Mediterranean Storms
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MEDITERRANEAN STORMS IN RUSSIA AND THE UKRAINE: GRID-SCALE FORCING OF HEAVY PRECIPITATION

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ABSTRACT

A sample of the Mediterranean storms causing heavy precipitation in the former USSR (including a case of catastrophic icing in the Ukraine in November 2000) is analyzed on the basis of surface observations and objective analysis data. The following grid-scale diagnostics are computed as describing dynamic forcing of precipitation: potential vorticity (and derived dynamic tropopause height); scalar frontogenetic functions; convective instability characteristics; and frontal parameter, F, developed for objective frontal analysis. The purpose of the work is to estimate to which extent heavy precipitation in the Mediterranean storms is determined by dynamic forcing and which dynamic differences exist between the Mediterranean storms and other precipitation-producing systems. It is shown that the Mediterranean storms are characterized by especially sharp fronts, strong frontogenesis, and thus by intense transverse circulations in the frontal zones.

1 INTRODUCTION

The Mediterranean cyclones moving to Russia and the Ukraine often bring heavy rains, snowfalls, icing, and stormy winds. Small size of these eddies and their fast growth over the Black Sea make difficult their forecasting.

In the paper, a diagnostic study of heavy precipitation in the Mediterranean cyclones is presented as a further development of *Chakina et al*. (2001). Characteristics of dynamic forcing in the Mediterranean cyclones and in averaged precipitation-producing systems over the former European USSR are compared. A case of extremely severe freezing precipitation in the Ukraine is considered in more detail.

2 DATA AND DIAGNOSTICS

Objective analysis of height, temperature, humidity, and wind at 00 and 12 UTC over European Region (December 1998 – May 2002) in 2.5x2.5^{o} geographic gridpoints and precipitation data at the stations in the former USSR are used, along with weather data from the Ukraine for November 25 – 30, 2000. The sample of the Mediterranean storms (1999-2001) associated with heavy precipitation (HP) in the former USSR includes 35 objective analysis times in which the HP is associated with the Mediterranean storms only, and not with other weather systems in the region.

The following diagnostics are estimated in the gridpoints:

- frontal parameter, F (dimensionless), as developed in (*Chakina et al., 2000*) and determined through equivalent temperature in 850-500 and 925-700 layers, surface pressure, 850 mb wind, and 700 and 850 mb heights;
- scalar frontogenetic function, G (^{o}C/500km.12h) at 850 mb level, as an indicator of frontogenesis /frontolysis associated with vertical transverse circulations in the frontal zones;
- neutral buoyancy level, B (km), as a characteristic of convective instability;
- potential vorticity, PV, and the dynamic tropopause, TR, as the surface of PV = 1 pvu.

3 DYNAMIC FORCING OF HEAVY PRECIPITATION

The diagnostics computed for 00 and 12 UTC for the period from December 1998 to May 2002 are compared against the corresponding 12-h precipitation amounts at the stations. Informativity is estimated of the diagnostics as predictors of HP, - that is, of solid precipitation > 6 mm/12 h and liquid one >14 mm/12 h.

In Fig. 1, for 4 winters, spectra of occurrence frequencies of different precipitation rates are shown as dependent on F; occurrence frequencies of F are also shown. It can be seen that occurrence frequency of precipitation >1 mm/12 h increases monotonously with F, and the heavier precipitation, the faster the growth. The value of F = 25 is chosen as a threshold between the airmass (F<25) and frontal conditions for HP.

