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ATMOSPHERIC CIRCULATION TYPES ASSOCIATED WITH STORMS ON THE ROMANIAN BLACK SEA COAST. APPLICATION OF A NEW AUTOMATED SCHEME

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ABSTRACT. The use of circulation types is a reliable way of describing the regional circulation and understanding the climatic variability. This paper presents the characteristics of the atmospheric circulation at about 5 km height (the 500 hPa level) during storm episodes along the Romanian Black Sea coast. A new automated classification scheme, performed on 500 hPa geopotential height is applied for the first time to atmospheric circulation in this region. Investigation and standardization of the circulation at this level is important since synoptic conditions are relied to the weather in the low atmosphere. As a result, 12 atmospheric circulation types (cyclonic and anticyclonic) are identified. Most of the storms occurred in 20 years in the western part of the Black Sea are relied to 4 cyclonic types. The computing of the 500 hPa anomalies for these types allows to better understand the peculiarities of the atmospheric circulation.

Keywords: automated classification scheme, circulation types, storms, western Black Sea

INTRODUCTION

The automated classification scheme represents an objective method which does not rely upon the researcher's knowledge and judgement and is also easily applicable. The automated classification scheme used in this study is performed on 500 hPa geopotential height in grid points and can be used throughout Europe (Anagnostopoulou et al., 2008). This new classification is based on a previous objective classification scheme (Maheras, 1988). Maheras and Anagnostopoulou (2003) applied a similar classification scheme to the 500 hPa level and studied the relationship between 14 classified circulation types and rainfall over Greece.

The classification scheme is applied to the Romanian coast and the western part of the Black Sea and to those days when storms situations described further have been identified.

The circulation types associated to storms in the western part of the Black Sea have been previously analysed using a manual classification (Chiotoroiu, 1999). Storms were first defined using two hydro meteorological parameters in order to further analyse their consequences on coastal navigation: wind speed higher than 12 m/s for at least 12 consecutive hours and state of the sea higher than 4 near the shore (wave height from 1.25 to 2.5 m).

The manual classification of the circulation types used 500 hPa and sea level daily synoptic maps from 1974 to 1993. Chiotoroiu (1999) identified three types of storms according to the position of atmospheric centres at sea level. Almost all these storm situations occur in winter, from November to March. More than 50% of these storms are the consequence of a "couple" anticyclone/depression (with travelling disturbances from the Mediterranean Sea to the Black Sea). The anticyclone is generally located over the northeastern part of Europe. They are also the most violent in this region in comparison with other types of atmospheric circulation and considering the maximum wind speed and the time when the Black Sea goes high.

The automated classification scheme based on the use of 500 hPa geopotential anomalies was applied only to the days when this type of storms occurred.

MATERIALS AND METHODS

The 500 hPa level was chosen because this level presents a strong relationship with surface variables and because synoptic conditions at 500 hPa level affect strongly the weather over this region.

The NCEP/NCAR mean daily 500 hPa geopotential heights are used for the period 1974-1993 (20 years). The horizontal resolution of these data is 2.5° x 2.5° (Kalnay et al., 1996).

Using these data, a new method of automatic classification of circulation types was applied in order to obtain the daily calendar (Tolika et al., 2007; Anagnostopoulou et al., 2008).

The selected window is characterised by $\Delta\Phi$ = 20°N - 75°N and $\Delta\lambda$ = 35°W - 50°E. The main central point is in Romania, with the following coordinates: latitude 45°N and longitude 27.5°E.

RESULTS AND DISCUSSIONS

Using this method, 12 circulation types are identified, 5 anticyclonic types (figure 1a) and 7 cyclonic types (figure 1b). The relative frequencies of the 12 circulation types related to storms are divided into two groups, anticyclonic and cyclonic, which are presented in Table 1. For the anticyclonic types, Ane presents the greatest relative frequency Ane = 6.4%. The cyclonic types favouring the storms genesis with

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the greatest frequencies are: Cse 24.5%, Cssw 20.1%, Cwsw 16.9% and Cne 10.8% (as shown in Table 1).

The description of the circulation types based on the composite synoptic patterns is presented in Table 2. Each pattern is produced by averaging the days of each circulation type for winter (Figure 2 and Figure 3).

