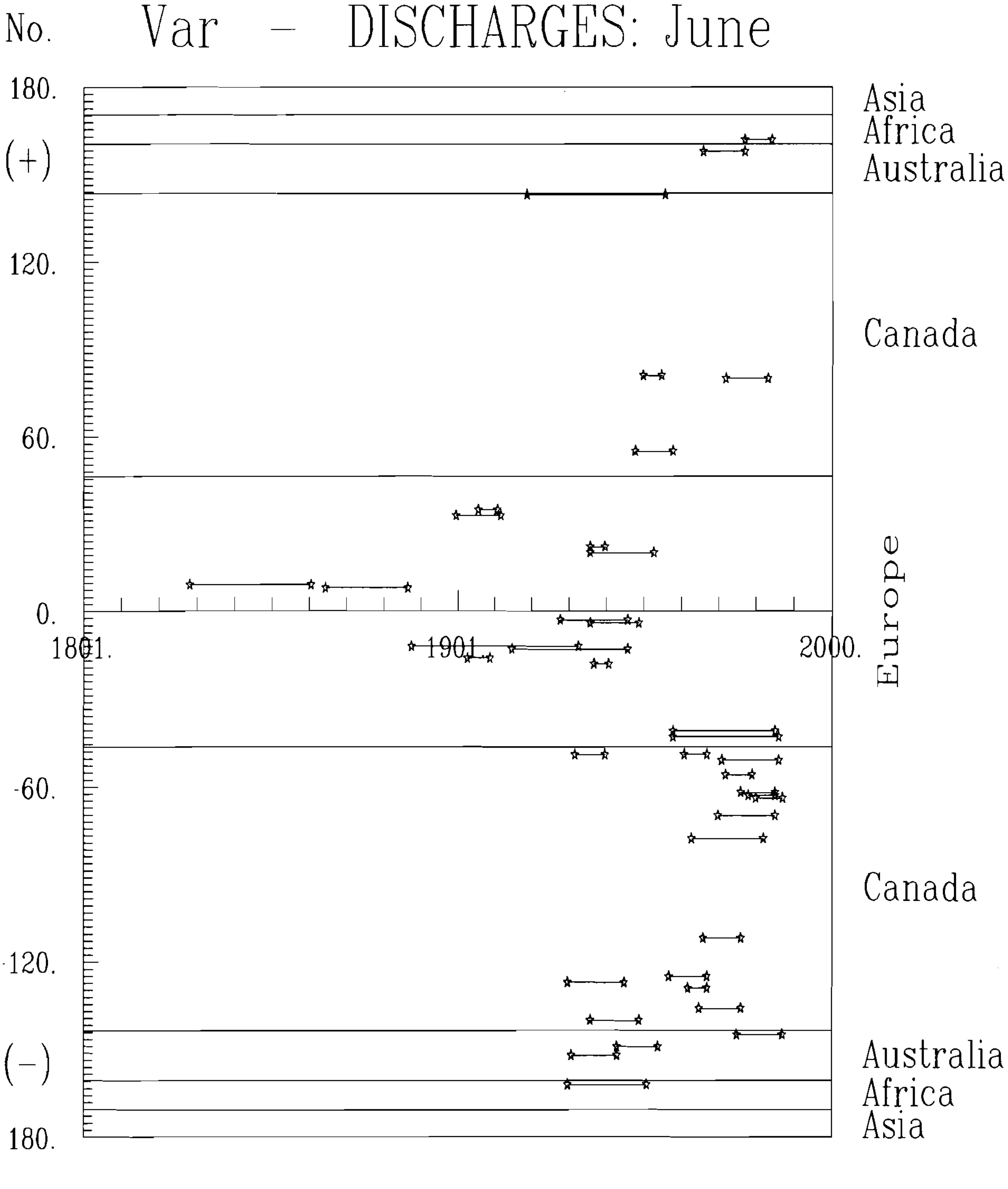

Fig. 6.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

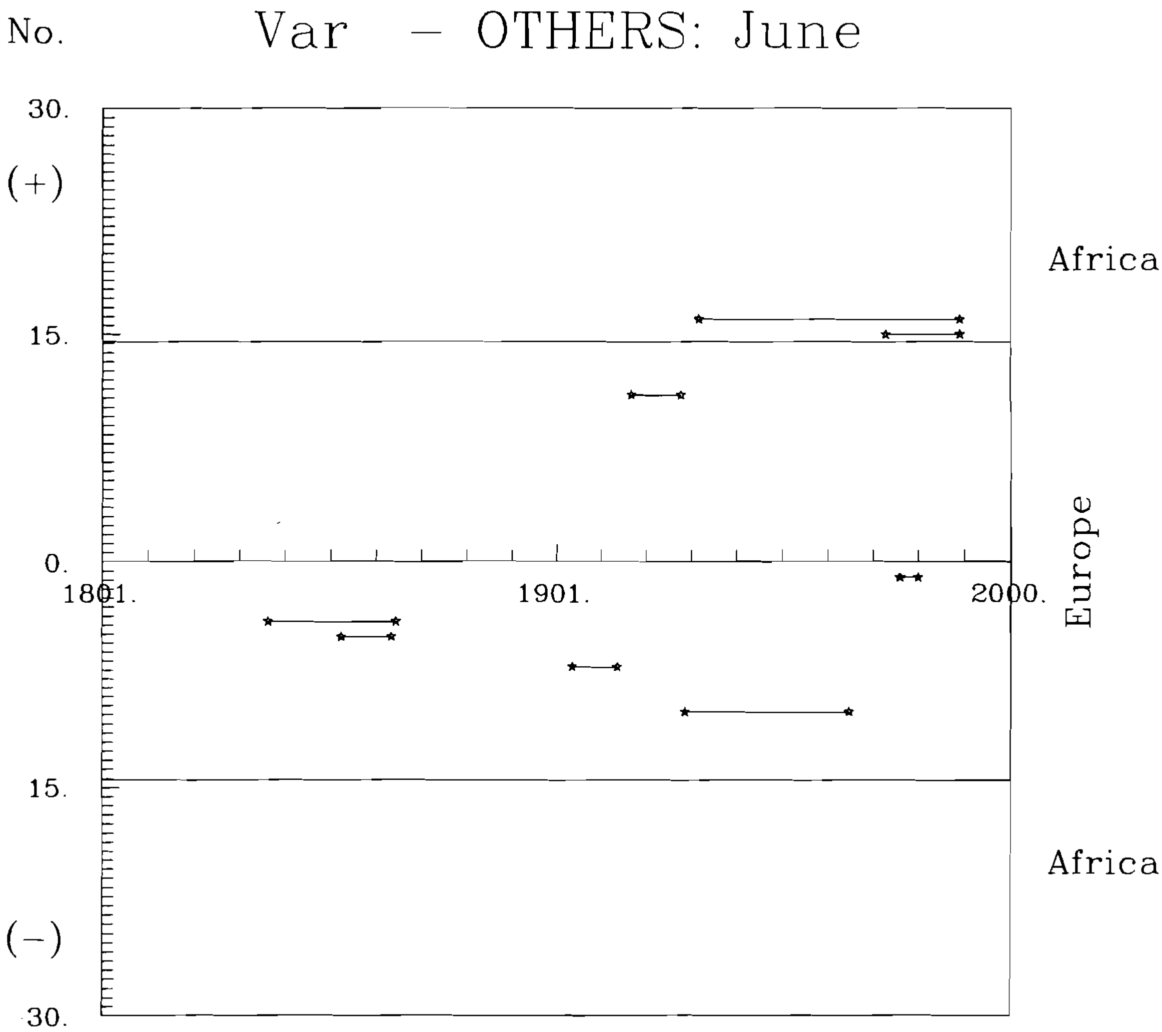

Fig. 6.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 7. RESULTS OF JULY

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 30 % of cases for Africa, in 19.6 % for Europe, in ca. 10 % for Australia and Canada, in 0 % for Asia and in 14.2 % for all discharges; (b) of *the others* had to be rejected in 35.7 %, and 20 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 7.4) that for about 85 % of all analyzed sequences, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 5.1 % and 8 % of cases of the discharges and of *the others*, respectively.

Tables 7.5 and 7.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 7.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 9.9 % and 3.5 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 3.3 % and 6.6 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, there are equilibrium of increasing and decreasing trends in the mean values. They occur in 14.2 % of cases. For *the others*, increasing and decreasing trends in the mean values are observed, respectively, in 20 % and 16 % of cases.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 13.1 % and 11.4 % of

cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 16 % to 20 % of cases.

For instance, trend in the mean value of the discharges appeared to decrease for Salzach at Burghausen (No. 10), the Nile at Aswan Dam (No. 162) and Styx River at Jeogla (No. 147) covering, respectively, 73.3 %, 68.4 %, and 68.7 % of the whole observation periods of 118, 78, and 46 years. The trend in the variance of discharges was the growing one for Parana at Corrientes (No. 143) and Weser at Vlotho (No. 9); it lasted 48 and 44 years, respectively. However, for *the others*, the trend in the mean value grows for temperatures in Warsaw (No. 6) and levels of Lake Vaenern at Sjoetorp (No. 3) during periods of 69 and 37 years, respectively. Increasing and decreasing trends in the variance were observed during 28 and 27 years, respectively, in Wa's (No. 16) and Wroclaw's precipitations (No. 12).

As it appears from the summarized results of Mann's test (Table 7.9), a trend has emerged in 28.4 % and 24.4 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in the same 36 % of cases in the mean value and in the variance.

Table 7.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi- cient
Europe	9/19.6	3/ 7.3
Canada	11/11.5	0/0
Argentina	0/0	0/0
Australia	2/12.5	1/14.3
Africa	3/30.0	4/66.7
Asia	0/0	-
Total	25/14.2	8/11.0

Others:

Region	Run test	Test of autocorr. coeffi- cient
Europe	5/35.7	1/ 9.1
Africa	0/0	0/0
Total	5/20.0	1/ 5.0

Table 7.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	6/13.0	1/ 2.2
Canada	4/ 4.2	4/ 4.2
Argentina	0/0	0/0
Australia	2/12.5	1/ 6.3
Africa	6/60.0	1/10.0
Asia	0/0	2/28.6
Total	18/10.2	9/ 5.1

Others:

Region	Mean	Variance
Europe	4/28.6	2/14.3
Africa	0/0	0/0
Total	4/16.0	2/ 8.0

Table 7.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	4/50.0	0/0	5/14.3	1/ 2.3
Canada				1/ 8.3	0/0
Argentina				0/0	0/0
Australia				0/0	0/0
Africa			1/100	2/33.3	6/85.7
Asia					0/0
Total	0/0	4/50.0	1/ 6.7	8/13.1	7/ 6.3

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	1/ 7.7
Africa					0/0	1/ 9.1
Total	0/0	0/0	0/0	0/0	0/0	2/ 8.3

Table 7.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	2/ 5.7	0/0
Canada				1/ 8.3	0/0
Argentina				0/0	0/0
Australia				1/14.3	0/0
Africa			0/0	0/0	2/28.6
Asia					0/0
Total	0/0	0/0	1/ 6.7	4/ 6.6	2/ 1.8

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	0/0	0/0	2/18.2	0/0
Africa					1/16.7	0/0
Total	0/0	1/33.3	0/0	0/0	3/17.6	0/0

Table 7.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	10/ 9.4	3/ 2.3
Canada	1/ 1.6	1/ 1.6
Argentina	0/0	0/0
Australia	0/0	1/ 6.7
Africa	9/64.3	2/14.3
Asia	0/0	0/0
Total	20/ 9.9	7/ 3.5

Others:

Region	Mean	Variance
Europa	1/ 2.3	3/ 6.8
Africa	1/ 5.9	1/ 5.9
Total	2/ 3.3	4/ 6.6

Table 7.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	–	+	–	+
Europe	8/17.4	5/10.9	6/13.0	11/23.9
Canada	11/11.5	14/14.6	13/13.5	4/ 4.2
Argentina	0/0	0/0	0/0	1/100
Australia	4/25.0	2/12.5	2/12.5	0/0
Africa	2/20.0	4/40.0	2/20.0	1/10.0
Asia	0/0	0/0	0/0	3/42.9
Total	25/14.2	25/14.2	23/13.1	20/11.4

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	3/27.3	4/36.4	4/36.4	1/ 9.1
Africa	1/ 7.1	1/ 7.1	0/0	4/28.6
Total	4/16.0	5/20.0	4/16.0	5/20.0

Table 7.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	13/28.3	17/37.0
Canada	25/26.0	17/17.7
Argentina	0/0	1/100
Australia	6/37.5	2/12.5
Africa	6/60.0	3/30.0
Asia	0/0	3/42.9
Total	50/28.4	43/24.4

Others:

Region	Mean	Variance
Europa	7/63.6	5/45.5
Africa	2/14.3	4/28.6
Total	9/36.0	9/36.0

