

# Synoptic situations and their relation with precipitation over the region of Thessaly

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## Abstract

The objective on this study is to analyze the impact of synoptic situations on precipitation amount over the area of Thessaly using a manual classification scheme, to identify synoptic situations, and daily records of precipitation from Larissa (2001-2010) and Trikala (2001-2004) weather stations. Identification of synoptic situations is based on the isobaric charts of 500hPa and the position and orientation of the trough axis. Following this approach the period 2001-2010 is classified, on a daily basis, into ten distinguished synoptic situations and daily rainfall is allocated in each synoptic situation. Synoptic situations and precipitation amount relationships are computed and analyzed on a yearly as well as seasonal basis. Results indicate that southwest (SW) and northwest (NW) flow are the most frequent synoptic situations observed over the area, whereas closed high and omega blocking are the least. Classification of observed precipitation into the identified synoptic situations revealed that the greatest amount of precipitation, over 50%, falls under synoptic situations related with the passage of troughs and low pressure systems over the area, followed by southwest flow. Conversely, the prevalence of synoptic situations related with high pressure systems exhibits negligible precipitation amount. Finally, seasonal analysis revealed a more complex distribution of precipitation for each synoptic situation.

**Keywords:** synoptic situations, precipitation, Thessaly.

## Introduction

Thessaly is located in eastern-central continental Greece, covering an area of about 13.700 km<sup>2</sup> with elevation ranging from sea level up to 2.800m. Precipitation regime of the area is the typical Mediterranean regime (wet winters, dry summers), exhibiting high inter-annual variation due to the prevailing atmospheric circulation from west to east. Thus, mean annual precipitation in the western mountainous areas exceeds 2.000mm, while central and eastern plain areas receive only 420mm (Flocas, 1994). According to Trenberth (1990) and Xu (1993), the atmospheric circulation is the main forcing factor for the regional variability of precipitation. Therefore, to identify and understand the relation between atmospheric circulation patterns and precipitation amount over the area of Thessaly is crucial and of great importance.

Although the eastern plain area is climatologically characterized by semi-arid conditions, Thessaly is one of the most agricultural productive regions of Greece producing cotton, wheat, maize, apples, olives and many more. The increased -and sometimes- inappropriate agricultural activities and the unproductive management of irrigation water have led to significant degradation at water resources of the area. The «DAPHNE» program aims to help in mitigating the drought conditions in Thessaly, by means of Weather Modification (Karacostas et. al, 2014) T and is focused in the development of necessary scientific tools to support the potentiality and applicability of a well designed precipitation enhancement program over Thessaly.

Synoptic classification schemes are increasingly useful approaches for analyzing the links between climate and a wide range of environmental variables. Some of the best-known

examples, that have been used in numerous applications around the world, are the Muller Classification (Muller, 1977), the Lamb Catalogue (Lamb, 1972), and Grosswetterlagen (Hess and Brezowsky, 1977). In Greece, classification schemes for a complete range of synoptic scale atmospheric circulation patterns have been proposed by various researchers (Karacostas et al., 1992; Kassomenos et al., 1998a, Maheras et al., 2000). These schemes have been employed to examine the relationship of the synoptic scale circulation with regional environmental variables including precipitation over the Greek area (Maheras 2000; Xoplaki et al., 2000, Anagnostopoulou et. al., 2009, Michailidou et.al., 2009).

The objective on this study is to analyze the relationship between synoptic scale atmospheric circulation and precipitation over the region of Thessaly on a daily basis and to investigate, in a yearly basis, the seasonal characteristics of this relationship. The resulted product could act as a useful tool in planning a rain enhancement program and particularly for the investigation of the feasibility potential of such a program (Bampzelis 2013). The classification scheme proposed by Karacostas et al. (1992) is adopted, which is mainly based on the isobaric level of 500hPa and the position and orientation of the trough or ridge axes.

### **Data and Methodology**

The data used for the purpose of this study are daily records of precipitation from two weather stations in the area of Thessaly; Larissa for the period 2001-2010 and Trikala for the period 2001-2004. Synoptic classification is performed on a daily basis for the period 2001-2010, from ECMWF gridded analysis data (geopotential height at 500hPa pressure level) at 12:00UTC. Synoptic classification is similar for both stations, since the distance between Larissa and Trikala is only 55km.

