Impact of upstream moisture structure on a back-building convective precipitation system in south-eastern France during HyMeX IOP13

By K. O. Lee et al.

Reply to the referees' comments

In the following, the comments made by the referees appear in black, while our replies are in red, and the proposed modified text in the typescript is in blue.

Referee #3 comments

General Comments

This study investigate the impacts of upstream moisture structure of the HyMeX IOP13 case through two sets of sensitivity tests, one altering the moisture content below 1 km in the marine boundary layer (MBL) while the other altering that over 1-2 km above sea-level (ASL). The topic is interesting and quite important and I do not have a major issue with the method and basic conclusion. However, I think that this paper can be much improved with some additional work (some of which I think is necessary). Therefore, I recommend "major revision" before acceptance. Below, some major and minor comments are given.

We appreciate the time and effort you put in this review as well your mindful comments on our paper. We have worked hard to comply with all of them. Replies to each major comment and minor comment are listed below.

Major comment

1. I do not think that the authors have picked all the important (and relevant) parameters (related to rainfall or precipitation system) to be shown and examined/discussed in this paper, in order to look deeper into what is going on physically in their numerical tests (beyond just describing their results). Right now, much of the discussion is quite descriptive, and in my opinion it does not shed enough light on the physical mechanisms leading to the differences in results as seen in the figures. I would like to see the authors put in more efforts to discuss how the changes in moisture (in MBL or in 1-2 km ASL) affect the rainfall system's structure (organization mode) and perhaps the back-building (BB) behavior in particular. One of the issues that affects the interpretation is the variables RR_{acc} and RR_{sum}, which are not defined very clearly in the text or reflective of what they mean (p.8), and I recommend the authors go through them carefully and perhaps use a table to summarize all those chosen. Some other parameters (linked to convective triggering, stability, and cold pool) that they may consider include (but not limited to): total water production (in ton or m3) from event, the production over land versus over sea, level of free convection (LFC, beside CAPE) and/or CIN averaged over the source region, duration of linear organization and/or BB behavior, strength/ size/duration of cold pool, etc. Another thing that may also help is adding four more experiments of ±3 g/kg. Right now, jumping from 2 to 5 g/kg (which is quite a big change as shown in Fig. 5) seems too much.

The way the changes in moisture below 2 km ASL effect the rainfall system structure (mechanism) is now more detailed in the manuscript as highlighted below.

The definitions of RR_{acc} and RR_{sum} and the related explanations are now clearly stated in the manuscript. The differentiated rainfall structure and mechanism is better described by including various parameters, e.g., precipitation production over land and sea, rainfall intensity, CAPE, equivalent potential temperature, virtual potential temperature in order to give more details on the water production, atmospheric stability, and cold pools.

♣ We have added parameters RR_{land} and RR_{sea} that are summarized in Table 2. We re-calculated RR_{sum} to show the 6-hour accumulated precipitation amounts in a fixed domain (north of 40.5°N, east of 3.5°E, i.e. to the northeast of the initiated bubbles) for CNTL and the 12 sensitivity experiments. Figures 6 and 12 have also been improved (see below).

Table 2. Deviation of domain-averaged 6-hour total accumulated precipitation amount over land (RR_{land}) and over sea (RR_{sea}) for the MBL and FA experiments with respect to the CNTL (RR_{land} of 14.2 mm, RR_{sea} of 1.5 mm) within the fixed area (3.5−9°E, 40.5−45°N) from 1200 UTC on 14 October 2012.

(a) Exp.	MBL1M	MBL2M	MBL5M	MBL1P	MBL2P	MBL5P
RR_{land}	−0.5	−0.8	−3.4	−0.7	−1.9	−3.2
RR_{sea}	−0.1	−0.4	−0.6	+0.6	+1.3	+0.8

(b) Exp.	FA1M	FA2M	FA5M	FA1P	FA2P	FA5P
RR_{land}	−0.6	−0.5	−0.7	−0.7	−1.2	−1.5
RR_{sea}	+0.2	+0.2	+0.3	+0.6	+1.1	+1.4

