

Answer to Reviewer #1

We would like to start by thanking you for all the time and effort which you spent reviewing our paper. All your comments, suggestions, and questions were taken into account and all the necessary corrections were made in the revised manuscript.

Furthermore, we address all your comments and suggestions below, point by point.

General comments:

The paper focuses on the factors affecting the interannual variability of stratospheric water vapor entry in the tropics in observations, CCM1 and CMIP6 models. The authors contrast the use of a variety of techniques: multiple linear regression and 3 machine learning methods. Cold point temperatures are the main factor explaining the water vapor variability. They discuss the merits of the different techniques and the relative importance of the QBO and ENSO. They also find non-linear interactions to be important. The comprehensive models, whilst will suffering from a QBO that is not deep enough, have nonetheless improved. The paper is well written and provides an good description of machine learning techniques applied to a geophysical problem. The figures are also mostly clear.

Specific comments:

(1) Make it clear earlier during the introduction that you are looking at interannual variability and not the seasonal cycle.

We clarified this in the introduction.

(2) Some of the CCM1 model have multiple ensembles. Do you average over all of them? If so, does this result in less variability and thus make it harder to compare to those runs with only 1 ensemble?

We include each ensemble member separately. We don't average the ensembles together before computing correlations, rather compute for each ensemble member separately. Now clarified.

(3) In the figures, would it be possible to have the models with a nudged QBO labeled in bold text? It would make identifying them easier.

We tried adding this information to the figure legend of figure 1 and 9, but the figures then looked strange. We added it to the caption instead.

(4) On line 4, page 6, you mean ERA5/ERA5.1 I think?

Yes, we corrected this.

(5) On page 6, line 11, "Note that the correlation of the BDC with the QBO is -0.66 (Figure 2), and hence including both in a single regression or ML model can lead to overfitting. " I disagree with this statement. Multicollinearity in your predictors causes a variety of problems but does not specifically cause overfitting. See page 283, Applied linear statistical models 5th edition by Neter et al. (2004). Your validation stage should show if overfitting is an issue.

Indeed, we rectified the sentence to say that multicollinearity can lead to erroneous model interpretation.

(6) Page 10, line 15, the non-linear predictors are interesting but I struggle to relate them to physical processes. Could you give the reader a sense of what ENSO² might be?

Garfinkel et al 2018 goes into great detail as to why physically La Nina can also lead to a moistening. The short answer is that the region of the cold point moves zonally within the tropics, and even though the lower stratosphere cools, the cold point actually warms.

This has been added to the introduction section where it seems more appropriate than at this point in the text:

"Both La Nina and El Nino can lead to a moistening if the cold point moves zonally within the tropics (to the Central Pacific for El Nino, and to the far West Pacific for La Nina), and even though the lower stratospheric response is opposite for El Nino and La Nina, the cold point warms for both (Garfinkel et al 2018)" We also added a similar sentence to the discussion.

(7) The values in Figure 6 are somewhat hard to read. Could you add a few labeled contour lines please?

Contour lines with labels were added to Fig. 6, Fig. 3 and Fig. 8.

(8) Figure 7 feels unnecessary since the same information can be conveyed with the text.

We removed Fig. 7 from the paper and updated the text to include the SHAP values for each predictor.

(9) In figure 9 (a to c), the text suggests that the solid black lines are observations (and they are not described in the caption) but where are there two parts and at different values? Label the models in 9(a).

We now note the solid black horizontal line is observations, and that entry water is defined separately for CCM1 and CMIP (80hPa and 70hPa respectively).

Adding labeling to panel 9a made the figure more visually distracting without any added content, hence we left 9a as is.

Minor comments

Page 1, line 164, Emissions

corrected

Page 2, line 5, through the its

corrected

Figure 1. Labels are a bit small and hard to read.

now larger

Figure 4. Are the units of the H₂O anomalies correct?

Yes, we clarified it in the caption.

Figure 5 and Figure 9. You use "std" and "std dev". Choose one to be consistent and also explain the abbreviation in the caption.

We have adopted the std.dev abbreviation and updated it in the caption.

Figure 5(a) I am confused about the histogram. Is it normalized? If so, why are the values >1?

The histogram is normalized in a way that the total area of the histogram equals 1. This means that some bars can indeed exceed 1. However, it may be confusing, thus, we replaced the figure with the "probability" normalization where the sum of all the bars equals 1. This changes only the y-axis values and not the shape of the histogram which is more important in the context of this paper.