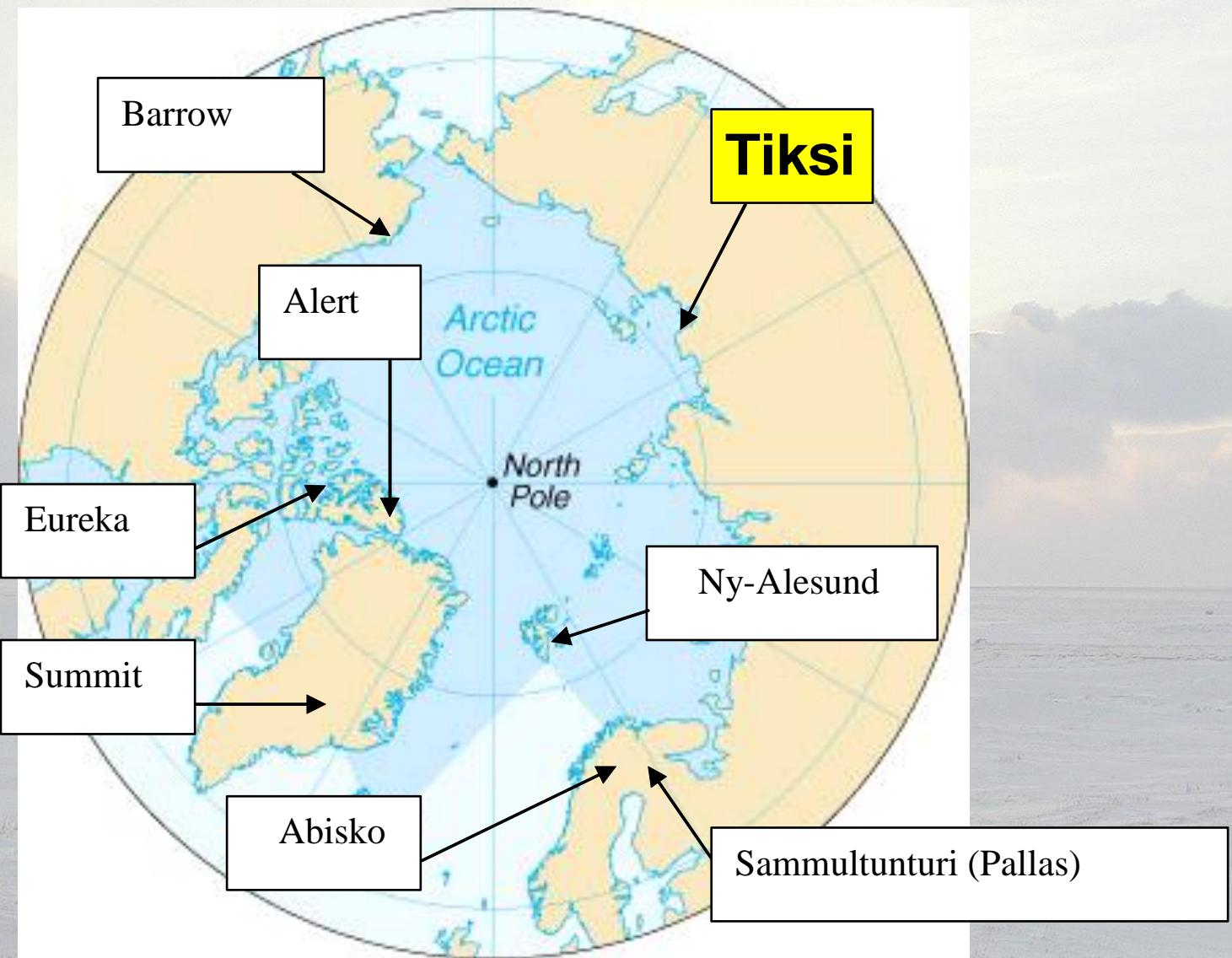


Climate of Tiksi region from the historical instrument records of surface and upper air observations

N. Ivanov, I. Bolshakova, O. Zukova, A. Makshtas



The Tiksi Hydrometeorological Observatory is designed for co-location of observations supporting networks such as BSRN, GAW, UV-NET, CRN, AeroNET, MPLNET and others (including permafrost and other measurements)

Existing positions of meteorological and radiosounding observations



Standard surface meteorological observations have been made with consistent methods since 1934



Radiosoundings in “ Polarka” started in 1935 and continue to present



The historical Tiksi data sets have recently been digitized
Example of original table of meteorological data (January 1966)

Номер		Номер		Год		Месяц		Дендротайм зернистого пояса		Срок		Московское время	
(1, 2, 3, 4, 5, 6)		(7, 8, 9, 10)		(11, 12)		(13, 14)		(15, 16)		(17, 18)		(19, 20)	
Номер	Температура воздуха	Номер	Температура воздуха	Номер	Температура воздуха	Номер	Температура воздуха	Номер	Температура воздуха	Номер	Температура воздуха	Номер	Температура воздуха
Номер	Сентябрь	Номер	октябрь	Номер	ноябрь	Номер	декабрь	Номер	январь	Номер	февраль	Номер	март
1	-40.0	2	-38.2	3	-37.1	4	-36.2	5	-35.0	6	-34.0	7	-33.0
8	-32.5	9	-30.2	10	-28.1	11	-26.2	12	-24.0	13	-22.0	14	-20.0
15	-19.5	16	-17.2	17	-15.1	18	-13.2	19	-11.0	20	-8.8	21	-6.5
22	-6.5	23	-4.2	24	-2.1	25	0.0	26	2.0	27	4.0	28	6.0
29	8.0	30	10.0	31	12.0	32	14.0	33	16.0	34	18.0	35	20.0
36	22.0	37	24.0	38	26.0	39	28.0	40	30.0	41	32.0	42	34.0
43	36.0	44	38.0	45	40.0	46	42.0	47	44.0	48	46.0	49	48.0
50	50.0	51	52.0	52	53.0	53	54.0	54	55.0	55	56.0	56	57.0
57	58.0	58	59.0	59	60.0	60	61.0	61	62.0	62	63.0	63	64.0
64	65.0	65	66.0	66	67.0	67	68.0	68	69.0	69	70.0	70	71.0
72	72.0	72	73.0	73	74.0	74	75.0	75	76.0	76	77.0	77	78.0
79	79.0	80	81.0	81	82.0	82	83.0	83	84.0	84	85.0	85	86.0
87	87.0	88	89.0	89	90.0	90	91.0	91	92.0	92	93.0	93	94.0
95	95.0	96	97.0	97	98.0	98	99.0	99	100.0	100	101.0	101	102.0
103	103.0	104	105.0	105	106.0	106	107.0	107	108.0	108	109.0	109	110.0
111	111.0	112	113.0	113	114.0	114	115.0	115	116.0	116	117.0	117	118.0
119	119.0	120	121.0	121	122.0	122	123.0	123	124.0	124	125.0	125	126.0
127	127.0	128	129.0	129	130.0	130	131.0	131	132.0	132	133.0	133	134.0
135	135.0	136	137.0	137	138.0	138	139.0	139	140.0	140	141.0	141	142.0
143	143.0	144	145.0	145	146.0	146	147.0	147	148.0	148	149.0	149	150.0
152	152.0	153	154.0	154	155.0	155	156.0	156	157.0	157	158.0	158	159.0
161	161.0	162	163.0	163	164.0	164	165.0	165	166.0	166	167.0	167	168.0
169	169.0	170	171.0	171	172.0	172	173.0	173	174.0	174	175.0	175	176.0
178	178.0	179	180.0	180	181.0	181	182.0	182	183.0	183	184.0	184	185.0
187	187.0	188	189.0	189	190.0	190	191.0	191	192.0	192	193.0	193	194.0
196	196.0	197	198.0	198	199.0	199	200.0	200	201.0	201	202.0	202	203.0
205	205.0	206	207.0	207	208.0	208	209.0	209	210.0	210	211.0	211	212.0
217	217.0	218	219.0	219	220.0	220	221.0	221	222.0	222	223.0	223	224.0
229	229.0	230	231.0	231	232.0	232	233.0	233	234.0	234	235.0	235	236.0
237	237.0	238	239.0	239	240.0	240	241.0	241	242.0	242	243.0	243	244.0
249	249.0	250	251.0	251	252.0	252	253.0	253	254.0	254	255.0	255	256.0
257	257.0	258	259.0	259	260.0	260	261.0	261	262.0	262	263.0	263	264.0
266	266.0	267	268.0	268	269.0	269	270.0	270	271.0	271	272.0	272	273.0
278	278.0	279	279.0	279	280.0	280	281.0	281	282.0	282	283.0	283	284.0
287	287.0	288	289.0	289	290.0	290	291.0	291	292.0	292	293.0	293	294.0
299	299.0	300	301.0	301	302.0	302	303.0	303	304.0	304	305.0	305	306.0
307	307.0	308	309.0	309	310.0	310	311.0	311	312.0	312	313.0	313	314.0
319	319.0	320	321.0	321	322.0	322	323.0	323	324.0	324	325.0	325	326.0
327	327.0	328	329.0	329	330.0	330	331.0	331	332.0	332	333.0	333	334.0
339	339.0	340	341.0	341	342.0	342	343.0	343	344.0	344	345.0	345	346.0
347	347.0	348	349.0	349	350.0	350	351.0	351	352.0	352	353.0	353	354.0
356	356.0	357	358.0	358	359.0	359	360.0	360	361.0	361	362.0	362	363.0
368	368.0	369	370.0	370	371.0	371	372.0	372	373.0	373	374.0	374	375.0
377	377.0	378	379.0	379	380.0	380	381.0	381	382.0	382	383.0	383	384.0
389	389.0	390	391.0	391	392.0	392	393.0	393	394.0	394	395.0	395	396.0
397	397.0	398	399.0	399	400.0	400	401.0	401	402.0	402	403.0	403	404.0
405	405.0	406	407.0	407	408.0	408	409.0	409	410.0	410	411.0	411	412.0
417	417.0	418	419.0	419	420.0	420	421.0	421	422.0	422	423.0	423	424.0
429	429.0	430	431.0	431	432.0	432	433.0	433	434.0	434	435.0	435	436.0
437	437.0	438	439.0	439	440.0	440	441.0	441	442.0	442	443.0	443	444.0
449	449.0	450	451.0	451	452.0	452	453.0	453	454.0	454	455.0	455	456.0
457	457.0	458	459.0	459	460.0	460	461.0	461	462.0	462	463.0	463	464.0
466	466.0	467	468.0	468	469.0	469	470.0	470	471.0	471	472.0	472	473.0
478	478.0	479	479.0	479	480.0	480	481.0	481	482.0	482	483.0	483	484.0
487	487.0	488	489.0	489	490.0	490	491.0	491	492.0	492	493.0	493	494.0
499	499.0	500	501.0	501	502.0	502	503.0	503	504.0	504	505.0	505	506.0
507	507.0	508	509.0	509	510.0	510	511.0	511	512.0	512	513.0	513	514.0
519	519.0	520	521.0	521	522.0	522	523.0	523	524.0	524	525.0	525	526.0
527	527.0	528	529.0	529	530.0	530	531.0	531	532.0	532	533.0	533	534.0
539	539.0	540	541.0	541	542.0	542	543.0	543	544.0	544	545.0	545	546.0
547	547.0	548	549.0	549	550.0	550	551.0	551	552.0	552	553.0	553	554.0
556	556.0	557	558.0	558	559.0	559	560.0	560	561.0	561	562.0	562	563.0
568	568.0	569	569.0	569	570.0	570	571.0	571	572.0	572	573.0	573	574.0
577	577.0	578	579.0	579	580.0	580	581.0	581	582.0	582	583.0	583	584.0
589	589.0	590	591.0	591	592.0	592	593.0	593	594.0	594	595.0	595	596.0
597	597.0	598	599.0	599	600.0	600	601.0	601	602.0	602	603.0	603	604.0
605	605.0	606	607.0	607	608.0	608	609.0	609	610.0	610	611.0	611	612.0
617	617.0	618	619.0	619	620.0	620	621.0	621	622.0	622	623.0	623	624.0
629	629.0	630	631.0	631	632.0	632	633.0	633	634.0	634	635.0	635	636.0
637	637.0	638	639.0	639	640.0	640	641.0	641	642.0	642	643.0	643	644.0
649	649.0	650	651.0	651	652.0	652	653.0	653	654.0	654	655.0	655	656.0
657	657.0	658	659.0	659	660.0	660	661.0	661	662.0	662	663.0	663	664.0
666	666.0	667	668.0	668	669.0	669	670.0	670	671.0	671	672.0	672	673.0
678	678.0	679	679.0	679	680.0	680	681.0	681	682.0	682	683.0	683	684.0
687	687.0	688	689.0	689	690.0	690	691.0	691	692.0	692	693.0	693	694.0
699	699.0	700	701.0	701	702.0	702	703.0	703	704.0	704	705.0	705	706.0
707	707.0	708	709.0	709	710.0	710	711.0	711	712.0	712	713.0	713	714.0
719	719.0	720	721.0	721	722.0	722	723.0	723	724.0	724	725.0	725	726.0
727	727.0	728	729.0	729	730.0	730	731.0	731	732.0	732	733.0	733	734.0
739	739.0	740	741.0	741	742.0	742	743.0	743	744.0	744	745.0	745	746.0
747	747.0	748	749.0	749	750.0	750	751.0	751	752.0	752	753.0	753	754.0
756	756.0	757	758.0	758	759.0	759	760.0	760	761.0	761	762.0	762	763.0
768	768.0	769	769.0	769	770.0	770	771.0	771	772.0	772	773.0	773	774.0
777	777.0	778	779.0	779	780.0	780	781.0	781	782.0	782	783.0	783	784.0
789	789.0	790	791.0	791	792.0	792	793.0	793	794.0	794	795.0	795	796.0
797	797.0	798	799.0	799	800.0	800	801.0	801	802.0	802	803.0	803	804.0
805	805.0	806	807.0	807	808.0	808	809.0	809	810.0	810	811.0	811	812.0
817	817.0	818	819.0	819	820.0	820	821.0	821	822.0	822	823.0	823	824.0
829	829.0	830	831.0	8									

