We thank Martin Dameris for being the editor of this paper. We also acknowledge the reviewers for the helpful comments on our manuscript. All comments were taken into account in the revised version and we feel that the manuscript has improved greatly through these revisions. Below, we reply point-by-point to the referee comments:

Reviewer #1:

- I wonder why the authors show the results for the vertical velocity, which are expressed in pressure-based units (Pa/day), on isentropic coordinates. Equation 9 gives the diabatic velocity on pressure coordinates, which can be directly compared to the vertical velocity given by Eq. 3. This comparison would be simpler than then interpolating both vertical velocities to isentropic levels. A related concern is how the interpolation of the residual circulation to isentropic surfaces is done. In order to evaluate the mass transport across an isentropic surface both the meridional and vertical components of the residual circulation should be considered since pressure and isentropic surfaces are not parallel. Could you clarify how the interpolation is done and if this issue could have any effect on the comparison? Indeed, comparing the results directly on pressure surfaces could avoid having to interpolate the residual circulation.

We agree with the reviewer that showing the velocities on pressure levels is straight-forward and more consistent than potential temperature coordinates. Therefore, we changed the vertical coordinate from potential temperature to pressure levels in Fig. 1, and Fig. 3-7 (Fig. numbers of old manuscript).

- The age of air results should be explained more carefully. It is an important point to what extent the different vertical velocities affect the age of stratospheric air calculations. More discussion on this point is highly desirable. For instance, the hemispheric pattern appears mostly below 800 K while the latitudinal shift of the tropical pipe (in boreal summer) is mainly observed above that level.
We have rewritten the age of air section in the paper. We added the analysis of residual circulation transit times (RCTT) to distinguish between residual circulation and mixing effects, which allows the differences like the hemispheric pattern to be explained in more detail.

- L11 P29944 "although their results are also affected by assimilation effects ": could you explain this?
This sentence means that these studies are based on reanalysis data. Thus, their results are not pure model results, instead they also include information from observations.

- L11 P29945 "it shifts the pressure boundaries of the grid boxes" –> the pressure boundaries of the grid boxes are not fixed
This has been changed as suggested by the reviewer.

- L27 P29945 remove "towards each other"
This has been changed as suggested by the reviewer.

- L9 P29946 Planetary waves that propagate on isentropic surfaces: what do you mean?
We agree that the formulation was confusing, so we changed the sentence in the following way: Planetary waves may induce upwelling and downwelling in the Eulerian zonal mean ω in different latitudes which is not related to net tracer transport.

- L19 P29946 remove TEM
This has been changed as suggested by the reviewer.

- Figure 2: It would be convenient to express in the same units as the other figures (Pa/day)

This figure is shown to demonstrate the general difference between w and w*, using the 'original' units of the TEM [m/s].
As explained in the test, it is not useful to calculate the zonal mean of w (i.e. upwelling in the polar regions.) Therefore, it is not necessary to compare the zonal mean of w directly to any other vertical velocity. In case of the TEM, the units are changed to Pa/day in the following figures.

- L17 P29949 This problem can be avoided if the transformation is applied to the data on pressure instead of hybrid coordinates.
This has been changed as suggested by the reviewer.

- Figure 3. Fix the figure caption. Also remove "grey".
The figure caption has been fixed.

- Figures 4 and 5 Perhaps it could be considered to select one representative month per season and have only one figure instead of showing the 24 panels.
We agree that the discussion of the monthly figures is too detailed for the main part of the paper. Though, we like to keep it for completeness and moved this part to the appendix.

- Figure 6 Perhaps it would be clearer to have lines at different levels, it is not easy to compare the magnitude on a contour plot (e.g. L7-8 P29953)
We tried different ways of plotting but came to the conclusion that the figure in its present way is most clear.

- L12-13 P29953 This is only true above 800 K
To be more precise in this sentence, we have added the height (~15hPa in pressure coordinates).

- L22 P29953 "more dispersive" this is known from previous works but it is not a result seen here
It is seen in e.g in Ploeger 2010, Schöberl 2003. We removed this part here.

- L25 P29953 The southward shift is only seen in summer
To be more precise, we changed the text*:* a~southward shift of maximum <u>upwelling</u> in the <u>diabatic</u> vertical velocity in <u>NH</u> summer.

- L25 P29953 What about the difference in the latitudinal extension of the upwelling?
The upwelling region is wider in the kinematic vertical velocity field, and wider in the diabatic vertical velocity field. We added this point to the list.

- L9-12 P29954 Could you discuss the contribution of the different velocities versus the different transport schemes in the models (ClaMS versus EMAC)?
We address this point by adding the RCTT analysis to the age of air discussion.

