

MM5 RAINFALL AND CUMULUS PARAMETERIZATIONS SENSITIVITY EXPERIMENT

Yoshihiro Yamazaki, Maria de Los Dolores Manso Orgaz
Physic Department – University of Aveiro – Portugal

1. Introduction

It is quite often found that there is a noticeable improvement in the precipitation forecast (among others, Colle et al, 2000), using the Pennsylvania State University – National Center for Atmospheric Research fifth-generation Mesoscale Model (MM5, Grell et al, 1995), as the horizontal resolution is increased. However, there is also some discussion pointing that such improvement, in going beyond certain resolution (~15-20 km) such improvement are restricted to heavy precipitation and light to moderate precipitation are over-prediction. On the other side, also are a vast number of problems related to cumulus parameterization response with differing conditions such as horizontal grid size, assimilation of observational data and topography of the region of integration.

The purpose is to present the results of sensitivity experiment of MM5 simulations, of a relatively extreme precipitation event (for the region of Portugal mainland), to 9 km grid resolution. The simulations results are discussed on the light of 10 minutes interval accumulated precipitations data collected over Portugal mainland.

2. MM5 Configuration and Observational Data

The MM5 (Grell et al, 1995) has been configured for three domains, with two-way nesting, for horizontal grid spacing of 81, 27 and 9 km respectively, hereinafter D1, D2 and D3, covering the areas as shown in Fig.1.

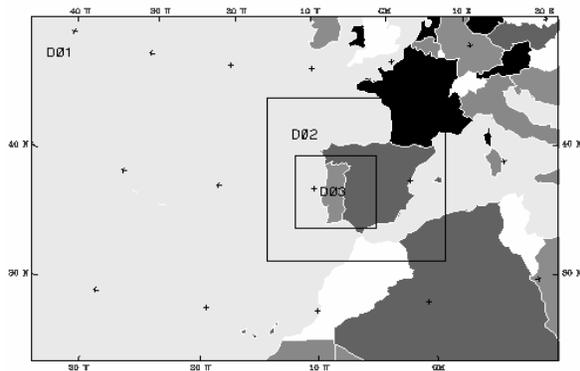


Fig. 1. MM5 Domains

All these domains were configured having the same vertical structure of 31 unequally spaced sigma levels. The shallow cumulus; the single ice explicit moisture for D1 and D2 and Reisner graupel for D3; the Hong-Pan PBL; the cloud radiation and the five-layer soil model schemes are held fixed for all domains simulations, except as

indicated, in order to test the cumulus parameterizations schemes.

The wind, temperature and the dew point temperature surface observation data collected by 93 automatic meteorological station network (EMA), of the Meteorology Institute of Portugal, are used for observation nudging applied during the first three hours of model integration. The EMA stations are installed in the points on which each one are located at approximately 50 km apart from each other, as shown in Fig.2.

The simulation has been made for a 3-day period, beginning at 00 UTC of October, 26 2003. The model integration was made using the 3 hour GFS (AVN-NCEP's) forecast fields.

