Dear Anonymous Referee #1,
Thank you for your careful work and constructive comments on “Tomographic retrieval algorithm of OH concentration profiles using Double Spatial Heterodyne Spectrometers”. The comments have substantially improved our paper a lot. We agree with points raised and modify them in the revised version of the manuscript.

On behalf of the authors
Kind regards,

Yuan An

A Point-by-Point response to the reviewer’s comments

General concerns

Reviewer: There are many points in this paper where the authors assert a value (e.g. for uncertainty) or conclusion (e.g. the tomographic retrieval is faster than the iterative retrievals) without providing a citation, clear chain of logic, or data to support those points. I list as many as I could find in the remainder of this document. These points need to be addressed so that readers can make their own assessment of these claims.
Reply: Thank you for your suggestions. We have considered your reminders in your document deeply and solved the problems. We hope the entire modification is clearly described in the revised version of the new manuscript.

Reviewer: What are the plans to test this algorithm in practice once the DSHS is operational. Balloon flights? Aircraft flights? Including this as a future direction would make clear what the next step is.
Reply: We agree to this point. The actual observed data is the key point for the algorithm. Some aircraft flights experiments have been done and the data is being analyzed. The DSHS and research results have been communicated with the related departments. It has been included in the relevant satellite projects for 2020 to 2030. We have added this part to what the next step is.

Specific comments

Sect. 2.2

Reviewer: Section 2.2 in this paper is intended to outline the observing strategy that this proposed instrument will follow in order to obtain spectroscopic information needed to infer the 3D OH fields. This is a key point that must be communicated clearly for the remote sensing community to evaluate whether this instrument is feasible. However, I found this section extremely difficult to read.

The main problem is it seems the authors are exploring different observing strategies and rejecting ones that will not accomplish their goals. It is not clear that this is what they are doing, and it is not clear how they determined whether a particular strategy meet their requirements, or even what those requirements are. I recommend this section be completely rewritten to improve its clarity, addressing the following points in order:

- First, clearly explain the criteria that a particular observing strategy must meet to be considered successful
- Second, explain how the strategies were evaluated to determine if they met these criteria
- Third, describe the final strategy that meets the necessary criteria
- Only then describe the alternate strategies considered and why they were rejected, making it absolutely clear that these are rejected strategies.

As an example of what makes this confusing, I point to lines 184–193:

It is not clear from this section that T2-1 and T2-2 are hypothetical positions, and the bolded text makes it sound like these are actual times when the satellite will make measurements.

I understand that, to some extent, it is necessary to explore these hypothetical options for different measurement times to explain the criteria **(e.g. line 194, "That means, the smaller distance between the P1 and R1 (or R2) is, the higher spatial resolution will be.")**. However, as written, it is unclear when hypothetical options are being considered and when the authors are describing the final option that is chosen.

Reply: We agree with your points deeply. We hope the entire modification is clearly described in the revised version of the manuscript especially the work mode of satellite.

Some more specific points of confusion:

Reviewer: p. 5, l. 141: "**The hierarchical detection of a series of observed radiances in the same target area comes true through the movement of the satellite platform**." Does "movement" refer to the satellite flying along its orbital path, or actively rotating to point the spectrometers at the target area?

Reply: We apologize for the unclear expression. The “movement” means the satellite fly along its orbital path.

Reviewer: p. 5, l. 139–140 vs. Fig. 3: The description of the two sensors as scanning along and across the satellite’s orbit implies, to me at least, that the main axes of the telescopes are pointing parallel to the satellite’s direction of flight, but Fig. 3 looks like the sensors are pointing to the right of the direction of flight.
– This is exacerbated by Table 3, which seems to indicate that there are different T2 points for different altitudes in the profile. Addressing the first point about describing how the satellite moves will help with this.
Reply: We agree with your points. The description about how the satellite moves will help to solve your question. The main axes of the telescopes are pointing parallel to the satellite’s direction of flight. Fig. 3 shows that DSHS monitors the OH in the target area using the data of SHS1 at the time of T1 and SHS2 at the time of T2 together. However, the telescopes points to the forward of the direction of flight.

Reviewer: p. 6, l. 154–170: Since it’s not clear how the satellite will move, it’s very hard to understand what’s going on here.
Reply: We have changed these parts in the revised version of paper. We hope the entire modification is clearly described in the revised version of the manuscript.

