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 #2 comments

General Comments

A case study of a heavy precipitation event over southern Italy during HyMeX IOP13 in October 2012 has been discussed by far-reaching and detailed interpretation of model output. However the only validation of the results presented are numerous rain-gauge data from stations in southern Italy. Although the analysis of the model results are sophisticated and as far as possible reliable and in accordance with known synoptic and sub-synoptic flow pattern, any link to real processes is missing due to missing observations.

By the title the authors guide the reader to a case study of combined convective and large scale precipitation formation. But this is only partly the case. Studying the manuscript we can learn, that with the use of the selected models, how much in detail we can interpret and consequently use the COSMOiso model for small scale precipitation analysis and thus for forecasting issues. This should clearly be indicated in the title and it should be stated in the abstract that trajectory calculation and simulated stable water isotope analysis give valuable additional information for weather interpretation and forecasting purposes. The authors are asked to rephrase the title accordingly and to rewrite the abstract and conclusions. Otherwise, a case study based on model data only and without any supporting data (with the exception of the precipitation data) is not sufficient for publication.

Agreed. This study is entirely based on model simulations. We have been looking at SWI measurement obtained from space-borne retrievals, the Infrared Atmospheric Sounding Interferometer (IASI). IASI measurements provide continuous datasets in space at the global scale with coarse vertical resolution and limited precision. A recent retrieval algorithm (Lacour et al., 2017) provides δD in the middle troposphere (3-6 km column) with an error of 38 ‰ in cloud free regions. Figure A shows the IASI-retrieved δD and q maps of the western Mediterranean on 15 October 2012. The enriched air mass (δD ≥ –150 ‰, q ≥ 7 g kg^{-1}) is captured by IASI in the strait of Sicily (around 12–22°E, 30–38°N), as similarly as seen in COSMOiso simulation (see Figure 4 of manuscript).

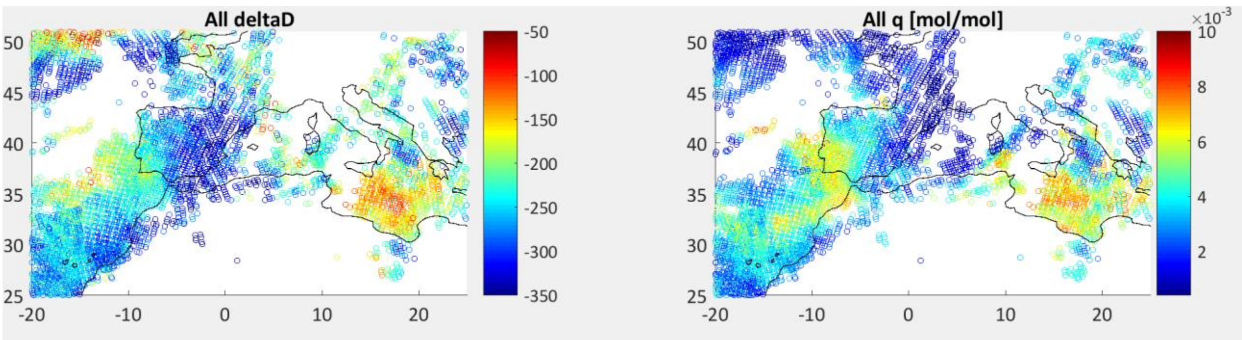

Figure A. Maps of δD (left) and q (right) measured by IASI on 15 October 2012 (both morning and evening orbit).

When comparing the IASI-retrieved δD and COSMOiso-derived δD in the western Mediterranean region (-10–25°E, 25–45°N) we see the IASI retrievals are biased high by more than 30 ‰ (Figure B). This comparison shows a reasonable agreement between IASI and COSMOiso, in spite of the bias. However, due to the temporally and spatially limited sample of IASI products associated with a single convection event, we have decided to use purely a modelling approach to demonstrate the usefulness of SWI data for understanding moist processes associated with a HPE. Correspondingly, the title, abstract, introduction, and conclusion have been corrected to specify this. Nevertheless, the comparison between IASI and COSMOiso provides a motivation for future studies to demonstrate the long-term (monthly to seasonal) SWI characteristics in connection to the HPE in the western Mediterranean basin.