Seasonal delimitation is based on an alternative, rather than, the usual seasons of the year (Karacostas and Pennas 1994; Pennas 2000). The warm period is defined by the months June, July, August and September, the cold period by the months December, January, February and March while two transitional periods, April-May and October-November denote the spring and autumn periods, accordingly. This seasonal delimitation has been made in order to have a more comprehensive view of precipitation regime of the area. The precipitation regime of March resemble similarities with those of the winter months, thus, it has been classified into the cold period, alike September to the warm.

The synoptic categorization is achieved by classifying every day into the ten distinct synoptic types proposed by Karacostas (1992), according to the 500hPa synoptic circulation. The synoptic types are schematically presented in Fig. 1 and are briefly described as follows:

**Zonal flow (ZON):** This synoptic situation (Fig. 1a) is related with the existence of a low amplitude trough to the west and north and a low amplitude ridge to the east and south, resulting in an almost zonal flow over the area of interest. Embedded low amplitude waves or short waves are developed and move very quickly.

**North-West flow (NW):** A long wave ridge (Fig.1b) is located to the west-northwest of the area of interest and a long wave trough to the east-southeast. The resulted northwest flow coexists with a series of embedded short wave troughs and ridges.

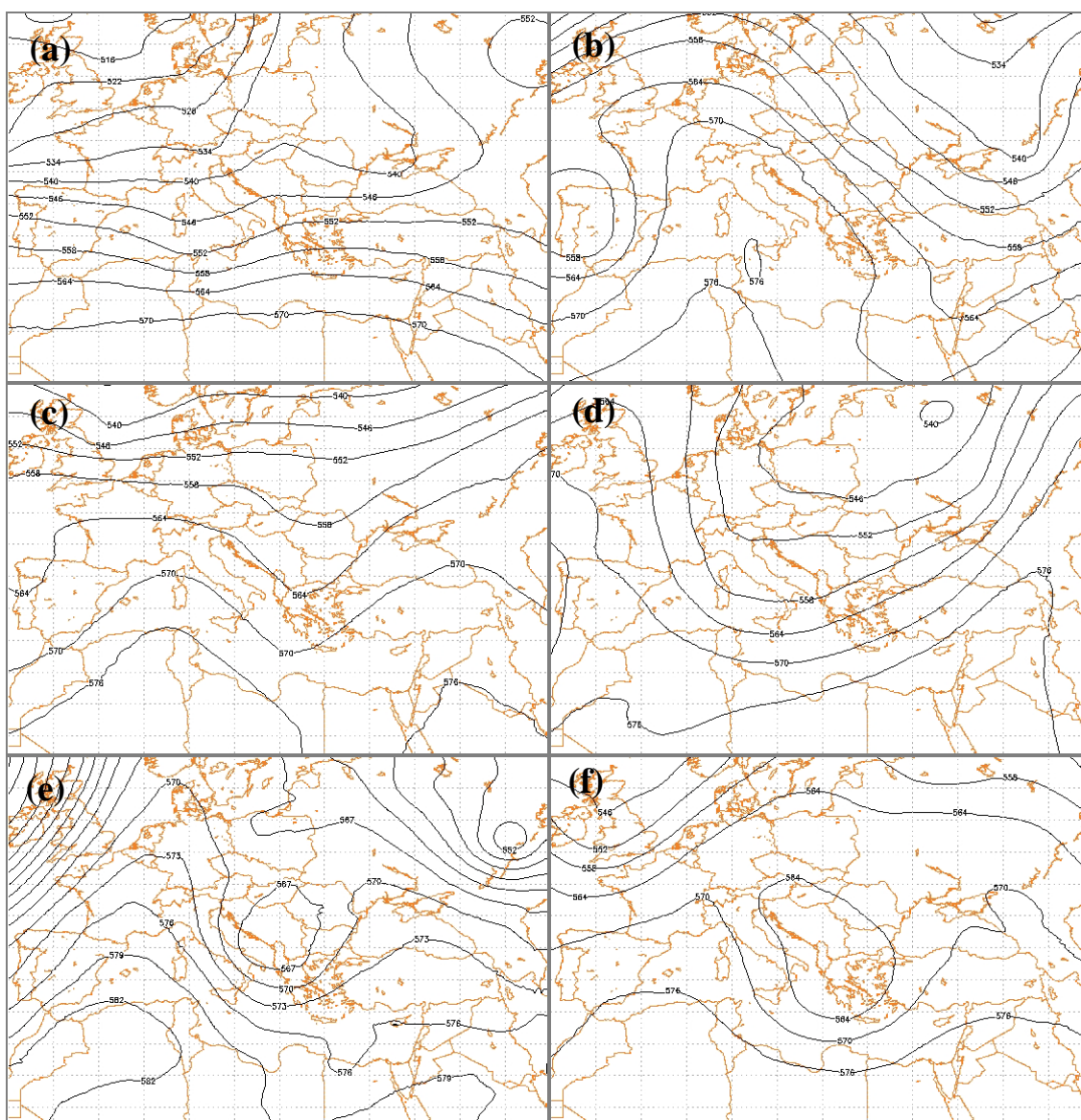


Figure 1. Schematic representation of 500hPa geopotential height (gpdam) for several synoptic flow types above the region of Thessaly: (a):Zonal flow, (b): North-west flow, (c): Open Long Wave Trough, (d): South-west flow, (e): Closed long Wave Trough and (f): Cut-off low.

**Open Long Wave trough (L-1):** A slow moving or a stationary long wave trough dominates the area (Fig.1e). The upper airflow is generally light, with a northwesterly to westerly component, while the air mass is characterized as moderately unstable. A high pressure system is generally located to the northwest resulting to a north-northwest surface flow.

**Closed Long Wave trough (L-2):** The same (Fig.1e) as the open long wave trough, with the difference that at least one closed contour exists in the upper flow. This synoptic situation usually is associated with a closed low pressure system to the north. The airflow has northerly component and the air mass is almost unstable because of the cold air advection to the trough.