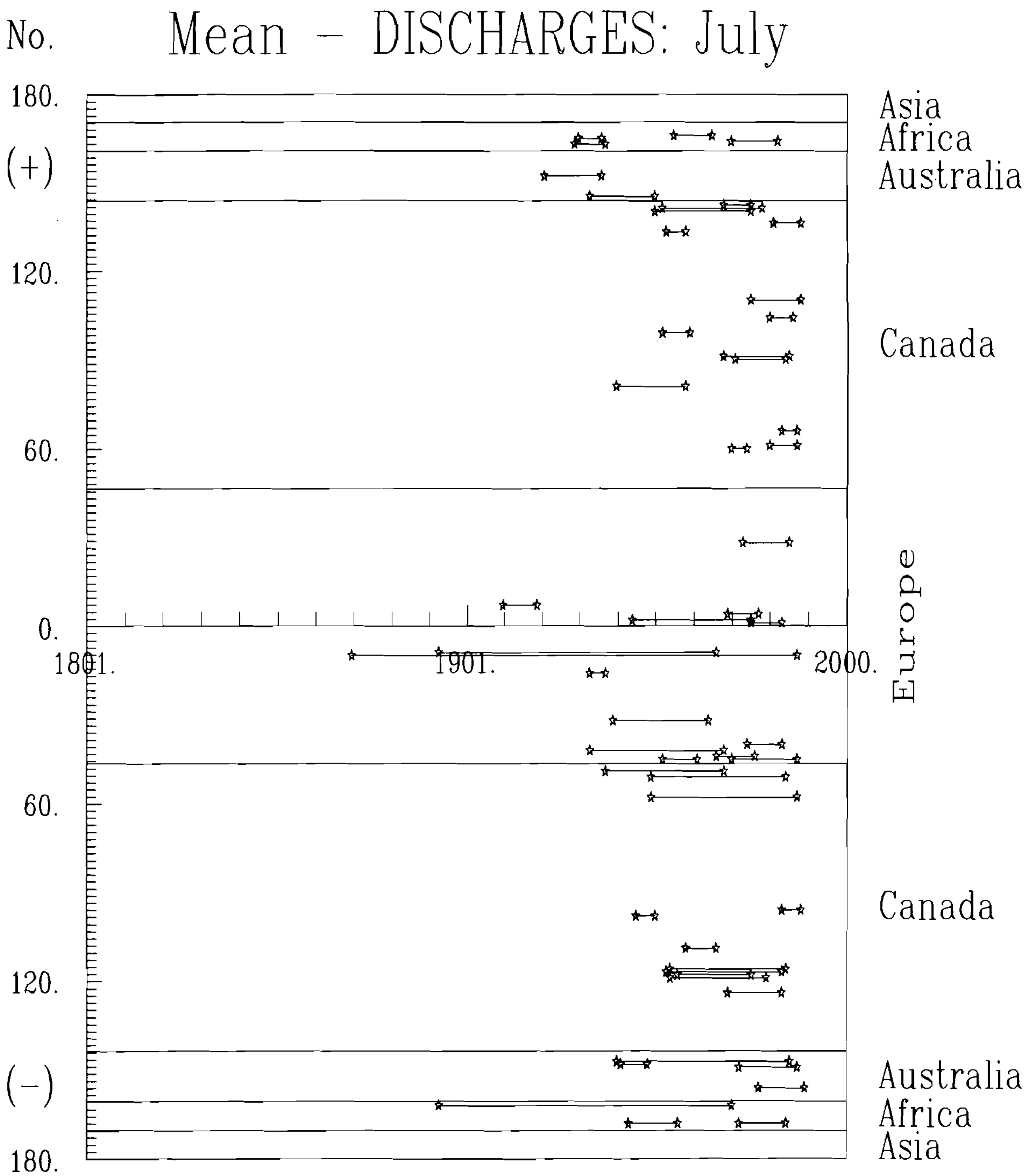

Fig. 7.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

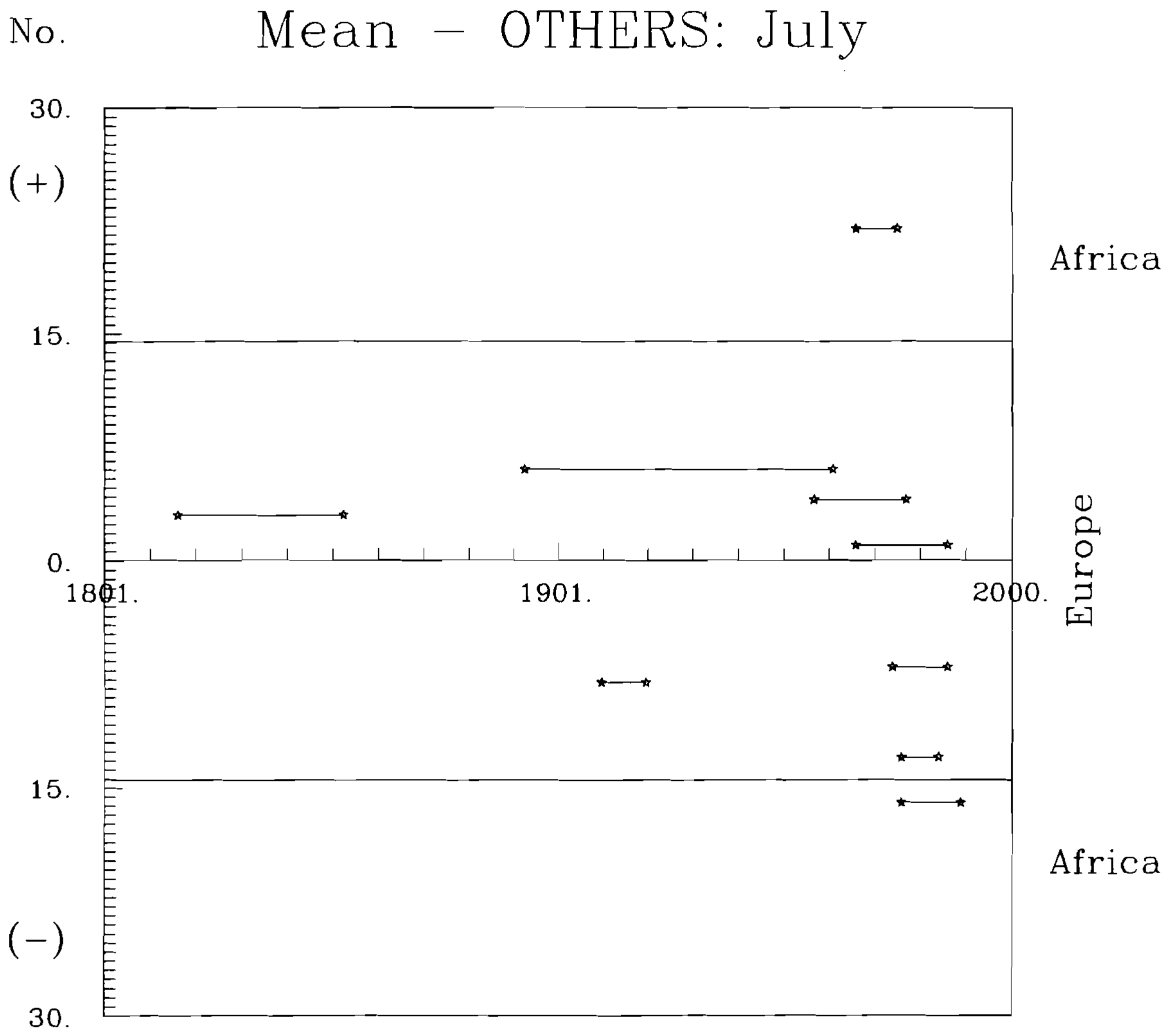

Fig. 7.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

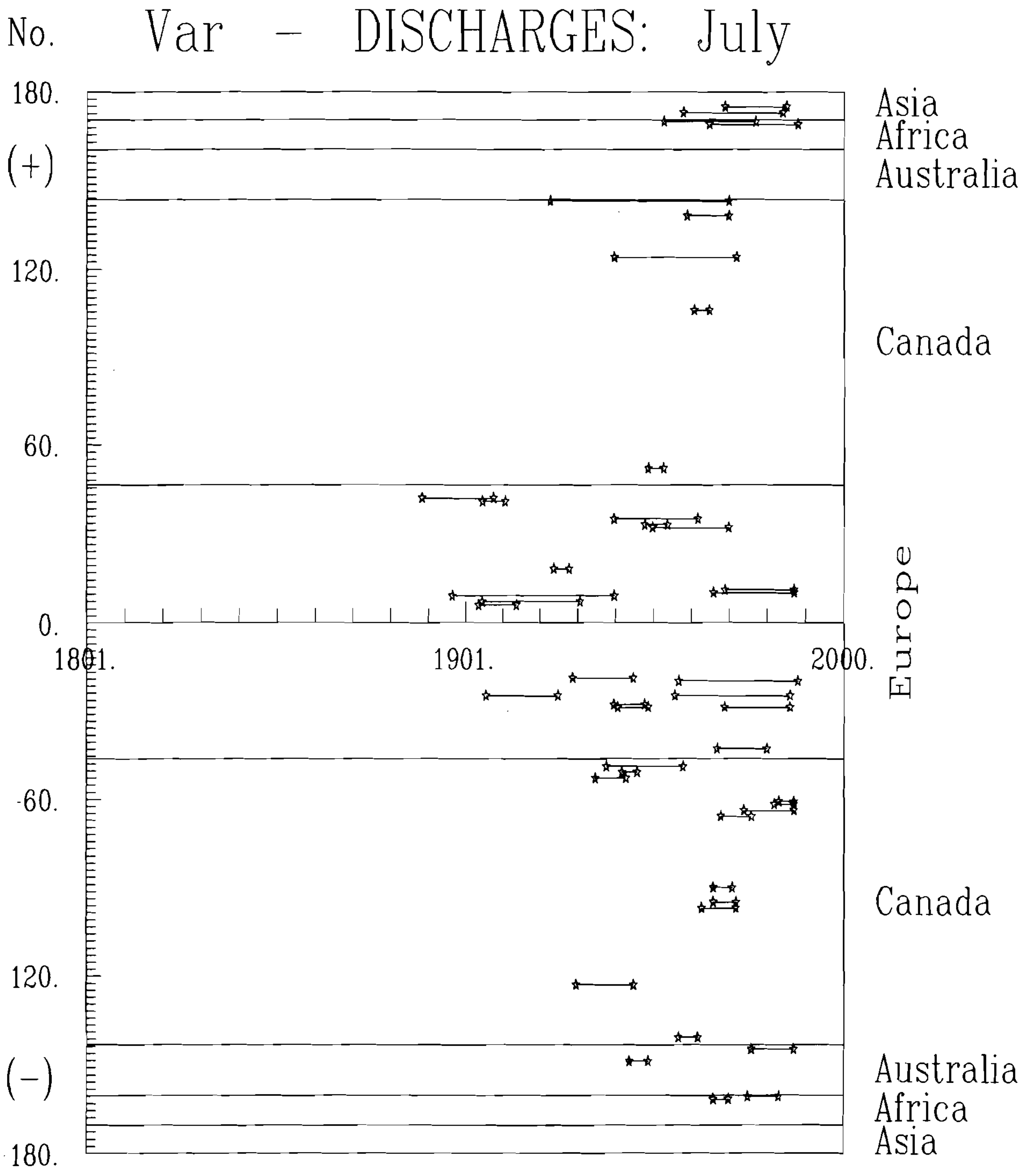

Fig. 7.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

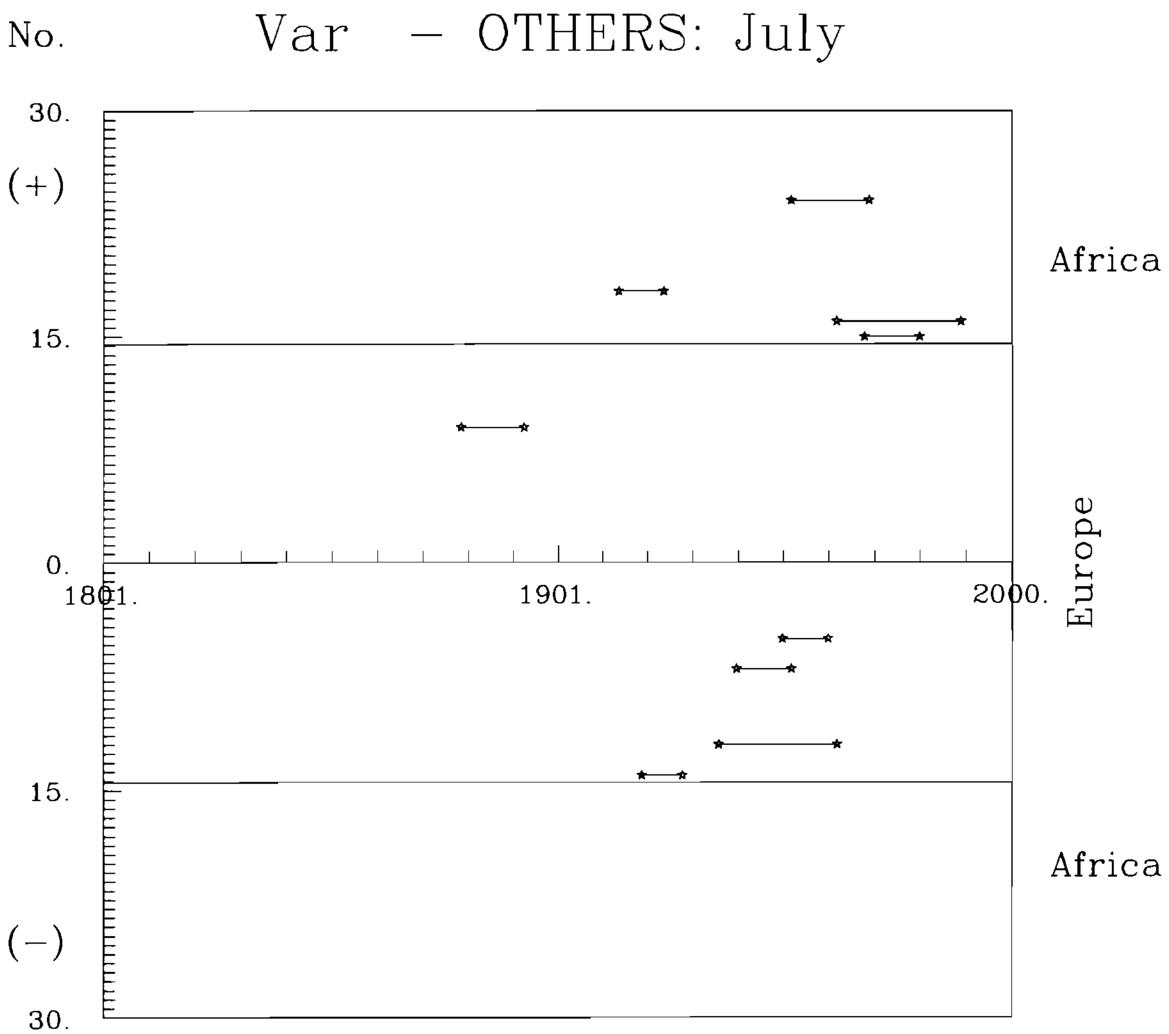

Fig. 7.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 8. RESULTS OF AUGUST

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 30 % of cases for Africa, in ca. 15 % for Europe and Canada, in 6.3 % for Australia, in 0 % for Asia and in 13.6 % for all discharges; (b) of *the others* had to be rejected in 21.4 %, and 16 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 8.4) that for about 85 % of all analyzed sequences, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 4 % and 0 % of cases of the discharges and of *the others*, respectively.

Tables 8.5 and 8.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 8.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 11.4 % and 5 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 3.3 % and 6.6 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, decreasing trends in mean values slightly prevail over increasing ones. Totally, in 13.6 % and 18.8 % of cases occur growing and decreasing trends in mean value, respectively. For *the others*, in 32 % of cases, increasing trends in mean value are observed, except for two cases of decreasing trends in Europe.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 14.8 % and 6.8 % of

cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 28 % to 16 % of cases.

For instance, trend in the mean value of the discharges appeared to decrease for Weser at Vlotho (No. 9), Salzach at Burghausen (No. 10) and the Nile at Aswan Dam (No. 162) covering, respectively, 69.3 %, 49.1 %, and 69.1 % of the whole observation periods of 113, 79, and 79 years. The trend in the variance of discharges was the growing one for Parana at Corrientes (No. 143) and decreasing for Grand at Loch Lomond (No. 123) and the Nile at Aswan Dam (No. 162); it lasted 39, 45 and 43 years, respectively. However, for *the others*, the trend in the mean value grows for temperatures in Pulawy (No. 8) and levels of Lake Vaenern at Sjoetorp (No. 3) during periods of 40 and 37 years, respectively. Decreasing trend in the variance was observed in precipitations of Poznan (No. 10), Malaga (No. 13) and Sunyani (No. 17) during 29, 23 and 18 years, respectively.

As it appears from the summarized results of Mann's test (Table 8.9), a trend has emerged in 32.4 % and 21.6 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 40 % and 44 % of cases in the mean value and in the variance, respectively.

Table 8.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi-cient
Europe	7/15.2	3/ 7.3
Canada	12/12.5	1/ 5.6
Argentina	1/100	1/100
Australia	1/ 6.3	0/0
Africa	3/30.0	4/66.7
Asia	0/0	-
Total	24/13.6	9/12.3

Others:

Region	Run test	Test of autocorr. coeffi-cient
Europe	3/21.4	1/ 9.1
Africa	1/ 9.1	0/0
Total	4/16.0	1/ 5.0

Table 8.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	10/21.7	1/ 2.2
Canada	12/12.5	4/ 4.2
Argentina	0/0	0/0
Australia	2/12.5	0/0
Africa	4/40.0	2/20.0
Asia	0/0	0/0
Total	28/15.9	7/ 4.0

Others:

Region	Mean	Variance
Europe	4/28.6	0/0
Africa	0/0	0/0
Total	4/16.0	0/0

Table 8.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	2/25.0	1/ 7.1	3/ 8.6	2/ 4.7
Canada				3/25.0	4/ 8.0
Argentina				0/0	1/100
Australia				1/14.3	0/0
Africa			1/100	1/16.7	3/42.9
Asia					1/33.3
Total	0/0	2/25.0	2/13.3	8/13.1	11/ 9.8

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	1/ 9.1	1/ 7.7
Africa					0/0	0/0
Total	0/0	0/0	0/0	0/0	1/ 5.9	1/ 4.2

Table 8.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	1/12.5	0/0	1/ 2.9	1/ 2.3
Canada				0/0	4/ 8.0
Argentina				0/0	0/0
Australia				1/14.3	0/0
Africa			0/0	1/16.7	1/14.3
Asia					0/0
Total	0/0	1/12.5	0/0	3/ 4.9	6/ 5.4

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	2/66.7	0/0	1/10.0	0/0	1/ 7.7
Africa					0/0	0/0
Total	0/0	2/66.7	0/0	1/10.0	0/0	1/ 4.2

Table 8.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	8/ 7.5	3/ 2.8
Canada	7/11.3	4/ 6.5
Argentina	1/100	0/0
Australia	1/ 6.7	1/ 6.7
Africa	5/35.7	2/14.3
Asia	1/33.3	0/0
Total	23/11.4	10/ 5.0

Others:

Region	Mean	Variance
Europa	2/ 4.5	4/ 9.1
Africa	0/0	0/0
Total	2/ 3.3	4/ 6.6

Table 8.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	14/30.4	6/13.0	7/15.2	4/ 8.7
Canada	14/14.6	14/14.6	16/16.7	6/ 6.3
Argentina	0/0	0/0	0/0	1/100
Australia	3/18.8	1/ 6.3	1/ 6.3	1/ 6.3
Africa	2/20.0	3/30.0	2/20.0	0/0
Asia	0/0	0/0	0/0	0/0
Total	33/18.8	24/13.6	26/14.8	12/ 6.8

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	2/18.2	6/54.5	6/54.5	3/27.3
Africa	0/0	2/14.3	1/ 7.1	1/ 7.1
Total	2/ 8.0	8/32.0	7/28.0	4/16.0

Table 8.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	19/41.3	10/21.7
Canada	28/29.2	22/22.9
Argentina	0/0	1/100
Australia	4/25.0	2/12.5
Africa	5/50.0	2/20.0
Asia	0/0	0/0
Total	57/32.4	38/21.6

Others:

Region	Mean	Variance
Europa	7/63.6	9/81.8
Africa	2/14.3	2/14.3
Total	10/40.0	11/44.0

