Numerical simulation of cloud and precipitation evolution and its connection with anomaly gravity fields

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INTRODUCTION

Numerical simulation of atmospheric phenomena connected with atmospheric fronts and their cloud systems that caused the damages in frame aircrafts, agriculture, transport etc have been fulfilled for several synoptic situations. Present work continues theoretical studies of heavy precipitation caused floods and damages in mountain regions of Ukraine. In recent years heavy precipitation causes flash floods in Crimearegion very frequently. Conditions of formation of high convective cells, supercells, long lasting precipitation and heavy rainfalls, horizontal and vertical rotor cells have been objected for investigation. Theoretical interpretation of atmospheric state by nowcasting numerical models and cloud evolution modeling by forecasting models were conducted and inner structure of modelled cloud at different stages of their development were investigated.

METHODOLOGY OF THE RESEARCH

The three-dimension diagnostic and prognostic models with non-elastic dynamics at detail microphysics have been adapted for theoretical interpretation of the investigated phenomena. There is proposed research methodology based on numerical integration of dynamic and thermodynamic full equation jointly with kinetic equation for cloud particles distribution function [1,2]. 3-D diagnostic models were used for construction of initial meteorological fields and analyses of current state of atmosphere at target time and space. Initialization of models was performed by rawinsound data from the regular network get up from British Atmospheric Data Centre (BADC).

NUMERICAL RESULTS

At first case of heavy rainfall and flash floods that place in Crimea region on August 5-10 2002 will be presented. Limited regions are strong flood location. Three dimension nowcasting and forecasting numerical models of frontal cloud systems passed over Ukraine accompanied strong precipitation, and heavy floods were constructed. Village Bogatoe is precipitation sum epicenter. 3-4 monthly sums falling down during August 5-10
At second case of heavy rainfall and flash floods that place in. Sim Kolodyaziv.
Initial coordinate point is Simferopol.

Numerical experiments for study of inter structure and features of evolution convective cloud clusters different mesoscales, and supercells and severe chimney clouds have been carried out. Nested grids differentscales were used for modeling. The 5 km space steps were used for supercells and cloud clusters. The 0.2-1km space steps were used for chimney convective clouds. The 200 m steps was used for vertical resolution. z-highest is 15 km. Meteorological fields get up by diagnostic models. P-T-Entropy have cell structure that caused next formation of the convective cells. Spatial attention was given to stream lines.

Three-dimensional diagnostic model

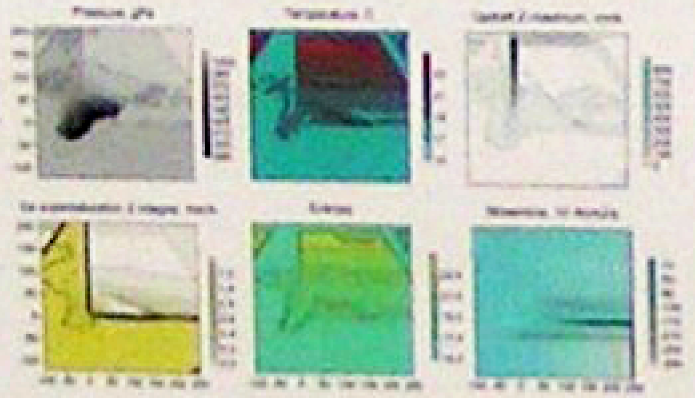


Fig. 1 Initial cloud futures

Three-dimensional forecasting numerical models

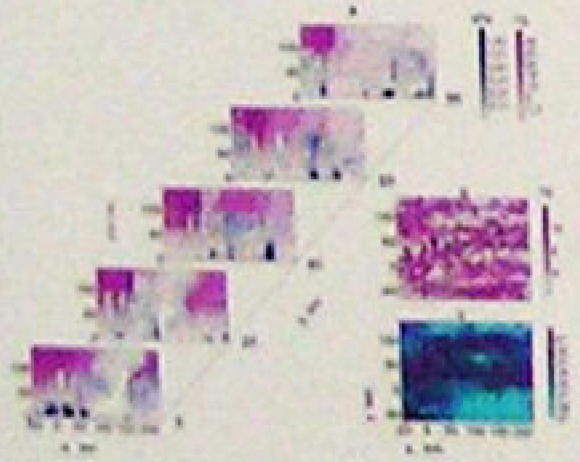


Fig. 2 Spatial distribution of clouds and entropy
a) ice concentration and water content vertical cross section at different Y
b) Ice cover (ice concentration Z-max)
c) entropy distribution at Z=3 km.

Horizontal step 5 km. Ice cover and entropy horizontal distribution depicted the cell structure. Vertical cross sections show presence of deep convective cloud clusters. Entropy min correspond to ice concentration maximum.