**Cut-Off Low (L-3):** This synoptic type (Fig.1f) usually coincides with the mature stage of open long wave trough and closed long wave trough. It is characterized by a closed low contour at 500hPa which is completely separated from the main general circulation. At this stage, the kinetic energy of the system has been transformed into dynamic energy and therefore it remains almost stationary and strong.

**South-West flow (SW):** A long wave trough (Fig.1d) is located to the west-southwest of the area and a long wave ridge to the east-northeast. The resulted southwest flow coexists with a series of embedded short wave troughs and ridges.

**Open Long Wave ridge (H-1):** This synoptic pattern is characterized by an almost stationary long wave ridge, which dominates the area. The upper airflow is generally light, with a southwesterly to westerly component, while the air mass is characterized as moderately stable.

**Closed Long Wave ridge (H-2):** This synoptic pattern is similar to the open long wave ridge situation, with the difference that at least one closed geopotential height contour exists at 500hPa level. It could be considered as a stage in the evolution of the previous described situation.

**Omega blocking ( $\Omega$ ):** This synoptic situation pattern consists of two low pressure systems and one high pressure system. They are combined in such a way that form a circulation that seems like the capital Greek letter «omega -  $\Omega$ », with the high pressure system to the north and the two low pressure systems southeast and southwest of it accordingly. This pattern acts as a blocking mechanism, forcing the easterly moving low pressure systems to move either to the north or to the south..

**Undetermined pattern:** In this situation there is no clear distinct pattern to categorize it to the previous synoptic situations. Sometime these patterns are diffluent-like flow circulations with variable low intensity winds.

The occurrence of each synoptic situation over the area in conjunction with precipitation appearance under each synoptic situation is examined over a seasonal basis for both Larissa and Trikala stations. Delivered results will show what kind of relation exists between synoptic situations and precipitation distribution in the examined area.

## Results

### 3.1 Annual distribution of synoptic situations and precipitation

Following the classification of the daily weather maps in the above described categorization, the number of days per year of each synoptic situation is presented, for both Larissa and Trikala areas, in Fig. 2a. In the same way the total annual precipitation amount attributed for each synoptic situation is depicted in Fig. 2b.