Table 1

Storms frequency by circulation type

	Anw	Ane	A	Asw	Ase	C	Cnnw	Cwnw	Cwsw	Cssw	Cse	Cne	Total
1974									1	3		1	5
1975						2			2	2	6		12
1976										1	2		3
1977	1	1		1		1			1	3	2	2	12
1978		1				2				2		7	12
1979	1	4			2	2			1	5	6	1	22
1980								1	1	4	2	2	10
1981		3				1			7	7	7		25
1982	1					2			2	2	4		11
1983		2			1	2			2	1	5	2	15
1984				1		1			6	3	7		18
1985		1		1	1	1		1	2	3	4		14
1986		1			2				5	2	2	2	14
1987					3				4	2	3	2	14
1988				1	1	1			4	3	1	5	16
1989	1	2		1		2			3	1	3		13
1990	1	1	2		1		1						6
1991	3				1	2				3	2		11
1992											3	1	4
1993	2				1	1			1	3	2	2	12
Total	**10**	**16**	**2**	**5**	**13**	**20**	**1**	**2**	**42**	**50**	**61**	**27**	**249**
Perc. (%)	**4.0**	**6.4**	**0.8**	**2.0**	**5.2**	**8.0**	**0.4**	**0.8**	**16.9**	**20.1**	**24.5**	**10.8**	**100**

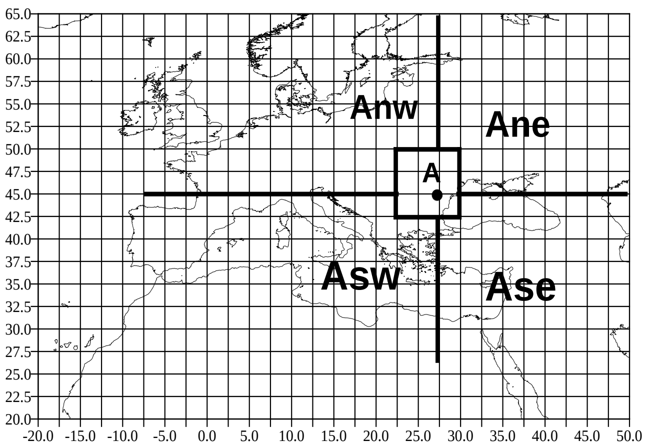

Fig. 1a Anticyclonic types

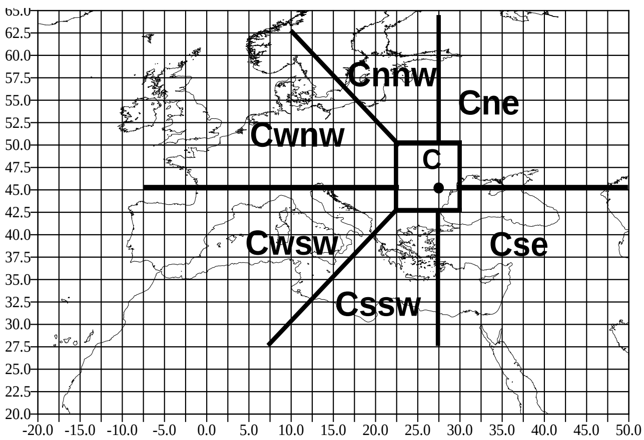

Fig. 1b Cyclonic types

Table 2

Description of the circulation types

Anw	The anticyclonic centre is located in the northwest of the study region, over northern and central Europe. The wind over the study region in the surface of the 500 hPa prevails from the northerly sector, with higher intensity during the cold period
Ane	The anticyclonic centre is located in the NE of the study region, over eastern Europe. Winds are from NE.
A	The anticyclonic centre is located over the study region, producing relatively strong winds in winter.
Asw	The anticyclonic centre is located SW from the study region, over Greece and the central Mediterranean basin. Wind will have a north westerly sector.
Ase	The anticyclonic centre is located over Turkey and winds over the area blows from the southerly sector.
C	The cyclonic centre is located over the study region. Winds blow from the southeasterly sector.
Cnnw	The cyclonic centre is located over northern Europe, in the NNW of the study region and the prevailing wind has a southwesterly flow over the study region.