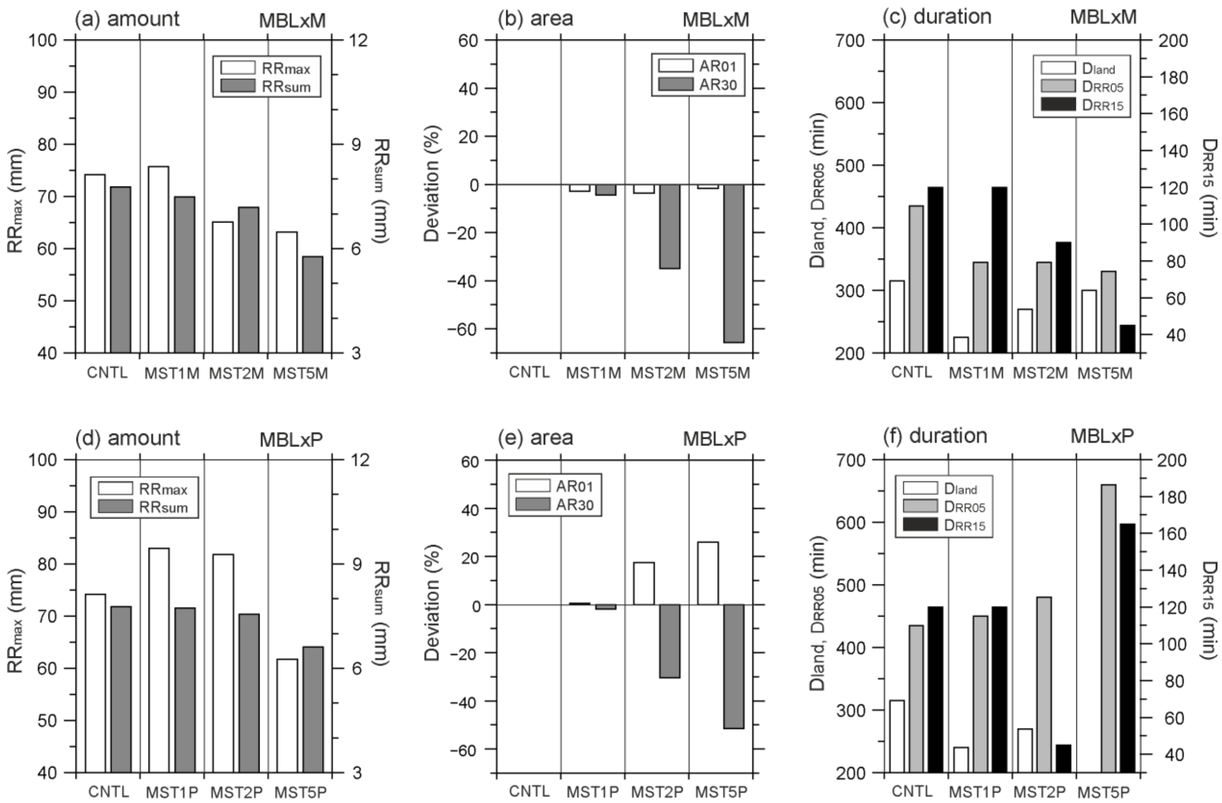

Figure 6. Results of CNTL, MBL×M (upper panel, a−c) and MBL×P (bottom panel, d−f) experiments: (a) and (d) maximum 6-hour accumulated precipitation amount (RR_{max}), and the domain-averaged total sum of the 6-h accumulated precipitation amount (RR_{sum}, mm) from 1200 UTC on 14 October 2012, (b) and (e) the deviation of areas (km^2) of $RR_{acc} \geq 1$ mm (AR01) and $RR_{acc} \geq 30$ mm (AR30) in MBL to ones in CNTL, and (c) and (f) duration of precipitation (≥ 5 mm) over the land (D_{land}), duration of precipitation ≥ than 5 mm per 15 min (D_{RR05}), duration of intense precipitation ≥ 15 mm per 15 min (D_{RR15}). The RR_{sum} and duration of precipitation were calculated at a fixed area of latitude of 40.5−45°N, longitude of 3.5−9°E where the sensitivity bubble passed though are used, respectively.

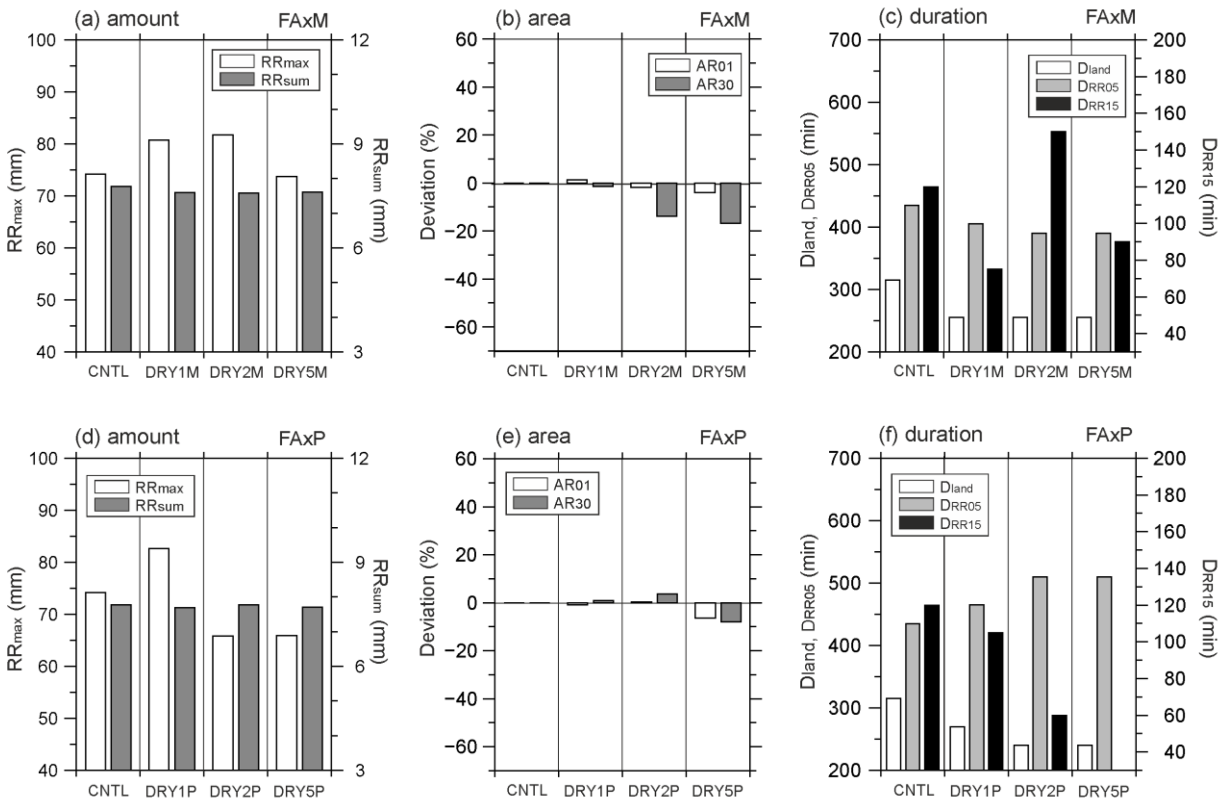

Figure 12. As Figure 6 but for CNTL, FA×M (upper panel, a–c) and FA×P (bottom panel, d–f) experiments.

We have added the information contained in the table and figures in the discussion of the results as:

♣ Page 9, line 13-15

"[...] The reduction of total precipitation seen over land (RR_{land}, between −0.5 and −3.4 mm) is more significant than that seen over the sea (RR_{sea}, between −0.1 to −0.6 mm) in MBL×M (Table 2a)."

♣ Page 11, line 15-17

"[...] For instance, excesses of 1.3 mm for RR_{land} and of 1.9 mm for RR_{land} are produced in MBL2P with respect to CNTL (RR_{land} of 14.2 mm, RR_{sea} of 1.5 mm) (Table 2a)."

♣ Page 13, line 10-12

"[...] The duration of precipitation (D_{RR05} and D_{land}) is also reduced (Fig. 12c). Correspondingly, RR_{land} is reduced to between −0.5 and −0.7 mm with respect to the value of 14.2 mm in CNTL (Table 2b)."

♣ Page 14, line 26-27

"[...] Table 2b shows the reduced RR_{land} values between −0.7 and −1.5 mm in FA×P, with respect to CNTL (1.5 mm), as well as the increased RR_{sea} values between +0.6 and +1.4 mm."

We have added Figure 16 to show the temporal evolution of rainfall intensity and virtual potential temperature (ϑ_v) upstream the convection to understand better the impact of moisture in 1-2 km ASL layer (FA×M and FA×P) on the cold pool intensification. We also examine the evaporation flux near the surface.

