Analysis of eddy and convective energies of cyclone formations on the territory of Siberia

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The investigation of eddy kinetic energy store and its balance in mid-latitude cyclones permits to define the degree of disturbance of atmospheric processes, and also reveal the character of interactions between the general flow and cyclonic formations. The study of convective flows permits to form a concept of mechanism of vertical motions occurrence in cyclones.

The purpose of this study is to investigate the energy characteristics in the convective motion zones and eddy motions of a mid-latitude cyclone in different stages of their evolution.

We use:

1. Reanalysis data NCEP/DOE AMIP-II Reanalysis (0, 6, 12, 18 h)
   http://www.cdc.noaa.gov/data/gridded/tables/subdaily.html
   - 17 standard isobaric levels
   - grid with resolution 2,5°
2. JRA-25 long-term reanalysis cooperative research project carried out by the Japan Meteorological Agency (JMA) and the Central Research Institute of Electric Power Industry (CRIEPI)
   http://ds.data.jma.go.jp/gmd/jra/download/data/
   - 23 standard isobaric levels
   - grid with resolution 2,5° and 1,25°
3. Synoptic maps (July of 2005)
4. The data of aerological sounding IGRA
   ftp://ftp.ncdc.noaa.gov/pub/data/igra
5. Daily MODIS data ftp://ladsweb.nascom.nasa.gov
   - Lifted Index

To calculate the estimates of eddy and convective motions we apply the energy balance equations:

$$\int_{V2}^{V1}\frac{\partial K}{\partial t}dV=-\int_{V2}^{V1}\nabla g\,KVdV-\int_{V2}^{V1}\frac{\partial K\tau}{\partial p}dV-\int_{V2}^{V1}Vg\nabla\Phi dV+\int_{V2}^{V1}\Delta_K dV$$

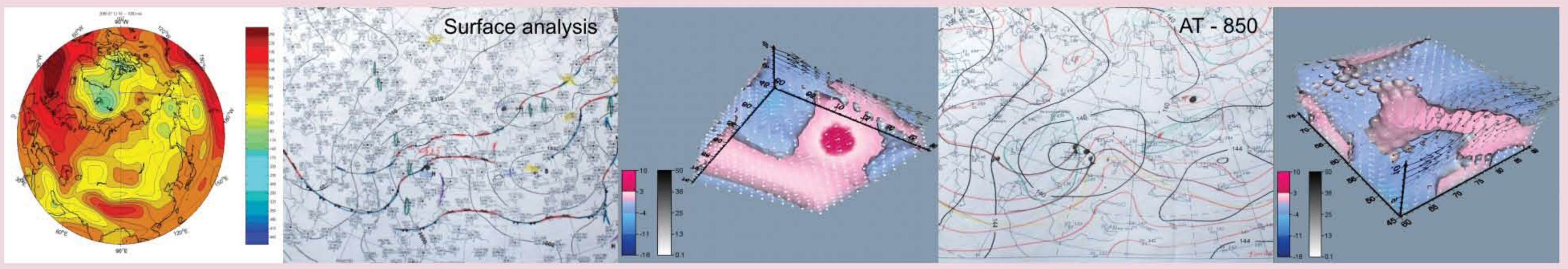
$$K_5 = K_1 - (K_2 + K_3 + K_4).$$

$$\int_{V2}^{V1}\frac{\partial K^*}{\partial t}dV=-\int_{V2}^{V1}\nabla g\,K^*VdV-\int_{V2}^{V1}\frac{\partial K^*\tau}{\partial p}dV-\int_{V2}^{V1}Vg\nabla\Phi\, dV+\int_{V2}^{V1}\tau\alpha\, dV-\int_{V2}^{V1}\Delta_W Lg\cdot 10^{-3}dV+\int_{V2}^{V1}\Delta_{K^*}dV$$