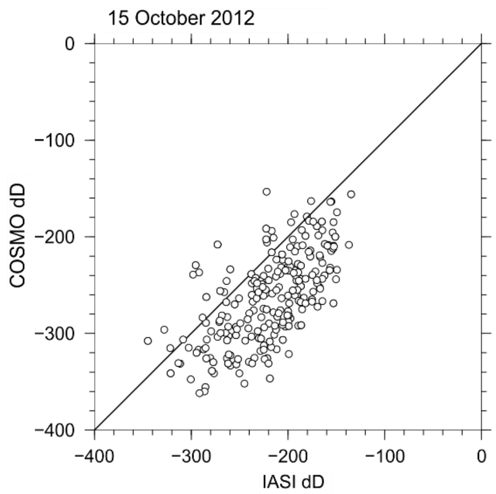

Figure B. The IASI-retrieved δD and COSMOiso-produced δD in the western Mediterranean region on 15 October 2012 (both morning and evening orbit).

Accordingly, the following changes have been made:

♣ Page 1, line 2-3 (title)

"Contrasting stable water isotope signals from convective and large-scale precipitation phases of a heavy precipitation event in Southern Italy during HyMeX IOP 13: a modelling perspective"

♣ Page 1, line 15-17 (abstract)

"The dynamical context and moisture transport pathways embedded in large scale flow and associated with a heavy precipitation event (HPE) in Southern Italy (SI) are investigated with the help of stable water isotopes (SWIs) based on a purely numerical framework."

♣ Page 4, from line 23 (introduction)

"SWI measurements are mainly obtained from space-borne retrievals (e.g. Schneider et al., 2016; Lacour et al., 2017) and ground-based in-situ laser spectroscopy (e.g. Aemisegger et al., 2012). The space-borne measurements provide continuous datasets in space at the global scale with coarse vertical resolution and limited precision. On the other hand, ground-based measurements with high temporal resolution are only available from a few locations and from dedicated field campaigns. In particular, the data availability for the Mediterranean region is very limited. A notable exception is the airborne dataset acquired around Corsica (Sodemann et al., 2017) during the first Special Observing Period of the Hydrological cycle in the Mediterranean

Experiment (HyMeX SOP-1, Ducrocq et al., 2014). However, it does not include SWI observations for the days under scrutiny in this paper. Due to these limitations, we use a model to demonstrate the usefulness of SWI data for understanding moist processes associated with a Mediterranean HPE, for the first time."

♣ Page 16, from line 5 (conclusion)

"[…] Although our study is entirely based on a model simulation, the results suggest that the information on mesoscale moist dynamical processes and moisture transport that is contained in SWI, when combined with SWI observations, can provide very useful constrains on the representation of such processes in numerical models.

Our study is the first study to investigate the potential benefit of SWI in the context of a HPE in the Mediterranean. As such, our study provides a proof of concept of the usefulness of SWI data to understand the variety of origins and moist processes associated with air masses feeding the convection over SI. This will be further investigated in future research using SWI measurements obtained from various platforms, e.g. ground-based, near surface, airborne (Sodemann et al., 2017), and space-borne. Our modelling study will also allow designing forthcoming tailored field campaigns in the Mediterranean region."

After redirection the scope of the paper, precipitation process information based on trajectory and SWI model output can be a helpful tool to examine actual weather situations governed by mutual evaporation-condensation processes. This is relevant scientific research and within the scope of ACP as the paper introduces additional parameters in operational weather analyses. The relevant SWI literature is cited by the authors, and the model set up is explained sufficiently. The analysis of the model results is accurate and detailed. The description of the flow field and the evaporation-condensation cycle are reliable. The structure of the paper is comprehensible. Some comments on figures, abbreviations, text etc. see "minor points".

I recommend the paper for publication in ACP after redirecting the purpose of the paper.

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.

Minor comment

1. P1, L15 (new): Moisture transport pathways embedded in large scale flow and associated…

Corrected.

2. P2, L26: The paper "Diagnostic study of a HyMeX heavy precipitation event over Spain by investigation of moisture trajectories (Rohner, L., Nerding, K.-U., Corsmeier, U., 2016, Quarterly journal of the Royal Meteorological Society)" shows the analysis of a HPE by combination of simulations and observations including moisture trajectories. In "Sodemann et al. (2017)" the potential of airborne measurements of SWI (during HyMeX) is shown.

Thanks for noting the reference of Röhner et al., 2016. We have included the paper in the reference list (P2, L27), while Sodemann et al. (2017) and the potential of airborne measurement of SWI have been emphasized in P16, L14.

3. P3, L15: better: … condensation cycles during…

Corrected.

