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 comments

Overview

This review comments on the revised version of the article. The authors have made a great effort to address the comments and rectify the substantial weakness of the manuscript, which were present in the first version. All major and minor points were adequately taken care of and I recommend publication of the manuscript after a number of minor revision. While the comments below are numerous, none of them warrant another round of major revisions, as all of them can be addressed without investing too much time.

We appreciate the time and effort you put in this review as well your insightful comments to improve our paper. Replies to each comments are listed below.

Minor Comments

1. While reading the manuscript, I still missed the basic justification for this article, as I have emphasized in my first round of comments. However, it turned out to be located in the last paragraph of the last section of the article. I suggest to present it toward the end of Section 1 and even make a short comment on the intentions behind this study in the abstract!

As suggested, we present the basic justification of this article: i) earlier at the end of Section 1, and ii) shortly in the abstract.

♣ Page 5, lines 21–26 (end of Section 1)

"Here we investigate these moisture transport processes using trajectory calculations and SWI data obtained from a COSMOiso numerical simulation with 7-km horizontal resolution with parameterized convection. This setup 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 that includes the moisture transport from Africa. More importantly, it 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? […]"

♣ Page 1, lines 21–25 (Abstract)

"[…] The moisture transport and processes responsible for the HPE are analysed using a simulation with the isotope-enabled regional numerical model COSMO$_{iso}$. The simulation at a horizontal grid spacing of about 7 km over a large domain (about 4,300 km × 3,500 km) allows to distinguish the isotopes signal due to local processes or large-scale advection. […]"

2. In section 2.1, the grid spacing and domain dimensions are mentioned at the very end of the section (p. 7, l. 2–6). I suggest to move them to the start of the model description or at the very least to the beginning of the second paragraph.

Agreed. The grid spacing and domain dimension are now mentioned at the beginning of the second paragraph of Section 2.1.

♣ From Page 6, line 26

"In this study, a horizontal grid spacing of 0.0625° (in a rotated grid), corresponding to about 7 km is used with 40 hybrid vertical levels. The model domain covers the northwestern Mediterranean, the east Atlantic, and the northern African regions (longitude ranging from –16.3 to 22.8°E and latitude ranging from 17.3 to 49.2°N, i.e. about 4,300 km × 3,500 km). […]"

3. While section 3 is greatly improved, the shortening had an unwanted side effect. Due to the density of the text, the third and fourth paragraph of section 3.2 (p. 10, l. 6–28) contain no less than 12 references to figures, more than one every two lines, referring to four different figures in the order 5, 3, 5, 3, 3, 4, 3, 4, 4, 5, 5, and then back to 2. I understand that it is necessary to refer the reader to the correct figure, but you should try to rearrange these two paragraphs a bit, such that they don't jump around between figures this often and contain at least slightly fewer references to figures.

The paragraph has been re-arranged to avoid jumping to different figures.

♣ From Page 10, line 10

"~~During the two precipitation phases at 20 UTC and 00 UTC, both ϑ and $\delta^{18}O_v$ drop dramatically (Figs. 5a) with the arrival of the upper-level trough and cold front in the TY region (Figs. 3c–f, and 4d–i), while the warm and moist air mass with large q and large $\delta^{18}O_v$ values coming from tropical Africa persists upstream of SI (Fig. 5b).~~ At 20 UTC (**Fig. 3**c, d), southerly winds (10–15 m s^{-1}) transport the warm and moist air mass with high ϑ values (≥ 325 K) from the Strait of Sicily to SI, and the convection occurred in the high ϑ region at the southern edge of the front (dashed line in **Fig. 3**d). The frontal wind convergence of south-westerly and southerly winds (10–15 m s^{-1}) can be seen upstream of the HPE at the 850-hPa level. Meanwhile, the African moisture plume including the SWI-enriched air mass (q ≥ 10 g kg^{-1} and $\delta^{18}O_v$ ≥ –16‰ in **Fig. 4**d–f) continues to advect toward SI.