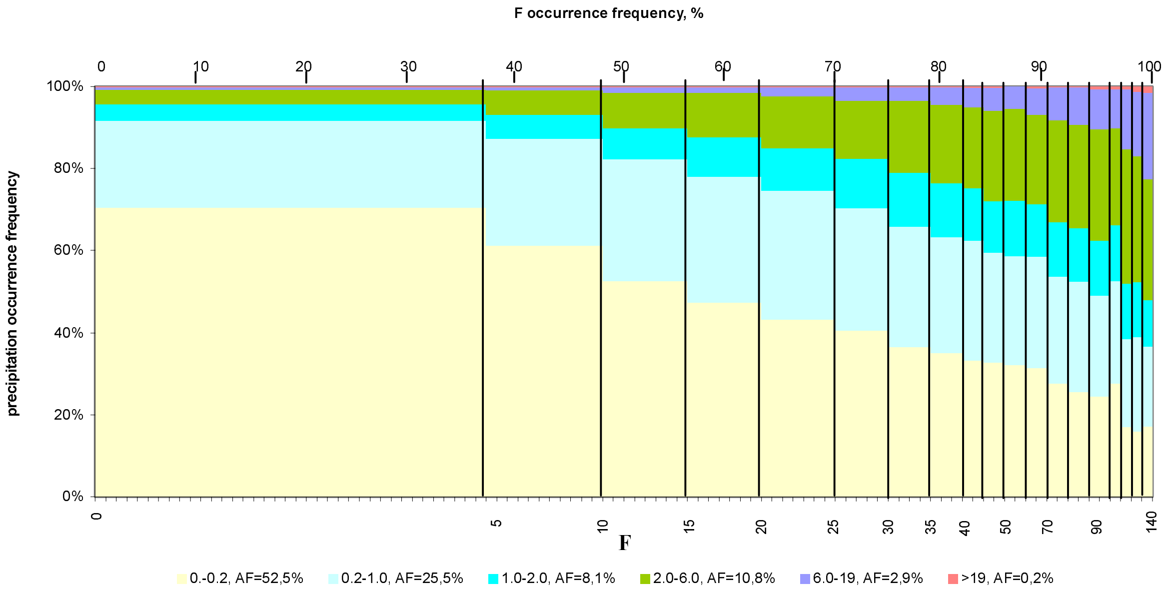

Figure 1. Spectra of precipitation occurrence frequencies as dependent on frontal parameter, F: 4 winters, former European USSR. AF - averaged frequency of the corresponding precipitation rate in mm/12h

The standard Peirce index PI = [φ (λ - k)] / [λ (1 – k)] is used as the informativity criterion. Here, φ is number of HP cases which are predicted and observed, in percentage of total HP cases (on the other words, the "hit rate" – percentage of actual occurrences that were correctly forecast); λ is number of HP cases which are predicted and observed, in percentage of total of cases in which HP is predicted (on the other words, the frequency with which HP is correctly forecast); k is HP frequency in the whole sample ("natural" frequency). PI > 0.25 correspond to forecasts better than the random one. In practice, the forecasts are considered valuable if PI exceeds 0.30.

For every diagnostic, PI is estimated for the simplest way of discrimination between HP occurrence and non-occurrence – through a threshold value rule. By varying the threshold values, PI_{max} is found as corresponding to the best combination of false alarms and aim missings. In an analogous way, PI_{max} is estimated for two or more diagnostics as predictors, - by tuning their most efficient threshold values.

In Table 1, PI_{max} and corresponding φ, λ are shown for F as a single predictor and for combinations of F,B; F,G; F,TR. One can see that F is valid as a single predictor in all the seasons. Significant PI>0.3 (not shown) are obtained also for B in all seasons but winter. For combinations of the two parameters, PI is higher than for F alone, though this effect is not strong, because the diagnostics are not independent. In particular, convective activity is, to a large extent, generated and triggered by frontal effects (*Carlson*, 1991; *Jansa*, 1997)

		F			TR			G			B		
		PI	λ	φ	PI	λ	φ	PI	λ	φ	PI	λ	φ
F	(1)	.37	.72	.02	.39	.66	.02	.40	.73	.02	.47	.70	.02
	(2)	.32	.67	.06	.32	.67	.06	.32	.66	.06	.42	.74	.06
	(3)	.45	.79	.03	.48	.75	.04	.49	.75	.04	.54	.81	.04
	(4)	.44	.74	.07	.45	.74	.08	.45	.71	.08	.46	.68	.09
	(5)	.48	.79	.11	.51	.80	.12	.54	.79	.13	.56	.81	.13

Table 1. Informativity of the diagnostics as HP predictors for average conditions over the former European USSR: 4 springs (1), 3 summers (2), 3 autumns (3), 4 winters (4) and 35 Mediterranean storms (5) correspond to 113152, 81301, 83029, 110222, and 5356 gridsquares, respectively, with HP occurrence frequencies of 0.9, 3.4, 1.4, 3.1, and 4.6%, respectively.

