(19)

XVIII. međunarodna konferencija za alpsku meteorologiju

XVIII. International Conference for Alpine Meteorology

Opatija, 25-29. IX. 1984

Zbornik

meteoroloških i hidroloških radova

10

Beograd

SEVERE STORM ANALYSIS IN THE ALPEX PERIOD
(THREE CASE STUDY)

Bojan Lipovšćak and Ivan Čačić
Hydrometeorological Institute
Zagreb, Yugoslavia

1. INTRODUCTION

Weather phenomena analysis by use of radar, satellite and dense meteorological station network contributes to a better knowledge and understanding of the nature of weather, particulary convective storms. The WMO (1981) publication points out the necessity of storm character investigation at several locations and especially their classification. Čačić and Lipovšćak (1982) proposed a method for composite radar picture elaboration which was used by Oreščanin (1982).

This work continues the investigation of the mesoscale phenomena, particulary of severe storm cloud systems. Three different storms over the area of the north-west Croatia during the ALPEX period have been presented. Analysis of storms on 29 June, 25 July and 31 July 1982 have used: radar data, sounding data from the Zagreb Observatory, raingague data, climatological and synoptical stations as well as data of launching stations of the hail-suppression polygons. The average distance between launching stations is 6000 meters.

2. CASE STUDIES

2.1. The case of 29 June (Zagorje storm)

The name of the storm comes from the area (Zagorje) where maximum hail stone size diameter was observed. Analysis of synoptic charts shows that the outbreak or unstable air is connected with a fast moving cold frontal zone over the area of north-western Croatia in the afternoon hours. The cloud cell trajectories selected from the radar cloud observations are presented in Fig. 1.

Precipitation analysis based on the meteorological station data indicates satisfactory agreement between cloud cell trajectory locations and precipitation distribution. The hail trace, 225 km long, was observed along the trajectory marked by no. 1 in Fig. 1. The maximum observed hail stone diameter was 70 mm. Hail stone samples, collected at the location, marked with a cross in the Fig. 1, are presented in the Fig. 2. The hail stones had several layers of clear and opal ice in their structure. According to Knight (1981) most hail stones have the characteristics of the graupel embryo type. The appearance of such hail stone structure points to complex vertical circulation within the cloud, the variation of available water content in the cloud layers and a relatively long period of hail stone growth. It comes out, as a characteristic, that the maximum precipitation is located on the left side of the cloud cell trajectory. Cloud cell 1 moved with an average speed of 24.1 m/s, and the radar top of the cloud reached the maximum value of 12.3 km. The cloud cell top penetrated the tropopause level

