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Abrupt excursion in water vapor isotopic variability during cold fronts at the Pointe Benedicte observatory in Amsterdam Island

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The manuscript “Abrupt excursion in water vapor isotopic variability during cold fronts at the Pointe Benedicte observatory in Amsterdam Island” presents two years of measurements of stable water isotopes in water vapour from Amsterdam Island. This time series is used together with measurements of gaseous elemental mercury and meteorological variables to analyse cold frontal passages at Amsterdam Island. Additionally, model simulation with ECHAM6-wiso and LMDZ-iso are evaluated using the measurements at Amsterdam Island.

This manuscripts presents a unique time series of stable water isotopes in water vapour in the under-sampled area of the Southern Indian Ocean. The calibration of the water vapour isotope data follows established standards in the community. While the dataset presented here is of unique coverage, the relevance of the analysis and the conclusions is not convincing. Furthermore, the figures presenting the analysis are often difficult to read and many important information is in the supplement figures. In its current state, the manuscript lacks a motivation for the presented analysis and how it improves the understanding of the atmospheric water cycle. It might be worth considering a submission to Earth System Science Data (ESSD) instead of ACP.

Major comments:

- **Model-measurement comparison**
  The comparison of ECHAM6-wiso and LMDZ-iso with the measurements at Amsterdam Island leads to the main conclusion that “the isotopic composition of water vapor is a powerful tool to identify aspects to be improved in the general circulation models, such as the horizontal resolution which may influence the representativity of the vertical dynamics.” Why are *isotope-enabled* models needed to illustrate that horizontal resolution influences vertical dynamics in GCMs? This is, for example, already evident when comparing the vertical wind fields in Fig.7. Which “aspects to be improved”, other than the horizontal resolution, were identified in this study?

- **Cold front analysis**
  The analysis is based on d18Ov excursions which are described as cold front events. The selection and analysis of these excursion with respect to cold frontal dynamics on a synoptic scale is missing. It is therefore difficult to interpret the described events with respect to the large-scale dynamics. In detail:
  - The analysis focuses on 11 events of cold fronts. These fronts and their spatial structure is not described in the manuscript and there are no synoptic figures describing a typical situation during a cold front passage, except for a few weather analysis charts in the supplementary information. How are the cold fronts identified? What are the properties of the cold fronts? How much of the annual precipitation is represented by cold frontal precipitation?
  - The 11 events are chosen using the following criteria: “ The green rectangles indicate the period with (1) correlation coefficient >-0.5 between d-excess and d18O of water vapor and (2) occurrence of a negative excursion in water vapor d18O.” There are (from eye) other events that could fall into these criteria. For example, before the event in ~March 2021 (6^{th} green rectangle in Fig. 3), there is an event agreeing with criteria (1) and showing a strong decrease in d18Ov. Why are other events not included? And how is a negative excursion in d18Ov defined?
  - The analysis of the 11 events is mainly qualitative, and it is difficult to follow the description of the 4 events from 01-03/2020. All map plots and most of the vertical cross sections of these events are in the Supplementary Information, which makes it difficult to understand the synoptic situation during the events and the model performance. Further, it is not clear why these four events where chosen for a detailed description. Also, the description of the events is scattered in different paragraphs of

Sections 3 and 4. The paragraphs should be better structure to lead the reader through the evolution of the cold front events.

Further general comments:

- The section headings are not very specific. While Section 3 “Data description” has many short subsections, Section 4 “Discussion” has no subsection while introducding a lot of information and new analyses.

- Water isotope measurements:
  Various information is missing in the description of the water isotope measurements:
  - What was the material and length of the inlet line to the Picarro instrument? Was the inlet line heated?
  - Was the water vapour mixing ratio measured by Picarro calibrated? How does it compare to other humidity measurements on the Island?
  - When was the humidity-isotope dependency calibration done and what kind of calibration device was used?

Detailed comments:

Lines 68-69: What is (18O/16O) and (D/H)? Does this represent the isotopic ratio?

Lines 90-93: “For this objective, several instruments have been installed either in observatory stations ... or on boat …”.
Is there a reason that this summary omits aircraft measurements?

Lines 97-99: “Such data comparison enables one to test the performances of the models either in the simulation of the dynamic of the atmospheric water cycle or in the implementation of the water isotopes.”
I agree with this statement but I don’t see how this study adds any new knowledge on model performance or isotope parametrisations. Can you elaborate further?

Line 101-102: “This region is poorly documented with present-day observations despite its primary importance in governing CO2 sinks”
Do you have a reference for this statement?

Line 102-105: “Moreover, we lack precise descriptions of atmospheric processes associated with cloud microphysics and surface-atmosphere exchange in polar regions, and the evolution of westerly wind locations and strength (Fogt and Marshall, 2020).”
Why is this relevant for the presented study? The study site lies in the mid-latitudes.

Line 134: “Climate is temperate, generally mild with frequent presence of clouds.”
What do you mean with frequent presence of clouds?

