P1.21 MESOSCALE CONVECTIVE SYSTEMS IN FRONTAL SYSTEMS OBSERVED BY METEOSAT-8 INFRARED IMAGERY

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1. INTRODUCTION

The Mediterranean basin is well known as a region of frequent cyclone formation and is affected by moving depressions generated either in the Atlantic Ocean or in north-western Europe. Preferred regions for cyclogenesis in the Mediterranean region were identified by Radinovic (1987). The depressions occurring in specific areas of the Mediterranean region and the cyclonic tracks have been the subject of extensive climatological research (e.g. Maheras 1979, 1983, 1988a, Katsoulis 1980, Prezerakos 1985, Flocas 1988, Kassomenos et *al.* 1998). In these studies, the depressions were identified and classified manually on the basis of synoptic charts.

The central Mediterranean is affected by depressions in the westerly circulation and at the same time is largely influenced by meridional circulations and depressions formed over the western and central Mediterranean or over the Sahara Desert. The meridional circulation is the main factor governing most of the precipitation over the whole of the Mediterranean basin (Maheras 1988a, b, Maheras et *al*. 1992).

In addition to the continental and synoptic-scale circulations that are part of the Mediterranean weather, two Mesoscale phenomena also play a large role, especially in precipitation. One is Mesoscale Convective Complexes (MCC's), first observed by Maddox (1980). These are well-organized mesoscale convective system producing severe weather and intense precipitation. The other mesoscale systems, Mesoscale Convective Systems (MCS's), are smaller and shorter-lived cloud systems that occur in connection with an ensemble of thunderstorms and produce a contiguous precipitation area ~100 kilometers or more in horizontal scale in at least one direction (Houze, 1993). MCC's occur very frequently in subtropical regions and in extensive continental regions such as the interior of North America, and the smaller-scale MCS's can be found on the Iberian Peninsula and in Western Europe, as well as North America.

The structure and life cycle of a MCS can be described depending on the data used: radar, precipitation, intracloud and/or cloud-to-ground lightning. The study of these atmospheric phenomena and others have been improved by the use of satellite imagery. The majority of the mesoscale work is based on infrared (IR) satellite images. Maddox (1980) provided the first MCC definition, and MCS's were later observed by Fritsch *et al* (1986) in the United States, and more recently in the vicinity of the Iberian Peninsula (*e.g.* (Riosalido, 1991; Canalejo et *al*, 1993; 1994; Carretero et *al*, 1993; Martín et *al*, 1994; Elvira et *al*, 1996; Hernández et *al*, 1998; Riosalido et *al*, 1998; Garcia-Herrera *et al*, 2005). In this paper, the brightness temperature T_B derived from Meteosat-8 IR imagery allows an objective and stable classification for the MCS's on the Iberian Peninsula related to the size of the cloud-top shield of the Mesoscale convective system.

While MCS's play a crucial role in frontal precipitation, particularly in cold fronts, their relationship with fronts has not yet been

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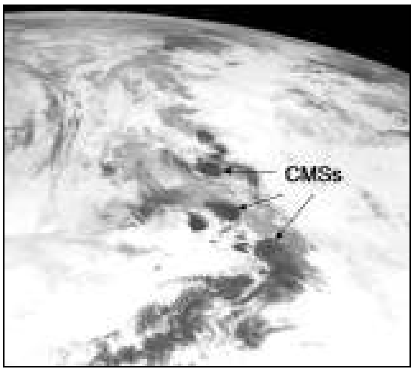


Fig. 1. IR10.8 image (inverted) with examples of MCS's (denoted here by "CMSs") in a front over South Europe and the Mediterranean Sea. From Met-8. (7 July 2006, 04:00 UTC).

adequately documented, nor has it been fully clarified. The intention of our work has been to study MCS's that form in a front when developing convective activity exists (Fig. 1). More specifically, we have examined the morphology, organization and dynamics at MCS's that develop at different levels in the nucleus of a front, and investigated the relationship between these MCS properties and those of the front.

2. DATA AND DATA ANALYSIS

2.1 Data

We have focused this work on a region of the Northern Hemisphere including Europe and the North Atlantic Ocean (Fig. 2). We used Meteosat images (www.eumetsat.de) obtained from the Departamento de Fisica de la Tierra II (Universidad Complutense de Madrid) for 7 July 2006, covering a region of the globe extending from the North Pole to a latitude of 23° N (Fig.2), with a major concentration on the Iberian Peninsula.

