Assessment of the influence of the steering current velocity on anomalous weather phenomena in the troposphere of the northern hemisphere in modern climate conditions

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Main goal of the study was to assess the role of the steering current (western transport) in the variability of meteorological anomalies at the end of the 20th – beginning of the 21st centuries over the Asian territory of Russia.

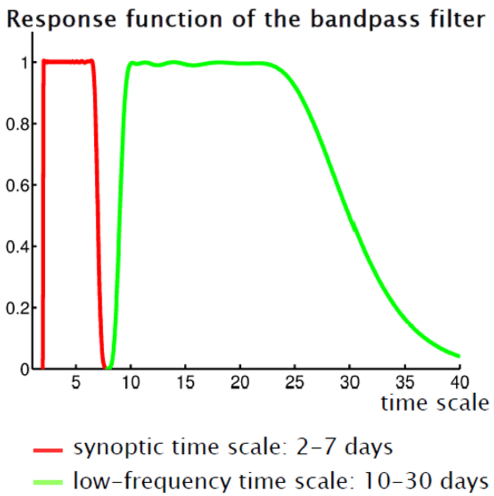
Traditionally, atmospheric (meteorological) variability is divided into components corresponding to different time and space scale intervals.

In this study we used a component, characterized the variability of the synoptic scale (SV) - with a period of 2-7 days and with a wave vector - $6 \le k \le 9$. The SV is usually associated with the manifestation of cyclonic and anticyclonic activity in the troposphere.

Blackmon M.L., Lee Y-H., Wallace J.M. // J. Atmos. Sci. 1984. V. 41. № 6. P. 961–980

Deviations from the normal (Gaussian) distribution of atmospheric variables may reflect nonlinear aspects of the atmospheric dynamics (Monahan, 2006; Petoukhov et al., 2008; Sura, Hannachi, 2015; Loginov et al., 2017). Moreover, such deviations affect 'tails' in the sampled probability density functions (PDFs) of weather-related anomalies of atmospheric variables. The latter may either enhance or diminish frequency of extreme weather events.

Filter characteristics



- Nonrecursive finite impulse response filter(FIR)
- the Hamming weight window
- Quantity decay
  - ~25 dB in low-frequency absorption band
  - ~40 dB in high-frequency absorption band
- Transition zones (0.5 of W function)
- Phase shift was removed by passing of filtered data through the filter in the forward and backward directions

Loginov S.V., Eliseev A.V., Mokhov I.I. // Izvestiya. Atmospheric and Oceanic Physics. 2017. T. 53. № 3. C. 269-278.

Characteristics of the vortex formations

1 Anomaly (>3σ)

$$X' = X - \langle X \rangle$$

$$\delta_{ji} = \begin{cases} 1, & X_i' \geq M\sigma_{X_i} \\ 0, & X_i' < M\sigma_{X_i} \end{cases}$$

Number of Anomaly

$$N^s{}_i = \sum_{j \in \Delta t} \delta_{ji}$$

$$N^s{}_v, N^s{}_u, N^s{}_w, N^s{}_T, N^s{}_q, N^s{}_z$$

Value of anomaly

$$A^s{}_i = \sum_{j \in \Delta t} \delta_{ji} \cdot X_i'$$

$$A^s{}_v, A^s{}_u, A^s{}_w, A^s{}_T, A^s{}_q, A^s{}_z$$

2 EOF Analysis

To estimate the spatial inhomogeneity in climatic values anomalies EOF3 was used

3 Steering current

Steering current V_{lead} was calculated in the layer 500-700 hPa in latitudinal zone 40N-60N:

$$V_{lead} = \langle V_{lat,lon} \rangle$$

$$V_{lat,lon} = \langle V_{\lambda,\varphi}^l \rangle \qquad V_{\lambda,\varphi}^l \geq V_R^l$$

