A. Geer (Referee)

This paper investigates the quality of stratospheric water vapour analyses of the 2009 major warming, by looking at their consistency with the meteorology and by comparing computed descent rates to independent estimates. Papers featuring water vapour analyses are still quite rare (perhaps surprisingly), so this will be a useful addition to the literature. The content and methods are appropriate, but there are some major structural changes required to improve the presentation of the work on descent rates.

We thank A. Geer for these positive words.

Major change

Descent rates are computed in both sections 3 and 5.3. However, the same features are being tracked in the vortex average (Fig. 2, Sec. 3) and in the equivalent latitude theta plots (Fig. 8, Sec. 5.3) so these estimates are far from independent. In fact, looking at the inconsistencies between estimates would provide a useful indication of their accuracy. These sections are also hard going for the reader due to the proliferation of numbers in the text. Therefore I would suggest:

(a) there should be just one section on descent rates, including also the last two paragraphs from Sec. 6

To address the reviewer's comments, we have re-organized the paper:

- ***Section 3 now presents the discussion on the meteorology, which we now introduce before the discussion of the behaviour of the water vapour analyses (the new Section 3 was the old Section 4);***
- ***Section 4 now presents the evolution of the water vapour analyses and PV fields in two sub-sections: 4.1 (Data Assimilation versus gridding picture, the old Section 5.1) – this also motivates the use of analyses to estimate vortex descent rates; and 4.2 (Combined 2-d maps/1-d along-orbit picture, the old Section 5.2);***
- ***Section 5 now presents the descent during the winter in three sub-sections: 5.1 (Vortex descent: vortex average picture, the old section 3); 5.2 (Vortex descent: equivalent latitude-theta picture, the old section 5.3); 5.3 (Summary of vortex descent, most material from old Section 6);***
- ***The old Section 6 has been removed, so the Conclusions are now Section 6;***
- ***The figures have been modified and/or renumbered to reflect these changes.***

We have also corrected typos and inconsistencies in the paper (e.g. removing references not cited in the text), and made an effort to remove redundancy (addressing a comment from referee # 4).

We think this improves the flow of the paper, and makes it easier to read.

(b) many of the numbers currently in the text should be moved to a table, along with the Manney et al. (2009) and Lee et al. (2010) estimates, at least for those referring to the dry mesospheric or moist lower stratospheric features, e.g. (i) and (ii) in the terminology of Sec. 3. This will make it much easier for the reader. Consideration could also be given to putting symbols on Figs. 2 and 3 at the points which are referred to in the text.

We introduce a Table (Table 1) summarizing the information on descent rates. Table 1 is introduced and discussed in the new Section 5.3. Symbols (A, B and C) are introduced in what is now Figure 7 (old Figure 2) and in Figure 8 (old Figure 8) to highlight the descent discussed in the text.

Put together, we think the changes discussed above address the major comment from the reviewer.

Minor

1)p24702 l25 - A reference to one of the long-established textbooks (e.g. Daley, Kalnay) on this subject might be appropriate. More generally, though the references in the introduction are all appropriate, and work on stratospheric water vapour analyses is rarely published, it would be nice to see a more exhaustive description of work on water vapour assimilation in the wider research community. For example, "An annual cycle of long lived stratospheric gases from MIPAS", Juckes, M. N., Atmospheric Chemistry and Physics, Volume 7, Issue 7, 2007, pp.1879-1897. More information explaining why published research has been so scarce to date (e.g. the lack of operational observations of stratospheric water vapour for NWP centres to assimilate) would also be useful.

We add references to Kalnay and Juckes, and comment on the scarcity of published research in stratospheric water vapour analyses (Section 1).

2) p24705 l25 "averaged for the period..." Presumably a typo? The standard deviations differences (Fig. 1 RH) could not be computed from two averages.

We address this by stating that statistics are calculated for the period January-February 2009 and over the latitude range 60N-90N, and clarify how we calculate the standard deviation (Section 2.3)

3) Sec. 3 / Fig. 2 (top) Why does a relative minimum appear at 1400K after 26th Jan? This needs to be considered briefly in the text.

This is discussed briefly in the text (Section 5.1), and associated with remnants of descent from the mesosphere.

4) p24707 l21 / Fig. 2 - "localized features .. are consistent with the meteorological data" - please be clear what is meant here, as many of the localized features appear to be noise coming from the observations, e.g. the jumpiness of the descent of the dry mesospheric air mentioned on p24708 l6.

We now provide examples of instances of localized features that are consistent with meteorological data (Section 5.1).

5) p24707 l28 "positive bias of order 0.25 - 0.5ppmv" this would be better justified if the difference between Fig. 2 (top) and Fig. 2 (bottom) were also shown as a figure.

We refer to values from a difference figure (now the bottom plot of Fig. 7).

6) Section 4 - It would be nice to see 16 January and 15 February in figure 3, seeing as they are referred to in the text.

We think including these new figures is not necessary, as the main points associated with the major warming are described in the figures already included in the text. Furthermore, Manney et al. (2009b) provide complementary information on the evolution of the winter (e.g. 15 February), and which is now referred to explicitly.

7) Section 5.2, first para. This paragraph could be made more concise by eliminating repetition.

This paragraph has been made more concise (now opening paragraph of Section 4.2).

8) p24714 l12 "MLS water vapour observations, linearly interpolated to the orbit indicated"- surely a typo, as this would be pointless?

This a typo, which has been corrected (Section 4.2).

9) p24718 l1-7 and l19-25 - this information could be better presented graphically, e.g. by lines on the relevant plots

The figures (which are now Figures 4-6) include horizontal dashed lines in the right-hand panels to present this information (Section 4.2).

10) Fig. 5,6,7 line plots show a feature on 24 Jan in profiles 1000 to 1010 (a vertical grey bar) where the MLS errors appear to be infinite. This feature stands out and should be explained in the text (unless I have missed that somewhere?)

These features correspond to particularly poor MLS retrievals – they are now removed from what are now Figures 4-6. Note these particularly poor retrievals were not assimilated.

11) p24717 l28 "MLS observations are noisy within the 1 sigma ... error" This is true but surely that "noise" could also be partly due to real geophysical variability? E.g. fine-scale filament structure.

The issue we want to highlight is that although the MLS observations present a higher variability than the BASCOE analyses, these two datasets agree to within the 1-sigma MLS random errors. We reword the text to reflect this (Section 4.2).

12) p24719 l3-4 "in the mid-stratosphere ... at 1700K on 8 January" a typo?

This is a typo which has been corrected (now done in Section 5.2).

Technical

1) p24704 l25 "are used" -> "were used" - use past tense to avoid confusion with the present tense list of constituents used in the current paper.

Corrected (Section 2.1).

2) Caption to Fig. 3 is highly repetitive and should be more concise.

Caption to (what is now) Fig. 2 has been made more concise.