Summary & general assessment

Fix-Hewitt et al. generalize the concept of atmospheric deserts (ADs) with a climatology for AD events over Europe from two years of reanalysis data. They focus on ADs from air masses originating over North Africa that are advected over Europe. They compute a large number of Lagrangian trajectories for such advection events and identify ADs in those. Based on the identified ADs, they assess key properties of ADs, including their frequency of occurrence and spatial extent, synoptic patterns during which they occur, their duration, vertical structure, and typical thermodynamic and vertical pathways.
The presented work is a logical continuation of previous research, and provides the first systematic climatological analysis of ADs for Europe. The methods used are appropriate for the application, and largely well explained in the manuscript. The paper is well structured, however, language in several sections could be improved for a slightly smoother read. Figures are appropriate and well chosen to visualize key findings, however, visualisation could be improved (see specific comments). Overall, I am pleased with the quality of the manuscript and deem the topic well suited for publication in Weather and Climate Dynamics.

Major comments

Title
I think the title has more potential to highlight the key novelty of the paper: A first climatology of AD events over Europe. Adding the term “climatology” would also make it easier to differentiate from the authors’ previous publication that explored ADs with form of a case study.

Methods
I acknowledge that many of the deployed methods require the selection key parameter values, and that this is partially based on previous work of the authors. However, I think this still requires more explanation and justification in the presented manuscript. In particular:

- Why exactly do you chose three clusters for the synoptic analysis? What would change with 4 or more clusters?
- Typical trajectories: why do you use a subjective selection and not a systematic one? You could cluster the trajectories and show the cluster mean composite, or the trajectory with the smallest deviation from the cluster mean.

Connection to other synoptic dynamics
While ADs are connected with particular weather situations and extreme weather, it would be interesting to see a broader discussion of these. Your synoptic analysis shows a situation that somewhat resembles that of North African cyclones (cluster 1). These are known to be efficient for dust emission in North Africa during spring, and can lead to dust transport towards Europe. References (e.g.):

- Bou Karam, D., Flamant, C., Cuesta, J., Pelon, J., & Williams, E. (2010). Dust emission and transport associated with a Saharan depression: February 2007 case. Journal of Geophysical Research: Atmospheres, 115(D4).
- Barkan, J., Alpert, P., Kutiel, H., & Kishcha, P. (2005). Synoptics of dust transportation days from Africa toward Italy and central Europe. Journal of Geophysical Research: Atmospheres, 110(D7).

Is there a connection between ADs and dust transport? Is there a seasonality of the synoptic situation that causes ADs? Also, a mention of the somewhat related term “atmospheric rivers” (ARs) might be interesting. Both, ADs and ARs are connected to extreme events, even though air masses have very different thermodynamic properties.

Language
The paper is mostly well written and the authors use adequate vocabulary. However, some sections would benefit from smoother flow of language and improved syntax.

- The abstract would benefit from better phrasing and consistent usage of the same terms that are later used in the paper. See specific comments.
- While it might be common in German to place the verb in the very end, English is much easier to read if you place the verb early. For example, “Persistence is an important feature of ADs, especially in the context of impacts.” reads much easier than “Another important feature of ADs, especially with regard to their consequences, is their persistence.”. See some suggestions for improvement in my detailed comments.
- I recommend abstaining from using inconcise language such as: almost all, seems, should. You can refer to the numerical values, or clearly state the definition or hypothesis.
- Trajectories. To my understanding, what you calculate forward in time is the location of the air parcel; the trajectory is the path that the air parcel takes/has taken. In the manuscript, the term “trajectory” is used for both. Please rephrase where necessary.

Figures
Some figures are hard to “read” due to the choice of colourmaps or feature colours.

- Multi-color but perceptually uniform colourmaps such as cividis or viridis can help to improve the details visible in the plots, while being colorblind-friendly and reproducing well in greyscale. You could further add contour lines to visually highlight the key values that you mention in the manuscript. Black background features such as coastlines are hard to see of you plot fields in dark grey on top of it. Consider changing colours.
- Colourbars use the same colour for low and high and the respective extensions. Either remove extensions or change colours.
- For consistency, I further suggest aligning the alphabetical plot labels (a, b, c, …) to a common location for all plots (e.g., the top left).

Also see specific comments on figures.

Specific comments

l. 2: Language consistency: here you write “*between* May 2022 and April 2024”, later you write “*through*”. Please use consistent term.

l. 3: “at every hour” – I assume you mean “every full our”?

p. 3f: Please add which atmospheric dataset you use for calculating the trajectories (→ ERA5).

l. 5ff: I suggest to reorder the first two paragraphs slightly: First paragraph - introduction of atmospheric deserts and where they occur. Second paragraph - what you do (track,technical details, etc.).

l. 9: “Typically, atmospheric deserts persist for about one day on average”. Typically or on average? Suggestion: On Average, atmospheric deserts ...

l. 12: “resides between the local boundary layer height and the troposphere”. I do not understand where this is. The top of the boundary layer usually marks the transition to the free troposphere. Please clarify.