At 00 UTC when the trough is located in the southern Tyrrhenian Sea with the low-level mistral air mass (q ≤ 3 g kg^{-1} and $\delta^{18}O_v$ ≤ –24‰ in **Fig. 4**g–h) at the western edge, strong cyclonic flow can be identified over the SI region while the warm and moist air mass (ϑ ≥ 325 K) over the Strait of Sicily is continuously advected towards SI (**Fig. 3**f). Higher up, at 600 hPa, the trough-related, strongly SWI-depleted air masses descending from higher altitudes show $\delta^{18}O_v$ values lower than −45 ‰ (**Fig. 4**i). In contrast to the trough, the African moisture plume is associated with large q values in excess of 10 g kg^{-1} at 850 hPa level extending to the SI region (**Fig. 4**g).

During the two precipitation phases at 20 UTC and 00 UTC, both ϑ and $\delta^{18}O_v$ drop dramatically in the TY region with the arrival of the upper-level trough and cold front (**Fig. 5**a), while the warm and moist air mass with large q and large $\delta^{18}O_v$ coming from tropical Africa persists upstream of SI (**Fig. 5**b). As ϑ decreases from 322 to 300 K in TY (**Fig. 5**a), the $\delta^{18}O_v$ drops more rapidly at altitudes above 3 km compared to the $\delta^{18}O_v$ drop seen in lower altitudes, where the trough-related dry airstreams are moistened by SWI-enriched fresh ocean evaporate. The minimum $\delta^{18}O_v$ value increases lowering the altitudes to near surface, for instance, the minimum $\delta^{18}O_v$ values of −23 and −36 ‰ are seen at 1–2 and 2–3 km ASL respectively, while values lower than −47 ‰ occur at altitudes above 3 km ASL. The hourly evolution of average $\delta^{18}O_v$ in the TY region shows the propagation of the surface front and upper-level trough at altitudes of 1–7 km ASL, and the associated subsidence of dry and cold air. It is worth noting that the arrival timing of cold and dry air subsidence in TY, 19–20 UTC, (**Fig. 5**a) corresponds to the onset of precipitation in SI, 19 UTC (vertical bars, **Fig. 2**)."

4. The manuscript contains multiple instances of the X values, where X can be a quantity like q or θ and so on, remove both, *the* and *value*, and just use X instead (e.g. p. 11, l. 4, 5, 6, 7, 27, 28–29, …).
Throughout the manuscript, *the* and *value* have been removed. For instance,

♣ Page 11, lines 8–11
"While ~~the~~ q ~~value~~ increases gradually to 13.5 g kg^{-1} until 19 UTC, just before P1, ~~the~~ $\delta^{18}O_v$ ~~value~~ maximizes to –13.6 ‰ at 16 UTC and then decreases during P1 to –15 ‰. During P2, ~~the~~ $\delta^{18}O_v$ ~~value~~ increases shortly to –14.6 ‰ whereas ~~the~~ q ~~value~~ continues to decrease to 8 g kg^{-1}."

5. It says on p. 11, l. 20 that *between 18 and 6 hours before arrival*… but looking at Fig. 7 shows evaporation more or less the instant the trajectories start passing over the sea, for some of them well above 24 hours before the event. Perhaps you should consider a less restrictive formulation here.
Agreed. The evaporation occurs instantly passing over the sea surface during 18–6 hours or 24–18 hours before arrival in SI region. The relevant sentence is now modified accordingly.

♣ Page 11, lines 24–27
"When the air parcels travel over the sea, e.g. during 24–18 hours, or 18–6 hours before their arrival in SI, the surface evaporation instantly increases. For instance, between 18 and 6 hours before arrival in SI, the median surface evaporation rate along the trajectories doubles from 0.15 to 0.32 mm h^{-1} with a peak 12 hour before the arrival in SI."

6. Section 4.1.1, third paragraph refers to dots following mixing/Rayleigh lines, but that doesn't really seem to be the case, at least not exactly. Do these lines depend on the constants in their equation, which might fit better for other values? If so, consider using them. If not, or if this is too much effort, explain more clearly how they agree with the scattered dots.
The relevant sentence has been further clarified to describe the scattered dots.