Fig. 2. Area of interest for this study.

The satellite image data used in this study was aquired by the Meteosat Second Generation (MSG) satellite, Meteosat-8, thermal IR channel IR108 (9.80-11.80µm), the so-called "atmospheric window" centered at 10.8 μm. These images were analyzed for the presence and properties of MCS's and fronts using the MAximum Spatial COrrelation Tracking TEchnique (MASCOTTE), developed by Carvalho and Jones (2001), as discussed below.

2.2 Data Analysis: MASCOTTE

The study of MCS's by means of satellite data has traditionally been done by observing the areas of cold cloud tops within different isotherms. Areas in excess of threshold values are considered indicative of the existence of an MCC or and MCS. Carvalho and Jones (2001) developed an automated and objective method, to identify MCS cloud shields and to describe their structural properties and evolution the maximum Spatial Correlation Tracking Technique (MASCOTTE). As described by Garcia-Herrera et al (2005), the set of structural properties computed by MASCOTTE makes it a useful tool to describe MCS morphology. Moreover, owing to its simple and efficient algorithm, a complete climatology over long periods can be readily developed.

To further paraphrase Garcia-Herrera et al (2005): The method is based on the Maximum Spatial Correlation Technique, which uses IR images converted to brightness temperature (T_B) as input. MASCOTTE isolates, one by one, the systems fulfilling the temperature and area identification criteria for MCS's at time t_i, it then correlates the MCS's in the image t_i with all those in the image t_{i+1}. The system in the image t_{i+1} representing the maximum correlation value over a minimum threshold is considered the next spatial position of the system in the image t_i. This technique is also used to compute mergins and splittings.

This study required two modifications of previous versions of MASCOTTE. First, it was necessary to adapt MASCOTTE for use with Meteosat-8 image data. Second, the temperature and area criteria needed to be adapted for two distinct analyses: one for MCS's and another for frontal regions.

MASCOTTE was originally designed to aid in the interpretation of GOES data, but it has been used with Meteosat-7 in prior work (Vázquez and Maqueda, 2005, Fenollar and Maqueda, 2006). In this work, it has been adapted to the Meteosat-8 imagery available from the Departamento de Fisica de la Tierra II (Universidad Complutense de Madrid, Spain), which provides 15 min. time resolution and 3 km horizontal resolution.

Changes included the T_B conversion parameters, spatial resolution, and time differences.

The initial definition of the MCC (Maddox, 1980) was based on *both* an area ≥ 100,000 km^2 colder than a T_B threshold of –32 °C *and* more than 50,000 km^2 below –52 °C. These temperature criteria as well as others have been used, since. MASCOTTE originally used the criterion of > 100 km effective radius of an area below -38 °C for MCS's. In the adaptation of MASCOTTE used here, we have separate criteria to identify and describe both MCS's and frontal regions. Following the criteria adopted by Augustine et al. (1989) and Riosalido et al. (1998), MCS's are defined as areas > 1000 km^2 within the brightness isotherm -52 °C. We found that a minimum area of 100,000 km^2 inside the -25 °C isotherm for T_B is a useful criterion to identify frontal regions.

Augustine et al. (1989) and Riosalido et al. (1998), using -52 °C as the threshold value of T_B, discuss the life cycle of an MCS in terms of the times at which it originates, reaches an area of 10,000 km^2, reaches its maximum area, and decreases to 10,000 km^2. Here, we also use -52 °C as the threshold value of T_B but precede with a somewhat different scheme. First, we refer to MCS's that grow to more than 1000 km^2 but not to more than 10,000 as "small" MCS's. Their life cycle begins when they first reach an area of 1000 km^2.and ends when it decreases to the same area. Those MCS's that obtain areas in excess of 10,000 km^2 are referred to here as "large" MCS's. We assign the time at which a large MCS reaches an area of 10,000 km^2 to its time of origination, and the time at which it decreases to only 1000 km^2 as the end of its life cycle. Presumably, the larger large MCS's can also be identified as MCS's with greater vertical development. We studied only MCS's of at least 3 h duration. Fig. 3 shows the enhancement of the area of temperature lower than the threshold of -52 °C.

Fig. 3. Enhance of temperature area lower than 221 K over Ireland.