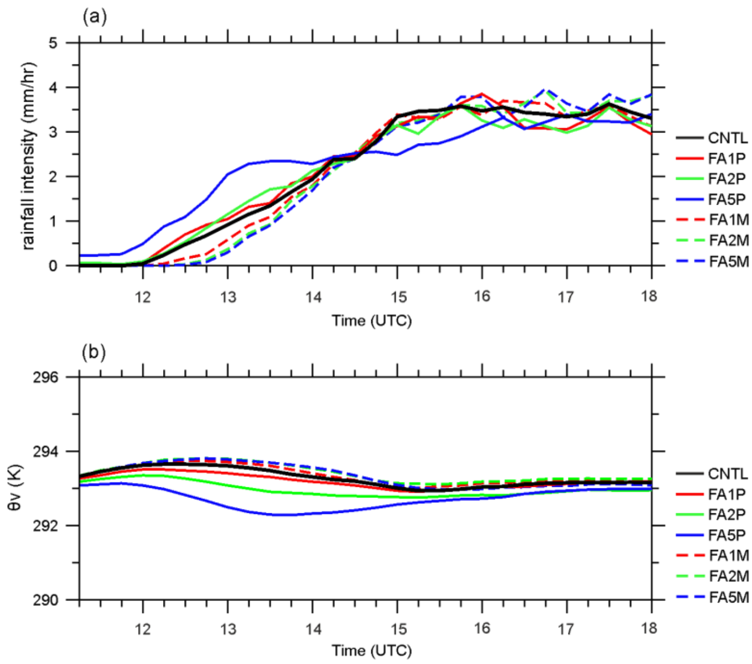

Figure 16. Temporal evolution of domain-averaged rainfall intensity (mm hr^{-1}) and virtual potential temperature (ϑ_v) at the first model level in a fixed domain of 5.5–7.5°E, 43–44.5°N, simulated by CNTL (black line), FA×P (solid lines), and FA×M (dashed lines) from 1115 to 1800 UTC on 14 October 2012.

We have add the information in result as:

♣ From Page 13, line 29

"Figure 16 shows that the rainfall intensity in FA×M simulation (dashed lines) is reduced by about 0.1–0.5 mm hr^{-1} compared to CNTL (black line) between 1200 and 1430 UTC, and the rainfall intensity ≥ 0.1 mm hr^{-1} starts about 45 min later (1300 UTC, dashed line) than in CNTL (1215 UTC, black line). Under the weakened precipitation, evaporation rate is reduced. The corresponding values of ϑ_v in the FA×M simulations are increased by about 0.2–0.5 K with respect to CNTL (dashed line, Fig. 16b). While the dried air mass in the 1-2 km layer is advected toward upstream the convection, it mixes with the moist air below, reducing the total moisture below 2 km. With the reduced moisture in the lower troposphere, the triggered convection near the Var coast produces less intensive rainfall and the weakened cold pool."

♣ Page 14, line 12-18

"In summary, decreasing the moisture content in the dry layer between 1 and 2 km ASL reduces the total amount of precipitation as well as the area affected by the precipitation and the duration of the precipitating episode. As the MABL is nearly saturated, the convection triggers easily along the coast but develops less intensively. The maximum of precipitation located along the eastern Var coast is reduced, corresponding to a weakened cold pool and weakened ascents at its southern boundary. This shows that around the coast, the dryness in the 1–2 km ASL layer is not a major ingredient for the convection development and the cold pool generation when the lowermost layer is nearly saturated."

♣ Page 15, line 15-24

"[…] Figure 16a shows the enhanced rainfall intensities (about 0.2–2.5 mm hr^{-1}) in FA×P simulations (colored solid lines) compared to CNTL (black line) between 1200 and 1430 UTC, especially FA5P produces the precipitation about 45 min earlier in time. Under the intensifying precipitation, the values of ϑ_v in FA×P simulations are about 0.2–1.7 K reduced, indicating the intensified cold pool formed by evaporative cooling than in CNTL (Fig. 16b). As the moistened air mass in the 1-2 km layer mixed with the moist air below during its advection towards the region of upstream convection, the total moisture below 2 km ASL increased. Thanks to the moistened lower troposphere, the convection triggered near the Var coast produces more intensive rainfall and correspondingly more intense cold pool. Also the moistened air masses in the lower troposphere initiate precipitation earlier while the precipitating area, particularly over the sea, is enlarged."

In the revised version of the manuscript, we now investigate the location of convection initiation in CNTL and all the sensitivity experiments. This information has been added in the text and Figures 2b, 8, and 14, as also suggested in minor comment #26.

♣ Page 5, line 17-23

"[…] Then the convection (highlighted by reflectivity values exceeding 45 dBZ, Lee et al., 2012) initiates upstream (yellow star, Fig. 2b), about 25 km further south than observed at 1200 UTC and maximum 15-minute precipitation over 5 mm is simulated approximately 93 km from the initiation at 1230 UTC (Fig. 2b). It develops preferably towards Marseille, then around the Argens valley region and the east coastal Var region (Figs. 2b and 3a−b), similarly as observed. The intense precipitation (≥ 15 mm per 15 min, red circle in Fig. 2b) is first simulated at 1400 UTC north of Marseille (5.6°E, 43.5°N) in a location distant of about 95 km from the bubble initiation."

♣ Page 10, line 3-5

"The sensitivity bubbles of MBL experiments travels north-eastwards over the sea as in CNTL, and it keeps its ellipse shape but with a slightly reduced horizontal size due to lateral mixing with the ambient air mass during its advection."

♣ Page 10, line 10-13

"[…] The intense precipitation (≥ 15 mm per 15 min) starts 3 hour later in MBL5M than in CNTL, MBL1M, and MBL2M. The convection at 1800 UTC is located at the eastern coast of Var, as in CNTL (square in Fig. 2b) and MBL×M (square in Fig. 8a−c), and then stays 2−3 additional hours in this region."

♣ Page 12, line 2-6

"[…] In MBL×P experiments (Fig. 8d−f), precipitation is initiated over the sea at 1200 UTC, and then the bubbles travel along similar pathways over the sea as in CNTL. However the inland precipitation starts later (e.g. 15, 45, and 90 min later in MBL1P, MBL2P, and MBL5P, respectively) than in CNTL. This late onset of inland precipitation is also consistent with more widespread precipitation over the sea in MBL2P and MBL5P (Fig. 7e, f)."

♣ Page 13, line 17-20

"[…] The sensitivity bubbles of FA experiments travel north-eastward over the sea as similar as seen in CNTL and MBL, but the horizontal extent is slightly reduced by mixing with the ambient air mass during the travel. The convection initiates about 20 km offshore of the Var coast (yellow star, Fig. 14a−c)."

♣ Page 15, line 8-11

"[…] The convection initiates near the Var coast, as in CNTL, however the horizontal extent of the convective region (reflectivity ≥ 45 dBZ) is relatively large compared to CNTL. The precipitation starts at 1200 UTC about 50 km offshore the southern Var coast, when the bubble reaches this region ~140 km distant from the location of initiation […]"

In this study, the purpose of experiments with ± 1 and 2 g kg^{-1} is to understand the impact of water vapour uncertainty observed during the IOP 13 (Duffourg et al., 2018) (as described in p.8), while the purpose of experiments with ± 5 g kg^{-1} is to understand the behavior in an extreme environment. We expect that the behaviors of experiments with ± 3 g kg^{-1} would be bounded by the results with 2 and 5 g kg^{-1}. For the sake of concision, we have decided not to add a discussion in the revised manuscript on four additional experiments based on ± 3 g kg^{-1}

WVMR variations. Rather, we decided to put more emphasis on the existing 12 experiments.

