A FOUR YEARS (2007-2010) CLASSIFICATION OF MARINE MESOSCALE CONVECTIVE SYSTEMS IN THE MEDITERRANEAN BASIN

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When dealing with deep convection, either from a research or an operational point of view, it is necessary to precisely know the conditions under which it takes place, in order to upgrade conceptual models or theories, and consequently to improve the quality of forecasts as well as to establish effective warning decision procedures (Brooks et al., 2008).

The extensive use of geostationary imagery from Meteosat Second Generation (MSG) satellites has revealed to be essential when integrated to "conventional tools" for monitoring deep convection, and also for real-time estimation of intense precipitation on large domains, covering for example open-sea area where few or no meteorological in situ sensors are available.

Deep convection occurrence over Mediterranean Sea is common; the eventual organisation of these convective cells into Mesoscale Convective System (MCS) is less frequent. MCSs are matter of study, being important also for what concern the hydrological cycle, and mainly because they are frequently associated to severe weather. MCS normally lasts several hours and travel hundreds of kilometres. In the Mediterranean Sea, which has a small areal extent and is characterised by the presence of several islands, it means a very high probability of land falling.

The aim of the present work is to collect 4-years (2007-2010) of MCS occurrences initiating over the Mediterranean Sea, and hence called "marine MCS" or "Mediterranean MCS", as well as analyse their spatial and seasonal variability. In addition, an analysis of the most favourable synoptic conditions for their formation, as well as the selection of some synoptic precursors indicative of convective activity is also addressed.

In a long-term perspective, this preliminary study aims at collecting a climatological database of deep convective systems occurring in the Mediterranean Sea that may critically impact on the Italian peninsula and potentially affect population, in order to develop an objective procedure able to support regional meteorological services in forecasting extreme events, their development and impact for taking proper early decisions.

II. DATA AND METHODOLOGY

In order to detect marine MCS, the Mediterranean basin has been divided into three principal Metarea-III areas (Western, Central and Eastern, that totally consist of 51 sub-areas), following the Global Maritime Distress and Safety System (GMDSS). For Mediterranean MCS definition, authors apply that proposed in previous work by Garcia-Herrera et al. (2005): a) cloud shield with continuously brightness temperature lower than -52°C and an areal extension of at least 10.000 km^2; b) the previous features must be maintained for a period of at least 3 hours. Once recorded, their start time was chosen as the time when they extend over the minimal area of 5x5 pixels (~ 25 x 25 km^2) and a brightness temperature value < -52°C. This allows to give a deep insight in their very early stage of cyclogenesis.

An MCS ends when hits land or it does not respect anymore the minimal areal extension, above defined. If two (or more) MCS merge together the younger MCS is considered terminated, and if a MCS splits in two, the new cell is counted as a new event (when begins satisfying conditions (a) and (b)).

A first skimming of the events was made by analysing the MSG IR images (channel centred @10.8 µm) at a revisit time of 15 minutes. This cloud recognition was performed by expert operational forecasters working at Consorzio LaMMA (Laboratory of Monitoring and Environmental Modelling for the sustainable development). The choice of the thermal channel was mainly due to the need of having 24 hours images. After the initial expert visual recognition, a second test was employed for the selected cases during daytime (when MSG images in the visible channels are available). These cases were cross checked with the MSG HRV channel (1 km spatial resolution) and MSG Severe Convection (SC) RGB product. This latter is a good indicator of deep convection, because it is sensitive in detecting cloud particle size and it is able to detect small ice particles in cumulonimbus' strong updraft differentiating from large ice particles in weak updrafts (Lensky and Rosenfeld, 2006).

For each MCS detected, initial and ending time, corresponding Metarea and subarea have been recorded. Statistics regarding MCS distribution (geographical and seasonal) have been computed.

To validate these detected MCSs with effectively recorded severe weather affecting population, the European Severe Weather Database (ESWD, http://www.essl.org) has been used. A definition of severe weather can be found in the ESWD website. The relation to the ESWD is essential because not all marine MCSs produce severe weather, and severe weather can be produced also from non convective systems. A careful investigation of the database has allowed discriminating this situation. Statistics are presented for this subset of documented severe weather events producing MCS in relation to distribution (both geographical and seasonal). An aspect that is worth to mention is that ESWD records almost exclusively severe weather convective systems occurring overland, thus events generating in open sea generally have no reports; in this context our general statistics (of all reported cases) could be a valuable tool.

III. DETECTION OF MCS

Some statistics are presented hereafter on both spatial and seasonal variability of detected MCS occurrence, as well as their phenomenological characteristics.