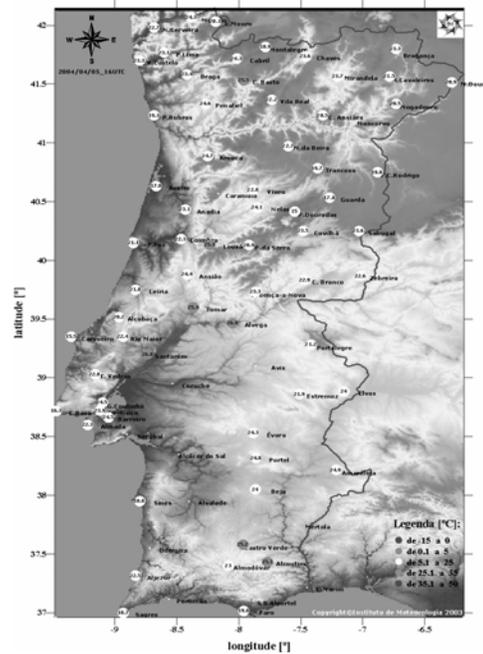


Fig. 2. Automatic Meteorological Station Network

3. The Observational Situations

Shortly after temperature records, in a number of locations in Europe during 2003 summer season, marked by periods of anomalous heat associated with the upper level ridge of high pressure on 500 hPa geopotential height fields, the typical fall season weather system pattern prevailed after the end of October. The summer condition which was favorable to cloud free condition, high solar radiation inputs to surface, or period of anomalous heat associated with a strong blocking pattern to develop over Western Europe, left its imprint on the 500 hPa geopotential anomaly pattern. This condition

prevailed persistently, with short time breaks, during a couple of summer days periods, until the complete change to the one more typical of fall season, as shown in Fig.3, for the 500 hPa geopotential field of October, 26. The outbreak occurred with the decreasing of intensity of the ridge and upper westerlies until became more zonal and moved eastward, quite far from Europe, which allowed the incursion of a NE-SW axis oriented trough over the Atlantic, nearby Western of Portugal. The system was also associated with a large scale blocking in the 500hPa geopotential field centered on 60°N, 30°W.

The Fig. 4(a, b) show the NOAA-16 Infrared satellite image, respectively for October 26 – 02:43 UTC and 27 – 22:54. The comma cloud associated with the large and intense low pressure system, very well defined on day 26 over Atlantic, at latitude around the western side of Lisbon city, was indicating the expected intense rainfall over Portugal.

The storm scale region of rotation resembling a mesocyclone, or more precisely a high precipitation supercell, with produces heavy precipitation and visually identified like a tornado, as is seems on image of day 27.

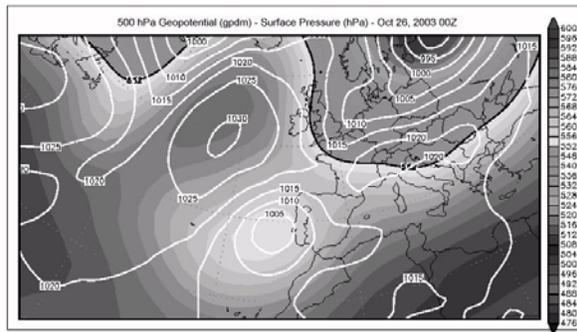


Fig. 3. 500hPa Geopotential – Surface pressure fields

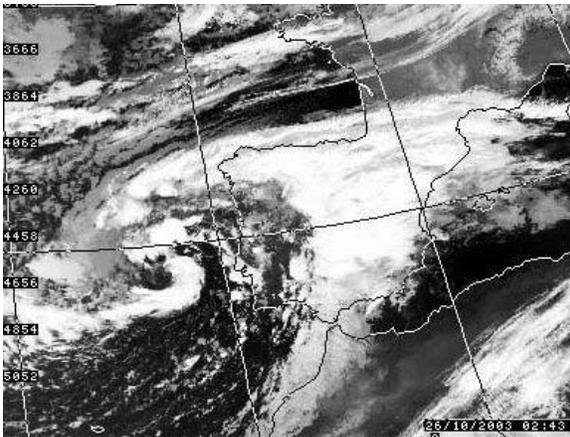


Fig. 4.a NOAA-16 –IR for Oct 26 – 02:43 UTC

Although it have been expecting a quite strong event due to intensification of cyclonic circulation over Atlantic, meso-cyclone system did not produced abnormal precipitation over Portugal Mainland. The 72 hours of accumulated precipitation, starting on day 26-00UTC, as shown in Fig. 5, present values which are less than 25 mm during the first day; 64 mm on second day and 20 mm during the last day. Also, as the Figure 5 also shows, since

only few stations presented such high values the analysis was mainly focused on 5 EMA's stations, presented in Fig. 6., with relatively significant values of precipitation during October, 27.

