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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Residual circulation trajectories and transit times into the extratropical lowermost stratosphere" *by* T. Birner and H. Bönisch

Anonymous Referee #1

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General Comments

This paper is a brief analysis of streamlines and transit times (from back trajectories) that is used to sort the stratospheric circulation into two branches, one in the lower stratosphere with short transit times, and the other in the middle and upper stratosphere with longer times. These sets of trajectories are also described in terms of their aspect ratio, that is, the height travelled vertically by a parcel relative to the meridional distance travelled. The seasonality of the two branches is also discussed. This paper treats transit times and 'minimum pressure visited' as though they are new ideas. The seminal paper on this topic is Hall (2000). Reithmeier et al (2008) is also extremely

relevant and discusses many of the same topics as this paper. This paper should not only reference these works but should place its results into the context of those studies.

A fundamental idea proposed in this paper is that the stratospheric circulation can be clearly separated into an upper and a lower branch. I don't find the figures or the arguments convincing - the circulation shown in the figures seems more like a continuum. The paper concludes with statements about different types of wave breaking that force these two branches, but there is no evidence presented that demonstrates this. I don't doubt that these sources of breaking waves are important to the circulation, but these statements, presented here as conclusions, are unsupported by evidence in the manuscript. As presented this argument is only speculation. Is it fundamental to the paper to approach this study from the perspective that there are two distinct branches? If not, can you reframe the results without the two-branch assumption? If the authors choose to stay with the two-branch approach, please provide diagnostic evidence for the wave forcings that cause them. Those forcings must then be shown to be physically linked to the calculated pathways and transit times.

I suppose there are some new results here to publish (e.g., results of the behavior of CMAM and the two met analyses). The issues that I would like to see addressed in a revised paper are stated generally in the previous paragraph and in greater detail in the section below. It is important that the revised paper place itself into the context of previous studies.

Specifics

Results and Section 3.1. I find the evidence for the separation of the circulation into two branches unconvincing. The trajectories shown in Figure 2 show a continuum of transit times, with longer times occurring poleward. This is a well known feature of the stratospheric circulation. In simple terms, the higher a parcel ascends in the tropics, the greater opportunity it has to travel poleward and hence the parcels arriving at the highest latitudes in the descending branch of the BDC are those that have travelled

to the highest altitudes. They are naturally the oldest. The relationships between mean age or transit time, pathways, and maximum altitude reached were thoroughly introduced and discussed by Hall (2000). The Hall (2000) study is in many ways an important foundation for this study but it is not referenced. Regarding the relationship between transit time and maximum altitude, while Rosenlof (1995) is referenced, other very relevant studies are Reithmeier et al (2008) and Douglass et al (2008). These references have already demonstrated what the authors report here, which is to say that much of this analysis is not new.

On p. 16843, l. 17-18. "A strong latitudinal gradient between 60-70 and below 50 hPa exist that supports the notion of two well separated branches of the residual circulation." The latitudinal gradient exists for two reasons, neither of which requires two branches. First, air poleward of 60-70 has a vortex for at least 3 months of the year. In those months, transport from lower latitudes is greatly restricted. Air inside the vortex has descended from the middle stratosphere where air is older. Although the vortex does not exist all year, the annual mean age will be influenced by this seasonal isolation and will thus be a notch older than the midlatitude air. This is an indication of a meridional transport barrier, not a different branch of the circulation. Second, there has to be a latitudinal gradient in transit times/mean ages which results, basically, from mass continuity. Air ascends in the tropics, but pressure decreases with height. By 10 hPa, 90% of the mass that began its ascent at 100 hPa must be transported poleward. Once that air leaves the ascending branch of the BDC and enters the midlatitudes, it will descend. The lower the altitude at which a parcel leaves the tropics, the less far poleward it travels before it has descended back down to the extratropical tropopause (and hence the shorter its transit time). (This is true in the context of the paper where transit along residual streamfunctions is discussed.) In the final analysis, the latitudinal gradient in transit times comes from mass continuity. See discussions in Hall (2000) and Reithmeier et al (2008) for related discussions on the topics in Section 3.1.

Summary and conclusions. 'Aspect ratio' is a novel way to label widely recognized

and long-understood aspects of the stratospheric residual circulation. I object to the second paragraph of this section. This paragraph explains what causes the proposed two-branch circulation: breaking synoptic waves above the subtropical jet and breaking planetary waves in the middle stratosphere. While I do not disagree about the importance of these waves to stratospheric circulation, what I do not agree with is that one can make these statements as conclusions based on the analysis presented. As previously stated in this review, I do not agree with the 2-branch diagnosis. But beyond that, the statements made here are speculations, not conclusions based on this analysis.

References:

Hall, T.M. (2000), Path histories and timescales in stratospheric transport, JGR, 105, 22,188-22,823.

Reithmeier, C., et al. (2008), Investigating lower stratospheric model transport, Climate Dynamics, 30, 225-238.

Douglass, A.R. et al. (2008), Relationship of loss, mean age of air..., JGR, 113, doi:10.1029/2007JD009575.

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