Reply TO 'Comment on egusphere-2025-2012', Anonymous Referee #1, 11 Jul 2025

Response to Referee #1's comments

Referee #1: egusphere-2025-2012

Synopsis: *The manuscript describes a novel upper air balloon observing system, consisting of a double balloon setup that allows for measurements during a long drift phase in the stratosphere and during the descent phase. The start of the drift phase and of the descent phase can be triggered remotely and steering the height is possible as well. The manuscript also describes the potential for using the system for targeting observations and how assimilation of the data improves analysis and forecasts.*

1.Overall comment: *It is certainly desirable to make better use of weather balloons than is currently the case with many conventional radiosondes where only data collected during the ascent phase are used. The longer residence of the balloons in the lower stratosphere may be useful for observing certain features there, e.g. gravity waves, with more detail.*

The authors claim a cost advantage of the new system launched at relatively few stations compared to maintaining or even enhancing the relatively dense Chinese radiosonde observation network for targeting if severe weather is approaching. While it is encouraging that the data of the new observing system have already been assimilated by weather forecast models in China, the impact on forecasts has been relatively weak but seemingly consistent. The papers referenced in this context (e.g. Wang et al. 2023) are in Chinese and thus impossible for me to follow. I did not try to use automatic translation for this. The results are based on relatively short validation periods (30 days) or on a case study.

Response: We thank Referee #1 (RC1) for her/his positive evaluation of our research. We have addressed RC1's comments and inquires point by point and revised the manuscript carefully.

The RDSS radiosondes of the balloons drifting in the lower stratosphere very useful for observing certain features of gravity waves. Previous studies have conducted gravitational wave inversion using the data of RDSS and achieved excellent results.

Based on the structure function and singular measure relationships, we quantify stratospheric small-scale gravity waves (SGWs) over China, using the Hurst and intermittency parameters, and discuss their relationship with inertia-gravity waves (IGWs). The results show that the enhancement of SGWs in the stratosphere is accompanied by weakening of the IGWs below, which is related to the Kelvin–Helmholtz instability (KHI), and is conducive to the transport of ozone to higher altitudes from lower stratosphere. The parameter space (H1, C1) shows sufficient potential in the analysis of stratospheric disturbances and their role in material transport and energy transfer (Y. He et al.2024).

REFERENCES:

He, Y., Zhu, X., Sheng, Z., and He, M.: Identification of stratospheric disturbance information in China based on the round-trip intelligent sounding system, Atmos. Chem. Phys., 24, 3839–3856, https://doi.org/10.5194/acp-24-3839-2024, 2024.

The initial assimilation forecast impact test did indeed show a relatively weak positive contribution, but it was not very significant. This might be because the assimilation techniques for the new RDSS observation data, such as observation error and sparsity schemes, were not optimal. Subsequently, we will further improve the observation error and sparsity schemes in order to obtain better analysis results.

At present, the assimilation experiment has only been completed for one month, which indeed cannot fully demonstrate its effect. Combining the optimization of observation errors and sparsity schemes, we are currently studying a comprehensive optimization plan. We plan to optimize the assimilation parameters such as observation error and sparsity before conducting a one-year batch trial.

Overall I do not consider the results presented as rigorous proof that the additional measurement data from the drifting balloons improve the quality of analyses and forecasts. While the figures generally support the statements in the text their technical quality is partly poor and should be improved.

This leads to the following assessment

Scientific significance: fair

Scientific quality: fair

Presentation quality: fair

Response: We sincerely thank the RC1 for their valuable feedback that we used to improve the quality of the manuscript. Based on the comments and suggestions from the RC1, we have carefully and substantially revised the manuscript. We have included a detailed response addressing each of the comments. The RC1's comments are laid out below in italicized font and specific concerns have been numbered. Our response is given in normal font and changes/additions to the manuscript are given in the blue text. The line numbers correspond to the revised manuscript without the track changes displayed. For precise details on the modifications made in the latest version, please consult the supplementary material, where track changes are enabled.

2.Major Comments:

(1)Some figures are practically unreadable, please redraw or omit:

Response: We thank the RC1 for the valuable and creative comments. Your statement is correct, Thank you for highlighting this issue. I've identified the problematic figures ([list them if possible, e.g. Fig. 4(a)(b), Fig. 6(a)(b)(c), Fig. 7, Fig. 8(a)(b)(c), Fig. 9(a)(b), Fig. 11(a), Fig. 12(a)(b)]) and redraw/omit them with clearer versions by [time/date]. Appreciate your patience!