- Figure 7 bottom: The color scheme is confusing (blue is usually used for negative values)
We chose the color scheme similar to the plots in the rest of the paper. (Red: negative, blue: positive). To make it clearer, the last sentence of the figure caption specifies the meaning of the colors in this plot: Blue colors indicate younger air in EMAC-FFSL, while red colors indicate younger air in EMAC/CLaMS.

- L5 P29955 Add reference
The work has not been submitted or published. We deleted the sentence, since there is no proper citation available.

- L14 P29955 Remove "In summary, the discussion above showed that" (This is discussed in this paragraph, not above)

This has been changed as suggested by the reviewer.

- L4 P29956 Remove "for the example of the EMAC/CLaMS model" (redundant)
This has been changed as suggested by the reviewer.

Reviewer #2:

1. Discussion of vertical velocities (Section 3): The discussion of differences in kinematic versus diabatic velocities is certainly interesting and worthwhile showing. I feel that it could be improved by the following points:
a) Presentation:
- move the monthly Figures 4/5 to Appendix / Supplement. Instead, I would find more illustrative of the relevant differences (e.g. shift of tropical pipe) a latitude-time plot at relevant heights (e.g. 500 K,..), including a difference plot.
We moved the monthly figures to the appendix and replaced them by a seasonal plot of DJF/JJA.

- I find it hard to see the relevant features in Fig. 6 (in particular in association with the discussion in Sec. 4). Maybe you can think of a different way to illustrate the relevant differences (see above).
We tried different ways of plotting but came to the conclusion that the figure in its present way is most clear.

b) Attribution:
While the differences are discussed in great detail, little explanation is given. I understand that this not an easy task, but some discussion should be added. For the diabatic velocities, it should be possible the separate the impact of the different processes. In this respect, the analysis in the Appendix are very interesting, and I encourage the authors to discuss those results more (and maybe move them to the main body of the paper). How large are the differences caused by using different convection parametrizations as compared to the differences between Kinematic to diabatic velocities?
Can those sensitivities reveal anything about the causes of differences kinematic vrs. diabatic velocities?
We followed the suggestion of the reviewer and moved the discussion of the effect of the different convection schemes to the main part of the paper. Additionally, we compared the diabatic vertical velocities resulting from the Tiedke scheme with the vertical velocities resulting from the two other convection schemes. We produced new difference plots (Fig. 4) using the same units and color scale as in Fig. 5.

2. Age of Air (Section 4):
Again, the investigation of the AoA differences resulting from the different vertical velocities, as well as different advection schemes is certainly relevant. While some explanations are given, and connections are made between the differences in the vertical velocities and AoA differences, they are on a rather speculative level. For example, in the conclusion it is stated that "there is a clear correlation between vertical velocity and age of air" - However, no correlations or robust connection is made. Possible additions
could be:
- If in any way it is possible to run either of the advection schemes with the other vertical velocity this would be a great comparison, and a clean separation of the two factors causing differences in AoA.
- Otherwise, analysis of the differences caused purely by the different vertical velocities could be obtained by an analysis of residual circulation transit times, as done in the cited papers by Garny et al., 2014 and Ploeger et al., 2015.
We address this point by adding the RCTT analysis to the age of air discussion.

Introduction, page 29942, line 5 to 10: If I'm not mistaken the vertical velocity in a model like ECHAM is a purely diagnostic variable, i.e. it is calculated for output, but not used in the calculation of the dynamics. So the fact that "spectral" and "FSSL" vertical velocities differ is important to keep in mind when analysing model output, but not an inconsistency per se in the model, correct? The fact that w_spec is purely a diagnostic output should be mentioned somewhere.
We agree and added this information in the section 'Kinematic vertical velocity'.

- page 29942, line: 26-27: "transport and mixing..." is not a good terming, as mixing is also a transport process. Change to e.g. "residual transport and mixing"
This has been changed as suggested by the reviewer.

- page 29945 / Section 2.1: can you comment on how relevant the discussed issue of different velocities in the dynamical core and the advection scheme is in general for climate models - is this an issue in almost any climate model (that uses an FSSL-like scheme?), or a specific "problem" in Echam ?
This is a general issue in climate models, but it is not a problem since the differences are small (see Jöckel et.al., 2001).

- Fig. 1: Is the difference shown the relative difference of the mean values, or the mean of the relative differences for e.g. each month?
It is the relative difference of the mean values for the year 2005, calculated using the formula on p. 29945, l.21 (page and line number of old manuscript).

- page 29944, line 18: can you give an equation for the FSSL vertical velocity, i.e. the tracer continuity equation, to make it more clear how w_FSSL is obtained?
An explanation how w_FSSL is obtained is given by Lin (2004) and Lauritzen et. al. (2011). We have added the references here.