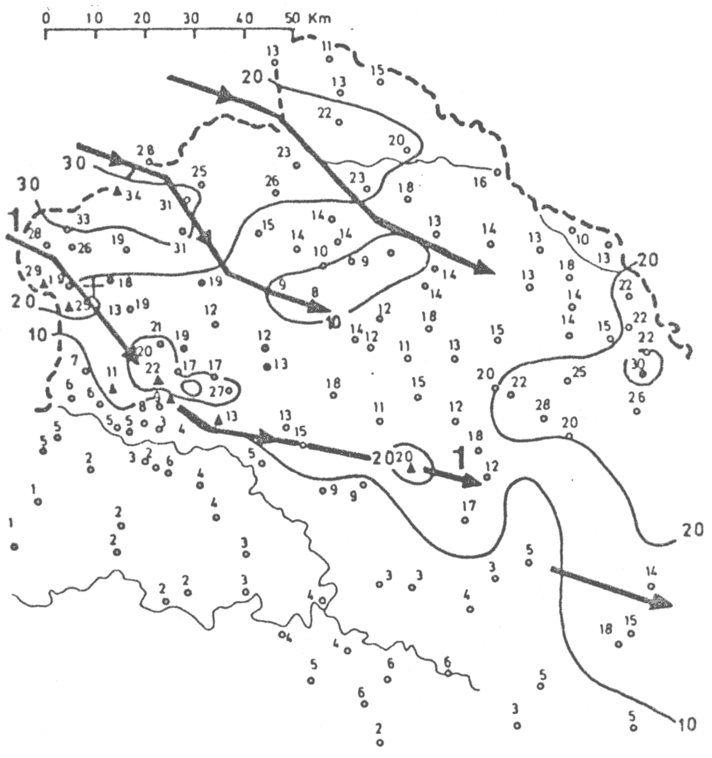

Figure 1. Cloud cell trajectories and the isohyet chart for the Zagorje storm.

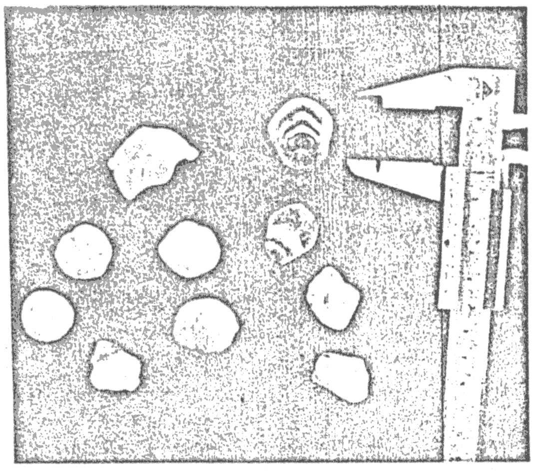

Figure 2. Hail stone samples collected at Kraljev Vrh from the Zagorje storm.

and lasted 2400 s. there. According to the WMO (1981) classification, the hail stones correspond to the cloud supercell which was merged in a cluster with ordinary Cb multi-cells.

Atmospheric stability was considered using the Brunt-Väisälä frequency in unsaturated (N^2) and saturated (Ne^2) air in the same manner as Čačić (1984). Static stability analysis (Tab. 1) in significant atmospheric layers shows the unsaturated air stability ($N^2>0$) across the whole troposphere, except in the low part of the planetary layer, whereas in saturated air alternating stable and unstable layers exist ($Ne^2>0$, $Ne^2<0$) in the lower half of the troposphere. Radar Cb characteristics, as well as atmospheric stability characteristics, indicate the existence of severe convection which was built as a superposition of the forced convection (because of the moving frontal system) and the free convection (because of the existence of the conditionally unstable air).

Table 1. Brunt-Väisälä frequency for the case of unsaturated and saturated air for Zagreb on 29 June 1982 at 12 GMT for the significant layers.

low layer boundary (m)	thicknes (m)	N^2 $\times 10^{-4}$ (s^{-2})	Ne^2 $\times 10^{-4}$ (s^{-2})
128	553	-.57	.17
681	212	4.07	-3.24
893	1148	.43	.30
2041	1231	1.34	-.15
3272	515	.64	1.58
3787	556	.99	-.48
4343	185	4.38	1.44
4528	324	.53	-.45
4852	337	3.30	.44
5189	1755	.81	.39
6944	1149	.52	.42
8093	747	.54	.26
8840	171	3.59	3.31
9011	1451	.96	.77
10462	364	3.00	2.91
10826	539	7.36	7.03
11365	618	2.15	2.05
11983	751	4.65	4.43

2.2. The case of 25 July (Moslavina storm)

Analysis of AT 500, 700 and 850 mbar shows the existence of high level cyclonic circulation over the northwestern part of Yugoslavia. A nongradient lower pressure field was on the surface at the same time. The basic radar picture characteristics are a cloud cell cluster which moves with an average speed of 5.2 m/s. Cloud cell trajectory and isohyet analysis indicate (Fig. 3) that the precipitation maximum (108 mm) corresponds to the cloud cell path marked with 1 and 2. The propagation speed of this cloud

Figure 3. Cloud cell trajectories and the isohyet chart of the Moslavina storm.