1) *Fig. 12 is unreadable.*

Response: Fig. 12 (a)(b) is a screenshot of an online prediction trajectory display system we established, with a relatively low resolution. Here, we have been omit it. And we have been delete "L471 (Fig. 12a and 12b)" in the revised manuscript.

2) *Fig. 11a): Please use thicker lines or make figure sharper. Red color is used for both showing the simulated vertical speed and the circle for highlighting the descent phase. This is confusing.*

Response: Thank you for your opinion. Based on your suggestion, we have redrawn Figure 11(a).

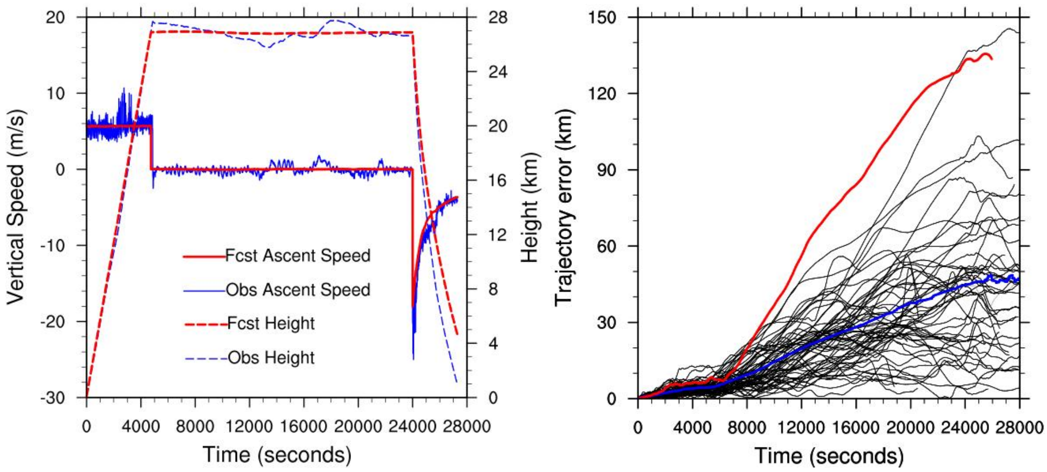


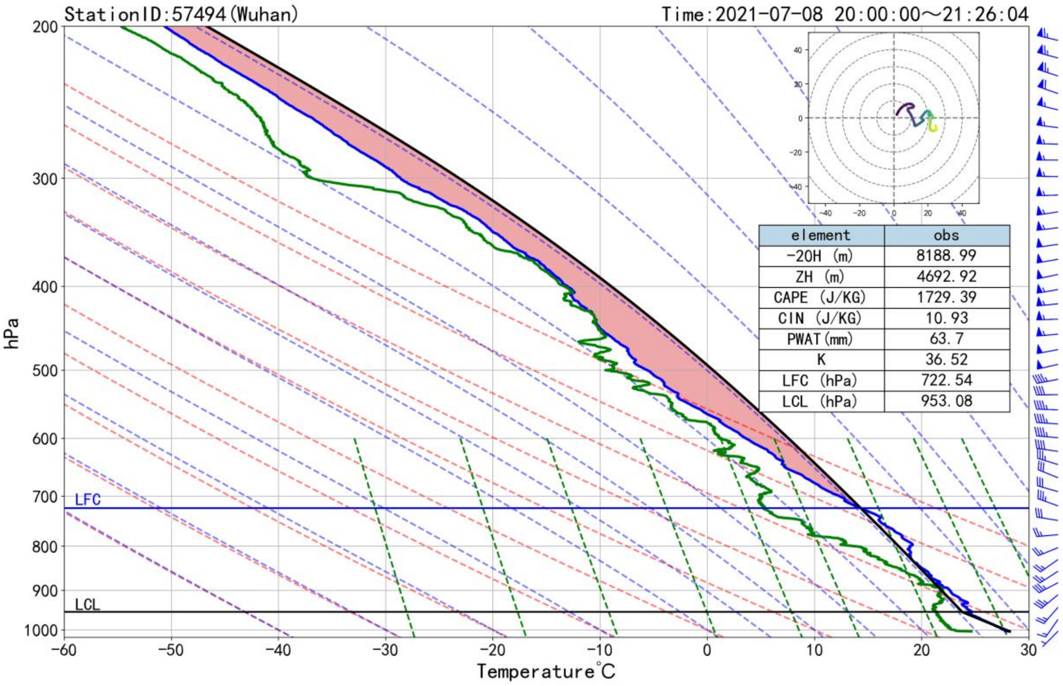
Figure 11. (a) Comparison of simulated (red line) and observed (blue line) vertical speeds of RDSS radiosonde data during the descent phase at the Anqing station at 11:17 on June 20, 2018; (b) Deviations of 63 pairs of simulated RDSS trajectories versus observed trajectories (black line), with the average deviation indicated by the blue line and the largest forecast deviation shown by the red line.