From Figure 2a, it is implied that the synoptic situation with the highest frequency is South-West flow (SW) for both Larissa and Trikala, appearing for 78 days (21.5%) and 69 days (18.9%) respectively. The least frequency of appearance exhibits synoptic situation  $\Omega$  for both areas with percentages close to zero, followed by synoptic situation H-2. Synoptic situations ZON, NW, L-1, L-2 and H-1 exhibit frequencies between 10% and 17% for both stations. Alike synoptic frequency distribution, precipitation (Fig. 2b) also exhibits the same pattern, thus, the highest amount of precipitation occurs during the prevalence of SW synoptic situation, while the minimum occurs under synoptic situation  $\Omega$ . Synoptic situations H-1 and H-2, denoting the prevalence of high pressure systems, also receive minimum precipitation amount. Conversely and even though ZON and NW synoptic situations appear to have high frequency, the precipitation amount is quite small. Thus, it is conceivable that during the prevalence of these synoptic conditions there is a small chance of rainfall.

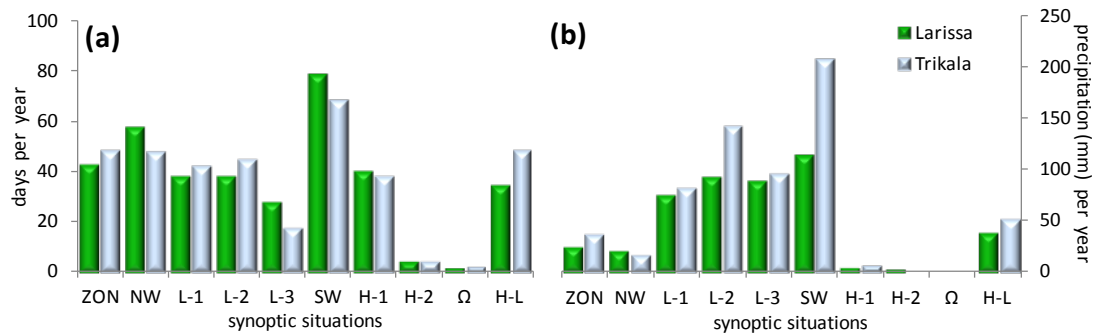


Figure 2. Frequency of appearance of synoptic conditions (a) and rainfall amount (b) for the stations in Larissa and Trikala.

It is concluded that 80% of the total annual precipitation, that both areas receive, is associated with the prevalence of four synoptic situations: L-1, L-2, L-3 and SW (Fig 2b).

The frequency of occurrences of actual precipitation is encountered for each synoptic situation, for both stations, in Figure 3. Results indicate that strong similarities exist between the two stations in precipitation occurrence under each synoptic situation. Thus, as it was expected, the synoptic situation L-3 appears to have the highest precipitation occurrence with over 50%, followed by synoptic situations L-1, L-2 and SW, having occurrences between 30% and 40%. Precipitation occurrence is limited under synoptic situations ZON and NW to about 10%.

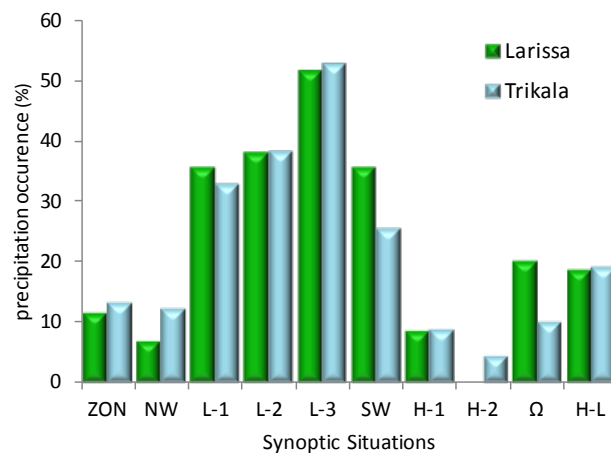


Figure 3. Precipitation occurrence for each synoptic situation for Larissa and Trikala.

### 3.2 Seasonal Characteristics

Following the seasonal delimitation, as described in Data and Methodology section, the seasonal analysis is performed dividing the year in two main and two transitional seasons. The main seasons are summer and winter (4 months each) and the transitional seasons are spring and autumn (2 months each). The analysis is performed for the common period for both stations which is 2001-2004. Synoptic situations as well as precipitation amount are computed as percentages of the annual values which are 365 days for synoptic situations and mean annual precipitation amount for precipitation. Results for each season are depicted in Figure 4. Regarding seasonal synoptic situation variations, it is observed that SW synoptic type exhibits higher frequency during the cold season and autumn (23%). Ω is almost absent during the warm period, while L-3 present the lower frequencies during the warm and autumn periods, as well.

