Reply to the Editor's comment:

(1) Thanks very much for your revisions of the paper. I think you have addressed the remaining points, but there is one question from my side that has arisen in your reply and revisions. You say that increased water vapour in the UTLS should lead to surface cooling (if I understand you correctly). I think this effect is correct in principle but is not applicable at UTLS altitudes but rather at say 10 hPa. At UTLS altitudes increased water vapour should lead to surface warming (see e.g. Fig. 1 in Riese et al., JGR, 2012). Perhaps you could clarify my confusion at this point.

Reply: We thank the Editor for the comment. In the manuscript we have not linked the increased water vapour in the UTLS to the surface cooling. The reference (Riese et al., JGR, 2012) provided by the Editor states that increase in water vapour in the UTLS increases the surface temperature. However, in the present manuscript we explained warming over the Tibetan Plateau and mid latitude at the altitudes between 300-200 hPa in response to enhanced carbonaceous aerosols transported in the UTLS. The warming in the UTLS (200-300 hPa) is partially due to transport of enhanced black carbon (BC) aerosols and water vapour at those pressure levels.

We have stated that "It is related to warming by BC aerosols and partially by water vapour. Figure S4 shows that BC aerosols are transported upward and northward from (latitudes 40°N - 48°N) regions of China, Mongolia, and southern Russia to the mid latitude upper troposphere which may contribute to this warming. In addition, the negative water vapour anomalies in the same region (in the UTLS of the mid latitude) seen in Figure 8b imply a decreased radiative cooling, which might have partially contributed towards the warming anomaly."

To show radiative cooling by the water vapour in the UTLS, we have plotted 'net radiative heating rates due to water vapour' from the model (figure-1 below). It shows negative heating rates (indicating cooling) due to water vapour in the upper troposphere and stratosphere. Also numbers of references below (Foster and shine, 1997; Gierens and Eleftheratos, 2016; Clough and Iacono, 1995) also support the model results (cooling of the upper troposphere and stratosphere by the water vapour present there). The figure-1 and references (below) justify our statement from the previous manuscript "negative water vapour anomalies in the same region (in the UTLS of the mid latitude) seen in Figure 8b imply a decreased radiative cooling, which might have partially contributed towards the warming anomaly (Pages 17-18, Line Nos. 378-384).

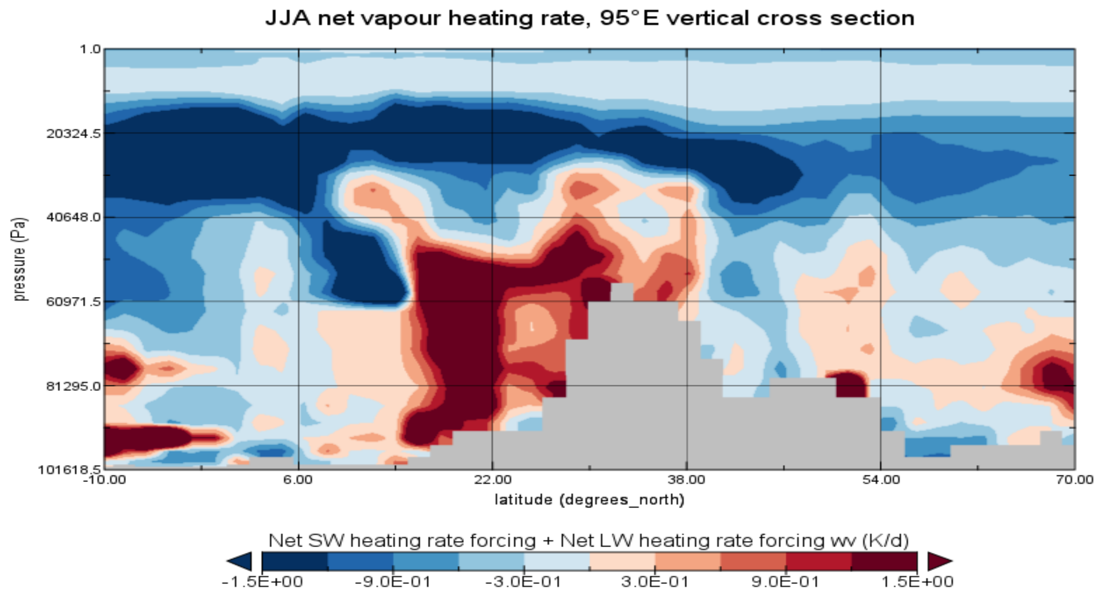

Figure 1: Latitude-pressure cross section at (95°E) of net (shortwave plus longwave) water vapour heating rate averaged for the monsoon season (JJA) from a reference ECHAM6-HAM2 model's simulation.

References

(1) Foster and shine (1997): (section 3.5)→ The effect of an increase in lower stratospheric water vapor has also been examined, using the 0.5 to 1% per year stratospheric water vapor increases between 1981-1994 observed over Boulder, Colorado [Oltmans and Homann,1995]. The water vapor increases (Figure 13) cause stratospheric cooling which are largest near the tropopause. Coolings of 0.3 K per decade are found at about 18 km.

(2) Klaus Gierens and Kostas Eleftheratos, Upper tropospheric humidity changes under constant relative humidity, Atmos. Chem. Phys., 16, 4159–4169, 2016 →
Although the amount of water vapour in these layers (upper troposphere and stratosphere) is only a small fraction of its total amount in the atmosphere, the contribution of water vapour in the upper troposphere to radiative cooling of the atmosphere (locally) is disproportionately large (Clough et al., 1992).

(3) Clough S. A. and Iacono M. J., Line-by-line calculation of atmospheric fluxes and cooling rates 2. Application to carbon dioxide, ozone, methane, nitrous oxide and the halocarbons JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 100, NO. D8, PAGES 16,519-16,535, AUGUST 20, 1995 →

The water vapor pure rotation region remains of critical importance with respect to the outgoing longwave radiation and to the cooling in the middle and upper troposphere.