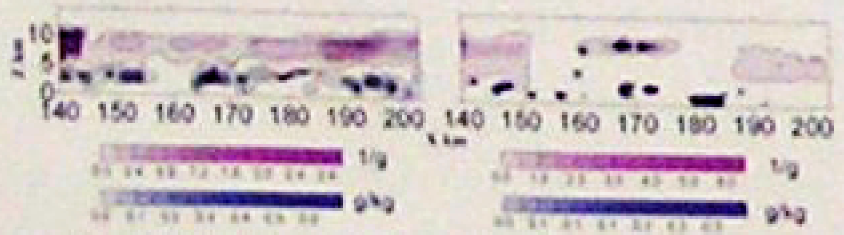


Fig. 3 Vertical cross section ice concentration and water content at different t and y =33 km. Sim Kolodyaziv. Horizontal step 1 km

At time from 1 h to 2 h chain of clouds transformed in several clouds and disappear after.

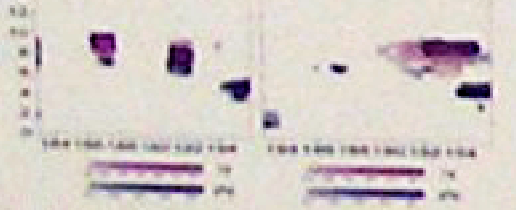


Fig. 4 Vertical cross section ice concentration and water content at different y. Sim Kolodyaziv. Horizontal step 200 m.

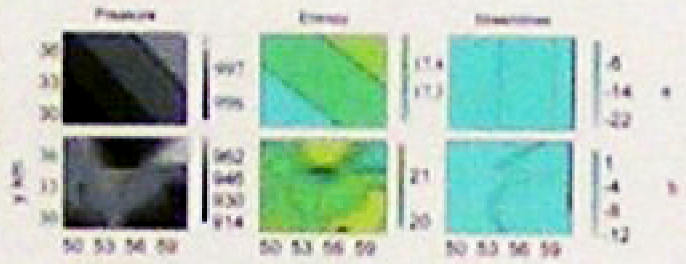


Fig.5 Initial conditions for Village Bogate:
a) Sea-level, b) By orography

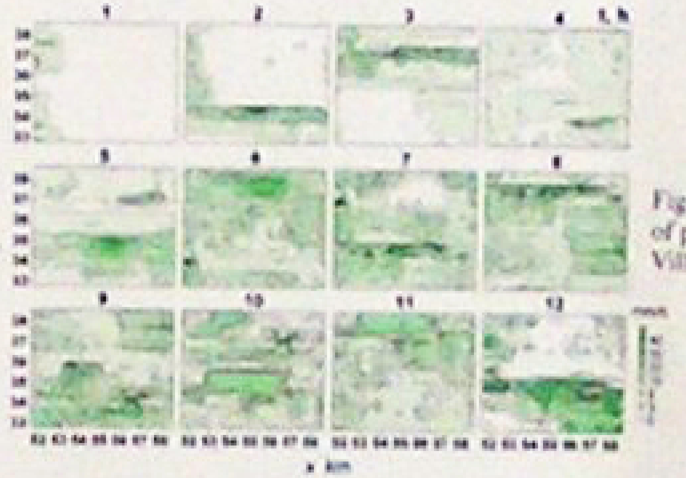
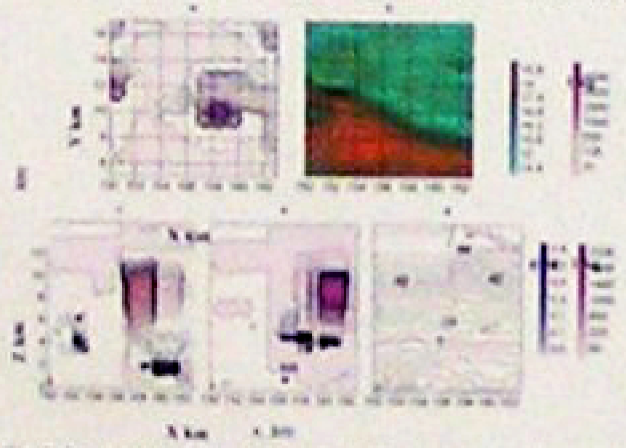


Fig 6. Modeled evolution of precipitation intensity. Village Bogate.

Interaction between cloud and entropy



For representation of several cells or clouds necessary decrease grid spatial step. Chimney-clouds have place at x=158 km and y=10 km and caused heavy precipitation. Near this point located entropy minimum. They have high ice tops and mixed under layer This condition let to grow ice crystal and rain drops to large size and get up to surface.

a)ice cover
b)Surface entropy (z=3000 m).
c)ice vertical cross section. y= 9.8 km.
d)ice vertical cross section. y= 10 km.
Temperature y=9.8 km.