For each system identified by MASCOTTE, a set of structural properties is computed for every image, including area extent, center of gravity, direction of displacement (clockwise angle between the north direction and the straight line joining the first and the last positions of the center of gravity) and velocity.

3. CASE STUDY: 7 JULY 2006

3.1 Synoptic Analysis

On July 7, 2006, a front developed in the Atlantic Ocean (Fig. 4) that can evolved until arriving near the Iberian Peninsula. At 00:00 UTC (Fig. 4), analysis of the isobaric chart presents the following characteristics. A cold front is approaching the Iberian Peninsula from the NW.

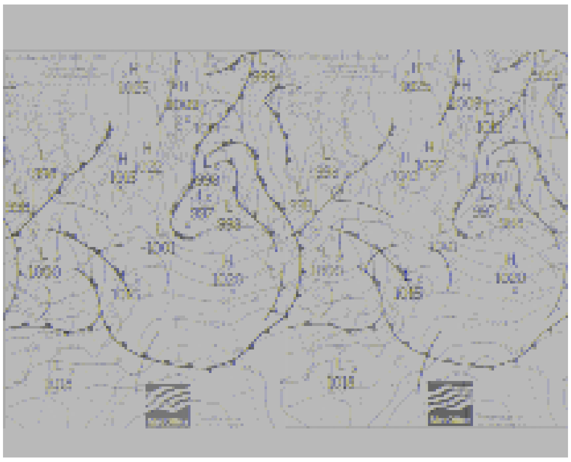


Fig. 4. Surface map (7 July 2006, 00:00 UTC).

3.2 Small MCS's

In this section, we show the results for the first storms detected inside a front.

Among the morphological characteristics of the Small MCS's within the approaching front, the statistical distribution of areas and ellipticities are of particular interest. The maximum area of each MCS was identified; their statistical distribution is plotted in Fig. 5(a). The mean maximum area reaches 5392 km^2. The ellipticity at the time of maximum area extent (e_{AMX}) has been chosen to represent the approximate shape of MCSs through their life cycle. Fig. 5(b) shows the e_{AMAx} distribution, which presents a mean value of 0.3.

MCS velocity (Fig. 6(b)) is an important dynamical parameter because it is related to the occurrence of floods: the total precipitation can be estimated from the speed and the size of the system, together with the average rainfall rate (Doswell et al., 1996). A slow MCS may lead to greater flood damage than a more rapidly moving system, for given similar average rainfall rates and spatial sizes. The criterion used by Carretero and Riosalido (1996) to characterize quasi-stationary MCS's, that represent a serious hazard due to the possibility of producing intense floods, was velocities below 15 km/h. The mean velocity distribution has a mean value of 64.5 km/h. The mean duration was 4 h (Fig. 6(c)), making it clear that small MCS's have short durations. Fig. 6(a) shows that the preferred direction for the MCS to propagate is northeast.

Finally, the distribution of the time of first detection (Fig. 6 (d)) shows two peaks, one from 00:00 to 03:00 UTC and the other from 06:00 to 09:00 UTC. The mean time of first detection of all small MCS's for the front of July 7, 2006 is 0752 UTC, so the maximum occurrence is in the morning.

(a)

(b)

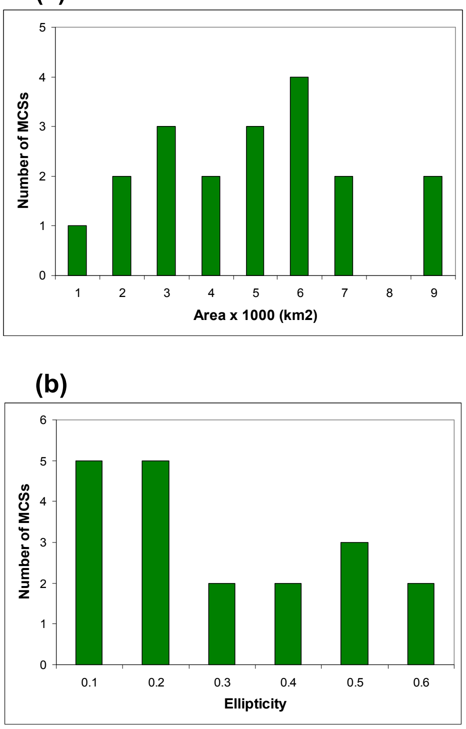


Fig. 5. (a) Maximum area extent distribution by 1000 km^2 intervals. (b) Ellipticity at the maximum area extent instant distribution. Values of A_{max} are divided into eight 0.1 intervals. (Small MCS's)

