Contrasting stable water isotope signals from convective and large-scale precipitation phases of a heavy precipitation event in Southern Italy 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

The reviewed article is a thorough case study performed using COSMOiso. While the analysis of the simulation results is highly detailed, the title and abstract of the manuscript lead the reader to expect a comparison to observations. However, the only observations used are precipitation measurements. Considering the emphasis on isotope modelling, I would have expected at least some measurements of this nature. For that reason, the purpose of the manuscript as a whole, and especially the long and detailed analysis of isotope distributions within the manuscript, is not clear.

The main question is: what additional insight is gained from the use of a model-only isotope analysis. This problem is further underlined by the presented trajectory analysis, which seems to provide the same information which is derived from the isotope concentrations. For a recommendation for publication, the authors need to better outline the purpose of the study, as well as their reasoning for using COSMOiso and its advantages compared to a trajectory analysis or even just passive tracers.

Assuming these problems can be addressed, a number of other issues remain. Below is a detailed listing of major and minor comments which should help the authors to improve their manuscript substantially.

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 comment are listed below.

Major comment

1. Section 4 is the core of the manuscript. However, even considering that, it seems out of proportion. It is not only very long but also difficult to read and descriptive over long spans. This sections would greatly benefit from being shorter and more concise.

Agreed. Sections 3 and 4 have undergone restructuring to describe the core results more concisely. The previous section 4.1 has been combined with section 3 to avoid the repetition about the synoptic context. Section 3 is now entitled "Overview of meteorological condition" with two subsections: "3.1 One HPE with two precipitation phases over southern Italy", and "3.2 Distribution of SWI over the Mediterranean". Sections 4 is now entitled "SWI distribution during two precipitation phases" with two subsections of "4.1 The convective phase of precipitation", and "4.2 The large-scale phase of precipitation".

2. Parts of the conclusion repeat contents of section 4 in too much detail, shorten and be much more concise and clear.

Agreed. The conclusion is now more concise after removing the content redundant with section 4.

♣ Page 15, from line 8 (conclusion)

"The 3-day backward trajectory analysis shows that the air parcels arriving in SI during P1 originate from the North Atlantic and descend within the upper-level trough over the north-western Mediterranean Sea. The SWI-depleted air mass (median $\delta^{18}O \leq -45$ ‰) within the descending air parcels ~~arriving at very low levels (below 1 km) are very dry and SWI depleted ($\delta^{18}O \leq -25$‰, water vapour mixing ratio, $q \leq 2$ g kg^{-1}), and~~ rapidly take up a large amount of water vapour from ocean evaporation (green encapsulated area in Fig. 14a)~~). As a consequence, it becomes enriched in SWI ($\delta^{18}O \geq -14$‰) in a very short time span~~ over the Tyrrhenian Sea and also from evaporated moisture from falling precipitation~~ as hinted by the analysis of the trajectory data in the q–δ space (points falling below the Rayleigh distillation line)~~. Additional moisture is taken up over the Strait of Sicily~~ at altitudes below 2 km ASL~~ from mixing with the enriched moisture plume coming from Africa ($\delta^{18}O_v \geq -16$ ‰). The SWI-enriched low-level air masses arriving upstream of SI are convectively pumped to higher altitudes, producing precipitation over SI, and the SWI-depleted moisture is transported towards the surface within the downdrafts ahead of the cold front (red and blue arrows, Fig. 14a).

During P2 (Fig. 14b), just a few hours after P1, the origin of the air parcels arriving at SI is distinct, i.e. mostly from North Africa. The air parcels are moist and associated with large $\delta^{18}O$ values (bottom most arrow, median $\delta^{18}O_v \geq -16$ ‰~~, median $q \geq 6$ g kg^{-1}~~). With the arrival of the upper-level trough ($\delta^{18}O_v \leq -45$ ‰~~ at 600 hPa~~) and ~~low-level~~ mistral ($\delta^{18}O_v \leq -25$ ‰~~ at 850 hPa~~) over the southern Tyrrhenian Sea, the strong cyclonic flow around the trough (grey dashed line in Fig. 14b) induces the advection of the moist plume towards SI and leads to large-scale uplift of the warm and moist African air mass along the cold front. It brings moisture and leads to gradual rain out of the air parcels over Italy~~ (following Rayleigh distillation)~~. For the convective precipitation phase (P1), most of the moisture processes producing the HPE take place during the last 18 hours before the arrival over SI, while the large-scale advection of SWI-enriched moisture from the African plume by strong cyclonic flow lasts about 72 hours during the large-scale precipitation phase (P2).~~ ~~In both phases, the air parcels take up substantial amount of water vapour over the Mediterranean."

3. The authors need to discuss their results in a critical way which includes an explanation of the insights gained by using COSMOiso over a normal mesoscale simulation, which would be possible at a much higher resolution too. This discussion can be part of the last section Conclusions and Discussion.

The chosen setup (COSMOiso simulation with 7 km grid spacing and parameterized convection) is a tradeoff between high enough resolution for including detailed dynamics of the mesoscale systems and still being able to run efficiently over a large domain that also includes the moisture plume over North Africa. Also this selected resolution and large model domain reduce the dependence on the much coarser isotope boundary data (spectral resolution of T62 in IsoGSM) and enables us to calculate backward trajectories consistently over longer periods. This discussion is added in section 5, Conclusion.

♣ Page 16, from line 14

"[…] In this study, COSMOiso simulation at a horizontal grid spacing of about 7 km with parameterized convection results from a trade-off between having high enough resolution for including detailed dynamics of the mesoscale systems and being able to run efficiently over a large domain (about 4300 km × 3500 km) that includes the moisture plume over North Africa. This setup allows addressing the question we are interested in, namely: which isotope signals are due to local processes, and which are due to large-scale advection? To further study the details of the fractionation processes in and around deep convective systems, complementary investigations will be conducted using higher resolution convection-permitting simulation with a 2 km grid to shed a light on cloud microphysical processes inside deep convection."

4. Multiple figures are difficult to read, be it due to bad coloring or their size. The authors could greatly improve the manuscript's readability by making sure that figures use more contrasting color table, fewer contour levels and that the figure size and shape make better use of the available space. I mention specifics for certain figures throughout the minor comments, but the other figures can also be improved following those same guidelines.
Agreed. We have improved Figures 1, 3, 5, 8, 10, 12, 13, and 14 for better readability.

5. Figures are often referenced out of order, try to keep this to an absolute minimum. This will likely require some restructuring of the text.
The order of reference of Figures is now corrected throughout the paper.