The results of this phase of detection led to 269 cases of MCS recorded in four years (68 in 2007, 53 in 2008, 78 in 2009 and 70 in 2010) over the Mediterranean basin. The autumnal season (Sept/Oct/Nov, hereafter SON) is the most active in generating strong convection, with 202 cases occurred (75% and a maximum of 78% in 2007). Among all the detected events (269), 94 cases (35%) were also reported in the ESWD database as severe weather (Tab. 1). Note that with "report" we mean that for a given storm there is at least one warning of severe weather (rain, tornado, hail, windgust or funnel cloud), but it may happen to have more than one of them (e.g. rain and tornado or rain and hail, etc). It is worth to mention that these 94 cases present characteristics of at least tornado and rainfall in the 34% and 61% of cases, respectively.

TOTAL EVENTS	2007	2008	2009	2010	TOT
	68	53	78	70	269
ESWD REPORT	17 (25%)	17 (32%)	33 (42%)	27 (39%)	94 (35%)
ESWD REPORT PER PHENOMENA					TOT
RAIN	8	8	24	21	61
TORNADO	7	5	15	7	34
HAIL	6	5	4	0	15
WINDGUST	1	4	1	2	8
FUNNELCLOUD	1	1	0	3	5

TABLE I: Statistics of the ESWD reports, divided by phenomena, related to the 269 cases of detected MCS.

Analysing the three marine zones defined in the previous section, the Central Mediterranean is the most populated with 191 cases out of 269 (71%), followed by the Western Mediterranean with 44 (16%), and finally the Eastern one with 34 cases (13%). For the most populated area, the quarter SON presents 129 cases out of 191 (68%). A more detailed analysis on the sub-areas (see Fig. 1) has revealed the existence of two principal active zones of genesis of these events, located in the Ionian (sub-areas 21, 24A, 25) and Sicilian channel (sub-areas 22, 23) with totally out of 34% of storms occurrence (in particular, 40 and 50 cases occurred in the Ionian and Sicilian channel, respectively). Note that the 75th percentile for the whole dataset consists of about 10 occurrences.

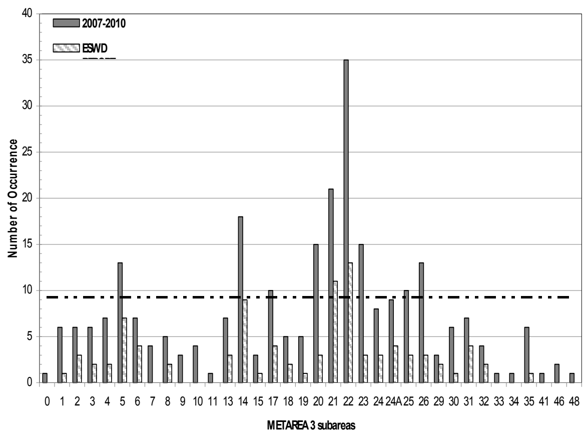

FIG. 1: Spatial distribution of detected MCS and ESWD reports for the 51 sub-areas, for the 2007-2010 period.

III. SELECTION OF SYNOPTIC FEATURES

As second step, we have tried to correlate synoptic precursors (SP) to MCS formation over sea. In literature two main approaches exist: the first links upper (and eventually lower) levels synoptic patterns affecting the Mediterranean to heavy precipitation events (mainly over land; Romero et al. 1999; Nuissier et al. 2011; Funatsu, 2008).

The second approach is based on the assessment of conceptual models (CMs) through the study of several case-studies. A CM "describes essential features of a meteorological phenomenon and identifies the principal processes taking place".

Finding that no one of the proposed synoptic patterns or CMs reconstructs satisfactorily the genesis of the MCS, we have tried to integrate such information with a proper set of numerical model fields. The choice of these fields has been made considering the above-mentioned works and the operational need of simplicity (fields might be of common use in the operational weather forecasting process).

The analysis has been performed using European Centre Medium Rang Weather Forecast (ECMWF) operational analysis at 0.25 degree of resolution at 6-hour intervals and at different standard levels. Data were checked for every date when an MCS was detected. In order to better identify the synoptic conditions in which these systems develop, data of the previous 6 hours (of the MCS start time) were checked and recorded. For each MCS, we have recorded:

- Geopotential at 500 hPa in meters (hereafter Z500);
- Mean sea level pressure in hPa (hereafter MSLP);
- Height of the dynamical tropopause (2 PV units geopotential, hereafter TROPHGT);
- Equivalent potential temperature at 850 hPa in °C (hereafter θ_{e850});
- $\Delta\theta_e$ in °C (difference between θ_{e500} and θ_{e850});
- Precipitable water in mm;
- Upper level jet at 300 hPa in m/s;
- Low-level jet at 850 hPa in m/s.