l. 13f: “The atmospheric desert air rarely enters the local boundary layer, and if it does, it happens at over...”. This sentence does not read smoothly. Suggestion: Rare intrusions of desert air into the boundary layer mainly occur over high orography and during the warm season.

l. 15: “lid” – consider briefly mentioning what this is.

l. 34: Reference: Schultz et al. (2025a). Why is this publication singled out? It overlaps with the previous sentence and references: origin of Spanish Plume air often further south that Iberian peninsula; in North Africa.

l. 36: “by e.g.” – remove “by”

l. 40: References. How are these ordered? I suggest sorting by year of publication.

l. 49 “for a few days” – for how long exactly? Use numerical value.

l. 50: “pathways of the trajectories” - pathways or trajectories?

l. 52: “almost preserving its thermodynamic properties and rising only slightly,” preserving/rising relative to what? I assume: relative to the thermodynamic properties of the air parcel at the start of the trajectory. Please clarify.

l. 48ff: Inconsistent use of present and past tense. Please stick to one tense in this section when you describe the results from Fix at al. 2024.

l. 59: “what area they span”. The following paper analyses what *distances* ADs *span* and what *areas* they *cover.*

l. 61-70: This section would benefit from a brief introduction, before saying which subsections cover what. I suggest reordering, e.g., you could start with the sentence “The focus period of this study…”, then say “The direct detection method requires the calculation …”, then “We use the ERA5 reanalysis…”.

l. 67: Why are computational requirements mentioned here? I suggest removing, moving to the discussion, or adding a reason why you need this info here.

l. 74: “1 hPa”. Here and elsewhere: There should be a narrow space between value and unit.

l. 77: Please reference figure 1 which shows the domain(s).

l. 77: **N**orth Africa but **n**orthern Africa

l. 82: “various contexts” - In which contexts exactly? You add four references; please also give examples what these publications use LAGRANTO for.

l. 84: “Naturally” – Why is North Africa “naturally” the source region of interest? Please add.

l. 91: “without affecting the results as tested for that case study”. I do not understand this sentence. Please rephrase.

l. 92 “but for this study” – Which study do you mean here? The here-presented study? Please clarify/rephrase.

l. 94: “Per definition AD air should…”. A clear definition would say “AD air originates in...” - not “should”.

l. 95: “the BL can grow to”. Suggestion: The BL can reach several km in depth.

l. 96: “It can be assumed” - Why can this be assumed? Please add reasoning.

l. 99f: What happens to air parcels that are first advected outside of the "curtain" and only then make their way to Europe? What about air from other source regions? It would be good to highlight more that you only focus on air that is advected from North Africa (where we assume most ADs to originate).

l. 108: no need to use parenthesis

l. 112: “decent vertical resolution”, “high enough numbers”. What do you mean by this? What criteria does the vertical resolution need to fulfil to be “decent”? High enough for what? I suggest to rephrase, give a reason, and add a numerical value (e.g., minimum numbers of trajectories per box),

l. 129: “2 days” – Why this threshold? Please give a reason.

l. 130: “geoh500” – “z500” is a more common notation.

l. 134ff: Is this the “elbow method”? Does k=3 fulfil the previously explained criterium regarding the total sum of squares? What would change with k=4 (or greater)?

l. 140: “on one day” - On the same date?

l. 145: Why 4 clusters? You say “as in Fix et al. (2024)”, but please also give a brief reason in this paper why you choose this value.

l. 147: “5th day before each of the maxima (as this is the trajectory length)”. This sentence is quite hard to understand, particular which duration of the trajectories you mean here. The information in parenthesis does not particularly help here. Please rephrase.

l. 148: “identified subjectively”. Why is the representative trajectory not chosen analytically? For example, you could cluster all trajectories and compute composites, or chose the closest trajectory to each cluster centre.

l. 157: “not without problems”. Problems with/of what? Please give relevant examples.

l. 172: “probability”. Probability of/for what? I think you mean for an AD being present over the time series analysed here. Please add.

l. 173: “weighted by grid cell area”. Even though you might use an area-weighted average for computation of the mean field values, I find this explanation quite confusing here. Figure 1 shows AD probability per hour and area (not per cell), and does not need further weighting for interpretation (I think).

l. 176: Notation “0.7**x**10”. Here and elsewhere: this looks line the letter x. Better use the correct "times" symbol, in LaTeX this is \times .

l. 178: “non-weighted”. It is not entire clear why you use weighted and unweighted probabilities here. Please add an explanation.

l. 181: “ADs cover between…”. You prominently introduced the frequency of ADs at the beginning of the section. For consistency, I think it would be more clear if you state that the second paragraph is about spatial properties of ADs.