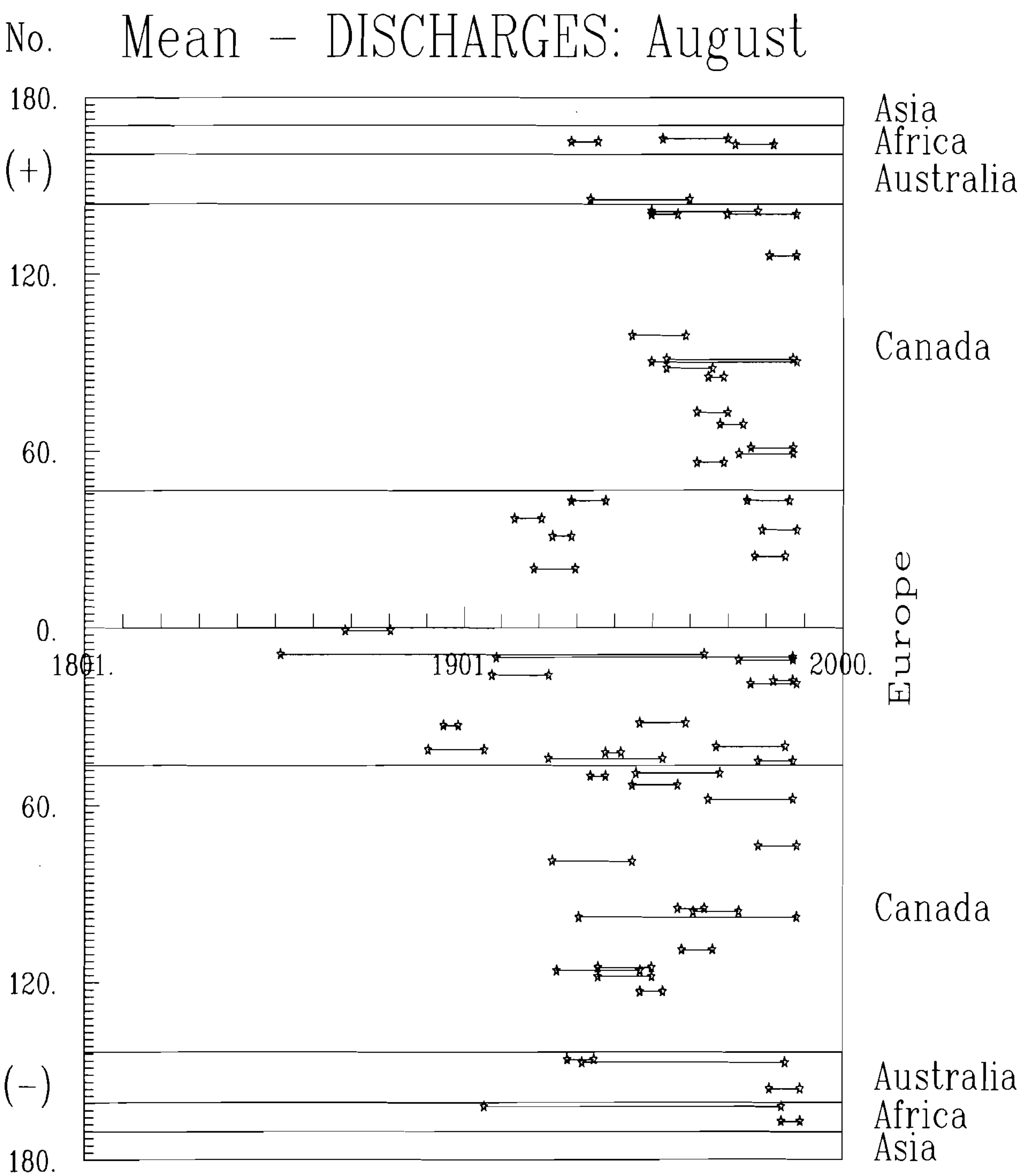

Fig. 8.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

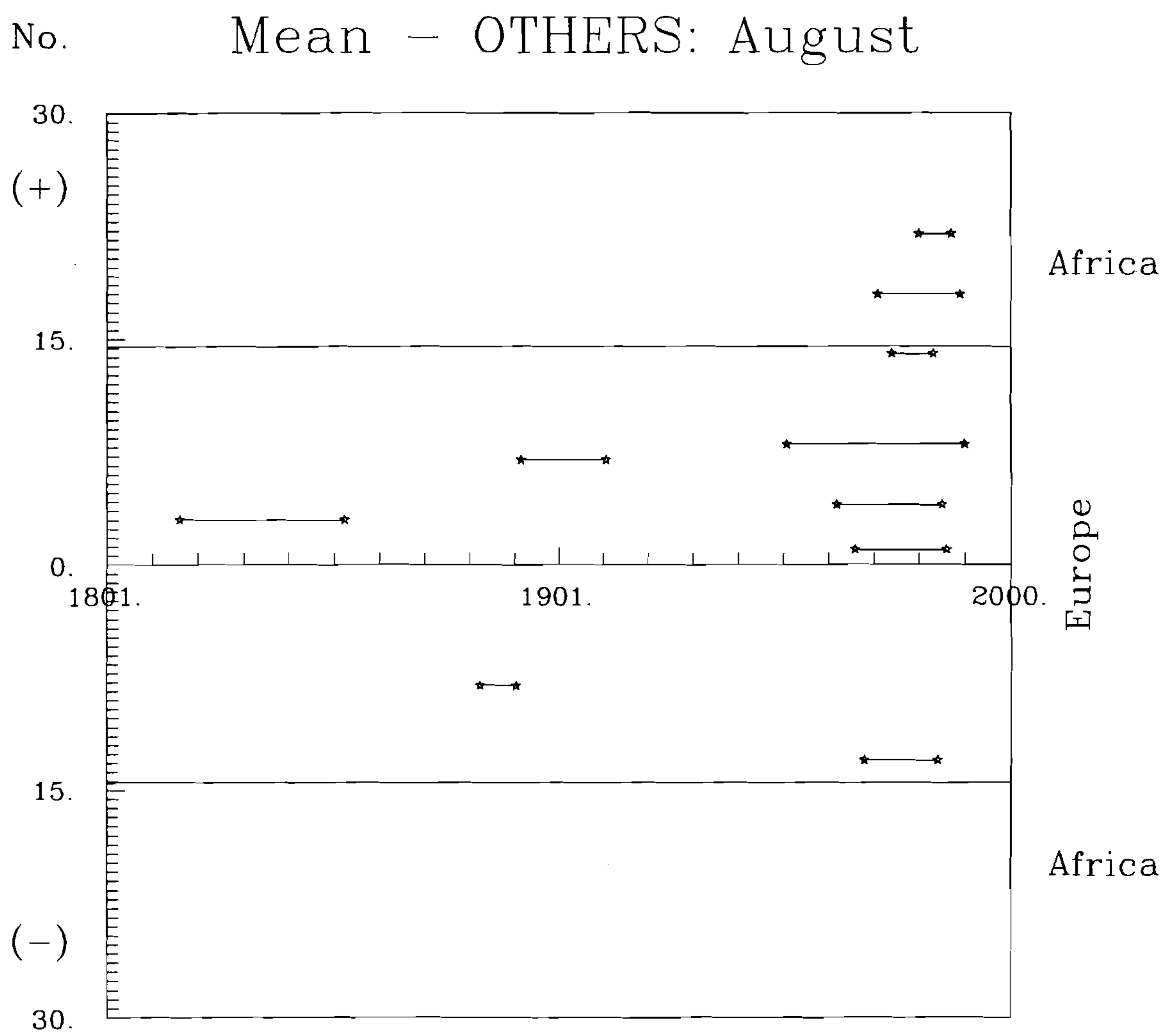

Fig. 8.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

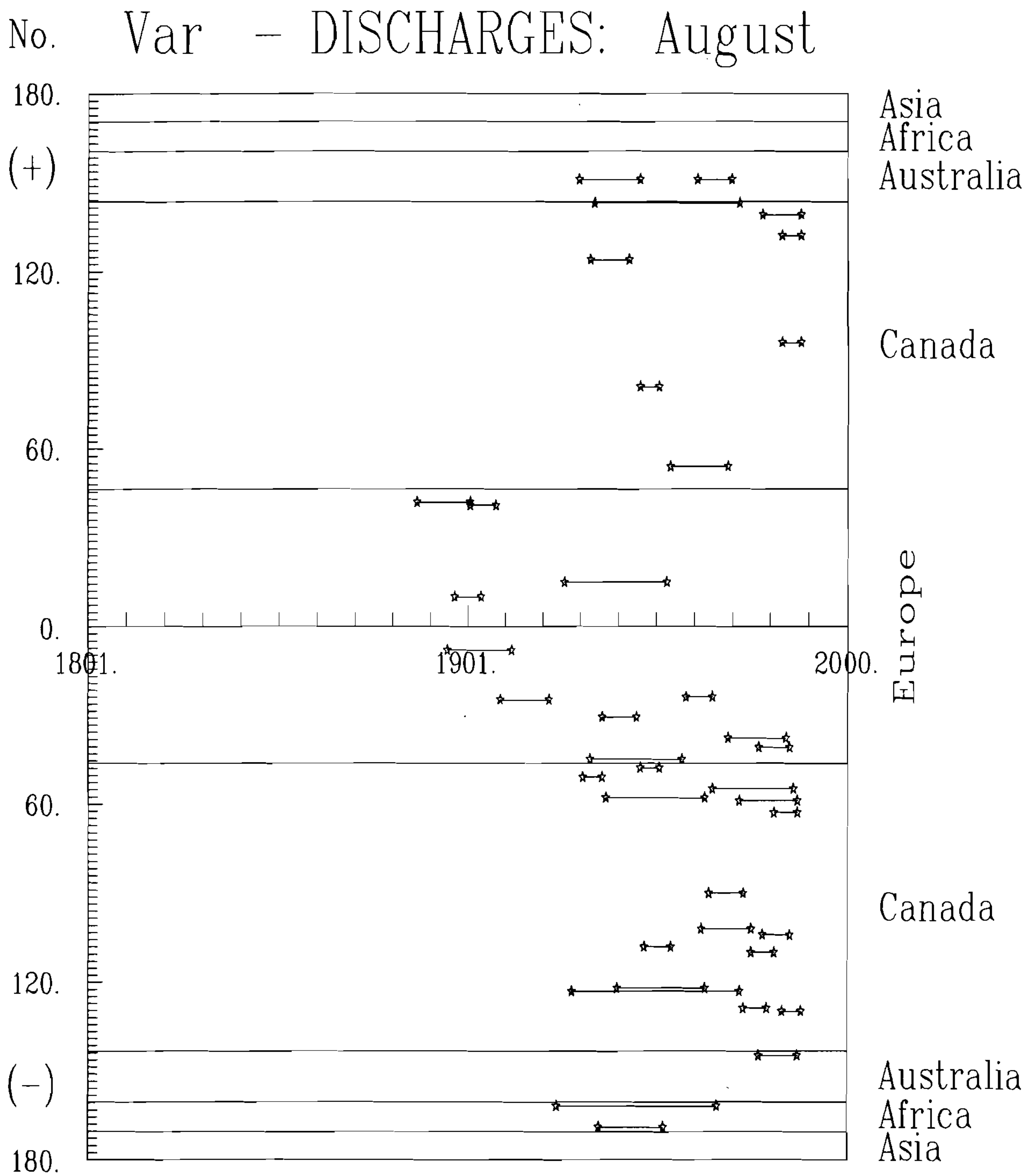

Fig. 8.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

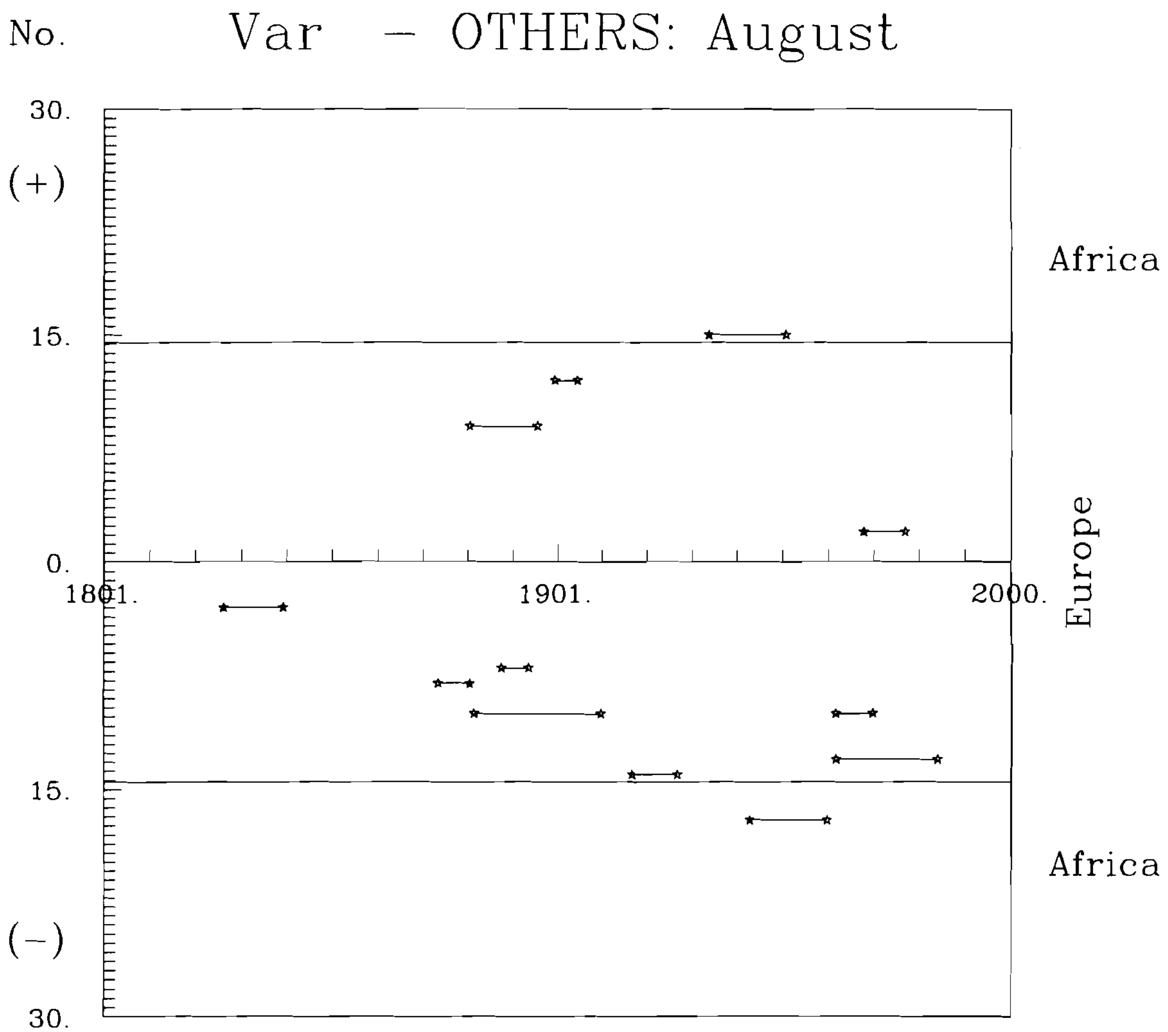

Fig. 8.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 9. RESULTS OF SEPTEMBER

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 40 % of cases for Africa, in ca. 15 % for Europe and Australia, in 9.4 % for Canada, in 0 % for Asia and in 13.1 % for all discharges; (b) of *the others* had to be rejected in 28.6 %, and 20 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 9.4) that for about 85 % of all analyzed sequences, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 4.5 % and 8 % of cases of the discharges and of *the others*, respectively.

Tables 9.5 and 9.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 9.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 11.9 % and 4.5 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 6.6 % and 3.3 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean values slightly prevail over decreasing ones. Totally, in 19.3 % and 14.8 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, in 28 % of cases, increasing trends in the mean value are observed, except for one case of a decreasing trend in Europe.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 11.9 % and 7.4 % of

cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 24 % to 16 % of cases.

For instance, trend in the mean value of the discharges appeared to decrease for Weser at Vlotho (No. 9), the Nile at Aswan Dam (No. 162) and Bow at Banff (No. 98) covering, respectively, 71.2 %, 64 %, and 59 % of the whole observation periods of 116, 73, and 46 years. The trend in the variance of discharges was the growing one for Labe at Decin (No. 1) and Weser at Vlotho (No. 9) and decreasing for Roseway at Lower Ohio (No. 117); it lasted 80, 56 and 48 years, respectively. However, for *the others*, the trend in the mean value grows for temperatures in Warsaw (No. 6) and precipitations in Accra (No. 18) during periods of 98 and 44 years, respectively. Decreasing trend in the variance was observed for temperatures in Warsaw (No. 6) during 67 years.

As it appears from the summarized results of Mann's test (Table 9.9), a trend has emerged in 34.1 % and 19.3 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 32 % and 40 % of cases in the mean value and in the variance, respectively.

Table 9.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi- cient
Europe	7/15.2	2/ 4.9
Canada	9/ 9.4	2/11.1
Argentina	1/100	1/100
Australia	2/12.5	0/0
Africa	4/40.0	6/100
Asia	0/0	-
Total	23/13.1	11/15.1

Others:

Region	Run test	Test of autocorr. coeffi- cient
Europe	4/28.6	1/ 9.1
Africa	1/ 9.1	0/0
Total	5/20.0	1/ 5.0

Table 9.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	14/30.4	3/ 6.5
Canada	9/ 9.4	1/ 1.0
Argentina	1/100	0/0
Australia	2/12.5	1/ 6.3
Africa	7/70.0	3/30.0
Asia	0/0	0/0
Total	33/18.8	8/ 4.5

Others:

Region	Mean	Variance
Europe	3/21.4	1/ 7.1
Africa	1/ 9.1	1/ 9.1
Total	4/16.0	2/ 8.0

Table 9.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	5/14.3	4/ 9.3
Canada				1/ 8.3	2/ 4.0
Argentina				0/0	1/100
Australia				0/0	2/25.0
Africa			1/100	1/16.7	6/85.7
Asia					0/0
Total	0/0	0/0	2/13.3	7/11.5	15/13.4

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	1/100	0/0	0/0	0/0	1/ 9.1	1/ 7.7
Africa					0/0	1/ 9.1
Total	1/100	0/0	0/0	0/0	1/ 5.9	2/ 8.3

Table 9.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	2/14.3	2/ 5.7	1/ 2.3
Canada				0/0	3/ 6.0
Argentina				0/0	0/0
Australia				0/0	0/0
Africa			0/0	0/0	1/14.3
Asia					0/0
Total	0/0	0/0	2/13.3	2/ 3.3	5/ 4.5

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	0/0	0/0	1/ 9.1	0/0
Africa					0/0	0/0
Total	0/0	1/33.3	0/0	0/0	1/ 5.9	0/0

Table 9.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	10/ 9.4	5/ 4.7
Canada	3/ 4.8	3/ 4.8
Argentina	1/100	0/0
Australia	2/13.3	0/0
Africa	8/57.1	1/ 7.1
Asia	0/0	0/0
Total	24/11.9	9/ 4.5

Others:

Region	Mean	Variance
Europa	3/ 6.8	2/ 4.5
Africa	1/ 5.9	0/0
Total	4/ 6.6	2/ 3.3

Table 9.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	13/28.3	7/15.2	7/15.2	7/15.2
Canada	7/ 7.3	19/19.8	11/11.5	2/ 2.1
Argentina	0/0	0/0	0/0	0/0
Australia	2/12.5	4/25.0	1/ 6.3	1/ 6.3
Africa	3/30.0	3/30.0	2/20.0	2/20.0
Asia	1/14.3	1/14.3	0/0	1/14.3
Total	26/14.8	34/19.3	21/11.9	13/ 7.4

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	1/ 9.1	5/45.5	6/54.5	2/18.2
Africa	0/0	2/14.3	0/0	2/14.3
Total	1/ 4.0	7/28.0	6/24.0	4/16.0

Table 9.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	19/41.3	14/30.4
Canada	26/27.1	13/13.5
Argentina	0/0	0/0
Australia	6/37.5	2/12.5
Africa	6/60.0	4/40.0
Asia	2/28.6	1/14.3
Total	60/34.1	34/19.3

Others:

Region	Mean	Variance
Europa	6/54.5	7/63.6
Africa	2/14.3	2/14.3
Total	8/32.0	10/40.0

