General comments:

The manuscript “Enhancing Long-Term Trend Simulation of Global Tropospheric OH and Its Drivers from 2005-2019: A Synergistic Integration of Model Simulations and Satellite Observations” estimates the tropospheric OH trend lead by NO_2, tropospheric ozone, H_2O, and HCHO on 1x1 model resolution. Quantifying the drivers of the global OH changes is essential for better understanding recent changes in the global CH_4 mixing ratio. The manuscript is generally well organized and clearly written. In this study, the ECCOH model estimates OH by machine learning method. Machine learning predicts OH by finding the correlation patterns between OH and the input factors. The cause-and-effect relationship is not necessarily captured by the machine learning method. The authors estimated the drivers of the OH trend based on the sensitivity of OH to different factors as given by machine learning parameterized OH. My main concern is whether the sensitivity of OH to different factors estimated by machine learning parameterization is consistent with that simulated by the M2GMI model. Is there any possibility of evaluating the sensitivity? Besides this, I only have a few minor comments. I recommend the paper be published on ACP after addressing these comments.

Specific Comments：

1 L25: How is the TOH estimated? Is it weighted by air mass, volume, or CH_4 reaction?

2 L191-193: Are the VOCs simulated by M2GMI distributed only in the first layer of the model? Why was the CO produced by VOCs released to the first vertical level of the model?

3 L224 “**E** is populated by the average sum of precision error squares the satellite product provides” . “**E**” should include instrument, representation, and forward model errors. However, here only the instrument error is included.

4 L225-226: The “mass-conserved linear barycentric interpolation method” should be described here.

5 L248: In my understanding, the chemical compounds including tropospheric ozone are prescribed in the ECCOH model. How do the improved NO_2 and HCHO represent for more accurate simulation of other chemical compounds?

6 Equation 4 what is the temporal resolution of y? When $\omega = 1$, the cosine function has a period of 1, how does it account for the seasonal cycle?

7 L265: How to use the Levenberg–Marquardt algorithm to optimize the estimation?

8 L359-L363: It is confusing here, do you mean the water vapor in the “Sanalysis” experiment the water vapor is from the GOES online simulation while in the SOHvv simulation, the water vapor is from the MERRA2 reanalysis?

9 L412-416: The Bayesian system gives low AK over the remote areas because the satellite observations give higher relative error over the regions with low NO_2 values while the B is arbitrarily set to 50% for all the model grid. Considering the NO_2 simulated by M2GMI may also have larger relative uncertainties over the remote areas, “low AK in remote areas shows rich information from OMI tropospheric NO_2 gravitates more polluted regions. “ is not a robust conclusion.

10 Figures S1 and S2, Are the grey regions in the figures indicating a non-significant trend? It seems that the M2GMI failed to capture the positive trend over most of the positive trends in tropospheric ozone over the Northern hemisphere, and over the tropical ocean, the M2GMI simulated a significant negative trend, which is not observed by the OMI/MLS data.

11 L529-543: Here is my main concern for this paper. Although the machine learning

approach can reproduce the OH distribution, how well the machine learning method can reproduce the sensitivity of OH to NO_2, HCHO, tropospheric O_3, etc. is not evaluated in Anderson et al. (2022; 2023). Nice et al. (2018) estimated that the NO_x increase can lead to a decrease in OH concentrations over the high NO_x regions. The negative sensitivity accounts for 10% of all the cases tested by the chemical box model. As shown in Figure 5, machine learning gives overall positive sensitivity. Also, for HCHO, which acts as both OH sink and HO_2 source, machine learning gives overall positive sensitivity. The sensitivity calculated by machine learning can have a large impact on the conclusion of this study. Is there any possibility to evaluate the sensitivity estimated by machine learning?

12 L543-543; L731: Are the increase in CH_4 means that the model is not fully-spin-up? Usually, 3 times of lifetime is required to reach a steady state.

13 L717-723: Does the global reduction of CO emissions contribute to the unexplained TOH trend?