Numerical study of precipitation formation during floods in Carpathian

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I. INTRODUCTION

The 3-D nowacasting and forecasting numerical models that have been developed in UHRI (Pirnach, 2005) for modeling of the winter and summer frontal cloud systems and modified by topography have been used for numerical simulation of the frontal rainbands and convective cloud clusters connected with heavy rainfalls during floods in Carpathian (see Bojko at al.,1999 and Bojko at al.,2001). Detail description of an evolution of cloud particles (cloud drops, rain drops, crystals, ice nuclei, etc.) are used to study widespread clouds and convective cloud clusters with long-lasting and heavy convective rainfalls. Models of frontal cloud systems passed over the Carpathian region of Ukraine and caused strong precipitation during floods were constructed

II. NUMERICAL RESULTS

The developed model uses a terrain-following "Z-sigma" coordinate system that followed terrain relief and keep top coordinate surface on a target constant high. 3-D diagnostic models were used for construction of initial meteorological fields for simulation of formation and development of frontal cloud systems passed over Ukrainian Carpathian. 3D prognostic models were use (Pirnach,2005) to simulate an evolution of frontal cloudiness within convective cells caused the torrential rainfall events in order to improve our understanding of these rain events. Initialization of models was performed by the radio sounding coming from regular grid.

Cases of heavy rainfall and flash floods that have place in Carpathian region on November 3-5, 1998 and March 3-6, 2001 will be presented as objects of numerical experiments.

Synoptical conditions and features of water flood on Carpathian rivers in 1998 November described in (Bojko at al.,1999). The total amount of precipitation was 47-277mm.

Date	*c*	3	6	9	12	0-12
11 2	1	3,9	7,1	4,9	1,9	16,8
11 3	1	0,1	0,1	1,0	2,9	4,1
11 4	1	4,6	4,8	5,3	1,9	16,6
11 5	1	3,9	7,9	8,3	8,0	29,1
Σ						66,6
11 2	0	2,8	6,1	11,6	8,9	29,4
11 3	0	0,1	0,1	1,3	3,8	5,3
11 4	0	5,2	5,6	7,3	6,7	24,8
11 5	0	4,2	7,5	16,0	28,0	54,7
Σ						114,2
11 5	0	1,5	2,7	16,5	22,9	43,6

TABLE I Maximums of 3-hrs precipitation sums (mm) on November 3-5 in area surrounded by $100 < x < 150$ km; $-30 < y < 20$ km. (x,y) =(0,0) are the Ughorod rawinsond state coordinates

Features of heavy precipitation in Ukrainian Carpathian and nearest environment were basically investigated by numerical simulation. Numerical results of precipitation formation during the synoptical period in mesoscale frontal rainbands and convective cloud clusters presented in Fig.1, and Tabl.1 and 2.

Tabl.1 shows distribution of maximal precipitation sums in the part calculated grid bounded by $100 < x < 150$ km; $-30 < y < 20$ km (small area) and included observed highest precipitation sums replaced in the west region of Ukrainian Carpathian. There is presented distribution of precipitation sums at different stage of synoptical processes. In tops of Table 3-hs sums was presented by their finite terms. Last column presented 12-hrs precipitation sums falling down during first 12-hrs of development (00 is beginning of runs). Letter *c* presented runs with coagulation (c=1) or without it (c=0). Symbol Σ noted total 4-days sums of the named 12–hrs precipitation sums. Last row illustrated numerical run without topography.

Excluding of relief from calculating caused decreasing number of precipitation cores, and decreased precipitation sums and intensity. November 2 in Table shows precipitation sums of previous synoptical process that had noticeable influence on investigated flood. New synoptical process begins on November 3. Rainband with precipitation cores moved into region with warm front and aligned along it. Heavy rainfalls have place on November 4-5 and have been caused by wave front and microcyclones connected with it. Maximal sums have place on November 5 during the decaying stage of synoptical process.

Date	*c*	3	6	9	12	0-12
11 2	1	4,1	8,8	6,4	5,2	24,5
11 3	1	4,2	7,2	4,5	8,1	24,0
11 4	1	8,2	9,2	9,2	9,4	36,0
11 5	1	13,6	9,9	10,8	13,0	47,3
Σ						131,8
11 2	0	4,2	6,1	11,6	14,3	36,2
11 3	0	2,1	5,8	11,1	17,1	27,1
11 4	0	9,0	7,0	12,0	20,0	48,0
11 5	0	18,1	8,4	17,4	28,2	70,1
Σ						181,4

TABLE 2: Maximums of 3-hrs precipitation sums (mm) on November 3-5 in total grid: $170 < x < 300$ km , $-250 < y < 220$ km

Tabl.2 illustrates distribution of maximal precipitation sums in total calculating grid bounded by coordinates $170 < x < 300$ km, $-250 < y < 220$ km (large area).

Numerical runs defined that maximums of precipitation sums in nearest regions exceed the same maximums into Ukrainian Carpathian. Clouds and precipitations propagated in it from nearest environment. They have been modified by relief and determined distribution of rainbands and convective cloud clusters in this small region.

Numerical runs with including and not including coagulation shown that, as rule, coagulation processes decreased precipitation sums. This feature was caused by the free for sublimation water vapor that permanently arrived in target region from nearest environment and maintained there long time. Condensation and sublimation processes with out coagulation delay falling down of precipitation. The cloud and precipitation particles remain in clouds more long time, and adsorbed moisture actively, and caused more strong precipitation during longer time.