4. P3, L20: explain the expression in brackets in a separate sentence for better readability.

Corrected.

♣ From Page 3, line 19

"[...] For instance, low δ^2H (typical range between –160 and –180 ‰) or $\delta^{18}O$ (i.e. range between –20 and –30 ‰) values in atmospheric water vapour at surface indicate low air mass temperatures and strong rainout of air parcels (e.g. Jacob and Sonntag, 1991; Yoshimura et al., 2010), whereas high δ^2H (typical range between –120 and –100 ‰) or $\delta^{18}O$ (range between –18 and –14 ‰) indicate high air mass temperatures and recent admixture of fresh ocean evaporate. The δ notation describes the concentrations of the heavy isotopes relative to the isotope ratio of the Vienna Standard Mean Ocean Water– RVSMOW, by for instance, $\delta^{18}O$ = (Rs/RVSMOW – 1) × 1000, where Rs = $[H_2{}^{18}O]/[H_2{}^{16}O]$ is the isotope ratio of a water sample."

5. P4, third paragraph: abbreviations SI, IOP, P1, and P2 have been explained before in the abstract.

The abstract and the main text should be considered as 2 separate entities. Hence, acronyms need to be defined in the main text, even if they already appear in the abstract.

6. P6, L21: refer to Fig. 1

Corrected.

7. P6, L26: refer to Fig. 2

Corrected.

8. P8, L13: ... transported from northern Africa...

Corrected.

9. P8, L15: isn't it 314−330 K instead of 308−326 K?

Corrected to 315−330 K with improved color scale of Fig. 3.

10. P8, L23: isn't it western edge of the Ty-box instead of north-eastern edge?

Corrected to western edge.

11. P8, last paragraph: this paragraph should be removed to section 4

Thanks for suggestions. The paragraph has been moved to the beginning of section 4.

12. P9, L9: The cold front is often mentioned in the text but never indicated in the figures (with exception of Fig. 14, conceptual model).

Agreed. 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.