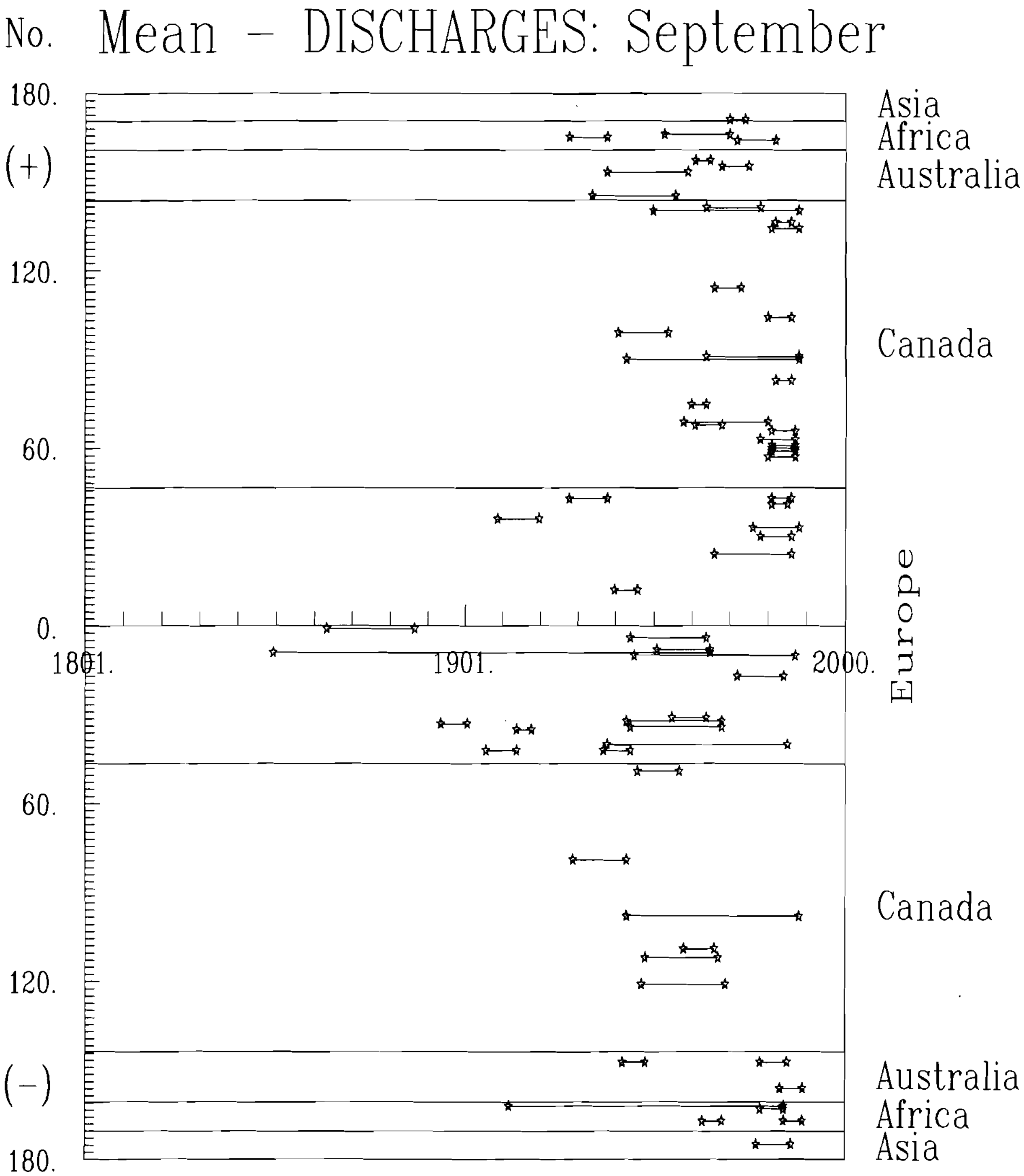

Fig. 9.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

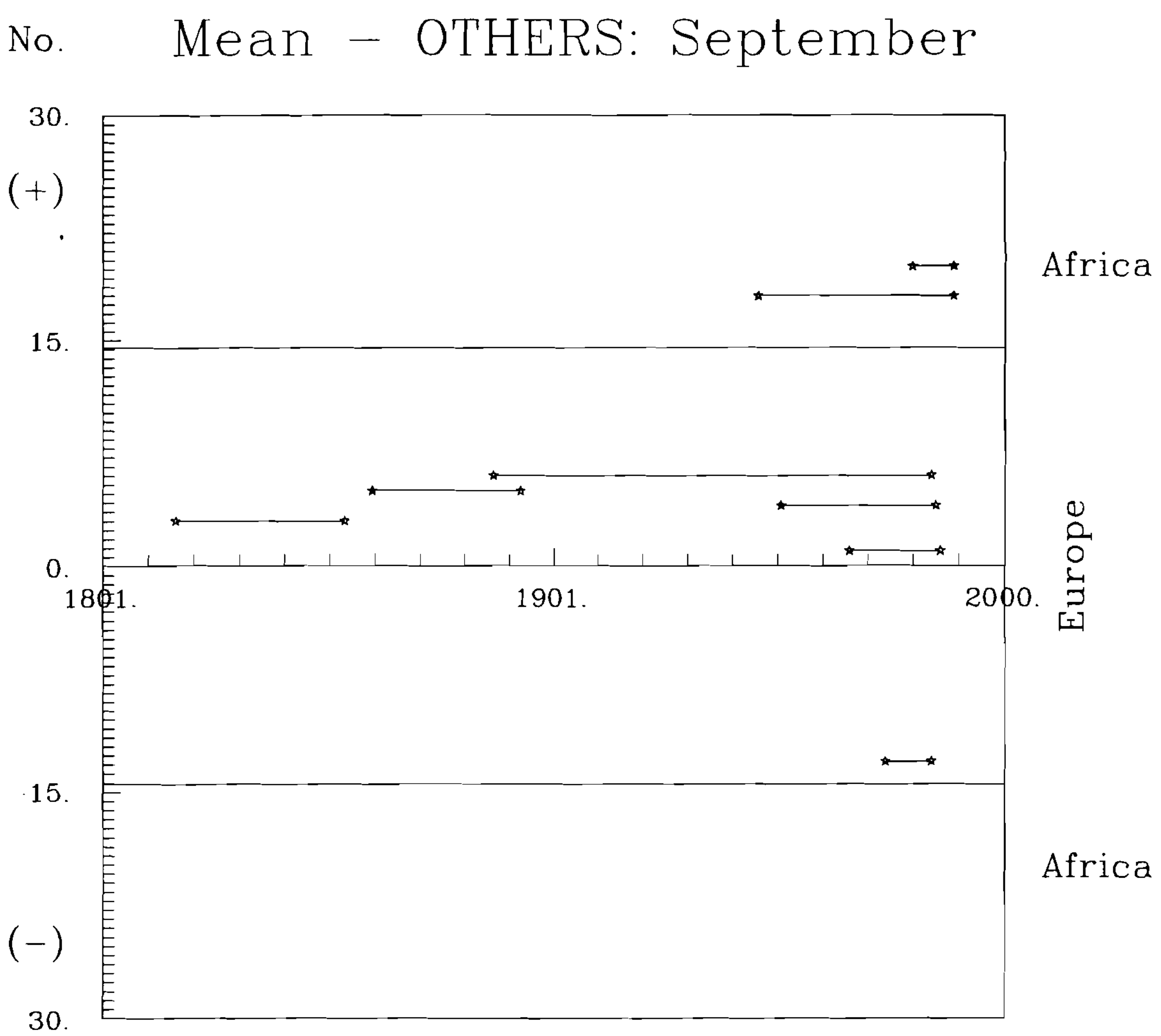

Fig. 9.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

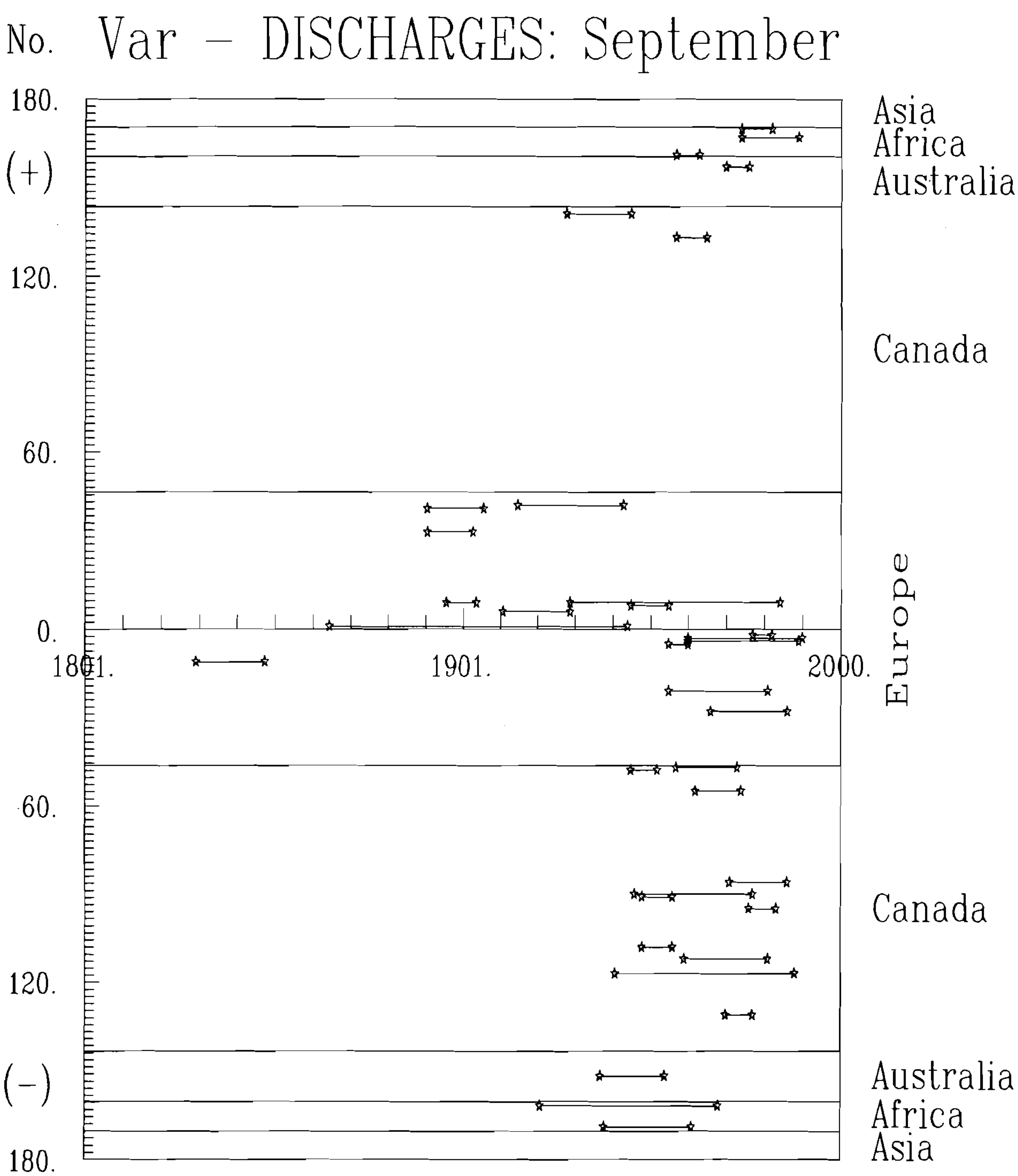

Fig. 9.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

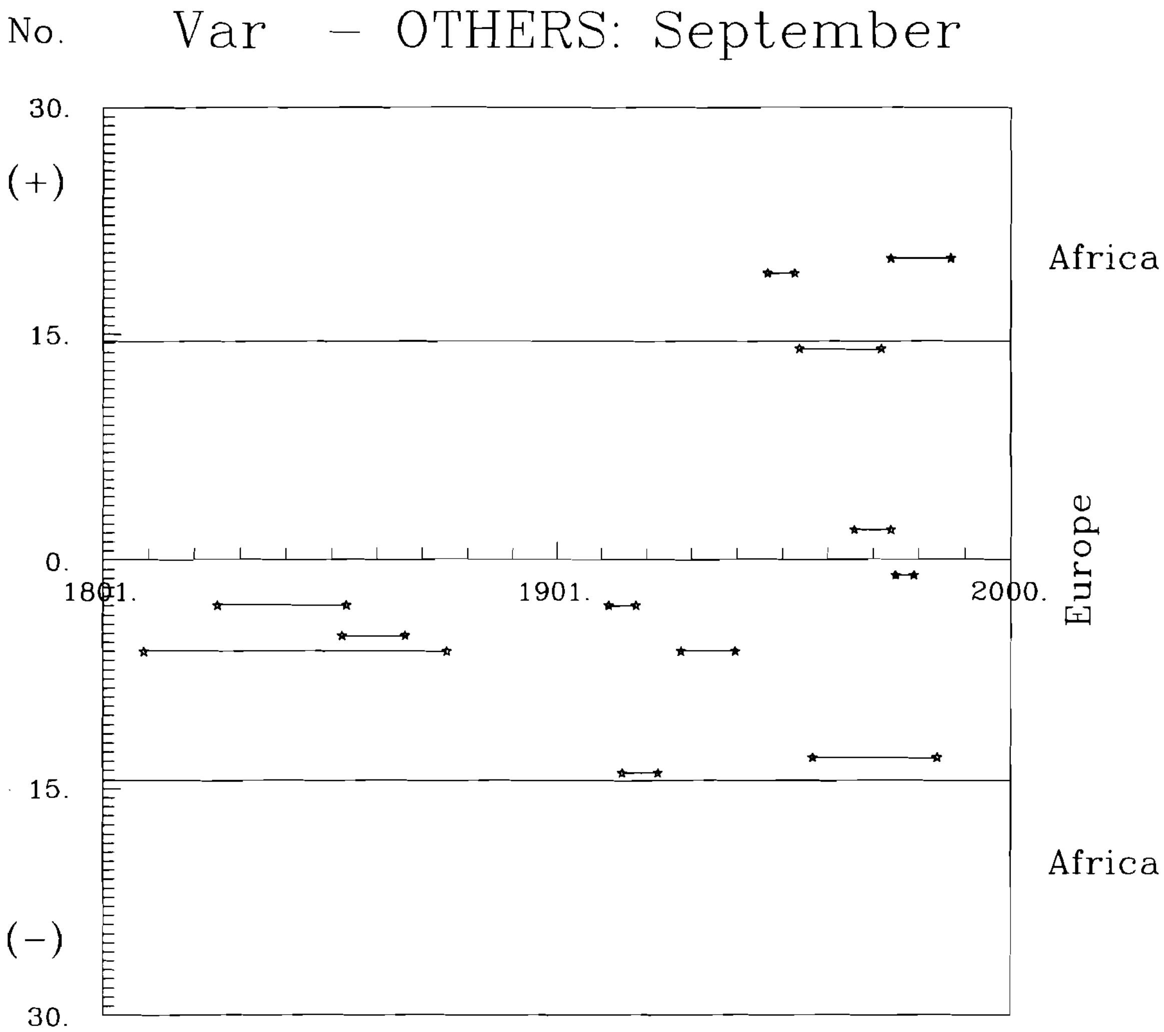

Fig. 9.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 10. RESULTS OF OCTOBER

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 50 % of cases for Africa, in ca. 10 % for Australia and Europe, in 4.2 % for Canada, in 0 % for Asia and in 9.1 % for all discharges; (b) of *the others* had to be rejected in 14.3 %, and 12 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 10.4) that for about 85 % and 75 % of analyzed sequences of the discharges and *the others*, respectively, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 5.1 % and 8 % of cases of the discharges and of *the others*, respectively.

Tables 10.5 and 10.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 10.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 15.8 % and 5.4 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 3.3 % of cases there occurs fluctuations in the mean value and in the variance. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, decreasing trends in mean values slightly prevail over increasing ones. Totally, in 14.8 % and 19.3 % of cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, decreasing and increasing trends in the mean value are observed in 32 % and 24 % of cases, respectively.

Decreasing and increasing trends in variance have totally

emerged for the discharges, respectively, in 16.5 % and 6.3 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 8 % to 12 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Labe at Decin (No. 1) and Niger at Koulikoro (No. 165) and to decrease for Waser at Vlotho (No. 9) and the Nile at Aswan Dam (No. 162) covering, respectively, 51.5 %, 53.7 %, 79.2 % and 63.2 % of the whole observation periods of 69, 44, 118, and 72 years. The trend in the variance of discharges was the growing one for the Rhine at Koeln (No. 14) and decreasing for Torrens River at Gorge Weir (No. 154) and the Nile at Aswan Dam (No. 162); it lasted 99, 46 and 43 years, respectively. However, for *the others*, the trend in the mean value grows precipitations at Accra (No. 18) and levels of Lake Vaenern at Sjoetorp (No. 3) during periods of 52 and 39 years, respectively. Decreasing trend in the variance was observed for levels of Lake Vaenern at Sjoetorp (No. 3) during 67 years.

As it appears from the summarized results of Mann's test (Table 10.9), a trend has emerged in 34.1 % and 22.7 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 56 % and 20 % of cases in the mean value and in the variance, respectively.

Table 10.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi- cient
Europe	5/10.9	3/ 7.3
Canada	4/ 4.2	1/ 5.6
Argentina	0/0	0/0
Australia	2/12.5	0/0
Africa	5/50.0	5/83.3
Asia	0/0	-
Total	16/ 9.1	9/12.3

Others:

Region	Run test	Test of autocorr. coeffi- cient
Europe	2/14.3	1/ 9.1
Africa	1/ 9.1	0/0
Total	3/12.0	1/ 5.0

Table 10.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	9/19.6	2/ 4.3
Canada	11/11.5	2/ 2.1
Argentina	0/0	0/0
Australia	3/18.8	1/ 6.3
Africa	6/60.0	3/30.0
Asia	1/14.3	1/14.3
Total	30/17.0	9/ 5.1

Others:

Region	Mean	Variance
Europe	3/21.4	1/ 7.1
Africa	3/27.3	1/ 9.1
Total	6/24.0	2/ 8.0

Table 10.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	1/16.7	4/50.0	2/14.3	4/11.4	5/11.6
Canada				1/ 8.3	5/10.0
Argentina				0/0	0/0
Australia				0/0	2/25.0
Africa			0/0	2/33.3	6/85.7
Asia					0/0
Total	1/16.7	4/50.0	2/13.3	7/11.5	18/16.1

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	1/ 7.7
Africa					0/0	1/ 9.1
Total	0/0	0/0	0/0	0/0	0/0	2/ 8.3

Table 10.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	1/16.7	0/0	0/0	2/ 5.7	1/ 2.3
Canada				0/0	2/ 4.0
Argentina				0/0	0/0
Australia				0/0	2/25.0
Africa			0/0	1/16.7	1/14.3
Asia					1/33.3
Total	1/16.7	0/0	0/0	3/ 4.9	7/ 6.3

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	0/0	0/0	0/0	0/0
Africa					1/16.7	0/0
Total	0/0	1/33.3	0/0	0/0	1/ 5.9	0/0

Table 10.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	16/15.1	4/ 3.8
Canada	6/ 9.7	2/ 3.2
Argentina	0/0	0/0
Australia	2/13.3	2/13.3
Africa	8/57.1	2/14.3
Asia	0/0	1/33.3
Total	32/15.8	11/ 5.4

Others:

Region	Mean	Variance
Europa	1/ 2.3	1/ 2.3
Africa	1/ 5.9	1/ 5.9
Total	2/ 3.3	2/ 3.3

Table 10.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	13/28.3	6/13.0	8/17.4	5/10.9
Canada	13/13.5	14/14.6	15/15.6	1/ 1.0
Argentina	0/0	0/0	0/0	0/0
Australia	2/12.5	1/ 6.3	3/18.8	1/ 6.3
Africa	5/50.0	4/40.0	2/20.0	3/30.0
Asia	1/14.3	1/14.3	1/14.3	1/14.3
Total	34/19.3	26/14.8	29/16.5	11/ 6.3

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	4/36.4	3/27.3	2/18.2	1/ 9.1
Africa	4/28.6	3/21.4	0/0	2/14.3
Total	8/32.0	6/24.0	2/ 8.0	3/12.0

Table 10.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	17/37.0	13/28.3
Canada	26/27.1	16/16.7
Argentina	0/0	0/0
Australia	3/18.8	4/25.0
Africa	9/90.0	5/50.0
Asia	2/28.6	2/28.6
Total	60/34.1	40/22.7

Others:

Region	Mean	Variance
Europa	7/63.6	3/27.3
Africa	7/50.0	2/14.3
Total	14/56.0	5/20.0