Data correction

Four steps of Archive corrections had been used for correction of about 1.23 million data prepared from hand written log books, sometimes of low quality, with a lot of improvements. For that EXEL files for each calendar month had been prepared to exclude seasonal variability.

1step. With EXEL graphic presentations of file for each month of each meteorological parameter rough errors had been deleted.

2 step. Mean square deviations of data rows had been calculated to be sure that all rough mistakes had been deleted.

3 step. Graphic analysis of probably wrong information had been done by comparison of dubious data with neighboring data in the same data row.

4 step. After 1-3 steps by number sequence of measured data x_i , $i=1,2,\dots,n$ the data rows and its sums had been calculated:

$$\delta x_i = |x_i - x_{i-1}|, i=1,2,\dots,n-1$$

$$\bar{\delta}^* = \frac{1}{n-1} \sum_{k=1}^{n-1} \delta x_k$$

In case $\delta x_i > D \bar{\delta}^*$ the data with numbers $i-1$, i , $i+1$ are assumed as doubtful and controlled by logbooks. We used $D=5$ for step 4.

Additional control had been executed by comparison of maximal daily variation of air surface temperature with data of maximal and minimal thermometers. Despite low accuracy of last measurements 72 mistake of air surface temperature had been found. The same procedure with comparison the values of total and low cloudiness had been made.

Example of files, stored in Meteorological Archive

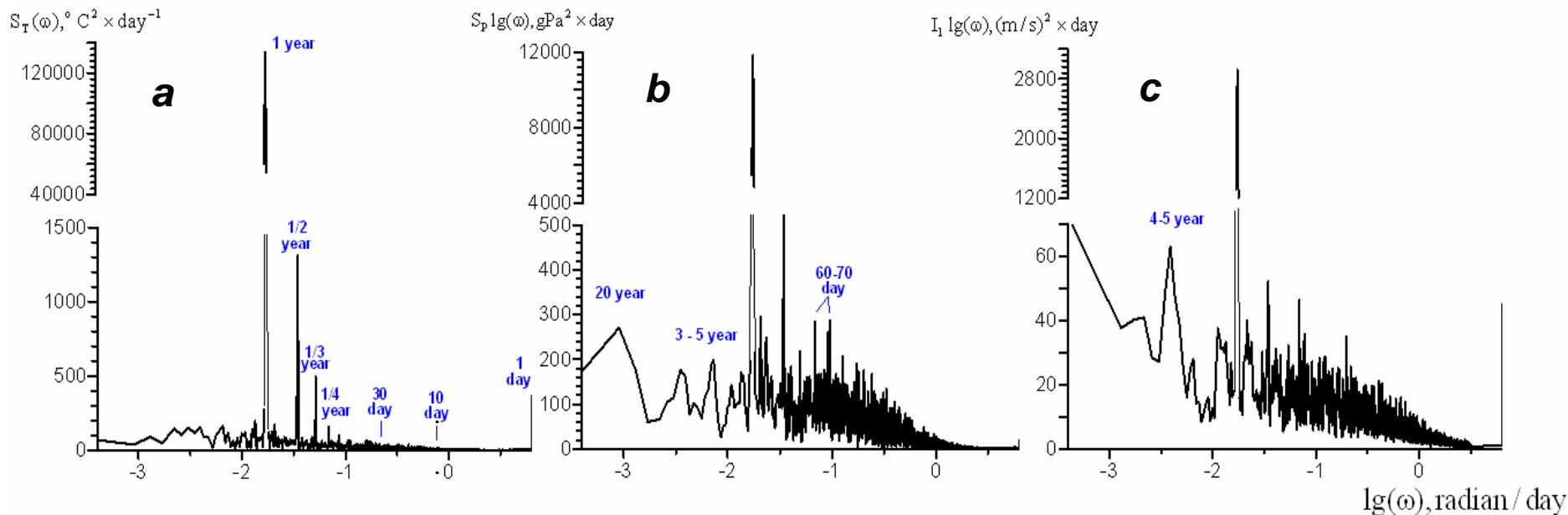
JULday	year	mnnth	day	Ta00	Ta03	Ta06	Ta09	Ta12	Ta15	Ta18	Ta21	Tamax	Tamin
1990	1990	1	1	-24.6	-24.1	-26.1	-25.7	-26.1	-33.3	-32.5	-29.1	-23	-34.7
1990.03	1990	1	2	-28.3	-33.3	-33.9	-33.2	-33.6	-27.3	-30.3	-26.5	-25.9	-34.8
Q00	Q03	Q06	Q09	Q12	Q15	Q18	Q21	Ts00	Ts03	Ts06	Ts09	Ts12	Ts15
0.0006	0.0006	0.0005	0.0005	0.0005	0.0003	0.0003	0.0004	-27	-26	-28	-27	-28	-37
0.0004	0.0003	0.0002	0.0003	0.0003	0.0004	0.0003	0.0004	-32	-36	-36	-37	-38	-30
Ts18	Ts21	Tsmax	Tsmin	NT00	NT03	NT06	NT09	NT12	NT15	NT18	NT21	NL00	NL03
-36	-32	-26	-38	10	10	10	10	6	0	0	0	0	0
-34	-31	-28	-39	0	6	3	4	2	3	0	0	0	0
NL06	NL09	NL12	NL15	NL18	NL21	vi00	vi03	vi06	vi09	vi12	vi15	vi18	vi21
0	0	0	0	0	0	63	97	64	62	80	82	82	82
0	0	0	0	0	0	82	97	83	81	82	80	81	81
RV00	RV12	slp00	slp03	slp06	slp09	slp12	slp15	slp18	slp21	WD00	W00	WD03	W03
0	0.4	1019.9	1019.9	1020.5	1021	1021.9	1020	1019.7	1019.3	0	0	220	8
0	0	1020.2	1019.8	1019.7	1019.9	1019.9	1022	1021.3	1021	40	3	100	2
WD06	W06	WD09	W09	WD12	W12	WD15	W15	WD18	W18	WD21	W21	hs	so00
250	6	225	6	225	6	205	2	245	2	220	4	2	8
0	0	0	0	0	0	200	3	0	0	220	4	2	8

The meteorological archive fir Tiksi will be available on WEB in summer 2008

Climate of Tiksi observatory area

Atmospheric surface layer

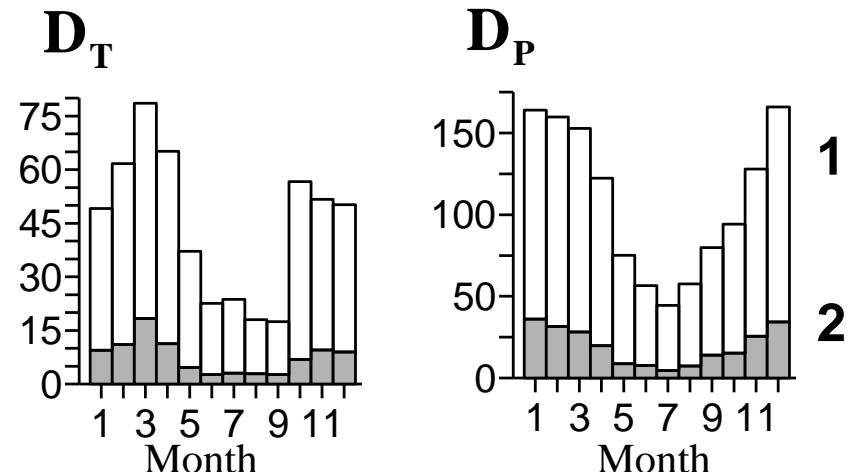
Spectral density of multi-year variability of air surface temperature (a), surface pressure (b) and wind velocity (c)



