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A quantitative evaluation of the atmospheric circulation and a long-range forecast of the monthly pressure fields and temperatures over the North Atlantic area

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At the Leningrad State Meteorological Institute (LGMI) Department of Meteorological Forecasting, in cooperation with the AtlantNIRO and PINRO scientists and with the active participation of the senior students, research was carried out on the quantitative evaluation of aerial transportation and the intensity of cyclonic activity over the North Atlantic area. From the yearly weather maps of the northern hemisphere for 1901-1939 and 1949-1969, the monthly indices of the zonal and meridian circulations (I_3, I_m and I_M), were obtained, the monthly assembly charts of barometric formations constructed and the total estimate of the cyclonic-anticyclonic activity over the North Atlantic area between 30°N and 85°N computed.

A typical mean monthly barometric field was made and also several synoptic-statistical and dynamic-statistical diagrams were worked out for a long-range forecast of the monthly atmospheric pressure fields and air temperatures over the North Atlantic area.

The quantitative estimates of the atmospheric circulation for a great number of years will hopefully be used in the analysis of the macrosynoptical conditions for the formation of the hydrological and biological characteristics in the fishing area of the North Atlantic, while methods for the long-range weather forecasting,after they have been tested in the field, will be useful in fisheries planning for several months

To obtain reliable quantitative estimates of the aerial transportations and the cyclonic-anticyclonic activity at the sea level, the archives of the weather maps published by the US Weather Bureau (1901-1931) and the USSR State Meteorological Centre (1949-1969) were used (1,2). These maps are the most reliable source of information about the barometric-circulation regime over the oceans.

The atmospheric circulation indices, I_3, I_M, and I'_M, were calculated by the Kats' method (3). The zonal index of circulation, I_3, was calculated from the equation (1)

$$I_3 = \frac{b \quad ni}{(_2 - _1)\ i} \qquad (1)$$

where b is a value characterizing the isobars density (b=5 mb); ni is a sum of the negative (westerly) and positive (easterly) crossings of the isobar with the i - lengths of the meridians between the parallels $_1$ and $_2$.

When I_3 is calculated for some area (i=1) the index value and sign characterize the meridian pressure gradient averaged by area. If an index is calculated for one length of the meridian (i=1), it will be a characteristic of the pressure on the given length. A positive value of I_3 corresponds to the case when the westerly transportation prevails over the easterly one.

Monthly values of I_3 were obtained for 5 latitude zones: 30°-40°N, 40°-50°N, 60°-70°N, and 70°-85°N, in each zone for several lengths of meridian (totally 27 lengths). Such method of calculation makes it possible to obtain a quantitative estimate of zonal transportation for any month of a series of years for any North Atlantic area.

The indices of the meridian circulation I_M and I'_M were computed using equation (2):

$$I'_M = \frac{b_j m_j k_j}{(_2 - _1) j} , \qquad (2)$$

where m_j is a number of positive (southerly) and negative (northerly) crossings of the isobars with the lengths of the parallels between the longitudes and ; the multiplier k_j considers the convergence of the meridians. ?

The positive values of I_M correspond to the case when the southerly carrying-outs prevail over the northerly ones. The index I_M presents the intensity of the air exchange between latitudes and for its estimations "northerly" and "southerly" crossings are used with one sign.

The analysis of the monthly indices I_3, I_M, and I'_M made it possible to determine the characteristics of the yearly process of the zonal and meridian transportations in the various areas of the North Atlantic between 30°N and 85°N. Being unable here to go into details of these characteristics, we give as an example Tables 1 and 2 presenting the monthly values of I_3 on the length of the 50° meridian between 40°N and 50°N and of I'_M on the length of the 60° parallel between 40°W and 60°W for years 1957-1969.

Six areas with a total of about 3,000 thousand km^2 were chosen in the North Atlantic. By using daily weather maps we estimated the number of barometric formations of various intensity and made a total evaluation of the cyclonic-anticyclonic activity for each area in every month of the series of many years. The variations in the intensity of the cyclonic activity seem to be rather significant.