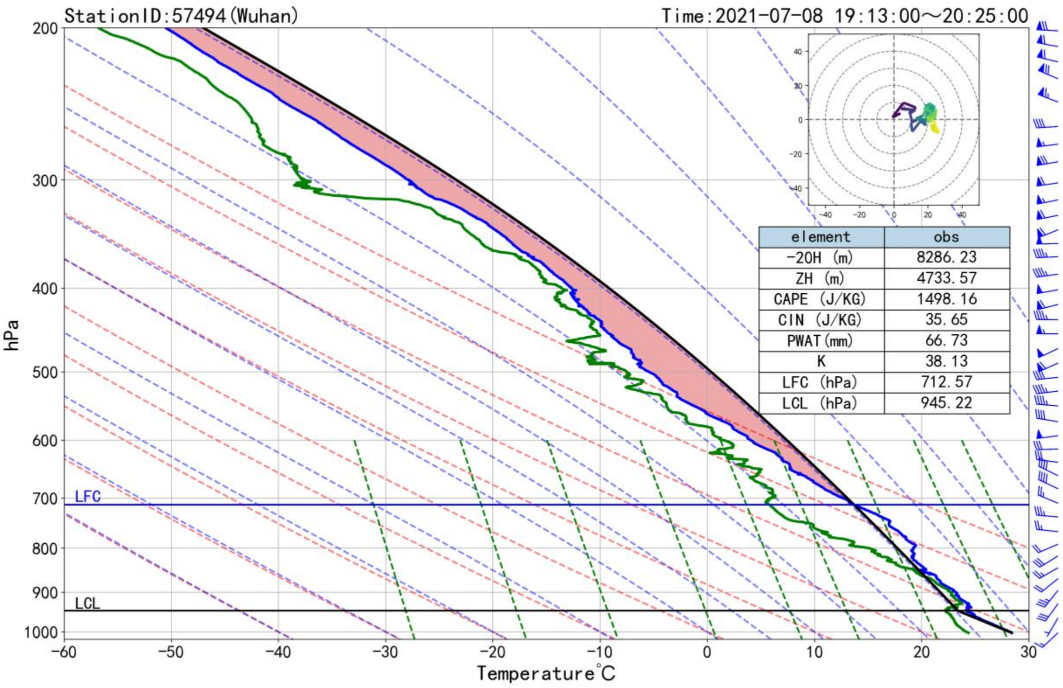
3) *Fig. 9: What do the dots exactly mean? For me it would be logical if red is the start of the ascent phase, green is the start of the drift phase and blue is the start of the descent phase. The end of the black lines would then be the location where the payload reaches the surface. However this is not consistent with how the colors are labelled.*

Response: Thank you for your suggestion. Indeed, Figure 9 is not very clear and definite, and "L391-393 The drifting trajectories of RDSS radiosondes in the middle and lower reaches of the Yangtze River in China from July to August 2021 (Fig. 9) uniformly followed a west-to-east path, aligning with the region's strong convective direction."causing confusion for you and the readers. We deleted Figure 9(a) (b) and L391-393. Thank you again for your suggestion, which makes this picture more readable.

4) *Fig. 8: The T-logp diagrams are almost unreadable and they also have different scales. For a publication in a serious journal these must be redrawn.*

Response: Thank you for your suggestion. Because these pictures are screenshots from our weather forecast operation system software, they are indeed not clear. Therefore, we redrew the T-logP plot (see Figure 8(a)(b)(c)) and unified the scale in the revised manuscript. And we **modify** "L402-403 Figure 8. Comparison of RDSS GTH3 and GTS1 radiosonde T-logP at the Wuhan station: (a) Wuhan Balloon Sounding at 19:15; (b) Wuhan RDSS ascent phase at 20:00; (c) Wuhan RDSS descent phase at 21:30." **to** "Figure 8. Comparison of RDSS and GTS1 radiosonde T-logP at the Wuhan station: (a) GTS1 operational sounding; (b) ascent phase of RDSS sounding; (c) descent phase of RDSS sounding."