So, the grid-scale diagnostics are tightly connected with HP occurrence frequency. The main factors of HP dynamic forcing are represented by frontal effects (baroclinicity and pressure field curvature), grid-scale convective instability, and transverse circulations, generated by frontogenesis/ frontolysis.

In the last line of Table 1, the results are shown for the sample of 35 Mediterranean cyclones with HP. For the Mediterranean cyclones, PI are generally higher than on average for all the situations over the region. This

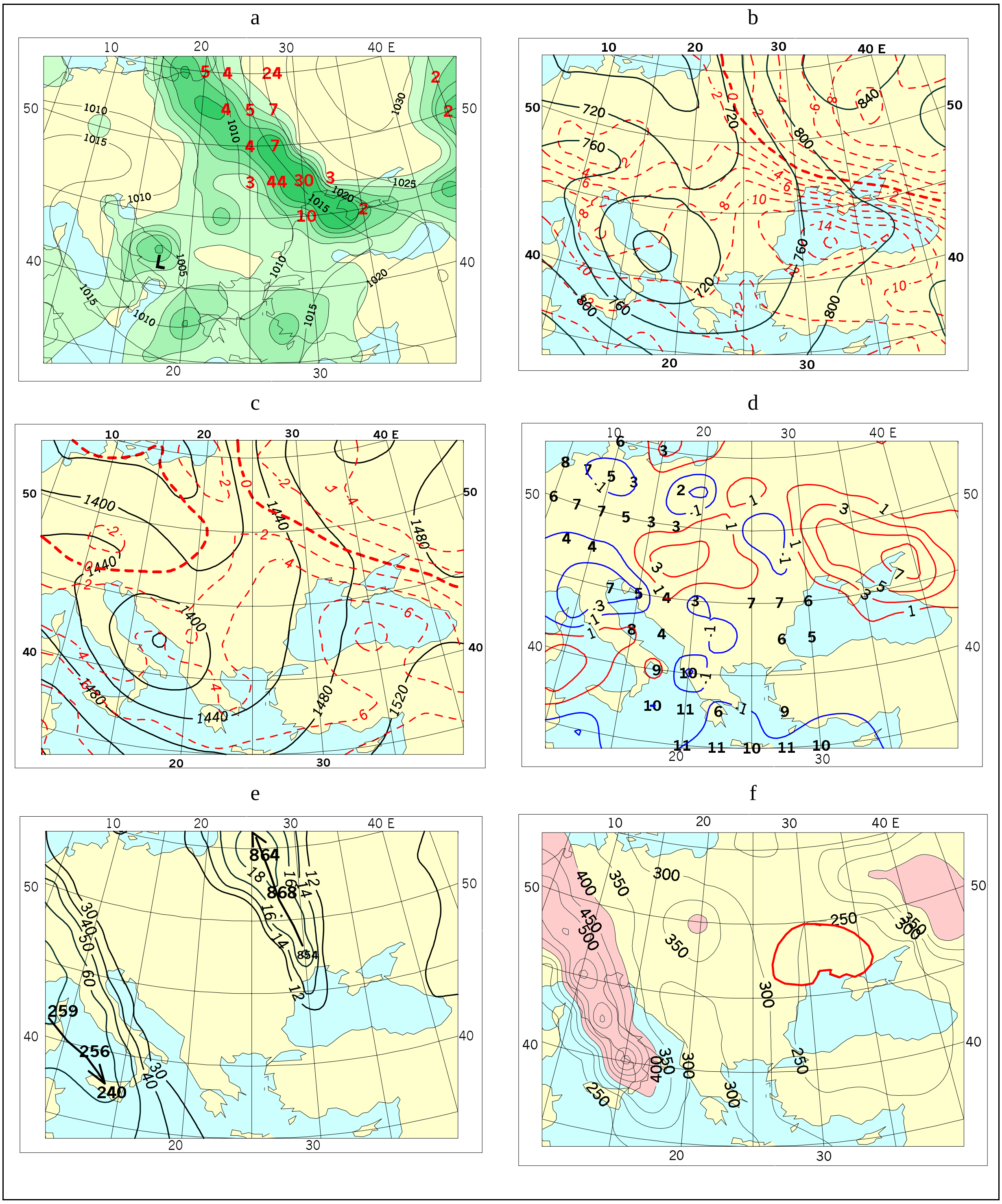

Figure 2. The icing event in the Ukraine, November 27 2000, 00 UTC: (a) frontal zones F>20 (green), precipitation, mm/12h (red digits), and surface pressure, mb (black lines); (b) 925 mb height, m (black lines), and temperature, ^{0}C (red lines); (c) 850 mb height, m (black lines) and temperature, ^{0}C (red lines); (d) G, ^{0}C/(500 km·12h), isolines, red and blue for positive and negative values, respectively, and B, km digits; (e) upper-tropospheric jet stream (isotachs 30 to 70 m/s) and low-level jet stream (isotachs 12 to 18 m/s), pressure at the core (mb) is shown; (f) TR, mb (black lines), p>400 mb shaded, and icing area boundary (red line).

implies that, in the Mediterranean cyclones, dynamic forcing of HP plays a very important role, and the characteristics of dynamic forcing – the diagnostics under consideration - are efficient predictors of HP in these cyclones.

Note that the upper-level PV anomalies (*Hoskins et al.*, 1985) are revealed in 32 of 35 cases of the Mediterranean cyclones.

4 DISASTROUS ICING IN THE UKRAINE

Cyclogenesis over the Mediterranean on November 25 – 29, 2000, led to strong icing in vast areas of the Ukraine. The freezing rain and drizzle developed in the pre-frontal zone of a cyclone moving from the Adriatic Sea to the Aegean and then Black Seas – a cyclone of type 6 according to *Campins et al*. (1997). The icing started in the night of November 25-26 in the Odessa Region. The day after, the icing developed in the most part of the Ukraine (Fig. 2). On November 27, freezing rain rate reached 35 to 44 mm/12 h. The ice deposit diameter at the wires reached 20-40 mm, with maxima (to 56 mm) in the Nikolaev and Odessa Regions. The railroads were blocked for several days. About 500 settlements were deprived of electricity due to wire lines broken. Vineyards, orchards, gardens, forests have been heavily damaged.

