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 #1 comments

General Comments

The authors present model simulations of isotope ratios, but there is no link to observations. Are the authors suggesting that observations from e.g. the HyMeX IOP 13 could be compared to their model results to gain additional insights? If yes, how? If not, why not just stick to a trajectory analysis? In other words, what additional insights (if any) are gained by using COSMOiso here?

In this study, a trajectory analysis based on a COSMOiso simulation has been done to investigate the moist processes in air masses associated with a heavy precipitation event (HPE) along their pathway. Stable water isotopes (SWI) experience fractionation during phase transition of hydrometeors, and hence can record information about evaporation and condensation processes during the transport of air parcels. Since the strength of fractionation depends on the meteorological conditions (temperature and saturation level), the SWI characteristics thus have led to an improved understanding of key processes affecting atmospheric humidity. Our study serves as a model-based proof of concept that such additional insights can also be obtained regarding convective precipitation events in the Mediterranean. In this way, we provide a basic motivation for future observational studies using SWI. To date, not many campaign datasets exist that would allow such observational studies yet, but with the recent advent of field deployable high precision laser spectrometric instruments, tailored field experiments become possible and will be done in the near future.

The analysis using three dimensional (3D) SWI (both $H_2^{16}O$ and $H_2^{18}O$) fields obtained from COSMOiso shown in Figures 5, 7, 8, 9, 10, 11, 12, and 13, give insights into the different moist processes occurring in the air parcels approaching Southern Italy. Especially the 3D q–δ analysis (shown in Figures 8, 9, and 12) reveal the importance of mixing, condensation, and enriching processes occurring along the moisture transport pathway. Previous studies demonstrated the usefulness of SWI to better understand meteorological processes and moisture transport, nevertheless there are still very few studies focusing on the application of SWI to investigate moist processes associated with HPEs. In particular, we see a great potential in the use of SWI for better understanding the moisture dynamics in HPEs occurring in the Mediterranean where deep convective systems are frequently observed and the origins of the moisture feeding the convection are diverse. The additional insights we can get from the COSMOiso simulation are now being more clearly emphasized in the conclusion section.

To address this, the following changes have been made.

♣ Page 16, line 1-14

"[…] We also highlight the role of the upper-level trough over the south Tyrrhenian Sea in driving the advection of the SWI-enriched plume from North Africa into the region of the deep convective system resulting in heavy precipitation over SI. Moreover, we demonstrate the importance of various moist processes such as mixing, condensation, and re-evaporation along the pathway based on the q–δ analysis using 3D SWI fields. 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 constraints 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."

It seems that the authors turn on a convection parameterization at 7 km horizontal resolution. Are the two parameterizations of microphysical processes consistent between the deep convection parameterization and the "large scale" microphysics parameterization? If not, how may this affect the results regarding the isotope ratios? Are the authors sure that the model skillfully represents the partitioning between parameterized and resolved precipitation or does this partitioning depend on details of the model formulation? What might be the effects of not representing this partitioning skillfully on the simulated isotope ratios? If the results were sensitive, would it even be worthwhile to try to improve the partitioning in the model or should one just wait until deep convection parameterizations become obsolete?
Of course the partitioning between convective and large-scale precipitation is somewhat artificial (there is not such separation in observations) and depends on the model as well as on the resolution (when going to finer resolutions, the model explicitly resolves a larger portion of the mesoscale convective activity). However, this partitioning is not the main aspect/goal of our study. In addition, we are confident that the current model setup is well-suited for the purpose of exploring the worth of isotope data for understanding mesoscale moist processes. The grid spacing of 7 km together with the Tiedtke convection scheme were 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.

I must admit that I do not fully understand the purpose of this manuscript. To me this study raises more questions than it answers. Major revisions will be necessary before I can recommend this study for publication.
We appreciate the time and effort you put in this review as well your mindful comments on our paper. In this study, using the hourly 3-D water vapour isotope data, we highlight the large variety of moisture sources and transport pathways that induced the two precipitation phases, and the isotopic characteristics of various air masses associated with upper-level trough, cold front, mistral, and African moist plume, that were involved in convection development. 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 constraints on the representation of such processes in numerical models. As such, our study provides a proof of concept of the usefulness of SWI data to understand moist processes associated with a Mediterranean heavy precipitation event with diverse origins and pathways of moisture feeding the convection. We have worked hard to comply with all of them. Replies to each comment are listed below.

Specific comment

1. Title and abstract: based on the title and abstract I would have somehow expected a connection with observations. The title should explicitly state that this is purely a modelling exercise.

Agreed. We have modified the title and abstract accordingly.

♣ 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."

2. Given that this is purely a modelling exercise, I would have expected either some sensitivity studies or else a more explicit description on how the model results presented here might be linked to either existing or to future observations.

Agreed. 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 from various platforms (also our response to the first general comment), can provide useful constrains on the representation of such processes in numerical models. In fact, several field campaigns involving SWI measurements are planned in the Mediterranean region.

♣ Page 16, line 9-14

"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."

3. Is the main point of this study a simulation of a quantity that has not been observed or are there fundamental new results that cannot be found in the existing literature? If this is the case, these points should at least briefly be discussed in the light of the existing literature.

Current SWI measurements are mainly obtained from space-borne retrievals (e.g. Schneider et al. 2017, Lacour et al., 2017) and ground-based in-situ laser spectroscopy (e.g. Aemisegger et al. 2012) as well as from monthly precipitation samples at various stations (GNIP; IAEA, 2006). 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 during the HyMeX SOP1 (Sodemann et al., 2017). 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. In this way, we provide a motivation and justification for future measurement efforts dedicated to this topic. As mentioned above, we have extended the conclusion section to make this clearer.

♣ 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."

♣ Page 16, line 5-14 (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."

4. Why was COSMOiso used and not just a simple trajectory analysis?

The additional insights we can get from COSMOiso simulation has been emphasized in conclusion section, as explained in the answer to the first general comment. The added value of an isotope enabled numerical simulation of this HPE event compared to a purely trajectory based study on moist processes, is that mixing, convective and cloud processes are included in a more detailed way. Trajectory-based studies have been done to investigate the contribution of different evaporative moisture sources for precipitation events (e.g. Sodemann and Zubler, 2010). But it is not straightforward to assess the relevance of different dynamical processes involved in moisture transport pathways solely based on trajectories. This is why a more sophisticated modelling approach is employed here.