Review of manuscript egusphere-2024-2984 Revision Round 2

Title: Shallow cloud variability in Houston, Texas during the ESCAPE and TRACER field experiments

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Summary:
The authors have made substantial improvements to the manuscript and the revised version is shaping up nicely into to a final product. I have a few suggestions to address minor gaps that can be resolved quickly. I recommend a minor revision. Red text indicates deletions, and blue text indicates additions. The line numbers in my comments below follow the numbering indicated in the author's tracked changes pdf file.

Thank you to Reviewer #1 for their multiple in-depth reviews of our manuscript. The improvements we have made in response have increased the manuscript's quality. We have included all our responses to individual points below.

MAJOR COMMENTS

Major Comment 1: (Lines 172-180) Unlike other parts of Section 2, this subsection currently lacks the detailed discussion on the relevance and application of the dataset chosen. Please provide additional context and explanation for choosing HRRR data over observed measurements (or a best-estimate product such as the ARM INTERPSONDE) for this analysis. Specifically, the text should clearly articulate the unique value of HRRR data such as its high-resolution sounding profiles and comprehensive meteorological fields that goes beyond what AMF1 observations offer. Furthermore, because the analysis relies on HRRR model soundings rather than direct observations, it is important to address whether a comparison has been made between HRRR profiles and AMF1 observations. In doing so, please clarify:

- (i) Which thermodynamic or kinematic features are well represented by the HRRR model.
- (ii) Which features exhibit significant biases.
- (iii) Whether these biases in the simulated meteorological variables might affect the accuracy of the results.

Thank you for this comment. To preserve the paper's flow, we decided to put our response to this comment in Section 4.5 rather than Section 2.4. In Section 4.5, before we discuss the results, we provide some justification as to why we are using the HRRR instead of the instrumentation at the AMF1. We made the following addition: "We use the meteorological observations provided by the soundings launched from the AMF1 site to establish our shallow vs deep classification in the radar data. The soundings and other instrumentation at the AMF1 site would be useful to quantify meteorological variability in the clusters, but point observations would limit our ability to look at variability across our large domain. So, we use HRRR model output, which has high spatial resolution of 3 km, to provide this meteorological context as the best alternative to real observations. We compare the HRRR soundings at the grid point closest to the AMF1 site to the real soundings and find the median correlation coefficients for temperature, moisture, and wind speed to be high (>0.8; not shown). Even with this strong performance, we only qualitatively interpret the spatial patterns shown in the HRRR model data in our subsequent analysis."

Here is the correlation analysis we mention if you are curious. We perform nearest neighbor interpolation to map the real observations onto the model's vertical grid. Sample sizes are in parentheses.

Median correlation coefficients between TRACER soundings and the nearest HRRR grid point to the sites at the launch hour

	0 LT	6 LT	11 LT	12 LT	13 LT	14 LT	15 LT	16 LT	17 LT	18 LT
M1 Temperature	**0.9997** (121)	**0.9998** (122)	**0.9998** (2)	**0.9997** (120)	**0.9997** (2)	**0.9998** (38)	**0.9998** (39)	**0.9998** (3)	**0.9998** (36)	**0.9998** (116)
S3 Temperature				**0.9997** (39)	**0.9992** (1)	**0.9998** (36)	**0.9997** (38)	**0.9996** (1)	**0.9997** (38)	**0.9997** (36)
M1 Specific Humidity	**0.9857** (121)	**0.9878** (122)	**0.9824** (2)	**0.9872** (120)	**0.9936** (2)	**0.9844** (38)	**0.9877** (39)	**0.9808** (3)	**0.9886** (36)	**0.9867** (116)
S3 Specific Humidity				**0.9831** (39)	**0.9903** (1)	**0.9873** (36)	**0.9825** (38)	**0.9892** (1)	**0.9886** (38)	**0.9882** (36)
M1 Wind Speed	**0.8922** (121)	**0.9074** (122)	**0.8422** (2)	**0.8877** (120)	**0.8815** (2)	**0.8307** (38)	**0.8536** (39)	**0.8722** (3)	**0.8689** (36)	**0.8862** (116)
S3 Wind Speed				**0.8556** (39)	**0.7538** (1)	**0.8472** (36)	**0.7888** (38)	**0.5365** (1)	**0.8818** (38)	**0.8406** (36)

M1 = Main Site
S3 = Ancillary Site

Major Comment 2: Please be consistent in usage of 'Figs' or 'Figures' throughout the manuscript.