Table 2. Brunt-Väisälä frequency for the case of unsaturated and saturated air for Zagreb on 25 July 1982 at 12 GMT for the significant layers.

low layer boundary (m)	thicknes (m)	N^2 $\times 10^{-4}$ (s^{-2})	Ne^2 $\times 10^{-4}$ (s^{-2})
128	235	7.26	4.18
363	541	2.31	-2.76
904	1499	.54	.71
2403	407	1.78	-1.44
2810	296	.45	1.73
3106	1497	1.53	-.22
4603	670	1.67	1.88
5273	581	.25	-2.52
5854	603	1.82	2.62
6457	3075	1.04	.48
9532	1643	.61	.45
11175	1209	7.07	6.69

cell is 3.6 and 4.4 m/s correspondingly. The propagation characteristic is deflection from the mean tropospheric flow 90 degrees to the right. Along the path of these cloud cells the trace of hail is observed with stone diameter between 9 and 20 mm. Other cloud cells were propagated along the mean tropospheric flow. Cloud cell on path 3 produced graupel of the week intensity and duration. According to the WMO (1981) classification the Moslavina storm consists of several Cb single-cells in different evolution phases and of super-cells (path 1 and 2).

Atmospheric stability analysis, Tab. 2, has pointed to the fact that, unsaturated air is statically stable across all tropospheric layers ($N^2>0$) whereas in the case of lower tropospheric saturated air there are alternating stable and unstable layers. ($Ne^2>0$ and $Ne^2<0$). Evaluated Brunt-Väisälä frequency values point to the possibility of the convection appearance as the consequence of instability following saturation which depends on horizontal and vertical water content fluctuation.

2.3. The case of 31 July (Petrinja storm)

Analysis of the synoptic situation is given in the paper of Tutiš (1984). Radar measurement analysis, Oreščanin (1982), discovered two cloud systems which penetrated over the area of northwestern Croatia one 90 minutes after the other. The first system is characterised by a mean propagation speed of 13 m/s and a direction of 220 degrees. The mean speed of the second system is 10.5 m/s and the direction is 270 degrees. Propagating cell trajectories and the isohyet analysis show that the precipitation maximum (70.6 mm) is related to trajectories 1 and 2. The precipitation maximum is registered on the southern slope of Medvednica (Fig. 4).

The storm produced a very rare phenomena of a tornado which was related to the cloud cell on path 3, with golf ball-sized hail. The tornado touch down was observed three times over a distance of approximately 1500 meters. The first touch down was observed at 6:55 p.m. Radar measurements of the Cb su-per-cell, related to the tornado, penetrated the

Table 3. Brunt-Väisälä frequency for the case of unsaturated and saturated air for Zagreb on 31 July 1982 at 12 GMT for the significant layers.

low layer boundary (m)	thicknes (m)	N^2 $\times 10^{-4}$ (s^{-2})	Ne^2 $\times 10^{-4}$ (s^{-2})
128.	322.	-1.01	-1.74
450.	446.	4.34	-1.10
896.	973.	2.14	-.51
1869.	1626.	.09	.51
3495.	572.	-.34	.74
4067.	2019.	1.33	.21
6086.	3319.	.82	.22
9405.	557.	1.09	.63
9962.	195.	4.16	3.90
10157.	1395.	1.34	1.29
11552.	394.	6.47	6.22
11946.	552.	1.44	1.39