♣ Page 12, lines 10–12
"[…] the upper to low-level trajectories (green to purple dots in Fig. 9a, b) follow a mixing line (dashed line) during their descent while the lowermost trajectories (black and grey dots) are distributed over wider domain and do not follow exactly a Rayleigh distillation line […]"

7. At multiple locations in the text, a moist plume over Africa is mentioned, and it is not always referred to in the same way (African moist plume, African moisture plume, the plume of …), please keep this consistent throughout the manuscript. Also, explain whether this is a climatological plume or a feature of this specific event.
The African moisture plume is often identified when the upper-level trough strengthens and deepens in a south-north orientation over the western Mediterranean. It has been reported in multiple studies, e.g. Chazette et al., 2015, Lee et al., 2015 and 2017. This tip of information has been included in the text, and 'African moisture plume' has been used consistently throughout the manuscript.

♣ Page 15, lines 22–27
"[…] the strong cyclonic flow around the trough (grey dashed line in Fig. 14b) induces the advection of the African moisture plume towards SI and leads to large-scale uplift of the warm and moist air mass along the cold front. The existence of an African moisture plume is often associated with the presence of a deepening, north-south oriented upper-level trough over the western Mediterranean (Chazette et al., 2015; Lee et al., 2016 and 2017).

It brings moisture and leads to gradual rain out of the air parcels over Italy […]”

♣ Page 17, line 24

Chazette, P., Flamant, C., Raut, J.C., Totems, J., and Shang, X.: Tropical moisture enriched storm tracks over the Mediterranean and their link with intense rainfall in the Cevennes-Vivarais area during HyMeX. Q. J. R. Meteorol. Soc., 142, 320–334, doi:10.1002/qj.2674, 2018.

8. Section 5 can still be slightly shortened by removing some of the values (not needed in the conclusions) and considering the text further, specifically the part on p. 15, l. 8–26.

Section 5 has been shortened by removing the values, especially in the second and third paragraphs (p.15, l. 11–29).

Typos and Formulation

Page 1, Line 20: replace *linked to a frontal feature* with *ahead of a cold front*

Corrected.

Page 2, Line 4: change to *large amount of convective precipitation*

Corrected.

Page 2, Line 6: replace *preceding the occurrence of* with *before*

Corrected.

Page 2, Line 8: remove comma after SI

Corrected.

Page 2, Line 9: replace *brings* with *lifts*, remove *masses*

Corrected.

Page 2, Line 10: remove *to higher altitudes*

Corrected.

Page 2, Line 23: change *mesoscale deep convection* to *organized deep convection*, add comma after *events*, and remove *along*

Corrected.

Page 2, Line 24: remove *content*, remove *deep*

Corrected.

Page 2, Line 25: replace *question* with *research topic*

Corrected.

Page 2, Line 28-29: Using *either… or* like this indicates that Africa or extratropical remnants of Atlantic tropical cyclones over the Atlantic are the only sources of moisture, but other sources are possible as well as a combination of sources. I suggest to rephrase this a bit to account for these possibilities or at least not exclude them.
Corrected.

♣ From Page 2, line 29
"[…] These studies found substantial contributions of subtropical and tropical moisture coming from various sources such as ~~either from~~ Africa (latitude ≥ 20°N) ~~or from~~ and the extratropical remnants of Atlantic tropical cyclones, among others."

Page 2, Line 29: Change sentence to *more recent studies (e.g. Lee et al., 2016 and 2017), pointed out a significant moisture contribution, one quarter of the total integrated water vapor, from North Africa…*
Corrected.

Page 3, Line 9: remove the *s* at the end of isotopes
Corrected.

Page 3, Line 11: replace *constraints* with *insights*
Corrected.

Page 3, Line 20: change *at surface* to *at the surface*
Corrected.

Page 4, Line 11: remove comma after *evaporation*
Corrected.

Page 4, Line 15, 17: repetition of *the free troposphere of …*
Removed the one of them.

