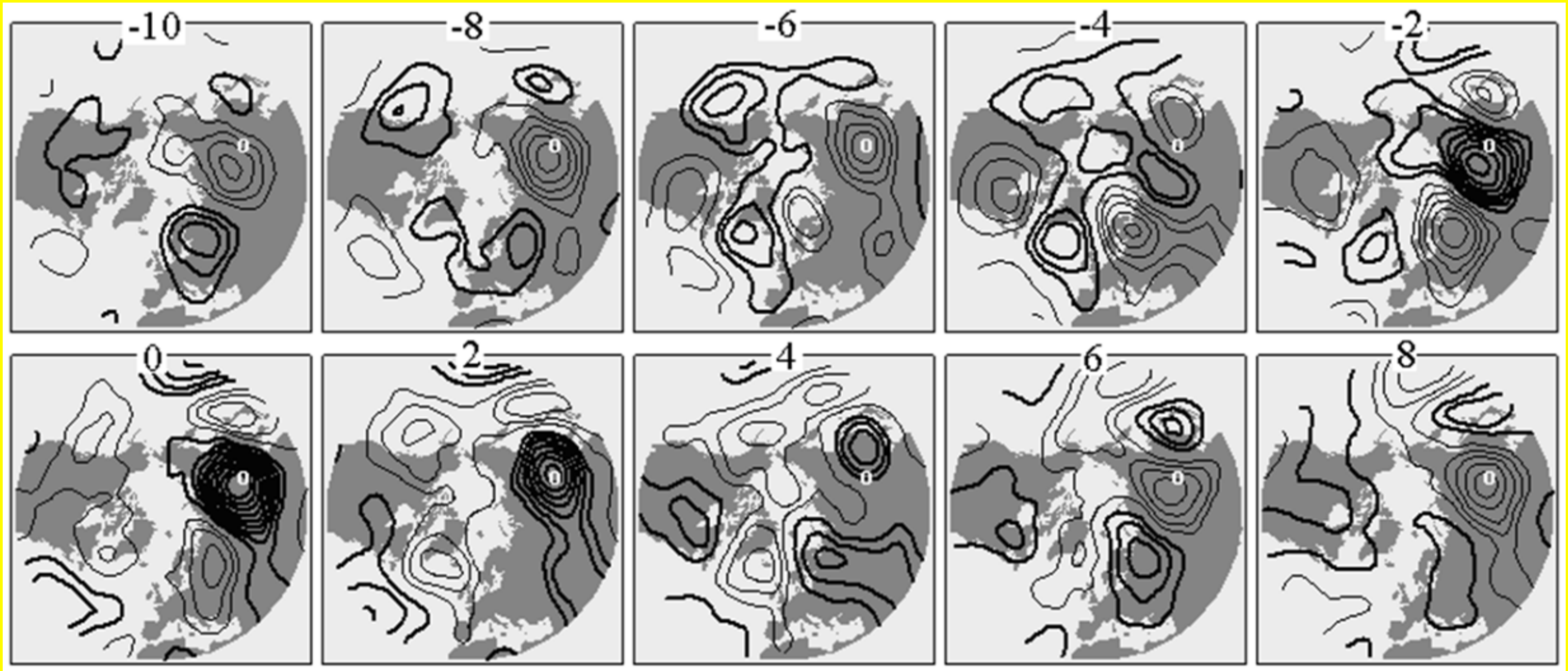
Simulation of the atmospheric low-frequency fluctuations propagation over Eurasia

Mordvinov V.I., Devyatova E.V.
Institute of Solar-Terrestrial Physics SB RAS, Irkutsk

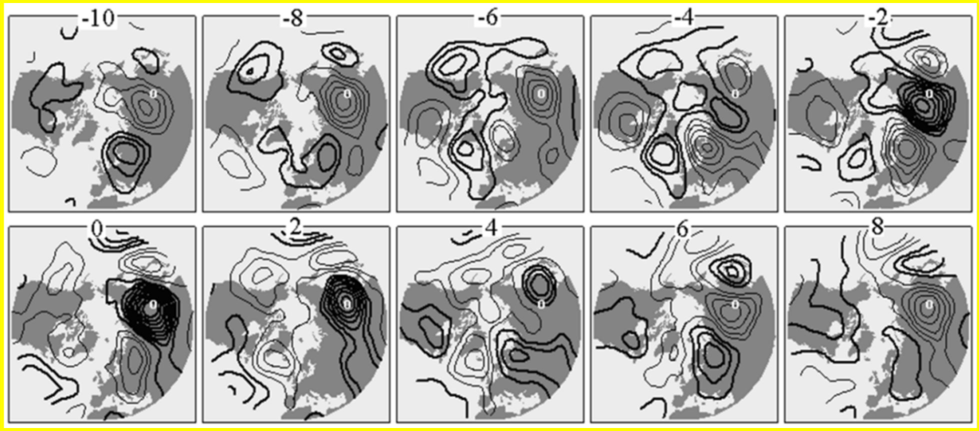


The lag-correlation pattern for 500 hPa height for the grid-point 55N, 108E averaged for period 1990 – 2000.

