We’d like to thank the editor for handling our manuscript, as well as anonymous referee #3 for reading our manuscript carefully and providing numerous professional comments and helpful suggestions. We believe they help us to improve the manuscript significantly and provide many useful ideas for our work.

We have carefully read through all the comments and questions and revised the manuscript accordingly. Please find our point-by-point response to referee #3 below. Here, the reviewer’s general and specific questions/comments are formatted in bold font and blue. Our responses are formatted in regular font and black, the manuscript changes are in red.

General comments:

This manuscript uses the radiative transfer model and the optimal estimation algorithm to simulate the inversion of atmospheric wind speed for terahertz limb sounding, screen out the target molecules in the THz band and the corresponding optimal frequencies, and analyze the influence of spectral bandwidth, resolution and NEDT on the inversion accuracy. But I have the following questions, which need to be revised and answered:

- **In “As of now, direct measurements of middle and upper atmospheric wind are still scarce” and “However, measurements of wind speeds are still lacking in these altitude regions, particularly between 30 and 60km, which is also known as the “radar gap””, could some more recent references be added here?**

Thanks for your suggestion. Two references have been added which described the “radar gap” and the challenge of measuring winds in the stratosphere and lower mesosphere.

Reference:

Hysell, D. L., Chau, J. L., Coles, W. A., Milla, M. A., Obenberger, K., and Vierinen, J.: The Case for Combining a Large Low-Band Very High Frequency Transmitter With Multiple Receiving Arrays for Geospace Research: A Geospace Radar, Radio Science, 54, 533–551, 2019.

Liu, X., Xu, J., Yue, J., and Andrioli, V. F.: Variations in global zonal wind from 18 to 100\,km due to solar activity and the quasi-biennial oscillation and El Niño–Southern Oscillation during 2002 2019, Atmospheric Chemistry and Physics, 23, 6145–6167, 2023.

- **For “and the observation method is limited”, compared with existing equipment, what are the advantages of space THz equipment?**

As we discussed in Sect. 1, the THz limb sounder has good performance in measuring middle atmosphere winds (especially 40-70 km), and less affected by diurnal variations. The current lidar such as Aeolus/ALADIN measures wind below 30 km, interferometer such as ICON/MIGHTI measured wind above 90 km, TIMED/TIDI measured wind above 70 km during the day and 80–105 km at night. The THz sounder can be a supplement to current space measurement.

- **In “THz limb sounder (TLS) is a concept instrument for lower thermospheric neutral wind/density/temperature and can provide wind profiles of 100–180km”, can a brief description of the pros and cons of this THz instrument be made?**

It is designed for small satellite platforms with very small mass (<3-5 kg) and power (<30 W). It can measures vector winds from a combined 45° and 135° views with wind speed uncertainty of <10 m/s. However, due to its DSB noise temperature of 7000 K, 10 s integration time is needed to obtain better measurement sensitivity. Thus, its horizontal resolution is 400 km and vertical resolution for two bands is 3.5 km and 6.4 km which are relatively bad but can meet the basic scientific needs.

- **In “However, investigations on the retrieval performance using a combination of different bands and the impact of instrument parameters were insufficient in the previous studies.” 。please briefly talk about where the previous research is insufficient and why it is important.**

Thanks for your comment. The previous research were mainly carried out by Baron et al., 2013, 2015. Their work investigated the performance of several focal frequencies and instrument configurations for wind measurements, but they were mainly oriented towards the design of SMILES-2. This study based on previous researches and focuses on more potential frequencies and combinations for providing a generalized reference for future instrument design.

- **For “Figure 1 shows the wind measurement principle of a radiometer”, it is necessary to briefly describe the detection principle and advantages, and further, explain the**

diagram in Fig.1.

Thanks for your suggestion. The explaination has been added: "Assuming the spectrum observed by a THz radiometer without the line of sight wind is shown in dark blue and the spectrum with the wind's Doppler shift is shown in red. The difference between these two spectra (ΔBT shown in Fig. 1) is shown in light blue. It can be seen that the wind signature is anti-symmetric and has two position of large spectral difference" and "…that is, when the modeled spectrum which considers no wind to compare with the measured spectrum, the wind information can be obtained. It is worth mentioning that the anti-symmetric signature of the wind makes it possible to be retrieved simultaneously with other parameters that have symmetric signatures (such as temperature, pressure, VMR)".

- **For "Therefore, the spectral resolution of measurement does not need to reach as high as 100kHz and the retrieval problem can be solved by the linear least-squares method", maybe there is a mistake here, the optimal estimation algorithm is used, not the least square method.**

Thanks for your comment. However, the optimal estimation algorithm is also one of the least square method. Essentially this algorithm is a fitting of the spectrum. We have added a statement to this sentence: "the retrieval problem can be solved by the linear least-squares such as the optimal estimation method (OEM)".