Cwnw	The cyclonic centre is located in the WNW of the study region, over central Europe. Winds blow from the southwest over the study region.
Cwsw	The cyclonic centre is located in the WSW of the study region and winds have a southerly flow.
Cssw	The cyclonic centre is located in the SSW of the study region, over the central-eastern Mediterranean and the northern Africa. Wind blows from the southeasterly sector.
Cse	The cyclonic centre is located in the southeast of the study region, over the eastern part of Turkey and Mediterranean Sea. The wind has a northeasterly sector.
Cne	The cyclonic centre is located in the NE of the study region. Winds blow mainly from the northerly - northwesterly sector.

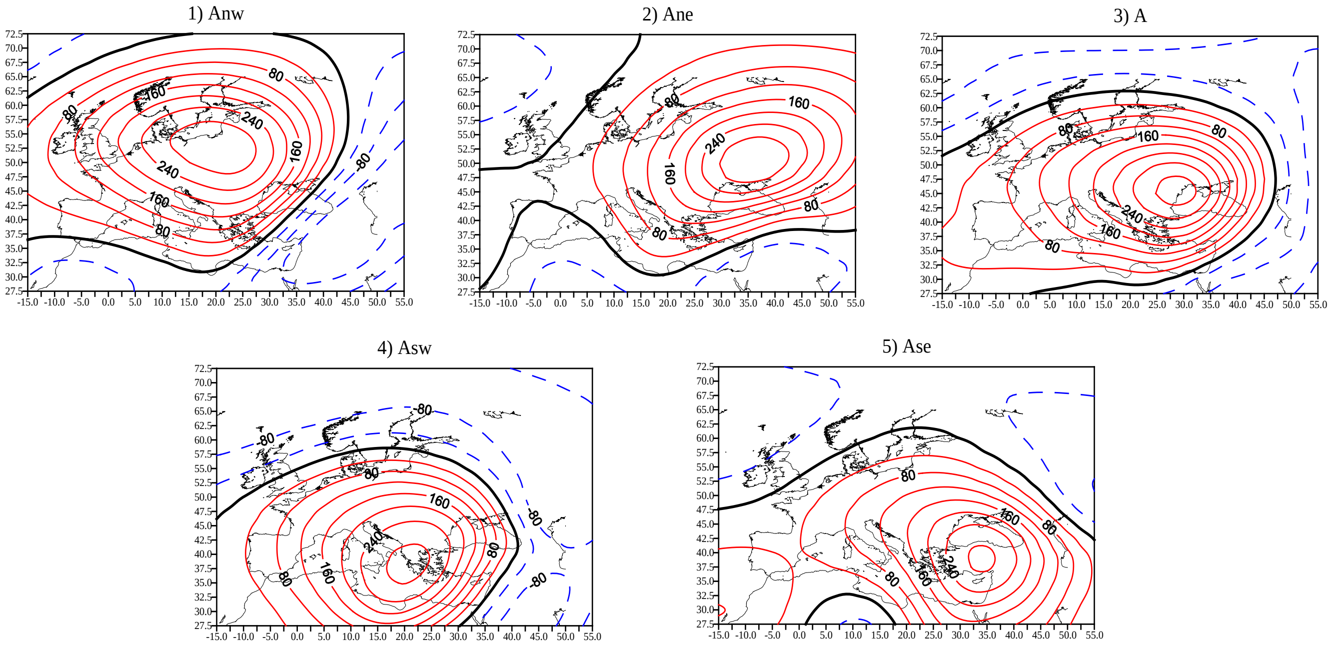

Fig. 2 The mean winter 500 hPa anomalies (x100) for anticyclonic types

The mean winter 500 hPa anomalies during the winter storm situations have been computed for the 4 most frequent cyclonic types Cwsw 16.9%, Cssw 20.1%, Cse 24.5%, and Cne 10.8% (figure 4). As it has been mentioned before, the mean composites of the four cyclonic types have been calculated and developed since these types are the most prevailing ones during storm days. Also, another set of composites have been constructed, demonstrating the anomaly differences between two fields: the mean field of the cyclonic types derived from averaging only the days of the types when there was a storm episode (aforementioned) and the general mean field of the equivalent type. Figure 4 illustrates the abovementioned results.

