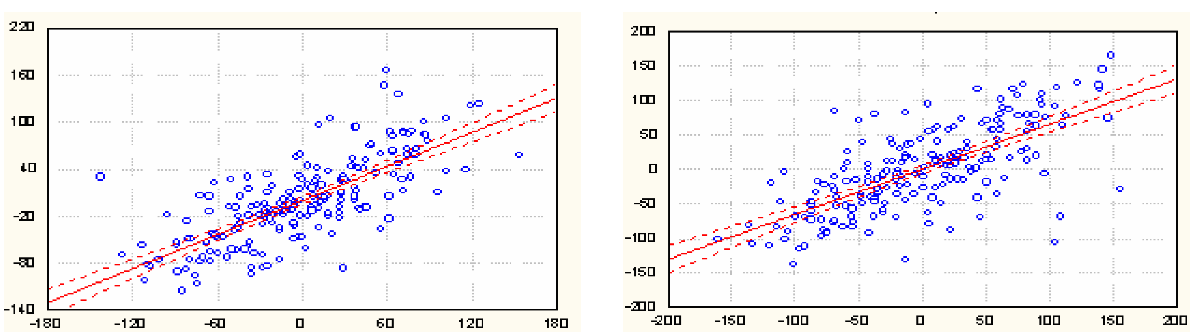
Circulation indices extremes in seasonal hindcast integrations

A.V.Muraviev, I.A. Kulikova, and E.N.Kruglova
Hydrometeorological Research Centre of the Russian Federation
Bol. Predtechensky per., 11-13, 123242 Moscow, Russia
e-mail: muravev@mecom.ru

Large scale circulation patterns may be described by characteristics, similar to the five well-known "pattern indices" (*Wallace, and Gutzler*, 1981), but calculated for daily rather then for monthly geopotential 500 mb height fields. Here the atmosphere is assumed to pass through different "weather" or "flow" regimes resulting from nonlinear synoptic-planetary scales interaction (*Reinhold, and Pierrhumbert*, 1982). These regimes are defined and assessed by extreme values of correspondent circulation indices (CI) thus reducing the problem to the analysis of outliers and extremes in daily quantized modeled and observed time series.

The global spectral T41L15 GCM has been integrated in a hindcast mode out to 90 days with initial data obtained from the NCEP/NCAR reanalysis archive starting from 31.06 and 30.11 every year during 1983-2002. This model is operationally used for monthly and seasonal hydrodynamic-statistical ensemble forecasts at the Russian HMC (*Muraviev et al, 2005*).

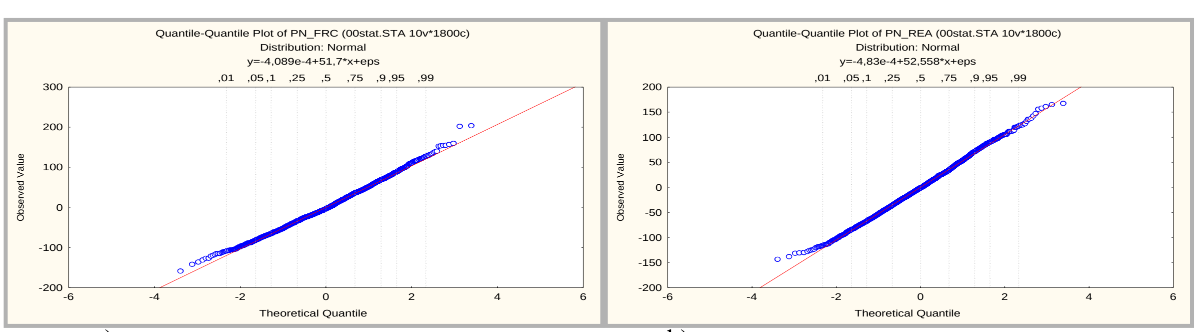
The scatter diagrams for the first 10 days show the correlation between modeled and observed index values (e.g. Fig.1). Let us label the correlation coefficients (CC) with the Wallace-Gutzler pattern notation. The CCs for all five circulation indices, depicting the GCM utility at medium-ranges, descend as follows:
summer CC_{PNA}=0.74; winter CC_{PNA}=0.70; summer CC_{WA}=0.69; winter CC_{WP}=0.68; winter CC_{EA} =0.65; summer CC_{EU} =0.64; winter CC_{EU}= 0.63; summer CC_{EA} =0.53; winter CC_{WA}=0.47; summer CC_{WP}=0.39.



(a) (b)

Fig.1. Scatter diagrams for PNA index in first 10 days summer (a) and winter (b) integrations. Dotted lines indicate 95%-confidence for regression. Index values are multiplied by 100.