$$K^*_6 = K^*_1 - (K^*_2 + K^*_3 + K^*_4 + K^*_5).$$

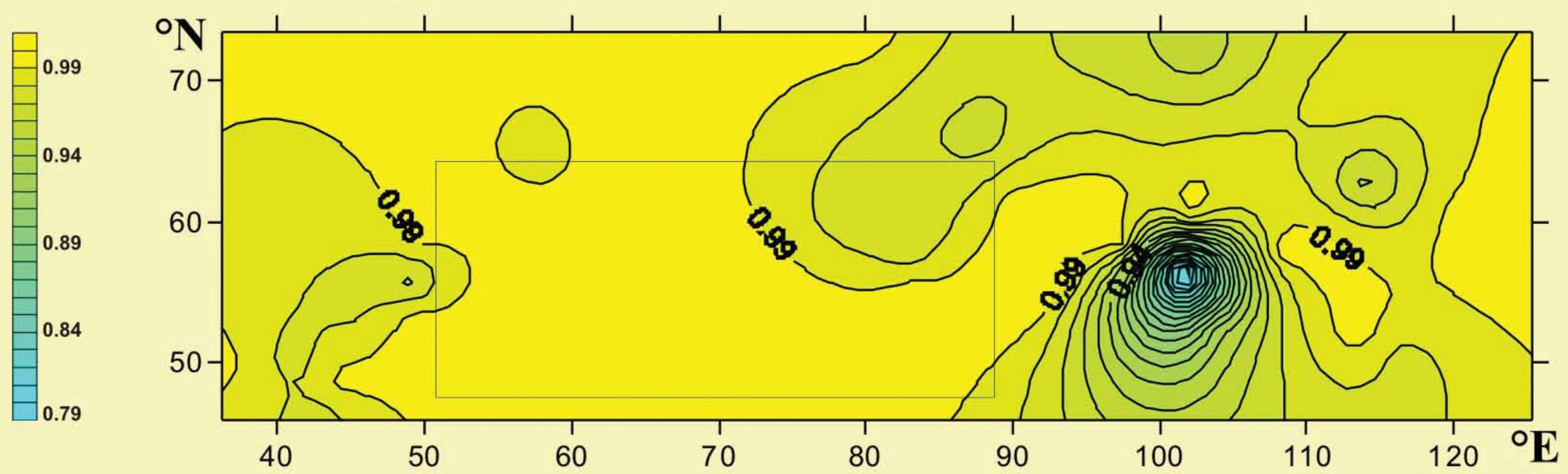
$$dV=\frac{1}{gS}\,dxdydp,\nabla=\frac{1}{\partial x}+\frac{1}{\partial y}$$

Using reanalysis data, we selected several cyclones on the territory of West Siberia, here you can see one of these cyclones Zn1. Also a temperature-wind field was constructed and this four-dimensional image was compared with the synoptic maps.



№	Stages of cyclone development	Dates of stage beginning and end
I	Initiation	18 h 12 of July 00 h 13 of July
II	Young cyclone	06 h 13 of July 12 h 13 of July
III	Maturation	18 h 13 of July 00 h 15 of July
IV	Decay	06 h 15 of July 12 h 16 of July

It was tested, how aerological and reanalysis data are matched in the cyclone zones to further calculations of energy balance components. For selected aerological stations (total number 46) on the given territory the estimates of correlation coefficients between time series at 11th standard isobaric levels were done, and upper and lower significance limits with confidence probability (α=0,95) were defined. The calculations show the high level of relationship (0,85-0,99) between aerological instrumentation and reanalysis data for geopotential and temperature quantities in the whole selected region. There are the greater values of correlation coefficients in the zone of cyclone development.



The spatial distribution of correlation coefficients for the geopotential quantity on the given region for Zn1 (altitude of 925 hPa)

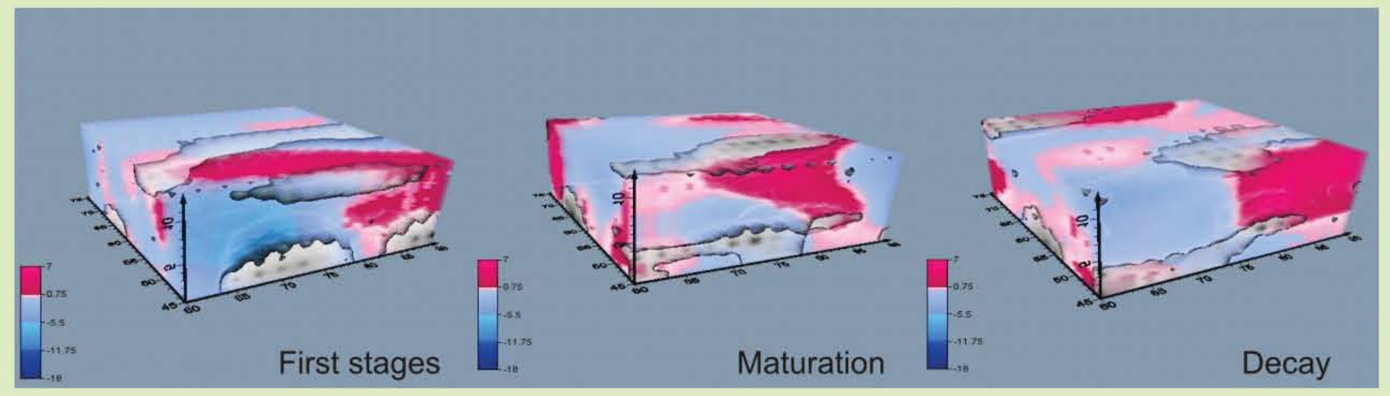
The zones of convective instability are defined in the region of cyclone by the CAPE (convective available potential energy) index calculated from the reanalysis data. An independent indicator is the Lifted Index (from the MODIS data).