StationID:57494(Wuhan)
Time:2021-07-08 20:00:00～21:26:04
element | obs
-20H (m) | 8188.99
ZH (m) | 4692.92
CAPE (J/KG) | 1729.39
CIN (J/KG) | 10.93
PWAT(mm) | 63.7
K | 36.52
LFC (hPa) | 722.54
LCL (hPa) | 953.08
LFC
LCL
hPa
Temperature℃


StationID:57494(Wuhan)
Time:2021-07-08 19:13:00～20:25:00
element | obs
-20H (m) | 8286.23
ZH (m) | 4733.57
CAPE (J/KG) | 1498.16
CIN (J/KG) | 35.65
PWAT(mm) | 66.73
K | 38.13
LFC (hPa) | 712.57
LCL (hPa) | 945.22
LFC
LCL
hPa
Temperature℃

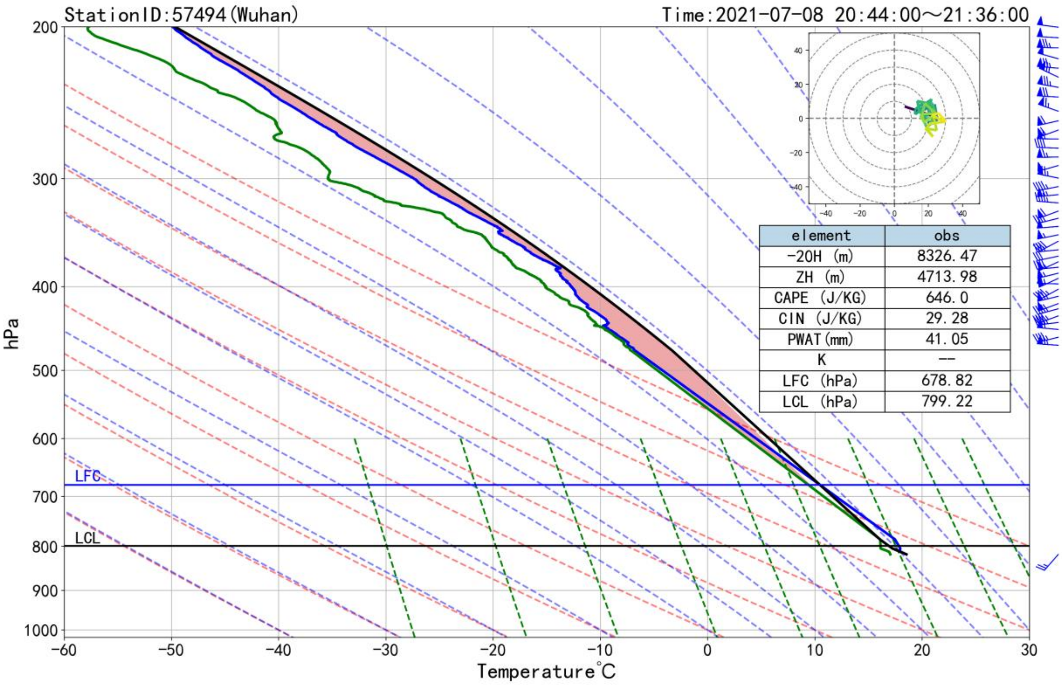


Figure 8. Comparison of RDSS and GTS1 operational soundingT-logP at the Wuhan station: (a) GTS1 operational sounding; (b) ascent phase of RDSS sounding; (c) descent phase of RDSS sounding.

5) *Fig. 7: Is it possible to zoom in? Most of the information East of Wuhan appears unimportant. The red writing in the chart is unreadable. Should it be "Wuhan"?*

Response: Thank you for your suggestion. We apologize for the inconvenience caused to you. The Fig.7 only shows one precipitation weather process. Deleting this picture not affect our discussion. So, we omit this picture and “L400 Figure 7. Combined Reflectivity Factor of Radar Mosaic in the Yangtze River Basin, China, at 20:00 on July 8, 2021.”modify “L375 June 8 (Fig. 7) to July 8” in the revised manuscript.

6) *Fig. 6: The 3D-plot is not helpful. Is it possible to draw the same trajectory information into panel b), using a multi-colored polygon with the color scheme indicating the height of the balloon?*

Response: Thank you for your constructive comments. We have plotted the trajectories on a two-dimensional map (Fig. 6) in the revised manuscript. The simulated and observed trajectories are represented by red and black, respectively. A color gradient based on pressure altitude is used to indicate the variation of trajectory height along the path. The Fig.6(b)(c) only shows Temperature and Wind field at 200 hPa in the middle and lower reaches of the Yangtze River. Deleting this picture not affect our discussion. So, we omit this picture in the revised manuscript. And we modify “L352 Figure 6. (a) RDSS three-dimensional trajectory diagram; (b) Temperature field at 200 hPa in the middle and lower reaches of the Yangtze River; (c)

Wind field at 200 hPa in the middle and lower reaches of the Yangtze River."to "Figure.6 Observation (black triangles) and simulation (red dots) trajectory diagram. The yellow pentagrams represent sounding stations, and the colour of the dots represent the corresponding pressure heights. The colour range from light to dark, indicating the process of the trajectory rising from low altitude (high pressure) to high altitude (low pressure)." in revised manuscript.