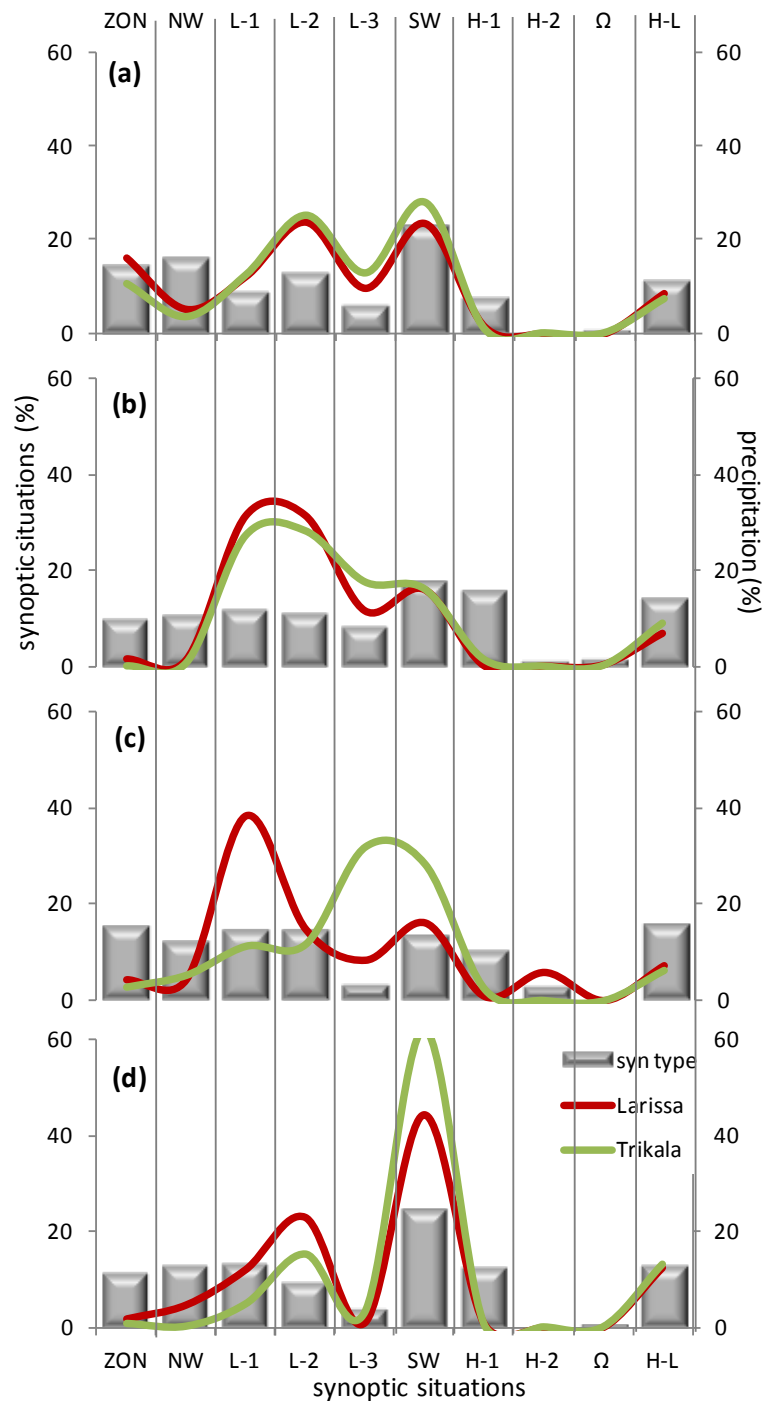


Figure 4. Seasonal frequencies of Synoptic Situations (bars, left vertical axis) and total precipitation (lines, right vertical axis) for the period 2001-2004 for: (a) cold period, (b) spring, (c) warm period and (d) autumn for Larissa and Trikala stations.