L 183: “is smaller”. Smaller than what? Please add what quantity or season you refer to.

l. 187f: “especially in the eastern Mediterranean, over Turkey and the Black Sea”. What about the Balkans? Figure 1d) suggests that at least the southern Balkans are equally affected.

l. 189: “noticeable”. What does noticeable mean here? Better mention some numerical values.

l. 190: “20%” - 20% of what?

l. 198: “does show that it is rare that no AD air is present in the domain north of 37◦ N”. It would be interesting to know how often this occurs over the analysed period.

l. 206: “during a fully developed AD-event”. Or rather leading to a fully developed AD event?

l. 209: “shown”. If you mention that features are shown somewhere, please also mention in which figure (here: reference figure 3).

l. 212: “typical trajectory cluster average paths”. Suggestion: “for the typical trajectory for this cluster.” Also, it would be interesting to see how this “typical trajectory” looks like. Consider adding this to the supplementary material.

l. 218: “trajectories being transported”. Air is transported, trajectories are located. Please rephrase.

l. 229: Fig. 4: Reference this figure where you first describe streak lengths (previous paragraph).

l. 233: “closer to a week in the Mediterranean in SON”. Figure 4 shows less than one week (7 days) in the Mediterranean for SON. Please clarify.

l. 235: Punctuation: “This indicates, that”. No comma.

l. 239: Language: “ADs seem to be”. Are they or are they not?

l. 242: “distribution”. Suggestion: spatial structure/pattern

l. 245: “The largest average distance between the highest and lowest AD-cells”. Suggestion: The largest vertical depth …

l. 251: “cell-hours”. What are cell-hours? Please introduce and explain.

l. 251f: “South of 55◦ N and west of 40◦ E […] . Beyond this [...]”. The former also includes the domain that was mentioned in the previous sentence and which shows a lid in 45% of daytime hours. Please rephrase. The latter could be rephrased to “In other parts of the domain”.

l. 265: “compared to a continental one, as it is often cooler and moister”. What does this mean for the development and persistence of a lid? Please add/explain.

l. 272: “simply due to its origin”. Origin in where? Please add/explain.

l. 273f: Any estimate how reliable ERA5 reproduces actual BLH, particularly in mountain regions?

l. 274: “entering” – intrusion?

l. 293f: You already said in the previous sentence that figure 9 is a schematic. You can add the reason that no scales shown to the figure caption.

l. 297f: “another favoured altitude is between 7 and 8 km”. I do not see how this band stands out compared to lower layers. There is not even a local maximum here. However, AD cells can frequently be found in up to about 10 km. Please rephrase or explain why/how you identify this band as particularly prominent.

l. 298: “medium altitudes”. Which altitude do you mean with “medium”? Please add numerical values.

l. 299 “significantly”. Did you do any significance testing? If not, better avoid this term.

l. 306: “At least one ... almost .. all”. This is quite blurry language, please rephrase.

l. 310: Punctuation: “trajectories that end up at lower altitudes, cooled considerably”. No comma.

l. 311: “fits well with cluster d (Fig. 9d, red), which also appears in many cases”. I think cases appear within the clusters, not the other way round.

l. 315: Based on Fig. 8c, I struggle to see how q remains almost unchanged between 2 and 6 km. Or do you mean Theta_E?

l. 323f: “few degrees”. This appears to be a temperature unit and should therefore say “Kelvin”. However, since you do not show any scales in your schematic, I suggest not referring to absolute values that cannot be seen in the figure.

l. 329: “due to distance to the source”. You might want to add that this is due to the longer advection time that is required to reach these locations.

Section 4. The section title promises an outlook, but I rather see a discussion with conclusions and an abrupt end. Has the outlook gone missing?

l. 351f: It would be interesting to see a seasonality analysis for the different synoptic clusters. E.g., cluster 1 aligns well with the synoptic situation we see during North African Sharav cyclones. These are known to be an important driver for dust emission during spring. Cluster 2 resembles frequent synoptic conditions during events of Saharan dust transport towards Central Europe. ADs might have an impact on predictability not only due to their thermodynamic properties, but also due to their potential aerosol load.

l. 359: “almost not happening”. Suggestion: “rarely happens (<20%)”

l. 385f: I did not see any lightning products in the presented figures nor any mentions in the manuscript. Potential copy/paste from previous paper?

l. 465ff: Remove link to Google books.

Specific comments on Figures

Figure 1

- Labels a, b, c, … I suggest to align locations, e.g., to top left.
- Colourbar: Extensions seem to have same colour as min/max field. Either remove extensions or chose different colours.
- Colourmap: While it is okay to use Greys, please use a different colour for the map features (coastline).
- Caption: You mention cells, but your colourbar legend shows area im km². Please clarify.

Figure 2

- I suggest to start (and) the x-axis tick labels with the boundaries of the time period that you analyse.

Figure 3

- Coastlines have same colour as high values of AD frequency. This makes it hard to locate the extreme values in cluster 3. Please change coastline colour/ AD frequency colourmap.
- What unit is AD frequency?
- It would be very interesting to see a seasonality analysis of these clusters.

Figure 4

- I find the maxima very hard to see. You could highlight key thresholds with contourlines.
- Consider choosing a different colour for the coastline, or the 90th percentile fields.

Figure 5

- I find it very hard to see clear structures in here. You could use another colourmap such as viridis or cividis (equally perceptually-uniform) that pop out more gradual changes in the fields. Consider adding contour lines for highlighting the values you mention in the manuscript.

Figure 9

- I think it is enough to mention once that this is a schematic. You can add "curves are relative and not to scale".

Figure A1

→ see comments for figure 5