The first case examined concerns the cyclonic type Cwsw whose frequency of occurrence reaches the value of 16.9%. The mean anomalies field (figure 4a2) shows a field with large negative anomalies (-320) whose center is located between southern Italy and Greece and covers the whole central and eastern Mediterranean. At the north, a second field of large positive anomalies can also be detected, covering central, eastern and northern Europe. It should be highlighted at this point the differences map (figure 4a3), where positive differences characterize almost all the Balkan Peninsula and the eastern Mediterranean and the positive center is situated south of Crete. On the other hand, larger negative differences (-200) with a center over the Baltic Sea, cover almost the rest of Europe. It is quite obvious that at sea level, the storms are due to the high pressure gradient between a strong anticyclone at the north and a deep depression at the south. These are the most intense storms along the Romanian shore.

Concerning the cyclonic type Cssw, it was found that its frequency of occurrence during storm episodes is 20.1%. The mean anomaly field (figure 4b2) shows, as in the previous case, a very intense negative anomaly field centered in the southern Aegean Sea and a second positive anomaly field at the north with its center in the Scandinavian region.

Even if the positions of the fields remain almost the same, the differences' map shows few characteristic features, comparing to the aforementioned one: a positive difference field is located at the south and a negative one at the north. Also, the differences fields are weaker than the Cwsw computed fields.