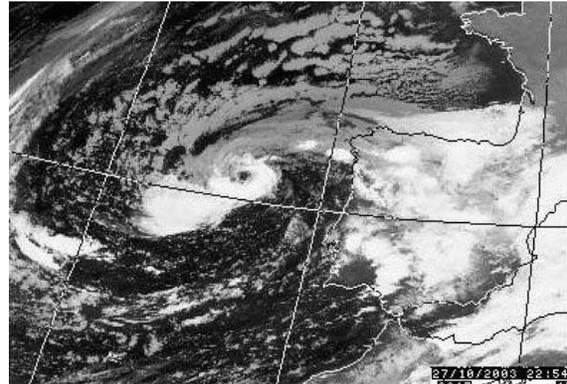


Fig. 4.b NOAA-16 –IR for Oct 27 – 22:54 UTC

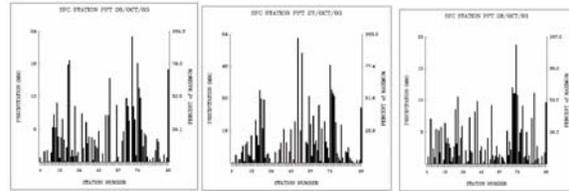


Fig. 5. Accumulated precipitation – 72 hs over 93 EMA's Stations

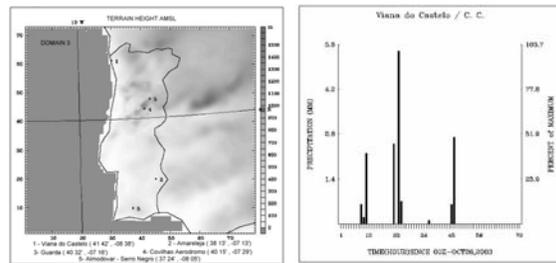


Fig. 6. EMA's stations and Terrain Height

Fig. 7a – Hourly accumulated precipitation – Viana Castelo (1)

The accumulated precipitation at each of these 5 stations, during the 72 hours is shown in Fig. 7 (a-e). The numbers indicates the location of the EMA station according with Fig. 6. The highest hourly accumulated precipitation values recorded by stations 1-5 were, respectively, of 5.6, 18.0, 14.0, 8.8 mm/h. The Viana do Castelo's (station-1) precipitation maximum, recorded around 13 UTC of October 26, was due to the NE-SW oriented moist air pulled by the mesocyclone tail. Other stations rainfall was due to the evolution of the cyclonic circulation.

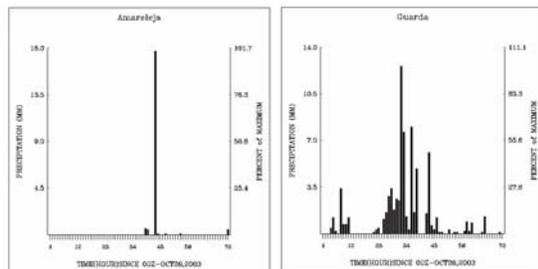


Fig. 7(b,c) Same as (a), for Amareleja (2) and Guarda (3)

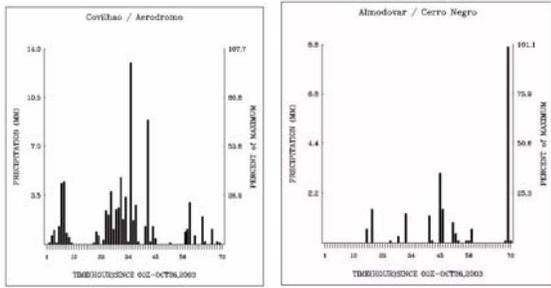


Fig. 7(d,e) Same as (a), for Covilhão (4) and Almodovar (5)

4. Results and Discussion

The Kain-Fritsch (KF) convective parameterization (Kain, 2004) was almost always considered on one of the 3 model domains. The Betts and Miller (Betts et al, 1993), Grell (Grell, 1993) and the Fritsch-Chappell (Fritsch et al. 1980) parameterizations have been considered as the variance. Table 1. show the cumulus parameterization configurations of 9 simulations.