Reviewer: How long will the spectrometers record at T1 and T2? Is it very briefly, or is the spectrometer recording as it sweeps across the target zone?
Reply: The DSHS has the function of hierarchical imaging in the spatial dimensional. It can obtain the data at different heights at the same time without scanning the target area for obtaining the data. So, The DSHS record at T1 and T2 is very briefly.

Reviewer: Perhaps more generally, what is happening between T1 and T2? Is the satellite reorienting to get the appropriate pointing vector for the measurement at T2? Are the spectrometers on during this time?
Reply: The satellite needs to reorient for getting the appropriate vector for the measurement at the T2 moment. The spectrometers are on during this time.

Reviewer: Do I understand right that the point of Fig. 3b is that one cannot use data collected at only one time to retrieve the target area? If so, why not? That is not explained.
Reply: Your understanding is correct. If only we use the data at only one time. There are no intersection regions between the field of view slices of SHS1 and SHS2s’ at the time of T1. The tomographic data cannot be obtained in this situation.

Reviewer: It’s not obvious to me why the strategy shown in Fig. 3c of using SHS1 at T1 and SHS2 at T2 is better than using both SHS1 and SHS2 at both T1 and T2. Surely having SHS1-T1 + SHS2-T1 + SHS1-T2 + SHS2-T2 would provide a better constraint on the OH fields?

Reply: On the one hand, a lot of data can provide a better constraint but will cause redundancy. The inversion efficiency will reduce. On the other hand, SHS1-T1 + SHS2-T1 + SHS1-T2 + SHS2-T2 will have a lot of noise, it will make the signal-to-ratio low.

Reviewer: In Fig. 4, why are there red boxes (presumably representing the satellite) on both ends of the T2-x lines of sight but not the T1 line of sight?
Reply: We apologize for the drawing error. The red boxes at the one end of the T2-x lines of sight.

Retrieval algorithm (sect. 4.2)

Reviewer: Given that the tomographic retrieval described in this section is the major advance in this paper, more detail on how the retrieval works is necessary to fully evaluate it. Specifically, in Fig. 16: what precisely is meant by "**SHS1/SHS2 observed data at time of T1/T2**"—radiance at a single wavelength, a few selected wavelengths, or all wavelengths measured by the spectrometer?
Presumably it is not a single wavelength because that would make it extremely difficult to disentangle the effects of the background radiance from that of OH fluorescence. But if it is at all measured wavelengths, that seems like it would result in an extremely high dimensionality to deal with in the interpolation.
Then, in the first paragraph of sect. 5.1, the authors state that there are four databases, one per season. How are transitions between seasons handled? If it's an abrupt switch (say May 31st uses the spring database and June 1st uses the summer database), won't that introduce discontinuities to the retrieved OH time series?
For Fig. 17, how does the inversion result compare with the true profile that was used to simulate the radiances? Similarly, on line 570, the sentence "**The OH concentrations obtained by the LSUV retrieval algorithm are credible in the upper atmosphere,**" is extremely vague. What level of agreement do you consider "credible"? How large a sample size did you use to determine this?
Reply: Thank you for your comments. 1) The SHS1/SHS2 observed data at time of T1/T2 mean the radiance at all wavelengths measured by the DSHS. 2) We count a large number of samples in each grid in the day. It shows that the number of samples is not uniform in the grid, the number of samples in most grids is too small, even there is no profile data in some grids. The less profile data will order to a larger random error. Averaging method cannot reach the goal of smoothing profile and reducing errors. Therefore, the month is determined as the time resolution. We average the profile data in the grid to obtain the monthly average concentration profile data. So, it will not introduce discontinuities to the retrieved OH time series when an abrupt switch happens. 3) The OH concentrations obtained by the tomographic retrieval algorithm are the results of inversion process. The OH concentrations used to simulate the radiance are the parameter of forward process. These OH concentrations have different meaning and are not comparable. The conclusion of results obtained by the LUSV has been proven by a lot of manuscripts. We have added some citations in the revised version of the paper.