We have added this information in the section 2.3. Initial conditions of sensitivity experiments (Page 8, line 14-17) as:
"In this study, experiments with ±1 and 2 g kg^{-1} were conducted to understand the impact of water vapour uncertainty in the vicinity of Balearic Island on precipitation downstream, while the experiments with ±5 g kg^{-1} are done to see such an impact in a more extreme environment."

2. From Figs. 6 and 12, it is clear that when the moisture is added (or removed) from the MBL (or 1-2 km ASL), some parameters change in a rather consistent fashion but others not (e.g., DRR15 in MST2P in Fig. 6f, or that in DRY1M in Fig. 12c). Also, some changes are easy to understand while others are trickier and not as straight forward (e.g., RRsum in MST5P in Fig. 6d), I suppose. While an understanding at the physical level is important (as stated in my major comment #1 above), before that, it is also important to clarify whether such an inconsistency is indeed a response to the change in the moisture in the model, or arises simply due to the nonlinearity of the processes. Right now, this possibility is not considered by the authors but I think they should. The authors should at least examine the trajectories in the ±5 g/kg tests to check whether the source region of the deep convection (and for the cold pool) remains the same in those runs as in CNTL (and they should also show those trajectories in the CNTL). If yes, runs an examination of what is going on physically would be more meaningful, but you would need a different interpretation if not.

We have examined the trajectories in the ±5 g kg^{-1} test. We compared the trajectories of FA5M and FA5P with CNTL because the convection activities in MBL5M and MBL5P are too weak to produce the cold pool. The horizontal and vertical projection of some of these backward trajectories for parcels at the top of the simulated convective ascent, and for parcels in the cold pool at 1600 UTC of the CNTL, FA5M, and FA5P experiments are displayed in Figure A, B, and C, respectively. In all figures, the locations of "sensitivity bubble" of the MBL experiments (previously named MST) and the FA experiments (previously named DRY) are superimposed. The comparison of three figures indicates that the origin of those air parcel affecting the convective system near the Var coast linearly comes from the area of the sensitivity bubbles. Also the initial altitude of the moisture supplying the precipitating system is below 1 km, and the initial altitude of air parcel feeding the cold pool is between 1 and 2 km.

We trust the model ability to respond to the change in the moisture of ±5 g kg^{-1}.In the few hours following the initial forcing, the model reaches an equilibrium state. In addition, the lateral boundary is forced every 3 hours to compute the rainfall system realistically.

We have added the sentence in page 8, lines 4-7 as:
"[…] Using backward trajectory analysis, we can assess that the origins of air parcels feeding the convective system and of air parcels feeding the cold pools are within the sensitivity bubbles of the FA and MBL experiments, respectively, (ellipsoids in Fig. 1) and that the trajectories do not deviate significantly from one experiment to the next, even though some differences exist."

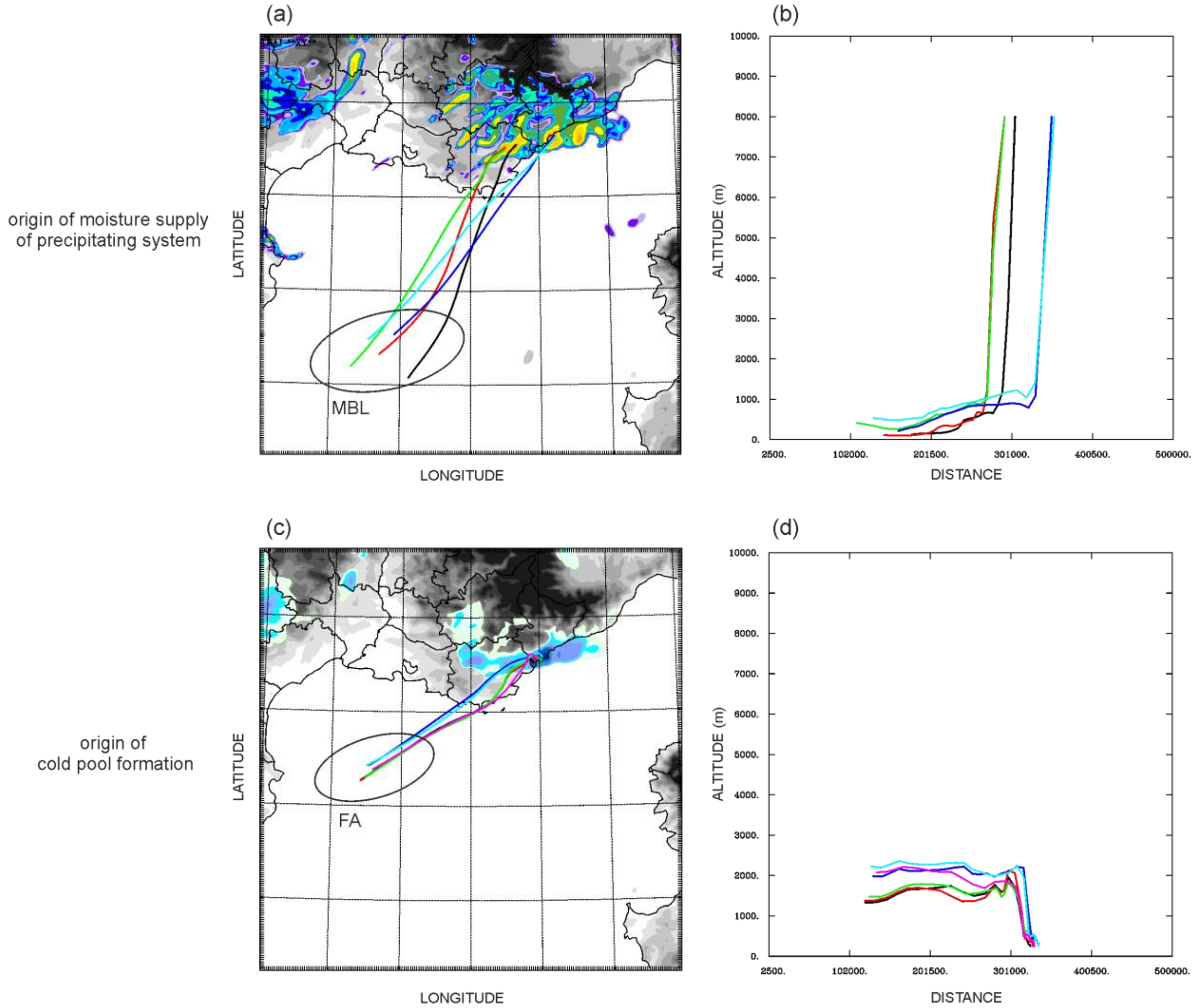

Figure A. CNTL: (a) and (b) backward trajectories of selected air parcels taken in the upper part of the convective system at 1600 UTC in horizontal and vertical projection, respectively., and (c) and (d) backward trajectories of selected air parcels taken in the cold pool at 1600 UTC in horizontal and vertical projection, respectively. The radar reflectivity at 2000 m is displayed in (a). The virtual potential temperature at the first model level is shown in (c). The location of sensitivity bubbles in the MBL and FA experiments are superimposed in (a) and (c).