Minor comment

1. P3, L1: large amounts of water vapor. How large?
Corrected.

♣ Page 3, from line 1
"[…] the intrusion of large amounts of moisture, about one quarter of the total integrated water vapour, […]"

2. P3, L10: observations of the most stable water isotopes alone can be limited this indicates that "normal" observations only look at this isotopes, but I assume that the sentence refers to classical observations which simply look at the total moisture without any regard for different isotopes. This should be more clear.
Corrected to "the SWI observation of other, less abundant SWIs, i.e. $H_2{}^{18}O$ and $HD^{16}O$".

3. P3, L14-15: replace *in the other phase (vapor)* with just *in vapor*
Corrected.

4. P3, L19-24: Please specify what *high* and *low* are in this context by giving typical values
The typical ranges of each values are indicated by referring to Jacob and Sonntag (1991) and Yoshimura et al. (2010).

♣ Page 3, line 19-23
"[…] For instance, low δ^2H values (typically ranging between –160 and –180 ‰) or low $\delta^{18}O$ values (i.e. ranging between –20 and –30 ‰) at the surface indicate air masses characterized by low temperatures and strong rainout of air parcels (e.g. Jacob and Sonntag, 1991; Yoshimura et al., 2010), whereas high δ^2H values (typically ranging between –120 and –100 ‰) or high $\delta^{18}O$ values (ranging between –18 and –14 ‰) indicate air masses characterized by high temperatures and recent admixture of fresh ocean evaporate."

5. P3, L29: remove commas
Removed.

6. P4, L16: change to *used **a** stable isotopic* or *used stable isotopic signal**s***
Corrected to "used stable isotopic signals".

7. P4, L20: add comma after mesoscale
Added.

8. P4, L25-27: move the part *that occurred (...) Mediterranean Experiment (HyMeX ...)* to a separate sentence
Corrected while the acronyms of HyMeX has been defined in the previous paragraph.

♣ Page 5, line 7-10
"[...] The target HPE occurred during the Intensive Observation Period 13 (IOP 13) of the HyMeX SOP-1. Using a combination of ground-based, airborne and space-borne observations and numerical simulations of this HPE, Lee et al. (2016) investigated the detailed dynamic and thermodynamic environments of the two precipitation phases of the HPE."

9. P5, L1-5: This description is difficult to follow if one is not familiar with Lee et al. (2016). This should be moved to section 3, where it can make use of Figs. 1-3 for a thorough but concise description of the event (see also comments on Fig. 1)
Agreed. The description about Lee et al. (2016) has been moved to section 3.2.

♣ Page 9, line 2-7
"The moisture structure upstream of the HPE; 1) the presence of an African moisture plume favouring the efficiency of the convection to produce more precipitation, 2) the importance of southerly flow from the warmer Mediterranean Sea south of Sicily in enhancing the convergence ahead of the cold front, and 3) the role of the upper-level trough over southern France extending to the western Mediterranean in organizing convection at the leading edge of the surface front, highlighted by Lee et al. (2016) has been further studied using SWI data [...]"

10. P5, L3: remove *wind* after *mistral*
Corrected.

11. P5, L4: change *convection activity* to *convective activity*
Corrected.

12. P5, L8: add *and* after the comma
Added.

13. P5, L10: change to *However, the origin and transport pathways of moisture have not been studied to date*
Corrected.

14. P6, L2: specify that this is a *deep* convection scheme, since the resolution of the model has not yet been mentioned at this point
Specified.

15. P6, L3: please add a very brief and concise description of what these physics and isotope parametrizations do, one to three sentences should suffice.
A brief description of isotope physics and parametrizations has been included.

♣ Page 6, line 7-18

"[…] All prognostic moisture fields, which are simulated by the model in terms of specific humidities, are duplicated twice, representing the specific humidities of $H_2^{18}O$ and $HD^{16}O$, respectively. From the prognostic specific humidity fields, the isotope ratios in usual δ-notation can be calculated. The heavy isotopes experience the same processes as the light isotope ($H_2^{16}O$), except during phase transition, when isotopic fractionation occurs. A one-moment microphysics scheme is used and deep convection is parameterised following Tiedtke (1989). In the microphysical scheme, transfer rates between the different water species during the formation of clouds and precipitation are specified. The heavy isotopes are affected by equilibrium fractionation during the formation of liquid clouds, and both non-equilibrium and equilibrium fractionation during the formation of ice clouds (using the predicted super-saturation) as well as the re-evaporation of rain drops. For the parameterisation of moist convection, all physical processes during simulated convective up- and downdrafts affect the heavy isotopes in a similar way as the standard light humidity, again taking into account equilibrium and non-equilibrium fractionation when appropriate."

16. P6, L11: please add some details about this model. Does it run operationally? Is it an analysis? Does it run only for specific cases?

The IsoGSM global simulation data is constrained to reanalysis data with the help of a nudging technique. The Scripps Experimental Climate Prediction Center's GSM was based on the medium range forecast model used at NCEP for making operational analysis and predictions. Isotope ratios in water vapour with a spectral resolution of T62 and on 17 vertical levels are obtained from the IsoGSM simulation. This information has been included in manuscript.

♣ Page 6, from line 25

"[…] For the water isotopes, initial and boundary data are taken from a historical isotope global circulation model IsoGSM (which is based on the Scripps Experimental Climate Prediction Center's GSM that was used operationally for medium range forecasts at NCEP) simulation by Yoshimura et al. (2008), who performed these simulations using a nudging technique (see also Pfahl et al., 2012). The Scripps Experimental Climate Prediction Center's GSM was based on the medium range forecast model used at NCEP for making operational analysis and predictions."

17. P6, L12-16: Why is a resolution of 7 km used? Is this to be able to differentiate between convective and other precipitation by using the convection scheme's precipitation? Resources? Other reasons? Please specify.

This resolution was used for operational predictions at the German Weather Service DWD for a long time, such that the model is very well tuned in this configuration. We also chose this relatively coarse resolution because it allows for a large model domain that reduces the dependence on the much coarser isotope boundary data (spectral resolution of T62 in IsoGSM) and enables us to calculate backward trajectories consistently over longer periods.

♣ Page 16, from line 14

"[…] In this study, COSMOiso simulation at a horizontal grid spacing of about 7 km with parameterized convection results from a trade-off between having high enough resolution for including detailed dynamics of the mesoscale systems and being able to run efficiently over a large domain (about 4300 km × 3500 km) that includes the moisture plume over North Africa. This setup allows addressing the question we are interested in, namely: which isotope signals are due to local processes, and which are due to large-scale advection? To further study the details of the fractionation processes in and around deep convective systems, complementary investigations will be conducted using higher resolution convection-permitting simulation with a 2 km grid to shed a light on cloud microphysical processes inside deep convection."

18. P6, L22: 5 days trajectories in a 5 day simulation? So just back to the start of the simulation or until they leave the domain?