IV. RESULTS

Concerning the analysis conducted on SP, it has been found that:

1. The totality of the cases have occurred for only two main mid-troposheric circulations: 1) a large amplitude trough (in the sense of meridional latitude extension) approaching from the west, and 2) a cut-off circulation with cold air trapped aloft.
2. A strong thermal ridge (anticyclonic curvature) is present on the downstream side of the mid-troposheric disturbance acting as a break to the movement and producing upper-level diffluence (consequent upward motion).
3. The mean MSLP is 1012 hPa; no cases were detected with MSLP lower than 1000 hPa. This is probably linked to the previous point.
4. A tongue of θ_{e850} with very high values (mean value of 52°C) is present. Figure 2 shows its occurrence for each circulation (cut-off and trough) for the 2007-2010 period of study. No cases were detected with θ_{e850} lower than 30°C. The mean value for $\Delta\theta_e$ is -5.7°C, indicating the

presence of latent instability. Only very few cases were detected with slightly positive values.

5. Mean value for Precipitable water is 36 mm. No values were detected lower than 30 mm.

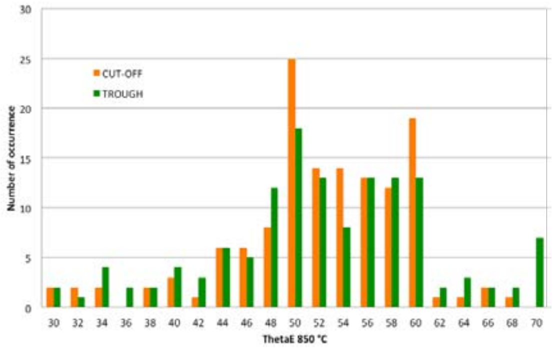

FIG. 2: Occurrence of θ_{e850} for each circulation (cut-off, trough) for the 2007-2010 period of record.

6. A tropopause folding, upstream of the area of MCS initiation, is present in 84% of the cut-off cases and in 78% of the trough circulations. Less clear the influence of Upper and Low Level Jets, counting for 68% and 71% for cut-off respectively, and for 47% and 63% for trough circulation.

Concerning the sub-set of those MCS that produced severe weather (in correspondence with ESWD reports), the main findings can be summarised as follows:

– For cut-off circulation, 36 out of 71 cases (50%) presented the simultaneous presence of TROPHGT, ULJ, LLJ. These cases have a mean θ_{e850} of 53.2°C, a $\Delta\theta_e$ of -7°C, a PW of 36.2 mm and a MSLP of 1011 hPa.

– For trough circulation, 21 cases out of 54 (38%) showed the simultaneous presence of TROPHGT, ULJ, LLJ. These cases have a mean θ_{e850} of 51°C, a $\Delta\theta_e$ of -5.7°C, a PW of 34.5 mm and a MSLP of 1010 hPa.

IV. CONCLUSIONS

Although this study is preliminary, in a long-term perspective some interesting hints have come out, that allow to foresee the possibility of building, at a regional scale, simple relationships among selected precursors, genesis and dynamic of extreme weather events up to expected effects over land. An objective procedure, which can help and support regional meteorological services in forecasting extreme events, their development and impact for taking proper early decisions, may reveal an extremely effective tool in this context.

In addition, this approach tries to address the problem that numerical models still have in resolving, for example, precipitation fields at regional and sub-regional scales, whereas strong convective phenomena may be very local in nature. In this way it could help a better comprehension of such events and improve the forecasting activity.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

Brooks H. E., Dotzek N., 2008: The spatial distribution of severe convective storms and an analysis of their secular changes. In: *Climate Extremes and Society*. H. F. Diaz and R. Murnane, Eds., Cambridge University Press, Cambridge, 35-53.

Funatsu B. M., Claud C., Chaboureau J.-P., 2008: A 6-year AMSU-based climatology of upper-level troughs and associated precipitation distribution in the Mediterranean region. *J. Geophys. Res.,* 113, D15120, doi:10.1029/2008JD009918.

Garcia-Herrera R., Barriopedro D., Hernandez E., Paredos D., Correoso, J.F., Prieto L., 2005: The 2001 Mesoscale Convective Systems over Iberia and the Balearic Islands. *Meteorol. Atmos. Phys.*, 90, doi:10.1007/s00703-005-0114-2.

Lensky I. M., Rosenfeld D., 2006: The time-space exchangeability of satellite retrieved relations between cloud top temperature and particle effective radius. *Atmos. Chem. Phys*., 6 2887-2894.

Nuissier O., Joly B., Joly A., Ducrocq V., Arbogast, P., 2011: A statistical downscaling to identify the large-scale circulation patterns associated with heavy precipitation events over southern France. *Q. J. of the Royal Meteor. Society*. doi: 10.1002/qj.866.

Romero R., Sumner G., Ramis C., Genovés A., 1999: A classification of the atmospheric circulation patterns producing significant daily rainfall in the Spanish Mediterranean area. *Int. J. Climatol.,* 19 765-785.