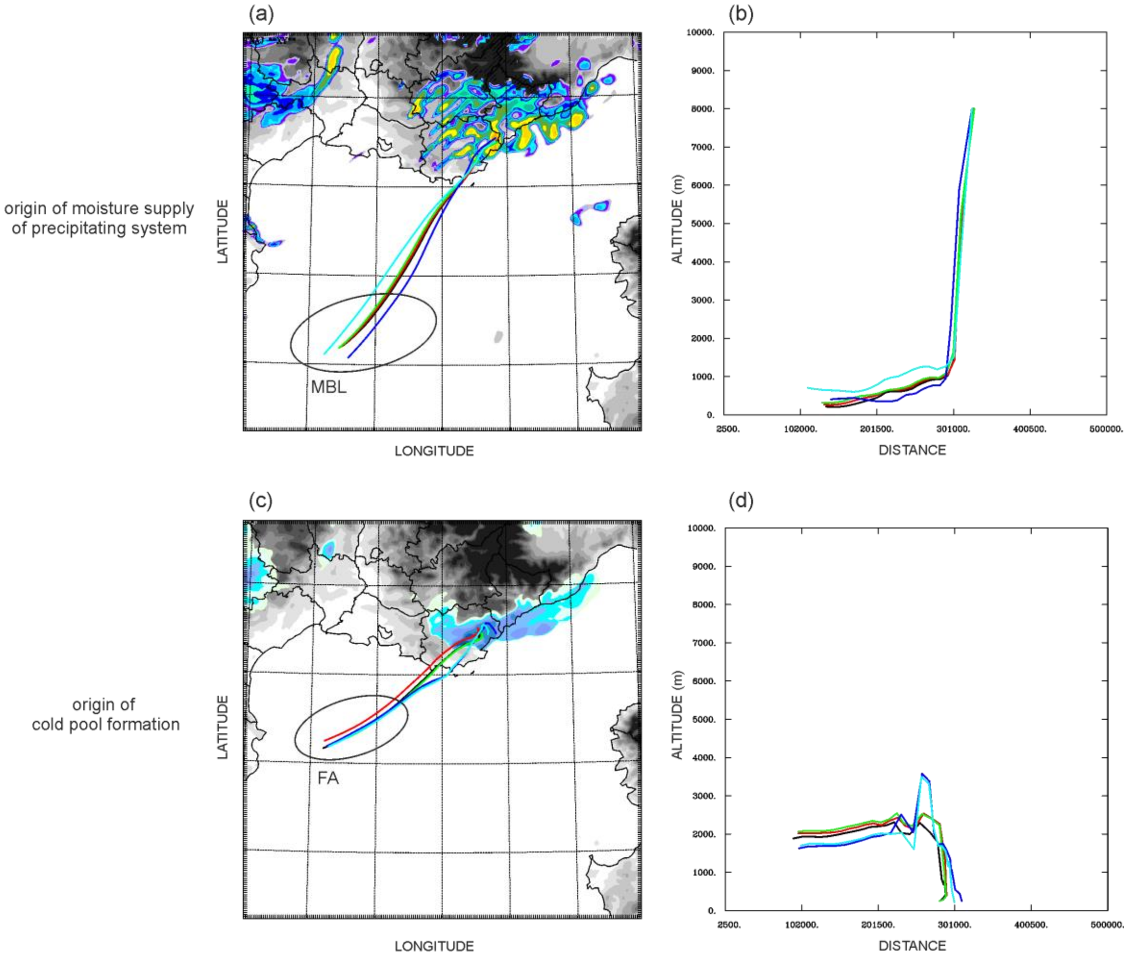

Figure B. Same as Figure A for FA5P.

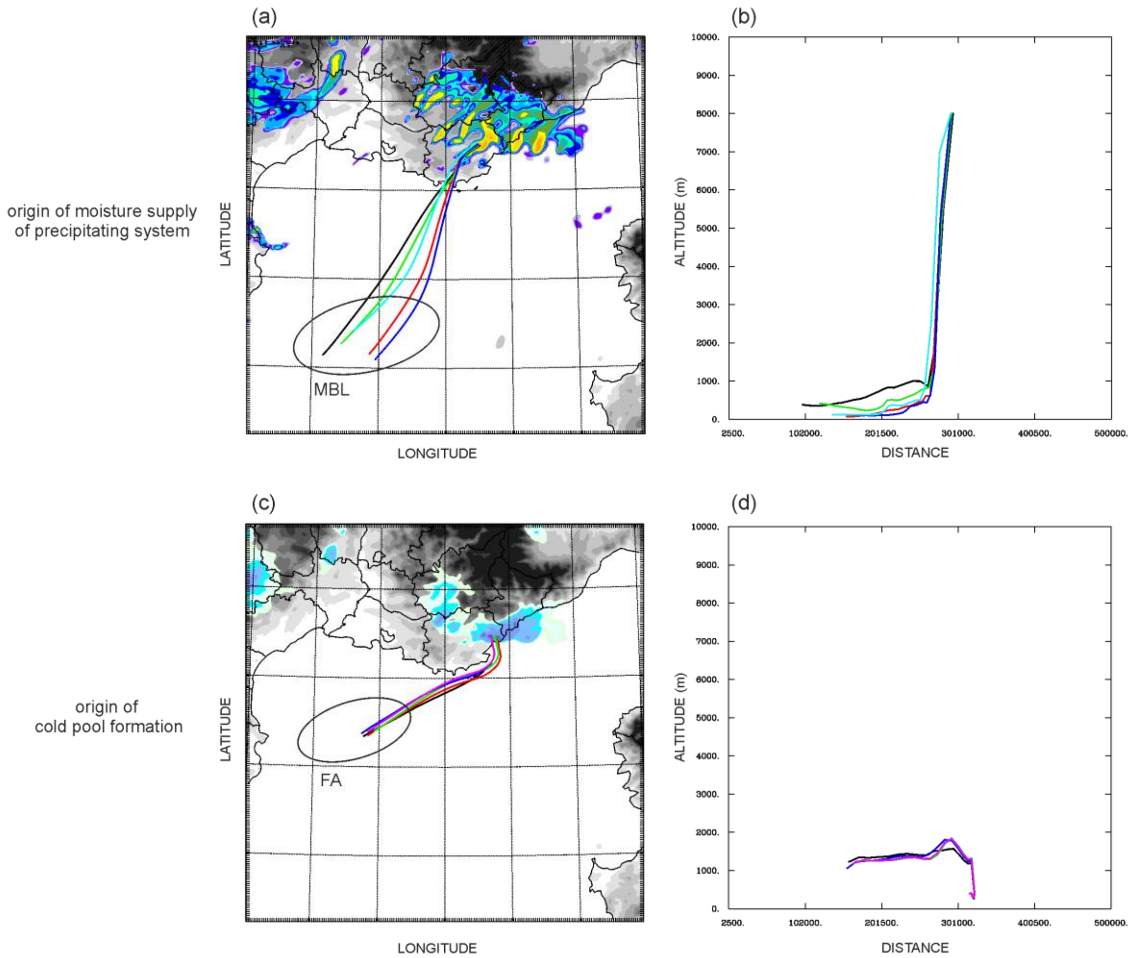

Figure C. Same as Figure A for FA5M.