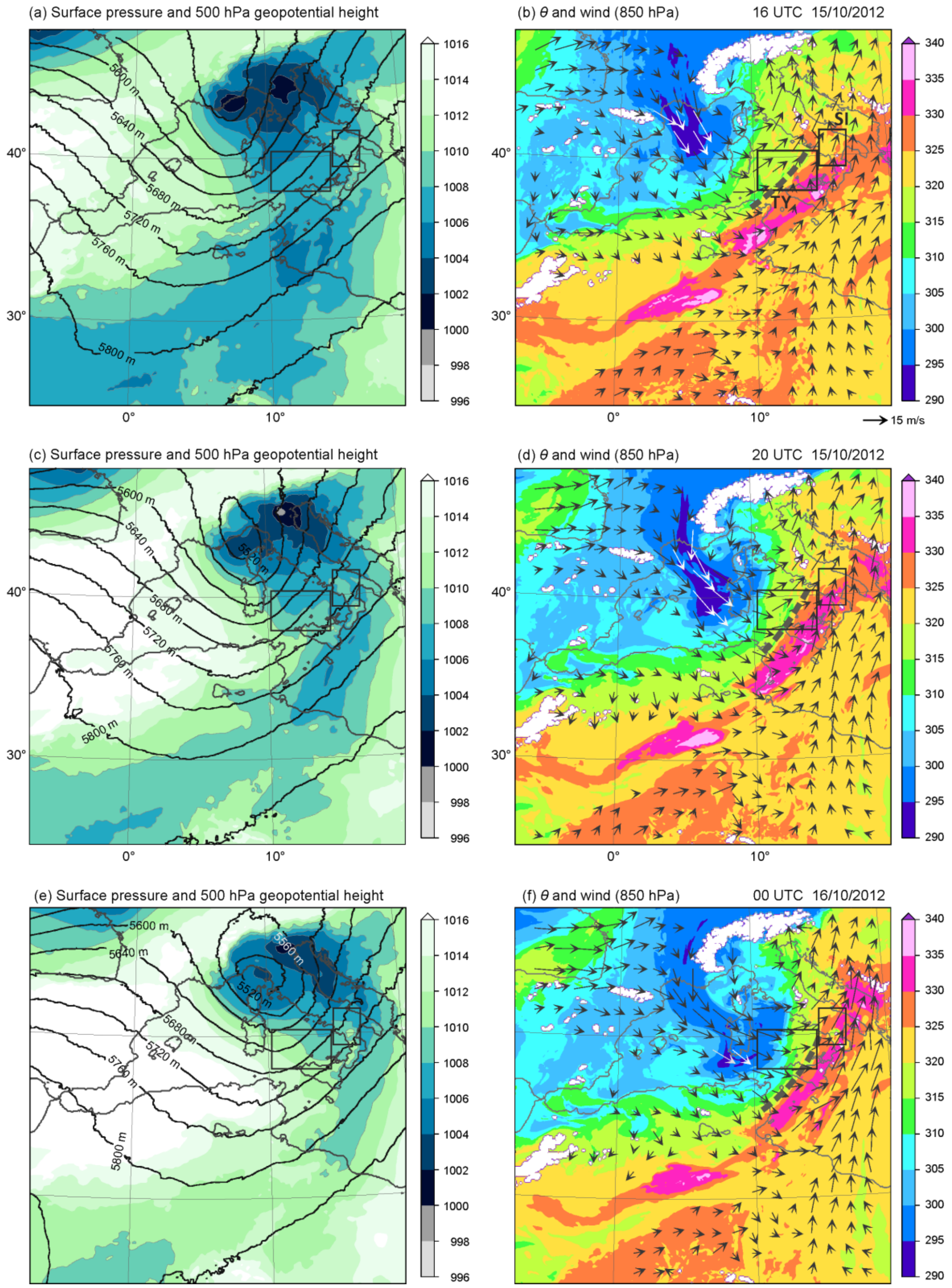

Figure 3. Horizontal distributions of sea level pressure (shading) and geopotential height at 500 hPa (contours) (left), and potential temperature, ϑ (shading), and wind (black and white arrows) at 850 hPa (right) at 16 UTC (top) and at 20 UTC (middle) 15 October 2012, and 00 UTC on 16 October 2012 (bottom) 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.

13. Section 4.1: The caption "Distribution of SWIs… prior to HPE" does not fit to the text: the interval with precipitation (16 UTC to 07 ITC) is discussed in this paragraph.
Agreed. We have restructured Sections 3 and 4. Section 4.1 has been combined with section 3, and the corresponding new subsection is entitled "Distribution of SWIs over the Mediterranean".

14. P12, L15: Figs. 8c and 8d do not exist.
Corrected to Figs. 10c, d.

15. P14, L24: … (grey encapsulated area in Fig. 14a). In the figure the area is called "blue encapsulated".
Corrected consistently to "green encapsulated area".

16. Figure 3: use isobars for showing the surface pressure field. Indicate the position of the cold front.
The sea surface isobar and geopotential height at 500 hPa have been shown in the left panels of Figure 3 to show the upper level trough. In the right panels, the horizontal wind at 850 hPa is indicated together with ϑ at 850 hPa, while the position of cold front is defined by a large ϑ gradient of 315–330 K (please see our reply for comment #12).

17. Figure 5: skip the upper and middle color bars.
As suggested the color scale has been adjust for sake of readability. With a suggestion from other referee, sections 3 and 4 have undergone restructuring to describe the core results more concisely. By this, Figure 5 have been re-ordered to Figure 4.