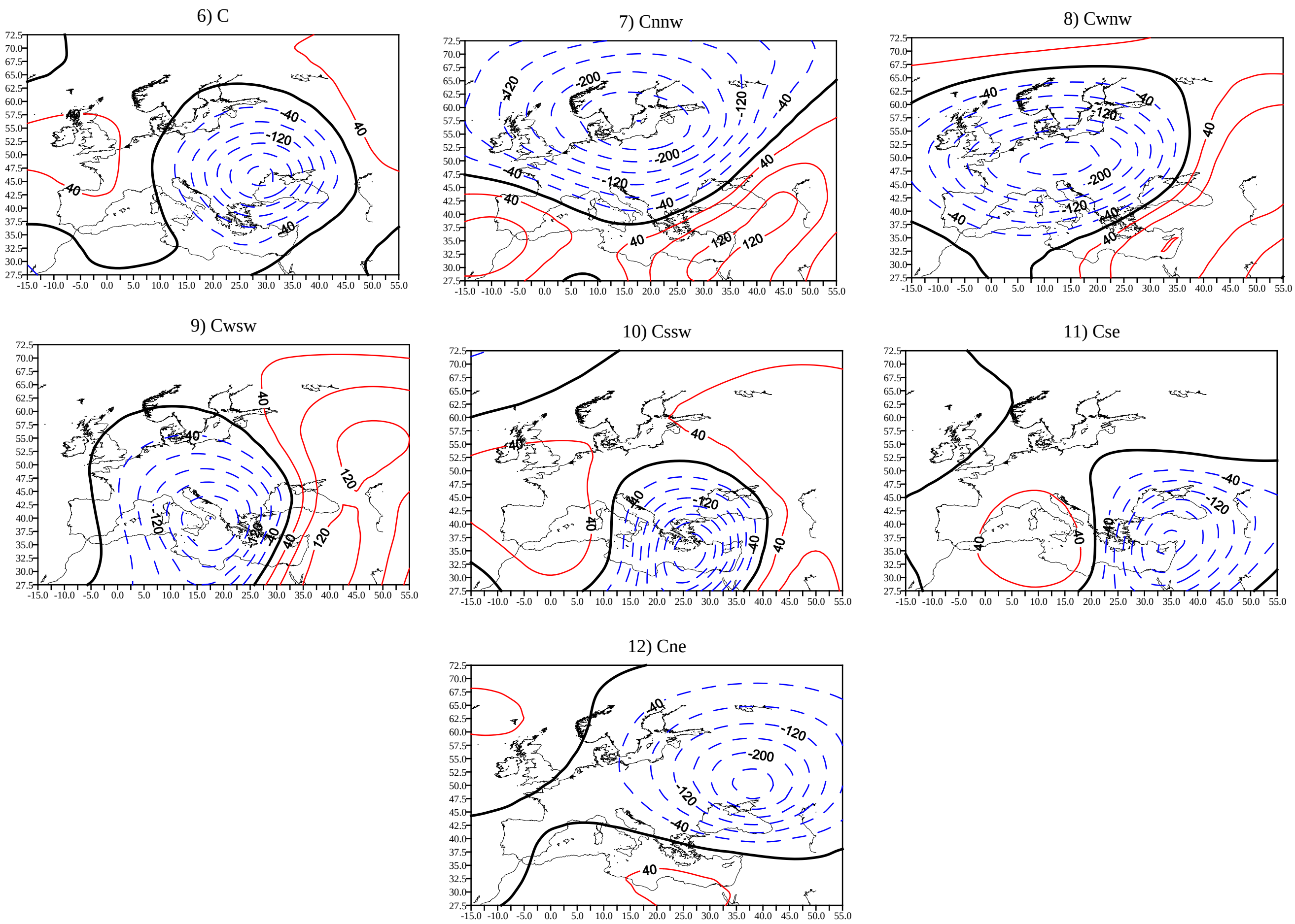

Fig. 3 The mean winter 500 hPa anomalies (x100) for cyclonic types

The third case concerns the cyclonic type Cse. This type presents the highest frequency of occurrence during storm days (24.5%). The mean anomaly field (figure 4c2) indicates a strong positive anomaly field at the north with a longitudinal orientation; at the south and east of this field, there is a negative anomaly field with a center at the north of Cyprus. Regarding the differences map (figure 4c3), it should be noted that the negative differences present almost the same layout as the positive anomalies on the previous map (figure 4c2). On the other hand, at the south, the positive differences present lower values and cover the whole Mediterranean. It is obvious that the storms at the surface are caused by the combination of two action centers (anticyclone at the north and depression at the south). However, winds are less intense than in the first cyclonic case (Cwsw).

Finally, the fourth case concerns the cyclonic type Cne whose frequency is 10.8 % during the storm days of the study period. Here, both the mean anomaly field (figure 4d2) and the differences field (figure 4d3) show that the storm episodes are due to the high pressure gradient value that form mainly from the high pressure field and not from its combination with the depression. Besides, the study of the mean surface pressure field (SLP - sea level pressure) reinforces this conclusion. It is the only mean composite at the surface (among the four examined cyclonic types) that does not present a low pressure field at sea level.

CONCLUSIONS

The main scope of the present study is the investigation and the standardization of the circulation at the 500 hPa level during storm episodes in the western part of the Black Sea. Their main cause is a combination of an anticyclone, generally located at the north and a depression with Mediterranean origin, at the south. For this purpose, a new objective classification of circulation types at the 500hPa has been employed. According to this classification, the circulation in Romania and in the Black Sea can be classified in 12 circulation types (5 anticyclonic and 7 cyclonic). It was found that most of the storms (80.3 %) are related to 4 cyclonic types, while the percentage of the anticyclonic types is only 18.4 %. This indicates that during the storm episodes (storm days) in the surface, there is a cyclonic circulation at the 500 hPa level, with a low pressure field located mainly at the south of Romania. The high pressure fields have an important role only at sea level and these anticyclones can be characterized as cold surface anticyclones.

In almost all of the cases of the cyclonic types related to storms, the negative anomalies at the 500 hPa level show a well organized deep low, with its centre at the south or at the northeast of Romania. The cyclonic type presenting the highest frequency of occurrence during the storm days (24.5%) is Cse. Its centre is located at the south-east of the study region. The circulation type that seems to cause the most violent storms from the eastern sector is Cwsw, due to strong pressure gradients along the Romanian coast and the Black Sea, both at sea and 500 hPa levels. Finally, the analysis of the composites during the prevalence of the cyclonic type Cne shows that storms are due to the strong pressure gradient of the cold surface anticyclone and not to the occurrence, south of the study region, of a weak depression.

As a future work, the authors plan to study and analyze all the storm situations and to extend the study period up to the present day. The authors are willing, by using GCM and RCM data, to investigate the characteristics of the storms until the end of the 21st century.