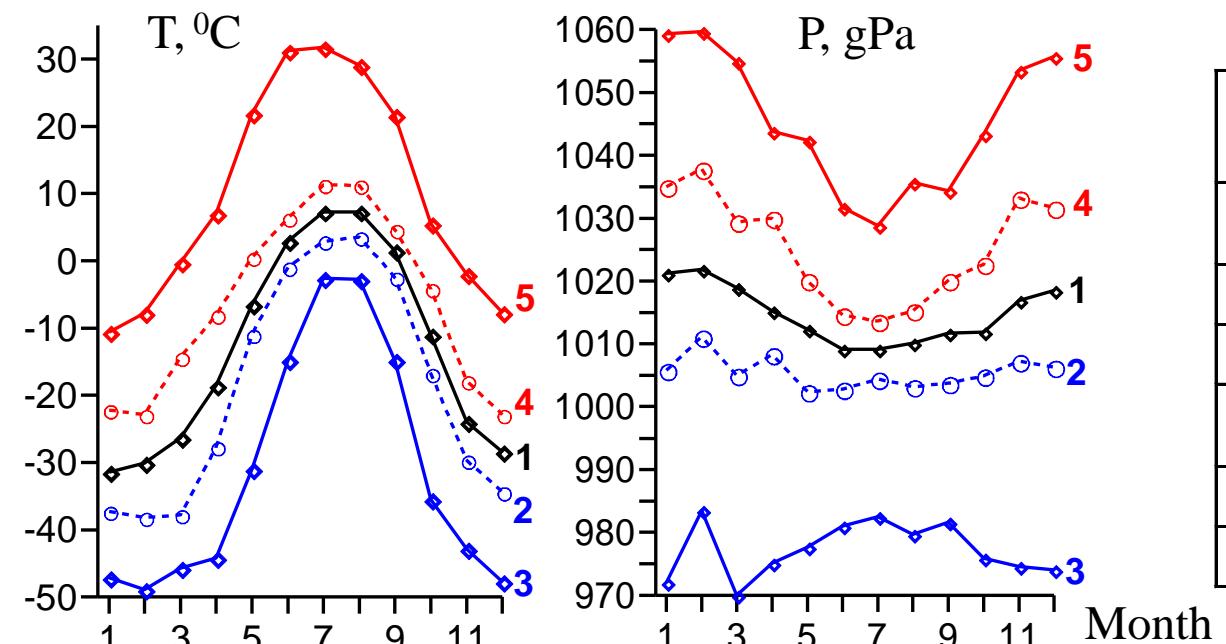
Spectral function $F(\omega) = \int_{\omega_1}^{\omega_2} S(\omega) d\omega$

	Multi-year	Seasonal	Synoptic
T	1%	83%	10%
P	2%	22%	46%
\vec{V}	4%	15%	69%

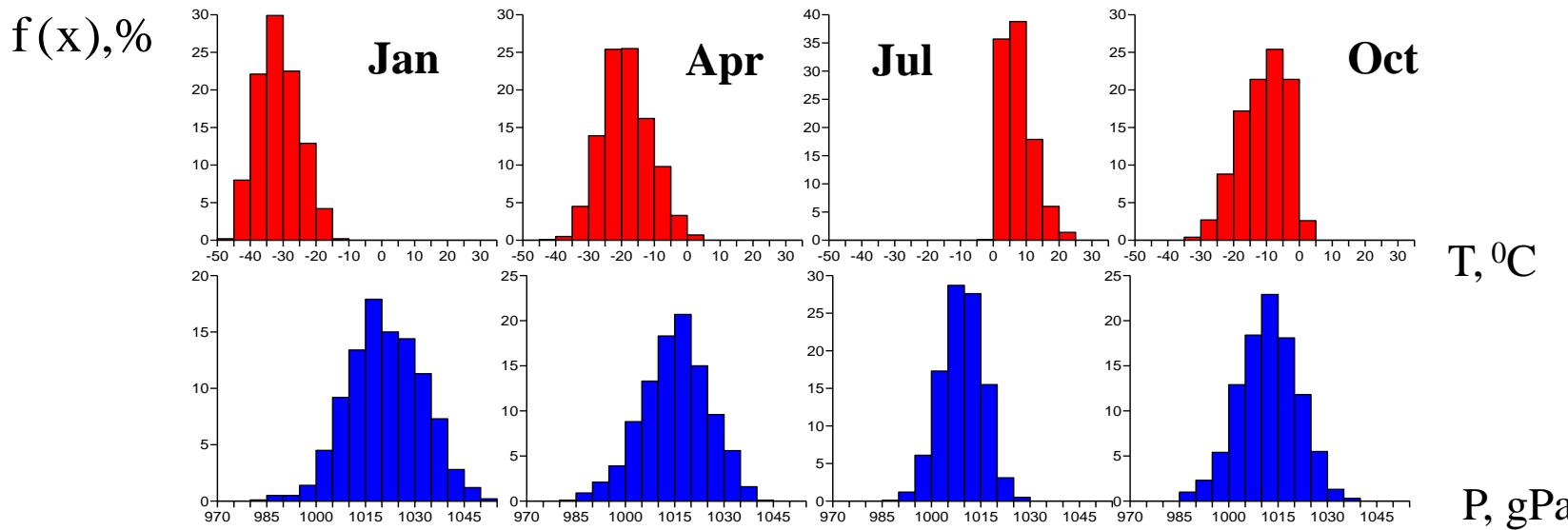
Seasonal variability of variance from daily (1) and monthly (2) data



Seasonal variability of monthly means (1) and extremes from daily (3, 5) and monthly (2, 4) averaged data



Seasonal variability of probability distribution temperature and pressure

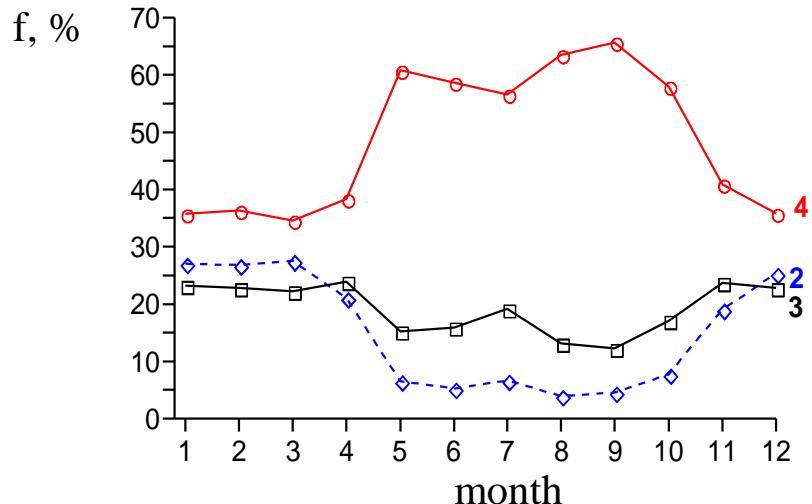
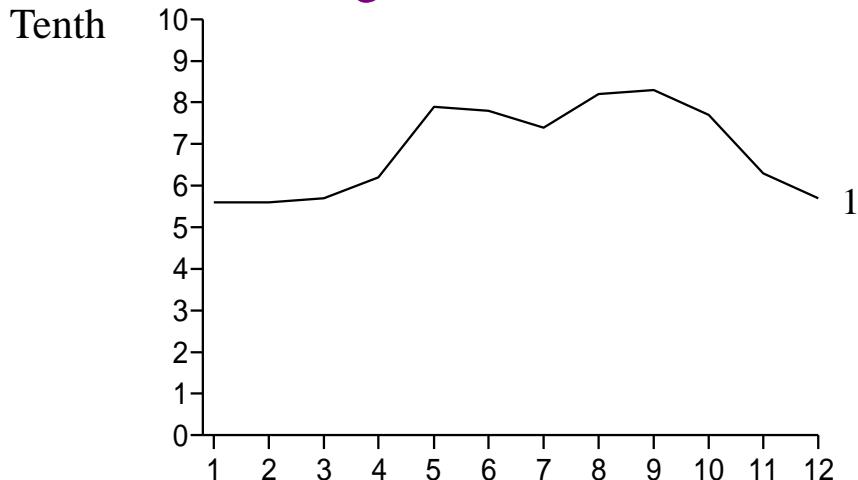


Seasonal A, E coefficients

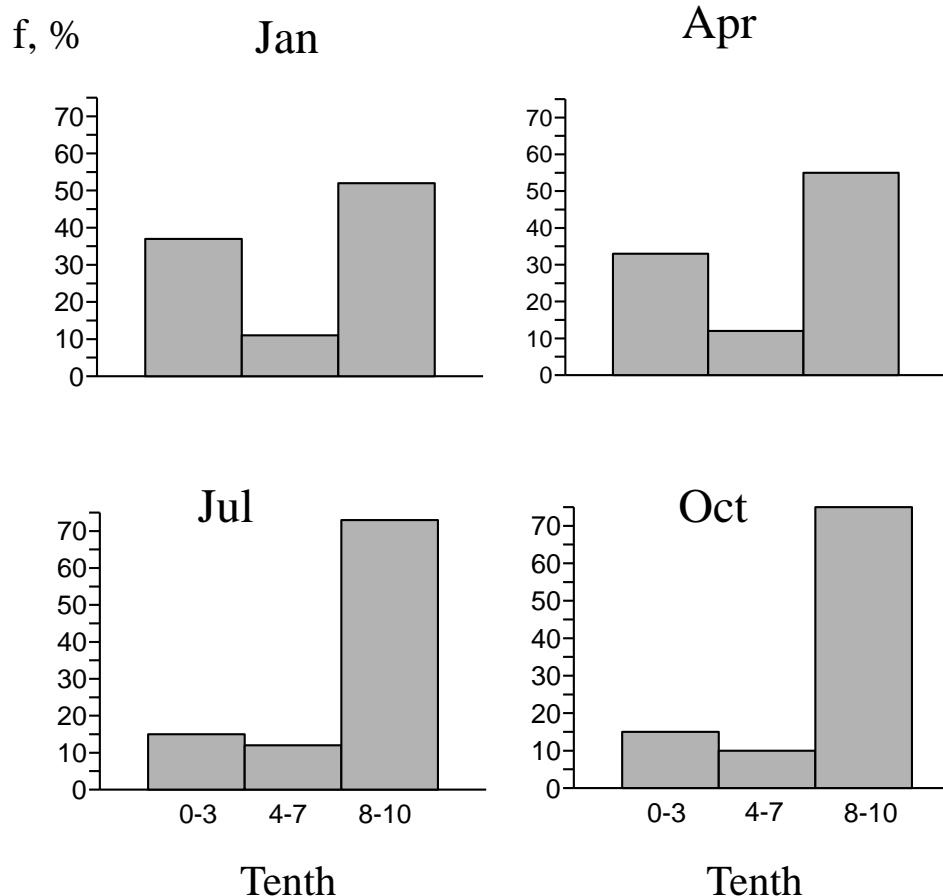
	Jan	Apr	Jul	Oct
Temperature				
A	0.21	0.22	1.04	-0.44
E	-0.52	-0.21	1.95	-0.47
Pressure				
A	-0.05	-0.22	-0.15	-0.11
E	-0.04	-0.15	-0.12	-0.08