Table 3 presents the estimates of the cyclonic activity for the western area of the Atlantic (=35°N, =55°N; =65°W, =45°W). The positive values of I_2 correspond to the case when the cyclonic circulations prevail over the anticyclonic ones.

It is known that in making long-term meteorological prognoses, the synoptic-statistical methods are widely used. In the USSR, the field forecasts for the Arctic areas are made based on the methodical calculations of G. Ya. Vangheim's school (AANII method). We obtained synoptic-statistical diagrams of the long-term forecast of the monthly fields of pressure and air temperatures for the North Atlantic area (5.6). These diagrams present some of the probable versions in the application of the methodological suggestions by Vangheim's school to the North Atlantic areas. The predictors in the forecast diagrams are homologists of the circulation, large pressure anomalies in the North Atlantic area and characteristics of the air exchange in the northern hemisphere. The forecast is made in advance of 1-6 months.

The other rather independent direction is the use of the dynamic-statistical method (7.8). The forecast diagrams foresee the estimate of the prognosis values of the pressure and air temperature at several "basic" stations in the North Atlantic.

The temporal succession Q(t) is presented as a sum of harmonic oscillations with a continuous spectrum. Each oscillation is accidentally changeable in time.

The process pertains to a stationary accidental processes type, if the following conditions are observed.

1. Temporal succession Q(t) is stationary: Q = const. Mathematical expectation does not change in time.

2. The correlation function R(t) of the temporal series Q(t) depends only upon temporal displacement of r.

3. The problem of the prognosis is solved by bringing to the minimum the mean quadratic error.

The prognosis operation is linear and made by the equation (3)

$$Qt = \sum_{\bar{i}=m}^{n} K_m(L)\, q(t-\bar{i}) \qquad (3)$$

where Qt are members of the Q(t) series in deviation from $\bar{Q}$; m = advanceness of the prognosis; $K_m(L)$ are members of the extrapolation function, and n is a number of members in the extrapolation function.

The method can be named as linear prediction by method of the least squares of the stationary temporal series.

The test of the prognosis of the monthly pressure values was made on the "basic" stations in the North Atlantic using the materials for years 1946-1956. The methodical prognoses appeared to be efficient as compared with the level of "random prognoses".

It will also be interesting to experiment with the routine prognoses of the monthly pressure fields and air temperatures over the North Atlantic area.

It is advisable to encourage and coordinate similar work on the evaluation of the possibility of using various methods for a prognosis of weather conditions in the North Atlantic area several months in advance.

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Table I

Monthly values of the zonal circulation index, I_3, on the 50°W meridian in the zone of 40°-50°N

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1957	1.10	0.75	-0.09	0.90	0.73	0.69	0.58	0.82	0.55	0.39	0.35	0.82
1958	-0.40	0.16	-0.67	0.40	0.24	1.34	1.00	1.52	0.77	0.43	1.09	0.75
1959	1.07	1.23	1.21	0.57	0.60	0.23	0.98	0.28	0.65	0.45	0.71	0.95
1960	0.32	-0.40	0.58	0.89	0.17	0.56	1.00	0.85	0.60	0.54	0.85	0.71
1961	0.13	0.63	-0.07	0.50	0.45	1.06	0.83	0.71	0.67	0.71	-0.02	0.76
1962	1.56	0.33	-0.21	0.96	-0.02	0.68	0.38	0.61	0.30	0.68	0.07	0.74
1963	0.22	0.76	0.84	0.48	0.72	0.74	0.59	0.61	0.41	0.75	0.60	1.04
1964	1.34	1.02	0.64	0.69	0.74	0.73	0.68	0.45	0.97	0.61	0.80	0.14
1965	0.82	0.14	1.00	0.72	0.38	0.88	0.98	0.61	0.76	0.90	0.47	0.85
1966	0.34	1.13	0.54	0.45	1.01	1.10	0.85	0.87	0.69	0.77	-0.28	0.35
1967	0.67	1.20	0.14	0.15	0.29	0.88	1.11	1.27	0.28	0.61	0.52	-0.05
Mean	0.68	0.63	0.55	0.61	0.48	0.80	0.81	0.78	0.59	0.62	0.47	0.64