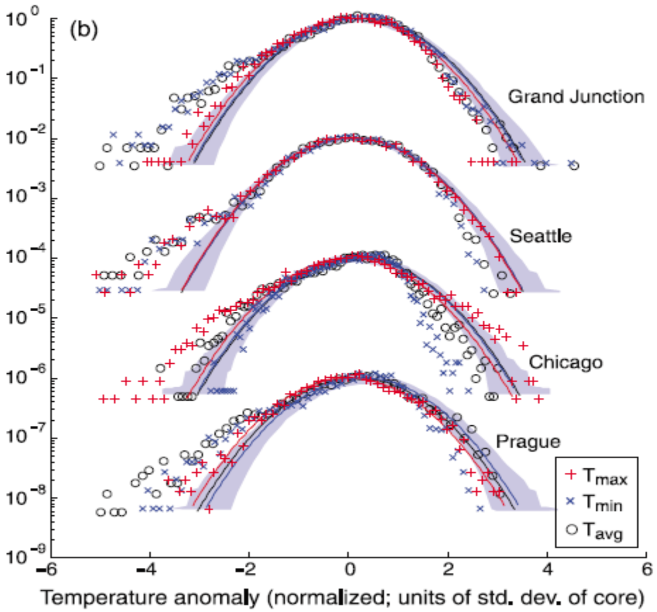
V_R^l - mean values of wind speed $V_{\lambda,\varphi}^l$ at the level l and region R $\quad \lambda, \varphi \in R$

4 Centers of action in the atmosphere

Intensity and placement:

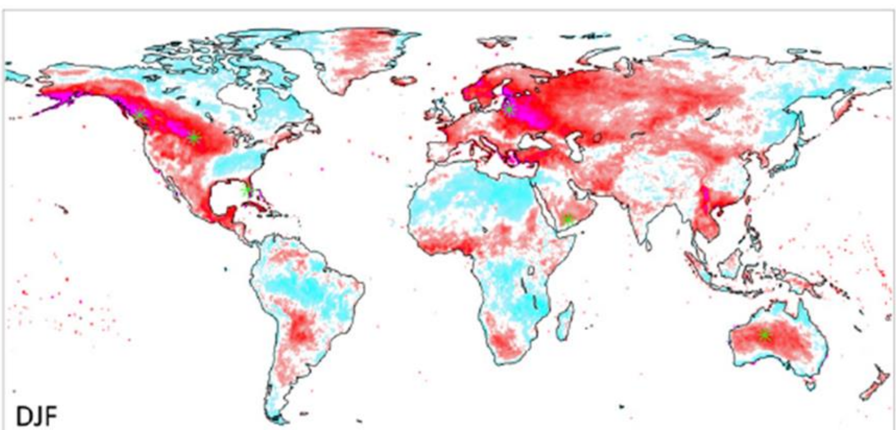
- Siberian High
- Azores Maximum
- Icelandic Minimum

Anomaly (>3σ)



Probability distributions (as normalized frequency of occurrence) of daily temperature anomalies, normalized by the standard deviation of a Gaussian fit to the core (fit for points exceeding 30% of the maximum, drawn as solid lines), at selected stations (vertically shifted for clarity) during DJF (winter). Stacked for each station are the variables Tmax (red), Tavg (black), and Tmin (blue). The shaded error envelope is shown for Tmax at each station (the envelopes for Tavg and Tmin are very similar).

Ruff, T. W., and J. D. Neelin (2012), Long tails in regional surface temperature probability distributions with implications for extremes under global warming, Geophys. Res. Lett., 39, L04704, doi:10.1029/2011GL050610.



Shift ratio (i.e., the ratio of the percent of days exceeding the preshifted 95th percentile of the actual distribution after a 0.5s uniform warm shift to the percent expected if the distribution were Gaussian) for (top) DJF and (bottom) JJA. Values greater than 1 indicate a shorter-than-Gaussian warm-side temperature PDF tail. White areas over land are where the warm-side tail is not significantly distinguishable from a Gaussian at the 5% level. Results are for the period 1979–2005 for the MERRA-CRU reanalysis. Stars identify where scatterplots are produced.

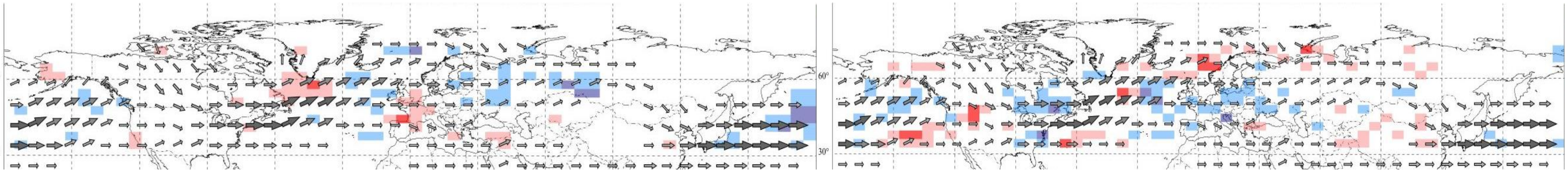
Paul C. Loikith; J. David Neelin; Joyce Meyerson; Jacob S. Hunter Short Warm-Side Temperature Distribution Tails Drive Hot Spots of Warm Temperature Extreme Increases under Near-Future Warming J. Climate (2018) 31 (23): 9469–9487.https://doi.org/10.1175/JCLI-D-17-0878.1