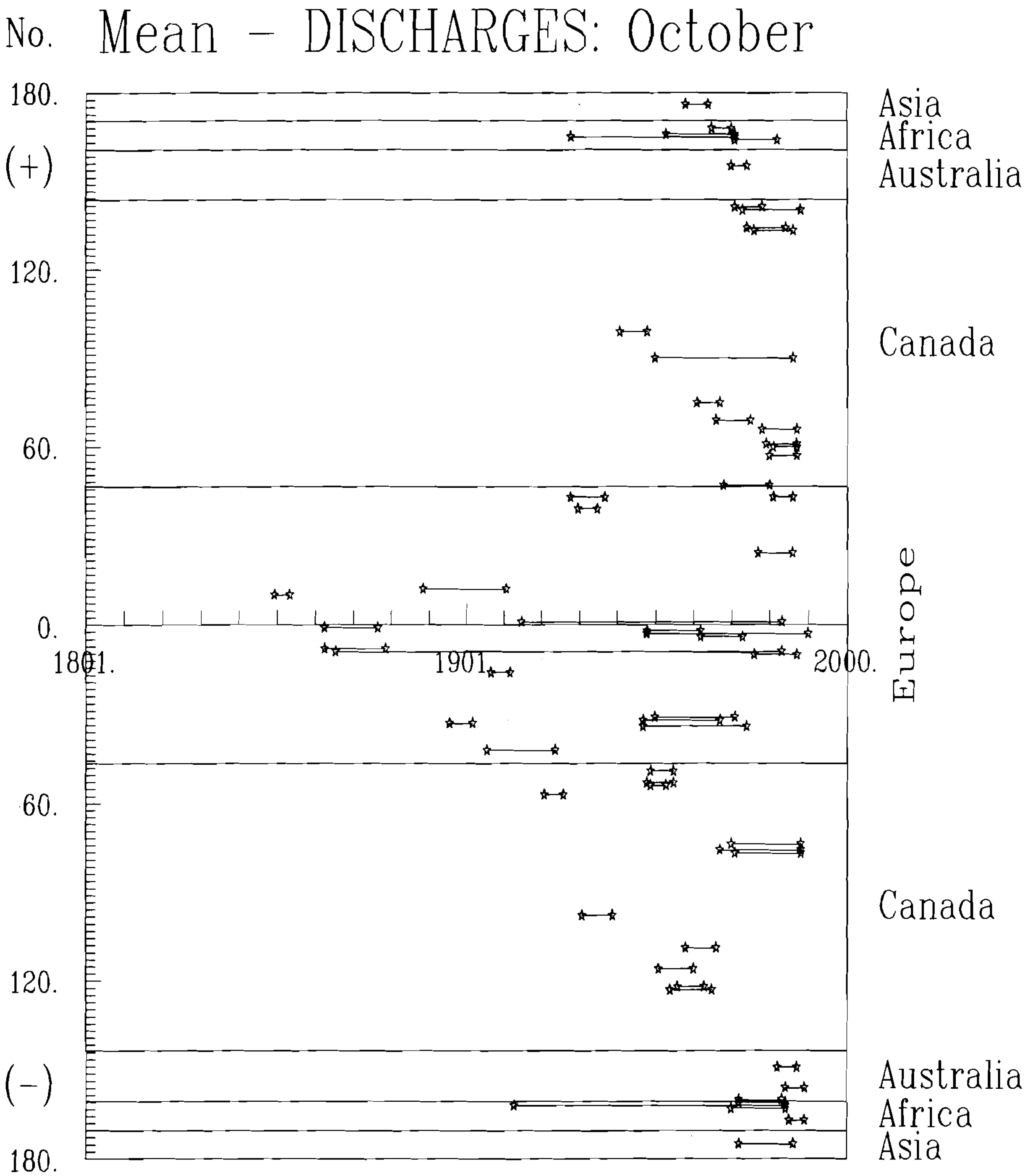

Fig. 10.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

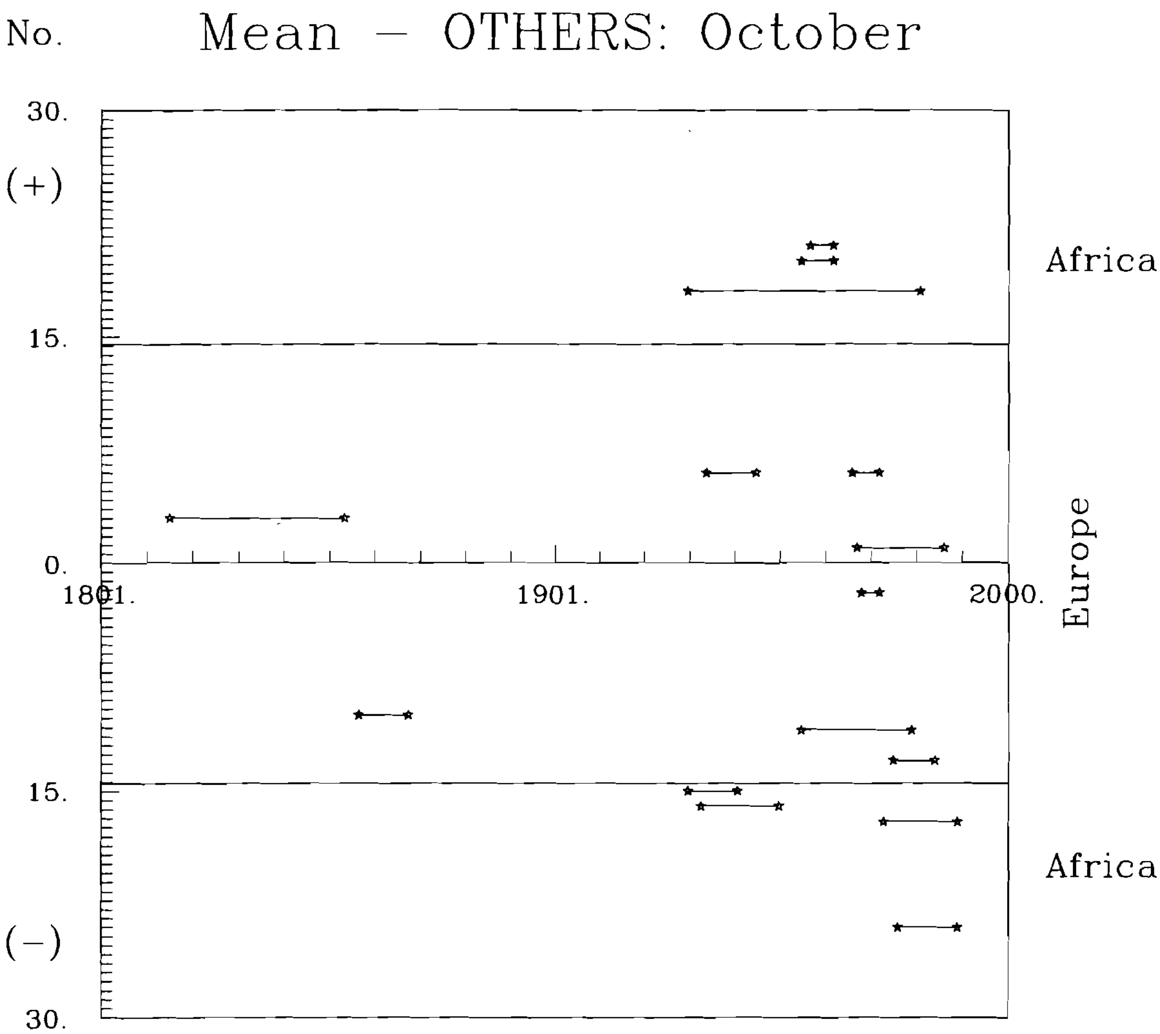

Fig. 10.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

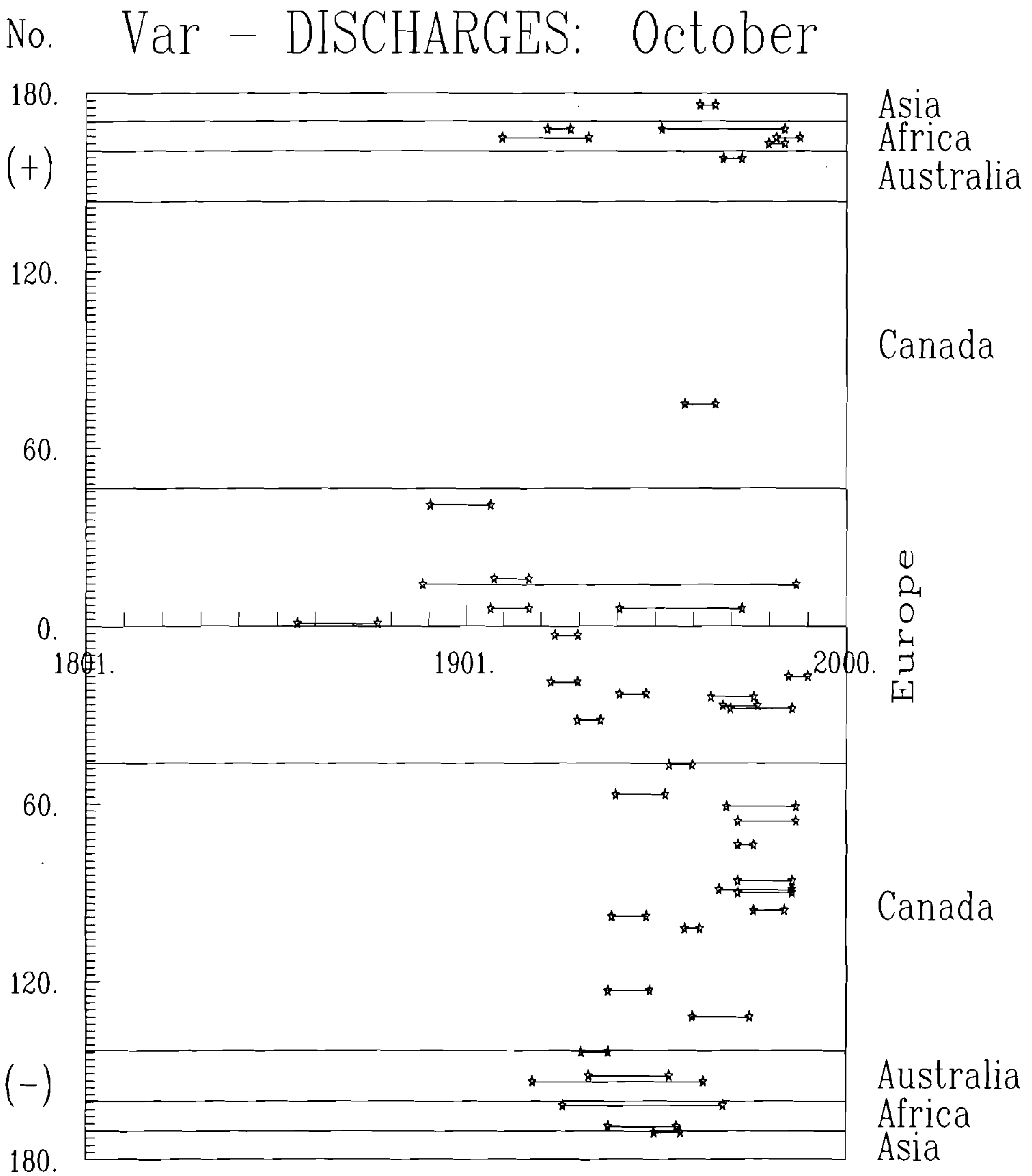

Fig. 10.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

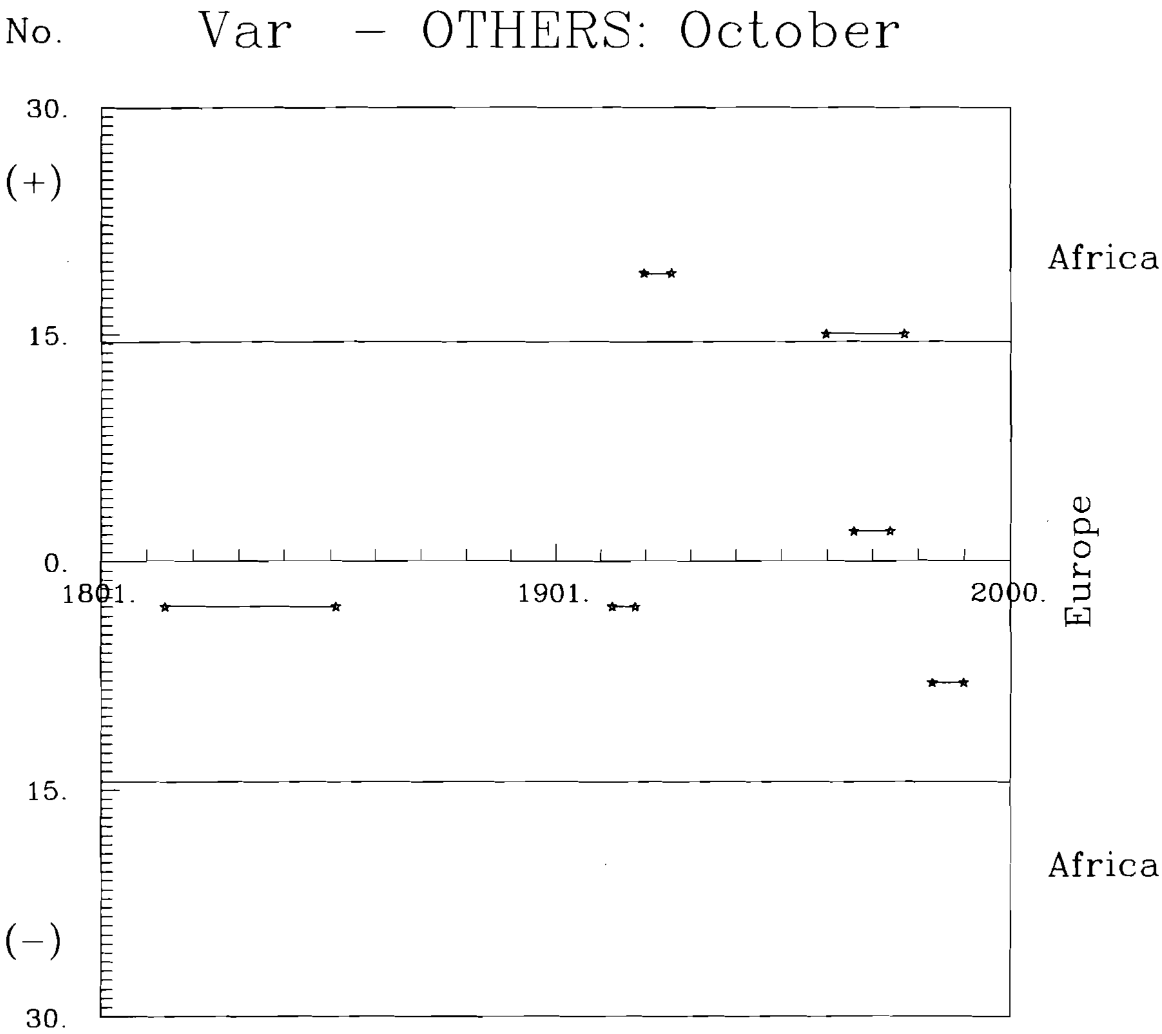

Fig. 10.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 11. RESULTS OF NOVEMBER

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 50 % of cases for Africa, in 15.3 % for Asia, in ca. 10 % for Australia and Europe, in 7.3 % for Canada and in 11.4 % for all discharges; (b) of *the others* had to be rejected in 14.3 %, and 12 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 11.4) that for about 90 % and 70 % of analyzed sequences of the discharges and *the others*, respectively, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 3.4 % and 12 % of cases of the discharges and of *the others*, respectively.

Tables 11.5 and 11.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 11.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 7.4 % and 5.9 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 11.5 % and 8.2 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: in 15.3 % and 16.5 % of the total cases there occur growing and decreasing trends in the mean value, respectively. For *the others*, decreasing and increasing trends in the mean value are observed in 24 % and 32 % of cases, respectively.

Decreasing and increasing trends in variance have totally

emerged for the discharges, respectively, in 15.9 % and 10.2 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 16 % to 8 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Tom at Novokuznetsk (No. 38) and to decreasefor Waser at Vlotho (No. 9) and the Nile at Aswan Dam (No. 162) covering, respectively, 67.4 %, 79.1 %, and 68.4 % of the whole observation periods of 62, 129, and 78 years. The trend in the variance of discharges was the growing one for Sajo at Felsozsolca (No. 16) and Saint John at Fort Kent (No. 124) and decreasing for Raneaelv at Miemisel (No. 46); it lasted 42, 39 and 34 years, respectively. However, for *the others*, trend in the mean value grows for temperatures at Warsaw (No. 6), Cracow (No. 4) and Poznan (No. 5) during periods of 58, 56, and 53 years, respectively. Decreasing trend in the variance was observed for temperature at Poznan (No. 5) during 31 years.

As it appears from the summarized results of Mann's test (Table 11.9), a trend has emerged in 31.8 % and 26.1 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 56 % and 24 % of cases in the mean value and in the variance, respectively.

Table 11.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi-cient
Europe	5/10.9	2/ 4.9
Canada	7/ 7.3	0/0
Argentina	0/0	0/0
Australia	2/12.5	0/0
Africa	5/50.0	4/66.7
Asia	1/14.3	-
Total	20/11.4	6/ 8.2

Others:

Region	Run test	Test of autocorr. coeffi-cient
Europe	2/14.3	2/18.2
Africa	1/ 9.1	1/11.1
Total	3/12.0	3/15.0

Table 11.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	5/10.9	2/ 4.3
Canada	6/ 6.3	0/0
Argentina	0/0	0/0
Australia	2/12.5	2/12.5
Africa	6/60.0	2/20.0
Asia	0/0	0/0
Total	19/10.8	6/ 3.4

Others:

Region	Mean	Variance
Europe	4/28.6	3/21.4
Africa	3/27.3	0/0
Total	7/28.0	3/12.0

Table 11.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	1/ 2.9	1/ 2.3
Canada				1/ 8.3	0/0
Argentina				0/0	0/0
Australia				0/0	2/25.0
Africa			0/0	3/50.0	6/85.7
Asia					0/0
Total	0/0	0/0	1/ 6.7	5/ 8.2	9/ 8.0

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	1/ 9.1	5/38.5
Africa					1/16.7	0/0
Total	0/0	0/0	0/0	0/0	2/11.8	5/20.8

Table 11.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	4/11.4	1/ 2.3
Canada				2/16.7	0/0
Argentina				0/0	0/0
Australia				0/0	0/0
Africa			0/0	2/33.3	1/14.3
Asia					1/33.3
Total	0/0	0/0	1/ 6.7	8/13.1	3/ 2.7

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	1/16.7	0/0	2/18.2	1/ 7.7
Africa					0/0	0/0
Total	0/0	1/33.3	1/16.7	0/0	2/11.8	1/ 4.2

Table 11.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	3/ 2.8	6/ 5.7
Canada	1/ 1.6	2/ 3.2
Argentina	0/0	0/0
Australia	2/13.3	0/0
Africa	9/64.3	3/21.4
Asia	0/0	1/33.3
Total	15/ 7.4	12/ 5.9

Others:

Region	Mean	Variance
Europa	6/13.6	5/11.4
Africa	1/ 5.9	0/0
Total	7/11.5	5/ 8.2

Table 11.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	14/30.4	11/23.9	11/23.9	10/21.7
Canada	9/ 9.4	9/ 9.4	15/15.6	4/ 4.2
Argentina	0/0	0/0	0/0	0/0
Australia	2/12.5	4/25.0	2/12.5	2/12.5
Africa	3/30.0	3/30.0	0/0	1/10.0
Asia	1/14.3	0/0	0/0	1/14.3
Total	29/16.5	27/15.3	28/15.9	18/10.2

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	2/18.2	7/63.6	4/36.4	1/ 9.1
Africa	4/28.6	1/ 7.1	0/0	1/ 7.1
Total	6/24.0	8/32.0	4/16.0	2/ 8.0

Table 11.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	23/50.0	20/43.5
Canada	18/18.8	19/19.8
Argentina	0/0	0/0
Australia	6/37.5	4/25.0
Africa	6/60.0	1/10.0
Asia	1/14.3	1/14.3
Total	56/31.8	46/26.1

Others:

Region	Mean	Variance
Europa	8/72.7	5/45.5
Africa	5/35.7	1/ 7.1
Total	14/56.0	6/24.0