Lines 149-150: “CO_2, CO, CH_4 and Hg species have been continuously measured since 1980, 2014, and 2012 respectively.”
There are four species but only three years are mentioned. It is not evident which species belongs to which year.

Lines 160-167: The elevation of the two meteorological stations at Pointe Bénédict observatory is given in meters agl, while the elevation of the station at Martin-de-Viviegs is given in meters asl. This makes it difficult to compare the elevations. Further, this paragraph gives a lot of detail on variables that are not shown later on.

Line 165: What is IGE?

Line 187: What is STP?

Line 202: “high altitude air masses (lower/ upper troposphere, or even above)”
This is very unspecific. What do you mean with lower/upper troposphere?

Lines 204-205: “ As mentioned above, mercury in the atmosphere is detected in three defined forms:”
This has not been properly introduced earlier.

Line 233: “outside at ~ 6 m above ground level.”
What is this relative to m agl/asl, i.e. compared to the other measurements?

Line 279: What do mean with “quadratic error”?

Line 290: Why are you starting the trajectories at 100m a.s.l.?

Line 324: “high spatial”: 0.9° horizontal resolution is high compared to the LMDZiso simulation of this study but low compared to convection permitting climate simulations. I would therefore skip “high”.

Line 389: “d-excess of the precipitation”. I don’t see this in Fig. 3.

Line 395, 395, 399: What is R^2? The correlation coefficient R to the power of 2? What kind of correlation are you calculating? R^2 is used before R is introduced.

Line 399-400. “...(R is calculated continuously from hourly records in 8 consecutive days)...”
Do you mean that you used an 8-day moving window?

Line 402-403: “$d\text{-}excess_v$” has not been introduced.

Lines 434 – 436: “...the agreement with measured precipitation amount is better for ECHAM6-wiso (R2 = 0.45) than for LMDZ-iso (R2 = 0.08 – 0.13 for VLR – LR)…”
The correlation of LMDZ-iso with the measurements is close to zero, i.e. there seems to be nearly no agreement. The statement that the agreement with measured precipitation is better for ECHAM6-wiso than for LMDZ-iso seems weak in this context.

Lines 437-439: “...they are in general more strongly expressed in the data series than in the model series which is only partly due to the hourly resolution of the d18Ov record compared to the 3h and 6h resolution of the outputs of the LMDZ-iso…).”
What is the basis of this conclusion?

Linbes 450-451: “ They always occurred during low pressure periods (atmospheric pressure below 1005 mbar).”
What is the synoptic situation leading to this low pressure and cold fronts?

Lines 501-503: “However, for the 11 events highlighted above, the d18Ov vs qv evolution follows an evolution characteristic of remoistening processes, i.e. a curve standing below the curve of the d18Ov vs qv evolution observed for the rest of the series…”
The single events show a much steeper evolution in the d18Ov-qv diagram than the remoistening curve. Why is this?

Lines 504-506: “Since relative humidity is relatively high during these events (values given in Table 1 compared to a mean value of 77 %), it more likely reflects rain-vapor diffusive exchanges than rain evaporation.”
Are you referring to the relative humidity at the surface? How about relative humidity above that will also influence the interaction of the rain with its surroundings?

Line 519ff.: As the trajectories are only shown in the supplement, it is difficult to follow this paragraph. The beginning of the paragraph leads to think that the trajectories indicate that subsidence is import but in the end the conclusion is that “back trajectories are however not supporting systematic subsidence for other cases”.

Lines 526-527: “... the maximum altitude of the envelope of the back trajectories increases from 5,000 to 8,000 m...”
What it the mean/standard deviation of the maximum trajectory height? How many days before arrival are the trajectories at their maximum height? How relevant is this for the isotopic composition upon arrival? E.g. if the trajectories descend over the ocean and take up moisture, their maximum height before the moisture take-up is less relevant for the isotopic composition at Amsterdam Island.
If you are using the full 10-days backward trajectories to calculate the maximum altitude, I don’t think that the maximum altitude is a good measure of subsidence in front of the cold front.

Lines 543-555: “ There is no evidence for changes in the horizontal advection of air over the 11 particular events from the observation of wind direction around these cold front events.”
How is the cold front identified? Does it divide different air masses? A cold front normally implies a horizontal transport of air, why is this not the case for these cold fronts?

Lines 556-558: “Such abrupt d18Ov events can hence be used as a test of the performances of general circulation models equipped with water isotopes.”
What was learned about the performance of the GCMs involved in this study? Was it necessary to include d18O in such a performance test instead of just using traditional humidity variables (e.g. relative humidity, specific humidity, precipitation)?

Line 562: What is “SOM”?

Lines 559-584: As both isotope-enabled models were nudged to ERA5 dynamics, it is to be expected that the GCMs reproduce the ERA5 reanalysis wind fields rather well with some caveats due to the lower horizontal resolution. This paragraph (and Fig.7) is mostly describing the smoothing of ERA5 due to the coarser resolution of the isotope-enables GCMs. Why do we need isotope measurements to see the effect of a coarser horizontal resolution? What do we learn about the GCM performances by decreasing the horizontal resolution?