- **For the "2.1 Retrieval method", suggestions are that 1. Introduce the variables in OEM in combination with the parameters to be inverted; 2. The parameters in the formula are not introduced one by one, such as b, A, I, and Gy.**

Thanks for your suggestion. All the variables and parameters are introduced one by one: "y is the measurement radiance, F is noiseless radiance calculated from the forward model including instrumental response, x is the target atmospheric state vector, x_a is the a priori state vector, b is the parameters in the model that are independent of the state vector" and "where A is the averaging kernel matrix which represent the sensitivity of the retrieved state to the true state and Gy named the contribution function matrix which expresses the sensitivity of the retrieved state to the measurement".

- **In "Since the brightness temperature is proportional to the molecule line intensity and volume mixing ratio (VMR)", the "proportional" is true?**

We are sorry for the mistake here. Because of the saturation of optically thick lines, the statement "the brightness temperature is proportional to … (VMR)" is not always true. The statement has been rephrased in Line 105: "The following molecules are expected to provide useful wind signals based on their spectroscopic line-strengths and typical Earth's VMR: H_2O, O_3, CO, O_2, HF, HCl and O atom (OI)".

- **In "the Doppler shift calculation is performed in the "on-the-fly" mode", can you explain the characteristics of this model?**

The "on-the-fly" mode in ARTS means that each absorption coefficient is obtained from line-by-line calculation of spectral data, rather than extracted from a pre-calculated cross-section look-up table. This means that for each layer of the atmosphere, all the observed frequencies are updated due to the wind and the absorption coefficients are recalculated. This description has been added in Line 114: "Since all the frequencies are updated for each layer of the atmosphere due to the wind and the absorption coefficients also need to be recalculated. To prevent interpolation errors, the radiative transfer calculation is performed in the ARTS "on-the-fly" mode which means that each absorption coefficient is obtained from instant line-by-line calculation".

- **For "The results in Fig. 3 demonstrated that BT induced by wind can be as large as 10 K and different molecules are sensitive to different altitudes", "Although the BT variation (i.e. wind signal) becomes larger with increasing frequency, the system noise temperature also increases correspondingly. From the perspective of SNR, most of the high frequencies do not have better SNR than the low frequencies. The BT of wind at 50km comes mainly from the numerous O3 spectral lines, and the BT induced by wind at 70km is significant at the O2 and H2O spectral lines. Furthermore, wind can be obtained up to 90km by strong spectral lines of O2 and H2O. Finally, BT of wind at 110km exists only at two spectral lines of OI. Therefore, based on the above simulation results", this**

paragraph needs to be re-expressed, because it is difficult to clearly conclude Table 1 from the above simulation results (Fig. 3), at least to explain the specific basis for the selection of these bands

Thanks for your comment. The explaination has been rephrased: "It can be seen that no signature of winds are noticeable at 30 km because of pressure broadening of the spectral lines. The number of ΔBT lines at 50 km is the largest and the most dense and comes mainly from the numerous O3 spectral lines. The ΔBT at 70 km is significant at the O2 and H2O spectral lines due to their large VMR or strong line intensity at this altitude region. Furthermore, wind can be obtained up to 90 km by the strong spectral lines of O2 and H2O. Finally, ΔBT at 110 km exists only at 2.06 and 4.74 THz which is the two spectral lines of OI since only this atom has large VMR at this altitude region in THz band molecules. Therefore, based on the above results, those prominent ΔBT positions compared to their surroundings are first selected, such as 118, 448, 487 and 556 GHz lines and so on. Second, other spectral lines that are commonly used or have been mentioned before, even though the ΔBT is not very large, are also taken into account, such as 183, 625 and 773 GHz lines. Third, it is also important to note that since this selection strategy is based mainly on the intensity of the ΔBTs, the O3 line groups with moderate intensity will be missed. Therefore, we have referred to the conclusions of the previous research (Baron et al., 2013a, 2015) such as 359, 655 and 837 GHz line groups and search for the groups of O3 lines with similar density and intensity".

- **"The spectral bandwidth and resolution of the radiometer in this simulation is 4GHz and 1MHz. The system noise temperature for a double sideband (DSB) radiometer at ambient temperature can be simply calculated as a function of frequency (Hubers, 2008)", can you briefly explain the connection between SSB and DSB?**

The THz radiometer uses superheterodyne receiver to obtain spectra. See the figure below, if the target spectrum is the upper band, the SSB is to extract the upper band and eliminate the lower band, while the DSB is to obtain the spectrum after the mixing of the upper and lower band. However, the noise of DSB will be almost the half of SSB.