The trajectories are computed back in time until they leave the domain. The sentence has been corrected for sake of the readability.

♣ Page 7, line 12-13

"[…] The trajectories are computed five days back in time. Note that generally the COSMO trajectories move out of the regional model domain after 3 days."

19. P7, L6-8: Why are these values chosen?

The values are chosen based on the near sea surface temperature of SI region.

20. P7, L20: Spell out *two* in the section title

Corrected.

21. P7, L23: hour is abbreviated with just *h*

Corrected also at other places.

22. Fig.1: Some dots have edges, others have none. Remove all edges and make sure the higher precipitation measurements are plotted on top of the lower values to keep them clearly visible and not hide maxima. The Figure is very small and the comparison is difficult to read. In Fig. 1b all contour colors from 5 to 25 mm look almost exactly the same in print, please use a color table which shows the differences more clearly. Fewer levels might help to achieve better contrast, do you really need 24 different ones?

As suggested the edges have been removed and the size of color dots has been enlarged, and the color scale has been adjusted for sake of readability.

♣ Page 23

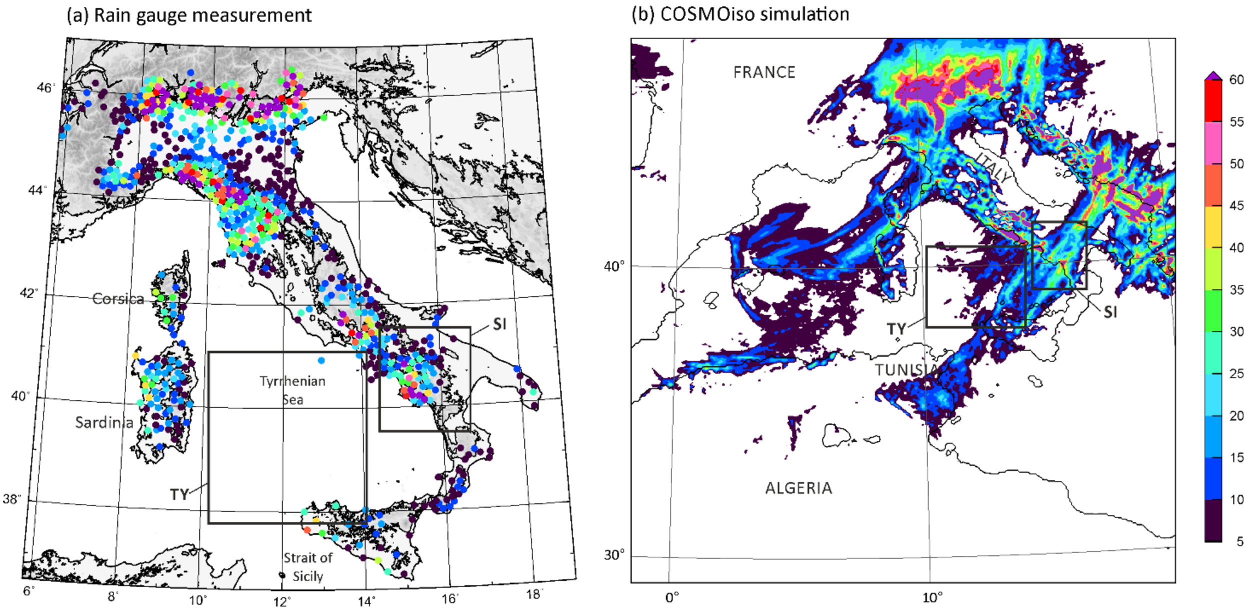

Figure 1. Accumulated precipitation during IOP 13 from 00 UTC on 15 October 2012 to 03 UTC on 16 October 2012 obtained from (a) rain gauge network, and (b) COSMOiso simulation.

23. P7, L26: *a large precipitation* rephrase
The sentence has been rephrased.

♣ Page 8, line 17
"shows precipitation in excess of 10 mm […]"

24. P7, L24-27: This sentence is too long and convoluted, simplify by moving the total precipitation amount to a separate sentence.
This sentence has been divided into two sentences.

♣ Page 8, line 15-20
"[…] The temporal evolution of the COSMOiso domain-averaged total precipitation within the SI area (bars in Figure 2) shows precipitation in excess of 10 mm within SI between 19 UTC on 15 October and 01 UTC on 16 October. The period has two distinct precipitation phases: 1) a convective precipitation phase (**P1**) in the late afternoon (19−21 UTC) on 15 October (dashed line in Fig. 2), and 2) a large-scale precipitation phase (**P2**) just before midnight (22−00 UTC) on that day (solid line). […]"

25. P8, L8: remove comma after *France*
Corrected.

26. Fig. 3: Change the colored contours of MSLP to lines, chose a good interval (not too dense) and smooth the field a bit if necessary. Add colored contours of 500 hPa geopotential to show the position of the trough. Move the vectors from the left panels to the right panes, they contain information of the same level.
The 500 hPa geopotential height is contoured on the shaded area of MSLP in the left panels of Figure 3.