Page 5, Line 12: change *in the low levels* to either *in the lower troposphere* or simply *at low levels*
Corrected to *in the lower troposphere*.

Page 5, Line 12: what exactly meant by *initiated over Algeria?* Is this where convection first occurred?
Yes, the convection first occurred over Algeria. For sake of clarify, the expression has been revised.

♣ Page 5, lines 14-15
"[…] first occurred over Algeria and […]"

Page 5, Line 13: replace *large* with *high*
Corrected.

Page 5, Line 14: add *s* after *temperature*
Added.
Page 6, Line 5: replace *sense* with *context*
Corrected.

Page 7, Line 15: replace *written as an output* to *extracted from the model* or just change to *written out*
Revised to *written out*.

Page 7, Line 20: insert *specific* before *humidity*, remove comma after *humidity*
Corrected.

Page 8, Line 4: add *s* after *ratio*
Added.

Page 8, Line 10: add *s* after *condition*
Added.

Page 8, Line 17: insert *region* after *SI*
Corrected.

Page 8, Line 23: replace *a reasonable* with *good*
Corrected.

Page 8, Line 25: add *s* after *observation*
Corrected.

Page 9, Line 2-6: The two parts of the sentence *The moisture structure (…) has been further studied…* are extremely separated and the sentence becomes difficult to read. You could rephrase it to something like: *The moisture structure upstream of the HPE studied by Lee et al. (2016) has been further analyzed. Three features are highlighted below: 1) the presence of …*
Corrected.

Page 9, Line 7: add commas before and after *located over south-eastern France*
Added.

Page 9, Line 8: The threshold of 1002 seems arbitrary, this might be a relic from back when the area of MSLP < 1002 hPa was the only shaded part of Fig. 3.
You are right. With the revised figure (better color scale), now the upper-level trough can be defined with a threshold of 1006 hPa.

Page 9, Line 10: remove comma after *air*
Removed.

Page 9, Line 11: remove commas before and after *q*, remove *thus*
Corrected.

Page 9, Line 15-16: change to *(…) is located ahead of the trough (red area in Fig. 3b)*
Corrected.
Page 9, Line 16: change to *Comparing the maps of q and* $\delta^{18}O_v$ *(crescent enclosed by a dashed line in Fig. 4a-b) reveals an additional…*
Corrected.

Page 9, Line 28, 29: repetition of *the hourly evolution of*
The later one has been removed.

Page 10, Line 3: move *slightly* to after *increase*
Corrected.

Page 10, Line 7: is it the upper level trough or the cold front? Those are two different things.
Corrected.

Page 10, Line 12: remove both, *the* and *level,* at the end of the sentence
Corrected.

Page 10, Line 13: remove *Then* at the beginning of the sentence, add a comma after *UTC*
Corrected.

Page 10, Line 14: which western edge?
It is the western edge of the trough. For sake of clarity, *at the western edge* has been removed.

Page 10, Line 27: insert *at* after *SI*
Corrected.

Page 11, Line 2: insert *the* before *two*
Corrected.

Page 11: Multiple instances of *history* where *evolution* might be the better word (e.g. lines 7 and 11)
We kindly propose to keep 'history' as it gives information about the evolution along the trajectory.

Page 11, Line 10: change title to *Phase one: the convective phase*
Corrected.

Page 11, Line 13-15: change to *The 3-day backward trajectories in Fig. 7 indicate that the air parcels arriving at SI in the 800-700 hPa layer originated over the North Atlantic.*
Corrected.

Page 11, Line 16: replace *are mostly* with *remain*
Corrected.

Page 11, Line 17: add *comma* after *SI*, *remove* rapidly
Corrected.

Page 11, Line 20: change *as well as* to *and*
Corrected.

Page 11, Line 22: change *mixing* to *they mix*
Corrected.