Fig.7 Spatialdistribution of clouds entropy and temperature. Horizontal step 200 m.
a)ice cover (z-max of ice concentration 1/g); b) entropy (z=3 km, cal/g grad, number near scale);
c) ice concentration (1/g, pink color) and water content (g/kg, blue color) vertical cross sections,
y= 9.8 km; d) as c y= 10 km; e) temperature C°, number near line, y=9.8 km

Conclusion

Numerical experiments are carried out with main goal to determine the role of various dynamics and microphysics parameters in formation of strong and catastrophic precipitation. Some key parameters, meteorological conditions and predictors caused the occurrence of dangerous phenomena were defined as follows: interaction between flows of different physical nature coming from opposite directions; strong vortex motions in air mass advanced to study region; presence of ice supersaturation layers; special distribution of heat flows and entropy; chimney clouds with ice tops and cirrus clouds above; tropopause shear, very strong ascending and compensative descending motions; necessary combinations of precipitation-forming mechanisms.

Series of numerical experiments have been carried out with aim to research the temporal and spatial distribution of entropy and its production. Interaction between entropy and cloud and precipitation had been estimated. Response of gravity variations on clouds and precipitation was display by appearance of additional cloud and rainbands.

Some features of meteorological of cloud atmosphere in period seismic activity were discussed.

Reference

1.Pirnach, A.M., 1998. Construction and application of the various numerical models for study the cloud dynamics and structure of the frontal rainbands. Atmos. Res. 45-47, 355-376.
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Evolution of cloud and precipitation evolution in period seismic activity in Crimea region

Spatial investigations have been fulfilled with aim to study of cloud and precipitation development during seismic activity in August and September 2002 characterized by high seismic activity. A series of numerical experiments was performed to investigate the effect of anomalies of the gravitational field on the development of clouds. Including of the gravitational field anomalies is taken into account in the form of additional terms in the equations. The calculations showed, the addition of the gravity δg in the equations was the order of 10^{-3}-10^{-1} cm/s². It is comparable with the pressure gradient. Examples of calculations are shown in Figures 11-12 and Table. This study was devoted to response on clouds and precipitation of gravity variations (anomalies of the gravitational field).
In Figs 8-9 presented material of gravimetric survey of the Crimean peninsula [3]. A map of Bouguer's anomalies at the density (σ) of the intermediate layer of 2,3 g/cm³ (Fig. 11) and map of residual anomalies (Fig. 12) received after their averaging in a sliding square window of 24x24 km was built. The Figs 11-12 show the inhomogeneous structures of presented fields. Anomalies of gravity fields (Fig. 11) varied from -200 to 120 mGal (10^{-3} cm/s²) [3].

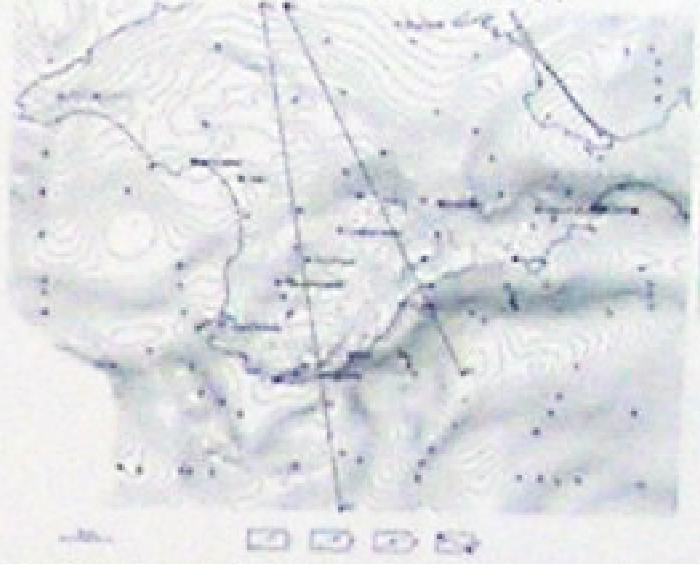

Fig 8 Anomaly gravity field (Bouguer's) Crimean peninsula and part of the Black Sea area. 1-3 is isoanomals gravity field δg, (1 presented negative values; 2 are zero; 3 are positive value). 4 are lines computer profiles.

