

Comments for article *essd-2026-115*

This study describes the generation of a dataset using the newest version of FLEXPART(V11), along with the new version HAMSTER(V2) for postprocessing, enabling the attribution of moisture and sensible heat source. The authors introduced the configuration of FLEXPART in domain-filling mode to obtain air parcels trajectories, and present analyses of global moisture sources for both continental and oceanic precipitation, as well as global sensible heat sources of diabatic temperature increments.

In addition to these climatological global analyses, two regional cases are also examined. The usability of the dataset is demonstrated for different research applications. Overall, the manuscript is well organized and clearly written. The dataset is accessible and can also be used with tools other than HAMSTER. The main area for improvement lies in enhancing the clarity of the post-processing (HAMSTERV2) and the structure of the dataset.

General comments:

1. HAMSTERV2 is a tool that reads the FLEXPART-ERA5 dataset and post-processes it to identify the moisture sources of precipitation or precipitable water via evaporation, as well as the sensible heat sources associated with potential temperature increments. This dataset can also be analysed using other tools for a broader range of research questions; therefore, a clear and detailed description of the dataset is essential.

To my understanding, the dataset is generated from forward simulations of FLEXPART driven by ERA5 as input. Approximately 20 million air parcels are released each year, each air parcel with a unique identifier. Outputs are provided every 3 hours, including the position of each air parcel (latitude, longitude, height) and other associated variables.

Although the primary focus of this study is not the configuration of FLEXPART itself, it is still necessary to clarify some key settings. For example, the simulations are conducted on a year-by-year basis, (i.e., including one additional month from both the preceding year and subsequent years), but how new air parcels are released.

For users applying Lagrangian approaches but not familiar with the detailed implementation of FLEXPART, these aspects are difficult to understand without further clarification.

2. The second main component of the manuscript illustrates how the dataset can be used in global and regional studies of moisture contribution to precipitation to precipitation and sensible heat sources to diabatic temperature increments. Taking moisture source attribution as an example: for one air parcel, the specific humidity is used to diagnose moisture uptake or loss when passing through a grid cell, which is straightforward. However, an additional “bias-correction” step is applied, in which the specific humidity change is adjusted proportionally according to the evaporation flux at each time step. This adjusted increase is then interpreted as the moisture contribution from that grid cell.

In principle, the evolution of specific humidity in an air parcel reflects evapotranspiration and moisture exchange among air parcels. Although the bias-correction ensures that the sum of E2P equals precipitation, it may distort the spatial pattern of E2P, potentially leading to an overestimation of moisture contribution from nearby regions and consequently a higher local recycling ratio. This is consistent with Fig.A1a in Appendix A, which suggests that this Lagrangian framework tends to overestimate contributions over continents.

For sensible heat tracking, the situation is more complex, as the change in diabatic temperature is also influenced by precipitation processes, introducing additional uncertainty compared with the moisture source attribution.

A discussion of uncertainties could also be included in the manuscript.

Specific comments:

Line64-46: “The second approach, introduced by Stohl and James (2004), and used in models such as the FLEXible PARTicle dispersion model (FLEXPART) (Stohl and James, 2004; Bakels et al., 2024), follows air parcels while explicitly tracking their evolving specific humidity and other state variables.” This description may require clarification as FLEXPART is a Lagrangian particle dispersion model used to derive air parcel trajectories and variables along trajectories, and may not directly correspond to either of the two moisture tracking frameworks discussed here. Actually, in the “Bakels et al., 2024” paper, this second approach is not mentioned.

Line66-67: The evolution of specific humidity represents the net balance between evaporation and precipitation; therefore, their individual contributions cannot be fully disentangled when they occur simultaneously. More importantly, the change in specific humidity of an air parcel is not only related to evaporation and precipitation within the

current grid cell, but may also be influenced by moisture flux/convergence from other grid cells. This point may need to be clarified.

Line 68-69: In the sentence: “Both types of Lagrangian approaches can provide high-resolution, flow-following diagnostics of moisture transport without reliance on a fixed grid.” It is unclear whether this refers to higher temporal resolution compared to Eulerian approaches, i.e., the use of small time steps to obtain a high-frequency, flow-following diagnostics. If so, please consider rephrasing this sentence for clarity.