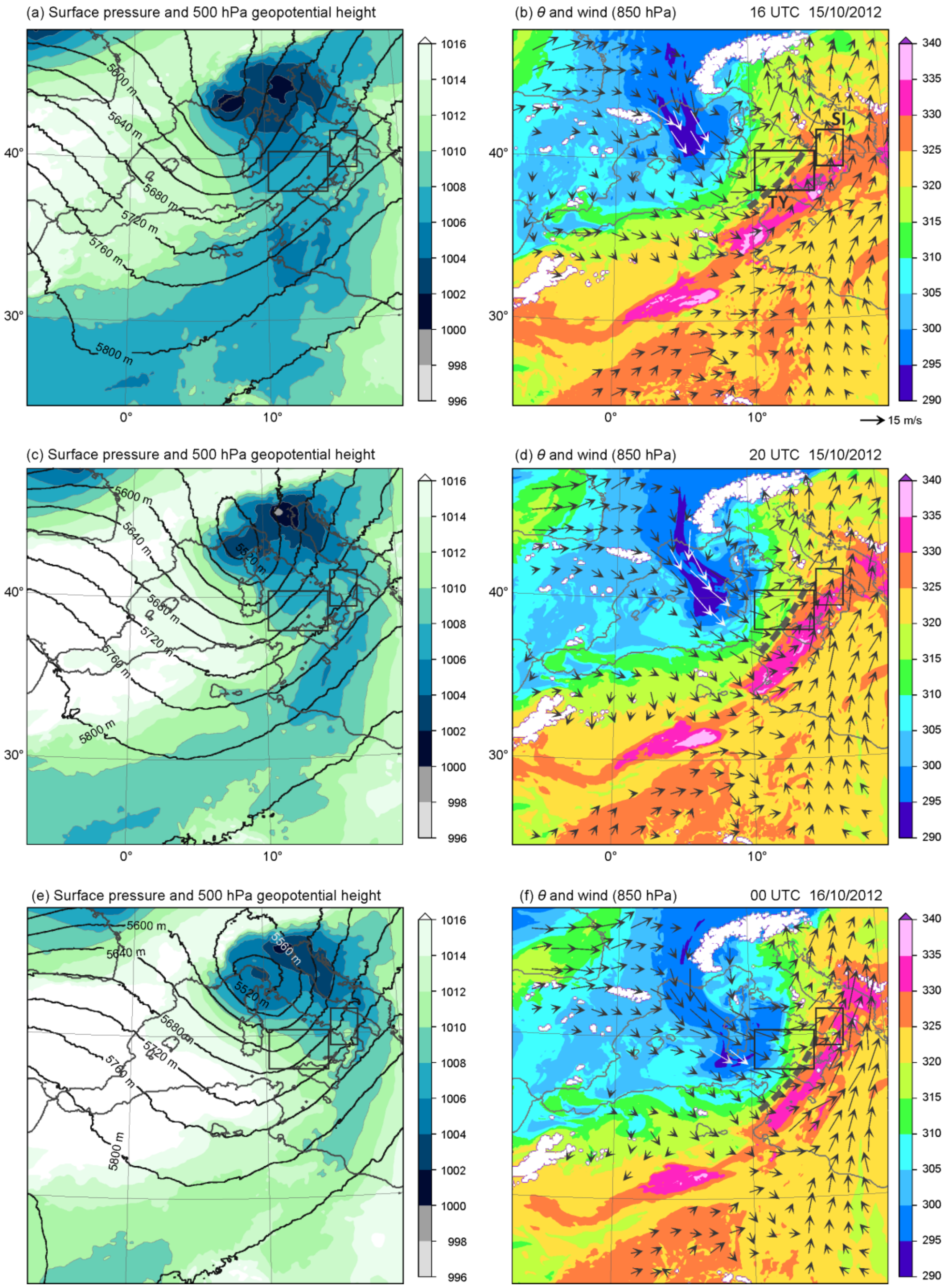

Figure 3. Horizontal distributions of sea level pressure (shades) and geopotential height at 500 hPa (contour) (left), and potential temperature, ϑ (shades), and wind (black and white arrows) at 850 hPa (right) at 16 UTC (top) and at 20 UTC (middle) 15 October 2012, and 00 UTC on 16 October 2012 (bottom) produced by the COSMOiso simulation. Coastal line is depicted by black line. The location of cold front is depicted by a dashed line in right panels.

27. P8, L11, 12: don't use *very* in scientific text, be specific.
Corrected.

♣ Page 9, line 10-15

"[…] winds associated with cold and dry air, with $\delta^{18}O_v$ less than −16‰ and q less than 2 g kg^{-1} (Fig. 4a, b), and thus low potential temperature, ϑ, are located over the Gulf of Lion (≤ 302 K, dark-blue area in Fig. 3b). […] the African moist plume with values of ϑ ≥ 330 K […]"

28. P8, L13: change *high* ϑ *values (≥ 330 K)* to *values of* ϑ *≥ 330 K*
Corrected.

29. P8, L16, 17: Could convection be causing the cool areas in the 850 hPa potential temperature map over TY?
The original sentence was "Over the Tyrrhenian Sea ('TY' box in Fig. 1b), upstream of SI, a large horizontal ϑ gradient (315–330 K) can be seen at 850 hPa, indicating the elongation of the surface cold front along a southwest to northeast axis".
The convection positioned at the southern edge of this front, where high values of ϑ (≥ 325 K) are seen.

30. P8, L17: It is never explained that the model does, in fact, not produce two peaks. They are only visible when separating precipitation from the convection scheme and precipitation produced by microphysics.
The model, in contrast to the observations, does not produce two peaks in the total precipitation. These peaks can be seen by looking at the two precipitation types separately. This criticism has been included in manuscript.

♣ Page 8, line 24-26

"[…] P1 is related to rain from the convection parameterization, and P2 is related to rain associated with large-scale vertical motion. The model, in contrast to the observation, does not produce two peaks in the total precipitation. These peaks can be seen by looking at the two precipitation types separately."

31. P8, L18: the trough is never shown, add reference to Fig. 3 after adding the 500 hPa geopotential as suggested.
In the left panels of Figure 3, the 500 hPa geopotential height is contoured on the shaded area of MSLP. Please see the answer for comment #26.

32. P8, L23: *strong cyclonic flow* there is only one arrow within the box, curvature is hard to see.
The Figure 3 (right panels) has been corrected to see better the cyclonic flow, but very weak wind at the core region is not displayed for sake of readability.

33. P9, L12, 13: *very low* and *large* are not helpful in this context, just use the values. However, a short explanation on why the threshold between these two values is important would be helpful.
Corrected.

♣ Page 9, lines 10 and 16

"[…] cold and dry air, with $\delta^{18}O_v$ values less than −16 ‰ […]$\delta^{18}O_v$ values in excess of −25 ‰ can be seen […]"

34. P9, L26: the front is not really close to SI
The cold front is indicated where potential temperature (ϑ) values show a large gradient (315–330 K) at 850 hPa and it is marked by a dashed line in right panels of Fig. 3. We can see the front is close to SI.

35. P10, L27: *mostly very dry* use values instead, be specific
Corrected.

♣ Page 11, line 15-16
"[...] These air parcels are mostly dry ($q \leq 5$ g kg^{-1}) along the track during the 3 days [...]"

36. P11, L2: remove *the* before q and $\delta^{18}O_v$, remove *values* after $\delta^{18}O_v$
Corrected.

37. P11, L6: change to *The median q value (...) factor of 2.5*
Corrected.

38. Fig 7: Figure has lots of white space and the way the map is shown causes even more. Try to reduce this to make the important parts a bit larger.
We have reduced much of white space and enlarged the figure.