Thank you for this comment. We changed the way we referenced figures throughout the manuscript. We abbreviated to Fig. when it appeared in running text, and we only stayed with Figure when it began a sentence. When putting the references to figure numbers in parentheses, we abbreviated to a singular "Fig." in all instances where we referenced a singular figure, even if we referenced multiple panels on that figure. We abbreviated to "Figs." when we referenced different figures.

MINOR COMMENTS

Minor Comment 1: (Line 149-150) ...provide a large statistical sample of precipitating and nonprecipitating clouds ~~and precipitation (both shallow and deep)~~ over the Houston area...

We made this change.

Minor Comment 2: (Line 151) Daily statistics are used to infer the different spatiotemporal patterns of both shallow and deep convective clouds...

We made this change.

Minor Comment 3: (Line 152) surface properties may not be the most accurate descriptor here. Suggesting replacing with ‘surface type’ instead.

We changed to “surface type” instead.

Minor Comment 4: (Line 154-155) Four main diurnal characteristics ~~properties~~ of shallow ~~cloudiness~~ clouds will be evaluated over land and water: domain fraction, frequency of occurrence, cloud top height, and cloud to-precipitation ratio. Also suggest replacing ‘domain fraction’ with ‘diurnal cloud fraction over land and water’ and ‘cloud-to-precipitation ratio’ with ‘precipitation fraction.’

We changed to “Four main diurnal characteristics of shallow clouds will be evaluated over land and water: cloud fraction, frequency of occurrence, cloud top height, and precipitation occurrence.”

Minor Comment 5: (Line 166) The ARM handbook cited here (Bartholomew, 2020) may be less relevant and perhaps outdated. The latest version of the Laser Disdrometer (LDIS) instrument handbook is likely more useful as a reference. If the authors agree with this assessment, I recommend citing Wang and Bartholomew (2023) instead.

References:

Wang, D, and MJ Bartholomew. 2023. Laser Disdrometer (LDIS) Instrument Handbook. U.S. Department of Energy, Atmospheric Radiation Measurement user facility, Richland, Washington. DOE/SCARM-TR-137.

Handbook available at https://www.arm.gov/capabilities/instruments/ldis

We agree. We will update the citation. The handbook listed with the dataset on the ARM Archive has changed since we started putting this manuscript together. Thank you for catching this!

Minor Comment 6: (Line 166) Did you mean to say (warm and cold cloud phase) instead of (warm and cold season)?

We meant “(liquid and frozen)”. We made this change.

Minor Comment 7: (Line 167) ...were performed at the AMF1 site.

We made this change.

Minor Comment 8: (Line 168) ...followed a ~~radiosonde launch~~ schedule of four radiosonde launches per day at six-hour intervals...

We made this change.

<u>Minor Comment 9</u>: (Line 200) ...resolution of ~~30m~~ 30 m and a ...

We made this change.

<u>Minor Comment 10</u>: (Line 250) and ~~has~~ a temporal resolution of 5 minutes

We made this change.

<u>Minor Comment 11</u>: (Line 252) and ~~has~~ a temporal resolution of 5 minutes

We made this change.

<u>Minor Comment 12</u>: (Line 269) ...Herbie ~~(Blaylock, 2024)~~ Python library (Blaylock, 2024), ...

We made this change.

<u>Minor Comment 13</u>: (Line 270) ...wind direction from model analysis (forecast hour 0) here.

We changed to "wind direction from model analysis at forecast hour 0 here".

<u>Minor Comment 14</u>: (Lines 385-386) The methodology in line 304 states that the KHGX analysis was confined to the region within the 112.5 km radial range (or 225 km diameter). How is the farthest range ~ 176 km then?

Thank you for catching this. We clarified the statement to read "At the furthest range considered in this study (112.5 km from KHGX), the minimum detectable signal is between 0 and 5 dBZ, so our threshold is applicable."

<u>Minor Comment 15</u>: (Line 402-403) highest echo-top height corresponding to what reflectivity threshold (0, 10, 20, 30, 40-dBZ)?