Line 86-87: “Bias-correction requires global simulations and was shown to substantially affect both the magnitude and spatial structure of inferred source–receptor relationships and reduce associated uncertainties (Keune and Miralles, 2019).” I don’t completely understand why bias-correction scheme in HAMSTER requires global simulations. This is also not consistent with line 151-152 “a user-defined region”.

Line 91: The statement “The availability of hourly ERA5 fields” indicates that the ERA5 reanalysis dataset is used. However, in lines 121-122, “For the present dataset, flex_extract is used to download 3-hourly ERA5 fields at 0.5° horizontal resolution and convert them into FLEXPART-ready input files.” appears that you download the original ERA5 reanalysis and preprocess it for FLEXPART, is it what you mean? If so, please consider rephrasing the 121-122 sentence.

Line 102: “a full description of the HAMSTER v2 post-processing tool as open-access resources.” Section 2.2 provides the first detailed presentation of HAMSTER v2 in the manuscript. However, the structure of this section is not entirely clear, for example: “Source regions are identified by analysing changes in specific humidity (q) and potential temperature (θ) along each trajectory. For moisture, HAMSTER integrates evaporation minus precipitation ($E - P$) along the parcel path, where positive (negative) values indicate moisture uptake (loss).” These two sentences are confusing; how do you relate ($E-P$) with specific humidity change? Also these are not whole steps, in lines 170-175, the “bias correction” step is introduced, maybe consider putting the steps together. Reorganizing the method description may improve readability and clarity for readers.

Line 151–152: The use of “forward or backward” may need clarification. For moisture attribution, backward tracking is typically applied. If HAMSTER also supports forward tracking for diagnosing moisture and sensible heat sinks, this could be clarified.

Line 159-160: H2T is derived from changes in potential temperature and is interpreted as the attribution of diabatic temperature tendencies along air-parcel trajectories to earlier surface sensible heat flux. However, potential temperature changes reflect the combined effects multiple diabatic processes, including both sensible and latent heating. It is therefore unclear how the contribution from sensible heat fluxes is separated from other heating processes, which may require further clarification.

Line 175: “Consequently, when only precipitation bias correction was applied, the correction reduced to a uniform scaling of the E2P field and did not affect the relative contributions of the different source regions.” It is unclear whether this step should be interpreted as a bias-correction procedure, or rather as a normalisation enforcing consistency with precipitation constraints. In the latter case, it would not alter the relative source attribution, but only rescale the E2P field. Clarification or rephrasing would be helpful.

Line 277-278: “Similarly, H in Fig. 5a will equate the sum of the H2T from all sinks, with mild deviations from ERA5 data due to internal consistency (Appendix A).” However, Appendix A only presents the difference between the sum of evaporation and sum of E2P, rather than any heat-related quantities. It would be helpful to also provide a similar figure of heat. Given the complexity of heat processes, the discrepancy between H2T and the total sensible heat flux may be larger and, may not be fully explained by deviations from ERA5 data alone.

Line 431-433: “This pattern is consistent with previous studies reporting exaggerated local land contributions (Li et al., 2024b) and lower remote ones in other FLEXPART-based frameworks (Cloux et al., 2021).”

FLEXPART primarily represents the dynamical component of moisture transport rather than a complete framework for moisture source attribution. Therefore, it may be more appropriate to refer to “WaterSip-based” approaches here, particularly as HAMSTER is built upon the WaterSip approach? In addition, Cloux et al (2021) also clarify that

FLEXPART itself is a Lagrangian particle dispersion model rather than a dedicated tool for moisture source analysis.

technical corrections

Line 21: what's the meaning of "influence climate impacts", should it be "influence climate" or "have climate impacts on..."

Line 62: The Dirmeyer and Brubaker method has also been used and tested in these studies: (Mu et al., 2026; Tuinenburg and Staal, 2020), so maybe consider mentioning these.

Line 151: "a user-defined the study region" -> "a user-defined study region".

References:

Mu, Y., Evans, J. P., Taschetto, A. S., and Holgate, C.: Refining the Lagrangian approach for moisture source identification through sensitivity testing of assumptions using BTrIMS1.1, *Geoscientific Model Development*, 19, 1367–1385, <https://doi.org/10.5194/gmd-19-1367-2026>, 2026.

Tuinenburg, O. A. and Staal, A.: Tracking the global flows of atmospheric moisture and associated uncertainties, *Hydrology and Earth System Sciences*, 24, 2419–2435, <https://doi.org/10.5194/hess-24-2419-2020>, 2020.