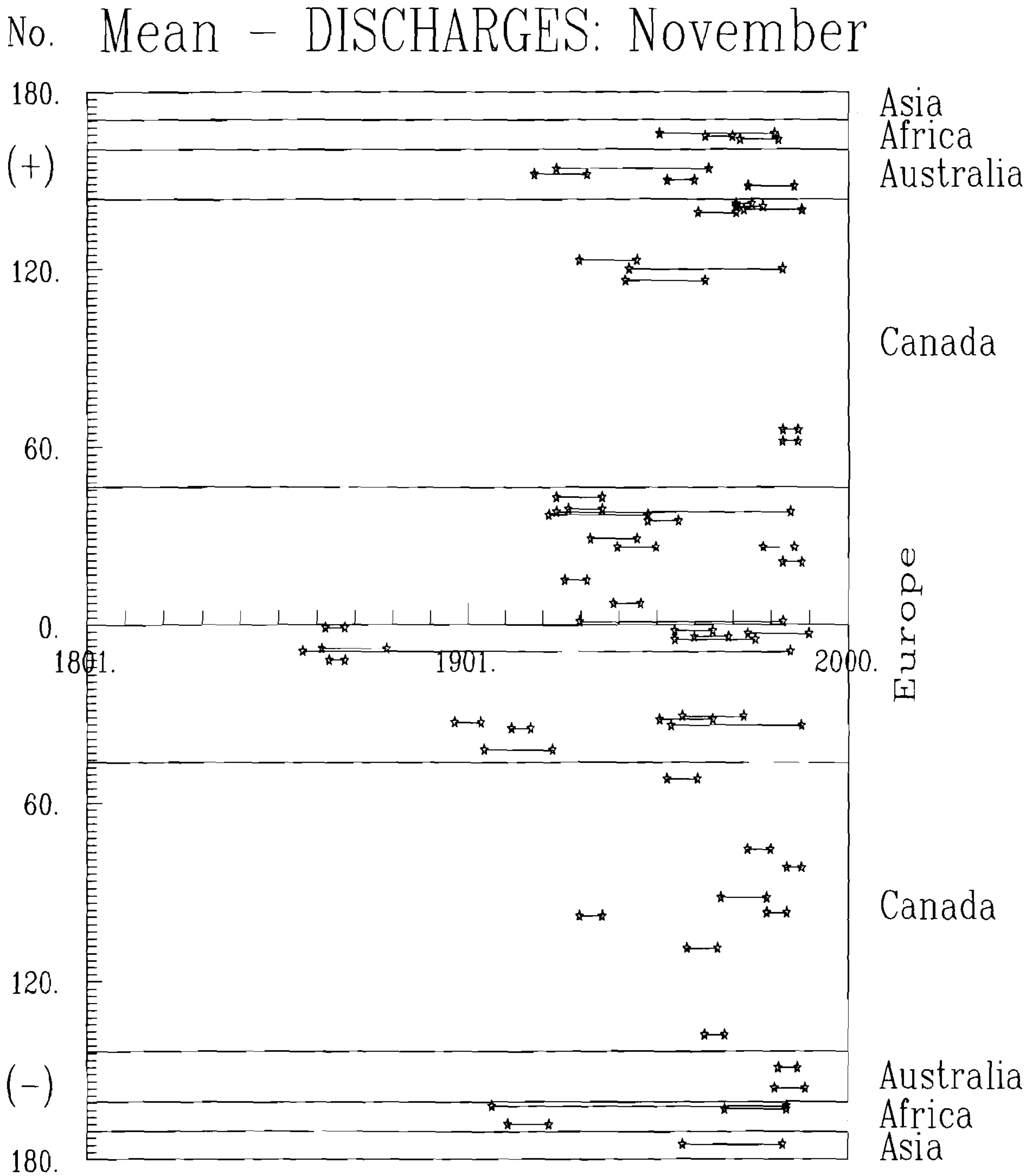

Fig. 11.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

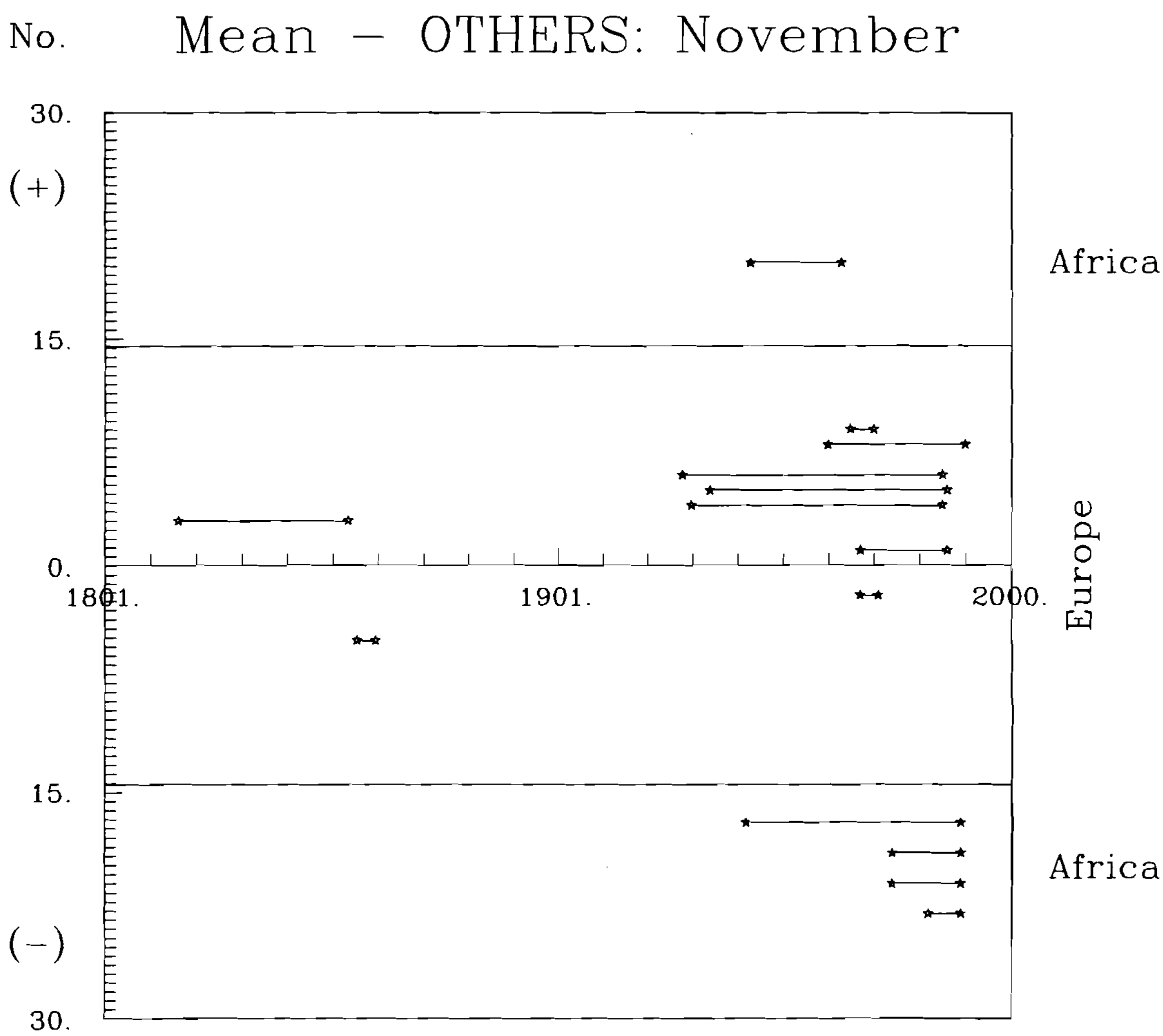

Fig. 11.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

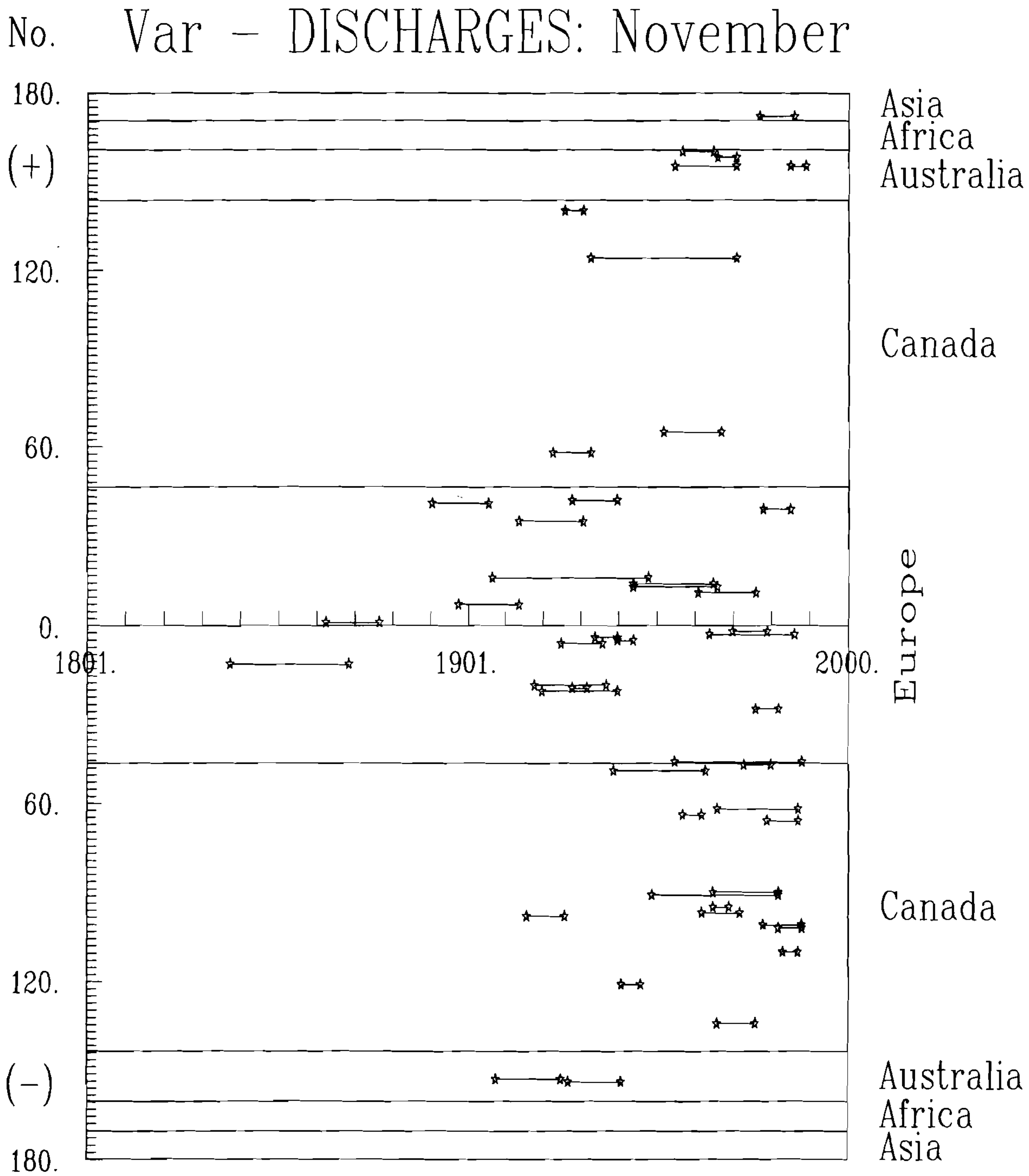

Fig. 11.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

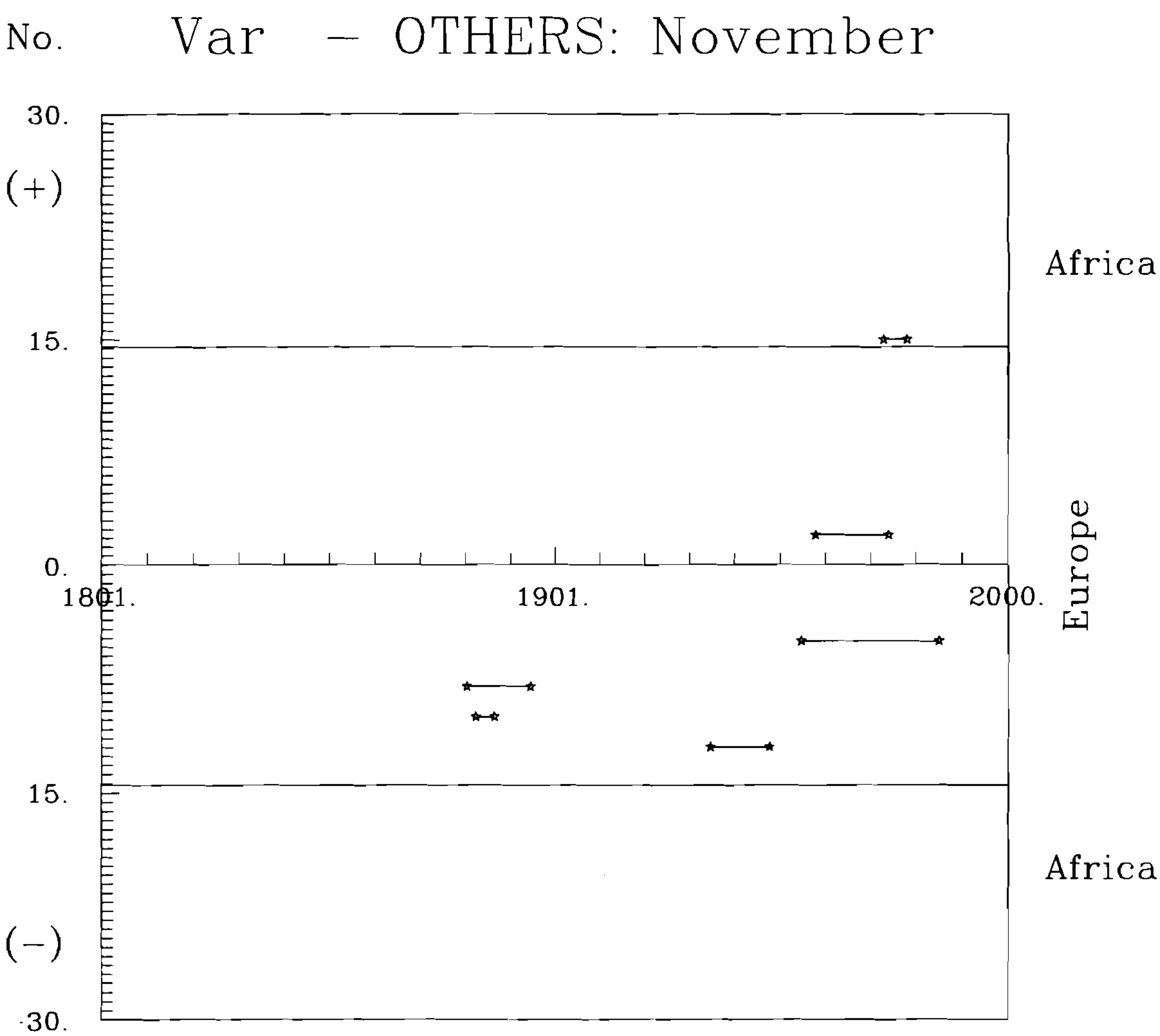

Fig. 11.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 12. RESULTS OF DECEMBER

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 60 % of cases for Africa, in 18.8 % for Australia, in ca. 10 % for Canada and Europe, in 0 % for Asia and in 14.2 % for all discharges; (b) of *the others* had to be rejected in 21.4 %, and 16 % of cases for Europe, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 12.4) that for about 80 % and 75 % of analyzed sequences of the discharges and *the others*, respectively, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 5.1 % and 0 % of cases of the discharges and of *the others*, respectively.

Tables 12.5 and 12.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 12.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 9.4 % and 4.5 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 9.8 % and 4.9 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean values slightly prevail over decreasing ones. Totally, in 17 % and 13.1 % of cases there occur growing and decreasing trends in mean value, respectively. For *the others*, decreasing and increasing trends in mean value are observed in 12 % and 32 % of cases, respectively.

Decreasing and increasing trends in variance have totally emerged for the discharges, respectively, in 15.3 % and 9.1 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 20 % to 12 % of cases.

For instance, trend in the mean value of the discharges appeared to decrease for Waser at Vlotho (No. 9), Belaya at Ufa (No. 42), and the Nile at Aswan Dam (No. 162) covering, respectively, 54 %, 76.9 %, and 48.1 % of the whole observation periods of 88, 83, and 78 years. Trend in the variance of the discharges was the decreasing for Salzach at Burghausen (No. 10), the Nile at Aswan Dam (No. 162), and Bug at Wyszkow (No. 32); it lasted 65, 35, and 32 years, respectively. However, for *the others*, trend in the mean value grows for temperatures at Warsaw (No. 6) and Pulawy (No. 8), and levels of Lake Vaenern at Sjoetorp (No. 3) during periods of 72, 37 and 40 years, respectively. Decreasing trend in the variance was observed for temperatures at Cracow (No. 4) and Warsaw (No. 6) during 74 and 44 years, respectively.

As it appears from the summarized results of Mann's test (Table 12.9), a trend has emerged in 30.1 % and 24.4 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in 44 % and 32 % of cases in the mean value and in the variance, respectively.

Table 12.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi-cient
Europe	5/10.9	5/12.2
Canada	11/11.5	2/11.1
Argentina	0/0	0/0
Australia	3/18.8	2/28.6
Africa	6/60.0	6/100
Asia	0/0	-
Total	25/14.2	15/20.5

Others:

Region	Run test	Test of autocorr. coeffi-cient
Europe	3/21.4	1/ 9.1
Africa	1/ 9.1	1/11.1
Total	4/16.0	2/10.0

Table 12.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	5/10.9	2/ 4.3
Canada	12/12.5	3/ 3.1
Argentina	0/0	0/0
Australia	5/31.3	0/0
Africa	8/80.0	4/40.0
Asia	3/42.9	0/0
Total	33/18.8	9/ 5.1

Others:

Region	Mean	Variance
Europe	4/28.6	0/0
Africa	2/18.2	0/0
Total	6/24.0	0/0

Table 12.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	2/14.3	2/ 5.7	2/ 4.7
Canada				0/0	0/0
Argentina				0/0	0/0
Australia				1/14.3	2/25.0
Africa			1/100	5/83.3	4/57.1
Asia					0/0
Total	0/0	0/0	3/20.0	8/13.1	8/ 7.1

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/16.7	1/10.0	0/0	3/23.1
Africa					0/0	1/ 9.1
Total	0/0	0/0	1/16.7	1/10.0	0/0	4/16.7

Table 12.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	2/ 5.7	2/ 4.7
Canada				0/0	1/ 2.0
Argentina				0/0	0/0
Australia				0/0	0/0
Africa			1/100	2/33.3	1/14.3
Asia					0/0
Total	0/0	0/0	1/ 6.7	4/ 6.6	4/ 3.6

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	1/16.7	0/0	0/0	0/0
Africa					0/0	1/ 9.1
Total	0/0	1/33.3	1/16.7	0/0	0/0	1/ 4.2

Table 12.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	6/ 5.7	4/ 3.8
Canada	0/0	1/ 1.6
Argentina	0/0	0/0
Australia	3/20.0	0/0
Africa	10/71.4	4/28.6
Asia	0/0	0/0
Total	19/ 9.4	9/ 4.5

Others:

Region	Mean	Variance
Europa	5/11.4	2/ 4.5
Africa	1/ 5.9	1/ 5.9
Total	6/ 9.8	3/ 4.9

Table 12.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	5/10.9	9/19.6	9/19.6	8/17.4
Canada	8/ 8.3	9/14.6	15/15.6	2/ 2.1
Argentina	0/0	0/0	0/0	0/0
Australia	4/25.0	4/25.0	2/12.5	1/ 6.3
Africa	5/50.0	2/20.0	1/10.0	3/30.0
Asia	1/14.3	1/14.3	0/0	2/28.6
Total	23/13.1	30/17.0	27/15.3	16/ 9.1

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	1/ 9.1	7/63.6	5/45.5	2/18.2
Africa	2/14.3	1/ 7.1	0/0	1/ 7.1
Total	3/12.0	8/32.0	5/20.0	3/12.0

Table 12.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	13/28.3	17/37.0
Canada	22/22.9	17/17.5
Argentina	0/0	0/0
Australia	8/50.0	3/18.8
Africa	7/70.0	4/40.0
Asia	2/28.6	2/28.6
Total	53/30.1	43/24.4

Others:

Region	Mean	Variance
Europa	8/72.7	7/63.6
Africa	2/14.3	1/ 7.1
Total	11/44.0	8/32.0