3.3 Large MCS's

The morphology of large MCS's is rather different from that of the small MCS's. The mean maximum area. Fig. 7(a), reaches 18,276 km^2, more than triple the mean area during the first storm phase. The ellipticity at the time of maximum area extent (A_{max}), Fig. 7(b), shows a mean value of 0.4, the same as during the first storm phase.**(a)**

(b)

(c)

(d)

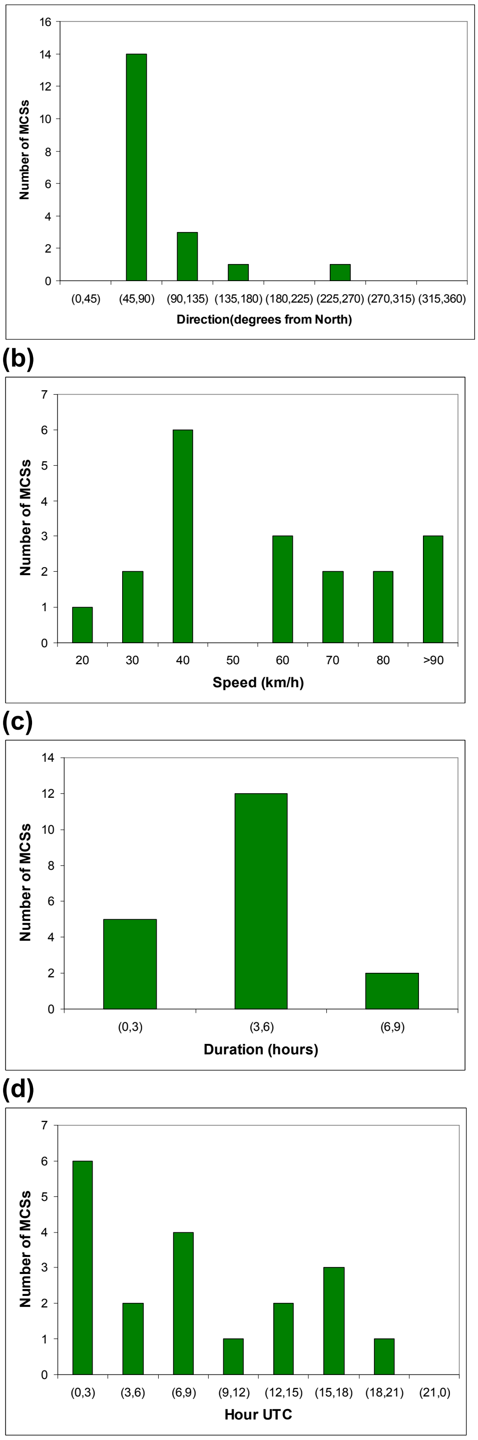
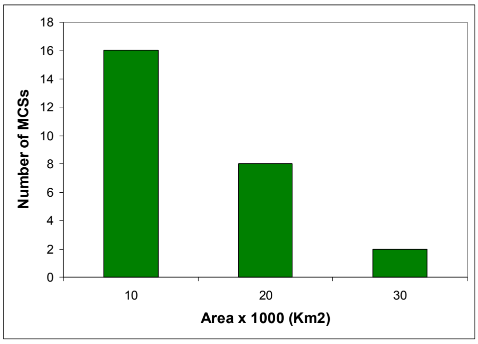


Fig. 6. (a) Direction of propagation. (b) MCS mean velocity distribution. (c) MCS duration histogram (d) Distribution of the time of first appearance. (Small MCS's).

Dynamical information about the large MCS's appears in Fig. 8. In Fig. 8 (b) the mean velocity distribution displays a mean velocity of 64 km/h, almost the same as for the small MCS's. The mean duration was 4 h (Fig. 8(c)), making it clear that the more developed MCS's also have the same short durations as the small MCS's. Fig. 8(a) shows that the preferred direction for the large MCS propagation is again 45 to 90 degrees relative to north (northeast).

The first detection distribution for the large MCS's (Fig. 8(d)) shows a peak, one from 00:00 to about 06:00 UTC, with a mean time of 0713 UTC. So, the maximum occurrence is also in the morning.