Spatial distribution of EOF3

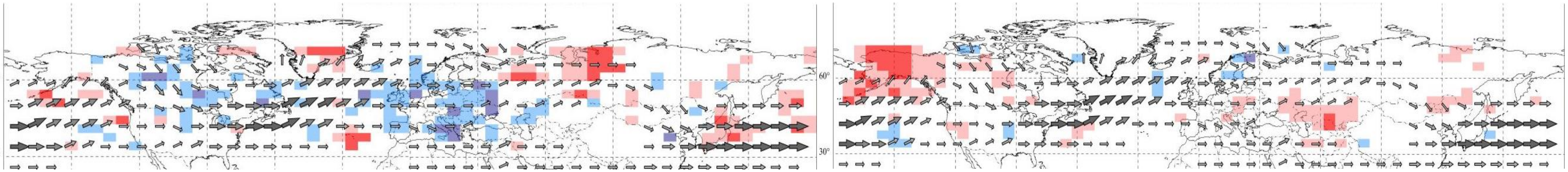
Value of anomalies (positive + negative)

Winter

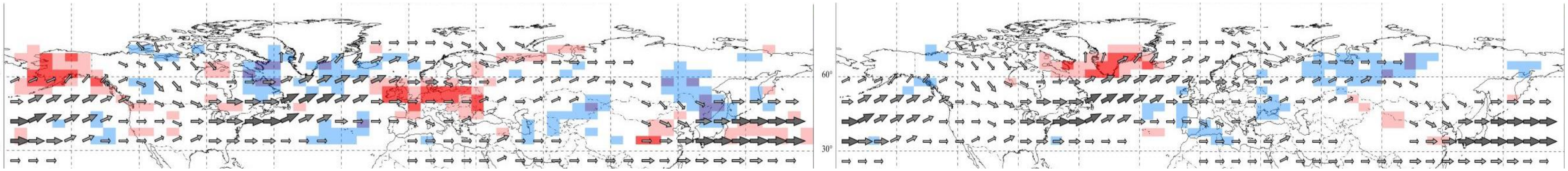
1000 hPa q 500 hPa



T



z



ERA-Interim reanalysis data (6-h) for the 1979–2017 interval with spatial resolution of 1.125×1.125°

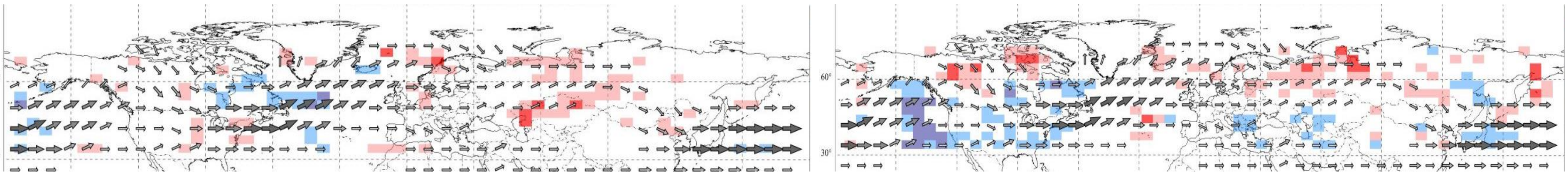
Spatial distribution of EOF3

Value of anomalies (positive + negative)