Total cloudiness

Seasonal variability of multi-year averaged characteristics



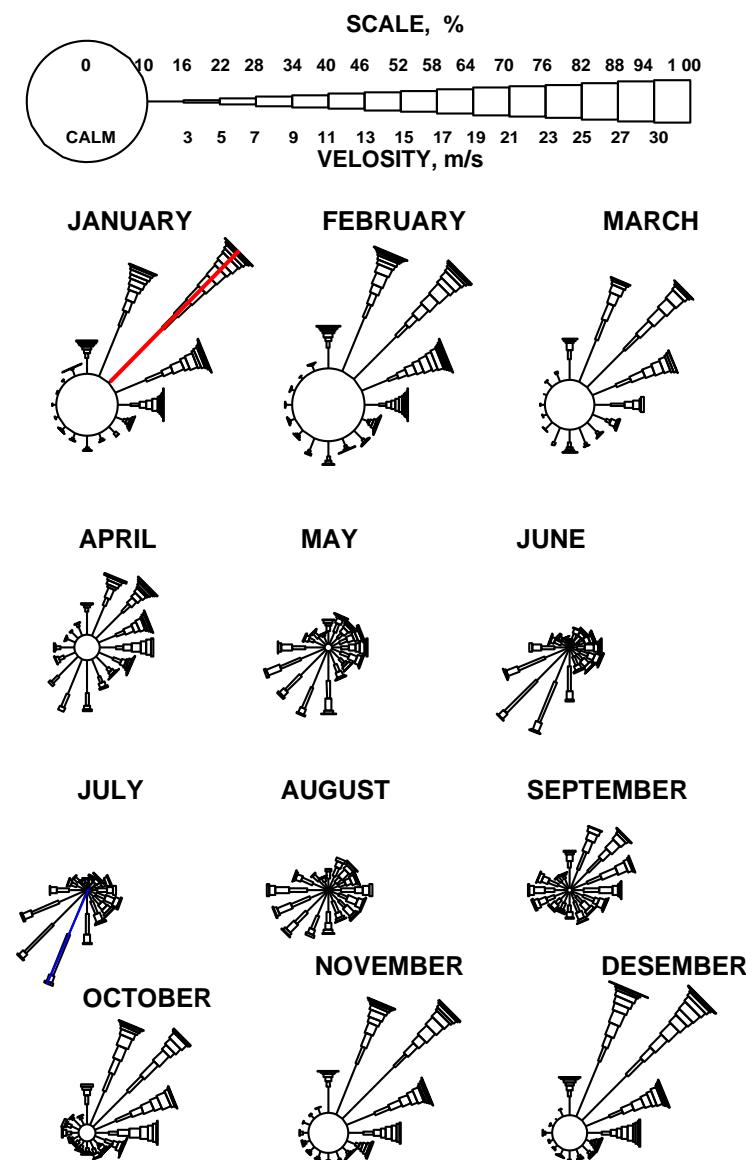
Seasonal variability of probability distribution



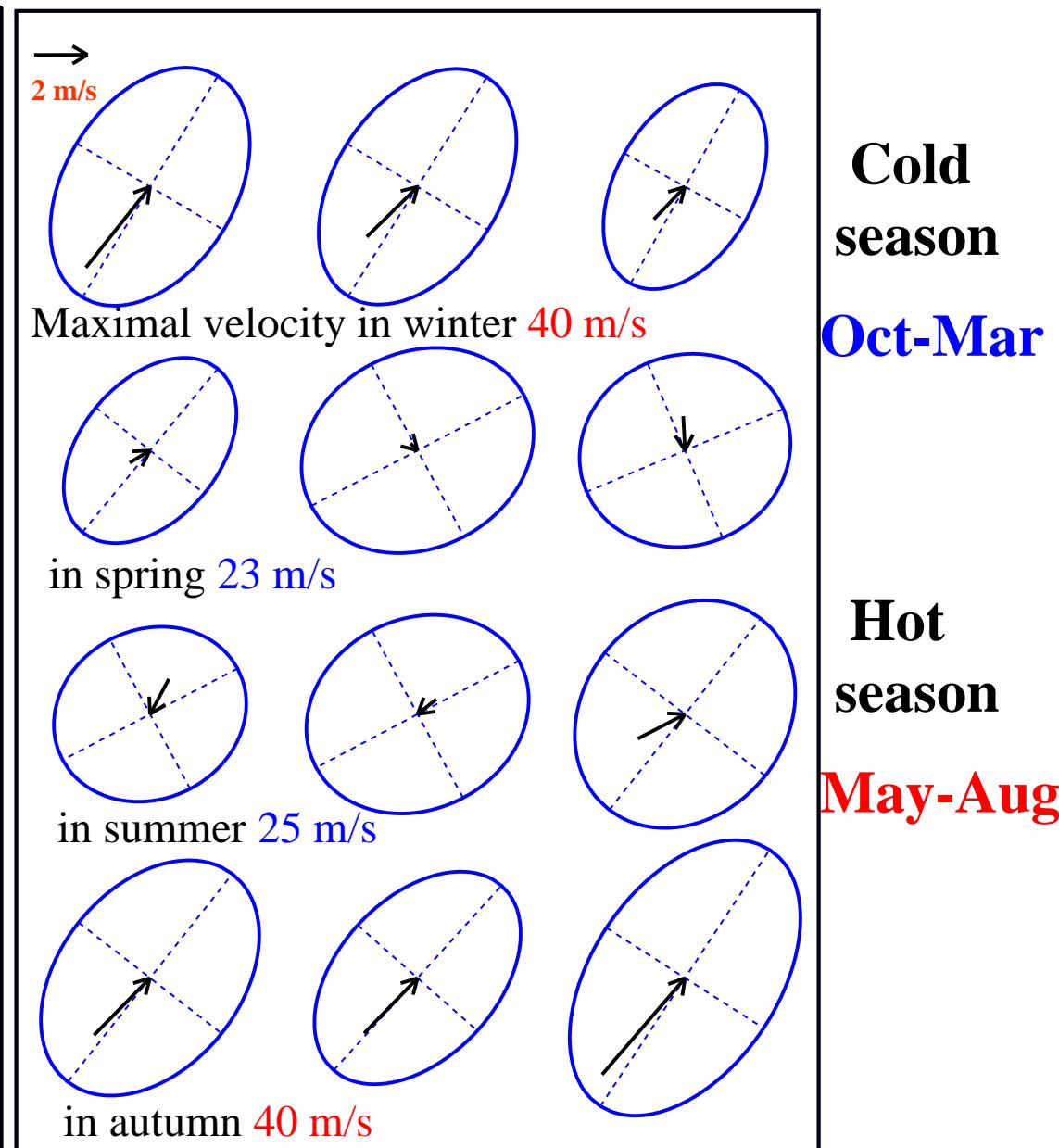
1 – cloudiness;

occurrence: 2 – 0-3 tenths, 3 – 4-7 tenths, 4 – 8-10 tenths

Wind roses in Tiksi



Vector of mean wind velocity and MSD ellipse in Tiksi

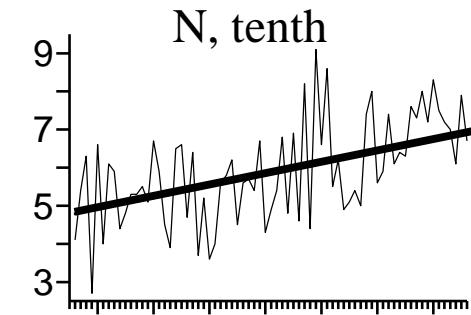
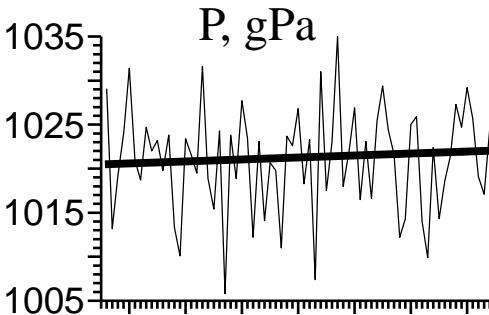
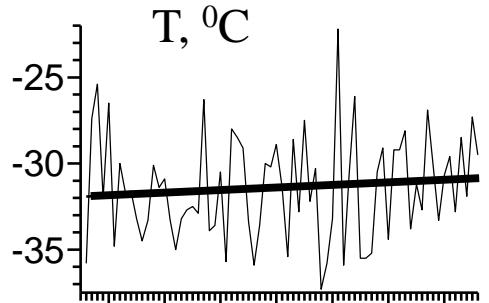