Precipitation amount appears to have similar distribution for the cold and the transitional seasons for both stations, with the exception that Trikala station exhibits higher precipitation amount, but not for the warm season of the year. This fact is fairly explained since during the warm season the area is dominated by isolated thunderstorm activity producing convective and scattered precipitation rather than well organized weather systems that produce widespread precipitation. This fact also explains the increased precipitation occurrence that appears in Fig. 3, for  $\Omega$  synoptic situation.

During the warm period the prevalence of L-1 synoptic situation for Larissa station exhibits the highest rainfall amount despite the fact that L-1 frequency is not especially high in relation with the other synoptic situations. The same fact applied for L-3 synoptic situation. Trikala station presents a different pattern with the highest precipitation amount attributed to SW and L-3 synoptic situations.

Comparing autumn transitional season for both areas (Fig 4d), the highest precipitation amount is observed during the prevalence of SW synoptic situation, which is also the most frequently appearing. Similarly, H-2 and  $\Omega$  synoptic situations exhibit the lowest precipitation amounts, presenting also the lowest frequency of appearance.

Finally, the occurrence of precipitation is examined on a seasonal basis for each synoptic situation for both stations and results are presented in Table 1. Results indicate the strong similarities that exist between the two stations in precipitation occurrence under certain synoptic situation, which are L-1, L-2, L-3 and SW, for all season. These findings can depict minor seasonal differences that appear among the seasons as well as the stations, but in general, coincide with the results of the previous section.

Table 1. Percentage (%) of rainfall occurrence for each synoptic situation on a seasonal basis for the areas of Larissa and Trikala.

syn type	Larissa					Trikala				
	yearly	winter	spring	summer	autumn	yearly	winter	spring	summer	autumn
ZON	13,1	21,2	12,3	8,4	9,1	11,4	26,1	4,3	4,1	3,7
NW	12,2	9,5	18,8	13,1	14,1	6,8	10,5	8,0	3,4	3,2
L-1	32,9	33,1	35,0	31,6	36,2	35,5	54,8	50,0	21,4	28,1
L-2	38,3	45,4	42,6	27,4	41,8	38,0	52,5	57,7	18,8	39,1
L-3	52,7	50,7	55,4	53,5	52,5	51,4	51,7	50,0	64,3	44,4
SW	25,5	32,9	16,8	15,7	36,6	35,4	45,5	21,4	21,9	40,7
H-1	8,9	10,0	2,7	1,2	2,7	8,5	10,8	10,8	6,1	6,7
H-2	4,4	0,0	0,0	3,4	25,0	0,0	0,0	0,0	0,0	0,0
$\Omega$	10,0	7,1	25,0	0,0	0,0	20,0	25,0	50,0	0,0	0,0
H-L	19,1	26,5	25,0	7,8	19,0	18,6	20,4	35,3	6,7	32,3

## Conclusions

An effort was made to analyze the impact of synoptic situations on precipitation amount over the area of Thessaly. Using a manual classification scheme, 9 distinct synoptic situations plus an undefined one were recognized and precipitation amount was assigned in each synoptic situation. Results indicated that southwest (SW) and northwest (NW) flow are the most frequent synoptic situations observed over the area, whereas closed high and omega blocking are the least. Classification of observed precipitation into the identified synoptic situations revealed that the greatest amount of precipitation, over 50%, falls under synoptic situations related with the passage of troughs and low pressure systems over the area (L-1, L-2 and L-3) as well as southwest flow (SW). Conversely, the prevalence of synoptic situations related with high pressure systems exhibits negligible precipitation amount mainly from summertime thermal convection and not from organized weather systems.

The seasonal analysis pointed out minor differences between precipitation occurrence for the cold and transitional periods of the year, but profound differences during the warm period, between the two examined stations.

Frequency analyses bring out evidences of precipitation occurrence under each recognized synoptic pattern, providing an integrated view of the expected conditions that prevail over the examined area on a yearly and seasonal basis. The analysis can act as a tool for developing the appropriate strategy aiming for rain enhancement feasibility potential.

**Acknowledgments.** *This research work is part of DAPHNE project and is co-funded by the European Union (European Regional Development Fund) and Greek National Funds, through the action "COOPERATION 2011: Partnerships of Production and Research Institutions in Focused Research and Technology Sectors" in the framework of the operational programme "Competitiveness and Entrepreneurship" and Regions in Transition (OPC II, NSRF 2007-2013).*

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