**Review RC1 - acp-2022-12**

This is a well-written and comprehensive article that help understanding processes leading to negative water vapor d-excess observed in surface air during the ACE campaign, within the warm sector of an extra-tropical cyclone, south of South Africa.

The authors combine regional atmospheric modelling with water isotopes (COSMOiso simulation) together with 3 single-process air parcel models to understand the drivers of observed changes in water vapor isotopic composition.

They show that regions of low d-excess in surface water vapor are created by decreasing ocean evaporation and dew deposition at the ocean surface. Low water vapor d-excess close to the ocean surface is assessed to result from local air-sea interactions and to overwrite the advected d-excess signal.

I think this article allows better quantification and understanding of processes driving d-excess signal in near-surface ocean water vapor. In addition, the article structure guides the reader toward a good understanding of the authors' conclusions. I found this article very pleasant to read, with adapted figures. Consequently, I recommend this article to be published with minors revisions detailed bellow.

**Reply:** We thank the reviewer for their positive feedback, and their comments, which helped to improve the clarity of the manuscript.

**Minor comments**

**L37 : 2RVSMOW2.2** : typo? is the final **.2** right?

**Reply:** The $^{2}R_{VSMOW2}$ atomic isotope ratio is multiplied by 2 because of the two possible positions of the deuterium in the water molecule (see equivalence of atomic vs. molecular ratios in Kerstel, 2004 and Iannone et al. 2010). To avoid confusion we now use the molecular isotope ratio for the standard and write $^{2}R_{VSMOW2}=3.1152\times10^{-4}$ , while removing the multiplication by 2 in the definition of $\delta^{2}H$. The text was adapted accordingly.

**L169 : « αe »** is not described in the text (even if I agree it's a standard notation)

**Reply:** We added the following description:

"$\alpha_e<1$ is the equilibrium fractionation factor, $\alpha_k\leq1$ the non-equilibrium fractionation factor of vapour with respect to liquid."

**L177 : « supplement Fig.S3 »** cited first, why not S1 ?

Re-number all supplement figures.

**Reply:** We adjusted the order of the supplement figures.

**L177-178 : « The simulation is initialized with qa,0=5 g kg−1 (and, thus, hs=0.5 because qs=10.0gkg−1 at 14°C), Δq=10−3·(qs − qa), δ2Ha,0=−137 ‰ and δ18Oa,0=−19.5 ‰ »**

Why this choice ?

How is chosen the Δq factor 10−3? Does it have an influence on the results ?

**Reply:** Thank you for pointing out that this needs further clarification. For this example simulation and also for the idealized simulations, which we compared to the trajectories, the initial conditions were chosen based on the following considerations:

- We chose typical values of $\delta^{18}O$, $\delta^{2}H$, *q* and SST that we observed along the trajectories arriving in the warm sector of the discussed Southern Ocean cyclone in our $COSMO_{iso}$ simulation. More specifically, our choice was guided by conditions observed along trajectories that were calculated with $COSMO_{iso}$ wind fields. We specifically selected air parcels that experienced strong ocean evaporation.
- The proportionality factor $10^{-3}$ (referred to as *ei* in the following) is needed to relate the uptake increment $\Delta q$ to the vertical gradient in *q* following the formulation of bulk surface evaporation flux parametrisation, while neglecting the effect of wind speed. *ei* is important as it defines how quickly the parcel is saturated with respect to SST. The larger *ei*, the faster the parcel becomes saturated and the shorter its traveling time over the SST

gradient. The $COSMO_{iso}$ trajectories used in this study experience a decrease in SST of -6.5 [-8.1 – -4.5] °C over a distance of approximately 1000km while they are taking up moisture and *d* is decreasing (the values in the brackets denote the 5 – 95 percentile range).