Time series and trend

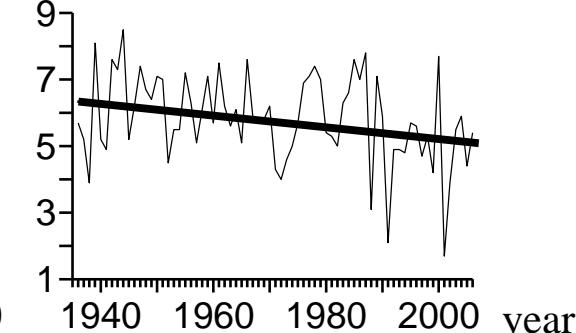
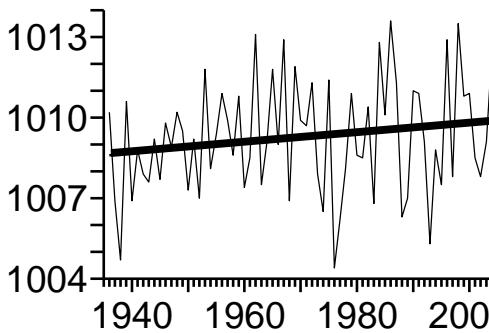
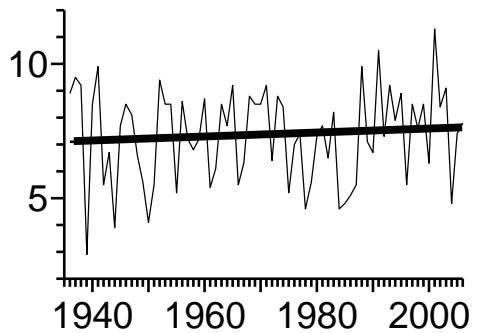


Interannual variability of temperature, pressure and total cloudiness

January



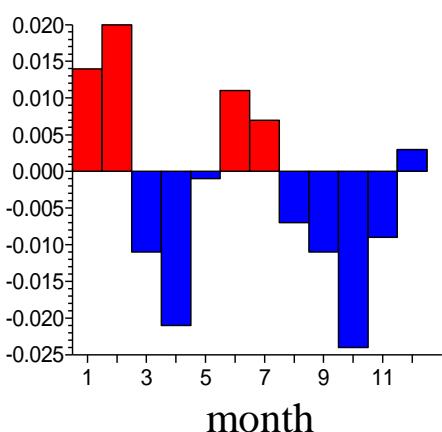
July



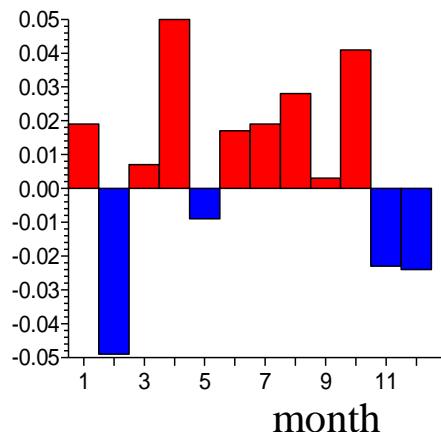
year

Seasonal variability of trend coefficient and relative input to variance

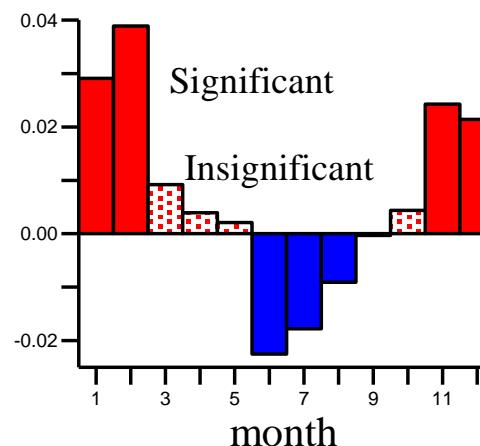
T, $^{\circ}\text{C}/\text{year}$



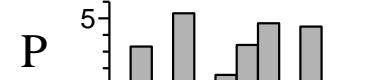
P, gPa/year



N, tenth/year



D_{tr}/D, %



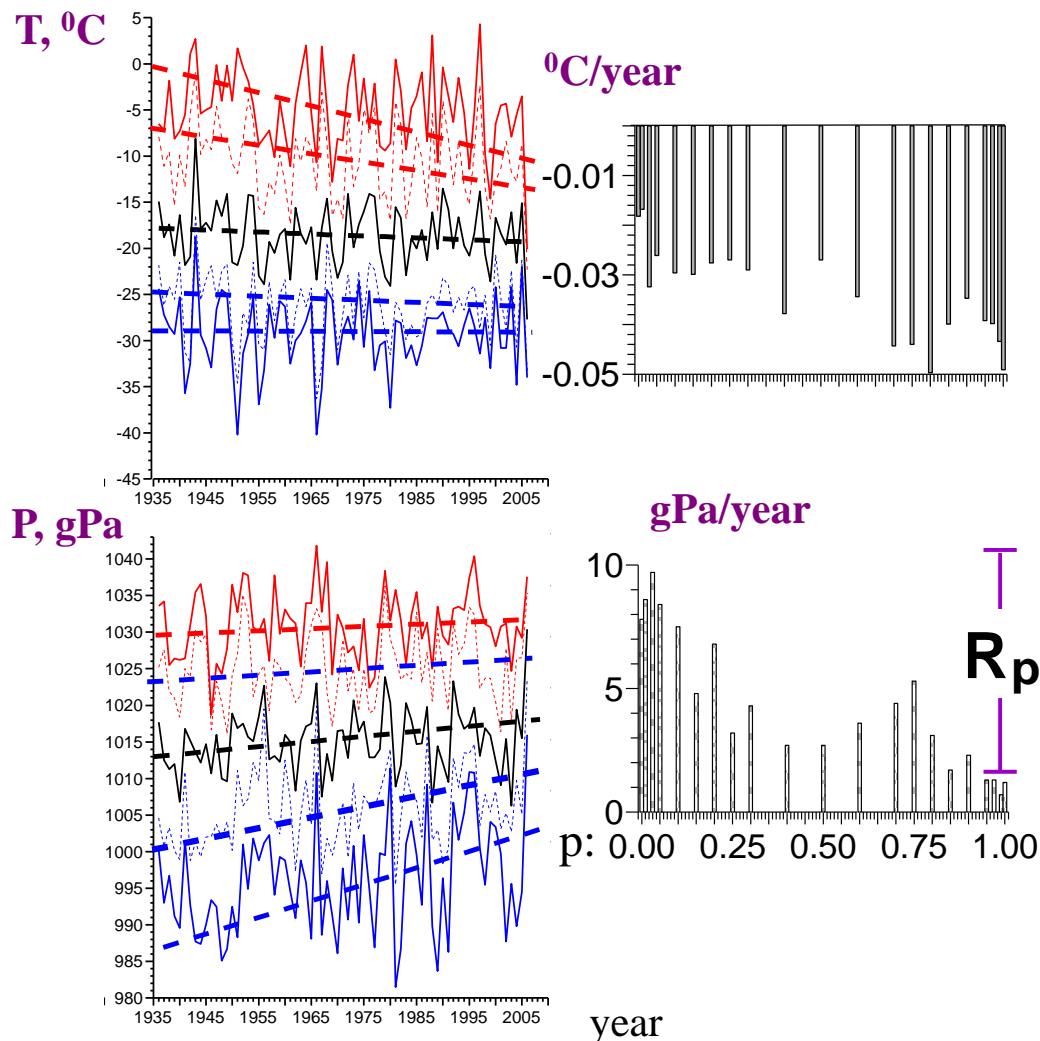
month

Trends of monthly quantile values of air surface temperature and surface pressure

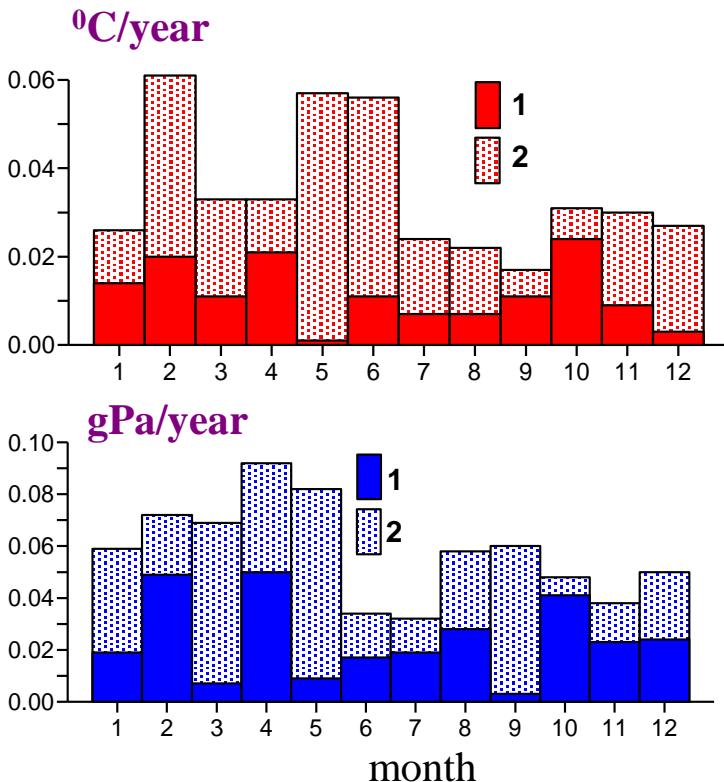
$$X_p(t) = a_p t + b_p, \quad p = \min, 0.1, \dots, 0.9, \max$$