Table 2 Monthly values of the meridian circulation index I_M' of the 50°N parallel in the zone of 40°-60°N

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1957	-1.92	4.17	-0,82	-0.73	-0.24	0.14	0.[illegible]9	0.38	0.53	-1.13	[illegible].55	0.05
1958	-0.57	0.19	0.94	-0.87	0.85	0.04	0.54	0.17	-0.74	-1.08	-0.68	0.15
1959	0.43	-0.90	-1.76	-0.58	0.00	-0.12	0.37	0.13	0.28	-1.14	0.51	-0.69
1960	-0.62	-0.38	-0.39	-0.76	0.16	0.46	0.37	0.72	-0.45	0.71	-0.80	-0.12
1961	-0.85	-1.33	-0.90	-1.06	0.01	0.05	0.[illegible]	-0.15	-0.97	0.67	0.45	[illegible]
1962	-0.67	-0.51	-0.02	-0.58	0.19	-0.05	0.25	0.05	-0.33	-0.59	-0.17	-0.24
1963	0.96	0.31	-1.46	-0.51	-0.15	0.07	0.22	[illegible].43	-0.36	-0.84	-0.28	0.15
1964	-0.55	-0.06	-1.44	-0.42	-0.49	0.25	-0.17	0.28	0.29	-0.46	-[illegible].39	-0.57
1965	-0.87	0.73	-0.28	-0.58	0.27	-0.27	0.48	0.18	0.01	-0.32	0.38	-1.10
1966	-1,12	-0.57	0.74	[illegible]	-0.17	0.[illegible]2	0.50	0.2	0.10	0.97	[illegible]	-0.80
1967	-0.69	-1.37	-1.20	-0.65	-0.67	-0.37	0.07	0.05	-[illegible].05	-0.61	[illegible].34	-0.30
Mean	-0.59	-0.43	-0.59	-0.69	0.10	0.02	0.27	0.22	-0.15	-0.33	-0.09	-0.33

Table 3 — Estimate of the intensity of the cyclonic activity in the western area (I_z)

	I	II	III	IY	Y	YI	YII	YIII	IX	X	XI	XII
I90I	I02	I24	78	-56	-56	-I7	23	-38	-60	42	46	II2
I902	88	94	I02	-32	-I2	I0	47	-28	-79	24	64	68
I903	I22	88	-62	-4	-33	-6	I8	-32	-44	46	-22	I22
I904	II4	50	22	-62	-29	-33	6	-73	-60	-28	II0	I02
I905	64	94	52	-9	-56	-6	I	-49	-49	76	I26	84
I906	76	I2	78	I4	-29	3	I6	-84	-9	74	I68	58
I907	72	36	II6	-22	-I2	-3	60	-I8	-26	4	I0	28
I908	52	I04	I6	-67	-30	-26	24	-37	-56	-I6	44	52
I9I0	-I0	62	-34	-46	-27	I5	-59	-85	-3I	-I0	I58	72
I9II	38	I24	48	32	-43	-23	-7I	-84	-75	36	42	74
I9I2	I28	I46	28	-63	-92	25	-54	-4I	-2I	76	36	4
I9I3	-6	II8	-64	9	-II	5	-47	-I09	-36	-48	30	I26
I9I4	I66	52	92	34	-27	-42	-60	-I03	3I	28	32	I4
I9I5	-6	78	I34	-30	44	-35	-II3	-36	I3	-40	I50	92
I9I6	86	-	I78	3I	22	-I5	-I09	-53	-37	-6	68	I74
I9I7	72	66	I32	77	33	-I3I	-87	-II8	-	-36	I34	I50
I9I8	I40	50	I78	I3	-26	-I9	-45	-3	-47	I2	II2	84
I9I9	98	I88	I32	-40	-54	-27	-93	-76	-6I	38	60	72
I920	I46	-6	I38	27	-33	-62	-I24	-III	-46	88	38	76
I92I	72	I06	36	-33	-32	-II	-73	-20	-53	54	64	82
I922	36	2	-I0	20	-	-I43	-I0I	-I05	-39	-I6	2I2	62
I923	I48	II0	-76	-46	-26	43	-73	-8	-43	-48	-	I08
I924	-44	I68	I30	28	-60	-68	-II0	-I22	-39	II6	22	56
I925	62	-32	84	37	-8I	-74	-48	-24	-59	I06	24	I34
I926	74	I28	I94	-23	I8	-I2	-73	-37	-I8	30	-2I2	I70
I927	-I2	II6	30	20	28	42	-I63	-64	-	46	-80	82
I928	56	62	I62	-I7	-I4	-30	-80	-48	-76	20	I40	20
I929	78	72	70	-23	-I26	-I7	-97	-6I	-66	-I6	I00	-I8
I930	-22	-2	I4	-40	7	-	-3I	-46	-2I	66	I2	60