Other major concerns

Reviewer: Line 580: I don't quite understand "**the undisturbed parts are taken as the actual parameters, and the results based on these parts are the true OH fluorescence emission radiance. Then, some certain amounts as the disturbances are applied to the three parts above. The OH fluorescence emission radiance based on these parts is the incorrect results." What are the "undisturbed parts**"? Do you mean that you take the values of each of the atmospheric model, Doppler effect, and instrument calibration from the actual retrieval, and add some error to one at a time? That could be much clearer. How do you determine how much error to add? Do you do this for every OH concentration in the test set or a subset?
Reply: Apologize for these unclear parts in your questions above. Your understanding is exactly what I want to express. We take the values of the atmospheric model, Doppler effect and instrument calibration from the actual retrieval process. Some explanations are given in the following parts to solve the problems about how much errors we add. We do this for every OH concentration in the test subset because the conclusion is representative.

- line 597: "**...the amount of ozone profile for the disturbances is set as ±30%.**" Why 30%?

Reply: We referred to the relevant parameters of the instrument likes SHIMMER which is similar to the DSHS in this part due to the DSHS has not been worked officially. Apart from this, we did a lot of experiments according to the conclusions of the research of SHIMMER and found the 30% is the best threshold to disturb the ozone profile for analyzing the influence of the atmospheric model.

Reviewer: Line 652: "**We assumed the instrument calibration errors are ±5%...**" Why 5%? Please provide either a citation or the line of reasoning used to arrive at this value.
Reply: We apologize for this unclear description. The instrument calibration error is given by the manufacturing and design department of sensor. Some citations have been added in the revised version of the paper.

Reviewer: Line 657: "**It is about 0.32% for the six-dimensional cubic spline interpolation of OH concentrations, date parameters, longitude, latitude, solar zenith angle and azimuth angle after research and related experiment.**" What experiment did you do to determine the 0.32% value?
Reply: Apologize for the missing the experiments. We give a certain disturbance to different parameters to calculate the effect of the interpolation algorithm on the OH concentrations.

Reviewer: Line 741: "**The speed of traditional iterative retrieval algorithms is slow and will cost a lot of time.**" Can you quantify this? How much faster is the tomographic algorithm for, say, a single target area or a day's worth of data?

Reply: The traditional iterative retrieval algorithm will take several or even tens of hours to obtain OH concentrations due to the complex iterative process. The tomographic algorithm just needs minutes for obtaining the OH concentration due to the usage of the lookup table method. It is difficult to quantify how much fast is the tomographic algorithm absolutely. The results obtained by the traditional iterative retrieval algorithm in the lower atmosphere are unscientific but the OH concentrations obtained by tomographic algorithm in the same area are accurate. The tomographic algorithm can improve the accuracy of data while acquiring OH concentrations quickly.

Technical corrections

Points for clarification

Reviewer: Lines 252–255: What is meant by "**The SCIATRAN absorption spectrum database is completed based on the HITRAN 2014 database....**" Does this mean that the forward model kept the HITRAN 2012 database, but added the UV absorptions from HITRAN 2014? Or does the forward model use HITRAN 2014 instead of HITRAN 2012? Or something else?
Reply: We apologize for these imperfect descriptions. The SCIATRAN uses HITRAN 2012 by default. However, the HITRAN 2012 database does not include the OH absorption profiles in the ultraviolet band. We use the OH absorption profiles in the HITRAN 2014 to solve this problem. We upgraded the SCIATRAN in this part by using the HITRAN 2014.

Reviewer: In Eq. (10) where does N(j) come from, if Ng(j) is either from the OH database or the iterative update?
Reply: We apologize for these unclear descriptions. The N(j) is the result of iteration. It can get though the y_j and $N_g(j)$ when the converges meet the accurate requirement or the number of iterations exceeds the iteration number threshold.

Reviewer: Is Section 5.2.4 where we switch from discussion errors in the OH radiance to errors in the actual OH concentration? Please make it clearer that we are transitioning if so; the section title could be "**Analysis of total errors in the OH concentrations**" and add a first sentence like "**We now move from considering errors in the OH radiances to errors in the retrieved concentrations.**"
Reply: Changed as suggested. Thank you very much! We have changed the title of Section 5.2.4 and added a first sentence "The retrieved results must be considered after the discussion of the OH radiance".

Reviewer: Line 704: "**It is a great improvement to compare with the results of the LSUV retrieval algorithm which has a characteristic of iteration.**" What are the LSUV errors, or where in the paper are they listed? I found some of them later in the paragraph (line 715 and on), but why are they not in Table 7 for immediate comparison with the tomographic errors?
Reply: The OH concentrations obtained by the LSUV algorithm in the lower atmosphere are unsuitable for scientific research. These limit the applicability of LSUV algorithm. This manuscript focuses on the new algorithm, we use the table to emphasize the errors of new algorithm and consider it is more reasonable to use the text for comparing two algorithms.