A sensitivity experiment (Fig. RC1.1) shows that changes in *ei* over several orders of magnitude leads to changes in the decrease of *d* of less than an order of magnitude. A change in *ei* will lead to only small changes in isotopic evolution of the air parcel. The thin red vertical lines show the value of *ei* $=10^{-3}$ in the example simulation, which represents SST changes in the lower range of what can be observed along the $COSMO_{iso}$ trajectories (Fig. RC1.1b). Thus, the choice of *ei* can be considered conservative in terms of the air parcel's travelling distance and perceived SST gradient. Based on this sensitivity analysis, we decided to decrease *ei* to $5 \cdot 10^{-4}$ to increase the SST gradient for the example simulation.

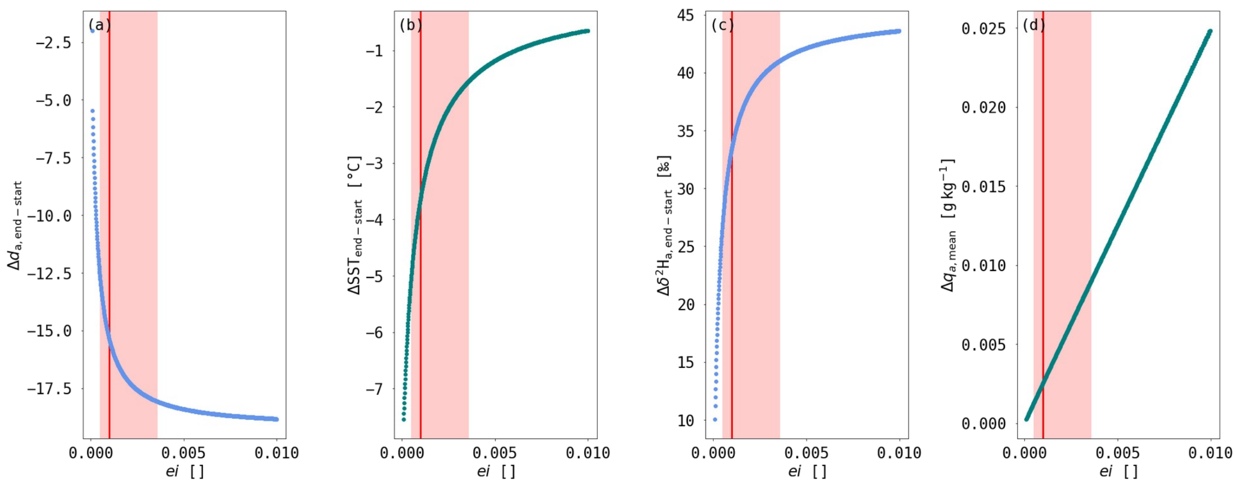


***Fig. RC1.1: Sensitivity experiment showing the change in d (a), SST (b) and $\delta^2H$ (c) for different values of ei with the same initial conditions as shown in the example simulation of APMevap, except for a lower isotopic composition of the ocean of -1.6‰ and -0.2‰ for $\delta^2H$ and $\delta^{18}O$, respectively (following a comment by reviewer RC2). (d) shows the mean $\Delta q$ during the simulations. The thin red vertical line shows the chosen ei value of $10^{-3}$ for the example simulation. The red shaded area denotes ei=$5 \cdot 10^{-4}$to 3.6 $10^{-3}$.***

- This assumption for $\Delta q$ is only needed for the idealised APMevap simulations. For the APMevap simulations for conditions along the trajectories, $\Delta q$ is defined by the change in *q* between two time steps diagnosed along the $COSMO_{iso}$ trajectories.

To clarify this point we added the following note:

"These initial values are chosen based on conditions observed during periods with ocean evaporation along the trajectories arriving in the warm sector of the discussed Southern Ocean cyclone in our $COSMO_{iso}$ simulation. We relate the uptake increment $\Delta q$ to the vertical gradient in *q* following the formulation of the bulk surface evaporation flux parametrisation, while neglecting the effect of wind speed and using a constant proportionality factor $5\cdot10^{-4}$. This proportionality factor determines the SST gradient perceived by the air parcel and sets the time until saturation in the air parcel is reached.”