<u>There are two main features:</u>

1)Anticlockwise «rotation» of the disturbances over eastern part of Eurasia with period about 16 days.

2)Wave train over northern parts of Northern America, Atlantica and western Europe. Probably this wave train arises because of wave’s refraction from the critical line of zero zonal wind in the tropics and wave’s interference in the mid latitudes.



Data

The daily NCEP/NCAR Reanalysis 1 data for 500 hPa height from 1950 to 2010 (Kalnay E. et al. 1996)

Method

The method of the one-point correlation with time lag was applied (Blackmon M.L. et al., 1984).

1. The fluctuations with time scale 5 – 20 days were filtered by moving average method;
2. The correlation patterns for 500 hPa height in the grid-points 2.5°*2.5° for the base grid-point 55N, 108E with time lags from -10 to +8 days were calculated.
3. The interval from 15 January to 15 March was chosen to calculate the correlation patterns because the atmospheric circulation is most intensive in this period.
4. The correlation patterns then were averaged over 10-year intervals.

Assuming that at least in part, the observational disturbances dynamics can be explained by two-dimensional waves dispersion from the travelling sources, we realized the simulations of these disturbances, using divergent «shallow water» model on a sphere. A travelling source crossing the eastern Eurasia from north-west to south-east was considered.

Our task - reproducing such features of the low-frequency fluctuation patterns as anticlockwise «rotation» of the disturbances over eastern part of Eurasia and dynamics of the wave train over northern parts of Northern America, Atlantica and western Europe.

The equation of the quasi-geostrophical potential vortex conservation in the spherical coordinate system with the Rayleigh friction and turbulent viscosity was used (Holton, 2004):

$$\frac{\partial \Delta \psi}{\partial t} = \frac{1}{a^2}\left[\frac{\partial \psi}{\partial \mu}\frac{\partial \Delta \psi}{\partial \lambda} - \frac{\partial \psi}{\partial \lambda}\frac{\partial \Delta \psi}{\partial \mu}\right] - \frac{2\Omega}{a^2}\frac{\partial \psi}{\partial \lambda} - r\Delta\psi - K\Delta^2(\Delta\psi)$$

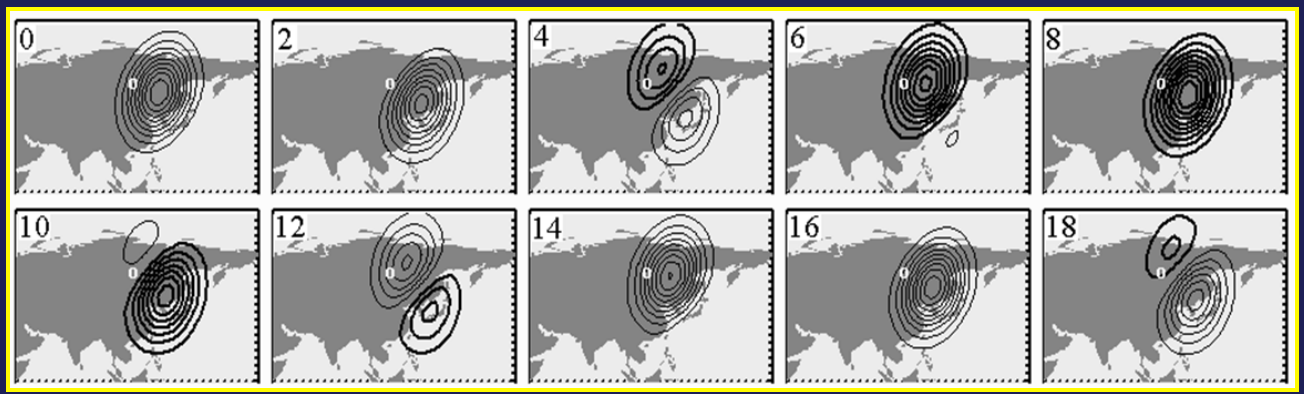
где ψ - stream function, R - vortex source (in general, time dependent), r - Rayleigh friction coefficient in the atmospheric boundary layer, K – horizontal diffusion coefficient, $\mu = \cos\theta$, a - the Earth's radius, Ω - angular velocity of the Earth's rotation.