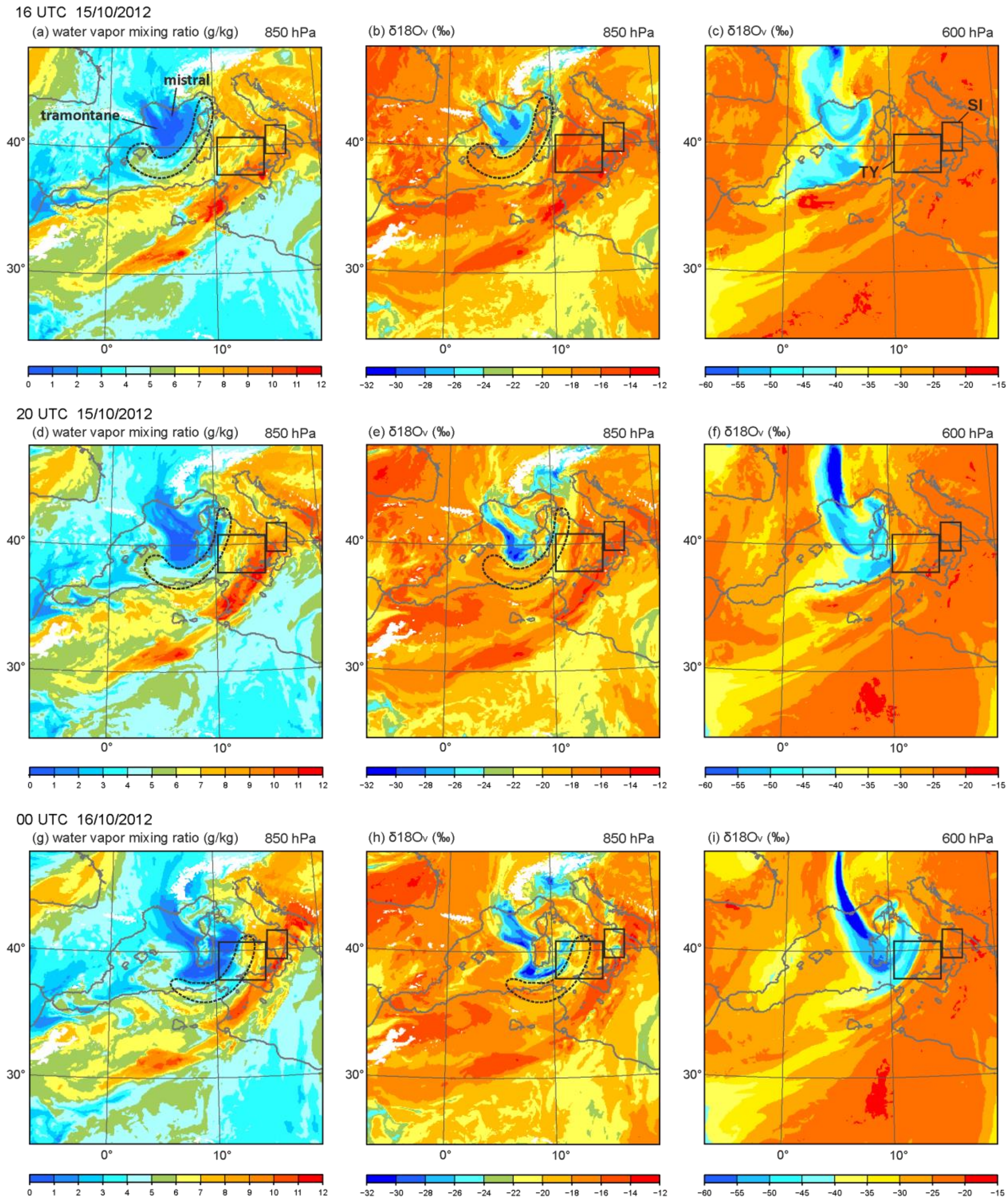

Figure 4. Horizontal distributions of water vapour mixing ratio at 850 hPa (left), $\delta^{18}O_v$ at 850 hPa (middle) and $\delta^{18}O_v$ at 600 hPa (right) at 16 UTC (top) and 20 UTC (middle) on 15 October 2012, and 00 UTC on 16 October 2012 (bottom).