**APMdew**

**L235-236 : « The simulation is initialised with hs=1.1, which means that qa,0=6.8gkg−1, Δq=8·10−4·(qs −qa), δ2Ha,0=−98 ‰, and δ18Oa,0=−13 ‰ .**

Again, why this choice? End of APMevap ? (seems yes from Figure 4, but with different hs)

Why Δq=8·10−4·(qs −qa) ?

**Reply:** The choices for the initial conditions of the APMdew simulations are based on the same considerations as for APMevap representing an air parcel in the warm sector that experiences dew deposition while being transported over an SST gradient. *ei* was chosen to represent the movement over a typical SST gradient by air parcels experiencing dew deposition in the warm sector. For $COSMO_{iso}$ trajectories calculated within the warm sector of the studied Southern Ocean cyclone, a typical SST change in such a situation is -1.5 [-4.0- -0.2] °C over a distance of approximately 500km.

A sensitivity experiment for different *ei* in APMdew simulations (Fig. RC1.2) shows, similar to APMevap, that *d* and $\delta^2$H change by less than an order of magnitude while *ei* changes up to two orders of magnitude. The simulated changes in isotopic composition are therefore only weakly sensitive to changes in *ei*.

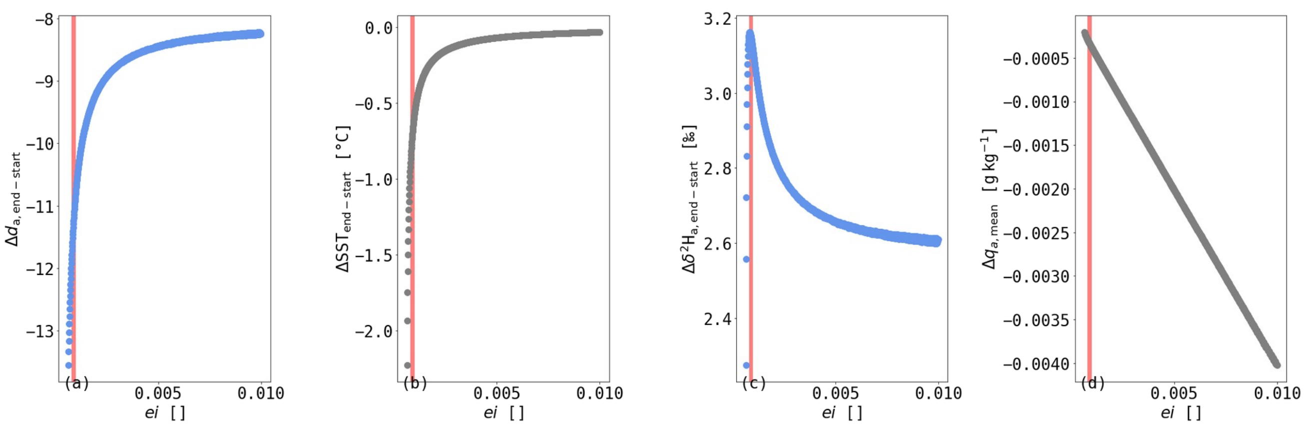


***Fig. RC1.2: Sensitivity experiment with APMdew showing the change in (a) d, (b) SST and (c) $\delta^2$H during the simulation for different values of ei with the same intital conditions as shown in example simulation of APMdew, except for a lower isotopic***

***composition of the ocean of -1.6‰ and -0.2‰ for $\delta^2H$ and $\delta^{18}O$, respectively (following a comment by reviewer RC2). (d) shows the mean Δq during the simulations. The red area denotes ei=8·10$^{-4}$ to 10$^{-3}$.***

We added a note on the reasoning behind the chosen initial values:

"As for APMevap, we chose the initialisation according to typical conditions observed during periods with dew deposition along the trajectories arriving in the warm sector of the discussed Southern Ocean cyclone in our $COSMO_{iso}$ simulation."

**Figure 3.h :** I was confused at the beginning between (h) above the purple line and hs in gray, maybe it's just me, it's clear for me now.