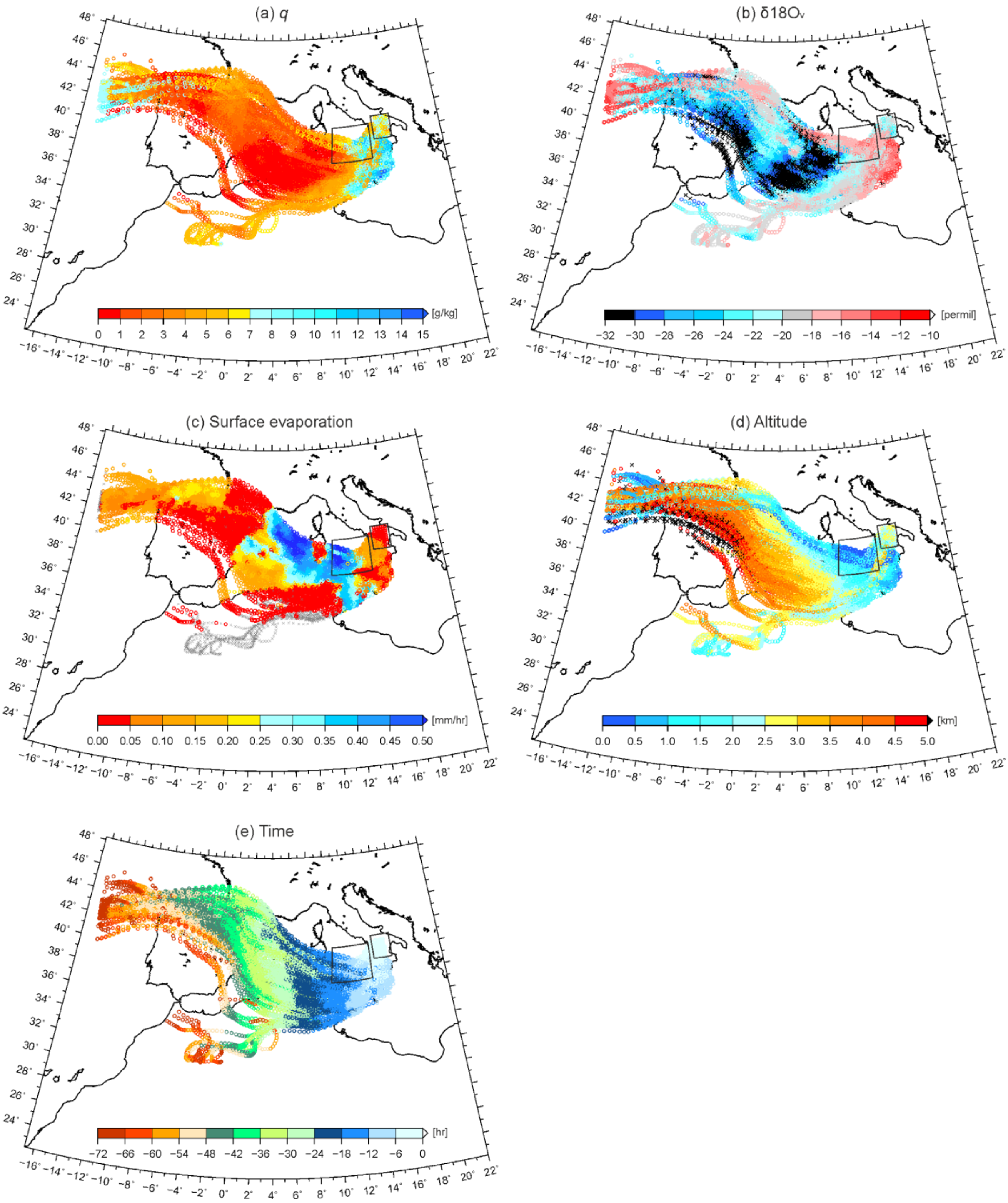

Figure 7. History of air parcel arriving at **SI** in layer of 800−700 hPa at 20 UTC on 15 October 2012. (a) water vapour mixing ratio, *q* (g kg^{-1}), (b) $\delta^{18}O_v$ (‰), (c) surface evaporation (mm h^{-1}), (d) altitude (km), and (e) time (h).

39. P11, L12: replace *the average q* with *q is about* 9 g kg^{-1} *on average*

Corrected.

40. P11, L14: It is never explained what a Rayleigh line is
Corrected.

41. P11, L19-21: This sentence is complicated. Also why?
The sentence was "This shows that the descending air parcels mix with the air parcels from lower altitudes, and near surface air parcels mix between surface evaporation and background vapour".
Figure 9a, b show that the lower to upper-level trajectories (0.1–7 km altitudes) follow a mixing line during their descent, and this indicates that the descending air parcels from upper levels mix with the air parcels from lower altitudes. The descent of drier air parcel to near the sea surface also increases evaporation. For sake of clarity, this sentence has been improved.

♣ Page 12, line 8-9
"[...] This shows that the descending dry air parcels mix with the warm and moist air parcels from lower altitudes, which also increases surface evaporation."

42. P11, L28: replace *many* with *multiple*, change *convection* to *convective*
Corrected.

43. P12, L2: usage of low/high seems inconsistent looking at the numbers
The sentence has been rewritten.

♣ Page 12, line 18-19
"[...] Within the precipitation area, relatively lower $\delta^{18}O_v$ values (≤ −16 ‰) than in the vicinity are found at 542 m ASL while relatively high $\delta^{18}O_v$ values between −20 and −24 ‰ are found at 2455 m and 5565 m ASL [...]"

44. P12, L13: change to *with values of* $\delta^{18}O_v$ *larger than;* replace *toward* with *around*
Corrected.

45. P12, L18-19: rewrite sentence
Corrected.

♣ Page 13, line 7-8
"The Lagrangian analysis indicates that most of the processes inducing precipitation during P1 take place during the last 18 hours over the Tyrrhenian Sea and the Strait of Sicily."

46. P12, L25: change to *convective mixing injects SWI-enriched moisture into higher altitudes*
Corrected.

47. Fig. 8: explain colors in the caption, some dots have edges and others don't, figure is small, you could change the aspect ratio to fit the page width for better readability. This also applies to the other figures of this type (9 and 12).
As suggested the Figure 8 has been improved for better readability. However we kindly propose to keep the aspect ratio of the figure to better identify the characteristics.