3. This is related to my major comment #1 above. In the DRY×P runs, where the layer of 1-2 km ASL in the source region (for the cold pool) is moistened, the cold pool at 1500 UTC apparently enhances with more moisture (Figs. 15d-f vs Fig. 4c). The reason is not yet completely clear to me. The authors should elaborate on this too, if possible.

With the moistened air mass in the 1−2 km ASL layer, similar CAPE values (≥ 1050 J kg^{-1}) were calculated offshore of the Var coast in the FA×P experiments and in CNTL. In an environment with instability similar to that of CNTL, but with higher moisture content, the triggered convection in the FA×P experiments can produce larger precipitation than in CNTL. For this reason, the horizontal extent of the cold pool (delineated by ϑ_v < 291 K) is larger than the one seen in CNTL.

We have added the sentence from page 15, line 28 as:
"[…]With the moistened air mass in the 1−2 km ASL layer, similar CAPE values (≥ 1050 J kg^{-1}) were calculated offshore of the Var coast in the FA×P experiments and in CNTL. In the environment with similar instability but with further moistened conditions in the lower troposphere, the triggered convection further intensifies with enlarged horizontal extent of cold pool and strengthened ascents at its southern boundary."

4. The English and fluency of this paper can be improved. I recommend that some of the authors can be of more help in this aspect.

The English has been improved through careful.

Minor comments

1. P.2, ln 15-16 and other places: Unusually, the references would be given according to the year of publication.
Corrected in Page 2, line 15-16 as:

"[…] (*e.g.* Nuissier et al. 2008; Romero et al. 1999; Trapero et al. 2013a, 2013b; Barthlott and Davolio, 2015)."

2. P.2, ln 16: Is Romero et al (1999) or (2000)? It is not consistent here with the reference list. Similar issue for Ricard et al. (2011) or (2012) in ln. 20-21.
Corrected. Romero et al. (1999) and Ricard et al. (2012) are right (Page 2, line 16 and 20).

3. P.3, ln. 11: Bielli et al. (2012) is not listed at the end. Similar issue for Ricard (2005) and Seity et al. (2011).
Added. Please note that the reference to Ricard (2005) is now excluded (Page 18, line 16 and Page 22, line 27).

4. P.3, ln. 19 (also ln. 21) and many other places throughout the text: Here, a hyphen in south-eastern is not needed (just southeastern).
Corrected throughout the text.

5. P.4, ln. 4: Has the term "Meso-NH" been defined already?
The definition has been added (Page 4, line 14).

6. P.4, ln 23: A reference for RRTM should be given here.
Mlawer et al. (1997) is added now (Page 4, line 26).

7. P.5, ln. 3: The acronym "AROME" is already defined two lines above.
Corrected (Page 5, line 5).

8. P.5, ln. 22: Here, it says that the horizontal wind (u/v) is at 500 m ASL, but at 925 hPa in the caption (p.24, ln. 5). Please check and correct the wrong one.
Corrected to 925 hPa (Page 5, line 28).

9. P.6, ln 12-17: From Fig. 5, I suppose that the mixing ratio (BTW, few would use an acronym for it, just the symbol *r*) is bounded by 0 and the saturation value. While the lower bound of 0 g/kg is noted here, the upper bound is not (and should be).
Improved in Page 7, line 20-21 as:

"[…] In other words, the water vapour value at saturation with respect to liquid water was calculated at each altitude and used as an upper threshold of the modified WVMR."

10. P.7, description of Fig. 5b: The mixing ratios converge back to the observed value at 2.1 km instead of 2.0 km similar to the MST tests. It is a minor point but is there a reason for this?
This is caused by smoothing.

11. P.8, ln. 4-11: Some of these parameters are not clearly described, especially RRacc and RRsum (please also see major comment #1). I understand that RRacc is the peak 6-h accumulative amount but its name should reflect this (by comparison, RRmax would be better). For RRsum, I suppose it is an averaged amount, but for where and for what accumulation period?

RR_{acc} is the maximum of 6-hour accumulated precipitation amount. For the sake of clarity and in order to comply with the referee's comment, we have renamed it RR_{max}, as suggested. RR_{sum} is the sum of the 6-h accumulated precipitation amount within the domain bounded by 3.5–9°E and 40.5–45°N. It is a measure of the averaged total amount of produced precipitation. The unit is changed to mm (Page 8, line 18-22). The text has been modified as:

"To investigate the impact of WVMR variability on the location, intensity and duration of precipitation, we consider several indicators, such as: the maximum of the 6-hour accumulated precipitation amount (RR_{max}), the domain-averaged total sum of the 6-hour rainfall accumulation (RR_{sum}), and the RR_{sum} produced over land (RR_{land}) and over the sea (RR_{sea}) in the fixed domain bounded by 3.5–9°E and 40.5–45°N, from 1200 UTC on 14 October 2012, to understand the impact of WVMR variability on precipitation amount [...]"

12. P.8, ln 12-20: Here, the authors do not need to go to such a detail and say which figure shows what later, but what will be shown (and for what purpose) should be enough.
To help guide the readers with the interpretation of the content of the section, we decided to keep these explanations.

13. P.9, ln. 1: The "x" in the experiment names (which represent 1, 2, or 5), at their first appearance in text, should be explained more clearly, if possible.
Corrected (from Page 8, line 29) as:

"[...] Figure 9 shows the temporal evolution of the maximum of CAPE in the "sensitivity bubble" every 15 min from 0930 to 1445 UTC in CNTL, MBL×M (i.e. MBL1M, MBL2M, and MBL5M), and MBL×P (i.e. MBL1P, MBL2P, and MBL5P)."

14. P.9, ln. 2: Shouldn't you use 0.67 and 0.4 for the factors here, instead of their reciprocals of 1.5 and 2.5?
Yes indeed, this is now corrected (Page 9, line 17).

15. P.9, ln. 3-4: ...the time for precipitation ≥ 5 mm...
Corrected (Page 9, line 18-19).

16. P.9, ln. 20: ...mountainous region close to...
For better understanding, the sentence has been simplified to "west of 6°E" by removing "mountainous region close to Marseille".