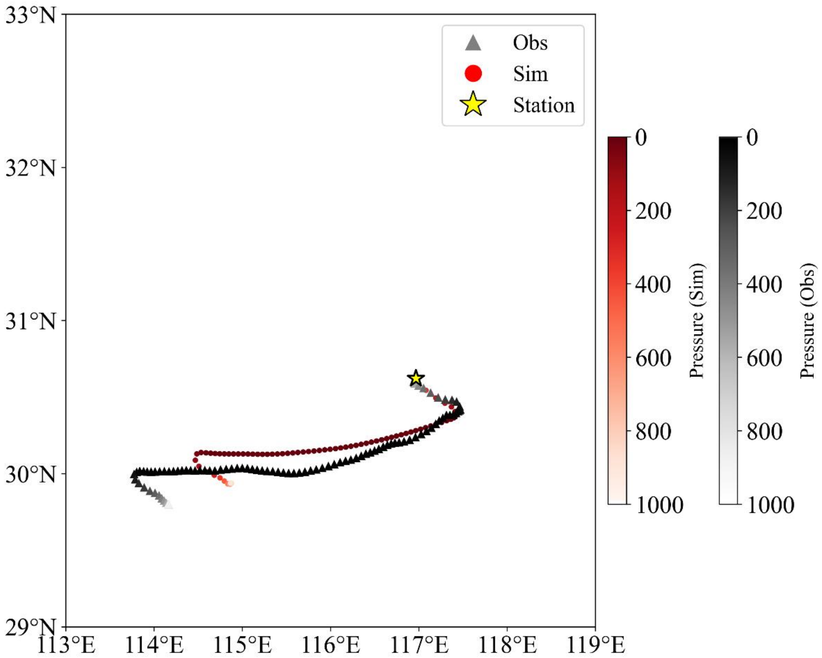


Figure.6 Observation (black triangles) and simulation (red dots) trajectory diagram. The yellow pentagrams represent sounding stations, and the colour of the dots represent the corresponding pressure heights. The colour range from light to dark, indicating the process of the trajectory rising from low altitude (high pressure) to high altitude (low pressure).

7) *Fig. 4: Same suggestion as for Fig. 6, draw the info of panel b) into panel a). While looking fancy, the extreme exaggeration of the vertical coordinate compared to the horizontal ones is somewhat misleading.*

Response: Thank you for your constructive suggestions. We apologize for the inconvenience caused to you. We have plotted the trajectories on a three-dimensional map (Fig. 4) and we modify L333-335 Fig. 4 caption in the revised manuscript.