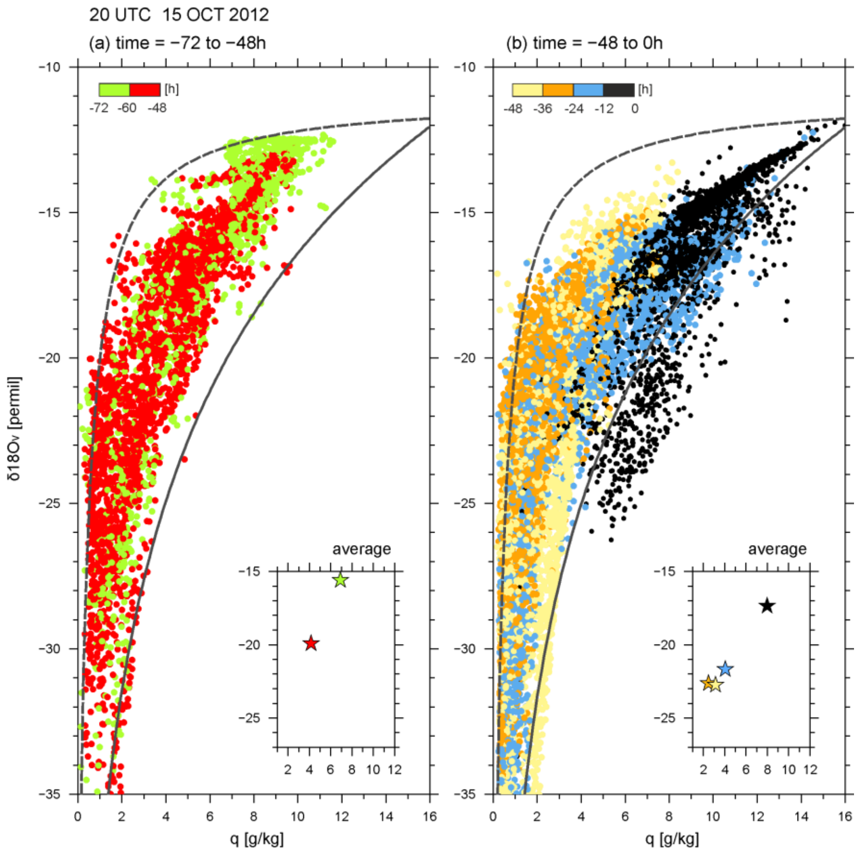

Figure 8. Scatter diagram of q and $\delta^{18}O_v$ along the backward trajectories of Figure 7 during (a) the times between −72 and −48 h, and (b) times between −48 and 0 h every 12 hours from 20 UTC on 15 October 2012. The colour of dot changes every 12 h. The mixing and Rayleigh lines are indicated in each panel by dashed and solid line, respectively. The averaged q and $\delta^{18}O_v$ every 12 hours is displayed in the bottom right corner of each panel.

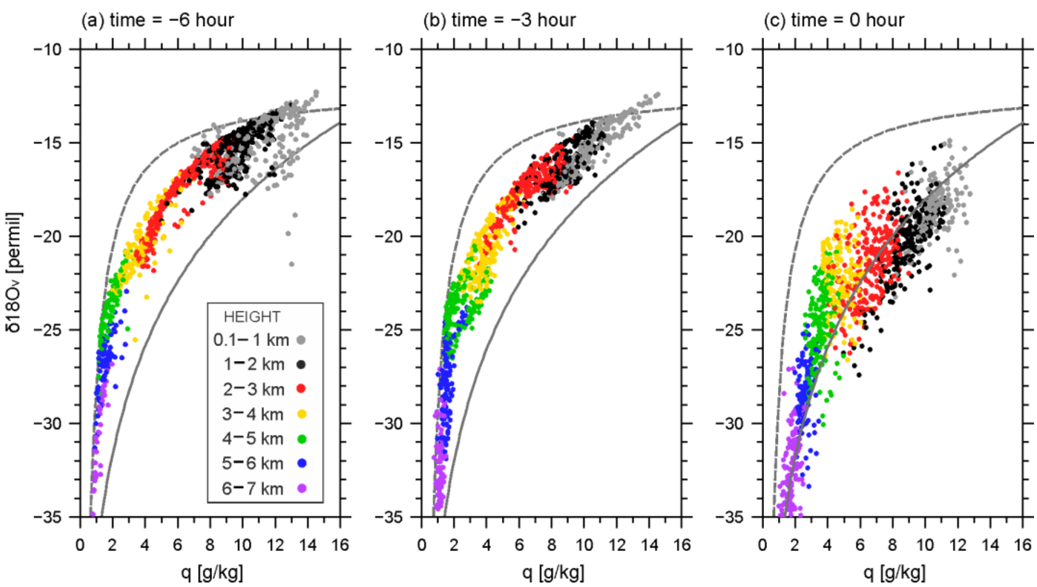

Figure 9. Scatter diagram of q and $\delta^{18}O_v$ along the backward trajectories of Figure 7 but for all altitudes of 1−2 km (black dots), 2−3 km (red dots), 3−4 km (yellow dots), 4−5 km (green dots), 5−6 km (blue dots), and 6−7 km (purple

dots) at (a) −6 h, (b) −3 h, and (c) 0 h from 20 UTC on 15 October 2012. The mixing and Rayleigh lines are indicated in each panel by dashed and solid line, respectively.