Page 11, Line 23: remove *occurs,* change *the median q value* to *the median of q*
Corrected.
Page 11, Line 27: change to *(…) before their arrival, showing that q and $\delta^{18}O_v$ increase rapidly in the last 12 hours before the parcels arrive over SI. Between 60 and 12 hours before their arrival (Fig. 8a, b), q and $\delta^{18}O_v$ are still relatively small, at around 2-6 g kg^{-1} and between -25 and -19 ‰, respectively. (Is there really in the dry pocket of upper-level trough? The trough itself should also be somewhere else this long before the event…)*
Corrected.

Page 12, Line 3: change to *for conditions in the Mediterranean*
Corrected.

Page 12, Line 3: *blue line* I do not see a blue line in the figure, does this refer to the dashed line?
Yes. It has been corrected to dashed line.

Page 12, Line 6: gray to purple – shouldn't this be green to purple?
Thanks for pointing this out. Green to purple is correct.

Page 12, Line 14: change to *Horizontal SWI distribution*
Corrected.

Page 12, Line 15: remove *feature,* remove *a region of enhanced convective activity and*
Corrected.

Page 12, Line 16-18: change *multiple convective cells* to *a convective line, which extends (…) and is located ahead of the surface cold front. Westerly and north-westerly winds prevail at 542 m ASL while south-westerly wind is dominant at 2455 m ASL.*
Corrected.

Page 12, Line 18-21: change to *Within the precipitation area, lower $\delta^{18}O_v$ values (< -16‰) than in the vicinity are found at 542 m ASL while locally higher $\delta^{18}O_v$ values are found at 2455 m and 5565 m ASL (Fig. 10d, f), indicating the presence of strong and deep convective mixing. This convection causes the vertical transport of SWI-depleted moisture…*
Corrected.

Page 13, Line 1: remove *large*
Corrected.

Page 13, Line 7: remove *of*
Corrected.

Page 13, Line 9: replace *at* with *along*
Corrected.

Page 13, Line 10: change to *Additional moisture is then…*
Corrected.

Page 13, Line 12: add *s* after *hour*, remove *the… values*
Corrected.

Page 13, Line 13: change *strongly increase* to *increase strongly*
Corrected.

Page 13, Line 19: remove third zero
Removed.

Page 13, Line 23: add comma after *altitudes*
Corrected.

Page 13, Line 24: the vapor take-up isn't over North Algeria, it's over the Mediterranean sea
Corrected to water *vapour in the Strait of Sicily*.

Page 13, Line 24: end sentence after *(Fig. 11a-b)* and remove *and* before *the median q,* change to *the median of q*
Corrected.

Page 13, Line 25-26: change *precipitation onset* to *the onset of precipitation*
Corrected.

Page 13, Line 26, 27: repetition of *moist and SWI-enriched*
Corrected.

Page 14, Line 2: add *s* at the end of *parcel,* add comma after *particular*
Added.

Page 14, Line 7: change to *Horizontal SWI distribution*
Corrected.

Page 14, Line 12: this is still hardly visible at 5500 m, all shades of blue look almost exactly the same in print
For sake of clarity, the values have been stated in the sentence.

♣ Page 14, lines 15-17
"[…] and $\delta^{18}O_v$ are relatively low from near the surface (between −22 and −26 ‰, 542 m ASL) to mid altitudes of 5565 m ASL (between −30 and −36 ‰) (Fig. 13b, d, and f)."

Page 14, Line 15: the black line shows very little decrease, it's visible for the others though multiple repetitions of *moisture plume over North Africa* or similar in this line.
Corrected to 'red to purple line' and the repetitions have been corrected.

Page 14, Line 23: replace *becomes more depleted* with *decreases*
Corrected.

Page 14, Line 24: replace *that* with *which*
Replaced.

Page 14, Line 24: I thought P2 was dominated by large scale ascent, not convection.
The sentence has been clarified.

♣ Page 14, line 27-28
"[…] the moistures which feeds the convection during P2 is related to large scale ascent from North Africa"

Page 14, Line 24-28: This paragraph seems like it belongs to section 4.2.1, not 4.2.2.
As this paragraph is a summary of Section 4.2, we kindly propose to keep the location at the end of the section.