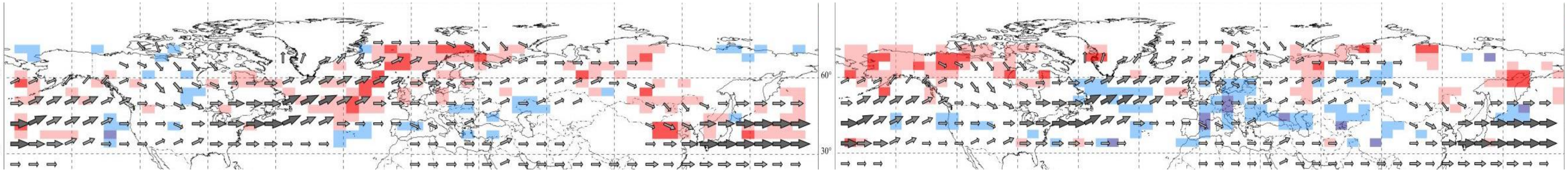
Winter

1000 hPa | 500 hPa

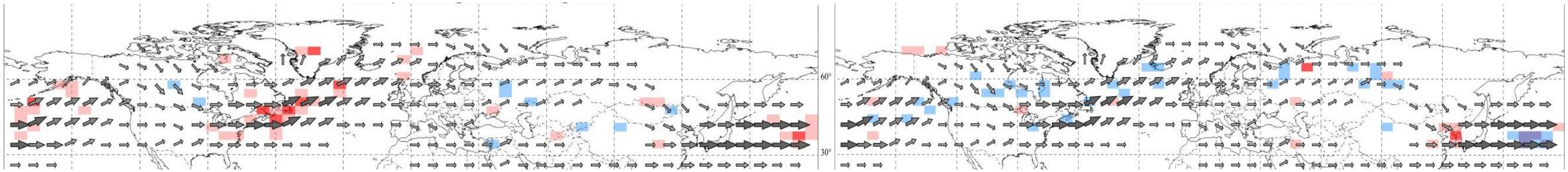
u



v



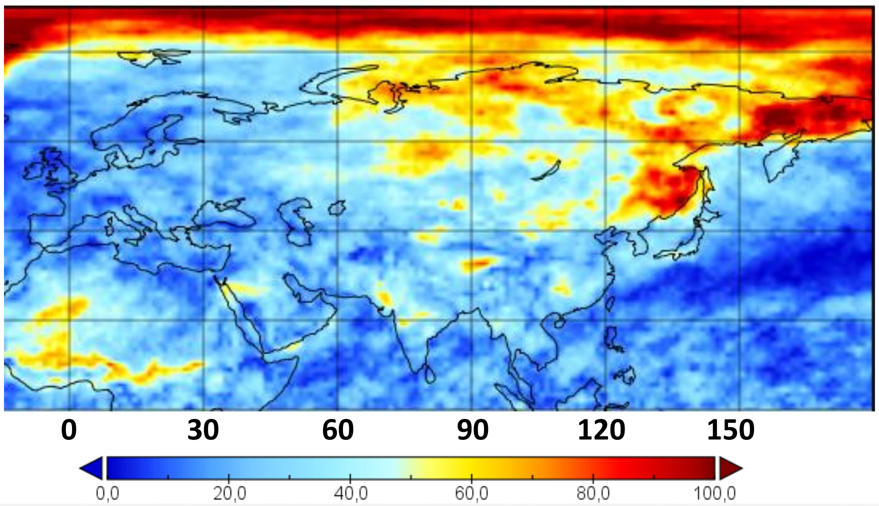
w

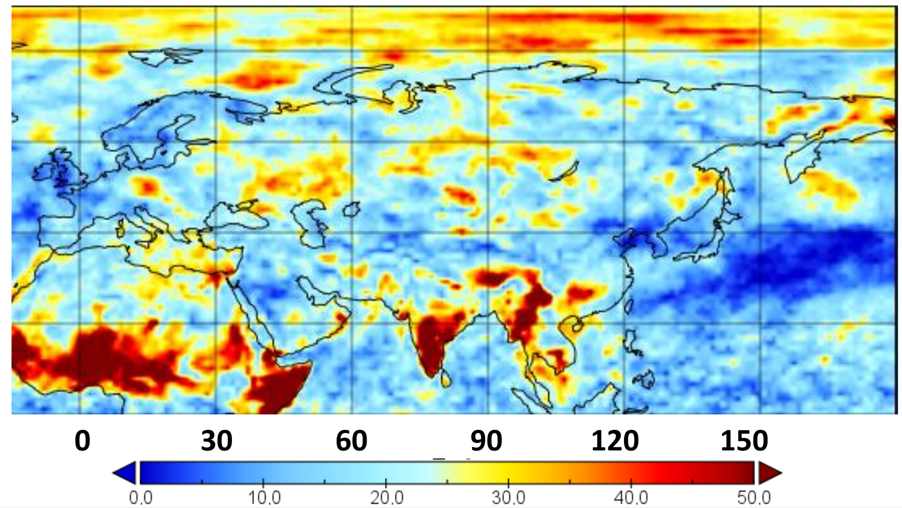


ERA-Interim reanalysis data (6-h) for the 1979–2017 interval with spatial resolution of 1.125×1.125°

