Review of Wang et al.
"Understanding Boreal Summer UTLS Water Vapor Variations in Monsoon Regions: A Lagrangian Perspective"
egusphere-2024-3260

Summary:

This paper uses Lagrangian back-trajectories calculated from ERA5 meteorological fields to reconstruct the horizontal and vertical distributions of water vapor in the tropical upper troposphere and lower stratosphere (UTLS) during the boreal summer. The paper poses three questions. First, how do reconstructed UTLS water vapor distributions compare to co-located measurements from SAGE-III ISS and MLS? Second, are moisture anomalies controlled locally or remotely by the Lagrangian (upstream) CPT? Finally, do the Lagrangian reconstructions agree with the finding of Randel et al. (2015) that stronger convection (in the Asian Summer Monsoon or ASM and the North American Monsoon or NAM) leads to drier air moving into the stratosphere?

The reconstructions are carried out using the CLaMS trajectory module (Konopka et al., 2022). Back trajectories are calculated for 180 days using the CLaMS model's trajectory module and were initiated from the satellite measurement locations and times. Results are presented for comparisons of the reconstructions with SAGE-III and MLS water vapor values at the back-trajectory initiation points. The water vapor reconstructions are based upon the coldpoint temperatures, with the coldpoints identified either from the local vertical temperature profile or from the back-trajectory minimum temperature (the Lagrangian CPT). Three types of reconstructions are thus done based on the type of CPT: (a) using local CPTs (LOC), (b) using the Lagrangian CPT for every single trajectory (LAG_single), and (c) using the average Lagrangian CPT for a cluster of 51 back trajectories.

From their results the authors conclude that (a) the Lagrangian approach significantly improves upon approaches based upon local CPTs, (b) despite a dry bias, the Lagrangian reconstructions successfully capture the horizontal distribution of moist anomalies in the ASM but not in the NAM, but (c) the reconstructions do not capture the relative drying and moistening associated with east-west shifts of convection in the ASM that was observed by Randel et al. (2015).

General and specific comments:

This paper addresses a topic that has received considerable attention over the past 20 years or so. And a positive feature of the approach that the authors have undertaken in this work is the direct comparison of their water vapor reconstructions with SAGE-III ISS and MLS water vapor observations.

One aspect of the study that deserves more explanation are the significant low biases of the reconstructed water vapor mixing ratios relative to both the SAGE-III and MLS observations that are evident in both Figs. 1 & 2. Following Liu et al. (2010) they attribute the dry bias to “missing cloud microphysics”, but that is not the end of the story. Indeed, using domain-filling approach, the reconstructed water vapor fields 100 and 82 hPa obtained by Schoeberl, Dessler and Tao (2013) display very little bias with respect to MLS - without including any microphysics other than allowing for a limited degree of supersaturation at the LCPs. In any case, I would recommend the authors include some commentary on this topic relative to the very interesting study of the dehydration occurring in StratoClim by Konopka et al. (2023) as this addresses the impact of microphysics on dehydration along CLaMS parcel trajectories.

One very interesting result is presented in Fig. 5. It shows that while the vast majority of the Lagrangian cold points upstream of the observations in the ASM are within the ASM, the NAM is a very different story. Although a small fraction of the NAM LCPs come from the NAM region, the majority of the LCPs lie within the ASM. This is an important finding since it emphasizes the dominant role of the Asian monsoon in controlling the moisture entering the stratosphere in boreal summer, while the North American monsoon is relatively speaking a bit player. This result could well be highlighted more explicitly in the Conclusions section.

In Section 4, the authors address the finding of Randel et al. (2015). They are able to repeat the Randel et al. results with the satellite water vapor observations but not with the reconstructed water vapor fields. They argue that the simple Lagrangian fails to properly capture the effects of convection and ice injection in monsoon regions. This is not a convincing argument given that Konopka et al. (2023) did not find that convective processes played a significant role in determining the final stratospheric water vapor entry values in the circulation around “dehydration carousel” in the Asian summer monsoon anticyclone.

As a general comment, I found the narrative flow of the text choppy and confusing, particularly in the Introduction. The Introduction certainly recognizes the long-standing consensus that the dominant control on the concentration of water vapor entering is through slow horizontal transport. However, this is restated in various ways multiple times, suggesting a controversy that does not exist (see comment #4 below). There are certainly many ramifications of this general principle, and indeed this paper explores some of those. At minimum, I would recommend a revision of the Introduction to make it shorter and read more smoothly

Specific comments:

1. I found the discussion of the methodology of the water vapor reconstructions (Section 2.3.3) is incomplete. They have adopted is to do three types of reconstructions (“experiments”), two obtaining water vapor values from the CPT along back trajectories (“LAG_single” and “LAG”) and a third that is based upon local CPTs (“LOC”). The first two types of reconstructions appear to be similar in

approach to the Lagrangian trajectories used in similar studies going back at least two decades [see, for example, Fueglistaler and Haynes (2005)]. However, the method of by which the "LOC" reconstructions are carried out is unclear, especially since it lumps all three of the reconstruction approaches in one paragraph.

2. It would have been helpful if the captions for Figs. 1 & 2 specifically stated that the reconstructions were obtained through the LAG "experiment".
3. (line 31) Pan et al. (2018) did not introduce the Lagrangian Cold Point, although they do provide a number of references to the Lagrangian approach to determining the effective dehydration temperature for air parcels entering the stratosphere. Of these, the oldest reference is to Fueglistar et al. 2004, although the exact phrase only appears in later papers such as Kruger et al. 2008, for example.
4. (L.25-36) Taken together these sentences, comprising the latter half of the first paragraph in the Introduction, restate the importance of the concept of the transport history of air parcels entering the stratosphere several times over. As the references attest, Lagrangian approaches have been used been for over two decades, but the paragraph gives little sense of what new insights the Lagrangian perspective has provided since the earlier papers such as Fueglistaler et al, 2005.

Recommendation:

Acceptance subject to minor revisions.