The stationary equation after linearization:

$$R = \frac{1}{a^2}\left[\frac{\partial \psi'}{\partial \mu}\frac{\partial \Delta \bar{\psi}}{\partial \lambda} - \frac{\partial \psi'}{\partial \lambda}\frac{\partial \Delta \bar{\psi}}{\partial \mu} + \frac{\partial \bar{\psi}}{\partial \mu}\frac{\partial \Delta \psi'}{\partial \lambda} - \frac{\partial \bar{\psi}}{\partial \lambda}\frac{\partial \Delta \psi'}{\partial \mu}\right] - \frac{2\Omega}{a^2}\frac{\partial \psi'}{\partial \lambda} - r\Delta\psi' - K\Delta^2(\Delta\psi')$$

The source was specified according to empirical analysis as traveling modulated wave moved from north-west to south-east over eastern part of Eurasia with period 15 days:

$$R=\partial(\Delta\bar{\psi})/\partial t = A\,\mathrm{Re}\left\{ e^{i\left[k_1\lambda+k_2\theta+\sigma t\right]} e^{-\left[(\lambda-\lambda_0)^2/d_1+(\theta-\theta_0)^2/d_2\right]} \right\}; \quad \boldsymbol{\sigma} = 2\pi/T; \; T = 15 \text{ суток}$$



Modeling disturbances are the parametrically time-dependent solutions of the stationary vortex equation.

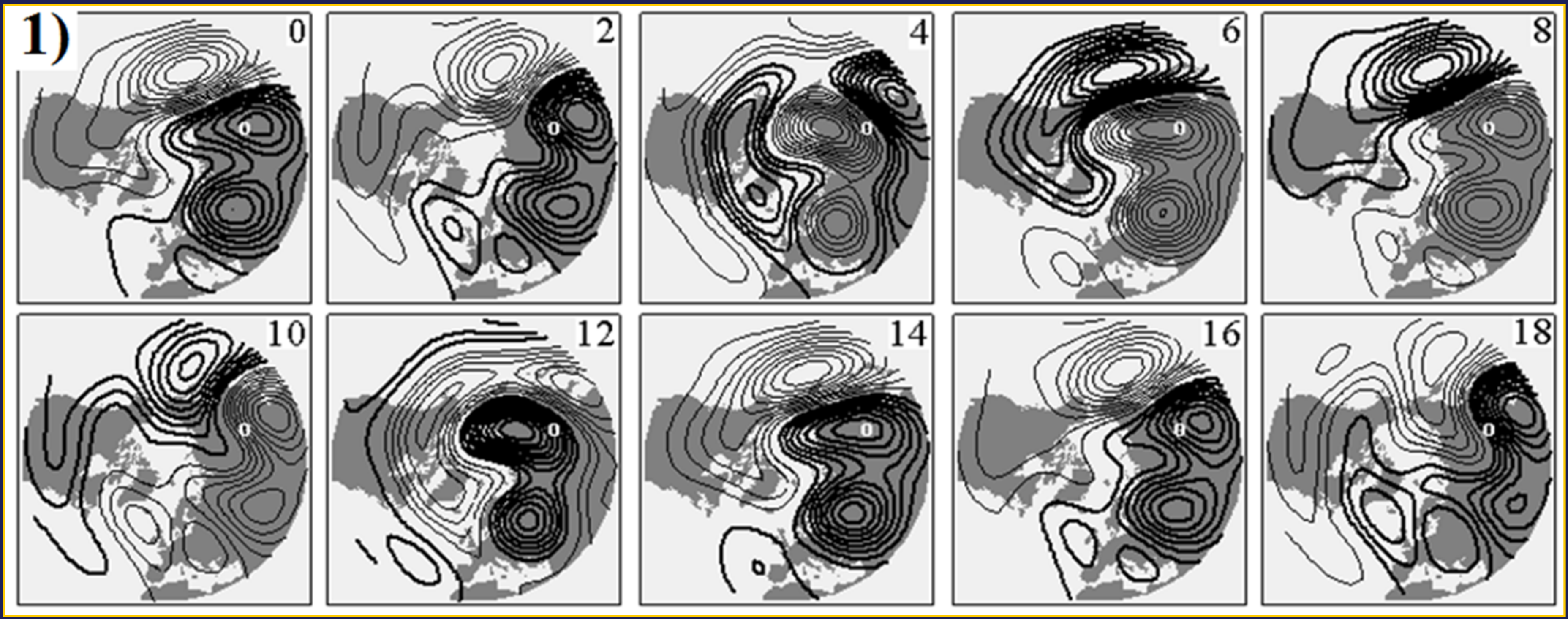
Spatial structure of the disturbances strongly depends on the structure of mean flow.