17. P.9, ln. 25-28: The description here is not clear.
Corrected in Page 10, lines 19-23, as:

"In MBL1M, MBL2M, and MBL5M, CAPE values increase gradually until 1445 UTC but remain lower than in CNTL. At 1400 UTC, the spatial distribution of CAPE values less than 1000 J kg^{-1} is highlighted offshore of the Var coast where the sensitivity bubble is located (i.e. 5.2–6°E, 42.4–43°N, dashed ellipsoid in Figure 10b) in MBL2M. It is worth noting that higher CAPE values (> 1400 J kg^{-1}) are displayed in the same region in CNTL (Figure 10a)."

18. P.9, ln. 29: Here, ϑ_e has already been defined, so why not just use it.
Corrected (Page 10, line 24).

19. P.10, ln. 4 (and other places): Please change vertical wind into vertical motion (or in this case, upward motion) for better clarify.
Corrected to vertical motion (Page 10, line 28 and Page 11, line 2).

20. P.10, ln. 5-6: The strength of cold pool and precipitation amount is a chicken and egg relationship in terms of the cause/effect, in my opinion.

Corrected (from Page 10, line 28) as:

"[…] This combination of decreased CAPE and weakened cold pool which are induced by the weakened precipitation (Figs. 7a–c) is found around the Argens valley region in particular."

21. P.10, ln. 20-23: The sentence here is not clear and should be improved.

Corrected (Page 11, line 14-17) as:

"[…] In MBL2P and MBL5P experiments, the increase of the moisture content in the MABL (0.1–1 km ASL) induces more precipitation over the sea than in CNTL. For instance, excesses of 1.3 mm for RR_{land} and of 1.9 mm for RR_{land} are produced in MBL2P with respect to CNTL (RR_{land} of 14.2 mm, RR_{sea} of 1.5 mm) (Table 2a)."

22. P.11, ln. 1-11: Some of the description here is quite repetitive.

Corrected in manuscript from Page 11, line 25 as:

"The 6-hour accumulated precipitation in MBL1P experiment displayed in Figure 7d confirms that in MBL1P, the largest accumulation on the eastern Var coast is increased (consistently with the increase of RR_{acc}, Fig. 6d) and slightly shifted offshore (consistently with the reduced D_{land}, Fig. 6f) (area enclosed by solid line, Fig. 7d). This is consistently seen in the temporal evolution of the location and amounts of the maximum of 15-min accumulated rainfall in Figure 8d which shows that this accumulation is due to a stationary system blocked over the Var coast, similarly as in CNTL."

23. P.11, ln. 23-26: This sentence needs to be revised for better clarity.

Improved in Page 12, line 21-25 as:

"The widespread and weaker precipitation over the sea seen more particularly in MBL5P is associated to a less organized precipitating system when the moisture content in the MABL is increased. The lesser degree of organization of the convective system in MBL5P is related to the absence of a cold pool (Figure 11f). CAPE values higher than 1500 J kg^{-1} lead to an increase of the degree of instability in the upstream environment (blue solid line in Figure 9)."

24. P.12, ln. 23: What does the part "a more realistic location" mean? Please clarify.

In CNTL, the overall precipitation distribution and the evolution of the target convective system occurring during IOP 13 were successfully produced by Meso-NH simulations. However, the convection is first observed over the land closer to Marseille than simulated in the CNTL run in which it is produced around the southern tip of Var coast (i.e. about 25 km from the observed convective initiation). The experiments with dry air mass in the 1-2 km ASL layer initiate precipitation over land at a more accurate location. We have clarify this information in manuscript as:

♣ Page 5, line 17-18

"[…] Then the convection (highlighted by reflectivity values exceeding 45 dBZ, Lee et al., 2012) initiates upstream (yellow star, Fig. 2b), about 25 km further south than observed at 1200 UTC […]"

♣ Page 17, line 12-13

"[…] Also it is true that dried air mass in the 1−2 km ASL initiates precipitation at a more accurate location, about 25 km closer to Marseille."

25. P.13, ln. 3-5: Can the authors elaborate on the reason why? Perhaps, it is related to the entrainment process (please see my major comment #1). Also, the authors use the term "bubble" too much, and it can be confusing.
The CAPE values in both CNTL and FA×M experiments (previously named DRY×M but modified to comply with Referee's #1 comments) slightly increased over time in the location of the sensitivity area as it mixed with the adjacent moister air (Page 10, line 3-5). For better understanding, we have decided to use the term of "sensitivity bubble" constantly throughout the text.

26. The authors may want to consider some plots showing the location of first convection initiation in different runs, if they can help to shed more light.
The location of first convection initiation is marked by a yellow star for the CNTL and all the sensitivity experiments in Figures 2b, 8, and 14.

27. P.15, ln. 24-27: Here, I suppose that the authors should broaden their scope and not focus on another single event.
Corrected (from Page 17, line 28) as:

"[…] By accumulating the event scale analysis in other regions of the Mediterranean basin, we can expand our knowledge what is the general impact of upstream water vapour on precipitation (e.g. categories of synoptic conditions). Another approach is to use stable water isotopologue data to disentangle the various moisture sources, i.e. evaporation over the sea, advected moisture upstream of the HPEs in the Mediterranean (Sodemann et al., 2017)."

28. P.23, Fig. 2b and other similar plots: The last point should be also labelled for better clarify, if possible. Also, if the color shades for topography can be lightened (since you already have Fig. 1), that may also help.
As suggested, the last point is marked by a square pointed by an arrow in Figures 2b, 8, and 14. As the precipitation develops over the topography, we have decided to keep the topography scale as it is to highlight this link.

29. P.26, caption of Fig. 6: The description here for RR_{acc} and RR_{sum} is not the same as that in the text (and not clear either). Please also see major comment #1 and minor comment #11.
Corrected as explained in minor comment #11.