**Reply:** We exchanged SST and $h_s$ in panels 3.g and 3.h to avoid confusion.

**APMray**

**L269-270 : « Ta,0=8°C (which gives qa,0=6.7gkg−1), ΔSST=1°C, δ18Oa,0 = −15.0‰ δ2Ha,0 = −98‰ »**

Again, can you briefly explain why you choose these values ? (I can guess end of APMevap from Fig. 4)

**Reply:** For the initial conditions of APMray, values in between the end values of APMevap and the start values of APMdew, were chosen. This choice is based on the assumption that the air parcel is lifted from the marine boundary layer to higher levels before condensation occurs. Due to a change in the isotopic composition of the ocean (based on a comment by reviewer RC2), we slightly adjusted the starting position of APMray in the example simulation to -15‰ and -110‰ for $\delta^{18}O$ and $\delta^2H$, respectively, and again choose values between APMevap end and APMdew intial conditions.

We added a note in the text:

"These initial values are chosen in between the end values of APMevap and the start values of APMdew,. This choice is based on the assumption that the air parcel is lifted from the marine boundary layer to higher levels before condensation occurs."

**Figure 4 :** This scheme highlights very well what you do in Section 3. Maybe you could move it at the beginning of Section 3 together with a small introduction of the APM and 3 example simulations presented after. It would help the reader to better understand the link between the 3 APMs, and also between the 3 examples (e.g. choice of start values in the examples).

**Reply:** This is a good idea. We moved Sect. 3.4 to the beginning of Section 3 thereby introducing the air parcel models with a comparison of the example simulations as shown in Fig.4 (new Fig. 2) and followed by the more detailed discussion of the APMs. This restructuring led to only small adjustments in the text (see revised manuscript).

**Figure 5 :** Use a continuous colormap for potential temperature, unless you can justify the threshold at 294 K to separate warm and cold sectors?

**Reply:** We adjusted the colormap of Figure 5.

Is **Θe** the same as **θe** in the text ?

**Reply:** Yes, thank you for pointing out this typo, we made this consistent throughout the text.

**« The white contours show that warm temperature advection mask. »** Add information of the definition of this mask, or refer to the text.

**Reply:** We added the information on the warm temperature advection mask. We now write at line 333:

"The region of the warm sector is defined by the near-surface air-sea temperature difference as described in Thurnherr et al. (2021). If the difference between the 2m air temperature and the sea surface temperature is above 1°C, the region is associated with the advection of warm and moist air defining the warm temperature advection mask indicated by the red contours in Fig. 5. The warm sector region encompasses a triangular region in between the cold and warm front which is dominated by warm temperature advection. When referring to the warm sector in the following, we are referring to this area of warm temperature advection."

**L304 : « sharp gradients in THE »** What is THE? TPE = **θe** ? or not?

**Reply:** Yes, THE = $\theta_e$. We made this consistent throughout the text. Furthermore, we justified our choice use $\theta_e$ at 900 hPa to identify the fronts of this Southern Ocean cyclone. We now write at L. 304:

"Both fronts are visible by clear kinks in the sea level pressure contours and sharp gradients in equivalent potential temperature ($\theta_e$)at 900 hPa indicating a transition zone between two airmasses, i.e. dry and cold airmass with low $\theta_e$ and warm and moist airmasses with high $\theta_e$ (see Schemm et al. 2017 for a discussion on objective midlatitude front identification)."

**L305 :** Define **θe** in the text

**Reply:** We added this on line 324:

“Both fronts are visible by clear kinks in the sea level pressure contours and sharp gradients in equivalent potential temperature ($\theta_e$) at 900 hPa”

**Figure S1 / Figure S2 / hs in Figure S4:** Rainbow-like colormaps are to be proscribed for continuous variables, use a continuous colormap instead.

https://www.climate-lab-book.ac.uk/2014/end-of-the-rainbow/
https://mycarta.wordpress.com/2012/10/14/the-rainbow-is-deadlong-live-the-rainbow-part-4-cie-lab-heated-body/

**Reply:** We carefully reassessed the colormaps in Fig. S1, S2 and S4 and replaced them with continuous colormaps.

**L317 : « A good agreement of measured and simulated hs and qa can be seen (Fig. 6). »** I cannot see $q_a$ in Fig. 6. Can you add air temperature in Fig. 6 too ?