Lines 586-590: “A rain event is associated with a strong ascending column in which d18Ov is depleted by progressive precipitation during the ascent and by interaction between rain and water vapor. This ascending column is coupled to the subsidence of d18Ov depleted air at the rear of the event which is pushed toward Amsterdam Island through a south west advection of cold air.”
How is the isotopic composition of the subsiding air behind the cold front connected to the progressive precipitation during the ascent? Can the ascending and descending column be differentiated in the d18O excursions?

Line 621: “hours/days”
Is there a cold front passage that has a duration of several days?

Lines 635-640: “This study highlighted the added value of combining different data from an atmospheric observatory to understand the dynamic of the atmospheric circulation. The two-year records are also a good benchmark for model evaluation. We have especially shown that the isotopic composition of water vapor is a powerful tool to identify aspects to be improved in the general circulation models, such as the horizontal resolution which may influence the representativity of the vertical dynamics.”
As also mention above, why are stable water isotopes needed to show that the horizontal resolution may influence the vertical dynamics? The vertical cross sections of vertical wind speed (Fig. 7) illustrates this already quite well.

Line 642: Data availability: The isotope measurements are poorly documented on the Zenodo platform, and the dataset does not include the water vapour mixing ratio.

Figures:
General: The figures are often difficult to read, especially the described phenomena are small (e.g. d18O excursions of a few hours in a 2-year or 3 month timeline). Additionally, the colors are not color-blinded friendly and the caption are not concise.

Fig.1: Is this figure needed? Fig.1 is not mentioned in the text.

Fig.3: x-axis too coarse, light green shading difficult to see.

Fig. 4: Colors red/blue/green are not colorblind friendly. The caption text includes many repetition and should be improved. A legend in the figure could improve the readability.

Fig. 6: What is φ=0.025?

Figure 8: What is SBL? The ascent of air in front of the cold front rises nearly vertical at a constant longitudinal position. As a cold front is moving system (mostly associated with an extratropical cyclone), the ascent does not occur at a constant location (in latitude and longitude). Further, all precipitation seems to fall in front of the cold front, which is unlikely. How is the subsidence at 100°E and ascent at 90°E related to the cold front? What does a composite of precipitation and d18Ov for all cold front events look like? Can it reproduce the schematic as shown in the "surface box"?

Technical comments

Generally: there are many abbreviations in the text that are only used a few times. Can you reduce the number of abbreviations?

Line 60-61 (and many others): The references are not in chronological order.

Line 65-66: "We express the abundance of the heavy isotopes D and 18O with respect to the amount of light isotopes 16O and H in the water molecules…" should be "We express the abundance of the heavy isotopes D and 18O with respect to the amount of light isotopes **H and 16O, respectively,** in the water molecules…"

Line 68: Eq. 1 has strange symbols (squares).

Line 88-89: "water cycle processes such as ~~water cycle processes such as~~ "

Lines 106-109: "Over the previous years, we have installed 3 water vapor analyzers on Reunion Island at the Maïdo observatory (21.079°S, 55.383°E, 2160m) (Guilpart et al., 2017) and in Antarctica (Dumont d'Urville and Concordia; (Leroy-Dos Santos et al., 2021; Bréant et al., 2019; Casado et al., 2016). "
Check usage of brackets.

Line 133: "from the nearest lands, Madagascar**,** and"

Lines 140-141: "...and were continuously monitored at the site **since** 1960…"

Lines 145-150: The section is very difficult to read, the websites and datasets should better be included as references. Same for link to AERIS on line 178 and 200.

Line 178: “AERIS ((Magand and Dommergue, 2022))”

Lines 180-181: “instrument models (Tekran Inc., Toronto, Canada) (Angot et al., 2014; Slemr et al., 2015, 2020; Sprovieri et al., 2016; Li et al., 2023). “

Line 202: “may possibly” Doubling, omit either.

Lines 211-221: This sentence is too long. Can you divide into two sentences?

Line 228: “The isotopic composition of near-surface water vapor (d18Ov and dDv ~~in ‰ versus SMOW~~)“

Line 242: “The calibration of the data is performed in ~~different~~**several** steps following previous studies”

Lines 301-303: “...identical **to** the atmospheric setup of IPSL-CM6A (Boucher et al., 2020) used for phase 6 of the Coupled Model Intercomparison Project (CMIP6, (Eyring et al., 2016)). “

Line 373: “… very close to the one observed in Angot et al**.** (2014).”

Line 374: “During the period (2020-2021) of water vapor isotope measurements in AMS…”
Do you mean: During the period 2020-2021 of water vapor isotope measurements in AMS.. ?

Lines 390-391: “The annual cycles are also not visible…” Do you mean: “An annual cycle is not visible…” ?