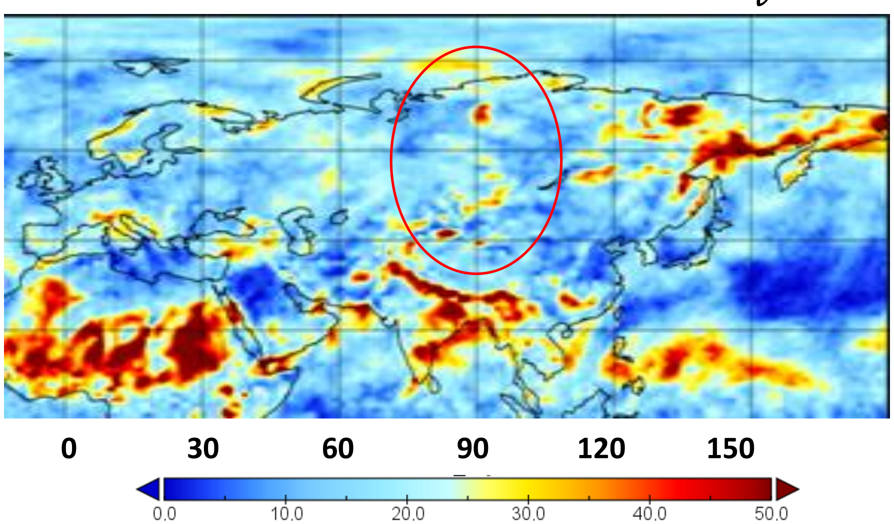
Spatial distribution of atmospheric anomalies $N^s{}_i$ (M=3) for the territory of Eurasia

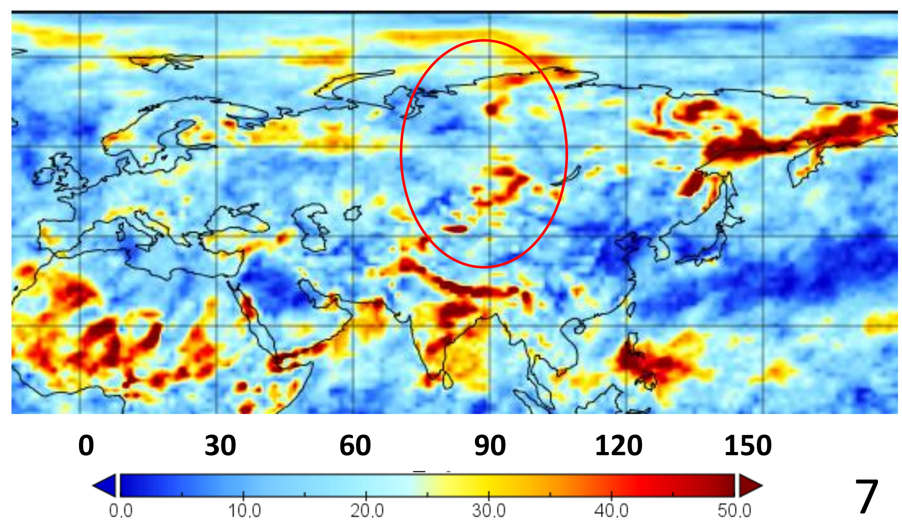
$N^s{}_q$ **Specific humidity** **at the beginning of the 21st century** **Temperature air** $N^s{}_T$





at the end of the 20th century $N^s{}_v$ **v-velocity** **at the beginning of the 21st century**