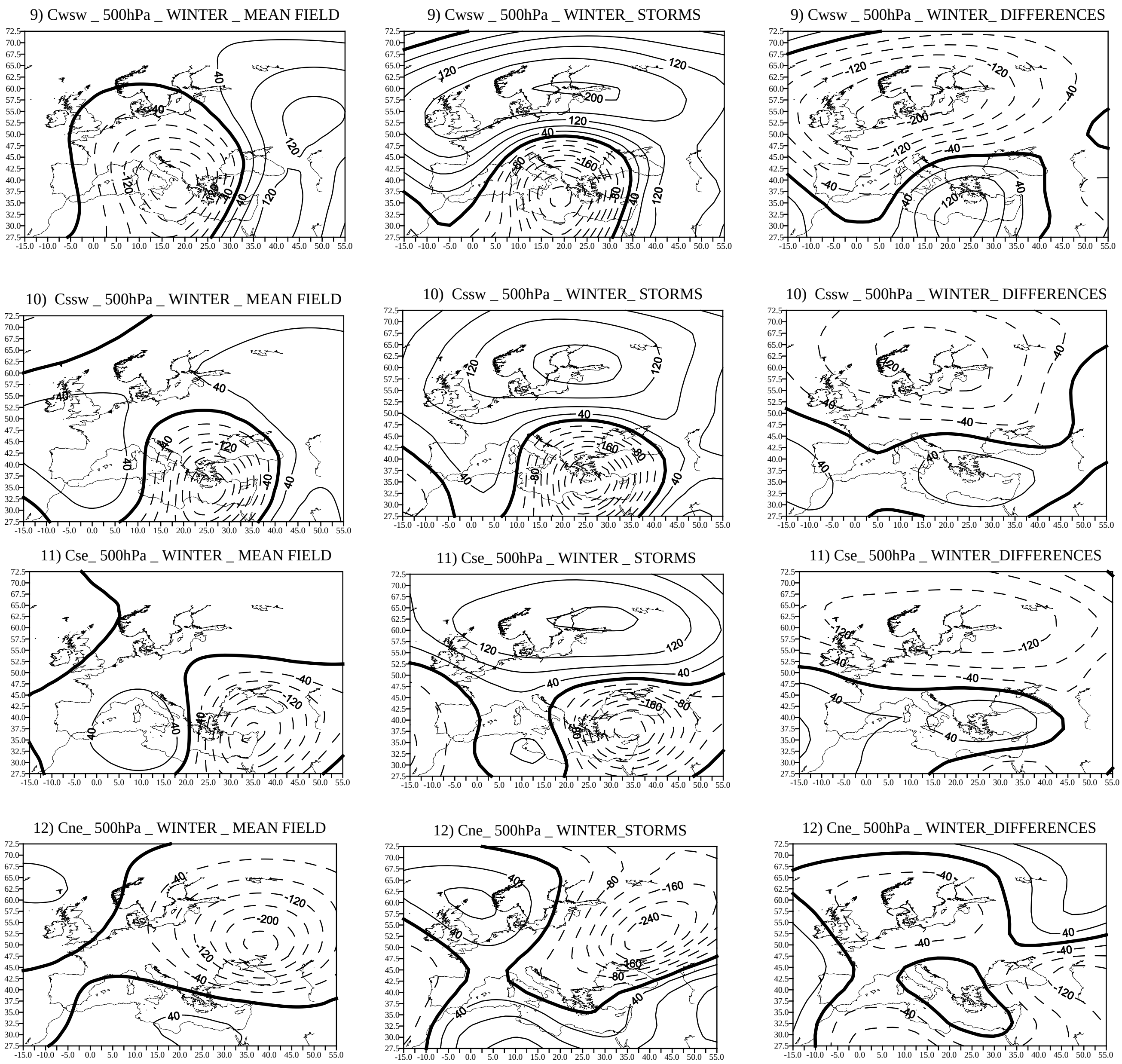

Fig. 4 Winter storm situations of 500 hPa geopotential heights for cyclonic types Cwsw, Cssw, Cse and Cne; column on the left: general mean field for each type; central column: mean field for storm situations; column on the right: differences between the 2 fields

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