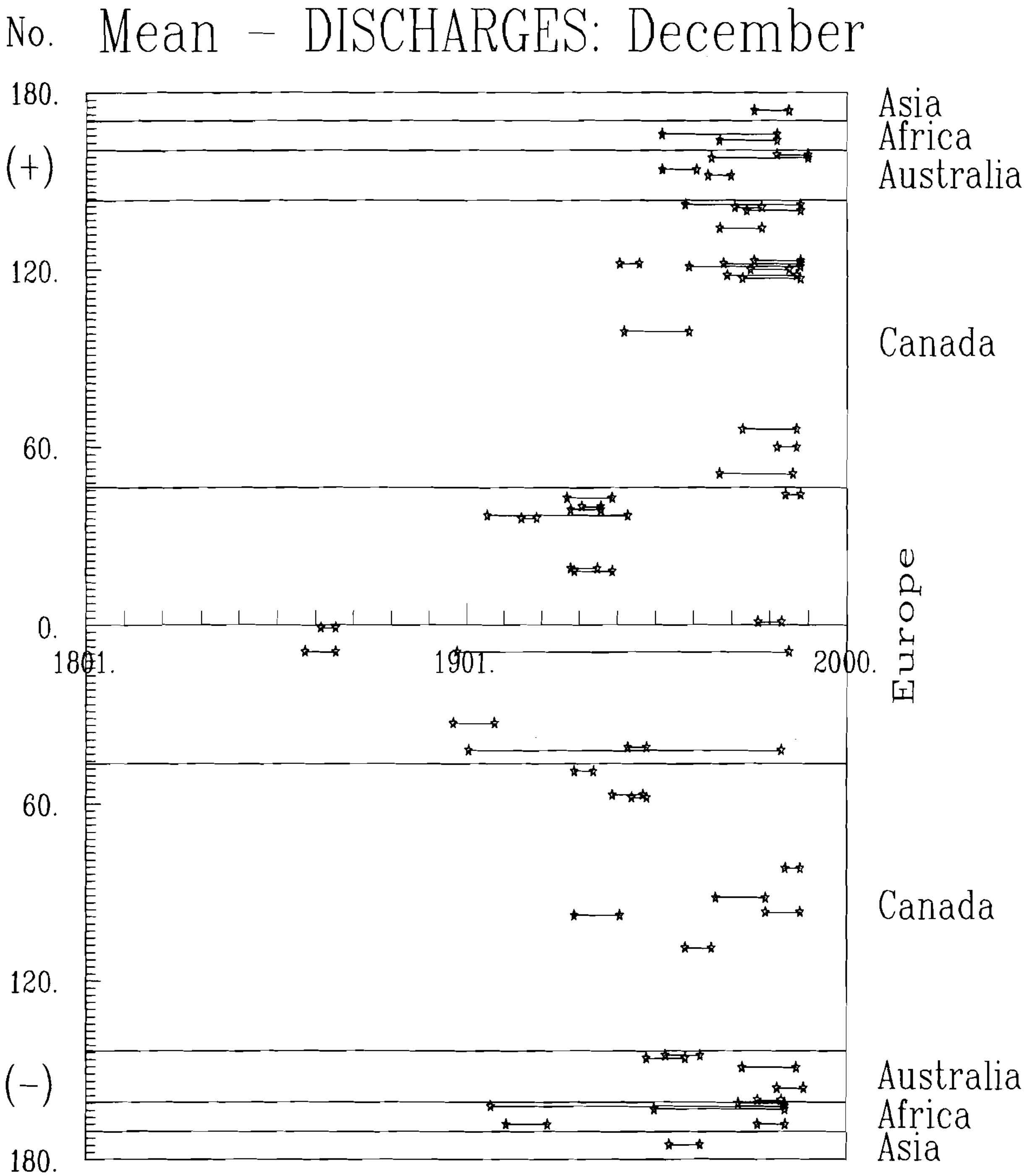

Fig. 12.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

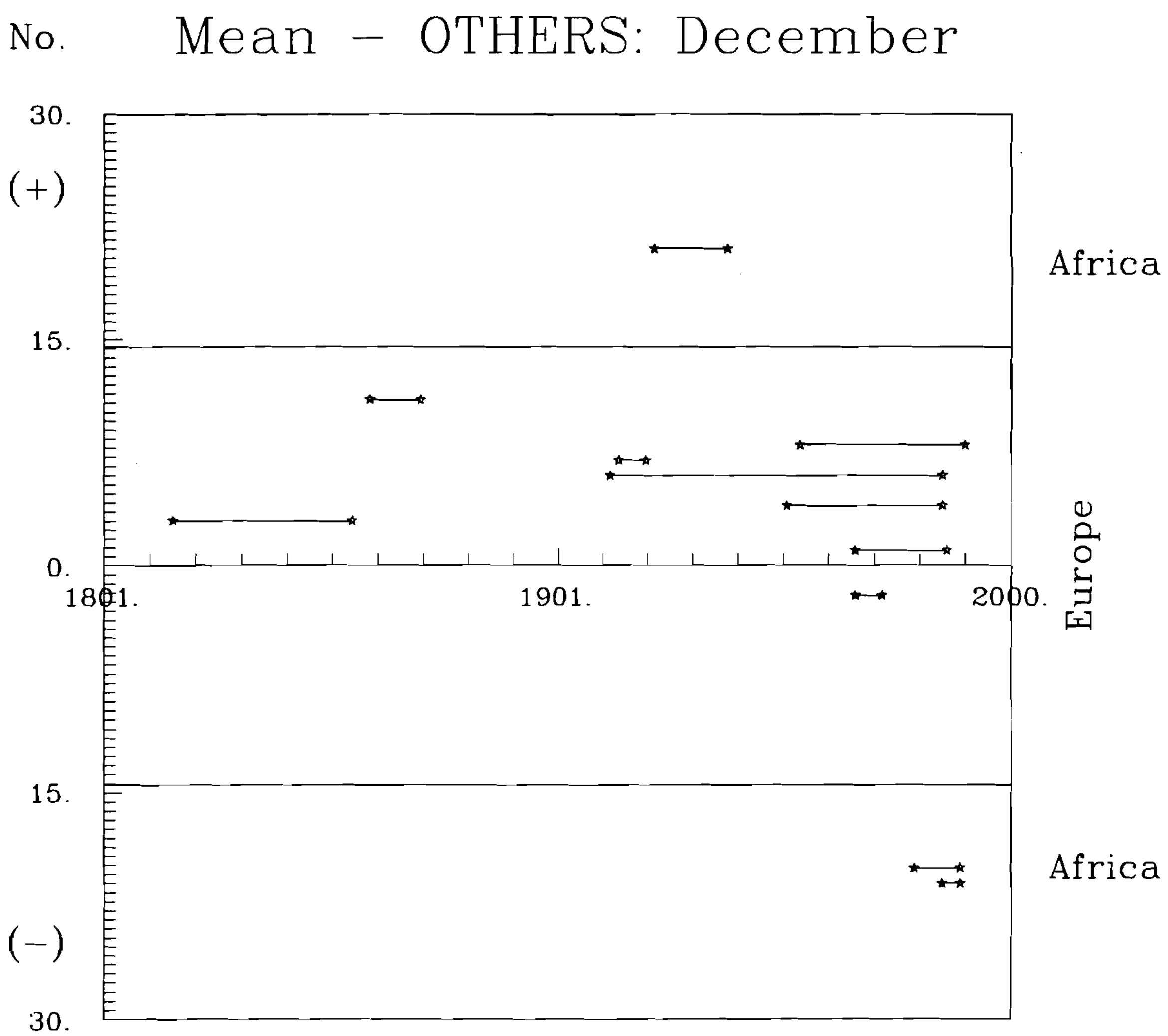

Fig. 12.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

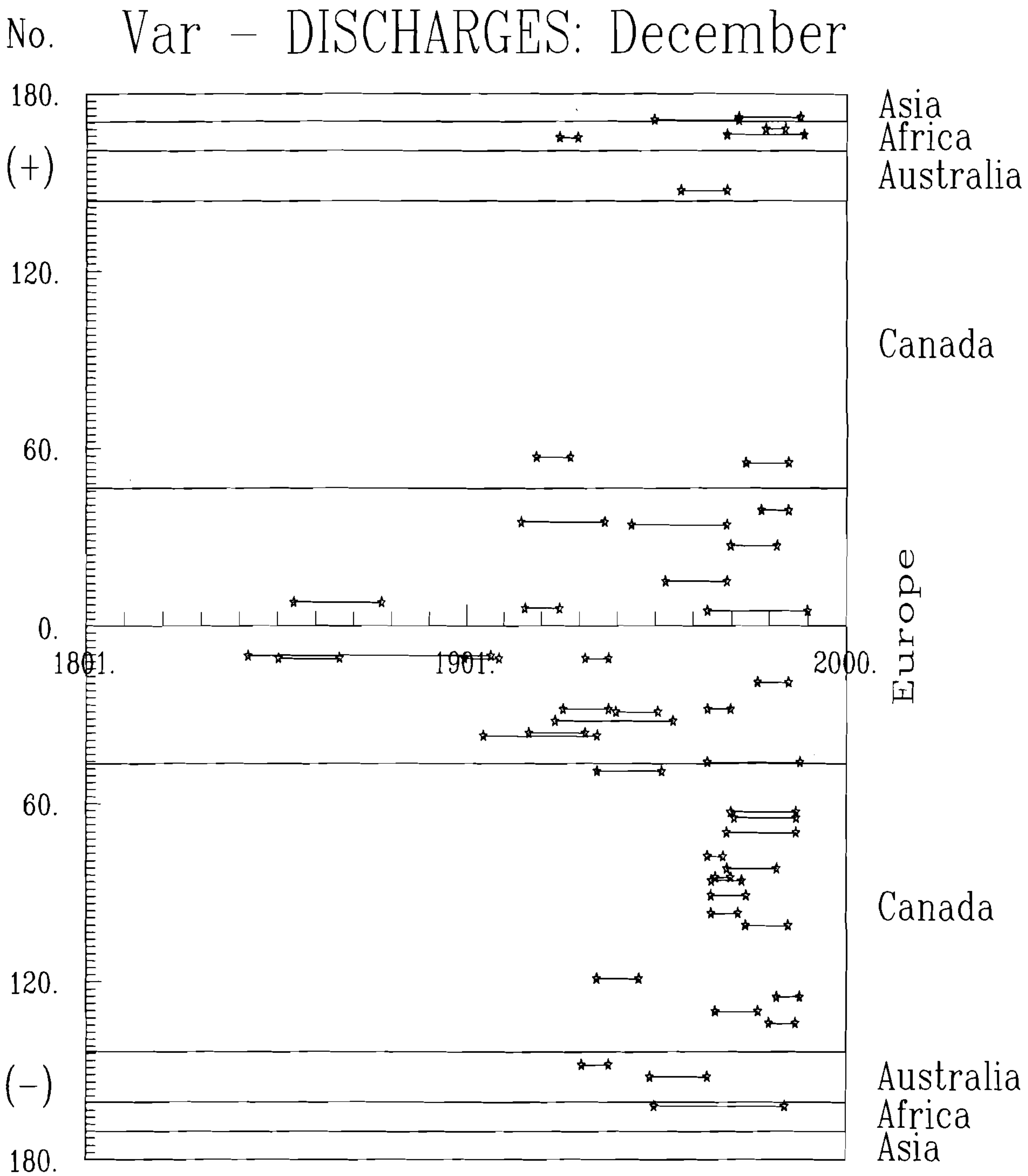

Fig. 12.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

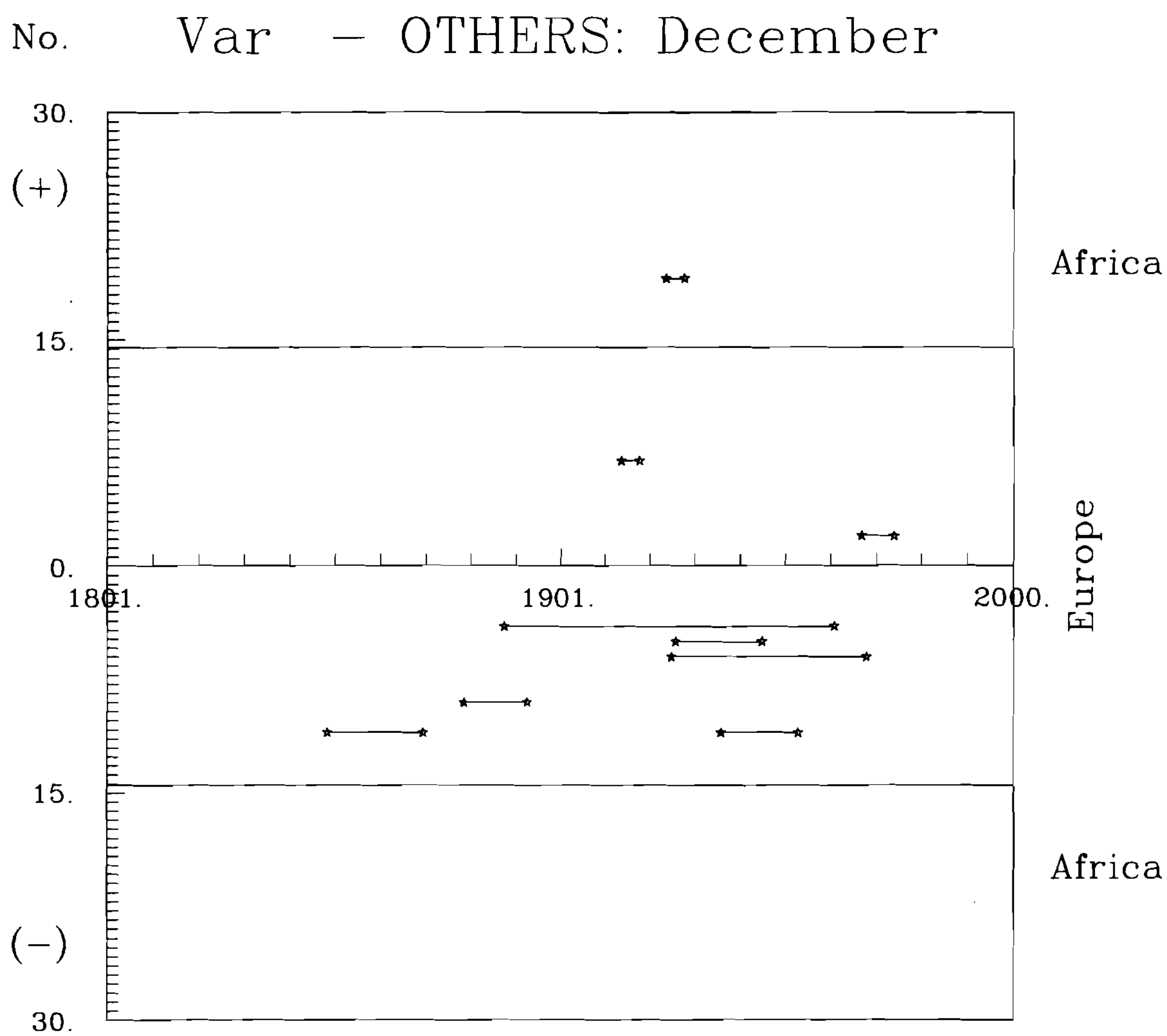

Fig. 12.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).

APPENDIX 13. ANNUAL RESULTS

From the results of the run test arise that the hypothesis about the independence of random variables (a) of the discharges had to be rejected in 80 % of cases for Africa, 34.8 % for Europe, 25 % for Australia, 17.7 % for Canada, 0 % for Asia, and in 26.1 % for all discharges; (b) of *the others* had to be rejected in 21.4 %, 0 %, and 12 % of cases for Europe, Africa, and the total, respectively.

It has appeared from the case A of Kruskall-Wallis's test (Table 13.4) that for about 75 % and 70 % of analyzed sequences of the discharges and *the others*, respectively, there was no ground for rejecting the hypothesis that the mean value is stationary and ergodic. Better results have been obtained for the assumption about the stationarity and ergodicity of variances. The assumption has been rejected in 5.7 % and 4 % of cases of the discharges and of *the others*, respectively.

Tables 13.5 and 13.6 show the distribution of the number of cases of the rejection of the hypothesis on the interval concerning identity of, respectively, the mean value and variance subintervals and of their percentage share in relation to all the cases of this hypothesis.

It follows from Table 13.7, which summarized the results of Kruskal-Wallis's test within the 30-year period (case (B)), that for the discharges in 14.9 % and 5.8 % of cases there occur fluctuations in the mean value and in the variance, respectively. However, for *the others* within the 30-year period, in 6.6 % and 9.8 % of cases there occur fluctuations in the mean value and in the variance, respectively. Those functions cannot be considered as admissible from the stationary and ergodic point of view.

Mann's test: for the discharges, increasing trends in mean values very slightly prevail over decreasing ones. Totally, in 22.7 % and 22.2 % of cases there occur growing and diminishing trends in the mean value, respectively. For *the others*, decreasing and increasing trends in the mean value are observed in 4 % and 56 % of cases, respectively.

Decreasing and increasing trends in variance have been the same for the total discharges. They emerged in 10.2 % of cases. However, for *the others*, decreasing and increasing trends in variance are totally in proportion 32 % to 28 % of cases.

For instance, trend in the mean value of the discharges appeared to grow for Namakan at outlet of Lac la Croix (station No. 140) and to decrease for Salzach at Burghausen (No. 10), Weser at Vlotho (No. 9) and the Nile at Aswan Dam (No. 162) covering, respectively, 69.7 %, 97 %, 78.5 %, and 70.2 % of the whole observation periods of 46, 156, 128, and 80 years. The trend in the variance of discharges was the growing for Warta at Gorzow (No. 26) as well as diminishing for the Nile at Aswan Dam (No. 162) and Weser at Vlotho (No. 9); it lasted 51, 68, and 56 years, respectively. However for *the others*, the trend in the mean value grows for temperatures in Warsaw (No. 6), Cracow (No. 4), Pulawy (No. 8), and Poznan (No. 5) covering periods of 100, 82, 75 and 72 years. Diminishing trend in the variance was observed for precipitation in Warsaw (No. 11) and temperature in Pulawy (No. 8) during 40 and 32 years, respectively.

As it appears from the summarized results of Mann's test (Table 13.9), a trend has emerged in 44.9 % and 20.5 % of cases of the total discharges in the mean value and in the variance, respectively. For total of *the others*, a trend has emerged in the same 60 % of cases in the mean value and in the variance.