Fig 1 presented precipitation that have place during synoptical period. Precipitation began in day of November 3 and come in target area from north-west (November 3-4) and from west and south-west (November 5). Formation of clouds and precipitation in this region was not found. They propagated in this region from the surrounding areas. There it has been modified by topography and convective cells caused heavy precipitation on November 4-5.

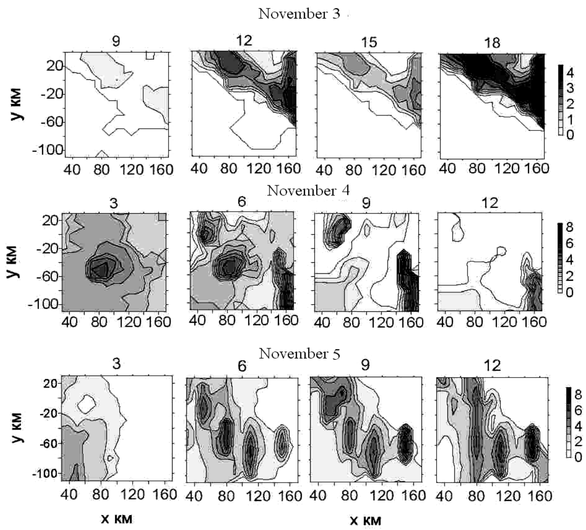

FIG. 1: Simulated 3-hrs and 12-hrs precipitation sums having place during synoptical process in 1998 on November 3-5. Numbers near tops are the finite times of sums. Numbers near scales are precipitation sums, mm.

Rainbands aligned along a wave front as well as in normal to it nearly. Precipitation cores have been noted very clearly. In particularly many precipitation cores have been found when frontal system was approach to decaying state on November 5. Chain of convective cells aligned along mountain ridge in normal to wave front nearly.

Synoptic situation in 2001 March in Carpathian described in detailed in (Bojko et al., 2001). Surface atmospheric front was oriented from south-west to north-east through Carpathian region. The essential feature of this hazard event was crucial influence of precipitation on the flood. The total amount of precipitation was 110-282 mm .

Fig.2 presented distribution of the precipitation sums in region $100 < x < 150$ km; $-30 < y < 20$ km and $170 < x < 300$ km, $-250 < y < 220$ km on March 5 connected with mature and decaying stage of synoptical processes followed the flood. The precipitating cores of different sizes and intensity have distributed in mountain regions of investigated areas ingomogenity. This feature, as rule, was observed at decaying stage of frontal cloud systems. Coagulation processes decreased precipitation sums and approached decay of precipitation cores. Picture of precipitation was more like to observed natural distribution.

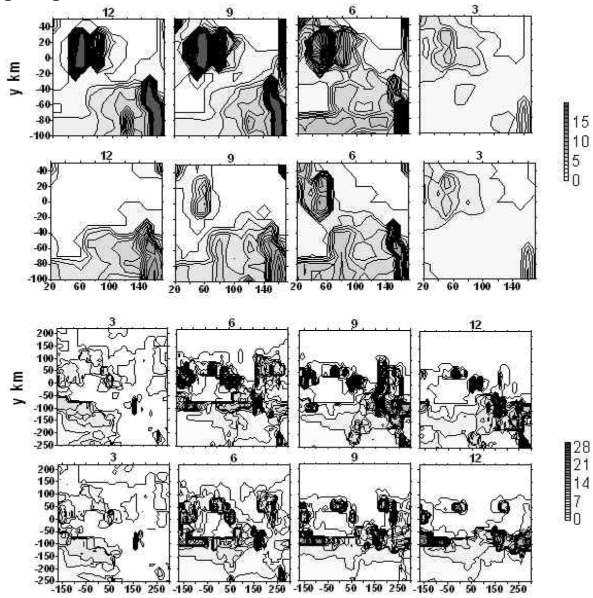

FIG.2. Simulated 3-hours precipitation sums without coagulation (first and third rows) and with coagulation (second and forth rows) on small area (first and second rows, the Ukraine Carpathian) and large area (third and forth rows) having place in 2001 on March 5. Numbers near tops and scale as Fig.1.

III. CONCLUSIONS

Numerical experiments with variation of vertical motions, different phase state, different mechanisms of ice, and liquid water, and mixing cloud formation, and precipitation formation were carried out. There are found that increasing of activity of coagulation and sublimation processes can to increase strong precipitation as well as decrease it. Numerical experiments with clouds of different phase states (liquid water, mixing, ice) shown that strong precipitation may to product the mixing and liquid water clouds. Ice clouds product the long-lasting rain with weak intensity. Increasing of ice formation mechanism did not cause the catastrophic precipitation.

Artificial increasing of ice concentration from natural to the enormous concentration (reached to 2-3 orders of natural values) can to cause the disastrous precipitation. Increasing of drop concentration did not caused catastrophic precipitation.

There was found that the inter sources of moisture do not due the strong precipitation. The free for condensation vapor, clouds and nuclei arrived into investigation area from neighbor regions from different directions and caused the strong precipitation. Most heavy precipitation have place when different sources of moisture meet and coupled.

IV. REFERENCES

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