(a)



(b)

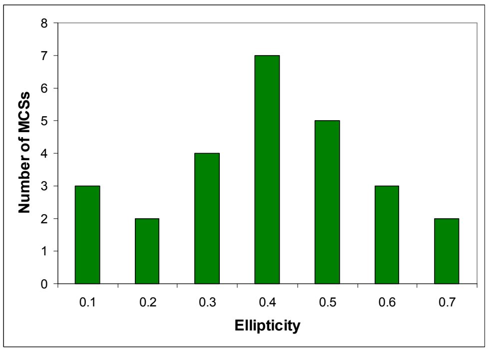
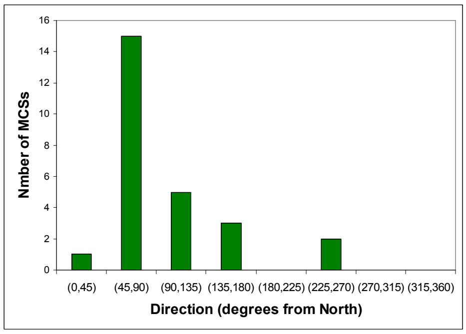
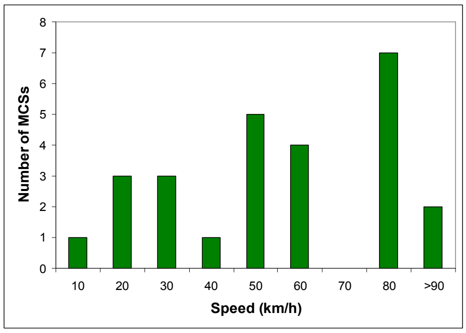


Fig. 7. (a) Maximum area extent distribution for large MCS's, in 10,000 km^2 intervals. (b) Distribution of ellipticity at the time of maximum area extent. Values of A_{max} are divided into eight 0.1 intervals. (Large MCS´s).

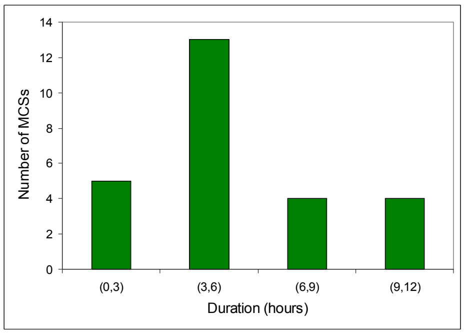
(a)



(b)



(c)



(d)

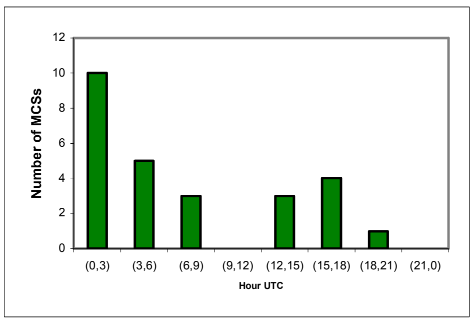


Fig. 8. (a) Direction of propagation. (b) Large MCS's mean velocity distribution. (c) Duration histogram (d) Distribution of the initiation time. (Large MCS´s)

4. SUMMARY AND CONCLUSIONS

MASCOTTE (Carvalho and Jones (2001), a simple, fully automated, and efficient method to determine the structural properties and evolution (tracking) of MCS cloud shields, has been described. This method is based on the maximum spatial correlation tracking technique for monitoring the evolution of MCS's using satellite images. MASCOTTE provides as MCS structural properties the following parameters: area extent, center of gravity, direction of displacement and velocity.

In this work, the objective method MASCOTTE has been modified, and used to identify and characterize MCS's inside a frontal system approaching the Iberian Peninsula on July 7 2006. By using appropriate threshold values of brightness temperatures determined from Meteosat-8 IR images, it has been possible to identify within the frontal region clouds (*i.e.*, MCS's) with different levels of vertical development.

We distinguish between small (small) and large (large) MCS's. The criterion that separates them is an area in excess of 10,000 km^2 within which the brightness temperatures are less than -52 °C. For the small MCS's, the mean values for maximum area (5392 km^2), duration (4 h 00 m) and ellipticity (0.3) show that these MCSs are small, short-lived and nearly circular in form. For the larger large MCS's (area ≥ 10,000 km^2), the mean values for maximum area (18,276 km^2), duration (4 h 00 m) and ellipticity (0.4), show that they are equally short-lived but slightly more eccentric in shape.

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