This case represents a "textbook" example of freezing precipitation formation in the warm frontal zone. Slightly negative temperatures at the surface and strong warm advection at the 925 and 850 mb levels (to $5x10^{-5}$ $^oC/s$) provided "classical" conditions for icing (*Marwitz et al*., 1997). The northern boundary of the icing area is in a good agreement with 0^oC-isotherm position at 850 mb level at the time of maximum intensity of icing.

At the same time, this case shows main typical features of the Mediterranean storms: a strong frontal zone (maximum F = 180) with high temperature contrasts at the surface (6 to $11^oC/100$ km) and in the lower troposphere, strong frontogenesis (to $7^oC/(500km\cdot12\ h)$) at 850 mb level over a vast area. Convective instability, also typical of the Mediterranean storms, does not occur over Ukraine in this case; instead, temperature inversion is observed in the lower troposphere.

Note also the warm low-level jet (with southern winds to 18 m/s at about 860 mb).

5 CONCLUSIONS

The diagnostic characteristics of heavy precipitation dynamic forcing in the Mediterranean storms are considered in comparison with averaged characteristics for the same precipitation over the former European USSR (regardless the synoptic situation). It is shown that relationships between the diagnostics and the HP occurrence frequencies are closer in the Mediterranean storms than on average for all situations and for large samples (3 and 4 seasons). This implies that the dynamic forcing plays a major role in HP formation, as well on average in the region, as especially in the Mediterranean cyclones. The frontal effects described by the frontal parameter are responsible for about 80% of HP cases.

A case is studied of disastrous icing in Ukraine, associated with a Mediterranean cyclone moving from the Adriatic to the Black Sea. Typical conditions for strong icing (warm air advection in the lower troposphere) occurred in a sharp, warm frontal zone with intense frontogenesis.

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