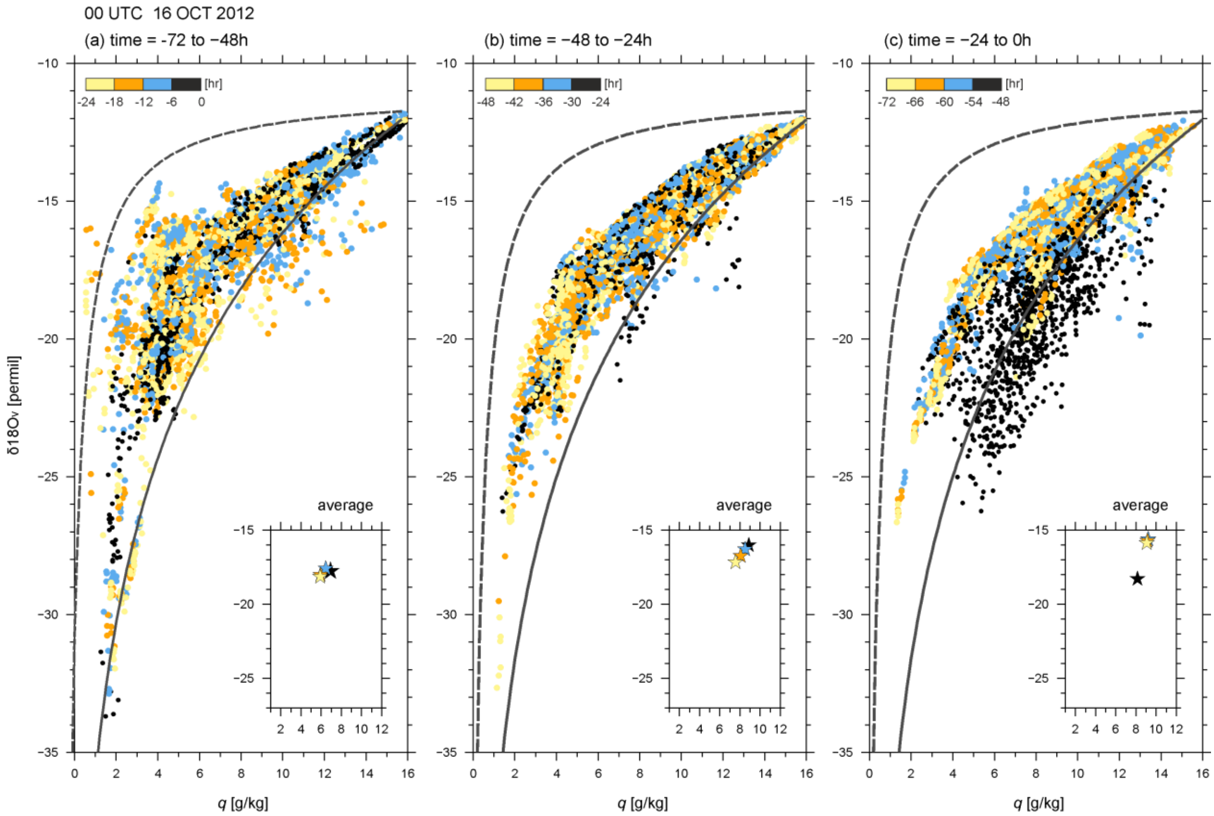

Figure 12. Scatter diagram of q and $\delta^{18}O_v$ along the backward trajectories of Figure 11 during (a) the times between −72 and −48 h, (b) times between −48 h and −24 h, and (c) times between −24 h and 0 h from 00 UTC on 16 October 2012 every 6 hours. The colour of dot changes every 6 h. The mixing and Rayleigh lines are indicated by dashed and solid line, respectively. The averaged q and $\delta^{18}O_v$ every 6 hours is displayed in the bottom right corner of each panel.

48. Fig. 10: panel titles say *vapour* and *rain water*, change them to clearly indicate that they show $\delta^{18}O_v$ **for** vapour/rain water. Also, model levels are not at a constant height. Does this have any effect over mountains? If so, explain which one? Better alternative: plots for certain altitudes above sea level, e.g. 500, 2500, and 5000 m, instead of model levels.

The panel titles have been corrected to $\delta^{18}O_v$, $\delta^{18}O_r$, and $\delta^{18}O_s$ correspondingly. The figure 10 shows $\delta^{18}O_v$, $\delta^{18}O_r$, and $\delta^{18}O_s$ at a model level 8, 16, and 23 which altitudes are about 542 m, 2455 m, and 5565 m above the sea surface, respectively, in regions without topography. However, as noted by the reviewer, the model levels follow the terrain and the fields are thus shown for different altitudes over topography. As the precipitation in SI region occurred mostly near the coast, and the associated moisture processes occurred over the Tyrrhenian Sea and Strait of Sicily, we keep the plot as it is, but a note has been added to the caption.

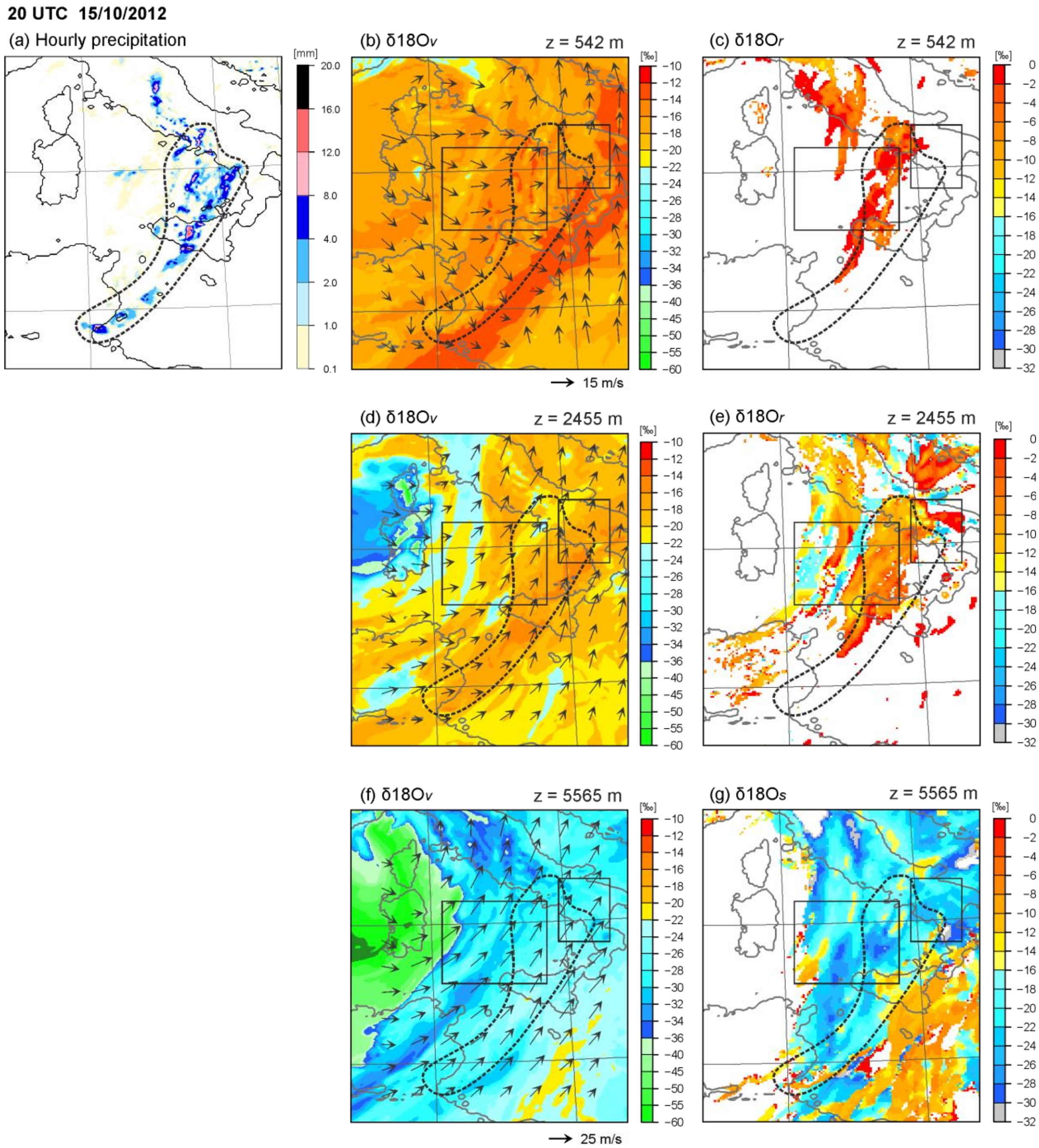

Figure 10. Horizontal distributions of (a) surface hourly precipitation (mm), $\delta^{18}O_v$ (‰) at (b) model level 8 (about 542 m ASL), (c) model level 16 (about 2455 m ASL), and (d) model level 23 (about 5565 m ASL, $\delta^{18}O_r$ (‰) at (e) 542 m ASL and (f) 2455 m ASL, and $\delta^{18}O_s$ (‰) at 5565 m ASL at 20 UTC on 15 October 2012. Note that, due to the terrain-following coordinates, the SWI values are partly depleted over topography, e.g. in central Italy. The precipitating area is marked by the area enclosed by the dashed line.