Value of meridional wind speed anomalies

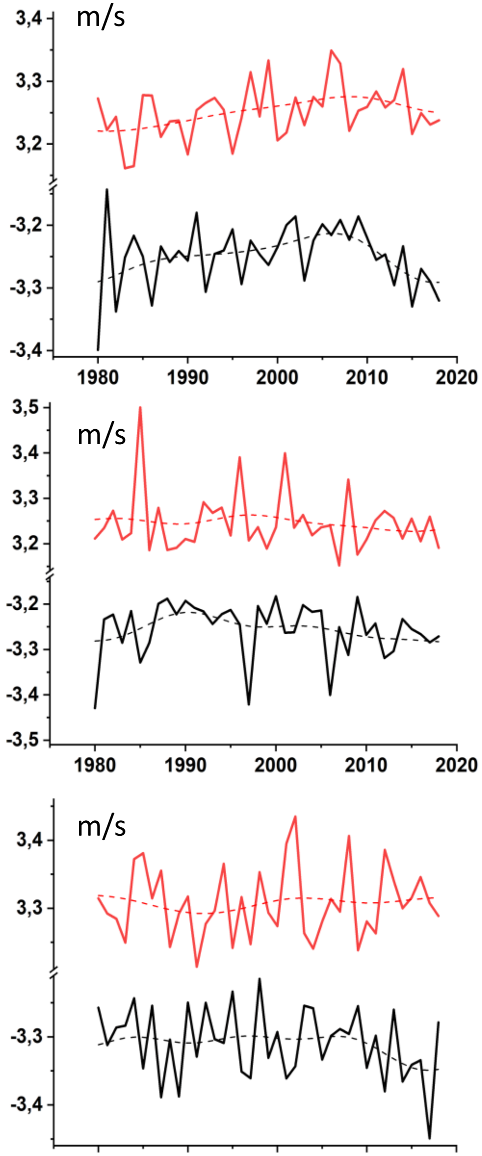
Steering current speed

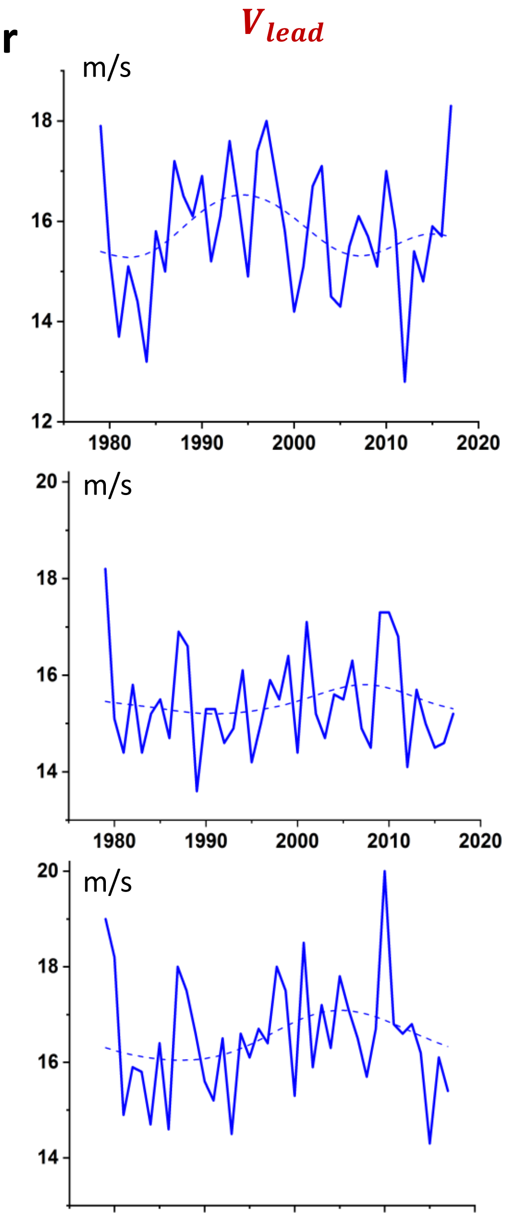
Winter

West Siberia (60 – 90E)

East Siberia (90 – 120E)

Far East (120 – 150E)