Effect of synoptic systems is significant $t \Rightarrow a_p \neq \text{const}$

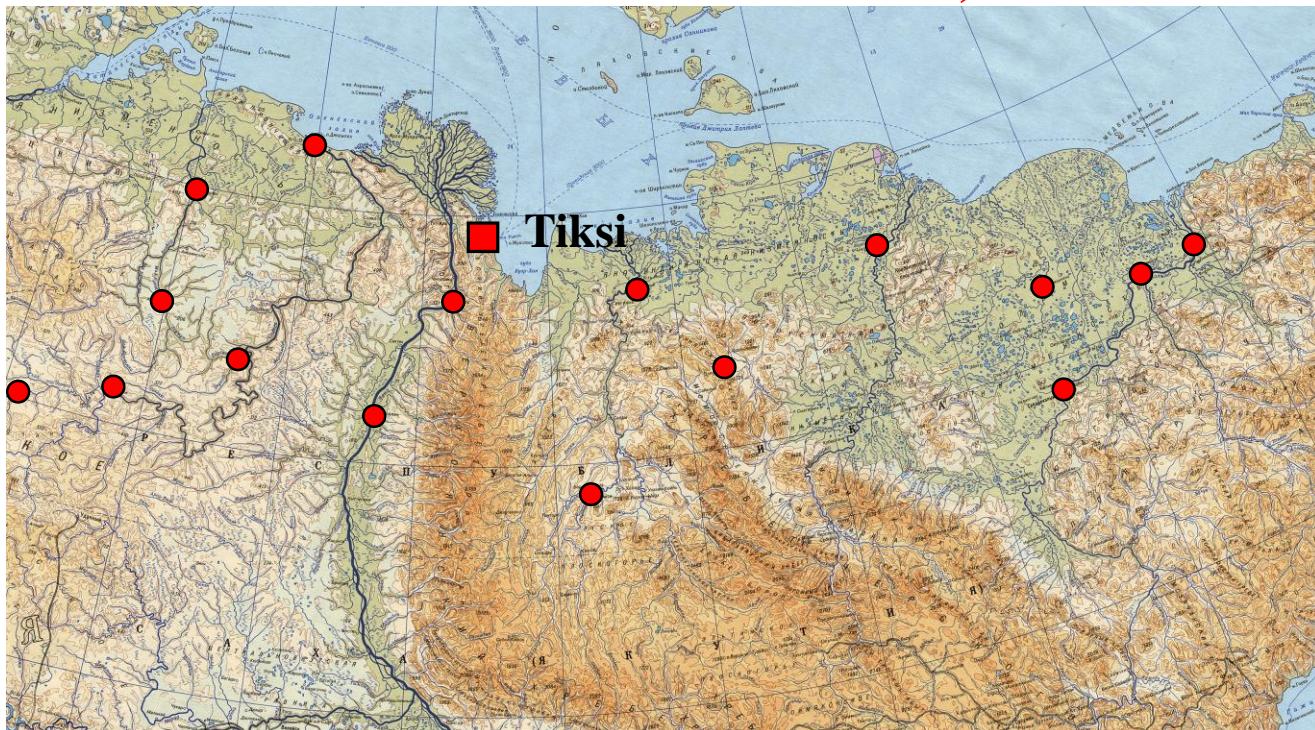
Temperature and pressure, April



Annual variations of monthly mean absolute values pressure trends (1)
and corresponding trends of ranges of deviation $R_p = a_{\max} - a_{\min}$ (2)



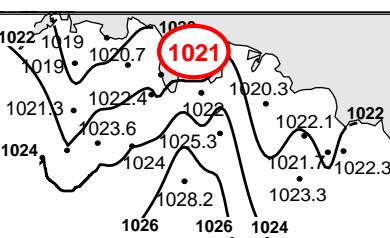
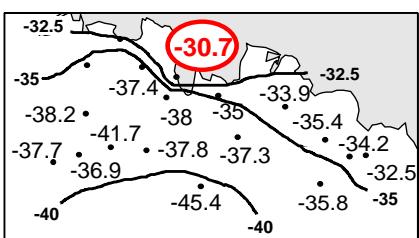
Created archive of data of meteorological stations in the Northern Yakutia, 1978-2010



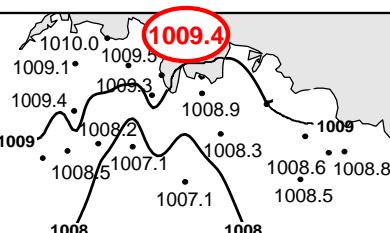
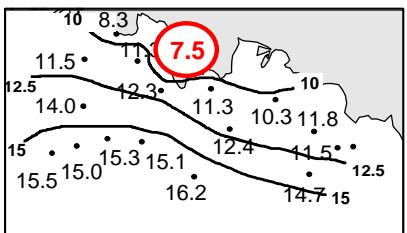
	Station	Latitude	Longitude	H, m		Station	Latitude	Longitude	H, m
1	Андрюшино	69.1	154.3	16	11	Джалинда	70.1	113.8	62
2	Верхоянск	67.3	133.2	138	12	Оленёк	68.5	112.6	217
3	Депутатский	69.2	139.5	284	13	Саскылах	72.0	114.1	16
4	Колымская	68.4	158.4	12	14	Сухана	68.8	118.0	77
5	Среднеколымская	67.37	153.4	21	15	Тюмти	71.9	123.4	28
6	Тикси	71.3	128.5	8	16	Усть-Оленёк	73.0	119.5	14
7	Черский	68.5	161.2	25	17	Ярольин	68.2	108.5	236
8	Чокурдах	70.4	147.5	61	18	Драган	68.7	124.0	14
9	Юбилейное	70.8	136.2	22		Кюсюр	70.7	127.4	36

Multi-year averaged, 1978 - 2010

Temperature, °C Pressure, gPa



Jan



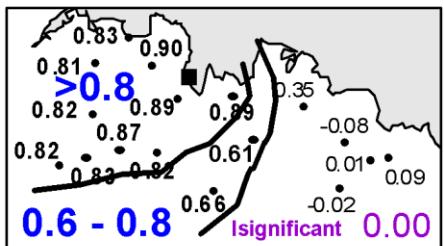
.Jul

Correlation of monthly means values

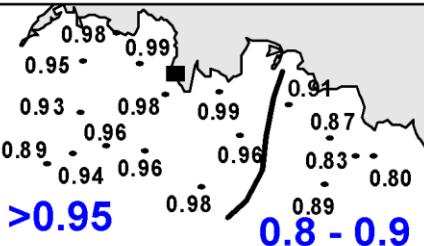
r: **0.90** – Significant, 0.05 - Insignificant

January

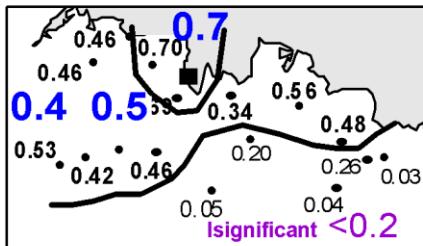
Temperature



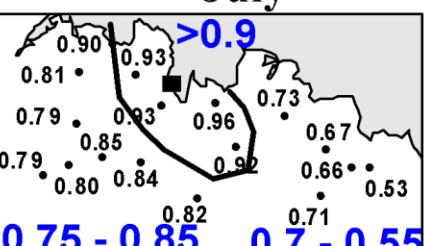
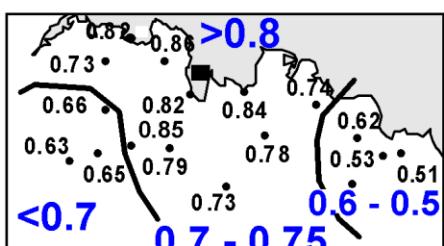
Pressure



Wind velocity vector

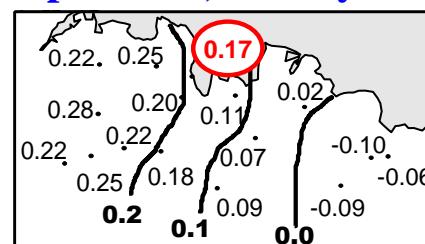


July



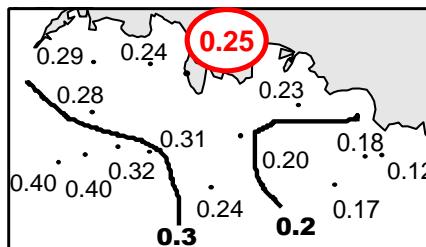
Time series and trend coefficient 1978 – 2010, January

Temperature, °C/10 year

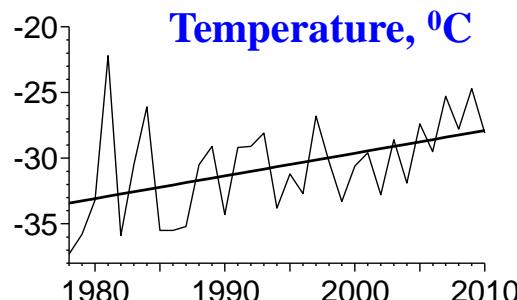


A map of the Arctic region showing pressure anomalies in gPa/10 year. The map includes a color scale from -0.05 to 0.02 and a red circle highlighting a positive anomaly of 0.05.

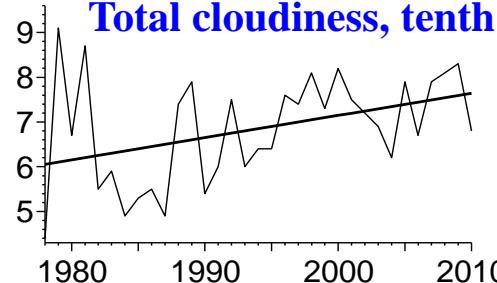
Total cloud., tenth/10 year



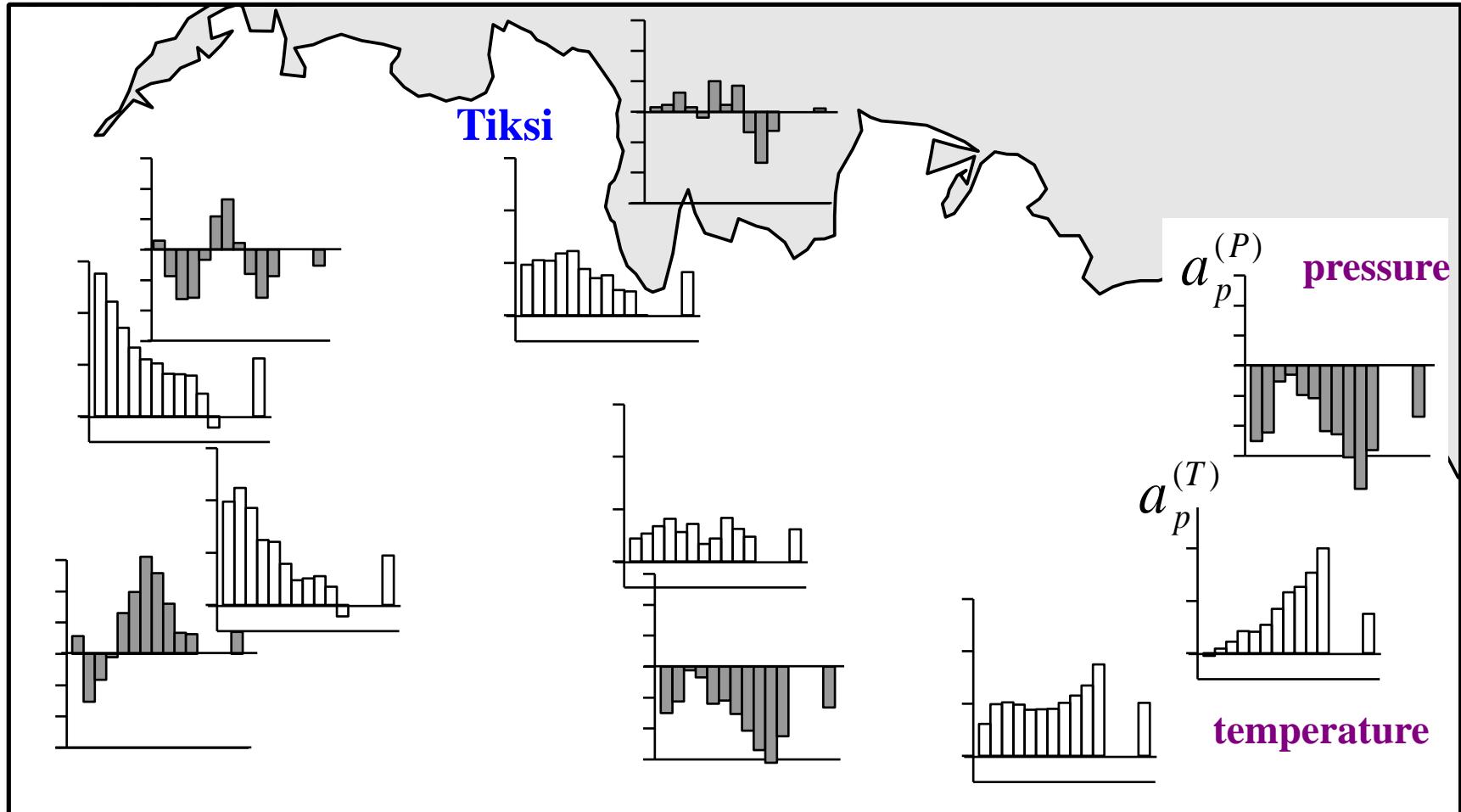
Temperature, °C



Total cloudiness, tenth



1978 – 2010. Trends of monthly quantile values
of air surface temperature (transparent) and surface pressure (black)