18. Figure 8: a color bar is missing.
The color bar is now added to Figure 8.

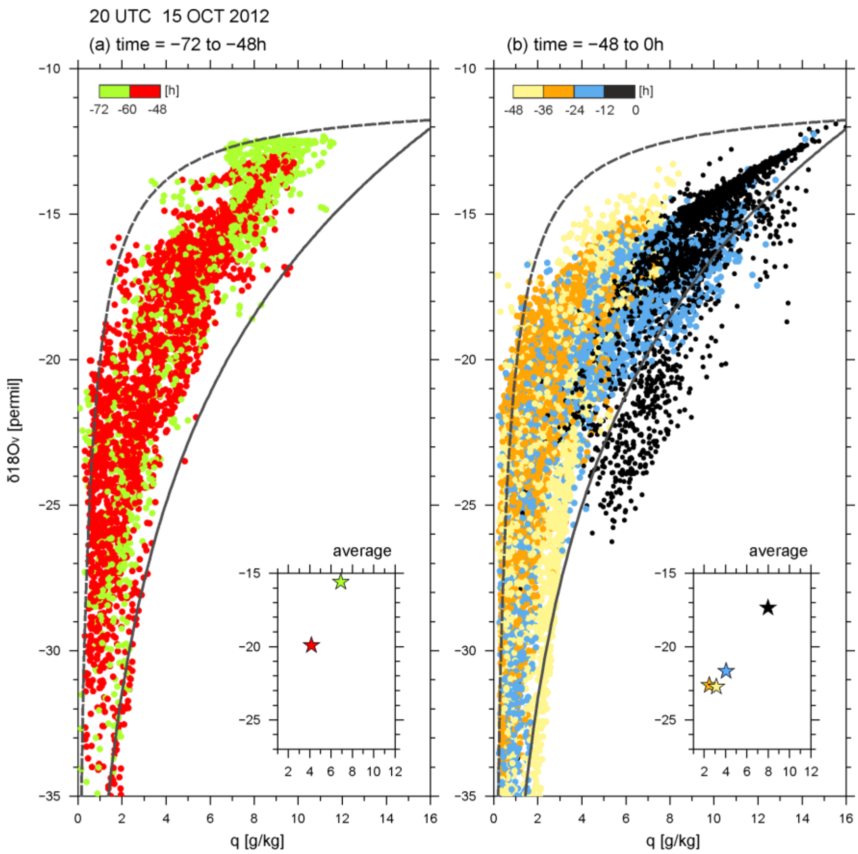

Figure 8. Scatter diagram of q and $\delta^{18}O_v$ along the backward trajectories of Figure 7 during (a) the times between −72 and −48 h, and (b) times between −48 and 0 h every 12 hours from 20 UTC on 15 October 2012. The colour of dot changes every 12 h. The mixing and Rayleigh lines are indicated 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.

19. Figure 10: changing color bars for the sub-figures makes it difficult to interpret figure differences.

As suggested, a single color bar has been used for plots related to $\delta^{18}O_v$ (Fig. 10b, d, and f), and a single color bar was used $\delta^{18}O_r$ (Fig. 10c, e) and $\delta^{18}O_s$ (Fig. 10g).