In this work two profiles of the zonal flow are considered:

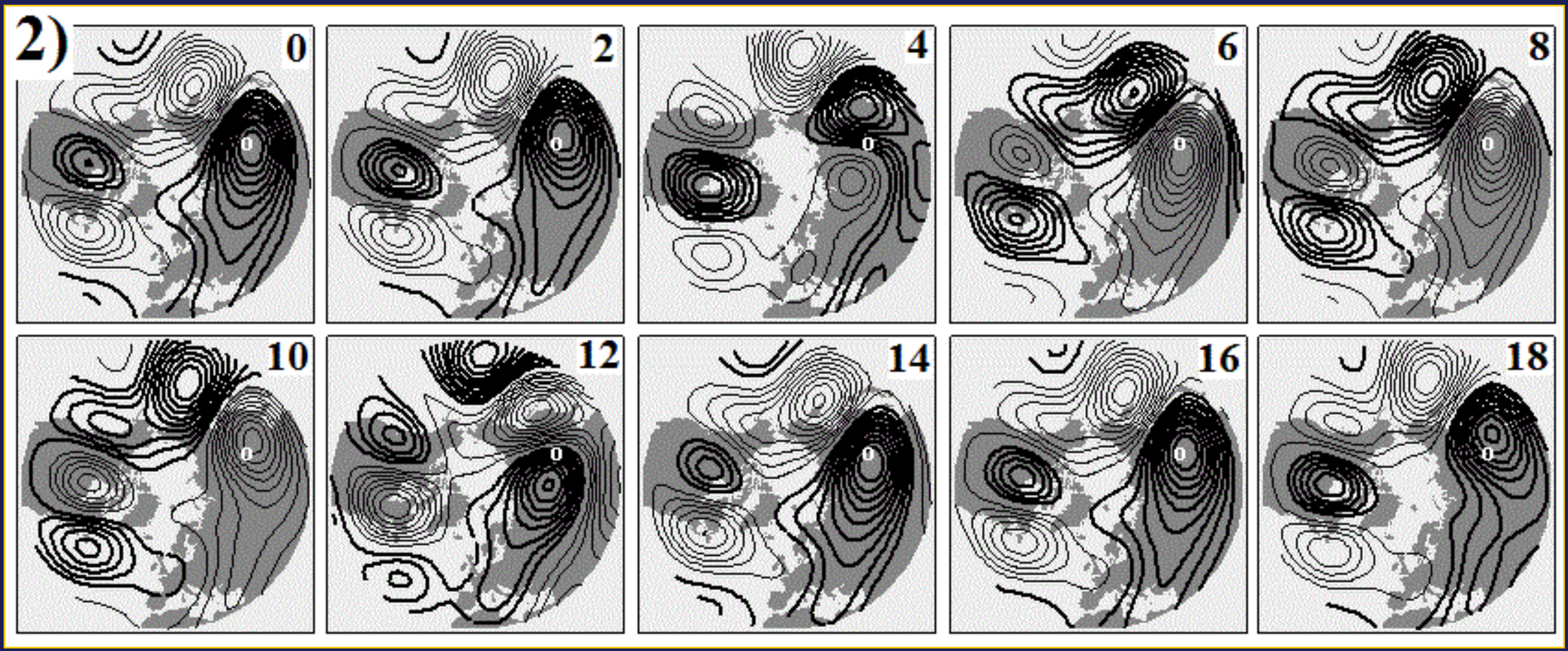
1) Profile specified analytically as a function of angular velocity on latitude $\alpha = \alpha_0 \sin^3(3\theta)$, reproducing easterly flow in the tropics;
2) The structure of the mean flow, derived from the NCEP/NCAR Reanalysis data.

The meridional component of velocity in both cases was assumed to be zero.

$$\alpha = \alpha_0 \sin^3(3\theta)$$



The structure of the mean flow, derived from the NCEP/NCAR Reanalysis data



Conclusion

The tropospheric low-frequency (time scales 5 – 20 days) disturbances propagated in the wintertime over Eurasia was investigated, using lag-correlation statistic.

The revealed features of disturbances propagation were simulated in the quasigeostrophic barotropic approximation.

Traveling source was specified as sign-changing Gaussian functions moved from north-west to south-east over eastern part of Eurasia.

In general the features of one-point correlation maps such as «rotation» of the disturbances over eastern part of Eurasia and wave train to the west from the base grid-point are reproduced in the model.