Atmospheric instability zones using CAPE and LI

$$CAPE=\int_{Zf}^{Zn} g\left(\frac{Tv_{parcel}-Tv_{env}}{Tv_{env}}\right)dz \qquad LI = Tv_{env}\,(500hPa) - Tv_{parcel}$$

	Reanalysis data		MODIS data
Time	**CAPE**	**h (height), level**	**LI**
13 of July 00 h	45-55°N 64-79°E	from 1 to 5	50-54°N 75-77 °E
15 of July 00 h	45-49°N 60-79°E 54-59°N 76-90°E	from 1 to 4 from 1 to 2	
16 of July 00 h	50-54°N 78-86°E 58-65°N 67-90°E	from 1 to 4 From 1 to 5	50-53°N 75-78°E

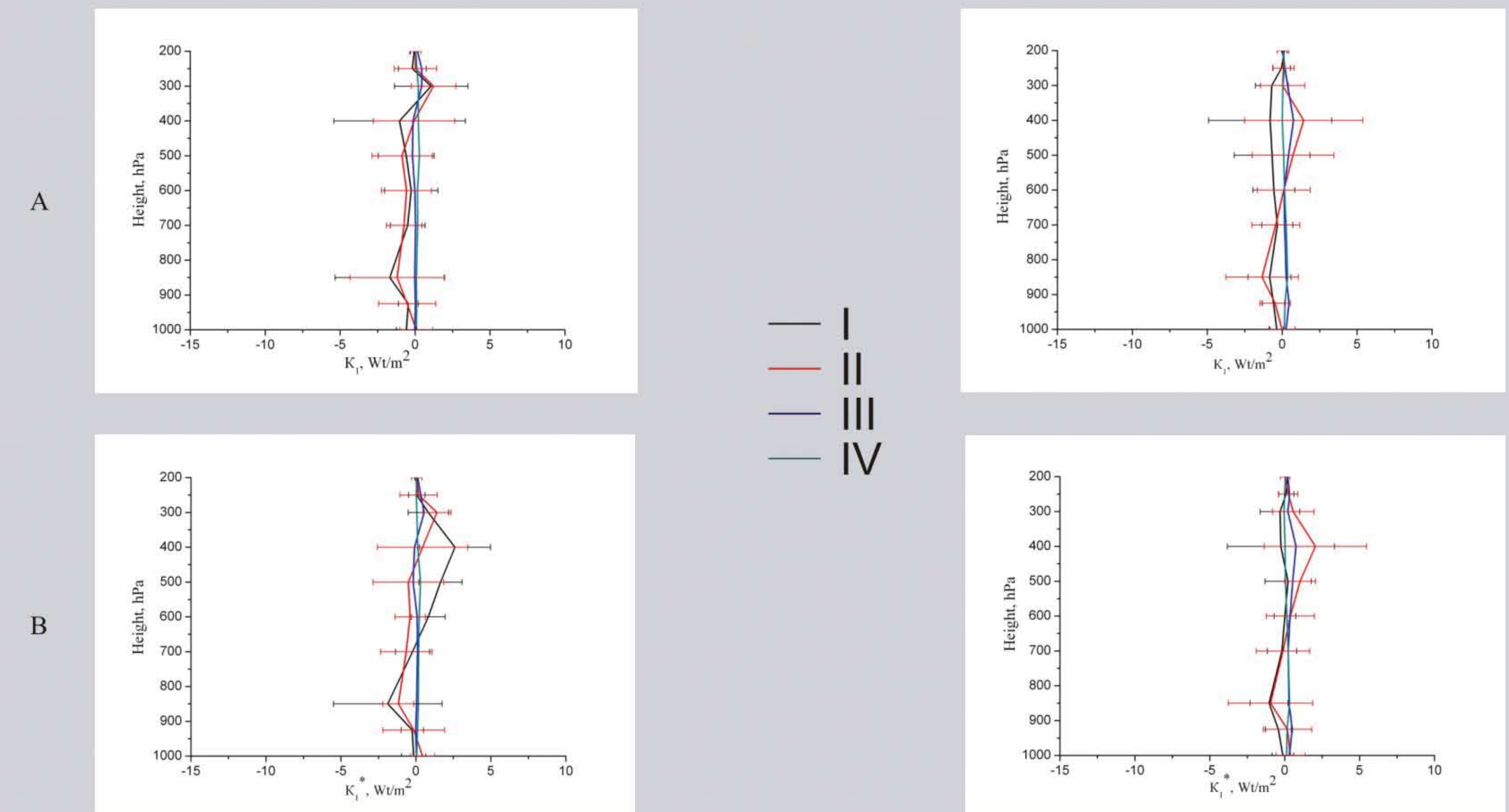
These zones are in good agreement with each other.



Spatial kinetic energy distribution and instability zones

The convective regions, colored in grey, where CAPE is more than zero, are the most distinct and vast in the first stages of evolution near the earth surface in the region of the cyclone.

We obtained the vertical profiles of kinetic and eddy energy changes in both zones



Kinetic energy store versus height (A) and store of eddy component of kinetic energy versus height (B) with its variance

The vertical profiles of kinetic and eddy component of kinetic energy in both zones (stability and instability) have the similar distribution. The presence of several convective zones at an altitude of 400 hPa in the first stage leads to the growth of K^* and the sink of K.

Results:

- **in the first stages of cyclone development the kinetic energy sink and the growth of eddy component of kinetic energy occure at an altitude of 400hPa, because of the presence of several convective zones at this altitude**
- **the kinetic energy store and eddy energy store for convective instability zones is nearly twice higher than that for the stability zones**
- **we verify to the investigation of cyclone development, based on a combined analysis of a synoptic situation and a four-dimensional temperature-wind field**