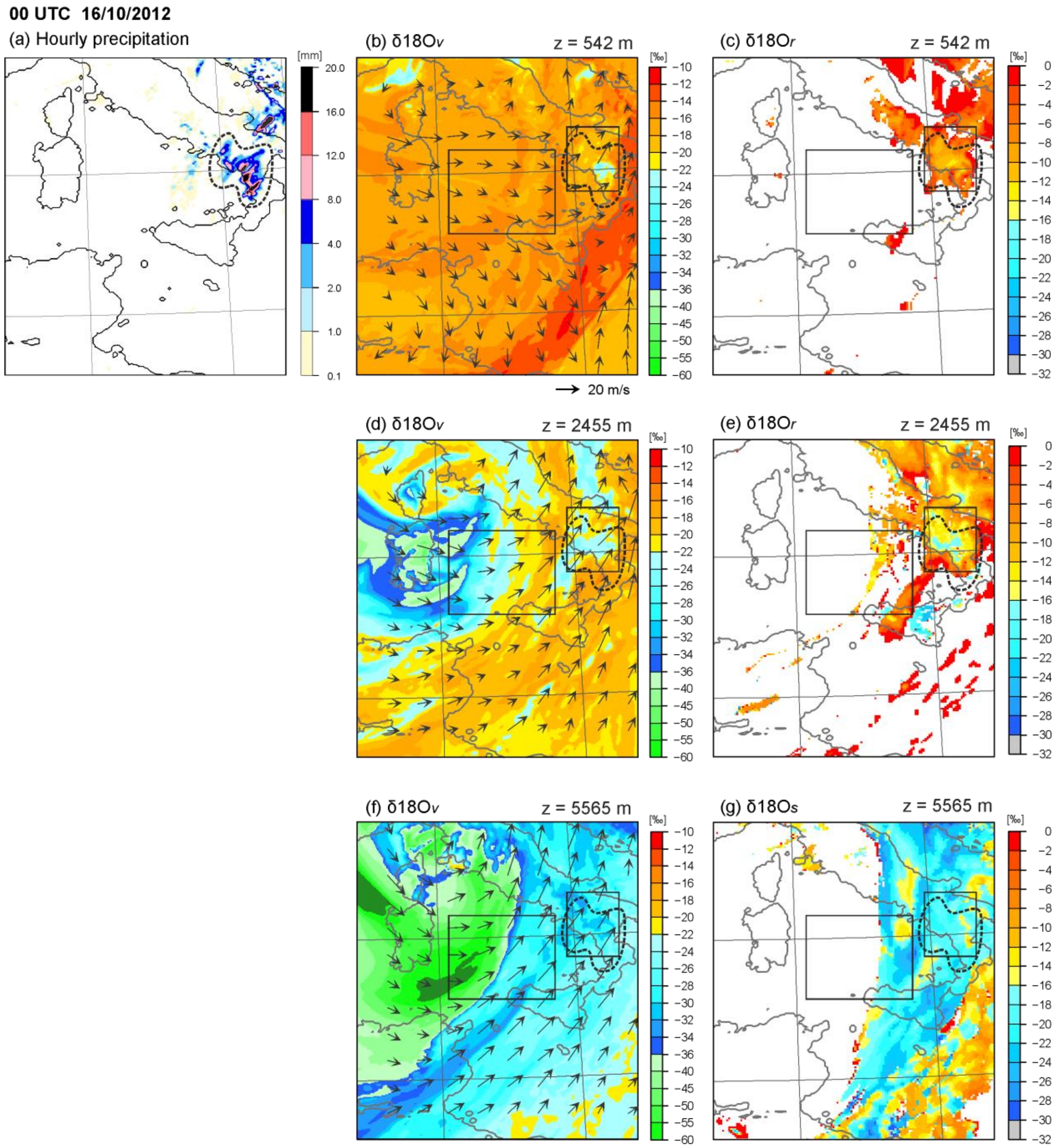

Figure 13. Same as Figure 10 but for 00 UTC on 16 October 2012.

49. P13, L2: replace *over* with *from*

Corrected.

50. P13, L3: Threshold of 5 g kg^{-1} is not visible in the figure

The value is obtained from an average over all trajectories, not those shown in Figure 11. For better understanding, the sentence has been corrected.

♣ Page 13, line 20-21

"The air parcels are consistently moist along the tracks (Fig. 11a), with average *q* value mostly ≥ 5 g kg^{-1} along the track, in contrast […]"

51. P13, L7: replace *for instance* with *and*

Corrected.

52. P13, L7, 8: Use a non-breaking space between multiple units, in LaTeX to avoid line breaks between them. This can be done by using ~ instead of a pace like this: 9~g~kg or in MS word by using Ctrl + Shift + Space

We appreciate the guide. The non-breaking space has been used entire manuscript.

53. P13, L20-21: rephrase, also, do not use *precipitation cell* unless explicitly referring to a single convective cell

Corrected.

♣ Page 14, line 8-10

"At 00 UTC on 16 Oct. during P2, stronger precipitation than that of P1 is produced, and the precipitation system is located mainly over SI (marked area closed by dashed line in Fig. 13a). In the vicinity of the precipitating region, strong cyclonic south-westerly flow ≥ 25 m s^{-1} is dominant at 2455 m and 5565 m ASL (Fig. 13d, f)."

54. P13, L24: The depletion is hardly visible at 5500 m

The depletion at 5565 m is visible with the improved color scale of Figure 13.

55. P14, L1-5: going back to earlier Figures is tedious and disrupting, try to avoid if possible by restructuring the text

Agreed. However we kindly propose to keep as it is to complete our comprehension from entire analysis.

56. P14, L6-8: rephrase sentence

Corrected.

♣ Page 14, line 24-25

"The Lagrangian analysis indicates that the moistures that feeds the convection during P2 is coming from North Africa and the air parcels take up additional moisture (2–3 g kg^{-1}) over the Mediterranean."

57. P14, L9: replace *entrainment* with *mixing,* entrainment is usually used in the context of convective updrafts

Corrected.

58. P14, L15: replace *convective* with *convection*

Corrected.

59. P14, L20: the three paragraphs starting here are especially long and too descriptive, be more concise. Do not simply repeat details from previous sections in the conclusions.

The three paragraphs become concise by removing the repeated description.

60. P15, L4, 5: do not use formulations like *totally different* in scientific texts

Corrected to "arriving at SI is *distinct*".