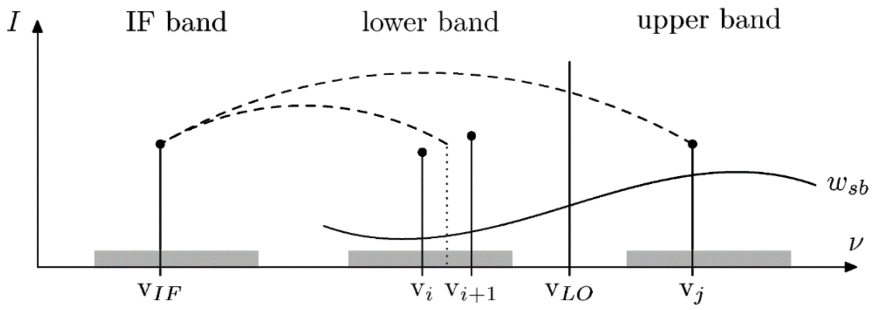

Figure. Schematic of sideband folding

Reference: Eriksson, P., Ekström, M., Melsheimer, C., & Buehler, S. A. (2006). Efficient forward modelling by matrix representation of sensor responses. International Journal of Remote Sensing, 27(9), 1793-1808.

- **In "Due to the purpose of channel selection, the a priori molecule profiles" which will affect retrieval precision is not considered in this study.", dose the "priori molecule profiles" refer to the accuracy of prior profiles? But the accuracy of the prior profile is included in Sn, how to explain?**

The a priori molecule profiles means the VMR of such as O_3, H_2O, OI, it is assumed accurate in the simulation and not included in Sn. The a prior error in S_n is from the wind a priori profile, as stated in Sect. 3.2: "The a priori wind profile and corresponding covariance used for retrieval regularization are assumed to be 0 m/s and 100 m/s, respectively".

- **In "Two cases of the same noise (i.e. noise from 0.5MHz resolution) and normal noise" are compared.", how to understand the normal noise?**

As the Eq(10) shown, higher spectral resolution leads to the higher noise. The same noise case means that all the resolution retrievals use the same noise (i.e. the noise is calculated in 0.5 MHz resolution), while the normal noise case means the noise is calculated from Eq(10).

- **Figures 16, 17, 18, etc. do not mark a,b, but a,b is mentioned in the article.**

Thanks for your correction, the marks has been removed.

- **In "The measurement noise induced by receivers is the main error source in OEM retrieval. System noise temperature and NEDT can be calculated according to the (9) and**

(10)", since the accuracy of the wavelength has a great influence on the inversion accuracy, does the measurement noise include the uncertainty of the wavelength? The accuracy of possible wavelengths also needs to be considered.

Thanks for your comment. The noise here only consider the thermal system noise (random noise), all systematic errors are not considered. The uncertainty of the frequency is an important systematic error. However, according to the current THz radiometer technology, the variability of the local oscillator frequency is less than 10 kHz which is quite small.

- **For the whole article, does the time resolution impact inversion accuracy? Maybe you can briefly explain the principle of the radiometer in the THz band, and then analyze which factors influence the inversion results.**

The time resolution will not impact the retrieval since a scan time (one profile) of limb sounder is usually less than 1 min. The microwave or THz radiometer system mainly consists of an antenna and scanning drive mechanism, an RF front-end receiver, and back-end digital spectrometers. The atmospheric radiation signal from the antenna is reflected to the receiver system through the main reflector. The first path is the radiation coming in from the antenna, the second is the radiation from the cold space background, and the third is the radiation from the calibration target blackbody. The radiation from the latter two paths is used for the two point calibration. The radiation received by antenna system enters the front-end of the receiver. The signal enters the receiver through feeds of different frequencies, and the front-end signal is transformed into an IF signal through the mixer, and the IF signal is further down-converted after amplification. Then IF down-converter module uses different fundamental frequencies to transform the frequencies to the frequency band suitable for the back-end spectrometers, and these transformed IF signals are fed to the back-end spectrometers and output the power spectrum which can be calibrated to radiance.

The NEDT from system thermal noise is a main factor that affects the retrieval, since it is the random noise which can not be calibrated. As discussed in paper, system noise temperature, spectral resolution and integration time together determine the NEDT. For other parameters, systematic errors from calibration hot-load temperature, radiance linearity assumption, sideband ratio, local oscillator frequency, antenna efficiency, spectroscopic parameters and

LOS azimuth and elevation angles will also impact the retrieval results. However, these factors are instrument-related and require specific analysis which is not the target of this study.

Reference: Baron, P., Murtagh, D., Eriksson, P., Mendrok, J., Ochiai, S., Perot, K., Sagawa, H., and Suzuki, M.: Simulation study for the Stratospheric Inferred Winds (SIW) sub-millimeter limb sounder, Atmos. Meas. Tech., 11, 4545–4566, 2018.

A new section of discussion (Sect. 5) has been added to analyze the general results, limitations and vertical resolution.