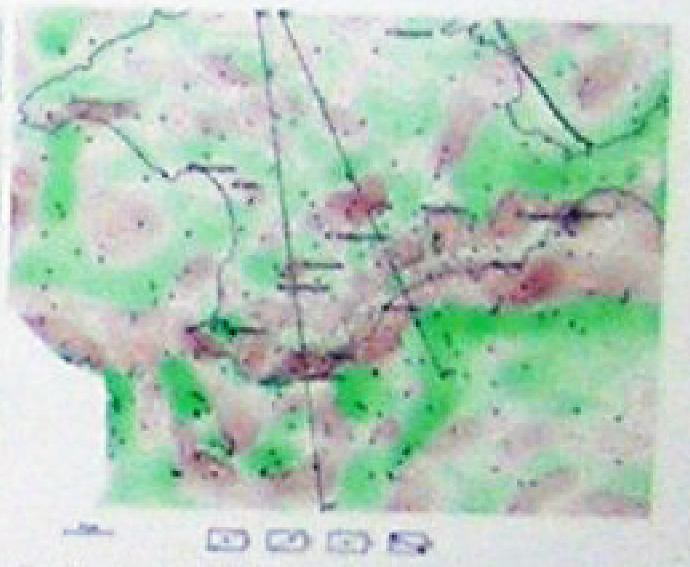

Fig 9 Local anomalies δg, (averaging in a sliding square window of 24x24 km), 1-3 are isoline gravity field δg, (1 presented negative values; 2 are zero; 3 are positive value). 4 are lines computer profiles.

Results of numerical simulation

Forecast modeling. Evolution of clouds and precipitation

Fig 11 Evolution of the 3h precipitation sums at different δg.
Numbers rows of figures correspond to rows of Table. Numbers near tops are dedline of sums.

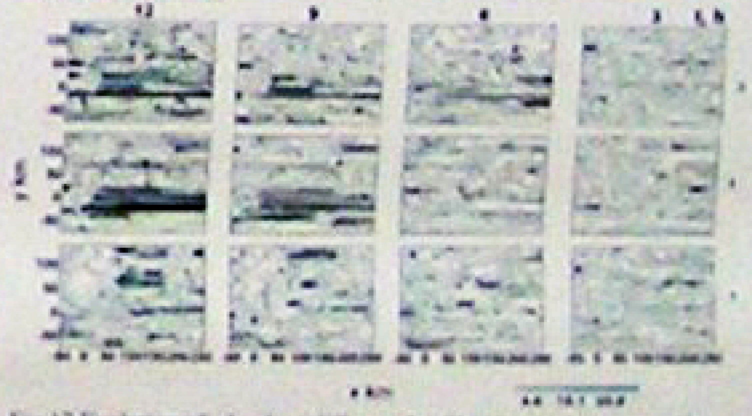

Fig 12 Evolution of clouds at different δg. Cloud cover is presented by sums of ice and water content z-integrals.
Numbers rows of figures correspond to rows of Table. Number near scale present the probable precipitation sums, mm. Numbers near tops are time of cloud development.

Diagnostic modeling

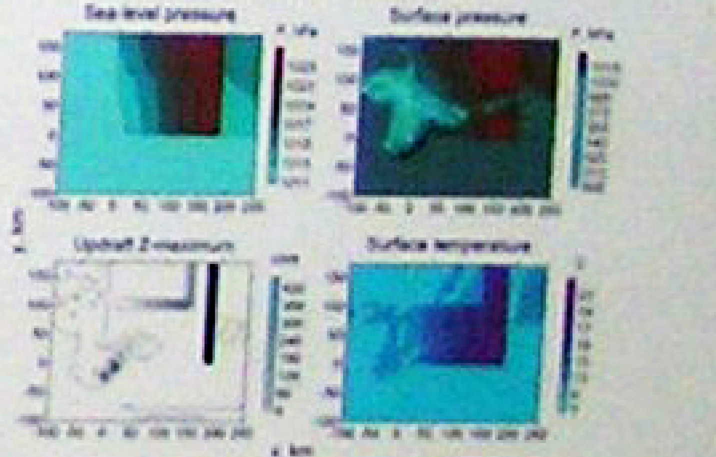

Fig10 Initial condition of meteorologic futures near of epicenter of earthquake (x= 192 km, y = 10 km) 2002 09 29, 03 h 08 mn GMT

Table 1. Maxima in area (-100 <x< 250, -100 <y< 150) of the 3h sums of precipitation at different δg.

Case	Time, h				δg, m/s²
	3	6	9	12	
1	0.9	2.5	10.1	9.9	6
2	0.4	1.1	5.6	6.0	0.2
3	1.0	15.1	5.0	7.6	0.02
4	1.0	4.5	3.6	1.9	0.002
5	1.0	2.8	4.7	11.2	0.001

Time presented the final hour of precipitation sum. δg, is parameter defined homogeneous distribution of gravity derivation along x and y direction.

In Table the area maxima of precipitation sums for different cases presented. Size of grid selected as in Figs 11-12. Time t presented the final hour of precipitation sum, δg, is parameter defined homogenious distribution of gravity derivation along x and y direction. Maximal values in Table was received for Case 3 for δg, with mean value at t = 6 h that was the fastest. Cases 2, 4 provided the minimal precipitation sums. But even Case 5 with minimal δg, provided the noticeable changing of precipitation.