**Reply:** Thank you for pointing this out. The text is referring to another version of the figure. We adjusted the figure by adding specific humidity and air temperature.

**L318-320 « The simulated precipitation compares well with the measurements except for the few hours around 00 UTC on 26 December 2016, during which enhanced precipitation is simulated, while no precipitation has been measured. »**

Why focus on the 26 December 2016 00 UTC when model-observation differences are way larger from 26/12 12h ?

Model mostly underestimate precipitation, I don’t understand the focus on the very show period when it is the opposite?

I would say that the first peak is well represented but the second peak is off (lower precipitation, and too late ?)

**Reply:** Thank you for pointing out this typo. The sentence is focusing on a time step which does not show the largest model-measurement differences and also lies outside of the warm advection event time period. We agree that the first peak in precipitation is represented better in the $COSMO_{iso}$ simulation than the second peak.

In our opinion precipitation is reasonably well simulated by $COSMO_{iso}$ in terms of intensity and timing. We cannot expect from COSMOiso or any other regional model to simulate precipitation exactly at the right place at the right time and with the right intensity, even in the case of a precipitation feature that is dominated by large-scale ascent such as along a front. We applied a spectral nudging of the large-scale winds above 850 hPa, but this does not prevent the model from developing mesoscale circulations, which deviate from the real meteorology and modulate the intensity, timing and location of high-intensity precipitation cells along the front.

We adjusted the text on lines 341-343 in the following way:

"The simulated precipitation compares well with the measurements on 26 December but is shifted and shows lower intensity on 27 December 2016, during which enhanced precipitation is measured around 6 UTC, while simulated precipitation occurs after 12 UTC with lower intensity. This shift and underestimation led to too low $h_s$ and $q_a$ in the simulation in this time period."

**L340** Is **Θe** the same as above, i.e. **θe,** i.e. equivalent potential temperature at 900 hPa ?

**Reply:** Yes, we made this consistent throughout the text.

**L354-356 « Furthermore, the back-trajectories arriving in region CF, were located in region WF 48 h before arrival also coming from a region of high d with values above 20 ‰ (Fig.7a and supplement Fig. S4). »**

For CF, Fig. 7a shows low d 48h before as in Fig.S4. In Fig. S4, high d for CF is around 72h before?

**Reply:** Yes, the CF trajectories were in a region of high dexc 72h before arrival in CF and 24h before arrival in a low d region which will form region WF at 22 UTC 26 Dec 2016. We adjusted the text as follows to make this clear:

"Furthermore, the backward trajectories arriving in region CF, were located in a region of low *d* 48h before arrival (Fig. 7a) also coming from a region of high *d* with values above 20‰ 72h before arrival in region CF (see supplement Fig. S1a)."

**References**

Iannone, R. Q., Romanini, D., Cattani, O., Meijer, H. A. J., and Kerstel, E. R. Th. (2010), Water isotope ratio ($\delta^2$H and $\delta^{18}$O) measurements in atmospheric moisture using an optical feedback cavity enhanced absorption laser spectrometer, *J. Geophys. Res.*, 115, D10111, doi:10.1029/2009JD012895.

Kerstel, E. R. T. (2004), Isotope ratio infrared spectrometry, in *Handbook of Stable Isotope Analytical Techniques*, edited by P. A. de Groot, chap. 34, pp. 759– 787, Elsevier, Amsterdam.

Schemm, S., Sprenger, M., Martius, O., Wernli, H., and Zimmer, M. (2017), Increase in the number of extremely strong fronts over Europe? A study based on ERA-Interim reanalysis (1979–2014), *Geophys. Res. Lett.*, 44, 553– 561, doi:10.1002/2016GL071451.

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