- page 29949/59: Do you expect an (computational) error from the transformation of diabatic velocities to w_Theta, and do you expect it to contribute to the comparison to the kinematic velocities? Probably in the continuity equation, the vertical velocity is a small residual compared to the other terms? (so the same problem arises as in the calculation of kinematic velocities).
We have done the following test, which shows that the error is small:

To calculate $\dot{\theta}$ from $\Omega = \dot{p}$, the following relation was used

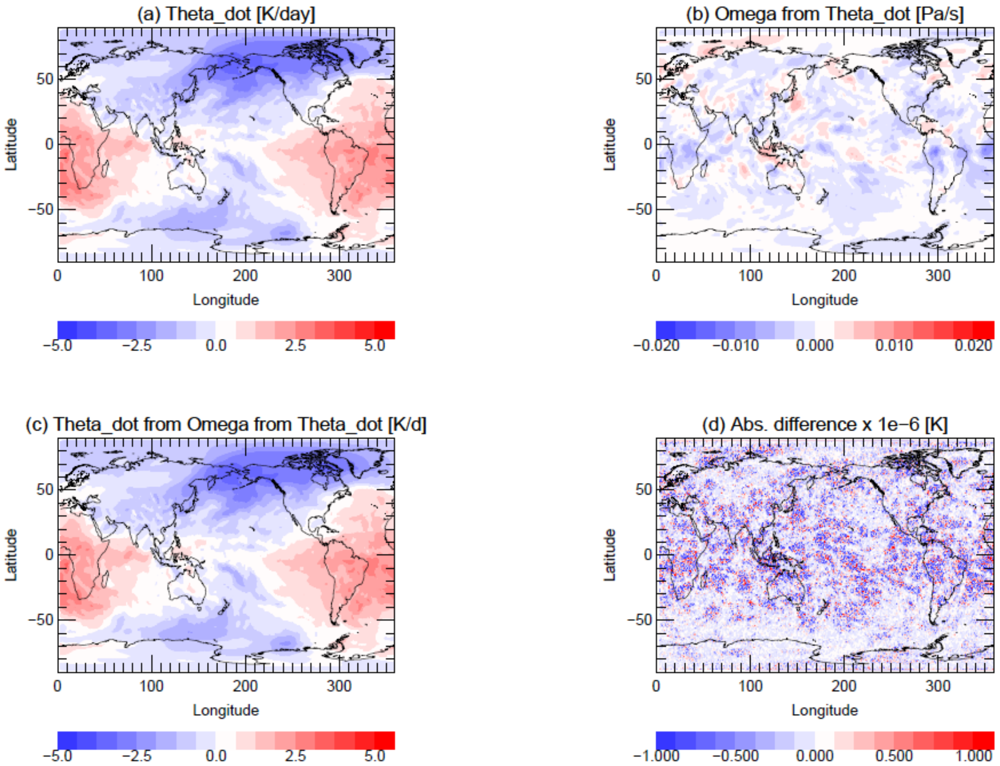
$$\dot{\theta}(\dot{p}) = (\partial_t + u\frac{1}{a\cos\phi}\partial_\lambda + v\frac{1}{a}\partial_\phi + \dot{p}\partial_p)\theta \tag{1}$$

with the horizontal velocity (u, v), λ/ϕ - longitude, latitude and a the Earth's radius. The inverse transformation is given through

$$\dot{p}(\dot{\theta}) = (\partial_t + u\frac{1}{a\cos\phi}\partial_\lambda + v\frac{1}{a}\partial_\phi + \dot{\theta}\partial_\theta)p\ . \tag{2}$$

Thus, to check the numerics, the relations (1) and (2) can be inserted into each other, i.e.:

$$\dot{\theta} = \dot{\theta}\left[\dot{p}(\dot{\theta})\right] \tag{3}$$



(a) $\dot{\theta}$ at model level 40 (ERA-Interim, 1.01.2006, 12 UTC) with mean pressure around 44 hPa and mean θ around 520 K. (b) Using relation (2), $\dot{\theta}$ is transformed to $\Omega = \dot{p}$ (c) Starting from this $\dot{p}$, $\dot{\theta}$ is calculated by using the relation (1) (d) The difference between (a) and (c) is shown which is smaller than 10^{-6}K.

- Fig. 7: Something is wrong in Fig. 7: My guess is that the difference shows EMACFSSL - EMAC/CLAMs and the label is the wrong way round. This would be consistent with the text and the last sentence of the Figure caption. It would also be interesting to show the relative difference here.
The color in this figure is correct, see also answer to Reviewer #1.

- page 29944, line 7: "than the vertical.." (insert the)
This has been changed as suggested by the reviewer.

- page 29946, line 20: redefining -> redefinition (?)
This has been changed as suggested by the reviewer.

- page 29949, line 3: E.g. -> For example

This has been changed as suggested by the reviewer.

- page 29952, line 4: above the equator -> at the equator
This has been changed as suggested by the reviewer.

page 29952, line 18: not so -> less
This has been changed as suggested by the reviewer.