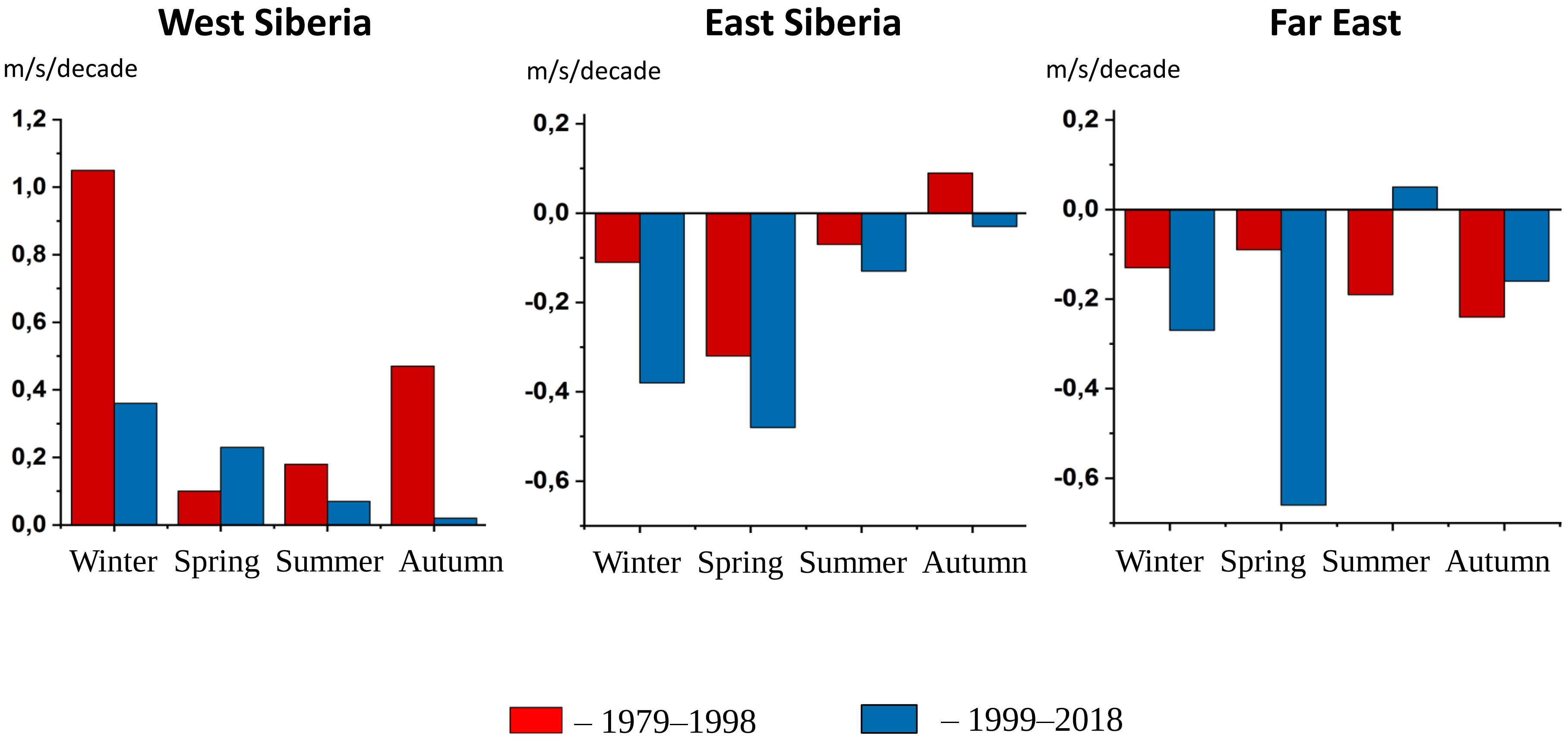


– positive anomalies

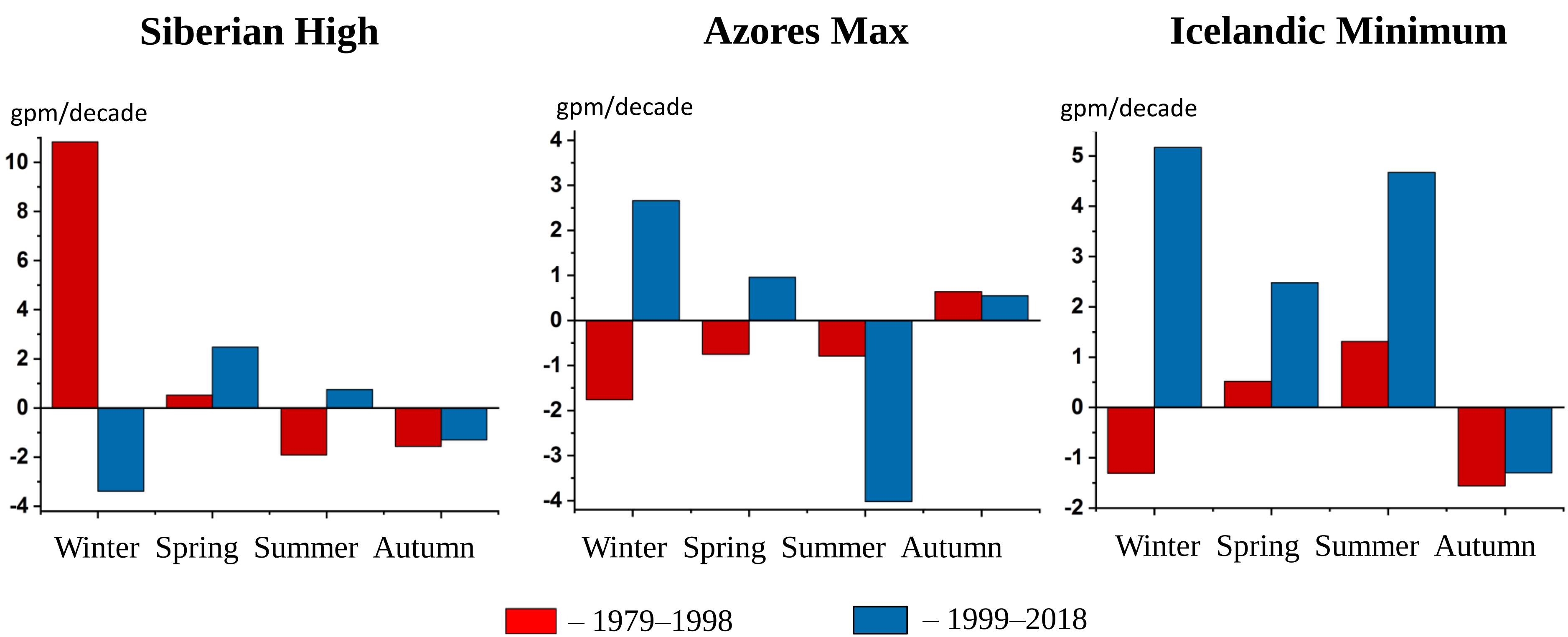
– negative anomalies

Trends of steering current speed

700–500 hPa



Trends of centers of action in the atmosphere



Correlations

WS:
0.72 → 0.32
(1979-1998) (1999-2018)

WS:
-0.46 → -0.01
FE:
-0.49 -0.39
(1979-1998) (1999-2018)

WS:
0.38 0.50
ES:
0.48 → 0.43
(1979-1998) (1999-2018)

Correlation coefficients

$$R_q(V_{lead}, A^s{}_v)$$

Negative anomalies

quantile	1979–1998 Winter	Spring	Summer	Autumn	1999–2018 Winter	Spring	Summer	Autumn
	West Siberia							
0,25	**-0,63**	**-0,71**	-0,52	-0,28	-0,59	**-0,60**	-0,58	-0,54
0,75	0,51	0,42	0,55	0,53	0,46	0,49	0,44	0,45
	East Siberia							
0,25	-0,56	-0,46	-0,58	-0,57	-0,38	**-0,72**	-0,56	-0,55
0,75	0,58	0,58	0,53	**0,68**	0,59	0,58	0,57	0,56
	Far East							
0,25	-0,35	-0,58	-0,56	-0,55	-0,37	-0,54	-0,58	-0,58
0,75	**0,65**	0,44	**0,62**	**0,68**	0,49	0,55	0,39	0,45

Positive anomalies

quantile	1979–1998 Winter	Spring	Summer	Autumn	1999–2018 Winter	Spring	Summer	Autumn
	West Siberia							
0,25	-0,37	-0,56	**-0,63**	**-0,66**	-0,54	**-0,70**	-0,55	-0,45
0,75	**0,64**	**0,60**	0,51	0,45	0,49	0,28	0,45	0,59
	East Siberia							
0,25	**-0,72**	**-0,70**	-0,53	**-0,68**	**-0,69**	**-0,72**	**-0,61**	**-0,61**
0,75	0,49	0,35	**0,60**	**0,87**	0,34	**0,74**	**0,70**	**0,60**
	Far East							
0,25	-0,57	-0,56	**-0,61**	-0,58	**-0,60**	-0,48	-0,52	-0,52
0,75	0,41	0,50	0,56	0,77	0,37	0,54	0,57	**0,66**

Results