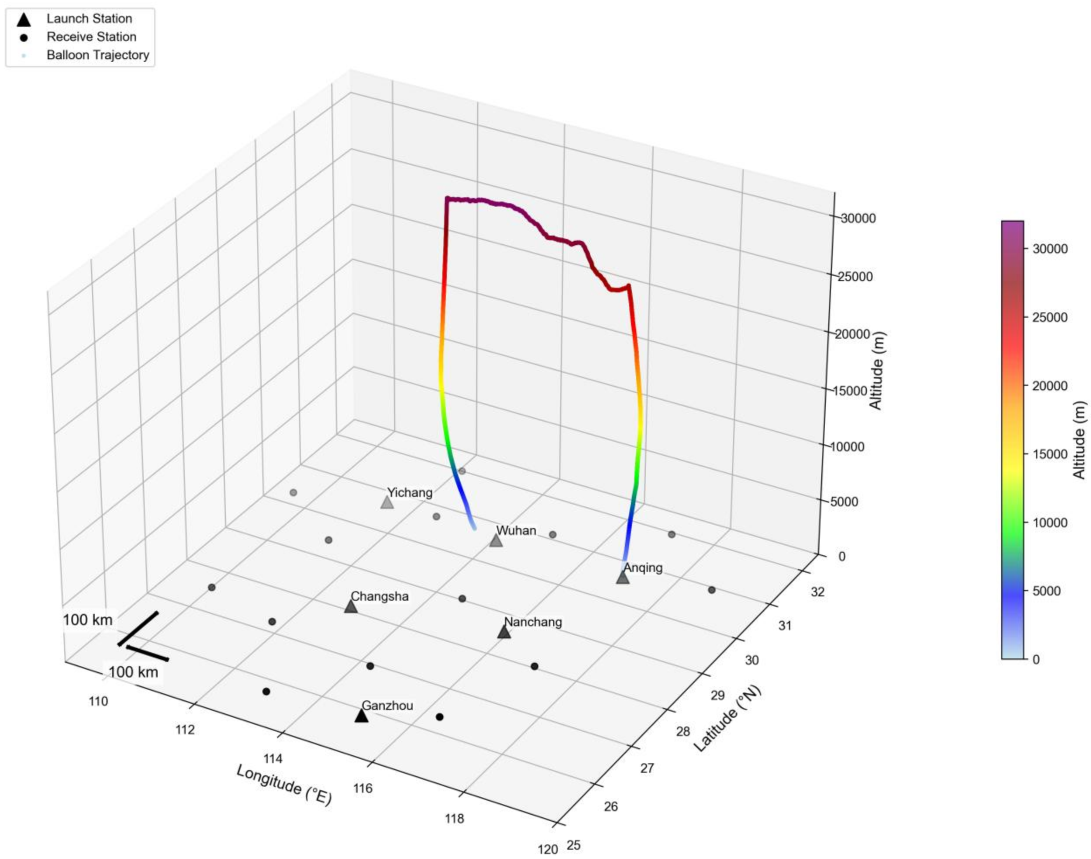


Figure 4 (a) The network distribution of RDSS and (b) an example of measurement: the trajectory for RDSS at the Anqing station at 12:00 UTC on 11 July 2021. The black triangles represent launch stations of RDSS , while the black dots represent Receive stations of RDSS.

(2)The added value of the RDSS compared to a sounding system that has just an ascent and a descent phase is unclear and appears limited. ECMWF reported about successfully assimilating descent data

https://www.ecmwf.int/sites/default/files/elibrary/102021/20225-newsletter-no-169-autumn-2021_1.pdf, similar to what is reported in this manuscript. There is very little information about the quality of data collected during the drift phase, except for the caveat that radiation errors may be larger than during ascent and descent due to lacking motion of the balloon relative to the atmosphere. However I wonder if the information during the drift may be useful for analyzing gravity wave activity, for example. This aspect is getting increasing attention. The authors appear to see the drift phase more as an opportunity to steer the balloon, less as a measurement period. However the chance to steer the balloon depends a lot on favorable wind conditions. So for targeting one needs to launch the balloon at the right position so that it can descend later into a weather system of interest. Wouldn't that be possible also with conventional radiosondes? The question is really if the money invested into the drifting capability would not be better invested into e.g. balloons that can reach as high up as possible (e.g.

https://www.researchgate.net/publication/384155227_Seasonal_and_geographic_via *bility_of_high_altitude_balloon_navigation) or into better humidity sensors that can measure reliably under cold low-pressure conditions.*

Response: We read the technical report about ECMWF successfully assimilating descent data carefully and were greatly inspired. We fully agree with the RC1's insights on the value of radiosonde descent data. As highlighted by recent operational implementations (ECMWF, 2021), carefully processed descent profiles from Vaisala RS41 radiosondes provide scientifically valid atmospheric data under specific conditions: Exclusion of data ≤150 hPa to mitigate high-speed descent errors; Mandatory pressure sensors for tropospheric pressure correction; Prioritization of ocean-derived profiles due to their unique ability to capture near-surface dynamics in data-sparse regions.

We fully agree that descent-phase observations are of great importance. By extending the drifting phase in RDSS, we are not only able to obtain long-duration observations in the lower stratosphere but also gain several additional benefits beyond those you pointed out, such as their application in gravity wave studies. The advantages of incorporating a longer drifting phase are as follows:

1) It provides a wealth of long-duration observational data in the lower stratosphere, which can be used for refined verification of stratospheric forecasts in numerical models.
2) With the inclusion of an extended drifting phase, the descent-phase observations often occur during the traditional radiosonde data gap periods (i.e., 06 and 18 UTC compared to the standard 00 and 12 UTC times), thus offering valuable supplementary data.
3) The addition of a drifting phase results in descent-phase observations occurring far from the launch site. This enables the acquisition of vertical atmospheric profiles in regions that are otherwise sparsely observed, such as the margins of the Tibetan Plateau or over the ocean near coastal stations. These observations provide unique, direct vertical data for numerical modeling and weather research that have not been previously available.