30. P.27, Fig. 7: What are those ellipses in the panels (also in many other figures)? I suppose that they depict the area of interests, but they are never explained in the caption of any figures.
Corrected (Figures 7 and 13) as in following page:

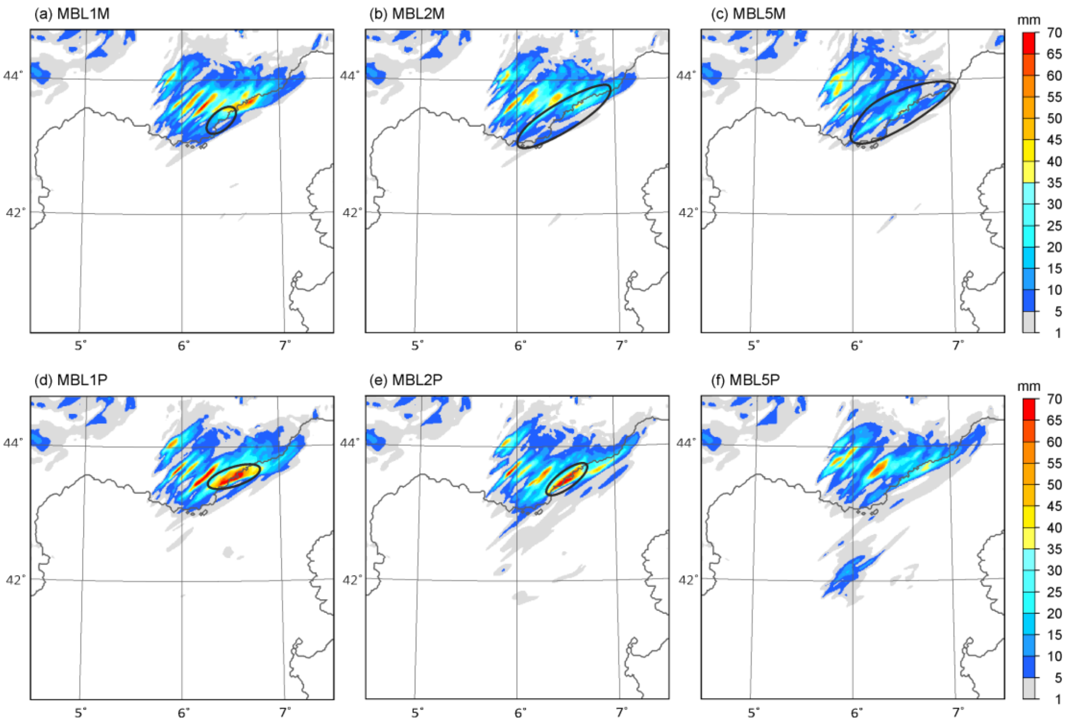

Figure 7. Distribution of the 6-hour accumulated precipitation simulated by (a) MBL1M, (b) MBL2M, (c) MBL5M, (d) MBL1P, (e) MBL2P, and (f) MBL5P at 18 UTC on 14 October 2012. Black contour line shows the coast of southern France. The ellipsoid in (a)−(c) indicates the area with less precipitation than CNTL, while the ellipsoid in (d)−(e) shows the shifted precipitation area.

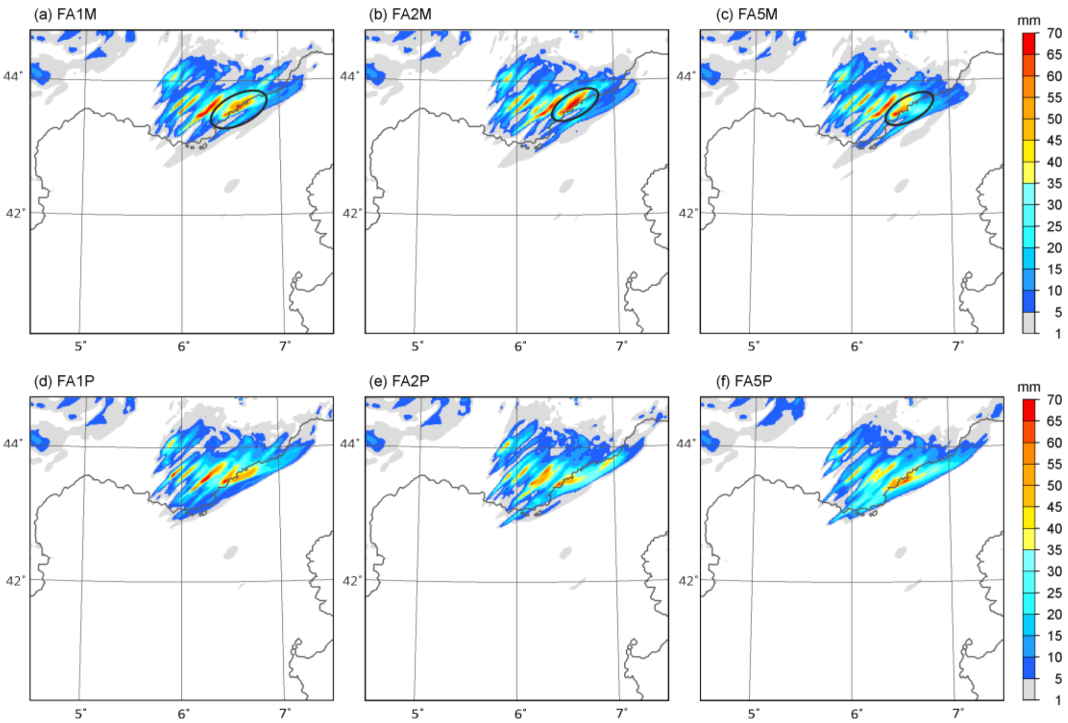

Figure 13. Same as Figure 7 for (a) FA1M, (b) FA2M, (c) FA5M, (d) FA1P, (e) FA2P, and (f) FA5P. In (a)−(c), the reduced precipitation around the coast is indicated by an ellipsoid closed with solid line.

31. P.28, Fig. 9: The y-axis is missing a title. And, is the CAPE calculated for surface parcels (same for Fig. 10)? Please clarify. Also, sensitivity area is better than sensitivity bubble…

As suggested, Figure 9 has been corrected. For better understanding, we now use the term of "sensitivity bubble" throughout the text as explained above.

We have added the information in manuscript in Page 10, line 15-16 as:

"[…] Figure 9 shows the domain-averaged CAPE values (using a rising air parcel having its initial height about 20 m) within the sensitivity bubble upstream of the precipitation area in CNTL […]"

For the sake of the readability, the Figure 9 has been improved with coloured lines as Figure 16.

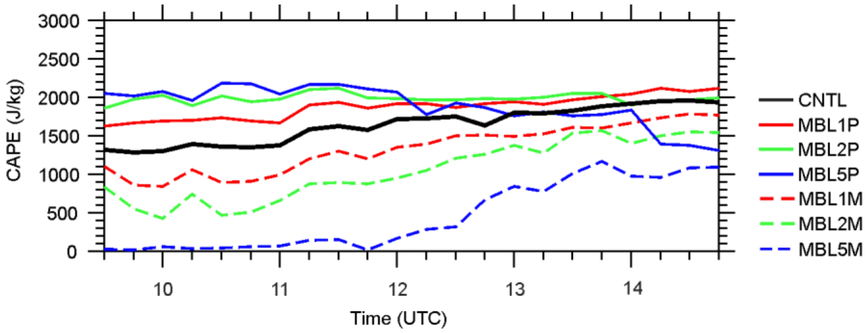

Figure 9. Temporal evolution of CAPE in the sensitivity bubble simulated in CNTL (black line), MBL×P (solid lines), and MBL×M (dashed line) from 0930 to 1445 UTC on 14 October 2012.