1. Thus a study of the number of anomalies in the main meteorological variables corresponding to extreme values revealed an increasing of negative anomalies in winter for the entire ATR. A magnitude increasing of the positive anomalies of the meridional wind speed is observed only in the Far East.
2. It is shown that the largest number of significant values of the correlation coefficients characterizing the seasonal relationship of processes in the lower troposphere is characteristic of the relationship between the steering current velocity and the number of positive anomalies of the meridional wind speed.
3. The use of EOF analysis made it possible to identify the wave structure of the steering current, while the regions of significant anomalies are located both in the zone of the current and in areas of a sharp change in its direction.
4. It was also established that at the beginning of the XXI century significant changes in the trends in the intensity of the action centers took place: in the winter at the Siberian maximum and the Icelandic minimum, in the summer at the Azores maximum and the Icelandic minimum.
5. In addition, it was shown that in winter in Western and Eastern Siberia, significant changes in the trends of the steering current velocity are observed, while in spring in Eastern Siberia and the Far East, and in autumn in Western Siberia.
6. Correlation analysis showed that significant decreasing of the intensity of the Siberian maximum in the winter season affected on decreasing of the steering current velocity in Western Siberia at the beginning of the 21st century, while the effect of the Icelandic minimum intensity on the current velocity, on the contrary, intensifies.