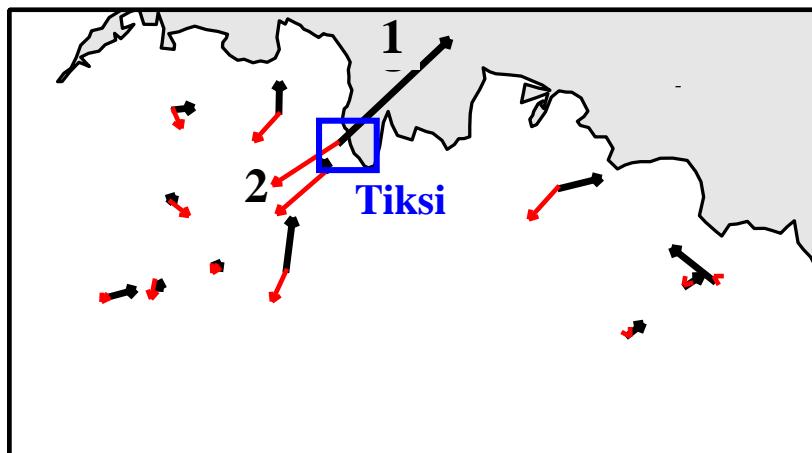


Monthly mean wind velocity (1) and vector trend (2), 1978 - 2010

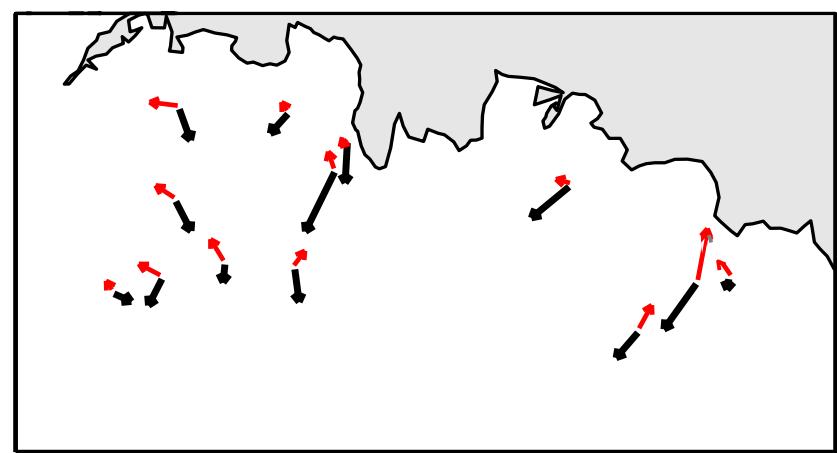
$$\vec{V}(t) = \hat{\vec{V}}(t) + \vec{\varepsilon}$$

Trend: $\hat{\vec{V}}(t) = \vec{a}(t) + \vec{b}$, anomalous $\vec{\varepsilon}(t) = \vec{V}(t) - \hat{\vec{V}}(t)$

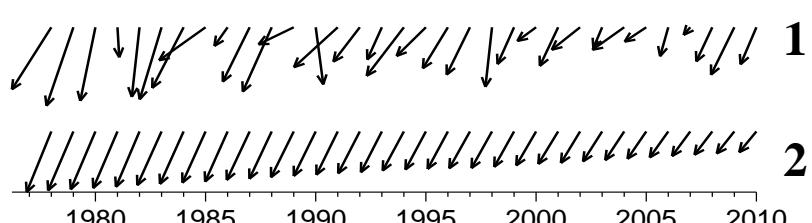
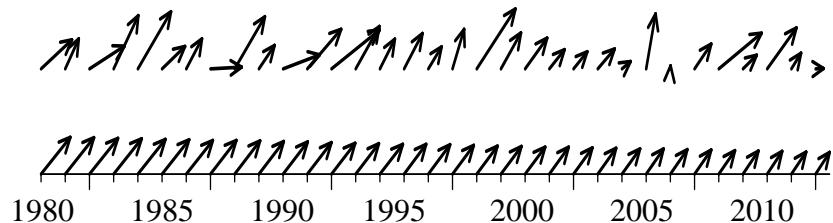
Winter



Summer



Attention on $\varphi_{\vec{V}} \Leftrightarrow \varphi_{\vec{a}}$: $\uparrow\uparrow$ – increase, $\uparrow\downarrow$ – decrease, $\uparrow\rightarrow$ rotation

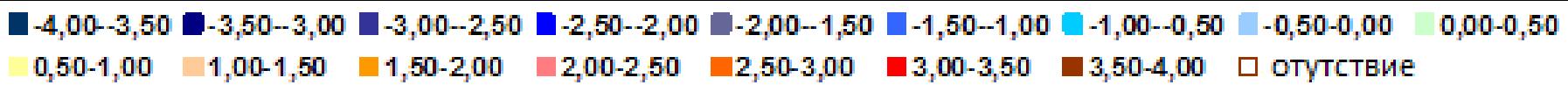
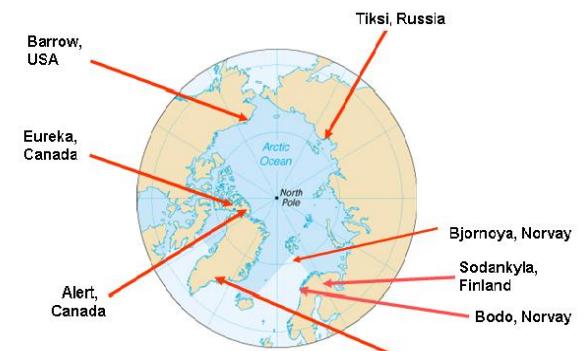
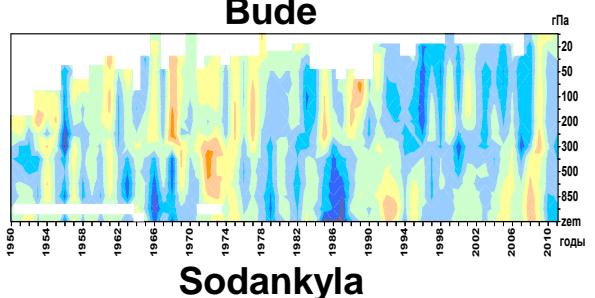
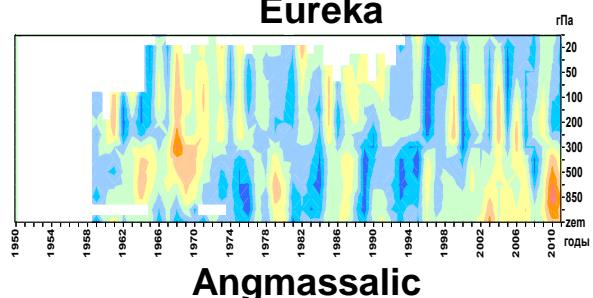
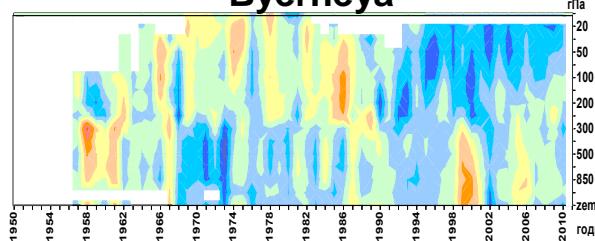
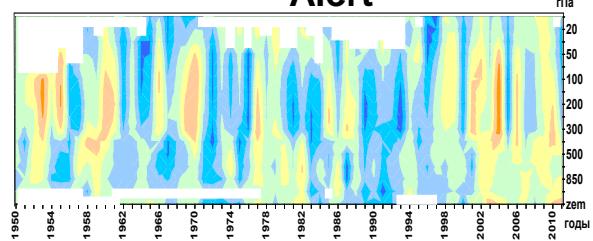
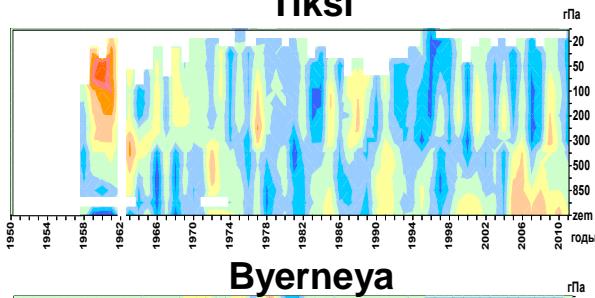
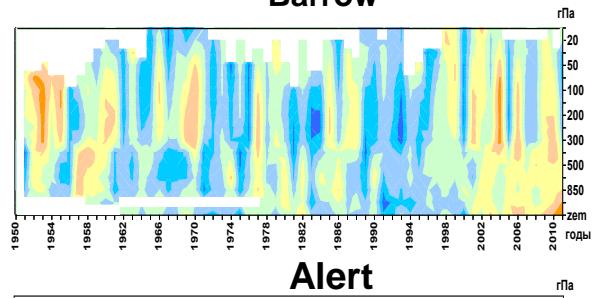
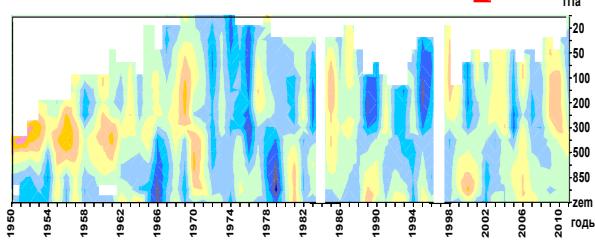
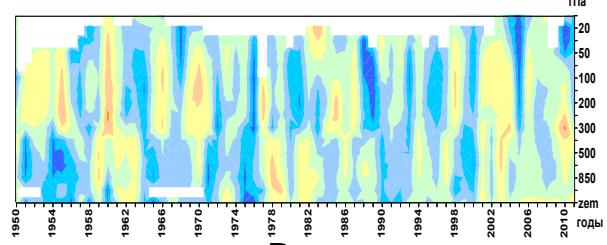