Table 13.3. Results of the tests of the run and of autocorrelation coefficient

Discharges:

Region	Run test	Test of autocorr. coeffi-cient
Europe	16/34.8	17/41.5
Canada	17/17.7	4/22.2
Argentina	1/100	1/100
Australia	4/25.0	1/14.3
Africa	8/80.0	6/100
Asia	0/0	-
Total	46/26.1	29/39.7

Others:

Region	Run test	Test of autocorr. coeffi-cient
Europe	3/21.4	3/27.3
Africa	0/0	0/0
Total	3/12.0	3/15.0

Table 13.4. The results of Kruskal-Wallis's test (case (A))

Discharges:

Region	Mean	Variance
Europe	10/21.7	1/ 2.2
Canada	19/19.8	4/ 4.2
Argentina	0/0	0/0
Australia	4/25.0	1/ 6.3
Africa	7/70.0	3/30.0
Asia	1/14.3	1/14.3
Total	41/23.3	10/ 5.7

Others:

Region	Mean	Variance
Europe	6/42.9	1/ 7.1
Africa	2/18.2	0/0
Total	8/32.0	1/ 4.0

Table 13.5. The results Kruskal-Wallis's test for the mean values within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	5/14.3	3/ 7.0
Canada				2/16.7	6/12.0
Argentina				0/0	0/0
Australia				0/0	2/25.0
Africa			1/100	3/50.0	7/100
Asia					0/0
Total	0/0	0/0	2/13.3	10/16.4	18/16.1

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	0/0	0/0	0/0	0/0	3/23.1
Africa					0/0	1/ 9.1
Total	0/0	0/0	0/0	0/0	0/0	4/16.7

Table 13.6. The results Kruskal-Wallis's test for the variances within the successive 30-year intervals (case (B))

Discharges:

Region	1831	1861	1891	1921	1951
Europe	0/0	0/0	1/ 7.1	1/ 2.9	3/ 7.0
Canada				0/0	1/ 2.0
Argentina				0/0	1/100
Australia				0/0	0/0
Africa			0/0	1/16.7	2/28.6
Asia					0/0
Total	0/0	0/0	1/ 6.7	2/ 3.3	7/ 6.3

Others:

Region	1801	1831	1861	1891	1921	1951
Europe	0/0	1/33.3	1/16.7	2/20.0	1/ 9.1	0/0
Africa					0/0	1/ 9.1
Total	0/0	1/33.3	1/16.7	2/20.0	1/ 5.9	1/ 4.2

Table 13.7. The cumulated results of Kruskal-Wallis's test for the mean value and variance within the successive 30-year intervals (case (B))

Discharges:

Region	Mean	Variance
Europe	9/ 8.5	5/ 4.7
Canada	8/12.9	1/ 1.6
Argentina	0/0	1/100
Australia	2/13.3	0/0
Africa	11/78.6	3/21.4
Asia	0/0	0/0
Total	30/14.9	10/ 5.8

Others:

Region	Mean	Variance
Europa	3/ 6.8	5/11.4
Africa	1/ 5.9	1/ 5.9
Total	4/ 6.6	6/ 9.8

Table 13.8. The results of Mann's test for the mean value and the variance

Discharges:

Region	Mean		Variance	
	-	+	-	+
Europe	16/34.8	6/13.0	5/10.9	9/19.6
Canada	17/17.7	27/28.1	10/10.4	6/ 6.3
Argentina	0/0	0/0	0/0	0/0
Australia	2/12.5	3/18.8	0/0	2/12.5
Africa	3/30.0	3/30.0	2/20.0	0/0
Asia	1/14.3	1/14.3	1/14.3	1/14.3
Total	39/22.2	40/22.7	18/10.2	18/10.2

Others:

Region	Mean		Variance	
	-	+	-	+
Europe	0/0	9/81.8	7/63.6	5/45.5
Africa	1/ 7.1	5/35.7	1/ 7.1	2/14.3
Total	1/ 4.0	14/56.0	8/32.0	7/28.0

Table 13.9. The summary results of Mann's test

Discharges:

Region	Mean	Variance
Europe	21/45.7	14/30.4
Canada	42/43.8	16/16.7
Argentina	0/0	0/0
Australia	5/31.3	2/12.5
Africa	5/50.0	2/20.0
Asia	2/28.6	2/28.6
Total	79/44.9	36/20.5

Others:

Region	Mean	Variance
Europa	9/81.8	11/100
Africa	6/42.9	3/21.4
Total	15/60.0	15/60.0

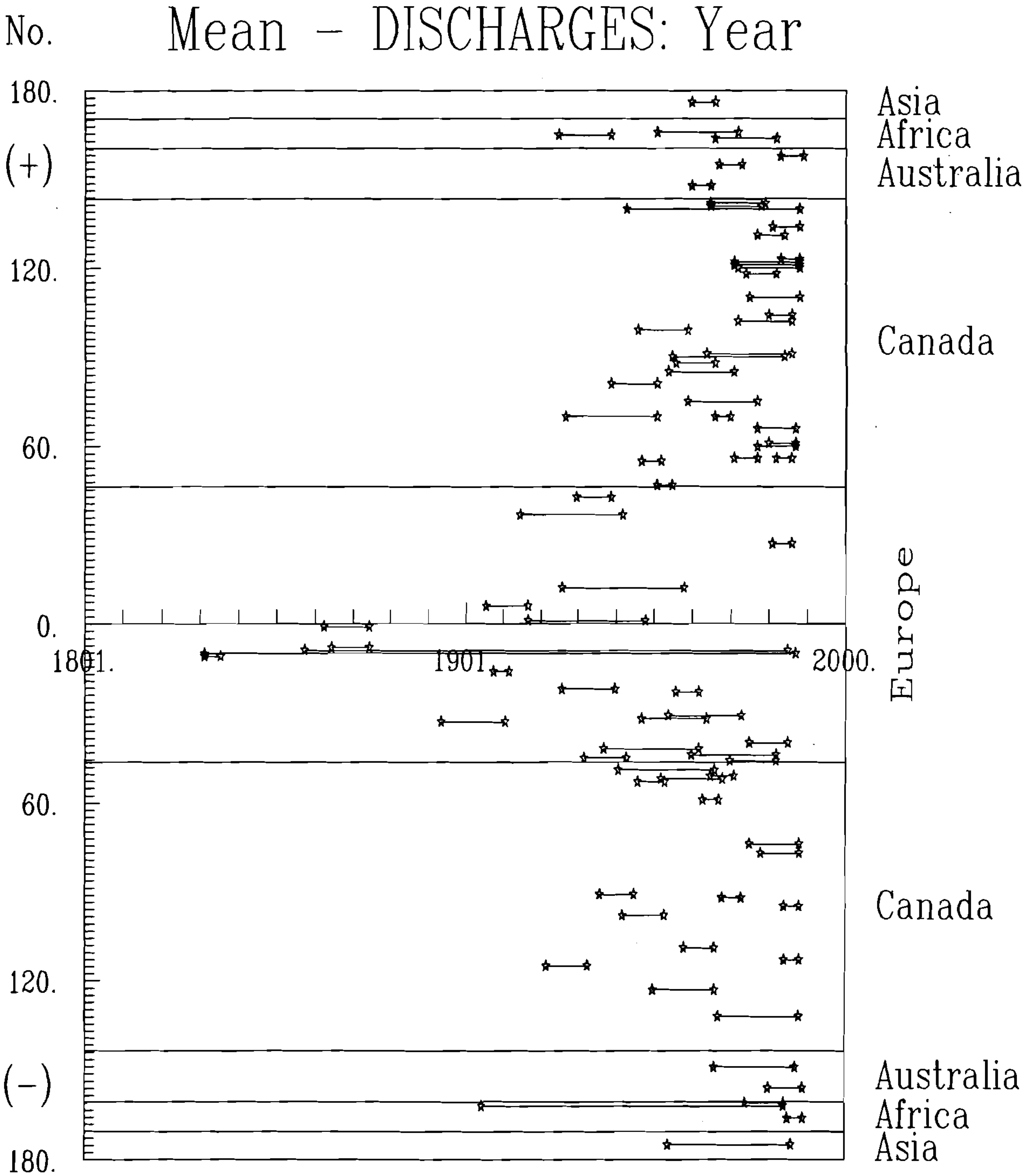

Fig. 13.1.a. Mann's test: the duration period of the assumed trends and of their directions in the mean value for the discharge phenomena (with a 5 % significant level).

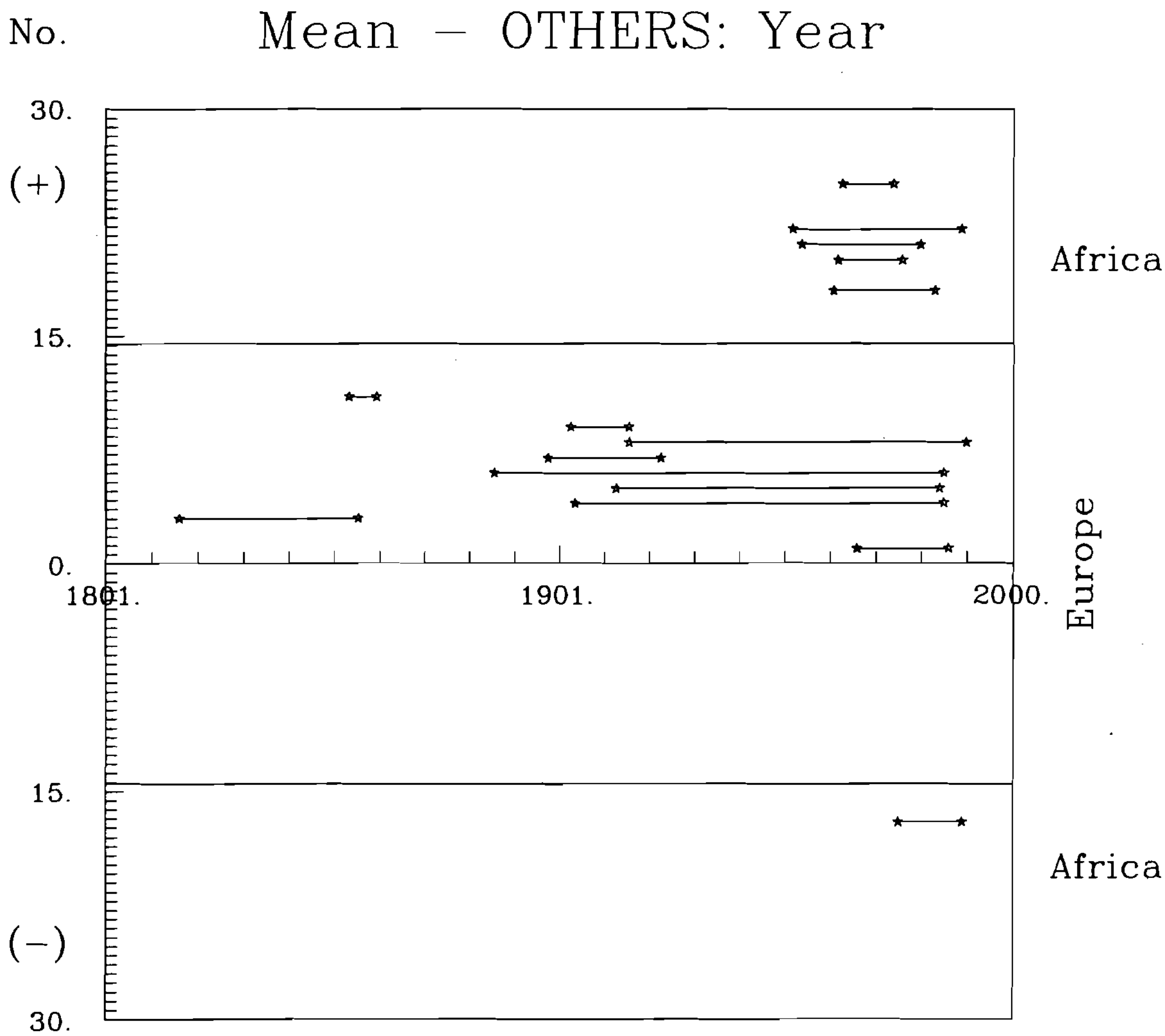

Fig. 13.1.b. Mann's test: the duration period of the assumed trends and of their directions in the mean value for *the other* phenomena (with a 5 % significance level).

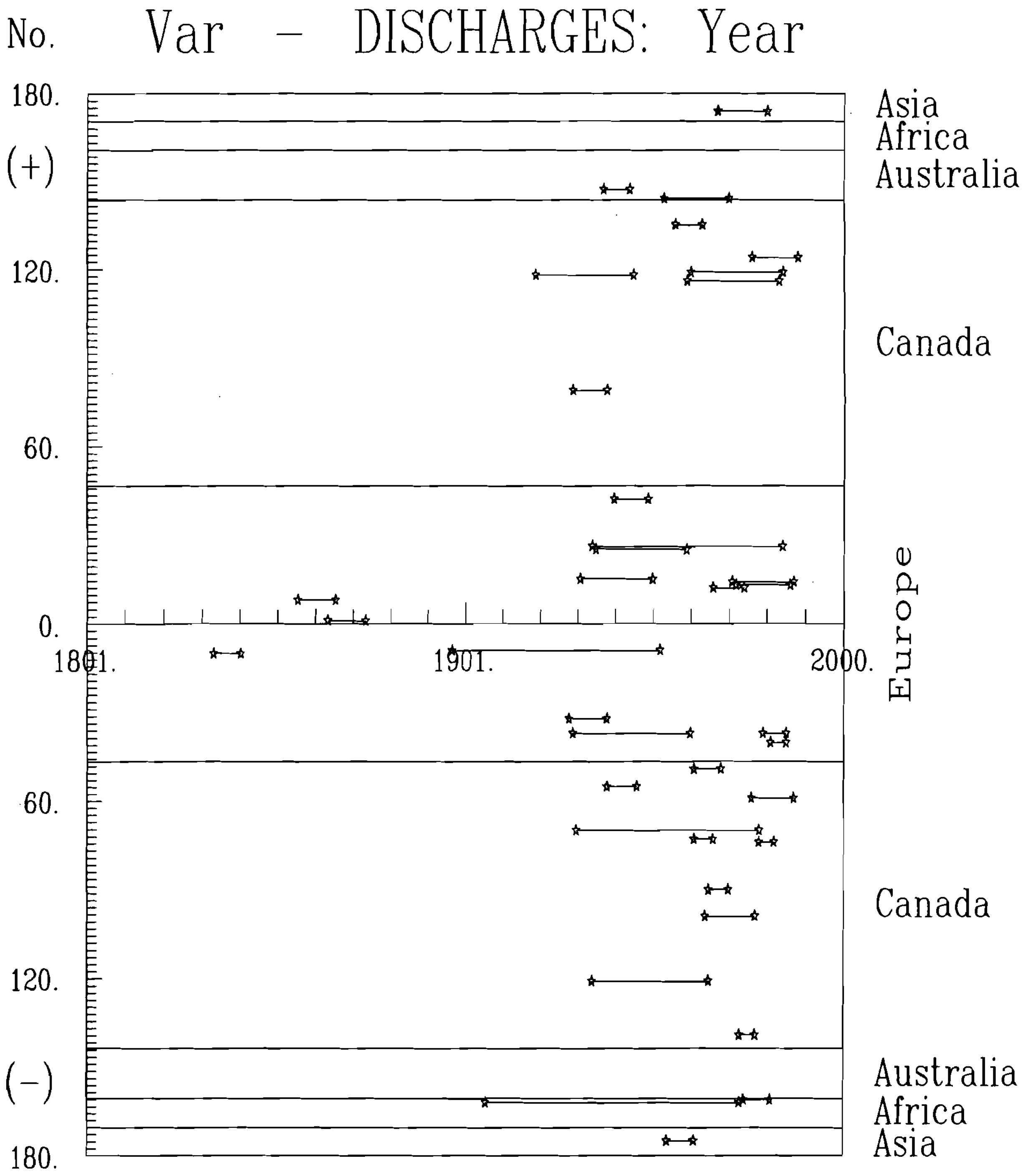

Fig. 13.2.a. Mann's test: the duration period of the assumed trends and of their directions in the variance for the discharge phenomena (with a 5 % significant level).

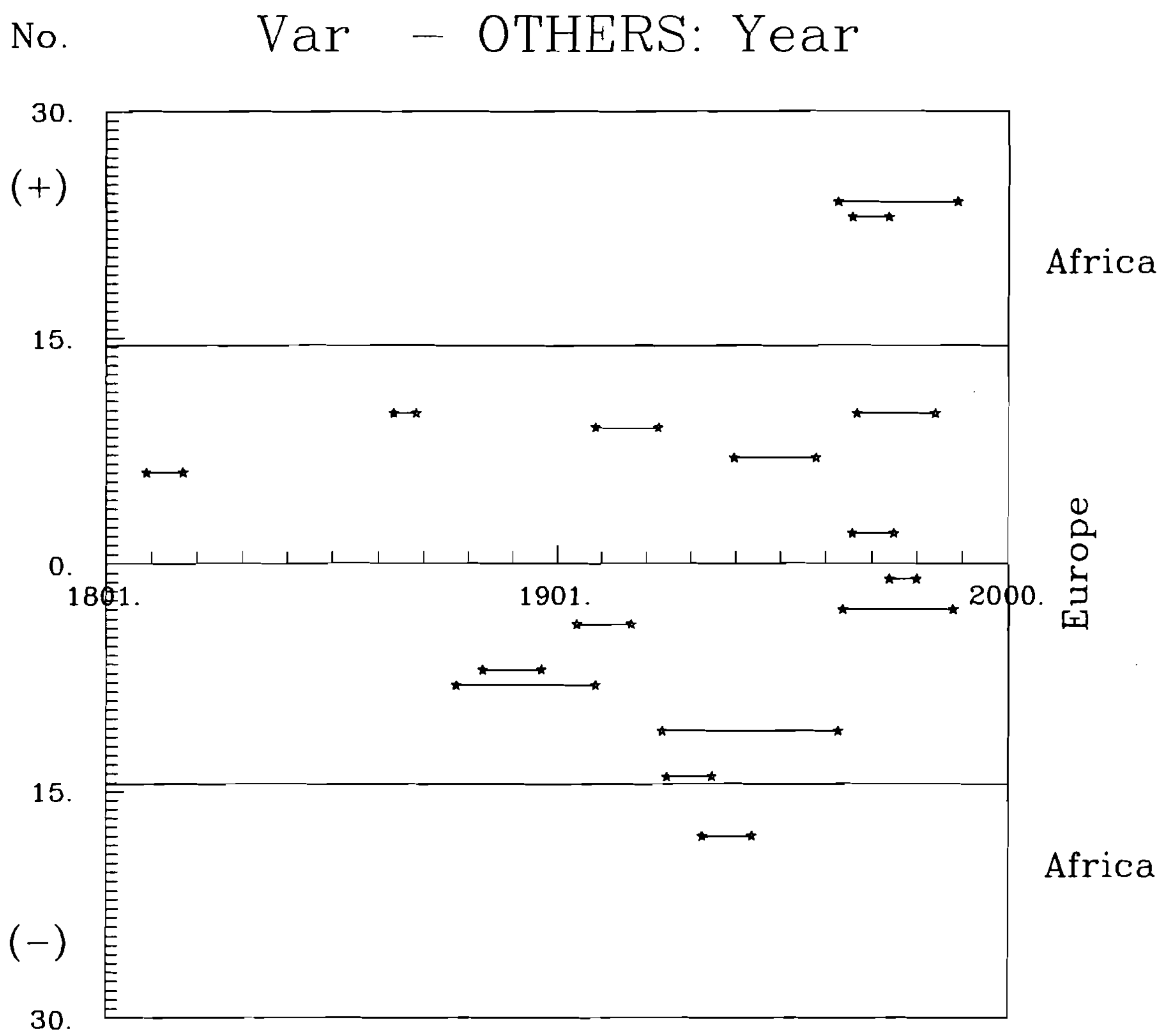

Fig. 13.2.b. Mann's test: the duration period of the assumed trends and of their directions in the variance for *the other* phenomena (with a 5 % significance level).