We have already utilized the RDSS trajectory simulation system to model the spatial distribution of descent-phase observation locations for 120 radiosonde stations across China. The results are shown in Figure R1, where different colors represent different months. Compared with traditional sounding observations, which are limited to the areas near sounding stations, the additional descent phase of the RDSS enables atmospheric vertical profile observations at virtually any location nationwide. This capability effectively supplements the atmospheric vertical profile data in regions far from sounding stations, sparsely distributed areas (e.g., the Tibetan Plateau and its surroundings), and regions where it is difficult to set up sounding stations (e.g., vast uninhabited regions of the Tibetan Plateau and the oceans). Once the nationwide RDSS network is established, it will provide extensive atmospheric vertical profile observations for regions where such data are currently scarce, thereby supporting the NWP and atmospheric science research. This advancement will be of great significance for improving the understanding of weather patterns in China and enhancing the accuracy of the NWP.

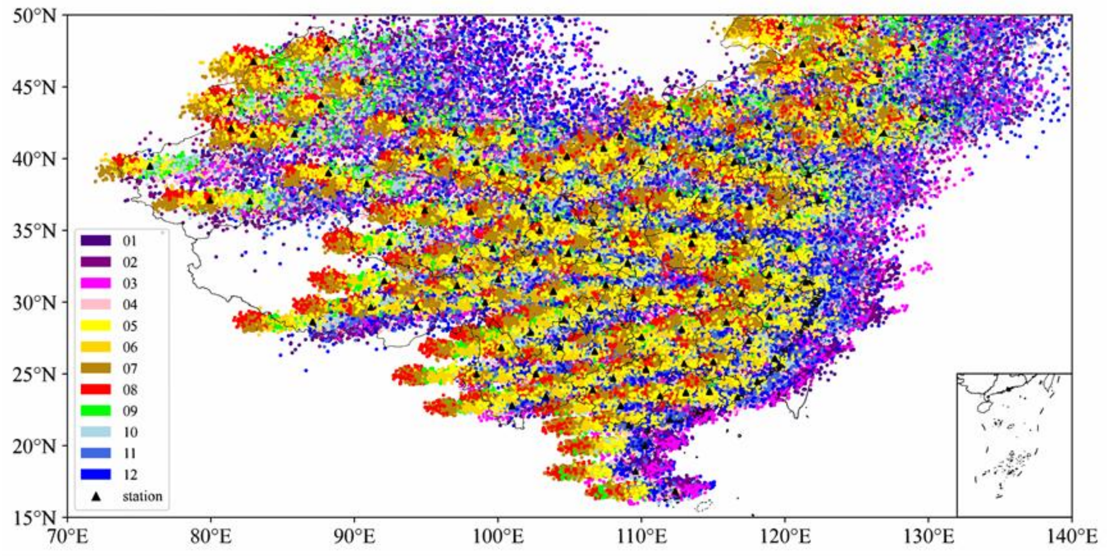


Fig. R1 Spatial distribution of the landing points (colored dots) for sounding stations (black triangles) across China from February 2022 to January 2024. Different colors represent different months.

(3) There is little information about availability of these data to the public. They are potentially valuable for weather centers around the globe or for atmospheric climate reanalysis. It would be important for the reader to know whether these data can be accessed and used under a general public license.

Response: The field experiments data of RDSS involves data policies and can only be shared to a limited extent. It can be shared on a small scale through cooperation between both parties. The CMA is actively studying and formulating the sharing strategy. The authors will actively strive to promote the sharing of this data.

3.Minor Comments:

1) Table 3: Please explain what "Airspeed" means. Is it the data transmission rate in bits per second?

Response: Yes, Thank you for your rigorous review. There is a word error.The "Airspeed" meaning is not clear, we will replace the "Data Transmission Rate" in revised manuscript.

2) L295: It is mentioned that the effect of radiation in the drift phase is greater than during ascent/descent. Can you quantify that, ideally with a plot or table showing the *increased measurement uncertainty during the drift phase. It is unclear to the reader how the CFD correction model works and how it performs.*

Response: Thank you for your constructive suggestions. We will draw a figure of "decreased effect of radiation uncertainty during the drift phase" in revised manuscript.