Climate of free atmosphere



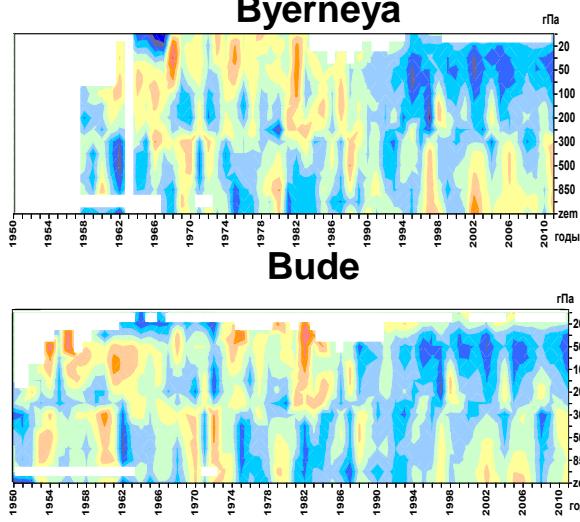
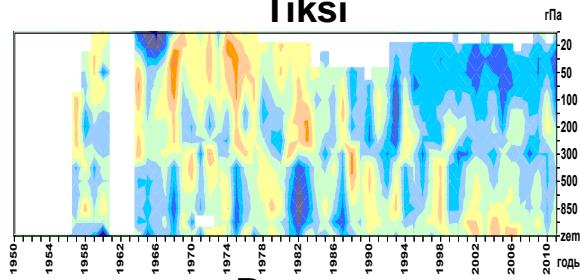
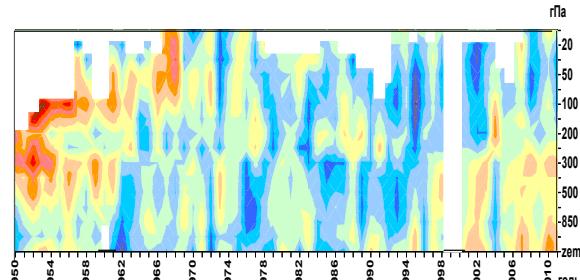
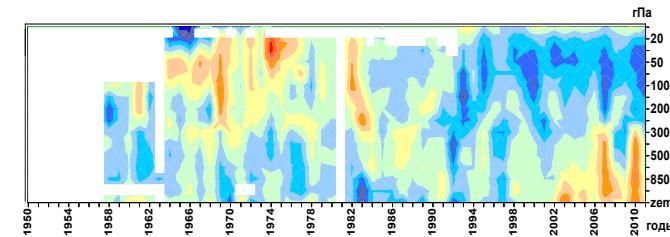
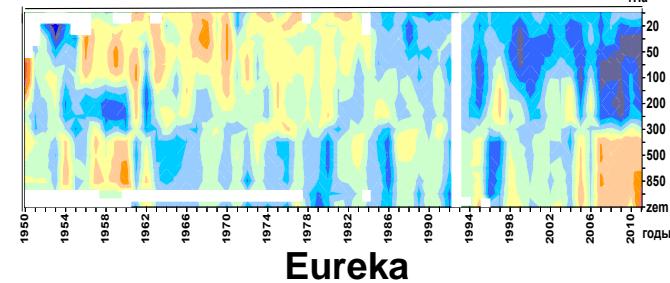
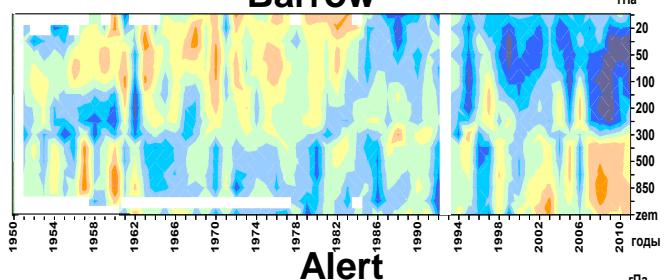
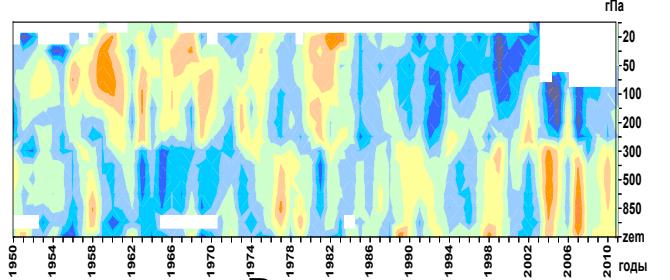
1950 – 2010

Normalized anomalies of air temperature, winter

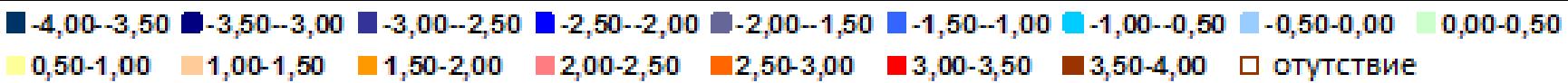


1950 – 2010

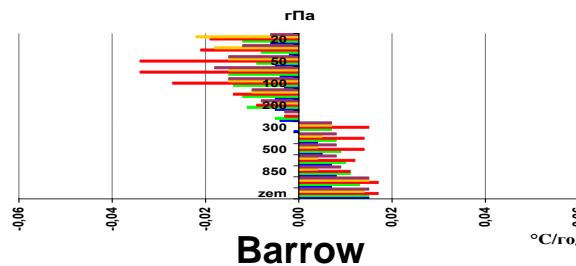
Normalized anomalies of air temperature, summer



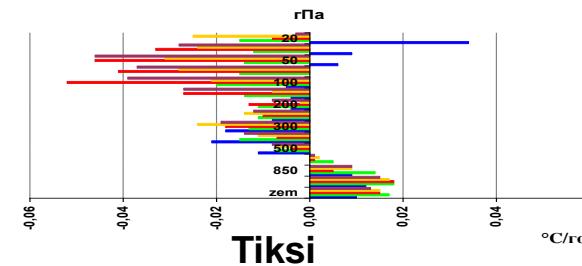
Sodankyla



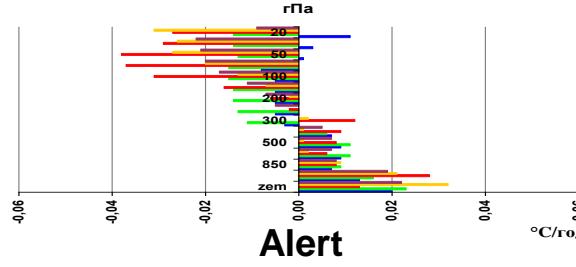
Trends of air temperature on the standard meteorological surfaces for 1950-2011



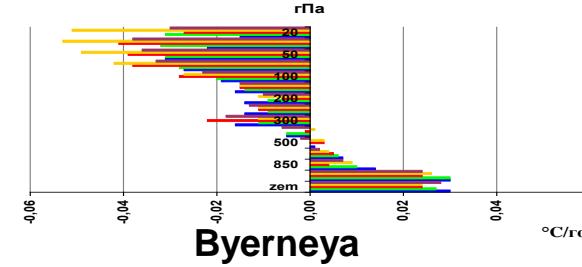
Barrow



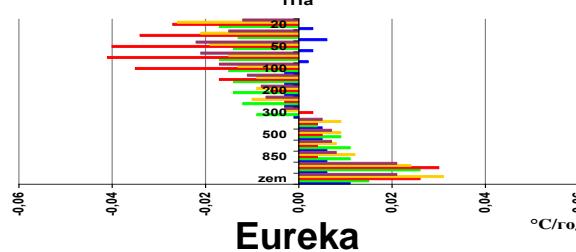
Tiksi



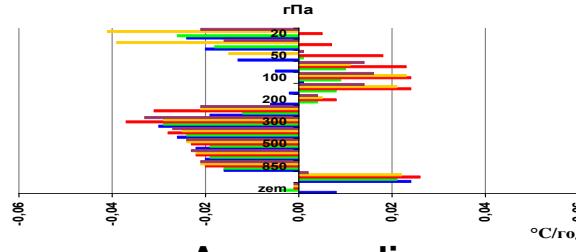
Alert



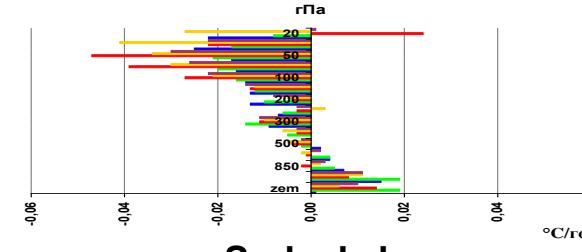
Byerneya



Eureka



Angmassalic



Sodankyla

SUMMARY

- digital archives of historical Tiksi meteorological data (1934 to present) and 18 other stations of the Northern Yakutia from 1978 to present have been created.
- the main input in variability of meteorological parameters is determined by seasonal cycle of monthly mean values and synoptic processes.
- trends of air temperature and surface pressure are not significant in Tiksi, its variances below 5%.
- strong trends in cloudiness (up to 20-30% increasing in winter and decreasing in summer) have been detected. It could be the reason of small positive trends of surface air temperature during winter and summer.
- quantile analysis supports conclusion about significant influence of synoptic systems on temperature trends.
- wind regime in Tiksi region is of monsoon type (in winter wind direction from south-west, in summer – from north-east). Wind velocity in Tiksi is maximal among all 18 stations - 40 m/s.
- the analysis, based on data of all meteorological stations in the Northern Yakutia, shows that mean values and MSD of air temperature and surface pressure are characterized by variability in meridian direction. Same time spatial variability of its trends has latitudinal direction.
- strong positive air temperature trends are revealed in low troposphere and negative – in low stratosphere, except Tiksi region and Eureka in winter.