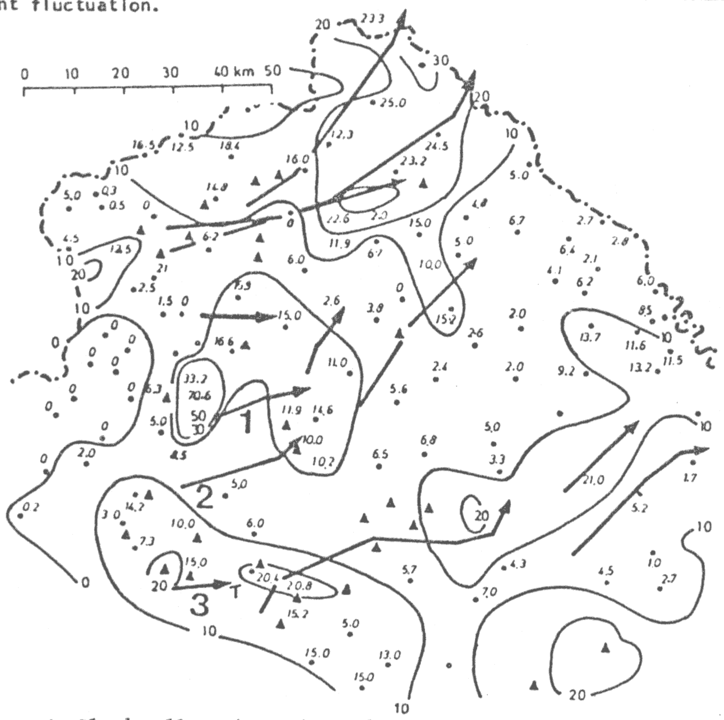

Figure 4. Cloud cell trajectories and the isohyet chart of the Petrinja storm.

tropopause and had a maximum height of 11.5 km. The radar echo cloud top lasted over the tropopause 2.700 seconds. The descent of the cloud top appeared immediately after the first tornado touch down.

The Brunt-Väisälä frequency review (N^2 and Ne^2) shows the existence of unstable layers within the planetary boundary layer, Tab. 3. The atmosphere is apsolutely stable over the planetary boundary layer. It might be concluded that the predominant mechanism of cloud development is forced convection caused by a frontal system movement.

3. CONCLUSION

Three different meteorological situations which produced Cb super-cells are considered.

The paper sets forth the thesis that Cb super-cells might be produced by different meteorological situations. The three case analyses point out that the common characteristics of super-cells are a long life, the existence of large hail stones and the existence of apsolutely stable air close over conditionally unstable layers. The super-cells are, however, different in speed of propagation and related amount of precipitation. It might be emphasized that tornado development related to the Petrinja storm is quite a phenomenon in the area of northwestern Croatia. Stability analysis suggests that Cb cloud development intensified immediately after a disturbance of the stable layer.

4. ACKNOWLEDGEMENTS

This research was supported by the Republic Association for Scientific Research of Croatia.

REFERENCES

Adler, R.F. and Fann, D.D., 1979: Tunderstorm Intensity Determined from Satellite Data, Journal of Applied Meteorology, 18, 517-522.

Čačić, I. and Lipovšćak, B., 1982: Radar Measurements Mesoanalysis on 29 June 1982 over the Region of North-West Croatia, Rasprave (Papers), 17, 50-57, Hydrometeorological Institute of Croatia, Yugoslavia.

Čačić, I., 1984: Conditions of Storm Motion over Medvednica, ICAM 84, Opatija.

Durran, D.R. and Klemp, J.B., 1982: On the Effects of Moisture on the Brunt-Väisälä Frequency, Journal of the Atmospheric Sciences, 39, 2152-2158.

Knight, N.C., 1981: The Climatology of Hailstone Embryos, Journal of Applied Meteorology, 20, 750-755.

Oreščanin, J., 1982: Radar Measurements Mesoanalysis on 31 July 1982 over the Region of North-Western Croatia, Hydrometeorological Institute of Croatia, Yugoslavia.

Tutiš, V., 1984: Spatial Analysis of Static Stability, ICAM 84, Opatija.

WMO, 1981: The Dynamics of Hailstorms and Related Uncertainties of Hail Suppression, Hail Report No 3, 22 p, Geneva.

CONTENTS - SADRŽAJ