REPLY TO REVIEWER #1

Dear Dr McGregor,

We would like to thank you for reviewing this paper and providing detailed corrections. We have incorporated all your comments (with two small exceptions as you will see below) in a revised version of our manuscript which we will resubmit. More specifically:

Minor Comments/Corrections

1. L122 “MacGregor (2011)” to “McGregor (2005)”
Done
2. L234 Remove the subscripts “jk” from phi_min L438
Done

Is it known which of the 150-hour distributions in Fig. 9 is more realistic?

The accuracy of available observation is not good enough to decide which of the modelled plumes is more realistic. Flemming and Inness (2013) have shown that there are considerable differences in the magnitude of SO2 volcanic plume observations from different satellite instruments such OMI, GOME-2 and SCIAMACHY for the eruption of Grimsvoetn.

Technical Corrections

1. L1 “MFA” to “MFAs”
Done
2. L15 “is not “ to “not”
Done
3. L21 spelled as “parametrisation” , but L82 different spelling
Done - use consistently "parametrization" everywhere in the text.
4. L25 “their location” to “its location”
Done - actually we have entered: "to the departure point location"
5. L42 Algorithms” to “Algorithm”
Done
6. L51 & L55 & L62 “MFA” to “MFAs”
Done
7. L75 You should say how many time steps
Done - entered: "same number of timesteps (1440) ..."
8. L139 “correcting” to “to correct”
Done
9. L162 & L176 & L183 & L185 It would be better to use a different superscript than p (maybe upper-case P) to avoid confusion with pressure p.
Done - we now use beta
10. L190 “is a” to “produced a”
Done
11. L205 “Priestley” to “Priestley’s”
Done
12. L213 & L214 “MacGregor” to “McGregor”

Done

13. L285 and caption to Fig 4. Should specify units of vertical axis

The vertical axis there has no units as it is the "model level number" as it is mentioned in the caption.

14. L292 I think you mean to say “see also Fig. 5”

Done

15. L308 “MF” to “MFA”

Done

16. L349 “10 forecast” to “10-day forecasts”

Done

17. L427 probably replace “MF” by “MFA”

Done

18. L465 “up half” to “up to half”

Done

19. L468 “from ... applied” to “from applying the quasi-monotone limiter”

We have made the following change: "Noticeable impact was found from the type of quasi-monotone limiter applied"

We have found that when the quasi-monotone limiter is removed completely the cold bias improves further. From the two types of limiter we tested, the less diffusive BS-limiter is better in terms of cold bias. This is consistent with Stenke et al where numerical diffusion of SL scheme is blamed to be one of the important contributing factors of the observed cold bias existing in some SL models.

20. L477 “results to” to “results in”

Done

21. L524 “MacGregor, J.” To “McGregor, J.L. L525 “2011” to “2005”

Done

22. Caption of Fig. 6 should state that the contours show the zonal mean temperatures.

In the caption we have "...Difference of vertical cross-sections of zonally-averaged annual mean temperature fields".

REPLY TO REVIEWER #2

Dear Dr Sørensen,

We would like to thank you for reviewing this paper and providing corrections and interesting comments for further discusiion. This is our reply:

Comment 1

Yes, indeed we have considered re-distributing. We had a test version in which the amount of tracer the limiter was truncating was distributed in the vertical. This was reducing the magnitude of re-distributions improving slightly further the cold bias in climate runs. However, at NWP runs in higher resolution was giving slightly negative skill scores.

We have also considered distributing in a full 3D fashion as it is done in ILMC filter by Sørensen et al. This would have been ideal but there are some difficulties with respect to its implementation in IFS:

(a) IFS is paralelized in a way which is highly efficient and safe for code development but puts limits in what can be done. According to the opinion of our experts in this area, for a safe and bit-reproducible implementation of ILMC in IFS, the cost of SL advection would have to increase significantly (about 30%).

(b) One additional subtle point is that IFS is not using density as a variable and tracers are represented by their specific mixing ratios. Therefore, redistributing interpolation over/under-shoots at different points means altering ratios inconsistently with their actual mass.

For these reasons we decided not to pursue further this idea.

Comment 2 (section 4.3)

We would prefer not to include further figures at this stage as we have asessed the mass fixers on a number of different situations and we believe that the given information is sufficient to expose the strengths and weaknesess of MFAs. Individual plots in Fig. 7 have features which stand out. For example, the strongly dissipative nature of linear interpolation, the unphysical mixing the unlimited cubic introduces as well as differences between individual MFAs and limiters are fairly visible (or example BC versus MG fixer).

Comment 3 (section 4.4)

We agree that this can be an issue for some mass fixers. However for the ones we consider here, this may only happen with PR fixer which can compute both positive and negative increments. Mass transfer from one plume to another implies that the MFA will decrease the mass of one plume and increase the mass of the other plume. For BC and ZE fixers equations (5)-(8) dictate that the sign of the correction is uniform and determined by the sign or global mass error (see delta M in eq. 5). This issue is discussed in the last paragraph of section 3.2. So when the total mass is overestimated then mass will be taken from all plumes but at different amounts which depend on the smoothness of the field in the region of the gridpoint which is corrected.

It is not so obvious what happens with MG fixer, however, if we make an additional assumption that the interpolation results are positive definite then after some algebraic manipulation we can show that same sign mass fixer increments are obtained as in BC and ZE fixers.

Technical corrections

Page 781: Done