Tabl.1 Parameterizations: K- Kain-Fritsch; B – Betts-Miller; G-Grell

Domain	Run #												
	#	1	2	3	4	5	6	7	8	9	10	11	12
1	K	K	B	B	G	K	B	K	B	K	B	B	B
2	G	K	F	G	G	K	K	G	G	K	K	K	K
3	B	B		G	B	G	G	G	B	K			G

The Fig. 8 (a to l) presents the MM5, 72 hours of total accumulated precipitation, indicated in white color the values less than 20 mm since all 5 selected station (Fig. 6) presented values over this one.

The results of Fig. 8 show that only Run #10 simulated the accumulated precipitation over 20 mm around the station-1. Other's simulation Runs presented under estimated values over this station region, although most of them presented values quite close to 15 mm.

The values for stations located on high land areas, stations 3 and 4, were relatively well simulated by almost all Runs. The Run #2 was the worse one, depicting results too far from stations 3 and 4; and the Run # 7 under estimated the precipitation.

Stations 2 and 5, located on the southern region of Portugal mainland recorded only a small amount of precipitation and the peek values were recorded only during very short time period (less than 1 hour). Surprisingly the Run #1, 9 and 10 were the one's that captured the occurrence of the peek precipitation values over those stations region.

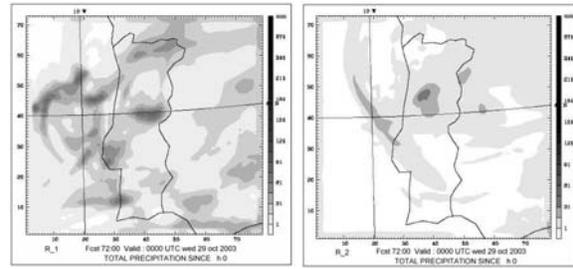


Fig. 8. (a-b) MM5 72 hours accumulated precipitation for Run #1-2. The inset R_* indicate the Run # as by Tabl. 1.

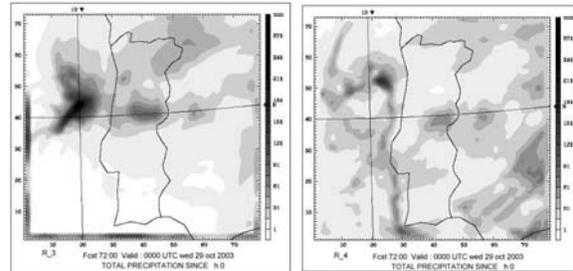


Fig. 8. (c-d) MM5 72 hours accumulated precipitation for Run #3-4.

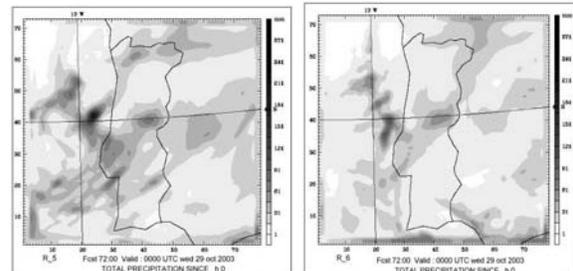


Fig. 8. (e-f) MM5 72 hours accumulated precipitation for Run #5-6.

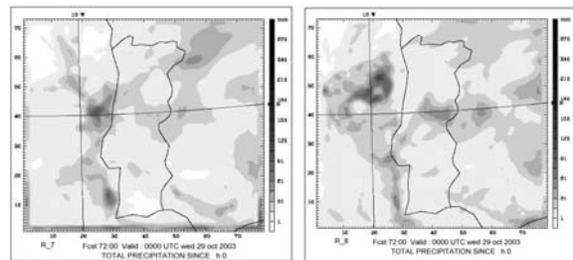


Fig. 8. (g-h) MM5 72 hours accumulated precipitation for Run #7-8.