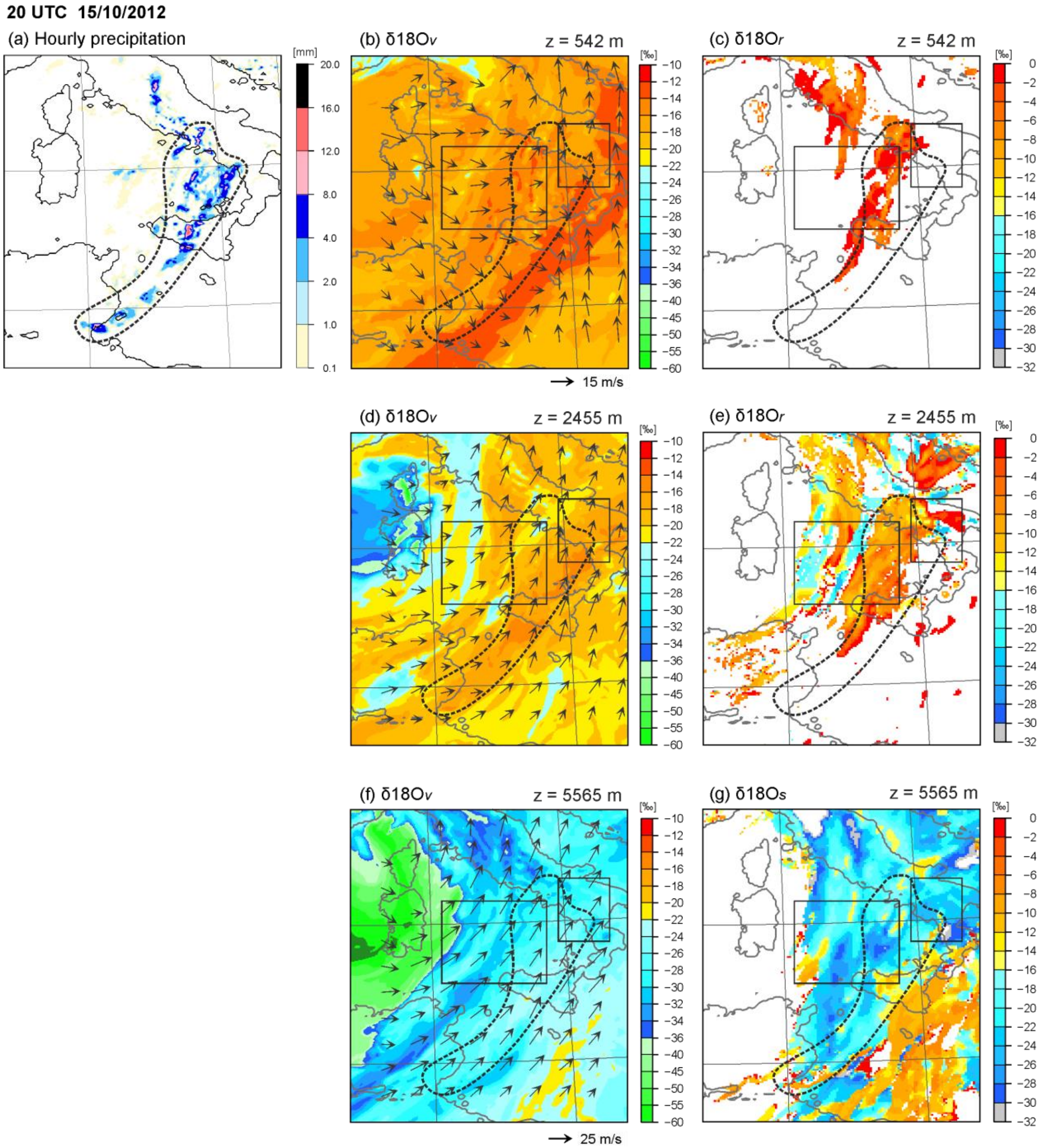

Figure 10. Horizontal distributions of (a) surface hourly precipitation (mm), $\delta^{18}O_v$ (‰) at (b) model level 8 (about 542 m ASL), (c) model level 16 (about 2455 m ASL), and (d) model level 23 (about 5565 m ASL, $\delta^{18}O_r$ (‰) at (e) 542 m ASL and (f) 2455 m ASL, and $\delta^{18}O_s$ (‰) 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.

20. Figure 13: as Fig. 10

Figure 13 has been improved in the same way of Figure 10.