Reviewer: Line 709: "**The corresponding accuracy ranges of MLS OH concentrations products are also given, and its useful height ranges are from 23 to 81 km.**" Where are these values given?
Reply: These values are given by the MLS data quality and description document which seems like the instructions of the data. It is given by the Jet Propulsion Laboratory to ensure the scientificity and accuracy.

Typographic comments

Reviewer: line 142: "**hierarchical detection**," not sure what is meant by this.
Reply: We apologize for the unclear description about "**hierarchical detection**". The DSHS will detect the altitudes from 15 to 85 km by the three-dimensional limb mode. This observation mode can obtain the OH data at the altitude of 15, 17, 19, 21,23 and the altitudes which follow this role. The atmosphere is divided into many layers. The hierarchical detection means the sensor can obtained the data in these layers like the multi-angle method.

Reviewer: line 228: "**The observed data received by the DSHS with an ultra-high spectrum resolution makes up by two parts in this research...**" does this mean that the data recorded by the spectrometers will be made up of two parts?
Reply: Correct. The data recorded by the DSHS is made up by two parts due to the ultra-high spectral resolution of spatial heterodyne spectroscopy. The atmospheric background radiance and the OH fluorescence emission radiance can be separated accurately for the following research.

Reviewer: line 247: Citation for the Lifbase software needed
Reply: Thank you for your suggestion about missing the citation for the Lifbase. The citation has been added in the revised version of the paper.

Reviewer: line 248: Citation for the Bremen atmospheric model needed

Reply: Thank you for your suggestion about missing the citation for the Bremen atmospheric model. The citation has been added in the revised version of the paper.

Reviewer: lines 236–275: there are several different ideas in one paragraph (the solar spectrum, the OH spectrum, the OH concentrations database). Please give each its own paragraph.

Reply: We agree with your points. These ideas have been separated clearly. We hope the entire modification is described in the revised version of the paper.

Reviewer: Eq. (5): units?

Reply: Apologize for missing the units. The Eq. (5) is the wavelength calibration equation. The δ_i is the symbol of intensity. So, the unit is $phot^{-1}s^{-1}cm^{-2}nm^{-1}sr^{-1}$.

Reviewer: line 429: "**However, it cannot be done to obtain OH concentrations in a converse way directly**"—should "converse" be "inverse"?

Reply: Apologize for this vocabulary mistake. We have changed the "converse" to "inverse" in this sentence.

Reviewer: Around line 575: it seems like there is a shift from comparing the iteration and lookup table methods to the formal error analysis of the lookup table method. This should be more clearly separated.

Reply: We agree with your points. These two parts in your question have been separated clearly in the revised version of paper. We hope the entire modification is clearly described.

Reviewer: line 646: "**The distributions of errors have the same tendency, but the relative errors of tomographic retrieval algorithm are smaller than LSUV retrieval algorithm.**" Does this mean that the distribution of errors due to the Doppler shift is similar between the LSUV and tomographic algorithm? As written, it sounds like the distribution of errors are similar to the relative errors.

Reply: Correct. The distribution of errors is similar between the LSUV and tomographic algorithm and is similar to the relative errors.

Reviewer: line 647: "**These indicate that tomographic retrieval algorithm can obtain more accurate OH concentrations although the Doppler effect cannot avoid**" The tomographic algorithm is more accurate than what? The LSUV algorithm? The Doppler effect cannot avoid what? Does this mean the Doppler effect cannot be avoided by either algorithm?

Reply: We apologize for being unclear about this. The OH concentrations which are obtained by the tomographic algorithm are more accurate than the results are obtained by the LSUV algorithm. The influence caused by the Doppler effect cannot avoid when the spectral resolution is extremely high when the sensors use the spatial heterodyne spectroscopy technology. So the Doppler effect can be avoided by some situations.

Reviewer: line 701: "**As the Table 7 indicates that the total errors of OH concentrations are increasing as the heights rise**." Since the errors only increase with altitude at first, perhaps instead: "**As Table 7 indicates, the total errors of OH concentrations initially increase with height...**"

Reply: Changed as suggested. Thank you very much.