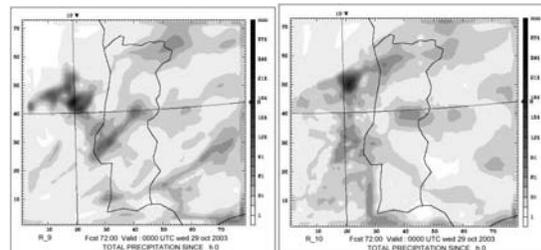


Fig. 8. (i-j) MM5 72 hours accumulated precipitation for Run #9-10.

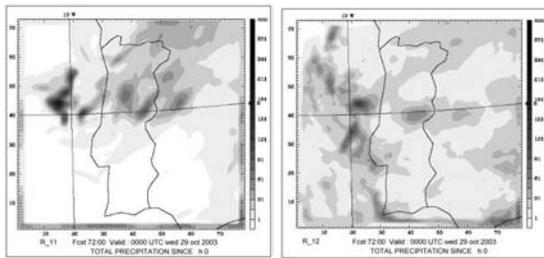


Fig. 8. (k-l) MM5 72 hours accumulated precipitation for Run #11-12.

The Run #1 estimated the total value quite well, over these regions, but the #9 simulated the maximum registered precipitation 4 hours before its occurrence, as registered by the observations.

The Fig. 9 presents the results of 1 hour accumulated precipitation of Runs 1 and 9 simulations, during 15:00 to 16:00 UTC of October, 27. Although it is not shown other's simulations did not presented any system development over those region in the due time period of its occurrence.

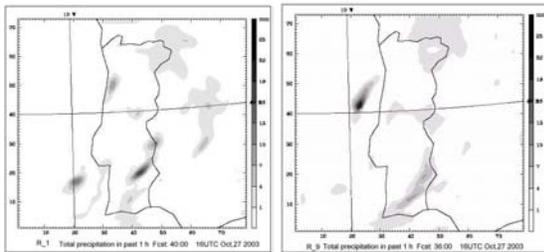


Fig. 9. (a-b) MM5 1 hour accumulated precipitation for Run #1, 9 15-16 UTC October, 27.

The simulations of R# 3 and 11 were made to look at the sensitivity of not using any cloud parameterization on D3. The results presented in Fig 8. (c, k) shows that over almost half south of D3 does not presented any accumulated precipitation over 20 mm during 72 hours of integration. However, looking at the time of occurrence of precipitation over mountain area regions, both simulations presented better results than Run # 2 and 7 simulations.

The precipitation maximum values over the Atlantic Ocean, due to the meso-cyclone system, which moved from its embryo stage position, always in the N-NE direction, therefore without hitting Portugal, as simulated by MM5 presented different Runs results. Although very intriguing, it is difficult to make any reasonable interpretation due to lack of observation over the Oceanic region.

5. Conclusion

The relatively light peak and short lasting rainfall event, especially similar to the one which occurred over 10 minutes, during the 3 days period starting on October 26, 2003, for the 9 km horizontal domain resolution (D3) of MM5, was well simulated by almost all 12 Runs.

However, almost all Runs presented consistently good results, when compared with one hour rainfall observational data, for relatively strong precipitation time periods, which occurred over mountain region. This fact has similar counterparts in several simulations conducted elsewhere for strong precipitation events.

Similar results have also been noticed for the rainfall occurrences during winter season, using the configurations of Run # 1. So that, further exploration is advisable in order to make a more conclusive assertion concerning the parameterization schemes.

Finally, the Kain-Fritsch scheme is the one with produced the most consistent result when configured for a horizontal grid scale of 27 km (D2).

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