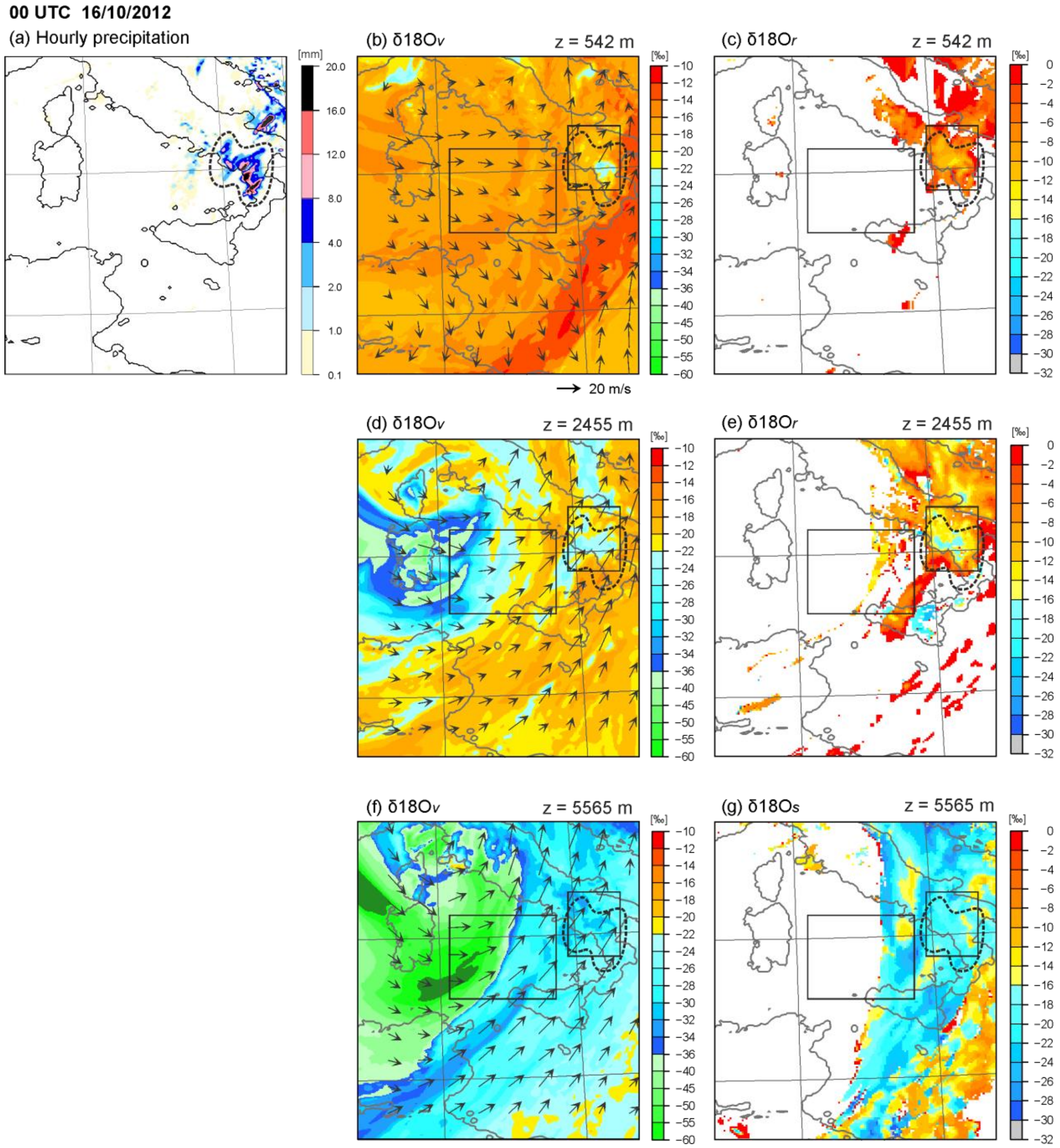

Figure 13. Same as Figure 10 but for 00 UTC on 16 October 2012.

21. Figure 14: the color differences (grey, blue, yellow shading) is difficult to read if manuscript is printed.
Corrected to green, yellow, and red shading for better readability.

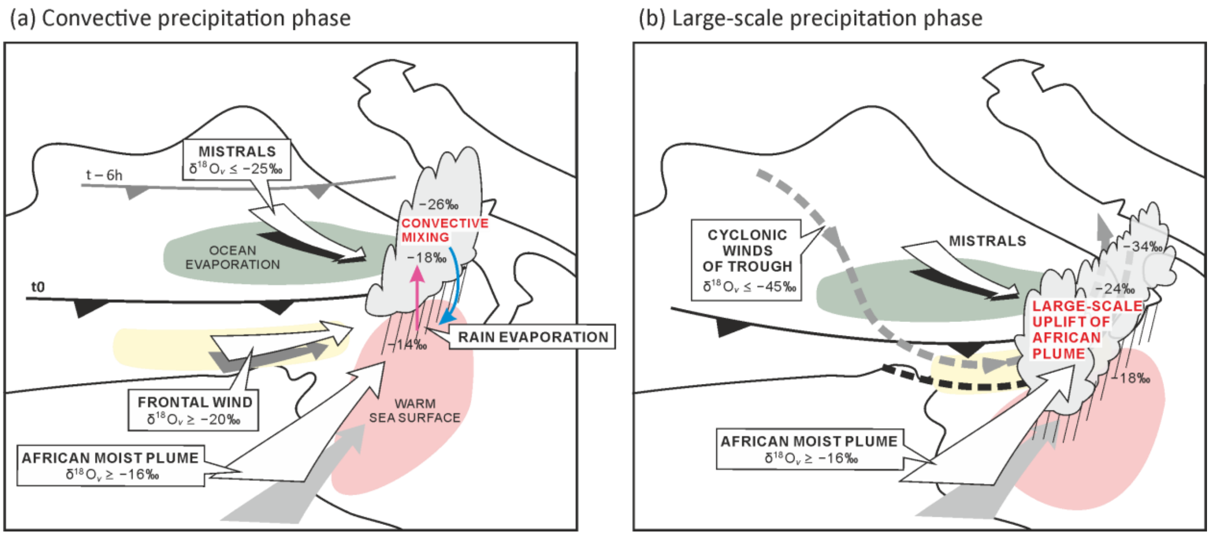

Figure 14. Schematics summarizing the main processes and the key features of water vapour isotopologues associated with deep convection upstream of SI and leading to the Phase 1 (a) and Phase 2 (b) of the HPE. In (a) and (b), white descending arrow indicate the mistral wind behind the edge of the cold front (thick black line). The white arrow in the yellow-shading encapsulated area illustrates the frontal wind at 850 hPa, and the white arrow in the red-shading encapsulated area (warm sea surface) indicates the elevated African moist plume. In (a), convective ascent and precipitating downdraft are depicted by red and blue arrows, respectively. In (b), the southern edge of upper trough is indicated by black dashed line and the cyclonic flow of the trough is indicated by grey dashed line.