We are not using a reflectivity threshold. We only identify the height of the last reflectivity echo, especially because data becomes sparse at those higher altitudes and the exact height of a reflectivity threshold would have to be interpolated somehow. We clarified: "comparing the highest KHGX echo top height (no reflectivity threshold considered) at that pixel…"

<u>Minor Comment 16</u>: (Line 767) Please specify the 'high spatial resolution' explicitly.

We changed to "Due to its high spatial resolution of 3 km".

<u>Minor Comment 17</u>: (Line 768) Suggest replacing 'forecast hour zero' by 'analysis.'

We made this change.

Minor Comment 18: (Lines 777-779) The description of the temperature gradient orientation is inaccurate. The 850 hPa isotherms in Clusters 1 and 4 are parallel to the coast, thereby making the gradient perpendicular to the coast. Conversely, clusters 2 and 3 have isotherms perpendicular to the coast and thereby the temperature gradient is parallel to the coast. This description also makes logical sense since the sea breeze is expected under a land- ocean temperature contrast forcing perpendicular to the coast (not parallel as suggested in the text). Please revise the text accordingly.

Thank you for noting this. We were incorrect in our conventions. We changed the text to read: "The isotherms are oriented parallel to the coast all day in C1 and C4 to create a temperature gradient perpendicular to the coast, which, combined with the winds and moisture, favors sea breeze conditions. Despite a parallel-to-the-coast temperature gradient orientation at 9 LT in C2 and C3 (Figure 12b-c), the gradient attains a more perpendicular-to-the-coast orientation later in the day, although it is not as pronounced as the ones shown in C1 and C4."

Minor Comment 19: (Line 842) Aided by the onshore flow ~~we showed~~ shown in Figure 12, we hypothesize...

We made this change.

Minor Comment 20: (Lines 851-853) The first sentence claims that higher shallow cloudiness at 15 LT is found east of HGB area, while the second sentence states the exact opposite. Please clarify and/or rephrase the second sentence.

Thank you for catching this; it was not clearly worded. We changed to: "In C4, two noticeable spatial patterns are observed at 15 and 17 LT (Fig. 13j-k), and these patterns are not associated with the coastline and the surface type transition. First, over land, higher shallow cloud frequencies (24-40%) are observed east of HGB while, west of the HGB area, lower shallow cloud frequencies (10-25%) are observed (Fig 13j-k). Second, at 15 LT, the maximum shallow cloudiness is observed over land (Fig. 13j), and, at 17 LT as well as at 19 LT, the maximum shallow cloudiness frequency is observed over water unlike in C1 (>40%; Fig. 13k-l)."

Minor Comment 21: (Line 906-907) ~~(< 0.1 mmhr-1)~~ (< 0.1 mm hr-1)

We made this change.

Minor Comment 22: (Line 909) ...we identify shallow and deep clouds, and associated precipitation ~~and deep clouds and associated precipitation~~

We made this change.

Minor Comment 23: (Lines 955-956) The meteorological set-up we showed in the HRRR composite maps suggest~~s~~ environmental conditions favorable for sea breeze ~~conditions~~ formation, though to confirm the passage of sea breeze frontal boundaries over the AMF1 site, low-level thermodynamics would be needed

We made this change.

<u>Minor Comment 24</u>: (Line 1121) Suggest either replacing ‘data’ with ‘dataset’ or ‘is’ with ‘are’

We made this change: “The HRRR dataset is acquired using…”

<u>Minor Comment 25</u>: (Figure 4) The reflectivity data in panel plots (f) and (g) shows some convective cells along the coast which should have been masked out for analysis (marked in red below). Can the authors clarify what’s going on here?

Several of the cells seen in Fig. 4e are not included in either Fig. 4f or Fig. 4g because they fall outside the range ring of our study. The low reflectivity, more stratiform edges of these clouds are not visible in Fig. 4f,g either, so we are focusing on the precipitation cores themselves. Beyond this, every precipitation core we see in Fig. 4e is accounted for in the cumulative view of Fig. 4f and 4g. We often see multicellular precipitation structures in the radar data, which accounts for why parts of the structures are classified as shallow and as deep and get split up.