Table 3 (Continued)

	I	II	III	IУ	У	УI	УII	УIII	IX	X	XI	XII
I93I	82	70	I64	-40	-73	-	-25	-52	-9I	-	56	I44
I932	62	I08	I38	9	-26	-26	-5	-58	-55	26	50	-I6
I933	90	48	II6	-7I	-27	-II	-	-62	-22	52	-I0	56
I934	2	-2	22	-33	-74	-24	-47	-89	-I0I	68	I30	I70
I935	I2	38	II0	-58	-I3	-36	-58	-60	-I8	-66	-34	I74
I936	I02	32	-I6	-69	-49	-4I	-44	-29	-3I	-I8	-44	-40
I937	-60	I56	70	-2	-32	- 4	-83	-I0I	-35	-72	22	26
I938	44	I06	92	-84	-2I	-82	-II2	-53	-79	22	-26	I02
I939	98	28	80	38	-	-	-	-	-	-	-	-
I949	I4	90	66	-23	50	-26	I4	-4I	-33	-I4	80	66
I950	24	I50	I78	33	2	-I	-52	-6	2	56	2	76
I95I	II6	I06	I64	50	-7	-3	-39	3	-28	I32	I24	II4
I952	88	242	I62	-5I	22	-5	-23	-59	-I3	90	54	2I4
I953	I55	48	II8	3I	50	-27	-34	-I3	-40	-I0	86	54
I954	I48	I02	I48	33	-25	29	-65	-I4	-65	42	72	96
I955	3I4	II8	II8	38	9	-II	-46	-52	-29	I26	242	I76
I956	I94	I80	I54	I	-26	2	-29	3	-43	76	8	80
I957	70	92	I98	-56	79	-I4	I0	-49	-I5	I26	82	I2
I958	I28	I62	202	89	-35	3	36	-I5	-35	I38	36	50
I959	I96	I30	44	43	-	- I	-6I	-I7	-I	62	-	84
I960	234	I44	208	55	39	-23	-I8	2	-88	I02	84	II2
I96I	I54	I84	206	- 8	64	- 8	-29	-27	-74	60	42	204
I962	-6	I96	332	93	-38	-I6	-I5	-3I	-20	56	94	I54
I963	I20	-24	I76	-53	-37	2	-68	40	-39	46	94	66
I964	I40	I62	I72	63	-5	I4	-49	-54	-53	I68	I0	I94
I965	I36	230	226	28	56	2	-3I	-25	-2I	72	-6	I58
I966	I80	I32	I36	56	33	-70	-2	-23	-I8	90	I22	-
I967	66	46	I46	55	-5	-92	-79	-I00	-48	-	-	-