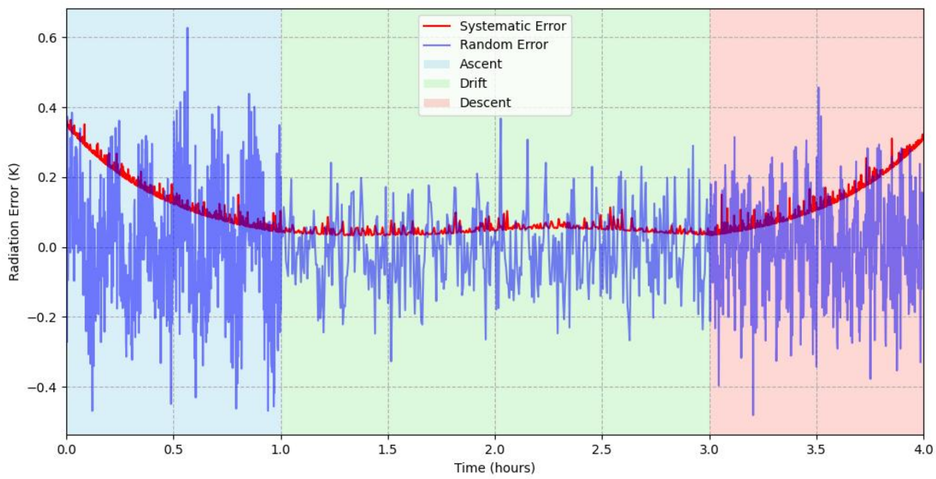


Fig. R2 decreased effect of radiation error during the ADD phase of RDSS.

3)Table 4.2: The assessment is rather crude, particularly for humidity. Having just one value for the whole troposphere is insufficient by today's standard. Can you give a profile of the humidity measurement uncertainty?

Response: Thank you for your constructive suggestions. We have another manuscript is under review:

Beidou Navigation Radiosonde Observation Experiment and Data Evaluation, Lebao Yao, Dan Shen, Xin Sun, Donghai Wang, Xiaozhong Cao, Jincheng Wang, Dan Wang, Chunyan Zhang, Qiyun Guo. Submitted to Atmospheric Research

which is assessment "profile of the humidity measurement uncertainty"

4)L368: track the occurrence of the entire convective system and the changes .. in real time... is a bit strong wording, given the fine grained structure visible in the RADAR picture which is by no means resolvable with a few radiosondes, even with drifting capability.

Response: We will replace the strong wording "... track the occurrence of the entire convective system and the changes .. in real time..." in revised manuscript.

5)L425: results from one month are not conclusive. There should be at least three months (e.g. used as minimum by ECMWF when upgrading their system), ideally from different seasons, to cover any dependency on the annual cycle.

Response: Sorry, At present, the assimilation experiment has only been completed for one month, which indeed cannot fully demonstrate its effect. Combining the optimization of observation errors and sparsity schemes, we are currently studying a comprehensive optimization plan. We plan to optimize the assimilation parameters such as observation error and sparsity before conducting a one-year batch trial.

6)L534: The reduction of the forecast trajectory error in one typhoon event must be considered anecdotal. While encouraging it is certainly not science-grade evidence of an improvement.

Response: Thank you for your constructive suggestions. The science-grade evidence of an improvement is a long process. But we will make persistent efforts to prove it. And we cite relevant paper in revised manuscript.

REFERENCES:

Qiushi Wen, Xuefen Zhang, Sheng Hu, et,al. Collaborative assimilation experiment of Beidou radiosonde and drone-dropped radiosonde based on CMA-TRAMS[J]. Atmospheric and Oceanic Science Letters, 2025, 18(2). doi:10.1016/j.aosl.2024.100555.

7)L550: It is not obvious from the material presented that the RDSS really reduces costs compared to conventional radiosondes. This needs more detailed explanation.

Response: In fact, one RDSS can provide 'Ascent-Drift-Descent' three-phase sounding in which all three phases of sounding observation are executed through single balloon launch. Compared to conventional (Ascent) soundings, it adds 'drift-descent' soundings. So, we modify "L550 Compared to intensive soundings,"to "Compared to two of conventional soundings," in revised manuscript.

8)L567: This statement on data availability is unacceptable by today's open science standards.

Response: The field experiments data of RDSS involves data policies and can only be shared to a limited extent. It can be shared on a small scale through cooperation between both parties. And we modify "L567 Requests for data that support the findings of this study can be sent to luohw_1@163.com."to "The CMA is actively studying and formulating the sharing strategy. The authors will actively strive to promote the sharing of this data. According to the relevant policies of the CMA, this data currently cannot be widely shared. For data sharing, you can contact us to discuss cooperation and data sharing." in revised manuscript.