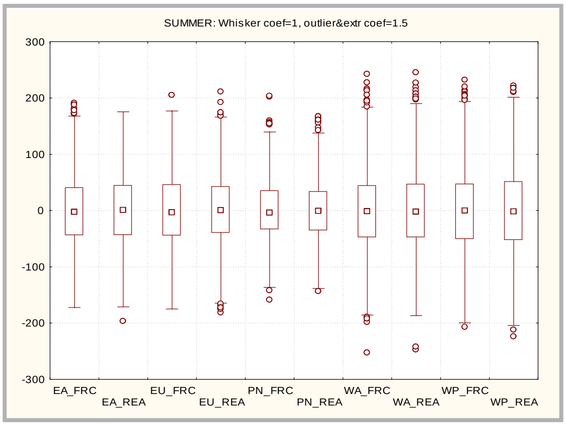
The variation of the correlation at medium ranges yields the PNA index as the most predictable, and the "seesaws" WA and WP in western ocean regions – as the least predictable, what quite good corresponds to the skill of the GCM in forecasting some other fields. The quantile-quantile plots of the full sample of 1800 values (90 days × 20 years) represent the outlier deviation from the normal distribution (Fig.2).



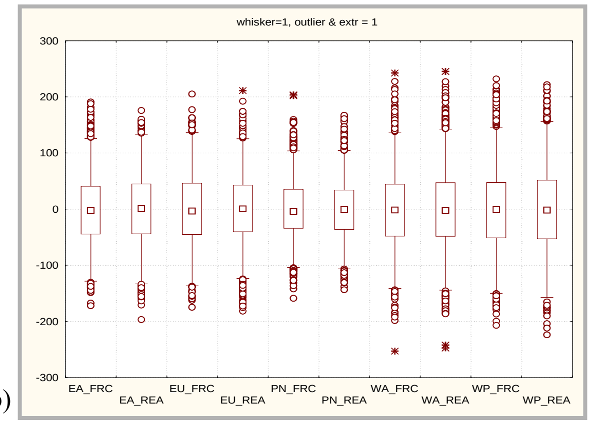
a) b)

Fig.2. Quantile plots against normal distribution for the winter PNA index. Left side (a) shows forecast data, right side (b) shows reanalysis data. Tail regions along the line indicate deviation of extremes from normal distribution. Index values are multiplied by 100.

In consideration of sampling errors a set of thresholds has been used for "box and whisker" plots (Fig.3). The quartiles L(25%) and H(75%) are used for calculating the span $\Delta = H - L$. Thresholds $\alpha(i)$, i=1 ...n , define *outliers* as index values being outside of $[L - \alpha(i)\cdot\Delta,\ H + \alpha(i)\cdot\Delta]$, and *extremes* as values being outside of $[L - 2\cdot\alpha(i)\cdot\Delta,\ H + 2\cdot\alpha(i)\cdot\Delta]$.



a)



b)

Fig.3. Box and whiskers for summer CIs: left side (a) shows *outliers* for α=1.5, right side (b) shows *outliers* and *extremes* for α=1.0. The box-whiskers correspond to EA, EU, PNA, WA, and WP indices with 'FRC' denoting forecast, and 'REA' denoting reanalysis. Boxes stand for $\Delta = H - L$, whiskers stand for 'non-outlier' interval, circles denote *outliers*, asterisks denote *extremes*.

A usual statistical approach in defining extremes is evidently crude in defining meteorologically 'large anomalies'. Fig.3 is to certify that thresholds near recommended α=1.5 exclude events which we would like to call *extremes* with statistical property. In particular the right side of Fig.3 yields several informal conclusions. For instance, the largest number of WA index extremes of both signs indicate the atmospheric *instability* and *variability*, which are more *predictable* in the extreme-statistical sense, than the EA or PNA indices.

Collected diagram data are used for extremes' statistics, their *recurrence* and *duration* (see Table). These statistics may be applied both to concomitant synoptic events and to the GCM skill in predicting these features at seasonal time scales. Comparing medium and seasonal ranges one may note, that the PNA and EU indices predictability may be considered as opposed (see Fig.1 and EU, PNA columns in Table).

Table.

Recurrence and duration for several summed CIs outliers and extremes in winter seasons 1983-2002. Columns denote upper and lower CI values (×100) for two α thresholds (from top +1.5, +1.0, -1.0, -1.5), days number with CI extremes (2), minimum (3) and maximum (4) duration in days, and mean duration (5) in days.

1	2	3	4	5
EU_FORECAST				
193	0	0	0	0
145	20	1	4	1.8
-145	15	1	5	1.7
-193	0	0	0	0
EU_REANALYSIS				
187	2	2	2	2
140	23	1	5	1.6
-140	21	1	5	1.4
-187	2	1	1	1

1	2	3	4	5
PNA_FORECAST				
161	5	1	1	1
121	37	1	4	1.8
-121	22	1	5	1.8
-160	3	1	1	1
PNA_REANALYSIS				
200	0	0	0	0
150	5	1	1	1
-150	19	1	3	1.5
-200	1	1	1	1

1	2	3	4	5
WP_FORECAST				
194	11	1	4	2.2
145	40	1	8	2
-151	22	1	5	1.7
-200	4	1	2	1.3
WP_REANALYSIS				
214	9	1	3	1.8
160	57	1	6	2
-164	19	1	4	1.9
-218	1	1	1	1

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2. Reinhold B.B., and R.T. Pierrehumbert, 1982: Dynamics of weather regimes: quasi-stationary waves and blocking. *Monthly Weather Review*, **110**, 1105-1145.
3. Muraviev A.V., I.A. Kulikova, E.N. Kruglova, V.D. Kaznacheeva, 2005: Using ensembles in hydrodynamic-statistical meteorological forecasting. *Russian Meteorology and Hydrology*, **7**, 3 – 15.